REPORT

ON

RUPTURE PROPERTIES OF A TURBINE-WHEEL FORGING OF "17-22-A"V STEEL AT 1100° AND 1200°F

By

R. Jackowski

J. W. Freeman

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THE TIMKEN ROLLER BEARING COMPANY
STEEL AND TUBE DIVISION
CANTON, OHIO

RUPTURE PROPERTIES OF A TURBINE-WHEEL FORGING OF "17-22-A"V STEEL AT 1100° AND 1200°F

The object of this investigation was to determine if the high ruptures strengths at 1100° and 1200°F characteristic of "17-22-A"V steel would be reproduced in an upset-pancake turbine-wheel forging. This work is a continuation of the program for The Timken Roller Bearing Company to develop "17-22-A"V steel for use in forgings of the type required in the gas turbines in the jet-aircraft industry.

In addition to the rupture properties, the report presents time-elongation curves for the tests, together with derived stress - time for total deformation data. Microstructures before and after testing are shown.

SUMMARY AND CONCLUSIONS

Examination of the data led to the following conclusions.

1. The rupture strengths and elongation values obtained for the forging were similar to those previously obtained for the alloy. The values were as follows:

Temp (°F)	Rupture Strength (psi)		Rupture Elongation (%)	
	100-hr	1000-hr	100-hr	1000-hr
1100	51,000	33,000	3.5	4.0
1200	25,000	14,000	10.0	9.0

2. The rather high stress levels used in the rupture tests resulted in early onset of third stage creep and restricted total deformation data to 1.0 and 0.5 percent.

3. The original structure of the specimen was fine bainite which showed evidence of additional tempering during testing, particularly at 1200°F.

TEST MATERIALS

A number of 0.250-inch diameter tensile specimens were supplied from a forging of "17-22-A"V analysis (Heat 11131), having the following reported chemical composition:

C	Mn	P	S	Si	Cr	Mo	V	Ni
0.25	0.59	0.016	0.013	0.73	1.34	0.53	0.82	0.30

The upset forging was 5 inches thick by 25 inches in diameter. Pie-shaped segments approximately 2 to 2-1/2 inches in width were normalized from 1850°F and tempered for 6 hours at 1200°F to 341 Brinell. The specimens were taken tangentially at the rim from these segments.

RESULTS

The rupture data obtained in this investigation are presented in Table I and in the stress - rupture time curves of Figure 1. The 100-hour and 1000-hour rupture strengths and elongation values at 1100° and 1200°F are as follows:

Temperature (°F)	Rupture Strength (psi)		Elongation (%)	
	100-hr	1000-hr	100-hr	1000-hr
1100	51,000	33,000	3.5	4.0
1200	25,000	14,000	10.0	9.0

The time-elongation curves obtained from the rupture tests at both temperatures are shown in Figures 2 and 3. The 1.0- and 0.5-percent total deformation data obtained from the time-elongation curves are compared with the stress-rupture curves in Figure 4 and the following tabulation:

Temp	100-Hour Strengths (psi)			1000-Hour Strengths (psi)		
	Rupture	Total Deformation of		Rupture	Total Deformation of	
(°F)	Strength	1.0%	0.5%	Strength	1.0%	0.5%
1100	51,000	45,500	36,000	33,000	30,000	--
1200	25,000	20,500	17,000	14,000	12,000	10,000

The microstructure prior to and after testing are shown in Plates 1 through 3. The original structure, Plate 1, consisted of a fine acicular, tempered bainite. There appears to be very little difference in the structure after testing other than some increase in the degree of tempering. The structure of the specimen rupture tested at 1200°F, Plate 3, showed considerably more transcrystalline cracking at the fracture than did the specimen tested at 1100°F, Plate 2. There were very few cracks visible at the surface of the specimens.

The tempering of the specimens during testing was substantiated by hardness tests taken on the longer time fractured specimens. The hardness tests showed a considerable decrease in hardness after testing, particularly at 1200°F, as may be seen by the following tabulation:

Test Conditions			
Temp (°F)	Stress (psi)	Rupture Time (hrs)	Brinell Hardness Number*
Original Material			333
1100	35,000	759	280
1200	13,000	1320	178

* Converted from 10 kg Diamond Pyramid Hardness Test.

DISCUSSION OF RESULTS

Appraisal of the rupture data at 1100°F for the forging from Heat 11131 and comparison with the results obtained for simulated forgings from Heat 02359 reported in Report Number 200 indicated similar properties, despite the differences in the normalizing temperature used and in the section size heat treated. The comparative 100-hour and 1000-hour rupture strengths for the forgings from the experimental heat and from Heat 11131 at 1100°F are as follows:

Heat No.	Heat Treatment	B H N	Strength (psi)		Elongation (%)	
			100-hr	1000-hr	100-hr	1000-hr
11131	N. 1850°F + Tempered 2 to 2-1/2 inch wide segments from a 5 x 25 inch diameter forging	341	51,000	33,000	3.5	4.0
02359	N. 1800°F + Tempered 2 x 22 inch diameter forging	302/337	45,000 to 53,000	30,000 to 36,500	5 to 8.5	3 to 4.5

Only limited rupture data at 1200°F from previous tests on bar stock are available for "17-22-A"V steels. These data presented in Report Number 204 suggested that the rupture strengths at 1200°F for "17-22-A"V bar stock in the condition giving the best response to heat treatment was in the order of 28,000 to 30,000 psi for 100 hours and 13,000 to 15,000 psi for 1000 hours with elongations of approximately 10 and 3 to 5 percent, respectively. Thus, the 100-hour strength of 25,000 psi and the elongation of 3.5 percent appear to be slightly low. The 1000-hour strength of 14,000 psi and elongation of 4 percent are well within this range.

The time-elongation curves obtained for this investigation show the type of deformation the material undergoes during relatively short duration, high stress - rupture tests. The early onset of the third stage of creep should be noted. The first and second stage creep of the time-elongation curves at both temperatures were of short duration.

The 1.0- and 0.5-percent total deformation curves obtained at both temperatures were approximately parallel to the stress - rupture time curves and fairly close together. There were no other total deformation data available for "17-22-A"V steel for use in comparison.

The microstructure of the forging consisted of a more uniform structure of fine acicular tempered bainite than that obtained for the simulated disk from Heat 02359. This may be a result of either the difference in section size of each heat, a difference in the normalizing temperature used for each heat, or a combination of both.

Comparison of the structures before and after rupture testing differed only in the degree of tempering, with the 1200°F fractured specimen showing the greatest amount of tempering. It appears that when bainite is tempered the sharp, clean cut acicular pattern of bainite transforms to a lighter structure that is very difficult to resolve under the microscope. The degree of tempering was more evident from the hardness tests than by the changes in microstructure.

TABLE I

Rupture Test Data at 1100° and 1200°F for an

Upset Pancake Forging of "17-22-A"V Steel (Heat 11131)

(Tangential specimens from the rim of a 2 to 2-1/2 inch wide pie-shaped segments cut from a 5-inch thick by 25-inch diameter forging normalized from 1850°F and tempered 6 hours at 1200°F to 341 Brinell hardness.)

Code No.	Temp (°F)	Stress (psi)	Rupture Time (hours)	Elongation (% in 2 in.)	Reduction of Area (%)
T1	1100	50,000	107	3.5	8.5
T3	1100	43,000	270	4.5	7.0
T5	1100	35,000	759	4.0	5.5
T2	1200	30,000	55	9.5	23.5
T4	1200	23,000	145	11.5	38.5
T6	1200	13,000	1320	9.0	16.5

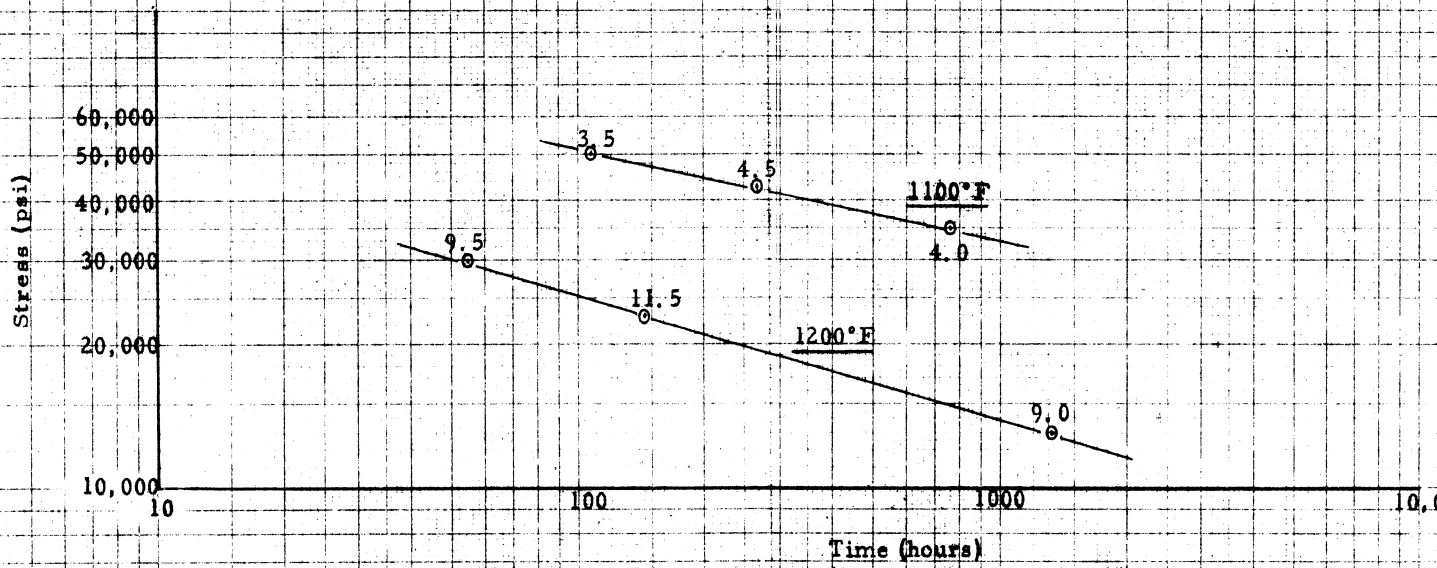


Figure 1. Stress-Rupture Time Curves for "17-22A" V Steel (Heat 1134) Forging at 1100°F and 1200°F. Tangential specimens taken from the rim of a 2 to 2-1/2 inch wide pie-shaped section taken from a 5-inch thick by 45-inch diameter forging. Segments normalized from 1850°F and tempered for 6 hours at 1200°F to 341 Brinell.

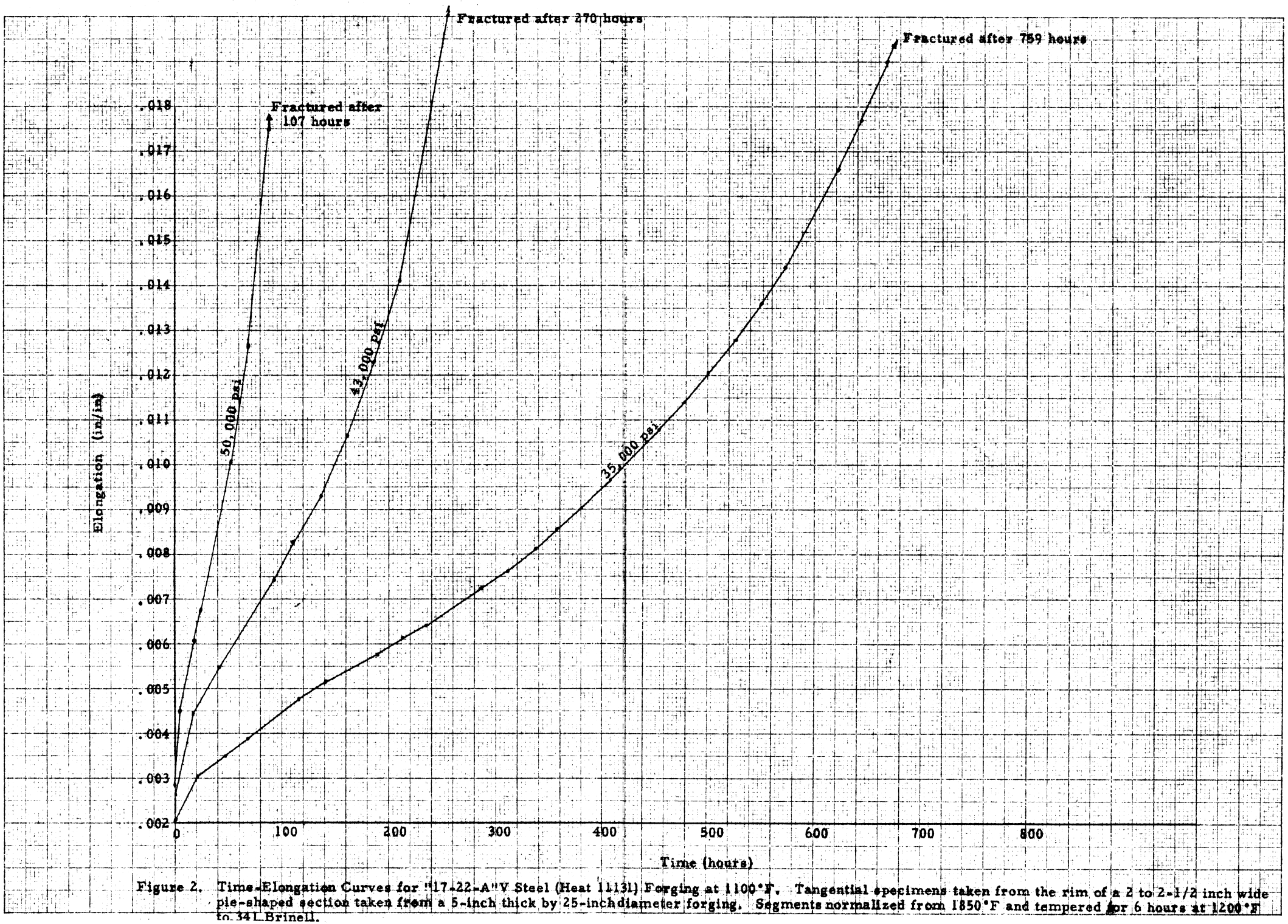


Figure 2. Time-Elongation Curves for "17-22-A"V Steel (Heat 11131) Forging at 1100°F. Tangential specimens taken from the rim of a 2 to 2-1/2 inch wide pie-shaped section taken from a 5-inch thick by 25-inch diameter forging. Segments normalized from 1850°F and tempered for 6 hours at 1200°F to 341 Brinell.

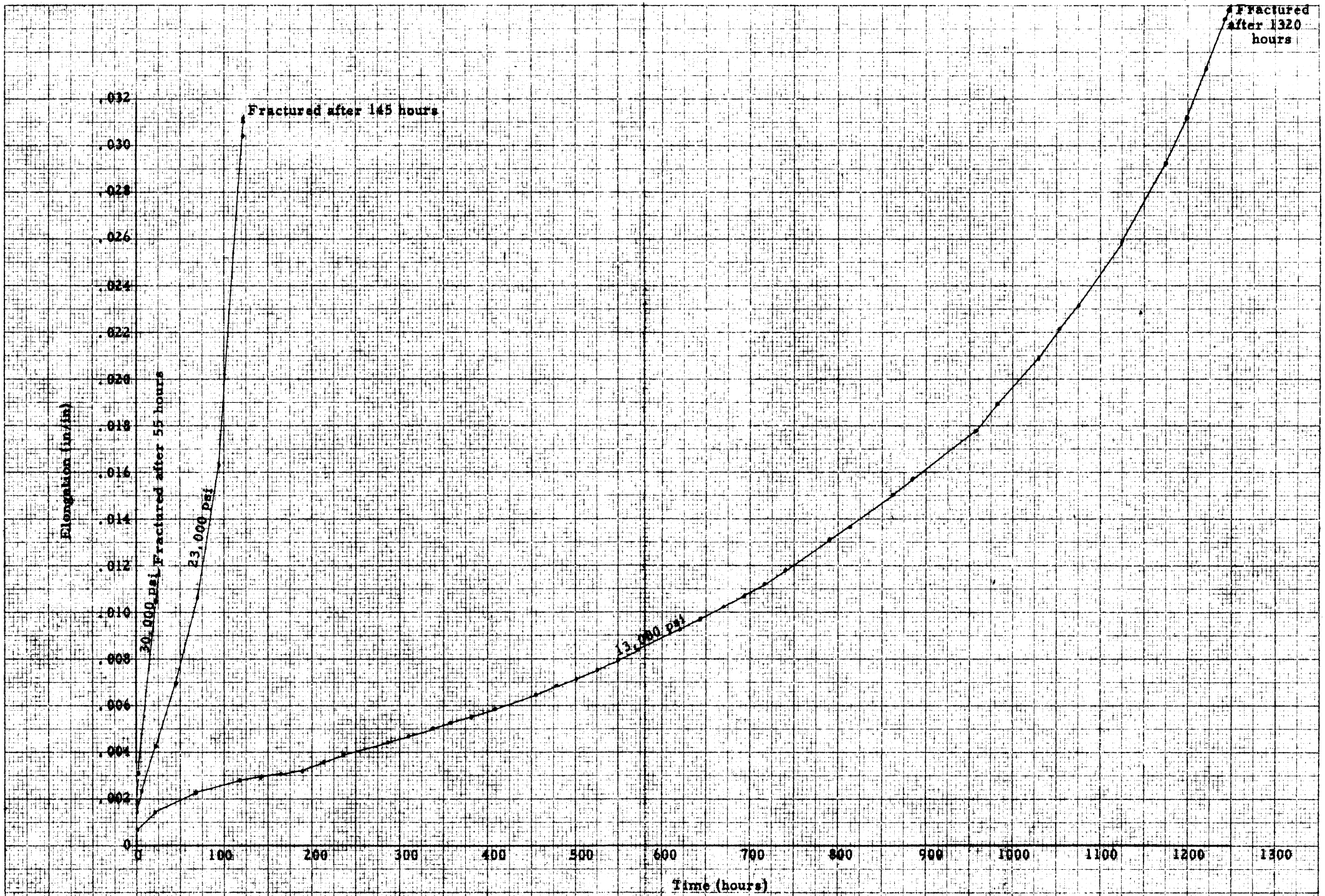


Figure 3. Time-Elongation Curves for "17-22-A"V Steel (Heat 11131) Forging at 1200°F. Tangential specimens taken from the rim of a 2 to 2-1/2 inch wide pie-shaped section taken from a 5-inch thick by 25-inch diameter forging. Segments normalized from 1850°F and tempered for 6 hours at 1200°F to 340 Brinell.

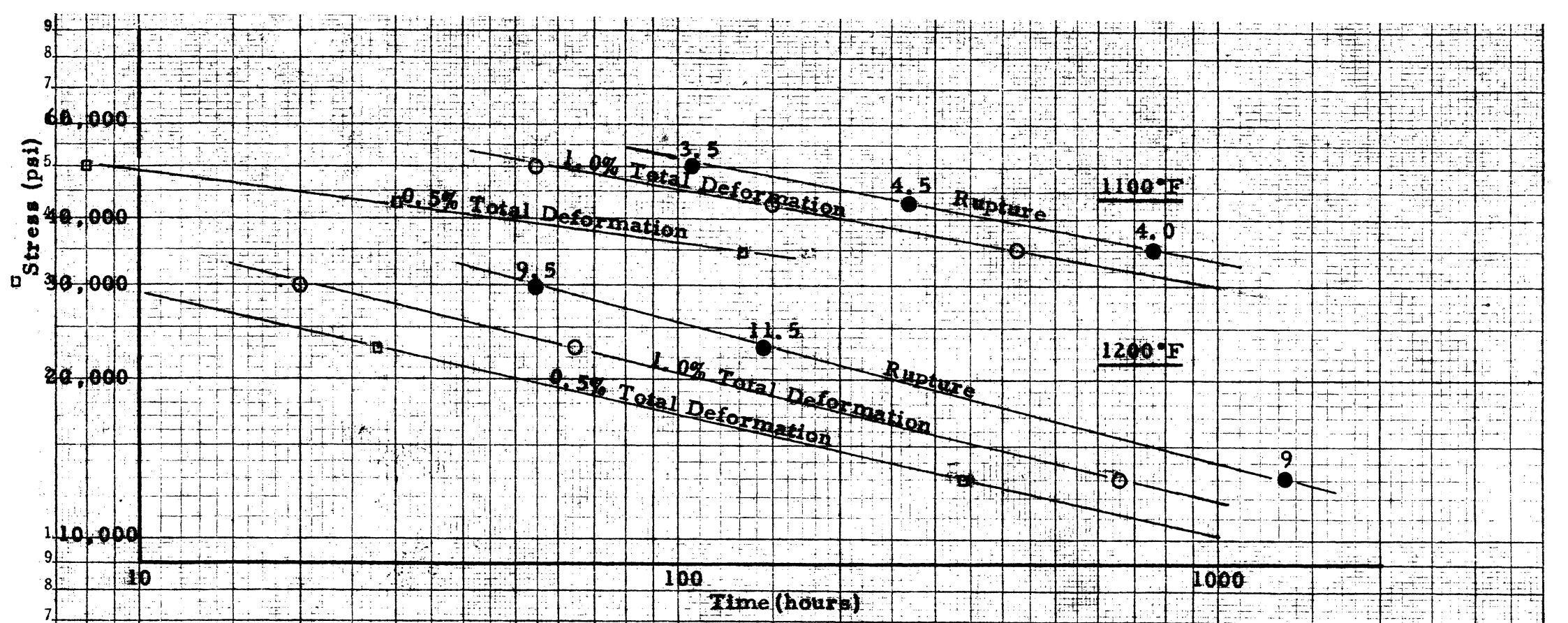
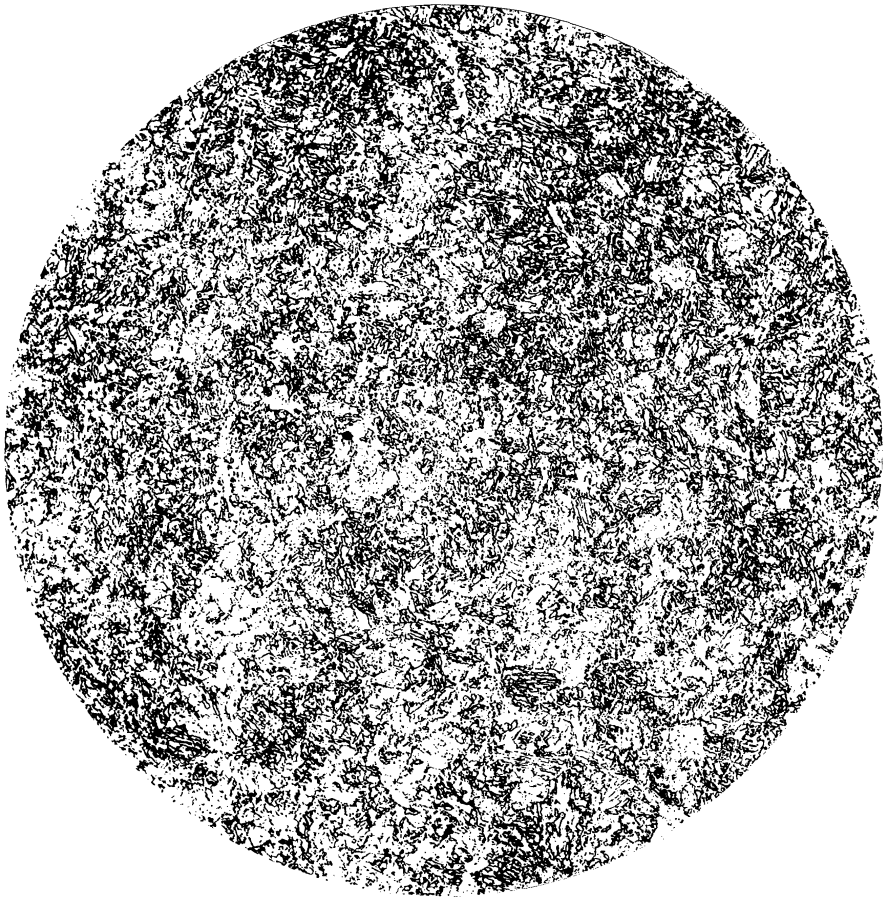
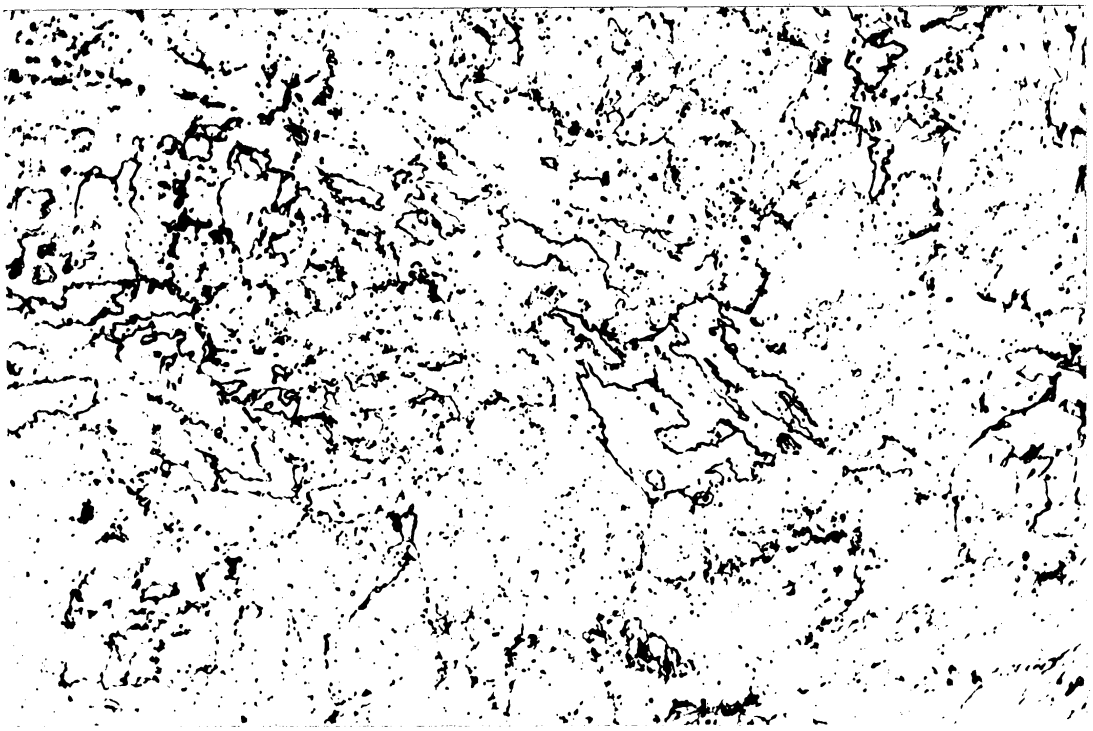


Figure 4. Total Deformation Curves for "17-22-A"V Steel (Heat 11131) Forging at 1100° and 1200°F. Tangential specimens taken from the rim of a 2 to 2-1/2 inch wide pie-shaped section taken from a 5-inch thick by 25-inch diameter forging. Segments normalized from 1850°F and tempered for 6 hours at 1200°F to 341 Brinell.

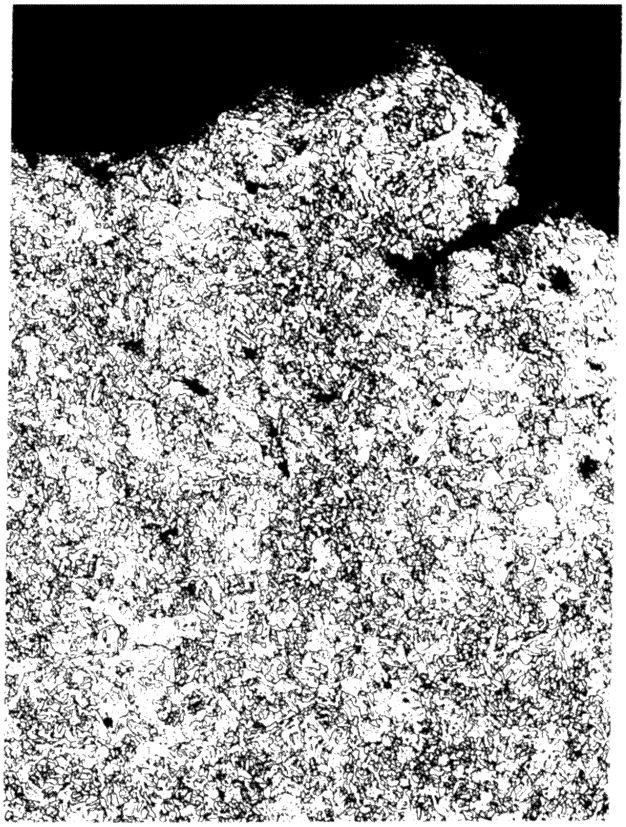


X100D



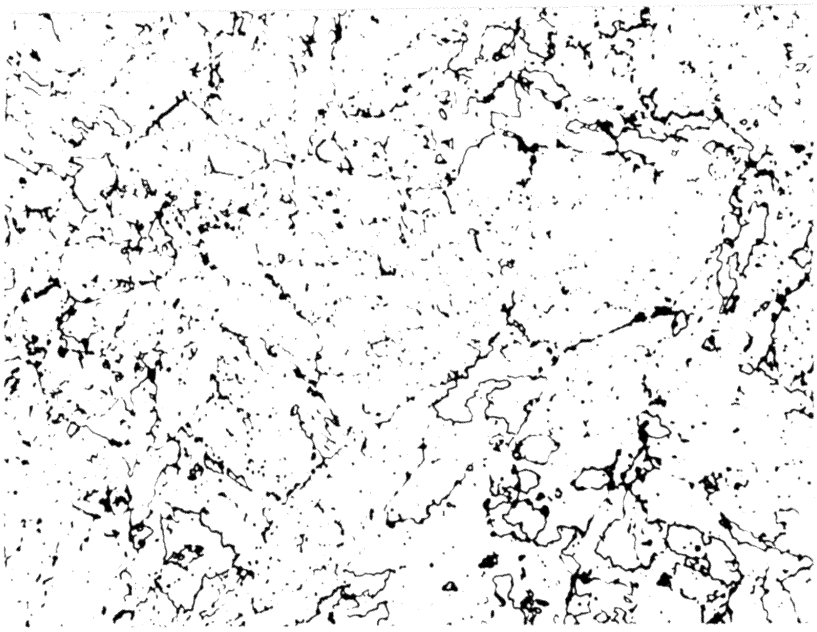
X1000D

Plate 1. Original Microstructure of Tangential Specimens from the Rim of a 2 to 2-1/2 Inch Wide Pie Shaped Section Taken from the 5-Inch Thick by 25-Inch Diameter Forging of "17-22-A"V Steel - Heat 11131. Segments normalized from 1850°F and tempered at 1200°F to 341 Brinell.



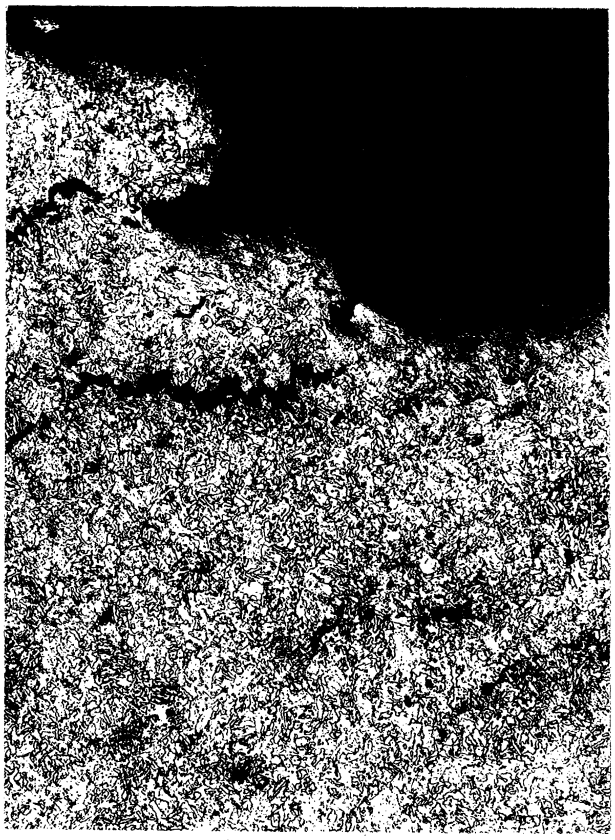
X100D
Fracture

X100D
Surface

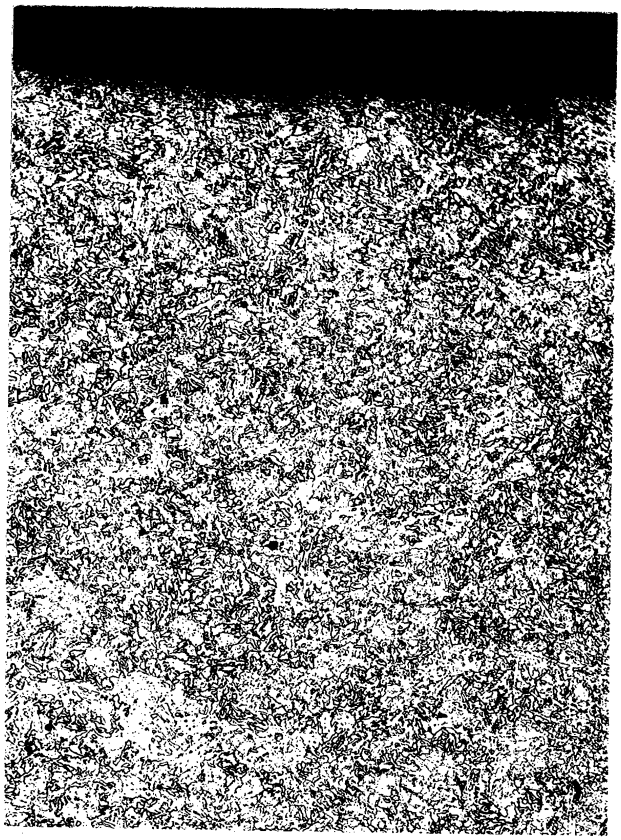


X1000D
Interior

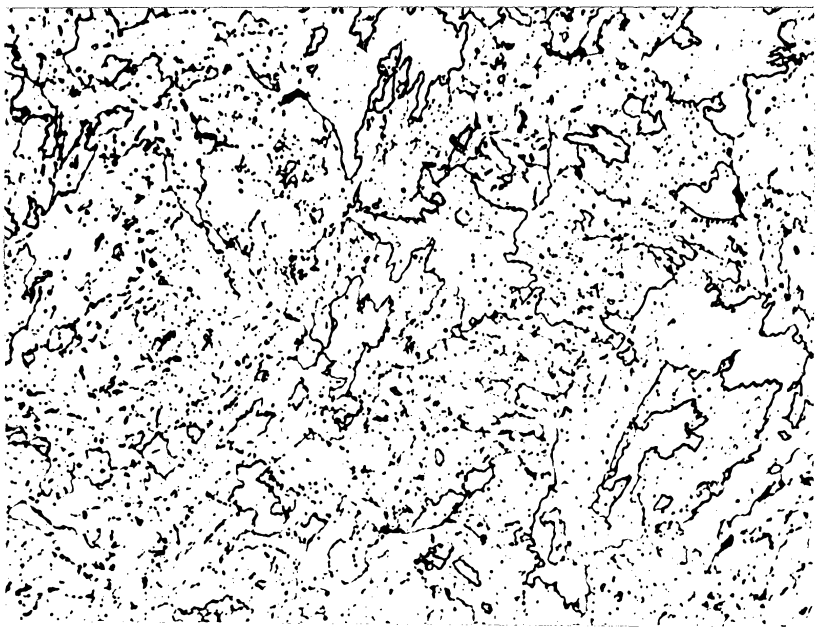
Plate 2. Microstructure of Rupture Specimens from the Forgings of "17-22-A"V Steel - Heat 11131. Normalized from 1850°F and tempered to 341 Brinell. Fractured after 759 hours at 35,000 psi and 1100°F.



X100D
Fracture



X100D
Surface



X1000D
Interior

Plate 3. Microstructure of Rupture Specimens from the Forging of "17-22-A"V Steel - Heat 11131. Normalized from 1850°F and tempered to 341 Brinell. Fractured after 1320 hours at 13,000 psi and 1200°F.