The University of Michigan • Office of Research Administration
Ann Arbor, Michigan

EFFECT OF SECTION SIZE ON THE RUPTURE STRENGTH OF ANNEALED DM STEEL AT 1050°F

by

R. Jackowski
T. M. Cullen
J. W. Freeman

Project 04603-58-T
Report 247

November 9, 1964

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

EFFECT OF SECTION SIZE ON THE RUPTURE STRENGTH OF ANNEALED DM STEEL AT 1050°F

This investigation was undertaken to determine whether section size had any appreciable effect on the rupture properties at 1050°F of 1¼Cr-½Mo (DM) steel. Stress-rupture time curves established in a previous investigation in which 0.250-inch diameter specimens were used had greater slope and lower extrapolated long time strengths than had been measured in prior investigations in which 0.505-inch diameter specimens were used. Severe oxidation of the specimens suggested that oxidation could have been a predominant factor influencing rupture strength at long times.

Creep-rupture tests were conducted on both 0.250-inch and 0.505-inch diameter specimens from the same lot of annealed DM steel in an effort to determine if section size had any influence on creep-rupture properties and, if so, whether oxidation was responsible.

SUMMARY AND CONCLUSIONS

The results obtained in this investigation do not conclusively confirm whether there is or is not an effect of section size on the 100,000 hour rupture strength of 1¼Cr-½Mo (DM) steel at 1050°F. The data recorded from the 0.250-inch diameter specimens are such that the stress-rupture time curve could be drawn in either of two ways. The preferred method yielded a 100,000 hour rupture strength very close to that obtained from the 0.505-inch diameter specimens (6,400 psi versus 6,700 psi) and indicated that section size had minor influence on the 100,000 hour rupture strength of the material. The second method yielded a much lower 100,000 hour rupture strength (5,000 psi).

The specimens were severely oxidized after long time exposure at 1050°F.

Oxidation, if it influenced the alloy, should have more adversely affected the smaller diameter specimens. No unambiguous data, however, were obtained to indicate that oxidation had more than a minor influence on the properties of the steel.

MATERIAL

The specimens used in this study were supplied by The Timken Roller Bearing Company. These specimens were machined from a 1¼Cr-½Mo (DM) steel tube.

The tube from which both the 0.505-inch and the 0.250-inch diameter specimens were machined had been produced from a billet from Heat 30773. This billet had been pierced and hot rolled to a tube having a 5.967-inch O.D. by 0.685-inch thick wall. This tube was annealed from 1650°F following the hot working operation.

RESULTS

Rupture tests were conducted at 1050°F on both 0.505-inch and 0.250-inch diameter specimens for time periods as long as 6,138 and 7,017 hours respectively. Observations of the degree of oxidation were made on fractured specimens. In addition, metallographic examinations were made before and after testing.

The data obtained at 1050°F are presented in Table 1 and are shown as stress-rupture time curves of Figure 1. The data for the 0.250-inch and the 0.505-inch diameter specimens are compared in Figure 2. The data indicate the following rupture properties:

Specimen Dia. (in.)	Rupture Strength (psi) 500 hr.	1000 hr.	10,000 hr.	100,000 hr.	Elong. (%) at Fracture 500 hr.	1000 hr.	10,000 hr.
0.505	21,000	18,000	11,000	(6,700)	39	36	72
0.250[(a)]	21,000	19,000	9,700	(5,000)	40	47	21
0.250[(b)]	21,000	18,500	10,000	(6,400)	40	47	21

(a) - solid line Figure 1

(b) - dashed line Figure 1

As indicated in Figure 1, the curves through the data for the 0.250-inch specimens could be drawn as a straight line or with an increase in slope at approximately 2,000 hours followed by a decrease at approximately 3,500 hours to a slope parallel to the initial slope.

The results obtained in this program are compared with results obtained in previous studies in Table 2. This table shows that previous investigations indicated that the 0.250-inch diameter specimens had low extrapolated long time strengths. Their low strengths may have been partially due to the different prior histories these materials had received as compared with the materials in other studies in which 0.505-inch diameter specimens were used. It is also possible that these previous investigations did not utilize sufficiently long-time tests which might have uncovered an upward break in the stress-rupture time curves. Such an upward break, if it existed, would have caused an increased value of the 100,000 hour strength of the material from which the 0.250-inch specimens were machined.

The creep curves obtained from the specimens tested in this study are shown in Figures 3 and 4. These curves show that the specimens exhibited very little first stage creep. This was particularly true of the lower stress tests (Figure 4).

The elongation percentages were lower for the 0.250-inch diameter specimens at the longer times than for the 0.505-inch diameter specimens. There was, however, little difference in reduction of area.

The microstructures of the two types of specimens both prior to and subsequent to long-time exposure are shown in Figures 6, 7, 8 and 9. Figures 7 and 9 show that some spheroidization developed during the long-time stressed exposures at 1050°F.

DISCUSSION

As previously stated, the stress-rupture time curve through the data points obtained using 0.250-inch diameter specimens can be drawn either of two ways. The drawing of a single straight line through the data is not favored since this would imply that a considerable amount of material variability existed which was not evident in the data from the 0.505-inch diameter specimens. Since no evidence of significant variability had been uncovered it is felt that the proper stress-rupture time curve is one which contains a double break. This curve (which is shown in Figure 1) goes through all the data points and has short-time and long-time portions which are approximately parallel to one-another.

While the type of rupture curves drawn through the data obtained from the specimens containing 0.250-inch and 0.505-inch diameters may be different, the extrapolated 100,000 hour rupture strengths are very similar, 6,400 psi versus 6,700 psi. It is not known at this time why the two curves should have different shapes. If oxidation was influencing the results obtained from the 0.250-inch diameter specimens then it would be expected that a stress-rupture time curve with a single downward break would be obtained. It would be very difficult to explain how oxidation might cause DM steel to exhibit a stress-rupture time curve with a double break at 1050°F.

It is not know at the present time why the apparent double break in the stress-rupture time curve of the 0.250-inch diameter specimens was obtained. The usual explanations for its occurrence (such as recrystallization during testing) would predict that if it occurs in the results of the 0.250-inch diameter specimens it should occur in the results obtained from the 0.505-inch diameter specimens as well. While the possible explanation that the apparent double break may be due to material variability is not favored, nevertheless, it should not be ruled out. Longer time tests on both the 0.250-inch and the 0.505-inch diameter specimens would be needed to determine with certainty the correct shape(s) of the stress-rupture time curves of this steel at 1050°F.

TABLE 1

Stress-Rupture Time Data at 1050°F from 0.505-inch and 0.250-inch Diameter Specimens from a 5.967-inch O.D. by 0.685-inch Wall 1¼Cr-½Mo Steel Tube

Stress (psi)	Rupture Time (Hours)	Elongation (%)	Reduction of Area (%)
	0.505-inch Diameter Specimens (a)		
24,000	273	41.5	54.0
20,000	769	36.0	58.0
17,000	1,393	62.0	70.0
14,000	3,405	52.0	71.0
12,000	6,138	72.0	77.0
	0.250-inch Diameter Specimens (b)		
24,000	271	39.0	52.0
20,000	661	47.5	47.5
17,000	1,594	39.0	52.0
14,000	2,683	21.0	67.5
12,000	3,558	31.0	69.5
10,500	7,017	21.0	72.0

(a) Elongation - % in 2 inches

(b) Elongation - % in 1 inch

TABLE 2

Rupture Strengths at 1050°F of DM Steel Tubes and Barstock

Material	Heat Treatment	Report No.	Rupture Strength (psi) for Indicated Time Periods			
			500 hr.	1000 hr.	10,000 hr.	100,000 hr.
0.505-inch Diameter Specimens						
5.967"O.D.x0.685"wall	H.R.+Ann. 1650°F	Present	21,000	18,000	11,000	(6,700)
10.5"O.D.x1.352"wall	H.R.+Ann. 1575°-1600°F	222(a)	19,000	16,000	10,500	(6,800)
Barstock	N. 1750°F+6 hrs. at 1200°F	183	30,000	25,000	14,000	(7,900)
0.250-inch Diameter Specimens						
5.967"O.D.x0.685"wall	H.R.+Ann. 1650°F	Present (b)	21,000	19,000	9,700	(5,000)
5.967"O.D.x0.685"wall	H.R.+Ann. 1650°F	Present (c)	21,000	18,500	10,000	(6,400)
2"O.D.x0.375"wall	C.D.+Ann. 1625°F	232	23,000	19,000	9,800	5,000
2"O.D.x0.375"wall	C.D.+Temp. 1375°F	232	20,000	16,000	8,000	4,000

(a) - and Supplement

(b) - Solid line Figure 1

(c) - Dashed line Figure 1

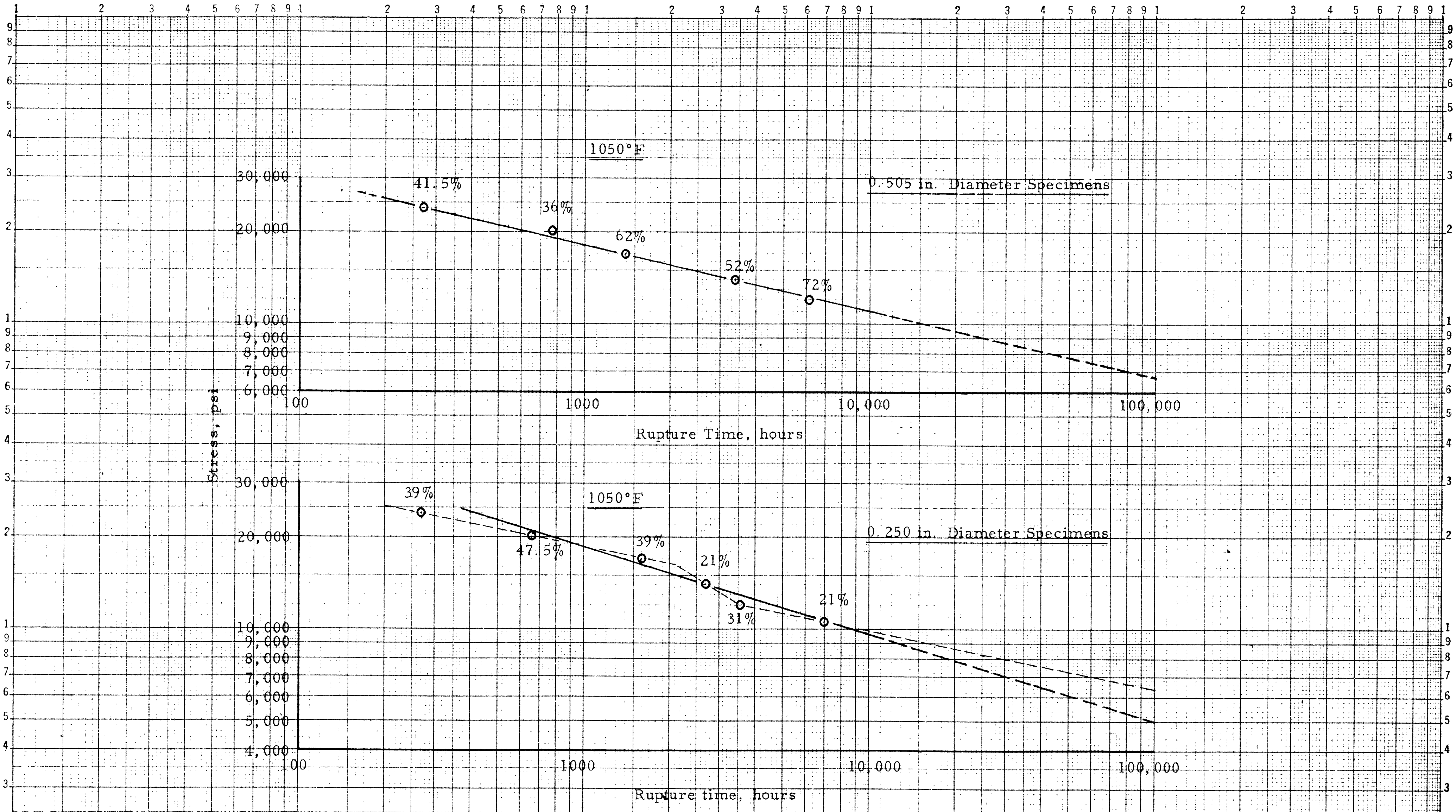

Figure 1. Stress-Rupture Time Curves at 1050°F for 1¼ Cr-½ Mo (DM) Steel. Tests run on 0.505-inch and 0.250-inch diameter tensile specimens from a hot rolled and annealed tube.

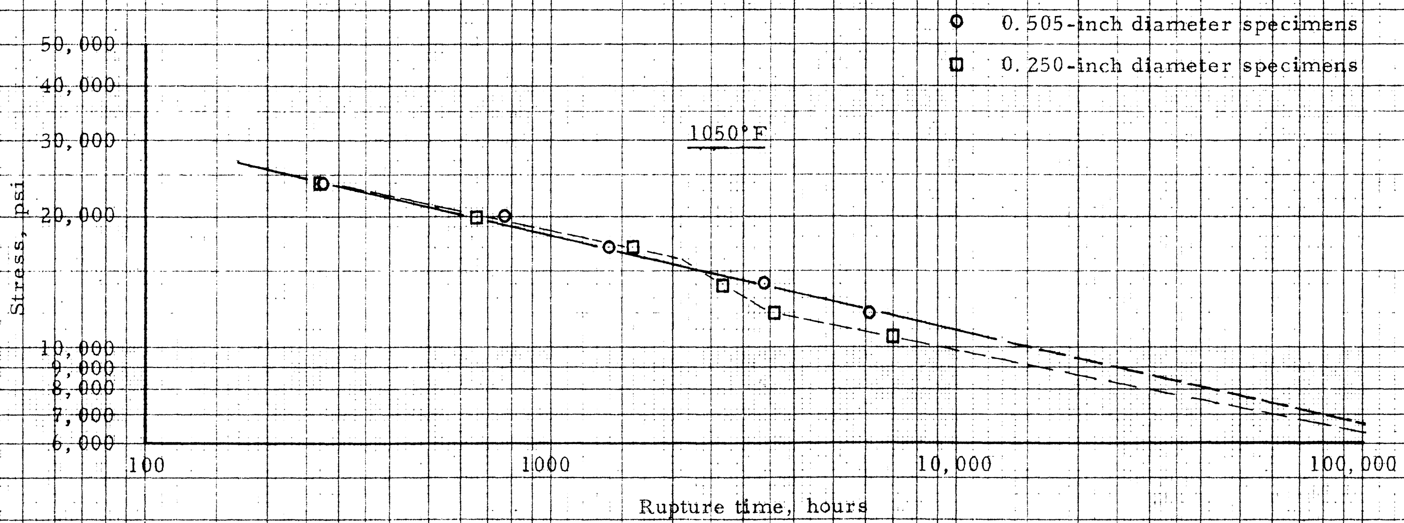

Figure 2. Comparison of Stress-Rupture Time Data at 1050°F for 0.505-inch and 0.250-inch diameter specimens from a hot rolled and annealed 1¼Cr-½Mo (DM) Steel Tube.

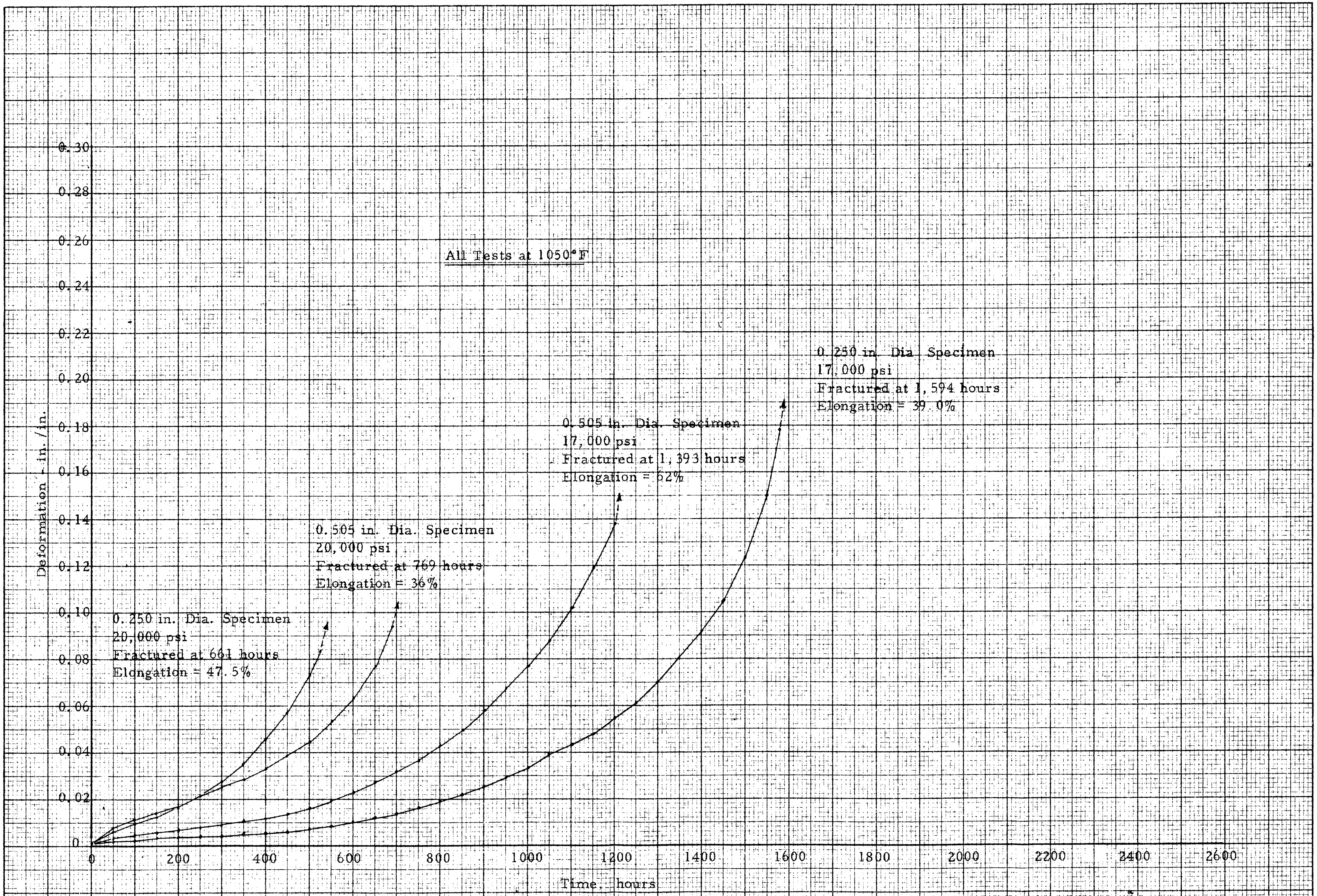

Figure 3 Time-Elongation Curves from Creep-Rupture Tests at 1050°F on 0.505-inch and 0.250-inch diameter tensile specimens from a hot rolled and annealed 1¼Cr-½Mo (DM) Steel Tube.

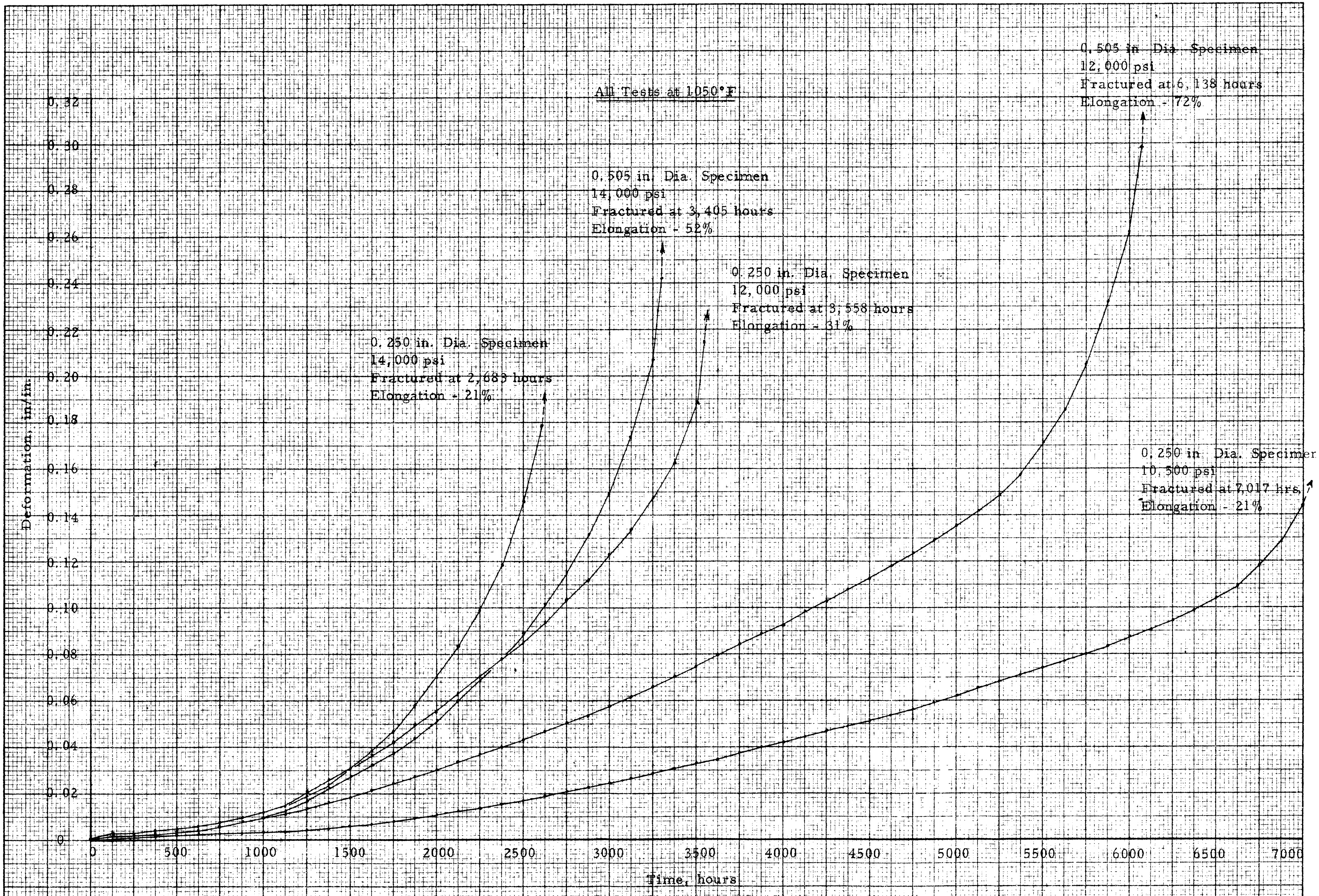

Figure 4. Time-Elongation Curves from Creep-Rupture tests at 1050°F on 0.505-inch and 0.250-inch diameter tensile specimens from a hot rolled and annealed 1¼Cr-½Mo (DM) Steel Tube.