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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 640/171

History of the
Subcommittee on Welding of Armor
Ferrous Metallurgical Advisory Board
Ordnance Department
U. S. Army

BY

DATE 1 July 1946

WATERTOWN ARSENAL
WATERTOWN, MASS.

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NUMBER WAL 640/171

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1 July 1946

History

of the

Subcommittee on Welding of Armor

Ferrous Metallurgical Advisory Board

Ordnance Department

U. S. Army

Approved 11/14/46
W. G. Ludlam
Col Ord.

[redacted]

FOREWORD

The Subcommittee on Welding of Armor was one of several similar groups, organized during 1940 under the Ferrous Metallurgical Advisory Board of the Ordnance Department, each of which was intended to serve as advisory on a particular ordnance problem. The particular province of the Subcommittee on Welding of Armor was that of fabricating armor structures by welding.

It was believed desirable to prepare this record of the Subcommittee for possible future reference so that all data pertinent to the Subcommittee Organization and Activities might be found under one cover for the following reasons:

(1) This Subcommittee was organized and functioned without precedent in dealing with an ordnance production problem never before encountered and particularly under the stress of a national defense emergency.

(2) The details of Subcommittee organization, membership and activities may be found in the minutes of its meetings, some fifteen (15) separate reports, as well as several Subcommittee Circulars and Technical Bulletins and quite voluminous correspondence in official files of the Ordnance Department.

In preparing this record liberal use has been made of extracts from the stenographic transcripts of the various Subcommittee meetings to show the trends of thinking and development of methods of operation relating to the various phases of the problem of producing armor weldments for combat vehicles as pioneered during World War II. Also included are certain pamphlets and forms and portions of correspondence pertaining to the organization and functioning of the Subcommittee to indicate the general policies followed during the hectic days of rearming Democracy for the contest with the legions of Facism.

William L. Warner

William L. Warner
Senior Welding Engineer
Secretary of the Subcommittee

[redacted]

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INTRODUCTION

The production of armor and armored structures for the U. S. Army is essentially a wartime problem since, in peacetime, the demand for such materiel is practically nil except for possibly a few items for development and training purposes. Prior to 1928 welding was not used in the manufacture of ordnance materiel but came into quite general use for construction of mobile gun carriages about 1935 with the advent of commercial low alloy constructional steels and covered welding electrodes.

During the decade between 1930 and 1940 when development of welding methods and materials was being actively carried on in the shops and laboratories of the artillery manufacturing arsenals of the Ordnance Department, the activities of these Ordnance agencies were concerned primarily with the application of welding to the manufacture of weldments for mobile gun carriages and similar structures fabricated of low alloy constructional steels. Since the production of armor structures is essentially a wartime problem the development of methods for welding armor received less attention during this period although a number of tests were made of welds in armor in the shops and laboratories of both Rock Island and Watertown Arsenals.

These tests consisted primarily of ballistic penetration tests made at Aberdeen Proving Ground of butt welded test plates in 1/4 inch and 1/2 inch thick rolled homogeneous armor. During this period it was generally considered that a satisfactory butt weld in armor should develop a ballistic limit for penetration with A.P. projectiles of not less than 85% of that developed by the unwelded armor plate. Practically all of these early test welds, made with commercially available covered ferritic type electrodes on the then available high hardenability armor plate, failed to meet this ballistic penetration requirement. One experimental weld in 1/2 inch plate made at Rock Island Arsenal using high manganese austenitic type weld metal did, however, show exceptionally good performance over previous materials which had been tried. Subsequently a series of three test butt welds made with 25/20 chrome-nickel austenitic stainless weld metal in 1/2 inch rolled armor at Watertown Arsenal and tested at Aberdeen Proving Ground met this standard penetration requirement quite successfully. The results are reported in Watertown Arsenal Laboratory Report No. 648/2, 2 March 1939.

The energetic start of the National Defense Program in 1940 marked the beginning of an active effort to apply welding to the fabrication of armor. When this program was initiated the plans for production of armored vehicles required to meet projected military needs necessitated the utilization of the industrial fabrication facilities of the country to the fullest extent possible and even the creation of new ones to obtain the desired production because the producing capacity of Ordnance manufacturing arsenals is inadequate to carry the wartime production load. The conversion of these industrial facilities from peacetime to wartime production was a colossal undertaking which could not be accomplished overnight and which, as far as the production of armored vehicles was concerned, was somewhat handicapped by the lack of established manufacturing practices for fabricating armor structures.

The initial production of armored vehicles was undertaken on a relatively small scale employing riveted construction and as more facilities became available production was increased. However, soon after riveted armor vehicles had been in action information on service performance which was received indicated the desirability of some method of joining armor plate which would eliminate the danger to the occupants of an armored vehicle from internally flying rivet and bolt heads caused by the shock of impact of projectiles overmatching the plate. This was a problem in which all of the using services were vitally interested. In addition, industry, as well as the Ordnance Department, desired a method of fabrication which would expedite the assembly of armored vehicles, permit more effective streamlining, and expedite production per man hour over that obtained by the riveting and bolting process.

Under the sanction of the Ferrous Metallurgical Advisory Board an advisory body of material and fabrication specialists was formed to study the problem of welding armor and to advise and assist the Chief of Ordnance in coordinating the development of methods and procedures for welding armor and the application of such methods to production of armored vehicles. This advisory body was organized as the Subcommittee on Welding of Armor by Lt. Col. S. B. Ritchie, then Director of the Laboratory at Watertown Arsenal, as Secretary of the Ferrous Metallurgical Advisory Board, at a meeting at Watertown Arsenal on 19 December 1940.

In organizing the Subcommittee it was considered that representation was desired from armor producers, welding fabricators, and suppliers of welding materials and equipment. Accordingly, invitations by letter* were sent to the following industrial companies together with an agenda for the meeting:**

A. Rolled Armor Plate Producers

Republic Steel Corporation
Carnegie-Illinois Steel Corporation
Henry Disston and Sons Company

*Inclosure I - Appendix A
** Inclosure I - Appendix B

[redacted]

B. Armor Casting Producers

American Steel Foundries
Lebanon Steel Foundries
Continental Roll and Steel Foundry Company
General Steel Castings Corporation

C. Welding Fabricators

A. O. Smith Corporation
York Safe and Lock Company
Baldwin Locomotive Works
Electromotive Corporation
American Car and Foundry Company
Diebold Safe and Lock Company

D. Welding Materials Suppliers

Metal and Thermit Corporation
Harnischfeger Corporation
Arcos Corporation

The various standard forms developed for use in administering the affairs of the Subcommittee are included in Appendix A together with Subcommittee Bulletins W-1 and W-2 which were issued for the information and guidance of Subcommittee members in 1942.

Copies of the Agendum prepared for each of the fifteen regular meetings of the Subcommittee are included in Appendix B.

Attendance at the various meetings as recorded at the start of each meeting is given in Appendix C.

It should be pointed out that the quotations included herein which were taken from transcripts of the discussions at the various meetings have been included essentially as given therein with certain introductory statements or paragraphs by the writer.

[redacted]

FIRST MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
THURSDAY, 19 DECEMBER 1940
WATERTOWN ARSENAL

The meeting convened at the Officers' Club, Watertown Arsenal, on Thursday, 19 December 1940 with 34 persons in attendance* representing the following organizations:

3 Rolled Armor Plate Producers
4 Cast Armor Producers
6 Welding Fabrication Companies
3 Welding Material Suppliers
Office, Chief of Ordnance
U. S. Navy, Bureau of Ships
Aberdeen Proving Ground
Watertown Arsenal

Brigadier General R. W. Case, Commanding Officer, Watertown Arsenal, and President, Ferrous Metallurgical Advisory Board, presided at the opening of the meeting and after brief introductory remarks turned the meeting over to Colonel Ritchie, who presided for the remainder of the discussions.

From the agendum** for this meeting it may be noted that the subjects of discussion were primarily concerned with the organization of the Subcommittee, specification requirements for welds in armor, and proposals for development of armor welding methods by co-operative activity between industrial and service agencies.

In his introductory remarks General Case indicated the general purpose of the Subcommittee as follows:

> "The Ordnance Department appreciates very much your giving your time to come here and consult with us and with each other in the solution of our problems--this one being particularly the welding of armor plate. The work of these Subcommittees will be coordinated by the Metallurgical Board, and their advice will be asked for in connection with the problems that are submitted to the various Subcommittees. We feel that by this method we can have a coordinated effort on these metallurgical questions, and get results that we probably would not be able to get in any other way."

*Appendix C
**Inclosure I - Appendix B

[redacted]

Lt. Colonel Ritchie further elaborated on the projected activity of the Subcommittee as follows:

"As stated in the agenda, the objective of the Subcommittee is to be directed toward developing suitable procedures and materials for welding of armor. As most of you know, considerable experimental and development work has been in progress for some time. The Rock Island Arsenal, Watertown Arsenal, the Aberdeen Proving Ground, and a number of industrial concerns have made progress in this field. Here at Watertown, we have a number of co-operative programs underway with certain outside firms. In view of the number of individual efforts, it seemed desirable to establish a group to advise and assist in this research and development. This group, or Subcommittee, would act as a coordinating agency and a clearing house for information. As General Case also mentioned, at this preliminary meeting, we have attempted to invite a cross section of those who have a knowledge of welding armor or who are actually doing it at the moment, as well as fabricators and electrode manufacturers and producers of plate.

"The work of the Subcommittee will cover the development of suitable welding procedures for rolled and cast armor, homogeneous and face-hardened, in thicknesses up to at least three inches. This will involve the development of suitable methods and materials for welding of armor for use in the construction of tanks and other armored vehicles and for field repair.

"The problem of the repair of defects in the manufacture of cast armor, with special reference to the foundry, presents certain questions. How far can we repair defects? If we do repair them, what tests are necessary, in order to insure that we are going to get serviceable performance and suitable treatments to insure the best condition in the weldments? Test procedures necessary to guarantee proper performance in service will be objects for consideration. This will bring into the picture standards for inspection of weldments, possibly to include magnaflux, X-ray, and visible characteristics.

"The matter of specifications, obviously, will be very important. They are very important at the moment because of the production programs which are under way and will soon be under way. I want to mention at this point that, of course, research and development will continue to insure that maximum improvement possible in welds, and they will continue to be one of the prime considerations of the Subcommittee. With that in mind, we have put a topic in the agenda asking for comments for a program to insure that that will be done, and to indicate facilities and procedures whereby it may be most effectively carried out."

[redacted]

At the time of this meeting there were no armor weldments being produced on a production basis for the armored vehicle program, although one or two experimental tank turrets had been fabricated for test at Aberdeen Proving Ground, but no standards of performance for such weldments had been established. Major McInerney, Office, Chief of Ordnance, commented on the problem as follows:

> "We have already made a decision that for our light tanks, the turrets will be of welded construction. The American Car & Foundry Co. has been directed to proceed along that line. That is the first definite decision that has been made, as the result of our experimental work. In addition, we propose to have the manufacturers of our vehicles each furnish one welded body. We have found that the turret can be satisfactorily welded. As a result of that, we are having two armor plate manufacturers weld complete hulls. The problem with the hull is entirely different from that of the turret. At the present time, we feel that there is no requirement in the turret which requires stress relieving. With the hull, which is a large structure, where a distortion is much more likely to take place, there is a likelihood of that problem. The stress of the turret is in no way similar to that to which the hulls will be subjected. With the medium tank, we have found that the cast hull meets all of our requirements. With the light tank, however, we feel that there is still a requirement for the rolled plate, and it will be of welded design. I think that our immediate problem is to set up some system by means of which we can coordinate all of these activities."

The fact that, at this period, all matters pertaining to armor plate manufacture and fabrication were classified as "Confidential" by the War Department, and so handled by the armor producers with respect to interchange of information between each other, presented an obstruction to the successful coordination of research and development activities in the welding of armor because it prevented free exchange of data and information between the people working on the problem. Each armor producer had his own armor composition and heat treatment procedure developed, or was in the process thereof, but the pertinent information pertaining thereto could not be disclosed to other industrial representatives outside his organization without violating security regulations. Thus correlation of data and free exchange of information between industrial people working on the problem of welding armor was stymied at the start.

This situation was rather forcefully emphasized by Mr. Smith (Republic Steel Corporation) in the following remarks:

> "I think before the information is freely given, it must come upon orders of the Management of the various large producing companies, at the request of Washington, properly constituted people there. Unless that request is made, I very much doubt whether you will get full co-operation. I will give

you a specific example of what I am talking about. I was called on the telephone the other day by a man who is a very good friend of mine; he is the head of a responsible company. He said to me, 'I would like to discuss the whole problem of armor plate with you.' I said to him, 'If you will come to me with an order from General Wesson and one of the executives of my company, I will tell you anything you want to know about it. Otherwise, I will tell you nothing.'

"There is no machinery set up with the steel producers, as yet, to provide for free interchange of information, and I think it would take executive order from the various executives to provide for free interchange, and I think it should be done. I see no reason for not doing it, but I would say that it would require executive order from the various people before it could be done on a full scale, and there is no use in doing it unless you do it on a full scale. I see no way in the world to get the work done if we are going to confine it to this circle. It is my opinion that there is a time in the not too distant future when any information available will be put into the hands of any reputable organization in or outside the group. I think there should be a definite understanding that goes back to the executives of responsible management. The ramifications of a big company are much more difficult to control than the ramifications of a small unit. Information that is in my possession here and in the possession of certain of my men has many more outlets that it can come in contact with than the information which might be in the hands of even this eight-foundry group. I don't know the number of men involved in the foundry group, but I know it must be modest. Now, if this type of information is to be pooled and is to be recirculated, I think Management of the big companies should issue that order, and it should be blunt and broad in its scope, so that whatever is present is not only available on request, but should be furnished.

"I believe there has been no withholding of information of anything that has been done in the steel plants from you gentlemen of the service; but, I think there would be a distinct feeling on the part of the executives, some of these people who have put in years, like Lightner's organization has, if they have to bring down everything and say, 'Here it is; give it to anybody in the country you see fit to give it to right now.' I think that the head of the Ordnance Department, or the head of the Navy, should bring out everything that could be brought out, and put it in your hands, to do with such as in your judgment it is correct to do with it. Otherwise, I don't think you will get it."

The sense of the meeting on this situation was summarized by Lt. Col. Ritchie as follows:

"It seems to be the feeling of the electrode manufacturers represented here that they would not deem it necessary

[redacted]

or probably could not disclose the compositions and other details pertaining to the coatings on electrodes, but that you could make available other information pertaining to the use of those electrodes, the composition of the alloy, and so on. The cast armor group, I believe, are willing to place the data they have on the table before the whole group. Some of the others present feel that it is necessary to go back and have, let us say, the Chief of Ordnance make a specific request to the firms for disclosure of this information to make it available to the Subcommittee. It seems to be the consensus of opinion that this letter should be signed by the Chief of Ordnance."

Discussion of ballistic tests of weldments indicated that a 25/20 stainless steel electrode is the only satisfactory electrode available for welding of armor at this time. It also appeared that welds made with this type of electrode in armor do produce ballistic limits in excess of the tentatively established acceptable minimum of 85% of that specified for the unwelded plate.

Experience at Aberdeen Proving Ground up to the time of this meeting was outlined by Mr. Harry Rouse as follows:

"Aberdeen, within the last six months, has tested a number of welded plates. We have also tested some welded turrets. The ballistic properties in the weld have run from 85 to 90 per cent; that is, of the plate. On some heavy plate, furnished by Carnegie-Illinois Steel Corporation, on which we ran comparative tests with a riveted structure, we have gotten ballistic qualities of approximately 85%. That was using a 37 mm. projectile for penetration. In comparing that to the riveted structure, it was rather difficult to give the ballistic value of the riveted construction because by our definition of complete penetration, which is defined as light passing through a plate, you can very readily see the difficulty of getting it, or rather knowing when you had a complete penetration in it, because of the riveted structure. You get a rivet, and at very little blasting, you can knock it out. So it is rather difficult to get a direct comparison, as far as penetration is concerned. Now, in shocking these two plates with a 75 mm. projectile, it was a contrast rather than a comparison. In the matter of the welded structure, it stood up very well. As a matter of fact, there was practically no effect on the weld. The velocities used were the specifications of velocity for that thickness of plate. With the riveted plate, the gunner was very fortunate that day; he hit the plate right in the center and there was one rivet left holding the two plates together. As far as structures are concerned, we have tested a turret for the medium tank, and as well as we can determine the ballistic limits, the weld ran approximately 85 to 90 per cent of the plate; it stood up very well on shock test, with 37 mm. This was one-inch face-hardened plate. There was very little cracking

[redacted]

of the weld, and in some of the complete penetrations, there was a little spalling on the face, or back. Within the last couple of months, we have tested two turrets, for the light tank M2-A4; one was of welded construction. In that case again, the welded construction stood up much better. With the riveted turret, we were able to shoot out the rivets with a 50-caliber at low velocity. With the same joint welded, we were able to get through at approximately 2500 f/s velocity. The shock testing of these two brought these results. In the welded turret, after practically the same amount and probably a little more, with a 37 mm., on one-inch plate, the welded structure was in much better condition than the riveted one. As far as other structures are concerned, on the hull structures for instance, we have practically no information; and, although we have given instructions to make the turrets welded, I don't think that will apply to hulls until we make more tests. Now, as far as ballistics are concerned, I think we have no worries with the welded hull."

Major McInerney commented briefly as follows:

"We have not yet made any tests of any welded structures, to see how they would stand up under the actual service conditions. Our only tests to date have been ballistic tests. We are satisfied that welded structures are more satisfactory, from the ballistic point of view.

"One of the objections which has been advanced regarding the cast turret and the welded structure is the difficulty of repair in the field. In other words, when they bolt or rivet a structure, we can take out that individual plate. So, in order to test what conditions we would have with a cast structure, we took one turret which had been fired at with both 75 and 37. The ballistic limit of the plate in the turret was established; there were large holes up to three and three and one-half inches in diameter, and these were rewelded and the ballistic limit re-established, which was somewhere between 90 and 95 per cent."

At the time of this meeting there were no Ordnance Department specifications for welding of armor in existence although Rock Island Arsenal had previously prepared a tentative specification for the procurement of one welded turret on an experimental basis. Standard methods of ballistic testing weldments or other types of armor structures had not yet been developed. Thus fabricators attempting to develop welding procedures and train personnel had no recognized standard method of comparing and evaluating results. This problem of specification and qualification testing of welds in armor was of primary importance and was discussed at length.

Mr. Libert, Continental Roll and Steel Foundry Company, emphasized the need for a standard test for weld repairs of armor castings as follows:

[redacted]

"That point is in the specifications, that they can be welded by a qualified method. In order for our method to be qualified, we have to have some standard to go by, to submit qualifications. On a small plate, on the first one, we didn't weld all the way through. In other words, we assumed that was the deepest crack we could get, and cut it out at that dimension, welded it up and shocked it. In other tests, we welded two plates together, so you got a ballistic limit on the complete weld. What I want to know is, what type of test are we going to have to submit to qualify in our specifications, so that any of this development work we are doing can be used intelligently after it is all finished?"

With regard to the question as to whether the test should be made of a flat test plate or a welded structure the Navy viewpoint was suggested by Lt. Watts, Bureau of Ships:

"Actually, our problem is a little different. Our structures are all incorporated into the basic structure of the ship. They aren't isolated structures in themselves. So that it would be rather difficult for us to make a test of the structure as it is finally completed."

The thought that structural serviceability rather than ballistic serviceability is more important was suggested by Mr. Sibley (Henry Disston and Sons):

"I don't think it is necessary to weld a structure so far as the ballistic tests are concerned. It is not necessary to fabricate the test plate into a box or structural thing, because the attack is so rapid and impact is absorbed so rapidly by the plate that the other joints are not affected. I do not think the ballistic angle is very important at all. We almost have it licked. What we are afraid of are the vibrational fatigues, the running fatigues, which we know nothing about. As far as we are concerned, we believe some of the practices we have used do harm as far as the weld is concerned structurally. We don't know that, but I think the structural angle is a most vital one. That is the big problem."

Major McInerney stated the immediate specification problem as follows:

"There are two immediate problems for us to solve. I told you this morning that we have decided we would weld our turrets for the light tanks. That, necessarily, means that we must get out a specification or some means of testing, to see that we are getting what we want. In addition to that, we have decided to use cast structures. In those structures, we will have to do a certain amount of welding. How much welding we will do and how to test; those are two immediate problems that must be solved in the form of a specification."

A proposal for a penetration test was made by Mr. Rouse:

"Here is what I will offer in the way of a penetration test. I think we can probably go a little bit better and say

[redacted]

ninety per cent of the specification for the plate. The way we go about that is that we actually should not be required to get a ballistic limit, but to do this. Put ten shots in an area and they will be an inch and a half to two inches from the weld at ninety per cent of the specification velocity. Three of those shots must be within an area three-quarters of an inch from the center of the weld. If we get no penetration, then that weld is acceptable."

With reference to the form of test weldment to use, Mr. Warner raised the question:

"Is a test of a flat joint, in a piece of flat plate, necessarily a proof that the weld procedure is a satisfactory one for the building of a turret or a structure of some sort? In other words, in a single joint, you don't get the stresses set up, it seems to me, that you do when you come to put a structure together of this hard tempered material. I should think that the proof of a procedure should require the building of some structure of some kind, like a box of a certain minimum size, and then fire at that, as Mr. Rouse states, not for penetration, but for resistance against vibration and shock. In other words, give it a bump test."

Mr. Emery objected to the idea of using a structural specimen instead of a flat plate specimen with the following comment:

"I don't think a box in itself would give you that. The mere fact that you have a square box shows that your stresses are all, more or less, related. I rather like the flat plate idea, with an H-weld. The two outside welds are made first, and then the leg of the "H" placed across the center. Now, if there is any way of confining more stresses to plate than that, I would like to find out. I think that would answer Mr. Warner's question regarding stresses, more nearly than any other form of structure."

It was considered that the problem of repair of castings is a separate and distinct problem from that of fabricating a welded structure of armor by reason of the following point suggested by Mr. Landgraf:

"I think one point has been overlooked or wasn't mentioned, and that is the fact that in repair welding, the strains of welding would be probably entirely relieved by subsequent heat treatment, whereas in fabrication work, that would be impossible."

The discussion of preheating and stress relieving indicated that the armor casting producers and plate fabricators did not desire to be tied down too definitely by specifications as indicated by Mr. Raymo:

"After all, you want these things built quickly, and we should look toward a welding procedure that will require no subsequent heat treatment, if possible. I think that is the direction in which our work should be pointed. Therefore, I would like to say again that if this Committee is going to carry on and develop metal work, this ought to be along the lines that will permit minimum difficulties in getting these things built in the minimum amount of time."

The sentiment indicated by Mr. Raymo appeared in keeping with the spirit of the meeting. It was evident that lack of production experience in fabricating armor weldments prevented agreement on establishing standard practices with respect to welding of armor plate structures or repair of armor castings by welding at this time.

With respect to qualification of welding procedures under specifications the proposed policy of the Ordnance Department was indicated by Col. Ritchie:

"I think that we will propose to continue our present procedure; that is, test plates welded together for structures, and also for qualification purposes for the cast people and for repair purposes. However, in the event that you propose to weld at two different stages and possibly with two different types of welds or two different types of rods, two different samples will have to be submitted. I think that we will have to continue that procedure until we find something better. We will draw up specifications according to the results obtained at Aberdeen, and I believe you all realize our specifications at all times have been fair and have been the result of accurate tests. That is what I propose that we continue to do."

The test specimens to be proposed were indicated by Major McInerney:

"We will propose two 18x36 plates, which will give us a test plate 36x36, with one weld. We will use that, until we find out by test that something else is more desirable. In the case of structures, we will propose to periodically and at different intervals take a completed structure and test it. We must always consider that when we had our riveted and bolted structures, we didn't test them to see what the efficiency of that joint was. So, I feel that we are heading in the right direction by continuing to press this procedure, unless some better procedure is recommended. If it is the consensus of this gathering that an "H" weld would set up stresses which would more nearly duplicate actual conditions, I would give it consideration."

With reference to the use of the "H" plate there was a confusion of ideas as to the significance of such a test. None had had any experience with it.

Major McInerney commented:

"Mr. Chairman, the point was brought up that if we weld an 18x36 together to get a 36x36, we have a plate in which there is very little likelihood of any residual stress, which probably

[redacted]

does not simulate the conditions that we get when we weld a number of sections together to make a built-up turret. Mr. Emery believes that the best proof as to whether we are getting residual stresses in this structure is to make a test plate of this nature; and, let us say, if we continued our 36 x 36, you would have four plates of different sizes which would make that particular dimension."

To which Mr. Emery replied:

"That is right. The weld would be in the form of an "H"; you make two vertical welds first, and then make the cross bar of your "H" last."

Mr. Sibley voiced a comment regarding the desirability for testing production weldments:

"I think that you will still have to revert frequently to testing parts of your final structure, because when you are welding hulls or welding turrets, they go into one position, and possibly the kind of welding you do on an "H" joint will be in favor of the weld. There may be things in the structure that make welding more difficult, and they certainly should be proved, because those are the welds that are going into action."

A general comment on the qualification of procedure was voiced by Col. Jenks:

"I see no reason why you should limit yourselves as to preheating or stress relief. If you are not going to damage the material by preheating and the welder desires to develop that method, why not let him? If you can stress-relieve and still not do any harm to the structures of your plate, why not let him do it? You are not ready to standardize on that. You must allow the fabricator to develop individually, at the present time, until you can answer some of these questions."

The Ordnance Department viewpoint on preheat and postheat of armor weldments fabricated of rolled plate was indicated by Maj. McInerney:

"At the present time, we have only approved the welding of turrets; and our tests, so far I think, have conclusively indicated that there are no dangerous stresses set up. If there were stresses set up in the turrets, they would certainly be relieved, after being shocked as severely as we have shocked them. I don't know how else to relieve them. Now, that part of the vehicle is not subjected to the same type of stress that will be put on the hull, when you get weaving and warping due to the type of service. A turret is not subjected to that type of service. We are concerned with the internal stress and should it be a case of where a slight shock would relieve the stress, then it would crack or fracture the plate. As I said, we are basing our approval on the fact that in both cases, no preheating and no subsequent heat treatment were required. But there, again, we will possibly not grant our approval."

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In response to a question as to whether the Ordnance Department would prescribe the type of joint in a welding specification Maj. McInerney replied:

"We are only interested in the ballistics. If one man can get the same ballistics by one joint, and another man can get it by another joint, I don't think it should be up to us to prescribe the method, unless we have definitely found out as the result of a number of tests that one particular joint has much more merit than others."

In the ensuing discussion of methods of qualifying welding procedure and limits on repairs for cast armor it was brought out that some standard would have to be established for the amount of repairing of castings which would be permitted. This standard will have to be dictated by experience. Strategic considerations did not enter these discussions.

It was suggested by Mr. Sibley that the shock test should not be made of the same test plate used to determine the ballistic limit for penetration. This method will require two test plates for each welding procedure to be tested.

There was agreement as to the use of the "H" plate for the shock test in qualification of welding procedure and in addition certain production check testing may be required as indicated by Maj. McInerney:

"That is correct. In other words, we might take one out of the first twenty-five, or two out of the first twenty-five; but, we will require a certain number, the same as we do in castings, to see that the manufacturer of the turret is doing what he did do in the test plate. We will put that in the specifications."

This thinking involved the production of welded turrets only. Whether this policy would also involve welded hulls as well was not indicated at this time.

The suggestion that all test plates and test weldments should be X-rayed before ballistic shock test was made by Dr. Lester:

"In regard to that, I would like to say this. I think we ought to X-ray every one of these before they are shocked."

There appeared to be general agreement that for test purposes and accumulation of data X-raying of test specimens should be done but the problem of lack of equipment limits the extent of use of this method at this time. A plea to give the fabricator a free hand in developing his welding methods was made by Mr. Miller:

"I would like to say before this committee that whatever we do along this line, we should all keep in mind not to tie the manufacturer down too tightly. I would like to see production gotten out. If you get too much theory and

and too much technicality in the performance, you won't get tanks. I have always figured that something was better than nothing. I wouldn't like to see too much detail. We have to make too many X-rays and magnafluxings."

The emphasis on production of armor weldments was indicated by Col. Ritchie:

"I am sure we don't disagree with you on that. Also, as a matter of safety to the manufacturer, as well as to the national defense, we want to insure that adequate tests are put in so that when this material gets into service, it will stand up. We should not, however, as you say, put anything in the way of production, providing we can safely insure the other end. At the same time, while we are going ahead with production, I believe it is highly desirable to push research and development, paralleling that, but not letting research and development handicap production and have production wait until we decide some technicality. We have to make a decision and go ahead on our best judgment, with the safeguards that can be put in the picture at the time. We must have production."

A suggestion was made by Mr. Rouse regarding the two test plates to be furnished for ballistic test for each procedure qualification:

"I was going to suggest if we furnish two plates, one of them of the straight weld, and the other the "H" type weld, for the shock test only, that would be satisfactory."

This was unanimously agreed upon.

The general policy as to scope of the proposed specification for welding armor was summarized by Col. Ritchie:

"We don't want to do anything that will complicate this picture in any way, shape or form. We will make the welding specifications complete in themselves. Put in what we agree is necessary and reasonable, and let it stand on its own feet, without having reference to the other one WXS-31, which applied to another type of welding, structural steel."

The thicknesses to be used for qualification of welding procedure for rolled armor plate were indicated by Col. Ritchie:

"We have settled the thickness of the plate for the face-hardened, which will be a quarter of an inch and an inch, and for the homogeneous plate, I think we can use the same thicknesses as are used in the specification which is AXS-488."

For cast armor plate Maj. McInerney suggested:

"On thin, cast plate, we will still require the same thicknesses as are required by AXS-493. We will, under all

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of these tests of plate, require a straight weld for resistance to shock."

From these discussions it was apparent that the specification for welding of armor to be prepared by Watertown Arsenal Laboratory was to include requirements for qualification of welding procedure, ballistic testing and inspection of welds as indicated above. A draft of the specification will be sent out for comment as indicated by Col. Ritchie:

"It is understood, then, gentlemen, that we will attempt to draft this specification as promptly as possible, and after it has been coordinated with the people in the service, or while we are doing that coordinating, we will send copies out for your comment and discussion and approval."

With respect to chairmanship of the Subcommittee, the problem was outlined by Col. Ritchie:

"Now, as to the Chairman of the group, these Subcommittees have been organized in the Ordnance Department and, in many cases, the Chairman of the group is named by industry or the members outside of the service organization, from one of their own group. I would like to have the feeling of the group with respect to that matter. We have had cases where the Chairman is named from the Service, but we would like to have the industrial people consider naming the Chairman from their own group. We have a very nice illustration of one phase of that in our present cast armor group. We have a Cast Armor Subcommittee, and the Chairman has to be in Watertown, but the group itself is organized into a Cast Armor Development Group, which functions nicely as a unit and ties in with the group as a whole, as well as the Service representatives."

Col. Ritchie was nominated by Mr. Miller:

"In view of the fact that four or five different industrial groups are represented here, if it is agreeable, I should like to nominate Colonel Ritchie, as Chairman of this group."

This nomination was unanimously endorsed, and Lt. Col. Ritchie was elected Chairman of the Subcommittee. It was decided to hold the next meeting at Aberdeen Proving Ground within the next month or so, subject to the call of the Chairman.

A discussion of research and development work considered desirable indicated that there was considerable interest in low temperature impact testing of welded joints and that work along this line should be carried on. The situation at Aberdeen Proving Ground on low temperature ballistic testing was indicated by Mr. Rouse:

"That has been under discussion, but it seems to me there will be a little distance to go yet. It is probably something that I don't know anything about."

Some work has been done at Watertown Arsenal with hard facing metals, but ballistic results are inconsistent. With respect to amount of reinforcement and design of joint, there was objection to prescribing these in a specification, and a feeling that such details should be determined by experimentation was indicated by Col. Jenks:

> "I think that you should determine that experimentally. You may throw a stress concentration alongside of your weld. If you throw it in the zones that have been weakened on account of heating, you may have failure alongside of the welds. You should determine that experimentally."

This viewpoint was also voiced by Mr. Loomis:

> "I believe you will find after a certain amount of research, certain types of joints are more desirable than others. There are fundamentals about joint design that should be incorporated in this."

It was agreed to leave the question open for future development as indicated by Col. Ritchie:

> "I agree that it should be left open. I am thinking how we could assimilate as rapidly as possible data pertaining to it, for use on future orders, as soon as possible."

The size of the membership of the Subcommittee was discussed and suggestions were made regarding the addition of representatives of companies engaged in development work in the welding of armor. The guiding thought in selecting those who were invited to this meeting was explained by Col. Ritchie as follows:

> "This group was based on those who have had experience in some form or another with welding of armor, or who are actually engaged right now on the welding production. There was a specific reason for selecting each of the three welding rod manufacturers. The group of welding rod manufacturers was so large that we didn't feel we could bring in any more than a few representatives. That was the guiding thought in selecting this initial group, to gather together those who had actually welded with the rod, and not necessarily involved in just the furnishing of electrodes, but who had some part in the welding, or working with us at the moment."

The Lincoln Electric Company was indicated as working with ACF, Diebold Safe and Lock Company, and others, so that that company was voted into membership.

In concluding the discussion Col. Ritchie summarized as follows:

> "I shall now turn the meeting back to General Case. Before I do so, are there any other questions that any of the members wish to bring up? I believe we left the next meeting open. Also, we shall ask the individual firms, through a letter from the proper channels, for a placing of the data on the table for future work, and we will proceed with the drawing

up of the specifications now, and submit the draft to you for further comments, and you will submit to us any comments that you may have with respect to research and development. We also agreed that low temperature tests should be carried out, and outside of the armor plate field, we should look into the specification that we have just discussed. We have decided to ask Mr. Lincoln to become a member of the Subcommittee."

In conclusion General Case thanked those present for their interest and co-operative attitude on the problem of welding armor and expressed the thought that this Subcommittee activity would result in definite accomplishment.

Lt. N. A. Matthews acted as Secretary for this meeting and prepared the minutes for distribution to those who attended.

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SECOND MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
21 JANUARY 1941
ABERDEEN PROVING GROUND

The second meeting of the Subcommittee was held at Aberdeen Proving Ground on 21 January 1941, with 40 persons in attendance from the industrial organizations and service agencies represented at the previous meeting. Representation from the Lincoln Electric Company was also present as noted at the previous meeting.

Immediately after roll call by Lt. Matthews, who had been designated as Secretary, the firm of Maurath, Inc. was elected to membership as represented by Mr. G. A. Maurath, who was present.

The meeting was welcomed by Brigadier General J. B. Rose, Commanding Officer, with the following opening remarks:

"The thing that impresses me most about the work of this committee (I have been looking over the minutes of the last meeting) is the fact that we are going about this matter in the right way and it is certainly gratifying to see the progress compared with past years. I mention this because I know all of you feel that it is difficult for you to arrive at conclusions because you don't have adequate data in many cases, but I ask you not to feel discouraged because that is the usual condition as most of us well know. We don't have the data and that is where the Proving Ground comes into the picture, as far as the ballistic elements of the proposition are involved. I have had quite a number of years in the preparation of specifications, and I know how we had to do it the last time. We worked in specifications the best way we could, but when they got out no doubt many people thought they were arbitrary. There was no intention of being arbitrary. Those preparing specifications make them up in the light of information they have on hand. Now we are preparing specifications and getting the most competent advice from those who are concerned in the work and it can only come to a satisfactory conclusion if we iron these things out right at the beginning."

As decided at the first meeting of the Subcommittee, a tentative draft of a specification for welding of armor (AXS-497) had been prepared at Watertown Arsenal under date of 30 December 1940 and sent out to those who had attended the meeting with the request that comments be prepared for discussion. It was planned that this draft of AXS-497 would be considered at this Aberdeen meeting.

In his opening remarks at the start of the discussion, Colonel Ritchie warned those present:

"I would like to mention at this time and caution you again in respect to the handling of 'restricted' material, or material of higher classification that might come into

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your hands through Subcommittee activities. We feel that special care should be taken that this material does not fall into unauthorized hands."

In addition Col. Ritchie briefly explained the status of the Subcommittee with respect to Ordnance Specifications as follows:

"Before we start the detailed discussion of specifications, I would like to again mention that the nature of this Subcommittee is only advisory. The decisions and discussion that we might have in this group cannot, of course, be taken as authority for change of specifications which are already approved by the Chief of Ordnance or any other change in any other aspect or procurement in the future, without authority of the Chief of Ordnance or other proper authority. I want to make that absolutely clear. If we discuss a change of specification in this group, it must not be taken as authority unless, or until, that change has been approved by other proper authorities. I am sure there is no misunderstanding on that point. This Subcommittee is merely advisory in nature to offer recommendations."

It was decided to discuss the draft of the specification paragraph by paragraph. As drafted the specification included coverage of both fabrication and repair of castings but was intended to apply only to arc welding. It was not intended to apply to repair of defects in rolled plate. After discussion it was decided that the question of repairs to base metal should be covered by the base metal specifications. In this draft of the specification an attempt has been made to specify the factors of a welding procedure as a general requirement. There was considerable discussion as to the desirable extent of delineation of the various factors specified.

With respect to weld metal deposition Col. Jenks commented:

"You have 'metal or beads'. I think you ought to have a knowledge of just how those beads or layers are laid down, whether you are laying them down with a weave or how you are laying them down. I think you ought to go a little more into detail there. It depends on just how you lay them down. Your heat factor depends on just how you lay them down."

It was suggested that thickness of base metal should be considered as a factor which was accepted as indicated by Mr. Warner:

"It seems that thickness has something to do with this as Col. Jenks suggested and we could add thickness so it should read 'Type, Class, Composition and Thickness of Armor.'"

An objection to close prescription of welding details was voiced by Mr. Bibber:

"In order to present the picture, I would like to point

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this out; in welding one of these tanks we are going to have many different thicknesses ranging from 1/2" to 2-1/2" or more, and we are going to have many different kinds of joints at 'cock-eyed' angles. In many cases the procedure of welding these will depend on how the welding is controlled (sometimes it warps on one side or the other), and we have many different types of joints and thicknesses. I don't quite feel that the information on the qualification test should be restricted too much."

Mr. Warner commented on this objection as follows:

"My understanding of this in the first place is that this list as mentioned by Lt. Watts is to furnish a common basis of understanding as to what the inspector means and what the contractor means by welding procedure. Now, Mr. Bibber means all sorts of variations from that. You can't expect to cover everything. What we are concerned about is whether the general method is going to work or not, and we have got to permit certain variations from that in the construction of tanks. We are trying to educate our inspectors at Watertown to use a certain amount of discretion and common sense and try to instill the idea that because a little different size electrode and different current are used that he is not to throw that joint out or prevent usage of such. The welding engineer should know something about welding; if they don't, the contractor should not have the job."

Delineation of these factors with respect to setting of tolerances was not attempted at this time because of lack of practical experience in production welding of armor. With respect to preheating and gas cutting, there appeared to be a desire to limit the former but not the latter as to scope of application.

The fundamental idea of qualification was expressed by Mr. Taylor as follows:

"You have no interest in how it was done at all. If the plates were gas cut or preheated or welded in any manner he may choose, it is all right if it passes your acceptance test. All the manufacturer has to do is to follow that same method."

It was suggested by Mr. Warner that this could be taken care of in the specification as follows:

"I think if we revise C-2a on page 2 to read something like this, 'No fabrication or repair of weldments or castings will be permitted except with welding procedure as specified in paragraph F-2,' that may be more satisfactory. In other words, if the manufacturer or contractor wants to gas cut or preheat on a particular type of material, then he should bring those processes into the making of this qualification test.

If ballistic test is passed all right, then he should be permitted to go on with the manufacturing program."

The matter of limitation of weld reinforcement was discussed at length. The ordnance designers' viewpoint was explained by Col. Christmas:

"I think the limit has to be made either on the specifications or on the drawings, or otherwise you can't be sure what you are putting inside. I have seen where a 3" reinforcement has been used. If you do that inside we cannot get our stuff inside. 3" makes a lot of difference inside a tank when you have to put in ammunition, oil tank, etc., even 1/2" makes a difference. We have got to know what those welds will amount to or we will not know what we can put inside of it. It is absolutely necessary because you can't let a man put in any amount of reinforcement and not know what amount it is. One of the first questions a man wants to know in laying down a tank is how close can I come to this corner, can I rest this thing on the floor? There has to be room for wiring, machine instruments, turret rings, ammunition, etc., and surely he has to know what he is working out."

This was further amplified by Mr. Bibber:

"We are talking about two different things here. I think Colonel Christmas has fillets in mind, which is covered in the next paragraph. As I understand it, we are talking about reinforcement on butt welds. The point has been raised here that this weld metal costs money. It has not been raised quite high enough. It is going to cost a lot more, and I don't think any manufacturer will throw it away recklessly. We would only want a modest reinforcement on our welds. Reinforcements on fillet welds is decidely undesirable. We should not be permitted to put them on."

A question regarding weld reinforcement on qualification test plates was raised by Mr. Warner:

"I would like to ask if there would be any objection to qualification of butt welds with the weld ground flush with the plate?"

This was commented on by Lt. Reed:

"I think that I could predict an objection there that we would not get 91% to 97%. In determining the difference between complete and partial penetrations, it makes quite a difference whether the weld is ground flush or not."

Upon questioning by Col. Ritchie, Mr. Bissell outlined the Navy practice as follows:

"We covered that by specifying '1/32" or not more than 1/8".' That is handled by the inspectors. As far as applying castings or fittings, I would say that you would save time by making castings standard and taking your reinforcement off. Reinforcements on the castings add that much more resistance

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at that point and we are very much against putting on excessive reinforcements. It is bad under other circumstances. I would say your qualification test should demand it to be within the reinforcement of this limit. 1/32" - 1/8" would give you the tolerance that you require."

The result of this discussion was the following wording for the paragraph D-2b of the draft of AXS-497 covering reinforcement of butt welds:

"The thickness of all reinforcements of butt welds and repair welds shall be not less than the percentage of the plate thickness used on procedure qualification test plates and test castings."

In addition it was decided that limitations required for clearances should be placed on the drawings to guide the fabricator in particular cases.

The question of repairs to castings was disposed of as suggested by Col. Ritchie:

"The question now arises should we put repair in this specification or in the casting specification; also, the matter is up as to whether or not this specification has, or will adequately cover the type of repair in question. I think it is the feeling of the group that we are entirely in the air. Perhaps we should refer this matter of repairing castings to our Subcommittee here today, who probably do not know the position on cast armor. Mr. Hamilton is Chairman of the Cast Armor Group, which includes all of the Cast Armor Submembers, and, if agreeable to you and in order to expedite matters on this, I would like to refer that matter to the Cast Armor Group and ask that they give us a draft of a paragraph or paragraphs for insertion in this draft, or the cast armor specification itself to cover welding on repairs of cast armor."

There was considerable discussion of joint design and size of fillets to be used with groove welds. It was generally agreed that all fillet welded joints should be full penetration welds. With reference to size of fillet to use, Mr. Bibber suggested:

"The Navy is using 1/2-T and we recently found it capable of bending very strong metal. It is a better way of going about it than picking something out of the air. This happened to be made in one that was not grooved out. In a grooved-out one I still think that the 1/2-T wouldn't be particularly bad, and I would have no objection to that. I am not telling you specifically to use 1/2-T, but I am suggesting that you do a little of this test work which can be done with small samples."

With regard to joint design the viewpoint of the fabricators was expressed by Mr. Bibber as follows:

"We would prefer that you leave the design of the joint

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to us, because we can obtain the efficiency in many different ways by different angles. By different corner designs, we can obtain the same answer in many different ways. It would depend on the method of assembly, torch cutting or various other factors. So long as we attain the results you want, we believe the means of doing it should be left up to the fabricator."

With reference to imposing limitations on the width of heat-affected zone of the welded joint in armor, there was considerable discussion as to how it should be measured and what the limit should be. One viewpoint was expressed by Col. Christmas:

"I think there should be a definite limit on the zone; that the criteria of the heat-affected zone should be hardness. It is not practicable to determine that ballistically to any great extent. I think that the Brinell hardness would be close enough to see how far the heat affected the plate. There should be a definite limit on that."

The fabricators' viewpoint was expressed by Mr. Smith, Republic Steel Corporation as follows:

"You have got to qualify these welders to do a high type of work. I doubt if you have any satisfactory method other than the skill of the men you put in there. The qualifications will have to be rigid as to the degree of skill used. You suggest hardness--it is possible--but only over the immediate area, and even one inch away from that may be something fundamentally different. I would highly recommend that you set up your qualifications so they depend upon the integrity of the organization that is doing it. Let the Navy comment on what they have done under similar circumstances. They can't take their battleships apart to look at them."

The Navy policy was outlined by Mr. Bissell:

"We require that the contractor, in producing each joint he is going to use, record his current, voltage and speed. The whole procedure, when we start production work, will not deviate from those conditions more than 10% or something like that. He has shown us what he can do. When he goes into production, if he follows the same procedure, we assume that he will get the same results that he has given us on the test plate."

In connection with limits on weld defects the draft of AXS-497 listed specific defects in paragraph D-4 and prescribed that in production welds these defects must not exist to an extent greater than that found in qualification test plates. The idea was that production welds need not be any more perfect than the condition which qualified in the test plates. This was pointed out by Col. Ritchie:

"We didn't want to be too severe. If the sample passed the ballistic qualification test and that plate had certain minor defects in it, why should we have more severe requirements in the article itself?"

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An objection to this principle was voiced by Col. Jenks:

"You are going to set up several different shops and you must have an absolute standard that is available at all places. You may get on with incomplete penetration in some plates without undue harm. It seems to me you have got to set up a standard of a general nature, and you have got to use some judgment in your interpretation of it. What are harmful defects?"

In the absence of production experience to indicate a better principle, the subject was left for future discussion as experience accumulated.

With respect to guarantees by the fabricator as to serviceability of vehicles, Mr. Sibley indicated the viewpoint of the fabricators:

"This business of guarantees, I think, brings up a question that some of us might want to comment on. If there is a guarantee in effect and the fabricator assumed a certain percentage of the failure, whatever that may be, they may affect the price to the Government. That also reacts, if it doesn't fail, as excess profit which he will not want to assume. That will make him look bad, too. I think the Government would be better off if they would assume that risk themselves. People of integrity are going to make these tanks according to specification and if the specification is proper, it should be a guarantee of good welding and good practice. Also, at that stage of the game I think it is very difficult to say how long that running test should be until we get into more detail of vehicles available to make that from actual test."

It was further stated that guarantees as to definite minimum mileage or minimum period of service would react to the detriment of the Government. Major McInerney insisted:

"That is the guarantee that you will find for all of these vehicles."

The subject was left for further consideration since it involves a matter of Ordnance policy.

In connection with prescription of a limit on joint fit-up, Mr. Bibber voiced an objection:

"I would like to bring up a point on D-8b. It says, 'Separation of edges for welding and tolerance thereof shall not be greater than those used in procedure qualification test plates.' That is a nice theory, but it isn't going to be obtained. In fact, we can make those edges any thickness we want them. When we make a tank with all kinds of cock-eyed angles and flame cut edges, they simply are not going to come like the qualification test plate. If they do not, we pay the penalty. We have to put in a lot more of expensive weld metal.

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In some respects you would be better off to have more opening than less. It seems to me that something ought to be done about D-8b. I don't think it is workable the way it is now. I don't think you are gaining anything by having it the way it is now."

Upon questioning by Col. Ritchie, Mr. Bibber further stated:

"In the making of these tanks, there are all sorts of peculiar angles—the welding is going to warp—pull some of these things quite a little bit. These fits are not going to be as nice as we want them to be. Now, suppose they are not what they should be. We have to put in more weld metal. It isn't harmful from your standpoint, so why have these limitations? I do not think this should be imposed on us as it stands now. I don't think it is worth it."

Mr. Bissell suggested:

"I think it should be 'not less than' rather than 'not more than.' We have a certain design of joint and in some cases we do set up tolerances. I think if you have a general line-up of joints that are to be followed, that have tolerances to them, that will take care of it. I think that 'not less than' will be very much more sensible and not harmful to you. We have considerable latitude in the design of the joints. The whole effort is to put in as little as you can of expensive metal."

To a suggestion that a tolerance of 1/16" be permitted, Mr. Bibber objected:

"1/16" is silly. We put in some very cock-eyed joints. From experience the fitting is a very difficult thing, with all these bevels and angles going in from several directions —plus or minus O.D. and even take off the minus—but I think 1/16" is just silly. It has got to be more than that."

Mr. Bibber continued with respect to a suggestion that 1/4" be permitted:

"The tolerances of 1/4" that you mention might be a good figure, as a start of an argument, I am reluctant to give any definite figure. I do think we should definitely not have less than a qualification test, and then make a plus and not over 1/4". There simply has got to be a reasonable figure, You can't sit here and decide they are going to fit—they are not going to fit."

It was evident that any limitation of this sort must be based on practical production experience and therefore cannot be established at this time.

With reference to requirements for minimum limits on penetration resistance of welded joints, experience at the Aberdeen Proving Ground

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and the basis for the figure given in the draft of AXS-497 was explained by Mr. Rouse:

"We have some data but I do not remember the figures, but I do think the thinner plates came up to 90%. As a matter of fact, when this 90% was settled upon, we were considering plates of 1" and greater. I don't think the thinner plate was taken into consideration."

Mr. Bibber voiced an objection:

"I don't want to intrude here all the time, but I protest against 90%. On certain ballistic tests we have just made the 90% and that is all. I think it should be lower than that--I think 85% would be better to attain consistently --90% is too high."

This was further amplified by Mr. Sibley:

"Sometime back we did some experimenting on 1/4" plate --I haven't the figures with me, but it sticks in my mind that the ballistics of the 1/4" weld are under 90%. I think the figures were about 60%. As the plate gets thinner, the type of bullet or shot makes a great difference. You get varying results from caliber.30--certain changes with caliber .50. I don't know whether 90% would hold on 37 m/m. Mr. Rouse has information on that, but I think 90% has to be revised. With respect to gauges on plate, I do not think we have enough information to make that a blanket specification."

As a result, Major McInerney suggested a compromise:

"We have obtained values above 90% but it has not been on production. I presume we can adhere to 85% at the present time and if we find it necessary to can change the figure back to 90%."

With reference to thicknesses for qualification, it was suggested that the fabricator be permitted to qualify on the minimum thicknesses actually to be used in production rather than on an arbitrary minimum when that arbitrary minimum is not actually to be used in production. This will satisfy the fabricators.

A policy with regard to procedure qualification tests was suggested by Col. Christmas:

"I think if you failed one of the two samples you should be required to pass two. Based on a mathematical standpoint, if two samples are submitted and one fails and he passes the other you don't know anything about it. If he passes two, then we know he is all right."

A discussion of qualification of welding operators with respect to position of welding was summarized by Mr. Bissell:

"By the American Welding Society he is qualified for welding in one position. If he is qualified with the seam vertical, he is qualified for that position and flat. If he is qualified for overhead, he is qualified for overhead, vertical and flat; however, he must be qualified for the seam horizontal in the vertical plate. No other qualification qualifies him for that. That is rather a difficult position."

If radiography is used for qualification plates, the procedure will be in accordance with AXS-476. Both X-ray and gamma ray procedures are included.

Objection to the limit of 1" from the weld for a fair hit in the shock test was made by Col. Christmas:

"I think shock test F-6b is very hard to meet. Do you agree with that, Mr. Rouse?"

This was corroborated by Mr. Rouse:

"Within 1" of the weld. With 75 A.P. I don't think we hit over 2" from the weld."

Col. Ritchie suggested that these details are matters for Ordnance personnel to straighten out among themselves.

The question of qualification testing of production weldments was discussed at length. The question as to who would pay for the cost of these weldments was raised by Mr. Miller (A.C.F.):

"I was just wondering here has anything been set up regarding the expense of this performance. If the weld stands up under ballistic test but is damaged pretty badly, whose expense is it?"

To which Col. Christmas replied:

"If the article passes specifications and satisfies ballistic requirements, we would pay for it. That has been done in the past."

This was further amplified by Major McInerney:

"I think in the early stages we will have to feel our way along and later on considerable of this will be eliminated. As Colonel Christmas says, if the weldment is deformed but passes the ballistic test, the Government will pay for it. I think a statement to that effect should be put in the specifications--that if a weldment passes the ballistic requirement but is so deformed in the ballistic, it should be paid for by the Government, whether used or not."

This concluded the discussion of the draft of AXS-497. Reference was made by Col. Ritchie to a draft of an "Armor Welding Data Sheet," which had been sent out since the last meeting for comment. It was indicated that this data sheet is to be used in connection with qualification test plates and acceptance of weldments for test. The data

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will be handled either as confidential or restricted. There were no comments from those present.

Since the time of this meeting was taken up by the discussion of the draft of AXS-497, the opportunity was not afforded to consider the other items on the Agendum. Col. Ritchie requested comments from those present in respect to desired research and development work which should be undertaken.

During the midday adjournment for luncheon the group was given an opportunity to inspect several welded and also riveted turrets and a cast upper hull which had been repaired by welding. These structures had been ballistically tested with A.P. projectiles with very encouraging results. It is indicated that welded armor structures are destined for a very promising future in the War Program.

It was decided that the next meeting would be held in Cleveland, Ohio, after revised draft of Specification AXS-497 has been issued and in operation for a time so that some practical experience can be had with its use.

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THIRD MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
20 JUNE 1941
HOTEL CLEVELAND, CLEVELAND, OHIO

The third meeting of the Subcommittee was held on 20 June 1941, at the Hotel Cleveland, Cleveland, Ohio with 34 persons in attendance representing the organizations represented at the last meeting. Mr. R. T. Gillette, General Electric Company, was present by invitation to discuss the possibilities of spot welding armor. The McKay Company, electrode manufacturers, and The Breeze Corporation, armor processors and fabricators, were elected to membership on the Subcommittee.

Approximately five (5) months had elapsed since the previous meeting of the Subcommittee in January at Aberdeen Proving Ground. During this period two M3 medium tank hulls had been fabricated by welding, one at Rock Island Arsenal and one by the Engineering Foundry Company, Youngstown, Ohio. The latter was carried on under general supervision of representatives of the Carnegie-Illinois Steel Corporation. Both of these hulls were built to a design made for riveted hulls which to some extent complicated the fabrication by welding. The success of these two pilot attempts demonstrated that such fabrication is not impractical.

It should be emphasized that these two fabrication jobs were completed without the use of any suitable positioning equipment. Thus, all welds had to be made "in position" which offered some complications because the stainless steel (18/8 or 25/20) electrodes available commercially were not of the "all position" type.

It was emphasized in connection with the fabrication of these two hulls that had suitable jigs and positioning fixtures been available appreciable savings of time and manpower could have been made. This was to become more apparent later as the welding program progressed. Experience in fabricating these two hulls indicated that the tentative draft of AXS-497 was generally satisfactory. The hull built at Rock Island Arsenal was completed with a manganese modified 18/8 (Lincoln Armorweld) electrode whereas 25/20 was used in the fabrication by the Engineering Foundry Company.

In the discussion at the meeting the question of continued membership of cast armor representatives on the Subcommittee was considered. There were at the present time four cast armor producers represented on the Subcommittee. Col. Ritchie raised the question in the following remarks:

> "At one of our recent meetings of the Cast Armor Subcommittee, the question was raised as to whether or not they would desire to continue membership on this Subcommittee. We have, as you know, four of our cast armor group as members of your welding Subcommittee. I think that is a matter probably

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which we might well leave to those individuals if they desire to continue participation, and if they have sufficient interest. The matter has been raised as to whether it would be advisable to have a separate group for the cast armor people, dealing more especially with the repair of armor castings by welding; that is, whether there is sufficient business that would come under that group to justify having a separate unit. I personally feel that the cast armor people probably would get something from these meetings, especially when topics are to be discussed in which they are interested, but the only objection I can see to such a procedure is that it does keep this Committee a little large."

Mr. Gezelius expressed the following comments:

"At the last meetings, there has been very little that pertained to the cast armor manufacturer, and for that reason I thought it was not only a waste of time, but it made this Committee cumbersome. There is no need of having a large group of observers sitting around. However, today I noticed that subject 3 is a subject which does pertain to the cast armor manufacturer directly, and I would suggest that that arrangement be flexible. If there is anything that pertains to the cast armor manufacturers, let them appear at those meetings. If the rest of the meetings have nothing to concern them, I see no point in their attending. I imagine that 75% of the time the agenda will have nothing of direct interest to the cast armor manufacturers."

This matter was disposed of by Col. Ritchie as follows:

"At present, we have just the four representatives. Only three are present. I believe if it meets with your approval, we can pass it up, and let it stand as is, with these people attending when they have topics of interest, and if there is sufficient business that develops in the field, then we can consider later the creation of a subgroup to handle it."

With reference to the medium tank hull fabricated at Rock Island Arsenal with the Lincoln Armorweld electrode (Mn modified 18/8), Mr. W. F. Schmitt commented as follows:

"We experienced very little difficulty in the actual fabricating of rolled homogeneous plate. One of the fabricators that was involved had very little time available for the experimental work to be done with the electrode that was used—the electrode was used at the recommendation of the manufacturer, and we had very little background with that. We had to develop this background as we proceeded with the fabricating. Cracking in the craters was eliminated by some variable in the technique of stopping or finishing up with the stub of the electrode. The joining of the armor castings to the rolled plate caused some difficulty, but only through the fact that we had very little equipment to correctly position the welding. We found,

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as we progressed, that we were able to control a great deal of the conditions by the proper technique. We could desire a great deal more accuracy in the sizing of plates, and also in the development of the proper joint. We assume that most of the joints could be made with possibly a 45- to a 55-degree included angle with the normal root of 1/8 inch. We found in some of the conditions that had been brought out during the welding that due to the improper flame cutting and sizing of the plate, we had a wide root condition which required re-building or building up of the plate, and it had quite a variable in it. Through this condition we found that we had the poor root conditions found under X-ray examinations such as poor fusion, slag inclusions, and, in some cases, cracks that did not appear on the surface. These can be very easily remedied and eliminated by use of templets in the sizing of the plates and exercising of a little care in conditioning the plate itself before it is incorporated into a weldment. By that I mean if there is a blowout or slag that is caught under the cutting torch and has blown a path through the plate itself, it should be dressed up before the thing is incorporated into the weld."

Mr. Taylor, Lincoln Electric Company, added the following comments:

"It seems to me that welding of armor plate, at least the type of armor that we had, is entirely feasible. I believe the problems are no more acute, probably less, than welding on mild steel, without stress relieving or heat treating afterwards. I was very much pleased with the progress which Mr. Schmitt and others had made on the welding of this hull. The cracking that Mr. Schmitt referred to, I believe, at least in my reports, shows they occurred only when it was badly diluted with the armor plate, and by changing the design of the joints and maybe doing additional buttering of the edges, it is our opinion that this will be entirely eliminated; so our conclusion is that the welding of hulls or turrets, or both, is a very easy thing to get into immediately. The speed and cost, I believe, should be mentioned. Our estimate, with proper fixtures and jigs, is that the Medium M3 hull can be welded in 200 hours, that is, 200 man hours, which we believe is a tremendous saving in cost and increase in speed in production."

With reference to the hull fabricated by the Engineering Foundry Company, Mr. Bibber commented as follows:

"Now our experiences in fabricating this tank were very easy, and I think one of the most striking things is the ease with which we were able to do it. It is not a difficult thing to do at all. We started with welders at the Youngstown plant, who had never seen a piece of armor plate in their lives, who were not qualified under any code, and who had never used a stainless steel rod in their lives, and with four hours of training on each welder, we qualified eight welders. We made 32 test plates, and put them through the X-ray 100%. I bring out this point to show you what can be done in the way with proper supervision of trained men to do this special welding. Actually, the welding is very easy, once they get into it. I will admit that we stood right over them. In other words, the supervision was 100%. Every move they made was properly supervised, but it shows these things can be done. We didn't have a single crack in our tank anywhere. I would definitely like to recommend that none of these plates be welded below 100°F. That is in a sense a preheat, but I think that is a good plan. That is just the same thing as welding the tank in the sun on a good hot summer's day, and that will work no hardship, and I believe it should be done, and I believe that in welding any castings the casting should be preheated."

In discussing the qualification of welding operators under AXS-497, it was pointed out that with positioning equipment and suitable fixtures about 80% of the welding on these hulls could be performed in the down-hand position; thus highly skilled operators would be required for only about 20% of the welding on the hull.

Mr. Brooker proposed a slotted test plate for qualification test of welding operators. This plate was intended to be restrained by a heavy slab during welding to make the test as severe as possible. Mr. Bibber commented as follows:

"Well, I would like to make a general comment here. In the first place, these tanks will be welded in such a way that they will not be locked up. The welding procedure will not be locked up so far as the manufacturing and welding of the tanks are concerned. You won't have it locked up in any joint."

Upon request by Mr. Warner for comment as to adequacy of the qualification test requiring a single 12" butt weld as now prescribed by the current draft of AXS-497, Mr. Bibber commented as follows:

"I think that your qualifications as you now have them with a simple twelve-inch joint are just as reasonable and sensible as anything we could ask. I am very well pleased with your stand there. By this plate you have demonstrated that we can make this weld. The X-ray is a very searching test, and I think your qualification test plate using this is fine. I don't think we could ask anything more reasonable than that."

Mr. Bibber's remark about the lack of restraint encountered in production of welded tank hulls in his comment on Mr. Brooker's proposal precipitated some discussion in which Lt. Reed asked the following question:

"Mr. Chairman, may I ask Mr. Bibber how he can weld two-inch armor plate without having any locked-up stresses."

To which Mr. Bibber replied:

"I said no locked-up stresses other than those that are inherent to any welding joint. Any time you weld a thick plate you are going to have certain locked up stresses, but I mean that plate would be free to move so far as external restraint is concerned."

In elaborating further on this point, Mr. Bibber indicated that the sequence of welding would be so laid out that one member of each joint would be free to move. He further added:

"In ordinary mild steel welding, you have a 60,000 pound base metal and you have a 70,000 pound weld metal; you have a 35,000 pound yield point and the weld metal can have 60,000. The weld is stronger than the base metal, and it will withstand the stress. The deformation must be absorbed in the base metal outside.

"In this armor plate metal, you have the opposite condition in that you will have a very high yield point outside and a weaker and tremendously more ductile material in the joint, and any giving is going to be done in the joint, and the thing that enables this material to work is the fact that it has such a tremendous ductility. That helps it in its locked-up condition in the welding of the joint. Now the proof of this all is that those ballistic joints have been tried and worked beautifully. That is the proof. That has been done. That has shown that they are good."

Mr. Warner summed up the qualification requirements of the specification AXS-497 as follows:

"The specification intends that every fabricator will have his process qualified by the two tests indicated in the specification. That is the straight butt joint and the H type of specimen. After the process procedure has been qualified, then the qualification of the welders requires no ballistic test, but these twelve-inch butt joints have the same thickness of plate, and are welded by the same procedure that is used in making the two pilot or primary procedure qualification plates. The specification is quite specific there, I believe, so it is necessary for each fabricator to qualify the process, and the welder qualification based on these butt weld tests."

In commenting on the prescribed procedure qualification test, Mr. Schmitt referred to a Y-type of test plate as follows:

"We have the Y joint, welding the legs of the Y in the sequence of one and two, and the lower leg of the Y third, which is throwing all of our locked stresses in this last joint. By using this particular type of joint, we have found that we have a great deal of difficulty in producing a sound weld with the electrodes that are now available."

In the ensuing discussion it was brought out that the procedure used in preparing the test plates for procedure qualification should be the same as used in production for similar welds. This was emphasized by Col. Ritchie:

"I believe that is covered in the specification. We say

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that you use the same procedure on the qualification plates as you are going to use in production. Therefore, if you want to flame cut and use it on the qualification, well and good."

The question of the Y plate versus the H plate for procedure qualification was discussed at some length. It was considered by some that locked up stresses are inevitable when welding certain of the M3 medium tank hull joints. Mr. Bibber pointed out that in contrast to this concept the austenitic stainless steel weld metal (25/20) has tremendous ductility and is therefore capable of deformation sufficiently to endure high stresses without rupture. Thus this type of weld metal is excellent for armor fabrication.

The method of procedure qualification used for production of welded turrets by the American Car and Foundry Company was outlined by Major McInerney:

"A long time ago, I don't recall how long ago it was, American Car and Foundry Company submitted a welded turret. That was before we had any of the specifications which we have since drawn up. We considered the results of the test of these turrets as being their qualification. At the present time they are still proceeding along that line. That is, using the same technique that was used in the welding of these turrets. We are going to require American Car and Foundry to qualify under this specification. At the present time, they have not. We want to let you know why they have not, and that is because they actually qualified in a turret which stood up ballistically and was satisfactory, and they are using, I presume, the same technique, the same welding rod as was used in the qualification test."

These remarks were supplemented by Mr. Osha as follows:

"We have had about three or four turrets down so far, and essentially the procedure has been the same. We made a few of the plates of the 36-inch type and had them shot with a few different rods to try to get an idea at first. We have got a method. Whether it is the last or the only method, I don't know; but, we are producing turrets. We believe they are good ones."

With reference to qualification of welding operators, Mr. Raymo brought out a point as follows:

"Before leaving the question of 497 here, I would like to recommend that you give definite consideration to reducing the number of specimens required for operator qualification, relative to thickness ranges. On our M3 hull, we have plate ranging from 1/2 inch to 2 inches in thickness. The thicknesses of plate involved will cover the three ranges set up in the specification. Qualifying in exact accordance with the specification necessitates specimens being prepared in each thickness range for each operator and for each position. I believe that preparation of a plate of the maximum thickness to be welded is sufficient, and

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would like to recommend that you give consideration to it.

"To definitely cite our own experience, at present our welding on sample 34 hull is confined merely to the attachment of the splash beads to the armor. Our local staff of inspectors is requiring qualification of operators in accordance with 497, and really there is enough plate on hand to build another tank. I don't believe that any useful purpose is being served in requiring each operator to qualify on all thicknesses of armor. Actually the procedure followed for the preparation of a 3/4 inch thick plate will vary little with that which could be followed in welding a 1-1/2 inch thick plate. In preparing an inch and a half thick plate you pass through the 3/4 inch thickness range, and on your ultimate examination of the plate, you are only concerned with radiographic soundness, and it is our observation and experience that the man who can weld an inch and a half plate can certainly weld a 1/4 inch thick plate and a 3/4 inch thick plate. Therefore, would not the preparation of the inch and a half plate suffice for qualification on the lesser thicknesses? It would certainly cut down on the quantity of plate that is involved, and again, in our own case where 25 men are involved, really the quantity of plate required is quite an appreciable item."

The intent of this argument was summarized by Mr. Warner as follows:

"As the specification requires it now, I think each operator would have to weld three plates, one in each thickness range, in each position to qualify. I understand your suggestion that that should be changed to only require one plate in each position for the maximum thickness to be qualified and cut the amount of plate down and the amount of welding down at least two-thirds."

There appeared to be agreement on this principle as stated by Mr. Warner on the basis of Mr. Raymo's argument.

Upon request of Col. Ritchie, Mr. Chyle discussed the subject of flash welding of armor plate as follows;

"We have made some flash welding tests of rolled and cast armor. Our tests indicated a very good weld obtained that way. Flash welding is limited to smaller sections, but it can be used very successfully on armor plate. We believe it is feasible on small parts, and for large sections you would have to build enormous machines to do that work, but on small sections it looks feasible. We made a number of joint tensile tests and it is feasible there. The tensile was not disturbed as far as making a good bend test on that. That is resistance flash welding."

In answer to a question as to how large a section it is feasible to flash weld, Mr. Chyle replied:

"Well, that depends entirely on the capacity of your resistance welding transformers. I think that two inches thick up to

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forty-eight inches in length can be flash welded satisfactorily."

Limitations were suggested by Mr. Chyle as follows:

"I think the process is limited to a butt joint rather than a butt joint at an angle. That is the butt joint at the same plane. Our tests were made chiefly to determine whether a flash weld would be satisfactory in armor plate and our test indicated that it could be done."

Upon request of Col. Ritchie, Mr. Gillette discussed spot welding as follows:

"I believe there must be many places where we could use spot welding, particularly this so-called pulsation method of spot welding for making assemblies and perhaps some of the major assemblies of the tanks. I am handicapped by not being familiar with the design of these tanks, and not particularly familiar with the material. Based on experience with other materials, using the pulsation method of spot welding, we have very successfully spot welded up to two pieces of one-inch material. In other cases, a piece of half-inch thickness was welded to a piece two-and-a-half inches thick. There are structures of that type, and particularly where there are multiple thicknesses of 3/8 or 1/2 inch that can be welded satisfactorily by this method.

"The question of equipment availability is not too serious, I think, for work of that type; resistance welding equipment could be built in six weeks or less. As far as equipment being available at the present time in the various manufacturing concerns, I don't know if there is any equipment heavy enough. We have two or three pieces of equipment down there welding up to two pieces on one-inch quite satisfactorily. We have satisfactorily welded two pieces of one inch, not in armor. We have had no experience in armor plate at all. Whether this face hardening material could be welded or not, I think that might be welded, particularly if the two softer faces could be brought together. I have one job in mind where we actually welded a piece of half-inch on each side of a piece of four-and-a-half inches thick. It was really a butt strap job you might say."

One viewpoint of the problem of spot welded armor was outlined by Mr. Warner as follows:

"In spot welding armor together in the tempered condition, you have got a situation which is entirely different from what you have when you spot weld together two pieces of structural steel. The homogeneous armor plate as we know it today, it is somewhere around 40 or 50 points of carbon, the hardness in the spot after it is made, even with a pulsating type of spot where we give it three shots of five cycles each or something like that, you will have a hardness in that spot area of 700 to 800 Brinell, it is the hardness of tool steel. You also will have fine grain cracks in that spot area. There is no way that I know of that you can get away from those cracks, because of the rapidity with which they form, even by an annealing operation. In face-hardened armor, we have a sample of one of the first samples we have tried so far--you are able to spot it all right, but the spot itself separates very readily by pulling the slug out of the angle, the low carbon angle, or pulling a piece out of the armor, after a few impacts of 30 caliber; in that case it was quarter-inch face-hardened plate.

"Now if you are going to lap two pieces of face-hardened armor and spot weld them you have got a layer of high carbon steel with a hardness to start of somewhere around 550 or 600 Brinell, against a layer of steel which is low carbon, 0.20 carbon but which has a hardness of 350 Brinell, and those two just simply don't stick together; they will weld, you can fuse them together, but the bond is so brittle, it is like a piece of glass. So it seems to me the most sensible all-around method of considering the spot welding method as applied to armor is to use auxiliary connecting pieces, spot weld it on the armor before it is treated, and fabricate your parts for assembly after heat treatment. That adds certain complications to the heat-treatment process, I realize, but I think those complications can be overcome, and I think that primarily the spot welding operation will be very advantageous for attaching armor to aircraft structures and so forth, putting on clips which can be used to bolt the armor onto the aircraft structure."

The practicability of spot welding tank hulls on a production basis was discussed by Mr. Bibber as follows:

"I am going to confine my remarks to homogeneous armor and the building of tanks only. Now even granting that they can make a successful spot weld in this material, which I very, very seriously doubt, in thicknesses we are talking about, one of the principal jobs would be one and a half inch to two inch or to something else. Even assuming that they can make a weld which would take a ballistic test, which I say I doubt very, very much, you are going to introduce applications in your tank design which we have gotten away from very beautifully with fusion welding. So far as I am concerned, so far as my company is concerned, we have no axe to grind. If you want steel to be spot welded, it is okay with us. If you want to fusion weld, it is okay with us, too. But you are going back to the butt straps; now the joint efficiency that you can get between a piece of inch and a half armor, having a tensile strength we will say of 140,000 pounds per square inch joined to a butt strap by a spacing, I don't care how close you put them, you are going to wind up with a static efficiency of 10% or 15% maybe, which is very poor. That is just straight static tension.

"Now we can give you 65% and more static efficiency with

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with this metal-arc weld metal and there are very few butt joints in the job. They are mostly all corner joints. When you have to put these butt straps in, they are at these odd angles. If you don't use the angle, then you use a bar to weld the plates onto. These bars are going to be at odd angles and they are not going to fit as nicely as you want to, and this spot welding machine has to come in here with big arms and heavy pressure to pull those things together and you are not squeezing together little pieces of 3/16 inch material. This is heavy stuff, and it is not mild steel either. Aside from complicating the design, you are going to put those straps back in there and you are going to jump the weight up. It is by elimination of these straps that we have been able to knock several thousand pounds off the weight of these tanks, a thing you desire. Perfectly frankly speaking, from what I know of the situation as of today, it looks very, very impractical to me to talk about spot welding tanks."

To which Mr. Gillette replied:

"I think in some way Mr. Bibber is right. I don't think you will ever make a complete spot welded tank, but there are undoubtedly auxiliary structures on this tank and some assemblies that can be satisfactorily spot welded. I realize we have got to study this thing from a metallurgical standpoint. You can't make a spot weld between two pieces of steel which has 100 or better points of carbon without some subsequent heat treatment, and get away with it; but I still believe that careful study of this will place it where it can be used to advantage."

The Ordnance viewpoint as to application of spot welding was outlined by Col. Ritchie:

"What we had in mind was to get the general feeling of the group. But with respect to applying this type of welding, we had in mind, say scout cars or those vehicles carrying light plate or aircraft armor, material of that kind."

The design problem was discussed by Col. Jenks:

"There is great difficulty in transmitting stresses across a resistance spot weld. The fillet weld is something somewhat the same as the spot weld in those difficulties that you have to move stresses around corners. In the fatigue work at the University of Illinois, there has been no design of a fillet weld joint made yet which is reasonably satisfactory for tension stresses. The efficiency is very low. There has been little or no work done on fatigue strength of spot welded joints. There is some work now that is about ready to go ahead in the measuring of the fatigue strengths of spot welds in aluminum alloys which will give us some idea of the behavior of spot welds under repeated conditions. I don't think you are going to be successful in transmitting stresses across these spot welds, and I think if

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your stress waves are of high order, you are going to break off these spot welds. There is more flexibility in the rivet because the rivet is generally softer than the plate itself, and will yield some. But your spot is harder, and you are going to have a bad stress condition around that spot. I doubt if you are going to have any applications. There may be some minor applications where you can get away with spot welding. I think it is worthy of investigation, but I don't think there is much hope of very many applications."

There was some discussion as to whether representatives of the resistance welding industry should be invited to sit in on the Subcommittee meetings but no definite decision was reached on this point.

With reference to production of welded tanks, Maj. McInerney explained the Ordnance policy as to where the welding would be done and indicated the desirability of having representation from such facilities on the Subcommittee:

"The only comment which might be in order under that subject is that if and when we do go to the manufacture of tanks by welding, that work will be done at the plants of the people now manufacturing the vehicles, not at armor plants, not at welding plants. Welding will be done by the manufacturer, such as American Car and Foundry, Chrysler, and so on. That must be definitely understood, and I think gradually we will have to bring them into the picture in these meetings. If we are going to do that type of manufacture, then they should have representatives attending these meetings. At least one engineer representative from each of these firms, I think, should attend these meetings hereafter."

The results of ballistic tests on welded turrets of face-hardened armor fabricated by ACF were given by Lt. Reed:

"They stand up well under penetration tests. Most of our welding has stood up well under penetration tests, but the shock tests are rather disappointing. I have noticed that all fillet welds on face-hardened armor fail under shock without question. On the turrets, we incorporated a high explosive test, and the great tendency to crack the whole structure, the whole turret, with high explosives, is seen, not necessarily in the vicinity of impact."

The present concept of differences between the performance of welded and riveted joints under a ballistic shock loading was outlined by Lt. Reed:

"We do not feel there is any comparison between riveted fabrication and welded fabrication. We say it is more of a contrast than a comparison. Riveted fabrication has so many more hazards to the tank. It is true that welded fabrication

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does not allow flying rivet heads and butt straps. When a test is made on a tank with 75 millimeter, the results showed that before any penetration had occurred in the tank, rivet heads and butt straps had been thrown around, and would have injured the crew. We mounted five figure boards in the tank and showed that those pieces do attain high velocity. You might imagine how high it is if you realize that one of those rivets from the turret in a light tank put a half-inch indentation in the back of face-hardened armor plate. A welded joint fails locally. A riveted joint fails throughout. In other words, if you shock a riveted joint, say you have a plate, one single plate, and you support it on your butt and you hit it, you will find that it is loose throughout from top to bottom, whereas a welded joint will fail locally and will be progressive toward the unsupported end."

Upon question by Mr. Warner as to serviceability of welded turrets versus riveted turrets Lt. Reed commented:

"I would say that a welded structure with the same impact as a riveted structure would be far superior. However, face-hardened armor plate, which composes all but one of the turrets we fired up there from A. C. F., breaks under impact. We have taken out pieces that are two feet in area. But the same thing happens on riveted turrets. Face-hardened armor plate is rather impervious to superquick fuse timing of high explosive shells. The same projectile will shock rivet heads off and send them flying about inside."

From this discussion an inspection criterion was suggested by Major McInerney:

"I think the criterion in the inspection of riveted structures should be based on the factor of this theory: Is this joint better than what we had previously? That should be the criterion. Even if a poor weld is better than a riveted joint, it should be considered acceptable. Does it afford more protection than what we had previously?"

Col. Jenks commented as follows regarding methods and purposes of inspection:

"The failure of a welded joint in a tank may be due to a number of causes and there is no inspection method which will eliminate failure due to some causes. Your first cause may be a question of design of your welded joint. Your next question is whether the welded joint is composed of a metal of a lower unit strength than your parent metal. That metal with a lower unit strength must absorb your shocks, both the shock from fatigue and the shocks from the impact. And the question of design of that joint, that is, the engineering of that joint, is important as far as failure goes. Now the question is what might have caused failure after the design of the tank has been fixed, and the main thing that will cause failure are stress raisers.

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Now I won't refer to the internal stresses because that is something that is a question of engineering and not the question of the inspection of the weld itself. But for the inspection of the weld itself, there is the question of elimination of the stress raisers. Now the most important stress raiser is the stress raiser at the surface, and the one you are most apt to find, is a crack, and it may be a crater crack or it may be a different type of crack, so your inspection should be such as to eliminate all cracks in your welded joint.

"Now another stress raiser which is more difficult to find, but that may occur, in the case of H welding, and that is the incomplete removal of slag in the fusion zone and if you leave very much slag in the fusion zone, and especially if that is anywhere near the surface, you may expect a premature failure of that joint due to the slag deposits. Now so far as the elimination of cracks goes, I don't know of any better method of inspection than the magnaflux method. So far as these slag deposits go, magnaflux will not pick those up reasonably, and the only way to find them would be to check up yourself once in a while, by radiographic methods which may not be practical under production; but I think you should study magnaflux methods of inspection of welds in tanks."

The current difficulties being experienced by the electrode manufacturers in obtaining raw materials for the 25/20 welding electrodes were discussed. Mr. Ewertz pointed out the difficulty:

"I agree with Mr. Taylor that the chief trouble is not with the manufacture of electrodes. There is enough processing capacity in the country to process enough electrodes provided the steel mills will give us the necessary materials to make the electrodes from."

This point was also commented on by Mr. Chyle:

"We have heard of the steel companies having trouble making this type of electrode, the 25/20 type, where the chrome is on the high side and there seems to be considerable difficulty in obtaining this material in large quantities. If the composition could be reduced in chromium and nickel a bit, it would be more easily obtainable, and I am wondering whether that could be done."

Mr. Taylor, Lincoln Electric Company, stated that his organization has developed an electrode for welding armor (Armorweld) which has a reduced nickel content as follows:

"We developed a rod that reduced the nickel content to about 40% of what has been used and increased the tensile to 110,000, from 85,000 to 110,000, and brought the elongation up to 45% in two inches to get it more ductile and increase the tensile strength up to the ultimate of the plates, so the joint

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efficiency would be raised."

The problem of the steel mills producing the core wire for the 25/20 stainless steel electrodes was outlined by Mr. Smith, Republic Steel Corporation, as follows:

"I heard yesterday a thing that will have to be looked at critically. The OPM have issued a flat order that in the future all stainless shall be made from 60% scrap. I don't know whether they are going to call stainless electrodes stainless when they are welded into tanks. We have not had OPM's discussion on that particular point; but suffice it to say that we have the problem in front of us in the steel industry of getting OPM to tell us whether or not we are going to have more than 40% primary nickel in any case that stainless steel is melted.

"No more than 40% of the nickel can be primary nickel, and beyond that the two other discussions are occurring constantly. There is a conflict between the bullet core and the welding rod for the rolling mills, and there is a conflict between the tool steel industry and the primary cogging hammers for the reduction of the billets from the ingot to the primary billets. In other words, that is a shortage of cogging hammers. There is a shortage of small mills. I don't know where we will finally end up on it, and I have asked this subcommittee of the American Iron and Steel Institute, who represent that work, to go to Washington and discuss the problem with the Army and Navy, and I expect myself, as soon as we have some fairly sound information, to discuss it with Mr. Whitney in the OPM, and present the problem to him; but, it is a very complicated and involved problem. Some months ago I called attention to Major McInerney that the conflict between the bullet core and the welding rod was going to arise, simply because of a lack of facilities in the way of the small mills to do this primary rolling. I don't know where it will finally end, because this OPM order was effective at eleven o'clock yesterday, so it is rather new."

On the question of priority for tank welding materials, Mr. Smith continued:

"The problem on tank welding rod is a problem of getting priority and you won't get tank welding rods unless you get priority in the industry, and I think we will have to ask OPM to give us a concession on compositions in certain cases in there. I don't believe it is going to be feasible to talk about or say that 40% or 60% of anything can be a primary requirement. We may have to make what we can make. For instance, on this stainless business, I am sure we are going to have to deviate from it, because as far as I know, nobody has ever made stainless tubing out of scrap, and that is one place we are going to have to ask OPM to allow us to have nickel enough to make stainless steel tubing, using whatever primary nickel we need to make it."

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The problem of electrode composition for welding armor was discussed by Mr. Thomas, Arcos Corporation:

"The question has come up from the steel mills several times regarding this 25/20 composition, whether we can not use as an electrode a 25% chrome minimum and a 20% nickel minimum, with the idea that that composition is easily rolled and does not have to be hammer cogged. At the same time, the steel mills, some of them, have been studying the processing of the slightly higher chrome composition of 26 and 26-1/2 which is required by welding rods to give a 25% minimum chromium deposit, to see if they can get this higher chrome composition in a form which can be rolled and does not have to be hammer cogged. It seems there are two fields of research that are going on now at the present time. One is in the steel mills processing a material which will give a weld deposit of 25% chrome, and the other is the fabricators, particularly the Navy, whether a lower chrome composition would be just as satisfactory. In other words, I think if it is absolutely necessary to use 25% minimum chrome in a weld deposit, I think the steel mills will be able to do it by rolling steel which gives sufficient chromium to meet that 25% chrome minimum. However, it is my personal opinion, without having made careful tests, that we can run down 24% chromium in the weld deposit without affecting the deposit. But I don't recommend changing or making any such change until we have the Navy change in composition, I think it would be very foolish to run two analyses of a type 310 alloy through the steel mills. In other words, our tendency is for standardization of composition and it would be far superior to maintain the same composition for the armor welding of tanks where 25/20 is required, as for the Navy requirement of our ships, and so I think we should follow possibly a little more quickly the steel mills' reaction to a higher--to 26% chromium in this steel, and work to determine the properties of a slightly lower chromium weld deposit."

With reference to the current situation on the 25/20 electrode, Mr. Deppeler made a suggestion:

"I think, therefore, it is a serious problem, but we have also Mr. Taylor's solution of it, not the lowering of the chrome but the lowering of the nickel, and that gives you a higher tensile strength and probably an electrode which will work as well; but in addition to that, we can also go back to the Cromansil rod that we have offered which has only 1-1/2% nickel, and which does give 116,000 yield. Now that electrode is going to give you trouble but if you ever get into difficulty on your 25/20, we can always help you out if you are willing to preheat the armor. That preheating is only to 300 degrees. The weld will develop all of the physical properties of the armor plate itself. But we can't offer any solution to this 25/20 because you are going to be up against it, I am afraid."

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This discussion pertained primarily to the use of 25/20 electrodes. Apparently no company except the Lincoln Electric Company visualized at this time the necessity of using a modified 18/8 type of stainless electrode. Mr. Schmitt referred to the experimental M3 medium tank hull welded at Rock Island Arsenal:

"We used the 19/9 composition. This electrode is supplied by the Lincoln Electric Company, made by those people for this particular project, and that electrode has very good qualities. We did not experience any difficulty in joining rolled plate to rolled plate or homogeneous plates together; but we had some difficulty joining a casting to a plate. Now we have not definitely found whether it could be traced back to the different compositions between the casting and the plate itself, and that would be inherent in that particular type of structure, or whether it was through technique faults, but we are working on that yet. We have not a definite conclusion as yet."

Mr. Taylor explained that the electrode referred to by Mr. Schmitt was a 19/9 with vanadium and manganese additions.

There ensued a considerable discussion about repairing cracks in rolled armor plate which often occur, particularly in face-hardened plate, between rivet holes and the plate edge. It was decided to make some tests of these conditions as indicated by Major McInerney:

"We will send letters from the Office of Chief of Ordnance to the Philadelphia District and to the Cleveland District to get some of these plates which have been rejected. They will be welded and sent to Aberdeen for tests."

It was suggested that both cracked plate and repaired plate should be included in the tests. The question was also raised as to whether a crack which runs into a rivet hole would extend under shock. To this question Major McInerney replied:

"It might not under one shock, but maybe after being in service for a length of time where there was fatigue, I would prefer to have them welded up if it can be done. Under most conditions it will be a better plate. It might be unnecessary in your estimation."

The problem of superficial surface cracks in face-hardened plate was indicated as being very troublesome at this time. Very frequently these cracks do not show up until the plate is cleaned and painted. It is not known how these cracks affect the service performance of the plate. Mr. Kirkhoff, Cleveland Ordnance District, expressed one viewpoint:

"Superficial cracks, appearing on the surface of these plates, don't run very deep. We have no magnaflux test down there. We can't tell exactly how deeply they go. You can grind them out. They probably go fifteen or twenty-thousandths deep, and as far as the naked eye is concerned, you can't see the crack any more, but it still may be there. We don't want to take the chance of passing those plates. I think some experimentation should be given those plates and see whether or not those cracks are detrimental. I don't think they are. We are rejecting armor plate every two or three days, so it is a serious problem."

It was decided to test some of these cracked plates at Aberdeen Proving Ground and Major McInerney expressed the Ordnance viewpoint as follows:

"I don't think, and I think most people agree, that it would not be advisable to try to weld those if they stand up ballistically as they will be satisfactory; but I wouldn't dare consider to start grinding out. What we want to know is are these cracks injurious first ballistically, and second in a fatigue way, if installed on vehicles, after any length of service. Those would be the two particular points we would have to consider."

Tests on effect of punching the rivet holes were conducted at Watertown Arsenal. This study was referred to by Col. Ritchie as follows:

"In the investigation of the effect of punching at Watertown, we had, as I said before, a number of those small cracks radiating from the holes, but they were only through the carburized surface. We tested those extensively, .50 and .30 caliber projectiles in and around the hole, but in no case did they open up any more than they were originally."

With reference to repairs to armor castings, Lt. Matthews reported the action taken at the last meeting of the Cast Armor Subcommittee:

"At the last meeting of the Cast Armor Subcommittee, I believe it was agreed that where these cracks occurred on surfaces that won't be machined they would be ground out, if the inspector considered them of such a magnitude that they should be removed, and welded with 25/20 without post heat treatment."

It was further indicated that stress relieving of castings is used only when some other electrode than 25/20 is used for repair. The casting producers object to burning out defects in castings, believing that chipping or grinding should be used; however, it was admitted that burning could be used if the surfaces to be welded were thoroughly cleaned prior to welding. Differences between Army and Navy policies were pointed out by Mr. Gezelius:

"There is one interesting thing in connection with that point on minor defects, and that is that these final heat treatments, just the opposite of what Mr. Miller says, for the Army we are required to chip them out and weld them. The Navy specification expressly prohibits that. We may chip them out or grind them out. We can't weld them. We have two standards in our shop, depending on where it is going."

These cracks are surface cracks as further explained by Mr. Gezelius:

"The stress cracks I am talking about are cracks in the decarburized layer, very seldom deeper than 1/16" or 3/32". We are working on nothing thicker than two inches in thickness."

On the matter of importance of these cracks with respect to design strength, Mr. Landgraf commented as follows:

> "I think there might be another idea injected into this discussion, and it is that cast armor on any vehicle is not there for structural strength, or it wouldn't have to be that thick. Considering an inch and a half of thickness with 130,000 pounds per square inch tensile strength, from a vehicle standpoint, it wouldn't have to be over a quarter of an inch."

A previous view regarding these cracks was recalled by Col. Ritchie:

> "A year or so ago, it was the consensus that if those cracks were left, it might not do damage, but from the matter of looks they wanted to fill them up."

This viewpoint was corroborated by Mr. Landgraf.

It was finally decided that no hard and fast rule could be established at this time. The matter of whether to remove and repair these cracks or leave them alone was considered desirable to be left to the judgment of the inspector. In the meantime, further study is to be given to this problem.

Tests in progress at Watertown Arsenal Laboratory concerned with weld bead hardness on rolled armor plate and armor castings were described by Mr. Warner:

> "We have been trying to find out what would happen to cast armor. We were experimenting with a one-inch thickness and running weld beads on the surface of the plate with both the low carbon electrode and the 25/20. We have taken sections through the bead to examine the heat-affected zone adjacent. All this welding had been done with a 400 degree Fahrenheit preheat. Now by so doing, we have not had any difficulty from cracking, but the heat-affected zone is pretty hard. It is up around 450 Brinell. Then following that welding operation, we have drawn these pieces, certain ones of them, at 600 Fahrenheit and 1000 degrees Fahrenheit, and we find no effect so far, at 1000 degrees, no effect on the hardness of the armor from this drawing operation. Those pieces were held at temperature for one hour and then pulled out and air cooled. We think that we have to go to a temperature higher than 1000 degrees Fahrenheit to get the hardness of that heat-affected zone down. We don't have to worry too much about the hardness of the heat-affected zone, but I don't know how high a temperature we can go to on this cast armor without knocking the hardness of the armor down. There is no difference in the hardness of the heat-affected zone between the low carbon or the 25/20. We do find a slight difference in the depth of heat penetration of 25/20 as compared to the low carbon. The heat zone is about 20% thinner; that is, the depth of the bottom of

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the heat zone from the surface of the piece is about 20% less with 25/20 than it is with low carbon electrode, using the same current and same arc voltage and same rate of travel."

With reference to defects in castings uncovered in machining, Mr. Raymo commented as follows:

"We are just beginning to get into this problem of the defects in machining and it is really more serious than is in evidence in our discussion thus far. It boils itself down into other factors which have to be taken into account rather than just the nature of the defect. It seems that you never find these things until the man has taken the last cut on the machine. Everything is down in terms of a thousandth of an inch, and all such as that, and it isn't only a question of making a repair, but whether you dare preheat it or give it subsequent post heat treatment or something like that. As for the defects being minor, we will start making an exploration of the minor defects, and very quickly it turns into a major one, and your problem is further complicated. I think that more could be accomplished in the way of solving the problem of the repair of defects here by first making a more thorough exploration of the areas to be machined, while the casting is perhaps even yet in the foundry, and before final heat treatment, and do your repair work there. When you have some opportunity to give some subsequent heat treatment that might reduce this heat affected zone on there. I don't believe that such examination will delay your total program to the extent of having to make these repairs after the castings have many machine hours on them, and have all of the subsequent heat treatment, and still stand the possibility of being thrown out as a result of not being able to make a satisfactory repair. We have found that where we have repaired some minor defect, and then as a check on the repair, explored by means of the X-ray, and adjacent to that there sometimes appears a really serious fault. All right, what are you going to do about that? You didn't see it until you X-rayed, and for that reason I would like to suggest very seriously a consideration of a more thorough examination by means of the X-ray of these castings in the machined areas prior to final heat treatment."

It was pointed out that Lebanon and American Steel Foundries are using radiography as a procedure control check on production of armor castings.

Another point in connection with the fabrication of tanks by welding was mentioned by Mr. Raymo as follows:

"If this program goes on, there is going to have to be a lot of welding done to correct machining errors too. That is coming into the picture all the time, and there again it is a question of how much welding can one permit of such a type?

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I think that very definitely is a matter that is not clear in the minds of the inspectors to date, for the matter."

To which Col. Ritchie replied:

"I don't know if you can say. That would depend on the extent of the defect and the type of casting and the extent of the machining and other factors which might enter into the picture. That may have to depend on a particular decision in each case."

Tests of butt welds in 1/4" plate at Watertown Arsenal were described by Mr. Warner as follows:

"One question that was raised by a representative of a fabricator of vehicles such as armored reconnaissance cars on which they use 1/4 inch face-hardened armor plate was what ballistic result did you get out of a fusion weld on a 1/4 inch butt joint of face-hardened armor. So we made up four samples, in which we tried two bevels; one was a double V bevel, equal bevel from both sides of the plate, and the other was a double V bevel in which the majority of the bevel was from the rear of the plate. It was a very small V, only a sixteenth of an inch deep from the face. One of those joints we welded by clamping down the plate, face down, on a steel table, and clamping it down tightly making the weld from the rear of the plate first, and turning it over and welding the face of the plate with a single pass. We tried both of these bevels that way. Then we took the same type of bevel, the same type of plate, two other specimens, and clamped those plates on blocks, immersed in water, so that the face of the armor plate was in contact with the water. The plate was down about 1/32 of an inch in the water. We wanted to see two things: one, whether the water would keep the plate cool enough, and second, whether we could weld in a wet condition like that, without having trouble with the arc. We found that by having the joint itself backed up with a strip, even though there was water on that strip, we didn't have any trouble with that 1/32 of an inch film of water in making the weld. Then, after these welds were made, they were X-rayed, and the X-rays looked all right, so we made ballistic tests with .30 caliber and at 100 yards, and these are the results we obtained. I will read them off quickly: for the 1/4 inch face-hardened armor, the specification is 1975 foot seconds. On the double V, the first one was a small V on the face, welded clamped on the table, we got 1450 foot seconds on the joint. With the equal double V bevel clamped on the table, we got 1550 foot seconds ballistic on the joint. It makes no difference whether you cool the plate in water or whether you clamp it on a cold table. The ballistics are about the same; but the interesting thing of the whole series is that you only have 70% to 75% ballistic efficiency on this face-hardened plate with the arc weld. Now whether that is indicative of what we should expect with fusion welding on face-hardened plate even with water cooling I don't know. This particular thickness of face-hardened plate, on thicknesses below half inch is quite a problem to weld and keep the ballistic efficiency up, because of the heat of welding.

"On the four similar specimens of homogeneous plate, beveled, however, with a single V bevel, completely through the plate, and welded with the plate clamped down on the same table, after the welding has been completed in the groove, turning the plate over, and after a slight grinding operation, putting on a seal bead, using 25/20, monel metal electrode, 18/8 and a 1/16" 25/20, the fourth one was welded with 1/16" 25/20. We got ballistics as follows: 1550 on the first one; the second one was 1450; the third one was 1450; and the fourth one was 1350. The specificied ballistics for the plate is 1050 foot seconds. That means that in every one of them we got over 100% ballistic efficiency, according to what is expected and specified for the plate. Number One was 1/8" 25/20. Number Two was monel. Number Four was 1/16" 25/20. We simply clamped those down to the table and welded them. It is pretty easy to get 100% efficiency on 1/4-inch homogeneous plate. It seems an impossibility on face hardened."

In addition to these tests, a series of three experimental boxes of 1" plate have been prepared, welded, and tested by a shock test at Aberdeen Proving Ground. Two of these boxes of 0.50% C Cr-Mo-V rolled homogeneous plate were welded at Watertown Arsenal as referred to by Mr. Warner:

"We have built two boxes of one-inch homogeneous armor plate, in which we have incorporated three butt joints, and have not made any special preparation of the corners. In other words, the type of corner joint we have made is probably the weakest type that could be conceived of. It is the poorest type ballistically, figuring if we could get ballistics on that type we could get them on any other type. A box of that type, the one face being open, this is 18 inches here, 18 here, 12 high, and 18 square otherwise. We have a butt joint across the top, and put a butt joint in the side here and a butt joint in this side here, and the way we did it in Watertown, we made the butt joint in the plate, so weproduced this face and this here, and the top, and then we put the thing together, then welded it."

The corner joints referred to were of the single fillet type and were welded with a carbon moly ferritic electrode. The butt welds in each of three faces were of the double-V type and were welded prior to the assembly of the box, using a 25/20 buttering layer with the body of the weld of carbon moly and the surface layer of a hard-facing material. The only difference between box number 1 and box number 2 was the welding sequence used in assembly.

Box number 1 was assembled and tack welded. A single layer was deposited in each joint, the box being moved and positioned so that the welds were each made in the flat position. After the first layer had been deposited in all corner joints the same process was repeated for the second layer, etc. until all corner joints were completed.

Box number 2 was assembled piecemeal, completely welding each corner joint as the assembly progressed. This procedure necessitated the use of tie bars and clamps to prevent distorting the parts out of position.

After completion of these two boxes radiographic examination of the welded joints disclosed transverse weld cracks from three to six inches apart in the corner joints. These cracks were not evident on visual inspection.

Box number 3 was of face-hardened plate and welded by the Lincoln Electric Company with Armorweld electrode (Mn modified 18/8) using a multiple bead technique. Examination of the completed box at Watertown disclosed numerous cracks adjacent to the weld joints apparently associated with the heat-affected zone.

All three boxes were shipped to Aberdeen Proving Ground for ballistic tests, the results of which were described by Lt. Reed as follows:

> "For the ballistic test on these boxes, we inverted them. That was the only way we could hold them down. Put a clamp on one end, lay one end against a rest, and fired 37 millimeter TP M51 at a velocity of 1768 feet per second. We hit six inches to the right of that weld and cracked every weld in the box. The ones on the back opened up 1/16 of an inch. This weld here cracked from the center down to the opening. Box number 2 we mounted to hit the top weld, and of the eleven welds on box number 2, the first impact on the top cracked seven of them. Now these cracks occurred not here, not here, but in here, about 1/8 inch on boxes number 1 and number 2.
>
> "Box number 3, the face-hardened box, was superior to either of the homogeneous boxes. We struck that six times; we struck it four times with this same projectile 37 TP M51 and twice with 37 millimeter AP M51. Twice cracks occurred on the metal side of the weld, but in no case did cracks run the full length, the way they did on the homogeneous boxes. We would have an impact. We would have a small crack here. The second impact would crack this and would crack this. The third impact might start a crack over here, but in no case did the whole thing give out as happened with the homogeneous boxes."

In this connection an observation was made by Mr. Warner as follows:

> "I just want to call attention to one thing. We are discussing cracks in the plate and the effect on ballistics. In this number 3 box, this face-hardened plate, there were some fine hairline cracks in this case. Some of those cracks were in there due to heat treatment and before the box was welded, and whether any

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of them occurred due to welding, I don't know, but they were there when the box went for ballistic tests, so that is another fact that enters into consideration. Apparently, they are not serious as far as ballistics go."

A common viewpoint held at this time was indicated by Mr. Landgraf:

"What would have happened if you welded that completely with 25/20? Probably it would be low in ballistic value, but how about holding the thing together? 25/20 would be considerably better. There is no doubt that 25/20 would have been better from that angle."

This viewpoint was emphasized by Mr. Emery:

"I believe Lt. Reed can tell you some of the things we tried down at Aberdeen. The combination of 25/20 and non-austenitic electrodes didn't work out so good, but when we used austenitic electrode altogether, it withstood the 75 millimeter shock test without any trouble. The minute we started to introduce other electrodes with the 25/20, they were not so good."

Some tests made at Rock Island Arsenal on welds in 1/4" face-hardened plate were described by Mr. Emery:

"We made a number of welds there on fatigue testing of 1/4" face-hardened plate, and they were welded with austenitic rods and with non-austenitic rods, but I personally prefer to use the austenitic rods. Some were welded by other people who used a non-austenitic rod, and the consensus of this test is that the austenitic rod is better than the chrome rod used on the other tests. I have had some other weldments made using an austenitic 25/20 rod, and facing it with a 4-6 chrome rod, after the 25/20 welding was complete, and that appeared to work out very good. It seems that the 4-6 chrome rod will combine with the 25/20 without many check cracks when you use it. With the other electrodes we have tried to use, there is a tendency to crack. You don't get many longitudinal cracks, but you get cross cracks right across the width, but 4-6 chrome does not appear to cross crack, if you make that weld last, but if you are to complete your outside weld and put the chrome on and then weld on the inside, you will cross crack your chrome deposit on the outside."

Certain electrode development work carried on by the Arcos Corporation was described by Mr. Thomas as follows:

"Our work has been mainly in the austenitic field and has been entirely with homogeneous armor and our tests started out in the laboratory. Since then we ran tensile impact tests, those being conducted with the co-operation of the Navy Department, taking various types of austenitic alloys and testing the joints by tensile impact. 25/20 showed up with breaks in the welds themselves which we would expect because of the lower tensile strength, with of course a value of 100 to 150 foot pounds. But we took a number of high strength austenitic alloys which we developed, which were as strong as the armor plate with the expected high tensile impact values which would be obtained from armor plate of 657 foot pounds. We carried it further with some disappointing results. In making up some of these test samples, we used a joint which gave us a locked-up condition. One of our austenitic weld metals which on static testing gave a strength of 125,000 pounds per square inch, we placed in this locked-up stress condition, actually failed when the weld was cut apart, with a crack adjacent to the weld junction or right in the weld junction. However, we took one of these high strength materials in a large inch and a half plate, similarly locked up, and we found that there again cracks occurred in the same way adjacent to the weld junction.

"We have come to a point where we are beginning to believe that some of these high yield strength alloys, austenitic alloys, leave a residual stress in heavy plate which is great enough to actually cause failure adjacent to the plate, whereas where we have a low yield strength material, such as 25/20, we are able to get a stress relieving at low temperatures, so the residual stress is low enough and we don't have this failure adjacent to the welds. I see how 25/20 fails to maintain ballistic penetration on face-hardened plate, but apparently from the tests I have heard today, it is satisfactory on the homogeneous armor. Face-hardened armor, as I see it, is largely in the thinner alloys, the one-quarter inch mainly, and in the thinner plates we don't have the locked-up stress condition in our structures that we have in the thicker armor. Consequently, it appears to me that we should think of these high strength austenitic alloys in connection with the welding of a thin face-hardened armor, and the homogeneous, of all thicknesses we should think of, in terms of welding with some material such as 25/20, with a fairly low strength yield to prevent high locked-up stresses adjacent to the weld."

This concluded the discussion of development work which had been done to date. Col. Ritchie briefly explained the significance of the Subcommittee activities as follows:

"As you probably recall, you have been receiving some reports through your subcommittee organization, covering matters pertaining to the welding of armor and other items of interest which I hope are of interest to you. Some ten reports were sent out since the last meeting, and unless there are comments on that, we will continue that procedure, making the distribution. Of course, bear in mind that much of that material is of a restricted nature and should not be allowed to fall in unauthorized hands. That brings me to another caution I would like to make now before I forget it. Of course, all of our discussion in these

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subcommittee meetings have no official standing so far as changing specifications until these recommendations we might make have been approved by proper authority. In other words, don't regard any of our recommendations here as authority to go ahead and make any changes in your procedure until that comes through the proper way. We are only an advisory agency, so to speak."

Since the last meeting of the Subcommittee some thought had been given to Subcommittee organization with the idea of expediting some of the development work which had been suggested and encouraging activity toward promoting new development projects. The results of this thinking were outlined by Col. Ritchie as follows:

"I have one proposition to make which I would like to submit for your consideration, and that is that we name a subgroup in this committee, consisting essentially of the fabricators, in order to keep the group small, with probably a representative from Rock Island Arsenal and Watertown Arsenal, the representative from Rock Island Arsenal to be Mr. Schmitt or someone designated from Rock Island to be the Chairman of the subgroup to study that research and development program, and formulate specific projects which we should now press, in addition to what we have under way, with the view of coordinating that work more thoroughly and also making specific recommendations as to the allocations of that work, that is, where it might be most effectively carried out; that subgroup to report, if it be your pleasure, to the Chairman of your subcommittee. I would like to propose that Mr. Schmitt at Rock Island be chairman of the group, or someone he might arrange with at Rock Island, and the group to consist of the industrial firms--A. O. Smith, Electro-Motive, Baldwin, American Car and Foundry, Diebold, and York Safe and Lock. I would like to restrict it to that group of fabricators, calling in the welding electrode people if necessary in their consultations, but restricting it to this group so they can sit down in a small executive unit and study the program and formulate definite recommendations. That is one proposition. Another one would be that service representatives only get together, but I would much favor the former.

"This subgroup, if appointed, would meet at the earliest date practicable to discuss this research and development program appended to your minutes of your former meeting, and submit to me specific recommendations. I have indicated I would distribute those to the proper agencies including all the members of this Subcommittee for your comments, and this would take place prior to the next meeting, which would be held in six weeks or within the next month, as you would recommend. Through this method of approach to this problem, we hope to have research work cleared out of the way or at least developed to such a point that it would be of maximum assistance to those people who are in production or who will go into production in the future."

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This suggestion was approved by the meeting and thus was started what came to be known as the Research Program Subgroup of the Subcommittee under the chairmanship of Mr. W. F. Schmitt, Rock Island Arsenal. It was intended that this Subgroup would be composed of representatives from manufacturing facilities concerned with fabrication of armored vehicles.

Discussion of current development work indicated that there might be some duplication, due to lack of coordination, and this is where the Research Program Subgroup could be of great assistance. This was indicated by Col. Ritchie:

> "Schmitt at Rock Island plus Warner at Watertown will be in a better position at the moment to recommend or at least criticize this research and development program and place those projects in such shape that we can better appraise them than could this whole group, working as a whole. I am trying to make these people use the pick and shovel to the extent of doing some work for us, and we will look this over after they send it in. I will send out to you a letter, and you can criticize it and hash over it at the next meeting. It is an agency to apportion the work, study the program, and make recommendations which might seem appropriate. One of the main functions of this Subgroup is to recommend where work should be done, utilizing the facilities of industrial plants, in order that we may not lose any opportunity to press the work as rapidly as we can and to utilize fully all available facilities and talent."

It was decided that the next meeting would be in Pittsburgh, Pennsylvania. In closing, Col. Ritchie expressed the appreciation of the group for the arrangements provided by Mr. Smith, Republic Steel Corporation:

> "If you have nothing further, I want to again express our appreciation and pleasure in having Mr. VanDreser of the McKay Company with us as a member of the Subcommittee. I also want to thank Mr. Smith for making these splendid arrangements for us and taking care of us so nicely, providing the stenographic help, and for the other things he has done to make our meeting so pleasant and genial."

It should be pointed out here that the organization of this Research Program Subgroup was the beginning of a system of organization of the Subcommittee membership into various groups of specialized interests, which was to facilitate the functioning of the Subcommittee later when its membership had reached such proportions as to prevent effective discussion in a one-day open meeting of all phases of its field of activity. The Group organization reached its height in late 1942.

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FOURTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
22 AUGUST 1941
DUQUESNE CLUB, PITTSBURGH, PA.

The fourth meeting of the Subcommittee was held on 22 August 1941 at the Duquesne Club, Pittsburgh, Pennsylvania, with 51 persons in attendance representing:

Fabricators	9
Electrode Manufacturers	8
Armor Producers	12
Ordnance Department	18
Navy Department	2
Guests	2

The Chrysler Corporation was elected to membership on the Subcommittee.

Since the arrangements for this meeting were made by Col. Knable, Carnegie-Illinois Steel Corporation, Col. Ritchie expressed the appreciation of the group in his opening remarks. Lt. Col. J. L. Guion, Executive Officer, Pittsburgh Ordnance District, presented Mr. Berg, District Chief and Chairman of the Board of the Dravo Corporation who complimented the Subcommittee in the following remarks:

"Colonel Ritchie, Gentlemen: It is a privilege to welcome your Committee on its first visit to the Pittsburgh District. We are very appreciative of the splendid work being done by you in furthering our technical knowledge and expediting in a practical manner the procurement of material needed by the Ordnance Department. It is not my intention to discuss the several problems to which you will devote your attention today, for the engineering skill and knowledge represented here preclude any possibility of my adding to the wealth of information that you have already gathered. I have had an opportunity recently to review some of the activities of your Committee, and I am certainly impressed with the thoroughness with which you gentlemen are attacking the problems of initial fabrication, and repair and maintenance of armor structures by the welding process. We anticipate increasing benefits from your work as you get deeper into the problem of production of ordnance materiel."

At the previous meeting of the Subcommittee in Cleveland in June, 1941, a Research Program Subgroup had been appointed consisting of representatives from the following organizations which are members of the Subcommittee:

Organization	Representative
A. O. Smith Corporation	J. J. Chyle
American Car & Foundry Company	W. C. Osha

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Organization	Representative
Baldwin Locomotive Company	A. J. Raymo
Electro-Motive Corporation	J. H. Hruska
Diebold Safe & Lock Company	A. L. Abbott
York Safe & Lock Company	W. B. Lair
Watertown Arsenal	W. L. Warner
Rock Island Arsenal	W. F. Schmitt, Chairman

This group had held a meeting on the preceding day in the Frick Building through arrangements made by Mr. Bibber who attended the meeting. At that meeting a development program had been formulated. Mr. Schmitt when requested for a report by Col. Ritchie requested deferment of consideration until later in the meeting because the typing of the minutes of the Group meeting was not yet completed.

The problem of supply and demand for stainless electrodes for welding armor was discussed. Major Atkins outlined the probable future requirements for production of tanks as follows:

> "The present requirement of tanks under contract are very well known. It is contemplated in the first quarter of 1942 to manufacture 1,000 medium tanks a month of which 300 will have cast hulls; the other 700 will have to be fabricated by welding or riveting. The casting manufacturers can only supply us with between 300 and 500 cast hulls per month, based on future expansion, and indications are that possibly 800 tanks will have to be subcontracted for welding and riveting to as many companies as have facilities for doing such work."

Mr. Brooker remarked as follows:

> "One point which may be of interest is that there was a meeting of the steel manufacturers and the OPM, Army and Navy, at which the possibility of changing 25/20 rod to something less strategic was discussed, since this 25/20 has to be broken down by hammers. The change will be to a lower alloy rod of 23/19 minimum to permit breakdown by rolls."

From Mr. Brooker's and Major Atkins' remarks, it was disclosed that OPM has been requested by the Office, Chief of Ordnance, as to availability of 400,000 lbs. of stainless steel electrodes of the 25/20 and 18/8 type by June 1942, for welding tanks during the remainder of 1942.

Some of the optimism recently expressed as to availability of alloys was criticized by Mr. Bibber:

> "There are in this country electrode salesmen, not present here, but at least representatives of two companies who have gone around stating there is no shortage of nickel and they can supply all the 25/20 rods anyone wants. We do not feel that that kind of talk about the shortage of nickel should be allowed. It is mentioned before this Committee to determine whether these two people have any justification for making such statements, and if so, we should be corrected."

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To which Mr. Landgraf replied:

"Nickel is very critical at present and a lot of foundries are lucky to get enough nickel to keep them going. Those statements are not justified and we will find all of a sudden OPM will stop all supplies of 25/20."

An interesting situation with regard to requirement for nickel was pointed out by Col. Rehm:

"There is one very interesting thing about this nickel situation--making a riveted tank using 3.50% nickel rivets, considering shanks and heads, there will be more nickel used in riveting the tank than by welding with 18/8 welding rods. We haven't started any welding yet but we do use a barrel of rivets, and the shortage of nickel - it is going through my mind that we might have to put them together with glue - 1,000 tanks a month will mean a lot of rivets. The OPM has said O.K. on 18/8."

The situation regarding the welding of armor in England was outlined by Mr. Hignett as follows:

"Gentlemen, I am very proud to have this opportunity of thanking officially all of those members of this Committee who have so kindly given me a wealth of information on the methods or technique of this country; secondly, for the opportunity of telling you something of what we are at present doing in England. I must confess that our methods or technique are inferior to what you have in mind. We are engaged in welding two different types of tank. Regarding welding itself, we have had no trouble whatever. The first tank we weld is very small. We use 60° single V's and we weld with an 18/8 electrode containing approximately 4% manganese. We have two types of rods in use, 1/2% manganese and 3 to 4% manganese. We find little difference in results between the two. Our plate problems are mainly due to internal stress. The second type is a heavy tank. From a purely welding point of view, we have less difficulty in welding the softer armor than the hard armor due to the reduced rigidity of the plates. The 18/8 electrode in welding the heavy armor gives too much dilution. This caused us cracking. On the other hand, 25/20 electrodes are particularly subject to hot cracking. We have been very unsuccessful in using them on heavy butt welds. As far as results go, we find that the thin plate requires an 8 m/m thick weld with 18/8 rod. Regarding heavy plates, our only tests are done with heavy projectiles. We made up a complete full size model of the nose of our new heavy tank. No vehicle is likely to meet such punishment in service. It is my honest opinion that any riveted or bolted tank is an unsafe vehicle in which to do any fighting.

"Preheating--our general practice over there varies between two sets of fabricators. One set keeps its plates in a hot storehouse and the weld is carried out at temperatures of 80 to 120° F.,

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depending on weather conditions. Another class of fabricator has no equipment for hot storing their plate and they use local preheating, the upper temperature limit being controlled at 150° C. or 300° F. In the case of the heavy tanks, we feel that stress relief is desirable at 450 to 500° C., or at a temperature which is 50° C. below the drawing temperature of the plate. In the case of the light tanks we do not believe stress relieving is essential."

Experience at Aberdeen Proving Ground with ballistic tests of welded joints made with Lincoln Armorweld was briefly discussed by Lt. Reed as follows:

"In firing at your plates we have struck joints with a straight side with no V; also, two V's which meet in center of plate with edges separated 5/8". When you hit this you get a penetration at 1450. 1450 went right through. Three corner welds where plates did not fit together quite properly give complete penetration at much lower velocity."

These remarks inspired comment by Mr. Thomas as follows with regard to the welding problem:

"On thicker plates we have more trouble than with thin plates. I feel that 19/9 or 18/8 analysis can be used very satisfactorily on the thinner gauge plates. What the limit is, I don't want to say. When we get into 2" plate and larger, we will run into more trouble. Only solution for that is to use 25/20 electrode for buttering; because the thicker the plate, the more tendency for a locked-up stress condition. The thicker we made the weld the more rigid the structure became, the more tendency for cracking. We have tests of welding which give satisfactory results on 1" plate. On 1-1/2" plate we ran into cracking. We feel that on thicker plate we will run into more trouble."

Production experience in welding the M-3 medium tank hull at the Baldwin Locomotive plant was outlined by Mr. Raymo:

"We are welding armor of all thicknesses, homogeneous type, and within the next week we'll complete our first all-welded hull. We are using the 25/20 type of electrode. We have been making very careful observations of the weld metal as deposited, particularly when looking for fusion cracks, and thus far there have not been any in evidence. This matter of crater cracking, which has been discussed here this morning, might possibly be a function of the individual electrode used; however, I'm pretty well convinced it is very closely allied with the technique used. In other words, the method of breaking off the arc can cause this crater cracking to be eliminated or it can be extenuated by carelessness on the part of the operator in how that arc is broken. Now, even on our medium tank we range from 1/2" to about 2" plate and thus far no cracks are in evidence to the eye. As soon as we

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complete this hull, we propose to radiograph many joints that are accessible for good radiographic examination, but frankly I do not expect to find evidence of cracking in the fusion zone or in the weld metal. I think it is going to be quite impossible for any of us at any time to produce 100% joints, particularly where we have to use the double V type of joint, because getting thorough penetration at the apex of the V's in there is a rather difficult job. We can say we will flame soften the edges and such, but you still have a very difficult job of chipping out roots of the welds. Other than for that fault in the joints, I feel that the welded hull looks more promising than ever, and we have actually found the M-3 hull of the present design to be far more easy to handle as a welded structure than I first thought when we started out. It looked as though it would be quite a job, welding inside, different positions, etc., but actually it has not turned out to be a very difficult job from the standpoint of the mechanics of manipulation or moving the tank to get at the welding with a minimum of difficulty."

With reference to crater cracks, mentioned by Mr. Raymo, Mr. Brugge suggested that a beading technique instead of a layer technique does assist in eliminating these cracks and tempering the heat-affected zone. Upon this point, Mr. Thomas commented as follows:

"Commenting on that beading technique, that tempering of the armor can just as well be done whether you use beading or weave technique. You are tempering by putting one layer on top of another, and the heat of the subsequent layer is going to temper the hardened zone produced by the bead of the previous layer, and it doesn't matter whether beading or weave type of technique is employed."

With reference to Specification AXS-497, it developed that no "H" plates had as yet been received at Aberdeen Proving Ground for test. Some preliminary tests with Arcos 29/9 electrode have been made at Rock Island Arsenal, using both rolled and cast homogeneous plate. The Breeze Corporation are welding 1/4" thick face-hardened plate, using a buttering technique according to Mr. Konarnitsky.

The policy of the Navy on this buttering technique was outlined by Mr. Bissell:

"We abandoned the idea about a half a year ago. We feel we get satisfactory results with 25/20 welding with commercial electrodes, and that is what we are using. We found out quite a while ago that you couldn't use ferritic rod on austenitic, so our present specification prohibits it. We are confining our work to 25/20 and expect to use modified 18/8 as soon as we get data to show it is all right."

An interesting suggestion with reference to set-up of butt joints for welding, using a spacer strip, was made by Mr. Bibber:

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"Early in our work in the welding of armor we found out that one of the most important things in connection with this entire business was chipping. We are inclined to think of welding and forget chipping. Chipping is a very difficult thing and we have spent as much time as 1/2 hour to avoid trying to chip out the root of a weld. So we gave birth to the idea of putting a 25/20 rod in bottom of the opening, 1/4" separation, and using 40° angle of bevel. Now that idea was all right but it had one bug, namely, 25/20 material is very hard material to chip. We were able to drill the rod out, but it was hard chipping. Then we gave birth to another scheme of using a soft welding rod. We decided this should be opened up 3/8". 3/8" x 1/4" soft iron bar, with a 25° bevel. Start right in with 1/4" electrode and go to town and when it comes time for the chipper to start work he can go in and clean it out very beautifully. This had eliminated to a certain extent the chipping problem. It can pass any X-ray tests. You can make very successful welds with 25/20. The scheme was used in fabrication of our first tank. It works very nicely."

With regard to effect of lack of penetration and fusion at the root of a double V joint, Lt. Reed remarked about recent tests at Aberdeen Proving Ground:

"In striking plate we knocked a piece out with two rounds of 75's and put considerable bulge in the plate, yet the unsound welds stood up."

In connection with the proposal for square-cut joints made by Mr. Brugge, Mr. Schmitt commented as follows:

"I would like to comment on the square type joint. Several points are advantageous. One fact is the joint is easily prepared; does not require scarfing, which promises rapid processing of plate and eliminates any further processing of plate. Promises greater accuracy in cutting plates, since square-cut plates are more easily processed. I believe this has a great deal of merit and more work should be done on this. It should be used or discarded completely, but more work is required to determine this."

An objection was voiced by Mr. Raymo:

"The use of the square type of joint has a lot of theoretical merit, but I think you will all recall this idea had its heyday in 1932. Everybody in the country thought their welding problems would be solved over night by going to square joints. To the best of our knowledge the square type of joint has not found a very prominent place in any of our immediate fields of fabrication; therefore, I doubt whether it has a great deal of promise in connection with the assembly of our tanks."

Following this comment it was suggested that welding the plate from one side only using a single V instead of a double V should be

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considered. Experiments to this end are in progress in England but no decision has been reached. The high cost of extra weld metal (Stainless Steel) versus the cost of the added preparation for the double V was cited for consideration. Also, it was pointed out the necessary positioning equipment would probably be available in the production setup so that welding could be easily performed from both sides of the plate.

Upon question by Lt. Reed the current practice was further commented on by Mr. Hignott:

"Well, sir, I think two factors account for our practice. The first is that we started to weld tanks before any development work has been done and we have done our development work while producing tanks. The second is that it is normal practice in England to do no chipping, merely knock out the slag. Third, under our conditions, lacking beautiful equipment which I have had the pleasure of seeing in your country, we have to makeshift to a considerable extent. The biggest shop in which our light tanks were produced had operations so crowded that we had to work the sequence of production out in order to avoid fouling of the two largest manipulators. We had to alter the sequence to get away from that. I believe that will give you some idea of how we are trying to build our tanks and in addition we are trying to make them as quickly as possible and any time lost in chipping is a serious matter which also makes it evident why we are buttering. We merely make a butt weld to form a 2'6" plate and at one end weld on a patch and fire at the opposite side of the plate from the patch. We have two tests for electrode quality, and I would say our views are in a state of flux. The first test is for boundary weakness which consists of taking two plates and carefully cutting in order to leave a standard single V. We strap them down to a base plate and fill in the weld with 25/20, that works every time. We get some 18/8 boundary cracks and we approve or disapprove electrodes on the basis of that boundary cracking. The other test is for hot ductility for ordinary rods, which is not a standard test but used to decide unofficially which rods we like. That consists of putting a fillet weld in here and while that weld is being made, rotating the top piece where the speed of rotation is controlled and the time at which cracking begins is observed in regard to the time at which the weld is started and measuring the angle at which the cracking takes place. We have not paid a lot of attention to ballistic properties of the plates and we are not too much concerned about unsoundness in the weld because in our heavy tanks we are doing something which I myself strongly disapprove in order to avoid slowing of production. Fastening of a plate to the nose plate we use at one end the horrible simple fillet weld. We have a natural unsoundness here far greater than normal in an ordinary weld."

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Lt. Reed made a comment as follows:

"My reason for asking Mr. Hignett if the British were more adept is because I am wondering if we weren't becoming a little too careful with our welding fabrication. We have learned the British are quite satisfied with molasses and straw to hold the plates together, and here we are worrying about small cracks. The reason I wanted to make sure, Mr. Brooker, is where a weld showed unsound but stood up and I think it would be well for us to not lean too heavily towards unsoundness but to be spending more time on other things than being absolutely sure no slag inclusions are in the weld."

This keynote raised a perplexing question regarding acceptable quality which was briefly commented on by Col. Ritchie as follows:

"If there is a tendency towards sloppiness in production, that will not become less, it will become greater. We must strive for the best we can obtain without undue interference with production. After all, it is tanks we want, but we want them welded as best they can be welded."

With reference to criteria for inspection acceptance raised by Mr. Jeffries, Col. Jenks commented as follows:

"Your technique, in my mind, as you proceed, should not be based on two or three stress applications. There is no reason why you shouldn't work out something to stand more than one or two stress applications, but when you come to production, you can't do that. You are just going to make some sort of examination which will be a rough test of your technique. But why not work out the technique that will stand a reasonable number of stress applications? You can't calculate the stress you are putting on these plates when they are hit. There is something more or less accidental about the thing. Your stress concentration will depend upon the geometry; you will have an unknown factor of stress concentration. It seems to me you have a rather serious problem here that gets more and more into the logic and rather than practical production in studying these things."

Mr. Bibber feels satisfied that using the method of set-up he suggested there will be no necessity for accepting welds unsound at the root. Since production of tanks is, at the present time, of greatest importance to the British, Colonel Ritchie requested Mr. Hignett to comment on British policy with respect to development of welded tanks. Mr. Hignett commented as follows:

"If we had time we would divert it to getting more perfect welds through carrying out more routine tests. I said before a bad weld was better than a riveted joint, and I stick to that, but do not want it interpreted as an encouragement to the production of bad welds. We have had to start by making any weld that would hold the armor together. Your state of affairs is entirely different and it wouldn't serve any purpose for you to start

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the same practice. You should start by making the welds to the best practice and technique. I think you should carry out research work to study what precautions can be relaxed and still give you satisfactory service performance. You may find you don't have to do certain things through proof under service conditions. Each of these things should be done under service conditions and you should release them later. That is the way we would have started had we had the opportunity. Your service conditions are different than ours; you may make tanks that will have to run thousands of miles."

In answer to questions regarding requirements for armor plate used in welded construction, Mr. Hignett replied as follows:

"We definitely restrict the carbon content in all plate to .30 maximum. We tried to get down to .28 maximum, but the steel makers would not agree. We have a great deal of material to justify this. Although small models may be made satisfactory, in production you will run into trouble. I would like to add a word regarding inspection. We aim to have a welding inspector in every fabricating shop to supervise the entire welding operation. We do not have enough of those people available. We do have a great many men running around the country popping in on fabricators and we rely on these men's reports."

In connection with this phase of the welding problem American specifications for armor at this time were as described by Col. Jenks:

"We have no limits on our carbon composition either on rolled or cast plate. In some cases the plate delivered has carbon in excess of .35 and in some cases, even .40. Therefore, there is a difference in the problems from the welding here and the British practice."

Mr. Hignett further commented that British practice involved local preheating up to 350°F. minimum.

At this point the activities of the Research Program Subgroup were discussed by Mr. Schmitt. Each member of the Group present was requested to explain the program which he proposed to carry out at his particular facility.

Mr. Rayno (Baldwin Locomotive Company):

"The Baldwin Locomotive Company proposes to prepare test specimens, both the shock and penetration type, in accordance with Specification AXS-497, using homogeneous armor of the rolled and cast type. Specimen combinations will include test plates all of one type of armor and other test plates made up of a combination consisting of rolled and cast plate. All test specimens will be 1-1/2" thick. The electrode to be used will be 25/20 type only. Our proposal for the preparation of plate does not contemplate any preheating or post heating; simply as existent under conditions under which you have to fabricate."

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There was some comment that 25/20 would not be available but Mr. Schmitt explained that:

"There are eight members of this committee and this work is broken up among eight members and others of the group will be performing work on the other types of electrodes. We are trying to fit this work in with the work already under way at the various plants."

A joint program on automatic welding (Unionmelt) is to be carried on by Electro-Motive Corporation and A. O. Smith Corporation as explained by Mr. Chyle (A. O. Smith Corporation):

"The program for automatic welding of armor plate is to be made jointly with Mr. Hruska of the Electro-Motive and myself, details of which will be worked out jointly as to procedures. Plate material for these tests will be furnished by the Ordnance Department. Joint progress reports may be furnished from time to time. Tests to be made on plate thicknesses of 1/2" and 1-1/2"."

As to electrodes Mr. Hruska explained that:

"We might use two types. The 25/20 if we can get it. We are trying others, but what they will be is still to be decided."

A comparison of the H and Y type test plates is to be made as explained by Mr. Lair:

"Subject to confirmation, York Safe & Lock Company will weld two 1-1/2" thick plates of homogeneous armor, using the Y and H types of joints with each of two electrodes, namely, 25/20 type and nonaustenitic. The plates will probably be furnished by Disston. All plates will be homogeneous. We have included 25/20 as a basis of comparison. Welding in the same shop in comparison with some austenitic wire. We don't contemplate any preheating."

A contemplated program by Carnegie-Illinois Steel Corporation was explained by Mr. Bibber:

"Tests will be made comparing the Y type of joint versus the H type of joint in 1-1/2" thickness only, using at least two different types of electrodes. It is possible that Carnegie-Illinois may also test a third type of slit joint. The reason for the third type proposed is that the H type with which you are all familiar takes something like 96" of weld metal and that is a lot of weld metal and makes these joints costly. The Y type has the advantage over the other two types in that there is something like only 66" of weld metal. Then the thought occurred similar to that which Mr. Hignett proposed but with one slight difference; taking a 36" x 36" plate and putting a hole here, using the type of joint I described this morning, 3/8" countersunk, those two operations are about the simplest machining operations. Take the top and slit to the type you propose to use, then you have a joint absolutely locked up. Our practice is to do our welding at what we consider

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the equivalent heat of a hot summer's day. I believe in doing this. Our workrooms are kept as nice and warm as can be, and I am of the opinion one of the simplest ways to get this heat would be before you do your welding on a production basis, to place a steam coil on the floor and pile the plates over the steam, thereby getting 125°F. to 150°F. very easily, but our practice in this case will be about 100°F."

Mr. Bibber explained that 25/20 and several other types of electrode would be used.

It was explained by Mr. Curtis that fatigue vibration tests are in process at Rock Island Arsenal on butt welds in 1-1/2" plate and T-joints in 3/4" plate.

The Bureau of Ships, Navy Department, are experimenting with a restrained joint test as described by Mr. Bissell:

"We have introduced the 'torture test' which is about the same, but the plate is tied down to a heavy plate. We get as extreme locked-up conditions as possible. We have used the worst conditions, because we wanted something that would be useful in actual practice. We have tried two high-strength electrodes which have given us very good results on tensile impact and static tensile in unrestrained deposits but both have cracked on the 'torture test' after about four passes. Further work is being done on high-strength electrodes but the program instigated by OPM to reduce the chromium and nickel in our electrodes has us pretty well sewed up now. The laboratory that does this work is up to their neck. It was interesting to note even with 1/4" electrodes starting at the root and coming right up through gave us a joint that did not crack with 25/20; that is why we are pretty much sold on the 25/20 and fighting to keep it."

This coordinated program on homogeneous plate as above outlined was approved by vote of those present.

Mr. Rouse proposed that the penetration test required by AXS-497 be dropped and that only the shock test be used as follows:

"I believe we could do away with the ballistic penetration test, probably, which would save quite a bit of work. I think we should be concerned chiefly with the shock test. Recently, at the Proving Ground, we more or less accidentally ran into an effective shock test projectile - a cast iron plug. Our present test requires 75 m/m A.P. and since the penetration qualities of the 75 m/m A.P. are quite good, they go right through the plate and do not give it a very effective shock test. If we can hit the plates and shoot some projectile that doesn't penetrate so readily we feel we have given it a much more effective shock test. As a matter of fact, in experimenting with Mr. Emery's and Mr. Brugge's plates, we used that. We were not firing under specification and found it very effective. We can raise to a velocity of

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1200 to 1300 f/s without very much effective penetration and the plate has to take all that shock whereas with the armor piercing projectile we can go through at that velocity and the plate doesn't take as much shock."

This proposal was not discussed because luncheon was then announced. Following luncheon Mr. Schmitt continued with the discussion of the research program dealing with face-hardened armor.

Mr. Osha (American Car & Foundry Company) stated that:

"American Car & Foundry will make test plates of both the Y and the H types with 1" face-hardened armor plate, using the 25/20, the modified 18/8 and a non-austenitic electrode. The plates will be supplied by the American Car & Foundry Company. We do not intend to include preheating or post heating."

Mr. Abbott (Diebold Safe & Lock Company) stated that:

"The Diebold Safe & Lock Company will furnish two face-hardened 'H' type joints 1/4" x 36" x 36", one welded with austenitic 25/20 electrodes, the second with modified 18/8 electrodes. They will also furnish a third joint of the Y type welded with 25/20 electrodes. The results of pending tests on plates welded with 29/9 rod will be tabulated and if the tests are satisfactory, an H type plate welded with this type of rod will be furnished the Arsenal. Otherwise, results of Diebold tests only will be furnished."

Mr. Schmitt requested a decision as to a suitable data sheet for recording necessary information regarding test plates. This matter had been mentioned before and at this time Col. Ritchie proposed the following action:

"I am wondering if we should not get this by correspondence. We have some forms to submit and these forms will be agreed upon, This will save time. The results of your criticisms will be correlated and a final form decided upon. Any objections to this procedure? We don't want to delay this, but I think that by handling it with correspondence that will be a better way. Your comments will be appreciated as promptly as possible."

Another point raised by Mr. Schmitt dealt with the situation where the Ordnance armor inspector could under present rules prevent the use of armor plate for test purposes, because the plate had not been proved satisfactory by ballistic test; and in addition all tests had to be witnessed by an Ordnance inspector and arrangements made through the Ordnance District Office for shipment to a Proving Ground. This situation could delay welding development if permitted and was cited by Mr. Schmitt as follows:

"One other phase--it was asked by the group that we should have relief from the Ordnance Inspector insofar as development

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work is concerned. We would not want to involve the Ordnance Inspectors on the development of plate. Plate being prepared for test purposes should be handled without going through an Ordnance Inspector."

A minimum requirement was brought out by Col. Ritchie:

"The inspector should be advised of the findings, but insofar as the tests are concerned, I don't think it will be necessary for them to be on hand to inspect."

and amplified by Maj. Atkins:

"We will have to be advised that tests are being made and material shipped to the different proving grounds."

After Mr. Schmitt further explained that:

"These tests will all be made on ballistically approved plate. The thought in mind was not to go around the District Ordnance Office, but to eliminate having an inspector witness the tests the same day, etc. Some plants may not have an inspector assigned to the plant, and he would have to call an inspector and this would become a burden."

Maj. Atkins expressed general agreement of the idea:

"Anything to facilitate getting the material to the proving grounds and back will be of help. This will eliminate a lot of inspection work."

This general program was agreed to by those present and Col. Ritchie suggested that all test plates be radiographed for record purposes. Also it seems desirable that the Research Program Subgroup should be continued as a functioning body.

This program of tests above outlined represented the immediate problems of interest to the other fabricators as far as making the weld is concerned. There are numerous other problems of tank fabrication that must be studied as indicated by Col. Jenks:

"These programs that you are undertaking now are immediate programs which concern the fabrication of welded structures and it is essential that we get into certain other phases. This program doesn't cover by any means the information that should be available in connection with the welding of tanks. In looking over some tanks that have been welded, there were some joints that I thought were pretty good and some other types that were rather doubtful. It seems to me we should undertake research to define what types of joints are permissible and desirable in welded tanks. One of our big problems in welded tanks is, as has been indicated, not the resistance to penetration, but resistance to shock, and this depends on many factors. One factor which is unknown and difficult to analyze, is the factor of internal stress. So far, we haven't considered that and we are going ahead without benefit of stress relief. I think that is a factor which ought to be studied by a laboratory program - to find out what the value of stress relief is - get some idea of what internal stresses are set up and the effect of them. In work of this sort, we are concerned with the metallurgy of the base metal and also the metallurgy of the welded joint, and the program so far does not go into these questions of studying those two phases. Eventually, I think we must give our attention to the chemical composition of our plates; we may have to limit some elements. The question of the dilution of the electrode material has already been mentioned and the undesirable qualities of the diluted electrode material has been referred to. A tank is a structure and the study of specimens does not give us an indication of how the structure is going to behave under certain sets of conditions. We might make fatigue tests and get some information on the behavior of the metal under these conditions, but those fatigue tests we make on a joint, especially a joint stress relieved, do not give us any information as to how the structure will behave. So I think we have an enormous amount of work to be done in connection with the structure itself. Therefore, it is my opinion that we shouldn't be content with laying out a research program to study some of these questions, which you as welding engineers are interested in, but we should study this whole question and organize work by which we would answer these questions in a scientific manner, and I hope this Committee will go ahead and make a study on a thorough basis on the metallurgy of tank welding!"

Col. Ritchie outlined, for the benefit of those present, other development and research activities which are in progress at this time:

"I agree with what Colonel Jenks said. However, the purpose of this Subgroup was to go into those problems which are more or less of immediate interest in connection with production of tanks; that phase of the work is more or less fundamental. The basic side of the work is being covered probably not as thoroughly as it should be, but we have recommended sometime ago to the National Defense Research Council such points dealing with welded structures as determining stress development, certain types of age-hardening alloys, effect of fatigue, a series of some six or eight problems which the N.D.R.C. has under consideration or has had under consideration and is now taking steps to put into process of solution. We also have at the Watertown Arsenal some tests which are touched on in a way in the program of the Subgroup, but which we didn't mention because the Subgroup was dealing with the problems of immediate concern; so the entire story was not told by the Subgroup as far as the fundamental side was concerned. The work which is being done through N.D.R.C. will, of course, be made available to this Subcommittee as soon as it becomes available to us and ought to be of benefit to us all."

[redacted]

The development work under way and planned at Watertown Arsenal was outlined by Mr. Warner:

"After the discussion yesterday of these industrial activities about which you've been informed already by Mr. Schmitt, the question came up as to what Rock Island and Watertown could do in the way of helping along on this project. Both institutions are carrying on research tests of various kinds and at Watertown we are carrying out some work on weldability studies. That work in the past has dealt with structural alloy steels, such as are used in ordinary ordnance gun structures. We expect to continue that and enlarge the study to include armor, both of the rolled and cast type, face-hardened and homogeneous compositions with probably a low carbon electrode such as we use on structural steels, and one or two modified ones, either 18/8 or non-austenitic electrodes to see what the reaction on these various plate materials will be. Different preheats will be tried when we weld with these electrodes. No joints or ballistic tests. With respect to the point mentioned by Colonel Jenks in regard to dilution, we might find some information by using spectrographs in studying the dilution of the weld metal and any effect it might have on the heat-affected zone. Some work is being done on low-temperature impact, using the bar without the notch, and as far as I know that work has been carried on on unwelded armor. That work will be continued and results may eventually be available."

Col. Ritchie emphasized that this program is not a program to end all programs of development and tests of welding armor:

"Supplementing these remarks, we will make tests of low temperature and temper brittle conditions. Are there any comments on the reports of the Subgroup with respect to the more fundamental side of the research? Don't get the thought that the report of the Subgroup closes the program. We are open for suggestions."

The problem of repairing armor castings by welding without stress relieving was brought up by Mr. Emery:

"I would like to have an expression from the Inspection Division and it may also involve some research work: To what extent can a fired but unmachined portion of a cast turret be welded with an austenitic electrode without stress relief? It seems to me that some imperfections will appear up to the point where the turret is ready for shipment - the final inspection will find some defect, sometimes large and sometimes small, and there seems to be a difference of opinion as to what extent that welding can be done. Now we have welded cast turrets under Lt. Reed's supervision with 25/20 and they have been fired and according to his report they stood up pretty good, and we'd like to know why that cannot be done on a turret that has passed everything but the final inspection?"

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This question is coming more and more to the forefront as a problem for consideration because of the desirability for salvaging castings in the steel foundry and fabricating shop. The inspection viewpoint on this problem was briefly explained by Col. Rehm:

"We had a meeting about two months ago and that question came up, and it was agreed where the casting had to be machined over the weld you have to stress relieve, but where cutting was not involved, you could weld without stress relieving. I thought that was gone into very thoroughly. As far as I am concerned, if anybody could repair a casting by welding so it could be machined without heat treating or stress relieving, I would accept it, but I haven't found anyone who could."

The question was referred to the Research Program Subgroup.

Col. Ritchie brought up the question of small surface cracks in plate and castings, which had been discussed at the previous meeting:

"Another matter which came up at the last meeting was the rejection of castings for small cracks and for internal cracks on face-hardened armor. I believe Diebold sent plates to Aberdeen which were tested, and I believe these tests didn't show any enlargement of the cracks. I would like to have some comment on that."

Major Atkins commented on the results of firing tests at Aberdeen Proving Ground:

"At Aberdeen, we fired on six plates. Four showed cracks; two showed no cracks at all under magnaflux. The four that showed up under the magnaflux had small cracks in the center from bolt holes out. We fired on those and got limits in the cracks but no material difference between ballistic limit of the plate and the cracks, but the cracks extended from the face to the back, but did not extend longitudinally; just went on through the plate. The matter is up for discussion in the Ordnance Office, whether or not we can accept plates showing cracks, or whether we will have to reject. No decision has been arrived at. Carnegie-Illinois did the same thing for us on rolled plate of homogeneous grade for repairing face tears and scores with welding, and we had decided in the case of rolled homogeneous plate that repair by welding is advisable in the same way as welded homogeneous castings."

Experience in the Philadelphia District with this problem was outlined by Mr. Jeffries:

"May I tell you of some experiences in the Philadelphia District with some plates which were face hardened. The plates were machined at one plant and returned to Henry Disston for straightening and inspection or heat treatment and inspection. We then ran into quite a few cracks in the hard facings, most of which do not extend into the back of the plate or very far from the edge of the plate into the hard-faced surface. At that time

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the Disston Company were repairing plates by welding without grinding out the crack. We took exception to this, feeling that if the crack was not a hazardous crack we might just as well leave it there and not weld it. We submitted some plates to Aberdeen, plates that were not repaired, plates where the crack was not ground out but was welded, and plates in which the crack was ground out without doing anything to it. The result of the tests, I don't know whether Lt. Reed knows anything about these tests, but it indicated that if the crack was not serious, you were just as safe leaving the crack without doing anything to it. Welding of the crack without grinding it out appeared to be no worse than welding the crack, if you did grind it out. We are not grinding out cracks; we are not welding cracks; and we are shipping plates containing slight cracks. By this I mean that if the crack does not go all the way through, we feel that this is not hazardous plate, and we accept this and ship it. We have taken the viewpoint that we can determine if the plate is not or is hazardous. We do not recommend from our experience that the plate be ground out and welded, or welded at all."

This question of surface cracks in armor is troubling both the Ordnance inspector and the armor producer. The viewpoint at Aberdeen Proving Ground was indicated by Mr. Rouse:

"We inspected quite a few plates which had been rejected in accordance with our specifications. Quite a number of the cracks are minute. We feel that a crack of this type should be acceptable unless, i.e., the plate is part of a structure, or that particular plate has to withstand structural stress. Insofar as ballistics are concerned, we believe it would be doing harm to weld such a plate. Too, our specifications state there shall be no cracks. The specification, however, does not mean this. I don't think that it would be possible to write a specification to cover it."

To which Mr. Jeffries added a note of caution:

"We must be very careful in accepting plates with cracks. It is difficult to describe the critical length or the dividing line between satisfactory and unsatisfactory plates."

Studies of weld bead specimens of 1" thick cast armor have been in process at Watertown Arsenal since the last meeting. These studies have indicated that a post heat of 1300°F. for one to two hours reduces the heat-affected zone hardness of the single weld bead to about 260 BHN., without affecting the hardness of the cast armor itself. This same result may also be accomplished by the use of a heating torch according to Mr. Warner:

"When we found 1300 would do the trick, then we wanted to find whether you could take the same weld heat-affected zone and torch heat to a certain temperature, watching the color by eye or using an optical pyrometer and get similar results. We simply heated up to a good color of cherry red somewhere between 1300

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and 1400°F., figuring the critical temperature of that plate material was around 1475 to 1500°F. I then checked these specimens just roughly with the pyrometer and the temperature in one case got up to 1450°, but it was a good red heat and when held at temperature with the torch for 15 minutes, then cooled in air, the section upon examination showed hardness around 250/260 Brinell, which is in the machining range. I am not saying you will not get a reduction in the hardness of the casting; if you heat too hot, you will, but an experienced operator should be able to judge proper heat. That takes care of the heat-affected zone. If you are using 25/20 electrode, it doesn't help much there. On surfaces which are not fully exposed to projectile fire, an ordinary low carbon electrode will make your repair all right, or better still, if you use an electrode which gives you a composition similar to your cast armor, this treatment will soften it. The interesting thing about these torch-treated specimens is that there is absolutely no heat-affected zone left. These data will be submitted to the Subcommittee as soon as we can get them worked up in suitable form."

It was pointed out by Mr. Brugge that a similar effect can be produced with a multiple-pass technique:

"We found by taking armor plate and welding, at first making one bead, then making two beads (illustrating on board), where one bead was laid on the armor plate, the armor plate was 40 Rockwell C and a maximum hardness of the fusion zone with one pass turned out to be 50 Rockwell C. With two passes of weld metal on there, not touching the armor plate in the second case, that hardness was brought back to 40 Rockwell C."

In the discussion which followed, it was pointed out that the method of torch annealing could probably not be effective for treating large weld repairs, and in no case would it afford the control of temperature which is obtained by a furnace treatment.

Mr. Hignett briefly discussed the use of stud welding in England as follows:

"We aren't actually using spot welding in production yet, but we have devised a method which we could use if we found it desirable. The difficulties of using are purely engineering ones, not metallurgical or welding ones. We are projection welding studs onto the face of armor in an ordinary projection spot welder, the studs held in the die and the projection weld handled in the usual way. The essentials are - we have found up to 5/16" diameter to be O.D., but over 5/16" diameter and with the machinery we have available, we can't apply the stud and get a complete weld on the surface and have to compensate by other means. When we merely projection weld that mild steel stud onto the armor we get a brittle zone in the region that has been heated to the critical point which we get rid of by post heating.

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And, we found it very necessary to control the post heating. We merely heat below the critical and never exceed the critical. If we exceed, we have the same state as we did before."

During the general discussion which followed, Colonel Rehm injected a pertinent question with regard to welding electrodes for armor:

"Most of the discussion appears to have referred to 25/20 electrode. You also tell us that you cannot get this electrode. Chrysler is going to start on this program - what electrode should they begin to use?"

Mr. Warner replied to this question as follows:

"In connection with the use of electrodes other than 25/20, there are, of course, quite a number of modified electrodes in 18/8 compositions proposed which, undoubtedly, have fields of usefulness. Perhaps not as extensive as 25/20 but nevertheless available. We have made tests recently with an electrode with 2% molybdenum in it. We have no impact or shock tests. As far as penetration is concerned, the welded material gives a butt joint either in single or double V of 100% resistance. Does not require any face hardening on it, any more than 25/20. No cracking. Our attitude has been, and still is, that even though a certain type of electrode has been approved, that does not mean that XYZ fabricators can use the same electrodes and get the same results. I think either the H or Y specification with a shock test is a satisfactory way of finding out what we want to know. That is one of the objects back of the Subgroup's work."

It was apparent that, at this period of the development of armor welding, it was considered necessary for each fabricator to qualify a welding procedure with each brand of electrode he plans on using for production of vehicles.

In this connection Mr. Jeffries raised a question about radiography:

"In that connection, I would like to ask a question. We are going to have quite a large number of procedure qualifications and welders qualifications. We understand that the plates are required to be radiographed by Watertown Arsenal, or can the district at the manufacturer's plant radiograph those test plates and use the procedure test plate radiographs, of course, to compare all welder qualifications test plates?"

To which Col. Ritchie replied:

"Not necessarily at Watertown Arsenal, but any place where adequate facilities are provided to do it. Under proper supervision, of course."

Mt. Hignett expressed appreciation for the courtesies shown him as follows:

"I want to thank you for the information given me which will make it possible for us to win the war. I am taking with me something more valuable than this, something much more easy

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to put over. I am taking home with me some of the kindest expressions to me through you and I can assure you that you will have the sincere thanks of everyone to whom I speak when I get back home."

It was suggested that the next meeting of the Subcommittee should be held in Philadelphia, Pennsylvania during the week of the National Metals Congress in October. This question will be considered by the Chairman.

The discussion during this meeting indicated that there were questions regarding quality standards for armor and welds in armor and methods of determining compliance therewith which were plaguing all concerned and which must be settled in some fashion before large-scale mass production of armored vehicles could be possible. It was also apparent that the expectation for accomplishment of this objective is quite optimistic.

It was notable that at this meeting the subject of spot welding and flash welding of armor was not discussed. However, a rather detailed discussion of this subject had occurred at the previous meeting in Cleveland in June 1941, and at that time the question of whether representatives of RWMA should be invited to join the Subcommittee was left undecided. However it was thought desirable by the Chairman of the Subcommittee that the aid of the Resistance Welding Industry be invited on this problem. Accordingly, representatives from several resistance-welding equipment manufacturers as well as Army Air Forces and Office, Chief of Ordnance were invited to a preliminary meeting at Watertown Arsenal on 27 August 1941 as explained on the next page.

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PRELIMINARY MEETING
SUBCOMMITTEE ON RESISTANCE WELDING
27 AUGUST 1941
WATERTOWN ARSENAL, WATERTOWN, MASS.

During the early part of 1941, when the Subcommittee on Welding of Armor was being organized and the welding of armor program was beginning to take on increasing importance, it was realized that the Subcommittee on Welding of Armor was not organized to cover the field of Resistance Welding. Since the importance and possibilities of this field of welding were realized in connection with the welding of armor and other items of ordnance, it was considered desirable to organize a Subcommittee on Resistance Welding to coordinate activities in this field.

Accordingly, with the approval of the Ferrous Metallurgical Advisory Board, steps were taken, in the summer of 1941, to organize such a Subcommittee consisting of representatives from companies engaged in the manufacture of equipment for resistance welding and representatives from interested services.

The original concept of the functions of this Subcommittee envisaged the application of resistance welding to all types of Ordnance items and the organization meeting of the Subcommittee proceeded on this basis. However, after a few months of activity (August 1941 - June 1942), it became apparent that, due to the urgency of the armor program, the work of this Subcommittee was concerned solely with the problem of resistance welding of armor. It was, therefore, decided to incorporate this Subcommittee on Resistance Welding into the Subcommittee on Welding of Armor as the Resistance Welding Group. This was accomplished in September 1942. During this relatively short period of existence there were held three regular meetings of this Subcommittee.

The first meeting of the Subcommittee on Resistance Welding was held on 27 August 1941 ~~at~~ Watertown Arsenal with 19 persons in attendance representing:

Resistance Welding Equipment Manufacturers	7
Ordnance Department	8
Army Air Forces	4

Brig. Gen. R. W. Case, C.O., opened the meeting and in his opening remarks explained the purpose of the Subcommittee as follows:

"I just want to express my appreciation to all of you gentlemen for coming here to help us out in connection with this work and to welcome you to Watertown Arsenal and assure you that we are very glad to have you here and will be very glad to co-operate with all of your firms to the fullest extent. I don't know whether you gentlemen know just what our set-up is or the status of our subcommittees. I will cover it briefly in order that you may know it. The Ferrous Metallurgical Advisory Board is headed up at

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this Arsenal. That is the advisory board on all ferrous metallurgical matters for the Ordnance Department. That includes, of course, all the other Ordnance establishments as well as this Arsenal. That Advisory Board is used by the Chief of Ordnance as his advisory body on ferrous metallurgical matters. Under the authority of that board, we have organized quite a number of subcommittees whose activities are coordinated and supervised by the Ferrous Metallurgical Advisory Board. Each of these subcommittees has a particular line of work or a particular problem assigned to it, such as the welding of armor plate. We have one on cast armor, one on rolled armor, one on aircraft armor and several others. These committees are composed, primarily, of the producers of the type of material covered by that subcommittee's activities. Now, the question for you gentlemen is whether or not a subcommittee should be organized for resistance welding. If so, if you gentlemen think it should, what should be the organization of it, who should compose it, and such other relating questions as should come up in connection with it."

Col. Ritchie, taking over at the conclusion of Gen. Case's remarks, further elaborated on the scope of activity of the Subcommittee:

"It would, as I see it, cover the matter as laid down in the objective, the development of suitable resistance welding methods for the manufacture of armored and other ordnance structures. This would involve research and development work as may be carried out through a co-operative program and facilities available either at your plants, at this Arsenal, or at other Ordnance establishments, the idea being to see wherein and to what extent it is possible to apply practically resistance welding to the manufacture of Ordnance structures. That involves not only armored structures and aircraft construction but also all Ordnance structures wherein resistance welding might be preferable or desirable."

The most immediate problem was emphasized by Col. Ritchie:

"The most immediate problem is the welding of armor, probably as applied to the aircraft construction, and also our armored cars and other lightly armored vehicles."

It was apparent from the discussion that those present were in general agreement that the organization of the proposed Subcommittee was desirable as expressed by Mr. Gillette:

"I think from the experience that we have had in various jobs, a committee of this kind could help tremendously because the experience of several users and manufacturers is always better than your own experience. There have been some jobs which have worked out very satisfactorily and other jobs which we still haven't whipped. It seems to me that a committee of the type represented here might be of a great deal of help toward coordinating a lot of this stuff and getting it into production much more quickly than the manufacturers working alone. I feel

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that there is a definite field for resistance welding in a great deal of the stuff I have had experience with. Based on civilian projects, other than ordnance, there has been a tremendous development and it has always helped us to speed things up and give us, perhaps, better quality in much shorter time."

The extent of interest of the aircraft industry was indicated by Mr. Spere:

"The aircraft industry is interested from the standpoint of clips and attachments which can be spot welded to the armor proper and then jig drilled or attached to the aircraft structure itself."

The question of exchange of information between subcommittee members was discussed by Col. Ritchie:

"Other subcommittees have certain material which they feel should be held as confidential or restricted with respect to their firm. They spend a lot of money and feel they should have the privilege of holding that back, at least for the time being. In those cases, they have usually made available to us, through the Subcommittee, all the information which they have. However, where they have material which they do not want to have disseminated fully, they tell us and we respect it accordingly. We have had no trouble whatsoever in that regard. I think all the members, 75 or 80, now on these various committees, represent about 75% of the steel capacity in the country. We have had no trouble; we have received much confidential information; and we have passed out many Subcommittee reports, a procedure which we follow. If we write a report here on any of our research work which we think would be of interest to the individual members, we make a copy and send it to them, either under restricted or confidential cover, as the case may be. We ask the companies to agree, however, that they will not disclose that information to unauthorized sources. In other words, keep it in their own confidential files and use it for their own development. I say again that where the company asks us to respect a certain phase, we do that."

Since the Resistance Welder Manufacturers' Association (RWMA) is an organization of manufacturers of resistance welding equipment the question of whether other RWMA member companies in addition to those represented at this meeting would desire to participate was discussed. The following pertinent comments were made:

Mr. Lewis:

"I believe that each company in the resistance manufacturing field has something to contribute to the industry or it would not stay in business. They all make individual contributions and it might be possible that the companies not represented might have something to offer."

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Mr. Kaunitz:

"The activities of such a committee may be made available to the RWMA. Some of the members are not fitted to do the type of work we are discussing today. I think you have the nucleus of the heavy machine welders. I know our company would be very interested in having a man on such a committee."

Mr. Ober:

"Of the twelve, I am sure there are perhaps four or five who wouldn't take any active part. I suppose you could extend an invitation and see what the reaction is. I still have a feeling that you would end up with perhaps six or seven members from the larger companies."

Mr. Wise:

"If it would be the will of this committee - if one of the members of the resistance group here would outline at one of the meetings, just roughly the purpose of the committee and what it is, and suggest if any one of the members desires membership he might write to the Chairman at the time and have it taken up at the next meeting. It is quite possible that there might not be any requests and you would still have the co-operation of every one of the group because they have had an opportunity to request membership. It would all hinge upon the will of this committee, permitting someone to advance that at one of the resistance welding meetings."

It was suggested by Col. Ritchie that the Subcommittee Chairman contact the President of RWMA and extend an invitation for membership on the Subcommittee of the various RWMA member companies who may be interested.

Mr. Benkert commented:

"That would be a smart idea. The next meeting is 18 or 19 September in Detroit and, when he brings up the communications, he can bring it up and whoever is present can give a verbal report and that would be the best way, I think."

It was agreed that this action should be taken and that a Subcommittee as outlined by Gen. Case and Col. Ritchie should be formed.

It was agreed that the Subcommittee Chairman should be a Service Representative because as Mr. Gillette put it:

"They understand the routine and know how to contact the various service groups better than the manufacturing concerns."

With the approval of the group assembled the selection of a Subcommittee Chairman was left to Gen. Case.

Mr. Lewis injected the following thought:

"There is one other point that I would like to bring up. I imagine before this is over 'control' is going to be brought

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into the picture. Of course, Mr. Gillette represents General Electric but he is not particularly a control man. I wonder if it would be desirable to have a control man on this committee."

To this thought an objection was made by Mr. Cooper:

"I would like to make a suggestion. If we consider control, then we must consider electrodes; if we consider electrodes, then we must consider handling facilities. Pretty soon you have about 50 on the committee. The association members have to be familiar with all of the angles, not only control but handling facilities, welding equipment, and actual design. I wonder if we wouldn't get more work done if we restricted it to a smaller committee and didn't break it down. It is going to go up very quickly. If you consider, for instance, we have General Electric and Westinghouse - then we have the others."

Which was amplified by Mr. Gillette:

"There is also another angle. If the committee becomes too large and there is a specific problem, you can always invite one of the control men or some other specialist to sit in at that particular meeting without being a particular member."

Col. Ritchie explained the requirements with regard to handling of Subcommittee data as follows:

"I mentioned this release and distribution of confidential data. I will mention it again. A considerable amount of this information which will come out to the individual members will probably be of restricted or higher classification as far as the service is concerned. In that case, of course, we have to ask that everyone who receives that information respect it accordingly and we naturally ask that you sign a receipt for it when you get it to keep on file. To be sure that we know where it is going we usually ask that the firm or membership name an individual who is to receive the correspondence. Is it the wish of each of the members present that you be the one, the representative, to receive the correspondence or do you wish to name someone else. In other words, with whom shall we correspond in reference to the business of the Subcommittee?"

The reply by Mr. Lewis:

"As far as my company is concerned, I would rather receive it,"

was agreed to by the other industrial representatives present.

Mr. Benkert raised a question about admittance to war plants for the purpose of making suggestions as to possible uses of resistance welding production and to obtain production information for the use of the Subcommittee. Mr. Lewis amplified Mr. Benkert's remarks as follows:

"Along the line Mr. Benkert was speaking - he and I are both from Detroit and Mr. Kaunitz. At present, unless you have some specific business at the Tank Arsenal or a specific

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machine to work on, it is impossible to get in there. Would there be any possibility of getting in there, making arrangements for some of the Detroit members to get into that arsenal? As I said awhile ago, it is just ignorance on my part as to how exactly these things are constructed. That is the way a lot of improvements have been made in resistance welding. I know there are several plants we go through regularly, look over the job and make suggestions as to possible changes in design or possible changes in manufacturing methods to utilize resistance welding more profitably."

Col. Ritchie expressed the thought that such a visitation might be arranged and that the matter would be looked into. This idea of arranging plant visitations was received with great enthusiasm by the industrial representatives present and was briefly elaborated on by Mr. Cooper:

"Could these meetings be rotated - here, Frankford, out there - each time in succession."

It was apparent that the Resistance Welder Manufacturers represented felt they were shut out of war plants and, therefore, welcomed the organization of this Subcommittee as a means whereby contacts could be made. This was further emphasized by Mr. Cooper:

"There are defense plants not represented here - Frankford, Berwick, Chrysler. If those plants were acquainted with the aim of this committee and arrangements were made, then it might not be necessary to rotate meetings. In a great many places where these problems come up, they have no knowledge of what is going on here at all. I appreciate the fact that the personnel here would fully co-operate, but a great many are not here."

Col. Ritchie suggested how the Subcommittee organization might help out in this situation:

"Well, through our committee organization they will, in a normal way, be informed. I think your point is good. There will be dissemination of the committee minutes. We can point out that certain representatives of the committee may be making contact with respect to the problems and recommend that they be given all advantages with respect to seeing equipment on which they are in a position to help."

With respect to assistance on production problems, Mr. Wise suggested:

"Some of your firms may not be informed that most of the resistance welding companies have rather well equipped laboratories for conducting welding resistance research. If any problem presents itself at any ordnance plant, we are happy to have them bring or send the problem with a couple of men, if they wish, and use the entire equipment of our laboratory to conduct research."

To which all industrial representatives present assented and emphasized their desire to co-operate.

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To a suggestion that Subcommittee members be given general entree to industrial war plants, Mr. Cooper suggested that:

"If we were to ask for general entree for all people in all plants, I don't know what the reaction would be. It might not be favorable. Suppose, through the chairmanship of this committee, a number of specific problems were sent out and the companies in answering and looking over such problems indicated that they had facilities for carrying on the work and were interested in carrying it further - some companies are not interested. If they were, at the time of making an answer to that particular problem they could ask for specific entree and have permission granted, if possible, to go to the particular plant where it is going to be manufactured and see more or less specific details. I should think that would be a better way to get prompt action than just generalized permission to see all the problems, concerns and ordnance.

"After all, we don't all want to go away with the general feeling and no specific line of action planned. We are all busy and we don't have time to hop all over the country on matters in which we have no particular interest. To overlook things where we can be of material benefit would be a big mistake."

With reference to development work which has already been done in attempting to resistance weld armor, Mr. Warner outlined the work done at Watertown:

"Our work here has been concerned primarily with homogeneous plate 1/4" thick. We have done some work with the face-hardened type 1/4" thick. We have had in mind two general methods: with the homogeneous plate, we thought of attaching the clips or plate to the homogeneous armor in the annealed condition and then heat treat the armor afterwards and drill holes and make connections; with the face-hardened type - of course we haven't done anything with that method - we have attempted instead to attach angles to the armor in the heat-treated condition, because with that material you have the fairly low carbon back and it is not so difficult to spot weld the material to that low carbon material. We haven't had much luck in putting on angles. On our samples, we used 3/16" or 1/8" backing strip. On the face-hardened plate, it stood up pretty well against 30 caliber armor-piercing ammunition. The sample which was made by the method I first mentioned, the angles stick completely to the 1/2" homogeneous plate during heat treatment. That is due to a slight buckling or warping of the plate in heat treatment. Just what the maximum thickness is, which limits us in applying the method, we don't know. We believe if we can spot weld all thicknesses up to and including 1/2", it would cover the field, at least as far as required by the combat and scout cars and aircraft industry."

It was further pointed out by Mr. Warner:

"We had in mind the armor alone, feeling that it was the major problem as far as metallurgical aspects were concerned.

[redacted]

The attachment of structural materials together by spot welding is a problem, of course. We don't consider it as much a problem as the attachment of armor plate. As far as the armored car is concerned, the armor does not furnish the structure. There is a frame used in the armored car."

The primary aircraft armor problem was outlined by Mr. Warner:

"It was thought about this clip proposition that in the aircraft the armor is attached to certain parts of the structure, to protect the pilot, or certain parts of the mechanism in the structure and that it is attached, as I understand it, after the aircraft fuselage is put together. One difficulty in putting this armor on is that it is quite difficult to drill holes in this hard stuff and having to drill the holes to fabricate the piece prior to heat treatment we might have certain distortions taking place. It makes it difficult to assemble afterwards. By using two clips of soft material, you need not be so fussy. Drilling can be done after heat treatment and the piece can be fitted very readily."

Which was amplified by Mr. Spere as follows:

"I think I can answer about aircraft. The immediate problem is clipping. That is, the present procedure is to hang armor protection into the airplane, more or less as we say 'draped in.' It does no good; it just rides along as protection. The other problem we some day may be able to answer is the possibility of providing a primary structure and using it for something beside protection. We are also shooting for more range and more load. Every pound for protection means losing that. Our problem is always trying to get a better, lighter structure."

It was pointed out by Mr. Warner that all spot welds in the armor tests at Watertown were made with a single impulse for each spot.

Mr. Brooker outlined the Ordnance viewpoint as follows:

"The two problems we are chiefly concerned with are the light tank and M2 half track by Diamond T and White Motor. The plates are now fastened on by heat-treated machine screws. The wish is to weld those plates instead of holding them by the machine screws. As far as I know, we have no information on the ballistic strength of these fastenings as compared with a fusion welding job, but we have been given a request to study the application of resistance welding to those M2 half tracks. There is an indication if anyone comes in and proposes resistance welding with straps and does not reduce the weight, it won't be favored. If we can eliminate butt straps and machine screws and reduce weight, we will have something. I would like very much to see someone interested in welding visit the White Plant or Diamond T or Diebold and discuss the thing with them, see what they are up against, and try to lick the problem there by reducing the weight and giving satisfactory ballistic performance.

That means finding a company interested in preparing some specimens for ballistic test, both by welding and machine screws. The M3 light tank uses armor 1/4" to 2" thick, mostly 3/8" thick. Maybe I am a little ambitious to talk about resistance welding that, but there again where we talk about welding a tank we should certainly try to eliminate reinforcement angles or butt straps. They say a rather poorly welded tank is better than the best riveted tank."

After a very brief discussion of facilities available for making experimental samples, Mr. Cooper asked:

"Has Mr. Warner had any detrimental effects of softening of the hard facing around the spot?"

To which Mr. Warner replied:

"It goes the other way. It shatters the bullet unless very high velocity projectiles are fired. Even then it is apt to crack the projectile."

The meeting adjourned for lunch and a short tour of inspection through the Arsenal Weld Shop.

In order to get started on planning some acceptable development program, Col. Ritchie made the following request:

"We want to get down to specific problems, if we can, with the thought of formulating something definite on which we can proceed. Perhaps, as a background for that, it might be well if each of you were to tell us very briefly about the type of work for which you have facilities, say, research and development, the thickness of the plate you could handle, or any other comments along that line which we could have available here for our own use as the problems come up."

The following replies indicated the general type of facilities available at the laboratories of the various apparatus manufacturers represented at this meeting:

Mr. Ober:

"Well, we have an experimental laboratory with equipment for several types of spot welding and butt welding. As far as capacity, we are somewhat limited as to power, but we can handle up to about 200 K.V.A. capacity in spot welding. A lot of this work would fall within that capacity."

Mr. Kaunitz:

"We are equipped quite similarly with a complete laboratory, with a furnace and equipment for all spot welding, seam welding, but no flash welding of any size. We could very conveniently handle spot welding."

Mr. Wise:

"We have in our laboratory a pretty complete line of spot

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welding equipment and projection welding; also, a rather large 700 K.V.A. job that will handle some sizable material in the nature of projection and spot welding. Then certain sizes of flash and butt welding equipment that will handle up to something about 3/8" x 20". But we have machines going through all the time, and occasionally you might catch a very large machine. As far as the laboratory is concerned, 3/8" by 20" would be about the maximum size for flash welding. On projection welding, we can handle about anything right in our laboratory."

Mr. Cooper:

"We have a flash welder that will take up to 8" x 1/4", a press welder, a 200 K.V.A. high-pressure spot welder."

Mr. Benkert:

"We have a 400 K.V.A. heavy duty welder, press welders, heavy portable guns and fixtures and some automatic welders too light for this class of work. Then we have a fairly good big laboratory except that we don't have any machines for tensile testing, shear tests - we get that done down in the commercial laboratory right in town."

Mr. Lewis:

"We have combined spot and projection welding up to capacities of about 1,000 K.V.A. and 1,000 K.V.A. for flash welding. On this we can get probably 3/8" by 20" in flat pieces or up to probably 20 square inches. We are limited by clamping capacity. We have fairly complete physical testing equipment but none for metallurgical examination and testing."

Mr. Gillette:

"With regard to spot welding equipment available, we can seam weld up to two pieces of 1/4" material, and with flash welding, up to 10" wide by 2" thick. That is about the maximum, anything within those two ranges. We have some other equipment adaptable for small work, complete testing equipment, X-rays, magnaflux, metallurgical equipment of any kind."

The facilities available at Watertown were outlined by Col. Ritchie:

"I would like to make it clear that we have, I think, facilities to do most any kind of that metallurgical investigation - X-ray, magnaflux, etching, microscopic examination - so if you have any of this subcommittee work or any problems bearing on resistance welding, if we can be of any assistance, please call on us."

It was evident that the first problem to consider was that of deciding where to start in the development of methods for resistance welding armor. Col. Ritchie asked for specific suggestions. Mr. Benkert indicated that the 1/4" thickness seemed the most logical and there was no disagreement with this suggestion.

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The establishment of a basic welding procedure was advocated by Mr. Gillette as a requisite for application of resistance welding to any armor plate:

"Isn't it logical to establish a basic welding procedure and find out just how well this welds and the physical properties you can get from the material? It seems to me you need a basic procedure the first thing before you can make actual application. You have to know that it is basically weldable and the procedure you should use for the welding; whether it requires subsequent heat treatment or not for these various types of plate - which phase is more satisfactory. If we can establish some basis for one type, it would help all the rest of the problems as I see it. You first have to know just how well it welds, if it does, and then the application should come after that. There is no use in making the application until we know how we should proceed."

With respect to the tests to be planned by the group, Mr. Wise made a suggestion:

"State a problem, call for volunteers, and see how you get along there. Apportion what is left to the group as a whole. In that connection I would suggest it would be a good idea if all the armor and material would come from one source. I had occasion to be involved in several co-operative research groups where we secured our own material and it was surprising the wide difference in material that was purchased. The results were considerably confusing and misleading. We should have secured steel from one common source. I suggest all the armor come from one source for all this research."

On the question of plate thickness and type of joint, Mr. Warner elaborated further:

"I am in agreement with what both Mr. Benkert and Mr. Gillette say. I think, unless the people from the air service have any other suggestion, the 1/4" is a good thickness to play with, at least to start with. That is, unless you want to consider two thicknesses - 1/4" and 1/2". I should think both types, homogeneous and face hardened, should be considered in any test because there may be differences in procedure between the two of them. I think that three different types of joints should be considered also. One is lap joint where you spot weld two pieces together, one on top of the other; another, the flash-welded butt joint; and a third, is to connect two plates by means of auxiliary angles, etc. You find that under certain conditions you can spot weld plate together, certain compositions in a certain way with certain limitations involved. You have to know that information in order to design the structure. If you can put clips on in some way or another and make use of that method of connection, it is necessary to know it; if you can flash weld and get satisfactory results, that is also an advantage. The designer would have to know those things."

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The thicknesses of armor plate now being used to which it might be desirable to apply resistance welding were outlined by Mr. Brooker:

"As regards structure, the M3 light tank has only three pieces of 1/2" armor, otherwise, mostly 1" material. I believe it is hard-faced and the M2 half track is almost entirely of 1/4". So there really isn't much 1/2" used. I admit 1" is a pretty big order."

The minimum size of test plates required for ballistic tests was indicated as 18" x 18" for test at Watertown although 12" x 12" can be used for 1/4" plate. Aberdeen Proving Ground uses test plates 36" x 36". It was indicated that there is probably no resistance flash welder available to flash weld a section of armor 18" x 1". A section 12" x 1/2" or even 18" x 1/2" might be handled according to Mr. Lewis. Also a minimum of fifty samples should be planned for in order to have sufficient material to test any one type of joint or plate thickness.

With respect to plate thicknesses on which efforts should be concentrated for development of welding methods, Mr. Warner commented:

"I think the biggest field for resistance welding is in the lighter gauges where it is impossible to fusion weld as yet, and get the ballistic strength out of it. If we can successfully resistance weld up to 1/2" we are going to cover a large field in fabrication at the present time. I would like to hear from the air service as to whether that would cover their need at the present time."

With reference to the needs of the aircraft industry, Mr. Spare replied:

"Well, the current limitation is 1/4", 3/8", and 1/2". We don't know when it is going to change and go thicker. What these people can do to the best advantage even with 1/4" plate to find out what can be done would be helpful."

Mr. Cooper made a suggestion with reference to the fundamental data desired to be recorded in connection with any test made and the allocation of work:

"It might be well to explore the field on 1/4" and find out what should be done, then go back and do it on 1/4" plus 1/2". One of the suggestions I have, if this program is going to be coordinated, is that the committee will not only distribute the jobs according to machines available, but get down a record of what we want reported in the way of welding variables so that we can interpret the results and make comparisons. We need that to start with. Somebody will come in and talk about currents and it is a matter of confusion."

It was further suggested that, in order to limit the variables involved, the test work be confined to 1/4" plate until the fundamental facts about resistance welding of armor are determined. This was emphasized by Mr. Gillette:

"I think, from several angles, we should determine first the weldability of it and the method to use in 1/4" because it is easier to handle, easier to test, and more economical than the heavier. If we can satisfactorily weld 1/4" plate, it simply means stepping up the equipment a little in order to weld heavier plate of both types."

The aircraft industry would like to apply resistance welding to light alloys according to Mr. Spere:

"This is the light alloy steel containing aluminum and magnesium."

However, it appeared desirable to confine the present activities to armor steels.

The probable ballistic requirements for judgment as to acceptability were discussed by Mr. Warner:

"The lap joint resistance spot welded, the butt joint resistance welded by either flash or seam welding, and the butt joint with the auxiliary connecting members spot welded to the plate are the three types which should be considered. What is the necessary requirement in each case? I suppose we would ask for a ballistic of not less than 85% as we do in fusion welding. Not only the resistance to penetration which gives us an 85% value, but resistance to shock where we require 100% of the resistance of the unwelded plate. Whether we can get that in resistance welding is a problem."

The performance values are determined as follows according to Mr. Warner:

"We have a certain specified limit for unwelded plate material with respect to velocity of the projectile, and whatever is specified for that particular thickness of plate we require at least 85% for the joint itself. That is, on penetration. As far as shock is concerned, whatever is specified for the plate as to caliber of projectile and velocity we have specified that the welded joint must stand up under the same test and to the same extent as the unwelded plate."

The desire to take advantage of any test data from previous work and to have all laboratories acquainted with what they are to do was emphasized by Mr. Wise:

"In order to keep in line with Mr. Cooper's remarks some time back and keep everyone straight, would it be possible to get together a brief outline of just exactly the type of procedure various companies should follow in undertaking these various tests - particularly giving us the benefit of your own experience with spot welding and some hints on fusion welding that might help us."

Col. Ritchie replied indicating as follows:

"By all means. I had in mind making up copies of the reports we have made here. We will include those made about four

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or five years ago and send those copies to you for what they are worth, if anything, and at the same time, as you have suggested, we will write up what we think might be the procedure and tests to be followed. I was hoping, however, to get a general indication from you gentlemen today as to what you thought about the various types of test we should carry out and also what the welding procedure should be."

In the ensuing discussion of flash welds the problem of removal of upset or flash burr was prominently considered. It was thought that this burr should be removed. Furthermore, since there is a considerable difference between homogeneous and face-hardened armor plate, it was suggested by Mr. Ober:

"I wonder whether it would save time - there are seven of us and six problems - whether it would be well for one firm to take the face hardened and another the homogeneous and do the same work on it, rather than one firm tackling both materials. If there wasn't much difference, one firm could do it readily; if there was considerable difference, it would take twice as long. You have six problems, three problems each as to different kinds of material. I would suggest that it be divided among six."

This appeared to be a good idea but after a brief discussion, the following offers were made:

Mr. Lewis:

"I will take both the homogeneous and face hardened for butt welding and flash welding."

Mr. Kaunitz:

"I will take the butt joint with spot welded angles on both face-hardened and homogeneous plate."

Then Mr. Lewis made a further suggestion:

"Why not let each of these firms that are going to work on spot welding work on both materials? That is on the chance that if they are not successful on one, they may be on the other."

It was brought out in the ensuing discussion that no one knows which armor composition has best weldability as far as resistance welding is concerned. Lt. Matthews indicated that the face-hardened plate is a 5% nickel steel with 0.20% carbon in the back and 1.0% carbon in the face.

Further offers were made by the other industrial representatives present as follows:

Mr. Gillette:

"I can make the lap weld on both face hardened and homogeneous."

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Mr. Ober:

"We can take on anything except the flash welding -- and seam welding. Any spot welding."

Mr. Cooper:

"May I make a suggestion? If he can't flash weld - I can duplicate the work on flash welding and you wouldn't have three on spot welding."

Mr. Benkert:

"I would like spot welding only. Frankly, I want to use both materials, and I want to try both types of joint. That is, after making a few welds, if I find one type of joint on plate impossible, I can go to the other. I do think, too, as a suggestion, that we have a standard such as we adopted in the last American Welding Society Handbook. We should forward these gentlemen a copy of that so that we can all speak the same language. That would be beneficial. We will all talk about the same definite terms and control as given there. It will only remain for us to standardize on the throat depths, throat heights, secondary amps., etc."

Since it is desirable, as previously pointed out by Mr. Cooper, to establish what fundamental data is to be recorded by each investigator so that all test data can be intelligently correlated, Colonel Ritchie made the following suggestion:

"I am wondering if it wouldn't be the sense of the committee that someone, such as Mr. Gillette or someone else here, pick one or two other men or as many as he wishes to constitute a subgroup to work up a report on those points. I don't know if we can consider them today. I think Mr. Gillette could do that. If it meets with approval, I would like to name you, Mr. Gillette, as Subgroup Chairman, to report on that particular phase. Will you select any others you may need to help you?"

Mr. Gillette selected Mr. Cooper and Mr. Kaunitz as the other members of the Subgroup.

Since Mr. Wise had not previously indicated a particular phase of the work which his organization could tackle, he raised a point as follows:

"Colonel Ritchie, have all the problems been assigned? We have none here. I have been laying back to see what would be left over. We could take any and we would take what is left. Is there any problem left? If not, what problem would you like us to undertake to duplicate?"

In this connection, Mr. Brooker raised a point:

"It strikes me, from the experience of Watertown Arsenal, that these welds made in hard-faced armor are going to be brittle. There remains the problem of post heating. That sounds fantastic,

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I suppose, but is fairly possible - either electrical or localized gas heating might be safe."

The question of post heating after completion of the spot weld was emphasized as an important part of the welding procedure which is to be determined.

The aircraft armor problem was emphasized by Mr. Spere:

"It makes no difference whether you make a continuous connector or use short clips as long as you get enough strength to take the shock and hold the weight of the armor."

He admitted that the proposed tests on butt, lap, and butt joint with auxiliary connectors would give the desired information to aircraft designers. This program, as noted from the previous discussion, lines up about as follows and was agreed to by the industrial representatives present:

A. Types of Joints

1. Butt joint - either flash or upset butt method
2. Lap joint - spot welded
3. Butt joint - with auxiliary connectors (butt straps or clip angles) attached to the armor by spot or projection welding.

B. Material

Both homogeneous and face-hardened armor on 1/4" thickness.

C. Allocation of Work

1.	Mr. A. H. Lewis	- Swift
2.	Mr. R. T. Gillette	- General Electric
3.	Mr. C. F. Kaunitz	- National
1.	Mr. J. H. Cooper	- Taylor-Winfield
2 & 3.	Mr. W. T. Ober	- Thomson-Gibb
2 & 3.	Mr. L. M. Benkert	- Progressive
2.	Mr. B. J. Wise	- Federal

Watertown will supply the armor plate.

With reference to design of aircraft armor, Mr. White emphasized the problem pointed out by Mr. Spere:

"Well, your experiment won't do us any good when we come to specify how big a clip must be to support certain armor plate unless you can tell us how strong it is going to be."

This point of view suggested that data other than ballistic data are necessary. Both shear and fatigue or vibratory tests were mentioned.

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The service loads on aircraft weldments are according to Mr. Spere:

"Well, it will be subject to a certain amount of normal vibration. The effect of shock enters in, but I am inclined to believe that the shock is more critical than the vibration in aircraft."

The Watertown viewpoint on fatigue testing was summarized by Col. Ritchie:

"We feel, in respect to welding armor structure and fusion welding, to get a real fatigue test, we must take the structure and subject it to all conditions of test."

According to Mr. Spere, the experience with fatigue tests of the cantilever rotating type at Wright Field has been as follows:

"We have had a similar set-up for aircraft material for at least the last twenty years running continuous fatigue tests on metal but have had no real method of evaluating the results. We know how many cycles, but how to evaluate it in terms of actual work has not been determined."

Mr. White emphasized a point of concern regarding the methods of test to be used on the Subcommittee program now formulated:

"I would like to make sure the results of these tests are directly comparable so that we won't come in with different methods of testing different sized specimens."

In order to obviate the difficulty suggested by Mr. White the proposal was made that all welded specimens be tested at Watertown Arsenal. This was acceptable to all concerned.

Mr. Kaunitz outlined a suggested method of procedure for each laboratory which is to weld specimens for test at Watertown Arsenal:

"I figure, in making spot welding samples, our procedure would be to determine the correct welding process, to produce the right weld, and repeat it on a sample plate for firing tests. Along with that sample plate, several specimens of each individual weld should be made for different tests. In other words, we might scrap two or three dozen pieces in determining the best combination of factors to produce the weld that will stand up under our tests, then take two final pieces and produce several specimens to send out here for approval."

It was agreed that Watertown would specify the performance desired of the test plates.

Mr. Marchant explained that with respect to fatigue testing:

"I think the general opinion of the group is that it is difficult to correlate the laboratory fatigue tests with service conditions in general. That is true, for in general the laboratory specimens are specially made, identical if possible, and it

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is impossible to produce in them service conditions such as you have in the service. However, we have one piece of equipment available, a 5,000-lb. mechanical oscillator with which we have made some tests on, and recently we found some surprising things. I think the fatigue testing would be of particular interest to the Air Corps if we could produce a sample which would have some semblance to the aircraft structure. I don't believe ordinary fatigue testing specimens are accurate."

Col. Ritchie suggested that:

"Suppose we leave it that the service representatives here today will write up what they think should be the test and send it to us. We will correlate it and send it out to the industrial members for their comment. Let them decide what test, type of specimen, etc., we should use."

This was agreed as desirable.

Some preliminary sketches of aircraft armor weldments made up by Mr. White were examined. The purpose of these sketches was explained by Mr. White:

"These brackets were made up just as suggestions to show you how large and what shape and type brackets might be needed to support rather large shapes of armor. Along with the brackets, we have given the size and shape of the armor which might be used. It was our first thought that perhaps we should give the exact installation of armor such as the pilot seat with armor plate on the back or bulkhead, but we decided since that we would just make up shapes like this and show how it might be attached and come as close to actual installation as possible. These are made up with one of our production lines in view. To be sure, they are really similar constructions, with the armor plate weight approximately as we want it. So, if you should happen to decide to take these brackets and these sizes of armor plate and test them, we would really have some qualitative evidence because we know this is approximately what is going to be used for the present anyway. Should we make the bracket thinner, thicker, increase the length, get more area, or what? These are just guesses but we sketched it out to give you an idea. There might not be enough brackets."

It was admitted that the sketches had been made with arc welding in view. It was suggested that similar samples be made up with rivets for comparison, but Mr. White stated that rivets had never been used for this type of installation. Although Mr. Wise expressed a willingness to try to weld up samples of this type, Mr. Spere commented as follows:

"It is already provided for in their welding of angles. This is an indication of an actual sized plate or similar to actual plate put in one of the planes at the present time, a typical pursuit job."

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On the problem of annealing plate Mr. Spere commented:

"We would be interested in that in only one way; in repair work or cutting holes through the plate to extend some control or change, but our aircraft manufacturers would be tickled to get information on anything in that line so they can relieve themselves of some of this trouble they are having with armor right now. This problem really isn't one that we have to handle ourselves. We would like to be able to tell the manufacturer the best information we have available."

In view of the offer of Mr. Wise to weld up some of the samples according to Mr. White's sketches, Mr. Warner made a suggestion:

"I was going to suggest that I think #2, the lap joint, is most difficult to weld satisfactorily. It probably requires the most work, and so far, we have two manufacturers on each of these problems. If Mr. Wise would consider that particular type of joint, I think it would be very desirable for him to tackle it. The idea seems to be, if possible, to get away - we are talking now about our scout cars primarily - to get away from auxiliary members and use spot welding. The idea of the designers has been to simply lap the armor plate as you would two pieces of structural steel, and spot weld them together. That is a very difficult problem. I was going to suggest that it would be a good one for Mr. Wise to tackle."

To which Mr. Wise replied:

"I would be very glad to do it or, if in the meantime you decide on something else, I will just leave it to your judgment, which problems you might prefer to have me work on. If some other problem comes up and you would like some immediate work, I would be glad to take it instead."

It was decided that for preliminary testing of welding machine settings prior to making the final test specimens, the experimenters would need some small scrap pieces of armor plate. For spot welding these strips 8" x 1-1/2" are satisfactory, but for flash welding the strip should be 8" x 4".

The interest of the artillery service was indicated by Lt. Ohls:

"We are of the opinion that this subject, as far as the artillery end of it is concerned, will more or less develop as the manufacturer gets around to see our material. The more they see of it, the more they will be able to find places where this can be used much better than we can."

With reference to the number of samples desired for each test in answer to questions from industrial representatives, Col. Ritchie remarked:

"Two or three of each particular type, both as to composition and treatment of plate and type of joint."

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The question of spacing of spot welds and amount of lap was discussed. It was apparent that no one had any data on which to base a recommendation. All experimenters would have to start from scratch. On the question of structural strength, Mr. Wise remarked:

"I am inclined to believe the structural strength will be far in excess of anything you will ever hope to use."

To which Mr. Warner added:

"If the welded joint would stand up better than the present bolted joint, that is a help. I am not particularly worried about the spots being better than what we need structurally. Four or five or six clips around a plate with two or three or four spots on each should be sufficient. I am not worried as far as the straight shear load is concerned. It is the impact of a projectile which must be withstood."

There was in the minds of some industrial representatives the thought that some laboratory test might be used on small specimens to enable prediction of ballistic performance. This was suggested by Mr. Lewis:

"When we make this test there is no one method we can use even to obtain the approximate resistance to penetration, just from hardness and impact values or anything else."

To which Col. Ritchie replied:

"Well, we can give you the hardness of the plate to determine resistance to penetration, but nothing on the welded joints."

Mr. Warner cited an experiment made at Watertown using .30 Cal. A. P. bullets:

"We tried one experiment a number of years ago. We took a 12" x 12" plate of 1/4" thickness, and put spots 1" apart all over it like a checker board, and then put spots in the middle of the squares. We had it full of spots. Well, the first two or three rounds we fired, the bullets just shattered; after about two or three hits, all of a sudden, a big hunk of the plate was punched right out."

With respect to the next meeting of the Subcommittee, it was decided that such a meeting should not be held until after the test program had been completed, so that the data would be available for discussion. This will depend on how soon Watertown can supply the armor and how rapidly the experimenters can produce the test plates. It was suggested that the date be left to the Chairman, to which Col. Ritchie replied:

"I expect we will probably have to leave it at that, because it depends on how soon we can get the plate into your hands; but the sense of the group is that we should have another meeting in a month or six weeks, at least as soon as we have some of this preliminary work cleaned up."

It was apparent from the concluding discussion that the industrial representatives desired an opportunity to visit the Detroit Tank Arsenal or some other war plant. In his closing remarks, Gen. Case thanked those present for attending the meeting.

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FIFTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
FRIDAY, 24 OCTOBER 1941
PENN. ATHLETIC CLUB, PHILADELPHIA, PA.

The fifth meeting of the Subcommittee was held on 24 October 1941 at the Penn Athletic Club, Philadelphia, Pa., with 60 persons in attendance representing:

Fabricators	9
Electrode Manufacturers	9
Armor Producers	7
Ordnance Department	17
Navy Department	1
Guests	17

This meeting at the Penn Athletic Club was arranged through the courtesy of the Arcos Corp., to which Col. Ritchie expressed the thanks of the group assembled in his introductory remarks.

The Reid-Avery Company was elected to membership on the Subcommittee.

There were a number of representatives at this Subcommittee meeting from prospective fabricators of armored vehicles who were considering taking Ordnance contracts to build tanks. These representatives were invited to attend at the request of the Office, Chief of Ordnance.

This meeting was arranged as a two-day meeting for the purpose of making a plant visitation on the second day as explained by Col. Ritchie:

"As a part of this general meeting, we have planned, through the courtesy of the Baldwin Locomotive Works and the Philadelphia Ordnance District office, for a plant visit to the Baldwin Locomotive Works tomorrow morning, for those who want to attend and who are entitled to attend."

Mr. Raymo explained details of the arrangements for the trip:

"The Baldwin Locomotive Works and the District Office of the Ordnance Department will be very pleased to have all who care to of this group visit the plant tomorrow morning. The instructions for getting there are very well indicated on the paper that has been passed around to you. We are going to do our very best to make the visit of interest to you. We propose to take you through our Welding Shop and also through the Tank Assembly Shop. As we adjourn for our luncheon here, or at such time as Lt. Col. Ritchie may designate, I have with me a series of passes that will admit us to the plant and all those who are desirous of going down there tomorrow are asked to sign this pass, so that I may return it to the plant office this afternoon and have badges and such as that ready for you as you enter the gate tomorrow morning."

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Col. Ritchie announced election of the Reid-Avery Company to membership and, in calling on Dr. Miller for a few remarks, added a comment on Subcommittee activities as follows:

"I might extend my remarks back to a month ago to say that the function of this Subcommittee is to carry forward research and development work on welding programs, the service and individual firms to act at the general meeting to exchange ideas for the development of welding and actual fabrication of armor. This is a welding forum for discussion of specifications, processing difficulties, and the like. We have a number of projects which are under way in the plants which were allocated at the last meeting - of which the Research Program Subgroup is an organization within this Subcommittee and which you will hear about later on."

Dr. Miller, Reid-Avery Company, commented as follows:

"We have been making quite a few 25/20 types of electrodes and recently the OPM requested that the various electrode manufacturers endeavor to substitute some other alloy for 25/20. Actually we are using 27/22. Our work on this subject has been done using X-ray diffraction. Now Mr. Thomas has done parallel work using magnetic tests. The object of the tests, of course, was to determine the relative amounts of austenite and ferrite in the weld, along with chemical analyses to find what would be our limit of the austenitic range in the weld metal as deposited, if an austenitic deposit were desired. Now, on the various tests which we have carried out to date, we have a range of alloys which may be substituted for 25/20, provided the austenitic alloy is desirable, and we know a large number of them which will not give us any austenitic deposit."

Since a considerable number of representatives of prospective armor fabricators were present, Col. Ritchie commented:

"A number of other firms have been proposed for membership to this group--Ford Motor Company, General Motors Corp. (Fisher Body Division), Champion Rivet Company, Lima Locomotive Works, Pullman Standard Car, United Engineering Company, Air Reduction Sales Company, and Oxweld Corporation. I think it would be appropriate at this time to call on each of the representatives, or at least one representative of each of those firms, just to make a few remarks as to their interest in the Subcommittee work."

Comments regarding the activities of the various companies represented in the field of welding armor were made as given below:

Mr. Vennerholm (Ford Motor Co.):

"We are conducting a number of experiments on different types of welding. We have been working on austenitic welding rods and we are also going into the work of investigating the possibility of using welding rods of the same composition as

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the plate. We also intend to investigate the ferritic electrodes. We haven't any data for publication yet, but as soon as tests are completed, we will."

Mr. Biederman (Fisher Body Corp.):

"I cannot tell you much now, Col. Ritchie, but really we are in the same position as Ford Motor Company. We are conducting a lot of tests and are spending a lot of money, but we don't know anything definite. We are just starting to crawl. I imagine we will be coming through with some valuable information soon because we are going to build tanks and will need a lot of information and might be able to develop of lot of these problems as we get going. We will be more of a proving ground and experimental stage."

Mr. Nick (Champion Rivet Co.):

"For a number of years Champion has been interested in joining metals and have been in the picture in the development of rods for low alloy steels, in particular. I believe that armor plate is right in the picture as far as low alloy steel is concerned. For the past year and a half, I would say, we have been working along with some members of this Committee, more or less in private, and have extended the use of our Laboratory and Research Department for the rods used in the territory made at our factory, and we wish to extend to the Committee as a whole the facilities of our plant and organization to work along with the Committee."

Mr. Miller (Lima Locomotive Co.):

"Well, we are in the experimental stage also. At present, all we are doing is practicing with welders on armor plate with 25/20, and as near as we can find out, that's the safest thing to use up to date. While we figure it costs a little more, at the same time we have not found anyone who could agree there is anything that compares with it at present. So, we figure on staying on the safe side until we know that we are safe in starting something else. So, you see, all we are doing is just practicing on armor plate with 25/20."

Mr. Boese (Pullman Standard Car Mfg. Co.):

"We have just practiced a little bit on armor plate, mostly with 25/20, although we have some particular plans, and as soon as our plans are ready, to go in for automatic welding for different types of steel. We are pretty much satisfied we have the type of joints we propose to use, and it is only a matter of getting our material in. Probably at the next meeting we will have an answer."

Mr. Eckberg (Eastman Kodak Co.):

"We are completely new at this game of armor plate welding. We have had lots of experience in welding the high nickel-chrome alloys and we are conducting some experiments in the welding of cast armor plate to the homogeneous plate using 25/20. We hope we can be of assistance in this program."

Mr. Ingram (Air Reduction Sales Co.):

"For a great many years the Air Reduction Company has done a considerable amount of work on various types of armor plate. Here in the past two years we have done considerable research so far as cutting is concerned. At the present time we are working on electrodes. Just what the development will be or how soon something may come along that will be valuable, I don't know. However, we are very much interested in machining, flame machining plate preparation, at the moment."

Mr. Outcalt (Linde Air Products Co.):

"The Linde Company has already been doing some work on armor welding at the Union Carbide Research Laboratory, but I think I can refer to Mr. Blake, of the Chrysler Corporation, Mr. Bibber, and Mr. Brooker for any remarks they might wish to make about it."

Mr. Danse (Cadillac Motor Car Co.):

"We are too new at this thing. We are just getting started - looking around - nothing at present."

Mr. Penn (Indiana Limestone Co):

"We too are just looking into this thing. We are sort of privileged observers today. We are exploring the possibility of intense activities in the welding field - are just starting."

At the conclusion of the above remarks there was some discussion of the question of limiting the size of the Subcommittee. The question was raised by Mr. Thomas:

"Colonel Ritchie, I wonder if there is any way in which we can tactfully handle the problem of keeping this membership as a live membership, and of dropping from the rolls those whose attendance has dropped or those who have not been able to get to the meetings for no reason which has been expressed. I am wondering if these is some way by which we can tactfully drop them from membership."

The membership policy was stated by Col. Ritchie as follows:

"The policy under which these memberships has been organized is just that, that the membership must be fluid to meet the changing conditions. We must add new members to meet the changing situation, and as you say, the members who are no longer interested in the proposition or no longer have anything to contribute, should be dropped. I don't know if we have any members who need to be dropped except possibly our Cast Armor Group."

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Col. Rehm objected to the suggestion that the Cast Armor Group be dropped:

"I would like to suggest that the Cast Armor Group stick to this committee because the welding of cast armor is a repair job, more than welding casting to the plate. And, furthermore, the casting is getting to be pretty big and you might have to break those castings up, etc., so this is no time to drop the casting people from the committee."

For the purpose suggested by Mr. Thomas, Mr. Warner made a suggestion:

"I think somewhat along the same lines, and furthermore, there are only four cast armor representatives on the group which is a very small percentage, but I do think there is something to what Mr. Thomas has said, and I have one individual in mind who has not attended the last three meetings of the committee and has not acknowledged the notices which were sent out notifying of the meetings and asking for an indication as to whether or not he would attend as an individual. I would suggest, as a matter of discussion, in case any representative or member of the Subcommittee does not attend or misses three Subcommittee meetings in succession, that he automatically be dropped from the Committee and receive no further communications therefrom."

After a short discussion of this suggestion it was adopted with the proviso that an alternate would suffice.

In a discussion of the Subcommittee organization which followed a suggestion was made that a Group comprising electrode manufacturers be formed to organize work on electrode developments. There was a comment from Mr. Thomas:

"Unless the rest of the group feels it very desirable, I see no reason for formulating it now. My only thought is what would this Subgroup do - and I think that is the point for discussion. It might be said perhaps that there is nothing for it to do, that we are handling the job satisfactorily. I personally feel there is a job for it, but I would like to have time to put it into very concrete suggestions."

There seemed to be some hesitancy on the part of the electrode manufacturers about the desirability of getting together for standardization at this time. This was evidenced by Mr. Brugge:

"I think the Subgroup might do a good bit of work on that line, although each electrode manufacturer at the present time is working independently along lines on which there will be no agreement in the group. There is a very small low alloy group, represented by my friend, Mr. Deppeler, and we ourselves are doing a certain type of work about which our friend with the Arcos Corporation here has different thoughts. I think that each one of us in that type of developmental work will do our best work individually. I don't think we can settle any problems there for certain types of electrodes that are already

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established, but we can come to agreement on procedures which different concerns are at the present time proposing, different procedures which only add to the confusion, and there is no reason why that shouldn't be stabilized. I think there are things along that line that can be straightened out."

An optimistic note regarding the size of the Subcommittee was sounded by Col. Rehm:

"This idea of Subgroups is new to me, but I think the feeling behind it is that the committee is getting to be rather big; but you have just got to brace yourselves for big business. There are lot more tank builders and we have to do business with the people who make the armor plate. The people who make the armor plate have to do business with the electrode people. How about the government inspectors? They've got to know the quality of the material and suppliers of same. So, we are going to be faced with a big committee. To expedite business, stick to the big business at hand. What we started to talk about was accepting the three firms to membership in this committee. I hereby move that we accept these three firms for membership in the committee."

The three companies referred to are listed in the Agenda and Col. Ritchie requested deferment of the vote temporarily for discussion of the Group organization of the Subcommittee. Col. Jenks made a comment regarding the electrode situation:

"You have problems of immediate production and you have problems that involve the future. I think this is no time when we must be limited by merely the individual efforts of various manufacturers or suppliers. I think we have got to have full co-operation in every particular. We have problems in the development of electrodes as well as problems in other fields, and I think it is highly desirable that we have the closest co-operation among the suppliers of electrodes, and the policy of development be laid down in co-operation. I believe also that a Subgroup of that sort should be headed by someone who is independent of the electrode industry itself."

Comments regarding proper activities of an Electrode Group were made by Mr. Landgraf and Mr. Emery:

Mr. Landgraf:

"However, I believe a real purpose could be served if, as soon as possible, a listing of electrodes and their appropriate applications could be made in sort of a summary form so that when any of us, or any future members of the group, may run across an unusual problem, at least they would have a starting point from which to work."

Mr. Emery:

"I am heartily in favor of that Subgroup if it merely lists the electrodes and the purpose for which they are to be

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used. Later on, it may develop into a full co-operative membership which I hope it will. I think we have a job to do, and the more we co-operate in order to get that job under way as quickly as possible, the better off we will be."

It appears that the general thought was while there would be no effective collaboration between electrode manufacturers on standardization of electrodes for welding armor yet, such a group might accomplish some good and should be organized. Approval was indicated by a show of hands and Mr. Thomas was directed to proceed by Col. Ritchie:

"It is the feeling we should have that subgroup. I am wondering if the electrode manufacturers themselves could get together today at the noon hour, as an individual group, and suggest your own Chairman - Chairman of your own Subgroup - similar to what we have on the consumers' side and have that ready for action this afternoon. Mr. Thomas, can that be arranged?"

The three companies listed in the Agenda were voted into membership by a show of hands, after which Mr. Outcalt commented:

"Oxweld Corporation of Chicago probably refers to the Oxweld Service Company of Chicago, which is one of the Union Carbide and Chemical Corporation organizations, I have a letter from the Oxweld Corporation, in which he suggests that the Linde Company be the representative on the Committee, that he had made no request for membership. It occurred to me that probably the Linde Company should be represented rather than the Oxweld."

Since the three companies voted on had been suggested by Mr. Brooker's office, he made the following comment:

"I should have known differently, but believe that the Linde people should be nominally mentioned. However, I would like to say that from the standpoint of our office we have prospective tank manufacturers and a few new electrode people coming in very frequently, and they are all anxious to get on this Committee."

According to Col. Ritchie this situation is appreciated and it is desired that all who are concerned with the tank program be associated with the Subcommittee.

Since the last meeting suggestions for a welding data sheet have been circulated to the members of the Subcommittee for consideration. The present thought is that a single-page form should be used to avoid the possibility that pages of a multiple page form may become separated and lost. The purpose of this data form was explained by Mr. Warner as follows:

"The purpose of this data sheet is that it will be filled out for each welded test plate which is tested at either Aberdeen Proving Ground or Rock Island Arsenal on which we want to

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preserve a complete story so that on this one sheet the complete story will be contained. It will not be necessary to have one or two or three additional sheets for record purposes. I don't know just the procedure for distributing this, but it will be necessary and very desirable that in case you make any test plates for formal test - ballistic test - that this sheet accompany those test plates."

It was suggested by Mr. Thomas that provision be made for including weld metal analysis, Mr. Warner commented further:

"Of course, we are interested in getting this form standardized and in use so that we don't want to take too much time to play around fixing it up to suit a personal idea on this. But the point Mr. Thomas makes is very pertinent, and we are going to take advantage of all those comments and make a sheet that would be acceptable to everyone. I don't think anybody will object to the fact that we have complete information on each test plate. We are going to correlate these results and try especially to alter the troubles of the past, such as 'We don't have complete ballistic information', or this, or that, or something else. On the other hand, the original data sheet submitted had space in it for four plates. Personally, I don't think there is any use for four plates on one sheet. One plate should be used for each sheet."

Col. Rehm questioned that armor composition could be given on the form in view of its confidential nature. Mr. Warner replied:

"A suggestion was made that space be provided for the type of plate. In other words, you could call it 30 carbon-nickel-chrome, or 25 carbon-chrome-moly to designate the type. We are concerned in this welding problem with the composition of the plate. People already in some of their experimental work have done some welding on plate metal, but they weren't sure of composition and ran into trouble. In spite of the fact that these compositions are confidential, we have to have some indication of the type of plate for welding. Space will be provided in the data sheet for the type and description of the plate if anyone is scared of putting the composition down."

The classified nature of the data was emphasized by Col. Ritchie:

"We should be careful of the composition as that is confidential. We don't want that information broadcast. Our discussion in this room is not to be discussed with unauthorized people. You will note that all of them are under a classified cover and should be handled accordingly."

There followed some discussion about handling data on plate compositions and electrode compositions. Col. Ritchie emphasized the confidential nature of the plate data:

"Where those compositions are furnished, they must be furnished under confidential cover so that paper will not be passed out to unauthorized persons. I would like to impress on the members of the Subcommittee that we have to handle this material under classified cover; first, because the regulations of the Ordnance Department require it, and second, because we don't want this to get out to unauthorized hands, because this is the kind of information for foreign agents."

The electrode manufacturers' viewpoint was stated by Mr. Ewertz:

"I would like to state that as far as we know, we publish in all of our literature, not the composition of the electrode, but the composition of the weld metal that you get from that electrode, which as we look at it is the important thing. It is what is holding your pieces together that is important and not what you start with, so if you ask us we will tell you what you are going to get in the unaffected or unadulterated part of the deposit, but we may not tell you what we actually start with."

The fundamental purpose of the data form is to accumulate data for future reference as explained by Mr. Warner:

"I was going to say that my personal opinion on the use of these data forms is that they are not to be broadcast by the members of the Subcommittee. They are to be filled out by the people who are making the test plate and sent in along with the test plate for official Ordnance Department records. They will not be broadcast generally. When the ballistic test is made, of course, the people who made the test plate and for whom the test plate is being made will have a copy of it. The purpose of the data sheet is to collect information to be used for official records for later correlation for any composite reports that are sent out to the Subcommittee. As a result, we will have that data for those reports. In those reports, composition will be filled in. Details are not necessary, neither are any commercial data or identifications given for obvious reasons. I don't think we need to worry about that phase of the data sheet."

Mr. Bibber summed up the situation as follows:

"I wonder if this whole subject is one for this Committee to decide. The restrictions that are on these armor plate compositions are placed by the Army. Now if the Army wants those disclosed on any kind of record or any form, all the Army has to say is that it shall be done. It seems to me that's a problem for the Army to decide for itself. One special agent says it shall be secret; another agency says that it shall be disclosed. It is up to the Army to say whether it shall be disclosed."

Col. Ritchie closed the discussion with the following comment:

"That ties in with my remark to the effect that material

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data furnished on these forms must be handled under classified cover so that it does not get into unauthorized hands. That, of course, will be the burden of those who receive this material to handle it properly. I think we can pass on from that topic and change the form to include the electrode analysis as suggested without bothering you again to get the form in operation."

At the request of Col. Ritchie, Mr. McDowell reported on the meeting of the Research Program Group held the previous day:

"One of the problems that the Research Subgroup is handling is to determine the relative merits of the H and Y welded plates for shock test on procedure qualification tests. At the present time, Specification AXS-497 calls for an H plate and in the past meetings there have been considerable discussions as to the relative merits of this H plate and the Y plate for shock test. Several members of the Subgroup have welded both H and Y plates using different types of electrodes. At present we have no complete results on the tests, but at the next meeting of the Subgroup we hope to have complete reports from all members of the Subgroup. At present, I think we can give you the progress that has been made to date. One of the big troubles some experienced was in obtaining armor plate. Some of the members of the Subgroup had no armor plate available, and it had to be procured, and there is some difficulty in connection with that."

There followed brief reports from various members of the Group who are engaged in preparing plates for ballistic test at Aberdeen. The York Safe and Lock Co. is now preparing two H type and two Y type plates for comparison of 25/20 with a low alloy non-austenitic electrode. The A. O. Smith Corporation, together with the Electro-Motive Corporation, is making H and Y test plates by machine welding. Some trouble is being encountered in welding the crossbar.

The results of work done by Diebold Safe and Lock Company were outlined by Mr. Abbott:

"For instance, in the 7/8" plate, we found that the principal troubles are difficulties into which we ran with distortion of the plate and cracking of the underlying layers of the weld metal. Going down to the thinner and 1/4", we did not have that occur because we don't have the multiplicity of passes in the thinner metal, but there was annealing of the zone adjacent to the weld which gave low ballistic results. Since the last meeting we have tested fifty-five different types of joints and welds, and it practically all adds up to the same thing. It doesn't seem to make much difference in the thin plate what rod you use, because annealing seems to compensate for any tendency to crack or distort in there. We are going ahead with our test, but up to date we always come to that one answer. Unless we can find someone to help us, I am afraid we are not going to progress any further than we have gone. We are the only ones experimenting with thin armor plate from 1/2" down, and there are

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considerable quantities of that armor plate used in aircraft work, cars, etc., and we would welcome the addition to the Subgroup of any other member who is making or fabricating thin armor plate that would be willing to consult and work with us."

Mr. Abbott further explained that these are being made of 25/20 and 18/8 with both H and Y plates.

The American Car and Foundry Co. is preparing three H and three Y plates welded, one pair with modified 18/8, one pair with 25/20, and a pair with non-austenitic low alloy electrode. The Carnegie-Illinois Steel Corp. in collaboration with Linde Air Products Co. and Chrysler Corp. is engaged in carrying on a program involving the welding of both H and Y plates in 1-1/2" and 2" thick cast and rolled armor using Unionmelt welding and also manual welding with seven different electrodes.

The Baldwin Locomotive Co. has completed preparation of test plates on 1/2" and 1-1/2" rolled plate as well as several sections of the upper front of the M3 hull for testing at Aberdeen.

At Watertown Arsenal weld bead hardness studies are in progress on 1/2" and 1-1/2" rolled and cast armor with the purpose as explained by Mr. Warner:

"We have two objects in view in these tests; one is to find out how much preheat is necessary to prevent the hardness under the weld bead from exceeding what we consider to be safe limits. I won't say what these safe limits are. This might have to be decided when the results are accumulated. Another object is to find out how much preheat we can use and not reduce the hardness of the base material. As I said, that material is being prepared. We haven't done any welding yet, but expect to next week."

According to Mr. McDowell a fatigue testing program is under way at Rock Island Arsenal:

"In connection with the fatigue program carried on by Rock Island Arsenal, preliminary reports to date were presented at the last meeting of the Subcommittee. However, the preliminary test included butt joints only, and in the proposed program we are planning to use four types of joints: the 90° corner joint, the butt joint, the 120° joint, and a T joint. These joints will be made using both cast to cast and cast to rolled plate. The plate thickness used will be 3/4". We plan to use a 25/20 electrode. At the present time, the plates have been prepared and we plan to start welding in the very near future, probably next week."

In connection with shock testing of welded test plates it was considered by the Group that a blunt nosed slug might be desirable as mentioned by Mr. McDowell:

"In connection with some of the other questions that came

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up at the Subgroup meeting, one of the questions was the shock testing of these plates which were welded on the Research Program. It seemed to be the consensus of opinion that the shock produced by a blunt nose slug fired at normal impact was much greater than the impact produced by an A.P. shell fired at an angle to the plate. It was suggested that this be discussed at the meeting of the Subcommittee, that in the firing of these welded test plates the blunt nose slug be used in all of these tests. It is believed it would present the most severe shock condition."

This controversy regarding slugs versus A.P. projectiles for shock testing was elaborated on by Major Atkins:

"A proof slug is a sore point at the present time. There has been a lot of controversy at the Proving Ground and the Office, Chief of Ordnance, as to whether we should take proof slugs of unknown composition which have been at the Proving Ground some twelve years, fire a piece of armor plate and get consistent results. The Automotive Department thinks one way and I am in the middle to make the decision. Personally, looking at the results of the plate, we do get bending with the proof slugs with the fracturing of the slugs, but not with a projectile which slides on through. However, there has been another development called the Semi-A.P., which will deform slightly and give us a bulge in the back. We are investigating the possibility of using that projectile or something similar to that - similar to the target practice projectile in the 37 m/m shells with the impact test, to see whether we can overcome the piercing of the projectile in the armor plate. Personally, I think it gives a better wallop to the plate than the A.P. projectile."

Lt. Reed commented on the development of the proof slug:

"We have developed the use of the proof slug sort of on the side and unofficially. It follows the T.P. We are of the opinion that any projectile that went sliding on through the plate, would not tend to bend the plate as much, would not come out on the plate. The next natural step was to get a soft deforming 75 m/m projectile, and having seen proof slugs around, we tried to get them. Our use of proof slugs has shown that the slugs break up and end up in twenty pieces, but the plate always receives a generous dish and in firing at welded plates I have been able to take the proof slugs and bend the plate 3" or 4" along the vertical leg of the Y, which in my opinion seems to give a good shock bending test to a weld."

Upon request of Col. Ritchie, Dr. Aborn, NDRC Investigator, commented on the metallurgical aspect of the armor welding problem:

"As far as I can gather from the meeting yesterday, there is no systematic plan to study metallurgical characteristics. It so happens that this survey being conducted by the NDRC was concerned with the welding aspects of welding steel. Therefore, this is one plate to start if the Army Service feels that is something that is desired. It seems there have been, as we size it up, a large number of tests made and now being contemplated on different types of armor plate with different types of electrodes, different types of joints, procedures, etc., but there has been no systematic study made to correlate the metallurgical aspects of those joints. I am not saying the correlation will give us the answer by any means, nor do I want for one minute to hold up production. Production is the vital need at the present. But, at the same time, I think research is definitely justified, and as production proceeds troubles may develop and at that time research may develop something to solve some of these troubles."

Col. Jenks commented on the general need for research in the field of welding armor:

"The research thus far undertaken is largely around the qualification test, which involves a flat plate in a condition of internal stress. Those tests are essential because you need to pass them before you have any assurance that your production welding is going to be at all satisfactory. Of course, the immediate thing is getting into production - but you are going to continually run into problems that you would like to have solved, and some of those are going to be concerned with the internal stress problems, and some of them are going to be concerned with the design of the joint and the design of the structure. I think that the magnitude of the work involved in the welding of tanks is going to increase vastly and warrants a careful approach by laboratory methods to all these problems. I think the Subcommittee should begin to organize systematic research by laboratory methods, independent of production, independent of qualification tests, and that some laboratories should be specialized on these problems. I would also urge that there is a difference between the behavior of a flat plate and the behavior of the structure. In the flat plate you have the metallurgical damage and the internal stress to contend with, and I am thoroughly in sympathy with what was said about the projectile for a shock test. You have to analyze the engineering information available and take the best bet we can on a proper procedure; but when you analyze what is the proper procedure, it isn't only the correct case of a welded joint, it is also a case of the welded structure, so you should have a consciousness of the stress concentration which is present in the welded structure when you consider what type of joint you want. We have no knowledge of the behavior of welded joints under shock except that limited small amount we have been able to obtain at the Proving Ground. We have done some work on repeated stressing on butt welds. We haven't the information on corner welds. We have no information on the behavior of a welded joint under impact stresses. We don't know how the presence of internal stresses affects the behavior of the joint itself, and there is a large field for investigation. It is a problem of next

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year, the year after, and the year after that. I might add here that the Welding Research Committee is proposing, through the National Research Council to the Defense Research Committee, some fundamental studies which involve the rate of cooling of a weld and the effect of various rates of cooling upon different steels."

Col. Ritchie elaborated on both subjects as follows:

"Just extending the remarks of Dr. Aborn a little further - his group, as he indicated, is making a survey of the existing literature in that field. In other words, to determine the state of the art of welding, and to secure information on the methods now in use or proposed for welding armor. That work was initiated as the result of the problems on fundamental study lines which we recommended for Watertown Arsenal about eight months or a year ago. I believe the work to which Colonel Jenks makes reference to, on the Welding Research Committee, is also based on some of these problems which were recommended."

To which reply was made by Col. Jenks:

"That's true. Those problems got over to the Welding Research Council. They asked the Council for some advice on those proposed welding problems. The Research comments which have been submitted are intended as a partial solution of those problems submitted by Watertown Arsenal."

Col. Jenks also made the comment that the research agencies of the American Welding Society will co-operate with the Subcommittee on any welding problem suggested. The fatigue testing facilities at the University of Illinois were cited as available.

The pressing need for tank production was cited by Major Atkins:

"Every manufacturer who comes into our office who even thinks he has cranes or floor space to do a welding job, we give all the information possible to see whether he can undertake welding. You must remember that there are very few places with the space necessary for this tank program, and we are terrifically pressed today to find people who can do this job. Within the next month I expect the program will increase. Where it ends we don't know, but every time I pick up the newspaper I find where increases in tanks are called for. We want to bear in mind, now, that what we discuss now will be a help in production in the next two or three months."

Col. Rehm stressed the need for welding research to be speeded up:

"Unless this research group works on a double and triple shift force, we won't be able to keep up with things. Just to see the magnitude of the thing, cast some figures about. We know that in about six months they will be using 300 tons of welding rod a month. If you can do something to improve your welding or save a pound of weld metal here, it must be done immediately, not next year."

In the ensuing discussion of the question of what to do and how it could best be accomplished several pertinent suggestions were made. Mr. Emery suggested a compilation of available data and experience:

> "If the various people that are starting these research programs to build these tanks would get their information on work that has been done, instead of starting from scratch in their own organization and building it up themselves, we will be a lot better off, because we will get better results."

It was suggested that a summary of the material would be very useful because at present the people interested do not have time to read all the details. Such a survey is now being made by NDRC and the report will be a summary of existing data according to Dr. Aborn:

> "Yes, our report will include all of the experimental data available as well as the practices which are being used or contemplated at the present time."

The general line of activity of the Subcommittee Research Group was explained by Mr. Warner:

> "Some of this discussion going on this morning is similar to what went on at the Subgroup meeting. I would like to say that the Subgroup which is now in existence has laid out the work which is being done by the various members of the Subgroup themselves. The Subgroup has not attempted to lay out any detailed program of research with the idea of pushing it off on somebody else. We don't know that the Subgroup will so function in the future. There is a possibility that it might, and that's one reason for suggesting the item of the Subgroup of Electrode Manufacturers so that they could have a group by themselves to consider these problems from the electrode standpoint, and either formulate a program which they can carry on themselves jointly, or suggest an allocation which would result in some work being taken on actively. I don't know just what program the Research Subgroup, which is now in existence and consists of representatives of users, fabricators, can do of itself. The problems, which they are considering, naturally, those practical problems first, are to be solved in the shortest practical way without going into involved research. I think, as Colonel Ritchie has said, that he is open for any different suggestions as to how he could make a definite allocation with a definite suggested line of work which would aid in the solution of a definite problem."

The viewpoint of the electrode manufacturers on this question of research and development was pointed out by Mr. Ewertz:

> "It has seemed to me for a long time that the Army Engineers should decide what they want and then give us a chance to help them achieve that result. The Army so far has some pretty general ideas of what they would like, but there's a lot of places where those ideas should be more specific. We, in our problem of developing electrodes, would be helped a great deal

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if we could have something definite laid down as a standard to which we could conform or try to reach. Maybe it will be too high to start with, but at least we would know in what direction we should be going. Our Committee of welding people, that is, the electrode manufacturers, can get together and we will co-operate with you in every possible way. I would like to urge you some unification of ideas as to the ultimate results that you want, then we can go ahead a lot faster."

It was pointed out by Col. Ritchie that ballistic requirements are prescribed by Ordnance specifications but Dr. Miller (Reid-Avery Co. pointed out that the electrode manufacturers have no ballistic testing facilities and would like to have some indication as to whether a 25/20 or an 18/8 electrode is more desirable. The Ordnance Department, of course, is unable to do this.

Mr. Raymo suggested that the tank fabricator should develop his own methods and that in the Baldwin plant:

"We are using only the 25/20 type of electrode. We have recently done a bit of developmental work on a non-austenitic type of electrode. Results were not at all favorable. I only want to say that our discussion about procedures and what to do is not going to be settled around the table here. The very best that we can do is to start with what appears to be the best available at the moment, giving due consideration to the fact that developmental work should be carried on, and something at a later date may come into the picture as a substitute, something even better, but our problem is that of building tanks at the moment. I have repeatedly told electrode manufacturers' representatives we are not interested in undertaking a developmental program of welding electrodes. I appreciate the point that Mr. Miller of Reid-Avery made that they do not have the facilities for making up test specimens that the manufacturer does. It is difficult for them to get the plate. It is perhaps also a bit of a prolonged procedure for them to arrange for proving tests when nothing more is at stake than a possible failure to be repeated many times. I have taken a rather arbitrary stand on the matter, but it springs from the point that I feel that our obligation is to build the tanks at the present time. I do not hold forth for 25/20 as the total ultimate in this thing and I'm sure of the fact that a shortage may exist sometime in the future. I don't believe it exists at the present time. We placed a substantial order last week for electrodes and it was snapped up so fast it wasn't even funny. Furthermore, every electrode manufacturer is camping on the doorstep telling me that he can furnish almost double or triple quantities in the meantime. Our electrode problem is not a problem at the present time. We have tanks to build, and tanks are under way."

Mr. Brooker explained the position of the Ordnance Department in this situation:

"The only comment I would like to make following Mr. Raymo's

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comments is to correct an impression he might have given in regard to giving ballistic tests on welded specimens. We are ready to give ballistic tests at any time. We try to avoid duplicating efforts. We like to have any test specimens come through the organized group to make tests, especially when there is a duplication of work already done."

Availability of armor plate for test purposes was emphasized by Major Atkins:

"There are fifty tons of test plate material at the Proving Ground. Anybody who wants to get test plates can get this material with the understanding that the material we give you will be that composition. Just write to the Office, Chief of Ordnance, Washington, D. C., attention Tank and Combat Vehicle Division. This is subject to the conditions that Mr. Brooker laid down to avoid duplication of test work."

It was indicated that 25/20 electrode has given good performance but there is no comparative data on 25/20 and modified 18/8 electrode.

Just prior to lunch the electrode representatives met and organized an Electrode Group.

Following lunch Mr. Raymo discussed the welding of medium tank hulls at the Baldwin plant. Only one has been completed so far and slides were shown of this hull.

A question on electrodes was raised by Mr. Biederman:

"Take your ballistic test such as we were talking about this morning on 18/8, 25/20, or another half dozen of them - there are placed on the hull on which it isn't necessary to use this high alloy rod. For instance, in the bottom of the floor, all inside welding, what possibilities are there of using other material there? Am I right or wrong in saying we shouldn't use this high alloy rod all over if it isn't necessary, if it isn't exposed to the ballistic test?"

The discussion of this question indicated there was a belief that, even though all joints in the hull are not directly exposed to ballistic attack, all connections to armor plate should be welded with a suitable armor welding technique. This was emphasized by Mr. Brugge:

"When you weld to the armor then it calls for the armor technique. That's in the present specs. If you get something hitting on the outside of the tank, then it is exposed to ballistic shock. I do not know of anything in a tank that is not exposed to ballistic damage. I'm afraid from the actual requirements that wherever you touch armor plate it will have to be welded with the same technique as your main joints."

This was further corroborated by Mr. Bibber:

"The welds joining the bulkheads to the inside of the tank,

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where the welds are on the tension side when the tank is subjected to external damage, are some of the most important connections and they should most certainly be made with the best electrode you can get your hands on. The other welds around the bottom are some of the smallest welds on the tank, but I believe that where the armor is touched the welds should be made with a good electrode."

The fabricators, as evidenced by Mr. Biederman's questions about electrodes and other comments, appear to want information as to electrodes and welding procedures which will produce satisfactory armor weldments. If such information were generally available, the fabricators could thereby save time and money required for development.

Mr. Bibber explained the general situation regarding approval of fabrication procedures by the Ordnance Department:

"There were certain questions this morning which led me to believe that some of the people here didn't appreciate the way the government had to specify some of these things. For instance, the government now requires a performance test, a ballistic performance test, a definite specification that the plate must have a resistance to penetration of so many hundred or thousand feet per second. They also have a specification limit which says that the weld must be, say 85% of that limit of the plate. Under the present scheme, if a joint welded with any kind of an electrode whatsoever on any kind of plate passes the requirements of the government, it is satisfactory to the government. The Army cannot tell the manufacturer what kind of electrode to use. He has to solve this problem himself, between the electrode manufacturer and himself. The electrode manufacturers have the data. It is their business to have the data, just as it is our business to be able to tell people how to weld armor. The manufacturers will have to straighten out those problems between themselves and the makers and then submit it to this performance test."

The present situation regarding availability of the stainless steel electrodes for armor welding was outlined by Mr. Brown, Office of the Under Secretary of War:

"The only comment in connection with the problems brought up by several is the availability of the supply of the high alloy electrodes, or rather the high alloy in welding rods. The Office of the OPM several months ago gave the impression there would be a serious shortage in that type of welding wire, based partly on the existing facilities of the steel mills and also on the nickel and other strategic materials that go into it. Even before they announced that, the War Department had undertaken an expansion in the capacity of making stainless and high alloy welding rods which will provide next year an additional five or six thousand tons of electrodes in those grades. We have been assured by the Nickel Branch of the OPM that whatever quantities of nickel are needed will go into those welding rods and welding wire. I don't believe that under the present

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tank program there will be any serious shortage of the high alloy type welding wire and rod."

Mr. Thomas reported on the formation of an Electrode Group as follows:

"It was rather the feeling in the group, as we met here just before lunch, that there was a very definite need for the electrode manufacturers to get together and arrive at certain standards and come to certain agreements which would help all fabricators. That was our first and main agreement. Our second was that we should choose as chairman of that group a man who is entirely outside the field of electrode manufacturing. We obtained the consent, if satisfactory with this Committee, of Mr. Ed. Brooker to head this group. We also arranged to meet in the very near future to discuss the problems and take up the various items which we feel from the discussion should be brought into some clear and concise report for this group. As I hear some of the recent discussion on electrodes and strategic materials, I rather feel that the getting together of these electrode manufacturers may clarify that whole situation."

Mr. Brooker explained the makeup of the Group:

"It may be of interest to this group to know that Arcos Corporation, Lincoln Electric Company, Harnischfeger Corporation, Reid-Avery Company, Murex, McKay, Champion Rivet, A. O. Smith Corporation, and Alloy Rods are now on the Committee. Maurath will be requested to send a representative, and there is one other under consideration. That gives a representation of the stainless and low alloy electrode manufacturers. That is the Subgroup we were speaking about."

For sometime the problem of joint design for welded tank hulls has been a matter of considerable argument among fabricators. The Ordnance Department has left the matter of joint design for welding to the fabricators themselves. This left the matter of joint design to be proved by ballistic tests and resulted in numerous differing ideas. In order to try to get some agreement on this problem the Baldwin Locomotive Company has called a meeting for Monday, 27 October, to consider this matter. Mr. Bibber commented on the purpose of the meeting:

"It might be a good idea to give this committee a little bit of the background that lies behind that meeting Monday. At the inception of the M4 design, it was felt by a number of us that it would be a good thing to draw the tank in such a way that the individual joint design would be left to the individuals who were going to build the tank. If there were going to be a number of ideas to design the joint, the proper thing to do would be to allow each individual to work out his own salvation. As the tank plans of the M4 progressed, the Aberdeen Proving Ground more or less fell in with that idea. For instance, if they were drawing a joint of this character, (illustrated with hands), an angle

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joint between the two plates, the drawing would only show a line between the two sections. That's a perfectly imaginary line. It does not exist. It does not enable the manufacturer to cut his plate. The plate manufacturer would have to redraw his plate manufacturing drawings in order to flame cut his plate. The welding rod manufacturer or the tank fabricator would have to redraw the tank in accordance with his own design before he could even estimate on the making of that tank. In view of certain discussions which transpired here this morning, it is apparent that there is a desire on the part of the fabricator, and I think a perfectly logical desire, to have the Army say what they feel would be the proper type of joint to use. In order to see if some sort of agreement can be obtained between the different individuals who have been working on the design and fabrication of welded tanks so far as it has been done, it is hoped that out of this meeting Monday will come, possibly, a standard design of joint for every joint in the M3 and M4 tanks, and thereby enable the drawings to be made with the idea of representing actual joints that would enable the fabricators and the estimators and bidders on these tanks to go right to work without worrying about the design of joints. Many of these fabricators have not had enough experience to design these things, and if this scheme works out Monday, I believe it will be a great step forward."

Mr. Raymo further elaborated on the purpose of the meeting:

"Supplementing Mr. Bibber's remarks - the Baldwin Locomotive Works has already been assigned to design and has been contracted by the Ordnance Department for the purpose of redetailing a design of the M3 hull for welded construction. Also the task of doing the same has been assigned in regard to the M4 hull. I simply want to let you all know that the matter remains wide open as far as the Baldwin Locomotive Works is concerned. We are simply a means to an end as far as getting the thoughts of all here down on paper in the form of a working drawing that will accomplish the things that Mr. Bibber indicated could not be arrived at with the designs as they are at the present time. We have placed preliminary drawings in the hands of as many as possible. The group that will meet Monday is substantially the same as is now here. Our Engineering Department will be represented there, and we hope that your comments and suggestions will be a starting point for them. So, I would like very much to re-emphasize the point that we are 100% open to your suggestions as regards anything that can be done to make this a very good, or rather the best design possible."

At the present time the attitude of industry on welding procedure qualification and operation qualification appears to favor use of a section of a tank hull instead of the H plate. Also a 400°F. preheat on homogeneous armor is believed possible but preheating of face-hardened armor

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is regarded with some suspicion. This attitude, as explained by Mr. Warner, appeared from the comments on revision of Specification AXS-497 which have been received. With reference to radiographic inspection of welds in armor the trend is approximately as follows, according to Mr. Warner:

> "There was considerable objection to being too definite or too specific on the subject of prohibition of any radiographic defects on welded joints in armor. The specifications now say that defects in welded joints may be accepted if they do not exceed in amount those which are found in qualification test plates. In other words, if you have a qualification test weld which satisfies ballistic requirements and that weld has a certain amount of lack of penetration or lack of fusion, then that becomes your standard for fabrication. Your armor structure may have that amount of defect. If you exceed that limit, then the weld becomes rejectable and has to be repaired. If we require absolutely perfect armor weld structures, it becomes, according to many objectors, too restrictive, so it seems to me after reading the comments submitted, that the paragraph should remain as it is for the present until we are definitely sure that we want absolutely defect-free welds. There are some cases where a complete penetration from both sides of the plate is not required by the designer and that might get somebody into trouble - perhaps, if some inspector happened to be on the job who was not completely familiar with the requirements for that design. That is about the way the thing stands."

With reference to using a section of a tank hull for qualification of a welding procedure, Mr. Brooker elaborated further:

> "I think I can shed a little light on this business of taking part of a tank to serve for qualification. That was proposed by several welding contractors because they thought that by preparing the plate in Specification AXS-497 it was not sufficient to prove to them they could weld a tank. They prefer to weld up a tank section which consists of two plates. They figure if they could weld those they could weld the rest of the tank. Now, if we have a contractor coming into the picture who wants to do that it is rather superfluous to ask him to prepare in addition the ballistic plate. Certainly the H and Y are really locked up, and the tank cannot be made in a locked-up condition, so that I believe that is something that would remain to those of us who arrange these qualifications with the manufacturers. It is our aim to get them qualified, to put it plainly--make it tough. There is another reason for taking a particular tank part. We have one welding contractor who is welding 1-1/2" thick cast armor to 3/8" rolled material. There is some question as to whether AXS-497, as now written, would actually qualify him for that job. In this case, the man thought that perhaps after trying a weld of cast and rolled, that those two thicknesses would be more of a test for him and for us as well. There are some questions regarding ballistic tests which complicate the thing a little."

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In connection with the inspection problem Mr. Boese raised the question:

"Is it necessary that the Ordnance inspector witness all the qualification tests on all welders? Is it true that they witness qualifications?"

To which Col. Ritchie replied:

"Yes. All qualification tests are to be witnessed by the inspector."

In discussing comparative ballistic tests of a riveted turret and a welded turret for a light tank, the turret being of 1" face-hardened armor, Lt. Reed indicated that on the welded turret:

"The only area that broke out of the shell was down below one of the pistol ports and was not supported. Our ballistic limit in the weld was around 90% in comparison with the ballistic limit of the face-hardened plate. There was no serious cracking of the weld. As many times as we have tested them, these structures have not failed progressively. You can see cracks in there that are really not detrimental. More rounds could be put on those joints and they would stand up well under those."

Whereas on the riveted tank:

"In the riveted turret, machine gun fire, both ball and AP, was sufficient to knock rivets out that weren't even touched."

Studies of cast armor welding repairs at Watertown Arsenal were summarized by Lt. Matthews:

"We simply took 1" slabs of cast armor, representing about the highest alloy that is being used in the cast armor composition. The deposited weld beads (of the weldability type Mr. Warner described before) using 25/20 carbon rod were subjected to various heat treatments and we found out we had to go in the neighborhood of 1200° to 1300° to soften it. The whole problem here was the repair of surfaces on cast armor, which must be subsequently machined, in order to work out some method that could be applied in production, if small defects are uncovered. We can say, to cover the situation, that to accomplish the best results we should heat material by torch for 10, 15 or 20 minutes to a good cherry red, in the neighborhood of 1350°, below the critical temperature of the plate. That does not adversely affect the cast armor. These surfaces are not exposed to the ballistic impact. We think that would be a suitable method for the repair of cast armor. We would propose perhaps that better results would be obtained with a low alloy rod."

Mr. Landgraf explained his experience in weld repairing certain armor castings:

"On the housings of the M3, defects that turned up under the surface after machining which were superficial were repaired. Matter of fact, some of them had sharp bottoms and there were, therefore,

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possibilities of propagation under vibration which meant they were not practical to repair at all. We finally decided on the procedure of chipping out defects to sound metal and using essentially the same technique that would be employed under AXS-497, that is, the austenitic rod. Obviously, machining would not be too easy to finish over that weld, but those cases, by experience, are so isolated that I don't believe it was really a point to take issue on. Out of the hundreds of housings we produced there were only about five or seven all told which were reparable at all, and it was a relatively easy job, possibly easier than heat treating, to finish that surface again by grinding."

In connection with the machining of weld repairs in armor Mr. Brugge pointed out the advantage of using the annealing bead technique. With reference to results of development work and test data available, Col. Ritchie commented as follows:

"If you have any questions in your mind in connection with any of this work, please do not hesitate to call on us. We may be able to solve your problem. Just write to Watertown Arsenal and we will do our best to help you. They have considerable data on file there in connection with this activity and other activities pertaining to armor. The Rock Island Arsenal is another source of data which ties in with the Subcommittee with us. The Office, Chief of Ordnance is another source. Major Atkins and Mr. Brooker and now we have this Subgroup on electrodes. We have two parallel groups on this Subcommittee, one on research development work and one on electrodes. These are two additional subsources of information, so please make known your problems and we will do our best to help you."

The estimated requirements for armor and vehicles were cited by Major Atkins:

"On armor castings for all tanks we estimate we are going to require 26,280 tons per month of armor castings. On armor plate, rolled armor plate, we estimate we are going to need 38,000 tons per month. I think our friend from the Under Secretary of War Section will be rather over-optimistic for the amount of nickel we are going to get when we take 38,000 tons of chrome and nickel steels per month. That includes 1000 light tanks, 5000 armored cars, 1000 aircraft, 1500 plate hulls, medium, 500 mediums with cast hulls, 100 heavy tanks and self-propelled gun mounts—3200 tons, aircraft 1000 tons per month and contingencies 4800 tons per month. We lumped it all together and got 38,000 tons. This is rolled plate alone."

The policy on welded vehicles was given by Major Atkins:

"Some of your people are going to be making riveted tanks. Everybody now coming into production will be on the welded job. Certain manufacturers are going to be kept on the riveted job until we can turn over. What the Russians are coming in for

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will have to be added to this total. The existing capacity for rolled plate and sources available to the Army is 13,000 tons per month, and the rest of it has to be built between now and the time the rest of you people get into production. On cast plate we are in a little better position."

With regard to the date of the next meeting, it was suggested that about two months would be satisfactory. The date is to be decided by the Chairman. The meeting was adjourned with the following remarks by Col. Ritchie:

"That indicates, of course, the importance of the welding problem and expansion of the program and suggests to me something which we have had under consideration. That is, pointing our compositions on armor toward those which are of the most weldable type, insofar as it is practical to do so. Unless there are further comments, I want to take this moment in closing, on behalf of the Subcommittee and on behalf of myself, to thank the District Ordnance Office for its assistance in helping us to arrange this meeting, Mr. Sibley, Henry Disston and Sons Company, for his assistance and also for bringing up the turret for display, the Baldwin Locomotive Works, Mr. Raymo, for the courteous invitation to visit the plant tomorrow and for all the arrangements to simplify and make it convenient for us to get out there to go through the plant. Incidentally, I believe the District Office has arranged transportation for us. And lastly, to the Arcos Corporation, Messrs. R. D. Thomas, Sr. and Jr., and other representatives of that firm, for arranging this meeting for us, for the stenographic help and for the luncheon. I am sure we are deeply indebted to them and to the others for helping us make what I believe is a satisfactory meeting."

The Electrode Group appointed at this meeting contrary to the suggestions of certain representatives of the electrode industry indicated a realization that standardization of electrode types and grades for welding armor is a necessity if mass production of armor weldments is to be realized effectively. The magnitude of the production problem as outlined by Ordnance representatives was beginning to be realized, but some relief in the matter of restrictions on exchange of information by members of the Subcommittee is needed. This was the last meeting of the Subcommittee prior to Pearl Harbor which put a more serious aspect to the problem of smoothing out some of the differences of viewpoint indicated at this meeting.

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SIXTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
WEDNESDAY, 7 JANUARY 1942
HOTEL STATLER, DETROIT, MICHIGAN

The sixth meeting of the Subcommittee was held in Detroit on 7 January 1942, at the Statler Hotel with 95 persons in attendance representing:

Fabricators	24
Armor Producers	7
Electrode Manufacturers	17
Ordnance Department	22
Guests	25

This meeting at the Detroit Statler was arranged by Major G. L. Cox, Acting Director of the Laboratory, who took over as Acting Subcommittee Chairman replacing Col. Ritchie who had taken over the job of Production Manager at Watertown Arsenal under Col. Mather, Commanding Officer, shortly after Pearl Harbor. Major Cox presided at the meeting and opened the meeting with the following comments:

"The word these days is production. All of you read the newspapers. You know the President's desires and we are not going to let him down. We have got a big job. We are going to do it. Forty-five thousand tanks in 1942 is a big job. We've got to weld them, and we are here today to learn how to weld them. We have a lot of talent around us. We want to first know the problem, and we hope that the talent can give us the answers. If not, we will find the answers. I want to caution you at this moment that the substance of these meetings is of a highly restricted nature and the transactions must not be allowed to reach the hands of those not authorized to receive it. It is with some regret that I have to tell you that it has come to my attention that certain of the minutes of other subcommittee meetings have gotten to people who were not supposed to get them. So, let's be careful about these transactions, gentlemen, and see that they are kept in the category where they belong."

After the roll call Major Cox continued:

"Colonel Ritchie has been assigned to other duties at Watertown Arsenal and is unable to serve as Chairman of these Subcommittees. Now, the floor is open for nominations for Chairman, and I'd be very glad to hear some nominations. I might point out that the membership elects the Chairman. That's the procedure we have set up and I have been the Acting Chairman."

Major Cox was elected Chairman of the Subcommittee. Mr. Bibber suggested a letter of appreciation to Col. Ritchie for his past work as Chairman of the Subcommittee to which Major Cox replied:

"I'd like to appoint a committee of one - Mr. Bibber - to

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formulate the letter just as he sees fit and let it be the expression of the membership, and so proceed Mr. Bibber. I'm sure Colonel Ritchie will appreciate it but before he gets the letter, however, I'll tell him the expression that was passed here."

With reference to Subcommittee membership, Major Cox continued:

"The attendance has grown tremendously, and yet everyone of you here has a very important part in this whole program. Each of you represent a cog in the gear and all of you are necessary for the complete functioning. In the past, it has been customary to elect as members to the Subcommittee, those people whose companies have actually gone into the production of certain ordnance materiel that requires welding, and in this case, welding of armor. In some of the other subcommittees, it is some other activity related to the subcommittee. We have in our files, certain lists of names of people who have been proposed for membership and Mr. Brooker I think, has those right in front of him and I'd like, as he calls these names off, that the gentlemen please rise and recite briefly what your company is doing so that the membership can hear it."

In response to this request of Major Cox comments were made by several of the guests present:

Mr. Smith (Marmon-Herrington Company):

"Marmon-Herrington Company is very gingerly approaching the problem of welding light tank hulls. I think that I can put it as being gingerly because very frankly we know nothing about it from the very beginning and the more we get into it, the less we seem to know, so anything anybody can tell us we will be very appreciative."

Mr. Boardman (Chicago Bridge and Iron Company):

"In a sense, the Chicago Bridge and Iron Company is an interloper here because it is not welding tank armor. It is, however, receptive to the idea of welding it provided it can be shown that by so doing, they would serve the country better than by welding ships. However, it seems probable now that the company will concentrate on ships in drydock rather than armored tank welding. Therefore, under the rules, the company does not qualify for membership in this committee."

Mr. Tarbell (Una Welding, Inc.):

"Well, our problem, of course, is in the manufacture of automatic welding equipment as it applies to welding of armor and the development of electrodes for welding of armor."

Mr. Stark (Richmond Engineering Company):

"Mr. Brooker, we are just in the stage of negotiating on the welding of hulls. We are not in the welding of armor plate at this time."

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Mr. Penn (Indiana Limestone):

"We are doing some machining of steel or war material and have been investigating the welding of armor plates. We have qualified at Aberdeen on the welding of some test plates and we hope and anticipate the welding of tank hulls."

Mr. Brady (Alloy Rods):

"Alloy Rods manufactures austenitic electrodes for the arc welding of armor plate."

Mr. Eder (Coast Metals, Inc.):

"We are doing some research work on low alloy austenitic rods. We don't know very much about it yet. We hope to have something before very long."

Mr. Humberstone (Arcrods Corporation):

"The metallic type of ferritic electrodes for arc welding."

At the conclusion of these remarks Major Cox commented:

"The firms whose representatives have spoken will be notified by letter of their appointment to membership in the Subcommittee, and if it is at all possible, gentlemen, we would like to have your companies represented by one man. We are attempting to do that for all of our Subcommittee activities and keep the group as small as possible. We are delighted to have all of you here and as I mentioned before, it is necessary; but if it should be possible, have one person designated as the representative of the company with an alternate so that one person can then be responsible for the transactions, the correspondence, and then if he should not be able to attend a function, he can be represented by his alternate. In your reply to our letter which will go out, we will ask you to designate one person, with another person as the official alternate. Now is that clear, gentlemen?"

There ensued a discussion of the activity of the Electrode Group which was organized at the previous Subcommittee meeting in Philadelphia. Since that time several programs have been started as outlined by several members. Mr. Emery remarked:

"Garriott's program and mine is the development and gathering of information on ferritic electrodes for the repairing and welding of cast armor and to gather all possible data on ferritic electrodes for the welding of homogeneous armor. We are undertaking a rather intensive program in connection with A. O. Smith Corporation with Mr. Garriott. I think we will have some results for the next meeting."

To which Mr. Brooker added:

"Thank you, Mr. Emery. The object of this work will be to acquaint the tank manufacturers with an official report on the electrodes available and furthermore, approach details of qualifications of those electrodes."

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Mr. Thomas remarked for himself and Mr. Brugge:

"Mr. Chairman, we hope to do a similar type of job on the austenitic electrodes to what Mr. Emery is doing on the ferritic type of electrodes with the hope of getting out a specification for electrodes of the 25/20 and the modified 18/8 type."

In this work referred to by Mr. Thomas it is thought that the weldability of the armor plate is an important factor and a suitable test should be incorporated in armor specifications. Mr. Thomas commented on this thought:

"Too often our development of electrodes is hindered by poor weldability in the armor plate and it is believed that the actual production welding of tanks is going to be hindered unless there is some very definite specifications for weldability of the armor. We have made a stride in the last three months by getting some sort of mention of weldability in the cast and rolled armor specifications. There has been data collected both in our group and particularly by Mr. Warner at Watertown Arsenal on weldability of armor. And it is hoped that we will be able to collect information which will provide a simple weldability test to be applied to armor which test can be incorporated in the armor specifications for armor being supplied for welding. Very briefly, our preliminary thoughts on it are for a bead test deposited by an automatic machine on a piece of armor; section the bead at a given point, and test the heat-affected zone for maximum hardness; then place a limit on the maximum hardness in the heat-affected zone which will be acceptable for that particular armor. It is also considered as desirable that the maximum heat-affected zone, after a second pass has been placed on that bead, be considered and a limit placed on that maximum hardness. It is proposed that the procedure be worked out within the next few weeks, established, and a limitation on the basis of tests now available be recommended and then be submitted to the cast and rolled armor groups with a recommendation that the tests be incorporated into the armor specifications."

Mr. Bibber commented on the alloy situation as presently viewed by the Office of Production Management:

"In discussion with Mr. H. LeRoy Whitney in Washington the other day, Mr. Whitney pointed out that the nickel situation will probably improve somewhat over the coming year. It is expected that by the end of possibly next year, that the nickel output will have been improved on the order of thirty per cent. On the other hand, the chromium situation apparently is going to get worse and we don't know how much worse. It may get considerably worse because chromium, as you all know, comes from areas that might be cut off from us in a greater or lesser degree. I cannot give you exact figures on the chromium.

"As a side point, I might inform you that the OPM is going through all of our low alloy and alloy steel specifications with

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a view of cutting out and reducing and minimizing all the strategic elements insofar as is possible, simplifying them with the view to utilizing existing scraps, and refusing the use of these strategic elements wherever possible.

"It might interest you to know that we have in scrap, chrome-molybdenum scrap and we have nickel scrap, scraps which are very different to segregate in making pure steel of any of these various groups, but if we can take any or all of these scraps and throw them in the pot and add a pinch of that and that elsewhere and come up with a steel which has possibly 50 points of this, that and the other thing, and have the desirable properties of a low alloy steel, we have really accomplished something, because the additions then merely consist of slight additions to build them up to the required amount. Now as a matter of my own personal opinion, frankly I don't know of any more important use for the chromium and the nickel than in these welding rods. That, of course, is my own personal opinion but I am of the opinion that the importance of this joining method is such that a consideration of the use of these chromium-nickel alloys is important for the tank builders' program."

Another project by the Electrode Group was indicated by Mr. Brooker:

"The welding of face-hardened armor is a big problem of a number of the builders of tanks and other armored vehicles. The Electrode Group has Mr. Van Dreser of the McKay Company who with the co-operation of the rest of the committee will prepare a welding manual on that subject."

At the conclusion of consideration of the proposed electrode activity Mr. McDowell gave a summary of the work of the Fabricators' Research Program Group as follows:

"The program of the Research Subgroup consisted of the welding of H and Y ballistic shock test plates, using various types of electrodes and various welding processes. Based upon the results of these ballistic tests of these plates and also on the fabricators' experience to date, the following conclusions have been drawn: First, that on one quarter and one inch face-hardened armor, it has been found that either 25/20 or the modified 18/8 electrodes have given favorable results. From the experience of the different members of the Subgroup of making these H and Y plates, it was the general consensus of opinion that the Y type of shock test plate was the easier of the two types to weld and consequently, it can be assumed from that that the H type contains more locked-up stresses than the Y type of plate.

"In regard to homogeneous rolled armor, it has been found that 25/20 has proven most favorable and that the modified 18/8 electrode in most cases has given very favorable results from welding both the rolled homogeneous and the cast homogeneous in all thicknesses. Up to the present time, several test plates have been welded with the ferritic type of electrodes which have

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proven satisfactory ballistically. However, to date, no fabricator has used this type of electrode in the welding of tanks. Ballistic plates have also been welded using automatic welding processes and in several cases, have passed the ballistic test. However, it is believed that the automatic process is still in the developmental stage and is not yet ready for production welding.

"The following recommendations were made by the Subgroup and are herewith presented for the consideration of the Subcommittee: That for the purposes of experimental and developmental work, the temperature of the ballistic plates at the time of firing be recorded. That the Ordnance Department set up definite standards for testing ballistic samples with 37 millimeter and 75 millimeter projectiles of the slug type. That the Ordnance Department seriously consider the standardization of chemistry for best weldability of armor plates and armor castings to be used in welded structures."

Lt. Reed briefly discussed ballistic testing of armor weldments at Aberdeen Proving Ground:

"In regard to the ballistic test of welded armor plate, hereafter except in the case of 1/4" face-hardened plates, we have ceased to use a penetration test because it did not give us any particular results other than the resistance to penetration of a weld and that resistance to penetration depends on the spacing of the plates, whether or not you had a hard surface on the weld, and depends on the strength of the deposited metal whereas the shock resistance shows us whether or not our vehicle will come out of battle after it has been hit a few times with a large projectile. As to the matter of data, available data, for drawing up standards for welding, the specification as it stands today is going to require 1/4", 3/4", 1-1/2" test plates for shock tests, the 1/4" face hardened, to have it resist penetration. Available data on 1/4", 3/4", and 1-1/2" armor welded plates is small. It isn't negligible, but it is very small and it is most difficult to tell a man whether he passes or fails when you haven't seen enough to know what will fail. However, we have drawn up some standards that we propose to present here for your comments, for the shock test, 1/4", 3/4", and 1-1/2" armor."

Lt. Reed continued the discussion and outlined proposed standards for ballistic tests under Specification AXS-497 as follows:

"On the H plate (indicating drawing) for recording our ballistic data, we have a form which contains three H plates to scale. After one round, we locate the position of the round on the scale and the cracking on the front of and the back of the plate to scale. Cracking on the front is represented by a broad solid line (indicating). On the back, cracking is indicated by cross hatch lines (indicating). The proposed velocity of impact on both the 3/4" and the 1-1/2" will be two rounds at 1100 and one at 1250. This is the 75 millimeter, flat nosed soft

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projectile, preferably 200 or less Brinell hardness. The 37 millimeter T.P. M51, the T.P. projectile, the T.P. standing for Target Projectile, is a projectile ranging in hardness from about 180 to 220. The deformation is similar to the deformation of the 75 millimeter, flat nosed projectile, a photograph of which I have here. That is shape on impact. The 37 millimeter projectile will be used against 3/4" plate, the 75 against 1-1/2" plate.

"If our marksmen are particularly poor that day and strike on all one leg here, our experience has shown that these plates will crack up to within the end of the plate. It is reasonable that this cross-weld is going to crack a certain amount. However, we have found that, for instance, one round up in here sometimes will produce no cracking. One round up in there will sometimes push through, but this weld here is supposed to be stronger than this weld in that the cross bar is a restrained weld. The welders are supposed to be able to make this one with great ease. A round here should shear the plate back. Hence we consider if that cracks all the way across, the three rounds on here are a failure. If it cracks a small portion of the way, it will be acceptable and then again, that depends on how far over that round lies.

"We have not had sufficient 1-1/2" homogeneous plates in there so that we can make a plot and find out in general for instance say with 25/20 electrodes and if we could make a plot of how much cracking there is with the location of the rounds in inches, then we could tell whether or not there should be cracking in this cross bar, for instance, with the rounds four inches from the corner. We cannot tell at this time. Colonel Jenks has suggested that in addition to the three forms, we have right on the forms, the radiograph of the plates prior to the test, so that we can note right on one form how the failure during shock tests progressed with respect to original cracks, slag inclusions, and undercuts. The 3/4" plate will be tested in the same way. The 1/4" plate homogeneous will be mounted at 75° obliquity and struck with a 37 millimeter T.P. M51 at 1400 feet per second, face hardened at 1200 feet per second. We have made tests on those plates and we found that the face-hardened plates will bounce that projectile off. The homogeneous will reject that projectile up to 1600 feet per second. This will be a single butt weld, location of impact will have to be with a quarter of one caliber on either side. Face-hardened plate will have to withstand caliber .30 A.P. resistance to penetration."

Since the specification proposes three standard thicknesses of plate for qualification tests, there was some question by certain fabricators as to what would be done when none of these standard thicknesses are involved in the particular vehicle being fabricated. Mr. Smith of Marmon-Herrington is concerned with 3/8" plate and 5/8" plate. American Car and Foundry have none of the three proposed standard thicknesses. Mr. Miller

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(ACF) made a suggestion:

"It was decided at a meeting sometime ago that we would be allowed to weld the thickness of armor approaching the nearest that is lined up in the specifications."

To which Lt. Reed replied:

"Many tank manufacturers are welding everything from 3/8" to 2". That in itself immediately lends trouble. The Chief of Ordnance deems it advisable to select three thicknesses to weld. In your case, I don't know what action they will take on that."

There was no definite answer to this question at this time and Lt. Reed continued the discussion of ballistic testing:

"Before I finish, there are several requests that I would like to make. We need more data on the plates that you are welding. Don't say Republic made it or Carnegie-Illinois made it. We would like to know how they made it. That information is maintained on a confidential status and as far as we are concerned, we will keep it on a confidential basis, so there seems no harm in presenting it. However, if someone takes Lincoln's 'Armorweld' and welds up a plate and says Carnegie-Illinois made it and it passes, well, we don't know just how Carnegie-Illinois made it and to use that information to advantage, we would like to know how Carnegie-Illinois made it. Maybe someone else is making plates the same as Carnegie-Illinois. The name of the man who welded the plate is very important. If you have a roof and a welding machine and you buy some armor plate and get a man in to weld it who isn't even in your concern and you send it to Aberdeen and don't tell us he welded it, we would like to think you are qualified for welding, but really, you aren't. It does not seem in order to hire an expert to weld a plate to qualify your plant, when that expert is not going to be welding on your production line. Chipping and grinding; if you weld for one hour and chip for four, we would like to know. Whether you use a weave or whether you use stringer beads in your welding, we would like to know. We have found that the amount of reinforcing on a weld greatly influences whether that weld cracks or not. We most urgently request that you keep the amount of reinforcement down. Now the temperature of the plate at the time you start welding and any cooling that you allow while you are welding, would be well recorded. We have had instances where one man would weld a little while and let it cool and go ahead and let it cool, and he got through all right and another man took his idea and welded it and didn't cool and it cracked."

Mr. Brooker emphasized some of the points referred to by Lt. Reed:

"Lieutenant Reed asked for a complete report of welding data. Does everyone know there is such a form as WAS-1 for the reporting of welding armor? If not, get acquainted with it and use it. Otherwise, data as Lieutenant Reed has just presented

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cannot be built up. As to type of reinforcement, that came in for some discussion yesterday in connection with other parts of 497. It was pointed out that the code has standards for the various defects, among them being reinforcements. Obviously a higher reinforcement such as we have got by some automatic processes is bad. The specification to date has permitted the same reinforcement in a welded tank as occurred in the test plates, qualification plates. There is nothing more to say than that we must keep that reinforcement down."

A thought regarding interpretation of results of ballistic testing of welded plates at Aberdeen Proving Ground was suggested by Mr. Raymo:

"Having been associated with the preparation of plates for about a year now and also having access to the results of other people's tests, I begin to doubt whether or not it is wise to have that data available at the time the firing is done. I think that the Ordnance Department could do a lot to reduce this test to a 'go' or 'no go' proposition. I have had no occasion to question the results as to whether or not a specimen failed or did not fail, but quite frankly, I do not agree in a number of instances regarding the interpretation placed upon the specimen as regards its probable cause of failure, and I am just wondering whether or not such interpretations are not made in the light of data that is available to you before you get your results. Furthermore, I think it might be just as well to do the firing of those specimens in private down there. I question whether we are getting the best interpretation upon our results when we have got the man who made the test standing over it telling you it's good regardless of whether it was or not. You probably recognize that as a problem down there and no doubt have had to contend with it; but in the long run, I think there is more to be gained by firing at these tests, deciding whether it is good or bad without knowledge of how the test specimen was made up than there is in the other manner."

This thought aroused considerable discussion, particularly from some of the fabricators present. Mr. Biederman suggested:

"I don't believe that information will hurt at all. I think that the more information we can get, the better off we will be. I don't think we have had any information. I think we have been working down at the bottom of this heap without enough knowledge of the job throughout. I don't think this information will hurt us because we can lay it aside if we don't want it, but it still would be available."

Upon questioning by Lt. Reed as to what data might influence the interpretation of the ballistic test Mr. Raymo replied:

"Let us say, you are perhaps a ballistic expert. You need not have any knowledge of welding at all. Let us say whether or not the plate is acceptable. Let someone else find out how the metallurgical data and procedure of preparation was

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associated with that failure and perhaps discard or improve upon his procedure for the preparation of better specimens, but if you know beforehand through radiographic results that you have incomplete penetration on the cross member, or such as that, you can't help but be influenced in your interpretation of that failure by what you knew beforehand. You are speculating on how far the crack should have gone and I think that ought to be taken out of the picture."

Lt. Reed pointed out that Aberdeen Proving Ground had no reason to arbitrarily pass or reject test plates because of the manner in which they were welded but that:

"Our primary interest is to get the plates tested so that we know that the tanks that are manufactured by the various people are going to stick together when they are hit. We want the data on hand so that you can get the return report quickly. That's why we want the data when we shoot. We are preparing while we are firing and when we get that over, we try to have the information back the same day if it is fired before three o'clock and the next day, if it isn't."

The procedure suggested by Mr. Trautman:

"I don't understand, Mr. Raymo, how you send plates to Aberdeen without the test procedure. At Pullman, we have the government inspector practically on top of us just looking at every move that we make. In fact, we had one plate there all welded up that he didn't see all the details on and it was just taken off the board. So probably we are obliged to do something we are not supposed to do. We have sent all our information right along with our test plates."

The desirability of radiographing test plates by the fabricator was indicated by Mr. Vennerholm:

"Ford Motor Company does the same thing. Every plate is radiographed before we send it, which I think is a very good procedure. In the event the radiograph results should show up cracks, inclusions, bad penetration, I wouldn't see any sense in sending them. Throw it out and get another. Get a good plate. That's what the department wants--good plates. They don't want bad ones."

Lt. Reed interjected a question:

"Some day, some of you gentlemen are going to say to me, 'If you had struck it there, it wouldn't have failed,' and I'm going to say to him, 'Why?' and Mr. Raymo, 'What are you going to say?'"

To which Mr. Raymo replied:

"That's the very question that came up yesterday and some of our people were very much incensed about the very matter that

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you have been discussing here this morning and that was the reason for one of our recommendations that the Ordnance Department standardize on testing procedures. We had the statement made to our committee---very strongly made, too---that if it's hit here the results would have been one thing; if it had hit here, it would have been another. Furthermore, the statement was made that what you have passed as satisfactory for one fabricator has been turned down for another. I have no knowledge of those test specimens, but I think that everyone on this committee, in particular, ought to eliminate any possibility of a basis for such statements, because I don't think it's the intent on your part that any such thought should be in the minds of anyone."

At this point Major Cox interposed a summarization:

"Well, I'm sure that the situation does boil down to this: The Army is trying to do all it can to insure that the material going into tanks is as good as we can make it and at the same time, it is not trying to put any undue restrictions on the manufacturers, because after all, it is asking for large numbers of tanks. We must expect 'ups and downs' but in the end, it will all come out all right. Now, carrying on further into the same subject of research and development program, I want to call on several other people but before doing so, is everyone familiar with WAS-1, the form for recording welded armor data?"

Mr. Brooker elaborated on the WAS-1 form and its use:

"The WAS-1 form is a printed form made on tissue paper which bears blanks for everything pertinent to the welding. That means the manner of preparing the grooves and the manner of weldit. In addition, on that form, there is a blank, or let me put it this way--there is a section for the ballistic tests, and a section for the welding details. The data on ballistics of the space for ballistics is obviously something that the contractor can't fill out. Nevertheless, it is on that form with other spaces that he can fill out. The object of this is that upon making a weldment, the contractor fills in what he can and sends the tissue to the proving ground where the tests is to be made--Aberdeen, in this case, for weldments. The proving ground then enters the ballistic data in the ballistic section of the form and duplicates it in sufficient quantity for distribution to arsenals and to the company. Now, I will be very glad to send forms to those people that don't have them. What is more, the districts know that such forms exist and the district should be able to take care of that distribution."

With reference to data on the armor composition which is regarded as confidential, Mr. Emery pointed out that:

"In regard to this WAS form, there is a question that calls for analysis of armor plates. The contractor never has that analysis. Now, I realize that analysis of the armor plate is a rather secret affair but shouldn't there be a space on that form

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to put the heat number of the armor plate that was welded? Then it's an easy matter to go back to the manufacturer of the armor and get the analysis for the Ordnance Department's private information. On a lot of plates we have welded, there has been no heat number. It was impossible to tell what heat number they came from and I feel that the heat number should be required on every welded plate."

Major Cox suggested that the Ordnance District Offices should see to it that all fabricators operating under their cognizance have a supply of these data forms. Consideration was then given to development and research at Ordnance Arsenals. Mr. Curtis summarized this activity at Rock Island Arsenal Laboratory:

"Rock Island has been working on fatigue testing of weld metals and fortunately, as regards the weldment, unfortunately for a detailed report, work is progressing slowly because fatigue testing takes considerable time. However, we have completed the preliminary tests which have been reported before, indicating that austenitic rods have considerably better fatigue properties than the ferritic rods. At the present time, we are running tests for rolled weldments, rolled to rolled, rolled to cast, and cast to cast weldments in armor plates. Those are all 3/4" weldments, 3/4" in thickness, and they have been made up in 90°, 120° tees and butt welds and the results are very, very promising, showing that so far at least, there doesn't seem to be much to worry about as regards fatigue. These fatigue tests are made in an oscillator in which we attempt to overstress the weld itself."

Mr. Warner outlined the work in progress at Watertown Arsenal Laboratory:

"We are carrying on the study of weldability of armor by means of our single bead weldability test, which a good many of you are quite familiar with. In that test, we have at present three compositions with two thicknesses on two of the compositions and one thickness on the third. We have made welds at room temperature, 100°F., 200°F., 400°, 600°, 800° and 1000° temperature with a low carbon covered electrode of covered type and a 25/20 electrode, also of commercial type. Those welds on the specimen are made with the two electrodes under the same current and voltage conditions with an automatic welding maching at a fixed travel speed of about five inches per minute.

"We have not yet been able to examine any of these specimens but they are in process at the present time. We have material of two conditions - one rolled and one cast, which we expect to continue with in the two thicknesses, 1/2" and 1-1/2", and we have the prospect of two additional compositions of the rolled homogeneous type. We are endeavoring to get as wide a spread of compositions in this study as possible. In this study, there is the chrome-moly type, we are examining one with the high chrome in the nickel-moly type, and one with the high nickel in the nickel-chrome-moly

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type with the medium carbon, both in the rolled and cast type. We hope by the next meeting of this committee to be able to present some curves of weld hardenability, of these various compositions, the effect of the preheated temperatures on that hardenability, and also the effect of the preheating temperatures on the original initial hardness of the armor itself. It may be also possible that we can have information on what temperature is necessary to heat a weld made at room temperature, which is approximately seventy degrees, and what the effect of various temperatures will be on the initial hardness set up in the heat-affected zone."

From these remarks it was evident that the development work is concerned primarily with welding of homogeneous armor. This was emphasized by Mr. Smith of Marmon-Herrington:

"Am I to understand that practically all the work that is being done from a research standpoint is confined to homogeneous plate at the present time, and, if so, where does that leave the people that are out on the limb with their face-hardened business? We have done some work on our own in welding of face-hardened plate and to date, it seems to indicate at least that cooling means for maintaining the hardness of that face are either essential, if you are going to go to a continuous bead type weld, or, as seems to be the case at the present time, these cooling means are highly impractical, to say nothing of being very expensive. It comes down to a method of fabricating that I think Mr. Abbott of Diebold is better qualified to describe than I am. It does increase the weight of the tank hull, there is no question about it, and in our case particularly, that's of extreme importance. But the method employed has some advantages from the standpoint of fabrication, from the standpoint of the elimination of the distortion problem and, particularly, from the standpoint of maintaining ballistic characteristics of the plate itself."

The method referred to by Mr. Smith involved a butt joint with backing strip to which the armor is connected by plug welds made in holes drilled through the armor along the joint.

Mr. Lair described the fabrication of a turret at the York plant:

"About 1939, we welded one turret which was made up of 3/4" thick face-hardened armor. We welded that using a ferritic electrode. At that time, the general market at least did not know about 25/20 regarding the welding of armor. We water-cooled, and faced the hard side. Our process of welding was that we had a double V which had unequal beads, that is, the heaviest part, or the greater part, of the bead was on the soft side. We completed our welding of the soft side first. While that welding was going on, we water-cooled the hard side and after that was completed, we welded the hard side. It was also necessary, in putting in the first beads, to peen in order to take care of contractional

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stresses. We made no attempt, of course, to preheat it or anything like that. We were instructed to keep the temperature of our plates below 250°F, and we did that by a continuous flow of water through a jig. We had very little contractional stresses set up, I would say, because we did alleviate those to a certain amount. I would say subsequent passes after the first pass on each side, we probably did peen a little or at least we did get that action when we cleaned the slag. All the welding at that time was done with alternating current with the diameter of wire of 1/8" and 5/32". We used an extremely low heat--that is, the low of the recommended range."

Experience with face-hardened armor fabrication at A.C.F. was given by Mr. Osha:

"Well, on face-hardened armor plate, for some time I think we welded about 1300 turrets of 1" face hardened. We have worked very little with anything under 1" or over. All of our work has been confined to that; we welded the first few with 25/20 and from there on, with modified 18/8. We don't worry too much about cooling. The edges of the plate were rotated in such a manner that the heat didn't build up very much. We had no outside cooling except the air. We did no preheating and we did no post heating. On lighter plates, my knowledge is practically nothing."

Dr. Aborn explained that recommendations had been made to NDRC that a project on welding face-hardened armor be set up at Rock Island Arsenal to make a systematic study of the problem.

There was some strong feeling among the fabricators that a welded test plate of the H type was not representative of the performance of a welded hull. As a result there was an agitation for a test of a complete hull of each type being manufactured at this time. This idea was developed by Mr. Raymo:

"Before we leave the subject of research and in keeping with Dr. Aborn's remarks also, I would like to recommend that this committee, through its Chairman, seek some means of associating the importance of this developmental work that we are doing with the ultimate production possible. By that, I mean to say that we are confining our efforts to date to developmental work on test plates, and these test plates are so far afield from the actual vehicle that we are trying to build that there is really no comparison. There are men in this room today that I think are still wondering whether or not armor can be welded, and I don't think that we have done anything this morning to tell them that it can. Our ultimate end that we are looking for is integrity of the vehicle that we are trying to build by a welding process, whether it is a heavy tank or a medium tank, a large tank, or whether it is one of these scout cars, or any such other armored vehicle. It was our desire to submit one or two hulls to the Ordnance Department to be fired at, destroyed, beaten right down into the ground or tested in whatever manner you people at the Aberdeen Proving Ground felt desirable. The answer that we

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got was 'No.' It is my understanding that the reason given was that we could not afford to lose or spare a single hull that had a possibility of going on to the production line. Why, within the next 30 days, there are going to be more man hours spent on the preparation of test plates than it takes us to build one of these tanks, and it's not until we fire one of these tanks, destroy it and let everybody see it, that we are going to get the degree of confidence in the process that it merits. There is no comparison between the failure of the test plate and what is going to happen on the vehicle. The mere mechanics of the assembly of the plate rule that out of the picture. Now, we have had two hulls - one at Rock Island and the other by the Carnegie-Illinois Steel Company fired at Aberdeen Proving Ground. What did you do? One, two, or three slugs were thrown at each vehicle and said, 'It looks good.' I must admit that they did stand up well, but it is positively impossible to draw any conclusions about the overall use of welding for the building of tanks from the firing that was done on those two vehicles. I know first hand because both hulls have been returned to our plant. I have examined them in detail. We are plugging the holes back up and putting the vehicles back into service, and the little bit of firing that was done on these vehicles tells us absolutely nothing about what we may expect from ours. I'd like to strongly recommend again that this committee in its interests in research on this, give reconsideration to firing at one of these hulls and bearing it right into the ground and coming up with a real answer as to what can be expected of it."

It was explained by Mr. Jeffries and Lt. Reed that ballistic tests of certain welded front sections of the M3 medium tank built at the Baldwin Locomotive Works had been made at Aberdeen Proving Ground. Lt. Reed asked Mr. Raymo:

"Would it be in order to ask Mr. Raymo who supervised the preparation of those front end sections, if the results of those tests caused him to comment as he did earlier in the day?"

To which Mr. Raymo replied:

"No, sir. I would say not. I think we had an absolutely fair test and I think the point that we wanted to find out was very amply proven by you down there. We find it impractical to give any consideration to the type of design that is being generally considered in the building of these vehicles, that is, the use of 1/4" to 3/8" root gap. Now, when the rest of you start putting these vehicles together, after you build the first one, you are going to forget about that gap and in consequence, our radiographs showed that with the type of joints that we are using, that there was a distinct line of incomplete fusion at the root of the double-bevelled joint; that it was characteristic throughout the structure rather than just a spot here and there. We were all very much concerned about it simply because our whole thoughts and theory prior to that time was that we should do everything possible to get 100% through joints. Realizing the impossibility on an overall average condition, we submitted these

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front plate sections as representative of the conditions that actually existed on the structures as we are building them today. The assembly that I speak of consists of the upper front plate, of the lower front plate, and the left side sponson plate, consisting of two sections of two-inch armor and one piece of 1-1/2" armor. These specimens were fired at, and I believe considered to be quite satisfactory, certainly giving evidence that there need not be much concern about that lack of 100% joint there."

Lt. Reed interposed a question:

"And, Mr. Raymo, did you explain that these plates were not prepared as you would probably prepare them for welding?"

To which Mr. Raymo replied:

"Well, that isn't quite so, Lieutenant. They were prepared just exactly as they would be, as we are building our structures at the present time. The only point that it might be well to explain to the group is that in going from a riveted structure to a welded structure, naturally there is a great deal of armor already in our plant that has been sized for riveting. Therefore, we have no choice about what there is to use. If the plates were sized differently, perhaps shaped a little bit differently in many instances on this vehicle, it would be possible to arrive at a far more desirable type of joint, both relative to volume of metal to be deposited as well as accessibility to the joints. That condition will be peculiar to our plant for some months to come, simply because the armor is there, sized and made up for another process of assembly. But the joints that were on this tank--on these fronts rather--are absolutely representative of what we are building into our welded assemblies today."

Lt. Reed explained the details of the ballistic tests and the cracking which resulted. These data appeared to indicate that a 100% welded joint is not essential necessarily to satisfactory ballistic performance as pointed out by Mr. Raymo:

"On that structure at that point, I think all will readily realize that the three-way, three-angle intersection there is an extremely difficult one to weld. As we examine that particular section by way of comparison with U-68 work or some such standard, one would be horror stricken to see the condition of the joint at that point, with big pieces of slag in there and completely unwelded sections. How could it be otherwise with the type of inner section that there is there? Yet, I believe one of the projectiles hit square on that inner section, did it not? And I think it shows that the joint still stands up fairly well."

Mr. Bibber objected strenuously to the argument:

"As the principal advocate and principal promulgator of the open type of joint, I cannot permit Mr. Raymo's statement that he made go unchallenged. I think that Mr. Raymo has given this meeting

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an idea which I personally believe is not true. I believe that the open type of joint is the best type of joint that can be used for the making of these tanks and I am advocating the open type of joints because it is easy to fabricate and easy to put together. I disagree heartily, 100%, with Mr. Raymo's statement that the tank cannot be built and in support of that statement, I point out that I have built a tank using the open joint. The idea of the open joint is wholly promoted to facilitate and make fabrication easy. It makes the easiest type of 100% penetration joints. If you don't want 100% penetration, you can make it easy. I feel strongly that we have something very definitely good to offer the tank committee and this tank building industry, and I hope that you will not merely condemn or accept this type of joint on what either Mr. Raymo or I say but will look into this matter for yourself and see if there aren't some very good things to be said for the open type of joint."

With reference to the location of cracking in the welded joint due to ballistic impact, Mr. Jeffries suggested an interesting viewpoint:

"There were several points which I would like to call to your attention. I have given it a great deal of thought and it seems to me that these particular points should be called to your attention. One of them is that in the cracks that developed in these weldments, only part of the cracks were in the weld metal and the rest of the cracks were at the interface between the filler metal and the plates. Now, if we are testing plates, then we are interested in the several velocities no doubt. If we are interested in the weld metal, we know what the ballistic characteristics of the weld metal are because, even though it is not a sound weld in the filler metal itself we are likely to get pretty close to 80% efficiency in the ballistic efficiency in the weld, but the thing that interested me most is the crack that occurred at the interface between the filler metal and the plate itself. If the weld is efficiently made, the crack, it seems to me, ought to be in the filler metal and not at the interface. If the weld is not properly made, the crack is more likely to occur at the interface. So, in looking at these welds, in that second assembly the impact at the crotch caused a crack to extend down to the next impact lower than the crotch. The impact above the crotch caused a crack to occur almost the entire distance between the crotch and the top, but the crack above the impact was in the filler metal, whereas it will probably be covered later on when we discuss the question of inspection of welds--that means that the weldment, that the integrity of the weldment, at the interface must be 100%."

Upon question by Mr. Biederman, Mr. Raymo stated that these tank front sections weigh about 2300 lbs., Mr. Biederman remarked:

"How much did that move when you hit it or did it move? Was that held just as rigid as our test plates? Just as rigid as if that was a 34-ton tank? That's a point that's going to prove out how good the weld was under shock. If it moved an

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inch under certain poundage, it is going to be different than if it moved six inches."

Lt. Pless explained the set-up for firing these front sections:

"It is impossible, as Lieutenant Reed says, for us at the Proving Ground to support a structure of this type as rigidly as it is on a tank, because we don't have the facilities. We don't have the jigs to put such a structure on, so the only way we can support it is merely to set it up in front of a butt consisting of heavy plates and block it up in back with heavy timbers, and that is the way these sections were set up and after each round usually the section is turned over by the impact and we have to set it up again by a crane before we can fire again. Naturally, that isn't the best procedure to use, but it is all we can use with these sections."

To which Mr. Biederman commented:

"Well, if we could take these test plates, as far as deciding that would be a good weld plate, take these test plates and hang them on a chain or cable and hit them. I don't think we will have any of them fail. If we put them into an abutment and hold it six inches on each side, with really only 24 or 26 or 28 inches of it exposed, you do not get the full impact on the weld. I think there is quite a difference. That is what you mean, Mr. Raymo, as to the difference between this and the test plates."

Mr. Raymo reiterated and emphasized his argument:

"Yes sir, Mr. Biederman, you have made a very strong point and it is exactly what I had in mind. We had a number of these test plates fired at, together with these front sections, and they have been reported satisfactory. For all I know, maybe we are still kidding ourselves but in the light of the testing that has been done for us to date, I don't think we know yet what to expect from the vehicle, and I don't think we will know until we fire at the vehicle and beat her right into the ground and find out, and I think all of us will after that. The preparation of these test plates has a very definite place in the developmental work that our subcommittees are carrying on, and the other is merely offered as a suggestion of getting overall a quicker and more conclusive result than what we have been able to get together on the basis of simple test plate data to date."

Upon request of Major Cox, Mr. Raymo made a motion that the Subcommittee recommend having a complete tank hull fired at for ballistic performance. The discussion of this motion occupied the remainder of the morning session and a vote was not taken until the afternoon session. Whereas, at first, the sentiment was strong for firing a complete hull, after consideration of the urgency of the production problem and the need for tanks and many of them, the trend seemed to be toward accepting ballistic tests of parts of the hull or typical weldments as prescribed by

Specification AXS-497. The general outline of discussion is indicated below:

Major Cox:

"Mr. Raymo, you are a member of our Subcommittee and therefore you have all the privileges of the Subcommittee. Now, if you want to make your remarks in the form of a motion, that the Subcommittee recommend having a complete tank fired at, if so, we can so go into the records that you have made this recommendation, in the form of a motion."

Mr. Raymo:

"Yes sir, I would like to do that. Whether or not it is one of our hulls or someone else's makes no particular difference to me. I think that there is much to be gained from that type of an examination of what we are accomplishing or what is possible to accomplish in the way of fabricating these vehicles by means of welding. I would like to make that motion."

Mr. Jeffries:

"Since I brought these points out, and even though I discussed it with you and also with Lieutenant Reed, I am a little doubtful whether a test on a complete hull will tell you very much more than you can get on a small section such as we tested a few days ago, and for the very specific reason that I still think we are testing the integrity of a weld rather than the integrity of the design. We must determine whether that weld is made so that it will hold together. If it is hit by a 37, it probably will. If it is hit by a 75, it probably will if the weld is good because of the ductility in the filler metal, so that I think in the interests of production--because I know how reluctant the Chief of Ordnance is to smashing up a completed hull--I still think we can get the same information from an assembly such as was recently tested without the economic cost of a hull and it will tell us more about what we want to know."

Mr. Biederman:

"Mr. Jeffries, you partly answered my question. If you do get a hull there, it would be very essential that you load that hull up with a weight in proportion to the weight of the tank due to the fact that the weight moving and impact have both got to be measured and if the welds aren't good enough, they will still hold."

Major Cox:

"Frankly, Mr. Biederman, I think you have a good point. If we are shooting at this tank with an over-matching A.P. projectile, I don't think it will make any difference whether you support it or not, but if we are shooting at it with some of the slugs, in so doing we are attempting to evaluate the resistance to penetration that the structure will give us, but are attempting in some way to feel out how sound those welds are. We know from firing experience that if you hang a 1/2" plate on a chain and shoot it with caliber .50, it makes little difference whether it is hanging freely or against a back stop that will hold it firmly."

Mr. Smith of Marmon-Herrington raised a point about interpretation of weld performance:

"Well, in this discussion, the stress seems to be about the plate, particularly upon the welds cracking, or cracking in the plate adjacent to the welds or something of that nature, but there seems to be very little importance attached to the fact that even the soft projectile goes through the plate adjacent to the weld as indicated there relatively at some distance from the weld. Am I supposed to understand then, that it is far more important that the weld hold up and the projectile go through the plate? If that is so, then we have been barking up the wrong tree for a long time. Our efforts have been confined chiefly to in some manner welding the plate so that the structure of the plate is not changed and reduce it below its ballistic limits as a normal plate. To date, whether it is shear luck or ignorance on our part, we haven't had a single weld fail from shock. We have had no weld at any time show cracking, even under radiographic inspection."

Mr. Smith went on to explain that his shock test for 3/8" face-hardened plate is:

"Machine gun bursts, caliber .50, service load. Also, it was our understanding that for the face-hardened, 3100 foot a second, .50 caliber, with the M2 projectile was standard and is the standard which we were trying to maintain. Our efforts have been, as I said, confined to perfecting the welding technique, to disturbing the plate characteristics as little as possible to prevent penetration of the slug. We have had no difficulty, as I said, with the welding itself failing or the cracking of the weld or adjacent metals."

Lt. Reed commented:

"The use of a small arms projectile like caliber .30 and caliber .50, rapid machine gun fire burst, 15 to 25 rounds at a shock test is questionable in my mind. Mr. Komarnitsky welds 1/4" face-hardened plate and tests according to the specifications of .30 caliber. Then he puts in caliber .50 and he ends up with an H weld and no plates present. In other words, he shoots the plate away from all around his weld. This (indicating) is what he had and he eats this out and he eats this out and his weld is still there uncracked which in itself indicates that that shock test is not adequate. If we consider the shock test of a weldment, a high velocity impact bend of the plane of the plate--for instance, you have a flat plate here and all of a sudden you make it look like this (indicating bowing). That is what we consider a shock test. That is why we have gone to the 37 millimeter projectile on 1/4" and 3/4" and 75 millimeter flat nosed projectile on 1-1/2". We know an A.P. will go whipping on through there and won't do this."

Mr. Smith gathered from Lt. Reed's remarks that on the 3/8" face-hardened plate a 37 mm. projectile with oblique impact should be used. Lt. Reed explained that such a test should be tried out to see whether it would produce the desired effect and continued:

"These are all developments that have taken place in a year. About a year ago at this time, AXS-497 was molded from a model into a nondescript shape. The Army had not much data to use for drawing up such a specification. There was much argument about fine points and there was a tendency to slide over rather rugged points. Since that time, we have fired at different welded plates, but we didn't really start firing at plates until about September of this year. We didn't get any data between January and September of any importance. We got a few things, but we couldn't back them up with other tests. Since September we have had plates from Carnegie-Illinois, Fisher Body, and Ford, of sufficient number that we can get an idea of what is what and that has led us to the conclusion that we must use a larger projectile either normal or at an angle such as will give it an impact bend."

Mr. Smith made an observation regarding ballistic testing:

"I believe that Mr. Brooker is more familiar, perhaps, with our problem and I stepped into this meeting completely unprepared, I find, to even talk in the same terms as you people have been discussing as to what to do and why you do it. Is the information in regard to face-hardened plate so new that there is no data on it?"

Lt. Reed replied:

"Well, the fact that we didn't do much shooting between a year ago and last September indicates that someone was a little slack on shooting at plates. We shot at plates which we had. We welded up a few ourselves, but I imagine it was assumed that those men who were going to weld armor plates would send in plates and find out what the story was. We went from January to about June shooting practically nothing. In June, the Research Subgroup was formed, or thereabouts, and we started getting in plates but as I said, there was no real impetus to this until hostilities started."

Mr. Smith was endeavoring to obtain some definite idea as to shock requirements for welds in face-hardened armor and asked for that information. Such data are not available at this time according to Lt. Reed, because there hasn't been enough testing of welded face-hardened armor. Aberdeen Proving Ground is accumulating data to standardize ballistic tests as soon as possible. Lt. Reed continued:

"The very fact that we have ceased penetration tests of the weld and the very fact that we admit you can get 85 to 90 to 105% expected penetration resistance indicates that we expect the weld not to be as good as the plates. The fact that it went through the plate and not the weld does not mean that we want the weld to withstand penetration better than the plate. Let's forget penetration except in the case of thin sections of face-hardened plates, and think only of shock. As yet, we have not had the experience to look at an X-ray and say that it is practically on a 20° to 40° plane to that X-ray. However, the little, and unconfirmed-but-once data that we have indicates that cracking during welding up along that plane will allow failure along that plane and will open up in some cases. Now, it looks as though Mr. Jeffries' problem is to see that the weld isn't finished with a crack in it at the plant. It seems that our problem is not at Aberdeen but right over the shoulder of the man who is welding."

Mr. Warner added a comment on the present welding situation:

"I just want to comment briefly on Mr. Jeffries' remark about the integrity of the weld and the last few remarks that Lieutenant Reed made that whether the weld cracked in the weld metal or in the fusion zone is not entirely a question of the integrity of the plate joint, as to whether it is hardenable along side of the weld. That also, to some extent, is a function of how the weld is made, it is true. That all leads me to say that we need to be cautious about condemning the armor plate manufacturers. Remember, gentlemen, that we are trying to switch over from an established practice of riveting in which the composition and the hardness of the plate do not play anywhere near the important part that they do in welding. These manufacturers of material have a procedure and method, a plant costing a good many thousands of dollars already set up to produce this plate to obtain satisfactory ballistic characteristics. Welding has come into the picture. Some day we may have a uniform composition of armor and processing which is very readily weldable and still obtain satisfactory ballistics. I believe that will come eventually but until it does, we will have to bear with it and as Mr. Raymo says, build tanks."

Lt. Reed continued his discussion of the problem of ballistically testing a complete tank hull:

"The thickness of the plates, the angle of obliquity and the difference in the types of weld on a tank make that problem much greater. It is not a linear function. We must also remember that when we shoot at a tank, the eyes that regard the tank are going to be eyes of men interested in different things. One man is interested in the aesthetic appreciation of a good weld. Another man wants to get tanks out no matter how they are made and there will be a middle man who will say, 'We have got to have tanks and they have got to be welded right.' Another man will say, 'No matter what the weld metal is, as long as it is welded, we will take it.' When these men get together, they won't agree because they haven't yet."

In the discussion which ensued questions were asked regarding the basis for evaluation of ballistic performance of a riveted tank but there were no answers. Mr. Jeffries insisted that from the viewpoint of inspection the desire was to determine the integrity of the weld not the integrity of a tank hull design and he remarked:

"I would like to offer an amendment to Mr. Raymo's motion, which is, that this committee, in the absence of any other information, at least tentatively accept an assembly for shock tests to determine the integrity of the weld similar to this one."

Mr. Taylor of Lincoln Electric Company who had raised a question about testing riveted tanks insisted on an answer to his question and Lt. Reed replied:

"We know that rivets are not as good as welds. We know that you don't even have to deform a plate to send rivets flying. We know that the width of vulnerable areas on riveted tank joints is the width of the butt strap. If you can deform your butt strap, you are going to shear off the rivet head. We know the width of vulnerable area on a welded tank is much smaller than that. It's reduced from 7" to about 3". Hence, we know it is going to be all the more difficult to get deformation on a welded tank. It means that we are going to have to hit in smaller areas when we are not too good with the bigger areas. Now, as for the details of the test on the riveted tanks, I don't think they are necessary here. I don't think there is a man here who couldn't hazard an opinion as to what would happen if you happened to hit right there (indicating). The only thing that we can do is hit rightthere. We are going to have to say, 'We may hit there' but the probability is that we wouldn't hit there. In that event, to make this test mean anything, we are going to have to shoot up more than one medium tank."

Upon further questioning Lt. Reed stated that firing tests had been made on an M2 light tank, an M3 light tank, and an M3 medium tank, all of riveted construction. On riveted test plates the following results were obtained:

"The riveted test plates consisted of two, four and six prepared plates. Two of them were prepared by Mr. Bibber, hot riveted, one for shock, and one for resistance to penetration. The shock test broke the plate in two. There were 10 rivets on each side of the butt. 18 rivets flew out of the top one. The one at the end on one side of the butt strap stayed in place and the one on the outside on the opposite end on the other side of the butt strap stayed in place and we had a Z affair. The resistance to penetration is, as we always knew, if you hit close, you might shear the rivets out. If you hit directly, you will knock it out. The other riveted plate was a cold-riveted plate, and we found out on cold-riveted plates, they seemed to fill the holes better and when hit the same as hot rivets, the heads didn't fly out."

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Mr. Taylor continued:

"What I am trying to find out is this. The test plate was hit by a projectile and certain results were obtained. Were those results more disastrous to the test plate than when you shot at the tank?"

To which Lt. Reed replied:

"You see, there is another variable in there. We can mount the plate in a butt. We can put one of these things near the butt, but the conditions under which the tank was tested were that the tank was radio-controlled and we had to see how well you could hit it coming head-on and how well you could hit it going sideways. Unfortunately, we never did hit exactly the same as we had hit the Carnegie-Illinois tank. Fortunately, however, we introduced seal welding of rivets and we did find that seal-welded rivets wouldn't shear unless hit head-on."

Mr. Taylor summarized the question as follows:

"If the riveted tank fired at showed less damage than the test plate, then it seems to me that we could jump from that over to the completely welded tank and say there is no use shooting at a completely welded tank because firing at these plates is more severe than the completed tanks."

Mr. Raymo injected a comment:

"A few remarks and I will call it quits. In taking issue with Mr. Jeffries down here, I think we are past the point of proving the integrity of the weld. I think that our qualification procedure tests have already demonstrated that, and I think we are now to the point of wanting to prove the integrity of the vehicle or prove the satisfactory application of the procedure for making sound welds as was arrived at through our procedure qualification test plates. Now, the objection to firing a hull that Lieutenant Reed made, I recognize. We could get away from some of that. For instance, the front end of the tank could be weighted in a manner equivalent to that accomplished by a transmission being there. By the same means, the gun housing, I think should be there. It can be stayed internally in a manner equivalent to the use of a rotary there. I think we could probably load the hull with sand bags, give you the total amount of resistance that a fully equipped vehicle would have. My prime thought in recommending the firing of a hull is to give more confidence to this group of men here of what is possible. I think that we have men who represent concerns who are desirous of getting into this thing and who stand to give us a lot of help, but in whose minds at this moment, still stands a question of whether or not a satisfactory vehicle can be built. I think that we have reached a point where we can demonstrate that fact. I think the Ordnance Department could give more impetus to this whole program by making a full scale demonstration than by any other single means."

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The question of similarity of performance of a riveted and a welded structure was commented on by Col. Jenks:

"In this test here, the plate was supported in such a way that there was no test of the rigidity of this structure, between this plate and these plates. It was impractical, from what Lieutenant Reed has told me, to get a rigid structure in this test. So, it seems to me, that in the test of this plate, we have an immediate test between your qualification plate and a structure. I don't think you tested the structure when you tested this plate because you didn't get the support of the structure. Now, the behavior of a structure under gun fire will depend upon several factors. The factor that you have been talking about mostly is the weld itself, the integrity of the weld. Now, in making these welds, you set up internal stresses and those internal stresses are of the greatest magnitude just adjacent to the weld. You get some test of those internal stresses when you test your H sections and you get some test of them when you test sections of this sort. Now, in these sections, that is, in the H sections and in this section, you have not tested a third factor in the behavior of a structure and that's the stress concentration factor. Now, that stress concentration factor depends upon the shape of these joints, that is, the shape of your structure, and it depends upon the rigidity of your structure, and there's nothing that has been done so far that shows how that structure is going to behave on account of the stress concentration set-up where you have a change in direction. If you test a complete hull, you should get some information on that stress concentration factor and how it is influenced by the presence of internal stresses, and I can see no way in which you can test that factor unless you test the structure itself--the whole hull, or a small structure in which you have the same type of joints. I see no connection between the relative behavior of riveted plate and a riveted structure in comparison with a welded plate and welded structure. Your rigidity factors are entirely different, and I can see no similarity because in the riveted structure, you undoubtedly have a much lower stress concentration in the neighborhood of your joints. You have a different factor of stress--I mean--you have a lesser internal stress; you have a different stress concentration factor on account of your punched rivet holes. That introduces a stress concentration factor but your joints between plates are not of the same rigidity as they are in a welded structure, and I can see no way in which you can draw any conclusions that a welded structure will behave in a certain way because a riveted structure behaved in a certain way."

The question of weld quality versus design of structure as affecting performance was discussed by Mr. Bibber, who brought out two very significant points for consideration:

"There have been certain thoughts underlying this whole thing that I don't think have been brought out. We have two things at our command. We have the weld and we have the design.

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Now, I believe that the best welds that we can make should be used, and then on top of that, any adva tage that we can get through design by placing plates at angles of obliquity, so that we may gain all that we may possibly get out of this tank, should be taken advantage of. I do not believe that the advantages of design should be used to shield inferior workmanship. Now, if those joints can be made well, as well as they can be made poorly, I think there is no excuse in this world for accepting poor workmanship. I think that any attempt to shoot at tanks to take advantage of design advantages to conceal an inferior weld, is wrong in principle and should not be done. We should make the best weld we can make and I contend we can make them well as well as we can make them poorly. There is no excuse for us making inferior welds, merely because we are able to hide behind some design advantages. Here's another point which I think very pertinent. We are all concerned with the building of tanks but there's another factor in that and that is the repair of tanks. If we build these tanks and they go into battle and they get hit a certain amount and get damaged, they have got to be put back in battle. They have got to be repaired in the field. Merely because a tank has got a certain amount of damage, we can't set it to one side and lose the advantage of that tank. Whether these tanks are split for six inches or six feet is a very important fact as to how quickly they get back into service and the quality of workmanship in those welds is going to have a definite bearing on the amount of repair work. I think the two points that I have raised here have a great deal of bearing on this problem. So far as I am personally concerned, it doesn't make much difference to me one way or another I would like to see a tank shot at and beat into the ground, as Mr. Raymo says, but I don't think that has a bearing on this fundamental problem of making good tanks."

After luncheon the motion was again brought before the meeting by Major Cox who was reminded by Mr. Jeffries of the proposed amendment to the motion that an assembly instead of a complete hull be used. When questioned by Major Cox, Mr. Raymo refused the amendment and remarked:

"No, sir, it doesn't. I think that in the light of our specifications as written, it is permissible to substitute these hull assemblies as was done. I still feel that we should examine the structure as a whole. I want to add one other point, if in my comments, this morning, I gave the impression that I was arguing for the acceptance of an inferior grade of workmanship, I would like to clear that up. Such a thought did not enter my mind."

This refusal to accept the amendment proposed by Mr. Jeffries in view of the argument presented by Lt. Reed and Col. Jenks left the question more or less uncertain as to intent in spite of Mr. Raymo's last statement. Major Frye added a comment:

"I was confused about whether it was a question of welding or design. I think Mr. Bibber's question clarified that point. If it is a question of design, then I believe that the research

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and engineering committee on tanks have considered that and quite possibly have had some tests made. I don't know but it would seem that that committee would more appropriately conduct such research work. However, if it can be used to determine satisfactory welding, then it would look like some experiment might be conducted. However, I don't believe that a complete hull would be considered as a welding proposition. It would seem to me that that would be getting back into research design work."

Mr. Raymo further elaborated on the intent behind his motion:

"I also think that in keeping with the Major's remarks here that we stand to learn something from this same test on design, the effectiveness of this particular structure. We must not lose sight of the fact that we are arbitrarily changing from one method of fastening to another, and we must also recognize the fact that we are compelled to build into this structure joints of a type and at certain locations that are not ordinarily associated with good welding design. I think it is entirely conceivable that as a result of this test, we may find that conditions will point to an immediate design change. I wonder, as we fire at the side of this hull, what is going to happen to the cover on the engine compartment? I am rather under the impression that the thing is going to pop right straight up in the air, and you may look for some better means of fastening than what is there now. I think that it has two possibilities of giving us desired information--one as regards the ability to apply a relatively new process to a structure as we have demonstrated we can do with a test plate, and the second is to find out just what the shape factor of this structure is in relation to such a method of fastening."

Major Frye indicated the thought that:

"Mr. Chairman, I believe the fact has been established by the Ordnance Department that they do want a welded structure, and I rather believe that it is beyond the scope of the committee to recommend that a change in that type of structure be made. Rather, I think it is the function of the committee to weld and weld as fast and as good as possible. I believe the welded structure has been adopted and certainly has been given some thought before adoption, so I believe that's beyond the scope of the committee."

When Major Cox then suggested that Mr. Raymo withdraw his motion and substitute it as a suggestion, Mr. Raymo replied:

"Major, I think we will get the same answer we already have, and I think this committee has a possibility of swinging a lot of weight into this thing and getting more out of it. I think it is quite in order to vote on the motion that I made and also the amendment that Mr. Jeffries made. Then, if you want to submit this recommendation as a suggestion to the Ordnance Department, I would say it is quite in order, but I think that you will find a clear-cut issue on this matter in this group right now. I would like to see what it is."

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Mr. Bibber also was not willing to abandon the idea entirely and suggested:

"There's another point that enters into this thing which I think should be considered. The M-4 design is the design which is going to go in big production. That's the one we are all getting ready to set up big production on, and M-4 tanks have not yet been built. This new design, however, is going to be built shortly. There are probably a number of builders in this country who may build these tanks by hand very shortly, and if it is a question of testing designs, I wonder if it would not be a good idea to take one of these M-4 designs on which we are about to embark on a big program, shoot at it, beat it into the ground, before we embark on this big program."

This thought, suggested by Mr. Bibber, was enthusiastically supported by several of the fabricators, and it was suggested by several that a hull from the first two or three built should be proof tested.

An additional thought was suggested by Mr. Bibber:

"There is still something further which remains to be said. I think a number of people in this room know the situation with regard to the production of armor. We have completed our armor schedule and production for the Chrysler Tank Arsenal of riveted tanks. We would like to roll and stack these plates up by the thousands, so that when the time came for you to get these armor plates that we could flood you with them. It would serve no purpose for us to cut up lots of plates and stack them up and have them wrong and have them be changed. Now, some of you may be saying to yourself, 'Why don't you ship us rectangular rolled plates and we will cut them?' We would like to do that, but you can't do that. One of the greatest things in the production of armor plate is the flattening, and if you do not have the facilities, or you do not have the skill, you cannot produce. It takes skilled men to do this. The thing to do is to furnish you with plates which are all flame cut, flame softened, ready to be put into the tanks. It is essential that these design points be considered so we can get going producing armor."

Mr. Biederman insisted on the sample hull being the 30th or 40th one to be representative of production, whereas Mr. Raymo and several others advocated the use of the first one or the second or third one from the production line.

Mr. Raymo commented:

"Major Cox, I'd like to suggest that tank number one is going to tell you more than anything else what to do on numbers two, three, four and five. I say that in the light of what we are doing. As of this week, we will have completed ten units of the M-3 welded hull. Thus far, we consider it one hundred per cent a developmental program, and I would know a whole lot more about

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what we can do on number ten unit if number one had been fired at the way I propose."

Mr. Trautman made a suggestion:

"I may not see this picture clearly, but we are after armor plate, as Mr. Bibber was saying, and we are going to roll armor plate and we shoot at this tank number one and we find that a point isn't just right and we want to change it. The plate is rolled to size. It seems that it all comes down to the question of picking out some particular joint for specimens, sample sections, and rigging up a fixture or jig or whatever you need to support them and test those specimens with the exact type of welding procedure that you are going to eventually use to weld the tanks, and I think that would prove more than shooting at a tank."

Major Frye agreed with this and added another thought:

"I quite agree with the recommendation. There is no question but what these M-4's are going to be put through the paces when they first come out. The Chief of Ordnance will want to know what they are good for. But I believe that it might prove embarrassing to the Chief of Ordnance if the certain tank was recommended to be taken out and fired. They might have other plans for that tank or there might be information developed which isn't generally quoted. I would like to suggest that the recommendation just made, that of making up typical joints and if necessary, make a jig or fixture to hold it, and firing those be adopted. I think that will give you all the data relative to welding that you can get or can be gotten by firing at a tank. If the committee does decide that they want a tank fired, I would recommend it constitute that as a recommendation rather than as a motion. Otherwise, it may be embarrassing to the Chief of Ordnance or to the committee."

Major Cox further emphasized the scope of Subcommittee activities:

"When we talk about complete tanks, we are getting out of our field. We have no right to any complete tank. This Subcommittee functions from a technical viewpoint. We can make any number of different parts of a tank and shoot them all we want to. Therefore, I think we should withdraw this as a motion and merely make a suggestion that it is the majority opinion of this Subcommittee that a section of a given model be built and be subjected to ballistic testing to determine characteristics of the weld joint. That's the way I'd like to see it handled."

On the above basis Mr. Raymo agreed to restate his motion:

"It is that this committee recommend to the Ordnance Department that consideration be given to including into the research program the testing of a type of tank, the M-3 or the M-4, for the purpose of determining the integrity of such structure as developed by the procedure with which we propose to build it, and as a measure of our success in applying procedures that have

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apparently been developed to a point of production application through our test plates to date."

It was emphasized that this proposed test is a part of the research program on welding of armor and not an acceptance test by Ordnance of any particular fabricator's work.

Major Cox closed the discussion on this question as follows:

"This committee was formed and met today to discuss largely the technical aspects of welding as an art, and that art as applied to armor. I think we can close the motion now without going to a vote and let the minutes show that there has been a discussion of this, that it seems desirable to give it consideration, and that the proper people to consider it are in the Engineering Advisory Committee in the Office of the Chief of Ordnance. I don't think it needs a vote. Does anyone disagree? Let's consider the matter closed, and Mr. Raymo, it is not that we refuse to vote on your motion, it just seems as if it is out of our jurisdiction to take action on that particular phase."

A discussion of AXS-497 followed. Mr. Brooker pointed out the trend of current thought at this time with respect to ballistic testing and defects in welds:

"A few of you have seen the tentative revision of 497 which was an attempt at simplifying the draft of 19 March 1941, and immediately after it was out, we realized there were other things to be improved in it, one of which is the Y plate in the back. That plate is out at the present time. There was considerable argument as to whether it should be out, but the majority seemed to feel the ballistic tests of that plate will not give consistent results; hence, the Y is out. You will also notice that the plane butt or I plate is out, the penetration test plate. The chief reason for taking it out was that there seemed to be no difficulty in meeting it in homogeneous armor. Now, since we will have to have it for welding face-hardened armor, we may find it desirable to put an I plate back in there. Other people have proposed that we ought to have an I plate there for homogeneous armor to avoid getting welds which have a shock but no resistance penetration, but we haven't yet found that sort of thing. The original specification said that these weld defects such as cracks, undercuts, incomplete penetration, and so forth, may occur in the vehicle to an extent not greater than the qualification of procedure plates. That particular clause is not in this draft and I would like to hear from you some discussion, Mr. Chairman, as to what this group thinks of classification in the weld metal of undercut and incomplete penetration. We understand from welding Navy armor that no welds are made up without some cracks in them. Now, what sort of a standard are we going to have for tanks?"

Mr. Bibber expressed the thought that there was no data available as to soundness of production welds in armor because X-Raying of production

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welds had not been done. However, test plates free from cracks could be produced.

Mr. Brooker continued:

"Am I to understand that all cracks show up in all X-rays? I think cracks must be those cracks we can see during inspection, as we know that we can't X-ray every piece. We'll do well if we even make a spot check. So, assuming then that the cracks we find will be visible to the inspector between beads or upon completion of the weld, what sort of standards will the inspector have as regards to cracks, visible cracks?"

The viewpoint at Aberdeen Proving Ground was expressed by Lt. Zweig:

"So far, in testing welded plates at Aberdeen, we found that all cracks are detrimental, and we have concluded that we would like to see all cracks eliminated. If we find them, repair the weld because cracks are places where great stress concentration exists, and you can get failures very easily and fatigue failures occur there, too."

In the ensuing discussion of crack formation and location, Mr. Raymo explained that two types of cracks are encountered, one at the bond and the other through the weld metal associated with craters, and he observed:

"I think that all cracks that you will have to be concerned about will show on your X-ray and the minute and microscopic intergranular cracking that may occur on some of these armor plates, how much of that will get by us, I don't think anyone knows at the present time, and I don't know what measure there would be of attempting to find that kind of cracking."

Mr. Bibber suggested that:

"I believe that the proper time to take care of cracks is when you are making the weld. I believe that that is part of the welder's job, to be watching for cracks, and I believe that every welder should have alongside of him a chipping hammer and, as the cracks open, they are cut out and corrected then and there, which is relatively simple and a part of his job."

The thought that soundness of the welded test plates would be representative of production welds was criticized by Mr. Raymo:

"You can make up welded test plates by the hundreds and, as Mr. Bibber said, get them X-ray perfect; but that average condition will not obtain on your structure, and I don't think there is any connection between associating soundness of test plates with acceptability of cracking in a structure because there is no way for the manufacturer to comply with that clause in 497 which says the manufacturer shall guarantee there will be no cracking or likely cracking to take place in that vehicle. I think we are going to have to look for some other measure of acceptability of defects in the structure other than what is in evidence on our test plates. Getting back to the whole point of my argument this morning, a test plate is an ideal structure. It represents nothing. You have associated with it 100% accessibility; complete control of selection of the size of electrodes; nice spacing of the joints. You can take every means of keeping the plate straight but those conditions are not true on your structure. On the front part of the hull of the M-3, the cross-member, as shown there with the joint that is in there now, in order to get at that, the operator has to practically get into quarters that would be equivalent to being under the table and only being partially able to see what he is doing; and the average integrity of a joint made under such conditions will not compare favorably with which you get on test plates that are made up here right in the open."

There was objection from several of the electrode manufacturers to requiring the chipping of craters as advocated by Mr. Bibber. Mr. Brady claimed it was unnecessary and cited certain tests as proof while Mr. Brugge advocated back-stepping on first passes.

Major Cox interrupted with a plea for suggestions as to what should be put into the specification:

"Gentlemen, it is a tremendous job to write a specification. We try to write specifications to insure getting a satisfactory product with the least possible pain, both from the user's and the builder's viewpoint. We have to list certain defects. We call you people together because we know you have had years of experience in welding. This is a question of armor, but it still is welding, and we must list certain of the defects to look for. What are we going to do? Are the ones we have listed so far (a), (b), (c), (d) and (e) adequate? Do they cover it all or do they cover too many? It seems that all we can possibly hope to do this afternoon on this specification is to get the thoughts of you people as to the things we are to list that we must be on the lookout for. I don't think we can hope to cover all the aspects of each one of those defects. We have to forget some of the details for this meeting and use the background of your many years of experience in welding to try to arrive at something which will be satisfactory to permit this production of tanks to go ahead. I would like some thought from the most experienced of you as to what we should put in this specification as a guide of getting reasonably good welds."

After a suggestion regarding welding technique made by Mr. Emery, Major Cox retorted:

"Mr. Emery, we don't intend to include in a specification of this sort the welder's technique. In view of that, how are we, as the consumer, to assure ourselves that we are getting crack-free welds. You say by a thin buttering operation you won't get any cracks, or at least you will heal them on the next pass, but how is the Army to assure itself in a specification -

its only means of assurance - against defects in materials?"

Mr. Emery suggested inspection of the underside of the first pass after the second has been applied. Mr. Thomas offered a suggestion:

"Mr. Chairman, may I suggest another method? Go back to the way the specification was worded prior to this revision. When the qualification plate was made up and there were some cracks in the first bead and yet on X-ray it was satisfactory and on ballistics it was satisfactory, then you can accept the same sort of thing when you make your joints in your tanks. I think you have all the protection that you need by the way the specification was worded in the former issue."

With reference to undercutting and its control, Mr. Raymo elaborated:

"There is no point in having any concern about undercuts. In the first place, it stands to be remedied as additional passes are applied and if you have got it, what are you going to do about it? You are not going to chip it out very fast because the undercutting is in the armor plate and not in the weld metal and it is really not a matter that you have to be concerned with on the austenitic type of electrode. There is not the tendency to undercut to the degree that there is with a medium steel electrode when welding on ordinary plates.

"I think that the best we can do is to put in there that it is not a condition that is to be left unrecognized but, as you are progressively building up a butt weld, that undercutting can be taken care of on succeeding layers, and, if we are talking about undercutting of the surface of the plates resulting from a deposition of the final pass, that's another matter. I think the way out of that is correcting it the same as we do on welding a medium steel - simply chasing a small bead in along at the toe of the reinforcement to fill up that undercut section. But we are attempting to set into our specifications something that varies 100% upon interpretation, depending upon who is looking at it. The Ordnance Department is giving consideration to training inspectors for the purpose of inspecting tank weldments, and they propose to put these prospective welders through a course in two weeks and turn out an inspector. Their source of man power is just as limited as any of the other trades that we are seeking help on these days. The chances are that we are going to have men who have never in their lives been associated with fabricating activity, and for them to begin to pass upon degrees of undercut and such as that after two weeks, or even recognizing it beyond the point that it is an undesirable condition and that the fabricator is responsible for minimizing it, which should be a part of his procedure qualifications."

Mr. Swan suggested an interpretation of the specification regarding undercuts:

"The specification definitely states the undercut alongside the weld reinforcement, which must be the last pass, and it strikes me that we will be entirely suited and so will the Ordnance Department if the undercut is not worse than the qualifying plate, which gives us some degree of undercutting, some amount which is acceptable."

With reference to weld inspection, Mr. Bibber emphasized a point:

"I think there is one principle about any inspection that should be taken cognizance of here and that is, that if you are going to inspect something, it has to be inspectable. For instance, we say here, incomplete fusion of the joint. You say, gas cavities and slag and those things are not inspectable as such. You have got to have inspection means. If cracks are in these metals, you have to have means of inspecting them. About the only one is Item Number (b) which is visible and can be inspected. Now, I am not advocating the X-ray inspection. I think it is going to be an awful job, but if those other things that you see here can only be tested by the X-ray, then you get into a discussion of X-ray."

To which Mr. Jeffries added a comment about the method of inspection:

"There is absence of a definite program as to how we are going to inspect the welds. In the Philadelphia District, we propose, as far as practicable, to exercise the utmost supervision over the actual laying of the weld. Our inspectors, as many as we can get, will actually watch the welding through a shield. They are going to have to be trained to pass or disapprove of welds depending on just exactly what those welds are. Now I think that men can be trained for that purpose without the necessity of schooling them in the fundamentals of welding just as we train a machine operator today to do a certain job in a certain way. There are comparatively few specific things that this welding inspector should see or rather disapprove of, and I don't doubt but what we can have an efficient corps of inspectors who will be on the job and inspect over the shoulder of the welder. It is the only way unless some other means is brought out by this discussion. Pending some better way of doing it, that's the way we propose to do. My thought isn't that we should go into such great detail as to have an inspector watching each individual welder. That would be economically impossible. In the first place, we do not have the men and it's doubtful that we could get qualified welding inspectors. The welding inspector should have some idea of the fundamentals of welding, but I think we can teach those welding inspectors in comparatively short time that they can intelligently look at the welder laying a bead and have some idea at least as to whether this welder is putting that bead down right. Now then, if the welding inspector feels that the welder is not doing his job right, he still has recourse to a supervising inspector who can be brought into the picture and the condition corrected. We haven't time to train inspectors. We haven't time to train men in the fundamentals of welding. That's the fabricator's job - to train welders. We must train men to look at a weld and to form some idea, without embarrassing the program in the least, as to whether that weld is or is not a good weldment. In addition to the supervising inspectors then, he has the chief welding inspector on the job. I think that the inspection service will furnish ample control without jeopardizing production, to visually examine these welds as they are made and, after all, gentlemen, I think that's the only way to insure adequate welding."

Other points were mentioned such as inspection of first passes and intermediate passes for contour, cracks and undercut and Mr. Brooker finally remarked:

"It looks like we could go on endlessly determining what the inspector should have as a guide. I am sure there are enough experts present who, in a relatively small group, can revamp this specification. So let us revamp part of the specification for the time being, and put it this way - that the specification will be revamped and will be submitted to the committee for comment. Those comments will be received and boiled down, and another revision of the specifications put out. I think that goes for all the rest of the discussion of 497."

Mr. Raymo made a suggestion about qualification of welding operators:

"Mr. Brooker, I would like to propose one amendment to 497 that has to do with the operator's qualifications. Under the present setup, you will qualify the operator by having him make up a butt weld in a given thickness of plate - twelve inches long - and that butt joint shall be examined and passed upon by means of the X-ray. The test is too easy. It is no real measure of operator qualifications. That's one point. The second is that there is too much armor plate involved in it, I want to qualify 300 welders. That is 18,000 pounds of armor just for the purpose of qualifying welders. That will build one tank. Having arrived at our qualification procedure, we are next concerned with the operator's ability to produce as sound a joint as possible and that hinges about his knowledge and practice and in the use of the electrode that will be used. Such cracking as will occur in the fusion zone is a matter that is beyond his control and, theoretically, should be solved in our procedure qualifications. I, therefore, feel that we can satisfactorily qualify welders on the welding of armor plate by having them prepare test specimens on medium steel with a given type of joint and with the electrode proposed for use on the structure. I don't think that the welding of armor plate is critical enough to make it necessary for the operator to use armor plate for his test plate."

Major Knode raised a pertinent question:

"If we are going to have spot checks and have men follow our welders up in their welding operations, is it necessary, therefore, to have these welders qualify at all?"

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To which Mr. Raymo replied:

"I feel that it is, Major. We are going to have to be dependent upon the men who are trained from scratch for doing this job and for our own satisfaction, we should have some knowledge of their ability to produce an acceptable joint. That fact has been recognized for all of these years in connection with all of our other existing codes, and it has rapidly boiled down to X-ray examination being an acceptable measure of performance and I thought it was a tremendous stride forward when the Ordnance Department recognized the effectiveness of such examination and said, 'We'll accept a welder's ability on the basis of X-ray soundness.' I say again, I think that's a tremendous step forward in the welding industry. There are a lot of people who are not willing to go that far as yet, but I think that such an examination of welders can be accomplished equally effectively on medium steel plates, but I would recommend having the welder make it with the electrode which is the medium through which he is applying his skill and which he should be familiar with in all respects."

In a discussion of conservation of AP projectiles which appears necessary due to war demands Lt. Reed explained that the use of proof slugs not only helped in that connection but also gave a better shock test because deformation without excessive cracking could be produced and this effect is more to be desired than punching through. Lt. Reed also suggested that the WAS-1 data form should be revised to permit more welding data to be included. A desire was expressed that each test plate be provided with a lifting hole at top center to facilitate handling in and out of the butts. As to size of the hole Lt. Reed suggested:

"I wouldn't take less than 2" on 3/4" plate. On 1/4" plate, the men usually handle it with their hands, so that trouble wouldn't be there, but we have run into a lot of trouble on this 1-1/2" and 2" plate but the 1-1/2" and 3/4" should have a 2" hole in the top."

There were no comments from the casting people or the Unionmelt representatives as to new developments and Major Cox remarked:

"One function of a Subcommittee is to assemble information to exhibit to you. I want to point out again that our transactions are of a highly restricted nature. Any information you give us, you can feel sure that it is going to be held in confidence, and I would like an expression from the group whether they are getting any good out of this distribution of information that's been coming in the form of these Subcommittee reports."

There were a few expressions of approval and then Mr. Abbott brought up the question of a manual for welding face-hardened armor which is to be prepared by the Electrode Group. Mr. Van Dreser stated that he would get in touch with the face-hardened armor fabricators for the necessary information.

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Major Cox announced arrangements for visiting the Detroit Tank Arsenal on Thursday, 8 January 1942. About 47 people have indicated a desire to make the visitation.

Following this announcement Mr. Taylor of Lincoln Electric Company made an extended speech of severe criticism of the Subcommittee:

"Probably what I am going to say is out of order in that I am a guest of the Ordnance Department. I have attended quite a few of these meetings, hoping to find out something of the problems in connection with welding and find out just where we could be of more use to this tank building program, and I will confess that I haven't learned anything from any of these meetings that would help us to make a better electrode or better welding machine to better do this job. I don't know whether the fabricators feel that way - whether they feel that they have gotten any information from these meetings that helped them to do a better job of building tanks, and particularly, the welding of armor plate. Possibly, that isn't the purpose of the meetings. If that is true, I am entirely out of order.

"This morning, Mr. Smith, of Marmon-Herrington, asked about welding face-hardened plate. I felt we threw him a bone instead of some real meat in the answers that we gave him. Now, it would seem to me if we are going to get anything out of this, that will be of practical benefit, that we ought to take our hair down and tell what we know. I think the Ordnance Department ought to give up the results about those tests made on homogeneous 1-1/2" plates, Carnegie-Illinois, Disston plates, or Ford, if Ford is on the general market--give us the results of welded plates, welded with various 18/8 or 25/20, and tell us if the material will be available and if that is still in the running.

"We ought to know something about the gap, the fitup, the problems of manufacture, the limits to the joint fitup, what the results are with welding against copper compared with the strip that Bibber has been talking about, and whether or not that is practical in production to use. We ought to know the various comparative speeds of welding against a strip. We ought to know about welding without any strip. We ought to know about buttering the edges. We haven't heard anything about that. Maybe we will all be back to buttering edges before we get through. I wouldn't be surprised if we did.

"We talk about shooting, firing - talk about firing at tanks - which is very interesting but it seems to me it doesn't have any direct bearing on the jobs that we have here. That's up to Ordnance. If they want to drop them out a 1,000-foot cliff or shoot at them or whatnot, I don't see that it concerns us any. It doesn't help me to make a better electrode to know that they are going to shoot at the joint with a 75, or 37, or a slug, or an armor-piercing bullet. It doesn't give us any definite thing that we can grab hold of and take back to go to work on. That is my frank opinion. It seems to me that we ought to cover things for each one of us to take back and go to work on. I have been frank to confess that as far as I am concerned, I just haven't got a thing out of the meeting today, or the last several, that I can take back that will do me any good. I don't think we are talking about the right things for this organization. We have got a group of busy men, as Mr. Biederman says; we are all working 7 days a week. When we come here and spend a whole day, we want to take something back that we can use. This is not criticism of the Chairman, or Ordnance, or the rest of the personnel. But I am trying to criticize the subject matter that we discuss and point out and make some of you agree with me that the subject matter hasn't anything to do with the problem of the members of this group."

This speech of Mr. Taylor's stirred the meeting because of its frankness and inspired a reply by Major Cox:

"Thank you very much for those remarks. They are just the kind of things we like to hear. This Subcommittee is less than 2 years old. It started out as a small group. We were able to do those things when we started out. We had a small group. We could sit down and talk over the problems and arrive at something. The group is large now. All we can hope to do is to provide a common ground for argument and then those who are concerned with the preparation of material after this meeting is over, at least, have a concept of what is wrong with the situation. Let's put it that way. They simply can't go home feeling too good about it. Mr. Brooker will have a lot of work piled up on him as a result of this meeting, and so will we at Watertown.

"It is not so much being able to gather in this meeting a hundred or more of us and find the answers to the questions. That was quite evident in Mr. Raymo's motion which actually created a lot of discussion, nothing definite, and the motion was never voted on. There are too many of us to sit down here and arrive at all the technical answers, but we do get the concept of what you gentlemen want and what your problems are. We are getting it because we have had the problem before us longer than you have. Watertown Arsenal has been working on welding of armor for fifteen years.

"Mr. Taylor, as Chairman, I speak for the whole Subcommittee when I say I appreciate your remarks and I am glad to have the criticism. It is very valuable. In order to produce greater efficiency, we have previously formed two subgroups - one on electrodes and the other on fabrication. That was originally about the size of the whole Subcommittee, and it's only by appointing smaller subgroups that we can hope to arrive at the answers. We can't do it here. There are too many differences of opinion. On this specification, for example, there was a day when perhaps the entire Subcommittee could sit down and write this specification. We can't do that now. You saw that when we were discussing it. Therefore, the best we can do in this problem is for you gentlemen to give us your ideas and give us your criticism, if there is any, and then those of us who are concerned with the actual task of doing the job like writing the specifications, can go back and do the job, then submit it to you for your comments."

In line with the last remarks of Major Cox, Col. Jenks made a suggestion:

"Most of the problems which have come up today have been problems in which the Ordnance Department desires information in connection with specifications or other matters. Now, we have an excellent body here. They are pretty well representative of the industry so far as the fabrication of armor is concerned, and I am wondering whether we are putting ourselves in the position of the fabricator sufficiently and answering the problems which he wants answered. He would like to know what procedure to use and I feel we have sufficient talent to write down a procedure and other recommended practices, and I am wondering whether this committee shouldn't be put to work, and when I say 'put to work', I don't mean the staff of the Ordnance Department to be put to work, but I mean the committee to be put to work to check over our existing knowledge and write up some standard practices according to the best available information. That is, to pick out men who are on this job and let them subdivide the work in such a way that they can write up the standard practice of what they consider best to meet this problem. The suggestion I would make is that you put more of our fabricator members, put more of our industrial members, to work to get this information and not attempt to handle it all at the Arsenal or at the Proving Grounds. I think that's what Mr. Taylor would like to have - the best authoritative information on existing engineering knowledge."

At the suggestion of Mr. Wise of Federal Welder Company, Col. Jenks outlined the method followed in standardizing welding practices in the aircraft industry as an example of what might be done for the Subcommittee. Col. Jenks concluded:

"I think that a similar method procedure could be worked out so far as tanks are concerned--that is, preparing the questionnaire, collecting the data, analyzing it, and drawing out of it recommended practices which you and the government would be willing to accept."

Mr. Brady of Alloy Rods made an impassioned plea for collaboration:

"The weld is no better than the electrode with which it is welded. I wonder if this group realizes that in this entire country of 130,000,000 people, there are seven men, whose average age is less than 35 years old, who are responsible for the coatings, the research on the coatings for these electrodes? Frankly, I came to Detroit with one idea in mind--to take my hair down. I haven't moved a single blade. I talked last evening with a number of the research men on coatings who were here. They all agreed with me that when the word is given, they will be very,

very happy to take their hair down and co-operate to the fullest. These men that I talked to last night, they all agreed they would be very happy to do it and especially is that true of the ferritic type of rods, of which we know very little. One company, the A. O. Smith Company, has had some success. I talked to the research man from A. O. Smith last night and he told me that he would be very, very happy indeed to collaborate with any company on what he had found out so far on ferritic steels. But I think that this movement will not take place by any individual - by my suggesting it, or by Mr. Taylor suggesting it, or by anybody else suggesting it. It will take place only when the Chairman of this committee says, 'Boys, let's get together. This is an emergency and after all, we are at war and I think that what we do in normal times should be forgotten and this secrecy that surrounds the coating business should be forgotten here for a moment. We should get together.'"

Mr. Taylor added a few remarks to Mr. Brady's theme:

"Mr. Brady has expressed a great deal better than I, the thing I had in mind. As he says, we are at war. There is no such thing as competition between ourselves any more. We can't get away from competition. We have to fight. We are all born and bred to that purpose, but we can transfer our competitive spirit to the Japs and Hitler, and take our hair down and exchange information in this group that will be of real help. As Mr. Brady said, we could really make things buzz here if we would do that. I think Lieutenant Reed ought to bring all of his records here. He has complete procedures. He knows just what happens to the test plate and he has test plates there showing that Lincoln Armorweld is good under certain conditions and certainly I would have no objections for him to tell the whole meeting that Lincoln Armorweld failed under these conditions and was all right under these conditions, was good with this type of fit-up and was not good with that type of fit-up. We could carry right through electrodes and every conceivable joint and fit-up, and when we got all through, particularly the newer companies that are getting into this, would say, 'Well, I can get into production immediately. I don't need to figure around with 20 or 30 different H plates and have them welded and sent to Aberdeen for test. I know that if I do it this way, I will at least be started. Then I can go ahead on my own research and development and try to improve the processes.'"

Mr. Raymo presented the fabricators' viewpoint of this matter:

"Major Cox, I agree with what the gentlemen have said here. As regards the fabricators, the picture is not quite as bad as it has been painted perhaps. Mr. Taylor is in a particularly enviable position of having no apologies to make for either machines or electrodes. I think it is a splendid tribute to his company and to the electrode manufacturers and machine manufacturing companies that they have got equipment that is doing the job right now. On the other hand, this problem of interchange of information is taking its logical course, and when A wants to know what B is doing, through the medium of getting acquainted at these meetings, we are talking to each other over long-distance telephone and going back and forth to each other's plants, and we are getting a lot out of it. It has been our pleasure to have within the last six months, I'd say, pretty nearly every man in this room at our plant. I have been in a good many others myself and I merely want to say, to promote this whole picture that Colonel Jenks brought before us here, that our company stands ready to have any of you visit the plant at any time to see what little we are doing on the welding of tanks."

Mr. Brooker expressed the desire to get the seven men referred to by Mr. Brady together to outline definite recommendations on electrodes.

Mr. Humberstone of Arcrods commented on the viewpoint of his organization on this matter:

"Mr. Chairman, since this thing has come out in the open, I would like to state our position on this. I think all the other electrode manufacturers know, and I don't know how many of the rest of you, that we haven't been represented up to the present time because we have not manufactured austenitic electrodes. We didn't attempt to become involved until there was an interest shown in ferritic rods. It means starting from the beginning, practically, and some have already started on it - those people who were represented at previous meetings. Along the lines of what Mr. Brady said when we started our investigation, as soon as we found out that we could be of assistance, it meant starting out with practically everything we could think of, or lay our hands on, in the way of various types of low alloy steels. Surely, if the whole group of electrode men got together with what has been done, there could be allocation of the work so that in a comparatively short time, we would come to some definite conclusion as to whether there is any possibility of using ferritic electrodes. One thing that I have been particularly interested in, in connection with this, is the question of preheating. Every time it has come up, why we just run around the bush awhile, and we don't get any place. If there is a definite feeling that there is to be no preheating, that certainly has a very definite bearing on the development of ferritic electrodes; so, if there is any interest in ferritic electrodes, I think that we should get together in the way it's suggested and thrash it out in a relatively short time so that each company doesn't start in and take every possibility that their various developmental men can think of and, believe me, each one of them can think of plenty."

Mr. Deppeler contributed a few remarks on the general subject of collaboration between Ordnance and Industry:

"The electrode manufacturers have always been willing

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to co-operate to this extent, but the difficulty is, as I have always said--I have gotten up on my feet every meeting--the difficulty is that we haven't got that same co-operation from the armor plate manufacturers. I mean, there are certain types of armor plates that will need preheating. There are other types that can be welded at room temperatures. If we could get from Lieutenant Reed those armor plates and those joint preparations and those electrode deposit analyses that had been succesful, that had passed, I think that that would be enough information for us. It would show not only what joint preparation was desirable, but also what electrode analysis was desirable. I think that is really necessary and I think that you have got to come to some conclusion on this matter of preheating which I have always harped on until I have gotten in wrong with everybody in the committee because, if we are going to preheat, then we can use the ferritic type of electrode. If we are not going to preheat, then the ferritic type is out entirely. Now, isn't is possible to preheat this armor plate to 200°, or to 300°, or some such temperature? If it is, then the electrode committee can talk ferritic electrode as well as talk the austenitic type. We have both and, therefore, we are willing to go along on either program but what we want is the ballistic data from Lieutenant Reed."

Following a ten-minute recess at 4:50 P.M., Major Cox reopened the meeting:

"Gentlemen, I think we have found the strategy. I am glad to see so much taking down of hair. It is good for us. It is good for our big job. I don't think we need to tarry here much longer today. I believe we can come right to the point quickly enough. The need is very obvious to assemble the information that we have. I repeat that we have in this group lots of good talent. Many of the representatives have been welding for years. Even if they never welded a piece of armor in their lives before, they know something about how to start welding and that, I think, is more than half of the battle. I think it would behoove you to get together in impromptu meetings of this committee. Just make it as unofficial as possible. Mr. Brooker has a suggestion regarding electrode manufacturers. I think that is our starting point."

During the intermission some of the electrode manufacturers had decided upon a meeting as outlined by Mr. Brooker:

"During the intermission, Mr. Chairman, a few of the electrode manufacturers got together - not only a few, but practically all of them, one or two having left - and decided that, assuming that we could get clearance from Washington for complete revelation of all information on armor and ballistic tests, we would have a meeting in Pittsburgh, at the William Penn Hotel on Friday, the 16th, at 9 A.M., to give the electrode manufacturers the benefit of all knowledge obtained and permit them to put their heads together and to come out with recommendations on electrodes based upon everything we know now, thereby eliminating the necessity for lengthy research that is bound to come unless they have full previous information."

The allegation by Mr. Deppeler that the armor manufacturers are not co-operative in divulging information aroused comment from the armor plate industry. Mr. Bibber led off by blaming Ordnance:

"During the latter part of the last act, the implication was to the effect that the armor manufacturers were various kinds of long-haired, long-eared individuals, and so forth. For the sake of the record, I want to point out that about a year and a half ago, the officials of our company offered to lay before the armor making people of this country all of our practices and analyses and everything. That was done more than a year and a half ago. I am quite sure that the officials of our company would be willing to do that today, should that come to pass. Furthermore, we now operate under a restricted specification. We are not allowed by the rules of Army Ordnance to divulge this information. I believe that something along the lines of what Mr. Brooker first spoke about, getting some kind of a release from the Army Ordnance, must be done before we can officially release this information."

Lt. Reed indicated that the armor industry was to a certain extent responsible for the present state of affairs:

"Mr. Bibber's statement regarding the fact that there was an impression given that the armor manufacturers were long-haired individuals is correct. He is also correct in stating that the Carnegie-Illinois Steel Corporation said that they would lay their facts before us as they did. It was requested of each individual armor manufacturer to give the chemical analysis in case it was face hardened. It was requested that the type of carburizing and subsequent heat-treatment be given with the firing records. That was over a year ago. To date, our records are still incomplete, due to the reluctance on the part of some armor manufacturers to divulge this information; and, a year and a half ago, when they said they would be willing to give freely, the other gentlemen said, 'Why should we divulge what we have spent years and millions to gain?' Those are facts. To date, we don't have all the knowledge. To date, we have to drag it out by a claw-hammer, to get it out of them.

"However, it is in order at this time to approach the Ordnance Office, it seems, and have all these data made available. Now, you have it put on a confidential status at the request of the armor manufacturers. It used to be on a secret basis because of the armor manufacturers. Now, the Ordnance Department doesn't care much what status you people want it on. We would be glad to print it with no restrictions on it. For the enemies to learn how to make armor plate, I don't know whether it would help them; I don't think they have the stuff to do it with. I think it would be wise for someone who could control the policy of the armor manufacturers to approach Washington and request that information to be as free as the wind or it be restricted - anything to get it out of this confidential status, and anything to get us the data would be highly acceptable."

Mr. Brooker offered to take the matter up with the proper authorities and requested suggestions as to how the armor industry felt about it:

"I am going to Washington to try to get a release on the information on armor plate and welding and ballistic tests for the electrode manufacturers. It would help some if I could convey some opinion. Mr. Bibber has already said that his company, I believe, will be glad to convey any information."

Mr. Whitmer of Republic Steel Corporation:

"You should go by the statement Morris made in that meeting about three or four weeks ago here in Detroit that if the Army Ordnance opens it up, O.K."

Mr. Komarnitsky of Breeze Corporation:

"I will just express the same thing as Mr. Whitmer; if it is desirable with the Army, we will open up."

Mr. Gezelius of General Steel Castings Corporation:

"I attend these meetings as a representative of the casting group as a whole, as well as representing my company, and I think that it has been very well established that the cast armor group as a whole has no objection whatever to the Ordnance Department releasing all information they want to."

Mr. Shiffli of American Steel Foundries:

"I concur with Mr. Gezelius's expression."

Mr. Abbott of Diebold Safe and Lock Company:

"I must confess that until 3 months ago, our company did keep most of its information in its vest pocket. But that policy has been changed and we put a broad interpretation on the word 'restricted.' We have given out quite a bit of information but it has been restricted to those companies who have been making the same type of armor plate that we have; if we can give any information to anyone that is connected with the defense program, providing it is O.K.'d by the Ordnance Department, why we will open up everything that we have got, including quite a number of tests that we have made and the results of which the Ordnance Department has not."

Mr. Vennerholm of Ford Motor Company:

"Ford Motor Company has no secrets and I would like to bring this to Mr. Brooker's attention."

[redacted]

Mr. Miller of American Car and Foundry Company:

"I am not in a position to say definitely how much information has been given to the Ordnance with regards to our work. I don't know about that definitely, but as far as the company coinciding with the general opinion of the meeting here, I believe you will find the American Car and Foundry Company will join. That is only my opinion. However, I would prefer to have that verified by the management of the company."

These remarks indicated a willingness of the armor makers to make their data available. The electrode people are planning to pool their data on electrodes. It was evident that there was a need for pooling information on welding methods used by various fabricators and the results obtained. Major Cox asked for suggestions:

"Now, gentlemen, what would you think of a group of several people putting their heads together and working out a standardized scheme of practices for welding? We assume that the electrode situation is now going to be taken care of very well and is quite in hand. We are going to exchange information freely and tell each other what each has found best for a particular job, even as far as to tell what the dozen things are you put in the coatings you want. I don't want to ask anybody to get this thing up because everybody is terribly busy, but, I think that with this group around here, we can get some suggestions. Who, among the fabricators who actually put these plates together and welded them, would head up a little group, where they can sit down, just the way the electrode people are going to do, and write out the form for welding procedure, technique, just anything that's involved in laying out a given structure in welding the things."

Mr. Deppeler voiced the thought that:

"That matter is different with different electrodes. You take, for instance, we prefer a straight gap preparation, or almost a straight gap preparation, because in the weld metal as it is deposited, the arc decreases the center and raises the side and makes a nice meniscus on the side walls. We rather prefer the single bevel or, at least a 10° total angle. Those things, it seems to me, are still in the air, although we can recommend a practice with a certain electrode. We can recommend that, but we can't say very well that that will apply to all of them."

Major Cox continued:

"Mr. Deppeler, I can fully appreciate that. I know that the technique of laying out a welding structure is not as standardized as measuring the diameter of a rod with a micrometer. Nevertheless, it does seem that with all of our backlog of experience and with what information we have gathered as lately as applied to modifications affecting armor, that we now have at least a basis on which we can arrive at some kind of standardized procedure. I would like to see a group get together, even though they find out it can't be done. Let's get a group together and see if there is any way of doing it. Mr. Deppeler, I think you can do it. You can have 8 or 10 different recognized procedures and let the manufacturers take whichever one he chooses."

Mr. Biederman argued for a prepared printed pamphlet of these data and Major Cox continued:

"I should like to modify what you have said to this extent: I know of no product where the user is more skeptical of the information that goes with the product than he is of welding rods. In other words, there isn't a man that will buy a particular brand of rod without trying it out first. He wouldn't take the manufacturer's word for it, would he?"

Upon Mr. Biederman's agreement with this idea, Major Cox continued:

"All right. Let's get the fabricators together and put down their experiences with the given rod and the given layout that they think best, and then, when we get the information from both of these groups, we will dovetail them right together and see where they stand and we will certainly be able to separate the sheep from the goats. We will know exactly where there is harmony and where there is discord."

Mr. Bibber pointed out that the Electrode Group proposed to do this:

"It is my understanding that the Electrode Group has already set up and has the mechanism in operation to do this thing. Frankly, most of these fabricators here haven't had anywhere near the amount of experience that the electrode manufacturers have had and, if the electrode manufacturers do this job as it should be done, wholly without their own commercial bias, would not that product of the mechanism which has now been set up be the proper one to get what you want so far as the recommendation of how to make a weld is concerned?"

Lt. Reed made a suggestion:

"Would it be in order at this time to suggest that the various and sundry men here who have made up their own particular designs, form a joint design and present that in writing on the letterhead of their company to Mr. Brooker; that he review them in the presence of our data on shock tests; and that the total amount of information be taken to the electrode manufacturers' meeting. I believe the electrode manufacturers have had almost as much experience with the different types of joint preparation as the fabricators."

Mr. Brooker offered an objection:

"I question whether submission of joint designs for homogeneous armor to me, or to a group, would mean a great deal because the builders of tanks and other vehicles of homogeneous armor have their ideas pretty well formulated and based upon good information."

The electrode people seemed to feel that a survey of joint designs and procedures would be desirable at this time. It was apparent that the data available in the hands of various individuals needed an overall appraisal to be of value. This was suggested by Major Cox:

"I repeat the thought I had before; that whether we found out anything or not, let's air the subject. Maybe we won't find anything out. Maybe we will; I think we will."

Mr. Bibber suggested that the two groups already organized might accomplish the result desired by the fabricators and proposed by Major Cox:

"There is another angle to this thing which I think has been overlooked in the main meeting here. We have a research committee, a Research Subgroup. In other words, it was appreciated some time ago that the big group here was too big to handle these problems; that the conversation got all off the tracks and that we needed these smaller groups; and, as a result of that decision, the Electrode Subgroup was set up and it is now functioning and they had a very fine meeting yesterday. However, I felt that Mr. Taylor's indictment of the committee was a little bit harsh this afternoon for this reason. The thing that he wanted to talk about was already working; namely, this Electrode Subgroup of the Committee--and if they didn't get together yesterday and take down their hair, it was their own fault. Now, this afternoon, they came around to it a little bit serious. Now, we have in addition to the Electrode Subgroup, this Research Subgroup whose function it is to work on these things, notably joint design, the question of the Y versus the H plate, unchipped versus chipped roots - those things were the function of the Research Subgroup. Now, it might be that the mechanism is already set up here between these two small subgroups which are composed primarily of those who are directly interested in these problems. It might be that if we had a joint meeting of the two Subgroups, the research and the electrode, that out of that combination would come the result that you want."

This argument by Mr. Bibber brought quite definitely the purpose of the original organization of groups within the Subcommittee, a point which many of the individuals present did not appreciate because they were new to the Subcommittee. However, the greatest stumbling block was the feeling that informed people were withholding information because of either commercial restrictions or confidential classification of data by the War Department. It was evident that the Subcommittee could not function effectively without the elimination of these restrictions.

Lt. Reed repeated his suggestion made previously:

"Let us not forget that outside of the Research Subgroup there has been quite a bit of experimental work done on plate edge preparation and joint design by the other people. If we have the people concerned here now send in on their letterhead to the Ordnance office their idea of a successful joint design and welding procedure; if we take that and look it over and separate the wheat from the chaff and take that to the combined meeting of the Research Subgroup and the Electrode Subgroup, then we will have something concrete to work on. I have only attended these meetings for a year, but I always know that if you stop and write something down on paper you are picking out one man's opinion and gradually building something. If you don't write something down, you air it and you never do recall it. All of these ideas having been aired, let's corral them and saddle one of them."

Mr. Biederman commented that he had seen no written or printed information from the groups which would help him build tanks, and Mr. Warner emphasized the necessity for complete welding data on test plates if any study is to be made:

"I agree with Mr. Biederman's remarks, and it leads me to make a comment with respect to the Subgroups - the Research Program Group. Primarily, the intention of that Research Program Subgroup was to find out if there was any difference in the performance of an H and Y weld with a qualification shock test under ballistic fire. Now, Lieutenant Reed has a lot of ballistic data on H and Y welds but, unfortunately, he does not have the complete information on the type of plate and its composition, hardness, how it was welded, how the joint was prepared, and so forth. If Lieutenant Reed and his assistants had all of that information, then, gentlemen, isn't what we want a complete analysis of that data which we can chew up and digest, and so forth? In order to get that analysis, we must have complete information as to how each of these specimens was prepared."

Lt. Reed made a plea for more test plates to be fired:

"The Aberdeen Proving Ground is just more than willing to shoot at any plate you send in. I am disappointed that we haven't had more plates. I tried to bring out this morning in the meeting that a year ago we decided to do something about this and in the last three months, we did do something. I was at the Navy last year. They said their work went back to early 1937. I had to tell them that mine went back to early September. Fisher Body has sent in about 20 plates. Ford had sent in about 10, 15, or 16. One plate fired in May, and another fired in September, and another one fired a week before this meeting does not give us the information we need. It does not give us the time to correlate. We have to mull these things over in our mind. It may come to you in your sleep, but you have to have time to draw conclusions if you want the conclusion to be proper, and you have to have data to draw conclusions from, and the data we have is principally based on

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the last three months. It is principally based on data from two or three plates."

With reference to the proposed survey by the Electrode Group, Mr. Brooker emphasized the desire that everyone submit ideas and data:

"The suggestion has already been made that those in the know submit details of joint design as best they know them or from their experience. Those people represented here, we have a number of people who have welded armor and some who haven't and we are concerned with both homogeneous and face hardened. Let me ask that those people who represent A.C. and F., Diebold, York Safe and Lock, Breeze, Republic, A. O. Smith, Una Welding, Baldwin, Pullman, Chicago Bridge and Iron, kindly make these notes. If I missed anybody, let them make the notes also. Get WAS-1 forms and put down your recommendations for joint design in homogeneous armor plate 3/8" thick, 1-1/2", 2", and 2-1/2". On face-hardened armor, 1/4", 1/2", 5/8", 3/4", and 1". Homogeneous should be cast and rolled."

Offers to co-operate were received from many of the fabricators present and Major Cox added a word of encouragement:

"Gentlemen, I want to add this: We are shunning a lot of red tape and saving time by asking you for this information at this meeting. This is our official request. We want you to go ahead and dictate the letter. We don't want to have to bribe you or remind you that we asked you for it today. We want you to do it day after tomorrow at the latest, preferably tomorrow."

A question was raised by Mr. Bibber about the importance of a notary's stamp on the data form. This stamp occupies valuable space and in some cases delays completion of the form for transmittal. Mr. Brooker stated:

"As far as I am concerned, it doesn't mean a thing. It is straight stuff. I have no doubt in my mind that any of you are going to send anything but the straight stuff, so just skip the notary. Let's save time."

Mr. Biederman asked whether the notary's stamp could be omitted and Major Cox replied:

"Mr. Biederman, I cannot answer that as Chairman of this Subcommittee, but I can offer a suggestion and that is that you shoot one copy through without the notary and let the other one in time come through. Send your carbon copy. Have the original signed and send the carbon right along. It always takes a little time to get decisions on policy so, rather than try to establish a policy without the bounds of this room and this meeting today, let's take the easy way out. Let's send Subcommittee stuff as a carbon copy without any notarization. If there are any plates at Aberdeen for qualification tests, send Lieutenant Reed a carbon copy, if you want, but have the original notarized until you are officially notified that is unnecessary. We cannot set up policy on that in this meeting."

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Mr. Bibber asked whether radiographs were necessary to be available prior to shooting test plates and Lt. Reed replied:

"Mr. Bibber, you know how things go in the Army. If I have these X-rays there personally, we can immediately start a report back to you after these things are fired, and we can immediately start the long procedure whereby the other people who are on the mailing list for that particular record can get the information. In particular cases, certain gentlemen call in and get the dope that they want on their plates after they know we have fired it. You cannot handle a hundred people a day that way, so we have to send out these firing records. The firing records take time enough as it is, and let's not delay it two or three or four days more by waiting for radiographs."

In a discussion of test plate types and thicknesses Mr. Outcalt agreed that the H plate is the most difficult with Unionmelt but that:

"I believe we can, and if that's what you have to have, we will make them."

It was considered that a test plate thickness of 1-1/2" would be representative of the armor to be welded for the M-4 medium tank and Mr. Bibber commented:

"It's my opinion after welding a number of these 2" and 1-1/2" plates that this electrode material is very expensive. It costs a lot of money and it takes a lot of time, and it is my own opinion, with some considerable background both in this and in other cases, that if you use 1-1/2" plate, using the electrodes that we are involved with here, you can weld a 2", and to require a 2", is an unnecessary hardship in time and money."

Lt. Reed commented also:

"Well, if the Army deemed it advisable for you only to use the H plate in 1-1/2" thickness, I think it is going to be a matter of your judgment as to whether or not you think you can weld 2" when you have passed 1-1/2", and if you don't think you can weld 2", go ahead and weld it up. We will test it, but if you think you can weld 2", all right. Just be satisfied with 1-1/2"."

It was decided that the next meeting would be held in Detroit on 1 March 1942. This was to be the first meeting on Sunday at the suggestion of Mr. Biederman:

"Sunday. (Laughter) Maybe that sounds like a joke, but we have been holding meetings on Sundays. Right now, we are getting to the point where we are building tanks. We have a major job on our hands. Sunday is my most available day because Sunday I will be working with a low force but the rest of the week it is going ahead, and Sunday is the best time for me."

The meeting was adjourned at 6:30 P.M. with a closing thought by Major Cox:

"Well, gentlemen, it is getting late and I certainly personally appreciate your staying over longer than the usual day of meeting on such things, but we are all in this thing together and I would like to leave this thought: We have some people on either side of us in these United States who would have applauded into an encore had they attended the meeting this morning. I think they would have gone away with a disgust of the show as the result of our meeting this afternoon. I wish to thank you all for coming."

The discussion at this meeting indicated the need for more freedom of exchange of information which is now classified as "confidential." Also there was indicated a desire on the part of the fabricating industry that ballistic tests be made of a completely welded tank hull to get some actual comparison with a riveted hull for propaganda purposes. The thought that such a test was more of a test of design of structure rather than a test of the welding was, however, emphasized by Col. Frye. As indicated by some of the argument for this test one might infer that proponents were really arguing for lowered requirements for weld quality which probably would not pass in H plates on the ballistic test because the H plate test is more severe on the individual weld than is the test of a complete hull.

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SECOND MEETING
SUBCOMMITTEE ON RESISTANCE WELDING
TUESDAY, 13 JANUARY 1942
WRIGHT FIELD, DAYTON, OHIO

The second meeting of the Subcommittee on Resistance Welding was held at Wright Field, Dayton, Ohio on Tuesday, 13 January 1942 with 17 persons in attendance representing:

Resistance Welding Equipment Manufacturers	4
Ordnance Department	8
Army Air Forces	2
U. S. Navy, Bureau of Aeronautics	1
Guests	2

The meeting was opened by Major Cox, Acting Chairman, since Col. Ritchie had been assigned to other work, and Col. Morgan welcomed the group on behalf of the Army Air Forces:

"Gentlemen, I am here to welcome you on behalf of the Air Corps. I hoped Major Boatner would be here this morning on behalf of the Air Corps, but I will express their pleasure at having this meeting here. I would like to say, on behalf of the Ordnance staff, Wright Field, that we are very pleased at your being here and the work you are doing. I hope before the day is over that you will have a chance to come to the office and talk personally with us. We feel the problem of resistance welding is going beyond the point of any academic development. It promises us better armor plate and today that means lives. This development in resistance welding of plate to brackets gives us a means of meeting this problem we have had to tolerances in installations and it will help us to put the plate in more readily, facilitate production, and expedite delivery of planes. On behalf of the Air Corps and Ordnance, I want to express appreciation for your coming today and for what you are doing and hope that your efforts will prove fruitful and obtain the objective we all desire."

With reference to the absence of Col. Ritchie, Major Cox remarked:

"Gentlemen, before we go into the main business of the day, I bring with me a message from Col. Ritchie, expressing his sincere regrets of having to drop out of taking an active part in our Subcommittee work. He is now Production Manager at Watertown Arsenal, and, as a result, is unable to carry on with this Subcommittee work. I've been acting as Chairman and the Subcommittee can now elect a Chairman as they wish."

Major Cox was unanimously elected Chairman and remarked:

"I wish to call to the attention of the group that transactions of the Subcommittee are to be considered as of a confidential nature. Whatever is discussed here should not be divulged to unauthorized persons. I might add, gentlemen, the principal requisites for membership on all of our Subcommittees are an active interest in actual production or research along the lines of the intent of the Subcommittee. Anyone actually doing resistance welding is eligible for membership. We, however, want to keep our Subcommittees as small as will represent an efficient working organization."

At the last meeting at Watertown Arsenal on 27 August 1941 certain test programs had been set up and Major Cox emphasized that one of the primary objects of the present meeting is to discuss developments from these tests for the benefit of the Army Air Forces.

Mr. Gillette summarized the test work done by him at Schenectady:

"We started out with small samples and tried to determine proper working procedure to give the heat treatment. Found temperature measurements served more or less as a guide to change quality of weld. In welds about the diameter called for in the specification, one difficulty was to eliminate porosity entirely. Other faults showed up in X-rays. By cleaning material carefully and using relatively high pressure practically eliminated porosity. Pressure had very little bearing on the final structure. Tests for hardness showed not too much change through area of weld, both in homogeneous and face hardened."

Lt. Matthews commented on ballistic tests of samples submitted by Mr. Gillette:

"We tested four face-hardened samples of varying characteristics. Some seemed adequate, but some failed on two or three rounds under shock tests; some failed on complete shock test of ten round bursts. Joints very brittle without pulling nuggets from the plate. Plates satisfactory showed hardness of 350 to 450 Brinell."

Mr. Gillette replied:

"Weld nugget pulled out rather than pull hole through plate. Weld may be too small in diameter. They run 54 on the hardened surface and 30 under that. Fifty in the edge of the weld then drop down to 45, 36, 38, 35, and 36 again."

Mr. Benkert summarized tests made by his company:

"We made samples of 1/4" face-hardened and homogeneous. Found heat treatment affected grain refinement, ductility. Ductility of major importance. Homogeneous takes much more current to weld. Variable pressure cycle was extremely important. Armor plate welds easier than open hearth, hot rolled, or cold rolled steel. There is only one way to make a weld and be sure; that is, by actually measuring the temperature of the weld and of the weld nugget directly underneath the point. This will be a constant gradient, other variables - pressure, electrodes, line voltage - will all vary. Just as long as you measure the temperature you get a weld every time. Many tests were performed and proved that the welds were all alike."

Lt. Matthews commented on ballistic tests of the test plates:

"Mr. Benkert's plates took the tests. No indication that spots were brittle or began to separate under tests applied."

A sample plate of 1/2" face-hardened armor, simulating that installed behind the airplane pilot, with mounting lugs attached by spot welding by Mr. Benkert's company was exhibited. This sample had been ballistically tested at Watertown Arsenal, and Lt. Matthews discussed the results:

"The armor is 1/2" face hardened. All the load was taken on the spots - machine gun projectiles striking normal and yawed impacts. The plate failed but welds are still good. One shot through edge of spot tore clip away. How strong should clip be? 7/16" bolt almost failed. Angles are 1/4". Perhaps, a thinner section could be used for this thickness of plate."

Major Cox commented:

"That plate was given a rather severe test and those spots have not shown the slightest sign of giving way."

Mr. Kaunitz mentioned his development testing:

"Working on welded joint with butt strap. Face-hardened plate takes about 50% more current. Working on 24" weld on 3/4" plate.

Mr. Wise described certain tests made by his company on 1/4" armor:

"Weld on samples of face hardened. Attempt made to stick to about 5/8" diameter and to keep hardness of weld to about the same as material. Weld showed same hardness. We want to get more hardness and indications are that we would have a larger diameter spot than 5/8"."

Mr. Kaunitz mentioned a spot spacing of 1-1/2" on this 1/4" plate which he considered proper. Mr. Marchant stated that samples for fatigue testing had been submitted by Mr. Benkert. All of the resistance welding people who attended the last meeting are not present and have not submitted any samples. The general opinion seemed to be that spot welds larger than the 5/8" used for mild steel would be desirable. The purpose of this development program is to give data for preparation of a spot welding specification.

Lt. Matthews observed:

"Might be well to forget about our specification for the time being. No reason to limit spots. Looks like larger spots and greater distance between will be the best condition."

And Major Cox suggested:

"Go ahead on the basis of what your common sense tells you and submit samples to Watertown. Resistance welding has large possibilities in fabrication of light armor."

Mr. Marchant observed:

"Appears we should be more concerned with 'brute strength'

[redacted]

than metallurgical perfection."

Samples of clip attachment have been submitted to Wright Field and Mr. White commented on the result:

"We are interested mostly in this piece with the lugs. The first shots were put on in the center. After around ten shots there was no change and so we started shooting closer. Then we started shooting actually at the lugs. This is an interesting one and the test came out very well. Cold rolled steel was used. The armor plate itself is face hardened and is tested on the face and the lugs just bend right over."

With reference to spot annealing Mr. Lawarre remarked:

"That was brought up with the purpose in mind of finding out what could be done for repairs or for reworking, possibly changes always after the plate had been made or repairs in the field, for some purpose such as that. We're leaving it stand right now until we find out if there is a real requirement for that."

Captain McInnes commented on the need for resistance welding and probable method of control of its application:

"1. Certain installations are punched full of holes affecting plate resistance. Resistance welding is an absolute necessity.

"2. Certain installations require very close tolerances.

"3. To keep under control, at present the only group of qualified manufacturers would be those here today. Approved list of manufacturers under Ordnance specification is needed.

"4. Specification is needed on resistance welding of armor plate. Data for tentative specification can be had from results of tests.

"5. List of approved manufacturers of resistance welding is needed. Make inspection the manufacturer's responsibility."

It was agreed that a check sample test plate about 18"x18" would be satisfactory for the thinner gauges of armor to qualify welding procedure.

Captain McInnes remarked:

"Define size of plate for weld and shock test of weld in tentative specification. After manufacturers submit test samples to Watertown, there will be sufficient data to approve tests. Have a specification and approved list of manufacturers. Then get the approved list in hands of Air Corps factory representative. Gives Air Corps factory representative some authority to back up statements."

It was further suggested by Captain McInnes that each type of part entering into plane construction should be qualified. Lt. Matthews suggested:

"Our job will be to set up a test which will simulate the most severe service test. Make that tough."

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Captain McInnes agreed that thisidea is desirable and in the meantime each resistance welding equipment manufacturer should:

"If you can, contact the aircraft manufacturers to work out the problem. Refer any objection to the Air Corps until approved list of specification is made up."

To which Mr. Lawarre replied:

"No objection to contacting aircraft manufacturers. That would be the simplest way to do it."

Mr. Braender pointed out the fabrication problem:

"Anywhere you can eliminate the tolerance you can flame cut. It is the drilling of the holes right now that presents the problem."

Another problem is that of bullet splash and it was pointed out that aluminum splash screens would be as effective as steel screens. Corrosion of spot welded joints should not be any greater than with riveted or bolted joints.

Major Cox commented:

"Preparation of tentative specification and submit it to you as quickly as possible. Get communication back as quickly as possible. Will not be long before we have a working directive."

To which Mr. Wise added:

"Suggest that first move, in view of speed with which we have to operate, is to set up some correlation between ballistic results, size of spot, hardness of spot. Detailed procedure involved in making spot welds not of as immediate importance as results. In order to do these things, we need some correlation between penetration, size, and tensile strength of both the weld and the distance with ballistic studies."

Mr. Warner pointed out:

"We could find out what we want to know on these plates 12" x 12". Ballistic data and variations of hardness through the plate. The general trend. How plates vary checks the general idea of how many spots and what size spot necessary."

Lt. Matthews summarized the data so far obtained at Watertown Arsenal:

"We have had positive indication that homogeneous or face hardened can be welded in either type joint. The problem is not too difficult, just a matter of working out details. Much easier to get results with a larger spot. Mr. Benkert's samples went through satisfactorily. Mr. Gillette's samples of face hardened all failed, perhaps because of the smaller spots."

It was agreed that a Subcommittee report should be prepared by Watertown

Arsenal on the test data obtained thus far. The benefit of such a job was emphasized by Mr. Gillette:

"That data should be correlated and then we would all have an advantage and would proceed more satisfactorily. Would not have to work out our own."

Major Cox suggested testing a smaller size of spot weld and proposed:

"Mr. Wise and Mr. Kaunitz could supply three sets of samples with three size spots and Mr. Benkert one with spot in between those supplied."

Major Cox also suggested preheating. None of the experimenters have tried it out. For spot welding the scale on plate surface must be removed. Pickling is not permitted by the Air Corps according to Mr. Braender. Sand blasting is objectionable according to Mr. Benkert because:

"It deteriorates the metal. Unfit, unsuitable under production."

Mr. Turnbull briefly outlined the aircraft fabricators' problem:

"Every airplane is different; even in our own planes, we are unable to control it. Armor is a heavy item and a stepchild as far as aircraft design is concerned. Affects interchangeability such as the Air Corps requires. In fact, mounting brackets spot welded onto a good ballistic plate are the most encouraging sign in the armor plate story. Would like to go farther and have the holes drilled when it comes to us. Another phase - treatment given armor plate prior to delivery and possibility of storage. If plate is in storage long and exposed to salt air, you will have plate that is inferior."

It was pointed out that the Navy has been working on the corrosion problem for some time.

Lt. Matthews observed:

"If we have to retain 100% of the ballistic limit of the plate, we can use homogeneous armor in the strap."

It was pointed out that attachment of brackets to the armor is another problem to the A.A.F. Mr. Marchant commented on the desirability of further fatigue test work:

"When it first began, the weld did not give strength comparative to plate. Looks better comparing results with results obtained with the bolts and rivets replaced. We want the best weld we can get. If spot welding is as strong as the bolts and rivets then we must use it. I agree with Mr. Warner to the extent that we must not put too much faith in the results of one or two tests."

It was considered that additional fatigue tests should be carried on.

[redacted]

In connection with the proposed specification, Lt. Matthews asked:

"Where is spot welding to be done? Who is going to do it?"

On this point Major Cox commented:

"It would be the responsibility of the manufacturer of armor, but there must be someone who can carry burden of proofing this. The government cannot take the responsibility of inspection of such plate."

And Captain McInnes added:

"Could be compared to small assembly job. Prime contractor gets the bid and subcontracts but is responsible for the final assembly. There are 13 on approved list. The aircraft manufacturer is prime contractor. He subcontracts the armor plate, produced by the armor plate manufacturer. It is up to the armor plate contractor to see that, if he gets the weld, that it meets with the specification."

Since the problem of who is to do the welding and who is to do the inspection may be different for vehicles than for aircraft, Captain McInnes suggested:

"May have to write two specifications - one for aircraft and one for tanks, scout cars. One is just as important as the other."

With reference to parts of aircraft which are armor plated, Mr. Turnbull remarked:

"In our particular type of aircraft, there are about 25 to 30 items which the Air Corps wants armor plated. Would anticipate that there would be more spot welding in airplane than in scout car. Statement made without any background of exact detail."

Major Cox observed:

"If we attempt to write the specification around aircraft armor, we will find that other specifications will be almost the same. We do not need two specifications."

To which Mr. Benkert added:

"If written around aircraft, you get more action than when you write it around combat cars. The Air Corps is eager to attempt something. If tried out and found successful, others will fall in line."

And Mr. Wise remarked:

"As to whether we should have one or two specifications. Design is the only thing that will be different between the two. We want what will give the best weld. We don't know until we are pretty well along. For the present time, we believe the joint design is best and will concentrate on the weld."

[redacted]

There was considerable discussion of what the proposed specification should cover and how generally it should be written. It was thought that a test plate 18"x18" with a spot welded attachment at each corner would be satisfactory for qualification by a ballistic test.

With regard to limit on spot size Major Cox suggested:

"If you get the spot too large, it becomes too soft. All we have to go by is what we have seen and tested. We want a spot about 7/8" not very much harder than the plate."

For the attachment Lt. Matthews suggested:

"The lug width, it seems, should be about twice the diameter of the spot."

In discussion of size of clip attachment, Major Cox observed:

"We don't want this plate to knock the bolts off before we finish our tests. Suppose we get 1/2" hole and use 3/8" bolt or 7/16". Tab is about 1/2 the thickness of plate. Must settle items of procedure. What shall we use as a starting point? What shall we set for the current, time, pressure?"

To which Mr. Wise objected:

"We don't want to specify those. Both the Army and Navy had experience in doing that. The present trend is for both not to specify procedure. What they do is to say a spot is to have a certain diameter, etc."

With regard to specifying minimum diameter, Captain McInnes commented:

"Would rather not. The diameter shall not vary more than plus or minus twenty or 10% from sample submitted."

There was some objection that this tolerance is not large enough. After discussion it was agreed that:

The armor plate size would be 18"x18", fitted with a tab on each corner of a specific material and, in general, of a thickness equal to one-half the thickness of the armor. The length of the tab and the overlap were to be specified so that the moment on the spot weld as the plate was supported for ballistic test would be constant.

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SEVENTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
SUNDAY, 1 MARCH 1942
STATLER HOTEL, DETROIT, MICHIGAN

The seventh meeting of the Subcommittee was held in Detroit on 1 March 1942 at the Statler Hotel with 119 persons in attendance representing:

Fabricators	29
Armor Producers	10
Electrode Manufacturers	23
Ordnance Department	27
Guests	30

This meeting was arranged by Major Cox, Subcommittee Chairman, Acting Director of the Laboratory, Watertown Arsenal. Major Cox opened the meeting with the following remarks:

"I am not going to take up any time with any remarks of my own. I wish merely to reiterate that at these meetings we discuss things that we don't want unauthorized persons to hear. We can feel free to discuss things amongst ourselves. We want to assure ourselves that there is no unauthorized person in the room, and I think we have done that, so you can feel that you are among friends and you can discuss your information as freely as you will. We are going to handle the distribution of the minutes of this meeting under a 'confidential' cover. The nature of this meeting is, of course, highly restricted. Just what category it will be put in in correspondence, and so on, we will decide later, but as we discussed at the last meeting, we want to consider ourselves in a room where we can discuss all of our confidential information that pertains to the welding of armor.

"I want to announce at this time that since our last meeting Mr. McDowell has been appointed Chairman of the Armor Fabricators' Subgroup, and, incidentally, there is a change in the designation of that Subgroup. The Armor Fabricators' Subgroup is the present designation."

The question of supply of alloys for steel making was now being given considerable attention by government agencies and Mr. Whitney of the War Production Board discussed the outlook for alloy supply at length. The meeting was started off with this discussion by Mr. Whitney as given in the following extracts:

"Gentlemen, the situation in regard to all of the alloys is very serious, because we are making more alloy steel than any of us ever thought would be made. We have an installed, operating, producing electric furnace capacity of three and a half million tons a year right now. By the end of 1942 that will be up to five million, and the total alloy steel, both basic open hearth, acid open hearth, and electric furnace, by the end of 1942 will be somewhere between thirteen and fourteen million tons, if we are to produce the alloy steels necessary for the

[redacted]

Victory Program. Now these steels can be produced with the alloys available, but we have two problems: One is habit and previous practice. Now to ask one of the steel companies making armor plate, who have developed a process for making that armor plate, using, we'll say, 3-1/2% nickel, 1.70 chromium, and that armor continually passes all the ballistic tests, you would naturally not expect him to change his practice unless there was some very good reason for changing.

"There is a very good reason for changing. We've got to change, because we cannot produce 1,700,000 tons of ingots for rolled armor with 3.5% nickel, just because the nickel doesn't exist, either in the form of scrap or primary product. And we can't go on running loose with the chromium situation, because even though our stockpile is in good shape, practically all of our chromium, until we develop our domestic deposits, has to come in on bottoms. Today the great problem is ships, both for sending our troops and materiel out of the country, and for bringing raw materials back into the country. If we had the ships, we wouldn't have the problem. Without the ships, it is a major problem.

"So, let's all call problem one the specification, those for steel, wherein the Army and Navy specify the analysis, or some other specification is used wherein the analysis is specified. We estimate that by just changing those specifications, the work done by the Subcommittee of the Iron and Steel Institute, the Alloy Subcommittee under the chairmanship of John Mitchell of Carnegie-Illinois, indicated that with that change, in the tonnage required, the 1942 tonnage, that we can save 47,625 net tons of nickel--that's 7,940,000 pounds a month--and our total income is only 12,000,000. We can save 24,210 net tons of chromium, 218 net tons of vanadium. Now when we change habit and practice, which is an industry problem--and that means armor plate, A.P. shot--on all the steel which the Army and Navy buy on the basis of ballistic properties, we estimate that 69,000 tons of nickel, 39,300 tons of chromium, 1,690 tons of vanadium, 2,400 tons of tungsten will be saved in a year.

"We need 22,800 tons of manganese. That is just a very small percentage of the total manganese consumed in the production of steel. That doesn't worry us. We've got a good stockpile of manganese, but we must maintain the bottoms to get that in. We've got to see that it gets here. Molybdenum, we need approximately 400,000 tons more. We have it, but we can't go hog wild on the use of molybdenum, either. Then we figure from Great Lakes Steel, and other practice, particularly German practice, going back as far as 1915 and 1916, that zirconium is a most useful element, and that with it we may be able to eliminate a great deal of vanadium and cut down our nickel and chromium content, and the zirconium is available, with 50% more in Brazil. We're going to have that shipped in at the rate of 2,000 tons a month, displacing manganese, until we get a sufficient stockpile.

"Then we'll need on our plan now of using less vanadium tool steel, we will have to increase the amount of tungsten used in tool steel, and the only way we are going to get the tungsten for tool steel is take it out of the noses of the armor-piercing shot, and I have just enough confidence in the men who have been heat treating steel, particularly the automotive industry and makers of accessories for the automotive industry, that this armor-piercing shot can be produced, with the proper kind of water quench, using a great deal less alloy.

"I have a very great feeling, also, that a lot of the information we are publishing in some of our technical magazines might be very helpful to the enemy, and I think we've got to watch that and be careful. What we are doing to save alloys and the kind of steels we are going to produce--I think that Adolph and his boys would like to have that very much, and I don't think we ought to let him get it if we can stop it.

"Manganese shows a stockpile--and this is not ore, this is manganese contained--we have a stockpile of about 850,000 tons, and revert from scrap amounts to only about 10,000 tons. That is all you get back from scrap. Now domestic production and revert from scrap amounts to only 100,000 tons. All the rest is imported. We hope to get 500,000 tons in this year, but there again, that is problematical, and if we don't get it in, down goes our stockpile. The total manganese estimated for our whole alloy program this year on this chart, some of the schedules were not in, so we could not estimate exactly, but I believe about 100,000 tons of manganese will fill our alloy program, even with the increased amount of manganese-molybdenum steels used, and all the rest of the manganese goes into ordinary carbon steel.

"Nickel is next on the list. Our stockpile is very small --10,000 tons. Revert from scrap, we estimate at about 75,000 tons; new, from Canada, 12,000,000 pounds a month. Now if we continue our present practices, with the present specifications, the present use of stainless containing nickel--weld rods, and so forth--we would use in 1942, 200,000 tons of nickel. When you look at this chart, you'll see that there are only 190,000 and we've got to have an additional 10,000 tons to make the steel that were not in the schedules when this report was made up, and all the nickel available from all sources, maximum, is 140,000 tons this year. So, we've just got a nice little shortage of 60,000 tons of nickel. That's a good many milling pounds. In other words, there is a demand of three pounds of nickel where only two pounds exist. So there aren't any ifs and buts about it; our practices and our specifications must be changed.

"Chromium--the chromium contained in the stockpile is approximately 170,000 tons. Revert from scrap, in electric furnaces, we figure is 40,000 tons; domestic production, 40,000 tons. That's 80,000 tons, total income, all again depending on bottoms, and most of it, mind you, comes from Africa and the East and Turkey. It is hoped we'll get in about 120,000 tons this year. If we continue our present practices and specifications, this year would be well over 200,000 tons of chromium. Now there, again, we've just simply got to change our habits and our specifications.

[redacted]

"Molybdenum--our stockpile, in spite of all that we shipped to the boys that we are now fighting, is 13,000 tons. Revert from scrap is estimated at 9,000 and I think as the molybdenum in steel increases that we are going to find that our revert from scrap is better than nine. I think it will be about eleven in 1942. And now, the best we can hope for is about 37,000 tons production, and that includes the molybdenum from Cheno Copper and from Utah Copper; and of course, as the copper output increases from those mines in which molybdenum is a by-product, we get an increase there, but from all sources, we figure about 37,000 tons this year. The demand is going to be approximately 35,000, so we are right up to our production, and we won't be able to go over that. We should not exceed 37,000 tons total consumption of molybdenum from all sources in the next two years, because it will be longer than that before we get an increase in production.

"Vanadium--two pounds are demanded where only one pound exists. We would like to use approximately 12,000,000 pounds, and we have only six. That means that vanadium has got to be taken out of everything that we can possibly take it out of, and one of the places where we can't take it out of is guns. As you well know, if you take the vanadium out of the gun steel, you've got to have three times as many annealing pits, and the time, according to Mr. Iverson, for whom I have a very high regard, is approximately 36 hours annealing time without the vanadium, and 12 hours with it, and he says, 'Where am I going to get the pits?' I told him, 'I don't know', because he has got every square inch of space occupied there now, and that's about the same with everybody. So we don't want to take vanadium out of guns. We hope, and we believe, we can take it out of the gun mounts, with the stress relieved. Vanadium high tensile steel is now specified.

"Tungsten--we have a stockpile of about 2,000 tons. We figure revert from scrap at about 4,500 tons; domestic production at about 5,000 tons, which is increasing; and imported at about 6,000 tons. The ceiling which the tungsten people have set from this year is 15,000 tons, from all sources; that is, what was used out of the stockpile, revert from scrap, domestic and imported. And so, we've got to watch our tungsten.

"In other words, we've got to watch everything, to get back to my original statement, because we are making more alloy steel than we ever thought would be made, and if this war lasts another year and a half, as we think it is, 20% of all the steel made in the United States is going to be alloy steel. To get up to a billion tons a year, we are going to make twenty million tons of alloy. That is what we're heading for. No one had any realization of it; no one would believe it, but that is the situation.

"But on our constructional alloys, the proof that these national emergency steels, for instance, the low chrome-nickel-moly is as good as the 4100 series. I don't think it is going to be difficult to prove. I think you will find it will weld more easily; you will have much better low temperature impact properties.

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It will be a very superior steel in every way. Now we have, in the steel mills today, 150,000 tons of scrap available for this chrome-nickel-molybdenum melt. It's all got chrome in it; it's all got nickel in it; it's all got molybdenum. And that scrap is of no use to make a straight nickel steel or a straight chrome steel, unless you disregard the other elements.

"Now on a cast tank armor, we propose to take all of the nickel out of it, use no nickel at all, and reduce the chromium to 1% instead of an average of 2.5%, and keep our molybdenum around .45 and take all of the vanadium out of it. Now two or three of the biggest companies have been making cast armor to those specifications, and if they can do it, it seems perfectly reasonable to believe that others can do it. There we can make a very big saving on the cast tank armor alone. With all cast armor we can save 30,000 tons of nickel and 18,000 tons of chromium. We estimate a total of rough castings, including gates and everything, of 1,200,000 tons to be made in 1942 of the cast tank armor; rolled tank armor for all purposes, 1,700,000 tons of ingots. Now we are reducing the nickel from 3-1/2 to 1, the chromium from 1.5 to .60, and keeping the molybdenum at about an average of .20--no vanadium. With that program, if industry does what I think they can do, we can save 39,000 tons of nickel and about 15,000 tons of chromium and about 17,000 tons of molybdenum.

"The Naval belt armor we don't propose to touch at all. To take that 16- or 18-inch armor and build up the side of a ship and shoot at it with 16-inch guns is a pretty major test program. The tonnage is not nearly as great as the tank armor, and I have no inclination, for one, to touch it or monkey with it. But instead of having the 20 to, say, 25,000 tons of scrap in Homestead to go back into the open hearths, with 1.5 chrome in it, and have all the chrome go up the flue, we propose to take that scrap from Homestead and use that in all the electric furnaces and acid open hearths making tank armor, dilute it down with hot metal and save that chromium, and give Homestead the primary nickel and hope that they will learn to add the chromium in the ladle and not waste as much as they do at present, and get all of the nickel and chromium out of that scrap by using it in electric furnaces instead of throwing it back in the open hearth. A very big saving can be made there."

Mr. Whitney referred to the steels used for bearings, engines, guns and projectiles indicating possibilities of composition changes to conserve alloys. As for high speed tool steels the limits which will determine composition used are vanadium supply and hammer cogging capacity.

With reference to stainless steel, Mr. Whitney continued:

"Now the stainless is very analogous to tool steel, and there again we have the hammer cogging, which seems to be absolutely necessary on the 25/20 rod; not necessary on the 18/8 or the 18/8 modified. The thing I want to impress on you men here today is the necessity for doing this. No one is asking you to do it just to be arbitrary. We're faced with a situation and we must meet it. I think that you will find you can weld with the 18/8 modified, and with the new analysis of the armor, perhaps you can use a ferritic rod. We can't ask you to prove that until we prove we can make the armor. Then if the armor with a low alloy analysis can be welded with ferritic rod, let's go on it! Save every pound of chrome, every pound of nickel that you can. We are hoping that the Navy, on the deck armor, can get away from the 25/20. If we are going to get our arms to the Philippines, get our guns produced, get our tanks produced, get our aircraft produced, get our ammunition produced, we've got to do the job. The tanks have got to come off the line, and nothing must be done to interfere with production."

Since this discussion by Mr. Whitney was the first detailed informal story of the general situation on alloys for steel making presented to the Subcommittee, his efforts were received with prolonged applause in appreciation. Many rumors had been floating around, but now those who were present appeared grateful for having been informed of the actual situation.

After cautioning the assembly as to the confidential nature of the data disclosed by Mr. Whitney, Major Cox requested Mr. Brooker for a report on the meeting of the Electrode Group, which had been held the previous day.

Mr. Brooker reported that:

"Thirty-six individuals representing 84 manufacturers and fabricators opened their discussion with the relative merits of manganese and moly for the modified 18/8 electrodes. It appears that due to the change in armor plate and due to other difficulties beyond their control, the program is not conclusive. However, it is generally agreed that the molybdenum modification gave less cracking, with a copper back-up bar, than the manganese modification. The electrode specification previously worked out by this group has now been further perfected and was approved for submission to the American Welding Society and the American Society for Testing Materials Committee, who are expected to release it in the near future. This is not for Army use only. You will find in this specification reference to 25/20 electrodes. The weldability specification for armor which was developed some time ago and placed bodily into our cast and rolled armor specifications was a little half-cocked, and we now have a revision of that, which I don't believe you will have much disagreement on. It will be submitted to the rolled armor and cast armor people.

"A manual for inspection of welded vehicles has been prepared, perhaps a little late, because we already have inspectors in training. Of course, we will have many more. That manual will be turned over to the Ordnance Inspection Staff within two weeks.

[redacted]

"The Field Service Division of the Ordnance Department asked us for instructions to cover welding of materiel in the field. They were given certain instructions on a few days' notice and now have a more lengthy manual available for them, prepared by the Electrode Group, which they can circulate to the field. Copies of this manual are already in the hands of the Electrode Group for further revision, if that is necessary.

"Specification AXS-497, for the welding of armor, which has not been revised for some time, is now in revised form. I don't have enough copies here to give to everyone, but to those who don't have them, we can send copies. With Major Cox's permission, I'd like to pass out what we have, before the day is over, and request that you send comments to the Ordnance Office within a week after receiving these qualifications. You will find in this revised version of the specification that the section on ballistic testing has been crossed out. The old wording is still there, but please disregard it. The state of ballistic testing is still a form that we cannot put down in black and white. However, I think those who have been with us closely know that some of the rubber, most of it, has been taken out of the yardstick. You will also note that the qualification of welders has been changed. Where formerly there was an official qualification, it is now worded so as to be a contractor's responsibility.

"We have had requests by the thousand for these WAS-1 forms. You're apparently using them for filling your files, for duplicate copies for informing Tom, Dick and Harry of what you are doing. For Heaven's sake, please don't do that, but make copies of the data if you wish. That paper is transparent. If you follow the instructions given for those forms, you will use one form for each welded plate. One district requested 5,000 forms. I don't think they're going to weld 5,000 plates. One hundred per cent rag paper is necessary for the job, and we can't get it, so please be reasonable.

"Anticipating the shortage of chromium and nickel, the Ordnance Department has sent teletypes to all districts, requesting that the use of 25/20 electrodes be discontinued, and that the modified 18/8 types be used as soon as possible. That means, of course, that those of you who are using the 25/20 and who have stocks of it can't be expected to change over night, but as Mr. Whitney has suggested, please try to come around. In order to anticipate the shortage of 18/8, the Ordnance Department has set up a program with A. O. Smith and Harnischfeger, and Metal and Thermit, to immediately begin a shotgun program to develop information on ferritic electrodes. That is worked out in some detail. Those three people will get plates immediately and will start welding immediately."

Mr. McDowell reported on a meeting of the Armor Fabricators Group held the previous day:

"We found that the majority of the fabricators are using the double "V" joint, with either the 45° or the 60° included angle, using a copper backing, and from 1/4" to 3/8" root opening. We found out that the majority of the fabricators prefer the molybdenum modified 18/8 electrode, from the standpoint that ballistic results tend to show slightly better results, and they concluded that they have slightly less trouble in the actual welding process. Another point that was brought out was that in the welding of these joints, better ballistic results have been obtained when a large number of small beads have been used to make the joint, rather than a fewer number of larger beads, and it was also the consensus of opinion that high welding currents are not satisfactory for producing the best quality welds. The welding currents should be held in the normal range.

"Some work is also being done on the study of the flame gouging of the mild steel root strip in the type of joint in which this strip is being used, and also additional research work and test plates are being prepared on the use of the monel strip in the root joint. No additional progress was reported by any of the fabricators who are using or experimenting with the Unionmelt process. However, in the multiple bead automatic welding, one fabricator has welded several test plates that have passed the ballistic test.

"There was also considerable discussion on ballistic tests. That is one of the topics that comes up at every meeting, and a resolution was drawn up, to be presented to the Subcommittee and I will read it as it was drawn at our meeting:

> "'The Fabricators' Subgroup recommends that the Ordnance Department standardize armor plate testing procedure, to this end: That research on welding techniques should be carried out on 1-1/2" plate of the several compositions, and ballistic testing should be done at a temperature of 70°F. by a standard procedure including three 75 mm. flat nosed, 15-lb. rolled steel test slugs at 1200 feet per second velocity. In order to develop this procedure, careful study should be made of the 75 mm. gun and mount, the interior and exterior ballistics of the piece and ammunition, the range at which the test firing is done, and other relevant features of the firing, in such manner as to provide for placing impacts in the desired locations and in the desired manner. The suggested sequence of impact is, first impact to center 6" above the center of the crossbar of the 'H', and in the center crosswise; the second timpact to center 6" below the crossbar of the 'H', and in the center crosswise; and the third impact to be in the center of the crossbar.'

"There was also considerable discussion as to how the welded joint will stand up under impact under low temperature, and in this regard the following recommendation was drawn:

> "'That a study of effects of temperature upon ballistics of welded test plates be made immediately.

[redacted]

> The firing is to be carried out at plus 180°F, plus 70°F., and minus 60°F. The plates are to be 38"x36"x1-1/2", and should originate from the same heat, should be welded by one fabricator under strictly identical conditions. The firing should be carried out in standard sequence of locations and velocity.'"

Since the development work outlined by Mr. McDowell involves homogeneous armor plate primarily, Mr. B. J. Smith of Marmon-Herrington Company made a few comments on the activity of the Armor Fabricators Group:

"Mr. Chairman, I would like to comment on the report of Mr. McDowell. I appreciate very much the position of the Research Subgroup in setting up a standardized test on ballistics, but again we find ourselves in a position of being the fringe group. While you are setting up standardized tests, why not include everybody in this standardization. We are working with plate somewhere in the twilight zone, below one inch, and it happens to be face-hardened plate, and none of the standardized tests, as set up, could even remotely apply to the particular problem that we have. This also is true, not only of ourselves, but of people like Diebold, people like the Breeze Corporation, people like Chevrolet. There are several others. Now insofar as the ballistic specification itself is concerned, as to where you are going to fire this projectile on the plate, again I find myself in the position of straddling the fence--being on the side of the Ordnance Department as well as on the side of the fabricators. For the life of me, I don't know how you are going to fire a plate like that. The patent impossibility of placing a shot at a specified point on a certain plate in a sequence of order such as mentioned--well, it just hasn't been done yet to my knowledge. Isn't it better to allow some kind of a rubber yardstick, if you will, but a more adequate interpretation of this rubber yardstick results."

Lt. Reed replied as follows:

"In regard to Mr. Smith's first remark on his need, it is indeed unfortunate that we don't have, in my opinion, the proper projectiles for testing his plate. We have made a lot of tests, with our rubber yardstick and our poor shooting, and those who have deemed it advisable to try enough tests to get sufficient data to draw a decent conclusion have drawn that conclusion, and haven't gone far afield. We figure that in four plates we might be able to place the shots sufficiently close to the welds to prove whether or not the welding is adequate. Now I realize that four plates, from every man who is going to qualify, is going to be more armor plate than anyone wantsto use. However, that is the system that the General Motors group have used, and I think they have gotten a lot of information out of it.

"In regard to the shooting, we know it's not accurate, and we have known it's not accurate for a long time. We've found that certain guns will shoot better than other guns; certain people will shoot better than other people; and we have three different ranges with three different crews--three different accuracies, three different techniques, and three different results. However, we don't think that one 36x36 plate, 1-1/2" thick, is conclusive. The testing of that plate is not conclusive, and considering all the variables, I think that if we have 3 or 4 plates from each man who wants to know whether or not his tanks are going to fall apart, we will be able to find out.

"Now I don't know what to do with thin face-hardened plate. Our problem is that we shoot what we receive, and we haven't received an awful lot. Most of the people, like the Breeze Corporation, Diebold, and Marmon-Herrington, have a range of their own, and they have been doing things for years that I am just beginning to find out about. We haven't shot over 10 thin face-hardened plates below 1"--well, say below 3/4", at Aberdeen."

Some 3/16" face-hardened plate had been fired at Aberdeen Proving Ground for Breeze Corporation, but that was for penetration only, not for shock.

Mr. Waterbury of Chevrolet commented:

"Mr. Brooker has already mentioned that the specifications revising the AXS-497 are in the making. We haven't seen those, but we do feel that your program is rather indefinite. Perhaps that also expresses Mr. Smith's feelings. We would like to have some thought given on that, making it more definite. Of course, the only way we could do that is to have more information, and that is being developed quite rapidly, as to what we can do and what we can't do. I think that perhaps in conjunction with Ordnance testing, with the knowledge of the various groups that are working on face-hardened armor, we could arrive at a fairly satisfactory specification, if you please, on what can be done, perhaps commercially, which would permit the manufacture of these vehicles in relatively large quantities that will give satisfactory service in the field."

Mr. Komarnitsky observed:

"I understand that this test is just to develop a certain yardstick to be applied very quickly so that the decision can be reached by inspection whether the methods used in a given plant are satisfactory or not. We never look at it from that standpoint whatsoever. In our tests we did development shooting. That is an entirely different procedure. Two or three tests with a heavier projectile will give you quick results, undoubtedly, but how to interpret them, I don't know. I think

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that the problem confronting us getting into this field is one of a different nature, namely, we have to develop some kind of a test which we can control and interpret. For instance, we found that with thin plates, like 1/4" and 3/8" and 1/2", shooting with the ball ammunition, with controlled bursts and controlled velocities, gives you more data for modification of procedure than standard bursts, namely, armor-piercing ammunition, 25-round bursts. I really don't know how it would be possible to develop a quick yardstick for thin plates, unless you revert to the same rather tedious procedure like we are doing."

Mr. B. J. Smith suggested the formation of a special group on face-hardened armor:

"The one thought occurs to me that perhaps I am asking for something that can't well be done by the present Research Group, and I'd like to make a suggestion that a separate group be set up to study the problems of the face-hardened welding group, and let's say, set up their own specifications. We seem fortunately to be favored with equipment to make tests to determine procedures within this group. Would it be out of line that such a separate group be set up to make such tests and establish that procedure?"

A comment was offered by Mr. Abbott:

"We have run a number of tests and we find that all specifications that have been put out in the field up to date, that we could not meet the ballistic requirements, so we have developed one type of joint which we have submitted to Aberdeen as more of an alternate, to get by and see whether or not our type of armor plate which we are concentrating on, gauges of 1/2" or less can be welded in the building or manufacturing of scout cars, and we have made some progress along those lines. We have been sending some bolted type plates for comparative tests, so as to get approval on the type of welded construction that we have sent down. Now I feel somewhat like Mr. Smith does, that if we get together, we will produce the best type of welded joint that we know how to produce, as of to date, and to use that as a starting point. We can improve on that joint from time to time, and we can raise our specifications as we did in the case of face-hardened armor plate. You remember 5 or 6 years ago we started with certain ballistic requirements on face-hardened, and that was raised as improvement was made on the plate. I think that is not only the best, but about the only proper way to handle the welding of face-hardened armor plate."

Major Cox replied:

"Now I'd like to add that the welding of face-hardened armor is a problem that has been recommended by the N.D.R.C., and has been allocated to Rock Island, and a study will be made.

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I think it would behoove us to consider the initial duty of such a group to consist of the preparation of a summary of existing data and to see what could be done, quickly, that would not, at the same time, represent a duplication or overlapping of the N.D.R.C. project. I am sure that project is going forward as rapidly as possible, and that will involve the technique of the welding, as well as the ultimate ballistic tests of the samples so compared."

Lt. Reed suggested the following membership for the proposed Group:

"Mr. Abbott of the Diebold Safe & Lock Company, Mr. Smith of the Marmon-Herrington Company, Mr. Komarnitsky of Breeze Corporation, Mr. Steinmeyer of the American Car & Foundry Company, or Mr. Osha, and I don't know the name of the gentleman from Chevrolet."

The Chevrolet member was Mr. Waterbury. Mr. Sibley of Disston was also appointed. The formation of a Face-Hardened Armor Fabricators' Group with the suggested membership was moved and carried.

In view of this action Major Cox remarked:

"I think in view of the motion just made and passed upon that we should now consider changing the name of the present Fabricators' Subgroup to Homogeneous Armor Fabricators' Subgroup, and then the third Subgroup will be the Face-Hardened Armor Fabricators' Subgroup. I don't think that needs a vote. I will leave that entirely up to Mr. McDowell to change the name himself."

Mr. Abbott was elected Chairman of this new Group by announcement of the Subcommittee Chairman.

Mr. Danse reported on a meeting sponsored by General Motors Metallurgical Committee at which flame cutting of armor plate was discussed:

"We appear to be laboring under a lot of misapprehension in that some of us as fabricators were fearful that we would not be able to procure plates having the accuracy of edge preparation that is necessary for weld fabrication. However, as the discussion went on, it appeared that we already have developed equipment which will cut with reasonable accuracy at the present time, and which can be further developed to cut with all desired accuracy in the near future. It appears that the equipment builders have staffs of competent engineers, who are ready and willing to discuss with the fabricators and the plate preparation people the use of this equipment, and we have also, as fabricators, ideas as to what constitutes a reasonable accuracy on plate edge, and that none of those three sets of ideas are in any way in conflict. I believe that the way the thing finally worked out at the plate edge preparation meeting everyone was quite happy. It was largely a series of misunderstandings, I believe as to the capabilities of existing equipment and existing personnel."

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Major Cox referred to the minutes of the last meeting in regard to machine welding of armor:

"In the second paragraph, Item C, it is stated that 'the automatic welding processes are not sufficiently developed for adoption of production welding at the present time.' The representatives who spoke on the subject of machine welding indicated that they were not then prepared to make a report to the Subcommittee on the status of this process, and we all then expressed the hope that by the time of this meeting they would be ready to tell us something."

Mr. Outcalt of Linde Air Products Company discussed the latest data on Unionmelt welding:

"During the period since the first of the year, we have submitted a total of 10 plates, 8 of which were 'H' plates, 2 of which were 'Y' plates--6 Republic, 4 Carnegie. These were welded in accordance with the procedure we developed for plate edge preparation and with welding conditions developed principally at our own laboratory. They were welded, some with preheat, some without preheat. It was found that with some of those plates which were welded without preheat, we unfortunately could not get consistently good results since under ballistic test they would sometimes fail along the line of the fusion zone between the base metal and the fused metal. That, I understand, is a rather important point. They should fail rather in the center of the weld than along that fusion zone. If the failure occurs in the center of the weld, apparently there's a tendency to consider it a better weld than if the same length of failure occurs along the edge of the weld. I don't know quite why that should be the case, but maybe we can find out. Of the plates we submitted, it appears at the moment, and all of this is predicated on a very limited number of plates, of course, that a preheat of about 300° F. is satisfactory for Republic plate.

"Incidentally, these 8 or 10 plates which have been submitted to Aberdeen by us, are not an indication, really, of the work which has been done; there has been much more done than you would think from the number of plates submitted. It looks as though much of this work may be lost, however, and we're apparently going to have to start immediately to produce a ferritic type of electrode and welding conditions for use with the ferritic electrodes on low alloy plates. There's one question in that connection on which I'd like to get a little definite information. As I understood the comments today, from Mr. Whitney, and from others, there is still nothing mandatory about the changes in the armor plate and the elimination of the 18/8 electrode from our consideration. If that is to be mandatory, I think we should know about it and should have some indication, perhaps not in this group, but maybe privately from the various producers of armor plate, just how much of the higher alloy

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armor plate is still to be available for welding. I think it's necessary that we all get some indication along those lines, so that we can determine what quantities of the higher alloy electrodes are to be required. I think that should be made definite before long, so those of us who are faced with the problem of building up stocks of electrodes, without which tanks can't be welded, will know what we have to do about it. It takes time to obtain the steels, and being faced with perhaps two-, three-, or four-month delivery dates from steel mills on special compositions of rod, we must know how this thing is going to go--whether we have to change to the ferritic type of electrodes next week, or whether it's June first, or when it's going to be."

Major Cox pointed out that the requests of the War Production Board for reduction of alloy content of plate and electrodes were to be considered later on in the course of the meeting.

Dr. Drury of Canadian Department of Munitions made a few comments on machine welding in Canada:

"In Canada, at the present time, we are making scout cars of homogeneous plate, and although the plates, the assemblies, have not been submitted or subjected to the shock test which you apply, they have been tested in service, and with A.P. shot, under standard ballistic requirements. Now the plates are sheared and flame cut. The shearing goes up as high as 5/8", and the angles for welding vary from 17° to 60°. The welding is a combination of the automatic and hand welding, and there's no preheating. The subassemblies are radiographed. We use the modified 18/8 for the hand welding, and the Unionmelt electrode for the automatic, but a combination of the two methods is, in our opinion, the best combination for making scout cars."

Mr. Outcalt explained the Unionmelt electrode used in Canada:

"The electrode, which Dr. Drury's people are using, is known as Oxweld No. 41. It's a rather high alloy composition, almost comparable, in chromium and nickel content, to the 25/20 electrode used for hand welding. It has, however, a higher manganese content than the 25/20 hand welding electrode. It's a relatively low carbon material."

Lt. Reed outlined the experience at Aberdeen Proving Ground with machine welded test plates:

"In regard to Mr. Outcalt's work, we have had one plate that looked as though it were homogeneous armor plate, and not welded armor plate. It didn't have a crack after three rounds. It was a beautiful job, and we were actually glad to see it. He sent one in later, and duplicated his work, and that one did have small cracks. When I first tested Unionmelt welded plate, the reinforcement was considerable. There was quite a notched

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effect at the edge of the "V", and we'd strike it and the crack would start and run right on down that line. Sometimes the plates would fall apart, and they wouldn't fall apart along a plane perpendicular to the surface of the plate. It would seem to lift right out, depending on where the impact was. If the impact was well in the parent plate, they would lift out in an area which you might call the heat-affected area. It has a great tendency to break on the parent metal side of the heat-affected area. If the impact were nearer to the center of the weld, it would break along what we might call the fusion zone of the weld, but those first plates came out quite clean. As a matter of fact, we almost unwelded them. I didn't know anything about it, and I didn't like the looks of it, so I failed it, and I would like to get an opinion from this group, should our welds be such that if a small crack occurs out there at the edge of the bead, between the weld metal and the parent plate, should that crack of necessity propagate all the way down that area, or should it go in and out?"

Having raised the question of significance of the location of the crack, Lt. Reed called on Col. Jenks, who responded:

"It's a difficult thing to answer. The important thing is where the crack starts. That's more important than how it goes. What you need to do is to find out where the crack starts, and what conditions are favorable to the origination of the crack. That's more important than where the crack proceeds."

Mr. Outcalt commented further:

"Now, my question about whether it makes any difference where the failure occurs, I think still should be discussed a little. I can't see why, if with three shots, we'll say, under certain conditions, we get a crack a foot long in one of the welds, I don't see why it makes any difference whether that foot-long crack is in the center of the weld or along the edge of the weld, provided, of course, that it is no longer in one instance than it would be in the other. If a specimen cracks a certain amount, that is some indication of the strength of the weld or the condition of the heat-affected zone, or the condition of the plate, or some characteristic of the specimen, and I can't see why it makes any difference whether the crack occurs in one location or whether it occurs in another location, if the magnitude of that crack is within the limits of acceptability. Now these cracks which occur along the fusion zone in the case of a highly reinforced weld, I think we all agree are perfectly natural. They would be expected to occur there because that's the point at which, with a highly reinforced weld, anyway, there is the most change in section in the specimen, and we all know that a change in section, even in a solid plate without any weld in it, is likely to be the place for failure to start. With a weld which is not highly reinforced, I can't see that it's particularly detrimental for the crack

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to occur along the fusion zone, and here again, remember that the fusion zone is not a distinct line related to the edge preparation, but is really a fusion zone - a transition zone. I don't see why it makes any difference whether the failure occurs there or somewhere else, provided, of course, that the failure is of a certain length which would be acceptable if it occurred, we'll say, in the center of the weld."

Lt. Reed continued:

"However, I have seen Unionmelt welded plates with a concave surface; I have seen them almost level fail in the same way; and I have also seen Unionmelt welded plates not fail at all in the same tests. Now whatever the limits of acceptability on cracking are, I don't think we want to consider any condition which will cause such failure, because it is a weak condition. Those types of cracks are much longer than the center cracks, if the center is any good, and when Dr. Drury said he was inspecting by radiograph, I was worried about that hard condition. Unfortunately, when we X-ray a plate, if the plate is sound, we can't tell how it is going to stand up on shock tests, because we don't know the chemistry of some of those areas between the center of the weld and the edge of the plate. We do know that an unsound weld will fail if you shock it, but we don't know that a sound weld will stand up. We do know that when you have a high reinforcement, you get cracking along the edge - but we also have seen that type of cracking, that type of propagation, down along that fusion zone, with a concave bead, and with a level bead, on the reinforcement."

Mr. Emery commented that a brittle heat-affected zone is undesirable under shock. Mr. Keating pointed out that in the A. O. Smith test plates the preheat was used to prevent a hard heat-affected zone.

Mr. Outcalt explained:

"Mr. Chairman, I perfectly agree with that. We don't agree with the other. The only point I want to make is, if the plate is acceptable, as Mr. Emery suggests, if the dishing is all right, if the crack is not too long, if it would be acceptable, had the crack occurred in the middle of the weld or at some other location in the plate, I don't see why it should be rejected because it happens to be at the transition zone between the deposited weld metal and the base metal--the heat-affected zone."

Mr. Emery made a suggestion:

"Lt. Reed, why don't you have as your rubber yardstick a specific, a certain amount of dishing, without a crack in the weld or fusion zone? Then you've got something."

To which Lt. Reed replied:

"The amount of dishing you get in a 1-1/2" welded plate depends on where you hit. As you found out yesterday, we don't

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know how to hit very well, and I question the advisability of doing that. However, I have seen Unionmelt plates dished and I have seen hand welded plates dished by two impacts, one on top of the other, and no cracking whatsoever. One had 400° preheat, and it was outstanding in its performance. You can get dishing without doing that."

It was admitted by several speakers that bond zone or heat-affected zone failures are not desirable. Mr. Keating emphasized preheating:

"Whether we like it or not, in this type of welding, before we get finished, we are going to have to work out preheating arrangements to work out the welding problem."

Mr. Danse commented on a metallurgical aspect of the problem:

"Mr. Chairman, Lt. Reed, I think the whole thing gets right back to metallurgy, in spite of the fact that most of you men don't like to talk to metallurgists. We have made great efforts, both the welding men, the electrode manufacturers, and the metallurgists, to so weld our armor plates as to minimize the heat input into the parent plate. By minimizing the heat input into the parent plate, we minimize martensite between the weld and the original metal. We have put multiple weaves and multiple beads in our hand welding in an effort to reduce the distance which the heat travels, and accordingly the width and the hardness of the martensitic zone. Naturally the characteristics of that martensitic zone depend on the armor plate composition. The hardenability of the armor plate has never been given sufficient attention, and the hardenability is not due alone to the alloy composition, but is largely due to the carbon content. It is a combination of the two, and it is neither carbon nor alloy alone.

"Hardenability is beginning to receive the study which it has long merited, and Lt. Reed is perfectly correct in criticizing the results of the Unionmelt plates, where the Unionmelt method causes a wider martensitic heat-affected zone between the weld and the original metal. That characteristic will be more marked in the plates of high hardenability than it will in the plates of low hardenability, witness the remarkably effective work by Unionmelt on some of the new low compositions. We are very much concerned with resistance to shock and propagation of crack due to repeated shock, and I think we should not straddle the fence in criticizing anything which may increase the tendency towards that kind of propagation.

"We will probably be glad to go along with some of the people who want to preheat, but so far our practice has not been to preheat, and so far our practice has dealt with plate of high hardenability, which, in the absence of preheat, is very difficult to weld, and our practice has been developed to keep the heat-affected zone as small and as narrow and as little embrittled as we could. Now I may be doing what I

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suggested--straddling the fence. I have no brief either for or against Unionmelt. I hope that Unionmelt becomes practical, because it seems preposterous to consider manufacturing armored vehicles by the hand-welding method.

"Some automatic method should be devised, whether it be Unionmelt or some other, but that automatic method will have to be premised on such conditions of plate and welding as to not cause a wide heat-affected zone which has a lot of very brittle martensite in it. Now with the new low-hardenability compositions, there is less martensite, and it is of such a nature that it is not quite so brittle, which will make the automatic welding problem easier."

Mr. Keating elaborated further on the subject of machine welding:

"The question of automatic welding, I think, is one of course we are all striving for. It is the thing to do, and if the Unionmelt process can be worked out, there is no question, I don't believe, in anyone's mind, that for certain thicknesses of plate, it is the ideal and fastest method, and those of us who are interested in winning the war want to see that thing come through. So far we haven't seen enough evidence to feel any assurance on that point. Undoubtedly, there will be some applications for that type of welding; I don't believe this job has to be all hand welded or all automatically welded. Unionmelt may have certain spots where it's the most economical and fastest method. You may have other spots where the coated electrode with the automatic head would be the most economical and fastest. But the automatic processes should be given a good trial. Now we haven't been able to, because of the great number of other engineering things that we have over there. We are a limited organization in the final analysis, and we have had a lot of problems thrown at us by the Army and Navy and different people, and we are working on some tough ones."

Mr. Outcalt summarized the problem of machine welding armor as follows:

"You have to do one thing or the other, if the material is hardenable. You're going to put in a certain amount of heat at one time with the Unionmelt process, because you're putting in large quantities of metal at one time. If you want to use a hardenable plate without preheating, then you must put weld metal in more slowly, and add less heat at one time. That seems to me to be a brief statement of the problem, and it's a question of whether you want to use the hardenable armor and preheat, whether you want to use the smaller electrodes without any preheat, or whether you want to use an armor which is not hardenable, in which case, you can do a lot of things with it."

After luncheon Major Cox called upon Mr. J. T. Catlett (General Electric Company) to give a report on the possibilities of machine welding

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for armor:

"As far as our company is concerned, we have done very little in the way of machine welding on armor plate. We have done some work in connection with Metal and Thermit Corporation, who have furnished the electrode for use in the machine. The welding head with which we weld is satisfactory for handling coated rod by introducing the current into the wire through a slot cut in the coating. We feel that we have a very satisfactory method of controlling the speed of the wire, by reference to arc voltage and, of course, as far as the application to armor plate is concerned, the machine will be no different than it would be for other types of plate. I think that the question of machine welding of armor plate rests a good deal with the electrode and not with the machine which feeds the electrode."

At the request of Major Cox, Col. Zornig gave a summary of latest developments in armor compositions:

"The trend is to lower hardenability; that is, the compositions themselves will have comparatively low hardenability, and the characteristics of the plate will be developed by drastic heat treatments, and the alloy content and the carbon content, if these plates show up to be successful, will be very much lower than what they are now."

To which Major Cox added:

"I should like to add to that, Gentlemen, by way of emphasis that we have borne in mind weldability in setting up this schedule. The carbons are kept low, and I think that you will find that if this low alloy program goes through, and makes satisfactory armor, that weldability has not been sacrificed. Maybe it will have been improved considerably."

It was further explained in answer to questions that just what the new compositions would be and when they would be available was not yet known. Col. Zornig remarked:

"We have to find something first that will work."

Since there is considerable interest in the possibility of substituting ferritic electrodes for the austenitic stainless electrodes for welding armor this subject was discussed at length.

Mr. Deppeler explained:

"These ferritic electrodes, as you know, have a tensile strength of roughly 125,000 and a yield of 116,000 which is almost the same as the armor plate. We believe that the weld can be very much narrower than the weld is now designed for the austenitic type of electrode, and that with 300° or 350° preheat, we will have everything that we need, but, in order to be sure, we want to get a lot of plates of the same heat

There have been some comments about honest electrode manufacturers this morning, and I would like to be honest with you for a moment regarding what some of our problems are. One mill cannot handle all the requirements and every time we get a new supplier, we've got to train that supplier on the surface of the wire which he supplies. Now I know some manufacturers have the problem in their own lap and have an advantage in that respect. A great many others, though, require the wire to be delivered in the manner which they can coat, and, furthermore, it has to be delivered, in addition, in the heat treatment condition which can be easily straightened and cut, sometimes without lubrication, sometimes with lubrication.

"There are a great many different types of problems there, but in general there is no way that I have been able to find yet to specify a wire surface which would give the same type of wire from one mill as comes from another mill, and we depend entirely on taking every batch of wire and running a test on it ahead of time before we coat it up to see whether that surface of the wire is going to give good adherence. You know, if you have done any experimental work or control testing, that you take a sample which you hope is representative, and you hope that when you have taken that sample, the results on that will be the results of the rest of the group. But you also know there are times when that is not the case and that we can take a sample, we can take one coil of wire, coat it up, and we will get a perfectly satisfactory result and send the rest of it through, and we know sometimes that the rest of it is not quite so satisfactory. We hope we catch that which is not satisfactory in the final inspection tests, but there again we are sampling. Mr. Garriott mentioned some with respect to the use of lime coatings and the use of the proper binders for them. There is the problem of the wire surface. There are a good many other problems which are involved in this adherence of the coatings to the electrodes."

And Mr. Maurath commented:

"I have overcome Mr. Thomas's difficulty. I lost a good many hours of sleep about 12 years ago, making coatings stick to wire. I overcame it by taking wire from any manufacturer there is, and grinding the surface of it."

Mr. Maurath advocated a center-grip electrode 18" long to avoid overheating. There was a lengthy discussion over the theoretical economies possible with Mr. Biederman arguing:

"I know you rod people don't want to go to the trouble of welding the holder to the end of the rod. It's a lot of trouble, but there are a lot of things we are going to have to do that we haven't done before. We are talking about a 50-, 60-, and 90-cent material against 2-1/4 cent material, and if the rod manufacturers don't want to do it, I suggest that we line up some individual source to do the job for us. You could coat your rod before you weld it on. You could weld it on before you coat your rod and have an automatic grinding outfit to grind a little flash off of it so that your rod would still go through your processing just the same as it does now beside the welding operation."

And Mr. Maurath countered with:

"Well, you have 15 feet of wire for the pound of 5/32, and about 11 feet to the pound of 3/16. Now you figure out the multiplicity of welds you make there and I don't believe you can save the price of that wire."

Mr. Biederman continued the argument for the mild steel end to be welded on to the stainless steel electrode prior to coating and made a motion:

"Mr. Chairman, I make a motion that maybe we could get some electrode manufacturer to co-operate and try this thing that we are talking about. Any information on butt, flash, or any other way to get the equipment, but I think the job should be processed with the electrode manufacturers."

Mr. Keating commented:

"That brings up the question of expense in trimming that flash, which, while it can be done - we know how to do it and all that sort of thing - yet it is kind of a nasty job, and, really, that little flash, as far as your welding is concerned, wouldn't bother you and you could go right ahead and weld, even though that flash is on these, but you couldn't extrude it, and the tolerances for extrusion are very, very small. We call them minus nothing or plus two or vice versa--within a couple of thousandths, and it has to be very straight. The least little lump will throw the thing off center, or it won't go through your wire guides. It is quite a ticklish process, because these things are shooting out of there 250 or 275 feet up to 600 feet a minute. That's pushing those things through there fast and we can't afford to have jams or anything that would introduce any more hazards in that process, so if you could do it afterwards, it would simplify things a whole lot."

Then Mr. Maurath added:

"Let's coat the rod up to the very top and arc tack the mild steel rod on top of it by going through a little automatic fixture and let the man come down and tack it on top of it. You are still saving, on every 1/4" to 3/16" rod, from 2 to 4 cents a rod with the mild steel piece on the end of it. Even if we do it by hand, we have got a terrific saving, and we save the high alloy strategic material."

Major Cox explained the position of the Subcommittee on this question:

"It is not a function of this Subcommittee to handle problems of that sort, which are really, in effect, detailed procurement problems, and we can't handle procurement. We can suggest, and

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we can devote the time to think about such things, and my only suggestion, unless somebody has a better one, is that between the electrode manufacturers and the users, that some scheme be worked out whereby this material that is being lost, which apparently averages close to 20%, can be saved. Mr. Biederman, I stand with you in principle, but I don't know what we can do to help you in this case."

Mr. Biederman requested comment from the McKay Company and Mr. Van Dreser responded:

"We have tried to get flash welding equipment to spot stubs on the stainless wire and so far have been unsuccessful. We have arc-welded stubs on at the rate of 30 a minute, which is considerably slower than our extruding process. However, if we put enough arc welders on the end of the extruding press, we can undoubtedly do the job, but it will cost us about 2-1/2 cents a pound for 3/16". The cost of the wire is 58 cents. The stub loss is 11 cents. We don't want to do it because it will clutter up our plant, but we will do it if the consumer wants to pay the additional cost."

Mr. Biederman commented:

"I was all enthused when Mr. Whitney spoke this morning. It interested me because I think one of these days we are all going to have to button up and go to work and try, because one of these days we are not even going to be able to go out and buy a pair of shoes. We are going to put Post Toastie boxes in our shoes to walk on, and that's just what we are getting to, and I think this Committee should start to co-operate and even if it's only a 1% saving, they should start saving right now--not wait 'til the thing gets critical--because that's what we have done, and have been in the habit of doing in this country. Things have come too easy for us, and they are going to come harder for us and we should start to work that way now."

At the suggestion of Mr. Danse this question was referred to Mr. Smyly of the War Production Board.

With regard to ballistic testing Major Cox referred to Lt. Reed:

"Lt. Reed has accumulated a lot of information in Aberdeen, for which we are all extremely appreciative. He is doing a good job, and part of his job is to get that information out to us. Will you tell us what your program is for getting this stuff out to us?"

To which Lt. Reed replied:

"The data that we have is not too conclusive, but we have learned something about testing. We have learned that on the 36"x36"x1-1/2" 'H' plate, you have to strike within about an inch and a quarter of the cross bar to cause any cracking on the first round. On the legs, you have to strike within two inches to cause

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any cracking on the first round. If you strike further away, you get no cracking, and if subsequent rounds go no nearer the weld than that, the plate comes through with flying colors, in spite of what the weld was. We have found that if the first round causes no cracking, and the second round causes cracking, the cracking caused by the second round is much more severe than it would have been had there been no previous round. Other than that, Major Cox, I'm afraid to say anything, because I started to say something yesterday and found out that I was basing conclusions on information that wasn't consistent with the name, to wit: electrode No. 1 wasn't always electrode No. 1."

Major Cox interposed:

"Mr. Brooker has just handed me a note, which I think you will be interested in. It's been approved by the Office, Chief of Ordnance, that WAS No. 1 forms do not require notarization --simply certification. That may expedite getting the plates out. The certification is the signature of any responsible official of your company."

Lt. Reed remarked that the WAS form had been revised at Aberdeen Proving Ground and that a WAS-2 form was in process. He distributed samples but cautioned that the samples were not yet in final approved form. This new form consists at present of three sheets instead of one as explained by Lt. Reed:

"It involves three sheets. He wasn't acquainted with the other two sheets yet. No. 1 gives ample space for describing joints and writing remarks on the opposite side, enough room for you to sign your name, and incorporate about all the information that the various people requested be on the WAS form. However, we find that they don't even fill the form out as it is now. Page 2 is the X-ray report, on which we place what we see in the X-rays. Page No. 3 is the ballistic report, showing what happens with each round, and there is a scale drawing of the 'H' plate here, on which the location of the crack and of impact is located to scale."

Mr. Smith of Marmon-Herrington commented:

"One thing that I would criticize on the form is that it's not spaced for typewriter use. It is adequate if it is going to be filled in by hand, but it takes up more space than I feel is entirely necessary, particularly if you are going to add two more sheets to it. Now, I have prepared an alternate suggestion here that is spaced for typewriter use, and still has the same amount of space for sketching as the original WAS 1 Form, which, as far as our work has been concerned, has been adequate. It does not provide space for a lengthy group of remarks, but I feel that where those remarks are necessary, it is entirely possible that a separate sheet of letterhead could be added to cover that.

"I have included on this sketch also the ballistic record, which appears on the original WAS form which does not appear on this one. However, since that has been supplemented by two additional sheets to cover that, I don't feel that that is entirely necessary, which will give us more space for sketching, or some remarks, if required. I think that just in the interest of conservation of materials--in this case, not so strategic, but from the standpoint of bulky volumes, I'd like to have it considered, at least, that it be reduced in size to the point where it can be a single sheet without a fold.

"Now, I would also like to voice an objection to the form of your shock test report sheet, which is sheet No. 3, in that it is limited entirely to tests of 'H' plates. We happen to be in a position, and know of two others of us in the face-hardened group, that an 'H' plate does not give us, I'm hard put as to what word to use, but a comparable test to that which would be found in a portion of the structure. This brings up a point that should later come up, according to the agenda, but I will confine my remarks at the moment to the statement that as far as radiographic inspection is concerned, there are at least two of us in which it is impossible to make a radiographic inspection of the weld structure. Now, that may seem very peculiar, but if you have ever tried to radiograph a butt strap weldment, you will know what I mean."

Major Cox replied:

"I would like to make this remark, to apply to all of you on this form: that you study this as soon as you can and write your comments into a letter to Mr. Brooker down at Washington. Then, Mr. Brooker can either attend to it himself or he can appoint a committee. He's closest to these specification details. He's closer to them than we are at Watertown. It all totals up to the fact that the acceptance of any official form has to be done in Washington, so we will let Mr. Brooker handle that."

Mr. Burgston of Deere and Company commented about a point of design of the tank hull:

"I happened to be over to the Rock Island Arsenal last week. Mr. Brooker was there, and on the conversation of welding rods, of the armor plate type, we ran into several jobs on parts that are out of the line of fire, like the back of the pistol port door, the back of the driver's door, and it seemed to us that a low grade welding rod could be very readily used. These parts are not highly stressed and it does seem that a straight carbon rod could be used in the fastening of hinges and clasps and parts that are not highly stressed, on the back, for example, of a pistol port door. Now certainly, if another type of welding rod could be used for parts of that type, it would represent quite a saving in the use of the 25/20 or the 18/8 weld rod. Of course, those are things that we can't do anything about, but it does seem to us that the Ordnance Department could well review some of those specifications and probably use a carbon steel welding rod on parts that are not heavily stressed and that are definitely out of the line of fire."

To which Mr. Brooker replied:

"In this particular thing that Mr. Burgston has in mind, the pistol port cover for the M-4, to go up to the Fisher Tank Arsenal, it is a closing lever, specified in the drawing to be 1045 steel and to be welded into the cast armor with a suitable electrode. The Ordnance Department has already changed that to 1020 steel. Those concerned will get an official notification and meanwhile we asked Mr. Burgston to consider and do some work on the use of a ferritic electrode with suitable preheat.

"Now, that part, and others fastened to armor, are not necessarily unimportant. We all, in the Ordnance Department, have seen what will happen to a pistol port or a door of a tank, if it isn't made right, or if the parts are not held together properly, so it isn't too easy to say that we could use the Fleetweld 5 instead of 18/8 in making welds, but to the Districts and to the contractors here, please be on the lookout for such applications of welding which have been missed and in which cases a qualification of welders and welding procedure by AXS-497 is actually ridiculous. We have worked this problem out with Mr. Burgston. There may be others."

Mr. Raymo commented:

"It has just been implied that the fabricators have been asleep. How do you suppose these pistol ports have been put on for the last year? That's all medium steel now. There's no stainless steel being wasted on that application at all. I think Mr. Bibber, of Carnegie-Illinois Steel Company, was the first one who sponsored the use of the ferritic rod for that application, and I think they are doing it at the present time."

To which Mr. Brooker replied:

"Mr. Raymo, there is no argument about splash beads at all; this is a new pistol port for the M-4. The fastening and part of the welding are on the back side of the door proper. It is part of the closing mechanism."

And Mr. Bibber added:

"I am a little bit more concerned about things on the inside than I am about things on the outside. Things on the outside can be shot away and not do a great deal of harm. I think we should be a little more careful about things on the inside, which can cause parts to fall off and be knocked around in the tank. I think that should be borne in mind in any of these ventures."

This point made by Mr. Bibber is considered to be a fundamental principle of welded construction and one of the main reasons for superseding riveting and bolting by welding.

Since Dr. Drury had not been permitted sufficient time before lunch to make a report on the welding of armor in Canada, Major Cox now called upon him at this time:

"Now we have one other little item to catch up on. Dr. Drury

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didn't finish this morning, I'm sure. I would like to give him this opportunity to complete his report. Dr. Drury."

Dr. Drury remarked:

"I was very much impressed this morning with the talk given by Mr. Whitney and in that connection I should like to refer to some compositions of armor plate which have been used in Canada. About a year ago we were using the nickel-chrome-moly steel that is around 3.5 nickel, 1.75 chromium, and .5 moly, but shortly after its production, it was found that you could get a better ballistic resistance plate, although I will have to qualify that statement, chrome-moly combination containing approximately .75% nickel. Now since that time, the composition of armor plate as used in Canada has changed again, and at the present time, for castings, we are using a chrome-moly without any nickel, and another manufacturer is using practically the same analysis with .75% nickel. For plate of 1/2" thickness and under, a composition approaching X-4130 has been proven to be very successful, and I believe that plate will be adopted before very long.

"At the present time, for 1/2" plate and under, one manufacturer is using a plate containing under 1% chromium, under 1% nickel and about 0.40 moly, but the vanadium has been dropped. No vanadium has been used in Canadian plate, Canadian armor steel, either for plate or castings, for possibly, oh, at least six months, so that falls in line with what Mr. Whitney mentioned this morning about being able to make armor plate which will stand ballistic attack without the use of vanadium, and also it is possible to use one which has a very much lower content in nickel.

"Now, in quenching, it has been found, I think, at practically every heat-treating plant, that a fully martensitic structure is not obtained on quenching, but more of a ferrite and possibly troostite. When that is drawn you are not able to get the tough sorbitic structure which is mostly desired. So, therefore, experiments have already been conducted which seem to indicate that with improved heat treating processes that a certain percentage of alloy may be saved.

"The question of the hardened zone in welding has caused considerable discussion, and I would like to note that our ideas on hardened zones are not similar to any which have been expressed here today. The alloy and carbon content regulates the critical cooling rate in the formation of the hardened zone. With high alloy and high carbon, the hardened zone is going to be considerably greater than you have the lower alloy and the lower carbon and that point, I think, can be solved better by metallurgical considerations because it is entirely a metallurgical problem that if you go high in alloy, it's necessary to reduce the carbon; but, on the other hand, if you reduce the alloy, you will get a lower hardened zone. For satisfactory vehicles, that is, welded vehicles, we place the limit of the hardened zone at approximately 400 Brinell and with the 400 Brinell in the hardened zone, we believe that it is quite possible to have a vehicle which will be entirely satisfactory in service.

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"About fifteen months ago the specification for armor plate was around 375 or 385 Brinell but since that time it has been reduced to 275, and on this plate, a hardness of about 190 Brinell has produced good ballistic resistance, so it is the feeling that there is a possibility of still lowering the Brinell hardness of the plate which is being produced at the present time from 275 to possibly 225 Brinell; and if that is the case, it may assist greatly in solving the problem which is presented to us by the hardened zone problem in connection with automatic welding. In automatic welding, the increase in hardness of the hardened zone runs from possibly 75 to 125 points Brinell depending on the thickness of the plate. With plate of around 7 millimeter you get practically no hardened zone whatever, but when you get up around 10 millimeter, 3/8", the hardened zone forms and the degree of that hardened zone depends on the initial hardness of the plate, because if you should start with a plate of 375 Brinell and get an increase of 125 points, then you would have a hardened zone running up to 500 points Brinell. The reason why I happened to mention 375 points Brinell for a thin plate is that the manufacturers get bigger production when they draw to 375 as compared with under 325, so the specification at the present time for plate up to 5/8" has been set around 320 to 340 Brinell with the result that when that is welded with the automatic machine, a hardened zone of around 400 Brinell is obtained.

"At the present time scout cars having plate up to 30 millimeters in thickness are being welded. The plate used is homogeneous. No face-hardened plate at all is used. The plate is being sheared. Plate up to 320 Brinell can be sheared up to 5/8" in thickness. Above that, flame cutting is practiced, and for plate 1" or over in thickness, a preheat goes ahead of the cutting torch.

"In welding, the automatic process is used for line welding, and for finishing of the various assemblies, hand welding is used. At the present time this amounts to about 50% of each one. There is no preheating of the subassemblies being welded, nor is the completed hull post heated. All the operations are conducted without any heating whatever. And then the order in which you weld parts: Ordinarily a person might just go ahead and weld subassemblies together and then you find when you finished that the last parts will not fit. There is a certain order to weld subassemblies together and that order will have to be found out. It cannot be laid down. The fabricator will work that out for himself. The electrodes which are being used are the ones on the basis of the 25/20, which is a modified, either with manganese or molybdenum, or the 18/8, which is the modified type of it as well, with the manganese or molybdenum. Both rods give satisfactory welds, and are resistant to ballistic attack, although no shock test is applied whatsoever.

"A number of those scout cars have been delivered and production on the assembly line is starting and will be proceeding quite rapidly as fulfilling the specifications as to dimensions, and one pilot model has been in service for several thousand miles and it has not shown or developed any cracking whatever. One interesting test which we have conducted within the past few weeks is to repair

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a tank in the field after a hole is blown through the side of a plate. It is possible to weld a patch on the side of a tank, and, after firing, the welded joint or patch did not loosen or show any cracks whatsoever. It is a development which will have to be studied, but the test which was conducted was done with a circular piece of plate, of the same thickness as the sides, which was welded over a shot hole and a number of shots were placed right adjacent to the weld, and there was no evidence whatever of cracking or loosening in any way which could be found. Tests have also been conducted to cut out a piece of plate, but that has not proved as successful as putting a patch on the outside."

On being questioned as to certain details, Dr. Drury remarked:

"On the automatic machine, we run up to 5/8" in one pass. With hand welding for the same thickness, four passes are used. In that connection, I mentioned sometime ago that we were shearing plate. Now if you take two square-edge plates and put them together to fit the side of the scout car, you have an included angle of 17°. That's according to the set-up of the design of the vehicle. At the start, everybody said you couldn't weld with a 17° included angle, but it is being done and most of the angles are under 45°, included angles, and we are getting excellent welds. The physicals on the weld metal run about 100,000 tensile and upwards of 65,000 yield, around 40 to 50 or 55% elongation on 2", and that's about the type of weld."

Mr. Keir asked:

"I would like to ask Dr. Drury if flame cutting is used to any extent in Canada on this program, and to what extent? Do you find it accurate enough for the purpose? Is there much deformation or are there any advantages at all you have found in the use of flame cutting?"

To which Dr. Drury replied:

"As I mentioned, up to 5/8" is sheared. Above that, 3/4" or over, it is flame cut. No difficulty is found in their cutting to within, I would say, possible 1/32" of the line with flame cutting. If you preheat, you don't have any trouble, but you preheat if you want to flame cut, especially an angle."

There ensued some discussion regarding details of a joint fit-up. Dr. Drury emphasized that a narrow groove with maximum root gap of 1/8" is used for machine welding. With reference to minimum temperature for welding, Dr. Drury remarked:

"The building on a cold day is just ordinarily heated as any other industrial plant, but we do not permit welding to be attempted if the plates are below 50°F."

To which Mr. Chyle replied:

"That's very interesting because all of our work, even on mild steel in heavy sections, requires that the temperature of the plate be at least 60°, and on alloy plate, we have found that they have to be at least 70°. We encountered trouble, cracking trouble, particularly over weekends, where the building isn't heated, and the temperature is liable to come down to 40°. Then on Monday morning you always have trouble on account of that."

Upon being questioned regarding armor plate hardness, Dr. Drury replied:

"As I mentioned, about a year ago, or a little more than that, all plate under 1/2" was drawn to a Brinell hardness of around 365 to 388--in that range--because it gave them good penetration, but to build vehicles it is necessary to cold form them, and you can't bend a plate of 375 Brinell and have it meet certain accurate specifications, so to do that it was necessary to work out some method of cold forming plates. The only way we could get it, and we got onto it accidentally, was to draw them to 275 Brinell, and those plates satisfied all of the standard ballistic requirements."

Dr. Drury further explained that in the tempering operation for 190 Brinell hardness the plate is held 8 hours at temperature. Mr. Vennerholm uses 6 hours.

Mr. Vennerholm explained:

"Dr. Drury stated that by lowering the Brinell hardness of the plate, he is able to lower the hardness of the heat-affected zone. We are of the opinion that the hardness of the heat-affected zone is more or less in direct proportion to the amount of heat put into the plate regardless of the Brinell hardness of the base metal."

To which Mr. Drury added:

"The lower the Brinell hardness, we have concluded that you will get a lower hardened zone, that is, the maximum hardness of the hardened zone. As to the reason for that, I can only express my own opinion. That is, when you draw a plate to a low Brinell hardness, you precipitate some chromium carbide, and if your quenching is done right, you end up with a very fine sorbitic structure. In welding, you reheat those precipitated carbides and it is only the alloy which goes into the solution that controls your hardened zone and if those alloys are not dissolved in the welding you do not get the hardness on cooling."

According to Dr. Drury nickel is not being used for homogeneous armor plate in Canada and with respect to tempering temperatures he added:

"That varies entirely with the thickness of the plate and the use of the plate. Plate is made from 1/8" to 3". On the thin plate, some of that is drawn about 35 or 40 minutes, about 1150°. On the thick plate, the drawing temperature is an average of about 1150 to 1175°, and the time varies with the thickness. That is, up to two to three hours. The plate is air quenched from the draw."

Major Cox raised a question:

"Thank you very much, Dr. Drury. I think that the one question in minds of most of us is that we don't have quite the same

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concept of the hardness of this thin plate, as the example that you cited, and I think just to clarify that, we would like to know if that wasn't a rather special instance, rather than general. In other words, we don't think of hardnesses as slightly under 200 Brinell in plate around 1/4" to 3/8". That was a rather special case, was it not?"

To which Dr. Drury replied:

"Well, Major Cox, it was just the result of an experiment which was undertaken. It wasn't on one plate. There were 8 plates drawn--8 plates measuring 75" x 58", which were drawn to that lower Brinell hardness. We don't believe ourselves, at the moment, that a lower Brinell plate, below 200, will withstand ballistic attack as well as the harder ones, especially at an angle attack. It was just the result of an experiment, but we are of the opinion that we may drop to around 250."

With reference to waldability test requirements proposed for armor specifications, Mr. Thomas explained the work done:

"Gentlemen, I would like to acknowledge first the work of the other people on that weldability proposal. When that was first written up, it was written up by me without having made one test. It was felt by everyone, including the fabricators, that there was a definite need for some sort of a control on weldability and we needed it fast, and in discussing it with a number of people, we just thought that possibly a bead test, such as Dr. Warner has gotten a considerable amount of data on, could be a control. So, that test was written up, originally almost entirely on the results of Dr. Warner's work, and the credit should go to him. Furthermore, the modifications that were made in writing that up were the results of tests made at the Lincoln Electric Company, and the proposal that a Rockwell C machine be used instead of the less common Vickers hardness tester. I have been given the credit for that work, and it should go to Doc Warner and the Lincoln Electric Company Laboratory. But, to go into it further, we did get a number of samples from Aberdeen. Lt. Reed sent me a number of different plates, or pieces of plates, and we did run some tests, in which we found out that there were very definite flaws in the way it was originally set up. Consequently, the copies which are now available have a revision as recommended by the Subgroup, taking into account those difficulties. I don't believe that we've got the final answer, by any means, on weldability testing of armor but we do have to have some sort of a test and here is something that we might as well find out whether it is any good right now. I believe Mr. Brooker said it's being incorporated in the specifications. It certainly will be put up before the armor suppliers' committees as soon as possible and the data which I have and the data which other people are getting can be discussed before those groups. I would like to urge any laboratories that are set up and are apt to run into different lots of armor plate of different classes, that has a control on whatever testing they are doing, that they run this weldability hardness survey. We are continuing the work on it with

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the idea of seeing whether the test is any good. I think the work that some of the fabricators who are making up welded joints all the time should keep in mind not only whether the test is any good, but whether the limits that are specified are correct. They are making up welded plates all the time, and if they feel that the difficulty they are getting into is on account of armor, let's find out what the hardenability by welding of the plate is, and consequently find out whether the limits which we have specified in that test are satisfactory. I think probably in another month or six weeks we ought to have sufficient data to prove one way or another whether that test will be an adequate control for weldability."

Copies of the proposed test specification have been distributed. Lt. Zweig referred to a proposed tentative specification for radiography known as WXS-71 for cast armor as an attempt to devise a method of acceptance without so much ballistic testing. It was indicated also that standardization of a shock test was in progress at Aberdeen Proving Ground. Lt. Reed discussed this activity for armor 1-1/2" thick.

Lt. Reed commented as follows:

"Through the full co-operation of many people who realize that a shock projectile, angle and velocity should be based on our equation; those people, realizing that they didn't learn too much by shock tests that we almost got 100% pass on the shock, concluded that something that didn't tend to penetrate and tried to expend all its energy on the plate would be more successful. We tried that projectile with very good results. Mr. Vennerholm over here said he didn't have any conception what he wanted to make in armor plate until it had been shot by that projectile, and finally we have standardized on a hot rolled, 1120 type, S.A.E. 1120 type steel, fifteen-pounds slug. I noticed the Manufacturers' Subgroup recommended three rounds at 1200 feet per second and we are at present using two rounds at 1100 and one round at 1250. If the manufacturers want us to shoot three rounds at 1200, and feel that the results we will get with three rounds at the same velocity will be comparable to the results we get with two rounds at 1100 and one at 1250, that will be perfectly satisfactory with us."

According to Mr. Danse, a 57 mm. slug of 6 lb. is to be used on 1" plate. Upon being questioned with reference to 1/2" and 3/4" plate and the test to be used, Lt. Reed, admitting nothing was being done at present, remarked as follows:

"That's why I was so willing this morning to let someone else test face-hardened armor plate. I do not have sufficient faith in the caliber .50 machine gun bursts as a shock test. I don't like to use 37 mm. A.P. at an angle, nor do I like to use a 37 mm. T.P. projectile which, at the velocity to give shock, either deforms considerably or else penetrates."

Lt. Reed continued his remarks pertaining to the mechanics of plate deformation:

"Well, there's a question there that I don't think we have

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thought enough about, and that is that we use a 36 x 36 plate consistently, but is the beam structure of the plate consistent? Is it true that the maximum fiber stress on a thin plate would be less than the maximum fiber stress on a thick plate, for the same deformation? I think that there are men in the room who have 1-1/2" welded plates, who have had a dish considerably greater than 1-9/16". We have made washbowls out of some of those plates without cracking, and then again, I don't think that the test on the plate is adequate. In other words, you are going to have to give the light plate in that large size much more deformation before you produce the conditions that you are requiring in the 1-1/2" plate, but we're so inconsistent I don't know why we should try to be consistent in that."

The question of the next meeting was discussed and Major Cox suggested:

"We still have to have a reason to hold a meeting. We won't just hold a meeting unless we have something to hold a meeting for, and we need results from the subgroups that have been formed. They have programs ahead of them. Why don't we leave the question of the next meeting and the place of the next meeting open, and we can settle it later on."

Major Cox then brought up the question of Chairman of the Subcommittee:

"Now, that about clears up the scheduled portion of our agenda, but there is still one topic that is not on your printed agenda, and that is the question of your Chairman. Due to the fact that your present Chairman is going to have a little different activity, he is going to step out of the Chair and in so doing nominate Col. H. H. Zornig, who is Director of the Laboratory at Watertown Arsenal, as your next Chairman. Gentlemen, I recommend him highly. He has a vast knowledge of the background of these things and when you get to know him, you'll thank me for nominating Col. Zornig."

There were no other nominations and Col. Zornig was elected. After a motion by Mr. Thomas:

"Before we adjourn, I would like to make one other motion—that this Subcommittee, by a rising vote, express its appreciation to Major Cox for his able direction of the work of our meetings."

The meeting was adjourned, following the reading of a telegram from the past Chairman, Col. S. B. Ritchie:

"Your kind sentiments recorded at last meeting and reported in Mr. Bibber's letter noted and appreciated. The feeling is mutual."

Since the previous meeting on 7 January, Col. H. H. Zornig had taken over as Director of Laboratory at Watertown Arsenal, replacing Col. S. B. Ritchie, and as such became the logical choice as Chairman of the Subcommittee. Also, it was apparent from Mr. Whitney's remarks that since the previous meeting of the Subcommittee the War Production Board had made a very comprehensive study of the metal alloy stockpile in the United States.

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Because of limitations in supply of certain alloys it appeared that industry must find ways and means of making armor with less alloy. This trend should facilitate the problem of fabricating armor by welding. It was also evident that the fabricators were becoming very critical of the Ordnance Department's method of ballistic testing their welded test plates, particularly face-hardened armor. As a result a Face-Hardened Armor Fabricators Group was organized and the Research Program Group then came to be known as the Homogeneous Armor Fabricators Group. This also was the first Subcommittee meeting to be held on Sunday.

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EIGHTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
SUNDAY, 21 JUNE 1942
HOTEL STATLER, DETROIT, MICHIGAN

The eighth meeting of the Subcommittee was held in Detroit on 21 June 1942 at the Statler Hotel, with 135 persons in attendance representing:

Fabricators	41
Armor Producers	4
Electrode Manufacturers	36
Ordnance Department	21
Army Service Forces Headquarters	1
U. S. Navy	3
War Production Board	1
National Research Council	2
Guests	26

The meeting was opened by Col. Zornig, Chairman of the Subcommittee, with introductory remarks:

"Good morning, gentlemen. I hope everyone here has signed an attendance slip. It will dispense with the necessity for calling the roll, if everyone has signed up. If not, will you please raise your hand? Is there anyone here who hasn't signed up? We will have lunch in the next room, and all those who expect to take lunch here have indicated on their sign-up slip, so there will be lunch provided for each one of those who has signed up. I want to call attention again to the fact that the welding of armor is a subject which is on the restricted list, and you should govern yourselves accordingly about discussing it outside of this meeting."

After welcoming the representatives of the British Army Mission as guests of the meeting, Col. Zornig briefly discussed Subcommittee organization and changes which had been planned since the last meeting:

"In considering the volume of the work that is coming through this committee, it has been decided to organize a small Specication Subgroup which will have on it one member from the Homogeneous Fabricators' Subgroup, one member from the Face-hardened Fabricators' Subgroup, one member from the Electrode Subgroup, and men from the Ordnance Office who have the power to make specifications or write specifications—the idea being that after the specifications or features of the specifications have been discussed at the large meetings, that we have a small group of those who can represent the industry, and those who represent the Ordnance Department, which can be called together quickly to do something about it and finish the matter up. If there are any objections to that scheme, I would like to hear them. I take it that you agree with that.

"Now the metallurgical research work of the N.D.R.C. has been turned over to a branch of the N.R.C. and they have organized a

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section in which Mr. Mikhalapov is the supervisor of the welding research. Mr. Mikhalapov is here and is a member of this committee, and later on will tell us what they are doing. He comes to the committee meetings for the purpose of reporting what progress has been made--when progress has been made--and to see what problems need to be worked on. In order to help them out as much as possible, and give them some direct contact with N.R.C., I think we ought to set up in this committee a Research Subgroup on which again we will have one member from each of the Fabricators' Subgroups, and from the Electrode Subgroup, and the people from the Ordnance Department who are concerned with it, who can furnish a direct pipe line, as it were, to recommend research problems to N.R.C., which may originate in this group. Are there any objections to that addition to our organization? If not, I will consider that it has been approved.

"We have a Subcommittee on Resistance Welding, separate from this Subcommittee. It was thought originally that the tank builders probably would not be interested in using resistance welding and that the aircraft people would only be interested in that. However, it turns out that resistance welding, spot welding, flash welding may become decidely of interest to the tank builders and combat vehicle builders, and arc welding may become of decided interest to the aircraft manufacturers. Therefore, it seems it may be desirable to amalgamate the Subcommittee on Resistance Welding with this Subcommittee, setting up in it a separate group, and to ask aircraft armor fabricators if they care to, to join this committee with a separate subgroup of aircraft armor fabricators. I propose to go ahead with that unless I hear objections to it. Do I hear objections to that proposal? If not, I will consider that you will agree with me on that. This will take some little time to get this all arranged, but I think it will provide much better facilities for the exchange of information."

As a result of this proposal the following Groups were organized and set up in the Subcommittee organization as announced by Col. Zornig:

Specification Group:

Captain J. V. Coombe (Chairman)	Office, Chief of Ordnance-Washington
Mr. B. J. Trautman	Pullman Standard Car Mfg. Company
Mr. A. L. Abbott	Diebold Safe & Lock Company
Mr. M. H. Rutishauser	Harnischfeger Corporation
Mr. E. Brooker	Office, Chief of Ordnance-Washington
Mr. E. L. Hollady	Office, Chief of Ordnance-Washington
Lt. W. C. Pless	Aberdeen Proving Ground
Mr. W. L. Warner	Watertown Arsenal
Lt. A. F. Boucher	Tank Engineering Office-Detroit

Research Group:

Lt. Col. J. H. Frye (Chairman)	Office, Chief of Ordnance-Washington
Mr. L. A. Danse	GMC, Cadillac Motor Car Division

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Research Group (cont.):

Mr. B. J. Smith	Marmon-Herrington Company
Mr. R. D. Thomas, Jr.	Arcos Corporation
Capt. J. V. Coombe	Office, Chief of Ordnance-Washington
Mr. E. Brooker	Office, Chief of Ordnance-Washington
Mr. Sidney Breitbart	Aberdeen Proving Ground
Mr. W. L. Warner	Watertown Arsenal
Mr. G. S. Mikhalapov	National Research Council

Resistance Welding Group:

Membership to consist of the members of the existing Subcommittee on Resistance Welding.

Aircraft Armor Fabricators' Group:

Membership to consist of representatives appointed by the various aircraft fabricating companies to the Subcommittee membership.

Following the remarks on Subcommittee organization, Col. Zornig continued a discussion of the general armor compositions currently being produced:

"The cast armor manufacturers have practically standardized on the compositions they will use. All of you, more or less, know what they are; I don't care to take up the time here in going into the details of each manufacturer's compositions. You all know they have gotten down very low in alloys, and that the armor is strictly a water-quenched job now - as drastic a quench as they can get. I think all the draw temperatures are well up along 1100. Unless something comes up which we don't know about now, the cast armor people will probably keep along on production on the compositions they are now using. I see nothing in the immediate future on which would change that.

"The face-hardened armor producers are getting pretty well down toward 3% nickel, and will try to get down another per cent of nickel. The other alloying element will vary with the manufacturer, but there probably will be only two, more or less, standard types of face-hardened armor.

"With the homogeneous rolled armor, there are two types which seem to be in the way of becoming the standard types. One of them is the manganese-molybdenum type. There will be small variations in composition in that; and the other one is the salt-and-pepper type with a little of everything in it - chrome, manganese, molybdenum. Some of them have a little nickel in it. That will vary from manufacturer to manufacturer, depending upon his scrap pile and his furnace equipment, and other local conditions. But of the alloys or the elements, there will probably be not much over 1/2%, if any over 1/2%. Just when they will get into production on the final compositions that are now being considered, I don't know; but it will probably be several months before they get really into production on these extremely low alloy steels. For the present, they are working down on certain intermediate compositions."

Following this summary, Mr. Wilson of the War Production Board gave a

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brief summary of the alloy situation:

"The nickel situation is more or less unchanged. Chromium is probably easing a little bit at the moment. We will probably always have trouble with vanadium, because that is, in the strict military sense, a strategic material - it comes over water. Last month we didn't get a boat; this month we did. The situation with regard to molybdenum is being considered very serious at the moment. But tungsten is probably in a little better shape now than it was six months ago. The manganese situation is not in such a comfortable position as it was. We will have to be careful to husband the manganese we have if we have large demands on that element for armor plate, helmet steel, or for use in magnetic mines. Finally, silicon - we have an unlimited supply of the raw material. It is a matter of supplying electric furnaces, and if we use the electric furnaces to produce more ferro silicon, it means we will be taking that furnace capacity away from chromium. I would like to point out that when we indicate that National Emergency steels are to be used, no virgin nickel or new vanadium is issued for the manufacture of those types. The nickel must be gotten out of scrap on hand or from other sources. Those alloys are, in the stricter sense, a good conservation. They contain half chrome and half nickel and some molybdenum. Along the same line, it looks like we have in prospect other fields even leaner in the total alloy content, but there will be still this mixture of chromium, nickel and molybdenum. It is proposed that these still lower alloy steels will contain probably about .25 nickel, around .25 chrome, and .20 molybdenum, may feature a little higher manganese, and will be over that, without molybdenum - probably 0.5%.

"Finally, I would like to tell you the good news, that we have an alloy scrap segregation order in 24-C. The purpose of this order is to compel the accumulation of scrap, even in comparatively small amounts in the hands of producers of scrap --that would be the people who do machine shop operations or collect forging scrap at the forging shop. The scrap is to be segregated according to composition, and we have groupings for the alloyed irons and steels. This is significant because as I mentioned a little earlier, we are not allowing the use of virgin nickel for the manufacture of the National Emergency chrome-nickel-molybdenum steels. Nor will we issue new nickel for any of the other alloy combinations that I just mentioned as being potential analyses. This means if the steel mills want it, and don't have the chrome-nickel-molybdenum scrap or nickel scrap, they can buy this material which is being collected on the market. The O.P.A. has priced these different scraps according to the combinations. As you know, the nickel and molybdenum are recovered with very good efficiency. The prospect, for example, in A.P. bullet core, where we have a very big tonnage, it looks as though, in a rough estimate, that two-thirds of the steel being supplied as shot bars and being machined, that we can probably recover 1,000,000 lbs. from that source alone by a careful selection and segregation of this scrap."

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In answer to a request about titanium Mr. Wilson replied:

"As between columbium and titanium we have been a little bit bothered to know which way to jump. As far as columbium and titanium are concerned, there is probably an even division of those types now. The recent tendency has been to shift from the columbium type into titanium. If you recall, a year ago, there was a shortage of nickel and people rushed into chrome-molybdenum, and as a result we had a pretty bad chrome shortage around the turn of the year. Since then we have advocated the shifting from the chrome steels to the molybdenum. So what we have to do now is not to make extensive and sweeping changes, and keep a balance all the while in the use of these materials. That applied to the columbium and titanium situation as well as it does to the other alloy metals."

In answer to a request about chrome and nickel for welding electrodes, Mr. Wilson replied:

"We are considering the chromium and nickel burden for all uses, and I would surely not be in a position to say what the situation would be with regard to that substitution. The point of view that I have given here has attempted to allow for the use of chromium and nickel in the use of stainless welding rod. Now, of course, as long as we have those extensive uses of chrome and nickel, that will be a big factor in the picture. I would be inclined to think that whatever the situation was several months ago with regard to the use of that stainless weld rod, probably hasn't been changed."

The connection between WPB and Army-Navy Munitions Board was explained by Mr. Wilson with respect to chrome and nickel control:

"In that particular case, I will say this, that since the PD-391 has come into use for the control of melting schedules in the steel mills, our working agreement is much better than before, and in fact, we are better acquainted with what each group is doing now than heretofore. With regard to the limitation of 10% 'max' nickel, that was an attempt to conserve nickel in a significant way, where it appeared it wouldn't be doing anything detrimental in the prosecution of this welding program on tank armor. As a matter of fact, we made provision for giving relief on that 10% 'max' nickel as soon as arrangements are made. It is also understood that as soon as experience is gained in the use of this material, maybe the limit can be lowered to a range like 9% to 11.50, or 8.50 to 10.0. If that is going to come about progressively as a result of your work, we are not going to interfere with the delivery of nickel in the meantime."

Mr. Chyle proposed a question:

"In some respects the use of vanadium in high tensile steel electrodes is absolutely necessary. We know of no other substitute for this element. The quantities of ferritic vanadium used are small. I think 5000 pounds to 10,000 a year would take care of most of the electrode requirements. Is it possible to get that minimum amount?"

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Mr. Chyle further explained that vanadium is used in high tensile electrode coatings in amounts:

"I believe on the basis of full weight of electrodes it would be about 1/100 to 1/500 of 1%."

This electrode is used for aircraft work as explained by Mr. Humberstone:

"One of the greatest uses at the present time is in the aircraft industry where they are after high tensile and high yield. After the welding is done, the final assembly has to be heat-treated. It is and has been used for quite a long time in that particular application."

Mr. Chyle further explained:

"We regularly make reports to the welding section there, to the WPB, in which we tell them the amount of rods we manufacture containing vanadium. I think .03 is about the amount we are using at the present time for coating. And we give them all those figures and report on our supplies on hand monthly. We have also written a letter to them explaining rather fully just how it is used, and what per cent is left in the weld, and the whole picture. You will find that on file. Of course, we run pretty much on priorities and beyond that its application is governed, I'd say, by the individual manufacturer in recommending where it is to be used. Otherwise, we don't use it indiscriminately. There is a definite use, and definite tensiles have to be required in order to use that. Of course, the price will govern the use to a certain extent. Nobody is going to use that kind of a rod when we find something cheaper to do the job."

To which Mr. Wilson replied:

"I will be very glad to carry that story to the Army-Navy Munitions Section, and the Board."

Mr. McDowell reported on the meeting of the Homogeneous Armor Fabricators Group held the day previously:

"Prior to the meeting of our Subgroup yesterday, two previous meetings had been held in the early part of June - June 1 and 8 to be exact, here in Detroit - and these two meetings were held for the purpose of standardization of plate edge preparation on the Medium Tank M-4. Prior to this time, of the several fabricators of the Medium Tank M-4, there was considerable variation in the plate edge preparation used by the different fabricators, and consequently this imposed a considerable hardship on the armor plate supplier who was forced to make, in his flame cutting of the plates, different templates for all the different fabricators that he was supplying. And in these two meetings, the fabricators of the Medium Tank M-4 agreed on the standard plate edge preparation for the majority of the plates on this particular vehicle. At the present time the standardized drawings are being prepared, and probably will be in use in the near future.

"The Subgroup went on record as being of the opinion that

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the shock test on the 1-1/2" plate as now specified in AXS-497, revision of June 1942, is too modest a requirement and is an inadequate measure of performance as regards the quality of the joint. This committee recommends that the test shall require a minimum of two impacts within the specified areas, but with one impact registered on each leg of the specimen. In regard to the shock test on the 1" homogeneous plate, the various fabricators were of the opinion that the present test using the 75 m/m slug was too severe. Work is also being carried out on an explosive test, using dynamite as a means of supplementing the present ballistic test. Now, this explosive test is by no means planned to do away with the ballistic test, because it is a known fact that it is impossible to exactly duplicate the result of the ballistic test. But this explosive test, if it can be worked out, would be used to test miniature specimens of a welded joint, to give the fabricator an idea of the quality of the weld without the necessity of making up a complete test plate for the ballistic test.

"With regard to automatic welding, it was brought out that several of the fabricators are using automatic welding at the present time, and production and advancement along that line is being accomplished every day. However, at the present time, it is limited mostly to the thinner plate sections. Very little work has been done on it - I should say very little work with appreciable success has been done on the heavier plate section. Also, in regard to electrodes, the specification for electrodes for armor plate welding recently drawn up by the General Motors Organization was discussed at the meeting and the Group went on record as being in favor of the adoption by the fabricators of the electrode specifications. In regard to welding procedure, it has come to the attention of the Subgroup that extra legal restrictions have been locally prescribed regarding welding procedure, and it is, therefore, recommended that welding of armor be controlled by, and in view of, AXS-497, of the latest revision; further, that this Subgroup recommends that any such local restrictions be immediately withdrawn."

The Group also recommends certain changes in AXS-497, draft of June 1942, according to Mr. McDowell:

"On page 6 of the specification, paragraph F-2b(1), the Subgroup recommends that this paragraph be changed to read as follows: 'There shall be no official Ordnance Department qualification of welders, this being the responsibility of the contractor. However, the Ordnance Inspector will be assured by the contractor that the welders are qualified. Each welder shall make one butt weld, 12" long, between two 1x12x4" minimum plates of mild steel or homogeneous armor which shall be radiographed and judged by the standards of WXS-171. In this test, the welder must use the same welding procedure as is used in preparation of the qualification of procedure test plates. The welder qualification test plate shall be made in that position corresponding to the position of welding of procedure qualification welds.'

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"On page 4, paragraph D-2c and D-2e, the Subgroup recommends that these two paragraphs be deleted from the specification and that such information as is dealt with in these two paragraphs should be added to the drawings of the vehicle in question."

These paragraphs refer to bevelling of tee joints on thicknesses above 1/4" and minimum size of fillets on bevelled joints respectively.

With respect to qualification testing, the Group recommended:

"The Subgroup also recommends that the qualification of 2" armor for the heavy tank contractors be deleted from the specification. It was the consensus of opinion that if the procedure was qualified on the 1-1/2" plate, that the procedure would also apply to the welding of 2" thick plate. In this latest revision of the specification, the composite test plate of cast and homogeneous armor has been deleted, and in its place the fabricator is required to make one of all cast armor, and one of all rolled. It was the consensus of opinion of the Subgroup that the composite plate made up both rolled and cast plate should be inserted in the specification."

Upon inquiry by Major Richardson as to local restriction referred to, Mr. McDowell remarked:

"The restriction referred to was a restriction placed on the use of the size of electrodes which order was put out by the Philadelphia Ordnance District. It restricts the size of the electrode to, I think, 5/32" in certain applications."

In connection with the suggestion about ballistic tests for qualifications, Lt. Pless remarked:

"Colonel Zornig, Mr. McDowell referred to the fact that it was the opinion that present tests are too severe at 1100 f/s. Rather, it isn't too severe you said. I can't agree with him there so far as the test is concerned for qualification. This test was set up by a long procedure of firing a great number of test plates. We started off using A.P. and finally got over to soft projectiles, and finally got into rolled slugs because it didn't break up. And we fired at first two rounds at 1100, and one at 1250 which, as you might expect, broke up most of the test plates before we were through firing. If it didn't break it into pieces at least you got a lot of cracking. And we were able to look at the weld and see things inside of them that we don't see now. We could see lack of penetration, and lack of fusion, or any other defects much better than you do now under the present test. But it was rather hard to judge, when the plates broke up that bad, whether one plate was better than another. So it was recommended that we try something else, and started shooting one round. I believe, at 1200 f/s, and we tried that a while and there were again plate failures. I don't know whether it was due to the armor plate composition we were getting, or whether it was due to welding heat, but we were getting too many plates broken up and we were continually asking the manufacturers to reweld the plates and submit them again - which is a waste of time and money. So, on the

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basis of the two types of test performed in the past, we have recorded data for each one of those plates, and we knew what happened after each round. We put down the amount of cracking we had on the first round at 1100 f/s and the second round at 1100, and the third round at 1250. We could go back over the records and determine just how much cracking we might expect to get if we fired one round at 1100 f/s, and how much we could expect at 1250 f/s. So we made a summary of all of that, and found if we set the limit for cracking at 18" - at which it now stands - we will eliminate about 18% of the test plates submitted. That was considered as a reasonable figure, and we didn't want to reject too many because, as you know, we need all the production we can get, and still we didn't want to let the poor welding technique go through. So we determined anywhere from 15 to 20% was a pretty good figure. We set it up at 18" and fired one round at 1100. That is the way it is carried on now."

Lt. Pless further stated that Aberdeen Proving Ground is working on development of a 57 mm. test for 1" plate. It is also questioned as to the value of testing a plate welded of cast and rolled armor.

On this point Mr. Brooker commented:

"The present specification calls for one H plate of all rolled and one of all cast. The point, I believe, that hasn't been quite as much emphasized as it should have been, is the fact that cast armor doesn't have the shock resistance of rolled armor. When you shoot a composite H plate you can't interpret your results. This plate isn't much good unless you can base some decent judgment on it."

Mr. Diebold raised a question:

"If we are going to have cast to cast and rolled to rolled, and the cast doesn't stand up as well as the rolled, or are you still going to shoot at the same velocity at cast as that of rolled?"

To which Lt. Pless replied:

"The only solution to that is to shoot the cast at the velocity it will stand which is probably about at 1000 f/s, which doesn't give you a very good test for that; but we have been having fair results at 1100 f/s and it may be we can continue for a while at the same standard tests we use for rolled plate. If we do begin to get plate failures, we will have to do something with that. For the time being, we are doing pretty well on these cast or rolled plates at 1100 f/s."

Mr. Raymo commented on the attitude of the armor fabricators regarding the single round ballistic test for qualification:

"Regarding increasing the number of impact specimens on the shock test, I would like to ask Lt. Pless the significance of this 18% rejection that they had. It was my recommendation yesterday, and it was the feeling of the fabricators in the Subgroup, that a single impact at 1100 f/s can be withstood by a very poorly

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welded specimen. And I think we all have very good reasons for feeling this way. If there has been any lessening of requirements for the purpose of getting more welding into production, I think we are wrong. Everybody has to learn at some time or other. We have all learned the hard way how to weld this armor, and there is no reason why we should now accept welding procedure that has proven satisfactory on the basis of a single impact at 1100 f/s, when we know that procedures have been developed and proven many times over in the past year and a half that can withstand two and even three of these 1100 f/s impacts. Perhaps I have not wholly understood the significance of the 18 to 20% rejection that had characterized the firing of the test plate down there, and which now is apparently reduced to zero. I would like to emphasize in Mr. McDowell's report that it was the very strong feeling of all present at the Fabricators' Subgroup, that this one shot was not enough, and that as a control factor for plates, all of us will periodically be resubmitting, with the changes of electrodes and armor composition that still remain in prospect, and that we would much prefer to be guided by the results that have been more in evidence by more severe testing."

Lt. Pless remarked in answer to Mr. Raymo:

"Anyway, the 18% has been set up because we had to draw the line somewhere, and you have to have some figure, and that figure was set. So the 18" was set and it gave us 18% rejection, and we found that rejecting 18% of them would eliminate the worst failures and all welding techniques that we should not accept. We can't get perfect welding - everyone knows that. We have to accept some average welding. In the last several weeks we found that when the same technique is put into a structure, a tank hull such as the one submitted by Republic Steel Corporation, and a turret submitted by the Ternstedt Manufacturing Division, that the welding will stand up much better in the structure than in the H plates. Any weld that passes the 1100 f/s test will be good enough for any construction. I can guarantee you that. When the welds are put in shear or tension, and they are on the structures, they should be good. We find when you put them in compression, even though the X-ray shows them to be rather bad, a good weld or a bad weld would stand up to the firing. But, if the weld is to be put in the shear or tension, it has to be good. When you hit one of these in the shear/tension, it always breaks. That was true in the Republic hull that we hit, and also true in other structures that we have tested."

Mr. Biederman further expressed a gripe about the single shot for qualification:

"When we fired three shots at the test plates I think we got a lot more information than when we started in with our present testing procedure. Our 18/8 electrodes today wouldn't be 16% of what they are if we had not gotten that information. We have an awful lot of work, and each electrode manufacturer has an awful lot of work trying to get an electrode that would give us a better bond and do a good welding job. I don't think we are ever going to

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do a good enough welding job, and the way the firing procedure is today, I don't think it is so much the welding technique as it is the electrodes. I have electrodes that pass the procedure at Aberdeen, and I wouldn't use them in production. I know they are definitely wrong, and I know that the welding with that electrode, regardless of how good the procedure, or how good the man, is wrong.

"Now I would like to see a little more severeness on the test. There is no sense of one man going out and fighting to get on top and the other fellow saying, 'You don't have to do that - Hell, I got this by.' I don't think we should stop the development, and don't think we should ease up on the test on these welds. As far as anybody having trouble getting tests passed at Aberdeen or anything of that sort, there is enough brains in this room to help any individual out to produce better welds. I think, if the condition exists where there is a series of failures, and the company is in trouble, I don't see why they can't be straightened out and helped. I am not getting near the information on firing plates today as I was when we were firing three shots. I don't know whether Lt. Pless recalls that we were working night and day, and had rod manufacturers working night and day, to try to get a better electrode. The only reason we did that was due to the fact of the three shots. If we had one 1100 shot at that time, we wouldn't have the weld development where it is today."

With reference to two rounds at 1100 f/s Lt. Pless replied:

"The only possibility is shooting two rounds at 1100, and going back to our figures when we were shooting two at 1100 and one at 1250, we probably could calculate the percentage of rejections that we would have. It has been done and I could give you that figure. We were at one time shooting two rounds at 1100 and one at the two shots at 1100, and one at 1250, and we looked at it, and we didn't know how much cracking we should allow. We never fired any welded plate before."

Col. Zornig commented on the question of qualification tests:

"Out of these test plates that you send to the Proving Ground we really get two types of information; one of which is whether the plate shall be accepted as qualifying a procedure, and the other is information for the manufacturer. Now, for some time when ammunition was short, they used to fire at the Proving Ground on armor plate, simply one shot which was at the limit of acceptance. If it did not go through, you accepted the plate, and all the manufacturer knew was that the plate had been accepted, but he didn't know whether it was barely accepted or whether it was well over the ballistic limit. The manufacturers raised quite a squawk about that, and the result was that now we get the ballistic limit of each plate. They fire enough shot to actually get the ballistic limit. That lets the manufacturer know whether he is way above the specifications or barely squeezing by. Now it seems to me that probably in this case, even though you don't change the specifications for acceptance, the Ordnance Department

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might well consider firing a couple of more rounds under more severe conditions in order to give welders some more information. I just put that out as a thought based upon the experience we have with the armor plate manufacturers."

Mr. Abbott reported on activity of the Face-Hardened Armor Group since the last meeting:

"When this Subgroup was formed and first got organized and went into the problem of welding face-hardened armor, and began to analyze the work that had been done and the possibility of quite a bit of work that was before us, we realized that we had an entirely different problem in the welding of face-hardened armor than we had in homogeneous material, inasmuch as to begin with we had in effect a by-metal product. In other words, a material in which the carbon content on one side was low, and of what we call a weldable content, and on the other side it was rather high, hard, and under ordinary conditions not weldable. We had quite a problem connected with that in that the face-hardened material is designed primarily to stop high velocity, small-type projectiles, rather than the larger type of projectiles. So it became a matter of ballistic penetration rather than a matter of shock."

Mr. Abbott explained that by collaboration between his company, Marmon-Herrington, and Chevrolet a lot of ballistic testing of welds was done and:

"I imagine in all we have tested upwards of 125 to 150 joints. With that data before us, and reviewing the summary of the old data, there were several questions in our minds that were answered, and quite a number, of course, that were unanswered. If we go back on the controversy of welding and which is one of the first things, I think which was in a degree answered in our minds, referring back to the records of the Diebold Safe and Lock Company we found that we made good joints with 25/20, 25/12, and 18/8. We further found that the so-called modified 18/8, as it is called today, does not give any better ballistic results than any of the rods we have treated before. Nor did we find in our private tests that the ballistic tests on any of the joints were any better than they were before.

"Then the next problem was to more or less standardize on the 18/8 rod because that represents the lower chemistry, and at that time the problems of the strategic metals were coming into play. We realized also that we would have to change the chemistry of the plates, but nevertheless we had before us the 5% nickel, and we went to work on that. The Diebold Company had selected this representative rod. I think the Chevrolet Company had tried out two rods and according to my understanding they were very satisfactory. Nevertheless, at any rate, there were about four or five different rods that seemed to work all alike, and we had more or less consistent results in that respect. Again, reviewing these tests, and going back to the records of three or four years, there was one peculiar thing that showed up in the Diebold records,

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and that is in using an austenitic rod or stainless rod, regardless of what it was or what it had in it, so long as it wasn't a purely ferritic rod, that your ballistic result always added up the same.

"So, we made a set of each of 1/4", 3/8", and 1/2". One set of 1/4" plates was made by welding before heat treatment. The second set of plates was made by welding after heat treatment, with a double V joint along the face of the plate. The third set of plates was made with a double V, with what we called a 'depressed' weld; that is, while the weld on the hard or face side was not brought up entirely flush, or welded to that portion of the metal that was welded or carburized, those plates were tested at Aberdeen, and the results there checked pretty closely with our private range results. We got those results and used those as a basis for computing a ballistic curve up to 1-1/8". We wrote up a specification which we had intended to recommend to this committee. We used that specification as more or less of a trial horse to make up 5/8" and 7/8" plate. We took those with the specifications to Aberdeen and handed the specifications to Lt. Pless who did the shooting with several of his assistants, and he was asked to shoot in accordance with those specifications. We found that while we understood the specifications as drawn up, there was a little bit of confusion when we introduced somebody who hadn't been in touch with them. As a result of this we are making several changes and simplifying the specification. We also found that the results on the heavier plate as compared with the results on the lighter plate, are in line, almost exactly. In other words, if we had drawn the curve after we had gotten the result, instead of before, we couldn't have done a better job. Then, compiling from the data that we had on hand, we have made up a manual. This manual was started by Mr. Jennings some time ago, and we took his idea and elaborated and improved on it. The manual shows four different types of welding on the face-hardened material. And again in our task it seems that it doesn't make a whole lot of difference what type of joint you make. One of the main facts is to keep the gap between the plates as small as you can to make the higher ballistics. The small plates were shot using the smaller ammunition, and the heavier plates, using the 37 m.m. TP M51 projectiles. We were a little over-ambitious inasmuch as we called for several shots of a velocity which destroyed the plate, while if a single shot was put on the plate, the plate would stand up according to the specifications. Nevertheless, if they didn't get the first shot in the area called for, and had to put a second shot on, the stresses set up in that plate from the first shot would cause the plate to go to pieces in the second shot. Those will be changed. We realize that the figures on the penetration of the weld, through the weld proper, although rather disappointing, are actual results that have been produced by welding methods, not by laboratory welding but by productive welding methods. There is a lot of room, we admit, for improvement, but they are representative of actual figures, and we are presenting those to this committee for their consideration.

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As to which of the three joint designs stood up best on shock, Mr. Abbott replied:

"The full weld or the weld with the annealing beads along the side showed slightly higher resistance when shots hit within the weld itself, but slightly lower when the shots hit within the heat-affected zone adjacent to the weld. In other words, it seems that the annealing beads put along the side of the hard case caused a greater heat to travel sideways or further into the plate than when you kept the weld depressed underneath the hard surface."

Following luncheon, during which a General Electric movie "Inside Arc Welding" was shown, Mr. Brooker reported on activities of the Electrode Group:

"The first topic on our agenda was electrode specifications. The Cadillac and Fisher Companies have one covering general specification. The General Motors has another specification which is practically the same, but different in name and number and miscellaneous detail requirements. The Navy Department have other specifications. The electrode manufacturers, of those present yesterday, disagreed considerably on the electrode specifications because our opinion as to what was needed varied considerably, and varies from week to week almost. Then, as to the qualification of electrodes - the Navy Department qualifies electrodes under a mechanical test. The Navy Department has qualifications for welding armor, but with no specification on electrodes, There has been some squawk from electrode manufacturers to get the Ordnance Department to qualify electrodes so there will be no duplication of electrodes and armor between one contractor and another. The Ordnance Department, as far as I know, has no intention of going into that.

"If you look over core wires, you find they are generally of two types; in one, the manganese runs 2%, and in the other, the manganese runs 3.5% to 4.5%. There are two types, probably because peacetime manufacturers of stainless steel make it that way. I would like to make one correction. The high manganese variety isn't a peacetime project. To some manufacturers high manganese is desirable, that is 3.5% to 4.5%. It was agreed there could be reported to the War Production Board that core wire will fall in these two following classifications: Carbon .07/.15, nickel 9.0/11.0. The one grade will have chrome 20.5/22.5, and manganese 1.6/2.0. The other grade, chrome 19.0/21.0, and manganese 3.5/4.5. That should pass the test. We have sent letters to manufacturers asking for information on their experiences with various arrangements with different manganese-moly ratios, It is obvious from the results obtained that a lower chrome composition will pass our ballistic tests. It was pointed out that if we can get recommendations on lower chrome-nickel contents than we are now using, we would make ordinary experimental heats and pass them out to electrode manufacturers for coating and preliminary work."

Mr. Brooker explained that tests are being made of a 12% chrome, 6% nickel, 4% manganese electrode and a 5% chrome, 5% nickel, 0.85% carbon

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electrode for armor. While one test has been made of the former with encouraging results no tests have as yet been made of the latter and:

"It is purely development. No H plates have been welded with it. Many of us think that with the high carbon content we would get such low ductility that it would not be satisfactory. At any rate, it shows we are working on both ends and in the middle as well, with the high tensile varieties, with this 12-6-4, and the ferritic. The ferritic program cooked up in Detroit several months ago has proceeded very nicely. Four participants - Harnischfeger, Arcrods, A. O. Smith, and Metal and Thermit - have sent down approximately 40 plates to Aberdeen, all preheated to 350; some were postheated, some not. Some were made automatically; some were made by manual process. The armor was an interim composition of Republic, approximately 1-1-1 nickel-chrome-moly which was soon found to be as difficult to weld as the old Republic. It had a deep 'hardenability' and we had considerable trouble with cross cracks. However, the results of this work showed that our chances for welding with low alloy electrodes, high automatic, and manual processes are very good. Furthermore, it appears as if there isn't much choice between single and double V welds. Also, it looks as if automatic ferritic welding is possible, and it is definite that the plates should be completed when you start; that is, they should not be allowed to cool down and come back the next day and be worked in the shop. Furthermore, it appears desirable to keep heat on the plates after the welding is completed. And, A. O. Smith reports that a postheat of 350 to 400° appears to give some advantage insofar as hardness character is concerned. What that will do to ballistics remains to be proven."

Mr. Brooker commented about the incomplete filling out of WAS-2 Forms and Mr. Raymo remarked:

"I am sorry to hear the Chairman of the Electrode Subgroup say that it is unlikely that the Ordnance Department would take a positive stand as to electrode qualifications. I think it is necessary that the Ordnance Department give real consideration to this matter for it is a very real problem for all of us. Specifically, we would only like to have a ruling on the intent of the specifications as regards procedure qualifications as affected not only by type of electrodes used. Now, 497 states any procedure qualification shall be construed to have been altered if the type of electrode is changed. Well, that is all right. That has been rather broadly interpreted in the different Ordnance districts, to the best of my belief, and with the prime contractors, wherein requalification of procedure may be required of new fabricators. The cost of these qualification test specimens runs approximately $1,500.00 per unit - a rather sizable expenditure if every contractor is confronted with the problem of having to prepare one or more plates simply to establish qualified sources of materials for himself. It is my personal opinion that we now have enough data relative to the several electrodes that have proven to be satisfactory; that with the data that can be made available to any fabricator, he can knowingly

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select a new brand of electrode without the necessity of actually duplicating the effort of some other fabricator in trying that electrode out. I would like to hear expression of opinion on the part of the others relative to this. My personal feeling is that we should not interpret the specification as requiring brand qualification, once a given type of modified 18/8 has been fairly satisfactorily established."

To which Mr. Emery added:

"Now, I am kind of leaning toward Mr. Raymo's sentiments inasmuch as I believe that if a plate X-ray is all right, it should fire all right, if welded with an electrode which has previously passed the test at Aberdeen under the same conditions. I don't know whether our cast or rolled plate cost is $1,500.00, but the cost is plenty, and according to the AXS-497, we will have to make six more plates before we can qualify."

Mr. Brooker explained the Ordnance viewpoint:

"Well, about the time you think that something like Mr. Emery has proposed will work, then you have a situation like this where one electrode manufacturer has consistently had failures - failures of the fusion zone. He changed his technique by burning in a little deeper and he passed with flying colors. Therefore, there is this matter of preparation, its angle of bevel, and manner of welding, and manipulation that occasionally makes the difference between a good weld and a bad one. And if we try to qualify electrodes, we will have to establish electrode sizes for every type of groove, of which there aren't too many, and require the inspectors to see that that welding procedure is used. What is more, the reason we have steered away from electrode qualifications is because the moment we qualify an electrode we feel that that manufacturer will stop development. The electrodes have improved very materially over the past month. Perhaps it was an inefficient manner of doing it, but they have all tried to beat each other on what they did previously. We couldn't have that development to the same degree if we qualified electrodes. And about the X-ray business, we did have a correlation between X-ray results and the ballistic results under a previous method of firing. We still had a lot of rubber in judging a good plate from a bad one. At the present time our X-ray ballistics correlation is not as good as it was formerly."

There was considerable discussion of the requirement for qualifying brands by the fabricators and their argument was summarized by Mr. Biederman:

"Mr. Chairman, I think in the beginning the manufacturer should definitely qualify the rod and plate and technique so that he knows what the Army wants, but after he has once qualified and gone into production, then that is when the other should come in; and we make a change here and there, and then if we do have to fire a plate, I'd say, if we are going to work on a new analysis, let one company get the plate and fire it; then

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the Ordnance approves that rod, and then we can all use the rod. But there is no sense in twenty different manufacturers doing it. Here is an item right here in 12-6. If there is a series of a half a dozen plates going down to Aberdeen and it proves out, the technique, and everything else, it seems foolish to have another hundred plates come down there from each manufacturer, and it is an absolute duplication of the work."

There was also some argument about how closely the H plate welding approximated the welding on a tank hull to which Mr. Brooker replied:

"If you weld your H plate with copper shields, you can weld your tank with copper shields. If you have a 3/4" - if you use 5/32" electrode in the first test on the H plate - you can use it on the tank in all places. In the bevels there will be some places in the tank where your bevels will not correspond to that in the H plate. There is a discrepancy there. You can't weld every part of the tank like you can the H plate to interpret it to the last degree."

On the matter of electrode qualification, Col. Zornig suggested a policy:

"My suggestion wasn't to go quite as far as you indicated, Mr. Biederman. I was simply suggesting that if you had, for instance, as one manufacturer qualified on electrodes of Type A, then if you made a change from brand to brand in Type A, you wouldn't have to requalify."

The Aberdeen Proving Ground's view of this question was expressed by Lt. Pless:

"I believe this morning we were talking about making the test a little more severe on 1-1/2" plate. It seems to me that we are trying to get away from it now and make it a little easier. I don't know, that is the way it appears, but I have seen plates welded with what seemed to be as good a technique as any Fisher Body ever used or any other manufacturer, on some of the best plates we ever had. And we fired them and had them fail, and that happened in the last few weeks; and I can't see ever allowing one manufacturer to make up a plate to cover about a dozen other manufacturers' welding. They just don't do it the same way. I don't know why, but it just isn't done in one plant like it is in another. At the present time, we don't have a standard electrode and until the time we do have, there is no chance of doing this. That is my view of it, and it looks like if we do this, we are getting away from all of the research and development work that we have done in the past to make it light on ourselves. We would just say, 'Go ahead, boys, do anything you like.'"

A question was raised by Mr. Kerkhoff:

"Has it ever come up where one manufacturer has successfully welded H plates with a particular type of rod or particular brand, and then changed to another brand, we will say, of a similar rod, and run into failures?"

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Lt. Pless agreed that this had happened and reaffirmed that procedure should be qualified with each brand of electrode:

"Unless the electrode manufacturers eventually agreed to make one rod, everyone making the same rod with exactly the same analysis, and no difference whatsoever, otherwise they will never be able to get the same welding."

Mr. Danse cited the object of the General Motors Corporation electrode specifications:

"It was in an effort to move in this direction that General Motors specifications were written. We hope that those specifications may be taken as a step in the right direction. The Electrode Subgroup made an effort, and apparently couldn't agree, and General Motors had the thought in mind that these test plates were very expensive. It was tedious and costly to make them, and have them fired, and it entailed almost endless delay. So the General Motors group agreed to pick out two types of electrodes, the idea being to do just as you indicated, and make the different makes or brands, and place them in those two types. We hope that the step will be in the right direction."

Mr. Raymo raised a very interesting point which apparently no one had given consideration to up to the present:

"If this matter of procedure and electrode and plate is as critical on our test as has been represented to us here, witness the statement that with one brand of electrode and a given procedure from one manufacturer, the brand of electrode is changed and the qualification plate subsequently submitted fails. During this entire program we have been completely ignoring the actual conditions under which we use this armor and electrode. In the vehicle that we build there are four brands of armor in there, and there is no choice about the electrodes we are going to use for making the hull weldment. You have got one electrode. I use it, but that has only been qualified on one brand of armor, If we are going to carry through with the nicety that pure research calls for, then we are wrong in going into this welded tank program the way we are at the present time. We say that welding of armor is on the bench. Every time you hear of two failing, two pass; or when two pass, five fail. Now I think that we ought to take advantage of everything that we have accumulated in knowledge of welding armor to date, quit drawing many of these points that are quite fine as regards the technical correctness of whether this is done or whether that is done. Just think about this problem of four armors in a single vehicle, and I see no reason why, within weeks to come - I am certain it is going to be five right now and possibly six - and there is no single brand of electrode that has qualified on all of those armors, as far as my company or any other company is concerned, with procedure qualifications. What is the answer to a condition like that?"

It was now suggested by Navy Representatives (Comdr. Blake and Comdr. Sutherland) that two analyses of electrode only should be permitted to be manufactured for welding armor and each electrode manufacturer should be required to certify each lot he supplies so that once these two analyses have been qualified no further qualification is necessary, unless a new analysis is produced.

Mr. Biederman made an observation:

"Aberdeen has enough plates, enough different compositions, and electrode rods, that the Ordnance Department can pick up the type immediately from the firing records of the different plates, and the cost, and say, 'Gentlemen, here are your two types.' That is all that has to be done, and can be done that easily."

To which Mr. Brooker replied:

"Mr. Chairman, that sounds very good, but unfortunately the welding contractors and electrode manufacturers have not reported their weld deposit compositions."

Lt. Boucher made a suggestion:

"Now, then, we are talking about submitting an analysis, and the difficulties involved with several manufacturers not being able to make the same rod, because, as Mr. Maurath said, he puts a pinch of salt in his, and sombody else uses a teaspoon. For that reason - and this statement, I think is probably revolutionary - I would like to suggest that consideration be given to establishing one manufacturer who would make all of the armor welding electrodes."

To which Mr. Keating objected:

"With regard to one manufacturer making all of the electrodes for the tanks, I am still pretty fond of the old American system, and I think that is what we are all fighting for here. And if we should do that we would stymie the very essence of our own competitive efforts here which has made possible the type of electrode which you see on the market today. You are going to have to keep enough people interested in this program to make progress. We haven't finished making progress; we have a lot to do yet."

Commander Blake further commented along a patriotic vein:

"Mr. Keating, there is one thing I'd like to say when this is over. Stainless electrodes are used for very few things besides welding armor. People are going to have secrets that aren't worth a damn. Whitey says that one guy puts in a pinch of salt, and the other guy a teaspoonful. True. Why not tell the other fellow what you did to make it work? We can actually come down to a few types and simplify everything.

"There has been, I am glad to say, and I know rather intimately, a great deal more exchange of information. It is not complete as yet, however, and if everybody would talk frankly to everybody else, it only concerns the present business, because the market for this thing diminishes to a point where it isn't worth talking about when we go out of the war. They say there is enough for everybody now. Let's talk frankly and freely and pass the information around and make the most rapid progress now. As

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we proposed in the two types of analysis, we are going to save a great deal of chrome and nickel probably by co-operative efforts to which Whitey is referring. We are going to have a further great saving and not sacrifice a single thing in the characteristics of the work we turn out. I'd just as soon use cheese for welding electrodes if it would give us the results we want. If everybody gets together along those lines, we will get results."

A suggestion was made by Mr. (Whitey) Maurath:

"Mr. Chairman, I will stick my neck out once more. Mr. Biederman says there are 21 different manufacturers of stainless steel electrodes. Prior to this war effort, there were about four of us in the United States who used to swap tricks for 15 years. The minute a tonnage program comes up, each one of those manufacturers is willing to sidetrack the necessary mild steel electrode needed for the shipping program which is bogged down for the want of electrodes at the present time, to go into making a stainless electrode. Each one of them had different characteristics. Each one required the tests Mr. Biederman spoke about. If the WPB and the Ordnance Department want to do something, let them allocate us boys - I am not running but 50 hours a week because in my territory there is every Tom, Dick and Harry, shipping from all over the country and high-pressuring somebody because he thinks he has something better and has everybody sandbagged. If the standard stainless steel electrode manufacturers originally could be handled together in a small group, and enjoy our confidences, we could make a uniform product. But you can't take 20 of them and make the same thing."

Mr. Raymo emphasized the action taken the previous day by the fabricators in regard to electrodes:

"I hope that the significance of part of Mr. McDowell's report this morning was not lost. All of the fabricators feel very strongly about this thing, about getting down to two compositions or preferably one. We all know the limit of doing it and why. It is undesirable, and all such as that, but nonetheless, all fabricators have agreed as of yesterday, and from here on out to purchase to a common specification as mutually prepared by the General Motors Group, and as will be kept revised in the light of progress that appears worthy of recognition by this Fabricators' Group, and the General Motors Group. And that I think is going to be, or has been quite a definite step in the direction that has been recommended by the Navy Department representative, and toward the solution that you suggested."

It was emphasized by Commander Sutherland that both the Army and Navy are working toward a standardization of two compositions. Mr. Bibber added another thought:

"As you probably all know, the delivery of armor plate to different manufacturers is all allocated. By that I mean a certain manufacturer gets a certain type of armor plate from a certain armor manufacturer. I wonder why something could not be done along the same lines with the electrode manufacturers. In other words, why couldn't a certain electrode manufacturer be designated to supply a certain tank manufacturer with a certain brand of electrode, and have that arrangement set up and maintained and not have the tank manufacturer be subjected to having to have so many different types of electrodes? That angle of the thing I have not heard discussed at any of these meetings. I wonder why it couldn't be considered here?"

To which Commander Sutherland replied:

"You get the maximum production, but isn't that what we are fighting? That is the totalitarian system throughout. We are inclined at times to want to do it that way because we can get there faster. But aren't we destroying the very thing we are fighting for if we do?"

And Mr. B. J. Smith added a patriotic touch:

"It strikes a particularly potent note right there. The old saying, 'You have to fight fire with fire' has a lot of merit in this situation. Suppose it is a totalitarian method of doing things; that is what we are fighting - we are fighting a totalitarian system. Now let's borrow some of the good points, some of the advantages of even the enemy's way of doing things. That seems to me to be a reflection of a defeatist attitude that seems to be prevalent in this committee for some reason. Why is it un-American in any sense of the word, to do that? The job has to be done in the shortest possible time. Why can't we coordinate our efforts along the lines that everyone of us know would give us that result in the shortest possible time? We sit here and spar among ourselves, all of us beating around the bush, just a little afraid to admit the truth of our feelings. Surely we all want to make a profit. Surely we all are trying to protect ourselves for what something in the future may bring. So what? That profit isn't going to mean a thing to us if we don't win the war. If we don't produce the product we are trying to produce at the present time, the peace that comes after won't be our making. Keep those points in mind when making decisions as to whether we are going to cooperate one with another, and get our cards on the table. And let's do something about it now and not wish we had later."

To which Commander Sutherland added:

"I believe my remarks were misinterpreted. I am talking for co-operation voluntarily rather than forcing people to do things, for two reasons: First, I believe as a matter of principle that is the way we should do things; but second, and more realistically, this country, having run on that basis for many, many years, can quite probably act faster by getting together, all of us, and saying, 'This is a war and we are going to win it' than we can by attempting a drastic change-over to other methods at this time. What we have to do is do this thing the fastest way possible."

Mr. Bibber further explained his idea:

"Mr. Chairman, I don't know how thisgot into this vein, but the thing I am talking about is the thing done commercially. If I were running a plant and wanted to buy not more than two manufacturers' electrodes, under peacetime conditions, I would be inclined to do that, because if I did not do that I would be testing somebody's electrodes every time I turned around. I think there is no reason in the world why a certain tank manufacturer cannot get together with a certain electrode manufacturer and say, 'We are going to buy your rod. There are possibly one or two, not more than two sources. We don't want to fool with the other types of rod, and we look to you to give us the decent proper type of electrodes,' and straighten out your battle with them. I see no reason why it couldn't work voluntarily. It doesn't take a dictator to do that."

It was stated by Mr. VanDreser that none of the fabricators had had any trouble getting all the electrodes they wanted from any source desired.

It was brought out that electrode stub ends would be acceptable to the steel mills as stainless scrap, if the coating is removed. The objection to charging the coated stubs into the melting furnace was explained by Mr. Whitmer:

"The coating is a form of slag but it isn't the particular slag you want in the furnace. I am afraid if you charge too many of the short ends with the flux on it, you might have half as much slag as you have steel. We don't want it. We want the slag off."

Mr. Mikhalapov reported on the development work being carried on under direction of the National Research Council:

"As you know, N.R.C. made a very thorough survey of existing practice and procedure in welding armor plate. And that has been published and is available to the Ordnance Department for those who have use for it. On the basis of that survey, certain projects have been decided upon, and have been set up, and those projects to date are merely what seems to be the most pressing. Now the projects which have been set up and are now underway are as follows: The project--first project--is the weldability of armor plate, and the development of suitable electrodes. That is a pretty broad subject, and since considerable progress has been made with the welding of armor plate with austenitic electrodes, that is, in production, we are concentrating our abilities on the development of ferritic electrodes and technique for welding. I may add that the results of the first tests were rather inconclusive except that it seemed to prove that armor plate of 1-1-1 composition can be welded with ferritic rods. Unfortunately, there doesn't seem to be very much correlation between the technique and the type of weld used and the ballistic results - that is, we cannot say, 'Here is a way of doing it.' We are just beginning to find that out. It isn't very complete because we still don't know what it is which makes some processes work better than others. Accordingly, we have the program of Carnegie, that is, the United States Steel Corporation laboratory, very kindly making an investigation for us trying to find out what it is that makes one weldment good, and the other poor. If we can find the physical difference, we immediately simplify the problem, because it means that we dispense with the very lengthy, costly ballistics test - not dispense with them entirely - but we can go a long way to produce the physical characteristics of the plate that performs ballistically well. So far we haven't been able to find any physical test, or in fact, any physical difference between the plate that performs very well and the plate which failed dismally. In fact, from the limited amount of tests done, we would expect the good plate to perform badly, and vice versa.

"In addition we are going to try and gather together all of the various types of electrodes now available on the market, no matter how odd they may seem, and we are going to try and write them in accordance with some simple physical test, such as is performed by the Navy; the torture and elasticity test, the weld elongation, the yield strength of the deposit metal, that is, metal that the electrode deposits in the armor plate. In this way we hope to accumulate enough data upon existing electrodes to pick out the most promising and apply them on the armor plate.

"The second project which we have is that of arc welding face-hardened steel; this steel is face-hardened armor plate, I should say. There is still no satisfactory method, as I understand, of welding face-hardened armor, and getting 100% ballistic efficiency, without either heat treating after the weld, or putting a strap in back of it which increases the weight, or using the present complicated technique, where the engineers are using a pre-cladding technique in confining the work, taking a finished hardened plate, welding it together and welding it, and getting a 100% ballistically efficient joint. First of all, the method of pre-cladding appears to be in some way promising of the shortest solution, because the inherent difficulties of arc welding on a carburized face are pretty synonymous. Now, the pre-cladding method has not been widely used because it necessitates pre-cladding of some kind, usually stainless steel, prior to carburizing, and that is frequently impractical. We are trying, therefore, to see if we can find some way of first pre-cladding of the carburized layer, either preheating or otherwise; and second, by developing a second method which would permit a little easier method of doing it than now is possible. Secondly, we are going to try to actually see if some technique will not help us welding on the armor in the finished condition as fully hardened condition.

"The third investigation which we have underway in connection with armor plate is the spot welding of armor plate. Now sometime ago through the auspices of this committee, two manufacturers, I believe, have been developing the technique of spot welding face-hardened armor, soft steel, and also in such a way that the welding is not brittle and falls apart at the slightest impact, but performs satisfactorily under the ballistic tests. That method, I believe, is now seriously considered by a number of fabricators. However, the chief objection to it is first, that not

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too much is known about complete structural problems in the structure of the weld; second, it is slow. The big advantage of spot welding is speed. When it takes anything from a minute to 2-1/2 to make a single spot, you have largely abolished the advantages spot welding has over, say, a plug weld. You can make a plug weld, I am told by Mr. Abbott to be specific, in about 20 to 30 seconds; that, of course, couldn't include the time of drilling a hole."

Mr. Mikhalapov emphasized that these three projects were presently being conducted, the one on face-hardened armor at Rock Island Arsenal. Others may be started if industry has problems on which assistance is desired.

At the request of Col. Zornig, Mr. Danse discussed the question of cleaning armor plate:

"It has been customary to clean armor plate by shot blasting and as those of us who have maintained shot blasting equipment are well aware, it is an expensive equipment, not only the equipment itself, but the maintenance cost of the equipment. We are wondering why it is necessary to shot blast, heat-treating scale or mill scale, or any other scale off the plate provided you don't have to weld on it. So satisfactory welding can be done, and provided also that a reasonable job of scratch or wire brushing could be arranged which would be an automatic operation, and is quite cheap in comparison with shot blasting, so as to remove any loose scale. We see no reason why we should remove the blue oxide and then put on a new coat of paint which is red oxide. We believe blue is just as good, if not better than red. We agree that any loose oxide should be removed, but we can't see the utility of removing the blue and putting red oxide on. Furthermore, it is the rule, not the exception, now that humid weather is here, than when the shot-blasted plates are shipped they accumulate considerable red oxide before they arrive, and if they are thoroughly flushed with some good rust-resisting compound, we introduce into our operation two more difficulties; one, a very difficult operation of removing the flushing compound, or if we don't remove it, we have a very unsatisfactory paint job because of poor adherence due to the flushing compound. We would like to have that discussed. We believe from our experience, from the work we have done with automotive fabrication and other work, it would be satisfactory to prepare the armor by cleaning back the edges when we flame cut them. We usually grind the sharp corners off anyway, and if there is any loose scale, wire brush it off."

Mr. Merriman remarked:

"I understand reliably that if you fail to remove mill scale from armor you may have flying scale of sufficient velocity to injure personnel, and as a result we feel, in the absence of anything to the contrary, that we should shot blast regardless of the expense. That brings up another question of corrosion properties and in Naval aircraft we use the thin armor plate, so we think about corrosion, and in the absence of other information, give it one coat of zinc chromide. I wonder if that is in accordance with the findings of the other investigators on the thing?"

Mr. Brooker explained the Ordnance viewpoint:

"In regard to tank armor, the Ordnance Department desires to limit shot blasting as much as possible. As for flying scale, our tanks are lined with Celotex and rubber, and we should have no trouble with that injuring personnel. What is more, in the water-quenched armor - and all of it is water-quenched today except the cast material - we should have practically all of the scale off, and the only harm the scale will do is to make for rough, bad flame cuts, and if there is any really heavy scale at the edge of the grooving, it is apt to give us poor welding; but the facilities section down there is trying to hold down the installation of shot blasting equipment."

Mr. Brooker further emphasized that the tank specifications and welding specifications require that the armor be cleaned for welding and painting, It was pointed out by several of the fabricators that clean plate surfaces are essential when welding on attachments to armor plate.

Mr. Bibber cited his company's practice with armor:

"As a manufacturer of armor plate, we shot blast all plate in order to get what we believe is a proper flame cut. We believe that by shot blasting this plate, we have better control over our flame cutting and can do a better job. Now the question of the adherence of this scale - I have seen scale on so tight that a power-driven brush will not remove it. A tight scale is not going to be easily removed. We have the equipment and facilities for shot blasting in our regular production line. So as far as we are concerned, we would prefer to do it in order to make better flame cutting."

Flame descaling was suggested to which Comdr. Sutherland replied:

"We have experimented on flame descaling. It works most satisfactorily. However, after a lot of consideration, we decided not to use it. For this reason you have to go above 350 to do any good. If you go above 400, you are apt to change the ballistic characteristics of your plate; and we are very much afraid to leave it in the hands of the average operator if it is that touchy. If you can control your temperatures accurately that is the answer to the problem."

It was pointed out that spray-quenched plate should be quite free from scale as mentioned by Mr. Brooker.

With reference to a paint primer, Comdr. Sutherland remarked:

"There has been considerable discussion of what you use for priming, Everybody uses zinc chromate primer. For goodness sake, don't use it unless you have to, It is bad enough that Army Ordnance has given or is considering giving up their lead projectiles. And the chromium is scarce, as we talked about on

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the electrode question. If you need ultimate durability and these things are going to have a long life, it may be advisable to use the zinc chromate, but if we expect a short life for the vehicle, I don't think we ought to spread zinc chromate on them. It seems that everybody is asking for zinc chromate. I wanted to show that because I know it is very scarce."

With reference to use of flushing compounds on finished vehicles, Mr. Danse complained:

"And there is another item on which we found some confusion, and that is on the finished vehicles. We are required to do some flushing and we find that the Ordnance and the Quartermaster Corps do not agree on the flushing compounds which are prescribed. We would like to ask the Ordnance and the Quartermaster Corps to get together on that. We would like to be able to use flushing oil where the vehicle is going into the fields, or where the spare part is going out to service. The vehicle going into the field has to be flushed with ordinary flush, and the third part, going into Service and Supply has to be flushed with Quartermaster flushing, and it is a very peculiar situation. We would like to get some relief."

To which Col. Zornig replied:

"Mr. Danse, will you kindly sum up the situation, and direct a good hot letter to Washington?"

Which Mr. Danse agreed to do.

Dr. Drury remarked:

"But speaking as a representative from Canada, I can only say that I wish to thank you most sincerely for the invitation to be here today. Our problems are practically the same as what you have here, and we are trying to solve them in more or less the same way. The information which we obtain at these meetings is of great help and assistance, and I don't know that I have anything more to say except to thank you again for the invitation you have extended."

It was decided to hold the next meeting in Detroit in about three months on a Sunday and the meeting adjourned at 5 P.M.

This was the first meeting at which Col. Zornig officiated as Chairman. Lt. Matthews, now Captain Matthews, officiated as Secretary. This meeting saw considerable agitation by the tank fabricators that the Ordnance Department set up on electrode specification and an approved list to eliminate some of the necessity for qualification testing of procedure. Also having tentatively standardized on a ballistic test for welded plates of 1-1/2" armor the Proving Ground was criticized by the fabricators for making the requirements too easy.

A further expansion of the Group organization of the Subcommittee was announced by Col. Zornig. This meant that four more groups were to be added—a Specifications Group, a Research Group, a Resistance Welding Group and an Aircraft Armor Fabricators' Group, making a total of seven groups each of which was intended to handle certain special phases of the welding of armor problem. The general thought behind this specialized subdivision was to make possible more detailed discussion of each of those phases by the individuals primarily concerned at the smaller Group meetings which were usually held the day previous to the Subcommittee meeting. When the occasion warranted any of these groups could meet independently to discuss the problems arising in the particular field of activity covered by the Group. This procedure relieved the main meeting of the Subcommittee of much of the discussion of matters pertaining to a particular group which might not be of interest to many of the others. As Col. Zornig once put it, "These Group meetings give the boys a chance to let off steam and gripe about their troubles so that when they come to the Subcommittee meeting they are more satisfied to just sit and listen to the Chairman's report without further argument." The result was that meetings of this large group of people could be more effectively directed to cover the subject matter and could be also terminated with dispatch without denying anyone the opportunity to state his mind when he desired to do so.

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NINTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
SUNDAY, 20 SEPTEMBER 1942
HOTEL STATLER, DETROIT, MICHIGAN

The ninth meeting of the Subcommittee was held on 20 September 1942 at the Hotel Statler, Detroit, Michigan, with 152 persons in attendance representing:

Industrial - United States	
Tank Fabricators	36
Armor Producers	6
Electrode Manufacturers	32
Core Wire Producers	5
Resistance Welding Equipment Mfrs.	6
Aircraft Fabricators	14
Individuals	3
Government - United States	
Ordnance Department	31
ASF Headquarters	1
U. S. Navy	2
Army Air Forces	6
War Production Board	2
National Research Council	1
Guests	7

This meeting was opened by Col. Zornig with the following remarks:

"We had originally, in the setup of the Subcommittee under the Ferrous Metallurgical Advisory Board, a Subcommittee on Resistance Welding. At that time it looked as though there would be the proper place for two subcommittees on welding. The picture is somewhat changed, and it seems advisable to combine all the armor welding work under one large subcommittee, so that the Subcommittee on Resistance Welding has voted to come into the Subcommittee on Welding of Armor and will form another Group in this committee. The Chairman of that group will be Mr. J. H. Cooper.

"Also it has seemed that the welding or fabrication of aircraft armor should be given some attention, and the metallurgical or welding representatives of a good many of the aircraft manufacturing companies have been invited to join this Subcommittee. They will form another Group now under this committee. The Chairman of the Aircraft Fabricators' Group will be Mr. Merriman for the East Coast, and Mr. North for the West Coast group."

The Subcommittee on Resistance Welding had had a meeting on the previous day, 19 September, conducted by Lt. Col. Cox as Chairman. At that meeting the Subcommittee discussed a draft of a specification for resistance spot welding of armor which had been prepared at Watertown Arsenal and voted to reorganize as a Resistance Welding Group of the Subcommittee on Welding of Armor. Mr. Cooper was then elected Chairman of

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the Group. Copies of the current drafts of Ordnance Specifications on Armor were also distributed to the members present.

Mr. F. A. Lee was added to the Group in view of the current activity of his company fabricating spot welded half-track scout cars. Professor W. F. Hess of Rensselaer Polytechnic Institute was suggested for membership because of his development work on spot welding methods. This meeting was the third and last meeting of the Subcommittee on Resistance Welding.

Since the question of supply of alloys for steel making was now becoming of increasing importance because of demand for alloy steels for armor and other Ordnance items as well as naval construction, representatives of the War Production Board attended these meetings to inform the Subcommittee membership of the current situation and trends and to find out how the various official regulations were working out in industry. This arrangement for interchange of information on official orders and ideas between War Production Board and Industry through the Subcommittee came about with the attendance of Col. Zornig at the Subcommittee meeting in Detroit on 1 March 1942.

Mr. Sweeney reported on the current alloy situation:

"Nearly all of the common alloying elements for steel are critical, but frequently you hear some referred to as 'easy' and some as 'tight'. Those that are referred to as 'easy' are easy only in relative sense, because for nearly all of these elements we are dependent, to a large extent, upon imports, and this picture might easily change at any time due to difficulties in obtaining these materials or by the switching of compositions of various steels.

"Manganese is a good example of a critical material which is referred to frequently as 'easy', because at the present time the supply is sufficient to take care of the demand, but of course, this comes from overseas to quite an extent, and in the case of a long war we might eventually be pinched for this material.

"The next element is silicon, and the main factor in the supply of silicon is electric power and the allocation of electric furnace capacity to the production of this element. One of the possible means of conservation that may eventually be necessary, because of the power situation, is the production of low silicon alloys rather than the high silicon alloys.

"The next element is chromium, and the long range plan for the production of chromium will eventually make this country independent of events outside of the Western Hemisphere. At the present time chromium is relatively easy, too, but it could be easily upset by a change in the requirements for steels.

"The next element is nickel. At the present time nickel is in the balance. That means that the supply we have now takes care of the demand but that is only because a great many conservation steps have been taken and this is a material which the future requirements indicate might easily be very tight once again.

"Molybdenum has had a heavy load to carry, because the original conservation of chromium and of nickel and of tungsten has put a

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very heavy load on this material. At one time the stockpiles of this were considered almost inexhaustible, but these have been very rapidly diminished and the trend now is to conserve molybdenum.

"Tungsten, at the present time, is just in a state of balance, but this again is one that could be very easily upset by a change in requirements.

"Vanadium has had a very heavy load to carry because of the very large increase in heavy forgings and in high speed cutting tools. Vanadium has been taken out of practically all constructional steels and practically all high speed steel, except those for cutting tools - for metal cutting tools.

"Copper is considered so critically necessary to the non-ferrous uses that it has been practically eliminated from most steels, and the only form of copper which is now being used in steel is that which is available in monel scrap.

"Zirconium, titanium, and boron are elements which deserve consideration because they are available and can be produced in much larger quantities, and these elements can possibly take some of the load off of the other more critical steel alloying elements.

"Now there are some new N.E. steels - the 9400, the 9500 and the 9600 series - and these steels were designed to make possible the utilization of the residual or incidental alloy content of most steel scrap. In the 9400 series, the manganese runs from .80/1.10, silicon from .40/.60, nickel .40/.60, and molybdenum .15/.25. There is a 9600 series, which is also the one that doesn't have any molybdenum. It is a manganese-silicon-chrome steel. The manganese is 1.20/1.60, chrome .40/.60 and silicon .40/.60. There is one thing that perhaps all of you will be interested in. In connection with these new N.E. steels the WPB hopes to work out a plan whereby experimental heats of these steels can be made without going through the long rigamarole of trying to get priority and permission to melt the various materials.

"Now there has been adopted by the Navy, and I understand it will be adopted by the Army also, a new analysis for welding armor, and of course, the dropping of the chromium and nickel from 25/20 to 19/9 results in a very appreciable conservation. This is a great aid in meeting the future requirements of nickel and chrome as the demand for more and more alloy steel increases. The one point I want to get across to you is that, while some of these materials are relatively easy now, that is, that the supply is equal to the demand, due to the rapidly increasing demand it is going to be necessary to make additional conservation as well as continue the present conservation of these various materials."

Mr. Ostrom added comments on the electrode situation:

"In the Electrode Group, the report for which I think will be presented later, there were two analyses of core wire that were selected as the analyses that will meet the needs of the military services, both for welding all of the ballistic type steels, with the modified 18/8 analysis. Now, if a different analysis can be developed to further conserve the alloy elements, why that is desirable, but the Welding Section of the War Production Board will recommend to the alloy group that no melting of any other analysis core wire will be made except these two analyses. These analyses are only steels for this particular use. It does not mean if a chemical processor, or some other manufacturer, has a need for say a straight 308 type or 307 type, that they must accept this analysis. For this particular use of welding of ballistic type steels, these analyses will be adopted. Now the reason is that it will make more uniform melting in the mills. The mills will know ahead of time what they will melt to. It will give them a chance to melt the larger heats and shift those heats to any of the electrode processes instead of having to hold on to little odds and ends of heats and save them for the particular processor who has a special idea of what he wants.

"We have, in the limitation order covering welding rods and electrodes, a 60-day inventory limitation. We have evidence, both in some of our shipbuilding construction and a good bit of the tankbuilding construction, that their inventories are as high as 160 days. Now that is really serious because it means that we have dead material in stock in the hands of the manufacturers with purchasing power. The larger manufacturers have much more purchasing power and ability, too, than the small manufacturers, and we are having quite a serious problem throughout the country with the small manufacturer who cannot get delivery of electrodes. He is the fellow who is making your subassemblies, perhaps making cast sections for you, and having to repair those castings with no welding electrodes to repair them. There is no objection at all to placing orders on the electrode processors, In fact, you will almost have to. The electrode processors at the present time cannot guarantee deliveries, because the demand in the rerating of priorities is just throwing everything out of balance, but you can place your orders and let the processors know what your requirements will be. In other words, you can tell the processor that you will need so many thousand pounds of electrodes per month for a period, but don't expect any processor to make a promise to you now for delivery in 1943, because he is in no position to guarantee that he will keep it. He may be, and we expect he will be able to, by the end of the year."

Mr. McDowell reported on the previous day's meeting of the Homogeneous Armor Fabricators' Group:

"One of the most important items that came up yesterday in the discussions of both manual and automatic welding is the use of larger sizes of electrodes in the manual welding procedures. Experimental work has been done with sizes up to 1/2", and it was the opinion of most of the fabricators in the group who have tried these larger sizes of electrodes that the weld joints would pass the ballistic tests very satisfactorily. To date several plates have passed these tests. At present, the Ordnance Department does not feel that there is enough information on hand to approve the use of the larger sizes of electrodes for production use and

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immediate steps are being taken to have more plates fired so as to obtain this necessary information.

"At the request of the Electrode Group, the fabricators agreed on several lengths for the various sizes of electrodes that they would use. For the 1/8" and 5/32" sizes, 14" lengths would be used; for 3/16" and 1/4" sizes, the 18" length; and for sizes from 5/16" to 1/2", the 24" length electrode would be used.

"In the work of the Unionmelt welds, experimental work is still being carried on by various fabricators, and Unionmelt is being used in production by several of the fabricators, but mostly on the thinner plates such as the joining of the sponson and floor plates to the main side plates.

"No important progress has been made in the use of ferritic electrodes since the last meeting. The results have been rather erratic and it is impossible to draw any definite conclusions from the results to date.

"In regard to electrode specifications, the Group went on record as urging that the Ordnance Department take immediate steps to adopt a uniform armor electrode specification, using either the General Motors or the A.W.S. specification as a basis. In the discussion of Specification AXS-497, it was recommended that upon the adoption of a uniform electrode specification, the electrode brand name be eliminated as one of the variables in the welding procedure. Paragraph D-4 states that no repair welding should be allowed on the procedure qualification test plates. In the discussion of this paragraph, it was brought out that there were various interpretations of this paragraph. Some of the fabricators had been repairing minor defects and some had been submitting plates with no repairs of any kind, and it is recommended that this paragraph be clarified. With reference to paragraph F-2b, concerning welder qualifications, it seems that in the different Ordnance Districts there are various interpretations as to the meaning and intent of this paragraph. The Group recommends that the provisions of this paragraph be strictly adhered to, as written, without local Ordnance addendums. In regard to the issuance of new revisions of Specification AXS-497, it is recommended that the Ordnance Department adopt a uniform method and means of issuing new revisions and that the specification cover letter should contain a statement as to when the revised specification becomes effective.

"Several of the fabricators complained of receiving armor plate that contained cracks, etc., in the flame-cut edges or in the plate itself, and also receiving plates where the flame-cut edges were extremely hard. In this regard, the Group went on record as recommending that the plate manufacturers be required to supply plates free of cracks and with the hardness of the flame-cut edges not to exceed 375 Brinell. In regard to standard means of running the hardness tests on the bead weldability test, it was the opinion of the majority of the Group that the hardness survey, using the Rockwell machine, was not accurate enough, and the Group agreed that, in the future, all hardness testing would be done using the Vickers hardness tester or the Vickers attachment for the superficial Rockwell.

using a 5 kilogram load, and that the initial hardness indentations would start in the bond line and extend at 1/32 intervals into the plate on a line at right angles to the plate surface. It was also recommended that this same procedure be adopted by the Electrode Group for their tests. In regard to welding symbols on engineering drawings, it was agreed that the use of the A.W.S. welding symbols was entirely satisfactory."

Mr. Komarnitsky asked:

"I understand that recommendation has been made by the Group that the present tolerances are entirely satisfactory. Well, we have quite a lot of drawings which require plus or minus 15/1000 tolerance on plates several feet long. Is this satisfactory? Those are the present tolerances. That is one question. The second question is this: Recommendation has been made by the Group to limit the hardness of the flame-cut edge on the plate to 375 Brinell. There is quite a lot of 1/2" plate manufactured right now to the upper limit of 380, which is entirely satisfactory so this limitation of 375 Brinell is not exactly in line."

Mr. McDowell replied:

"That question came up in this discussion, and it is evident that some of the fabricators are not familiar with the hardness requirements on some of the thinner plate sections. The majority of them deal with the heavier plates, in our group, and that is probably why that was set at 375."

Mr. Bissell remarked that in the Navy spec. the minimum permissible temperature for armor when welded had been set at 60°F. instead of 70°F.

Upon being reminded, Mr. McDowell recalled a point missed in his previous report:

"In AXS-497, on the M5 light tank hull and the M4 medium tank hull, for shock test plates, the requirement of a cast and rolled composite plate is left up to the option of the manufacturer, whether they furnish a composite plate or not, and it was felt that, since this had been left to the option of the manufacturer, it should be dropped from the specification because it was felt that the majority of the fabricators would not furnish this composite plate under these requirements in the present specification."

With regard to gas cutting of armor, Major Knode remarked:

"We had considerable difficulty with cracking when we first started to cut armor plate. We soon found out that due to the rapid cooling and hardenability of the plate, we got a martensitic structure on the flame-cut surface. By preheating that with burners under it, up to about 400°F., I think we have fairly overcome the trouble and it appears that that cracking condition does not exist any longer."

With reference to repair of processing cracks in armor there was considerable discussion:

Mr. Kerkhoff:

"Some of our hull fabricators have a considerable amount of cracked plate on hand. Now we are asking them to do this: To pick out the worst plate, weld up the cracks along the edges, or wherever they may be, and submit this plate to Aberdeen. We can tell from that, after the ballistic test, whether their repair procedure has been satisfactory, and on that basis we feel we can go ahead on the balance of the plates."

Mr. Jeffries:

"I think you will find that Aberdeen has a record where we sent quite a number of plates down there. The results indicated that if the crack was too large, you had better reject the plate; if your crack isn't too large, you had better leave it there - if it terminates in a hole, for example. There is no particular advantage to be gained by welding cracks, if the crack will not go any further than a hole, for example, from the edge of the plate to a hole along the edge of the plate. We have got to approach this question of welding up cracks in a stressed structure with a great deal of care. If you don't, you are very likely to extend that crack and think you have it welded up."

Mr. McPherson:

"We have had a little experience with welding up cracked plates, over at Milwaukee, and I find that in an attempt to grind out these smaller cracks, you will drive that crack all the way through the armor, so anyone who is welding up those armor plate cracks, in grinding them out you had better take a radiograph of them because we had several instances where those cracks were put all the way through the plate. That is in homogeneous plate."

Mr. Diebold:

"There has been a lot of discussion here about minor cracks and unimportant cracks and major cracks. What constitutes a minor crack and what constitutes an all-important crack?

"Another question that occurs to me is, it is all very well for the fabricators to say the plates should come to them crack-free. It is another thing to get them that way. Now, if you have got a plate welded into a hull and you discover a crack, what do you do about it?"

Lt. Pless:

"There has been a test run at Aberdeen about cracked plate, and extensive proof tests on two or three vehicles with various sizes and shapes of plates and cracks that began at the edge of the plate and ran into the holes and cracks of a more extensive nature. When those proof tests were sent through, those cracks extended very little, and in most cases, not at all. Since that test run there has been a recommendation made to the Office of the Chief of Ordnance as to the standards for accepting cracks, and I think you will find there that it has been agreed to accept small cracks which begin at the edge of a plate and end in a hole, or

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cracks of not too great a length. That, of course, has not been issued to the Ordnance Districts, but I think with some revision, and the approval of Ordnance, possibly this work can be settled."

It was indicated by Major Coombe that this subject is being considered and a standard policy will be established.

Mr. Abbott reported on the activity of the Face-Hardened Armor Fabricators' Group:

"The first phase of the work of the Face-Hardened Armor Fabricators' Group has been completed, to the point that the data and methods of welding, and so forth, have all been combined into a specification which was submitted to the Specifications Group, from which the Specification AXS-743 has been made up.

"Three of us, with some information that we obtained from a fourth concern, that is, the Diebold Company, the Marmon-Herrington Company, the Breeze Company, and at first the Chevrolet Company, who were going to make face-hardened armor vehicles, which later on was changed to homogeneous, did all of the experimental work in the preparation of plates which were sent to Aberdeen, tested for both shock or ballistic resistance, this data compiled and a ballistic chart made up, as I say, the shock requirements made up, which is now Specification AXS-743. There is only one bone of contention among those of us who are now welding face-hardened plate, really three organizations, and that is the method by which we should qualify our welders. I think that we will always be pretty much up in the air on face-hardened plate, but the requirements as set forth in this specification now are more or less of a compromise, and I think it is all right. We are undergoing an electrode change and we are undergoing a change in the chemistry of our plates which will make a considerable difference in the technique of welding, and I don't think that the Group can really make much more progress than it has or do any experimental or research work that will be of great value, unless those two points are stabilized - that is, the welding rod and the composition of face-hardened plate. We expect to stabilize the composition of the face-hardened plate, the base chemistry.

"We had a 'cookbook' or a manual, showing the various types of joints that were made, and with more or less instructions as to how to make and weld those joints. That has been turned over, as I recall, to Mr. Brooker, who was going to have it published. He was going to make some revisions and corrections."

Major Coombe indicated that this manual will be available within a couple of weeks.

Lt. Randall reported on a meeting of the Electrode Group held the previous day. Since Mr. Brooker had left the Ordnance Department, Lt. Randall, Tank-Automotive Center, Detroit, had been appointed Chairman of the Group by Col. Zornig:

"The meeting was opened with a report of the status of the development on the 12/6/4 or 12/6/6 electrode. The chief development in connection with that was that there seems to be a wide range of compositions under test. While there have been a number of samples submitted, they are not of a standard composition. They vary from perhaps 4% manganese to as high as 6% or 6-1/2% manganese. There is apparently not sufficient data on any one composition to justify any definite conclusions.

"The next subject that was discussed was the matter of reporting deposited metal analysis to fabricators. It was not expected that there would be any definite conclusion reached, and there wasn't. The methods that are in use by the various electrode manufacturers, as far as their control over analysis is concerned, are so different that it doesn't seem practical for them to agree on any standard method of accomplishing that objective. It had been recommended sometime ago that a Core Wire Manufacturers' Group be formed, or that the core wire manufacturers be represented as a part of the Electrode Group, and there were several members or several representatives of the core wire manufacturers present at this meeting. It was agreed by both representatives of the core wire manufacturers, and in general by discussion with members of the present Electrode Group, that this was a desirable step in an attempt to reach agreement in the various items that are of mutual interest to these two groups. It has been recognized for some time, and discussed at some previous meetings, that it will be desirable to provide a standard core wire analysis to which electrode manufacturers would conform in placing their orders with the steel mills. The Navy Department had been very much interested in this subject, undertaking the initiative in bringing together the electrode manufacturers and the core wire group, and at a recent meeting in Philadelphia, had reached certain conclusions.

"There is one which is known as a modified type 307. Now these are core wire. They have nothing to do with deposited metal.

Carbon	.07/.12
Chromium	19.0/21.0
Nickel	9.2/10.7
Manganese. . . .	3.75/4.75
Silicon.	.25/.60
Phosphorus . . .	.05 Max.
Sulphur.	.03 Max.
Molybdenum . . .	.25 Max.

"The modified type 308, which is the other type of core wire:

Carbon	.07/.12
Chromium	20.5/22.5
Nickel	9.0/11.0
Manganese. . . .	1.6/2.0
Silicon.	.25/.60
Phosphorus . . .	.04 Max.
Sulphur.	.03 Max.

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"As Mr. Ostrom has said in his previous remarks at this meeting, and as he said at this Electrode Group meeting yesterday, it is the intention of the War Production Board to standardize these two analyses as those which will be available for electrode manufacturers who are making electrodes for the welding of armor plate, and they apparently are going to be the only ones available. It developed that there were a number of electrode manufacturers, five to be exact, who were unable to coat electrodes in lengths exceeding 18". There were still others. Well, there was one who was limited to 22", two others who were limited to 24", and approximately three who could coat electrodes as long as 36". However, in this discussion there was considerable point made of the fact that changes in electrode length, when you are coating the same size electrode, interfere with production.

"Mr. Ostrom of the War Production Board has pointed out previously the shortage of electrode coating capacity in this country, and it was felt for that reason it would be desirable, if possible, to standardize electrode lengths, and a motion was made and carried to ask the Homogeneous Fabricators to recommend a single electrode length for each diameter of electrode. These recommendations were discussed by the Electrode Group, and there were some points on which the two disagree, which is to be expected, perhaps. On the 1/8" and 5/32" diameters, both agree on the 14" length. On the 3/16" diameter electrode, the fabricators requested an 18" length. The electrode manufacturers, the Navy specifications, and opinions voiced at the meeting informally, agreed that 14" was desirable with the 3/16". For electrode sizes of 1/4" and over, there was no general agreement in the Electrode Group. As a result, a motion was made and carried that each electrode manufacturer would, in the electrode sizes 1/4" and over, submit to the Philadelphia Navy Yard immediately, electrodes of the various lengths under discussion. That was felt desirable, as the Navy Department specifications call for certain electrode lengths.

"There was a very brief discussion of the 5% chromium-5% nickel-0.85% carbon electrode, which has been discussed at previous meetings, and on which the preliminary tests have been made. Briefly, those preliminary tests indicated that the compositions submitted did not have any appreciable ductility and had considerably greater hardness than had been expected. Further modifications, we understand, are being worked upon. There was one other item, concerning the shortage of armor for experimental work. This shortage of armor is something with which all of you are familiar, and the necessity for development work, development of electrodes, and so forth is recognized. Each request that is made for such experimental armor should be justified with a statement as to the type of tests that are planned and the results or the benefits that are to be obtained, if the results are satisfactory."

Lt. Randall referred to a new type of shock test being used at the Naval Research Laboratory by Mr. Jackson. This test will be discussed

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later. In connection with the tests of electrodes by the Navy both 14" and 18" lengths of the 3/16" diameter will be tested.

Mr. Biederman explained the case for large diameter electrodes:

"We have done a lot of work on these electrodes, and the Army has an entirely different problem than the Navy, due to the fact that on our work, since we have introduced the large electrodes that are into production up to 3/8", we have picked up 17-1/2% more production. That means that we will have a couple of hundred less welders in our plant. The Navy's test on that electrode doesn't meet our requirements due to the fact that we are laying down almost double the pounds per weld that the Navy is. We are working in restricted space. We have got very expensive fixtures. We have got to get that part out of that fixture as quickly as possible, and if we do get some restrictions, it means we have to go out and build other fixtures, get more floor space, put more men to work. For instance, on the 3/8" rod, it was possible for one man to lay down 18 to 21 pounds in one hour. Now those figures have been unheard of before, when you talk about welding at two pounds an hour, average, and it is important for us as a manufacturer of these vehicles to get these lengths due to the fact that the longer length also gives the man a lot more relaxation as a welder. He is farther away from his work. When he starts his weld, he works through a longer arc. That lets the man stay on the job longer. If the man is using a 14" length, his nose is always down in that weld. The only way he gets his nose out is to stop welding."

The purpose of two basic compositions for core wire were explained by Mr. Bleecker:

"I think it ought to be brought out, on these two analyses that Lieutenant Randall mentions, namely the 307 and 308, that it isn't the intention, as discussed in the meeting yesterday, that the use of the 307 with manganese in the core wire be compulsory. That is, for Ordnance work modification can be done, as has been done, and I suppose if the tank manufacturers wish it, will continue to be done on the 308 specification. That is, that can be modified with either manganese or molybdenum. The reason for the 307 is that the Navy wants a 3-position rod, and they feel that the manganese in the wire is necessary."

The desirability of standardizing electrode sizes was emphasized by Mr. Ostrom:

"It is just to set some standard. Now we agree that a lot of benefit can be gained by using larger diameter electrodes, and also longer lengths, and it is just to set some standard. Our electrode manufacturers have been asked for 18", 20", 22", 24", 28", 30" and 36" lengths. Now that in itself is going just a little too far. If we can standardize on one length, it will make a saving and also allow the electrode manufacturers to produce one size and not have a lot of odds and ends in their shop, laying around waiting for somebody to demand the odd lots, and what not, and also to get a uniformity of use. I think we will all benefit."

Lt. Randall explained the purpose of the Navy tests which were referred to in his report:

"There is one other thing which perhaps I failed to bring out clearly in connection with that report, and that is that the War Production Board is in the process of issuing a standardization order on length of electrodes, and it makes this question one of somewhat more importance, that we arrive at a proper answer which will be satisfactory to everybody concerned. In other words, the questions as to the standards, or proposed standards which were read to us the other day would not have been in accordance with the recommendations of the Homogeneous Armor Fabricators' Group, nor exactly in accordance with some of the opinions of the electrode manufacturers. So that was one purpose in getting some experimental work done, to facilitate that."

Mr. Biederman was quite insistent that the problem of armor fabricators be recognized:

"I would suggest that the WPB come up and see our actual problems and see these rods right in production before they would even attempt to say that a certain length rod should be used. I believe we are pouring more welding rod into armor plate than any company today, at this time, and we would be only too willing to have them investigate our problem before they make any decisions which will affect our over-all program. It is getting to the point where one little change is a big item to us."

With reference to composition of the core wire, Major Richardson commented:

"In connection with this composition, referring specifically to carbon content, in the process of making stainless steel the amount of scrap that can be melted depends upon the carbon content. If you specify a .07% maximum, very little scrap can be used in most processes. If it isn't necessary to specify .07% maximum, .10% can be used, or even .12%, permitting the use of a large quantity of the stainless steel scrap. I think most mills accumulate about 45% themselves. In a .07% carbon, they can perhaps use 10 to 20% in the charge. If you given them .10% carbon, the average probably would run up to 35%, and .12% carbon, perhaps 50%. That permits considerable saving of the virgin alloys, nickel and chromium. We have contacted the steel mills about it frequently, but they state that the core wire manufacturers insist on the lowest carbon. It isn't necessary, but it is going to be a help all the way around."

It was pointed out by Col. Zornig that the carbon range permitted by the proposed standard is 0.07% to 0.12% which should satisfy everybody in view of the Major's remarks.

With reference to the use of the Navy Torture Test for testing the various sizes of modified stainless electrodes, Mr. Miller (Reid-Avery) commented:

"If that is the case, I certainly recommend that you do not use a root sample on the 5/16" and 3/8". It is almost impossible

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to control the 5/16", down to a very narrow gap as on your torture test, and it is not a process being carried out in production."

Mr. Bissell replied:

"It is probable that with the heavier electrodes it would be desirable to use the gap they use in the tank construction. I think that is the better way to do, but use the restrained gap."

Mr. Bissell further remarked, upon question by Mr. Biederman, that three brands of modified 18/8 electrodes had been accepted on the basis of the torture test. Mr. Biederman then expressed the thought that these three brands need not be again tested. To this Mr. Bissell replied:

"Mr. Biederman, there is no definite program agreed upon. The idea was vaguely to use the torture test, but there will be no decision until we get together with you and others to determine what test to use to determine the properties of electrodes that would be a perfectly fair test. This test is to determine the length of the electrode, as I understand it. We will run the test, however, the way the armor people want it."

Major Coombe reported on the meeting of the Specifications Group held the previous evening:

"We met again last night to discuss yesterday's Group meetings and their recommendations on these specifications. We reviewed the items that were mentioned by the Chairman of the Fabricators' Group, and decided that they did not merit the Specifications Group having an immediate meeting for another revision, but that rather these items under discussion would be reviewed by the Office of the Chief of Ordnance, and where necessary, directives would be issued which would clarify these questions or would make certain changes. I might add that any changes in specifications from now on will be made on the basis of the engineering facts and not opinions.

"On the subject of specifications, the Ordnance Department, not the Specifications Group, has added the AXS-770 on Welding Nomenclature. We have in process, now, specifications on Standards and Symbols. These are American Welding Society and Navy Department specifications, and will be adopted by Ordnance, or I should say, are being adopted. I think they will help the specification problem. This Specifications Group has been of great help to the Office of the Chief of Ordnance in clarifying specifications and helping us on our specification work. I, at this time, would like to suggest that the armor makers have a similar group on specifications, and that there be co-operation between such a specification group for the armor makers and the welding people, because our problems are running hand in hand. If the armor people would give consideration to our problems and would ask us what they are, I think that they could hit a little nearer on the armor compositions.

"There is now a specification on armor which calls for a .30% carbon maximum, on thicknesses from 1/4" to 1-1/8". A specification on thicker armor, which is under discussion, will call for the same limitation. It seems that it was brought out yesterday, by a member of the Fabricators, that not all of this armor is being welded, that strategic alloys could be reduced in armor castings which are not to be welded, if a higher carbon content were permitted. Now I think that is something that the armor fabricators and casters could take up."

There was some comment about heat treating difficulty with a 0.30% C maximum plate and Major Coombe again emphasized his suggestion about co-operation between armor producers and fabricators. Mr. Biederman outlined a test he planned to make to show effect of carbon, if any:

"Major Coombe, we have been up against this higher carbon, and we didn't know if it causes trouble or whether it didn't cause us trouble, and you might be interested in a test we are going to make. We are going to take the same composition pretty near all the way through, and we will have four plates of 0.25% carbon; four plates, 1-1/2", at 0.30%; four at 0.35% carbon; and four at 0.40% carbon; and those plates will all go to Aberdeen, and we wish that Aberdeen would take pains with them, because that might answer a lot of questions on this carbon. We will weld all plates with the same plan and procedure all the way through, with exactly the same electrode, good or bad, so that we get the difference in the carbon."

On the effect of the carbon content, Mr. Komarnitsky commented:

"I am afraid that the carbon content is a convenient goat to hang quite a lot of welding troubles on, and is used rather as a simplified approach to the problem. We found out in our work that the carbon content alone is not the criterion as to whether the plate can be welded or not. The criterion is the hardenability characteristics of the steels, and they are not dependent alone on the carbon content. They are dependent on the combination of other elements in the steel. We found definitely, for instance, that the steel with .26/.27 carbon had hardenability characteristics in such a manner that, generally, when hardenability tests on the surface give a maximum Rockwell hardness above 50, you get in trouble, regardless of the carbon content. And we found otherwise that the carbon content of the hardenability curves are such that maximum Rockwell hardness on the surface obtainable is less than 50."

Which was corroborated by Mr. Mikhalapov:

"I would like to substantiate Mr. Komarnitsky's statement; the carbon content alone doesn't mean a thing. We have evidence that steel armor plate with carbon content as high as 0.45 carbon has a far better welding characteristic than armor with lower carbon content, providing that the other alloying elements are not present. In other words, it is entirely a question of hardenability of the steel and the matter of heat treatment ensuing. The thing which gives you trouble in welding is what happens to the plate after quenching, which is experienced during welding. Now if the plate itself has been quenched more drastically beforehand than the weld can quench it, then the weld will not affect the plate. So it is not the carbon alone, but the hardenability and the way it has been quenched, and the heat treating, which affects the welding."

In order to get better agreement on this subject, Col. Zornig suggested:

"Along the line of this discussion, I will take it upon myself to make arrangements to get representatives of the welders and the armor plate manufacturers together in the not too distant future, to go into the matter further."

Mr. Vennerholm pointed out that:

"There are quite a lot of inconsistencies, as far as the carbon content is concerned. As manufacturers of test armor, at the present time, we are permitted to use up to 0.35 carbon, and for the manufacturers of rolled armor the limit is 0.30. That in itself is very inconsistent. Furthermore, this 0.30 carbon limitation of rolled armor forces the manufacturer to use considerably more alloying elements, strategic elements, than would be necessary."

Mr. Cooper presented a report of the resistance welding situation:

"On behalf of the Resistance Welding Group, as new members, we wish to state that this is going to help answer a lot of our headaches. We have lacked the connection with the applications and that has been a great deal more important in the case of resistance welding than it is in arc welding, because the geometry of the work, flatness of your plates, whether they can be pressed together, alloys, the rest of it, is a great deal more important to us than perhaps it is to an arc welding process which is much more flexible in application.

"About a year ago, certain members in the services, because of their connection with resistance welding, thought that there might be a possibility of applying either flash welding or spot welding, and, since there was no mechanism set up to say for sure, no research council as we have now, they approached several members of the Resistance Welder Manufacturers Association, and at least one user, to form this committee in conjunction with the service units from the different arsenals and one aircraft group. This work of attachments to armor plate of low carbon steel, low alloy, stainless or armor plate, had to be investigated. The lapping of joints, the use of butt straps and the question of face-hardened plate versus homogeneous were discussed. Nobody knew whether they could be resistance welded. So the manufacturers divided up certain projects, approximately equal, between spot welding and flash welding, and started in to make their samples.

"Flash welding was a little bit different because while you could work out techniques in a laboratory, which could be basically judged only by the criterion of hardness, that is, Vickers-Rockwell plots across the weld zone trying to keep the maximum hardness similar to the plate, it couldn't go very far on ballistic tests because the samples, which are adequate for ballistic firing, are almost beyond the range of available machines. However, we were

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fortunate in having one of the members convince his management that they should build large machines to try this out, and if it was satisfactory, they could go ahead and make some production welds. This limitation on machines in flash welding is a serious one. Large flash welders involve machines with a price of six figures. In some cases, a quarter of a million dollars isn't at all out of range and the question of power demand and supply is another important feature. We have almost come to a dead end on flash welding work unless some of you fellows, as users, can give us some specific applications through proper channels. If, as homogeneous or face-hardened fabricators, your committee chairman cannot report to our committee chairman some specific applications, we are almost at a dead end. I think that is an important point, because we have gone about as far as we can without knowing specific applications.

"One of the main items under consideration is the Specification WXS-169 which we hope to have out as a complete specification to be turned over to the Specifications Group in the next few weeks. That has been dragging along because of lack of technical information. We think now we can fill in the gaps and submit that to the rest of the groups, after it has passed the Specifications Group, as a qualified specification for process and inspection requirements during fabrication.

"The factor of hardenability of steels has been a headache to us. We started out at a time a year ago when everybody was considering 5% nickel, and that maybe was fortunate, because if we could weld the analysis a year ago I think we could easily weld the ones that are being stabilized now. On the other hand, there are still two schools of thought as to the effect of the analysis as concerned with the resistance welding processes. One school of thought is that the more drastic quenching rate makes the peak hardnesses greater on resistance welding processes. Other groups, and they have equally good reasons, seem to think that the temperature from which the quench is started in the arc makes the gradient so much steeper than that obtained in resistance welding, particularly with the so-called austempering process, or post-heating, that the process of spot welding is less critical. To date we have no exact data. Mr. Mikhalapov's committee should in the near future be able to answer that question for us.

"As far as the project underway is concerned, the work in the laboratories of the Group members is going very slowly. It is going slowly because it is tied up with the applications, and similarly to flash welding, we ask that you fabricators furnish through your Chairman as many specification applications as you can. We are faced right off in spot welding with the questions: What throat depth do you need? What range of thicknesses? What are some of the power limitations? Mainly we need to know just the thicknesses, the type of joints, whether butt joints are practical."

Col. Zornig made a suggestion:

"I would like to make a suggestion - that your Group get up a

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questionnaire as to the type of information that you would like, as to gaps and things of that sort, and we will attempt to circulate that to the fabricators and get it back to you. I think that is probably the best preliminary step that we can do in that line. Is that satisfactory? If you will send that to me at Watertown, I will see that it gets circulated to the fabricators' groups and back to you."

This suggestion was agreed to by Mr. Cooper and Mr. Biederman made a suggestion about flash welding:

"We have done some flash welding in the very beginning, with a couple of the manufacturers, on 3/4" plate, and had it fired ballistically. We had some good ones and bad ones but, if the flash welding could be controlled then it would be a 100% job. I think the resistance welder manufacturers have got a big job here that can help this whole program by working with the steel mills. They run plates now where they cut half of the plate out to ship half of it. If it's a foot too small, they have got to send it back as scrap, where by means of flash welding, they could weld a piece on the end and get another plate. In other words, the steel manufacturer could cut his scrap from 40% to 50% down to 30% to 40% and it would mean that everybody would have to have a big machine. It could be a sort of setup there where all the scrap from the plate manufacturer would go to this one source and be flash welded into larger plates so they in turn could be cut into new units, and it would save an awful lot of melting new steel all the time, especially 3/4", 1/2", 3/8" and 1" plate. I offer that just as a suggestion of salvage."

Major McInnes reported on the Aircraft Armor Fabricators' Group:

"The Aircraft Group is a brand new Group. The first meeting was held yesterday and we covered merely the groundwork of what was wanted. The primary function of the Group is as much installation as it is fabrication, but the two are so interlinked that we thought it was good to tie in with this Subcommittee. For that reason, the Chairman of this Committee and personnel at Wright Field decided to go ahead and request the representative aircraft manufacturers to organize this Group, with the idea of keeping it strictly to aircraft manufacturers to prevent the group from being too large, and also recognizing the fact that there were so many structural problems coming up which were of very little interest to steel people and a good percentage of the welding people. By including the knowledge of this Committee we get a much broader field to attack the problem, because it can bring in the problem of welding clips, which is the first item of importance. It eliminates bolt holes, decreases tolerance restrictions, which has always been a bugaboo for the aircraft people, or not so much to them as it has been the people trying to supply them, and it ended up that the main problem at present is the method of attaching clips, either by the resistance welding method, by the fillet type of arc welding, or a plug type of arc weld.

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of just how these various vehicles or various fabricators' vehicles are going to stand up in combat. There may be other comments that other representatives of the Ordnance Department will make for a new requirement of the ballistic test on a fabricated hull."

Major Coombe commented further:

"We have no reports on the performance of these vehicles in battle. As Lieutenant Pless has explained, the qualification test plate does not give us any indication of the performance of what you are putting into the tank. Our inspection is far from adequate. We do not have 100% radiographic inspection. We have inexperienced inspectors. We cannot tell how these joints are made. I think we all know that you can't tell by looking at a weld what is inside of it. The only proof we know on that is to shoot at it and see how the tank hull stands up, (1) as a structure, (2) how the welded joints stand up. Until we can provide a 100% radiographic inspection, I know of no other way of proving these structures except shooting at them."

Mr. Raymo commented generally on production and fabrication difficulties of tank fabricators:

"I am very much in accord with what you are saying here and the thing that gives me concern is the snail-like pace at which the opinions move along in engineering tanks that you are going to be guided by hereafter. I think it was at the Pittsburgh meeting that someone made a suggestion that what we needed was an electrode of one composition. It was thoroughly rejected at that time because of the reluctance of all of us to sacrifice our prerogative to build an electrode as we thought best, or as a fabricator thought best to meet his needs and such. We have waited until Old Mother Necessity brings us down to one electrode. I think it was the finest thing that was reported to the Committee thus far. The same holds true for these vehicles that we have now decided to find out what they really are by actually shooting at them. What I am wondering by now is, how much longer we are going to fuss around on this armor proposition. Tolerances on dimensions of plate, for example--the subject was very thoroughly kissed this morning, and everybody, I think, got the impression that there is nothing to be concerned about. Yesterday, we were concerned with getting corrugated plate. We were not talking about plus or minus, 1/16th of an inch, nor were we talking about 15/1000ths. We were talking about lousy layout and cutting, where the plate was coming 1/2" or 3/4" undersize, oversize, and such as that. We haven't talked to date about the problems that we are actually concerned with, the subject of gas cutting procedure. It is all solved, yet we are getting plate with the gas-cut edges running to 600 Brinell. How are we going to make a sound weld on that kind of stuff? Who has got to live with that problem? We know why it is 600 Brinell, and we know why it is split from one end to the other. Are we happy about these things? I see no reason why we should be. The repair of cracks--well, that is a very trivial subject. Suppose due to gas-cutting technique with the composition of the armors

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that we are trying to make you get a plate into a vehicle, let us say, a side plate and find that it is split over an area of a foot with no opportunity for radiographic inspection of that. I am talking about splits in a plate - it doesn't develop until the plate is substantially welded into the vehicle. How do we repair it and what does it mean to you when you have too many of these plates? I think this committee as a whole ought to go on record, and I would like to put it in the form of a motion for that matter that you, as you offered this morning, to bring every bit of pressure possible to bear on the steel makers and fabricators, though I see no place for the fabricators in the picture at all, to get down to uniform requirements for armor as regards weldability. If the reports that were made to us yesterday are correct, we as the fabricator, who have been welding hulls for better than a year now, stand to start from scratch again because of lousy armor compositions and poor workmanship in connection with it. Now, what are we going to do about it? Are we going to let it work itself out in another 6 months or are we going to do something about it now?"

Col. Zornig suggested making a survey by questionnaire:

"With respect to what Mr. Raymo brought out about armor compositions, I think you will find that the compositions which you get from the manufacturer from now on have pretty well settled down into certain grooves. Those have been developed on the basis of being able to pass ballistic tests under the pressure of the lowering of alloys. Now, it may be that there are other things to be considered which will show one or more compositions superior to another one, such as fabrication difficulties. These things you have brought up. And the question now comes up as to how to find that out. It just occurs to me that maybe we are going to have to send around a questionnaire to the various fabricators to find out what their experience is with certain types of plates, in the fabrication. We can tell very easily which type of composition of which plate is all right ballistically because every one of them is tested and we know what is there but when it comes to the fabrication difficulties and the experience with cracks and so forth, that isn't so easy to get hold of, and I know of no other way than to start right out in detail and find out from your fabricators what experiences you are having. Then we can put that up to the plate manufacturers. I would like to hear some comments on that question. I simply suggest this, that before you start standardizing on something, that you better find out which ones of those that pass ballistic tests are the most satisfactory from the other respects."

To which Mr. Raymo replied:

"I quite agree with you in that respect, Colonel, although I think that it would be a step backwards to let our efforts rest while we are finding out whether or not some new composition is going to equal that which over a long period of time in the past has been furnished, let us say, by the Carnegie Steel Company, one of the makers of armor for the longest period of time. It is quite possible that somebody who started making armor tomorrow will surpass them in ballistic characteristics as well as weldability characteristics. I don't think we should wait until tomorrow to find out."

Col. Zornig asked what Mr. Raymo proposed as a method of finding out what compositions are most weldable. Mr. Raymo replied:

"Obviously, continued research and developmental work has got to be carried on. Our steel companies are well equipped to do that and we know that they are going to do it. We also have such efforts as may be devised or directed or financed, let us say, through this National Research Council, but I can't see any reason for fooling around with compositions that border on difficult weldability. This high hardness that results from the most efficient or the most expedient method of gas cutting that you use when we know that we have other compositions, that, if made by one, should reasonably be able to be made by another manufacturer, and let's get going. Every last plant in the country making tanks today is practically stopped off for lack of sufficient plate, and I can see no reason why we should have to repeat a year's cycle of investigating compositions when we have gotten proven armor compositions."

Col. Zornig continued:

"I didn't get your answer to my question as to which one, or ones, of the present compositions which are being made, and are proven ballistically, that you object to, or how we are to find out which ones we object to."

Mr. Raymo replied:

"All right. The Standard Steel Spring Company. That was brought out and no names were mentioned yesterday, about the compositions that were being proposed through that group. Well, it is the one I object to. It looks to me like we are starting around on another merry-go-round to find out how to make and how to weld armor again. I don't think there is any time for it."

Major Coombe interjected:

"Colonel Zornig, may I interrupt? I should like to point out that there are several compositions being treated by Standard Steel Spring. I believe that some of those are more acceptable than others. Would Mr. Raymo care to clarify that question?"

Mr. Raymo replied:

"You have a number of problems right there, Major. There are several compositions. Why not one?"

Col. Zornig replied:

"I can tell you why there isn't one composition. That is because the mills, by virtue of their equipment, have to use different melting processes. Some of them work with electric furnaces, and some of them use open-hearth, and you can't change that. Therefore, those who work with the several processes, use the compositions

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which are the most economical with a viewpoint to saving alloys and scrap and that lend themselves best to their particular process. That's one reason why you will probably never get just one composition. But I agree with you that they may be narrowed down to less, maybe, than what we are getting now. Now, if we had some positive data to go to the steel people with, as to the objectionable features of these various compositions to the fabricators, we would have some basis on which to try to standardize but, unless we have that in pretty positive form, we are not in a very good position to go to one company and say, 'Well, your stuff isn't any good,' because they have passed the ballistic test with it."

Mr. Heusel added some comment regarding his troubles:

"Now that the problem of Standard Steel has been brought up, I would like to state this: we are doing the same thing Mr. Raymo is, having varying compositions in the same vehicle. Our two sources of armor are Great Lakes and Jones and Laughlin. Of the two, we have more trouble with Great Lakes. But there is another problem there that I would like to see if it can't be straightened out. I realize it is a tremendous problem. I don't think the compositions of the alloys are anywhere near as important in the Standard Steel Spring setup as the methods of heat treatments which are being performed all over the country in small establishments with improper equipment. It doesn't seem to me the composition, regardless of how it is changed, will ever be any good unless we heat treat it properly. The hardenability of the alloys and the weldability of the alloys are going to be a problem as long as heat treating is a problem and, until some proper facilities for heat treating are made, armor composition is going to be a problem."

It was brought out by Mr. Zoog, that there is a shortage of gas cutting equipment in some of the armor plants. Mr. Ostrom, War Production Board, expressed the desire of that organization to assist as far as possible.

Mr. Komarnitsky discussed the situation which Mr. Raymo had just criticized:

"Colonel Zornig, I would like to try to answer several points which were brought up by Mr. Raymo, especially in conjunction with the Standard Steel Spring Company. By inference or by direct statement he stated that the tank production is stymied by the Standard Steel, and this and that and what not. Our figures show that we have furnished the armor for several thousand vehicles already and more than approximately 2000 of them are welded. Quite likely some fabricators are experiencing trouble but not to such an extent as pictures. There are troubles with armor plate which we are furnishing. There is bound to be. In the first place, Standard Steel Spring Company was started as an emergency combine. Our sources of steel had never made armor plate before. Some of them had not made it for 20 or 30 years. Moreover, they didn't have any experience and couldn't get it from established sources because they had started with the low carbon alloys which nobody is even making as yet. So it was necessary to do research work on these newer compositions, establish melting and mill practices for alloys, and to make deliveries. Granted that it can be improved considerably, and it will be improved. If you take into consideration that this project was started, roughly, in February of that year and examine the record of the performance of this combine in that time, I then think the statements Mr. Raymo made are a little out of place when regarded in the proper light.

"Now the question was raised by one of your prime contractors, the accusation has been made that the effect of weldability depends also upon the heat treatment. Well, I would like to see the proof of that. We found out that if it is possible to control a little bit closer the compositions in open-hearth furnaces, perhaps it can just simply be done, but we found out that, so far, if we are heat treating the plate, within certain limitations of core hardness - incidentally, nobody else does that to my knowledge - the plate performs rather uniformly ballistically and the physical test is rather uniform. We started just simply with the furnaces which we were using to do anything from springs to earthenware and enameling furnaces. We rationalized the production of armor plate. We found out that in order to achieve uniform results we should simply take certain tests, like core hardness tests after quenching, and we are doing that right now. We feel that our plate is made more uniform and on a more rationalized basis than makers of armor plate have been doing for the last twenty years. We achieved that in a few months. Granted that we are not perfect, and we cannot be perfect under those conditions, but we are improving. There is no question about it - quite a bit of ground has to be covered yet by close coordination of steel producers, heat treaters and ultimate users of the plate. These things have to be achieved gradually. They cannot be achieved this afternoon or tomorrow either. It is a question of a gradual process, of the combined efforts of these three groups."

To which Mr. Raymo replied:

"In the light of Mr. Komarnitsky's very admirable statement of his position, I will not hesitate for a moment to make public apology for any remarks that I made that may seem to have carried the intent of disparaging or belittling what I believe to be a very sincere effort on the part of an emergency setup, as named, and I have nothing more to add to that."

In view of this discussion, Col. Zornig remarked:

"I was just sitting here thinking whether it might not be a good idea to have some of the representatives of the fabricators invited to the next meeting of the Subcommittee of the armor plate manufacturers and let them express their views to the plate manufacturers, and I think I will see whether I can arrange that for the near future."

Mr. Raymo agreed that this suggestion was a good one and continued:

"Before leaving the discussion, I am going to come back to electrodes - the 12/6 composition that was discussed a little while ago. We were told that certain elements were very critical and such as that. We have had opportunity to try out, and my remarks hinge upon only the small amount of work that has been done in our own plant, this critical element-saving material which was initiated by Whitey Maurath. We said here this morning that further developmental work on this project, on this particular composition, was held in abeyance, or was slowed down by the fact that this gentleman was unfortunate enough to have his plant destroyed by fire. Are we going to sit around and wait until he has a chance to get back on his feet while we are trying to find out more about this composition? I don't think we should."

It was explained by Mr. Rutishauser that work with this composition, 12% chrome, 6% nickel, 4% manganese, will be carried on as development by other electrode manufacturers.

Mr. Maurath commented:

"For the information of all concerned, the heat of steel, which was made by Republic, was in that wire mill. When the fire occurred, it had to be removed and taken to another mill for fabrication. The plates that I subjected to the courtesy and co-operation of Mr. Biederman and Mr. Raymo all passed and the statement has been made that it be set in abeyance, to be considered as an experiment, which means that we will just have to wait until we get somebody else to help it along."

Mr. McPherson, Chain Belt Company, aired some of the troubles he has been having with armor from the Standard Steel Spring Company:

"We have got a lot of plates in our plant right now that have high hardness on the edges; they are all over the lot on tolerances and the like. Again, too, let's judge these heat treaters and fabricators by how far they have gone, not what they are right now. I'd like to put a question, especially to the gentlemen from Standard Steel Spring. We have in our plant today about 100 tops for the M-5 turrets, We have a good many of them over there and we have been struggling along trying to put those in turrets. We are turning out turrets, yes, but we are greatly curtailed by the tolerances on these plates. We have been playing along with these fellows because we know that they are doing a swell job. They are doing the very best they can do, but I'd like to hear from Standard Steel Spring. Are we going to go on like this - on and on? If you are not straightened out on that, let's go to the Ordnance Department, let's go to the National Research Council, go wherever we may, to get an answer to that. I think there are men right here in this room who can give Standard Steel Spring the answer to that problem if they are not straightened out on it. I'd like to hear from Standard Steel Spring at this time."

Mr. Zilch commented:

"Most of our plate is cut before heat treatment so you shouldn't get much hardness. There would be some, depending on the way we have to cut it, if we have to heat treat before we cut. I'd say 60% of our plate is cut before heat treating, so the hardness, if any, is going after heat treating."

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Mr. McPherson continued:

"So I think that Standard Steel Spring deserves a lot of credit for their work as far as they have gone. There are a lot of problems and we have to iron them out, and I think we will iron them out eventually. That brings out the point exactly that I wanted to put before this Committee this afternoon, and I think we don't want to limit that criticism to Standard Steel Spring alone. I think Mr. Zilch's explanation of that will ease the feeling that many of us in the room have towards the Standard Steel Spring Company, and also let's spread that out to the Great Lakes Steel Corporation. Now, there is just one more question I'd like to ask Mr. Zilch, and that is with reference to these tolerances, We have some plates over there in our plant at the present time, namely, they are tail pieces for the roof tops of the M-5 tank. Those plates are at least 3/8" short. Well, we used part of them and the others we absolutely can't use. Is there some reason why you are getting those plates out short that come through to us? Are you straightened out on that?"

Mr. Zilch replied:

"You know we have about 30 odd subcontractors, just like Mr. Komarnitsky said, but they made bumpers and everything else you can think of and they also have green men. Although we are Standard Steel Spring, we get blamed for all of the trouble, and we have got 30 subcontractors under us. We might do 100% at Coraopolis but what the subcontractor which we don't know anything about, but whom somebody in our organization does know something about, and all you can do is to travel around to these different concerns, when you hear they are in trouble, and try to correct it. If you are getting plates 3/8" short, it is liable to come from anybody in our organization. You have the same problem Massey-Harris has, yet, on the other hand, we have to answer to Massey-Harris when some of our products aren't just exactly right. I think it is your responsibility to see to it that your subcontractors, before they start cutting around on this expensive armor plate, are properly informed as to the method of cutting, the procedure of cutting, and send one of your representatives out there from the Coraopolis plant, which is doing a fine job, and see if you can get straightened out. We are wasting a lot of valuable armor plate here. We have got some of it in our plant we can't use. I agree 100%, but you don't have enough manpower to do that."

Mr. McPherson offered the assistance of his organization:

"All right, right here in this room we have men whom you might call the cream of the country, men requested to come here by the Ordnance Department, and if the Standard Steel Spring Company can't get men, I think it is the responsibility of the Ordnance Department to call on men experienced in flame cutting to come to the aid of these subcontractors, and I would go on record as saying that the Chain Belt Company will gladly offer help to any of your subcontractors who are in our territory. I believe we'd be far better off in the long run."

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And continued to emphasize a point in regard to Ordnance inspection:

"The turrets we ship, although they bear a bomb stamp, are still the responsibility of the Chain Belt Company, if anything is wrong with them. I may be off on the wrong foot there in speaking for the Ordnance Department, and I wish the Ordnance Department would correct me, and also our resident Ordnance inspector if that is not true, because I know that's the way he looks at it. We spoke at great length about that thing before we came over here. If it is true that you are shipping plates that your Ordnance inspector won't O.K., keep them over there in your own plant because we don't want to be bothered with them. We've got a lot of plates over there and a lot of inspectors and have them go over every one of those plates with a fine tooth comb. We get a plate on the turret, we have got to take it out and throw it away, so I think it's the responsibility of the Ordnance Department to see to it that those plates are not shipped if they are undersized, and I think that is perfectly sound reasoning."

To which Major Coombe added:

"Yes, as long as we are on this subject, there has been no end of pressure put upon our Department in Washington to waive specification requirements on certain material in order that they shall be accepted. The situation as I understand it is this: our tank producing facilities are in excess of the material available. I should like to be corrected by WPB representatives, if there are any present, if that is not correct. It so happens that with that situation, certain of these armor producing facilities can be cut out of the picture until they learn how to make the proper armor. It is the responsibility of any reliable corporation, especially in war times, to produce material to specifications. If they can do that in certain plants, and can't do it in others, then let them shut down those inadequate plants, produce with the facilities that can produce the proper stuff and learn how to do it in the other plants, and don't burden the Ordnance Department with all of your officials coming down to Washington and putting the pressure on us to accept material that does not answer to Ordnance specifications."

Mr. McPherson continued and touched upon a very important point regarding Ordnance inspection:

"I'd like to say a word here, and I'd like to ask a question. What do we gain here by getting the specifications waived at Standard Steel Spring and not waive the specifications over at Chain Belt? What in the world do we gain by getting that plate over there and cluttering up the railroad facilities, which are overburdened, with plates which our inspectors won't let us use? What are we going to do with that stuff? We can only do one thing--pack it up and burden the railroads and send it back again. I imagine Raymo and a lot of the other fellows get the same thing. If they are going to waive the specifications for Standard Steel Spring, for heaven's sake, fellows, somebody go over and inform our Ordnance

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"In addition to the facilities of the U. S. Steel Corporation Research Laboratory at Kearney, we had two in Illinois, both to speed up the preparation of metallurgical specimens and also to enable us to use other tests which were beyond the range of equipment available at Kearney. In the Illinois plant, in addition to the usual metallurgical examinations, we intend to make tests of weld specimens which will cover welds 2" or 3" in width, to full plate thickness, both bend and tensile strength. This, of course, involves very large testing equipment. We will also attempt to make other types of impact tests and a very accurate determination of the limitation of the welds. I may add that to help us guide this work we have organized a very small group of 6 people who are generally considered as the leading welding experts in the country, chiefly from the heavy pressure industries who are trying to help us steer this program insofar as the study of electrode properties is concerned, in an endeavor to ascertain something of help to us. We have conducted a number of restrained joint tests on commercial types of ferritic electrodes and to date it appears that none of these electrodes, when used on armor plate, can be used without preheat. We have done some work with fillers of 5% nickel and 1% carbon composition. That is an austenitic deposit. Unfortunately, so far it has not proven to be sufficiently ductile to stand even a common bend test or any other kind of a test. It is extremely brittle material.

"We are conducting a series of dilatometer studies to find out if there is any relation between the dilatometric properties of weld metal and the sensitivity to cracking on the face-hardened armor plate. We have not been able to move very far because we have not been able to get armor plate at all. On the spot welding of armor plate we have had very interesting work on 1/4" and 1/2" plate of NAX 9115 molybdenum bearing. That is not strictly armor, but has physical properties similar to that of some homogeneous armor being made. On the basis of this material, it looks as if it is practicable to spot weld almost anything. In fact, materials which cannot be arc welded with comparative ease and obtain excellent results. Frankly, the flash welding picture does not look too encouraging right now. Although Mr. Cooper told you that it is chiefly a matter of getting the user and the manufacturer together, I think we are not ready for that, since so far we have not found any flash-welded joint which is completely free from the decarburized zone. That applied to heavy armor. On thin armor, that is, up to 1/4" and 1/2", I think some excellent results have been obtained. We have been very glad to find that a test which we have been trying to develop, and which was originally suggested by Col. Zornig and Mr. Danse of Cadillac Motor Company, has been very successful. It is not definitely proven that the test will tell us everything that a ballistic test will, but to date there appears to be very close correlation between that type of test and the ballistic results. For your own information, I may describe the test to some extent. It simply consists of taking a piece of welded joint, the test specimen being 8" long by 2" wide, with the welding going at right angles to the long axis of the specimen. The butt weld specimen is supported at the two ends and an explosive is applied to the center of the specimen or the weld. Not only have we been able to find a superlative type of fracture with austenitic welds where the weld deforms and plastically flows to the extent that the specimen bends nearly 50° before fracturing, while the ferritic welds fracture without any deformation. Briefly, the highest charge was required to break the austenitic specimens. A medium charge was required to break the ferritic weld cut out of a plate which performed ballistically well. Specimens cut out of the plate which performed ballistically very poorly took the lowest amount of explosive to break.

"I have mentioned to you earlier in the game that the carbon content is not the only thing which determines weldability of armor plate. The reason for my saying this was that in one of our investigations we have been able to produce armor with carbon-manganese steel grainal treated. That armor is not entirely satisfactory yet. The significant part is that those armors containing .70 manganese and over .40 carbon are very freely weldable. There is no evidence of any cracking in it. In fact, when welded with either ferritic or austenitic electrodes in thicknesses up to 1/2" no tendency for cracking of any kind was observed. Anything that the weld can do to it, that is, any rate of cooling which occurs on welding, is less drastic than that of the quench. As a result, the tendency is for the metal to be annealed on each side of the weld rather than to be hardened. There has been no evidence of a high hardened zone near the weld; rather, the zone is softened. Whether the grainal treatment which does increase ductility to a large extent has also something to do with the lack of hardness, I don't know. Possibly, it has. It looks if that investigation is successful, we will have material which is extremely readily weldable."

With reference to the mechanical stress relief mentioned, Mr. Mikhalapov continued:

"The first mechanical stress relief we got was entirely accidental and unpremeditated. It was simply obtained by the crossbar weld cracking in two places on each end of the crossbar transverse to the weld, which apparently relieved the stress action to some extent because the crack opened up after the plate cooled down. This plate was repaired and passed the ballistic shock test. Another plate, which didn't crack, failed in the shock test. Now, to see if that had any significance, on the next two plates we left a gap of about 1" long on each end of the crossbar weld right next to where it touches the leg. After the plate was cooled down and set for a while, we filled up those gaps with austenitic weld metal. We had two plates welded that way. The third type of stress relief, I should say, was where the back of the plate was shot blasted with heavy shot."

It was further emphasized by Mr. Mikhalapov, upon questioning that the ferritic welds performed better than the austenitic welds on ballistic tests:

"Now, I say the best results, from the shock point of view, we have had from those 5 plates. They stood up well and took a tremendous punishment. Some of them had as many as 5 shots, from 1100 to 1300 f/s without any semblance of a crack in the weld metal. One of them had a slight crack through the parent plate originating at the crack which was started at the gap which was filled up with austenitic material. Another had a crack through the parent metal away from the weld and the heat-affected zone. It looks better than anything which I have seen with austenitic material."

And yet on the direct explosive test the reverse occurred:

"That is right. Now, one reason for it was this: The specimen used was not of the very best plate we had. That is, those plates which stood up so well had been so hammered out of shape by dishing that it was difficult to get many specimens out of them, so we took some other plates, which did about as well as the austenitic plates did. If I remember right, that plate we used stood about 3 shots and fractured at one leg, part way, but it had some sound unaffected welds which could be used for specimens. That may be one explanation."

Upon request from Mr. Merriman:

"Would the Research Committee feel that if things had to be crystallized to you, we would be safe in standardizing on the austenitic rod, that is, the main thing? Then should we drop the ferritic rod?"

Mr. Mikhalapov replied:

"No, I don't think so. First of all, one of the great reasons for the ferritic rod is because of the scarcity of alloy material. If we can develop a good ferritic rod we can save a lot of nickel and chrome even if it is not as good as the austenitic. Furthermore, my personal opinion is this, that as the war progresses, with the demand for better vehicles and stronger armor, we may find that the present methods are not adequate. It finally may develop something with ferritic electrodes or austenitic which will be much better than we have now. We know now that actually it fractures at a lower velocity than the parent plate does, but we have by no means a perfect joint. So the second purpose for ferritic investigation is to see if we can't find a type of joint which will be better than we have now, but I certainly wouldn't say we are ready to do any changing over at this point."

Mr. Merriman mentioned that he was concerned chiefly with plate thicknesses up to 1/2" and Mr. Bibber commented:

"I would like to make a suggestion, George, if I may, in regard to those explosion tests that you are making. If you are using relatively small section bars such as you mentioned, the stress situation of those narrow bars is quite different from that in a large plate. The character of the fracture is quite different because the actual stress situation is not developed in the narrow bar that is developed in the wide plate. I believe that you would

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be better off to do the testing of the type you mentioned on plates approximately square whatever you may decide the dimension to be. I think that that may have some bearing on the question that Mr. Merriman raised. If you can get a piece 12" square or 18" square just as readily as you can get the 2" by 18", it doesn't seem to me that the amount of armor is particularly significant. We have ample experience both in practice and in testing to show that the performance of a narrow specimen is such that it will elongate like molasses candy and is quite different from a wider plate. It seems to me that you are starting off with a wrong specimen, and the question of the size of the armor I don't think is particularly significant. Make it any size or any thickness you want it, but make it of the same shape, namely, square."

To which Mr. Mikhalapov replied:

"We have tried 2" wide, 3" wide and 6" wide, and so far the fracture appears to be of the same type, the brittle fracture, that is, in the ferritic electrode with practically no elongation and the change of explosive is the same. We can still go higher; we can go to 12", buy why go to bigger specimens if we can get the same correlation between that and the ballistic tests on that small specimen? The moment we run into some apparent contradiction, such as ballistic tests showing one thing, explosive tests showing another thing, let's stop then and look for something else; but if you have three things all performing about the same, wouldn't you choose the one, the smallest specimen, and the least amount of welding?"

It was indicated that this work is being continued to answer the point raised by Mr. Bibber.

Mr. Jackson, Naval Research Laboratory, explained a laboratory ballistic test being developed at that station:

"We have used .50 cal. Ball ammunition in order to get a shock test. We have tried the .50 cal. armor-piercing projectiles, but they have not proven satisfactory because it is impossible to get the energy into the test piece. The energy is used up in going through the piece rather than the energy going into the piece. We have made probably between 50 and 100 shots, so our work is entirely in the preliminary stage, and one of the reasons for bringing it out at the present time is that it does show promise and we hope to be able to make a larger number of test pieces in the near future. We are using a ballistic pendulum for measurement of our projectile velocity. Our velocity measurements are within 1/3% of correct value. In the simplest form, we are using a corner joint for holding up the sample. The corner joint is made up in 1" thick plate with a weld joining the two sections. We have tried several types of joints, the double V, the single V groove, and the single V groove backed up with a fillet. The original piece is much longer so that the welding is somewhat similar to that in a joint of this type. The small side of the test piece is flame cut off, and the rest of the test piece

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is prepared by us with a hacksaw. The hacksaw cuts the discard off and a hacksaw cut is made down through the joint. The piece is set up in this position, and the projectiles are aimed at a point which we can control within 1/32" on each one of these shoulder pieces. The velocity is controlled so that we have a velocity below that necessary to fracture that joint. The test as it has developed so far will require considerably more work, and we hope that as the test progresses, that it will be of service as a preliminary test for the study of new electrodes. One of the series of tests that we have underway is using the 12/6/6 combination, and we also have tests underway using standard electrodes, so that possibly we can arrive at some definite velocity in feet per second that would be characteristic of a good weld. We do not feel that it will replace in any way the H plate, but we do feel that it should serve as a development test preliminary to the stage of the game where the process and the materials are suitable for the H test."

Colonel Zornig commented:

"Thank you very much, Mr. Jackson. I think you gentlemen will see that there are becoming available, means by which you may be able to do some preliminary testing of your welds before you go to one of those $1200 H plates. We hope so, at least, with what the Navy is doing and what N.R.C. is doing, it may prove to be of some use in that respect."

Mr. Danse raised a point:

"Mr. Chairman, General Motors Division is still interested in the subject of shot blasting plate. We thought we had made that and planted it and got daisies growing on it. I wonder if something could be done to get the Ordnance inspectors called off and stop talking about shot blasting plate."

Colonel Zornig stated that he did not know the "ins" and "outs" of this question and Mr. Danse continued:

"Well, Mr. Chairman, the 'ins' and 'outs' amount to considerable investment if it's required to shot blast. We don't think it is. We don't believe that Ordnance thinks it is, but apparently Ordnance is getting to be a pretty big organization and 'the right hand knows not what the left hand doeth.'"

Major Coombe agreed to look into this question and try to find the answer.

Mr. Kerkhoff raised a question about the qualification of a welding procedure:

"When a manufacturer intends to change his procedure of welding, we will say, from the hand arc method to the Unionmelt method, there is a period of development, of course, he must go through. Is there a definite number of plates he must submit for development? A manufacturer will send in, we will say, Unionmelt plates where previously he had been welding with the hand arc

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method. The plates, of course, will come back. The reports from Aberdeen will say 'experimental plates.' Well, now, no one seems to know how far he must continue on with these experimental plates before one will be accepted as the qualification plate. I think that definite standards should be set in that regard."

To which Major Coombe replied:

"I quite disagree with that. When you introduce a new method, that has not been tried before, we cannot allow you to qualify on one plate, or two plates, or three plates, or any arbitrary number of plates. When you have demonstrated your ability by submitting several satisfactory plates, then the Ordnance Office will review that data at hand and will give you a decision. That has been true in the case of one of the fabricators who has qualified with Unionmelt welding on thin plates. That's using the ferritic electrode."

Mr. Kerkhoff cited a current situation as an illustration and Major Coombe replied:

"So long as you mark your plates 'development plates', or so long as they are considered development plates, they will be considered as such and only when we have sufficient data will we give a decision. Well, I think this is a matter that is not adding to the general meeting. If you will take that up with the office by correspondence and get all your facts before me, I can give you an answer, but I don't know exactly what your case is."

With reference to the location of the next meeting, Mr. Danse commented:

"Mr. Chairman, sometime ago it was suggested that the meetings that are held in Detroit are not so convenient for the Eastern Ordnance Districts and those representatives since then have been conspicuous by their absence. We have missed them. That is just a hint."

To which Mr. Jeffries added:

"I have heard that same reason for spreading these meetings out expressed among several of the Eastern people who are interested, and I think we ought to give some consideration to coming East once in a while. I don't know - Philadelphia or Pittsburgh wouldn't be so bad. I would rather see it in Philadelphia; then I wouldn't have to travel."

It was finally decided that the next meeting of the Subcommittee would be held in Philadelphia about 6 December 1942 after which the meeting adjourned.

The Subcommittee on Resistance Welding is now the Resistance Welding Group of the Subcommittee on Welding of Armor. This meeting marked the termination of Lt. Col. Cox's connection with the Subcommittee as well as that of Captain Matthews. The writer took over as Secretary of the Subcommittee at this meeting for Captain Matthews was sufficiently occupied as Secretary of the Rolled Armor Subcommittee, the Cast Armor Subcommittee and the Aircraft Armor Subcommittee.

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Mr. Merriman resigned as Chairman of the Aircraft Armor Fabricators Group - Eastern Division, and Major McInnes was appointed by Col. Zornig.

At this meeting some very caustic criticism was directed by the tank fabricators toward the Standard Steel Spring Company. This criticism was most ably answered by Mr. Komarnitsky who explained a situation in the armor production program which had never been realized by the tank fabricators. This prolonged discussion about fabricator troubles with armor plate suggested to Col. Zornig the idea of Liaison Group between Subcommittees so that the question of mutual difficulties could be discussed and argued firsthand.

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TENTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
SUNDAY, 6 DECEMBER 1942
BELLEVUE-STRATFORD HOTEL, PHILADELPHIA, PENNSYLVANIA

The tenth meeting of the Subcommittee was held in Philadelphia on 6 December 1942 at the Bellevue-Stratford Hotel with 158 persons in attendance representing:

Industrial - United States	
Tank Fabricators	28
Armor Producers	6
Electrode Manufacturers	26
Core Wire Producers	7
Resistance Welding Equipment Mfrs.	7
Aircraft Fabricators	9
Individuals	6
Government - United States	
Ordnance Department	36
ASF Headquarters	2
U. S. Navy	6
Army Air Forces	3
War Production Board	2
National Research Council	2
Guests	18

The meeting was opened by Col. Zornig who introduced Col. D. N. Hauseman, Chief of the Philadelphia Ordnance District, who made several comments about the current procurement job:

"I know what a good job you have been doing on this committee and I think you are to be congratulated. We have to rely on you fellows more and more. I know it is General Campbell's idea that our whole destiny, so far as research and production are concerned, is going to be on what industry gives us; and on the production end, which I am more familiar with, we are turning more and more to industry to get their advice and help. I think it is appropriate. I just want to say about two words on what I can see for the future in the Ordnance Department this coming year. We have a lot of orders - in some cases almost too many. The result is that our requirements are constantly changing and are going to change. As General Campbell has recently said, 'War is not static; the requirements are changing from day to day.' Planes have to give way to tanks and tanks have to give way to planes, and planes give way to ammunition, and so on, and there is nothing as fluid as the requirements. We in the Districts and you manufacturers, I know, are finding that out because one day we want something and tomorrow we want something else; or we are reducing schedules or upping schedules. It is disturbing, but so is war disturbing.

"I think as a result we are going to have to look more and more to quality this coming year. We are not going to accept material that is below specifications. Manufacturers are going to be required to meet the specifications, and in many cases the specifications will be improved. And I think that in turn leads to more and more research and adopting many of the ideas and improvements and suggestions that come from your committee and other such committees."

Following Col. Hauseman's remarks, Col. Zornig introduced Col. H. G. Hoare, Inspection Board United Kingdom and Canada, who commented on recent developments in England and Canada in regard to welding of armor:

"Colonel Zornig and Gentlemen: I thank Colonel Zornig very much for giving us the opportunity of coming to these meetings because I feel that it is only by this means of co-operation that we are going to get this job done, which is in front of us. I think in connection with co-operation we have had a remarkable example set to us by these operations in North Africa. It is one which will go down in history. But I would like to suggest to you gentlemen, as manufacturers, that such co-operation as that could not be accomplished unless it was commenced with the manufacturers, because it is only by technical co-operation that such big things are made possible. We have got to supply the equipment whereby such things can be done, and so the very essence of co-operation lies with us here. And I am sure that by that means, getting together, we shall be able to more quickly finish this job that is in front of us. So this occasion reminds us of the necessity of it.

"It is the anniversary, to the day, of Pearl Harbor, and as I remember, somebody in Detroit, a speaker, recently said, 'The Japanese committed an act of jiu-jitsu in Pearl Harbor; the day is coming when they will commit hara-kiri in Japan.' And it is by this co-operation that we shall bring these things about.

"Well, I will just outline, gentlemen, what is being done in connection with armor plate and welding in England. We have gone into this welding, but in a much smaller scale than you have in this country. The welding in England is chiefly concerned with the welding of thin, bullet-proof plate, up to 14 mm. in thickness, for preparing of armored cars, reconnaissance cars, and so forth. The project was taken up early in 1939 in the interests of production; the suggestion was made that we should start welding armor plate, and all these manufacturers came back to us and said, 'You can't do it.' But they arose, and there is a proverb in England – I don't know whether you have it here – which says that 'Necessity is the mother of invention', and I am sure that necessity has enabled us to invent these methods of welding armor plate and bring them to the perfection that they are today. A step was taken, as I say, early in 1939 to place a contract, the first one that we placed, for 50 welded bodies, and I can assure you that we had some headaches.

"The problems which face you here are the same problems which are facing us in England, and it is by means of this co-operation

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that we shall make each one's job in relation to them so much easier. So now, in England, we are considering welding this thicker armor. The first tank which is coming out is going to be welded and a sample will be in this country soon.

"At present we are only doing hand welding in England. There is no automatic process such as you have here. They feel that for the preparation of the armored cars and the things they are doing that the run of welding is not of sufficient length to permit of automatic welding being done, and so it is only being done by hand. They started out originally on a lot of the bodies with riveted construction, and consideration was given to changing over in the interests of production to welded construction; but we very soon learned that if you are going to have a welded structure you have to design for welding. It is no good trying to take an original design which is designed for something else and then say 'Weld it.' It is not so easy as that. Some of the designers may think so, but I am sure you manufacturers will understand the difficulties that you encounter if you attempt it. The problem as regards the amount of carbon for welding is one which is very much to the fore in England. They have welded up to 0.36, but at a meeting with the various fabricators there was a very insistent cry that the carbon limit must be about 0.30. I have heard the same cry in this country, so apparently we are on common ground as regards that.

"In connection with the welding, one of the tests that we are carrying out in England, before we agree that any welding can satisfy, is the restrained welding test. The electrodes we are using are ordinarily high chromium-nickel, and chiefly it is limited to about 12% manganese and 5% molybdenum, and the rod is, as a rule, supplied as wire and is not coated, although there are some coated electrodes being used; but the tendency there is to use them as wire, not coated. For most of the tests that are carried out, we build a sample and subject that to actual firing tests. In our opinion that is more satisfactory, although it may be more expensive in proving your welding that way. So we have come to the conclusion that we will prove the welded bodies, the completed bodies, and then occasionally take subassemblies and send them out for actual firing tests. The manufacturer, when he prepares a subassembly and takes it out to a firing test, has no idea of how it is going to take it, and I feel sure that that gives us a more all-round picture of what the actual welding is.

"So there is the same difficulty with manufacturers in England as you experience here. We issue certain specifications and say we want to do this, that, and the other, and we get the same objections as you people raise here. But what we do is the same as you are doing here - we get everybody around a table and everyone airs his views, and as a rule we come to some sort of conclusion as a result of it. There are experiments now being carried out comparing the effect of the slug test and the effects of high explosive shell, the point being that high explosive shell is the

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"Chromium comes next for November 2.48; December 2.50 - a slight increase.

"Nickel, 3.5 in November; 4.0 in December.

"Molybdenum, 21.1 in November, and in December, 22.0.

"Vanadium showed improvement - 66.8 in November; 55.0 in December.

"These figures are based on all of the factors that enter into making a material check, that is, the production, the consumption, the availability in this country or by import. So that you see that vanadium comes with a high figure, 66.8 or 55.0, because possibly half of our vanadium is imported. On the other hand we don't use very much of it, and we don't have very much of it at our disposal.

"Now in the order of availability, I can't give you actual tonnage figures, but I can say this, that if you take vanadium as unity, for every pound of vanadium in the country that we have available we have four pounds of molybdenum, about 40 pounds of nickel, about 53 pounds of chromium, and about 250 pounds of manganese. I am advised by the alloy section that in connection with your new specification for electrodes, that they would like to see the chromium range changed from the present 20.5 to 22.5%, to 19.5 to 22.0%.

"We are not only faced in this war with a scarcity of the alloys that go to make up alloy steels, but we are short of alloy steel itself, and we are also short of alloys in different degrees. For example, you cannot talk of ferro-manganese as a unit - you must talk of low carbon and high carbon grades of each. The low carbon grade of chromium and ferro-manganese are scarce. We haven't got enough of low carbon ferro-chromium and manganese to go around to make these materials, such as you would like to have for the welding rod, and when it comes to low carbon ferro-manganese, that becomes an electric furnace problem, and electric furnace capacity is short - we haven't got it, so any trend that can be promoted towards higher carbons in any materials at all, is a trend in the right direction. And for this reason, this lowering of the amount of chromium in the material, the amount of low carbon chromium used, so that you can have a range of 19.5 to 22.0% in place of 21.5 to 22.5%, is a step in the right direction.

"Here I have a case in point: one lot of 24,000 pounds of material to make electrodes, and I think many of you would like to have 24,000 pounds of electrode wire. There are four heats in this lot which are now being held up for deviation from specifications of this order. One heat is held up for silica, because the silica is .21% with a .25% minimum in the specifications; a maximum, yes, but I don't think you need a minimum in silicon. So, for that reason, here is one that is being held up because it has .21% instead of .25% minimum. The next heat has a little high silicon - .72% silicon. There may be some argument there, because it is above the upper limit which I think is .60%. The next heat has a little low manganese, 1.42%. All of these have chromium and nickel within the requirements. The carbon ranges are .08 to .10%, and these are being held up, at least these two, one with the .09% and

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one with .10% carbon, are being held up because the electrode manufacturer says that he has to have below .08% carbon. I don't think that is the proper requirement under your present set-up. Now the last one is one with chromium a little shy - it is 20.37%. I submit that those heats are probably all right for electrode use."

To which Col. Richardson added:

"One thing, of course, that those figures do not reflect is the requirement for additional alloy steel, and that is a very severe requirement right now, and it particularly affects the nickel and the molybdenum supply; the only minimum out of which we can get additional nickel and molybdenum is our own specifications. In addition to that, we are faced with the loss of a sizable proportion of our nickel supply for certain military reasons. We need to make, or needed to make, in September over 25% more alloy steel in order to meet the requirements for tanks and planes and other military equipment and we are meeting that requirement. We are meeting it through conservation. People say often that no matter how much we conserve, the alloy still seems to be more scarce. Of course, that is due to this rising amount of alloy steel. From the month of November on, we have to make another 150,000 tons of alloy steel a month, in order to meet Army and Navy requirements, and it is very important, particularly in the case of your stainless steel, that we reduce the nickel amount, if it can be done because nickel is the one element in addition to molybdenum in which we are going to be caught short."

Mr. McDowell reported on a meeting of the Homogeneous Armor Fabricators' Group held the previous day:

"One of the first items to be considered by the Homogeneous Armor Fabricators' Group yesterday, and one that usually brings forth considerable discussion was Specification AXS-497, Revision 3, on the welding of armor. The first change that was recommended in the specification has to do with the composite test plate made of two types of armor. As the specification shows the H plate now, one type of armor is put in the two outside legs, and the second type of armor is used for the two center sections of the H plate. The Group would like to have this changed so that the one side section and one center section is made of one type of armor, and the other center section and other side section is made of the second type of armor.

"There seems to be considerable confusion and misunderstanding as to what constitutes a 'procedure qualification' test plate and what constitutes a 'development' test plate. The Group would like to have this clarified in the specification, and in regard to the qualification of new procedures, it would also like to have a more definite understanding as to the number of test plates required to qualify a new procedure. As regards H plates sent to Aberdeen Proving Ground for test, there have been instances where the plate has failed in the X-ray examination and consequently was not subjected to proof firing. In cases like this, the Group would like to

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have the individual fabricator whose plate has been rejected, notified by Aberdeen to this effect, but they would like to have the plate classified as a 'development' plate and proof fired for any information that they might gain from it. On page 11 of the Specification, on the welding of the H plate, there is a paragraph that says the interpass temperature during welding of the test plate shall not exceed the preheat temperature, if any, to be used in production. It was generally agreed that few fabricators, if any, had paid attention to this paragraph, and that it should be changed.

"At the present time a survey is being conducted by the Tank-Automotive Center to determine the average interpass temperatures encountered in the actual welding of the tank hulls, and before any changes are suggested or recommended, nothing will be done until the results of this survey have become available. The first one deals with paragraph F-2a(4) which, in the case of the rejection of an H plate, now reads that 'Another test plate may be submitted which must pass the ballistic requirements.' The proposed change would require two test plates after the first failure, and both plates must pass. In paragraph F-2a(5), the following sentence is to be added: 'And the results shall be approved by the Tank-Automotive Center.' This deals with the visual and radiographic examination of the test plates. In Table II, the following note, which deals with the shock test of the H plates is to be added: 'If any cracking occurs in the cross bar weld, as a result of an impact occurring at a distance of 3" or more from the cross bar, the plate shall be failed.' Paragraph F-2b(3) shall be changed to read as follows: 'The welding operator qualification test plate shall be made in the most difficult position encountered in welding the production vehicle. Where the thickness of the plate in the structure to be welded does not exceed 3/4", the qualification weld shall consist of a butt weld, 12" long, between two plates, each 3/8" x 12" x 4" minimum. Where the thickness of the plate in the structure to be welded exceeds 3/4", the thickness of the plate shall be 1".' Another item to be added to the specification is that 'No weld repairs of regular qualification test plates shall be made after the initial radiographic examination.'

"Considerable difficulty has been experienced by some fabricators in identifying the heat and lot number of the armor castings that they receive, and the Group recommended that in place of the present system now being used, where both the heat and lot number is stamped on the casting, that the castings be identified by serial numbers, and that the heat and lot numbers will be tied in with the serial number of the casting.

"With reference to the use of stringer beads on the last pass of a butt weld for the annealing effect, this practice is being followed by some fabricators and not being followed by others, and there was no agreement at all as to the value of this particular procedure. Some fabricators claimed that they had as good results by not using the annealing beads and others claimed that in their experience they had found that the use of the annealing beads had given them better results. In order to have a clear picture of the

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situation, Lt. Pless has agreed to make a survey of all the test plates that have been fired at Aberdeen with the result as to the number of plates which passed and failed with and without the use of annealing beads.

"The Group as a whole felt that there was a need for some test, either ballistic or physical test, that would show the relative values of the different welding procedures that are used for depositing the fillet welds, but no decision could be reached, or any good suggestion offered as to how this test might be drawn up. The maximum carbon content for rolled armor which was agreed on at a recent meeting of the Liaison Groups of the Subcommittees on Rolled Armor and Welding of Armor at Watertown Arsenal, came in for considerable discussion. There was considerable disagreement as to what the results would be when using armor plate of the maximum carbon content set at this meeting. Some fabricators expressed themselves as being fearful of the results that would occur in production welding.

"In connection with the use of large diameter electrodes, to date 25 plates have been proof fired at Aberdeen; of these, 10 have failed. While these results show that a greater number of plates have passed than have failed, the proportion of those that have passed is not great enough to prove definitely that the use of larger electrodes can be given approval by the Ordnance Department. Also, of these plates that have been fired, there was no uniform welding procedure used in the fabrication."

Lt. Pless added a comment with reference to X-ray tests of welded H plates:

"I think it would be wise to clarify the X-ray situation as explained in the report. The practice at Aberdeen in the past has not been to reject any H welded plates on X-ray. We have only judged them by standards which we would call feasible, and make a report as to whether we consider them satisfactory or unsatisfactory. That information had no bearing on whether the plate was accepted or failed. Plates have been passed or failed on the ballistic test only. The idea now is that we will put into effect, immediately or as soon as the Tank-Automotive Center advises, the X-ray judgment of H welded plates, in addition to ballistic tests, and we will pass or fail the tests on X-ray and advise the manufacturer if the plate fails, so that they may tell us whether they wish us to fire it or return it to him, and prepare him for possible grinding out the welds or making another plate so that the armor will not be wasted. If he desires us to fire the plate we will be glad to fire that plate for development, and use it for our ballistic purposes as well as any purposes he might have for that."

Some individuals thought from these remarks of Lt. Pless that no more welded plates made with 3/8" and 1/2" electrodes should be sent in for test. Lt. Pless added:

"That does not mean that we are not going to accept them or do not plan to at all - absolutely not. We are not making a flat statement to that effect, but our statement is that our results so

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far have not shown conclusively that these sizes of electrodes are suitable for production welding on these vehicles. I don't believe anyone can say that ten failures out of twenty-five is a very good showing.

"Suppose we eliminate two of the plates which you are talking about, the two plates which would seem out of all question. They do not seem to be production procedure at all. They used several small sizes of electrodes, I think it was five sizes in one case and six sizes in another case, and those two plates passed. If we subtract those from the total number of plates, we have ten failing out of twenty-three. Suppose we take three more plates of high carbon, .40 carbon, we take those from the twenty-three - that gives us seven failing out of 20 - that is still not good."

Mr. Biederman commented on this electrode question:

"I might mention the fact that when we started in welding armor plate we have very small rods, and we had very bad failures. We also had a lot higher alloy, which was 25/20. I think with a little co-operation from Aberdeen on tests of these rods we can prove to you that they will make a better welded vehicle. Take the question of your bevel or any other part; I would rather have a gallon can to fill a gallon pot than use a little teacup. Now, if you are filling up the teacup, then use the teacup, but I think that with the larger volume the large electrode gives you a better fusion zone all the way through on a 1-1/2" plate. It will carry from 50 to 70 Brinell lower than when finishing up with a 1/4" electrode due to the fact that the temperature rises and you cool slower. I think instead of criticism, that somebody tried to lay a rat in there and cover it up with the weld. I think this thing is a lot more serious than saying this is no good, and that is no good. I think we had better learn something of all these welds - small wires up to the heavy wires - and we are sure of what we can do."

And Lt. Pless added:

"We want to learn something about these things and of different electrodes, and we are willing to have it proven that they can be used in production. I hope everybody that is interested in using that size of electrode will do everything they can to prove it to us. We would like to have as many plates as they can send us, and I would advise them to stick to one procedure only and prove the one procedure to us rather than use a dozen different procedures. Then we would be willing to O.K. these rods."

Mr. Smith, Midland Steel Products Company, raised a question of interest to many fabricators:

"Personally, from my own angle we have said we are up against a manpower problem, but what I am trying to find out is, what is qualification? How many plates must I submit before I am qualified or must I go on indefinitely? Obviously, with plates costing us $1400 for every plate we are sending down there we can't go on

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forever. We can't keep sending down ten or twelve a week. If I can use large electrodes which expedite the technique in welding, I can take an operator and use the 3/16 or 1/4", or take the 1/2" electrode and get a much sounder weld. But the only reason I bring up the electrodes question is, can we be qualified? What must I do to qualify? I haven't an answer on that yet."

To which Major Coombe replied:

"I am very sorry, Mr. Smith. I have tried to answer your question. The problem is that I have not given you a 'Yes' - that is why you say that I haven't answered your question. At the last meeting I told you that I couldn't tell you how many H plates you would have to submit. We can't give an answer yet. The same thing applied to bare wire or any other procedure which we consider as unusual, not proved by experience in welding. It is one of those situations in which you can't arbitrarily say that you submit three H plates and we will qualify you. We just cannot do it that way. We are not operating that way."

And Mr. Smith asked:

"If I can qualify, say on 90% of whatever number of plates that might arbitrarily be sent Jones over here, unfortunately who cannot qualify, must I be penalized because he can't qualify? Why can't I go ahead and use the procedure in our own plant and take advantage of whatever we might be the better in?"

To which Major Coombe answered:

"Because we are still not convinced that you or anybody else can produce a satisfactory weldment."

Mr. Biederman commented:

"Mr. Chairman, I had hoped that the Ordnance Department would pick up this program and work with the people who know what this electrode situation is, who know how to use the large electrode and know how to prepare for it, and set up a program with the large electrode. In comparison with the small electrode, I feel they will be very much surprised. So I think that program should be taken up here to be definitely developed by the people that know what it is, and the Ordnance Department should be satisfied that the job is O.K. You can't blame them for turning them down. That is what we are here for, to set up programs, to prove these things. It means an awful lot of difference to the manufacturers if they can lay down 15 pounds of rod in an hour, as against 40 or 45 pounds. It means an awful lot to the wire manufacturers to save 20% of the waste in stub ends, an item which is as involved as when you are using the small electrodes. There is a lot of difference when you use one electrode per pound against eight per pound. Electrode manufacturing facilities can turn out double the tonnage with the 3/8" electrode in the day's run, approximately, than they can with the 3/16 or the 1/4" rod. That is very important with reference to machinery for coating and also the wire producing mills. If they run the 3/8" rod, they can run a lot more tonnage of rod than they can with the 5/32", 3/16", and 1/4". It means extra drawing operation to bring that rod down. I definitely think it is worth a program set up by the Ordnance Department to prove that because every advantage is in favor of the big rod, There is not one objection to the big rod as regards manufacturing facilities, saving of alloys, and saving of manpower."

Upon question by Col. Zornig as to a definite program for this study, Major Coombe explained:

"At the last meeting of this Group, those people who are now speaking about this problem agreed uniformly to submit a number of plates which they have. Due to the pressure in our office, I assumed that those people were going to outline the program among themselves. Mr. Smith submitted several plates, and Mr. Biederman has submitted several plates, and I don't recall who the others were. Now, Lt. Pless, will you tell me, or can you tell me, how many different procedures out of the twenty-five plates that were received, how many different procedures were submitted?"

And Lt. Pless added:

"I can't give you the exact number, but I can show that I don't believe more than two plates were welded alike, but I don't believe you can have more than two or three sets of those two plates that are alike. All the rest are different procedures."

Mr. Smith continued:

"Major, I am willing to rest with the Automotive and Tank Group to give us a decision. Is it out of order that you appoint someone? They can go up to Mr. Biederman's plant and they can see this thing in action, which is better. You can get more in five minutes that way than you can otherwise in a whole day. They can come to my plant and can report directly to you; in that way maybe it could be correlated, if that were possible."

To which Major Coombe replied:

"I suggest that you serve as Chairman of an informal committee of your own, between the people who are interested in this project, and that you get all the information together, get any proposed additional plates, procedures that are outlined, and call me up and we will sit down and talk it over. But I repeat, on the basis of the information that we have now we cannot give a decision and we will not."

Col. Zornig summarized:

"It seems to me that the thing has gotten far enough that there should be a definite program arranged. And I think your suggestion is a very good one; of those manufacturers who are primarily interested in wanting to use the large electrodes, that they get together and arrange with the Tank-Automotive Center a definite program which is so drawn that, when it is finished, conclusions can be drawn from it. I think, Mr. Smith, then if you will try to work out with Mr. Biederman and others who are interested, some definite program so designed that when it is

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finished some conclusions can be drawn from it, and work that up with the Tank-Automotive Center, I think we will get somewhere on it.'

Mr. Abbott reported on activities of the Face-Hardened Armor Fabricators' Group:

"Ever since the organization of the Face-Hardened Armor Fabricators' Group the principle energies of the Group have been devoted to the producing of a welded joint in face-hardened armor plate, of a character that would withstand the punishment that is required in the several vehicles in which the plate is assembled. The Group first met and agreed that the best way to handle this would be to make up its own joints and do its own pretesting and later submit plates made up according to the best practices that we knew of at the time. We would submit those then to Aberdeen and from the data obtained in our tests and from those tests at Aberdeen, Specification AXS-743 was formed. This specification has been in operation in several of the fabricators' plants now for a few months. Prior to the issuance of Specification AXS-743, several fabricators were welding joints in accordance with either tentative specifications made up at that time, or by agreement or understanding with the contracting agencies and the various inspection departments, the object, of course, being to produce the best that we knew how. These joints have been generally satisfactory; I would say they were generally satisfactory because we have had some reports from battle conditions, and from some tests that were made at Aberdeen, and with the exception of the failure of some types of joints which I believe were due to the design rather than the welding, there have been comparatively few failures.

"Recently there have been cracks that have been appearing not immediately adjacent to the welded section but about a sixteenth of an inch away from the junction of the weld in the parent metal about an eighth of an inch away, and in some cases the cracks run at right angles with the line of weld. We face-hardened fabricators are not in agreement among ourselves as to whether these cracks are caused by the inherent mechanics of the welding technique, or whether or not it is due to the chemistry of the plate. Immediately, when we saw that rejections were assuming a serious proportion we had a meeting. The first meeting about two weeks ago at Middletown was held under the auspices of the Integral Group of the Armor Plate Production Committee, and the second meeting was held yesterday. We got to the point where we decided that we would have to have another meeting to outline a further program for further development of the work, and that meeting, of course, we will call very shortly because, as I say, the rejection has assumed serious proportions.

"AXS-743 specification was also discussed at the meeting, and in general, we were of the opinion that it is a workable specification. At the time of making up Specification AXS-743, we condensed our experiences with development of joints into a manual which has been published and distributed to some of the people who are interested in the welding of face-hardened material,

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and in general, we say that it is our opinion that in regard to the joints as shown in the manual we have no desire to make any changes. It is merely a satisfactory guide for you who want to take up welding of face-hardened armor plate. It is a guide for you as a starting point. You have your different vehicles, assemblies, etc., and you will have to develop the joints accordingly. In welding armor plate, you simply cannot just put two plates together as you do an H plate, and weld them and carry that idea out throughout a structure. If you have an angle, or a bend, or two plates coming together, you have then got to provide for that - so don't take this manual as a complete guide or instruction book. It is just simply to act as a starting point.

"We have developed some new joints. One in particular that looks mighty good was developed by Mr. Osha and Mr. Steinmeyer of the American Car and Foundry Company. However, Mr. Steinmeyer has stated that their experience on that type of joint has been very limited, so far, that he would like to do further development work before he has his final recommendations to make concerning this joint. The Diebold Safe and Lock Company has made a modification of some joints on a thinner plate which we will incorporate in this manual, and which we have found for welding purposes, will eliminate some of the passes that are shown in this welding manual. In some places, instead of making five passes, we can do the same work and get the same results with three passes, etc. That weld was in thin plate. I qualify further by saying that our work has been done up to and including 1/2". Most of the work is in 3/8" and 1/2" plate and we have previously welded that with five passes with a broadening of the heat-affected zone. When we make it in three passes, we have narrowed our heat-affected zone. Our welded zone apparently remains the same. That welding is after heat treatment. Perhaps, I had better say a little more - perhaps my report was incomplete. The Diebold Company is welding by three methods. We weld an aircraft set prior to the heat treatment. The shape of the set and the nature of the weld is such that we can do that and do a very good job. When we do that, the cracking that has appeared in other types of welding is practically negligible. I doubt if we had more than one or two sets in 1000 sets rejected because of cracking in the welds. We also do a limited amount of the butt type of welding, and it is in this case that I have just cited, where we have reduced the number of passes, we have narrowed our heat-affected zones and we have not decreased the ballistics in these zones by welding. It has generally been a very satisfactory job.

"We also do quite an amount of welding of gun shields, particularly the 20 mm. gun shields by the plug-strap welded construction. I think everyone who has attempted that type of welding where they are permitted to use that type of strap, have been very well pleased with that type of welding and I don't have any improvement over that type of structure to offer at this time. But, as I say, it seems the larger the rod you can use, Mr. Biederman, and the fewer the passes you can lay down, the better joint you get. That is our experience on thin face-hardened plate."

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Lt. Pless added:

"I might add, just as information, that we recently have had an opportunity to test a number of face-hardened plates in the heavier thicknesses, that is, around 1", and these tests have proven to us the inadequacy of the present shock test. In AXS-743, not only have they proven the inadequacy of that shock test, but also it is obvious that we will have to increase the severity of the shock test for primary face-hardened plates, at least in the heavier thickness, and probably in the thickness of 1/2" and 3/4". I think that is what we are going to look for in the near future, and there will be some definite changes made in those specifications, I can assure you. That is on the 1" thickness plate. The shock test on welded plate may be satisfactory. Our experience so far has not indicated that we need a change in the lighter thickness, but the heavier thickness of 7/8" and 1" will definitely need a change."

Lt. Randall reported on a meeting of the Electrode Group held the previous day:

"You will recall that at the last meeting, the Electrode Group submitted two standard analyses for core wire, a modified type 307, and a modified type 308. To give a little background on that, it is not the intention that those core wire analyses be adopted by the Ordnance Department as specification requirements. I think there has been a little misunderstanding about that. It is our understanding that it is the desire of the War Production Board that standards of core wire analysis for modified 18/8 electrodes used in the welding of ballistic steels be adopted, the purpose being to prevent the use of a special specification by every electrode manufacturer. I believe that the statement was made at the meeting yesterday that there were almost as many varieties of specifications for what is supposed to be the same type of electrode as Heinz has a variety of products.

"The Ordnance Department received a letter from WPB requesting that consideration be given to lowering the chromium content, from 20-1/2% to some lower figure. That was on the basis of recommendations from the core wire producers and who, perhaps, had not been adequately represented at the previous meeting.

"There were certain modifications made as a result of this meeting. I can give you those two new analyses as introduced at the end of the meeting, and as they have been recommended to WPB through the Minutes of that meeting.

"<u>Modified type 307</u> - Carbon, .07/.12; Manganese, 3.75/4.75; Silicon, .25/.60; Chromium, 19.0/21.0; Nickel, 9.0/10.5 (that is a change from 9.2/10.7 in the previous one); Phosphorus, .05 max.; Sulphur, .03 max.; Molybdenum, only residual permitted with report of analysis required. Now that is a change.

"<u>Modified type 308</u> - Carbon, .07/.12; Manganese, 1.6/2.2 (that is a change); Silicon, .25/.60; Chromium, 20.0/22.0 (that represents a half a point reduction in those original limits. It does not go down quite as far as has been suggested by the core wire manufacturers); Nickel, 9.0/10.5 (that is narrowing of a half point of that range); Phosphorus, .04 max.; Sulphur, .03 max.; Molybdenum, only residual permitted with report of analysis required.

"Unfortunately, it seems to be true that the balance of alloy which is best from the standpoint of the steel mills and core wire producers is not suited so well for the electrode manufacturers. These analyses, as stated here, will probably require the electrode manufacturers in certain cases to make additions of chromium to their coatings in order to get what they consider the proper electrode. That will be in the cases where the nickel is on the high side. This specification, if you call it that, is not intended to do anything except ease the situation as far as the steel mills are concerned. As I understand it, they are the people who want this specification. Primarily, the electrode manufacturers, as was evidenced at this meeting yesterday, would vastly prefer to continue as is. Each one of them specify their own particular analyses and try to get them.

"The Navy representatives at the meeting agreed to recommend certain necessary modifications in their electrode specifications to take care of this lowering of the chromium content.

"The next subject which was discussed for the second time at the meeting was the matter of electrode lengths. The homogeneous armor fabricators will recall that at the Detroit meeting they were requested to submit their recommendations for electrode lengths to the Electrode Group. Again, in this case, it was our understanding that the Welding Section of the War Production Board desired to accomplish a reduction in the number of lengths in the electrodes produced to facilitate production. The homogeneous armor fabricators selected the following lengths as being those which they prefer:

5/32	-	14-inch
3/16	-	18-inch
1/4	-	18-inch
5/16 and over	-	24-inch

"At the last meeting, when this was reported to the Electrode Group, at the meeting in Detroit, it was felt that they were not prepared to go along with these recommendations on the basis of data available. The Navy Department very kindly consented to make some tests at their Electrode Approval Laboratory on the longer lengths of electrodes to see whether they were considered suitable for either Navy or Army purposes. A report of these tests was rendered at the Electrode Group meeting yesterday, and, as a result of those recommendations, the Electrode Group arrived at the following conclusions:

"The lengths of 1/8" and 5/32" electrodes should be 14". The length of 3/16" electrodes should be 14" for all positions, and 18" for flat positions; 1/4" electrodes, 18" - that was identical with the fabricators' recommendation; 5/16" and over, either 18" or 24". The Navy reported that with the exception of the 3/16" diameter 18" electrode, for all positions of work, the longer

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lengths requested by the fabricators were satisfactory. It is understood that the Navy representatives are going to recommend the adoption of these lengths in their specifications.

"We then had a request from the National Research Council representative, Mr. Humberstone, that electrode manufacturers furnish or obtain test data on electrodes which they produce, capable of giving physical properties equivalent to armor plate after heat treatment, and by that we mean after the weld metal has gone through the same heat treatment cycle as the armor plate. That is desirable for several reasons. In the first place, that procedure is being employed today in the repair of castings - they are repaired before heat treatment. There is the possibility that if such electrodes were available - if that data are available - there are certain subassemblies in rolled armor which might be fabricated in that manner. The electrode manufacturers agreed to submit this information to the National Research Council. The Automotive Center has offered to facilitate the submission of any samples for test which the electrode manufacturers require and can show that the results will be of value."

Mr. Biederman brought up the question of an electrode specification:

"We have six or seven separate suppliers of electrodes and without this standardization in manganese and all the other alloys that go into electrodes, we have trouble with our operators. A little different coating from one manufacturer might take more power. For one electrode the operator might have 180 amperes set on his machine. He might have two or three types of electrodes in his container. Maybe the electrode that he picks up will take 200 amperes to do what we know as a satisfactory welding job. I do feel that a specification is absolutely necessary. We have attempted at General Motors to put one out, but it should be done by the Ordnance Department and the Electrode Group. I know that the only one that is injured by not having this specification is the manufacturer, and it does cause us quite a little trouble. There are no two different manufacturers that control the same amount of amperes on the operator's machine, and those welding machines on the production floor are always 5 or 10 feet away from the operator. A lot of times the operator is in the vehicle, and if the rod does not perform correctly he has to climb out of the vehicle and set the welding machine."

To which Lt. Randall replied:

"Speaking as a representative of the Tank-Automotive Center now, and not as the Chairman of the Electrode Group, the Ordnance Department recognizes the desirability of having an electrode specification, and it is hoped that that will be one of the subjects on the Agenda of the next Electrode Group meeting."

Major Coombe reported on activities of the Specification Group:

"The Specification Group met last night for the purpose of going over the specification for the welding of armor by resistance spot welding methods. That specification has been prepared by the Resistance Welding Group, and in going over it last night we found that it is in the main acceptable to Ordnance, and we propose to hand that to the specification printers sometime this week, and it will be issued just as soon as we can get the wheels turning.

"With reference to Specification AXS-497 that Mr. McDowell mentioned, there are some changes which were in general proposed by the Ordnance Department. They were discussed at the Homogeneous Armor Fabricators' Group yesterday and were accepted by that Group. They were again discussed last night by the Specifications Group and were accepted with some, might we say, 'editorial polishing up?' Those amendments will be issued just as soon as we can get the necessary red tape cut, which won't be long.

"Specification AXS-743 has come in for a great deal of criticism. Might I point out that AXS-743 is a new specification. The Face-Hardened Armor Fabricators' Group today have done a nice job in bringing out a new specification or recommendation for one. Those recommendations were accepted by Ordnance. Experience since then has convinced us that certain changes are needed. I am very glad to hear that the Face-Hardened Group has it in their plans to recommend certain changes. Ordnance will also recommend certain changes. As a matter of fact, the change which was incorporated into AXS-497, regarding welding operator qualifications will also be incorporated into AXS-743, because the welding operator qualification in each specification is identical. We wish to keep it that way. We have been in the main part guided by the experience which has been available to us, which unfortunately the Ordnance Department has not had first hand. We believe that the qualifications of welding operators as set up in these two specifications is as good as can be accomplished in that short a space. We would consider the adoption of the Navy Department specification in lieu of the one that we have now. I might go on to say that the Ordnance Department has adopted two new specifications, AXS-799 and AXS-800, which are exact replicas of Navy Department specifications.

"I believe there is another specification involved there, as a matter of fact, AXS-700. There is, unfortunately, on the part of some of the fabricators, a feeling that the Ordnance Department is being arbitrary about this. As I mentioned in a meeting three months ago, the emphasis on production has now changed into emphasis on quality. Quality standards can only be upheld by specifications, intelligent specifications. If any fabricator has certain things which he thinks should be included in the specifications, and which apply to his particular case, the Ordnance Department has no objection to that fabricator writing up his own specifications. As I have explained to Mr. Smith, in the case of electrodes, we have no objection to your writing your own electrode specifications until such a time as Ordnance shall have an electrode specification. In the meantime, we cannot recognize any tests, any acceptance tests, on electrodes that any individual company has which are not in accordance with our own tests. That is one of the chief gripes that comes to my ears on our Ordnance specifications: that the fabricators have to submit so many different qualification test plates in order that they may qualify all of the different electrodes that they wish to use. Recently, I had the same familiar gripe come to me. The gentleman in question pointed out the geometrical progression of plates that would be required in qualifying a certain number of electrodes. We asked him why he had to have that many electrodes. Well, he stammered a little bit and then said, 'All right, I guess I can get along on two electrodes in that plant.' Some of your requests for waivers are reasonable and some are highly unreasonable, gentlemen. I wish you would consider them seriously before you request them. The Ordnance Department will consider requests for waivers provided they are supported by adequate information to back up that request, and not otherwise."

Mr. Mann raised a question about waivers:

"Here are Specifications AXS-494, 488, 711, 606 and 490 which have clauses that there shall be no local heating after heat treatment. Standard Steel Spring requires their heat treating requirements or facilities to flame cut after heat treatment. Also, it is at the discretion of the Inspector. I think that those clauses should be modified, limits set up, or waivers issued. We have requests for waivers about once a week from these facilities."

To which Lt. Reed replied:

"Most people are heating and cutting as they please, and it is only when their conscience hurts them a little bit that they ask for a waiver. The welding specification, I believe that is AXS-497, prescribes maximum temperature we can use on homogeneous plates; and AXS-743 says how high we can heat a carburized plate. The reason for having that clause in there is not because the Ordnance Department was afraid of what might result from local heating, but they did not want people to do things that were unreasonable. The clause can be removed and probably will be removed. As to waivers, I think Standard Steel has all the waivers they need. The Ordnance Department wishes that more people would take advantage of the waivers they have, and do a proper job of flame cutting and annealing."

Col. Frye discussed the activities of the Research Group:

"The Research Group had its first meeting yesterday afternoon. This was more in the way of an organizational meeting to devise policies and means of operation. Colonel Zornig attended the meeting and gave us some 'Ground Rules' to play by, and after the usual amount of discussion, we evolved two objectives for the Group.

"The first, and perhaps the most important objective, is to eliminate duplication of effort in research work. Research facilities are as critical as most anything else, and obviously when a research program is being carried on at one piece, any research work of similar character should at least be coordinated or perhaps held in abeyance until the first job is completed. Therefore, the Group's duty is to examine and disseminate information having to do with the research work and research projects being carried on. These projects are carried on by N.D.R.C., Government arsenals, industry and a few other places perhaps, so it is the intention now to compile a list of such projects and the Chairman of this Subcommittee will see that these lists are distributed to the Subcommittee members. In the event there is research work of similar character going on, it is suggested that it be coordinated.

"The second job of the Research Group is to examine preliminary results and data from research projects, and advise on the practicability of many of them. When the project reaches a point where it can be commercialized, the information should be disseminated to all the members so that they can all take advantage of that information and data. There are some complications involved there, since some of this is of a confidential nature, but Colonel Zornig thinks that that can be surmounted and this data made available to people who actually have need for it. Then, there are a number of research projects that apparently have merit, going into the project, but which later are shown to be rather lacking in practicability, or practicability of application. Those projects should be noted as such and discontinued wherever possible, and particularly those of academic value - but of no practical value. At this time we are interested in information and data which will help in the production of better materiel, so that the co-operation of all the industrial members of the Subcommittee would certainly be appreciated in listing such research work and projects which they have under way, so that they can be coordinated properly. We hope to include what the Canadians and the British are also doing in a research way, with proper approval, of course, but there is a rather indistinct, imaginary line between development and research. There is no possibility of one not going over to the other's field, and I believe we will have to analyze each particular instance, each project, to decide whether it is a development project, a design problem, or pure research. In the event of design, I do not believe that our Group would like to get into that. That is a development project which we want to steer clear of."

After luncheon, Mr. Cooper reported on activities of the Resistance Welding Group:

"Briefly, our work can be divided into two parts: one of flash welding; the second, spot welding. As far as the flash welding situation is concerned, it hasn't changed much since the last meeting, mainly because of the one difficulty of finding big enough machines to do our welding work. Incidentally, in that connection adequate machinery is simply waiting for adequate power supply, and we should have some flash welded H plates proof-fired some time in the next month. If you take a flash welded joint and heat treat it as a complete unit, being a homogeneous product with no filler metal, the joint itself becomes completely uniform and there is no apparent difference between across the weld and across the plate. When you try to predict and translate that from small sections and small plates into large plates in the actual application, we just do not know yet whether that is feasible. There are certain cases where we would know definitely that you cannot heat treat the structure, that there may be a possibility of localizing heat treatment in the welder. If you take long sections in the flash welder and try to give it a possible heat treatment by slowing down the cooling rate, you are up against the problem of uniformity of heating or retarding of cooling, and that, in the heavier sections may not be possible. There are other angles on the application that are items to which we have no solution yet. One of them is to get an adequate production requirement to justify the expenditure for equipment of a cost of six figures in some cases, to weld these big sections. As yet we can make no definite recommendations without this developmental work so that the resulting welding work can be considered.

"On spot welding, however, we have gone a long way since the Detroit meeting. To cite an example, one of the vehicle manufacturers is spot welding with 20 machines or more, armor approximately 5/16" thick for half-track bodies and to that he is attaching various thicknesses of reinforcements for parts as well as butt straps, angle butt straps, flat butt straps, to make a ballistically strong joint. He is having a high degree of success and it speaks well for this company's foresight that specification or no specification they went ahead and got the job under control. Ballistically, this job has gone ahead very well. There are two companies that are spot welding crash pads to the inside of tank hulls. In one case these rubber crash pads have holes punched in them and by using the resistance welding process, rivets are pushed through into the hulls to attach the crash pads. In the other case, the rubber crash pads simply have bare spots and they are spot welded directly, none having structural joints in any way. There is one aircraft manufacturer who is spot welding stainless steel plates to armor and his application is performing very satisfactorily.

"Through the National Research Council project, an impact test consisting of crossing two plates, we'll say 8" x 3" wide, and supporting the outer ends on a definite spacing, dropping a weight and tearing that apart under impact, seems to be the only satisfactory comparable test that will indicate progress in changing technique to get a good joint. One of the things that has delayed this specification that Major Coombe told you was accepted last night has been the fact that we have lacked the technical data to make a specification mean something, and at our meetings yesterday we have set up certain qualification tests to prove the process, the equipment and the operator under the particular fabricator's jurisdiction.

"As a second part of that specification there is the point of production testing. That, by necessity, must be as sensitive as possible, and yet be a practical method. I think that for the first time, at least to my knowledge of welding specifications, an impact test has been approved in such a simple form that

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it becomes even simpler to make than a test of the type where you normally take a shear specimen and pull it or machine it down, for machine section tests or comparable set of tests. In these hardenable steels, the impact test is the only sensitive way that we have found to know what is going on. You can take a good weld and a bad weld - and when I say 'good' or 'bad' they may have the same nugget diameter and yet not have the ductility of the other, and in shear they will fail at almost equal values. But you give those two welds an impact test and the one that is tempered has many times the strength as well as a much higher degree of consistency of strength than the untreated one. We can do what you cannot do in arc welding, in that where you may have a stainless steel cushion in your joint. In those specimens you can tear out a solid slug of metal there that has all the strength requirements. And there are only two criteria items indicative of a satisfactory weld. The first one is nugget diameter. That must be so big in proportion to the material thickness that you will get the strength you want in that one spot. Second, it must be treated to the right degree of ductility. As a measure of that we use the impact test. That is different from aluminum welding where the material is non-magnetic, and as the work progresses into the throat, your conditions do not change due to the material itself. Steel, as a magnetic material, presents quite a problem, and it is unanimously agreed that you must have some type of current compensation to change the machine characteristics to keep the same welding conditions. Incidentally, the ballistic test of a structural joint consists of two plates, 24" x 9", to which is welded a butt strap to make a standard ballistic test specimen. Now, in itself, that might have no connection with the machine, but if you so set it up that the long axis is in the spot welder and you make the successive series of spots in from the end, and you take the coupons out which include the first and last nugget, then section them and measure the nugget diameter, etc., you have a good criterion as to whether the machine and the operator are functioning properly. We have a little different problem than you arc-welding fellows have in that the human element is almost entirely ruled out. Now, when it came to production checks, there were a great many arguments pro and con as to what would be a satisfactory production check. Should you put a couple of pieces welded together in a vise and bend them 90° and say if they break, 'There is too much of the human element in the testing?' At first the question was quite a subject of dispute in our meeting yesterday, that here you are welding along on a large block of steel that is in and out of the throat of the machine, presenting variable conditions or combinations of impedence, as far as the machine is concerned. Now you are going to make a spot check each 8 hours or at least each 400 welds. You are going to make that spot check entirely different from the conditions under which the production pieces are welded, but it was pointed out that that is the most critical type of check you could put on the machine of the type, because if the controls of these automatic

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compensators do not work, you would simply blow up the electrode tips. Fortunately, it has worked out that way. So the production checks and the qualifications are pretty well under control.

"In the specification for different combinations of armor thickness and attachment thickness necessary, we have specified minimum nugget diameters. There is also a second column that specifies the shear strengths. Those shear strengths, as a measure of the weld quality, do not mean very much. If the welds have met the requirements of nugget diameter and the impact test, they are an indication to the designer as to just about what he should expect to get in shear strength if he has an adequate weld, as proven by the other methods. Incidentally, I should point out that these specifications at the present time cover the welding of armor and attachments, clips and butt straps to armor. The values given in here are given for the butt straps and attachments, for low carbon steel only.

"Incidentally, to give you some idea of the foot-pounds a typical joint should stand: If you put in a 3/16" attachment to any thickness of armor plate other than very thin sections which hardly appear for, after all, 1/4" armor is the thinnest we list, each weld must pass a test of dropping a 100-pound weight five feet or a minimum of 500-foot-pounds, and those values by necessity, at this time, are somewhat on the conservative side. They can be easily exceeded. As far as the 1/4" attachment to armor over 1/4" or more, drop a 100-pound weight six feet and have a minimum of 600-foot-pounds. When these weights fall from a sufficient height, not just 'go' and 'no go' tests, but sufficiently high to fracture the specimen, they do a very good job of drawing a complete slug out of the low carbon attachment like a deep draw operation. The joints never break through the armor plate."

Mr. Raymo commented on a flash welding problem:

"At the present time there is a party touring the country who has an 'answer' to this resistance welding problem. Unfortunately, he is gathering the endorsement of the Ordnance Department right on up to the President of the United States himself. At least they have acknowledged the letters from him anyway. I don't believe the man's got a great deal to offer. At least it is not sufficiently developed. I see no point in, at least, not acquainting the man with the fact that there is a very definite effort being made to utilize this process. We should not be giving a fellow, whom I believe is spending his money in all sincerity, the run-around. That is just what is happening to the fellow. There is no point in the man coming into my plant and saying that if I will tell him that the process will be used, somebody will give him money for putting up a plant and building machinery, and all such things as that. And I just don't think that we ought to do anything like that. Leastwise, we should give the man the benefit of the work that we are doing. All that I can tell you is that I did my very best to discourage the man, after spending about 3 hours showing him how impractical I thought it would be to put the M-4 together with flash welding.

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By the sheaf of papers that he has got, carrying the endorsements that he has on there the man has reason for encouragement."

Major Coombe commented also:

"I should like to contribute to this question. The gentleman in question called the Ordnance Department the other day and said that he has welded up some small pieces with this process and that those were sent to Watertown for examination. I don't believe the report was entirely satisfactory. However, he was given some additional armor plate, but the pieces were so large that it would take $50,000.00 to build a machine to weld them together for experimental purposes. The question was asked, 'Would the Ordnance Department please be so kind as to furnish the $50,000.00?' I suggested that if he was so sold on this process, since the Ordnance Department was not actually building vehicles, the next move was to contact industry and see if they were sufficiently interested to finance him. The Ordnance Department would not. So he asked me whom he could see. Well, the gentleman lives in New Jersey, I believe, so the first man who came to my mind was Mr. Raymo because he was nearby. The man wanted to spend money to go out to Detroit, and I suggested that he probably could get an answer from Mr. Raymo and save himself the difference in fare between Detroit and Philadelphia. That is the run-around I gave him."

To which Mr. Raymo replied:

"Major, I surmised as much, and I hope I convinced the man. I don't know. I was really surprised to see the endorsements that the fellow has been reinforced with by the time he got to me, and there was nothing on which to turn him down. They were all alike, noncommittal letters. The fellow had every reason to keep on trying, even as of this date, unless he could visualize, as I tried to impress upon him, what he was up against in trying to put such a vehicle together as against any one of our present methods of building tank structures."

And Major Coombe added:

"I should like to point out that American industry would not be what it is today if people had not kept on trying. However the United States Government Ordnance Department, or any other Governmental agency, cannot hand out $50,000.00 just for the asking."

Mr. Abbott raised a question about spot welding:

"Mr. Chairman, getting back to spot welding, with reference to any development work that is being done on resistance welding of face-hardened material, is there any such work being done?"

Mr. Cooper replied:

"On the spot welding, the majority of this has been on a homogeneous plate."

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To which Lt. Boucher added:

"There is a little misstatement there. There has been considerable work done on spot welding face-hardened armor. The only thing holding that up, and there has been spot welding of butt straps with no failures, but the Air Corps and the aircraft manufacturers have been holding back waiting for these specifications. In other words, they are perfectly willing to spot weld but the specifications have been tentative, and until such time they are issued they don't want to spend any money for equipment. Spot welding has been done on both the face side and the soft side of the armor. I believe you have shot some samples."

Mr. Abbott pointed out that:

"We have shot some samples and have done some of the work. One of the things we are primarily interested in is whether or not a development of the spotting of accessories to the face of the plate has been successful. I know that during the time that we were experimenting with you people that that was not altogether successful, and that was about the only phase, I believe, with which we didn't meet success. We are making three scout cars and half tracks, and there are hinges and other accessories to be attached. When you add them up, there are quite a few per unit which are now attached by riveting or screws to the hard side of the plate, and we are vitally interested. I was wondering if we could spot weld those successfully?"

Prof. Hess commented:

"We are developing spot welding of armor to the back face, a spot welding of structural steel to the back face, and also a spot welding of armor to armor - both face-hardened and homogeneous - but we did not realize there was interest in attachment to the hardened face. I don't believe that there is any difficulty whatever. We could work those conditions out very readily."

Major McInnes reported on activities of the Aircraft Fabricators' Group:

"In the aircraft phase of it, it is a little bit different, as far as specification handling is concerned, than most of the other ones brought up today, in the fact that there are approximately four Government agencies interested in any work, and in a good many cases they are directly affected; whereas most of the other information going on today comes directly in contact with the Ordnance Department alone. So that brings up additional problems, especially on the paper work end, and everybody gets blamed for the slow paper work. But there is more coordination necessary.

"The specifications discussed previously in regard to the arc welding of face-hardened armor plate and resistance welding, and also in reference to homogeneous plate, is of interest to the aircraft people, especially where it deals with thin sections down in the neighborhood of 3/8" which is one of the most common thicknesses. The attachment clips, etc., by the method of resistance or by the method of arc welding is at present of primary importance.

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Butt welding is of minor importance. On the conditions of the test plate in that respect, it was felt that the H test plate would not represent any anticipated design in aircraft structure. With regard to the butt weld, there may be a change on that, but as of yesterday it was felt that a straight seam or butt weld for shock test would take care of any conditions they can anticipate. In regard to the clips, in the preliminary specifications on resistance welding we recommended a thickness of approximately one-half of the plate thickness, but due to the fact that the structure upon which those clips are joined are generally considerably less than that, it makes the problem very difficult.

"In addition to check on shock test, the armor plate specifications are now in the state that the Air Forces have a specification specifically for their needs on homogeneous plate. There is another one on its way for face-hardened, and in view of these conditions, the shock test is breaking away from previous established shock tests. In fact, they are going to 20 mm. and 37 mm. in the shock test. Also, regarding tests on thin clip material, the tests are to be made to determine tensile requirements of the clip material. It is desired that the tensile properties of the weld be given in terms of the thickness of clip material rather than the thickness of armor plate. Really, that is the way most people expect to use it in the design work, and those figures can be used for the basis of design as well as for the basis of the tests of the weld. That is both for arc welding and for resistance welding where it applies to aircraft, and that seems to be in agreement to what was previously mentioned."

Mr. Mikhalapov discussed the NRC Research and Development activities:

"Probably the phase of our work of greatest interest to you is the ferritic welding of armor plate. In connection with this problem, I would like to state now that we have been very fortunate in securing the full-time services of Mr. Humberstone, formerly of the Arcrods Corporation, to give his whole time to this problem. Before proceeding to give you the details of our investigation, I think it would be well to try and crystallize in our mind what it is that we are trying to do in this particular research. Briefly, the so-called ferritic welding of armor resolves itself into two problems which could be defined as follows: Problem No. 1 - To develop a practical production welding procedure and technique which will permit elimination, or at least reduction of the strategic materials now required for welding armor plate. In other words, what can we do to substitute for the 18/8 electrodes you are now using, something which will not have the strategic materials, and yet will not seriously affect our production methods?

"The second problem is to develop practical production welding procedure techniques resulting in plate welded joints possessing shock resistance superior to the welded joint now being manufactured, and if possible, equal or superior to that of the prime armor plate. Before developing any improved method, probably the best way of telling how to go about it is to find what is the source of weakness

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in the process which we are attempting to improve, or in the process which we are substituting for it. As you know, for this reason we have been busily cutting up ballistic plates, shock plates - good and bad - and looking at them through microscopes, spectroscopes and everything you can think of, pulling them apart slowly, rapidly, bending them, twisting them, doing just about everything you can think of to see why it is that some plates are good and others are not good. To date there seems to be no relation between properties of the joint, such as hardness, and to a certain extent, tensile strength and the shock performance. There is some evidence of relationship between the combined ductility and tensile strength of the weld metal, and the performance of the plate, provided the unknown factor, 'X', which has been bothering us, is removed. That is, if you had a stress-relieved plate, then it would seem that a very high tensile weld metal with a slight ductility will be good, but a very high ductility metal with a fairly medium tensile is good also. However, a medium ductility metal with low tensile strength is no good.

"I think by now we have enough tests of all kinds to prove that the unknown factor 'X' to which I refer, and which appears to confuse all comparisons, is the combined locked-up stresses of certain magnitude in the weld because when we can relieve those or at least minimize those stresses, we have no trouble in having a good ballistic joint. It looks as if we will very definitely have to forget the idea of ever welding armor plate or any other alloy steel of approximately the same composition, with other electrodes than austenitic, without preheat. Various reports have reached us about the fact that so and so have welded a plate without preheat, without cracking, but when tracked down, it always has boiled down to the fact that they did not consider the heating produced by welding as a preheat. They started as cold plate and then warmed up, cracking until the plate warmed up to 200 or more degrees, when they proceeded all right. Now, when you go to a joint which is superior to austenitic electrodes, we are confronted with what looks like a definite necessity to heat treat the weld metal in the joint. In other words, the use of the highest strength electrodes probably induces stresses of magnitude which cannot be relieved without a thermal stress treatment which will seriously affect the ballistic properties, that is, the ballistic penetration properties of the plate. Therefore, it appears that at the present time we will be forced to seek some immediate practical application or attempt to develop a method wherein assembly or subassembly will be welded with a high tensile rod prior to the plate being heat treated, with the completed subassembly then heat treated. This is not an easy job. We have been working in the past two or three weeks in preparing a comprehensive report of all work which has been done by N.R.C., or of which N.R.C. is cognizant, to submit to you people so that you know exactly the status to date.

"We have also been working on these explosive tests about which you have heard at the last meeting. Briefly, the explosive test looks promising, particularly for testing welding electrodes.

There are some questions as to whether that test will ever give you the whole story however, because it can only tell, so it seems now, how good the weld joint is when there are no locked-up stresses, since any size specimen which can be handled on a laboratory scale will probably not have sufficiently large locked-up stresses. However, we have tested by this means a number of joints or sections of joints 2" wide, made with different types of electrodes and have been able to grade those electrodes in approximately the same order as with the ballistic shock test of the H plates. That is something which we have not been able to do by any other test. There are some refinements to be made, particularly in determining exactly how much better one weld is than the other because at the present we express the relative merits of the weld in the amount of explosive necessary to effect a complete break. That is sometimes misleading because twice the amount of explosive does not mean twice the energy has been applied to the weld, since by increasing the charge the effect of the increment becomes smaller and smaller as the number of increments increases.

"We have a very interesting development which is coming to a head very soon, I believe, in differentially quenched carbon-manganese armor plate, 1/2" and thinner. It looks as if we will have an armor which, although not quite as good as face-hardened, is slightly better than hard homogeneous, in addition to which we will have an armor which can be readily welded with ferritic electrode, with the resultant weld or joint being in all respects equal to the parent plate.

"The spot welding has been gone into by Mr. Cooper to some extent. Professor Hess and his colleagues have done some excellent work with 1/4 and 1/2" alloy steel and 1/4 and 1/2" face-hardened armor. Their work has been directed chiefly towards shortening the time necessary to make the weld. We understand and we realize that in order to compete with arc welding, the process must be fast. I would not say 'compete' with arc welding, but because the process is slow compared with spot welding and in order to make the best showing, the process must be as fast as possible, and the heat treating requires some time which in normal spot welding practice at first appears excessive. At the present, we are busy comparing the impact test with the performance of ballistic plates, so we have pretty close correlation, or will have eventually. We are going to study the hard homogeneous plate as soon as we can get hold of some. We have not done much work on face-hardened armor. We had great difficulties as far as arc welding face-hardened armor is concerned. We had some difficulty in getting that armor because the compositions were changing. We have now finally obtained some of it and Rock Island Arsenal is working on it."

Col. Zornig referred to an action suggested at the last meeting:

"At the last meeting of this Subcommittee, we spoke about making arrangements to get liaison between the committee for Welding of Armor and the Armor Manufacturers' Committee. At this time I appointed a Group of this committee to act as liaison with the armor groups, and I also appointed a group in the Armor Subcommittee to act as liaison with the Welding Subcommittee. Mr. Raymo was made Chairman of the Liaison Group from this Subcommittee, and I will ask him to state what has been done."

Mr. Raymo reported for the Armor Liaison Group:

"At the time of our last meeting in Detroit, you will recall that there was considerable discussion as regards the quality of armor plate that was being delivered to all of the manufacturers, and which appeared to be the butt of our manufacturing difficulties. This had to do with the physical condition of the plate, straightness, sizing, edge preparation, subsequent weldability as may have been effected by the method of processing the armor. In order to try and see what could be done in the way of developing standardization of armor making processes, and to minimize the difficulties that were affecting production of vehicles, these Groups, named by Colonel Zornig, met in Watertown, consisting of 7 members representing plate manufacturers, five members representing users of the plate, one representative of welding electrodes, and seven of the service representatives. Considerable discussion was given to the weldability of armor plate as affected by current compositions and as likely to be affected by prospective compositions. At the present time our armors fall into three basic classifications, namely, manganese-nickel-chromium-molybdenum type, the manganese-molybdenum type, and the manganese-silicon-chromium-molybdenum type. I am personally of the opinion that the whole trend will eventually come to the manganese-molybdenum type of armor. Two of the basic reasons given for difference in characteristics of armor appear to be associated with the heat treating of the armor that is required to produce the ballistic properties, namely, quenching facilities, and it was developed that at the present time spray quenching equipment is not universally available. The problem of scrap availability as it now affects the chemistry is another item, but with the lessening of the availability of our alloys, everything certainly seems to indicate to me that the trend is toward one chemistry of armor. How soon that is going to be is rather hard to predict at the present time.

"Another subject that perhaps meant the most to us, and which subsequently has placed the Ordnance Department in a very difficult position, or I'll say 'unfair' position, had to do with the repair of armor plate. At the time the subject was brought up there were only two kinds of repair given any consideration whatsoever, that is, mechanical defects resulting from the flame cutting of the plate for one. Now there are but two types of defects that are common there; one is the wrong sizing of the plate, that is to say, if the plate has been cut 1/4" or 1/2" short, is it permissible to build up that edge with weld metal? All of us are doing it. We have done it since the day we started to build tanks, even by the riveting process. If the welding is satisfactory for making the joints, I see no reason why it isn't satisfactory for correcting some dimensional deficiencies. The same holds for the gouging of plates resulting from gas cutting, which, if not corrected, as you know, gives a beautiful pocket that is likely to be filled with slag at the time of your welding. Furthermore, these gougings are invariably covered with a heavy coating of oxide in there, resulting from your flame cutting that has not been removed by any subsequent cleaning of the armor. I see nothing wrong with the removing of that oxide by grinding or with a little scaling hammer, and filling the gouge up with the same type of filler metal that you are making the joint with. Those were the only kinds of repairs that were given any consideration whatsoever. Only complimentary mention was made of correcting plates having defects commonly referred to as laminations, segregations, dirt, or inclusions, or any other polite or impolite term you want to identify the condition by. I don't think this committee at any time will recommend the attempted salvage or repair of plate that is likely to be found ballistically deficient as a result of such inherent imperfections in the quality of the plate. Apparently, our recognition of the repair of the first type of defect was seized upon by some as the go-ahead signal on salvaging all plate, and I simply wanted to emphasize that particular point, because I do believe this, that the Tank-Automotive Center has been placed in an unfair position with respect to giving permission to such practices.

"It was brought out earlier in the day here that since the last meeting, in all the Districts there has arisen a defect consciousness, perhaps detrimental in some instances by virtue of being too conscious about the inspection, but I think it has had a very stimulating effect in general and I want to tell the users of the plate that I honestly think that we stand to get considerably better plate in the future."

These remarks about future prospects stirred Mr. B. J. Smith to comment rather caustically:

"That is beautiful, but what are you going to do with this million pounds of plate that happens to be in one manufacturer's hands right now, that he is moving heaven and earth and the Ordnance Department too, to find some way to cram it down people's throats? Mr. Chairman, I sat here today and listened to as beautiful a mess of bunk as I have listened to in all the time I have come to these meetings. We have heard everybody talk in terms of sweetness and nobody has raised any particular controversial issue. We have sat here like a bunch of bumps on a log and taken it all in. It is fine! It is wonderful! With my apologies to the gentlemen who have tried to keep this thing in that spirit, but I cannot conscientiously sit here and agree with all that somehow. We know among us that there are people in this room who have had trouble - I mean big trouble. We have men in this room who have backyards full of tanks that God only knows what they are going to do with, unless the Ordnance Department can talk them into selling them for training purposes. We also know that there are people in this room who have got armor plate that comes into their plant, and they do not know what to do with it. They get a couple of dozen plates, when and if, and after they have waited a long

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time for it they try to make it weld and it won't weld. They get armor plate that is ostensibly according to a certain formula, and they weld it. It welds beautifully. They get it out on the job, and it falls apart. We also have some armor plate that I am just a little more familiar with, perhaps, than some of the rest of you. The chemistry is beautiful on it, the physical properties apparently are fine, being according to the primary plate tests that we run ballistically. A nice example of craters on the shock test, so-called; a matter of throwing a burst of fire out of a machine gun and call that, with a piece of face-hardened armor, a shock test. Then when we weld that plate and we subject that plate to the ballistic tests, according to specifications, for shock, if you please, what happens? You can't shock test the weld because the plate falls apart.

"I am not talking about 1 plate, 2, or 3, or 5. I am talking about dozens of plate that we welded. I am talking about a condition that we all know exists. Why kid ourselves about it? Why not come out here and say what you think? Let's cut out this thing of hiding your head in the sand. We would then know what can be done in the future certainly. Let's quit kidding ourselves about the future. If you can't use the stuff that is on the dock now, why worry about what the future brings? Let's quit kidding ourselves about the conscientious efforts that are being made. What are we doing about what we have now? I would like to hear somebody answer that."

Lt. Reed commented on the armor development situation:

"I don't think Mr. Smith is quite fair, although I do not say that all of his points are not well taken. You gentlemen know that two years ago - two and a half years ago - you had to almost kill your brother to get enough money to do anything. The Government, Congress, the people were not inclined to spend money on things that a good many of the people here knew were necessary on research work that somebody else was doing, and we did not have the money to do it. We had the time to do it, but not the money. We had 3,000 miles of water on one side, and God knows how many thousands on the other, that were going to keep us free, and we were going to be the only democracy left. Then we got drawn into a war, and we were told we were going to have a program, so hit and go to it! We didn't have the facilities. We fought like the devil to get facilities. We went here and there and asked for this or that item, and so on, throughout the country, until we built up what we thought was going to hit what we thought was a program, something so big. Unfortunately, at the time we did that, we did not have five or ten or twenty years' good background on which to go ahead. The willing ones stepped forward and said they would give it. The rest either might have given or would rather see someone else make the efforts first and then come in. And due to the unprepared situation, we have run into millions and millions of things, some of which were similar to Mr. Smith's troubles. Now this matter of the five rounds for shock test on face-hardened plate. I have been aware of that for a long time. As a matter of fact, I think I made myself a little unpopular at the last Army-Navy specification meeting by asking that that be thrown out. It had already been proved on other specifications. We know that the shock test is bad, but during the last six months we haven't had the time or materials to develop a proper shock test. I know that a man is sitting in the back there, calling me some sort of a so-and-so, because I tested virgin plate with one thing, and Major Coombe and Lieutenant Randall came along and threw the kitchen sink at it, and it failed, and he said, 'Why do you do this to welded plate, and you do this to virgin plate?' It takes time, equipment and material to coordinate all this stuff. We are working on it, maybe not quite as fast as we can, but our rate of progress is increasing. This matter of cracks, this matter of a million pounds of plate that is being shoved down someone's throat, this matter of repair welding, I can remember the day when certain manufacturers, if they could have gotten mill steel plate would have put it into tanks, just to get the tanks out. That was the attitude of industry. We wanted quantity.

"As Major Coombe said this morning, we are going to go short on quantity and hit hard on quality. Supposing today we decide we are going to hit for quality; we have got a lot of stuff in float. We have material for, say, 5,000 vehicles in float, and we decide we are going to make 2,000 vehicles. It takes time to work that out of our system. Some people have it in their system, and it doesn't look as though it is going to be worked out; but I challenge the vehicle manufacturers for not bringing their complaints to the right focus, in the right spot. I challenge them for using material that they knew was questionable when they had to have it, 'By God, to get vehicles out,' and I wait for my challenge to be answered."

Mr. Smith replied:

"I will be glad to answer that. I can only speak for one organization, of course, the Herrington Company. Our problem has not been and, unfortunately, is not even yet a matter of production. It has been from the very beginning, and this I am sure will be backed up by the men with whom we have worked, it has been a matter of quality from the very beginning. Our argument with the Specifications Committee is not one of trying to get waivers to do the thing simple or easier for us. It has been one of insistence upon higher standards. Our argument with the steel manufacturers has not been one of wanting to get by. Our argument is diametrically opposite to that. We are absolutely opposed to a waiver which they may get, forcing us to use steel which we can weld, we have proven that, but which in our knowledge is not good material from an armor plate standpoint and the ballistic integrity phases of it. We are in no way allied with anybody who is endeavoring to do a high speed job of getting a lot of production out, in order to get a lot of dollars in. We have spent many, many, many dollars in trying to make sure that the product that comes off the Marmon-Herrington production line is in keeping with the reputation that we have tried to build. It might be interesting to some of you to know the Marmon-Herrington

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Company was building tanks, not last year or the year before, but six or eight years. Our vehicles have been in actual service long before any of those made by other fabricators in this room were in actual service. We know what we want and what we have to have in order to meet those service requirements. We can show you records on the performance of vehicles in all theatres of this war, long before Pearl Harbor, so it is hardly in keeping with that kind of background that we would be asking for anything less than the best. We are asking not for waivers, gentlemen, to get by. We are asking for assistance from where we thought we could get it, in seeing that the material that we work with and the specifications we work to, are strong enough and good enough to do the job we know has to be done."

Lt. Reed continued:

"This is the first time that I have had the communication directly from Marmon-Herrington, that Marmon-Herrington was having a lot of trouble. I did not know how bad the situation was there. I am pretty well acquainted with the tanks in the backyard, and I am pretty well acquainted with the armor plate that is in the backyard here and there throughout the country. I do not know of any manufacturer who is not pushing or has not been pushing to get quantity out or who was not pushed by us to get the quantity out. When Mr. Raymo says that the Ordnance Department is in an unfair position, he is not far from wrong, not that I want to make alibis, but when strangers are forced to talk in a language they never knew and almost do not understand at the present time, you cannot expect them to say much, and that is what we have in some of our armor organizations. We have strangers in a field being pushed to talk a language that they never knew before and in which they haven't had very good teaching.

"Now I still say that there was a day when we would take anything and put it in a vehicle. I still say that the time has changed when we need to do that. We have been told that we are no longer at the point where we must produce. God knows, I have granted millions of waivers on armor plate, not because I thought I was right, but because production had to be kept up. There was always a group of men going some place, or a boat going some place that had to be loaded, and I think, as a group right here, if we talk with one another and with the Ordnance Department about our troubles, bring them out in the open and not circulate them behind closed doors, we will bring our present problems up to the quality, up to the level we all want. The Ordnance Department wants quality and I think all of the industries want it.

"Regarding this business of repair welding, because of surface defects or dimensional deficiencies or checks and cracks, and things like that, the minutes of the last meeting indicated that one group in particular had been chosen as the guinea pig, maybe rightly so, for comment regarding defects in armor plate that had been delivered. The practices being used by that company were not what they knew were the best practices, but it was about the best job they could do with the equipment they had. Take Bill Boese for example. He would be gas welding armor plate if he didn't have electric equipment. But what I am trying to point out is that you would be doing the best you could with what you had. That is just what the people have done. They have had priorities that were AA-3 and AA-2. Deliveries of everything else came before deliveries of some of the armor manufacturers. All our spray quenchers have been cut off now. That is one thing we have been fighting for. We sit here and glibly knock down alloy in one meeting, and then at another meeting have to stand up and tell you that delivery of spray quenchers has been stopped. We consider them one of the No. 1 necessities for our armor plate, so you are going to be getting plate that is dunked in some spots and sprayed in other spots. The delivery of preheating equipment for flame cutting has been stopped. The companies have taken the material, the equipment on hand, and have tried to do the best job they knew how. In some cases they didn't know how! And people tried to go in and show them what was right. I have seen a remarkable improvement in the work done by people who could not go out to an open market and buy everything they needed to do the job right in the beginning, piece by piece, at time intervals that would drive most of us crazy. I think that right now the questionable material they might have turned out is down there in Africa and places all around, taking a beating along with the good stuff. That is one thing that we should temper all of our criticism by - the fact that certain companies, and I think all companies, did not have the equipment they needed to do the job right. Nevertheless, they went ahead and stuck their necks out to do it. It may have been the dollar sign; it may have been patriotism; but I still think that Bill Boese would be using gas welding, and Mr. Biederman, too, if they didn't have the electric welding equipment. I can remember when they used to be welding H plates. They used to be on the phone all the time asking, 'How is this production going?'"

Mr. Biederman interposed:

"The manufacturer is only one part of this whole program. We are just a little unit of it, trying to cooperate. Now we run all of our tests and we are sure of what we want and how we want it. We cannot build into our vehicle a better grade of armor plate when we do not receive that better grade of armor plate into our plant. There is no method or any machinery that we can have to build up the ballistics of that plate after it reaches our plant. The trouble we have has been mainly because the armor people maybe did not have the necessary equipment. As I understand it, there are specifications which should prevent that that plate be in anybody's plant if it isn't good. The tank manufacturer starts where the other fellow ends, and if there is a waiver put through to let the first man cut down on the quality, that quality is just going to be the same on the finished tank because nobody after that first man can do that man's job. The vehicle then is lacking in quality, only due to the fact that somebody made a mistake and somebody else made a very big mistake by waivers."

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Lt. Reed continued:

"I do not negate the existence of waivers. They started long before I got in Washington and have continued since. I can remember when we had boats somewhere around New York that were waiting for vehicles that had not been started, and the production group was told that those boats had to be loaded with a vehicle of a certain type, and the manufacturer went to work on that certain type of vehicle, and we didn't have ballistically approved armor. Well, I think the design was changed to the effect that we could use low alloy, high tensile, for part of the plate on that vehicle. So, we went ahead and by hook or by crook, all the armor on that vehicle finally did get ballistically approved, and those parts that we could not have ballistically approved went ahead as low alloy, high tensile. But I don't think you gentlemen here have been fully acquainted with the urgency of some of our production. Right now we will say that last week it looked as though we were on easy street. I don't think that we are still so sure that we are on easy street right now. There are a lot of rumors about or I heard a lot of rumors that somebody was saying the war was going to be over in three months. I will wager the people saying that a week ago have changed their minds right now. What we are going to strive for from now on to the end of the war is to keep waivers at a minimum to get as much sound material to Fisher, etc., so that Fisher's tank won't be judged by the quality of the material in it - that he had nothing to do with. No one would hold Fisher responsible for the quality of the armor in the vehicle. I don't think anyone of us is sufficiently unreasonable to presuppose that the shipment of armor to Fisher Tank Plant and its storage there for a certain period of time would give Mr. Biederman an opportunity to change his quality. I am sure that with each vehicle produced, the armor will be judged by the armor manufacturer, and the fabrication of that vehicle and its operation will be judged by the properly responsible person or people. And that holds not only for Fisher, but Marmon-Herrington and Baldwin, etc."

Mr. Smith explained:

"To be a little more specific, you were not informed personally, but others in the Department were informed, forcibly, and have been informed the very minute we discovered this very difficulty. I would say that there have been some very competent men from both industry and from the Ordnance Department, very deeply engrossed in this problem. We have worked as closely and as co-operatively as we knew how with everybody that had anything to offer in solving some of these problems. Not only that, but at the invitation of a duly constituted body, we attended a meeting at Middletown, Ohio, and at that meeting no punches were pulled. Everybody was extremely honest, and the wraps were off. We told our story, and believe me, we have no possible axe to grind, except that we insist that we will not use material which is not satisfactory ballistically. I think that that is parallel exactly with the Ordnance Department's intentions and purposes. We have not entered this thing with the spirit of antagonism in any sense of the word. The minute that material was available for us to make tests on it, we made tests and we are continuing to make tests. For anybody interested enough to come down and see what our problems are, we will repeat these tests. As a result of this meeting, or at this meeting I should say, it was agreed that the findings of the committee at this meeting would be turned over to all of those present at the meeting, so that further examination of our findings might lead to some further results. Instead of receiving those findings of the meeting as the minutes of the meeting, they were boiled down and reinterpreted to somebody's particular satisfaction and distributed, and the intent of this boiled-down version was almost directly opposite the intent of the meeting in their detailed findings. Further than that, a statement was made by the party who is responsible for distributing those meeting notes that there would not be any distribution of the detailed minutes, because he felt it was too confidential, that the information contained therein was too valuable and had too many implications. That is the sort of thing that I haven't any use for and that is the specific instance that I am referring to."

Mr. Abbott remarked:

"I presided as Chairman at that meeting, Colonel, and I think that at our meeting yesterday I made known to you the facts that Mr. Smith is now bringing forth. What Mr. Smith says is entirely true and accurate. I was sent a detailed report of the minutes of the meeting with a letter that they sent for my confidential file and instructed that I was to keep those minutes only because they were considered too confidential to distribute among those present at the meeting. The Face-Hardened Fabricators' Group was the one that was most vitally interested at that meeting. I assured the members that these minutes were not confidential or restricted as far as they were concerned, that copies would be made of those minutes and distributed to them, to which they were entitled. I think I would say that that was just a misjudgment or, rather I would say, lack of judgment on one individual's part, and it was clearly against the spirit of the meeting. In these meetings, I say now, that if I have anything to do with these meetings, all the members are going to have as much as information as I get. I do not want it misinterpreted that I am responsible for those minutes not being distributed."

Lt. Col. Enos also commented on the point brought up by Mr. Smith:

"I was at that meeting and I also received the abbreviated minutes. There was some confusion in the minds of the gentlemen who called the meeting as to just who should take up what, and after he had clearly understood that there was an advisory subcommittee on welding that had various units, such as Mr. Abbott's unit, then it became very evident that the technical problems involved were a proper function of Mr. Abbott's committee and were therefore referred to him. In fairness to the gentleman who prepared the abstracted minutes, I should say that when the invitation went out, it was not known just who was going to be needed and there were people there, anyone of whom probably it would not have mattered much if they saw the whole minutes. They heard the arguments, but it was probably not necessary to inform everybody in that room of all the details, and I think that was the spirit in which this information was withheld, rather than any attempt to keep it to one individual. I want to congratulate Mr. Smith for his fine attitude all through this. It is only fair to point out, however, that the variables concerned here go clear back to the steel making process. They involve the making of the steel, the rolling, the heat treating, the welding. This is among the first attempts to weld face-hardened armor, in the particular designs at least, which are going to be used on this vehicle and, therefore, there are new problems. The steel as presented first from the mill was made by the best knowledge then available. If it is not what is needed for the future it can be corrected. The problem as I see it is the salvage of considerable material on hand, if it can be salvaged. Mr. Smith, by implication, has said that the Ordnance District has been co-operating fully, and I can assure you that it has. I personally spent all of Thanksgiving Day and a lot of other days on this problem and I expect to continue, and others of our organization have done that. We have not tried to hide anything from the higher-ups. The Integrating Committee is thoroughly informed and it is a problem that cannot be solved overnight. There are tests in progress today, I believe, that will throw more light on it. I think Marmon-Herrington wants to solve their own problems, if they can, and they are getting all the help that can be given."

Col. Frye commented:

"We are forgetting that we are learning this business together. Three years ago the personnel in the Ordnance Office consisted of somewhere around 300 officers, of which only a small part knew anything about armor plate. That is, they knew something about armor plate back in the lush days when they could use all the nickel and chromium and all the alloys that they wanted to. There have been a great many changes since then. At that time there were possibly two or three steel mills which had made armor plate in comparatively small quantities. Many of the tank fabricators today never dreamed of making a tank before, most of them haven't. We all had a devil of a lot to learn. But it is typically American that when everything is going swell, to sit around and gripe about everything. However, I don't think we want to lose sight of the fact that we still have a lot to learn, all of us. I think Mr. Eddy made a remark here awhile ago that was quite pertinent. He didn't come up here to lick his troubles, but he comes up here to get an idea here and there and go back and use a bit of good old American ingenuity and lick his own troubles. I think that is what this meeting is for, because every shop is different - different in personnel, equipment, and management. All we can do is get an idea here and there and take it back and apply it to the situation which exists in your own particular plant. We are all trying to drive at an ideal

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and that is splendid. We can't damn the other fellow when he makes a mistake, because the one that is doing the criticizing probably turns out as many errors in his own line of activity. So I appreciate the criticism which goes on. I think it is a healthy condition, but let's keep in the back of our mind that we are learning together."

Col. Zornig remarked:

"I am not an armor plate manufacturer. I don't know anything about it except what I have heard, but I have heard a lot of this in the last year since I have had to sit and listen to all of their discussion. And last February they were called in, you fellows were lucky you weren't, they were called in and told that the days of using alloys were finished. From then on, and very quickly, they would get down to the place where they would make armor plate with next to nothing. That was told to them by WPB. Then the Ordnance Department got up and said, 'Yes, and we won't change the specifications either.' Now you cannot bring down your alloys and have air hardening steels like you have been making before. You have got to have something to quench it in, and just dunking it in a tub of water doesn't do the business either. When they pound you down far enough the question of being able to get the equipment it takes to do some of this work is a grave one. Now certain mills have been required to go into the manufacture of armor plate that never were set up for armor plate. They were built for different purposes. Mould equipment, furnace equipment, mill equipment and rolling mill equipment were not designed for armor plate and if you wait until somebody designs some of these mills especially for armor plate, you won't have any armor plate, or you wouldn't have had any, and the Japs would still keep coming. We happened to be in the position that we did not have to use a good deal of it that was not up to first class quality, but I can't help but have a little sympathy for both sides, because I sit around and listen to all these sides. However, I do not take it so seriously because we have made a lot of good armor plate too. I happened to hear the same gripe about the castings. Now there, it so happens that we have control charts on the castings that were made in the last six months and a lot of talk that has been pushed around about castings is not warranted by the statistics of the case. I had hoped that Colonel Colby would be here today, to tell us how our stuff has stood up on the other side, but all that I have been able to get on it is that it has done a pretty good job. The other fellows, however, do have their problems, too. The welders aren't the only ones having problems."

Mr. Smith added:

"We have a satisfactory source for armor plate that has stood up very well. We had plenty of trouble with it. We helped develop the armor plate to the point where it did not give us much trouble. We worked consistently with whomever we had to work with in order to provide ourselves with the quality of material that we thought necessary.

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As far as the lowering of alloys is concerned, our experience has been that with the lower alloy plates we have gotten as good results as we ever got with the higher alloys. We have no gripe in that connection, at all. We haven't any gripe with reference to the weldability of it because as I said, we can weld it, and we have welded it. We have developed means of preparing the plates so that it could be welded satisfactorily. But the problem we are faced with is not the problem of welding that armor plate, far be it from that. It is not one of our problems. We are asking only that the armor plate that we receive be as good as the armor plate can be made, and if one man can make it, our feeling is that anybody else can make it. If one mill can, with similar equipment, produce satisfactory armor plate for us, there is hardly any reason why the other mill cannot. Our argument is not with the mill, it is not with the heat treater, it is merely with the idea behind the principle of trying to save material which is not satisfactory and has not, over a period of a considerable number of efforts, to this point been proven saveable. If that material can be saved, we are just as happy to use it as anybody else. After all, it does mean considerable to us that here is plate available, because we would have to start out and find some more material somewhere else if that material is not available. But we do not want to see that material used if in the finished vehicle it is not going to do a good job on the battlefield."

Col. Zornig concluded this discussion:

"I do not think anybody is going to use any second-grade material because we do not have to any more. It is saving what you have got because every time you put that stuff through the furnace you lose some more alloy, of which we haven't too much. You lose practically all your chromium every time you pass it through the furnace, and nobody wants to do that if they can help it. If the stuff cannot be used, the percentage of the total production is very small. Undoubtedly, they won't use it, but if it can be used, I think it should be used. Some satisfactory way should be found to do it."

There followed a lengthy discussion of the problem of electrode deliveries which was introduced by Lt. Randall:

"It was agreed by all electrode manufacturers present that the deliveries of stainless steel electrodes in the future cannot be expected in less than four months from the time the order is placed. That statement was supported by the War Production Board representative present. There was a feeling of the Electrode Group that all of the fabrications should be apprised of that fact."

This question was commented on by Mr. Raymo:

"I think the saddest chapter that will be written in the reporting of the effort of this Subcommittee will be written in reporting the effort of this Subcommittee's Electrode Group this morning. I think that 95% of the men who were at the last Detroit

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meeting left with the impression that two types of composition had been agreed upon and would be available to us shortly thereafter. We were informed this morning that progress had been made and these compositions had not gotten under way as yet. I don't think the Electrode Group is any farther along with their efforts than they were one year ago, particularly when the Chairman states that everyone still expresses a preference for specifying the types of core wire that will best suit the individual needs. I would like to be able to get as much coffee as I could right now, too, and I don't think that is at all encouraging to the user of the electrode, particularly when we know that many of our electrode friends voluntarily and publicly announced that they were ready to pool every resource and bit of information that they had. If the Chairman's report is to be interpreted literally, then their efforts have been nil for their entire period of existence.

"What I am going to say will not reflect upon the present Chairman, but I think we are wrong in having a Service representative heading up that body. I don't think that the Chairman or the man who should initiate action, when placed in the position Lieutenant Randall is in now, or Mr. Brooker was, is altogether in a fair position. He is neutral. I think that is why he was chosen for the job. I think a Chairman of that Group, if he is going to standardize on electrode composition, has to have ideas of his own, and the report that we got this morning, combined with the announcement of four-month delivery, doesn't sound promising to me at all."

Mr. Rutishauser replied for the Electrode Group:

"That specification of core wire which Lieutenant Randall read, the change was necessitated by the War Production Board through the core wire manufacturers. As far as the Electrode Group was concerned, I think they were pretty well set on what it was, but we were asked to change, and in trying to comply with both the War Production Board and the wire producers, we changed the specification. It hasn't been changed much and as I recall, there were no changes contemplated in the deposited weld metal merely in the core wire."

The situation from a different angle was elaborated on by Mr. Brady:

"It is very, very difficult, if not impossible to get the point over to the fabricators of tanks, the fact, that it does take three months to obtain wire from the steel mill. We continue getting orders, even as late as two days ago. Companies are completely out of electrodes. They place an order Thursday, and if the electrodes are not in the shop by Monday, they shut down. They aren't fooling because they do actually shut down. There is something wrong somewhere, when that thing happens. Now the electrode people are not responsible in any respect for this three or four-month delivery. It is controlled entirely by WPB, entirely so. The 20th day of the month is the last day of the month that we can place orders for core wire. For instance, on the 20th day of December we have until that time to place orders for wire. That permits the steel mill to purchase their chromium and nickel and other alloys for February melting, for March rolling and possibly delivery at the end of March, but most likely in April.

"Five months ago we were required to inform Washington as to how many pounds of electrodes we expected to manufacture during the fourth quarter. That was five months ago, and we had to give the information on a special form. It was simply a form the fabricators had to fill out, telling how many pounds of electrodes they expected to use in the fourth quarter. Now something has slipped along the line, because the contemplated number of pounds of electrodes that the fabricators are using in the fourth quarter is possibly two or three times what five months ago they told WPB they were going to use during the fourth quarter. We are allocated so many pounds of bare wire per quarter. We receive this allocation in the fourth quarter based upon our estimate of five months ago, which in turn was based upon the estimate of our customers they had given to us five months ago and on orders we had on the books at that time. Because of the increased production, we tried to fill that gap. Because of the oversight of some purchasing agent or some shop individual who failed to requisition the proper number of pounds, we were permitted to ask for 'interim assistance.' In no case to my knowledge has there been one single pound granted to any welding rod manufacturer on 'interim assistance' that was asked for for the fourth quarter. We personally asked for 625,000 pounds of wire which is sufficient to make roughly 750,000 pounds of electrodes for the fourth quarter. We were turned down. We didn't obtain one single pound. The mills are keeping to their schedules, the electrode people are keeping to their schedules, but we cannot possibly fill the gap of almost two to one when it is a matter of unravelling a lot of red tape down in Washington, a matter of dotting somebody's I's, a matter of paper work. All it took was a telegram to my office to grant this 'interim assistance.' The wire didn't have to be melted. The wire was laying on the shipping platforms, drawn to size in coils; the truck backed up ready to take it away. It wasn't something the steel mills had to make. It was something that way lying around there for three months and I guess it will continue to lie there until somebody wants to give somebody 'interim assistance' to keep these plants going. These Detroit people are operating on a three or four-day basis. I walked into the shops up there and they had a three days' supply of electrode on hand. When the truck was a day late, they shut the plant down."

Upon questioning by Mr. Eddy, it was admitted by Mr. Brady:

"Everybody didn't make the mistake. They required more electrode for this reason: They received a certain contract, we'll say, a contract to make 30 or 40 tanks. He orders sufficient wire to fill that contract. He has completed his 40 tanks or whatever it was and waited around for the red tape to unwind. He knew he was going to keep right on making tanks, but he would not order welding rod until he actually had the order from Washington to make 40 or more, or 400 more, whatever the case may be. He refused to order welding rod until the day when he actually got this second order from Washington. The day he got that order from Washington, that day he placed an order for welding rod, but that day he was also out of welding rod, and he wanted to continue production, so he gets on the phone and says, 'I have to have 40,000 or 100,000 pounds in my shop next week.'"

And he continued:

"The point is, is there somebody in the Ordnance Department who has the authority, the power or whatever it takes, to take a walk over to the War Production Board and sit down with some individual there, the responsible man, and say: 'Here's the situation. We are not asking you to do the impossible. This wire is lying in the steel mills. It is ready for delivery. The steel mills are ahead of production in many cases. Will you permit us to buy it?' But that is not being done, and there is where the tie-up comes in and the slow-up of production. There is no co-ordination between the Ordnance Department and the War Production Board."

Mr. Foley of WPB commented:

"It is ridiculous to think that those two statements could be true. In my experience when anybody comes down to the War Production Board with any such story as that, he gets immediate assistance, and I am sure that anyone who comes and places the case as it has been placed here just now, he will get the relief he needs. It just doesn't make sense to have a thing like that, having wire on the wharf, and all it requires is delivery, and somebody says he will have to shut down a plant if he doesn't get it. It just doesn't make any sense. I cannot go along with that statement. Something is wrong somewhere. Either the contact has not been made or the wire is not there."

Since the question of allocations by WPB was no proper business for the Subcommittee, Col. Zornig commented:

"This is getting into matters of production schedules with which this committee has nothing to do. I think you have your Integrating Committee and what not. You have the War Production Board and your own Industrial Committee. I take it that you have one that covers this, anyway, but it would seem to me that that is a proper thing to be taken up by them. This Subcommittee only concerns itself with the technical arrangements, the technical phases of manufacture of armor structures by welding and I think we would be decidedly out of place if we started to play with the systems by which allocations take place in quantities of requirements. That is not the function of this committee, and I think we should stay away from that. I would like to see us stay away from that because it is none of our business."

Mr. Foley stated the policy of WPB:

"Having wire on the wharf for delivery and when it goes back to melting are two different stories. It is a question there of whether the armed forces are taking them all together, wanting to use their nickel for this thing or that thing. They are the ones

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that decide that. The War Production Board never denies the Army or Navy of their materials: they have their own way about them; the War Production Board sits in. They advise, but they don't say, 'You can't have this for making a tank, or you can't have that.' They get what they want."

Mr. Raymo repeated emphasis on his original point:

"Mr. Brady's remarks are of interest. It was not my intent to elicit any such comment. I am appreciative of the condition which the electrode manufacturers have in ordering their electrodes. But the point that is of interest to all of us is when are we going to get down to that one type of electrode, and if we have to wait four months, or five, to get delivery of the electrode, that means we must place our orders, but what are we ordering. Will the specifications be as reported to us this morning? I hope so. I was under the impression that that had been started three months ago; that deliveries perhaps would be coming to us within another month; that we would be within 30 days of one electrode; that there would no longer be this brand qualification requirement and all such."

Lt. Randall emphasized the purpose of core wire standardization:

"I think there are one or two things that Mr. Raymo may have overlooked. The first one is that this core wire specification has nothing whatsoever to do with the final electrode. That is not an Ordnance Department specification. That is an agreement which was reached at the request of the War Production Board. It is unfortunate that I made the remark this morning that the Ordnance Department, I am speaking in this case as a representative of the Tank-Automotive Center and not as the Chairman of the Electrode Group, hopes to have on the Agenda of the next Electrode Group meeting an electrode specification which is what Mr. Raymo is talking about, I believe. One thing that Mr. Raymo has overlooked, and that is that this composition of core wire does not determine any of the things which he is talking about. Neither will it be used by the Ordnance Department as a basis for interchangeability of brands for procedure qualification purposes. An electrode specification is the only thing that will perform that function, and we will be very glad to have Mr. Raymo attend the next Electrode Group meeting and present his views to the electrode manufacturers there. But I think he has misunderstood the purposes of this core wire standardization. It cannot be used for any such purpose as he proposes, and it will not accomplish the objective that he is talking about. It was never intended to."

The core wire situation was explained by Dr. Braley:

"As a representative of the core wire manufacturers, I would like to state that I think there has been progress made, in that some three or four months ago, we had 54 specifications for core wire on our books, primarily for armor welding. Today we have two. When we came to bringing that 54 down to 2, we had to do some adjustment and find out where we were going, because we had not that

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continuous and consecutive production on this one type of wire. At the time that those two specifications were stated, the core wire manufacturers made some objection thereto, in that they had not the best balanced set-up for rolling. We stated that we would go along until we had further information. With the change over to those specifications, we had continuous operation on those two analyses for this purpose and accumulated sufficient data to find that we were losing a tremendous amount of material. I would hesitate to tell you how much dead material I have in my stock right now that does meet those specifications, so far as they are stated, but is not rolled. Now that is not conservation and consequently the request for this change was to permit a balanced set-up. Now on the other point, since this has been brought up, I wish to issue a further clarification as far as deliveries are concerned. That is entirely as Mr. Brady has said, but it is outside the realm, I feel, of this meeting and also of the realm of the requirements, because we cannot just get the material to produce other than it is granted us by WPB and there is a certain cycle through which that has to pass. That is undoubtedly necessary because we only have a certain amount of material and we are allowed to use that material only in strategic places which is entirely as it should be. There are deliveries being made today in much less than three or four months. Every time that that is done, the law is broken. If you want to go back on the core wire manufacturers on that basis, the major portion of the tank plants today would be down, if the core wire manufacturers held up to the letter of the law. Now we are not doing this and we are not going to do it, as long as it is possible for us to deliver the things, but we have to have the permission from the users of the core wire to get that through so that we can produce and deliver as they desire. If they will tell or order the amount of material that they are going to be using in March or April, that is all that is necessary. Then we can adjust close enough and make arrangements with WPB to permit melting of that material and their specification will be as it is desired. Nobody is more interested in standardizing than are the core wire manufacturing companies."

Col. Zornig commented on the electrode situation:

"I think that a point has been brought up here, particularly as to the necessity for the welders to look ahead further maybe than they have been doing, because that apparently is important. Now as far as the compositions or the standardizing of welding electrode is concerned, it is one of the first things I heard of when I came to this committee. I have never been associated with the welding people before, so, therefore, I am probably a little bit neutral and can see the humorous side of it. As I gather from listening in on the various discussions the electrode manufacturers are individualists. Each one makes his own. One puts it in a red bundle and another in a green bundle, and another one in some other kind of bundle, and to get them all to agree to making one kind of electrode, I am afraid it is going to be very difficult. I can, however, see the trend moving definitely to the point where the parties will either agree to it or get it thrust upon them, and I am afraid, Mr. Raymo, you will have to have a little patience with those people."

Mr. Maurath advocated strong action:

"We are at war and as Mr. Raymo stated, a standardized electrode would be a blessing to everybody connected with the industry. If you make a standardized core wire and let these tank manufacturers get together and decide which one of these fellows' coating they like and take it away from them it would help. I am perfectly willing to make whatever coating I have, if that will do the job to the satisfaction of everyone concerned. But you are not going to get it by any agreement. You are going to have to have somebody get over them and take it away from them. There is only one manufacturer in this group where we couldn't interchange. We could not use his analysis and he could not use ours. I am going to bring that out very specifically, and if you turn the analysis of his coating over to us there is nobody in this room can make that work in an extruder. But the bigger part of the electrodes are made by the extruder method and every extruder can use the same type of coating, if you find out which one is the best and which one the users want. I am willing to do anything that anybody in this room wants to do to make the thing a success."

This suggestion by Mr. Maurath was rather startling but in line with what many Ordnance people and fabricators were thinking. He was referring to the Arcos Corporation.

Mr. Brady responded to the question raised by Mr. Maurath:

"I have worked for four welding rod manufacturers in the capacity of research engineer on coatings. As an aftermath of working with these companies, I find that their coatings are very, very similar. It is only natural that they should be. There is not, in other words, ten cents' worth difference between the four companies I have worked for in their coatings. They have made some slight changes since I have left them but not essential ones. Fundamentally, they are the same combinations. Now, with two other companies with whom I have never been employed there has been an interchange of information. I can say that of six companies who represent probably 80% of the electrodes made. I am fully aware of their formulas. I can write them down this minute, and I would not miss by more than a half of one per cent, but they change a little bit from day to day, and they go along and do this and do that and over a period of years they do change a little bit. Now, if there is a little bit of difference in the six companies, to my knowledge that little bit of difference is not worth their salesmen going out and mentioning it. That little bit of difference is not worth saying, 'There is a difference,' but that difference is just enough and the color of the rod is just enough different, which brings us back to the Prima Donnas who use this welding rod. The rod is just a little bit off shade, just a

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trifle, not a different color mind you, but a shade different. It doesn't operate the same. It is not good. Some are partial to green, some to black. I have got that thing going through a certain shop just this minute.' I am looking at the individual now, where there is that psychological reaction, that psychology of color. You would be surprised what it means. It is terrific. I could write a book on it. Here are six big producers who could get together on one coating and stick to it until the war is over. If we find improvements we will all agree to make that improvement the same day. Unless we do that I don't think it is practical. It is a plan I advanced a long while ago when we had a meeting in Pittsburgh and I spent my money and so did everybody else to go to Pittsburgh to exchange this knowledge. My little talk is on the record, willingness to co-operate in that respect, but they had a change of heart and the research men did not appear at that meeting. The salesmen came."

Mr. Raymo commented:

"Yesterday there was a man who told us that in order to maintain sources of supply he had to have four or five different brands of electrodes in the plant, that he absolutely could not use those electrodes interchangeably. I would not permit such a condition to exist in my own plant. The men would never be given an opportunity to make that distinction between brands of electrodes. I think that that is a matter that can be handled within our own organization. The reason this condition exists is because of these slight differences in operating characteristics; color of the coating, color on the end, and all such. As long as in the ultimate use of the electrode we are at the mercy of the psychology of the man less informed upon the tool he is using, why not take all of those variables out and make the electrode all of one color, all of one coating, the same constituent. I will go right along with Mr. Biederman and say I don't care whose coating you put on the electrode, just make them all the same."

Mr. Danse offered the co-operation of the General Motors Welding Committee in preparing a specification:

"General Motors stands ready and willing to call a special meeting of the Armor Plate and Welding Committee to get together with the electrode producers or such of them who want to co-operate in this. We will finish the job by going on from a deposited metal analysis specification to a complete electrode specification. We would like to get together with the Electrode Group and we will co-operate and we will finish our specification by writing in a coating composition, figuring on using what the Electrode Group has already formulated for specification of core wire."

Mr. Brugge voiced some difficulties of standardization of electrodes:

"In the first place, all the electrode manufacturers have slightly different manufacturing problems which call for some different solution there. There aren't any of them that have the same drying ovens, the same drying processes, nor are there any of them that use the same pressure of equipment or one thing

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and another. That probably all could be worked out. Another thing in standardizing the coating, it would stop development. You standardize the coating, then you would have to get six people together to move forward again to get together with all the users, and I think that at the present time everyone of the electrode manufacturers is spending all the efforts to make a more usable electrode, and to date I would say that probably 150 or 200 combinations have been tried out in different shops with different degrees of success, and some were so accepted.

"Now if the electrodes are pretty well similar, I think it would be better to go along with the present set-up than to make a change to one electrode for those various reasons. I think you will have a great deal of difficulty in standardizing. The fabricators will have to get together and they will find that they have some difficulties because the Face-Hardened Fabricators' Group like one type of electrode which is different from the Homogeneous Fabricators' Group, and there are other problems involved. The Navy has another problem and they will call for slightly different operating characteristics than are desired in some of the Army tank works. I think it is a very, very complicated problem that can be approached by a discussion of getting together rather than going to the ultimate that you are talking about now."

Lt. Randall suggested:

"I think this discussion is one which can properly take place in the next meeting of the Electrode Group. It is not contemplated at the present time that that group meeting will have to wait for the next meeting on Welding of Armor. I think it probably will be better, however, and more profitable to get the electrode manufacturers together and see how close we can come to this agreement we are talking about."

Mr. Goodford added:

"May I suggest that if this takes place that people from the Ordnance Department and also the Navy be invited to attend the meeting. I agree with Mr. Brady we should standardize and we are going to go along, but I also feel the same as Mr. Brugge does for this reason: We are talking about standardization but are we talking about standardization for Ordnance work for tanks or in general the Army and the Navy? If we are talking for Army and Navy, there are two different coatings involved right there immediately."

And Mr. Brady suggested:

"If this special meeting is held of electrode manufacturers, with due respect to Mr. Danse and his willingness to co-operate, it is my suggestion that the only people at that meeting be research men, and I do mean research men of the welding rod manufacturers, no Ordnance men, no fabricators, just the manufacturer for this simple reason - we do not patent our coatings. Their complexity is such that we do not have to copy. Nobody can copy a coating. It is a marvelous business to be in. Nobody can copy or even come close to it. So we don't want as manufacturers of

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welding rod any outsiders at this meeting because when the war is over they will have a good formula that they can start in business with."

Col. Zornig concluded the discussion:

"Any more to be said of the subject? Time is moving. I hesitate to ask you to bring up any new business because I don't know as we can get very far with it. Unless there is something urgent in the line of new business, I will pass on to the time of the next meeting and date."

It was decided that the next meeting would be held on Saturday, 6 February 1943 at Cleveland, Ohio.

At this meeting it was apparent that the problem of electrode standardization had not yet been settled and some misunderstanding existed regarding electrode delivery schedules to the fabricating plants. Some fabricators wanted approval to use large diameter electrodes for the purpose of expediting production but had made no coordinated effort to demonstrate satisfactory performance by which Ordnance could authorize their use. The practice of issuing waivers to armor plate producers was severely criticized by the fabricators on the grounds that fabricating difficulties were thereby increased in the fabricating plants because of the poorer quality armor plate received. Thus, the net result is to hinder tank fabrication rather than expedite it. Also, this leaves the tank fabricator in the middle with no way out as the fabricator looks at it. Some of this attitude is due to misunderstanding the problems of the armor plate producers who are trying to supply the great demand for armor in the shortest possible time. The electrode manufacturers, though advocating standardization of one grade of stainless electrode, are still waiting for someone to make the first move in that direction. Spot welding is being applied to the light armor of half-track vehicles by one fabricator. A specification for spot welding of armor has been tentatively approved.

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ELEVENTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
SATURDAY, 6 FEBRUARY 1943
CLEVELAND HOTEL, CLEVELAND, OHIO

The eleventh meeting of the Subcommittee was held in Cleveland on 6 February 1943 at the Cleveland Hotel with 143 persons in attendance representing:

Industrial - United States	
Tank Fabricators	29
Armor Producers	3
Electrode Manufacturers	28
Core Wire Producers	6
Resistance Welding Equipment Mfrs.	5
Aircraft Fabricators	7
Industrial - Allied Countries	
Fabricators	3
Individuals	6
Government - United States	
Ordnance Department	27
ASF Headquarters	1
Navy Department	7
Army Air Forces	2
War Production Board	3
National Research Council	2
Government - Allied Countries	3
Guests	11

The meeting was opened by Col. Zornig with the following remarks:

"Gentlemen, I had hoped this morning to have Colonel Colby here to tell us something of the performance of welded armored vehicles in combat, but I had a telegram from him yesterday which states, 'Urgent business takes me to Camp Hood, February 6th. Regret cannot accept invitation to speak before Welding Subcommittee.' So, all I can say is, I will try at the next meeting to have somebody tell us something about it. I thought I had it fixed up this time, but apparently I did not."

Mr. Sweeney of WPB reported on the alloy situation:

"Apparently there is a misconception generally prevalent that manganese is not critical. This idea is particularly called a long range view, as the ore must come across the ocean. It is imperative to save manganese, and it is essential. Low carbon type manganese is critical now because of the shortage of facilities for manufacturing it. Higher carbon manganese is now in balance; that is to say, the present supply equals the present demand.

However, care must be exercised to see it does not become unbalanced. The significant factors in the supply of silicon are power and furnace capacity. The shortage of both of these items has resulted in the lowering of silicon content of manganese steels, and the significant reduction of silicon content in constructional steels.

"With chromium, it is no longer the availability of ore which is the most critical factor, but the productive capacity for making low carbon ferro-chrome. The demand for 0.6 low carbon ferro-chrome far exceeds the present supply. Other grades of ferro-chrome are less critical but cannot be squandered. Any modification or substitution for 0.10 low carbon ferro-chrome will permit the consumption of more scrap. The nickel situation is in balance at the present moment; however, any radical changes in specifications or anticipated demand for steels containing nickel would upset this balance. Vanadium is likewise now in balance, but due to the small overall supply, the large portion needed for any unusual demand would result in a definite shortage.

"Molybdenum, at the present time, is considered to be the most critical of all elements commonly added to steel. For some months consumption has exceeded production, with the result that the stock pile has been reduced to a large extent. At the present rate, this stock pile would be depleted before the end of the year. The overall picture for 1943 indicates that the demand exceeds the supply and it is going to be necessary to save molybdenum wherever possible. Columbium is also very critical and is permitted only where carbon stabilization, as in the case of stainless steels, is necessary. Tungsten is now in balance, but like the others, could be upset by any unusual change. Copper is so urgently needed in non-ferrous metals that its use in steel has been practically eliminated. Zirconium, titanium and boron are effective substitutes for the more critical elements.

"The use of steels which require no raw material change except scrap has increased from 6-1/2% on 15 July to 15% in December. The savings accomplished have been made possible by an increase of alloy steel production. The fact that is not commonly known is that a large portion of stainless steel production is directed to electrodes for welding armament. In January and February, 14% and 13% respectively of all stainless steel production was for this one activity, whereas the demand for 0.6 and 0.10 low carbon ferrochrome has been very much greater. January and February requirements of these grades for welding electrode production were 16% and 20% of all the 0.6 carbon, and 44% and 39% of the 0.10. This was a total of 25% of all the 0.6 and 0.10 low carbon ferro-chrome required. This situation has been aggravated by quotas specifying .07 or .08 maximum of carbon instead of the previously agreed upon range of .07 to 0.12. The alloy situation is so critical now that a 25% cut in all stainless steel production for the Army and for the Navy and for all other users has been proposed for February.

"The War Production Board hopes that the compromise agreed upon will make a better weld deposit and yet permit the greater utilization of scrap and a corresponding degree of low carbon ferro-chrome consumption. At the same time, we hope this change will not lower the steel mill requirements, and we hope that the quality of the

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material that will be furnished will permit, in the near future, the elimination of molybdenum for electrode coating, except for some specific applications. An appreciable amount of alloys are consumed in electrode coating. Instructions have been mailed to coaters, instructing them in the procedure for filling out Form PD 707 on which they obtain these alloys. From the data on these forms, we plan to study these compositions and hope to make worthwhile savings of the critical alloy elements in the future. We do not know of any logical reason why we cannot and should not standardize the most economical coating, from the standpoint of alloy consumption. We suggest to the coaters that they start their experimental program now, to see what reductions they can make in the alloy consumption in coatings.

"The 'V' value for February is: Manganese, .6; silicon, 4.0; chrome, 3.7; nickel, 3.7; molybdenum, 22; vanadium, 43. Now, of course, one thing I want to point out about the vanadium, the reason it has such a high value is that there is such a small supply, and the bulk of it goes in the production of high speed steel. That leaves such a small amount for any other purpose that in order to make a comparison with the others, which are produced in such greater quantities, it is necessary to give it a higher value. Now that means, roughly, that at the present time it is better, for instance on nickel which is 3.7, to substitute 5% nickel for 1% molybdenum. And, of course, one thing that I don't have here in these figures is the supply and demand picture, but I recall offhand that manganese was in balance; that the value for it was one, which means that the supply is equal to the demand now. But as I pointed out, that is one of the worries that prays on those who are in charge of alloys, that if manganese ever gets in the doghouse and really gets critical it will be really just too bad because you can do without chrome and you can do without nickel and without molybdenum but under the facilities that we have now for making steel, it is necessary to have manganese to make every type of steel properly.

"Molybdenum, I don't have the value for it, but I know that it is not equal to one because approximately 30% more is being used than is being produced at the present time so that means that the stockpile that we do have is, before long, going to run out and then, of course, its value will have to come down to one because you can't use any more than you have. At the present time zirconium is not as critical as the others, and at the present time there hasn't been such a shift that would indicate that it would be extremely critical like molybdenum is being now."

Lt. Col. Richardson raised a question:

"Mr. Chairman, could Mr. Sweeney tell us how he gives us a figure of 43 for vanadium, which he says is in balance, and a figure of 22 for molybdenum, which he says is critical?"

Which Mr. Sweeney answered:

"Yes, the 'V' values which I gave there of 22 for molybdenum and 43 for vanadium mean that in the substitution of one type of constructional steel for another it is better to use 5% nickel, say, because it is 3.7, than it is to use 1% of molybdenum, because five times 3.7, you see, is still less than 22. Those are equivalent values. But the vanadium is in balance because it is being carefully watched and these figures have no relation to it being in balance except that they are based on the available supply. You see, if vanadium had a low value, then if you substituted very much for it, why, it would throw it completely out of balance because there is such a small amount of it available compared to the molybdenum or the nickel. All those figures are based not only on the supply and demand, but also on the total production figures. Vanadium has been eliminated from all tool steels except high speed steel and it has been eliminated from practically all the constructional steels so that right now it is in balance because it is only permitted in such a very few applications."

Mr. McDowell reported on the activities of the Homogeneous Armor Fabricators' Group:

"The first item to be considered by the Group was the proposed specification for armor welding electrodes. The reason this was taken up first was so that the decisions or recommendations of the Group could be carried over to the Electrode Group to be considered in their discussion of the specifications. The first change that was recommended in this specification was the elimination of the colored tips on the electrode. Most of the fabricators were of the opinion that this was not necessary and that in some respects it was a hardship, when as some of the fabricators are doing, the mild steel tips are welded onto the stainless electrodes. It was suggested that if it was necessary to identify the electrodes by colors, that a colored band be applied to the coating. Some of the members were of the opinion that an additional type should be added which was to be called the A.C.-D.C. type, but it was finally decided that if a footnote was added to this table as follows that this would remedy this situation satisfactorily. I will quote the footnote that was suggested:

> "If a rod can be used on A.C. or D.C., it may be used by the fabricator with that type of current for which he has been qualified."

"It was suggested that these chemical requirements should include limitations on sulphur and phosphorus. In respect to the critical moly situation, after some discussion it was unanimously recommended that the Grade VI, or moly-modified electrode, be taken from the specification. In paragraph E-2, it was suggested that the elongation requirements on the tensile test for qualifications of electrodes be defined more clearly.

"In regard to Specification AXS-497, on the welding of armor, amendment 3 to this specification, which included most of the changes that were discussed at the last meeting of this Group, was read by Major Coombe and the Group had no comments or changes to recommend in this amendment as it had been drawn up. It was brought out in a discussion on the welding of H plates that some fabricators were using a different welding procedure in welding the crossbar of the H than when welding the legs of the H, and it was the opinion of the Group that it was not in the intent of the specification to approve such practices and that in the future this practice should not be followed. It was generally agreed that the practice of welding both legs of the H at the same time would be permissible, and it was recommended that the wording of this sentence be changed so that it shall read, 'The crossbar F-E shall be welded after A-B and C-D have been completed.'

"There was considerable discussion on the question of interpass temperature, and Major Coombe told the Group that the Tank-Automotive Center is considering a change in the requirement for welding H plates so that during the welding of the H plates the interpass temperature shall not exceed the minimum preheat temperature used in production by more than 100°F. For instance, if no preheat temperature was used in production, the maximum allowable interpass temperature on the welding of the H plate would be 170°F., or 100° above room temperature. This proposed change was not readily acceptable to all the members present, but it was brought out that in a survey of actual welding conditions in several of the fabricators' plants, it was found that interpass temperature often did drop to a low figure and it was brought out that the welding of the H plates should represent the worst possible condition as would be encountered in actual production.

"In regard to large diameter electrodes, at the last meeting of the Subcommittee, Mr. Smith of Midland Steel Products Company was appointed Chairman of a committee to draw up a test program so that more information could be obtained on the ballistic performance of plates welded with electrodes up to 1/2" in diameter. At the present time, all of the plates have not been completed yet, and since it is desired to send these plates to Aberdeen as a group, the testing of these plates will not be started until they all can be sent to Aberdeen at the same time. At the present time there are several fabricators who have been qualified for the use of electrodes up to 3/8" in diameter.

"In regard to ferritic welding, one of the fabricators has developed a satisfactory procedure using the Unionmelt process on plate up to 1/2" thick, and is actually using this process in production. At the last meeting, Lieutenant Pless offered to make a survey of welded H plates to determine if there was any advantage to the use of the annealing beads of the last pass. The first grouping is for the 1-1/2" rolled homogeneous plates, and included all plates that have been fired since last year. The grouping of the welding techniques has been divided into four classes: Those that used the overlapping beads with no annealing beads; those that used the overlapping beads with annealing beads; those that used full weave beads with no annealing beads; and, those that used full weave beads and annealing beads.

"In the first class, out of a total of 14 plates, 85.71% of these plates were satisfactory, both in the shock test and in the X-ray test.

"In the second class, out of a total of 62 plates, 91.94% of the plates passed both the ballistic and X-ray test.

"In the third class, out of a total of 36 plates, 36.11% passed both the ballistic and the X-ray test.

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"And in the fourth class, which is the full weave with the annealing beads, out of a total of 16 plates, 81.25% of these plates passed both the ballistic and the shock test.

"In an attempt to show the effect of the difference in X-ray quality of the welds between those procedures which used overlapping beads and those which used the full weave beads, it was brought out that in those plates in which overlapping beads were used only 8% of the plates failed to pass the X-ray test, and of those plates using the full weave bead, 37% of those plates failed to pass the X-ray test.

"Now, going down to 1" rolled homogeneous armor we have the same four classes again, and while this group does not include as many plates, it showed a definite trend, I think similar to that shown in the 1-1/2" thick armor.

"In the first class, which is the overlapping bead but no annealing beads, 60% of the plates passed both the ballistic and the X-ray test. However, this group included only five plates.

"In the second group, the overlapping beads with the annealing beads, in this group, including 20 plates, 60% of these plates passed both the ballistic and the shock test.

"In the third class, which is a full weave with no annealing beads, out of a total of 35 plates, 25.71% of these plates passed both the ballistic and the shock test; and, in the fourth class, 54.55% of the plates passed both the ballistic and the shock test.

"In the comparison of the quality of the weld by X-ray examination, in those plates in which the overlapping beads were used only 4% failed to pass the X-ray test, and in those plates in which full weave was used, 35% failed to pass the X-ray test.

"In a discussion on the quality of cast armor, it was agreed that many of the cast armor producers are producing satisfactory castings, but there are also a great many producers who can make considerable improvement in their product. In respect to rolled armor, it was brought out that the quality of the plate, especially in regard to dimensional accuracy has improved considerably, and most of the fabricators are getting along fairly well and with fairly satisfactory results in this respect.

"In regard to plate scale and the effect it has on the welding procedure, one of the members raised the question as to what procedures were being used by the different fabricators to remove this scale. It was almost the unanimous opinion of the group that it was necessary to remove the scale both from the flame cut edges and also from the surface of the plate where any welding is to take place, and while this is in some cases taken care of by shot blasting, other fabricators use hand grinding methods to take care of this."

Mr. Dansé brought up the question of welder qualification:

"Mr. Chairman, I don't want you to think that I came here to kick everything into a cocked hat, but that situation regarding the qualification of welding operators is far from being composed. I should like to have the cards all out on the table and have everybody look at them - instead of pushing it into the background

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and attempting to hide it. Ordnance wants to qualify the welders. Ordnance does not desire the contractors to qualify the welders. We have no objection to Ordnance qualifying the welders, but we do object to a subterfuge in the wording of the specification. Let us please change the wording of the specification back to the way it was, requiring Ordnance to qualify the welders, and then we will all understand it and we will all be happy. As it is legally, and we have had the best legal minds in the country interpret the wording, the contractor qualifies the welders and Ordnance does not and that is not satisfactory to Ordnance, and they keep arguing about it. Now, if Ordnance wants to qualify the welders, certainly Ordnance is the customer and the customer is always right, and we want to do what the customer wants. So please let us change the wording the way it should be."

Major Coombe commented:

"I can only say that the situation was discussed in the meeting, as Mr. McDowell has reported. It was the unaminous agreement of the members present that the situation was not such as to warrant a change in this wording. Mr. Danse and Mr. Smith of Midland are the only ones of all of the fabricators who were represented yesterday who have any trouble with Ordnance on this issue. Mr. Smith retracted his statements so that it enabled unanimous agreement of the Group against changing the wording."

And Mr. Danse replied:

"I have discussed the situation with Major Coombe, Lieutenant Randall and Major Pippel. They are perfectly frank about it that they would prefer to have the Ordnance inspector on the job make the qualification of the welder. We have no objection to that being the case. Our objection is to the wording of the specification which says that the contractor shall qualify the welder, when it is their desire and intention that the Ordnance should qualify the welder."

Mr. Raymo remarked:

"Well, the qualification to an Ordnance Department specification is merely qualification to another of many codes that we have to deal with in this welding game. We have our A.S.M.E. boiler codes, and the Navy Department specification requirement, and probably three or four others if you break them down as individuals, and in no instance does the representative of the party requiring qualification actually assume responsibility for the qualification of the welder. I think that properly remains the function of the contractor and that it is still only necessary for him to produce sufficient evidence to the customer's representative that the qualification specifications and requirements have been met. I can't see why the customer should be required to assume responsibility for qualifying the welder at all."

To which Mr. Danse replied:

"Mr. Raymo's sentiments are very fine, and they are in accord with the wording of the specification and we will continue to work

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according to the wording of the specification as legally interpreted by General Motors' Legal Department which is that General Motors Divisions will qualify the welders. However, we know that if the Ordnance inspector at the plant would do the qualifying examination of the negatives rather than our X-ray technicians, we are not opposed to that; we are perfectly agreeable to having it done but not so long as the wording is such as it is. As long as the wording is such as it is, we will continue to have our X-ray technicians look at the negatives and pass or reject the welder out of the school on to production. Then we will show that negative to the Ordnance inspector and tell him, 'Here it is.' If he opposes it we will consider his opposition, but that will not necessarily keep the welder from going from the school on to production. If our X-ray technician considers that he is qualified he will go out to the floor and weld and we will continue to have the arguments we have had in the past six months about those men being on the floor. Those arguments are continuous, constant; they recur every day, but we will continue to put up with it. Every week we have 15 or 20 arguments, and those arguments occupy a lot of our X-ray technicians' time which would much better be devoted to examining castings or plates or welds, rather than to these constantly recurring arguments."

Mr. Raymo suggested:

"My observation is that marginal cases are few and far between; either a fellow produces a good plate or it is a bad plate and usually the difference is so distinct that there isn't much question about it."

Mr. Danse explained:

"That is also our opinion, but it isn't Ordnance's opinion and that is why the arguments are continuing."

Mr. Jeffries raised a question:

"Mr. Chairman, the specifications say the contractor shall prove to the Ordnance inspector that each welder has been so qualified. I would like to ask Major Coombe how the contractor can prove to the inspector that he is qualified."

Major Coombe replied:

"I would say it is very simple. If the requirements of F-2b(3) are carried out, if the welding operator makes his qualification test plate, that qualification test plate is radiographed as specified and if the radiograph meets the requirements of AXS-476 as specified, all that remains is for the contractor to prove to the inspector that that operator made that plate from which that radiograph was taken. You then have a permanent record and I can't see why there should be all this discussion."

Mr. Jeffries continued:

"For example - we are perfectly willing in the final inspection, to believe that the welder has made a good plate, but just

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the same our experience leads us to believe that that plate has written all over it, 'Caveat Emptor.' We still can't prove that the contractor has produced a welder who will pass the qualification test and there is nothing here to help us. We say that he shall be proved to be qualified, but then we are kind of lame in our interpretation. I think it should be clearer, Major; I don't think it is clear enough."

Mr. Christensen remarked:

"Mr. Chairman, I think we should like to go on record the same as Mr. Jeffries has and we feel it should be clear. We have always had our inspectors actually witness the production of the qualification plates. We would rather not do that."

Mr. Jeffries remarked that Ordnance inspectors were not allowed to use Ordnance radiographic standards for operator qualification and added:

"Because we say here, 'The contractor shall prove to the Ordnance inspector that each welding operator has been so qualified,' but how is he going to prove it?"

Mr. Raymo commented:

"We have pretty sharp ideas on what constitutes an acceptable weld. It is literally one that has no faults of any nature whatsoever in evidence in the radiograph. Regardless of how small the defect is, I throw it out. In consequence of which, when the radiograph is presented to the Ordnance Department representative, he has no choice but to accept it because it is an acceptable radiograph with no fault in evidence to question it. In consequence of which, that is proof to him that the man has produced a good plate and the scheme works all right."

Mr. Jeffries pointed out the deficiency in the specification:

"That's right; it works just right in Baltimore. I am perfectly satisfied with it. But the radiograph is submitted to the inspector; this doesn't say it should be, and that is Mr. Danse's argument. Many of these fabricators have been told it is not necessary to submit the radiograph to the inspector."

Mr. Raymo added:

"Well, I think it is poor policy to advise anyone not to submit the radiographs to the Ordnance inspector. That is my feeling on the matter. You would be taking the only evidence that you have for proof, the only concrete evidence, out of the picture and it is only your word against mine thereafter."

Mr. Jeffries suggested:

"I think that can be easily corrected by merely stating in the specification that the radiograph shall be submitted to the inspector."

Mr. Danse concurred:

"I think that would settle the thing once and for all. The interpretation of what constitutes proof is a moot question of how the proof shall be offered."

Mr. Raymo argued:

"We come back to the point that was raised yesterday. How is Ordnance to know that they are not being shown the same radiograph all the time?"

Mr. Danse replied:

"It is quite simple; the radiographs are all serially numbered and dated, and the plates are offered with the radiographs. The officer has the plate and he has the radiograph."

Mr. Raymo added:

"That is all right; you can change that. Serial numbers are put on there with lead letters and you can shoot the plate a hundred times and have them come up with a different number and identification stamp every time."

Mr. Jeffries remarked:

"That is a pretty good reason for the inspector witnessing the radiograph."

Mr. Swan objected and remarked:

"Mr. Chairman, it strikes me that we are admitting that there is almost an accusation of dishonesty here. There has to be some attempt, on the part of everyone concerned, to admit that there is honesty on both sides of the fence. The fact remains that this calls for an X-ray test and it appears to me that the only proof which will fit into an X-ray test is an examination of the X-rays. That is all that is necessary. And I think there is one other phase of that wherein if the inspector, the Ordnance inspector, disagrees with the interpretation of the X-ray, that is his privilege, to say that the welder is not qualified and that is also included in the specification as written. That is part of the proof. If he doesn't agree with it his word is final."

Mr. Danse disagreed and remarked:

"We don't agree with that. If it is the contractor's job to qualify the welder we will permit the Ordnance inspector to argue against the qualification, but we won't permit him to throw it out. If we consider that his argument is a valid one and the X-ray technician can't agree with him, then it goes from him to the Chief Metallurgist. If the Chief Metallurgist can't agree that the argument is valid, then the thing goes to the Works Manager and the Senior Ordnance Inspector at the plant. Their word is final.

"We won't permit Ordnance to have the final word because the legal interpretation of the wording of the specification is that the contractor does the qualifying - not Ordnance. And we won't allow that Ordnance has the final word because in that case Ordnance does the qualifying and not the contractor. That is the legal interpretation of it. The inspector can shut the plant down, Mr. Raymo - he can stop the plant. We have no objection to his doing that, but with the wording of this specification the contractor has the final decision. The contractor qualifies the welder. Please

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change the wording to permit Ordnance to qualify the welder; then we will back down and give Ordnance the final word."

Mr. Clark remarked:

"Mr. Chairman, as a visitor who is not welding armored vehicles, but one that has had quite a bit of experience with inspection agencies, I am very much surprised to hear such a discussion at a meeting like this because the prime purpose of this meeting is to help win the war. These are things that ought to be taken care of in our own backyard! Other people are doing it - day in and day out - and it seems to me we are wasting a lot of time."

To which Mr. Danse replied:

"Mr. Chairman, I refuse to subside. We have been quibbling in our own backyard for months, and we cannot get the argument settled, and we would just love to build more vehicles and help win the war."

Col. Zornig commented:

"Well, I think the question has been thoroughly aired. There is no one in here that can make a final decision except the Tank-Automotive Center. I think we have heard enough on the subject from all sides now, and we have other business. I think we ought to move on to it unless there is some objection to that."

Lt. Randall reported for the Electrode Group:

"The principal subject discussed, in fact, practically the only subject discussed yesterday at the Electrode Group meeting was a proposed electrodes specification. It is not intended that Ordnance Department welding specifications will require that fabricators use only electrodes covered by the specification. In other words, this specification is not intended to restrict a fabricator to the use of only the electrodes that have been found to be in compliance with the proposed specification. The primary purpose of the specification for electrodes is to provide the necessary tests to insure that electrodes of a given grade, type and class are essentially identical. Approval of a brand of electrodes, in any particular grade, type and class, under this specification, will operate to eliminate the necessity for ballistic qualification of that brand by an individual fabricator, provided that fabricator has previously qualified the same welding procedure with another brand of the same grade, type and class. In other words, a particular fabricator using a single welding procedure would be permitted to use any electrode of the same grade, type and class as that used in the original ballistic qualification test made. And the other item, which of course is fundamental, is that the use of electrode requirements of this specification does not in any way constitute ballistic acceptance or approval of any weld produced therewith. Welds remain the responsibility of the fabricator.

"The question of color tipping, as the Fabricators' Group knows, was discussed and no definite decision was arrived at as to

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whether color tipping was necessary. Most of the electrode manufacturers, of course, want to eliminate it. The Navy Department is inclined to insist upon it on their electrodes.

"New core wire standards, with slight changes, were agreed upon and I will read those in case any of you would like to take them down. I will indicate what changes were made compared to those recommendations now in the hands of the War Production Board:

"Type 307: Carbon, .07 to .15% (that represents an increase of 3 points in maximum carbon content); manganese, 3.75; silicon, .25 to .60%; chromium, 19.5 to 21.5% (that is a shift of 1/2% upwards of that chromium range); nickel, 9.0 to 10.5% maximum; sulphur, .03% maximum.

"Type 308: Carbon, .07 to .15% (again an increase of three points in maximum carbon content); manganese, 1.6 to 2.2%; silicon, .25 to .60%; chromium, 19.5 to 21.5% (that represents a shift of 1/2% downward in chromium on that material); nickel, 9.0 to 10.5%; molybdenum, residual only, report required; phosphorus, .04% maximum; sulphur, .03% maximum. These core wire specifications as drafted were, after a great deal of argument, agreed upon. The Navy Department indicated it is their plan to revise their electrode specification to include these two core wire compositions, and in addition have proposed a requirement for a minimum ratio of chromium to nickel of two to one. It was this ratio which caused the most discussion. The core wire producers, in order to avoid immediate application of this ratio, made a concrete proposal as to the procedure which they would attempt to follow. They agreed that their welding instructions were that they require 20.5% chromium and 10.0% nickel, and stated that 98% of all heats would fall within the range of 20.2 to 20.8% chromium, and 9.75 to 10.25% nickel. It was the recommendation of the Group and was carried as a motion, that it be suggested to the Navy that they withhold for a 60-day trial period the application of the two to one ratio.

"The specification under discussion yesterday will include the core wire analyses but no reference to the ratio. The deposited metal requirements were modified from those shown in the draft of the specification which was passed out in the committee meetings yesterday to read as follows:

"Grade V: Carbon, .07 to .17%; manganese, 3.3 to 4.75%; silicon, .80% maximum; chromium, 18.0 to 20.5%; nickel, 9.0 to 10.7%; molybdenum, 0 to 1.0%. It was understood at the meeting that the Navy representatives present had agreed to recommend that their Grade V analyses correspond with ours.

"Grade VI, about which more will be said later - Carbon, .07 to .17%; manganese, 1.25 to 2.25%; silicon, .80% maximum; chromium, 18.0 to 20.5%; nickel, 9.0 to 10.7%; molybdenum, 1.85 to 2.25%. There were no phosphorus and sulphur limits specified, although this matter of phosphorus was discussed in considerable detail. It was frankly admitted that no one knew exactly where they could safely be put. There is practically no data available indicating the effect of phosphorus on all metal compositions of these types. The Navy Department has agreed to institute an immediate study of the effect of phosphorus on these all-weld metals.

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As soon as that information, as to what limits can be established, is available it is anticipated that it will be entered in the specification.

"Grade VI electrode was discussed by the Electrode Group which, of course, was somewhat surprised by the recommendation that came from the Fabricators' Group. Unfortunately, as Colonel Zornig mentioned, the Face-Hardened Fabricators' did not have a meeting yesterday, and they have been the principal advocates of the Grade VI type electrode. It was not felt that in the absence of an opinion from that Group the Electrode Group would care to recommend the deletion of Grade VI at this time. At the close of the meeting, a motion was unanimously carried stating that the Electrode Group believes that this specification is the best that can be arrived at at this time, and recommends its acceptance by Ordnance."

Col. Zornig remarked:

"In connection with the maintenance of the Grade VI type of electrodes, in the specification, I want to point out that, of course, the Homogeneous Fabricators are not compelled to buy any of those. But rather than eliminate them entirely from some special welding process that might need them, you could just as well leave them in the specification. We may want to add other types from time to time as other special needs come up, but to conserve molybdenum, just don't buy any Grade VI. Buy Grade V. Because the electrode that you fellows use is still up to the fabricator. The only thing this specification accomplishes is that if you qualify with one maker's electrodes that agree with these specifications, then you use without requalification any other maker's electrodes that comply. It is simply an attempt, as I see it, to cut down on this everlasting making of H plates. Now, are there any discussions on the work of the Electrode Group which is essentially the preparation of this specification? I might say, incidentally, that at the last meeting I was led to believe that the preparation of such a specification was simply something that could be done in 10 minutes, but I can assure you that it was not. It has been a very hard job and a lot of people have had to work on it."

Lt. Col. Richardson proposed a question:

"The Steel Industry Advisory Committee, which is a committee of operating executives in the steel industry under the general charge of the War Production Board, have made the statement, and have asked for a check of the fact that certain types of armor, certain compositions, as made by various producers require more welding than do other compositions. You see, the Steel Industry Advisory Committee had the last word, in large measure, as to the composition of armor and requirements, and apparently the idea back of it was that certain compositions might be satisfactory, from a conservation standpoint, in the armor, but requires the expenditure of so much welding rod that the end result wasn't a saving."

Mr. Raymo remarked:

"I was just wondering whether Colonel Richardson is discreetly

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asking about the relative weldability of armors. Certainly there are some armors that you start to weld on, your welds crack and you chip that out, and you require twice as much electrode as you did for an armor that doesn't crack when you are welding it."

Col. Zornig commented:

"It is mostly a function of the mill rather than the composition itself."

There were cries of "No, No" but upon Col. Zornig's request there were none willing to come forward and offer any explanation of the question. Mr. Brady commented in reference to the new electrode specification:

"According to the War Production Board, we apply for nickel and chrome by the first of the month for the following 60-day melt, then we have 30 days to melt and 30 days to produce, which means about 60 to 90 days minimum. That then, added to another two or three weeks or possibly 30 days more for the rod manufacturer to put it in process, will mean about four months from now will be the time that the fabricators actually receive this new analysis."

And Dr. Braley added:

"Colonel Zornig, I might add to that that as far as this is concerned, some of these will undoubtedly start to change without the necessary formality of going through the War Production Board because the change in analysis is very slight. The principal difference is the two to one ratio, which I might add, the core wire producers object to. I would like to go on record to that extent. But, nevertheless, that change can be made without going through this process and will undoubtedly start on Monday, which will shorten that time somewhat. However, you must remember this - that there is a lot of material in process between the melt and the receipt of material by the consumer, the fabricator. Consequently, that will be shortened somewhat, but it will be a minimum of 60 to 90 days."

This situation indicated by Dr. Braley aroused a question from Mr. Emery:

"Will we be able to get electrodes? Small quantities of electrodes for qualification purpose in advance of that time? I understood you to make a remark that led me to believe that."

Dr. Braley replied:

"Colonel Zornig, in answer to that question I might say this: I would assume that at the present time there is somewhere between 75 and 90% of all the electrodes being produced which falls within this new specification."

And Mr. Brady added:

"I certainly wouldn't put the figure over 75%. I would be more inclined to put it at 50% of the wire which is being manufactured today would fall within this two to one ratio, but it is the other 50% outside of the two to one ratio that we find is what is causing the trouble in the fabricators' shops, cracking and so forth. So it will be four months, I would say, before we have this

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trouble of cracking thoroughly under control. That is what this whole thing is for. We won't have a foolproof product before four months."

The situation with electrode manufacturers was outlined by Dr. Miller:

"I believe there is some confusion regarding 307 and 308. Now, a large number of fabricators have requested that we have electrode manufacturers change to 307 base wire, and in that respect I don't think there is any on the market available today. We have ordered on the three-month basis, so it will be at least three months before we get this old 308 worked out of our plants before we can start on the 307 even if the mills start on it within 60 days. We certainly can't scrap all the 308 heats we have at hand at this time. I believe we should keep it straight whether we are talking about 307 or 308."

Mr. Emery commented:

"There might be some brands that can already qualify under these that they would immediately start on. My object in asking that question was to take up the interim in qualifying so that when we did get the electrodes we would be ready to shoot on them; and that we wouldn't delay when that electrode was the only one available - and it wouldn't be available for three months. If it took us a month to qualify, which is very likely to happen, we would be waiting for electrodes for another month."

Mr. Fugate suggested:

"Colonel Zornig, it seems to me that, if a fabricator is qualified now in using an electrode and it is going to be the electrode manufacturers' responsibility to qualify this rod under the new specification according to Lieutenant Randall's statement I don't think it is going to be necessary for the fabricator of the tank or the man that is going to use the welding wire to do anything other than just start to use the wire when it comes into the plant."

To which Lt. Randall replied:

"Mr. Fugate, that is an administrative procedure which will have to be tied in with the Ordnance Department Welding Specifications which bear no relation to this electrode specification. If you don't mind, I think we had better defer the answer to that question until we get a chance to see just exactly what change it means in the welding specifications."

Mr. Emery explained:

"If you eliminate Grade VI, why I will have to requalify. I evidently backed the wrong horse. I backed the moly; that is why I am so anxious to get electrodes to requalify."

An interpretation was suggested by Lt. Pless:

"It seems to me that, just to qualify it a little, everyone who is using manganese need not requalify if they plan to go to Grade V. All of those other people are going to have to requalify

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on ballistic tests. For those people who use electrodes falling under the Grade V type, but outside of the new chemical range, it seems to me they are also going to have to requalify their position. And those people who are using an electrode which falls exactly within the chemical and physical requirements of this specification at the present time, the procedure under which they have qualified is such that they will not have to requalify. They will be ready to go and can use any of the electrodes which qualify them under this electrode specification."

Lt. Randall remarked:

"Colonel, I think it is fairly apparent from what Lieutenant Pless said that there isn't a 'yes' or 'no' answer to that question about requalification and it is for that reason that I suggest that we withhold making any definite commitments until we have had an opportunity to review the situation."

An urgency was explained by Mr. Emery:

"I have a mess of plates coming in now. I don't want to qualify those under the moly qualification and as long as everybody is here I would like to have some information on what electrodes will conform with this new specification so I can qualify those plates immediately."

A purpose of the new specification was pointed out by Dr. Miller:

"The object of this was to improve the electrode. Now, if you have already passed your qualification test, with what we know to be an inferior analysis, just because we increase our chrome-nickel ratio to make it superior, I don't see why we should have to go through any more qualification tests on that."

Lt. Randall emphasized:

"Colonel Zornig, there is one thing that there seemed to be a slight misunderstanding about. I believe I stated it, but maybe didn't make it clear enough. That is that insofar as this specification which was approved by the Electrode Group yesterday is concerned, at the present time that two to one ratio is not a definite part of it and I think that these questions of detail as to what electrode is going to fall where and so forth, are questions that can't be settled at a meeting of this sort."

And Mr. Thomas remarked:

"Colonel Zornig, in answer to Mr. Emery's question as to what electrode will meet the present specifications that are on the market now, any electrode that has passed the present Navy specifications is in line with the present Ordnance specifications. I think you will find that the Navy actually is using these electrodes, so I think you will find on the market electrodes to meet the new Ordnance specifications."

Mr. Goodford raised a question:

"Colonel Zornig, there seems to be a trend towards the Grade

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V electrode and we might forget about Grade VI. Some months back, at the Navy meeting in Philadelphia we thought or decided that any electrode steel which would not conform to the Navy specification would be satisfactory for the Army use. Now, if we go to Grade V manganese modification, it seems that we don't have as much recovery on that because it isn't as flexible as if we add moly to it. I am afraid we are going to some heats that will have to be rejected. We have a heat now with 1% moly; it could not meet the test. But if we went to 2% moly, it would meet it without any trouble. The consensus of opinion seems to be, of the electrode people, that you must have a ratio of two to one. If you do not have that ratio, what are you going to do with the heat? I am just pointing out the trend."

Col. Zornig replied:

"Well, I don't know what that is going to be. Now, mind you, nobody is taking Grade VI off of the market and anyone who chooses to buy Grade VI can continue to buy them unless the War Production Board cracks down on them and won't let you. It also seems that the Face-Hardened people are the ones who still use a great deal of moly modified, and don't know how to get away from it. I have a sneaking hunch that there will be plenty of market for it if you have heats that will be converted into Grade VI. I think you will find plenty of buyers for it."

Major McInnes reported on Aircraft Armor Fabrication:

"There are in transition specifications from the old Army or Navy type over to an Army-Navy standard. In neither of the types coming into being is there any requirement for armor plate to be welded. It was decided to eliminate that factor. In many cases the fabricator of the armor plate is not getting enough information from the armor plate manufacturers to know whether that plate is anything like the previous plate he received. In addition to that, they are fabricating structures wherein the armor plate is becoming more highly stressed than previously. There are no physical requirements for the plate in the specifications, but the fabricators desire information as to the physical properties of the armor plate. Otherwise, they will have to do considerable testing - physical and chemical - of their own. The main thing they have been interested in is getting that information from the plate manufacturers.

"Another part of the program that was previously started in the last meeting is to determine the effect upon clip thickness of the variation that you may have in the different armor plate thicknesses which will be available for the aircraft manufacturer. Some test plates have already arrived at Aberdeen but not in time to be fired before this meeting. In addition to that, a request has been initiated to set up and develop a program of study of stress in aircraft structures. The formulating of that request is going through the paper work stage, and so far seems to be going without anyone stopping it on the red tape set-up.

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"One thing came up in a discussion of whether a program should be set up to determine the weldability of the various analyses that are now proposed for aircraft armor plate. It seemed to be the consensus of opinion of the majority present that after they did get the results of certain weldability tests such as the single bead on a flat plate, it would not do them much good as far as the shop procedure is concerned, especially if they had no basis of reference and with someone new just getting started in the work."

Colonel Zornig remarked:

"I would just like to mention that the aircraft fabricators, in addition to makers of aircraft, are designers of aircraft and, therefore, they have certain problems in connection with their armor which the tank fabricators don't have. And, you will find often in their discussions that they seem to be wandering off into the subjects which the tank fabricators don't have to consider."

Mr. Cooper reported for the Resistance Welding Group:

"Since the last meeting in Philadelphia there has been nothing that has required the attention of the Group, but this doesn't mean there hasn't been work going on as far as research is concerned. Mr. Mikhalapov will give you a report this afternoon, and as far as production is concerned, the one biggest fabricator using resistance welding is using about 30 machines and obtaining very satisfactory results. He has been spot welding mostly 5/16" hard homogeneous armor plate to low carbon steel attachments. The flash welding has not progressed to any great extent, and perhaps we will have more to report to you next time."

Major Coombe reported for the Specifications Group:

"The activities of the Specification Group have been confined in the past two months solely to this electrode specification. The individual members of that Group have given us a great deal of assistance on this electrode specification. The Group met last night and rehashed the recommendations of the Electrode Group and the Homogeneous Armor Fabricators' Group. Lieutenant Randall has given you the report of the Electrode Group and there is very little that the Specifications Group can add to that, with the exception that the Group made a unanimous motion to recommend the passage of this specification on to Ordnance, and its acceptance."

Mr. Raymo reported for the Armor Liaison Group:

"As regards cast armor, the Ordnance Department has recently taken steps to make recommendations to the foundry people to make more use of the X-ray equipment that they have, or that they should have. And, the practices that have been recommended to the foundry people with a view to making more searching and thorough examinations and studies of their style of castings before putting a given type of casting into production and passing them on to us is certainly sound and should result in much improved quality of castings over what we are getting now, though castings as a whole are very

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good and decidely much better than they were a year ago. Some of the difficulties that we were having three months or six months ago as regards dimensional discrepancies have been corrected to a large degree, and most of the fabricators report satisfaction with the sizing of the plates, as well as the condition relative to laminations and other mechanical faults that have characterized these plates in the past. There are still a couple of the compositions that are not as readily weldable as we feel that we would like to have and believe possible. The data that were presented relative to results obtained with different techniques of deposition is certainly very significant and very pertinent at this time. We feel that the further study that we propose to make of attempting to correlate the response of a given type of armor to techniques of deposit is very definitely going to tell us what type of armor has the best weldability characteristic, and it is the one that we should insist be delivered to us. That is to say, we have the multiple layer method and the full weave with minimum number of pads method of deposition. If we find that a given type of armor responds equally well to both techniques of deposition, it would certainly indicate, as regards the method of plates passed and the number failed, that the plate is superior to another type that might have a maximum number of failures recorded against it, using both techniques. It is a rather long way around to the point of getting down to uniformity of composition or armor, as would appear to have been now attained on our electrodes, but I think that at our next meeting we are going to have a pretty definite indication of a single armor composition."

With reference to a single armor composition, Col. Zornig remarked:

"All of these armor manufacturers, of course, have been beat down on their alloy until their hardenability is right smack on the edge of where they can manufacture, and a couple of them have at times gone too far and have had to back off a little. And, I have heard it stated on pretty good authority that some of them couldn't get the quenching equipment that it took to handle those alloys of lower hardenability because the War Production Board wouldn't given them priorities on quenching equipment. Now, you can't beat a man down on alloy, if you won't give him quenching equipment."

Lt. Col. Richardson added:

"Of course, one reason for a variation in composition lies largely in the scrap situation. Some mills producing armor have a surplus of alloy-bearing scrap. You should bear in mind these figures, that of every ingot of alloy steel made, over 64% of it ends in the scrap pile. Out of every ingot of alloy steel made, 25% ends in turning which, with today's production, is a problem to dispose of. It is a terrific problem to supply outlets for that, particularly the turnings, which are more or less unpopular with the steel industry, and some of the alloy makers or armor makers have a surplus of this alloy scrap. And, that more than probably any one feature is responsible for their armor composition as against some of the apparently leaner ones."

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And Col. Zornig continued:

"The cast armor people are practically all now operating on three types of compositions. There are small variations within these types that are not important. The rolled armor plate manufacturers are making essentially four types of compositions. There are minor variations as far as composition is concerned in these four types which I don't think is probably of any importance as far as weldability is concerned. I have recently gotten some information which leads me to believe that possibly the rolled armor compositions will also, in the not too distant future, be reduced to three general types. I don't believe that we will ever be able to get down to just one type of armor because of the scrap situation and the variations in furnace equipment that exists in the various plants that are making armor. So, I don't believe you will ever get down to just one composition."

After lunch Mr. Mikhalapov reported on NRC Welding Research:

"To start with the homogeneous armor, we have concentrated mostly on methods of welding armor plate with ferritic electrodes prior to heat treatment. We have reasons to believe that we will obtain very much superior joints in this manner and it would seem that as long as some form of heat treating or stress relieving by applying heat is necessary, we might just as well go the whole hog and give the armor a complete heat treatment after welding. We have been very fortunate to get very excellent co-operation from Standard Steel Spring people, who have got up a welding-testing set-up and put it at our disposal and are working with us 100%. I think that will enable us to find out eventually the type of assemblies, let us say sub-assemblies, which can be processed in this manner. Needless to say, the advantages will be that you will have a practically homogeneous assembly with a joint strength equal to that of parent plates. We are also trying to lay some fundamentals on the amount of preheat required to completely eliminate cracking with different types of electrodes. It has been very fairly definitely proven that a moly electrode possessing a fairly high strength is essential if the welded parts are to be made out of armor. That means that some form of preheat is almost imperative.

"Recently we have been cheered by the Army telling us that they have what looks as a fairly satisfactory test for half-inch armor. Half-inch armor and-less is used quite extensively. The problem of welding half-inch armor is very much easier than welding 1-1/2", and we should have started on that lighter armor in our thermal electrode studies were it not for the fact that until recently there was no very good, or better, well accepted test for shock testing than half-inch armor. Now that such a test appears to be available, we are concentrating very much on both the hand and Unionmelt welding of 1/2" armor, spurred on by the fact that one of the fabricators has actually welded a number of half-inch weldments with Unionmelt, using a ferritic electrode, before he had to stop due to other causes. It is our intention to gather enough data on the variations to be accepted in Unionmelt welding of 1/2" plate to enable the Ordnance Department to make some decision, or at least form an opinion, on how generally this process should be permitted. That is, the ferritic Unionmelt welding of half-inch armor.

"On our old friend the explosive test, we are still trying to find out some way of taking the stresses into account in testing different welds. We know we can test very nicely difference in the impact resistance of weld metal. We do not know to what extent we can test locked-up stresses. We went so far as to make a number of plates, 15" wide x 15" long, which were in effect torture plates, and we made them of two types of electrodes, and we tested them by means of explosive tests. Well, we got a big difference between them, but it was more or less between the same proportions as the difference we got in the smaller pieces - on the 2" wide pieces - using the same types of electrodes, so perhaps we haven't got quite the right stresses there. Of course, one thing about an explosive charge, it is easily applied and can be applied accurately. On the other hand, we don't know that its effect is exactly that of a projectile.

"A small amount of data we have indicate that it would be unwise to try to weld face-hardened plate, that is, if you have to have any kind of a weld which is generally accepted as satisfactory without preheat. But, again, I say the data are too limited for us to make a definite statement.

"On resistance welding, Professor Hess has prepared and issued for distribution a very elegant report, summarizing the findings on spot welds in armor plate. The report established several rather interesting facts which I will not enumerate for you, but simply summarize in the statement that it appears possible to spot weld any steel satisfactorily and with excellent structural strength. I said 'any steel', and I mean 'any steel'; any steel which is of the type that may not be wise to attempt to arc weld without high preheat."

Mr. Rice commented on Canadian developments:

"Colonel Zornig, I haven't got much I can say except that we have been experimenting over a period of the last three months with ferritic rod and Unionmelt. At the present time, we are welding the sides of a vehicle from 1/2" low alloy plate, passing the ballistic test successfully. Now, that is the British specification. We are using No. 40 rod and No. 80 flux."

Col. Hoare remarked briefly about British development:

"I will just mention, Mr. Chairman, that I understand experiments are being carried out in England on ferritic welding, but have not yet got very far."

Mr. Mikhalapov remarked:

"May I say, unless you have some form of shock test, ferritic welding is now no problem. That is, using a certain amount of preheat. It looks swell unless you try to hit it with something not very sharp."

[redacted]

The aircraft armor situation in aircraft fabricating shops was discussed by Mr. Hibert:

"Mr. Chairman, I want to ask George if he investigated the new plate that is coming out for spot welding - the nitrated plate? The difficulty we have, we don't know what they make the plate out of. There seems to be so much secrecy about the whole thing. We don't know what plate we have in the shop. It is supplied by various vendors. Some of it is one analysis; some of it another analysis. The only identification on there is probably a serial number. I don't know whether it is Government furnished material or not. After it gets into the shop, it more or less loses its identity as to who furnished the material. It would be very nice if we had one type armor to work with. It is something new to us, because in the aircraft industry the Army and Navy specifications have prohibited welding. That is the problem: They go up to Engineering and they are required to go back to some office somewhere thousands of miles away to get approval on a process. They say, 'The h--- with it; let's rivet it.' If they insist on welding, we would have to change all our present designs. It is all bolted now and clamped."

These remarks indicated a certain lack of coordination in this instance. Whether such was true of others was not brought out by the discussion.

With reference to nitriding Mr. Danse remarked:

"I believe Cadillac was the first concern this side of the water to use the nitriding process, and we used it for many, many years, and we made many different kinds of parts out of it - aircraft parts, car parts and tank parts - but the characteristics of nitrided steel that we have ever experimented with are not so good in impact. They are very good in fatigue, but they are not so good in impact. And, I would be very anxious to learn of any kind of steel which could withstand impact after nitriding."

Lt. Boucher called attention to a recent development in manufacture of face-hardened armor for welding purposes:

"I would like to mention a development, which Mr. Mikhalapov may or may not know about, which is being carried on by one of the manufacturers for attaching face-hardened armor. That is a method which eliminates the carburization of the edge to be welded. It is true that the ballistic limits in this zone are dropped somewhat from the ballistic limits required of the plate. However, the zone in which there is this slight drop in ballistic limits is not considered for that type of fabrication. Experiments so far have indicated that ballistic limits can be obtained which will be equivalent to our so-called hard homogeneous armor, and are at least 150 f/s higher than the requirements for homogeneous plate of the same thickness. That experiment is going on at the present time and is being employed in production, and it looks as though that development has very definite possibilities. I would like to suggest that the Air Corps, or anyone else who is having difficulties with the fabrication of face-hardened plate, consider using unmasked areas in the portions that are to be welded.

Col. Zornig added:

"That is a process in which you cut your plate before carbonization, then mask the edges and carbonize and heat treat?"

And Mr. Jeffries added:

"It is not promising on 1" plates. On lighter gauges it is."

Mr. Sherman remarked:

"Colonel Zornig, being from Canada, I want to say that we appreciate being invited to these conferences. I am afraid this one is too peaceful. I attended one in St. Louis the other day that was a honey. There is something wrong here. There isn't enough scrapping and all, but I think you are doing grand work and I don't think I have anything to add."

After some discussion it was decided to hold the next meeting in Chicago, Illinois during the first week of June. The meeting adjourned at 2:15 P.M.

The closing remarks by Mr. Sherman were significant in that this meeting was considerably more peaceful than had been the two previous meetings. It was apparent that armor compositions were becoming more standardized. Ordnance was about ready to adopt an electrode specification standardizing stainless electrodes for welding armor which industry had been clamoring for. There was some argument about interpretation of specification requirements for operator qualification by one fabricator. Other fabricators apparently had had no serious trouble on this point.

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TWELFTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
SATURDAY, 5 JUNE 1943
PALMER HOUSE, CHICAGO, ILLINOIS

The twelfth meeting of the Subcommittee was held in Chicago, Illinois on 5 June 1943 at the Palmer House with 139 persons in attendance representing:

Industrial - United States	
Tank Fabricators	34
Armor Producers	7
Electrode Manufacturers	22
Core Wire Producers	5
Resistance Welding Equipment Mfrs.	6
Aircraft Fabricators	8
Industrial - Allied Countries	
Fabricators	2
Individuals	4
Government - United States	
Ordnance Department	29
ASF Headquarters	1
Navy Department	7
Army Air Forces	3
War Production Board	3
National Research Council	1
Government - Allied Countries	3
Guests	5

Due to lack of availability of a stenotype transcript of the discussions at this meeting the official summary of these discussions is herewith presented. This summary was prepared from notes made during the meeting.

1. The Alloy Situation

According to information presented by representatives of the War Production Board the only metals for which the supply is at present greater than the demand are zirconium, boron, and titanium. It was suggested that wherever possible these metals should be substituted for the more critical elements; manganese, chromium, nickel, molybdenum, vanadium, tungsten, and cobalt.

The policy now should be to regard all alloys as critical rather than trying to designate the degree of criticalness of each element become some elements are only potentially short and not actually short at the moment. Any sudden demand for one element may produce a critical shortage in that element.

Much emphasis was placed on cutting down the use of molybdenum in electrode coatings and core wires, and it is expected that the use of the molybdenum modified 18/8 stainless electrode will be restricted to the welding of face-hardened armor plate in the near future. Fabricators were requested to switch to the manganese modified 18/8 electrode as soon as and wherever possible.

The use of carbon steel stub ends welded to the fully coated stainless electrodes has been advocated to reduce the stainless steel stub end loss. The problem seems to be to decide who will do the welding on of these stub ends. Both the electrode manufacturers and fabricators of vehicles have advanced valid objections to doing the work themselves. It was emphasized that segregation of scrap is important to the war effort in order to conserve nickel and chromium.

An effort is being made to determine the stocks of stainless steel welding electrodes available in the electrode manufacturers' and tank fabricators' plants in order to obtain an idea as to the probable amount of stainless steel which may be needed for armor welding electrodes in the future. The cooperation of all concerned was requested.

2. Homogeneous Armor Fabrication

Engineering Bulletins are proposed by the Tank-Automotive Center requiring fabricators to submit weld deposit analyses of Unionmelt welds and requesting that welding procedures be qualified with manganese modified 18/8 electrodes where molybdenum modified 18/8 electrodes are now qualified. It is expected that the War Production Board will impose certain restrictions on the use of molybdenum modified 18/8 electrodes.

The requirements for the ballistic shock test as now prescribed by Specification AXS-497-3 are being changed somewhat to increase the severity of the test for 1-1/2" rolled homogeneous armor. A velocity of 1200 f/s will be required with the same limits on cracking as now specified. For 1-1/2" cast plate, the limit on cracking for 1050 f/s striking velocity will be 10" instead of 15". The new limit on plate cracking is to be 6" instead of 8". Slug impacts must touch the weld to be considered fair, whereas the center of H.E. impacts must be within 1-3/4" of the weld. For 1" rolled homogeneous plate, the striking velocity with the 75 mm. slug will be 725 f/s with 17" as the limit on weld cracking,

Ballistic tests of H plates welded with large diameter austenitic stainless electrodes up to 1/2" diameter indicate passable performance and the data are being reviewed by Tank-Automotive Center for a decision as to acceptability. Those fabricators using automatic welding methods, primarily Unionmelt, have not qualified their procedure on the armor compositions being used at the present time. It is expected that an order will be issued by the Tank-Automotive Center requiring such qualification within thirty days.

Some criticism was made of the contradictory reports which have been received by the armored vehicle fabricators concerning the performance of welded armor in combat. It is felt that the Ordnance Department should have a qualified observer in the

[redacted]

field to report back through the Subcommittee so that Industry could be adequately informed. In this connection the vehicle fabricators feel that more actual hulls and welded components thereof should be tested ballistically in order to obtain information on performance under simulated combat conditions. It was explained that the Ordnance Department has started such a program.

It is contended by many of the vehicle fabricators that the present welder qualification test required by AXS-497 is not adequate because it requires a butt weld, whereas many of the welds required in the construction of the armor hull are corner joints. A corner joint qualification test is considered desirable.

With reference to limitations in armor plate, the Armor Integrating Committee recommends the following limits of acceptance:

Max. Depth of Lamination	Max. Length Permitted to Repair
1/4" Plate Thickness	50% of Length of Joint
3/8" " "	25% " " " "
1/2" " "	15% " " " "
over 1/2" " "	4" total in any one joint edge

A lamination was defined as any visible opening in a machined or flame-cut edge which would permit entry of a razor blade. These recommendations are intended to apply only to rejected plate now in the plants of several tank fabricators. These defects should be removed by grinding and the cavity so made welded to produce a solid plate edge.

3. <u>Face-Hardened Armor Fabrication</u>

Only a small percentage of the face-hardened armor plate being produced is welded. Three methods are used; namely, the "buttering" or precladding method, the masked type of joint, and the double V type of joint. These methods have been developed by the three fabricators of face-hardened armor who are using welding on plate thicknesses of 1/4" to 1".

Qualification of these methods has been made under AXS-743 with H plates, but on the actual structures there are no joints like the joint in the H plate. This situation arouses a certain amount of argument between fabricator and inspector as to whether the fabricator is welding according to the procedure qualified by the H plate.

4. <u>Ballistic Testing</u>

The recurring argument concerning the value of the H-plate test of welding procedure as a measure of the service performance of a welded armor structure fabricated with that procedure was again discussed. Various experiences were cited to prove that welded armor structures give better shock performance than the ballistic shock test of the H plate would indicate. The feeling is that the test of the H plate is a very severe test and determines joint performance without introducing the factor of design

[redacted]

of the welded structure.

It is also evident that industry desires a test of a corner joint or a fillet welded joint which would simulate a larger percentage of production welding. This test would be in addition to the H-plate test.

5. Welding Electrodes

Difficulties have been encountered by the Navy in welding joints in armor over 1-1/2" thick, using the Grade V manganese modified 18/8 stainless electrode. This has necessitated the use of 25/20 for thick plate to a certain limited extent. Approximately one-sixth of the stainless electrodes used by the Navy for welding armor are 25/20.

Electrode manufacturers are being limited by WPB to 20 lbs. of molybdenum per ton of welding electrodes produced. It is expected that this limit will be lowered to 16 lbs. per ton in July.

No definite decision was reached as to the use of low carbon steel stub ends welded to fully coated stainless electrodes. It is generally believed, however, that the saving of stainless steel which would result from the use of these stub ends would be of minor significance. The most practical suggestion seems to be to either limit the bare portion for the holder grip to 1/2" or fully coat the electrode and use holders of a type which would permit welding to the end of the electrode by the welding operator. Many fabricators seem to want fully coated stainless electrodes. If the carbon steel stub ends are attached to stainless steel electrodes, it complicates the salvage of stainless stub end scrap by the steel mills and also prevents recoating the stainless electrodes which are returned to the electrode manufacturer by the armor fabricator for processing where the coating is performed by the extrusion process.

6. Aircraft Armor Fabrication

An inspection trip was arranged for the members of the Aircraft Group to the plant of the Marmon-Herrington Co., Indianapolis, and International Harvester Co., Springfield, Ohio, on the two days, June 3rd and 4th, prior to the Subcommittee meeting. This trip was arranged as an educational tour in order that representatives of the aircraft industry might observe the application of both arc welding and resistance welding methods to the manufacture of armor structures as used for land vehicles.

The importance of the design being proper for the method of welding to be employed was demonstrated. Also the importance of an understanding of the type and properties of the base material being welded was emphasized. The extent of use of welding for fabrication of armor by the aircraft industry appears to be somewhat limited at present, possibly due to the higher hardenability armor necessary for aircraft because of weight limitations together with requirements for maximum resistance to penetration.

7. Resistance Welding

Resistance spot welding of 5/16" hard homogeneous armor plate is now being accomplished on a production basis for half-track vehicles. Automatically controlled spot welding machines are used with periodic production check tests for inspecting the uniformity of the weld. On butt joints with 3/16" low carbon steel butt straps, the resistance to penetration is stated to be some 40% above specification requirements for the unwelded armor plate. A tentative Ordnance Specification AXS-969, covering resistance spot welding of armor has been prepared. It was admitted that a butt joint in armor with a butt strap spot welded to the back of the joint will not completely prevent entry of bullet splash.

8. Specifications and Inspection of Welds

Specification WXS-169, Resistance Spot Welding of Armor, has been revised and issued as AXS-969, dated May 6, 1943. Amendment No. 4 to Specification AXS-497-3, incorporating the revisions referred to under Homogeneous Armor Fabrication, is being prepared for issue.

With reference to inspection of welds, emphasis has, in the past, been placed on thorough visual inspection of first passes of the weld and final visual inspection of the finished weld. Radiographic inspection has been required of test plates only. As a result of ballistic tests of test plates and parts of welded hulls, and experimental radiographic examination of welded hulls selected at random from the production line, there has been an increasing realization by Ordnance and Industry that radiographic examination is desirable as a method of production control. By intelligent use of this inspection method improper fabrication procedures can be corrected and the general quality of the finished job improved and maintained. The use of the method, however, does not eliminate the need for careful supervision and inspection of the work as it progresses. It was suggested by several representatives that the use of radiographic examination be made mandatory for inspection of welds in armor.

9. Welding Research

Work under the direction of the National Research Council on the development of ferritic weld metal substitutes for the stainless austenitic weld metal has indicated some rather surprising results with a manganese-molybdenum composition. On the light plate of 1/2" and less in thickness, no preheating appears necessary. On heavy plate, a preheat of 250°F. is required. No postheat treatment is necessary in either case. In a few cases plates welded with this electrode have withstood firing tests to higher velocities than any plates welded so far with the austenitic type of electrode.

Studies of stress relieving of weldments for machining stability indicate that a temperature of 1000°F. for two hours removes from 60% to 70% of the internal stress. At 1200°F. for two hours, about 90% of the internal stress is removed.

Work with the explosive test for determining performance of welded joints under high velocity impact indicates that there is a correlation between the width of the weld on the tension side

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and the amount of explosive required to just break the specimen. The wider the weld is, up to a certain point, the greater is the amount of explosive required.

Weldability studies at Watertown Arsenal Laboratory on alloy steels of high hardenability show that removal of moisture and hydrogen-containing ingredients from the electrode coatings is effective in preventing root crack in the heat-affected zone of the initial weld bead.

10. Ballistic Tests at Low Temperature

Studies of the welded H plates ballistically tested at subzero temperatures at Camp Shilo, Canada, last winter are in progress at the Research Laboratories, U. S. Steel Corporation, Kearny, New Jersey. It is expected that based on the results of these studies a new program will be prepared for cold testing welded plates during the coming winter and in sufficient time that the material can be obtained and the test plates prepared without any last minute rush.

11. Minutes of Meetings

It was decided that an abstract of the discussion at the meeting would be satisfactory for distribution and that it is not necessary to send out verbatim copies of the transcript of the discussion. Copies of the transcript will be filed in the Office, Chief of Ordnance and at Watertown Arsenal for any future reference.

12. Next Meeting

It was voted to hold the next meeting in New York City on or about Thursday, October 7, 1943.

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THIRTEENTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
THURSDAY, 7 OCTOBER 1943
HOTEL PENNSYLVANIA, NEW YORK, N. Y.

The thirteenth meeting of the Subcommittee was held in New York City on 7 October 1943 at the Hotel Pennsylvania with 127 persons in attendance representing:

Industrial - United States	
Tank Fabricators	26
Armor Producers	4
Electrode Manufacturers	17
Core Wire Producers	4
Resistance Welding Equipment Mfrs.	6
Aircraft Fabricators	6
Industrial - Allied Countries	
Fabricators	2
Individuals	8
Government - United States	
Ordnance Department	29
ASF Headquarters	1
Navy Department	5
Army Air Forces	4
War Production Board	2
National Research Council	2
Government - Allied Countries	3
Guests	8

Col. G. E. Knable presided, in the absence of Col. Zornig who was suddenly called to Washington, and opened the meeting with the following remarks:

"Colonel Zornig has been called to Washington and has asked me to pinch-hit for him. If you will bear with me, I will try to do my best."

Mr. Sweeney reported on the alloy situation:

"Now, as most of you have probably heard, the supply-demand ratio has improved somewhat. That improvement, however, is valid only as long as the present metallurgical pattern is maintained. At the present time, about 50 percent of the nickel, and about 44 percent of the molybdenum and about 25 to 30 percent of the chromium come from scrap. Because of the necessity for maintaining that metallurgical pattern and because the situation has not improved sufficiently to justify any revision of the conservation policy, the decision has been made to continue with all the conservation measures as in the past. What the future will hold, of course, we don't know--and I don't believe that anyone knows at this time."

[redacted]

Mr. E. P. S. Gardner discussed the British developments:

"Our forward program for 1944 envisages a considerable increase in the welding of hulls and turrets. We are naturally very anxious to benefit by your wide experience in this field. At the same time, we should like to compare notes on current practice—that is to say, in so far as they are comparable—having regard to the wide difference that exists in relative outputs. As you will probably appreciate, most of our production units are small and widely dispersed, for strategic reasons. In the United Kingdom, welding as a fabricating process has been approved for the construction of wheeled fighting vehicles since 1938, and for tanks since early 1941. Upward of some forty different types of welded armored vehicles have been designed and developed for production, apart from numerous special turrets and devices for various operational roles. Nevertheless, the main bulk of our production in the medium and heavy tanks has yet to be changed over; we hope to effect that in the very near future. In general, from what we have seen so far, it would appear that the technical methods, procedures and development on both sides of the Atlantic are very similar and are progressing along parallel lines, except for one or two points which are of minor importance.

"One subject to which I think reference should be made is, of course, the matter of joint detail design. In the early development of welded construction in United Kingdom for tanks, we gave careful consideration to the desirability of using full penetration butt joints in view of their relative superiority in withstanding shock and dynamic loadings. However, having regard to the production advantages offered by fillet welded joints in permitting wider or more generous profiling, flatness and assembly tolerances, and also in reduced welding times and electrode consumptions, attention was drawn to the use of that type of construction which has since proved ballistically and structurally sound, according to United Kingdom requirements confirmed by battle experience in North Africa. So far as electrodes are concerned, we have employed the normal 18/8 or 19/9 modified type since 1938. The electrodes are tested and approved for universal use, and lists of approved electrodes are issued periodically.

"Electrodes offered for welding armor up to 30 mm. in thickness are submitted to weldability (R. D., Rigid Butt) and hot cracking (Ring type) tests. Firing trials on targets welded with these electrodes are not now required unless they are of an entirely new type of composition. Electrodes for welding armor in thicknesses exceeding 30 mm. are submitted to weldability (Reeve) and hot cracking (Ring type) tests, and a fillet welded box type target in 3-1/2" thick armor is prepared for firing trials which include attack by 25 pdr. slug and 6 pdr. A.P. Tentative approval is issued on satisfactory completion of the qualification tests outlined above, and final approval is given after a period of satisfactory performance in production has been completed. Following extensive experimental and production trials with ferfitic type electrodes, we have recently approved the use of deep-

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penetrating-type rods for welding on a plate up to 40 mm. in thickness with square edge preparation. Those permitted for ferritic welding at the moment, and on which we are now starting two production lines, are as follows:

"One we refer to as our A.V.1 type of armor. It has .18 to .22 carbon, 1.0 to 1.25 manganese, .9 to 1.2 nickel, .6 to .7 chromium, and .3 to .4 molybdenum.

"There is also a chrome-vanadium type of steel with .20 to .23 carbon, .40 to .55 manganese, .45 to .55 nickel, .65 to .75 chromium, and .2 to .3 vanadium. With this type of electrode, in order to control the minimum heat input and the rate of cooling, we require a minimum size of electrode of 3/16.

"I might mention that our experimental work has persuaded us to place quite considerable importance on the hydrogen content of electrode coatings with regard to its influence on bonds and crack susceptibility. As you know, such cracking is liable to occur within an hour after welding or many days after welding. In order to accentuate and accelerate that type of cracking, we now (as a standard supplementary test) submit our weldments, mock-ups or complete house to a low-temperature reversal test, consisting of ten reversals from 32°F. to 0°F. That has been found to be quite successful.

"Automatic welding has not been employed so far in United Kingdom for the construction of fighting vehicles. The reasons for this are that in the light wheeled and tracked vehicles the complexity of the hull shapes and shortness of individual joints has precluded the advantageous use of automatics, and in the medium heavy classes the output planned for production lines set up so far has hardly warranted their employment. So far as Unionmelt is concerned, all the equipment that has been shipped over from this country has been allocated to shipbuilding and to pressure-vessel work, where I believe the advantages are rather more important than in connection with fighting vehicle construction."

Col. Knable remarked:

"We are very fortunate in having with us today Major Pippel, who has recently made a trip to the other side. Major Pippel's remarks should be off the record; they are in a restricted category, and the final report is not yet out."

Major Pippel spoke off the record for about one-half hour. The substance of his remarks was that American welded armored vehicles had performed very satisfactorily in the North African campaign.

Col. Knable remarked:

"Thank you very much, Major Pippel; I am sure that your talk was most interesting to all the gentlemen here. I want to caution everybody again that this information is not to be used or discussed outside of this room."

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Mr. McDowell reported for the Homogeneous Armor Fabricators' Group:

"At the meeting of the Homogeneous Armor Fabricators' Subgroup held here yesterday, the majority of the time was spent in a discussion of the proposed revision of AXS 497. Prior to that time, however, there was some discussion of the latest developments in the use of ferritic electrodes. At the last meeting of the Homogeneous Armor Fabricators' Subgroup a new ballistic test plate was suggested to replace the present H plate, due to the fact that the results on the present H plate are often hard to interpret. The plate that was suggested to replace it was exactly the same as the H plate, except that it contained no cross bar. It was suggested that the fabricator send in plates of this type so that the necessary information could be obtained. To date, however, only five of these plates have been tested, and three of these results have had to be discarded on account of poor plate material. In regard to the numerous ferritic welded H plates that have been fired, all these plates have been tested in shock only, and no resistance to penetration tests have been conducted on those plates.

"Aberdeen has also conducted some interesting explosive tests on full-sized H plates in which deformations very comparable to, or even more severe than those obtained with the 75 mm. proof projectile, have been obtained. Enough of these tests have not yet been carried out, however, to allow the drawing of any definite conclusions.

"The greater part of the time at the meeting was spent in discussing the proposed revision of AXS 497. I will outline briefly some of the important changes made in the specification with respect to the previous revision. The proposed revision form will carry manual welding only. In regard to automatic welding processes, TAC plans to issue an engineering bulletin in the near future which will cover qualification of all automatic welding processes. One of the most important additions to this specification is the inclusion of a welding procedure outline which all manufacturers must submit for all joints on the vehicle to be welded. This outline will have to be submitted to the Office of Chief of Ordnance before the manufacturer is permitted to start procedure qualification and operator qualification tests. In addition, a workmanship standard plate has been included in the specification. This plate will provide a visual inspection standard which will be used as a guide, both by the contractor and by the inspectors. However, the wording in the proposed specification was changed so that it was very definitely stated that this standard was to be used as a guide only, as a goal to shoot at, rather than as a standard for inspection or rejection.

"In regard to radiographic inspection, all operator qualification test plates will be radiographed and judged according to Standard 1 of AXS 476; the procedure qualification plates will be judged according to Standard 2; and, for radiographic inspection of production weldments, Standard 3 of AXS 476 will be used. This particular requirement caused perhaps the longest discussion of any single item in the proposed revision of the specification. Some

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of the fabricators said that under present conditions it would be impossible to meet the requirements of Standard 3. However, it was decided to go over some of the radiographs of weldments that have been made recently and to try to get an idea as to exactly what the quality of the welding is at the present time, before any definite decision is made in regard to the standards to be used for production inspection.

"In the welding of the H plates, as far as the joint design goes, all H plates will be welded with the minimum included angle to be used in production, the minimum root opening, and the maximum root face. One other important change in regard to H plates is that repair welding up to a total length of 8" will be permitted on H plates welded in accordance with this Provision 4 of the specification. At the present time for 1-1/2" rolled plate, for instance, the projectile is a 75 mm. T-21, and the striking velocity has been increased to 1200 foot-seconds, with allowable weld cracking of 15". For 1-1/2" cast homo, the striking velocity--using the same projectile--is 1050, and the allowable weld cracking is 10". For 1" rolled homo, 75 mm. T-21 projectile, the striking velocity is 725 foot-seconds, with an allowable weld cracking of 17". For 1" cast homo, 57 mm. T-1 projectile, the striking velocity is 800 foot-seconds, and the allowable weld cracking is 12". For 1/2" rolled homo, 37 mm. high explosive M-54, the striking velocity is 1625 and the allowable weld cracking is 12". In regard to impacts of the various projectiles: where the 75 mm. proof projectile is used, the impact must touch the weld; in the case of the 37 mm. projectile, the distance between the center of impact and the center line of the weld should be 1-3/4".

Captain Randall reported for the Electrode Group:

"The first item discussed was a presentation by the Navy of a brief summary of some of the work on which they have been proceeding in connection with the stainless-steel type of electrode. As most of you know, analysis limits were set by the Navy for certain residual elements in a late revision of their specification. It was then found that standard methods of analysis were not available on which all parties concerned could agree. Further checking indicated that it was also true that general agreement was not being obtained on some of the standard elements. The Navy reported yesterday that an agreement had been co-operatively reached on standard methods of analysis for the following elements: carbon, manganese, sulphur, silicon, copper and titanium, as applied to the modified 18/8 type of material. Copies of these standard methods have been reproduced by the Navy Department; and it is understood that if any fabricator, electrode manufacturer, or other party is interested in obtaining copies of these standard analyses, the Navy will be glad to make them available. Such requests should be addressed to Commander O. R. Sutherland, Laboratory Officer, Building 121, Philadelphia Navy Yard.

"The Navy reported that residual elements had been found in appreciable quantities in some of the standard coating materials, and there was considerable variation in some of the elements, such

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as sulphur, and phosphorus, and so forth. An offer was made by the Navy to work with the electrode manufacturers on standard methods for analysis of important coating materials. There was no immediate acceptance of that offer.

"Mr. Hignett presented a detailed discussion of the investigational work which has been conducted in England relative to both austenitic and ferritic electrodes as affected by hydrogen in the electrode coatings. Two British reports--one dated March 1942, and the other dated August 1943--are available on this subject. It might be mentioned that as early as March of 1942 certain of the difficulties encountered with bond zone failures in austenitic electrodes were attributed to hydrogen-forming materials in the electrode coatings; that was in connection with the work done in England.

"A question has been raised by a number of electrode manufacturers as to the possibility of providing acceptance of electrode material at the source. As most of you probably know, both the Army and Navy specifications provide an absolute minimum of acceptance and inspection tests insofar as individual lots of electrodes are concerned. Both specifications have contained a clause providing for rejection of material if, at any time within six months, it was found either to exhibit unsatisfactory operating characteristics or failed to meet the requirements of the specification. It was recognized that perhaps the phrase 'exhibits unsatisfactory operating characteristics' was unfair, since it provided at least the possible conclusion that a manufacturer could decide that an electrode did not operate satisfactorily and reject it. That, of course, was not intended. Inspection at the source for full acceptance would involve a testing program at each electrode manufacturer's plant, provisions for facilities for such tests, and a complete rewriting of both the Army and Navy specifications (as it would change the entire basis on which they had been prepared). Accordingly, as a suggestion to improve this situation, a motion was made and carried to recommend the deletion of the phrase 'exhibits unsatisfactory operating characteristics' from the sentence that I quoted previously. This motion was carried after considerable discussion. It is understood that both the Army and the Navy will give careful consideration to the possibility of taking that action."

After luncheon Major McInnes reported on Aircraft Armor Fabrication:

"Our Group meeting is to be held tomorrow for the simple reason that some of the aircraft members wanted to see some of the latest developments in welding at Watertown Arsenal. During the summer months, a tentative Army Air Force specification was released only tentatively, as I have said, and it should be used merely in the interim until an A.-N. specification is finally approved. The specification number is 20030 AAF. As far as spot welding is concerned, the only specification to be used by the Army Air Force will be the same one used by the Ordnance--AXS 969, I believe. There are quite a few aircraft manufacturers, as well as armor plate manufacturers who are welders of aircraft armor plate, who have contracts both with the Navy and the Army. It is

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highly desirable, then, to have an A. N. specification. In the meantime, the other specification to which I have referred will be used because of necessity."

Mr. Cooper reported for the Resistance Welding Group:

"At our meeting yesterday, the first item was a report, in rather careful detail, of the work that is being done by Professor Hess and his associates under the auspices of NDRC. The committee discussed not only the work that had been done but what was going to be done if Dr. Hess's proposed schedule of work was carried out. Everyone agreed that this work was extremely vital, that what had been done was almost indispensable, and that it was necessary to carry on a program in the same manner; they all wished to express what was more or less of a vote of confidence in the work that was going on, and a hope that it would be furthered.

"As far as the use of Specification AXS 969 for aircraft fabricating work is concerned, if an aircraft fabricator wishes to qualify on that, he should go to the Tank Automotive Center for certain information and approval. If there are any items on which he does not get the exact answer he wishes, he comes back to the Air Corps, to Major McInnes.

"It seemed to be somewhat evident to the committee that the knowledge of what has been going on in resistance welding of armor plate in the last two years has been rather restricted. Of course, all of us are working under certain restrictions; outside of the limited dissemination of the reports of this group, NDRC, and the restricted personnel that comes here, there is very little that can get by such censorship in the matter of giving data that is necessary to acquaint people with what is going on. It comes back to the normal channels of you people passing the information on to your own fabricator, to your own companies, as regards possibilities of resistance welding of armor plate within its scope of application. First of all, this Specification AXS 969 covers the welding of butt straps or attachments of low-carbon steel up to a thickness of a half-inch to armor up to and including a thickness of 1", face hardened and homogeneous. Perhaps the various reports that you get at each one of these meetings about the work that is going on at R.P.I. have not been clarified by myself to indicate that this is not experimental. Over a year ago, the process got beyond the stage that you have in the arc-welding of H plates when you prove a process, qualify that process and some operators, and then go ahead and arc weld all the necessary vehicles and aircraft attachments and so forth--which, in turn, must be proven as design applications. The work going on at R.P.I. is a development of design applications; it is not the proving of success.

"A specific request was made of this group in Chicago at the last meeting--I believe that it was in Chicago--that we duplicate some 36x36 H plates to compare specifically with some H plates arc welded. We have gone through the necessary identification of the materials to match these specific arc-welded plates; but we have come to the conclusion, as a committee, that the H plate is in no way representative of a proper test of a resistance weld. It is

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our understanding that the H plate was set up to indicate somewhat the degree of locked-up stresses in the cross member where you tie the cross weld into the two other welds. That item does not come up in a resistance weld. The nearest equivalent to a check on a 36x36 plate, resistance welded, is a double I plate; three pieces, 12x36, welded with two joints butted together with a backing strap, and that center plate hung unsupported from the testing butts, except through the spot welds. One of our members--Mr. Lee, of International Harvester--is now in the process of making up some plates. It is his estimate that, in another month or two months, the results of such welding should be known."

Capt. Pless commented:

"I believe it was I who asked for these resistance-welded plates at the last meeting, to compare to the regular butt-welded plates—and at the time it was mentioned that the plates would be made the same way. Actually, however, there is no reason why resistance-welded plates cannot simply be, as Mr. Cooper said, three sections of plates with two parallel welds. As you have probably heard, we are even working on that type of test plate now for regular butt welds, and we hope that perhaps eventually all the test plates will consist of just two parallel welds. We don't know that they will, but it is possible. There is no reason why we cannot use resistance-welded plates of that type. If you will submit those plates, we will be glad to test them. I think the results will be just as good as, if not better than, the H type of plate."

Upon request of Col. Knable Mr. Raymo remarked:

"I was under the impression that perhaps Colonel Zornig had appointed another chairman for the Liaison Committee and that perhaps a report would be made by that chairman. I regret that I saw fit to tender my resignation as chairman of the committee. However, due to the fact that the Baldwin Locomotive Works is withdrawing from the tank program—our work is substantially 90% completed—I felt that the interests of the group could best be served by a man who would be more closely associated with the armored vehicle program. I think the respective liaison groups for rolled armor and cast armor have served a useful purpose, and I think we have accomplished a lot towards our initial aim of bringing about uniformity of electrodes and armor. Certainly, we are closer to that picture today than we have been ever before. While I hope to be able to follow with first-hand interest the activities of the committee as a group, I again say that I regret having had to tender my resignation."

Mr. Mikhalapov reported on NRC Research:

"The program concerning weldability of armor plate has been confined primarily to the examination of the plates which were tested last winter at Fort Shilo at sub-zero temperatures. The report is just being finished. The examination of the plates was very thorough, and consisted of examination of the path of fracture and of the metallurgical study of the welded metal and the metal

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next to the weld. In general, it was found that two types of failure were prevalent: in one, the failure took place in the heat-affected zone of the metal; and, in the other, it took place in the fusion zone. The difference between the two types of failure is accounted for by the difference in the rate of cooling during welding. In the plates in which the rate of cooling was low, the failure occurred in the heat-affected zone; where it was high, the failure occurred in the fusion zone. Another interesting point appears to be that the reason for the failure in the fusion zone can be traced to the amount of dilution which occurred at the root of the weld during welding. It was possible to correlate the plate which failed and the plate which passed with the iron content at the root of the weld. If the iron content was above a certain figure, showing a great amount of dilution, the plates failed; if it was below that figure, they passed.

"The part of our investigation dealing with the development of armor welding electrodes of lower alloy content than customarily used has been progressing quite satisfactorily, and I believe I can now report that we have very promising results. The particular electrode developed has passed all of the tests of the laboratory type to which we could subject it, including a quantity of H plates. You will be interested to know that a total of 35 1/2" plates were welded, 5 of which had reinforcement on them and 30 of which had the reinforcement ground off. Of the 30 plates with reinforcement ground off, 23 passed, 3 were classified as 'no test' because of excessive plate cracking, and 4 were borderline cases. That is a considerably higher average than has been experienced with the 1/2" plates welded with austenitic electrodes. Of the plates that had the weld reinforcement on, only one passed, 2 were failures, and 2 were classified as 'no test' because of excessive plate cracking. These plates were welded without any preheat, and apparently without great danger of cracking. They were welded of Great Lakes armor, Carnegie-Illinois armor, and Jones & Loughlin armor composition: no significant difference in performance was encountered.

"In so far as 1-1/2" plates are concerned, a total of 14 plates were welded with this electrode. They were tested at Aberdeen. These plates were of Jones & Loughlin composition, Carnegie-Illinois composition, and Disston composition. Twelve of these plates had reinforcements ground off, and two did not have them ground off. No significant difference in performance was encountered on the plates with reinforcements ground off. In other words, in the case of a 1-1/2" plate, there does not appear to be any difference between plates with reinforcements ground off and plates without reinforcements ground off. Performance under shock test of all of these plates, judged by the present standard, was excellent. All the plates withstood at least four, and some up to 7, impacts at velocities ranging from 1100 to 1550 foot-seconds. In only one case was there cracking, as a result of any one impact, over 15" in length. In addition to that, the electrode was tested under sub-zero temperatures. Three 1/2" plates were tested at temperatures ranging between minus 30 and minus 15. Three austenitic welded plates which were tested at the same time failed. Of these three, two failed at the first shot at 1100; the other stood up under 3 or 4 shots and failed at 1200. The ferritic plates, if I am correct, took velocities up to 1400.

"Of the 1/2" plates, two passed without appreciable cracking, while the third was classified as 'no test' because the armor broke badly without damaging the weld. It may be mentioned that 1-1/2" plates were welded with preheat ranging from 150 to 250, depending on armor composition. It now appears that that preheat is necessary in the case of the heavier armor. We are trying, of course, to see whether we cannot develop a rod which will require no preheat at all on heavier plate and further increase the ballistic performance. We are now pretty close to the limit of average armor plate itself, but not quite up to the performance of really good armor. I don't want you to feel, however, that because of these successful laboratory tests the electrode is ready to be put into immediate production use. Nothing is further from the truth. Considerable work will have to be done by fabricators themselves, to find out the characteristics of the electrode under production conditions. We have been fortunate in that Fisher Body has started experimenting with this electrode under production conditions. I believe they have secured tentative approval of two joints on a vehicle they are building, subject to certain specific radiographic tests.

"The development of spot welding of armor plate has been confined chiefly to finding the most efficient way of attaching clips to armor plate of aircraft type. Dr. Hess has been concentrating his activities on finding a spot-welded backing-strap-to-armor combination which would stand the highest shock impact as determined by a 20 mm. high explosive shell.

"On explosive test development, we have definitely established the fact that no specimen of small physical dimensions, such as a plate 2" or 3" wide and 1-1/2" thick, can be considered representative of the welded joint under impact conditions of testing. The test on 2" and 3" wide specimens do not correlate at all with the performance of big plates. Of course, it was our hope to be able to develop a test wherein we could use a comparatively small piece of explosive and a small testing specimen. It would appear now that, due to entirely different internal stress conditions on a small specimen, the small specimen is not representative of the conditions existing on a large weldment.

"There is a weldability investigation conducted at Lehigh University, wherein an attempt is being made to find a test which will quantitatively determine the weldability of electrode and plate combination. Briefly, the test consists of depositing weld metal in a torture plate very similar to the Navy torture plate, except that it has a double V joint and except for the fact that the width of the window frame around the joint is varied at will by cutting slots in the plate perpendicular to the line of the weld, which introduces a variable amount of restraint. The amount of restraint at which cracking first occurs can be then considered as typical of a particular electrode plate composition. A change in composition would involve a different restraint number associated with that steel."

Several questions were asked of Major Pippel regarding the performance of fillet welded and spot welded armored vehicles in the North African Theater. These questions were answered off the record.

It was decided to hold the next meeting in Cleveland in February 1944. Meeting adjourned at 2:15 P.M.

It was notable that these meetings were now apparently free from the bitter, prolonged arguments about controversial subjects such as occurred at previous meetings. This could be ascribed to two factors, either of which may be primarily responsible. Possibly the production situation had more or less settled down to a standardized condition in which requirements and procedures were better understood and followed with confidence or the Group meetings of the previous day were functioning as a sort of escape valve for the gripes and arguments which could be more effectively debated and settled in the smaller group of interested persons than in the larger Subcommittee meeting. It is probable that both factors are to some extent involved. It was noted that in many instances individuals often attended Group meetings in which they were interested and did not attend the meeting of the Subcommittee.

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FOURTEENTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
THURSDAY, 11 MAY 1944
HOTEL CLEVELAND, CLEVELAND, OHIO

The fourteenth meeting of the Subcommittee was held in Cleveland, Ohio on 11 May 1944 at the Cleveland Hotel with 120 persons in attendance representing:

Industrial - United States	
Tank Fabricators	33
Armor Producers	5
Core Wire Producers	7
Electrode Manufacturers	27
Resistance Welding Equipment Mfrs.	2
Aircraft Fabricators	2
Individuals	7
Government - United States	
Ordnance Department	22
Headquarters, ASF	1
Navy Department	4
Army Air Forces	2
War Production Board	2
National Research Council	1
Government - Allied Countries	2
Guests	3

After brief opening remarks by Col. Zornig, Mr. Sweeney reported on the general alloy situation:

"The alloy situation is considerably better than the last time when I gave this report. However, it is not nearly as good as some of the reports and rumors would lead you to believe. And there are so many variables that are connected with future programs. One of them is what the Army refers to as the fluidity of war. They find, after having actual battle experience, that they need more of one type of equipment and less of another, or they make some other change in program as the war necessitates. So far the War Manpower Commission has not given a great deal of recognition to the manning of metal ores. And the people that are responsible for the alloys are quite worried.

"At the present time the consumption of molybdenum is in excess of the production. Fortunately, in the good period a fairly good stockpile was built up. But it makes it necessary to keep a careful watch on all of these alloys. Another factor that varies, of course, is the shipping. Chrome that is required in the production of ferro-chrome, a lot of it comes from overseas. And you have to get it down to the port, and there is trouble with the railroad there. You have to get shipping space

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and that is pretty well occupied now. In addition to that, you have to compete with many other items. Suddenly it may be necessary to give one of our allies quite a considerable amount of nickel or chrome or molybdenum, or some other alloy. And that in turn effects the amount that is available for us.

"At the present time one of the reasons we feel that the alloy situation is as favorable as it is because of the concerted effort to make use of the alloys that are in alloy steel and alloy iron scrap. And one of the phases that help to use this is the triple alloy program. That is not only the utilization of the alloys, but that is supposed to help take up the slack, or the excess stocks, of alloy scrap which are available, and ease the strain on the carbon steel scrap which has been dwindling at a rather alarming rate."

Mr. Danse raised a question:

"I should like to ask Mr. Sweeney about the molybdenum situation, the Type 6 electrode, whether the Type 6 electrode is still restricted to face-hardened armor, or whether it is permissible for other armor."

Mr. Sweeney replied:

"There is no restriction, Mr. Danse, on the use of molybdenum in welding electrodes. The electrode producers were notified of that, if I recall correctly, some time in January, that the restrictions would be removed as of February 1. They could start production of either the Grade 5 or Grade 6 electrode for any end use. Of course, in that connection we feel that any plates that anyone wants to use molybdenum in, where it can help do a better job, that that is all right. We wouldn't want somebody to just put a lot of molybdenum in if they didn't feel it was necessary."

Col. Zornig commented:

"During the time when moly was very short, everybody, of course, got down, further down and further down. Now, of course, some of the stuff is coming home to roost. And in our trouble-shooting work at Watertown we have run into a couple of cases of what looks like bona fide temper brittleness. If that turns out to be prevelant at all, why, we are going to be in a pretty bad way. And I am not so sure but that in those products which depend for their usefulness on their behavior in the ballistic range that we are not due for a very serious upping of moly, from a third to a half, probably because of the possibility of real temper brittleness that we are running into. We have now run into a couple of cases that look like bona fide temper brittleness."

And Mr. Sweeney added:

"You might find from your experience, or maybe the Navy will find out, too, that they need more chrome or more nickel, or maybe theirs is more molybdenum, too. So for someone to try to project into the future what the alloy requirements are going

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to be and say you never have to worry about them any more is rather risky, we feel."

Mr. McDowell reported for the Homogeneous Armor Fabricators' Group:

"The Homogeneous Armor Fabricators' Subgroup has held two meetings since the last meeting of the main subcommittee. We held a meeting in Detroit on March 2nd. The main point of business at that meeting was consideration of Revision 5 of Specification AXS-497. This revision has been in effect for several months now.

"However, at the meeting yesterday Lieutenant Dillon of the Office of Chief of Ordnance, in Detroit, informed us that another amendment to the specification, Amendment 2, will be issued shortly. I will try to cover some of the changes that this amendment deals with. Under the first one, it was on Page 4 of the specification, Item 6 under Table I, which lists the factors in the welding procedure specification. Factor 6, which covers electrode sizes, an addition has been made to Column 1 under this item which requires that the diameter or diameters of electrodes which will be used in the root pass of a joint for the various root dimensions from minimum to maximum shall be stated in the procedure specification. On page 10, Paragraph F-2b(4), which covers position of welding for operator qualification plates, there evidently has been some misinterpretation of the requirements of this paragraph in respect to the position in which the operation qualification test plate was welded. And these notes have been added:

"'To qualify the operator in the flat position, test plates shall be placed in approximately a horizontal plane and the weld metal shall be deposited from the upper side.

"'To qualify the operator in the horizontal position, the test plates shall be placed in an approximately vertical plane, with the welding groove in an approximately horizontal plane.

"'To qualify the operator in the vertical position, the test plate shall be placed in an approximately vertical plane with the welding groove in an approximately vertical position.

"'To qualify the operator in the overhead position, the test plate shall be placed in an approximately horizontal plane and the weld metal shall be deposited from the underside position.'

"On page 13, Paragraph H-3, the entire paragraph shall be deleted and the following substituted: It was suggested that in order to obtain accurate measurements of the welding current, a tong type tester should be used. On Page 13, Paragraph H-4, in order to clarify the requirements of the meaning of this paragraph, the following has been added:

"'Radiography of production weldments under this specification is limited in amount, and the provisions are intentionally stated in such a manner that no interference

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with production will result. As provided for, radiography is to be used as a tool for the development of satisfactory procedures and to provide sufficient spot checking at intervals so that a contractor will know when something has gone wrong with the procedure and can take steps to make the necessary corrections. Radiography as incorporated in this specification is not intended to be used for the purpose of ascertaining that every weldment accepted meets the specified standard. Instead it is intended to assure that lowering of quality will be disclosed and that remedial measures will be taken by the contractor.'

"On page 13 add as Paragraph H-7--this covers the explanation of the change in requirement of Item 6 in Table II--'The contractor shall specify in his welding procedure the diameter of the electrode to be used for the deposition of the root pass in each width root opening from the minimum to the maximum. In the operation of the specification the contractor may use a smaller diameter of electrode than that specified for the particular root opening, but he may not use a larger electrode than that specified without requalifying his procedure.'

"Another note has also been added as Paragraph H-8, which covers the definition of what is the front of a ballistic test plate.

"'Metal groove joints, the front of the ballistic test plate shall represent the side on which welding, excluding backing, is begun in each leg and crossbar. For single groove joints the front of the ballistic test plate shall be that side which represents the outside or ballistically exposed surface of the weldment. When a plate represents several single groove joints of a weldment, some of which have the wide side of the groove on the inside surface, the wide side of the groove shall be the front side.'

"On page 11, Table II, the allowable weld cracking for H-plates made from 1/2" rolled homogeneous armor has been changed from 12" to 15". This change was made as a result of a survey of a considerable number of 1/2" ballistic test plates which had been fired at Aberdeen Proving Ground during the period of April 1, 1943 to February 1, 1944. In this survey 113 test plates were considered, and only those welded with austenitic electrodes, and plates with impacts within the required limits of accuracy and velocity. Of these 113 plates it was found that 32.8% failed on a basis of 12" of allowable cracking. If all the plates of these 113 plates were eliminated which failed to pass the radiography test, this left a total of 93 plates. Of these 93 plates, 32.3% failed on the basis of 12" of allowable cracking. If the allowable cracking was changed to 15", it was found that 21.2% would fail, if the 113 plates were considered; or if the 93 plates which had passed the radiography test were considered, then the percentage of failures on the basis of 15" of allowable cracking would be 19.4%. The survey was carried on further, and only those plates were considered on which the first impact was fair. This gave a total of 83 plates. And on a

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basis of 12" of allowable cracking, the percentage of failures was 36.2. Based on 15" of allowable cracking, the percentage of failures dropped off 25%. Of these 83 plates, eliminating those which failed to pass the radiography test left a total of 69 plates. And based on an allowable cracking of 12", the percentage of failures was 33.8. While based on 15" of allowable cracking, the percentage of failure was 23%.

"On page 5 of the specification, Paragraph D-3c, the radiography requirements for operator qualification specimens were changed so that these plates now must meet Standard II of Specification AXS-476, Appendix I, instead of Standard I as previously required. On page 9, Paragraph F-2a(1)f, the following has been added for clarification of the intent of the specification: 'The radiograph shall be reviewed by the inspector as prescribed in Specification AXS-476 to determine compliance with Specification AXS-476, Appendix I, Standard II. Radiographs accepted by the inspector shall be subject to review by the testing agency and the decision of the testing agency shall be final.'

"At the request of the Electrode Group, consideration was given to a suggestion that representatives from each group attend the other group meetings in order that the electrode manufacturers may become more familiar with the problems of the fabricators, and also that the fabricators might present any electrode problems that they might have encountered in the course of their work. The group expressed a willingness to accept representation from the electrode manufacturers' group to sit in at the fabricators' meetings. But the question of sending representation to the electrode group was not definitely settled.

"Many of the fabricators are desirous of obtaining permission to use the ferritic electrode which has been developed as the result of work on NRC-2 experimental projects. And considerable dissatisfaction was expressed with the fact that no definite steps have been taken to approve ferritic welding for production use. A motion was made requesting that the Office, Chief of Ordnance, Detroit, take steps to approve ferritic welding according to requirements and procedures of NRC-2 to either place NRC-2 ferritic welding under Specification AXS-497 of the latest revision, or immediately issue a specification to cover NRC-2 ferritic welding to the Homogeneous Armor Fabricators for immediate production schedules. It is planned that in the near future a meeting will be held for the purposes of standardizing the joint designs used by the various fabricators, and that such a standardization will probably be based on the joint designs and the specification AXS-800."

Mr. Abbott reported on activities of the Face Hardened Armor Group:

"In the past year, particularly the past six months, there has been considerable curtailment in the production of face-hardened armor, with the result that a number of organizations have stopped making it altogether, and the few that are now making it are making it in rather limited quantities. The group as it now exists is of only a few members, and I am making a report from

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what has been gathered from these members, not as gathered in a meeting but rather from personal contact. The current use of face-hardened material in combat vehicles has been now so restricted that it is generally applied to only special applications, and the bulk of it is in thicknesses of 1/2" and under, with a small amount of 5/8" material being used. Of the fabricators remaining now producing this material, each has a process of carburizing the material and heat treating that is applicable to his equipment. And in a great many cases the technique of welding that works satisfactorily in one organization is not altogether satisfactory in another one.

"With the pack method of carburizing, by which perhaps the greater bulk of face-hardened material is produced, the welding of that has been generally satisfactory in the gauges mentioned, in that they pass the requirements of the existing Specification 747, together with the necessary radiographic requirements. There has been some discussion with the Tank Automotive Center as to the performance of weldments that were made prior to the heat treatment, on the possibility of carbon migration from the high carbon face of the plate to the weld metal, and aggravating a brittle zone adjacent to the weld. That subject has been under investigation for quite a while. And the results so far are inconclusive. The plates have been submitted to Aberdeen which have passed very satisfactory tests. By the welding of face-hardened before heat treatment we find that the weakened zone that appears in weldments after heat treatment is reduced to only the zone that is created by the weld metal itself. And there is considerable stress relieving in the hardened face during the heating of the material prior to the quench, with the result that there is less cracking. And we think it is a decidely superior joint. We can further eliminate quite a bit of distortion by that method.

"We have also found that a weldment of hard homo, aircraft homo, that is being produced under AXS-1 specification can be successfully welded to face-hardened material, particularly if the technique is used that is the same as used for the welding of face-hardened. The type of rod that we use originally started out with a Type 6. That is the moly modified rod, and the producers were supposed to have a stock of that available for those who were welding face-hardened. But we found when we went to get it that it wasn't available. So we have switched over to the manganese modified rod, which we can obtain without much trouble. And we find that we are getting pretty good results with the manganese modified. It takes a little more skill on the operator's part to use it. But we are getting very good results with it, so we are satisfied in that respect.

"The X-ray at one time was very severely criticized because the contention was raised at the early stages of the committee meetings that it did not tell the true story. I think that is still true. However, it does one thing that I think if it did this one thing only would warrant a continuance of the use of X-rays in determining the acceptability of a joint. We have set up a school in which we prefer now to take green men and educate him, keep him away from

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structural steel and others and start him in on armor plate, teach him the hard way, so to speak. In that way we are developing welders that we find are superior welders insofar as armor plate is concerned over that type of welder that has had experience on other types of steel. But we have found that X-ray enters into this on a psychological manner. Before a welder is allowed to advance from one test to another we have him make up sample plates, and those joints are X-rayed. And his attention is called to the quality of the work through the X-ray. We find that this is a far better means for explaining the objective of the welding to that welder than any other method that we know of. And we perhaps believe, and it is more so applicable to fillet welds, that the X-ray certainly is playing its part in developing a good joint, although it doesn't tell the story, I think, that has been expected.

"There are not very many of us that are producing face-hardened, and a number of them that are producing face-hardened material produce it in such small quantities that they don't feel that the expense of entering into an experimental program to try to increase the efficiency of the weldments of face-hardened material warrants going into this group. And I believe that if this group were permitted to branch out and to either combine with or join in with another group that we could make better progress faster."

Col. Zornig suggested:

"Mr. Abbott, in that connection, I don't like to disband the group as such, because no one can tell in this war what is going to happen next; I should like to see you maintain yourselves as a separate group, but meet with the Homogeneous Fabricators' Group or the Aircraft Fabricators' Group, as you and their chairmen see fit."

Mr. Abbott agreed to this suggestion and Mr. Warner raised a question:

"I think Mr. Abbott stated that if the weld is heat treated after welding, the heat effect is confined to the weld itself. And I want to ask him if the weld which is performed prior to heat treatment is done with an austenitic electrode or ferritic electrode?"

To which Mr. Abbott replied:

"The welding in all cases as reported today is austenitic rod. I thought I made that clear. Austenitic rod, manganese modified. We have tried some ferritic welding with indifferent results. The heat-affected zone in armor plate practically disappears by heat treating after welding."

Mr. Warner asked:

"Is it the practice to remove the reinforcements on the weld, or to leave them on just as they are deposited?"

To which Mr. Abbott replied:

"We leave reinforcements on the welds as far as possible."

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Mr. Diebold raised a question about ferritic electrodes:

"There was considerable discussion of the ferritic electrode yesterday and I am afraid it was one-sided because the Ordnance Department wasn't ready to discuss it. I would like to ask Capt. Randall, if he is so willing, to state his departmental policy on ferritic welding as of today."

To which Captain Randall replied:

"I am sorry that there has been any misunderstanding as to the policy of our office on the subject. But I might outline very briefly about four or five things on that connection. First of all, as most of you know, our office has been very much interested in the ferritic program, and as a development program we consider it to be a very outstanding contribution to the knowledge of welding. However, from the standpoint of the practical aspects of the tank program as it stands today, there is no intention on the part of the Office, Chief of Ordnance, Detroit, to make any attempt to convert over existing jobs to ferritic welding so far as instructions from that office are concerned. There are certain cases where under controlled conditions it may be advantageous to everybody concerned. Accordingly, the policy has been established that our office will review and consider any request for use of the ferritic process which a fabricator cares to submit. To date I think such requests have come from a total of one fabricator. And I can make this statement, that up to about eight weeks ago, at any rate, we were still seeing ferritic welded H-plates, one and one-half inches thickness, made with electrodes which supposedly were of the same general type as this electrode, at least the deposited metal range was the same, and they had stainless steel type coatings on them. One of them that I can think of at the moment, a 1-1/2" plate, 1200 foot-seconds fell in two pieces. I can think of another series of five, welded with an electrode--four or five--on which I think only one out of the four or five plates passed the austenitic requirements. As a result of that experience NRC has narrowed the range of electrodes which they consider to come within the scope of this development, to exclude the electrodes which I just referred to. As a result of that exclusion an attempt to define the ferritic electrode specification was prepared by National Research Council in an attempt to more firmly define what we are talking about when we talk about this ferritic electrode, that we didn't know before.

"There has been an additional suggestion made which our office considered desirable, not only in connection with this problem but in connection with some others, with many others, not only ferritic welding but all types of welding in the tank program. And that is that periodic meetings, perhaps monthly, be arranged with a small group of fabricators and Office, Chief of Ordnance, Detroit, including those fabricators who are actively involved in the fabrication of vehicles, at which time perhaps it will be possible to present some of the data to them with which they of necessity cannot be familiar, and on which our office bases certain of its decisions."

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Following this explanation Captain Randall reported for the Electrode Group:

"The Electrode Group yesterday had an unusually quiet meeting. The first item was the use and development of electrodes suitable for both AC and DC operation. The problem requires a little amplification, because the present electrodes have been used on both currents. However, it is understood that some manufacturers have developed an electrode, or, I should perhaps say an electrode coating, which does not fit either the present definition of a lime coating or that of a titania coating. The Navy Department has indicated a considerable interest in this electrode coating for use on 25/20 rod for emergency purposes in connection with fleet use. The reason for that being that they have both AC and DC machines, and it is highly undesirable to furnish two types of electrodes under those conditions. Because some ordnance facilities in the tank program have AC equipment, some exclusively, and some mixtures of AC and DC, ordnance is interested in tests of this type of coating on 18/8 electrodes. As yet, the test information available to ordnance is so limited that no comments can be made on it. But it is contemplated that if the electrode proves to be equally good in all respects to the present lime and titania types, a new designation will probably be added to Specification 886, if and when that time comes, to take care of this new development.

"The second item very briefly was one which is also of interest to the fabricators. It refers to the status of electrode approvals under Ordnance Specification AXS-886. It is understood at present that all the tests have been completed by Philadelphia Navy Yard and that all of the reports are now in the mail en route through channels to our office. That being the case, it should be possible to issue the list within the next three to four weeks, assuming that those reports come through promptly. The delays were not by any means all due either to Army or Navy procedure, or to delays in testing. In many cases electrodes had to be resubmitted because of failures on the initial tests. In fact, I believe that the statement was made that in the case of one or two electrodes, that had to be done three or four times, which meant repetition of the tests. So that actually instead of going through a single series, it was several on some electrodes.

"The next item was the matter of liaison between the Electrode Group and the Homogeneous Armor Fabricators' Group, which was mentioned by Mr. McDowell. And after some discussion the Electrode Group decided and carried in the form of a motion that it would be desirable to have 3 representatives of electrode producers, and one representative of core wire producers to act as liaison with the Homogeneous Armor Fabricators' Group so that the complaints, arguments, and other items discussed by the Fabricators' Group that related to electrodes could be properly transmitted for consideration. Temporary representatives were picked from those present at the meeting yesterday, and they attended, I believe, the latter part of the Homogeneous Armor Fabricators' Group meeting.

"Mr. Humberstone, National Research Council, discussed the next item on the agenda, which was the proposed specification for

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NRC-2A type of electrodes. This specification was prepared by National Research Council and had as its primary purpose a definition of the electrodé with which they had been working. It was not intended to indicate that there might not be electrodes outside the scope of that specification which would be equally satisfactory. But it was fairly clearly brought out at the meeting that as written the specification was intended to be a definition not in one sense a performance specification. It does not cover a class of electrodes. It covers a specific electrode. The next item on our agenda was a report by representatives of the Navy Department on work which they have in progress. However, upon analysis of their data they concluded that they were not ready to make such report. The other two subjects discussed at this meeting were mentioned by representatives of the War Production Board. Mr. Sweeney gave a report of the alloy situation, which will not be covered in the Electrode Group report since it was largely included in his discussion this morning. Mr. Hale of the War Production Board mentioned a new specification now in process of preparation for export packing for shipment of electrodes."

Major Dunlap reported for the Aircraft Armor Fabricators' Group:

"I do not have a report to make, except I would like to state that the joint Army-Navy specification covering the arc welding of aircraft armor has finally been approved and is now in the hands of the printers and should be ready for distribution within the next few days."

Mr. Cooper reported for the Resistance Welding Group:

"Yesterday our subgroup meeting was a continuation of the work that has been going on since this group started, and basically applied to information concerning perhaps the eventual completion of AXS-969. In the last year or so these various tentative specifications being drawn up have included certain values without having an opportunity to correlate the listed firing with the various types of plates and the different types of alloys, backing strips, and so forth. Last fall the AC, realizing this deficiency, started to get some tests made of the new Double I plates, 36x36, which were to be the equivalent for resistance welding of the H-plate for arc welding, since the H-plate doesn't lend itself to be a proper judge of good or bad resistance welding and joint efficiency. At the request of OSRD, Professor Hess and associates made a complete recording of variables under which the plates were welded. They were proof fired at Aberdeen. Captain Pless presented a report on the proof firing, which was also discussed. In both cases they covered the plates proof fired with both 20 and 37 mm. HE. It is somewhat the opinion of the Committee that the present Army Ordnance contracts do not call for very many possible applications of spot welding to butt joints on their type contract. However, there is a possibility of a great many applications for the aircraft welding of armor on clip attachments, and I am sure you will be interested in as many of the details as Dr. Hess can give you on the results of those firing tests which have gone on in the last few months."

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Prof. Hess reported on the program referred to by Mr. Cooper:

"Probably in accordance with Mr. Cooper's suggestion you would like to hear a little bit about the work which we did in connection with measuring the variables which went into the plates prepared and fired in the form of Double I plates. There were four duplicate Double I plates prepared, using 5/16" armor with six different butt strap combinations, including three thicknesses of mild steel and three thicknesses of armor butt straps. The plates were welded using a machine employing thermocouple control. And this type of control was intended to compensate for changing reactance for residual heat in the plates and for short circuiting effect of adjacent spot welds. The measurements of currents were made for each weld of a complete row of ten welds across a typical plate for each of the six combinations. Typical thermal records were made of the heat treatment, since these welds were first used and then grain refined and subsequently tempered automatically within the welding machine. Measurements were also made of the pressure cycle used.

"The plates were not very successful in the firing. We could have predicted that from the measurements for these reasons: Current variations from weld to weld were apparent from the measurements. This indicated that the automatic current compensation feature which was used in this equipment was not functioning properly. Variations in the temperature reached during heat treatment noted on typical thermal records indicated that the heat treatments were also not being duplicated. Since previous experience in our own laboratory has shown that if current compensation is not effective and if heat treatments are not duplicated that erratic results would be obtained, we didn't expect to have too much success from these plates. One of our men was present at the firing of these plates. A great many of the welds were not even fused at all, and numbers of others were only from 1/4 to 1/2 the proper diameter. The combination which they had been welding in production was the weakest of the six combinations used, and the least exacting from the standpoint of control. Their experiments and our own experiments have shown that armor backing strips are considerably superior ballistically to mild steel backing strips. In spite of the quality of the welding, which was not very good, the mild steel backing strips cracked. The 3/16" mild steel back strip cracked in almost every case, indicating that the backing material used in that case was not adequate for ballistic firing. Not only had they developed an excellent procedure for the control of the welding of 5/16" homogeneous armor to mild steel, which would work satisfactorily in production, but also they bought the best equipment which was available at the time.

"For instance, the type of grain refinement which they use is what we would call a 'peak grain refining treatment' in which the temperature is brought up to the grain refining level and held there for a few seconds. The great advantage of this type of treatment is that it avoids a steep thermal gradient resulting in a condition of grain refinement possible at the edge and remelt in the center of the weld. Typical microphotographs which were taken of sections of these

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welds indicate remelt areas in the center of the weld. If the controls had not been set to produce a remelted area in the center, then an equally objectionable condition would have prevailed, namely, that the edge of the weld would not have been grain refined and the center would have been grain refined. In addition, only about 4 or 5 months ago an equipment has become available for maintaining automatically exactly constant current, regardless of line voltage variations, reactants variation, due to variations in the amount of metal in the throat. This type of equipment was not available at the plant where these plates were made. Another point, by the way, perhaps should be mentioned, namely, that whenever the 3 armor backing strips differed not only in thickness but in composition, whenever a situation like that arises, considerably additional material is required in order to make up sample welds and section them, examining the section both for weld size and for proper tempering and grain refinement as determined by microsection examination, and hardness surveys. Under the present circumstances the material didn't happen to be available for this most important consideration.

"I would like to turn for a moment and tell you a little bit about some other firing which has recently been completed in which spot welding is used with the attachment of small clips to armor for the support of the armor. We prepared a number of plates involving again the determination of the size and number of welds required to provide a support which would adequately hold 1/2" hard homogeneous armor. We had investigated the size of clip material and the type of clip material. And under those conditions, the plates were so turned that the clips were toward the gun and the welds were placed immediately in tension by the result of the impact. Under the most recent tests conducted on May 5, we again submitted some of the same type of welds, the only difference being that firing was now conducted with the clips at the back. These plates, by the way, were mounted in a rigid frame with a distance from the edge of the welded plate to the frame of approximately 1-1/8", that is, the support was extremely rigid with reference to the welds. The 3 spot cluster showed an estimated ballistic limit of 2500 foot-seconds. And at this particular value of impact energy, the armor plate broke up in many places, but no damage to the welds. Another set of clips was prepared using two spot welds in line rather than a 3 spot weld cluster in a triangular form. And these plates had 1/4" thick clips, only 2" wide instead of 3, with the 2 spots in line, the estimated ballistic limit being 2300. In other words, when the welds were turned around facing the gun, failure occurred at about 2450 foot-seconds. Turning around the other way, the armor plate broke up at 2500 foot-seconds. In the case of the 2" wide clips with 2 spots, estimated ballistic limit 2300, at which spot weld failure began.

"We wanted to get quantitative information as to the improvement resulting from first simple grain refinement of this type of armor, and second, grain refinement followed by tempering within the machine. For this purpose, single spot specimens were welded. A single spot in the as-welded condition had a ballistic limit less

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than 1200 foot-seconds. By grain refining a single spot its ballistic limit was brought up to 1550 foot-seconds. And by tempering it was brought up to 1800 foot-seconds. Where the welds were on the same side as the direction of firing, the 1/8" X-4130 base pulled to shreds around the weld. In these tests where the clips were at the back of the plate, the 1/8"x2" X-4130 was sheared off perfectly straight across the width of the clip. No weld failures. The difficulties of welding the extremely high carbon armor are not much greater. A little more care is required than in welding the ordinary armor. But the beauty of spot welding process as applied in this case is the fact that you can actually control the structure automatically within the machine to get the maximum possible quench and the highest possible draw, and, therefore, the best physical properties that you can hope to get out of this steel."

Col. Zornig asked regarding the failure of the low carbon steel buttstops referred to by Prof. Hess and he replied:

"Failures did occur in the mild steel backing material in spite of the fact that the welds were not what they should have been. In other words, these backing strips were made up apparently so that the long direction of the backing strip was parallel to the direction of rolling. And the backing strips split in a direction parallel to the direction of rolling when they were subject to impact. On all the clips which we have welded in this condition the length of the clip was parallel to the direction of rolling, so that stresses across the direction of rolling were not produced."

Col. Zornig commented:

"We have recently had occasion to examine some low carbon structural plate at Watertown. And we have examined it both parallel and transverse to the direction of rolling. And in spite of the fact that this low carbon plate has such fine ductibility, when you measure it as ordinarily done on a testing machine, its properties when in the normalized or as-rolled condition, with respect to resistance to shock and resistance to notches, are most disappointing."

Major Campbell remarked:

"With reference to the testing of equipment attached to armor plates by resistance spot welding: We have done quite a bit of work of a similar nature with the fillet weld type. In comparing the results obtained in both types of welding, I find that both the 3 spot cluster and the 2 spot cluster check very favorably with the fillet weld. They are practically identical in results, and would actually meet the standards we have tentatively set up for acceptance of armor on the aircraft welding specification."

Mr. Warner raised a question:

"I would like to ask Dr. Hess a question or two. He made reference to the performance of these plates which were made under a production procedure, and also a reference to plates which have

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been produced under a laboratory procedure by spot welding. I would like to ask him what definite laboratory tests are necessary to establish a spot welding procedure; and if such a procedure can be set down in some form of a procedure specification such as we are requiring under Specification 497."

Prof. Hess replied:

"The procedure qualification should, and I understand does, include the preparation of spot welds and sectioning to determine the proper size of weld. That is, sectioning through a group of welds to determine that they are of proper size. If this had been done in the case of these Double I plates, we would have known before they were ever fired that the diameters of the welds were actually inconsistent. We knew it from the results, but we didn't feel it was our position to say those plates shouldn't be fired. We were only there as observers.

"Let me say this, also: Samples were made by the metallurgist and electrical engineer in setting up conditions to show that for the sample welds made the proper type of treatment was used. But no one can be supernatural enough to insure that the welds made under the test conditions for setting up the machine will be reproduced unless it has been previously shown that the machine itself can reproduce. As I mentioned before, it was unfortunate that the most modern type of control equipment was not available for the preparation of these plates. Such equipment was not necessary for the application which the manufacturer was making prior to these tests."

Mr. Warner added:

"The point I am driving at is this: That in order to insure consistency or uniformity on production, where you have a certain job to do of a certain type, you must have the procedure all worked out and set up in advance and some way of controlling the operation of the machine to insure that it actually is following that procedure."

Prof. Hess replied:

"Well, what you have to do is to check the operation of the equipment to see if it does consistently reproduce itself; by making a number of welds and sectioning them as to whether the diameters are the same. It is mainly macro. That is all that is necessary, because of the size of the welds involved."

Mr. Warner raised another question:

"Should there be any requirements in applying this process for the equipment which is used to apply the process, requirements as to control, apparatus, characteristics, and so forth?"

To which Prof. Hess replied:

"There should be requirements for automatic current compensation for differences in reactants. That is one of the most important features to insure that the machine will reproduce itself. If that

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type of equipment is available and has been shown by tests to be consistent, then we are ready, you might say, to go into production."

Col. Hoare raised a question about resistance welding of studs to armor. This method has apparently not been very successful in some cases as evidenced by the comments made by various individuals:

Mr. McCormack:

"Well, some work was done in our plant, Colonel Zornig. I don't have the results. The results were not written up in any way. I know they tried out a few of them, but I didn't see it done. I understand that it was reasonably successful, and the report was generally favorable."

Mr. Warner:

"Some small outfit submitted samples. I have forgotten the name myself. They were in Detroit. They were putting studs on to face-hardened armor. Well, I think it is a matter of capacity of equipment only, Colonel. In this particular case the examination of these studs showed some very excellent results in some cases and lousy results in others, indicating they did not have adequate control in their equipment. It seems to be indicated that it was possible if you had adequate control to assure consistency or uniformity. I think it is possible."

Mr. Nixon:

"Some work was done with the type of stud developed by the Nelson Specialty Company. This particular stud involves a hole in the end of the stud into which flux is placed and, then, a cap put in there and clinched in to hold the whole thing together. These studs were successfully welded when the carbon content was low. When the carbon content was higher, as has been considered desirable for armor plate attachment studs, the hard zone underneath the stud was considered too brittle, and no further work was done on it. This experimental work was done in part in our plant and in part over at Cadillac. The actual welding was done, again, with the equipment of the Nelson Specialty Company, a portable hand welding gun which in itself is quite easy to operate and within the limits of its possibilities, a good piece of equipment to consider. Mr. Baker has just pointed out to me that this welding more strictly should be considered arc welding rather than resistance welding."

Mr. Dense:

"In that connection I wonder if there would be any interest in the Temple gun. Colonel Enos was asking me about the use of the Temple gun which we had demonstrated to a number of General Motors Divisions about a year and a half or two years ago, the Temple gun being widely used by the Navy for salvage and repair work. It shoots the stud through the plate. And, due to the rapidity with which the stud projectile penetrates the plate, the plate metal expands and contracts against the stud so tightly that

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the stud cannot then be shot out of the plate or pulled out or fatigued out. It will fatigue off, but you can't pull it out; you will break the stud, either in fatigue or impact or static tension. It has found very wide acceptance in the Navy for emergency repairs and salvage purposes. I have tried to popularize it among armor people, but they always say, 'Oh, hell, we shoot projectiles through to ruin the plate, not to build the vehicle.' I still think that shooting the projectile stud in there has merit, if not for anything else, for field repair work, because you can shoot half a dozen studs through the plate in a decimal fraction of the time you can weld in a repair or bolt in a repair. You can fasten a patch on very quickly. I can see no reason why it shouldn't have merit for constructional purposes. We tried it on both the mild steel and heat treated. The powder charge utilized for the propellant has to be varied according to the physical properties of the plates. Of course, this is another instance where it is difficult to penetrate the plate with a very much undermatching projectile. The stud projectile must be of a size that is suited to the physical properties and thickness of the plate."

The general situation with regard to use of spot welding in the aircraft industry was cited by Col. Jenks:

"Douglas has an equipment suitable for spot welding of armor, and they are now spot welding armor on production work, both to attach the stainless steel splice plate, and also to attach the clips and things of that sort. North American has a machine with only partial heat treatment controls that is suitable for light gauge work, but not suitable for armor."

Mr. Danse reported for the Armor Liaison Group:

"I am afraid the Liaison Group is a good deal in the same innocuous position as the Specification Group this time. We haven't had any meetings. We have had a number of contacts, and a number of our members have attended rolled and cast armor meetings. There have been a number of special meetings attended by members of our group. There have also been contacts with a number of rolled armor producers, welding equipment manufacturers and cast armor producers. The effort being to keep the co-operative work going along without lapse and without the need for tremendous spurts.

"One thing we are very much interested in is the development work which Colonel Zornig himself is doing in connection with the heat treatments and compositions of particularly heavy thicknesses of materials. Our Liaison Group is probably paying more attention to the possibilities along that line than along any other line, because the Watertown laboratory is making disclosures which have not been available from any other source. I believe they are fundamental in their aspects. I think they will have a very far reaching effect on our conception of heat treatment and possibly of welding, too. Certainly we will have to modify our ideas of design and proportion and metallurgy for that design and proportion, in view of

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the disclosures at Watertown. I believe that activity is the most likely thing that the Liaison Group has been connected with."

Col. Zornig commented on armor development:

"I might explain a little further that the armor is getting, at least on some of the special vehicles, thicker and thicker. They are talking about 6", 8". I think some 10" is even being talked about. As you all know, we have found that the best homogeneous armor you can get is made of steel which is first of all sound, and, secondly, is in the tempered martensitic condition. Well, it is easy enough to talk about tempered martensite as long as your sections aren't over 4" thick. But when the sections get over 4" thick, we haven't found yet any way to get straight tempered martensite into such sections. So that when the sections get thicker than that we have had to get the resistance to shock by tempering back to a low hardness which, of course, reduced our resistance to penetration, particularly against undermatching projectiles at high velocity. So there is quite a bit of work going on at Watertown, also at Battelle, to try to develop some method of getting either tempered martensite or low tempered bainite, which seems to be also satisfactory, which will have at the higher hardness levels the same resistance to shock that we would expect from straight tempered martensite, so that as we get to the thick plates we won't have to drop our Brinells to 200 or less, but can keep them up to 300 and 320, where we would like to have them for the best resistance to penetration. All we can do today is to make the plates reasonably soft on those heavy sections. But there will be something coming out on it before too long, which we hope will give us better armor. When we see what that looks like, then we will be prepared to look into how that will affect the welding. I don't think we can do anything with respect to welding until we see what the armor is going to look like, if and when we get some of it that is better than what we have today."

Captain Randall commented:

"It has been found necessary in connection with some of the heavy armor thicknesses in the rather limited production applications which have been made to date, to resort to preheat in order to obtain welds free from cracks, even though using modified 18/8, or austenitic type electrodes."

Major Knode commented:

"In that connection, in order to get this so-called fiber structure in thicker armor plates, castings are sometimes necessary to increase your alloy contents. The difficulty of that is when you go to quench them you get cracks in them. Now, has any study been given to the welding up of these cracks which are caused by quenching armor plate that we had to put more alloy in in order to get the fiber structure?"

Col. Zornig replied:

"Making good armor in thick sections is tough. It is going

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to be tough. I think the cast people that are equipped to make those heavy sections are prepared to tackle a tough job. If they are going to get the amount of cracking that you seem to fear, I don't know howpractical that heavy armor is going to be. I can't answer your question yet. It is a very difficult question, to say the least."

Col. Zornig commented regarding the Research Group:

"Colonel Knable, as you know, is Chairman of our Research Group, and he has been transferred from the Ordnance Office to the Office of Defense Transportation, I think they call it now, or the Department or Division of Defense Transportation that is within the War Department; and hence we have lost the Chairman of our Research Group. I have asked Mr. Jennings to take over the Chairmanship of that group, which he has very kindly consented to do. He hasn't had a chance to have any meetings of that group, but the next time we have a meeting he will probably have something to say to us."

Col. Richardson commented on specifications:

"I was interested in the remark a gentleman made about the adoption of joint Army and Navy specifications. There is a good deal of work being done on that sort of thing in the Army and the Navy. But at least anything that is of mutual advantage and mutually used within the Army and the Navy is a fit subject for joint specification, and if there is anything that the chairmen of these groups have that we haven't gotten around to, there is a commission working on this, surveying everything that the Army and the Navy use, which you can appreciate is a considerable job, with the idea of coming out with a joint specification: The ultimate objective being, of course, that the Army and Navy can use out of the same barrel, as it were. This welding specification on aircraft armor happens to be the first one, I guess, that affects this group. There are other specifications in the works relating to things of that sort."

Following luncheon Col. Hoare reported on a recent trip to England:

"We in England realized very early in the war the additional production that could be obtained by producing a welded vehicle, but we made the fatal mistake of trying to take a vehicle that has been designed for a riveted construction and make that into a welded vehicle. We soon found that if you were going to have a satisfactory welded vehicle you had to design for welding right in the beginning. And it was no good trying to switch over. I refer to the little carrier vehicle--it is still being made of riveted construction--we having been set up for it, and the production has been maintained, and we haven't had the time, as it were, to alter all of our fixtures to change over to welding. But all new vehicles that are being produced now are of welded construction.

"In Canada today at present we are producing some light armor fighting vehicles, wheel vehicles, and also we are producing some

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self-propelled mountings made of 1-1/2" plate, very similar to what you are doing here. We are using both Unionmelt and hand welding equipment. In the case of the hand we are using both AC and DC equipment. The Unionmelt equipment is being used on 14 and 30 millimeter plate which we are building into a scout car. We had a lot of difficulty with that to start with, but now that is going fairly well, and we are using Unionmelt for welding up the lower hull of the SP mounting, which is very similar to your M-4 tank you have in this country. The Unionmelt method certainly does assist production, and it is likely to be more uniform than the hand welded methods, because it doesn't require so much supervision, that is, personal supervision of the actual welder, because the human element doesn't come into it so much.

"Both austenitic and ferritic electrodes are now being used in Canada today. In the case of the scout car, that is the one which is being done with Unionmelt welding, we are using the ferritic Ox-weld No. 40, with the 80 flux. That has been running, now, for nearly two years and, as I have said, is producing fairly satisfactory results. Regards the hand welding, quite recently we have authorized three brands of ferritic electrodes, namely, the Murex 2% chrome, the Harnischfeger AW2C, the Duroid 1. They are being used now and giving fairly satisfactory results. We are getting trouble with 6 millimeter plate when welding attachments on the inside. We are getting cracks right through that plate. We haven't yet solved the mystery, but it is a problem which is exercising me rather considerably at the present time, as this amount of cracking is getting very severe. The lower hull of the M-4, we are using Ox-weld No. 42 wire with the Unionmelt equipment, and 80 flux. The hand welding that we are doing on that vehicle, we are using the Harnischfeger AW2C, Lincoln Armorweld and Chrome A.

"In most cases we are using austenitic electrodes for welding on the attachments. The interior attachments on one of the welds we are building, we have tried steel rod Fleet Weld No. 7. That has up to the present given quite satisfactory results for these attachments on the inside. We have subjected it to firing tests and find that they are very good as regards resistance for shock. The joint designs we are using are very similar to the joint designs that you are using here. Production in Canada is the same as it was with you here, trying to push it very hard. And there is a danger of pushing production, that is, the question of quantity at the expense of quality. So we have had to be very rigid as regards the question of inspection of the root gaps, and also the question of making certain that all the flux has been removed and the slag taken out between the various passes of the weld.

"In Canada I don't use H plates to qualify, the same as you gentlemen are asked to here, but I take the actual sub-assemblies of the vehicle that the firm is building and subject those to the test that the vehicle will be subjected to. I suggest that is a better method, because then we are testing the actual production that the manufacturer is doing instead of an artificial production, as you do with an H plate. In addition to taking these sub-assemblies,

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periodically I take a complete hull, whatever they are welding, and I subject that complete hull to a firing test; and by that means ascertain whether the welding is maintained satisfactorily or not. The manufacturers in Canada appear to appreciate that method. We invite them down to see these tests so that when we complain about the unsatisfactory welding technique they see actually what has been done. I found that had a very great morale effect, that it gave the actual operators who were doing the welding a deeper sense of their responsibility to do a good job, and the firm in question thanked me very much.

"I was interested in the discussion this morning about the Temple gun. It has set me thinking as to whether that could not be used for testing both welds and armor plate by measuring the depth of the penetration. We can get by that means a constant attack, that is, we know by the charge that is used in the gun what the pressure exerted on the projectile is. I have been investigating in Canada the one shot ballistic method, which I think Aberdeen is interested in; but as a result of the discussion this morning, I am certainly going to turn my thoughts as to whether this Temple gun cannot be used to ascertain the ballistic quality, not only of the weld but of the armor plate, by having a definitely defined charge and measuring the depth of penetration as a result of it. If we can get some of these guns sent over to the forces we can get a very quick answer as regards the condition of the armor on enemy vehicles. We won't have to ship the vehicle over here. We won't have to carry out elaborate firing tests like we had to in North Africa, inasmuch as we set up an experimental range in North Africa with the express purpose of firing at enemy vehicles as soon as we could get hold of them so we could find out something about their armor.

"As regards inspection of these armored vehicles: I am using X-ray examination a great deal, but I am not using it to accept or reject a hull. We are simply using it to give us an indication of where we suspect that the weld is faulty, and at that spot we are firing at it when we test. When we test the sub-assemblies or these complete hulls, it is radiographed to start with and as a result of the radiograph we decide precisely where we are going to attack that hull; and also, I have found that these X-ray negatives have a very great psychological effect on the welding operatives. We, the same as you do here, qualify all the operatives. I have found that now they realize there is a means of looking inside, that it has a great effect. We take these X-ray negatives. We show the foremen and we show the actual welder the result of his weld, and that certainly has improved the workmanship.

"Chiefly what we are doing is that we are investigating the question of cooling rates and cooling diagrams for various weld sections, with a view to seeing if we can reproduce the effects that you get in the heat-affected zone in actual armor, and to find out how we can overcome it. I would like to mention that we are now exclusively using what I might term the static explosive test for testing welds. Prior to that we were firing at these welds with either a slug or an AC shell, but we never hit the weld just where we wanted to. A matter of 1/2" makes all the difference as regards judging the results of a firing test, and, now we have used the static explosive test for some time. Initially we were using the 37 or the 40 millimeter high explosive shell, which we laid just along the weld longitudinally, and, then exploded it by means of a detonator. That seemed to go on very satisfactorily for some time, and we appeared to get quite consistent results; but suddenly we ran into some trouble that we found we had welds which by the X-ray we conceived were almost identical, and yet we got inconsistent results from this test. On investigating we found that there were several variables that are introduced into a high explosive shell. A high explosive shell was simply made as a shell with no indication or no idea of governing its explosive effects. As long as it exploded, that is all the people wanted to know. So we found that there was a variation in the density of the explosive. We found there was a variation in the method of filling the shell, inasmuch as we got cavities in the shell and when we exploded it we got the hollow charge effect, which is a very different effect from exploding an ordinary solid explosive. So now we are using a plastic explosive, which is manufactured in Canada. We can mold this explosive into any form which we like, and, incidentally, we have found that the form of the explosive materially affects the results. We can vary the amount of explosive at will, and, we have found, too, that this explosive can be produced very uniformally as regards density. We've got to get down to a standard test, if we can, for testing welds, because only by that means can we get comparative results. It is for that reason that I am most interested in the suggestion of the Temple gun, to see that we can get possibly with that some standard method of testing, at least, the ballistic integrity of the welds. It won't give us an answer from the shock point of view, but it certainly will give us a very good indication of the ballistic integrity of the welds.

"In England there is a great preponderance of AC welding equipment. In fact, there is very little DC welding being done there at all. Up to the present they have not had any automatic welding. All of the work done has been done by hand, but experimental work is going on in England with this automatic welding. I must say on behalf of England how much we appreciate this liaison work which is going on. It is a great help to us all. This is one war that we are all in, and this reciprocation of information has been a wonderful help. I'm sure it will result in a greater unity between the two countries, more return of information between us. All the armor in England of over 30 millimeters in thickness is being welded with larger electrodes, and you might be interested to hear that they have gone up to 1/2" electrodes, in spite of, I know, the difficulties which are experienced in this country.

"Towards the latter part of 1943 a policy was decided on in England to develop the use of ferritic welding with all vehicles with plates up to 14 millimeters in thickness; small gauge austenitic welding with plate 14 to 25 millimeters thickness; and

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heavy gauge, austenitic electrodes for plates over 30 millimeters in thickness. Electrodes, 5/16", 3/8" and 1/2", are all on the approved lists for armor over 30 millimeters in thickness. There was a great problem in England to get suitable armor plate. As you know, we cannot concentrate the work there in large plants, because we have to spread it out, due to the air raids, which are still prevalent; and for that reason we used to melt armor in one plant, roll it in another, heat treat it in another, straighten it in another, in various parts of the country. We used all sorts of methods for heat treating armor, methods which I expect you gentlemen here would throw your hands up in horror at. We use brick kiln. We use annealing ovens, and all sorts of things, whatever they could get hold of, because production was essential; but in spite of that I think they did fairly well as regards the quality of armor that was produced.

"Three brands of ferritic electrodes which are now approved are the Lincoln SA 85, Murex Fastex, and Quasi Arc Celto. They are the electrodes which England is using at the present time, but there has been no great production with the last two I mentioned, namely, the Murex Fastex and the Quasi Arc Celto. The research department at Woolwich have produced one now which they called the RD 1. It is a hydrogen controlled coating, and the core wire contains manganese. Realizing the necessity of getting down to the electrode question, they have set up a special electrode committee which is studying this question, and considerable interest has been taken in the work that is being done here by the NRC in the ferritic electrodes. A supply of electrodes from here has been received and they are now distributed to the various manufacturers for special test purposes.

"In England all the joints are designed for fillet welding, and the corner joints, wherever possible. The main reason that England did that is purely a production problem. They had not the facilities that you had here. We had to go out to wagon builders and all sorts of people to get them to build these armor fighting vehicles, and so the advantages that we have obtained by using the fillet welding is that the plate tolerances can be generous and a greater latitude in assembly is possible. There are not the facilities in England of setting up the elaborate jigs which you can do here. They have not the space to do it. They have not the means of obtaining it. They haven't the machining facilities for making them; and so this was a great advantage if we didn't have to work to such close tolerances as regards plate sizes, as you do here. And, then, also another important point was that England's resources were tapped to the absolute limit and the fillet welding requires much less welding rod than the other method, and all that is a thing which one has to pay considerable attention to, is the conservation of materials, because we are dependent upon outside sources. And, then, also it is suggested that there is less likelihood of cracking with the fillet welding than there is with the butt welded joints that you are using here. And the question of structural strength also comes into it, because you can design for fillet welding and take up a lot of your stresses in the plate itself instead of transmitting a lot of those stresses to the weldment. The joints admittedly may have less shock resistance than the joints which you are using, but if care is taken in the design of the hull, or the turret, and you consider the structure as a whole, then that is not such an important point. If the vehicle does its job, what it is supposed to do, with the least possible amount of work or worry, why, then I think we have achieved the answer that we are all looking for. So, as I say, battle experience up to the present has not necessitated any change in design, or the view that is being taken by the designers here, and they propose, therefore, to go along with those methods.

"But what I must stress is that the design in England, the question of resistance to penetration of weld, is taken more account of than their resistance to shock. We feel that if you fire at a weld under battle conditions, that is, if you hit it with a projectile you are going to be hit with in the field, if the vehicle will stand up to that, not only from the question of ballistic immunity, but from the question of structural strength of the vehicle, then I think we have got the answer which we are looking for. You don't expect it to be shot at in the field with slugs or anything like that. It is usually either high explosive or armor piercing shells, and for that reason a greater stress is put on the ballistic integrity of the vehicle rather than on the shock side. In order to achieve this ballistic integrity the welds are built up, say, about 20% greater than the thickness of the plate, in order to obtain it. Once a vehicle has been approved, it has been tested ballistically, we say 'We don't mind what you do, but you cannot depart from this method of welding. There is no time to do a lot of experimenting. You have done all the experimenting. We have got a vehicle which is satisfactory. Go ahead and build as many as you can.' As I say, our resources are not the same as yours. They are very limited, and the question of the quantity is vitally important. As long as we know that quantity will do its job, we haven't a lot of time to get into developing what you might call the perfect vehicle. So the greater onus is placed on design than in this country. Once the designer has said, 'Yes, this is satisfactory', that is the vehicle they are going to build, and a lot of time is not wasted in trying to develop another type of vehicle.

"Radiography is not being used to any extent in England. They are entirely depending upon the actual test of the vehicle. There is an investigation going on as regards the cooling rates, and in relation to welding procedure, very similar to what I mentioned in Canada, and also there is a consideration now being given to the development of a hydrogen controlled electric coating. As they have found, the same as you have here, that excessive hydrogen is considered to be a cause of a lot of their cracking troubles. The electrode manufacturers in England are still experimenting to utilize existing core wire for changed plate composition. One of their difficulties there is of getting consistent plate compositions and in endeavoring to try and strike an average composition and get an

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electrode which will suit it. So far they have been fairly satisfactory.

"We have not had an opportunity of seeing very much of the recent work in Germany. We feel that the vehicles that we have seen most about were possibly made in 1942, and so that is chiefly the basis of the information we have got. Those vehicles, the Germans use much harder armor than we were using in England, much harder armor than you are using here. She built vehicles according to the armament that she was going to be up against, and she knew very well that there was no overmatching projectiles for the armor when she put it into the field. It was only when we started using overmatching projectiles against their harder armor that it began to fall to pieces. Until the higher caliber artillery could be brought to bear on them there was a great danger of them getting right through North Africa. They certainly got right through Europe and it almost looked as if their policy was going to pay dividends. They found that the difficulty with the harder armor was that it wouldn't stand up to overmatching attack. For that reason they are now considerably reducing the hardness of their armor. They are exclusively using welded construction for their tanks, but their welding, as with their armor, does not stand up to overmatching attacks. They do a considerable amount of machining and dovetailing with their plates, and they just stick a bit of welding on the outside to hold them together. They rely entirely upon dovetailing of the plates for the mechanical rigidity of their vehicles. That, as you can understand, involves a considerable amount of machining. When they came up against the problem of the overmatching projectiles, they went to spaced armor. That is, in order to increase the ballistic immunity of their tanks, they put armor on the outside to increase the thickness, and at varying spacings from the main armor. In many cases this additional armor was welded on, but, as I have said, their welding is not too good, and as soon as that additional armor was attacked with a heavy projectile, the welding just broke up and the armor fell off. They were also bolting it on, but that was not entirely successful when we altered our ammunition and were using capped shot.

"We have found that they have been haphazard in the use of electrodes. A large variation of electrodes has been found to be used, and possibly that is the result of the excessive bombing of Germany. Their facilities have not been available for producing one or two definite type electrodes. It may also have been the question of using what was at hand when they were making these vehicles, and also the question of repairing them in the field. Apparently a fellow just took the first electrode he could put his hand on to do the weld repair in the field. Both the austenitic and ferritic weld deposits have been found in the analysis of their armor, and most of the repair welding, as far as we can ascertain, that they have done in the field, has been done with ferritic electrodes, which is rather interesting. So it looks as though greater stress has been paid to the question of getting the repair out rather than the quality of the repair after it was got out.

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"There was a considerable amount of face-hardened armor in their original vehicles, but now mostly it is the homogeneous type. And so it appears that Germany pays particular attention and gives greater reliance on joint designs for maintaining the structural strength of the vehicle rather than depending entirely upon the welding. All their wheeled vehicles, their armor fighting vehicles, are all completely welded construction."

Mr. Humberstone reported on NRC Development:

"The first one, Project No. 1, weldability of commercial armor plate, is one of the projects which has been used in connection with the investigation of weldments produced with the fer- fitic electrodes. As most of you know, we have also been engaged in the development of an S-curve weld metal from NRC-2a electrodes. The upper portion of the S-curve of NRC-2a weld metal has been determined. It reveals a transformation of austenite from ferrite begins very quickly, but progresses slowly. No carbide appears to be formed until a very large proportion of the austenite has transformed to ferrite, while the transformation of regicide austenite to ferrite and carbide is so sluggish that completion of the transformation as to temperature levels about 1000°F. appears to require several days.

"Project 2, on the development of armor welding electrodes, has involved, in addition to actual development activity on electrodes, the welding of many sections of various natures. Evaluation of results of ballistic tests of side section of M-10 tank welded with NRC-2a electrodes indicates considerably less cracking in the weld metal or in the parent plate affected by the welding process than in similar sections welded with austenitic electrodes. However, there appears to be a somewhat greater proportion of crack failure of armor plate away from the region affected by welding. Looking at it from an overall standpoint, it appears very difficult to fire subassemblies or structures of that nature in such a way that you can obtain real comparisons between austenitic electrode and ferritic electrode. And in addition to that, it is somewhat difficult to analyze the results, because there is variation in the location of the impacts. So I do not believe that we are prepared to say that subassemblies or special sections is a particularly worthwhile method of arriving at conclusions where you are interested in research or development. It may be from a standpoint of whether production vehicles are satisfactory or not. I won't argue that point, but you can't use them to arrive at any real conclusions when yourreal purpose is research or development.

"The hull of an M-5 tank completely welded with NRC-2a electrode has been completed. The welding was carried out at the Heil Company, following their standard procedure used on M-5 hulls. There was no attempt made to train the welders for a new type electrode. Preheat was used to the extent that they normally used it, with the possible exception that there may have been more care taken in following or maintaining a definite minimum. The preheat was 125°F. The results indicate that with the procedure used no undue difficulty would be encountered in the application of

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the ferritic electrode. Defects seemed to be confined to those locations in the structure where it was very, very difficult, or nearly impossible, to thoroughly clean the back side of the first pass. The greatest value of the project, so far as I am concerned, was that experience gained from the actual welding operations and any of the relatively minor repair operations that were necessary.

"A number of corner joints of the M-4 tank have been prepared with the use of NRC-2a electrode, alone, as well as with the use of NRC-2a electrode in combination with ferritic Unionmelt. There is work going on all the time to overcome two primary problems in connection with this electrode: One, the tendency towards porosity, which in practically all cases at the present time necessitates preheating the electrode; the other, a desire on everybody's part to improve the operating characteristics. Recently there is every indication that improvement of this nature can be expected.

"Project No. 3, stress relief of weldments from machining stability being carried out at Ohio State, is progressing satisfactorily. There have been some reports issued. At the present time work is nearing completion to determine the effectiveness of time as compared to temperature. It appears, on the basis of the work done, that temperature is a far more important factor than time; that the idea that many have had in the past that you can decrease the temperature if you use a longer time, does not necessarily hold true; that, as a matter of fact, you can decrease the temperature, and you don't have to go very far down, where for instance, if you could accomplish at 900°F., it would require an unnecessarily long time to approach the same condition that could be obtained at 1100° or 1200, for a couple of hours, if it can ever be attained.

"A final report is being prepared on NRC Project 16r, which has to do with the welding of face-hardened armor. I think the report is prepared, but it has not been submitted for publication yet. And unless I am entirely incorrect, the findings are all negative, that is to say, you will not find anything in the report that will make it easy for you to weld face-hardened armor.

"On Project NRC 25, direct explosive tests for welded armor plate, that project has been going on for some time and has gradually gotten around to the point where the majority of the work has been done and is being done in connection with the development of direct explosive tests that could be used on armor proper. There has been up to the present no indication that a satisfactory small shop test can be developed for welded joints employing attack by explosives. There has been Part 1 of a final report on the effective locked-up stresses on ballistic performance of welded armor. I believe it must have been issued by now, and work is progressing to complete it.

"A final report has been issued on Project NRC 59, which had to do with non-metallic welding backup strips for armor plate joints. That project was closed because it was felt that practically all materials had been investigated and that means of using them

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successfully had been developed, or at least indicated.

"There are a couple of fundamental projects on weldability that have been going on for some time that do not necessarily apply to armor, but they do apply to welding in general. One has to do primarily with the development, at the present stage at least, of a test wherein we hope to be able to determine difference in crack sensitivity between classes of electrodes and between brands of electrodes within a given class. Now, that has to do primarily with the crack sensitivity of the deposited metal. We hope that the same test could be applied to plate material.

"There is a project, No. 71, on the effect of oxygen cutting on weldability of armor plate. This project has been going along very slowly, primarily due to the fact that many of the difficulties that have been reported from time to time seem to be quite impossible to duplicate in the laboratory. The work done on the finished plate, that is a plate that has been fully heat treated, indicates that there should be no great problem in the cutting there, or the development of cracks due to cutting. So the work is now being concentrated on plate in the as-rolled condition, that is, cutting which must of necessity be done before heat treatment.

"There is also another project, NRC 73g, which covers the investigation of methods of repairing ~~east~~ armor by welding. Again, the work is progressing on that project. There is nothing of great importance to report at this time.

"There is another project, NRC 76, being carried on at Battelle covering the development of improved electrode coverings, which is actually correlated with the project NRC 2. In this case, the atmosphere produced by these electrodes under certain controlled conditions is being analyzed. The amount of hydrogen in weld metal from these electrodes is also being determined, and as a result of all of this work there is one point that I would like to make fairly definite, that there has been a tendency on everybody's part to lay all of the blame for underbead cracking, and so forth, on hydrogen. It is true that where they have encountered no underbead cracking hydrogen has been reduced. However, it is also true that you can make an electrode which will have low hydrogen content in the atmosphere and will show no underbead cracking, but will also perform very unsatisfactorily under shock. As a matter of fact, one electrode in particular has about half the amount of hydrogen of another electrode which has proven satisfactory. That presents the idea that all of the trouble may not be due to hydrogen, We can't say that is definite. There may be something--we know definitely that there must be some other factor involved."

Col. Zornig remarked:

"Mr. Humberstone has brought to my attention that there seems to be some misapprehension as to the connection of this committee with the War Metallurgy Committee and the work that they are doing. This committee is a subcommittee of the Ferrous Metallurgical Advisory Board to the Ordnance Department. That is a Board which

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exists during war and during peace time and has been in existence ever since 1923; and the purpose is to keep the Ordnance Department's work tied up as close as we can with what industry is doing.

"When the war came along it became evident that this Board, which only has a normal membership of about 15 or 20 members, couldn't do all the work. So the subcommittees were organized to take care of the work on the special ordnance steels, such as armor, cast and rolled, gun forgings and the welding of armor; and the original purpose was so that the few old-timers that had been in this business could impart whatever information they had to the new ones. Of course, in welding of armor there wasn't anything. That was a virgin field.

"Then, when the War Metallurgy Committee was organized the problem came up of getting them in close touch with the members of industry who were involved in this, and Clyde Williams and I arranged that we would use these subcommittees as a means of getting the reports of the NDRC work, or the War Metallurgy Committee's work, to industry, that is, we use the membership lists of this subcommittee as the mailing list for NDRC reports; also that the supervisors would report verbally at these meetings so you would get what information there was as soon as possible; and also to give the War Metallurgy Committee research supervisors an opportunity to contact the industry and find out what problems were to be worked out. Then, later on when the WPB found it necessary to get in contact with industry, they also decided that they would use these subcommittees instead of organizing some new ones. So that is the reason that we have WPB and War Metallurgy Committee activities carried on to some extent through these subcommittees. In other words, these subcommittees have no control over NDRC's work, and we have no control over WPB's work."

Then Col. Zornig added:

"The directors of the various branches of research that is carried on by the War Metallurgy Committee speak only for the War Metallurgy Committee and speak only technically. They have nothing to do with what policies are then adopted by the War Department or the Ordnance Department, but they also come here and use this committee for their contacts with industry. So what started out to be just a subcommittee where we were going to swap our own experience has branched out until the Ordnance Department is using it as a means of getting contact with industry; WPB is using it, and War Metallurgy Committee is using the Committee for that purpose."

Col. Zornig then introduced Dr. Aborn with the following remarks:

"Now, there has been quite a bit of work going on in the metallurgical examination of weld joints, which has not yet been published but which is extremely interesting, and I have asked Dr. Aborn if he will tell us something of what he has been finding in the pure metallurgy of welded joints."

Dr. Aborn stated as follows:

"It is just two years ago this month that the NRC asked us

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to look into the matter of improvement in the weldability of armor plate, particularly from the standpoint of post ballistic stress of shock tested plates. Well, as you can imagine, those of you who have been making the plates, you have been on the delivering end and we have been on the receiving end now for two years, and if any of you have had post mortem jobs to handle you know that they aren't always the simplest thing, particularly because you can't revive the patient and talk to him and ask him what happened to him in the course of his life history. I don't blame any of the fabricators. I know it is the rush of war time. Some CIO paid clerk is putting in the records and has no knowledge of metallurgy, and no knowledge of welding, and really some very ridiculous things sometimes appear there in those WAS 2 or 3 forms. We have been forced to develop detective methods to figure out just what happened in a number of cases, and since any one of several things might have given the same result, it has not been too satisfactory in trying to deduce just what went on.

"Now, I would like to say just a few words about the origin and path of fracture in the shock tested H plate. We feel that the origin of fracture depends on two main things, the particular set of ballistic test conditions that are used and the variables in those test conditions, and second, local unsoundness that is in the region of the impact; and since those are not predictable entirely, or entirely under control in advance, the origin of fracture is in a sense gratuitous, that is, it is chance. The most significant factors in a tested H plate, we believe, are these: The degree of resistance to the propagation of that fracture once started; and, second, the path that that fracture takes through the weld metal or base metal, or both. It is extremely complex in this respect, that the path is influenced by so many factors which are not under controlled, practical considerations.

"But we believe that there are three main factors that do control that path of fracture for any given set of ballistic test conditions. First is the geometry of the joint. By that I mean, the shape and size or amount of weld metal; and, then, the width of the zones in the base metal that are affected by the welding; and, then, the severity of the notch is always present to a greater or less degree at the junction of weld metal and base metal at the surface of the plate, both faces. That is the first factor, the geometry, and the second is the matter of general or local unsoundness along the joint, and that sometimes can be tied in with the radiographic data, although not always; and third, the nature of the micro structure in the weld metal and base metal. Now, it is that last named point that I want to speak on a little further now.

"Let's first name martensite. I think it has been bandied around a great deal. It is simply the hardest obtainable structure of steel. Ferrite is the opposite end. It is the softest structure and is characteristic of soft iron. Pearlite is the structure you get in the carbon rich areas of steel when it is slowly cooled. Now, Col. Zornig mentioned this morning tempered martensite as the structure unquestionably that we want, not only in the unwelded plate, but throughout the joint under ideal

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conditions; but unfortunately martensite, for its original formation, requires 100% formation of austenite, the high temperature form of iron, and that only forms for armor plate on the average, we can say, above 1500, that is to be completely austenitic. And since in making any weld you have a gradient of temperature from room temperature up to the melting point, obviously there is going to be a range below 1500, where the material, which was originally tempered martensite as delivered by the armor maker, first goes through an excessive softening, which is near 1300, we will say, and, then between 1300 and 1500, roughly, in temperature terms (all Fahrenheit I am speaking of) gradually changes from ferrite over to austenite; and, then, it never gets any farther than that, because the weld is completed and it cools down again. So in any metal-arc weld you are bound to have a region there in that approximate temperature range where you have a mixture of ferrite and the product of that part of austenite, which may go to a variety of structures, and that in general is an undesirable zone. If tempered martensite is the best structure and the ideal one from the standpoint of ballistic shock resistance, then opposite to that, ferrite is one of the poorest structures to resist shock, and ferrite with pearlite is probably the worst of all shock resisting structures. In the average mild steel, structural steel, under shock test conditions corresponding to ballistic shock it is far from satisfactory in resistance as compared to tempered martensite. And we think the primary reason is the nature of the constituents. It is the structural constituents we believe that control the qualities, and in mild steel it is ferrite and pearlite that are there. Now, then, it is this zone between 1300 and 1500 that gives an inherently undesirable structure. Part of it can be satisfactory, because that went to austenite, but that part that didn't is a thorn in the flesh, so to speak, and we have to put up with it because it is inherent in any metal-arc weld.

"Another factor is the so-called tempered regions. If you are making a weld in one pass, then there is no tempering other than the original heating and cooling, but most welds are made in multiple passes, and each successive pass will temper the heat-affected region of the base metal to a greater or less degree. A tempered structure, unless it was originally martensitic, in general is not as resistant to ballistic shock as it was before it was tempered. In NRC Report M-265 the initial structures are shown as compared with the temper structures of heat-affected regions of several different types of armor. In a number of those you can see that in the tempered region there has been an excessive amount of either migration of carbides, or a lining up of some precipitated material along grain boundaries, some former grain boundaries, possibly of the austenite; at any rate, an inter-granular condition which quite probably reduces the shock resistance.

"We recently examined three different types of ferritic weld metal which have been used at various times in the course of this ferritic electrode development, though they were formerly used and gave fairly good results until a new one came along and, then, a

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third one, this new NRC-2a type. The third type, the new one for which the specification was issued or proposed yesterday, shows three characteristics which are not present in the others. In the first place, it is very much cleaner, a whole different order of magnitude of improvement in cleanliness. Another characteristic of the new electrode is, as Mr. Humberstone mentioned, that it is relatively immune to underbead cracking. That apparently is associated with the gas content in the weld metal, and possibly by diffusion into the base metal adjoining; but, as Mr. Humberstone says, it doesn't seem to explain the improved shock resistance; and that, we feel, is logical, because the shock resistance seems to be intimately tied up with the micro-structure of the metal. And the other characteristic which is very unusual, to us at least, in examining ferritic metal: the ferrite occurs in elongated grains, and those elongated grains are intimately mixed, practically, you might say, almost in interlocking fashion, with the martensitic areas, which represent, of course, the high carbon regions in the cooling operation. That combination of the elongated ferrite with the interlocking martensitic areas is certainly associated with, and we believe may well be responsible for, the greatly improved shock resistance of this new ferritic weld metal. In fact, the shock resistance is so good when the weld metal is properly made that the cracking, if it occurs at all, is generally in the base metal or the plates, and if it is in the base metal, it will occur there apparently in an amount dependent upon the ability of that particular combination of armor composition and welding procedure to produce a predominantly martensitic zone in the heat-affected region of the base metal."

The meeting was tentatively suggested for Cleveland, Ohio, during the week of October 9, 1944 after which the meeting adjourned at 3:10 P.M.

At this meeting the results of tests of production spot welding of armor, to which the Resistance Welding Group had several times in the past referred to with pride, were disclosed to the Subcommittee. The results of these tests were not all they had been expected to be. Also at this meeting certain metallurgical explanations for ballistic shock performance of welded H plates were disclosed as resulting from studies made by NRC facilities. It was apparent that a better understanding of the effects of metallurgical factors involved in welding armor was in process of realization as the result of laboratory studies and that emphasis on mass production had been considerably reduced.

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FIFTEENTH MEETING
SUBCOMMITTEE ON WELDING OF ARMOR
THURSDAY, 9 NOVEMBER 1944
HOTEL CLEVELAND, CLEVELAND, OHIO

The fifteenth meeting of the Subcommittee was held in Cleveland, Ohio, on 9 November 1944 at the Hotel Cleveland, with 97 persons in attendance representing:

Industrial - United States	
Tank Fabricators	25
Armor Producers	3
Electrode Manufacturers	20
Core Wire Producers	5
Aircraft Fabricators	1
Individuals	5
Government - United States	
Ordnance Department	20
ASF Headquarters	1
Navy Department	4
Army Air Forces	2
Transportation Corps, U.S.A.	1
National Research Council	4
Government - Allied Countries	3
Guests	3

The meeting was opened by Major N. A. Matthews, Acting Chairman, with the following remarks:

"Colonel Zornig is on a special mission, and he is presently abroad. And how long he will be abroad is anybody's guess. So we are trying to carry on in his absence. He is definitely on a temporary duty status, but there is no knowledge at present as to how long he'll be away from us. I think we might as well go right into the first item on the agenda and ask if there is anybody here representing the War Production Board this morning who can report to us on the alloy situation as it exists at the present time. Is anybody here from the War Production Board? Is Colonel Richardson here this morning? Apparently we are not represented by those agencies but I'm sure all of us appreciate that the alloy situation long ago corrected itself and that there probably won't be anything of significance to report any way, except that alloys are available to do important jobs."

Mr. McDowell reported on the activities of the Homogeneous Armor Fabricators' Group:

"The Homogeneous Armor Fabricators' Group has held only one meeting since the last meeting of the Subcommittee, and that was held yesterday here in Cleveland. The first item on the agenda

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for discussion was the armor welding specification AXS-497. There have been no changes in this specification in the last six months, and Captain Boucher of OCO, Detroit, informed us that no changes are contemplated. This specification will in the near future be issued as a United States Army specification.

"In regard to the repair welding made necessary by defects found in X-ray examinations, some fabricators felt that since the intent of the specification was primarily quality control of the welding rather than an inspection tool, that the X-ray standard requirements, if closely adhered to, were quite severe for X-raying which covered only a percentage of the weldments being fabricated. Captain Boucher stated that the specification AXS-476 on radiography is to be revised in the near future and that if anyone had any comments or suggested changes for the specification, it would be appreciated if they were forwarded to his office.

"In regard to the workmanship standard specimens required by specification AXS-497, the majority of the fabricators felt that the use that had been made of them did not warrant the expense involved in their preparation.

"In regard to specification AXS-886, the all-position type of electrode as required at present is made in the 14" length, and the down-hand type of electrode in the 18" length, and a poll was taken of the members of the group to find out their preferences in this matter, and it was the opinion of the majority that they would prefer the two different lengths, the 14" length for the all-position type, and the 18" length for the down-hand type.

"At present two manufacturers are producing ferritic electrodes which have been found acceptable under the present NRC specification. Some trouble is still experienced with porosity in the welds deposited by this electrode, but considerable improvement has been made and it is hoped to eliminate this condition entirely in the near future. An attempt is also being made to change the characteristics of this electrode to provide the full benefits of complete heat treatment after welding. At the present time weldments produced with the ferritic electrode without any heat treatment after welding have shown up slightly better in ballistic test than those which had been subjected to complete heat treatment after welding. The M-5 light tank hull which was completely welded with the NRC-2A type electrode and reported at the last meeting has been subjected to ballistic test, and comparing the results of the test on this hull with a similar hull which had been completely welded with the austenitic type of electrode, there was a little difference in the performance of the two hulls. Any fabricator desiring to use the ferritic electrode on a production application is required to submit a request to the Office, Chief of Ordnance, Detroit, who will be glad to take action on it.

"Mr. Smith, appointed chairman of the Weld Joint Standardization Committee for the M-4 tank hull (appointed at the last meeting), reported that this committee had completed a drawing showing cross-sections of all the joints on the M-4 hull, and of the three fabricators represented on the committee, complete agreement had been reached between two of them on 100% of the joints involved. The

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third fabricator disagreed on three joints, which, due to his jig and fixture setup, could not be readily changed. In the future, all joint designs of new vehicles will be prepared in accordance with the Weld Joint Design Specification AXS-800. Any deviations therefrom desired by the contractor, it will be necessary for the contractor to obtain approval from the Office, Chief of Ordnance, Detroit.

"Engineering Change Order No. 9253 outlining requirements for cast armor repair has been issued. This order was the result of an extensive testing program carried out by the Office, Chief of Ordnance, Detroit, in co-operation with the cast armor manufacturers. It involved a large number of plates, both of the I type and the simulated weld defect type. The plates were tested in the as-welded condition; also, after the plate had been subjected to complete reheat treatment after welding; also, tempering only after welding, and the fourth type was stress relief only after welding. There was little difference in the ballistic performance of any of these plates.

"Captain Pless of Aberdeen Proving Ground reported that cold temperature testing facilities have been completed at the Proving Ground and that a rather extensive low temperature testing program is now under way. This program involves several different armor compositions and several types of welding procedures. Before closing the meeting it was decided that no future meetings of the group would be scheduled unless some problems arise which in the opinion of the fabricators, or the Office, Chief of Ordnance, Detroit, would make such a meeting desirable."

Mr. Webster added:

"Tentative specifications are set up under the cognizance of the group that is responsible, without reference to any standardization whatsoever by our Ordnance Technical Committee. These specifications are so set up in this form that we anticipate changes from time to time within the near future, and if standardized, such a specification would be out of the question of handling, due to the inertia of standardization. For that reason our armor and armor welding specifications, along with a good many others, have been in this form during the stress of production where changes can be made by, in this case, our Office, Chief of Ordnance, Detroit, who has control of those, and by their engineering bulletins they can handle some of the differences for a while; but it is impossible to handle everything that way, and they will call for either an amendment or revision, which can be put through in very short order. I might say in our Ordnance Welding Committee meeting last June we set up in a rather specific form quite a welding specification grouping, and we are carrying that out as fast as we can. Office, Chief of Ordnance, Detroit, is coming through with the specifications that this group is interested in as fast as they can develop drafts, and at the present time this 57-207-1 is being issued as a result of that. Also, the standards, such as Mr. McDowell mentioned, in joint design, symbols, and such as those, are being carried forward. Joint design AXS-800 is being carried

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through and is about ready to get a final draft on. The appendix one which applies to combat vehicles is practically ready for use. That will be issued under Specification 57-205-4, and as I told the Electrode Group yesterday, within this month, old specification AXS-886 will be issued as 57-203-3. I believe that covers pretty well the specification setup that you deal with.

"The one thing is within the Ordnance for the past year and nearly a half now there has been a regulation whereby tentative specifications can be kept in the existing form for a period of six months only. It may be needless to say that it is impossible to change over all of our specifications within six months. So that hasn't been completely complied with."

Col. Richardson added:

"The question is, what is the tentative specification in relation to United States Army specification? I think that is familiar to everybody in the Army, but may not be familiar to all the contractors. As we view it from headquarters, a tentative specification is a specification issued by any one of the services for that service's particular use, as Ordnance, or Engineers, or Quartermaster. Now, in order to prevent confusion within the Army on the part of the contractors who may be providing one thing for the Engineers and something else for Quartermaster, and something else for Ordnance, the Army requires that after six months a tentative specification be withdrawn and a United States Army specification substituted; and that is coordinated with every service of the Army, including the Air Forces. The idea is to prevent conflict between tentative specifications. The Navy has the same setup, calling their tentatives Interim Specifications, but otherwise it is the same procedure."

Major Matthews commented:

"I just wanted to make clear to the contractors that the essence of these specifications was not being changed necessarily. In other words, if slight changes are indicated, then, they, of course, will be made when we make the transition from tentative to United States Army specifications; but the important thing for you people to take away with you is that requirements are not being essentially changed. It is just a change in form of the specifications."

Captain Randall reported on activities of the Electrode Group:

"The last two meetings of the Electrode Group have been unusually free from argument and discussion. It would appear that the subjects being discussed by that group are becoming more a matter of general agreement than they were for quite a period of time. The principal subject that was discussed at the meeting yesterday was the proposed draft of a specification for electrodes of the NRC-2A type. It is proposed to issue this as an Ordnance tentative specification, recognizing that this material is in a state of transition, and it is inadvisable at present to attempt to make an Army specification out of it. The draft of this specification

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was distributed to all members of the Electrode Group approximately two weeks before the meeting. The technical requirements in that draft were based on the detailed recommendations of the National Research Council, and with the exception of editorial changes, there was only one fundamental change made at the meeting yesterday. That was the addition of one type of electrode. By 'type' in that case we mean type as defined in the specification which refers to the type coating used. The original specification was restricted to so-called lime type coatings, which were defined as having a maximum titania content of 9%, and a minimum CO_2 content of 15%.

"One electrode which had shown quite satisfactory results had a somewhat higher titania content than the 9% maximum in the specification. The National Research Council agreed that sufficient work had been done with this electrode to justify its inclusion in this specification, and recommended the addition of the new type. This type coating is known as a lime-titania type, and is defined as one having a maximum of 15% CO_2 and between 9 and 15% titania. It was agreed by the group that this change would be made.

"There is no intention at the present time of making any change in AXS-886, which does provide for both the 14" and 18" lengths as it is now written. However, in the case of the NRC-2A type electrode, the 3/16" diameter has been furnished by all producers to date in only the 14" length. The question arose as to whether the system for that specification should be the same as that for stainless electrodes, that is, whether we should have both the 14" and 18" lengths. It was agreed by all producers of the electrode that the NRC-2A type of electrode was not similar to stainless in this respect, in that no producer felt that an 18" electrode of this type would be satisfactory. The reason for that being that higher currents, as those of you know who have used the electrode, are used with the NRC-2A type than is the case with the stainless of the same diameter. It was the opinion of the electrode manufacturers that an 18" electrode in 3/16" diameter would severely overheat before it had been completely consumed at these high current values. Accordingly, the proposed draft of the specification was modified so that the 3/16" diameter will be obtainable only in the 14" length for the present time. That applies only to the NRC-2A type—let me emphasize that again—not to the stainless.

"There has been considerable discussion, of course, of NRC-2A electrodes in connection with their various applications, and it was felt desirable by Ordnance to have available a tentative specification defining these electrodes. It is for this reason that this proposed draft was prepared and submitted to the Electrode Group. After discussion by the group, the specification as changed during the discussion was recommended by the group for approval by Ordnance.

"There has been considerable objection to classifying electrodes by grade, type, and class. In order to completely define stainless electrode as covered by AXS-886, you may say it is a specific grade, a specific type, and a specific class. That gets a little bit involved, and in the process of converting a number of Ordnance tentative specifications into United States Army specifications, the problem of nomenclature has become quite complicated. Mr. Webster presented a plan which had been worked out for classifying the electrodes, using various code symbols in the general system originally followed by the American Welding Society in connection with their E-6010, E-6020 and so forth. Mr. Deppeler, who is Chairman of the A.W.S.-A.S.T.M. Filler Metal Committee, agreed to review the possibilities of designating these electrodes, together with members of his committee, and to forward to Ordnance within approximately three weeks, specific recommendations for nomenclature and designation in the various types of stainless electrodes, as well as the NRC-2A type. Further action was accordingly deferred on this question by the Electrode Group, except that it was recommended by the Electrode Group, that a system of nomenclature, generally similar to that outlined by Mr. Webster, and to be modified in all probability by Mr. Deppeler's group, be adopted in place of the present grade, type and class designations.

"With reference to 57-203-3 there is absolutely no change in the technical requirements of that specification as compared to the Ordnance Specification AXS-886 as you know it. It will not be necessary for electrode manufacturers to resubmit electrodes for approval. The same list of qualified brands will be carried over into the Army Specification 57-203-3 without any further testing.

"Captain Boucher briefly discussed the problems of cast armor repair, mentioning one particular thing. That was that for the information of the electrode producers, it was believed extremely doubtful that they would be able to meet the new requirements for the repair of cast armor with the average low tensile electrode of the E-6010 or E-7010 classifications. In all probability it would be necessary to resort to an electrode of the NRC-2A type. For the information of those of you who may not be familiar with them, the new cast armor repair requirements which involve the testing of 2" plate employ 105 millimeter slug for the shock test. That is a change from the previous 75 millimeter, which had been previously used, and it is probably the first time that we have had an adequate shock test for 2" plate."

Mr. Abbott reported on activities of the Fabricators of Face-Hardened Armor:

"A survey of the fabricators of the face-hardened armor shows that this year there has been a serious cutback in the volume requirements of face-hardened armor, that the production of this type of armor is limited generally to aircraft applications, gun shields, and a few special applications on some vehicles, and in consequence of this, there has been practically no development in the experimental work going on in the welding of face-hardened armor. Practically all welding outside of production welding is done in the furnishing of qualification plates and the like under a new

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specification JAN-W-41. The welding on these plates is being done by the methods that we had qualified plates under specification for vehicles, that is, old AXS-743, and there have been few results so far, and not sufficient to know what the general trend is as of the present time.

"There has been one little development since we reported last meeting, and that is that in some aircraft structures, using a heavier type of face-hardened armor that extends above the aircraft that is subject to direct impact of projectiles, and below where the projectile itself might hit some part of the fuselage, they are using a thinner type of A.M. and one homo, these two being welded together. The welding technique that is used in welding these two is in general the same as the welding technique that has been used for welding face-hardened. Outside of one type of armor, that is, a homogeneous type of armor which was carburized and processed, the general opinion is that in order to bring up the ballistics of face-hardened plate, there will be either or both a change in the chemistry of the plate and in the method of processing the plate. This will bring new problems in the welding of the plate, which, of course, at the present time we can't anticipate what these problems are until we produce the plate that does have these high ballistic qualities."

Mr. Danse reported on activities of the Armor Liaison Group:

"It has been rather gratifying during the last period that we haven't had to have any very heavy discussions. The particular item which has been followed most assiduously has been the cast armor repair, and then again, we have also had some contacts on ferritic. The cast armor repair thing is something that we can all be grateful for. We can thank the project on the NRC-2A electrode for making this very much easier. But, in view of my past reputation for being hard on the cast armor folks, I want to say they are doing a wonderful job now in stepping up to something which will eliminate the complaints of the fabricators. The fabricators have felt rather bitter, at times, about the way cast armor repairs have been made, and I think that feeling has been entirely eliminated. I think the fabricators are quite happy with the way the situation is developing."

Major Dunlap reported on activities of the Aircraft Armor Fabricators' Group:

"The Aircraft Armor Fabricators' Group met yesterday for the purpose of discussing a proposed outline of the form in which the fabricators would submit their welding procedure. The idea of this is to get some uniform or standard form in which the welding specification procedures used by the fabricators are to be submitted. This form may be slightly modified, but will probably be adopted and become an addendum to Specification JAN-41."

Mr. Jennings reported on activities of the Research Group:

"The Research Group had a meeting yesterday to discuss some

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fourteen problems, which were handed in by the members as possible subjects for research work. As you know, the Research Group is primarily an advisory body. We do not do any research ourselves. All we do is get ideas and discuss them to try to determine whether or not the problems are of such a nature that work should be done. In addition to that, we are supposed to review work that has already been done and make recommendations to the committee as to its value and how it should be used.

"One problem, more research work should be done, is along the lines of spot welding and heat treating in the spot welding machine. NDRC had a project of this type at Rensselaer Polytechnic Institute. This has now been completed, and I think it has been shown definitely that such a system is feasible. It was the general consensus of opinion by the Ordnance Department and the Aircraft Group that there was little need for spot welding of armor because of the thickness of armor used, and the fact that they are now doing a very good job with arc welding. For this reason, it was decided that no additional work should be done on this subject at this time. Mr. Warner wanted a process specification so that he could use spot welding of this type, and the NRC agreed to prepare such a specification on the basis of work already done if they received a formal request to do so.

"A second problem--more information is desired with regard to the use of needling agents and their effect on hardenability and weldability. We were interested in the group primarily on the matter of weldability. It was brought out that considerable work has already been done on effect of needling agents; that at the present time reports prepared by NDRC and WEB, taht is the War Engineering Board, are being grouped together for distribution. Captain Randall pointed out that all armor plate today contains needling agents and a great many N.E. steels contain needling agents. Consequently, we already have a great deal of information available, although many of us probably did not know it.

"A comparison of characteristics of welded joints in armor materials used by Russia, England, and other Allied countries were requested. It was brought out in discussion that such reports have already been made. They have been distributed only to a very limited extent, I believe. They are available at, I believe, the Ordnance Department in Washington, if you care to obtain them. There have been many, many reports prepared by private industries, by the Ordnance Department, and by NRC on different phases of the welding of armor. What is needed probably more than anything else is for somebody to collect this data, compile and condense it into a brief form so that it can be made usable by the interested parties. This is a very large job, and although I believe, technically speaking, the Research Group is supposed to do things like that, I don't think there are any of use that would have the time to do it. About all we can do is to recommend that something be done.

"Development of a suitable weldability test or tests to determine the characteristics of a steel for fabrication by welding is desired. This is a problem that is now being worked on by a

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great many agencies. Watertown Arsenal is working on it. The National Research Council is working on it. The Welding Research Council is working on it. The Naval Research Lab is working on it, and private industry is working on it. At the present time we do not have a final answer. Someone should investigate why austenitic weld deposits sometimes crack and determine methods of preventing cracking. It was brought out at the meeting that the Rustless Iron Company started an investigation on this subject with NRC which was later taken over by the United States Navy; that they have arrived at some definite decisions and conclusions regarding this matter. It is desired to study the possibility of eliminating requirements of preheating on plates over 3/4" thick when welding with ferritic electrodes, that is, the electrodes of the NRC-2A type. The National Research Council is doing work of this type at the present time.

"Development of a direct explosive test for welding armor should be continued. As you know, Aberdeen has done considerable work along this line. NRC has had a project at the Trojan Powder Company doing the same thing. It was recommended by the Research Group that the direct explosive test investigations be continued.

"Someone should investigate causes for different types of welded joint failures under ballistic impact and investigate and inaugurate a program to investigate methods of preventing fusion zone failures. Again, there has been a lot of work done on this subject, and it was the consensus of opinion of the committee that nothing new should be started, but some effort should be made, first, to correlate all information that is available. Mr. Danse agreed to make available what information they collect on this subject.

"The Research Group passed a motion recommending that the NRC Projects 1 and 2 (those deal with the weldability of commercial armor and development of ferritic electrodes) be classified together as to importance, and that work on both projects be continued. Apparently, in the last classification of these projects the NRC 1 was not classified as important as the NRC 2.

"The object of the Research Group is to review problems that are considered to be important and on which research work should be done. If any of you have any such problems or you know of any that you think should be considered, if you will please send them directly to me or send them to the Chairman of the Subcommittee, who can pass them on to me, the Research Group will be very glad to give them their consideration and make a definite recommendation."

Major Matthews commented:

"The Research Group meeting yesterday was very interesting. Rather heated arguments developed, and I am sorry that more of you couldn't have heard the discussions that went on. It lasted until about 6:00 o'clock last evening. I would like to reemphasize the fact that a lot of you people get ideas, I am sure. Everybody gets ideas, and we would be very happy to have those communicated to somebody, some group that is in position to evaluate them and decide whether or not they should be pursued by NRC contracts, by the Ordnance Department. If the Ordnance Department

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is capable of helping you, we would very, very happily receive any suggestions that anybody might have in these connections.

"I'd like to say something more about one of the items that Mr. Jennings mentioned, and that was the matter of the use of needling agents. Actually, it is essentially an armor problem, but it might be well at the present time to discuss the situation as it affects the welding people in a little more detail. Back in February of 1942 all the armor people were called to Washington and told in no uncertain terms that they had to reduce the alloy content of armor plate. The armor industry, as you all know, did a magnificent job, and in approximately six months a complete transition had taken place from the higher alloy types of steels which had been used to low alloy types. First, the main requirement was to eliminate as much as possible the elements nickel, chromium and vanadium, and that was accomplished very, very satisfactorily. Well, then, everybody swung to moly steels, as you all know. And so the element molybdenum became very tight, probably tighter than any situation we had had with respect to the other elements. So, some additional work had to be done in order to lower the molybdenum contents of armor steels. Eventually that problem was licked also. At one time the average moly content for the armor being produced for the Army was in the neighborhood of 0.25%; perhaps somewhat lower over a period of a few months. Well, it was at this time that the significance of the effect of boron was generally recognized. And it was about this time that boron was initially added to armor steels. So that over a period of about a year, at least a year, from the last of 1942 through 1943, and until the alloy situation eased again in general, boron was habitually used in rolled armor, that is, the rolled homogeneous armor that you people were using for armored vehicles. So, boron treated steels have been used and thousands of tons have been made, and lots of you people, I believe, haven't realized that. Now, we can state rather categorically that boron does not have an adverse effect upon weldability, that is, if you use boron and obtain a hardenability that is equivalent to a greater amount of alloy, other of the normal alloys, to attain equivalent hardenability, there is no evidence to indicate that the weldability of the boron treated steel is inferior.

"Now, there are other problems in the use of boron which the steel industry has been battling with for some time, but which they have overcome rather nicely. One is the 'fading' effect that they get in heats of steel when they add boron. As the steel is held, the hardenability effect tends to become somewhat less, but that is a matter of the manner in which the boron addition is made. And that problem has been rather satisfactorily solved, I believe. So that in the case of rolled armor you have been using boron steels right along. Now the use of boron is not quite as general, because people have gone back to moly and have eliminated boron in some cases, but boron is still being used in three or four of the larger production steels that are presently being used for rolled homogeneous armor. The cast armor industry did not go to

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boron in general. They tried it rather early in the game and I think we might have missed a bet or two, but the cast armor industry never adopted boron treated steels. I think with the experience of the steel industry as a whole in this country, they could handle the boron treated steels, at least in the basic open hearth furnaces, if it was necessary at any future date."

Following this summary by Major Matthews a discussion of what is meant by "commercial armor" took place:

Mr. Jeffries:

"What is commercial armor? I have been plagued by that term in several instances, and I wonder what commercial armor is."

Mr. Jennings:

"I don't know the answer to that. You see, all I was doing was giving you the definition of NRC 1, and that is the name of the project."

Major Matthews:

"George Mikhalapov here just said commercial armor is armor you buy on the market as opposed to armor which may be made in a laboratory or some other sources."

Mr. Jeffries:

"I have in mind the procurement of armor, and also the disposing of a lot of armor on contracts due to excess, which I come in contact with, but I thought perhaps Mr. Jennings referred to commercial armor as the type of armor which is used in various vehicles, such as bank trucks and that the bootleggers used in prohibition days. There was a lot of that used."

Major Matthews:

"I think I can give you something more specific. I would say that commercial armor is armor which has been accepted under any of our outstanding specifications, is submitted for inspection and test under standard specification. It is not commercial, but it is commercial so far as the Army Ordnance program in the use of armor is concerned."

Major Matthews raised a question:

"I understand some of the fabricators have had trouble with some of the light plate that is boron treated. Now, would anybody care to discuss that at this time? I would like to know particularly whether those troubles have been overcome, and so forth. There was a time when there was a little heated feeling developing among the fabricators with respect to the use of boron treated steels. Now, I would just like to know whether that situation has been clarified."

Mr. Diebold remarked:

"We are using that armor plate today, and our criticism of boron treated armor wasn't criticizing the use of boron, but criticizing the lack of control present at that time of hardenability. We found that boron as a material didn't influence weldability, but hardenability such as we got it, some of the boron treated steels were terrific, with the result that we had a great deal of difficulty in welding it. I believe that was also true with Fisher Tank Arsenal on the same type of conditions. In other words, boron steel with high hardenability we found was consistently poor for weldability. If we cracked one plate of the heat we cracked them all, and if it was low in hardenability, relatively speaking, then no trouble was experienced at all. So far as we were concerned it was a question of controlling hardenability in the manufacture of the steel."

Major Matthews continued:

"The problem here, I think, you all recognize. The steel mills have to roll armor for the various and sundry contracts, covering, we'll say, thicknesses from 1/4" to 2". Obviously, because of the order situation, it develops in certain cases so that they have to use heats which probably had been melted for heavier thicknesses on light plate orders. That is one source of the difficulty. The tremendous effect of boron hasn't been recognized. If you take a steel consisting of multiple alloy steel and all your elements happen to be on the high side, and if you boron treat it, then, you will probably get a 100% higher hardenability than you would if all the elements were on the low side. That is one of the inherent difficulties of N. E. steels; the same thing applies."

Mr. Mikhalapov reported on NRC Research and Development Projects:

"The first is the project, the title of which perhaps I had better skip in view of the objections raised to the term commercial, but it has to do with the welding of armor. As you remember, about a year ago, there was an extensive program of welding armor plate and testing it under cold conditions in Canada. Well, we finally wound up that investigation by the issuance of the final report dealing with one batch of plate, that is, the plate welded with chrome-nickel-molybdenum electrodes. Looking over the experience gained with the examination of these plates, as well as other plates welded with austenitic electrodes which have been examined as part of the program, it would appear that we can now safely say that the most probable cause of failure of these welds is carbide and silicate segregation and precipitation on the inner face of the weld, a few thousandths from the ferrite, or ferritic material, in the austenitic material; and depending on the extent of the precipitation and on the shortness of the path through the plate along that layer precipitation, the plate fails or does not fail. But in manually welded plates where the rate of cooling is such that the base plate is not appreciably affected, it would appear that failure is a function of this carbide precipitation, and also of the length of the path in which that precipitation is present.

"A study of the 1/2" plates welded with ferritic and austenitic electrodes reveals on the other hand that in the thin plate the cooling rate is insufficient to produce quenched out martensite next to the weld, and for this reason a weakened zone adjacent to the weld in the heat-affected material is found. In an examination of a number of plates it was definitely found that approximately 70% of all failures occurred in that heat-affected zone, and that in those cases that heat-affected zone contained equi-axed ferrite, which it appears is particularly susceptible to cracking. Combinations of joint design and welding procedure which result in a high percentage of acicular formation products in the heat-affected base metal are definitely superior to those joints and procedures which result in the formation of appreciable free ferrite. In other words, the joints which result in the less heating of the metal next to the weld and the most rapid rate of quench after are the superior.

"In connection with the development of ferritic armor welding electrode, a study has been made of the isothermal transformation of the weld metal obtained with this type of electrode, and a short report is now being submitted on that. Two observations may be of interest in connection with this study. The tendency to form acicular ferrite is considerably greater with this type of weld metal than with any other type of ferritic electrode examined. Also, the acicular ferrite formed in the neighborhood of 1000°F. causes the residual austenitic pools to acquire sufficient carbon to suppress transformation at intermediate temperatures, with the result that the final deposit consists of acicular ferrite and tempered martensite. This deposit does not readily lose its acicular nature on reheating.

"Insofar as the development of NRC-2A ferritic electrode is concerned, we have been attempting to do three things. We have been attempting to reduce porosity and to lower the preheat temperature necessary to deposit that weld metal in the restrained joint without cracking. It would appear that those two phenomena are not dissimilar and that the same factor may cause them both, that is, may contribute to them both. In addition, we have concentrated rather heavily on modifying the chemistry of the weld metal to permit a better suitability for heat treatment, such as found in cast armor specifically. Briefly, the present weld metal composition is susceptible to tempering treatments at about 1200° F, or higher. The hardness drops off very drastically and the joint suffers as a result. We are attempting to develop a composition which would not drop off in hardness at those temperatures and still be equally crack resistant, that is, better say, equally non-crack sensitive. About the only statement I can make is to quote Captain Boucher when he said yesterday to the Homogeneous Group that in general the ballistic shock resistance of butt welds made with ferritic electrode are superior to those made with austenitic electrode, but the performance of corner joints and T joints, due to the geometry and the stress concentration factors involved, is about the same, and since 90% of tank joints are of that nature, the over-all performance of structure of the tank type made of the two types of electrode is very, very similar.

"The work on spot welding of armor plate has been completed.

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A final report is coming out. The work has established pretty well that spot welding of armor plate is possible and that considerable strength can be obtained. Unfortunately, we have not had a chance or time to go into the phase of this work which is perhaps more in the realm of development than research, and that is the actual evaluation of a spot welded joint in terms of arc-welded joint. At present we don't know really as to how a spot welded joint compares when subjected to ballistic shock with arc-welded joint subjected to the same type of shock. Since it seems at present that the field for spot welding of armor plate is quite narrow, we are not contemplating conducting this development.

"The direct explosion test for welded armor plate, on which there has been considerable controversy in the research circles as to its validity is more or less coming to an end, though it may be revived. Briefly, we have been able, by the means of a low velocity explosive to establish a general correlation between the shock performance of a welded butt joint 18" long by 18" square when subjected to explosive test, and that of H plates when subjected to ballistic shock. The amount of work done has not been sufficient to permit a clear decision as to whether or not this test is practical and helpful. We have also tried to test a series of fillet attached plates using austenitic and ferritic electrodes by means of this test. The results have not been too clear, because we are attempting to test both the test and the electrodes with it. We have developed very nice ways of measuring the biaxial stresses through the thickness of the plate, and found that it varies considerably, that the stress of the surface is quite different, much lower, than the stress in the middle of the plate. We have also established the fact that the residual stresses produced of austenitic, ferritic, and NRC-2A electrodes are all about the same order of magnitude. Such improvement in performance as may be found with the austenitic and NRC-2A electrodes can be attributed to metallurgical factors and not to residual stresses. Actually, if you are not careful, stress relief particularly in austenitic joints may do far more harm in shock resistance than it can do good, depending on temperature, I suppose, at which it is done.

"On flame cutting of armor plate: We have considerable trouble in obtaining cracks, except for internal corners, and those only would crack when the radius was very small, less than 3/16". By internal corner, of course, I mean a square cut in a plate. On an external corner or straight cut on the armor examined, which has been 1-1/2" in thickness, on the nickel-chrome, moly-chrome manganese, chromium series, we just couldn't get any cracks whether the armor was heat treated or whether it was not heat treated. The variations of cutting variables and procedures did not appear to affect the tendency for cracking at all. In other words, we went beyond all possible ranges of practical cutting procedures and still couldn't find any difference insofar as cracking tendency is concerned. Insofar as the cracking on the internal corners is concerned, the factors which are most important in influencing the cracking is rigidity of the structure.

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For instance, if you have a hole in the middle of the plate you are much more apt to get a crack than if you have a hole right close to the edge of the plate, because, there, of course, the restraint produced by geometry is much less. The temperature of the plate, of course, and the residual stress pattern in the plate has a good deal to do with it. A rather tentative conclusion, but nevertheless which appears to be quite definite, is that the residual stress present on the surface of flame-cut armor is compression, not tension. That appears to be due to the fact that you have a very high hardness, essentially pure martensite, on the surface, and that martensite has a larger volume than the ferrite back of it, therefore, under compression.

"There is one more investigation which is to us most interesting, and that is the study of the effect of the arc atmosphere on the properties of the joint. I think we can now say without any shadow of a doubt that hydrogen is responsible for most of our trouble. When an atmosphere of pure CO and CO_2 without any hydrogen is present, no cracking, underbead cracking, will be produced no matter what the hardenability of the material is. With an extremely high hardenability plate, using a plate which was practically refrigerated from the bottom by ice brine, and in that atmosphere we still cannot get any cracks. However, the moment hydrogen is introduced, cracks begin to appear. The interesting part is that the first manifestation of the introduction of hydrogen is porosity. The next manifestation is cracking, and as the hydrogen content increases the porosity tends to disappear and cracking tends to increase. We do know that when the volume of the total gas atmosphere per linear inch of electrode drops way down, that we can stand very much higher percentage of hydrogen. In other words, there has got to be a certain volume of hydrogen and also a certain concentration of it in order for these adverse conditions to exist. A rather curious phenomenon which we don't quite understand is that in an atmosphere of completely pure hydrogen with nothing present the arc just won't arc. It just won't exist."

After lunch Col. Hoare commented on armor welding developments in Canada and England:

"They are still building some heavy armored cars out of homogeneous hard armor, that is, about 400 Brinell, of 7, 10, and 12 millimeter. We had some trouble with that in the early days of the war, as I think I have told you before, due to the cracking of welding; but, now, they are postheating this vehicle that they are making up to about 200° C. and are using 18/8 electrode, and as far as I could discover they were not having any cracking troubles. There is only one firm over there that is using X-ray examination to any extent. The other people are just doing it by visual examination, and one formed the impression, after being around the plants here, that they seemed rather casual about the method of inspecting welds. They are also welding a heavy tank over there with 5-1/2" and 6" armor, which is rather interesting. All the welds are being done by hand welding. All these thick plates, they

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are preheating them to about 110° Centigrade. Some of them in the thinner plates, they are using rather high carbon, and to counteract the troubles they are using 25/20 electrodes when welding the higher carbon material.

"They are using two methods of testing for cracks over there. There is the Swinden T test, which consists of 14 millimeter plate, strips about 3-1/2" or 4" wide, and welded by means of a T, and underneath the weld on the head of it, there is a section of about 3/4 mild steel, which makes it rigid. And, then, there is the ring-weld cracking test which they use for assessing the relative weld cracking susceptibility in various types of electrodes, that is, the base of the alloy you are going to use, 1" thick, and there is a circular hole cut 4" diameter, and into that is welded a center piece, after V-ing each side. The center piece is tacked in and there is a definite sequence of welding it. There is a certain amount of experimental work going on on the weldability of light armor plate up to and including 14 millimeters. The tests are on a large number of different analyses, most of which were of a high hardenability. The conclusions that have been arrived at as a result of those tests are that the carbon content has the greatest single influence in cracking in the fusion zone, and that the alloys exert only a secondary influence, and the report also concludes that the difference in the heat treating methods has no influence on the cracking susceptibility. They consider that 0.35 carbon is the allowable maximum, in contrast to the 0.30 allowable in Canada.

"There are some experiments on the manganese-moly-ferritic electrodes going on. Samples have been prepared, and they have come to the conclusion that these electrodes are not suitable for the welding of light armor that is being produced in England. They have experienced the same trouble as has been experienced here with the porosity on the NRC ferritic weldments. They suggest that the use of mild steel wire and the introduction of hardening elements by means of the coating might overcome the trouble. They also suggest that if core wire in the one and one-half chrome-moly content was used that it might ease the situation. The cracking that they have had, although it looks serious from a production point of view, they have not found it to be very detrimental when the vehicle actually goes into service.

"In Canada I subjected the vehicles to very strenuous cross-country running, and also did an extensive amount of firing at the cracks; and we had no trouble with the cracks extending or the ballistic immunity of the vehicle suffering, nor its mechanical stability. It is only a psychological question that when the troops in the field see that there are cracks they begin to suspect there is something wrong with the vehicle. Certain cracks have been found in vehicles when they have gone into service, but they have not seriously affected the utility of the vehicle or its ballistic immunity. So it is considered that these repaired cracks, although they certainly look better, they make very little difference to the battleworthy condition of the vehicle.

"Up to the present they have been welding plates, that is,

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rolled plates, into the cast turrets, and although they have been made in .35 carbon steel, that welding has been successfully accomplished by buttering the edges with 25/20 electrodes, but new vehicles coming into production would require extensive welding of cast armor, and they have thought, then, buttering was not practical. An attempt has been made to arrange a change over to steels containing a maximum of .35 carbon, but it has produced a difficult problem because it means water quenching, and no facilities existed for doing that at the various firms where they were being made. They have been doing some experiments with the hard surfacing of ferritic welds in one and one-half chrome-moly armor to determine the resistance to impact and armor-piercing attack of the surface hardened welds on this one and one-half chrome-moly homogeneous armor, and have come to the conclusion that the immunity of joints in armor welded with mild steel electrodes may be increased considerably by hard surfacing. And they have come to the conclusion with that, that repair welding of cast armor to a depth of up to three-quarters of the thickness does not affect the ballistic properties, but a repair weld which goes right through the thickness definitely lowers the immunity. They have used the 25/20 and 18/8 austenitic electrodes, and having subjected it to the attack laid down in their standard specification, they have not found any difference between the results with the 18/8 and the 25/20 electrodes.

"As regards Canada, we are still building self-propelled mounts up there. One of the troubles we have had is getting the root weld cleaned satisfactorily so as to get adhesion between the next runs. We took a series of welds and ground them out, and a similar series and burnt them out, and are carrying out firing tests to see if there is any difference, because we have found out that if we burned them out that it is much easier from a production point of view than grinding them out. With reference to the cracking of six millimeter homogeneous soft bullet-proof plates, we have come to the conclusion that the only way of overcoming that trouble is to reduce the hardenability of the plate, and so all those plates that are being welded into a body have to lie within a definite range of hardenability. If they don't, then, we have to use those plates on a riveted structure instead of on a welded structure. There is still a fair amount of ferritic welding being done on these bodies in Canada, and we have had very good results with it so far. We are still employing the direct explosive test that I told you about last time.

"I have just one or two notes on German armor which may be of interest to you. We have found that in examining German armor that there is still a variety of electrodes used on the same hull, but there appears to be some definite reason for it, inasmuch as the steel that they are using also varies. There are some mild steel welds we have found, and they are used for the internal attachments to the inside of the tank for various fitments, and some of those are made with mild steel and some with manganese modified austenitic rod. In all the cases that were examined, there was a tremendous amount of undercutting noted, which rather points to a

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lack of proper welding technique. And also, there was a very high hardness in the parent armor, and brittleness in the heat-affected zones around where these attachments are put on, which rather points to the fact that they are experiencing difficulty in getting satisfactory welds. From samples taken from a German tiger tank, we found that the root bead deposit on these were austenitic in character, and other beads were found of the manganese-chromium-nickel composition of a non-austenitic character. The rods used to make these deposits appear to be borderline austenitic, and the differences that were found are possibly due to pickup, and it has resulted in some cases in a ferritic deposit. The deposit of the weld metal was very irregular, and some very high hardnesses were noted in the adjacent zone, which gave failures in the fusion zone of the metal.

"As far as the present exploration has gone, there have been some austenitic electrodes used at the roots of all butt welds. There has been an alloy ferritic used in the main body of the welds. There has been a ferritic used in the mild steel parts, and a hard surfacing electrode has been used where the welds are exposed to direct ballistic attack. And we found, also, varying hardnesses due to the varying thickness. For each thickness the hardness is about 50 Brinell points higher than we used in England. The composition of the plates, which may be of interest to you, fell within carbon 0.33 to 0.38, manganese 0.36 to 0.42, chromium 2.4 to 2.57, and moly 0.35 to 0.47. All the German weldments that we looked at gave indication of an inferior quality, but it seems that this is more than compensated by the structural strength that they put into their joint designs. All the joint designs on a German tank are such that they depend for the rigidity of the structure on the fit of the plates together rather than on the weldment."

Major Matthews remarked:

"We would like to tell you people of some of the work that we have been doing at Watertown; not to pat ourselves on the back, but to indicate that we are striving very hard to evaluate the factors which influence the ballistic properties of welded joints. In other words, we are trying to take the mystery out of it and show you by analyses, which we hope all of you can understand, that when the plates fail there is usually a very good reason for it. When plates are good, there is a lack of deficiency in the welded joint which would account for a failure. Now, the work has gone along to quite an extent. We have confined ourselves so far to commercial material that has been made available to us. Samples from 50 to 60 plates have been analyzed rather completely. The work is continuing, as you may imagine, and we hope to be able to outline to you people today tests by which the fabricators themselves can go a long ways in evaluating new welding procedures, new electrodes, new joint designs and things of that sort."

Mr. Warner explained:

"I don't want to take very much time, because I know you are going to be interested in the results of the work on armor welds.

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Primarily today we want to give you the results of studies of armor welds and some brief concept or idea of what the future result of those studies may be, as far as steel structures are concerned, which may not be and probably won't be armor weldments. The results of some of this work have been issued in the form of experimental laboratory reports, restricted reports. Because of paper shortages and other reasons, those reports have not been distributed to the Subcommittee membership. They have been distributed to the members of the Research Group, though some of this probably will be an old story to the members of the Research Group who have received copies of these reports and have studied them. Some of the information will be given you is the result of more recent studies which have not yet been published. I am going to ask Lieutenant Herres to tell you something about his examination of welds in armor."

Lt. Herres commented:

"I have four subjects here to discuss. I am going to spend the most time on the first one and very briefly summarize the conclusions on the others. The first one is evaluation of shock properties of welded armor joints by laboratory tests. Now, we had a number of photographs which would have shown many of the specific defects that I wanted to talk about much better than I can tell you, but we don't have the projector available to show these photographs. I would like to start out with a definition of weldability which we have used in structural studies. It fits into armor and is a fairly good introduction to the test work. This definition is that 'weldability is the capacity of the steel to be fabricated by a prescribed welding procedure without detriment to its service properties.'

"On that basis, <u>the first step in evaluating weldability</u> is a description of the significant welding procedure variables. These variables must be controlled within the limits of commercial fabrication, and if no control is possible, you must represent the worst conditions for the test. The welding procedure specification AXS-497 has a table listing the welding procedure variables, For the procedure qualification the H plate is the final test of weldability. One factor which cannot be represented is external restraint, so the H plate is designed to represent the worst possible condition in that respect.

"<u>The second step in weldability evaluation</u> is a decision as to the desired service properties, how to test for them, and the degree to which they are required. For ordinary structural weldments we can say that strength, toughness and soundness in base metal and all components of the welded joint are the requirements. For armor weldments we say resistance to ballistic penetration and resistance to ballistic shock. We don't worry too much about resistance to penetration. The austenitic weld has about 80 to 90% ballistic limit of the base metal. Some attempts have been made to use hard facing electrodes as Colonel Hoare mentioned, but we have really concentrated in this country almost entirely on shock resistance. The established laboratory tests have not been too

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successfully correlated with ballistic properties, so we started an investigation at Watertown about a year and a half ago. Since ballistic shock resistance is really toughness, we defined toughness as the ability to absorb energy by ballistic deformation. It is established that toughness depends on the rate of loading, the temperature, at the time of loading, and the constraint against deformation. Major Matthews' armor section and Dr. Zener and Capt. Hollomon have worked on that and established mathematical equivalents between rate of loading and temperature. It has also been established for a long time that there is a qualitative equivalent between those two and the constraint against deformation.

"We can evaluate the toughness of the weld metal and of the unwelded base metal by notch bar testing over a suitable range of temperatures, but a fracture test produces the same results on a large scale. Brittle failure indicates little or no plastic deformation and gives you a characteristic crystalline appearance of the fracture. There are many small facets formed which reflect the light to produce this effect. On the other hand, a steel with a tough fracture, giving a high energy of the impact, has a fibrous fracture. The metal is deformed at the fractured surface and doesn't reflect the light, We may say that there are four general conditions of the steel which influence its toughness: first, amount, form and distribution of carbides; second, amount, form and distribution of non-metallics; third, grain size and related effects; and fourth, aging characteristics, which include temper brittleness, and precipitation hardening. As far as welding goes, we are almost entirely confined to consideration of the first two factors, the carbides and the non-metallics. We use this knick break fracture test across the weld joint. Whether the fracture is crystalline or fibrous, it gives you an indication of the toughness of the heat-affected zone, the unwelded plate, and the weld itself. We know that is a size effect that comes into these tests, that is, on 1-1/2" plate with a given metallurgical structure which may produce brittle failures in a standard notch bar test, it will also produce brittle failures in a heavy plate. In a light plate to get the same effect we have to go to a sub-zero temperature or a fairly rapid rate of loading.

"We examined 33 plates that were tested at Aberdeen, and 31 that were included in the Canadian cold test program, and our principal conclusions are based on these two tests and a little microscope work. We found transverse tensile and hardness tests measured the properties of a welded joint under static loading conditions, and they didn't give us any correlation with ballistics or any indication of the path of fracture under ballistic loading conditions. With a certain steel quenched and tempered and also normalized, at identical hardness and from a tensile test you couldn't tell the difference. With a Charpy test at room we get 49 foot pounds with a fibrous fracture when the steel is in the quenched and tempered condition, and only 7 foot pounds with a crystalline fracture when the steel is in the normalized condition. Well, that is one condition we run into in welded joints in the heat-affected zone. With certain welding processes you put so much heat into the plate

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so that it cools very slowly and produces an essentially pearlitic structure. With that condition of the heat-affected zone your ballistic fracture will tend to proceed through the heat-affected zone almost any where, depending upon the geometry and location of the loading. A second type of failure, and the most important, is a fusion zone type. We found two conditions to which we can attribute most of the fusion zone failures. The first one, for a type of fracture which gives you a scale of weld metal over the whole fractured surface, shows the rims of the weld bead and has a scale of weld metal of not more than one to three thousandths of an inch over most of the fracture, of austenitic weld metal. However, that amount of weld metal is enough to get away from most of the metallographic conditions of martensite, or dilution effects from the plate metal. So the failure is not in the austenite. That type of failure we have found to be associated with a very fine precipitant of non-metallic inclusions, parallel to the fusion zone and one to two thousandths of an inch from it. That is the predominant type of bond zone failure. The second one is brought about by a carbide precipitant right at the bond. That gives you an entirely different type of failure. You have a fine crystalline appearance on the fractured surface. We found that in some of the cold tests where apparently they hadn't controlled the inner-pass temperature and let it go up high enough in this region where your carbides precipitate.

"Other types of failure found in these investigations were a slack quenched cast armor, which failed in the unaffected base metal. That was a result of not enough alloy and not severe enough quenches. Another type of failure was right through the austenite. It is a dendritic type of fracture that is variously tied up with the segregation due to the austenite being off balance. We have an etch that shows that up in the micro-examination, and whenever it is excessive you get this very brittle dendritic failure right through the austenite. The last type of defect disclosed in these tests was due to dirty armor plate. Directional properties mostly apparent where the armor was straight away rolled and excessively dirty, it started at the weld reinforcement and proceeded through the unaffected plate, giving a woody type fracture. We took some Charpy bars out of it and transverse to the rolling direction. The value at room temperature was down to 20 foot pounds on the Charpy V notch. It should be about 45 foot pounds at that same hardness level.

"Some ferritic welds were included in the samples that we investigated, and I have just briefed it down that the three principal causes of trouble with ferritic electrodes are: Underbead cracking problem, which may be solved by use of modified electrode coatings, or a small amount of preheat; second, weld metal cracking, which with available ferritic electrodes of the NRC type requires 200 to 300° of preheat for 1-1/2" gauge armor plate--no preheat for 1/2" gauge plate--; and three, shock properties of sound weld metal, which is largely a matter of carbide distribution. We do know at least that sufficient alloy is required to give a martensitic type microstructure in the weld heating and cooling cycle. The present NRC electrode, we have found, will not quench out in weld plates of greater than 3/4" thickness. The Charpy values of a Unionmelt ferritic

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welded joint: At room temperature we have 13 foot pounds; at zero we have seven; at minus 40 we have six. That is .17 carbon, .92 manganese, and 0.42 moly. A manually welded ferritic with the NRC type electrodes gave us Charpy values of 30 to 45 at room temperature; 12 at zero; and nine at minus 40. The analysis was .13 carbon, 1.50 manganese, and .60 moly.

"We had a program on welding of .40 carbon armor plate with 8740 type analysis supplied to us by Republic, 1-1/2" gauge. The first two plates that we welded we used a procedure which we regarded at the time as quite good; 45° double bevel, small annealing beads with a 5/32 electrode. When they were fired at Aberdeen, however, they failed, showing excessive ballistic cracking in the weld metal adjacent to the weld metal bond. We got them back to Watertown and examined them, and we couldn't see that the type of failure was associated with the base metal composition. We started welding other plates, and we found that the .30 carbon was just as bad as the .40 carbon when welded with the same procedure. We had indicated that this was associated with these non-metallics, and we see those in practically every weld we look at. Rather than trying to cure that, we tried to avoid it by throwing the failure either into the plate or into the weld metal. If we can get failure into either one of those—and they are tough—the failure won't proceed very far in the ballistic H plate. Finally we arrived at using very large, or comparatively large, 3/16 diameter electrodes for the annealing beads. That helped a lot, but to be safe, we ground an extra little bevel for them at the edge of the groove which is a great help to the welder, as he can guide his annealing bead along that second bevel. And with this type of failure we did throw it into the weld metal. It gave very tough bend bar tests that showed a great deal of deformation. We welded two additional .40 carbon plates and one .25 carbon with this procedure, and also a .25 carbon plate with the original procedure. Well, the three made with the improved new procedure were tested at Aberdeen and took a total of 12 rounds. On no round was there more than 3" of cracking. The .25 carbon plate welded with the original procedure cracked 18 inches on the first round. Included in this program were two ferritic welded plates with which a 300 preheat was used to avoid a weld metal cracking, but once the plates were welded they performed very well at Aberdeen, about equivalent with the austenitic. One of them was slightly better and the other one was worse.

"On examination of German armor weldments, Colonel Hoare has already told us a good deal about them, and our investigations bear out his conclusions in general. The first joint we examined was from a PZKW-3. It was made with an armor of .50 carbon, .60 manganese, 1.50 chrome, .20 vanadium, and .58 moly. They welded this thing was a .18 carbon, .27 manganese, 1.23 chrome, 2.00 nickel, .30 moly and .87 tungsten. They used a mortise joint and they got considerable cracking during welding, but apparently the mortising gives them some ballistic stability. We made a rather complete examination of armor and weldments on PZKW-4, that is their medium tank, and on the heavy tank. The Armor Section of the Laboratory carried out all of the armor investigations and the Welding

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Section carried out examinations of the weld joints. The medium tank was made with cross rolled armor of two general types. The thin plates, 1/2" gauge, were homogeneous at a hardness of about 450 Brinell. The type composition was 0.40 carbon, 0.80 manganese, 1.50 silicon, 1.25 chrome, no nickel or moly. The heavy plates, which went up to 2" in thickness, were made with 0.40 carbon, 0.40 manganese, 0.40 silicon, 2.5 chrome and 0.25 moly. These plates were flame hardened, and we have a face hardness of approximately 600 Brinell, and a core hardness of about 330 to 370. It was a very beautiful flame hardening job. The armor in general was of a very good quality, too.

"The design of the principal joints is characterized by grooves machined in the heavy armor section to give fitted or mortised joints, which were in compression on impact from the direction of principal ballistic attack. These joints are held by outside welds placed in a V, and having a depth of penetration of about three-quarters of the thickness of the light armor section, and by inside fillet welds with no preparation and having very slight penetration. So, the net result was not very deep penetration of the weld metal, nothing like our standards. The inside fillet welds and the body of the outside welds were made with an electrode which gave austenitic deposits analyzing about 0.13 carbon, 1.10 manganese, 6.0 to 9.0 nickel, 13.0 to 16.0 chrome, and 0.50 to 1.75 moly. The crown deposits on the outside welds were made with a hard facing type electrode which contained 0.75 carbon, 4.5 nickel, approximately 2.0 to 3.0 chrome, and 0.50 tungsten. However, the welds which were intended to be hard faced actually did not have very high hardness. Extensive base metal cracks were present in the heavy base metal sections of two complete weld joint samples, and failure of three broken weld joint samples was entirely through these base metal cracks. A fourth broken weld joint sample appeared to represent an angle joint made by butting plate edges and welding with too shallow penetration electrode, a very poor type of weld. The heavy tank used cross rolled homogeneous armor of two type compositions. The 1" hull roof plate and turret roof plate contained 0.50 carbon, 1.0 manganese, 1.0 chrome and 0.2 moly, plus 0.1 vanadium. The hardness of that plate was about 363. The main plates, side plates and front plates went up to 4" in thickness; had a hardness of approximately 320, with 0.50 carbon, 0.6 manganese, 2.5 chrome, 0.6 moly analysis. The joint design was the same as on the lighter tank. Most of the welding was done with an electrode which gave a ferritic deposit containing approximately 0.17 chrome, 7.0 manganese, and 1.0 nickel. I think they probably intended to have an austenitic deposit there, but they didn't. An electrode which gave an austenitic deposit containing approximately 20.0 chrome, 4.5 nickel, and 3.0 manganese, was used apparently indiscriminately. Sometimes you find it in the roof; sometimes in the body; and quite often in the crown.

"The rough surface appearance and undercutting, as Colonel Hoare indicated, showed inexperience or carelessness on the part of the welders. All the welds were made of multiple overlapping beads and appeared to have been made on this armor in the final heat treat condition without preheating. Very extensive base metal cracks

[redacted]

were present in this tank, as in the other one. We have the conclusion here that this examination revealed an amazing lack of concern by German fabricators and inspection facilities for base metal cracking, which you would expect in this high carbon plate, which must have occurred during welding and been present when the vehicles went out of the shop, and which had a very apparent and universally recognized effect on the shock resistance of the structure. The type of cracking that we find in these German armor weldments is a hot crack, intergranular hot crack, in the base metal. And we found that with a commercial American electrode we had to go to 300°F. preheat to avoid entirely this type of cracking."

Major Matthews added:

"I think it might be well to summarize what Lieutenant Herres has said by stating that with the use of these two simple test bars here it is possible to narrow down your source of difficulty. If, for some instance, you decide that you want to change your welding procedure in some way or another, you can weld up a small test specimen, some 12" long, a butt weld or what have you, with the armor you are going to use, and the electrode that you plan to use in production, and by performing these simple tests you can pretty much channel your deficiencies, if there are any, in the joint that you have made into one of three difficulties. In other words, you can immediately tell whether your failure is in the heat-affected zone, that is, of the parent metal, or whether it is at the fusion line, or whether it is through the weld metal; and you will immediately know a lot about what your possible sources of difficulty are.

"For instance, if your failure is in the heat-affected zone, then, obviously you have a poor metallurgical structure in the base metal. And that is usually caused, if the armor was right when you started, by an excessive heat input which has caused the development of a poor structure in the plate metal itself, that is, in the parent metal in the heat-affected zone. And the same thing is true of your fusion zone failures. That is a little more complex story, but certainly if you have a fusion zone failure, then, you know that your weld metal is all right, perhaps. You are rather sure that your deposited weld metal has satisfactory properties, and you can be pretty certain also that your base metal properties are satisfactory. And if you get a failure through your weld metal, then, there is not much use of worrying about your plate metal or possibly also the technique that you have used. It is then a function of the analysis of the deposited electrode and its resulting properties. So I would just like to leave that with you, that these tests do allow a rather nice selection of the variables that are involved, and their channeling into two or three types of characteristic failures which you can see very nicely by performing these tests."

Dr. Muller asked:

"What kind of a setup do you use in connection with the bend test, the small specimen?"

[redacted]

Lt. Herres replied:

"We put this on a couple of blocks, using a standard span of six inches. We place a 1/2" square bar across and parallel to the center of the weld, and a plate on top of it to protect the machine, or the drop weight, and drop the weight. On 1-1/2" plate we find we can make the test as slowly as we want to. Apparently this size effect which nobody has explained too adequately has a great influence. On 1/2" plate we use an impact test. On the 1-1/2" we use a slow bend test. This is just a quantitative test that you can use in your own shops if you want to increase the severity by increasing the rate of loading, or decreasing the temperature. But for the ordinary types of austenitic weld that we have found, in which failure is attributable to a large extent to geometry or gross defects, it does give you a very nice test. You can increase the severity according to what you want."

Prof. Hess asked:

"How do you break the eight by eight plate?"

Lt. Herres replied:

"We break all of those in a steam hammer, using the same type of setup; a bar across the middle of the weld, a plate on top of that to protect the hammer. And, then, we use a 3,000 pound steam hammer which breaks them very easily in one blow."

Major Matthews remarked:

"We'd very much like to see somebody else do some work along these lines to confirm our contentions that they are useful tests. I think they can be developed by fabricators so that they can materially save them a lot of H plates and the cost, material and man hours that are entailed in preparing H plates. Any further discussion on this whole business? If not, I am going to ask Mr. Warner to tell us something about the influence of what we have learned in armor welding on the future of welding in, shall we say, structural steels for various and sundry applications."

Mr. Warner continued:

"I am going to take just a few minutes to show a few tests we made at Watertown on a common commercial grade of structural steel. It happened to be Yoloy, 0.12 carbon, 1.54 nickel, and about 0.75 copper, with the usual manganese and silicon. As rolled it has a yield of about 54,000, a tensile of about 75,000. After 1150°F. stress relief, that drops a little to about 50,000 yield and about 70,000 tensile. After a quench from 1600°F. in water, and a temper from 1150°F. with the air cool, it shows a yield strength of 80,000 pounds per square inch and a tensile of about 90,000. After stress relieving at 1150°F., that yield of strength drops to about 75,000, with a tensile of about 85,000.

"Now that particular material is only 3/16" thick, and it is too thin; therefore, to make a standard Charpy test, we had to make a half standard Charpy test. This specimen is only 3/16" in width and the usual .394 in the thickness. We test it in the usual manner for the Charpy test. In the 'as rolled' condition tested at room temperature a specimen like this of 3/16 Yoloy plate gave us 11 foot pounds. At 70° below zero the same material gave us 3 foot pounds. Quenching this material from 1600°F. and tempering from 1150°F., at room temperature we obtained 15 foot pounds which is a little bit higher than the 'as rolled', you see. At 70 below zero it gave us 14 foot pounds.

"So, we were interested to see what you could do with this sort of thing in the way of a small structure of such a size and shape that we could test the whole structure with an impact test. So we built some small beams. Each beam was of the box girder type, with two web plates each about 5" wide and 33" long, two flange plates each about 3" wide and 33" long, and a single pass fillet weld, about a 1/4" fillet, on the outside only, at each of the four corners longitudinally. We set this up on blocks about a 31" span and dropped a 200 pound weight, striking it in the center. We had previously put a square block in the center of the beam to again prevent Brinelling of the weight into the beam. We tested these beams at room temperature and also at minus 90°F. below zero. Welding this material, now, which is a 0.12 carbon steel 'as rolled', with a commercial 6012 type of electrode and testing at room temperature, we dropped a 200 pound weight 13 feet three times. All we could do was produce just a little bit of deformation, or a little bit of bending. That beam was bent slightly.

"And I want to show you what happened to a similar beam when we tested it at 90°F. below zero, and also similar beams out of this same material quenched and tempered. In our armor we are looking for fully quenched and tempered material to get maximum toughness for the hardness level to which we are heat treating. For structural purposes we may not need a fully quenched and tempered material. We may be able to hit for some intermediate value on our quench and temper and still have adequate toughness for the structural use to which we want to put the material. We don't know what that is, where it may be. I am just pointing this out to show you what a big field for research or development, whatever you want to call it, lies ahead of us if we are going to investigate this subject fully. In order to refrigerate these beams, all we did was to put a block of wood on one end--these are hollow beams--set it up on one end and fill it full of acetone and dry ice and let it set for half an hour or so. We had thermocouples stuck on the side plates here on both sides to measure the temperature. Actually the temperature as measured by those thermocouples showed 101 degrees below zero.

"Testing the beam built of 'as rolled' 0.12 carbon Yoloy, welded with E-6012 electrode, at minus 90 below zero, the beam fractured completely with one blow. And those beams broke so quickly and so readily that the striking of the bottom edge of the fracture here on the base plate of the machine marred the edge pretty badly so that it is difficult to examine the fracture of that lower flange plate. This flange plate snapped like a piece of glass, and so did the web plates--one blow of the weight.

"The same type of beam welded with E-6012 electrode, but the

[redacted]

plate material now being in the fully quenched and tempered condition, after two blows of the same 200-pound weight at minus 90 below zero showed only slight bending without fracturing. I just want to show you what can be done with a very readily weldable garden variety of structural steel by a quench and temper. Now, if the structure which we are to build is to be stress relieved after welding, we must limit the draw temperature, or the tempering temperature, to such a temperature that we can safely stress relieve it after welding. In other words, if we are going to stress relieve at 1150°F., it is foolish to draw it at a lower temperature than 1150°F. If we are not going to stress relieve, then, we can produce a higher yield strength by drawing at 1000°F. or 1050°F., or something of that sort, but these beams are of plate all tempered at a temperature of 1150°F.

"Here you can see a crack had started in the weld metal. Low carbon weld metal is pretty brittle at minus 90 below zero. This crack was apparent after the first blow, but its progression of its travel into the quenched and tempered base material was unappreciable on the second blow. I don't know how many times we would have had to wallop this to actually make the crack go clear across the beam.

"And I might say Ordnance designers, I think, are talking of yield strengths of 150,000 pounds per square inch for gun mounts, and that may bring on some more interesting possibilities as far as welding steel structures is concerned. I am sure that structural engineers who have to build steel structures out of commercial low carbon steels which have to stand vibration, impact and low temperatures, and so forth, might possibly be interested in this concept of structural material."

Mr. Webster added:

"I just had one of our artillery people approach me the other day in regard to this development of this, say, 150,000 stock that they are worried about in lightening the structures of field carriages. Apparently, as far as strength is concerned, and the welded joints, with the proper material properly relieved they shouldn't experience any trouble. Of course, the other thing in the design was the matter of getting enough rigidity with the lightened material, and that was something I went over with them several months ago. I believe they have about satisfactorily solved that problem."

Mr. Warner continued:

"We have to bear in mind that about the maximum yield strength we can get out of weld metal at the present time, as far as I know, is obtained with electrodes of this NRC-2A type and other electrodes similar to that, of the order of 90,000 to 100,000 pounds per square inch; tensile running 110,000 to 115,000. Now, if we are using a base material of 150,000 pounds per square inch, unless the design is such that the weld is not the limiting feature in that design, we can't make use of 150,000 pounds per square inch. So the design and welding must go together on this."

[redacted]

Major Matthews added:

"There is another item that I would like to clarify here, and that is that in making weldments for gun carriages, and so forth, we have to worry about dimensional stability in certain cases, for instance, top carriages and things of that sort. Under those conditions, of course, a stress relieving treatment is required, and to properly relieve the stress in a reasonable time, we need a temperature in the neighborhood of 1100°F. So, that does limit the yield strength that we can obtain, also, even in the quenched and tempered material, to a certain extent. It certainly does with the type of electrodes that are presently available to us. So we have two problems there. There are certain members of weldments, Ordnance weldments, like trails and things of that sort, wherein dimensional stability is not of great importance and where we could go to the higher yield strengths, up in the neighborhood of 120,000, 140,000 pounds per square inch. Some weldments cannot be made of those high yield strength materials at the present time if considerable machining is involved and dimensional stability must be considered.

"I think you can see that there is a whale of a need for electrode development here; that is, we need an electrode of the type of the NRC-2A variety which does not give us base metal cracking in welding of hardenable steels. In other words, we are limited, now, in the maximum yield strengths that we can attain with a stress relieving treatment, we will say, to a rather low carbon steel, because of the type of electrodes which are presently being used. If we could avoid base metal cracking, then, we could go to higher carbon contents and could retain 120,000 yield after a suitable stress relieving treatment. So, the problem is rather complex. There are many factors involved. I think the matter of electrode is one of the major deficiencies at the present time, for that very reason.

"The only point I was trying to make is that the use of present type electrodes limits the carbon content that we can use in the base metal to a rather low figure. We feel that we can go up to 0.15 carbon without any trouble; beyond that, we may get base metal cracking. I think you can see that the Ordnance Department is interested in this problem. I think it presages a field for steels that must come into the picture if steels are to compete with some of the lighter alloys.

"The Watertown Arsenal Laboratory has a very hot project right now to work out materials and heat treatments and welding procedures which can be applied for high strength weldments, and with the obvious intention of making up some designs for gun carriages in which considerable weight saving can be effected by the use of higher yield strength materials. Of course, it is a big design problem, too. This question of rigidity, and so forth, is involved. I would like to report that in the case of armor plate we have been working right along to effect improvements in it and I would like to hark back to something that Lieutenant Herres said about some armor plate which was made a long time ago, I believe. We don't see much of that type of armor any more. In other words, we have improved the quality of armor very materially by introducing tests, other than

[redacted]

ballistic tests, by which we can evaluate the essentials of armor plate.

"We feel that armor can be resolved into three problems: Resistance to penetration, resistance to spalling, and resistance to brittle failure, and we know how to test for those three characteristics without shooting at them. That is the trend, towards lesser amounts of ballistic testing, and the control of the quality of the material by these other laboratory tests or, rather, shop tests, which can be performed in the plant. For various reasons that is desirable. Now, in connection with armor work, we find that one of our big bugaboos at the present time is temper brittleness. It is a subject that hasn't been given too much attention by American metallurgists unfortunately. Our British friends have done practically all the good work, and most of the work that they did was during and following the last war. The only work on temper brittleness that has been done since then has been done by the Russians, Germans, and Japanese.

"We, however, at Watertown are very actively pursuing the subject now, and I think we have arrived at the point where we know all about its effects, but we still don't know what is causing it. We can tell you just what the effect of temper brittleness is, what the effect of alloy content is on its development, and the whole subject is perfectly familiar to us. We have narrowed the field down and we are pretty certain it is not a carbide. We are pretty certain it is not a phosphide. We are pretty certain that it is only one of two possibilities, either a nitride or an oxide. Well, if it turns out to be an oxide, there is not too much we can do about it, unfortunately. If it turns out to be a nitride, there is not too much we can do about it either, although there are some possibilities there; but that whole thing is pretty well buttonholed now, and we will have a report out shortly which will in a condensed manner evaluate everything that is known about temper brittleness. We find that a great majority of the data on the subject is not usable.

"For instance, a test for temper brittleness susceptibility, a classic test that was developed by Greaves and Jones during the last war, is not truly valid. That is, it will show you for practical purposes whether the embrittlement has caused poor properties or not, but it will not tell you whether or not a precipitation or transformation has taken place, which is really what we need to know to attack the fundamentals of this problem. So, practically all the data that is available on temper brittleness tells you what the effect is on properties and not what has been happening as a function of alloy content, and so forth. The recent work which we have done indicates that the susceptibility to temper brittleness increases almost linearly with hardenability. That is not saying that hardenability causes temper brittleness. It is just by chance that they happen to go along parallel. So, the problem of temper brittleness becomes much more serious in four- and five-inch thick sections than it does in half-inch or one-inch sections. We can say now that temper brittleness is limiting us on what we can do with armor plate in certain thicknesses and certain grades of steel.

[redacted]

The whole subject is being pursued rather actively."

With reference to the next meeting of the Subcommittee, Major Matthews remarked:

"We at Watertown, in conjunction with the people in Washington and O.C.O.-Detroit, have pretty much decided that we shall not schedule meetings of this Committee in the future, that is, definitely schedule them for a certain month or what have you. Instead, we plan to keep the Committee organization intact and call it when the necessity arises. You will continue to receive information that we think will interest and be of value to you. And we hope that you will continue to send to us any suggestions that you have for research projects, for needs for gatherings of the individual groups of the Committee, or for the Committee as a whole. In other words, if the Chief's office in Detroit decides that another meeting is necessary six months hence, it will be held, and the people will attend who can and, who are interested in the things that will be discussed. So, that is the procedure henceforth. You will be notified if and when meetings are scheduled in plenty of time so that you can make arrangements, as we have been doing in the past.

"I would like to hear any discussions on that subject that anybody might have. We are trying to serve the armor welding industry here. That has been the purpose of the Committee, to provide a means for interchange of information and the discussion of new developments. We certainly appreciate the co-operation that we have had from everybody. I am sure the Ordnance Department as a whole does also."

The meeting adjourned at 2:45 P.M.

This meeting marked the conclusion of the active work of the Subcommittee as an organized body. Many of the members attending this meeting were from organizations no longer engaged in the problem of welding armor, although the individuals themselves were interested in the latest developments in that field. This was apparent by the attention given to the discussion of the metallurgical aspects of armor welding during the meeting. No further meetings of this Subcommittee were scheduled.

[redacted]

APPENDIX A

I. Miscellaneous Subcommittee Correspondence Relating to

a. Arrangement of Meetings
b. Organization and Membership
c. Transmission of Data

II. Subcommittee Circular W-1 (Outline of Organization)

III. Standardized Subcommittee Forms and Usage

IV. Subcommittee Circular W-2 (Membership List, 1 January 1944)

[redacted]

APPENDIX A

Part I-a

Arrangement of Meetings

The first meeting of the Subcommittee, held at Watertown Arsenal, 19 December 1940, was arranged by invitation as outlined by letter of R. W. Case, Brigadier General, Commanding Officer, Watertown Arsenal, 6 December 1940, to Chief of Ordnance, Washington, D. C. (Inclosure 1). Letters sent to industrial companies selected are shown by Inclosure 2, letters to Service Agencies in Inclosure 3, and letters to members of the Ferrous Metallurgical Advisory Board by Inclosure 4. Attendance at this meeting was by invitation. The list of persons attending is given by Appendix C and Agenda by Appendix B.

The second meeting of the Subcommittee, held at Aberdeen Proving Ground, 21 January 1941, was also attended by invitation as per Inclosure 5. At this meeting a preliminary draft of a specification for welding armor was discussed as indicated by that inclosure.

The third meeting was arranged through the courtesy of Mr. Earle C. Smith, Republic Steel Corporation, to be held at Hotel Cleveland, Cleveland, Ohio, as indicated by Inclosure 6. Stenotypic service was provided by Mr. Smith. Notices of this meeting were sent to individuals (Inclosure 7) who attended the previous meeting at Aberdeen Proving Ground and to interested Ordnance organizations (Inclosure 8).

The fourth meeting was arranged through the courtesy of the Pittsburgh Ordnance District and the Carnegie-Illinois Steel Corp. (Inclosures 9, 10, and 11). A special invitation was extended to the Chief of the Pittsburgh Ordnance District (Inclosure 12). Notices of this meeting were sent to members of the Research Program Group, which had been organized since the previous Subcommittee meeting, as indicated by Inclosure 13. Notices to other persons not members of this Group carried no reference to the Group meeting. Service agencies were advised of the meeting as per Inclosure 14.

Attendance at a meeting to organize a Subcommittee on Resistance Welding was invited from selected industrial companies (Inclosure 15) and interested Service agencies (Inclosure 16) early in August 1941. A second communication (Inclosure 17) transmitted the Agenda (Appendix B) and a reply form for this meeting.

In connection with an industrial survey of methods being used to weld armor, which was being conducted by N.D.R.C. in late 1941, letters of explanation and introduction (Inclosure 18) were sent to all industrial members of the Subcommittee and Service agencies involved to facilitate the task of the official investigators.

As a result of action taken by the meeting of the Subcommittee on Resistance Welding, 27 August 1941, an invitation to membership (Inclosure 19) was extended to the Resistance Welder Manufacturers' Association.

[redacted]

SBR/gmm

December 6, 1940

Subject: Subcommittee for Welding of Armor

To: Chief of Ordnance, U.S.A.
Washington, D. C.

Attn: Industrial Division - Engineering Division

1. The problems and activities on welding of armor, rolled and cast, have become so important that it appears desirable to create a small subcommittee to advise and assist in the research and development in this field. In line with the recommendations of the Metallurgical Advisory Board, as reported in letter to the Chief of Ordnance dated July 19, 1940, it is proposed to call a preliminary meeting of a group for organization of such a subcommittee at Watertown Arsenal on December 19, 1940. Those who have been invited to attend are as follows:

Fabricators

A. O. Smith Corporation
American Car & Foundry Company
York Safe & Lock Company
Baldwin Locomotive Company
Electromotive Corporation
Diebold Safe & Lock Company

Rolled Armor Manufacturers

Henry Disston & Sons, Inc.
Republic Steel Corporation
Carnegie-Illinois Steel Corporation

Cast Armor Manufacturers

American Steel Foundries
General Steel Castings Corporation
Lebanon Steel Foundries
Continental Roll & Steel Foundry Company

Electrode Manufacturers

Metal & Thermit Company
Harnischfeger Corporation
Arcos Corporation

Service Representatives

Office, Chief of Ordnance

[redacted]

Service Representatives (cont.)

Rock Island Arsenal
Aberdeen Proving Ground
Watertown Arsenal
U. S. Navy - Bureau of Ships

2. It is requested that the Office, Chief of Ordnance, take the necessary steps to extend an invitation to Lt. Snyder, U. S. Navy, Bureau of Ships, to attend the coming meeting. Information would also be appreciated, at as early a date as practicable, as to the representatives who will attend from the Office, Chief of Ordnance.

3. The Agendum, in triplicate, is attached.

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

1 Incl. in trip.
Agendum

(Inclosure 1)

[redacted]

SBR/gmm

December 6, 1940

A. O. Smith Corporation
Milwaukee
Wisconsin

Gentlemen:

The problems and activities on welding of armor, rolled and cast, have become so important that it appears desirable to create a small subcommittee to assist in the research and development in this field. As approved by the Chief of Ordnance, this subcommittee would function under the Ordnance Department Metallurgical Advisory Board and would meet from time to time at Watertown Arsenal or other suitable place to discuss such matters as would normally come within its cognizance.

It is planned to hold a preliminary meeting of this group at Watertown Arsenal on December 19, 1940. You are invited to send a representative to this meeting. It is understood that such attendance will be without expense to the government. It is requested that you advise us as early as practicable the representative, if any, who will attend.

A copy of the Agendum is attached. Your coöperation in this matter is appreciated.

Very truly yours,

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board.

1 Incl.
Agendum

(Inclosure 2)

[redacted]

SBR/gmm

December 6, 1940

Subject: Subcommittee for Welding of Armor

To: Commanding General
Aberdeen Proving Ground
Maryland

1. Reference is made to letter W. A. 334/818 dated November 26, 1940, Subject: Formation of Subcommittee for Welding of Armor. It is proposed to hold a meeting at Watertown Arsenal on December 19, 1940 for the purpose of organizing a Subcommittee for Welding of Armor. A copy of the Agendum for the meeting is attached.

2. It is believed highly desirable that a representative be designated for this subcommittee from Aberdeen Proving Ground. It is requested that this representative, if practicable, attend the preliminary meeting. Advance information as to the name of this representative would be appreciated.

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

1 Incl.
Agendum

(Inclosure 3)

[redacted]

SBR/gmm

December 6, 1940

Carnegie-Illinois Steel Corporation
Carnegie Building
Pittsburgh, Pennsylvania

Attention: Col. G. Elkins Knable, Member Ferrous Metallurgical Advisory Board

Gentlemen:

It is proposed to hold a preliminary meeting of the Subcommittee for Welding of Armor at Watertown Arsenal on December 19, 1940. In this connection reference is made to your letter of November 16, 1940 in which you indicated that the formation of such a committee met with your approval.

It is requested that you advise us, as early as practicable, the representative from your firm who will attend this meeting. It is understood that such attendance will be without expense to the government.

A copy of the Agendum is attached. Your interest in this matter is appreciated.

Very truly yours,

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

1 Incl.
Agendum

(Inclosure 4)

[redacted]

SBR/emg

January 15, 1941

Mr. W. E. Crawford
A. O. Smith Corporation
Milwaukee, Wisconsin

Dear Mr. Crawford:

An agendum for the coming meeting of the Subcommittee for Welding of Armor, to be held at Aberdeen Proving Ground on January 21, is attached. It is to be noted that the meeting is scheduled to begin at 10:00 A.M. It is not anticipated that all of the topics included in the appendix to the agendum will be covered in detail. This appendix was added in an effort to outline a general program for research and development work. It is requested that it be considered in that light.

There is also attached a copy of a proposed draft of a specification for welding of armor (AXS-497), prepared in accordance with the suggestions made at the recent meeting of the subcommittee at Watertown Arsenal. Please note that this specification is in draft form only and that certain proposed changes have been written in pencil on the draft. In view of the fact that it is in draft form only, it is requested that you bring the copy herewith to the meeting in order that it may be returned to us after the necessary changes have been made as may be suggested. As a review of this specification is one of the main topics for discussion at the coming meeting, it is requested that, if practicable, you review it in advance in order that your views may be fully obtained at that time. Another topic for discussion is the attached data sheet.

The following information is submitted with the thought that it may be of assistance to you in your visit to the Proving Ground in case you have not previously visited that place. As stated above, the meeting is scheduled to start at 10:00 A. M. Government transportation will meet trains at Aberdeen to bring visitors to the Proving Ground between 8 A.M. and 10 A.M. (The Proving Ground is approximately five miles from the Aberdeen Station). In this connection it is understood that there is a train leaving Philadelphia at 8:45 A.M. (Broad St. Station), known as No. 403, which it is believed will stop at Aberdeen if requested at the ticket office. This train arrives at Aberdeen at approximately 9:45 A.M. The meeting will be held on the second floor of the Administration Building. In order to save time, passes are being arranged in advance so that Subcommittee members, upon arrival at the Information Desk of this building, can obtain the pass promptly upon identification. It is understood that an exhibit of welded material will be held from 12:30 to 1 P.M. Lunch will be served between 1 and 2 P.M. at the Officers'

[redacted]

Club at a nominal charge. It is planned to close the meeting at or before 4 P.M., and transportation will be available to take Subcommittee members to the railway station.

If you have not already done so, please let me know by not later than Monday noon, January 20, whether or not you will attend and the number that will be in your party.

Yours very truly,

S. B. Ritchie
Lt. Col., Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

Encls.
Agendum
Spec. AXS-497 (draft)
Data Sheet

(Inclosure 5)

[redacted]

NAM/SBR/emg

June 14, 1941

A I R M A I L

Mr. Earle C. Smith
Member, Subcommittee for
Welding of Armor
Chief Metallurgist
Republic Steel Corporation
Republic Building
Cleveland, Ohio

Dear Mr. Smith:

There is enclosed a carbon copy of a letter to the Hotel Cleveland confirming the date of June 20, 1941 for a meeting of the Subcommittee for Welding of Armor. Attached also are two copies of the Agenda prepared for the meeting.

As you know, it has been customary to make a record of the minutes and for this purpose we have in the past used either a stenotype operator or a stenographer. If it would be practicable and convenient for you to provide suitable clerical help to take down the notes for us, later to be transcribed and submitted to us, we can prepare a record of the meeting from them. If it is not convenient for you to do this, please advise by wire and we shall attempt to arrange for a stenotype operator from here.

We will advise you and also the Hotel Cleveland as soon as possible as to a more exact number of persons expected to attend.

Your co-operation in arranging for this meeting is very helpful and very much appreciated.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

Encs.
cc. letter Hotel Cleveland
2 copies Agenda

(Inclosure 6)

[redacted]

NAM/ELF/amv

June 12, 1941

Mr. A. J. Raymo
Member, Subcommittee for Welding of Armor
Baldwin Locomotive Company
Eddystone, Pennsylvania

Dear Mr. Raymo:

The date for the next meeting of the Subcommittee for the Welding of Armor has been selected as Friday, June 20, 1941, the meeting to be held at the Hotel Cleveland, Cleveland, Ohio. A copy of the agendum for this meeting is attached.

It is requested that this office be advised as soon as possible as to the names of those from your company who will attend the meeting in order that the necessary arrangements for the meeting may be completed.

In order to maintain the size of the group within reasonable limits for effective conduct of the meeting it is suggested that attendance be limited to two representatives from each company.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

Incl.
Agendum

(Inclosure 7)

[redacted]

NAM/ELR/amv

June 12, 1941

Subject: Meeting of Subcommittee for the Welding of Armor

To: Executive Officer
Detroit Ordnance District
1832 National Bank Bldg.
Detroit, Michigan

1. Attached are two copies of the agendum prepared for the meeting of the Subcommittee for the Welding of Armor scheduled to be held at the Hotel Cleveland, Cleveland, Ohio on June 20, 1941.

2. Reply is requested by teletype as to those who will attend from your district. In the interest of maintaining the group as small as possible for efficient conduct of the meeting it is desirable that not more than two representatives attend from each district.

3. Additional topics for discussion at this meeting should be forwarded to this arsenal as soon as possible.

For the President of the Board:

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

1 Incl.
Agenda in dup.

(Inclosure 8)

[redacted]

Laboratory SBR/gmm

July 28, 1941

Lt. Col. J. L. Guion
Executive Officer
Pittsburgh Ordnance District
1202 Chamber of Commerce Bldg.
Pittsburgh, Pennsylvania

Dear Guion:

At the meeting of the Subcommittee for Welding of Armor held in Cleveland June 20 the matter, as usual, as to the place for the next meeting came up. It was the feeling of the group, I believe, that it would be preferable to hold the next meeting in Pittsburgh. As I recall, Major Swauger indicated that he thought arrangements could be made for a meeting place in Pittsburgh, and I assumed that it would probably be in or near your office.

Normally we have about thirty-five to fifty people in attendance at these meetings. Plans are now being made for the next meeting and I am wondering how you are situated for suitable space for us. It will probably be several weeks before the meeting actually takes place. I think Major Swauger has something definitely in mind with respect to the meeting place and the arrangements that might be made. Perhaps you have a conference room which you maintain for such purposes.

Your good reaction on this proposition, at an early date, would be appreciated.

Sincerely,

S. B. Ritchie
Lt. Col., Ord. Dept.

(Inclosure 9)

C O P Y

[redacted]

WAR DEPARTMENT
Pittsburgh Ordnance District
1202 Chamber of Commerce Building
Pittsburgh, Pa.

JLG/dsd

August 8, 1941

Lt. Colonel S. B. Ritchie
Watertown Arsenal
Watertown, Mass.

Dear Sam:

In response to the teletype signed by General Case, I have written him, officially, notifying him that arrangements can be made for the meeting of the Subcommittee on Welding Armor in Pittsburgh, Pa., on August 21 and 22. I believe that the tentative arrangements made will be very satisfactory despite the fact that the preliminary meeting and the general meeting will be held in different buildings.

It is proposed that the preliminary meeting be held August 21, 1941, in the conference room of the Carnegie Illinois Steel Corporation, Frick Building, Pittsburgh, Pa., while the general session will be held in the Duquesne Club, Sixth Avenue, Pittsburgh, Pa. I have tentatively reserved both of these rooms, and await your reply before making definite reservations.

You spoke to Major Swauger concerning the possibility of a plant visit as a part of the program of this meeting. Unfortunately, the amount of welding that is being done on armor plate or cast armor in this district is so insignificant that it is doubtful if a satisfactory program can be arranged. The Carnegie Illinois Steel Corp., which is the only local company holding a membership in the subcommittee, is doing no welding in the Pittsburgh District on this class of materiel. They are doing welding at Farrell, Pa., in the Cleveland Ordnance District, but Farrell is about eight-five miles from Pittsburgh.

Will you please let me know your wishes in this matter as we would like to render every assistance to make the proposed meeting most successful.

Sincerely,

/s/ JAMES L. GUION
Lt. Col., Ord. Dept., U.S.A.
Executive Officer

(Inclosure 10)

[redacted]

SBR/gmm

Laboratory

August 12, 1941

Lt. Col. James L. Guion
Executive Officer
Pittsburgh Ordnance District
1202 Chamber of Commerce Building
Pittsburgh, Pennsylvania

Dear Guion:

I have your letter of August 8 in further reference to the proposed meeting of the Subcommittee for Welding of Armor. The dates of August 21 and 22 have definitely been scheduled. On August 21 the meeting will consist only of eight designated representatives from the subcommittee membership who constitute a Research Program Subgroup. They will meet on the 21st at 9:00 A.M. EST to go over the welding research projects. This is merely a preliminary meeting to the main meeting which is to be held August 22. We desire to restrict the subgroup meeting on the 21st to those who are members of the subgroup in order that they may work more effectively. We, therefore, are not giving any publicity to the subcommittee as a whole that the subgroup is meeting before the main meeting.

As stated above, there will probably be around eight or ten present at the subgroup meeting. Mr. Schmitt at Rock Island Arsenal is Chairman of this subgroup and he or some other representative from Rock Island Arsenal may make contact with you in connection with the meeting. I am merely mentioning this so that you understand the arrangements. You will note, therefore, that a comparatively small room would suffice for the first meeting. We do not believe that a stenographer will be necessary at the first meeting, although, if you have someone who is not too busy and who could be spared, it might be well to have a stenographer present. However, this is not important for the preliminary meeting. An Agenda covering the preliminary meeting is attached. This will also be sent out to those who will attend the meeting.

The Agenda will advise those who are to attend that the meeting (preliminary) is to be held in the conference room of the Carnegie Illinois Steel Corp., Frick Building, Fifth Avenue, Pittsburgh, Pa.

We are notifying the whole subcommittee through an Agenda, a copy of which is attached, that the subcommittee meeting will be

[redacted]

held in the Duquesne Club, Sixth Avenue, Pittsburgh, Pa. on August 22 starting at 9:00 A.M. EST. It is expected that approximately forty persons will attend. These meetings usually run well into the afternoon. It is customary to make a record of the meeting and for that purpose we have usually had either a stenotype operator or two stenographers present to record the discussions. It would be appreciated if you could arrange for this stenographic help. Let me know if it is not convenient to make arrangements for this.

With respect to the rooms you are reserving, we assume, of course, that there is no financial obligations involved as we had no arrangements so far to handle such matters.

In view of the conditions you mentioned, it is believed that we should forget about any shop visitation during the meeting.

The arrangements you are making to help us out in this matter are certainly appreciated. We, of course, expect you to be present at least to make some opening remarks at the beginning of the meeting, especially on the second day.

Sincerely,

S. B. Ritchie
Lt. Col., Ord. Dept.

2 Incls.
Agenda

(Inclosure 11)

[redacted]

SBR/gmm

Laboratory

August 16, 1941

Mr. J. D. Berg
Chief, Pittsburgh Ordnance District
1202 Chamber of Commerce Building
Pittsburgh, Pennsylvania

Dear Mr. Berg:

Plans are being made by the Subcommittee for Welding of Armor, of the Ferrous Metallurgical Advisory Board, to hold a meeting at the Duquesne Club, Pittsburgh, Pa., August 22. A copy of the Agenda is attached. This matter has been discussed by Lt. Col. S. B. Ritchie, of this arsenal, Chairman of the Subcommittee, with the Executive Officer, of the Pittsburgh Ordnance District, who has kindly made arrangements for the conference room.

You are invited to attend this meeting. If you cannot find time to participate in the whole session, possibly you could be present at the beginning of the meeting and make opening remarks.

The assistance being rendered by the Pittsburgh Ordnance District in this connection is greatly appreciated.

Very truly yours,

JOHN MATHER
Col., Ord. Dept.
Commanding

For: R. W. CASE
Brigadier General, U.S. Army
President, Ferrous Metallurgical Advisory Board

1 Incl.
Agenda

(Inclosure 12)

[redacted]

NAM/amv

Laboratory

August 12, 1941

Mr. A. J. Raymo
Member, Subcommittee for Welding of Armor
Welding Engineer
Baldwin Locomotive Company
Eddystone, Pennsylvania

Dear Mr. Raymo:

In accordance with the recommendation of the Subcommittee at its last meeting and after consultation with Rock Island Arsenal, it has been decided to hold a meeting of the Research Program Group, of which you are a member, at the conference room of the Carnegie-Illinois Steel Corporation in the Frick Building, Pittsburgh, Pennsylvania, beginning at 9:00 A.M., August 21, 1941. The subgroup meeting is for the purpose of considering a coordinated welding research program to be allocated among the firms represented on the subcommittee.

On the following day, August 22, 1941, a regular meeting of the Subcommittee for the Welding of Armor will be held at the Duquesne Club, Pittsburgh, the meeting scheduled to begin at 9:00 A.M., E.S.T. Copies of the Agenda for the two meetings are attached.

Please indicate on the attached form the names of those from your firm who will attend the meeting of the subgroup and the meeting of the Subcommittee and return in enclosed envelope in order that arrangements may be completed for the meetings.

For the President of the Board:

Yours very truly,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

4 Incls.

(Inclosure 13)

[redacted]

SBR/gmm

Laboratory

August 12, 1941

Subject: Meeting of Subcommittee for Welding of Armor

To: Chief of Ordnance, U.S.A.
Washington, D. C.

Attn: Industrial Service - Tank Division

1. In accordance with the recommendations at the last meeting of the Subcommittee for Welding of Armor held at Cleveland, Ohio on June 20, another meeting has been scheduled to be held at the Duquesne Club, Sixth Avenue, Pittsburgh, Pennsylvania, beginning at 9:00 A.M. EST August 22, 1941. Contact has been made with the Pittsburgh Ordnance District with respect to this matter. The date for the meeting is satisfactory to Rock Island Arsenal. Copies of the Agenda, which have been distributed to subcommittee members, are attached herewith.

2. It is requested that this arsenal be notified at the earliest date practicable giving the names of those who will attend the meeting from the Office, Chief of Ordnance.

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

Incl.
Agenda in dup.

(Inclosure 14)

[redacted]

SBR/emg/mod

Laboratory

August 9, 1941

President
Thomson-Gibb Electric Welding Company
Lynn, Massachusetts

Dear Sir:

There is being organized a small Subcommittee on Resistance Welding, to function under the Chairman of the Ordnance Department Ferrous Metallurgical Advisory Board, to advise and assist in research and development in the application of resistance welding to Ordnance materiel, notably as applied to the construction of tanks and armored cars. Co-operative research and development programs on resistance welding as may be recommended by the subcommittee will be matters for consideration. The subcommittee will meet from time to time at Watertown Arsenal or other suitable place and will afford a common meeting ground for discussion of such matters as specifications, inspection, compositions, treatments and processing methods involved in connection with resistance welding.

The following members of the Resistance Welder Manufacturers Association are being invited to become members of the subcommittee:

Thomson-Gibb Electric Welding Company, Lynn, Massachusetts
Taylor-Winfield Corporation, Warren, Ohio
Federal Machine & Welder Co., Warren, Ohio
National Electric Welding Machines Co., Bay City, Michigan
Progressive Welder Co., Detroit, Michigan
Swift Electric Welder Co., Detroit, Michigan

There will also be representation from the Office, Chief of Ordnance, Rock Island Arsenal, Aberdeen Proving Ground and Watertown Arsenal. It is expected that Mr. R. T. Gillette, Works Laboratory, General Electric Co., Schenectady, New York will also attend meetings which may be held.

In view of the urgency of some problems which have recently arisen in connection with spot welding of armor, it is desired to hold a meeting of the subcommittee at this arsenal on August 27, beginning at 9:30 A.M., EDST. If the formation of this subcommittee for the purpose intended meets with your approval, it is requested that you designate someone as a member to represent your organization. Information as to the name and address of the one so designated who will attend the coming meeting is requested.

[redacted]

It is hoped that the date selected for the meeting will be convenient for your representative to be present. It is to be noted, however, that attendance would have to be without expense to the Government. An agendum covering the matters to be discussed is being prepared and can be furnished in the near future. In order that proper arrangements may be accomplished, it is requested that reply be made at the earliest date practicable. Your co-operation in this matter will be appreciated.

Yours very truly,

R. W. CASE
Brigadier General, U. S. A.
President, Ferrous Metallurgical
Advisory Board

(Inclosure 15)

[redacted]

SBR/emg/mod

Laboratory

August 9, 1941

Subject: Meeting of Subcommittee on Resistance Welding

To: Commanding General
Rock Island Arsenal
Rock Island, Illinois

1. There is being organized a small Subcommittee on Resistance Welding to function under the Ordnance Department Ferrous Metallurgical Advisory Board to consider problems of resistance welding of Ordnance materiel. Rock Island Arsenal is invited to designate a representative for this subcommittee. Information as to the one so designated would be appreciated.

2. It is planned to hold a preliminary meeting of the group at Watertown Arsenal on August 27, 1941. An Agendum is being prepared covering the topics to be discussed at this meeting. Any material which Rock Island Arsenal desires to have included therein should be submitted as early as practicable. Copies of the Agendum, when prepared, will be submitted to those concerned.

R. W. CASE
Brigadier General, U.S.A.
Commanding

(Inclosure 16)

[redacted]

SBR/gmm

Laboratory

August 19, 1941

Mr. R. G. English
Swift Electric Welder Co.
Detroit, Michigan

Dear Mr. English:

This will acknowledge receipt of your letter of August 14, 1941 in reference to the Subcommittee on Resistance Welding. We are pleased to note that you will designate a representative as a member of this subcommittee and that Mr. A. H. Lewis and Mr. Floyd E. Taylor will be present at the coming meeting to be held at Watertown Arsenal on August 27. As suggested in your letter, a copy of the Agenda is attached from which you may be able to determine which of the two should come.

Please indicate on the attached form, and return in the envelope enclosed for that purpose, the hour and station at which of the above-named representatives will arrive in Boston, or the hotel where they may be located, in order that transportation may be made available to bring them to the arsenal.

Your co-operation in the proposed activities is appreciated.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Sec'y, Ferrous Metallurgical
Advisory Board

3 Encls.
Agenda
Form
Envelope

(Inclosure 17)

[redacted]

SBR/eam

Laboratory

September 2, 1941

Mr. A. L. Abbott
Diebold Safe & Lock Company
Canton, Ohio

Dear Mr. Abbott:

Watertown Arsenal, in connection with the research and development program on welding in general, recommended to the Chief of Ordnance sometime ago for allocation to the National Defense Research Committee certain fundamental studies pertaining to the weldability of steels and to residual stresses in welded structures, the nature and extent of these stresses, and the determination of their effects with a view to possible corrective measures where practicable. It is believed that an analysis of this problem will develop information and data which should be of much assistance in the defense program.

Preliminary to the possible allocation to research organization for solution of the several problems submitted which are to be covered in the studies, the Metallurgical Subcommittee of the National Defense Research Committee has decided to have a survey made and a report prepared on all existing data and information on the subject. This work is now underway. A critical analysis of the material being collected should indicate wherein and to what extent additional fundamental research in this field should be undertaken at this time.

This letter is to introduce to you Messrs. R. H. Aborn and J. R. Stitt who have been designated by the National Defense Research Committee to make the survey referred to above. It is understood that these gentlemen have been granted leave of absence from their regular employment to do this work. In this connection, they will desire to visit firms, personnel and technical agencies who may have important knowledge bearing on the subject. Undoubtedly they will make contact with you by correspondence in the near future with that in mind.

Messrs. Aborn and Stitt realize full well that the personnel with whom they would like to discuss this problem on welding are pressed with other work. However, in view of the importance of the task which has been assigned to them and the value of the report which they will prepare for the Ordnance Department and which will be made available to others entitled thereto, it would be greatly appreciated if you

[redacted]

Mr. A. L. Abbott September 2, 1941

could afford them time for discussion of the matter, if and when they make contact with you, or place them in contact with others in your organization who may have knowledge bearing on this subject.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee
for Welding of Armor

(Inclosure 18)

[redacted]

SBR/gmm

Laboratory

October 13, 1941

Mr. Malcolm S. Clark
President, Resistance Welders
Manufacturers Association
President
Federal Machine & Welder Company
Warren, Ohio

Dear Mr. Clark:

At a preliminary meeting of a group of resistance welding manufacturers held at Watertown Arsenal sometime ago a Subcommittee on Resistance Welding was organized to function under the general cognizance of the Ferrous Metallurgical Advisory Board. The representatives who attended that meeting and who now constitute the Subcommittee are:

Mr. A. H. Lewis, Swift Electric Welding Co., Detroit
Mr. C. F. Kaunitz, National Electric Welding Machines Co., Bay City
Mr. R. T. Gillette, General Electric Co., Schenectady
Mr. J. H. Cooper, The Taylor-Winfield Corp., Warren
Mr. W. T. Ober, Thomson-Gibb Electric Welding Co., Lynn
Mr. L. M. Benkert, Progressive Welder Co., Detroit
Mr. B. J. Wise, Federal Machine and Welder Co., Warren

At the meeting it was suggested that possibly other members of your association might desire membership on this Subcommittee who possibly might be in a position to contribute to its activities. It was further suggested that you be contacted with a view to ascertaining what additional members of your association should be included. It is thought that possibly you would bring this matter up at one of your association meetings. Your courtesy in doing this and advising me of the results in order that I may be able to pass them along to the individual members of the Subcommittee would be greatly appreciated.

You may be interested to know that at the preliminary meeting a research program, applicable more specifically to the resistance welding of light armor, was formulated and specific problems were agreed upon for assignment to individual concerns. A subgroup, of which Mr. Gillette was named chairman, was also designated to prepare an outline of required welding data to be recorded on all tests. That subgroup has completed its work and the program has been distributed to the individual members.

It was also agreed at the meeting that the service representatives would prepare a program of tests to be applied to the individual welded specimens, which would be prepared by the several companies participating. That program is now being stencilled and copies will be mailed

[redacted]

to the individual members some time this week.

The matter of obtaining necessary plate material has been delayed further than we originally anticipated, in view of production difficulties and pressure of activities in the firms normally furnishing suc material. However, we are now about ready to ship to the individual firm participating in the programs samples for their research work. These should go forward this week. As soon as these samples have been welded and preliminary tests have been completed, it is planned to hold another meeting of the Subcommittee. This we hope can be done some time next month.

The foregoing is presented in order to give you a brief picture of what has been done. In case you desire further details, it is suggest that you obtain the minutes of the preliminary meeting from Mr. Wise, of your firm, or in case it is not readily available, we will be pleased to send you a copy for your personal file. Your co-operation in this matter is greatly appreciated.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Sec'y, Ferrous Metallurgical
Advisory Board

(Inclosure 19)

[redacted]

The fifth meeting of the Subcommittee was arranged through the courtesy of the Arcos Corporation (Inclosure 20) and the Philadelphia Ordnance District (Inclosures 21 and 22). A request was made for suggestions, as to topics to be included in the agenda, from the industrial members (Inclosure 23) and certain Ordnance agencies (Inclosure 24). When plans had been completed, notices were sent to industrial representatives and interested Service agencies (Inclosure 25). To certain companies, which had expressed a desire to have representatives attend the meeting, notices (Inclosure 26) were sent. Preliminary arrangements for the plant visitation are indicated by Inclosure 27. Arrangements for the Subcommittee luncheon are indicated by Inclosure 28. In addition to the Subcommittee meeting on Friday and the plant visitation on Saturday a meeting of welding fabricators was arranged for Monday, 27 October 1941, by the Baldwin Locomotive Company (Inclosure 29).

Letters of appreciation were sent to the Philadelphia Ordnance District (Inclosure 30), the Arcos Corporation (Inclosure 31) and Baldwin Locomotive Company (Inclosure 32). A change in Subcommittee Chairman is indicated by Inclosure 33.

The sixth meeting of the Subcommittee was arranged shortly after Pearl Harbor as indicated by Inclosure 34. It was evident that the Ordnance District Offices were pretty busy just at this time. The Manager of the Boston Statler was most co-operative in arranging this meeting. Final arrangements are indicated by Inclosure 35. Notices were sent to members of the Electrode Group (Inclosure 36), the Fabricators' Group (Inclosure 37), and others expected to attend the meeting (Inclosure 38). The return form referred to was similar to that shown by Inclosure 52 or 56. The notices sent to Service agencies were as shown by Inclosure 39. Invitations to attend the meeting were issued to individuals suggested by the Office, Chief of Ordnance (Inclosures 40 and 41). Similar requests by Ordnance District Offices were honored (Inclosure 42). Arrangements regarding minutes of the Group meetings for this meeting record are indicated by Inclosures 43 and 44.

Notices of the second meeting of the Subcommittee on Resistance Welding sent to the industrial members are indicated by Inclosure 45. The return form referred to was similar to Inclosure 52 or 56.

The seventh meeting of the Subcommittee on Welding of Armor was arranged directly with the Detroit Statler. At this meeting, which was arranged and conducted by Major Cox, Colonel Zornig was elected chairman. Arrangements and notices (Inclosure 46) were similar to those of the previous meeting. However, the attendance had increased so enormously that the roll-call by the Secretary consumed appreciable time at the start of the meeting. This was the first meeting to be held on Sunday.

[redacted]

SBR/emg/kg

Laboratory

September 27, 1941

Mr. R. D. Thomas
President
Arcos Corporation
401 North Broad Street
Philadelphia, Pa.

Dear Mr. Thomas:

This will acknowledge your letter of September 8, 1941, in which you kindly extended an invitation to the Subcommittee for Welding of Armor to be your guest at the next meeting to be held in Philadelphia some time during the Metal Congress in October.

We have the matter of dates under consideration, and tentatively it appears that October 24th would probably be most suitable, in view of the activities to be carried out by the Metal Congress.

Please be assured that we greatly appreciate your kind offer in this connection, and I shall make contact with you again in the near future, at which time more definite commitments will be given.

For the President of the Board:

Yours very truly,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee
for Welding of Armor

(Inclosure 20)

[redacted]

SBR/gmm

Laboratory October 8, 1941

Subject: Meeting of Subcommittee for Welding of Armor

To: Executive Officer
Philadelphia Ordnance District
Room 1417 Mitten Building
Broad & Locust Streets
Philadelphia, Pennsylvania

1. Plans are being made to hold a meeting of the Subcommittee for Welding of Armor in Philadelphia during the week of the Metal Congress, beginning October 20. The date tentatively set for the meeting of the Subcommittee is Friday, October 24. Mr. R. D. Thomas, Jr., Senior President of the Arcos Corporation, 401 North Broad Street, has extended an invitation, as a result of a suggestion at the last meeting held in Pittsburgh, for the group to hold the meeting at the Penn Athletic Club as his guest. The Baldwin Locomotive Works has also extended an invitation to visit its plant on Saturday, October 25 after the meeting, to observe welding operations.

2. The purpose of this letter is to advise you of these invitations and to indicate that it is customary to handle these arrangements through the District Ordnance Office concerned. If agreeable to your office, and in case it will not impose an undue burden, it would be appreciated if you could make the contacts and handle the arrangements with respect to the meeting place and the plant visitation. It is expected that approximately fifty Subcommittee members and others who are entitled to attend the meeting will be present. You are invited to have a representative attend this meeting. As indicated above, Mr. Raymo of the Baldwin Locomotive Works, who is a member of the Subcommittee, has extended the invitation on behalf of his firm. It is believed that such a visit would be a highlight of the meeting and would be very interesting and constructive in connection with the Subcommittee activities. Your comments and advice, preferably by teletype, in reference to the suggested plant visit would be appreciated.

3. The tentative plans to hold this meeting and the invitation that has been extended by the Baldwin Locomotive Works to the Subcommittee to visit this plant have been reported to the Office, Chief of Ordnance, but no reply has yet been received confirming the date selected for the meeting.

4. An Agenda is being prepared, a copy of which will be submitted

[redacted]

later. It is requested that any topics which you might wish to have included therein be forwarded to us at your early convenience.

For the President of the Board:

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 21)

WA 334/2235
POD 334.8 Sub-Committee
Meeting of Welding of Armor 1st Ind. AJS/APR

Philadelphia Ordnance District, 1300 Mitten Building, Philadelphia, Pa. October 16, 1941. TO: Commanding General, Watertown Arsenal, Watertown, Mass. Attention of Laboratory.

1. Final arrangements have been made to accept the invitation of Mr. R. D. Thomas, Jr., Senior President of the Arcos Corporation, who has provided facilities at the Penn Athletic Club and also provided for luncheon for fifty (50) members of the subject Committee, on October 24th. It is understood that your office has notified the Sub-Committee of the time and place of the meeting.

2. Arrangements have also been made for a space at this office to hold a meeting of approximately ten (10) people on October 23rd, in accordance with your teletype of October 14th, 9:20 A.M., JC SBR/GMM. It is understood that you will notify the members of this meeting as to time and place. It will be held in Room No. 1523 of the Mitten Building, Broad and Locust Streets, Philadelphia, Pennsylvania.

3. Final arrangements have been completed for a plant visitation to the Baldwin Locomotive Works on October 25th for approximately fifty (50) people. Transportation plans and arrangements for the day will be announced at the meeting of the 24th. The Baldwin Locomotive Works will provide luncheon for the group. The visit is planned to terminate with the luncheon at noon.

For the District Chief:

A. J. SEILER
1st Lt., Ord. Dept.
Assistant

(Inclosure 22)

[redacted]

SBR/amv

Laboratory

October 9, 1941

In accordance with the suggestions at the meeting of the subcommittee which was held in Pittsburgh on August 22, plans are being made to hold another meeting in Philadelphia during the week of the Metal Congress, which begins October 19. The tentative date selected for the meeting is Friday, October 24, which appears to be the one day when technical activities of the Congress are at a minimum.

Tentative plans are also being made for a plant visitation at the Baldwin Locomotive Works on Saturday morning after the meeting on Friday to observe welding operations. This visitation, of course, if arranged will be optional to the members of the subcommittee.

The Agenda for the meeting, which will give the hour and the place, will be forwarded to you in the near future. In case you have any topics which you would like to have included therein, please let me have them at your earliest convenience.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 23)

[redacted]

SBR/gmm

Laboratory

October 11, 1941

Subject: Meeting of Subcommittee for Welding of Armor

To: Commanding General
Aberdeen Proving Ground
Maryland

1. At the recommendation of the Subcommittee for Welding of Armor at its last meeting held in Pittsburgh on August 22, arrangements have been made to hold the next meeting in Philadelphia, the date for which has been set for October 24. The Baldwin Locomotive Company, through its subcommittee member, Mr. Raymo, has extended an invitation to the subcommittee to visit their plant at Eddystone some time during this meeting to witness the production assembly line of tanks and the welding procedures being followed. It is expected that this visitation, if made, will be on Saturday, October 25, following the subcommittee meeting on October 24, as it is not believed that time would be ample for both the subcommittee meeting and the plant visitation on one day. The dates selected were those which could be best utilized, in view of the Metals Congress, which is to be held in Philadelphia the week beginning October 20.

2. An Agenda is being prepared, a copy of which will be submitted in the near future. It is requested that, if there are any topics which Aberdeen Proving Ground desires to have included, they be forwarded at as early a date as practicable.

For the President of the Board:

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee
for Welding of Armor

(Inclosure 24)

[redacted]

SBR/emg

Laboratory

October 17, 1941

Subject: Meeting of Subcommittee for Welding of Armor

To: Chief of Ordnance
Washington, D. C.

ATTN: Industrial Service, Engineering

1. Plans have been completed to hold a meeting of the Subcommittee for Welding of Armor at the Penn Athletic Club in Philadelphia on October 24, beginning at 9:30 A. M., E. S. T. On Saturday morning, it is expected that the group will visit the Baldwin Locomotive Works upon invitation of that firm to observe welding operations in the manufacture of armored vehicles. These arrangements have all been made through the Philadelphia Ordnance District.

2. There is attached in duplicate the Agenda for the meeting on October 24.

3. It is requested that the name or names of those who will attend from the Office, Chief of Ordnance be furnished, preferably by teletype; also, there should include the names of those who will make the plant visitation on October 25.

For the Commanding General:

S. B. Ritchie
Lt. Col., Ordnance Dept.
Director of Laboratory

1 Incl, in dupl.
Agenda

(Inclosure 25)

[redacted]

SBR/emg

Laboratory

October 18, 1941

Mr. C. E. Sorenson
Ford Motor Co.
Dearborn
Michigan

Dear Mr. Sorenson:

There is attached in duplicate the Agenda for the coming meeting of the Subcommittee for Welding of Armor, to be held at the Penn Athletic Club, Philadelphia, Pa., on October 24, beginning at 9:30 A. M. In this connection, reference is made to your telegram of October 17 in which you advised that Mr. Vennerholm would be present at this meeting. We shall look forward with pleasure to his participation in these activities.

On Saturday morning, October 25, it is planned to make a plant visitation to the Baldwin Locomotive Works, Eddystone, Pa., to observe welding operations in the manufacture of armored vehicles. Details with respect to this plant visitation will be made available at the meeting on October 24. It is assumed that possibly Mr. Vennerholm will desire to remain over for the plant visitation.

For the President of the Board:

Yours very truly,

S. B. Ritchie
Lt. Col., Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

Enc.
Agenda in dupl.

(Inclosure 26)

[redacted]

SBR/gmm

Laboratory October 18, 1941

Mr. A. J. Raymo
Member, Subcommittee for
Welding of Armor
Welding Engineer
Baldwin Locomotive Company
Eddystone, Pennsylvania

Dear Mr. Raymo:

We have already sent you a copy of the Agenda for the meeting of the Subcommittee for Welding of Armor in Philadelphia on October 24. Thanks to your kind invitation and the arrangements you are making with the District Ordnance Office in Philadelphia, we are planning to make the plant visitation with you on Saturday morning as you suggested. It appears, at the moment, that approximately fifty people will be present at the meeting on October 24 and possibly this same number may be present on Saturday morning to go to the plant. However, it seems to me that we will have to give you more specific figures on this a little later, possibly exact figures would be given on the date of the subcommittee meeting.

I naturally assume that we will want to confine the plant visitation to those who are directly concerned or in attendance at the subcommittee meeting, and that the name or names of those who are to go to the plant will be available definitely not later than the morning of the subcommittee meeting on the 24th. We have taken steps here to ascertain specifically those persons who desire to make the plant visitation. I am happy to know that this plant visitation can be made, as I am sure that it will constitute one of the highlights of the meeting. I understand from a teletype we have just received from Colonel Hauseman of the Philadelphia Ordnance District that his office will furnish transportation from Philadelphia to the plant and return. Therefore, it is expected that the meeting place for the members will be at the District Ordnance Office, on Saturday morning, or at some place at which that office may later designate, so that the group may proceed to the plant in a body.

If you have any further comments at this time or any suggestion of things we should do from this end to help you in any way in connection with the plant visitation, please let us have them.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee
for Welding of Armor

(Inclosure 27)

[redacted]

SBR/emg

Laboratory October 20, 1941

Mr. R. D. Thomas
President
Arcos Corporation
401 North Broad Street
Philadelphia, Pa.

Dear Mr. Thomas:

In further reference to my letter to you under date of September 27, it appears that the number who will attend the meeting of the Subcommittee for Welding of Armor, to be held in Philadelphia on October 24, may slightly exceed fifty. This is due to the fact that the Office, Chief of Ordnance has asked us, in a teletype received a few days ago, to extend invitations to several other firms who are interested in welding of armored vehicles to send representatives to the meeting. It is expected that possibly an additional ten or eleven persons may attend as a result of these invitations which are now being sent out. I trust we can advise you within the next few days more definitely with respect to the exact number.

We appreciate greatly the arrangements you have made to hold this meeting at the Penn Athletic Club. We also realize that for you to act as host for such a large group may entail an undue burden. It has been customary at many of these meetings where similar arrangements have been made for those who attend to pay for their luncheon. Such arrangements, of course, will be entirely agreeable and appropriate on the coming occasion. In fact, it always seems to us best to handle the luncheon arrangements in this way.

For the President of the Board:

Yours very truly,

S. B. Ritchie
Lt. Col., Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 28)

[redacted]

C
O
P
Y

War Department
Office of the Chief of Ordnance
Washington

Ind. Serv.-Tank Div. Brooker/mbg/ec

October 16, 1941

Subject: Drawings of the Welded M-3 Medium Tank Hull - M-4 Hull and M-4 Turret

To: Commanding General
Watertown Arsenal
Watertown, Mass.

Attn: Lieut. Colonel S. B. Ritchie
Director of Laboratory

1. The Baldwin Locomotive Works at Eddystone, Pennsylvania has an engineering contract to prepare a revision of all Ordnance Department drawings for the construction of the welded M-3 medium tank hull and the hull and turret of the M-4 tank. In addition to these units, which are almost entirely of armor plate, the work will also include that section of the M-4 tank, with cast upper hull, which is of plate below the sponson line. This lower section is almost identical with the corresponding part of the all welded M-4 hull.

2. The designs of welded joints in these welded structures must be detailed with proper root openings, angles of bevel, types of groove, and welding procedure. The manner in which adjoining armor plates meet in the various joints, can be either of two possibilities. A number of fixed factors such as position for welding, choice of grinding or chipping, and facilities of the welding contractor, must be considered to establish the manner in which plate edges are to be prepared for welding.

3. The Ordnance Department has hesitated to exactly define plate edge preparation, but in order to get perfect interchangeability of plates and produce standard welded tanks and because of your interest in welding armor, you are kindly requested to send representatives to the Eddystone plant of the Baldwin Locomotive Works on Monday, October 27, 1941, where a meeting of twenty-four welding contractors will be held beginning at 9 A.M., for the purpose of getting agreement on the optimum design of joints and welding procedure to be used for the tanks mentioned in the first paragraph.

4. The Baldwin Locomotive Works will mail directly to you isometric views of the two tanks augmented by details of all component parts.

[redacted]

To: Commanding General
Watertown Arsenal
Attn: Lt. Colonel S. B. Ritchie (cont'd) 10/16/41

These drawings will enable you to see where the joints are to be located and to make notes on the plate edge preparation necessary. In this way, it is hoped that the meeting on the 27th will be consummated in the most efficient manner.

By order of the Chief of Ordnance:

/s/ E. L. CUMMINGS
Major, Ordnance Dept.
Assistant

(Inclosure 29)

SBR/gmm

Laboratory October 27, 1941

Subject: Meetings of Subcommittee for Welding of Armor

To: Executive Officer
Philadelphia Ordnance District
Room 1417 Mitten Building
Broad and Locust Streets
Philadelphia, Pennsylvania

Attn: Lt. Col. D. N. Hauseman

1. It is desired to express appreciation for the cooperation and assistance rendered by the Philadelphia District Ordnance Office during the meetings of the Subcommittee for Welding of Armor, October 24 and 25, 1941. It is understood that the detailed arrangements handled by that office made possible the accomplishment of two successful meetings, one at the Penn Athletic Club on October 24, the other a plant visitation at the Baldwin Locomotive Works on October 25.

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

(Inclosure 30)

[redacted]

Laboratory

October 27, 1941

Mr. R. D. Thomas
President
Arcos Corporation
401 North Broad Street
Philadelphia, Pennsylvania

Dear Mr. Thomas:

I have been informed by Lt. Col. S. B. Ritchie, Chairman of the Subcommittee for Welding of Armor, of the courtesies extended by the Arcos Corporation as host to the Subcommittee during its meeting in Philadelphia, October 24.

On behalf of the Ferrous Metallurgical Advisory Board I would like to express to you our appreciation for your consideration in this connection and for your assistance in arranging the meeting place at the Penn Athletic Club, for your stenographic help, and for the luncheon for the Subcommittee. Your cooperation in handling these matters made possible the accomplishment of a successful meeting to facilitate, to the benefit of national defense, the solution of problems in which we are all mutually interested.

Very truly yours,

R. W. Case
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

(Inclosure 31)

[redacted]

October 27, 1941

Mr. Charles E. Brinley
President
Baldwin Locomotive Works
Eddystone, Pennsylvania

Dear Mr. Brinley:

I have been informed by Lt. Col. S. B. Ritchie, Chairman of the Subcommittee for Welding of Armor, of the courtesies extended by the Baldwin Locomotive Works during the meetings of this Subcommittee in Philadelphia and at your plant on October 24 and 25, respectively. On behalf of the Ferrous Metallurgical Advisory Board I would like to express to you our appreciation, especially for the cooperation and assistance rendered by your company in acting as host to the Subcommittee on October 25.

The plant visitation arranged by your Mr. Raymo was, I understand, very instructive for those who attended and who are concerned with the manufacture of armored vehicles. The interchange of information through conferences, and by observation of actual production, as was the case on this occasion, should facilitate the solution, to the benefit of national defense, of those problems in which are are all mutually interested.

Very truly yours,

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

(Inclosure 32)

[redacted]

GLC/gmm

Laboratory

November 17, 1941

Mr. R. D. Thomas, Jr.
Member, Subcommittee for
Welding of Armor
Metallurgist
Arcos Corporation
401 North Broad Street
Philadelphia, Pennsylvania

Dear Mr. Thomas:

We greatly appreciate the fine way in which you handled the recording of the meeting of the Subcommittee for Welding of Armor, held at the Penn Athletic Club in Philadelphia on October 24. The recorded minutes have been received and we are taking the necessary steps to have them reproduced to be sent to the members of the Subcommittee.

Colonel Ritchie has been assigned new duties as Production Manager at the Arsenal and for the time being I shall attempt to handle the details of the Subcommittee work, although I am glad to say the Colonel Ritchie will still be available to consult with us in these activities.

For the Commanding Officer:

Very truly yours,

G. L. COX
Major, Ord. Dept.
Acting Director of Laboratory

(Inclosure 33)

[redacted]

Telephone Conversation between Maj. Cox and Col. Crane, Detroit, 12/19/41.

Maj.: . . . meeting of the Subcommittee for Welding of Armor. It was decided last meeting to hold it in Detroit and it is about time now to get out the agenda and notify all the members and we would like to have you help us if possible in arranging a room to have this meeting, and we are having in mind one of the rooms at the Statler or perhaps some one of the other hotels. Now, one complication is this - there are two subgroups to this Subcommittee, one dealing with electrodes, the other dealing with fabrication. Brooker in Washington heads up the Electrode and Schmitt at Rock Island the other one. Now, they will want to hold meetings on the 6th, that is a day ahead of the main meeting. Now, they won't need as large a room - they will have perhaps 15 in each group. Our group on the 7th will have about 75 people. I thought I would like to ask you if you know of any place that we can get or just to ask you if you could help us out and find a place.

Col.: Why can't you use these committee members to get this done? We are just up to our ears here. I would be glad to look around, but I don't know very much about it, how many members you have, what size is needed. Why couldn't you get somebody to sponsor it? Is Great Lakes Steel on that?

Maj.: No, they are not in on this at all.

Col.: What representatives are on that Committee?

Maj.: Col. Rehm is on that Committee - I wonder if he could help us out? I imagine he is in worse shape than you.

Col.: He is just taking over the Rock Island and he has to establish an Eng. Office - all by the 1st of January. I'll look into it - it seems to me that - well, if it has got to be done, it has got to be done, but frankly as far as I'm concerned, that has an awful low priority in the things we've got to do. We are working day and night here - pressure on things - getting work under way and work out.

Maj.: Suppose we leave it this way, Col. Crane. I'll check through the Statler Hotel here in Boston and see if they can arrange anything for us and if we can't I may have to get in touch with you later.

Col.: Do you have any resources for renting that?

Maj.: We will each have to pay our share. We generally do it by paying a high price for lunch; in other words, $1.50 to $1.75 for lunch which covers the room. That is what we have done in the past, and it is about the most satisfactory way. I'll check with the Statler Hotel here in Boston - they may be able to arrange something with the Detroit Statler.

Col.: If I get time here I'll get what information I can.

Maj.: I'll appreciate that very much.

(Inclosure 34)

[redacted]

GLC/gmf

Laboratory

December 22, 1941

Mr. W. F. Schmitt
Member, Subcommittee for
Welding of Armor
Rock Island Arsenal
Rock Island, Illinois

Dear Mr. Schmitt:

I have just completed making arrangements for the forthcoming meeting of the Subcommittee for Welding of Armor on January 7, and the two Subgroup meetings on January 6.

These meetings will be held at the Statler Hotel in Detroit, and the management of that hotel is reserving two rooms that will handle the Subgroup meetings on January 6, and one large room to handle at least seventy-five people on the 7th. I do not yet have the exact details of the method of payment for these rooms, but presumably, the cost will be included in the price of the luncheon, which can be served in the room. I do not have the specific room numbers or names, but they will be furnished you when available.

Copies of the agenda will be mailed to you shortly.

For the President of the Board:

Very truly yours,

G. L. COX
Major, Ordnance Dept.
Acting Chairman, Subcommittee
for Welding of Armor

cc: Col. R. Z. Crane
Col. H. W. Rehm

P.S. This will also acknowledge your letter of December 18 which I have just noticed since dictating the above.

(Inclosure 35)

[redacted]

NAM/WLW/amv

Laboratory December 31, 1941

A meeting of the Subcommittee for Welding of Armor has been scheduled to be held at the Statler Hotel, Detroit, Michigan, on Wednesday, January 7, 1942, beginning at 9:00 A.M., E. S. T. A copy of the Agenda to be used at the meeting as well as a copy of the revision of Specification AXS-497, which will be a topic for discussion, are attached.

A meeting of the Electrode Research Subgroup is being called by the chairman, Mr. E. Brooker, and will be held at the Statler Hotel, Tuesday, January 6, 1942 beginning at approximately 9:00 A.M.

Plans have been completed for a plant visitation at the Detroit Tank Arsenal on Thursday, January 8, 1942, details of which will be announced at the subcommittee meeting.

Please indicate on the attached form the names of those persons from your organization who will attend both meetings.

For the President of the Board:

Very truly yours,

G. L. Cox
Major, Ordnance Dept.
Acting Chairman, Subcommittee
for Welding of Armor

4 Encls.
Agenda
Specification
Return Form
Return Envelope

(Inclosure 36)

[redacted]

NAM/WLW/amv

Laboratory

December 31, 1941

A meeting of the Subcommittee for Welding of Armor has been scheduled to be held at the Statler Hotel, Detroit, Michigan on Wednesday, January 7, 1942 beginning at 9:00 A.M., E.S.T. A copy of the Agenda to be used at the meeting as well as a copy of the revision of Specification AXS-497, which will be a topic for discussion, are attached.

A meeting of the Fabricator Research Program Subgroup is being called by the chairman, Mr. W. F. Schmitt, and will be held at the Statler Hotel, Tuesday, January 6, 1942 beginning at approximately 9:00 A.M.

Plans have been completed for a plant visitation at the Detroit Tank Arsenal on Thursday, January 8, 1942, details of which will be announced at the subcommittee meeting.

Please indicate on the attached form the names of those persons from your organization who will attend both meetings.

For the President of the Board:

Very truly yours,

G. L. Cox
Major, Ordnance Dept.
Acting Chairman, Subcommittee
for Welding of Armor

4 Encls.
Agenda
Specification
Receipt Form
Envelope

(Inclosure 37)

[redacted]

NAM/WLW/amv

Laboratory

December 31, 1941

A meeting of the Subcommittee for Welding of Armor has been scheduled to be held at the Statler Hotel, Detroit, Michigan on Wednesday, January 7, 1942 beginning at 9:00 A.M., E.S.T.

A copy of the Agenda to be used at the meeting is attached.

Plans have been completed for a plant visitation at the Detroit Tank Arsenal on Thursday, January 8, 1942, details of which will be announced at the subcommittee meeting.

Please indicate on the attached form the names of those persons from your organization who will attend the subcommittee meeting.

For the President of the Board:

Very truly yours,

G. L. Cox
Major, Ordnance Dept.
Acting Chairman, Subcommittee
for Welding of Armor

3 Encls.
Agenda
Return Form
Return Envelope

(Inclosure 38)

[redacted]

GLC/nw

Laboratory December 30, 1941

Subject: Subcommittee Meeting for Welding of Armor

To: Executive Officer
Detroit Ordnance District
1832 National Bank Bldg.
Detroit, Michigan

1. A meeting of the Subcommittee for Welding of Armor has been scheduled to be held at the Statler Hotel, Detroit, Michigan, on Wednesday, January 7, 1942, beginning at 9:00 A.M., E.S.T. Copies of the Agenda for the meeting are attached.

2. Plans have been completed for a plant visitation at the Detroit Tank Arsenal on Thursday, January 8, 1942, details of which will be announced at the Subcommittee meeting.

3. Please indicate on the attached form the names of those persons from your organization who will attend the subcommittee meeting.

For the President of the Board:

G. L. Cox
Major, Ordnance Dept.
Acting Chairman, Sub-
Committee for
Welding of Armor

3 Incls.
Agenda (in dup.)
Return form
Return envelope

(Inclosure 39)

[redacted]

NAM/ELR/amv

Laboratory January 2, 1942

Mr. J. H. Humberstone
Arcrods Corporation
P.O. Box D
Sparrows Point, Maryland

Dear Mr. Humberstone:

As suggested by the Office, Chief of Ordnance, you are invited to attend the meeting of the Subcommittee for Welding of Armor to be held at the Statler Hotel, Detroit, Michigan on Wednesday, January 7, 1942 beginning at 9:00 A. M.

Mr. E. Brooker will invite you to attend the meeting of the Electrode Subgroup on January 6, 1942.

A copy of the Agenda to be used at the meeting is attached. Please indicate on the attached form the names of those from your organization who will attend both meetings.

Your interest in the activities of this subcommittee is appreciated.

For the President of the Board:

Very truly yours,

G. L. Cox
Major, Ordnance Dept.
Acting Chairman, Subcommittee
for Welding of Armor

3 Encls.
Agenda
Form
Envelope

(Inclosure 40)

[redacted]

NAM/ELR/amv

Laboratory

January 2, 1942

Mr. R. M. Hannum
Coast Metals, Inc.
1006 McKinley Avenue, S. W.
Canton, Ohio

Dear Mr. Hannum:

At the request of the Office, Chief of Ordnance you are invited to attend the meeting of the Subcommittee for Welding of Armor to be held at the Statler Hotel, Detroit, Michigan on Wednesday, January 7, 1942, beginning at 9:00 A. M.

A copy of the Agenda for the meeting is attached.

Very truly yours,

G. L. Cox
Major, Ordnance Dept.
Acting Chairman, Subcommittee
for Welding of Armor.

1 Incl.
Agenda

(Inclosure 41)

[redacted]

NAM/amv

Laboratory-NAM

January 3, 1942

Mr. Joseph Crowley
Libbey-Owens Ford Company
Toledo, Ohio

Dear Mr. Crowley:

A telegram has just been received from Lt. Col. R. Z. Crane, Detroit Ordnance District, asking permission for you and Mr. Michael Christjohn to attend the meeting of the Subcommittee for Welding of Armor to be held at the Statler Hotel, Detroit, Michigan on January 7, 1942.

We shall be very glad to have you attend and hope the meeting will be helpful in acquainting you with the methods which appear most promising for the fabrication of armored vehicles by welding.

Attached are two copies of the Agenda for the meeting.

For the President of the Board:

Very truly yours,

G. L. Cox
Major, Ordnance Dept.
Acting Chairman, Subcommittee
for Welding of Armor

2 Encls.
Agenda

(Inclosure 42)

[redacted]

GLC/gmf

Laboratory

January 17, 1942

Mr. E. Brooker
Member, Subcommittee for Welding of Armor
War Department
Office, Chief of Ordnance
Industrial Service - Tank & Combat Vehicle Division
New Social Security Building
Washington, D. C.

Dear Mr. Brooker:

I have just received copies of the transcripts of the three meetings in Detroit on the 6 and 7. For your information, I inclose the original copies of the minutes of the two subgroups for your record. I am not sure whether it is your desire to have them reproduced, although I think it is unnecessary to do that unless you should have definite requests from some of the members. We feel that it will be unnecessary to reproduce the minutes of the Fabrication Research Subgroup.

A copy of each of the subgroup meetings was sent to Lt. Reed at Aberdeen, in order that he might have the information for his immediate need. There was also sent to Lt. Reed a copy of the transcript of the main meeting.

We are currently editing the minutes of the subcommittee meetings and as soon as they have been reproduced, copies will be forwarded in the usual manner.

For the President of the Board:

Very truly yours,

G. L. COX
Major, Ord. Dept.
Chairman, Subcommittee
for Welding of Armor

2 Incls.
Transcripts

(Inclosure 43)

[redacted]

GLC/emg

Laboratory

January 28, 1942

Air Mail

Subject: Minutes of Meeting, Research Program Subgroup
Subcommittee for Welding of Armor, January 6, 1942

To: Commanding General
Rock Island Arsenal
Rock Island, Illinois

Attn: Mr. J. K. McDowell, Chairman, Research Program Subgroup

1. Reference teletype from Rock Island Arsenal, dated January 27, 1942, 4.40 PM VRC JKM/EF, the minutes of the meeting of the Research Program Subgroup of the Subcommittee for Welding of Armor, held at the Hotel Statler, Detroit, on January 6, 1942, are attached. Additional copies have also been furnished Mr. Brooker, Office, Chief of Ordnance, Tank & Combat Vehicle Division, and Lt. W. B. Reed, Automotive Section, Aberdeen Proving Ground.

2. Since the minutes of the main meeting contained a report from the chairmen of the subgroups, it is considered unnecessary to reproduce for distribution the transactions of the subgroups. Also, in the future, it is believed desirable not to make a stenographic record of the subgroup meetings, but rather let these meetings be free and open. The chairman of the subgroup, or a secretary designated by him, can take whatever notes are necessary in the preparation of the summary report to be presented at the main meeting. His comments on this proposal would be appreciated.

3. The minutes of the main meeting have been edited and are now ready for transcription. It is desired to include in this transcript the summary which the subgroup chairmen will prepare. It is therefore requested that 60 copies of the summary of the minutes of the Research Program Subgroup be submitted as promptly as possible.

For the President of the Board:

G. L. COX
Major, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

1 Incl.
Minutes

cc: Mr. E. Brooker, OCO

(Inclosure 44)

[redacted]

Laboratory NAM/amv

January 5, 1942

At the request of the Air Corps a meeting of the Subcommittee for Resistance Welding is being scheduled to be held at the Materiel Division, Wright Field, Dayton, Ohio on January 13, 1942 beginning at 9:00 A.M., E.S.T.

The Air Corps has requested that attendance be limited to as small a number as possible and has asked that only one representative attend from each industrial company.

Transportation will be provided at the Union Station, Dayton at 8:30 A.M. to carry those attending the meeting to Wright Field.

A copy of the Agenda for the meeting is attached, Please return the enclosed form at your earliest convenience in order that complete arrangements can be made.

For the President of the Board:

Very truly yours,

G. L. Cox
Major, Ordnance Dept.
Acting Chairman, Subcommittee
for Resistance Welding

3 Encls.
Agenda
Return Form
Return Envelope

(Inclosure 45)

[redacted]

NAM/amv

February 19, 1942

A meeting of the Subcommittee for Welding of Armor is scheduled to be held at the Statler Hotel, Detroit, Michigan, on Sunday, March 1, 1942, beginning at 9:30 A.M.

A copy of the Agenda to be used at the meeting is attached. Please indicate on the enclosed form the name of the person from your organization who will attend and return at the earliest possible date.

In order to keep the size of the group as small as possible, it is requested that attendance be limited to one person from each organization where practicable.

For the President of the Board:

G. L. Cox
Major, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

3 Encls.
Agenda
Return Form
Return Envelope

(Inclosure 46)

[redacted]

The eighth meeting of the Subcommittee, held at the Detroit Statler, was conducted by Col. Zornig with Captain Matthews as Secretary. Notices were sent to industrial members (Inclosure 47) and the usual letters to Service agencies. The previous meeting on 1 March 1942 marked the first time that representatives of WPB had attended a Subcommittee meeting. Since it was considered desirable that industry be kept informed regarding availability of materials, the Subcommittee Chairman requested (Inclosure 48) that representation from WPB be designated to attend meetings.

The ninth meeting of the Subcommittee, held at the Detroit Statler, marked the incorporation of the Subcommittee on Resistance Welding as the Resistance Welding Group. The third meeting of the Resistance Welding Committee was held at the Detroit Statler on the day before the meeting of the Subcommittee on Welding of Armor as indicated by Inclosures 49 and 50. Notices to industrial members of the Subcommittee on Resistance Welding and the return forms are indicated by Inclosures 51 and 52 respectively. A stenotype reporter was not available for that meeting.

Arrangements for the meeting of the Subcommittee on Welding of Armor are indicated by Inclosure 53. The Welding Supervisor, NRC was advised of the meeting arrangements (Inclosure 54). Notices (Inclosure 55) and Return Forms (Inclosure 56) were sent to the industrial members of record. The usual official letters were sent to Service agencies concerned.

For these meetings two copies of the stenotypic transcript of the discussions were usually prepared. Prior to preparing this transcript a list of attendance was forwarded for use of the stenotypist (Inclosure 57). Upon completion of the transcript the first copy was forwarded to the Subcommittee Secretary (Inclosure 58). Upon receipt, acknowledgment was made (Inclosure 59) and carbon copy with original notes was then transmitted. This procedure was always followed to insure that one copy would be available for reproduction should the other become lost in transmission. After editing by the Secretary the transcript was reproduced and distributed to the Subcommittee membership.

In October 1942, a meeting of the Liaison Groups of the Subcommittee on Welding of Armor and the Subcommittee on Rolled Armor was held at Watertown as indicated by Inclosure 60. At this meeting the main topic of discussion was standardization of armor plate and casting composition with a maximum of carbon by ladle analysis of 0.30%.

[redacted]

NAM/amv

May 29, 1942

A meeting of the Subcommittee for the Welding of Armor is scheduled to be held at the Hotel Statler, Detroit, Michigan on Sunday, June 21, 1942 beginning at 9:30 A.M.

A copy of the Agenda for the meeting is attached as well as a return form and envelope. Please indicate the names of the persons from your organization who will attend. It is desired to limit the attendance to one person from each organization wherever practicable.

For the President of the Board:

Very truly yours,

H. H. ZORNIG
Colonel, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

3 Encls.
Agenda
Return Form
Return Envelope

(Inclosure 47)

[redacted]

NAM/amv

Laboratory-NAM

June 1, 1942

Subject: WPB Representation on Subcommittee for Welding of Armor

To: Chief of Ordnance, U.S.A.
Pentagon Building
Arlington, Va.

Attn: Industrial Service - Research and Engineering

1. To date the War Production Board has not appointed a representative to the Subcommittee for Welding of Armor. It is desirable that the activities of this committee be coordinated with the WPB organization, and, in this connection, it would be helpful if the same person could attend consistently.

2. It is requested that his office contact the proper section of WPB and ascertain if some individual can be so designated. It is particularly important that a WPB representative attend the coming meeting as Topic II on the Agenda (duplicate copies attached) indicates.

3. Please notify this arsenal as to who has been designated and will attend the meeting.

For the Commanding General:

E. H. ZORNIG
Colonel, Ordnance Dept.
Director of Laboratory

(Inclosure 48)

[redacted]

WLW/eck

Laboratory (WLW) September 2, 1942

Mr. J. H. Cooper
Member, Subcommittee for
Resistance Welding
Senior Welding Engineer
The Taylor-Winfield Corp.
Warren, Ohio

Dear Mr. Cooper:

A meeting of the Subcommittee for Resistance Welding is tentatively scheduled for Saturday, September 19, 1942, at the Hotel Statler, Detroit, Michigan. On Sunday, September 20, 1942, a regular meeting of the Subcommittee for Welding of Armor will be held also at the Hotel Statler in Detroit.

It is expected that the members of the Resistance Welding Subcommittee will attend the Sunday meeting of the Subcommittee for Welding of Armor, an agenda for which will be forwarded as soon as prepared. Suggestions as to items to be included in the agenda for both meetings would be appreciated. The matter of forming a Resistance Welding Subgroup of the Subcommittee for Welding of Armor will be considered during the Saturday meeting.

For the President of the Board:

Yours very truly,

G. L. Cox
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Resistance Welding

(Inclosure 49)

[redacted]

WLW/ahk

Laboratory (WLW) September 3, 1942

Subject: Meeting of Subcommittee for Resistance Welding

To: Assistant Chief
Materiel Branch
Wright Field
Dayton, Ohio

1. A meeting of the Subcommittee for Resistance Welding is tentatively scheduled for Saturday, September 19, 1942, at the Hotel Statler, Detroit, Michigan. A meeting of the Subcommittee for Welding of Armor is being planned for Sunday, September 20, to be held also at the Hotel Statler in Detroit.

2. At this meeting on September 19, the matter of forming a Resistance Welding Subgroup of the Subcommittee for Welding of Armor will be considered. Suggestions as to items to be included in the agenda for this meeting will be appreciated.

For the President of the Board:

G. L. Cox
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Resistance Welding

(Inclosure 50)

[redacted]

WLW/ahk

Laboratory (WLW)

September 12, 1942

Dear Sir:

A meeting of the Subcommittee for Resistance Welding is scheduled to be held at the Hotel Statler, Detroit, Michigan on Saturday, September 19, 1942, beginning at 9:30 A.M. A copy of the Agenda for this meeting is attached.

On Sunday, September 20, beginning at 9:30 A.M. there will be a meeting of the Subcommittee for Welding of Armor, to be held at the Hotel Statler, Detroit. A copy of the Agenda for this meeting is also attached.

As matters will be discussed which are in the "restricted" category, only members of these Subcommittees and authorized individuals will be admitted to either meeting.

To facilitate admittance to these meetings it is requested that you present this notice at the door.

It is requested that you kindly indicate on the attached form whether or not you will attend either or both Subcommittee meetings, and return the form in the inclosed envelope.

For the President of the Board:

Yours very truly,

G. L. Cox
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Resistance Welding

4 Incls.
- Agenda (2)
  - Resistance Welding
  - Welding of Armor
- Return Envelope
- Return Form

(Inclosure 51)

[redacted]

R E T U R N   F O R M

DATE________________________

(PLEASE CROSS OUT WORDS NOT APPLICABLE IN THE FOLLOWING)

I (WILL - WILL NOT) attend the meeting of the Subcommittee for Welding of Armor, scheduled to be held at the Hotel Statler, Detroit, Michigan, Sunday, September 20, 1942.

NAME________________________

TITLE________________________

ORGANIZATION________________

I (WILL - WILL NOT) attend the meeting of the Subcommittee for Resistance Welding, scheduled to be held at the Hotel Statler, Detroit, Michigan, Saturday, September 19, 1942.

(Inclosure 52)

[redacted]

WLW/ahk

Laboratory (WLW) September 3, 1942

Mr. Joseph B. Shea
Sales Manager
Hotel Statler
Detroit, Michigan

Dear Mr. Shea:

We are contemplating holding a meeting of our Subcommittee for the Welding of Armor, similar to past meetings, on Sunday, September 20, 1942 in Detroit, and wish to request accommodations for this meeting as you have done in the past. It is possible that meetings of the various subgroups of our subcommittee may be held on Saturday, September 19, and we are requesting each of the subgroup chairmen to get in touch with you if such meetings are to be held. There are at present five subgroups of which two subgroups consist of only about ten members each. It is not known at present just what plans the subgroups may make in connection with this meeting.

On September 19 also, we are calling a meeting of our Subcommittee for Resistance Welding, consisting of approximately fifteen persons. We would appreciate it very much if you could provide a small room suitable for the meeting of this subcommittee on September 19.

We will communicate with you later with regard to room reservations for individuals who may be attending from this arsenal.

For the Commanding Officer:

Yours very truly,

G. L. Cox
Lt. Col., Ord. Dept.
Assistant

(Inclosure 53)

[redacted]

WLW/ahk

Laboratory (WLW) September 10, 1942

Mr. G. S. Mikhalapov
Member, Subcommittee for
Welding of Armor
Supervisor of Welding Research
National Research Council
1222 Citizens Building
Cleveland, Ohio

Dear Mr. Mikhalapov:

Inclosed are copies of the agenda for the meeting of the Subcommittee for Resistance Welding on Saturday, September 19, and the meeting of the Subcommittee for Welding of Armor on September 20, both of which will be held at the Hotel Statler, Detroit, Michigan. It is expected that the Subcommittee for Resistance Welding will be incorporated into the membership of the Subcommittee for Welding of Armor to function as a Resistance Welding Subgroup. It is suggested that if possible it would be desirable for you to attend the meeting on Saturday as well as Sunday.

Will you please indicate on the attached form whether or not you will attend either or both meetings, and return the form in the inclosed envelope.

For the President of the Board:

Yours very truly,

G. L. Cox
Lt. Col., Ord. Dept.
Acting Chairman, Subcommittee
for Welding of Armor

4 Incls.
Agenda (2)
Sub. for Res. Weld.
Sub. for Weld. of Armor
Return Form
Return Envelope

(Inclosure 54)

[redacted]

/ahk

Laboratory (WLW)

September 12, 1942

Dear Sir:

A meeting of the Subcommittee for Welding of Armor is scheduled to be held at the Hotel Statler, Detroit, Michigan on Sunday, September 20, 1942, beginning at 9:30 A.M. A copy of the Agenda for this meeting is attached.

As matters will be discussed which are in the "restricted" category, only members of this Subcommittee and authorized individuals will be admitted to this meeting.

To facilitate admittance to the meeting it is requested that you present this notice at the door.

It is requested that you kindly indicate on the attached form whether or not you will attend and return the form to me in the inclosed envelope.

For the Chairman of the Subcommittee:

Very truly yours,

N. A. MATTHEWS
Capt., Ordnance Dept.
Secretary, Subcommittee for
Welding of Armor

3 Incls.
Agenda
Return Form
Return Envelope

(Inclosure 55)

[redacted]

RETURN FORM

DATE ____________________

(PLEASE CROSS OUT WORDS NOT APPLICABLE IN THE FOLLOWING)

I (WILL - WILL NOT) attend the meeting of the Subcommittee for Welding of Armor, scheduled to be held at the Hotel Statler, Detroit, Michigan, Sunday, September 20, 1942.

NAME ____________________

TITLE ____________________

ORGANIZATION ____________________

(Inclosure 56)

[redacted]

ahk

Laboratory (WLW) September 26, 1942

Mr. Merle A. Leader
Accurate Court Reporters
414 Ford Building
Detroit, Michigan

Dear Sir:

In compliance with your request of September 24, we are inclosing herewith the attendance list for the meeting of the Subcommittee for Welding of Armor held at the Statler Hotel, Sunday, September 20, 1942.

For the President of the Board:

Yours very truly,

H. H. Zornig
Colonel, Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

1 Incl.
Attendance List

(Inclosure 57)

C
O
P
Y

[redacted]

Accurate Court Reporters
414 Ford Building
Detroit, Michigan

October 10, 1942

The Commanding Officer
War Department
Watertown Arsenal
Watertown, Mass.

Attention Lt. Col. G. L. Cox, Ord. Dept.

Dear Sir:

Enclosed you will find one complete copy of the transcript of the proceedings of the Minutes of the meeting of the Sub-Committee for Welding of Armor taken at the Hotel Statler, Detroit, Michigan, on Sunday, September 20, at 9:30 and 4:30.

We still have your other copy together with our stenotype notes and they will be forwarded to you immediately when you acknowledge receipt of the original.

Thanking you again for the opportunity of serving you and trusting you find the transcript in good order, I am

Respectfully yours,

/s/ Merle A. Leader
ACCURATE COURT REPORTERS

ML

(Inclosure 58)

[redacted]

/rmd

Laboratory - GLC

October 12, 1942

Accurate Court Reporters
414 Ford Building
Detroit, Michigan

Gentlemen:

This will acknowledge receipt of your letter of October 10, 1942 and original copy of transcript of the meeting of the Subcommittee for Welding of Armor.

Please forward the carbon copy of the transcript and the original notes.

For the Commanding Officer:

Very truly yours,

H. H. Zornig
Col., Ordnance Dept.
Director of Laboratory

(Inclosure 59)

[redacted]

NAM/ahk

Laboratory (NAM)

October 12, 1942

Mr. A. J. Raymo
Member, Subcommittee for Welding of Armor
Supervisor of Welding
Baldwin Locomotive Works
Paschall P. O.
Philadelphia, Pennsylvania

Dear Mr. Raymo:

You will recall that it was agreed at the last meeting of the Subcommittee for Welding of Armor to establish a Liaison Group of the subcommittee to meet with a similar group of the Subcommittee for Rolled Armor to discuss the mutual problems involved and arrive at decisions agreeable to the armor manufacturers and fabricators. Your Liaison Group has been selected and consists of the following:

A. J. Raymo (Chairman), Baldwin Locomotive Works (Homogeneous Armor Fabricators' Group)
L. A. Danse, Cadillac Motor Car Division (Homogeneous Armor Fabricators' Group)
B. J. Smith, Marmon-Herrington Co., Inc. (Face-Hardened Armor Fabricators' Group)
P. H. Merriman, Glenn L. Martin Co., Inc. (Aircraft Manufacturers' Group)
F. A. Lee, International Harvester Co. (Resistance Welding Group)
Dr. J. W. Miller, Reid-Avery Company (Electrode Group)

A meeting of the above two Liaison Groups is scheduled to be held at this arsenal on Thursday, October 22, 1942, beginning at 10:00 A.M. The meeting will be attended by the above representatives and eight persons representing the Subcommittee for Rolled Armor. In addition, several Ordnance representatives will attend. A copy of the Agenda for the meeting is attached, as well as a form which should be completed and returned at the earliest possible date.

Because of gasoline rationing and the tire shortage, it will be impossible to provide motor transportation to the arsenal. It is suggested that you detrain at the South Station, Boston, and take the subway to Central Square, Cambridge. At Central Square you can board a streetcar which will bring you directly to the arsenal.

For the President of the Board:

Yours very truly,

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

3 Incls.
Agenda
Return Form
Return Envelope

(Inclosure 60)

[redacted]

Arrangements were made for the tenth meeting of the Subcommittee and its Groups through the courtesy of the Philadelphia Ordnance District Office (Inclosures 61, 62 and 63). The meeting proceeded as planned and appreciation of the co-operation of the District Office was expressed by the Chairman (Inclosure 64). By this period the methods and forms used in preparing for and conducting meetings had become standardized as indicated by Part III, Appendix A, and the procedures outlined in Part III were generally followed for the remaining meetings of the Subcommittee. Acknowledgment of receipt of transcript of this meeting is indicated by Inclosure 65.

The plans for the eleventh meeting of the Subcommittee, held in Cleveland, intended that data on field performance of welded armored vehicles be disclosed to the Subcommittee (Inclosure 66). This objective was not accomplished due to lack of available informed personnel at this time. Arrangements for this meeting were made through the Cleveland Ordnance District Office (Inclosures 67, 68, and 69). Stenotype service was obtained from a qualified commercial company in Cleveland by the Subcommittee Secretary.

The twelfth meeting of the Subcommittee was arranged through the courtesy of the Chicago Ordnance District Office (Inclosures 70, 71, 72, and 73). The thanks of the Subcommittee for this assistance were expressed as indicated by Inclosure 74. The transcript of discussions of the Subcommittee meeting was forwarded as indicated by Inclosures 75 and 76. The first copy of the transcript was forwarded to Office, Chief of Ordnance for file (Inclosure 77) as was customary for these meetings.

The thirteenth meeting was held at Hotel Pennsylvania, New York City, arrangements for which were made directly with the hotel management. At this meeting observations of field performance of welded armored vehicles in the North African Theatre of Operations were given, off the record, by Major Pippel, recently returned from an overseas mission. Stenotype service was supplied by a commercial company.

The fourteenth and fifteenth meetings held at Hotel Cleveland during 1944 were arranged directly with the hotel management. Stenotype service was supplied by the same commercial company which handled the eleventh meeting as referred to above. The fifteenth meeting on 9 November 1944 was the last regular meeting of the Subcommittee.

C
O
P
Y

[redacted]

Philadelphia Ordnance District
150 South Broad Street
Philadelphia, Pa.

W.J.Jeffries/mst

November 2, 1942

Mr. W. L. Warner
Welding Engineer
Watertown Arsenal
Watertown, Mass.

Dear Mr. Warner:

Confirming telephone conversation today, I have just concluded arrangements for the meeting of December 6, 1942, at 9:30 A.M. in the Bellevue Stratford Hotel, Phila., Penna. The luncheon will be $1.65, including gratuities.

The meeting will be held in the North Tower which is a nice light room and will hold 150 people comfortably on comfortable chairs. The luncheon will be served in an adjoining room. I have arranged with the Adelphia Reporting Bureau, Adelphia Hotel, Phila., Penna., for 2 stenotypists at the rates given to you in my letter of October 31, 1942. The bureau suggested that one man was sufficient because of his long and wide experience in reporting meetings. However, if we thought two would be necessary, they would be glad to furnish 2 and they are arranging to furnish 2 for that date. The notes will be transcribed and delivered to me together with the stenographic tape. These will immediately be forwarded to you as soon as I receive them.

With regard to the meetings of the sub-sub groups, if any are to be held, the hotel management suggested that if the meetings were small, that some of those concerned might arrange for a suite, in which case the sitting room would be large enough for a meeting of 15 to 20 people. Ample seating capacity will be provided if additional accommodations are necessary. It is understood, from our telephone conversation that the Chairman of the sub-sub group will get in touch with me in order to make the necessary arrangements. This should be done sufficiently in advance so that a small room will be available. As you know, many small events take place under hotel accommodations. It is suggested that the notice invite attention to the necessity for making hotel reservations early by those who will arrive before the day of the meeting.

As suggested, I will arrange for proper security of the meeting with guards at the door of the meeting room.

Very truly yours,

/s/ W. J. JEFFRIES
Chief Metallurgist

(Inclosure 61)

C
O
P
Y

[redacted]

Philadelphia Ordnance District
150 South Broad Street
Philadelphia, Pa.

W.J.Jeffries/mst

November 25, 1942

Col. H. H. Zornig
Chairman, Armor Welding Sub-Committee
Watertown Arsenal
Watertown, Mass.

Dear Col. Zornig:

This will acknowledge your letter of November 21st regarding the recording of the minutes of the Armor Welding Committee on December 6, 1942. Arrangements will be made accordingly.

I am enclosing a copy of the schedule of Sub-Committee meetings to be held on Saturday, December 5, 1942. You will note that all of the Sub-Committee meetings are being held in the District Office building and its annex, 1420 Walnut Street. These arrangements have been made because of a lack of knowledge as to who would sojourn in the hotel and thereby make it possible for the hotel to allocate some rooms for Sub-Committee meetings. It is to be reminded also, that all hotels in Philadelphia are fairly well crowded at the present time and the Bellevue Stratford Hotel especially so. The several conference rooms in the District building and its annex, 1420 Walnut Street, are comfortable and I will be in attendance to arrange everything so that the Sub-Committee meetings can function smoothly.

Very truly yours,

/s/ W. J. JEFFRIES
Chief Metallurgist

1 Incl.

(Inclosure 62)

[redacted]

ARMOR WELDING SUBCOMMITTEE

SUB-GROUP MEETINGS

SATURDAY, DECEMBER 5, 1942

GROUP	TIME	PLACE
Aircraft Armor Fabricators Col. C. H. Morgan, Chairman	9:30 A.M.	Room 402, 4th Floor 1420 Walnut St.
Face-Hardened Armor Fabricators Mr. A. L. Abbott, Chairman	10:00 A.M.	Room B, 3rd Floor 1420 Walnut St.
Armor Fabricators J. K. McDowell, Chairman	10:00 A.M.	Room 401 150 S. Broad St.
Electrode Lt. J. F. Randall, Chairman	9:30 A.M.	Room A, 3rd Floor 1420 Walnut St.
Resistance Welding J. H. Cooper, Chairman	9:30 A.M.	Room 621 150 S. Broad St.
Research Col. J. H. Frye	4:00 P.M.	Room 804 150 S. Broad St.
Specifications Major J. V. Coombe	8:00 P.M.	Room 621 150 S. Broad St.

150 S. Broad Street is the Philadelphia Ordnance District and is directly across the street from the Bellevue Stratford Hotel on the northeast corner of Broad and Walnut Streets.

1420 Walnut Street is an office building at that address just a few doors west of the Bellevue Stratford Hotel on the south side of Walnut Street.

(Inclosure 63)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD WLW/ahk

Laboratory (WLW) Subcommittee on Welding of Armor

December 9, 1942

Mr. W. J. Jeffries, Member
Chief Metallurgist
Philadelphia Ordnance District
150 South Broad Street
Philadelphia, Pennsylvania

Dear Mr. Jeffries:

Inclosed is a list of names of the persons attending the meeting of the Subcommittee on Sunday, December 6, 1942, for your information and the stenotype reporters who took the notes of the discussions.

We wish to express our appreciation to you and the Philadelphia Ordnance District Office for the excellent arrangements made for the Group meetings on Saturday and the Subcommittee meeting on Sunday. I am sure that all of the members of the Subcommittee appreciate the efforts of you and your associates toward the success of the meeting.

We are looking forward with a great deal of interest to receiving the transcript of the discussions in accordance with the verbal arrangement between you and the Secretary.

For the President of the Board:

Yours very truly,

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

1 Incl.
List

(Inclosure 64)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD   WLW/ahk

Laboratory (WLW)   Subcommittee on Welding of Armor

December 31, 1942

Mr. W. J. Jeffries
Chief Metallurgist
Philadelphia Ordnance District
150 South Broad Street
Philadelphia, Pa.

Dear Mr. Jeffries:

On December 19, 1942, your letter transmitting the original draft of the transcript of the meeting held on December 6, was indorsed back (PHA 400.171/19, WA 334/4132(r)) acknowledging receipt of this copy and requesting that the carbon copy and original stenotype notes which you were holding be forwarded to us. Up to the present time we have not received this material, and are wondering whether you received this indorsement.

It is our feeling that the Adelphia Reporting Bureau did a very good job on this transcript, and we desire to settle up the account, but the Procurement Division refuses to authorize this until the carbon copy and original stenotype notes are received here. We would very much appreciate your forwarding them to us at your earliest convenience.

May I take this opportunity to thank you for your kind collaboration and assistance in arranging the details of the meeting.

Yours very truly,

W. L. Warner
Sr. Welding Engineer
Secretary, Subcommittee on
Welding of Armor

(Inclosure 65)

O.O. 334.8/15415
W.A. 334/4050 2nd Ind. WLW/ahk

Watertown Arsenal, Watertown, Massachusetts, December 8, 1942
To: Chief of Ordnance, U.S. Army, Washington, D. C. Attn: SPOTB

1. The comment made in paragraph 2, preceding indorsement, has been noted and it is considered very desirable that whatever information is available and can be divulged to the Subcommittee should be given at the first opportunity.

2. The next meeting of the Subcommittee on Welding of Armor is tentatively scheduled for Saturday, February 6, 1943, to be held in Cleveland, Ohio, possibly at either the Hotel Cleveland or Hotel Statler, depending upon the arrangements which can be made. If possible, as suggested in paragraph 3 of preceding indorsement, it is requested that arrangements be made to present the data in question at that meeting.

3. More complete information regarding the meeting of the Subcommittee tentatively scheduled for February 6 will be forwarded at a later date as soon as arrangements have been completed. It would be appreciated if this office could be informed as to the person designated by his office to present this information at the meeting.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 66)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD

Subcommittee on Welding of Armor WLW/ahk

Laboratory (WLW) December 26, 1942

Subject: Meeting of Subcommittee to be Held in Cleveland

To: District Chief
Cleveland Ordnance District
1450 Terminal Tower Building
Cleveland, Ohio

1. It is planned to hold the next meeting of the Subcommittee on Welding of Armor in Cleveland on Saturday, February 6, 1943. The usual practice has been to arrange with some hotel to supply a suitable meeting room and provide a luncheon for the mid-day meal, the cost of the luncheon to cover the expense of the room for the meeting. In this case it is desired, if possible, to hold the meeting at the Hotel Cleveland, if suitable arrangement can be made.

2. The assistance of his office is desired, if possible, to arrange this meeting at the Hotel Cleveland on the above date, and information is requested in regard to available stenotype service which may be procured for this meeting. It has been customary to utilize two (2) stenotype operators to record the discussion which takes place during the Subcommittee meeting. The arrangements for obtaining these stenotype operators have in the past been handled directly with the reporting bureau by this arsenal. In order to do this it is necessary to know what reporting organization should be contacted because clearance for handling restricted data must be arranged, and it is also desirable to know the charges which are to be made for such service.

3. If someone in his organization could be designated to handle the arrangements with the hotel in conjunction with this arsenal it would be appreciated.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 67)

[redacted]

LABORATORY

JANUARY 4, 1943

DISTRICT CHIEF

CLEVELAND ORDNANCE DISTRICT, 1450 TERMINAL TOWER BUILDING, CLEVELAND, OHIO

REOURLET 12/26/42, W.A. 334/4208, INFORMATION REQUESTED REGARDING ARRANGEMENTS FOR MEETING SO THAT GROUP CHAIRMEN MAY BE INFORMED AND GROUP MEETINGS CAN BE ARRANGED. IF DESIRED THIS ARSENAL ARRANGE DIRECT WITH HOTEL CLEVELAND, PLEASE ADVISE. INFORMATION REGARDING STENOTYPE OPERATORS REQUESTED. EXPECTED SUBCOMMITTEE ATTENDANCE AT MEETING ABOUT 175 AND ADEQUATE TIME IS REQUIRED TO PREPARE AND SEND NOTICE TO MEMBERS. END. CITE LABORATORY ZORNIG.

MATHER, WATERTOWN ARSENAL

H. A. WILLIS
COLONEL, ORDNANCE DEPT.
ADMINISTRATIVE OFFICER

(Inclosure 68)

COPY

CLEVE ORD DIST 1/43 052320Z BSH/MM EXECUTIVE OFFICER CITE--EP227

COMMANDING OFFICER/WATERTOWN ARSENAL

REURTEL 7954 MATHER-LABORATORY ZORNIG, ARRANGEMENTS HAVE BEEN MADE WITH HOTEL CLEVELAND FOR THE USE OF THE EMPIRE ROOM FOR 175 PEOPLE, FOR MEETING OF "SUBCOMMITTEE ON WELDING OF ARMOR," SATURDAY MORNING AND AFTERNOON, FEBRUARY 6, 1943. ARRANGEMENTS HAVE ALSO BEEN MADE FOR A LUNCHEON IN THE ADJOINING ROOM FOR $1.40 PER PLATE INCLUDING TAX AND TIP. NO CHARGE IS TO BE MADE FOR THE EMPIRE ROOM. HIS OFFICE WILL BE ADVISED LATER AS TO STENOTYPE OPERATORS.

REEDALL

(Inclosure 69)

[redacted]

C.O.D. 001/192
Attn: Industrial Division
Tank-Automotive Br.
W.A. 334/5320 1st Ind. Warner/ahk

Watertown Arsenal, Watertown, Massachusetts, March 27, 1943.

To: District Chief, Chicago Ordnance District, First National Bank Building, Chicago, Illinois
Attn: Captain S. C. Massari

1. With reference to paragraph 3 of basic letter, the date of the meeting will be Saturday, June 5, 1943. It is expected that between 150 and 175 will attend this meeting, and that possibly about 100 individuals may desire luncheon. The exact number who will attend the luncheon cannot be ascertained definitely until the registration of attendance is completed during the morning of the day of the meeting.

2. At these Subcommittee meetings it is desirable, and has been the custom in the past, to have stenotype reporters present for the purpose of taking down the discussion during the meeting. If his office can make preliminary arrangements with some qualified reporting company for this service and advise this arsenal as to the rates charged by such company for this kind of work, then it will be possible to initiate a purchase order for the job. It is, of course, necessary that the company selected be cleared through G2 to be able to handle this work because it involves material of a "restricted" nature.

3. The assistance and cooperation of his office in arranging these details will be very much appreciated.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 70)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD Warner/ahk

Subcommittee on Welding of Armor

Laboratory (WLW) April 22, 1943

Subject: Meeting of Subcommittee on Welding of Armor, June 5, 1943, Chicago, Illinois

To: District Chief
Chicago Ordnance District
First National Bank Building
Chicago, Illinois

Attn: Industrial Division, Tank-Automotive Branch,
Captain S. C. Massari

1. With reference to C.O.D. 001/192, W.A. 334/5320, 1st Ind., dated March 27, 1943, information is requested regarding the place of meeting and arrangements for stenotype reporters.

2. As has been customary in the past, certain of the Subcommittee Groups will probably plan on meeting the day before the Subcommittee meeting, and it will be necessary for this office to notify the various Group Chairmen of the time and place of the meeting in order that they may plan meetings of their respective groups. It is desired to inform these Group Chairmen at the earliest possible date and to instruct them to contact his office in connection with the arrangements for the meetings of their respective groups.

3. The names of the Group Chairmen are as follows:

Maj. C. McInnes, Chairman, Eastern Division, Aircraft Armor Fabricators' Group - Wright Field
Mr. H. North, Chairman, Western Division, Aircraft Armor Fabricators' Group - Douglas Aircraft Company, Inc.
Mr. A. L. Abbott, Chairman, Face-Hardened Fabricators' Group, Diebold Safe & Lock Company
Lt. J. F. Randall, Chairman, Electrode Group, Tank-Automotive Center
Mr. J. K. McDowell, Chairman, Homogeneous Armor Fabricators' Group, Rock Island Arsenal
Col. G. E. Knable, Chairman, Research Group, Office, Chief of Ordnance
Mr. J. H. Cooper, Chairman, Resistance Welding Group, War Production Board
Maj. J. V. Coombe, Chairman, Specifications Group, Tank-Automotive Center

It is possible that some or all of these Chairman will be contacting his office.

[redacted]

4. The assistance and cooperation of his office in arranging these details will be very much appreciated. The information above requested will be appreciated at his earliest convenience.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 71)

[redacted]

Chicago Ordnance District
First National Bank Building
Chicago, Illinois

SCMassari/gg

Industrial Division
Tank-Automotive Branch

April 27, 1943

SUBJECT: Meeting of Subcommittee on Welding of Armor, June 5, 1943, Chicago, Illinois

TO: Ferrous Metallurgical Advisory Board
Watertown Arsenal
Watertown, Massachusetts

ATTN: Col. H. H. Zornig
Chairman, Subcommittee on Welding of Armor

1. Referring to his letter under date of April 22, 1943, WA 334/5393, this office wishes to advise that arrangements have been made to hold subject meeting at the Palmer House on Saturday, June 5, 1943.

2. Tentative reservations have been made to hold this meeting in private dining room No. 14 and luncheon in private dining room No. 18, both rooms being adequate in size for the attendance anticipated. In the event that previous reservations for these rooms interfere, facilities will be provided in the dining room of the Club Building for the meeting and the lounge of the Club Building for the luncheon, also at the Palmer House.

3. The only reason that the first location would be preferred to the second is that it is in the air conditioned portion of the hotel, which may or may not be important early in June. In either case, you may consider that suitable space is available.

4. The cost of the luncheon, including tax, tips and the use of the meeting room, will be $1.75 per person. This office will provide a stenotypist from its staff as well as a receptionist to keep a record of those attending the meeting.

5. As soon as his office advises as to any additional meeting room facilities which might be required for the various Group Chairmen, every attempt will be made to provide accordingly.

For the District Chief:

/s/ S. C. Massari
Captain, Ord. Dept.
Assistant

For: J. E. KANALEY
Chief, Tank-Automotive Branch
Chicago Ordnance District

(Inclosure 72)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD   Warner/ahk

Subcommittee on Welding of Armor

Laboratory (WLW)   May 3, 1943

Subject: Meetings of Subcommittee Groups, June 4, 1943

To: District Chief
Chicago Ordnance District
First National Bank Building
Chicago, Illinois

Attn: Industrial Division, Tank-Automotive Branch,
Captain S. C. Massari

1. Attached is a copy of the letter sent out to all of the Subcommittee Group chairmen, as listed in letter sent to his office April 22, 1943 (W.A. 334/5393), calling attention to the desirability of contacting his office if arrangements are desired for the respective Group meetings.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

1 Incl.
cc. letter of
Group chairmen

(Inclosure 73)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD Warner/ahk

Subcommittee on Welding of Armor

Laboratory (WLW) June 8, 1943

Captain S. C. Massari
Industrial Division, Tank-Automotive Br.
Chicago Ordnance District
38 South Dearborn Street
Chicago, Illinois

Dear Captain Massari:

It is desired to take this opportunity to thank you and your organization for the excellent arrangements made for the meeting of the Subcommittee which was held at the Palmer House on June 5. The activities in connection with this meeting were carried out very expeditiously due to the cooperation of your organization. Your assistance in this matter is very much appreciated, and I am sure that all the members of the Subcommittee who attended appreciate this fact.

For the President of the Board:

Very truly yours,

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 74)

[redacted]

W.A. 334/4568(r)
Chgo. O.D. 400.273/419
Attn: Ind. Div.,Tank-
Automotive Br. — 1st Ind. — Warner/ahk

C.O., Watertown Arsenal, Watertown 72, Massachusetts. 10 July 1943

To: District Chief, Chicago Ordnance District, First National Bank Bldg., Chicago, Illinois 3. Attn: Ind. Div., Tank-Automotive Branch.

1. Copy of transcript referred to in basic letter has been received.

2. Forwarding of carbon copy and stenotype notes is requested.

For the Commanding Officer:

H. H. Zornig
Colonel, Ordnance Dept.
Assistant

1 Incl.
w/d

(Inclosure 75)

W.A. 334/4568(r)
Chgo. O. D. 400.273/419
Attn: Ind. Div., Tank-
Automotive Br. — 3rd Ind. — Warner/ahk

C.O., Watertown Arsenal, Watertown 72, Massachusetts. 20 July 1943

To: District Chief, Chicago Ordnance, District, First National Bank Bldg., Chicago, Illinois 3. Attn: Ind. Div., Tank-Automotive Br.

1. Receipt of the material referred to in preceding indorsement is hereby acknowledged.

2. The assistance of his office in preparing this record of the meeting in question is appreciated.

For the Commanding Officer:

H. H. Zornig
Colonel, Ord. Dept.
Assistant

Incls. w/d

(Inclosure 76)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD Warner/ahk

Subcommittee on Welding of Armor

Laboratory 20 July 1943

Subject: Transcript of Meeting - Subcommittee on Welding of Armor

To: Chief of Ordnance
Pentagon Building
Washington, D. C.

Attn: SPOTB - Colonel S. B. Ritchie

1. Forwarded herewith is the first copy of the transcript of the discussions at the meeting of the Subcommittee held in Chicago on June 5, 1943. This copy is forwarded for file by his office, and a carbon copy has been retained for file at this arsenal, together with stenotype notes.

2. A summary of the discussions covered by this transcript has been prepared for distribution to the membership of the Subcommittee in accordance with the procedure established by all of the subcommittees to avoid excess typing and bulkiness of the minutes of these meetings. This summary will be forwarded in due course.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

1 Incl.
Transcript of meeting

(Inclosure 77)

[redacted]

APPENDIX A
Part 1-b

Organization and Membership

As indicated in Part I-a, attendance at the first Subcommittee meeting at Watertown and the second meeting at Aberdeen Proving Ground was by invitation. This was also to some extent true for the third meeting in Cleveland and the fourth meeting in Pittsburgh, although for both of these meetings a tentative membership roster had been prepared. Also, at the Cleveland meeting a Research Program Group had been organized from the fabricator representation (Inclosures 1 and 2) which marked the beginning of Subcommittee organization as a working body.

During June and July of 1941 plans were made to organize a Subcommittee on Resistance Welding (Inclosure 3). At the Subcommittee meeting in Pittsburgh, August 22, 1941, a number of companies were invited to attend as suggested either by the Office, Chief of Ordnance or by representatives of companies already members of the Subcommittee. At these early meetings of the Subcommittee prospective armor fabricators or companies otherwise interested in the welding of armor problem, as indicated from time to time, were elected to membership by majority vote of those in attendance at the meeting. As a result of such action notifications were sent to the management of the companies involved (Inclosure 4). The Office, Chief of Ordnance was generally kept informed of Subcommittee action on Ordnance Office requests by indorsement (Inclosures 5 and 6). The Subcommittee procedure of this period is also indicated by Inclosure 7. The policy as to membership at this time is indicated by Inclosures 8 and 9.

In addition there were requests, direct to the Subcommittee Chairman, regarding membership which were individually answered (Inclosures 10 and 11). This involved considerable correspondence, the volume of which was on the increase at this period.

At the fifth meeting in Philadelphia, October 1941, a number of representatives were invited to attend at request of OCO-Washington (Inclosure 12). The vote on membership of these companies was taken by correspondence with the current Subcommittee membership (Inclosures 13 and 14). When the vote had been taken, communications (Inclosure 15) were sent to the individuals referred to (Inclosure 12).

The tendency of industrial companies in such matters is indicated by Inclosure 16. In such cases a more detailed explanation of Subcommittee policy (Inclosure 17) was always necessary. In most cases, one explanation was usually sufficient (Inclosure 18) although such situations continued to arise as the Subcommittee membership expanded. Each was individually and diplomatically dealt with.

[redacted]

SBR/gmm

Laboratory

June 26, 1941

Subject: Research Program Subgroup

To: Commanding General
Rock Island Arsenal
Rock Island, Illinois

1. At the meeting of the Subcommittee for Welding of Armor held in Cleveland, Ohio, June 20, 1941 it was indicated that a Research Program Subgroup should be created within the subcommittee. The specific problem would be to critically examine the research and development program of this subcommittee with a view to a thorough examination of the projects now underway, the indication of additional projects which should be undertaken and suggested allocation for work to be done.

2. Accordingly, at this meeting a Subgroup, as mentioned, was named. This Subgroup consists of representatives of the six fabricators as follows:

A. O. Smith Corp., Milwaukee, Wisconsin
Baldwin Locomotive Co., Eddystone, Pennsylvania
Electro-motive Corp., LaGrange, Illinois
Diebold Safe & Lock Co., Canton, Ohio
York Safe & Lock Co., York, Pennsylvania
American Car & Foundry Co., Canton, Ohio

together with a representative of Rock Island Arsenal and Watertown Arsenal. It was suggested that the Rock Island Arsenal representative be named as chairman of this Subgroup. This appeared especially desirable in view of the fact that the matters to be considered deal largely with research matters pertaining to production and the experience Rock Island Arsenal has had in this field.

3. It was the consensus of feeling at the meeting that this Subgroup should meet shortly to consider a coordinated research program and make recommendations to the committee as a whole for consideration of the projects proposed. Mr. W. F. Schmitt and Mr. J. F. McDowell, who attended the meeting from Rock Island Arsenal, are familiar with the view of the subcommittee on this matter. The subcommittee recommended that Mr. W. F. Schmitt of Rock Island Arsenal be the one to assume chairmanship of this Subgroup. In view of the recommendation of the subcommittee, it is requested that he or some other qualified civilian or officer whom you may specify be permitted to serve in this capacity.

[redacted]

4. Early advice on this matter, together with information as to the date when the Subgroup meeting could be held, would be appreciated. A copy of the minutes of the meeting held in Cleveland, June 20 will be forwarded as soon as prepared. A copy of a letter to the Office, Chief of Ordnance under date of June 25, which gives a summary of the discussions at the meeting, is attached.

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board.

1 Incl. cc letter

(Inclosure 1)

[redacted]

R.I.A. 400.112/417
W.A. 334/1720 2nd Ind. SBR/gmm

Watertown Arsenal, Watertown, Massachusetts, July 9, 1941.
To: Commanding General, Rock Island Arsenal, Rock Island, Illinois.

1. This arsenal is pleased to note that the arrangements suggested in basic letter are satisfactory to Rock Island Arsenal and that Mr. Schmitt can act, at least to a limited extent, in the capacity suggested. As outlined in the preceding indorsement, it is believed that, due to the nature of the work involved in the Subgroup, Mr. Schmitt will be in position to handle it effectively. This is due to the fact that it was intended that this Subgroup examine the research and development program, which was attached to the agendum for the meeting of January 21, 1941 held at Aberdeen Proving Ground, and make recommendations as to research and development work which should be undertaken, the place or places where this work could most readily be accomplished (including Rock Island Arsenal and Watertown Arsenal and the industrial firms) and report its findings to the Welding Subcommittee as a whole. The recommendations of the Subgroup would then be reviewed by the whole Subcommittee and the direction and supervision of the work would fall within the sphere of its activity. This, therefore, would relieve the Subgroup chairman of the responsibility for direction of the research program and for that reason, it is believed the time which Mr. Schmitt may have available for the Subgroup activity work, as referred to in preceding indorsement, would be ample.

2. In view of the discussions at the meeting of the Subcommittee for Welding of Armor, held at Cleveland June 20, it is believed that a meeting of the Subgroup should be held at the earliest date practicable. It is therefore suggested that the Subgroup chairman arrange for such a meeting, the time and place to be at his discretion or as may be decided by Rock Island Arsenal. The following individuals are representatives on the Subcommittee for those firms indicated in paragraph 2, basic letter who constitute the industrial Subgroup members:

J. J. Chyle	-	A. O. Smith Corp.
A. J. Raymo	-	Baldwin Locomotive Co.
J. H. Hruska	-	Electromotive Corp.
W. C. Miller	-	Diebold Safe & Lock Co.
W. B. Lair	-	York Safe & Lock Co.
W. C. Osha	-	American Car & Foundry Co.

Mr. W. L. Warner, Welding Engineer, is the representative for Watertown Arsenal. It is requested that this arsenal be notified, as far in advance as practicable, of the date and place for the Subgroup meeting.

3. It is expected that the minutes of the meeting held at Cleveland on June 20 can be forwarded to Rock Island Arsenal on or before July 16. Any additional material available at Watertown Arsenal which the Subgroup chairman may need will be furnished upon request.

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

(Inclosure 2)

[redacted]

O.O. 400.273/37
W.A. 400.273/229 1st Ind. WLW/gmm

Watertown Arsenal, Watertown, Massachusetts, July 1, 1941
To: Chief of Ordnance, U.S.A., Washington, D. C.
Attn: Artillery Division - Technical Staff

1. The facilities available at Philadelphia referred to in paragraph 1 of basic letter are noted with interest and it is thought that advantage can be efficiently taken of these facilities by the proposed subcommittee on resistance welding which is in process of formation. It is believed that action on the request in paragraph 3 of basic letter should be held in abeyance for consideration by the resistance welding subcommittee.

2. The following members of the Resistance Welder Manufacturers Association are being invited to become members of the Subcommittee on Resistance Welding of the Ferrous Metallurgical Advisory Board:

Taylor-Winfield Corp., Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Federal Machine & Welder Co., Warren, Ohio
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Co., Detroit, Mich.
Swift Electric Welder Co., Detroit, Mich.

There will, of course, be representation from the Office, Chief of Ordnance, Rock Island Arsenal, Aberdeen Proving Ground, and Watertown Arsenal. It is contemplated to invite the General Electric Co. to designate Mr. R. T. Gillette, Schenectady Works Laboratory, an authority on spot welding, as a member of the subcommittee. He attended as an invited guest the recent meeting of the Subcommittee for Welding of Armor held in Cleveland, Ohio.

3. It is suggested that the question of permitting Mr. Riddell to offer his services to the subcommittee be left to the decision of the subcommittee on which his company will be represented.

Incl. - w/d
cy. ltr. fr. D. J. Riddell
O.O. 400.273/35

R. W. CASE
Brigadier General, U. S. Army
Commanding

(Inclosure 3)

[redacted]

August 30, 1941

Laboratory

Mr. E. J. Hunt
Operating Manager
Detroit Tank Arsenal
P.O. Box 1258
Detroit, Michigan

Dear Mr. Hunt:

At a meeting of the Subcommittee for Welding of Armor, held in Pittsburgh, Pennsylvania, August 22, 1941, the Chrysler Corporation, as represented through the Detroit Tank Arsenal, was suggested for membership on the Subcommittee. The suggestion was unanimously approved, and it was understood from Messrs. Dodt and Blake, who were in attendance at the meeting, that membership was desired. We are pleased to have your organization, as a member of the Subcommittee, participate in these activities.

It is requested that you designate the person to be the official representative in this connection and who is to receive correspondence pertaining to the work of the Subcommittee.

It is to be noted that some of the correspondence and reports are of a restricted or confidential nature, and it is assumed that the one designated to receive this material will safeguard it in the proper manner.

Very truly yours,

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

(Inclosure 4)

[redacted]

O.O. 334.8/4955
W.A. 334/1950 1st Ind. WLW/NAM/keb

Watertown Arsenal, Watertown, Massachusetts, September 22, 1941.
To: Chief of Ordnance, U.S.A., Washington, D. C.
Attn: Industrial Service - Tank Division.

1. In accordance with customary subcommittee procedure, the company referred to in basic letter will be considered for membership at the next meeting of the subcommittee and the company will be notified of committee action.

2. The Air Reduction Sales Company is being notified directly of the action being taken with respect to its membership.

For the Commanding General:

S. B. Ritchie
Lt. Col., Ordnance Dept.
Director of Laboratory

(Inclosure 5)

O.O. 334.8/5194
W.A. 334/2061 1st Ind. SBR/emg/kg

Watertown Arsenal, Watertown, Massachusetts, October 9, 1941
To: Chief of Ordnance, U.S.A., Washington, D. C. Attn: Industrial Service, Tank Division

1. In accordance with customary procedure, the Subcommittee members are being contacted with reference to membership of the firms listed in basic letter. The two companies are being notified accordingly.

2. With reference to the Oxweld Corporation, it is believed that they are interested primarily in gas welding. So far, the Subcommittee for Welding of Armor has membership only of those firms concerned with electric fusion welding. It is possible that an additional group should be organized consisting exclusively of firms interested in gas welding, such as was the case for resistance welding. Comments from the Office, Chief of Ordnance on this matter would be appreciated.

For the Commanding General:

S. B. Ritchie
Lt. Col., Ord. Dept.
Director of Laboratory

(Inclosure 6)

[redacted]

SBR/gmm

Laboratory

September 27, 1941

Mr. R. D. Thomas, Jr.
Member, Subcommittee for
Welding of Armor
Metallurgist
Arcos Corporation
401 North Broad Street
Philadelphia, Pennsylvania

Dear Mr. Thomas:

This acknowledges receipt of your letter of August 28 confirming our discussion at the last meeting of the Subcommittee for Welding of Armor in reference to the possible membership of the Reid Avery Company on the subcommittee.

In accordance with our usual practice, we are asking the individual members for their recommendations on this matter. I trust we will be in a position at least to invite a representative from the Reid Avery Company to attend the next meeting of the subcommittee. Your interest in this matter is appreciated.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee
for Welding of Armor

(Inclosure 7)

[redacted]

SBR/emg/kg

Laboratory

October 9, 1941

Major D. J. Crawford
Industrial Service, Tank & Combat
Vehicle Division
Office, Chief of Ordnance
New Social Security Bldg.
4th St. & Independence Ave., S.W.
Washington, D. C.

Dear Crawford:

In correspondence we have had with the Pullman Standard Car Manufacturing Company, they have indicated that you are desirous that they get into the welding of armor. They also indicate that they have already placed orders for experimental welding of hulls of the M3 Medium Tanks, and that the work will be underway in the very near future.

As you probably know, we have attempted to keep the Subcommittee within a reasonable size and have more or less restricted membership to those firms actually engaged in the welding of armor or qualified for it, and to those electrode manufacturers who are engaged on development work along this line. We, of course, want to include all those firms who should have membership in order to make the Subcommittee most effective and serve to best advantage.

Please let me have your comments and recommendations as to whether or not the Pullman Standard Car Manufacturing Company should be included on the Subcommittee or at least invited to the next meeting which we plan to hold in Philadelphia on October 24th. I trust you will be able also to join us at this meeting.

Sincerely yours,

S. B. Ritchie

(Inclosure 8)

[redacted]

War Department
Office of the Chief of Ordnance
Washington

Ind. Serv - Tank Div.

October 15, 1941

Colonel S. B. Ritchie
Director of Laboratory
Watertown Arsenal
Watertown, Mass.

Dear Sam:

Receipt of your letter of October 9, 1941 is acknowledged regarding the advisability of placing representatives of the Pullman Standard Car Manufacturing Company in the membership of the Subcommittee for Welding of Armor.

We realize that your Committee is already larger than desirable for the most efficient action but the number of contractors interested in producing welded tanks and other vehicles is growing daily. From one viewpoint, all of these concerns should have an opportunity to voice their opinions concerning Ordnance Department requirements in the welding of armor. Likewise, the electrode manufacturers should be represented but obviously, if all contractors concerned are allowed to have representatives on the Committee, your group will be much too large. Hence, it appears desirable to divide the membership into groups as follows:

a. Manufacturers of cast armor concerned with weld repair castings.

b. Welding contractors interested in making welded materiel.

c. Electrode manufacturers.

At the present time, group c meets with both a and b above. Furthermore, the electrode manufacturers do perform a useful function at these meetings but it is believed that groups a and b can perform their expected function without the presence of group c. Up to this time, the Ordnance Department has avoided that policy regarding electrodes which has been adopted by the Navy Department. As you know, the latter has an electrode qualification test which is met by 25-20 only. I think you will agree with me that other stainless electrodes will be found suitable for welding of armor, hence, the War Department would be unwise to adopt the present Navy policy, but in order to insure quality welds in our equipment, it appears that we shall soon have to assemble all we know about electrodes and develop some sort of electrode qualification tests.

[redacted]

It will be appreciated if, on your next visit to Washington, you pay us a visit in the Tank Division so we can discuss these various angles that are opening up as the result of the increased activity in the construction of welded materiel.

Sincerely yours,

/s/ D. J. CRAWFORD

(Inclosure 9)

[redacted]

SBR/emg/kg

Laboratory

October 9, 1941

Mr. B. J. Trautman
Chief Engineer
Pullman Standard Car Mfg. Company
Hammond Plant
Hammond, Indiana

Dear Mr. Trautman:

The matter with respect to membership on the Subcommittee for Welding of Armor, as referred to in your letters of September 4 and 5 has been referred to the Subcommittee members, and you will be advised prior to the next meeting with further reference to the matter.

We appreciate your interest and trust that you will have a representative at the coming meeting, the date for which it is expected can be submitted to you in the near future.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 10)

[redacted]

SBR/gmm

Laboratory October 22, 1941

Reid Avery Company

Attn: Mr. John W. Miller

Gentlemen:

A meeting of the Subcommittee for Welding of Armor is scheduled to be held at the Penn Athletic Club, Philadelphia, Pa. on October 24, 1941, beginning at 9:30 A.M.

It is understood that you desire membership on this subcommittee. You are invited to send a representative to the coming meeting. Please advise the name of the representative, if any, who will attend.

A copy of the Agenda for the meeting is attached.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee
for Welding of Armor

1 Incl.
Agenda

(Inclosure 11)

[redacted]

War Department
Office of the Chief of Ordnance
Washington

O.O. 334.8/6669

Brooker/mbg

Ind. Serv - Tank Div.

October 20, 1941

Subject: Subcommittee for Welding Armor - Membership in

To: Commanding General
Watertown Arsenal
Watertown, Mass.

Attn: Lt. Colonel S. B. Ritchie
Director of Laboratory

1. This is to confirm a teletype from this office dated October 15, 1941 and comply with the request in your teletype of October 16, 1941 - 10:48 A.M. EST JC SBR/GMM. Following are the names and addresses of manufacturers listed in our teletype of October 15, 1941 - 9:08 A.M., Atkins/ltm:

a. Mr. C. E. Sorenson
Ford Motor Company
Detroit, Michigan

b. Mr. E. Murphy
Pressed Steel Car Company
Hegeswich Station
Chicago, Illinois

c. Mr. B. J. Trautman
Pullman Standard Car Mfg. Company
Hammond, Indiana

d. Colonel H. W. Rehm
Detroit Tank Arsenal
P. O. Box 537
Detroit, Michigan

e. Mr. R. B. McColl
American Locomotive Company
30 Church Street
New York City

f. American Car & Foundry Company
Berwick, Pennsylvania

g. Mr. A. J. Raymo
Baldwin Locomotive Works
Eddystone, Pennsylvania

[redacted]

To: Watertown Arsenal
(Colonel S. B. Ritchie)

October 20, 1941

h. Mr. H. W. Snyder
Lima Locomotive Company
Lima, Ohio

i. Montreal Locomotive Company
P. O. Box 1350
Place D'Armes
Montreal, Quebec

All of the above should be members of the Subcommittee on Welding.

2. In addition, the following manufacturers' names are recommended to you for membership on the Subcommittee for Welding Armor. These, as well as the above, should receive agenda and invitations to the meeting in Philadelphia on October 24, 1941:

a. Mr. V. W. Whitmer
Republic Steel Corporation
Massillon, Ohio

b. Mr. D. S. Harder
Fisher Body Division
General Motors Corporation
General Motors Building
Detroit, Michigan

c. Mr. Bernard
Oxweld Corporation
Chicago, Illinois

d. Mr. Charles B. Lansing
322 Anisfield Building
Cleveland, Ohio

e. Mr. C. T. Penn
Indiana Limestone Corporation
Colorado Building
Washington, D. C.

By order of the Chief of Ordnance:

/s/ E. L. CUMMINGS
Major, Ordnance Dept.
Assistant

(Inclosure 12)

[redacted]

Laboratory NAM/GLC/amv

November 12, 1941

At the last meeting of the Subcommittee for Welding of Armor held in Philadelphia, Pa., on October 24, 1941, representatives from several firms anticipating the building of tanks and electrode manufacturers who are working on the general problem of welding of armor were in attendance at the suggestion of the Ordnance Office.

The following companies are expected to become fabricators of welded tanks and should, therefore, be added to the subcommittee membership:

Ford Motor Company
Fisher Body Division, General Motors Corp.
Lima Locomotive Company
Pullman Standard Car Manufacturing Company
Pressed Steel Car Company
Cadillac Motor Car Company
American Locomotive Company
Graver Tank Manufacturing Company

The following companies as electrode or welding equipment suppliers have been experimenting with the welding of armor and should, therefore, be considered for membership:

Linde Air Products Company
Air Reduction Sales Company
Champion Rivet Company
Crucible Steel Company of America
General Electric Company

Please indicate on the attached form and return at your earliest convenience any objections you may have to adding the above firms to the membership of the subcommittee. If no objections are received, within two weeks, these companies will be invited to designate representatives.

For the Commanding Officer:

Very truly yours,

G. L. Cox
Major, Ord. Dept.
Acting Director of Laboratory

Encl.
Form

(Inclosure 13)

[redacted]

Ordnance Department

Ferrous Metallurgical Advisory Board

Subcommittee for Welding of Armor

Membership Vote

Fabricators	Yes	No
Ford Motor Co.		
Fisher Body Corp.		
Lima Locomotive Co.		
Pullman Standard Car Mfg. Co.		
Pressed Steel Car Co.		
Cadillac Motor Car Co.		
American Locomotive Co.		
Graver Tank & Mfg. Co.		
Welding Equipment Mfgrs.		
Linde Air Products Co.		
Air Reduction Sales Co.		
Champion Rivet Co.		
Crucible Steel Co. of America		
General Electric Co.		

Remarks

Signed ______________________

Date ______________________

(Inclosure 14)

[redacted]

NAM/ELR/amv

Laboratory

December 5, 1941

Mr. B. J. Trautman
Chief Engineer
Pullman Standard Car & Mfg. Co.
Hammond Plant
Hammond, Indiana

Dear Mr. Trautman:

Since the last meeting of the Subcommittee for Welding of Armor, your firm has been approved for membership on the subcommittee. It is our desire that you designate a technical representative to serve on the committee and forward to him the attached minutes of the last meeting for information and file as well as return of the attached receipt form.

We are looking forward with interest to the co-operation of your firm in the activities of the subcommittee.

For the Commanding Officer:

Very truly yours,

G. L. Cox
Major, Ordnance Dept.
Acting Director of Laboratory

3 Encls.
Report
Form
Envelope

(Inclosure 15)

C
O
P
Y

[redacted]

Pullman-Standard Car Manufacturing Company
Hammond Plant
Hammond, Ind.

Subcommittee on Welding of Armor

December 11, 1941

G. L. Cox
Major, Ordnance Department
Acting Director of Laboratory
Watertown Arsenal
Watertown, Mass.

Dear Sir:

We have your letter of December 5, 1941 informing that Pullman-Standard Car Manufacturing Company has been approved for membership on the Subcommittee for Welding of Armor.

Kindly recognize the following as members:

R. M. Fox
B. J. Trautman
Wm. Boese
Wm. Bernhardt
W. Allan

also, F. C. Hasse, and A. A. Bernard of the Oxweld Railroad Service, Chicago, as recognized members or attendants at meetings as our consultants.

Thank you kindly for your consideration.

Respectfully yours,

/s/ B. J. Trautman
Assistant Works Manager

BJT-Jp

(Inclosure 16)

[redacted]

NAM/ELR/gmf

Laboratory

December 20, 1941

Mr. B. J. Trautman
Assistant Works Manager
Pullman-Standard Car Manufacturing Co.
Hammond, Indiana

Dear Mr. Trautman:

We asknowledge your letter of December 11 in which you indicate representatives on the Subcommittee for Welding of Armor.

While we should like very much to have the people you have suggested as members, we find it is necessary to limit the membership to one representative from each company to whom correspondence can be conducted. Due to the highly restricted nature of the activities of the subcommittees, it is also necessary that one person should be responsible for keeping all transactions and documents such as minutes of meetings, reports, etc. These subcommittees are becoming quite large and it is mandatory that the membership be limited to an efficiently functioning group.

We shall, therefore, appreciate your designating one representative from the list you have suggested.

For the President of the Board:

Very truly yours,

G. L. COX
Major, Ordnance Dept.
Acting Chairman, Subcommittee
for Welding of Armor

(Inclosure 17)

C
O
P
Y

[redacted]

Pullman-Standard Car Manufacturing Company
Hammond Plant
Hammond, Ind.

December 27, 1941

G. L. Cox
Major, Ordnance Department
Acting Chairman, Subcommittee
for Welding of Armor
Watertown Arsenal
Watertown, Mass.

Dear Sir:

Your letter of December 20 regarding representation on the Subcommittee for Welding of Armor.

To comply with your request to submit but one representative from each company, will you kindly recognize -

B. J. Trautman, Assistant Works Manager - member.

Wm. Boese, Welding Engineer - alternate member.

Thank you for your consideration.

Yours respectfully,

/s/ B. J. Trautman

Assistant Works Manager

BJT-Jp

(Inclosure 18)

[redacted]

Shortly after the first of the year 1942 a change of organization at Rock Island Arsenal required that the Chairman of the Research Program Group, now the Armor Fabricators' Group, sever his connection with the Subcommittee activities. A proposal for replacement was made (Inclosure 19) which was approved by Rock Island Arsenal.

Early in 1942 the policy of permitting industrial companies to designate an alternate in addition to a regular member was adopted (Inclosure 20). During the summer of 1942 it was recognized that manufacturers of core wire for stainless electrodes used in welding armor should have a better understanding of some of the welding problems involved in armor fabrication and steps were taken to bring certain of them into Subcommittee activities (Inclosures 21 and 22).

As the Subcommittee was now rapidly increasing in size and representation from various branches of the welding industry was being added for coordination of effort in the welding of armor problem, it appeared desirable to merge the Subcommittee on Resistance Welding with the Subcommittee on Welding of Armor as explained in Inclosures 23 and 24. The Office, Chief of Ordnance was informed of this proposed organization (Inclosure 25). The plans were explained to Ordnance Office, Army Air Forces, Wright Field, as per Inclosure 26.

Following this Subcommittee merger, it appeared desirable to add to the membership of the Resistance Welding Group as suggested by Inclosure 27, because the two individuals referred to had been and were associated with considerable resistance welding development work. The work on a Specification for Resistance Welding of Armor is indicated by Inclosure 28.

During late 1942 the organization of the Subcommittee reached probably its highest stage of development as indicated by Subcommittee Circular W-1, included as Part II of this Appendix. During this period there arose the problem of representation of Canadian and British organizations by foreign nationals, who, because of War Department regulations, had to be cleared to receive classified data before they could become Subcommittee members (Inclosures 29, 30, and 31). Such clearance was usually obtained (Inclosures 32, 33, and 34). In February 1943, Subcommittee Circular W-2 was first issued. This Circular was revised and reissued in January 1944 (Part IV, Appendix A). Notification of clearance to individuals concerned was usually sent by the Subcommittee Chairman (Inclosure 35). Certain alternates for foreign members were also cleared to attend meetings (Inclosure 36).

[redacted]

NAM/gaf

Laboratory (NAM) February 11, 1942

Subject: Chairman, Armor Fabricators Subgroup, Subcommittee for Welding of Armor, Ferrous Metallurgical Advisory Board

To: Commanding General
Rock Island Arsenal
Rock Island, Illinois

1. Recently Mr. W. F. Schmitt, who has been Chairman of the Armor Fabricators Subgroup of the Subcommittee for Welding of Armor, has been unable to participate in the activities of the subgroup because of his assignment to other duties at your Arsenal. It is suggested that Mr. J. K. McDowell be appointed as chairman of the subgroup to replace Mr. Schmitt, in view of the fact that Mr. McDowell has been acting as chairman and is familiar with the activities of the committee.

2. The scope of the investigations now being carried out on the welding of armor is increasing steadily, and it is necessary that all possible efforts be devoted in an attempt to coordinate these activities. It is the opinion of this Arsenal that Mr. McDowell can serve in an extremely important capacity as chairman of the subgroup.

JOHN MATHER
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

(Inclosure 19)

[redacted]

Laboratory-NAM

NAM/ELR/amv

February 10, 1942

Vice President
Marmon-Herrington Co., Inc.
Indianapolis, Indiana

Dear Sir:

Your company has been approved for membership on the Subcommittee for Welding of Armor formed under the jurisdiction of the Ferrous Metallurgical Advisory Board of the Ordnance Department. Mr. B. J. Smith of Marmon-Herrington attended the last meeting of the subcommittee held in Detroit on January 7, 1942.

It is requested that you designate an individual to represent your company at the meetings and to receive correspondence and, if desirable to you, an alternate to participate in subcommittee activities when the designated member is not available.

It is desirable that your reply be received at an early date in order that correspondence with reference to the coming meeting of the subcommittee may be directed to the proper person.

For the President of the Board:

Very truly yours,

G. L. Cox
Major, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 20)

[redacted]

Laboratory (WLW) WLW/ahk

September 9, 1942

Subject: Core Wire Manufacturers' Representation on Subcommittee for Welding of Armor

To: Chief of Ordnance, U. S. Army
Washington, D. C.

Attn.: Industrial Division, Tank Branch, Armor Section

1. Reference TT40960 SPOIT Armor Brooker, regarding representation of core wire manufacturers on the Subcommittee for Welding of Armor, it is believed that core wire manufacturers are most concerned with reaching an understanding with electrode manufacturers as to standard requirements for core wire. For this purpose it is considered desirable that they be members of the Electrode Subgroup.

2. Crucible Steel Company and Page Steel and Wire Company now have membership and it is understood that American Steel and Wire Company also desires membership. Accordingly notices of the meeting of the Subgroup on the 19th are being mailed to the companies listed in above teletype, and American Steel and Wire Company. The names of those representatives who will attend are expected to be available prior to the start of the meeting.

For the President of the Board:

G. L. Cox
Lt. Col., Ord. Dept.
Acting Chairman, Subcommittee
for Welding of Armor

(Inclosure 21)

[redacted]

WLW/ahk

Laboratory (WLW)

September 9, 1942

President
Pittsburgh Steel Company
1670 Grant Building
Pittsburgh, Pa.

Dear Sir:

It has been suggested that your company may be interested in obtaining membership on the Subcommittee for Welding of Armor of the Ordnance Department Ferrous Metallurgical Advisory Board in connection with the activities of that Subcommittee toward standardization of electrode materials for welding of armor.

If such is the case, will you designate a representative, and an alternate, who will receive and be responsible for all Subcommittee correspondence and reports to be forwarded to your company, and who will attend Subcommittee meetings. It is desired that someone who is both technically trained and can speak with authority for your company be designated to serve on this Subcommittee.

The next meeting of the Subcommittee is scheduled for Sunday, September 20, 1942, to be held at the Hotel Statler, Detroit, Michigan. On Saturday, September 19, at the Hotel Statler, there will be held a meeting of the Electrode Manufacturers Subgroup of this Subcommittee which your designated representative may wish to attend. As soon as the name of this representative is received, a copy of the Agenda for the Subcommittee meeting on September 20 will be forwarded.

For the President of the Board:

Yours very truly,

G. L. Cox
Lt. Col., Ord. Dept.
Acting Chairman, Subcommittee
for Welding of Armor

(Inclosure 22)

[redacted]

WLW/ahk

Laboratory (WLW) July 24, 1942

In view of the increasing interest in the application of resistance welding to the fabrication of light armored vehicles, as well as aircraft, it appears desirable to incorporate the present membership of the Subcommittee for Resistance Welding into the Subcommittee for Welding of Armor to handle problems on resistance welding which from time to time are brought before the Subcommittee.

The present Subcommittee for Welding of Armor has organized within its membership several groups, each under its own chairman, that deal with problems pertaining to certain phases of the general subject of welding of armor. The groups organized at present are:

Homogeneous Armor Fabricators
Face-Hardened Armor Fabricators
Electrode Manufacturers
Welding Specifications
Research Program

These groups meet with the Subcommittee and also independently at the call of their respective chairmen to consider problems related to their particular phase of the armor welding problem.

It is proposed that the present members of the Subcommittee for Resistance Welding will constitute a group on Resistance Welding of the Subcommittee for Welding of Armor, under its own group chairman, and that this group will handle problems on resistance welding which may be referred to it for consideration from time to time by the chairman of the Subcommittee.

It is desired to obtain your concurrence in this proposed change. An early reply would be appreciated.

Your present chairman will relinquish his chair to the Chairman of the Subcommittee for Welding of Armor (Col. H. H. Zornig, Watertown Arsenal) and the chairman of your group can be elected at your first meeting. It is preferred that your chairman be selected from the industrial members of the group.

For the President of the Board:

Very truly yours,

C. L. Cox
Major, Ordnance Dept.
Chairman, Subcommittee for
Resistance Welding

(Inclosure 23)

[redacted]

GLC/gmf

Laboratory (GLC)

August 7, 1942

Mr. B. L. Wise
Member, Subcommittee for Resistance Welding
Chief Electrical Engineer
The Federal Machine and Welder Company
Warren, Ohio

Dear Mr. Wise:

We appreciate your letter of July 28 and the position you have taken with regard to relationship between the Subcommittee for Resistance Welding and the Subcommittee for Welding of Armor. Perhaps in my earlier letter I did not make myself clear as to what our real intention is.

The most urgent problem that the Ordnance Department has at this time where resistance welding will apply is in connection with the fabrication of armor. Undoubtedly there are many other applications of resistance welding in connection with equipment other than armor but these are not as important and they are perhaps further along in their development and application than the resistance welding of armor.

The membership of the Subcommittee for Welding of Armor includes numerous fabricators who should have the benefit of the knowledge that has been developed in the resistance welding of armor. Therefore, we thought it desirable to incorporate the Subcommittee for Resistance Welding into the Subcommittee for Welding of Armor, and the present membership of the Subcommittee for Resistance Welding could remain intact as the subgroup to the main subcommittee. The effort of the subgroup could then be directed toward development of resistance welding methods for armor. In this manner the development of work which you and representatives of other companies have been doing will be brought before many using establishments and, consequently, the Ordnance Department can make use of the data to a greater advantage. The membership of this Resistance Welding Subgroup would not necessarily have to divorce itself from any other consideration for welding and in its same membership could form any committee they wished to carry forward any other program having to do with resistance welding of structures other than armor. Should the need become sufficiently acute for development work into these other fields, consideration could then be given for the formation of another subcommittee to handle those phases.

Tentatively we are planning to hold a meeting of the Subcommittee for Welding of Armor, possibly in Detroit, on September 20.

[redacted]

Mr. B. L. Wise, p. 2, 8/7/42.

We think, therefore, that it would be highly desirable to hold a meeting of the Subcommittee for Resistance Welding on the 19th and the members of the Subcommittee for Resistance Welding could then stay over and attend the meeting of the Subcommittee for Welding of Armor. I believe that by such a procedure we can discuss openly the situation regarding the subcommittees and the advantages and disadvantages of the incorporation as suggested in my earlier letter.

For the President of the Board:

Very truly yours,

G. L. COX
Major, Ordnance Dept.
Chairman, Subcommittee
for Resistance Welding

(Inclosure 24)

[redacted]

WLW/ahk

Laboratory (WLW) July 25, 1942

Subject: Subcommittee for Resistance Welding

To: Chief of Ordnance, U. S. Army
Washington, D. C.

Attn: Service Branch, Technical Division

1. There is attached for your information and file, a copy of a letter which has been sent to the industrial members of the Subcommittee for Resistance Welding, proposing a change of organization. It is considered that this reorganization is desirable in view of the increasing interest on the part of armored vehicle fabricators' interest concerning the possibilities of using resistance welding methods to expedite the production of such vehicles.

For the President of the Board:

G. L. Cox
Major, Ordnance Dept.
Chairman, Subcommittee for
Resistance Welding

1 Incl.
cc. of letter

(Inclosure 25)

[redacted]

W.A. 334/3759 2nd Ind. WLW/amt

Watertown Arsenal, Watertown, Massachusetts, September 15, 1942
To: Ordnance Office, Wright Field, Dayton, Ohio. Attn: Major McInnes

1. It is planned that the Subcommittee for Resistance Welding will become a Subgroup of the Subcommittee for Welding of Armor to handle all matters pertaining to resistance welding of armor which may arise or be referred to it by the main subcommittee or its other subgroups.

2. At the present time there are the following subgroups functioning under the Subcommittee for Welding of Armor:

Homogeneous Armor Fabricators' Subgroup
Face-Hardened Armor Fabricators' Subgroup
Electrode Manufacturers' Subgroup
Specifications Subgroup
Research Subgroup

3. It is expected that an Aircraft Armor Fabricators' Subgroup will be organized from the representatives of the aircraft companies as suggested in 1st Indorsement W. F. 00 470.5, W.A. 334/4040 of September 9th, 1942, to consider the problems relating to fabrication of aircraft armor by welding and to develop procedures for this fabrication with such assistance from the other subgroups and subcommittee membership as may be possible. It is not believed desirable to combine the Resistance Welding Subgroup with the Aircraft Armor Fabricators' Subgroup to form a Subgroup on Welding of Aircraft Armor Plate because, as indicated in paragraph 2 of 1st Indorsement, the welding of aircraft armor will undoubtedly involve arc welding as well as resistance welding. Also, such a subgroup would involve too large a membership for effective action.

4. The suggestions for the agenda for the meeting of the Resistance Welding Subcommittee are appreciated and copies of the specifications requested will be available at the Hotel Statler for the meeting. It is suggested that Major McInnes should devote his attention to getting the aircraft fabricator representatives organized as a subgroup with himself acting as temporary chairman. In this organization meeting opportunity should be presented for the representatives present to elect a permanent chairman who will conduct subgroup meetings and present subgroup reports to the main committee. There should also be appointed a representative of this subgroup to the Specifications Subgroup of which Major J. V. Coombe, Office, Chief of Ordnance, Industrial Division, Tank Branch, is chairman. This Specification Subgroup consists of an appointed representative from each of the other subgroups and its function is to consider and take final action on specifications referred to it by the chairman of the Subcommittee for Welding of Armor.

For the President of the Board:

1 Incl. w/d

G. L. Cox
Lt. Col., Ord. Dept.
Chairman, Subcommittee for Resistance Welding

(Inclosure 26)

[redacted]

WLW/ahk

Laboratory (WLW) October 3, 1942

Subject: Membership, Resistance Welding Subgroup - Subcommittee for Welding of Armor.

To: Office, Chief of Ordnance, U.S.A.
Washington, D. C.

Attn: Technical Division, Service Branch

1. It is desired to add to the membership of the Resistance Welding Subgroup of the Subcommittee for Welding of Armor the following individuals because of their experience with the development and application of resistance spot welding to armor:

Professor Wendell F. Hess
Associate Professor, Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

Stuart M. Spice
Welding Engineer, Buick Motor Div., General Motors Corp., Flint, Michigan.

2. Before inviting these two men to the above membership, it is desired that they be cleared by G-2. When this information is received, invitations will be extended to them by this arsenal.

For the Commanding Officer:

H. H. Zornig
Colonel, Ord. Dept.,
Chairman, Subcommittee for
Welding of Armor

(Inclosure 27)

[redacted]

WLW/ahk

Laboratory (WLW) October 5, 1942

Subject: Meeting of Subcommittee for Resistance Welding

To: Chief of Ordnance, U. S. Army
Washington, D. C.

Attn: SPOTB

1. At a meeting of the Subcommittee for Resistance Welding held Saturday, September 19, 1942, at the Hotel Statler, Detroit, Michigan, recent developments in spot and flash welding were discussed. Consideration was given to revision of Tentative Specification WXS-169, "Spot Welding of Armor for Aircraft," and it was agreed that this specification should be redrafted to cover spot welding of armor in general.

2. The Subcommittee voted to disband as a Subcommittee and to become affiliated with the Subcommittee for Welding of Armor as a Resistance Welding Group. Mr. J. H. Cooper, Taylor-Winfield Corporation, was elected Chairman of the Group.

3. A small Subgroup of five members was designated by the Chairman to meet with Prof. W. F. Hess at Rensselaer Polytechnic Institute, Troy, New York, on September 28, to establish definite physical requirements for spot welds in armor from 1/4" to 1" in thickness, inclusive.

4. At the meeting of the Subgroup on September 28, attended by:

Mr. J. H. Cooper, Taylor-Winfield Corp.
Mr. L. M. Benkert, Progressive Welder Co.
Mr. W. A. Stanley, " " "
Mr. F. A. Lee, International Harvester Co.
Mr. W. T. Ober, Thomson-Gibb Welding Co.
Mr. W. L. Warner, Watertown Arsenal
Prof. W. F. Hess, Rensselaer Polytechnic Institute,

values for minimum size of spot weld nugget, spacing, shear strength were established, together with recommendations for procedure qualification and production check testing in connection with production of armored vehicles.

5. A revision of Tentative Specification WXS-169 is being drafted, incorporating the recommendations proposed by the Subgroup. As soon as concurrence of the Resistance Welding Group of the Subcommittee for Welding of Armor is obtained, the draft will be forwarded for consideration.

For the President of the Board:

H. H. Zornig
Colonel, Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 28)

[redacted]

O.O.M. 334.8/122
W.A. 334/4017 1st Ind. WLW/ahk

Watertown Arsenal, Watertown, Massachusetts, November 26, 1942
To: Chief of Ordnance, U.S.A., Pentagon Building, Washington, D. C.

1. The gentlemen mentioned in basic letter have been asked to attend the meetings of the Subcommittee on Welding of Armor to be held in Philadelphia, Penn. on December 5 and 6 as visitors.

2. Major Coombe has indicated by telephone that clearance for membership on the Subcommittee on Welding of Armor for these gentlemen, who are Canadians, has not yet been obtained from G-2. It is requested that such clearance be obtained so that they may be made members as requested.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 29)

O.O.M. 470.5/487
W.A. 334/4048 1st Ind. WLW/ahk

Watertown Arsenal, Watertown, Massachusetts, November 27, 1942
To: Chief of Ordnance, U.S.A., Pentagon Building, Washington, D. C.

1. The gentlemen mentioned in basic letter have been asked to attend the meetings of the Subcommittee on Welding of Armor to be held in Philadelphia, Penn. on December 5 and 6 as visitors.

2. It is believed that clearance for membership on the Subcommittee on Welding of Armor for these gentlemen who are Canadians has not yet been obtained from G-2. It is requested that such clearance be obtained so that they may be made members as requested.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 30)

[redacted]

WLW/ahk

FERROUS METALLURGICAL ADVISORY BOARD

Laboratory (WLW) Subcommittee on Welding of Armor November 27, 1942

Subject: Clearance for Membership

To: Chief of Ordnance, U. S. Army
Washington, D. C.

Attn: Technical Division - Service Branch

1. The Tank-Automotive Center, Detroit, has requested that Mr. L. W. Williams of the Inspection Board of the United Kingdom and Canada, Pigot Building, Hamilton, Ontario, Canada, be invited to become a member of the Subcommittee as per copy of TT17426 attached.

2. Clearance for such membership is requested in order that his name may be added to the Subcommittee list.

3. Mr. Williams has been invited to attend the meetings in Philadelphia on December 5 and 6 as a visitor. In such capacity he is not eligible to receive transcripts of the meetings.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

1 Incl.
Copy of TT17426

(Inclosure 31)

C
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[redacted]

War Department
Office of the Chief of Ordnance
Washington, D. C.

O.O. 334.8/16549
SPOTB

January 1, 1943

Subject: Technical Liaison with our Allies in regard to "Ordnance Steels"

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. Reference is made to letter from his office dated October 16, 1942, W. A. 334/3914 - Technical Liaison with our Allies in regard to "Ordnance Steels."

2. The Military Intelligence Service has approved the following named representatives for membership on Subcommittees of the Ferrous Metallurgical Advisory Board of the Ordnance Department:

a. Mr. T. A. Rice, Superintendent
International Harvester Co. of Canada, Limited
Hamilton, Ontario

b. Mr. F. A. Sherman, Vice President and General Manager
Dominion Foundries and Steel Limited
Hamilton, Ontario

c. Colonel H. G. Hoare
Inspection Board of the United Kingdom and Canada
Ottawa, Ontario

3. It is assumed that these representatives will be notified of their membership by the Chairman of the Subcommittees concerned.

By order of the Chief of Ordnance:

/s/ S. B. Ritchie
Colonel, Ord. Dept.
Assistant

(Inclosure 32)

[redacted]

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War Department
Office of the Chief of Ordnance
Washington, D. C.

O.O. 334.8/16528
W.A. 334/4287
SPOTB

January 8, 1943

Subject: Member of the Subcommittees of the Ferrous Metallurgical Advisory Board

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

Attn: Colonel H. H. Zornig

1. The appointment of Mr. G. B. Findon as member of the Subcommittees of the Ferrous Metallurgical Advisory Board of the Ordnance Department has been approved. It is understood that Mr. Findon will make contact with the Chairman of these Subcommittees (Colonel Zornig) in reference to future meeting dates. Mr. Findon's present address is British Supply Mission, Kedrick Bldg., 1801 "K" Street, N.W., Washington, D. C.

2. Approval has not yet been received with respect to membership of Major A. W. Senior on these Subcommittees. Further advice will be furnished on this as soon as definite decision has been made.

By order of the Chief of Ordnance:

/s/ S. B. Ritchie
Colonel, Ord. Dept.
Assistant

(Inclosure 33)

[redacted]

C
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War Department
Office of the Chief of Ordnance
Washington

O.O. 470.5/14270
Attn: SPOTB

April 1, 1943

Subject: Mr. J. A. Balcom of the Tanks Inspection Division (Inspection Board of United Kingdom and Canada)

To: Commanding Officer
Watertown Arsenal
Watertown, Massachusetts

Attention: Colonel H. H. Zornig

1. At the request of Brigadier MacKenzie, Deputy Inspector General (Washington) and Director Technical Services (Armaments), Inspection Board of United Kingdom and Canada, Mr. J. A. Balcom of the Tanks Inspection Division (Inspection Board of United Kingdom and Canada) has been cleared for attendance at meetings of the following subcommittees of the Ferrous Metallurgical Advisory Board:

Subcommittee on Rolled Armor
Subcommittee on Cast Armor
Subcommittee on Welding of Armor

2. It has been suggested to Brigadier MacKenzie that he notify Mr. Balcom of this clearance. It is requested that the Chairmen of these Subcommittees also notify Mr. Balcom and indicate to him the dates for the coming meetings of the various subcommittees involved.

3. It is assured that Mr. Balcom's membership on the Subcommittees is satisfactory to the Ferrous Metallurgical Advisory Board and the committees involved. This is on the basis of the original recommendations submitted by Watertown Arsenal for membership of Canadian representatives of these groups.

By order of the Chief of Ordnance:

/s/ S. B. RITCHIE
Colonel, Ord. Dept.
Assistant

(Inclosure 34)

[redacted]

NAM/amv

Laboratory (NAM) April 5, 1943

Mr. J. A. Balcom
Tanks Inspection Division
Inspection Board of United Kingdom and Canada
5-146 General Motors Building
Detroit, Michigan

Dear Mr. Balcom:

Confirming teletype of this date, clearance has been obtained from Washington for your membership on the following Subcommittees of the Ferrous Metallurgical Advisory Board:

Subcommittee on Rolled Armor
Subcommittee on Cast Armor
Subcommittee on Welding of Armor

For your information there are attached copies of Circulars Nos. 1 and 2 for the first two subcommittees above which describe their organization, functions, and list the membership at the present time. It is our understanding that you have these circulars for the Welding Subcommittee.

We shall be pleased to have your participitation in the activities of these committees and hope that you will benefit thereby.

For the President of the Board:

Very truly yours,

H. H. ZORNIG
Colonel, Ordnance Dept.
Chairman, Subcommittee on Armor

4 Encls.
Circulars Nos. CA-1, CA-2,
RA-1, and RA-2

(Inclosure 35)

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[redacted]

War Department
Office of the Chief of Ordnance
Washington, D. C.

O.O. 334.8/18675
Attn: SPOTB

April 29, 1943

Subject: Subcommittee of the Ferrous Metallurgical Advisory Board

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

Attn: Colonel H. H. Zornig

1. This office has been requested by Inspector-General, Inspection Board of United Kingdom and Canada, Colonel Hoare, that alternates be named for him on the Subcommittees of the Ferrous Metallurgical Board for Cast Armor, Rolled Armor, and Welding of Armor. Colonel Hoare is now a member of these Subcommittees.

2. Colonel Hoare suggests that Lt. Col. P. S. Blowey and Lt. Col. A. V. Golding be designated as alternates for him. The above-named alternates have been cleared by Military Intelligence and your records should be revised accordingly.

By order of the Chief of Ordnance:

Very truly yours,

/s/ G. Elkins Knable
Col., Ord. Dept.
Assistant

(Inclosure 36)

[redacted]

One of the problems of the Subcommittee Chairman from the beginning of Subcommittee organization had been to obtain continuity of representation from various agencies of the Government. It was recognized, however, that changing duties of personnel, as the organization for the war effort grew, might prevent this being accomplished in a stable form and communications were usually sent officially notifying the agency of date of meeting and requesting information as to the representatives who would attend (Part I-a).

Late in 1943 and early in 1944 (as shown by Circular W-2) designation of representation was obtained (Inclosures 37 and 38). In such cases the limitation of two members imposed on industrial companies was not applied.

This limitation of two members to a company was very infrequently challenged but in the few cases which occurred the Chairman of the Subcommittee was not over-ruled by the Office, Chief of Ordnance. One of the latest incidents of this sort which arose is illustrated by Inclosures 39 through 47. Such incidents were quite rare, however.

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD Warner/ahk

Subcommittee on Welding of Armor

Laboratory (WLW) 10 March 1944

Subject: Ferrous Metallurgical Advisory Board - Subcommittee Membership

To: Commanding General
Office, Chief of Ordnance-Detroit
Detroit 32, Michigan

Attn: Engineering Branch, Materials Section,
Armor and Welding Unit

1. The current membership list of the Subcommittee on Welding of Armor contains the following as representing his office:

Major J. V. Coombe, SPOME - EE
Major D. C. Pippel, " "
Capt. J. F. Randall, " "
Capt. A. F. Boucher, " "
Lt. J. J. Matt, Development Branch

For Group assignments, reference is made to the inclosed copy of the Subcommittee Membership List, Circular No. W-2 (Rev. 1).

2. Information is desired as to whether this representation is satisfactory to his office, and if not, what changes in Subcommittee records are desired.

For the President of the Board:

1 Inc.
Cir. W-2 (Rev. 1)

H. H. Zornig
Colonel, Ordnance Dept,
Chairman, Subcommittee on
Welding of Armor

(Inclosure 37)

C
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[redacted]

OOM 334/Watertown Arsenal (10 Mar 44)
Attn: SPOMB-EE
Wtn 334/6099 — 1st Ind. — Pippel/dw 2995/24th Fl.

A.S.F., Office, Chief of Ordnance-Detroit, Detroit 32, Michigan, 28 March 1944

To: Commanding Officer, Watertown Arsenal, Watertown 72, Mass.
ATTN: Col. H. H. Zornig, Chairman, Subcommittee on Welding of Armor, (Laboratory-WLW)

1. Representation as listed in basic letter satisfactory to this office.

By order of the Chief of Ordnance:

/s/ D. C. PIPPEL
Major, Ord. Dept.
Assistant

1 Incl: W/D

(Inclosure 38)

[redacted]

Subcommittee Membership Designation Form

Date February 8, 1943

The President
Ferrous Metallurgical Advisory Board
Watertown Arsenal
Watertown, Massachusetts

Sir:

The A. O. Smith Corp.
(Company)
of Milwaukee, Wisconsin
(Address)
desires to be represented on the Ferrous Metallurgical Advisory Board's Subcommittee on Welding of Armor. It desires to designate as its representative on this Subcommittee the following persons:

John J. Chyle, Director of Welding Research
(Name) (Position)
Dr. K. Blanchard, Electrode Development Eng.
(Name) (Position)

These individuals are citizens of the United States and the Company is willing to vouch for their loyalty to the United States.

Our company desires a representative on this Subcommittee because we are manufacturers of electrodes and also are offering our welding experience to help on armor welding problems.

Very truly yours,

/s/ John J. Chyle

Alternates - for J. J. Chyle - Mr. M. M. Millette
for K. Blanchard - Mr. E. Steidl

(Inclosure 39)

C
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P
Y

[redacted]

A. O. Smith Corporation
Milwaukee
Wisconsin

March 30, 1944

Colonel H. H. Zornig
The Watertown Arsenal
Watertown, Massachusetts

Dear Colonel Zornig:

One of our men who has been most active in the armor plate welding program and has attended most of the meetings advises me that he is not on the list to receive notification of the regular meetings on this subject and has therefore had to identify himself each time.

We would appreciate it if you could add to your list the name of A. E. Steidl of our company for future notification.

Thanking you for your consideration of this request, we are

Very truly yours,

/s/ L. M. Keating, Manager
Special Products Division

LMK;AJ:as

(Inclosure 40)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD   Warner/ahk

Subcommittee on Welding of Armor

Laboratory (WLW)   3 April 1944

Mr. L. M. Keating, Manager
Special Products Division
A. O. Smith Corporation
P.O. Box 584
Milwaukee 1, Wisconsin

Dear Mr. Keating:

With reference to your letter of 30 March 1944, we note from our Subcommittee records that your company is now represented by Dr. M. K. Blanchard and Mr. J. J. Chyle.

In accordance with the organization of the Subcommittee whereby the representation of industrial companies has been limited to not more than two members, which limitation is desirable to prevent the Subcommittee from becoming too large to be effective, Mr. Steidl is not regarded as a regular member and, therefore, does not receive official notices of the meetings. If it is desirable to substitute Mr. Steidl for one of the two present representatives of your company, we would appreciate further advice in that connection.

For the President of the Board:

Very truly yours,

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 41)

[redacted]

A. O. Smith Corporation
Milwaukee 1
Wisconsin

April 5, 1944

Colonel H. H. Zornig
The Watertown Arsenal
Watertown, Massachusetts

Dear Colonel Zornig:

In Mr. Keating's letter of March 30 he requested that I be put on your mailing list to receive notification of the regular armor plate meetings.

However, I note that a typographical error appeared in this letter, inasmuch as my initials were transposed, and I ask that you kindly correct your records to show my name as given below so that my mail will be addressed correctly.

Thank you in advance for this courtesy.

Very truly yours,

/s/ E. A. Steidl
Welding Equipment Division

(Inclosure 42)

rs

C
O
P
Y

[redacted]

A. O. Smith Corporation
Milwaukee 1
Wisconsin

April 27, 1944

<u>Laboratory (WLW)</u>

Colonel H. H. Zornig, Chairman
Sub-Committee on Welding of Armor
War Department
Watertown Arsenal
Watertown 72, Massachusetts

Dear Colonel Zornig:

Thank you for your letter of April 3 in connection with placing Mr. Steidl on your list to receive notifications of regular Armor Plate Meetings.

Since Doctor M. K. Blanchard is interested in attending the Electrode Group Meetings only, we are wondering whether it would be agreeable to you to substitute Mr. E. A. Steidl's name for attendance at the General Committee Meetings.

We will appreciate your help in making this arrangement possible.

Very truly yours,

/s/ L. M. Keating, Manager
Special Products Division

LMK:AJ:as

(Inclosure 43)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD Warner/ahk

Subcommittee on Welding of Armor

Laboratory (WLW) 4 May 1944

Mr. L. M. Keating, Manager
Special Products Division
A. O. Smith Corporation
Milwaukee 1, Wisconsin

Dear Mr. Keating:

With reference to your letter of 27 April in connection with representation of the A. O. Smith Corporation on the Subcommittee on Welding of Armor, we find that under date of 8 February 1943 a Subcommittee Membership Designation Form was received signed by Mr. J. J. Chyle, Director of Welding Research. This form designates as representatives of the A. O. Smith Corporation on the Subcommittee the following:

Mr. J. J. Chyle, Director of Welding Research
Dr. K. Blanchard, Electrode Dev. Engr.

As alternates the following are named:

Mr. M. M. Millette for Mr. Chyle
Mr. E. Steidl for Dr. Blanchard

Alternates are not listed as Subcommittee members, but may attend meetings in the absence of the member for whom they are alternate. Alternates do not receive Subcommittee notices or reports except as may be passed on to them by the designated company representatives. Individual company representatives are not members of a Subcommittee Development Group without also being members of the Subcommittee. This is a rule of organization of the Subcommittee.

If the representation as indicated above is not as desired by the A. O. Smith Corporation, we would be glad to be informed. In this connection the principle of Subcommittee organization referred to in our letter of 3 April should be kept in mind.

For the President of the Board:

Very truly yours,

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 44)

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD   Warner/ahk

Subcommittee on Welding of Armor

Laboratory (WLW)   4 May 1944

Mr. J. J. Chyle, Member
Director of Welding Research
A. O. Smith Corporation
Milwaukee 1, Wisconsin

Dear Mr. Chyle:

There are inclosed for your information, copies of letters between Mr. L. M. Keating and this office relative to membership of Mr. E. A. Steidl on the Subcommittee. In our latest letter we trust we have explained the organizational set-up of the Subcommittee in a sufficiently satisfactory manner.

For the President of the Board:

Very truly yours,

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

4 Incls.

cc.	ltr.	to	L.M.K.	4 May
"	"	"	"	3 April
"	"	from	"	27 April
"	"	"	"	30 March

(Inclosure 45)

[redacted]

A. O. SMITH CORPORATION
Milwaukee 1
Wisconsin

May 15, 1944

Col. H. H. Zornig, Chairman
Subcommittee on Welding of Armor
Ferrous Metallurgical Advisory Board
War Department
Watertown Arsenal
Watertown 72, Massachusetts

Dear Col. Zornig:

This will acknowledge your letter of May 4 with regard to Subcommittee membership on the Welding of Armor.

I was not aware of the members and alternates originally suggested by Mr. Chyle. After reviewing the matter we feel they are entirely satisfactory as they stand.

Thanking you for your suggestions in this matter, I am

Very truly yours,

/s/ L. M. Keating, Manager
Special Products Division

LMK:AJ:gb

(Inclosure 46)

[redacted]

A. O. SMITH CORPORATION
Milwaukee 1
Wisconsin

June 26, 1944

Colonel H. H. Zornig
Ordnance Department
Chairman, Subcommittee on Welding of Armor
Watertown Arsenal
Watertown 72, Massachusetts

Dear Colonel Zornig:

With reference to your letter of May 4 on the subject of membership in the subcommittee we believe that your last letter is entirely satisfactory to us. Mr. Steidl will be our alternate for Dr. Blanchard on the subcommittee.

Very truly yours,

/s/ John J. Chyle
Director of Welding Research

JJC/fdb

(Inclosure 47)

[redacted]

APPENDIX A
Part I-c

Transmission of Data

One of the functions of the Subcommittee on Welding of Armor was to facilitate the exchange of information relating to welding of armor and developments relating thereto. At the same time care had to be exercised to prevent such data from falling into unauthorized hands.

Because of this responsibility certain requirements were established for acknowledgment of receipt of Subcommittee data by industrial members of the Subcommittee. In the beginning of Subcommittee activity this requirement was applied alike to Service personnel as well as Industrial personnel who received Subcommittee data (Inclosures 1 and 2). The policy involved was indicated by Inclosure 1.

Following each regular Subcommittee meeting a summary of the meeting was usually prepared and transmitted for information of the Office, Chief of Ordnance (Inclosure 3). This practice was followed for each meeting of the Subcommittee (Inclosures 5, 6, 8, 9, 20, 23 and 24). Receipts for such communications were not required.

Usually the summaries of meetings were not sent out to individual members of the Subcommittee except as an incorporated part of the regular minutes. In some isolated cases, however, a summary might be sent to an individual who had attended the meeting by special invitation (Inclosure 4) for his information and file.

The minutes of each Subcommittee meeting consisted of a mimeographed copy of the stenotyped transcript of discussions together with the summary (Inclosures 3, 5, 6, and 8 etc.) and minutes of the Group meetings with lists of attendance. These minutes were usually sent to all industrial Subcommittee members of record and all Service and Governmental agencies represented at the meeting. Transmittal was by official letter (Inclosure 7). A receipt was required of all industrial representatives to whom the minutes were sent. This principle is indicated by Inclosures 10 and 11.

One of the problems encountered in the early development activities of Subcommittee on Resistance Welding was that of getting all pertinent data on preparation of test specimens into the record (Inclosures 12 and 13) because the maker of the test specimens did not take the time to determine and record all conditions involved. This trouble was also encountered by the other Subcommittees and the development of the various standard data forms RAS, CAS and WAS was the result. Submission of such forms with each test plate eventually became a requirement before tests would be made by the facility involved.

[redacted]

SBR/amv

January 3, 1941

There is attached a copy of Welded Armor Report No._____ covering the ballistic tests on a welded cast turret. The material contained therein was extracted from an Aberdeen Proving Ground letter report dated December 10, 1940. This report is also being sent to members of the Cast Armor Subcommittee. It is planned to distribute other reports of a similar nature to the Subcommittee on Welding of Armor from time to time.

In order to save time and work, future reports may be forwarded to subcommittee members without transmittal letters. Such reports, however, will be accompanied by receipt forms similar to the one inclosed herewith, which individual members should sign and return to this arsenal for record purposes.

It is to be noted that the attached report is marked "Restricted." A different classification may be indicated on other reports submitted in the future. Care should be taken to insure that the attached report and others which may be furnished later do not fall into unauthorized hands and that these reports will be used in accordance with the procedure for material of this nature agreed upon at the recent subcommittee meeting.

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee on
Welding of Armor

3 Incls.
Report
Receipt Form
Envelope

(Inclosure 1)

[redacted]

February 27, 1941

I hereby acknowledge receipt of Restricted copy of Report of Meeting of Subcommittee for Welding of Armor, January 21, 1941, held at Aberdeen Proving Ground.

Signed________________________

J. H. Frye
Major, Ordnance Dept.
Office, Chief of Ordnance

(Inclosure 2)

[redacted]

SBR/NAM/gmm

Laboratory June 25, 1941

Subject: Meeting of Subcommittee for Welding of Armor (Cleveland, Ohio, June 20, 1941).

To: Chief of Ordnance, U.S.A.
Washington, D. C.

ATTN: Industrial Service - Artillery Division

1. Representatives from five fabricators of welded structures, two suppliers of rolled armor plate, three suppliers of cast armor, six electrode manufacturers, Office, Chief of Ordnance, Aberdeen Proving Ground, Rock Island Arsenal, Watertown Arsenal, and the Chicago, Pittsburgh, Philadelphia, and Cleveland Districts attended the subject meeting.

2. The following action was taken regarding the matters listed on the Agenda, a copy of which is attached.

a. The McKay Company, York, Pennsylvania, was named as an additional member of the subcommittee.

b. The Breeze Corporation, Newark, New Jersey was named as a member of the subcommittee to be represented by Mr. R. S. Komarnitsky because of his experience in the welding of light armor.

c. It was agreed that the present cast armor representatives on the committee would retain membership for the time being and would participate in the committee activities when subjects pertaining to cast armor were involved.

d. In general, Specification AXS-497, Welding of Armor, Arc has been found to be satisfactory as far as the experience with the fabrication of two M3 medium tank hulls by welding is concerned. The statement was made by the representative of one fabricator and agreed to by others present that the amount of plate required for individual welder's qualification is greater than necessary. It was felt that qualification on the maximum thickness of homogeneous plate to be used on the contract rather than qualification on the minimum thickness of each of several thickness ranges would be satisfactory. Accordingly the following revision of paragraph F-2b(1) of Specification AXS-497 was recommended and is concurred in by this Arsenal:

(1) Paragraph F-2b(1) to read as follows:

"A complete qualification test for each welder

[redacted]

to weld on homogeneous armor shall consist of the making of at least one butt joint not less than 12" long, of the greatest homogeneous plate thickness to be welded under the contract, and using the qualified welding procedure. For welder qualification on face-hardened armor the plate thicknesses used shall be in accordance with Paragraph F-2a(2)."

e. The applicability of resistance welding to the fabrication of armored structures was discussed. The idea was expressed by the representatives of one industrial firm that flash welding is feasible for butt joints of homogeneous armor up to 2" in thickness forming a joint up to 48" in length. With reference to face-hardened armor no definite suggestions were made. Mr. R. T. Gillette, General Electric Company, Schenectady, New York, an authority on resistance welding, who attended the meeting as a guest, suggested that the pulsation type of spot welding probably is the most satisfactory type of spot welding to use in the fabrication of armored structures. Mr. Gillette emphasized that scale must be completely removed from all surfaces to be spot welded.

Adverse comment from several representatives suggested that spot welding is not as applicable to heavy plate as it may be for light plate. The opinion was also expressed that the spot welded type of joint would not be particularly efficient from the stress transmission viewpoint. It was agreed that a small group of resistance welding experts should be organized to study the problem of spot welding of armor.

f. It was stated by the two firms which have been involved in the fabrication of medium tank M3 hull assemblies that the welded type of fabrication can be easily and economically accomplished resulting in a lighter and ballistically superior structure.

g. From the discussions which took place regarding the ballistic testing of welded structures there appears to be a need for standardization of the methods of test.

h. It was indicated that there is likely to be a shortage of electrode materials occasioned by the overload of small merchant mills with the demand for small arms armor piercing bullet core stock. It was stated that an electrode of the austenitic 25-20 or similar type is most satisfactory for welding of armor where preheating is not used. Several companies are engaged in developing other electrode compositions which may be suitable.

i. With reference to cracks which occur between the edges of plates and rivet holes and the surface cracks which develop upon heat treatment in face-hardened armor, samples of plates having both types

[redacted]

of cracks will be sent to Aberdeen Proving Ground for test to determine if defects of this type are cause for rejection. Some cracks developing between rivet holes and plate edges will be repaired by welding to determine if repair can be satisfactorily made to salvage such plates. These plates are to be sent to Watertown Arsenal for metallurgical examination after test at Aberdeen Proving Ground.

j. The problem of the repair of casting defects which are uncovered during machining was discussed and the opinion was expressed that whether or not the defect should be repaired must be left to the discretion of the inspector.

k. The experimental programs on the welding of armor which are in progress and have been completed were discussed.

l. A Research Program Subgroup of the committee was designated by the chairman and approved by the members present. This group will consist of representatives of the six fabricators who are members of the subcommittee, a representative of Rock Island Arsenal and Watertown Arsenal. The Rock Island Arsenal representative was suggested as chairman of the group. This group will convene shortly to consider a coordinated research program to carry out the necessary work on the development of welding of armored structures. The group will suggest allocation of specific projects and report to the committee as a whole for consideration of the projects proposed.

3. Copies of the minutes of this meeting will be forwarded as soon as possible.

R. W. CASE
Brigadier General, U. S. Army
President, Ferrous Metallurgical
Advisory Board

1 Incl. in dup.
Agenda

(Inclosure 3)

[redacted]

SBR/gmm

Laboratory

July 18, 1941

Mr. R. T. Gillette
General Electric Company
Schenectady, New York

Dear Mr. Gillette:

Attached, for your information and personal file, is a copy of the Report of the Meeting of the Subcommittee for Welding of Armor, held at Cleveland, Ohio on June 20, 1941.

Please note that the report is marked "Restricted". It should, therefore, be handled accordingly and not be permitted to fall into any unauthorized hands.

This is to thank you again for your attendance and participation in the discussions covered in the attached report.

For the President of the Board:

Very truly yours,

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee
for Welding of Armor

1 Encl.
Rpt. of Minutes
of Meeting

(Inclosure 4)

[redacted]

NAM/mmg

Laboratory August 28, 1941

Subject: Meeting of the Subcommittee for Welding of Armor (Pittsburgh, Pennsylvania, August 22, 1941)

To: Chief of Ordnance, U.S.A.
Washington, D. C.

ATTN: Ind. Service - Tank Div.

1. A meeting of the subcommittee was held at the Dusquesne Club, Pittsburgh with arrangements supplied through the Ordnance District Office and the courtesy of the Carnegie-Illinois Steel Corporation. Mr. J. D. Berg, Assistant District Chief, introduced by Lt. Col. J. L. Guion, welcomed the group and expressed his interest in the activities of the subcommittee.

2. On the previous day, August 21, 1941, the Research Program Subgroup, appointed at the last meeting of the subcommittee, assembled to devise a coordinated research program consisting of projects directly applicable to the problem of the fabrication of armored vehicles by welding.

The seven companies involved in this program are the Baldwin Locomotive Works, the A. O. Smith Corporation, Electro-Motive Corporation, York Safe & Lock Company, American Car & Foundry Company, Diebold Safe and Lock Company, and the Carnegie-Illinois Steel Corporation. The program as proposed, subdivided among the seven companies, will consist of the determination of the resistance to penetration and the ability to withstand shock tests of welded joints on homogeneous rolled and cast armor and face-hardened armor covering the thickness ranges now in production. Included in the program will be a comparison of the Y and H test plate in several thicknesses and a qualification of numerous electrodes including the 25-20 type, the modified 18-8 electrodes, and promising non-austenitic electrodes.

Watertown and Rock Island Arsenals will cooperate in the ballistic testing programs and subsequent metallurgical examinations of the welded joints. Watertown Arsenal will continue its program on the basic weldability of the armor materials, as well as other tests necessary to compare the quality of the joints produced. Rock Island Arsenal will continue its program of fatigue testing and impact testing of the various types of welded joints.

The programs outlined by the subgroup were approved by the subcommittee. It was agreed that the subgroup would continue its activities and sponsor other research projects as quickly as time will allow.

[redacted]

3. The subcommittee meeting was attended by representatives from twenty-two industrial firms including fabricators, rolled and cast armor manufacturers, electrode manufacturers, the Navy, Bureau of Ships, the Ordnance Office, Rock Island Arsenal, Aberdeen Proving Ground, Watertown Arsenal, the Chicago, Philadelphia, Pittsburgh, and Cleveland Ordnance Districts, and Mr. H. W. G. Hignett, Welding Engineer, representing the British Ministry of Supply. The following subjects were discussed by the subcommittee:

a. The program for the production of medium tanks, with special attention to the welding requirements, was outlined briefly by an Ordnance Office representative. It was stated that by June, 1942, 300,000 pounds of 18-8 welding rod would be required per month. Further discussion indicated that the cast armor manufacturers at the present time have only sufficient nickel and chromium for immediate use and that in several instances chromium shipments by truck have been necessary to prevent curtailment of production. The steel scrap situation is also becoming serious at the plants of the cast armor manufacturers.

b. Mr. H. W. G. Hignett discussed the welding of tanks in England, stating the British are fabricating light tanks by welding and are about to begin production of a heavy tank fabricated by welding.

c. Recent tests at Aberdeen Proving Ground on welded plates were outlined. Y joint test plates on 1½" rolled homogeneous plate made up with 25-20 and Lincoln "Armorweld" electrodes, with and without softening of flame cut edges, withstood shock tests satisfactorily. A joint made with a low alloy non-austenitic electrode on surfaces buttered with 25-20 was not satisfactory, cracking occurring in the weld metal and at the junction of the low alloy rod and the austenitic weld deposit.

d. Mr. A. J. Raymo, Baldwin Locomotive Works, stated that the first medium tank hull fabricated by welding has been completed at the Baldwin plant. 25-20 austenitic electrode was used successfully, and without the formation of cracks. This experience indicates that the fabrication of the hull by welding is a much easier task than was anticipated.

e. The merits of several types of butt joints were discussed. The Lincoln Electric Company proposed a square cut joint. The Carnegie-Illinois Steel Corporation suggested a double V joint with a mild steel bar at the apex upon which one side of the weld is built up. The bar is then chipped out and the opposite side welded, resulting in complete penetration. Mr. Hignett proposed a single V, 5° included angle joint which requires a minimum of weld metal and no chipping or grinding.

f. A lengthy discussion occurred on the problem of surface checks or cracks in face-hardened armor occurring between holes

[redacted]

and the edges of plates and internally or removed from holes and edges. A considerable percentage of face-hardened plate is being rejected for cracks which sometimes are barely visible. Ballistic tests have indicated that the ballistic qualities of the plates are not affected and the cracks do not propagate. Standards of rejection in the various districts are not uniform. Evidence indicates that armor plate is being rejected which would be as satisfactory as plate without these cracks for the service intended.

g. Further research work for the subcommittee to consider such as fatigue tests of armor joints, joint design, and internal stresses were outlined. It was agreed that many of these problems are important and would be given attention when the more immediate problems outlined by the subgroup had been satisfactorily settled.

h. The problem of the repair of defects in cast armor uncovered during machining was discussed. The results of an investigation conducted at Watertown Arsenal were outlined. The defect can be chipped or ground out, and welded using a 400°F. preheat with a low carbon electrode or an electrode of a composition approximating that of the cast armor. Tests indicate that by subsequent local heating of the weld-affected area with a gas torch to a temperature of from 1300–1450°F. for approximately fifteen minutes, the hardness can be lowered to that of the cast armor for ease of machining.

i. The Chrysler Corporation was proposed for membership on the subcommittee by Lt. Col. H. W. Rehm and approved by the subcommittee.

j. It was agreed to hold the next meeting of the subcommittee in Philadelphia during the period of the American Welding Society and American Society for Metals conventions.

4. Copies of the minutes of the meeting will be forwarded as soon as prepared.

For the President of the Board:

S. B. Ritchie
Lt. Col., Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 5)

[redacted]

Laboratory NAM/ELR/amv

August 30, 1941

Subject: Preliminary Meeting of Subcommittee
for Resistance Welding
(Watertown Arsenal, August 27, 1941)

To: Chief of Ordnance, U.S.A.
War Department
Washington, D. C.

Attention: Industrial Service, Tank and Combat Vehicle Div.

1. An organizational meeting of a Subcommittee for Resistance Welding was held at Watertown Arsenal on August 27, 1941. Present at the meeting were technical representatives from seven outstanding companies manufacturing resistance welding equipment, together with service representatives from the Office, Chief of Ordnance, Wright Field, Rock Island Arsenal, and Watertown Arsenal.

2. The following is a summary of the discussions and recommendations reached at the meeting:

a. The scope of the subcommittee was defined as the application of resistance welding methods to the production of Ordnance and other defense materiel wherever practicable and desirable from the standpoints of serviceability and economy. An immediate problem placed before the committee was the fabrication by resistance welding of armored vehicles or assemblies from light homogeneous or face-hardened armor plate up to 1/2" in thickness. In this connection the specific problem of the attachment of armor in aircraft by clips and angles proposed by Wright Field was discussed. It was felt that the results of the program outlined below would indicate a satisfactory method. Subsequently it is expected that experimental programs will be conducted to determine where resistance welding methods can be used as a substitute for fusion welding or riveting in the fabrication of gun mounts, shields, and other Ordnance materiel fabricated from structural steels.

b. It was agreed that the size of the committee should be maintained as small as practicable and that the chairman should be a service representative. Mr. Malcolm Clark, president of the Resistance Welder Manufacturers Association, will be contacted to determine if other resistance welding equipment manufacturers should be represented. When the need for specialists in the field of resistance welding equipment such as control equipment and

[redacted]

electrodes is required for purposes of a meeting, such representatives will be invited to attend.

c. It was brought out by the industrial representatives that if their technical men could be put in contact with the proper personnel at Ordnance and industrial plants producing defense materiel, applications for resistance welding methods could be undoubtedly developed which would result in more rapid and economical production of these items.

d. A definite program for research and development as applied to the fabrication of armor was outlined. Three general types of joints will be investigated made from 1/4" homogeneous and face-hardened armor. The types of joints are the lap joint, the butt joint formed by butt or flash welding from the armor alone, and the butt joint formed by the joining of two armor plates through a third intervening member such as a butt strap. The following programs are to be instituted by the several companies at the earliest practicable date on samples 12"x12" to be subjected to ballistic test after preliminary tests on small specimen joints have indicated the best techniques:

(1) Mr. W. T. Ober, Thomson-Gibb Electric Welding Company, will investigate spot welding using a butt strap joint and a lap weld joint in both types of armor.

(2) Mr. C. F. Kaunitz, National Electric Welding Machine Co., will investigate spot welding using a butt strap joint on both types of armor.

(3) Mr. R. T. Gillette, General Electric Co., will investigate the possibility of lap joints in both types of armor by spot welding.

(4) Mr. J. H. Cooper, Taylor-Winfield Corporation, will investigate the butt welding and flash welding methods of forming joints in both types of armor.

(5) Mr. L. M. Benkert, Progressive Welder Company, will conduct a program on spot welding using a butt strap joint and a lap joint on both homogeneous and face-hardened armor.

(6) Mr. A. H. Lewis, Swift Electric Welder Company, will carry out a program on butt and flash welding of both types of armor.

[redacted]

(7) Mr. B. J. Wise, Federal Machine and Welder Co., will undertake a program on lap weld joints or any other immediate problem which requires attention.

e. Rock Island Arsenal and Watertown Arsenal will assist in the work by conducting ballistic tests of sections, physical testing of specimen joints, fatigue testing, and metallurgical examinations of joints produced.

3. Watertown Arsenal will undertake to procure the necessary homogeneous and face-hardened armor for these tests. It is proposed to use only the nickel-molybdenum type of armor in the tests of face-hardened armor and the nickel-chrome-molybdenum armor as the homogeneous material.

4. A subgroup consisting of Mr. R. T. Gillette, Chairman, Mr. J. H. Cooper and Mr. C. F. Kaunitz was appointed to consider the data which should be recorded and submitted with the experimental joints to be tested. Service representatives from Wright Field, Rock Island Arsenal, and Watertown Arsenal will decide the type of physical tests to be applied to the specimen joints formed by resistance welding.

5. It was the consensus of the group that the next meeting of the subcommittee should be held in Detroit and as soon as the programs on light armor have been completed. At that time methods of fabrication of high tensile structural steels by resistance welding will be considered as well as the best methods of resistance welding armor which develop as a result of the experimental programs.

For the Commanding General:

S. B. Ritchie
Lt. Col., Ord. Dept.
Director of Laboratory

(Inclosure 6)

[redacted]

SBR/ahk

Laboratory

September 15, 1941

Subject: Report of Preliminary Meeting of Subcommittee for Resistance Welding

To: Chief of Ordnance, U.S.A.
Washington, D. C.

Attn: Industrial Service

1. There is attached, in duplicate, a copy of the Report of the Preliminary Meeting of the Subcommittee for Resistance Welding, held at Watertown Arsenal, Watertown, Mass., August 27, 1941, for information and file.

For the President of the Board:

S. B. Ritchie
Lt. Col., Ord. Dept.
Chairman, Subcommittee for Resistance Welding.

1 Incl. in dupl.
Report

(Inclosure 7)

[redacted]

NAM/WLW/eam

Laboratory November 5, 1941

Subject: Meeting of Subcommittee for Welding of Armor
October 24, 1941, Penn Athletic Club, Philadelphia, Pa.

To: Chief of Ordnance
U. S. Army
Washington, D. C.

Attn: Industrial Service, Tank and Combat Vehicle Division

1. A meeting of the Research Program Subgroup was held on the day preceding the subcommittee meeting.

a. The status of the test program on H and Y welded plates, inaugurated at the meeting on August 22, was discussed. Work on the test plates is under way at Baldwin Locomotive Works, American Car & Foundry Company, York Safe & Lock Company, and A. O. Smith Corporation. The Electro-Motive Corporation is using the Unionmelt process to weld H and Y test plates in its own plant. Diebold Safe & Lock Company has shipped three plates two H and one Y, fabricated from 1/4" face-hardened plate to Aberdeen Proving Ground for shock test. Carnegie-Illinois Steel Corporation is carrying out a series of tests of H and Y plates with hand welding, as well as a cooperative program with the Union Carbide & Carbon Research Laboratories, Inc. at Niagara Falls to study the possibilities of the Unionmelt process in welding 2" thick homogeneous armor.

b. It was recommended that all shock tests on the H and Y welded plates for research and development work should be made with a square-nosed slug at normal impact.

c. It was recommended that Mr. E. A. Clapp, Linde Air Products Company, Niagara Falls Laboratory, be added to the subgroup and subcommittee membership as an expert on the Unionmelt process.

d. It was suggested that a program of low temperature impact testing of welded joints in armor be undertaken, the testing to be done at Watertown Arsenal or some other suitable place. Carnegie-Illinois Steel Corporation agreed to furnish sample butt welds in 3/4" armor, using the spacer bar for some of the welds and not in others for the low temperature impact tests at Watertown.

2. The meeting of the subcommittee was held at the Pennsylvania Athletic Club, Philadelphia, on October 24, 1941. The following items of importance were discussed by the group:

a. The following companies are to be added to the subcommittee

[redacted]

as prospective tank manufacturers or companies active in the development or armor electrodes:

Fisher Body Division, General Motors
Ford Motor Company
Lima Locomotive Company
Pullman Standard Car Mfg. Company
American Locomotive Company
Cadillac Motor Car Company
Graver Tank Mfg. Company
Pressed Steel Car Company
Linde Air Products Company
Air Reduction Sales Company
Champion Rivet Company
Reid Avery Company

b. A subgroup of electrode manufacturers was set up with Mr. E. Brooker, Ordnance Office, as chairman to coordinate and expedite the development of substitute electrodes and procedures for the most satisfactory use of present electrodes.

c. The fabricator subgroup reported on the progress of the H and Y test plate program. It was reported that two plates fabricated by the Unionmelt process have been tested at Aberdeen Proving Ground with encouraging results.

d. Weldability studies on armor are being continued at Watertown Arsenal, and Rock Island Arsenal will continue its work on fatigue of welded joints testing 90°, 120° and T joint welds.

e. The manufacturers who are at present welding tank turrets or hulls outlined their practices. American Car & Foundry Company uses a modified 18-8 electrode in welding the light tank turrets. Baldwin Locomotive Works are using 25-20 in the welding of the medium tank hulls.

f. The proposed amendments to Specification AXS-497 were approved to provide for an alternate qualification test consisting of a section of a typical weldment, a limitation of 400°F. preheat and homogeneous armor, and a 200°F. preheat on face-hardened armor.

3. On Monday, October 27, 1941, a meeting of the fabricators and prospective fabricators, as well as electrode manufacturers and service representatives, convened to discuss joint design for the M3 and M4 medium tanks for welded fabricators.

a. Considerable discussion occurred regarding the question of how to insure complete penetration of butt joints and avoid check cracking without excessive chipping or grinding. The advantages of using spacer bars were discussed, and it was decided that spacer bars

[redacted]

are permissible if desired to avoid excessively difficult chipping of the weld root.

b. It was decided that there must be no exposed raw flame-cut plate edges. Either these edges must be flame softened, or the flame cutting must be done prior to final heat treatment of the plate.

c. For corner joints, one plate is to be located such that it strikes the side of the other plate rather than corner to corner, and this plate is to be beveled from one or both sides to permit complete weld penetration. The beveling for machine welding shall be such that the weld can be made from the outside of the tank hull. All backing strips are to be removed. For hand welding, the bevel may be such that the backing strip is on the outside to permit accessibility for chipping.

d. It was agreed that the general requirement for all welds to have complete penetration should be adhered to except for lap joints. In this case, two independent fillets are to be used.

e. A discussion of the attachment of 75 m/m gun housing casting to the hull brought out that distortion of the casting due to welding threw the rotor bearing sockets out of round and alignment when finish machined before welding. It was suggested that final machining could be done after welding. It was decided to weld in this housing casting. From information supplied by Rock Island Arsenal, this welding requires the use of 25/20 without question.

f. In discussing the design of the M4 medium tank hull, it was explained by Ordnance representatives that qualification of welding procedure and welders would be required under Specification AXS-497.

g. It was disclosed that several of the prospective fabricators contemplate using the Unionmelt process for welding armor. It was suggested by one representative that about 70% of the welds required could be done by machine welding and 30% by hand.

h. Discussion of attachment of the turret ring to the roof plate brought out that the use of shims tack welded to the roof plate was permissible provided that the shims are no more than 1/8", and that suitable gaskets for waterproofing are used.

4. Copies of the minutes of the subcommittee meeting, as well as a summary of the Research Program Subgroup meeting, will be submitted as soon as available.

For the President of the Board:

S. B. Ritchie
Lt. Colonel, Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 8)

[redacted]

NAM/amv

Laboratory

January 19, 1942

Subject: Meeting of Subcommittee for Resistance Welding

To: Chief of Ordnance, U. S. A.
Washington, D. C.

Attn: Industrial Service, Research and Engineering Supervision

1. Reference to TT 4010, 12/31/41, 4:02 PM EST, OM Quinn/GT, a meeting of the Subcommittee for Resistance Welding was held at Wright Field on January 13, 1942. Duplicate copies of the Agenda for the meeting are attached. The attendance consisted of representatives from:

Progressive Welder Co.
General Electric Co.
Federal Machine & Welder Co.
National Electric Welding Machines Co.
Glenn L. Martin Co. (National Aircraft Standards Committee)

Office, Chief of Ordnance
Navy Dept., Bureau of Aeronautics
Ordnance Office, Wright Field
Materiel Division, Wright Field
Rock Island Arsenal
Watertown Arsenal

2. Experimental work which has been completed to date was reviewed and discussed and the following conclusions may be drawn as to the applicability of the method to the fabrication of light armor.

a. Lap weld joints or butt strap joints can be satisfactorily made with speed and economy with both face-hardened and homogeneous armor in thicknesses up to at least 1/2 inch. Construction of this nature will eliminate the majority of machining operations necessary on this armor and produce joints from which bolt heads and other possible missiles are eliminated.

b. With specific reference to the attachment of armor to aircraft structures, clips or angles have been spot welded to 1/4" and 1/2" face-hardened armor and subjected to ballistic test on the plate which is more severe than that specified for the armor itself. This method seems most immediately applicable to aircraft installations to eliminate the excessive drilling operations for bolt holes and the severe dimensional tolerances now required.

[redacted]

c. Fatigue tests which have been completed at Rock Island Arsenal indicate the spot welded joint has satisfactory fatigue-resisting properties. Single-spot joints deflected 3/8" on a 6" moment across the joint have withstood 250,000 cycles of stress reversals without fracturing the spot weld.

3. Anticipating a request by the Air Corps for a specification to cover the Resistance Welding of Armor, Watertown Arsenal is to prepare a preliminary draft for submission to the subcommittee and the services for approval. The following general characteristics are to be incorporated:

a. Only armor which meets the requirements of either specification AXS-490 or AXS-495 will be considered for resistance welding. Heats of armor which have been qualified for other Ordnance applications will be further tested as a resistance-welded assembly of a definite type.

b. The resistance-welded assembly will consist of a piece of armor 18"x18" square to which four attachments are welded onto the corners. The attachments will be of a specified size and shape for each thickness of armor and the assembly will be attached to a proof butt in a prescribed manner. Procedure qualification of the resistance welded assembly will consist of the ballistic testing of this assembly with attention focused on a severe shock test.

c. It was suggested by the Ordnance Section of Wright Field that for purposes of simplifying inspection, it would be advisable to qualify armor producers as prime contractors for the resistance welded assemblies in finished form for installation in aircraft. Subsequent inspection after qualification would consist of a simple physical test plus periodic tests of the specified qualification test assembly. Variations in procedure on machine setting will require requalification of the process. Emphasis will be placed upon the qualification of a certain type of machine with a definite control cycle.

4. Copies of the minutes of the meeting will be forwarded at the earliest possible date.

For the Commanding General:

G. L. Cox
Major, Ordnance Dept.
Chairman, Subcommittee for
Resistance Welding

Incl. (Dupl.)
Agenda

(Inclosure 9)

[redacted]

WLW/ahk

Laboratory (WLW) August 29, 1942

Subject: Resistance Welding Report No. 8

To: Chief of Ordnance, U.S.A.
Washington, D. C.

Attn: Technical Division, Aircraft Armament Development Branch, Lt. Col. H. A. Quinn

1. There is inclosed herewith a copy of Resistance Welding Report No. 8, "Tests of Single Spot Welded Joints for Attachment of Clips to 1/4" Homogeneous and Face-Hardened Plate," for your information and file.

For the President of the Board:

G. L. Cox
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Resistance Welding

1 Incl.
Report

(Inclosure 10)

[redacted]

WLW/ahk

Laboratory (WLW) August 31, 1942 .

Mr. J. H. Cooper
Senior Welding Engineer
The Taylor-Winfield Corp.
Warren, Ohio

Dear Mr. Cooper:

There is inclosed herewith a copy (No. 9) of Resistance Welding Report No. 8, "Tests of Single Spot Welded Joints for Attachment of Clips to 1/4" Homogeneous and Face-Hardened Plate." Please return the inclosed receipt form, properly filled out as indicated.

There is also inclosed a form for indicating your correct mailing address. Please return this form at your earliest convenience.

For the President of the Board:

Yours very truly,

G. L. Cox
Lt. Col., Ord. Dept.
Chairman, Subcommittee for
Resistance Welding

4 Incls.
Report
Receipt Form
Address Form
Return Envelope

(Inclosure 11)

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The Taylor-Winfield Corporation
Warren
Ohio

March 10, 1942

Watertown Arsonal
c/o Major G. L. Cox
Chairman of Sub-Committee for Resistance Welding
Watertown, Mass.

Dear Major Cox:

Subject: Resistance Welding Reports

We have received a copy of your recent report No. 7 and wish again to call to your attention the fact that these reports are not fulfilling the agreements made at the initial meeting at Watertown, August 27, 1941.

At that meeting, whereby the various resistance welding companies agreed to make available the services of their laboratories at no expense to the Ordnance Department, the division of work was made with the understanding that all information on the various projects was to be reported.

A small committee was formed and headed up by Mr. R. T. Gillette, as Chairman, to make up a tabulation of the variables in making the welds so that all information would be recorded in a uniform manner. In the case of spot welding, such recorded variables would be pressure, current, timing, electrode size, etc.

The various reports which have been issued have had none of this information, and as such, only indicate that welds are ballistically satisfactory or unsatisfactory, without carrying any vital information as how to reproduce such welds. Any information as to hardness plots is of limited value, if it cannot be correlated with the conditions under which the welds were made.

We feel quite strongly about this lack of information, and are hesitant to proceed with a program, which appears to be inconclusive in its results.

Please advise if the previously issued reports can be supplemented by the missing data.

Yours very truly,

THE TAYLOR-WINFIELD CORPORATION

JHC:TT

/s/ J. H. Cooper - Welding Engineer

cc: R. T. Gillette
Works Laboratory
General Electric Company
Schenectady, New York

(Inclosure 12)

[redacted]

NAM/amv

Laboratory-NAM

March 14, 1942

Mr. J. H. Cooper
Member, Subcommittee for Resistance
Welding
The Taylor-Winfield Corporation
Warren, Ohio

Dear Mr. Cooper:

We are in receipt of your letter of March 10, 1942 with reference to the data being included in the resistance welding reports. We are in sympathy with your criticism, but the reports contain all the information supplied to us with the test plates. Apparently the companies making the test plates have recorded the data but are unwilling to divulge the complete welding techniques at the present time.

The whole subject will constitute a topic for discussion at the next meeting of the subcommittee. It appears that each company intends to proceed and evolve a proper technique. Undoubtedly these techniques will be divulged when the ultimate in quality of welds has been achieved, at which time a correlation of welding technique and ballistic results can be made.

Your interest in these matters is appreciated.

For the President of the Board:

Very truly yours,

G. L. COX
Major, Ordnance Dept.
Chairman, Subcommittee for
Resistance Welding

(Inclosure 13)

[redacted]

Early in 1942 the demand for production of armor weldments reached such proportions that the Office, Chief of Ordnance, in March 1942 issued instructions to all Ordnance Districts (Inclosures 14 and 15) urging qualification of the Unionmelt process for welding armor by ballistic tests. This action encouraged all armor fabricators to obtain this type of welding equipment and attempt to qualify a procedure by ballistic tests.

It should be pointed out that the "recent ballistic tests of Unionmelt welded H plates" referred to were of plates welded of the then current high-alloy, oil quenched armor. At this particular period, March-April 1942, pressure had begun to be applied to the steel industry to reduce the alloy content of armor and as a result fabricators encountered great difficulty subsequently in obtaining qualification of the Unionmelt process. Qualification was, however, obtained for certain specific joints of armor hulls by certain fabricators.

Care was taken by the Subcommittee Chairman to insure accuracy of Subcommittee minutes in connection with discussion of the Unionmelt process (Inclosure 16). A copy of the unedited transcript of discussions at this meeting was loaned to General Motors for their information in connection with their possible use of the Unionmelt process (Inclosure 17).

The enthusiasm for commercial exploitation of welding developments was, in one or two instances, responsible for overstepping the limitations prescribed by the Espionage Act. Mostly such incidents occurred because of ignorance of security regulations. In such cases the Chairman of the Subcommittee took steps to prevent such commercializing of classified data (Inclosures 18 and 19). Inclosure 19 was sent to all Subcommittee industrial members for their information.

A preliminary draft of Specification WXS-169 and proposed draft of data form for resistance welded test plates (result of Inclosure 12) were forwarded for criticism and comment to the Resistance Welding Group (Inclosure 21). As a result of agitation by the Resistance Welding Group at the ninth meeting of the Subcommittee in September 1942, a questionnaire (see SC-12 and SC-13, Part III of this Appendix) as indicated by Inclosure 22 was prepared and circulated to the industrial members of the Subcommittee. Replies were forwarded to Mr. Cooper for compilation and report to the Resistance Welding Group. Resistance welding was not seriously contemplated by tank fabricators because of the thicknesses of armor involved in the usual tank fabrication.

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War Department
Office of the Chief of Ordnance
Washington

BROOKER/ged

O.O. 470.5/9045
Ind. Serv., Tank Div.
Armor Plate Section

March 17, 1942

Subject: Welding Armored Hulls by the Unionmelt Welding Process

To: Commanding General
Watertown Arsenal
Watertown, Massachusetts

1. Copy of letter, above subject, sent to district offices, under date of March 14, 1942, is forwarded for your information.

By order of the Chief of Ordnance:

/s/ JOHN L. ATKINS
Major, Ordnance Dept.
Assistant

1 Inclosure
Copy letter Cleveland Ord
Dist., Cleveland, Ohio,
3/14/42.

(Inclosure 14)

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Ind. Serv., Tank Div.
Armor Plate Section

War Department
Office of the Chief of Ordnance
Washington

BROOKER/ged

March 14, 1942

Subject: Welding Armored Hulls by the Unionmelt Welding Process

To: Cleveland Ordnance District Office
1006 Terminal Tower Building
Cleveland, Ohio

1. On the basis of recent ballistic tests of Unionmelt welded H plates at Aberdeen Proving Ground, the Ordnance Department approves this welding process for armored vehicle hulls of homogeneous armor. Welding contractors desiring to use Unionmelt must now be urged to qualify in their plants on the basis of information and materials from the Linde Air Products Company. A stock of the proper Unionmelt welding wire is immediately available. The necessary steps are being taken to increase the supply to meet production demands.

2. The specification for welding armor, AXS-497, specifically applies to manual arc welding. No specification has yet been prepared for qualification of procedure with the Unionmelt process. However, such a specification is being prepared, and you are advised that welding contractors must submit a minimum of welded H plates. The thickness of these shall be 1-1/2" to qualify welding contractor on medium tank hulls. All of these contractors shall furnish one H plate of rolled homogeneous armor. If cast armor is to be welded to cast armor, or to be welded to rolled armor, H plates made of these combinations must be submitted. That is, an H plate half cast and half rolled, and one H plate of all cast armor must be submitted to Aberdeen.

3. Inspection. An inspection manual for Unionmelt welding is being prepared and will be forwarded to you as soon as available. Meanwhile, your inspectors must assure themselves that the same currents, feeds, speeds, melt and electrode, used in production welding, are used for the qualifying H plate or plates submitted by the welding contractor.

4. You are requested to circulate the above information to those welding contractors in your District who are concerned with welding armor, and are urged to expedite qualification of contractors and production by the Unionmelt process.

By order of the Chief of Ordnance:

W. E. BECKER
Colonel, Ordnance Dept.
Assistant

(Inclosure 15)

[redacted]

NAM/amv

Laboratory--NAM

March 23, 1942

Mr. F. G. Outcalt
Member, Subcommittee for Welding of Armor
Linde Air Products Co.
30 East 42nd Street
New York, New York

Dear Mr. Outcalt:

As you requested, there are attached pages removed from the minutes of the meeting of the Subcommittee for Welding of Armor held in Detroit on March 1, 1942 which contain your remarks on the progress made on Unionmelt welding of armor. Please edit your remarks as you desire and return at the earliest possible date.

We learned in a communication from the Ordnance Office today that the Unionmelt process had been approved for tank hull welding. We believe proper application and control of the process will provide a fine production welding method and expect to see its beneficial effect upon the tank welding program.

For the President of the Board:

Very truly yours,

H. H. ZORNIG
Colonel, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

Encl.

(Inclosure 16)

[redacted]

NAM/amv

Laboratory-NAM

April 7, 1942

Mr. L. A. Danse
Chairman, General Motors Metallurgical
Subcommittee
Cadillac Motor Car Division
General Motors Corporation
Detroit, Michigan

Dear Mr. Danse:

Attached is a copy of the unedited minutes of the meeting of the Subcommittee for Welding of Armor held in Detroit on March 1, 1942 which are being forwarded to you at the request of the Ordnance office. Please return to this arsenal when they have served your purpose.

With reference to your letter of April 2, 1942, we have written to Mr. C. W. Laufle of Great Lakes and with his permission will forward a copy of the report to you as soon as we have heard from him.

Upon the occasion of your visit to this arsenal, you remarked that in your laboratories tensile specimens are not threaded but are provided with shoulders which are gripped by special adapters. In the past this type of specimen has been investigated here but without complete success. We would appreciate receiving blue prints of your various sizes of tensile specimens as well as a drawing or photographs of the tensile machine fixtures.

Your co-operation in these matters is appreciated.

For the Commanding General:

Very truly yours,

H. H. ZORNIG
Colonel, Ordnance Dept.
Director of Laboratory

1 Encl.
Report

(Inclosure 17)

[redacted]

HHZ/hlm

April 16, 1942

Subject: Publicity on Armor Welding

To: Chief of Ordnance
U. S. Army
Washington, D. C.

Attn: SPOIE (Col. Borden)

1. Attached is a photographic copy of an advertisement of the Arcos Corporation relative to the use of modified 18-8 alloy electrode for welding armor, that appeared in the April 1942 issue of the Welding Journal, the official organ of the American Welding Society.

2. The development of the welding of armor plate by commercial companies has been coordinated through the Subcommittee for the Welding of Armor (of the Ferrous Metallurgical Advisory Board) at whose meetings, of necessity, the composition and ballistic characteristics of the armor plate and welding method proposed have been discussed. All those present at the meetings of this Subcommittee have been repeatedly cautioned that this information is classified as restricted. It seems, therefore, that the publication of the information contained in the subject advertisement is decidedly out of place, as disclosing the line along which our developments are proceeding and the progress that has been made.

3. The Arcos Company is represented on the Ferrous Metallurgical Board's Subcommittee for Welding of Armor through Mr. R. D. Thomas, Jr. Mr. Thomas, himself, from all appearances has been very active on the Subcommittee and most cooperative in its work.

4. It is believed that the publication of information such as is contained in the attached advertisement should not be allowed to go unnoticed, but at the same time, care must be taken not to push a reputable manufacturer out of the development and production picture. It is, therefore, suggested that one or both of the following lines of action be taken:

a. A letter be written by the Office, Chief of Ordnance to the Arcos Corporation indicating to it that the publication of the information contained in the subject advertisement is considered to be contrary to the best interest of the national defense.

b. A circular letter such as the draft attached be addressed to all members of the Subcommittee for Welding of Armor.

[redacted]

5. It is requested that this arsenal be informed of any action that is taken in this matter.

For the Commanding General:

H. H. ZORNIG
Colonel, Ord. Dept.
Chairman, Subcommittee for
Welding of Armor

2 Incls.
(Incl. 1 - photograph copy of
advertisement) in dup.
(Incl. 2 - Proposed letter to
members of Subcommittee
for Welding of Armor) in trip.

(Inclosure 18)

[redacted]

HHZ/amv

Subject: Disclosure of Information on the Welding of Armor

To: Members of the Ferrous Metallurgical Advisory Board's Subcommittee for the Welding of Armor

1. It has come to the attention of the Ordnance Department that an advertisement recently published by a corporation which is represented on the Ferrous Metallurgical Advisory Board's Subcommittee for the Welding of Armor contains the following statements:

> "A manganese modified 18/8 electrode.
>
> Developed solely for armor welding.
>
> Announced only after exhaustive tests.
>
> Has met the Army Ordnance ballistic tests.
>
> Does not crack under a severe locked-up stress test."

2. It is considered by the Chief of Ordnance that the publication of such information is not in the best interest of the national defense, and it is requested that the members of the Subcommittee use their best influence with the Advertising Department of the companies they represent to prevent the publication in advertisement or elsewhere of information which might disclose to our enemies the lines along which the developments in the welding of armor are proceeding in this country or the progress that has been made in these developments.

For the President of the Board:

H. H. ZORNIG
Colonel, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 19)

[redacted]

WLW/ahk

Laboratory (WLW)

October 7, 1942

Subject: Meeting of Subcommittee for Welding of Armor

To: Chief of Ordnance, U. S. Army
Washington, D. C.

Attn: SPOTB

1. A meeting of the Subcommittee for Welding of Armor was held at the Hotel Statler, Detroit, Michigan, on Sunday, September 20, 1942 with approximately 150 persons in attendance, representing armor manufacturers, fabricators of armored vehicles, welding electrode manufacturers, manufacturers and users of resistance welding machines, Ordnance Districts, Office, Chief of Ordnance, Canadian armor fabricators, Rock Island Arsenal, and Watertown Arsenal. The discussion may be summarized as follows:

a. The Alloy Situation (W.P.B.). Continued conservation of manganese, silicon, chromium, nickel, and vanadium is necessary. Vanadium and copper have been eliminated from structural steels; titanium and boron are suggested as possibilities. While there is at present sufficient manganese available, molybdenum is being consumed faster than produced. Production of chromium from low grade ore should eventually insure future supply of that metal. The supply of nickel about equals the demand because of conservation now being practiced. Monel metal scrap is the only source of copper for use in steel.

The following two core wire compositions have been adopted as standard for austenitic modified 18/8 welding electrodes. No others will be melted. Electrode manufacturers are expected to maintain a 60-day inventory, and it is expected that the core wire manufacturers will be in production with these two compositions by December 1.

	Modified #307	Modified #308
Carbon	0.07-0.12	0.07-0.12
Chromium	19.0-21.0	20.5-22.5
Nickel	9.2-10.7	9.0-11.0
Manganese	3.75-4.75	1.6-2.0
Silicon	0.25-0.60	0.25-0.60
Phosphorus	0.05 max.	0.04 max.
Sulphur	0.03 max.	0.03 max.
Molybdenum	0.25 max.	----

The modified #307 core wire is intended for the all-position type of electrode and the modified #308, for the downhand type in which either or both manganese and molybdenum are added from the coating. In reporting weld metal composition, the pad analysis uncontaminated by plate metal will be given in all cases.

[redacted]

b. Homogeneous Armor. The use of electrodes of the modified 18/8 type for manual welding of armor, in diameters of 3/8" and 1/2", by several fabricators has indicated that greatly increased rates of production and freedom from weld defects has resulted. In one instance an increase of approximately 17-1/2% resulted from the use of 3/8" electrode in place of the 3/16" and 1/4" electrode normally used. However, no definite conclusions have yet been reached regarding the use of ferritic type electrodes for welding armor. The application of the Unionmelt process appears to be confined to joints in armor of not over 1" in thickness.

An Ordnance Department Specification for Electrode for Welding Armor was recommended, to be based on either the General Motors Specification or the American Welding Society Specification. It was further suggested that when such a specification is adopted, the requirement for qualification of electrodes by brands should be discarded as a basis for the qualification of procedure.

The following comments were made regarding Specification AXS-497:

(1) Requirement for minimum temperature of 70°F for armor plate when welded presents a difficult problem in a number of fabricating plants.

(2) Clarification of requirements for rejection under paragraph D-4 is desired.

(3) Welder qualification procedure under paragraph F-2b is interpreted differently in several Ordnance Districts. The specified procedure should be strictly followed.

(4) Each new revision of specifications should be accompanied by a covering letter stating the date the revised specification becomes effective.

Some difficulties are being experienced with cracks in rolled armor as received at the fabricator's plant. Also in some instances dimensions of plate parts as received do not comply with tolerances shown on drawings. There appears to be general agreement that ± 1/16" tolerance is satisfactory. Standards for acceptance of cracks in armor are being prepared by Aberdeen Proving Ground.

c. Face-Hardened Armor. Specification AXS-743 has been prepared and is considered to be workable even if not entirely satisfactory. A manual of welding procedure is in process of publication. Procedure for welder's qualification on face-hardened armor as prescribed by the specification is not entirely acceptable. At present the plate composition and electrode types are not standardized so that standardization of welding procedure for face-hardened armor is not possible.

d. Aircraft Armor. Representatives of a number of aircraft

[redacted]

fabricating companies have organized an Aircraft Armor Fabricators' Group of the Subcommittee with Mr. P. H. Merriman, Glenn L. Martin Company, Baltimore, as Chairman of the Eastern Division, and Mr. H. North, Douglas Aircraft Company, Santa Monica, Cal., as Chairman of the Western Division. The immediate problem in welding armor for aircraft appears to be that of attaching clips and auxiliary connections.

e. Resistance Welding. The Subcommittee for Resistance Welding has been organized as a Resistance Welding Group of the Subcommittee with Mr. J. H. Cooper, Taylor-Winfield Corp., Warren, Ohio, as Chairman. Revision of tentative specification WXS-169 to become a Tentative Specification for Resistance Spot Welding of Armor is in process. The possibilities of using flash welding, particularly for salvaging scrap pieces of heavy armor, was suggested. One obstacle in the study of the application of resistance welding to fabrication of armored vehicles is the lack of knowledge, on the part of the welding machine manufacturer, of application requirements. This information may be obtained by questionnaire distributed through the Chairman of the Subcommittee.

f. Armor Specifications and Processing. Since present armor specifications for welding quality plate prescribe a carbon limit of 0.30% max., it was suggested that for armor which is not to be welded the permissible carbon limit could be considerably higher and thus reduce the alloy content necessary. It was also suggested that, since for weldability characteristics carbon content is limited, limits should be placed on alloy content as well. It is recognized that carbon content alone is not an index of weldability. Though not entirely a measure of weldability, hardenability is a better criterion.

Processing practices which produce flame-cut edges of high hardness and armor plate parts containing numerous cracks were emphatically condemned. There is apparently a need for the producers and processors of armor to discuss with the armor fabricators the mutual problem of weldability and armor composition and heat treatment. This contact is being arranged through the medium of the Subcommittee.

g. Ballistic Testing. Determination of acceptance standards for ballistic performance of qualification test plates of homogeneous armor less than 1" in thickness is in progress at Aberdeen Proving Ground. The requirements set up by Specification AXS-743 appear to be satisfactory for face-hardened armor.

h. N.R.C. Research Projects. The work on these projects is progressing slowly due to difficulty in obtaining the necessary armor plate. This situation is improving, however.

2. It was decided to hold the next meeting of the Subcommittee in Philadelphia, Pa., on or about Sunday, December 6, 1942.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 20)

[redacted]

WLW/ahk

Laboratory (WLW) October 14, 1942

Mr. J. H. Cooper
Chairman, Resistance Welding Group
Subcommittee for Welding of Armor
Welding Engineer
Taylor-Winfield Corp.
Warren, Ohio

Dear Mr. Cooper:

In accordance with the understanding reached at the meeting of the Resistance Welding Group in Detroit on September 20, and the meeting of the Subgroup at Rensselaer Polytechnic Institute, Troy, New York on September 28, there is inclosed a preliminary draft of Specification WXS-169, entitled, "Welding of Armor, Resistance, Spot" and Data Form RWS-1, for comment

It is desired that this draft be reviewed and comments submitted as soon as possible so that this specification may be reported to the Specification Group of the Subcommittee for Welding of Armor. If comments are not received from you within two weeks of receipt, it will be assumed that the present draft is satisfactory to you.

Copies of this draft, together with a similar covering letter, have been forwarded to the following members of the Resistance Welding Group:

L. M. Benkert, Progressive Welder Co.
R. T. Gillette, General Electric Co.
Prof. W. F. Hess, Rensselaer Polytechnic Institute
C. F. Kaunitz, National Electric Welding Machines Co.
F. A. Lee, International Harvester Co.
A. H. Lewis, Swift Electric Welder Co.
W. T. Ober, Thomson-Gibb Electric Welding Co.
B. L. Wise, The Federal Machine & Welder Co.

Please fill out and return the inclosed form acknowledging receipt of this draft and form. Your co-operation and comments on this proposed draft will be very much appreciated.

For the President of the Board:

Yours very truly,

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

4 Incls.
Draft of Spec. WXS-169
Data Form RWS-1
Receipt Form
Return Envelope

(Inclosure 21)

[redacted]

WLW/ahk

Laboratory (WLW) October 16, 1942

Mr. J. H. Cooper
Chairman, Resistance Welding Group
Subcommittee for Welding of Armor
Welding Engineer
Taylor-Winfield Corp.
Warren, Ohio

Dear Mr. Cooper:

At the September 20th meeting of the Subcommittee for Welding of Armor, a suggestion was made that information regarding application requirements for resistance welding of armored vehicles is desired from the fabricators of those vehicles. It was proposed that a questionnaire be circulated to obtain this information, and that this circulation be done by the Chairman of the Subcommittee.

I would like to circulate such a questionnaire to the fabricator members of the Subcommittee, and am hereby requesting the preparation of a questionnaire as above outlined by your Resistance Welding Group. When you have completed the outline of information which you consider would be suitable for the purpose, will you please forward me a draft so that we may have it reproduced and circulated from this office.

Any suggestions regarding the compilation of the information after it has been received would be appreciated.

For the President of the Board:

Yours very truly,

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

(Inclosure 22)

[redacted]

WLW/ahk

Laboratory (WLW) December 14, 1942

FERROUS METALLURGICAL ADVISORY BOARD

Subcommittee on Welding of Armor

Subject: Meeting of Subcommittee on Welding of Armor

To: Chief of Ordnance, U. S. Army
Washington, D. C.

Attn: SPOTB

1. A meeting of the Subcommittee on Welding of Armor was held at the Bellevue-Stratford Hotel, Philadelphia, Pa., on Sunday, December 6, 1942, with approximately 170 persons in attendance, representing armor manufacturers, armor processors, fabricators of armor vehicles, welding electrode manufacturers, manufacturers and users of resistance welding machines, Ordnance Districts, Office, Chief of Ordnance, Tank-Automotive Center, Canadian armor fabricators, Rock Island Arsenal, Aberdeen Proving Ground, and Watertown Arsenal.

2. Colonel D. N. Hauseman, on behalf of the Philadelphia Ordnance District, welcomed the members and guests of the Subcommittee, stressing the importance of the activities of American industry to the success of the War Production Program. He emphasized that greater importance is now being placed on quality of the result rather than quantity, and thanked the representatives present for the good work which has been accomplished in the field of welding armor.

3. Colonel H. G. Hoare, Inspection Board of the United Kingdom and Canada, expressed his appreciation for the privilege of attending the meeting and emphasized that co-operation between the Allied Nations makes such projects as the North African Campaign possible. The welding problems in England are very similar to those in America, and co-operation of effort will help in avoiding duplication of work thus expediting the Allied War Effort. It is hoped to have British and Canadian representation on the Subcommittee and thus secure a freer exchange of data on the mutual problems concerned with welding of armor.

4. The discussion is summarized as follows:

a. The Alloy Situation. The alloy situation was outlined by a representative of the War Production Board. In essence, it has not changed much since the last meeting, although the situation on molybdenum has tightened. The following indices were given as indicating relative scarcity of alloys for the months of November and December. These figures are derived by means of an arbitrary rating system which was not defined.

[redacted]

Alloy	November	December
Mn	0.92	1.00
Cr	2.48	2.50
Ni	3.50	4.00
Mo	21.10	22.00
Va	56.80	55.00

It was explained that these figures indicate that for each pound of vanadium available there are four (4) pounds of molybdenum, two hundred fifty (250) pounds of manganese, etc. The War Production Board desires that the chromium content of core wire for modified 18/8 stainless electrodes be kept under 22.0%.

b. Homogeneous Armor Fabrication. Upon request for clarification of the question as to how many test plates must be submitted for procedure qualification, it was explained that the Ordnance Department cannot set up a definite limit on this requirement. It is necessary to submit a sufficient number of plates to show that results to be expected from the procedure being tested will be consistently good. Quite often variations in the welding procedure used for a series of plates are such as to prohibit drawing definite conclusions from the tests.

Upon request of the fabricators, the acceptance or rejection of welded H-plates by Aberdeen Proving Ground will be on the basis of X-ray examination. If desired by the fabricator, rejected plates will be fired for information of all concerned.

Certain revisions of Specification AXS-497 were recommended and are acceptable to the Tank-Automotive Center: Paragraph F-2a(4) - two plates will be required on a retest instead of one and both of these plates must pass the required ballistic test in order to qualify the welding procedure; paragraph F-2a(5) - the visual and radiographic characteristics of the welds in the test plates must be acceptable to the Tank-Automotive Center paragraph F-2b(2) - will be deleted together with the footnote; paragraph F-2b(3) - will be revised to provide for welder qualification on 1/2" plate for production welding of armor in thicknesses of 3/4" and less, and on 1" plate for armor above 3/4" in thickness. On all procedure qualification test plates no repairs will be permitted after X-ray examination.

Table II of the specification, covering the requirements for shock testing, will be enlarged to include other plate thicknesses. A note will be added to the effect that cracks in the crossbar of an H-plate caused by an impact 3" or over from the crossbar weld will be considered as failure of the plate.

With reference to the use of large diameter welding electrodes for armor fabrication it was explained that the Tank-Automotive Center is not yet satisfied, based on the results of ballistic tests at Aberdeen Proving Ground, to give general approval to this method of welding. The latest

[redacted]

test of a series of twenty-five (25) H-plates welded with large size electrodes (above 1/4" dia.) showed ten (10) failures or 40% rejection in the shock test. The general criticism was made by the Tank-Automotive Center that the many variations in welding procedure used made definite conclusions impossible. The desire in all cases is to determine by a sufficient number of tests whether the results from a certain welding procedure are consistent. Unless the series of tests is carefully planned and the plans adhered to, no definite decision can be made from the results of the tests.

c. Face-Hardened Armor Fabrication. There has been considerable difficulty encountered in welding certain types of face-hardened plate due to cracking in the plate adjacent to the weld. Rejections due to this trouble have indicated that some research to determine the cause is necessary. There appears to be no general agreement as to whether these cracks are due to the mechanics of the welding procedure used or the metallurgical characteristics of the armor plate. A research program is to be undertaken in the very near future to try to find the answer. Specification AXS-743 may require some modification as a result.

A joint design suggested by American Car & Foundry Company appears promising. Experiments with this design using larger electrodes with three (3) passes instead of smaller electrodes with five (5) passes indicate that the heat-affected zone is decreased.

d. Aircraft Armor Fabrication. For qualification testing of welding procedure for aircraft armor fabrication, a straight butt joint is believed to be more applicable than the welded H-plate. It is considered that resistance spot welding is most applicable to aircraft armor fabrication which nullifies the need for the H-plate used for fusion welding.

e. Welding Electrodes. The standard composition for core wires of modified 18/8 stainless steel electrodes for welding armor has been slightly changed since the September meeting of the Subcommittee. The standard compositions to be recommended to the War Production Board are:

Element	Mod. #307	Mod. #308
Carbon	0.07 - 0.12%	0.07 - 0.12%
Manganese	3.75 - 4.75%	1.60 - 2.20%
Silicon	0.25 - 0.60%	0.25 - 0.60%
Chromium	19.00 -21.00%	20.00 -22.00%
Nickel	9.00 -10.50%	9.00 -10.50%
Phosphorus	0.05% Max.	0.04% Max.
Sulphur	0.03% Max.	0.03% Max.
Molybdenum	Residual only	Residual only

Standard lengths of welding electrodes for armor were agreed upon as follows:

[redacted]

Diameter	Length - All Position	Length - Flat Position
1/8"	14"	14"
5/32"	14"	14"
3/16"	14"	18"
1/4"		18"
5/16" and over		18" or 24"

A desire was expressed by vehicle fabricators for an Ordnance standard electrode specification as a protection against unnecessary electrode qualification testing. This question is to be considered by the Electrode Group at its next meeting.

With reference to availability of electrodes for welding armor it was stated that the minimum delivery obtainable from the electrode manufacturer would be four (4) months. This situation emphasizes the need for preplanning electrode requirements well in advance of actual usage.

f. Resistance Welding. Experiments with flash welding have been directed toward removing the decarburized layer which occurs through the center of the weld. The idea has been to remove this layer by greater push-up but this has not been accomplished because the amount of force required to produce this push-up in armor plate is beyond the capacity of existing equipment.

Experiments with spot welding of armor have shown that the weld nugget must be of the proper minimum size and be properly heat treated to withstand the ballistic shock test. Both of these requirements are readily met with proper setting of the welding machine and control. A tentative specification, WXS-169 "Resistance Spot Welding of Armor," has been prepared and turned over to the Specifications Group for approval. This specification incorporates a drop impact test as a method of production check testing.

g. Specifications. The spot welding specification, WXS-169, as submitted has been approved by the Specifications Group. Specification AXS-497 will be revised as previously suggested by the Homogeneous Armor Fabricators' Group. Specification AXS-743 probably will be revised to some extent depending on future developments in processing and welding face-hardened armor.

h. Ballistic Testing (Aberdeen Proving Ground). The method of shock testing used on 7/8" and 1" face-hardened armor appears inadequate and requires some study to develop an adequate test. Acceptance or rejection of test plates will be based on X-ray examination with the proviso that plates rejected on X-ray examination will be subjected to the ballistic test upon request of the company submitting those plates.

i. Welding Research. The Research Group outlined its main purpose as follows:

(1). Eliminate duplication of research effort by keeping an up-to-date list of all research projects in progress on armor.

[redacted]

(2). Serve as a clearing house for dissemination of research data to the Subcommittee.

(3). Activities in connection with design problems will not be considered compatible with the purpose of the Group.

The research studies in welding of armor being conducted by N.R.C. are planned to develop a suitable ferritic electrode substitute for the modified 18/8 electrode now being used for welding armor and also to develop a practicable welding procedure for the substitute electrode. In order to start such development it is desirable to find out the weaknesses of the procedures currently being used in order to try to explain the differences between the good and bad performances of those procedures. Results thus far appear to indicate no relation between hardness and physical properties of the weld metal and ballistic performance of the welded joint.

5. The consensus of opinion was that meetings should be held more often than at three-month intervals and that meetings should not be held on Sunday. It was decided to hold the next meeting in Cleveland, Ohio, on or about Saturday, February 6, 1943.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 23)

As indicated in Subcommittee Circular W-1 (Part II of this Appendix) information and data considered to be of interest to members of the Subcommittee were distributed either as Technical Bulletins or Reports depending on the size and scope of the information and data involved. Subcommittee Technical Bulletins were distributed as indicated by Inclosure 25. Between March 1943 and November 1943 seven Technical Bulletins were distributed.

During 1941 and 1942 at least seventeen (17) reports relating to studies of arc welds in armor were distributed to the Subcommittee on Welding of Armor. Prior to the merger of the two Subcommittees, late in 1942, at least eight (8) reports relating to studies of resistance welds in armor were distributed to the Subcommittee on Resistance Welding.

During the middle of 1943 statistical studies of ballistic reports from Aberdeen Proving Ground were initiated at Watertown Arsenal Laboratory. Several of these were distributed to the Subcommittee membership during late 1943 and early 1944. The first of these reports is referred to in Inclosure 26. As indicated by this inclosure receipts were required for such reports. When these receipts were not returned within about thirty (30) days from date of transmittal a check-up letter (Inclosure 27) was sent. Fortunately only a few such check-ups were necessary.

In early 1943 the practice of reproducing the stenotype transcript for distribution was stopped and the summary of discussions became the minutes of the Subcommittee. This practice was inaugurated with the twelfth (12) meeting of 5 June 1943 and is referred to in Inclosure 28.

Late in 1944, due to paper and material shortages, Watertown Arsenal reports were distributed only to the members of the Research Group of the Subcommittee and to a few other members considered to be particularly interested in the subject matter (Inclosure 29). The Subcommittee held its last meeting on 9 November 1944.

[redacted]

WLW/ahk

Laboratory (WLW) February 16, 1943

FERROUS METALLURGICAL ADVISORY BOARD

Subcommittee on Welding of Armor

Subject: Meeting of Subcommittee on Welding of Armor

To: Chief of Ordnance, U. S. Army
Washington, D. C.

Attn: Technical Division - Service Branch

1. A meeting of the Subcommittee on Welding of Armor was held at the Hotel Cleveland, Cleveland, Ohio, on Saturday, February 6, 1943, with approximately 140 persons in attendance, representing armor manufacturers, armor processors, fabricators of armor vehicles, welding electrode manufacturers, manufacturers and users of resistance welding machines, Ordnance Districts, Office, Chief of Ordnance, Tank-Automotive Center, Canadian and British producers and fabricators, Rock Island Arsenal, Aberdeen Proving Ground, and Watertown Arsenal.

2. The discussion may be summarized as follows:

a. The Alloy Situation. The alloy situation was outlined by a representative of the War Production Board. It was explained that the current common idea that manganese is not critical is very much in error. The present demand for low carbon ferro-manganese and ferro-chrome exceeds the capacity for production. This may force the use of higher carbon ferro-alloys for certain steel making. At the present rate of demand for molybdenum the stockpile will be depleted by the end of 1943. Of the steel made for welding electrodes 13% and 14% of it went, in January and February respectively, into making stainless austenitic electrodes for welding armor. In view of the very critical alloy situation, a 25% cut in stainless steel production has been proposed. The following indices were given for February, 1943:

Manganese	0.60	Silicon	4.00	Molybdenum	22.0
Chromium	3.70	Nickel	3.70	Vanadium	43.0

b. Homogeneous Armor Fabrication. There is considerable interest among the vehicle fabricators in the fact that the Ordnance Department may soon have a specification for stainless austenitic electrodes for welding armor which it is hoped will permit classification of brands of electrodes. There appears, however, to be little concern with the details of that specification. There is apparently a considerable degree of variation in the procedures used for welding H plates. It is intended that the crossbar weld be made after the leg welds have been completed and with the welding

[redacted]

procedure the same as used for the leg welds. In some cases different procedures have been used for the cross-bar than have been used for the legs. This practice should not be accepted. A limitation on interpass temperature has been suggested by Tank-Automotive Center; namely, that the interpass temperature shall not exceed, by more than 100°F., the preheat temperature to be used in production. In general, it is considered that the welding of H plates should be representative of the worst production conditions to be encountered.

A program of H plate tests, as suggested at the last meeting, of procedures involving large diameter electrodes is in progress. All of the H plates planned have not yet been completed and it is expected to forward the entire series to Aberdeen Proving Ground as a group.

The procedure for ferritic welding of armor up to and including 1/2" thickness by the Unionmelt process has been developed by one laboratory.

A survey by Aberdeen Proving Ground of ballistic shock tests of H plates welded with and without annealing beads in the surface layer indicates the following percentages as passing the shock test:

1-1/2" Homogeneous Plate

(1)	Overlapping Beads	71.0%
(2)	" " with annealing bead	91.4
(3)	Full Weave	36.1
(4)	" " with annealing bead	81.2

1" Homogeneous Plate

(1)	Overlapping Beads	60.0%
(2)	" " with annealing bead	60.0
(3)	Full Weave	25.7
(4)	" " with annealing bead	54.5

These preliminary figures indicate an advantage in the use of annealing beads in the surface layer of the welds. It was suggested that this survey be continued to differentiate between armor compositions.

There was some complaint about difficulties with armor castings but none were serious. It was believed desirable to invite the Cast Armor Liaison Group to attend the next meeting of the Homogeneous Armor Fabricators' Group. It was emphasized that armor plate should be cleaned for welding. Both shot blasting and grinding are used by the fabricators for this purpose and it was emphasized that a thick preservative on edges to be welded is very undesirable.

Some objection was raised to the present wording of Specification AXS-497 with reference to qualification of welders since a strict interpretation is taken to mean that the Ordnance Inspector does not have authority to decide whether a welder qualifies or not. An expression from

[redacted]

several fabricators indicated that when mutual co-operation between the fabricator's inspector and the Ordnance inspector is obtained no difficulty is encountered with the present wording.

c. Welding Electrodes. A tentative electrode specification has been prepared for austenitic electrodes for welding armor and has been submitted for Ordnance Department approval. This specification prescribes two standard core wire compositions, two electrode grades (one manganese modified and one molybdenum modified), and four types of each grade depending on whether titania coated or lime coated for either A.C. or D.C. The qualification test requirements are similar to those required by U. S. Navy Specifications such that one qualification test should suffice for both Services.

With reference to the standard core wire compositions #307 and #308 as agreed upon at the last meeting, the chromium range was narrowed to from 19.5% to 21.5% and the upper carbon limit set at 0.15% instead of 0.12%. The Navy desires a minimum chrome-nickel ratio limit of 2 to 1 for the #307 core wire, but for the present this requirement will be omitted from the specification in order to find out whether the core wire producers can meet the requirement. Past experience has indicated that, when this ratio is less than 2 to 1 in the #307 core wire, molybdenum must be added in the coating to produce a satisfactory electrode. It is desired to prevent such use of molybdenum if possible. The wire producers will attempt to melt for a chromium content of 20.5% and a nickel content of 10.0% in the core wire.

d. Aircraft Armor Fabrication. The problem of welding aircraft armor is complicated by the fact that there are at present some six or seven compositions of plate being supplied, all of which are of a higher carbon variety than the homogeneous armor being welded for vehicles. It appears that some preheating may be required for successful welding of this material. There is also the problem of identifying and segregating lots of plate received at the aircraft plant in order to maintain the identity of compositions for the information of the welding organization.

e. Specifications. The proposed tentative welding electrode specification has been approved, as submitted by the Electrode Group, by the Specifications Group. It is considered that the specification should include provisions for both the manganese modified and the molybdenum modified grade of electrode in order to be complete.

f. Welding Research. The studies being carried on by the National Research Council indicate that preheating will be necessary when ferritic type electrodes are used. A report has been prepared on the resistance spot welding of NAX 9115 steel plate for N.R.C. distribution. This plate material is the same composition as Great Lakes' armor except for the lower carbon content. Studies are being made of a manganese-molybdenum electrode composition for arc welding and the results from preliminary tests are quite encouraging.

[redacted]

g. <u>Miscellaneous</u>. Some difficulties are still being encountered with sizing of armor plate parts which causes varying root-gaps in the joint. This condition can be taken care of, to some extent, by building up the edges with welding.

h. <u>Next Meeting</u>. It was decided that the next meeting is to be held in Chicago, Illinois, during the first week in June, 1943. It was suggested that any or all of the various Groups could meet at any time at the call of their respective Chairmen.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

(Inclosure 24)

[redacted]

/ahk

May 6, 1943

FERROUS METALLURGICAL ADVISORY BOARD

Laboratory (WLW) <u>Subcommittee on Welding of Armor</u>

Subject: Reports - Subcommittee Technical Bulletins

To:

1. There are inclosed for his information and file, the following Restricted Subcommittee reports:

	Copy No.
a. Technical Bulletin W-4, entitled "Butt Welds in 1" Rolled Homogeneous Armor with Mn-Cr-Mo Ferritic Electrodes"	________
b. Technical Bulletin W-5, entitled "Welding of H Plates for Qualification"	________
c. Technical Bulletin W-6, entitled "H Plates in 1" Rolled Homogeneous Armor Welded with Ferritic Electrodes"	________

2. There is also inclosed revision sheet to cover corrections and additions of Subcommittee Circular W-2.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

4 Incls.
Tech. Bul. W-4
Tech. Bul. W-5
Tech. Bul. W-6
Rev. of Cir. W-2

(Inclosure 25)

[redacted]

Warner/ahk

24 September 1943

FERROUS METALLURGICAL ADVISORY BOARD

Laboratory (WLW) Subcommittee on Welding of Armor

Col. G. E. Knable, Ord. Res.
Chairman, Research Group
Office, Chief of Ordnance
SPOTB, Special Steels & Welding Section
Pentagon Building
Washington 25, D. C.

Dear Colonel Knable:

There is forwarded for your information a copy of Watertown Arsenal Report No. 640/84, entitled "Welding of Armor, Summary of Ballistic Shock Test Results on 1-1/2 Inch Homogeneous Armor 'H' Plates Welded with Austenitic Electrodes and Tested at Aberdeen Proving Ground during the Period from 1 October 1942 through 31 March 1943."

From a conversation which I had with Captain Thoben after the visit to your office on 22 September, I gather that some of the information contained in this report may be of value to you in making a decision with respect to the use of rolled or cast armor for armored vehicles. Copies of this report have been forwarded officially to the Technical Report Section of SPOTB, and also to the Armor and Development Branch, Proving Center, Aberdeen Proving Ground. This report deals with the 1-1/2" thickness only and the next report, which is in process of preparation, will deal with the 1" thickness only. It is expected that a third report may deal with the 1/2" thickness. The data included are the results of ballistic tests of welded "H" plates obtained between 1 October 1942 and 31 March 1943.

The preparation of reports of this sort is, of course, rather lengthy and time-consuming. However, if sufficient time is available it is hoped that by this system we may eventually cover all of the firing tests on welded "H" plates which have been conducted at Aberdeen Proving Ground. These reports are intended to be distributed to the membership of the Subcommittee on Welding of Armor.

For the President of the Board:

Very truly yours,

3 Incls.
Report No. 640/84
Receipt Form
Return Envelope

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

By ______________________
Secretary

(Inclosure 26)

[redacted]

Warner/ahk

31 December 1943

FERROUS METALLURGICAL ADVISORY BOARD

Laboratory (WLW) Subcommittee on Welding of Armor

Dear Mr.

On or about 23 November 1943, the following Watertown Arsenal Laboratory Reports, of Restricted classification were mailed to you together with a receipt form and return addressed envelope for your convenience in acknowledging receipt of the reports:

Report of Meeting of Subcommittee on Welding of Armor held at the Hotel Pennsylvania, New York, N. Y. on 7 October 1943, and

Subcommittee on Welding of Armor, Technical Bulletin W-7, entitled "Plate Edge Stresses in Welded Corner Joints."

To date this receipt form has not been received, and we would like to know whether you have received the reports so that, if you have not, we may start a check-up to locate them if possible.

For the President of the Board:

Very truly yours,

H. H. ZORNIG
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

By______________________
Secretary

(Inclosure 27)

[redacted]

/ahk

20 June 1944

FERROUS METALLURGICAL ADVISORY BOARD

Laboratory (WLW) Subcommittee on Welding of Armor

Subject: Transcript of Meeting of Subcommittee held 11 May 1944, Cleveland, Ohio

To: Chief of Ordnance, ASF
Pentagon Building
Washington 25, D. C.

Attn: SPOTB - Colonel S. B. Ritchie

1. Forwarded herewith is the first copy of the transcript of the discussion at the meeting of the Subcommittee held in Cleveland, Ohio on 11 May 1944. This copy is forwarded for file by his office, and a carbon copy has been retained for file at this arsenal, together with stenotype notes.

2. A summary of the discussions covered by this transcript is being prepared for distribution to the membership of the Subcommittee in accordance with the procedure established by all of the subcommittees to avoid excess typing and bulkiness of the minutes of these meetings. This summary will be forwarded in due course.

For the President of the Board:

H. H. ZORNIG
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

1 Incl.
Transcript of meeting

(Inclosure 28)

[redacted]

Warner/ahk

13 September 1944

FERROUS METALLURGICAL ADVISORY BOARD

Laboratory (WLW) Subcommittee on Welding of Armor

Inclosed is a copy of Watertown Arsenal Laboratory Experimental Report No. WAL 648/6, entitled "Evaluation of Shock Properties of Welded Armor Joints at Subnormal Temperatures - Examination of Samples from 31 Commercially Welded 'H' Plates Ballistically Shock Tested as Part of the 1942-1943 Canadian Cold Test Program."

It is thought that because of your work with the problem of welding armor you might be interested in this report. Since there are no additional copies of this report available, it would be appreciated if you would make this copy available to other qualified members of your organization who may be interested in it.

Please acknowledge receipt of this report by filling out and returning the attached form in the inclosed addressed envelope.

For the President of the Board:

Very truly yours,

H. H. ZORNIG
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

By____________________
Secretary

3 Incls.
Report WAL 648/6
Receipt Form
Return Envelope

(Inclosure 29)

[redacted]

APPENDIX A
PART II

Subcommittee Circular W-1

Circular No. W-1
November 25, 1942

War Department

ORDNANCE DEPARTMENT

Ferrous Metallurgical Advisory Board

SUBCOMMITTEE ON WELDING OF ARMOR

Its purpose, organization, method of operation and membership.

Watertown Arsenal
Watertown, Mass.

Table of Contents

Ferrous Metallurgical Advisory Board

SUBCOMMITTEE ON WELDING OF ARMOR

INTRODUCTION

Armor weldments* are procured under drawings and specifications which prescribe their physical dimensions, the ballistic properties of the material in them, and the degree to which the material and the welds must be free from the defects that are usually encountered in the processing of the material and in welding. The manufacturing processes are limited only to those general procedures which have been proved acceptable by prescribed qualification tests. This leaves the fabricator of armor weldments the maximum possible freedom in the choice of manufacturing processes. It also places upon him the burden of developing manufacturing processes which will produce satisfactory armor weldments.

Prior to the beginning of the present war, armor weldments for Army materiel had not been manufactured. In times of peace experimental armor structures, constructed by riveting or bolting, had been made by Government Arsenals and Navy Yards and by a few commercial companies which have, to a limited extent, been engaged in this highly specialized activity and have accumulated certain necessary equipment and manufacturing experience. In peace time the research and development work on armor structures and the application of welding thereto has been conducted almost entirely in the laboratories and shops of the Government Arsenals and Navy Yards who engage in such activities aided by the proving grounds of the Army and Navy.

THE SUBCOMMITTEE

History

In the summer of 1940 when it became evident that this country was going to have to produce more armor structures than it ever had before, and that the industrial fabrication and welding facilities of the country would have to be utilized to a considerable extent for this work, the Chief of Ordnance asked his Ferrous Metallurgical Advisory Board to organize a Subcommittee on Welding of Armor to advise him with respect to the development of methods of welding armor and the specifications under which armor weldments are procured. This Subcommittee originally was composed of technical representatives of 18 industrial companies engaged in

a. the production of armor and armor structures
b. the fabrication of welded steel structures for industrial use
c. the manufacture of welding materials and equipment

* In this circular the term "armor weldment" is used in its broadest sense to indicate a metal structure of armor or armor and structural steel built up by welding the various parts together.

together with representatives of the Army Ordnance Department and the Navy Bureau of Ships.

The demand for armor weldments increased to such an extent that it became necessary to have them produced by a large number of commercial companies whose equipment was more or less suitable for this work or could be adapted for it even though their organizations were not experienced in the special manufacturing processes involved. To facilitate the acquisition by such companies of a knowledge of the special metallurgical features involved in the construction of armor weldments and to promote the development of materials and methods of welding armor by those companies, they were invited to designate representatives to become members of the Subcommittee on Welding of Armor.

In the fall of 1941 the fortunes of war began to seriously limit the availibility of some of the alloying elements that are ordinarily contained in the steels which are used in welding electrodes and armor. The War Production Board which is responsible for obtaining these strategic materials in quantities sufficient to meet the minimum requirements of our necessary industries, finding ways of reducing their consumption, and allocating the available supplies to those uses which will contribute most to our war effort, was invited to be represented on this Subcommittee as a means of keeping informed of the technical activities of the Subcommittee and the Subcommittee's efforts to effect conservation in the manufacture of armor weldments. The membership of the Subcommittee now includes representatives of the War Production Board.

The laboratory facilities of the Government and the plants that are welding armor are, at present, engaged to their capacity in work on their own immediate problems connected with process development and the conservation of strategic materials. Their staffs consequently do not have much time to spare to devote to research work on the more general problems which have as their objective the perfection of materials and technique for welding armor, increasing production, and still further reducing the use of strategic materials. Much of this research work can and should be done in the laboratories of educational institutions and in privately owned or endowed laboratories. Such work can be financed and directed by the Office of Scientific Research and Development through the National Defense Research Committee and the National Research Council's War Metallurgy Committee. To facilitate the initiation and coordination of such research work and the speedy dissemination of the results obtained to those who can make the most use of it, a representative of the War Metallurgy Committee holds membership in the Subcommittee on Welding of Armor. In addition, members of the Subcommittee serve on the Advisory Committees that are appointed by the Chairman of the War Metallurgy Committee to guide the work that is being done on various welding research problems that have been undertaken.

Thus the Subcommittee on Welding of Armor has grown to be an organization which provides facilities through which all those concerned with the technical phases of the development and application of the welding process to the welding of armor can discuss their problems and exchange their views.

Purpose

The purpose of the Subcommittee on Welding of Armor is to plan and coordinate, through complete interchange of technical information, the work being done by the fabricators, the manufacturers of equipment and supplies, and the Government agencies concerned, on the development of the processes, techniques, equipment and materials used in the fabrication of armored military materiel by welding with a view to producing the best possible quality, in the required quantities, with the materials, equipment and operating personnel that are or can be made available.

ORGANIZATION

Development Groups

Welded armor structures are now made by two welding processes which in the order of their application are:

Metal Arc Welding
Resistance Welding.

In the development of the procedures for welding of armor, problems are encountered that are peculiar to the process employed, the type of armor that is being welded, and the design of the structure. It has therefore, been found desirable to provide a means for the consideration of such special problems by those who are directly interested in them. This has been accomplished by the organization within the main Subcommittee of five Development Groups, i.e., the

Homogeneous Armor Fabricators' Group

Face-Hardened Armor Fabricators' Group

Aircraft Armor Fabricators' Group

Electrode (Arc Welding) Group

Resistance Welding Group

The purpose of each Development Group is the same as the purpose of the main Subcommittee as stated above. The only difference is that each operates in a narrower field.

Members of the Subcommittee may choose the Development Group to which they wish to belong. They may also attend the meetings of the other Development Groups if they desire to do so. They are, however, obligated to take an active part in the activities of only the Development Group to which they belong.

Research Group

In the prosecution of the development work on the welding of armor which the industrial companies may have under way, need arises for research work of a general nature which they cannot undertake to carry out in their own laboratories. There are institutional and other laboratories available in the country where such research work can be undertaken and successfully carried out if properly guided and there are Government agencies that are prepared to finance and supervise such work. The members of this Subcommittee should be more competent than any other group in this country to know what research work in this field should be undertaken, to assist in guiding it along the lines that are likely to be practically useful and to judge the value of the results obtained. In order to put this phase of the Subcommittee's work on an orderly basis there has been organized within the Subcommittee a Research Group.

Specifically the functions of the Research Group are:

a. To study the needs for research work that should be done to further the development of the welding of armor and to bring them to the attention of the proper agencies through the Chairman of the Subcommittee;

b. To assist the agencies undertaking such research work in guiding it along lines that are likely to be practically useful;

c. To evaluate, for the benefit of the Subcommittee, the practical value of the results obtained.

The members of the Research Group are appointed from the membership of the Subcommittee by the Chairman of the latter.

Specifications Group

The preparation of the specifications which govern the welding of armor is a responsibility of the Ordnance Department. The Ordnance Department tries to keep these specifications abreast of the latest developments. When changes in these specifications are proposed, they are, before final adoption, generally submitted to the industry for comment, through its technical representatives on this Subcommittee. The comments received from the individual members are usually more or less contradictory and the various views must be reconciled with those of the Ordnance Department. It is impractical to do this in the meetings of the whole Subcommittee because of its size. To provide for doing this in an orderly way there has been organized within the Subcommittee a Specifications Group.

Specifically the functions of the Specifications Group are to assist the Ordnance Department in preparing specifications for the welding of armor and in keeping them in line with military requirements, the best manufacturing practices and the availability of equipment and raw materials.

The members of the Specifications Group are appointed from the membership of the Subcommittee by the Chairman of the latter. The members are so chosen that all of the Development Groups and the interested Divisions of the Ordnance Department are represented.

Armor Liaison Group

The technical representatives of the industrial companies and the Government agencies that are concerned with the manufacture of armor are members of the Subcommittee on Rolled Armor and the Subcommittee on Cast Armor, while the technical representatives of those concerned with the fabrication of armor into combat vehicles and aircraft are members of this Subcommittee. From time to time the fabricators of armor and the manufacturers of armor encounter problems in which both are involved and experience has shown that there is a need for a channel through which such problems can be considered by both interests meeting together. To provide such a channel there has been organized within this Subcommittee an Armor Liaison Group.

The specific functions of the Armor Liaison Group are to maintain liaison with the Subcommittee on Rolled Armor and the Subcommittee on Cast Armor for the consideration of problems in which both are interested. This liaison is to be accomplished either through attendance at the meetings of the Subcommittees of the other interests involved or through joint meetings of the Liaison Groups of the Subcommittees involved.

The members of the Armor Liaison Group are appointed from the membership of the Subcommittee by the Chairman of the latter. The members are chosen so that each Development Group is represented.

Watertown Arsenal Laboratory

The Laboratory at Watertown Arsenal is an agency of the Ordnance Department. Its principal functions are to:

a. Advise the Chief of Ordnance in matters pertaining to ferrous metallurgy;

b. Conduct research and development work in the ferrous metallurgy of Ordnance Materiel and Ammunition;

c. Perform such other duties in the field of ferrous metallurgy as may be directed.

Under c. it is charged, among other things, with performance of the administrative work of the Subcommittee on Welding of Armor. The Director of the Laboratory acts (with the consent of the membership) as Chairman of the Subcommittee and the Chief of the Laboratory's Welding Section acts (with the consent of the membership) as its secretary. This arrangement provides a convenient means for coordinating the activities of the Subcommittee with those of the Ordnance Department.

In addition, the Welding Section of the Watertown Arsenal Laboratory collects all the information that it can on current development work being done in the plants represented by the members of the Subcommittee, tabulates it and distributes it to the Subcommittee membership.

MEMBERSHIP

The membership of the Subcommittee includes:

a. Technical representatives of U. S. industrial companies that are engaged in the welding of armor for the Ordnance Department or manufacture materials or equipment therefor;

b. Individuals who are expert in fields of science or technology that are involved in the welding of armor;

c. Technical representatives of the Army and Navy;

d. Technical representatives of other Government agencies that are concerned with the welding of armor;

e. Technical representatives of allied Governments;

f. Technical representatives of industrial companies in allied countries that are engaged in the welding of armor.

Industrial Representatives

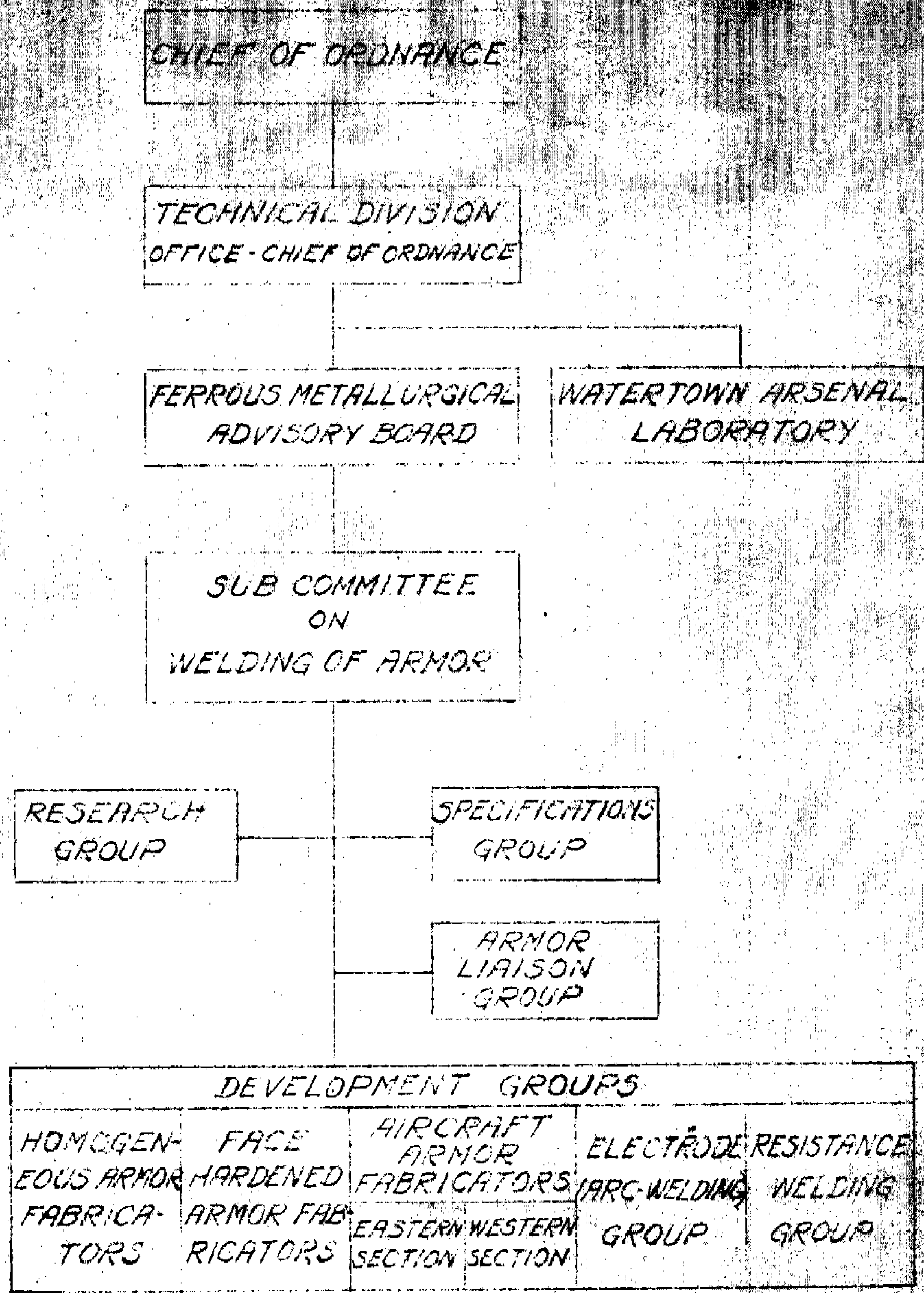
Technical representatives of U. S. industrial companies that are engaged in activities connected with the welding of armor are nominated for membership by the companies they are to represent. As matters that are classified as "confidential" or "restricted" are often discussed at Subcommittee meetings and are communicated to the members in writing, it is necessary that persons nominated as industrial representatives be cleared by the Office, Chief of Ordnance, before they can be admitted to membership on the Subcommittee.

The representation of industrial companies is normally limited to not more than two from each concern. This limitation is desirable to prevent the Subcommittee from becoming too large to be effective.

As this Subcommittee deals entirely with the technical aspects of welding of armor it is necessary that the industrial representatives be men who are familiar with the technical phases of the work being done by their companies and are authorized to speak for their companies regarding their technical practices and policies.

Individual Scientists and Technologists

Individuals who are expert in those fields of science or technology that are involved in the welding of armor may be appointed to membership on the Subcommittee by the Chief of Ordnance.



ORGANIZATION CHART
OF
SUB COMMITTEE ON WELDING OF ARMOR

FIG. 1.

Government Representatives (U.S.)

Technical representatives of the Army and Navy and of other Government agencies that are concerned with the welding of armor are designated by the Chiefs of the Offices or agencies that they represent. They are in some cases designated for continuing membership and in some cases as representatives for one meeting only.

Representatives of Allied Governments and Industrial Companies of Allied Countries

Technical representatives of allied Governments and of industrial companies in allied countries are designated by their Governments upon invitation to membership extended by the Chief of Ordnance through channels.

Membership Lists

A list of the members of this Subcommittee, indicating the interests they represent and the groups to which they are assigned, is issued as Circular No. W-2.

MEETINGS

It is obvious that most of the detailed work of the Subcommittee must be done in meetings of the Groups. The frequency with which the Groups meet is dependent upon the number and the importance of the matters pending at any time. In order to coordinate the work of all the Groups and to consider matters of general interest, meetings of the whole Subcommittee are held at less frequent intervals.

Group Meetings

Groups meet at the call of the Group Chairman who also arranges for a meeting place.

Stenographic records of the proceedings at Group meetings are ordinarily not made. Instead "Minutes" are kept to indicate the matters considered and the conclusions reached or actions taken. A copy of these Minutes is transmitted promptly by the Group Chairman to the Chairman of the Subcommittee.

Subcommittee Meetings

The whole Subcommittee meets at the call of its Chairman. The Secretary of the Subcommittee arranges for a suitable room in which to hold the meeting.

Stenographic record of the proceedings at meetings of the Subcommittee are ordinarily made and distributed to the members.

Attendance at Meetings

As many of the matters discussed at meetings of the Groups and the Subcommittee are classified as "confidential" or "restricted" it is necessary to restrict the attendance at these meetings to Members of the Subcommittee as recorded on the official membership list and guests invited by the Chief of Ordnance. All others will be excluded from the meetings. The Chairman of the Subcommittee and the Chairmen of the Groups are responsible that attendance at the meetings they preside over is limited accordingly.

DISTRIBUTION OF INFORMATION

The primary means for the exchange of information between the members of the Subcommittee will always be the discussions at the Group and Subcommittee meetings.

In addition, there are distributed from time to time to the members of the Subcommittee:

Circulars

Containing information of a general and nontechnical nature.

Technical Bulletins

Containing information of a technical nature.

Reports

Reports of investigations of interest to committee members. Such reports may originate from various places such as Watertown Arsenal Laboratory, investigators employed by N.D.R.C., War Metallurgy Committee, etc.

H. H. Zornig
H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

[redacted]

APPENDIX A
Part III

Subcommittee Forms and Usage

During the latter part of 1942 the attendance at Subcommittee meetings reached a maximum and due to rapid increase of membership in 1942 it was decided to check the industrial companies represented to obtain official confirmation of their desired representation. Accordingly a mimeographed form letter (Form SC-1) was sent to the management of all member companies of record together with a reply form (Form SC-2) for designation of representatives. The replies to these letters were the basis for preparation of an official Subcommittee membership list as indicated by Subcommittee Circular W-2 (Part IV of this Appendix). These forms were used only for those companies whose representatives had been attending recent meetings of the Subcommittee and were not used a second time. In September 1943 a second check-up was made using Form SC-11, which was sent out with the notices of the 13th Subcommittee meeting, October 1943, to the individual industrial members. This second check formed the basis for Revised Circular W-2 (Part IV of this Appendix).

From time to time information was received by the Subcommittee Chairman indicating the desirability of including membership of certain industrial companies not heretofore represented. In such cases a typed form letter (Form SC-9) was sent to the management of the company involved together with a typed reply form (Form SC-10). Upon receipt of these forms the names of individuals designated were referred to OCO-Washington for clearance for membership on the Subcommittee. These forms (SC-9 and SC-10) were not used for membership check and only for new members.

These various forms as prescribed herein and the usage indicated were evolved after considerable planning and study during the expanding Subcommittee activities in 1942 in order to standardize administration policies and rules of Subcommittee conduct. Their usage did accomplish just that and permitted the details to be more efficiently handled by clerical personnel thus relieving the Subcommittee Chairman and Secretary of considerable burden. They were first used for the Subcommittee meeting of 6 December 1942.

In connection with conduct of Subcommittee meetings one of the most burdensome tasks was that of checking attendance. In order to simplify this procedure standard forms (SC-3 through SC-8) were evolved and a procedure standardized whereby admission to the meeting was by standard identification form.

Notification of meeting date was sent to all industrial representatives and individual specialists by mimeographed form letter (Form SC-3) with which was included a copy of mimeographed reply form and admission card (Form SC-7) together with addressed return envelope. The top half

[redacted]

of this latter form was returned by the individual and the lower half was retained to be turned in at the door of the meeting room for admittance. These admission cards were checked from a typed attendance list by an attendant at the door. In cases where such an attendant was not available the Secretary had to take over.

For those individuals, invited to attend as visitors and not as regular members, a typed letter (Form SC-6) was used with mimeographed form (SC-7) for reply and admission to the meeting. If a particular Group meeting was considered to be of interest to the individual, his attention was called to it in the last paragraph of Form SC-6. Such invitations were limited to those instances in which requests for such attendance were received from OCO-Washington, OCO-Detroit, Ordnance Districts or regular Subcommittee members in which cases the Chairman assumed that the responsibility for clearance lay with the agency initiating the request.

Notification to Government agencies was accomplished by two types of typewritten form letters (Form SC-4 and Form SC-5). For those agencies whose representatives were carried on the Subcommittee membership list Form SC-4 was used. For those agencies which were not so represented Form SC-5 was used. Notification of attendance was by indorsement thereon. In both cases an admission card (Form SC-8) was forwarded, one for each individual who might attend.

By use of these attendance forms and admission cards it was readily possible to take the list of actual attendance without a roll call or otherwise interrupting the progress of the meeting, particularly for late arrivals. In those instances where individuals arrived without admission cards the door attendant usually had a supply of both Form SC-7 and Form SC-8. Service personnel were most frequent offenders in this respect.

Form SC-12 and Form SC-13 show the Resistance Welding Questionnaire circulated in late 1942 to the tank fabricators represented on the Subcommittee as referred to in Part I-c of this Appendix.

[redacted]

WLW/ahk

November 7, 1942

FERROUS METALLURGICAL ADVISORY BOARD

Laboratory (WLW) Subcommittee on Welding of Armor

Dear Sir:

The Ordnance Department Ferrous Metallurgical Advisory Board's Subcommittee on Welding of Armor is, as you know, the medium through which the industrial companies that are engaged in the welding of armor for combat vehicles and aircraft and the various Government agencies that are concerned therewith exchange information and coordinate their development work on the steels, processes, and the materials used in the welding of armor. Its membership is composed of technical representatives of these industrial companies and Government agencies.

The work done by this Subcommittee is very important in improving the quality of the combat equipment of our Armed Forces. To keep its effectiveness to a maximum it is most desirable to include in its membership technical representatives of all those industrial companies and Government agencies that are actively engaged in this work and at the same time keep it down to a workable size. The frequent shifting of personnel that is taking place in these times makes it necessary from time to time to consider a revision of the Subcommittee's membership list.

An examination of the current list of members of this Subcommittee indicates that it contains representatives of some industrial companies that may no longer be engaged in the welding of armor and that some industrial companies may be represented by individuals who are now engaged in other than technical activities. It has, therefore, been decided to make a check of the membership with a view to revising it if that is shown to be necessary. Your co-operation in making such a check is requested.

Will you therefore kindly fill out the attached form and return it in the inclosed official envelope at your earliest convenience. In order to keep the Subcommittee down to a workable size it is desired to limit each industrial company to not more than two representatives, preferably one, with a thorough technical knowledge of the subject.

Form SC-1

[redacted]

Your company is now represented by -

____

____

It is proposed in the future to limit attendance at meetings to designated representatives.

Your co-operation in this matter will be greatly appreciated.

For the President of the Board:

Yours very truly,

H. H. Zornig
Colonel, Ordnance Dept.
Secretary, Ferrous Metallurgical
Advisory Board

2 Incls.
Form letter
Return envelope

[redacted]

Date_______________

Chairman
Ferrous Metallurgical Advisory Board
Watertown Arsenal
Watertown, Mass.

Dear Sir:

As requested in your letter of November 7, 1942, the following information is submitted:

1. Our company is engaged in the welding of armor and would like to be represented on the Subcommittee for Welding of Armor.

2. We would like to designate as our representatives the following persons:

(Name)	(Position in Company)
(Name)	(Position in Company)

3. These gentlemen are authorized to speak for this company on technical matters.

Very truly yours,

____

By _______________________

Form SC-2

[redacted] WLW/ahk

Date____________

FERROUS METALLURGICAL ADVISORY BOARD

Laboratory (WLW) Subcommittee for Welding of Armor

Dear Sir:

A meeting of the Ferrous Metallurgical Advisory Board's Subcommittee for Welding of Armor will be held at the ______________________ in ________________ on ______________________ at _____ A.M. A copy of the Agenda for this meeting is attached.

As matters will be discussed which are classified as "restricted" only members of this Subcommittee will be admitted to this meeting. Members cannot be allowed to send substitutes or alternates.

To facilitate admittance to the meeting it is requested that you present the attached admission slip at the door, completed as indicated.

It is requested that you kindly indicate on the attached form whether or not you will attend and return the form to me in the inclosed envelope.

For the President of the Board:

Yours very truly,

H. H. ZORNIG
Colonel, Ordnance Dept.
Chairman, Subcommittee for
Welding of Armor

By______________________
Secretary

3 Incls.
Agenda
Form (Admission slip and Reply form)
Return Envelope

Form SC-3

[redacted]

WLW/ahk

FERROUS METALLURGICAL ADVISORY BOARD

Laboratory (WLW) Subcommittee on Welding of Armor December 19, 1942

Subject: Meeting of the Subcommittee on Welding of Armor

To:

1. A meeting of the Ferrous Metallurgical Advisory Board's Subcommittee on Welding of Armor will be hald at the ______(Hotel)__________ (City & State) on (Day and Date) at ____ A.M.

2. The records of the Subcommittee show that the following are now members representing his (office or district):

(Fill in names of members)

3. It is requested that the undersigned be notified by indorsement hereon which of the above-named persons will attend this meeting. If, due to the present conditions, any of the named persons are no longer available to act as representatives of his (office or district), it is requested that the undersigned be notified of this also and that someone be designated in his stead.

4. As matters will be discussed at this meeting which are classified as "restricted" only members who have been so designated to represent his (office or district) and who present one of the attached admission cards properly executed will be admitted to the meeting.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

2 Incls. (in ____)
Admission card
Agenda

Form SC-4

[redacted]

WLW/ahk

FERROUS METALLURGICAL ADVISORY BOARD

December 19, 1942

Laboratory (WLW) Subcommittee on Welding of Armor

Subject: Meeting of the Subcommittee on Welding of Armor

To:

1. A meeting of the Ferrous Metallurgical Advisory Board's Subcommittee on Welding of Armor will be held at the (Hotel), (City & State) on (Day and Date) at ______ A.M. His ________* is invited to be represented.

2. It is necessary to limit attendance at this meeting to those who are actually concerned with the subject dealt with by the Subcommittee. His consideration of this in designating his representatives will be appreciated.

3. As matters will be discussed at this meeting which are classified as "restricted" only those who have been designated and who present one of the attached admission cards properly executed will be admitted to the meeting.

4. It is requested that the undersigned be notified by indorsement hereon who has been designated to represent his ________*.

For the President of the Board:

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

* office or district

2 Incls. (in trip.)
Admission card
Agenda

Form SC-5

[redacted]

WLW/ahk

FERROUS METALLURGICAL ADVISORY BOARD

Date ________

Laboratory (WLW)   Subcommittee on Welding of Armor

Mr.

Dear Mr. ________:

The Chief of Ordnance has directed me to extend to you an invitation to attend the meeting of the Ferrous Metallurgical Advisory Board's Subcommittee on Welding of Armor which is to be held at the ____(Hotel)____ in ____(City and State)____, ____(Date)____ at ____(Time)____. A copy of the Agenda for this meeting is attached.

As matters will be discussed which are classified as "restricted" only members of the Subcommittee on Welding of Armor or invited guests will be admitted to this meeting.

To facilitate admittance to the meeting it is requested that you present the attached admission slip at the door, completed as indicated

It is also requested that you kindly indicate on the attached form whether or not you will attend and return the form to me in the inclosed envelope.

On ____(Day and Date)____, there will be held a meeting of the ________ Group in ________ ____(Address)____, at ____ A.M. If you desire to attend this meeting it is suggested that you bring this letter with you for identification.

For the President of the Board:

Very truly yours,

H. H. Zornig
Colonel, Ordnance Dept.
Chairman, Subcommittee on
Welding of Armor

3 Incls.
Agenda
Form (Admission slip
and Return form)
Return envelope

By________________
Secretary

Form SC-6

[redacted]

SUBCOMMITTEE FOR WELDING OF ARMOR

Date ____________________

Secretary
Subcommittee for Welding of Armor
Watertown Arsenal
Watertown, Massachusetts

Dear Sir:

I have received the notice of the meeting of the Subcommittee on Welding of Armor to be held at the ___(Hotel)___ in ___(City)___, ___(State)___, on ___(Day and Date)___.

I WILL (WILL NOT) attend this meeting.

NAME ____________________

ORGANIZATION ____________________

ADDRESS ____________________

____

(DETACH HERE AND RETURN THE ABOVE IN INCLOSED ENVELOPE)

SUBCOMMITTEE FOR WELDING OF ARMOR

ADMISSION CARD
(THIS CARD MUST BE PRESENTED AT THE DOOR)

Admit ___(to be filled in at W. A.)___ to the meeting of the Subcommittee on Welding of Armor to be held at the ___(Hotel)___ in ___(City and State)___, on ___(Day and Date)___ at ______ A. M.

/s/ H. H. Zornig, Colonel, O.D.
(Chairman)

To enable the secretary to keep his records up to date, it is requested that you fill in the following:

ORGANIZATION REPRESENTED ____________________

MAIL ADDRESS OF FIRM ____________________

MAIL ADDRESS PERSONAL ____________________

POSITION OCCUPIED ____________________

Luncheon desired Yes / No (Cross out word) (not applicable)

Form SC-7

SIGNATURE ____________________

[redacted]

SUBCOMMITTEE FOR WELDING OF ARMOR

ADMISSION CARD

(THIS CARD MUST BE PRESENTED AT THE DOOR)

________________________ has been designated to represent the

(To be filled in at W.A.) at the meeting of the Subcommittee on

Welding of Armor to be held at the (Hotel) in (City),

(State), on (Day and Date), at ______ A.M.

SIGNATURE __________________

RANK or
DESIGNATION __________________

To enable the secretary to keep appropriate records it is requested that the designated representative fill in the following:

Subdivision Represented ____________________________

Position Occupied ____________________________

Luncheon desired Yes / No (Cross out word) (not applicable)

SIGNATURE __________________

RANK or
DESIGNATION __________________

Form SC-8

[redacted]

FERROUS METALLURGICAL ADVISORY BOARD WLW/blh

Laboratory (WLW) (Date)

President

Dear Sir:

The President of the Ferrous Metallurgical Advisory Board has been informed that your company should be represented on that Board's Subcommittee on Welding of Armor. The purpose of the Subcommittee on Welding of Armor is to plan and coordinate, through complete interchange of technical information, the work being done by the fabricators, the manufacturers of equipment and supplies, and the Government agencies concerned, on the development of the processes, techniques, equipment and materials used in the fabrication of armored military materiel by welding with a view to producing the best possible quality, in the required quantities, with the materials, equipment and operating personnel that are or can be made available.

If your company desires such representation, will you please fill out the inclosed application form and return same to me.

In order to keep the Subcommittee down to a workable size, it is desired to limit each industrial company to not more than two representatives, preferably one, with a thorough technical knowledge of the subject dealt with.

As the members of this Subcommittee are entrusted with information that is classified as "restricted" it is necessary that they be cleared for membership by the Office, Chief of Ordnance. As soon as this clearance has been received, you will be notified.

For the President of the Board:

Very truly yours,

2 Incls.
Application form
Return envelope

H. H. Zornig
Colonel, Ordnance Dept.
Secretary, Ferrous Metallurgical Advisory Board

Form SC-9

[redacted]

(Date)

The President
Ferrous Metallurgical Advisory Board
Watertown Arsenal
Watertown, Massachusetts

Sir:

The ____
(Company)

of ____
(Address)

desires to be represented on the Ferrous Metallurgical Advisory Board's Subcommittee on Welding of Armor. It desires to designate as its representative on this Subcommittee the following persons:

____________________ (Name)	____________________ (Position)
____________________ (Name)	____________________ (Position)

These persons are citizens of the United States and the Company is willing to vouch for their loyalty to the United States.

Our company desires representation on this Subcommittee because

Very truly yours,

____

(one copy to be submitted to the company)

Form SC-10

[redacted]

Watertown Arsenal
Watertown 72, Massachusetts

Subcommittee on Welding of Armor

13 September 1943

Dear Mr.

In order to keep the Subcommittee records up to date, it is desired to determine whether your company is now concerned with the fabrication of armored vehicles by welding and still desires to retain representation on the Subcommittee. It is therefore requested that you fill out and return this form in the inclosed addressed envelope.

/s/ H. M. Zornig
Colonel, Ordnance Dept.
(Chairman)

THE ______________________________ (COMPANY)

STREET NUMBER ______________________________

CITY ______________________________

STATE ______________________________

IS
IS NOT engaged in the fabrication of armored vehicles

by welding and therefore

DOES
DOES NOT desire to retain representation on the Subcommittee.

SIGNED ______________________________

DATE ______________________________ TITLE ______________________________

Form SO-11

[redacted]

SUBCOMMITTEE FOR WELDING OF ARMOR

RESISTANCE WELDING GROUP

APPLICATION DATA SURVEY

Resistance Spot Welding of Armor Plate or Welding of Attachments to Armor Plate

1. Are you doing any spot welding of armor plate at present? ______

   a. If so, please give brief description of the applications. ______
   (Use separate sheet if necessary)

   b. If you are spot welding armor plate, please briefly describe the procedure control you use in production. ______

   c. If you have any, please forward a copy of your design standards and note if forwarded. ______

2. Do you desire to weld face-hardened or homogeneous armor? ______

3. What range of material thicknesses do you desire to weld? (If combinations are of unequal thickness, please state both.) ______

4. What types of joints predominate: (Please check numerically to indicate preference, and note a, b and c are stress-bearing joints.)

   a. Straight butt joints with flat butt straps. ______

   b. Corner joints with angle butt straps. ______

   c. Lap joints of armor plate. ______

   d. Attachment of clips or other small attachments to armor plate. ______

5. What maximum throat depths should spot welders for armor plate have? (Unused throat depth carries a heavy power demand penalty). ______

[redacted]

6. What range of plate thicknesses do you estimate spot welders should cover? (Please state this in terms of several progressively heavier welders to cover the range of plate desired to weld.) ______

______

7. How do you prefer to clean plate surfaces preliminary to spot welding?

   a. Steel grit blasting. ______

   b. Alundum or other artificial abrasive blasting. ______

   c. Grinding. ______

8. Do you know of any other method of cleaning, other than those listed in Question 7, which has proven to be satisfactory? ______

______

9. What, in your opinion, is the best method of checking procedures in production? (Please outline what you consider to be a satisfactory method.)

______

______

______

______

10. What, in your opinion, are the major unsolved problems in the application of the spot welding process to the welding of armor plate? ______

______

______

______

______

______

IMPORTANT

Please fill out this questionnaire and mail in the inclosed envelope to: Commanding Officer
Watertown Arsenal
Watertown, Mass.

SIGNATURE ______

TITLE ______

ORGANIZATION ______

ADDRESS ______

DATE ______

Form SG-12

[redacted]

SUBCOMMITTEE FOR WELDING OF ARMOR

RESISTANCE WELDING GROUP

APPLICATION DATA SURVEY

Resistance Flash Butt Welding of Armor Plate or Welding of Attachments to Armor Plate

1. Are you doing any flash butt welding of armor plate at present? ____________

   a. If so, please give brief description of the applications. ____________
   (Use separate sheet if necessary.)

   ____

   ____

   ____

   b. If you are flash butt welding armor plate, please briefly describe the procedure control you use in production. ____________________

   ____

   ____

   ____

   c. If you have any, please forward a copy of your design standards and note if forwarded. ______________________________

2. Do you desire to weld face-hardened or homogeneous armor? ____________

   ____

3. What range of material thicknesses do you desire to weld?
   (If combinations are of unequal thickness, please state both.) ____________

   ____

4. What types of joints predominate: (Please check numerically to indicate order of preference.)

   a. Straight butt welds between two pieces of the same material of equal thickness. ______________________________

   b. Straight butt welds between a piece of armor plate and a piece of some other steel, such as low carbon steel. ____________________

   c. Welding of armor or low carbon steel attachments to the edges of armor plate. ______________________________

[redacted]

5. The length of the longest joint you desire to weld is ____________________

6. Presuming the weld quality and operation economy justifies the changes, would you change your product design to permit applying flash welding? ____________

7. What, in your opinion, is the best method of checking procedure in production? (Please outline what you consider to be a satisfactory method.)

____

____

____

____

8. What, in your opinion, are the major unsolved problems in the application of the flash welding process to the welding of armor plate? ____________________

____

____

____

____

____

SIGNATURE ____________________

TITLE ____________________

ORGANIZATION ____________________

ADDRESS ____________________

DATE ____________________

<u>IMPORTANT</u> - Please fill out this questionnaire and mail in the inclosed envelope to: Commanding Officer
Watertown Arsenal
Watertown, Mass.

Form SC-13

[redacted]

APPENDIX A
PART IV

Subcommittee Circular W-2

[redacted]

The Agenda for meetings of the Subcommittee on Welding of Armor were usually prepared by the Chairman and Secretary in advance of the date of meeting based upon suggestions received by correspondence from other interested agencies and individuals in response to requests from the Chairman as indicated by certain inclosures of Part I-a, Appendix A. This procedure was followed in general until late 1942 when standardization of Subcommittee procedure and organization into Groups tended to produce general discussions of particular or special subjects in the Group meetings instead of in the main Subcommittee meeting.

After the September 1942 meeting the pattern of Subcommittee meetings developed into a standardized form in which the Chairmen of the various Groups occupied most of the meeting time by presenting reports of the deliberations of their respective Groups. This procedure enabled standardization of Agenda which is apparent from that of the meeting, 6 December 1942. From then on a standard Agenda was quite consistently followed for the main Subcommittee meeting.

The copies of Agenda which are included here are arranged in chronological order according to dates of meetings.

Circular No. W-2 (Rev.1)
1 January 1944

War Department

ORDNANCE DEPARTMENT

Ferrous Metallurgical Advisory Board

SUBCOMMITTEE ON WELDING OF ARMOR

Membership List

ARMY SERVICE FORCES
Ordnance Department
Watertown Arsenal
Watertown 72, Mass.

Symbols Used to Indicate Primary Interest

A - Producer of Armor

H - Processor of Armor

F - Fabricator of Armor Weldments

W - Producer of Arc Welding Equipment Including Supplies and Electrodes

E - Producer of Electrodes

C - Producer of Core Wire for Electrodes

R - Producer of Resistance Welding Equipment

T - Technical Phases (Design and Development)

I - Procurement, Production and Inspection

P - Aircraft

V - Vehicles

S - Ships

1 January 1944

Ferrous Metallurgical Advisory Board
SUBCOMMITTEE ON WELDING OF ARMOR
List of Members

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INDUSTRIAL REPRESENTATIVES - UNITED STATES			Development Groups									
					Aircraft Armor Fabricators							
Name	Representing	Primary Interest	Homo. Armor Fabr.	F. H. Armor Fabr.	East. Div.	West. Div.	Elec. Mfgr.	Resistance Weld.	Spec. Group	Research Group	Armor Liaison Group	
Mr. H. L. Ingram, Jr.	Air Reduction Sales Co. Washington 6, D. C.	EI					X					
Mr. J. K. Findley	Allegheny Ludlum Steel Corp. Brackenridge, Penn.	OT					X					
Mr. J. R. Kuner, Jr.	" " " "	CI					X					
Mr. E. J. Brady	Alloy Rods Company York, Penn.	MT					X					
Mr. G. C. Beishline	American Car & Foundry Co. Berwick 6, Penn.	FTV		X								
Mr. W. C. Osha	" " " "	FTV		X								
Mr. E. J. Edwards	American Locomotive Co. Schenectady 5, New York	FTV	X									
Mr. H. S. Swan	" " "	FTV	X									
Mr. A. E. Taylor	American Rolling Mill Co. Middletown, Ohio	AI	X									
Mr. L. H. Dunham	American Steel & Wire Co. Cleveland, Ohio	OT					X					
Mr. H. N. Ewertz	Arcos Corporation Philadelphia 5, Penn.	MI					X					
Mr. R. D. Thomas, Jr.	" "	MT					X			X		
Mr. F. G. Anthor	Arcrods Corporation Sparrows Point, Maryland	MT					X					
Mr. A. J. Raymo	Baldwin Locomotive Works Philadelphia 42, Penn.	FTV	X									
Mr. D. Burleigh	Beech Aircraft Corp. Wichita 1, Kansas	FTP			X							
Mr. H. Rawdon	" " "	FTP			X							
Mr. J. C. Christian	Boeing Aircraft Company Seattle 14, Washington	FTP				X						
Mr. C. P. Keeble	" " "	FIP				X						
Mr. E. Bertram	Brewster Aeronautical Corp. Johnsville, Penn.	FTP			X							
Mr. E. C. Courtemanche	Briggs Mfg. Co. Detroit 14, Michigan	FTP			X							
Mr. C. W. Dalton	" " "	FIV	X									
Mr. C. E. McCormick	Cadillac Motor Car, Div. GMC Detroit 32, Michigan	FTV	X							X	X	
Mr. L. C. Bibber	Carnegie-Illinois Steel Corp. Pittsburgh 19, Penn.	AFV	X									
Mr. P. R. Wray	" " " "	OT					X					
Mr. P. B. Greenawald	Carpenter Steel Company Reading, Penn.	OT					X					

Ferrous Metallurgical Advisory Board
SUBCOMMITTEE ON WELDING OF ARMOR
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INDUSTRIAL	REPRESENTATIVES - UNITED STATES		Development Groups								
					Aircraft Armor Fabricators						
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Mr. T. P. Champion	Champion Rivet Company Cleveland 5, Ohio	EI					X				
Mr. D. S. Connelly	" " "	ET					X				
Mr. E. O. Mann	Chevrolet Motor, Div. GMC Detroit 11, Michigan	FTV	X								
Mr. W. W. Spaninger	Chicago Steel & Wire Co. Chicago 17, Illinois	CT					X				
Mr. N. J. Blake	Chrysler Tank Arsenal Detroit 31, Michigan	FTV	X								
Mr. H. C. Dodt	" " "	FIV	X								
Mr. C. V. Foerster	Coast Metals, Inc. Canton 6, Ohio	ET					X				
Mr. C. L. Hibert	Consolidated Aircraft Corp. San Diego 12, Calif.	FTP				X					
Mr. J. E. Madden	" " "	FTP				X					
Mr. A. F. Barnard	Consolidated Vultee Aircraft Corp. Allentown Div., Allentown, Penn.	FTP			X						
Mr. G. O'Hare	" " " " Nashville Div., Nashville, Tenn.	FIP			X						
Mr. W. B. Libert	Continental Roll & Steel Foundry Co. East Chicago, Indiana	AT	X								
Mr. J. A. Goodford	Crucible Steel Company of America Harrison, N. J.	ET					X				
Mr. C. G. Merritt	" " " " "	ET					X				
Mr. R. S. Jenkins	Curtiss-Wright Corporation Buffalo 5, N. Y.	FTP			X					X	
Mr. C. G. Trimbach	" " "	FTP			X						
Mr. O. H. Burgston	Deere & Company Moline, Illinois	FTV	X								
Mr. A. L. Abbott	Diebold Safe & Lock Co. Canton 2, Ohio	AFT		X*					X		
Mr. R. Sibley	Henry Disston & Sons, Inc. Philadelphia 35, Penn.	AT		X							
Mr. W. D. Harrison	Douglas Aircraft Co., Inc. Santa Monica, Calif.	FTP				X					
Mr. H. E. North	" " " "	FIP				X*				X	
Mr. R. F. Cooper	Federal Machine & Welder Co. Warren, Ohio	FIV						X			
Mr. D. L. Wise	" " " "	ET						X			
Mr. E. Biederman	Fisher Tank, Div. GMC Grand Blanc, Michigan	FIV	X								
Mr. R. Hensel	" " " "	FTV	X								

* - CHAIRMAN of Group

INDUSTRIAL REPRESENTATIVES - UNITED STATES

Name	Representing	Primary Interest	Development Groups: Homo. Armor Fabr.	F. H. Armor Fabr.	Aircraft Armor Fabricators: East. Div.	West. Div.	Elec. Mfgr.	Resistance Weld.	Spec. Group	Research Group	Armor Liaison Group	
Mr. C. Grotke	Fleetwings, Inc. Bristol, Penn.	FTP			X							
Mr. F. M. Morris	" "	FIP			X							
Mr. J. W. Thwing	Ford Motor Company - (home address) 3718 Brewster Rd., Dearborn, Mich.	FTP			X							
Mr. G. Vennerholm	" " " - (company address) 3000 Schaefer Rd., Dearborn, Mich.	FTVP	X		X							
Mr. R. T. Gillette	General Electric Company Schenectady, N. Y.	FT						X		X		
Mr. L. A. Danse	General Motors Corp. Detroit 2, Michigan	FTV	X							X	X*	
Mr. J. M. Diebold	GMC Truck & Coach Division Pontiac 11, Michigan	FTV	X									
Mr. R. A. Geselius	General Steel Castings Corp. Eddystone, Penn.	AT	X									
Mr. G. W. Benner	Grumman Aircraft Engineering Corp. Bethpage, Long Island, N. Y.	FTP			X							
Mr. W. F. Partridge	" " " "	FIP			X							
Mr. M. H. Butlshauser	Harnischfeger Corp. Milwaukee 14, Wisconsin	EI					X		X			
Mr. M. G. Sedam	" " (Smootharc Div.) Milwaukee 7, Wisconsin	ET					X					
Mr. C. Hart	Heil Company Milwaukee, Wisconsin	FTV	X									
Mr. A. F. Meyer	" "	FTV	X									
Mr. J. O. Cavanagh	Hollup Corporation Chicago 50, Illinois	ET					X					
Mr. R. E. Long	" "	ET					X					
Mr. H. E. Elliott	Hughes Aircraft Company Culver City, Calif.	FIP				X						
Mr. R. E. Hopper	" " "	FTP				X						
Mr. W. V. Emery	Ilco Ordnance Corp. Bedford, Indiana	FTV	X									
Mr. C. B. Lansing	" " "	FIV	X									
Mr. C. D. Evans	International Harvester Co. Bettendorf, Iowa	FTV	X									
Mr. F. A. Lee	" " " Springfield, Ohio	FIV						X			X	
Mr. N. J. Barry	Joslyn Mfg. & Sup. Co. Ft. Wayne 6, Indiana	CI					X					
Mr. L. S. Fry	" " " "	CI					X					

* - CHAIRMAN of Group

1 January 1944

Ferrous Metallurgical Advisory Board
SUBCOMMITTEE ON WELDING OF ARMOR
List of Members

INDUSTRIAL REPRESENTATIVES - UNITED STATES

Name	Representing	Primary Interest	Development Groups: Homo. Armor Fabr.	F. H. Armor Fabr.	Aircraft Armor Fabricators: East. Div.	Aircraft Armor Fabricators: West. Div.	Elec. Mfgr.	Resistance Weld.	Spec. Group	Research Group	Armor Liaison Group	
Mr. J. W. Juppenlatz	Lebanon Steel Foundry, Lebanon, Penn.	AT	X									
Mr. H. D. Phillips	" " "	AI	X									
Mr. O. B. Schultz	Lima Locomotive Works, Inc. Lima, Ohio	FTV	X									
Mr. W. A. Smith	" " " "	FTV	X									
Mr. J. M. Keir	Linde Air Products Co. New York 17, N. Y.	WT					X					
Mr. W. B. Miller	" " " "	WT					X					
Dr. M. Belles	Lockheed-Vega Aircraft Corp. Burbank, Calif.	FTP				X					X	
Mr. E. R. Siefkin	" " " "	FTP				X						
Mr. W. G. Guy	Glenn L. Martin Company Baltimore 3, Maryland	FTP			X							
Mr. P. H. Merriman	" " " "	FTP			X							
Mr. A. M. Adams	The Massey-Harris Co., Inc. Racine, Wisconsin	FTV	X									
Mr. K. H. Krause	" " " " "	FTV	X									
Mr. G. A. Maurath, Sr.	Maurath, Inc. Cleveland 5, Ohio	EI					X					
Mr. F. C. Whitmer	" "	ET					X					
Mr. M. J. VanDreser	McKay Company York, Penn.	EI					X					
Mr. J. H. Deppeler	Metal & Thermit Corp. New York 5, N. Y.	ET					X					
Mr. D. L. Mathias	" " "	ET					X					
Mr. W. E. Smith	Midland Steel Products Co. Detroit, Michigan	FTV	X								X	
Mr. C. F. Kaunitz	National Electric Welding Machines Co. Bay City, Michigan	ET						X	X			
Mr. F. Dobbs	New York Air Brake Co. Watertown, N. Y.	FTV	X									
Mr. C. B. Harley	Northrop Aircraft, Inc. Hawthorne, Calif.	FTP				X						
Mr. T. Piper	" " "	FTP				X						
Mr. F. A. Logue, Jr.	Page Steel & Wire Monessen, Penn.	EI					X					
Mr. J. E. Skinner	" " " "	EI					X					

INDUSTRIAL Name	REPRESENTATIVES - UNITED STATES Representing	Primary Interest	Development Groups: Homo. Armor Fabr.	F. H. Armor Fabr.	Aircraft Armor Fabricators: East. Div.	West. Div.	Elec. Mfgr.	Resistance Weld.	Spec. Group	Research Group	Armor Liaison Group
Dr. S. A. Braley	Pittsburgh Steel Company Pittsburgh, Penn.	CT					X				
Mr. L. M. Voyer	" " "	CI					X				
Mr. C. C. Cross	Plymouth Motor Car Co. Detroit 31, Michigan	FTV	X								
Mr. C. E. Carter	Pressed Steel Car Co., Inc. Chicago 33, Illinois	FTV	X								
Mr. L. M. Benkert	Progressive Welder Co. Detroit, Michigan	RT						X			
Dr. J. W. Miller	Reid-Avery Company Dundalk, Baltimore 22, Maryland	RT					X				X
Mr. C. H. Symington	" " "	RI					X				
Mr. H. O. Klinke	Republic Aviation Corporation Farmingdale, Long Island, N. Y.	FTP			X						
Mr. R. W. Miller	" " "	FTP			X						
Mr. T. Lichtenwalter	Republic Steel Corporation Massillon, Ohio	AT	X								
Mr. V. W. Whitmer	" " "	CT					X				
Mr. P. Hickman	Richmond Engineering Co., Inc. Richmond 5, Virginia	FTV	X								
Mr. J. K. McDowell	Rock Island Arsenal Rock Island, Illinois	FTV	X*								
Mr. A. L. Feild	Rustless Iron & Steel Corp. Baltimore 13, Maryland	CT					X				
Mr. W. B. Pierce	" " " " "	CI					X				
Mr. M. Sciaky	Sciaky Bros. Chicago 38, Illinois	RI						X			
Dr. M. E. Blanchard	A. O. Smith Corporation Milwaukee 1, Wisconsin	RT					X				
Mr. J. J. Chyle	" " " "	FT	X								
Mr. D. R. B. Genter	Standard Steel Spring Co. Detroit, Michigan	RI	X								
Mr. A. H. Lewis	Swift Electric Welder Co. Detroit 10, Michigan	RT						X			
Mr. J. H. Cooper	Taylor-Winfield Corp. Warren, Ohio	RT						X*			
Mr. S. M. Humphrey	" " "	RI						X			
Mr. R. Baker	Ternstedt Mfg., Div. GMC Detroit 9, Michigan	FTV	X								
Mr. C. F. Nixon	" " " "	FTV	X								
Mr. W. T. Ober	Thomson-Gibb Electric Welding Co. Lynn, Mass.	RI						X			

* - CHAIRMAN of Group

Ferrous Metallurgical Advisory Board
SUBCOMMITTEE ON WELDING OF ARMOR
List of Members

INDUSTRIAL REPRESENTATIVES - UNITED STATES

Name	Representing	Primary Interest	Development Groups: Homo. Armor Fabr.	F. H. Armor Fabr.	Aircraft Armor Fabricators: East. Div.	Aircraft Armor Fabricators: West. Div.	Misc. Mfgr.	Resistance Weld.	Spec. Group	Research Group	Armor Liaison Group	
Mr. F. C. Knight	Una Welding, Inc. Cleveland 10, Ohio	WT					X					
Mr. B. Brooker	U. S. Spring & Bumper Co. Los Angeles 11, Calif.	HT	X	X		X		X				
Mr. F. Garratt	Universal-Cyclops Steel Corp. Bridgeville, Penn.	CI					X					
Mr. J. O. Rinck	" " " "	CI					X					
Mr. R. R. Palmer	Vought-Sikorsky Aircraft Stratford, Conn.	FTP			X							
Mr. E. A. Schneider	" " "	FTP			X							
Mr. C. E. Jennings	Westinghouse Electric & Mfg. Co. East Pittsburgh, Penn.	HT					X					

Name	Representing	Primary Interest	Development Groups: Homo. Armor Fabr.	Development Groups: F. K. Armor Fabr.	Development Groups: Aircraft Armor Fabricators: East. Div.	Development Groups: Aircraft Armor Fabricators: West. Div.	Development Groups: Elec. Mfgr.	Development Groups: Resistance Weld.	Spec. Group	Research Group	Armor Liaison Group	
INDUSTRIAL	**REPRESENTATIVES - ALLIED COUNTRIES**											
Mr. F. A. Sherman	Dominion Foundries & Steel, Ltd. Hamilton, Ontario, Canada	AI										
Mr. F. A. Sherman, Jr.	" " " " "	AI										
Mr. A. Granik	General Motors of Canada, Ltd. Oshawa, Ontario, Canada	FT	X									
Mr. T. A. Rice	International Harvester Co. of Can., Ltd. Hamilton, Ontario, Canada	FI	X									
Mr. R. Sidebotham	" " " " " "	FT	X									
GOVERNMENT	**REPRESENTATIVES - ALLIED COUNTRIES**											
Mr. G. B. Findon	British Supply Mission, Kedrick Bldg., 1801 K St., Washington 6, D. C.	IV										
Mr. J. A. Balcom	Inspection Bd. of United King. & Can. Gen. Motors Bldg., Detroit 2, Mich.	IV										
Col. H. O. Hoare	" " " " " " " Ottawa, Ontario, Canada	TV	X									
INDIVIDUAL	**MEMBERS - UNITED STATES**											
Name	**Mailing Address**											
Dr. R. H. Aborn	U. S. Steel Research Laboratory Kearny, New Jersey	T										
Mr. R. C. Chapman	Combustion Engineering Company Chattanooga 2, Tennessee	T										
Mr. R. V. Clark	General Electric Company Schenectady 5, New York	T					X					
Mr. G. A. Ellinger	National Bureau of Standards Washington, D. C.	T					X					
Prof. W. F. Hess	Rensselaer Polytechnic Institute Troy, N. Y. (Dept. of Met. Eng.)	T						X				
Mr. C. E. Jackson	Naval Research Laboratory Anacostia Station, Washington, D. C.	T					X					
Col. G.F. Jenks, USA Ret.	232 Avondale Avenue Los Angeles 24, Calif.	T	X	X				X				
Mr. S. M. Spice	Buick Motor, Div. GMC Flint 3, Michigan	FT						X				
Prof. J. R. Stitt	Ohio State University Columbus 10, Ohio	T	X	X			X					

1 January 1944

Ferrous Metallurgical Advisory Board
SUBCOMMITTEE ON WELDING OF ARMOR
List of Members

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GOVERNMENT REPRESENTATIVES - UNITED STATES Name	Representing	Primary Interest	Development Groups: Homo. Armor Fabr.	F. H. Armor Fabr.	Aircraft Armor Fabricators: East. Div.	Aircraft Armor Fabricators: West. Div.	Elec. Mfgr.	Resistance Weld.	Spec. Group	Research Group	Armor Liaison Group	
Mr. J. H. Humberstone	National Research Council, 850 Euclid Ave., Cleveland, Ohio (Asst. Weld. Sup.)	T	X				X					
Mr. G. S. Mikhalapov	" " " (Welding Sup.)	T	X	X	X			X		X		
Chief of Bureau (Attn. ~~Orl. Howland~~) W.M.HAILE	W.P.B., Weld. & El. Br., Gen. Ind. Equip. Div., Rm. 5-220, Bldg. Temp. E, Washington 25, D. C.	I					X					
Chief of Bureau (Attn. W.O. Sweeny)	W.P.B., Met. & Cons. Br., Steel Div., Rm. 1348 Soc. Sec. Bldg., Washington 15, D. C.	I	X				X					
Lt. W. J. Harris, Jr. USNR	U.S.N., Bureau of Aero., Armament Sec., Washington, D. C.	TP			X							
Mr. B. A. Kornhauser	" " " " Equip. & Mat. Sec.	TP			X							
Lt. Comdr. J.C. Blake	U.S.N., Bureau of Ships, Weld. & Cast. Sec. Washington, D. C.	TS					X					
Mr. A. G. Bissell	" " " " " " " "	TS					X					
Comdr. W. S. Newton	U.S.N., Naval Gun Factory, Navy Yard, Washington, D. C.	T	X	X				X	X	X		
Comdr. O.R. Sutherland	U.S.N., Philadelphia Navy Yard, Bldg. 121, Philadelphia, Penn.	TX					X					
Attn: Lt. Col. Stanley A. Richardson	Hq., Army Service Forces, Prod. Div., Con. Br., Pentagon Bldg., Washington 25, D. C.	I										
Col. G.E. Knable, Ord. Res.	Office, Chief of Ordnance, Tech. Div., Ser. Br., Pentagon Bldg., Washington 25, D. C.	T	X							X*		
Capt. M. MacFayden	" " " " " " (Spec. Steels & Welding Sec.)	T	X	X				X		X		
Lt. L. J. Cogan	(Office, Chief of Ordnance) Philadelphia Ordnance Dist., Franklin Inst., Phila., Penn.	T	X				X					
Mr. E. L. Hollady	Office, Chief of Ordnance, Tech. Div., Ser. Br., Pent. Bldg., Washington 25 (Spec. Unit)	T							X			
Maj. C. E. Drewes	" " " " Tech. Div., Air. Arm. Dev. Br.	TP			X			X				
Maj. J. V. Coombe (Eng. Br., Ar. & Weld.)	Office, Chief of Ordnance - Detroit Union Guardian Bldg., Detroit 26, Mich.	TV	X	X				X	X*	X		
Maj. D. C. Pippel "	" " " " "	TV	X									
Capt. J. F. Randall "	" " " " "	TV					X*			X		
Capt. A. F. Boucher "	" " " " "	TV	X	X				X	X			
Lt. J. J. Matt (Dev. Br.)	" " " " "	TV	X									
Maj. R. H. Mott	Wright Field, Materiel Command, A.A.F. Dayton, Ohio - Prod. Eng. Sec., Stand. Br.	IP			X	X						
Capt. R. E. Bowman	" " " " Eng. Div., Mat. Lab., Weld. Unit	TP			X	X			X			
Lt. J. Koss	" " " " Mat. & Proc. Br., Insp. Div.	IP			X	X						
Mr. B. G. White	" " " " Eng. Div., Air. Lab., Spec. Proj. Br.	TP			X	X						

* - CHAIRMAN of Group

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1 January 1944

Ferrous Metallurgical Advisory Board
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GOVERNMENT REPRESENTATIVES - UNITED STATES			Development Groups									
					Aircraft Armor Fabricators							
Name	Representing	Primary Interest	Homo. Armor Fabr.	F. H. Armor Fabr.	East. Div.	West. Div.	Elec. Mfgr.	Resistance Weld.	Spec. Group	Research Group	Armor Liaison Group	
Maj. W. N. Dunlap	Wright Field, Ordnance Aircraft Service, Material Command, AAF, Dayton, Ohio	TP			X*	X						
Lt. Col. G. McInnes	" " " " "	TP			X	X						
Capt. W. C. Pless	Ordnance Research Center, Armor Dev.Br., Aberdeen Proving Ground, Maryland	T	X	X			X		X	X		
Col. H. H. Zornig, CHAIR.	Watertown Arsenal, Laboratory, Watertown 72, Mass.	T	X	X	X		X	X	X	X		
Mr. W. L. Warner, SEC'Y.	" " "	T	X	X	X		X	X	X	X		
To be designated by District Chief	Cincinnati Ordnance District Big Four Bldg., Cincinnati 1, Ohio	I										
" "	Chicago Ordnance District 38 So. Dearborn St., Chicago 3, Ill.	I										
" "	Cleveland Ordnance District, 1006 Terminal Tower Bldg., Cleveland 13, Ohio	I										
" "	Detroit Ordnance District, 1832 National Bank Bldg., Detroit 26, Michigan	I										
" " (Attn: W. J. Jeffries)	Philadelphia Ordnance District 150 So. Broad St., Philadelphia 20, Penn.	I										
" "	Pittsburgh Ordnance District, 7th Ave. & Smithfield St., Pittsburgh 19, Penn.	I										
" "	Rochester Ordnance District 25 North St., Rochester 4, New York	I										

* - CHAIRMAN of Group

[redacted]

APPENDIX B

Agenda

for

Meetings

Subcommittee on Welding of Armor

[redacted]

FIRST MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Place - Preliminary meeting at Watertown Arsenal

Date - December 19, 1940 (Assembly - 9:45 A.M. at Officers' Club)

I. Objective.

The work of this Subcommittee is to be directed toward developing suitable procedures and materials for welding armor.

II. Organization.

(a) Discussion of scope of work to be covered,

(b) Size and membership of Subcommittee.

(c) Coordination of activities - chairman.

(d) Release and distribution of confidential data.

III. Results of tests of weldments completed or in progress.

IV. Requirements for welded joints in armor.

(a) Types of tests - proof, physical, metallurgical, ballistic, non-destructive.

(b) Standards of quality - physical properties, soundness.

(c) Types of joints desirable from fabrication standpoint.

V. Welding methods permissible and limitations as to plate thickness.

(a) Arc welding.

(b) Gas welding.

(c) Resistance welding.

VI. Standardization.

(a) Inspection standards.

(b) Discussion of specifications.

[redacted]

VII. Co-operative programs and allocation of work.

It is suggested that representatives give consideration in advance and be prepared to discuss problems for inclusion in the Research and Development Program and facilities which may be utilized for the prosecution of the work.

VIII. Arrangements for the future.

(a) Determination of general frequency of meetings.

(b) Decision of time and place of next meeting.

[redacted]

SECOND MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Aberdeen Proving Ground

21 January 1941

10:00 A. M.

I. Standardization

(a) Discussion of proposed draft of general specification for arc welding of armor, AXS-497

(b) Discussion of methods of inspection and inspection standards.

(c) Weldability of armor and suitable tests therefor

II. Scope of work.

To develop procedures for welding of homogeneous and face-hardened armor of both the rolled and the cast type in thicknesses up to and including 3". The work also involves the heat treatment and testing of welded armor structures.

III. Release and distribution of data

(a) Welding procedures

(b) Results of tests

(c) Welding data sheet for specimens submitted for ballistic test

IV. Tests completed and in progress

(a) List of ballistic data from tests completed

(b) List of companies to whom armor plate has been sent for welding development work and status of the work

V. Research and development program (see appendix)

(a) Discussion of problems

(b) Facilities available

(c) Details of tests

VI. Arrangements for the future

(a) Approximate time and place of next meeting

(b) Preparations to be made

[redacted]

THIRD MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Place - Hotel Cleveland, Cleveland, Ohio

Date - 20 June 1941, 9:00 A.M., E.S.T.

I. Membership.

(a) Addition of The McKay Company.

(b) Discussion of possible membership of Mr. R. S. Komarnitsky of the Breeze Corporation.

(c) Representation of cast armor manufacturers.

II. Fabrication of Weldments.

(a) Experience with Specification AXS-497.

(b) Application of resistance welding to fabrication of armored structures.

1. Thicknesses to which applicable.

2. Practicability of application on tempered plate.

3. Should additions be made to the Committee of representatives from spot welding firms.

(c) Production problems.

(d) Methods of inspection and inspection standards.

(e) Supply of electrode materials.

III. Repair of Armor Castings

(a) Minor defects which develop during final heat treatment.

(b) Defects which are uncovered during machining.

1. Report of experimental tests conducted at Watertown Arsenal.

IV. Tests Completed and in Progress.

(a) Discussion of reports distributed to subcommittee members.

[redacted]

(b) Welding tests in progress.

V. <u>Research and Development Program</u>.

(a) Discussion of problems.

(b) Facilities available.

(c) Fatigue testing of welds.

(d) Proposed research program.*

*It is not anticipated that time will allow discussion of the research program. However, it is suggested that you bring to the meeting copies of this program which appeared as an appendix to the agenda used at the last meeting and as an appendix in the minutes of that meeting.

[redacted]

FOURTH MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Place: Duquesne Club, Pittsburgh, Pa.

Date: 22 August 1941

Hour: 9:00 A.M., E.S.T.

I. Membership.

(a) New members.

II. Research and Development Program.

(a) Discussion of outline prepared by Research Program Subgroup.

1. Weldability of armor.
2. Methods of shock testing of welded joints.
3. Miscellaneous projects proposed.

(b) Allocation of specific problems.

III. Fabrication of Weldments.

(a) Comments on specification AXS-497.

(b) Production problems.

(c) Methods of inspection and inspection standards.

(d) Supply of electrode materials.

IV. Repair of Armor Castings.

(a) Report of investigation at Watertown Arsenal.

(b) Production problems.

(c) Comments on welding sections of cast armor specifications AXS-492 and AXS-493.

V. Discussion of Proposed Welding Data Sheet.

VI. Discussion of Reports Distributed Through Subcommittee.

[redacted]

AGENDA

FIRST PRELIMINARY MEETING

of

SUBCOMMITTEE FOR RESISTANCE WELDING

Place: Officers' Club, Watertown Arsenal, Watertown, Mass.
Date: 27 August 1941
Time: 10:00 A.M., E.D.S.T.

Anticipated Attendance

It is expected that representatives from the following organizations will attend:

Office, Chief of Ordnance
Aberdeen Proving Ground
Rock Island Arsenal
Wright Field (U. S. Army Air Corps)
Bureau of Ships (U. S. Navy)
Watertown Arsenal
Taylor-Winfield Corp.
Thompson-Gibb Electric Welding Co.
Federal Machine and Welder Co.
National Electric Welding Machines Co.
Progressive Welder Co.
Swift Electric Welder Co.

I. Objective

The work of this subcommittee is to be directed toward development of suitable resistance welding methods for manufacture of armored and other ordnance structures.

II. Organization

(a) Size and membership of subcommittee.
(b) Coordination of activities - Chairman.
(c) Release and distribution of confidential data.

III. Resistance Welding of Armor

(a) Methods of welding permissible.
(b) Limitations - composition, plate thickness, type of plate, and heat treatment.
(c) Type of joint desirable from both the fabrication and welding standpoint.
(d) Welding and testing facilities available.
(e) Problem proposed by Wright Field for aircraft armor.

[redacted]

IV. Co-operative Research and Development Program

It is suggested that representatives give consideration in advance and be prepared to discuss problems for inclusion in the Co-operative Research and Development Program.

Facilities which may be utilized for the prosecution of the work should also be considered.

V. Resistance Welding of Structural Alloy Steels

General discussion of ordnance manufacturing problems to which methods of resistance welding might be applied.

VI. Future Meetings

(a) General frequency of meetings.
(b) Time and place of next meeting.

[redacted]

FIFTH MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Place: Penn Athletic Club, Philadelphia, Pa.

Date: 24 October 1941

Hour: 9:30 A.M., E.S.T.

I. Membership.

(a) New members proposed.

1. Pullman Standard Car Co.

2. Air Reduction Sales Co.

3. Oxweld Corp., Chicago.

II. Research and Development Program.

(a) Report on Welding Data Sheet.

1. Discussion.

(b) Report of progress from Program Subgroup.

1. Tests of H and Y welded plates.

2. Fatigue tests at Rock Island Arsenal.

3. Weldability studies at Watertown Arsenal.

4. Development of substitute electrodes.

5. Extension of research projects listed under basic research program with special reference to design of joints, effect of internal stresses, and procedures.

III. Fabrication of Weldments.

(a) Report on revision of Specification AXS-407.

1. Discussion.

[redacted]

(b) Progress in fabrication since last meeting.

(c) Inspection problems.

IV. Repair of Castings

(a) Heat treatment after weld repair on surfaces to be machined and not to be machined.

V. Distribution of Data

(a) Reports distributed since last meeting.

1. Discussion.

[redacted]

SIXTH MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Place: Statler Hotel, Detroit, Michigan
Date: 7 January 1942
Hour: 9:00 A.M., E.S.T.

I. Membership

(a) Approval of Una Welding, Inc., and Alloy Rods Company

(b) Scope of membership

II. Specifications

(a) Discussion of revision of AXS-497

(b) Specification for machine welding

III. Fabrication of Weldments

(a) Experiences with Armor Fabrication since last meeting

(b) Production requirements

(c) Inspection methods

(d) Suitability of WAS-1

IV. Research and Development Program

(a) Report of Electrode Manufacturers' Subgroup

1. Outline of research program

2. Collection of electrode data applicable to armor welding

3. O.P.M. viewpoint on Electrode situation

(b) Report of Fabricator Research Program Subgroup

1. Results obtained on H and Y program

2. Weldability research at Rock Island and Watertown Arsenals

(c) Specific research projects which should be initiated

[redacted]

V. Ballistic Testing of Weldments

(a) Slug shock test

(b) Conservation of ammunition

VI. Distribution of Data

(a) Reports distributed

(b) Further interchange of information

[redacted]

SECOND MEETING

AGENDA

for

SUBCOMMITTEE FOR RESISTANCE WELDING

Place: Materiel Division, Wright Field, Dayton, Ohio

Date: 13 January 1942

Hour: 9:00 A.M., E.S.T.

I. Membership

(a) New members since last meeting.

II. Resistance Welding of Armor

(a) Results obtained on experimental program.

1. Face-hardened plate.

2. Homogeneous plate.

(b) Specific projects to be undertaken.

1. Tests of typical aircraft armor installations.

III. Application of Resistance Welding to Aircraft Structures

(a) Present use of resistance welding methods.

(b) Possible additional applications.

1. Suggested tests.

IV. Proposals for Laboratory Research

(a) Welding cycle vs. heat effect in spot welding.

(b) Size and spacing of spots vs. physical properties.

(c) Effect of preheating.

(d) Physical properties of flash welds.

[redacted]

SEVENTH MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Place: Statler Hotel, Detroit, Michigan

Date: Sunday, 1 March 1942 - 9:30 A.M.

I. Report of Subgroup Activities

(a) Electrode subgroup meetings.

(b) Fabricators' subgroup meetings.

(c) Flame cutting preparation of plates.

II. Electrode Situation

(a) Status of ferritic electrodes

III. Revisions of Specifications

IV. Armor Plate Developments

(a) Steels containing lower alloys.

V. Ballistic Test Results Summary

(a) Practices to be recommended.

VI. Radiographic Standards for Weld Soundness

[redacted]

EIGHTH MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Place: Hotel Statler, Detroit, Michigan

Date: Sunday, 21 June 1942, 9:30 A.M.

I. Status of Low Alloy Armor Compositions

II. Remarks on Alloy Situation of W.P.B. Representatives

III. Reports of Homogeneous Armor Fabricators Subgroup

IV. Report of Face-Hardened Armor Fabricators Subgroup

(a) Manual for welding of face-hardened armor

(b) Specification for welding of face-hardened armor

V. Report of Electrode Subgroup

(a) Ferritic electrode developments

VI. Report of Welding Supervisor for National Research Council

VII. Other Business

[redacted]

NINTH MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Place: Hotel Statler, Detroit, Michigan

Date: Sunday, 20 September 1942

Hour: 9:30 A.M., E. W. T.

I. Discussion of Low Alloy Armor Compositions

(a) Ballistic Tests on H Plates

II. Report on Alloy Situation by W.P.B. Representatives

III. Report of Homogeneous Armor Fabricators' Subgroup

(a) Tolerances on Dimensions and Flatness

(b) Procedures for Gas Cutting of Armor

(c) Repair of Processing Cracks in Plate

IV. Report of Face-Hardened Armor Fabricators' Subgroup

V. Report of Electrode Subgroup

VI. Report of Specification Subgroup

VII. Report of Resistance Welding Subgroup

(a) Chairman

VIII. Report of Aircraft Manufacturers' Subgroup

(a) Chairman

IX. Report of N.R.C. Supervisor of Welding Projects

X. Other Business

[redacted]

TENTH MEETING

AGENDA

for

SUBCOMMITTEE FOR WELDING OF ARMOR

Place: Bellevue-Stratford Hotel, Philadelphia, Pa.

Date: Sunday, 6 December 1942

Hour: 9:30 A.M., E.W.T.

I. Report on Alloy Situation (W.P.B.)

II. Report of Homogeneous Armor Fabricators' Group (Mr. McDowell)

III. Report of Face-Hardened Armor Fabricators' Group (Mr. Abbott)

IV. Report of Electrode Group (Lt. Randall)

V. Report of Specifications Group (Maj. Coombe)

VI. Report of Research Group (Lt. Col. Frye)

VII. Report of Resistance Welding Group (Mr. Cooper)

VIII. Report of Aircraft Armor Fabricators' Group (Maj. McInnes)

IX. Report of N.R.C. Supervisor of Welding Projects (Mr. Mikhalapov)

X. Report of Armor Liaison Group (Mr. Raymo)

XI. Other Business

(a) Next meeting

[redacted]

ELEVENTH MEETING

AGENDA

for

SUBCOMMITTEE ON WELDING OF ARMOR

Place: Hotel Cleveland, Cleveland, Ohio

Date: Saturday, 6 February 1943

Hour: 9:30 A.M., E.W.T.

I. Discussion of Alloy Situation (W.P.B.)

II. Report of Homogeneous Armor Fabricators' Group (Mr. McDowell)

III. Report of Face-Hardened Armor Fabricators' Group (Mr. Abbott)

IV. Report of Electrode Group (Lt. Randall)

V. Report of Aircraft Armor Fabricators' Group (Maj. McInnes)

VI. Report of Resistance Welding Group (Mr. Cooper)

VII. Report of Specifications Group (Maj. Coombe)

VIII. Report of Armor Liaison Group (Mr. Raymo)

IX. Report of N.R.C. Supervisor of Welding Projects (Mr. Mikhalapov)

X. Other Business

(a) Next Meeting

[redacted]

TWELFTH MEETING

AGENDA

for

SUBCOMMITTEE ON WELDING OF ARMOR

Place: Palmer House, Chicago, Illinois

Date: Saturday, 5 June 1943

Hour: 9:30 A.M., C.W.T.

I. Discussion of Alloy Situation (W.P.B.)

II. Report of Homogeneous Armor Fabricators' Group (Mr. McDowell)

III. Report of Face-Hardened Armor Fabricators' Group (Mr. Abbott)

IV. Report of Electrode Group (Lt. Randall)

V. Report of Aircraft Armor Fabricators' Group (Maj. McInnes)

VI. Report of Resistance Welding Group (Mr. Cooper)

VII. Report of Specifications Group (Maj. Coombe)

VIII. Report of Armor Liaison Group (Mr. Raymo)

IX. Report of N.R.C. Supervisor of Welding Projects (Mr. Mikhalapov)

X. Other Business

(a) Next Meeting

[redacted]

THIRTEENTH MEETING

AGENDA

for

SUBCOMMITTEE ON WELDING OF ARMOR

Place: Hotel Pennsylvania, New York City

Date: Thursday, 7 October 1943

Hour: 9:30 A.M., E.W.T.

I. Discussion of Alloy Situation (W.P.B.)

II. Report of Homogeneous Armor Fabricators' Group (Mr. McDowell)

III. Report of Face-Hardened Armor Fabricators' Group (Mr. Abbott)

IV. Report of Electrode Group (Capt. Randall)

V. Report of Aircraft Armor Fabricators' Group (Maj. McInnes)

VI. Report of Resistance Welding Group (Mr. Cooper)

VII. Report of Specifications Group (Maj. Coombe)

VIII. Report of Armor Liaison Group

IX. Report of N.R.C. Supervisor of Welding Projects (Mr. Mikhalapov)

X. Other Business

(a) Next Meeting

[redacted]

FOURTEENTH MEETING

AGENDA

for

SUBCOMMITTEE ON WELDING OF ARMOR

Place: Hotel Cleveland, Cleveland, Ohio

Date: Thursday, 11 May 1944

Hour: 10:00 A.M., E.W.T.

I. Discussion of Alloy Situation (W.P.B.)

II. Report of Homogeneous Armor Fabricators' Group (Mr. McDowell)

III. Report of Face-Hardened Armor Fabricators' Group (Mr. Abbott)

IV. Report of Electrode Group (Capt. Randall)

V. Report of Aircraft Armor Fabricators' Group (Maj. Dunlap)

VI. Report of Resistance Welding Group (Mr. Cooper)

VII. Report of Specifications Group (Maj. Coombe)

VIII. Report of Armor Liaison Group (Mr. Danse)

IX. Report of N.R.C. Supervisor of Welding Projects (Mr. Mikhalapov)

X. Other Business

(a) Next Meeting

[redacted]

FIFTEENTH MEETING

AGENDA

for

SUBCOMMITTEE ON WELDING OF ARMOR

Place: Hotel Cleveland, Cleveland, Ohio

Date: Thursday, 9 November 1944

Hour: 10:00 A.M., E.W.T.

I. Discussion of Alloy Situation (W.P.B.)

II. Report of Homogeneous Armor Fabricators' Group (Mr. McDowell)

III. Report of Face-Hardened Armor Fabricators' Group (Mr. Abbott)

IV. Report of Electrode Group (Capt. Randall)

V. Report of Aircraft Armor Fabricators' Group (Maj. Dunlap)

VI. Report of Resistance Welding Group (Mr. Cooper)

VII. Report of Armor Liaison Group (Mr. Danse)

VIII. Report of Research Group (Mr. Jennings)

IX. Report of N.R.C. Supervisor of Welding Projects (Mr. Mikhalapov)

X. Report on Weld Studies at Watertown Arsenal Laboratory

XI. Other Business

(a) Next Meeting

[redacted]

APPENDIX C

Meeting Attendance Record

[redacted]

ATTENDANCE SUMMARY TABLE

Subcommittee on Welding of Armor

GROUP	19 Dec. 1940	21 Jan. 1941	20 June 1941
Industrial - United States			
Tank Fabricators	8	7	6
Armor Producers	7	11	8
Core Wire Producers			
Electrode Manufacturers	4	5	6
Resistance Welding Equipment Mfrs.			
Aircraft Fabricators			
Industrial - Allied Countries			
Fabricators			
Individuals			
Government - United States			
Ordnance Department	13	14	13
Headquarters, Army Service Forces			
Navy Department	2	3	
Army Air Forces			
War Production Board			
National Research Council			
Government - Allied Countries			
Guests - Fabricators			
Electrode Manufacturers			
Allied Countries			
Liaison Group			
Armor Producers			
Resistance Welding Equipment Mfrs.			1
TOTAL ATTENDANCE	34	40	34

Aug. 1941	RWSC 27 Aug. 1941	24 Oct. 1941	7 Jan. 1942	RWSC 13 Jan. 1942	1 Mar. 1942	21 J
9		9	24		29	
12		7	7		10	
8		9	17		23	
	7			4		
18	8	16	21	7	24	
		Un. Sec. of War 1	Un. Sec. of War 1	Un. Sec. of War 1	Un. Sec. of War 1	
2		1		1		
	4			2		
					2	
		N.D.R.C. 2			N.D.R.C. 1	
		11	15	2	22	
		4	8		6	
2			2		1	
51	19	60	95	17	119	1[illegible]

1942	20 Sept. 1942	6 Dec. 1942	6 Feb. 1943	5 June 1943	7 Oct. 1943	Special 9 Feb. 194
	36	28	29	34	26	
	6	6	3	7	4	13
	5	7	6	5	4	
	32	26	28	22	17	
	6	7	5	6	6	
	14	9	7	8	6	3
			3	2	2	
	3	6	6	4	8	
	31	36	27	29	29	10
	1	2	1	1	1	
	2	6	7	7	5	
	6	3	2	3	4	4
	2	2	3	3	2	
	1	2	2	1	2	2
			3	2	3	
	5	6	5	2		
	2	7			3	
		5	6	3	5	
						1
	152	158	143	139	127	33

11 May 1944	9 Nov. 1944	Meetings Represented
33	25	15 Regular
5	3	15 Regular, 1 Special
7	5	7 Regular
27	20	15 Regular
2		8 Regular*
2	1	7 Regular, 1 Special
		3 Regular
7	5	7 Regular
22	20	17 Regular, 1 Special
1	1	12 Regular
4	4	13 Regular
2	2	9 Regular, 1 Special
2	Trans. Corps 1	8 Regular
1	4	10 Regular, 1 Special
2	3	5 Regular
2		
1	3	
120	97	

*Total of 9 meetings.

GENERAL NOTE:
Representatives of various groups attended meetings as guests prior to becoming regular members of the Subcommittee. Such representation is not included above.

[redacted]

LIST OF ATTENDANCE

Meetings of

SUBCOMMITTEE ON WELDING OF ARMOR

FIRST MEETING - 19 December 1940

WATERTOWN ARSENAL

INDUSTRIAL REPRESENTATIVES
(Fabricators)

American Car and Foundry Company	W. C. Osha
American Car and Foundry Company	G. W. L. Miller
A. O. Smith Corporation	W. E. Crawford
Baldwin Locomotive Company	A. J. Raymo
Diebold Safe & Lock Company	A. L. Abbott
Diebold Safe & Lock Company	W. C. Miller
Electromotive Corporation	J. H. Hruska
York Safe & Lock Company	W. B. Lair

(Plate Producers)

Carnegie-Illinois Steel Corporation	M. W. Lightner
Henry Disston & Sons, Inc.	R. Sibley
Republic Steel Corporation	E. C. Smith

(Casting Producers)

American Steel Foundries	H. J. Shiffli
Continental Roll & Steel Foundry Company	W. B. Libert
General Steel Castings Corporation	R. A. Gezelius
Lebanon Steel Foundry	G. F. Landgraf

(Electrode Manufacturers)

Arcos Corporation	R. D. Thomas, Jr.
Harnischfeger Corporation	W. F. Barron
Harnischfeger Corporation	W. V. Emery
Metal & Thermit Corporation	J. H. Deppeler

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Col. G. F. Jenks
Office, Chief of Ordnance	Maj. J. E. B. McInerney
Office, Chief of Ordnance	Maj. W. J. Crowe
Office, Chief of Ordnance	Maj. J. H. Frye
Office, Chief of Ordnance	Lt. L. Hainer

[redacted]

ATTENDANCE (cont.)

FIRST MEETING - 19 December 1940

(Ordnance Department, U. S. A.)

Aberdeen Proving Ground	H. J. Rouse
Watertown Arsenal	Brig. Gen. R. W. Case
Watertown Arsenal	Lt. Col. S. B. Ritchie
Watertown Arsenal	Lt. C. W. Lueders
Watertown Arsenal	Lt. N. A. Matthews
Watertown Arsenal	Dr. H. H. Lester
Watertown Arsenal	Dr. E. L. Reed
Watertown Arsenal	W. L. Warner

(U. S. Navy)

Bureau of Ships	Lt. C. R. Watts
Bureau of Ships	C. A. Loomis

[redacted]

LIST OF ATTENDANCE

SECOND MEETING - 21 January 1941

ABERDEEN PROVING GROUND

INDUSTRIAL REPRESENTATIVES
(Fabricators)

American Car & Foundry Company	G. W. L. Miller
American Car & Foundry Company	W. C. Osha
A. O. Smith Corporation	J. J. Chyle
Diebold Safe and Lock Company	A. L. Abbott
Diebold Safe and Lock Company	W. C. Miller
Electromotive Corporation	J. H. Hruska
York Safe and Lock Company	W. B. Lair

(Plate Producers)

Carnegie-Illinois Steel Corporation	C. J. Hunter
Carnegie-Illinois Steel Corporation	L. C. Bibber
Henry Disston & Sons, Inc.	R. Sibley
Republic Steel Corporation	H. Dittmar
Republic Steel Corporation	V. W. Whitmer
Republic Steel Corporation	I. Bower
Republic Steel Corporation	E. C. Smith

(Casting Producers)

American Steel Foundries	H. J. Shiffli
Continental Roll & Steel Foundry Company	W. B. Libert
General Steel Castings Corporation	R. A. Gezelius
Lebanon Steel Foundry	G. F. Landgraf

(Electrode Manufacturers)

Arcos Corporation	R. D. Thomas, Jr.
Harnischfeger Corporation	M. G. Sedam
Lincoln Electric Company	C. M. Taylor
Maurath, Inc.	G. A. Maurath
Metal & Thermit Corporation	J. H. Deppeler

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Col. G. F. Jenks
Office, Chief of Ordnance	Lt. Col. F. J. Atwood
Office, Chief of Ordnance	Maj. J. E. B. McInerney
Office, Chief of Ordnance	Lt. Hainer

[redacted]

ATTENDANCE (cont.)

SECOND MEETING - 21 January 1941

(Ordnance Department, U. S. A.)

Aberdeen Proving Ground	Lt. Col. J. K. Christmas
Aberdeen Proving Ground	Capt. J. C. Atkins
Aberdeen Proving Ground	Lt. W. B. Reed
Aberdeen Proving Ground	H. J. Rouse
Rock Island Arsenal	H. A. Curtis
Rock Island Arsenal	J. K. McDowell
Watertown Arsenal	Lt. Col. S. B. Ritchie
Watertown Arsenal	Lt. N. A. Matthews
Watertown Arsenal	W. L. Warner
Philadelphia Ordnance District	J. W. Magoun

(U. S. Navy)

Bureau of Ships	Lt. C. R. Watts
Bureau of Ships	A. G. Bissell
Bureau of Ships	C. R. Loomis

[redacted]

LIST OF ATTENDANCE

THIRD MEETING - 20 June 1941

HOTEL CLEVELAND, CLEVELAND, OHIO

INDUSTRIAL REPRESENTATIVES
(Fabricators)

American Car & Foundry Company	W. C. Osha
A. O. Smith Corporation	J. J. Chyle
Baldwin Locomotive Company	A. J. Raymo
Diebold Safe & Lock Company	A. L. Abbott
Diebold Safe & Lock Company	W. C. Miller
York Safe & Lock Company	W. B. Lair

(Plate Producers)

Carnegie-Illinois Steel Corporation	C. J. Hunter
Carnegie-Illinois Steel Corporation	L. C. Bibber
Republic Steel Corporation	I. Bower
Republic Steel Corporation	E. C. Smith
Republic Steel Corporation	V. W. Whitmer

(Casting Producers)

American Steel Foundries	H. J. Shiffli
General Steel Castings Corporation	R. A. Gezelius
Lebanon Steel Foundry	G. F. Landgraf

(Electrode Manufacturers)

Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Ewertz
Harnischfeger Corporation	W. V. Emery
Lincoln Electric Company	C. M. Taylor
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Col. G. F. Jenks
Office, Chief of Ordnance	Maj. J. E. McInerney
Office, Chief of Ordnance	E. Brooker
Aberdeen Proving Ground	Lt. W. B. Reed
Rock Island Arsenal	W. F. Schmitt
Rock Island Arsenal	J. K. McDowell
Watertown Arsenal	Lt. Col. S. B. Ritchie
Watertown Arsenal	Lt. N. A. Matthews
Watertown Arsenal	W. L. Warner

[redacted]

ATTENDANCE (cont.)

THIRD MEETING - 20 June 1941

(Ordnance Department, U. S. A.)

Chicago Ordnance District	Maj. E. P. Reed
Cleveland Ordnance District	M. Kirkhoff
Philadelphia Ordnance District	W. J. Jeffries
Pittsburgh Ordnance District	Maj. G. H. Knode

GUESTS

General Electric Company	R. T. Gillette

[redacted]

LIST OF ATTENDANCE

FOURTH MEETING - 22 August 1941

DUQUESNE CLUB, PITTSBURGH, PENNSYLVANIA

INDUSTRIAL REPRESENTATIVES
(Fabricators)

American Car & Foundry Company	G. L. Miller
American Car & Foundry Company	W. C. Osha
A. O. Smith Corporation	J. J. Chyle
Baldwin Locomotive Company	A. J. Raymo
Breeze Corporation, Inc.	R. S. Komarnitsky
Diebold Safe & Lock Company	A. L. Abbott
Diebold Safe & Lock Company	W. C. Miller
Electromotive Corporation	J. H. Hruska
York Safe & Lock Company	W. B. Lair

(Plate Producers)

Carnegie-Illinois Steel Corporation	L. C. Bibber
Carnegie-Illinois Steel Corporation	R. B. Cooney
Carnegie-Illinois Steel Corporation	M. W. Lightner
Carnegie-Illinois Steel Corporation	G. E. Knable
Republic Steel Corporation	E. S. Bowers
Republic Steel Corporation	H. Dittmar
Republic Steel Corporation	V. W. Whitmer

(Casting Producers)

American Steel Foundries	H. J. Shiffli
Continental Roll & Steel Foundry Company	W. B. Libert
Continental Roll & Steel Foundry Company	R. C. Heaslett
General Steel Castings Corporation	R. A. Gezelius
Lebanon Steel Foundry	G. F. Landgraf

(Electrode Manufacturers)

Arcos Corporation	R. D. Thomas, Jr.
Harnischfeger Corporation	W. V. Emery
Harnischfeger Corporation	M. G. Sedam
Lincoln Electric Company	C. M. Taylor
Lincoln Electric Company	B. J. Brugge
Lincoln Electric Company	M. Dodt
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler

[redacted]

ATTENDANCE (cont.)

FOURTH MEETING - 22 August 1941

DUQUESNE CLUB, PITTSBURGH, PENNSYLVANIA

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Col. G. F. Jenks
Office, Chief of Ordnance	Lt. Col. F. J. Atwood
Office, Chief of Ordnance	Maj. J. L. Atkins
Office, Chief of Ordnance	E. Brooker
Aberdeen Proving Ground	Lt. W. B. Reed
Aberdeen Proving Ground	H. J. Rouse
Rock Island Arsenal	W. F. Schmitt
Rock Island Arsenal	H. A. Curtis
Watertown Arsenal	Lt. Col. S. B. Ritchie
Watertown Arsenal	Lt. N. A. Matthews
Watertown Arsenal	Dr. E. L. Reed
Watertown Arsenal	W. L. Warner
Detroit Tank Arsenal	Lt. Col. H. W. Rohm
Chicago Ordnance District	Lt. Col. F. R. Zimmerman
Cleveland Ordnance District	Capt. C. W. Francis
Philadelphia Ordnance District	W. J. Jeffries
Pittsburgh Ordnance District	Lt. Col. J. L. Guion
Pittsburgh Ordnance District	Maj. G. H. Knode

(U. S. Navy)

Bureau of Ships	Lt. Comdr. J. C. Blake
Bureau of Ships	A. G. Bissell

GUESTS

British Ministry of Supply	H. W. G. Hignett
John Mohr	H. A. Laude

[redacted]

LIST OF ATTENDANCE

Meetings of

SUBCOMMITTEE ON RESISTANCE WELDING

FIRST MEETING - 27 August 1941

WATERTOWN ARSENAL

INDUSTRIAL REPRESENTATIVES
(Equipment Producers)

Federal Machine & Welder Company	B. L. Wise
General Electric Company	R. T. Gillette
National Electric Welding Machines Company	C. F. Kaunitz
Progressive Welder Company	L. M. Benkert
Swift Electric Welder Company	A. H. Lewis
Taylor-Winfield Corporation	J. H. Cooper
Thomson-Gibb Electric Welding Company	W. T. Ober

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Lt. W. C. Ohl
Office, Chief of Ordnance	E. Brooker
Ordnance Office, Wright Field	Capt. C. McInnes
Rock Island Arsenal	D. W. Marchant
Watertown Arsenal	Brig. Gen. R. W. Case
Watertown Arsenal	Lt. Col. S. B. Ritchie
Watertown Arsenal	Lt. N. A. Matthews
Watertown Arsenal	W. L. Warner

(Army Air Forces)

Wright Field	L. M. Keefe
Wright Field	J. A. Lawarre
Wright Field	C. J. Spere
Wright Field	R. C. White

[redacted]

LIST OF ATTENDANCE

FIFTH MEETING - 24 October 1941

PENN ATHLETIC CLUB, PHILADELPHIA, PENNA.

INDUSTRIAL REPRESENTATIVES
(Fabricators)

American Car & Foundry Company	G. L. Miller
American Car & Foundry Company	W. C. Osha
A. O. Smith Corporation	J. J. Chyle
Baldwin Locomotive Company	A. J. Raymo
Breeze Corporation	R. S. Komarnitsky
Detroit Tank Arsenal	N. J. Blake
Diebold Safe and Lock Company	A. L. Abbott
Electromotive Corporation	J. H. Hruska
York Safe & Lock Company	W. B. Lair

(Plate Producers)

Carnegie-Illinois Steel Corporation	L. C. Bibber
Henry Disston & Sons, Inc.	R. Sibley
Republic Steel Corporation	V. W. Whitmer

(Casting Producers)

American Steel Foundries	H. J. Shiffli
Continental Roll & Steel Foundry Company	R. C. Heaslett
General Steel Castings Corporation	R. A. Gezelius
Lebanon Steel Foundry	F. G. Landgraf

(Electrode Manufacturers)

Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Ewertz
Harnischfeger Corporation	W. V. Emery
Harnischfeger Corporation	M. G. Sedam
Lincoln Electric Company	B. J. Brugge
McKay Company	M. J. VanDreser
McKay Company	C. R. Carlen
Metal & Thermit Corporation	J. H. Deppeler
Reid-Avery Company	Dr. J. W. Miller

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Col. G. F. Jenks
Office, Chief of Ordnance	Maj. J. L. Atkins
Office, Chief of Ordnance	Lt. A. A. Parquette
Office, Chief of Ordnance	E. Brooker

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ATTENDANCE (cont.)

FIFTH MEETING - 24 October 1941

(Ordnance Department, U. S. A.)

Office, Under Secretary of War	F. X. Brown
Aberdeen Proving Ground	Lt. W. B. Reed
Rock Island Arsenal	P. C. Cunnick
Rock Island Arsenal	J. K. McDowell
Detroit Tank Arsenal	Lt. Col. H. W. Rehm
Watertown Arsenal	Lt. Col. S. B. Ritchie
Watertown Arsenal	Lt. N. A. Matthews
Watertown Arsenal	Dr. E. L. Reed
Watertown Arsenal	W. L. Warner
Chicago Ordnance District	Lt. A. L. Spurlock
Cleveland Ordnance District	Lt. R. W. James
Philadelphia Ordnance District	W. T. Jeffries
Pittsburgh Ordnance District	Maj. G. H. Knode

(U. S. Navy)

Bureau of Ships	Lt. Comdr. J. C. Blake

(N.D.R.C.)

Welding Committee	Dr. R. H. Aborn
Welding Committee	Prof. J. R. Stitt

GUESTS
(Fabricators)

Cadillac Motor Car Div., GMC	L. A. Danse
Cadillac Motor Car Div., GMC	F. M. Prucha
Eastman Kodak Company	A. C. Eckberg
Eastman Kodak Company	H. H. Brown
Fisher Body Div., GMC	E. Biederman
Ford Motor Company	G. Vennerholm
Graver Tank Manufacturing Company	F. C. Kardevan
Indiana Limestone Corporation	C. T. Penn
Lima Locomotive Works	M. Miller
Pullman Standard Car Manufacturing Company	W. Boese
Pullman Standard Car Manufacturing Company	W. Allan

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram, Jr.
Champion Rivet Company	R. Nick
Linde Air Products Company	F. B. Outcalt
Linde Air Products Company	J. Keir

[redacted]

LIST OF ATTENDANCE

SIXTH MEETING - 7 January 1942

HOTEL STATLER, DETROIT, MICHIGAN

INDUSTRIAL REPRESENTATIVES
(Fabricators)

American Car & Foundry Company	G. L. Miller
American Car & Foundry Company	W. C. Osha
American Locomotive Company	H. S. Swan
American Locomotive Company	C. B. Langsthoth
A. O. Smith Corporation	J. J. Chyle
Baldwin Locomotive Company	A. J. Raymo
Baldwin Locomotive Company	J. R. Burg
Breeze Corporation	R. S. Komarnitsky
Cadillac Motor Car Division, GMC	W. S. Jacobs
Detroit Tank Arsenal	N. J. Blake
Diebold Safe & Lock Company	A. L. Abbott
Diebold Safe & Lock Company	W. C. Miller
Diebold Safe & Lock Company	A. E. Frick
Fisher Body Div., GMC	E. Biederman
Fisher Body Div., GMC	R. J. Hansel
Ford Motor Company	G. Vennerholm
Ford Motor Company	C. A. Newman
Lima Locomotive Company	O. B. Schultz
Pressed Steel Car Mfg. Company	E. Murphy
Pressed Steel Car Mfg. Company	L. G. Burtenshaw
Pullman Std. Car Mfg. Company	B. J. Trautman
Pullman Std. Car Mfg. Company	A. M. Unger
Pullman Std. Car Mfg. Company	W. Boese
York Safe & Lock Company	W. B. Lair

(Plate Producers)

Carnegie-Illinois Steel Corporation	L. C. Bibber
Republic Steel Corporation	H. Dittmar
Republic Steel Corporation	V. W. Whitmer

(Casting Producers)

American Steel Foundries	H. J. Shiffli
Continental Roll and Steel Foundry Company	C. K. David
General Steel Castings Corporation	R. A. Gezelius
Lebanon Steel Foundry	H. D. Phillips

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram
Air Reduction Sales Company	M. Yock

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ATTENDANCE (cont.)

SIXTH MEETING - 7 January 1942

(Electrode Manufacturers)

Arcos Corporation	R. D. Thomas, Jr.
Champion Rivet Company	T. P. Champion
Champion Rivet Company	G. L. Willins
Crucible Steel Company	C. G. Merritt
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	W. V. Emery
Harnischfeger Corporation	M. H. Rutishauser
Harnischfeger Corporation	G. J. Friebel
Lincoln Electric Company	C. M. Taylor
Lincoln Electric Company	B. J. Brugge
Linde Air Products Company	F. G. Outcalt
Linde Air Products Company	R. F. Flood
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler
Metal & Thermit Corporation	D. L. Mathias

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Col. G. F. Jenks
Office, Chief of Ordnance	Maj. J. H. Frye
Office, Chief of Ordnance	Lt. R. M. Shepherd
Office, Chief of Ordnance	E. Brooker
Office, Under Secretary of War	Maj. D. P. Gaillard
Aberdeen Proving Ground	Lt. M. J. Zweig
Aberdeen Proving Ground	Lt. W. B. Reed
Aberdeen Proving Ground	Lt. W. C. Pless
Aberdeen Proving Ground	G. H. Oshry
Rock Island Arsenal	H. A. Curtis
Rock Island Arsenal	J. K. McDowell
Detroit Tank Engineering Office	Lt. R. Mauck
Watertown Arsenal	Maj. G. L. Cox
Watertown Arsenal	Lt. N. A. Matthews
Watertown Arsenal	W. L. Warner
Chicago Ordnance District	Lt. A. L. Spurlock
Cleveland Ordnance District	Lt. Henderson
Cleveland Ordnance District	J. L. Haibet
Detroit Ordnance District	Lt. Flag
Detroit Ordnance District	Lt. Muller
Philadelphia Ordnance District	W. J. Jeffries
Pittsburgh Ordnance District	Maj. G. H. Knode

GUESTS

British Purchasing Commission	I. K. MacGregor
British Purchasing Commission	M. Clipsham

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ATTENDANCE (cont.)

SIXTH MEETING - 7 January 1942

(Fabricators)

Babcock & Wilcox Company	E. F. Wilson
Chevrolet Motor Car Div., GMC	E. O. Mann
Chicago Bridge & Iron Company	H. C. Boardman
Federal Machine & Welder Company	B. L. Wise
Indiana Limestone Corporation	C. T. Penn
Kurtland & Baker Company	P. P. Moran
Libby-Owens-Ford Company	J. Crowley
Libby-Owens-Ford Company	M. Christjohn
Marmon-Herrington Company	B. J. Smith
Marmon-Herrington Company	L. N. Bowman
Ransome Concrete Machinery Company	L. Ransome
Richmond Engineering Co., Inc.	T. J. Starke
Richmond Engineering Co., Inc.	A. A. Adock
Richmond Engineering Co., Inc.	P. Hickman
Ternstedt Mfg. Div., GMC	R. Baker

(Electrode Manufacturers)

Alloy Rods Company	E. J. Brady
American Steel & Wire Company	S. R. Warwadell
American Steel & Wire Company	H. B. Maguire
Arcrods Corporation	J. H. Humberstone
Coast Metals, Inc.	M. L. Eder
Coast Metals, Inc.	R. M. Hannum
Page Steel & Wire Div., American Chain Co.	J. E. Skinner
Una Welding, Inc.	R. P. Tarbell

[redacted]

LIST OF ATTENDANCE

Meeting of

SUBCOMMITTEE ON RESISTANCE WELDING

SECOND MEETING - 13 January 1942

WRIGHT FIELD, DAYTON, OHIO

INDUSTRIAL REPRESENTATIVES
(Equipment Producers)

Federal Machine & Welder Company	B. L. Wise
General Electric Company	R. T. Gillette
National Electric Welding Machines Company	C. F. Kaunitz
Progressive Welder Company	L. M. Benkert

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Maj. H. A. Quinn
Office, Under Secretary of War	Lt. Col. W. R. Slaughter
Ordnance Office, Wright Field	Lt. Col. C. H. Morgan
Ordnance Office, Wright Field	Capt. C. McInnes
Rock Island Arsenal	D. W. Marchant
Watertown Arsenal	Major G. L. Cox
Watertown Arsenal	Lt. N. A. Matthews
Watertown Arsenal	W. L. Warner

(Army Air Forces)

Wright Field	J. A. Lawarre
Wright Field	B. C. White

(U. S. Navy)

Bureau of Aeronautics	Dr. I. N. Zavarine

GUESTS

National Aircraft Standards Committee	M. Turnbull
Carnegie-Illinois Steel Corporation	W. P. Braender

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LIST OF ATTENDANCE

SEVENTH MEETING - 1 March 1942

HOTEL STATLER, DETROIT, MICHIGAN

INDUSTRIAL REPRESENTATIVES
(Fabricators)

American Car & Foundry Company	G. L. Miller
American Locomotive Company	H. S. Swan
American Locomotive Company	J. B. Nolan
A. O. Smith Corporation	J. J. Chyle
A. O. Smith Corporation	F. E. Garriott
A. O. Smith Corporation	L. M. Keating
Baldwin Locomotive Company	A. J. Raymo
Baldwin Locomotive Company	T. Tomaino
Breeze Corporation	R. S. Komarnitsky
Cadillac Motor Car Div., GMC	L. A. Danse
Cadillac Motor Car Div., GMC	W. J. Jacobs
Cadillac Motor Car Div., GMC	W. D. Millington
Chevrolet Motor Car Div., GMC	G. Burrows
Chevrolet Motor Car Div., GMC	E. O. Mann
Chevrolet Motor Car Div., GMC	H. R. Nickerson
Chevrolet Motor Car Div., GMC	R. J. Waterbury
Detroit Tank Arsenal	N. J. Blake
Detroit Tank Arsenal	F. Iapalucci
Detroit Tank Arsenal	H. W. Lipke
Detroit Tank Arsenal	R. C. McCleary
Diebold Safe & Lock Company	A. L. Abbott
Fisher Tank Div., GMC	E. Biederman
Ford Motor Company	G. Vennerholm
Lima Locomotive Company	O. B. Schultz
Marmon-Herrington Company	B. J. Smith
Pressed Steel Car Mfg. Company	G. J. Lindroth
Pullman Standard Car Mfg. Company	W. Boese
Richmond Engineering Company, Inc.	P. Hickman
York Safe & Lock Company	W. B. Lair

(Plate Producers)

Carnegie-Illinois Steel Corporation	L. C. Bibber
Carnegie-Illinois Steel Corporation	R. B. Cooney
Carnegie-Illinois Steel Corporation	C. J. Hunter
Carnegie-Illinois Steel Corporation	G. W. Linkhauer
Carnegie-Illinois Steel Corporation	M. A. Thompson
Henry Disston & Sons, Inc.	R. Sibley
Republic Steel Corporation	V. W. Whitmer

(Casting Producers)

American Steel Foundries	H. J. Shiffli
Continental Roll and Steel Foundry Company	C. K. David
Lebanon Steel Foundry	G. H. Gingrich

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ATTENDANCE (cont.)

SEVENTH MEETING - 1 March 1942

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram, Jr.
Alloy Rods Company	G. M. Hohmann
Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Ewertz
Arcrods Corporation	E. B. Lutes
Champion Rivet Company	G. L. Willins
Coast Metals, Inc.	R. M. Hannum
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	W. V. Emery
Harnischfeger Corporation	M. H. Rutishauser
Lincoln Electric Company	B. J. Brugge
Linde Air Products Company	J. M. Keir
Linde Air Products Company	E. D. Morris
Linde Air Products Company	F. G. Outcalt
Maurath, Inc.	G. A. Maurath
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler
Metal & Thermit Corporation	D. L. Mathias
Page Steel & Wire Div., American Chain Co.	J. E. Skinner
Reid-Avery Company	C. H. Symington
Una Welding, Inc.	R. P. Tarbell
Westinghouse Electric & Mfg. Company	C. H. Jennings
Westinghouse Electric & Mfg. Company	E. H. Turnock

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Col. G. F. Jenks
Office, Chief of Ordnance	Maj. J. H. Frye
Office, Chief of Ordnance	E. Brooker
Office, Chief of Ordnance	C. Handova
Office, Chief of Ordnance	J. P. Klinker
Office, Under Secretary of War	S. A. Richardson
War Production Board	J. B. Smyly
War Production Board	H. L. Whitney
Aberdeen Proving Ground	Lt. M. J. Zweig
Aberdeen Proving Ground	Lt. W. B. Reed
Aberdeen Proving Ground	Lt. C. J. Yaeger
Aberdeen Proving Ground	C. H. Oshry
Rock Island Arsenal	J. K. McDowell
Rock Island Arsenal	D. H. Drury
Watertown Arsenal	Col. H. H. Zornig
Watertown Arsenal	Maj. G. L. Cox
Watertown Arsenal	Lt. N. A. Matthews
Watertown Arsenal	W. L. Warner
Watertown Arsenal	P. E. Woodward

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ATTENDANCE (cont.)

SEVENTH MEETING - 1 March 1942

(Ordnance Department, U. S. A.) (cont.)

Chicago Ordnance District	E. S. Hansen
Cincinnati Ordnance District	F. G. Brune
Cleveland Ordnance District	Capt. W. B. McClelland
Cleveland Ordnance District	Lt. M. K. Henderson
Detroit Ordnance District	D. H. Corey
Philadelphia Ordnance District	W. J. Jeffries
Philadelphia Ordnance District	D. E. Metzler
Pittsburgh Ordnance District	Maj. G. H. Knode

(N.D.R.C.)

Welding Committee	Prof. J. R. Stitt

GUESTS

Canada, Department of Munitions	Dr. C. W. Drury

(Fabricators)

Briggs Manufacturing Company	W. H. Pierson
Clark Grave Vault Company	R. C. Boehnice
Clark Grave Vault Company	A. F. Beck
Clark Grave Vault Company	H. W. Earnshaw
Clark Grave Vault Company	V. D. Worth
Deere & Company	C. H. Burgston
General Motors Corporation	W. L. Barth
General Motors Corporation	A. L. Boegehold
General Motors Corporation	B. Smith
General Motors Corporation	C. L. Hecker
International Harvester Company	C. D. Evans
International Harvester Company	T. W. Russell
Lehigh Structural Steel Company	J. M. Schaeffer
Midland Steel Products Company	W. E. Smith
Ternstedt Manufacturing Div., GMC	M. B. Evans, Jr.
Ternstedt Manufacturing Div., GMC	R. Baker
Ternstedt Manufacturing Div., GMC	C. F. Nixon
Ternstedt Manufacturing Div., GMC	C. F. Taylor
Whitehead & Kales	H. C. Neitzel
Yellow Truck & Coach Div., GMC	J. M. Diebold
Yellow Truck & Coach Div., GMC	W. P. Eddy, Jr.
York Ice Machine Company	E. J. Anderson

(Electrode Manufacturers)

American Steel & Wire Company	C. R. Horwedel

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ATTENDANCE (cont.)

SEVENTH MEETING - 1 March 1942

(Electrode Manufacturers) (cont.)

Hollup Corporation	C. D. Cavanagh
Hollup Corporation	R. E. Long
Hollup Corporation	R. P. Monroe
Oxweld Railroad Service Company	A. A. Barnard
General Electric Company	J. T. Catlett

[redacted]

LIST OF ATTENDANCE

EIGHTH MEETING - 21 June 1942

HOTEL STATLER, DETROIT, MICHIGAN

INDUSTRIAL REPRESENTATIVES
(Fabricators)

American Car & Foundry Company	G. L. Miller
American Car & Foundry Company	W. C. Osha
American Car & Foundry Company	H. C. Smith
American Locomotive Company	H. S. Swan
A. O. Smith Corporation	J. J. Chyle
Baldwin Locomotive Company	A. J. Raymo
Briggs Manufacturing Company	W. H. Pierson
Briggs Manufacturing Company	F. Kennedy
Cadillac Motor Car Div., GMC	L. A. Danse
Cadillac Motor Car Div., GMC	A. A. Weidman
Cadillac Motor Car Div., GMC	D. R. Kelker
Chevrolet Motor Car Div., GMC	E. O. Mann
Chevrolet Motor Car Div., GMC	R. J. Waterbury
Chevrolet Motor Car Div., GMC	A. G. Spencer
Deere & Company	C. H. Burgston
Detroit Tank Arsenal	N. J. Blake
Detroit Tank Arsenal	R. Iapalucci
Detroit Tank Arsenal	H. X. Reece
Detroit Tank Arsenal	C. C. Cross
Diebold Safe & Lock Company	A. L. Abbott
Diebold Safe & Lock Company	D. B. Tschudy
Fisher Tank Div., GMC	E. Biederman
Ford Motor Company	G. Vennerholm
Ilco Ordnance Company (Indiana Limestone)	C. B. Lansing
Ilco Ordnance Company (Indiana Limestone)	W. V. Emery
International Harvester Company	C. D. Evans
Lima Locomotive Company	J. W. Kelker
Lima Locomotive Company	E. E. Miller
Marmon-Herrington Company	B. J. Smith
Marmon-Herrington Company	L. N. Bowman
Midland Steel Products Company	E. Almdale
Midland Steel Products Company	W. E. Smith
Pullman Standard Car Manufacturing Company	B. J. Trautman
Pullman Standard Car Manufacturing Company	W. Boese
Pullman Standard Car Manufacturing Company	R. R. Baugh
Richmond Engineering Company, Inc.	P. Hickman
Ternstedt Manufacturing Div., GMC	T. P. Moran
Yellow Truck & Coach Div., GMC	J. M. Diebold
Yellow Truck & Coach Div., GMC	G. C. Farnsworth
Yellow Truck & Coach Div., GMC	C. Hecker
York Safe & Lock Company	W. B. Lair

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ATTENDANCE (cont.)

EIGHTH MEETING - 21 June 1942

(Plate Producers)

Carnegie-Illinois Steel Corporation	L. C. Bibber
Henry Disston & Sons, Inc.	R. Sibley
Republic Steel Corporation	V. W. Whitmer

(Casting Producers)

American Steel Foundries	H. J. Shiffli

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram, Jr.
Air Reduction Sales Company	A. H. Yock
Air Reduction Sales Company	C. D. Welcomb
Alloy Rods Company	E. J. Brady
Alloy Rods Company	C. H. Hohmann
Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Ewertz
Arcrods Corporation	J. H. Humberstone
Champion Rivet Company	R. R. Applegate
Coast Metals, Inc.	C. V. Foerster
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	M. H. Rutishauser
Harnischfeger Corporation	M. Sedam
Harnischfeger Corporation	G. J. Friebel
Lincoln Electric Company	B. J. Brugge
Lincoln Electric Company	C. H. Buckmaster
Lincoln Electric Company	W. R. Persons
Linde Air Products Company	F. G. Outcalt
Linde Air Products Company	E. D. Morris
Linde Air Products Company	J. M. Keir
Linde Air Products Company	N. G. Schreiner
Linde Air Products Company	W. B. Miller
Maurath, Inc.	G. A. Maurath
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler
Metal & Thermit Corporation	D. L. Mathias
Page Steel & Wire Div., American Chain Company	J. E. Skinner
Page Steel & Wire Div., American Chaim Company	W. H. Bloecher
Reid-Avery Company	Dr. J. W. Miller
Reid-Avery Company	C. H. Symington
A. O. Smith Corporation	F. E. Garriot
A. O. Smith Corporation	M. M. Millette
A. O. Smith Corporation	L. M. Keating
Una Welding, Inc.	P. J. Cella
Westinghouse Electric & Manufacturing Company	C. H. Jennings
Westinghouse Electric & Manufacturing Company	E. H. Turnock

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ATTENDANCE (cont.)

EIGHTH MEETING - 21 June 1942

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Lt. Col. J. H. Frye
Office, Chief of Ordnance	Capt. J. V. Coombe
Office, Chief of Ordnance	E. Brooker
Ordnance Office, Wright Field	Maj. C. McInnes
Aberdeen Proving Ground	Lt. W. C. Pless
Aberdeen Proving Ground	G. H. Oshry
Rock Island Arsenal	J. K. McDowell
Rock Island Arsenal	D. H. Drury
Tank Engineering Office-Detroit	Lt. A. F. Boucher
Watertown Arsenal	Col. H. H. Zornig
Watertown Arsenal	Capt. N. A. Matthews
Watertown Arsenal	W. L. Warner
Chicago Ordnance District	Lt. A. L. Spurlock
Chicago Ordnance District	G. T. Mann
Chicago Ordnance District	E. S. Hansen
Cincinnati Ordnance District	R. G. Fugate
Cleveland Ordnance District	E. J. Kerkhoff
Detroit Ordnance District	H. W. Holden
Philadelphia Ordnance District	W. J. Jeffries
Pittsburgh Ordnance District	Maj. G. H. Knode
Rochester Ordnance District	Capt. J. S. Ewing

(Headquarters, A. S. F.)

Steel Branch	Maj. S. A. Richardson

(U. S. Navy)

Philadelphia Navy Yard	Lt. Comdr. O. R. Sutherland
Bureau of Ships	Lt. Comdr. J. C. Blake
Bureau of Aeronautics	I. N. Zavarine

(War Production Board)

War Production Board	R. Wilson

(N. R. C.)

War Metallurgy Committee	Prof. J. R. Stitt
War Metallurgy Committee	G. S. Mikhalapov

GUESTS

Canada, Department of Munitions & Supply	Dr. C. W. Drury

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ATTENDANCE (cont.)

EIGHTH MEETING - 21 June 1942

GUESTS (cont.)

British Armor Mission	Dr. C. J. Dadswell
British Armor Mission	M. Brown
British Armor Mission	T. R. Middleton
British Armor Mission	E. R. Mort

(Fabricators)

Chain Bolt Company	E. G. Caspari
Fitzgibbons Boiler Company	D. E. Hawk
Fitzgibbons Boiler Company	R. A. Parnell
Fitzgibbons Boiler Company	E. Hoefer
Heil Company	C. Hart
Heil Company	H. French
Plymouth Motor Car Co., GMC	J. Burns
Plymouth Motor Car Co., GMC	A. Kanner
Plymouth Motor Car Co., GMC	W. H. Allen
Welding Committee, GMC	W. L. Barth
Reo Motors, Inc.	J. J. Miller
Reo Motors, Inc.	G. Stuart

(Plate Producers)

Standard Steel Spring Company	R. S. Komarnitsky
Standard Steel Spring Company	H. J. Zoog

(Electrode Manufacturers)

Oxweld Railroad Service Company	F. C. Hasse
Oxweld Railroad Service Company	A. A. Bernard
Union Carbide & Carbon Research Laboratory	E. A. Clapp

(Resistance Welding Subcommittee)

International Harvester Company	F. A. Lee
Glenn L. Martin Company	P. H. Merriman
Progressive Welder Company	L. M. Benkert
Carnegie-Illinois Steel Corporation	W. P. Braender

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LIST OF ATTENDANCE

NINTH MEETING - 20 September 1942

HOTEL STATLER, DETROIT, MICHIGAN

INDUSTRIAL REPRESENTATIVES
(Tank Fabricators)

American Locomotive Company	H. S. Swan
Baldwin Locomotive Company	A. J. Raymo
Cadillac Motor Car Div., GMC	L. A. Danse
Cadillac Motor Car Div., GMC	F. R. Kelker
Chain Belt Company	R. W. McPherson
Chevrolet Motor Car Div., GMC	E. O. Mann
Chevrolet Motor Car Div., GMC	A. G. Spencer
Clark Grave Vault Company	M. A. Beck
Clark Grave Vault Company	R. C. Boehnke
Clark Grave Vault Company	V. Worth
Detroit Tank Arsenal	N. J. Blake
Detroit Tank Arsenal	F. Iapalucci
Diebold Safe & Lock Company	A. L. Abbott
Fisher Tank Div., GMC	R. J. Heusel
Ford Motor Company	G. Vennerholm
Heil Company	C. Hart
Ilco Ordnance Company	C. B. Lansing
Ilco Ordnance Company	M. V. Emery
International Harvester Company	C. D. Evans
International Harvester Company	F. A. Lee
Lima Locomotive Company	O. B. Schultz
Lima Locomotive Company	W. A. Smith
Marmon-Herrington Company	B. J. Smith
Midland Steel Products Company	W. E. Smith
Pressed Steel Car Company	H. C. Bunnin
Pressed Steel Car Company	G. H. Lindroth
Pullman Standard Car Manufacturing Company	W. M. Bernhardt
Pullman Standard Car Manufacturing Company	W. Boese
Richmond Engineering Company, Inc.	P. Hickman
A. O. Smith Corporation	J. J. Chyle
Ternstedt Manufacturing Div., GMC	T. P. Moran
Ternstedt Manufacturing Div., GMC	O. G. Lorf
Yellow Truck & Coach Div., GMC	J. M. Diebold
Yellow Truck & Coach Div., GMC	W. P. Eddy, Jr.
Yellow Truck & Coach Div., GMC	C. L. Hecker
York Safe & Lock Company	W. B. Lair

(Plate Producers)

Carnegie-Illinois Steel Corporation	L. C. Bibber
Henry Disston & Sons, Inc.	R. Sibley

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ATTENDANCE (cont.)

NINTH MEETING - 20 September 1942

(Plate Producers) (cont.)

Republic Steel Corporation	T. R. Lichtenwalter
Standard Steel Spring Company	R. S. Komarnitsky
Standard Steel Spring Company	H. J. Zoog

(Casting Producers)

American Steel Foundries	H. J. Shiffli

(Electrode Core Wire Producers)

American Steel & Wire Company	C. R. Horwedel
Pittsburgh Steel Company	Dr. S. A. Braley
Rustless Iron & Steel Corporation	F. K. Bloom
Rustless Iron & Steel Corporation	W. B. Pierce
Universal-Cyclops Steel Corporation	J. O. Rinek

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram, Jr.
Air Reduction Sales Company	R. R. Woods
Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Ewertz
Arcrods Corporation	J. H. Humberstone
Arcrods Corporation	F. R. Strate
Champion Rivet Company	R. P. Nick
Coast Metals, Inc.	C. V. Foerster
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	G. J. Friebel
Harnischfeger Corporation	M. H. Rutishauser
Harnischfeger Corporation	M. G. Sedam
Lincoln Electric Company	B. J. Brugge
Linde Air Products Company	R. F. Flood
Linde Air Products Company	J. M. Keir
Linde Air Products Company	W. B. Miller
Linde Air Products Company	E. D. Morris
Linde Air Products Company	F. G. Outcalt
Linde Air Products Company	H. J. Roberts
Maurath, Inc.	G. A. Maurath
Maurath, Inc.	F. C. Whitmer
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler
Metal & Thermit Corporation	D. L. Mathias
Page Steel & Wire Div., American Chain Company	W. H. Bleecker
Page Steel & Wire Div., American Chain Company	W. G. Hoagland
Page Steel & Wire Div., American Chain Company	W. G. Rinehart
Reid-Avery Company	C. H. Symington
Reid-Avery Company	Dr. J. W. Miller

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ATTENDANCE (cont.)

NINTH MEETING - 20 September 1942

(Electrode Manufacturers)

A. O. Smith Corporation	M. M. Millette
Una Welding, Inc.	P. J. Cella
Westinghouse Electric & Manufacturing Company	C. H. Jennings

(Resistance Weld Equipment Manufacturers)

Federal Machine & Welder Company	B. L. Wise
General Electric Company	R. T. Gillette
Progressive Welder Company	L. M. Benkert
Progressive Welder Company	W. A. Stanley
Taylor-Winfield Corporation	J. H. Cooper
Thomson-Gibb Electric Welding Company	W. T. Ober

(Aircraft Fabricators)

Beech Aircraft Corporation	M. A. Barrett
Boeing Aircraft Company	C. P. Keeble
Brewster Aeronautical Corporation	C. C. Covucci
Brewster Aeronautical Corporation	T. Santore
Consolidated Aircraft Corporation	J. E. Madden
Curtiss-Wright Corporation	E. S. Jenkins
Curtiss-Wright Corporation	C. G. Trimbach
Douglas Aircraft Co., Inc.	H. A. Carhart
Douglas Aircraft Co., Inc.	H. E. North
Fleetwings, Inc.	F. E. Morris
Lockheed Aircraft Corporation	Dr. M. Nelles
Glenn L. Martin Company	P. H. Merriman
Vega Aircraft Corporation	E. R. Siefkin
Vought-Sikorsky Aircraft	E. A. Schneider

INDIVIDUALS

Ohio State University Research Foundation	Prof. J. R. Stitt
Naval Research Laboratory	C. E. Jackson
U. S. Bureau of Standards	G. A. Ellinger

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Lt. Col. J. H. Frye
Office, Chief of Ordnance	Maj. J. V. Coombe
Office, Chief of Ordnance	Lt. J. F. Randall
Office, Chief of Ordnance	E. L. Hollady
Ordnance Office, Wright Field	Maj. C. McInnes
Aberdeen Proving Ground	Lt. W. C. Pless
Aberdeen Proving Ground	G. H. Oshry

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ATTENDANCE (cont.)

NINTH MEETING - 20 September 1942

(Ordnance Department, U. S. A.) (cont.)

Rock Island Arsenal	D. H. Drury
Rock Island Arsenal	J. K. McDowell
Tank Engineering Office-Detroit	Lt. A. F. Boucher
Watertown Arsenal	Col. H. H. Zornig
Watertown Arsenal	Lt. Col. G. L. Cox
Watertown Arsenal	Capt. N. A. Matthews
Watertown Arsenal	W. L. Warner
Chicago Ordnance District	A. F. Banas
Chicago Ordnance District	E. S. Hansen
Chicago Ordnance District	G. T. Mann
Cincinnati Ordnance District	F. W. Schmitz
Cincinnati Ordnance District	R. G. Fugate
Cleveland Ordnance District	E. J. Kerkhoff
Detroit Ordnance District	A. P. Capitani
Detroit Ordnance District	W. D. Cattero
Detroit Ordnance District	A. Cotton
Detroit Ordnance District	M. Furlong
Detroit Ordnance District	H. B. Holden
Detroit Ordnance District	D. S. Levitt
Detroit Ordnance District	M. C. Wood
Detroit Ordnance District	R. G. Hill
Philadelphia Ordnance District	W. J. Jeffries
Pittsburgh Ordnance District	Maj. G. H. Knode
Rochester Ordnance District	H. R. Newcomb

(Headquarters, A. S. F.)

Steel Branch	Maj. S. A. Richardson

(U. S. Navy)

Bureau of Ships	A. G. Bissell
Bureau of Aeronautics	Dr. I. N. Zavarine

(Army Air Forces)

Wright Field	Lt. R. E. Bowman
Wright Field	Lt. R. H. Mott
Wright Field	Lt. W. C. Norton
Wright Field	W. P. Braender
Wright Field	C. J. Spere
Wright Field	B. C. White

(War Production Board

War Production Board	K. W. Ostrom
War Production Board	W. O. Sweeney

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ATTENDANCE (cont.)

NINTH MEETING - 20 September 1942

(N. R. C.)

War Metallurgy Committee	G. S. Mikhalapov

GUESTS

British Inspection Board	J. A. Balcom
British Inspection Board	E. S. Sunde

(Fabricators)

General American Transport Corporation	B. R. Smith
General Motors Corporation, Welding Committee	W. L. Barth
Dominion Foundries & Steel Ltd., Canada	F. H. Sherman
International Harvester Company, Canada	E. G. Sidebotham
Ontario Research Foundation, Canada	Dr. G. E. Willey

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LIST OF ATTENDANCE

TENTH MEETING - 6 DECEMBER 1942

BELLEVUE-STRATFORD HOTEL, PHILADELPHIA, PA.

INDUSTRIAL REPRESENTATIVES
(Tank Fabricators)

American Car & Foundry Company	W. C. Osha
American Locomotive Company	H. S. Swan
Baldwin Locomotive Company	A. J. Raymo
Cadillac Motor Car Div., GMC	L. A. Danse
Chevrolet Motor Car Div., GMC	E. O. Mann
Detroit Tank Arsenal	N. J. Blake
Diebold Safe & Lock Company	A. L. Abbott
Fisher Tank Div., GMC	E. Biederman
Heil Company	C. Hart
Ilco Ordnance Company	C. B. Lansing
International Harvester Company	F. A. Lee
International Harvester Company	C. D. Evans
Lima Locomotive Company	O. B. Schulz
Marmon-Herrington Company, Inc.	B. J. Smith
Marmon-Herrington Company, Inc.	G. H. Ford
Midland Steel Products Company	W. E. Smith
Plymouth Motor Car Company	C. C. Cross
Pressed Steel Car Company	C. K. Carter
Pullman Standard Car Manufacturing Company	B. J. Trautman
Pullman Standard Car Manufacturing Company	W. Boese
Richmond Engineering Company, Inc.	P. Hickman
A. O. Smith Corporation	J. J. Chyle
Ternstedt Manufacturing Div., GMC	T. P. Moran
Ternstedt Manufacturing Div., GMC	C. F. Nixon
Yellow Truck & Coach Div., GMC	J. M. Diebold
Yellow Truck & Coach Div., GMC	W. P. Eddy, Jr.
Yellow Truck & Coach Div., GMC	C. L. Hecker
York Safe & Lock Company	W. B. Lair

(Plate Producers)

Carnegie-Illinois Steel Corporation	L. C. Bibber
Republic Steel Corporation	V. W. Whitmer
Standard Steel Spring Company	R. S. Komarnitsky
Standard Steel Spring Company	D. H. E. Genter

(Casting Producers)

General Steel Castings Corporation	R. Gezelius
Lebanon Steel Foundry	J. W. Juppenlatz

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ATTENDANCE (cont.)

TENTH MEETING - 6 December 1942

(Electrode Core Wire Producers)

Allegheny Ludlum Steel Corporation	C. B. Boyne
Allegheny Ludlum Steel Corporation	J. R. Kumer
American Steel & Wire Company	C. R. Horwedel
Carpenter Steel Company	R. V. Mann
Pittsburgh Steel Company	Dr. S. A. Braley
Pittsburgh Steel Company	L. M. Voyer
Universal Cyclops Steel Corporation	J. O. Rinck

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram, Jr.
Alloy Rods Company	E. J. Brady
Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Swortz
Arcrods Corporation	F. R. Strate
Champion Rivet Company	R. P. Nick
Coast Metals, Inc.	C. V. Foerster
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	M. H. Rutishauser
Harnischfeger Corporation	M. G. Sedam
Hollup Corporation	R. E. Long
Hollup Corporation	J. O. Cavanagh
Linde Air Products Company	J. M. Keir
Linde Air Products Company	W. B. Miller
Lincoln Electric Company	B. J. Brugge
Maurath, Inc.	G. A. Maurath
Maurath, Inc.	F. C. Whitmer
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler
Page Steel & Wire Div., American Chain Company	J. E. Skinner
Page Steel & Wire Div., American Chain Company	W. G. Rinehart
Page Steel & Wire Div., American Chain Company	K. G. Huback
Reid-Avery Company	Dr. J. W. Miller
A. O. Smith Corporation	E. A. Steidl
Una Welding, Inc.	F. C. Knight
Westinghouse Electric & Manufacturing Company	C. H. Jennings

(Resistance Weld Equipment Manufacturers)

Federal Machine & Welder Company	B. L. Wise
General Electric Company	R. T. Gillette
National Electric Welding Machines Company	C. K. Kaunitz
Progressive Welder Company	M. Leathers
Progressive Welder Company	L. M. Benkert
Taylor Winfield Corporation	J. H. Cooper
Taylor Winfield Corporation	S. M. Humphrey

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ATTENDANCE (cont.)

TENTH MEETING - 6 December 1942

(Aircraft Fabricators)

Boeing Aircraft Corporation	C. P. Keeble
Consolidated Aircraft Corporation	J. E. Madden
Curtiss-Wright Corporation	E. S. Jenkins
Curtiss-Wright Corporation	C. G. Trimbach
Fleetwings, Inc.	F. M. Morris
Grumman Aircraft Engineering Corporation	W. F. Partridge
Grumman Aircraft Engineering Corporation	G. W. Benner
Lockheed Aircraft Corporation	Dr. M. Nelles
Glenn L. Martin Company	D. S. Elliott

INDIVIDUALS

Buick Motor Car Div., GMC	S. M. Spice
General Electric Company	R. W. Clark
National Bureau of Standards	G. A. Ellinger
Naval Research Laboratory	C. E. Jackson
Ohio State University	Prof. J. R. Stitt
Rensselaer Polytechnic Institute	Prof. W. F. Hess

GOVERNMENT REPRESENTATIVES (Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Lt. Col. J. H. Frye
Office, Chief of Ordnance	E. L. Hollady
Ordnance Office, Wright Field	Maj. C. McInnes
Aberdeen Proving Ground	Lt. W. C. Pless
Aberdeen Proving Ground	Lt. R. E. Beyer
Rock Island Arsenal	J. K. McDowell
Rock Island Arsenal	D. H. Drury
Tank-Automotive Center, Detroit	Maj. J. V. Coombe
Tank-Automotive Center, Detroit	Lt. J. F. Randall
Tank-Automotive Center, Detroit	Lt. W. B. Reed
Tank Engineering Office, Detroit	Lt. A. F. Boucher
Watertown Arsenal	Col. H. H. Zornig
Watertown Arsenal	W. L. Warner
Chicago Ordnance District	Lt. R. J. Dombrow
Chicago Ordnance District	G. T. Mann
Chicago Ordnance District	E. S. Hansen
Cincinnati Ordnance District	Lt. Col. G. M. Enos
Cincinnati Ordnance District	R. G. Fugate
Cleveland Ordnance District	S. A. Daniels
Detroit Ordnance District	Maj. E. Greenbaum
Detroit Ordnance District	Lt. D. D. Bowman
Detroit Ordnance District	A. Cotton

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ATTENDANCE (cont.)

TENTH MEETING - 6 December 1942

(Ordnance Department, U. S. A.) (cont.)

Philadelphia Ordnance District	Col. D. N. Hauseman
Philadelphia Ordnance District	Maj. R. G. Allen
Philadelphia Ordnance District	Lt. J. G. Jessen
Philadelphia Ordnance District	Lt. M. H. Patterson
Philadelphia Ordnance District	H. A. Daggers
Philadelphia Ordnance District	R. P. Farrington
Philadelphia Ordnance District	C. O. Guernsey
Philadelphia Ordnance District	W. T. Jeffries
Philadelphia Ordnance District	G. Kazansky
Philadelphia Ordnance District	H. B. LaRue
Philadelphia Ordnance District	W. M. Roberts
Pittsburgh Ordnance District	Maj. H. T. Garvis
Pittsburgh Ordnance District	Maj. G. H. Knode
Rochester Ordnance District	C. MacQueen

(Headquarters, A. S. F.)

Services of Supply	Lt. Col. S. A. Richardson
Services of Supply	Lt. Col. P. Llewelyn

(U. S. Navy)

Bureau of Ships	A. G. Bissell
Bureau of Ships	C. A. Loomis
Bureau of Aeronautics	Comdr. Flynn
Bureau of Aeronautics	Lt. (jg) W. J. Harris, Jr.
Philadelphia Navy Yard	Lt. Comdr. O. R. Sutherland
Naval Gun Factory	W. E. McKenzie

(Army Air Forces)

Wright Field	Capt. R. H. Mott
Wright Field	Lt. R. E. Bowman
Wright Field	B. C. White

(War Production Board)

Steel Branch	F. B. Foley
Weld Branch	H. R. Smith

(N. R. C.)

War Metallurgy Committee	G. S. Mikhalapov
War Metallurgy Committee	J. H. Humberstone

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ATTENDANCE (cont.)

TENTH MEETING - 6 December 1942

GUESTS
(Fabricators)

Welding Committee, GMC	W. L. Barth
New York Air Brake Company	E. S. Groves
Dominion Foundries & Steel, Ltd., Canada	F. Sherman, Jr.
General Motors of Canada	A. Granik
International Harvester Company, Canada	E. Sidebotham
Standard Steel Spring Company	I. K. McGregor

(Allied Countries)

Army Engineering Design Branch	C. W. Drury
Ontario Research Foundation	Dr. G. E. Willey
Ontario Research Foundation	J. McMulkin
British Ministry of Supply	H. W. G. Hignett
Inspection Board, United Kingdom & Canada	Col. H. G. Hoare
Inspection Board, United Kingdom & Canada	J. A. Balcom
Inspection Board, United Kingdom & Canada	L. W. Williams

(Weld Liaison)
(Rolled Armor Subcommittee)

American Car & Foundry Company	J. Steinmeyer
E. C. Atkins & Company	R. L. Fitzsimmons
Carnegie-Illinois Steel Corporation	C. J. Hunter
Great Lakes Steel Corporation	C. R. Schroder
Jones and Laughlin Steel Corporation	W. P. Getty

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LIST OF ATTENDANCE

ELEVENTH MEETING - 6 February 1943

HOTEL CLEVELAND, CLEVELAND, OHIO

INDUSTRIAL REPRESENTATIVES - UNITED STATES
(Tank Fabricators)

American Car & Foundry Company	W. C. Osha
American Locomotive Company	H. W. Swan
Baldwin Locomotive Company	A. J. Raymo
Cadillac Motor Car Div., GMC	L. A. Danse
Chain Belt Company	R. W. McPherson
Chevrolet Motor Car Div., GMC	G. Burrows
Detroit Tank Arsenal	N. J. Blake
Deere & Company	C. H. Burgston
Fisher Tank Div., GMC	E. Biederman
Heil Company	C. Hart
Ilco Ordnance Company	W. V. Emery
International Harvester Company	C. D. Evans
International Harvester Company	F. A. Lee
Joslyn Manufacturing & Supply Company	M. J. Barry
Joslyn Manufacturing & Supply Company	L. S. Fry
Lima Locomotive Company	O. B. Schultz
Lima Locomotive Company	W. A. Smith
Marmon-Herrington Company, Inc.	B. J. Smith
Midland Steel Products Company	W. E. Smith
New York Air Brake Company	J. F. Dobbs
New York Air Brake Company	J. C. McGrath
New York Air Brake Company	E. S. Groves
Pressed Steel Car Company	C. K. Carter
Pullman Standard Car Manufacturing Company	W. Boese
Richmond Engineering Company	P. Hickman
Ternstedt Manufacturing Div., GMC	T. P. Moran
Ternstedt Manufacturing Div., GMC	C. F. Nixon
Yellow Truck & Coach Div., GMC	J. M. Diebold
Yellow Truck & Coach Div., GMC	W. P. Eddy, Jr.

(Plate Producers)

Carnegie-Illinois Steel Corporation	W. P. Braender, Jr.
Carnegie-Illinois Steel Corporation	L. C. Bibber
Republic Steel Corporation	W. V. Whitmer

(Electrode Core Wire Producers)

Allegheny Ludlum Steel Corporation	J. K. Findley
American Steel & Wire Company	C. R. Horwedel
Carnegie-Illinois Steel Corporation	P. R. Wray
Carpenter Steel Company	P. B. Greenwald
Pittsburgh Steel Company	Dr. S. A. Braley
Rustless Iron & Steel Corporation	A. L. Feild

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ATTENDANCE (cont.)

ELEVENTH MEETING - 6 February 1943

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram, Jr.
Air Reduction Sales Company	A. H. Yock
Alloy Rods Company	E. J. Brady
Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Ewertz
Arcrods Corporation	F. R. Strate
Coast Metals, Inc.	C. V. Foerster
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	M. H. Rutishauser
Harnischfeger Corporation	M. G. Sedam
Hollup Corporation	J. O. Cavanagh
Hollup Corporation	R. E. Long
Lincoln Electric Company	B. J. Brugge
Linde Air Products Company	J. M. Keir
Linde Air Products Company	W. B. Miller
Maurath, Inc.	G. A. Maurath
Maurath, Inc.	F. C. Whitmer
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler
Metal & Thermit Corporation	D. L. Mathias
Page Steel & Wire Div., American Chain Company	J. E. Skinner
Page Steel & Wire Div., American Chain Company	W. G. Rinehart
Reid-Avery Company	Dr. J. W. Miller
Reid-Avery Company	C. H. Symington
A. O. Smith Corporation	M. M. Millotte
A. O. Smith Corporation	E. A. Steidl
Westinghouse Electric & Manufacturing Company	C. H. Jennings
Westinghouse Electric & Manufacturing Company	C. B. Stadum

(Resistance Weld Equipment Manufacturers)

Federal Machine & Welder Company	B. L. Wise
General Electric Company	R. T. Gillette
Progressive Welder Company	L. M. Benkert
Taylor-Winfield Corporation	J. H. Cooper
Thomson-Gibb Electric Welding Company	W. T. Ober

(Aircraft Fabricators)

Consolidated Aircraft Corporation	C. L. Hibert
Douglas Aircraft Company, Inc.	H. E. Shay
Fleetwings, Inc.	C. Grotke
Grumman Aircraft Engineering Corporation	G. W. Benner
Grumman Aircraft Engineering Corporation	W. F. Partridge
Vought-Sikorsky, Aircraft	E. A. Schneider
Vultee Aircraft, Inc.	G. O'Hare

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ATTENDANCE (cont.)

ELEVENTH MEETING - 6 February 1943

INDUSTRIAL REPRESENTATIVES - ALLIED COUNTRIES

Dominion Foundries & Steel, Ltd.	F. A. Sherman
General Motors of Canada	A. Granik
International Harvester Company	T. A. Rice

INDIVIDUALS

General Electric Company	R. W. Clark
Buick Motor Div., GMC	S. M. Spice
National Bureau of Standards	G. A. Ellinger
Naval Research Laboratory	C. E. Jackson
Ohio State University	Prof. J. R. Stitt
Rensselaer Polytechnic Institute	Prof. W. F. Hess

GOVERNMENT REPRESENTATIVES - UNITED STATES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Col. G. E. Knable
Office, Chief of Ordnance	Capt. M. MacFayden
Office, Chief of Ordnance	Capt. C. E. Drewes
Office, Chief of Ordnance	R. W. White
Ordnance Office, Wright Field	Maj. C. McInnes
Aberdeen Proving Ground	Lt. W. C. Pless
Aberdeen Proving Ground	Lt. F. J. Roth
Rock Island Arsenal	J. K. McDowell
Tank-Automotive Center, Detroit	Maj. J. V. Coombe
Tank-Automotive Center, Detroit	Lt. J. F. Randall
Tank-Automotive Center, Detroit	Lt. A. F. Boucher
Watertown Arsenal	Col. H. H. Zornig
Watertown Arsenal	W. L. Warner
Watertown Arsenal	P. E. Woodward
Chicago Ordnance District	E. S. Hansen
Chicago Ordnance District	M. P. Christensen
Cincinnati Ordnance District	Lt. Col. G. M. Enos
Cincinnati Ordnance District	R. Fugate
Cleveland Ordnance District	E. J. Kerkhoff
Cleveland Ordnance District	G. J. Rigot
Cleveland Ordnance District	S. A. Daniels
Cleveland Ordnance District	M. R. Glickman
Detroit Ordnance District	A. Cotton
Philadelphia Ordnance District	W. J. Jeffries
Pittsburgh Ordnance District	Maj. H. G. Garvis
Rochester Ordnance District	C. B. Frazer
Rochester Ordnance District	C. E. MacQueen

(Headquarters, Army Service Forces)

Services of Supply	Lt. Col. S. A. Richardson

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ATTENDANCE (cont.)

ELEVENTH MEETING - 6 February 1943

(U. S. Navy)

Bureau of Aeronautics	Lt. (jg) W. J. Harris, Jr.
Bureau of Aeronautics	B. A. Kornhauser
Bureau of Ships	C. A. Loomis
Naval Gun Factory	Lt. Comdr. W. S. Newton
Naval Gun Factory	W. E. McKenzie
Philadelphia Navy Yard	Lt. Comdr. O. R. Sutherland
Philadelphia Navy Yard	J. E. McCambridge

(Army Air Forces)

Wright Field	Lt. R. E. Bowman
Wright Field	B. C. White

(War Production Board)

Metals Conservation Branch	W. O. Sweeney
Weld Equipment Branch	O. L. Howland
Weld Equipment Branch	R. L. Hawkins

(National Research Council)

War Metallurgy Committee	G. S. Mikhalapov
War Metallurgy Committee	J. H. Humberstone

GOVERNMENT REPRESENTATIVES - ALLIED COUNTRIES

British Ministry of Supply	G. B. Findon
Inspection Board, United Kingdom and Canada	Col. H. G. Hoare
Inspection Board, United Kingdom and Canada	J. A. Balcom

GUESTS

Babcock & Wilcox Company	H. K. Kerr
Briggs Manufacturing Company	E. O. Courtmanche
Briggs Manufacturing Company	H. T. Platz
Combustion Engineering Company, Inc.	E. C. Chapman
U. S. Steel Corporation	Dr. E. S. Davenport

(Weld Liaison)
(Cast Armor Subcommittee)

Kelsey Hayes Wheel Corporation	T. Weidig

(Rolled Armor Subcommittee)

E. C. Atkins & Company	R. L. Fitzsimmons
Carnegie-Illinois Steel Corporation	C. J. Hunter

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ATTENDANCE (cont.)

ELEVENTH MEETING - 6 February 1943

(Rolled Armor Subcommittee) (cont.)

Great Lakes Steel Corporation	C. L. Altenburger
Jessop Steel Company	A. B. Cooper
Jones & Laughlin Steel Corporation	W. P. Getty

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LIST OF ATTENDANCE

TWELFTH MEETING - 5 June 1943

PALMER HOUSE, CHICAGO, ILLINOIS

INDUSTRIAL REPRESENTATIVES - UNITED STATES
(Tank Fabricators)

American Car & Foundry Company	W. C. Osha
American Locomotive Company	H. W. Swan
American Locomotive Company	E. J. Edwards
Baldwin Locomotive Company	A. J. Raymo
Breeze Corporation, Inc.	W. Semonyna
Breeze Corporation, Inc.	L. Hrusovsky
Briggs Manufacturing Company	E. O. Courtemauche
Cadillac Motor Car Div., GMC	L. A. Danse
Chain Belt Company	R. W. McPherson
Chevrolet Motor Car Div., GMC	E. O. Mann
Detroit Tank Arsenal	N. J. Blake
Deere & Company	C. H. Burgston
Diebold Safe & Lock Company	A. L. Abbott
Fisher Tank Div., GMC	E. Biederman
Fitzgibbons Boiler Works	J. D. Lannon
Fitzgibbons Boiler Works	E. Hoefer
Ford Motor Company	G. Vennerholm
Heil Company	C. Hart
Ilco Ordnance Company	C. B. Lansing
Ilco Ordnance Company	W. V. Emery
International Harvester Company	C. D. Evans
International Harvester Company	F. A. Lee
Lima Locomotive Company	O. B. Schultz
Marmon-Herrington Company, Inc.	B. J. Smith
Midland Steel Products Company	W. E. Smith
New York Air Brake Company	J. F. Dobbs
Plymouth Motor Car Company	C. C. Cross
Pressed Steel Car Company	C. K. Carter
Pullman Standard Car Manufacturing Company	W. Boese
Reo Motors, Inc.	J. J. Miller
Richmond Engineering Company	P. Hickman
Ternstedt Manufacturing Div., GMC	C. F. Nixon
Ternstedt Manufacturing Div., GMC	R. Baker
Yellow Truck & Coach Div., GMC	J. M. Diebold

(Plate Producers)

American Rolling Mill Company	A. E. Taylor
Carnegie-Illinois Steel Corporation	W. P. Braender, Jr.
Republic Steel Corporation	T. Lichtenwalter
Standard Steel Spring Company	R. S. Komarnitsky
Standard Steel Spring Company	D. H. E. Genter

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ATTENDANCE (cont.)

TWELFTH MEETING - 5 June 1943

(Casting Producers)

Continental Roll & Steel Foundry Company	W. B. Libert
General Steel Castings Corporation	R. A. Gezelius

(Electrode Core Wire Producers)

Allegheny Ludlum Steel Corporation	J. K. Findley
American Steel & Wire Company	C. T. Gilchrist
Pittsburgh Steel Company	Dr. S. A. Braley
Rustless Iron & Steel Corporation	A. L. Feild
Rustless Iron & Steel Corporation	W. B. Pierce

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram, Jr.
Air Reduction Sales Company	A. H. Yock
Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Ewertz
Arcrods Corporation	E. B. Lutes
Coast Metals, Inc.	C. V. Foerster
Crucible Steel Company	C. G. Merritt
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	M. G. Sedam
Linde Air Products Company	J. M. Keir
Linde Air Products Company	W. B. Miller
Maurath, Inc.	G. A. Maurath
Maurath, Inc.	F. C. Whitmer
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler
Metal & Thermit Corporation	D. L. Mathias
Page Steel & Wire Div., American Chain Co.	J. E. Skinner
Page Steel & Wire Div., American Chain Co.	W. G. Rinehart
Reid-Avery Company	Dr. J. W. Miller
A. O. Smith Corporation	Dr. K. Blanchard
Una Welding, Inc.	F. C. Knight
Westinghouse Electric & Manufacturing Company	C. H. Jennings

(Resistance Weld Equipment Manufacturers)

Federal Machine & Welder Company	B. L. Wise
General Electric Company	R. T. Gillette
National Electric Welding Machines Company	C. F. Kaunitz
Progressive Welder Company	L. M. Benkert
Progressive Welder Company	G. H. Schliecker
Taylor-Winfield Corporation	J. H. Cooper

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ATTENDANCE (cont.)

TWELFTH MEETING - 5 June 1943

(Aircraft Fabricators)

Beech Aircraft Corporation	H. Rawdon
Boeing Aircraft Company	C. P. Keeble
Douglas Aircraft Company	H. E. North
Grumman Aircraft Engineering Corporation	G. W. Benner
Grumman Aircraft Engineering Corporation	W. F. Partridge
Lockheed Aircraft Corporation	Dr. M. Nelles
Glenn L. Martin Company	L. Barrett
Vought-Sikorsky Aircraft	E. A. Schneider

INDUSTRIAL REPRESENTATIVES - ALLIED COUNTRIES

General Motors of Canada	A. Granik
International Harvester Company of Canada	T. A. Rice

INDIVIDUALS

Buick Motor Div., GMC	S. M. Spice
Naval Research Laboratory	C. E. Jackson
Rensselaer Polytechnic Institute	Prof. W. F. Hess
Taylor-Winfield Corporation	Col. G. F. Jenks

GOVERNMENT REPRESENTATIVES - UNITED STATES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Maj. C. E. Drewes
Office, Chief of Ordnance	Capt. M. MacFayden
Office, Chief of Ordnance	Capt. J. W. Campbell
Ordnance Office, Wright Field	Maj. C. McInnes
Ordnance Office, Wright Field	Maj. W. M. Dunlap
Aberdeen Proving Ground	Lt. W. C. Pless
Rock Island Arsenal	J. K. McDowell
Tank-Automotive Center, Detroit	Capt. J. F. Randall
Tank-Automotive Center, Detroit	Lt. A. F. Boucher
Tank-Automotive Center, Detroit	E. N. Weistman
Watertown Arsenal	Col. H. H. Zornig
Watertown Arsenal	W. L. Warner
Watertown Arsenal	P. E. Woodward
Chicago Ordnance District	Capt. S. C. Massari
Chicago Ordnance District	Capt. E. C. Bauer, Jr.
Chicago Ordnance District	C. L. Boucon
Chicago Ordnance District	E. S. Hansen
Chicago Ordnance District	L. W. Hollebrands
Chicago Ordnance District	W. D. Enders
Chicago Ordnance District	A. C. Mason
Cincinnati Ordnance District	Lt. Col. G. M. Enos
Cincinnati Ordnance District	R. Fugate
Cleveland Ordnance District	Capt. M. K. Henderson
Detroit Ordnance District	A. Cotton

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ATTENDANCE (cont.)

TWELFTH MEETING - 5 June 1943

(Ordnance Department, U. S. A.) (cont.)

Philadelphia Ordnance District	W. J. Jeffries
Pittsburgh Ordnance District	Maj. G. H. Knode
Pittsburgh Ordnance District	Maj. H. G. Garvis
Rochester Ordnance District	J. O. Cooney
Rochester Ordnance District	C. E. MacQueen

(Headquarters, Army Service Forces)

Services of Supply	Lt. Col. S. A. Richardson

(U. S. Navy)

Bureau of Aeronautics	Lt. W. J. Harris, Jr.
Bureau of Aeronautics	B. A. Kornhauser
Bureau of Ships	A. G. Bissell
Bureau of Ships	C. A. Loomis
Naval Gun Factory	Lt. Comdr. W. S. Newton
Naval Gun Factory	W. E. McKenzie
Philadelphia Navy Yard	Lt. Comdr. O. R. Sutherland

(Army Air Forces)

Wright Field	Capt. R. H. Mott
Wright Field	Lt. R. E. Bowman
Wright Field	B. C. White

(War Production Board)

Metal Conservation Branch	W. O. Sweeney
Weld Equipment Branch	O. L. Howland
Weld Equipment Branch	R. L. W. Hawkins

(National Research Council)

War Metallurgy Committee	J. H. Humberstone

GOVERNMENT REPRESENTATIVES - ALLIED COUNTRIES

Inspection Board, United Kingdom & Canada	Col. H. G. Hoare
Inspection Board, United Kingdom & Canada	J. A. Balcom

GUESTS

General Motors Corporation	W. L. Barth
Oxweld R.R. Equipment Company	A. A. Bernard

[redacted]

ATTENDANCE (cont.)

TWELFTH MEETING - 5 June 1943

(Weld Liaison)
(Rolled Armor Subcommittee)

American Car & Foundry Company	J. Steinmeyer
Jones & Laughlin Steel Corporation	W. P. Getty
Kelsey Hayes Wheel Corporation	T. A. Weidig

[redacted]

LIST OF ATTENDANCE

THIRTEENTH MEETING - 7 October 1943

HOTEL PENNSYLVANIA, NEW YORK, N. Y.

INDUSTRIAL REPRESENTATIVES - UNITED STATES
(Tank Fabricators)

American Locomotive Company	H. S. Swan
Baldwin Locomotive Company	A. J. Raymo
Breeze Corporation	W. Semenyna
Cadillac Motor Car Div., GMC	L. A. Danse
Cadillac Motor Car Div., GMC	C. E. McCormick
Chevrolet Motor Car Div., GMC	G. Burrows
Chevrolet Motor Car Div., GMC	E. O. Mann
Detroit Tank Arsenal	N. J. Blake
Fisher Tank Div., GMC	E. Biederman
Heil Company	C. Hart
Ilco Ordnance Company	C. B. Lansing
International Harvester Company	C. D. Evans
International Harvester Company	F. A. Lee
Lima Locomotive Company	B. G. Bishop
Lima Locomotive Company	O. B. Schultz
Midland Steel Products Company	W. E. Smith
New York Air Brake Company	J. F. Dobbs
Plymouth Motor Car Company	C. C. Cross
Pressed Steel Car Company	C. K. Carter
Pullman Std. Car Manufacturing Company	B. J. Trautman
Pullman Std. Car Manufacturing Company	W. Boese
A. O. Smith Corporation	J. J. Chyle
Ternstedt Manufacturing Div., GMC	R. Baker
Ternstedt Manufacturing Div., GMC	C. F. Nixon
U. S. Spring & Bumper Company	E. Brooker
Yellow Truck & Coach Div., GMC	J. M. Diebold

(Plate Producers)

American Rolling Mill Company	A. E. Taylor
Carnegie-Illinois Steel Corporation	L. C. Bibber
Republic Steel Corporation	V. W. Whitmer
Standard Steel Spring Company	R. S. Komarnitsky

(Electrode Core Wire Producers)

Allegheny Ludlum Steel Corporation	J. K. Findley
Allegheny Ludlum Steel Corporation	J. H. Kumer
American Steel & Wire Company	C. R. Horwedel
Pittsburgh Steel Company	Dr. S. A. Braley

[redacted]

ATTENDANCE (cont.)

THIRTEENTH MEETING - 7 October 1943

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram, Jr.
Alloy Rods Company	E. J. Brady
Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Ewertz
Coast Metals, Inc.	C. V. Foerster
Crucible Steel Company	C. G. Merritt
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	M. G. Sodam
Linde Air Products Company	W. B. Miller
Maurath, Inc.	G. A. Maurath
Maurath, Inc.	F. C. Whitmer
Metal & Thermit Corporation	J. H. Deppeler
Page Steel & Wire Div., American Chain Co.	J. E. Skinner
Page Steel & Wire Div., American Chain Co.	W. G. Rinehart
Reid-Avery Company	Dr. J. W. Miller
A.O. Smith Corporation	Dr. M. K. Blanchard
Una Welding, Inc.	F. C. Knight

(Resistance Weld Equipment Manufacturers)

Federal Machine & Welder Company	B. L. Wise
General Electric Company	R. T. Gillette
Progressive Welder Company	L. M. Benkert
Sciaky Brothers	M. Sciaky
Taylor-Winfield Corporation	J. H. Cooper
Thomson-Gibb Electric Welding Company	W. T. Ober

(Aircraft Fabricators)

Boeing Aircraft Company	C. P. Keeble
Fleetwings, Inc.	F. M. Morris
Grumman Aircraft Engineering Corporation	G. W. Benner
Grumman Aircraft Engineering Corporation	W. F. Partridge
Glenn L. Martin Company	W. G. Guy
Vought Sikorsky Aircraft	E. A. Schneider

INDUSTRIAL REPRESENTATIVES - ALLIED COUNTRIES

Dominion Foundries & Steel, Ltd.	F. A. Sherman
General Motors of Canada, Ltd.	A. Granik

INDIVIDUALS

Buick Motor Div., GMC	S. M. Spice
Combustion Engineering Company	E. C. Chapman
General Electric Company	R. W. Clark
Los Angeles, California	Col. G. F. Jenks
National Bureau of Standards	G. A. Ellinger

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ATTENDANCE (cont.)

THIRTEENTH MEETING - 7 October 1943

INDIVIDUALS (cont.)

Naval Research Laboratory	C. E. Jackson
Rensselaer Polytechnic Institute	Prof. W. F. Hess
U. S. Steel Corp. Research Laboratory	Dr. R. H. Aborn

GOVERNMENT REPRESENTATIVES - UNITED STATES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Col. G. E. Knable
Office, Chief of Ordnance	Maj. C. E. Drewes
Office, Chief of Ordnance	Capt. M. MacFayden
Office, Chief of Ordnance	Capt. J. W. Campbell
Office, Chief of Ordnance	Lt. L. J. Cogan
Ordnance Office, Wright Field	Lt. Col. C. McInnes
Ordnance Office, Wright Field	Maj. W. M. Dunlap
Aberdeen Proving Ground	Capt. H. C. Thoben
Aberdeen Proving Ground	Capt. W. C. Pless
Rock Island Arsenal	J. K. McDowell
Tank-Automotive Center, Detroit	Maj. D. C. Pippel
Tank-Automotive Center, Detroit	Capt. J. F. Randall
Tank-Automotive Center, Detroit	Capt. A. F. Boucher
Tank-Automotive Center, Detroit	Lt. J. J. Mott
Watertown Arsenal	Col. H. H. Zornig
Watertown Arsenal	W. L. Warner
Watertown Arsenal	P. E. Woodward
Chicago Ordnance District	C. Boucon
Chicago Ordnance District	A. E. Mason
Cincinnati Ordnance District	Lt. Col. G. M. Enos
Cincinnati Ordnance District	J. K. Murphy
Cincinnati Ordnance District	G. J. Rigot
Cincinnati Ordnance District	W. F. Baker
Detroit Ordnance District	A. Capitani
Philadelphia Ordnance District	W. J. Jeffries
Pittsburgh Ordnance District	Maj. G. H. Knode
Rochester Ordnance District	C. E. MacQueen
Rochester Ordnance District	P. F. Miner
Rochester Ordnance District	S. F. Certin

(Headquarters, Army Service Forces)

Services of Supply	Lt. Col. S. A. Richardson

(U. S. Navy)

Bureau of Aeronautics	Lt. (jg) R. H. Brown
Bureau of Ships	A. G. Bissell
Bureau of Ships	C. A. Loomis
Naval Gun Factory	W. E. McKenzie

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ATTENDANCE (cont.)

THIRTEENTH MEETING - 7 October 1943

(U. S. Navy) (cont.)

Philadelphia Navy Yard	Comdr. O. R. Sutherland

(Army Air Forces)

Wright Field	Capt. R. H. Mott
Wright Field	Capt. R. E. Bowman
Wright Field	Lt. J. Koss
Wright Field	B. C. White

(War Production Board)

Steel Branch	W. O. Sweeney
Equipment Branch	R. L. W. Hawkins

(National Research Council)

War Metallurgy Committee	G. S. Mikhalapov
War Metallurgy Committee	J. H. Humberstone

GOVERNMENT REPRESENTATIVES - ALLIED COUNTRIES

British Supply Mission	G. B. Findon
Inspection Board, United Kingdom & Canada	Col. H. G. Hoare
Inspection Board, United Kingdom & Canada	J. A. Balcom

GUESTS

British Supply Mission	E. P. S. Gardner
British Supply Mission	H. W. G. Hignett
Massey-Harris Company	C. E. Krause

(Weld Liaison)
(Rolled Armor Subcommittee)

Carnegie-Illinois Steel Corporation	C. J. Hunter
Jessop Steel Company	A. B. Cooper
Jones & Laughlin Steel Corporation	W. P. Getty

(Cast Armor Subcommittee)

Kelsey-Hayes Wheel Corporation	T. Weidig
Symington-Gould Corporation	W. J. Phillips

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LIST OF ATTENDANCE

SPECIAL MEETING - 9 February 1944

AIRCRAFT GROUPS

ROLLED ARMOR SUBCOMMITTEE

AND

WELDING OF ARMOR SUBCOMMITTEE

HOTEL MORRISON, CHICAGO, ILLINOIS

INDUSTRIAL REPRESENTATIVES
(Aircraft Fabricators)

Consolidated Vultee Aircraft Corporation	J. E. Madden
Douglas Aircraft Corporation	G. P. Harman
Glenn L. Martin Company	W. G. Guy

(Plate Producers)

Allegheny Ludlum Steel Corporation	L. F. Lippert
American Rolling Mill Company	A. E. Taylor
Jones & Laughlin Steel Corporation	W. P. Getty
Republic Steel Corporation	H. Dittmar
Youngstown Sheet & Tube Company	G. A. Reinhardt

(Plate Producers and Fabricators)

Breeze Corporation, Inc.	W. Semenyna
Detroit Michigan Stove Company	E. F. Gehrig
Diebold, Inc.	A. L. Abbott
Henry Disston & Sons	R. Sibley
Reading Hardware Corporation	R. J. Sullivan
Simonds Saw & Steel Company	H. A. Pavitt
U. S. Spring & Bumper Company	E. Brooker
Van Dorn Iron Works	E. W. Kronbach

GOVERNMENT REPRESENTATIVES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Capt. J. W. Campbell
Office, Chief of Ordnance	R. A. Webster
Office, Chief of Ordnance-Detroit	Capt. A. F. Boucher
Office, Chief of Ordnance-Detroit	Lt. E. S. Bower
Ordnance Office, Wright Field	Maj. W. M. Dunlap
Aberdeen Proving Ground	Capt. W. C. Pless
Watertown Arsenal	Col. H. H. Zornig
Watertown Arsenal	W. L. Warner

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ATTENDANCE (cont.)

SPECIAL MEETING - 9 February 1944

(Ordnance Department, U. S. A.) (cont.)

Cincinnati Ordnance District	R. G. Fugate
Los Angeles Proof Range	Capt. W. E. Langen

(Army Air Forces)

Wright Field	Maj. H. O. Green
Wright Field	Maj. R. H. Mott
Wright Field	Capt. R. E. Bowman
Wright Field	Lt. J. Koss

GUESTS

National Research Council	J. H. Humberstone
National Research Council	J. H. Zoog
National Research Council	Prof. W. F. Hess

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LIST OF ATTENDANCE

FOURTEENTH MEETING - 11 May 1944

HOTEL CLEVELAND, CLEVELAND, OHIO

INDUSTRIAL REPRESENTATIVES - UNITED STATES
(Tank Fabricators)

American Locomotive Company	J. P. Fransden
American Locomotive Company	H. S. Swan
Baldwin Locomotive Company	A. J. Raymo
Breeze Corporation	W. Semenyna
Breeze Corporation	L. Hrusovsky
Briggs Manufacturing Company	J. A. Hipfel
Cadillac Motor Car Div., GMC	C. E. McCormick
Cadillac Motor Car Div., GMC	J. Hassler
Chicago Vitreous Enamel Products Company	J. Tucker
Chicago Vitreous Enamel Products Company	E. E. Howe
Detroit Tank Arsenal	N. J. Blake
Detroit Tank Arsenal	E. C. Dodt
Detroit Tank Arsenal	F. Iapalucci
Diebold, Inc.	A. L. Abbott
Fisher Tank Div., GMC	E. Biederman
General American Transportation Corporation	H. C. Esgar
General American Transportation Corporation	B. R. Smith
General American Transportation Corporation	L. G. Bertenshaw
General Motors Corporation	L. A. Danse
Grand Rapids Stamping Div., Fisher Body	V. E. Holmes
Heil Company	C. Hart
International Harvester Company	C. D. Evans
International Harvester Company	F. A. Lee
Lima Locomotive Company	B. G. Bishop
Lima Locomotive Company	O. B. Schultz
Massey-Harris Company	A. W. Hubbard
Midland Steel Products Company	W. E. Smith
Plymouth Motor Car Company	C. C. Cross
Pressed Steel Car Company	M. Griffith
Ternstedt Manufacturing Div., GMC	R. Baker
Ternstedt Manufacturing Div., GMC	C. F. Nixon
Union Metal Manufacturing Company	E. Peters
Yellow Truck & Coach Div., GMC	J. M. Diebold

(Plate Producers)

American Rolling Mill Company	A. E. Taylor
Carnegie-Illinois Steel Corporation	L. C. Bibber
Republic Steel Corporation	T. Lichtenwalter
Standard Steel Spring Company	J. E. Shoemaker

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ATTENDANCE (cont.)

FOURTEENTH MEETING - 11 May 1944

(Casting Producers)

General Steel Castings Corporation	R. A. Gezelius

(Electrode Core Wire Producers)

Allegheny Ludlum Steel Corporation	J. K. Findley
Allegheny Ludlum Steel Corporation	J. H. Kuner
American Steel & Wire Company	H. H. Smith
American Steel & Wire Company	C. R. Horwedel
Pittsburgh Steel Company	Dr. S. A. Braley
Pittsburgh Steel Company	L. M. Voyer
Rustless Iron & Steel Corporation	F. K. Bloom

(Electrode Manufacturers)

Alloy Rods Company	M. G. Sedam
Arcos Corporation	R. D. Thomas, Jr.
Arcos Corporation	H. N. Ewertz
Arcrods Corporation	J. H. Humberstone
Champion Rivet Company	D. S. Connelly
Coast Metals, Inc.	C. V. Foerster
Crucible Steel Company	C. G. Merritt
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	M. H. Rutishauser
Harnischfeger Corporation	Dr. D. C. Smith
Harnischfeger Corporation	W. G. Rinehart
Hollup Corporation	J. O. Cavanagh
Linde Air Products Company	J. M. Keir
Linde Air Products Company	W. B. Miller
Maurath, Inc.	G. A. Maurath
Maurath, Inc.	F. C. Whitmer
Metal & Thermit Corporation	J. H. Deppeler
Metal & Thermit Corporation	D. L. Mathias
Page Steel & Wire Div., American Chain Company	F. A. Logue, Jr.
Page Steel & Wire Div., American Chain Company	J. E. Skinner
Page Steel & Wire Div., American Chain Company	J. L. Filbert
Reid-Avery Company	Dr. J. W. Miller
A. O. Smith Corporation	Dr. M. K. Blanchard
A. O. Smith Corporation	E. A. Steidl
Una Welding, Inc.	F. C. Knight
Una Welding, Inc.	G. W. Woods
Westinghouse Electric & Manufacturing Company	C. H. Jennings

(Resistance Weld Equipment Manufacturers)

General Electric Company	R. T. Gillette
Taylor-Winfield Corporation	J. H. Cooper

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ATTENDANCE (cont.)

FOURTEENTH MEETING - 11 May 1944

(Aircraft Fabricators)

Glenn L. Martin Company	W. G. Guy
Glenn L. Martin Company	L. Barrett

INDIVIDUALS

Buick Motor Div., GMC	S. M. Spice
National Bureau of Standards	G. A. Ellinger
Naval Research Laboratory	C. E. Jackson
North American Aviation Corporation	Col. G. F. Jenks
Ohio State University	Prof. J. R. Stitt
Rensselaer Polytechnic Institute	Prof. W. F. Hess
U. S. Steel Corporation, Research Laboratory	Dr. R. H. Aborn

GOVERNMENT REPRESENTATIVES - UNITED STATES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Capt. J. W. Campbell
Office, Chief of Ordnance-Detroit	Capt. J. F. Randall
Office, Chief of Ordnance-Detroit	Lt. J. F. Dillon
Office, Chief of Ordnance-Detroit	Lt. J. J. Mott
Ordnance Office, Wright Field	Maj. W. M. Dunlap
Aberdeen Proving Ground	Capt. W. C. Pless
Rock Island Arsenal	J. K. McDowell
Watertown Arsenal	Col. H. H. Zornig
Watertown Arsenal	W. L. Warner
Watertown Arsenal	P. E. Woodward
Chicago Ordnance District	Lt. H. J. Sprecken, Jr.
Chicago Ordnance District	W. A. Owens
Chicago Ordnance District	W. D. Enders
Chicago Ordnance District	A. E. Mason
Chicago Ordnance District	R. L. Welch
Cincinnati Ordnance District	Lt. Col. G. M. Enos
Cincinnati Ordnance District	C. Cuthbertson
Cleveland Ordnance District	E. Bonekamp
Detroit Ordnance District	A. P. Capitani
Philadelphia Ordnance District	W. J. Jeffries
Pittsburgh Ordnance District	Maj. G. H. Knode
Rochester Ordnance District	C. B. Frazer

(Headquarters, Army Service Forces)

Services of Supply	Lt. Col. S. A. Richardson

(U. S. Navy)

Bureau of Aeronautics	Lt. W. J. Harris, Jr.

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ATTENDANCE (cont.)

FOURTEENTH MEETING - 11 May 1944

(U. S. Navy) (cont.)

Bureau of Ships	A. G. Bissell
Naval Gun Factory	W. E. McKenzie
Philadelphia Navy Yard	Comdr. O. R. Sutherland

(Army Air Forces)

Wright Field	Lt. Col. H. W. MacDonald
Wright Field	Lt. J. Koss

(War Production Board)

Steel Branch	W. O. Sweeney
Equipment Branch	W. M. Haile

(National Research Council)

War Metallurgy Committee	H. J. Zoog

GOVERNMENT REPRESENTATIVES - ALLIED COUNTRIES

Inspection Board, United Kingdom & Canada	Col. H. G. Hoare
Inspection Board, United Kingdom & Canada	J. A. Balcom

GUESTS

Buick Motor Div., GMC	V. Hense
Ohio State University	M. M. Renter

(Weld Liaison)

Jones & Laughlin Steel Corporation	W. P. Getty

[redacted]

LIST OF ATTENDANCE

FIFTEENTH MEETING - 9 November 1944

HOTEL CLEVELAND, CLEVELAND, OHIO

INDUSTRIAL REPRESENTATIVES - UNITED STATES
(Tank Fabricators)

American Locomotive Company	H. S. Swan
Baldwin Locomotive Company	A. J. Raymo
Breeze Corporation	W. Semenyna
Breeze Corporation	J. Hrusovsky
Cadillac Motor Car Div., GMC	C. E. McCormick
Cadillac Motor Car Div., GMC	A. H. Smith
Chicago Vitreous Enamel Company	E. E. Howe
Chicago Vitreous Enamel Company	J. Tucker, Jr.
Detroit Tank Arsenal	N. J. Blake
Diebold, Inc.	A. L. Abbott
General American Transportation Corporation	H. C. Esgar
General American Transportation Corporation	B. R. Smith
General Motors Corporation	L. A. Danse
Heil Company	C. Hart
Joslyn Manufacturing & Supply Company	M. J. Barry
Lima Locomotive Company	O. B. Schultz
Lima Locomotive Company	B. G. Bishop
Massey-Harris Company	A. W. Hubbard
Midland Steel Products Company	W. E. Smith
Plymouth Motor Car Company	C. C. Cross
Pressed Steel Car Company	H. C. Bunnin
A. O. Smith Corporation	J. J. Chyle
Ternstedt Manufacturing Div., GMC	C. F. Nixon
Truck & Coach Div., GMC	J. M. Diebold
U. S. Spring & Bumper Company	E. Brooker

(Plate Producers)

American Rolling Mill Company	A. E. Taylor
Standard Steel Spring Company	J. E. Shoemaker

(Casting Producers)

General Steel Castings Corporation	R. A. Gezelius

(Electrode Core Wire Producers)

Allegheny Ludlum Steel Corporation	J. K. Findley
Allegheny Ludlum Steel Corporation	J. H. Huner
American Steel & Wire Company	H. H. Smith
Pittsburgh Steel Company	Dr. S. A. Braley
Rustless Iron & Steel Corporation	F. K. Bloom

[redacted]

ATTENDANCE (cont.)

FIFTEENTH MEETING - 9 November 1944

(Electrode Manufacturers)

Air Reduction Sales Company	H. L. Ingram, Jr.
Alloy Rods Company	M. G. Sedam
Arcrods Corporation	J. H. Humberstone
Coast Metals, Inc.	C. V. Foerster
Crucible Steel Company	C. G. Merritt
Crucible Steel Company	J. A. Goodford
Harnischfeger Corporation	Dr. D. C. Smith
Harnischfeger Corporation	W. G. Rinehart
Linde Air Products Company	J. M. Keir
Linde Air Products Company	W. B. Miller
Maurath, Inc.	F. C. Whitmer
McKay Company	M. J. VanDreser
Metal & Thermit Corporation	J. H. Deppeler
Metal & Thermit Corporation	D. L. Mathias
Page Steel & Wire Div., American Chain Company	J. L. Filbert
Page Steel & Wire Div., American Chain Company	F. A. Logue, Jr.
Reid-Avery Company	Dr. J. W. Miller
A. O. Smith Corporation	Dr. M. K. Blanchard
A. O. Smith Corporation	E. A. Stoidl
Westinghouse Electric & Manufacturing Company	C. H. Jennings

(Aircraft Fabricators)

Glenn L. Martin Company	W. G. Guy

INDIVIDUALS

Buick Motor Div., GMC	S. M. Spice
Naval Research Laboratory	C. E. Jackson
Ohio State University	Prof. J. R. Stitt
Rensselaer Polytechnic Institute	Prof. W. F. Hess
U. S. Steel Corporation, Research Laboratory	Dr. R. H. Aborn

GOVERNMENT REPRESENTATIVES - UNITED STATES
(Ordnance Department, U. S. A.)

Office, Chief of Ordnance	Maj. J. W. Campbell
Office, Chief of Ordnance	R. A. Webster
Office, Chief of Ordnance-Detroit	Capt. J. F. Randall
Office, Chief of Ordnance-Detroit	Capt. A. F. Boucher
Office, Chief of Ordnance-Detroit	Lt. J. J. Matt
Ordnance Office, Wright Field	Maj. W. M. Dunlap
Aberdeen Proving Ground, Research Center	Capt. W. C. Pless
Rock Island Arsenal	J. K. McDowell

[redacted]

ATTENDANCE (cont.)

FIFTEENTH MEETING - 9 November 1944

(Ordnance Department, U. S. A.) (cont.)

Watertown Arsenal	Maj. N. A. Matthews
Watertown Arsenal	Lt. S. A. Herres
Watertown Arsenal	W. L. Warner
Chicago Ordnance District	C. L. Boucon
Chicago Ordnance District	W. E. Enders
Cincinnati Ordnance District	Capt. L. D. Lowe
Cleveland Ordnance District	M. J. Principe
Cleveland Ordnance District	G. J. Rigot
Detroit Ordnance District	A. P. Capitani
Pittsburgh Ordnance District	Maj. G. H. Knode
Philadelphia Ordnance District	W. J. Jeffries
Rochester Ordnance District	C. B. Frazer

(Headquarters, Army Service Forces)

Services of Supply	Lt. Col. S. A. Richardson

(U. S. Navy)

Bureau of Aeronautics	Lt. W. J. Harris, Jr.
Naval Gun Factory	Comdr. R. H. Lambert
Naval Gun Factory	W. E. McKenzie
Bureau of Ships	Lt. L. B. Sykes

(Army Air Forces)

Wright Field	Capt. A. C. Schultz
Wright Field	Lt. J. Koss

(Transportation Corps)

Office, Chief of Transportation	Capt. M. L. Kahl

(National Research Council)

War Metallurgy Committee	G. S. Mikhalapov
War Metallurgy Committee	Dr. A. Muller
War Metallurgy Committee	H. W. Hiemke
War Metallurgy Committee	H. J. Zoog

GOVERNMENT REPRESENTATIVES - ALLIED COUNTRIES

British Supply Mission	G. B. Findon
Inspection Board, United Kingdom and Canada	Col. H. G. Hoare
Inspection Board, United Kingdom and Canada	J. A. Balcom

[redacted]

ATTENDANCE (cont.)

FIFTEENTH MEETING - 9 November 1944

GUESTS

(Weld Liaison)
(Rolled Armor Subcommittee)

Carnegie-Illinois Steel Corporation	C. J. Hunter
Jessop Steel Company	A. B. Cooper
Jones & Laughlin Steel Corporation	W. P. Getty

[redacted]

APPENDIX D

A Postscript by the Author

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When the preparation of this report was initiated, it was planned to present the story of the Subcommittee strictly in accordance with the actual record as shown by the official minutes, Subcommittee correspondence and publications included herein. It was intended that the reader of this report should obtain an understanding at first hand of the functioning of the Subcommittee and thereby have a better appreciation of what it did, how it did it, and what the significance of its activities was in the Ordnance production program for World War II. In accordance with this objective a minimum of introductory and editorial comment will be found up to this point and the reader may, therefore, wonder why a report of this sort was prepared without some comment from the author, who was quite closely associated with the affairs of the Subcommittee from its beginning.

The comments or criticisms of this appendix are presented neither in a spirit of apology nor in a spirit of censure. They are presented for the purpose of pointing out and emphasizing certain trends which may or may not have significance from the overall viewpoint of the National Defense Program of World War II. The reader must ultimately judge those matters by himself and make his own decisions from a study of the record. It is desired to suggest, however, that such judgment should not be made too hastily and certainly not until that part of the record of the World War II effort, with which the Subcommittee was concerned, has been studied and adequately analyzed. Therefore, this Subcommittee Record has been prepared as a small part of the overall story.

As has been pointed out in numerous discussions at Subcommittee meetings and in Part II of Appendix A, the Subcommittee was organized to act as an advisory body to the Ordnance Department and functioned as such through the cooperation of industry with the Ordnance Department. The Subcommittee was organized and sponsored by the Ordnance Department but had no authority to commit either Ordnance or industry to any specific policy or course of action. It served as a common meeting ground for discussion and argument of technical problems relating to fabrication of armor by welding. It was an agency for distribution of classified technical information and data concerned with such fabrication to those individuals and agencies which could best make use of it to expedite the war effort. In some cases policies were originated and courses of action planned as a result of these arguments and discussions but, before such agreements could become effective, official consideration and approval by the Ordnance Department were required.

This status of the Subcommittee was sometimes forgotten in the heat of argument as indicated by the minutes of some of the meetings. Ordnance policies and requirements were sometimes severely criticized, particularly during the period of preparation for offensive military action when "the heat was on" for all-out production of combat equipment. In this respect then, the Subcommittee functioned somewhat as a safety valve and a liaison agency between the Ordnance Department and industry, as far as the technical phases of fabrication of armor by welding were concerned. In these meetings, where Ordnance representatives and industrial representatives of the tank fabricators, armor producers, and welding electrode manufacturers could sit down around one conference table and each argue about his own difficulties, there was opportunity afforded for

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all parties concerned to know more about the troubles of the other fellow and obtain at first hand some idea of what could be and would be done to expedite the production of armor weldments. It is believed that participation in the activities of this Subcommittee was an education for all concerned.

The method of development of the Subcommittee organization is believed interesting. In the beginning representation was invited from three fields of industrial activity--the welding fabricators, armor plate manufacturers, and the welding electrode manufacturers--because it was regarded that these three groups would be most certainly involved in any major production of armor weldments by American industry. At first it was thought that token representation from these three industrial fields would be preferable in order to restrict the size of the Subcommittee to something workable. However, it soon became apparent that this principle would not be acceptable to industry, as each company which became involved in this problem of fabricating armor by welding became also interested in membership on the Subcommittee as a means of keeping up with the latest technical developments in welding of armor and Ordnance policies pertaining thereto. Also, the production organization of the Ordnance Department, being desirous of expanding the potential industrial capacity for producing armor weldments for combat materiel, encouraged industrial companies, who might be interested in engaging in such production, to affiliate with the Subcommittee for purposes of indoctrination and education. As a result, within a period of one year the membership had doubled and within two months after Pearl Harbor had doubled again. The Subcommittee reached its maximum size in late 1942 and from then on attendance at meetings gradually diminished.

After the first or organizational meeting of the Subcommittee in December 1940 additions to the membership, proposed either by Ordnance or industrial representatives, were made by vote in open meeting. In late 1941 the number of additions was becoming too great to allow the time for voting in open meeting, and so voting was conducted by correspondence. During early and middle 1942 the pressure for industrial productivity in fabricating armor weldments caused such rapid expansion of industrial interest in Subcommittee activities that additions to membership were made when proposed by canvassing the membership without the formality of voting.

In late 1942 a membership check-up was made as indicated in Part III, Appendix A, and a formal membership list as of 1 January 1943 was prepared similar to that shown in Part IV, Appendix A. From this period on memberhip on the Subcommittee was obtained by appointment with approval of Office, Chief of Ordnance. Each industrial company was limited to not more than two members as indicated in Part II, Appendix A. Several prolonged arguments by correspondence occurred between the Chairman and certain industrial company managements regarding this limitation to two members. One such example is given in Part I-b of Appendix A. In all of these instances the decision of the Subcommittee Chairman was never reversed by the Office, Chief of Ordnance.

As indicated previously, it was at first considered desirable to limit the size of the Subcommittee to a token representative working body but when the scope of the war production effort began to increase to all-out proportions this thought had to be abandoned and the Subcommittee increased in size by leaps and bounds. After the first two or three meetings, it was decided that

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a small working group should be activated to plan and coordinate some of the many suggested researches, which had been proposed by discussions at the meetings. This was accomplished at the third meeting of the Subcommittee on 20 June 1941 and resulted in the activation of the Research Program Subgroup, consisting of representatives of welding fabricators then on the Subcommittee. This Subgroup later became the Homogeneous Armor Fabricators' Group but in the initial stages was concerned primarily with development of test data on performance of welds in armor and suitability of available welding materials for welding armor.

By the fifth meeting in October 1941 the representation of the electrode manufacturing industry on the Subcommittee had grown considerably and it was decided that the problem of development of electrodes for welding armor had become of such importance as to warrant the attention of a special group, so the Electrode Group was activated. By this arrangement of working groups on special phases of the welding of armor problem it was felt that the Subcommittee meetings could be freed from much of the specialized discussion by interested groups and more attention could be given to the broader aspects of the problem of welding armor. Also it was felt that the Groups could, because of their smaller size and specialized membership, make faster progress in solving the special problems in their particular field and could meet independently of the Subcommittee itself for discussion of their specialized problems, thus facilitating exchange of information.

Up to the beginning of the second quarter of 1942 the aircraft fabricating industry and the resistance welding industry were not represented on the Subcommittee. During the summer of 1941 a Subcommittee on Resistance Welding had been formed but progress in the development and application of resistance welding methods for fabrication of armor had been very small because of the recognized limitations in the use of this process for armored vehicles. At the start it was thought that this process would be of greatest interest to aircraft fabricators because of the gauges of armor involved in aircraft construction. The heavy gauges of armor involved in tank fabrication appeared to exclude the use of resistance welding. Actually, the aircraft fabricators eventually became more interested in metal-arc welding for armor plate fabrication.

Therefore, in order to stimulate interest in and facilitate the use of armor weldments for combat aircraft and possible applications of resistance welding to tank fabrication the Subcommittee on Resistance Welding was merged with the Subcommittee on Welding of Armor in the second quarter of 1942 and the aircraft fabricating industry was invited to membership on the Subcommittee at the same time. This addition to the Subcommittee resulted in the activation of a Resistance Welding Group and an Aircraft Fabricators' Group at the meeting of 20 September 1942.

At this meeting a Specifications Group and a Research Group were also activated making a total of seven (7) Groups of the Subcommittee as follows:

Homogeneous Armor Fabricators' Group
Face-Hardened Armor Fabricators' Group
Aircraft Armor Fabricators' Group (Eastern and Western Division)

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Electrode Manufacturers' Group
Resistance Welding Group
Specifications Group
Research Group

The Face-Hardened Armor Fabricators' Group had been activated at the meeting in March 1942, when the Research Program Subgroup became designated at the Homogeneous Armor Fabricators' Group. By the end of 1942 an Armor Liaison Group had been activated to maintain contact with the activities of the armor producers so that the problems of the fabricators with respect to base metal could be presented to the makers of plate and castings and the problems of armor production could also be better understood by the welding fabricators. Similar liaison groups were designated from the Subcommittees on Rolled and Cast Armor.

Members of these groups received notices of all Subcommittee meetings and were privileged to attend as guests but did not receive the minutes or other Subcommittee publications. This system of organization is explained in Part II of Appendix A.

With reference to development of ballistic testing methods at Aberdeen Proving Ground the reader will note from the minutes of the meetings in January and March 1942 that the so-called "rubber yardstick" was a popular subject of argument and criticism by industrial representatives. Even at some of the later meetings references to this subject were made.

The difficulties involved in standardizing a ballistic test as a "go" and "no go" proposition can be better understood if the "conditions of the times" at that period can be realized. The armor compositions and requirements were in a state of change due to the alloy situation. Many compositions were being tested. Welding procedures for test plates were not standardized. Projectiles were in process of development and because of no previous peacetime production of armor weldments a background of experience with ballistic performance of welds in armor was lacking and, therefore, standardization of the test at this time was not feasible. Representatives of Aberdeen Proving Ground and Office, Chief of Ordnance "took it on the chin" in many of these arguments but it is believed that generally they handled the situation very well as shown by the extracts from the minutes.

The lesson which may be gained from this situation points out the need for keeping up ordnance development and testing activities in order to maintain an adequate background of up-to-date experience upon which adequate decisions can be based with some degree of reliability in any future national emergency.

Welding was a new and untried process for fabricating armor at the start of hostilities on 7 December 1941, but within six months industry was producing welded tanks, not perfect perhaps from the welding standpoint, but nevertheless effective in combat. The welded design was possibly not the main factor in this effectiveness but was an important contributing factor and sufficiently so that later designs all involved welding in some form.

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The problem of standardization of electrodes for welding armor was the subject of many hot arguments in the discussions of the Subcommittee and the Electrode Group. In the early days of the Subcommittee, the 25/20 stainless steel electrode was the only available commercial product for welding of armor. After the beginning of hostilities the shortage of the alloys--nickel and chrome--indicated the desirability of reducing, if possible, the amount of alloy required in the electrodes for welding armor and ways and means to that end were sought by all facilities concerned. This search eventually resulted in the development of the manganese and molybdenum modified types of 18/8 electrode for the welding of armor. Certain types of low alloy ferritic electrodes (NRC-2A) were also developed for this purpose but limitations as to the use of this type of electrode prevented general adoption and the majority of armor welding was performed with the modified 18/8 type of electrode.

The problem of standardization of the stainless steel electrode classifications was complicated by the fact that each electrode producer had his own special core wire composition and coating. This situation hampered mass production of steel for core wire and also necessitated that each armor fabricator must qualify his welding procedures with each brand of electrode he desired to use. This qualification became a costly and time-consuming proposition both for the fabricators and the Ordnance Department, since a great amount of duplication of testing was required.

As a result there was much agitation for an Ordnance Specification for stainless steel electrodes for welding armor. The fabricators were loudest in this agitation but the electrode producers generally refrained from commiting themselves very strongly on the subject. For a time the Ordnance Department resisted this agitation on the grounds that it was industry's responsibility, but eventually it was recognized that Ordnance would have to develop a specification in order to standardize classifications of electrodes for welding armor and that such standardization might simplify the problem of procedure qualification by the fabricators. This also would lighten the burden of ballistic testing on the facilities of Aberdeen Proving Ground.

With the advice and assistance of the Electrode Group, Specification AXS-886 was finally developed and, with the advent of this specification, one of the most persistent gripes of the fabricators disappeared. With the development of approved lists of brands under this specification, it now became possible for a fabricator to qualify a welding procedure using one approved brand in a particular classification and be then automatically qualified with all other brands approved under AXS-886 for the same classification.

In this process of standardization and development of Ordnance Specification AXS-886 two compositions of core wire were standardized by agreement between the War Production Board and the Electrode Producers and producers of the core wire. This was a major accomplishment since, as has already been mentioned, each electrode producer had his own "pet" core wire composition and coating. Also the strong commercial, competitive attitude of the electrode manufacturers hindered this standardization to some extent until the War Production Board and Steel Industry literally laid down the law for standardization of core wire composition in order to conserve the alloy stock pile. The shortage of molybdenum forced the use of the manganese modification for the majority of the armor welding.

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As this is written the armed forces of the Allied Nations have achieved their objective, destruction of the armed forces of the Axis Powers, and the need for the Subcommittee activities no longer exists. The people of America should rejoice that this is so and while so rejoicing might remember that the activity of this Subcommittee illustrates the practical working of a fundamental American principle, namely, that the solution of certain common problems can be quite effectively realized if all interested parties can have the opportunity, and will take advantage of it with constructive intent, to express their views in open meeting to discuss their mutual problems, and will actively support a majority agreement for the common good of all.

Here was a situation in which American industry was given a production job to do on a product with the welding problems of which neither it nor Ordnance had had previous experience. By co-operative effort through the technical activities of the Subcommittee and associated facilities these welding problems were worked out to such an extent that the production job was made possible. How different the outcome might have been had the Ordnance Department taken a dictatorial stand and arbitrarily issued orders instead of inviting the co-operation of industry in the solution of the technical problems of fabricating armor by welding through the agency of this Subcommittee and others.

In conclusion, it is considered proper to recognize the valuable assistance rendered by the various Group Chairmen in conducting the work of the Subcommittee. This involved arranging for and conducting meetings of their respective Groups and preparing minutes of those meetings for record. Without such assistance and co-operation successful conduct of the affairs of the Subcommittee would have been exceedingly difficult, if not impossible.

The following served as Chairmen, for certain periods, of their respective Groups:

Group	Chairman	Affiliation
Homogeneous Armor Fabricators'	W. F. Schmitt	Rock Island Arsenal
Homogeneous Armor Fabricators'	J. K. McDowell	Rock Island Arsenal
Electrode Manufacturers'	E. Brooker	OCO-Washington
Electrode Manufacturers'	Capt. J. F. Randall	OCO-Detroit
Face-Hardened Armor Fabricators'	A. L. Abbott	Diebold, Inc.
Resistance Welding	J. H. Cooper	Taylor-Winfield Corp.
Aircraft Armor Fabricators'		
Eastern Division	Lt. Col. C. McInnes	O.A.S.-Wright Field
Eastern Division	Maj. W. M. Dunlap	O.A.S.-Wright Field
Western Division	H. E. North	Douglas Aircraft Co.
Specifications	Maj. J. V. Coombe	OCO-Detroit
Research	Col. G. E. Knable	OCO-Washington
Research	C. H. Jennings	Westinghouse Mfg. Co.
Armor Liaison	A. J. Raymo	Baldwin Locomotive Co.
Armor Liaison	L. A. Danse	General Motors Corp.

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Directing the organization and management of Subcommittee affairs as Chairman were the following in succession:

Lt. Col. S. B. Ritchie	19 December 1940 to 7 December 1941
Major G. L. Cox	December 1941 to March 1942
Col. H. H. Zornig	March 1942 to September 1944
Lt. Col. N. A. Matthews	September 1944 to March 1946

William L. Warner

William L. Warner
Senior Welding Engineer
Secretary of the Subcommittee