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REPORT

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ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1595.

Investigation on Failure of S.A.P. Nose Pieces for 20-mm. S.A.P. Incendiary Ammunition.

(Copy No. 10.)

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Origin of Request and Object of Investigation:

On January 19th, 1944, under Analysis Requisition No. O.T. 4122, sixty nose pieces (12 from each of five heats) for 20-mm. S.A.P. incendiary ammunition were submitted to these Laboratories by J. M. Gilmartin, I.O.M., for Inspector of Materials, Inspection Board of United Kingdom and Canada, Ottawa, Ontario, for examination.

In an accompanying letter (File No. 12/4/5, Investigation #10), Mr. Gilmartin stated that the nose pieces from two heats (Nos. D 2756 and E 2317) had been failing by breaking, at a rate of one per 200 inspected. The other specimens had passed proof satisfactorily and were submitted for comparison purposes. The heat-treating sequence was given.

It was requested that the metallurgical tests be conducted in order to establish a comparison between the nose pieces from the different heats.

Chemical Analysis:

The nose pieces from three heats were annealed and drilled to get samples for chemical analysis. The results of this chemical analysis were as follows:

		Heat No.		
		E 2317	D 2756	E 2326
		- Per cent -		
Carbon	-	0.83	0.81	0.83
Manganese	-	0.83	0.89	0.88
Chromium	-	0.13	0.17	0.13
Molybdenum	-	0.35	0.33	0.33
Nickel	-	Nil.	Nil.	Nil.

Hardness Tests:

Hardness measurements were made on sections of the nose pieces. The hardnesses obtained on the Vickers machine (30-kilogram load) were given in a previous letter.* However, as stated in that letter, it was suspected, after the etching test, that some samples had been heated on sectioning. Checks were made on two heats (Nos. D 2524 and C 2956) and have shown that the first hardness in these cases had been definitely lowered by tempering the steel on cutting. However, a check on Heat No. D 2756 was impossible because no sample was available. Yet, many measurements made on points apparently not heated, according to the etching test did not show any hardness number higher than 757 V.H.N.

The hardness numbers obtained in each case were constant at different points extending from the nose tip to the base.

These average hardness numbers (V.H.N.) were as follows:

Heat No.		Vickers Hardness Number
D 2756	-	757
E 2317	-	849
D 2524	-	752
C 2956	-	746
E 2326	-	746

* Dated January 31st, 1944, to Inspection Board of United Kingdom and Canada, Ottawa, Attention of Mr. R. O. McGee, I.O. (M).

Microscopic Examination:

The microscopic examination has shown the following features:

In Heat No. D 2756 (see Figure 1) the structure is typical of a slightly tempered martensite. A few small carbides barely resolvable at X1500 magnification are observed.

In Heat No. E 2317 (see Figure 2) the structure is typically martensitic. Very small carbides are also observed.

In Heat No. D 2524 (see Figure 3) the structure has lost its acicular nature, showing an evidence of more advanced tempering. The carbide particles are much bigger.

In Heats Nos. C 2956 (see Figure 4) and E 2326 (see Figure 5), the structure is again tempered martensite. Lack of homogeneity was observed in these two samples. A typical example is shown in Figure 6.

Discussion of Results:

The chemical analysis of the nose pieces is in accordance with Specification FXS 381, which is a carbon-molybdenum type of steel.

The hardness measurements have shown that the pieces were fully hardened on quenching. The pieces from Heat No. E 2317 have definitely not been tempered after quenching, since their hardness (849 V.H.N. - 66 Rockwell 'C') is the maximum hardness attainable with this type of steel. The failure of the nose pieces from this heat might be attributed to this defect.

Since the main requirement of nose pieces is good impact strength allied with high hardness, it must be emphasized that all the characteristics of a steel which lower the impact strength without increasing the hardness should be eliminated. Among these are (1) the free carbides, which can be eliminated by soaking for a proper period of time at the correct temperature before quenching and by avoiding slack quenching; (2) the

(Discussion of Results, cont'd) -

inhomogeneities of the steel, which can be taken away by a proper hot working practice; and (3) the internal stresses which are set up on quenching.

The nose pieces are heated for quenching in a continuous-type controlled-atmosphere furnace. They are placed one layer deep on the hearth of this furnace and are automatically discharged into an oil tank from the furnace. The quenching temperature and the time in furnace are unknown.

These nose pieces are machined from rolled bar stock and the normal structure of the steel, when supplied, would probably be spheroidite. The size of the carbides of the steel can vary according to the previous thermal history. In any case, the size of the spheroids is a definite factor in the proper choice of the austenizing treatment and should be checked before establishing the heating practice before quenching. This practice would ensure a proper elimination of the undissolved carbides.

Another way of producing carbides in this steel, which is hypereutectoid, is a slack quenching practice which would produce proeutectoid carbides.

Although most of the free cementite observed in this steel is spheroidized and would then be present as a result of prior incomplete solution, some amount of proeutectoid cementite may possibly also be present.

The history of failure of these nose pieces reveals that the quenched-but-not drawn nose pieces have passed the proof test with 100 per cent penetration as readily as the quenched-and-drawn nose pieces and have shown no greater tendency to break up in the gun barrel. This fact would suggest that the relief of internal stresses would

(Discussion of Results, cont'd) -

not be of great importance in this instance.

It would seem that the internal stresses set up on quenching are not high enough to cause shattering when the steel is properly heat-treated to eliminate all carbides. However, it is possible that if a large number of carbides remain undissolved before quenching, the presence of these carbides will so weaken the steel that it will be very sensitive to shattering. Under these circumstances, so long as micro-quenching cracks have not been produced, tempering would decrease the quenching stresses and therefore reduce the tendency to shatter. However, if the steel has been so weakened by the presence of carbides that micro-cracks have formed on quenching, tempering will be of little value. This is submitted as a probable explanation of how the presence of carbides could influence the shattering characteristics of the steel and why, in some cases, tempering apparently did not improve the conditions.

Factors that could affect the stress pattern set up on quenching are inhomogeneity of the steel and the position of the piece as it enters the quenching tank. The homogeneity of the steel is a function of the hot-working treatments that the steel received during its manufacture into bar stock. Proper commercial practice will assure good homogeneity.

In any case, the shattering of the pieces can be definitely attributed to the internal stresses. The presence of carbides and inhomogeneities would enhance the detrimental effects of the internal stress pattern.

CONCLUSIONS:

1. Heat No. E 2317 was submitted in the "quenched" condition. All other heats had been quenched and tempered.

2. Shattering of nose pieces is caused by internal stresses generated by quenching.

3. Carbides are present to a greater or lesser degree in all nose pieces examined.

4. Carbides can cause failure by making the steel more sensitive to shattering from quenching stresses.

Recommendations:

1. The hot-working practice should be set up to eliminate inhomogeneities.

2. A microscopic examination of the rolled bar stock is recommended to determine the size of the carbides in order to choose the proper austenizing treatment.

3. These pieces should be given the proper austenizing treatment, i.e., to ensure solution of carbides.

4. Any possibility of slack quenching should be avoided.

5. These pieces should be tempered after quenching.

Since the conditions of this investigation have not permitted an exhaustive study to be made of the actual manufacturing conditions, conclusions and recommendations submitted should be regarded as purely tentative.

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AD:HVK:GHB.

Figure 1.

X1500, nital etch.
MICROSTRUCTURE OF
HEAT NO. D 2756.

Figure 2.

X1500, nital etch.
MICROSTRUCTURE OF
HEAT NO. E 2317.

Figure 3.

X1500, nital etch.
MICROSTRUCTURE OF
HEAT NO. D 2524.

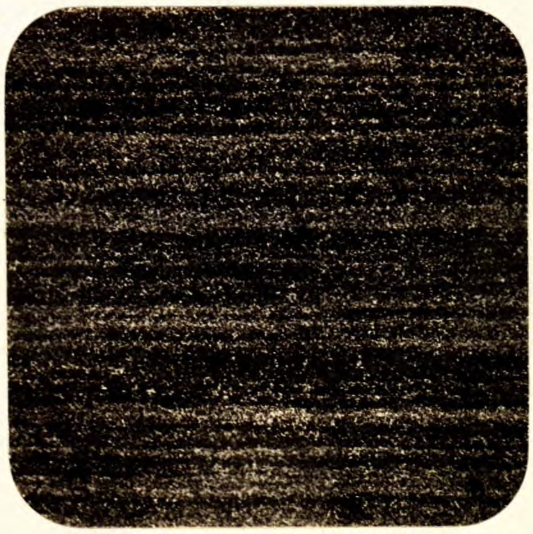
Figure 4.

X1500, nital etch.
MICROSTRUCTURE OF
HEAT NO. C 2956.

Figure 5.

X1500, nital etch.
MICROSTRUCTURE OF
HEAT NO. E 2326.

Figure 6.



X100, nital etch.
AN EXAMPLE OF INHOMOGENEITY
OBSERVED IN HEATS NOS. D 2956 AND E 2326.

AD:GHB.