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O T T A W A May 11th, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1219.

Cold-Temperature Tests on Armour.

(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 Problem and Object of Investigation:

In a letter dated April 14th, 1942 (File ADH/50/2/1), Mr. F. Creedy, of the Inspection Board of the United Kingdom and Canada, 55 Lyon Street, Ottawa, Ontario, suggested that a series of physical tests be conducted on Dominion Foundries standard armour at normal temperatures and -40° F., including tensile strength, elongation, yield point, reduction in area, and izod impact tests.

Investigative Procedure:

In the course of this investigation, both izod and Charpy impact tests were conducted. Charpy impact tests are more universally used for investigating low-temperature notch sensitivity. Because of lack of equipment, it was not possible to conduct low-temperature tensile tests. However, low-temperature bend tests were performed. These tests indicated that the modulus of elasticity might be lowered at sub-zero temperatures.

The yield strengths were calculated from the data accumulated from these tests, as follows:

$$S = \frac{Mc}{I}$$

S = Maximum fibre stress in pounds per square inch.
M = Bending moment.
c = Distance from neutral axis to extreme fibres.
I = Moment of inertia of the area about the neutral axis.

Table I is a list of the armour plates investigated.

Table I.

Identification Number	Type of Plate	CHEMICAL ANALYSIS, PER CENT C	Mn	Si	P	S	Ni	Cr	Mo
1	12 mm. plate	0.25	0.54	0.34	0.014	0.019	0.75	0.88	0.53
2	20 mm. plate	0.28	0.60	0.24	0.008	0.032	0.72	2.27	0.40
3	Cast armour	0.28	0.77	0.38	0.021	0.015	0.99	2.10	0.55

Heat Treatment:

These steels received the following heat treatment:

Table II.

Steel No.	Heat Treatment: Annealing temperature, degrees Fahr.	Water-quench temperature, degrees Fahr.	Draw-and-quenched at (degrees Fahr.)	Hardness, Rockwell "C"
1	1700	1600	1100	39
2	1700	1600	1200	36
3	1700	1600	1100	38

Bend Tests:

The results of the bend tests are given in Figures 1 to 4. They are summarized in Table III:

Table III. - Summary of Bend Tests.

Steel No.	Beam dimensions, inches	Span, in inches	Max. load, pounds		Yield strength, p.s.i.		Coefficient of rigidity, p.s.i.	
			Room temp.	-40°F.	Room temp.	-40°F.	Room temp.	-40°F.
1	10x.48x$\frac{3}{4}$	8	6,500	6,250	192,100	180,500	1,960,000	1,680,000
2*	10x$\frac{3}{4}$x$\frac{3}{4}$	8	8,225	8,250	123,000	138,000	1,891,000	1,380,000
2**	10x$\frac{3}{4}$x$\frac{3}{4}$	8	8,325	8,250	123,700	132,100	1,791,000	1,408,000
3	7x5/8 dia.	5	7,350	6,250	227,000	255,000	3,783,000	2,220,000

* With grain.

** Across grain.

The value termed "Coefficient of Rigidity" is actually not an absolute figure but is useful only for comparison between tests conducted in exactly the same way, i.e., same size of test piece and same span. It is the ratio of the maximum fibre stress at the yield point to the actual deflection.

The "Coefficient of Rigidity" is, however, a function of the modulus of elasticity. In view of this fact, the trend shown by these tests is interesting. It will be noted that in every case the value of "Coefficient of Rigidity" at -40°F. is lower than the corresponding value at room temperature. This would indicate that at sub-zero temperatures the modulus of elasticity is lowered.

Impact Tests:

Three groups of impact tests were conducted. The first group were izod and the second and third groups were Charpy impact tests. The Charpy test method was chosen because of the rapidity with which the test piece can be

(Impact Tests, cont'd) -

placed in the machine and broken. In all of the low-temperature Charpy impact tests the test piece was broken in less than three seconds from the time it was removed from the cold-temperature bath. The corresponding time for the izod tests, even under the best conditions, is seldom under six seconds.

Also, a considerable part of the izod bar is gripped in the vice, while the ends only of the charpy bar are resting on warm metal.

Table IV. - Impact Test Results.

	Izod impact, in foot pounds		Charpy impact, in foot pounds	
	Room temp.	-40°F.	Room temp.	-40°F.
Steel No. 1.				
Maximum	43	44	24	26
Minimum	40	38	16	13
Average	42	41	18	20
Steel No. 2, (With grain).				
Maximum	65.5	65.5	71	86
Minimum	63.5	60.5	51	45
Average	64.5	62.8	63	61
Steel No. 2, (Across grain).				
Maximum	22.5	19	23	26
Minimum	23	20	16	14
Average	23	20	20	20
Steel No. 3.				
Maximum	31	22	41	33
Minimum	29	18	31	28
Average	30	20	36	30

Each set of Charpy tests included six fractures, while only three fractures were made in the izod tests.

It will be noted that, while in every case there is wider variation in the cold-temperature tests than in the room-temperature tests, there is no significant difference in the averages obtained. A statistical analysis of the data

(Impact Tests, cont'd) -

accumulated from these tests indicated that there are irregularities, due either to technique or to temperature, causing this wide spread in cold-temperature results. This work is being continued in an effort to improve the technique of these cold-temperature tests. In the meantime, from the data obtained it would not appear that the impact properties of any of the steels tested are seriously impaired, although there is some indication that there might be a tendency toward lower impact strengths of the 2 per cent chromium steels at minus 40° F.

Conclusions:

1. There are not sufficient data on hand to conclusively indicate any definite trend of impact properties at sub-zero temperatures. What data has been accumulated would tend to indicate that if there is such a trend it does not assume serious proportions down to minus 40° F.

2. The modulus of elasticity of all steels tested is apparently lower at minus 40° F. than at room temperature.

3. Except in the case of the 12-mm. plate, the yield strength was improved at minus 40° F.

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Figure 1.

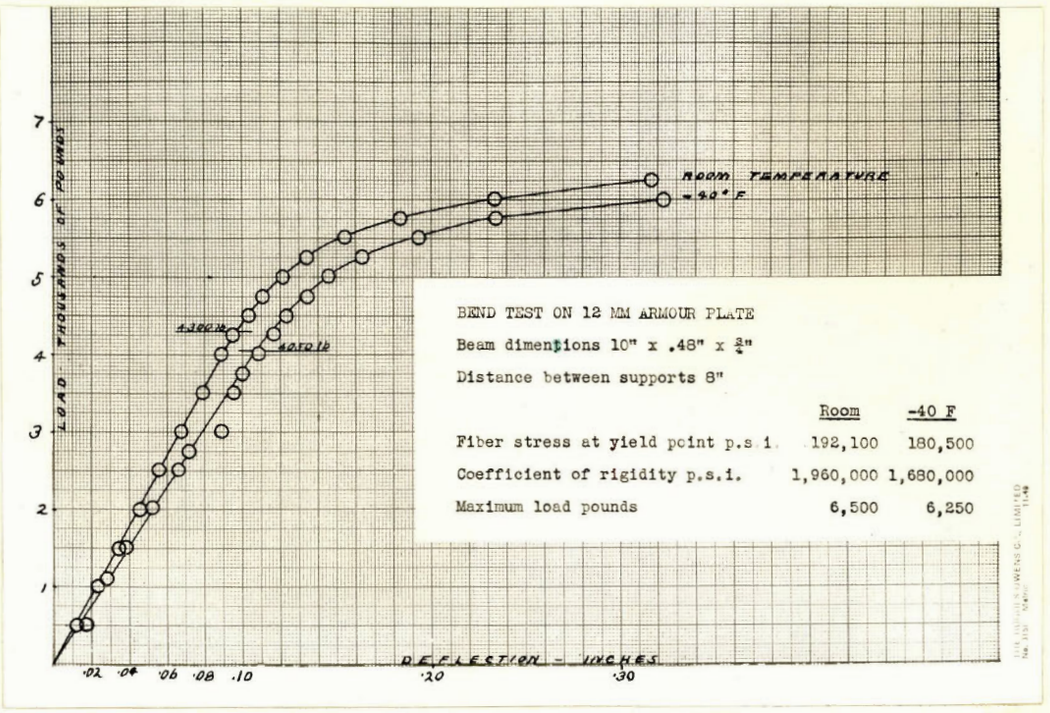


Figure 2.

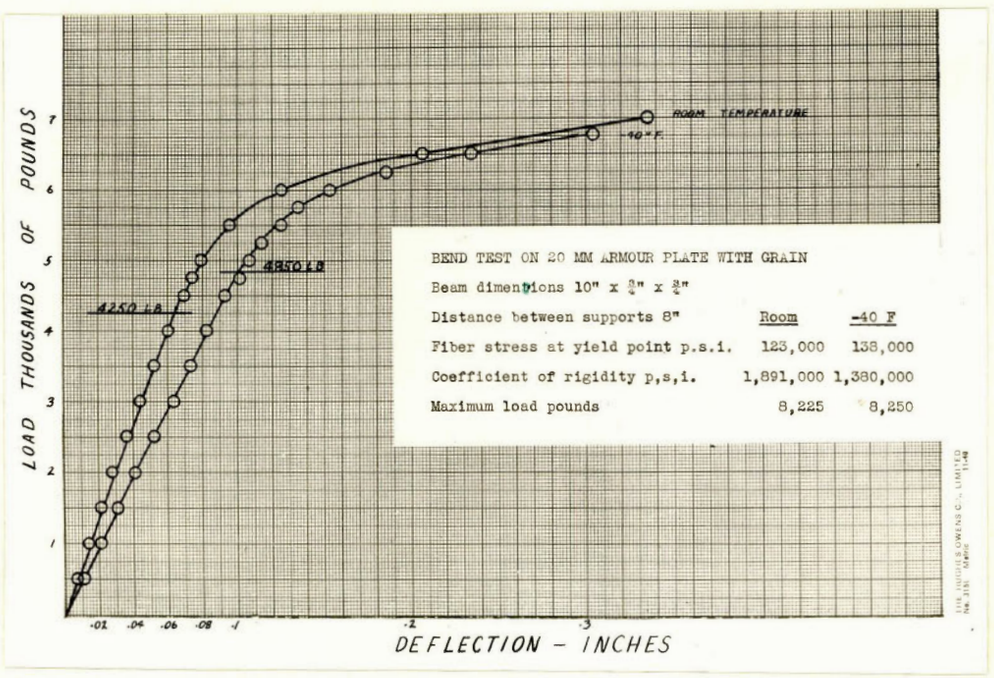


Figure 3.

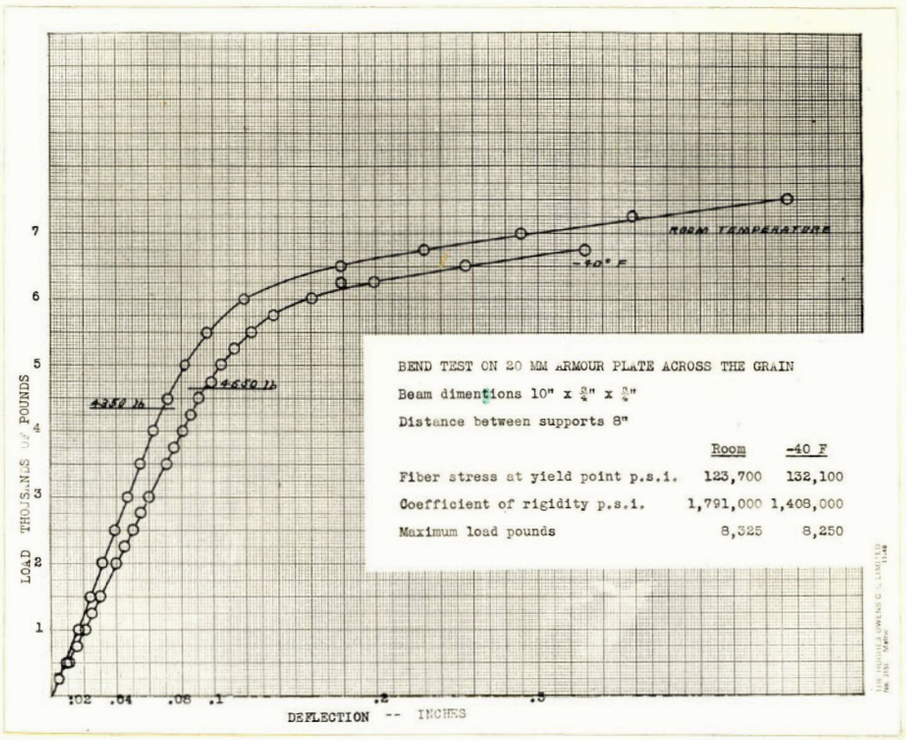
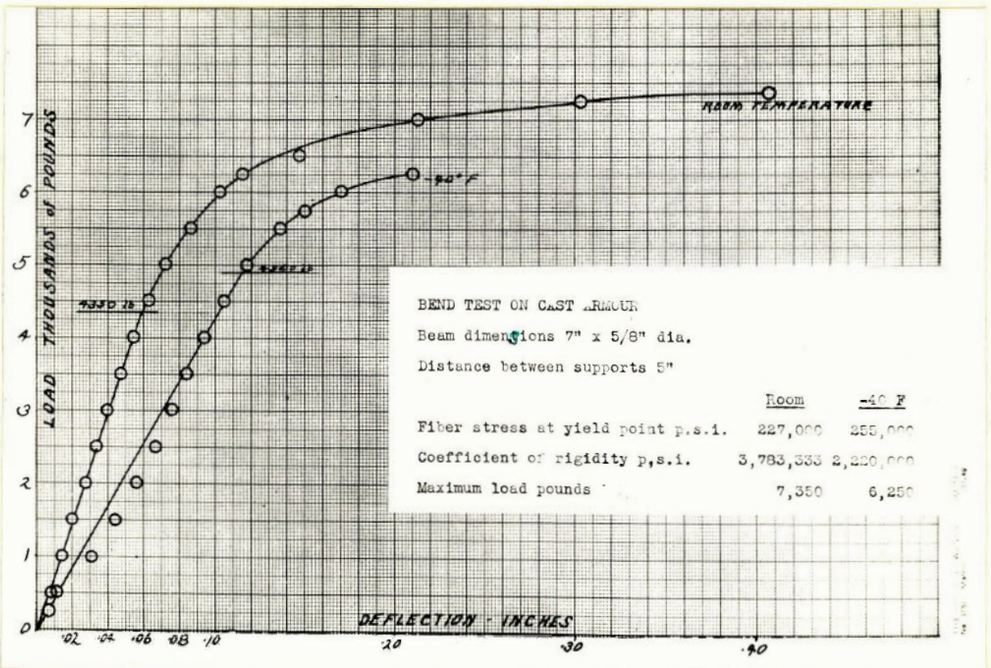


Figure 4.



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