DEPARTMENT OF ENGINEERING RESEARCH

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Report

on

CREEP PROPERTIES OF HASTELLOY A, HASTELLOY B AND TIMKEN 16CR-25NI-6MO MATERIALS AT 1300°F.

by

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CREEP PROPERTIES OF HASTELLOY A, HASTELLOY B AND TIMKEN 16CR-25NI-6MO MATERIALS AT 1300°F.

This report sets forth the results of creep tests at 1300°F. on Hastelloy A, Hastelloy B and Timken 16Cr-25Ni-6Mo materials. Stresses of 8000 and 15,000 pounds per square inch were used on each material and the tests were continued for 1460 hours. The results of room temperature tensile, impact and hardness tests, as well as a metallographic examination, on the completed creep test specimens are included.

These tests were authorized by Mr. Robert Matters in letter form on October 4, 1940. The specimens tested were submitted on November 12, 1940.

Creep Properties.

Two specimens each of Hastelloy A, Hastelloy B and Timken 16Cr-25Ni-6Mo materials were submitted for creep testing at 1300°F. A stress of 8000 pounds was used on one specimen of each material and a stress of 15,000 pounds on the other. Constant temperature and stress procedure was used in accordance with A.S.T.M. standard procedure for such creep tests. The tests were continued for 1460 hours, rather than the standard 1000 hours, since certain of the tests showed decreasing creep rates up to 900 hours of testing. The creep rates during the last 500 hours of testing were reported, since the slope of the time-elongation curves were reasonably constant during this time period.

The time-elongation curves obtained are presented in Figures 1 through 3. The creep rates obtained from these curves for the last 500 hours of testing are presented in Table I. These values are the second stage creep rates except in the case of the Hastelloy A specimen under 15,000 pounds stress which went into the third stage of creep after 900 hours. The final creep rate in this latter case was 5.48 per cent per 1000 hours as compared to 4.12 per cent per 1000 hours in the second stage.

On the basis of the creep rates obtained the 16Cr-25Ni-6Mo material has the best load carrying capacity at 1300°F. of the three materials considered. Hastelloy B is intermediate in this respect and Hastelloy A is the weakest. The creep rates under 8000 pounds stress were 0.016, 0.097 and 0.19 per cent per 1000 hours in the order mentioned above; under 15,000 pounds the rates were 0.076, 0.24 and 5.48 per cent per 1000 hours.

Ordinarily such creep data is plotted to logarithmic coordinates for the purpose of extrapolation to obtain a stress to give a creep rate of 0.01 or 0.10 per cent per 1000 hours. However, more than two points are generally considered necessary to establish such curves. In the present case the creep data has been plotted on Figure 4 only for the purpose of presenting the data in a familiar form. The points for each material have been connected by dotted lines. It is evident from this figure that

Table I

Creep Rates for Hastelloy A, Hastelloy B and 16Cr-25Ni-6Mo Materials Under Indicated Stresses at 1300°F.

(Creep Rates were obtained from time-elongation curves over the 900 to 1400 hour time period)

Material	Temperature Deg. Fahr.	Stress Lb./Sq.In.	Creep Rate %/1000 Hours
Hastelloy A	1300	8,000	0.19
Hastelloy A	1300	15,000	5.48 (4.12 in 2nd stage)
Hastelloy B	1300	8,000	0.097
Hastelloy B	1300	15,000	0.24
16Cr-25Ni-6Mo	1300	8,000	0.016
16Cr-25Ni-6Mo	1300	15,000	0.076

the data obtained for Hastelloy A do not allow approximation of either of the standard creep stresses. The stress for a creep rate of 0.1 per cent per 1000 hours for Hastelloy B is somewhat greater than 8000 pounds per square inch; the data gives no indication of the stress for a creep rate of 0.01 per cent per 1000 hours because the experimental values are much greater than that rate. The data for 16Cr-25Ni-6Mo material indicate that the stress for a creep rate of 0.01 per cent per 1000 hours is between 6000 and 7000 pounds and for 0.10 per cent per 1000 hours above 16,000 pounds.

Stability Tests.

The tensile, impact and hardness properties of the completed creep test specimens were determined at room temperature. The specimens creep tested under a stress of 8000 pounds were used for the tensile tests; and the 15,000 pound specimens were cut up to provide two modified Izod impact specimens, hardness specimens and sections suitable for metallographic examination.

Tensile Tests: The results of the room temperature tensile tests on the 8000 pound completed creep test specimens are given in Table II. These results show that the strength properties of Hastelloy B were much higher than either Hastelloy A or Timken's 16Cr-25Ni-6Mo material. Hastelloy A was somewhat stronger than the 16Cr-25Ni-6Mo. The ductility properties were the direct reverse of the strength properties, since the

Table II

Room Temperature Tensile Properties of Completed Creep Test Specimens

Material	Temp. °F.	Stress Lb./Sq.In.	Time Hrs.	Tensile Strength Lb./Sq.In.	Yield Stress Lb./Sq.In. 0.1%	Yield Stress Lb./Sq.In. 0.2%	Proportional Limit Lb./Sq.In.	Elongation % in 2 In.	Reduction of Area %
Hastelloy A	1300	8000	1460	123,500	56,500	59,500	40,000	12.0	12.6
Hastelloy B*	1300	8000	1460	191,500	159,000	168,000	130,000	2.0	1.5
16-25-6	1300	8000	1460	108,000	44,000	49,000	25,000	20.0	24.4

*The original specimen broke in the threads at 105,000 lb./sq.in. (below the proportional limit). A specimen with a diameter of 0.313 inches and a gage length of 1.3 inches was then machined from the broken specimen and the reported tensile properties obtained.

Table III

Impact and Hardness Properties of Completed Creep Test Specimens

Material	Creep Test Conditions: Temp. °F.	Stress Lb./Sq.In.	Time Hours	Izod Impact* Ft.-Lb.	Hardness: Rockwell "B"	Rockwell "C"	Converted Brinell
Hastelloy A	1300	15,000	1460	14, 11	100	----	240
Hastelloy B	1300	15,000	1460	3, 3	---	49	472
16Cr-25Ni-6Mo	1300	15,000	1460	22, 23	94-96	----	200-216

*Specimens smaller than standard: 0.365" Sq. with 0.050" V-notch.

16Cr-25Ni-6Mo material possessed the highest elongation, Hastelloy A intermediate and Hastelloy B lowest with only 2 per cent elongation.

The tensile properties of the Hastelloy B specimen were obtained on an undersize specimen, since the original creep specimen fractured in the threads during testing at a stress below the proportional limit. An undersize specimen, 0.313 inches in diameter, was then machined from the creep specimen and the reported values obtained.

<u>Impact Tests</u>: Modified Izod impact specimens were obtained from the 15,000 pound completed creep test specimens after removing a section three-eighths of an inch long from the center of the gage section for metallographic examination. The remaining halves of the specimens were machined into bars 0.365 inches square with a V-notch 0.050 inches deep. The results obtained are given in Table III. The 16Cr-25Ni-6Mo material possessed an impact value of 22 foot-pounds, the Hastelloy A, 12 foot-pounds and the Hastelloy B, 3 foot-pounds.

<u>Hardness</u>: Suitable Rockwell hardness values were determined on the metallographic samples and are also presented in Table III along with the converted Brinell hardness. The Hastelloy B possessed a Brinell hardness of approximately 472 as compared to 240 for Hastelloy A and 210 for the 16Cr-25Ni-6Mo material.

<u>Metallographic Examination</u>: Longitudinal sections from the center of each of the 15,000 pound specimens were prepared for metallographic examination and electrolytically etched with 10 per cent NaCN solution. The structures were photographed at 100X and 1000X magnification and are presented in Charts 1 through 3.

Examination of Chart 1 indicates that the Hastelloy A consisted of three phases. A globular phase, which was stained lemon color when lightly etched, was in the form of bands lengthwise to the specimen. This constituent became black on longer etching. In addition a constituent consisting of small spheroidal particles was distributed throughout the matrix although it was heavier in the grain boundaries and twins.

The Hastelloy B material also contained a globular phase strung out lengthwise to the specimen as is shown in Chart 2. This phase seemed more resistant to etching than that in Hastelloy A and did not color up as much. There was also a fine constituent distributed through the matrix and somewhat concentrated in the grain boundaries. This latter constituent is not as evident as in the Hastelloy A material since the matrix was completely filled with strain lines.

The structure of the 16Cr-25Ni-6Mo material is shown in Chart 3. This material likewise contained a globular phase strung out in the direction of rolling. It was very rapidly attacked by the NaCN during etching. It stained a light blue in color on light etching and was entirely removed on further etching. In addition a generally precipitated phase was present, although it likewise was somewhat heavier in the grain boundaries.

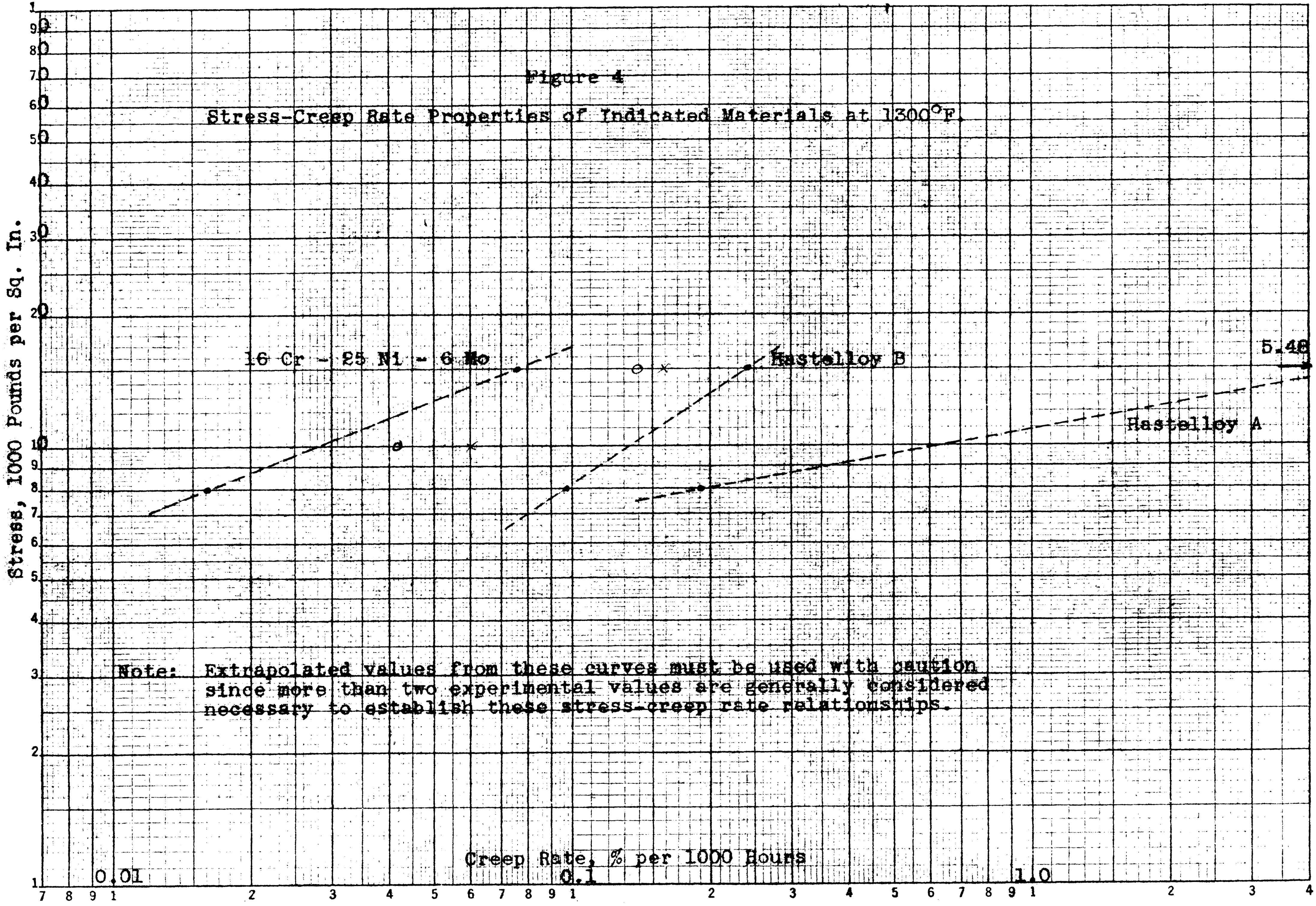
CONCLUSIONS

Creep tests under stresses of 8000 pounds and 15,000 pounds per square inch were conducted at 1300°F. for 1460 hours on specimens of Hastelloy A, Hastelloy B and Timken 16Cr-25Ni-6Mo materials. The best creep rates were obtained on the 16Cr-25Ni-6Mo material, Hastelloy B was intermediate and Hastelloy A showed the highest rates of creep.

Room temperature tests on the completed creep test specimens indicated that the 16Cr-25Ni-6Mo material possessed the lowest strength and hardness, the highest ductility and impact strength of the three materials considered. Hastelloy A was intermediate in regard to these properties. Hastelloy B possessed very high strength and hardness but very low impact and ductility. Photomicrographs at 100X and 1000X magnification of the completed 15,000 pound stress creep test specimens are also included.

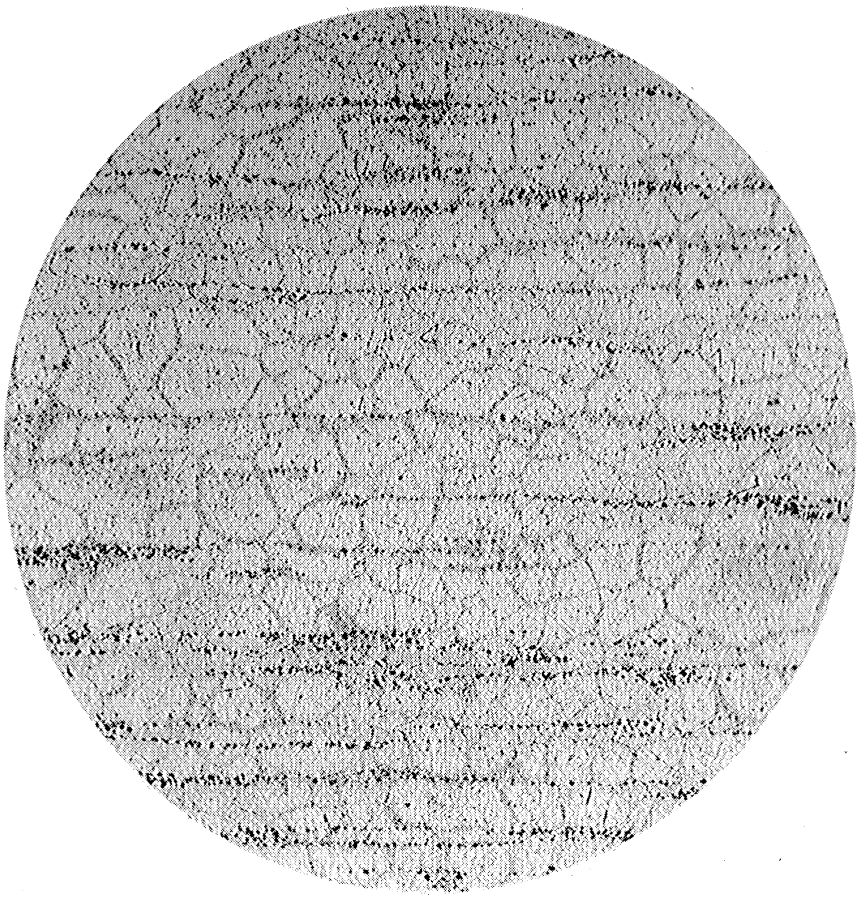
Figure 4

Stress-Creep Rate Properties of Indicated Materials at 1300°F.

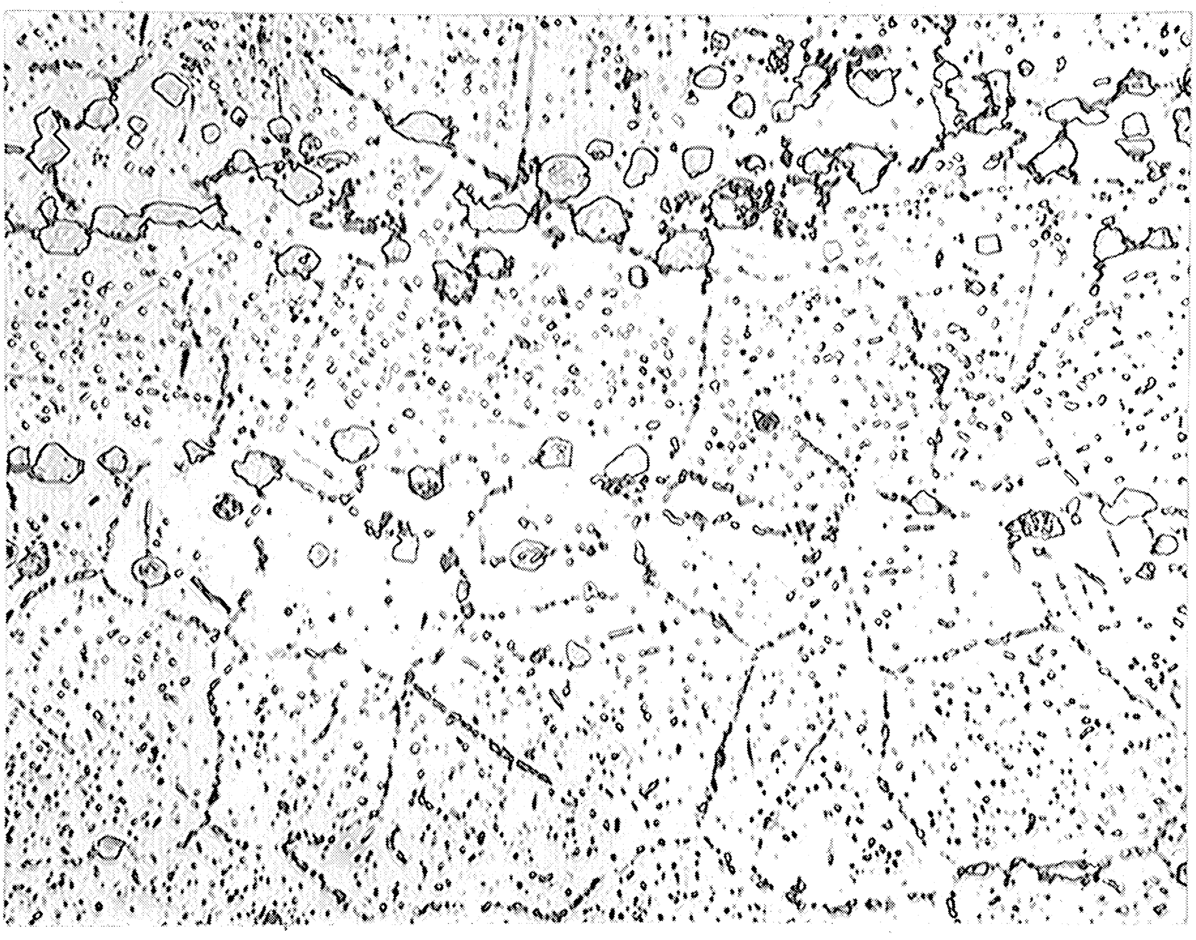


Note: Extrapolated values from these curves must be used with caution since more than two experimental values are generally considered necessary to establish these stress-creep rate relationships.

Chart 1
Microstructure of Hastelloy A Creep Specimen
1460 Hours at 1300°F. Under a Stress of 15,000 Pounds
Electrolytic NaCN Etch

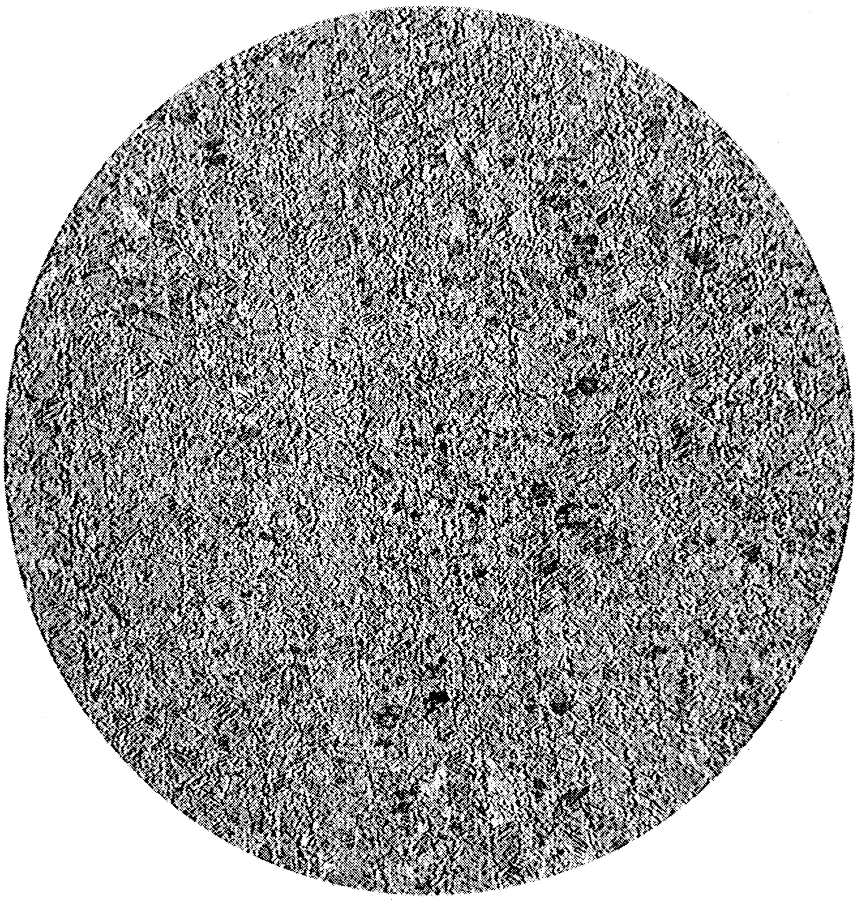


X100D (10467)

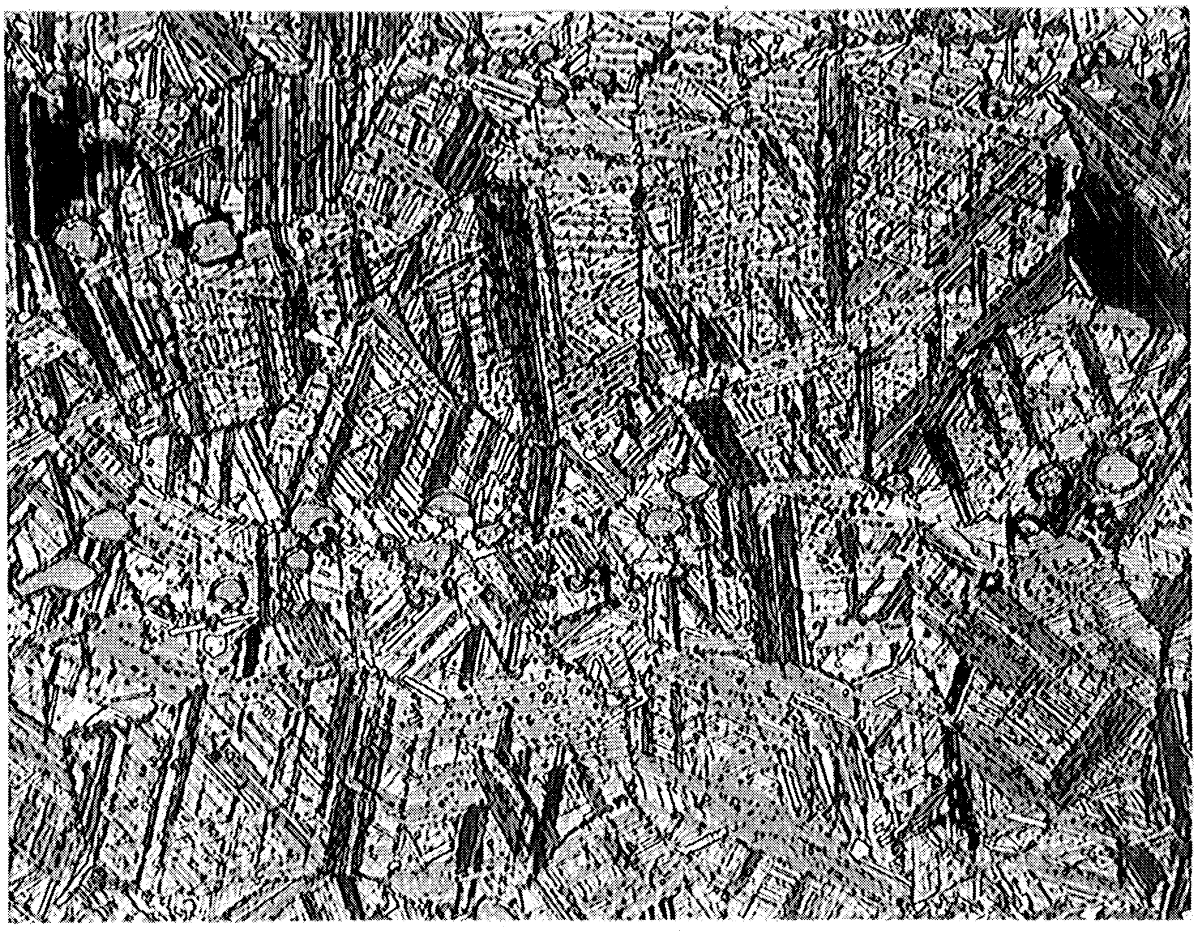


X1000D (10468)

Chart 2
Microstructure of Hastelloy B Creep Specimen
1460 Hours at 1300°F. Under a Stress of 15,000 Pounds
Electrolytic NaCN Etch

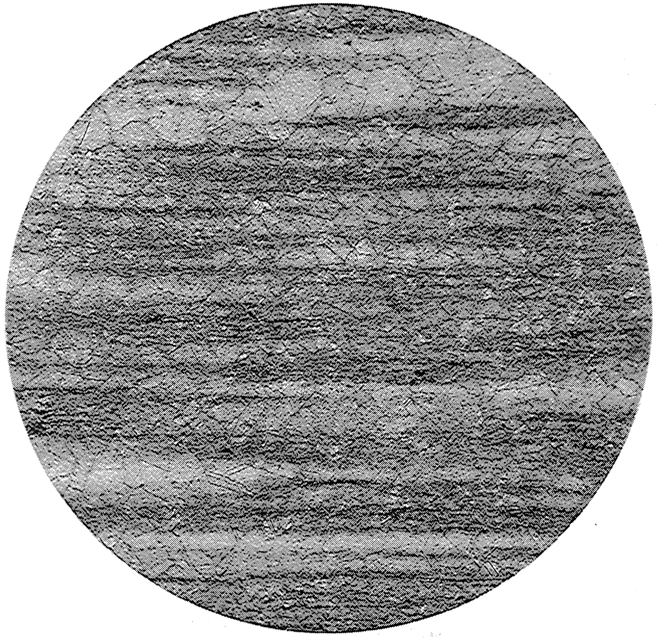


X100D (10469)

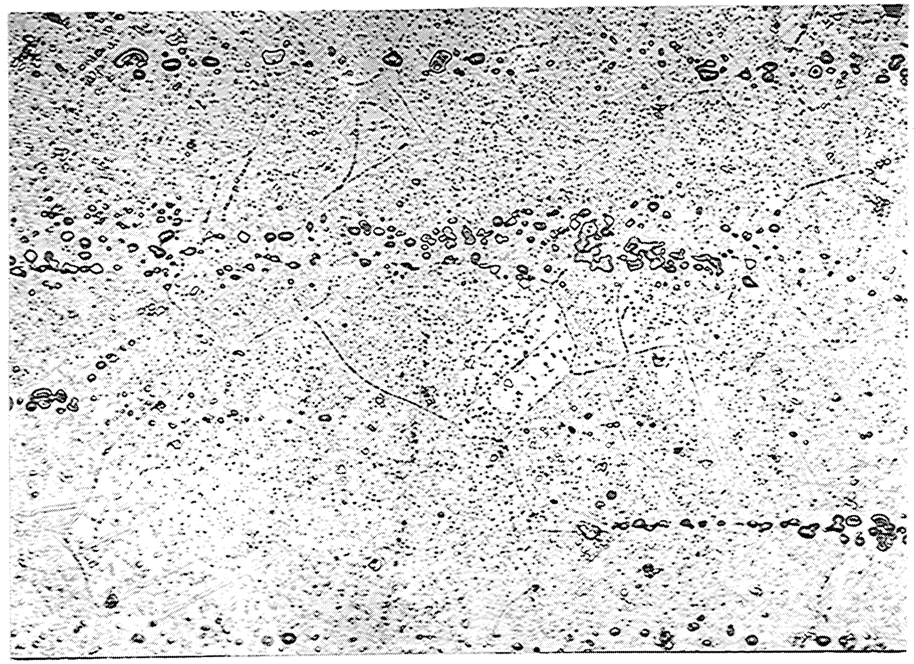


X1000D (10470)

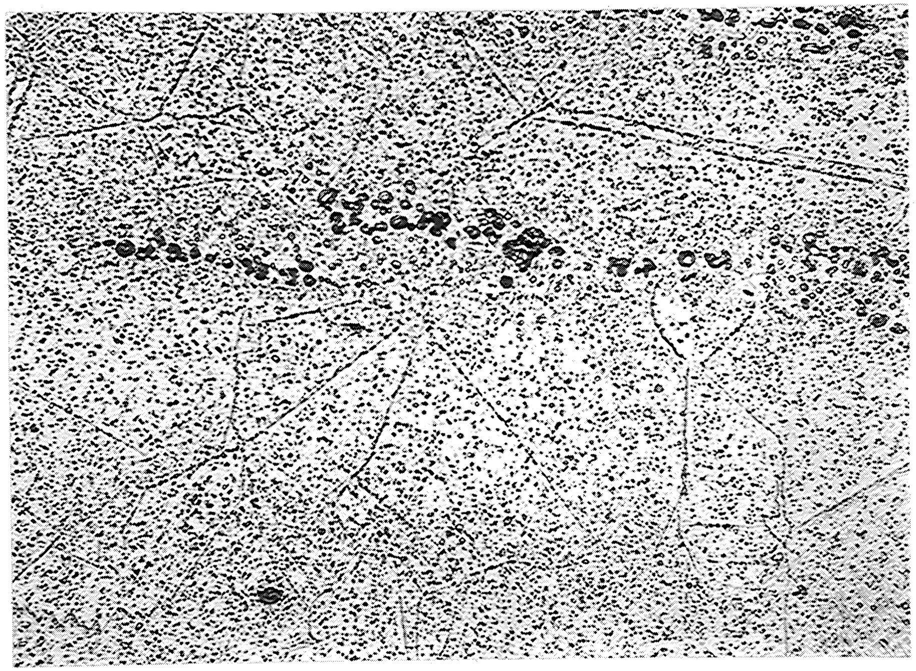
Chart 3
Microstructure of Timken 16-25-6 Creep Specimen
1460 Hours at 1300°F. Under a Stress of 15,000 Pounds
Electrolytic NaCN Etch



a) X100D (10471)



b) X1000D - Etched 2 Seconds (10472)



c) X1000D - Etched 10 Seconds (10473)