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OTTAWA April 1st, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1617.

Examination of Rods Turned from Two
Pieces of Heavy Boiler Plate.

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(Copy No. 10.)

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:

A letter from Mr. F. A. Forward, British Columbia War Metals Research Board, Vancouver, B.C., dated March 3rd, 1944, requested chemical analysis and metallurgical examination of two rods which had been turned from two pieces of heavy boiler plate. Plate No. 1, represented by Rod No. 1, was satisfactory but Plate No. 2, represented by Rod No. 2, developed cracks during hot forming. The two plates had been forged under identical conditions, by the same operator, but behaved differently.

Chemical Analysis:

The chemical analysis of the two rods are shown below:

		Rod No. 1	Rod No. 2
		- Per cent -	
Carbon	-	0.28	0.22
Silicon	-	Trace.	0.21
Manganese	-	0.48	0.68
Sulphur	-	0.040	0.033
Phosphorus	-	0.007	0.007
Nickel	-	0.05	0.13
Chromium	-	0.008	0.07
Molybdenum	-	Trace.	0.03
Boron	-	Nil.	Nil.
Aluminium*	-	Nil.	Trace.

* Spectroscopic determinations.

Physical Tests:

The following physical tests were made on sections machined from each rod:

I. - Izod impact test (2-notch bar).

II. - Microtensile test (two specimens from each rod) for

(i) - Per cent reduction in area,
(ii) - Per cent elongation,
(iii) - Yield stress, and
(iv) - Maximum stress.

Results of Izod Impact Tests:

		Rod No. 1	Rod No. 2
1st notch	-	19 ft-lb.	62 ft-lb.
2nd notch	-	14 "	42 "

Results of Microtensile tests:

Test		Reduction in area, per cent	Elongation, per cent	Yield stress, p.s.i.	Maximum stress, p.s.i.
Rod No. 1	A	55	39	47,500	66,250
	B*			32,500	62,500
Rod No. 2	A	55	38	47,500	75,000
	B	58	40	47,500	72,500

* Test pieces not broken.

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McQuaid-Ehn Tests for Grain Size:

Three tests were made on each rod, as follows:

A. - Carburized at 1700° F.
B. - " " 1900° F.
C. - " " 2100° F.

The samples were all hand polished, etched, and examined under the microscope. The following grain sizes had resulted (see Figures 1 to 6):

Test No.	Rod No.	Grain Size	Figure No.
A	1	1-2	1
	2	5-6	2
B	1	1	3
	2	5-6	4
C	1	-	5
	2	1-2	6

Microscopic Examination:

One longitudinal and one transverse section were cut from each rod, hand polished, etched in 2 per cent nital for 10 seconds, and examined under the microscope. Figures Nos. 7 to 10, at a magnification of 100 diameters, show the similarity between the test rods. Figure 9 clearly shows that the rod was cut across the direction of rolling.

Discussion of Results:

Chemical Analysis -

There was no appreciable difference in the chemical composition of the two steels. The spectroscopic analysis showed that the steel represented by Rod No. 1 was silicon-killed and the steel represented by Rod No. 2 was aluminium-killed.

Physical Tests and Microscopic Examination -

The results of the Izod and microtensile tests indicate that boiler plate forged from Steel No. 2 should be

(Discussion of Results, cont'd) -

preferable to plate forged from Steel No. 1. The microscopic examination showed no important difference between the steels represented by the rods submitted for examination.

McQuaid-Ehn Tests -

These tests, in agreement with the spectroscopic analysis, showed that Steel No. 1 was deoxidized with silicon and Steel No. 2 with aluminium. The grain size of the aluminium-killed steel did not increase until the temperature had been raised to between 1900° and 2100° F. (see Figures 2, 4 and 6).

In his paper, "The Forgeability of Metals" (Engineering Journal, October 1941), O. W. Ellis* describes various tests on the forgeability of different steels. His work indicates that the forgeability of a steel might be expected to be very noticeably affected by the austenitic grain size of the steel at the forging temperature. Two steels of similar chemical composition and forged at the same temperature would behave differently if the austenitic grain sizes were different, the steel having the larger austenitic grain size being more easily deformed or forged than the steel having the smaller austenitic grain size.

This would seem to be directly applicable to the two rods examined. Rod No. 1 (silicon killed) had a large austenitic grain size even when measured at 1700° F., hence this steel should forge or withstand deformation at the usual temperature of forging. Rod No. 2 (aluminium killed) had a small austenitic grain size when measured at 1700° F. and also at 1900° F. Hence, Steel No. 2 would not forge as readily as Steel No. 1 at temperatures much below 2100° F. if the forging were done in an exactly similar manner to that used to forge Steel No. 1. Steel No. 2, having a fine austenitic grain size, if forged at a temperature

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* Director of Department of Engineering and Metallurgy, Ontario Research Foundation, Toronto, Ontario.

(Discussion of Results, cont'd) -

much below 2100° F. might tend to crack during the operation.

The American Society for Metals Handbook (1939 Edition) gives 2350° F. as the maximum forging temperature for steel of this type.

Conclusions and Recommendations:

Plate forged from the steel represented by Rod No. 2 should be preferable to plate forged from the steel represented by Rod No. 1. The impact strength, yield stress and maximum stress for the No. 2 steel are all greater than for the No. 1 steel.

Relatively large grain size is preferable for forging, so that the No. 2 steel should be forged at a high temperature (close to 2350° F., the maximum temperature recommended for this type of steel). If this temperature is beyond the ability of the forging shop, it is suggested that the forging be done as slowly as possible. Small reductions in many stages would require less deformation of the steel at any particular instant and should result in a plate free from cracks.

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ELC:GHB.

Figure 1.

X100, nital etch.
McQUAID-EHN AT 1700° F.,
ROD NO. 1.
Grain size: 1-2.

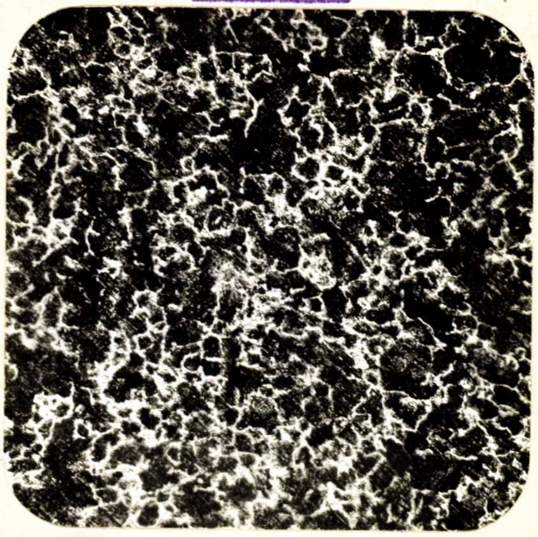
Figure 2.

X100, nital etch.
McQUAID-EHN AT 1700° F.,
ROD NO. 2.
Grain size: 5-6.

Figure 3.

X100, nital etch.
McQUAID-EHN AT 1900° F.,
ROD NO. 1.
Grain size: 1.

Figure 4.

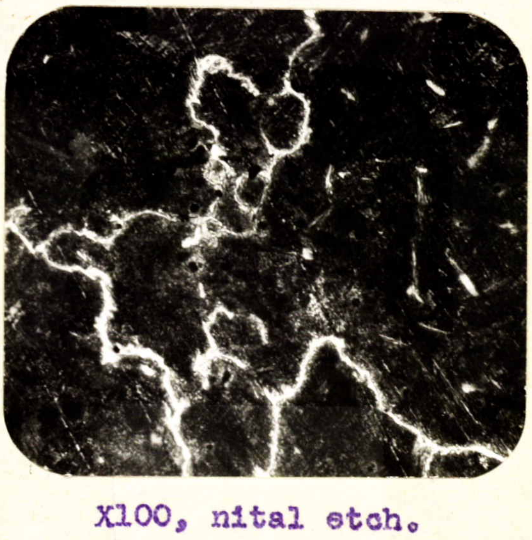


X100, nital etch.
McQUAID-EHN AT 1900° F.,
ROD NO. 2.
Grain size: 5-6.

Figure 5.

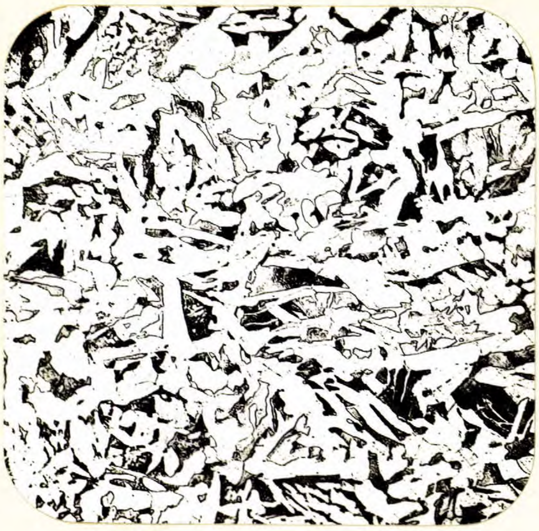
X100, nital etch.
McQUAID-EHN AT 2100° F.,
ROD NO. 1.

Figure 6.



X100, nital etch.
McQUAID-EHN AT 2100° F.,
ROD NO. 2.
Grain size: 1-2.

Figure 7.



X100, nital etch.

ROD NO. 1,
TRANSVERSE SECTION.

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Figure 8.

X100, nital etch.

ROD NO. 1,
LONGITUDINAL SECTION.

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Figure 9.

X100, nital etch.

ROD NO. 2,
TRANSVERSE SECTION.

Note direction of rolling.

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Figure 10.

X100, nital etch.

ROD NO. 2,
LONGITUDINAL SECTION.

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ELC:GHB.