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CREEP-RUPTURE PROPERTIES OF 6061-T6 ALUMINUM ALLOY AT 450 AND 500 F

By

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The creep-rupture characteristics were determined for commercial 6061-T6 (61S-T6) aluminum alloy at 450 and 500 F. The results are presented as design and creep-rate curves. Stress-rupture strengths at 450 F were 17,000, 13,000, and 9,000 (estimated) psi for rupture in 10, 100, and 1000 hr, respectively. At 500 F, stress-rupture strengths were 10,500, 9,100, and 7,200 (estimated) psi for rupture in 10, 100, and 1000 hr, respectively.*

INTRODUCTION

When maximum strength is desired, the 6061 aluminum alloy (61S) is used in the precipitation-hardened condition (T6). The hardening is obtained after a high-temperature quench by aging at 320 to 350 F for times up to 20 hr. Subsequent exposure of the alloy at temperatures above 350 F, or for longer times at the aging temperature, leads to overaging and gradual loss of strength. Consequently, not many data have been reported in the literature on the creep-rupture properties of the 6061-T6 alloy at temperatures much above the aging temperature. Some data are available on properties at 400 F.

The present work was undertaken to determine the creep-rupture characteristics of the 6061-T6 alloy in air at 450 and 500 F for times up to 1000 hr.

MATERIAL AND METHOD

Most of the tests of the 6061-T6 alloy were performed on commercial 0.125-in. sheet, with the axes of the specimens machined longitudinal to the rolling direction. Also, a few specimens were taken with axes transverse to the rolling direction to determine the possibility of variation in the creep-rupture properties with orientation. In addition to these, several specimens were machined from commercial 6061-T6 0.040-in. sheet. Chemical analyses of these materials are given in the tabulation. →

*Designation prior to October 1, 1954.

Element	Composition, w/o		
	Nominal	0.125-In. Sheet	0.040-In. Sheet
Magnesium	1.0	0.97	1.00
Silicon	0.6	0.74	0.56
Copper	0.25	0.30	0.30
Chromium	0.25	0.28	0.24

Specimens for the creep-rupture tests had an over-all length of 8 in., with a gage section 2 in. long and 1/2 in. wide. The tests were conducted in conventional wire-wound resistance furnaces, which maintained the temperature to ±2 F. The specimens were loaded within 2 to 3 hr after reaching temperature, and extensometer readings were taken periodically thereafter. These readings were taken on ruled platinum reference strips attached to the gage section of the specimen; a filar micrometer microscope with a sensitivity of 0.00005 in. was used. These data were converted to percentages and plotted as time-deformation curves from which design and creep-rate data were obtained.

RESULTS

A summary of all tests of the 6061-T6 alloy sheet are presented in Table 1. Design curves at 450 and 500 F are shown in Figures 1 and 2. Figure 3 shows the relationship between stress and minimum creep rate at 450 and 500 F for the alloy.

On the basis of the few check tests made on specimens made from 0.125-in. sheet transverse to the rolling direction, it would appear that the transverse and longitudinal creep-rupture strengths of this alloy are quite similar. At 450 F, the rupture strength of the transverse specimen coincided with the rupture curve for the longitudinal specimens. At 500 F, the two transverse specimens ruptured in less time than did the longitudinal specimens under similar loads. The transverse material appeared to be about 200 to 500 psi weaker than the longitudinal material for the conditions of test.

A comparison between the 0.040-in. and the 0.125-in. 6061-T6 alloy sheet shows that at the higher stresses the two materials displayed about the same rupture strengths. However, at the lower stresses and longer rupture times, the lighter gage material was about 1000 psi weaker. Chemical analyses of the specimens indicated that the 0.040-in. sheet contained somewhat less silicon than did the 0.125-in. sheet. Also, the 0.040-in. sheet had a larger grain size than did the thicker material. The difference in grain size is shown in Figure 4. Inasmuch as specimens were obtained from commercially heat-treated alloy, it is probable that the conditions of heat treatment were different for the two sheets. →

At 450 and 500 F, the loss of strength in the 6061-T6 alloy with increasing temperature tends to proceed at a slightly slower rate than at lower temperatures. In Figure 5, creep and stress-rupture data at 212, 300, and 400 F* are combined with similar data obtained in the present investigation to illustrate this behavior.

HAS/JAV/JTS:dp

* From unpublished work by Battelle Memorial Institute, August 8, 1948.

TABLE 1. CREEP AND CREEP-RUPTURE DATA FOR 6061-T6 ALUMINUM-ALLOY SHEET AT 450 AND 500 F

Specimen	Temperature, F	Stress, psi	Initial Deformation, per cent	Minimum Creep Rate, per cent per hr	Transition to Third-State Creep		Rupture Time, hr	Elongation, per cent	Time, hr, for Indicated Total Deformation, per cent								
					Hr	Per Cent			0.2	0.3	0.5	0.7	1.0	1.5	2.0	3.0	5.0
							Longitudinal Direction										
2-47[a]	450	17,000	0.20	0.11	—	—	10.7	10.0	—	0.5	2.6	4.7	—	—	—	—	—
61S-L11	450	15,000	0.20	0.024	—	—	34.0	5.7	—	4.0	12.0	20.5	—	—	—	—	—
61S-L2	450	13,500	0.15	0.033	45.0	1.00	84.3	13.3	—	—	10.0	30.0	35.0	56.0	60.0	70.0	—
61S-L1	450	12,000	0.15	0.019	65.0	1.50	125.4	8.3	—	10.0	20.0	35.0	50.0	76.0	86.0	110.0	—
61S-L7	450	11,000	0.15	0.0036	70.0	0.50	288.7	3.8	12.0	38.0	80.0	120.0	170.0	210.0	246.0	—	—
61S-L9	450	10,000	0.10	0.0023	195.0	0.60	672.6	9.1	25.0	75.0	160.0	235.0	315.0	410.0	485.0	530.0	650.0
61S-L12	450	9,800	0.14	0.0026	168.0	0.60	553.9	6.9	20.0	56.0	134.0	204.0	280.0	370.0	335.0	514.0	—
2-48[a]	450	9,000	0.12	0.0018	175.0	0.53	472.7	4.4	22.0	70.0	174.0	250.0	354.0	434.0	—	—	—
61S-L3	450	6,000	0.06	0.000047	—	—	1338.0[b]	0.25	760.0	—	—	—	—	—	—	—	—
							Transverse Direction										
61S-T1	450	12,000	0.25	0.0127	70.0	1.25	187.7	20.5	—	6.0	14.0	34.0	54.0	80.0	100.0	125.0	156.0
							Longitudinal Direction										
61S-L4	500	12,000	1.20	8.4	0.3	3.70	0.4	12.5	—	—	—	—	—	—	0.1	0.2	—
2-50[a]	500	11,000	—	—	—	—	9.5	9.2	—	—	—	—	—	—	—	—	—
61S-46	500	10,000	0.15	0.10	—	—	33.0	12.3	0.2	1.6	4.0	6.6	9.4	13.6	17.8	26.4	—
61S-L8	500	9,000	0.10	0.012	25.0	0.50	119.0	7.5	6.0	12.0	27.0	38.0	52.0	68.0	80.0	98.0	—
2-46[a]	500	7,500	0.10	0.012	75.0	1.00	180.7	10.8	4.0	10.0	30.0	50.0	70.0	97.0	117.0	145.0	170.0
2-49[a]	500	7,500	0.10	0.015	66.0	1.50	147.3	7.2	5.0	10.0	22.0	35.0	52.0	78.0	95.0	115.0	—
61S-L5	500	6,000	0.09	0.0012	340.0	5.50	1007.8[b]	3.0	50.0	125.0	290.0	430.0	575.0	750.0	865.0	995.0	—
							Transverse Direction										
61S-T2	500	10,000	0.15	0.33	—	—	20.8	11.4	—	0.4	1.0	1.6	2.6	4.0	5.6	8.6	15.0
61S-T3	500	9,000	0.10	0.022	25.0	0.65	63.9	10.1	4.0	8.0	17.5	26.0	33.0	44.0	—	—	—

(a) Indicates 0.040 in. thick material; balance of specimens 0.125 in. thick.

(b) Test discontinued.

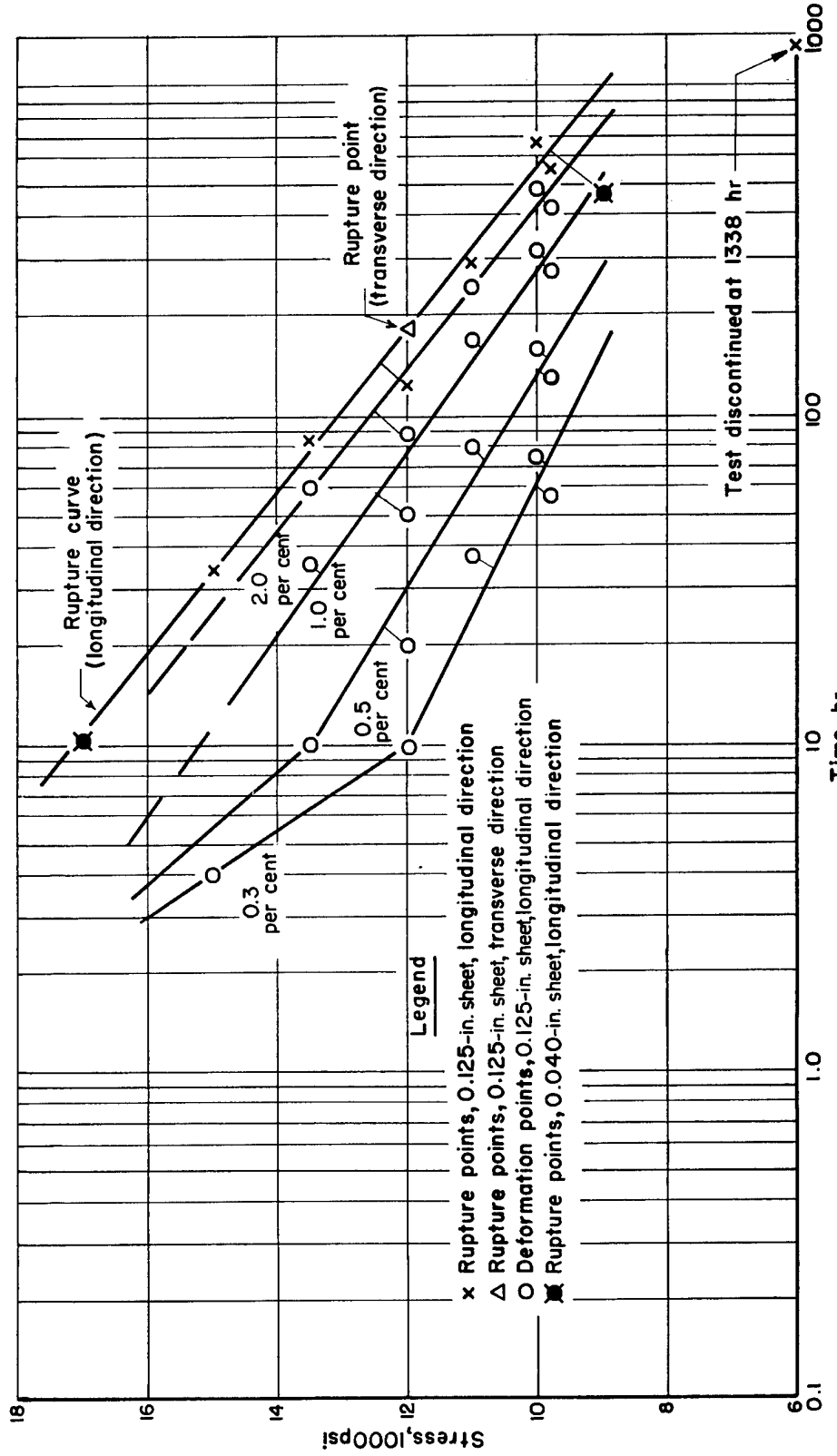


FIGURE 1. DESIGN CURVES FOR 6061-T6 ALUMINUM ALLOY SHEET TESTED AT 450F IN THE LONGITUDINAL DIRECTION WITH CHECK POINT IN THE TRANSVERSE DIRECTION

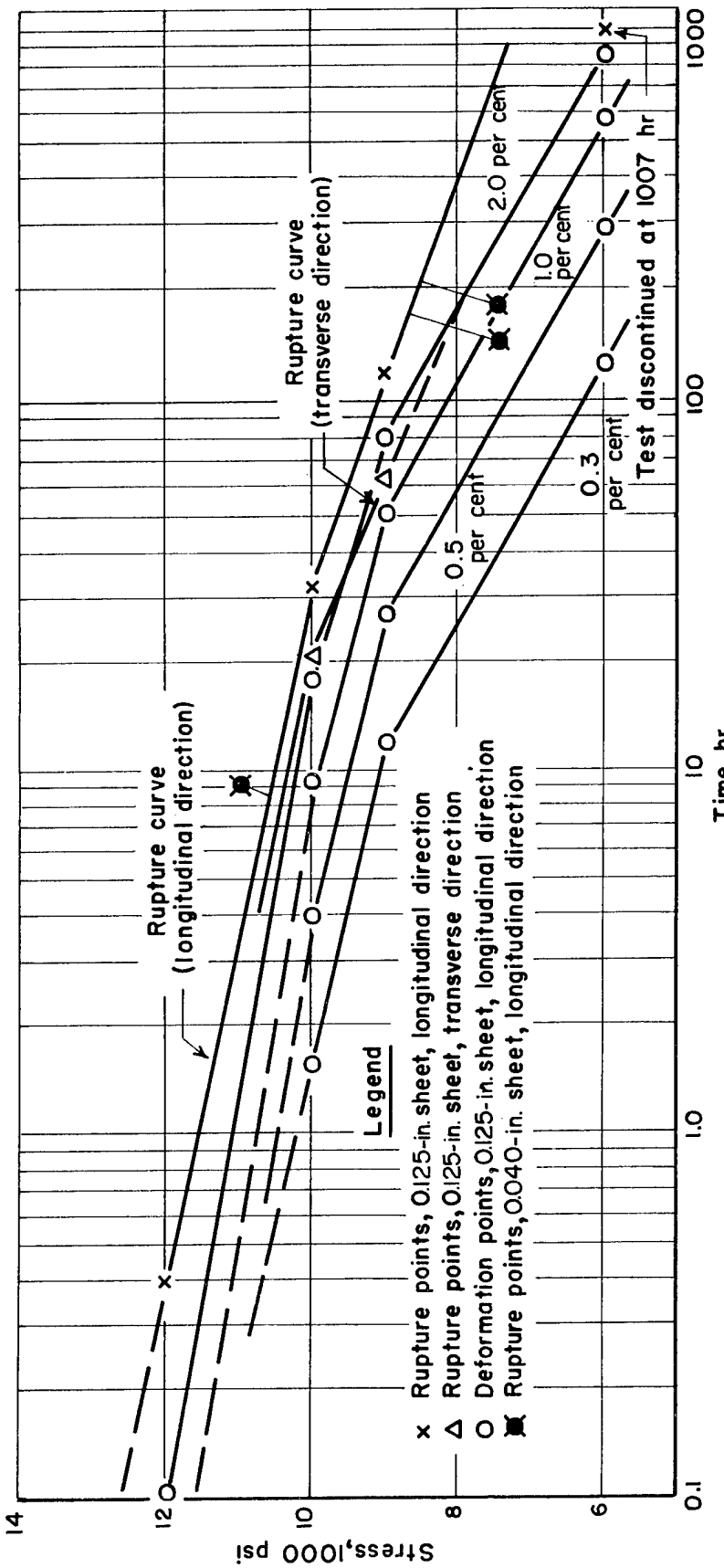


FIGURE 2. DESIGN CURVES FOR 6061-T6 ALUMINUM ALLOY SHEET TESTED AT 500 F IN THE LONGITUDINAL DIRECTION WITH CHECK POINTS IN THE TRANSVERSE DIRECTION

A-13149

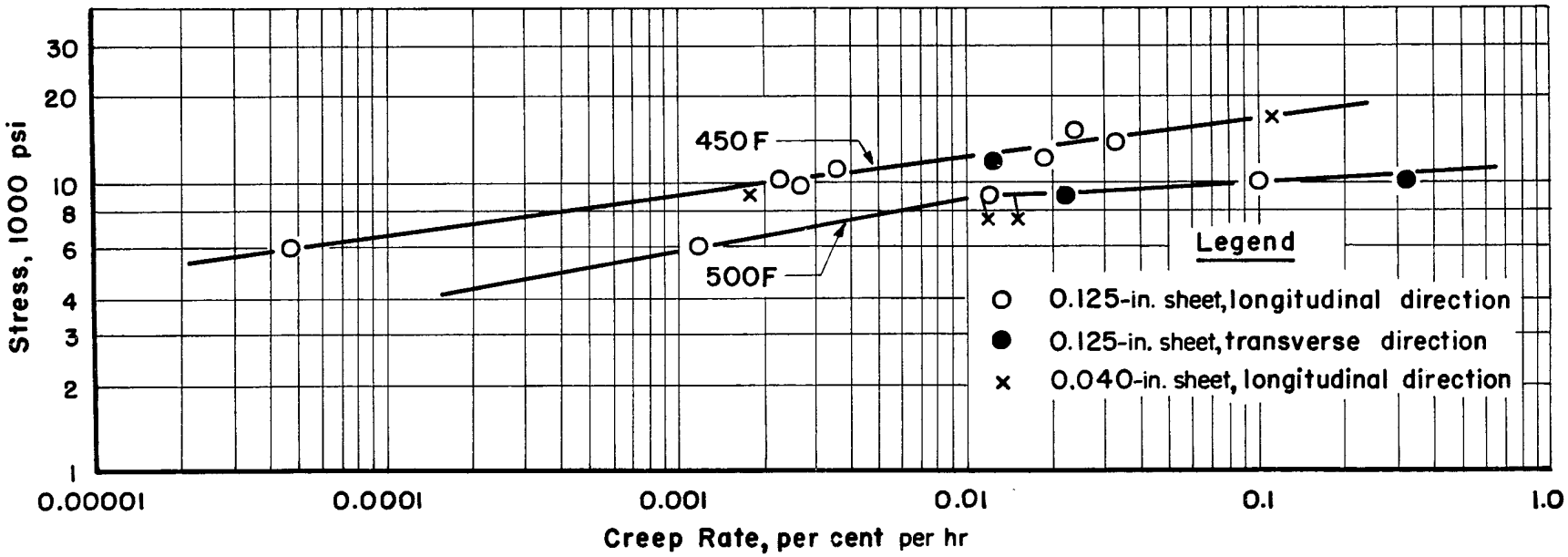
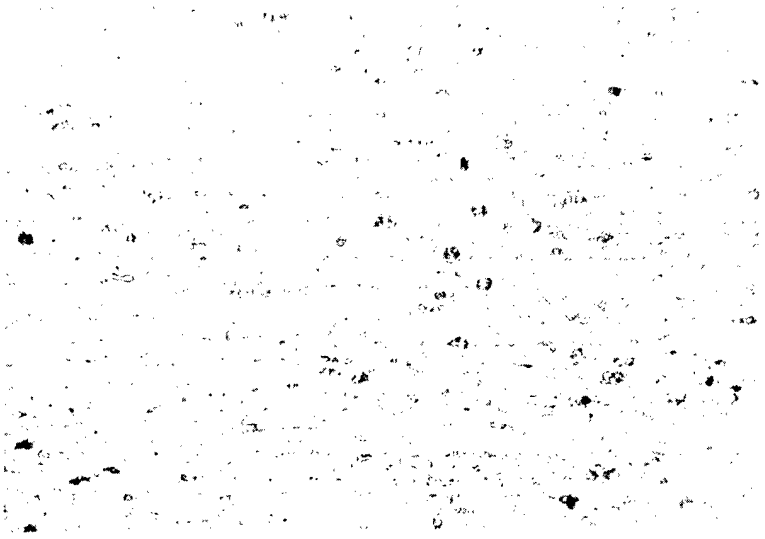


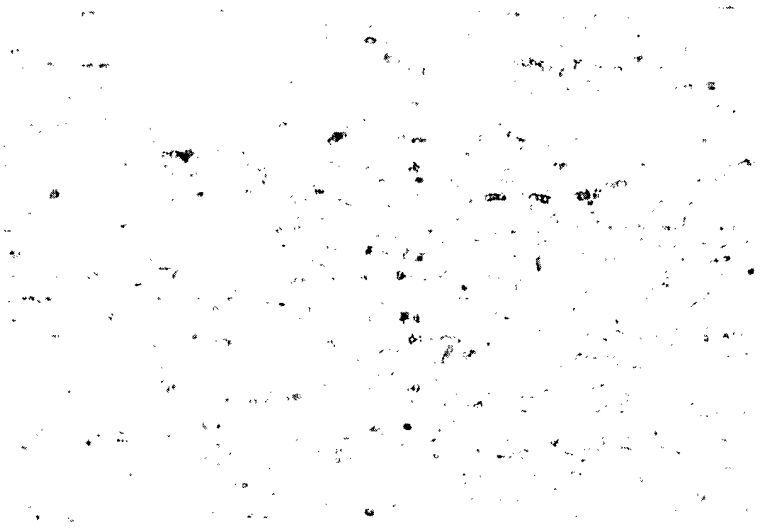
FIGURE 3. STRESS VERSUS CREEP-RATE CURVES FOR 6061-T6 ALUMINUM ALLOY SHEET AT 450 AND 500 F

A-13150



250X 1/2 w/o HF Etch N18095

Specimen 61S-L5 (0.125-In. Sheet) After 1008 Hr at 500 F Under a Load of 6000 PSI



250X 1/2 w/o HF Etch N18094

Specimen 2-46 (0.040-In. Sheet) After 181 Hr at 500 F Under a Load of 7500 PSI

FIGURE 4. LONGITUDINAL SECTIONS FROM 0.040 AND 0.125-IN. 6061-T6 CREEP SPECIMENS SHOWING STRUCTURE AFTER TEST

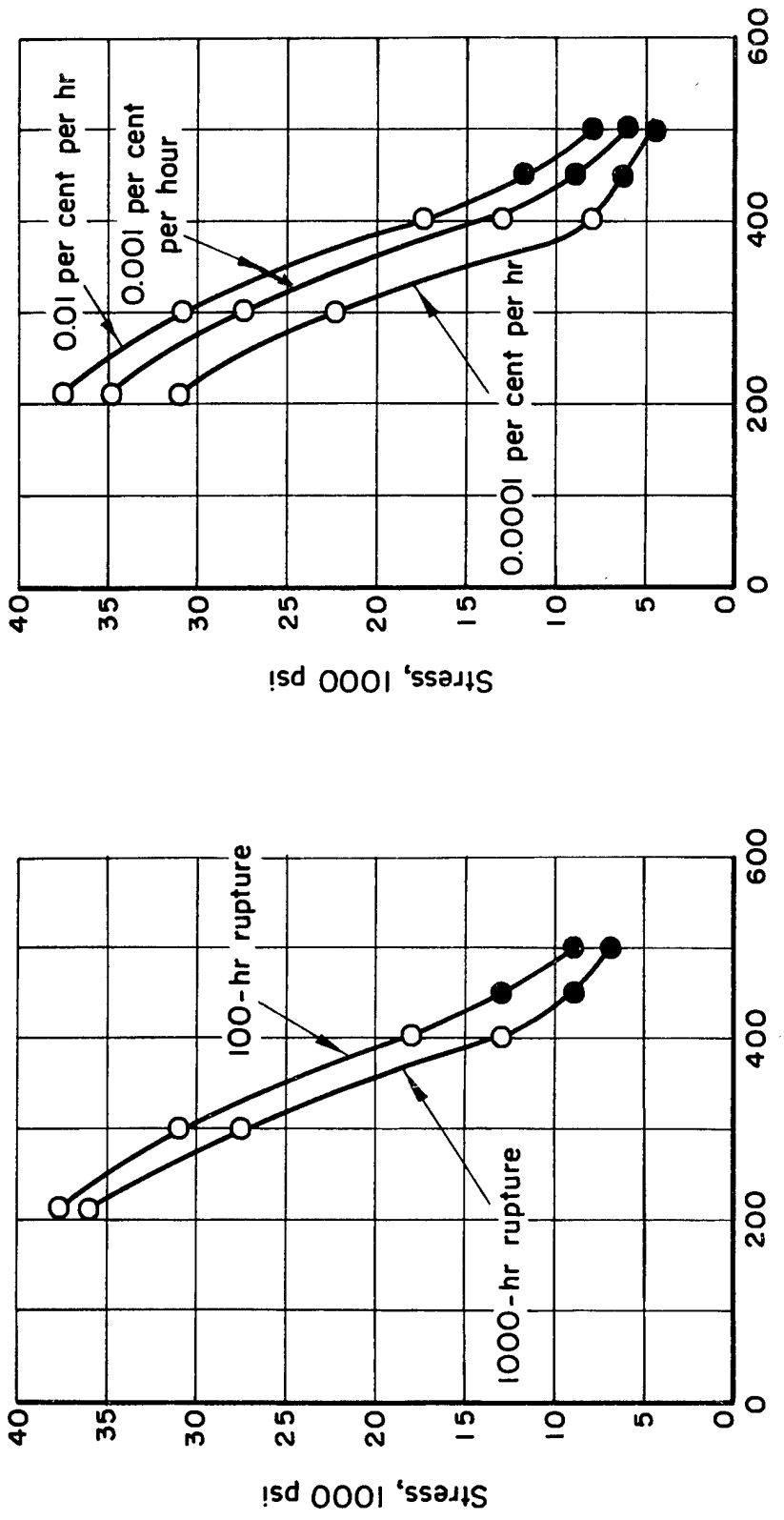


FIGURE 5. RUPTURE LIFE AND MINIMUM CREEP RATES OF 6061-T6 ALUMINUM ALLOY AT TEMPERATURES UP TO 500 F
Open points taken from Rand Report, R-104

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