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O T T A W A December 11th, 1941.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1132.

Tensile Tests on Steel for Tribal Class Destroyers.

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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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Tensile Tests on Steel for Tribal Class Destroyers.

Origin and Nature of Work:

On December 2nd, 1941, one steel test bar and one steel angle was received from the Bethlehem Steel Company, U. S. A., and on December 4th, 1941, eight steel samples were received from the Lukens Steel Company, Coatesville, Pa. This steel was offered by these companies as a substitute for "D" quality steel. The Admiralty specifies that "D" quality steel shall not contain more than 0.30 per cent

(Origin and Nature of Work, cont'd) -

carbon and that it shall meet the requirements of the following clauses in the specification:

"Test pieces are to be in accordance with test piece A cut either lengthwise or crosswise" -

"Ultimate strength not less than 37 tons and not more than 44 tons p.s.i. of section" -

"Minimum elongation of 17 per cent in a length of 8 inches" -

"The elastic properties shall be tested by means of a Ewing extensometer of 8-inch gauge length. The test is to be carried out as follows:

(1) A load of 4 tons p.s.i. of section shall be applied to the test piece and an extensometer reading taken.
(2) The load shall be increased to 17 tons p.s.i. and a second reading taken.
(3) The load shall be reduced to 4 tons p.s.i. and a third reading taken.
(4) The third reading shall not exceed the first reading by more than 0.0004 inch." -

The samples submitted by the United States steel companies were said to be representative of steel that they were willing to supply. The Bethlehem steel was said to have the following composition:

% Carbon	% Manganese	% Phosphorus	% Sulphur	% Silicon	% Vanadium	% Nickel	% Chromium	% Copper
0.16	1.00	0.018	0.033	0.14	0.09	0.11	0.05	0.13

The last three elements reported are undoubtedly present as residuals. The steel was reported to have the following physical properties:

Tensile strength, p.s.i.	Elastic limit, p.s.i.	Elongation in 8 inches, per cent	Reduction of area, per cent
79,940	62,760	23.7	59.3

Presumably, the Lukens Steel Company product is of

(Origin and Nature of Work, cont'd) -

the same type, but we have no data on this material. This steel has probably been supplied to U. S. Specification 46 S1 (INT), for high tensile steel, which specifies that the steel shall have the following composition and properties:

% Carbon	% Manganese	% Phosphorus	% Sulphur	% Silicon	% Copper	% Other elements	% Vanadium
0.18	1.45	0.04	0.05	0.25	0.25	0.25	0.08-0.14

	Tensile strength, p.s.i.	Yield point, p.s.i.	Elongation, per cent in 8 inches
Up to 3/8"	90,000	50,000	20
3/8" to 5/8"	87,000	50,000	20
5/8" to 1"	85,000	50,000	20
Over 1"	85,000	48,000	20

The United States manufacturers were willing to meet the British requirements with the exception of those governing the proof testing. Their position, in effect, was "take it or leave it."

The following tests were undertaken in order to determine the elastic properties of the Bethlehem and Lukens steels. The tests were witnessed by Commander (E) J. F. Bell and Lieut. (E) R. H. Scrivener.

Nature of Test Specimens:

With one exception, all samples were machined in the machine shops of the Bureau of Mines, Ottawa. Two specimens were machined from the angle supplied by the Bethlehem Steel Company, one to U. S. A. specifications (1.5 inches wide) and one to British specifications (2.0 inches wide), in order that the effect of specimen width might be determined. Only 1.5-inch-wide specimens were used in testing Lukens

(Nature of Test Specimens, cont'd) -

material, as the size of the samples submitted would not permit the use of a wider test specimen.

The following table gives data on the test specimens used:

Specification Identification	Identification number for this report.	Specimen thickness, in inches
Bethlehem $1\frac{1}{2}$" specimen	1.	0.625
Bethlehem $1\frac{1}{2}$" specimen machined from angle	2.	0.625
Bethlehem 2" specimen machined from angle	3.	0.623
Lukens 166122 TT	4.	0.383
" 166122 LT	5.	0.3675
" 19619-9 TT	6.	0.667
" 19619-9 LT	7.	0.666
" 19658-10 TT	8.	0.238
" 19658-10 LT	9.	0.229
" 23562-2 TT	10.	0.482
" 23562-2 LT	11.	0.473

Tensile Tests:

Tensile tests were made in an Amsler Universal testing machine set for 100,000 pounds capacity. Checks on elastic properties were made in accordance with the requirements of British specification for "D" steel, i.e., by measuring plastic deformation that occurred in loading from 4 to 17 long tons per square inch. A Riehle dial extensometer was used for this purpose. Results obtained are given in the following table. Values given for the yield point may only be regarded as approximate, being determined by the "drop of beam" method.

(Continued on next page)

(Tensile Tests, cont'd) -

Specimen No.	Ultimate strength, p.s.i.	Yield point, p.s.i.	Elongation, % in 8 in.	Apparent plastic deformation under proof load, in inches
1.	78,800	N.D.	22.7	0.0030
2.	81,400	60,500	22.6	0.0000
3.	82,400	57,800	26.0	0.0000
4.	96,500	68,700	18.1	0.00058
5.	94,800	71,600	21.0	0.0005
6.	74,600	55,200	25.0	0.0011
7.	75,000	54,300	26.5	0.0008
8.	72,600	55,500	22.5	0.0002
9.	74,500	56,300	21.5	0.0003
10.	85,400	63,500	21.2	0.0018⊛
11.	81,500	61,800	22.0	0.0003⊛

N.D. - Not determined.
⊛ - Measured at 4/3 proof load.

(Single copies of Stress-Strain Curves, plotted from results obtained after proof testing, have been forwarded to the naval department concerned. Duplicate copies may be obtained on request.)

Checks on Bethlehem Samples:

Proof test results obtained from the original Bethlehem test specimen and from test specimens machined from the Bethlehem angle varied so markedly that these materials were examined in order to find the reason for this difference. Samples for chemical analysis and microscopic examination were taken from each material. The following

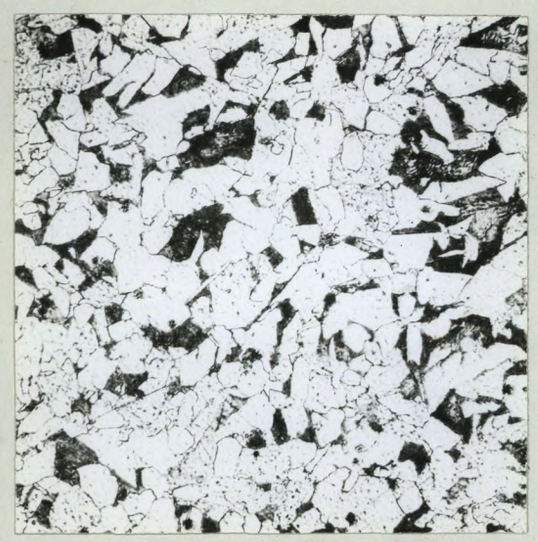
(Checks on Bethlehem Samples, cont'd) -

table gives the results of the chemical analysis:

SAMPLE	% Carbon	% Manganese	% Silicon	% Sulphur	% Phosphorus
Test specimen -	0.16	1.00	0.15	0.024	0.012
Angle -	0.16	1.02	0.14	0.025	0.013

Figures 1 and 2, photomicrographs at X200 magnification, show the respective structures of the two specimens, as revealed by an etch in 2 per cent nitric acid in alcohol.

Figure 1.



X200, nital etch.

TEST SPECIMEN.

Figure 2.

X200, nital etch.

ANGLE.

The white areas shown are ferrite and the black areas are pearlite, the eutectoid of iron carbide and ferrite. The structures are identical save that the angle appears to contain somewhat more pearlite.

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DISCUSSION OF RESULTS:

Proof Test Results Obtained from Bethlehem Samples -

The results obtained from chemical analyses and tensile tests made on the Bethlehem material check very closely with the values supplied by the manufacturer. These results indicate, then, that values given by the Bethlehem Steel Company can be relied upon. No effort was made to determine the alloys in the Bethlehem steel. The extremely close agreement between Bethlehem and Bureau of Mines results, however, indicates that both test specimen and angle were supplied from the same heat, which Bethlehem indicated contained some alloying elements. Although the chemical results showed that the Bethlehem test specimens and angle had the same analyses, the microscopic examination showed that the two materials had slightly different structures. The presence of a somewhat greater amount of pearlite in the angle indicates that it was cooled from the rolling temperature at a somewhat faster rate than was the test specimen. This accounts for its better elastic properties.

Shape of Test Specimen -

The British specification provides for the use of wider test specimens when thin plates are to be tested.

Results obtained from the 2-inch (the specified size) and 1½-inch Bethlehem specimens were quite similar, which would indicate that the use of a 1½-inch specimen throughout would not be expected to introduce a serious source of error.

Tensile Tests -

As mentioned on the attached graphs, Specimens 11 and 12 were tested at 4/3 proof load. Inasmuch as they show only 0.0018-inch and 0.0003-inch permanent elongations at

(Discussion of Results, cont'd) -

(Tensile Tests, cont'd) -

these loads, and as the proof load is below the bend on the stress-strain curve, these specimens must, in so far as the proof test is concerned, be regarded as satisfactory, as must Specimens 2, 3, 8, and 9, which meet the specified requirements. Specimens 4 and 5 show slightly more than the specified deviation under proof load but because the deviation from the specified value is so small and because the proof load is below the bend in the stress-strain curve, the material may be regarded as having met the proof test specification requirements. The same might be said of Specimens 6 and 7 although with less emphasis as the deviation from the required plastic deformation is greater for these specimens and their elastic limit more closely approaches the proof load.

Only one specimen, the test specimen supplied by Bethlehem, failed badly in the proof test. All other materials have satisfactory or very nearly satisfactory elastic properties, although the elastic properties of materials represented by Specimens 4 to 7 are definitely marginal in character.

It should be pointed out that Specimen 1 and Specimens 6 to 9 have ultimate strengths below the specified value. In the case of the last four specimens this is not of importance, as the materials have quite satisfactory elastic properties.

Conclusions:

If Bethlehem adhere to steel of the type represented by the angle they submitted, their material should be quite satisfactory. Nor should trouble be encountered with Lukens steel if the material supplied is similar to that of the test specimens tested. The presence of material with marginal elastic properties in the samples supplied by Lukens and the failure of one Bethlehem test specimen indicate, however, that material manufacture should be carefully controlled. Increasing the manganese content of the steel to around 1.25 to 1.50 per cent should considerably reduce the chance of off-grade material being encountered. The examination of Bethlehem material indicates that the cooling rate is of importance, so this should be watched. Check proof tests should be made from time to time, in order to determine whether or not the steel is meeting the elasticity requirements.

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