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RUPTURE PROPERTIES OF "17-22-A"S STEEL BASED ON PROLONGED TESTS AT 1000°F

by

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RUPTURE PROPERTIES OF "17-22-A"S STEEL BASED ON PROLONGED TESTS AT 1000°F

In previous investigations of the rupture strength of "17-22-A"S steel at 1000°F (Report 198) the tests had maximum rupture times less than 2000 hours. Due to the sharp breaks in the slopes of the curves and some scatter in the test results, there was uncertainty of the reliability of the extrapolations to prolonged time periods. Accordingly a program was undertaken to improve the reliability of the extrapolation by conducting tests to longer time periods. Another reason for conducting the tests was to check the indications of Report 198 showing considerably higher long time rupture strengths from tempering at 1300°F than at 1200°F.

The material used for the tests was from a different heat than was used for the tests recorded in Report 198. Both were taken from bar stock, normalized from 1725°F and tempered at 1200 °F in one case and at 1300°F in another. Only longer time tests were conducted for the present report. The rupture times were expected to be longer than the breaks in the curves shown in Report 198.

CONCLUSIONS

The data obtained by extending the rupture testing times at 1000°F to the order of 6,000 hours indicated the following:

(1) The stress for rupture of normalized and tempered "17-22-A"S steel at 1000°F for 100,000 hours was about 12,000 psi when tempered at either 1200° or 1300°F.

(2) Apparently the lower initial level of strength from tempering at 1300°F as compared with 1200°F decreased with increasing time and disappeared at about 100,000 hours.

(3) The high long time strengths indicated by Report 198 for tempering at 1300°F instead of 1200°F was not supported by the longer tests. Apparently the original tests were too short in duration to define a break in the stress-rupture time curve.

(4) Low ductility seemed to limit rupture strength, particularly for tempering at 1200°F. Slightly higher ductility from tempering at 1300°F apparently offset somewhat higher creep resistance from tempering at 1200°F.

(5) The indicated stresses for rupture in 100,000 hours of 12,000 psi were within the range for DM steel. The initial high strengths from carbon and vanadium apparently were not retained at long time periods.

EXPERIMENTAL MATERIAL

The Timken Roller Bearing Company furnished 0.505-inch diameter specimens machined from heat treated bar stock from a production heat. The chemical composition furnished with the specimens is compared with that for the Heat Number 16030 material used for Report 198 in the following tabulation:

	Chemical Composition (%)								
Heat No.	C	Mn	P	S	Si	Cr	V	Mo	Ni
24797	.30	.63	.016	.018	.60	1.25	.25	.52	.25
16030*	.32	.60	.013	.017	.74	1.23	.21	.49	.28

* From Report 198

Bar stock was normalized from 1725°F and tempered for 6 hours at 1200°F and 1300°F. The resulting Brinell hardness values were:

	Tempering Temperatures	
Heat No.	1200°F	1300°F
24797	331	255
16030	311/331	241/255

For those tests in which the stress exceeded 40,000 psi, the gage length of the specimens was reduced to keep the load requirements within the limits of the rupture test units.

RESULTS

The rupture tests were conducted at 1000°F for both tempering treatments using the specimens from Heat 24797. The results (Table 1 and Figure 1A) show the following:

(1) Using the data from the present investigation together with that for Heat 16030 from Report 198 for curves based on the combined data indicates the following rupture strengths in comparison with those originally included in Report 198:

Tempering Temperature (°F)	BHN	Rupture strengths (psi) for indicated Time Periods 100 hr.	1000 hr.	10,000 hr.	100,000 hr.	Data Source
1200	331	74,000	58,000	26,500	12,000	present report
1200	311/331	75,000	60,000	28,500	-	Rpt. 198
1300	255	62,000	43,000	24,500	12,000	present report
1300	241/255	56,000	44,000	(32,000)	-	Rpt. 198

(2) Individual treatment of the data for the stress-rupture time curves (Figure 1B) shows that the curve for the material tempered at 1300°F for Report 198 probably had a break in slope and therefore did not have the high long time strengths in comparison with tempering at 1200°F indicated by Report 198. This is further supported in that drawing the curve for the material tempered at 1300°F with the break results in a slope consistent with tests at 1100°F in Report 198. As drawn for Report 198, the curve for 1100°F had a far greater slope than the curve for 1000°F.

(3) The data suggest that the difference in tempering temperature had very little effect on long time strengths at 1000°F.

(4) Values for elongation and reduction of area also indicate little difference at the longer time periods.

The time-elongation curves for the rupture test are shown in Figures 2 and 3. Figure 4 shows the higher stresses for a given creep rate required for the higher hardness material (i.e. tempered from 1200° rather than 1300°F). These data suggest that low elongation may have limited rupture time with the result that the stress-rupture time curves converged as indicated by Figure 1A. Otherwise the higher creep resistance of the material tempered at 1200°F should have resulted in longer rupture times.

The test at 27,500 psi for material tempered at 1300°F was discontinued due to overheating as a result of failure of the temperature controller. The creep curve for the test (Figure 3) however, indicates that the test had nearly reached rupture when the overheating occurred. While it was necessary to show this point as a discontinued test (Figure 2) there is no doubt but that the actual rupture time would have been on the curve as drawn.

Microstructures

The microstructures were similar to those for Heat 16030 in Report 198. The longer time tests had very little effect on microstructure (Plates 1 through 4). Tempering at 1300°F resulted in more cracking adjacent to the fracture than did tempering at 1200°F. While tempering at 1200°F resulted in higher creep resistance, it would appear that cracks propagated easier once they were nucleated than when tempered at 1300°F. Rupture thus occurred with very little cracking evident.

DISCUSSION

The prolonged tests of this investigation indicated somewhat lower stresses for rupture than did the previously determined stress-rupture time curves for Report 198. Combining the data from the two investigations seems to provide the most reliable extrapolations. The possibility still remains that there were differences in strength between the two heats which were not delineated by the tests conducted.

The estimated stresses for rupture in 100,000 hours at 1000°F are within the range of this strength for DM steel. Evidently the initially higher strengths of "17-22-A"S steel are not maintained to prolonged time periods at 1000°F. The carbon and vanadium in "17-22-A"S steel apparently are only effective at the shorter time periods.

The microstructural examinations of the specimens did not show appreciable differences other than the cracking adjacent to the fracture. It would seem, nevertheless, that there must have been changes in microstructure as a result of testing and in initial structures from tempering at the two temperatures. Evidently the light microscope did not have sufficient resolving power to show these differences. The cracking indicated that the long time rupture strength of the material tempered at 1300°F was in part due to slower rates of crack propagation. than when the tempering temperature was 1200°F.

TABLE I

Stress-Rupture Data at 1000°F for "17-22-A"S
(Heat 24797)

Stress (psi)	Rupture Time (Hours)	Elongation (% in 2 ins.)	Reduction of Area (%)
Normalized at 1725°F - Tempered at 1200°F - (331 BHN)			
60,000	650	3.5	4.0
50,000	1278	2.0	(a)
32,000	5754	2.0	2.5(a)
Normalized at 1725°F - Tempered at 1300°F - (255 BHN)			
44,000	814	6.5	13.5
32,000	4250	2.0	(a)
27,500	Discontinued after 6,317 hrs.		

(a) Broke in or near fillet

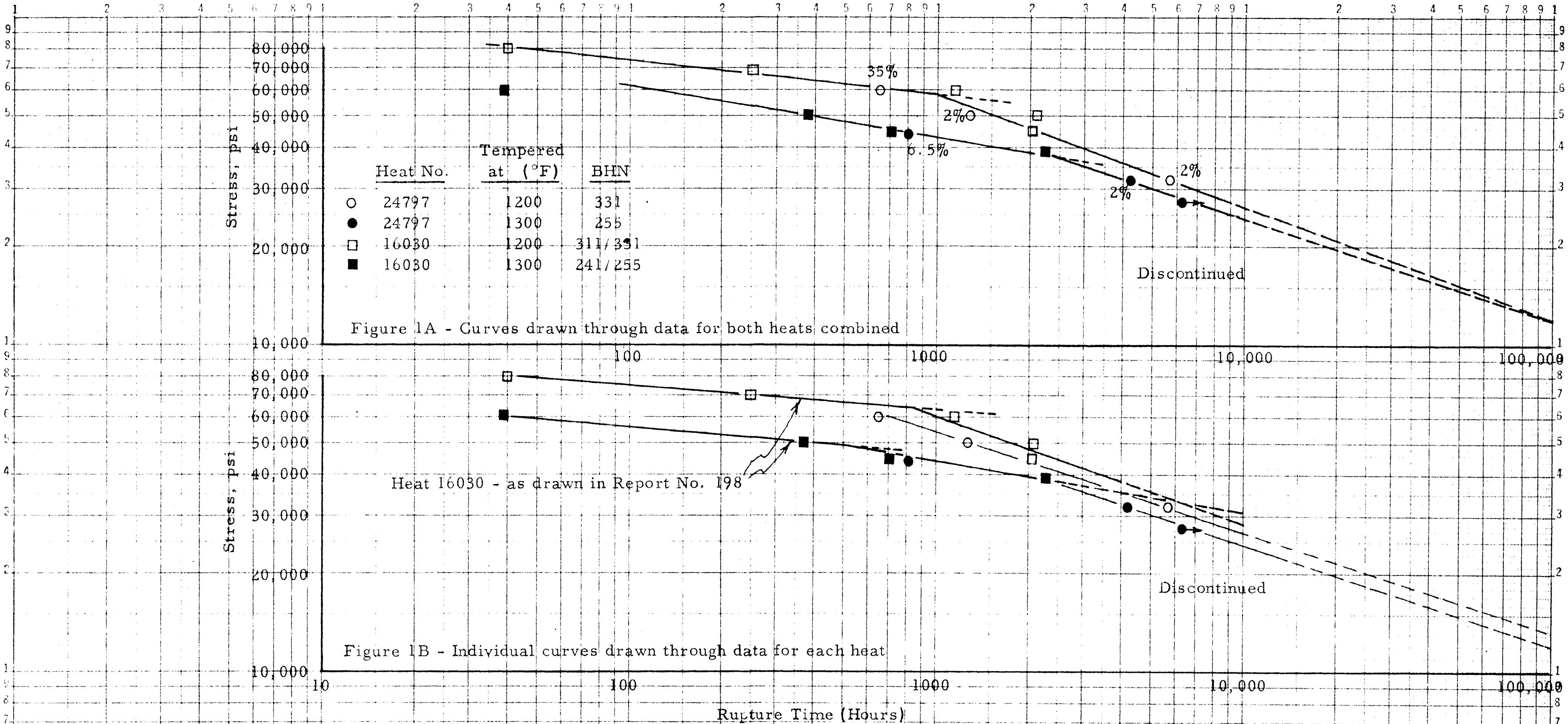

Figure 1. Stress-rupture time curves at 1000°F for two heats of "17-22-A"S steel normalized from 1725°F and tempered as indicated.

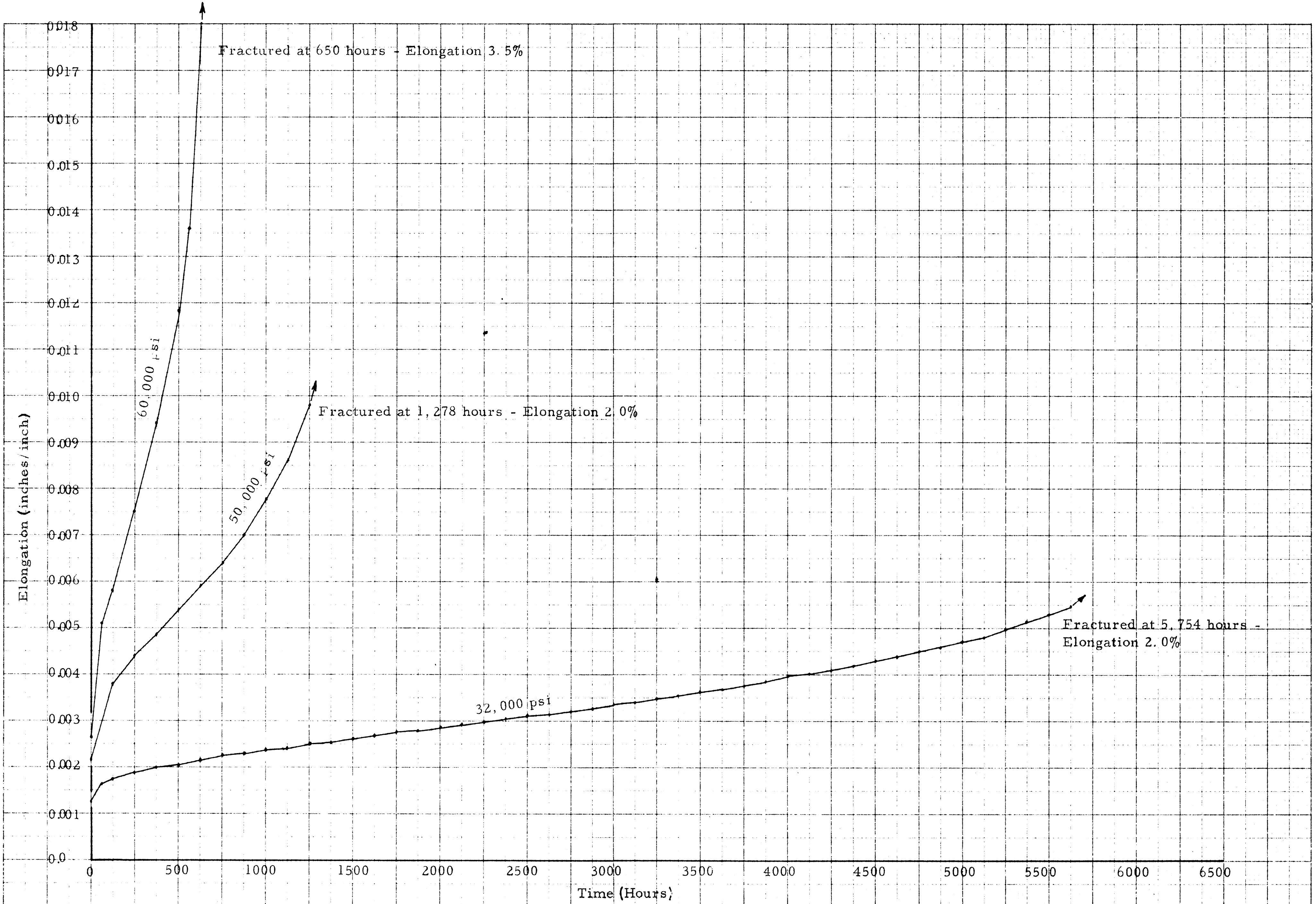

Figure 2. Time-Elongation curves from rupture tests at 1000°F on "17-22-A"S steel (Heat 24797) normalized from 1725°F and tempered at 1200°F to a hardness of 331 Brinell

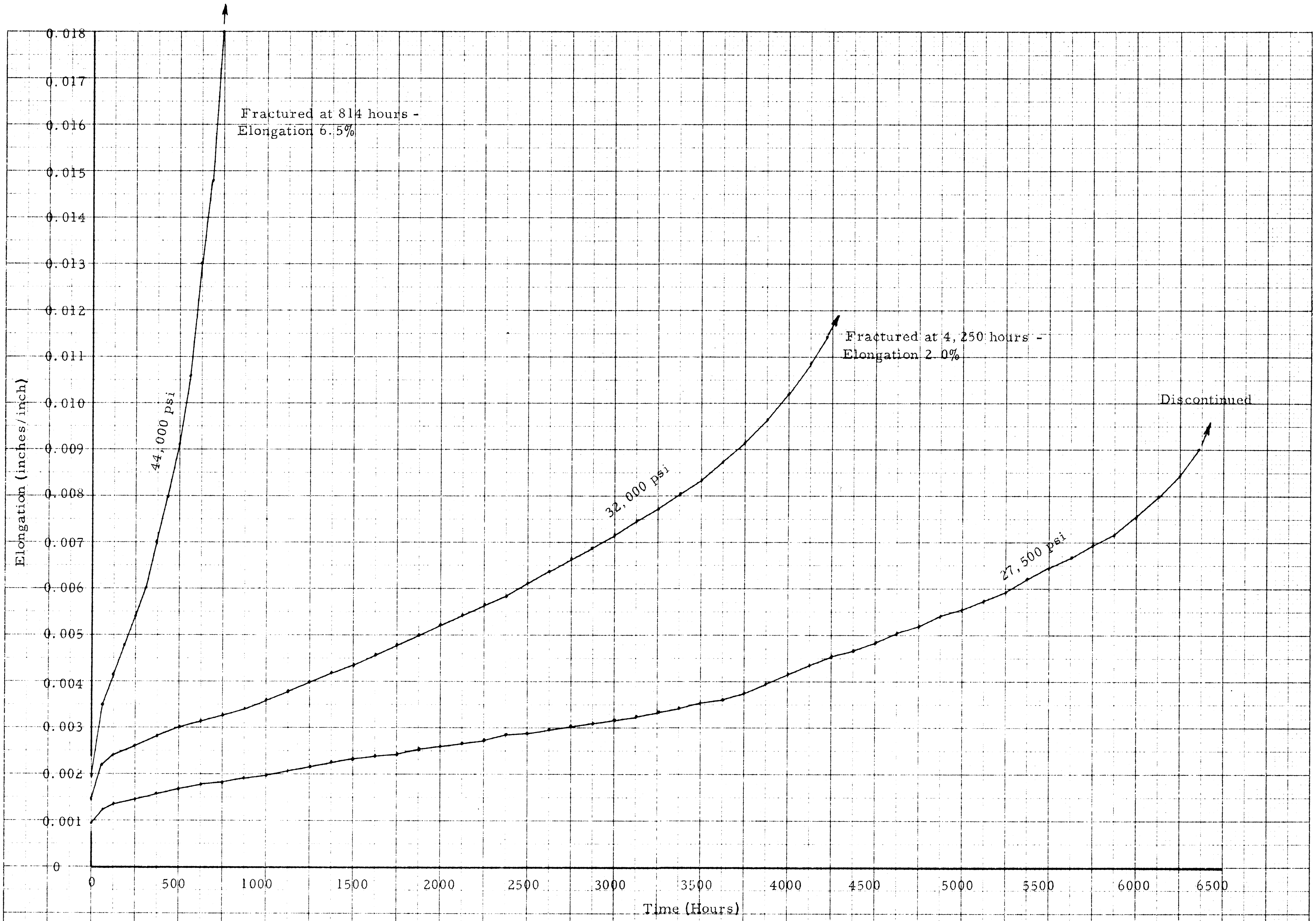

Figure 3. Time-Elongation curves from rupture tests at 1000°F on "17-22-A"S steel (Heat 24797) normalized from 1725°F and tempered at 1300°F to a hardness of 255 Brinell.

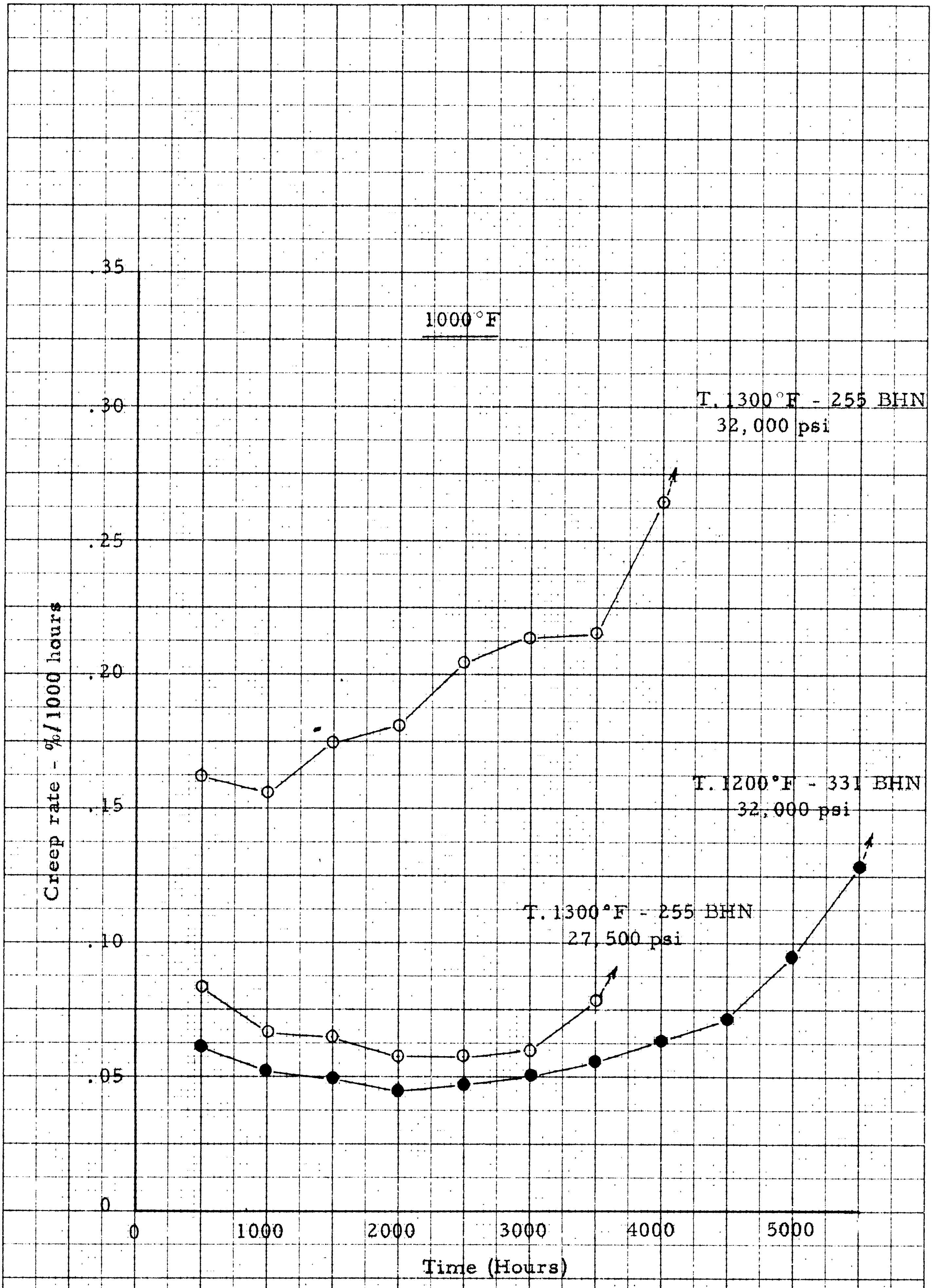

Figure 4. Creep rate time curves from creep-rupture tests at 1000°F on "17-22-A"S steel (Heat 24797) normalized from 1725°F and tempered as indicated.