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OTTAWA August 23rd, 1943.

# REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1481.

Investigation to Determine Cause of Defects Found in 20-mm, Hispano-Suiza and Oerlikon Shell Cases.

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(Copy No. 10)

Bureau of Mines
Division of Metallic
Minerals
-
Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA August 23rd, 1943.

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**Origin of Material and Object of Investigation:**

On August 5th, 1943, Mr. J. M. Gilmartin, Inspecting Officer (Materials), of the Inspection Board of the United Kingdom and Canada, Ottawa, Canada, sent in for examination eight cracked 20-mm. Hispano-Suiza shells; five cracked 20-mm. Oerlikon shells; and twelve bars of 27/32-in.-diameter steel, identified as follows:

Heat No. 81552-M -

Three pieces from end of three bars.
Three pieces from middle of three bars.

Heat No. 82494-M -

Three pieces from end of three bars.
Three pieces from middle of three bars.

A covering letter (File No. 12-4-3) from Mr. Gilmartin and an attached I.B.U.K. and C. Materials Division Requisition No. O.T. 4060 gave details of the material shipped and drew attention to the cracking of the shells

(Origin of Material and Object of Investigation, cont'd) -

submitted. The bar stock received was said to be typical of material from which these types of 20-mm. shells are machined but was not necessarily the same steel from which the cracked shells had been machined as the heat identity is lost in the machining operation. Mr. Gilmartin's letter stated that comparatively few cracked shells had been discovered prior to loading but a large number of shells had prematured at proof. An examination of the material submitted was requested in order to determine, if possible, the reason for the cracking and premature failures encountered.

Inspection Procedure:

Mr. Gilmartin's letter stated that the shell material had been subjected to chemical analysis, etch test at the bloom stage, tensile tests, visual examination, and some type of magnetic examination of material tested. The bars received were said to be of the composition given in Table I. Both the ladle analyses and the check analyses were supplied by the Inspection Board of the United Kingdom and Canada.

Table I.

| | | Heat No. 81552-M. | | Heat No. 82494-M | |
|---|---|---|---|---|---|
| | | Ladle analysis, per cent | Check analysis, per cent | Ladle analysis, per cent | Check analysis, per cent |
| Carbon | - | 0.33 | 0.36 | 0.35 | 0.37 |
| Manganese | - | 1.26 | 1.35 | 1.29 | 1.30 |
| Phosphorus | - | 0.032 | 0.038 | 0.030 | 0.030 |
| Sulphur | - | 0.146 | 0.160 | 0.143 | 0.143 |
| Silicon | - | 0.16 | 0.16 | 0.32 | 0.32 |

A memorandum from Wing Commander J. L. Burgess, for D.D.S.A.A., which Mr. Gilmartin enclosed stated that the same type of steel has been used throughout production and that the

(Inspection Procedure, cont'd) -

steel had always been within the Hispano specification.

Macroscopic Examination:

Figure 1 shows two of the shells. Note that one of these shells has a longitudinal split down its entire length. This type of defect is characteristic of all the shells but one. This exception is also shown in Figure 1. Note the shell with the longitudinal line of surface markings.

Sulphur prints were made on sections cut from shells showing the split, and these showed sulphur concentration at these splits.

Sections cut from the bars were hot-etched in 50 per cent HCl but no signs of defects were observed.

Some of the cracks were broken open and it was observed that the fractured surfaces were oxidized.

Chemical Analysis:

Samples from both the Hispano-Suiza and Oerlikon shells were prepared for chemical analysis. The results are submitted in Table II.

Table II. - Chemical Analysis of Shell Cases.

| | | Hispano-Suiza | Oerlikon |
|---|---|---|---|
| | | - Per cent - | |
| Carbon | - | 0.35 | 0.36 |
| Manganese | - | 1.12 | 1.09 |
| Phosphorus | - | 0.021 | 0.014 |
| Sulphur | - | 0.14 | 0.12 |
| Silicon | - | 0.19 | 0.19 |

Microscopic Examination:

Both transverse and longitudinal sections of the cracks were prepared for microscopic examination. A longitudinal section is shown in Figure 2 and a transverse section in Figure 3. A transverse section was also prepared from the shell showing the longitudinal markings (see Figure 1). This is shown in Figure 4.

Discussion:

The cracks shown in the specimen shells submitted are not fresh cracks. It is evident, from their oxidized condition, that they originated at some early stage in the fabrication of the bars.

There are two possible sources of these cracks:

1. Possibly the trouble may originate in the ingot stage. Gas holes just under the surface of the ingot or slivers on the surface of the ingot may be rolled out into seams. Such seams could open up to form cracks in machining and filling the shells.

2. Secondly, owing to its high sulphur content, this steel is hot short and the correct hot-rolling temperature is lower than that for unalloyed carbon steel. For this reason the reduction in area per pass in hot rolling is lower. This means that while this steel is being produced production will be retarded. If a higher temperature and more severe reductions are employed, cracks may develop that are very difficult to detect until the finished shell is produced.

Seams or cracks of the first type, originating from ingot conditions, are not characteristic of high-sulphur steels but may occur with equal frequency in any steel. However, when gas holes form in high-sulphur-steel

(Discussion, cont'd) -

ingots there is a sulphur segregation in the neighbourhood of the gas hole, so that it would be expected that rolling seams originating from this cause would be characterized by a sulphur segregation. Sulphur printing showed a sulphur segregation at these cracks.

Sulphides are found in the lap shown in Figure 4. Similar sulphides were found in some of the radial cracks, although Figure 2 does not show this. These cracks also appear to contain oxides.

While it is rather difficult to be certain about the origin of these cracks, it is likely that they originated from rolling seams caused by gas holes or slivers in the ingot. The danger of this occurring could be minimized by more thorough scarfing of the ingots.

There is a definite possibility that cracking of the shells could cause premature explosions. Certainly, if the pressure of loading were to set up stresses in the shell that would encourage the opening of cracks, possibly after loading, then the charge would become looser. Irregularities in loading practice, of course, might also favour premature detonations.

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CONCLUSION:

The defects in the specimen shells submitted apparently are seams that probably originate in blow-holes or slivers in the ingots. These defects might cause premature detonations.

Recommendations:

More careful inspection and scarfing of ingots might minimize the occurrence of these defects. Attention should also be paid to the careful control of rolling mill practice, in view of the tendency of this steel toward hot shortness.

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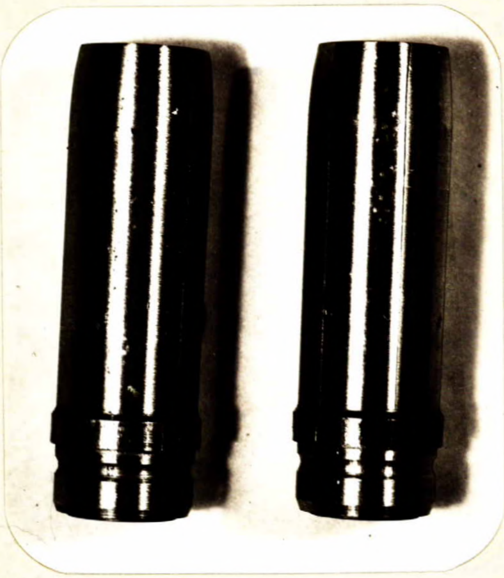
HVK:GHB.

Figure 1.



PHOTOGRAPH, ACTUAL SIZE, SHOWING
DEFECTIVE 20-MM. SHELLS.

Note crack in right-hand shell and
line of surface markings in left-hand shell.

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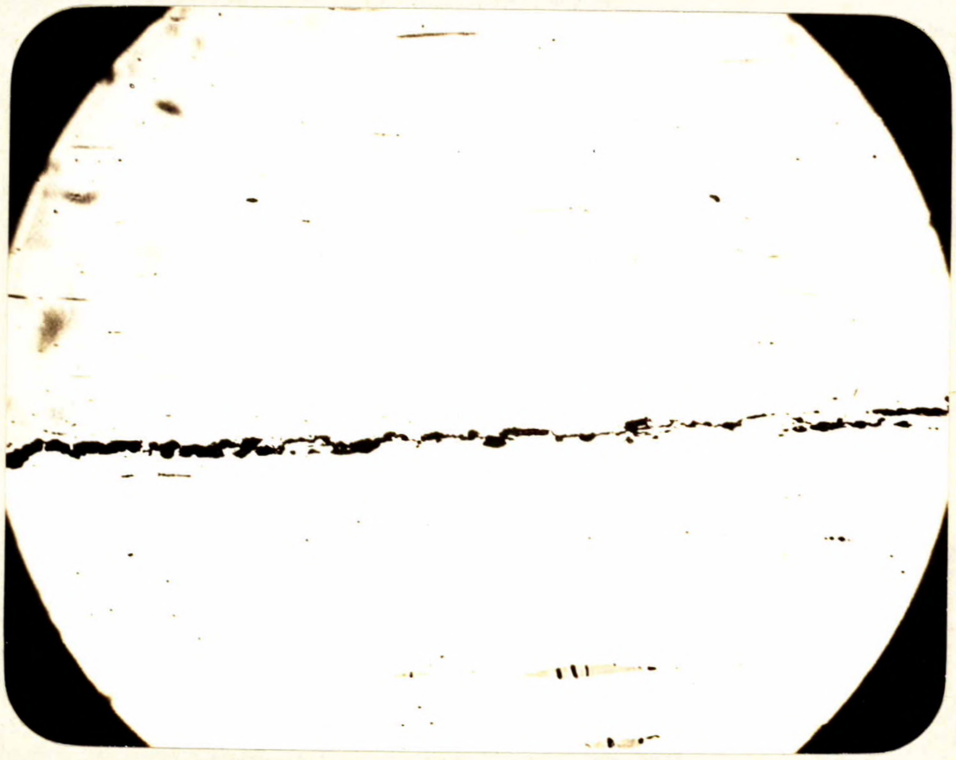
Figure 2.



PHOTOMICROGRAPH, X100, UNETCHED, SHOWING
A LONGITUDINAL SECTION OF CRACK.

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Figure 3.

PHOTOMICROGRAPH, X100, UNETCHED,
SHOWING A TRANSVERSE SECTION OF A CRACK.

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Figure 4.

PHOTOMICROGRAPH, X100, UNETCHED, SHOWING
CROSS-SECTION OF SURFACE OF SHELL ON
LEFT-HAND SIDE OF FIGURE 1 AT
LINE OF SURFACE CRACKS.

Note sulphides in crack.

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HVK:GHB.