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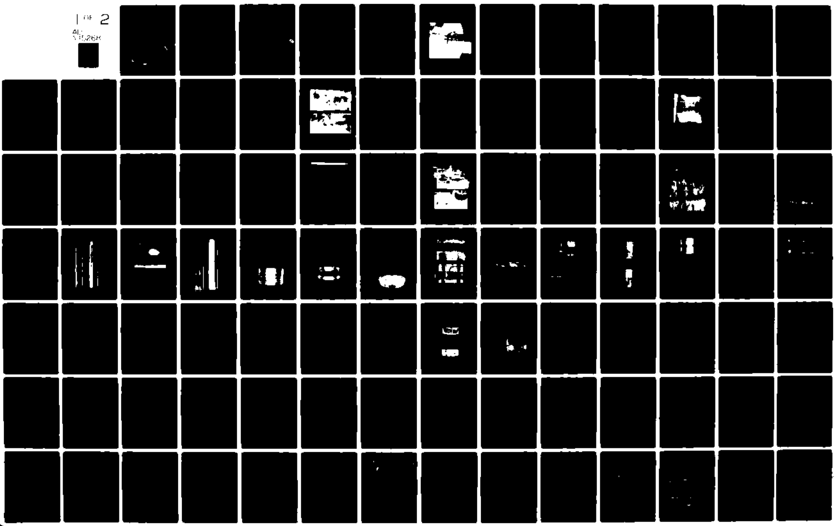

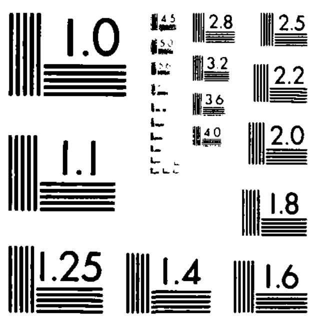

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INVESTIGATION OF INERTIA-WELDING PROCESS FOR APPLYING GILDING METAL ROTATING BANDS TO PROJECTILE, 155-MM, M483A1

Warren Depperman

Chamberlain Manufacturing Corporation
East 4th and Esther Streets
Waterloo, Iowa 50705

JULY 1978

FINAL TECHNICAL REPORT FOR PERIOD 29 MARCH 1976 - 31 MARCH 1978
CONTRACT DAAA25-76-C-0345

Prepared for

U.S. ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND (ARRADCOM)
Dover, New Jersey 07801

Chamberlain

Chamberlain Manufacturing Corporation
Research and Development Division

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M483A1	Inertia Welding	Rotating Bands	Calibration
8-Inch	Welding	Scanning	Transducers

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Contract DAAA25-76-C-0345 was conducted by Chamberlain Manufacturing Corporation to develop inertia welding as a process for assembling 90 Cu/10 Zn gilding metal rotating bands to AISI 1340 steel bodies used with the 155-mm, M483A1 Projectile. As a result of the effort it was demonstrated that the process is practical and, with some additional effort to gain insight into the effects of several variables, can be made into an efficient, cost effective production operation. Under a modification

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19. Key Words (Continued)

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20. Abstract (Continued)

to the contract, the Company also demonstrated the feasibility of welding the two copper rotating bands to the 8-Inch, M509 Projectile. The program isolated the three most important machine parameters as: (1) flywheel moment of inertia, (2) flywheel angular velocity, and (3) axial thrust delivered by the machine ram which results in radial pressure at the weld interface through action of the collet draw ring. These combine to isolate the energy transfer rate as the primary process parameter, governed by: (1) coefficient of friction between components, (2) relative velocity between components, and (3) the normal force between the sliding surfaces. Recommendations are made for exploring related aspects such as the effect of body heat treatment on banded projectiles, and establishing methods of monitoring the inertia welder to automate the process. Ultrasonic scanning is an effective inspection technique, and results from ultrasonic scans were verified by both local laboratory destructive tests and dynamic firing tests at Charge, Zone 8, 145°F, the worst firing condition. An economic analysis indicates a savings of $.836 per projectile over the welded overlay banding process when considering a production rate of 21,600 M483's per month.

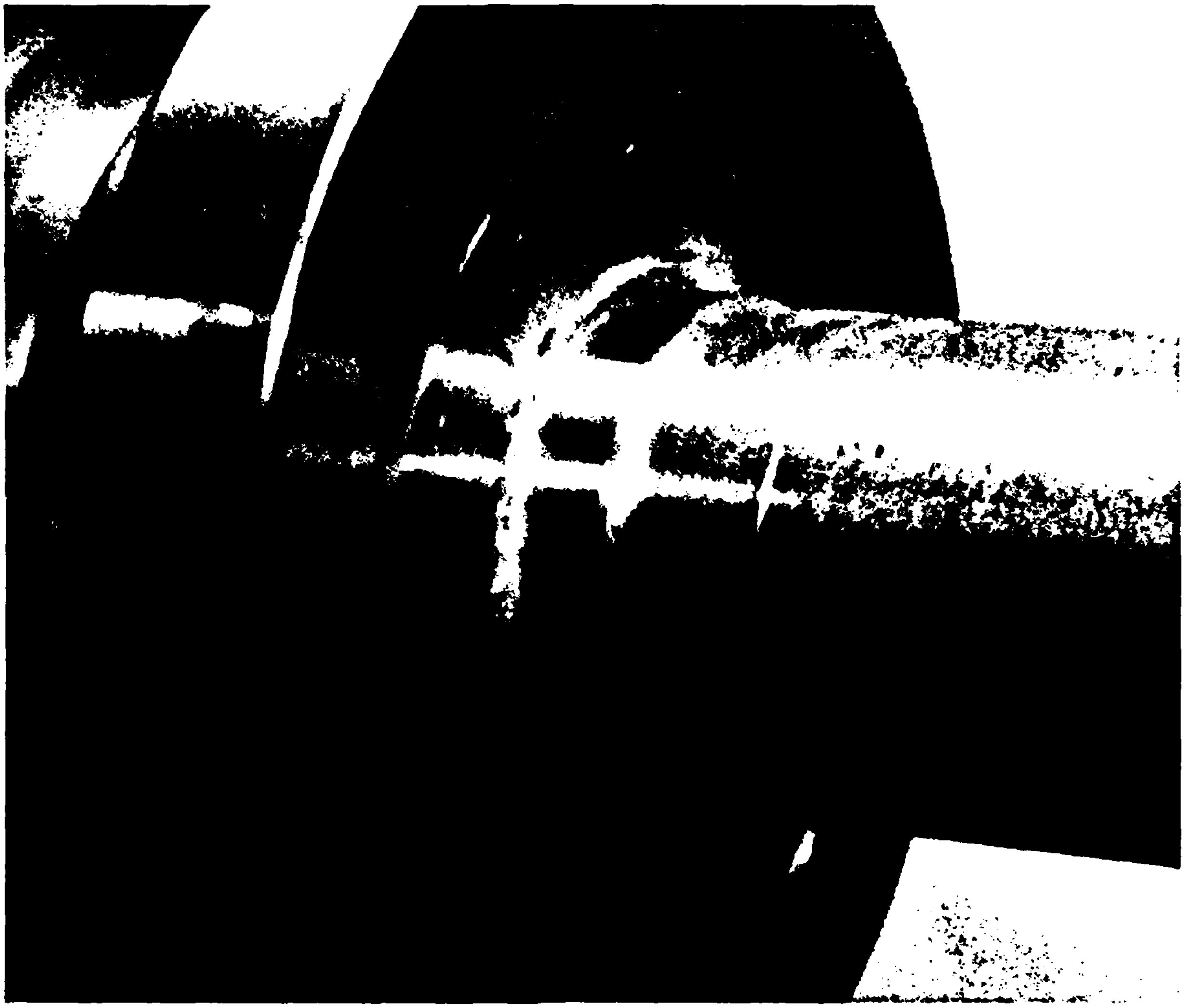
ABSTRACT

This Report provides a summary

Contract DAAA25-76-C-0345 was conducted by Chamberlain Manufacturing Corporation to develop inertia welding as a process for assembling 90 Cu/10 Zn gilding metal rotating bands to AISI 1340 steel bodies used with the 155-mm, M483A1 Projectile. As a result of the effort it was demonstrated that the process is practical and, with some additional effort to gain insight into the effects of several variables, can be made into an efficient, cost effective production operation. Under a modification to the contract, the Company also demonstrated the feasibility of welding the two copper rotating bands to the 8-Inch, M509 Projectile. The program isolated the three most important machine parameters as: (1) flywheel moment of inertia, (2) flywheel angular velocity, and (3) axial thrust delivered by the machine ram which results in radial pressure at the weld interface through action of the collet draw ring. These combine to isolate the energy transfer rate as the primary process parameter, governed by: (1) coefficient of friction between components, (2) relative velocity between components, and (3) the normal force between the sliding surfaces. Recommendations are made for exploring related aspects such as the effect of body heat treatment on banded projectiles, and establishing methods of monitoring the inertia welder to automate the process. Ultrasonic scanning is an effective inspection technique, and results from ultrasonic scans were verified by both local laboratory destructive tests and dynamic firing tests at Charge, Zone 8, 145°F, the worst firing condition. An economic analysis indicates a savings of $.836 per projectile over the welded overlay banding process when considering a production rate of 21,600 M483's per month.

Chamberlain

Chamberlain Manufacturing Corporation



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INERTIA WELDING GILDING METAL ROTATING BAND TO 155-MM, M483A1 PROJECTILE BODY.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 This is a summation of work accomplished on Contract DAAA25-76-C-0345 which was received on 2 April 1976. Chamberlain was required to perform the following tasks.

1. Establish welding parameters to provide an acceptable weld consistently.

2. Finalize rotating band blank and band seat design.

3. Finalize tooling design for the inertia welder.

4. Optimize ultrasonic inspection techniques for inspecting weld continuity, and establish standards.

5. Determine inertia welding machine requirements to perform inertia welding of the rotating band to the 155-mm, M483 Projectile on a production basis.

6. Provide a complete description of the welding process including drawings of tooling, welding parameters, band and band seat design, process controls, and inspection procedures and standards.

7. Prove the viability of the welding process through ballistic testing at Yuma Proving Ground. A minimum of 30 and a maximum of 60 projectiles will be fired during the ballistic testing phase.

8. Make a production run of 970 to 1,000 projectiles using the established process and inspection procedures. A "map" of the weld interface, as determined by the ultrasonic inspection equipment, will be supplied for each projectile.

9. Provide a thorough economic analysis comparing inertia welding to overlay welding.

Item No. 8, above, was reduced to 450 projectiles when the contract was modified during June 1976 to include welding of the two rotating bands to a minimum of 20 each 8-Inch, M509 Projectiles. The reduction in quantity for the 155-mm, M483A1 paid for the tooling required for the M509.

1.2 Consistent, high quality band welds were achieved on 236 successive projectiles during February and March 1977. These were achieved using standard, machined band seats from the New Bedford Defense Products Division

M483A1 production line. The tooling sustained no breakdowns. Ultrasonic inspection was established as a viable inspection method, and a phased array transducer setup appears capable of inspecting body assemblies 100% at normal production rates. The 70 rounds which were fired, plus local laboratory tests, have corroborated ultrasonic scans, since almost all failures occurred where the scans had indicated areas of poor bonding at the band-body interface.

1.3 At the conclusion of the program Chamberlain had isolated three machine parameters basic to achieving good welds and had determined that the energy transfer rate is of prime importance. With the thrust bearing collet arrangement which compresses a spinning band onto a stationary body, machine ram force was found to be the key factor for speeding the energy transfer rate. This aspect of the process could not be explored fully for two reasons: (1) above 2,200 rpm spindle speed we tended to lose bands out the forward end of the headstock collet, and (2) we were operating our ram at 10% above the design operational limit of the machine. Both of these problems were taken into consideration when a Purchase Description was prepared for a machine to be procured for the Mississippi Army Ammunition Plant. These two facts also influenced the Company's recommendations (Section 3) which were made to help achieve a comprehensive, cost efficient manufacturing process.

1.4 In addition to dynamic firing tests there are several laboratory tests which, while being destructive tests, are more economical than dynamic firing and show promise of being good predictors of ballistic performance. These are shear tests, dye penetrant examination, peel tests, and acid etching -- a variation of the peel test which was not explored fully under this program. All of these tests would be useful in studying the effects of projectile body heat treating on any areas of disbond. Late in the program the discovery was made that the heat treatment cycle enhanced ultrasonic response to areas of disbond, indicating that ultrasonic inspection should be performed after heat treating. However, there was no evidence that fully bonded interfaces were affected. Time and funds were depleted before this effect could be explored fully.

1.5 In an economic analysis prepared during April 1977 inertia welding was compared to two types of overlay welding -- the first being the voltage feed back controlled welders with four-minute cycle operated at the New Bedford Defense Products Division of Chamberlain. The second was the laser external adaptive control welder with three minute cycle which was slated to replace the voltage feed-back controlled machine. In the first 12 months of operation at a production rate of 21,600 per month, inertia welding would result in a saving of $151,389 over the laser controlled overlay welders, and $216,690 over the mechanically controlled overlay welders. The savings accrue primarily from the speed of the inertia welder, requiring fewer machines, less energy, less maintenance, etc. With amortization, transportation and installation costs taken into account, there is a net saving of $.836 per projectile for a quantity of 259,200 spread over a year. These are 1977 prices, but the savings ratio should be the same, even with inflation affecting machinery prices and operation costs.

2. CONCLUSIONS

The following conclusions are based on effort summarized in this report, results of dynamic firing tests conducted at Yuma Proving Ground, related action not funded under this contract -- but reported in monthly reports for this contract, and previous work conducted under Contract DAAA25-74-C-0492 where feasibility was established.

2.1 It is practical to inertia weld a 90/10 gilding metal rotating band to the AISI 1340 steel body of the 155-mm, M483A1 Projectile. The study has isolated several factors which, with an additional effort to add to the state-of-the-art, can result in an efficient, cost effective production operation.

The above conclusion was based on several occurrences. During February and March 1977 the Company ran 236 successive welds which checked out excellent using ultrasonic inspection equipment prior to heat treatment. The latest firing test of 37 rounds at Yuma Proving Ground was a success when firing at maximum charge (Zone 8) at elevated temperature (+145°F). Two projectiles sustained loss of approximately 1/2 square inch of rotating band material under this severe firing environment. One of these projectiles was Round 23B which was banded before heat treatment. Ultrasonic scans had shown this round to be the "worst sample". The other projectile was Round 4A which was banded after heat treatment and had a sound weld as shown by the results of ultrasonic scanning. It should be noted, however, that both rounds impacted within acceptable dispersion limits within the group.

2.2 Ultrasonic inspection is an acceptable test method for checking the weld interface.

With the above-described single exception, returned rounds from firing tests indicated correlation between ballistic results and the ultrasonic scans -- with failures occurring where the scans indicated that bonding at the band-body interface was suspect. Local destructive laboratory tests, such as the peel test, shear test, and chemical etching also showed a correlation with predictions of ultrasonic test data. Some experiments conducted during December 1977 showed that phased array transducers with appropriate electronics would allow ultrasonic inspection to keep apace with production on a 100% inspection basis.

2.3 Three machine parameters have been isolated as basic to achieving good welds. These are: (1) flywheel moment of inertia expressed as a weight moment of inertia in units of pound-feet squared, or WK^2, where W is the weight of the flywheel in pounds and K is the radius of gyration in feet, (2) flywheel angular velocity, expressed in revolutions per minute (rpm), and (3) axial thrust delivered to the system by the inertia welder ram which holds the projectile body stationary, expressed in pounds.

The total energy stored in the system is a function of the flywheel moment of inertia and its angular velocity, expressed as:

$$\text{Total Energy} = \frac{WK^2\ (\text{rpm})^2}{5{,}873}\ \text{ft-lb}$$

To complete a weld, energy is required to heat the interface materials to a temperature where welding can occur. On butt welds with steels and certain other materials of a given cross-sectional area, this energy level is fairly predictable from empirical data generated by the machine manufacturer. However, for the type of weld accomplished on this program, very little is known about energy level requirements.

2.4 Energy level in itself is not a primary process parameter for producing a sound weld, but the energy transfer rate is primarily important. This is true because the gilding metal rotating band is an excellent heat conductor, and if the energy input is slow, most of the heat will be conducted to the collet and the rotating band will never reach welding temperature. In order to reach welding temperature, the energy must be dumped into the band very rapidly.

2.4.1 The energy transfer rate is governed by: (1) the coefficient of friction between the components to be welded, (2) relative velocity between components, and (3) the normal force between the sliding surfaces. The coefficient of friction is governed by component materials, surface finishes, and surface contaminants. All of Chamberlain's experience indicates a high energy transfer rate is desirable; therefore, any surface contaminants which can act as a lubricant must be avoided.

2.4.2 The basic component materials are fixed; therefore, that aspect of the coefficient of friction is fixed. Surface finishes can be varied, and the Company studied this aspect during the program. It appears that rough surfaces provide higher coefficients of friction, but roughness should not be so exaggerated that there are voids at the weld interface. An optimum surface finish still is not known. However, excellent results were achieved with band seat finishes received "as machined" from New Bedford Defense Products Division of Chamberlain. Since one objective of the program was to develop a process adaptable to existing production practice, standard band seat dimensions and finishes appear acceptable. It should be noted that preparatory to banding bodies which had been heat treated, some of the seats had furnace scale and discoloration present which the Research and Development Division removed by sanding -- in effect, providing a smoother band seat surface. Welding proved difficult. At first, the difficulty was attributed to hardness and the possibility of in-depth furnace contamination, but the difficulty may have been caused by the smoother band seat surface.

2.4.3 The relative velocity between the band and body is governed by flywheel angular velocity and the perimeter of the surfaces, which is an initial setting on the machine and cannot be controlled once the machine cycle is underway. Apparently this factor should be as high as possible for two reasons: (1) the higher the surface velocity, the higher the transfer rate, and (2) with all other factors being equal, the weld begins to seize at a given angular velocity. For a given energy input to the weld, a smaller amount of energy remains stored in the flywheel as the weld starts to seize when a smaller flywheel and high angular velocity are employed than the converse of a large flywheel and small angular velocity. With the smaller flywheel, shock loading is reduced on the tooling and equipment. All of this was borne out by experience during the program. The Company uses the highest flywheel angular velocity possible that permits retention of the rotating band in the present design headstock collet. This corresponds to flywheel rotation at 2,200 rpm, even though the machine is capable of 3,600 rpm, but a collet modification will be required to achieve the higher rate.

2.4.4 With the present design tooling, ram force was found to be extremely important. The machine arrived pre-set from the factory, set too low. When this was discovered, and higher ram pressures were employed, better welds were achieved immediately. However, it should be noted that during the latter stages of this program Chamberlain was operating its ram at 10% over the design operational limit (but not over the design safety limit), prompting the Company to specify a larger ram capacity in a machine Purchase Description prepared for the Mississippi Army Ammunition Plant.

The ram force acts axially and generates normal force (radial) on the band through a tapered shoulder acting on a draw collet. The taper angle, of course, also affects the mechanical advantage of the system. With small draw ring angles, larger radial forces are produced from a given tailstock ram force than if a large angle is used. However, small angles require more longitudinal motion of the projectile to compress the band a given amount than if a large angle is used.

2.5 The production heat treatment operation conducted after banding was found to enlarge areas of disbond at the band-body interface, but did not seem to adversely affect areas where good welds were achieved.

The above would indicate that nearly perfect welds are necessary or the overall production process will be self-defeating. It also suggests that ultrasonic inspection would be necessary both before and after heat treatment. However, in Section 3 the Company has made recommendations for inertia welding machine attachments which can make the machine self-monitoring, allowing placement of one ultrasonic inspection station after heat treatment. If a decision is made to weld after heat treatment, additional study should be undertaken because, as explained in Section 2.4.2, difficulties were encountered which have not been analyzed to the Company's satisfaction.

2.6 Copper rotating bands can be welded to the 8-Inch, M509 Projectile AISI 4140 steel body, but additional work remains to be done because pure copper behaves differently than gilding metal when subjected to the inertia weld environment.

As explained in Section 4.1.10 of this report, good welds were obtained, but only after modifying tooling to account for pure copper's tendency to flow more than gilding metal. In continuing work on the M509 there is the following parametric base:

SPINDLE RPM	TAILSTOCK RAM PRESSURE (psi)	FLYWHEEL TOOLING WK^2
1,900	3,800	425

Actually, there is greater potential for cost saving with the 8-Inch, M509 than for the 155-mm, M483A1 because the M509 uses two bands and its larger diameter is a factor adversely affecting the speed of the welded overlay band process. Inertia welding is not as sensitive to diametrical differences as the welded overlay operation.

2.7 Economic analysis indicates inertia welding will save over $.80 per projectile compared to the welded overlay process.

These are 1977 prices assuming a production rate of 21,600 per month over 12 months. A comparison was made with voltage feedback and external adaptive controlled overlay welders. Savings are net, after machine procurement, transportation, installation, and amortization.

2.8 Unless otherwise stated, all ultrasonic scans were taken prior to heat treatment. However, experiments conducted near the end of the program showed that heat treating tended to enhance ultrasonic response in unbonded areas, which results in more reliable ultrasonic data if the weld is inspected after heat treatment.

3. RECOMMENDATIONS

The program just completed established certain equipment and parts parameters, and process variables for which additional information is required to attain the goal of using inertia welding as a production process with full assurance that quality welds will be produced consistently. Following are recommendations for additional effort aimed at eliminating potential problem areas.

3.1 In order to make a smooth transition from the research and development effort to a production operation, development of an automatic control system for the inertia welder should be addressed. An ideal control system would have appropriate sensors, a decision making device such as a microprocessor or mini-computer, final control elements, and interfaces between these components. This system would monitor welding operations, control parameters as indicated by sensory information, and provide alarm indications if the monitored variables exceed prescribed tolerances. Primary machine parameters and in-process variables resulting from these parameters which should be measured and controlled are listed below.

1. Flywheel angular velocity at cycle initiation.
2. Tailstock linear motion during welding which is related to upset.
3. Tailstock ram pressure-time relationship during welding.
4. The torque-time relationship during welding.
5. The interface temperature-time relationship during welding.

Instrumentation is available from the inertia welder manufacturer to measure the first two parameters listed. However, the accuracy of the instrumentation must be established, and methods for in-process control of these parameters should be investigated. The remaining variables are time related functions of the welding process, and data concerning these quantities must be generated to determine if they are suitable for use as weld quality indicators.

3.2 Component parameters which should be measured and controlled are:

1. Physical dimensions of the rotating band (I.D. and O.D.).
2. Diameter of band seat.
3. Surface finish of the band seat and the rotating band I.D.
4. Cleanliness of the band seat and the rotating band I.D.

3.3 The following program is recommended as a follow-on to the recently completed effort.

1. Procure and/or develop instrumentation required to measure the five machine parameters and in-process variables.

2. Install this instrumentation on the inertia welder at Waterloo.

3. Prepare a control group of components to be welded, with carefully controlled physical dimensions, surface finish, and surface cleanliness.

4. Perform an adequate number of welds to obtain a statistically significant data bank for the parameters being monitored.

   Vary surface velocity, energy level, and ram pressure over a range that produces poor quality to high quality welds. For each group of samples, vary only one parameter at a time so that the results can be correlated with a specific variable.

5. Determine from these data which parameter or combination of parameters are the most effective indicators of weld quality.

6. Define the equipment necessary to measure the physical parameters of component parts in the production environment.

7. Establish rejection criteria, or go-no go limits for the measured variables.

8. Determine the type of alarm indicators to be used, and the action to be taken for each specific alarm.

9. Establish the type of process controller to be utilized, such as mini-computer, microprocessor, etc.

10. Establish interface requirements between the sensors, the process controller, and the control elements.

11. Develop the software required for the process controller.

Completion of these activities will define the parameters that should be monitored and controlled, and the equipment needed to do so, for a viable production control system for the inertia welding operation.

3.4 Additional effort should be undertaken to establish inertia welding as a production process for the 8-Inch, M509 Projectile copper bands.

The reason for the recommendation is purely economic. The M509 offers excellent opportunity for cost savings because two bands are required, and the larger diameter slows production by the welded overlay process. Inertia welding is not as sensitive to larger diameters as is overlay welding.

3.5 Work should continue on correlation of weld quality with ultrasonic data. More comparisons need to be made between data obtained on the Waterloo equipment and data obtained from high speed phased array transducer scanners. A complete production inspection system must be specified and calibration standards for the production equipment must be established.

4. PROCESS DEVELOPMENT

4.1 Equipment/Tooling

4.1.1 The key equipment item for this contract was the Model 250B inertia welding machine shown by Photograph No. 10734 on the following page. Our machine was manufactured by Production Technology, Inc., Division of Caterpillar Tractor Company, Peoria, Illinois. However, all patents and business since have become the property of Manufacturing Technology, Inc., Division of Adams Engineering, Mishawaka, Indiana. Some of the people operating Manufacturing Technology, Inc. formerly were associated with Caterpillar, and they have a complete history of Chamberlain's Model 250B machine. As a matter of record, throughout the contract they maintained a high degree of interest in this unique application of their machine, and were very helpful when technical matters arose concerning the machine itself. Other major equipment necessary for the performance of the contract was the entire 155-mm, M483A1 production line established at Chamberlain's New Bedford Defense Products Division, New Bedford, Massachusetts. Personnel at New Bedford assisted the project by providing projectile bodies to be banded, and by finish machining banded bodies via standard production processes.

4.1.2 Generally, in inertia welding, one component is held stationary in the tailstock of the welding machine while the other component is clamped in a spindle chuck and is spun. At a predetermined angular velocity, the driving torque is removed and simultaneously the components are thrust together with a predetermined force. Friction between the components decelerates the moving part, converting the stored kinetic energy to heat which softens but does not melt the faces of the parts. Just before motion stops, the two parts bond, and the remaining energy is utilized in hot working the metal interface; the weld is complete when motion stops. Parameters which influence the weld are: (1) rotating mass which can be adjusted by the size of a flywheel attached to the spindle, (2) angular velocity, and (3) the radial pressure used in joining the parts. When these parameters are controlled, the result is a very repeatable, reliable welded joint. The weld zone is very narrow with a strong fine grain structure resulting from vigorous hot working.

4.1.3 The main contribution of this project is the design of tooling which makes possible radial inertia welding of a metal ring to a smaller cylindrical structure. Heretofore only three methods existed for assembling copper, brass, gilding metal or sintered metal rotating bands to projectiles, to wit: (1) pressing the band radially into a band seat with a special multi-jaw press, (2) continuous overlay welding of the heliarc or plasma arc types,

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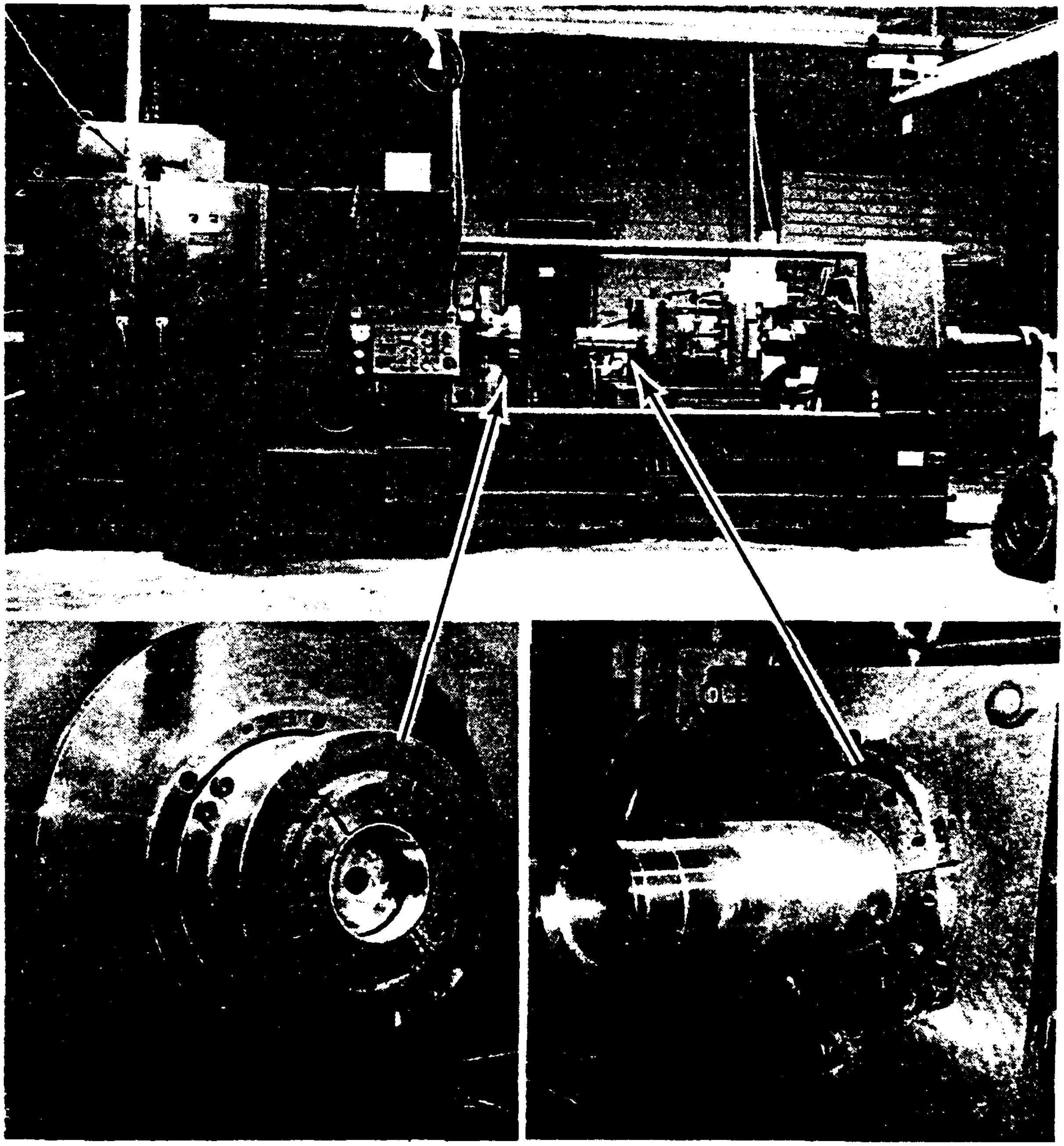


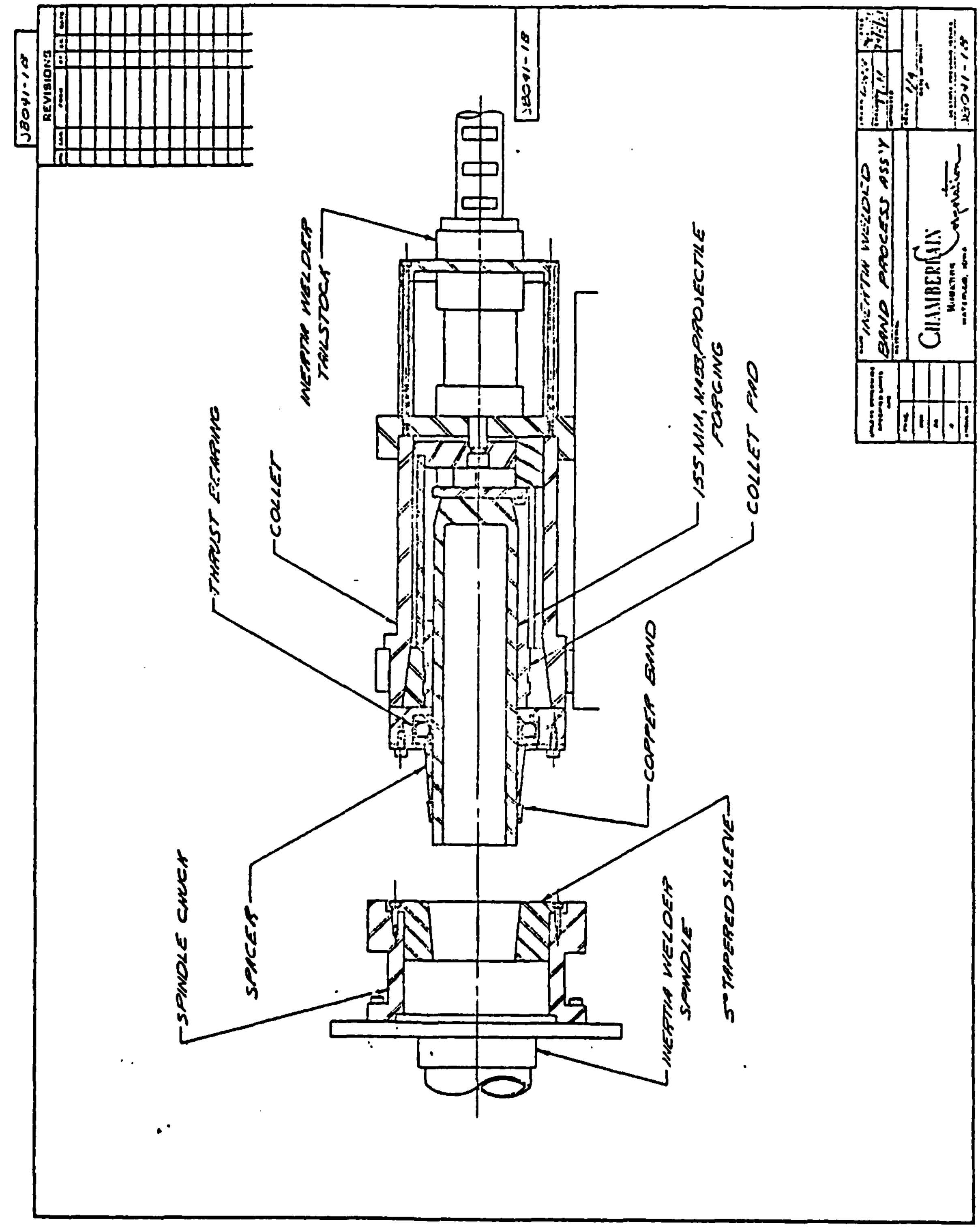
PHOTO NO. 10734

TOP: MODEL 250B INERTIA–WELDING MACHINE.
LEFT: CLOSEUP OF HEADSTOCK SHOWING FLYWHEEL AND 6–JAW COLLET CONTAINING ROTATING BAND.
RIGHT: CLOSEUP OF TAILSTOCK SHOWING 155MM, M483A1 PROJECTILE BODY IN 6–JAW COLLET.

and (3) swaging with a special press through a special swage die. Problems exist with (1) and (3) on thin-wall projectiles like the M483A1, particularly with reference to sidewall collapse and secondarily with discard of rotating bands when subjected to higher than normal ballistic stresses extant in the Army's new gun/propellant systems. Item (2) provides a ballistically sound structure but is a very slow manufacturing process. A faster, more economical means was required to assemble rotating bands, resulting in proposals by Chamberlain Manufacturing Corporation to try inertia welding, and evolving into the tooling which is the subject of this Section.

4.1.4 On 28 March 1974 Chamberlain received Contract DAAA25-74-C-0492 from Frankford Arsenal to conduct inertia welding studies for assembling the rotating band to the M483 Projectile. At that time the rotating band blank (cut from tubing) was compressed onto the projectile body by a forcing cone headstock collet arrangement of the type shown by Drawing No. J8041-1B on the following page. The forcing cone concept was inadequate for a projectile of this diameter for several reasons, chief among those were: (1) the gilding metal in the rotating band often showed a tendency to squirt away from the taper of the collet, and (2) the band edge on the high side of the taper often did not become bonded to the projectile body because there was not sufficient force available to compress the band evenly across its width.

4.1.5 Prior to inception of the subject contract Chamberlain engineers had a new design collet built in 105-mm size which improved the inward radial displacement of the band onto the body. The machine's headstock was adapted to accept a collet which incorporated a thrust bearing which is activated by pressing the base of the projectile body against the front race of the thrust bearing. A schematic of the collet's operation is shown on Page 14. The band blank indicated is placed in the open headstock collet while the body is held in a separate tailstock collet. The inertia welding machine's tailstock is advanced until the body passes through the band blank and encounters the front race of the thrust bearing assembly. At this point the band blank is located properly with relation to the body seat where inertia welding will occur. Slight pressure on the front race acts to compress the collet assembly onto the band blank, holding it in place while the headstock is activated to reach a high rotation rate. The collet compresses against the band through the actuator mechanism. The collet with the band is rotated at high rpm and free wheels once the desired rotation rate is reached. The front race of the thrust bearing remains stationary. At the selected rotation rate the machine is programmed to advance the tailstock holding the body against the front race at a rate of 5 inches/second with a force of 192,000 pounds (advance rate and force are for this application only). Activation of the thrust bearing closes the jaws rapidly, causing the band blank to compress into and onto the body band seat. Friction between the band blank and body heats the parts -- resulting in a welding action. The band blank then seizes onto the body. Free wheeling rotation stops when all energy in the system is absorbed by the weld action.



JB041-1B
REVISIONS
JB041-1B
INERTIA WELDER TAILSTOCK
155 MM, M483 PROJECTILE FORGING
COLLET PAD
COLLET
THRUST BEARING
COPPER BAND
SPACER
SPINDLE CHUCK
INERTIA WELDER SPINDLE
5° TAPERED SLEEVE
INERTIA WELDED BAND PROCESS ASS'Y
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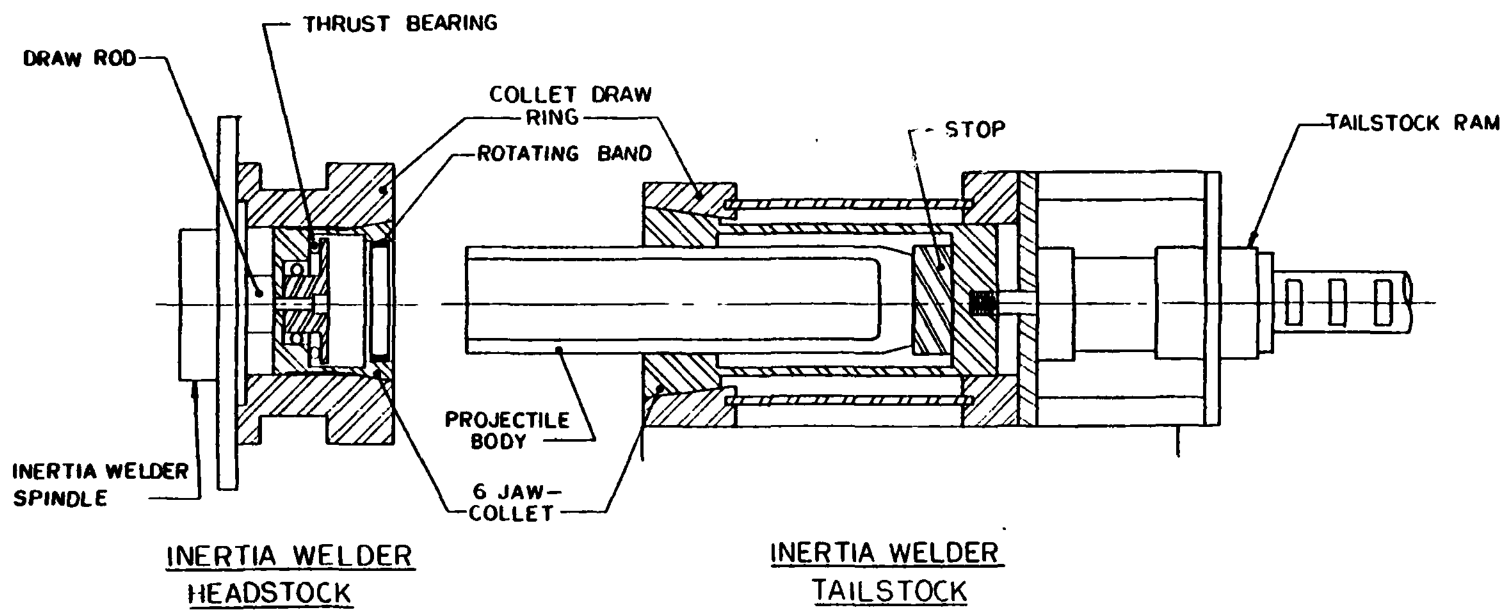


Illustration of Setup for Inertia Welding Rotating Bands to Projectile Body with a Radial Headstock Collet

A timer in the machine signals the tailstock to retract, releasing pressure on the thrust bearing assembly, and causing the headstock collet jaws to open. As the tailstock retracts, the banded body is extracted from the headstock collet to the load/unload position of the tailstock. Both collets now are ready for reloading of their respective parts to repeat the cycle. Additional drawings of the headstock collet are presented in the Appendix to show details of the mechanism.

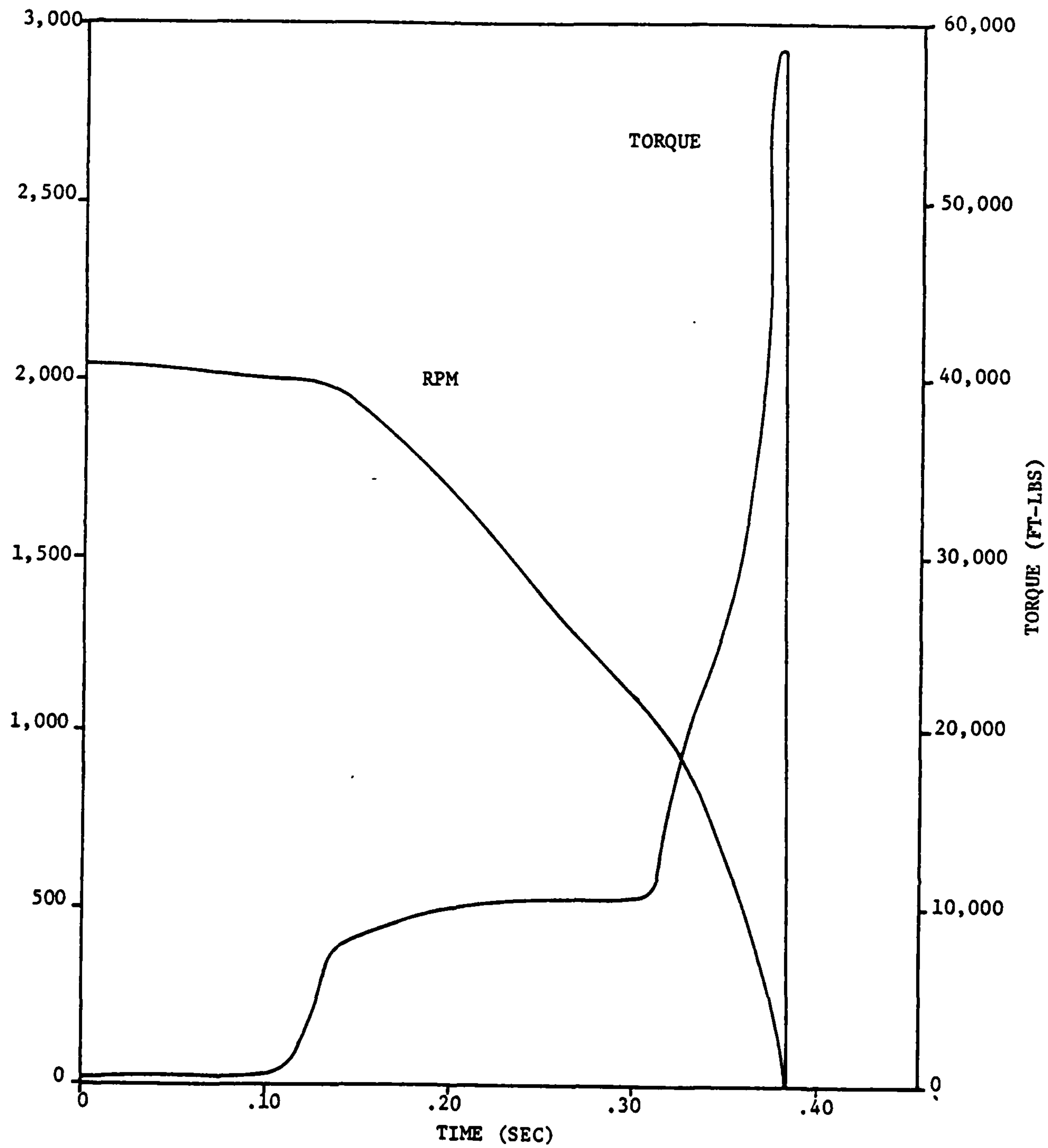
To the best knowledge of Chamberlain Manufacturing Corporation, Production Technology, Inc., and Manufacturing Technology, Inc. of Mishawaka, Indiana (present holders of all patents for inertia welding machines), there is no precedent for the collet mechanism which allows radial inertia welding 90° to the centerline of the parts. Inertia welding by the free rotating mass method is a relatively new technology; therefore, it is safe to say that the tooling used in this application represents a unique advancement in the state-of-the-art. The Company has processed a patent disclosure to ARRADCOM under the terms of the basic contract.

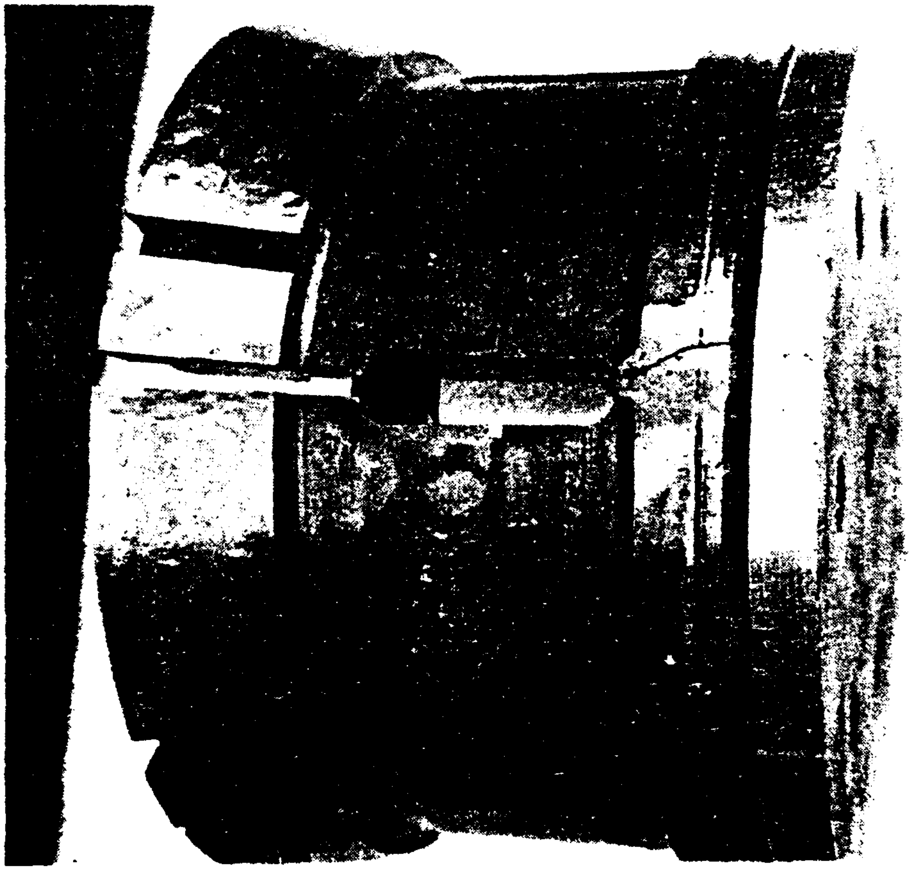
4.1.6 Tremendous shock loads are applied to the tooling during the welding operation. This is indicated by the graph on the following page, which is a plot of flywheel rpm and torque on the components during a typical welding operation. This chart was derived by recording the flywheel angular velocity during a weld, and the torque was calculated from the change in angular velocity. As can be seen the torque peaks at about 55,000 ft-lbs at the end of the weld.

During the initial phase of the program, a considerable amount of tooling breakage occurred as a result of the peak torque load. A headstock collet was broken, as shown in Photograph No. 10710 on Page 17. A tailstock collet was also broken, as were a number of collet pads and retaining keys.

When a component did fail, it was redesigned to take into account the previously unexpected high loads that occur during the welding cycle. New materials were used when indicated, care was taken to minimize stress concentration areas, and heat treatment procedures were specified as needed. It is interesting to note that we have not had any failures in any of the redesigned hardware, and Chamberlain is confident that the current tooling design is adequate for its intended purpose.

It should be pointed out here that the peak torque loading can probably be reduced by using a smaller flywheel and higher angular velocity. This is true because, with all other factors equal, a weld begins to seize at a given rpm. With a smaller flywheel, less energy would be left in the system when the weld starts to seize than would be the case if a large flywheel were used. This area should be investigated further to determine if tooling loads can be minimized by rather simple changes in initial parameters.


3,000
2,500
2,000
1,500
1,000
500
0
60,000
50,000
40,000
30,000
20,000
10,000
0
TORQUE
RPM
TORQUE (FT-LBS)
0
.10
.20
.30
.40
TIME (SEC)



PHOTOGRAPH NO. 10710
COLLET SHOWING BREAK SUSTAINED IN THE ROOT OF THE TANG.

4.1.7 On the following page is a summary tabulation of welding trials conducted in behalf of the program. Initial efforts began on the 105-mm, M60 Projectile in order to test the efficiency of the radial collet concept while a similar set of tools was being built for the 155-mm, M483. Our goal was to establish machine settings and parameters which would result in consistent, repeatable welds from part to part.

Fifty-eight (58) welds were made on 105-mm parts, with flywheel rpm ranging from 1,250 to 2,800, tailstock ram pressure ranging from 300 to 1,000 psi, and energy levels ranging from 27,000 to 135,000 ft-lbs. Consistently good welds were obtained using the following parameters, and are suggested for future welds for this band.

PARAMETERS FOR 105-MM BANDS

FLYWHEEL (WK^2)	FLYWHEEL (rpm)	RAM PRESSURE (psi)	SURFACE VELOCITY (fps)	ENERGY (ft-lbs)
101	2,650	1,000	2,845	121,000

A total of 431 welds were made on M483 bodies or body forgings. Flywheel angular velocity was varied between a low value of 1,375 rpm to a high value of 2,600 rpm. The tailstock ram pressure was varied over a range of 2,800 to 3,800 psi. The flywheel moment of inertia was varied from 425 to 1,175 lb-ft^2. Energy levels ranged from 350,000 to 494,000 ft-lbs. During these trials, it was eventually determined that the tailstock ram pressure was one of the most critical parameters, and this pressure was increased 2,900 to 3,500 psi. At this pressure level, a marked improvement in weld quality was observed. Six projectiles that were fired in the first Yuma test were welded using this pressure, and none of these units experienced band failures, even though three were fired at Zone 8, Excess.

The Company continued experiments to improve weld quality from November 1976 through March 1977. Tabulated below are the January 1977 trials which helped us determine the energy requirement for the M483A1 Projectile banding operation.

JANUARY 1977 TRIALS (1.750-INCH WIDE BAND)

TEST RD. NOS.	FLYWHEEL (WK^2)	FLYWHEEL (rpm)	RAM PRESSURE (psi)	SURFACE VELOCITY (fpm)	ENERGY (ft-lbs)
28-32	500	2,025	3,500	3,280	352,000
33-37	500	2,150	3,500	3,485	391,000
38-42	465	2,100	3,500	3,400	352,000
43-47	465	2,225	3,500	3,605	391,000
48-52	425	2,200	3,500	3,565	352,000
53-57	425	2,325	3,500	3,765	391,000

WELDING TRIALS

	105-MM (M60-XM710)	155-MM, M483 (OLD STYLE BODY)	155-MM, M483A1 (NEW STYLE BODY)	8-INCH, M509
Apr 76	15 (M60)			
May 76				
Jun 76	16 (M60)			
Jul 76		23*		
Aug 76		30*		
Sep 76		7*		
Oct 76			44**	
Nov 76	17 (XM710)		10**	
Dec 76			15**	
Jan 77		57		
Feb 77		57		
Mar 77		122		
Apr 77				
May 77				
Jun 77		10		68
Jul 77				
Aug 77			56 (Shipped 37)	
Sep 77				
Oct 77				
Nov 77				
TOTALS	58	306	125	68

NOTES: * Body Forgings.
** Shipped 32 From This Group.

At the conclusion of the above tests, it appeared that going below 391,000 ft-lbs energy input started edge disbond. At 352,000 ft-lbs a few pieces start showing disbond entering the final machined area of the band. Therefore, the Company specifies 391,000 ft-lbs as the minimum base for band blanks 1.750 inches wide. During February and March 1977 additional experiments were conducted with band blanks 1.600 inches wide. Also, in an effort to further improve weld quality, the tailstock ram pressure was increased to 3,800 psi, which is 300 psi above the recommended maximum limit of the Model 250B inertia welder. Again, an improvement in weld quality was observed with the increase in tailstock ram pressure.

During March we accomplished 122 welds on M483 bodies without tooling failure and with excellent bonding achieved. Of this quantity, 116 were welded as a prototype production situation, five were welded for representatives of Manufacturing Technology, Inc., so they could better understand the tooling, and one was welded and sectioned for Chamberlain New Bedford personnel so they could compare results with the present welded overlay process. Machine settings for Units 115 through 230 were as tabulated below. All bands were 1.600 inches wide. These parameters were later used to weld all projectiles that were fired in the second test group at Yuma.

TAILSTOCK RAM PRESSURE (psi)	FLYWHEEL (WK^2)	FLYWHEEL (rpm)	SURFACE VELOCITY (fpm)	ENERGY (ft-lbs)
3,800	425	2,200	3,483	350,000

Ultrasonic scans were taken on all rounds. They revealed little or no disbond, even at the outer edges of the band. No scans are reproduced in this report because there is little or nothing to see. Based on results accumulated since 1 January 1977, Company personnel are confident that the present process can be transferred to the production floor, and that inertia welding will significantly lower the cost in comparison to the welded overlay process used currently.

Chamberlain recommends using the narrower band to save metal, with the above settings as reference parameters. The overriding parameter appears to be the radial pressure used to squeeze the band into the seat which results from the tailstock ram force acting via the thrust bearing arrangement and the collet draw ring.

4.1.8 During March 1977 the Research and Development Division of Chamberlain Manufacturing Corporation cooperated with Mason-Chamberlain, Inc., to specify basic inertia welding equipment for the Mississippi Army Ammunition Plant. This work was outside the Scope of the subject contract, and was funded separately, but is included in this report for the record. The following recommendations were made.

Application: Inertia weld rotating band to 155-mm, M483A1 Projectile

System Production Rate: 260/hour at 80% efficiency

BAND-SHELL DIMENSIONS

BAND O.D.	BAND I.D.	BAND WIDTH	PROJECTILE BAND SEAT
6.615 In.	6.190 In.	1.600 In.	Standard for Overlay Weld

MACHINE SETTINGS (REFERENCE)

TAILSTOCK RAM PRESSURE	FLYWHEEL/COLLET/ THRUST BEARING WK^2	FLYWHEEL rpm	SURFACE VELOCITY fpm	ENERGY INPUT (ft-lbs)
3,800 psi	425	2,200	3,483	350,000

Base Machine:

Work Bed, Frame and Slide -- Basic Model 320
Spindle, Hydraulics and Electrical -- Basic Model 250
Tailstock Ram Pressure -- 4,000 psi, 250,000 Pounds Maximum
Maximum rpm -- Tentative 2,500; Open pending engineering meetings to discuss single purpose or multiple purpose application (no cost factor involved).
Main Frame -- 146 Inches Long by 50 Inches Wide by 70 Inches High
Electrical Panel -- 60 Inches by 13 Inches by 70 Inches
Hydraulic Group -- 60 Inches by 90 Inches by 45 Inches
Hydraulic Temperature Monitor
Hydraulic Level Monitor and Indicator
Electrical: 440 3Ph to 480 3Ph -- Final determination based on available power supply at site selected (no cost factor involved).
Electric Motors:
- Main -- 125 HP at 1,800 rpm
- Charge -- 15 HP at 1,800 rpm
- Clamp -- 25 HP at 1,800 rpm

Warm-Up Cycle Accessory
Speed and Pressure Monitor with Recorder
Leveling Blocks

OSHA Equipment:

Noise Shrouding
Rear Enclosure
Front Enclosure
Any Other to Meet OSHA Human Factors Requirements

Options Available -- Based on Final Tooling Design:

Projectile Body

1. Front Loading and Unloading
2. Pass Through System -- Front Loading, Rear Unloading
3. Top Loading and Unloading Self-Centering, Split Fixture

Band

Front Loading and Positioning

Tooling must be able to withstand operational longitudinal load against headstock thrust bearing of 250,000 pounds and peak torque loads of at least 80,000 ft-lbs.

4.1.9 During May 1977 the purchase description was formalized for bidding purposes and was forwarded to Mason-Chamberlain, Inc., who, in turn, obtained quotations from Manufacturing Technology, Inc. The final decision on purchase of equipment for MSAAP rests with U. S. ARRADCOM, based partly on work accomplished on this contract and on financial and engineering judgment. At the time this report was prepared, Chamberlain had no news of any decision.

4.1.10 8-Inch, M509 Projectile

4.1.10.1 In compliance with Modification P00002 to the contract Chamberlain acquired forged tubing from the Company-operated Scranton Army Ammunition Plant and conducted trials to determine the feasibility of inertia welding copper rotating bands to the M509. This projectile resembles the M483A1 by having a thin sidewall and a machined interior to contain and deliver parasitic hardware by base ejection.

4.1.10.2 During June 1977 the Company conducted 68 welding trials with 8-Inch tubing having band seats machined in a manner that allowed us to seat two bands per tube section. The following dimensions apply to the metal parts used.

BAND DIMENSION (In.)			BAND SEAT DIA. (In.)	
I.D.	O.D.	WIDTH	FIRST 28	REMAINING 40
8.085±.020	8.51-.020	.77-.02	7.935-.010	7.975 - .010

The difference in band seat diameter indicated above stems from the behavior of the copper under working conditions. When the machine was cold, good welds could be obtained on a 7.935-inch diameter seat when other parameters were right (See data sheet on the following page). As the collet jaws absorbed

JUNE 1977 EXPERIMENTS WITH 8-INCH M509 TYPE BAND

TEST RD. NO.	TAILSTOCK RAM PRESSURE (psi)	FLYWHEEL WK^2	FLYWHEEL RPM	SURFACE VELOCITY (fpm)	ENERGY (ft-lb)	REMARKS
1	3,800	425	1,650			Not Enough Energy.
2	3,800	425	1,900			1/2 Weld, Band Slipped In Jaws.
3	3,800	425	1,900			Good Weld.
4	3,800	425	1,900			Copper Squirted - Band Jaws Interfered - No Weld.
5) 6) 7)	3,800	425	1,900			Good Weld.
8	3,800	425	1,900			No Weld - Same as No. 4.
9-14	3,800	425	1,900			Varying Degrees of Good Weld.
15	3,800	425	1,900			Acid Cleaned Bands From Here On - Good Weld.
16-27	3,800	425	1,900			Varying Degrees of Good to Bad Welds Because of Undersize Band Seat.
28	3,800	425	1,900			7.975 Band Seat - Good Weld.
29-68	3,800	425	1,900			Good Welds - Some Edge Effects Where Copper Migrates Out of Band Seat.

heat, the bands flowed more, causing the collet jaws to work inward until they touched each other, before the weld was completed. This action released pressure on the band and caused a poor weld. This situation was eliminated when the band seat diameter was increased. Some typical ultrasonic scans are shown on Page 25. Round 8 is a typical result of jaws contacting before a weld was achieved. Other welds are typical for the conditions included with each scan. The edge effects seen on Units 45 and 47 are not significant. What we see here as disbond actually is where the copper flows outside the band seat. Actually, about .25 inch would be machined away from each side to finish an M509 band profile, leaving only soundly welded areas under the finished band.

4.1.10.3 Note that the first 14 bands were welded without chemical cleaning except for wiping the band I.D. and the band seat with trichlorethylene prior to activating the inertia welder. From Unit 15 on, the bands were dipped in an acid bath consisting of 10% nitric acid solution, followed by cold water rinse, hot water rinse, and blow drying. At the machine the bands and band seats were given a trichlorethylene wipe. We found evidence that the cleaning helped bonding, particularly at the outer edges. Note in the scans on Page 25 the edge effect differences between Band 12 and Bands 45 and 47. This corresponds to early work done on the 155-mm, M483A1 bands and suggests that chemical removal of impurities should be incorporated in a production process, or that the bands be welded following a dry machining operation (no cutting fluids or lubricants) where a thin surface cut is made to remove contaminants.

4.1.10.4 By and large we are satisfied that the M509 band can be inertia welded to the body. We believewe have demonstrated feasibility. In continuing this work on the M509 we would establish as a base the following parameters.

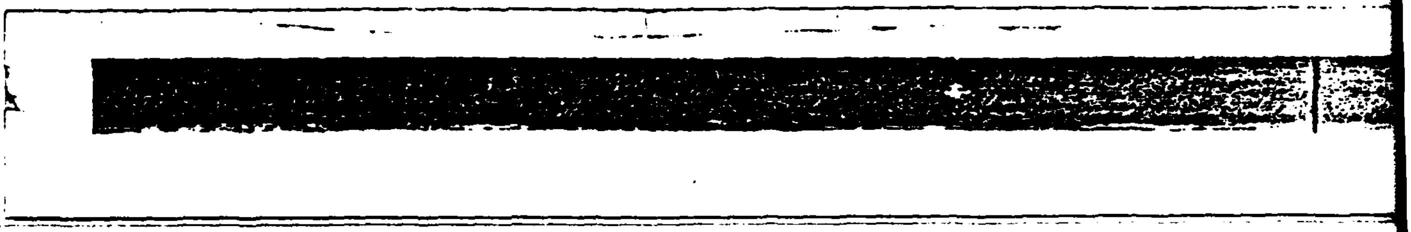
SPINDLE RPM	TAILSTOCK RAM PRESSURE (psi)	FLYWHEEL TOOLING WK^2
1,900	3,800	425

4.2 Non-Destructive Test Procedures

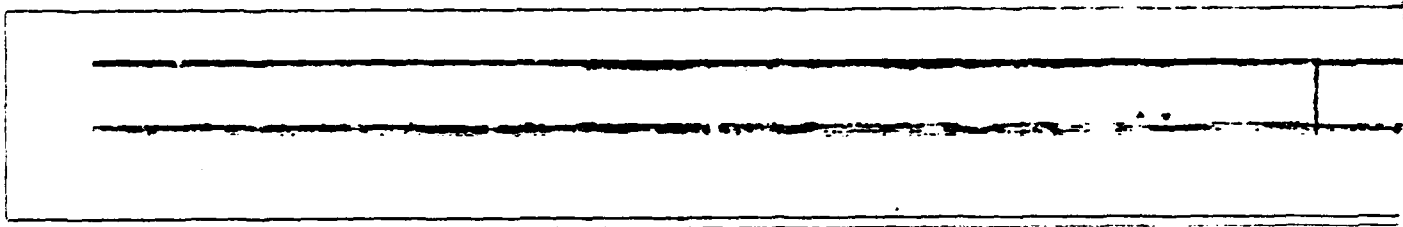
4.2.1 Ultrasonic Testing - Single Path Transducer

4.2.1.1 The basic test unit consists of a Sperry UM721 Reflectoscope[1] having a 10-N pulser-receiver unit and an automatic gating system. The

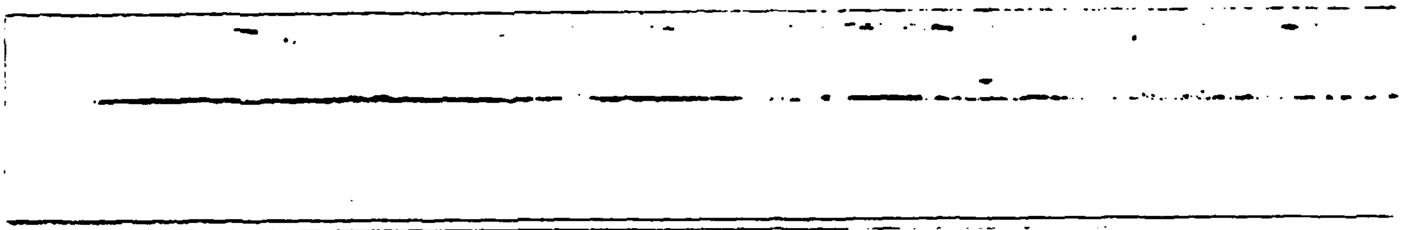
[1] A product of Automation Industries, Inc., Sperry Products Division, Danbury, Connecticut.



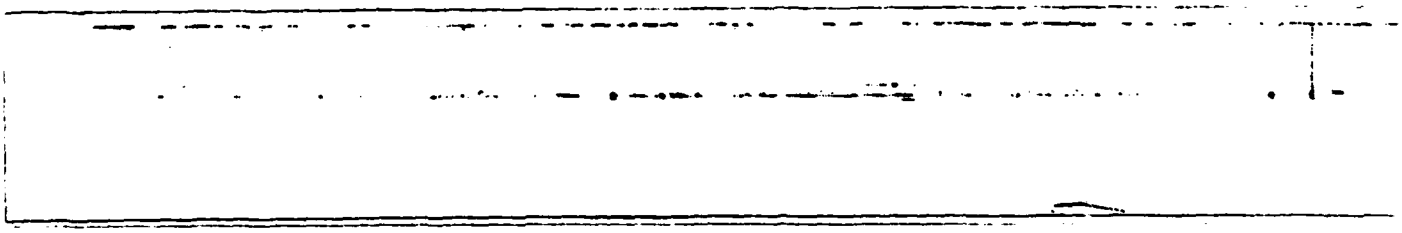
BAND 8: 1900 RPM, 3800 PSI Tailstock Pressure, 425 Wk^2 Flywheel. Result of 7.935 Inch Dia. Band Seat when jaws interfered with each other.



BAND 12: 1900 RPM, 3800 PSI Tailstock Pressure, 425 Wk^2 Flywheel. Only Trichlorethylene wipe on band and seat.



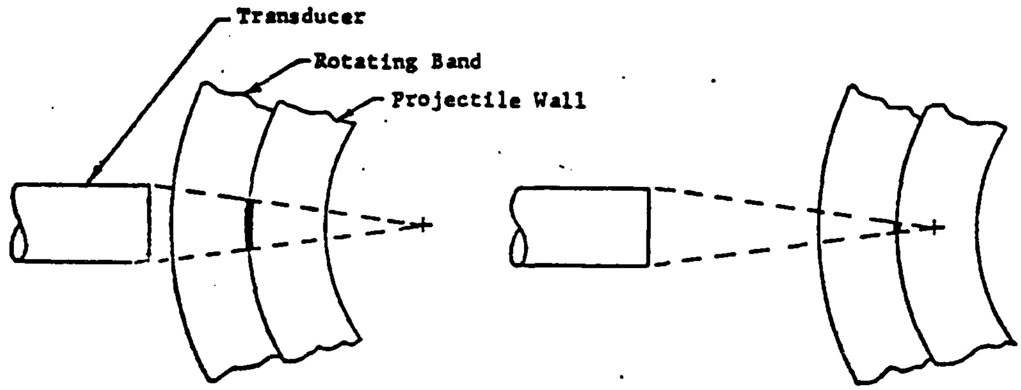
BAND 45: 1900 RPM, 3800 PSI Tailstock Pressure, 425 Wk^2 Flywheel. Chemically cleaned. 7.975 Inch Dia. Band Seat.



BAND 47: 1900 RPM, 3800 PSI Tailstock Pressure, 425 Wk^2 Flywheel. Chemically cleaned. 7.975 Inch Dia. Band Seat.

PHOTOGRAPH NO. 10785

TYPICAL ULTRASONIC SCANS FOR COPPER BANDS WELDED TO 8 INCH TUBE UNDER CONDITIONS INDICATED search unit is a 5 MHz lithium sulphate, 0.375-inch diameter, medium focus, Type SIL-5 transducer. It has a focal distance of 2.2 inches in water, and a beam diameter of 0.050-inch at the sound wave converging point. A focused beam transducer provides the advantage of adapting to an increase or decrease of the diameter being investigated merely by varying the water path distance. The test item and the transducer are placed under water which acts as a medium through which the sound waves are transmitted between the transducer and the test item. Connected with the search unit is an attachment having an electric stylus which marks on electrically-sensitive paper in the event the search unit senses an area of disbond in the weld. The complete ultrasonic scanning setup is shown by Photograph No. 10732 on the following page. Below is a simplified view illustrating the focused-beam transducer feature. The sketch does not show the angle of refraction that occurs as the beam enters metal from water in an actual test situation.



4.2.1.2 Calibration

The ultrasonic equipment must be properly calibrated in order to obtain meaningful results. This is usually done by scanning a test part with known defects to determine if the equipment is faithfully reproducing the defects. It did not appear possible to make an actual weld with known defects, so another approach was taken. The aft end of a projectile containing the rotating band was cut off from a shell that appeared to have a good weld. The rotating band area was sectioned into quarters and flat bottom holes ranging from .025" to .080" were electrically machined through the steel body to the weld interface. The quarter sections were then welded back together to form a test block that could be used to calibrate the ultrasonic equipment. A drawing of the test block is shown in Drawing No. J8041-10, Page 28.

In use the test block is mounted in the ultrasonic tank instead of the projectile. The block is then scanned in the normal manner, and the sensitivity and gating circuits on the reflectoscope are adjusted so the system will respond to the smallest flaw size one wishes to detect. Early in the program the equipment was adjusted so it would detect the .050" diameter hole but not the .045" diameter hole. Later the sensitivity settings were increased

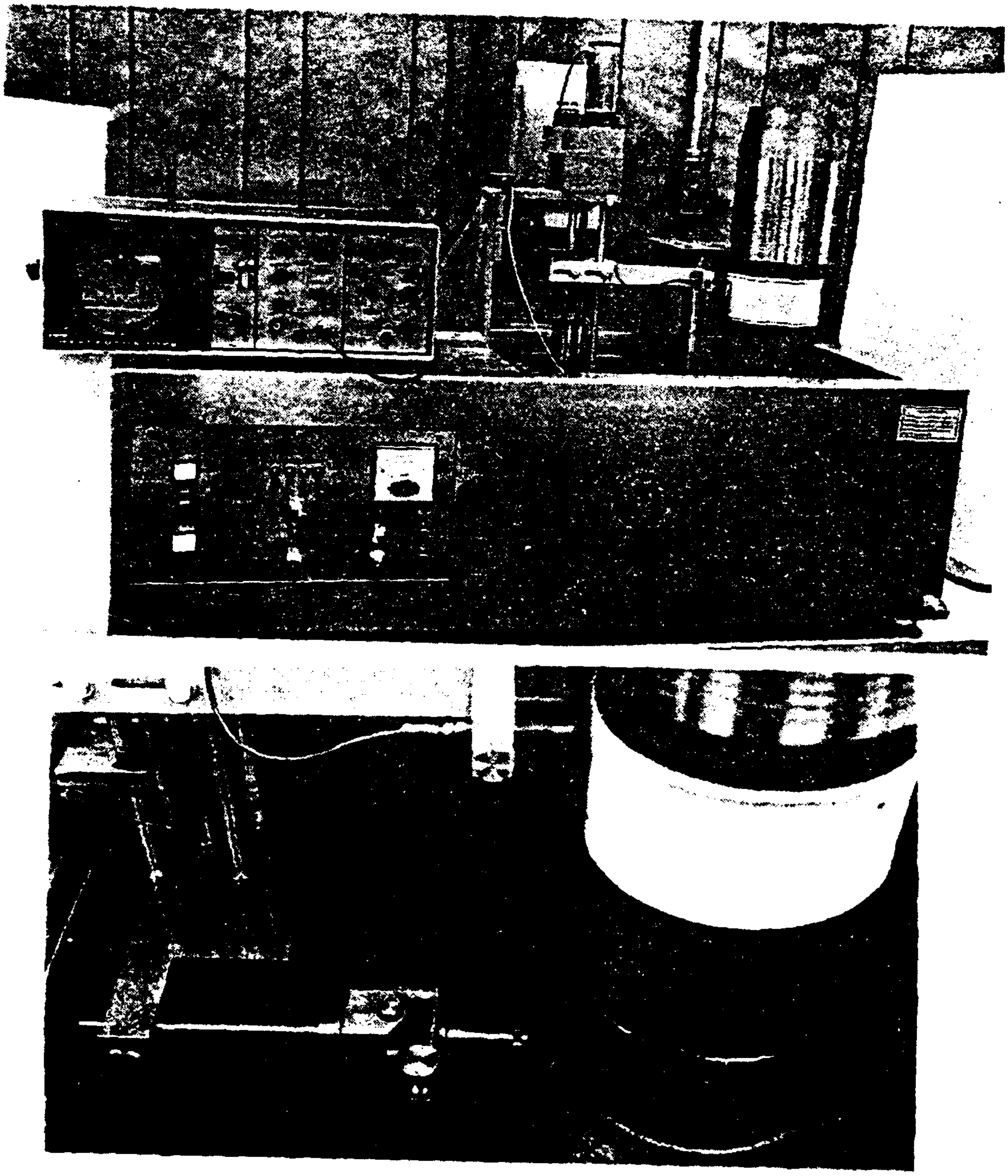
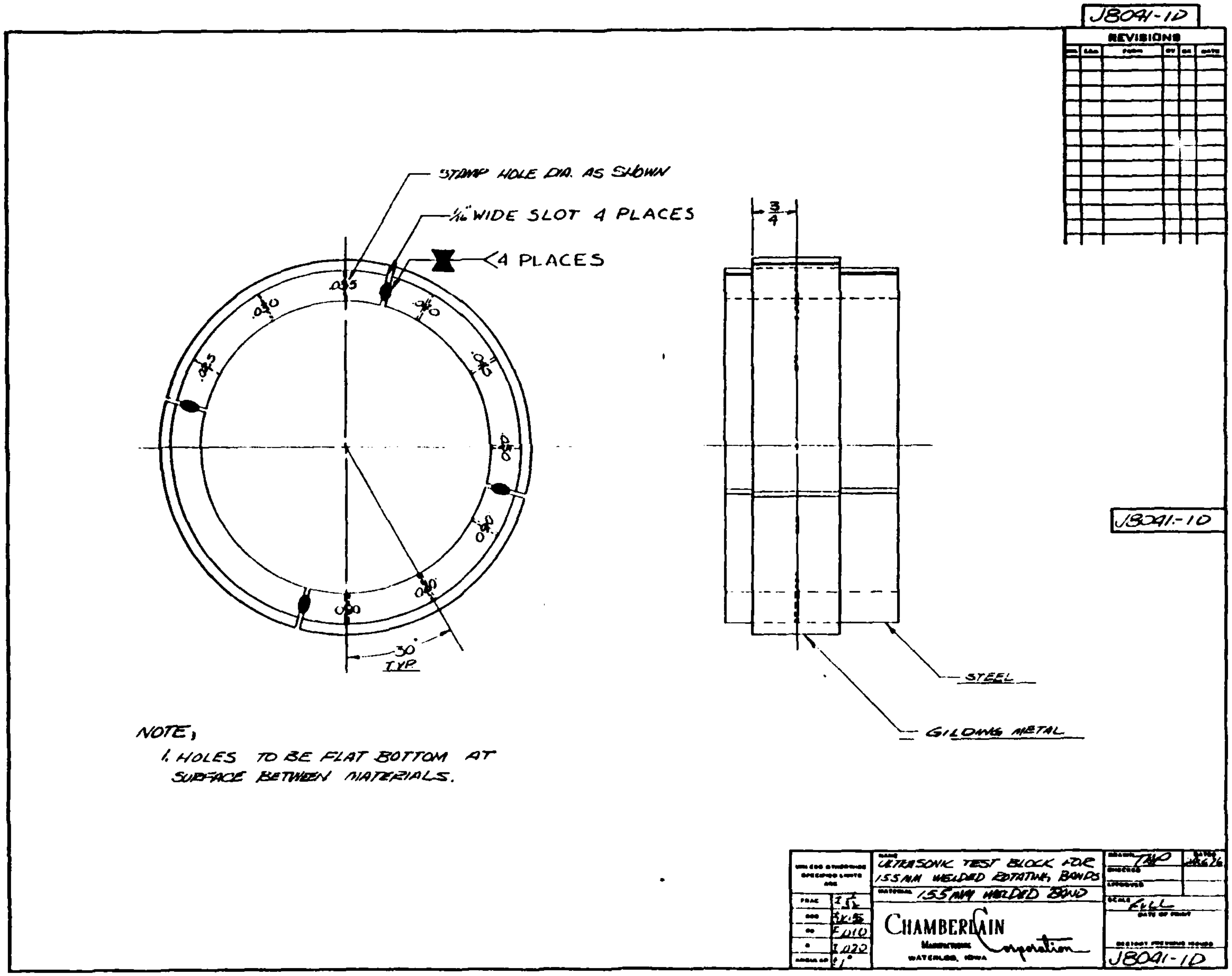


PHOTO NO. 10732

ULTRASONIC SCANNING EQUIPMENT--INSET: PROBE AT BOTTOM AND CHART RECORDER AT TOP.


J8091-1D
REVISIONS
STAMP HOLE DIA. AS SHOWN
1/16" WIDE SLOT 4 PLACES
4 PLACES
.035
.030
.040
.045
.050
.020
30° TYP
3/4
STEEL
GILDING METAL
NOTE,
1. HOLES TO BE FLAT BOTTOM AT SURFACE BETWEEN MATERIALS.
J8091-1D
ULTRASONIC TEST BLOCK FOR 155MM WELDED ROTATING BANDS
155MM WELDED BAND
CHAMBERLAIN Manufacturing Corporation
WATERLOO, IOWA
FULL
J8091-1D

34

so that even the .025" diameter hole could be detected. All the projectiles that were welded during the process verification run and for the second test firing group at Yuma were scanned using the higher sensitivity setting. This setting apparently is adequate to faithfully indicate good and bad weld regions. In practice, the calibration ring should be scanned before and after a lot of projectiles are checked to insure that machine settings have not drifted.

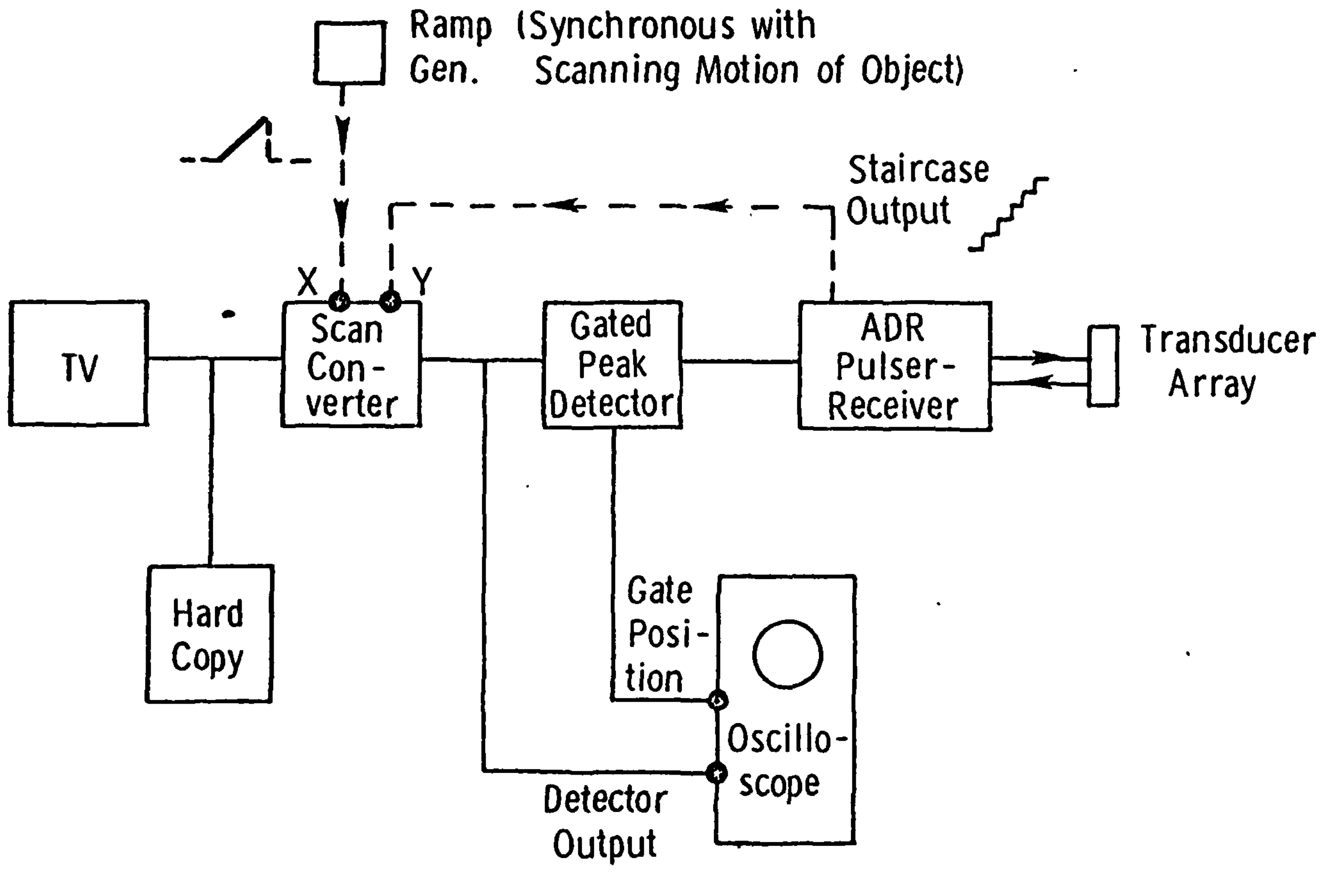
4.2.1.3 Listed below are the steps in the ultrasonic scanning procedure:

- Scan calibration ring and adjust sensitivity as required.
- Place shell on spindle in tank with the transducer aligned with rotating band area.
- Attach electrically-sensitive paper to shell in line with electric stylus.
- Adjust stylus to contact the paper.
- Turn main switch of machine to "On" position to activate reflectoscope and scanner.
- Turn "Manipulator" switch to "Clockwise" (CW) or "Counterclockwise" (CCW) position. (Note: Set rotation of shell in direction that will allow lapped joint in paper to pass stylus without peeling.)
- When "Manipulator" switch is activated as above, specimen will begin rotation and will stop automatically when cycle is completed.
- Turn main switch to "Off" position to disconnect electric power.
- Retract stylus and remove paper and shell.
- Rescan calibration ring.

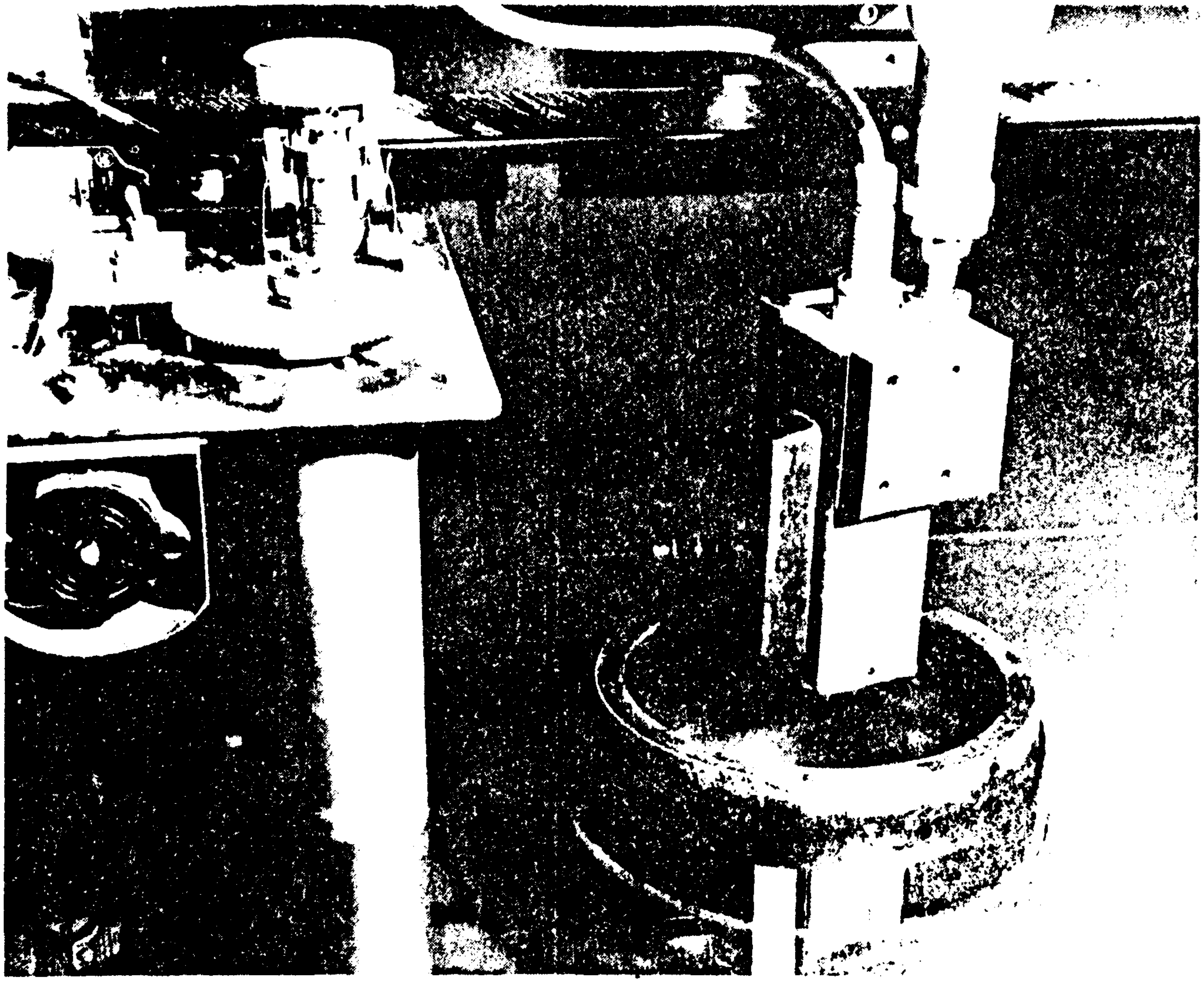
4.2.2 Ultrasonic Testing - Phase Array Transducers

4.2.2.1 During November 1977 a meeting was held at U. S. Army Material Mechanics Research Center to witness the quick scanning capability of their phase array ultrasonic test equipment. Samples of M483A1 and M509 banded bodies were transported to the site by Chamberlain personnel. The purpose of the phase array setup is to provide a scanning technique which will keep up with a production line situation by scanning an entire banded area in seconds. An electrical diagram of the system they have developed is shown on the following page. The phase array transducer consists of 64 elements, is nonfocusing, and a flaw is detected by reflection of the ultrasonic pulse. A picture of the transducer is shown by Photograph No. 10840 on Page 31.

The system can be used to test for disbond areas between a band and a shell by placing the transducer inside the shell or outside of it. Four elements of the phase array transducer operate at one time, and are sequenced automatically to the next higher element; i.e., elements number one through four are pulsed first then two through five, and then three through six, etc. All 64 elements are pulsed in 1/40 second. Each element is 0.055 inch wide and 0.4 inch long, so that when four elements are pulsed the activated area is 0.22 inch by 0.4 inch. The transducer elements operate at 5 MHz.



Block Diagram of Electronic System



PHOTOGRAPH NO. 10840

TRANSDUCER HEAD BEING LOWERED INTO SAMPLE WELDED BAND

4.2.2.2 The signal received from the transducer is processed electronically and is displayed on an oscilloscope screen as the scan is being taken, or imaged onto a TV screen, as shown by Photograph No. 10841, Page 33, when the scan is completed. The image is stored on a vidicon tube, which can hold the signal for as long as 12 hours. Using an electrostatic copier, a hard copy of the image can be made for a permanent record of the disbond areas in the welded band/shell interface. A particular area in the displayed image can be magnified on the TV screen for a closer examination.

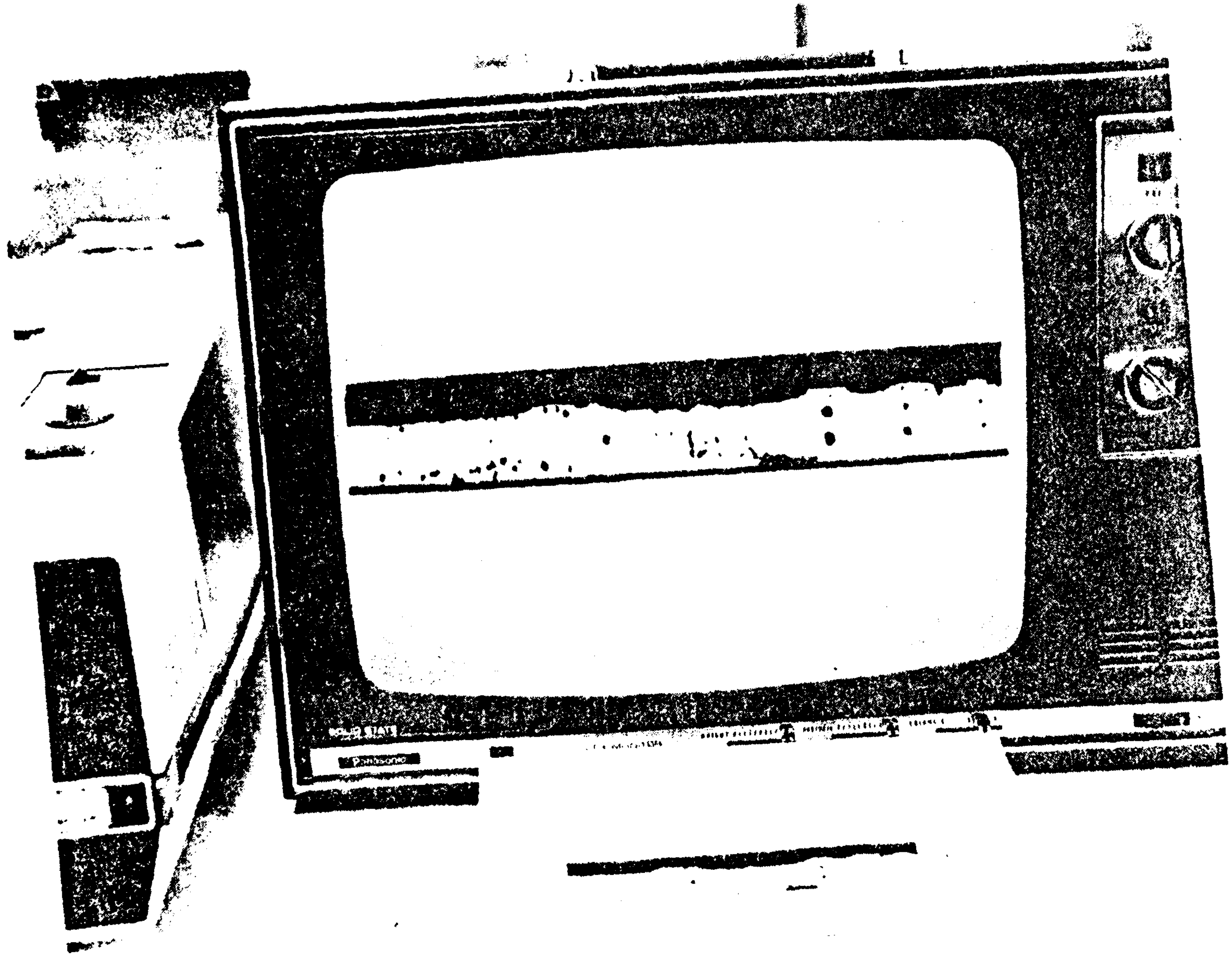
4.2.2.3 The immersion tank and the associated electronic unit were supplied by J. B. Electronics. Most of the remaining electronic hardware was from equipment available in the USA MMRC laboratory. Presently, the electronic system converts a B-scan, which is taken with the available electronic hardware, to a C-scan. A price quote is being sought to determine the cost to produce a similar system commercially. Present estimates indicate the cost to be $40,000 to $50,000. The system would be sold through a commercial supplier, such as Tek Tran.

4.2.2.4 Samples of the 155-mm and 8-Inch inertia welded bands were used to compare the disbond areas obtained with their test equipment to those obtained with Chamberlain's equipment. On Page 34 are shown the patterns obtained with Chamberlain's equipment using a spherical focusing transducer and placing it outside the shell for testing for disbond areas in the weld joint. Photograph 10842 on Page 35 shows the results obtained using the equipment in Watertown. The patterns shown are Polaroid pictures taken from the TV screen (the electrostatic copier was not operating properly at the time). The top view shows the pattern when the transducer elements are located outside the shell, and the bottom view is when it is located inside the shell. The difference in the two patterns is due more to changing the resolution settings of the instrument than in actual differences between the two test methods. The results show that voids in the welded band/shell interface can be detected either by placing the transducer elements inside or outside the shell. Photograph No. 10843 on Page 36 is a magnification of one of the flaws shown by Photograph No. 10842 demonstrating the magnification capabilities of the TV monitor.

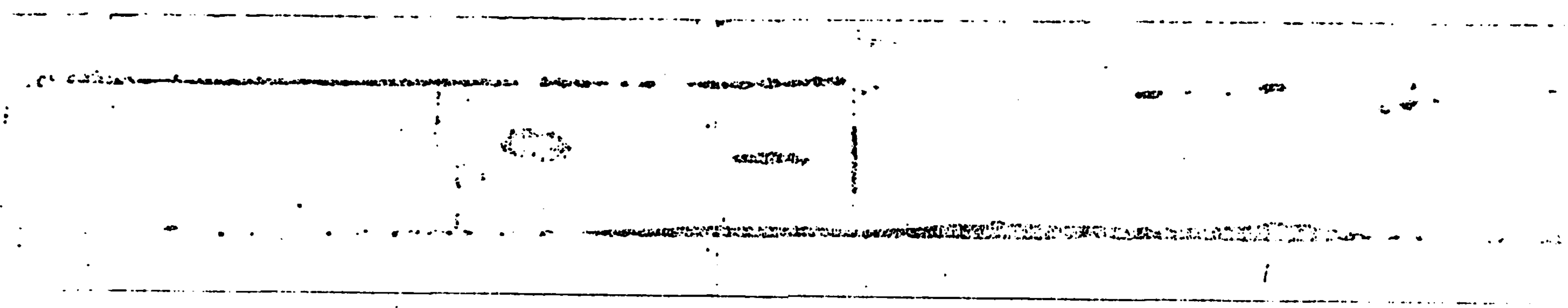
4.2.2.5 Photograph No. 10844 on Page 37 shows the results from the TV monitor for the 8-Inch sample. In the top view, the transducer was located on the outside of the shell, and in the bottom view, it was located inside the shell. The two flaws (small dark areas) shown in the bottom view are not shown in the top view due to the setting of the electronic gate on the instrument. These two flaws were very small and difficult to detect. Only one of the two spots was detected with the equipment available at Chamberlain. Again, this probably derived from the selection of the electronic gate for detecting these flaws.

4.2.2.6 It would be possible to test the inertia welded bands on a production basis with equipment similar to that used at the Watertown facility. The time required for inspecting the band with this method was approximately ten seconds. Previous studies performed at Chamberlain indicated that the band on the 155-mm projectile could be inertia welded on a production basis at a rate of one every 30 seconds. This would allow 20 seconds for loading,

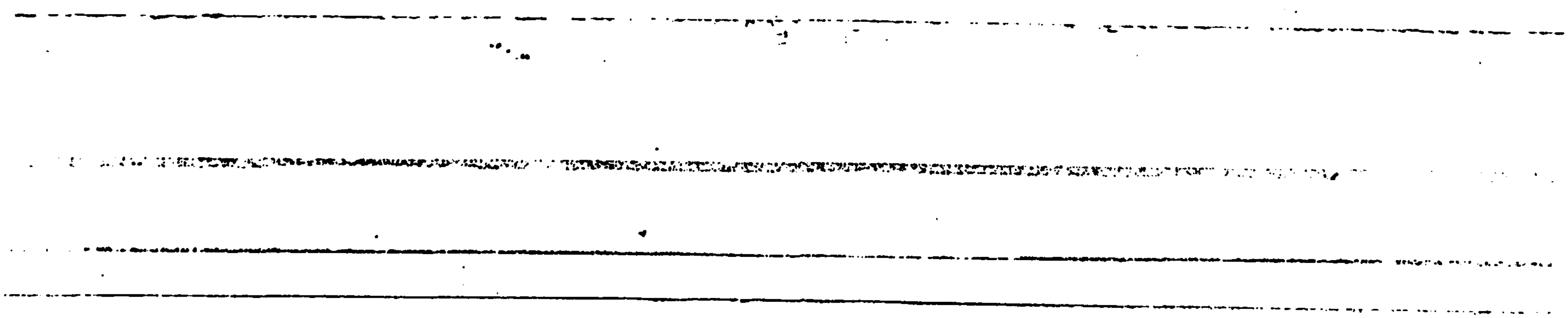
(Text Continued on Page 38)



PHOTOGRAPH NO. 10841
PHASE ARRAY OUTPUT DISPLAY ON TV SCREEN AND ELECTROSTATIC HARD COPY.

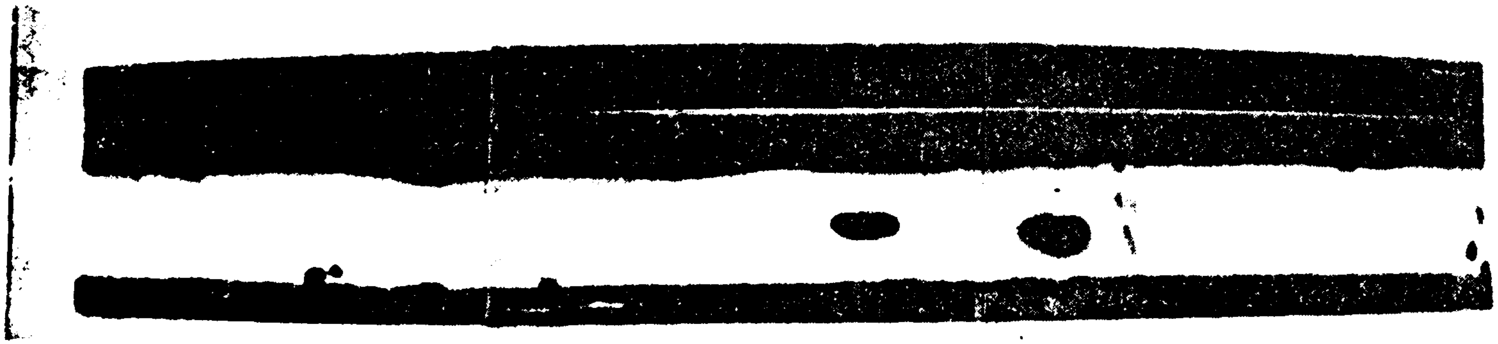


Sample 155-mm, M483 Inertia Welded Band From Chamberlain's Ultrasonic Scanning Equipment



Sample 8-Inch, XM509 Inertia Welded Band From Chamberlain's Ultrasonic Scanning Equipment

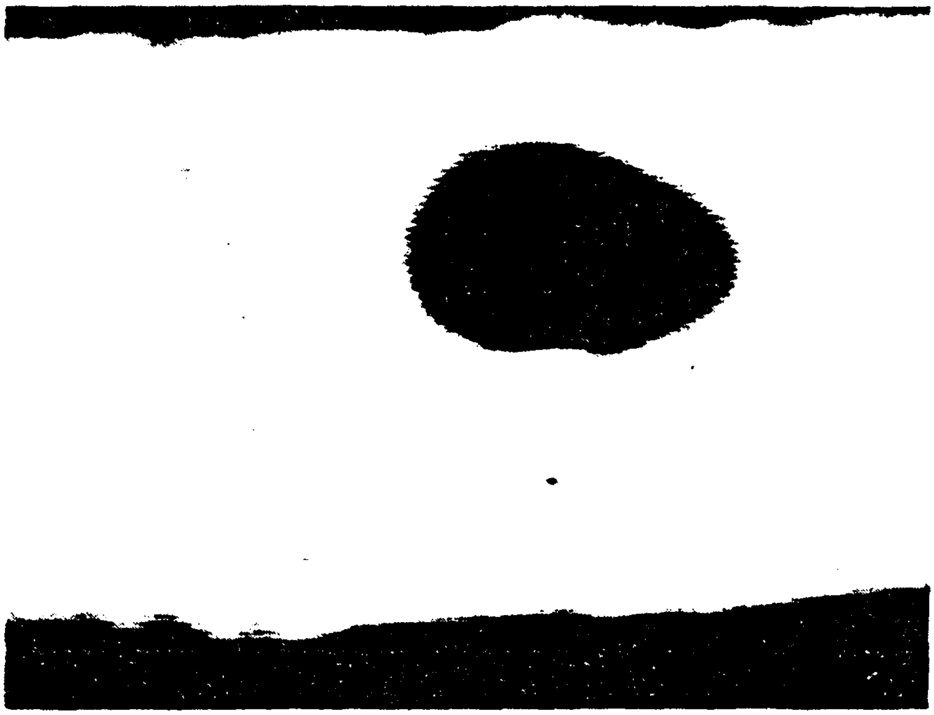
Transducer Located Outside Shell



Transducer Located Inside Shell

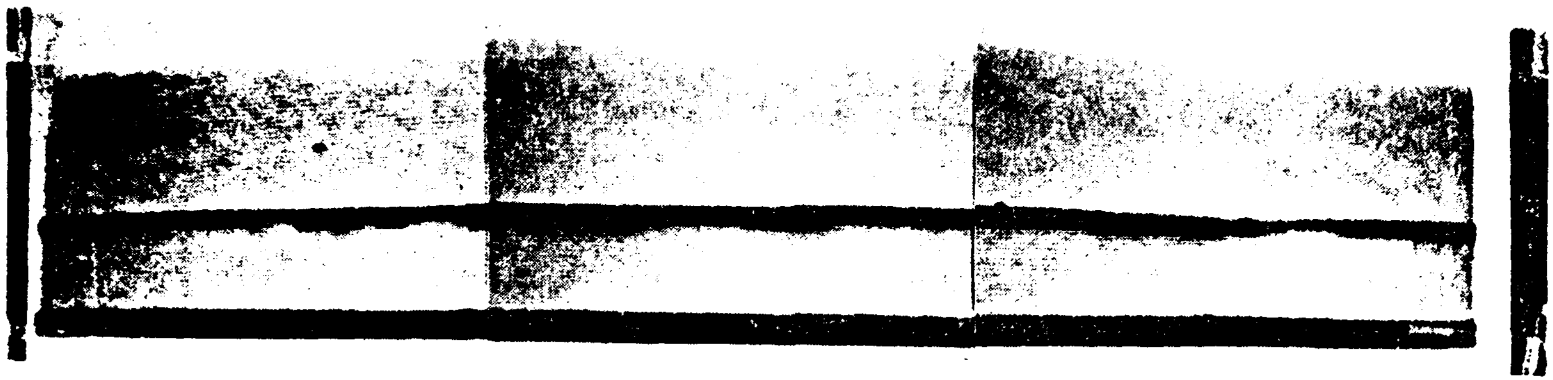
PHOTOGRAPH NO. 10842

SAMPLE 155-MM, M483 INERTIA WELDED SCAN FROM TEST EQUIPMENT AT U. S. ARMY MATERIALS AND MECHANICS RESEARCH CENTER.

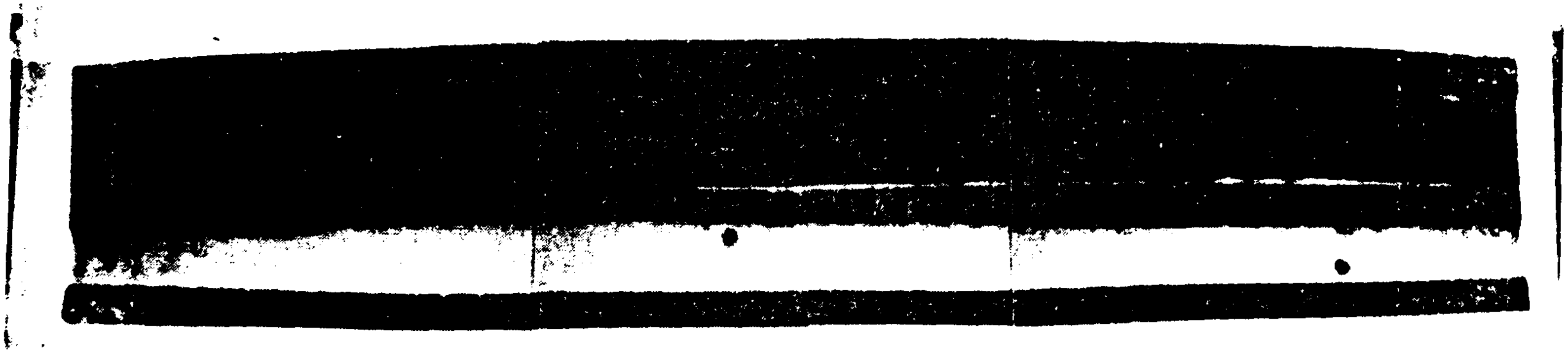


PHOTOGRAPH NO. 10843

MAGNIFICATION FROM TV MONITOR OF FLAW IN INERTIA WELDED BAND ON 155–MM SAMPLE



Transducer Located Outside Shell



Transducer Located Inside Shell

PHOTOGRAPH NO. 10844

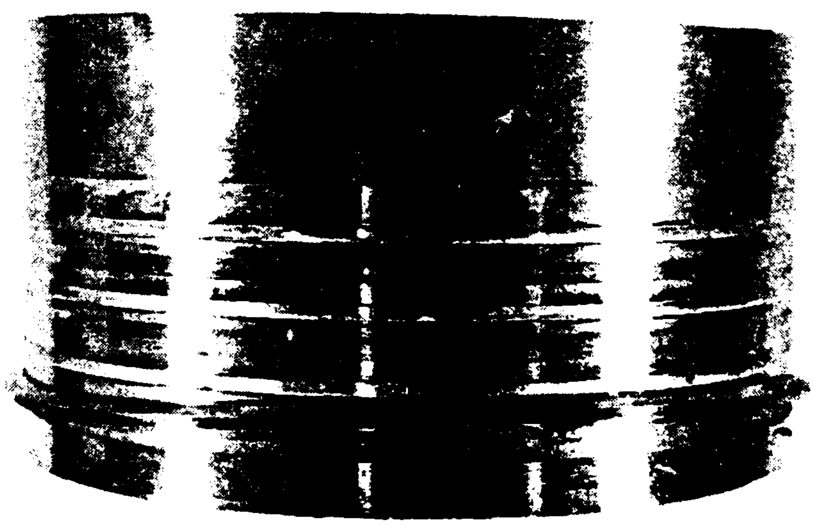
SAMPLE 8-INCH, XM509 INERTIA WELDED BAND FROM TEST EQUIPMENT AT U.S. ARMY MATERIALS AND MECHANICS RESEARCH CENTER positioning, and unloading the projectile for the inspection process. This method should be examined closer when further work on inertia welding bands onto projectiles at high production rates are pursued.

4.3 Destructive Tests and Correlation

A number of destructive tests were used as a cross-check on the efficiency of ultrasonic scanning. In mass production destructive tests are regarded as a necessary evil to cross-check non-destructive techniques, but a careful approach during development sometimes can negate the requirement for destructive tests, or at least hold them to an absolute minimum. The reason is obvious -- the amount of money invested in a projectile at the time it undergoes destructive testing. Furthermore, there always seems to be room for diverse interpretations and argument any time a destructive test is held up as a "standard" for a non-destructive method. The time invested in the destructive method adds to production personnel's abhorrence of this approach because of the data lag while machines are producing rounds. Thus, as a minor goal of the program, the Company sought first to established performable destructive methods, and then to determine their reliability and desirability.

4.3.1 Shear Tests

4.3.1.1 Shear tests can be conducted wherever there are hydraulic or mechanical presses instrumented to indicate the load exerted on the items to be sheared. In Chamberlain's case, we used an Instron Universal Test Machine, tooled to fit our shear sample, with a continuous chart recorder to record the data. Samples are prepared by machining away parts of the band, leaving concentric rings of band material as shown in the photograph below.



Shear Ring Test Specimen

4.3.1.2 The bands were machined from the steel, leaving three shear rings 0.10 inch wide spaced about 1/2 inch apart. The bands were machined in this manner in order to be able to apply a reasonably "pure" shear load to a known area of weld. These tests were performed on both 105-mm and 155-mm samples. On the 105-mm samples, the radial width of the shear ring was .13 inch, and on the 155-mm samples, the radial width was 0.20 inch. The shear stress required to shear the rings on the 105-mm samples averaged 29,600 psi, and on the 155-mm samples, it averaged 24,300 psi. According to hardness tests performed on the band material, it should have a shear strength of 32,500 psi. It is believed the lower values were obtained because the rings can not be put into pure shear.

4.3.1.3 The weld also is put into tension because the shear ring tends to roll over in the shear test fixture. This effect was more pronounced on the wider shear rings on the 155-mm specimens than on the narrow shear rings on the 105-mm specimens, and we believe this is the reason for the lower values obtained on the 155-mm tests. It should be noted that no unbonded areas were observed when the ultrasonic records indicated the weld was good.

The complete band was sheared on five test specimens. A photograph of one of these is shown below. These bands were sheared in a 250-ton press. The average force required to shear these bands was 468,000 pounds. This represents an average stress on the weld area of about 14,000 psi. However, the

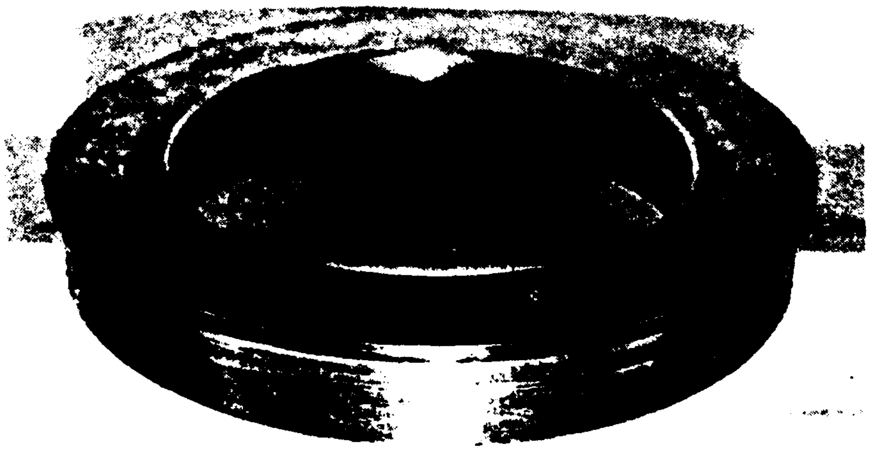
Band Shear Test Speciman

weld did not fail initially. The band flowed and spread and sheared through the band material until it was more than half sheared. At this point the weld began to fail, but the weld area supporting the load had been reduced to less than 1/2 the original area. This being the case, the weld stress had reached at least 30,000 psi, and it can be expected to fail in this region. It seems fair to conclude that the weld essentially is as strong as the band material itself.

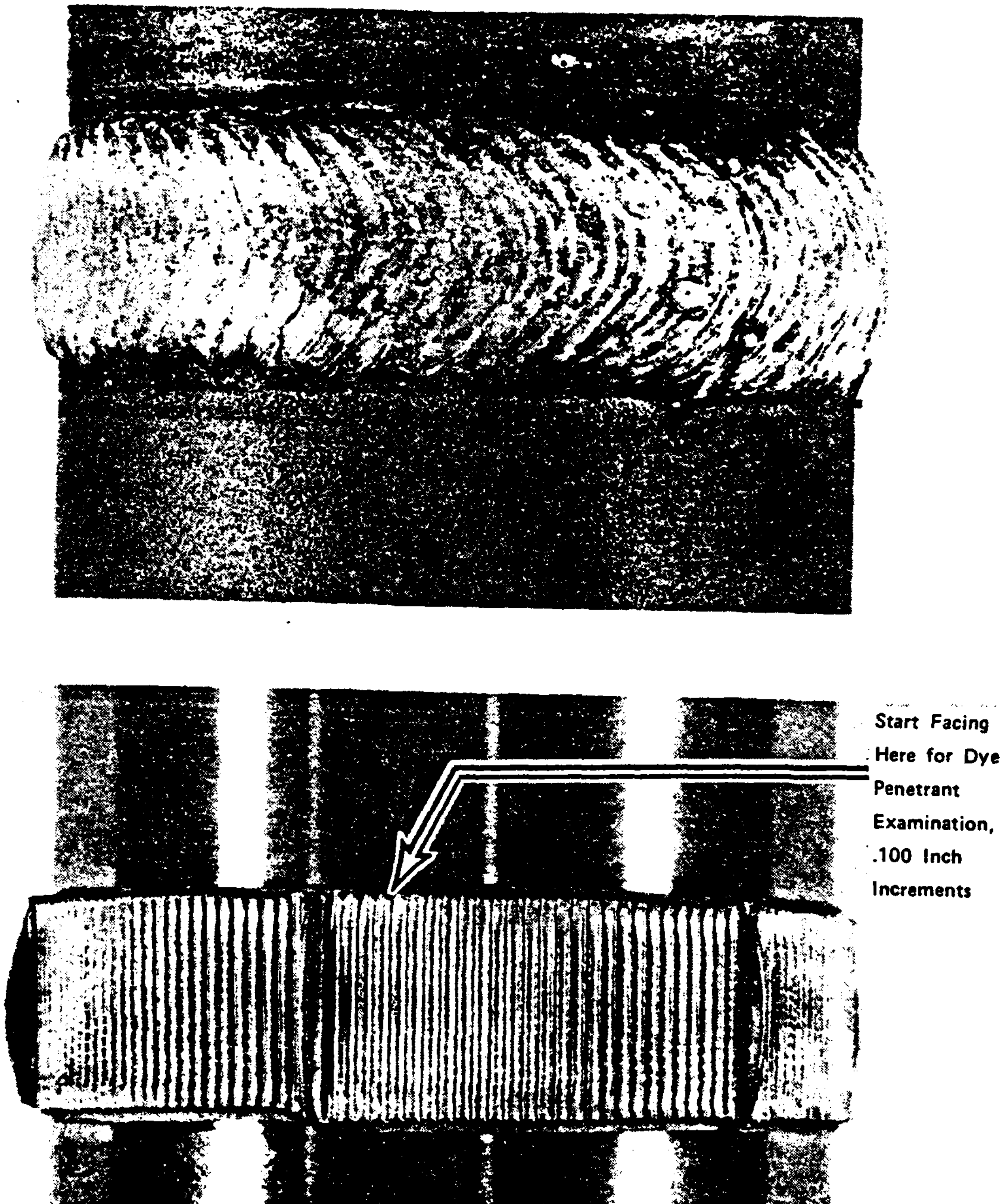
4.3.1.4 A MIG welded overlay band also was sheared in this manner in order to compare the processes. Although the welded area essentially was the same, the radial thickness of the MIG welded band was only about 1/2 that of the inertia welded band. The force required to shear this band was only 280,000 pounds. It seems fair to conclude that the force required to shear the band is a function of band thickness as well as weld strength, so a direct comparison could not be made.

4.3.2 Dye Penetrant Examination

4.3.2.1 Dye penetrant examinations were conducted on both 105-mm and 155-mm projectiles after the bands were inertia welded in place. Our method was to examine an entire projectile body-band interface. Projectiles were machined to present a flat, shear interface at the forward end of the band -- use Photograph No. 10736 on the following page as a reference to how a recent banding appears before machining down into the projectile to expose the interface. We then cleaned the faced-off band area with Zyglo ZC-7 cleaner and sprayed on Zyglo AC-22 dye penetrant. The penetrant was left to work for one-half hour. We then cleaned the surface with ZC-7 cleaner and sprayed on Zyglo ZP-9 developer and subjected the surface to ultraviolet light to determine if any of the dye penetrated the interface between the band and body. After the examination was completed, we machined away .100 inch to present a new interface surface and repeated the process until the entire band area was machined away (See photograph below).



Specimen for Dye Penetrant Examination



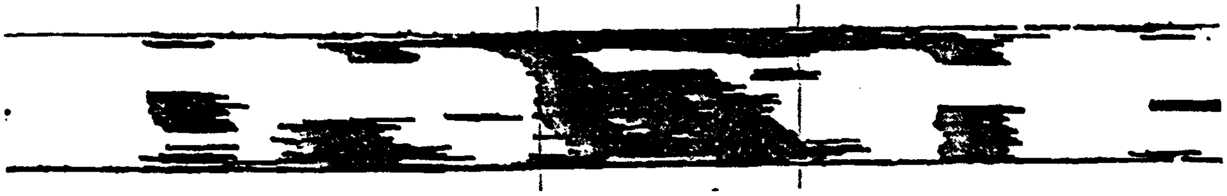
PHOTOGRAPH NO. 10736

TYPICAL MIG–WELDED ROTATING BAND (TOP) AND INERTIA–WELDED ROTATING BAND (BOTTOM) IN AS–WELDED CONDITION.

4.3.2.2 The results with dye penetrant examinations during May 1976 were inconclusive. Some flaws indicated by ultrasonic scanning could be located with the dye and others could not. During November 1976 another attempt was made with somewhat better results, possibly because the disbond areas were more gross and possibly because of better technique with the dye penetrant process. On the whole, we believe we achieved correlation between the ultrasonic scans and dye penetrant examination, but in examining a band by increments we accumulate a great deal of time between lathe facing and the dye process itself. We do not regard the process as a good production check, but possibly as a reference check where conflicting opinions are raised concerning results achieved by ultrasonic scanning.

4.3.3 Peel Tests

4.3.3.1 Another method used to establish correlation between ultrasonic scanning and actual disbond was to mechanically peel sections of the band from the projectile body and compare the bonded areas with those indicated on the ultrasonic scan. Specimen No. 39 had a particularly poor weld because the band slipped in the collet. The ultrasonic scan for this weld is shown below. This specimen was selected for the "peel test" since the large unbonded areas would make it easier to remove the band sections. The area of the band that was removed is indicated in the photograph which represents a length on the circumference of the band of about four inches. The

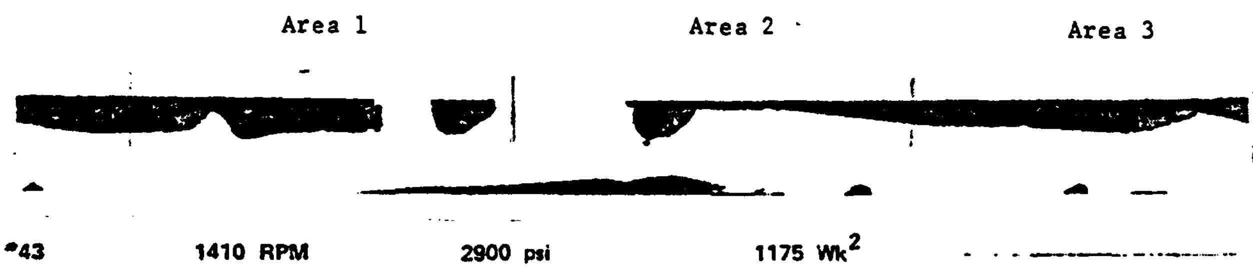


Ultrasonic Scan of Specimen No. 39

band was slit longitudinally into sections about one-inch wide, and these sections were chiseled from the steel surface. The bonded areas could be determined by the difficulty encountered when removing the strips, and by the surface texture of the material at the separation plane. The bonded areas compared very well with the ultrasonic record. A photograph of the specimen is shown on the following page. This test is only applicable to gross defect determination.

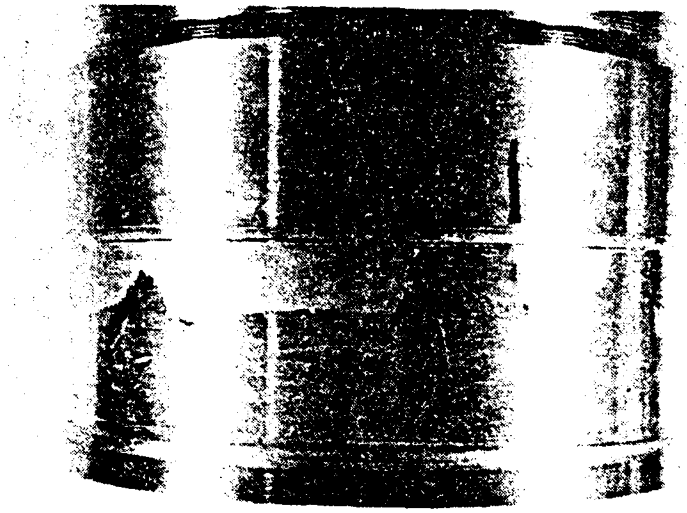
Photograph of Specimen No. 39 Showing Peeled Sections

4.3.3.2 Perhaps the most revealing method for comparing the ultrasonic scans with actual results is to turn the band in a lathe until only a thin layer about .005 inch thick, is left on the steel. This foil layer can easily be peeled from the steel in areas where it is not welded, and these areas can be compared with the ultrasonic scan. This has been done on several specimens, and photographs of a typical specimen are included. Below is a copy of the ultrasonic scan for Specimen No. 43.



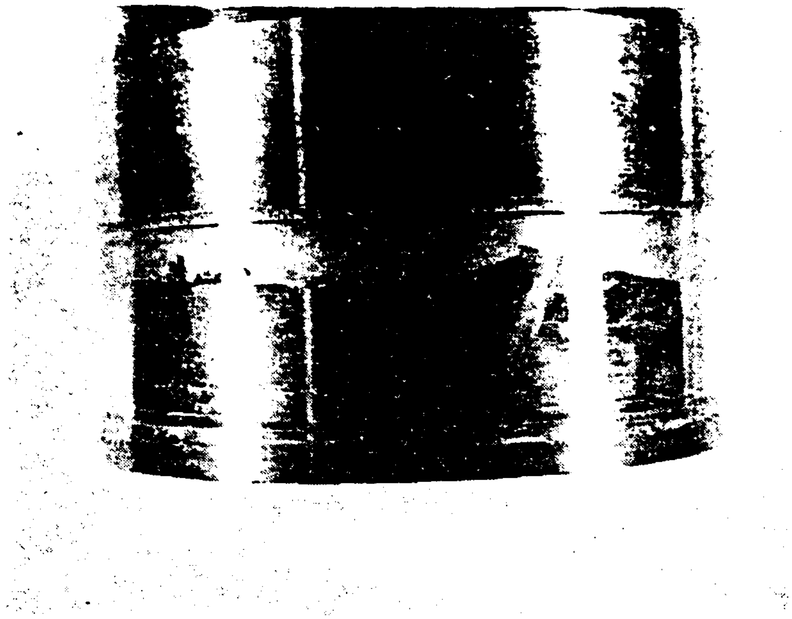
Ultrasonic Scan for Specimen No. 43

Photographs of the peeled band, which was removed on the forward edge only, are shown in the next three photographs. The areas of the band corresponding to each photograph are indicated in the ultrasonic scan on the previous page.



Photograph of Area 1, Specimen 43

Photograph of Area 2, Specimen 43



Photograph of Area 3, Specimen 43

As can be seen, the peeled areas are practically perfect replicas of the dark, or unbonded, area of the ultrasonic scan. Several specimens have been compared with the ultrasonic scans in this manner, and good correlation was always obtained. These results indicate that the ultrasonic scanning technique is adequately detecting the unbonded areas.

4.3.3.3 A variation of the above technique was suggested by a U. S. ARRADCOM representative during a visit to Chamberlain during October 1977. He suggested turning down the band until a foil layer remained and then acid etching the layer. Patterns left in steel band seat would indicate the presence of voids. The Company did not have time to use the technique but we can see its possibilities, once an etchant solution strength and time in solution had been established.

4.4 Special Laboratory Tests

During the course of the program it became necessary to conduct special tests in our metallurgical laboratory to aid attempts to understand more fully what occurs in the band interface zone during the weld process, and during production heat treatment after the band is seated. One must realize that stresses and high heat often can cause metallurgical phenomena not considered during the early planning stages of a program, but which must be understood or at least acknowledged if the program is to be drawn to a successful conclusion.

4.4.1 Grain Growth Analysis

4.4.1.1 After the first firing test conducted during June 1977 we became alerted to possible problems occurring during production heat treatment of M483A1 Projectiles after the bands had been applied by inertia welding. There is definite evidence that the heat treat cycle definitizes any disbond indication at the body-band interface. This is supported by before and after heat treatment ultrasonic scans, some of which are shown in Photograph Nos. 10786 and 10787 on the following two pages.

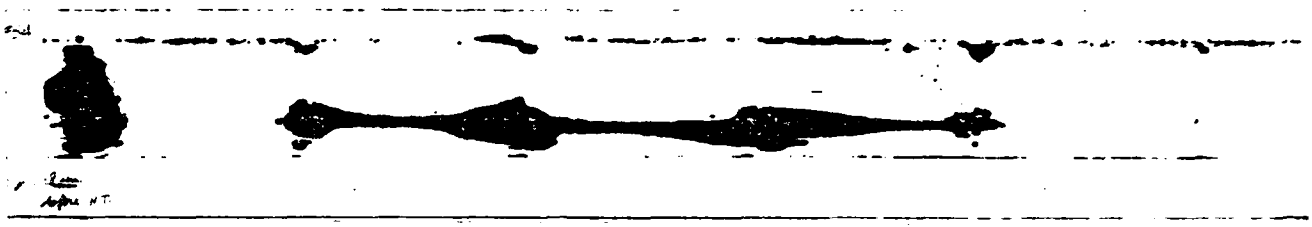
4.4.1.2 The scans for Bands 77-191 and 77-225 prompted another investigation. Note the "grainy" appearance of the scans where before heat treatment we assumed we have 100% bond. The question was raised as to whether the copper experienced grain growth during heat treatment to the extent that we may pick up this growth as a signal after heat treatment. Accordingly, the metallurgical laboratory was requested to furnish grain size data from new band tubing, before and after heat treatment of a projectile banded before final machine parameters were established during January 1977, and before and after heat treatment of projectiles banded to final machine parameters. The analysis was conducted during July 1977, with four projectiles selected as follows:

PROJECTILE NO.	REMARKS
58	Early Process (Before January 1977), as Welded
49	Early Process, Welded and Heat Treated
A	Present Process, as Welded
204	Present Process, Welded and Heat Treated

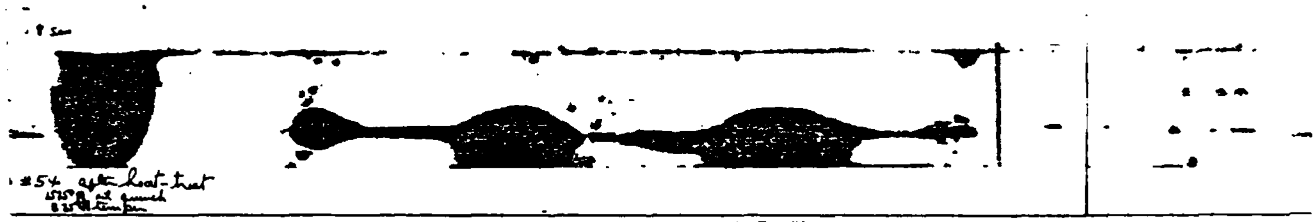
4.4.1.3 Our first consideration was to check hardness, which yielded the following:

PROJECTILE NO.	ROCKWELL 15-T HARDNESS
Material As Received	52.9
58	71.6
49	59.3
A	73.6
204	61.2

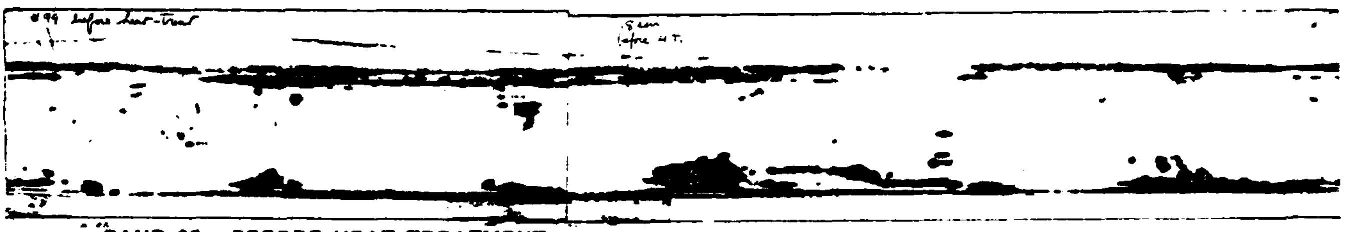
The above are average values across the thickness of the bands, except for the narrow, five-grain region near the band-body interface. All four processed bands were harder than the as-received bands, an unexpected situation in view of the length of the projectile body heat treat cycle. Microscopic



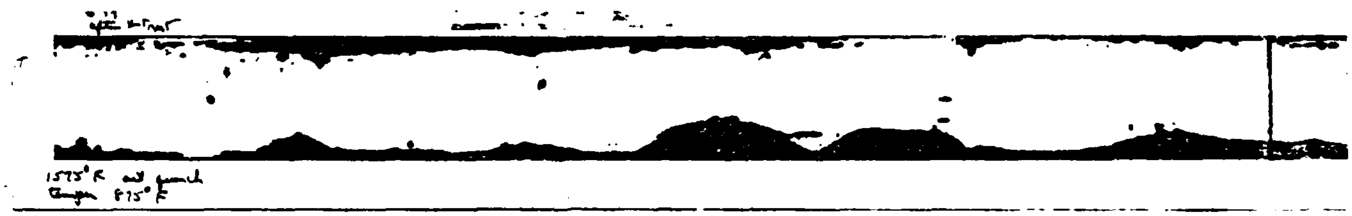
BAND 54: BEFORE HEAT TREATMENT
.8 SENSITIVITY



BAND 54: AFTER HEAT TREATMENT
.8 SENSITIVITY; 1,575° F OIL QUENCH; 875° F TEMPER

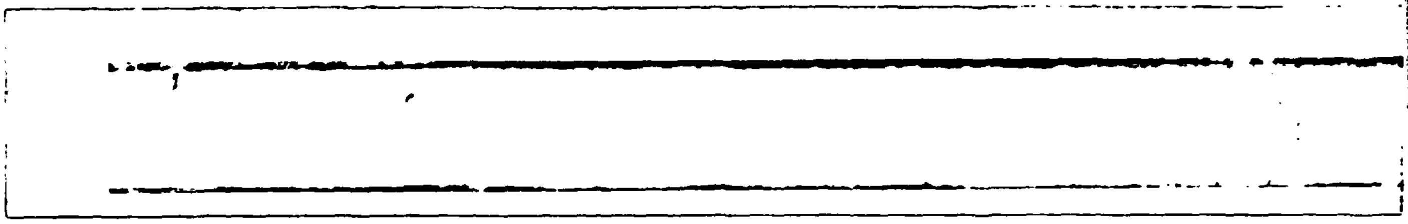


BAND 99: BEFORE HEAT TREATMENT

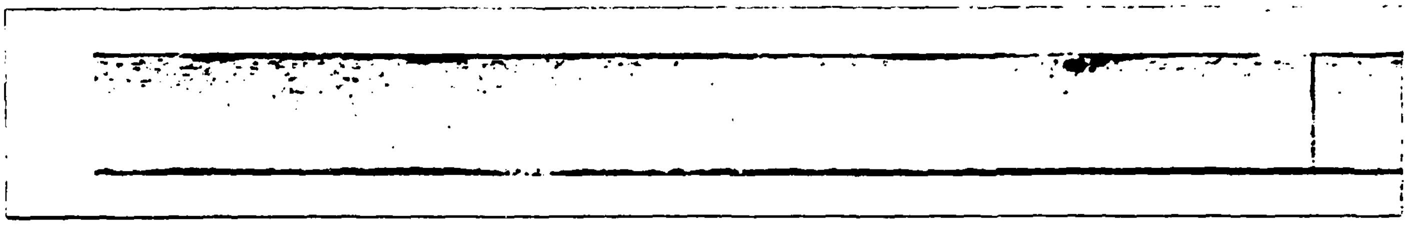


BAND 99: AFTER HEAT TREATMENT
1,575° F OIL QUENCH; 875° F TEMPER

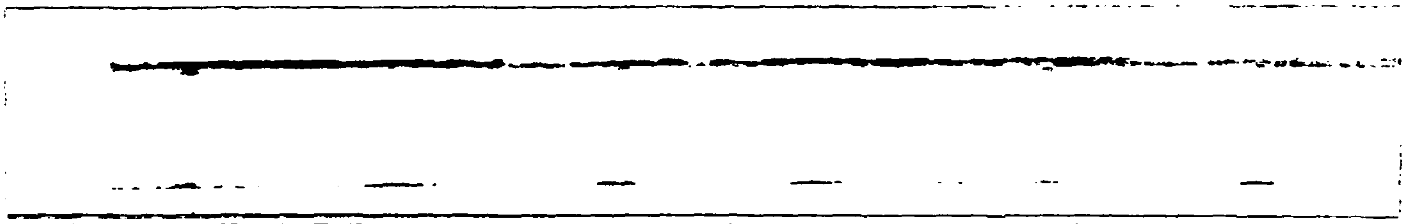
PHOTOGRAPH NO. 10939
TWO M483A1 INERTIA WELDED BANDS FROM GROUP PROCESSED BEFORE FINAL PARAMETERS WERE ESTABLISHED. HEAT TREATMENT INCREASES ANY PREVIOUS DISBOND INDICATION.



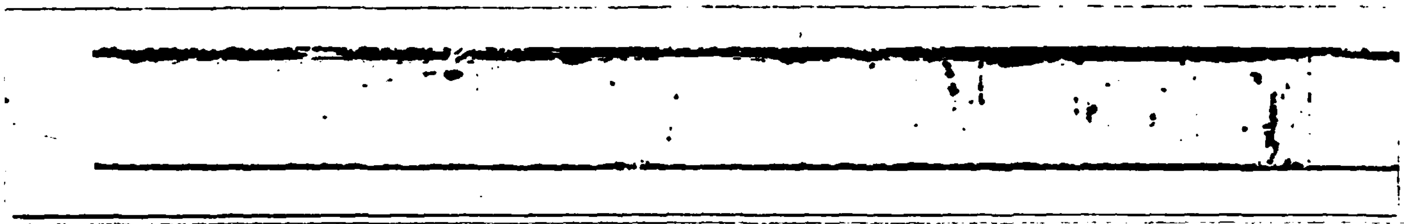
BAND 77–191: BEFORE HEAT TREATMENT



BAND 77–191: AFTER HEAT TREATMENT



BAND 77–225: BEFORE HEAT TREATMENT



BAND 77–225: AFTER HEAT TREATMENT

PHOTOGRAPH NO. 10787

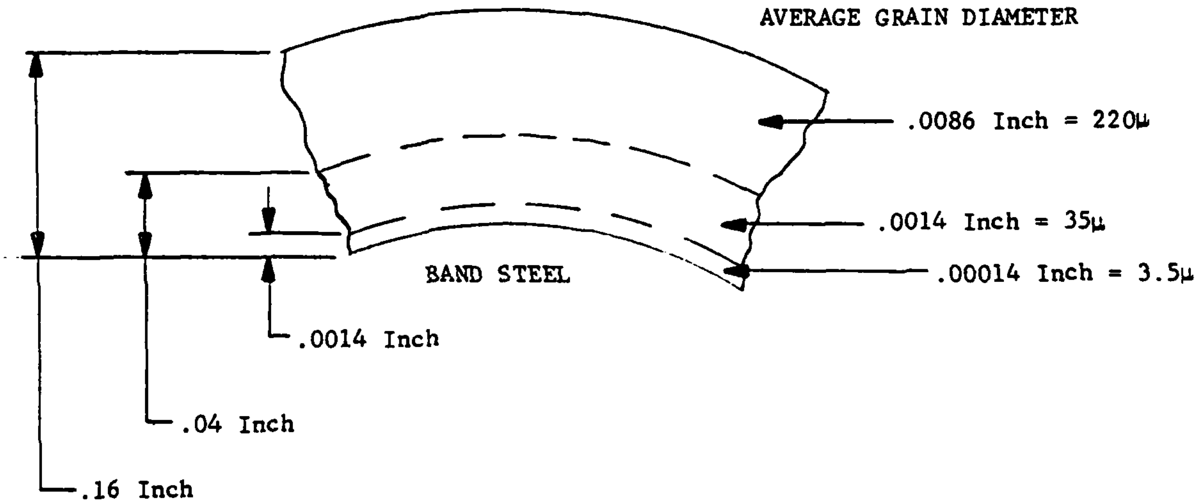
TWO INERTIA WELDED BANDS WELDED AT 2200 RPM, 3800 PSI TAILSTOCK PRESSURE, 425 WK^2 FLYWHEEL. HEAT TREATMENT INCREASES ANY PREVIOUS DISBOND INDICATION.

examination showed a number of slip lines (evidence of deformation) in both the as-welded and heat treated samples. These slip lines could explain the higher hardness by virtue of: (1) insufficient time or temperature during heat treatment to eliminate them, or (2) stresses induced in the gilding metal during cool-down from high temperatures, accentuated by the differences in thermal expansion-contraction between the gilding metal and the steel body.

4.4.1.4 The as-received bands have a uniform mean diameter grain size of .008 inch or 200 microns. The sketches which follow show differences observed from the as-received condition.

PROJECTILE 58

AS WELDED, EARLY PROCESS

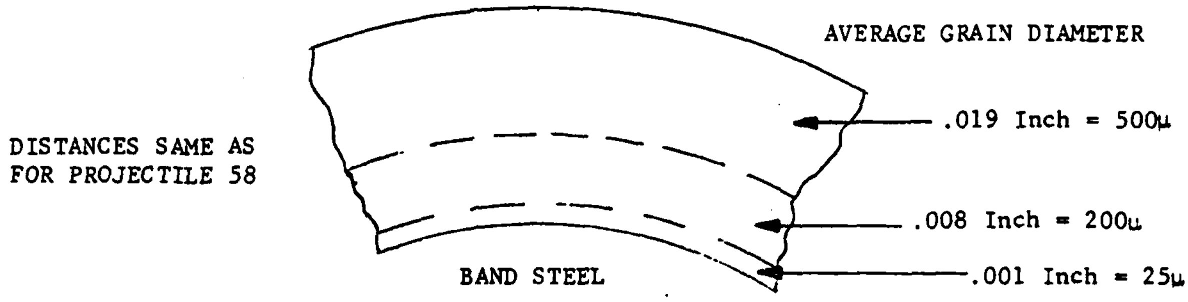


The cold deformation and heating during welding were sufficient to cause recrystallization in the band for about .040 inch from the interface. The heavier deformation very near the interface gave a very fine grain size. Slight grain growth may have occurred in the region beyond .040 inch from the interface.

5?

PROJECTILE 49

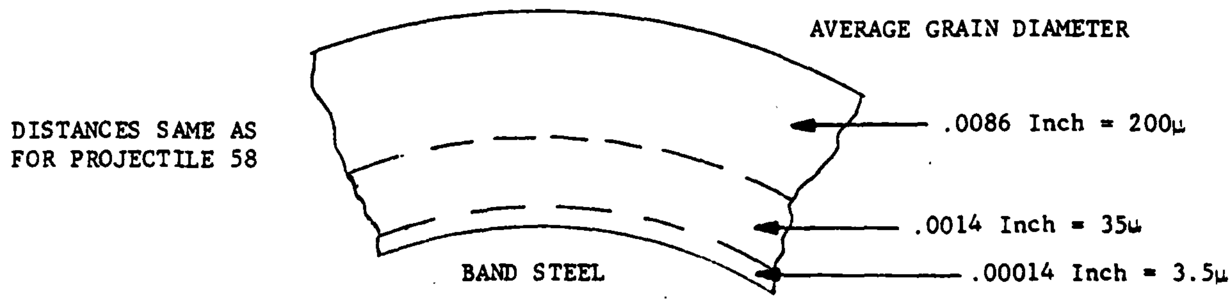
WELDED, EARLY PROCESS, HEAT TREATED



The grains in all three zones grew; there was significant annealing as shown by the decrease in hardness presented previously.

PROJECTILE A

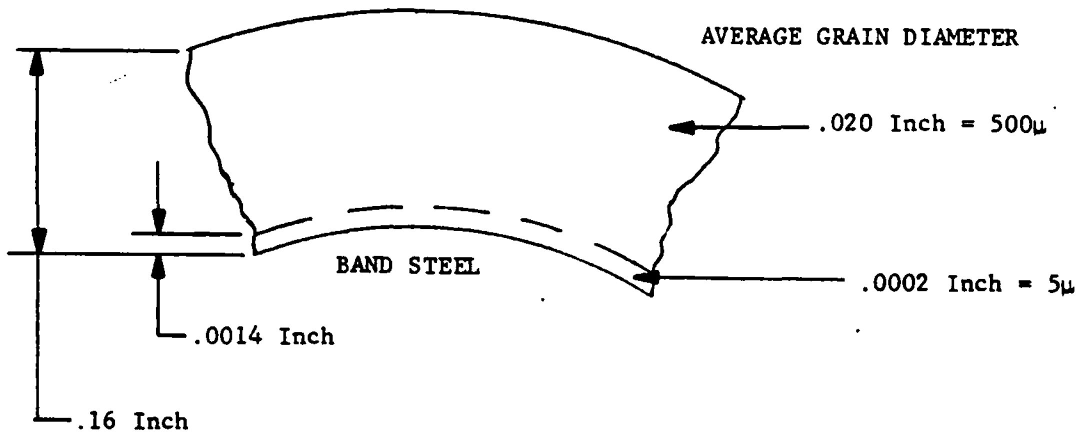
AS WELDED, CURRENT PROCESS



Same observations as for Projectile No. 58.

PROJECTILE 204

WELDED, CURRENT PROCESS AND HEAT TREATED



Grain growth and softening; the only difference from Projectile 49 is that the intermediate grain size region does not remain. Generally we concluded that there is slight grain growth in the band, but not enough to affect the ultrasonic scanner.

4.4.2 Decarburization Analysis

4.4.2.1 During August 1977 problems were experienced applying rotating bands to projectiles which had been heat treated prior to the inertia welding operation. The problem was compounded by the fact that finished band seats had been machined into the projectiles prior to heat treatment. All the projectiles arrived from New Bedford slightly scaled and discolored from heat treatment. While the bourrelets were being turned down to fit the tailstock collet, the band seats were cleaned with emery paper, but some discoloration still persisted in the bottoms of tool marks left in the band seats. On the first two inertia welding attempts the bands did not bond as well as on the non-heat treated bodies, with edge effects pronounced on the ultrasonic scanner. Note that at this stage of process development our term for poor bonding differs considerably from the same terminology used before January 1977. What we now term as poor bonding still is superior to the bonds achieved on the first 33 rounds fired at Yuma Proving Ground.

4.4.2.2 After the first two attempts the band seats continued to be cleaned in the lathe using emery paper, but a shot blast operation was added to effect added cleaning. Welds started to improve. The only additional cleaning was the usual wipe with trichlorethylene solvent at the inertia welder. Edge effects still were more pronounced than with the non-heat treated bodies. We attempted further cleanup on the last four band seats by taking a slight skin cut in a lathe, but welding remained about on a par with those which were shot blasted. Twelve (12) projectiles were selected for firing.

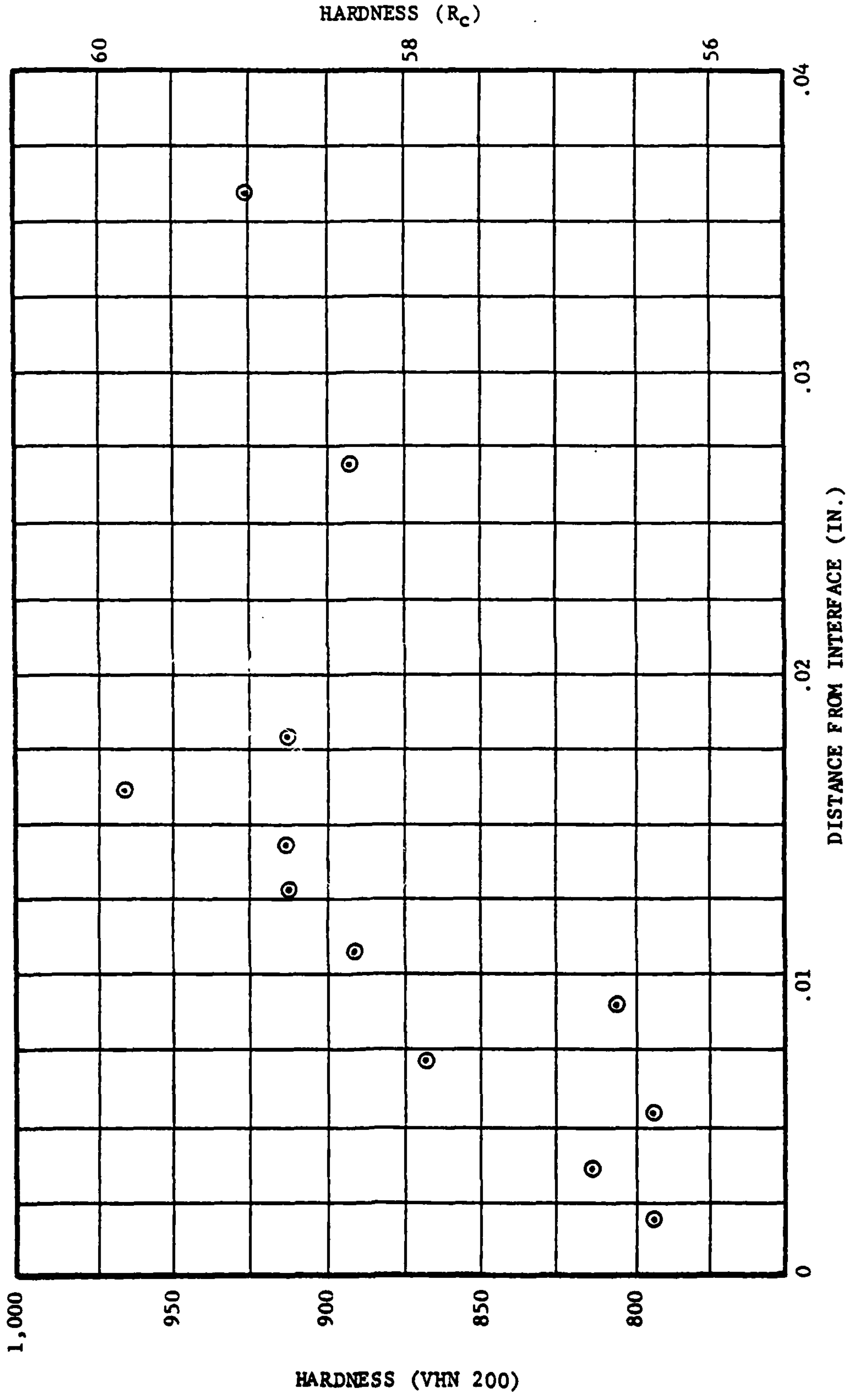
4.4.2.3 As a result of processing the pre-heat treated projectiles, Company personnel raised the question among themselves as to whether poorer bonds were attributable to the presence of baked-in quench oil residue, decarburization or hardness. The last four band seats which were lathe turned eliminated the quench oil residue question, but we were not certain about decarburization. Accordingly, a laboratory analysis was set up to determine whether decarburization existed.

4.4.2.4 During October 1977 Chamberlain completed its analysis for decarburization of the band seats on rounds heat treated prior to banding. Band seat areas were sectioned from projectiles held at Chamberlain, these units having bonding which we considered too poor for subjecting the projectiles to dynamic firing tests. Optical examination of the band-body interface prior to an etch revealed nothing. Parts were etched with 3% Nital/97% Methyl Alcohol and were resubjected to optical examination at 100X to 1,000X magnification. Unfortunately, the gilding metal in the interface interfered with optical determination of decarburization because of interaction with the etchant.

4.4.2.5 An alternate approach was taken. Since hardness is sensitive to a martensitic condition and this condition is a sensitive function of carbon content, a decision was made to check microhardness in the band-body interface region. Parts were heated to 1,600°F and were given a severe quench in room temperature brine. In the graph on the following page, 0 is the interface, with the horizontal axis going deeper into the body. As shown by microhardness, there is a slight area of decarburization beneath the band seat of the projectile. Data were found which allow a reasonably good conversion of Vickers hardness to Rockwell-C hardness. The Rockwell-C values are shown on the right-hand ordinate of the graph. While absolute values of Rc are approximate, differences should be reliable. The data show a decrease of about 3.0 - 3.5 Rockwell-C points from the interface to the level value far away from the interface. Information in "Republic Alloy Steels," a publication of the Republic Steel Corporation, shows that a decrease in hardness of martensite of 3.0 - 3.5 Rockwell-C points corresponds to a decrease in carbon content from 0.40 to 0.35%.

4.4.2.6 For the 1340 steel used in this test, the data indicate the decarburization at the surface was not very significant. Whether it was enough to interfere with the bond achieved by inertia welding is problematical. If projectiles do not have to be heat treated before banding, we can ignore the questions, but if vice-versa, we simply will machine the band seat following heat treatment, ridding us of any decarburized zone.

4.4.2.7 Another related problem also is raised by inertia welding after heat treatment. As the band seizes onto the projectile body, the band seat temperature exceeds the critical transformation temperature of AISI 1340 steel. This leaves a thin zone of brittle, untempered martensite just below the band. This condition was telephoned to the Project Officer who instructed the Company to proceed with finish machining operations on the final test quantity.


HARDNESS (R$_c$)
60
58
56
.04
.03
.02
.01
0
DISTANCE FROM INTERFACE (IN.)
1,000
950
900
850
800
HARDNESS (VHN 200)

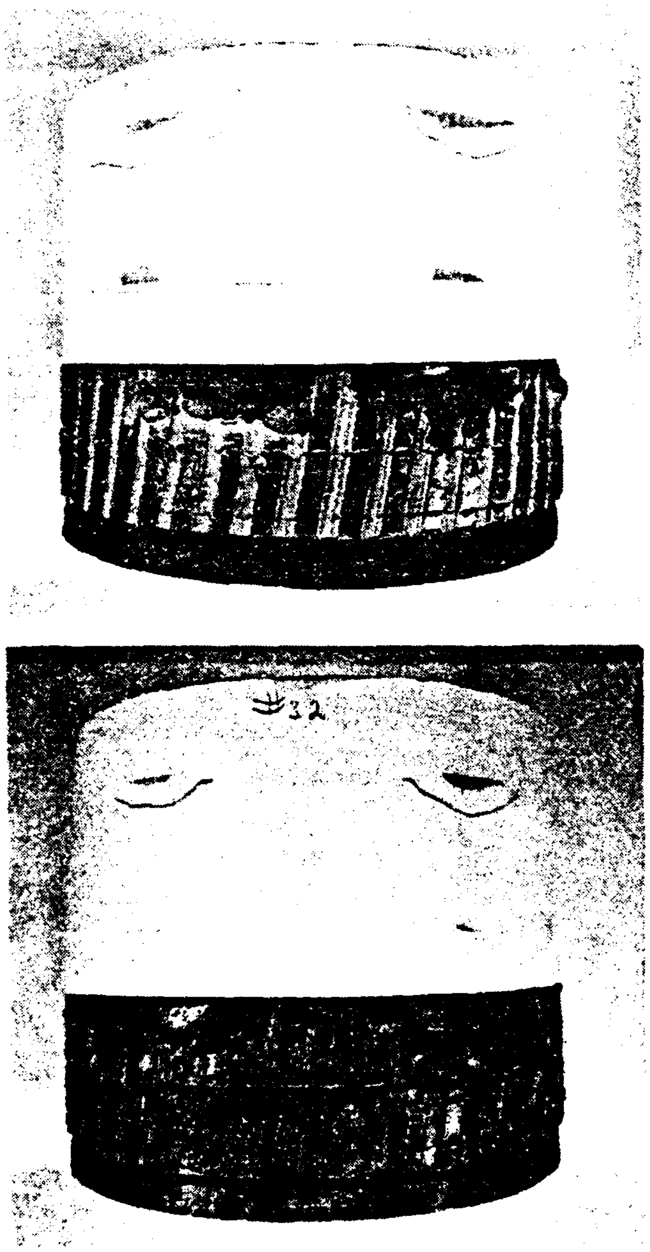
5. DYNAMIC FIRING TESTS

5.1 Test No. 1

5.1.1 On 24 May 1977 TPR AD-E-B-2067 was undertaken at Yuma Proving Ground using 33 M483A1 Projectiles with inertia welded bands and the XM198 Howitzer. All projectiles were loaded with special test grenades from another program, live expelling charges, and live M577 Fuzes. The portion of the test applying to this contract concerned performance of the inertia welded rotating band. Bands assembled to these projectiles were applied during the period from 1 October to 31 December 1976, prior to the time the Company discovered that tailstock ram pressure is the governing parameter for achieving consistent bonding. As a result, bands in this group of 33 had varying degrees of disbond as determined by ultrasonic scans with Chamberlain's Sperry UM721 Reflectoscope prior to heat treatment. The first 21 rounds were selected by the Project Officer during a visit to the Company. The remaining 12 rounds were selected by Company personnel following direction of the Project Officer. Appendix 2 to this report shows ultrasonic scans for Rounds 1 through 69. These projectiles selected for firing are indicated on the photographs.

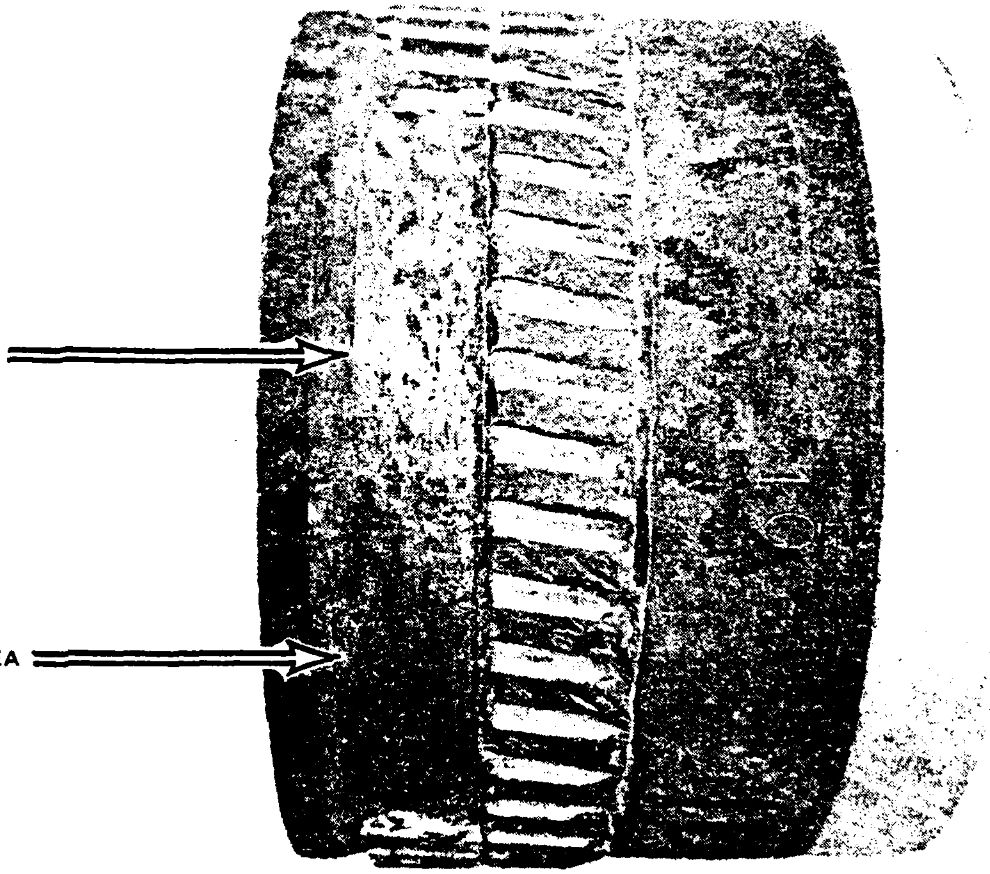
5.1.2 On 9 August 1977 the Company received 32 aft body sections recovered from the dynamic firing test conducted at Yuma Proving Ground. The projectiles had been sawed in two, providing Chamberlain with the banded portion for examination, leaving the forward end at Yuma Proving Ground for checking other test objectives not related to this program. All but Test Round No. 7 had been recovered, and this was in the group of 15 fired from the XM198 Howitzer at Charge, Propelling, M3A1 (Zone 3). None of the 14 recovered rounds fired at Zone 3 sustained any separation of bands from bodies.

5.1.3 Eighteen (18) rounds were recovered which were fired at Charge, Propelling, M203 (Zone 8). Six of these rounds survived without damage or loss of band material. The remaining 12 sustained varying degrees of separation at the leading and trailing edges. Unfortunately, it has proven very difficult to equate the band loss with ultrasonic scans because in the process of transferring the round numbers during the machining operations the angular reference mark apparently was not retained, causing us to be uncertain of our witness mark location. We were able to approximate the damage areas to ultrasonic scans on some rounds, typified by Rounds 14 and 32, shown in Photograph No. 10800 on the following page. We also can see that band shear started in areas of disbond and carried through into bonded areas as shown by Photograph No. 10801 on Page 56. Note that gilding metal still adheres to the band seat next to an area of disbond. There were a number of sheared areas on other projectiles which exhibited the same characteristic.



PHOTOGRAPH NO. 10800

RECOVERED M483A1 BANDS SHOWING RELATION OF SEPARATION TO ULTRASONIC SCAN INDICATION OF A NON-BONDED CONDITION.



PHOTOGRAPH NO. 10801
RECOVERED M483A1 BAND SHOWING HOW SEPARATION CONTINUES FROM NON-BONDED AREA INTO BONDED AREA.

5.1.4 After full examination of all returned hardware, we believe that band failure occurred in-bore, and that failure started in areas of disbond. A reappraisal of Zone 8 firing data substantiates this conclusion. Note in the data sheet on following page that the undamaged bands produced more consistent chamber pressures, range, and muzzle velocities. All of the "shorts" indicated by the range column occurred with rounds having damaged bands. It is our opinion that the short range rounds resulted from extra aerodynamic drag induced by partially adhered pieces of band material. On the encouraging side, chamber pressures and muzzle velocities were remarkably consistent. No bands sheared away completely, thus maintaining obturation all the way in-bore. None of the bands showed indications of in-bore projectile balloting, generally indicated by multiple rifling impressions in the band. Since these projectiles do not represent current capability with final inertia welding process, Company personnel were not overly disturbed that damage was sustained. We had an indication at this stage of the program that little, if any, disbond should be allowed on production projectiles. The complete Yuma data package for this test group is included in Pages 59 through 64.

5.2 Test No. 2

5.2.1 Firing of 37 M483A1 Projectiles was undertaken during the week of 1 January 1978 at Yuma Proving Ground. The test was interrupted for a day and a half by severe storms, and was completed on 13 January. Test projectiles were divided into two groups comprised of M483A1 Projectiles having rotating bands welded before and after heat treatment of the projectile body. Of those welded before heat treatment, the Company shipped Projectiles 1B through 27B except for 2B, 8B, and 23B, leaving a total of 24 of these projectiles for firing. Projectiles 2B and 8B had been discarded at the Waterloo plant immediately after welding, and 23B was discarded at New Bedford after heat treatment. In the after-heat treatment ultrasonic scans there was added evidence of non-bonded areas, particularly on Round 23B. However, the Project Officer indicated he would like to include this round in the test as a "worst" example, so it was included to bring this lot up to 25 projectiles. Twelve (12) rounds were shipped which had bands welded after heat treatment. These are Projectiles 2A, 3A, 4A, 7A, 15A, 20A, 21A, 23A,26A, 27A, 28A and 29A. Ultrasonic scans of these projectiles were included with the report for August 1977.

5.2.2 All rounds were fired from the XM198 Howitzer using an XM199E9 Tube having 1,747 previous firings. An M203 Propellant Charge (Zone 8) was employed, with rounds temperature conditioned at 145°F for 24 hours minimum prior to firing. Only two test rounds were fired on 10 January 1978 when the storm occurred. Five test rounds were fired on 12 January and 30 were fired on the following day. Round Nos. 3B, 4B, 5B, 16B, 21B, 22B and 27B were fired with inert nose fuzes, no expelling charge, and inert grenades in order to compare ballistic repeatability with M483 reference rounds. The remainder of the rounds carried live M577 Fuzes and expelling charges to check grenade ejection characteristics and fuze performance. Available firing data are tabulated on Pages 65 through 67.

Text Continued on Page 68

ROUND NO.	RAM PRESSURE (psi)	FLYWHEEL WK^2	FLYWHEEL RPM	CHAMBER PRESSURE (psi)	TEMP. (°F)	RANGE (Meters)	DEFLECT. (Meters)	MUZZLE VELOCITY (fps)
				DAMAGED				
4	2,900	1,175	1,490	57,300	70	-890	60L	2,731
6	2,900	1,175	1,490	57,700	-65	-280	80R	2,738
8	2,900	1,175	1,490	57,800	70	-240	45L	2,730
10	2,900	1,175	1,490	57,000	70	+160	20L	-
12	2,900	1,175	1,410	59,200	-65	-90	30R	2,738
13	2,900	1,175	1,410	59,700	+145	-1160	70L	2,741
14	2,900	1,175	1,410	58,800	70	+60	20L	2,731
22	2,900	1,175	1,490	58,400	70	+210	0	2,736
30	2,900	1,175	1,490	58,100	+145	-120	40L	2,731
31	2,900	1,175	1,490	57,400	+145	-200	60L	2,738
32	2,900	1,175	1,490	57,300	+145	-820	-	2,727
33	2,900	1,175	1,490	60,900	-65	-80	40R	2,763
				NO DAMAGE				
15	2,900	1,175	1,410	58,900	-65	+140	5R	2,736
36	2,900	1,175	1,410	58,100	-65	+240	40R	2,742
37	2,900	1,175	1,375	58,000	+145	0	20L	2,727
60	3,500	575	2,000	58,500	-65	+40	40R	2,745
62	3,500	575	2,000	58,100	+145	+180	10L	2,733
69	3,500	575	2,000	56,800	+70	+220	40L	2,733

M483A1 PROJECTILES FIRED AT CHARGE, PROPELLANT, M203 (ZONE 8)

ZONE 3

FIRING DATA SHEET

DATE OF FIRING	TEST NO.	ROUND NO.	PROPELLANT			PROJ. TEMP. (°F)	CHAMBER PRESSURE (Average psi 100)	MUZZLE VELOCITY (fps)	CAMERA COVERAGE	AIR BURST		BAND ENGRAVING (Good or Bad)	REMARKS
			ZONE		TEMP.					RANGE (M)	DEFLECT. (M)		
24 May 77	1250	63	3	M3A1	70°F	70°F	8.7	852		-210	40R	Good	No Band Failure
24 May 77	1251	67	3	M3A1	70°F	70°F	8.7	855		-260	20R	Good	No Band Failure
24 May 77	1252	20	3	M3A1	70°F	70°F	8.7	856		-250	5R	Good	No Band Failure
24 May 77	1253	16	3	M3A1	70°F	+145°F	8.4	858		-230	10R	Good	No Band Failure
24 May 77	1254	141	3	M3A1	70°F	+145°F	8.5	858		-220	20R	Good	No Band Failure
24 May 77	1255	39	3	M3A1	70°F	+145°F	8.5	859		-240	5R	Good	No Band Failure
24 May 77	1256	11	3	M3A1	70°F	+145°F	8.4	852		-230	0	Good	No Band Failure
24 May 77	1257	46	3	M3A1	70°F	+145°F	8.5	859		-220	0	Good	No Band Failure
24 May 77	1258	7	3	M3A1	70°F	+145°F	8.4	857		-	-	Good	Dud
24 May 77	1259	53	3	M3A1	70°F	-65°F	8.6	860		-230	0	Good	No Band Failure
24 May 77	1260	19	3	M3A1	70°F	-65°F	9.1	855		-240	0	Good	No Band Failure
24 May 77	1261	18	3	M3A1	70°F	-65°F	8.8	862		-190	0	Good	No Band Failure
24 May 77	1262	21	3	M3A1	70°F	-65°F	9.2	855		-250	0	Good	No Band Failure
24 May 77	1263	58	3	M3A1	70°F	-65°F	8.8	862		-200	10R	Good	No Band Failure
24 May 77	1264	17	3	M3A1	70°F	-65°F	9.1	857		-240	0	Good	No Band Failure

ZONE 3

PROJECTILE AND BAND DATA SHEET

TEST NO.	PROJ. NO.	PROJ. WEIGHT (Lbs.)	C.G. (In. FROM BASE)	MOMENT OF INERTIA ($Lbs.-In.^2$) AXIAL	MOMENT OF INERTIA ($Lbs.-In.^2$) TRANSVERSE	WELD %	DIAMETER REAR BAND (6.066-.005) (In.)	DIAMETER FWD. BOUR. (6.095-.005) (In.)	VISUAL (NON CLEAN-UP)	BAND WIDTH (In.)	LENGTH FR. REAR TO BAND (In.)	CONC. BAND LIP (In.)	CANNELURE GROOVE (VISUAL) FWD.	CANNELURE GROOVE (VISUAL) REAR	CANNELURE DIAMETER (In.) FRONT 6.02±.01	CANNELURE DIAMETER (In.) REAR 6.15±.01	BAND LIP DIA. (In.)	BAND DIAMETER (In.) FWD.	BAND DIAMETER (In.) REAR	WEIGHT AFTER (Lbs.)
1250	63	103.8	13.16	541.6	5834.8															
1251	67	104.1	13.16	542.6	5847.6															
1252	20	104.3	13.15	544.2	5862.4															
1253	16	104.2	13.16	544.4	5850.9	95.9														
1254	141	104.2	13.16	543.5	5857.0															
1255	39	104.2	13.16	544.1	5844.6															
1256	11	104.4	13.16	545.1	5865.9															
1257	46	104.2	13.16	542.7	5848.9															
1258	7	104.4	13.18	544.5	5868.0															
1259	58	104.1	13.16	542.0	5838.6															
1260	19	104.1	13.15	543.9	5847.5															
1261	18	104.4	13.16	544.9	5875.3															
1262	21	104.5	13.15	542.5	5885.6															
1263	68	104.0	13.16	542.0	5835.5															
1264	17	104.3	13.16	544.4	5853.0															

ZONE 3

BORE CAVITY DIAMETER MEASUREMENTS BEFORE AND AFTER FIRING

	BORE CAVITY DIAMETER BEFORE FIRING (In.)						BORE CAVITY DIAMETER AFTER FIRING (In.)											
	1 INCH FROM AFT		1-1/2 INCHES FROM AFT		2-1/2 INCHES FROM AFT		1 INCH FROM AFT		PERMANENT SET		1-1/2 INCHES FROM AFT		PERMANENT SET		2-1/2 INCHES FROM AFT		PERMANENT SET	
	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°
53	5.060	5.056	5.060	5.056	5.059	5.056												
57	5.058	5.055	5.058	5.055	5.058	5.055												
20	5.059	5.058	5.058	5.058	5.058	5.058												
16	5.056	5.054	5.056	5.053	5.056	5.053												
41	5.062	5.059	5.062	5.059	5.062	5.059												
19	5.056	5.053	5.056	5.051	5.056	5.052												
11	5.055	5.054	5.056	5.054	5.054	5.053												
36	5.056	5.051	5.056	5.051	5.056	5.050												
7	5.054	5.055	5.055	5.055	5.053	5.054												
58	5.058	5.055	5.058	5.055	5.059	5.054												
19	5.054	5.051	5.053	5.054	5.052	5.051												
8	5.055	5.052	5.055	5.052	5.055	5.051												
1	5.055	5.051	5.051	5.054	5.054	5.050												
8	5.056	5.057	5.057	5.058	5.056	5.057												
7	5.057	5.051	5.057	5.051	5.056	5.051												

ZONE 8

FIRING DATA SHEET

DATE OF FIRING	TEST NO.	ROUND NO.	PROPELLANT			PROJ. TEMP. (°F)	CHAMBER PRESSURE (Average psi 100)	MUZZLE VELOCITY (fps)	CAMERA COVERAGE	IMPACT		BAND ENGRAVING (Good or Bad)	REMARKS
			ZONE		TEMP.					RANGE (M)	DEFLECT. (M)		
26 May 77	1270	12	8	XM20382	+145°F	-65°F	59.2	2,738		-90	30R		
26 May 77	1271	15	8	XM20382	+145°F	-65°F	58.9	2,736		+140	5R		
26 May 77	1272	6	8	XM20382	+145°F	-65°F	57.7	2,738		-280	80R		
26 May 77	1273	60	8	XM20382	+145°F	-65°F	58.5	2,745		+40	40R		
26 May 77	1274	36	8	XM20383	+145°F	-65°F	58.1	2,742		+240	40R		
26 May 77	1275	33	8	XM20383	+145°F	-65°F	60.9	2,763		-80	40R		
27 May 77	1278	4	8	XM20382	+145°F	70°F	57.3	2,731		-890	60L		
27 May 77	1279	10	8	XM20383	+145°F	70°F	57.0	-	Camera Out	+160	20L		
27 May 77	1280	8	8	XM20383	+145°F	70°F	57.8	2,730		-240	45L		
27 May 77	1281	14	8	XM20382	+145°F	70°F	58.8	2,731		+60	20L		
27 May 77	1282	69	8	XM20383	+145°F	70°F	56.8	2,733		+220	40L		
27 May 77	1283	22	8	XM20382	+145°F	70°F	58.4	2,736		+210	0		
27 May 77	1284	62	8	XM20382	+145°F	+145°F	58.1	2,733		+180	10L		
27 May 77	1285	31	8	XM20383	+145°F	+145°F	57.4	2,738		-200	60L		
27 May 77	1286	37	8	XM20382	+145°F	+145°F	58.0	2,727		0	20L		
27 May 77	1287	30	8	XM20382	+145°F	+145°F	58.1	2,731		-120	40L		
27 May 77	1288	13	8	XM20382	+145°F	+145°F	59.7	2,741		-1160	70L		
27 May 77	1289	32	8	XM20383	+145°F	+145°F	57.3	2,727		-820	?		

ZONE 8

PROJECTILE AND BAND DATA SHEET

TEST NO.	ROUND NO.	PROJ. WEIGHT (Lbs.)	C.G. (IN. FROM BASE)	MOMENT OF INERTIA (Lbs.-In.^{2}) AXIAL	MOMENT OF INERTIA (Lbs.-In.^{2}) TRANS-VERSE	WELD %	DIAMETER REAR BAND (6.086-.005) (In.)	DIAMETER FWD. BOUR. (6.095-.005) (In.)	VISUAL (NON CLEAN-UP)	BAND WIDTH (In.)	LENGTH FR. REAR TO BAND (In.)	CONC. BAND LIP (In.)	CANNELURE GROOVE (VISUAL) FWD.	CANNELURE GROOVE (VISUAL) REAR	CANNELURE DIAMETER (In.) FRONT 6.084±.01	CANNELURE DIAMETER (In.) REAR 6.15±.01	BAND LIP DIA. (In.)	BAND DIAMETER (In.) FWD.	BAND DIAMETER (In.) REAR	WEIGHT AFTER (Lbs.)
1270	12	103.8	13.14	541.4	5822.3															
1271	15	104.1	13.16	543.9	5851.0															
1272	6	103.9	13.16	542.5	5851.3															
1273	60	104.0	13.16	542.0	5840.8															
1274	36	104.1	13.15	543.3	5840.3															
1275	33	104.2	13.15	543.2	5846.3															
1278	4	104.2	13.16	543.2	5872.3															
1279	10	104.2	13.16	543.8	5858.6															
1280	8	104.1	13.16	543.2	5870.1															
1281	14	104.2	13.16	544.2	5850.0															
1282	69	104.0	13.16	542.3	5853.1															
1283	22	104.2	13.15	543.2	5844.5															
1284	62	103.9	13.15	541.7	5847.9															
1285	31	104.0	13.15	542.6	5859.9															
1286	37	104.4	13.15	545.4	5840.8															
1287	30	104.4	13.15	544.9	5869.8															
1288	13	104.0	13.15	542.5	5845.3	97.4														
1289	32	104.2	13.15	543.8	5847.2															

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ZONE 8

BORE CAVITY DIAMETER MEASUREMENTS BEFORE AND AFTER FIRING

	BORE CAVITY DIAMETER BEFORE FIRING (In.)						BORE CAVITY DIAMETER AFTER FIRING (In.)													
	1 INCH FROM AFT		1-1/2 INCHES FROM AFT		2-1/2 INCHES FROM AFT		1 INCH FROM AFT		PERMANENT SET		1-1/2 INCHES FROM AFT		PERMANENT SET		2-1/2 INCHES FROM AFT		PERMANENT SET			
	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°	0°	90°		
12	5.060	5.058	5.058	5.057	5.059	5.055														
15	5.060	5.057	5.061	5.057	5.060	5.056														
5	5.058	5.056	5.058	5.056	5.057	5.054														
50	5.060	5.054	5.060	5.054	5.059	5.053														
38	5.056	5.056	5.057	5.056	5.056	5.056														
33	5.057	5.062	5.057	5.062	5.057	5.062														
6	5.056	5.058	5.056	5.058	5.056	5.056														
10	5.055	5.056	5.057	5.056	5.057	5.056														
3	5.056	5.058	5.056	5.058	5.055	5.057														
14	5.057	5.054	5.057	5.054	5.055	5.053														
69	5.062	5.059	5.059	5.060	5.059	5.060														
22	5.057	5.057	5.057	5.057	5.055	5.055														
52	5.057	5.057	5.057	5.057	5.057	5.057														
31	5.063	5.056	5.063	5.057	5.063	5.055														
37	5.052	5.053	5.051	5.054	5.051	5.053														
30	5.053	5.052	5.053	5.052	5.052	5.052														
11	5.060	5.055	5.060	5.054	5.061	5.052														
32	5.059	5.055	5.058	5.055	5.057	5.055														

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FIRING DATA SHEET

DATE OF FIRING	TEST NO.	ROUND NO.	PROPELLANT			PROJ. TEMP. (°F)	CHAMBER PRESSURE (Average psi 100)	MUZZLE VELOCITY (fps)	CAMERA COVERAGE	IMPACT		BAND ENGRAVING (Good or Bad)	REMARKS
			ZONE	OZ.	TEMP. (°F)					RANGE (M)	DEFLECT. (M)		
10 Jan 78	1752	4B	8	-	145	145	-	2,713	-	+435	140R		
10 Jan 78	1754	16B	8	-	145	145	-	-	-	+180	110R		
12 Jan 78	1759	3B	8	-	145	145	-	-	-	+150	60L		
12 Jan 78	1761	5B	8	-	145	145	-	-	-	+200	60R		
12 Jan 78	1763	20B	8	-	145	145	-	2,710	-	-	-		
12 Jan 78	1765	22B	8	-	145	145	-	2,716	-	-	-		
12 Jan 78	1767	27B	8	-	145	145	-	-	-	+100	30R		
13 Jan 78	1771	11B	8	-	145	145	-	-	-	+100	18L		
13 Jan 78	1772	6B	8	-	145	145	-	-	-	+330	80L		
13 Jan 78	1773	15B	8	-	145	145	-	-	-	+248	10L		
13 Jan 78	1774	7B	8	-	145	145	-	-	-	+100	95L		
13 Jan 78	1775	17B	8	-	145	145	-	-	-	+230	95L		
13 Jan 78	1776	26B	8	-	145	145	-	-	-	-	-		
13 Jan 78	1777	14B	8	-	145	145	-	-	-	+378	60L		
13 Jan 78	1778	23B	8	-	145	145	-	-	-	+158	100L		
13 Jan 78	1779	18B	8	-	145	145	-	-	-	+320	40L		
13 Jan 78	1780	12B	8	-	145	145	-	-	-	+230	80L		
13 Jan 78	1781	14B	8	-	145	145	-	-	-	-	-		
13 Jan 78	1782	24B	8	-	145	145	-	-	-	+370	140L		
13 Jan 78	1783	9B	8	-	145	145	-	-	-	+240	150L		
13 Jan 78	1784	1B	8	-	145	145	-	-	-	+360	80L		
13 Jan 78	1785	25B	8	-	145	145	-	-	-	+20	40L		
13 Jan 78	1786	21B	8	-	145	145	-	-	-	+280	38L		
13 Jan 78	1787	19B	8	-	145	145	-	-	-	+235	35L		
13 Jan 78	1788	10B	8	-	145	145	-	-	-	+100	80L		

FIRING DATA SHEET

DATE OF FIRING	TEST NO.	ROUND NO.	PROPELLANT ZONE	PROPELLANT OZ.	PROPELLANT TEMP. (°F)	PROJ. TEMP. (°F)	CHAMBER PRESSURE (Average psi 100)	MUZZLE VELOCITY (fps)	CAMERA COVERAGE	IMPACT RANGE (M)	IMPACT DEFLECT. (M)	BAND ENGRAVING (Good or Bad)	REMARKS
13 Jan 78	1789	29A	8	-	145	145	-	-	-	+380	95L		
13 Jan 78	1790	27A	8	-	145	145	-	-	-	+340	280L (?)		
13 Jan 78	1791	15A	8	-	145	145	-	-	-	+310	80L		
13 Jan 78	1792	2A	8	-	145	145	-	-	-	+395	80L		
13 Jan 78	1793	28A	8	-	145	145	-	-	-	+400	80L		
13 Jan 78	1794	23A	8	-	145	145	-	-	-	+340	75L		
13 Jan 78	1795	3A	8	-	145	145	-	-	-	+425	60L		
13 Jan 78	1796	7A	8	-	145	145	-	-	-	+340	80L		
13 Jan 78	1797	4A	8	-	145	145	-	-	-	-	-		
13 Jan 78	1798	20A	8	-	145	145	-	-	-	+400	95L		
13 Jan 78	1799	26A	8	-	145	145	-	-	-	+240	110L		
13 Jan 78	1800	21A	8	-	145	145	-	-	-	+340	95L		

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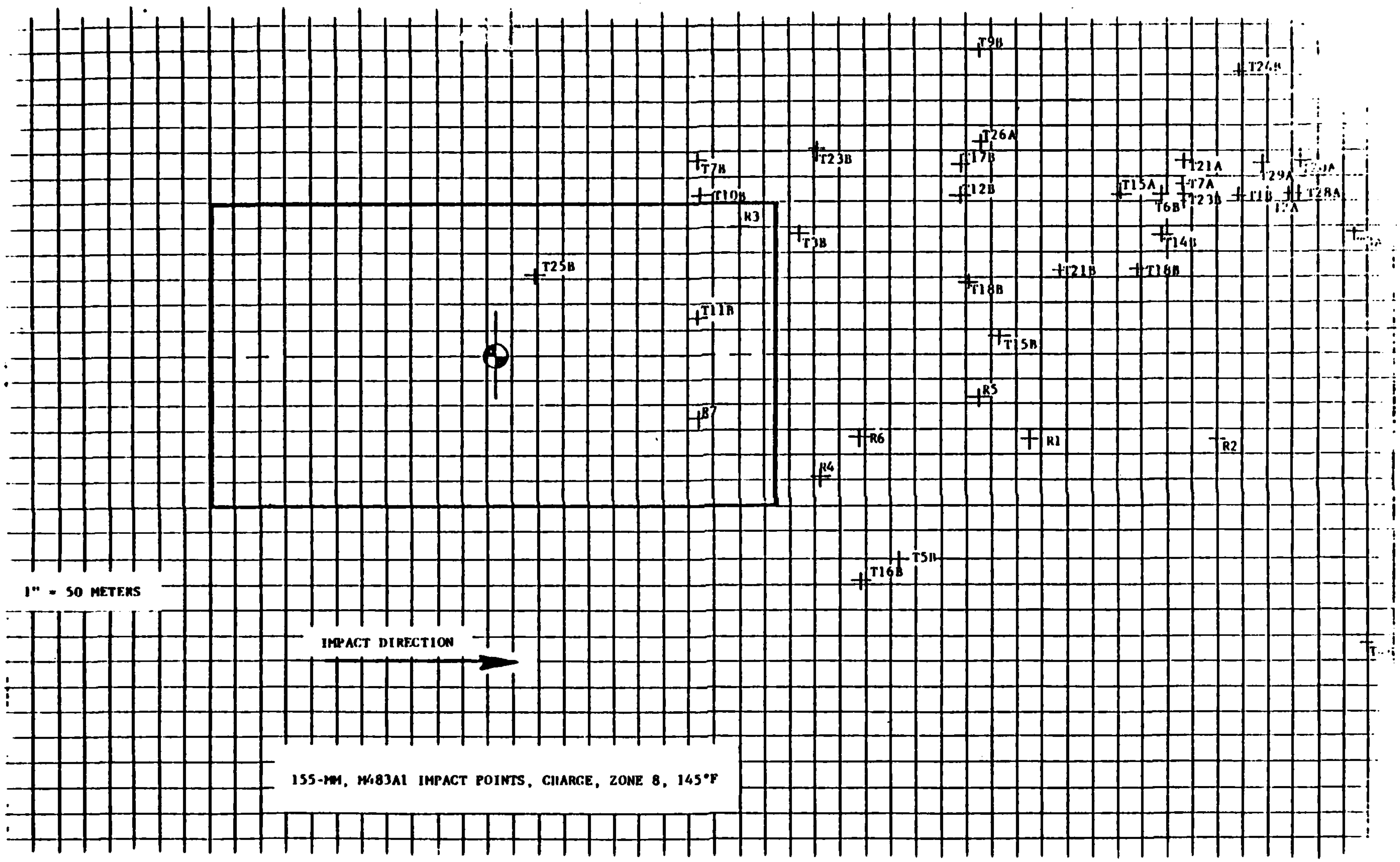
1" = 50 METERS
IMPACT DIRECTION
155-MM, M483A1 IMPACT POINTS, CHARGE, ZONE 8, 145°F
T9B
T24B
T26A
T17B
T12B
T7B
T10B
T23B
R3
T3B
T25B
T11B
B7
R4
R6
R5
R1
R2
T18B
T15B
T21B
T16B
T5B
T15A
T6B
T21A
T7A
T23B
T14B
T29A
T1B
T28A
T2A

5.2.3 There was no evidence of rotating band failure caused by the firing environment on any of the test rounds except 23B, which was the "worst case" sample. One other round sustained minor damage which probably occurred on impact or recovery. All rounds landed at the impact zone (approximately 18,500 meters). For the seven inert rounds muzzle velocity matched the spotters and reference rounds. Nine spotters and reference rounds for which velocity data are available ranged from 2,658 to 2,732 fps for an average of 2,713 fps. Velocity data were available for three of the seven inert test rounds, reading 2,710, 2,713 and 2,716 fps for an average of 2,713 fps. No chamber pressure data were available to the Company when this report was written. Dispersion figures for reference rounds fired on 10 and 12 January were 260 meters in range and 112 meters deflection. The seven inert test rounds fired on those days had dispersion of 285 meters in range and 200 meters delfection.

5.2.4 On 13 January 1978 the 30 test rounds were fired with fuzes set to function at 1,500 feet altitude. Eighteen (18) "B" rounds (banded before heat treat) had dispersion of 360 meters range and 115 meters deflection. Twelve (12) "A" rounds (banded after heat treat) had dispersion of 185 meters in range and 50 meters deflection. When all test projectiles were recovered they were shipped to U. S. ARRADCOM for examination. The Company has unofficial information that, with the exception of the above mentioned rounds, they were well engraved with no shearing of band material like that which occurred during the first test. Our unofficial conclusion was that the test firings were successful. Round 23B reinforces the belief that ultrasonic inspection after heat treatment is an adequate indication of weld quality and band performance.

6. ECONOMIC ANALYSIS

During April 1977 the Company completed a cost comparison of inertia welding the band versus MIG overlay welding. We compared two types of MIG overlay machines -- the first being the mechanically controlled welders now on hand at our New Bedford facility, and the second being a laser controlled machine on order as part of plant modernization at New Bedford. The old MIG machines have an individual rate of 12.8 bands per hour, while the new MIG machines are rated at 20 bands per hour. We have prepared our cost estimates on DD Form 1106, a standard form for modernization programs, and one which enables direct comparison of the two types of processes.

Note that in the first 12 months of operation at the current rate of 21,600 M483's per month that the inertia welder would result in savings of $151,389 over the laser controlled MIG overlay welder, and $216,690 over the current MIG welders. The savings accrue predominately from the speed of the inertia welder, requiring fewer machines, less power, less maintenance, etc. With amortization, transportation and installation costs accounted for, we have a net savings of $.836 per projectile for a nominal contract quantity of 259,200 spread over one year. We have no data on the television controlled MIG overlay welders ordered for the new 8-Inch, XM509 line at Scranton Army Ammunition Plant (Chamberlain-operated), but we would expect greater savings because of the added circumference of the round over the 155-mm, M483. The inertia welder welds at approximately the same rate regardless of whether the round is 155-mm or 8-Inch, while the MIG process would be sensitive to added circumference.

MACHINE TOOL REPLACEMENT ANALYSIS WORK SHEET	ANALYSIS NUMBER: Old Machines DATE: 14 April 1977	Form Approved Budget Bureau No. 22-R179

1. ACTIVITY	2. LOCATION	3. SHOP	4. BUILDING NO.
Based on Yearly Production of Banding 259,200 155-mm, M483 Shells	New Bedford, Massachusetts	M483 Line	

5. PRESENT EQUIPMENT				6. PROPOSED EQUIPMENT	
a. DESCRIPTION: Metal Inert Gas (MIG) Arc Welding Machine				a. DESCRIPTION: Automatic Feed Inertia Welder (IW)	
b. MANUFACTURER: Taylor-Winfield Warren, Ohio		c. MODEL NO.: Special		b. MANUFACTURER: Manufacturing Technology, Inc. Mishawaka, Indiana	c. MODEL NO.: Special
d. PRODUCTION EQUIPMENT CODE: No Equivalent				d. PRODUCTION EQUIPMENT CODE: No Equivalent	
e. DEPARTMENTAL IDENTIFICATION NO	f. YEAR BUILT: 1969	g. TOTAL ACQUISITION COST: $460K	h. QUANTITY: 6	e. QUANTITY: 1	f. PRODUCTIVITY INCREASE RATIO: With Automatic Feed 6.25:1

7. OPERATING COST ANALYSIS FOR EQUIVALENT OUTPUT (Next Year)

FACTOR	a. PRESENT EQUIPMENT	b. PROPOSED EQUIPMENT
a. MACHINE LOAD (Hours next year)	20,250	3,240
b. DIRECT LABOR	$ 34,573	$ 16,595
c. INDIRECT LABOR	$ 73,986	$ 35,514
d. FRINGE BENEFITS	$ 10,372	$ 4,978
e. MAINTENANCE	$ 9,420	$ 1,927
f. POWER	$ 24,603	$ 14,140
g. ~~XXXXXXXXXX~~ Material - Processing Cost	$ 1,000,823	$ 866,038
h. TOOLING (N/A Because Part of Initial Capital Cost)	$ --	$ --
i. SAVINGS/OTHER OPERATIONS, ASSEMBLY	$ --	$ --
j. OTHER COSTS (G&A, Profits)	$ 219,080	$ 178,335
k. TOTAL OPERATING COSTS	$ 1,372,857	$ 1,117,527
l. NET OPERATING COSTS FAVORING PROPOSED EQUIPMENT (k, col a, minus k, col b)	$	255,330

8. CAPITAL COST ANALYSIS OF PROPOSED EQUIPMENT (Next Year)

a. ACQUISITION COST	$ 200,000
b. INSTALLATION, TRANSPORTATION AND MISCELLANEOUS COSTS	$ 40,000
c. TOTAL INSTALLED COSTS (8a plus 8b)	$ 240,000
d. PRESENT DISPOSAL VALUE OF PRESENT EQUIPMENT	$ N/A
e. NET REQUIRED INVESTMENT (8c minus 8d)	$ 240,000
f. SERVICE LIFE	14 Years
g. CHART PERCENT	16.1 %
h. TOTAL CAPITAL COST (8e X 8g)	$ 38,640
i. NEXT YEARS SAVINGS FROM REPLACEMENT (7l minus 8h)	$ 216,690

DD FORM 1 AUG 57 1106

1. Based on New Bedford Rate of 21,600 Units/Month.

6f. Based on New Bedford Records of 12.8 Parts/Hour for MIG Welder, Compared to an Estimated IW Production of 80 Parts/Hour.

7a. MIG: $\frac{\text{259,000 Parts/Year}}{\text{12.8 Parts/Hour}}$ = 20,250 Hours/Year

IW: $\frac{\text{259,200 Parts/Year}}{\text{80 Parts/Hour}}$ = 3,240 Hours/Year

7b. Based on New Bedford Rate of $4.20/Man-Hour and 82% Efficiency/Man:

MIG: 20,250 Hours/Year x $4.20/Hour ÷ 82% Efficiency/Man ÷ 3 Operating Machines/Man = $34,573

IW: 3,240 Hours/Year x $4.20/Hour ÷ 82% Efficiency/Man = $16,595

7c. Based on New Bedford Rate of 214%:

MIG: 214% x $34,573 (Direct Labor) = $73,986

IW: 214% x $16,595 (Direct Labor) = $35,514

7d. Based on New Bedford Rate of 30%:

MIG: 30% x $34,573 (Direct Labor) = $10,372

IW: 30% x $16,595 (Direct Labor) = $ 4,978

7e. Assume 2.5% of Machine Load Time:

MIG:	Direct Labor: 2.5% x 20,250 Hours x $4.20/Hour ÷ 82% Efficiency/Man	$2,593
	Indirect Labor at 214%	5,549
	Fringe Benefits at 30%	778
	Material	500
		$9,420
IW:	Direct Labor: 2.5% x 3,240 Hours x $4.20/Hour ÷ 82% Efficiency/Man	$ 415
	Indirect Labor at 214%	888
	Fringe Benefits at 30%	124
	Material	500
		$1,927

7f. Assume 4.5 cents/kwh Electricity Cost:

MIG: Each Welder Requires 27 kw Power Supply

20,250 Hours x 27 kw x $0.045/kwh = $24,603

IW: 130 hp Motor Required to Power IW

130 hp x 0.746 kw/hp x 3,240 Hours x $0.045/kwh = $14,140

7g. MIG: Material and Processing

New Bedford Rate of $4.03/Shell[1] for Band Materials, Process Materials, and Inspection Plus $0.17/Shell for Cleaning[2] = $4.20/Shell

$4.20/Shell x 259,200 Shells/Year = $1,088,640

Recoverable Cost

New Bedford Rate of 1.54 lbs/Shell[3]; Recoverable Material at Quoted Scrap Price of 22 cents/lb[4]

1.54 lbs/Shell x 259,200 Shells/Year x $0.22/lb = $87,817

Net Material Cost: $1,088,640 - $87,817 = $1,000,823

IW: Material and Processing

Quoted Price of $3.15/Shell[5] for Material, Plus $0.19/Shell for Inspection[6] Plus $0.34/Shell[2] for Two Cleaning Operations = $3.68/Shell

$3.68/Shell x 259,200 Shells/Year = $953,855

Recoverable Cost

Assume Same Recoverable Cost as With MIG = $87,817

Net Material Cost: $953,855 - $87,817 = $866,038

7j. Based on New Bedford Rate of G&A of 7.1%[7] and Assumed profit of 10% of[7] Total Cost

8a. Estimated for a Machine with Custom Modifications.

8b. Assume 20% of Acquisition Cost.

See Next Page for Footnotes.

8f and 8g.

Service Life and Chart Percent Taken from AMC Plant Equipment Modernization Program, AMC Regulation Number 700-22, Dated 18 August 1964.

Although no data are available for an Inertia Welder, the Service Life and Chart Percent is assumed to be an average of the following Equipment:

1. Accounting for the Speed of an IW, an Automatic, Multiple Spindle, Horizontal Lathe has a Service Life of 11 Years, and a Chart Percent of 18.9%.

2. Accounting for the Power of an IW, a Hydraulic Shell Banding Press has a Service Life of 17 Years, and a Chart Percent of 13.3%.

Average Service Life: 14 Years

Average Chart Percent: 16.1%

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[1] From New Bedford Cost Estimate (Upper Right Hand Corner of Attached Sheet).

[2] From Telephone Conversation with New Bedford 5 cents/Shell Unburden, Burden Rate 244%.

[3] From Telephone Conversation @ David Nelson, Materials Manager, New Bedford.

[4] From Telephone Conversation @ Ralph Scholtz.

[5] Price Quote from Revere Copper & Brass, Inc.

[6] From Telephone Conversation @ New Bedford.

[7] From New Bedford Cost Estimate (Upper Right Hand Corner of Attached Sheet).

MACHINE TOOL REPLACEMENT ANALYSIS WORK SHEET	ANALYSIS NUMBER: New Machines	Form Approved Budget Bureau No. 22-R177
	DATE: 14 April 1977	

1. ACTIVITY	2. LOCATION	3. SHOP	4. BUILDING NO.
Based on Yearly Production of Banding 259,200 155-mm M483 Shells	New Bedford, Massachusetts	M483 Line	--

5. PRESENT EQUIPMENT		6. PROPOSED EQUIPMENT	
a. DESCRIPTION: Automatic Overlay Shielded Metal Inert Gas (MIG) Arc Welding Machine W/800 Amp Power Pak		a. DESCRIPTION: Automatic Feed Inertia Welder (IW)	
b. MANUFACTURER: Taylor-Winfield Warren, Ohio	c. MODEL NO.: Special	b. MANUFACTURER: Manufacturing Technology, Inc. Mishawaka, Indiana	c. MODEL NO.: Special
d. PRODUCTION EQUIPMENT CODE: No Equivalent		d. PRODUCTION EQUIPMENT CODE: No Equivalent	

e. DEPARTMENTAL IDENTIFICATION NO	f. YEAR BUILT	g. TOTAL ACQUISITION COST	h. QUANTITY	e. QUANTITY	f. PRODUCTIVITY INCREASE RATIO
	1977	$305,400	4	1	With Automatic Feed 4:1

7. OPERATING COST ANALYSIS FOR EQUIVALENT OUTPUT (Next Year)

FACTOR	a. PRESENT EQUIPMENT	b. PROPOSED EQUIPMENT
a. MACHINE LOAD (Hours next year)	12,960	3,240
b. DIRECT LABOR	$ 22,127	$ 16,595
c. INDIRECT LABOR	$ 47,351	$ 35,514
d. FRINGE BENEFITS	$ 6,638	$ 4,978
e. MAINTENANCE	$ 6,209	$ 1,927
f. POWER	$ 15,748	$ 14,140
Material - Processing Costs	$ 1,000,823	$ 866,038
h. TOOLING (N/A Because Part of Initial Capital Cost)	$ --	$ --
i. SAVINGS/OTHER OPERATIONS, ASSEMBLY	$ --	$ --
j. OTHER COSTS (G&A, Profits)	$ 208,660	$ 178,335
k. TOTAL OPERATING COSTS	$ 1,307,556	$ 1,117,527
l. NET OPERATING COSTS FAVORING PROPOSED EQUIPMENT (k, col a, minus k, col b)		$ 190,029

8. CAPITAL COST ANALYSIS OF PROPOSED EQUIPMENT (Next Year)

a. ACQUISITION COST	$ 200,000
b. INSTALLATION, TRANSPORTATION AND MISCELLANEOUS COSTS	$ 40,000
c. TOTAL INSTALLED COSTS (8a plus 8b)	$ 240,000
d. PRESENT DISPOSAL VALUE OF PRESENT EQUIPMENT	$ N/A
e. NET REQUIRED INVESTMENT (8c minus 8d)	$ 240,000
f. SERVICE LIFE	14 Years
g. CHART PERCENT	16.1 %
h. TOTAL CAPITAL COST (8e X 8g)	$ 38,640
i. NEXT YEARS SAVINGS FROM REPLACEMENT (7l minus 8h)	$ 151,389

DD FORM 1 AUG 57 1106

1. Based on New Bedford Rate of 21,600 Units/Month.

5g. Four New MIG Welders are Being Purchased at New Bedford at a Price of $76,350 each.

$$4 \times \$76,350 = \$305,400$$

6f. Based on New Bedford Estimated Production of Each New MIG Welder of 20 Parts/Hour, Compared to an Estimated IW Production of 80 Parts/Hour.

7a. MIG: $\frac{259,200 \text{ Parts/Year}}{20 \text{ Parts/Hour}} = 12,960$ Hours/Year

IW: $\frac{259,200 \text{ Parts/Year}}{80 \text{ Parts/Hour}} = 3,240$ Hours/Year

7b. Based on New Bedford Rate of $4.20/Man-Hour and 82% Efficiency/Man:

MIG: 12,960 Hours/Year x $4.20/Hour ÷ 82% Efficiency/Man ÷ 3 Operating Machines/Man = $22,127

IW: 3,240 Hours/Year x $4.20/Hour ÷ 82% Efficiency/Man = $16,595

7c. Based on New Bedford Rate of 214%:

MIG: 214% x $22,127 (Direct Labor) = $47,351

IW: 214% x $16,595 (Direct Labor) = $35,514

7d. Based on New Bedford Rate of 30%:

MIG: 30% x $22,127 (Direct Labor) = $6,638

IW: 30% x $16,595 (Direct Labor) = $4,978

7e. Assume 2.5% of Machine Load Time:

MIG:	Direct Labor: 2.5% x 12,960 Hours x $4.20/Hour ÷ 82% Efficiency/Man	$1,660
	Indirect Labor at 214%	3,551
	Fringe Benefits at 30%	498
	Material	500
		$6,209

IW:	Direct Labor: 2.5% x 3,240 Hours x $4.20/Hour ÷ 82% Efficiency/Man	$ 415
	Indirect Labor at 214%	888
	Fringe Benefits at 30%	124
	Material	500
		$1,927

7f. Approximately 4.5 cents/kwh Electricity Cost:

MIG: Each Welder Requires a 56 Amp 480 VAC (27 kw) Power Supply

12,960 Hours x 27 kw x $0.045/kwh = $15,746

IW: 130 hp Motor Required to Power IW

130 hp x 0.746 kw/hp x 3,240 Hours x $0.045/kwh = $14,140

7g. MIG: Material and Processing

New Bedford Rate of $4.03/Shell for Band Materials, Process Materials, and Inspection, Plus $0.17/Shell for Cleaning = $4.20/Shell

$4.20/Shell x 259,200 Shells/Year = $1,088,640

Recoverable Cost

New Bedford Rate of 1.54 lb/Shell, Recoverable Material at Quoted Scrap Price of 22 cents/lb.

1.54 lb/Shell x 259,200 Shells/Year x $0.22/lb = $87,817

Net Material Cost: $1,088,640 - $87,817 = $1,000,823

IW: Material and Processing

Quoted Price of $3.15/Shell for Material, Plus $0.19/Shell for Inspection, Plus $0.34/Shell for Two Cleaning Operations = $3.68/Shell.

$3.68/Shell x 259,200 Shells/Year = $953,855

Recoverable Cost

Assume Same Recoverable Cost as With MIG = $87,817

Net Material Cost: $953,855 - $87,817 = $866,038

... New Bedford Rate of G&A of 7.1% and Assumed Profit of 10% of

... Custom Modifications.

8b. Assume 20% of Acquisition Cost.

8f and 8g.

Service Life and Chart Percent Taken from AMC Plant Equipment Modernization Program, AMC Regulation Number 700-22, Dated 18 August 1964.

Although no data are available for an Inertia Welder, the Service Life and Chart Percent is assumed to be an Average of the following equipment:

1. Accounting for the Speed of an IW, an Automatic, Multiple Spindle, Horizontal Lathe has a Service Life of 11 Years, and a Chart Percent of 18.9%.

2. Accounting for the Power of an IW, a Hydraulic Shell Banding Press has a Service Life of 17 Years and a Chart Percent of 13.3%.

Average Service Life: 14 Years

Average Chart Percent: 16.1%

MACHINE TOOL REPLACEMENT ANALYSIS WORK SHEET	ANALYSIS NUMBER	Form Approved Budget Bureau No. 22-R179
	DATE: 14 April 1977	

1. ACTIVITY	2. LOCATION	3. SHOP	4. BUILDING NO.
Based on Yearly Production of Banding 259,200 155-mm M483 Shells	New Bedford, Massachusetts	M483 Line	--

5. PRESENT EQUIPMENT				6. PROPOSED EQUIPMENT	
a. DESCRIPTION: See Previous Forms				a. DESCRIPTION: Automatic Feed Inertia Welder (IW) IW - 180 Parts/Hour	
b. MANUFACTURER		c. MODEL NO.		b. MANUFACTURER: Manufacturing Technology, Inc. Mishawaka, Indiana	c. MODEL NO.: Special
d. PRODUCTION EQUIPMENT CODE				d. PRODUCTION EQUIPMENT CODE: No Equivalent	
e. DEPARTMENTAL IDENTIFICATION NO	f. YEAR BUILT	g. TOTAL ACQUISITION COST	h. QUANTITY	e. QUANTITY: 1	f. PRODUCTIVITY INCREASE RATIO: With Automatic Feed 14:1 (9:1)

7. OPERATING COST ANALYSIS FOR EQUIVALENT OUTPUT (Next Year)

FACTOR	a. PRESENT EQUIPMENT	b. PROPOSED EQUIPMENT
a. MACHINE LOAD (Hours next year)	S	1,440 Hours/Year
b. DIRECT LABOR	$ E E	$ 7,376
c. INDIRECT LABOR	$ P	$ 15,784
d. FRINGE BENEFITS	$ R E	$ 2,213
e. MAINTENANCE	$ V I	$ 1,133
f. POWER	$ O U	$ 6,284
g. ~~XXXXXXXXXXXX~~ Material - Processing Costs	$ S	$ 866,038
h. TOOLING (NA Because Part of Initial Capital Cost)	$ F O	$ --
i. SAVINGS/OTHER OPERATIONS, ASSEMBLY	$ R M	$ --
j. OTHER COSTS (G&A, Profits)	$ S	$ 170,670
k. TOTAL OPERATING COSTS	$ 1,372,857 (1,307,556)	$ 1,069,498
l. NET OPERATING COSTS FAVORING PROPOSED EQUIPMENT (k, col a, minus k, col b)	$ 303,359	(238,058)

8. CAPITAL COST ANALYSIS OF PROPOSED EQUIPMENT (Next Year)

a. ACQUISITION COST	$ 250,000
b. INSTALLATION, TRANSPORTATION AND MISCELLANEOUS COSTS	$ 50,000
c. TOTAL INSTALLED COSTS (8a plus 8b)	$ 300,000
d. PRESENT DISPOSAL VALUE OF PRESENT EQUIPMENT	$ N/A
e. NET REQUIRED INVESTMENT (8c minus 8d)	$ 300,000
f. SERVICE LIFE	14 Years
g. CHART PERCENT	16.1 %
h. TOTAL CAPITAL COST (8e X 8g)	$ 48,300
i. NEXT YEARS SAVINGS FROM REPLACEMENT (7l minus 8h)	$ 255,059 (189,758)

DD FORM 1 AUG 57 1106

1. Based on New Bedford rate of 21,600 Units/Month.

6f. Estimated IW Production of 180 Parts/Hour.

7a. IW: $\frac{259{,}200 \text{ Parts/Year}}{180 \text{ Parts/Hour}} = 1{,}440$ Hours/Year

7b. Based on New Bedford Rate of \$4.20/Man-Hour and 82% Efficiency/Man:

IW: 1,440 Hours/Year x \$4.20/Hour ÷ 82% Efficiency/Man
= \$7,376

7c. Based on New Bedford Rate of 214%:

IW: 214% x \$7,376 (Direct Labor) = \$15,784

7d. Based on New Bedford Rate of 30%:

IW: 30% x \$7,376 (Direct Labor) = \$2,213

7e. Assume 2.5% of Machine Load Time:

IW:

Direct Labor: 2.5% x 1,440 Hours x \$4.20/Hour ÷ 82% Efficiency/Man	\$ 184
Indirect Labor at 214%	394
Fringe Benefits at 30%	55
Material	500
	\$1,133

7f. Assume 4.5 cents/kwh Electricity Cost:

IW: 130 hp Motor Required to Power IW

130 hp x 0.746 kw/hp x 1,440 Hours/Year
x \$0.045/kwh = \$6,284

7g. IW: <u>Material and Processing</u>

Quoted Price of \$3.15/Shell for Material, Plus \$0.19/Shell for Inspection Plus \$0.34/Shell for Two Cleaning Operations = \$3.68/Shell

\$3.68/Shell x 259,200 Shells/Year = \$953,855

<u>Recoverable Cost</u>

New Bedford Rate of 1.54 lbs/Shell, Recoverable Material at Quoted Scrap Price of 22 cents/lb.

1.54 lbs/Shell x 259,200 Shells/Year x \$0.22/lb = \$87,817

APPENDIX 1

ULTRASONIC SCANS--ROUNDS 1 THROUGH 69

ROUNDS SELECTED FOR FIRING TEST NO. 1 INDICATED

SCANNED BEFORE HEAT TREATMENT

SENSITIVITY-RESOLVES .050"DIA. HOLE ON TEST BLOCK

Net Material Cost: $953,855 - $87,817 = $866,038

7j. Based on New Bedford Rate of G&A of 7.1% and Assumed Profit of 10% of Total Cost.

8a. Estimated for a Machine with Custom Modifications.

8b. Assume 20% of Acquisition Cost.

8f and 8g.

Service Life and Chart Percent Taken from AMC Plant Equipment Modernization Program, AMC Regulation Number 700-22, Dated 18 August 1964.

Although no data are available for an Inertia Welder, the Service Life and Chart Percent is assumed to be an average of the following equipment:

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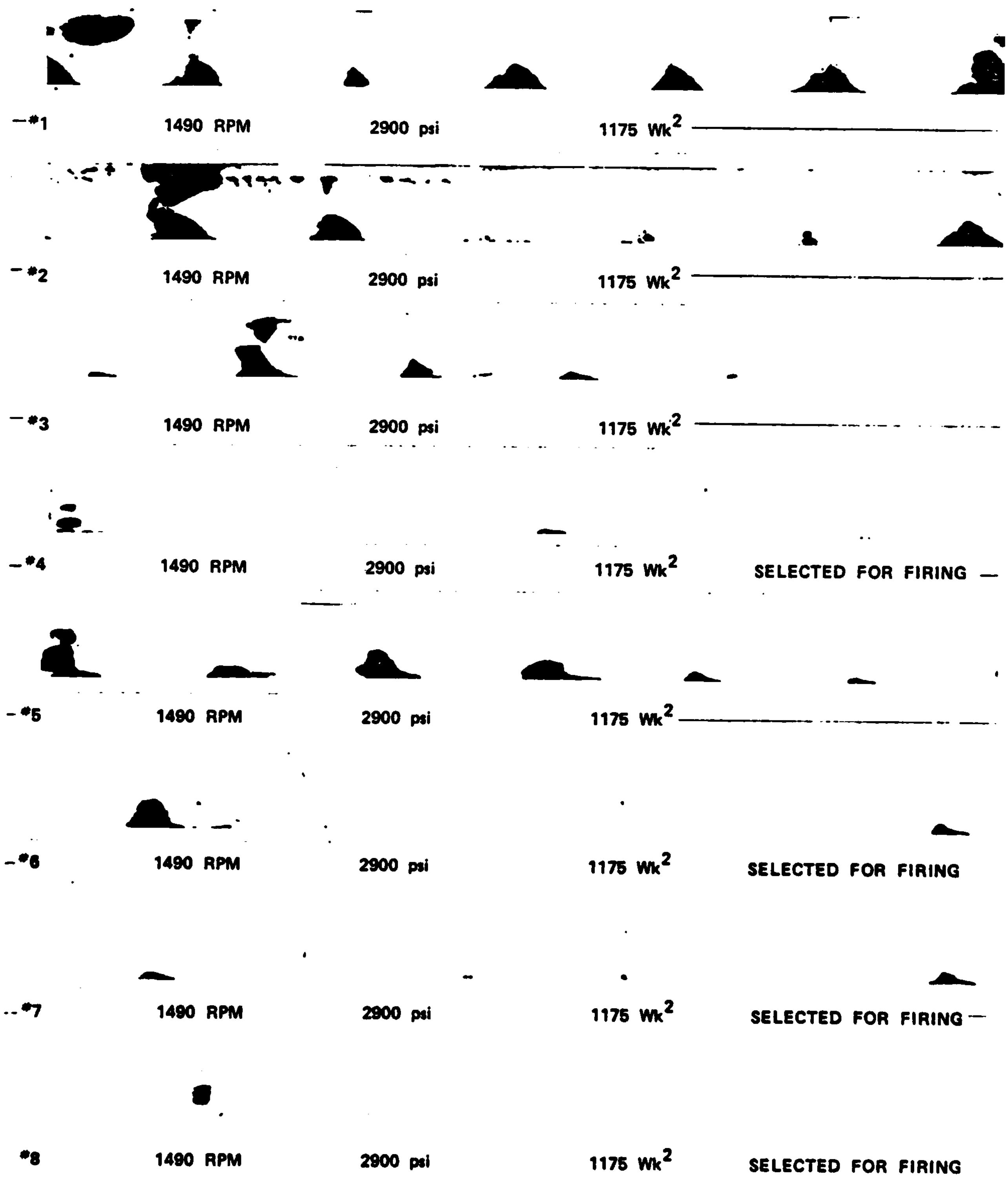
2. Accounting for the Power of an IW, a Hydraulic Shell Banding Press has a Service Life of 17 Years, and a Chart Percent of 13.3%.

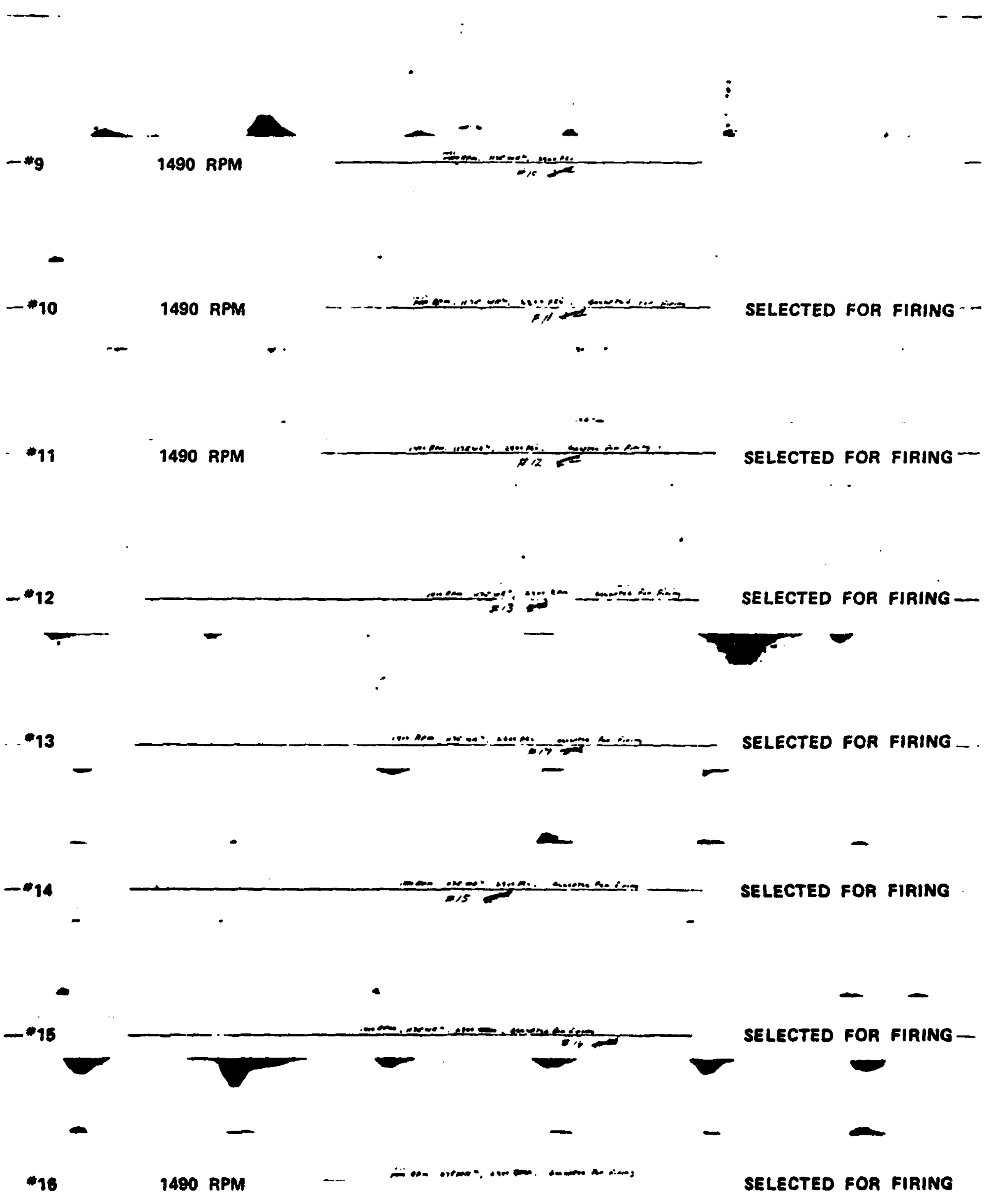
Average Service Life: 14 Years

Average Chart Percent: 16.1%



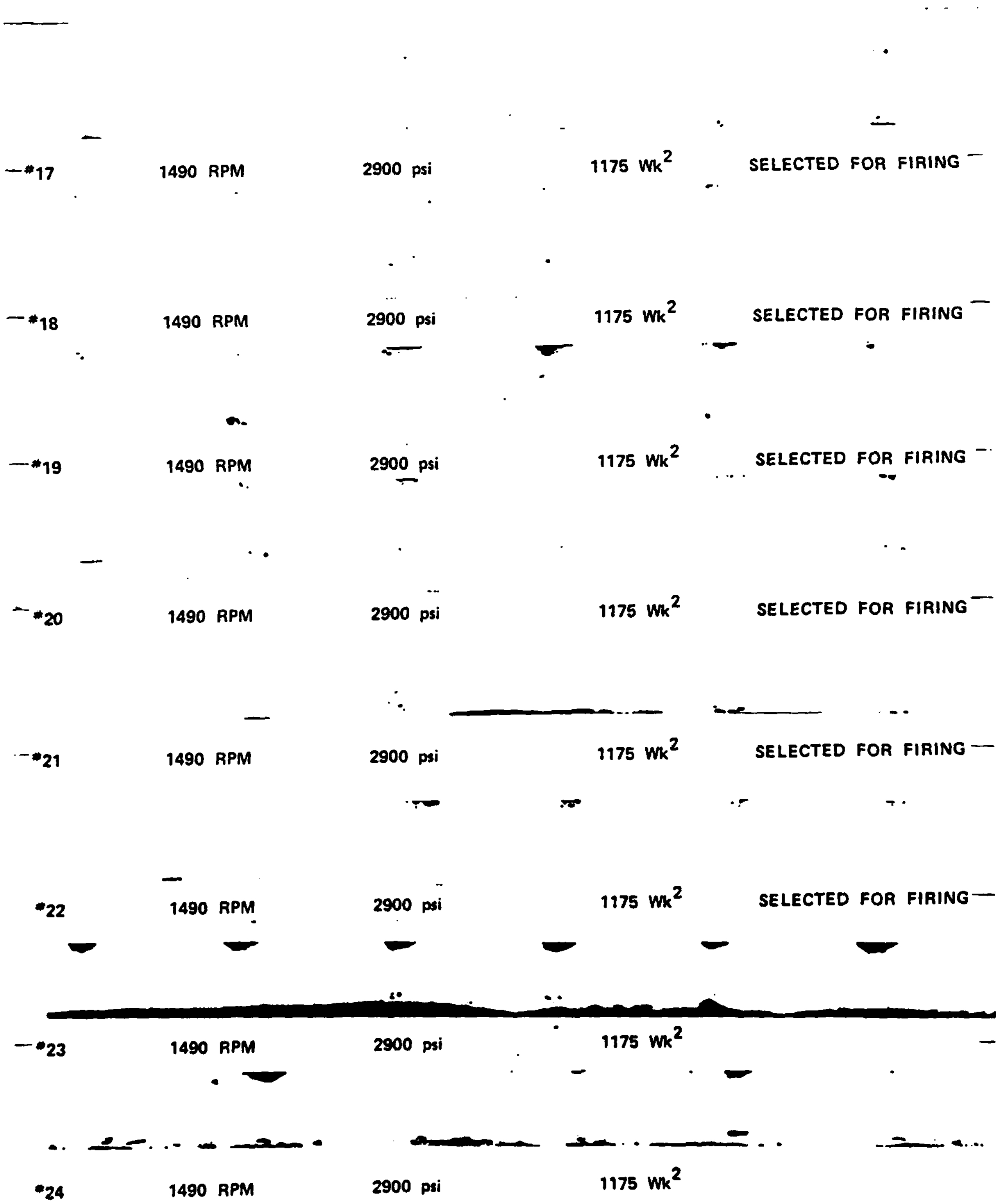
PHOTOGRAPH NO. 10670 Scans #1 through #8 Page 1 of 5

ULTRASONIC SCANNING RESULTS FOR BANDS 1 THROUGH 35 INERTIA WELDED TO M483 PROJECTILE BODIES. DARK AREAS INDICATE NO BONDING.



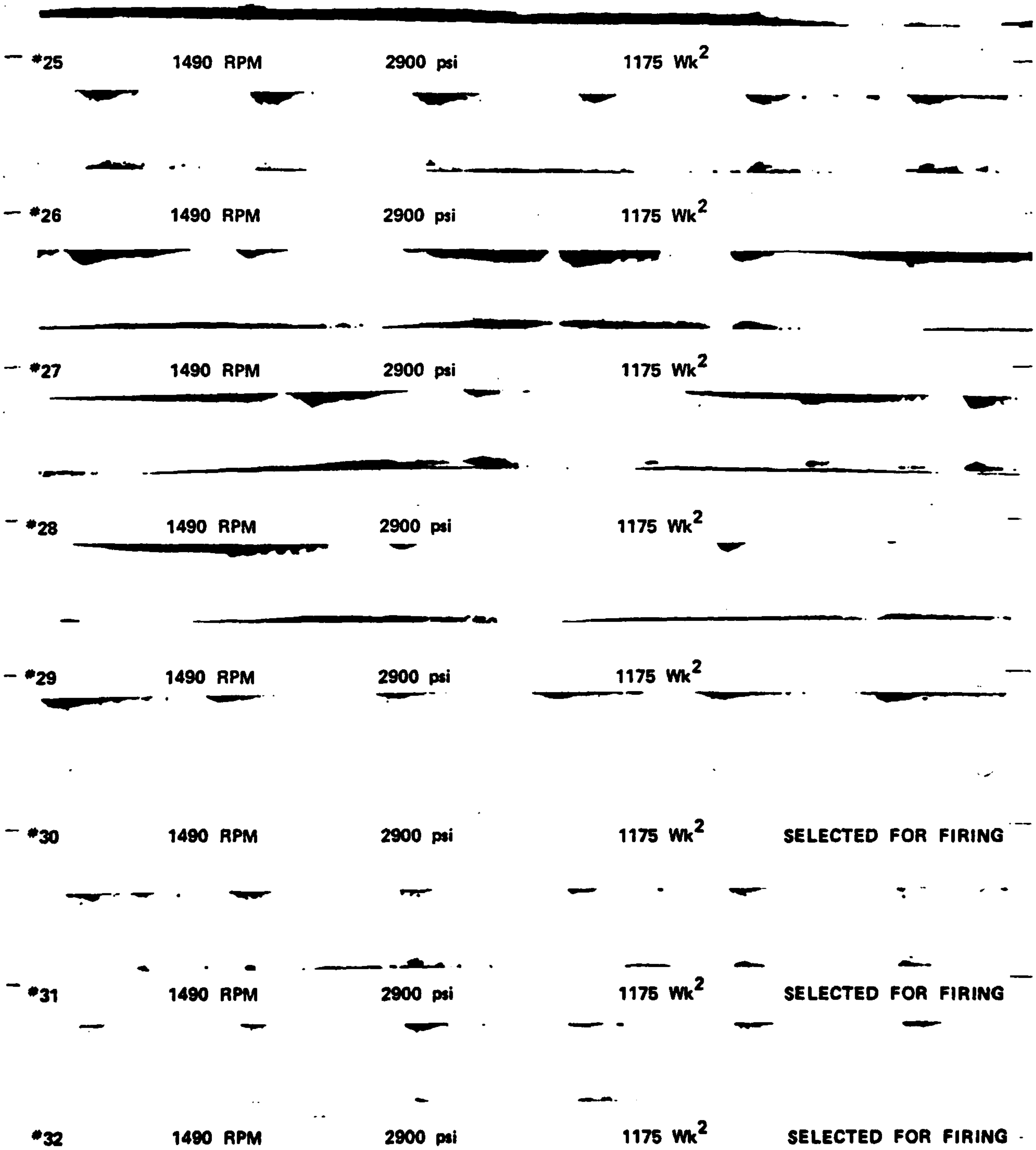
PHOTOGRAPH NO. 10670 Scans #9 through #16 Page 2 of 5

ULTRASONIC SCANNING RESULTS FOR BANDS 1 THROUGH 35 INERTIA WELDED TO M483 PROJECTILE BODIES. DARK AREAS INDICATE NO BONDING.



PHOTOGRAPH NO. 10670 Scans #17 through #24 Page 3 of 5

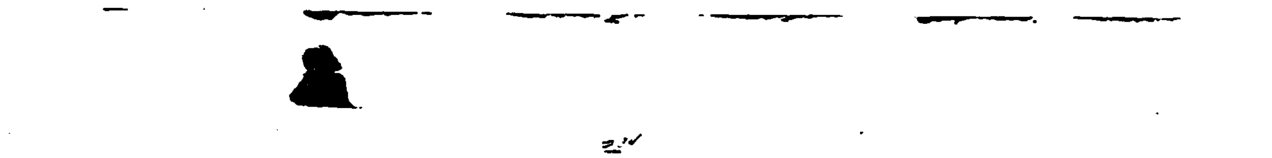
ULTRASONIC SCANNING RESULTS FOR BANDS 1 THROUGH 35 INERTIA WELDED TO M483 PROJECTILE BODIES. DARK AREAS INDICATE NO BONDING.



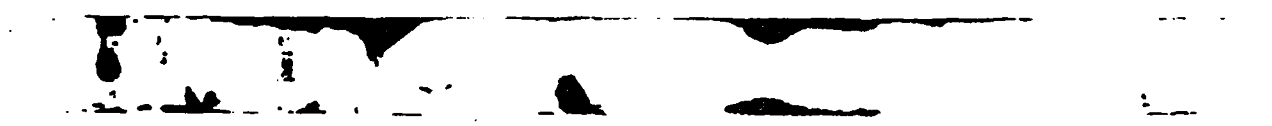
PHOTOGRAPH NO. 10670 Scans #25 through #32 Page 4 of 5

ULTRASONIC SCANNING RESULTS FOR BANDS 1 THROUGH 35 INERTIA WELDED TO M483 PROJECTILE BODIES. DARK AREAS INDICATE NO BONDING.

#33 1490 RPM 2900 psi 1175 Wk^2 SELECTED FOR FIRING



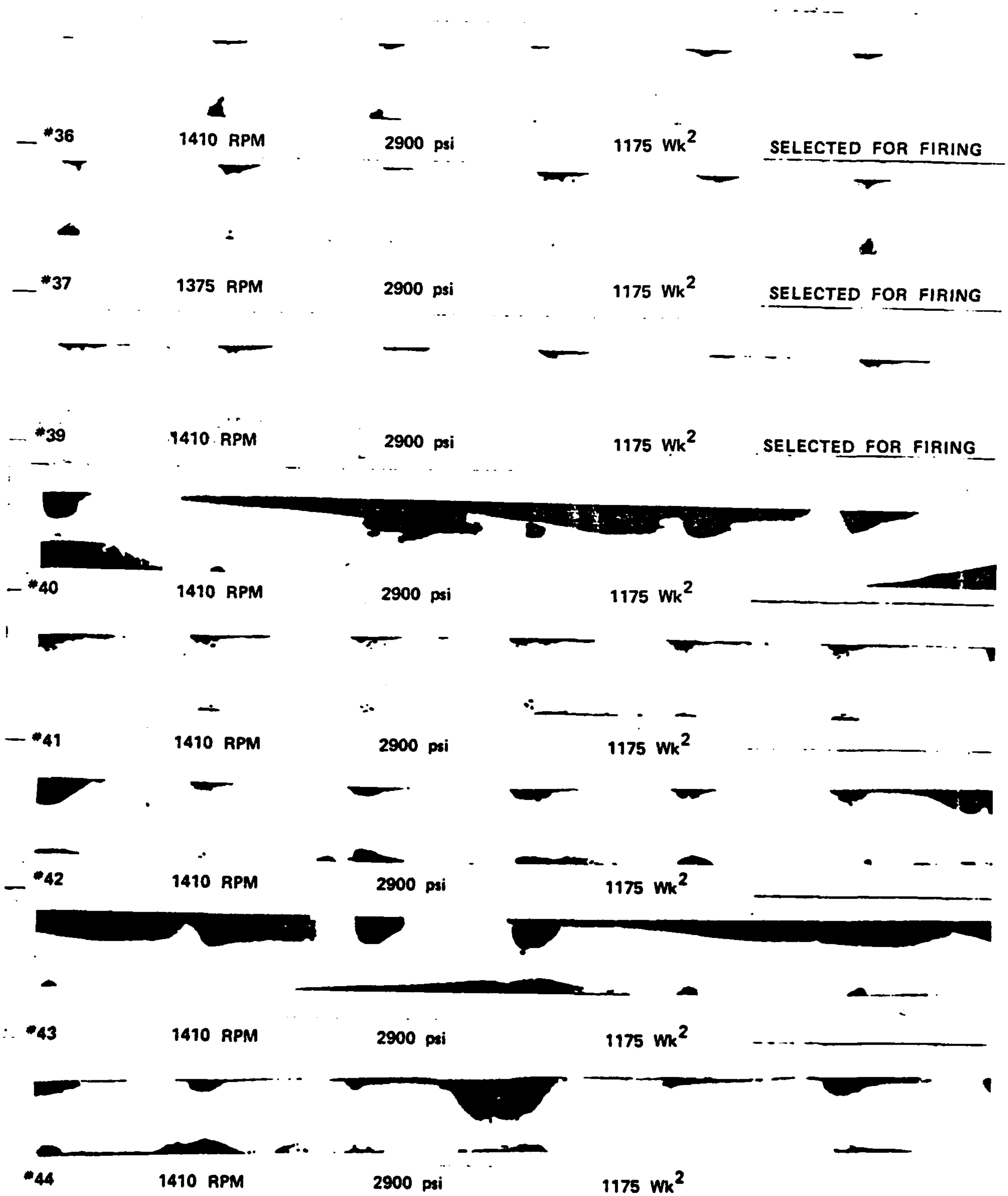
#34 1490 RPM 2900 psi 1175 Wk^2



#35 1490 RPM 2900 psi 1175 Wk^2

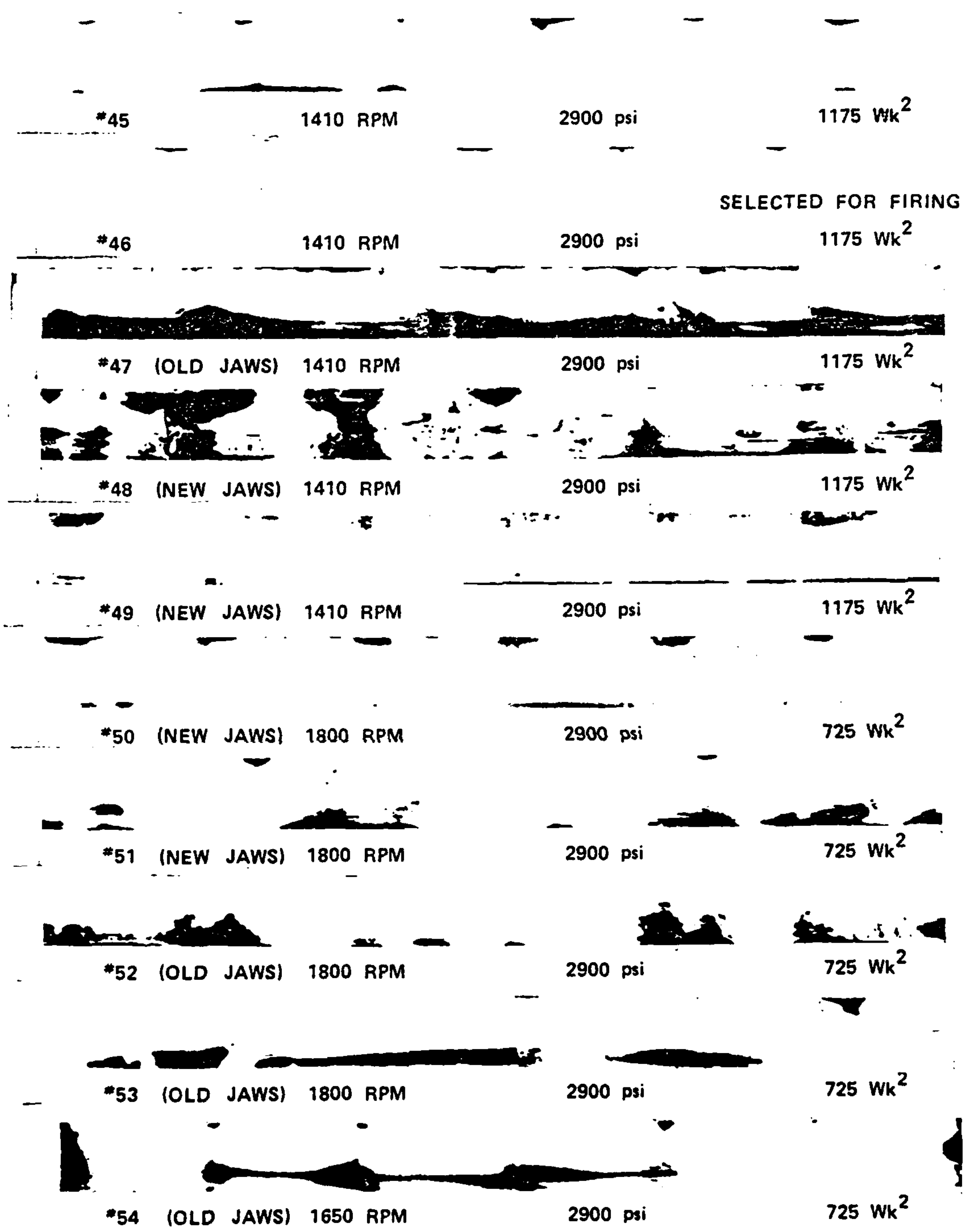
PHOTOGRAPH NO. 10670 Scans #33 through #35 Page 5 of 5

ULTRASONIC SCANNING RESULTS FOR BANDS 1 THROUGH 35 INERTIA WELDED TO M483 PROJECTILE BODIES. DARK AREAS INDICATE NO BONDING.



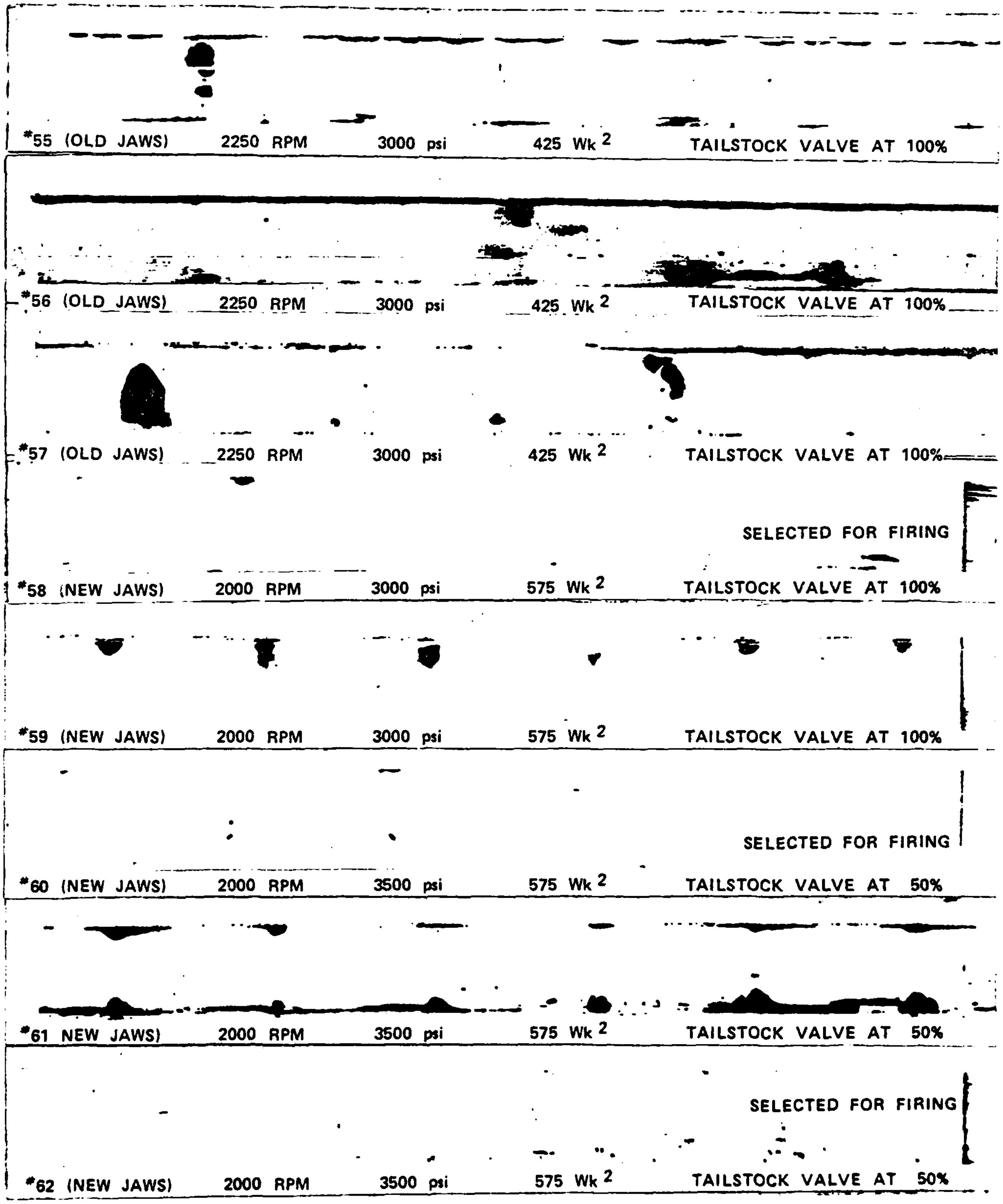
PHOTOGRAPH NO. 10669 Scans #36 through #44

ULTRASONIC SCANNING RESULTS FOR BANDS 36 THROUGH 44 INERTIA WELDED TO M483 PROJECTILE BODIES. DARK AREAS INDICATE NO BONDING.



PHOTOGRAPH NO. 10713 Scans #45 through #54

ULTRASONIC SCANNING RESULTS FOR BANDS 45 THROUGH 54 INERTIA WELDED TO M483 PROJECTILE BODIES. DARK AREAS INDICATE NO BONDING.



PHOTOGRAPH NO. 10724 **Page 1 of 2**

ULTRASONIC SCANNING RESULTS FOR BANDS 55 THROUGH 69 INERTIA WELDED TO M483 PROJECTILE BODIES. DARK AREAS INDICATE NO BONDING. 1 - 2

AD-A115 268 CHAMBERLAIN MFG CORP WATERLOO IOWA F/G 19/1

INVESTIGATION OF INERTIA WELDING PROCESS FOR APPLYING GILDING M--ETC(U)

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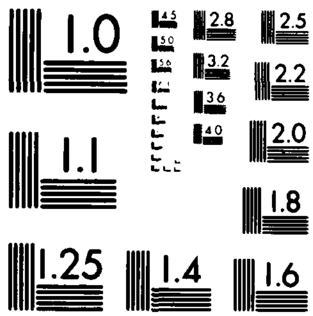
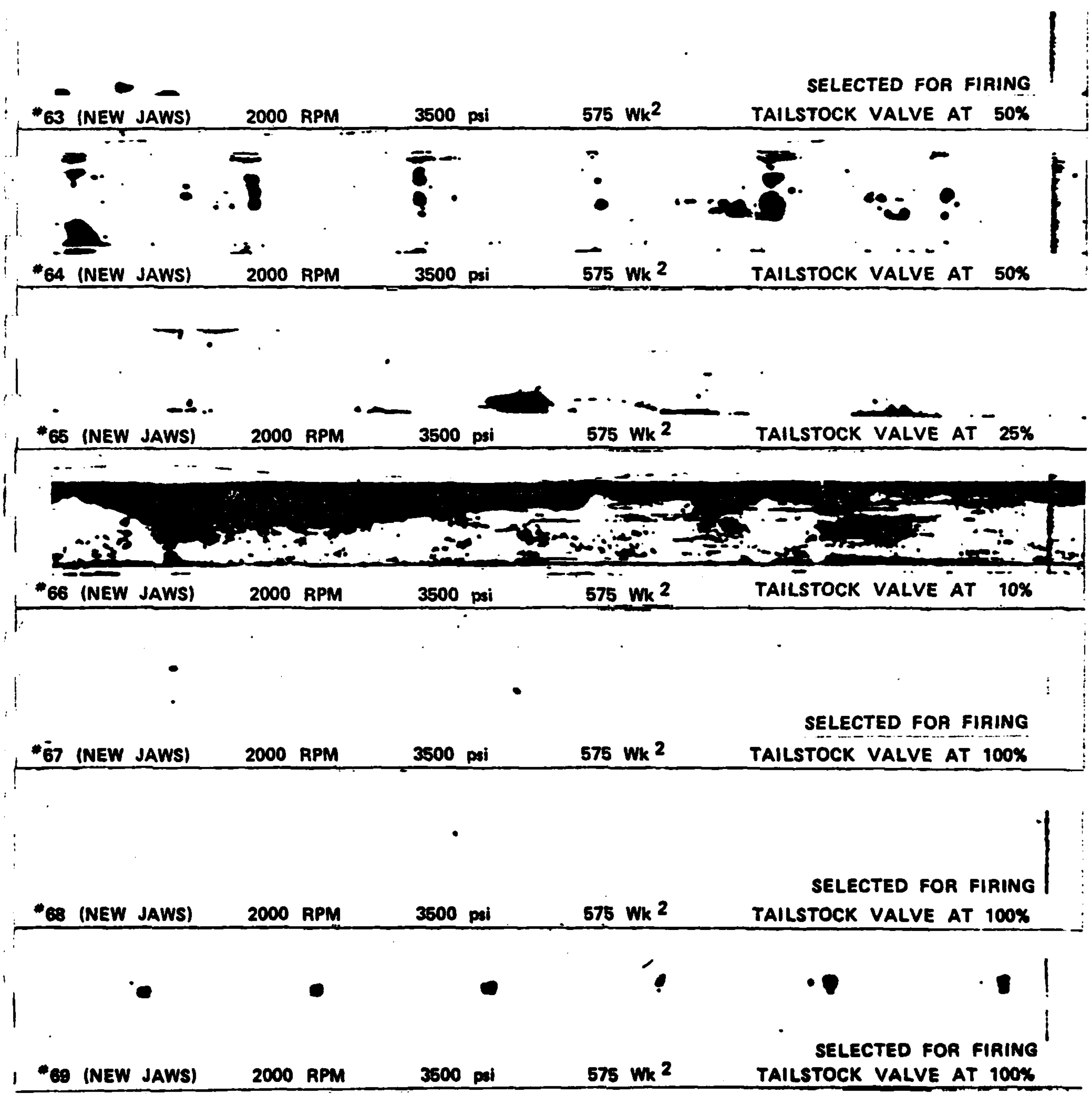


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A



PHOTOGRAPH NO. 10724 Page 2 of 2

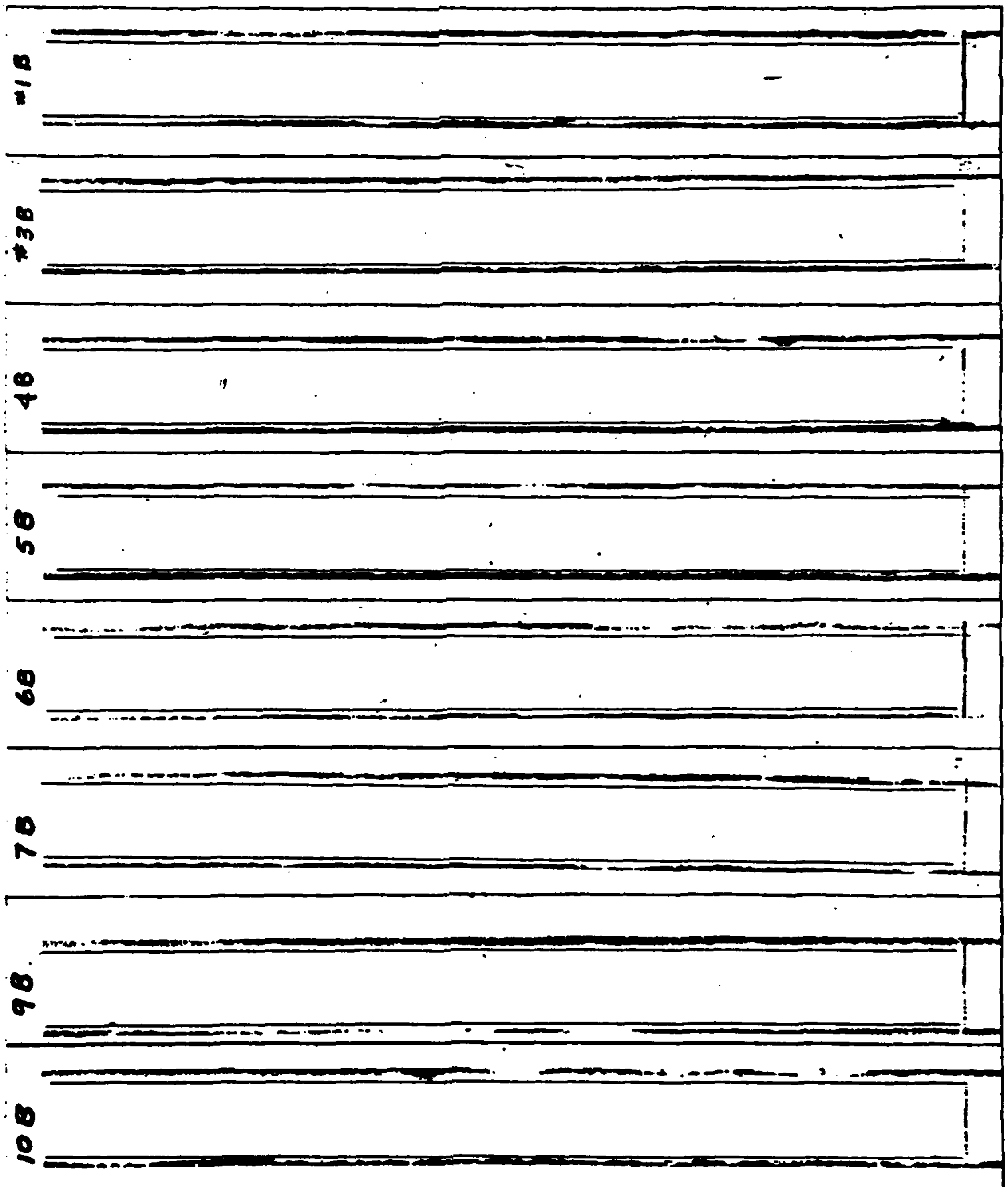
ULTRASONIC SCANNING RESULTS FOR BANDS 55 THROUGH 69 INERTIA WELDED TO M483 PROJECTILE BODIES. DARK AREAS INDICATE NO BONDING. 2-2

APPENDIX 2

ULTRASONIC SCANS -- M483A1 PROJECTILES BANDED AND SCANNED

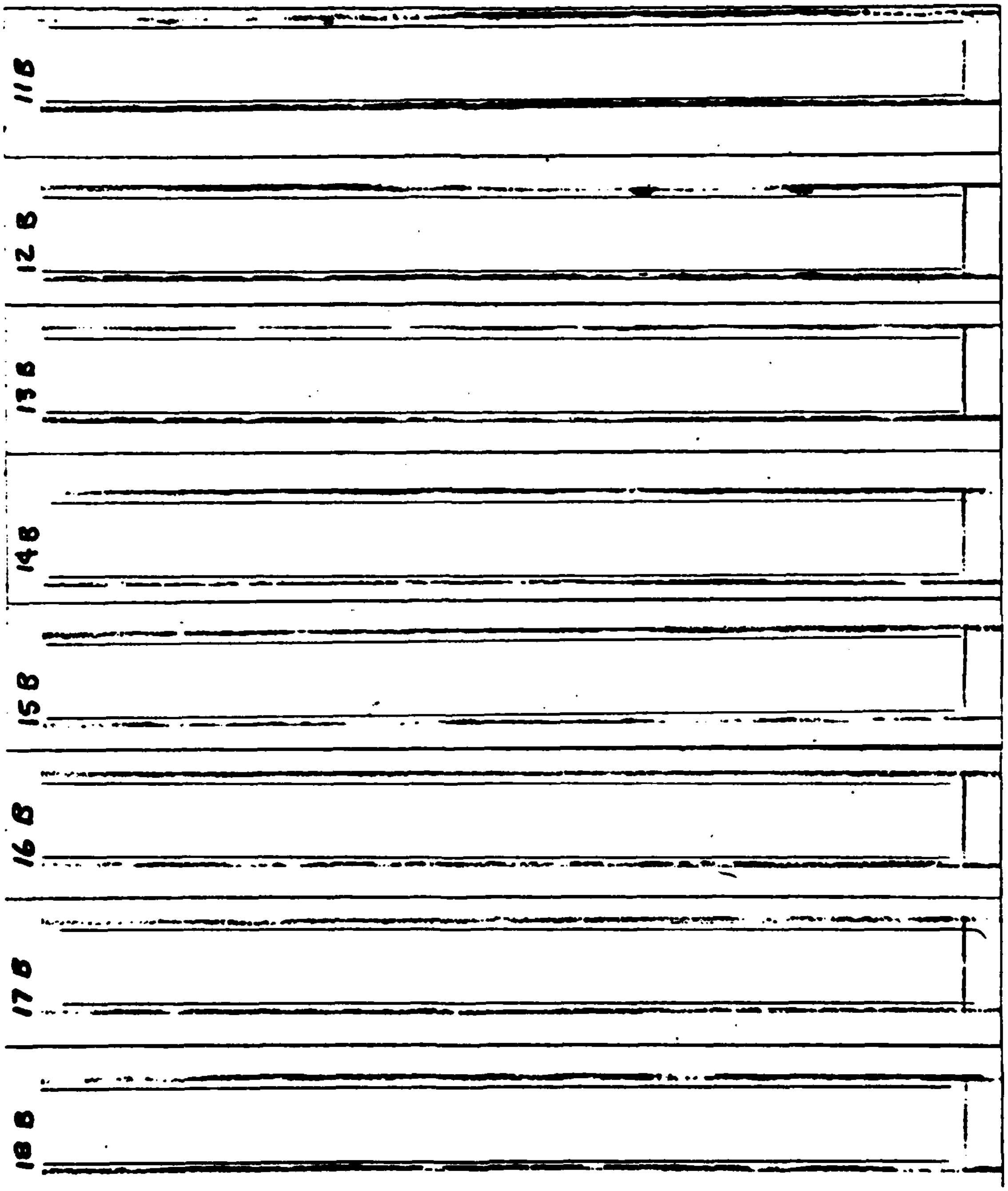
BEFORE HEAT TREATMENT FOR FIRING TEST NO. 2

SENSITIVYT - RESOLVES .025" DIA. HOLE ON TEST BLOCK



PHOTOGRAPH NO. 10802 1 of 3

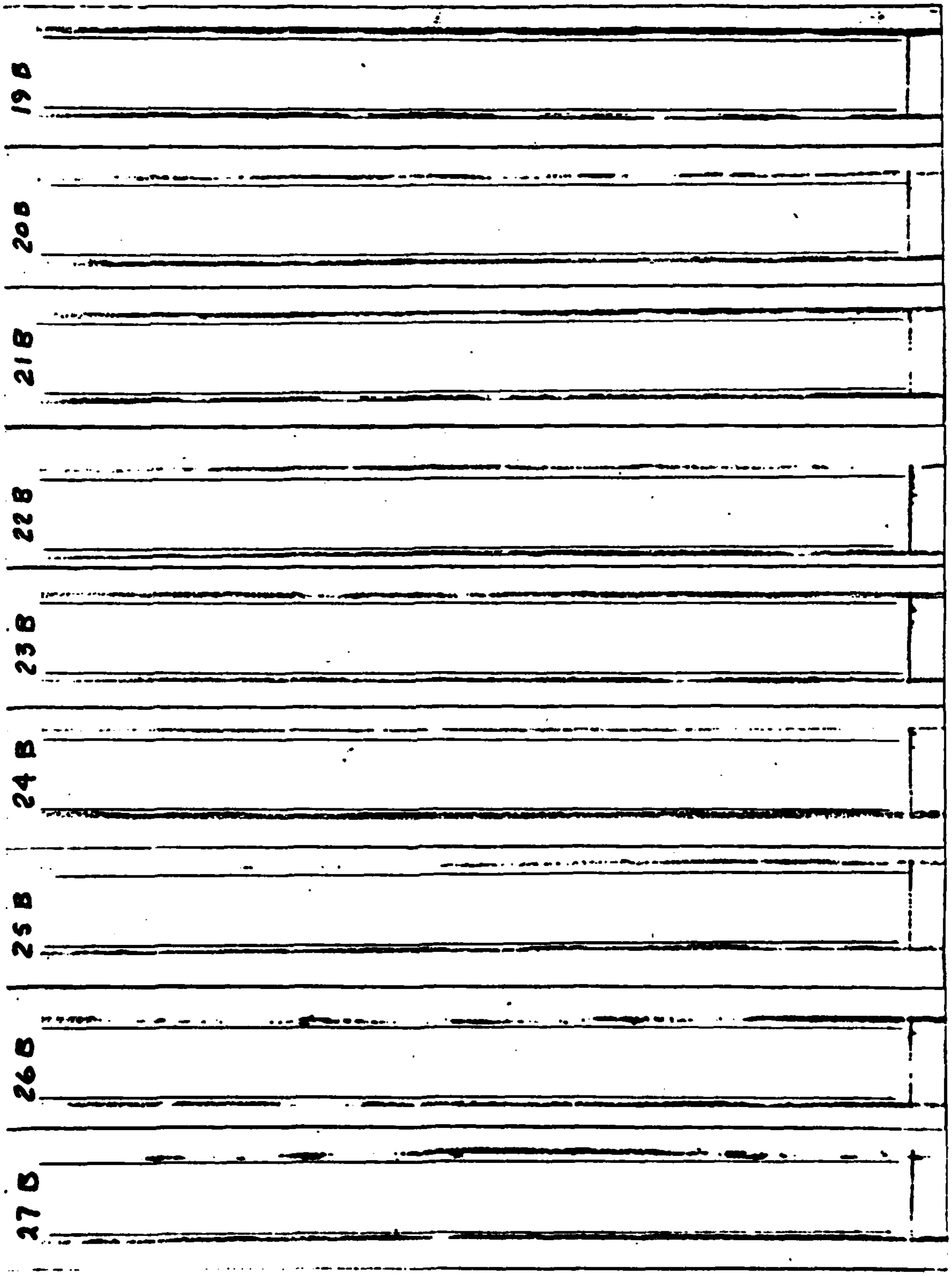
Ultrasonic Scans For 25 M483A1 Projectiles Having Rotating Bands Inertia Welded Before Projectile Heat Treatment. Inertia Weld Parameters - - - 2,200 rpm Flywheel Rate, 425 wk^2 Flywheel, 3,800 psi Tailstock Ram Pressure.



2 of 3

PHOTOGRAPH NO. 10802

Ultrasonic Scans For 25 M483A1 Projectiles Having Rotating Bands Inertia Welded Before Projectile Heat Treatment. Inertia Weld Parameters - - - 2,200 rpm Flywheel Rate, 425 wk^2 Flywheel, 3,800 psi Tailstock Ram Pressure.



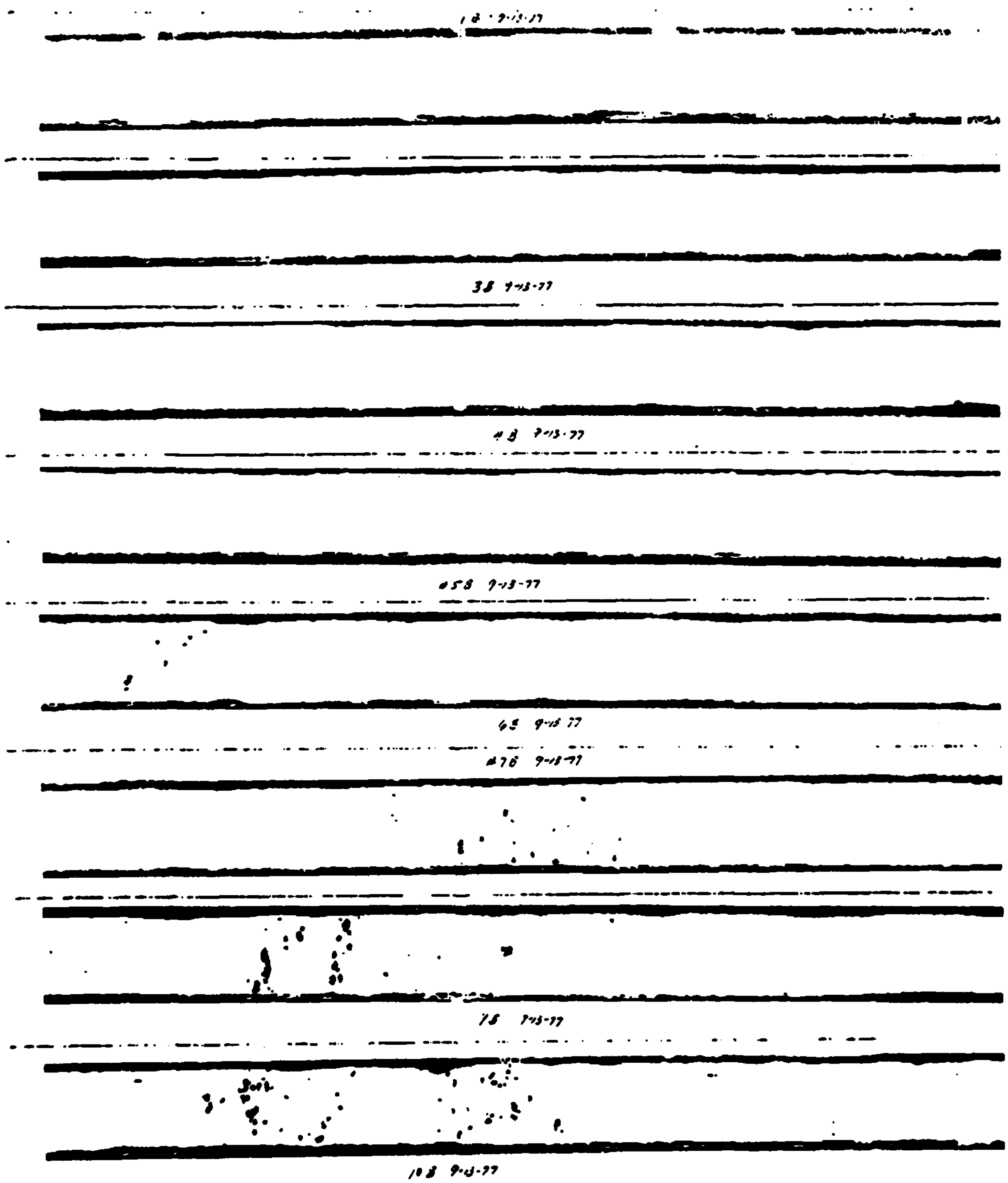
3 of 3

PHOTOGRAPH NO. 10802

Ultrasonic Scans For 25 M483A1 Projectiles Having Rotating Bands Inertia Welded Before Projectile Heat Treatment. Inertia Weld Parameters - - - 2,200 rpm Flywheel Rate, 425 wk^2 Flywheel, 3,800 psi Tailstock Ram Pressure.

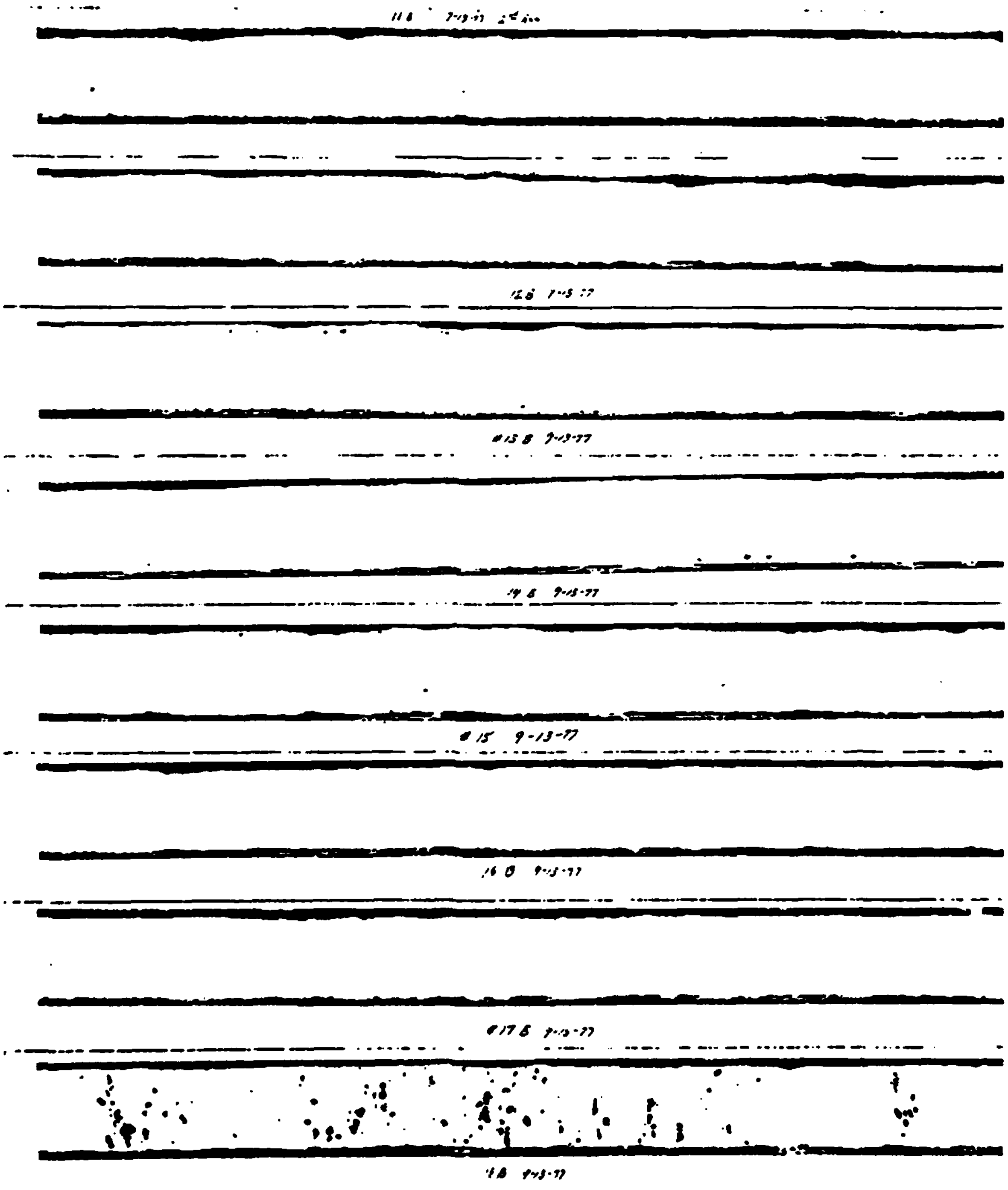
APPENDIX 3

ULTRASONIC SCANS M483A1 PROJECTILE
BANDED BEFORE HEAT TREATMENT AND SCANNED
AFTER HEAT TREATMENT FOR FIRING TEST NO. 2
SENSITIVITY - RESOLVES .025" DIA. HOLE ON TEST BLOCK



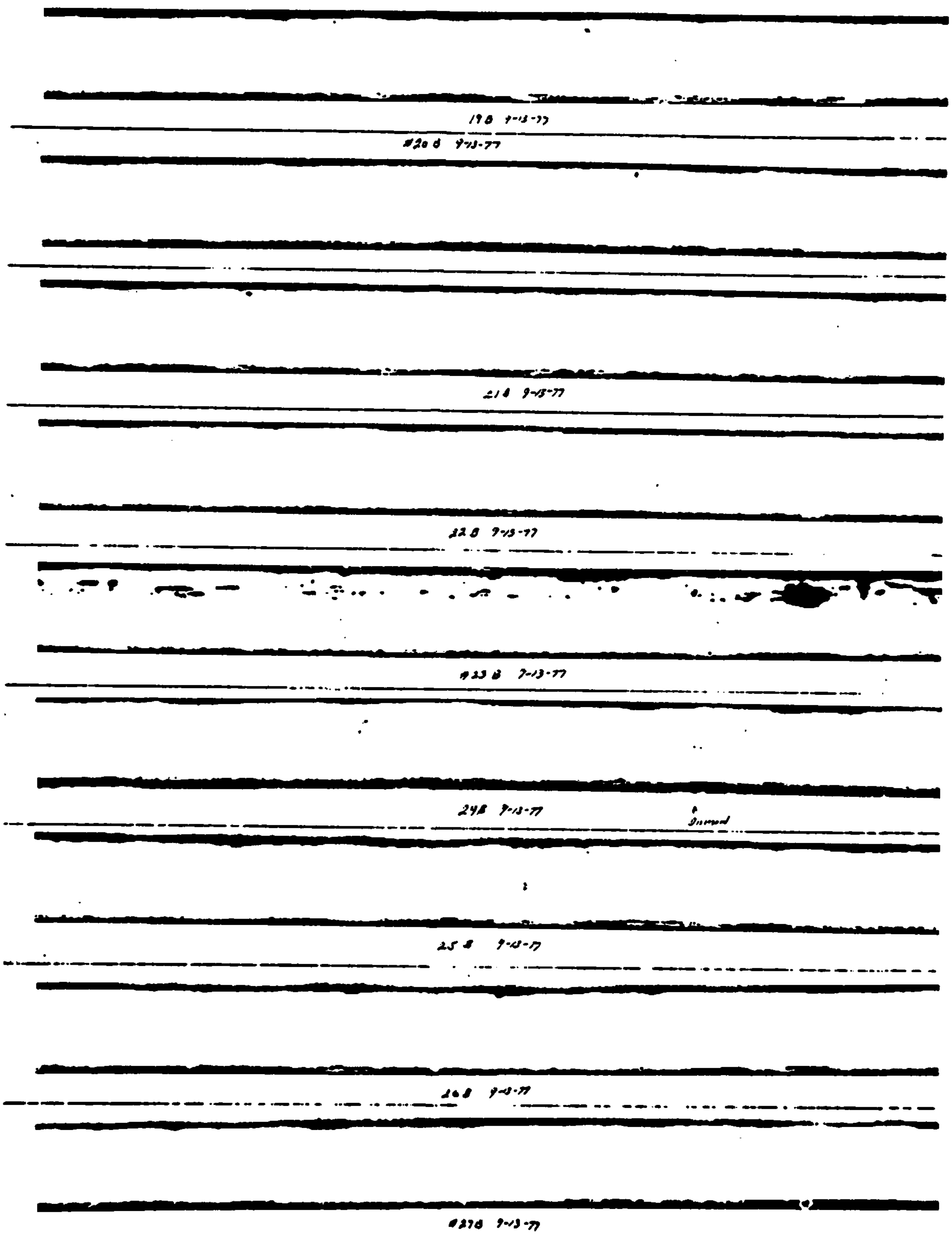
PHOTOGRAPH NO. 10818

AFTER HEAT TREATMENT ULTRASONIC SCANS OF M483A1 PROJECTILES BANDED BEFORE HEAT TREATMENT. HEAT TREATMENT ACCOMPLISHED DURING SEPTEMBER 1977.



PHOTOGRAPH NO. 10818

AFTER HEAT TREATMENT ULTRASONIC SCANS OF M483A1 PROJECTILES BANDED BEFORE HEAT TREATMENT. HEAT TREATMENT ACCOMPLISHED DURING SEPTEMBER 1977.

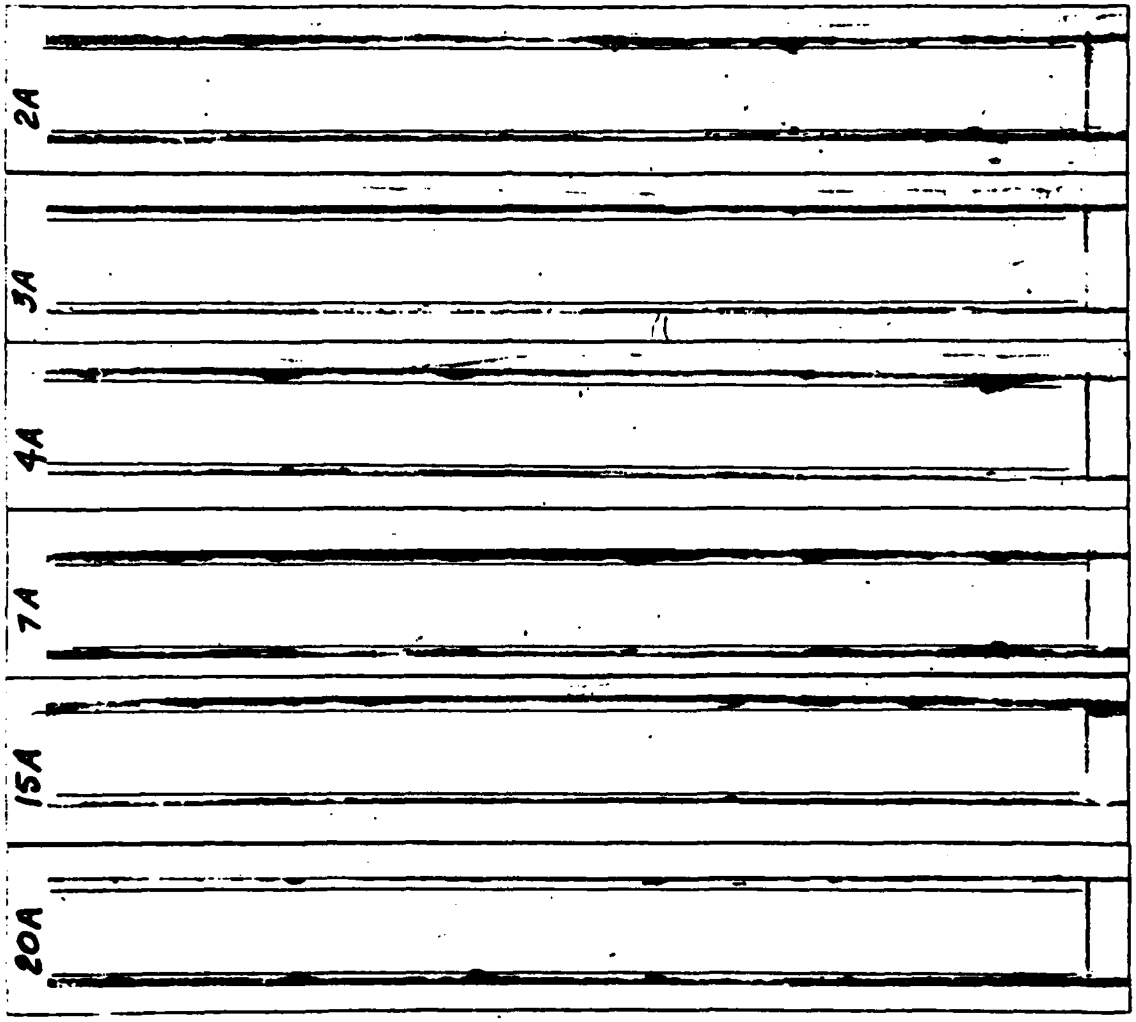


PHOTOGRAPH NO. 10818

AFTER HEAT TREATMENT ULTRASONIC SCANS OF M483A1 PROJECTILES BANDED BEFORE HEAT TREATMENT. HEAT TREATMENT ACCOMPLISHED DURING SEPTEMBER 1977.

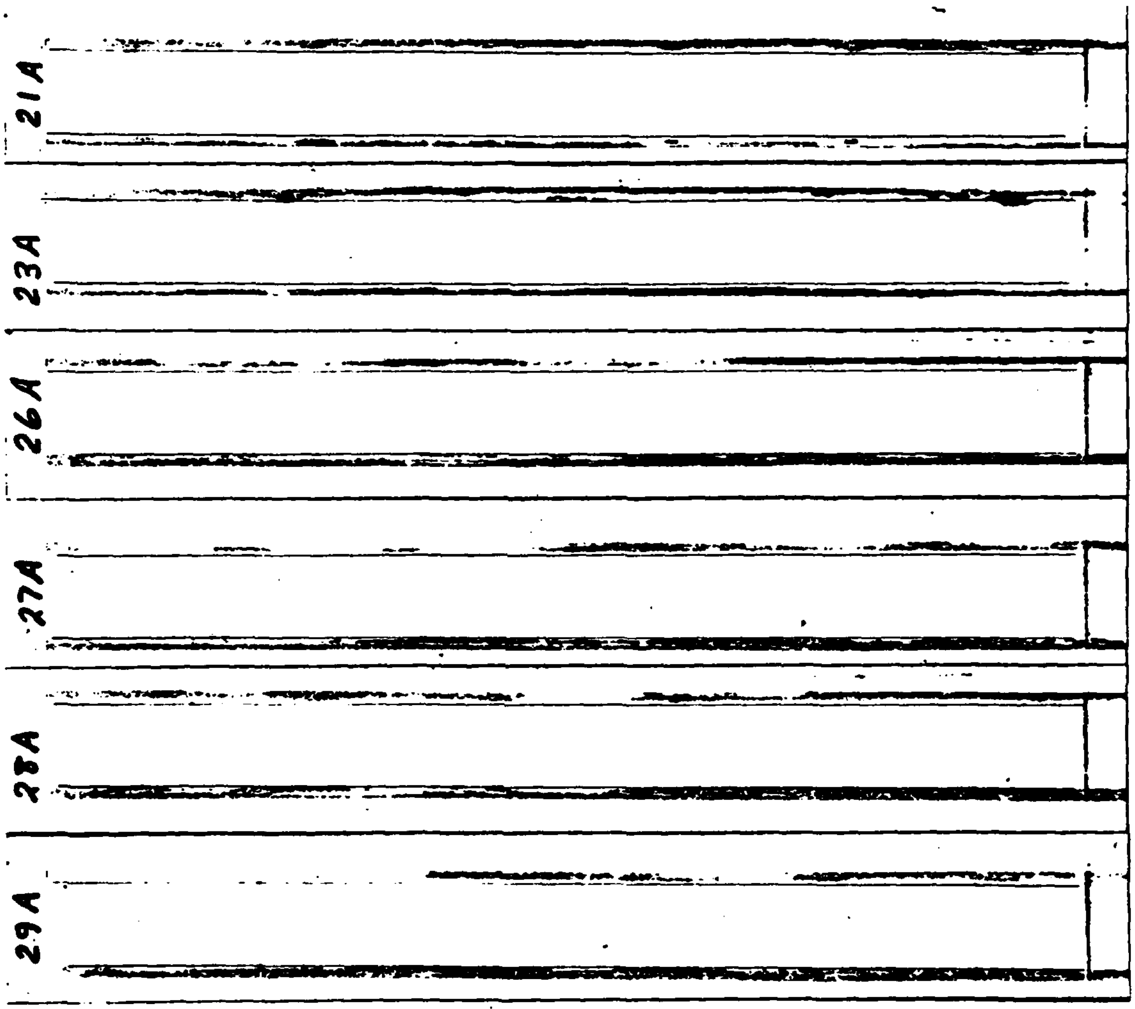
APPENDIX 4

ULTRASONIC SCANS -- M483A1 PROJECTILES BANDED AND SCANNED
AFTER HEAT TREATMENT FOR FIRING TEST NO. 2
SENSITIVITY - RESOLVES .025" DIA. HOLE ON TEST BLOCK



PHOTOGRAPH NO. 10803

Ultrasonic Scans For M483A1 Projectiles Banded By Inertia Welding After Heat Treatment. These Rounds Selected For firing. Weld Parameters - - - 2,200 rpm Flywheel Rate, 425 wk^2 Flywheel, 3,800 psi Tailstock Ram Pressure.



PHOTOGRAPH NO. 10803 2 of 2

Ultrasonic Scans For M483A1 Projectiles Banded By Inertia Welding After Heat Treatment. These Rounds Selected For firing. Weld Parameters - - - 2,200 rpm Flywheel Rate, 425 wk^2 Flywheel, 3,800 psi Tailstock Ram Pressure.

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