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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/586

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Metallurgical Examination of 20 M1 Helmets, Made by the
Schlueter Manufacturing Company, Which Cracked after Aging

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BY

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Associate Metallurgist

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Watertown Arsenal Laboratory

Memorandum Report No. WAL 710/586

Partial Report on Problem B-7.3

DEC 14 1984

29 January 1944

Metallurgical Examination of 20 M1 Helmets, Made by the
Schluster Manufacturing Company, Which Cracked after Aging

ABSTRACT

Twenty M1 helmet bodies produced by the Schluster Manufacturing Company were examined to determine causes of cracks formed at front brim of helmets upon aging. It is concluded that the severely stressed condition of the helmet visor coupled with notches caused by trimming die defects are responsible for the failures. Defective steel is an additional factor in some cases and undoubtedly increases the percentage of similar failure. Improved fabrication methods appear necessary to fully overcome the cracking tendency.

1. At the request of the Office, Chief of Ordnance,¹ twenty (20) M1 helmets, produced by the Schluster Manufacturing Company, were forwarded to this arsenal for study. Each of the helmets contained a crack extending vertically up from the edge of the visor for a distance of from $\frac{1}{2}$ to 2 inches. According to information communicated to this laboratory by Capt. W. W. Hewitt of the Office, Chief of Ordnance (SPOIS), the Schluster Manufacturing Company had started in June of 1943 the practice of setting aside 10% of its production and submitting the helmets to periodic inspection to check if any cracks had developed. Very few cracks were reported to have been found at that time. In December of 1943, a shipment of 14,000 helmets was re-examined after being packed and shipped from the plant of the Schluster Manufacturing Company, and 450 helmets, comprising 3.2% of the total, were found to contain cracks similar to those on the twenty helmets submitted to this arsenal.

2. Exactly similar cracking occurred in seven of twenty helmets which were forwarded from the McCord Radiator and Manufacturing Company

1. Teletypes dated 17, 21 January 1944, See Appendix A.

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to this arsenal in July of 1943. The helmets had been carefully examined in Detroit and were ascertained to be free of cracking, but upon receipt at this arsenal, cracks from 0.3" to 2" in length were found extending vertically up from the edge of the visor of seven of the helmets.² It was believed that the cracking was associated with the highly stressed condition of a steel that is very notch sensitive. The visors are cold worked to a severe degree in the spanning operation; the hardness in this region usually exceeds Rockwell C 50. Examination of several hundred helmets at this arsenal and at the plant of the McCord Radiator and Manufacturing Company disclosed that notches and irregularities at the edge of the helmet occur with great frequency during the trimming operation, and that the notches and irregularities are confined almost exclusively to the edge of the visor. Many cracks were observed which undoubtedly originated from notches at the rim. A combination of severely cold worked metal, notches, and a notch sensitive steel would be expected to result in frequent failure by cracking.

3. Visual and metallurgical examination disclosed the following:

- a. The cracks occur in a relatively constant position in helmets from one lot, with the position varying from lot to lot.
- b. Fifteen of the twenty cracks emanate from distinct notches at the rims of the visors.
- c. Metallographic examination of eight of the twenty helmets indicate that the steel of Lot S-164A contains no defects, while that of Lot S-199A contains streaks of untempered carbides, and that of Lot-S-192A contains networks of grain boundary carbides.
- d. Hardness surveys made in the vicinity of the cracks on ten of the helmets show hardnesses of Rockwell C 50-53 in the visor.

It is concluded from the foregoing that the cracking is associated with the severe cold working of the visor, notches at the rim of the visor and with metallurgically defective steel in some, but not in all, cases. The constancy of the position of the cracks on the helmets from each lot suggests a trimming die defect which produces notches at the edge of the visor.

4. Details of the metallurgical examination are as follows:

- a. Material and Test Procedure. The stainless steel edgings were removed from the helmets, the visors examined for notches, and the positions of the cracks located by starting at the middle of the visor as the zero degree position and rotating clockwise.

The data are contained in the following table:

-
2. See Watertown Arsenal Laboratory memorandum report no. WAL 710/575 "Metallurgical Examination of Defective and Satisfactory Helmets and Helmet Steel Stock Furnished by the McCord Radiator and Manufacturing Company, Detroit, Michigan." 23 December 1943, Pages 10 and 11.

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<u>W.A. Number</u>	<u>Schluter Mfg. Co. Lot No.</u>	<u>Sharon Steel Corp. Heat No.</u>	<u>Location of Crack Position in Degrees</u>	<u>Edge Condition at Crack</u>	<u>Condition of Helmet</u>
1	S-164A	72868	348	Notch	Finished, painted
2	S-164A	"	352	"	" "
3	S-164A	"	1	"	" "
4	S-164A	"	347	"	" "
5	S-164A	"	354	"	" "
6	S-164A	"	352	"	" "
7	S-164A	"	352	No Notch	" "
8	S-164A	"	354	Notch	" " "
9	S-164A	"	352	"	" "
10	S-164A	"	352	"	" "
11	S-199A	72965	15	Notch	Finished, unpainted
12	S-199A	72965	15	Notch	Finished, unpainted
13	S-199A	"	16	"	" "
14	S-199A	"	14	"	" "
15	S-199A	"	14	"	" "
16	S-192A	72970	10	No Notch	Finished, painted
17	S-192A	"	13	"	" "
18	S-192A	"	13	"	" "
19	S-192A	"	10	Notch	" "
20	S-192A	"	10	No Notch	" "

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A photograph of a typical visor crack emanating from a notch at the rim which also shows typical irregularities at the edge of the visor, and a schematic representation of the locations of the cracks in the helmets from the three lots are shown in Figure 1.

Except for one crack, located at 1°, all the cracks from the 10 helmets of Lot S-164A are located in a relatively constant position on each helmet, from 347° to 354°. The cracks on the 5 helmets from Lot S-199A are located from 14° to 16°, and those on the 5 helmets from Lot S-192A are located from 10° to 13°. The constancy of the locations of the cracks on helmets from one lot suggests a trimming die defect producing a notch or edge irregularity in a constant position on a series of helmets from one lot. The trimming dies apparently become quickly chipped, particularly in the region of the visor. This is indicated by the large number of notches and irregularities observed on hundreds of helmets.

In September of 1943, 20 helmets were sent to this arsenal from the McCord Radiator and Manufacturing Company³, 10 of which had cracked after aging and 10 which were ostensibly uncracked after aging. Nineteen of the helmets were from the same lot. Three of the ten uncracked helmets were found to be cracked upon receipt at this arsenal. The thirteen cracked helmets were all cracked in the visor, in the 333° position, and all cracks were associated with notches in the rim. Four of the uncracked helmets also contained notches in the rim at 333°, while the remaining two uncracked helmets were free of notches at 333°. Metallographic examination of some of the helmets indicated that the steel quality was satisfactory and magnetic tests performed on all helmets indicated freedom from harmful decarburization. It was concluded at that time that the cracking was associated with notches resulting from a trimming die defect and with the highly cold worked condition of the visors.

b. Hardness Surveys. Rockwell C hardness surveys were made on sections cut from the visors of ten of the submitted helmets. In the vicinity of the cracks, the hardness was in the range of Rockwell C 50-53. Numerous hardness surveys made in the past have indicated that the visor, as well as two regions at the back of the helmet, namely at 140-170° and 190-240° and approximately 1½" vertically up from the rim, possess the maximum hardnesses encountered on the M1 helmet. The hardness of the crown is generally in the range of Rockwell C 35-40 and at the sides Rockwell C 40-45.

It is precisely in the zones that have been cold worked to the maximum hardness that service and aging cracks have been found to occur. A statistical study of more than 200 service cracked helmets examined at this arsenal show an exact coincidence between the zones of maximum hardness and maximum frequency of cracking. A serious condition of overstrain in specific zones on the helmet shell is indicated by this evidence. The severe cold working results from an extremely deep draw produced in one operation, while

3. Letter File O.O. 421/2880, Wtn. 421/364 and 1st Indorsement, See Appendix A.

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the visor is further cold worked by the spanking operation which produces the reverse bend at the front of the helmet.

c. Metallographic Examination. Specimens for microscopic examination were cut from helmets, Nos. 1, 2, 3, and 7 of Lot S-164A, from Nos. 11 and 15 of Lot S-199A, and from Nos. 17 and 20 of Lot S-192A. The steel of all specimens from Lot S-164A was free from metallurgical defects, see Figure 2A, the microstructure consisting of austenite showing evidence of cold working. The microstructure of the specimens from Lot S-199A showed undissolved carbides and some grain boundary network of carbides as well as cold worked austenite. This condition results from improper heat treatment and indicates either a too low austenitizing temperature or insufficient time at temperature to become fully austenitic. The microstructure of the specimens from Lot S-192A contains grain boundary networks of carbide, also resulting from improper heat treatment.

5. The results of the metallurgical examination indicate that in the case of the helmets from Lots S-199A and S-192A, the cracking is associated with an undesirable microstructure as well as with severe cold working and the presence of notches. Hadfield manganese steel is embrittled when undissolved carbides are present in the microstructure, and it would be expected that the increased brittleness would be a factor in promoting crack formation, both during the forming of the helmet, and later in service.

The fact that the helmets of Lot S-164A are made of steel of good quality indicates that the combination of severe cold working and the presence of notches are alone enough to cause failure of helmets. This condition is very serious. Corrective measures may involve redesign of the shape of the helmet shell, changes in manufacturing technique, or both.

A. Hurlich

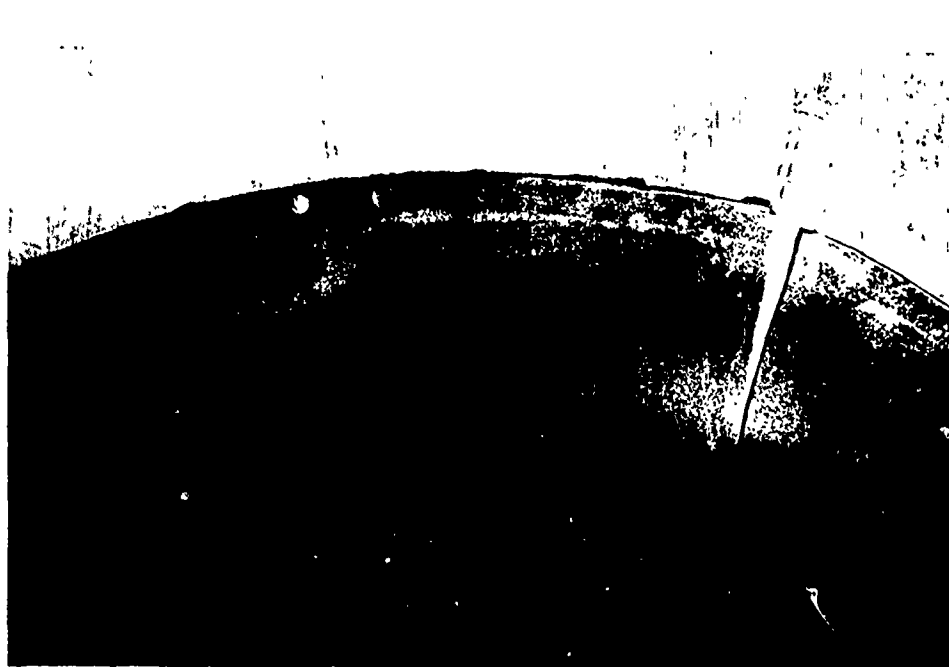
A. HURLICH
Associate Metallurgist

APPROVED:

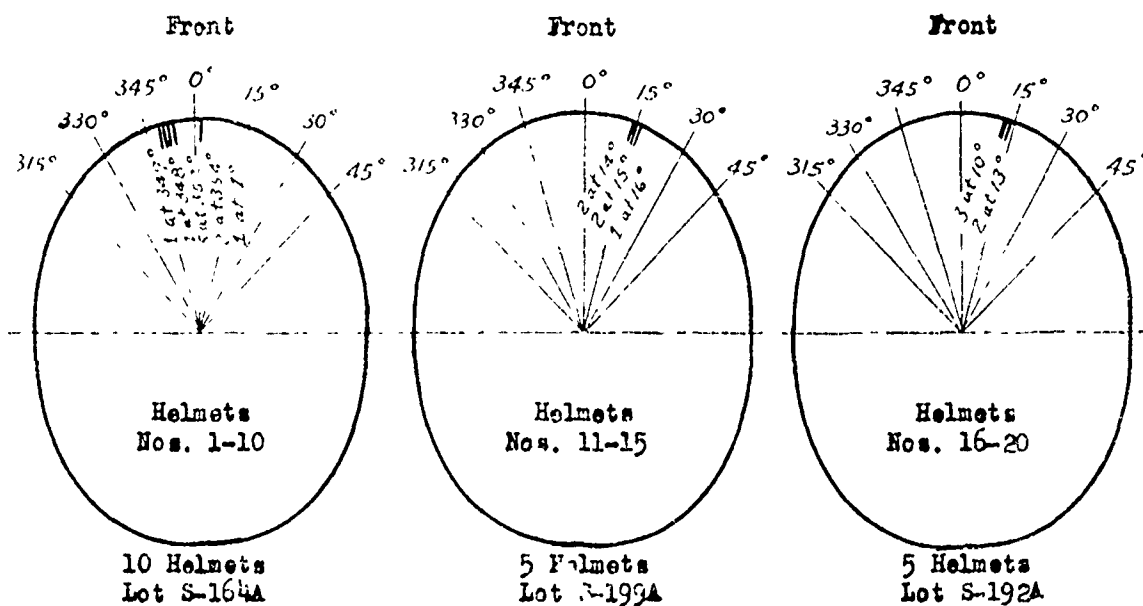
M. A. MATTHEWS
Major, Ordnance Dept.

Accession For	
NTS GRA&I	☒
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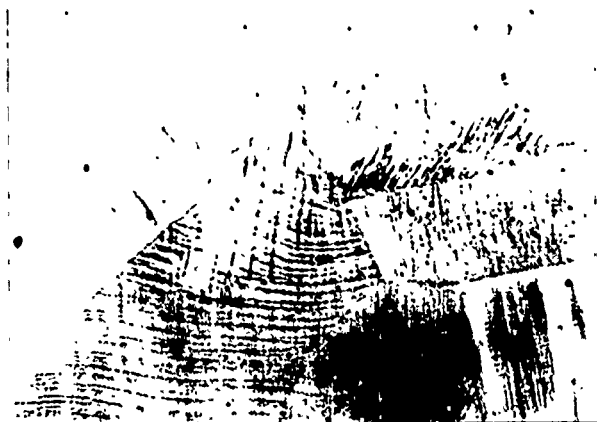
Location of crack in visor of Helmet No. 14
 Schluster Lot No. S-199A. Sharon Heat No. 72965. Magnification $\times 1\frac{1}{2}$
 Note notch at edge of visor at beginning of crack and also irregular edge of
 visor after trimming. Stainless steel edging has been removed.



Locations of Cracks on 20 Helmets Manufactured by the
 Schluster Manufacturing Company

FIGURE 1

MICROSTRUCTURE OF SCHLUETER MFG. CO. HELMETS
THAT CRACKED IN STORAGE



-A-

X1000

Helmet No. 7. Schluster Lot 164A. Sharon
Heat 72368. Satisfactory Microstructure.
Cold worked austenite.



-B-

X1000

Helmet No. 11. Schluster Lot 199A. Sharon
Heat 72965. Streaks of undissolved carbides
and some carbide boundary network.



-C-

X1000

Helmet No. 20. Schluster Lot 192A. Sharon
Heat 72970. Grain boundary networks of
carbide found mainly in the middle half of
the cross-section.

FIGURE 2.

APPENDIX A

COPY

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FROM KIRK WASH DC C OF ORD ASF 172135Z JAN 44

TO WATERTOWN ARS

REPHONE CONVERSATION HEWITT THIS OFFICE HURLICH YOUR OFFICE REQUEST
YOUR ARSENAL EXPEDITE TESTS ON RELIEVING STRESSES IN M1 HELMET BY SHOT
BLAST OR THERMAL MEANS HELMETS SHIPPED FROM SCHLUTER MFG. CO CRACKED
AFTER AGING ADVISE BY TT IF CRACKS WERE DUE TO FAULTY STEEL OR
INDUCED STRESSES END CITE SPOIS HEWITT

180126Z T2

COPY

LABORATORY

21 JANUARY 1944

AH/AM/8
J

CHIEF OF ORDNANCE

ARMY SERVICE FORCES, PENTAGON BUILDING, WASHINGTON 25, D. C.

SPOIS - CAPT. W. W. HEWITT

REURTT 172135Z JAN. 1944, SPOIS HEWITT, METALLURGICAL EXAMINATION COMPLETED ON 8 OF 20 SCHLUETER HELMETS. FOUR FROM LOT S-164A CONTAIN NO DEFECTS, TWO FROM LOT S-199A CONTAIN STREAKS OF GLOBULAR CARBIDES, TWO FROM LOT S-192A CONTAIN GRAIN BOUNDARY CARBIDES. CRACKS OCCUR AT RELATIVELY CONSTANT POSITION ON HELMETS FROM EACH LOT, LOT S-164A AT 347-352°, LOT S-199A AT 14-16°, LOT S-192A AT 10-13°, GENERALLY ORIGINATING FROM NOTCHES AT EDGE OF VISOR. THIS INDICATES CONSTANT TRIMMING DIE DEFECT WITH EACH LOT. VISOR IS SEVERELY COLD WORKED. CRACKS RESULT FROM SEVERE STRAINING WITH METALLURGICAL DEFECTS BEING ADDITIONAL FACTOR IN SOME CASES. END. CITE LABORATORY HURLICH

MATHER, WATERTOWN ARSENAL

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

COPY

IMMEDIATE ACTION

Hewitt/ver
73819

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

Attention
SPOIS

4 Sept. 1943

Subject: Helmet, Steel, M1

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

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

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

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

By order of the Chief of Ordnance:

F. M. VOLBERG
Major, Ord. Dept.
Assistant

1 Incl.
SAD 3396 in dupl.

IMMEDIATE ACTION

COPY

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IMMEDIATE ACTION

Wtn 421/364
O.O. 421/4880
Attn: SPOIS

1st Ind.

Matthews/amv

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

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

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

10 Cracked Helmets

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

10 "Uncracked" Helmets

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

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

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

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

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

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

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COPY

IMMEDIATE ACTION

Wtn 421/304
O.O. 421/2880
Attn: SPOIS

1st Ind.
(Cont'd)

4 October 1943

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

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

For the Commanding Officer:

G. L. COX
Lt. Col., Ord. Dept.
Assistant

1 Incl. w/d

cc-SPOTL
Detroit Ord. Dist.

IMMEDIATE ACTION

COPY