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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1608.

Examination of Three 21-Inch-Torpedo Connecting Rods.

(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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Description of Material and Object of Investigation:

On February 26th, 1944, Mr. G. E. S. Hornby, Chief Chemist, British Admiralty Technical Mission, Ottawa, Ontario, personally submitted for examination three samples of connecting rods for the 21-inch torpedo. Figure 1 is a general view of one of these connecting rods partly machined. Figure 2 shows a completely machined connecting rod. These two photographs are about $\frac{1}{3}$ actual size.

The main part of this connecting rod is a steel forging. Bronze is burnt onto either end. The gate through which the bronze is poured may be seen in Figure 1. Figure 2 and Figure 5 show how much of the bronze is retained in the finished connecting rod.

To burn-on the bronze, the forging is placed in a core sand mould. Bronze is poured on the concave end first, at a temperature of 2300° F. After this has solidified, the mould is rotated through 90° and bronze is poured on the end at a temperature of 2250° F.

Recently a number of these connecting rods developed cracks in the steel just under the bronze. The cracks occurred

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

while the bronze was being burnt on and were filled with bronze. An example of these cracks is shown in Figure 3 and also in Figure 4. The sample shown in Figure 3 was obtained by cutting off the bronze just down to the bronze-steel interface. This was the third sample supplied by the British Admiralty Technical Mission.

The occurrence of this cracking seemed to coincide with the use of a lot of steel forgings from a different source. The object of this investigation was to determine whether or not the change in steel was responsible for cracking.

For identification purposes, the unfinished connecting rod (Figure 1) showing the cracks in the end was designated as Sample No. 1; the completed connecting rod that showed no cracks at all (Figure 2), Sample No. 2; and the section of connecting rod that was badly cracked (Figure 3), Sample No. 3. Samples Nos. 1 and 3 are considered to be characteristic of the cracked connecting rods, and Sample No. 2 characteristic of the sound ones.

Chemical Analysis:

The results of the chemical analysis of these three samples are given in Table I.

TABLE I. - CHEMICAL ANALYSIS.

	Sample No. 1	Sample No. 2	Sample No. 3
	- Per cent -		
Carbon -	0.47	0.50	0.50
Silicon -	0.24	0.21	0.23
Manganese -	0.62	0.67	0.67
Sulphur -	0.029	0.030	0.034
Phosphorus -	0.008	0.014	0.014
Nickel -	0.44	0.04	0.03
Chromium -	0.15	Nil.	Nil.
Molybdenum -	0.05	Trace.	Trace.
Vanadium -	Nil.	Nil.	Nil.
Aluminium -	Trace.	Trace.	Trace.

Microscopic Examination:

Sections were obtained from all three samples, for microscopic examination. Photomicrographs of the structures adjacent to the bronze-steel interface and of the original structure of the steel are presented at a magnification of 500 diameters. The specimens were etched in 2 per cent nital. Figure 6 shows the structure at the bronze-steel interface of Sample No. 1; Figure 7, the original structure of this sample; Figure 8, the structure at the bronze-steel interface of Sample No. 2; Figure 9, the original structure of this sample; Figure 10, the structure at the bronze-steel interface of Sample No. 3; and Figure 11, the original structure of this sample.

It is interesting to note that Figures 7, 9 and 11 show approximately the same grain size as do Figures 6 and 8, while the grain size shown in Figure 10 is much finer.

The McQuaid-Ehn grain size of the steel in Samples Nos. 1, 2 and 3 was determined at 1700° F. The results of this test are shown in Figures 12 (Sample No. 1), 13 (Sample No. 2), and 14 (Sample No. 3), and are tabulated below:

	McQuaid-Ehn grain size at 1700° F.
Sample No. 1	- 6 to 7
" No. 2	- 4 to 5
" No. 3	- 4 to 5

Discussion of Results:

An examination of the results obtained from chemical analysis and the McQuaid-Ehn test shows conclusively that the steel in Samples No. 2 and 3 is identical both in chemical analysis and in grain-coarsening characteristics, while the steel in Sample No. 1 contains some residual alloying elements and is inherently a finer-grained material. Since there are

(Discussion of Results, cont'd) -

only two sources of the steel used in these forgings, it is reasonable to conclude that the steel in Samples Nos. 2 and 3 came from one supplier and the steel in Sample No. 1 from the other.

In view of the fact that Samples Nos. 1 and 3 are both characteristic of cracked connecting rods and of the two sources of steel used, it is very improbable that the cracking encountered is identified with either type of steel. It is more likely that it is due to some variations in the practice of burning-on the bronze. This view is substantiated to some extent by Figures 6, 8 and 10. The structure in Sample No. 3 adjacent to the bronze-steel interface (see Figure 10) is much finer than the structures in either Sample No. 1 or Sample No. 2 (see Figures 6 and 8). Sample No. 3 cracked badly, Sample No. 1 cracked slightly, and Sample No. 2 did not crack at all. These changes in structure indicate a difference in the thermal history of Sample No. 3 from that of Samples No. 1 and 2. The steel at the bronze-steel interface in Sample No. 3 either did not get as hot as the steel in Samples Nos. 1 and 2 at the same location or was at that temperature for a very short length of time.

CONCLUSIONS:

1. The steel in Sample No. 1 is from one source of supply and that in Samples Nos. 2 and 3 is from another source.

2. The development of cracks during the burning-on of the bronze is not identified with either source of steel.

3. There is evidence that there are some irregularities in the practice of burning the bronze onto the steel.

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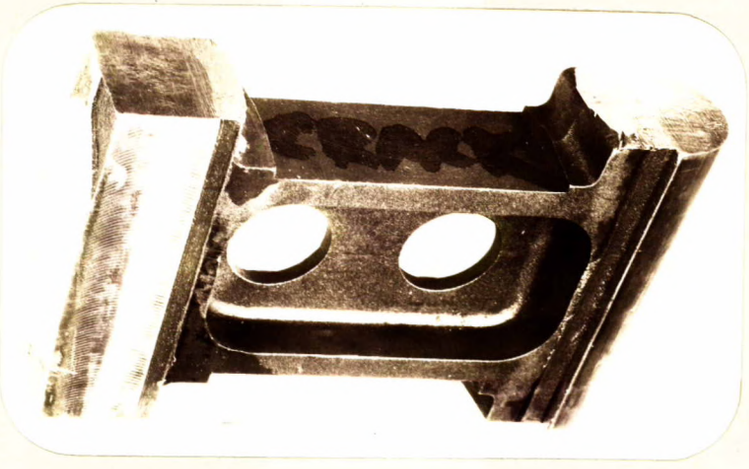
HVK:GHB.

Figure 1.



GENERAL VIEW OF SEMI-FINISHED
CONNECTING ROD. SAMPLE NO. 1.

The bottom end has been rough-machined.
Note location of pouring gate.
(Photograph, about ½ actual size).

Figure 2.

GENERAL VIEW OF A FINISHED
CONNECTING ROD.
THIS IS SAMPLE NO. 2.
(About ½ actual size).

Figure 3.

PHOTOGRAPH OF SAMPLE NO. 3, SHOWING NETWORK OF BRONZE-FILLED CRACKS AT STEEL-BRONZE INTERFACE.

(About $\frac{3}{4}$ actual size).

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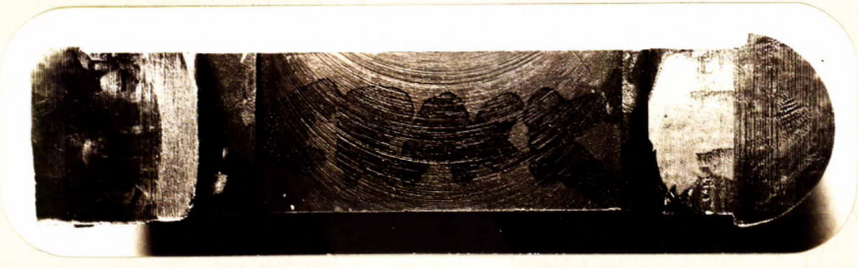
Figure 4.



SIDE VIEW OF CONNECTING ROD IN FIGURE 1, SHOWING LOCATION OF BRONZE-STEEL INTERFACE AND CRACKS.

(About $\frac{3}{4}$ actual size).

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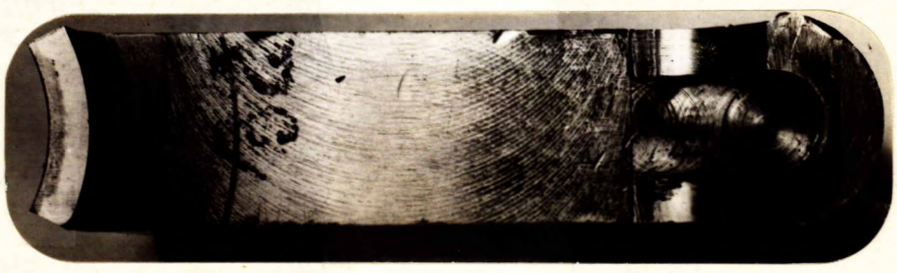
Figure 5.



SIDE VIEW OF CONNECTING ROD IN FIGURE 2, SHOWING AMOUNT OF BRONZE LEFT ON FINISHED CONNECTING ROD.

(About $\frac{3}{4}$ actual size).

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Figure 6.

X500, nital etch.
SAMPLE NO. 1, STRUCTURE AT BRONZE-STEEL INTERFACE.

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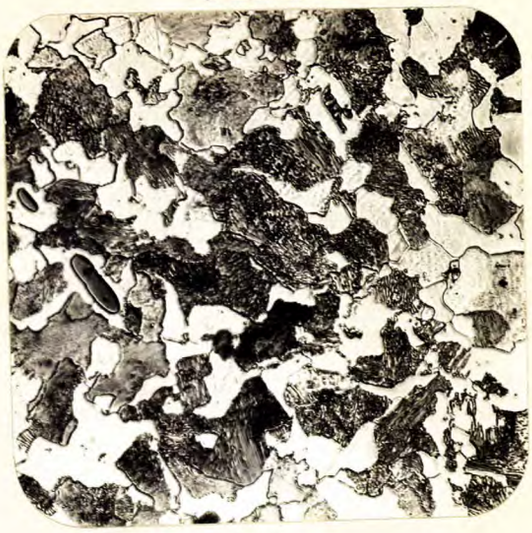
Figure 7.



X500, nital etch.
SAMPLE NO. 1, ORIGINAL STRUCTURE.

—

Figure 8.

X500, nital etch.
SAMPLE NO. 2, STRUCTURE AT BRONZE-STEEL INTERFACE.

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Figure 9.

X500, nital etch.
SAMPLE NO. 2, ORIGINAL STRUCTURE.

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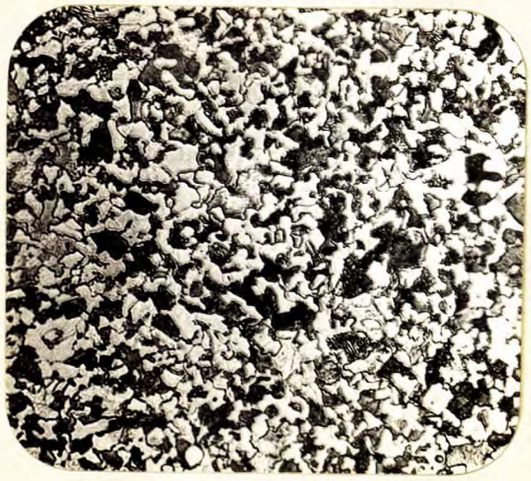
Figure 10.



X500, nital etch.
SAMPLE NO. 3, STRUCTURE AT BRONZE-STEEL INTERFACE.

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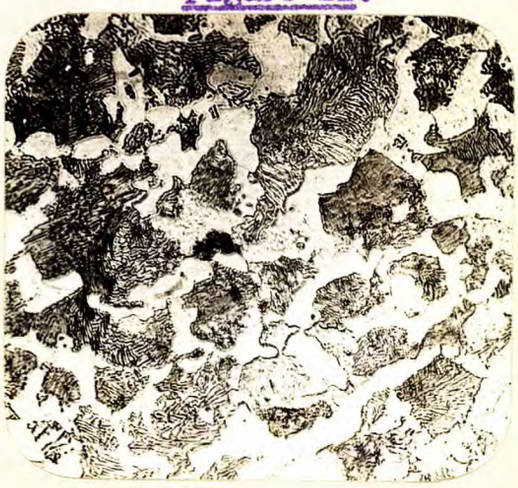
Figure 11.



X500, nital etch.
SAMPLE NO. 3, ORIGINAL STRUCTURE.

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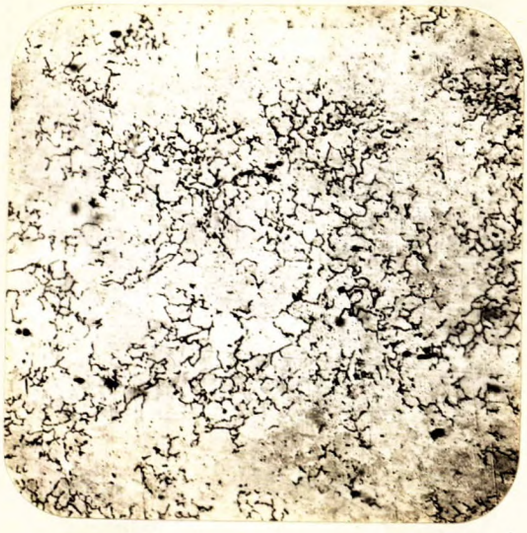
Figure 12.



X100, nital etch.

SAMPLE NO. 1,
MCQUAID-EHN GRAIN SIZE, 6-7.

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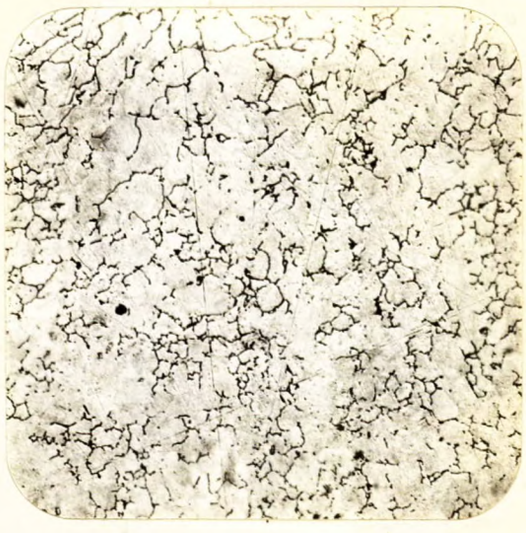
Figure 13.



X100, nital etch.

SAMPLE NO. 2,
MCQUAID-EHN GRAIN SIZE, 4-5.

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Figure 14.

X100, nital etch.

SAMPLE NO. 3,
MCQUAID-EHN GRAIN SIZE, 4-5.

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HVK:GHB.