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O T T A W A April 6th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1620.

Metallurgical Examination of Two Recoil Cylinders.

(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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Origin of Material and Object of Investigation:

On March 14th, 1944, two recoil cylinder forgings were received, for metallurgical examination, from the British Admiralty Technical Mission, Ottawa, Ontario.

In a covering letter (File No. 11-11-5-4) dated March 13th, 1944, Lieut.-Commander (E) G. Taylor, R.N.V.R., requested that the forgings be examined with particular regard to inclusions and also with regard to conformity with the chemical, physical and heat treating specifications. These forgings had been made by the Trenton Industries Limited, Trenton, N.S.

Mr. H. A. Beeson, Admiralty Inspector, Trenton Industries Limited, Trenton, N.S., in a letter dated March 10th, 1944, stated that the two forgings submitted to these Laboratories, Serial Nos. 266 and 271, were

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

rejected because of sand splits which were visible on the outside diameters and in the bores, also that the sand splits were more numerous in the bore of Forging No. 266 than in the bore of No. 271.

It was stated that the forgings had been heat treated as follows:

(1) Heated to 1550° F. and held for 12 hours;
(2) Cooled outside until $KClO_3$ reaction satisfactory;
(3) Heated to 1100° F. and held for 12 hours; and
(4) Cooled in air.
----- Stress-relieved by heating to 1100° F., held for 12 hours, and cooled in air.

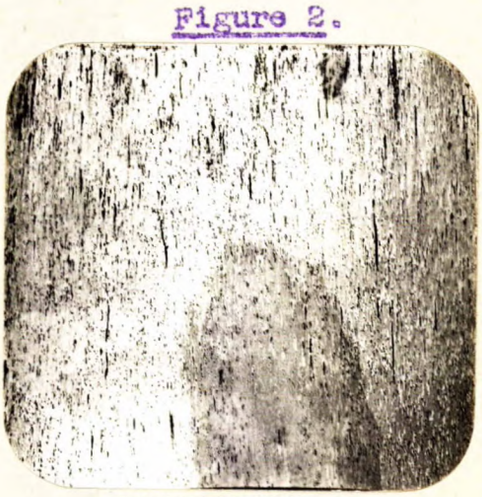
Macroscopic Examination:

The bore of Forging No. 271 had been machined to a smooth surface near the large end, and therefore this forging was taken for the metallurgical examination. The "sand splits" or inclusions were visible to the naked eye on both forgings but were especially noticeable on the machined surface of the bore of Forging No. 271. Figure 1 is a photograph of one of the cylinders in the "as received" condition. No inclusions are visible in the photograph. Figure 2 is a photograph of a deep-etched section of the cylinder. The inclusions are plainly visible in this section.

Figure 1.

RECOIL CYLINDER "AS RECEIVED".
(Approximately 1/10 size).

Figure 2.



PHOTOGRAPH OF
DEEP-ETCHED SECTION.
(Approximately ½ size).
Note "sand splits"
or inclusions.

Chemical Analysis:

The chemical analysis of the forgings, as determined at these Laboratories, is shown below. A chemical analysis made at Trenton is also shown, for comparison.

	Bureau of Mines	Trenton Steel Works
	- Per cent -	
Carbon -	0.32	0.32
Manganese -	0.74	0.81
Silicon -	0.31	0.30
Sulphur -	0.024	0.028
Phosphorus -	0.026	0.030
Nickel -	3.61	3.45
Chromium -	0.09	-
Molybdenum -	0.28	0.16

Physical Tests:

Examination of fractured surfaces (one longitudinal and one transverse surface) did not give any indication of flaking due to hydrogen. Fractures of the bars broken in the Charpy impact tests also showed no sign of hydrogen flakes.

Charpy impact tests were made using standard section, vee-notch bars of both single and double width. This method of impact testing was decided upon because it would more readily show any notch sensitivity of the steel. If the steel was notch-sensitive, approximately the same amount of energy would be required to break the double-width bars as to break the single-width bars. If the steel was not notch-sensitive, the double-width bars would require approximately twice the energy required to break the single-width bars.

The following results were obtained on the Charpy impact tests:

	LONGITUDINAL BARS		TRANSVERSE BARS	
	Single width	Double width	Single width	Double width
	- Foot-pounds -			
	30.0	66.0	11.0	24.5
	32.5	55.0	12.5	20.0
	34.0	70.5	13.5	33.5
Average -	32.2	63.8	12.3	26.0

(Continued on next page)

(Physical Tests, cont'd) -

Tensile tests were made on both longitudinal and transverse standard tensile test bars (0.564-inch diam., 2-inch gauge length). The results of the tensile tests are shown below, together with the results of the same tests performed, for inspection, at Trenton. The required specifications for the forgings are shown for comparison.

TENSILE TEST	Yield strength, p.s.i.	Maximum strength, p.s.i.	Per cent elongation, 2-inch gauge	Reduction in area, per cent
Specification	60,000	90,000 - 110,000	16	
Bureau of Mines				
Longitudinal bar	85,200	110,000	22.5	45.6
Transverse bar	82,800	104,000	8.5	12.0
B.A.T.M. Inspection				
Longitudinal bar	96,000	114,400	23.0	59.4
Transverse bar	96,000	114,400	17.0	34.2

Microscopic Examination:

A longitudinal sample showing a large inclusion was mounted in bakelite, hand polished, and examined under a microscope.

Two other samples were also mounted and polished. These samples were etched in 2 per cent nital for 30 seconds and examined under the microscope to check on the structure of the steel and hence note the results of the heat treatments.

The inclusion was examined under various lighting arrangements and appeared to be mostly iron sulphide. Figure 3, at a magnification of 20 diameters, shows this inclusion. A sulphur print (using 4 per cent H_2SO_4) from the mounted sample proved that the inclusion was a complex sulphide of iron with some manganese. Figure 4, at a magnification of 20 diameters, shows the inclusion after a sulphur print was taken. A comparison of this figure with Figure 3 shows that the acid

(Microscopic Examination, cont'd) -

strongly attacked the inclusion.

Microscopic examination of the etched surfaces showed that the heat treatment was satisfactory (see Figure 5).

Discussion of Results:

The chemical analysis of the cylinder forging agrees with that made at Trenton.

There were no signs of hydrogen flakes in any of the fractured or broken surfaces examined.

The results of the Charpy impact tests were quite satisfactory. The double-width bars required approximately twice the energy needed to break the single-width bars, showing that the inclusions did not make the steel notch-sensitive.

The tensile tests results agree with the specifications in all but the per cent elongation of the transverse test bar. This result is very low, probably due to the large inclusions. The test results are in agreement with the results obtained at Trenton. There was very little elongation or reduction in area in the transverse bar but this is explained by the very large and numerous inclusions in the steel. All of the inclusions noted in the two cylinders submitted ran in a longitudinal direction, that is, lengthwise on the cylinder.

The heat treatment given the forgings was satisfactory, resulting in a normal structure.

CONCLUSIONS:

The cylinder forgings, aside from the inclusions, are satisfactory.

Inclusions occurred throughout the cylinder; they are not merely surface defects.

The sulphide inclusions found in both forgings are

(Conclusions, cont'd) -

objectionable. However, they are not considered to be sufficient cause to reject these cylinders.

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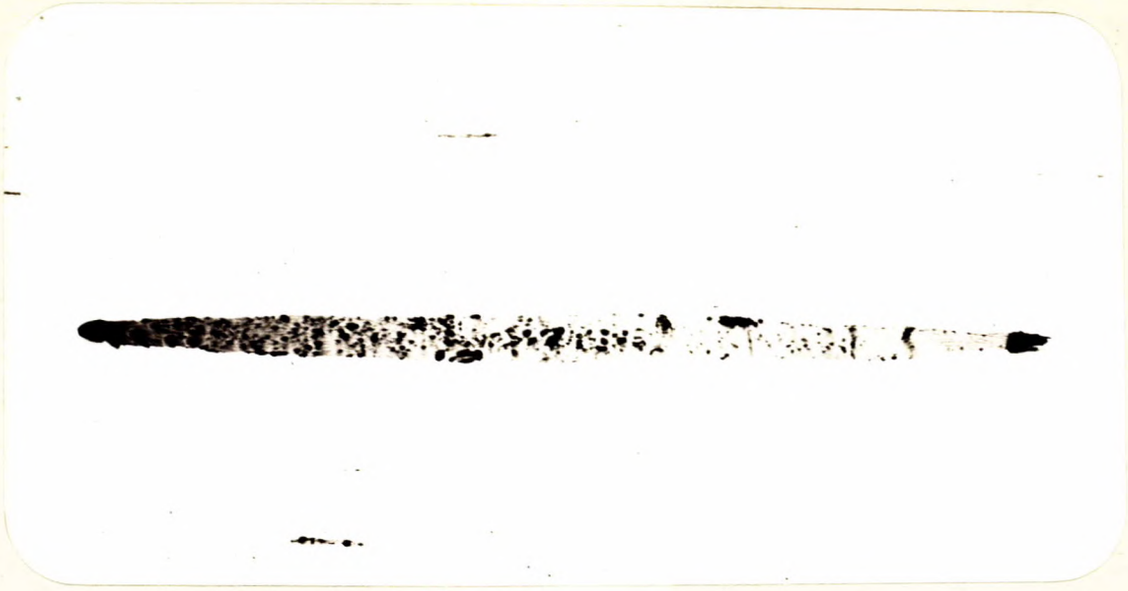
ELC:GHB.

Figure 3.



X20.

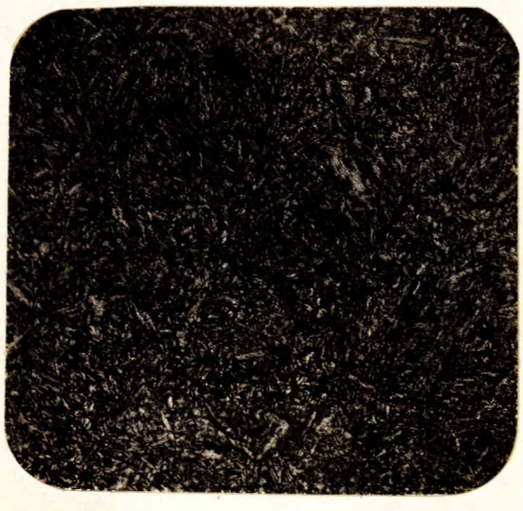
SULPHIDE INCLUSION BEFORE TAKING SULPHUR PRINT.

Figure 4.

X20.

SULPHIDE INCLUSION AFTER TAKING SULPHUR PRINT.

Figure 5.



X100, nital etch.

SHOWS NORMAL STRUCTURE AFTER HEAT TREATING.

ELC:GHB.