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OTTAWA July 10th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1676.

Examination of Defective Bronze Spigots and Steel Studs from H.M.C.S. Amherst.

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(Copy No. 10.)

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

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

O T T A W A July 10th, 1944.

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Source of Material and Object of Investigation:

On June 15th, 1944, two bronze spigots and eight steel studs were received for metallurgical examination, from the Department of National Defence, Naval Service, Ottawa, Ontario.

In a covering requisition, No. 13, File No. 8360-331/4, Vol. 1 (Staff), dated June 16th, 1944, Cdr. J. R. Millard, Director of Technical Research, requested that the spigots be analysed and then be examined under the microscope for inclusions and grain size. In addition, it was requested that the steel studs be subjected to chemical analysis and a full range of mechanical tests.

Part I of this report deals with the examination of the bronze spigots and Part II with the steel studs.

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PART I. - SPIGOTS.

Macro-Examination:

Figures 1 and 2, below, show the fractures of the No. 1 Boiler safety valve spigot and scum valve spigot.

Both castings appeared to be free from surface imperfections. However, it will be noted, in Figure 2, that the wall thickness of the scum valve spigot is greater on one side than on the other. Both fractures were coarse grained. The fractures were covered with an oxide film which made it impossible to tell the condition at the time of failure.

Figure 1.

NO. 1 BOILER SAFETY VALVE SPIGOT.

(Approximately to size).

Figure 2.

NO. 1 BOILER SCUM VALVE SPIGOT.

(Approximately 1/2 size).

Chemical Analysis:

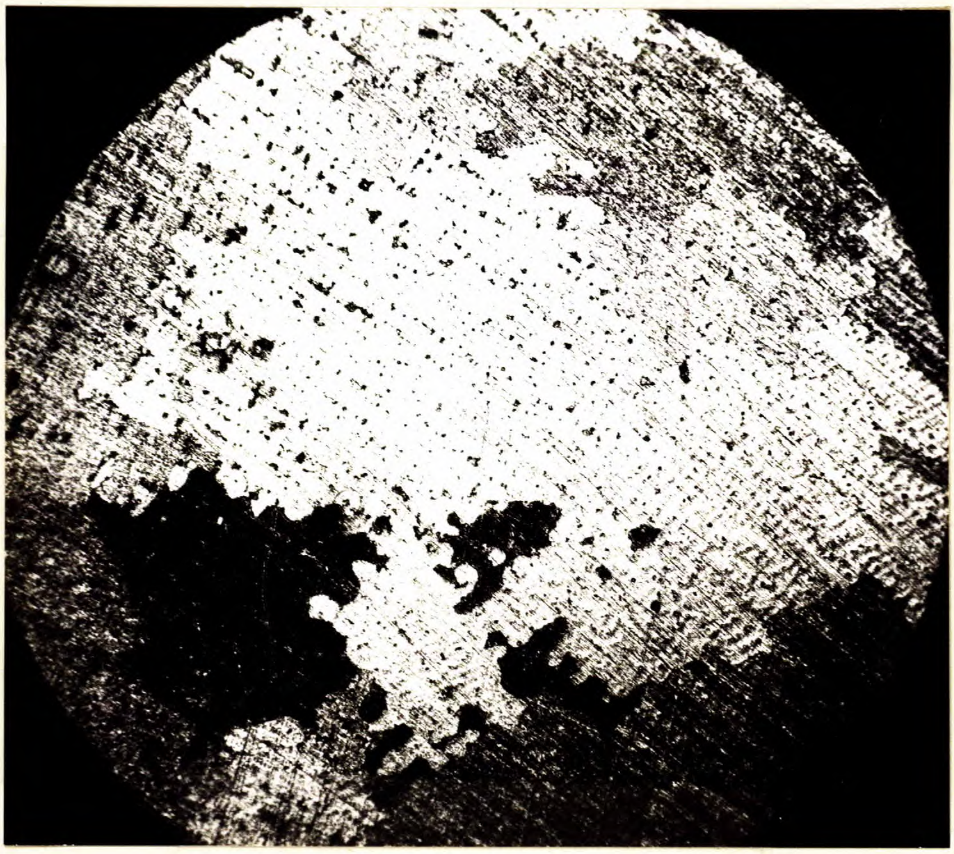
	No. 1 Boiler Safety Valve Spigot	Typical Admiralty Gunmetal	No. 1 Boiler Scum Valve Spigot	Typical Nickel-Bronze
	- Per Cent -			
Copper -	87.63	Remainder.	87.72	88.0
Tin -	9.37	9.75-10.25	4.69	5.0
Nickel -	0.10	-	4.71	5.0
Zinc -	1.71	2.00 max.	1.58	2.0
Lead -	1.12	0.50 max.	0.35	-
Iron -	0.03	-	0.66	-
Phosphorus -	0.002	-	0.027	-
Manganese -	Nil.	-	Nil.	-

Microscopic Examination:

Specimens from the No. 1 Boiler safety valve spigot were mounted in bakelite, polished, etched in a solution of ferric chloride,* and examined under the microscope.

Both specimens had a coarse-grained structure characteristic of cast bronze. Although slight porosity was observed in it, the No. 1 Boiler safety valve spigot was, on the whole, composed of fairly sound metal. The scum valve spigot, however, was quite porous. The respective structures of these materials are illustrated in Figures 3 and 4.

Figure 3.



X30, etched in
$FeCl_3$-HCl-H_2O solution.

SHOWING A POROUS SECTION AND COARSE-GRAINED STRUCTURE OF NO. 1 BOILER SAFETY VALVE SPIGOT.

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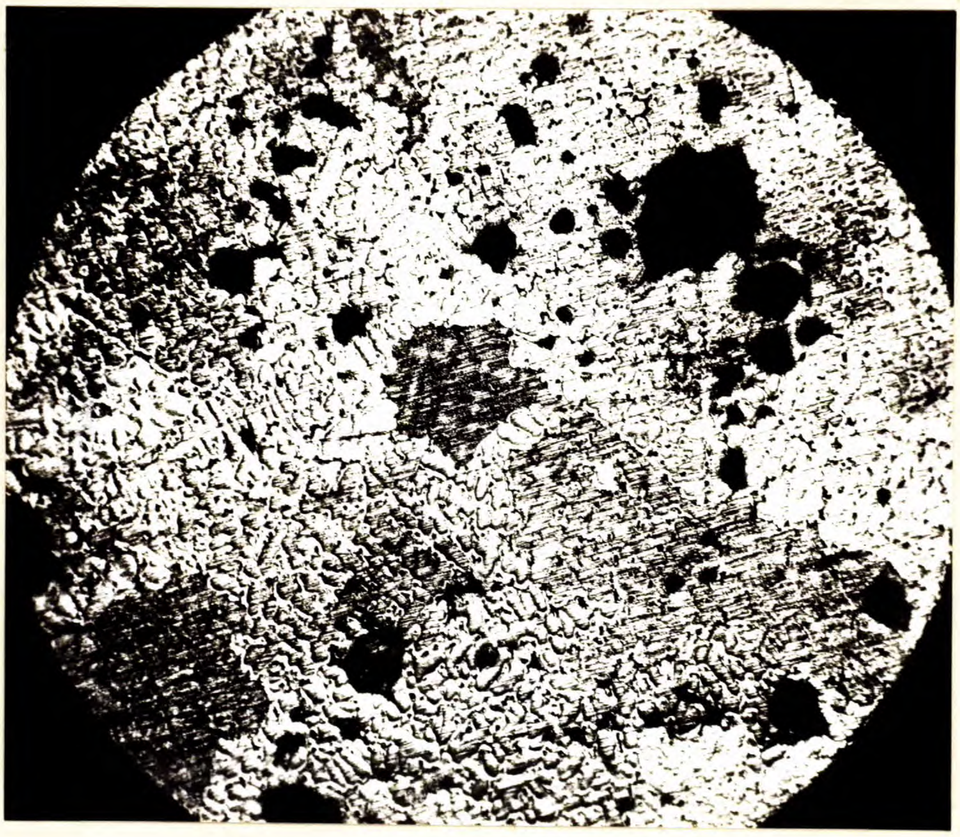
* Etching solution: 5 grams $FeCl_3$, 10 cc. HCl, and 100 cc. H_2O.

(Microscopic Examination, cont'd) -

Figure 4.



X50, etched in
$FeCl_3$-HCl-H_2O solution.

SHOWING POROUS SECTION AND COARSE-GRAINED DENDRITIC STRUCTURE OF SCUM VALVE SPIGOT.

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Discussion of Results:

The No. 1 Boiler safety valve spigot was found to have a composition similar to that of Admiralty gunmetal, except for the lead content, which was above the limit specified for high-pressure systems, e.g. for working pressures above 1,000 pounds. The high amount of lead would lower the hardness and strength of the casting. The addition of lead, however, will improve the machinability of the casting but additions in excess of the specified maximum, namely 0.5 per cent, do not give proportional improvement in machinability. The composition of the No. 1 Boiler scum valve spigot was similar to that of a nickel bronze (88 per cent Cu, 5 per cent Sn, 5 per cent Ni, 2 per cent Zn). The presence of lead in a nickel-bronze

(Discussion of Results, cont'd) -

casting also lowers the strength and elastic properties but the 0.35 per cent is not considered to be serious, as good properties can be obtained with additions up to 1.0 per cent lead. If, however, the castings are to be heat-treated, lead should be absent as a very small amount (0.05 to 0.10 per cent of lead) retards or completely inhibits response to age hardening.

The irregular wall thickness and the unsoundness of the metal in the scum valve spigot casting are due to serious moulding defects and might account for the failure of this casting. The slight porosity and the high lead content observed in the No. 1 Boiler safety valve spigot are only minor defects, however, and under normal operating conditions this casting should have proved satisfactory.

PART II. - STEEL STUDS.

The steel studs are referred to in this report as Nos. 1 to 8, inclusive. The identity of the studs is given in Table I.

Table I. - Location of Studs.

Steel No.		Location	
1	-	Main stop valve shell stud,	No. 1 Boiler.
2	-	Scum valve shell stud,	" " "
3	-	Safety valve shell stud,	" " "
4	-	Auxiliary stop valve stud,	" " "
5	-	Main stop valve stud,	No. 2 Boiler.
6	-	Main check valve stud,	" " "
7	-	Generator steam valve stud,	" " "
8	-	Blow-down valve stud,	" " "

Macro-Examination:

All eight steel studs appeared to have been made from good, sound metal. The studs were of three sizes, namely

(Macro-Examination, cont'd) -

3/4, 7/8 and 1 inch diameters, and were threaded on each end. One of the threaded ends of the bolt was apparently damaged on being removed from the boiler with a pipe wrench.

Hardness Tests:

The hardness of the bolts was determined by the Brinell method, using a 3,000-kg. load. The hardness values obtained and the sizes of the s tuds are given in Table II.

Table II.

Steel No.		Material	Diameter of stud, inches	Brinell hardness number (3,000-kg. load)
1	-	Main stop valve shell stud	1	255
2	-	Scum valve shell stud	3/4	277
3	-	Safety valve shell stud	7/8	255
4	-	Auxiliary stop valve stud	3/4	255
5	-	Main stop valve s tud	1	255
6	-	Main check valve stud	3/4	255
7	-	Generator steam valve stud	3/4	255
8	-	Blow down valve s tud	3/4	100

Mechanical Tests and Heat Treatment:

Due to lack of material it was not possible to carry out a full range of mechanical tests on each stud. Tensile tests (see Table III) were carried out on Nos. 4, 5 and 8, as these represented various sizes, hardnesses, and compositions. Izod impact tests (see Table IV) were carried out on Nos 1 and 6 in the "as received" condition, and on No. 3 after a quench-and-draw heat treatment.

The following heat treatment was used:

Hardened in water from 1525° F.
Tempered at 1100° F.
Quenched in oil from the draw temperature.
Time at temperature, 1 hour per inch.

(Mechanical Tests and Heat Treatment, cont'd) -

Table III. - Mechanical Tests.

Steel Sample No.	Diameter of test bar, inches	Ultimate tensile stress, p.s.i.	*Yield stress, p.s.i.	Elongation, per cent in inches	Per cent reduction in area
4	0.282	120,000	100,000	14.0**	55.0
5	0.505	120,500	97,500	18.5	52.0
8	0.282	43,900	24,800	42.5**	69.3

* Yield determined by the dividers method.

** Per cent in 1 inch.

Table IV. - Izod Impact Tests.

Sample No.	Condition of Specimen	Izod Impact, in ft-lbs. Notch No. 1	Notch No. 2
1	As Received	18	15
6	As Received	17	16
3	Heat-Treated	78	70

Chemical Analysis:

Drillings machined from Samples 1, 6, 5, 3 and 8 were found to have the following chemical compositions:

Sample No.	Carbon	Manganese	Sulphur	Phosphorus	Nickel	Chromium
			- Per cent -			
1	0.34	0.74	0.021	0.009	1.48	0.70
6	0.37	0.74	0.020	0.015	1.44	0.74
5	0.34	0.75	-	-	1.28	0.68
3	0.38	0.72	-	-	1.22	0.66
8	0.04	Trace.	0.009	0.047	Nil.	Nil.

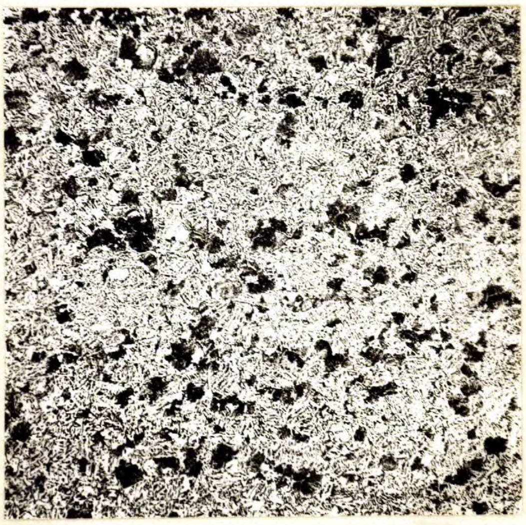
Microscopic Examination:

Specimens of the studs in the "as received" and "heat treated" conditions were polished, etched in 2 per cent nital, and examined microscopically. The structure of the steel in the "as received" condition is shown in Figures 5 and 6 and consists of large areas of free ferrite and fine pearlite, together with dark etching areas of sorbitic pearlite. The nital-etched structure of the steel after heat treating is

(Microscopic Examination, cont'd) -

shown in Figure 7. The structure consists of tempered martensite.

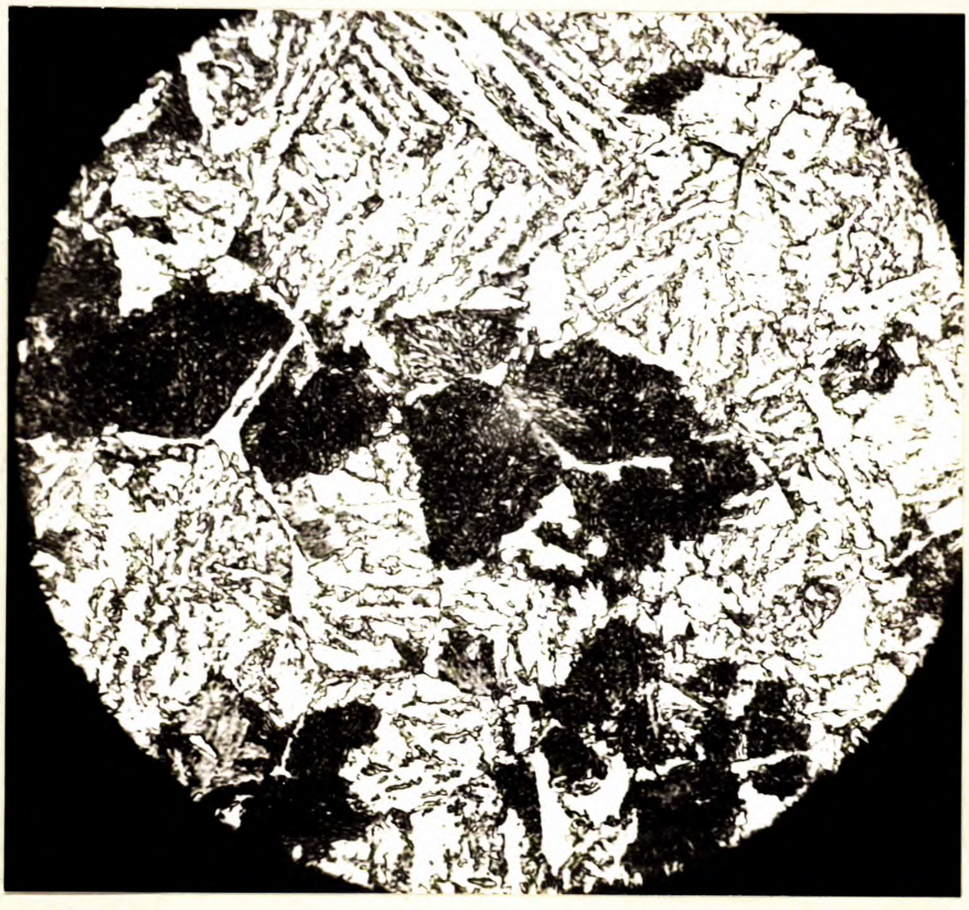
Figure 5.



X100, etched in
2 per cent nital.

STEEL NO. 7, "AS RECEIVED".

Figure 6.



X1000, etched in
2 per cent nital.

STEEL NO. 7, "AS RECEIVED".

(Microscopic Examination, cont'd)

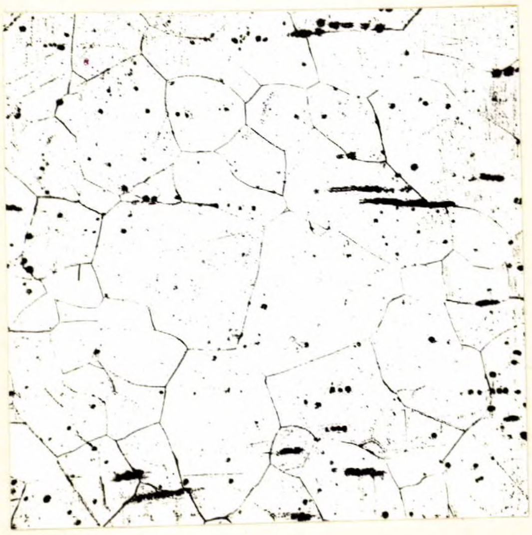
Figure 7.

X1000, etched in
2 per cent nital.

STEEL NO. 3, "HEAT-TREATED".

The nital-etched structure of Steel 8 (Figure 8) consists essentially of fairly large grains of ferrite and long stringers of sulphide inclusions.

Figure 8.



X100, etched in
2 per cent nital.

UNALLOYED, LOW-CARBON STEEL STUD NO. 8.

Discussion of Results:

The steel studs were found to have a composition similar to that of an SAE 3130 steel, a medium-carbon, low-alloy nickel-chromium steel. Steel No. 8 is one exception, as it was found to be an unalloyed low-carbon steel. Steels Nos. 1 to 7 were all heat-treated to approximately the same hardness. Apart from the low impact values, mechanical properties are considered generally satisfactory.

The microscopic examination showed a large amount of free ferrite to be present, which would indicate that the quenching rate was too low. This was confirmed by experimental heat-treatments, carried out on several of the studs, which showed that with proper heat treatment, free ferrite could be eliminated and high impact values obtained by a quench in water from 1525° F. and a draw at 1100° F. The steel was quenched in oil from the draw, as SAE 3130 steel is subject to temper brittleness. The tempered material had a Brinell hardness of 269. SAE 3130 steel of this hardness should have the following mechanical properties:

Ultimate stress, p.s.i.	-	132,000
Yield strength, p.s.i.	-	117,000
Reduction in area, per cent		35.0
Elongation, per cent in 2 inches	-	20.0

(End of Part II)

CONCLUSIONS:

1. No metallurgical defects were observed in the safety valve spigot casting.

2. The scum valve spigot was found to have two casting defects; namely, uneven wall thickness and unsound metal.

3. Steel studs Nos. 1 to 7 were made from an SAE 3130 steel. The alloy steel used was considered satisfactory. Stud No. 8 was made from unalloyed low-carbon steel.

4. The heat treatment of the alloyed steel studs was found to be faulty.

5. Experimental tests showed that high impact strength could be obtained by a suitable heat treatment of the alloyed steel studs.

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