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FINAL REPORT – DEVELOPMENT AND TESTING OF VACUUM MELTED NICKEL – MOLYBDENUM ALLOYS WITH MINOR ALLOYING ADDITIONS

O. Preston
N. J. Grant
C. F. Floe

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INTRODUCTION

A report entitled "Final Report on Development and Testing of Nickel - Molybdenum Alloys" by Monkman, Grant and Floe was issued as ORNL-1990 Metallurgy and Ceramics, on 10 November 1955. This report covered a series of five simple vacuum melted nickel - molybdenum alloys in which the molybdenum increased progressively from 17 to 36%. Air melted Hastalloy B was included for comparison purposes.

The test program included (for 3 heat treatments)

a. Creep rupture tests up to about 500 hours at 1350, 1500 and 1650° F,

b. Room temperature tensile tests, and

c. Room temperature tensile tests after 100 hours exposure at 1500° F to determine the degree of embrittlement.

Because of severe embrittlement at room temperature after high temperature exposure of these simple binary Ni - Mo alloys, two of the intermediate molybdenum compositions were selected and additions of Cr, Fe, V and Cb were made to determine the degree of stabilization conferred by these various addition elements.

PROCEDURE AND RESULTS

Two base alloys were chosen from the previous study, containing 22 and 27 percent molybdenum, respectively, to which were added 0.7 percent manganese. Fixed amounts of Cr, Fe and V, based on Hastalloy B, were added to several of the alloys. About 1.3 percent columbium was added to two of the alloys to determine its stabilizing effect. See Table I for the compositions.

Six vacuum melted heats were prepared by Utica Drop Forge and Tool Corporation and shipped to this laboratory in the form of hot forged 1-1/4 inch rounds. These were then further forged to 3/8 inch rounds. Alloys 4, 5, and 6 were readily forged at 2100° F, alloys 1 and 3 at 2000° F. Alloy 2 showed numerous cracks in the as received condition, but after removal of all visible cracks by grinding, it could not be forged at any temperature in the range of 1900° to 2200° F. Therefore, no tests were conducted on alloy 2.

The remaining five alloys were solution treated for 1/2 hour at 2000° F, and air cooled. In addition a portion of each alloy was aged for 16 hours at 1500 F and air cooled. Test bars of 0.225 inch diameter by 1 inch gage length were machined after these heat treatments.

Stress-rupture tests were conducted at 1350, 1500 and 1650° F on the five alloys in the two conditions of heat treatment. Stresses were chosen to give rupture lives covering the range from one hour to 500 hours. Values of stress, temperature, rupture life, elongation and reduction of area are shown in Tables IV through VIII. Plots of log stress versus log rupture life are shown in Figures 1 through 5. A summary of stress-rupture values for each of the test temperatures is shown in Figure 6, 7, and 8, along with the values obtained for Hastalloy B in the previous investigation.

The stress for 1000 hours rupture life was obtained by extrapolation of these plots, and the values are listed in Table II. Values of elongation for 100 hour rupture life, shown in Table III, were obtained by interpolation, and are considered quite accurate.

Room temperature tensile tests were conducted in duplicate for each alloy and each heat treatment. Duplicate tests were also made on each alloy and each heat treatment after an embrittlement treatment which consisted of heating for 100 hours (without load) at 1500° F and air cooling. Data on tensile strength, yield strength (0.2 percent offset), elongation and reduction of area are given in Tables IX and X.

Metallographic specimens were prepared from each alloy

in both conditions of heat treatment, and from the stress-rupture bars which had approximately 100 hour rupture life at each of the three test temperatures. By this means the effects of heat treatment, and the structural changes taking place during testing could be observed. Photomicrographs are shown in Figures 9 through 13.

DISCUSSION OF RESULTS

Forgeability

The alloys were readily forgeable with the exception of alloy 2. The cause of cracking during forging of this alloy is not known. In the remaining five alloys, those containing the higher amounts of molybdenum, alloys 4, 5, and 6, showed appreciable higher resistance to deformation at the forging temperatures, but nevertheless they did not exhibit any greater tendency to cracking.

Room Temperature Tensile Data

In the solution treated condition, all five of the modified vacuum melted alloys showed yield and tensile values which were not significantly dissimilar to the values of commercial Hastalloy B. In terms of elongation and reduction of area, the vacuum melted alloys all showed a small but definite advantage. Alloy 3, showed the lowest yield and tensile values

but the highest ductility.

In comparison with the simple binary vacuum melted Ni - Mo alloys (see ORNL-1990) of comparable molybdenum content, the current alloys showed slightly higher tensile values and slightly higher elongation figures.

In the 16 hours aged (1500° F) condition these modified (or more correctly, stabilized) alloys did not suffer the sharp decrease in ductility which the simple binary alloys suffered. In the lower molybdenum group, alloys 1 and 3, aging did not alter any of the room temperature properties significantly. Of the higher molybdenum group only alloy 5 (high Fe) did not respond to aging. Alloy 4 showed an increase in both yield and tensile strength with a small loss of ductility. Alloy 6 (1.29% Cb) showed a marked increase in yield and tensile strength with only a moderate decrease in ductility. The photomicrographs, see Figure 13, show the formation of a grain boundary precipitate in alloy 6 after the 1500° F aging treatment. This precipitated phase becomes more pronounced and less highly dispersed during stress rupture testing at 1650° F. Alloy 4 also shows some rather coarse precipitation in the creep rupture specimen tested at 1500° F (Figure 11).

In view of the severe embrittlement suffered in the 100 hour aging tests at 1500° F by the prior simple Ni - Mo

binary alloys, much attention was given to this phase of the program. Table X shows that there was no significant difference between the solution treated and solution treated and aged groups since the 100 hours additional aging at 1500° F effectively resulted in the two groups showing about the same values.

Alloys 1, 3, and 5 were virtually unchanged by the 100 hour aging embrittlement test except that alloy 5 showed a somewhat larger loss of ductility. Alloys 4 and 6, which had responded to the 16 hour aging treatment, showed still greater increases in yield and tensile strength when the aging was increased by 100 hours. Alloy 4 showed a drop in ductility which was appreciable, whereas alloy 6 showed a large decrease in ductility, including a tendency toward notch sensitivity as indicated by the fracture through the gage marks.

An interesting tensile test was the one run on a stress rupture bar of alloy 4 which had been in test for 840 hours at 1350° F at a stress of 12,000 psi (the total deformation had been less than about 1%). It will be noted (Table X) that there had been a further loss of ductility and the fracture occurred through a gage mark of the specimen.

Stress Rupture Tests

Close examination of Figures 1 to 5 shows that alloys 1, 3, 4, and 6 all show greater aging effects than alloy 5. Alloy 1 (see Figure 1) shows less and less benefit of aging as temperature increases and stress decreases (longer rupture time). At 1600° F there is no benefit due to aging.

Alloy 3 (see Figure 2) shows significant aging benefits at both 1350 and 1500° F out to 1000 hours but no benefit at 1650° F.

Alloy 4 (see Figure 3) shows short time aging benefits at all three temperatures but the effect at 1650° F is exceedingly small.

Alloy 5 (see Figure 4) is obviously the least affected by aging and certainly the most stable of the group since there are no breaks in the curves over the stress and temperature range investigated.

Alloy 6 (see Figure 5) also shows only short time aging benefits at 1350 and 1500° F but is weaker over the entire test range at 1650° F.

DISCUSSION AND SUMMARY

1. Iron at about 5% (in alloy 5) is apparently quite effective in stabilizing the Ni - Mo structure at about 26% Mo. Unfortunately alloy 2 was lost to the program to determine the effect at the

22% Mo level. The nature of this stabilization is unknown since the microstructures in Figure 12, at 1350 and 1500° F, indicate structural changes to be taking place in alloy 5.

2. The same compositional variations at the 22% Mo versus the 27% Mo level show that certain alloying elements have a greater effect on structure instability at the 27% level. For example, 1.3% Cb has a small effect in the 22% Mo alloy, No, 3, but a large effect in the 27% Mo alloy No. 6. Similarly, alloy 1 is a stable alloy compared to alloy 4.

3. From an overall consideration, the changes in structure and properties with alloying additions are due not only to a shift in solvus boundaries but must be due in part to the rate of change of the γ Ni solid solution into the β structure.

4. The addition of a number of alloying combination appears to decrease or prevent embrittlement which was readily noted in the simple vacuum melted Ni - Mo alloys.

5. Examination of Figures6 to 8 shows the interesting effect of temperature on the relative strength of the 5 vacuum alloys compared to commercial Hastqlloy B. At 1350° F, alloys 4, 5, and 6 all show greater strength than Hastalloy B out to about 500 to 1000 hours; at 1500° F, only alloys 4 and 6 show greater strength to about 500 to 1000 hours. At 1650° F however, Hastalloy B is considerable stronger than any of the 5 vacuum alloys. Furthermore the difference in strength at

1650° F among the 5 experimental alloys is the least for all three temperatures. It is possible that the relative improvement of Hastalloy B over the 5 experimental alloys, with increasing temperature, may be ascribed to its generally higher alloy content, which would include silicon, cobalt and nitrogen.

TABLE I

Composition of Alloys in This Investigation

Alloy	C	S	Cr	Mo	Fe	V	Mn	Cb	Ni
1	0.02	0.004	0.65	22.3	0.43	0.38	0.72	-	bal.
2	0.01	0.005	0.64	22.4	4.86	0.39	0.66	-	bal.
3	0.02	0.005	-	22.5	0.70	-	0.74	1.30	bal.
4	0.02	0.005	0.65	28.5	0.16	0.34	0.66	-	bal.
5	0.02	0.006	0.62	26.5	4.80	0.37	0.65	-	bal.
6	0.03	0.005	-	26.5	0.82	-	0.65	1.29	bal.

TABLE II

Summary of Extrapolated Values of Stress for 1000 Hour Rupture Life

Alloy	1350° F	1500° F	1650° F
(a) 1/2 hour at 2000° F, air cooled			
1	9,200	3,000	2,000
3	13,500	5,400	2,800
4	27,500	12,500	3,200
5	19,000	7,500	2,900
6	27,500	13,000	3,700
Hastelloy B	21,000	11,000	6,000
(b) 1/2 hour at 2000° F, air cooled; 16 hours at 1500° F, air cooled			
1	8,200	2,700	1,800
3	17,500	6,600	2,700
4	23,500	6,000	1,600
5	23,000	9,500	2,600
6	23,000	9,000	2,700

TABLE III

Summary of Interpolated Values for Elongation at 100 Hour Rupture Life

Alloy	1350° F	1500° F	1650° F
(a) 1/2 hour at 2000° F, air cooled			
1	4 %	3 %	5 %
3	10	9	10
4	7	12	15
5	19	37	10
6	2	12	8
(b) 1/2 hour at 2000° F, air cooled; 16 hours at 1500° F, air cooled			
1	10	5	4
3	26	22	13
4	2	9	7
5	20	25	25
6	3	8	17

TABLE IV

Stress-rupture Data for Alloy 1

Temp, ° F	Stress, psi	Elongation, %	Reduction of Area, %	Rupture life, hour
(a) 1/2 hour at 2000° F, air cooled (Code 11)				
1350	40,000	6	10	4.2
	35,000	7	8	9.9
	25,000	9	9	33.6
	25,000	4	4	34.2
	15,000	-	2	175.4
1500	20,000	12	13	4.4
	15,000	9	7	7.7
	10,000	3	3	25.8
	6,000	2	3	117.1
	4,000	-	5	382.5
1650	12,500	-	4	0.7
	10,000	9	10	2.5
	7,500	5	5	5.5
	5,000	-	3	20.1
	4,000	4	6	49.1
	3,000	7	10	263.2
(b) 1/2 hour at 2000° F, air cooled; 16 hours at 1500° F, air cooled (Code 12)				
1350	50,000	12	14	1.8
	50,000	12	20	2.7
	45,000	12	14	16.4
	40,000	10	16	19.1
	30,000	12	13	48.4
	25,000	13	11	69.6
	20,000	9	8	128.7
	12,500	5	3	294.5
1500	20,000	11	14	6.8
	15,000	7	8	16.5
	10,000	7	7	56.3
	7,500	5	6	88.5
	5,000	-	4	191.7
1650	10,000	9	9	3.3
	7,500	6	8	4.7
	5,000	4	9	24.7
	3,000	-	12	176.4
	2,000	test discontinued at 425.6 hours		

TABLE V

Stress-rupture Data for Alloy 3

Temp. ° F	Stress, psi	Elongation, %	Reduction of Area, %	Rupture life, hours
(a) 1/2 hour at 2000° F, air cooled (Code 31)				
1350	50,000	11	14	1.8
	40,000	9	13	10.3
	30,000	9	9	78.0
	25,000	12	14	125.5
	25,000	6	9	136.7
	20,000	5	5	270.6
	20,000	8	8	279.0
1500	30,000	10	11	4.4
	20,000	13	13	13.7
	15,000	14	14	31.4
	10,000	6	10	154.7
	7,000	-	11	397.6
1650	15,000	8	17	4.1
	10,000	11	18	23.0
	7,500	11	13	39.7
	5,000	-	20	178.9
	3,500	-	12	469.7
(b) 1/2 hour at 2000° F, air cooled; 16 hours at 1500° F, air cooled (Code 32)				
1350	50,000	11	20	2.3
	40,000	14	17	14.9
	30,000	28	24	114.1
	25,000	14	15	208.1
	20,000	test discontinued at 593.7 hours		
1500	30,000	17	16	4.0
	25,000	30	26	10.8
	20,000	45	42	28.3
	15,000	22	33	92.9
	10,000	15	16	292.3
	10,000	17	21	303.0
1650	20,000	-	1	1.1
	15,000	38	33	4.9
	10,000	-	26	27.2
	7,500	15	21	57.3
	5,000	10	14	186.1

TABLE VI

Stress-rupture Data for Alloy 4

Temp, ° F	Stress, psi	Elongation, %	Reduction of Area, %	Rupture life, hr
(a) 1/2 hour at 2000° F, air cooled (Code 41)				
1350	70,000	1	3	0.3
	60,000	6	4	16.6
	50,000	1	3	10.4
	45,000	1	3	17.5
	40,000	10	9	180.9
	30,000	broke in threads		358.1
	20,000	test discontinued at 839.9 hours		
1500	35,000	13	39	5.7
	30,000	bar split longitudinally		17.4
	25,000	11	27	17.6
	20,000	12	14	101.9
	15,000	5	4	332.2
1650	15,000	34	33	2.2
	10,000	15	29	16.9
	9,200	16	23	20.5
	7,500	27	35	26.8
	5,000	-	7	145.9
(b) 1/2 hour at 2000° F, air cooled; 16 hours at 1500° F, air cooled (Code 42)				
1350	80,000	4	3	0.9
	70,000	2	6	9.5
	50,000	3	5	87.7
	40,000	1	4	179.4
	35,000	11	13	294.4
	30,000	8	10	441.0
1500	50,000	6	8	1.6
	40,000	6	11	7.8
	30,000	8	15	31.8
	25,000	11	17	65.5
	20,000	10	20	80.8
	15,000	8	24	144.6
1650	15,000	29	37	5.8
	10,000	29	32	14.5
	7,500	-	25	46.5
	5,000	-	11	121.2
	3,500	-	26	205.1

TABLE VII

Stress-rupture Data for Alloy 5

Temp, ° F	Stress, psi	Elongation, %	Reduction of Area, %	Rupture life, hrs.
(a) 1/2 hour at 2000° F, air cooled (Code 51)				
1350	60,000	13	15	3.4
	50,000	21	31	10.0
	40,000	18	24	43.4
	30,000	19	29	168.1
	25,000	20	32	286.1
	20,000	6	14	541.2
1500	35,000	47	52	6.6
	25,000	49	66	14.9
	20,000	32	55	30.8
	15,000	37	39	111.9
	10,000	21	14	316.9
1650	20,000	43	50	2.7
	15,000	29	39	6.6
	10,000	13	14	28.8
	7,500	10	15	35.2
	4,000	-	20	362.6
(b) 1/2 hour at 2000° F, air cooled; 16 hours at 1500° F, air cooled (Code 52)				
1350	60,000	19	23	4.9
	50,000	17	21	13.1
	40,000	21	32	63.4
	30,000	20	47	124.2
	25,000	test discontinued at 667.0 hours		
1500	40,000	47	59	2.3
	30,000	46	50	7.6
	25,000	37	43	23.4
	20,000	44	45	46.3
	15,000	22	34	125.4
1650	20,000	45	53	2.0
	15,000	26	22	7.2
	10,000	23	44	18.9
	7,500	16	12	63.3
	5,000	42	31	120.8
	3,000	test discontinued at 255.5 hours		

TABLE VIII

Stress-rupture Data for Alloy 6

Temp, ° F	Stress, psi	Elongation, %	Reduction of Area, %	Rupture life, hours
(a) 1/2 hour at 2000° F, air cooled (Code 61)				
1350	60,000	8	14	2.0
	50,000	broke in radius		10.5
	40,000	2	1	34.2
	35,000	broke in threads		159.3
	30,000	2	2	458.8
1500	35,000	9	17	13.7
	30,000	25	29	12.1
	25,000	11	21	33.1
	20,000	13	19	142.1
	17,500	7	16	171.3
1650	20,000	33	41	1.7
	15,000	21	26	5.3
	10,000	2	10	34.1
	7,500	10	26	44.2
	5,000	-	13	302.7
(b) 1/2 hour at 2000° F, air cooled; 16 hours at 1500° F, air cooled (Code 62)				
1350	100,000	2	3	0.1
	90,000	3	1	0.2
	70,000	2	6	18.3
	50,000	3	4	64.7
	40,000	3	3	129.4
	30,000	5	9	391.4
1500	45,000	29	11	8.3
	40,000	14	33	2.1
	35,000	10	15	23.0
	25,000	7	10	43.5
	20,000	9	12	123.4
	15,000	4	5	149.2
1650	15,000	41	51	5.2
	10,000	17	23	15.0
	7,500	-	28	35.9
	5,000	-	23	96.8
	3,500	test discontinued at 569.1		

TABLE IX

Room Temperature Tensile Data for Alloys in This Investigation

Alloy	Tensile Strength, psi	Yield (0.2% offset)	Elong. %	Red. of Area, %
(a) Solution treated condition (1/2 hr. 2000° F. A. C.)				
1	133,000	58,000	53	69
	134,000	58,000	57	73
3	132,000	55,000	60	70
	128,000	54,000	57	71
4	139,000	63,000	51	60
	145,000	65,000	50	57
5	146,000	74,000	51	59
	143,000	68,000	53	63
6	145,000	66,000	55	63
	143,000	64,000	58	64
Hastelloy B	136,000	64,000	42	57
(b) Aged condition (1/2 hr. A. C.; 16 hr. 1500° F. A. C.)				
1	138,000	63,000	51	70
	128,000	55,000	55	70
3	127,000	51,000	52	61
	127,000	52,000	61	59
4	155,000	83,000	46	48
	153,000	81,000	43	56
5	148,000	78,000	52	63
	140,000	62,000	50	63
6	176,000	108,000	36	52
	181,000	96,000	37	45

TABLE X

Room Temperature Tensile Data After 100 Hours at 1500° F

Alloy	Tensile Strength, psi	Yield (0.2 % offset), psi	Elong. %	Red. of Area,
(a) Solution treated condition (1/2 hr. 2000° F. A. C.)				
1	126,000	53,000	53	71
	125,000	51,000	56	71
3	123,000	53,000	56	59
	122,000	54,000	58	57
4	188,000	108,000	21*	18*
	186,000	100,000	36	34
5	147,000	73,000	49	55
	143,000	67,000	47	53
6	176,000	-	4*	8*
	183,000	114,000	6*	8*
Hastelloy B	134,000	74,000	30	22
(b) Aged condition (1/2 hr. 2000° F. A. C.: 16 hr. 1500° F. A. C.)				
1	131,000	56,000	56	74
	129,000	57,000	54	73
3	123,000	53,000	58	62
	121,000	50,000	62	61
4	191,000	109,000	32	37
	185,000	101,000	36	36
5	145,000	73,000	43	44
	148,000	74,000	42	50
6	172,000	110,000	5*	8*
	190,000	109,000	11*	10*
(c) After 840 hours at 1350° F under stress of 12,000 psi				
4	135,000	113,000	2*	2*

* Broke at gage mark

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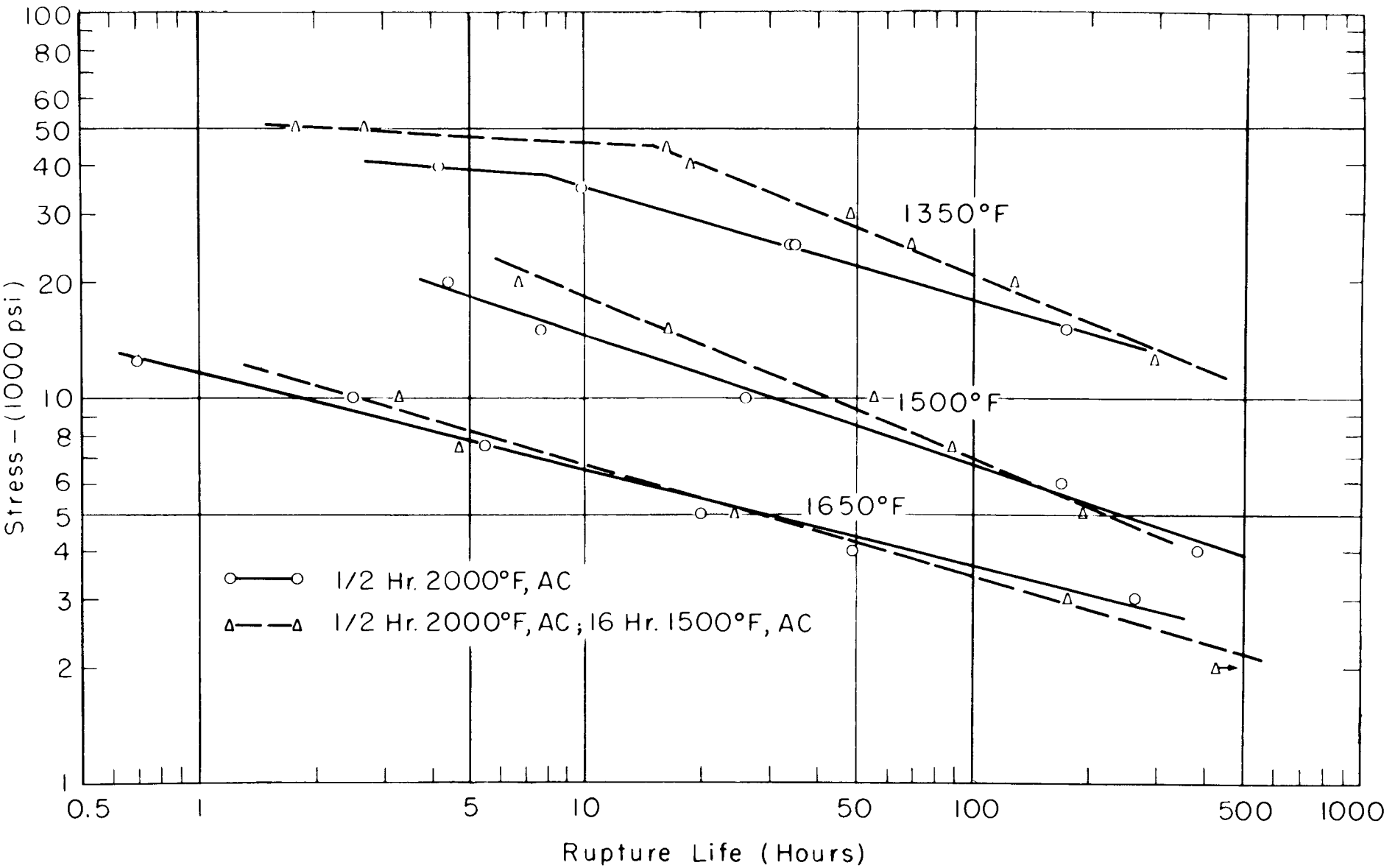

FIG. 1 - STRESS RUPTURE DATA FOR ALLOY NO. 1

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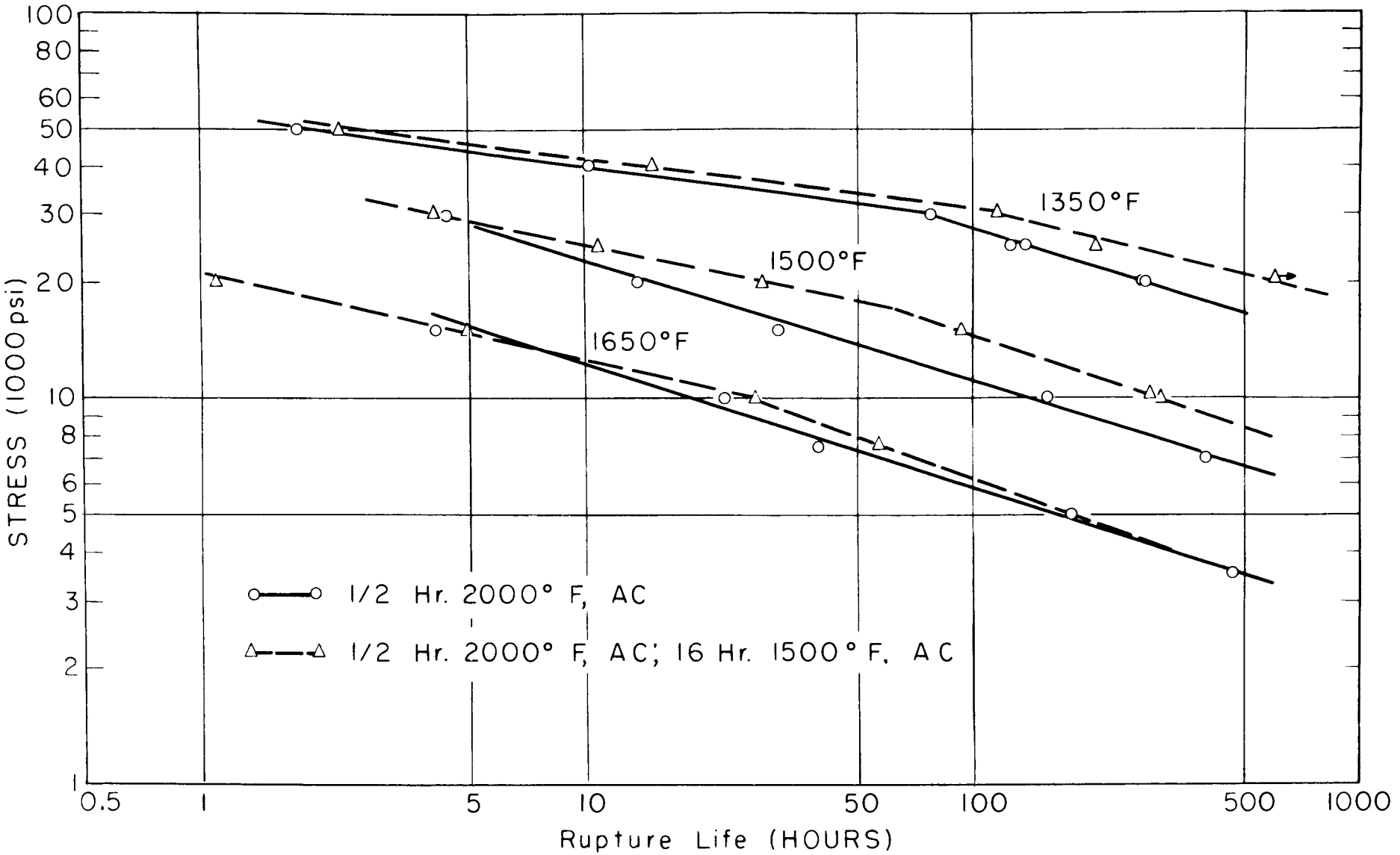

FIG 2 - STRESS RUPTURE DATA FOR ALLOY NO. 3

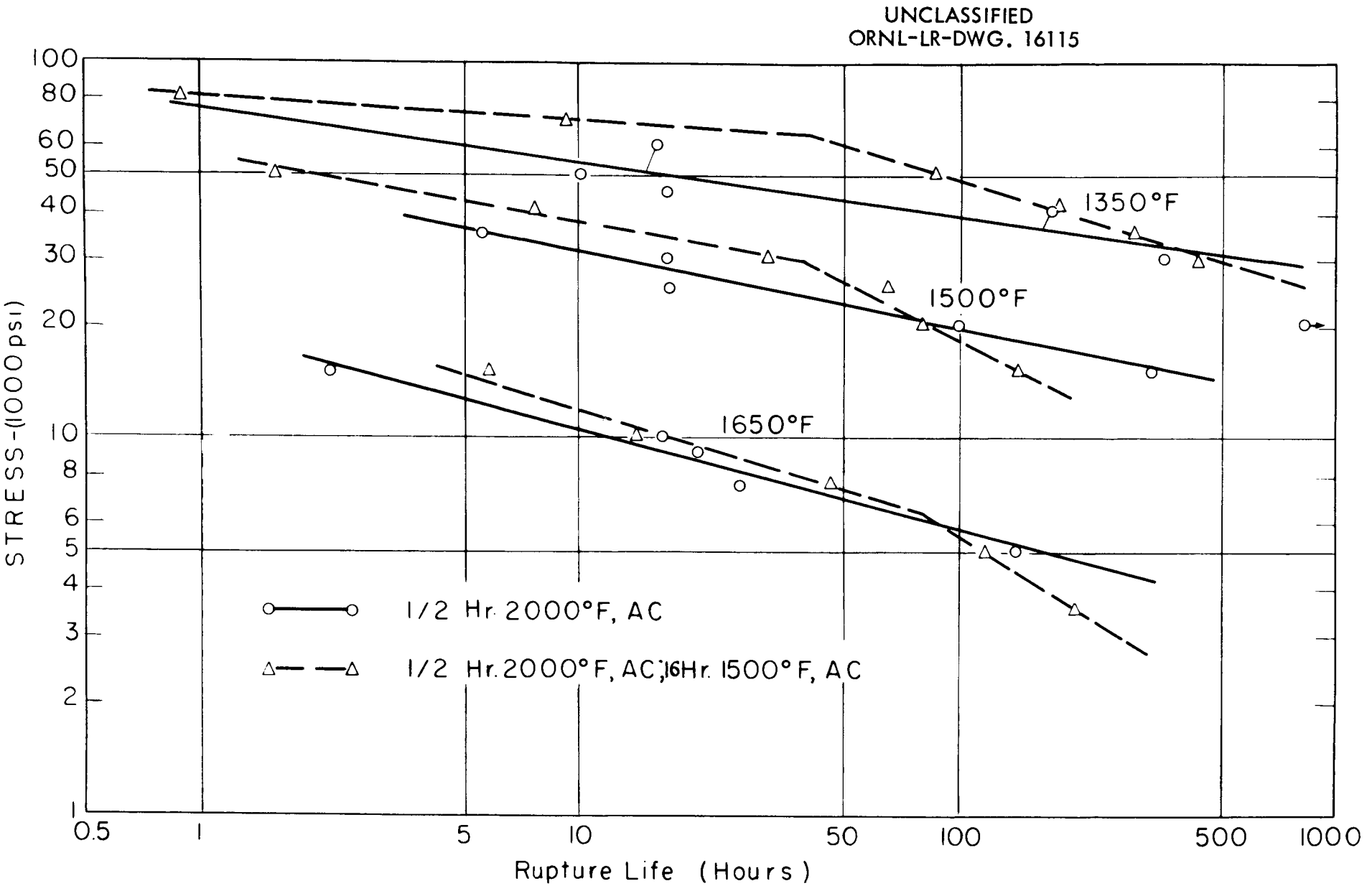

FIG 3 - STRESS RUPTURE DATA FOR ALLOY NO. 4

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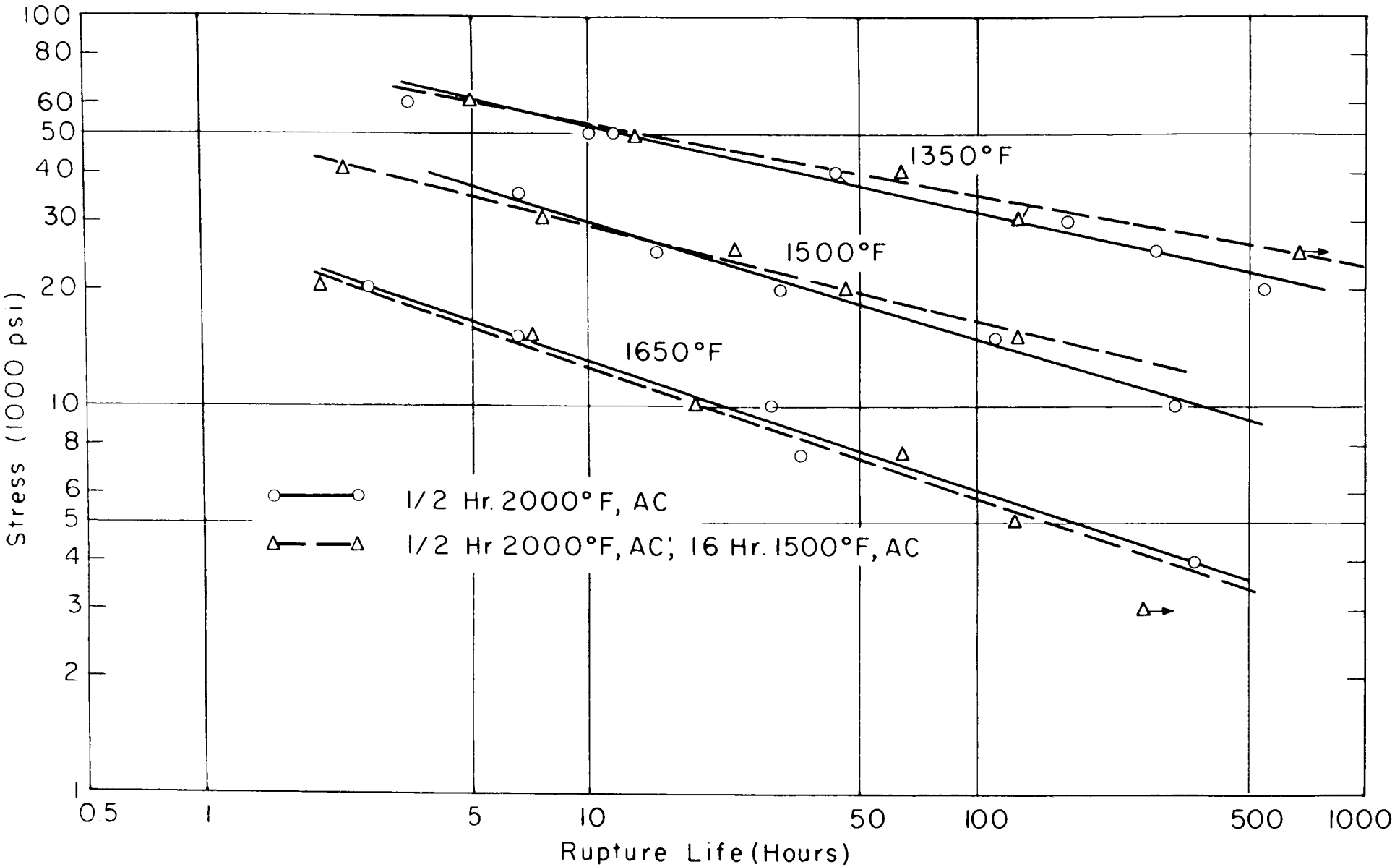

FIG 4 - STRESS RUPTURE DATA FOR ALLOY NO. 5

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ORNL-LR-DWG. 16117

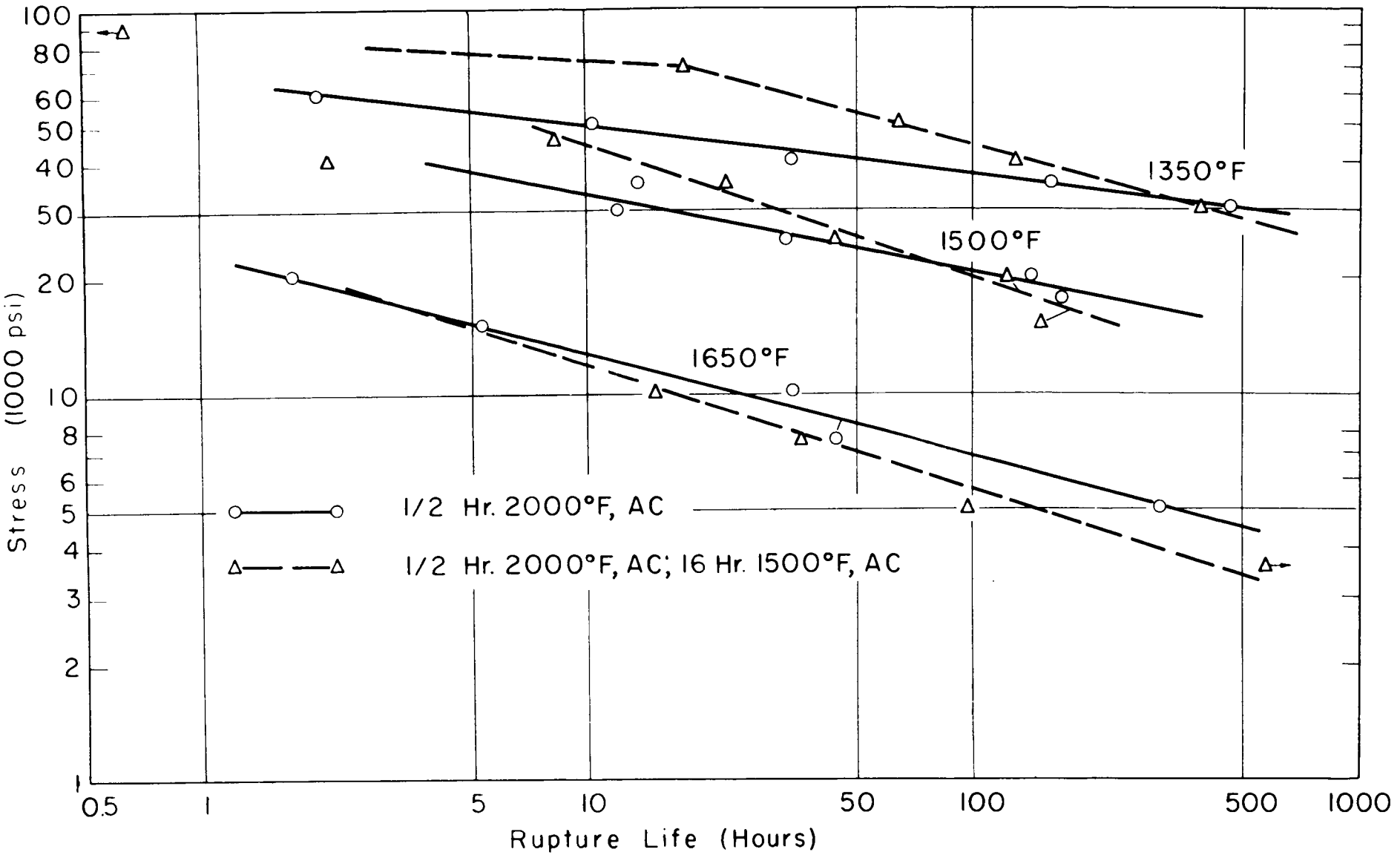

FIG 5 - STRESS RUPTURE DATA FOR ALLOY NO. 6

UNCLASSIFIED
ORNL-LR-DWG. 16118

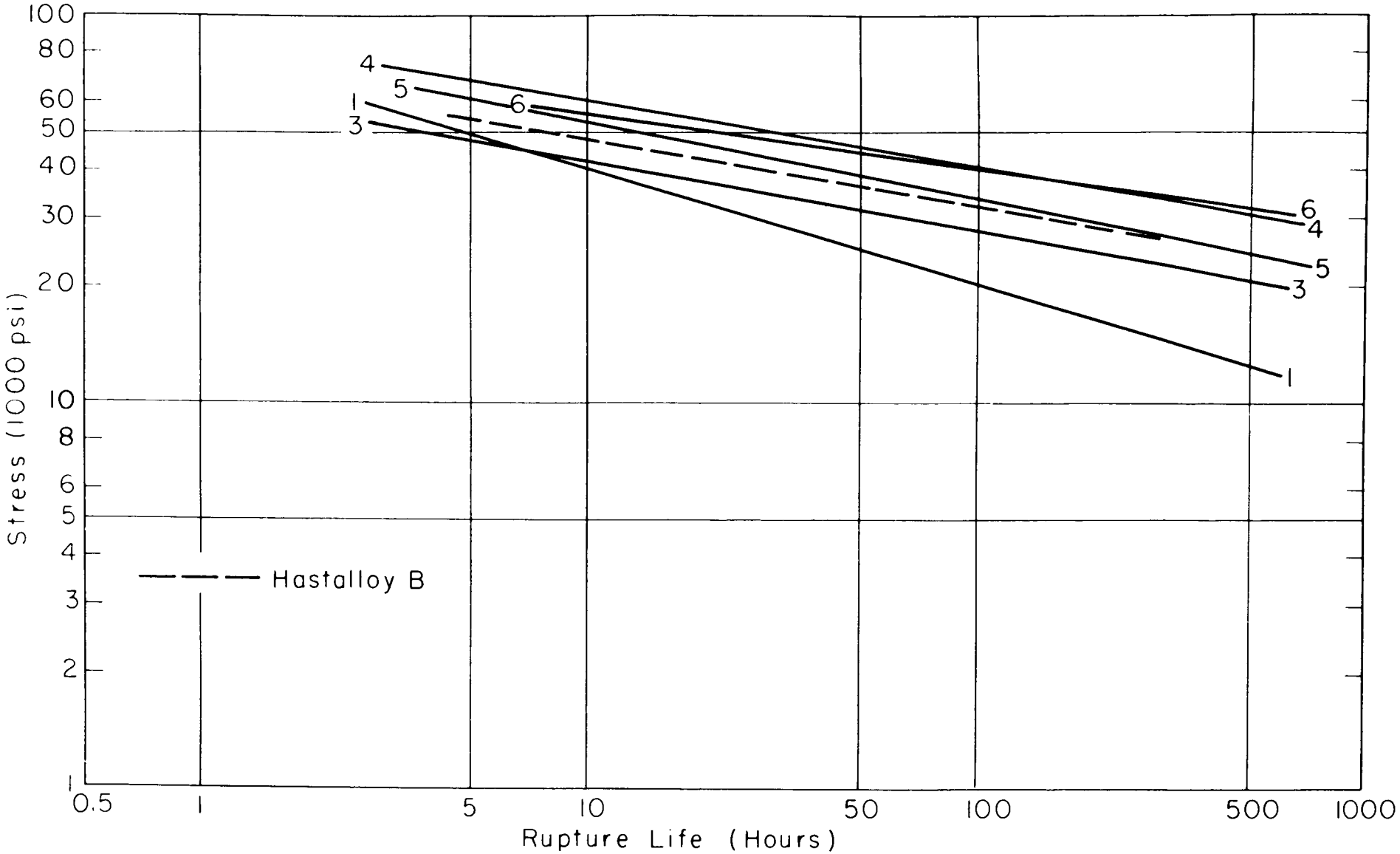

FIG 6-SUMMARY PLOT OF STRESS RUPTURE DATA AT 1350° F

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ORNL-LR-DWG. 16119

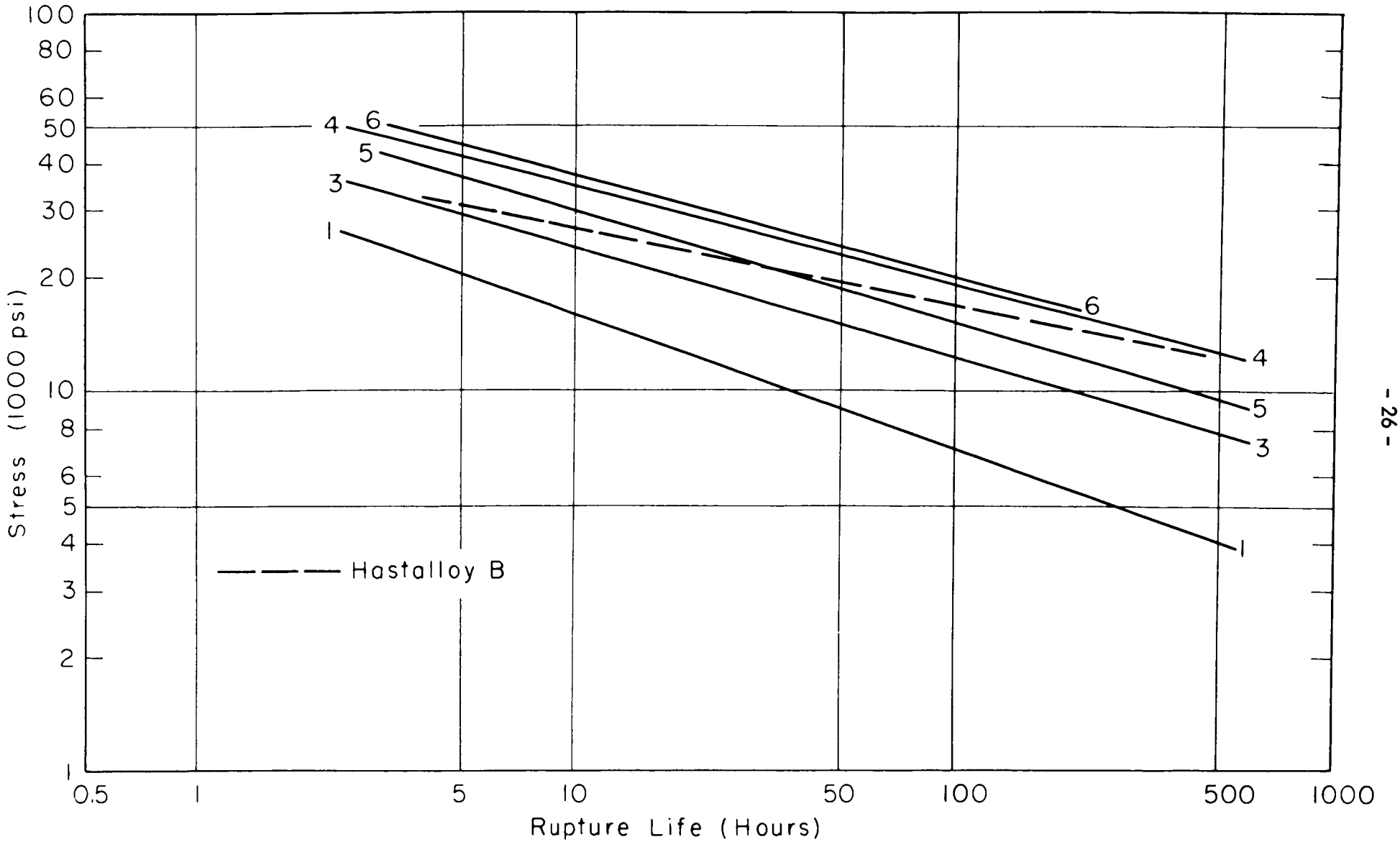

FIG 7- SUMMARY PLOT OF STRESS RUPTURE DATA AT 1500°F

UNCLASSIFIED
ORNL-LR-DWG. 16120

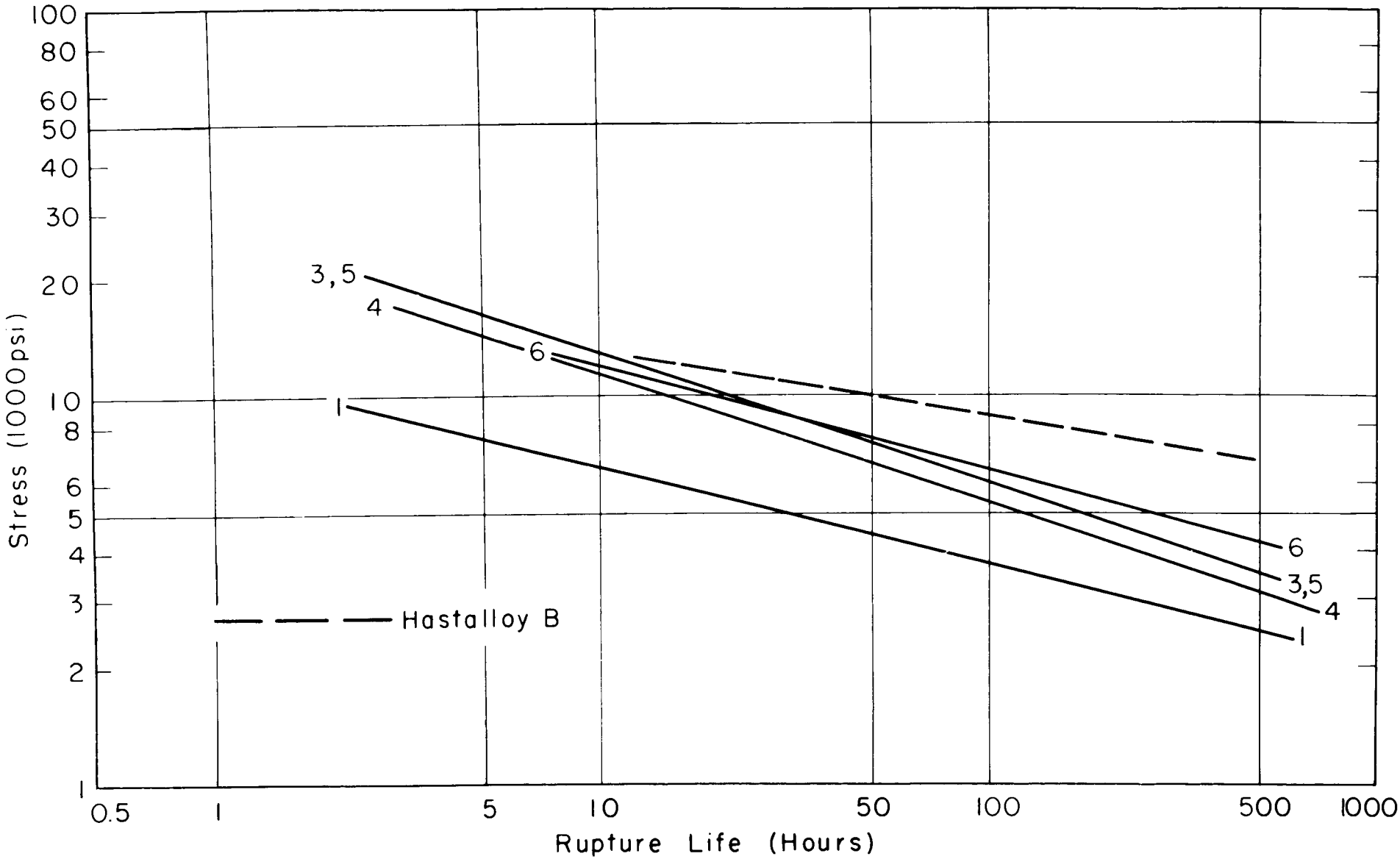

FIG 8 - SUMMARY PLOT OF STRESS RUPTURE AT 1650°F

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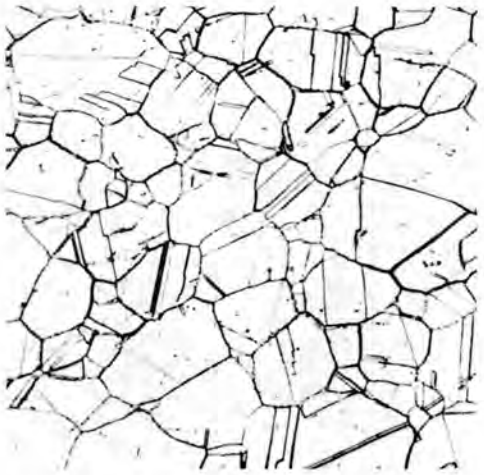
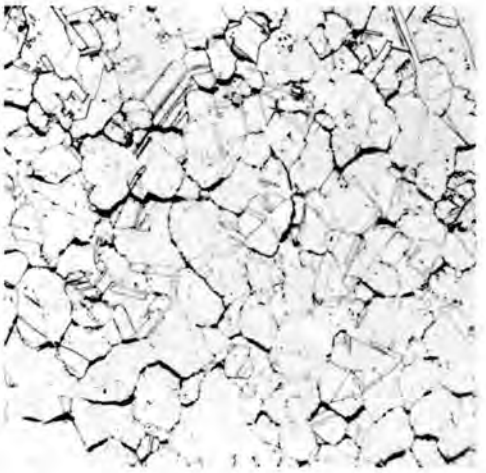
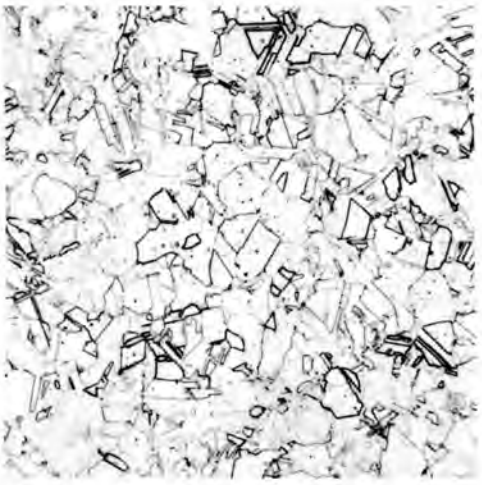


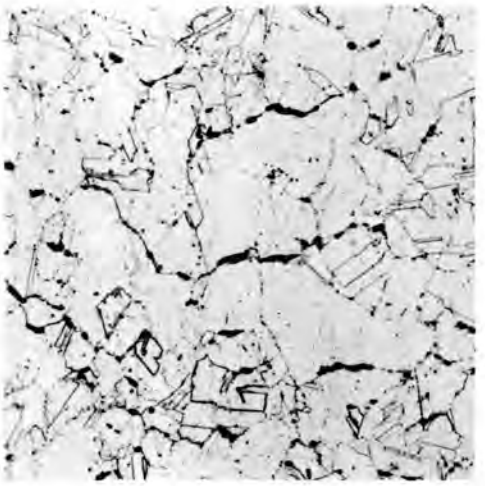
Code 11: 1/2 hr 2000°F, A.C.
As heat treated



Code 11: 30,000 psi at 1350°F
Rupture life 40.2 hr



Code 12: 1/2 hr 2000°F, A.C.
16 hr 1500°F, A.C.
As heat treated



Code 12: 30,000 psi at 1350°F
Rupture life 48.4 hr

Figure 9. Photomicrographs of alloy 1 in the solution treated condition, in the solution treated and aged condition, and after stress-rupture testing as indicated. Etched with 1/3 HCl, 1/3 HNO_3, 1/3 H_2O. 250X.

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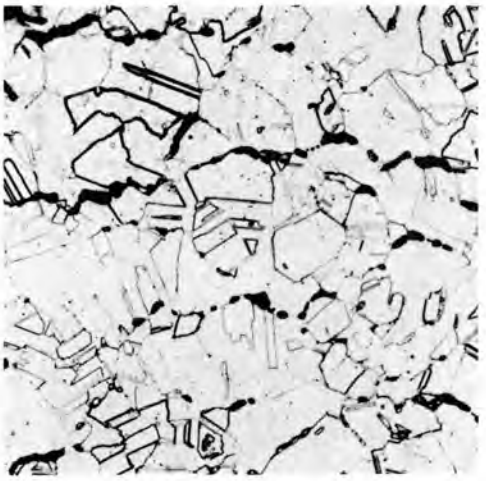
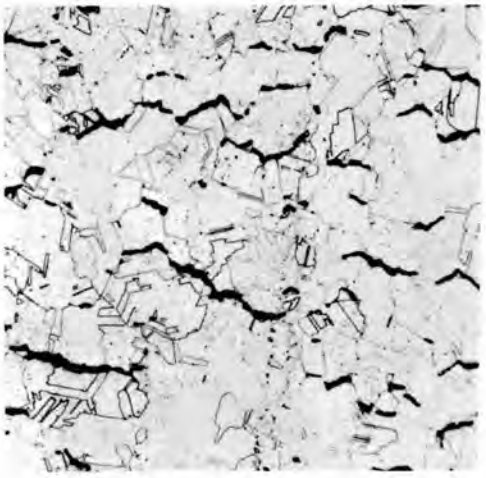
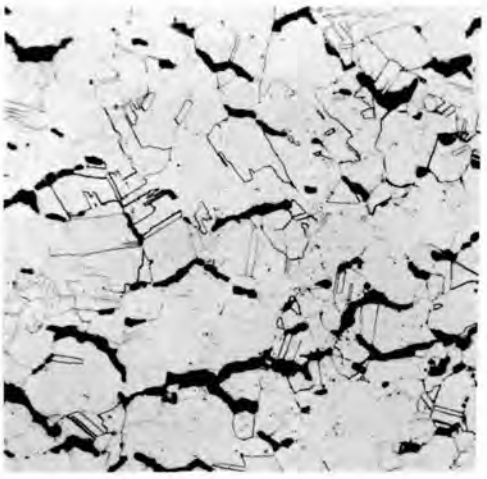
Code 11: 10,000 psi at 1500°F
Rupture life 25.8 hr



Code 11: 5,000 psi at 1650°F
Rupture life 20.1 hr



Code 12: 10,000 psi at 1500°F
Rupture life 56.3 hr



Code 12: 5,000 psi at 1650°F
Rupture life 24.7 hr

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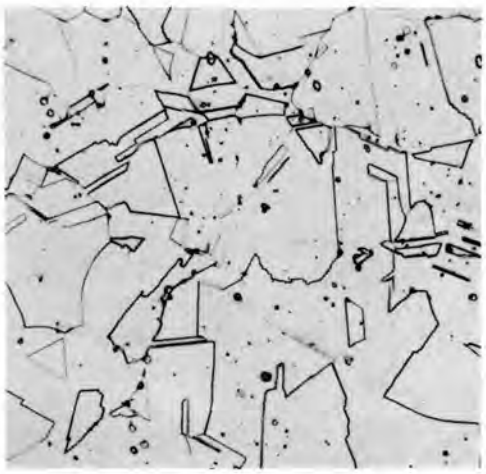
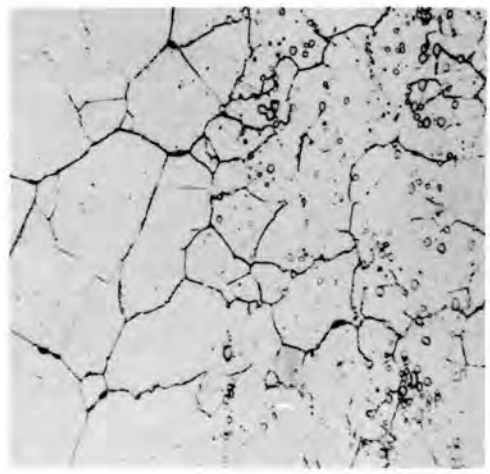
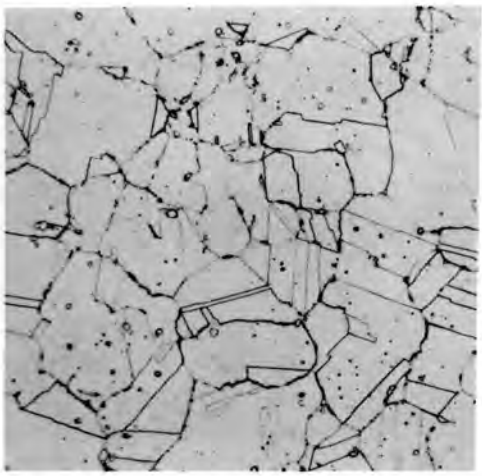
PHOTO 18516



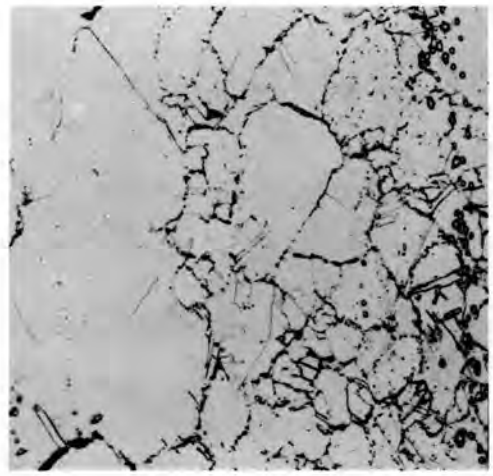
Code 31: 1/2 hr 2000°F, A.C.
As heat treated



Code 31: 30,000 psi at 1350°F
Rupture life 78.0 hr



Code 32: 1/2 hr 2000°F, A.C.
16 hr 1500°F, A.C.
As heat treated



Code 32: 30,000 psi at 1350°F
Rupture life 114.1 hr

Figure 10. Photomicrographs of alloy 3 in the solution treated condition, in the solution treated and aged condition, and after stress-rupture testing as indicated. Etched with 1/3 HCl, 1/3 HNO_3, 1/3 H_2O. 250X.

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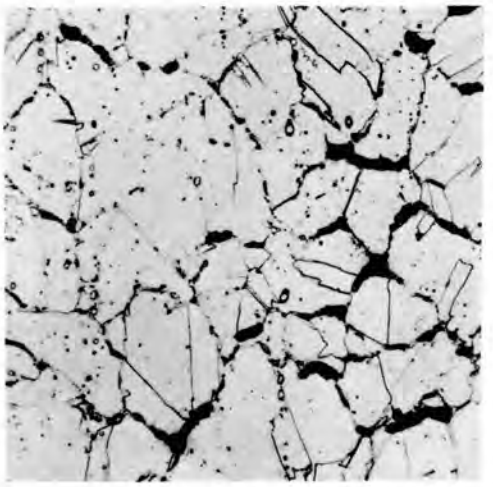
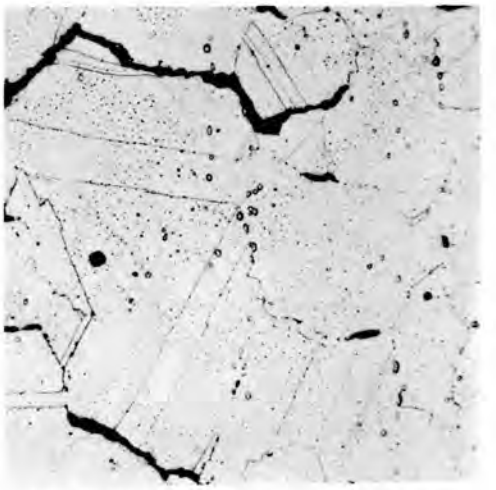
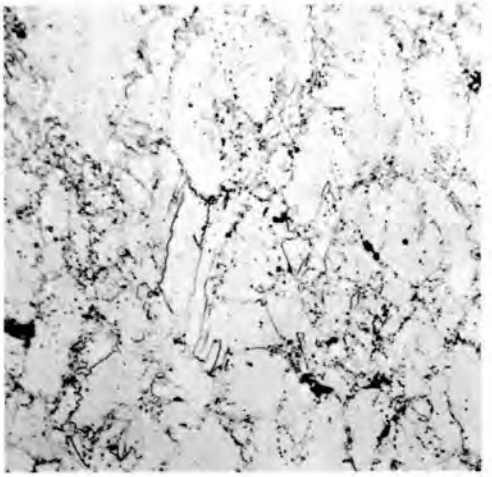
PHOTO 18517



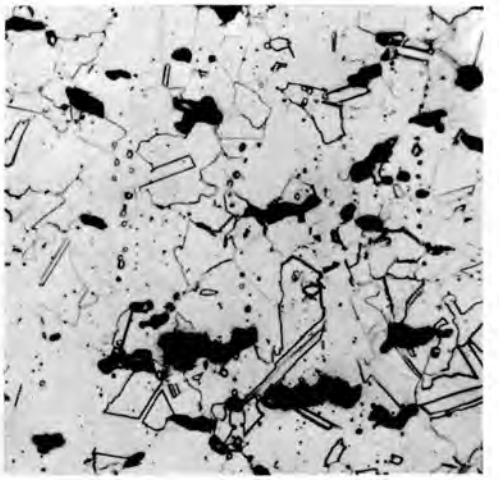
Code 31: 15,000 psi at 1500°F
Rupture life 31.4 hr



Code 31: 7,500 psi at 1650°F
Rupture life 39.7 hr



Code 32: 20,000 psi at 1500°F
Rupture life 28.3 hr



Code 32: 7,500 psi at 1650°F
Rupture life 57.3 hr

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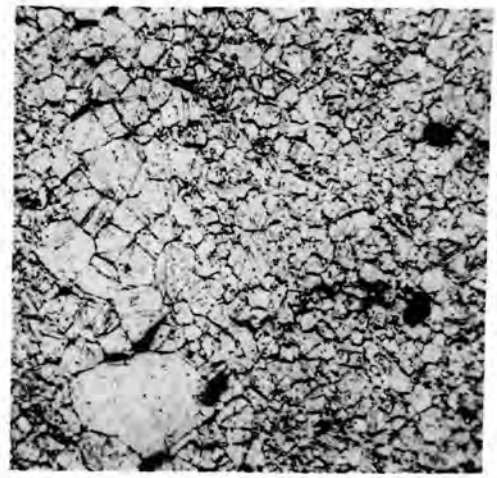
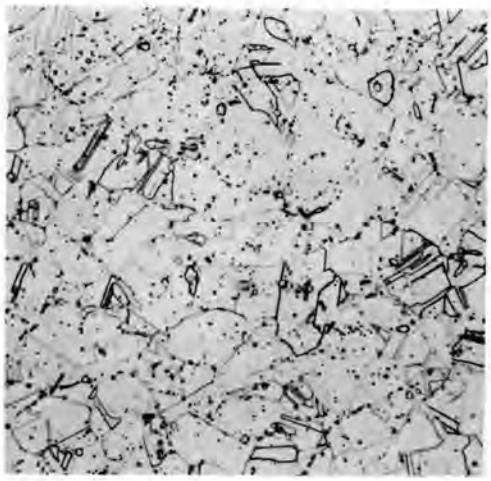
PHOTO 18518

Code 41: 1/2 hr 2000°F, A.C.
As heat treated



Code 41: 40,000 psi at 1350°F
Rupture life 180.9 hr



Code 42: 1/2 hr 2000°F, A.C.
16 hr 1500°F, A.C.
As heat treated

Code 42: 40,000 psi at 1350°F
Rupture life 179.4 hr

Figure 11. Photomicrographs of alloy 4 in the solution treated condition, in the solution treated and aged condition, and after stress-rupture testing as indicated. Etched with 1/3 HCl, 1/3 HNO_3, 1/3 H_2O. 250X.

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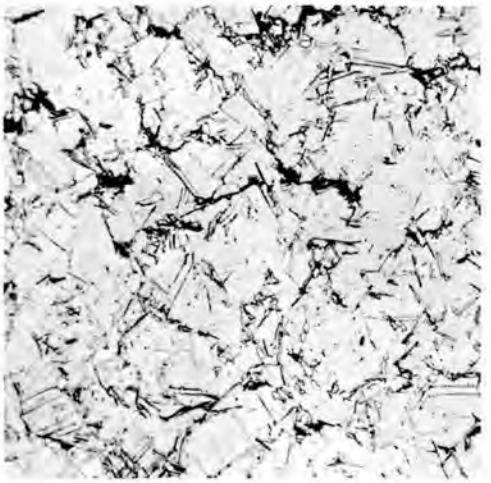
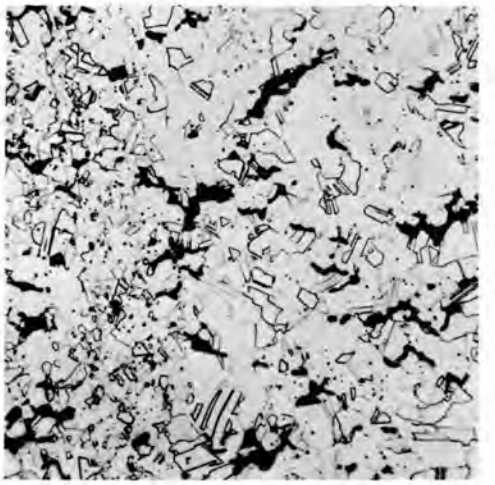
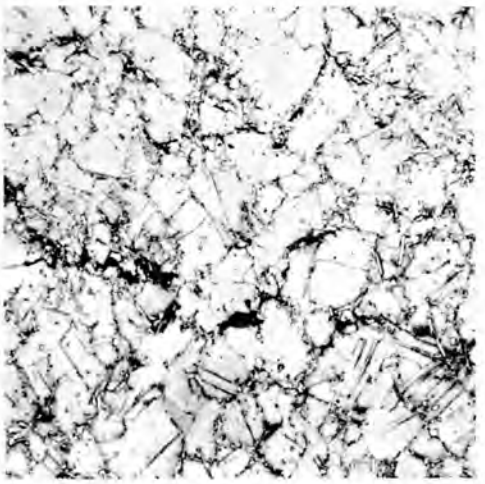
PHOTO 18519



Code 41: 20,000 psi at 1500°F
Rupture life 101.9 hr



Code 41: 7,500 psi at 1650°F
Rupture life 26.8 hr



Code 42: 20,000 psi at 1500°F
Rupture life 80.8 hr

Code 42: 7,500 psi at 1650°F
Rupture life 46.5 hr

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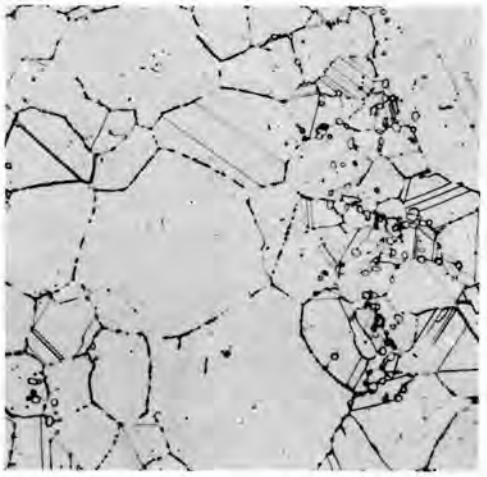
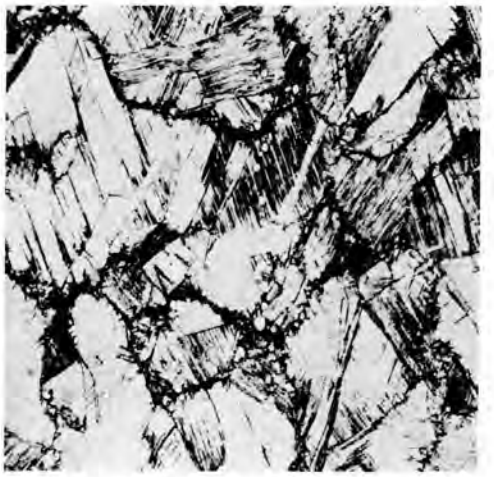
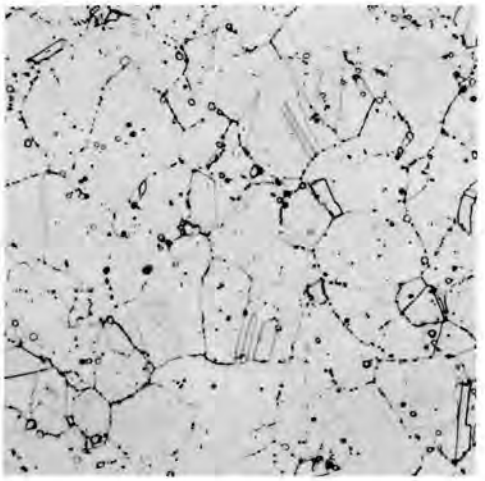
PHOTO 18520



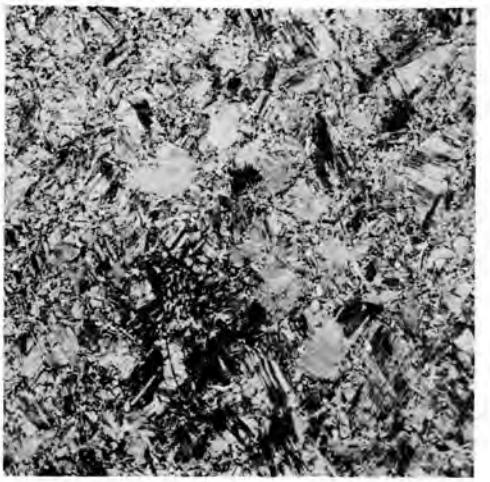
Code 51: 1/2 hr 2000°F, A.C.
As heat treated



Code 51: 40,000 psi at 1350°F
Rupture life 43.4 hr



Code 52: 1/2 hr 2000°F, A.C.
16 hr 1500°F, A.C.
As heat treated



Code 52: 40,000 psi at 1350°F
Rupture life 63.4 hr

Figure 12. Photomicrographs of alloy 5 in the solution treated condition, in the solution treated and aged condition, and after stress-rupture testing as indicated. Etched with 1/3 HCl, 1/3 HNO_3, 1/3 H_2O. 250X.

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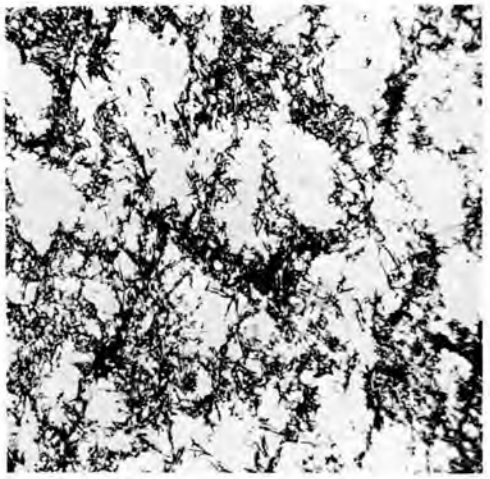
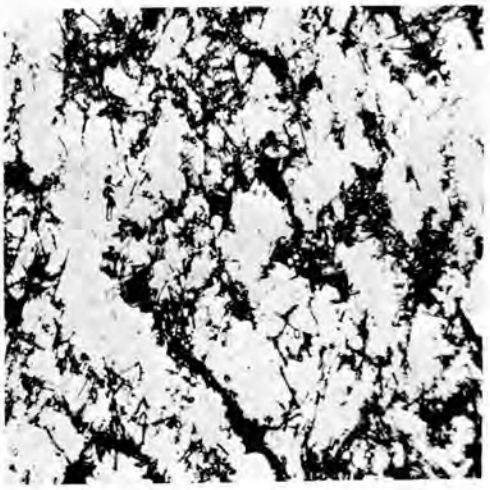
PHOTO 18521

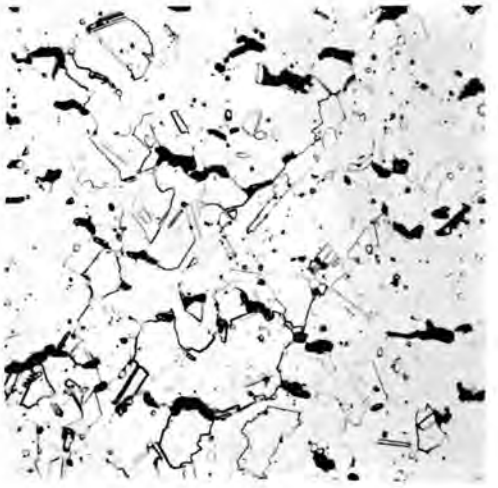


Code 51: 20,000 psi at 1500°F
Rupture life 30.8 hr

Code 51: 10,000 psi at 1650°F
Rupture life 28.8 hr

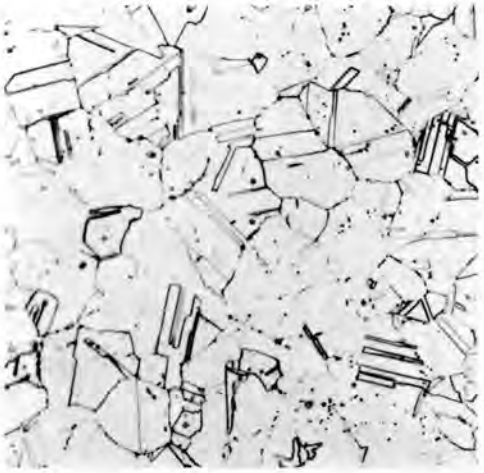


Code 52: 20,000 psi at 1500°F
Rupture life 46.3 hr

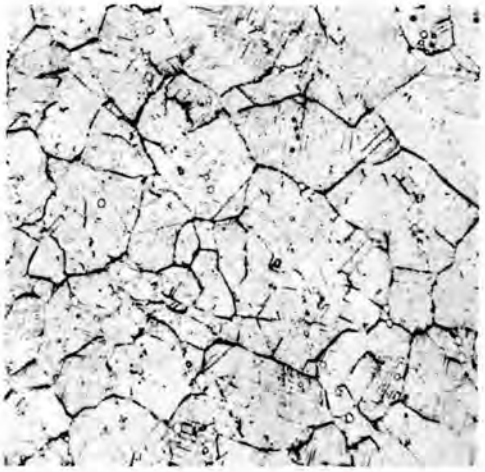


Code 52: 7,500 psi at 1650°F
Rupture life 63.3 hr

UNCLASSIFIED
PHOTO 18522

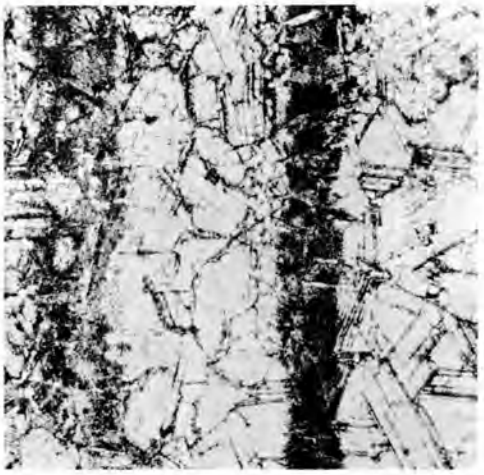


Code 61: 1/2 hr 2000°F, A.C.
As heat treated



Code 61: 40,000 psi at 1350°F
Rupture life 34.2 hr

Code 62: 1/2 hr 2000°F, A.C.
16 hr 1500°F, A.C.
As heat treated



Code 62: 40,000 psi at 1350°F
Rupture life 129.4 hr

Figure 13. Photomicrographs of alloy 6 in the solution treated condition, in the solution treated and aged condition, and after stress-rupture testing as indicated. Etched with 1/3 HCl, 1/3 HNO_3, 1/3 H_2O. 250X.

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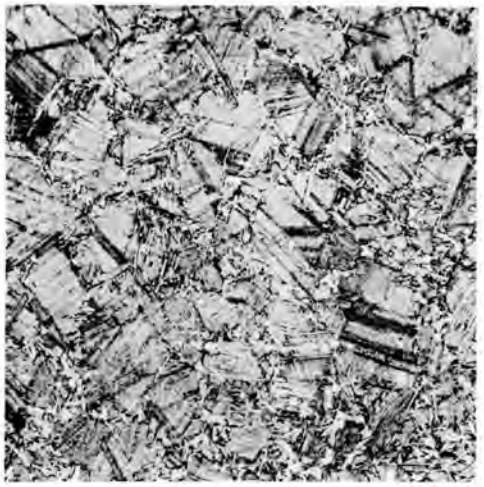
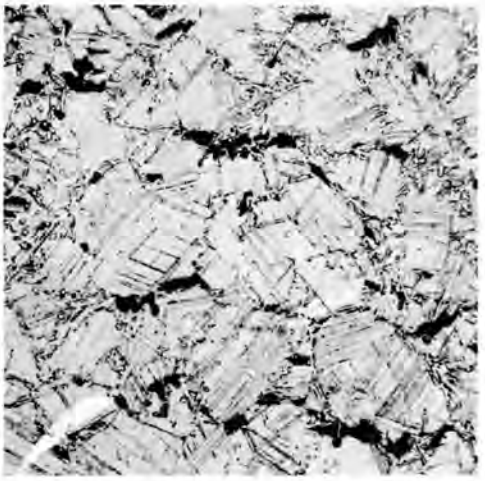
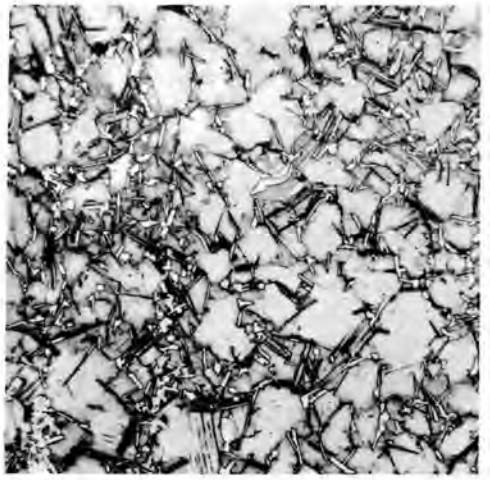


Code 61: 20,000 psi at 1500°F
Rupture life 142.1 hr

Code 61: 7,500 psi at 1650°F
Rupture life 44.2 hr



Code 62: 20,000 psi at 1500°F
Rupture life 123.4 hr



Code 62: 7,500 psi at 1650°F
Rupture life 35.9 hr