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OTTAWA March 19th, 1942.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1186.

Examination of Bracket Castings for Tanks.

(Copy No. 8.)

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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Origin of Request and Object of Investigation:

On February 11th, 1942, this Department received from the Inspection Board of the United Kingdom and Canada, 58 Lyon Street, Ottawa, Ontario, three broken castings from tanks. These castings were accompanied by Analysis Requisition No. O.T. 98 and Mr. C. C. Pettet's letter of February 11th, 1942, File No. 7/4/2.

Request was made for an expression of opinion as

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

to the casting generally - if the metal can be considered to be homogeneous, free from shrinkage cracks, inclusions, etc. We were also supplied with copies of U. S. A. Ordnance Department Drawing No. D-37893, which is a drawing of a bracket, and Drawing No. C-66429, which is a drawing of a spring bottom seat.

Identification tags were attached to each of the castings. These castings will be numbered 1, 2, and 3, in this report and are described as follows:

Casting No. 1. - (Figure 1)	Spring bottom seat (C-66429). Manufacturer: M.L.W. Broken during field test.
Casting No. 2. - (Figure 2)	Schenectady suspension. Broken at Camp Borden. Vehicle: Ram I, M3 41-1-3601. Centre assembly suspension (Left side). Mileage: 1128. Date: 19-1-42.
Casting No. 3. - (Figure 3)	M.L.W. suspension bracket (D-37893). Piece of suspension bracket broken during field test, Jan. 30th, 1942.

X-Ray Examination:

Casting No. 3 was submitted to X-ray examination at the National Research Council, Ottawa. It was found to be quite sound, indicating good foundry practice. On subsequent cutting-up of all castings for physical test purposes, no evidence of poor foundry practice could be found.

Chemical Analysis:

These castings were analysed and the results are reported in Table I.:

(Continued on next page)

(Chemical Analysis, cont'd) -

Table I. - Chemical Analysis.

	Casting No. 1.	Casting No. 2.	Casting No. 3	Specification
Carbon, per cent	0.30	0.29	0.34	0.30 - 0.35
Manganese, per cent	1.22	1.76	0.67	1.00 - 1.25
Silicon, "	0.50	0.49	0.51	0.35 - 0.45
Nickel, "	0.75	0.11	2.75	0.70 - 0.80
Chromium, "	0.66	-	-	-
Sulphur, "	0.015	0.032	0.016	-
Phosphorus, "	0.028	0.033	0.021	-

Physical Tests:

Tensile and izod impact bars were cut from each casting. The results of these tests are given in Table II.

Table II. - Physical Properties.

	Casting No. 1.	Casting No. 2.	Casting No. 3.	Specification
Tensile strength, p.s.i.	111,300	129,000	113,500	110,000 min.
Yield strength, p.s.i.	88,700	98,000	91,500	85,000 "
Elongation, per cent	16	15	6	18 "
Reduction of area, per cent	28.6	29.6	13.9	25 "
Izod impact, ft.lb.	5	4.6	13.8	40 "
Brinell hardness	221	248	248	260 max.

Microscopic Examination:

The structure of the metal was examined in the "as received" condition.

The photomicrographs showing the results of this examination are tabulated in Table III.

Table III. Photomicrographs of Metal As Received.

Casting	Figure	Magnification	Etchant
No. 1	No. 4	X100	Picral
No. 1	No. 5	X500	"
No. 2	No. 6	X100	"
No. 2	No. 7	X500	"
No. 3	No. 8	X100	"

-

Heat Treatment Tests:

Specimens from each casting were given various heat treatments, with the object of ascertaining whether or not it would be possible to obtain the desired physical properties with the metals at hand. Normalizing treatments only were investigated, as these seemed to be most practical for general foundry application. The specimens used were approximately one square inch in cross-sectional area with a minimum dimension of 3/4 inch. The final heat treatments arrived at, resultant physical properties, and microstructures are tabulated in Table IV.

Table IV. - Summary of Heat Treatment Tests.

	Casting No. 1.	Casting No. 2.	Casting No. 3.
Final heat treatment:			
Normalize -	1850° F.	1525° F.	1850° F.
" -	1550° F.	1425° F.	1525° F.
Draw -	1300° F.	1200° F.	1250° F.
Tensile strength, p.s.i.	114,000	105,000	123,000
Yield strength, p.s.i.	83,600	75,000	105,000
Elongation, per cent	21	27	25
Reduction in area, per cent	27.4	55	55
Izod impact, ft.lb.	53.5	56	40
Brinell hardness	254	227	282
Microstructures	Fig.9, X100 Fig.10, X500	Fig.11, X100 Fig.12, X500	Fig.13, X100 Fig.14, X500

In conducting these heat treatments the effects of various drawing temperatures were investigated for the metal in Casting No. 3, and a similar, though less complete, investigation was made for Casting No. 2. The results of these tests are shown in Figure 15.

Discussion of Results:

A comparison of the microstructures of all three alloys before and after heat treatment would indicate that the low impact properties were due to a relatively coarse microstructure. In the heat treatment tests conducted these

(Discussion of Results, cont'd) -

structures were refined by normalizing at a temperature near the AC_3 temperature. Care should be taken to interpret the heat treatment procedure used in these tests in terms of the size of pieces used and relative cooling rates.

There will be a certain critical cooling rate, reflected in the fineness of microstructure obtained, to give the desired physical properties. In commercial practice the cooling rate, for a normalizing treatment, will be governed by the type of heat-treating equipment available, i.e., continuous furnaces, batch-type car furnaces, etc.

The cooling rate at 1330° F. for the pieces used in these tests was in the neighbourhood of 4.2° F. per second. This rate is estimated from the data supplied on Pages 32 - 33 of "The Quenching of Steels" by H. J. French, published by the American Society for Steel Treating, Cleveland, Ohio. The author states that the relation between the diameter or thickness and the cooling velocity at 720° C. (1330° F.) is closely represented by the equation

$$VD^n = c$$

where

V = Cooling velocity at 720° C. in degrees centigrade per second,

D = diameter of rounds or spheres or thickness of plate, and

n) constants.
c)

Table 3 on Page 33 of the above-mentioned book, gives the following values for *n* and *c* for rounds cooled in motionless air:

$$n = 1.5$$
$$c = 1.74$$

From these data it would appear that for all three of these alloys a minimum or critical cooling rate of from

(Discussion of Results, cont'd) -

4½ fahrenheit degrees per second to 5½ fahrenheit degrees per second in the critical temperature range is necessary.

The trend shown in the Reduction in Area, Elongation, Yield and Ultimate Strength curves for the metal in Casting No. 3 (Figure 15) would indicate that a drawing temperature above 1250° F. might be expected to lower the impact value.

The effect of drawing temperatures above 1200° F. on the metal in Casting No. 2 was not investigated but in view of the trends shown in Figure 15 the strength should not be lowered appreciably. It will be noted that the ultimate strength and yield strength for this metal are slightly below specification. Higher strengths could be obtained without lowering the impact value by an oil-quench-and-draw treatment. It might be found necessary in practice to develop such a treatment for this alloy. The same could conceivably hold true for the other two alloys should the heat treatment equipment available be the batch-type car furnace in which the design, loading, or surroundings of the car did not permit a cooling rate in excess of 5½ fahrenheit degrees per second at 1330° F. in the part of the charge having the slowest cooling rate.

Conclusions:

1. The castings, as received, failed to meet the physical specifications required of them.

2. By proper heat treatment the metal in these castings can be made to meet all the physical specifications.

3. All castings submitted were found to be commercially sound, indicating good melting and moulding

(Conclusions, cont'd) -

practice in the foundry.

4. Subsequent heat treatment tests indicated that there might be some irregularities in the heat treatment processes to which the castings were subjected.

Recommendations:

The following general type of heat treatment cycle should be developed for all three of these alloys:

1. A homogenizing treatment, consisting of:
   - (a) heating to a fairly high temperature (1800 to 1900° F.);
   - (b) holding at this temperature for a long enough time to completely break up the original "as cast" structure; and
   - (c) cooling in still air.
2. A refining treatment, consisting of:
   - (a) heating to a temperature higher than but as close as practical to the AC_3 temperature;
   - (b) holding at this temperature for a long enough time to permit complete solution of the carbides; and
   - (c) cooling at a rate faster than the critical rate of the alloy used (for the alloys examined, this critical rate will probably be in the neighbourhood of $5\frac{1}{2}$ fahrenheit degrees per second at 1330° F.).
3. A tempering treatment to meet the required physical

(Recommendations, cont'd) -

properties. The temperature will probably be in the neighbourhood of 1150 to 1250° F.

If there are a quantity of these castings of the three different analyses on hand at the present time, these could be salvaged by subjecting them to a common heat treatment consisting of Stages 2 and 3 of the complete treatment outlined. The recommended temperature for Stage 2 is 1525° F. and for Stage 3, 1250° F.

The success or failure of this heat treatment will depend on whether or not the conditions outlined in "2(c)" are complied with.

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Figure 1.

BROKEN SPRING BOTTOM SEAT.

(1/6 actual size).

Figure 2.

BROKEN SCHENECTADY SUSPENSION BRACKET.

(1/10 actual size).

Figure 3.

BROKEN M.L.W. SUSPENSION BRACKET

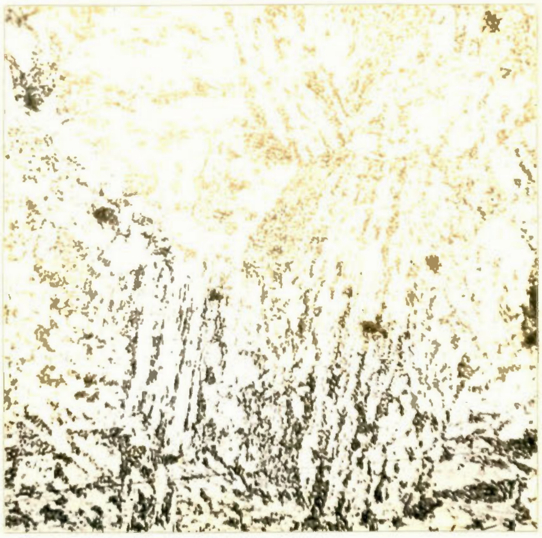
(Drawing D-37893). (1/10 actual size).

Figure 4.

X100, picral etch.

PHOTOMICROGRAPH SHOWING "AS RECEIVED" STRUCTURE OF STEEL IN CASTING NO. 1.

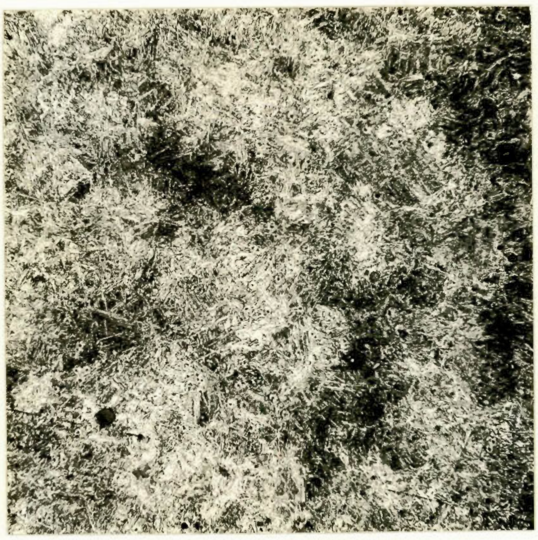
Figure 5.



X500, picral etch.

PHOTOMICROGRAPH SHOWING "AS RECEIVED" STRUCTURE OF STEEL IN CASTING NO. 1.

Figure 6.



X100, picral etch.

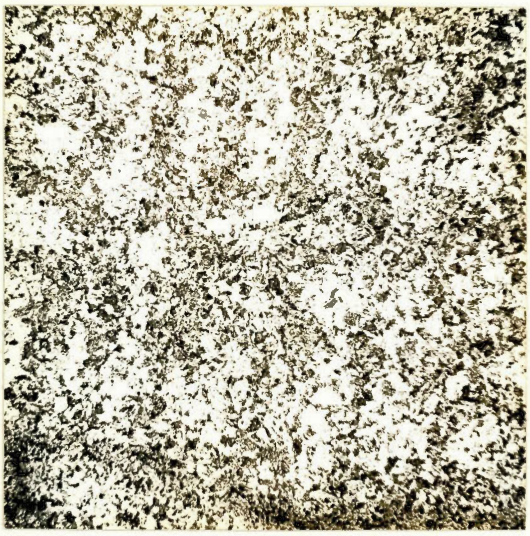
PHOTOMICROGRAPH SHOWING "AS RECEIVED" STRUCTURE OF METAL IN CASTING NO. 2.

Figure 7.

X500, picral etch.

PHOTOMICROGRAPH SHOWING "AS RECEIVED" STRUCTURE OF METAL IN CASTING NO. 2.

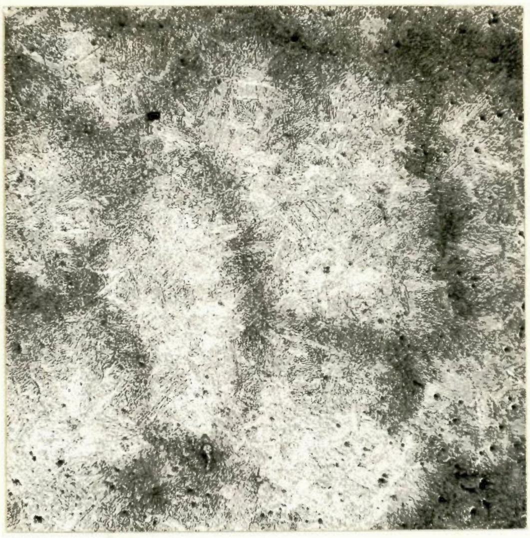
Figure 8.



X100, picral etch.

PHOTOMICROGRAPH SHOWING
"AS RECEIVED" STRUCTURE OF
METAL IN CASTING NO. 3.

Figure 9.



X100, picral etch.

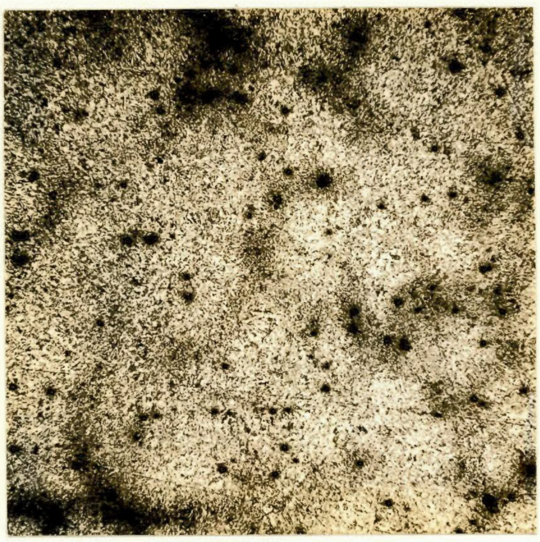
PHOTOMICROGRAPH SHOWING
MICROSTRUCTURE OF METAL IN
CASTING NO. 1 AFTER HEAT TREATMENT.

Figure 10.

X500, picral etch.

PHOTOMICROGRAPH SHOWING
MICROSTRUCTURE OF METAL IN
CASTING NO. 1 AFTER HEAT
TREATMENT.

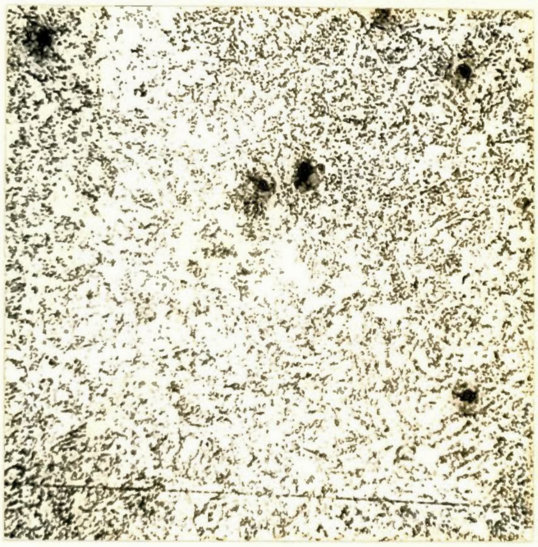
Figure 11.



X100, picral etch.

PHOTOMICROGRAPH SHOWING MICROSTRUCTURE OF METAL IN CASTING NO. 2 AFTER HEAT TREATMENT.

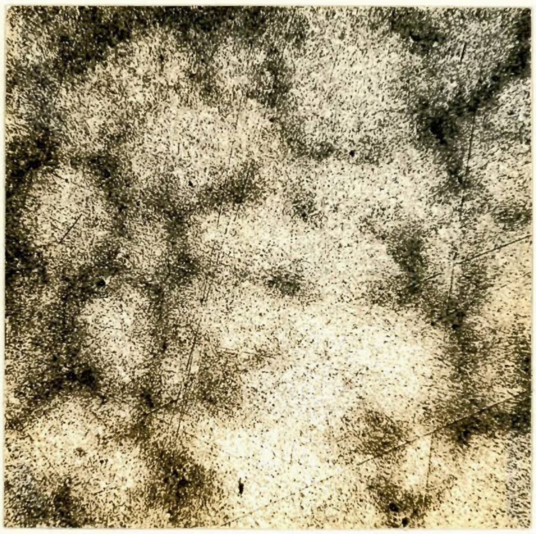
Figure 12.



X500, picral etch.

PHOTOMICROGRAPH SHOWING MICROSTRUCTURE OF METAL IN CASTING NO. 2 AFTER HEAT TREATMENT.

Figure 13.



X100, picral etch.

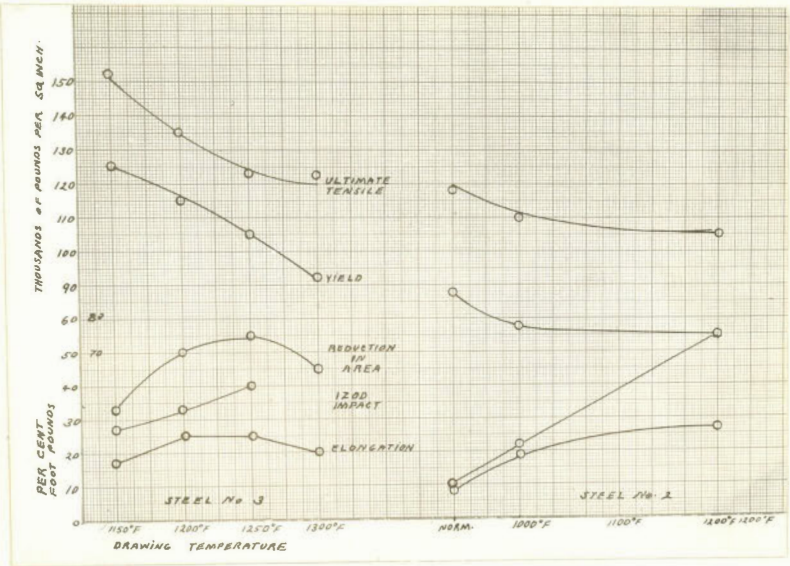
PHOTOMICROGRAPH SHOWING MICROSTRUCTURE OF METAL IN CASTING NO. 3 AFTER HEAT TREATMENT.

Figure 14.

X500, picral etch.

PHOTOMICROGRAPH SHOWING MICROSTRUCTURE OF METAL IN CASTING NO. 3 AFTER HEAT TREATMENT.

Figure 15.



HEAT TREATMENT CHARTS FOR

CASTINGS NOS. 2 AND 3.

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