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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/612

A Study of the Seam Welding Process Applied to Prevent Stress Cracking of the Visor of the M1 Helmet

BY

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DATE 13 April 1944

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Watertown Arsenal Laboratory

Memorandum Report No. WAL 710/612

Partial Report on Problem B-7.3

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A Study of the Seam Welding Process Applied to
Prevent Stress Cracking of the Visor of the M1 Helmet

Abstract

The edge-annealing process has been found effective in preventing the progress of cracks through the annealed zone. Since any cracks which may form between the edge and the annealed zone are short enough to be covered by the stainless steel edging it is believed that the application of the edge-annealing process immediately after the visor spanking operation would correct the visor cracking difficulties being presently experienced by the helmet fabricators. Recent experience with a 3½% nickel manganese steel shows a sufficient superiority over normal manganese steel that the edge-annealing process probably would not be required to safeguard against delayed visor cracking.

1. During the past months, the Schlueter Manufacturing Company of St. Louis, Missouri has been encountering considerable fabrication difficulty consisting of a high incidence of delayed visor cracking. As a result of this difficulty, the company has adopted an inspection procedure whereby the helmets are carefully examined for cracks, held in storage for 15 days, then re-examined for cracks. It has been their experience that the major proportion of delayed visor cracking usually manifests itself within four or five days after the helmet is manufactured.

2. Delayed cracking has been observed to occur between the time the helmets are shipped from the fabricator's plant and the time they arrive at their destination, resulting in serious delays and financial loss.

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A metallurgical examination[1] has been made of helmets which cracked after having been accepted by the Ordnance Department, as a result of which it was concluded that the visor cracking was caused by a combination of the severely stressed condition produced by the cold forming operations and notches in the rim of the visor caused by trimming die defects. It has been noted that cracks tend to occur in constant positions in the visor in a group of helmets successively produced, and that the position varies from lot to lot, corresponding to the position on the trimming die which becomes nicked during operation.

3. Some experimental tests have been performed at the Schlueter plant in an attempt to solve the delayed visor cracking problem. In one test, a lot of approximately 6000 helmets made from one heat of steel was subdivided into three groups, one group of 2000 helmets had the rim at the visor carefully ground to remove all notches, one group of 2000 helmets had the rim of the visor annealed by a rapid heating and quenching cycle in a seam welding machine, and the balance held as a control sample. The test proved unsatisfactory since only four helmets developed visor cracks, two in the control sample, one in the edge-annealed sample, and one in the edge-ground sample. The only significant information obtained from this test resulted from the examination of the crack in the edge-annealed helmet. The crack did not extend beyond the annealed zone whereas the cracks in the other helmets extended up into the body of the helmet.

4. In the second test, a group of uncracked helmets was selected from another heat which had already evidenced an excessive degree of delayed cracking in storage. The helmets were split into two groups, one of which was edge-annealed and the other held as the control. After the elapse of 15 days, reinspection of the two groups showed that age cracking continued to occur to roughly the same extent in both groups, amounting to approximately 4.8%. The cracks in the control sample extended up into the body of the helmet whereas those in the edge-annealed samples did not extend beyond the weld. Since the welded zone lies only 0.1 to 0.2 inches from the edge, the cracks in the edge-annealed helmets would be hidden by the stainless steel edging which is spot welded around the brim of the helmet. If it can be established that the cracks are not likely to progress through the welded zone, it would seem that the application of the edge-annealing process would correct the present delayed cracking difficulties.

5. Four helmets made from the same heat of steel, two being edge-annealed and two produced in the normal manner, were forwarded to this arsenal for metallurgical examination. As a result of the tests performed on the submitted samples it is concluded that:

<u>a</u>. The edge-annealing treatment effectively prevents the progress of cracks through the welded zone.

<u>b</u>. The edge-annealing treatment produces no deleterious change in the ballistic properties of the M1 helmet.

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1. Watertown Arsenal Rpt. No. WAL 710/586 - "Metallurgical Examination of 20 M1 Helmets, Made by the Schlueter Manufacturing Company, Which Cracked after Aging" 29 January 1944.

c. 90° bend tests conducted upon vertical sections cut from the visors of helmets demonstrate the improvement in ductility of the welded zone over the original cold worked condition.

d. The edge-annealing treatment produces a recrystallized, soft zone approximately 0.10 to 0.15 inch wide approximately 0.15" away from the edge of the visor.

e. It is believed that the application of the seam welding process will solve the visor cracking problem at the Schlueter plant. The additional expense should be justified by the savings resulting from its application.

6. The four submitted helmets were fabricated from Sharon Steel Corp. heat No. 73191 and are included in Schlueter Lot 213B. Two of the helmets were fabricated from discs contained in spider No. 2 and two from spider No. 3. The numbers stamped on the inside of the visors are as follows:

Edge-annealed Helmets	Regular Production Helmets
213B2-S	213B2-S
213B3-S	213B3-S

The helmets were subjected to the following tests:

a. Visual examination

b. Ballistic tests

c. 90° bend tests on sections cut from the visors

d. Hardness surveys of the seam welded zone

e. Microscopic examination

7. Details of the metallurgical and ballistic tests follow:

a. Visual examination. Each of the two regular production helmets had one crack located at the 26° position,* one 2.2" and the other 0.43" in length. Both cracks originated at a notch at the edge, see Figure 1A. The two edge annealed helmets also contained visor cracks, both at the 26° position, one 0.12" and the other 0.16" in length, and both originating from edge notches. The significant feature of the visor cracks in the edge-annealed helmets is that the cracks do not extend through the welded zone, terminating in both cases approximately at the beginning of the zone, see Figures 1B and C.

Another significant observation is that the cracks occur in a constant position in all helmets and in every case are associated with notches. This correlates with previous observations that trimming die defects are responsible for the notches, which, being located in highly stressed regions, promote the formation of cracks.

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*Starting at the middle of the visor as 0° and rotating clockwise.

In order to ascertain if the edge-annealing is effective in preventing the growth of cracks beyond the boundaries of the annealed zone, one edge-annealed helmet and one regular production helmet were tested in the following manner. The helmets were clamped in a vise, and the inside surfaces of the visors in the region of the cracks were each struck 10 blows with a hammer. The crack in the regular production helmet grew from its original length of 0.43" to a length of 1.35", while the crack in the edge-annealed helmet increased from its original length of 0.16" to 0.20". The distance from the edge of the helmet to the boundary of the annealed zone was approximately 0.20" in this helmet. Ten additional hammer blows failed to extend the crack in the edge-annealed helmet beyond 0.20".

b. Ballistic tests. To determine if the edge-annealing process affects the ballistic properties of the visor, one edge-annealed helmet and one regular production helmet were impacted with caliber .45 ball ammunition at service velocity (approximately 900 ft./sec.). The shots were aimed at the visors as closely as possible to the edge. The helmets were supported in an inclined position to make the impacted area normal to the line of flight of the projectile.

The regular production helmet was impacted with one bullet which struck the edge of the visor approximately two inches away from the 2.2" long crack at 26°. The crack was lengthened to 2.5 inches, and another crack, 0.6" long, developed at 22°, see Figure 2A. The edge-annealed helmet was impacted with four rounds which struck at or near the edge of the visor at a distance of 1 to 3 inches away from the 0.16" long crack at 26°, see Figure 2B. The crack was extended to 1.7" in length but no new cracks were developed. This test, although conducted upon only one helmet, indicates that the edge-annealing process causes no deleterious change in the ballistic properties of the visor.

c. 90° bend tests. Approximately two inch square sections were cut from the visors of the four helmets in the region lying between 350° and 10°. The sections were clamped in a vise with approximately one inch protruding, and the projection was hammered down to produce a 90° bend in a direction perpendicular to the edge of the helmet. The sections from the regular production helmets broke completely apart, as did the cold worked region above the weld zone of the edge-annealed helmets. The section from one of the edge-annealed helmets showed no cracking whatsoever from the edge to the far boundary of the weld zone, while the other section showed some slight surface cracking in the cold worked zone between the edge and the weld, see Figure 2C. This test demonstrates the improved ductility imparted to the edge of the visor by the annealing process.

d. Hardness Surveys. Sections were cut transversely through the annealed zones, mounted in lucite, and metallographically polished. After etching in nital, Knoop hardness surveys were made through the weld zone and the cold worked base metal. The results of a typical hardness survey are shown in Figure 3. The hardness from the edge to a distance of 0.15" from the edge averages approximately 500 Knoop Hardness Number,* then falls

*The Knoop Hardness Number is nearly equivalent to the Vickers Pyramid Hardness Number over the range of 200 to 500 Knoop.

sharply to approximately 275 KHN through the weld zone which is approximately 0.08" wide, then rises again to the base metal hardness of 500 KHN. A photomicrograph of a portion of a Knoop hardness survey through the weld zone is shown in Figure 4B.

e. Microscopic Examination. The appearance of a cross-section of the edge-annealed zone at low magnification is shown in Figure 4A. The dendritic structure in the oval weld nugget indicates that the melting temperature had been reached in this zone, resulting in the dendritic solidification structure. The weld nugget is surrounded by a very fine grained recrystallized zone in which all traces of cold working have been eliminated. The extremely fine grain size probably resulted from the very short thermal cycle, and accounts for the relatively high hardness of the annealed zone. Normally annealed Hadfield steel, having a grain size of A.S.T.M. #4-5, has an average hardness of Rockwell C 10-11, whereas the annealed zone in the edge-annealed helmets has a hardness equivalent to Rockwell C 27-28.

Flanking the annealed zone is a region averaging 0.02" in width in which carbides have been precipitated by heating in a temperature range between approximately 700°F. and the temperature of recrystallization.

8. General Considerations

Recent experience with a 3½% nickel-manganese steel* showed it to possess improved ductility and drawability over normal manganese steel to such an extent that it is believed that the edge-annealing process would not be required to assure against visor cracking if that steel were used.

The edge-annealing process could, however, be advantageously applied to normal manganese steel helmets, especially by the Schlueter Manufacturing Company, which has reported numerous instances of visor cracking.

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APPROVED:

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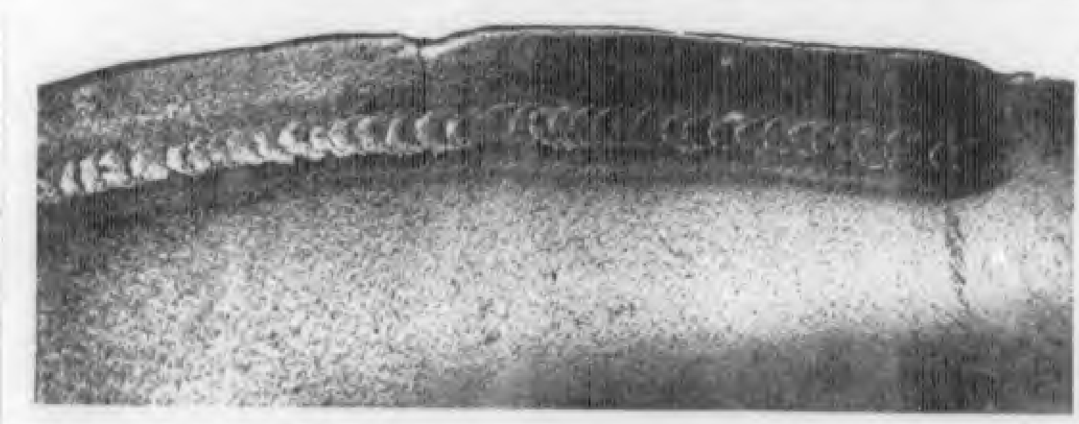
*Watertown Arsenal Memorandum Rpt. No. WAL 710/609 - "Metallurgical and Ballistic Investigation of a 3½% Nickel Modified Hadfield Manganese Steel Proposed for Use in the M1 Helmet", 12 April 1944.

A. Lot 213B2. Magnification $X\frac{1}{2}$. Looking down upon visor from top of helmet. 2.2" long crack at 26° position extending from notch at rim.

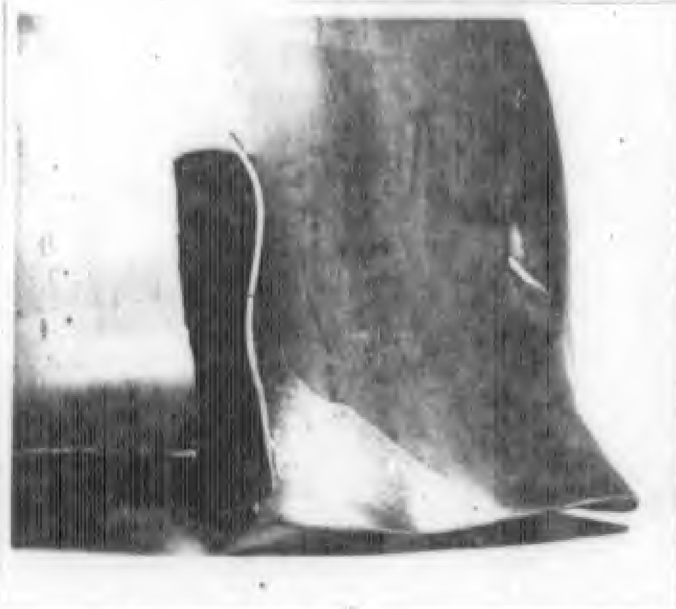
B. Lot 213B3. Magnification $X\frac{1}{2}$. Visor seam-welded to anneal cold worked rim. Note small crack at notch at A.



C. Lot 213B3. Magnification X2. Area at A in above photograph. Note that crack extends to, but not through, seam-welded zone. Length of crack - 0.16".

FIGURE 1

Ballistic Tests of Helmet Visors

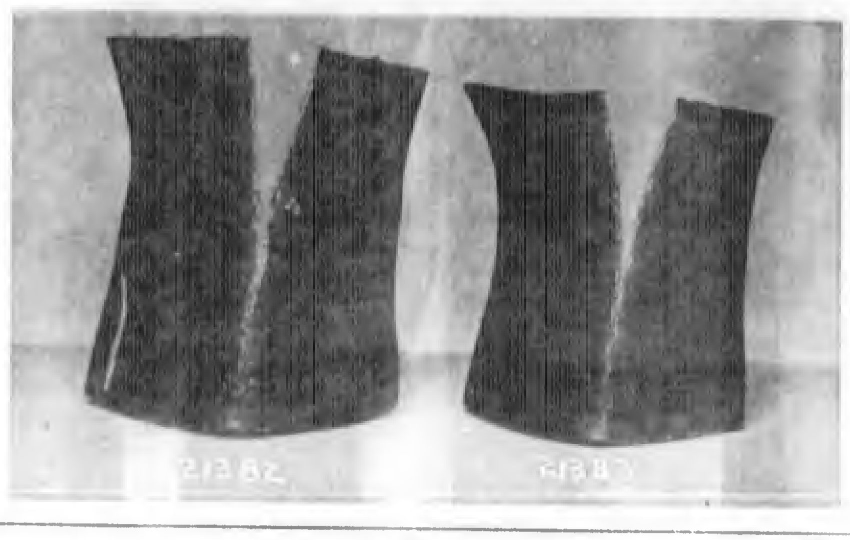


Lot 213B2. -A- X½

Cracks resulting from impact of Cal. .45 ball upon visor. Velocity approx. 900 ft./sec. Edge of helmet not annealed by seam-welding. Cracks at 22° and 26° positions.

Lot 213B3. -B- X

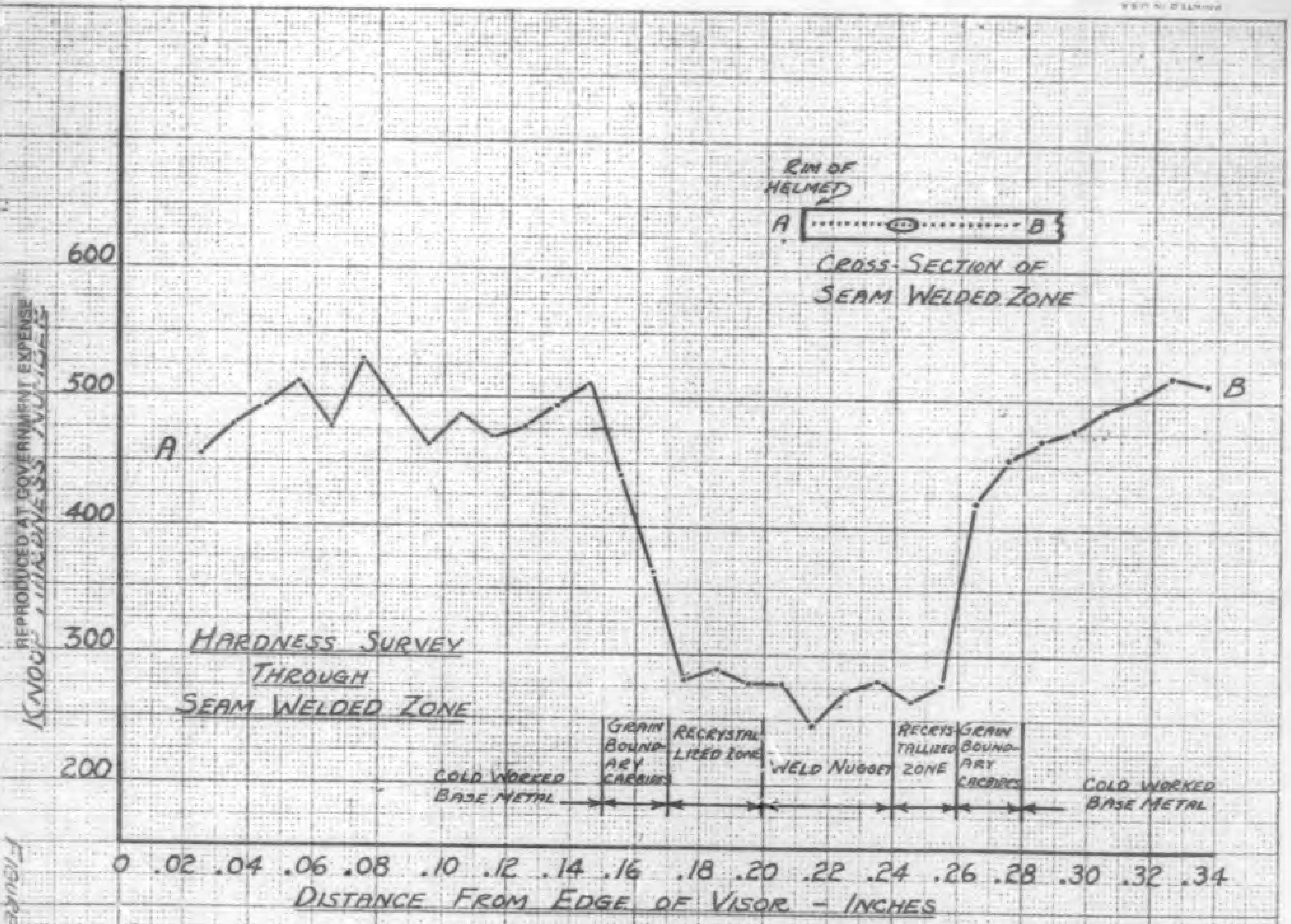
Crack resulting from impact of Cal. .45 ball upon visor. Velocity approx. 900 ft./sec. Edge of helmet annealed by seam welding. Crack at 26° position.



-C- X1

90° bend tests on sections cut from visors of edge annealed helmets. Similar tests on helmets without edge-annealing resulted in complete breakage.

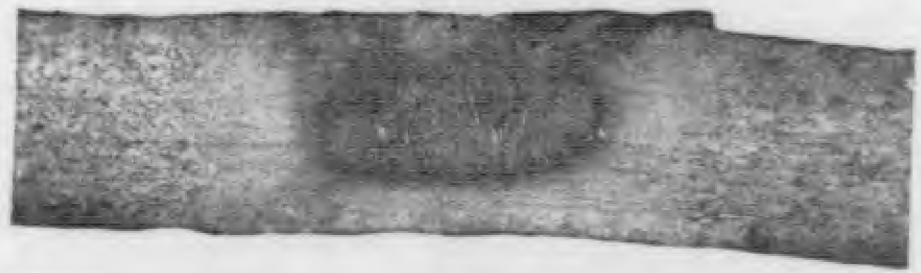
FIGURE 2



HARDNESS SURVEY
THROUGH
SEAM WELDED ZONE
RIM OF HELMET
A
B
CROSS-SECTION OF
SEAM WELDED ZONE
KNOOP HARDNESS NUMBERS
600
500
400
300
200
0 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .22 .24 .26 .28 .30 .32 .34
DISTANCE FROM EDGE OF VISOR - INCHES
COLD WORKED BASE METAL
GRAIN BOUNDARY CARBIDES
RECRYSTALLIZED ZONE
WELD NUGGET
RECRYSTALLIZED ZONE
GRAIN BOUNDARY CARBIDES
COLD WORKED BASE METAL

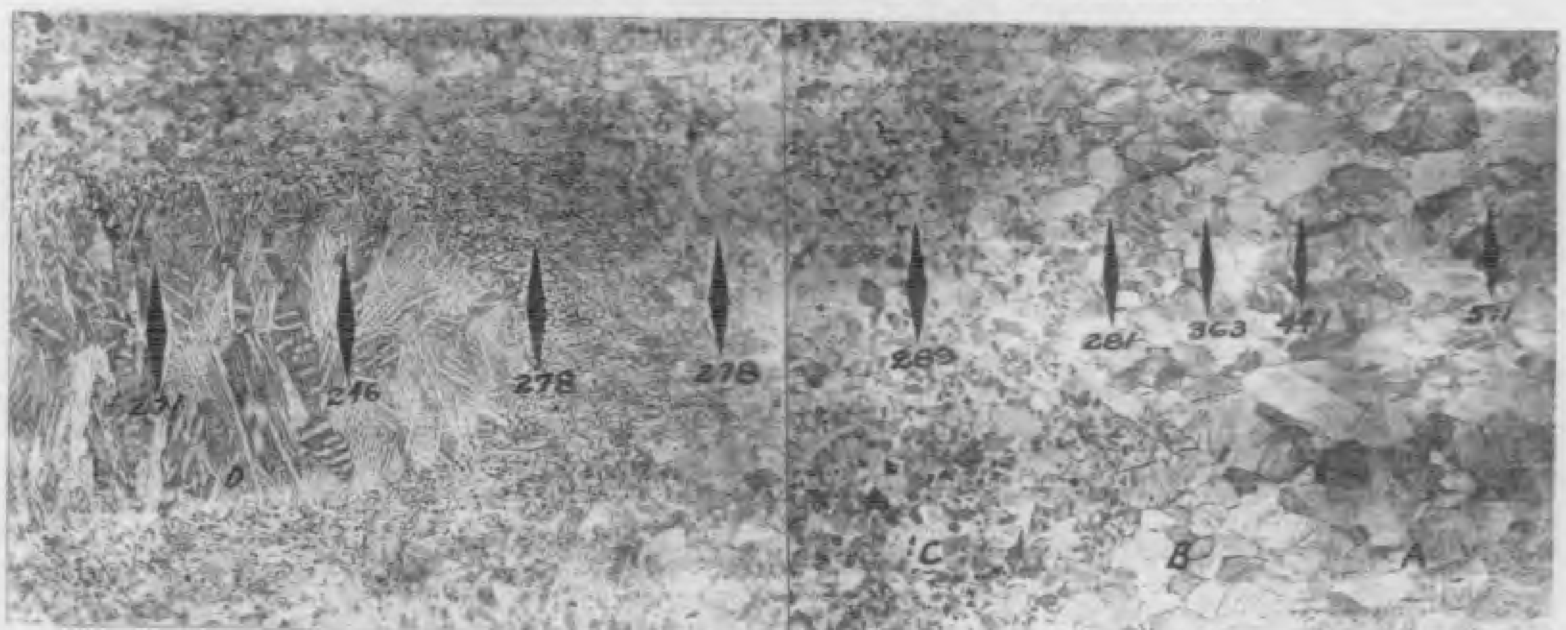
FIGURE 3

Nital Etch



Lot 213B3 -A- X25

Longitudinal section through seam-welded zone. Dendritic structure of weld nugget indicates melting and resolidification.



Same as above after Knoop Hardness Survey. -B- X100

A is cold worked base metal. B is zone in which carbide precipitation at grain boundaries has occurred. C is zone of recrystallized, annealed metal. D is weld nugget having dendritic structure. Zone D is surrounded by area in which carbide precipitation occurred.

FIGURE 4