File

FILE COPY

O T T A W A June 13th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1663.

Examination of a Fractured Steel Control Rod for a 4" Mk. XIX Gun Twin Mounting.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

O T T A W A June 13th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1663.

Examination of a Fractured Steel Control Rod for a 4" Mk. XIX Gun Twin Mounting.

==========

Source of Material and Object of Investigation:

On May 9th, 1944, Lt.-Cdr. (E) G. Taylor, R.N.V.R., British Admiralty Technical Mission, 58 Lyon Street, Ottawa, Ontario, submitted a fractured, roughly machined control rod for a 4" Mk. XIX Gun twin mounting manufactured by Trenton Steel Works Limited, Trenton, N.S. The accompanying request letter (May 9th, File No. 11-11-5-1) asked that the composition and mechanical properties be checked and also that any recommendations for change in heat treatment be included in the report.

In a conversation with Lt.-Cdr. Taylor, it was stated that a flaw was observed in the rod during the machining operation. The forging had therefore been removed from the lathe and, after placing on a bench, broken with a hammer.

N.B.B
12cc
1663

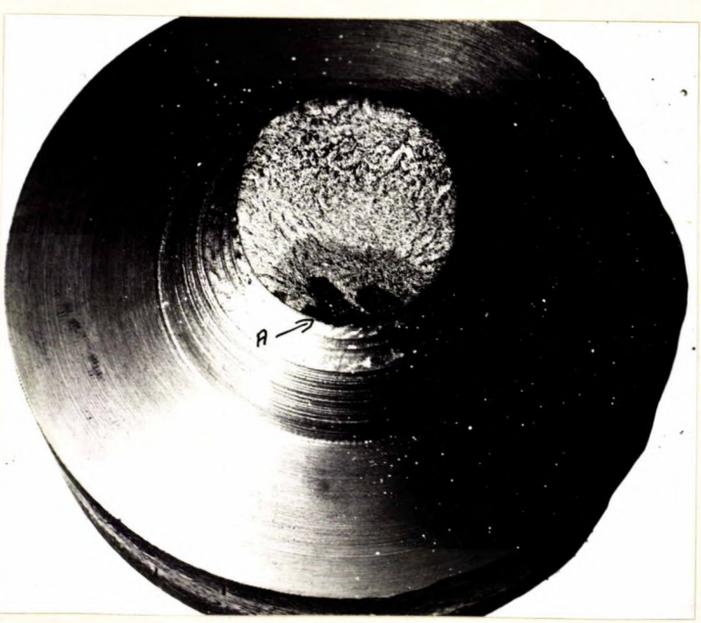
X-Ray Examination:

The work of X-raying the forging was referred to the National Research Council. No cavities or defects were observed in the radiographs obtained.

Macro-Examination:

Figures 1 and 2 show the ends of the fracture of the semi-machined steel forging in the "as received" condition. It is thought that no significance should be attached to the dark areas at "A" as they are probably oil stains.

Figure 1. Figure 2.



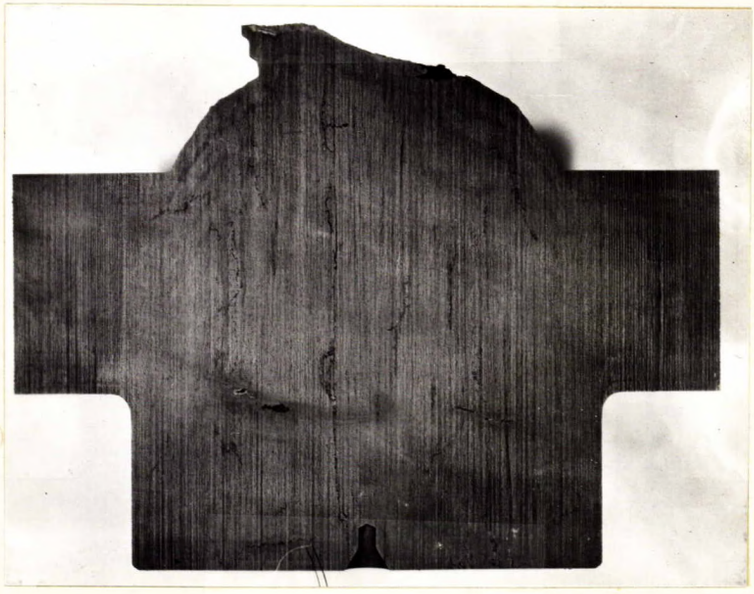
(Approximately $\frac{1}{2}$ size). (Approximately $\frac{1}{2}$ size).

Figure 3 shows the cross-section of the heavy end of the forging shown in Figure 1. A number of cracks and cavities were observed in the metal. The other half of this section and a cross-section of a portion of the rod adjacent to the fracture were polished on a surface grinder and then macro-etched for 45 minutes in a solution of 50 per cent hydrochloric acid in water

(Macro-Examination, cont'd) -

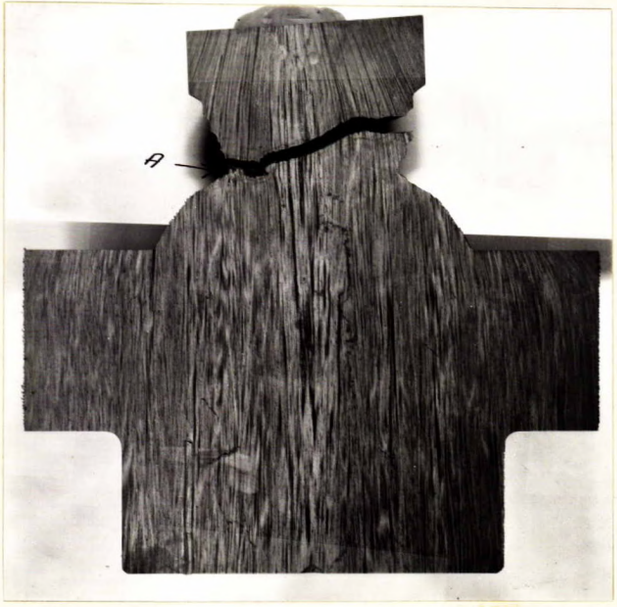
heated to 160 to 175° F. The flow lines of the two macro-etched cross-sections are illustrated in Figure 4.

Figure 3.



(Approximately $\frac{1}{2}$ size).

Figure 4.



(Approximately 2/5 actual size).

(Macro-Examination, cont'd) -

A cross-section of the forging was fractured and examined for hydrogen flakes. Some flakes were observed in the steel at the locations marked A and B in Figure 5. Cracks and porous metal were also noted. These are shown in Figure 6.

Figure 5.

(Approximately to size).

-

Figure 6.

(Approximately to size).

-

Chemical Analysis:

The results of chemical analysis made of the forging by these Laboratories, together with the composition reported by Trenton Steel Works Limited, are given in the following table:

TABLE I.

	Trenton Steel Works	Bureau of Mines
	- Per Cent -	
Carbon -	0.37	0.39
Manganese -	1.02	1.03
Silicon -	0.252	0.300
Phosphorus -	0.029	0.030
Sulphur -	0.016	0.020
Nickel -	3.42	3.37
Molybdenum -	0.22	0.20
Chromium -	-	0.17

-

Mechanical Properties:

The mechanical properties of the steel as reported by Trenton, together with the results of tests on the material in "as received" condition and after quenching in oil from 1500° F. and tempering at 1100° F. for 12 hours, are tabulated in Table II. The section of the heat-treated bars was 3 inches in diameter.

TABLE II.

	Ultimate stress, p.s.i.	Yield stress, p.s.i.	Elongation, per cent in 2 inches	Reduction in area, per cent	Brinell	Izod impact, ft-lb.
Trenton	124,400	106,000	21.0	55.2	-	27,27,30
"	124,800	106,000	23.0	56.8	-	33,33,40
B. of M.*	125,750	102,500	21.0	54.5	269	18,17,19
" **	130,400	98,800	23.0	54.8	269	64,62,62
" ***	131,250	97,000	21.0	53.5	269	56,62,59
Required properties	112,000	67,200	17.0	-	-	20.0

* "As received".

** Quenched in oil from the draw.

*** Air-cooled from the draw.

Note: After a 24-hour draw at 1100° F. an Izod value of 64 foot-pounds was obtained (air-cooled from draw temperature).

Dilatometric Tests:

The change points of the steel were determined with an electronic dilatometer. The dimensions of the specimen used were: $2\frac{1}{2}$ in. long x 1 in. wide x 0.04 in. thick, with a $\frac{1}{4}$-inch hole drilled in each end. The Ac_3, on slow heating, was found to be 1370° F. and the Ac_1, 1275° F.

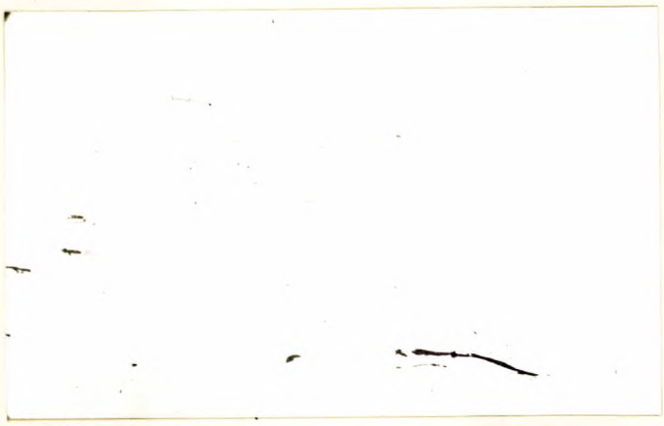
Microscopic Examination:

A specimen of the steel adjacent to the flaw in the fracture was cut from the forging, polished, and examined under the microscope in the unetched condition. The steel was found to be fairly clean and no inclusions were observed at the edge of the fracture. Some sulphide and silicate inclusions, however, were seen in the steel, and these are illustrated in Figure 7, a

(Microscopic Examination, cont'd) -

photomicrograph at X100 magnification.

Figure 7.



X100, unetched.

—

Figures 8 and 9 show the nital-etched structure of the "as received" steel at X100 and X1000 magnifications respectively. The structure consists of ferrite, the iron content (the light etching material), and fine pearlite, the iron-iron carbide constituent (the dark etching material). The structure is typical of a normalized-and-drawn steel of this composition. There appears to be a fairly coarse distribution of carbides.

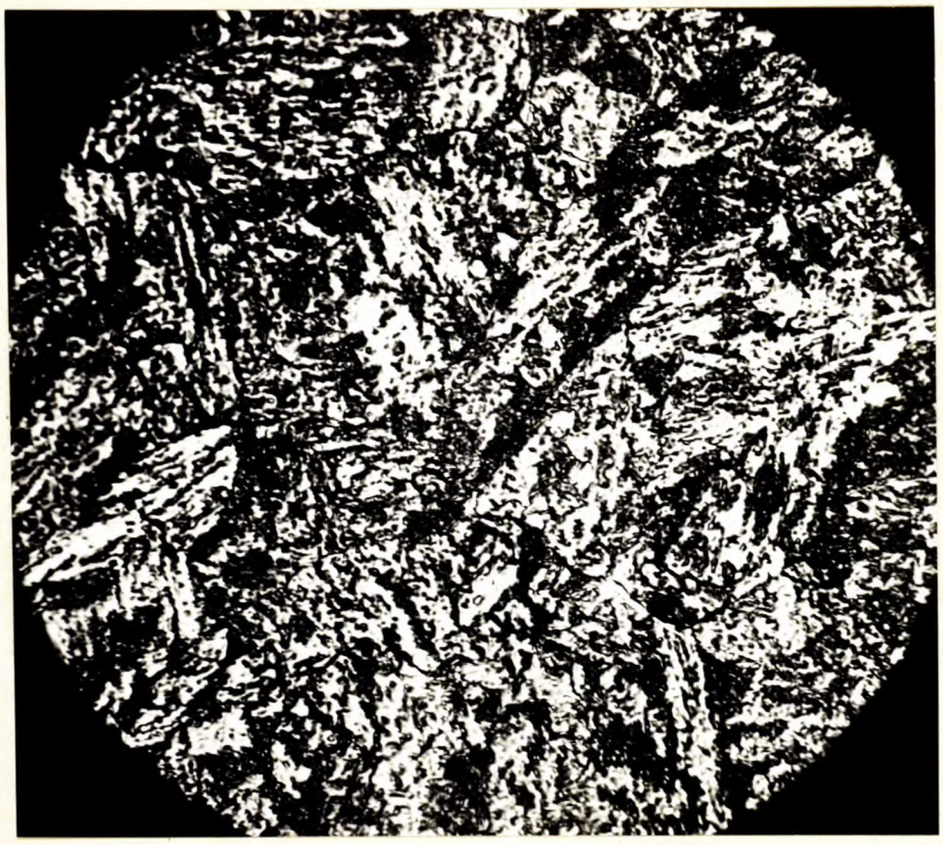
Figure 8.

X100, etched in 2 per cent nital.

STRUCTURE OF STEEL "AS RECEIVED".

—

Figure 9.

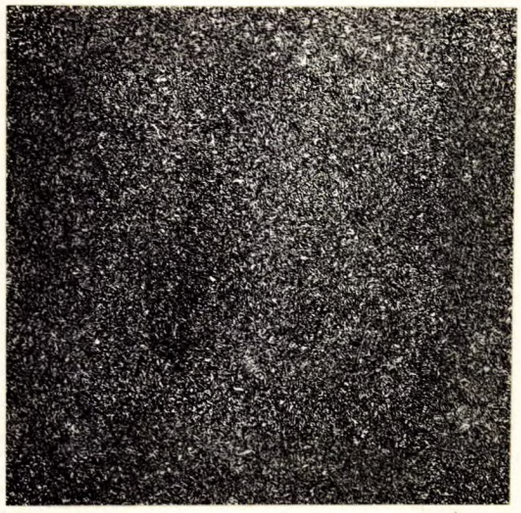


X1000, etched in 2 per cent nital.
STRUCTURE OF STEEL "AS RECEIVED".

—

The structure of the steel after being heat-treated in these Laboratories is shown in Figures 10 and 11. The structure consists of tempered martensite and is much finer than the "as received" structure.

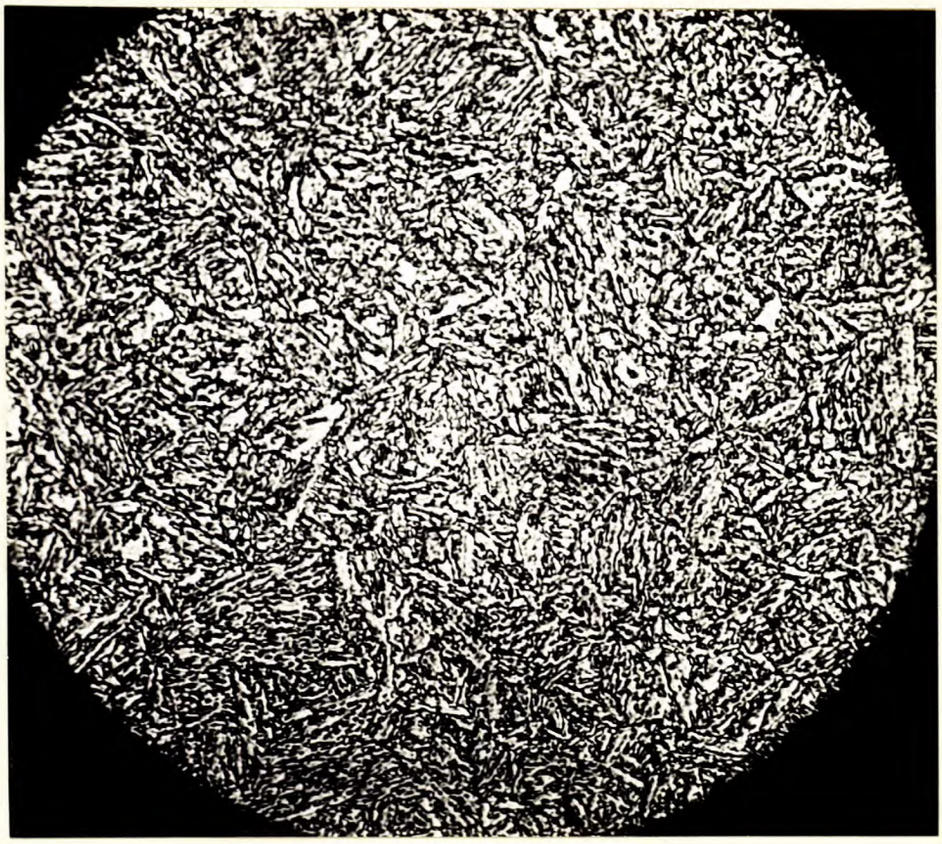
Figure 10.



X100, etched in 2 per cent nital.
STRUCTURE AFTER OIL QUENCH AT 1500° F.
AND DRAW FOR 12 HOURS AT 1100° F.

—

Figure 11.



X1000, etched in 2 per cent nital.
STRUCTURE AFTER OIL QUENCH AT 1500° F.
AND DRAW FOR 12 HOURS AT 1100° F.

—

The grain size of the steel was determined by the McQuaid-Ehn method and was found to be 6 (see Figure 12).

Figure 12.

X100, etched in 2 per cent nital.

CARBURIZED AT 1700° F.
AND SLOWLY COOLED.
Grain size, 6.

—

Discussion of Results:

The results of chemical analysis and mechanical tests agreed with the values reported by the Trenton Steel Works inspection department, with the exception of the Izod impact strengths which were found to be approximately 50 per cent lower. No defects were noted in the forging radiographs. However, after sectioning the thick portion of the forging a number of cavities and cracks were observed. Fractures taken in the unsound section of the forging showed slight evidence of hydrogen flakes and definite evidence of lack of soundness. Steel in this condition would fail more readily under impact stresses. Partial failure probably occurred prior to final failure, due to the unsoundness of the metal and the presence of hydrogen flakes, the former defect being considered the more serious. A microscopic examination showed that the flow lines of the forging were satisfactory. The microscopic examination revealed that apart from a few quite large silicate inclusions the steel did not contain an unusual number of non-metallic inclusions. The small inclusions present were chiefly sulphides and, in the amounts present, are not considered to be harmful. The fairly coarse carbide distribution produced by a normalizing-and-draw heat treatment would account for the relatively low impact values obtained on the steel in the "as received" condition. It was demonstrated that good mechanical properties could be obtained by a quench-and-draw heat treatment and that a long time draw was required if satisfactory properties were to be obtained.

Conclusions and Recommendations:

1. The failure of the forging was due to unsound metal and, possibly, the presence of a few hydrogen flakes.

2. The low impact values obtained from the "as received" material (as compared with the values of the quenched-and-drawn steel) are to be expected in view of the slower cooling rate in normalizing. To obtain optimum properties the following heat treatment is recommended:

Harden in oil from 1500° F.;
Time, 1 hour per inch.

Temper at 1100° F.;
Time, 4 hours per inch.

Cool in air from the draw.

3. The steel is not subject to temper brittleness.

oooooooooooo
oooooo
oo

NBB:GHB.