DEPARTMENT OF ENGINEERING RESEARCH

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Report

on

STRESS-RUPTURE TEST PROPERTIES OF TWO BETHLEHEM STEELS AT 1000°F.

by

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STRESS-RUPTURE TEST PROPERTIES OF TWO BETHLEHEM STEELS AT 1000°F.

Two groups of specimens were submitted by the Bethlehem Steel Company under date of January 10, 1941 for the determination of rupture test characteristics at 1000°F. One group was designated 23G258-ND and the other 28J343-ND. Sufficient tests were to be conducted to determine the usual logarithmic stress versus rupture time curves.

Conclusions

The 1000°F. rupture strength of material 28J343-ND was 41 and 58 per cent greater than for material 23G258-ND on the basis of the stresses for rupture in 10,000 and 100,000 hours, respectively. For time periods up to 100 hours the latter material was slightly stronger. The difference in the longer time strength of the two materials was due to the relative instability of material 23G258-ND.

Materials Tested

Originally six specimens, numbered consecutively from 1 to 6, of each material were submitted. During May it became evident that more specimens would be required to determine the rupture test curves with certainty. Two more specimens of each material, bearing the numbers 7 and 8, were submitted. These latter two specimens were specially heat-treated and the following room temperature physical properties were included in a

letter dated May 29, 1941 as evidence of the duplication of properties during the two heat treatments:

Specimen Designation	Heat Treatment	Yield Point Lb./Sq.In.	Tensile Strength Lb./Sq.In.	Elongation, % in 2 In.	Reduction of Area, %	Brinell Hardness
23G258-ND	First	114,600	137,600	20.5	55.0	269
23G258-ND	Second	112,000	135,000	18.5	54.9	269
28J343-ND	First	109,000	128,000	21.0	59.1	262
28J343-ND	Second	117,500	130,500	20.0	59.3	262

These results indicate that for all practical purposes the specimens heat treated at the two different times were duplicates.

Rupture Test Characteristics

The rupture test data obtained from the tests are given in Table I and shown graphically in Figure 1. The curves for both materials were the usual two intersecting straight lines when plotted to logarithmic coordinates. This type of curve is typical for materials which are subject to either structural or surface instability under the conditions of the tests.

The material designated 23G258-ND was somewhat stronger than the 28J343-ND material before the breaks in the stress-rupture time curves occurred. After the breaks occurred the latter material was considerably stronger. The stresses corresponding to definite fracture time periods were read from these curves and included in Table I.

The stresses for the two longer time periods are based on extrapolations which experience has indicated to be quite reliable.

Table I

Rupture Test Data for Two Bethlehem Steels at 1000°F.

Specimen Designation	Stress Lb./Sq.In.	Rupture Time Hours	Elongation % in 2 In.	Reduction of Area %
23G258-ND-5	86,750	S.T.T.T.	22.0	71.6
23G258-ND-6	80,000	0.04	22.5	72.3
23G258-ND-1	75,000	0.18	22.5	72.3
23G258-ND-8	65,000	19.2	22.0	51.9
23G258-ND-2	50,000	230.0	8.0	26.0
23G258-ND-3	42,000	512.0	8.0	14.6
23G258-ND-7	40,000	709.0	6.0	8.1
23G258-ND-4	35,000	1300.0	7.0	12.9
28J343-ND-6	85,250	S.T.T.T.	22.0	79.6
28J343-ND-5	70,000	1.12	28.0	81.3
28J343-ND-1	65,000	6.28	26.0	78.7
28J343-ND-2	50,000	494.0	16.0	75.0
28J343-ND-4	45,000	1184.0	20.0	70.8
28J343-ND-7	45,000	683.0	26.0	70.8
28J343-ND-8	42,000	1673.0	22.0	67.9

S.T.T.T. = Short-time tensile test.

Material	Stress for Rupture in Designated Time Periods, Hours 1	10	100	1000	10,000	100,000
23G258-ND	72,000	66,000	60,000	37,000	23,000	14,500
28J343-ND	71,000	63,000	56,000	45,000	32,500	23,000

For time periods less than 100 hours the strength of the 230258-ND material was slightly better than that of the 28J343-ND material. For time periods greater than 100 hours the strength of the 230258-ND material falls off more rapidly than does the other with the result that the latter material was almost 41 per cent stronger for fracture in 10,000 hours and about 58 per cent stronger for fracture in 100,000 hours.

The ductility characteristics of the 28J343-ND material were much better than for the other material. It showed practically no decrease in ductility with increasing rupture time while the other decreased from 22 to as low as 6 per cent elongation. These ductility characteristics indicate that the 230258-ND material may be subject to brittle failures in service at this temperature while the other material apparently will retain its ductility much better under the combined influence of time, temperature and stress.

Discussion of Results

The tests were conducted in accordance with A.S.T.M. specifications for high temperature testing of metals. The shorter time tests were run on a hydraulic tensile testing machine using the standard 0.505 inch diameter specimens. The first tests run were short-time tensile tests and the data obtained from these tests were as follows:

Tensile Properties at 1000°F.

Specimen Designation	Tensile Strength Lb./Sq.In.	Yield Stress 0.1%	0.2%	Proportional Limit Lb./Sq.In.	Elongation % in 2 In.	Reduction of Area %
23G258-ND5	86,750	68,000	72,500	45,000	22.0	71.6
28J343-ND6	85,250	66,000	70,500	42,500	22.0	79.6

The two materials were very nearly the same on the basis of this shorter time test.

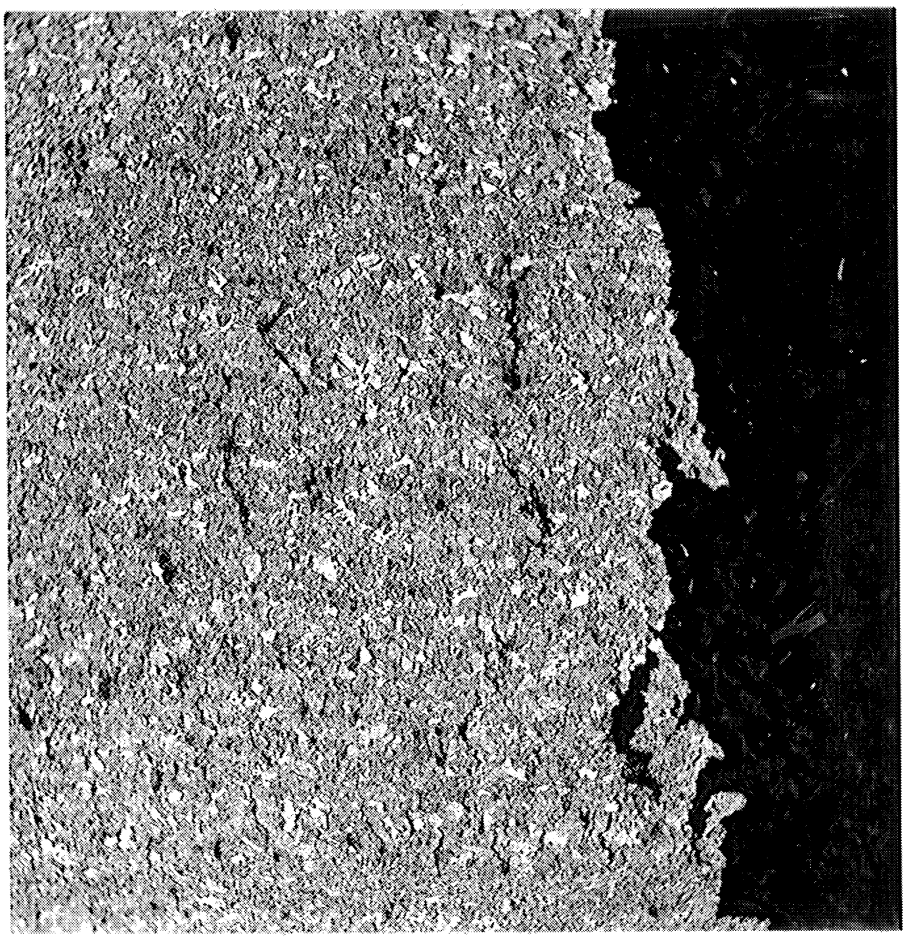
The longer time tests were conducted in machines which apply a constant load by means of a lever and a series of knife edges. Each specimen was in an individual furnace and the temperature maintained by an automatic controller. When this work was started, rupture test units large enough to apply the required stresses on 0.505 inch diameter specimens were not available. Therefore the diameters of the specimens were reduced to 0.250 inches. The smaller specimens have been found to give the same results as larger specimens provided that the material possesses surface stability under the conditions of the test. Therefore the results for time periods longer than 100 hours were obtained on the smaller diameter specimens using a two inch gage length, except for specimen number 7 of each material. At the time the last two specimens were submitted rupture test units were available which could apply the required stresses. Therefore tests were conducted on the number 7 specimen of each material using 0.505 inch diameter specimens.

In the case of material 23G258-ND very good agreement was obtained between the two size specimens. The agreement was not as good for the other material. This may be due to some variation introduced by the specimens being heat treated at different times. It should be pointed out that the longest test on the undersize specimens from material 28J343-ND was also conducted on the second shipment of specimens and good agreement obtained with those previously tested. It may well be that the difference was due to different deformation characteristics of the two size specimens of this relatively ductile material.

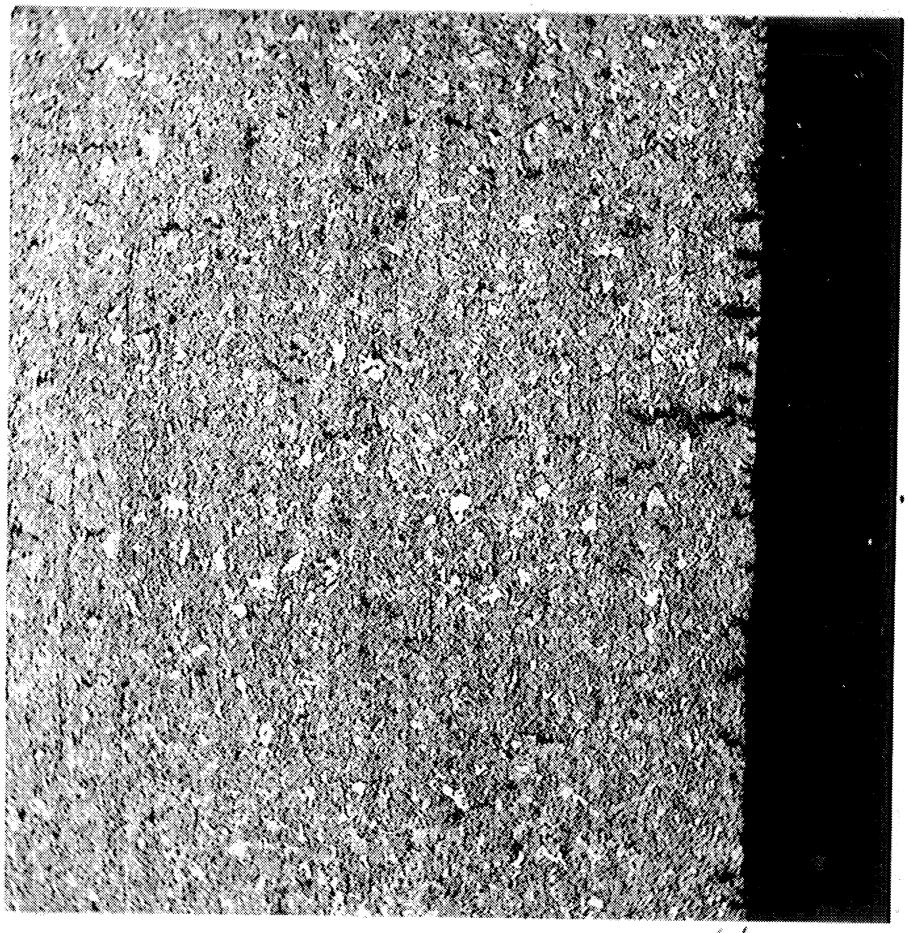
The two longest time rupture test specimens of each material were examined metallographically and photomicrographs taken of the surface and fracture of each specimen. The photomicrographs are shown in Charts 1 and 2. The grain size of the 28J343-ND material was much finer than that of the other material. The surface of both materials was slightly oxidized. However, there were numerous small cracks of the intergranular type present at the surface and near the fracture of the 23G258-ND specimen, and the fracture was relatively strain free. The specimen of 28J343-ND material showed no evidence of cracking and strained and distorted crystals were present near the fracture.

The lower strength and low ductility of material 23G258-ND was either due to the appearance of these cracks or to the development of a brittle condition which made it subject to cracking.

Chart 1
Microstructure of Bethlehem 23G258-ND-4 Steel Rupture Test Specimen
1300 Hours for Rupture at 1000°F. Under a Stress of 35,000 Pounds

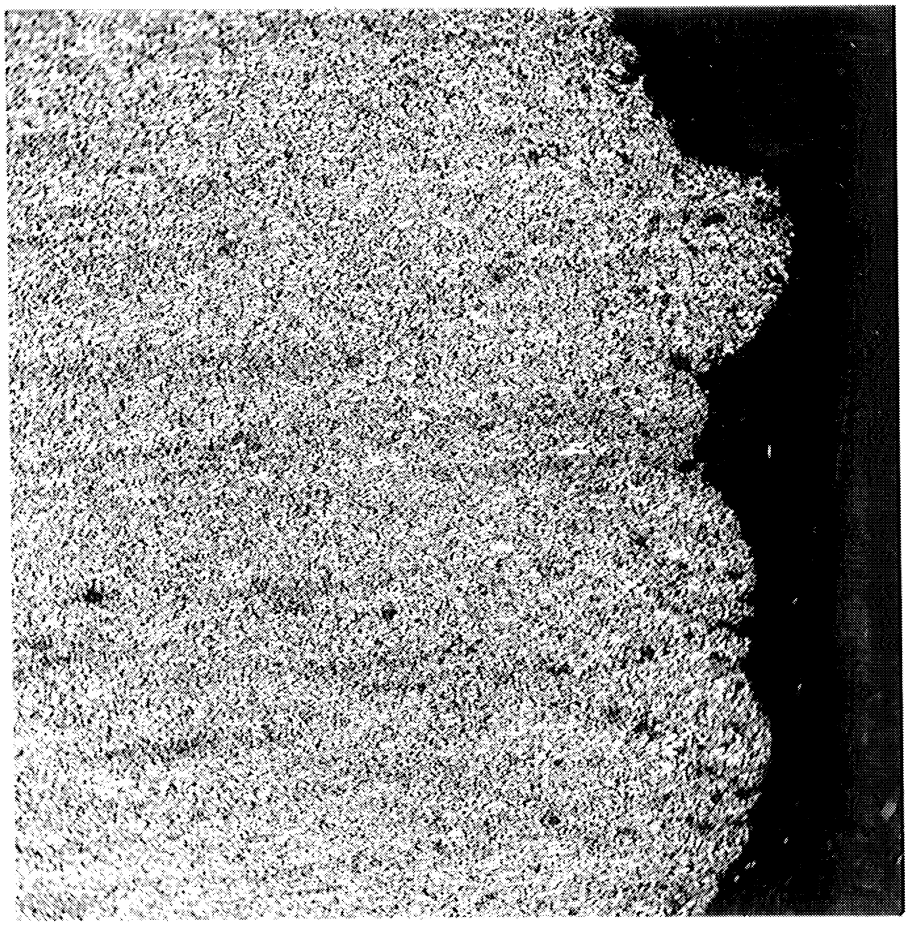


Fracture - X100D 10620



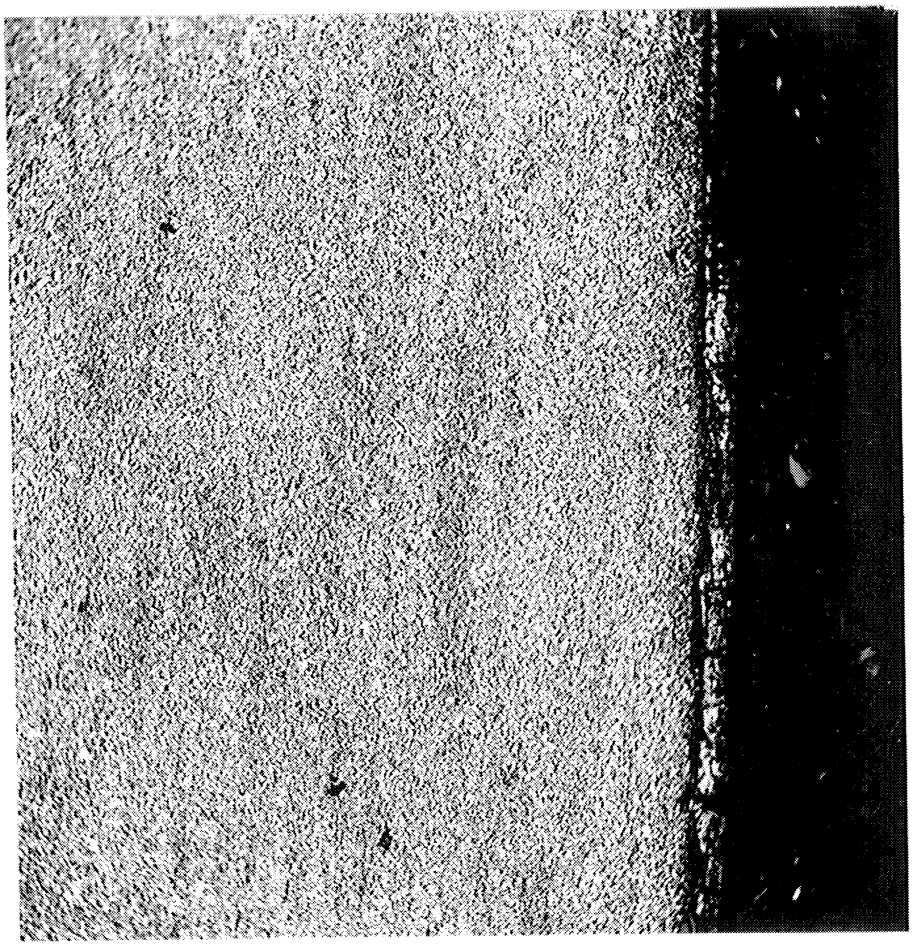
Surface - X100D 10621

Chart 2
Microstructure of Bethlehem 28J343-MD-8 Steel Rupture Test Specimen
1673 Hours for Rupture at 1000°F. Under a Stress of 42,000 Pounds



10622

Fracture - X100D



10623

Surface - X100D