WATERTOWN ARSENAL LABORATORY

EXPERIMENTAL REPORT

NO. WAL. 710/700

HELMETS

Investigation of Factors Responsible for Service Cracking of M1 Helmets

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Investigation of Factors Responsible for Service Cracking of M1 Helmets

OBJECT

To examine helmets which cracked in service and during processing with the view of assisting the helmet fabricators and the helmet steel producers in improving the quality of the steel and the methods of fabrication to eliminate service failure and to reduce the manufacturing breakage to a minimum.

SUMMARY

Examination of helmets which cracked in service and during processing indicates that breakage is primarily associated with a highly stressed condition resulting from extremely severe cold forming operations. Notches, generally confined to the rim of the visor, act as stress raisers and increase the tendency towards edge cracking. These notches result from nicks in the trimming dies and may be eliminated by more frequent dressing of the dies. Improperly controlled heat treatment of the austenitic manganese steel employed, resulting in the formation of brittle martensite layers, grain boundary carbide networks, streaks of undissolved carbides, etc. embrittle the steel sufficiently to greatly increase the tendency to crack in service and break while being formed.

A new specification has been put into effect to control the quality of the steel being delivered to the helmet fabricators. It is believed that better control of the steel quality will decrease, but will not entirely eliminate, the tendency of the M1 helmet to crack in service. Changes in manufacturing techniques or in the type of steel used for helmets are believed necessary to completely eliminate the cracking tendency.

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INTRODUCTION

In accordance with instructions[1] from the Office, Chief of Ordnance, seven M1 helmets which were turned in at Camp Livingston, La. as defective due to cracks developing near the brim were forwarded to this arsenal for metallurgical examination. Shortly thereafter[2], this arsenal was requested to send a metallurgist to the plant of the McCord Radiator and Manufacturing Co., Detroit, Michigan to discuss and outline a program covering the investigation of the factors responsible for service cracking of helmets with personnel from the Detroit Ordnance District and the McCord Radiator and Manufacturing Co.

Of 245,000 helmets which had been examined prior to May 1943 at seven army posts in this country and in Africa, a total of 6,062, or 2.5%, were defective due to cracking which occurred after the helmets were issued. Several hundred cracked helmets were subsequently returned to the McCord Radiator and Manufacturing Co. where they were examined for the number and the locations of the cracks. Ninety-five (95) cracked helmets which had been returned from Camp Pickett, Va. and one hundred and three (103) cracked helmets which had been returned from North Africa were forwarded to this arsenal from the McCord plant for metallurgical examination.

The production of the M1 helmet shell involves an extremely severe deep drawing operation. The steel employed is austenitic Hadfield manganese steel, essentially a 1.3% carbon, 13% manganese alloy, which is very ductile in the quenched condition but work hardens extensively upon cold deformation. The use of any other steel is precluded by the specification of non-magnetic properties and certain minimum ballistic requirements. The steel is supplied to the fabricator in the form of dead soft, flat discs, 16½" in diameter, having an average thickness of 0.044 ± .002".

The discs are formed into the shape of the helmet shell in one cold drawing operation. The hold-down portion of the disc is sheared off in a set of trimming dies, after which the visor is produced by what is termed a "spanking" operation. The inner surface of the front of the helmet is held down against a die and the outer surface is struck by a descending die which stretches this portion of the helmet shell out to form the visor. This operation completes the formation of the helmet shell. Breakage in production occurs in all three operations, but is most severe in the initial deep drawing stage.

Production of the present M1 helmet started in September 1941 at the McCord Radiator & Manufacturing Company. The following is quoted from a letter to the Office of the Quartermaster General[3]:

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1. O.O. 421/2730, Wtn 421/344, See Appendix A.

2. Teletype dated 31 May 1943, See Appendix B.

3. Letter of 20 May 1943, Appendix A.

"This change (from the M1917 "Dishpan" type to the M1 "Pot" type) presented a serious manufacturing problem in the combination of the deep straight sided pot shape, the limitation that only Hadfield Manganese steel might be used, and a limitation on blank thickness in order to be within a maximum finished weight limit. Notwithstanding the experience of the McCord Radiator and Manufacturing Co. in manufacturing a million of the M1917 helmets, breakage in the drawing and forming operations of the new type helmet averaged 30% during manufacture of the first 200,000 helmets. This percent of breakage was progressively decreased through the continued study and experience of McCord, and the assistance of the Carnegie-Illinois Steel Corp, until it leveled off at an average of slightly less than 2%, which may be considered better than normal with the problems involved."

In October 1941[4], Mr. P. L. Barter, Vice-President of the McCord Radiator and Manufacturing Co. submitted to this arsenal nine samples of Hadfield manganese steel representing various lots of steel exhibiting excellent, average, and poor performance when drawn into helmets. Metallographic examination of these samples indicated a close correlation between a high percentage of draw breakage and the presence of stringers of undissolved carbides and grain boundary carbides resulting from inadequate heat treatment.[5] The results of this examination were transmitted to the McCord Radiator and Manufacturing Co. and to the Carnegie-Illinois Steel Corp.

The arsenal was not subsequently consulted until April 1943, when the occurrence of helmet cracking in the field was brought to the attention of Ordnance authorities.

Early in the course of the investigation of the cracked helmets, it became apparent to this Laboratory that an intimate correlation must exist between the service cracking of helmets and the breakage which occurs during manufacture. It was reasonable to assume that possibly milder degrees of the same factors responsible for production breakage were also responsible for the cracking which occurred in service. Although nothing could be done to alleviate the cracking of helmets already issued to the troops, the causes of such cracking had to be determined immediately in order to institute the proper corrective measures to prevent the subsequent service cracking of current production helmets.

It was accordingly decided to first study samples from various heats of steel, showing both high and low incidences of production breakage. These samples were submitted by the two helmet fabricators; the Schlueter Manufacturing Co. of St. Louis, Mo. and the McCord Radiator and Manufacturing Co. All the helmet steel is manufactured by two facilities, the Sharon Steel Corp., and the Carnegie-Illinois Steel Corp. The first two groups of samples investigated comprised 65 samples of satisfactory and defective helmets and helmet steel

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4. Wtn 470.14/11064, See Appendix C.

5. Wtn 470.14/11065, See Appendix C.

submitted by the Schlueter Mfg. Co. and 86 samples of similar material submitted by the McCord Radiator and Manufacturing Co. Various other groups of helmets and helmet steel were subsequently forwarded to this arsenal for metallurgical examination. The results of these investigations were reported to the interested agencies in a series of Watertown Arsenal Laboratory Memorandum Reports, a bibliography of which is included at the end of this report.

The results of the examination of numerous lots of helmets and helmet steel indicated a close relationship between production breakage and the following factors:

1. Steel Quality Factors

   a. Surface decarburization resulting in the formation of surface layers of martensite.

   b. Streaks of globular carbides resulting from insufficient time at the austenitizing temperature for complete carbide solution.

   c. Grain boundary segregations of carbides resulting from too low austenitizing temperatures.

   d. Combinations of globular carbides and grain boundary carbides described in 2 and 3.

   e. Martensite streaks below the surface of the sheets resulting from residual ingot piping.

2. Helmet Fabrication Factors

   a. Severity of cold working as manifested by residual stresses and hardnesses developed.

   b. Notches at the edge of the helmet produced by nicks in the trimming dies.

   c. Condition of the dies: roughness, alignment, cleanliness, lubrication, etc.

   d. Gage thickness and its effect upon hold-down force and severity of cold working.

Up to the time that this arsenal was consulted regarding the service cracking of helmets, Specification AXS-645 (Rev. 1) "Helmet, Steel, M1" covered the purchase of the steel and the fabrication and assembly of the helmet. The only requirements as to steel quality consisted of a magnetic test and a 180° cold bend test. The magnetic test consisted of determining whether a sensitive compass placed 2½ inches away from the helmet would be deflected. This test was too insensitive to be capable of detecting surface decarburization unless the decarburization was extremely severe, in which case the helmet would

most likely have been broken in the drawing operation and consequently would never reach the stage where the magnetic test would be applied. The 180° cold bend test was found to provide a good check on steel quality and is a satisfactory criterion of the formability of the helmet steel. The 180° bend test was not, however, applied by the helmet fabricators to check the quality of the steel delivered to them and was applied neither often enough nor rigidly enough by the steel producers to lead to the rejection of sufficient steel possessing inferior formability.

Since the helmet fabricators could exercise no control over the steel quality factors previously listed, it became obvious that a specification covering the steel used for helmets should be developed. A draft of a specification incorporating the opinions of this Laboratory was prepared and submitted to the Office, Chief of Ordnance on 17 September 1943.[6] After various recommendations and suggestions, offered by the Office, Chief of Ordnance, the steel mills, and the helmet fabricators, were incorporated in the original draft, Specification AXS-1170 "Steel, Nonmagnetic, Sheet and Strip (for Body Armor)" was invoked on 25 March 1944 to cover the quality of the steel being used for helmets and body armor components.

A series of tests designed to accept only that steel which may be expected to perform satisfactorily when drawn into helmets were incorporated into the specification. These tests consist of a magnetic test developed at this arsenal, microscopic examination of samples selected at random from the material being tested, a 180° bend test which was a part of the former helmet specification, and a ballistic test of selected samples.

The magnetic test, described in detail in reference no. 2 in the Bibliography, will reject material which has excessive surface decarburization. Severe decarburization depletes the surface layers of sufficient carbon to result in the decomposition of the non-magnetic austenite into magnetic martensite. The martensite layers are very hard and brittle and crack extensively upon deformation. These cracks are readily transmitted through the otherwise ductile austenitic core, resulting in the breakage of the disc upon deep drawing.

Microscopic examination is necessary to detect unsatisfactory heat treatment resulting in incomplete austenitization as well as to check upon the extent of the decarburization. An insufficiently high austenitizing temperature or too short a hold at temperature prior to quenching of Hadfield Manganese steel results in incomplete solution of the carbides and the migration of carbides to the grain boundaries where a network of carbide is formed. Both grain boundary carbide networks and streaks of globular undissolved carbides decrease the ductility of austenitic manganese steel. Since the magnetic properties are but very slightly influenced by the presence of undissolved carbides, the magnetic test is incapable of revealing improper heat treatment except when decarburization occurs.

The bend test was included in the specification because it was found to be an excellent gage of overall ductility and formability. The bend test not only checks upon factors which influence the results of the magnetic test and

6. Wtn 421/362 - O.O. 421/2875 1st Ind., See Appendix D.

microscopic examination, but also responds to other ductility factors which are influenced by chemical composition, melting practice, and other inherent properties of the steel. The bend test thus integrates all factors which influence the ductility of helmet stock and is consequently of considerable value. The bend test is described in detail in reference no. 3 of the Bibliography.

The ballistic requirements of the specification were obtained from a series of ballistic tests conducted at this arsenal upon groups of annealed sheet of varying thicknesses submitted by the Carnegie-Illinois Steel Corp. and the Sharon Steel Corp. These tests are incorporated in the report listed as reference no. 8 in the Bibliography.

In March 1944 a Helmet Industry Integration Committee was organized[7] for the purpose of integrating all the research on helmets and helmet steel being conducted by various agencies and to make the results of this research quickly available to the steel producers and helmet fabricators. Notes covering the various committee meetings are incorporated in Appendix E.

The subject report is concerned primarily with an investigation of the 205 service cracked helmets returned from Camp Livingston, Camp Pickett, the North African theatre of operations, and a group of 34 helmets which had been in storage at Watertown Arsenal since 9 April 1942. The results of this investigation are correlated with those of various studies which have been conducted upon helmets produced at a later date.

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7. O.O. 334/3758 - Wtn 334/6105, See Appendix E.

MATERIAL AND TEST PROCEDURE

The helmets examined in the course of this investigation consisted of the following groups:

Source	Number of Helmets
Camp Livingston, La.	7
Camp Pickett, Va.	95
North Africa	103
In storage at W.A. since 9 April 1942	34

All of the subject helmets were manufactured by the McCord Radiator and Manufacturing Co. The Schlueter Mfg. Co. had not begun the manufacture of the M1 helmet at the time the subject helmets were produced. The McCord lot numbers, which are stamped on the inside of the helmet visors, were recorded. These numbers are listed in Inclosure 1. A large number of the subject helmets are from lots lower in number than McCord lot 554. These helmets were all manufactured prior to 24 January 1942. The following dates of manufacture of other lots are given to assist in dating the remainder of the helmets:

McCord lot 88 - made 8 April 1942
McCord lot 148 - made 24 July 1942

It is necessary at this point to describe the McCord lot numbering system. At the time the subject helmets were fabricated, the Carnegie-Illinois Steel Corp. was the sole producer of the helmet steel, and supplied the McCord plant with daily shipments of thousands of discs. Each disc is stamped with its McCord lot number before being drawn into a helmet. A McCord lot number is assigned to discs from each heat of steel melted and processed by the Carnegie-Illinois Steel Corp. Since an enormous number of discs are produced from one heat, the heats are subdivided at the steel producer's plant into "lifts" which are processed in groups. The steel is shipped in disc form in groups of "lifts" to the McCord plant, where each "lift" is assigned a letter of the alphabet in chronological order based upon the date of receipt of the "lifts" at the McCord plant. An average "lift" generally contains 2000 discs.

As an example of the numbering system described above, McCord lot 596C represents a group of helmets produced from Carnegie-Illinois Steel Corp. heat no. 255799, lift no. 50697, and McCord lot 596E was made from the same heat, but lift no. 50695.

Details of the production of the helmet discs at the plants of both the Carnegie-Illinois Steel Corp. and the Sharon Steel Corp. are contained in Appendix F.

Upon receipt of the helmets at this arsenal, the stainless steel edgings spot welded around the rims of the helmets were removed, after which all helmets were examined for cracks. Samples for microscopic examination were cut from various helmets for the purpose of checking the steel quality.

DATA AND DISCUSSION

1. Locations of Cracks

It was necessary to remove the stainless steel edgings because small cracks extending from the rims of the helmets were frequently completely covered by the edgings. The small cracks could not be neglected because sufficient evidence was accumulated to show that these cracks tend to grow and in time will lead to the rejection of the helmet. It was also necessary to examine the helmet rims for notches caused by chipped edges of the trimming dies. Observation of numerous cracked helmets indicated a tendency for cracking to originate at notches. The notches in the rims were confined almost exclusively to the visors of the helmets.

The locations of the cracks were determined according to instructions from the Office, Chief of Ordnance[8], by measuring the position of the cracks in degrees, starting from the middle of the visor as zero degrees and rotating clockwise around the helmet. The outline of the M1 helmet was projected upon a piece of plywood and each five (5) degree step was laid off as shown in Figure 1. The cracks were located by placing the helmets down on the plywood and recording the position of the cracks as lying between two five (5) degree steps.

The cracks were divided into three types; cracks extending from the edge of the helmet and apparently originating from distinct notches, cracks extending from the edge of the helmet and not originating from notches, and cracks confined to the body of the helmet and not extending to the rim. The very great majority of the cracks extending from the rims of the helmets occurred in the visor of the helmet, or that portion lying between 320° and 40° in Figure 1. The body cracks were generally confined to the back of the helmet in the region between 130° and 240° and consisted of vertical cracks occurring in the straight sidewall sections lying between 1" and 3" up from the rim and were generally from 1" to 1½" in length. The cracks extending from the rims varied in length from 1/8" up to 5". The appearance of typical cracks occurring in helmets returned from the field are shown in Figure 2.

The distribution of the cracks observed in the various lots of helmets examined at this arsenal are plotted in Figures 3, 4, and 5. Figure 3 shows the distribution of cracks found in the 7 helmets from Camp Livingston and the 103 helmets from North Africa. Figure 4 shows the crack distribution in the 34 unused helmets which had been in storage at Watertown Arsenal since 9 April 1942 and the crack distribution observed in a series of 20 additional helmets which were submitted by the McCord Radiator and Manufacturing Co. This last group of helmets is more fully discussed in a letter to the Office, Chief of Ordnance, a copy of which is included in Appendix B[9]. Figure 5 shows the crack distribution in the group of 95 helmets from Camp Pickett and the sum of the crack distributions in the helmets from Camp Pickett, North Africa, and Watertown Arsenal.

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8. O.O. 421/2302 - Wtn 421/347, See Appendix A.
9. Wtn 421/364 - O.O. 421/2880, 1st Ind., See Appendix A.

From the lower chart in Figure 5 it is apparent that the service cracking of helmets is confined to three unique zones: (1) the visor, extending from 320° to 40°, where the cracks generally extend up from the rim; (2) the right rear of the helmet, from 130° to 160°, where the cracks occur in the body of the helmet; and (3) the left rear of the helmet, from 190° to 240°, where the cracks occur similarly to those in the right rear of the helmet.

It is noteworthy that a large preponderance of rim cracks occur in the visor between 325° and 335°, and that this preponderance was observed in every group of helmets examined except that from Camp Livingston, which was too small to yield significant results. Except for the group of helmets from Camp Pickett, the great majority of cracks in the zone between 325° and 335° are associated with notches resulting from trimming die defects.

A discussion of the notches observed in the helmet rims is in order at this point. A crack was designated as being associated with a notch when a very apparent nick in the rim was observed at the base of the crack, as shown in the lower photograph of Figure 2 where the crack at 9° is very definitely associated with a notch. When no nick was observed, the crack was assumed to have occurred in a region free from notches. It must be recognized, however, that once the crack has occurred, the evidence of a small notch which may have existed prior to the cracking may be removed by the crack. Hence, a greater number of rim cracks must have been actually associated with notches than are indicated in Figures 3 and 5.

The group of 103 helmets from North Africa had an average of 3.1 cracks per helmet, and of the total number of cracks, 37.0% were body cracks, 32.7% were rim cracks associated with notches and 30.3% were rim cracks not associated with notches. The group of 102 helmets from Camps Pickett and Livingston had an average of 4.1 cracks per helmet. Body cracks averaged 51.0%, rim cracks associated with notches averaged 27.2%, and rim cracks not associated with notches averaged 21.8% of the total.

2. Hardness Surveys

Four helmets were selected at random from the group of helmets returned from Camp Pickett. These helmets were numbered 4, 12, 45, and 71. Nine sections, each 40° in width, were cut from the circumference of the helmets, each section extending approximately 3" to 3½" up from the rim. These sections included all the areas of the helmets in which cracks tend to occur. Three Rockwell C hardness surveys were made on each section along rows parallel to the helmet rims ½", 1", and 1½" up from the rims with the hardness impressions spaced ½" apart.

It was immediately noted that the areas in which cracks tend to occur coincide with the areas of maximum hardness. It was decided to represent the correlation between hardness and crack distribution by plotting the hardnesses of the areas in which cracks tend to occur against the position around the circumference. The curve shown in the upper chart of Figure 5 is the average hardness ½" up from the rim in the region of the visor, and 1½" up from the rim along the sides and back of the helmet.

It is apparent that the service cracking of the M1 helmet is almost exclusively confined to those regions which have been strain hardened to hardnesses of Rockwell C 48-53. Niconoff[10] has demonstrated that the maximum strain hardness attainable in austenitic manganese steel is practically independent of the prior structure and hardness and lies within the range of Rockwell C 49-52. Various zones of the M1 helmet are, therefore, cold worked to the maximum extent possible and are thus in a highly strained condition. Helmet breakage in the drawing operations and in service is obviously related to the extreme cold deformation necessary to shape the M1 helmet.

3. Stresses Resulting from Cold Working

In view of the extremely severe cold deformation experienced in deep drawing the M1 helmet from a flat disc in one major operation, it is to be expected that very high residual stresses would be present in the finished helmet. Residual stress determinations, made at this arsenal[11] on uncracked helmets, indicated the existence of residual stresses which may approach the magnitude of the tensile strength of the material. In general, the highest stresses were found in the vicinity where service cracking generally occurs.

It was at one time proposed to thermally stress-relieve the helmets after the drawing operation. Research at the United States Steel Corp. Research Laboratory[12] showed that a stress relieving temperature above 500°F. could not be employed because decomposition of the cold worked austenitic steel occurred at temperatures above 500°F. Since very little, if any, stress relief can be expected to occur at such low temperatures, thermal treatment is believed to show no promise in relieving the high stresses induced by cold working.

Appendix G contains a letter to the Office, Chief of Ordnance[13], expressing the doubts of this laboratory as to the practicability of a thermal stress-relief treatment for the M1 helmet.

4. Microscopic Examination

Specimens for microscopic examination were cut from each of the seven helmets returned from Camp Livingston and from forty-three (43) helmets of the group returned from Camp Pickett. The specimens were mounted in transparent lucite mounts, polished, etched in picral, and examined at magnifications of X1000 and X250. The results of the microscopic examination of the 50 specimens are contained in Inclosure 3.

The microstructures of many of the service cracked helmets are similar to those previously observed in helmets which broke during the forming operations. Figure 6 shows some of the conditions which have been found responsible for draw breakage[14]; namely, surface decarburization and networks of carbides

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10. D. Niconoff. "Some Aspects of Strain Hardenability of Austenitic Manganese Steel". Trans. of the A.S.M., Vol. XXXI, No. 3., Sept. 1943, pages 716-734.

11. Reference No. 9 in Bibliography.

12. Reference No. 16 in Bibliography.

13. Wtn 421/397, 20 January 1944.

14. References Nos. 2 and 3 in Bibliography.

at the austenite grain boundaries resulting from insufficiently high austenitizing temperatures prior to quenching. Figures 7 and 8 contain photographs of some of the different microstructures observed in the service cracked helmets.

The data contained in Inclosure 3 show that, in the 50 helmets examined, poor steel quality resulting from imperfect heat treating practices was a factor in 74% of the helmets. It is obvious that in a highly stressed structure such as the M1 helmet, additional factors promoting brittleness such as grain boundary carbide networks, surface layers of martensite, and streaks of undissolved carbides would be particularly dangerous. The data further indicates that cracking can also occur in helmets made from steel free from metallurgical defects. It appears that the M1 helmet as presently made involves extremely severe forming operations which stress the steel to a degree sufficient in itself to be responsible for some of the breakage encountered in manufacture and in service.

From an examination of the subject helmets as well as numerous helmets which broke during forming, it appears that body cracking is more generally associated with poor microstructure whereas edge cracks at the visor are primarily associated with factors involving high stress concentrations resulting from a combination of severe cold working and the presence of notches at the helmet rim. The above observation has been borne out by production experience following the introduction of specification AXS-1170. Since the application of this specification the incidence of body cracking during forming and upon aging has decreased considerably because of the improvement in steel quality, whereas edge cracking is still occurring with sufficient frequency to seriously hamper production, particularly at the plant of the Schlueter Mfg. Co.

5. General Considerations

The examination of a number of service cracked helmets indicate that the cracking is associated primarily with a highly stressed condition resulting from severe cold forming operations. Poor steel quality resulting from insufficiently careful control of the heat treating by the steel producers is an additional factor which will greatly increase both the draw breakage and the service cracking. Improvement of the steel quality is not, however, believed to be alone sufficient to eliminate the service cracking of the M1 helmet. Changes in either the manufacturing techniques or in the material used for helmets are considered necessary to solve the service cracking problem.

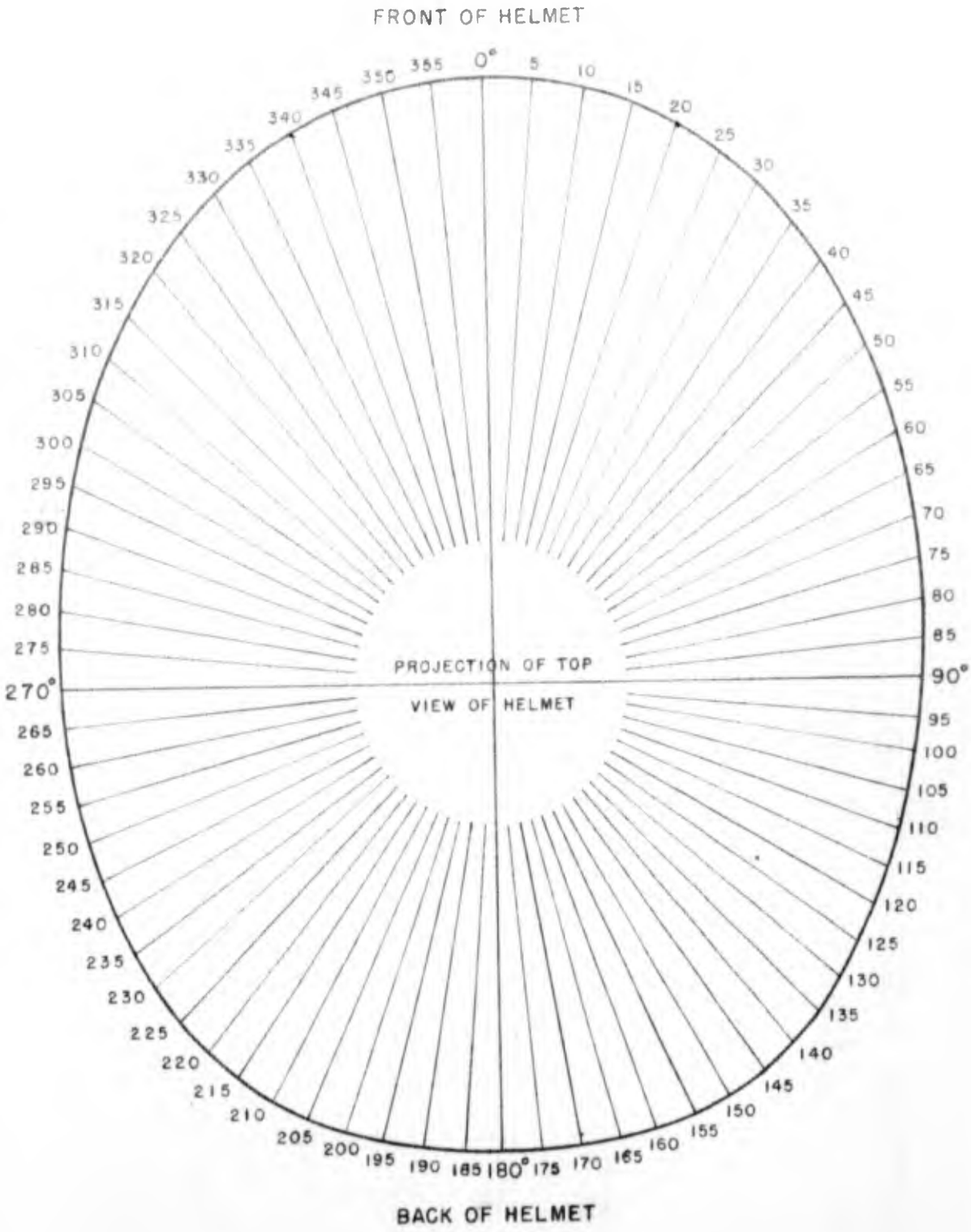
Experiments have been conducted with a 3½% nickel modified Hadfield Manganese steel[15] which indicate that this material work hardnes to a lesser extent than does normal Hadfield steel, is more ductile than normal Hadfield steel when drawn into helmet form, and has but slightly inferior ballistic properties.

Since the cracking in the visor always originates at the edge of the helmet, annealing cycles have been employed to soften the edge to stress relieve this critical zone[16]. These annealing cycles have been found effectiv

15. Reference No. 6 in the Bibliography.
16. References Nos. 7 and 10 in the Bibliography.

in preventing the extention of cracks through the annealed zone. The annealed zone is sufficiently narrow in width to be almost completely covered by the stainless steel edging spot welded around the helmet.

It may be possible to draw the helmet shell in two or three stages with annealing cycles between the stages. This method would greatly reduce the residual stresses and helmet breakage, but would involve additional heat treating equipment and forming dies and may not consequently be economically feasible. It must be recognized, however, that if the present production procedures and material remain unchanged, service cracking will always be a problem.



SYSTEM USED TO DETERMINE LOCATIONS OF CRACKS ON MI HELMETS WHICH CRACKED IN SERVICE

FIGURE 1

Typical Service Cracked M1 Helmets

Helmet No. 79. McCord Lot 40B1. Camp Pickett. Mag. X½
Body cracks at back of helmet. Numbers refer to positions shown in Figure 1.

Helmet No. 98. McCord Lot 149A. Camp Livingston. Mag. X1
Edge cracks at visor of helmet. Crack at 9° definitely associated with notch. Stainless steel edging has been removed.

FIGURE 2

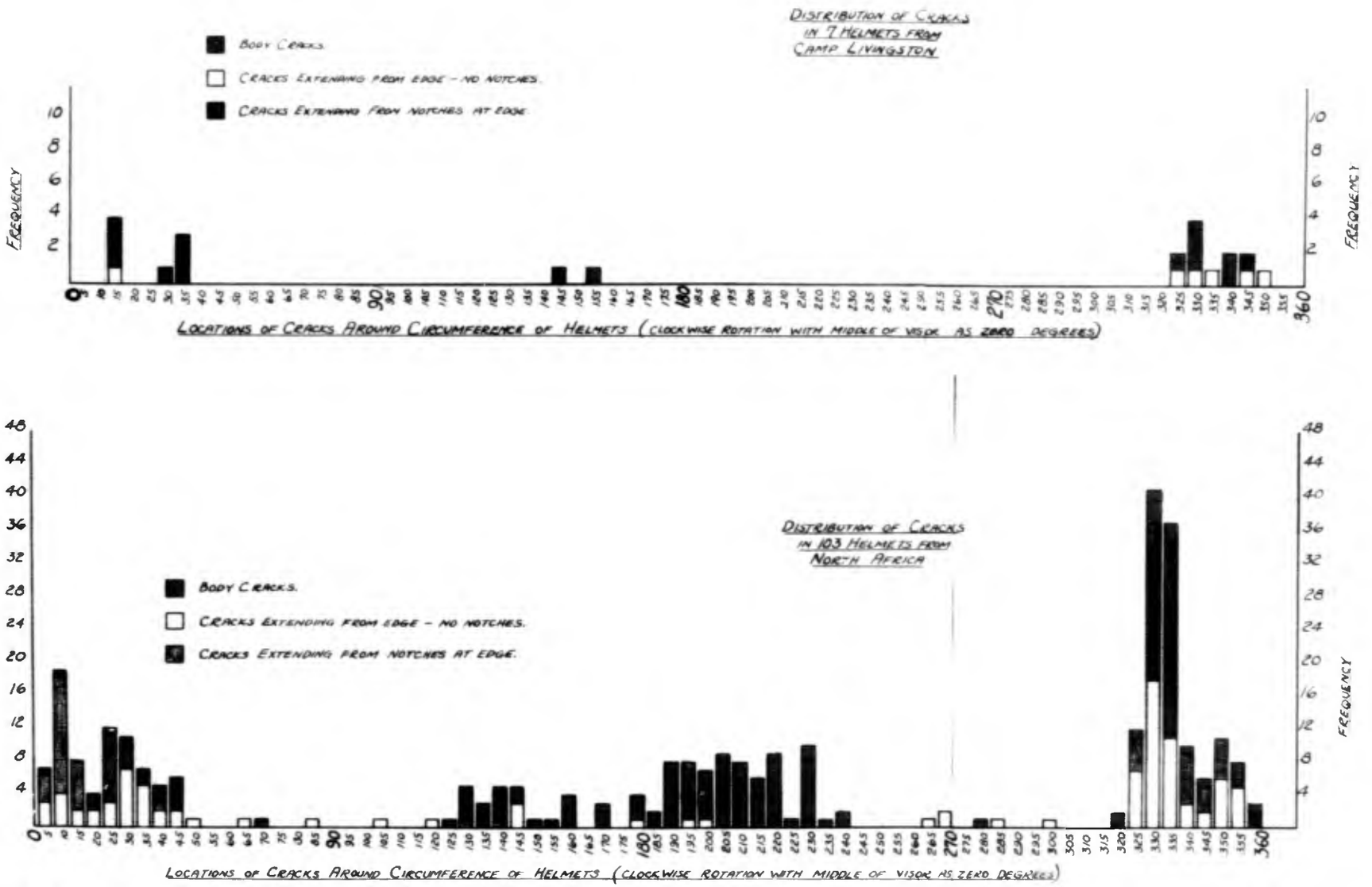


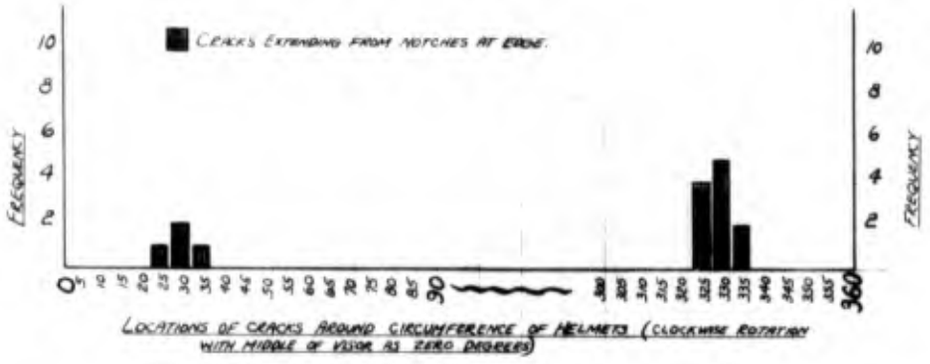
FIG. 3

WTN.639-6852

DISTRIBUTION OF CRACKS FOUND AFTER REMOVAL OF EDGINGS FROM 34 HELMETS (UNUSED) IN STORAGE AT WATERTOWN ARSENAL SINCE APRIL 9, 1942.

CRACKS AVERAGE $\frac{1}{8}" - \frac{3}{16}"$ IN LENGTH

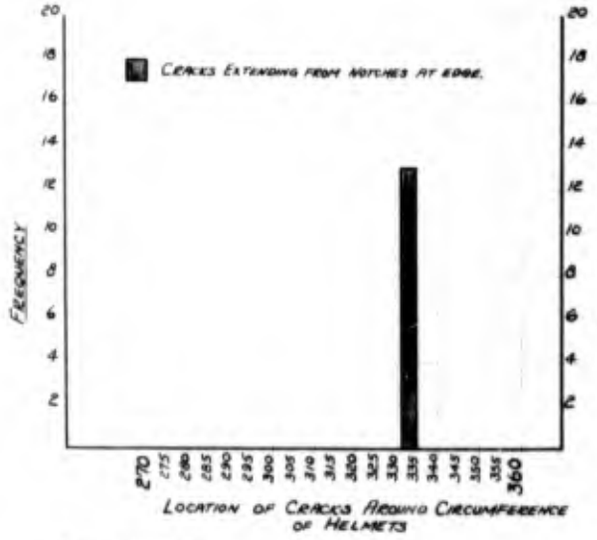
14 HELMETS CRACKED
20 HELMETS FREE OF CRACKS



LOCATIONS OF CRACKS AROUND CIRCUMFERENCE OF HELMETS (CLOCKWISE ROTATION WITH MIDDLE OF VISOR AS ZERO DEGREES)

20 HELMETS FROM McCORD RADIATOR & MFG. CO.

{10 CRACKED HELMETS - LOT 608A
10 "UNCRACKED" HELMETS - 9 FROM LOT 608A, 1 - LOT 643D



LOCATION OF CRACKS AROUND CIRCUMFERENCE OF HELMETS

10 CRACKED HELMETS :
ALL HAVE A CRACK AT 333° EXTENDING UP FROM A NOTCH AT THE EDGE OF THE HELMET.

10 "UNCRACKED" HELMETS :
3 HELMETS HAVE A CRACK AT 333° EXTENDING UP FROM A NOTCH AT THE EDGE.
5 HELMETS HAVE NO CRACKS, BUT HAVE NOTCHES AT RIM AT 333° (INCLUDES HELMET FROM LOT 643D)
2 HELMETS HAVE NO CRACKS AND NO NOTCHES.

10/15/43 A.M.

WTN. 639-6854

FIG. 4

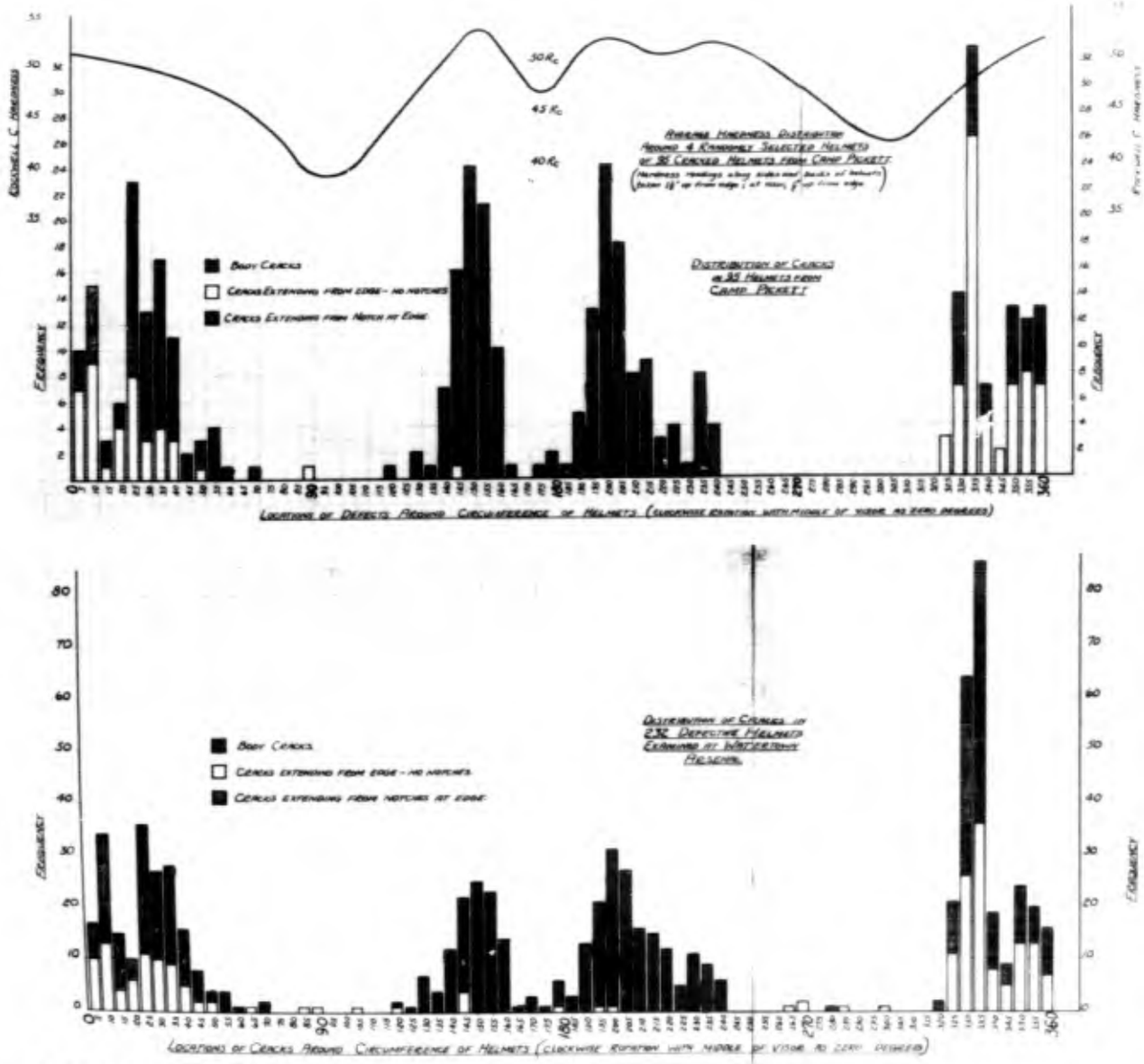
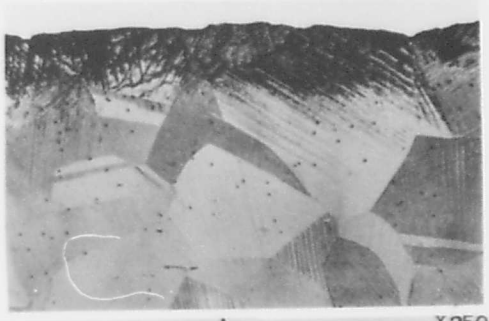


FIG. 5

WTN.639-6855

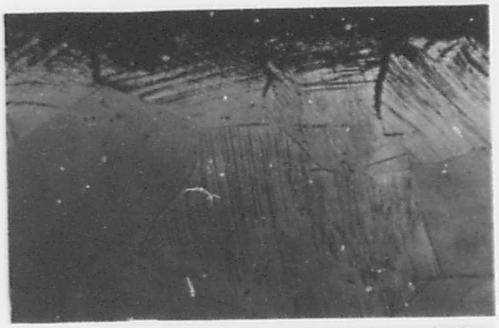
Microstructures of Helmets That Broke
in the Forming Operations

Nital Etch



-A- X250

Helmet D4, McCord Lot 544B, Carnegie Heat 255739. Martensitic surface layer resulting from decarburization. Width of layer - 0.0016". Magnetic Traverse - 23.0".



-B- X250

Helmet D4. Typical cracks in martensite layer resulting from deformation of brittle constituent.

-C- X1000

Helmet E1, McCord Lot 541C, Sharon Heat 72203. Network of undissolved carbides at grain boundaries. Magnetic Traverse - 3.0".

-D- X1000

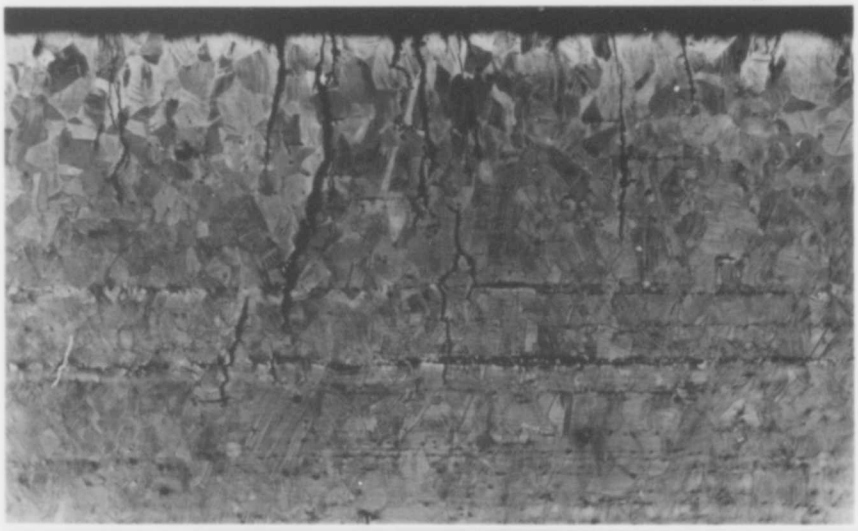
Helmet E2, McCord Lot 549B, Sharon Heat 72198. Undissolved carbides. Magnetic Traverse - 1.0".

WTN.639-6165

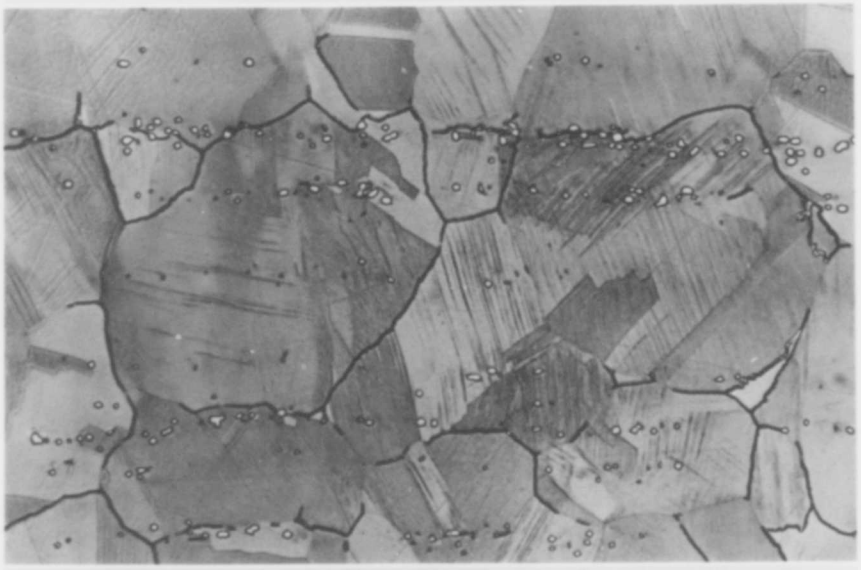
FIG. 6

Microstructures of Helmets Which Cracked in Service
at Camp Pickett

Picral Etch



Helmet No. 34. McCord Lot No. 39A3 X100
Cracks originating at outside surface of helmet. Microstructure contains heavy streaks of undissolved globular carbides and some grain boundary carbide network.



Helmet No. 95. McCord Lot No. 165 X1000
Streaks of undissolved globular carbides and grain boundary carbide network.

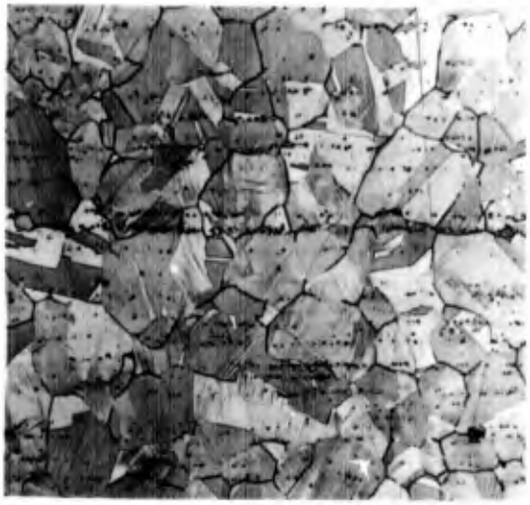
WTN.639-7227

FIGURE 7.

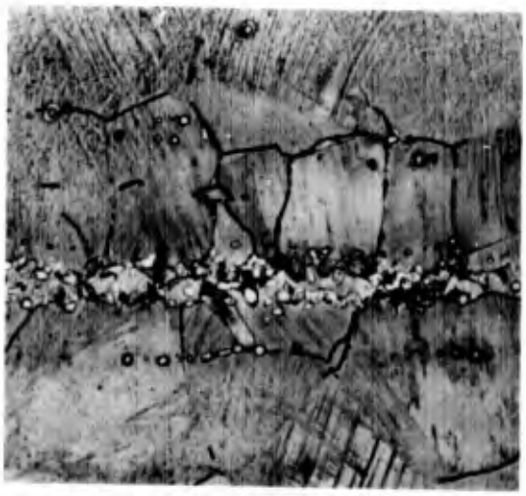
Microstructures of Helmets Which Cracked in Service
at Camp Pickett

Picral Etch

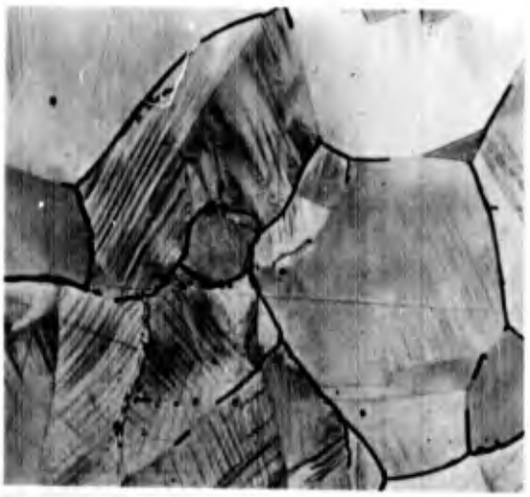
Helmet No. 93 X250
McCord Lot No. 149C
Satisfactory microstructure. No undissolved carbides.



Helmet No. 95 X250
McCord Lot No. 165
Streaks of globular carbides and grain boundary carbide network.



Helmet No. 16 X1000
McCord Lot No. 37C3
Segregation of globular carbides and grain boundary carbides.



Helmet No. 92 X1000
McCord Lot 148B
Grain boundary carbide network.

FIGURE 5.

WIN.639-7228

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3. WAL Memo. Report No. 710/575. "Metallurgical Examination of Defective and Satisfactory Helmets and Helmet Steel Stock Furnished by the McCord Radiator and Mfg. Co., Detroit, Mich." A. Hurlich, 23 December 1943.

4. WAL Memo. Report No. 710/586. "Metallurgical Examination of 20 M1 Helmets, Made by the Schlueter Mfg. Co., Which Cracked in Service." A. Hurlich, 29 January 1944.

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7. WAL Memo. Report No. 710/612. "A Study of the Seam Welding Process Applied to Prevent Stress Cracking of the Visor of the M1 Helmet." A. Hurlich, 13 April 1944.

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12. WAL Report No. 710/418. "Helmets - Metallurgical Examination of Helmets from Germany, the Netherlands, France, and the Irish Free State." E. L. Reed and A. Hurlich, 26 March 1942.

13. WAL Report No. 710/439. "Helmets - Comparison of Helmets Made from NAX and Hadfield Manganese Steel." J. F. Sullivan and A. Hurlich, 20 June 1942.

14. WAL Report No. 710/543. "Helmets - Ballistic and Metallurgical Investigation of Amola Steel Helmets." E. L. Reed, 20 Aug. 1943.

15. WAL Report No. 710/670. "Helmets - Metallurgical and Ballistic Investigation of Fifty Captured German Helmets." A. Hurlich, 28 June 1944.

16. Report File No. WAL 710/639. "Factors Involved in Stress-Relief Annealing of Cold-worked Hadfield Manganese Steel". E. S. Davenport and R. A. Grange, United States Steel Corp. Research Laboratory Report No. 502, October 1943.

Inclosure 1

Helmets Examined at Watertown Arsenal

HELMETS FROM CAMP PICKETT

W.A. No.	McCord Lot No.	W.A. No.	McCord Lot No.	W.A. No.	McCord Lot No.	W.A. No.	McCord Lot No.
1	28B1	25	39A1	49	39B2	73	40A3
2	28B2	26	39A1	50	39B2	74	40A3
3	34D2	27	39A2	51	39B2	75	40A3
4	35C2	28	39A2	52	39B2	76	40B1
5	36C1	29	39A2	53	39B2	77	40B1
6	36D1	30	39A2	54	39B2	78	40B1
7	37B3	31	39A2	55	39B2	79	40B1
8	37C1	32	39A2	56	39B3	80	40B1
9	37C1	33	39A3	57	39B3	81	40B1
10	37C1	34	39A3	58	39B3	82	40B1
11	37C2	35	39A3	59	39B3	83	40B2
12	37C2	36	39A3	60	39B3	84	40B2
13	37C2	37	39A3	61	39C1	85	40B2
14	37C2	38	39A3	62	39C2	86	40B3
15	37C2	39	39A3	63	39C3	87	40B3
16	37C3	40	39A3	64	39C4	88	40B3
17	37C3	41	39A3	65	39F2	89	41A2
18	37C3	42	39A3	66	39F3	90	41A2
19	37C3	43	39A3	67	40A1	91	42A1
20	38A3	44	39A3	68	40A1	92	148B
21	38B4	45	39B1	69	40A1	93	149C
22	38C2	46	39B1	70	40A1	94	154B
23	38C2	47	39B1	71	40A2	95	165
24	38C2	48	39B1	72	40A3		

HELMETS FROM CAMP LIVINGSTON

W.A. No.	McCord Lot No.
96	148C
97	148C
98	149A
99	149C
100	unknown
101	unknown
102	unknown

Helmets in Storage at Watertown Arsenal since 9 April 1942

W.A. No.	McCord Lot No.	W.A. No.	McCord Lot No.	W.A. No.	McCord Lot No.	W.A. No.	McCord Lot No.
103	55F	111	86	119	88A	128	88C
104	77C	112	86C	120	88A	129	88C
105	83F	113	86C	121	88A	130	88C
106	83F	114	87	122	88A	131	88C
107	83F	115	87B	123	88A	132	88C
108	84D	116	87B	124	88A	133	88C
109	84D	117	88A	125	88A	134	88C
110	85E	118	88A	126	88A	135	88D
				127	88A	136	90A

HELMETS FROM NORTH AFRICA

W.A. No.	McCord Lot No.	W.A. No.	McCord Lot No.	W.A. No.	McCord Lot No.	W.A. No.	McCord Lot No.
137	14C	163	75E	189	103B	215	154B
138	14C	164	77B	190	103C	216	156A
139	18B	165	77E	191	107B	217	158C
140	30B	166	77E	192	108A	218	162B
141	32B	167	77E	193	108A	219	162C
142	54C	168	79A	194	134B	220	163A
143	54D	169	79C	195	137A	221	163B
144	55C	170	80D	196	139B	222	164A
145	66C	171	80D	197	142B	223	164A
146	67C	172	81B	198	143B	224	164A
147	67E	173	82E	199	143C	225	164B
148	68D	174	83B	200	153A	226	164B
149	68H	175	83C	201	153A	227	166A
150	68H	176	83C	202	153A	228	167A
151	68H	177	83C	203	153B	229	169A
152	70E	178	83F	204	153C	230	171B
153	71B	179	84A	205	153C	231	174C
154	73D	180	84C	206	154B	232	174C
155	74A	181	84D	207	154B	233	174D
156	74A	182	85B	208	154B	234	174D
157	74A	183	87A	209	154B	235	175
158	74A	184	87D	210	154B	236	178C
159	74B	185	88B	211	154B	237	187A
160	74B	186	97B	212	154B	238	188
161	74D	187	103B	213	154B	239	189B
162	75A	188	103B	214	154B		

Inclosure 2

Hardness Surveys of Service Cracked M1 Helmets

Rockwell C Hardness Surveys of Sections Cut from Helmets

Helmet #4 (340°-20°)

Hardness - Rc

A-B[1]	C-D[2]	E-F[3]
47	47.5	49.5
48	50	50.5
47.5	48.5	50.5
46	49.5	52.5
46	49	53
45	48	52

#4 (20°-60°)		
45	48	51
44	47	50
45.5	48.5	50.5
45	48	48
46.5	47	46

#4 (60°-100°)		
46.5	-	44
45.5	-	43.5
43.5	-	39
41.5	-	41.5
44	-	42.5

#4 (100°-140°)		
47	-	44
49	-	46.5
49	-	47
52	-	46.5
49.5	-	44.5

#4 (140-180°)		
50.5	48.5	49
53	50	48.5
50.5	50.5	47
48.5	49	49.5
44.5	43.5	44

#4 (180°-220°)		
49.5	45	46
54	47.5	47.5
53.5	48.5	45
49	47.5	48.5
50.5	46.5	47

#4 (220°-260°)		
50	47	46
49.5	45.5	44
45.5	46	48
47	48	47
46.5	46.5	45.5

Helmet #12 (340°-20°)

Hardness - Rc

A-B	C-D	E-F
47	48.5	48.5
45	50	50.0
46.5	50	52
48	49	51.5
47	49.5	50
47.5	49	50

#12 (20°-60°)		
47	48	50
46	47.5	51
47.5	48.5	48.5
46	47	47
46.5	47.5	47

#12 (60°-100°)		
45.5	43.5	44
40	44	43.5
42	43.5	41
42.5	41.5	40.5
42.5	41.5	41.5

#12 (100°-140°)		
41	40	42
42.5	41	42
42.5	41.5	43.5
49	44	40
49.5	45.5	43.5

#12 (140°-180°)		
54.5	50	49.5
54	49	51
50.5	49.5	50.5
48	52	49
46.0	46	48.5

#12 (180°-220°)		
49.5	46	47
53	44.5	48.5
52.5	45	48
50.5	48.5	46
52.5	48.5	47

#12 (220°-260°)		
52.0	48.5	47.5
51	47	46
49	50	48
51	49	47
50.5	49.5	46.5

Helmet #45 (340°-20°)

Hardness - Rc

A-B	C-D	E-F
46	48	50
47	48.5	51
46.5	48	50.5
45.5	49	50
46	48	49.5
46.5	47	49.5

#45 (20°-60°)		
45	47	49
45.5	47.5	48
46	46	46
45	45	47.5
44.5	44	47

#45 (60°-100°)		
42	41.5	44.5
38	40	41.5
37.5	39.5	39.5
38	41.5	41.5
36.5	38	39

#45 (100°-140°)		
44.5	42.5	40.5
47.5	45.5	43.5
50	49	44
51.5	48	47
51.5	46	46

#45 (140°-180°)		
51	46	45
50.5	45.5	43.5
47.5	47	44
46	44	46.5
48	43.5	47

#45 (180°-220°)		
47.5	48	44
52.5	50	49
50.0	47.5	47.5
51.5	47.5	46
50	45	48.5

#45 (220°-260°)		
49	46.5	48
48.5	46	48.5
47	44.5	46
48.5	45	45.5
47	42.5	46

Helmet #71 (340°-20°)

Hardness - Rc

A-B	C-D	E-F
47	48	47.5
48	47.5	49.5
48	49.5	51
47.5	49	51
46	47	50
46.5	46.5	49

#71 (20°-60°)		
45	45	49
42	45.5	49
44.5	45	47.5
41.5	44	45
42	46.5	46

#71 (60°-100°)		
40.5	-	43
46.5	-	44.5
39	-	41
41.5	-	41.5
39.5	-	38.5

#71 (100°-140°)		
45.5	-	41.5
46	-	44
48	-	43.5
51	-	46
51.5	-	45

#71 (140°-180°)		
53.5	49	43
49.5	48	45.5
45.5	45	47.5
46	46.5	46
46.5	48.5	47

#71 (180°-220°)		
51.5	47.5	45.5
49.5	46.5	47
52.5	48	46
49.5	48	45
50.5	47	44.5

#71 (220°-260°)		
53	49	44.5
50	50	46
50	49	47.5
46.5	47	45
45	43.5	43

1. A-B - row parallel to edge and 1½" up from edge.
2. C-D - row parallel to edge and 1" up from edge.
3. E-F - row parallel to edge and ½" up from edge.

#4 (260°-300°) Hardness - Rc		
A-B	C-D	E-F
46	44	41.5
46.5	42.5	43.5
47.5	41	42
45.5	43.5	41.5
44	42	41.5

#12 (260°-300°) Hardness - Rc		
A-B	C-D	E-F
48.5	48	43
48	46	44.5
48	47.5	44
46.5	44	41
43	46.5	40.5

#45 (260°-300°) Hardness - Rc		
A-B	C-D	E-F
45.5	45	42.5
45	44	41.5
43	44.5	43
41	40	44
39.5	41.5	44.5

#71 (260°-300°) Hardness - Rc		
A-B	C-D	E-F
44	43	40
42.5	44	42.5
42.5	42.5	40
41	40	41.5
43.5	41.5	40

#4 (300°-340°)		
45.5	43	45.5
46	44	48
46	46.5	48
47	47	48.5
48	48.5	50

#12 (300°-340°)		
43	46.5	42
44	44.5	47.5
43.5	46.5	46.5
46	47	49
48	44.5	48.5

#45 (300°-340°)		
40	43.5	43.5
39.5	43	46
43.5	44	44.5
44	45	49
45.5	48.5	50.5

#71 (300°-340°)		
42	44	44
43.5	45.5	48
46	47	49
47	48.5	50.5
46.5	49	50

Inclosure 3

Metallographic Examination of Service Cracked Helmets

Results of Microscopic Examination of Fifty Service Cracked Helmets

Helmets having satisfactory microstructures: - Total Number 13 Helmets

W.A.# 7, 31, 35, 37, 39, 67, 70, 72, 73, 84, 93, 96, 102

Helmets having unsatisfactory microstructures: - Total Number 37 Helmets

A. Helmets exhibiting surface decarburization: - Total 12 helmets

W.A.# 8, 9, 11, 14, 25, 32, 53, 75, 86, 91, 97, 101

B. Helmets exhibiting intense streaks of undissolved carbides and some grain boundary carbides: - Total - 10 helmets

W.A.# 16, 18, 34, 46, 55, 61, 62, 94, 95, 100

C. Helmets exhibiting extensive grain boundary carbide networks: - Total 9 helmets

W.A.# 13, 44, 65, 79, 85, 87, 92, 98, 99

D. Helmets exhibiting small amounts of grain boundary carbides associated with undissolved carbides or decarburization: - Total 6 helmets

W.A.# 21, 47, 48, 52, 63, 77

APPENDIX A

Correspondence on Cracking of Helmets in Service in American and Foreign Theatres of Operations

COPY

Booth/ver
73789

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON

O.O. 421/2730
Attn: SPOIS
W.A. 421/344

27 April 1943

Subject: M1 Helmet

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. There are being forwarded to his Arsenal, by shipping order, SAD 3186, inclosed in duplicate, seven M1 helmets that were turned in from the field as defective due to cracks developing near the brim.

2. An investigation made at the manufacturer's plant in August of 1942, showed a temporary increase of cracking during the forming processes due to a change made in the steel believed at that time to improve ballistic properties. Prompt corrective action was taken by the manufacturer at that time and conditions adjusted to normal. It was expected, and later confirmed, that a number of helmets with latent defects that could not be detected during manufacture or inspection, would be accepted and develop cracks later in the field. Helmets here forwarded are among this group.

3. It is believed that normal latent defects that now pass through inspection in low percentages are of the type represented by the above noted seven helmets. An additional quantity is being forwarded from Camp Pickett. It is requested that a metallurgical examination be made of these helmets with the view of aiding McCord Radiator and Manufacturing Co., and Carnegie-Illinois Steel Co. in more successfully coping with the age cracking of helmets. Your Arsenal will be further advised regarding the activities of McCord and Carnegie and arrangements may be made for direct cooperation with these companies in working together on this problem.

By order of the Chief of Ordnance:

(S/T) F. M. VOLBERG
Major, Ord. Dept.
Assistant

1 Incl.
SAD 3186 in dupl.

COPY

Booth/ver
73789

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON

20 May 1943

Attention of
SPOIS

Subject: M1 Helmet

To: Office of the Quartermaster General
Washington, D. C.

Attn: Clothing & Equipment Branch

1. Through past and current correspondence with this office, your office is familiar with the difficulties encountered and several reports received in connection with the M1 Helmet cracking in the field. The summation which follows is set down as a convenient reference as to the extent that such difficulties have been experienced and the corrective steps that have been taken by the Ordnance Department.

2. Manufacturer of helmets connected with the present war commenced with the production of M1917 "Dishpan" type in February 1941. The M1 "Pot" helmet was adopted by the Army in the summer of 1941 and the change over in production took place in September of that year. This change presented a serious manufacturing problem in the combination of the deep straight sided pot shape, the limitation that only Hadfield manganese steel might be used, and a limitation on blank thickness in order to be within a maximum finished weight limit. Notwithstanding the experience of the McCord Radiator and Manufacturing Co. in manufacturing a million of the M1917 helmets, breakage in the drawing and forming operations of the new type averaged 30% during manufacture of the first 200,000 helmets. This percent of breakage was progressively decreased through the continued study and experience of McCord, and the assistance of the Carnegie-Illinois Steel Co., until it leveled off at an average of slightly less than 2%, which may be considered better than normal with the problems involved.

3. In August of 1942 the breakage took a sharp upward trend from 2% to 7%. Through prompt investigation it was determined that the difficulty was due to a variation in the steel analysis, intended by the mill to improve ballistic properties. Corrective measures were taken to readjust the steel analysis and to screen out defectives at McCord. During this production period, 123,000 helmets were manufactured with the lots numbered 144-149 (lot number is stamped on the inside of helmet visor). Subsequently, reports from the field have been received, reporting approximately 4,000 cracked helmets out of 123,000 manufactured. An examination

COPY

Subject: M1 Helmet
To: Office of the QMG

Booth/ver
20 May 1943

of cracks shows that the cracks developed after some usage. It is reasonable to assume that additional such instances will occur. A helmet crack ordinarily does not exceed two inches, commencing at the brim. Ballistic resistance is lowered only if a missile strikes directly on the crack. Actual firing tests have indicated that even when struck directly on the crack ballistic resistance is not considerably lowered.

4. An indication on how helmets have been standing up in the field which has been gained by contacting several posts and camps and through complaints received in correspondence is as follows:

a. Ft. Meyer - Captain Cross, Post Q.M., advised on 4/19/43 that of 2,000 helmets issued, none reported cracked.

b. Ft. Belvoir - Mr. McLaren, C & E Warehouse advised on 4/19/43 of 25,000 helmets issued, none reported cracked.

c. Ft. Washington - Capt. Cannon advised on 4/19/43 that of 4,000 helmets issued, three were later turned in cracked.

d. Ft. Benning - Capt. Cross advised on 4/19/43 that of 50,000 helmets issued, a large number were turned in with broken "D" loops although none were turned in cracked. The "D" loops were of a special large type of which 50,000 had been fabricated for paratroopers. There will be no further manufacture of this style loop, inherently weak, as the regular M1 design is now standard for paratroopers.

e. Camp Livingston - Capt. Barringer advised on 4/19/43 that of 25,000 helmets issued, 18 have been turned in cracked. Sixteen of these helmets have been obtained by this office. Seven each were sent to McCord Radiator Co. and Watertown Arsenal for metallurgical study. Lot number of these helmets were among the 144-149 group from which a limited number of latent defects were believed to exist as noted in paragraph 3 above.

f. Camp Pickett - Information was received from Col. Pagatt that of approximately 85,000 men staged through Camp Pickett, 873 unserviceable helmets had been turned in. Capt. Whelan of this office visited Camp Pickett on April 24, 1943 to examine the helmets in question. The lot numbers of these helmets were in general confined to 35-42. The condition of these helmets such as dents, cracks, broken loops, straps, etc. appeared to indicate severe usage making it difficult to predict whether the cracks were latent defects confined locally in the above mentioned heat numbers and embracing a particular division by reason of carload shipments or whether they were the direct result of the abuse normally encountered in maneuvers and training work. This matter will be further investigated and an attempt will be made to gather additional information.

COPY

Subject: M1 Helmet
To: Office of the QMG

Booth/ver
20 May 1943

6. Africa - Information covered in files 00 421/2493, 0.0. 421/193(c), and 0.0. 421/20(6) advises that of 54,000 helmets inspected in the 5th Army, 5,168 were defective due to cracking. In order to determine whether such cracking was due to normal abuse or to latent defects, request was made of the Office of the Quartermaster General to obtain 100 representative samples for examination in this country. These helmets have been received at McCord and examination indicates that the majority were fabricated in August of 1942 of the lot numbers 145-148 in which steel difficulties were experienced and corrective steps as outlined above.

5. It is understood from your office that factors on which A.S.F. requirements are based is initial procurement 1.06, zone of the interior .106, and theatre of operations .53. The equivalent of this is understood to be that for 100 men initial helmet procurement would be 106, that 10.6 helmets per year would be supplied for replacement in the zone of the interior and 53 per year in the theatre of operations. The information available (paragraph 4 above) indicates that cracking in the field will amount to less than 1% of total production. Therefore the established maintenance factors appear adequate to cover replacement of these helmets.

6. Through close inspection control, manufacturing defects which can be observed are carefully screened out; however, in the mass production of an item such as the helmet, it is recognized that some defects may occasionally leak through. Where latent defects are present which cannot be observed in the final inspection, it is possible for a considerable number to pass inspection and reach the field before corrective action is commenced. It is also possible, through undue lateral flexing to crack the helmet since shape and materials employed have been selected primarily for ballistic resistance and head protection, with general utility value as a second consideration.

7. In light of the above it is evident that while the Ordnance Department has experienced difficulty with the cracking of helmets during manufacture, and with latent defects reaching the field, the latter amount has been relatively small, with vigorous steps being taken both in the line of product inspection and basic research to improve inherent steel characteristics. Maintenance factors, as stated in paragraph 5 above, recognize the replacement and repair of helmets as with other Army equipment. Accordingly, it is recommended that instructions be issued to the field, possibly in the form of a letter from the Adjutant General's Office to all theatres, commands and overseas bases. Such instructions might state, "As a result of field experience, it is evident that approximately 1% of the helmets manufactured have latent cracks which developed after field usage. In most cases the difficulty has consisted of one or two small cracks extending an inch or two up from the brim. They do not greatly impair the protective qualities of the helmet. Specific reports show that the majority of cracked helmets were made in the early stages

COPY

Subject: M1 Helmet
To: Office of the QMG

Booth/ver
20 May 1943

of manufacture and have heat numbers 144-149. The heat numbers may be read on the inside of the helmet directly under the front visor. It is recommended that a periodic inspection of helmets be made to locate and replace any helmets which have developed cracks. The heat numbers should be noted and any incidence of cracking outside the range of the above mentioned heats should be reported through proper channels."

8. Continued research and study are being carried on by McCord Radiator and Manufacturing Co., Carnegie-Illinois Steel Co., and by Watertown Arsenal to keep the present situation under control and to further improve steel analysis and forming practice. This office will appreciate being advised on the action taken with regard to the recommendation in paragraph 7 above.

For the Chief of Ordnance:

J. KIRK
Brig. Gen., Ord. Dept.
Assistant

COPY

HEWITT:js
73819

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON, D. C.

22 May 1943

O.O. 421/2302
Attn: SPOIS
W.A. 421/347

Subject: Helmet, Steel M1

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. Reference is made to a letter from this office dated April 27, 1943, advising your Arsenal of the defective helmets which were being forwarded your Arsenal for study. It is requested that your Arsenal locate the cracks in the helmet in your report as follows: From the center of the visor rotate in a clockwise direction in five (5) degree steps, indicating the location of the cracks as so many degrees in a clockwise direction from the center of the visor.

By order of the Chief of Ordnance:

(S/T) F. M. VOLBERG
Major, Ord. Dept.
Assistant

COPY

WAR DEPARTMENT
WATERTOWN ARSENAL
WATERTOWN, MASS.

LABORATORY
NAM/cmv

2 JUNE 1943

CHIEF OF ORDNANCE, U.S.A.

PENTAGON BUILDING, WASHINGTON, D. C.

SPOIS

OBSERVED INCIPIENT CRACKS ASSOCIATED WITH NOTCHES ON MCCORD M1 HELMET BODIES CAUSED BY DIE ACTION DURING BLANKING OPERATION. THIS CONDITION 35 DEGREES LEFT OF FRONT AND 12 DEGREES RIGHT OF FRONT COMMON TO ALL HELMETS ON HAND AT THIS ARSENAL AND RESPONSIBLE FOR MOST OF CRACKING ON HELMETS RETURNED FROM FIELD. INCIPIENT CRACKS UNDER BEADING ON NEW HELMETS. CONDITION NEVER SHOULD HAVE BEEN TOLERATED BECAUSE OF STRESS CONCENTRATION RESULTING. SUGGEST IMMEDIATE CHECK AND REMEDIAL ACTION. END. CITE MATTHEWS LABORATORY.

MATHER, WATERTOWN ARSENAL

G. L. COX
LT. COLONEL, ORD. DEPT.
ASSISTANT

COPY

BWA CDO 66

DET ORD DIST JUNE 3, 1943 BALDWIN IS

WATERTOWN ARS

REURTT MATTHEWS LABORATORY TT1031 CDO BWA 37 NC RE INCIPIENT CRACKS ASSOCIATED WITH NOTCHES. CONDITION HAS BEEN OBSERVED ON PAST TESTS BUT THIS O CANNOT CONCUR WITH HIS ARS THAT NOTCHES ARE PRIMARY CAUSE FOR CRACKS. HELMETS RECD FROM FIELD WILL BE OBSERVED FURTHER BY THIS O AS SUGGESTED. INTERNAL STRAIN SET UP AT 4 CRITICAL STRESS SECTIONS OF HELMET WILL CRACK WHETHER NOTCHES ARE REMOVED OR NOT. EDGE OF HELMET GROUND REGULARLY TO REMOVE EXCESS IRREGULARITY CAUSED BY TRIMMING DIE. SUGGEST METALLURGIST ARRIVE DETROIT AFTER JUNE 9 AS MR. H MOSER METALLURGIST AT FACILITY WILL BE OUT OF CITY BEFORE THAT DATE. TWX REQD COVERING SCHEDULE OF VISIT. END SPOEF 2044Z

QUINTON

W.A. 421/353

COPY

WAR DEPARTMENT
WATERTOWN ARSENAL
WATERTOWN, MASS.

LABORATORY
NAM/mpb

19 JUNE 1943

CHIEF OF ORDNANCE, U.S.A.

PENTAGON BUILDING, WASHINGTON, D. C.

SPOIS

OF 34 M1 HELMETS WHICH HAVE BEEN IN STORAGE AT THIS ARSENAL, 14 OR 41.2% HAVE CRACKS ASSOCIATED WITH NOTCHES AT BRIM. CRACKS AVERAGE 1/8 TO 3/16" LENGTH, LOCATED AT EDGE OF VISOR. END CITE LABORATORY MATTHEWS.

MATHER, WATERTOWN ARSENAL

G. L. COX
LT. COL., ORD. DEPT.
ASSISTANT

COPY

IMMEDIATE ACTION

Hewitt/ver
73819

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON, D. C.

4 Sept. 1943

O.O. 421/2880
Attn: SPOIS
Wtn 421/364

Subject: Helmet, Steel, M1

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. Your arsenal is being forwarded twenty helmets from the Detroit Ordnance District on shipping order, SAD 3396, inclosed herewith in duplicate. These helmets are representative samples of lots of helmets fabricated from Hadfield Manganese steel as manufactured by the Sharon Steel Co., Sharon, Penn. The helmets are to be listed as follows:

10 helmets which have cracked after aging and
10 helmets which have not cracked after aging.

2. Considerable difficulty has been encountered at the McCord Radiator & Mfg. Co. with the Hadfield Manganese steel as manufactured by the Sharon Steel Co. It has been found that helmets are cracking after being aged for approximately one week. It is believed that this steel is cracking as a result of precipitated carbides. It is desired that your arsenal make whatever study is deemed necessary in an attempt to determine the causes for these helmets to crack after aging. It is requested that this office be advised by indorsement hereon the results of your study.

By order of the Chief of Ordnance:

(S/T) F. M. VOLBERG
Major, Ord. Dept.
Assistant

1 Incl.
SAD 3396 in dupl.

COPY

IMMEDIATE ACTION

Wtn 421/364
O.O. 421/2880
Attn: SPOIS 1st Ind. Matthews/amv

C.O., Watertown Arsenal, Watertown 72, Massachusetts, 4 October 1943

To: Chief of Ordnance, Washington 25, D. C. Attn: SPOIS

1. Reference basic letter, the subject helmets, nineteen (19) of which were processed from steel lot Number 608A and one (1) from lot Number 643D have been received and given a preliminary examination with the following results:

10 Cracked Helmets

All from Lot 608A, after removal of the edgings it was found that every helmet had the crack associated with a notch caused by the trimming die. The position in every case was 333° in a clockwise direction from the center of the visor.

10 "Uncracked" Helmets

Three (3) helmets cracked at 333° position with notch as origin of crack.

Five (5) helmets with no cracks but notches present at the 333° position. The helmet from Lot 643D was one of these.

Two (2) helmets with no cracks and no notches at the 333° position.

All helmets were subjected to the magnetic test and judged satisfactory indicating that the steel was free from excessive decarburization or laminations.

2. It will thus be seen that the cracks are definitely associated with the notches resulting from the trimming operation since in the case of these helmets, which were probably processed on the same dies, notches occurred on eighteen out of the twenty in an identical location. The helmet body is in an extremely highly stressed condition as formed. Any stress concentration such as results from the presence of the notch will foster cracking. After six months of service in the field it is probable that many of the "uncracked" helmets would be in a condition comparable to those rejected for cracks at manufacture.

3. On 2 June 1943 the following teletype was sent to his office with a copy to the Detroit Ordnance District office:

COPY

IMMEDIATE ACTION

Wtn 421/364
O.O. 421/2880
Attn: SPOIS

1st Ind.
(Cont'd)

4 October 1943

"OBSERVED INCIPIENT CRACKS ASSOCIATED WITH NOTCHES ON MCCORD M1 HELMET BODIES CAUSED BY DIE ACTION DURING BLANKING OPERATION. THIS CONDITION 35 DEGREES LEFT OF FRONT AND 12 DEGREES RIGHT OF FRONT COMMON TO ALL HELMETS ON HAND AT THIS ARSENAL AND RESPONSIBLE FOR MOST OF CRACKING ON HELMETS RETURNED FROM FIELD. INCIPIENT CRACKS UNDER BEADING ON NEW HELMETS. CONDITION NEVER SHOULD HAVE BEEN TOLERATED BECAUSE OF STRESS CONCENTRATION RESULTING. SUGGEST IMMEDIATE CHECK AND REMEDIAL ACTION. END. CITE MATTHEWS LABORATORY. MATHER, WATERTOWN ARSENAL."

3. It is the opinion of the laboratory that these difficulties are not of such a character as may be solved by metallurgical examination. The processing is decidedly at fault; satisfactory helmets of this design cannot be produced consistently with the notched-edge condition. The McCord Radiator and Manufacturing Company must be made to realize that they are not forming the helmet from plain-carbon deep-drawing stock. Even in commercial deep drawn articles, the presence of notches at trimmed edges would be considered poor practice. It is suggested that drastic steps be taken, if necessary, to insure freedom from irregularities at the edges of the helmet body after trimming.

For the Commanding Officer:

(S/T) G. L. COX
Lt. Col., Ord. Dept.
Assistant

1 Incl. w/d

cc-SPOTB
Detroit Ord. Dist.

COPY

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON 25, D. C.

Hewitt/ver
73819

21 July 1944

Attention of
SPOIS

SUBJECT: Helmet, Steel, M1

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

Attn: Major N. A. Matthews

1. Attached herewith are duplicate copies of shipping order, SAD 3997, covering the shipment of the following helmets:

a. 5 helmets which have cracked selected from lots of helmets which have been rejected due to age cracking.

b. 15 helmets which have been tested for ballistics, selected from lots which have been rejected for ballistic reasons.

2. It is requested that these helmets be tested metallurgically to determine if there are any inclusions, excessive surface decarburization, or excessive precipitated carbides. It is requested that the results be submitted to this office by indorsement prior to the submission of a memorandum report.

By order of the Chief of Ordnance:

(S/T) F. M. VOLBERG
Major, Ord. Dept.
Assistant

1 Incl. (in dupl.)
SAD 3997

COPY

ARMY SERVICE FORCES
DETROIT ORDNANCE DISTRICT
1832 National Bank Building
Detroit 32, Michigan

Baldwin/mr

1 August 1944

DOD 160/3-56234
McCord Rad. & Mfg. Co.
Attention of
IS

Subject: Helmet M1

To: Watertown Arsenal
Watertown, Massachusetts

Attn: Major N. A. Matthews - Metallurgical Laboratory

1. Reference is made to the manufacture of Helmet M1 at the McCord Radiator & Manufacturing Company, Detroit, Michigan. The above facility has been experiencing some cracking in the body of the M1 Helmet at the approximate location of 200°. The facility has checked these helmets in every way but have not found a satisfactory answer, to date. It is requested that his Arsenal examine these helmets and try to ascertain what would cause this type of failure.

2. The following data, covering five (5) cracked helmets which have been forwarded to his Arsenal by railroad express along with three (3) ballistic failure helmets on 27 July 1944, will be described below. The five (5) helmets were taken from several Carnegie heats and McCord production lots.

a. Information covering the individual helmet identification.

McCord Lot & Lift #	Carnegie Heat Number	Carnegie Lift Number
864F	170292	70471
863B	130239	70417
861H	140304	70445
863A	130239	70429
864G	170292	70473

b. Information covering the drawing operation of the helmets.

Ordnance Lot #	Manufacturing Lot Size	Date Drawn	Cracked Helmets	Breakage Percentage
105	5980	10 July 1944	51	1.95%
108	5760	11 July 1944	17	3.1%
120	5100	15 July 1944	20	2.0%

COPY

Watertown Arsenal, Watertown, Massachusetts (Cont'd) 1 Aug. 1944

3. Regarding the three (3) helmets, which have failed ballistically, an explanation in the change of the testing procedure should be forwarded to his office at this time. Previous to this time, a sample was withdrawn from each 500 circles, then drawn into a helmet and ballistically tested. We have found that the drawing operation will produce as much as 19% of the production, below a thickness of .031". Taking circles at random, there was a good chance of selecting samples that would produce helmets with a thickness of .031" or heavier. This procedure is not in accordance with the intent of the specification, so the following teletype was forwarded to the Office of the Chief of Ordnance, outlining the change of selecting ballistic samples.

> Re helmet M1 spec AXS-645 rev 2 dated 10 Feb 1944 para F-3b PD Effective 1 August 1944 3% of each lift of steel but not less than 25 circles selected at random and drawn into helmets PD Sample to be measured and 15 thinnest will be used for ballistic test PD First test sample will be 5 thinnest helmets PD If a penetration is obtained at 725 ft/sec or lower using copper jacket .45 Cal bullet a double sample will be tested PD If one penetration is obtained with above velocity lot of steel will be rejected PD

4. Following the later procedure, this office obtained several ballistic failures in helmets whose thinnest section is or will be above a minimun thickness. It is requested that his Arsenal examine these samples and report his findings.

5. The following information covers the above helmets.

Date Drawn	Carnegie Heat#	Carnegie Lift #	McCord Lot & Lift #	Thickness After Draw	Velocity	Penetration
7-19-44	130297	70489	865G	.031	726	X
"	130239	70419	863C	.031	720	X
"	130239	70419	863C	.032	710	X

For the District Chief:

(S/T) P. J. JENSEN
Major, Ordnance Dept.
Assistant

COPY

Wtn 421/445
O.O. 421/3228
Attn: SPOIS

1st Ind. Hurlich/NAM/drj

C.O., Army Service Forces, Ordnance Department, Watertown Arsenal, Watertown 72, Mass. 4 August 1944.

To: Chief of Ordnance, Army Service Forces, Pentagon Building, Washington 25, D. C. Attn: SPOIS - Major F. M. Volberg

1. Reference basic letter, five (5) age cracked helmets, McCord Lots 861H, 863A, 863B, 864F, and 864G, have been subjected to metallurgical examination, from which it is concluded that the steel is of good quality with respect to those factors which have been investigated at this laboratory. The steel is reasonably clean, and is free from decarburization and precipitated or undissolved carbides.

2. The occurrence of the cracking at the approximate location of 200° suggests an unfavorable residual stress distribution in this zone which is one of the regions very susceptible to age cracking. Watertown Arsenal Laboratory Report No. WAL 710/673, entitled "Helmets - Determination of Residual Stresses in M1 Helmets", contains, on pages 20 through 23, an excellent summary of the factors influencing stress cracking and residual stress distribution. These factors are not related to the metallurgical properties of the helmet steel, but concern gage of the helmet sheet, alignment and surface condition of the forming dies, lubrication of the dies, hold down force and its distribution, temperature while forming, etc.

3. It is apparent from the above considerations that good steel quality is not alone sufficient to guarantee helmets that will not be susceptible to age cracking.

4. It is suggested that the McCord Radiator and Manufacturing Company be instructed to test samples of the remaining uncracked helmets from the same lots from which the 5 subject helmets were selected for susceptibility to age cracking. According to information supplied by the Detroit Ordnance District, the age cracked helmets were part of a group of approximately 16,000 helmets comprising Ordnance Lots Nos. 105, 108, and 120.

5. A satisfactory test to determine susceptibility to age cracking consists of immersing the helmets for 20-30 hours in a 5% solution of phosphoric acid in water. Acid etching of helmets as an accelerated test to cause cracking of helmets having a tendency to age crack was described in a letter to his office, Wtn 421/440, dated 11 July 1944. It is believed that many of the helmets in the lots from which the 5 cracked helmets were selected are susceptible to age cracking and should develop a high percentage of service cracking if they are accepted and issued to troops.

COPY

Wtn 421/445
O.O. 421/3228
Attn: SPOIS

1st Ind.
(Cont'd)

4 August 1944

6. If the helmets are painted, it will be necessary to remove the paint before attempting the acid etching test. This test can easily be performed at the McCord plant since a dilute phosphoric acid solution is customarily used at that plant to clean the helmets prior to painting.

7. Three (3) of the fifteen (15) helmets which were to be forwarded for examination because of ballistic failures have been received, and the examination of these helmets is in progress.

For the Commanding Officer:

(S/T) H. H. ZORNIG
Colonel, Ord. Dept.
Assistant

1 Incl. w/d

APPENDIX B

Correspondence on Visit to McCord Radiator and Mfg. Co.

COPY

W.A. 421/348 Laboratory(NAM)
D.O.D. 421/884 1st Ind. Baldwin/jm

Detroit Ordnance District, 1832 National Bank Building, Detroit, Michigan, May 28, 1943.

To: Commanding General, War Department, Watertown Arsenal, Watertown, Mass.

1. Reference is made to the reduction in the number of helmets and discs required, which was requested in paragraph 2 of the basic letter. This reduction would help this office and the McCord Radiator Company very much if it was possible for the facility to distinguish before hand, whether the material would crack in the drawing or spanking operations. To further complicate the cracking problem, this office has received reports that approximately 10 percent of the helmets are cracking after they leave the point of manufacture. This problem is being investigated very thoroughly by this office and McCord Radiator Company.

2. In a letter to the Chief of Ordnance, 1st Indorsement, D.O.D. 523/4159, dated May 22, 1943, this office requested that a meeting with representatives from his Arsenal, be held at the McCord Radiator Company as soon as practical. Until that time it is the thought of this office, that the development work on the cracking of helmets will be unorganized and each group will be working at cross purposes.

3. If personnel from his Arsenal can determine by micro-examination, before the drawing operation, whether the Hadfield Manganese steel will or will not crack, it is requested that the McCord Radiator Company and this office be informed. The metallurgist at the facility has not been able to definitely determine whether a disc will or will not crack before it is drawn.

4. If his office desires that the reduced number of helmets be shipped as taken from production, this office will be glad to comply. It is suggested that the shipment consist of helmets that are producing high and low percentage of cracking in the drawing and spanking operations. The discs could be taken before drawing operation under the above conditions.

For the District Chief:

P. J. Jensen
Major, Ord. Dept.
Assistant

AW A 5

BWA WAO B 106

C OF O MAY 31 2256Z 1943

WATERTOWN ARS

RE METALLOGRAPHICAL STUDY HELMET STEEL M1. DESIRE METALLURGIST FROM YOUR ARSENAL SPEND APPROXIMATELY THREE WEEKS AT MC CORD RADIATOR, DETROIT MICHIGAN, RE CURRENT STUDY OF STEEL HELMET. ADVISE THIS OFFICE EARLIEST DATE METALLURGIST WILL BE AVAILABLE. END CITE SPOIS HEWITT

KIRK

31 2332Z EB

WTN 421/350

COPY

W.A. 421/348
D.O.D. 421/884 2nd Ind. Matthews/mpb

C.O., Watertown Arsenal, Watertown, Massachusetts, June 2, 1943.

To: District Chief, Detroit Ordnance District, 1832 National Bank Bldg., Detroit, Michigan. Attn: Captain J. B. Scarborough

1. Reference your 1st Indorsement, the Office, Chief of Ordnance, SPOIS, has requested that a metallurgist from this Arsenal visit his District and the McCord Radiator and Manufacturing Company, reference the production of the M1 helmet by that company, and the recent reports of cracking tendencies under field conditions.

2. Mr. A. Hurlich, Assistant Metallurgist at this Arsenal, accordingly will arrive at his office on the morning of June 7, 1943. It is anticipated that Mr. Hurlich will be able to complete his survey and obtain the necessary information in approximately four days. His orders, however, will be written to cover a stay of one week if that becomes necessary.

3. It is desired that his office provide Mr. Hurlich with any helpful information available and that arrangements be made for his clearance in and out of the subject facility. It will also be possible for Mr. Hurlich to select samples from good and poor lots of steel with respect to percentage of breakage for his subsequent metallurgical study at this Arsenal. Reference second paragraph, it is considered highly desirable that a meeting be called at McCord shortly after Mr. Hurlich has returned to this Arsenal. This plan meets with the approval of the Office, Chief of Ordnance, and the meeting should include representatives from the Office, Chief of Ordnance, his office, this Arsenal, McCord, and the steel sources supplying the material for this operation.

For the Commanding Officer:

E. E. ZORNIG
Colonel, Ord. Dept.
Assistant

COPY

Hurlich/amv

14 June 1943

From: A. Hurlich - Armor Section

To: Colonel Zornig, Lt. Col. Cox, Major Matthews - Laboratory

Subject: Notes on Visit to the McCord Radiator and Mfg. Co. of Detroit, Mich. in Connection with Cracking of M1 Helmets

1. As a result of field experience it has been discovered that approximately 1% of all M1 helmets have latent cracks which develop after field usage, with considerably more cracking occurring in foreign service than within the United States. Of 54,000 helmets inspected in the 5th Army in Africa, 5,168 or 9.55% were defective due to cracking. Cracks, rarely more than 2" in length were found, some commencing at the brim and some occurring in the bodies of the helmets.

2. At least 500 cracked helmets were returned to the McCord plant for study and 7 forwarded to this Arsenal. Examination at this Arsenal indicated the cracking was frequently associated with notches and irregularities in the edge of the helmet shell, particularly at the visor. In one instance, cracking was associated with undissolved carbides in the austenitic Hadfield steel resulting from improper heat-treatment.

3. A visit to the McCord plant was planned for the purpose of studying their manufacturing procedure, to obtain information regarding the processing of the steel, and to select samples for metallurgical study at this Arsenal to - (a) decrease breakage during fabrication, and (b) eliminate, if possible, cracking of helmets in service.

4. The results of the preliminary study and the plant visit indicate that latent cracking may be traceable to at least three conditions:

a. Notches at the edge of the helmet shells.

b. Improper heat-treatment resulting in undissolved carbides in the austenitic manganese steel employed.

c. Unfavorable stress concentrations in four critical zones, at about -15-35°, 135-155°, 200-220°, and 320-340°, starting at the middle of the visor as 0° and proceeding in a clockwise direction.

5. The McCord plant is forwarding to this Arsenal numerous helmets that broke in the various stages of manufacture, some uncracked helmets for stress-relieving experiments, and some blanks from which helmets are stamped.

COPY

6. Lt. Hewitt, of the Industrial Division, Small Arms Branch, expressed concern about possible cracking which may develop in storage of M1 helmets after the termination of hostilities. He suggested that the 32 M1 helmets which have been at this Arsenal for the past year and a half have their edgings removed and the brims examined for cracks. Three or four of these helmets initially investigated revealed the formation of small cracks, approximately 1/4" long, at notches in the edge of the visor.

7. The Detroit Ordnance District Office will request that their inspectors insist upon complete removal of notches from the brims of the helmets. These notches were found to result from chipped edges on the trimming dies and can be corrected by more frequent dressing of the dies. It is estimated that 250,000 helmets are trimmed by a set of dies at the present time prior to dressing.

8. In conjunction with Captain Scarbrough of the Detroit Ordnance District, and Lt. Hewitt a program was outlined to study the cracking of helmets as well as some other features which arose during the preliminary study and discussions. This program includes:

a. Metallurgical examination of helmets that cracked during the various stages of manufacture.

b. Metallurgical examination of helmets that cracked in service, both foreign and domestic.

c. Metallurgical study of the welds between the stainless steel chin strap loops currently employed and the helmet shells.

d. Stress analyses of uncracked helmets to detect possible undesirable stress concentrations.

e. The application of various stress-relieving heat-treatments and other stress-relieving processes and the performance of subsequent stress analyses.

f. Experiments to improve the adherence of paint to the stainless steel edging strip applied to the helmet brims.

9. Several individuals expressed a desire to see the specification regarding the non-magnetic properties of the helmets be relaxed sufficiently to allow for the use of low carbon steel strip to replace the stainless steel edging. The McCord plant has been recently allowed to replace the stainless steel chin strap loops with low carbon steel, and the brass strap fittings with steel stampings. It is extremely difficult to make paint adhere to the stainless steel strip whereas it adheres well to carbon steel.

10. It is believed that many of the problems being encountered now in the production of the M1 helmet should have been dealt with in the early development stage of production. Since helmets are being made to this day that contain notches at the brim, it is felt that considerable cracking in service and in storage will continue to develop. Since the McCord plant does not purchase its steel to any specification, and improper heat-treatment is found to be a serious cause of breakage, it is recommended that specifications covering the Hadfield Manganese steel used in this application be drawn up.

A. Hurlich
Asst. Metallurgist

COPY

2 July 1943

From: A. Hurlich - Armor & Projectile Section

To: Major N. A. Matthews - Armor & Projectile Section

Subject: Investigation of Defective M1 Helmets

In accordance with the proposed program covering the study of the M1 helmet manufactured by the McCord Radiator and Mfg. Co., it is necessary to study the stress pattern produced in the helmet during the forming operation.

Examination of several hundred defective helmets discloses that cracks occur in the helmet body in four distinct zones:

Zone 1 35-60°
Zone 2 135-170°
Zone 3 190-235°
Zone 4 325-340°

starting from the middle of the visor as 0° and proceeding clockwise. These cracks occur in a region approximately $1\frac{1}{2}$-$2\frac{1}{2}$" up from the rim and extend vertically up and down.

It is proposed that the Applied Mechanics Section conduct tests on as many of the 10 uncracked helmets now at this Arsenal as necessary in an effort to correlate the cracking with areas of high stress concentrations.

It is desirable to have this information within four weeks.

A. Hurlich
Asst. Metallurgist

APPENDIX C

Initial Correspondence on Quality of Helmet Steel

COPY

MCCORD RADIATOR & MFG. CO.
DETROIT, MICHIGAN

October 14, 1941

Lt. Col. S. B. Ritchie
Chairman, Subcommittee for
Helmet Steels and Body Armor
War Department
Watertown Arsenal
Watertown, Mass.

Dear Col. Ritchie:

This will acknowledge your letter of October 8th with enclosures giving data on tests conducted on various type of helmets, for which I thank you.

In accordance with conversation I had with Dr. Reed at the meeting in Washington, we are forwarding today, by parcel post, nine pieces of Hadfield Manganese steel cut from helmets that broke in our drawing operation. These are marked with the Carnegie-Illinois heat numbers as well as our own. I might say that our heat No. 28C represents a particularly poor lot of steel from which we experienced a lot of breakage; No. 26B is what our people consider a good lot of steel; and No. 29A perhaps an average of what we may expect over a production run.

Carnegie-Illinois have been doing a lot of work on this proposition, particularly during the last month or two, and we are lead to believe that the characteristics of the steel will be held more closely in future shipments and, on the whole, we would say that steel we are now getting probably averages somewhat better in its drawing qualities than that supplied for the old style helmet, but, of course, the new draw is so much more difficult that the breakage has increased.

If anything of interest is developed in your examination of these samples, it will no doubt be interesting to the Committee as well as to this Company and to Carnegie-Illinois.

Yours very truly,

(S/T) P. L. Barter
Vice-President

PLB-o

COPY

WAR DEPARTMENT
WATERTOWN ARSENAL
WATERTOWN 72, MASS.

November 18, 1941

Wtn 470.14/11065
Attention of
LABORATORY

Mr. P. L. Barter
Vice Chairman, Subcommittee for
Helmet Steels and Body Armor
McCord Radiator & Mfg. Co.
Detroit, Michigan

Dear Mr. Barter:

We are submitting on the attached data sheet the results of the metallographic examination on the samples of Hadfield Manganese steel Nos. 26B, 28C, and 29A which were submitted with your letter dated October 14, 1941.

The results of this investigation indicate that failure was probably due to the presence of carbide stringers and grain boundary carbide in the material. It is believed that this condition can be corrected by a suitable quench, either an air blast or water spray, from 1800°F or by finishing on the mill at a higher temperature followed by rapid cooling. Carbide stringers are considered objectionable since they are potential planes of weakness during the forming operation.

Sample No. 26B which was considered a good lot of steel was relatively free from carbide segregations, see Figure I.

Sample No. 29A, representing the average lot, showed the presence of some carbide stringers, see Figure II.

Sample 28C which represented a lot of poor forming steel contained numerous carbide stringers and some grain boundary carbides, see Figure III.

Sample No. 26B had an average Rockwell C hardness of 41, while samples Nos. 29A and 28C had an average Rockwell C hardness of 46.

COPY

5/23/42 - rhm

Mr. P. L. Barter, 11/18/41, page 2.

We are sending copies of these results to Major Moore, Mr. Grodrian, Carnegie-Illinois Steel Corp., and to the Detroit Ordnance Office.

For the President of the Board:

Very truly yours,

(S/T) G. L. COX,
Major, Ord. Dept.,
Acting Chairman, Subcommittee for
Helmet Steels and Body Armor

2 Encls.
Data Sheet
Figs. I, II, III

cc - Major W. T. Moore
Mr. J. A. Grodrian
Detroit Ordnance Office

COPY

DATA SHEET

FIGURE I

Microstructure representative of three helmets from Lot 26B of steel with good forming properties having a great deal of strain lines caused by cold working operation. Large stringers of inclusions were found in the specimen cut in the longitudinal direction. Small circular inclusions were found near the surface of the steel plate.

X1000 MA-3756

FIGURE II

Microstructure representative of two helmets from Lot 29A of steel with average forming properties containing banded precipitated carbides. There were no strain lines found in the austenite grains. Small circular inclusions were found near surface of plate.

X1000 MA-3757

FIGURE III

Microstructure representative of four helmets from Lot 28C of steel with poor forming properties containing banded precipitated carbides. No strain lines were found in the austenite grains. There were small circular inclusions near the surface of the plate.

X1000 MA-3755

All specimens etched in Vilella's Reagent.

MICROSTRUCTURE OF HADFIELD STEEL

FIGURE 1

TYPICAL STRUCTURE OF GOOD FORMING STEEL

LOT # C.I. 225299
Mc C. 26B

VILELLA'S ETCH

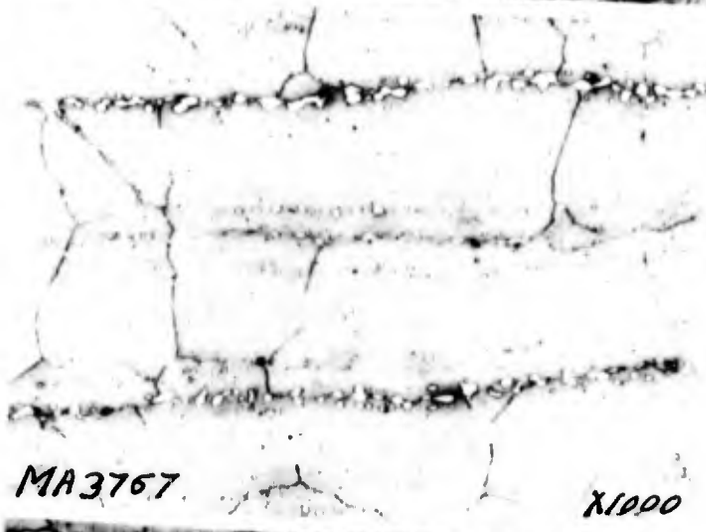


FIGURE 2

TYPICAL STRUCTURE OF AVERAGE FORMING STEEL

LOT # C.I. 175764
Mc C. 29A

FIGURE 3

TYPICAL STRUCTURE OF POOR FORMING STEEL

LOT # C.I. 254463
Mc C. 28C

W.A.639-4153

COPY

MCCORD RADIATOR & MFG. CO.
DETROIT, MICHIGAN

December 18th, 1941

Attention of
Mr. P. L. Barter

Major G. L. Cox
Watertown Arsenal
Watertown, Mass.

Dear Major Cox:

I wish to apologize for the delay in acknowledging your letter of November 18th submitting data sheet covering the results of your metallographic examination of samples of Hadfield Manganese steel submitted by our company. However, in the meantime you have received a copy of Carnegie-Illinois letter of December 1st, and we have received a copy of your reply thereto dated December 10th, together with photomicrographs, which plainly indicate the result of heat treatment.

I am pleased to advise that the results recently secured from various heats of steel coming from Carnegie have been more encouraging, and, with the work they are now doing, we are reasonably confident that our breakage in forming, caused by carbide segregation, is now on the way to elimination, or at least it will be reduced in the future to a minimum. I thought, however, you might be interested in the comments of our metallurgist, Mr. H. E. Moser, on Carnegie's letter of December 1st, so I am enclosing copy of our letter to them herewith.

Yours very truly,

(S/T) P. L. Barter
Vice-chairman, Subcommittee for
Helmet Steel and Body Armor

PLB-o
enc.

COPY

MCCORD RADIATOR & MFG. CO.
DETROIT, MICHIGAN

December 18th, 1941

Attention of
Mr. P. L. Barter

Mr. A. L. Kaye
Carnegie-Illinois Steel Corporation
208 South LaSalle St.
Chicago, Illinois

Dear Mr. Kaye:

Your letter of December 1st, commenting on a copy of a metallurgical report emanating from the Watertown Arsenal, was referred, upon receipt, to our Mr. H. E. Moser, who has submitted the following, which we are sending to you as a matter of record, as we are of the opinion that the matter in question is well in hand.

"We are desirous of being helpful in every way possible to aid in producing helmet steel of uniform drawing quality. With this thought in mind, we have been making a study of each heat of steel received to date. At the present status of our investigation, we feel we are not qualified to pass on the advisability of changing the carbon requirements of the U.S. Army Specifications."

"Briefly, the results of our study indicate that the present major factor is the amount and distribution of the carbide segregations. We have been able to complete the solution and retention of the carbides by annealing at 1850 degrees F. for six minutes and quenching in water. The grain-size increased to a size similar to heat No. 27 (Carnegie 175605) as received from the mill. This treatment increased the drawing quality as that the breakage dropped from 29 percent to six percent on a lot of 600 pieces. To obviate this factor requires that the minimum amount of carbides be allowed to segregate during the cooling period after hot rolling. That the annealing temperature and time be sufficient to complete the solution of these carbides, and that the steel be water quenched while the carbides are still in solid solution. Obviously this can be accomplished by rapid cooling after hot rolling, annealing temperature of approximately 1850 degrees F., annealing time as determined by microscopic examination and prompt quenching from the annealing temperature."

"A second factor that is indicated and will probably become predominate after the carbide factor is eliminated is the presence of inclusions as connecting stringers and in grain boundries. This condition probably is tied up with the melting practice. Due to our limited experience with heats having this factor exclusively, we simply mention it as a matter of information and for possible future consideration."

COPY

"Assuming that the steel mentioned as being on hand contains no other defects than the steel we have been receiving, it appears that obtaining the proper solution of the carbides will condition it for drawing."

We have also noted with interest Major Cox's letter of the 10th to you and the photomicrographs enclosed therewith, indicating quite definitely what heat treatment will do in the way of dissolving the segregated carbides.

Yours very truly,

(T)P. L. Barter
Vice President

PLB-c

APPENDIX D

Correspondence on Specification for Helmet Steel

COPY

IMMEDIATE ACTION
AIR MAIL SPECIAL DELIVERY

Hewitt/ver
73819

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON, D. C.

31 August 1943

Attn: SPOIS

Subject: Helmet, Steel, M1

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. Reference is made to telephone conversation between Major Matthews of your arsenal and Lt. Hewitt of this office relative to the study of steel for use in fabricating Helmet Steel M1. It is desired that your arsenal write a rough draft of the detailed requirements of Hadfield Manganese steel for use in fabricating Helmet, Steel M1. It is desired that these requirements include tests of the steel before fabrication into the helmet together with the detailed requirements of tests of the helmet after it is fabricated.

2. In the present study your arsenal is making on the causes for cracked helmets, it is desired to know what the effect is on the helmet of temperatures of -60° and +115°. It is understood that your arsenal is in a position to make such an analysis. It is requested that this office be advised by indorsement hereon the data to be included in the rough draft of the steel specification.

3. Inclosed herewith are two copies of specification AXS-645, covering Helmet, Steel, M1.

By order of the Chief of Ordnance:

(T) F. M. VOLBERG
Major, Ord. Dept.
Assistant

1 Incl. (in dup.)
Spec. AXS-645

COPY

RESTRICTED

W.A. 421/362
O.O. 421/2875 1st Ind. Matthews/drj

C.O., Watertown Arsenal, Watertown 72, Massachusetts, 17 September 1943.

To: Chief of Ordnance, Pentagon Building, Washington 25, D. C.
Attn: SPOIS

1. Reference basic letter, there are attached three (3) copies of a proposed draft of a specification covering the procurement of the steel sheet for helmets and body protection armor entitled Armor, Body Protection, Steel Sheet, Non-Magnetic. This draft represents the best information available at this arsenal at the time concerning the factors requiring control in the procurement of this material. The draft is submitted for consideration by his office.

2. Reference specification AXS-645, covering the Helmet, Steel, M1, this arsenal has the following comments:

a. Paragraph F-4. Magnetic Test. This test is not adequate and should be deleted. It has been found that a decarburized sheet having decidedly inferior ballistic properties will not cause deflection of the compass needle.

b. Security of attachment of chin strap clips. Many of the helmets produced have been unsatisfactory in this respect. A test should be devised to assure a strong attachment and the direction of the applied force should not be along the plane of the attachment clip but at an angle to this plane since the security of the attachment is greatly influenced by cracks or stress concentrations in and adjacent to the weld nugget respectively. It is understood that the Detroit Ordnance District office has been working on this problem. That office should be encouraged to complete a new design of the attachment clip and a test to determine the integrity of the method of attachment.

For the Commanding Officer:

(T)G. L. COX
Lt. Col., Ord. Dept.
Assistant

1 Incl.
Withdrawn 1 incl-Incl 1.
Added 1 Incl.
Incl. 2. Proposed Draft (in trip.)

COPY

Hewitt/ver
73819

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON, D. C.

Attn: SPOIS

27 November 1943

Subject: Helmet, Steel, M1

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. This office is in receipt of a copy of the comments on the specification for Hadfield Manganese Steel as received by your office from the Carnegie Illinois Steel Corp. It is desired that your office rewrite the proposed draft of specification in cooperation with the suggestions and recommendations of the steel mills that are feasible. It is believed that your office will receive the comments of the Sharon Steel Corp. within a few days.

2. This office should be advised by indorsement hereon when the proposed redraft of specification will be ready.

By order of the Chief of Ordnance:

(T) F. H. VOLBERG
Major, Ord. Dept.
Assistant

COPY

RESTRICTED

Wtn 421/387
O.O.421/2950
Attn: SPOIS

1st Ind. Matthews/amv

C.O., Army Service Forces, Ord. Dept., Watertown Arsenal, Watertown 72, Massachusetts, 22 December 1943.

To: Chief of Ordnance, Army Service Forces, Ord. Dept., Pentagon Building, Washington 25, D. C. Attn: SPOIS

1. Reference basic letter, attached are five (5) copies of the revised draft of the specification for Hadfield Manganese Steel. The comments received from Carnegie-Illinois Steel Corporation have been incorporated wherever feasible as well as those prepared by Mr. Hollady of the Specifications Unit - Technical Division together with the specification draft also prepared by Mr. Hollady. The comments in writing of the Sharon Steel Company have not been received, but it is felt that their opinions on the matter were probably rather completely expressed at the recent meeting on helmet steels held at this arsenal.

2. Should the specification appear satisfactory, prints of the photomicrographic standards can be provided by this arsenal when the numbers desired and other details are known.

For the Commanding Officer:

(T) H. H. ZORNIG
Colonel, Ord. Dept.
Assistant

1 Incl.
Specification (5 copies)

COPY

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON, D. C.

Hewitt/ver
73819

Attn: SPOIS

6 March 1944

Subject: Steel for Helmet M1 and Armor Flyer's

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. Reference is made to U.S.A. Specification AXS-1170 covering Steel, Non-Magnetic Sheet and Strip (For Body Armor). It is requested that your Arsenal compare the standards on the bend test, grain boundary carbides, grain size and stringer carbides as submitted by the Carnegie-Illinois Steel Corp. in an effort to make them government standards. These standards should be prepared so that they may become an increment part of the specification. It is requested that this office be advised if his Arsenal will be in a position to transpose the Carnegie-Illinois steel standards into government standards.

By order of the Chief of Ordnance:

(S/T) F. M. VOLBERG
Major, Ord. Dept.
Assistant

COPY

Wtn 400.114/14894
O.O.421/3028 1st Ind. Hurlich/NAM/amv

C.O., Army Service Forces, Ordnance Dept., Watertown Arsenal, Watertown 72, Massachusetts, 29 March 1944.

To: Chief of Ordnance, Washington 25, D. C. Attn: SPOIS - Major F. M. Volberg

1. At the meeting of the Helmet Industry Integration Committee held at the Sharon Steel Corporation on 16 and 17 March 1944, it was agreed to tentatively accept the metallographic and pictorial standards submitted by the Carnegie-Illinois Steel Corporation. Mr. M. J. Day has offered to supply this arsenal the prints necessary to assemble the required number of copies of the Carnegie-Illinois standards.

2. McCord, Schlueter, Sharon, and this arsenal already have copies of the Carnegie-Illinois standards. It is requested that this arsenal be notified of the number of additional copies desired so that the prints may be obtained from Mr. Day.

For the Commanding Officer:

(S/T)H. H. ZORNIG
Colonel, Ord. Dept.
Assistant

APPENDIX E

Correspondence on Helmet Industry Integration

Committee and Notes of Committee Meetings

COPY Matthews/amv

25 February 1944

From: Major M. A. Matthews - Armor Section

To: Colonel H. H. Zornig, Lt. Col. G. L. Cox - Laboratory

Subject: Helmet and Body Armor Steel Specification.

1. The writer attended meetings held at the Office, Chief of Ordnance, SPOIS, on 22nd and 23rd of February for the purpose of discussing the draft of the specification AXS-1170 with all parties concerned. The meeting on the first day was held with representatives of Carnegie-Illinois Steel Corporation and on the second day with representatives of Sharon Steel Corporation. Representatives of McCord Radiator & Mfg. Company attended the meetings on both days.

2. Major F. H. Volberg opened the meetings by stating the problem of producing a better ballistic helmet with less processing troubles such as draw breakage and age cracking. Major Volberg proposed a committee to undertake the coordination of all development work on helmets and the steel for helmets and body armor. This committee would be composed of a representative from each of the two companies producing the steel, each of the two companies fabricating helmets, SPOIS, and this arsenal. All interests represented at the meeting agreed that this was desirable. The committee, in the first phase of its activities, will visit the several agencies which have been doing work on the problem to assimulate all data and thoughts on the matter as presently understood. With this knowledge the committee will then be in a position to outline any experiments considered necessary. The first meeting of the committee was tentatively scheduled to be held at Watertown on 6 March 1944.

3. The requirements of the specification were reviewed in detail and minor modifications made to reduce the sampling required. Complete agreements were reached on all requirements except the ballistic values which cannot be determined until more data has been obtained. The steel companies will begin immediately to apply the specification on a non-rejection basis and samples for ballistic test from each lot will be forwarded to Watertown for test. This will enable the proper establishment of limits of acceptability for the bend, magnetic, microscopic and ballistic tests.

4. The McCord people are, of course, in favor of the steel specification. The writer stated that given perfect steel as far as can be determined, there is still the likelihood of age cracking. Changes in fabricating practice are indicated, but it will be difficult to effect such changes. The writer explained the probability of a carefully controlled shot blasting operation being helpful in reducing age cracking. Those present at the meeting agreed that it appeared to be one possibility which should be investigated.

M. A. MATTHEWS
Major, Ord. Dept.

COPY

Meeting of Helmet Industry Integration Committee

Watertown Arsenal, 6 and 7 March 1944

As a result of a meeting held at Washington, Office, Chief of Ordnance on 22 and 23 February 1944, a meeting was called at Watertown Arsenal for the purpose of forming a Helmet Industry Integration Committee to cope with the various problems confronting the helmet fabricators and the helmet steel producers. Captain Hewitt, of SPOIS, in explaining the organization of the Committee announced that General Kirk, Chief of the Small Arms Branch, Office, Chief of Ordnance, will be the Chairman, Major F. M. Volberg the Deputy Chairman, and that a representative of one of the four interested industrial organizations would be selected as the Operating Chairman.

During the course of the meeting, Dr. R. Beeuwkes, assisted by Mr. R. N. Hegge, kindly consented to present a discussion of methods of residual stress measurements as applied to the helmet problem. The various factors connected with service cracking of helmets were reviewed.

A listing of the attendance and a summary of the discussions follow:

ATTENDANCE

INDUSTRIAL REPRESENTATIVES

Individual	Organization
Mr. H. E. Moser	McCord Radiator and Mfg. Company
Mr. C. A. Schlueter	Schlueter Manufacturing Company
Mr. M. J. Day	Carnegie-Illinois Steel Corp.
Mr. C. W. Weesner	Sharon Steel Corporation

SERVICE REPRESENTATIVES

Capt. W. W. Hewitt	Office, Chief of Ordnance, Small Arms Branch
Capt. F. P. Calabrese	St. Louis Ordnance District
Mr. E. F. Baldwin	Detroit Ordnance District
Dr. E. L. Reed	Watertown Arsenal
Mr. A. Hurlich	Watertown Arsenal

COPY

SUMMARY OF DISCUSSIONS

1. Mr. H. E. Moser of the McCord Radiator and Manufacturing Company was elected Chairman of the Industry Integrating Committee on Helmets, subject to approval by his company.

2. Capt. W. W. Hewitt outlined the organization, scope, and purposes of the Industry Integrating Committee on Helmets, and explained some of the legal aspects regarding expenditure of funds and dissemination of information.

3. The various helmet programs being conducted at Watertown Arsenal were reviewed. These programs consist of:

a. Metallurgical examination of service cracked helmets returned from the field.

b. Metallurgical examination of helmet steel forwarded by the helmet fabricators and the steel producers.

c. Study of the stresses and stress distribution resulting from the cold forming of the helmet shell and visor.

d. Ballistic testing of helmet blanks to obtain further information regarding effect of gage of sheet upon the ballistic properties.

e. Study of the effect of thermal stress-relieving treatments upon the properties of austenitic manganese steel.

f. Study of the effect of shot blasting upon the ballistic properties and stress distribution of the M1 steel helmet.

g. Study of the ballistic and metallurgical characteristics of 50 German helmets forwarded from the North Africa theatre of operations.

4. More extensive ballistic testing of helmet blanks indicate the necessity for a downward revision in the ballistic resistance requirements of Specification AXS-1170.

COPY

5. The photographic standards prepared by the Carnegie-Illinois Steel Corporation covering the bend test and microscopic examination for undissolved and precipitated carbides and grain size were tentatively approved for use in conjunction with Specification AXS-1170. The final decision as to the acceptance of these standards will be dictated by the results of the fabricators' experience with steel which complies with the requirements of the standards. The Carnegie-Illinois Steel Corporation will supply Watertown Arsenal with copies of photomicrographs to prepare a sufficient number of the standards.

6. It was agreed to change the amendment to Specification AXS-1170 regarding chemical analysis of the helmet steel to read as follows:

E-1. Chemical Composition.

E-1a. Material shall meet the chemical requirements shown in Table I. The quantity of residual elements shall be reported with the heat analysis when the nickel is in excess of 0.25%, chromium in excess of 0.20%, and molybdenum in excess of 0.06%.

TABLE I, CHEMICAL REQUIREMENTS

Carbon, per cent	1.20 - 1.50
Manganese, per cent	12.00 - 15.00
Phosphorus, per cent, maximum	0.08
Sulfur, per cent, maximum	0.04
Silicon, per cent, maximum	.55

7. Samples of a heat of steel recently produced by the Carnegie-Illinois Steel Corp. containing 3½% nickel as an austenite stabilizer will be shipped to Watertown Arsenal for examination. Circles produced from this heat have already been shipped to McCord for fabrication into helmets. This heat will be closely watched throughout processing to determine if a nickel addition to the standard Hadfield manganese steel composition is beneficial.

8. It was decided that alloy additions to Hadfield steel should be investigated with a view to determine if:

a. The austenite can be stabilized to a degree that the danger of surface decarburization during processing would be markedly reduced.

b. The work hardening properties of the material can be modified so as to result in lower residual stresses and lower hardnesses upon deep drawing into helmet bodies.

COPY

9. It was proposed to collect all data pertaining to the helmet problem and to make a survey of the literature on Hadfield manganese steel to make available all useful published data to assist the committee in its investigations. Watertown Arsenal will be requested to furnish copies of the eight experimental and memorandum laboratory reports covering the various phases of the helmet problem investigated by its laboratory.

10. An electrical device developed at the Sharon Steel Corp. for the purpose of detecting surface decarburization is being submitted to Watertown Arsenal for comparison with the magnetic method proposed by Watertown and incorporated into Specification AXS-1170. The device will be approved as a substitute for the magnet if found satisfactory.

11. The inspection procedure for detecting helmets subject to delayed cracking was reviewed. It was agreed that the resulting storage problem is very serious. Attempts will be made to develop an accelerated test whereby cracking tendencies would be immediately revealed. Thermal cycles were proposed in this connection.

12. Dr. R. Beeuwkes described the methods by which residual stresses in helmets were measured. Resistance strain gages were cemented to the surfaces in the areas to be studied, and the metal around the gages was cut out of the helmet. The change in curvature resulting from the release of the constraint of the surrounding material produces changes in the electrical properties of the strain gage proportional to the change in the strain of the material. The stresses thus measured are called the cutting-out stresses.

Further stress measurements were made by etching away one side of the pieces having the strain gages cemented to the other side. The strain gages were protected with a coating of acid resisting paint. As the stressed metal is etched away, further changes in curvature result. In this way, stresses as high as 85,000 p.s.i. were measured. It was found that the maximum stresses occur in the areas most susceptible to service cracking. These areas also coincide with the regions of maximum hardness. Dr. Beeuwkes expressed the opinion that the residual stresses are of such magnitude as to be considered dangerous.

13. It was decided to hold the next meeting at the plant of the Sharon Steel Corp., Sharon, Pennsylvania, on 16 March 1944.

A. Hurlich
Assoc. Metallurgist

COPY

AGENDA FOR MEETING AT WATERTOWN ARSENAL
WATERTOWN, MASS.
6 March 1944

I. Steel Inspection:

a. Discussion of application of specification AXS-1170.

b. Examine manufacturing procedures to determine wherein specification AXS-1170 may be amended to become more effective.

c. Compile standards covering bend test.

d. Compare standards used by Carnegie & Sharon in detecting steel defects:

(1) Decarburization
(2) Precipitated carbides
(3) Laminations
(4) Grain boundary carbides

e. Set procedure for development of magnetic testing device for 100% inspection.

f. Proposals for new ingredients in steel to stabilize carbon, such as nickel. Austenite stabilizer: - 3½%

g. Development by steel mill of some method of fabricating steel as inspection instrument.

II. Fabrication of Helmet

a. Inspection procedure for detecting helmets subject to delayed cracks.

(1) Subject to aging period
(2) Subject to hot and cold chamber cycles.

b. Program for eliminating cause of delayed cracks:

(1) Application of specification AXS-1170 at fabricators plant in addition to application at steel producers.
(2) Heat discs to temperature 100°F to 400°F before being drawn.

(a) Determine optimum temperature by running samples of known good, and known bad lots of steel at varying temperatures.

(3) Application of two draw operation with full anneal between drawing operations.
(4) Thermal stress relief after fabrication.
(5) Stress relief or stress redistribution by shot blasting after helmet is fabricated.

COPY

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON

Davis/ik

00 334/3758
Attention of
SPOIS

11 March 1944

Subject: Helmet Industry Integration Committee

To: Commanding Officer
Watertown Arsenal
Watertown 72, Mass.

1. As you have already been advised, the Small Arms Branch is to organize a Helmet Industry Integration Committee. This will be effected at a meeting to be held at the Sharon Steel Corporation, Sharon, Pa., 16 March 1944. Watertown Arsenal will become a member of this committee ex officio in an advisory capacity. It has not been the policy of Ordnance that representatives from Ordnance or Ordnance establishments become active members of Integration Committees.

2. Mr. H. E. Moser of the McCord Radiator and Manufacturing Company, Detroit, Michigan, has indicated his willingness to accept the appointment of Assistant Chairman of the Committee. Due to the small size of the committee and the character of the work to be done, no Ordnance Officer will be especially assigned to it as Ordnance Representative. All matters usually assigned to such officers will be handled by the Hand Arms and Equipment Section under Major F. M. Volberg who is Chief of that Section.

3. Mr. T. G. Davis of this office will attend the above meeting in order to explain the provisions under which Integration Committees are to operate. It is understood that Watertown Arsenal will be represented.

By order of the Chief of Ordnance:

J. KIRK
Brig. Gen., USA
Assistant

(S/T) By: T. G. Davis
Exec. Asst., Industrial

COPY

Hurlich/MAM/drj

21 March 1944

From: A. Hurlich - Armor Plate

To: Major Matthews, Lt. Col. Cox, Col. Zornig - Laboratory

Subject: Meeting of Helmet Industry Integration Committee at Struthers, Ohio and Sharon, Pennsylvania Plants of Sharon Steel Corporation.

The entire day of the 16th and a portion of the morning of the 17th of March were spent in inspection of the production facilities of the Sharon Steel Corp. The second formal meeting of the Helmet Industry Integration Committee occupied the remainder of the 17th.

A list of the attendance, summary of the meeting, and a description of the facilities and the manufacturing procedure employed at the Sharon Steel Corp. follow. The agenda of the meeting is contained in the Appendix.

ATTENDANCE

INDUSTRIAL REPRESENTATIVES

NAME	PLANT
Mr. C. W. Weesner	Sharon Steel Corporation
Mr. W. J. McCune	Sharon Steel Corporation
Mr. W. J. Day	Carnegie-Illinois Steel Corporation
Mr. O. A. Schlueter	Schlueter Manufacturing Company
Mr. W. Schlueter	Schlueter Manufacturing Company
Mr. E. Walters	McCord Radiator & Manufacturing Co.

ORDNANCE REPRESENTATIVES

Major F. M. Volberg	Small Arms Branch, O.C.O.
Capt. F. P. Calabrese	St. Louis Ordnance District
Mr. T. G. Davis	Staff of Chief, Small Arms Branch, O.C.O.
Mr. E. F. Baldwin	Detroit Ordnance District
Mr. A. Hurlich	Watertown Arsenal

COPY

Summary of Discussion

1. Mr. T. G. Davis described the organization of the Helmet Industry Integration Committee, particularly with reference to its legal aspect and defined the scope and limitations of its activities. Booklets prepared at the Office, Chief of Ordnance, containing a list of the membership, the procedure of Industry Integration Committees, and a copy of Part 56 of Ordnance Procurement Instructions - "Ordnance Department Industry Integration Committees" were distributed.

The members of the Helmet Industry Integration Committee are the following:

Chairman	Brig. Gen. J. Kirk Chief, Small Arms Branch Office, Chief of Ordnance	Washington D. C.
Deputy Chairman	Major F. M. Volberg Small Arms Branch Office, Chief of Ordnance	Washington D. C.
Assistant Chairman	Mr. H. E. Moser Chief Metallurgist McCord Radiator & Mfg. Co.	Detroit, Mich.
Ordnance Representative	Capt. W. W. Hewitt Small Arms Branch Office, Chief of Ordnance	Washington D. C.

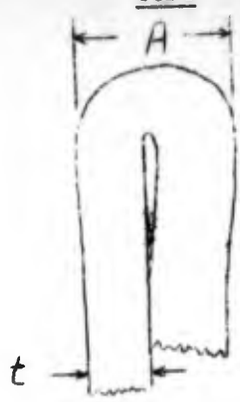
MEMBERS	PLANTS	REPRESENTATIVE
McCord Radiator & Mfg. Co.	Detroit, Michigan	Mr. H. E. Moser
Schlueter Mfg. Company	St. Louis, Missouri	Mr. C. A. Schlueter
Carnegie-Illinois Steel Corp.	Chicago, Illinois	Mr. M. J. Day
Sharon Steel Corporation	Sharon, Pennsylvania	Mr. C. W. Weesner
Watertown Arsenal	Watertown, Massachusetts	Mr. A. Hurlich

Watertown Arsenal is a member of this committee ex officio in an advisory capacity.

2. In the absence of Mr. H. E. Moser, who is seriously ill, Mr. M. J. Day was elected Temporary Assistant Chairman and conducted the remainder of the meeting.

3. It was agreed that the Bend Test, as described in Specification AXS-1170, was not defined precisely enough for referee work. It was decided that the minimum severity of the bend could best be standardized in terms of a micrometer measurement of the widest diameter at the bend as shown in the following illustration:

COPY



$$A = 2t + \frac{X}{1000} \text{ inches}$$

Watertown Arsenal was asked to suggest a suitable value of X to the Small Arms Branch, Office, Chief of Ordnance, within a few days.

4. The date of imposition of Specification AXS-1170 was changed from the 20th to the 25th of March 1944 due to the necessity of informing the concerned Ordnance District Offices of the waiver of the ballistic requirements because of the lack of the necessary range facilities and the need for revision of the ballistic limit requirements.

5. The heat of Hadfield steel containing 3½% nickel, described in the minutes of the previous meeting, gave excellent results when fabricated into helmets. Only 20 out of a total of 12,000 broke in either the drawing or visor spanking operations. It was reported that the deep drawing properties of the nickel bearing steel seem superior to those of the regular Hadfield steel apparently forming more easily, and having better ductility after severe cold working.

6. Surface decarburization presents a serious problem to the Carnegie-Illinois Steel Corporation because its manufacturing process involves hot rolling of the helmet sheet to the final gage. Mr. M. J. Day reports that the nickel addition by stabilizing the austenite, aids materially in over-coming the tendency to form brittle surface layers of martensite. Carnegie-Illinois desires to produce a large volume of the nickel modified Hadfield steel.

7. Due to the fact that the Carnegie-Illinois Steel Corporation claims that the imposition of Specification AXS-1170 would result in the rejection of at least 15% of its produce, Mr. M. J. Day reported that his company would be forced to raise the price of the steel manufactured to meet that specification. The nickel modified steel is also offered at an increased price.

8. During the discussion of alloy modified Hadfield manganese steel, the writer suggested that various companies known to have experimented with the addition of other alloying elements to austenitic manganese steel be contacted to obtain as much information as possible before the Committee recommends embarking upon experimental programs. It was agreed that either the Office, Chief of Ordnance or Watertown Arsenal will write for information from the following companies:

COPY

Stulz-Sickles Company	International Nickel Company
Taylor-Wharton Company	Union Carbon and Carbide Company

9. The Office, Chief of Ordnance, will consider the procurement of five heats of the nickel modified Hadfield steel, made by both open hearth (Carnegie-Illinois) and electric furnace (Sharon) processes. It is believed that the experience gained from these five heats will determine if the use of the modified alloy is justified.

10. A change in the wording of section 4c-3 of Specification AXS-1170 was recommended. The proposed wording is as follows:

"Decarburization shall be determined by measuring the depth of a non-austenitic layer on the surface. A depth exceeding 0.0005" shall be considered rejectable".

11. The results of two experiments performed at the Schlueter Manufacturing Company were reported. The first consisted of selecting a group of 6000 helmets immediately after fabrication; 2000 helmets had the edge of the visor carefully ground to remove all notches and irregularities, 2000 helmets had a 3/16" wide band at the edge of the visor annealed in a seam welding machine, and 2000 were left in the as-trimmed condition for the control sample. At the end of fifteen days only the 1 annealed helmet, 1 ground helmet, and 2 of the control samples developed visor cracks. The extremely low incidence of cracking in all three samples precluded any conclusions as to the effect of edge annealing and careful grinding of the edge of the visor.

In the second experiment, a number of uncracked helmets were selected from a group which after fifteen days aging developed visor cracks in approximately 50% of all helmets. Half of the samples had the visor edge annealed and the other half was retained as the control. At the end of fifteen days both groups showed the same percentage of cracking, namely 4.8%. The important difference was that the unannealed helmets developed cracks which extended up into the body of the helmet, averaging approximately 2" in length, while the helmets which were edge annealed developed cracks which extended up only to the boundary of the annealed band, roughly 3/16" wide, and in no cases extended beyond this zone. Had the stainless steel edging been spot welded around the rim of the helmet, the cracks in the visor of the edge annealed helmets would not be visible.

12. The Schlueter Manufacturing Company reports that some Sharon heats require an extremely large pressure to form the circles into helmets. Pressure gages are attached to their presses, and it was noted that occasionally some heats of steel required an average of 120 tons pressure, while other required but 80 tons to form into helmets. Considerable breakage always accompanies the higher drawing pressures. This is evidence of variation in steel properties. For some, as yet inexplicable, reason some heats of Sharon steel are stiffer and more resistant to elastic as well as plastic flow than other heats.

13. The Schlueter Manufacturing Company is at present experiencing a considerable amount of visor cracking, while the McCord Radiator and Manufacturing Company has no difficulty whatever with this type of breakage. The fact that Sharon steel is used exclusively at Schlueter indicates factors concerned with steel quality. On 3/21 visor cracking was reported at McCord.

14. Mr. C. W. Weesner of the Sharon Steel Corporation distributed a report covering metallographic examination of heats of Hadfield steel. The report checked similar work performed at this arsenal.

Manufacturing and Processing of Helmet Steel at The Sharon Steel Corporation

The Sharon Steel Corporation has two plants, one at Struthers, Ohio and one at Sharon, Pennsylvania approximately 17 miles away. The steel is melted, poured into ingots, and rolled into slabs at the Struthers plant, then rolled into strips, heat treated and cut into circles at the Sharon plant.

The melting unit consists of a 15-ton, 3-electrode, electric arc furnace. The change is predominately Hadfield scrap to which is added steel and ferro-manganese. The steel is poured into 4000 - 5000 pound ingots which after solidification are transferred into soaking pits. The ingots are rolled down to billets in a reversible mill, the hot top is sheared, and then the billets are rolled down to 2" thick slabs and sheared to length. After cooling, the slabs are inspected and defects are burnt out with gas torches.

The slabs are sent to the Sharon plant and are processed into helmet sheet as follows:

1.	slabs	2" thick
2.	Hot strip	17-3/8" wide and .109" thick
3.	Austenitize	Approximately 1800°F
4.	Pickle	Dilute H_2SO_4
5.	Tandem Roll	0.080" thick
6.	Austenitize	Approximately 1800°F.
7.	Pickle	Dilute H_2SO_4
8.	Tandem Roll	0.060" thick
9.	Austenitize	Approximately 1800°F.
10.	Pickle	Dilute H_2SO_4
11.	Tandem Roll	0.0420/0.046" thick
12.	Austenitize	Approximately 1800°F,
13.	Pickle	Dilute H_2SO_4
14.	Straighten and cut 83-3/8" long, 17-3/8" wide, .042/.046" wide	
15.	Blank each sheet into 5 discs, 16-1/2" diameter	

COPY

In heat treating, three coils of Hadfield steel strips are unrolled and simultaneously fed into an oil fired furnace having a maximum temperature of roughly 1950°F. The operation is continuous, the strips moving slowly through the furnace, emerging at the other end approximately three minutes after entering, and reaching a maximum temperature of approximately 1800°F. As the strip emerges from the furnace, it is struck by a water spray. The quench is very drastic, the strip turning black immediately upon contact with the water.

The steel is cold rolled from a thickness of 0.109" to the final gage of approximately 0.044" with three intermediate anneals. Due to the fact that the steel is not exposed to the atmosphere while hot, the process results in very little surface decarburization, and consequently Sharon steel is generally free from brittle martensitic surface layers.

It is reported that the finished helmet circles represent a 30% recovery of the total charge.

The electromagnetic device developed at Sharon for detecting surface martensite layers is extensively used at that plant. It appears to be a very useful tool, and can be applied for 100% inspection of the product without interference in production schedules.

The Olsen cupping test is applied as a routine test to all heats of steel. Electrically operated Olsen cup testers are employed, and the maximum pressures and the heights of the cups at fracture are recorded.

(S/T) A. HURLICH
Associate Metallurgist

COPY

APPENDIX

AGENDA

1. Discussion of Bend Test.

2. Hadfield Steel modified with alloy additions.

   a. Results of Carnegie heat containing 3-1/2% nickel.

   b. Further experimental programs.

3. Factors affecting age cracking of Helmets.

   a. Steel Quality.

   b. Manufacturing processes.

4. Imposition of Specification AXS-1170.

   a. Discussion of waivers to be made due to lack of ballistic testing facilities.

   b. Magnetic test, Sharon instrument vs. Alnico magnet.

COPY

WAR DEPARTMENT
WATERTOWN ARSENAL
WATERTOWN 72, MASS.

LABORATORY
AH/NAM/drj

21 MARCH 1944

CHIEF OF ORDNANCE
ARMY SERVICE FORCES
PENTAGON BUILDING, WASHINGTON 25, D. C.

SPOIS - MAJOR F. M. VOLBERG

RE STANDARDIZATION OF BEND TEST OF SPECIFICATION AXS-1170, THIS STATION RECOMMENDS MICROMETER MEASUREMENT OF THICKNESS AT BEND. MINIMUM SEVERITY OF BEND DETERMINED BY FORMULA A=2T +0.020 INCHES, WHERE A IS THICKNESS AT BEND AND T IS THICKNESS OF SHEET. END. CITE LABORATORY HURLICH.

MATHER, WATERTOWN ARSENAL

G. L. COX
LT. COL., ORD. DEPT.
ASSISTANT

APPENDIX F

Manufacturing Processes for Hadfield Manganese Steel at Carnegie-Illinois Steel Corp. and Sharon Steel Corp.

COPY

SHARON STEEL CORPORATION

Struthers, Ohio
Sharon, Pa.

Steel melted in 15-ton, 3-electrode arc furnace at Struthers plant. Charge is predominately Hadfield scrap to which is added steel and ferro-manganese.

Steel is poured into 4000 - 5000 pound ingots. Ingots rolled down to billets in reversible mill, hot top sheared. Billets rolled down to 2" thick slabs, sheared to length. Slabs are cooled, inspected, cleaned, and shipped to Sharon plant.

1.	Slabs	2" thick
2.	Hot strip	17-3/8" wide and .109" thick
3.	Austenitize	Approximately 1800°F.
4.	Pickle	Dilute H_2SO_4
5.	Tandem Roll	0.080" thick
6.	Austenitize	Approximately 1800°F.
7.	Pickle	Dilute H_2SO_4
8.	Tandem Roll	0.060" thick
9.	Austenitize	Approximately 1800°F.
10.	Pickle	Dilute H_2SO_4
11.	Tandem Roll	0.042/0.046" thick
12.	Austenitize	Approximately 1800°F.
13.	Pickle	Dilute H_2SO_4
14.	Straighten and cut 83-3/8" long, 17-3/8" wide, .042/.046" thick.	
15.	Blank each sheet into 5 discs, 16½" diameter.	

Finished helmet circles represent approximately 30% recovery of total charge.

Carnegie-Illinois Steel Corporation

South Works

Flow sheet for rolling of Hadfield Manganese Steel.

South Works

Open Hearth Furnace

Pouring temp. 2800°F

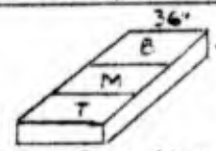
Ingot

One ingot - 15 tons

Soaking Pit - 24 hrs.
2050°F

60" - 2 high mill
36 passes to slab

Possible course



Slabbing Mill

Blooming Mill

One slab unless it contains flaws makes 1 lift -

2000 pieces - 250 sheets
10,000#

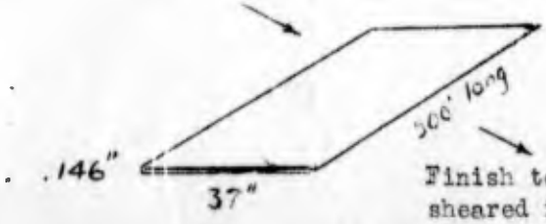
Slab is chipped or scarfed at 900-200°F

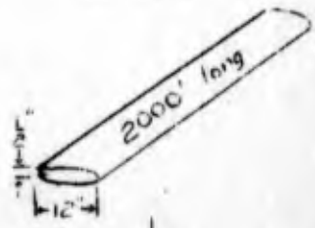
Bloom is chipped or scarfed at 900-200°F

While steel is still in the form of thick sections it must be kept hot.

96" plate mill
8 stand continuous mill

Bar mill





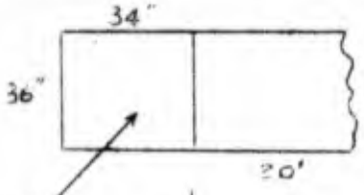
Finish temp. - 1400°F
sheared into 20' lengths.

Gary sheet mill

Gary sheet mill

Gary Sheet Mill

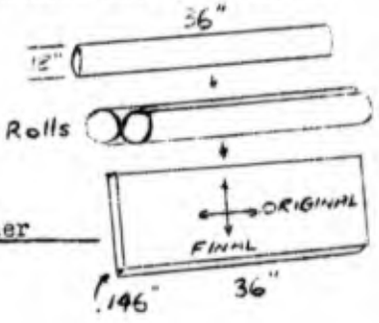
Strip .146 x 36" x 20 feet



Strip breakdown

Sheet bar ½ x 12" x 300 feet

Sheared into 36" lengths

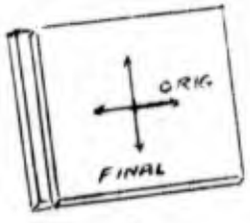


2 pieces rolled together

Hand Rolling Mill

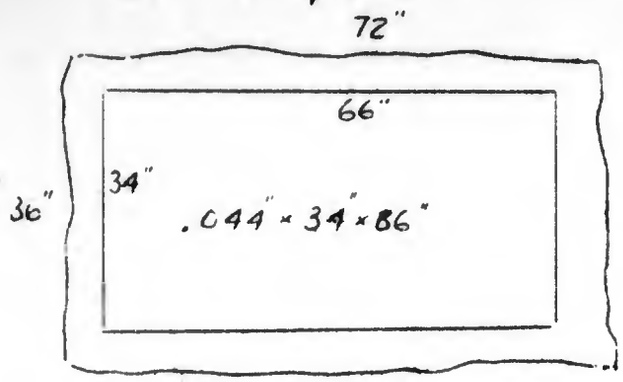
HR

2 high Reversing mill
1800 - 1200°F



Doubled

Reheated to 1800°F
HR - 2 high Reversing Mill



one sheet pack ⟶ 4 sheets

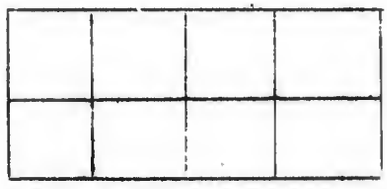
Heated 1840°F

Quenched cold water

Pickled

Oiled

Sheared into squares 17" x 17"



Circles sheared (16½" circles)

Inspected and crated

32 circles heat treated together in form of 4 sheets

4 sheets heated treated as ragged, warped, sheets.

APPENDIX G

Thermal Stress Relieving of Helmets

COPY

WAR DEPARTMENT
WATERTOWN ARSENAL
WATERTOWN 72, MASS.

Laboratory(NAM) 20 January 1944

Subject: Thermal Stress Relieving of Helmets

To: Chief of Ordnance
Army Service Forces
Ordnance Department
Pentagon Building
Washington 25, D. C.

Attn: SPOIS - Captain W. W. Hewitt

1. In reference to the telephone conversation of 15 January 1944 between Mr. Hurlich and Captain Hewitt, the following reasons are presented to show why this laboratory deems it inadvisable to advocate a thermal stress relieving treatment for the purpose of reducing or eliminating service cracking of the M1 Hadfield manganese steel helmet without first undertaking a rather elaborate and time-consuming series of experiments.

2. The discussion to follow includes not only limited experimental experience but also certain deduction of the Metallurgical Staff of this arsenal.

3. The problem of the thermal stress relief of an austenitic steel presents theoretical difficulties not encountered with ferritic steels. Austenitic manganese steel is a relatively unstable alloy, decomposition to martensite and precipitation of carbides occurring either upon heating at sub-critical temperatures or upon cold working. Howe[1] and Hall[2] have demonstrated that cold working results in both the formation of martensite and the precipitation of carbides in the slip lines, while both Hall[2] and Niconoff[3] found that tempering the water quenched manganese steel to temperatures above 450°C. (840°F.) results first in the precipitation of carbides at grain boundaries and needles of carbides in the austenite grains and then the formation of fine nodular pearlite growing around the carbide nuclei. The microstructural changes occurring both upon cold working and heating are accompanied by increases in the hardness and brittleness of the material.

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1. H. M. Howe - "Are the Deformation Lines in Manganese Steel Twins or Slip Bands?" Trans. A.I.M.E. (1915) 51, 881.
2. J. H. Hall. "Studies of Hadfield's Manganese Steel with the High Power Microscope". Henry Marion Howe Memorial Lecture. Transactions of the Iron and Steel Division of the A.I.M.M.E. (1929) 84, 382-427.
3. D. Niconoff. "Some Aspects of Strain Hardenability of Austenitic Manganese Steel". Trans. of the A.S.M. Vol. XXXI, No. 3. Sept. 1943. pages 716-734.

COPY

Subject: Thermal Stress Relieving of Helmets 20 January 1944
To: Chief of Ordnance, A.S.F., Ord. Dept., Pentagon Bldg., Washington 25, D.C.
Attn: SPOIS - Captain W. W. Hewitt

4. There is reason to believe that severe cold working will lower the temperature at which carbide precipitation and transformation to martensite will begin upon heating. Niconoff[3] reports microstructural changes occurring upon tempering cold worked manganese steel at 400°C. (750°F.), and tests conducted by personnel of the Detroit Ordnance District Office[4] upon cold formed helmets indicate the occurrence of carbide participation at temperatures as low as 625 F. (330 C.). Hardness surveys made at this arsenal upon numerous helmets show that several areas have been cold worked to a very severe degree, having hardnesses of 50-53 Rockwell C. These areas are the same ones in which service cracking predominates, indicating a relationship between severe straining and helmet breakage. The effect of thermal treatment upon severely strained austenitic manganese steel must be determined, and it will be shown that the determination must necessitate a long period of time.

5. Approximately one year ago, the following test was conducted at the McCord Radiator and Manufacturing Company. A group of helmets was stress relieved at a temperature of approximately 500°F. The ductility of some of the stress relieved helmets was determined by compressing them between the jaws of a tensile machine, and noting the compression required to produce cracking of the helmet. Some improvement in ductility over the as cold worked condition was noted. Six months later, the remainder of the stress relieved helmets were subjected to the same test and were discovered to be more brittle than those in the as cold worked condition, indicating that during the six months, decomposition of the austenite had occurred in a degree sufficient to increase the brittleness of the material.

6. Work by Hadfield and Hopkinson[5] shows that the decomposition of austenitic manganese steel is both a temperature and time dependent reaction. This latter statement and the experiment described in paragraph 5, above, demonstrates that the effect of prolonged time at room temperature subsequent to a thermal stress relieving treatment must be investigated. It is the belief of this laboratory that a thermal stress relief at some temperature in the range of 400-600°F. will decrease the stability of highly strained austenite to such an extent that decomposition and carbide precipitation will occur after a finite time at room temperature, the exact length of time depending upon the stress relieving temperature and the time at temperature.

7. Work has been initiated at this arsenal upon the problem of thermal and mechanical stress relieving but reliable data will not be immediately available because the nature of the problem is such that the effect of the time factor, as explained in paragraphs 5, and 6, must be investigated.

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3. See footnote 3.
4. Letter, File DOD 400.163/25042-752 SA
5. R.A. Hadfield and B. Hopkinson, "The Magnetic and Mechanical Properties of Manganese Steel". Journal of the Iron & Steel Institute (1914) Vol. LXXXIX, No. 1, pages 106-137.

COPY

Subject: Thermal Stress Relieving of Helmets 20 January 1944
To: Chief of Ordnance, A.S.F., Ord. Dept., Pentagon Bldg., Washington 25 D.C.
Attn: SPOIS - Captain W. W. Hewitt

8. It is suggested that the opinions of the metallurgists of the Taylor-Wharton Iron and Steel Company, of High Bridge, New Jersey: of the Stulz-Sickles Co., 134-142 Lafayette St., Newark, New Jersey; of the Jessop Steel Company, Washington, Pennsylvania; and of Mr. John Howe Hall be sought. The Stulz-Sickles Co. has investigated the effects of additions of nickel, chromium, and molybdenum to Hadfield manganese steel. The Taylor-Wharton Iron and Steel Company has produced Hadfield manganese steel and has conducted extensive research upon its properties. Mr. John Howe Hall was formerly Chief Metallurgist of the Taylor-Wharton Company and is now a consulting metallurgist. His address is 6802 Lincoln Drive, Germantown, Pennsylvania.

For the Commanding Officer:

(S/T) H. H. ZORNIG
Colonel, Ord. Dept.
Assistant