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December 2nd, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1331.

Investigation to Identify Inclusions
in Fractured Transverse Tensile Test Pieces
from a Gun Barrel.

(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

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Source of Material and Object of Investigation:

On November 23rd, 1942, under Materials Division Analysis Requisition No. O.T. 3310, the Inspector General, Inspection Board of United Kingdom and Canada, 70 Lyon Street, Ottawa, Ontario, submitted for examination two broken tensile test bars which had been taken from a gun barrel in a transverse direction. The fracture of these bars showed minute shiny streaks all oriented in the direction of rolling. The analysis requisition requested

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

"a microscopic examination to determine the nature of the slag-like marking in the metal." It was assumed that the "slag-like" markings referred to were the tiny shiny elongated marks.

History of Pieces:*

The two fractured pieces of tensile test bars were marked A and B and were taken in a transverse direction from Barrel No. 0448, Heat No. 12918-2. Bar A had an elongation of 14.5 per cent; Bar B, of 12.5 per cent.

The steel was basic electric steel made in accordance with Specification S 44, Type KK. This calls for a yield of 39 to 52 tons per square inch, an elongation of 15 per cent, and an izod impact value of 20 ft.lb.

The approximate analysis given was as follows:

- Per cent -

<u>C</u>	<u>Si</u>	<u>Mn</u>	<u>S</u>	<u>P</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>V</u>
0.31	0.22	0.59	0.022	0.012	2.48	0.66	0.32	0.10

The ingot size was $16\frac{1}{2} \times 19\frac{1}{2} \times 46$ inches. The pouring temperature was 1570° C. The final heat treatment after forging was a double oil quench from 870° C. and 850° C., followed by tempering at 660° C.

* This information has been supplied from the records of the Materials Division, Inspection Board of United Kingdom and Canada.

Physical Tests:

A single notch, 0.45-inch-diameter ized impact bar was turned out of Bar A. This gave a value of 54 foot pounds.

Microscopic Examination:

A specimen for microscopic examination was prepared from Test Bar B. Upon examination before etching, two principal types of inclusions were observed. A very few normal elongated sulphide inclusions were found. One of these is shown in Figure 5 at 1000 diameters. At 100 diameters, the majority of them appeared to be a very dark grey (see Figure 1). Figure 1 also shows three small sulphide inclusions. One of the dark-grey elongated inclusions in Figure 1 was photographed at 1000 diameters and is shown in Figure 2. Compare this with Figure 5.

Wohrman's "Systematic Analysis," as given on Pages 126-127 of METALLOGRAPHIC HANDBOOK FOR ETCHING,^c was employed to identify these inclusions.

The first step is a 10-second etch in 10 per cent nital. The results on the two types of inclusions are shown in Figures 3 and 6. This is followed by an etch in 10 per cent chromic acid in water for 5 minutes and the results of this treatment are shown in Figures 4 and 7. Note that the inclusion shown in Figure 2 has not been affected, while that shown in Figure 5 has been strongly attacked. This means that the dark-grey elongated inclusions shown in Figure 1 and enlarged in Figure 2 are not sulphides.

(Continued on next page)

^c By Torkel Berglund, Lecturer in Metallography, Royal Technical College, Stockholm, Sweden. Translated from the Swedish by William H. Dearden, M.Sc., A.I.C., and published by Sir Isaac Pitman & Sons, Ltd., Kingsway W.C.2, London, England.

(Microscopic Examination, cont'd) -

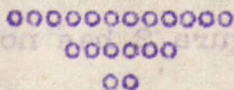
This etching was followed by etching for 5 minutes in boiling alkaline sodium picrate and then 10 minutes in a saturated alcoholic solution of stannous chloride. Neither of these reagents affected this type of inclusion. This eliminates the possibility that it is an oxide.

The next treatment was to etch for 10 minutes in 20 per cent hydrofluoric acid in water. Figure 8 shows the results at 100 diameters and Figure 9 at 1000 diameters.

This etchant has severely attacked these inclusions, identifying them as silicate inclusions.

CONCLUSIONS:

From these results it is apparent that the steel contains an appreciable number of silicate inclusions. These would be brittle and on fracture could easily break out leaving small shiny cavities.



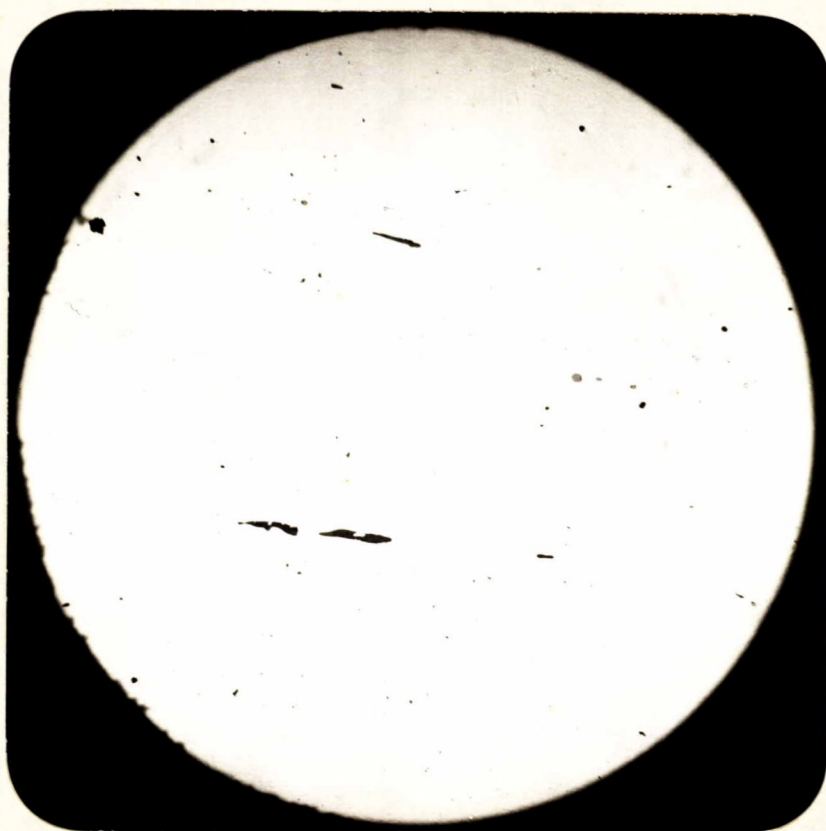
HVK:GHB.

(Continued on next page)

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Figure 1.



X100, unetched.

GENERAL VIEW OF INCLUSIONS.

Note appearance.

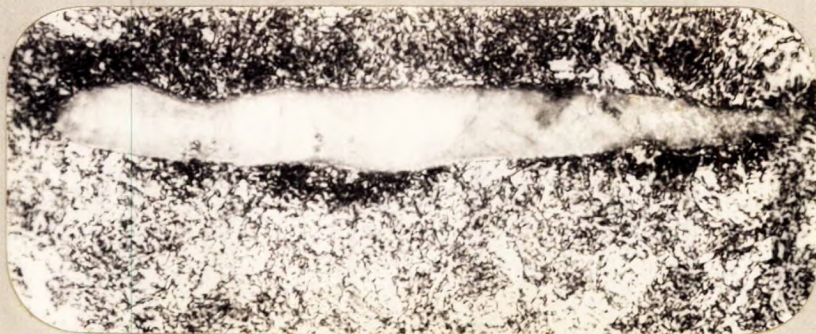
Figure 2.



X1000, unetched.

Same as one of the dark elongated inclusions in Figure 1.

Figure 3.



X1000, etched for 10 seconds
in 10 per cent nital.

Same type of inclusion as
shown in Figure 2.

Note absence of attack.

Figure 4.



X1000, etched in 10 per cent chromic
acid in water for 5 minutes.

Same type of inclusion as
shown in Figure 2.

Note absence of attack.

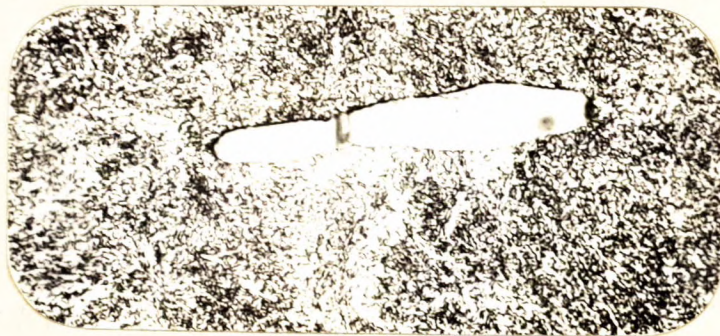
Figure 5.



X1000, unetched.

An elongated sulphide type inclusion.

Figure 6.

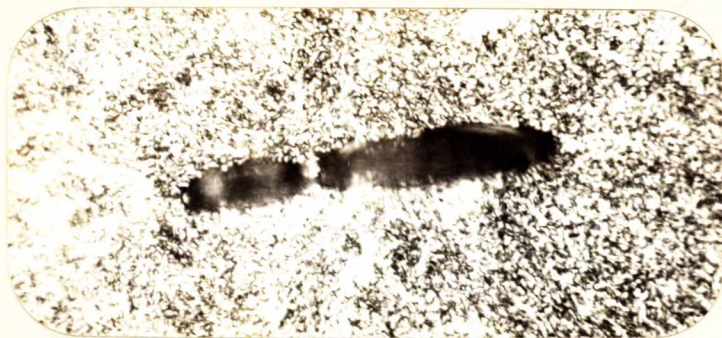


X1000, etched for 10 seconds
in 10 per cent nital.

Same as Figure 5.

Note absence of attack.

Figure 7.



X1000, etched in 10 per cent chromic
acid in water for 5 minutes.

Same inclusion as Figure 5.
This is a sulphide inclusion.

Note severe attack.

Figure 8.



X100, etched in 20 per cent
aqueous HF for 10 minutes.

These are silicates.

Note that most of the inclusions are attacked.

Figure 9.



X1000, etched in 20 per cent
aqueous HF for 10 minutes.

Same type of inclusion as shown
in Figure 2. This is a silicate.

Note attack.