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OTTAWA June 26, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2069.

Metallurgical Examination of Defective Steel Castings.

(Copy No. 3.)

Bureau of Mines
Division of Metallic
Minerals

Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

June 26, 1946.

O T T A W A

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Origin of Material and Object of Investigation:

On May 4, 1946, William Kennedy & Sons Ltd., Owen Sound, Ontario, per M. W. Hollands, submitted for metallurgical examination three broken tensile bars representing three separate heats of steel. These steels, which had been annealed after casting, were found to have very low ductility. The fractures on all three bars were most unusual, having a rather coarse-grained, crystalline appearance with bright facets (see Figure 1). The covering letter, dated May 2, 1946, requested photomicrographs of the three bars and, if possible, an explanation for the defects. The following information regarding the physical properties of

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

the bars was supplied in the covering letter:

Heat No.	Yield Strength p.s.i.	Ultimate Strength p.s.i.	Elongation per cent in 2 inches.	Reduction of area per cent.
540	63,200	88,000	* 6.2	* 11.6
550	56,800	82,000	7.8	11.6
555	54,000	82,000	16.4	16.8

* Note low ductility.

On June 11, 1946, a sample of 0.40 per cent carbon steel casting which had cracked badly (see Figure 2) was also submitted for examination. The covering letter, dated June 7, contained the information that subsequent to the pouring of this casting the deoxidation practice had been altered.

The standard practice of using an aluminium addition, three pounds per ton of steel, was discontinued and the calcium silicide addition was increased.

The letter also stated that cracking had been prevented by allowing the castings to remain in the sand for a minimum of 5 days before removal.

Figure 1.

TEST PIECE FRACTURE.
(Approximately twice actual size.)

Figure 2.

CRACKED STEEL CASTING SECTION.
(Approximately 1/2 actual size.)

Procedure:

(1) Chemical Examination:

The results of chemical analyses made on each of the three test pieces and the cracked casting are as follows:

		No. 540	No. 550	No. 555	Casting
		- P e r C e n t -			
Carbon	-	0.28	0.27	0.27	0.41
Manganese	-	1.15	0.86	0.88	0.98
Silicon	-	0.42	0.55	0.35	0.53
Sulphur	-	0 048	0.046	0.052	0.049
Phosphorus	-	0.023	0.022	0.024	0.023
Chromium	-	0.10	0.11	0.04	-
Nickel	-	Trace	Trace	Trace	-
Molybdenum	-	Trace	Trace	Trace	-

(2) Hardness Examination:

The following hardness readings were obtained:

Sample No.		Hardness Rockwell "C"
540	-	10
550	-	6 - 6½
555	-	3 - 6

(3) McQuaid-Ehn Test:

A McQuaid-Ehn grain size test was performed on samples cut from each of the bars submitted. Samples were carburized at 1700° F. for 8 hours and cooled in the furnace. The grain size was found to be normal.

(4) Hydrogen Determination:

An analysis was made on the cracked casting to determine the hydrogen content. This was found to be 0.000049 per cent, and is not considered high.

(5) Microscopic Examination:

Figures 3 to 8 show the microstructures of the test specimens at X50 and X250 magnifications.

Figures 9 and 10 show the microstructure of the cracked casting at X100 and X500 magnifications respectively.

(Procedure, cont'd) -

Note the inclusions characteristic of this steel, probably manganese silicate.

Figures 11, 12 and 13 illustrate the degree of dirt or inclusions found in the test pieces and the cracked casting. The inclusions in some cases appear to outline large, original, austenite grains. This is shown in Figure 13.

Figure 14, taken at X100 magnification, clearly shows the depth of decarburization existing along the fractured edge of the cracked casting.

(6) Macro-Examination:

Samples were etched in hot 50 per cent HCl for 1/2 hour and examined. This examination revealed nothing of an abnormal nature.

Discussion:

The chemical analysis, hardness and microstructure of the samples examined were found to be normal for that of an annealed medium-carbon cast steel, and offered no clue as to the reason for the low ductility of the metal.

The appearance of the fracture is suggestive of high casting temperature which would result in a large austenite grain size. This large grain size would be obscured by the subsequent annealing operation, but the deleterious effect may, nevertheless, still be present.

Examination of the steels in the unetched condition revealed the presence of an unusually large quantity of non-metallic inclusions which appear to be manganese silicates (see Figure 10). Some of these inclusions seem to be arranged in such a way as to outline large grain boundaries, probably those of the original austenite grains. It is suggested that the presence of excessive quantities of these inclusions at the grain boundaries may be responsible for the low ductility and also the peculiar crystalline fracture. However, it is

(Discussion, cont'd) -

difficult to see how this condition would result in cracking.

The considerable depth of decarburization found existing along the cracked edge suggests that the crack most likely occurred while the casting was in the mould and that decarburization resulted during the subsequent annealing operation.

In the light of the above statements it is felt that the low ductility may be accounted for by deoxidation and melting practice, and it is suggested that some changes, such as decreasing the aluminium content, might be tried. According to some authorities (see Reference 1), there is a critical amount of aluminium which will result in minimum ductility and impact resistance.

Conclusions:

1. The metallurgical examination failed to reveal anything of a positive nature to account for the low ductility and cracking in the steels examined.

2. The presence of excessive quantities of inclusions, some apparently outlining the original austenite grain (a condition common to both the tensile test pieces and the cracked casting section), may be responsible for the defects.

3. The presence of excessive amounts of inclusions in the steel may be attributed to the deoxidation and melting practice.

4. Another contributing factor may be high pouring temperature. No definite evidence of this was found, however.

Recommendations:

It is recommended that experiments be carried out to determine the effect of altering the deoxidation practice, such as decreasing the aluminium content. It is thought that

(Recommendations, cont'd) -

the reported use of three pounds of aluminium per ton may be too high.

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Reference

(1) C. E. Sims and F. B. Dahle: "Effect of Aluminum on the Properties of Medium Carbon Cast Steel."

TRANS., AMERICAN FOUNDRYMEN'S ASSOCIATION, Vol. XLVI, 1938, P. 65 et seq.

(Figures 3 to 14 follow,)
(on Pages 7 to 10.)

Figure 3.

Figure 4.

X50, nital etch.

X250, nital etch.

MICROSTRUCTURE OF TEST PIECE NO. 540.

Figure 5.

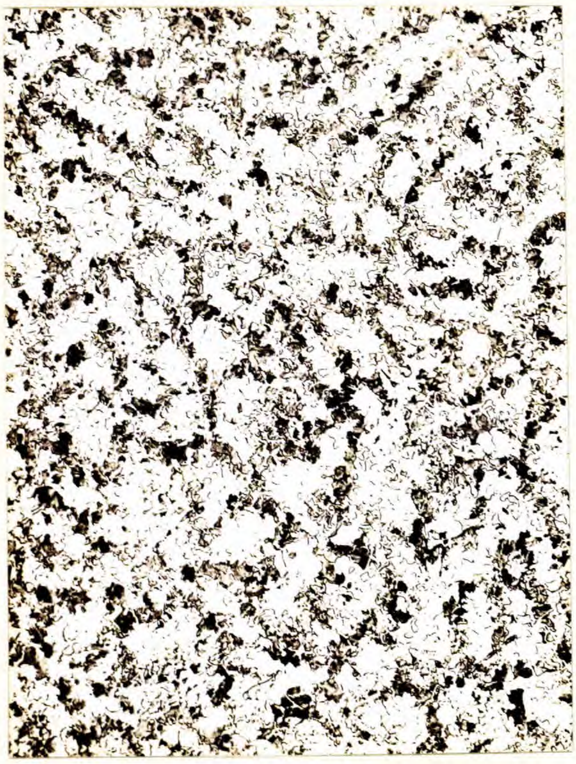
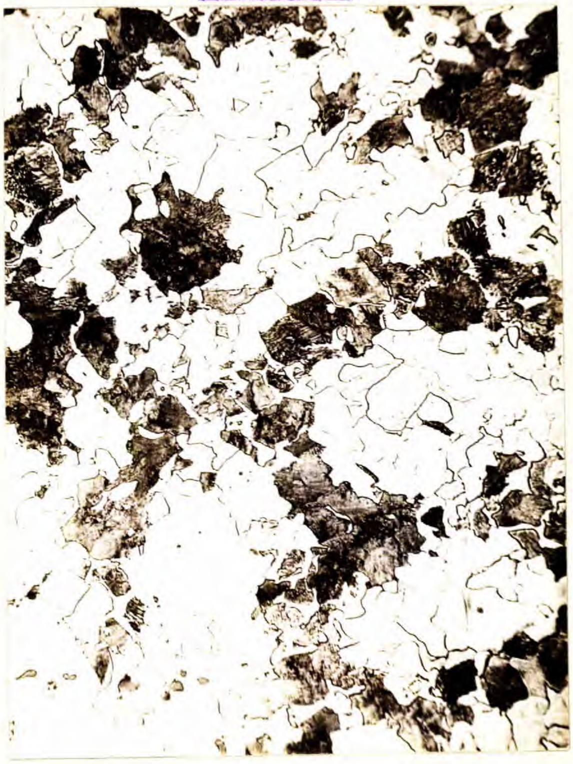


Figure 6.



X50, nital etch.

X250, nital etch.

MICROSTRUCTURE OF TEST PIECE NO. 550.

Figure 7.

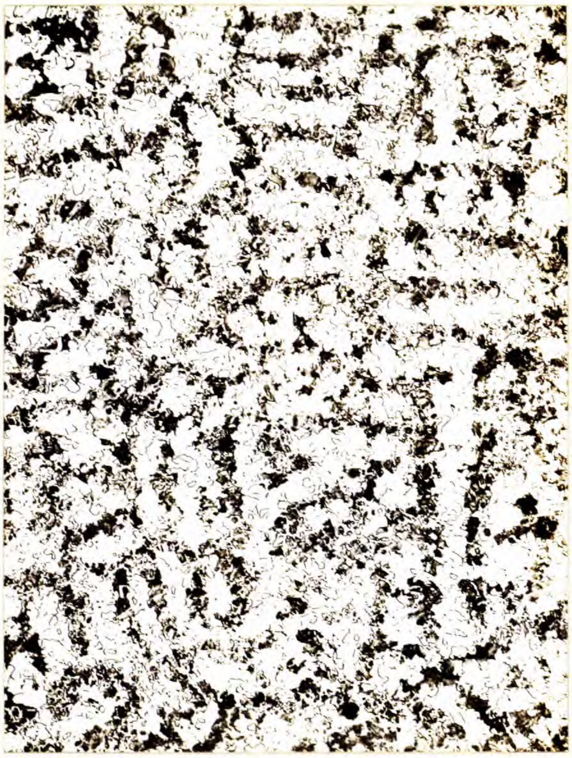
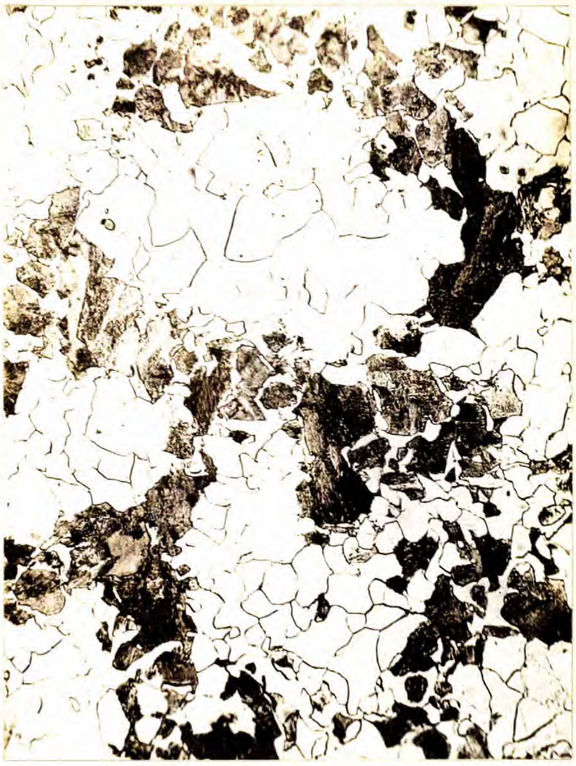


Figure 8.



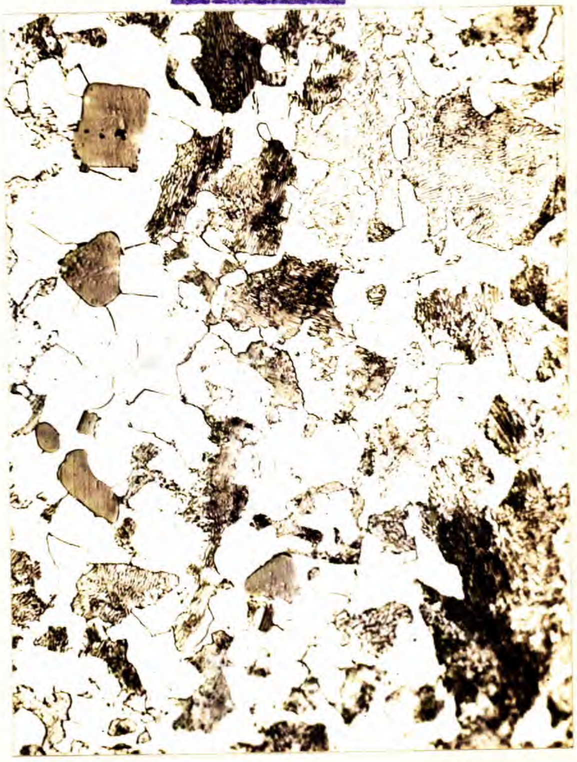
X50.

X250.

MICROSTRUCTURE OF TEST PIECE NO. 555.

Figure 9.

Figure 10.



X100, nital etch.

X500, nital etch.

MICROSTRUCTURE OF CRACKED CASTING.

Note: Manganese silicate inclusions.

Figure 11.

X50, unetched.

SAMPLE NO. 540.

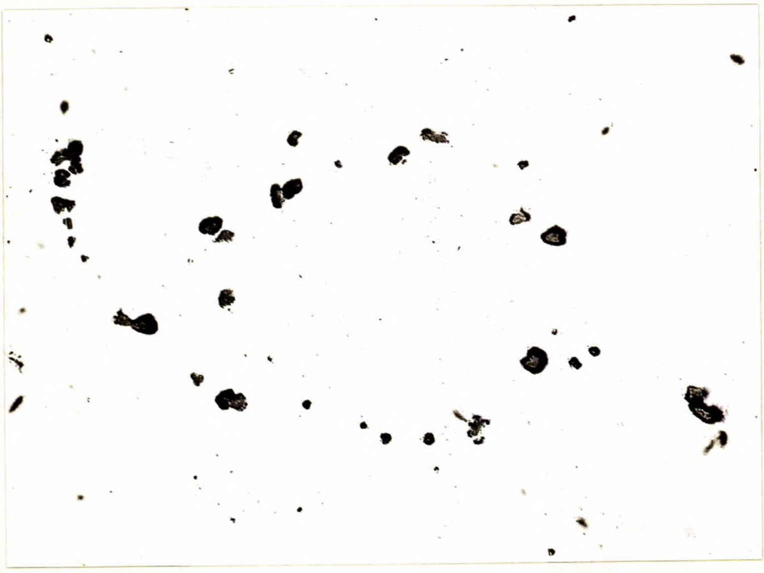
Figure 12.

X100, unetched.

CRACKED CASTING.

Note excessive dirt in steel. Probably inclusions pulled out in polishing.

Figure 13.

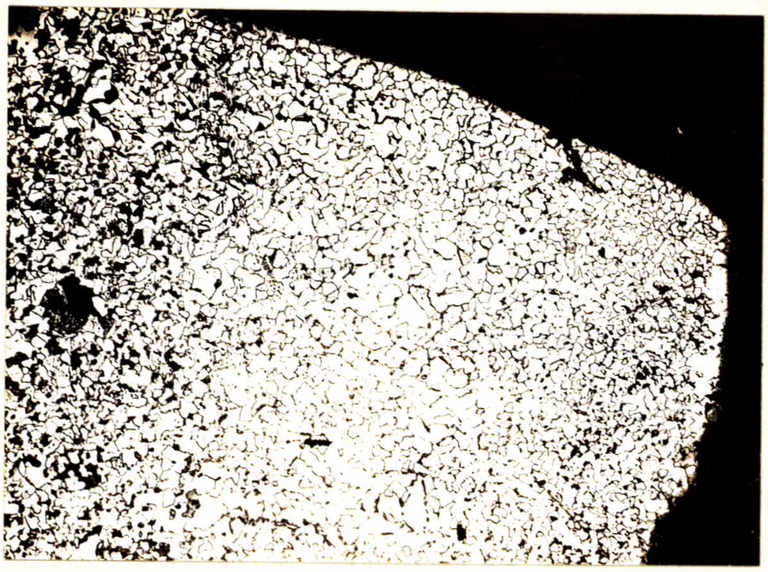


X100, unetched.

CRACKED CASTING.

Note non-metallic inclusions, partly pulled out during polishing, apparently outlining original austenite grain.

Figure 14.



X100, nital etch.

CRACKED CASTING.

Showing depth of decarburization along cracked edge.

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