NASA-CR-177940

NASA Contractor Report 177940

NASA-CR-177940
19860001845

MECHANICAL PROPERTIES OF INCONEL 718 AND NICKEL 201 ALLOYS AFTER THERMAL HISTORIES SIMULATING BRAZING AND HIGH TEMPERATURE SERVICE

William F. James

Kentron International, Inc.
Aerospace Technologies Division
Hampton, Virginia 23666

Contract NAS1-18000
September 1985

NASA

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

PREFACE

The NASA technical monitor was Thomas T. Bales, Metallic Materials Branch, NASA Langley Research Center. I would like to acknowledge Dick Royster, senior research engineer in the Metallic Materials Branch, Langley Research Center, for his work on stress rupture testing. I would also like to acknowledge H. Ross Wiant of Kentron International, Incorporated, Aerospace Technologies Division, for his work on the low temperature braze cycle development.

Values for the physical quantities are given in U.S. customary units. Calculations were made in U.S. customary units. Identification of commercial products in this report is to adequately describe the materials and does not constitute official endorsement, expressed or implied, of such products or manufacturers by the National Aeronautics and Space Administration.

TABLE OF CONTENTS

	Page
SUMMARY	1
INTRODUCTION	2
MATERIALS AND TEST SPECIMENS	3
TEST PROCEDURES	3
Mechanical Properties	4
Metallurgical Study	5
RESULTS AND DISCUSSION	6
Mechanical Properties	6
Metallurgical Study	8
CONCLUSIONS	9
REFERENCES	11

LIST OF TABLES

Table Number	Title	Page
1	Chemical Composition of the 0.050 Inch Sheet Nickel Alloy Materials	12
2	Ni-201 Mechanical Properties	13
3	In-718 Mechanical Properties	14
4	Stress Rupture Test Results	15

LIST OF FIGURES

Figure Number	Title	Page
1	Test Specimens	16
2	Tensile Properties of Ni-201 Material As Received and After Thermal Exposures	17
3	Tensile Properties of In-718 Material As Received and After Thermal Exposures	18
4	Stress-Rupture Data on Ni-201 with Indicated Thermal Exposure	19
5	Stress Rupture Data on In-718 with Indicated Thermal Exposure	20
6	Microstructure of 0.050 Inch Ni-201 After Various Thermal Exposures	21
7	Effect of Thermal Exposure on Ni-201 Grain Size	22
8	Microstructure of 0.050 Inch In-718 After Indicated Thermal Exposures	23

SUMMARY

An experimental investigation was made to evaluate two nickel base alloys (Nickel-201 and Inconel-718) in three heat treated conditions for high temperature applications. These conditions were: 1) annealed, 2) after thermal exposure simulating a braze cycle, and 3) after a thermal exposure simulating a braze cycle plus one operational lifetime of high temperature service. For the Nickel-201, two different braze cycle temperatures were evaluated. A NASA Langley Research Center developed braze cycle utilizing a lower braze temperature resulted in less grain growth for Nickel-201 than the standard braze cycle used for joining Nickel-201 to Inconel-718. It was determined, however, that Nickel-201, was marginal for application at the temperatures investigated due to large grain growth. After the thermal exposures described above, the mechanical properties of Nickel-201 were degraded, whereas similar exposure on Inconel-718 actually strengthened the material compared with the annealed condition. The investigation included tensile tests at both room temperature and elevated temperatures, stress-rupture tests, and metallographic examination.

INTRODUCTION

Considerable research effort has been expended on the design and fabrication of hardware for a high temperature application which will be needed to power future high performance, high-speed aircraft. With an expected operational lifetime for elevated temperature service of at least 1000 hours, there is a need to evaluate the effects of thermal exposures arising from both fabrication and expected service on materials potentially suitable for such application.

The objective of this study was to determine the effect of thermal exposures resulting from fabrication by brazing and simulated service high temperature exposure on the mechanical properties of the two materials investigated (In-718 and Ni-201). These materials were tested in three heat treated conditions: 1) annealed, 2) annealed material thermally exposed to simulate fabrication by brazing of Ni-201 to In-718, and 3) annealed material thermally exposed to simulate fabrication by brazing plus exposure typical of one service life at elevated temperature.

Tests performed during this study include room temperature and elevated temperature tensile tests and elevated temperature stress rupture tests. A metallographic study was also conducted to relate the results of the mechanical property tests to metallurgical changes occurring in the material through processing and simulated service.

MATERIALS AND TEST SPECIMENS

Both Ni-201 and In-718 were experimentally evaluated in the study. The Ni-201 was tested in two nominal sheet thicknesses, 0.050 inch and 0.015 inch. The In-718 was tested with a nominal sheet thickness of 0.050 inch. The chemistries of the materials are listed in table 1. Both alloys were received in the annealed condition.

Tensile and stress rupture specimens were machined with the specimen axis longitudinal to the rolled direction of the sheet, as shown in figure 1. Doublers were spot welded to the specimen ends to prevent bearing failures during loading. Specimens were tested in three thermally treated conditions: 1) annealed, 2) annealed material thermally exposed to simulate fabrication by brazing of Ni-201 to In-718, and 3) annealed material thermally exposed to simulate fabrication by brazing plus exposure typical of one service life at elevated temperature.

TEST PROCEDURE

Thermal Exposures

Simulated Braze Cycle.-Two braze cycles were investigated to join In-718 to Ni-201. The standard braze cycle taken from reference 1 used Palniro 1® as the braze alloy. The reported braze cycle involved specimens that were solvent cleaned, heated in a vacuum furnace to 2070°F, held at 2070°F for 15 minutes to permit Palniro 1® braze alloy to melt and flow into the joint, and subsequent furnace cooling to room temperature. Ni-201 thermally exposed to simulate the standard braze cycle is herein identified to be in "condition A." The thermal exposure used to simulate the braze cycle consisted of heating solvent cleaned specimens in a vacuum furnace to 2070°F, holding at 2070°F for 15 minutes, and furnace cooling to room temperature. The effect of the braze alloy interaction on the mechanical properties of Ni-201 was not investigated.

A second braze cycle using selectively plated pure gold and nickel to form a solid solution alloy having a melting point of approximately 1750°F during brazing was included in the study. The lower brazing temperature compared to Palniro 1® was expected to result in less grain growth. This lower temperature braze cycle involved specimens that were solvent cleaned, heated in a vacuum furnace to 1850°F, held at 1850°F for 1 hour to permit selectively plated gold and nickel braze alloy to melt and fill the joint, and subsequent furnace cooling to room temperature. Alloy In-718 or Ni-201 specimens thermally exposed to this simulated braze cycle are herein identified to be in "condition B." The thermal exposure used to simulate the braze cycle consisted of heating solvent cleaned specimens in a vacuum furnace to 1850°F, held at 1850°F for 1 hour, and subsequent furnace cooling to room temperature. The effect of the braze alloy interaction on the mechanical properties of the two alloys was not investigated.

Both In-718 and Ni-201 0.050 inch thick tensile and stress-rupture test specimens were subjected to the thermal exposure of condition B. For comparison, additional Ni-201 0.050 inch thick tensile test specimens were subjected to the thermal exposure of condition A.

Simulated Lifetime Exposure.-Following the thermal exposure to condition B, selected specimens were also subjected to a thermal exposure representative of one operational lifetime at elevated temperature and herein are identified to be in condition C. This exposure simulates maximum thermal operating conditions which results in a maximum temperature of 1450°F for the Ni-201 material and 1180°F for the In-718 material. Ni-201 and In-718 specimens which were first exposed to condition B were exposed for 1,000 hours at their appropriate temperatures to simulate one operational lifetime. To prevent oxidation during exposure, the specimens were enveloped in Fiberfrax® felt and inserted into seam welded 0.009 inch thick Haynes alloy 25 envelopes. The envelopes were evacuated to approximately 10 μ Hg with a mechanical vacuum pump and then welded gas tight.

Mechanical Properties

Tensile tests.- Tensile tests were run at room temperature, 1000°F, and 1200°F for In-718, and room temperature, 1200°F, and 1450°F for Ni-201. The 1000°F test temperature for In-718 and 1200°F test temperature for Ni-201 were chosen for comparison with published data (ref. 2-4). These tests were performed on 0.050 inch thick sheet in the annealed condition, condition B, and condition C. Tensile tests were also made on as-received 0.015 inch thick Ni-201 sheet in the annealed condition and on 0.050 inch sheet in condition A. Measurements were taken of the ultimate tensile strength, yield strength, and total elongation to fracture (elongation measured across the fracture). Tensile specimens were tested at a strain rate of 0.005 in/in/min until the 0.2 percent strain yield point was reached. Strain rate was then increased to 0.05 in/in/min until failure. Strain was measured with resistance type strain gages for the room temperature tests. For high temperature tensile tests, the strain was measured by two linear variable differential transformers connected to knife edges impinging on the test specimen by connecting rods. All tensile tests were performed in air and the elevated temperature tests were conducted using an electrical resistance heater type furnace. Load measurement was made by load cells integral with the 10,000 pound capacity screw powered testing machine.

Stress-rupture test.- The stress-rupture specimens were tested at constant load using creep machines equipped with resistance heated air furnaces. For the Ni-201, tests were performed at 1200°F and 1450°F; test temperatures for In-718 were 1000°F and 1200°F. The creep machines used digital timers which identify test duration time at specimen rupture. Tests on specimens that did not rupture were terminated after approximately 1,000 hours exposure except for one Ni-201 specimen tested at 1450°F which was terminated after 900 hours. Temperatures were continually monitored on strip chart recorders using thermocouples mounted to each test specimen surface.

Metallurgical Study

A metallographic study was made on material taken from the shoulder region of specimens after mechanical testing, to evaluate any changes in microstructure due to the thermal exposures. The specimens were sheared, mounted, and polished using standard metallographic techniques. The Ni-201 required a mechanical-chemical polishing technique to remove fine scratches. Polished Ni-201 specimens were etched with a mixture of equal volumes of ten percent aqueous solution of ammonium sulphate and ten percent aqueous solution of sodium cyanide to reveal the microstructure. In-718 specimens were electrolytically etched in a ten percent aqueous solution of oxalic acid.

RESULTS AND DISCUSSION

Mechanical Properties

Nickel-201 tensile tests.- The data obtained from tests on Ni-201 material are tabulated in table II and shown in figures 2a and 2b. The room temperature tensile properties of the 0.050 inch thick Ni-201 sheet in the as received condition were within the nominal range given by the manufacturer (ref. 2). As shown in figures 2a and 2b, the tensile properties of the 0.050 and 0.015 inch thick Ni-201 were similar. Shown in figures 2a and 2b are the 1450°F tensile test results for the 0.050 inch annealed material. These tensile and yield strengths are also in close agreement with data reported on 0.030 inch annealed Ni-201 tested at 1400°F (ref. 1).

The results of mechanical tests on Ni-201 in conditions A and B are also shown in figures 2a and 2b. Specimens exposed to both simulated braze cycles exhibited decreased yield strength, tensile strength and total elongation compared to the data obtained from the annealed Ni-201. The ultimate tensile strength for Ni-201 in condition B was approximately five percent higher than the data for Ni-201 in condition A. The Ni-201 in condition B had approximately 20 percent higher elongation than in condition A. Data on 0.030 inch Ni-201 exposed to a simulated 2070°F braze for 10 minutes (ref. 1) agreed with the test results obtained for the 0.050 inch thick Ni-201 in condition A.

Also shown in figures 2a and 2b are the mechanical property data for Ni-201 in condition C. The yield strength of Ni-201 in condition C was much higher than Ni-201 in condition B for both this study and previous work (ref. 1). This trend held true at all test temperatures (room temperature, 1200°F and 1450°F). In general, the thermal exposures decreased the ultimate tensile strength, yield strength and total elongation of Ni-201 compared to the annealed condition. Ni-201 in condition A had the lowest ultimate strength of the four conditions.

The effect of higher test temperature was to decrease both the ultimate and yield strengths, and increase the total elongation, as shown in figures 2a and 2b.

Comparing the 1,000 hour thermal exposure results of this study to previous results (ref. 1), the total elongation is much higher in this study and may be due to the use of vacuum bagging which reduced oxidation during thermal exposures. For the Ni-201 test specimens heated in air (ref. 1), oxidation reduced the load bearing cross section of the test specimens by one-half. This resulted in low total elongations, averaging 6 percent, for two different thermal exposure conditions. Comparable exposures of specimens in this study using vacuum bagging resulted in average total elongations of 43 percent. This higher elongation, which would lead to greater reduction in area, would be beneficial to low cycle fatigue life. Specimens in this study which experienced limited oxidation during exposure also had a higher ultimate strength compared to the material exposed in air. The difference in yield strengths were less noticeable. The more conservative results would be those samples exposed to high temperatures in air for the 1,000 hours. Actual oxidation rates would likely depend on the oxygen partial pressure associated with a given service application.

Inconel-718 tensile tests.- Tensile tests were run on Inconel 718 specimens in the annealed condition and conditions B and C. The data obtained from these tests are tabulated in table III and shown in figures 3a and 3b. Data from reference 3 for sheet and bar annealed 15 minutes at 1850°F are very close to the as-received values. In-718 is an age hardenable alloy, and the yield and ultimate tensile strengths in condition B were substantially higher than those of the annealed material, as shown in figure 3a. These increases were noted for all test temperatures.

The yield and tensile strengths of In-718 in condition C are similar to results for material given a standard strengthening aging heat treatment plus thermal exposure to 1,000 hours at 1200°F (ref. 3) and are higher than In-718 in condition B. Higher strengths in condition C were observed at all test temperatures. This long duration thermal exposure decreased the total elongation for all test temperatures compared to data for the annealed and condition B material (see figure 3b). The annealed specimens had the highest total elongation and the In-718 in condition C the lowest total elongation.

Although not tested in this study, the brazed In-718 to In-718 underlying structure could be given an aging treatment to provide either a full strength or a stress-rupture resistant condition. The ultimate strength values in this study were less than those achievable by using a fully aged treatment. Following thermal exposure for 1,000 hours at 1180°F, the In-718 tensile strength data were in close agreement with those values reported in reference 3 for aged In-718 which was exposed for 1,000 hours at 1200°F. If an optimum aging treatment is given before service, over aging may occur during service conditions.

Stress-rupture tests.- The stress-rupture data for Ni-201 is shown in figure 4 and tabulated in table IV. The upper smooth curve faired through the data points is for material in condition B tested at 1200°F. The effect of the 1850°F simulated braze cycle was to slightly lower the curve compared to data obtained for annealed material at 1200°F (ref. 2). For example, after 100 hours at 1200°F, the rupture stress for annealed material is 11,800 psi compared to 9,800 psi for Ni-201 in condition B. Increasing the test temperature to 1450°F dramatically lowered the stress-rupture curve as shown in figure 4. Specimens of Ni-201 exposed to condition C fractured soon after loading during two tests.

The stress rupture data for In-718 are plotted in figure 5 and tabulated in table IV. Data for material exposed to condition C raised the stress-rupture curve for the 1000°F test above that obtained for In-718 in condition B. Increasing the test temperature from 1000°F to 1200°F lowered the stress-rupture curve by almost one-half. The 1200°F test temperature curves shown in figure 5 are less than previous stress rupture data (ref. 4) for material following an aging treatment for high strength (1800°F for 1 hour, water quenched, aged at 1325°F for 8 hours, furnace cooled to 1150°F, and held at 1150°F for a total aging time of 18 hours). The age hardening characteristic of In-718 provides a good candidate alloy for the temperatures investigated based on the tests and exposures evaluated in this study.

Metallurgical Study

Photomicrographs of the Ni-201 microstructure after various thermal exposures are shown in figure 6. The microstructure of the annealed (as-received) Ni-201 consists of a single phase twinned grain structure. Following etching, the grains have a speckled appearance attributed to localized pitting of the Ni-201. The Ni-201 had an initial mean intercept length between grain boundaries, referred to herein as grain size, of 5.79×10^{-4} inches as measured by the line intercept method. As shown in figure 6b, c and d the grain size increases as a result of thermal exposure. The effect of thermal exposure on grain size is also shown in figure 7. Metallurgical specimens exposed at 2070°F (condition A) and also at

2070°F plus one operational lifetime, resulted in larger grain sizes than the 1850°F braze cycle exposures, condition B as well as condition C.

The proposed use of Ni-201 for application at these elevated temperature levels would result in very severe temperature conditions for this material. For high heat flux applications, the temperature gradient through the thickness of the material would be very severe. Under these conditions, the material would undergo plastic deformation. When exposed to these conditions, Ni-201 undergoes grain growth to the extent that a single grain may encompass the entire thickness of the material if the gage thickness is 0.015 inches or less. As a result, Ni-201 is considered to be marginal for this application.

The as-received In-718 microstructure (figure 8) showed nearly equiaxed grains with twinned grains present. Material exposed to condition B resulted in the beginning of a discontinuous network of precipates in the grain boundaries. The discontinuous network outlining the grain boundaries becomes a continuous network after a simulated thermal braze and exposure cycle (condition C). Slight grain growth was observed as a result of the thermal cycles.

CONCLUSIONS

The effects of thermal exposure simulating fabrication by brazing and high temperature service on the mechanical properties of Nickel-201 and Inconel-718 were determined. The following concluding remarks are based on the results of this study.

1) A lower temperature braze cycle using selectively electroplated gold and nickel having a brazing temperature of 1850°F resulted in Ni-201 having a somewhat greater tensile strength and substantially higher total elongation compared to material exposed to a more conventially used braze cycle.

2) Thermal exposures simulating brazing and brazing plus one operational lifetime at elevated temperature (1,000 hours at 1450°F) degrades the material properties of Ni-201 (ultimate, yield and stress-rupture strengths, and elongation). However, after 1,000 hours at 1450°F, the

yield strength increases substantially from the thermally simulated brazed condition.

3) Nickel-201 is considered to be marginal for application at the temperatures investigated because of excessive grain growth during the high temperature exposure. Grain growth can result in individual grains through the entire 0.015 inch sheet thickness.

4) Exposures simulating brazing and simulating brazing plus high temperature service actually strenghtens In-718 material in the annealed condition because of its age hardening characteristics. The yield, tensile, and stress rupture strengths all increased, but total elongation decreased after thermal exposure.

5) As a result of testing conducted in this study, In-718 is considered to be a good candidate alloy for 1000 hour service at the use temperature investigated.

REFERENCES

1. "Monthly Progress Report, Advanced Fabrication Techniques for Hydrogen-Cooled Engine Structures." AiResearch Report 75-12234 (15), December 31, 1976.

2. Huntington Alloys Nickel Alloys 200, 201, 270, 301. Huntington Alloys, Incorporated, 1979. (Available from Huntington Alloys as 10M2-709 T-15.)

3. Aerospace Structural Metals Handbook. Battelle Columbus Laboratories, 1981.

4. Huntington Alloys Inconel Alloy 718. Huntington Alloys, Incorporated, 1973. (Available from Huntington Alloys as 10M10-73 T-39.)

TABLE I. - CHEMICAL COMPOSITION OF THE .050 INCH SHEET NICKEL ALLOY MATERIALS

	Composition (Weight %)			
	Nickel 201		Inconel 718	
Elements	As-Received*	Nominal***	As-Received**	Nominal***
Ni	99.48	99.5	54.06	52.5
Fe	0.07	0.2	18.70	18.5
Cu	0.02	0.1	0.59	0.2
Ti	0.02	-	0.58	0.9
Si	0.05	0.2	****	0.2
Mn	0.25	0.2	0.26	0.2
C	0.006	0.01	****	0.04
Cr	****	-	18.75	19.0
Cb	****	-	4.36	Cb + Ta = 5.1
Mo	****	-	2.92	3.0
Al	****	-	0.0	0.5
S	****	0.005	****	0.008

*Vendor supplied
**X-Ray Chemical Analysis at Langley Research Center
***Not for specification, data from Huntington Alloys, Publication 10M 8-78 S-9, pg. 5.
****Not analyzed.

TABLE II. - NI-201 MECHANICAL PROPERTIES

Material Description	Sample #	Test Temp.	Tensile Strength (Ksi)	Yield Strength (Ksi)	% Total Elonga-tion
I. Annealed (As-Received)					
0.050" sheet	100	70°F	57.2	16.7	39
	101	70°F	57.6	18.4	41
	102	70°F	57.2	17.5	38
0.050" sheet	129	1200°F	23.9	9.7	60
	132	1200°F	25.3	9.2	62
	134	1200°F	25.0	7.4	64
0.050" sheet	118	1450°F	15.3	5.7	72
	155	1450°F	14.9	5.9	69
	162	1450°F	14.9	5.6	70
0.015" sheet	8	70°F	58.1	18.1	44
	16	70°F	60.1	20.2	-
	25	70°F	56.6	17.1	51
	18	70°F	58.0	17.4	-
II. Thermally Exposed Simulating Brazing (Conditions A and B)					
0.050" sheet 15 min. at 2075°F	110	70°F	49.9	6.3	31
	111	70°F	51.0	8.6	32
	114	70°F	50.2	7.6	34
0.050" sheet 1 hour at 1850°F	104	70°F	53.1	7.5	41
	105	70°F	53.3	6.9	39
	106	70°F	52.3	6.7	42
0.050" sheet 1 hour at 1850°F	130	1200°F	24.6	3.7	41
	133	1200°F	24.0	3.6	44
	137	1200°F	24.5	3.9	42
	138	1200°F	24.6	3.6	44
0.050" sheet 1 hour at 1850°F	135	1450°F	14.6	3.2	49
	136	1450°F	14.1	-	52
III. Thermally Exposed Simulating Low Temperature Braze Plus 1 Operational Lifetime (Condition C)					
0.050" sheet Brazed + 1,000 hours at 1450°F	107	70°F	51.9	13.4	38
	108	70°F	51.9	13.1	40
	109	70°F	51.8	14.4	40
0.050" sheet Brazed + 1,000 hours at 1450°F	126	1200°F	19.9	6.6	32
	131	1200°F	21.7	7.0	36
	139	1200°F	19.9	7.2	37
0.050" sheet Brazed + 1,000 hours at 1450°F	125	1450°F	12.5	4.5	41
	127	1450°F	13.0	5.9	40
	128	1450°F	12.6	5.6	47

TABLE III. - IN-718 MECHANICAL PROPERTIES

Material Description	Sample #	Test Temp.	Tensile Stress (Ksi)	Yield Stress (Ksi)	% Total Elongation
I. Annealed (As-Received)					
0.050" sheet	11	70°F	125.7	62.5	-
	12	70°F	123.9	62.5	52
	20	70°F	124.0	62.7	52
0.050" sheet	35	1000°F	102.2	47.3	55
	36	1000°F	101.3	46.3	61
	38	1000°F	102.9	50.2	62
	48	1000°F	103.2	48.0	59
	55	1000°F	102.9	48.5	62
	58	1000°F	102.3	48.8	58
0.050" sheet	56	1200°F	107.4	-	51
	57	1200°F	109.9	-	55
	59	1200°F	106.1	-	-
II. Thermally Exposed Simulating Brazing (Condition B)					
0.050" sheet	41	70°F	175.7	129.2	28
	42	70°F	176.0	129.8	28
	43	70°F	175.3	128.4	-
0.050" sheet	1	1000°F	137.6	104.0	29
	3	1000°F	130.8	100.4	-
	53	1000°F	129.1	97.5	-
0.050" sheet	5	1200°F	136.0	101.0	24
	7	1200°F	135.6	100.0	23
	8	1200°F	126.8	103.0	23
III. Thermally Exposed Simulating Low Temperature Braze Plus 1 Operational Lifetime (Condition C)					
0.050" sheet Brazed + 1,000 hours at 1450°F	44	70°F	201.5	-	20
	45	70°F	201.8	171.8	20
	46	70°F	199.2	168.9	-
0.050" sheet Brazed + 1,000 hours at 1450°F	4	1000°F	164.1	147.4	18
	9	1000°F	158.4	139.0	17
	41	1000°F	166.9	-	25
0.050" sheet Brazed + 1,000 hours at 1450°F	2	1200°F	151.6	135.1	12
	10	1200°F	149.0	135.6	11
	54	1200°F	151.3	137.5	10

TABLE IV. - STRESS RUPTURE TEST RESULTS

Material	Test Temperature (°F)	Stress (Ksi)	Time (hours)
Condition B, Ni-201 Thermally Exposed Simulating Brazing	1200	10	49.2
	1200	10	65.2
	1200	9	243.3
	1200	9	307.3
	1200	8.5	346.0
	1200	8	430.0
	1200	7.5	563.9
	1200	7.0	1140.6
	1450	5	85.9
	1450	4	114.8
	1450	3	1312.8+
	1450	2	892.0+
	1450	3.5	3738.8+
Condition C, Ni-201 (Condition B Plus 1 Operational Lifetime 1,000 hrs at 1450°F)	1200	9	1.
	1200	7.5	.85
In-718 (Condition B)	1000	140	0
	1000	135	0
	1000	130	243.8
	1000	125	295.
	1000	120	1627.2+
	1000	115	1005.7+
	1000	110	1003.0+
	1000	122.5	530.4
	1200	120	2.1
	1200	115	3.8
	1200	105	11.0
	1200	85	82.7
	1200	80	135.3
	1200	70	383.7
	1200	65	760.9
Condition C, In-718 (Condition B Plus 1 Operational Lifetime 1,000 hrs at 1180°F)	1000	135	515.7
	1000	130	746.5
	1000	122.5	1385.8
	1200	85	93.1
	1200	80	168.6
	1200	70	389.1

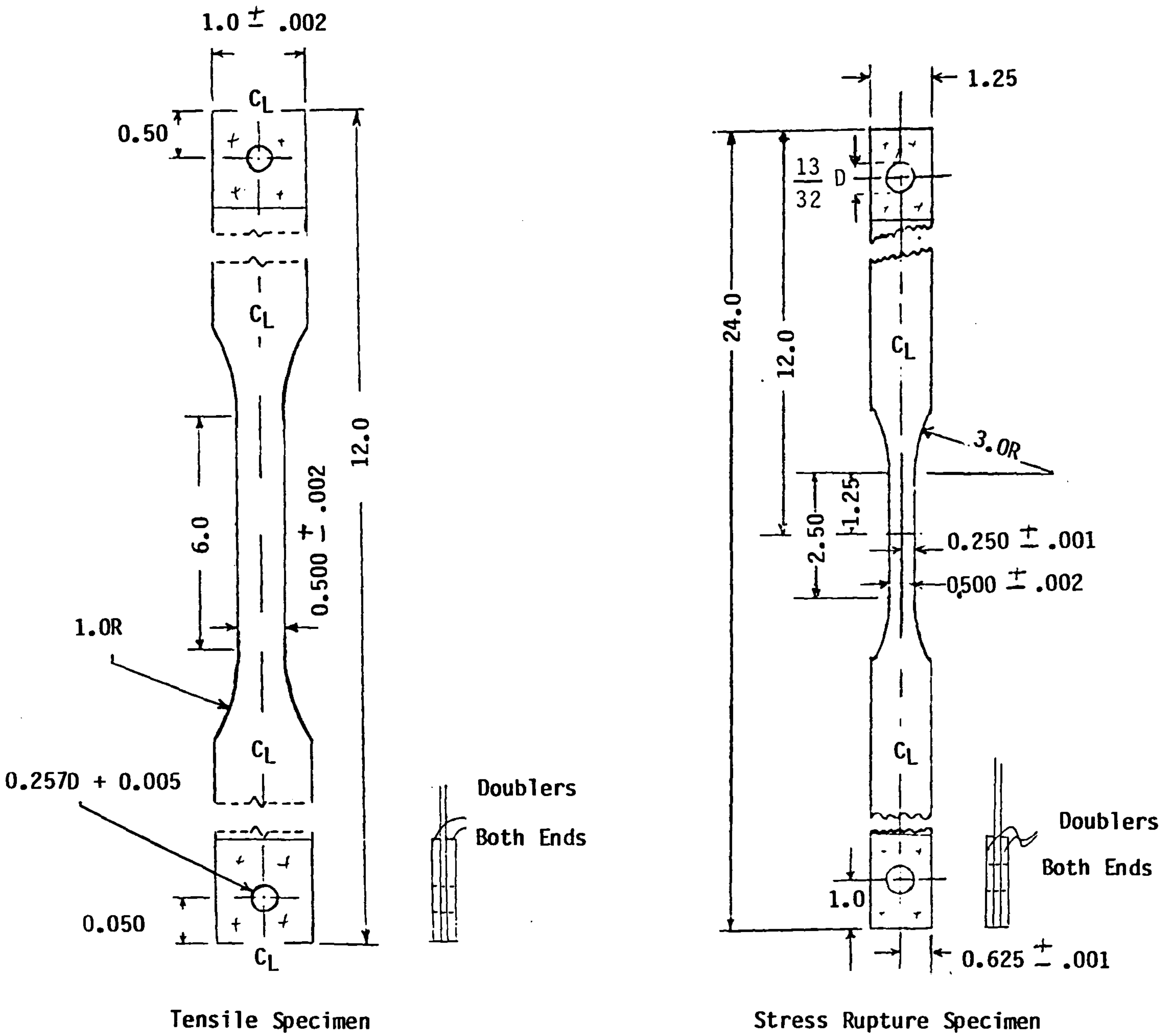


Figure 1. - Test Specimens (All Dimensions are in inches)

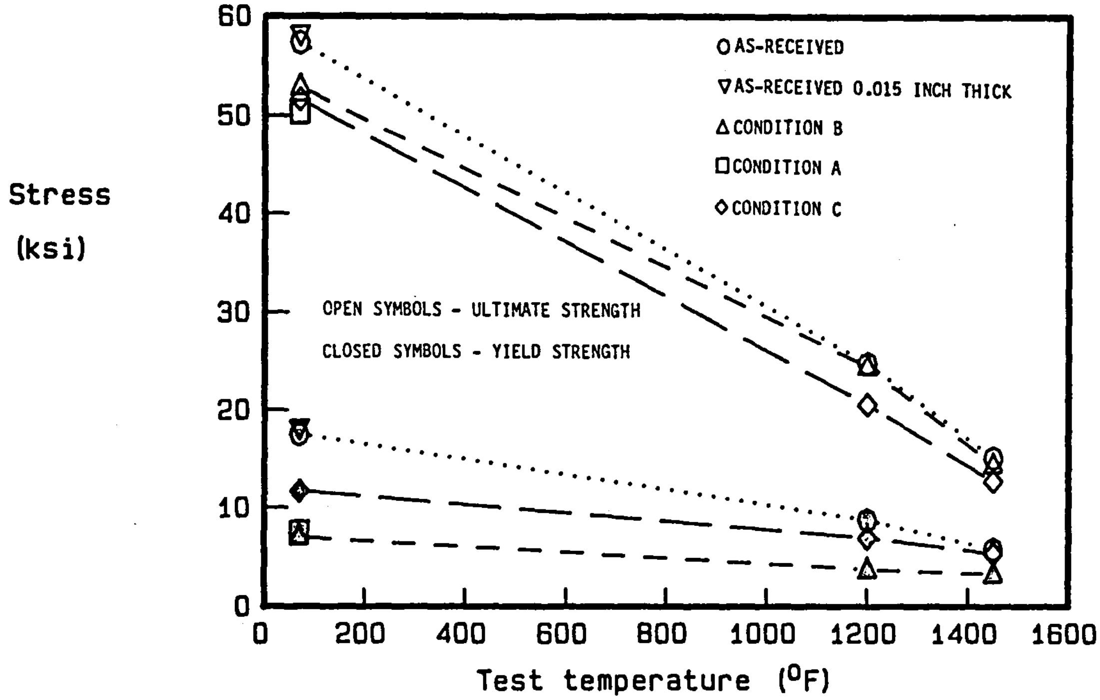


Figure 2a.- Ni-201 ultimate and yield strengths (0.050 inch sheet except as noted, average of 3 tests).

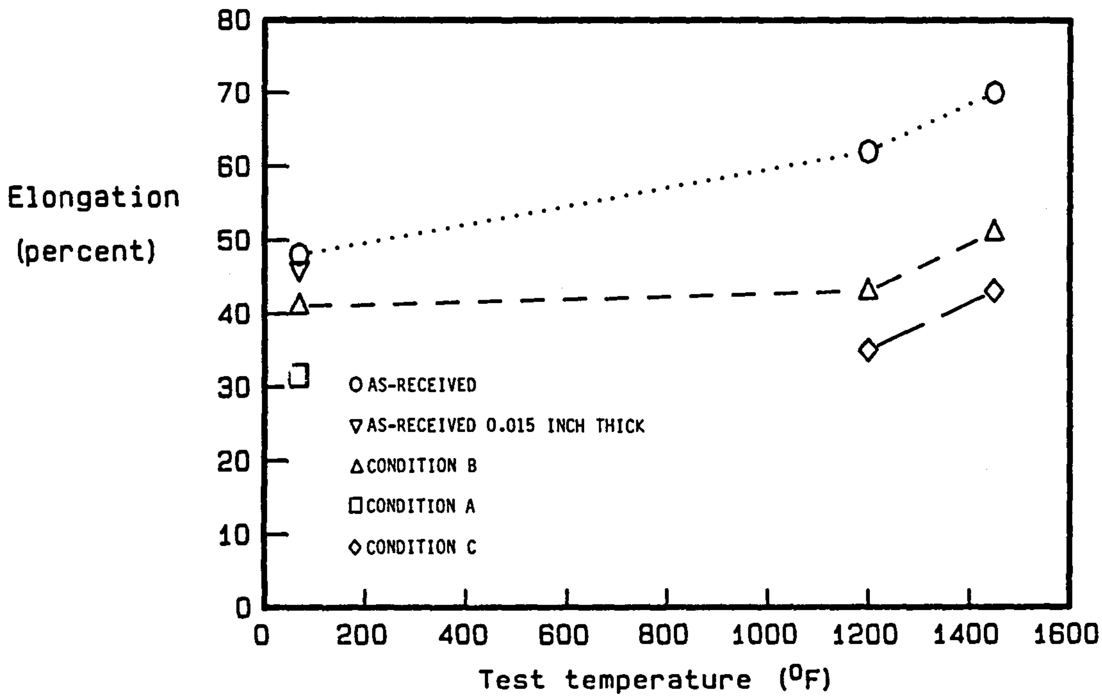


Figure 2b.- Ni-201 elongation (0.050 inch sheet except as noted, average of 3 tests).

Figure 2. - Tensile Properties of Ni-201 Material As Received and After Thermal Exposures.

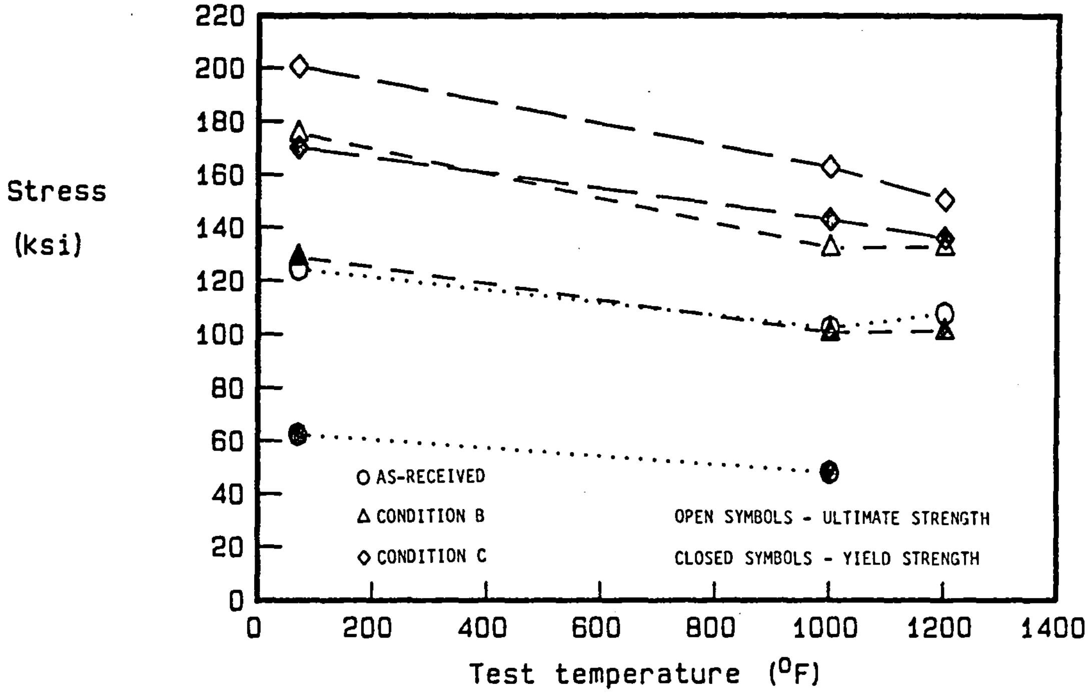


Figure 3a.- In-718 ultimate and yield strengths (0.050 inch sheet, average of 3 tests).

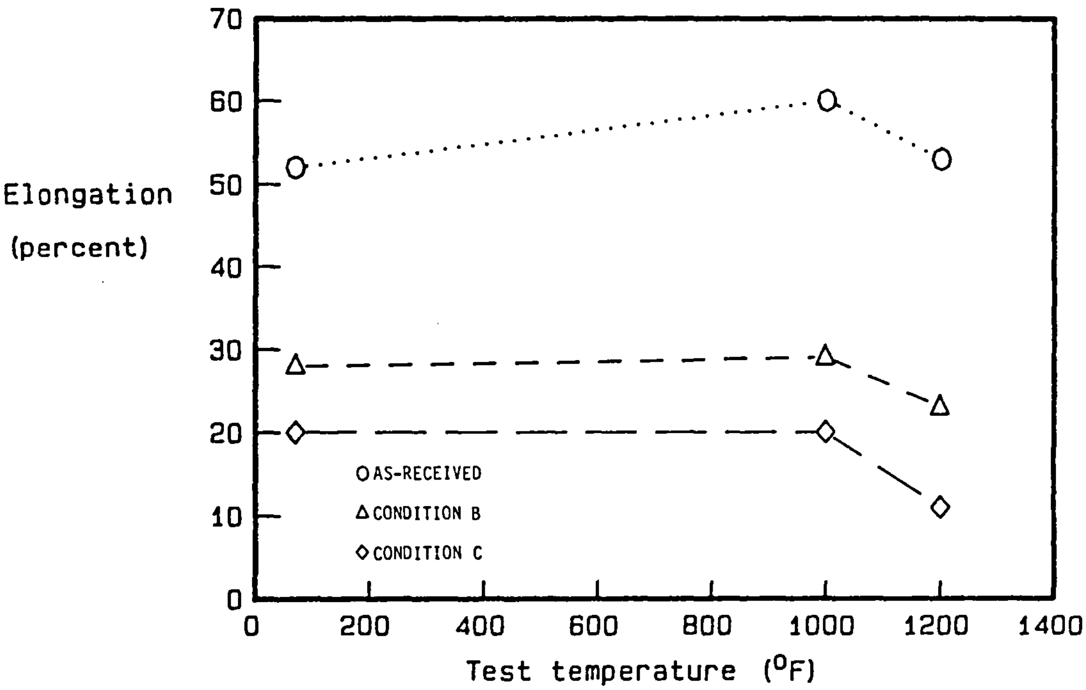


Figure 3b.- In-718 elongation (0.050 inch sheet, average of 3 tests).

Figure 3. - Tensile Properties of In-718 Material As Received and After Thermal Exposures.

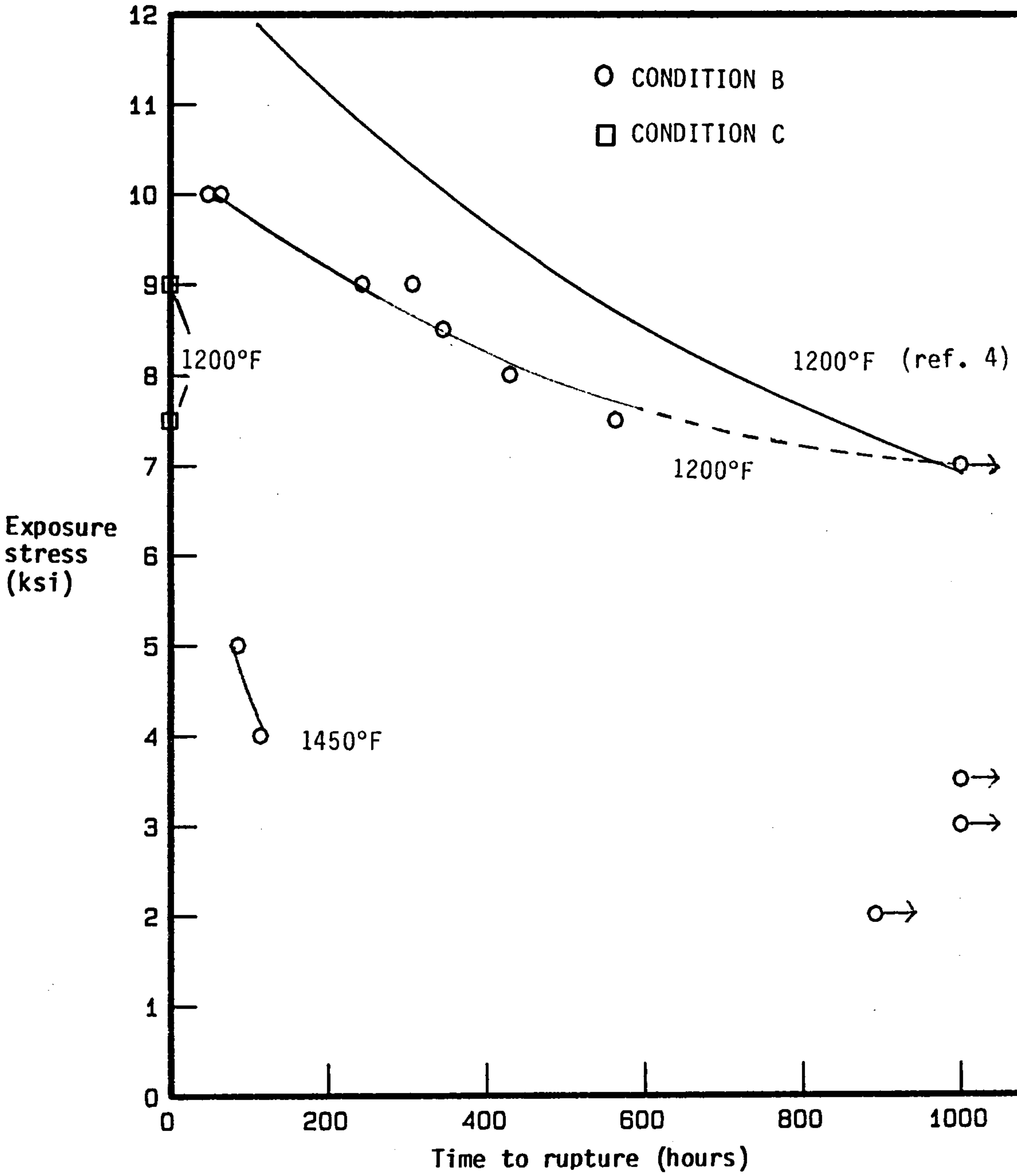


Figure 4. - Stress-rupture data on Ni-201 with indicated thermal exposure.

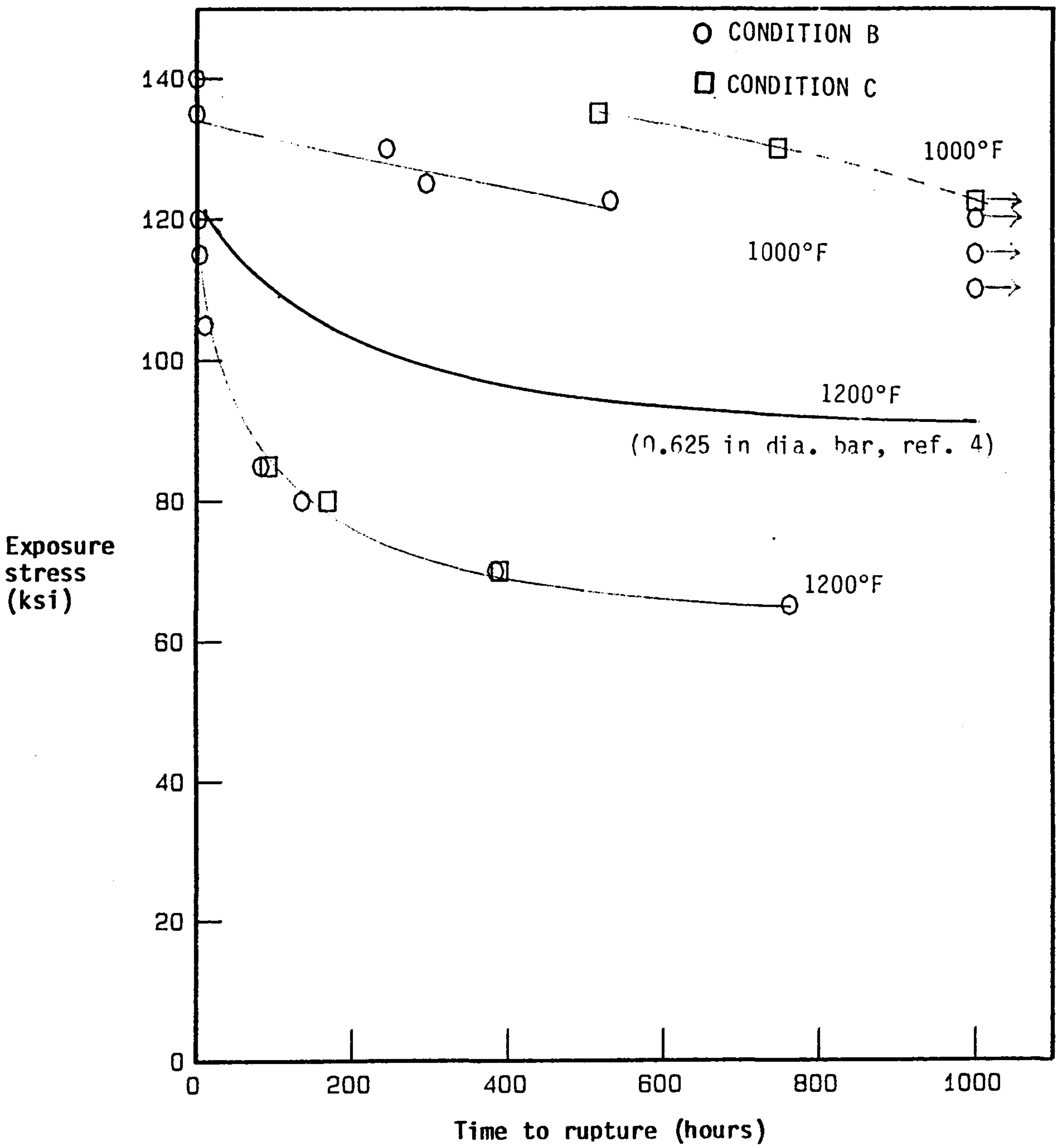
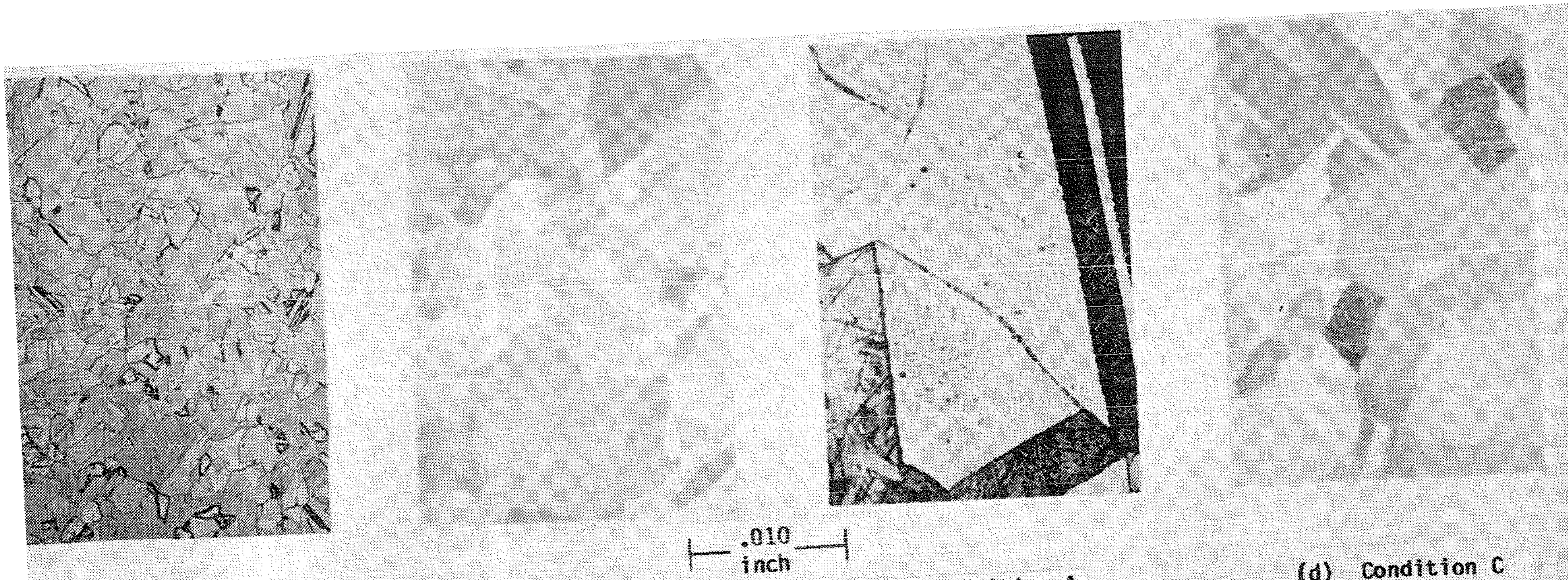


Figure 5. - Stress rupture data on In-718 with indicated thermal exposure.



(a) Annealed (As-Received)

(b) Condition B

(c) Condition A

(d) Condition C

Figure 6. - Microstructure of 0.050 inch Ni-201 after various thermal exposures.

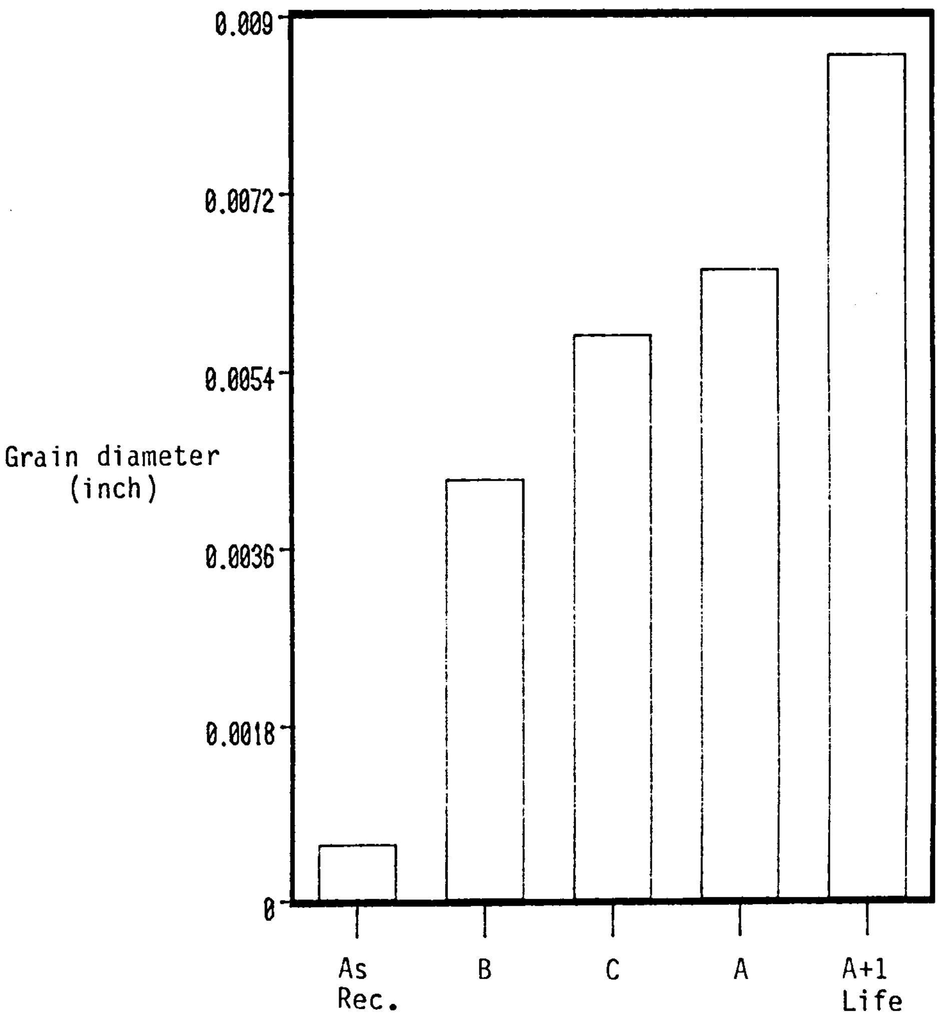
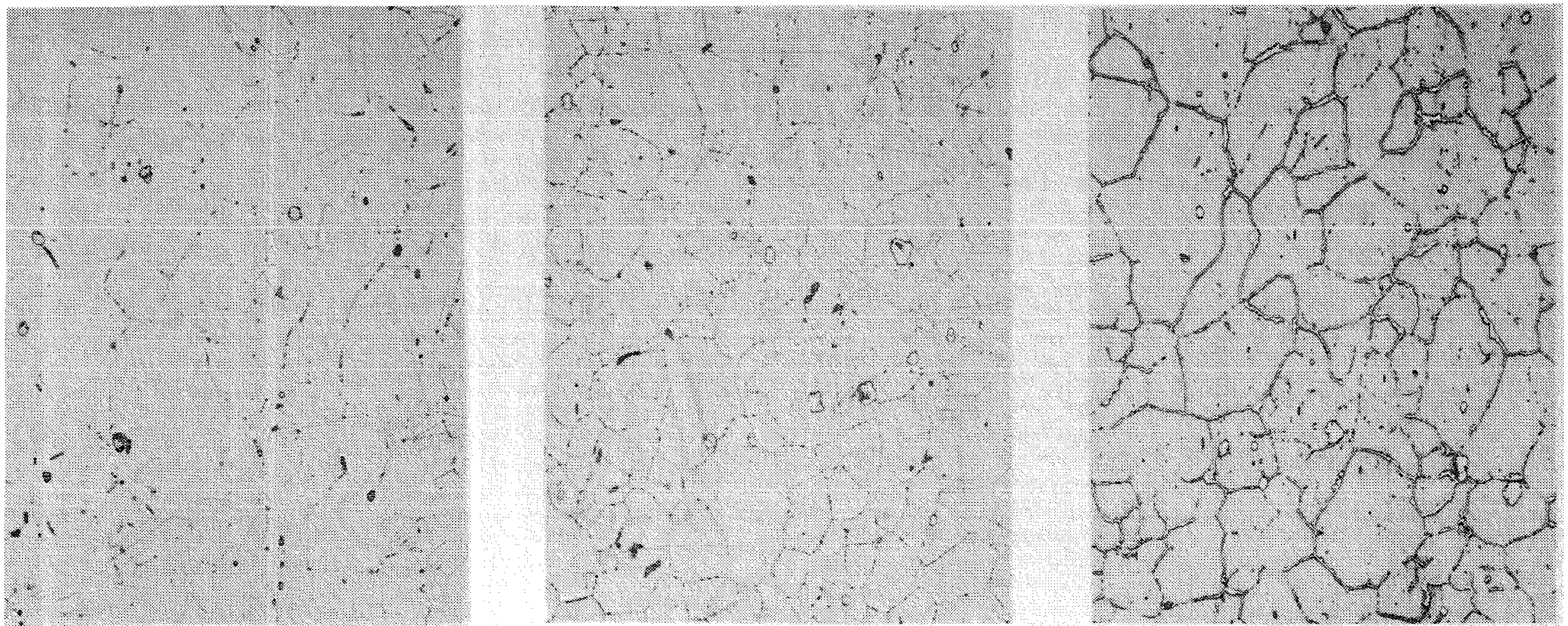


Figure 7. - Effect of Thermal Exposure on Ni-201 Grain Size.



(a) Annealed (As-Received)

(b) Condition B

(c) Condition C

.0025 inch

Figure 8. - Microstructure of 0.050 inch In-718 after indicated thermal exposures.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-177940		

4. Title and Subtitle	5. Report Date
Mechanical Properties of Inconel 718 and Nickel 201 Alloys After Thermal Histories Simulating Brazing and High Temperature Service	September 1985
	6. Performing Organization Code
7. Author(s) William F. James	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address Kentron International, Inc. Aerospace Technologies Division 3221 N. Armistead Avenue Hampton, VA 23666	11. Contract or Grant No. NAS1-18000
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546	13. Type of Report and Period Covered Contractor Report
	14. Sponsoring Agency Code 505-43-43-06

15. Supplementary Notes

Langley Technical Monitor: Thomas T. Bales

16. Abstract

An experimental investigation was made to evaluate two nickel base alloys (Nickel-201 and Inconel-718) in three heat treated conditions. These conditions were: 1) annealed, 2) after thermal exposure simulating a braze cycle, and 3) after a thermal exposure simulating a braze cycle plus one operational lifetime of high temperature service. For the Nickel-201, two different braze cycle temperatures were evaluated. A NASA Langley Research Center developed braze cycle utilizing a lower braze temperature resulted in less grain growth for Nickel-201 than the standard braze cycle used for joining Nickel-201 to Inconel-718. It was determined, however, that Nickel-201, was marginal for temperatures investigated due to large grain growth. After the thermal exposures described above, the mechanical properties of Nickel-201 were degraded, whereas similar exposure on Inconel-718 actually strengthened the material compared with the annealed condition. The investigation included tensile tests at both room temperature and elevated temperatures, stress-rupture tests, and metallographic examination.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Nickel 201 Inconel 718 Brazing Mechanical Properties	Unclassified - Unlimited Subject Category 26

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	27	A03

N-305

For sale by the National Technical Information Service, Springfield, Virginia 22161

End of Document