File

OTTAWA May 13th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1648.

Metallurgical Examination of Specimens From a Lower Racer Plate, 4" Mk. XXIV Steel Casting.

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(Copy No. 10.)

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

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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Source of Material and Object of Investigation:

On May 2nd, 1944, Commander (E) H. Greenwood, R.N., of the British Admiralty Technical Mission, 58 Lyon Street, Ottawa, Ontario, sent in eight Charpy impact bars for test and metallurgical examination. In an accompanying letter (File No. 11-11-10-1), it was requested that the following points be checked:

(a) Physicals.
(b) Chemicals.
(c) Normal and sub-zero impacts.
(d) Suitable heat-treatments to obtain good impacts at low temperatures.

Impact Tests:

Charpy impact tests were carried out at room and low temperatures on the eight standard 45° V-notch specimens submitted, and the following values were obtained:

Lab. Test No.	Temperature, ° F.	Charpy, foot-pounds
1	70	7
2	70	8
3	0	5
4	0	4
5	-30	3
6	-30	3
7	-50	3
8	-50	3

Note: All fractures were coarse-grained.

Chemical Analysis:

A sample milled from the residue of the Charpy impact bars analysed as follows:

	Carbon, per cent	Manganese, per cent	Silicon, per cent	Phosphorus, per cent	Sulphur, per cent
Bureau of Mines -	0.22	0.58	0.41	0.025	0.028
Riverside Iron Works, Ltd. -	0.26	0.46	-	-	-

Heat Treatment:

Two pieces of the broken Charpy bars were given the following heat treatments:

Lab Test No.	Normalized, ° F.	Water Quenched, ° F.	Draw, ° F.
1	1650	--	--
2		1600	1000

-

Fracture Test:

Unfortunately, there was not enough of the heat-treated material available to run standard impact tests. However, the two heat-treated specimens were notched and fractured with a hammer. A specimen of the steel in the "as received" condition was also notched and fractured. The heat-treated steels were much tougher to break than the "as received, double-annealed" sample and also were much finer-grained.

Hardness Tests:

The hardnesses of the heat-treated and "as received" specimens were determined by the Brinell method, using a 3,000-kilogram load. The following values were obtained:

Condition of Bar		Brinell Hardness Number
As Received, Double-Annealed	-	121
Normalized, 1650° F.	-	156
Water-Quenched, 1600°; Draw, 1000° F.	-	201

Microscopic Examination:

Metallographic specimens were prepared from one of the broken Charpy bars in the "as received" condition and from two broken Charpy bars which had been heat-treated.

The steel was first examined in the unetched condition. Typical eutectic sulphide inclusions were observed in the steel. These are shown in Figure 1. The nital-etched structure of the "as received" and "heat-treated" steel specimens are shown in Figures 2, 3 and 4.

(Figures 1 to 4 follow, on Page 4)
(Text is continued on Page 5.)

(Microscopic Examination, cont'd) -

Figure 1.

X100, unetched.

PHOTOMICROGRAPH SHOWING EUTECTIC SULPHIDE INCLUSIONS.

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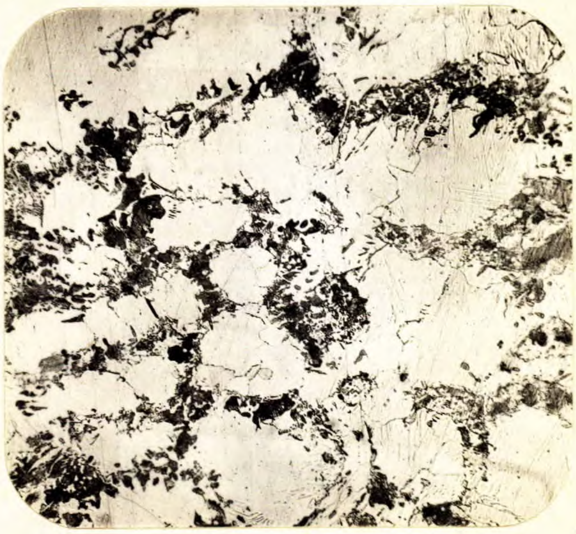
Figure 2.



X100, etched in 2 per cent nital.

STRUCTURE OF STEEL IN THE "AS RECEIVED" CONDITION. Pearlite (dark); ferrite (white).

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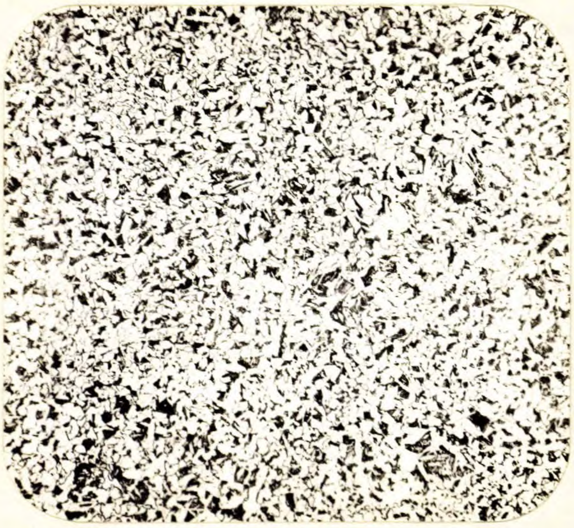
Figure 3.



X100, etched in 2 per cent nital.

MICROSTRUCTURE: Pearlite (dark); ferrite (white).
HEAT TREATMENT: Normalized, 1650° F.

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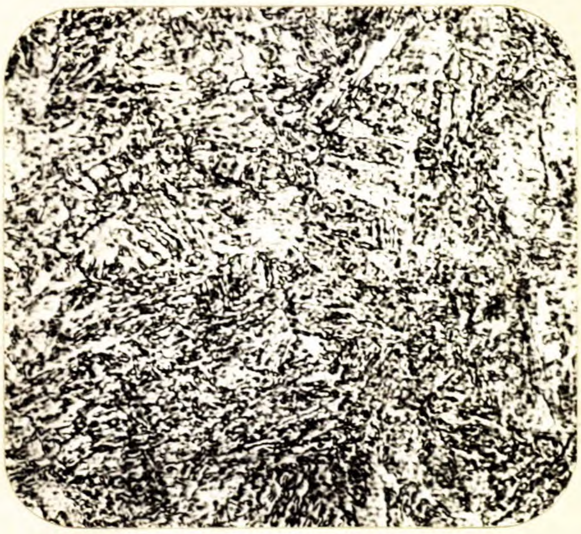
Figure 4.



X1000, etched in 2 per cent nital.

MICROSTRUCTURE: Tempered martensite.
HEAT TREATMENT: Water-quenched, 1600° F.; Drawn, 1000° F.

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Remarks:

The results of chemical analysis of the bars submitted do not check with the values given by the manufacturer. The impact properties of the "as received" steel at room and low temperatures are very poor. The notch fracture test carried out on broken Charpy impact specimens after heat treatment indicated quite definitely that higher impact properties of the steel could be obtained. The microscopic examination showed typical eutectic sulphide inclusions to be present. These inclusions are generally associated with the deoxidation practice. Steels containing this grain boundary sulphide inclusion have low impact and elastic properties. Avoidance of an intermediate addition of aluminium will prevent the precipitation of these inclusions at the grain boundaries. The microstructure of the experimental heat-treated specimens, compared with the "as received" specimens, shows a better distribution of the pearlite and also a definite refinement of the grains. The large-grained structure of the double-annealed specimen indicates that the steel was heated to a temperature considerably above its upper critical range. An examination of the annealed steel at high magnification revealed a coarse lamellar pearlitic structure, showing that the steel was cooled fairly slowly through the critical range. This slow cooling from a high temperature would account for the low impact properties obtained. Steels in the properly normalized or properly quenched-and-drawn condition will be finer-grained and will have higher impact strength. A quench-and-draw heat treatment will give the optimum mechanical properties. The choice of the heat treatment will depend upon the composition, size and design of the casting.

RECOMMENDATIONS:

1. From information supplied regarding the shape of this lower racer plate casting, it is recommended that it be normalized from 1650° F.

2. If future castings have a higher carbon and manganese content, it may be necessary to draw the casting around 1200 to 1250° F. after normalizing, in order to develop the most satisfactory properties in the steel.

3. Some consideration should be given to the deoxidation practice used in making the steel for these castings.

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References:

Sims, C.E. and Lilliequist, G.A.: "Inclusions - Their Effect, Solubility and Control in Cast Steel." Transactions, American Institute of Mining and Metallurgical Engineers, Vol. 100 (1932), p. 154.

Sims, C.E. and Dahle, F.G.: "Effect of Aluminum on the Properties of Medium Carbon Cast Steel." Transactions, American Foundrymen's Association, Vol. 46 (1938), p. 65.

Timmons, G. A.: "Factors Affecting Ductility of Cast Steel." - Transactions, American Foundrymen's Association, Vol. 51 (1943), p. 417.

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NBB:GHB.