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OTTAWA July 29, 1946.

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REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2085.

(Further to Investigation Report)
(No. 2069, dated June 26, 1946.)

Metallurgical Examination of Defective Steel Casting.

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(Copy No. 4 .)

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

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA July 29, 1946.

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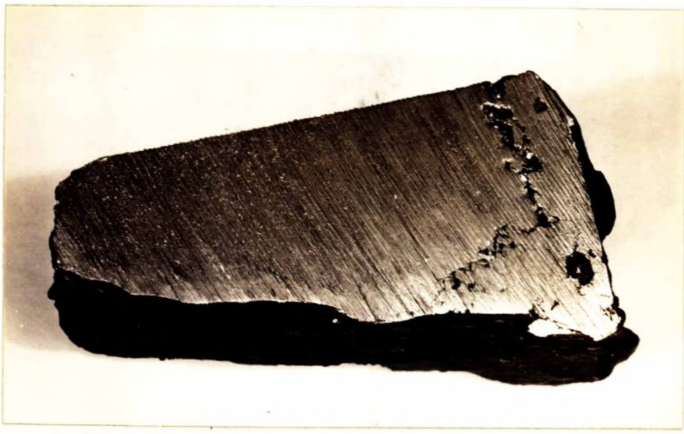
Origin of Material and Object of Investigation:

On June 11, 1946, William Kennedy & Sons Limited, Owen Sound, Ontario, per M. W. Hollands, metallurgist, submitted for metallurgical examination, a sample of 0.40 per cent carbon steel casting which had cracked badly in the mould. (see Figure 1). This casting was typical of a series of medium carbon-steel castings which showed unusually low ductility even after careful annealing. A metallurgical examination was made and reported in Investigation No. 2069, dated June 26, 1946.

The purpose of the present report is to describe some additional work carried out on this problem subsequent to the printing of Investigation No. 2069.

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

Figure 1.



SECTION OF CRACKED STEEL CASTING.

(Approximately ½ actual size).

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PROCEDURE:

1. Chemical Analysis.

The results of the chemical analysis, reported in Investigation No. 2069 are repeated as follows:

TABLE I.

		Per cent
Carbon	-	0.41
Manganese	-	0.98
Silicon	-	0.53
Sulphur	-	0.049
Phosphorus	-	0.023

2. Spectrographic Analysis:

A qualitative spectrographic analysis was made on the steel, the results of which are given in the following table:

TABLE II.

Decreasing magnitude

1	2	3	4	5
Fe	Mn	Si	Ni Al Cu	Mg Sn Mo

3. Hardness Test:

Hardness readings were made on a sample cut from the casting as received, that is, annealed after casting. The results are as follows:

	Rockwell "C"	Brinell Hardness Number
Hardness "as received" -	24-25	229

4. Heat Treating Experiments:

Two bars were cut from the casting and heat treated in the laboratory in order to determine the possibility of restoring the ductility by such means. The heat treatments are as follows:

Sample No. 1 - Quenched in water from 1550° F., and drawn at 900° F.

Sample No. 2 - Quenched in water from 1550° F., and drawn at 1100° F.

5. Mechanical Tests:

One 0.505 inch tensile test bar was machined from each of the heat treated bars Nos. 1 and 2, and from the casting as received. A comparison of the mechanical properties are given in the following table:

TABLE III.

Sample No.	Ultimate Tensile Strength (p.s.i.)	0.2 per cent Proof Stress (p.s.i.)	Elongation in 2 inch, per cent	Hardness BHN
* 1 -	137,500	N.d.	3.0	302
** 2 -	105,500	"	3.5	241
3 -	85,000	58,750	5.0	179

*Sample No. 1 - Quenched into water from 1550° F., and drawn at 900° F.

**Sample No. 2 - Quenched into water from 1550° F., and drawn at 1100° F.

Sample No. 3 - As received - (annealed).

N.d. - Not determined, specimen too short.

6. Microscopic Examination:

Figure 2, taken at X30 magnification shows a crack found in a tensile bar after breaking in the tensile machine. The crack was found at the surface and appears to be intercrystalline.

Figures 3, 4 and 5 taken at X250 magnification show typical inclusions found in the steel. The inclusions in Figure 3 appear to surround a large austenite grain.

Discussion:

The spectrographic analysis failed to disclose the presence of harmful elements in the steel, in quantities great enough to cause low ductility.

The heat treatments performed on two bars cut from the casting had no effect whatever in restoring the ductility (see Table III). This proves rather conclusively that the defects in the steel are of a permanent nature and cannot be restored by heat treatment. It was also noted that the fractures were very similar to that obtained on tensile test pieces machined from the steel in the "as received" condition, that is, they were crystalline with shiny facets.

Since the writing of Investigation No. 2069, it has been learned that a similar problem had been encountered in another steel foundry, and it was recognized that very low ductility was caused by the presence of grain-boundary inclusions, which were due to faulty deoxidation practice. In each case, where low ductility occurred, it was found that the aluminium had not reached the steel but had been burnt off at the top. High ductility was obtained by increasing the quantity of aluminium and by taking special precautions to ensure complete immersion of the aluminium.

(Continued onnext page)

(Discussion, cont'd) -

Reference was made in the Investigation No. 2069 to a paper by C. E. Sims and F. B. Dahle, published by the American Foundrymen's Association, entitled "Effect of Aluminium on the Properties of Medium Carbon Cast Steel." In this paper it was stated that "in the deoxidation of medium carbon cast steel, there is a critical quantity of aluminium which will produce minimum ductility and impact resistance. This critical quantity is the amount which will give complete deoxidation (elimination of FeO) without leaving an appreciable excess. Smaller amounts of aluminium allow the sulphides to precipitate as globules with no change in ductility, but such amounts do not deoxidize the steel. Amounts of aluminium large enough to leave an excess, form aluminium sulphide which lowers the solubility of the complex sulphides to the extent that they precipitate earlier as large irregular masses, which give a ductility almost as high as when no aluminium is used."

Since the quantity of aluminium used, as reported in the paper mentioned, was in the nature of 1 pound per ton, and since the reported quantity used at the plant was 3 pounds per ton, it was suggested in the previous report that the amount of aluminium be reduced. However, it is possible that although 3 pounds per ton were used, insufficient care may have been taken to ensure complete solution of the aluminium in the steel, a large portion having been lost in the slag, and hence only a small portion actually reaching the steel. It is therefore suggested that, if 3 pounds of aluminium be used, special care should be taken to hold the aluminium well under the surface of the molten steel to ensure optimum conditions of deoxidation. If this does not produce satisfactory results, the aluminium added should be increased to 4 pounds per ton.

(Discussion, cont'd) -

It should be pointed out that the order of ductility encountered in this problem is very much less than that reported in the paper by Sims and Dahle. Because of this important fact it is felt that factors in addition to the quantity of aluminium, may be operating to result in the extremely low ductility reported. This factor may be faulty melting practice resulting in an excessive quantity of dirt in the steel, and it is thought that a careful review of the melting practice may reveal information which would aid in the solution of the problem.

Conclusions and Recommendations:

1. The spectrographic examination failed to account for the defects in the steel.

2. The ductility was not improved by heat treatment, indicating that the defects were inherent in the metal and of a permanent nature.

3. Microscopic examination revealed the presence of large quantities of inclusions which appeared to be located at the grain boundaries.

4. It is suggested that, although 3 pounds per ton of aluminium were used (and this amount is considered excessive), the possibility of failure to ensure complete solution of the metal in the steel may have resulted in inadequate deoxidation.

5. The extremely low ductility encountered in the steel under examination suggests the existence of other factors, such as improper melting practice, which may have an important contributing influence to the lack of ductility.

Recommendations:

1. It is recommended that special precautions be taken to ensure complete immersion of the aluminium in the molten metal.

(Recommendations, cont'd) -

2. The effect of increasing the aluminium content to 4 pounds per ton should be determined.

3. A study of the melting practice should be made to determine the existence of any deviations from the normal standard practice.

AF:LC.

(Figures 2 to 5 follow,)
(on Pages 8 to 9.)

Figure 2.

X30 (unetched)

CRACK IN TENSILE BAR AFTER TENSILE TEST. CRACK EXTENDS INWARDS FROM THE SURFACE AND APPEARS TO BE INTERCRYSTALLINE.

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Figure 3.

X250 (unetched)

INCLUSIONS IN STEEL CASTING. INCLUSIONS APPEARS TO OUTLINE A LARGE AUSTENITE GRAIN.

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Figure 4.

X250 (unetched)

TYPICAL INCLUSIONS FOUND IN THE STEEL. (PROBABLY MANGANESE SILICATE WITH SMALL DARK ALUMINA PARTICLES).

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Figure 5.

X250 (unetched)

TYPICAL INCLUSION CLUSTERS FOUND IN THE STEEL. (PROBABLY MANGANESE SILICATE ASSOCIATED WITH ALUMINA).

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