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PART I
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EFFECTS OF TEMPERATURE-TIME-STRESS HISTORIES ON THE MECHANICAL PROPERTIES OF AIRCRAFT STRUCTURAL METALLIC MATERIALS

Part I. Temperature-Time Studies for 2024-T3 and 7075-T6 Alclad Sheet

ROBERT E. FORTNEY
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NORTHROP AIRCRAFT, INC.
HAWTHORNE, CALIFORNIA

SEPTEMBER 1957

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WADC TECHNICAL REPORT 56-585

PART I

ASTIA DOCUMENT No. AD 142907

**EFFECTS OF TEMPERATURE-TIME-STRESS HISTORIES
ON THE MECHANICAL PROPERTIES OF AIRCRAFT
STRUCTURAL METALLIC MATERIALS**

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**ROBERT E. FORTNEY
CHARLES H. AVERY**

**NORTHROP AIRCRAFT, INC.
HAWTHORNE, CALIFORNIA**

SEPTEMBER 1957

**MATERIALS LABORATORY
CONTRACT No. AF 33(616)-3026
PROJECT No. 7360**

**WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO**

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FOREWORD

This report was prepared by Northrop Aircraft, Inc. under WADC Contract No. AF33(616)-3028. The contract was initiated under Project No. 7360, "Materials Analysis and Evaluation Techniques", Task No. 73605, "Design Data for Metals". The work was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. R. F. Klinger acting as project engineer.

This report covers work conducted from June 1955 to December 1956.

The authors acknowledge the assistance of personnel of Northrop's Engineering Metallurgical Laboratory in performance of exposure, tensile and hardness tests, Mr. A. Scow in data reduction and report preparation and Mr. T. Osa in data analysis.

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ABSTRACT

In order to establish realistic design criteria applicable to aerodynamically heated materials and their complex combinations of temperature, time and stress exposure and inspection criteria for materials after exposure to complex service conditions, the tensile properties of 2024-T3 alclad and 7075-T6 alclad sheet were determined at room temperature, 200, 300 and 400°F after single and sequential multiple exposure in the range 250 through 600°F. In addition, the Rockwell hardness properties at room temperature after the above exposure conditions were determined to provide a basis for inspection of aircraft after service exposure to aerodynamic or engine heating.

Five tensile properties were determined for each exposure and test condition. Three of these, the proportional limit, modulus of elasticity, and percent elongation were tabulated and graphed in a non-dimensional form to generalize the data with respect to test material variability. Since the yield and ultimate strengths determine the load carrying ability, these tensile properties were analyzed carefully and generalizations with respect to exposure temperature and time and testing temperature were accomplished. Statistical calculations were made to determine the accuracy of the various analyses. The conclusion was reached that the yield and ultimate strength analysis is adequate for establishing design criteria in the range room temperature through 400°F, after complex exposures to times from 1.0 to 1000 hours at temperatures from 250 to 600°F.

Material, equipment, specimens and procedures are described in detail. Test results are presented in the form of tables and curves to illustrate the effect of the exposure and test conditions on the materials under investigation and the effect of normalization analyses on the generalization of the data.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



RICHARD R. KENNEDY
Chief, Metals Branch
Materials Laboratory

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HIGH EXPLOSIVE (H.E.)

A material which normally detonates when subjected to heat or shock; it will not burn except under special conditions. High explosives are characterized by the extreme rapidity with which decomposition and blast occur. They decompose almost instantaneously either by extremely rapid combustion, or by rupture and rearrangement of the molecules themselves. In either case, gaseous and/or solid products of reaction are produced. The disruptive effect of the reaction makes a high explosive valuable as a bursting charge, but precludes its use as a propellant because the gases are formed so quickly that excessive pressures are developed which would likely burst the barrel of the weapon.

IGNITION TEMPERATURE

The minimum temperature of an explosive at which deflagration will begin within a specified time period, usually of five seconds. In the case of high explosives deflagration takes place so quickly as to produce a detonation.

INHIBITOR

A substance which is introduced into an explosive compound to stop or depress undesirable chemical reactions during storage, or to reduce the rate of chemical reaction upon explosion.

LOW EXPLOSIVE (L.E.)

See PROPellant

LOW-ORDER DETONATION

See DETONATION

MOHAUDI EFFECT

See SHAPED CHARGE

MURROE EFFECT

See SHAPED CHARGE

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EFFECTS OF TEMPERATURE-TIME-STRESS HISTORIES ON THE MECHANICAL
PROPERTIES OF AIRCRAFT STRUCTURAL METALLIC MATERIALS

PART 1. TEMPERATURE-TIME STUDIES FOR 2024-T3 AND 7075-T6
ALCLAD SHEET

INTRODUCTION

The extension of aircraft operating speeds into the aerodynamic heating region presents an extensive and important need for information relating the effects of service temperature-time-stress histories to the mechanical properties of metallic materials. Therefore, this investigation was established through WADC by Contract AF33(616)-3025 in Mar. 1955 to obtain such information for aircraft design and inspection purposes.

To test aircraft metallic materials under all of the complex and changing combinations of temperature, time and stress to which aerodynamically heated parts are subjected would be time consuming and economically unfeasible. However, it is feasible to sample through the range of temperature, time and stress expected during supersonic flights and from the tests performed deduce generalizations applicable to all combinations of the above variables.

The investigation consequently was limited to simple multiple temperature-time exposure sequences followed by tensile testing at room and elevated temperatures. Tests to include the variable of stress were not included in this program but are contemplated as an extension of the program.

The objectives of this investigation were specifically to (1) determine the tensile properties between room temperature and 400°F and the room temperature hardness of two aluminum alloys after single and multiple exposures in the range, room temperature through 600°F and zero through 1000 hours, (2) tabulate the data and plot the properties versus exposure time for various exposure and testing temperatures and exposure temperature for various exposure times and testing temperatures and (3) draw conclusions regarding limits for prediction of mechanical properties under complex temperature-time conditions from the relationships obtained under the simpler test conditions.

MATERIAL

Two .064" gauge, 48" x 144" sheets each of the metallic materials, 2024-T3 alclad aluminum alloy, specification QQ-A-362a, and 7075-T6 alclad aluminum alloy, specification QQ-A-287 were used for all tests of this program. For each alloy the sheets were selected from a single lot of material taken at random from stock in the production warehouse of Northrop Aircraft, Inc. From one sheet of each alloy verification tests of the room temperature tensile properties and chemical composition were determined. The properties were found to be within the limits of the applicable specifications as shown below.

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ALLOYING ELEMENTS - PERCENT

	Cu	Mg	Zn	Mn	Cr	Fe	Si	Ti
2024 (Core Material)								
Verification Test	4.12	1.64	.10	.67	.01	.23	.13	-
QQ-A-362a Limits	3.8 to 4.9	1.2 to 1.8	0.10 to Max.	0.3 to 0.9	0.25 to Max.	0.5 Max.	0.5 Max.	
7075-T6 (Core Material)								
Verification Test	1.56	2.72	5.47	.026	.25	.39	.16	.07 ^h
QQ-A-287 Limits	1.2 to 2.0	2.1 to 2.9	5.1 to 6.1	0.03 to Max.	0.18 to 0.40	0.7 to Max.	0.5 Max.	0.20 Max.

TENSILE PROPERTIES

	Yield Strength psi	Ultimate Strength psi	Elongation % in 2" g.l.
2024-T3 Alclad, .064 gauge			
Verification Test	43,700	67,500	20.0
QQ-A-362 Limits	40,000 min.	62,000 min.	15 min.
7075-T6 Alclad, .063 gauge			
Verification Test	66,800	77,000	11.5
QQ-A-287 Limits	62,000 min.	72,000 min.	9 min.

TEST EQUIPMENT

The apparatus used to perform the experimental portion of this investigation consisted of:

- (1) Two furnaces, one oven and one aging block for unstressed exposure of tensile specimens to elevated temperatures prior to tensile testing.
- (2) A furnace for exposure of tensile specimens to elevated temperatures while tensile testing.
- (3) Two universal testing machines and associated equipment for tensile testing of specimens.
- (4) Three potentiometer type multi-channel temperature recorders, for multiple, continuous exposure and testing temperature records.
- (5) A Rockwell hardness tester.

The exposure and testing equipment utilized in this investigation are shown in Figures 1 through 10.

Circulating Air Exposure Furnaces and Related Equipment

For unstressed exposure of tensile specimens, two Pacific Scientific Co., Du-Al 1350 furnaces shown in Figure 1 were utilized for all exposure times. These furnaces are of the circulating air type with fan located in vertical rear wall of working chamber and heating elements in vertical side walls, shielded from working chamber by double sheet metal baffles. The fan blows air to front of working chamber and then between baffles and heating elements back to fan where it is mixed and recirculated. Insulation is provided by lightweight, high temperature, insulating brick. Working chamber is 15.5 x 11 x 14 inches in height, width, and depth respectively. Rated electric power input is 5 kw maximum, rated temperature range is 200°F to 1350°F. Temperature control is by a calibrated C-A 20 gauge solid wire thermocouple located in air at center of working chamber and two and one-half inches below top furnace wall.

The control system includes a Wheelco 407 Capacitrol stepless proportioning indicating controller with a zero to 1600°F range, a Wheelco 610 magnetic amplifier and a Burton 5 Kva saturable reactor. The control thermocouple voltage is fed into a galvanometer, the pointer of which indicates temperature. A vane carried by the temperature pointer acts as a valve for the heating control system. As this vane approaches the set control point, it starts to pass between the pickup coils of a single tuned grid, tuned cathode oscillator. The oscillator is designed to give maximum oscillation when the vane is at or above the set temperature control position.

Proportionally less and less oscillation occurs over a band of temperatures below the set control position as the temperature difference between the vane and set control position increases. The action of the oscillator controls the output signal voltage of the 407 controller. Maximum oscillation gives minimum signal voltage and vice-versa. The signal voltage is fed to the 610 magnetic amplifier (pilot reactor) where the signal power is boosted sufficiently to provide the strong magnetic field necessary to saturate the Burton load reactor. When fully saturated due to maximum control signal power the load reactor delivers maximum power to the heating elements. Conversely, minimum power is delivered to the heating elements when the load reactor has minimum saturation, i.e., when minimum control signal power is received. Rated accuracy of the 407 controller is 0.25% of full scale temperature range. The input voltage to the control system is stabilized by a voltage regulator to prevent drift in the temperature control point.

To provide a more constant exposure temperature and a greater rate of approaching exposure temperature for the tensile specimens than are possible with air contact, specimens were placed on metallic plates within the above furnaces. For 0.1 and 1.0 hour exposures the double platen heater shown in Figure 2 was used. These platens were designed to provide a constant temperature heat sink during the insertion and removal of specimens from the exposure furnace. In addition, as the result of being sandwiched between the platens the specimens approached and reached the exposure temperature in less than 30 seconds permitting close control of exposure time. Essentially, the platens are two large masses of aluminum and steel which are heated by the furnace to the correct exposure temperature. Each platen is solid aluminum block, 2.75 x 9 x 13 inches, surrounded on five sides by .375 inch steel plate. Due to its lower heat conductivity as compared to aluminum, the steel plate is used to reduce heat losses in the platens during periods of loading and unloading specimens. The mating surfaces of the platen are aluminum for good heat conduction during exposure of specimens. The upper platen is lifted as needed by a detachable lever arm.

For the 10, 100, and 1000 hour exposures in the above furnaces the temperature stabilizing plates shown in Figure 3 were used. These plates also provided a constant temperature heat sink for the specimens, and the somewhat longer time to reach exposure temperature is negligible in relation to the exposure times.

Circulating Air Oven and Related Equipment

This oven, shown in Figures 1 and 4, was constructed some years ago by Northrop for elevated temperature use up to 500°F. It is of the circulating air type with external fan which blows air through a duct into the bottom of the work chamber through the rear vertical wall and exhausts the air at rear of top wall into the return duct. There are two separately controlled electric heating units: a 2.1 Kw finned unit located in the inlet air duct; and a 1.25 Kw unit on a vertical baffle near the rear wall of the working chamber. Insulation is provided by transite sheet and glass wool batting. Working area is 20 x 11 x 15 inches in height, width, and depth respectively.

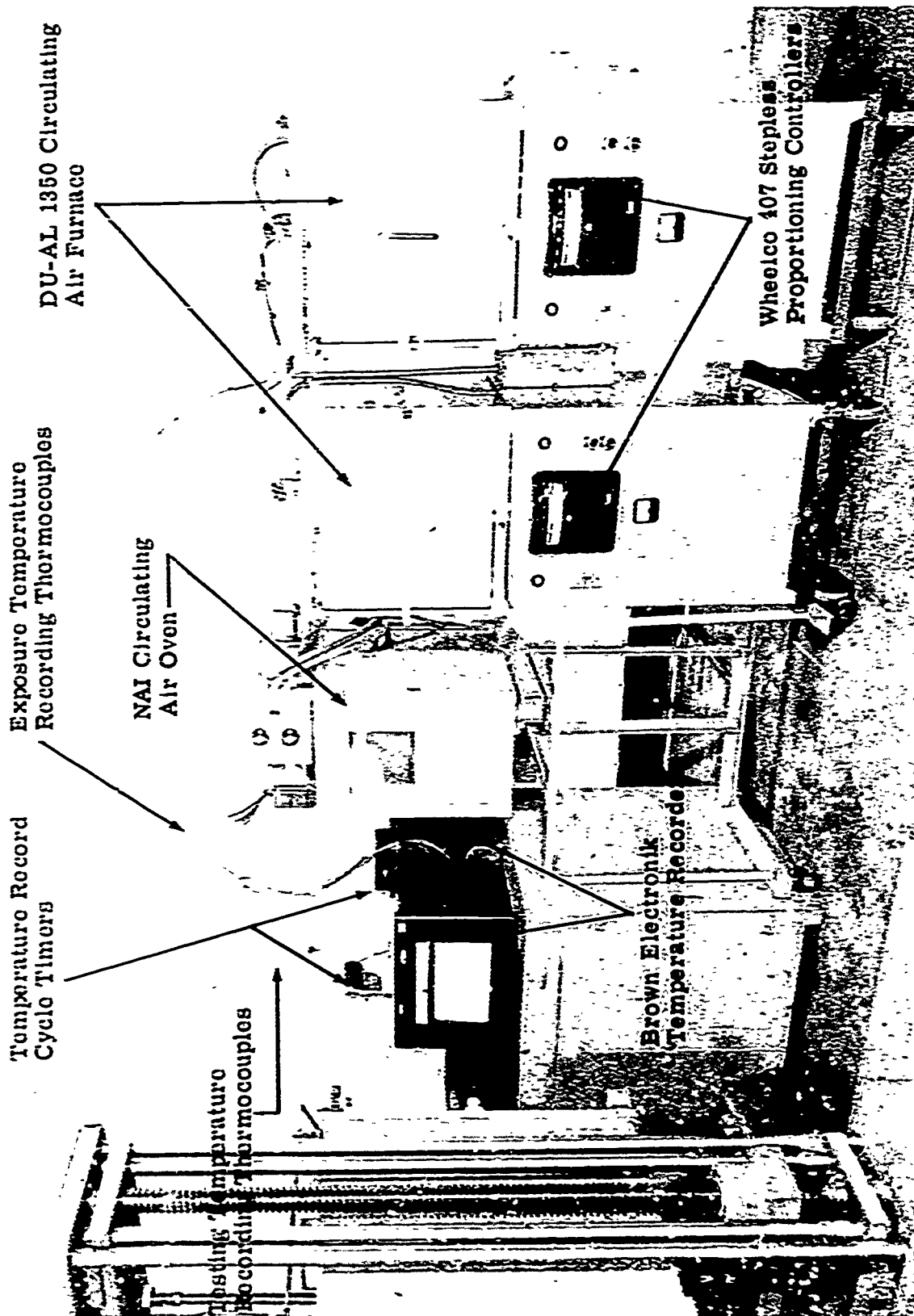


Figure 1. Elevated Temperature Exposure Apparatus Showing Circulating Air Furnaces, Circulating Air Oven, and Temperature Recorders

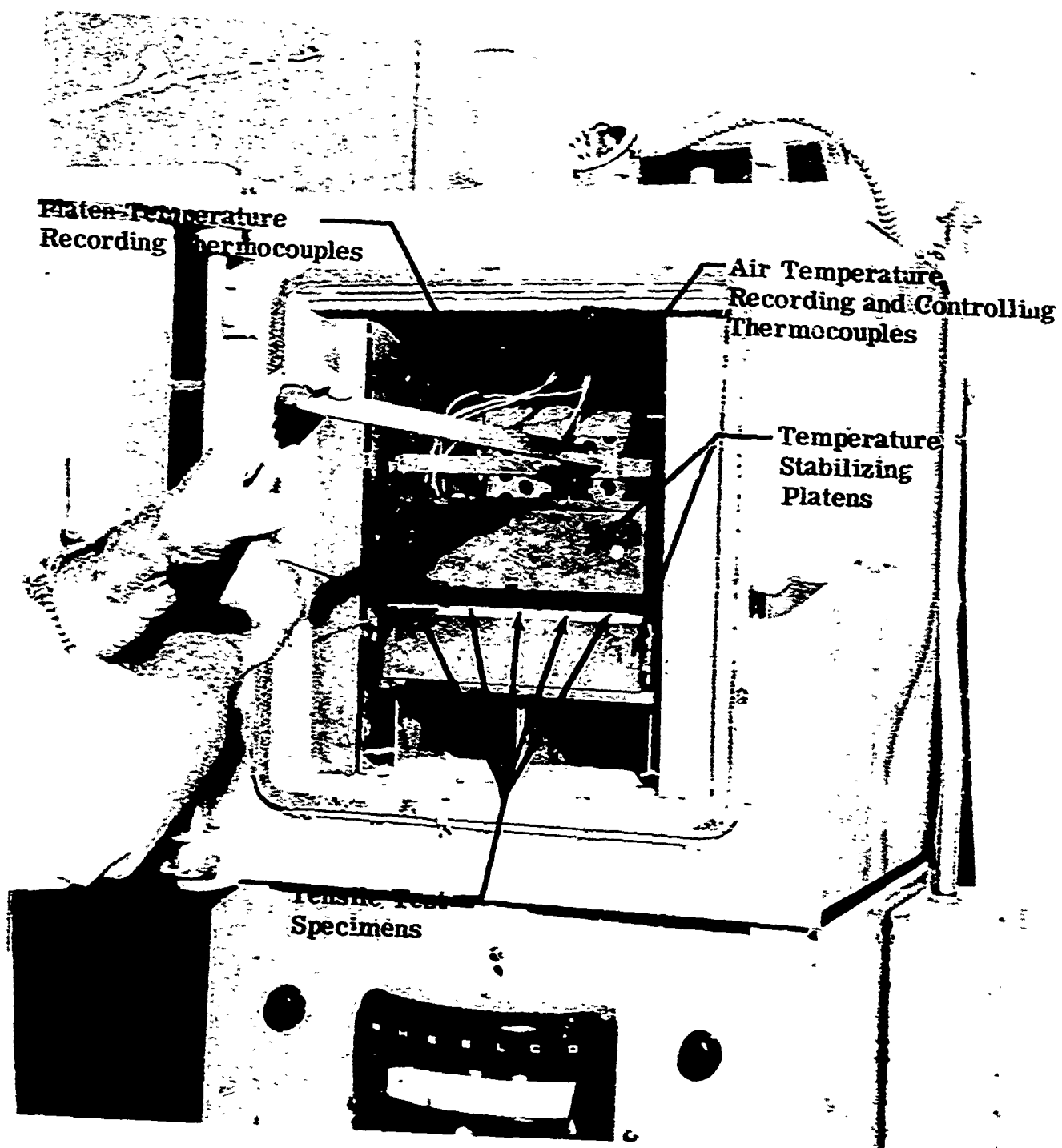


Figure 2. DU-AL 1350 Circulating Air Furnace Interior Showing the Stabilizing Platens Used for the 0.1- and 1.0-Hour Exposures, Tensile Test Specimens, and Controlling and Recording Thermocouples

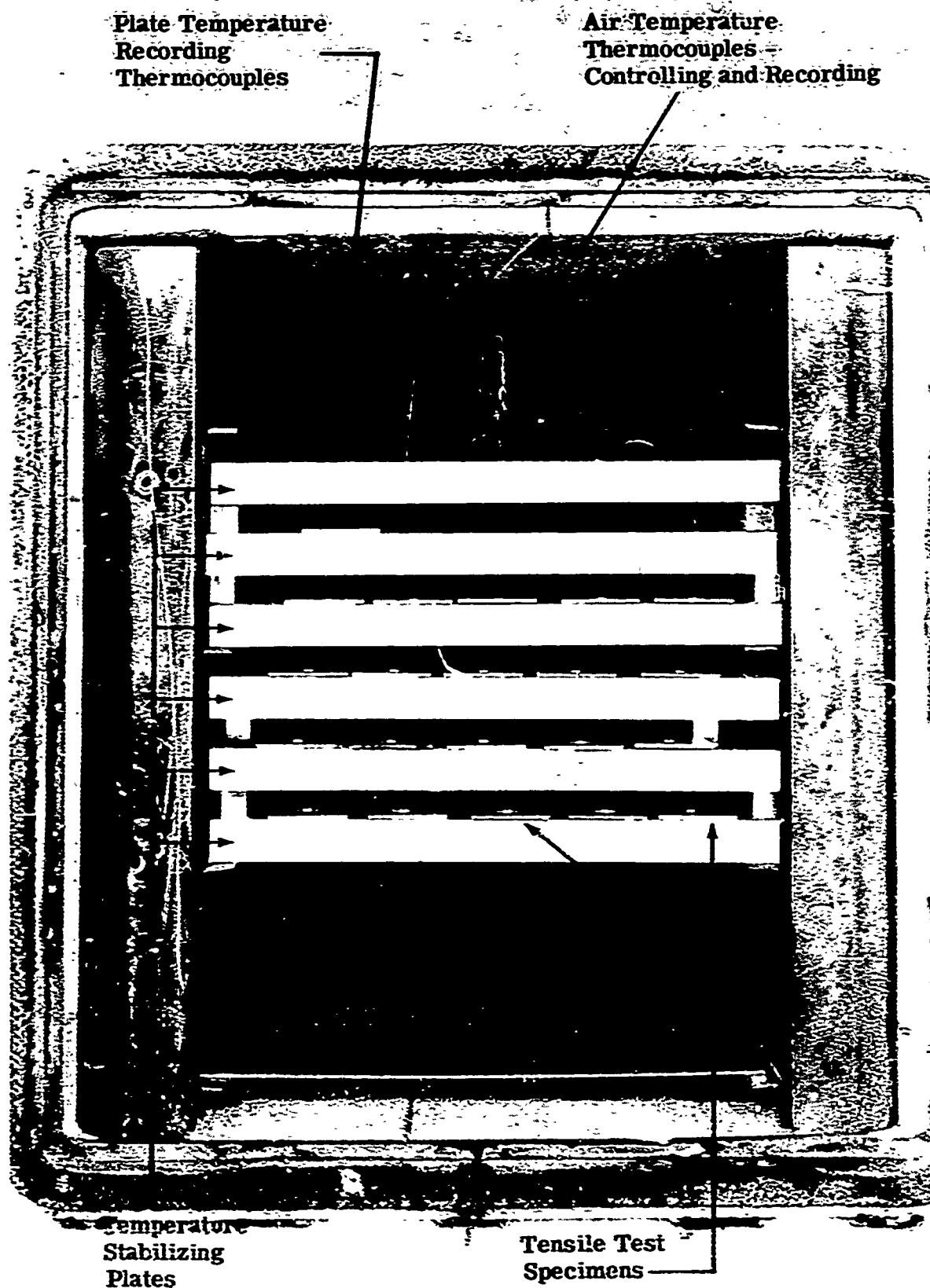


Figure 3. DU-AL 1350 Circulating Air Furnace Interior Showing Temperature Stabilizing Plates, Tensile Test Specimens, and Controlling and Recording Thermocouples

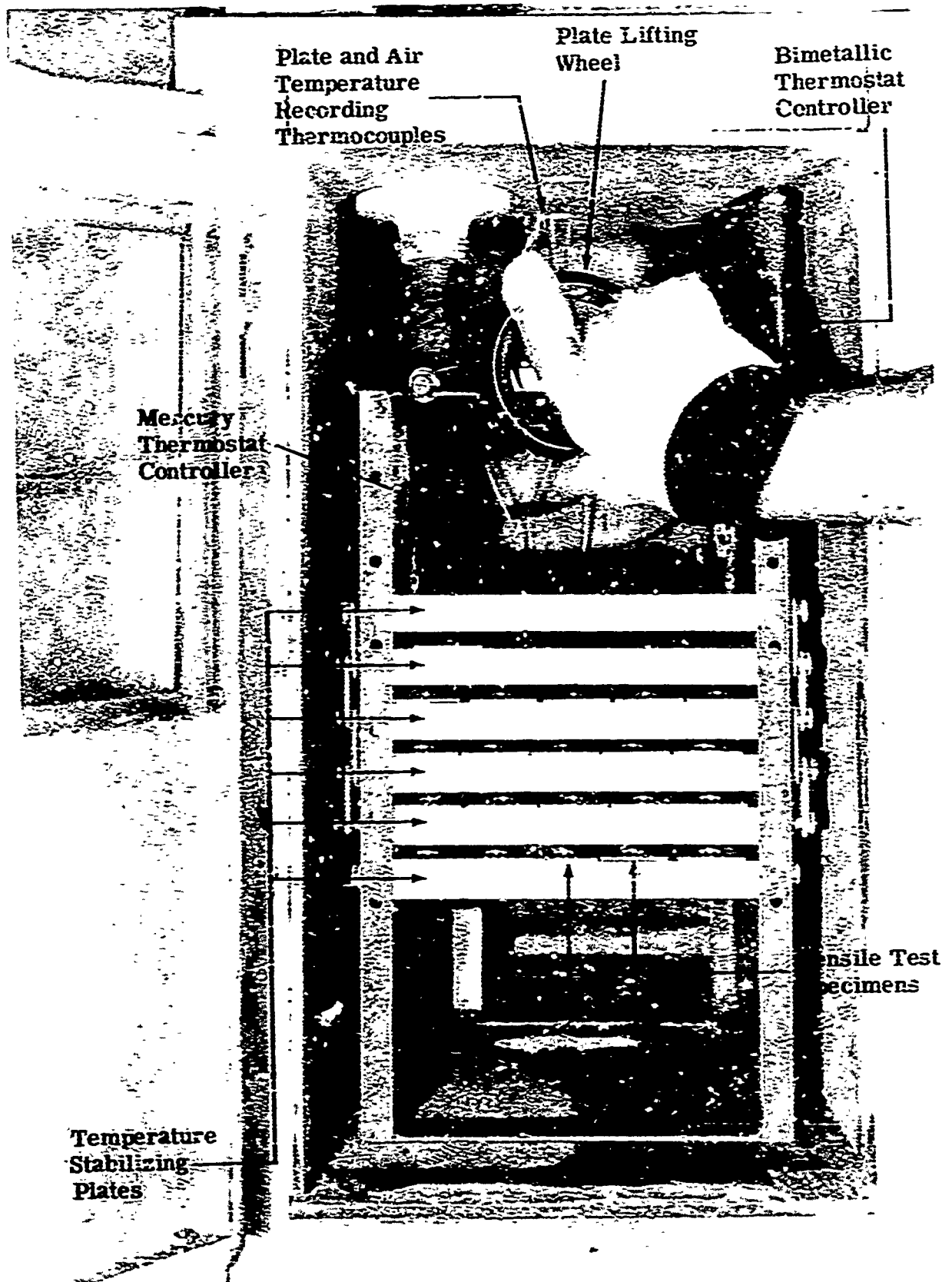


Figure 1. AAI Circulating Air Oven Interior showing Temperature Stabilizing Plates, Tensile Test Specimens, Recording Thermocouples, and Controlling Thermostats

A Fenwal thermostat, located at upper left corner of working chamber, controls the 2.1 Kw heater. A Chromalox #AR-5524 sealed mercury type thermostat controls the 1.25 Kw heating unit, and the sensing element of this thermostat is centered in front of the vertical baffle at the rear wall of working chamber.

Temperature control of the air in this furnace is rather poor with about $\pm 20^{\circ}\text{F}$ variation about control point after stabilization. However, metal to metal contact of specimens between the aluminum plates of the fixture shown in Figure 5 reduced exposure temperature variation of the specimens to acceptable limits. This fixture has provision for raising and separating the individual plates to permit insertion of specimens between the plates.

This furnace was pressed into service for 10 and 100 hour exposures during the sequential exposure tests when it was found that at least three furnaces were required to permit time for temperature stabilization of furnaces.

Aging Block

As an alternate third specimen exposure furnace during occasional breakdown and repair of some of the above furnaces, the Comet Model 600 laboratory aging block shown in Figure 5 was used for some 100 hour specimen exposures. This block consists of a solid precision machined block of aluminum about 18 inches in diameter and 15 inches high with 13 wells, each open at the top. The wells are 1.75 inches in diameter and 11 inches deep. An aluminum plate completely covers the bottom of the block and is removable for ease of maintenance. The wells are symmetrically arranged in the block on a 10.5 inch centerline diameter. Five 500 watt, 220 volt, 60 cycle heater cartridges are arranged symmetrically in holes in the block on a five inch centerline diameter. Unit is designed for close temperature control from 100°F to 600°F . Manufacturer is Product Packaging Engineering, Culver City, California.

Two temperature controllers in series with each other and with the heating cartridges are used for control. A Fenwal Thermostat, Model 17352, located in a hole in the center of the aging block, is set slightly higher than the operating temperature of the Partlow instrument and acts as a safety instrument to prevent temperature override in case of malfunction of the Partlow instrument. The Partlow Indicating Temperature Control, Model E18R 6K1P110, controls the temperature of the unit. It is a mercury bulb, impulse type, proportioning-thermostatic control incorporating a stiff-leaf spring attached to a switch as the proportioning device. The spring-switch is attached to and follows the movement of the block temperature indicating pointer arm. This pointer arm is moved up or down the temperature scale in response to the expansion or contraction of the mercury bulb sensing element. As the pointer approaches the control proportioning band, the switch approaches, as constantly turning cam. At the lower edge of the proportioning control band, the switch contacts the high point of the cam and opens for a very short time each cycle. At upper edge of the proportioning band the switch is opened for all of the cycle and power is furnished continually. The control point will be at some temperature within the proportioning band depending on the power required to just maintain a constant temperature. For this instrument, width of proportioning band is

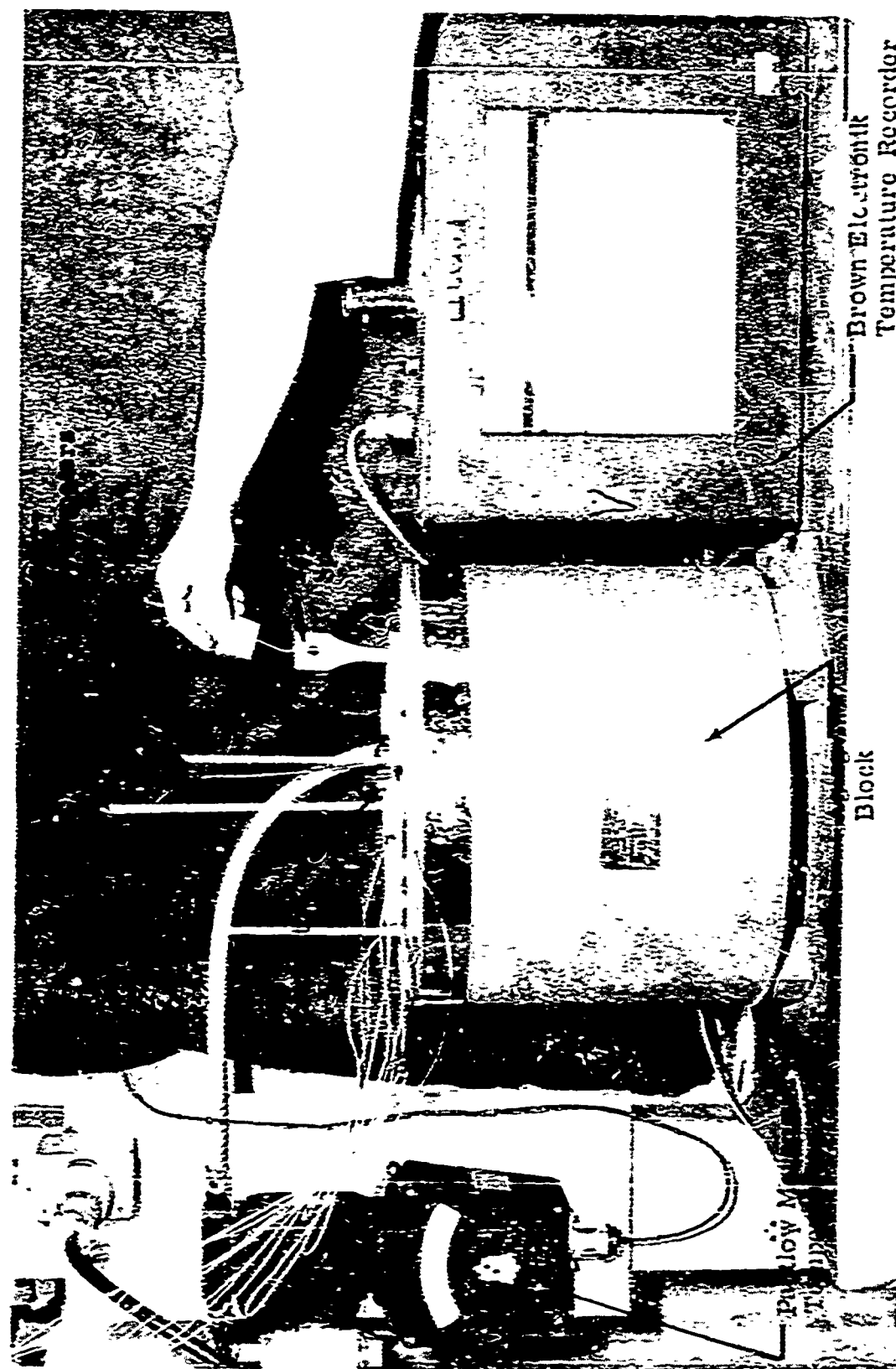


Figure 5. Aging Block Used for 100-Hour Elevated Temperature Exposures with Temperature Controlling and Recording Instruments

500°F: Scale range is 100-650°F; line voltage is 220V, 60 cycle. The Partlow instrument mercury bulb is located in a hole in the aging block between two of the wells.

Circulating Air Testing Furnace & Related Equipment

The Pacific Scientific TM82020AS Testing furnace was used for all exposures of tensile specimens during tensile testing. This furnace, shown in Figure 6, is of the circulating air type with fan located in vertical rear wall of working chamber and heating elements in vertical side walls, shielded from working chamber by double sheet metal baffles. The fan blows air to front of working chamber and then between baffles and heating elements back to fan where it is mixed and recirculated.

Insulation is provided by lightweight, high temperature, insulating brick. Working chamber is 20 x 7.5 x 20 inches in height, width, and depth respectively. Rated electric power input is 7 kw maximum. Rated temperature range is 200°F to 1000°F.

Temperature control is by a calibrated C-A 20 gauge solid wire thermocouple located near test specimen in working chamber. The temperature control instrument is a Minneapolis-Honeywell Brown Elektronik recorder, 0-1200°F range, with an Electropulse time proportioning relay. By proper adjustment, this control turns the heater power on and off in a series of pulses, varied so that the temperature control position is approached at the optimum rate and reached without overshooting. Overall calibrated accuracy of the recorder is 0.25% of full scale temperature range.

Temperature Recorders

Three Brown Elektronik potentiometer type strip chart temperature recorders were utilized to record temperatures during specimen exposure and testing. These instruments are equipped with one second, 12-point printing wheels and an additional timer to permit recording for 30 seconds every 30 minutes during 10, 100 and 1000 hour exposure periods. Continuous 12 point cycle recording was used during the 0.1 and 1.0 hour exposure tests. Each recorder has a rated accuracy of 0.25% of full scale temperature range. Two of the recorders have a full scale of 0. to 800°F and the other -75 to 575°F. Thermocouples used with the recorders are 20 gage solid I-C (B-S) wire, calibrated at Northrop by comparison with secondary standard thermocouples.

5000 lb. Capacity Universal Testing Machine

The Baldwin-Fate-Emercy, Model PTE, universal testing machine of 5000 lb. maximum capacity shown in Figure 7 was used for tensile testing in all but the last series of sequential exposure tests (Tables XXVII & XXVIII). This machine incorporates an Emery hydraulic load measuring cell and a Fate-Emercy hydraulic-pneumatic load indicator. The load indicator has four ranges 5000 lb., 1000 lb., 200 lb., and 50 lb. However, only the first two ranges were used. These ranges are rated to have an error less than 0.5% of load reading or one

division, whichever is greater. The least scale divisions are 5 lb. for the 5000 lb. load indicator range and 1 lb. for the 1000 lb. range. The machine is capable of loading in either tension or compression.

Loading and straining occurs when the crossheads are separated by the mechanical power system. Straining crosshead is driven by two screws which are rotated by a gear drive. The gear drive is powered by a DC motor (one HP) through a two-speed chain drive transmission. Variable crosshead separation is provided through electronic control of the power input to the DC motor. Any setting of the speed control rheostat provides a constant rate of crosshead separation at that setting. Crosshead separation rates are steplessly variable in two ranges, 0.0025 to 10 inches per minute or 0.005 to 20 inches per minute.

For tensile testing hemispherical self-adjusting loading seats in test machine crossheads connect to high temperature extension loading rods, pin-joint specimen loading heads and tensile specimens. Figures 6, 7, 8, 9, and 10 show details of specimen loading assembly.

To graph load versus strain this machine incorporates a Baldwin MA-1, microformer type recorder as shown in Figure 9. The pen of this recorder is attached mechanically to the load indicating pointer of the machine to record load. The recorder drum with graph paper rotates in response to a strain follower extensometer signal to record the strain in a tensile specimen. Minimum load division on recorder graph is 0.01 of recorder load range. Graph record is on a drum permitting a maximum chart length of 12 inches for strain recording. Possible strain record magnifications with either the Baldwin PS-5M or PSH-8MS strain follower (extensometer) are 250:1, 500:1, and 1000:1. During this program only the 250:1 magnification with a minimum graph division of 0.0004 inch strain was utilized.

Figure 6 shows a typical test assembly in the furnace.

120,000 lb. Capacity Universal Testing Machine

A Baldwin-Fate-Emery Universal testing machine of 120,000 lb. maximum capacity was used for the last series of sequential exposure tests in this program because of repairs and alterations to the 5000 lb. capacity machine. This machine incorporates an Emery hydraulic load measuring cell and a Fate-Emery hydraulic-pneumatic load indicator. The load indicator has three ranges 120,000 lb., 24,000 lb., and 6,000 lb. Only the lowest load range was used. This range has a least division of 5 lb. and a rated maximum error of 0.7% of load or 0.10% of range, whichever is the greater. The machine is capable of loading in either tension or compression.

Loading and straining occurs when the crossheads are separated by the ram of the hydraulic power system. The rate of crosshead separation is controlled by two hydraulic valves, one for loading and one for unloading the crossheads. Crosshead separation rates are steplessly variable from zero to six inches per minute. Any setting of the loading or unloading valve provides

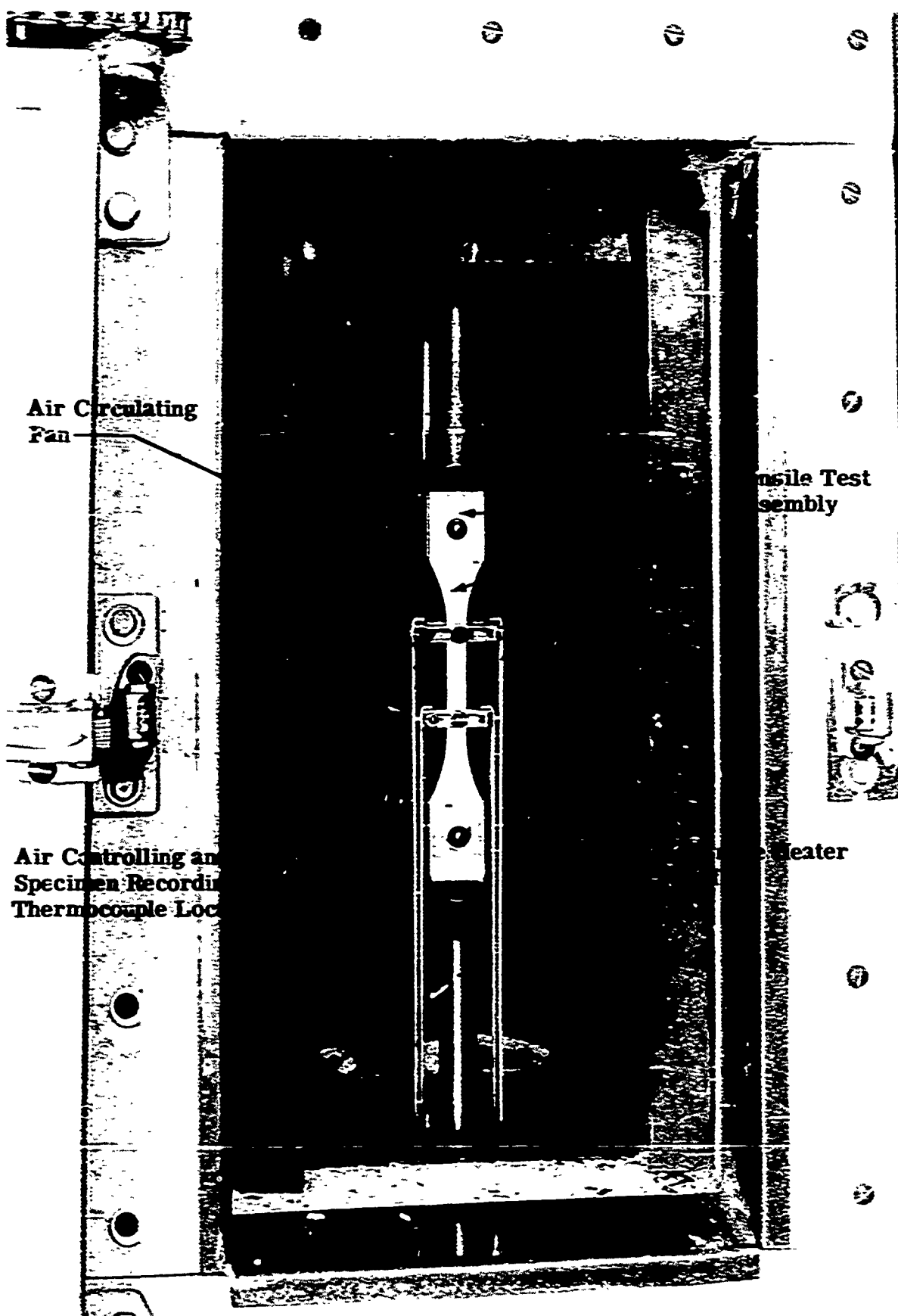


Figure 6. Elevated Temperature Tensile Testing Apparatus Showing Interior of Circulating Air Test Furnace and Tensile Testing Assembly

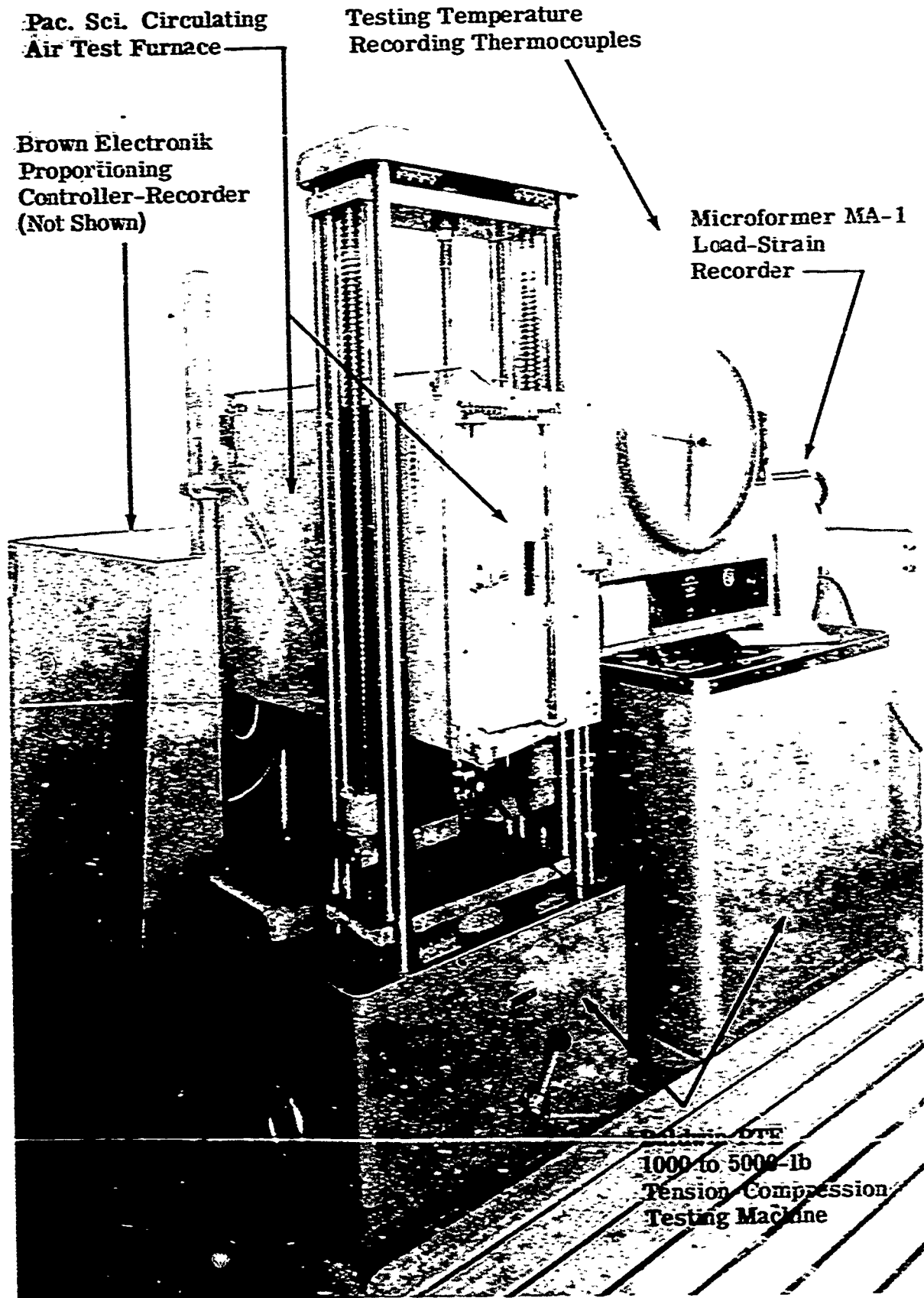


Figure 7. Elevated Temperature Testing Apparatus Showing Circulating Air Test Furnace, Tension Testing Machine, and Microformer recorder

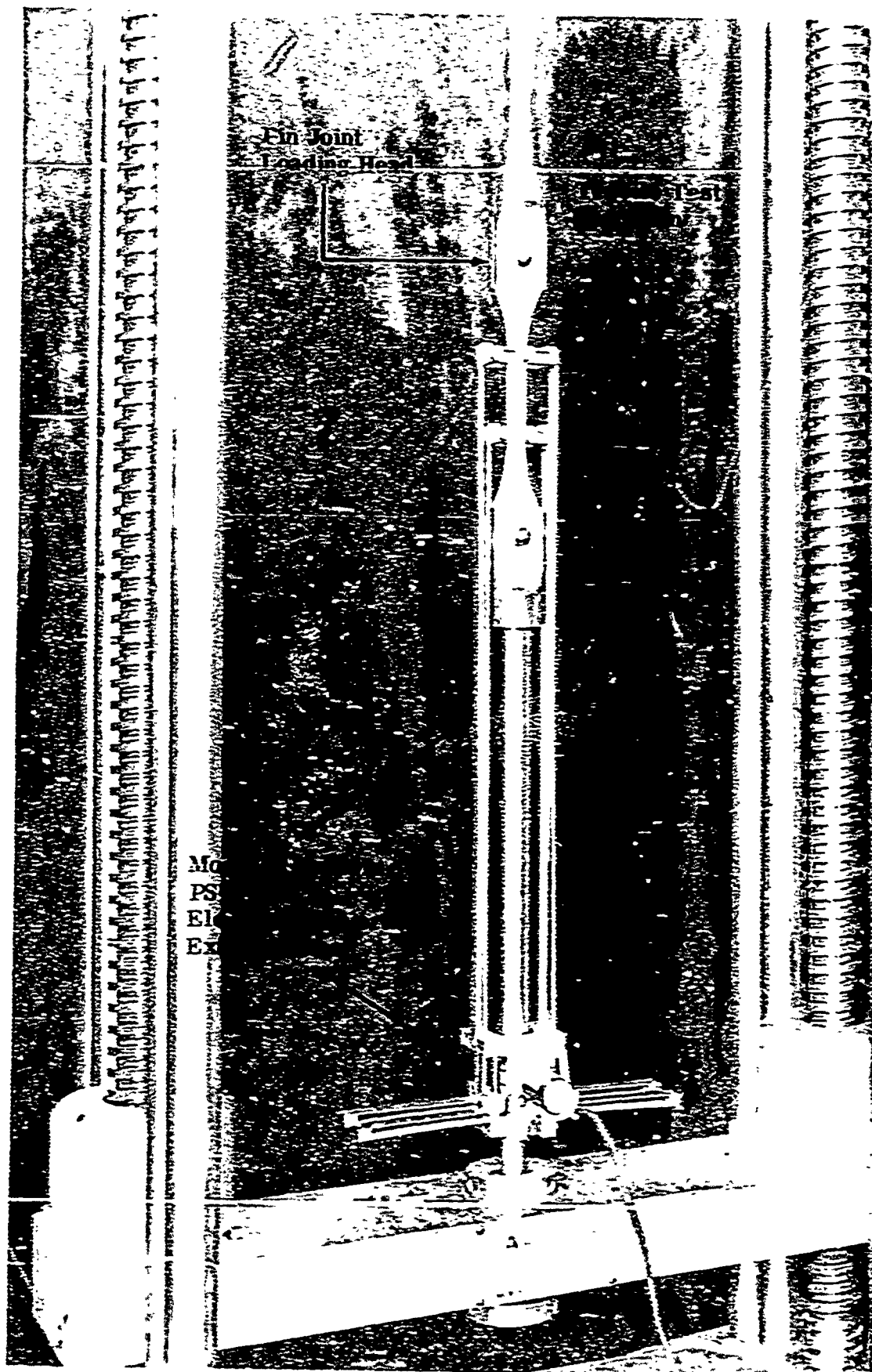


Figure 8. Elevated Temperature Tensile Testing Assembly Showing extensometer, Tensile Test Specimen, and Pin Joint Loading Heads

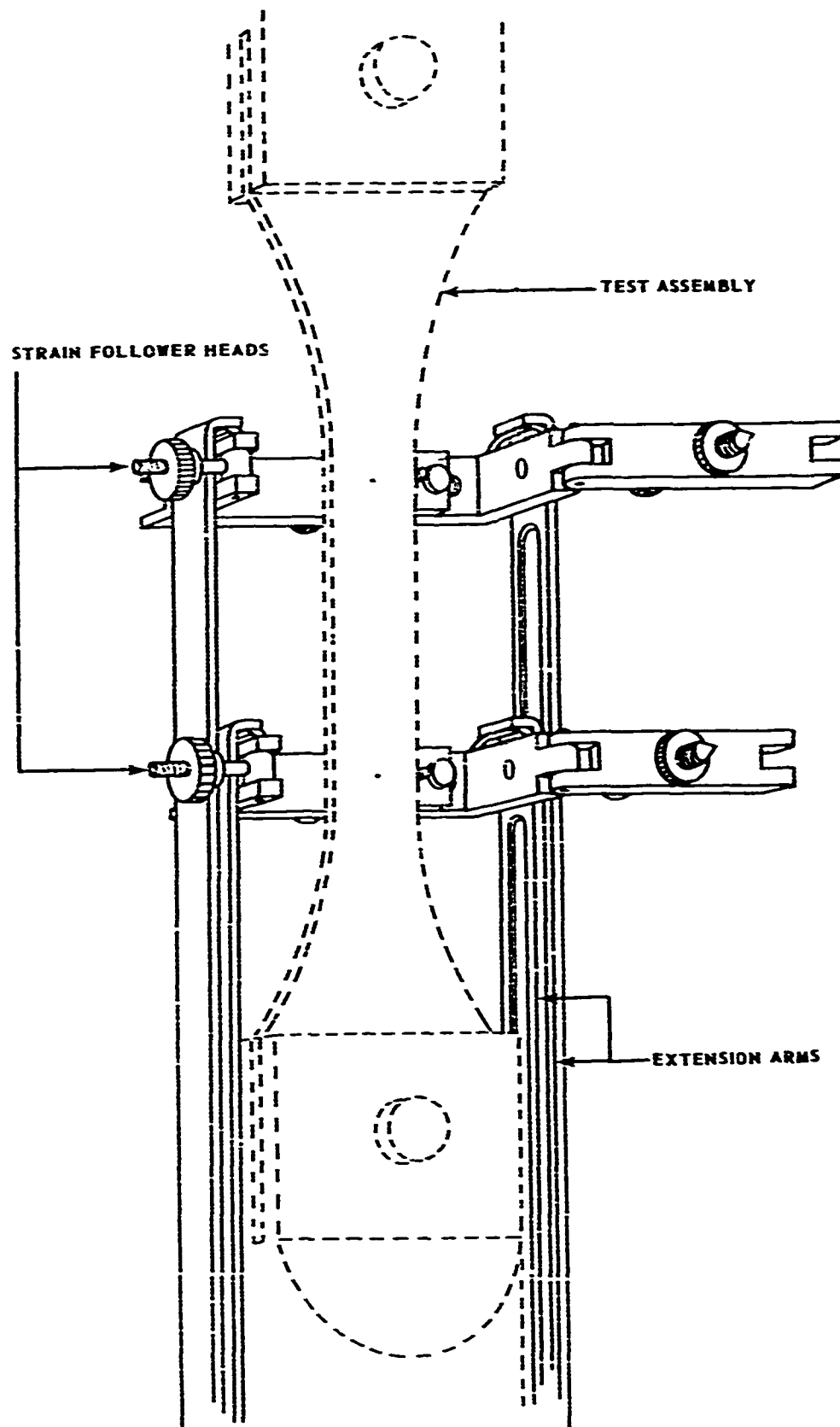


Figure 9. Modified Strain Follower Head and Extension Arms
for Baldwin PSH-8MS Extensometer

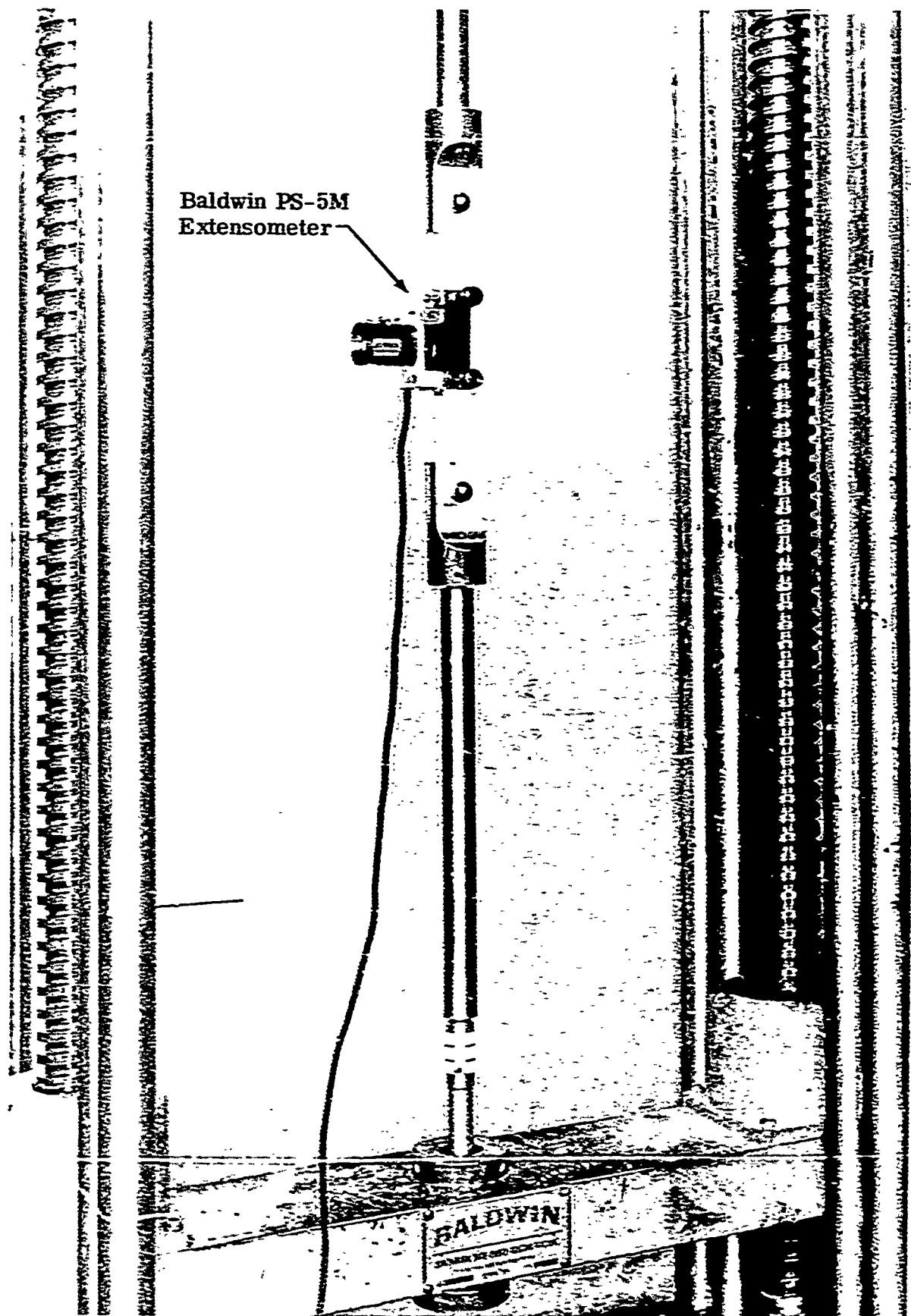


Figure 10. Room Temperature Tensile Testing Assembly

a constant speed of the hydraulic ram.

For tensile testing the same specimen loading assembly is used with this machine as with the 5000 lb. machine.

To graph load versus strain the same type of recorder is incorporated with this machine as with the 5000 lb. machine.

Room Temperature Extensometer

A Baldwin PS-5M strain follower extensometer was used for strain measurements during all room temperature tensile tests. This extensometer is of the averaging, separable type incorporating conical points for contacting opposite sides of the test specimen, a two inch gage length and .04 inch maximum extension. It can be used in testing flat and round specimens with maximum dimensions of .505 inches square or .505 inches diameter. A typical room temperature testing assembly is shown in Figure 10.

Elevated Temperature Extensometer

A Baldwin PSE-6MS strain follower extensometer was used for strain measurements during all elevated temperature tensile tests. This extensometer is of the averaging, separable type incorporating conical points for contacting opposite sides of the test specimen, a two inch gage length and .04 inch maximum extension during testing. It is designed for use at temperatures up to 1600°F on sheet, plate, and round specimens with maximum dimensions of .505 inches square or .505 inches diameter. This extensometer has been modified using longer extension arms and a specimen strain follower head of Northrop design. The strain measuring lever and microformer coil system is unchanged. Figure 9 shows details of the strain follower heads and extension arms in relation to a tensile test specimen while Figure 8 shows details of a typical extensometer, tensile specimen assembly.

Hardness Tester

Two Rockwell standard hardness testers, one model 3R and one model 4JR-P1, manufactured by the Wilson Mechanical Instrument Division of American Chain and Cable Co. were used to determine the hardness of tensile test specimens. Instrument accuracy was determined periodically by comparing instrument readings with known hardness of a calibrated test block.

EXPERIMENTAL PROCEDURES

The experimental portion of this investigation consisted of:

- (1) Preparation of tensile specimens.
- (2) Unstressed exposure of tensile specimens to selected temperature - time conditions.

- (3) Tensile tests at selected temperatures with and without prior unstressed exposure.
- (4) Room temperature tensile tests of specimens from each material panel for comparison with above tensile tests.
- (5) Determination of inherent errors in measuring temperature, time, load and strain.
- (6) Measurement of room temperature hardness on all specimens tested at room temperature.

Specimen Preparation

Each sheet used for testing was cut into panels large enough for 14 specimens placed side by side and the axis of each specimen transverse to the rolling direction of the sheet. Each panel was designated with a letter, starting with A and going to Z, then to AA, BB, etc. The panels were used in this sequence. The twelve outer specimens in each panel were numbered consecutively from one to twelve and used for elevated temperature exposure and testing. The middle two specimens were numbered C1 and C2 and used for room temperature control tests with which to compare the elevated temperature tests of the same panel. The complete designation for each specimen was typically

2A1, 7Z12, 2MC1

where the first digit designates the alloy, 2 for 2024 and 7 for 7075, the first letter designates the panel, the second letter, C, designates room temperature control specimen, only, and the second number or pair of numbers designates the specimen.

This panel system of specimens was adopted primarily to minimize the material variability factor in data analysis.

Each specimen was machined to the configuration of Figure 11. This pin joint configuration was chosen since it was believed that improved alignment and more uniform stressing could be obtained than with the standard QQ-M-151 specimen clamped in jaws. In addition, for elevated temperature testing the pin joint type specimen was assembled more easily and rapidly than the standard type, thus causing less temperature drop of the testing furnace during assembly of specimen and less recovery time to the testing temperature.

To prepare the specimens, panels were cut into individual specimen blanks with their axis in the direction transverse to the original sheet rolling direction. Then, eight blanks at a time were milled in a fixture to the required length, width, and reduced test section. Next each specimen was fastened securely in a simple drill fixture which assured correct alignment of the holes with respect to the test section and each pin joint hole drilled. Finally, the milled edges and surfaces of the reduced test section of each

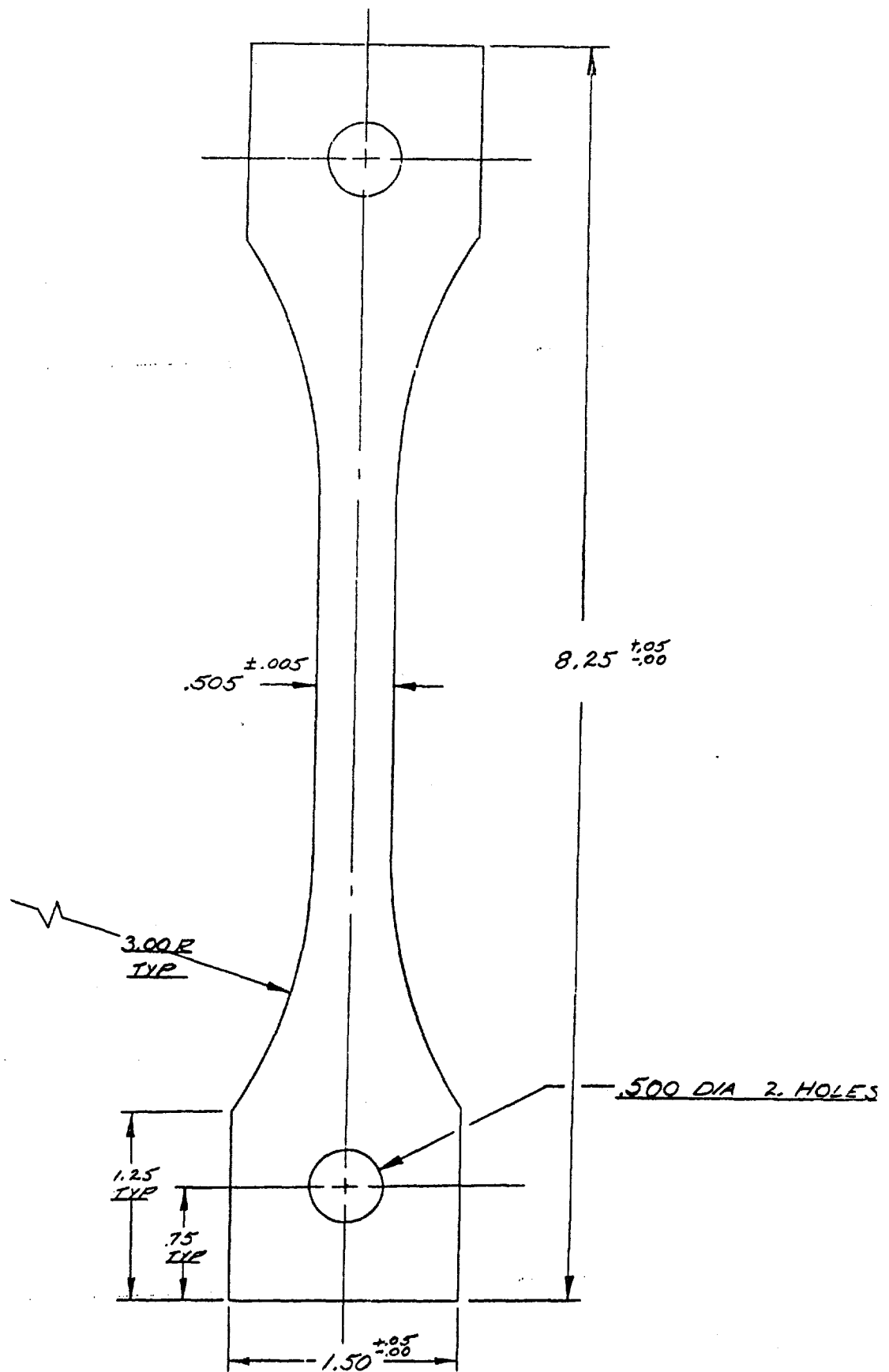


FIG. 11 TENSILE TEST SPECIMEN (PIN JOINT TYPE).

specimen were smoothed of all milling marks and surface scratches with 400 grit paper, the resultant finishing marks being in the axial direction only.

Unstressed Exposures

Specimen exposure conditions were confined to sampling the temperature-time span in which aluminum alloys would be structurally useful when subjected to aerodynamic heating. Single exposures as well as sequences of exposures were investigated. To each single or sequential multiple temperature-time condition a different group of twelve specimens were exposed. During exposure none of the specimens were subjected to externally applied stresses.

First, a series of single exposures were performed as follows to serve as a basis for comparison with the more complex exposure conditions.

Single Exposure Conditions

<u>2024-T3</u>		<u>7075-T6</u>	
<u>Temp., °F</u>	<u>Time, Hours</u>	<u>Temp., °F</u>	<u>Time, Hours</u>
300	0.1, 1.0, 10, 100, 1000	250	100, 1000
400	0.1, 1.0, 10, 100, 1000	300	0.1, 1.0, 10, 100, 1000
500	0.1, 1.0, 10, 100, 1000	400	0.1, 1.0, 10, 100, 1000
600	0.1, 1.0, 10	500	0.1, 1.0, 10, 100, 1000

Then a series of simple, sequential exposures were performed as follows to approximate complex exposure conditions. These exposure sequences were arranged before testing to attempt to adequately sample the useful temperature-time span for the subject alloys.

Sequential Exposure Conditions

<u>Sequence Number</u>	<u>1st Exposure</u>	<u>2nd Exposure</u>	<u>3rd Exposure</u>	<u>4th Exposure</u>
	<u>1.0 Hour</u>	<u>10 Hours</u>	<u>100 Hours</u>	<u>1000 Hours</u>
<u>2024-T3 Alloy</u>				
1	500°F	400°F	-----	-----
2	500°F	400°F	300°F	-----
3	600°F	500°F	-----	-----
4	600°F	500°F	400°F	-----
5	600°F	500°F	400°F	300°F
<u>7075-T6 Alloy</u>				
6	400°F	300°F	-----	-----
7	400°F	300°F	250°F	-----
8	500°F	400°F	-----	-----
9	500°F	400°F	300°F	-----
10	500°F	400°F	300°F	250°F

Finally, an additional series of simple sequential exposures were performed as follows to fall entirely on the critical inclined portion of modified Larsen-Miller curves as determined from analysis of data from the first and second series of exposure tests.

Additional Sequential Exposure Conditions

Sequence	1st Exposure		2nd Exposure		3rd Exposure		4th Exposure	
	Temp. °F	Time, Hrs.	Temp. °F	Time, Hrs.	Temp. °F	Time, Hrs.	Temp. °F	Time, Hrs.
2024-T3 Alloy								
11	600	1.0	555	5.1	510	18.7	465	99.6
12	555	1.0	510	4.3	465	21.5	420	126.1
13	510	1.0	465	4.6	420	25.2	375	165.0
14	465	1.0	420	5.0	375	30.0	330	219.0
7075-T6 Alloy								
15	500	1.0	460	3.9	420	17.5	380	90.5
16	460	1.0	420	4.2	380	20.2	320	113.4
17	420	1.0	380	4.5	340	23.4	300	145.1
18	380	1.0	340	4.8	300	27.7	260	191.7

The method of exposure included rapidly heating test specimens to the required temperature, soaking for the required combination(s) of temperature and time in circulating air furnaces, ovens and aging block, and transferring as rapidly as possible between furnaces or to the tensile testing equipment. The method was designed especially for the shorter (0.1, 1.0 and 10 hour) exposure periods, i.e., tensile specimens were inserted in the furnace so as to minimize the time to reach the exposure temperatures with the minimum possible deviation and transferred to the next exposure furnace or tensile testing machine in the minimum possible time.

During the 0.1 and 1.0 hour exposures specimens were inserted between the platen heaters shown in Figure 2. With these platens the time to reach exposure temperature and the temperature deviation during exposure were the least of any of the exposure methods utilized. Further, the furnace doors could be opened without changing the temperature of heated platens or specimens already on the platens, thus permitting sequential insertion of the specimens. Measurement of exposure time started at the moment a specimen was inserted between the platens and ended the moment the furnace door was opened to remove the specimen. The time for specimens to reach within 50°F of the maximum soaking temperature, 600°F, was 15-25 seconds. The time from opening the furnace door to removing a specimen was 5-10 seconds.

During the 10 hour and longer exposures specimens were sandwiched between or laid upon 0.75" thick aluminum plates in the circulating air furnaces shown in Figures 3 and 4 or suspended by wires from corks and suspended in air in plugged individual wells of the aging block shown in Figure 5. Time to reach the exposure temperature for these longer exposures was negligible (0.1% or less

of exposure time) in comparison to the exposure times. The temperature of specimens already on the aluminum plates or in an aging block well were not changed by opening a furnace door or removing the cork from adjacent aging block wells, thus permitting sequence insertion of specimens. Exposure time measurement started the moment a specimen was laid on an aluminum plate or inserted in an aging block well and ended the moment the furnace door was opened or cork removed from aging block well.

Temperature measurement during exposure was by 20 gauge solid wire iron-constantan thermocouples. These thermocouples were calibrated prior to use by comparison with a platinum - 10% rhodium, platinum thermocouple which had been standardized within the previous six months at the National Bureau of Standards. Temperature recording thermocouples were imbedded in the platens and plates .05 inch below surfaces contacting specimens or inserted in aging block wells adjacent to specimens. Three or more couples were utilized to record temperatures at the minimum, mean and maximum temperatures of each furnace or aging block. Each thermocouple temperature was recorded on one of the Brown "Elektronik" potentiometer type recorders shown in Figures 1 and 5 at intervals of 30 minutes during 1.0 hour and longer exposures and at intervals of 15 seconds during 0.1 hour exposures and the start and end of all exposures.

Deviation of recorded specimen temperatures from the nominal temperatures listed above and in the data tables was $\pm 2\frac{1}{2}^{\circ}\text{F}$ or less for all 0.1 hour and 1.0 hour single exposure conditions and $\pm 5^{\circ}\text{F}$ or less for 10 hour and longer single exposure conditions as well as all the sequential exposure conditions, with the following exceptions:

Further deviation of the actual exposure temperatures from the listed nominal temperatures is possible for the following reasons: (1) Temperature readings of the calibrated thermocouples varied from the equivalent standard thermocouple readings up to $\pm 1^{\circ}\text{F}$ throughout the exposure temperature range, (2) the N.B.S. standardized thermocouples used for calibrating the recording thermocouples are certified to have no more than $\pm 0.9^{\circ}\text{F}$ error or departure from the standard Iron-Constantan temperature emf relationship, (3) the maximum error in Brown strip chart temperature records was $\pm 1^{\circ}\text{F}$ when determined by substituting accurate voltages to simulate thermocouple signals in the recorders. Since corrections for these errors were not made during testing, a $\pm 2.9^{\circ}\text{F}$ additional deviation of actual temperature from the listed values in the data tables is possible.

Tensile Testing

Following unstressed exposure, each group of twelve specimens, representing one single or sequence exposure condition, was separated into subgroups of three specimens each and a different sub-group tensile tested at each of the following exposure temperatures:

Room Temperature
200 $^{\circ}\text{F}$
300 $^{\circ}\text{F}$
400 $^{\circ}\text{F}$

In addition to the above test three specimens each of each alloy were tested at 200, 300 and 400°F without prior exposure to serve as a zero exposure reference with which to compare all other exposure tests. Also, two tensile specimens from the middle of each panel (see Specimen Preparation) were tensile tested at room temperature in the "as received" condition.

During testing the sequence of events consisted of (1) taking a specimen from an exposure furnace or aging block, (2) transferring the specimen about fifteen feet to the tensile testing equipment, (3) opening the test furnace door and assembling the specimen into the loading heads, (4) closing the test furnace door and applying and maintaining a small load on the specimen, (5) opening the furnace door and attaching the extensometer to the specimen, (6) closing the furnace door and adjusting and maintaining the load at a slightly higher value, (7) heating the specimen until the required temperature is reached and (8) starting the tensile test.

Transfer time of each specimen including the time the exposure furnace door or aging block well was opened until the specimen and extensometer were completely assembled and started to heat to the testing temperature was no more than 60 seconds. The time required to heat a specimen to the testing temperature depended on the recovery rate of the testing furnace and varied from 7 minutes for the 200°F testing temperature to 12 minutes for the 400°F testing temperature. The exposure time at elevated temperature during tensile testing depended on the length of the tensile testing period and was about 0.4 minute for each percent elongation a specimen withstood. Testing time varied from about 3 minutes for specimens with 7 percent elongation to about 33 minutes for specimens with 82 percent elongation.

During each tensile test the rate of testing machine crosshead travel was held constant and was selected to give a strain rate, prior to yield, as nearly .005 in./in./min. as possible. Since some yielding in bearing at the pin joint holes occurred on some specimens because of the large range of exposure and testing conditions the rate of crosshead travel was varied somewhat so as to maintain a nominal .005 in./in./minute strain rate prior to yield. The strain rate and head travel rate of each specimen are listed in the data tables.

The load-strain measuring system composed of extensometers to follow the strain on a two inch gage length of each specimen, a mechanical linkage between the tensile machine load measuring system and an autographic recorder to follow the load, and an autographic load-strain recorder to continuously graph the load strain curve up through the yield point during testing was utilized to provide data for calculation of the modulus of elasticity, proportional limit and yield strength.

The system error in strain readings was determined for each extensometer

by several calibrations at periodic intervals throughout testing. Calibration equipment consisted of a Baldwin strain follower calibrator and a set of calibrated Eoke gage blocks. Each calibration consisted of comparing autographic recorder readings versus gage block dimensions for five to ten increments of strain through the useful range and averaging the results for three or more runs. Error in the Eoke gage blocks (.000003" in./in. maximum) was 7 to 100 times smaller than the error in the strain measuring system and was considered negligible. Error in the strain measuring system is shown in Table I and is 10% or less of any strain. The errors of Table I remain uncorrected in calculation and tabulation of the data.

The load indicator reading on the testing machine at maximum load was used to provide data for the calculation of the ultimate strength. The load indicator errors and the autographic recorder errors were determined for each testing machine with standardized dead weights and proving rings. Both the load indicator and autographic recorder errors are shown in Table II and are 1% or 6% respectively for any load. Each calibration shown is the average of three or more runs at the stated loads.

Gage marks, 2.000 inches apart on the original test specimens were used to determine the total percent elongation after fracture. Dividers were used to determine length between gage marks on mated halves of fractured specimens. Accuracy of measurement was .01 inches or 0.5% elongation.

Hardness Testing

After completion of testing, hardness determinations were made on all specimens that had been tensile tested at room temperature. Rockwell hardness indentations were made only near the unstressed four corners of the pin joint loading section of each half of each specimen. Each hardness value listed in this report on the average of three or more hardness readings. Early in the hardness tests it was discovered that two hardness scales, B scale and H scale, were necessary. The range of mechanical strength and hardness was so great that the softer specimens exhibited the anvil effect, i.e., the work hardening of the specimen extended completely through and was visible on the opposite side from the impression. The "B scale" with a 100 kilogram load and a 1/16 inch ball was used originally. The "H" scale with a 60 kilogram load and a 1/8 inch ball was added for softer specimens. B and H scale readings were taken on all specimens. All hardness determinations that exhibited excessive anvil effect and scatter between readings were eliminated from inclusion in this report. The hardness readings in each determination varied no more than 2.5 numbers for each value presented in this report.

EXPERIMENTAL RESULTS

Preparation of the experimental results consisted of:

- (1) Determining the mechanical properties from tensile and hardness test data and listing of the results of each test in a logical tabular form.

- (2) Comparing the tensile properties of material subjects to the various exposure and testing conditions with the room temperature tensile properties of material from the same panel in the "as received" condition, expressing the comparison in terms of "percent of room temperature properties" and listing a summarization of this data in a logical tabular form.
- (3) Plotting summarized tensile properties versus exposure time for various exposure temperatures and testing temperatures.
- (4) Plotting summarized tensile properties versus exposure temperatures for various exposure times and testing temperatures.
- (5) Plotting the average hardness value of each specimen tensile tested at room temperature versus tensile yield strength and tensile ultimate strength.

TABLE I

STRAIN CALIBRATION DATA

Extensometer Displacement (1) in./in.	Autographic Recorder Strain Error Separate Calibrations in./in.			Maximum Error Percent
PSM EXTENSOMETER				
	1	2	3	
0.001000	.00006	.00002	.00002	8.0
0.002000	.00013	.00003	.00002	6.5
0.003000	.00022	-.00002	-.00004	7.3
0.004000	.00029	-.00008	-.00007	7.2
0.005000	.00034	-.00010	-.00008	6.8
0.006000	.00039	-.00012	-.00007	6.5
0.008000	.00054	-.00010	-.00012	6.7
PSH-8MS EXTENSOMETER				
	1	2	3	
0.001000	.00003	-.00010	-.00008	10.0
0.002000	-.00002	-.00014	-.00009	7.0
0.003000	-.00004	-.00013	-.00020	6.7
0.004000	-.00007	-.00014	-.00021	5.2
0.005000	-.00006	-.00016	-.00009	3.6
0.006000	-.00006	-.00021	-.00016	3.5
0.008000	-.00012	-.00026	-.00020	3.3

- (1) Extensometer displacement was measured by the difference in length of successive Pratt and Whitney Calibrated Gage Block stacks from a fixed reference plane.

TABLE II

LOAD CALIBRATION DATA
5000 LB., CAPACITY TEST MACHINE

Actual Load Lbs.	Load Indicator Error Separate Calibrations, Lbs.		Maximum Error Percent
	1	2	
100	0.0	0.0	0.00
150	0.0	0.0	0.00
200	1.7	-0.8	0.85
300	-2.0	-2.0	0.66
400	1.6	-2.5	0.62
450	0.4	0.4	0.09
600	-3.6	-5.2	0.87
800	1.8	-6.0	0.75
980	-9.0	-9.5	0.97
1000	-5.2	1.7	0.52
2000	9.7	7.1	0.48
2500	6.0	5.5	0.24

Actual Load Lbs.	Autographic Recorder Load Error Separate Calibrations, Lbs.						Maximum Error Percent
	1	2	3	4	5	6	
100	-0.8	0.2	-2.8	---	---	---	2.8
150	8.7	-0.1	-0.2	-1.0	1.5	0.5	5.8
200	1.1	1.9	-1.4	1.7	1.2	---	0.9
300	6.3	-0.8	-3.0	-3.0	---	---	2.1
400	1.6	1.4	1.1	-1.5	---	-0.1	0.4
450	8.1	1.0	-1.0	-4.0	0.9	0.4	1.8
600	1.3	-3.2	-5.0	-8.8	-3.5	-6.7	1.5
800	-4.8	-5.1	-3.1	-2.8	---	---	0.6
980	-13.0	-3.7	-10.0	-10.5	---	---	1.3
1000	-5.6	-0.9	-10.0	-16.0	-5.2	-6.5	1.6
2000	10.3	5.0	-5.0	11.6	10.1	---	0.9
2500	2.0	-1.5	-1.5	0.0	3.2	---	0.1

Mechanical Properties Determination

The mechanical properties determined during tensile testing were:

- (a) Modulus of elasticity.
- (b) Proportional limit.
- (c) Yield strength (0.2% offset).
- (d) Ultimate strength.
- (e) Total elongation after fracture.

The modulus of elasticity is the slope or tangent of the secondary modulus portion of the load-strain record, divided by the original cross-sectional area of the tensile specimen. The proportional limit is the upper load at which the secondary modulus deviated from a straight line, divided by the original cross-sectional area of the specimen. The yield strength is the load intercept with the load-strain curve of a line having the same slope as the secondary modulus but offset from it to the right by 0.2% strain, divided by the cross-sectional area of the specimen.

Since the materials for this program were alclad aluminum alloys, both primary and secondary modulus slopes were present within the elastic region of the load-strain autographic records. The secondary modulus slope was chosen for determining the modulus of elasticity, proportional limit and yield strength for two reasons. For the majority of the tests the secondary modulus line was the longer, i.e. from one-half to four-fifths of the elastic portion of the load-strain graph. This longer line presented the possibility of a more accurate determination of the modulus, proportional limit and yield. On the other hand, the load-strain graphs characteristically often contained deviations or irregularities near the beginning of the curves which masked a true determination of these properties.

Another characteristic of the load-strain graphs, made it extremely difficult to determine a modulus slope, i.e. those tests of long time and high temperature exposures often resulted in load-strain graphs that continuously decreased in slope with increasing strain. In this case, any short flat portion of the curves that corresponded fairly well with a typical secondary modulus for the material were utilized to represent it.

As the result of the characteristics described above which tended to prevent determination of the true modulus slope and since the load and strain errors of the autographic records (see Tables I and II) are large enough to cause considerable error in the determination of the modulus of elasticity, this property should be considered as an approximation only. However, the yield strength shows little error with relatively large changes in the modulus slope since the slope of the curves at the yield intercept is sufficiently small that the load shows little change with variation of location of intercept.

The ultimate strength is the maximum load each specimen withstood prior to fracture, divided by the original cross-sectional area of the specimen. The percent elongation after fracture is one hundred times the difference in the length between two gage marks before test and after fracture divided by the gage mark length before test.

Tabulated Data

The tabulated data is presented as an appendix on pages 151 through 197. These data are presented in two types of tables. First, a series of tables presenting the complete tensile test results of each test specimen have been prepared. These Tables XXIII through XXXIV also average the results of the three or more individual tests of each alloy and test condition. Results of three tests are presented for each alloy and test condition, except where test results have been deleted because of exposure or testing difficulties and the consequent unreliable data. For this exception, these tensile properties that were reliable from the original three specimens are presented along with the test results of additional specimens to fill-in the missing properties on the first three specimens.

The final tabulation of data, consisting of Tables XVII through XX in the appendix, summarizes the tensile properties for each alloy and test condition. In these tables the tensile properties are presented for each alloy and test condition as the "average percent of room temperature properties". Each value in the table is obtained by calculating the percent ratio of the mechanical properties of each test specimen to the room temperature mechanical properties of the "no exposure" or "stock control" specimens from the same panel and then averaging the percent ratios that represent each discrete alloy and test condition. This non-dimensional procedure was utilized to eliminate the normal variation in mechanical properties of the materials from these summarized data tables.

Hardness versus tensile properties test data are also presented in Tables XXI and XXII for all tensile specimens tested at room temperature.

Graphical Data

A graphical presentation of the summarized tensile properties of each alloy and test condition is shown in Figures 24 through 103 of the appendix. These graphs include plots of percent of room temperature tensile properties versus exposure time and percent of room temperature tensile properties versus exposure temperature for each tensile property, alloy and test temperature.

Hardness versus yield strength and hardness versus ultimate strength graphs are presented in Figures 104 through 111 for both Rockwell hardness scales and both alloys.

ANALYSIS OF RESULTS

The test data presented in this report present over seventy test conditions for each of the materials investigated, 7075-T6 Alclad sheet and 2024-T3 Alclad sheet. These data present a challenge to develop general expressions which will most advance the knowledge of the elevated temperature properties of these aluminum alloys which are the ones most commonly used in airframes.

The alloys tested, 7075-T6 and 2024-T3, have been known to suffer from over-aging when exposed to elevated temperatures. They suffer doubly from elevated temperature. Therefore, it is necessary to know the time spent at temperature as well as the temperature in order to evaluate the strength properties of these materials. But seldom is a service condition so simple as a given time at one temperature. Therefore, it is desirable to be able to predict the remaining strengths of these materials at any temperature, within the temperature range providing usable strength, after they have been exposed to any sequence of various exposure times at various temperatures.

Analysis of Basic Data

The basic test data consist of various single exposures (specimens exposed to one temperature for a given time), then pulled as tensile coupons at room temperature, 200°F, 300°F, and 400°F. Data thus obtained include maximum elongation in 2 inches, modulus of elasticity, and proportional limit, but only the ultimate tensile stress and the tensile yield stress data have been analyzed as these are the mechanical properties which provide load carrying ability.

A semi-empirical analysis was utilized as no generally accepted analytical method is known to exist at this time. The analysis is built upon the rate-process theory which has been applied to such diverse processes as creep, tempering, and diffusion of metals and offers a known method of combining temperature and time to obtain a single parameter by which can be measured the degree of an exposure condition. This theory expresses the rate at which a process takes place as $r = A e^{-Q/RT}$, where A is a constant, Q is the activation energy for the material and process, R is the gas constant and T is the absolute temperature. A simple time-temperature parameter has been derived from the rate-process theory by F.R. Larson and James Miller, and is published in Transactions of ASME, July 1952, page 765, "A Time-Temperature Relationship for Rupture and Creep Stresses". Their parameter has the form $T (C + \log_{10} t)$ where T is the absolute temperature in degrees Rankine and t is the time in hours. Preliminary plotting of the test data vs. $T_0R (20 + \log_{10} t)$ gave excessive scatter and was therefore modified empirically to provide a more accurate analysis.

a) Analysis of the Ultimate Tensile Stress of 7075-T6 Alclad Sheet

The ultimate tensile stress data of 7075-T6 clad sheet were first plotted as percent of room temperature ultimate tensile stress versus the Larson-Miller time-temperature parameter, $\theta = T_{0R} (20 + \log_{10} t_{hr.})$

This procedure resulted in only fair resolution of test points, and the plots are shown on Figure 12 for the four test temperatures, (R.T., 200°F, 300°F, and 400°F). It was observed that the longer times for a given θ are more severe in reducing F_{tu} than the shorter time (times indicated on Figure 12). No theoretical reason for this has been determined; however, as a second step an empirical adjustment of θ was made. This resulted in a modification of time by the 1.46 power in the time-temperature parameter, θ , to give $\theta' = T_{0R} (20 + 1.46 \log_{10} t_{hr.})$. This modified Larson-Miller time-temperature parameter provides much better agreement with the test data as is readily apparent in Figure 13 where the percent of room temperature ultimate tensile stress of 7075-T6 clad sheet is plotted against θ' , the modified time-temperature parameter. The statistical analysis given in Table IV shows that the curves of Figure 13 fit the data within plus or minus 4.7% of room temperature ultimate stress for approximately 95% of the tests. (Between $\pm 2\sigma$, are 95.5% of the test points for normal distribution.)

At this point the similarity of the curves of Figure 13 for the various test temperatures suggested the possibility of normalizing the data for the four test temperatures. This was successfully done by dividing the percent of room temperature ultimate stress values by the corresponding percentage for the 0.1 hour exposure at 300°F at each respective test temperature. The resulting normalized curve is presented in Figure 14. Analytical expressions for the curve have been determined as follows:

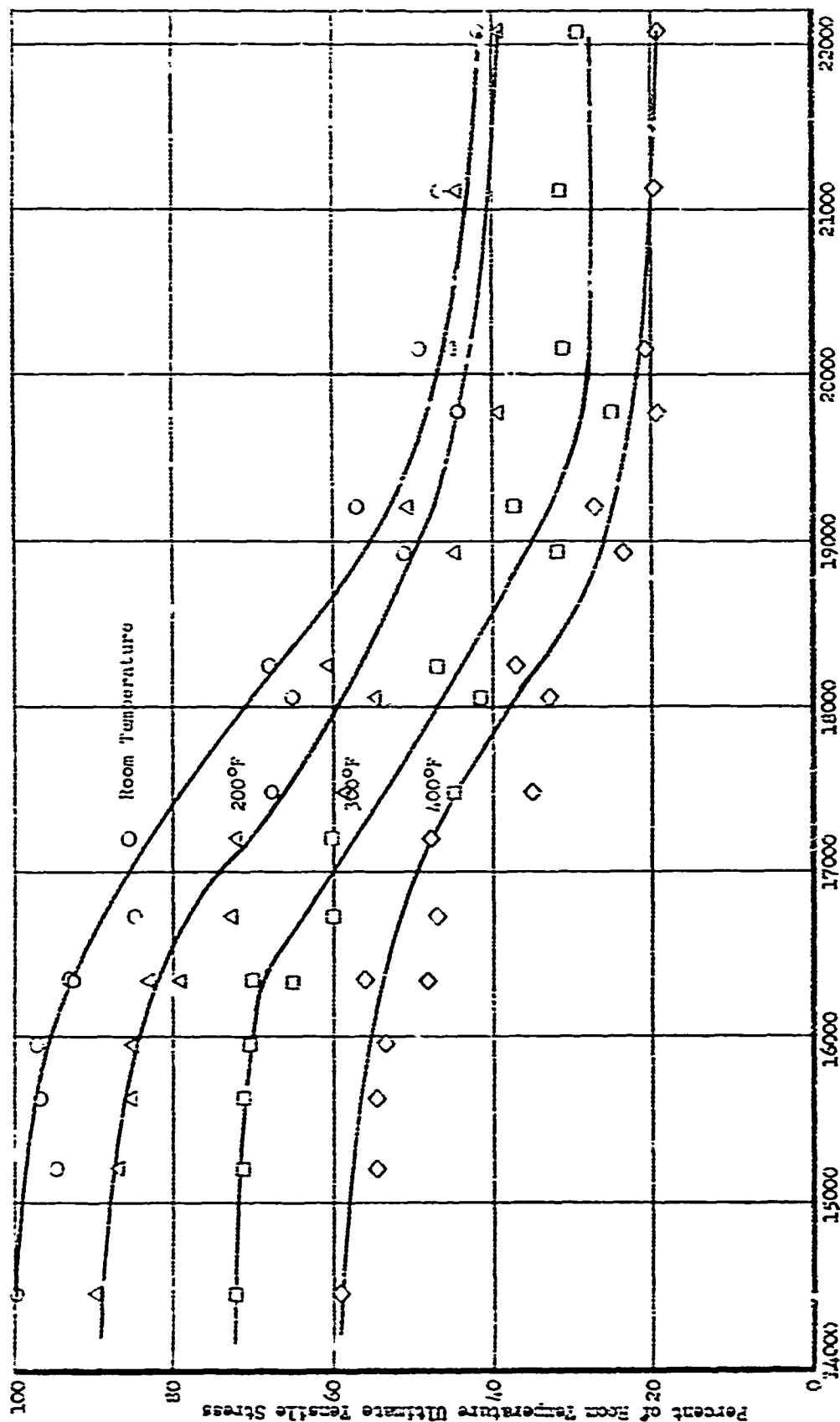
$$\theta \leq 16,580 \quad R = 1.163 e^{-0.00001071\theta'}$$

$$16,580 \leq \theta' \leq 20,230 \quad R = 44.70 e^{-0.00023\theta'}$$

$$20,230 \leq \theta' \quad R = .421$$

R = The decimal fraction of the no exposure ultimate tensile stress at any given temperature which remains when tested at this same temperature after exposure of magnitude θ' .

The 0.1 hour exposure at 300°F was chosen as the basis for normalizing the test data versus θ' because it represents the minimum exposure as measured by θ' . It was assumed that this 0.1 hour at 300°F exposure does not affect the ultimate tensile stress of 7075-T6 clad sheet and thus the ultimate tensile stress at the test temperatures are assumed to represent the ultimate tensile stresses after no



$$\theta = T_{0R} (20 + \log_{10} t_{hr.})$$

Percent of Room Temperature Ultimate Tensile Stress of 7075-T6 Alclad versus Time-Temperature Parameter, $\theta = T_{0R} (20 + \log_{10} t_{hr.})$ for Test Temperatures of Room Temperature, 200°F, 300°F, and 400°F.

Figure 12.

TABLE III

MODIFIED LARSON-MILLER PARAMETER FOR 7075-T6 ALCLAD

$$\theta' = " \text{ or } (20 \neq 1.46 \log_{10} t_{\text{hr}}.)$$

Exposure Temperature of	Exposure Time, Hour	Modified Larson-Miller Parameter	Exposure Temperature of	Exposure Time, Hour	Modified Larson-Miller Parameter
300	0.1	14,090	300	1000	18,530
300	1	15,200	500	1	19,200
400	0.1	15,940	600	0.1	19,650
250	100	16,270	400	100	19,710
300	10	16,310	500	10	20,600
400	1	17,200	400	1000	20,970
250	1000	17,310	600	1	21,200
300	100	17,420	500	100	22,000
500	0.1	17,800	600	10	22,750
400	10	18,460	500	1000	23,400

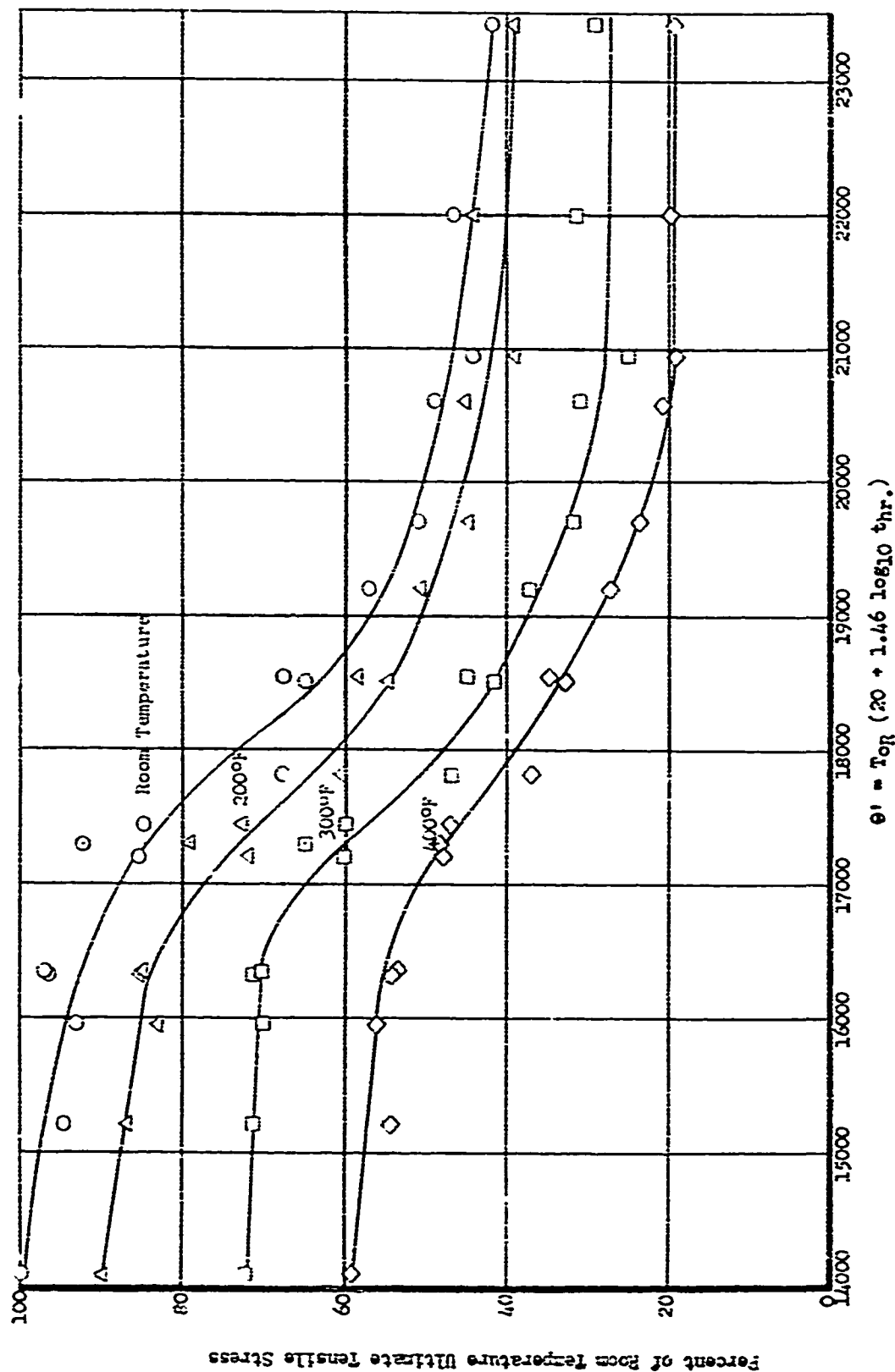


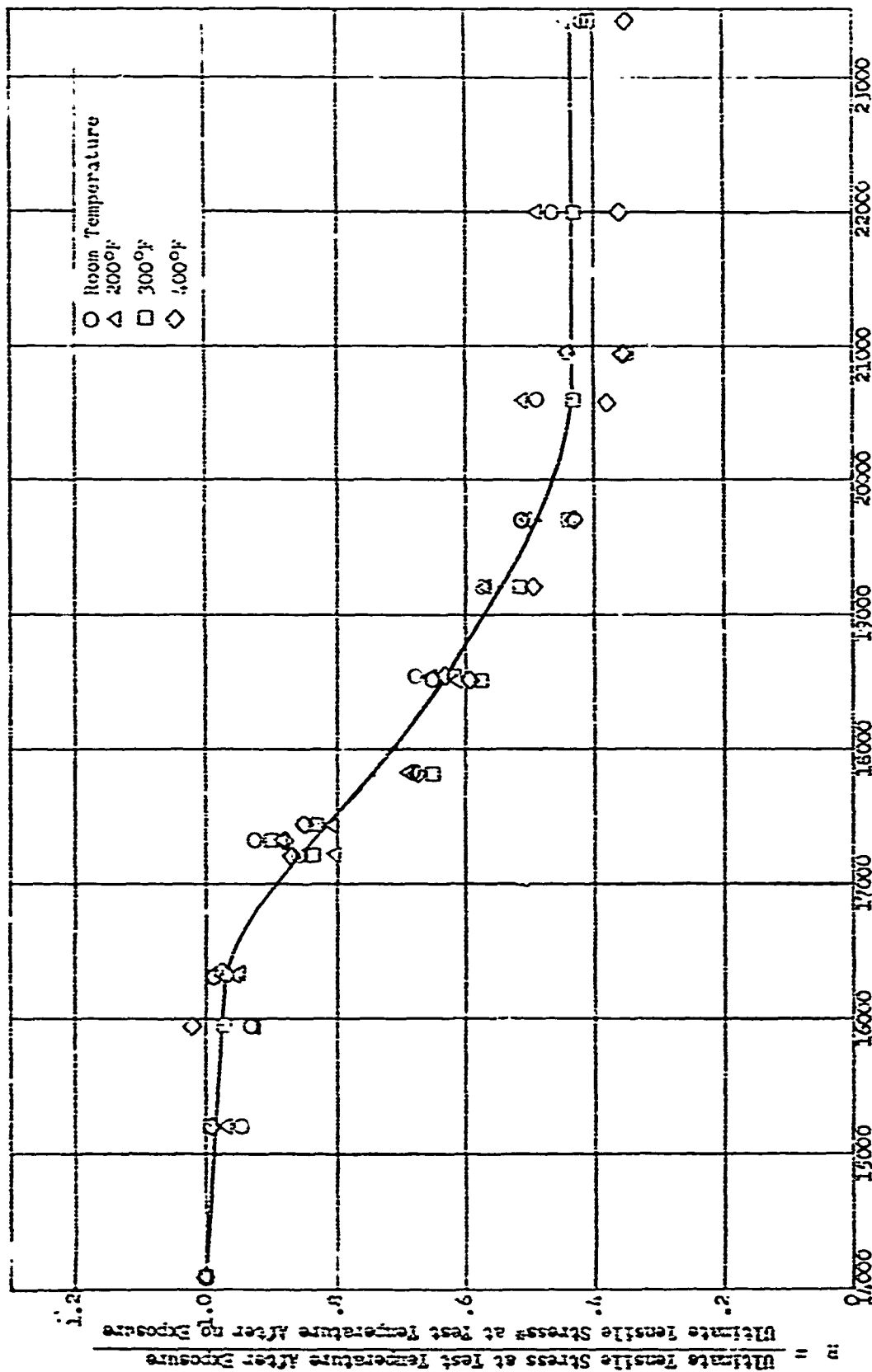
Figure 13- Percent of Room Temperature Ultimate Tensile Stress of 7075-T6 Alclad versus Modified Time - Temperature Parameter, $\theta' = T_{0R} (20 + 1.46 \log_{10} \text{thr.})$ for Room Temperature, 200°F, 300°F, and 400°F Test Temperatures.

TABLE IV
STATISTICAL ANALYSIS OF ULTIMATE TENSILE
STRESS OF 7075-T6 ALCLAD versus θ°

Class Midpoint	a	w	w ²	(w+1) ²	aw	aw ²	a(w+1) ²
8	1	4	16	25	4	16	25
6	3	3	9	16	9	27	48
4	6	2	4	9	12	24	54
2	15	1	1	4	15	15	60
0	26	0	0	1	0	0	26
-2	11	-1	1	0	-11	11	0
-4	2	-2	4	1	-4	8	2
S	64				25		
SS						101	215
S ² /n						<u>10</u>	<u>124</u>
SSD						91	91
S _w ²						1.443	
S _w						1.20	
S/n					.391		

$$\bar{t} = 2 (.391) = .782$$

$$St = 2 (1.20) = 2.40$$



$$\theta' = T_{\text{ex}} (20 + 1.46 \log_{10} t_{\text{hr.}})$$

Ratio of Ultimate Tensile Stress of 7075-T6 Clad Sheet at Test Temperature After Exposure to Ultimate Tensile Stress of 7075-T6 Clad Sheet at Test Temperature After No Exposure Versus Modified Time-Temperature Parameter, $\theta' = T_{\text{ex}} (20 + 1.46 \log_{10} t_{\text{hr.}})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures.

* F_{ex} at Test Temperature after 0.1 hr., 300°F exposure.

Figure 14

exposure. Tests were run with no exposure which verify this assumption as indicated by the tabulated results below. The maximum difference of 2.9% is well within the scatter of the material itself.

<u>Test Temperature</u>	<u>6 H.R. Ultimate Tensile Stress 7075-T6</u>	
	<u>0.1 hour at 300°F</u>	<u>No Exposure</u>
R.T	99.7	100
200°F	89.7	91.1
300°F	72.1	75.0
400°F	55.0	55.2

The statistical analysis given in Table V shows that the normalized curve fits approximately 95% of the test data within plus or minus 8% of the room temperature ultimate tensile stress.

b) Analysis of the Tensile Yield Stress of 7075-T6 Alclad Sheet

The tensile yield stress data of 7075-T6 clad sheet were first plotted as percent of room temperature tensile yield stress versus the Larson-Miller time-temperature parameter, $\theta = T_{\text{R}} (20 + 1.46 \log_{10} t_{\text{hr.}})$. This procedure produced results similar to the results of the ultimate tensile stress in that only fair correlation was obtained. As with the ultimate tensile stress data, much better consistency is obtained by using the modified Larson-Miller time-temperature parameter, $\theta' = T_{\text{OR}} (20 + 1.46 + \log_{10} t_{\text{hr.}})$. The percent of room temperature tensile yield stress for 7075-T6 clad sheet has been plotted against θ' in Figure 15. The statistical analysis of the correlation achieved in Figure 15 is given in Table VI and indicates that 95% of the data are within 4.72 percent of room temperature tensile yield stress of the respective curves.

The plots in Figure 15 cannot be nearly so easily normalized as that of the ultimate tensile stress. This is due to the tensile yield stress of 7075-T6 clad sheet becoming less temperature dependent with increasing degree of exposure as measured by θ' . Generalization warrants the utilization of a fairly complicated normalization procedure. Therefore, normalization was accomplished by dividing the percent of room temperature tensile yield stress at the test temperature at exposure $\theta' = 14,090$ by the percent of room temperature tensile yield stress after 0.1 hour at 300°F. This provides the desired normalization at $\theta' = 14,090$. Then the divisor is varied linearly with θ' to provide no normalization at $\theta' = 32,690$. The value of 32,690 is off the abscissa, but is the value required to provide good normalization. Mathematically this is expressed as:

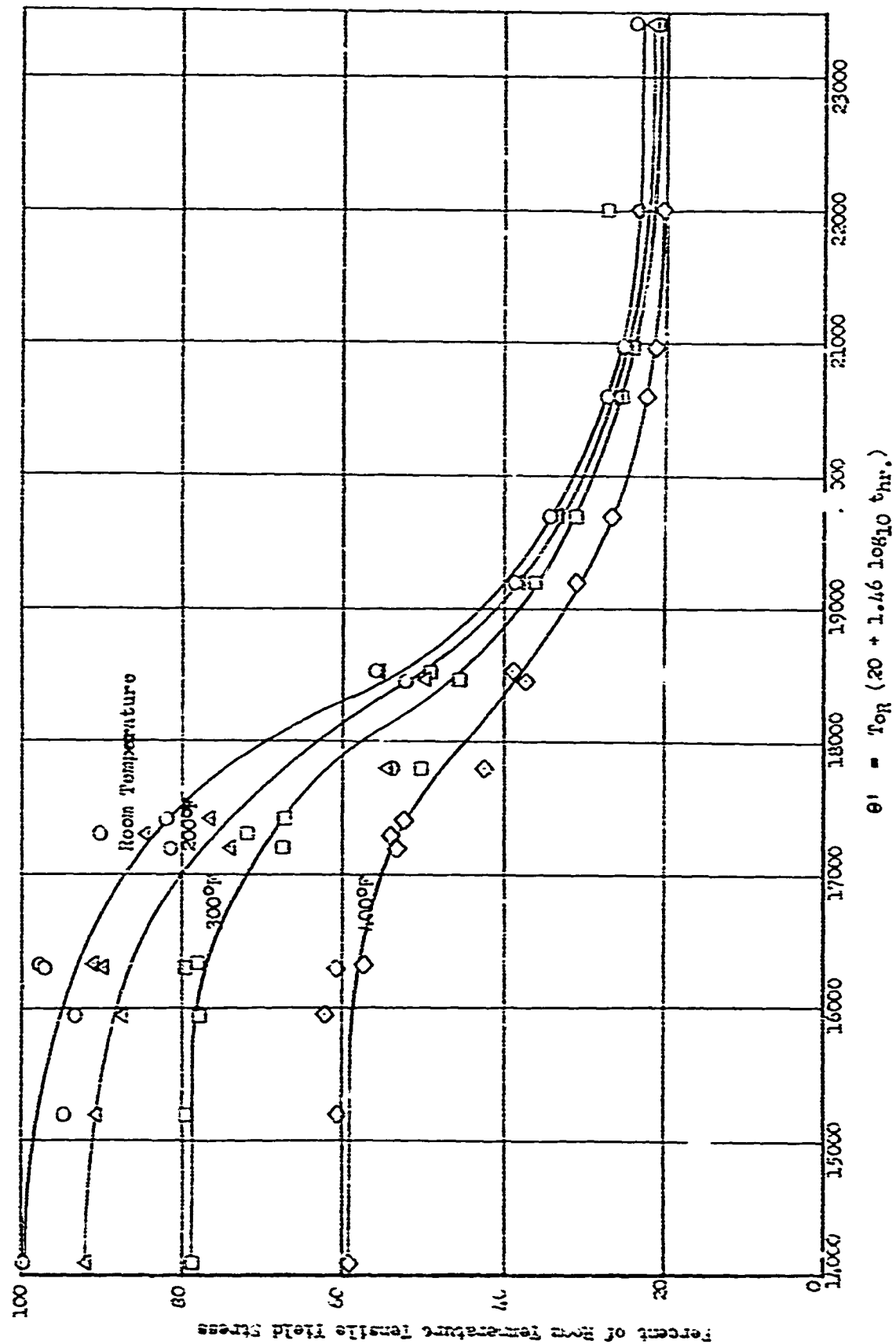
TABLE V

STATISTICAL ANALYSIS OF NORMALIZED ULTIMATE TENSILE
STRESS OF 7075-T6 ALCLAD versus θ'

Class Midpoint	a	v	v^2	$(w+v)^2$	av	av^2	$a(w+1)^2$
8	2	4	16	25	8	32	50
6	3	3	9	16	9	27	48
4	6	2	4	9	12	24	54
2	9	1	1	4	9	9	36
0	20	0	0	1	0	0	20
-2	8	-1	1	0	-8	8	0
-4	6	-2	4	1	-12	24	6
-6	9	-3	9	4	-27	81	36
-8	5	-4	16	9	-20	80	45
S	68				-29		
SS						285	295
S^2/n						$\frac{12}{273}$	$\frac{22}{273}$
SSD						$\frac{273}{273}$	$\frac{273}{273}$
S_w^2						1.075	
S_w						2.02	
S/n					-.427		

$$\bar{t} = 2 (-.427) = -.853$$

$$S_t = 2 (2.02) = 4.04$$



Percent of Room Temperature Tensile Yield Stress of 7075-T6 Alclad versus Modified Time - Temperature Parameter, $\theta' = T_{0R} (20 + 1.46 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F, and 400°F Test Temperatures.

Figure 15.

TABLE VI

STATISTICAL ANALYSIS OF TENSILE YIELD STRESS
OF 7075-T6 ALCLAD versus θ^1

Class Midpoint	a	v	w^2	$(w+1)^2$	av	aw^2	$a(w+1)^2$
8	1	4	16	25	4	16	25
6	2	3	9	16	6	18	32
4	6	2	4	9	16	32	72
2	7	1	1	4	7	7	28
0	37	0	0	1	0	0	37
-2	5	-1	1	0	-5	5	0
-4	2	-2	4	1	-4	8	2
-6	1	-3	9	4	-3	9	4
S	63				21		
SS						95	200
S^2/n						$\frac{7}{88}$	$\frac{112}{88}$
SSD							
S_w^2						1.419	
S_w						1.19	
S/n					.333		

$$\bar{t} = 2 (.333) = .667$$

$$S_t = 2 (1.19) = 2.38$$

$$R = \frac{x}{y + (100-y) \left(\frac{\theta' - 14,090}{18,600} \right)}$$

where R = The decimal fraction of the no exposure tensile yield stress at any given temperature which remains when tested at this same temperature after exposure of magnitude θ' .

x = The percent of room temperature tensile yield stress at the test temperature after being exposed to elevated temperature.

y = The percent of room temperature tensile yield stress at the same test temperature as for x after having been exposed to 0.1 hour at 300°F.

θ' = The modified Larson-Miller parameter $\theta' = T_{OR} (20 + 1.46 \log_{10} t_{hrs})$ calculated for the exposure condition which determined x .

As with the ultimate tensile stress data, the 0.1 hour at 300°F exposure was assumed to be the same as no exposure. This assumption is not quite so good for the tensile yield stress data as for the ultimate tensile stress data, but does not invalidate the assumption. The tensile yield stress data are presented below for the 0.1 hour at 300°F exposure and no exposure. The biggest discrepancy is seen to be 5% at the 300°F test temperature.

<u>Test Temperature</u>	<u>% R.T. Tensile Yield Stress</u>	
	<u>0.1 hour at 300°F</u>	<u>No Exposure</u>
R.T.	99.8	100
200°F	92.0	96.5
300°F	78.8	83.8
400°F	59.2	60.1

Analytical expressions for the normalized curve of tensile yield stress data for 7075-T6 Alclad sheet have been determined as follows:

$$\begin{aligned} \theta' \leq 16,700 & \quad R = 1.27 e^{-0.0000167\theta'} \\ 16,700 \leq \theta' \leq 20,400 & \quad R = 223.3 e^{-0.000327\theta'} \\ 20,400 \leq \theta' & \quad R = 1.541 e^{-0.0000828\theta'} \end{aligned}$$

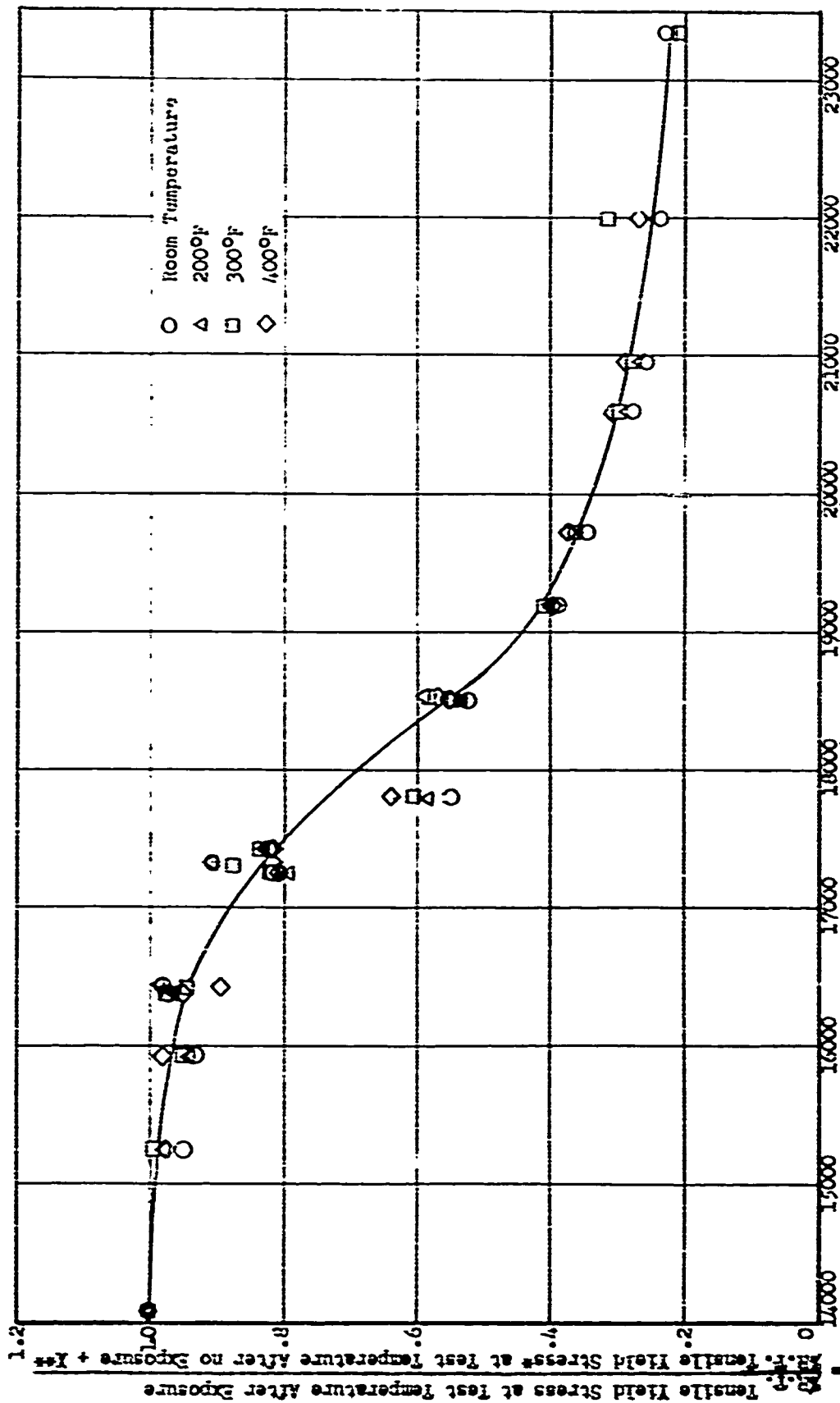


Figure 16. Ratio of Tensile Yield Stress of 7075-T6 Clad Sheet at Test Temperature After Exposure to Tensile Yield Stress of 7075-T6 Clad Sheet at Test Temperature After no Exposure + X^{**} Versus Modified Time-Temperature Parameter, $\theta' = \text{Top } (20 + 1.46 \log_{10} \text{ thr.})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures.

* F_{ty} at Test Temperature after 0.1 hr., 300°F exposure.
 ** $X = (100 - \frac{F_{ty} \text{ at } 0^\circ\text{F}}{F_{ty} \text{ at } 300^\circ\text{F}}) \left(\frac{300 - T}{18,000} \right)$

TABLE VII

STATISTICAL ANALYSIS OF NORMALIZED TENSILE YIELD
STRESS OF 7075-T6 ALCLAD versus θ

Class Midpoint	a	b	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$	
7.5	2	5	25	36	10	50	72	
6.0	2	4	16	25	8	32	50	
4.5	0	3	9	16	0	0	0	
3.0	1	2	4	9	2	4	9	
1.5	11	1	1	4	11	11	44	
0	13	0	0	1	0	0	13	
-1.5	11	-1	1	0	-11	11	0	
-3.0	5	-2	4	1	-10	20	5	
-4.5	2	-3	9	4	-6	18	8	
-6.0	1	-4	16	9	-4	16	9	
-7.5	3	-5	25	16	-15	75	48	
-9.0	0	-6	36	25	0	0	0	
-10.5	0	-7	49	36	0	0	0	
-12.0	1	-8	64	49	-8	64	49	
S	52				-23			
SS						301	307	
S^2/n						10	16	
SSD						291	291	Chk.
S_w^2						5.71		
S_w						2.39		
S/n					-0.442			

$$\bar{e} = 1.5 (-0.442) = -0.663$$

$$S_e = 1.5 (2.39) = 3.50$$

The curve so defined fits the test points within 7% approximately 95% of the time. This method provides slightly greater accuracy for tensile yield stress of 7075-T6 alclad sheet than that for the ultimate tensile stress of 7075-T6 alclad sheet.

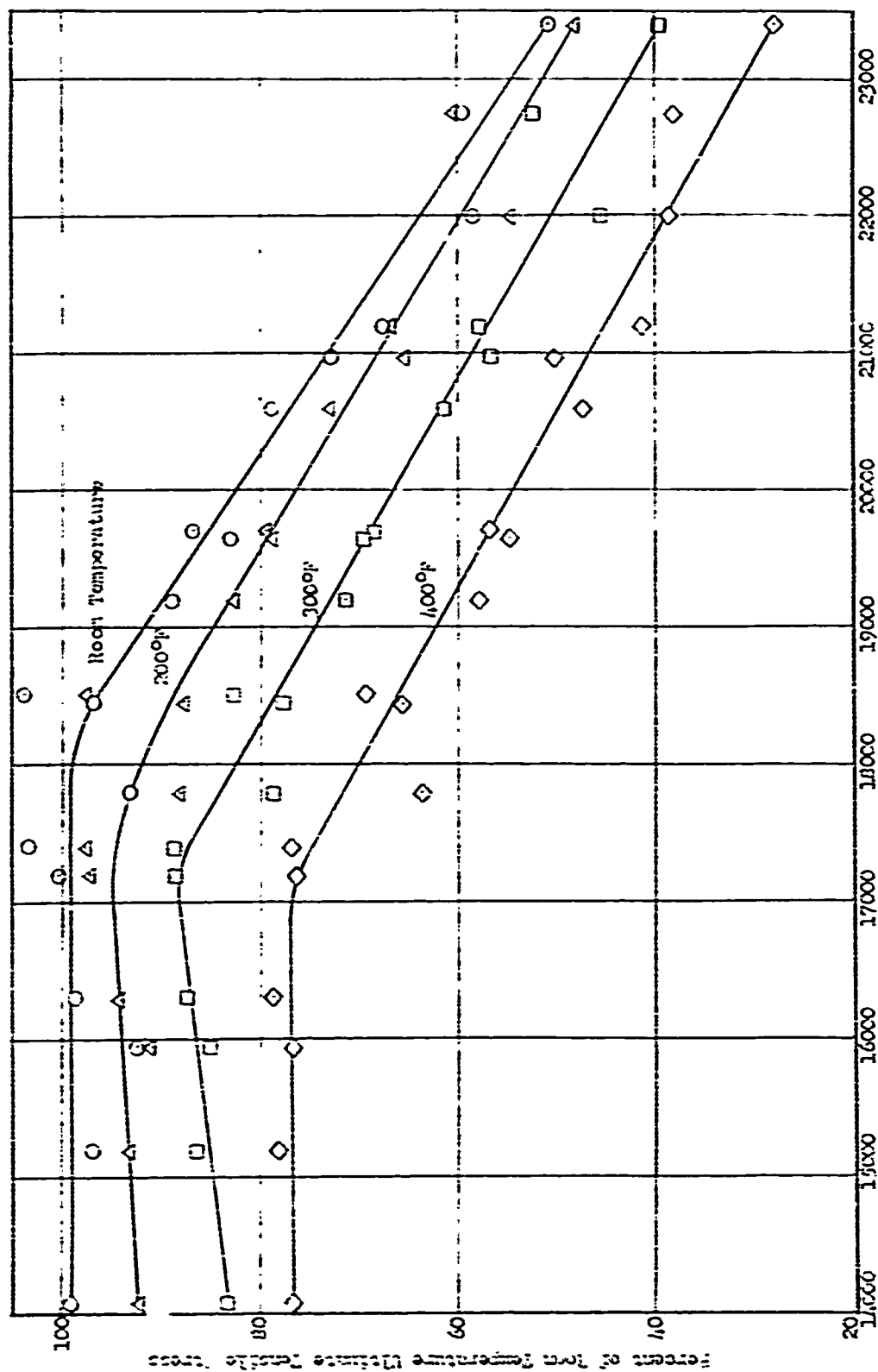
c) Analysis of the Ultimate Tensile Stress of 2024-T3 Alclad Sheet

First, the percent of room temperature ultimate tensile stress data of 2024-T3 alclad sheet were plotted against the Larson-Miller time temperature parameter, $\theta = T_{OR} + \log_{10} t_{hr.}$). As with the 7075-T6 data, this parameter was found lacking the desired degree of correlation. Next, the percent of room temperature ultimate tensile stress data of 2024-T3 were plotted versus the modified Larson-Miller parameter, $\theta' = T_{OR} (20 + 1.46 \log_{10} t_{hr.})$ on Figure 17. Disappointingly, θ' does not provide the desired fit to the experimental points as is apparent in Figure 17. A statistical analysis was made to check the general usefulness of θ' and it is presented in Table VIII. This analysis includes the test data for both 7075-T6 and 2024-T3, ultimate and yield stresses. The results indicated that θ' is very marginal as to general ability to fit the test data for both properties of both materials. As θ' provided an acceptable fit for 7075-T6 property data, it was concluded that θ' does not fit the 2024-T3 test data satisfactorily. This led to another modification of the Larson-Miller parameter.

Study of the results achieved utilizing θ and θ' indicated that the desired modification of θ which would prove satisfactory for 2024-T3 test data must be some compromise of θ and θ' . The modification of θ which was determined to best fit the 2024-T3 test data is $\theta'' = T_{OR} (20 + 1.3 \log_{10} t_{hr.})$. The plot of the percent of room temperature ultimate tensile stress data for 2024-T3 alclad sheet against $\theta'' = T_{OR} (20 + 1.3 \log_{10} t_{hr.})$ is presented in Figure 18. The statistical analysis of this plot is presented in Table IX and reveals that approximately 95% of test points lay within 6% of the respective curves.

The first effort towards normalization of the ultimate tensile stress data of 2024-T3 was straight normalization. That is, the percent of room temperature ultimate tensile stress at temperature $\bar{I}$ after exposure $\bar{I}$ is divided by the percent of room temperature ultimate tensile stress at temperature $\bar{I}$ after 0.1 hour exposure at 300°F. The results of such a normalization procedure indicated that the test points at smaller θ'' values were not normalized enough and at larger θ'' values the test points were normalized too much. Therefore, the ultimate tensile stress data of 2024-T3 were normalized about $\theta'' = 17,200$ with the results as shown in Figure 19. Mathematically, this normalization is written as:

$$R = \frac{X}{\bar{y} - (100 - \bar{y}) \left(\frac{17,200 - \theta''}{8730} \right)}$$



$$\theta' = T_{0R} (20 + 1.46 \log_{10} \theta_{r.})$$

Percent of Room Temperature Ultimate Tensile Stress of 2024-T3 Alclad versus Modified
 Tling - Temperature Parameter, $\theta' = T_{0R} (20 + 1.46 \log_{10} \theta_{r.})$ for Room Temperature,
 200°F, 300°F, and 400°F Test Temperatures.

Figure 17.

TABLE VIII

STATISTICAL ANALYSIS OF ULTIMATE TENSILE STRESS AND
TENSILE YIELD STRESS OF 7075-T6 AND 2024-T3
VERSUS $\theta' = T_{0r}(20 + 1.36 \log_{10} t_{hr.})$

Class Midpoint	a	w	w ²	(w+1) ²	aw	aw ²	a(w+1) ²
12	1	6	36	49	6	36	49
10	4	5	25	36	20	100	144
8	7	4	16	25	28	112	175
6	11	3	9	16	33	99	176
4	29	2	4	9	58	116	261
2	45	1	1	4	45	45	180
0	103	0	0	1	0	0	103
-2	43	-1	1	0	-43	43	0
-4	9	-2	4	1	-18	36	9
-6	8	-3	9	4	-24	72	32
-8	6	-4	16	9	-24	96	54
-10	1	-5	25	16	-5	25	16
-12	5	-6	36	25	-30	180	125
-14	2	-7	49	36	-14	98	72
-16	3	-8	64	49	-24	192	147
-18	0	-9	81	64	0	0	0
-20	1	-10	100	81	-10	100	81
S	278	-34			-2		
SS						1350	1624
S ² /n						0	274
SSD						1350	1350
S _w ²						4.86	
S _w						2.21	
S/n				.00719			

$$\bar{t} = 2(.00719) = .01438$$

$$S_t = 2(2.21) = 4.42$$

TABLE IX

Modified Larson-Miller Parameter for 2024-T3 Alclad, $\theta' = T'_{or}$ (20 + 1.3 LOG₁₀ thr.)

Exposure Temperature Of	Exposure Time, Hour	Modified Larson-Miller Parameter	Exposure Temperature Of	Exposure Time, Hour	Modified Larson-Miller Parameter
300	.1	14,210	400	10	18,320
300	1	15,200	500	1	19,200
400	.1	16,080	400	100	19,440
300	10	16,190	600	.1	19,820
300	100	17,180	500	10	20,450
400	1	17,200	400	1000	20,550
500	.1	17,950	600	1	21,200
300	1000	18,160	500	100	21,700
			600	10	22,580
			500	1000	22,940

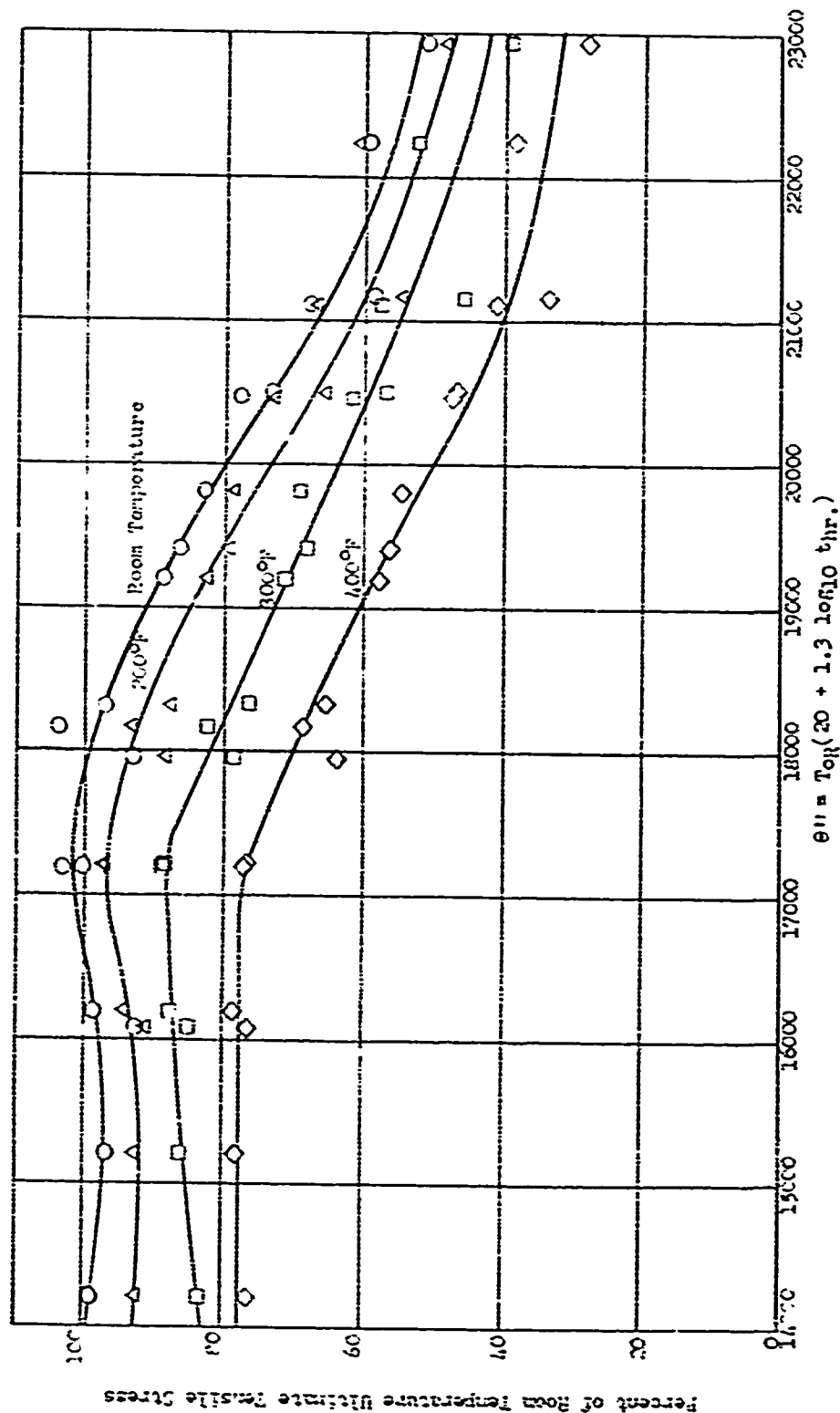


Figure 18. Percent of Room Temperature Ultimate Tensile Stress of 2024-T3 Alclad versus Modified Time - Temperature Parameter, $\Theta'' = T_R(20 + 1.3 \log_{10} t_R)$ for Room Temperature, 200°F, 300°F, and 400°F Test Temperatures.

TABLE X

STATISTICAL ANALYSIS OF ULTIMATE TENSILE
STRESS OF 2024-T3 ALCLAD VERSUS θ''

Class Midpoint	a	v	w^2	$(w+1)^2$	av	aw^2	$a(w+1)^2$
9	1	0	81	100	9	81	100
8	0	8	64	81	0	0	0
7	0	7	49	64	0	0	0
6	2	6	36	49	12	72	98
5	2	5	25	36	10	50	72
4	2	4	16	25	8	32	50
3	3	3	9	16	9	27	48
2	8	2	4	9	16	32	72
1	9	1	1	4	9	9	36
0	20	0	0	1	0	0	20
-1	9	-1	1	0	-9	9	0
-2	4	-2	4	1	-8	16	4
-3	3	-3	9	4	-9	27	12
-4	2	-4	16	9	-8	32	18
-5	3	-5	25	16	-15	75	48
-6	2	-6	36	25	-12	72	50
-7	1	-7	49	36	-7	49	36
-8	1	-8	64	49	-8	64	19
S	72				-3		
SS						647	713
S^2/n						0	66
SCD						647	647
S_w^2						9.11	
$S_w = S_t$						3.02	
$S/n = \bar{t}$					-.04167		

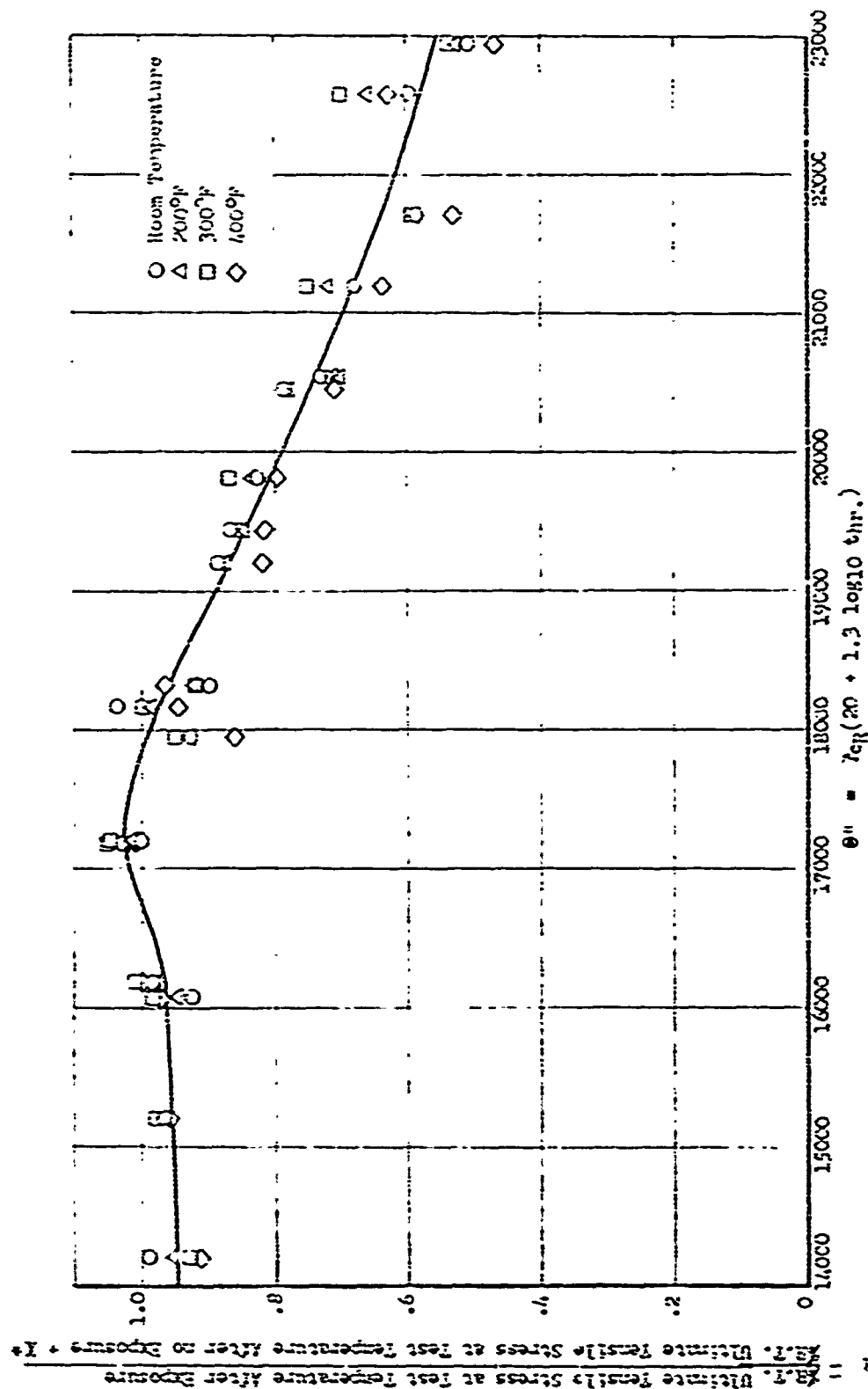


Figure 17.

Ratio of Ultimate Tensile Stress of 2024-T3 Clad Sheet at Test Temperature After Exposure to Ultimate Tensile Stress of 2024-T3 Clad Sheet at Test Temperature After No Exposure * X * Versus Modified Time-Temperature Parameter, $\theta = T_0(20 + 1.3 \log t_0 \text{ thr.})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures

$$*X = (100 - \% \text{ R.T. } F_{tu} \text{ at } 0^\circ\text{F, no exposure}) \left(\frac{17,200 - \theta}{8730} \right)$$

TABLE XI

Statistical Analysis of Normalized Ultimate Tensile
Stress of 2024-T3 Alclad Versus θ

Class Midpoint	x	y	x^2	$(x+1)^2$	xy	xy^2	$a(y+1)^2$
12	1	6	36	49	6	36	49
10	0	5	25	36	0	0	0
8	1	4	16	25	4	16	25
6	3	3	9	16	9	27	48
4	9	2	81	9	18	36	81
2	15	1	225	4	15	15	60
0	15	0	225	1	0	0	15
-2	9	-1	81	0	-9	9	0
-4	13	-2	169	1	-26	52	13
-6	3	-3	9	4	-9	27	12
-8	1	-4	1	9	-4	16	0
-10	1	-5	1	16	-5	25	16
-12	1	-6	1	25	-6	36	25
Σ	72				-7		
$\Sigma \Sigma$						295	353
$\Sigma x^2/n$						<u>1</u>	<u>59</u>
$\Sigma \Sigma$						294	294
Σxy^2						4.14	
Σy						2.03	
$\Sigma x/n$							

$-.0972$

$$\bar{x} = 2 (-.0972) = -.1944$$

$$s_x^2 = 2 (2.03) = 4.06$$

where R = The decimal fraction of the no exposure ultimate tensile stress at any given temperature which remains when tested at this same temperature after exposure of magnitude θ^n .

x = The percent of room temperature ultimate tensile stress at the test temperature after being exposed to elevated temperature.

y = The percent of room temperature ultimate tensile stress at the same test temperature as for x after no exposure.

θ^n = The modified Larson-Miller parameter $\theta^n = T_{\text{on}} (20 + 1.3 \log_{10} t_{\text{hr.}})$.

Only fair normalization was thus achieved, the range within which approximately 95% of the tests fall having been increased to 8% of the room temperature ultimate tensile stress.

In the first normalization, the assumption was made that 0.1 hour exposure at 300°F does not appreciably change the material properties. This assumption was satisfactorily checked by the no exposure tests as tabulated below.

<u>Test Temperature</u>	<u>% R.T. Ultimate Tensile Stress 2024-T3</u>	
	<u>0.1 hour at 300°F</u>	<u>No Exposure</u>
R.T.	99.1	100
200°F	92.4	95.25
300°F	83.4	84.5
400°F	76.6	75.6

The greatest difference exists at the 200°F test temperature and amounts to only 2.85% of room temperature ultimate tensile stress.

d) Analysis of the Tensile Yield Stress of 2024-T3 Alclad Sheet

As stated in (c) above, the tensile yield stress data of 2024-T3 was included in the analysis evaluating the modified Larson-Miller parameter $\theta^n = T_{\text{on}} (20 + 1.46 \log_{10} t_{\text{hr.}})$. The plot of percent room temperature tensile yield stress against θ^n is presented in Figure 21. Again, as with the ultimate tensile stress data of 2024-T3 the parameter θ^n does not give the desired agreement among the various exposures.

The modified Larson-Miller parameter $\theta^n = T_{\text{on}} (20 + 1.3 \log_{10} t_{\text{hr.}})$ gives better resolved curves than did θ^n . The statistical analysis presented in Table III shows that the curves in Figure 22 are within 4% of approximately 95% of the test points.

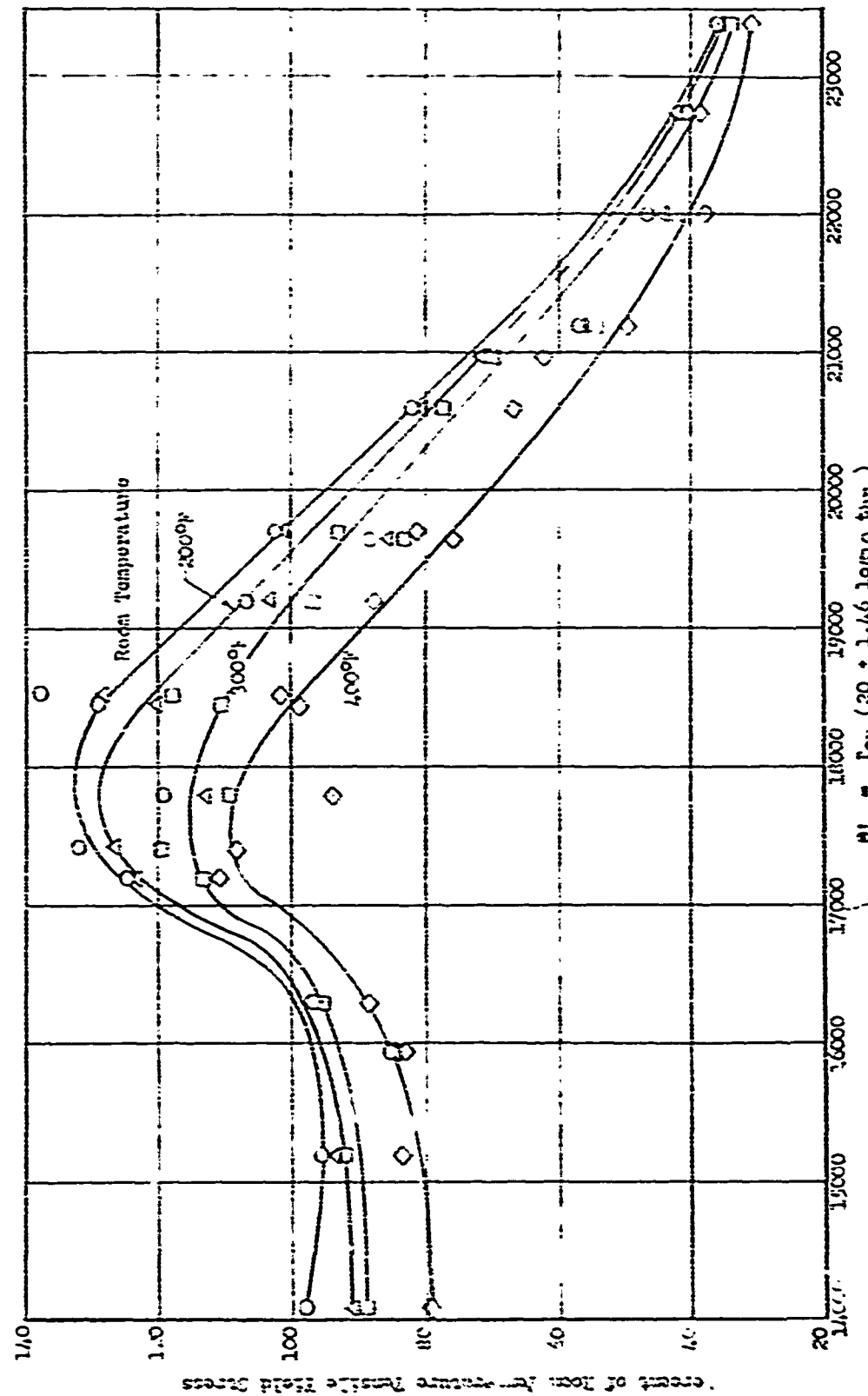


Figure 20. Percent of Room Temperature Tensile Yield Stress of 2024-T3 Alclad versus Modified Time - Temperature Parameter, $\theta_1 = \text{Toil} (20 + 1.46 \log_{10} \text{thr.})$ for Room Temperature, 2000F, 1000F, and 4000F Test Temperatures.

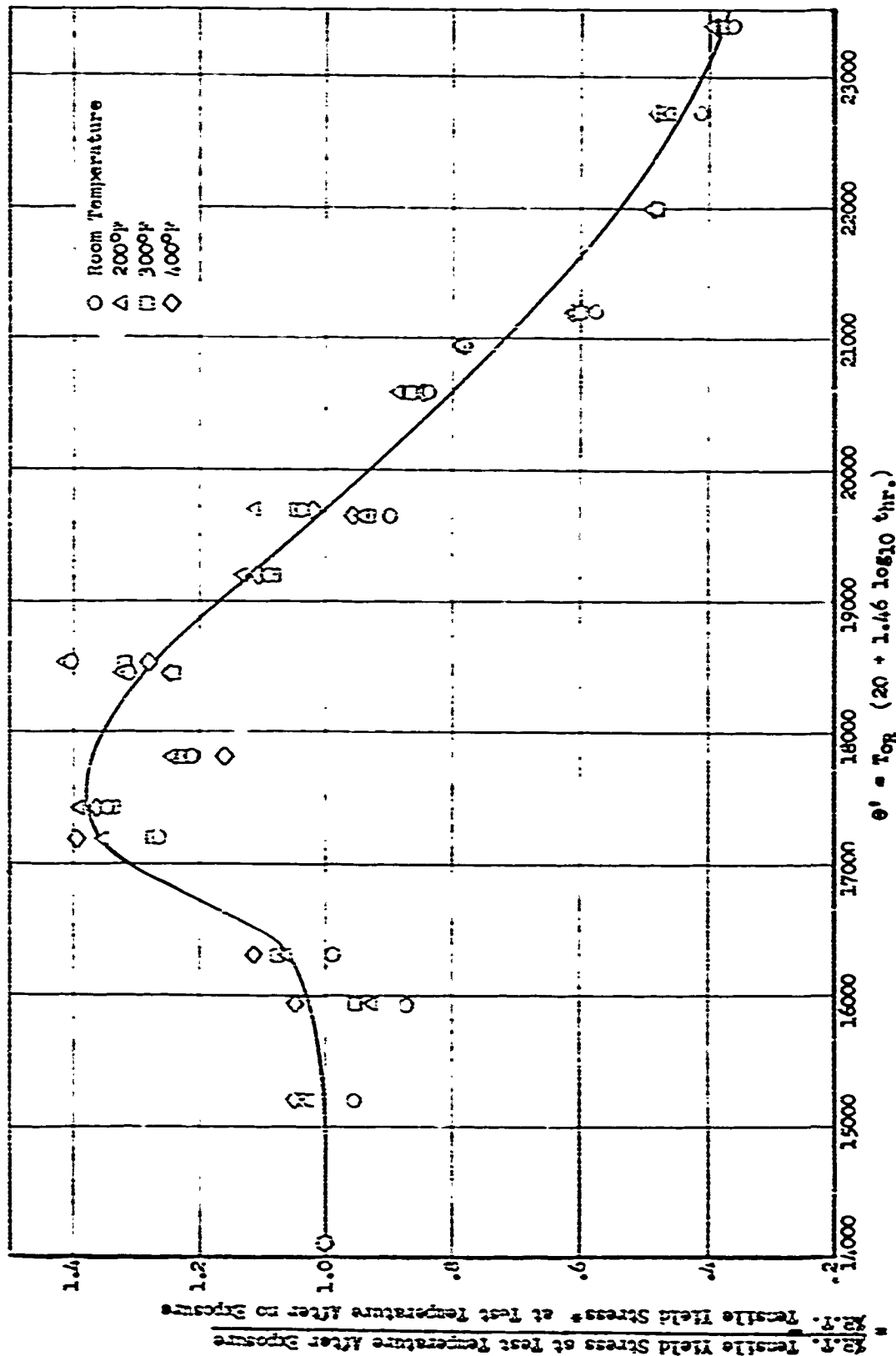


Figure 21. Ratio of Tensile Yield Stress of 2024-T3 Clad Sheet at Test Temperature After Exposure to Tensile Yield Stress of 2024-T3 Clad Sheet at Test Temperature After no Exposure Versus Modified Time-Temperature Parameter, $e' = T_{0r} (20 + 1.46 \log_{10} \text{thr.})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures. $e' = T_{0r}$ at Test Temperature after 0.1 hr., 300°F exposure.

Normalization of the tensile yield stress data is indicated in Figure 23. Normalization in this case has been achieved as follows:

$$R = \frac{x}{y - (100-y) \frac{22,940 - \theta^n}{17,460}}$$

where R = The decimal fraction of the no exposure tensile yield stress at any given temperature which remains when tested at this same temperature after exposure of magnitude θ^n .

x = The percent of room temperature tensile yield stress at the test temperature after being exposed to elevated temperature.

y = The percent of room temperature tensile yield stress at the same test temperature as for x after no exposure.

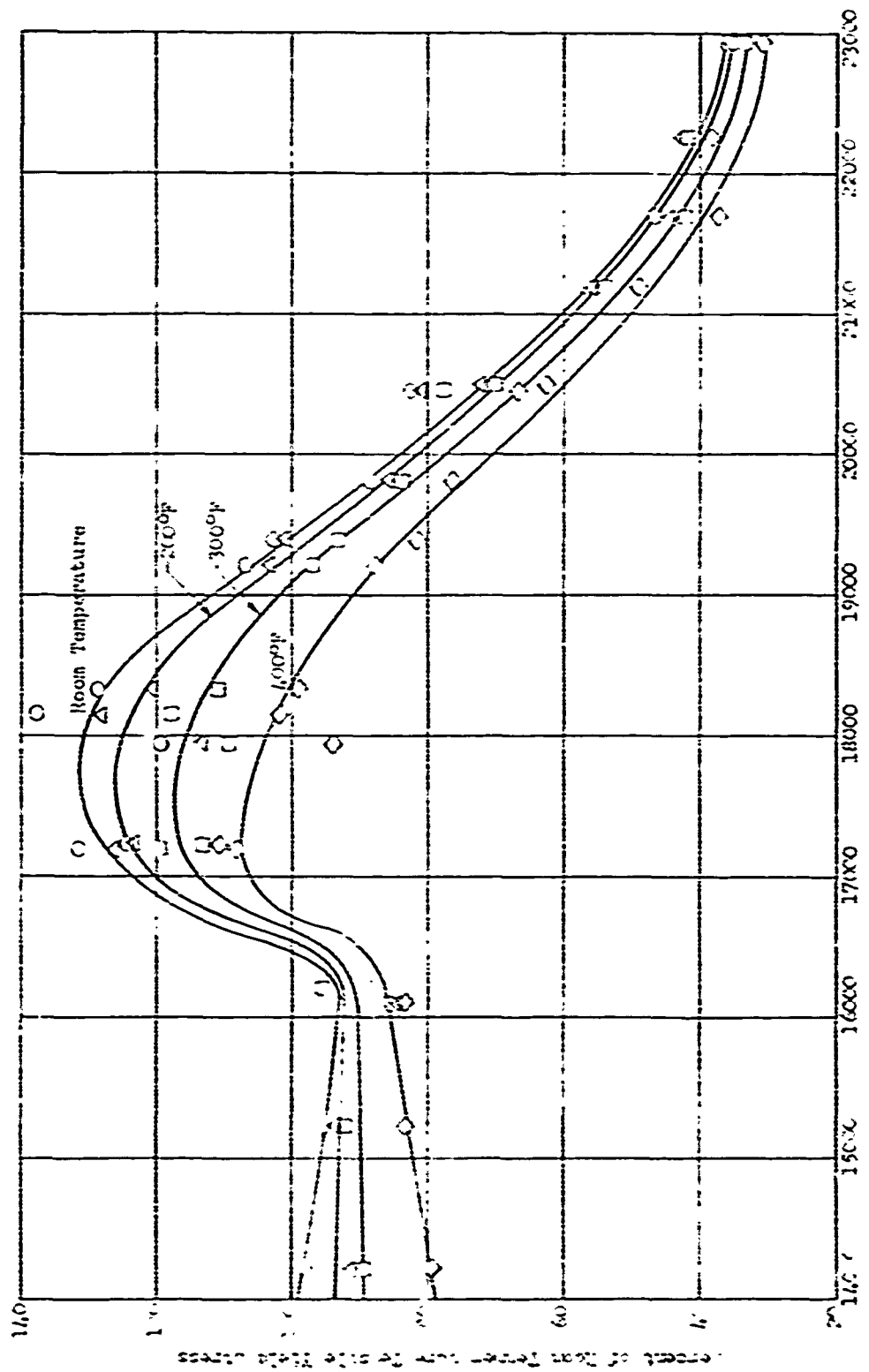
θ^n = The modified Larson-Miller parameter $\theta^n = T_{\text{on}} (20 - 1.3 \log_{10} t_{\text{hr.}})$ calculated for the exposure condition which determined x .

Although greater generalization resulted from the normalization procedure, accuracy was lost to the degree that the range to include approximately 95% of the test points is $\pm 8\%$ of the room temperature tensile yield stress. The assumption that 0.1 hour exposure at 300°F is the same as no exposure is valid with the exception of the tests made at 200°F. The table below tabulates the test data for 0.1 hour exposure at 300°F test data for the 2024-T3 tensile yield stress.

<u>Test Temperatures</u>	<u>% of Room Temperature Tensile Yield Stress</u>	
	<u>0.1 hour at 300°F</u>	<u>No Exposure</u>
R.T.	98.0	100
200°F	91.1	98.8
300°F	89.2	92.8
400°F	79.5	77.6

Analysis of the Sequential Tests

Structural components of aircraft are not exposed to simple time-temperature exposures such as analyzed in the previous section. Instead, parts of airplanes are exposed to various temperatures for varying lengths



$\theta = T_{01} (20 + 1.3 \log_{10} t_{hr.})$

Figure 22. Percent of Room Temperature Tensile Yield Stress of 2024-T3 Alclad versus Modified Time - Temperature Parameter

TABLE XII

STATISTICAL ANALYSIS OF TENSILE TEST
STRESS OF 2024-T3 ALCLAD VERSUS θ

Class Midpoint	a	w	w ²	(w+1) ²	aw	aw ²	a(w+1) ²
-12	2	-6	36	25	-12	72	50
-10	1	-5	25	16	-5	25	16
-8	2	-4	16	9	-8	32	18
-6	1	-3	9	4	-3	9	4
-4	3	-2	4	1	-6	12	3
-2	5	-1	1	0	-5	5	0
0	28	0	0	1	0	0	28
2	11	1	1	4	11	11	44
4	10	2	4	9	20	40	90
6	1	3	9	16	3	9	16
8	3	4	16	25	12	48	75
10	1	5	25	36	5	25	36
12	0	6	36	49	0	0	0
S	71				9		
SS						291	380
S ² /n						<u>1</u>	<u>90</u>
SSD						290	290
S _w ²						4.14	
S _w						2.03	
S/n						.125	

$$\bar{x} = 2(.125) = .250$$

$$s_x = 2(2.03) = 4.06$$

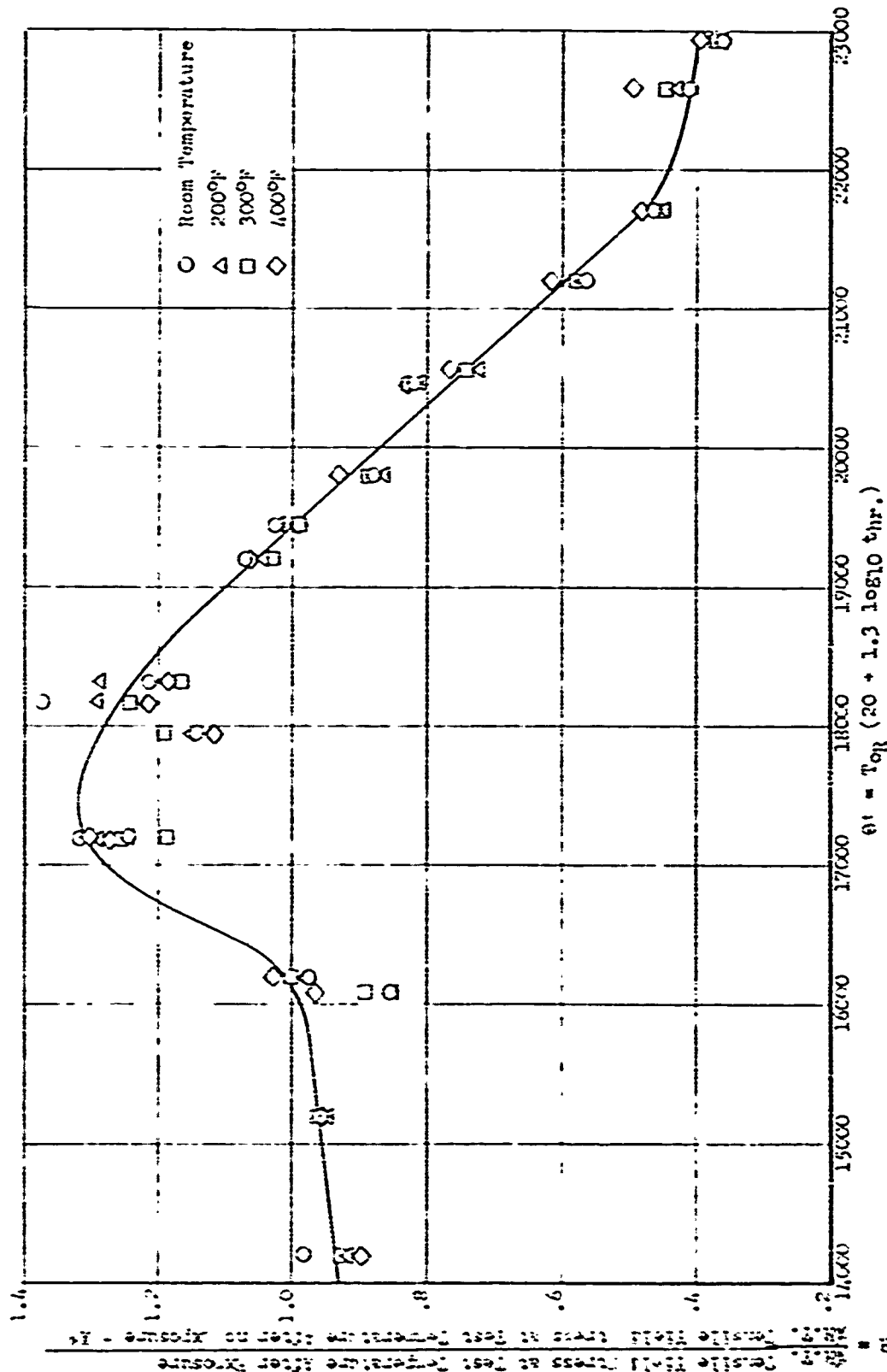


Figure 23. Ratio of Tensile Yield Stress of 2024-T3 Clad Sheet at Test Temperature After Exposure to Tensile Yield Stress of 2024-T3 Clad Sheet at Test Temperature After No Exposure + X* Versus Modified Time-Temperature Parameter, $\theta_1 = T_{0R} (20 + 1.3 \log_{10} \text{thr.})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures.

$$* X = (100 - \frac{F_{ly}}{F_{ly}} \text{ at } 0^\circ\text{F, no exposure}) \left(\frac{22,940 - \theta_1}{17,480} \right)$$

TABLE XIII

STATISTICAL ANALYSIS OF NORMALIZED TENSILE YIELD
STRESS OF 2024-T3 ALCLAD VERSUS θ°

Class Midpoint	a	w	w ²	(w+1) ²	aw	aw ²	a(w+1) ²
12	1	6	36	49	6	36	49
10	0	5	25	36	0	0	0
8	1	4	16	25	4	16	25
6	4	3	9	16	12	36	64
4	4	2	4	9	8	16	36
2	6	1	1	4	6	6	24
0	15	0	0	1	0	0	15
-2	16	-1	1	0	-16	16	0
-4	10	-2	4	1	-20	40	10
-6	5	-3	9	4	-15	45	20
-8	0	-4	16	9	0	0	0
-10	0	-5	25	16	0	0	0
-12	1	-6	36	25	-6	36	25
S	63				-21		
SS						247	266
S ² /n						7	28
SS _T						240	240
S _w ²						3.67	
S _w						1.97	
S/n					-0.333		

$$\bar{c} = 2(-0.333) = -0.667$$

$$S_c = 2(1.97) = 3.94$$

of times. The sum of the individual times at each temperature is then looked upon as the exposure experience of the metal. It is desirable to evaluate what such a time temperature spectrum will do to the strength properties of the material, and to do so in terms of the simple exposure test data.

It is a simple calculation to determine the equivalent θ'_t or θ'_t for any sequence of exposures. The procedure for calculation of θ'_t , for example, of any sequence of exposures at temperatures $T_1, T_2, \dots, T_n$ for times $t_1, t_2, \dots, t_n$ respectively, is summarized as follows:

1. Choose a reference temperature T_r
2. Calculate $\theta'_1, \theta'_2, \dots, \theta'_n$
3. Determine $t_{r1}, t_{r2}, \dots, t_{rn}$, the times at T_r which would give $\theta'_1, \theta'_2, \dots, \theta'_n$ respectively.

$$t_{ri} = \text{antilog}_{10} \frac{\theta'_i - 20}{\frac{T_r}{1.46}}$$

4. Add $t_{r1}, t_{r2}, \dots, t_{rn}$ to obtain t_r , the total effective times at T_r which gives the equivalent θ'_t for the given sequence of exposures.
5. Calculate $\theta'_t = T_{r0.2} (20 + 1.46 \log_{10} t_{rnr})$. θ'_t is independent of the value chosen for T_r .

The above procedure will be evaluated by comparison with the sequential exposure test data.

a) Analysis of the Ultimate Tensile Stress of 7075-T6 Alclad Sheet

The values of the modified Larson-Miller parameter θ'_t for the nine sequential exposures are indicated with their respective time temperature spectrum in Table XIV. The first five spectra, although providing good agreement between calculated values for the percent of room temperature ultimate tensile stress and those obtained by tests, must not be considered as indicative of the accuracy of the analysis.

The reason for qualifying these results is due to the fact that the highest temperature of each sequence dominates the respective t_r .

TABLE XIV
SEQUENTIAL EXPOSURE OF 7075-T6 ALCLAD

Θ	Sequential Exposure				Test. Temp. °F	% R.T. F _{ty} After Expos.				% R.T. F _{tu} After Expos.			
	Time and Temperature					Normalized				Normalized			
	First	Second	Third	Fourth		Indiv.	R	%	Test	Indiv.	R	%	Test
17,250	1 hr.	10 hr.											
	400°F	300°F			R.T.	83.7	.883	88.0	79.8	84.8	.845	84.1	84.1
	400	300			200	76.1	.883	82.4	76.5	73.4	.845	76.8	73.0
	400	300			300	69.0	.883	72.4	66.2	60.8	.845	61.0	58.6
	400	300			400	53.2	.883	58.3	52.6	48.4	.845	46.5	46.0
17,300	1 hr.	10 hr.	100 hr.										
	400°F	300°F	250°F		R.T.	83.4	.835	83.2	79.4	84.4	.835	83.2	83.0
	400	300	250		200	75.7	.835	77.9	76.9	72.9	.835	74.8	72.7
	400	300	250		300	68.7	.835	68.8	66.5	60.1	.835	60.2	58.8
	400	300	250		400	53.1	.835	56.3	53.1	47.6	.835	46.0	46.7
19,360	1 hr.	10 hr.											
	500°F	400°F			R.T.	37.7	.394	39.3	37.5	54.0	.530	52.8	54.1
	500	400			200	36.2	.394	37.2	37.0	48.7	.530	47.5	46.9
	500	400			300	34.1	.394	33.4	34.7	34.8	.530	38.2	33.9
	500	400			400	29.0	.394	27.9	29.3	25.9	.530	29.1	25.4
19,380	1 hr.	10 hr.	100 hr.										
	500°F	400°F	300°F		R.T.	37.6	.392	39.1	38.7	53.7	.524	52.3	53.7
	500	400	300		200	36.0	.392	37.0	37.7	48.4	.524	47.1	45.7
	500	400	300		300	34.0	.392	33.3	35.0	34.7	.524	37.8	33.1
	500	400	300		400	28.9	.392	27.8	29.1	25.8	.524	28.8	25.3
19,400	1 hr.	10 hr.	100 hr.	1000 hr.									
	500°F	400°F	300°F	250°F	R.T.	37.4	.389	38.8	38.4	53.5	.521	51.9	53.4
	500	400	300	250	200	35.8	.389	36.7	36.9	48.2	.521	46.7	45.0
	500	400	300	250	300	33.8	.389	33.0	34.1	34.5	.521	37.5	32.5
	500	400	300	250	400	28.8	.389	27.5	29.0	25.6	.521	28.6	25.2
17,540	1 hr.	4.8 hr.	27.6 hr.	191.7 hr.									
	380°F	340°F	300°F	260°F	R.T.	79.8	.792	78.9	80.7	80.9	.794	79.2	82.5
	380	340	300	260	200	71.7	.792	74.0	79.2	68.8	.794	71.2	72.1
	380	340	300	260	300	65.5	.792	65.6	72.9	55.1	.794	57.2	62.4
	380	340	300	260	400	50.6	.792	52.8	58.4	42.2	.794	43.7	50.4
18,370	1 hr.	4.5 hr.	23.4 hr.	145.1 hr.									
	420°F	380°F	340°F	300°F	R.T.	57.3	.599	59.8	56.2	65.5	.656	65.4	65.6
	420	380	340	300	200	54.1	.599	56.2	53.7	55.9	.656	58.8	55.3
	420	380	340	300	300	48.3	.599	50.1	49.5	42.8	.656	47.2	43.2
	420	380	340	300	400	39.8	.599	41.1	38.3	34.8	.656	36.1	33.8
19,210	1 hr.	4.2 hr.	20.2 hr.	113.4 hr.									
	460°F	420°F	380°F	300°F	R.T.	39.8	.412	41.1	41.8	55.0	.547	54.5	56.2
	460	420	380	300	200	38.4	.412	38.8	41.1	49.5	.547	49.1	47.9
	460	420	380	300	300	35.9	.412	34.8	38.5	36.0	.547	39.4	34.7
	460	420	380	300	400	30.4	.412	29.0	32.8	27.0	.547	30.1	28.0
20,040	1 hr.	4.0 hr.	17.5 hr.	90.5 hr.									
	500°F	460°F	420°F	380°F	R.T.	31.2	.336	33.5	30.8	50.1	.462	46.1	48.2
	500	460	420	380	200	30.0	.336	31.8	29.6	45.0	.462	41.4	43.4
	500	460	420	380	300	28.7	.336	28.8	29.2	30.6	.462	33.3	30.3
	500	460	420	380	400	24.6	.336	24.3	25.3	21.8	.462	25.4	22.2

Put more bluntly, the first five sequences differ but slightly from a single exposure environment. It is not surprising, therefore, that the percent of room temperature ultimate tensile stress of 7075-T6 calculated utilizing the individual curves of Figure 13 and the normalized curve of Figure 14 correlate with the test results to a degree comparable to the single exposure tests points themselves.

The last four sequential exposures are such that each temperature of the spectra provides equal contribution to t_r and are as true sequential exposures as are possible when consisting of only four individual exposures. Also, these last four sequential exposures are in the range of θ' , where R is changing the most rapidly. This increases the meaningfulness of the agreement between the calculated values of percent room temperature ultimate tensile stress and the test results. The agreement achieved utilizing the individual curves of Figure 13 may be appraised by the average error which is only 2% of the room temperature ultimate tensile stress. The largest error is 8.2%. When the normalized curve of Figure 14 is used, an average error of slightly less than 3% of the room temperature ultimate tensile stress is obtained. And the greatest error obtained is 6.7%. These data are tabulated in Table XVI.

b) Analysis of the Tensile Yield Stress of 7075-T6 Alclad Sheet

The values of the modified Larson-Miller parameter θ' for the nine sequential exposures are listed with their corresponding time temperature spectrum in Table XIV. As was pointed out in (a) above, the first five exposures provide very good agreement between calculated values and tests results. But these results are not to be considered as any more than further substantiation of the accuracy of the curves in predicting the single exposure behavior of 7075-T6. It is worth reiterating that the last four sequential exposures are as severe in checking the validity of the method of calculation as any four-step sequential exposure can be. The substantiation obtained from these four sequential exposures is, therefore, considered extremely indicative of the correctness of the procedure utilized. The average error between the values calculated from the individual curves and the test values of the last four sequences of Table XIV is 2.6% of the room temperature tensile stress. When the normalized curve is used to obtain the calculated values, this average error is 2.9%.

c) Analysis of the Ultimate Tensile Stress of 2024-T3 Alclad Sheet

The nine sequential exposure values, θ' , for 2024-T3 alclad sheet are tabulated in Table IV with their respective time temperature spectrum. Again, as with the 7075-T6 sequential tests, the first five sequences are of no value in evaluating the method for calculating the mechanical properties after a sequence of exposures.

TABLE XV

SEQUENTIAL EXPOSURE OF 2024-T3 ALCLAD

θ'	Sequential Exposure Time and Temperature				Test Temp. of	% R.T. F _{ty} After Expos. Normalized Test				% R.T. F _{tu} After Expos. Normalized Test			
	First	Second	Third	Fourth		Indiv.	R	%	Test	Indiv.	R	%	Test
19,300	1 hr.	10 hr.											
	500°F	400°F			R.T.	103.4	1.031	103.1	105.5	88.0	.862	86.2	87.5
	500	400			200	100.0	1.031	102.1	103.2	81.8	.862	81.1	80.5
	500	400			300	95.6	1.031	97.3	95.4	70.2	.862	69.6	68.8
	500	400			400	85.9	1.031	84.9	83.7	57.6	.862	60.3	57.7
19,310	1 hr.	10 hr.	100 hr.										
	500°F	400°F	300°F		R.T.	103.2	1.029	103.2	106.7	87.9	.861	86.1	87.8
	500	400	300		200	99.8	1.029	101.8	103.8	81.7	.861	81.0	80.4
	500	400	300		300	95.4	1.029	97.0	93.1	70.1	.861	69.5	68.2
	500	400	300		400	85.7	1.029	84.8	81.3	57.5	.861	60.2	56.7
21,350	1 hr.	10 hr.											
	600°F	500°F			R.T.	53.6	.561	56.1	60.0	63.2	.669	66.9	66.3
	600	500			200	52.2	.561	55.4	56.3	58.3	.669	62.2	61.8
	600	500			300	48.6	.561	52.4	53.5	52.3	.669	51.6	50.8
	600	500			400	44.4	.561	44.6	48.8	38.0	.669	43.0	38.4
21,370	1 hr.	10 hr.	100 hr.										
	600°F	500°F	400°F		R.T.	53.0	.554	55.4	56.4	62.9	.663	66.3	62.3
	600	500	400		200	51.6	.554	54.8	51.2	58.2	.663	61.6	54.9
	600	500	400		300	48.2	.554	51.7	49.4	52.2	.663	51.1	46.4
	600	500	400		400	44.2	.554	44.1	46.4	37.9	.663	42.6	37.5
21,380	1 hr.	10 hr.	100 hr.	1000 hr.									
	600°F	500°F	400°F	300°F	R.T.	52.8	.552	55.2	60.6	62.8	.662	66.2	65.1
	600	500	400	300	200	51.4	.552	54.1	56.4	58.1	.662	61.5	57.0
	600	500	400	300	300	48.0	.552	51.6	54.3	52.1	.662	51.0	49.4
	600	500	400	300	400	44.0	.552	43.9	49.7	37.8	.662	42.4	39.7
18,880	1 hr.	5 hr.	30 hr.	219 hr.									
	465°F	420°F	375°F	330°F	R.T.	115.3	1.130	113.0	127.2	92.4	.902	90.2	99.0
	465	420	375	330	200	111.1	1.130	111.9	118.8	86.0	.902	80.7	88.9
	465	420	375	330	300	104.2	1.130	106.8	108.9	73.9	.902	73.5	76.5
	465	420	375	330	400	92.8	1.130	93.9	95.9	61.8	.902	64.0	64.2
19,810	1 hr.	4.6 hr.	25.2 hr.	164.0 hr.									
	510°F	465°F	420°F	375°F	R.T.	89.0	.916	91.6	101.6	82.3	.807	80.7	86.6
	510	465	420	375	200	86.2	.916	90.6	92.0	75.7	.807	75.8	75.6
	510	465	420	375	300	81.8	.916	86.2	83.8	65.5	.807	64.4	63.1
	510	465	420	375	400	74.5	.916	74.7	74.6	52.2	.807	56.3	52.1
20,750	1 hr.	4.3 hr.	21.5 hr.	126.1 hr.									
	555°F	510°F	465°F	420°F	R.T.	66.1	.699	69.9	68.2	70.2	.718	71.8	69.4
	555	510	465	420	200	64.0	.699	69.2	65.3	64.6	.718	67.0	62.8
	555	510	465	420	300	60.0	.699	65.4	61.1	57.1	.718	56.2	52.0
	555	510	465	420	400	55.0	.699	56.2	55.6	42.3	.718	47.3	42.7
21,760	1 hr.	6.0 hr.	16.6 hr.	99.6 hr.									
	600°F	555°F	510°F	465°F	R.T.	47.0	.469	46.9	51.7	59.3	.635	63.5	61.8
	600	555	510	465	200	45.6	.469	46.4	43.3	55.0	.635	58.8	52.2
	600	555	510	465	300	42.3	.469	43.7	43.5	49.3	.635	48.5	44.4
	600	555	510	465	400	38.7	.469	37.1	39.2	35.7	.635	40.1	33.8

Visual appraisal of the results of the first five sequential tests and the calculated values indicates that the agreement is not as good as that of the comparable 7075-T6 values. But, it is judged that the agreement between the calculated values and the respective test results for the first five sequential exposures of Table IV are in close agreement with the single exposure results.

The last four sequential exposures appearing in Table IV provide a valid check of the method of calculation of the mechanical properties after exposure. These results show an average error of 2.6% when the calculated values are based on individual curves of Figure 18. When the normalized curve of Figure 19 is the basis for the calculated values then the average difference is 4.1%. The difference between these two mean deviations is comparable to the difference between the average errors for the single exposure.

d) Analysis of the Tensile Yield Stress of 2024-T3

As for the ultimate tensile stress of 2024-T3, the tensile yield stress data for the nine sequential exposures is given in Table IV. As previously, the first five sequences are only a further check of the single exposure analysis.

The last four sequential exposures given in Table IV provide the check of the method for calculating the tensile yield stress of 2024-T3 after the material has been exposed to a spectrum of time-temperature exposure. In this particular case, the normalized curve of Figure 23 provides a lower average error than do the individual curves of Figure 22 in predicting the tensile yield stress. The normalized curve gives an average error of 3.62% of the room temperature tensile yield stress and the individual curves give an average error of 3.85% of the room temperature strength.

e) Consideration of Sequential Exposures More Complex than Four Single Exposures

Although no sequential exposures more complex than four single exposures were tested, the results may be extended through the assumption that intermittent heating of 2024-T3 and 7075-T6 aluminum alloys is equivalent to continuous heating. This assumption has been made for a number of years, having been recommended by the AWC-5 Bulletin, "Strength of Metal Aircraft Elements", June 1951. Test data has been obtained by the Aluminum Company of America which shows that the properties of 2024-T4 rolled and drawn bar and similarly the properties of 7075-T6 extended bar do not differ appreciably whether heated continuously or in 20 hours increments under the following conditions:

- 1) At room temperature and 300°F after 100 hours exposure to 300°F.
- 2) At room temperature and 300°F after 200 hours exposure to 300°F.
- 3) At room temperature and 400°F after 100 hours exposure to 400°F.
- 4) At room temperature and 400°F after 200 hours exposure to 400°F.

These data are published in NACA TM 1419.

Single exposures, to four different temperatures, may be considered as ten single exposures to each of four temperatures or a total of 40 exposures. Therefore, the test results of the last four sequential tests tabulated in Tables 14 and 15, represent test results after 5 sequential exposures where each of the sequential exposures may be considered to consist of 40 exposures divided evenly among four separate temperatures. These test results are in good agreement with the calculated values. For the individual curves, the calculated values average 1.725 percent lower than the test results and for the normalized curves, the calculated values average .275 percent lower than the test results. Although the normalized curves provided the smaller difference between calculated values and test results, the range was -14.2% to +6.6% while the comparison between calculated values from individual curves and the test results ranged from -125% to +6.6%. All of the extreme differences came from the 2024-T3 test results. As the significant error is conservative, the individual curves and normalized curves can be used for more complex sequences than 40 exposures.

CONCLUSIONS

Conclusions based upon the analysis presented in Table XVI and in the previous section may be stated as follow:

- 1) The ultimate tensile stress and tensile yield stress of 7075-T6 and 2024-T3 Alclad sheet can be predicted at room temperature, 200°F, 300°F and 400°F after single exposure with a 95% confidence that the results are within 5.9% of the respective room temperature stress of the actual strength by using the individual curves presented in Figures 13, 15, 18, and 22.
- 2) The strength properties of 7075-T6 and 2024-T3 Alclad sheet can be predicted at any temperature from room temperature to 400°F after single exposure with a 95% confidence that the results are within 7.7% of the respective room temperature strength of the actual strength by utilizing the normalized curves presented in Figures 14, 16, 19, and 23.
- 3) The individual curves of Figures 13, 15, 18, and 22 can be used to predict the strength properties of 7075-T6 and 2024-T3 Alclad sheet at room temperature, 200°F, 300°F, and 400°F after sequential exposures, as complex as four single exposures, to within 6.9% of the respective room temperature strength 95% of the time.
- 4) The normalized curves of Figure 14, 16, 19, and 23 can be used to predict the strength properties of 7075-T6 and 2024-T3 Alclad sheet at any temperature from room temperature to 400°F after sequential exposures, as complex as four single exposures, to within 8.4% of the respective room temperature strength 95% of the time.
- 5) The individual curves of Figures 13, 15, 18, and 22 can be used to predict the strength properties of 7075-T6 and 2024-T3 Alclad sheet at room temperature, 200°F, 300°F, and 400°F after sequential exposures as complex as 10 single exposures to each of four temperatures (40 exposures) or even more complex exposures with good agreement.
- 6) The normalized curves of Figures 14, 16, 19, and 23 can be used to predict the strength properties of 7075-T6 and 2024-T3 Alclad sheet at any temperature from room temperature to 400°F after sequential exposures as complex as 10 single exposures to each of four temperatures (40 exposures) or even more complex exposures with good agreement.

TABLE XVI

ANALYSIS OF SEQUENTIAL EXPOSURE OF
7075-T6 ALCLAD AND 2024-T3 ALCLAD

	7075-T6				2024-T3			
	Yield		Ultimate		Yield		Ultimate	
	Indiv.	Norm.	Indiv.	Norm.	Indiv.	Norm.	Indiv.	Norm.
	-0.9	-1.6	-1.6	-3.3	-11.9	-14.2	-6.6	-8.8
	-7.5	-5.2	-3.3	-0.9	-7.7	-6.9	-2.9	-8.2
	-7.4	-7.3	-7.2	-5.2	-4.7	-2.1	-2.6	-3.0
	-7.8	-5.6	-8.2	-6.7	-3.1	-2.0	-2.4	-0.2
	1.1	3.6	-0.1	-0.2	-12.6	-10.0	-4.3	-5.9
	0.5	2.5	0.6	3.5	-5.8	-1.4	0.1	0.2
	-1.2	0.5	-0.4	4.0	-2.0	2.4	2.4	1.3
	1.5	2.8	1.0	2.3	-0.1	0.1	0.1	4.2
	-2.5	-0.7	-1.2	-1.7	-1.7	1.7	0.8	2.4
	-2.7	-2.3	1.6	1.2	-1.3	3.9	1.8	4.2
	-2.6	-3.7	2.1	4.7	-1.1	4.3	5.1	4.2
	-2.4	-3.8	-1.0	2.1	-0.6	0.6	-0.4	4.6
	0.4	2.7	1.9	-2.1	-4.7	-4.8	-2.5	1.7
	-0.5	-0.4	0.3	2.0	2.3	3.1	2.8	6.6
	-0.7	-1.0	-0.4	3.2	-1.2	0.2	4.9	4.1
					-0.5	-2.1	1.9	6.3
Absolute Sum.	39.2	43.9	31.0	43.1	61.7	59.8	41.6	65.9
Absolute Ave.	2.6	2.9	2.1	2.9	3.8	3.6	2.6	4.1
Algebraic Sum.	-32.2	-19.7	-16.0	2.1	-57.1	-27.2	-1.8	25.5
Algebraic Ave.	-2.1	-1.3	-1.1	0.2	-3.6	-1.7	-0.1	1.7
S_t	2.4	3.6	2.4	4.0	4.0	3.9	3.0	4.0
$\bar{t}$	0.7	-0.7	0.8	-0.9	0.2	-0.7	-0.04	-0.2

Absolute Ave.		S_t	
Indiv.	Norm.	Indiv.	Norm.
2.6	2.9	2.4	3.6
2.1	2.9	2.4	4.0
3.8	3.6	4.0	3.9
2.6	4.1	3.0	4.0
Sum	11.1	11.8	15.5
Ave.	2.78	2.95	3.88
$\frac{1}{2}$ Ave.	3.48		

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APPENDIX I

TABULATED AND GRAPHICAL DATA

Summarized tensile properties for each alloy and condition are presented in Tables XVII through XX.

Graphical presentation of the summarized tensile properties for each alloy and condition is presented in Figures 24 through 105.

Hardness test data are presented in Tables XXI and XXII and Figures 104 through 111 for both alloys.

Tensile test results for each specimen are presented in Table XXIII through XXXIV.

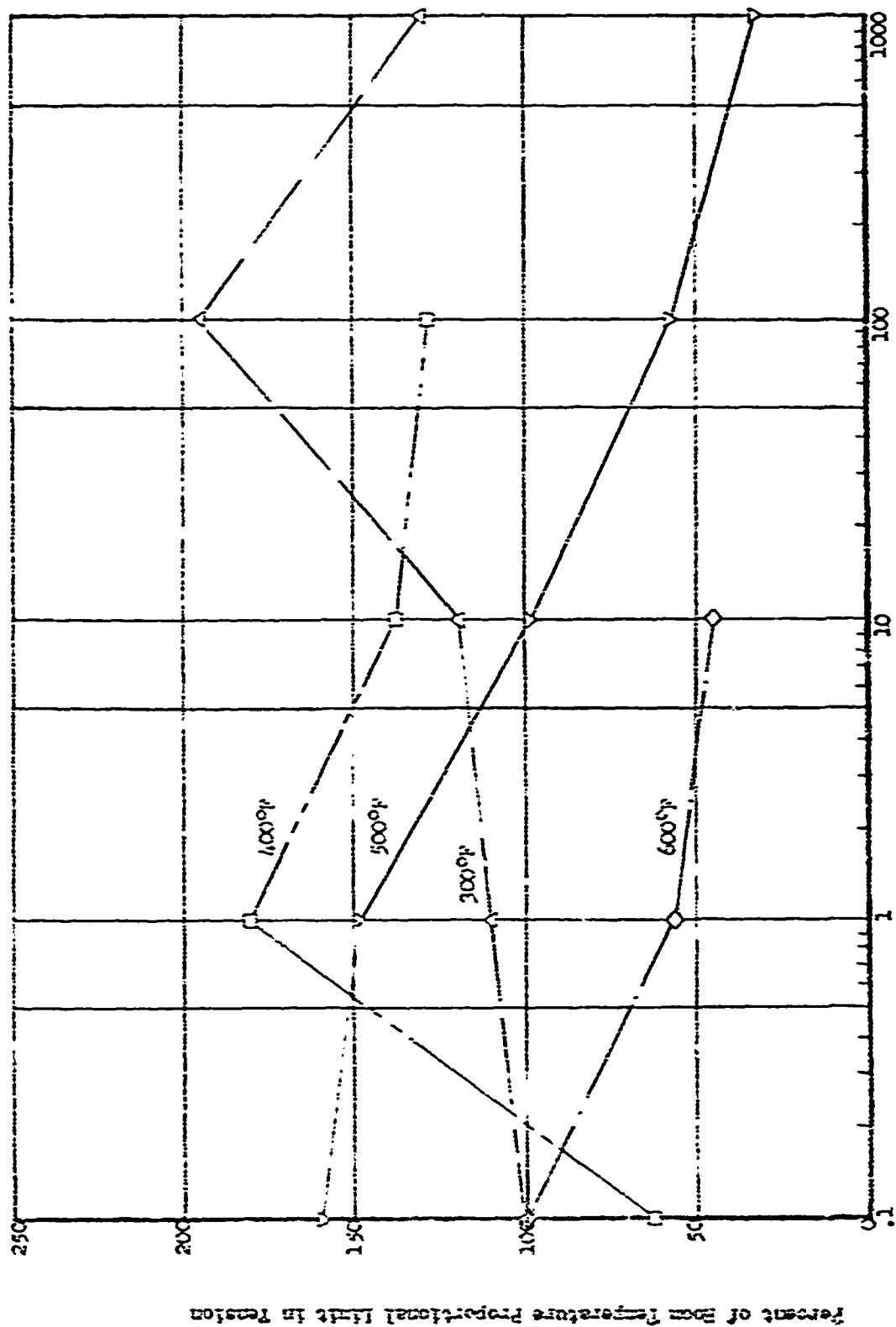


Figure 24. Proportional Limit in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

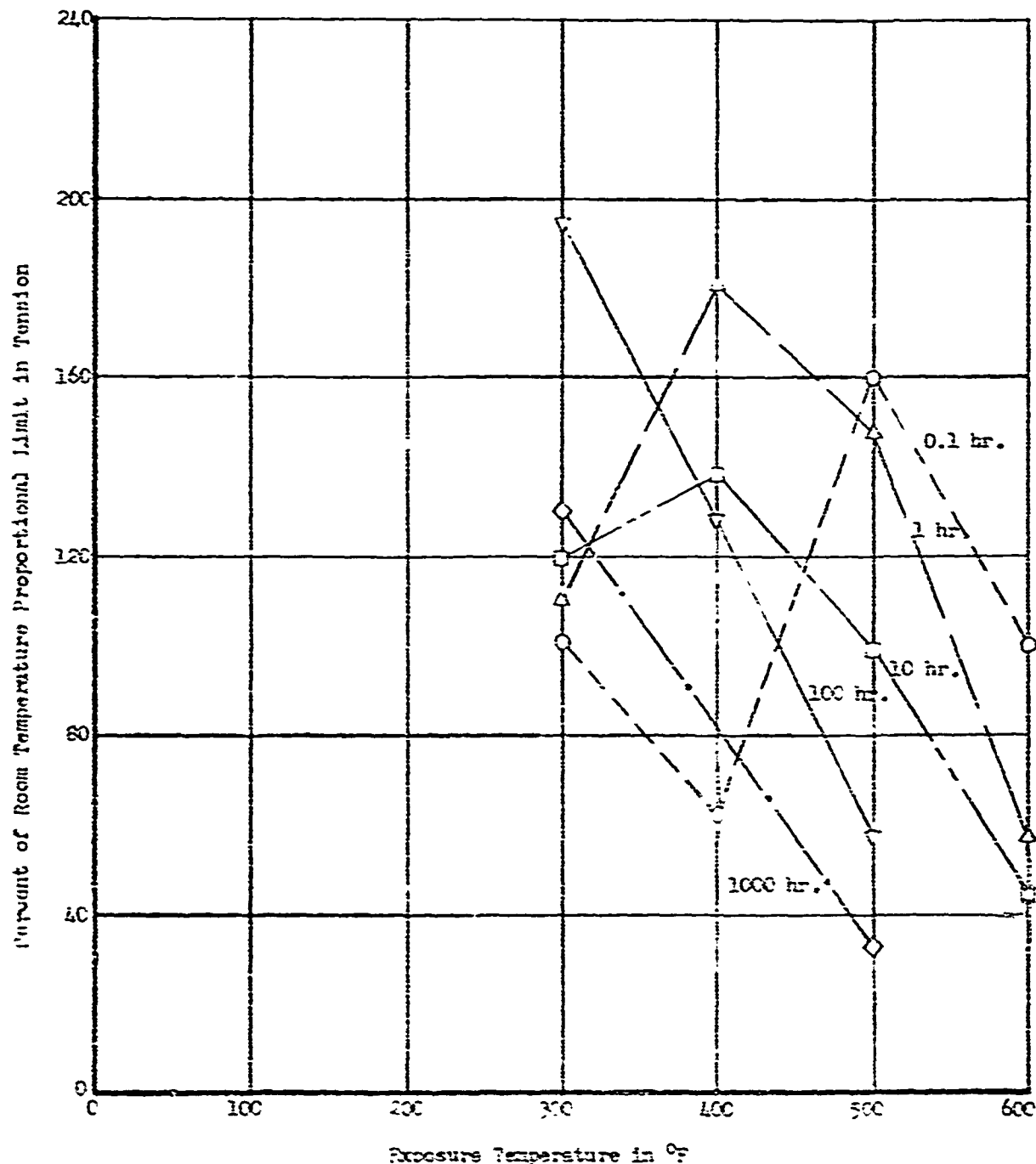


Figure 25. Proportional Limit in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

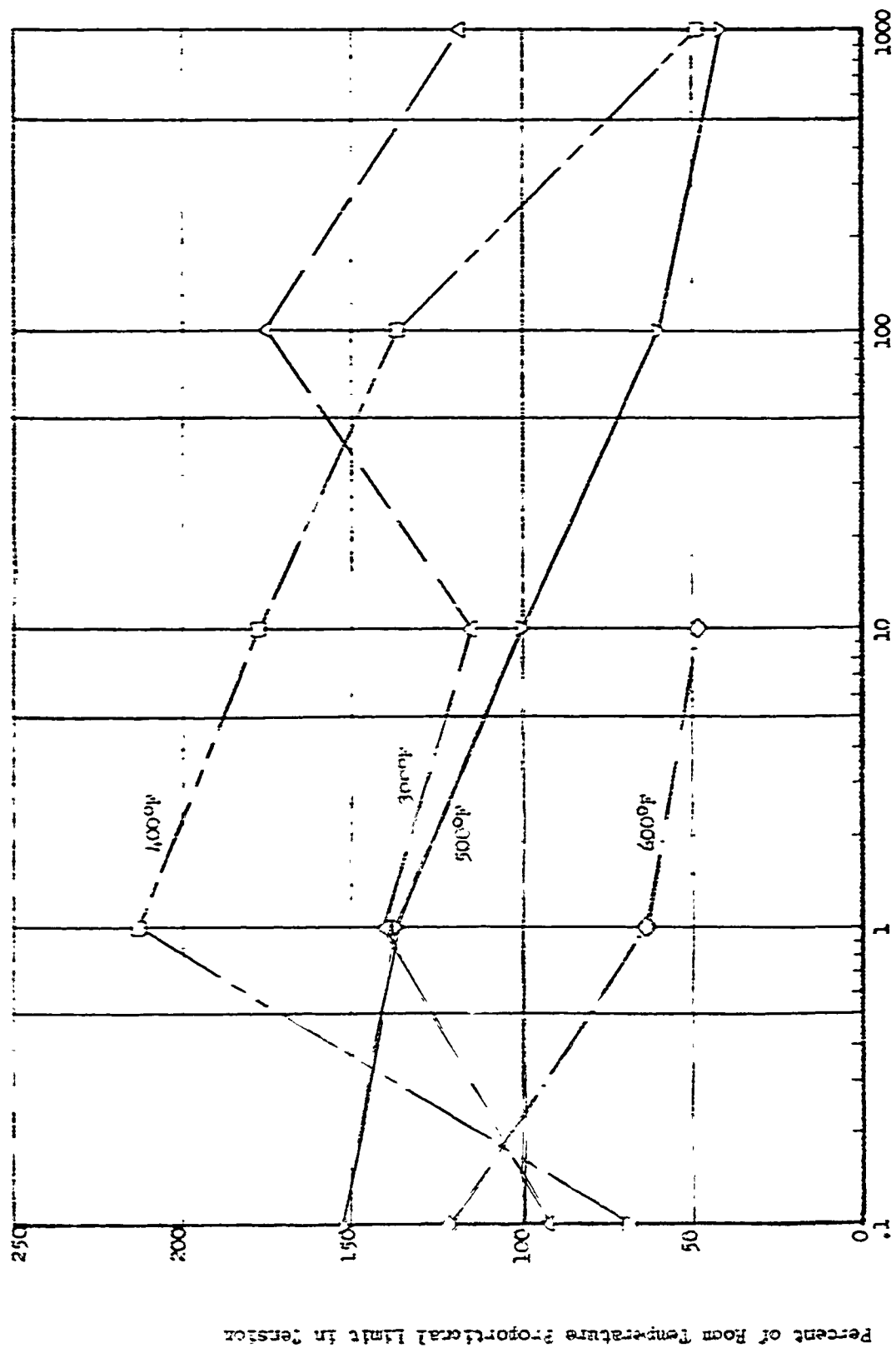


Figure 26. Proportional Limit in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

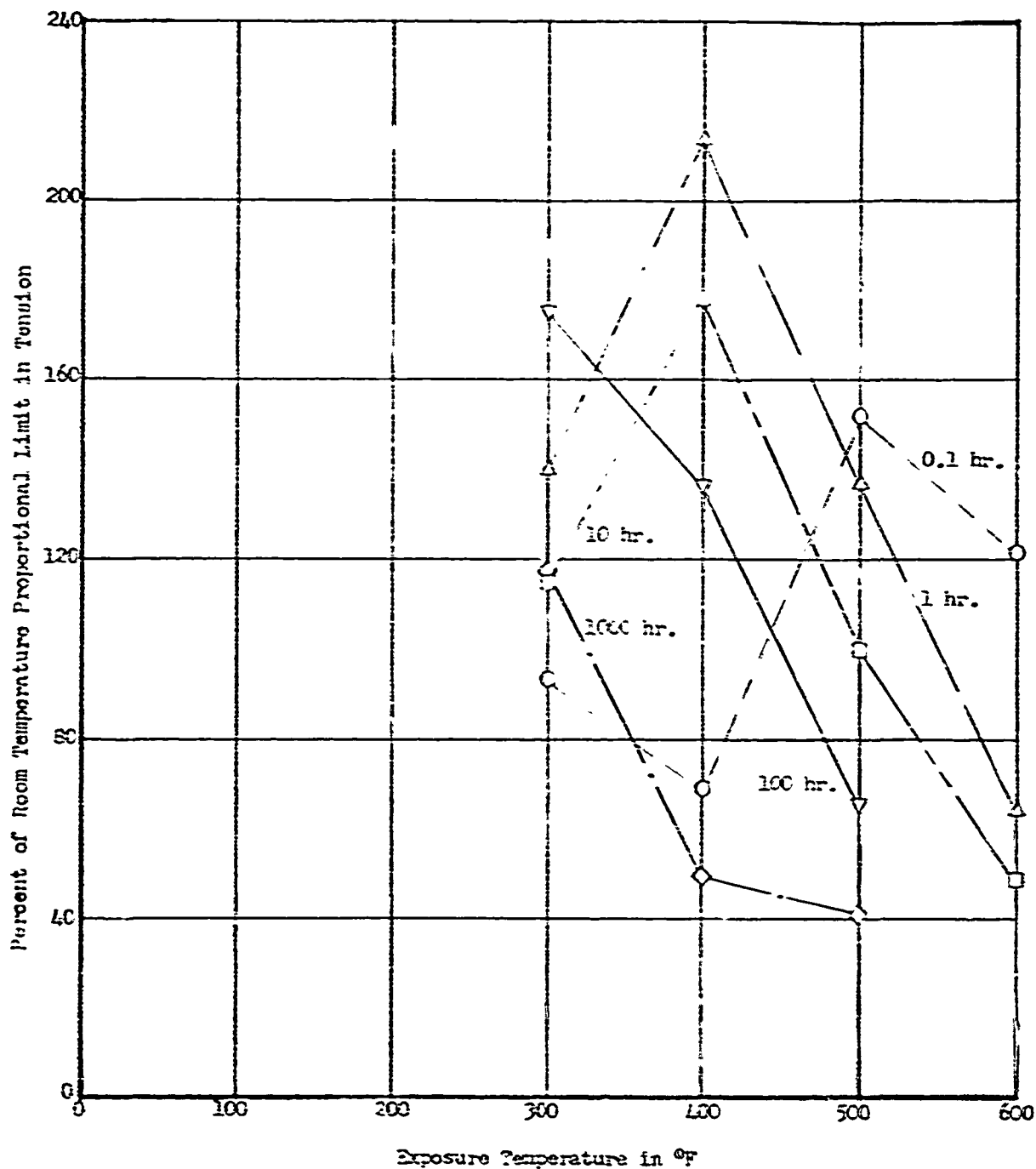


Figure 27. Proportional Limit in Tension of 2024-T3 Aluminum Sheet at 200°F After Exposure to Elevated Temperatures

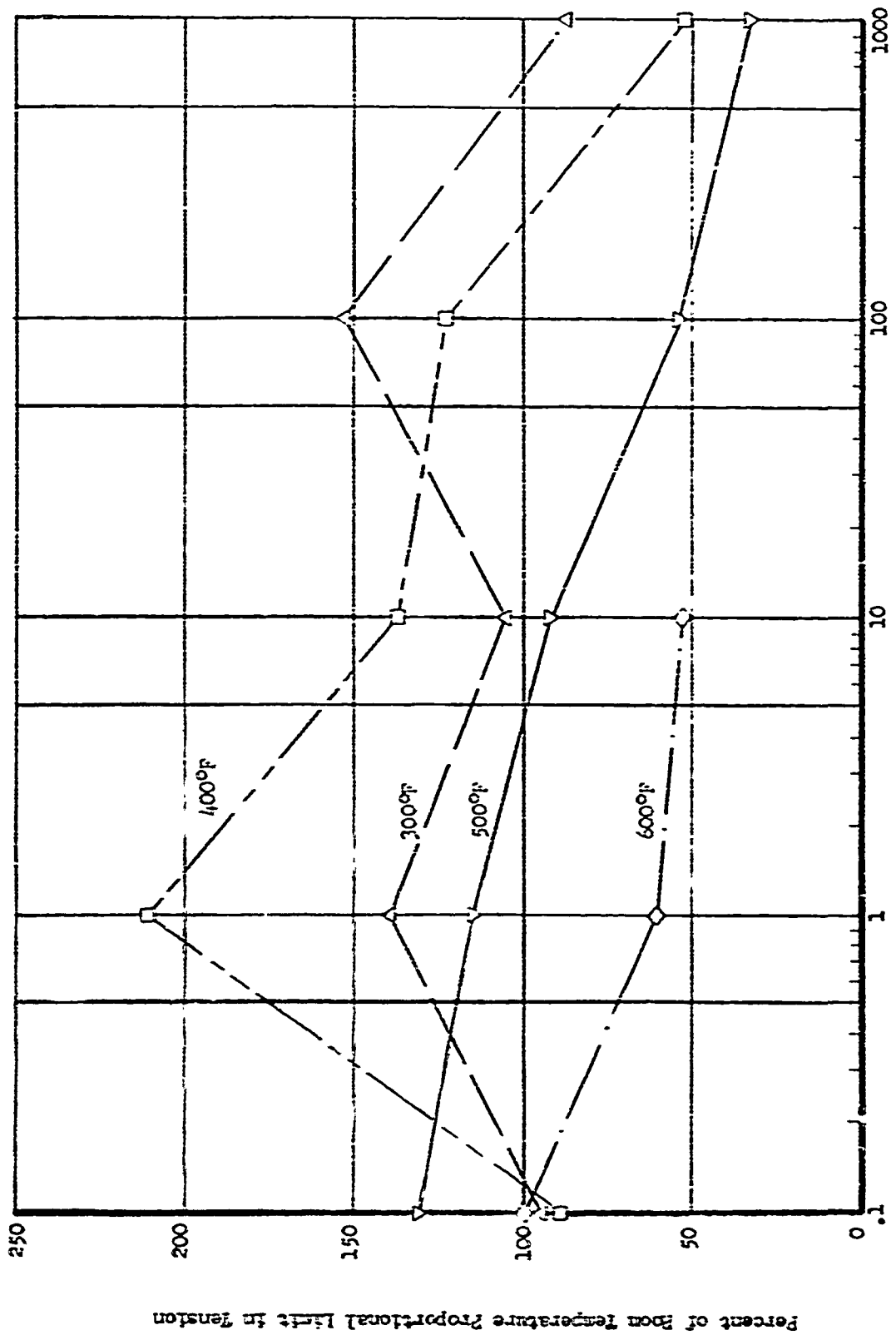


Figure 23. Proportional Limit in Tension of 2024-T3 Clad Sheet at 3000F After Exposure to Elevated Temperatures

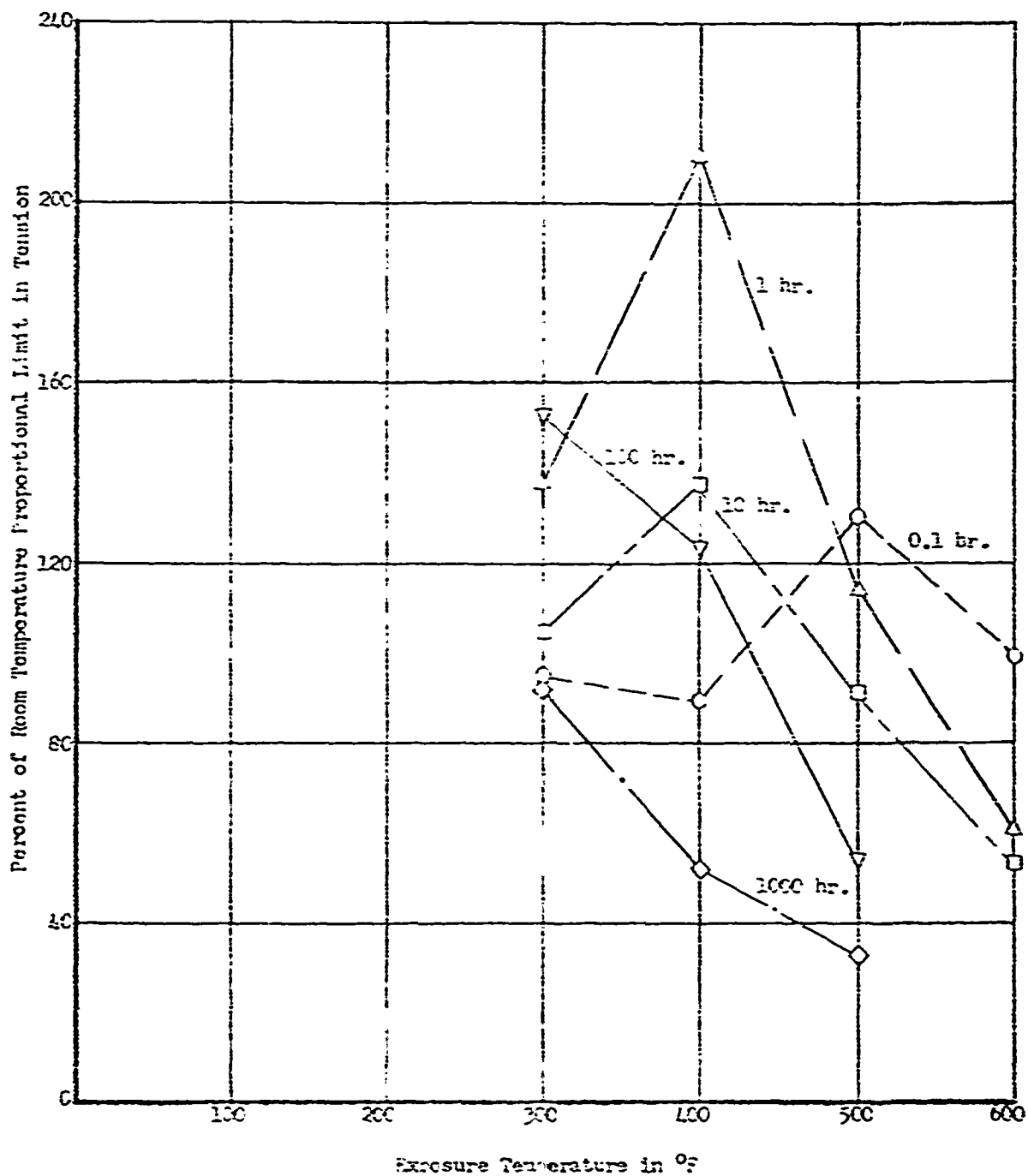


Figure 29. Proportional Limit in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

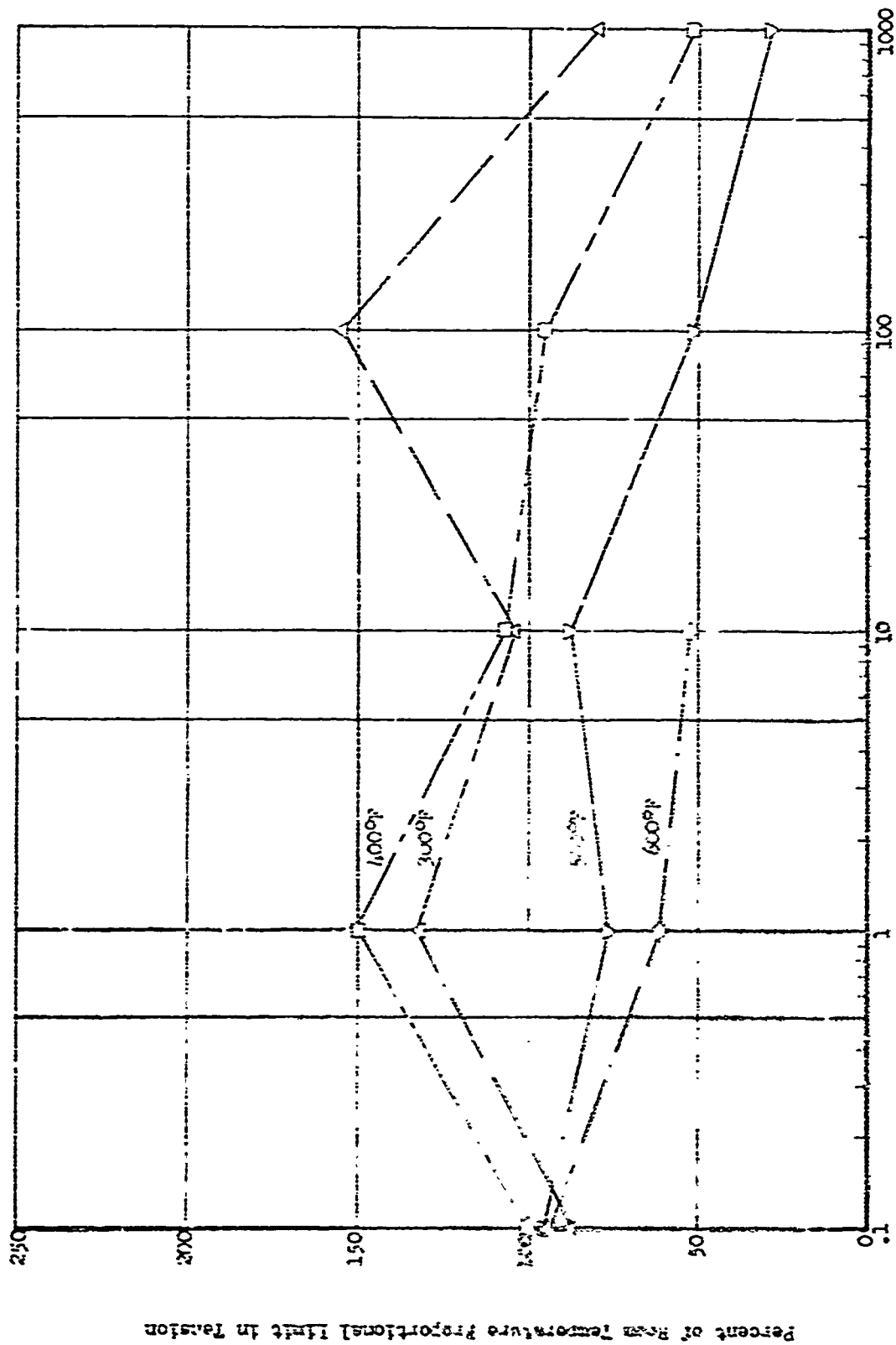


Figure 30. Proportional Limit in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

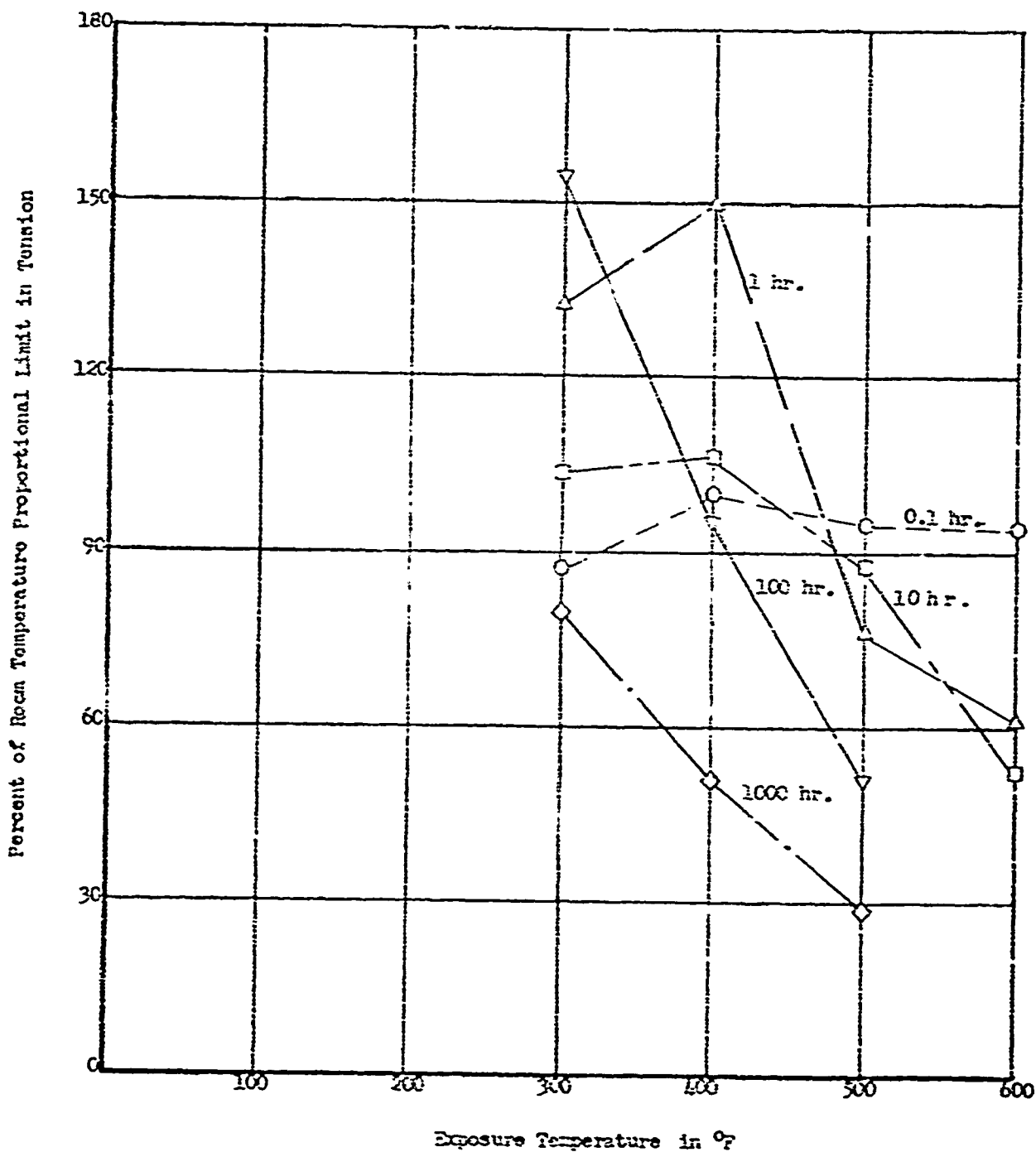


Figure 31. Proportional Limit in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

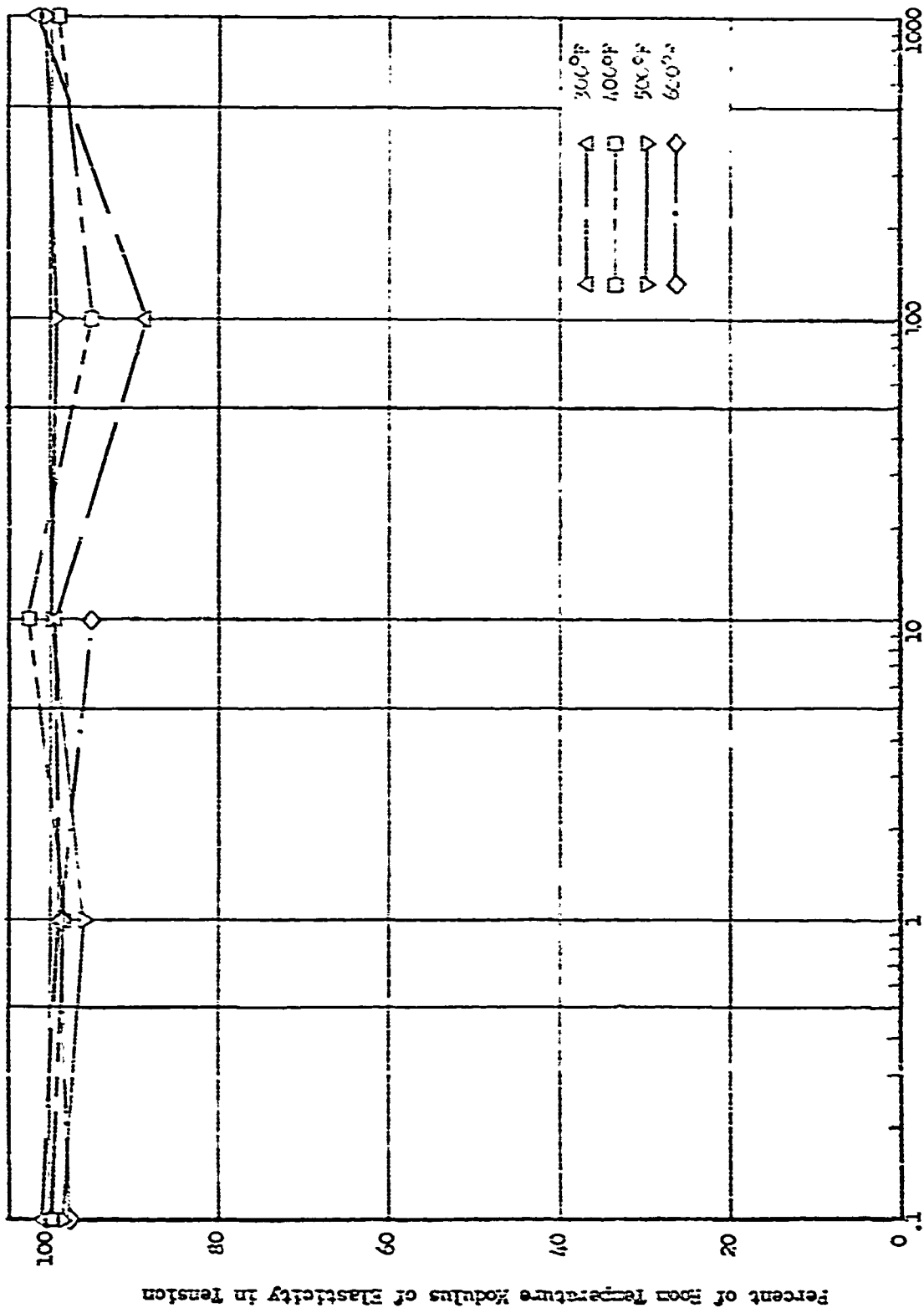


Figure 32. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

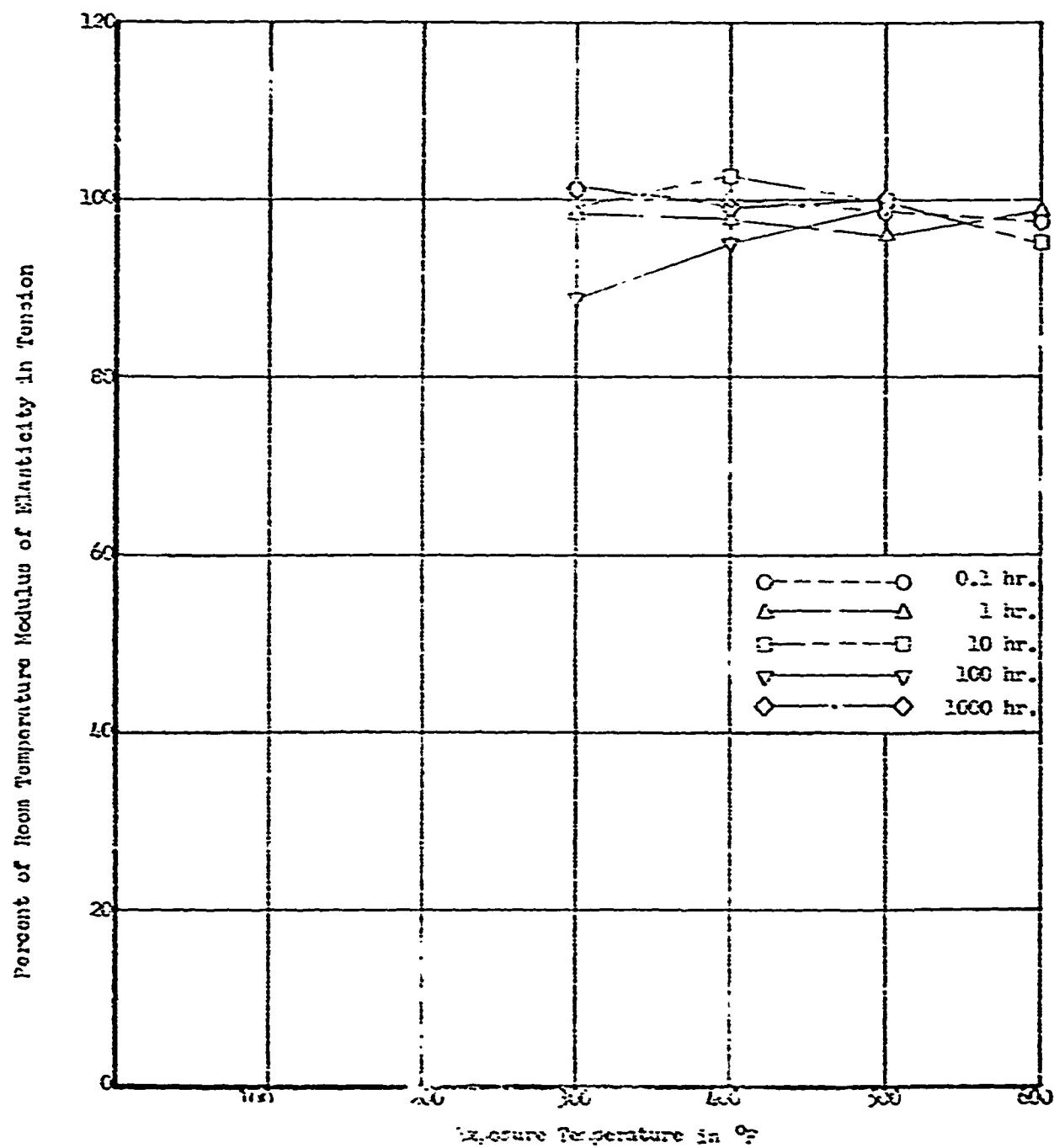


Figure 33. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

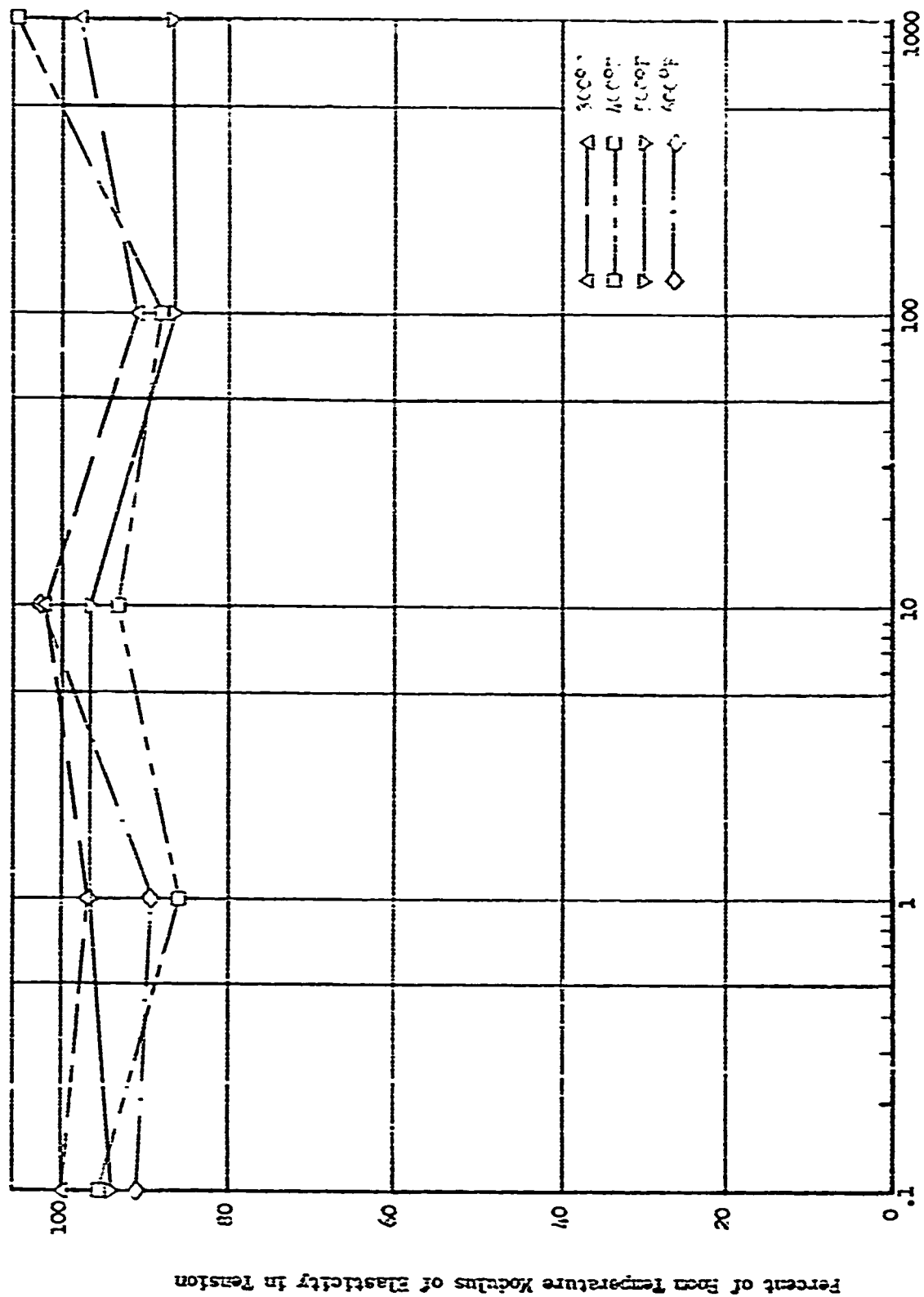


Figure 34. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 2000F After Exposure to Elevated Temperatures

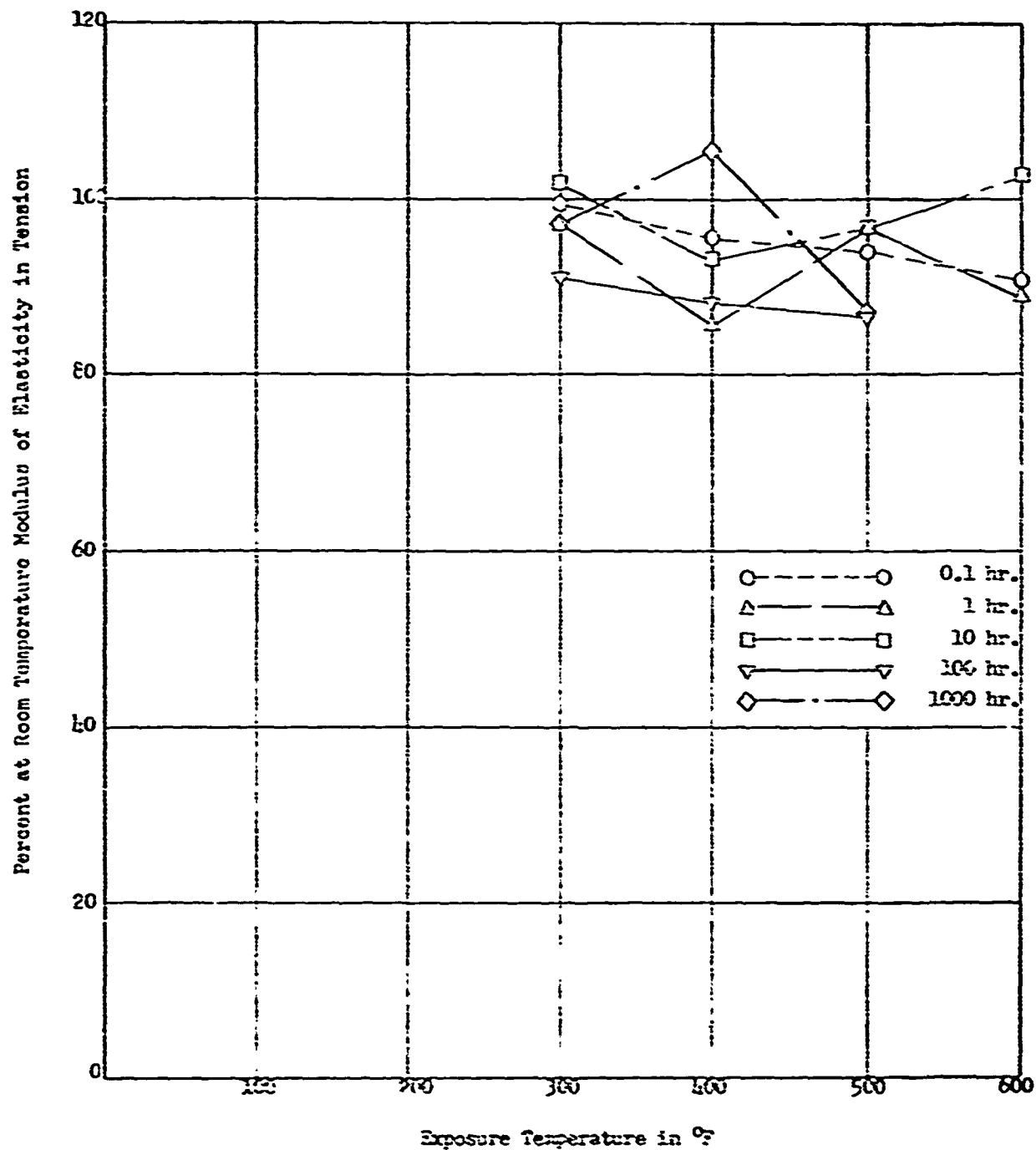


Figure 35. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

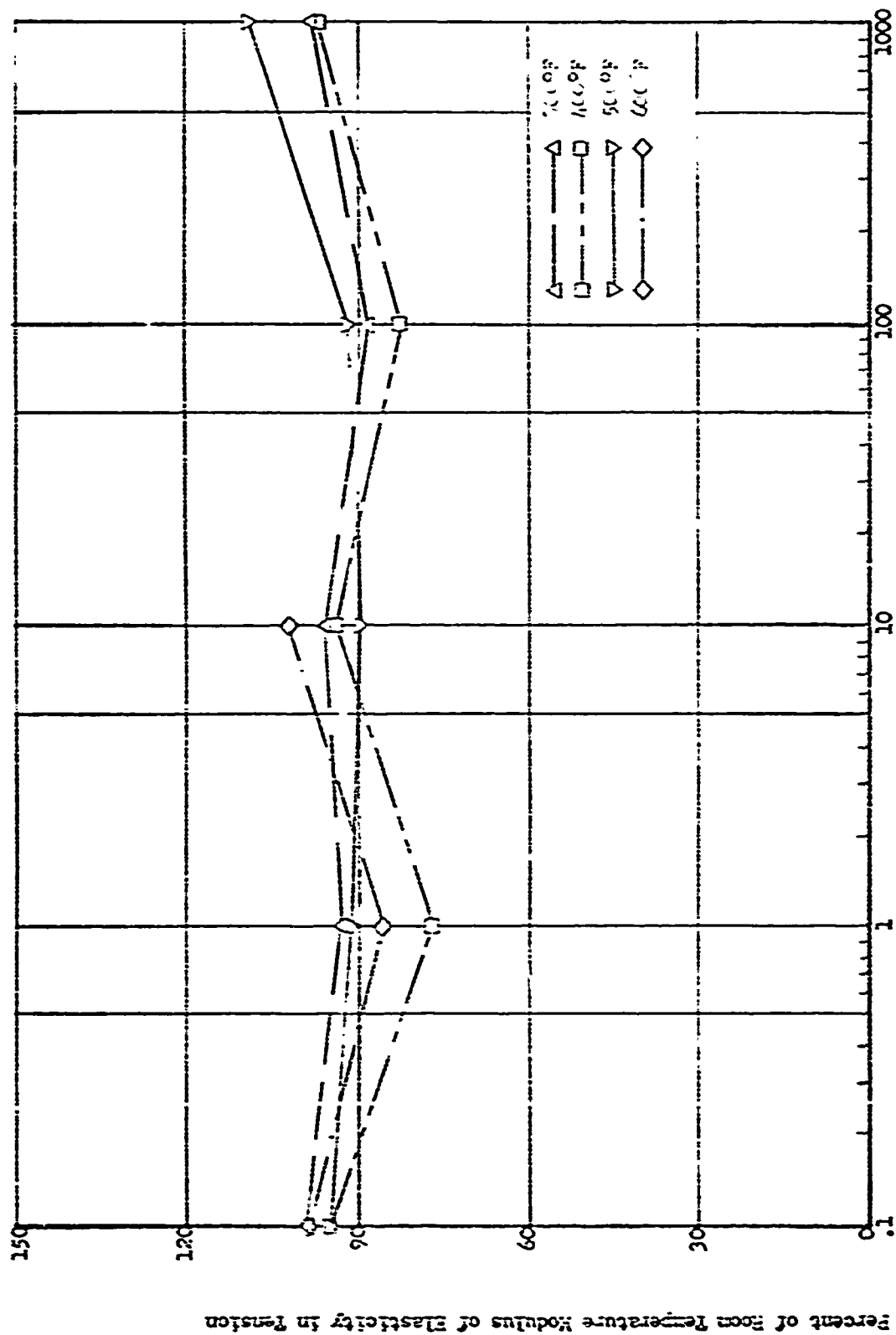


Figure 36. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

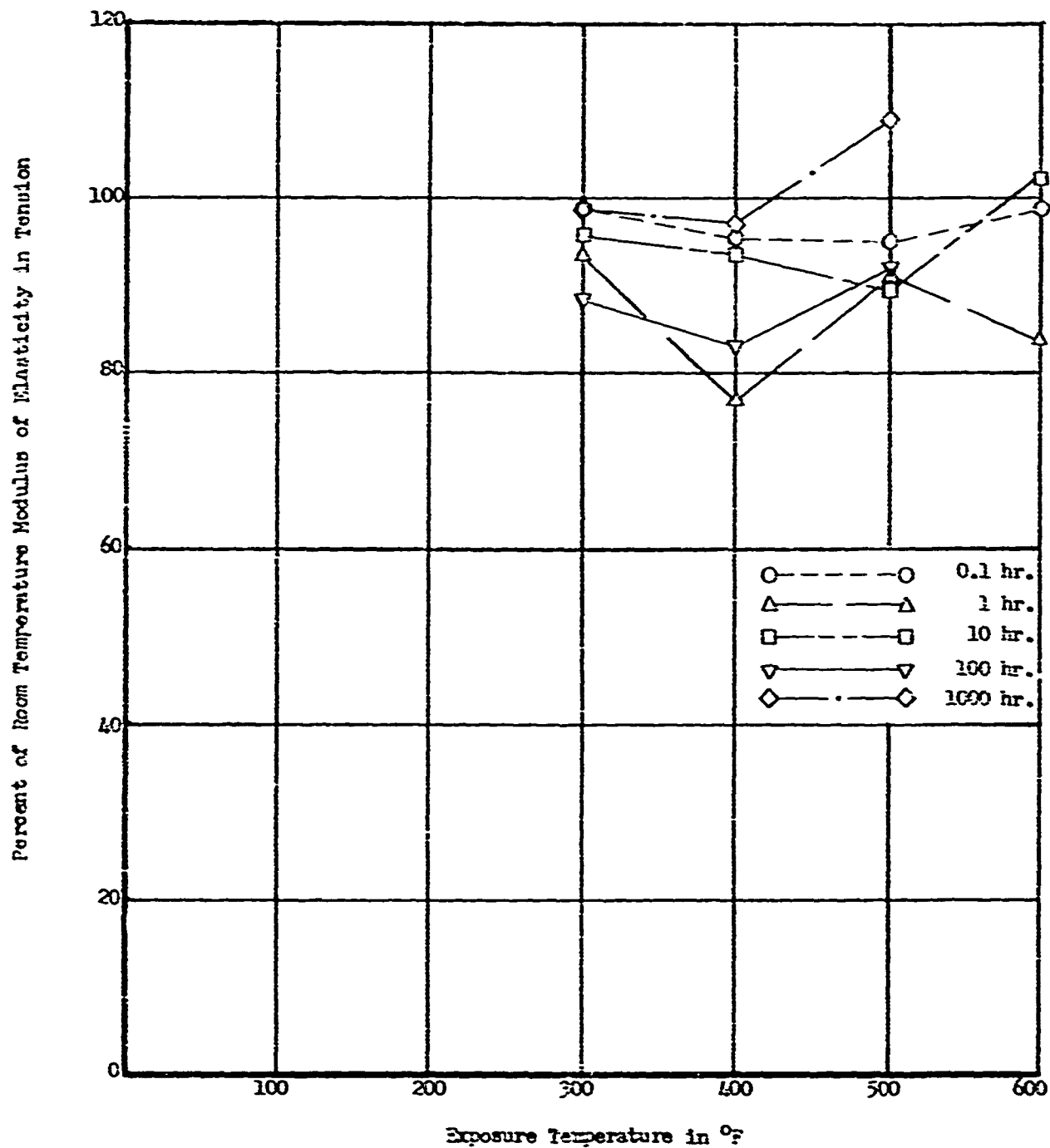


Figure 37.

Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

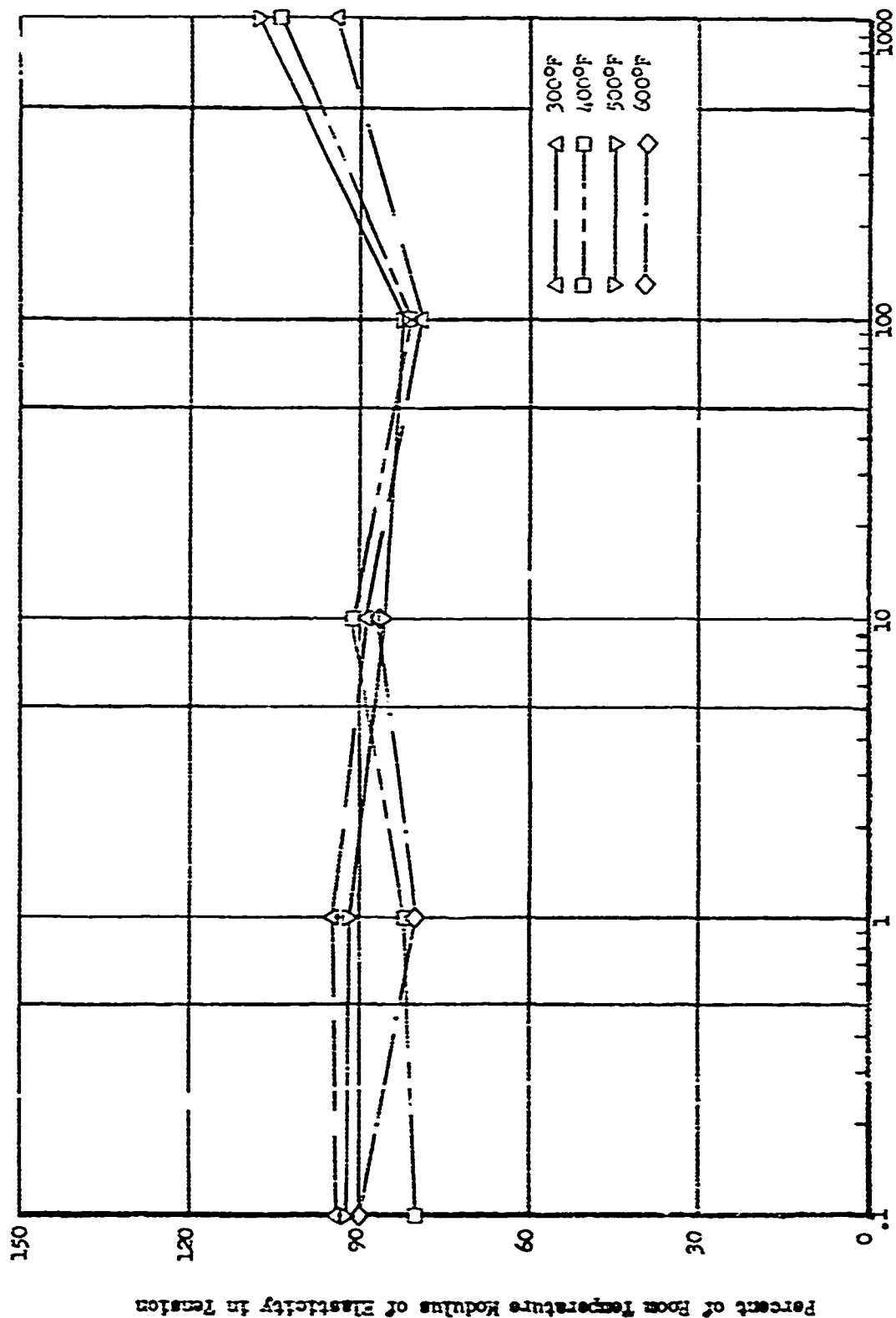


Figure 38. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

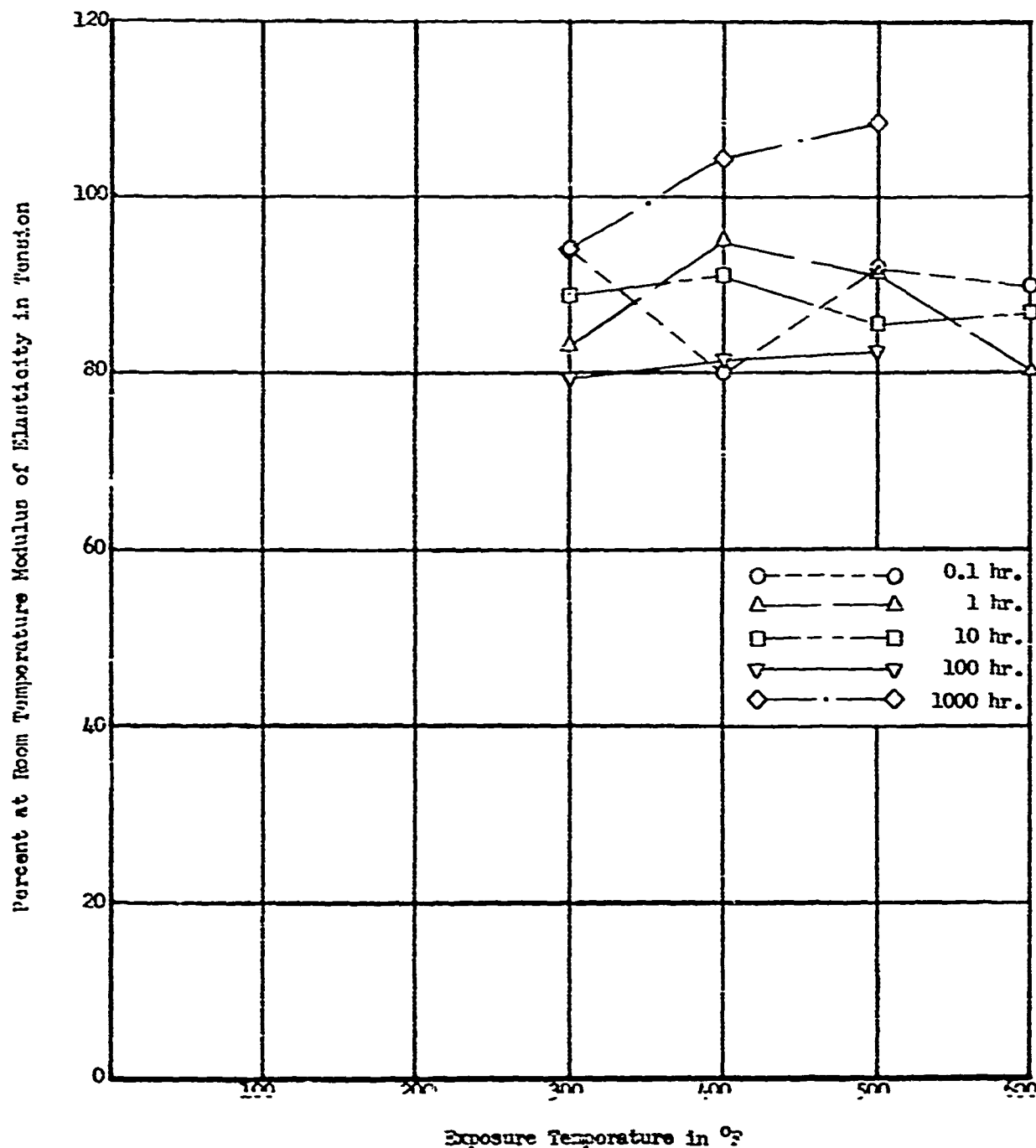


Figure 39.

Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

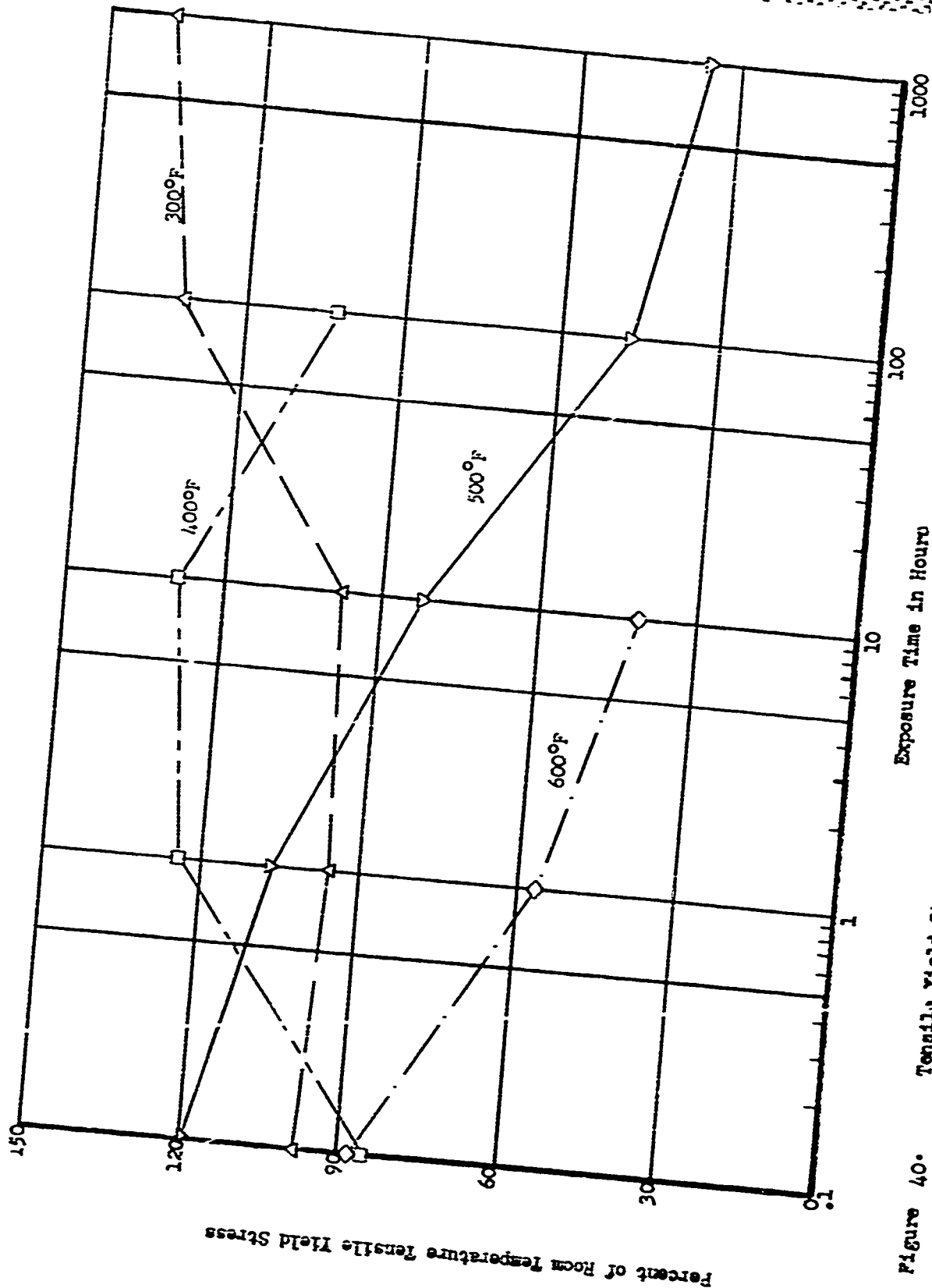


Figure 40. Tensile Yield Stress in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

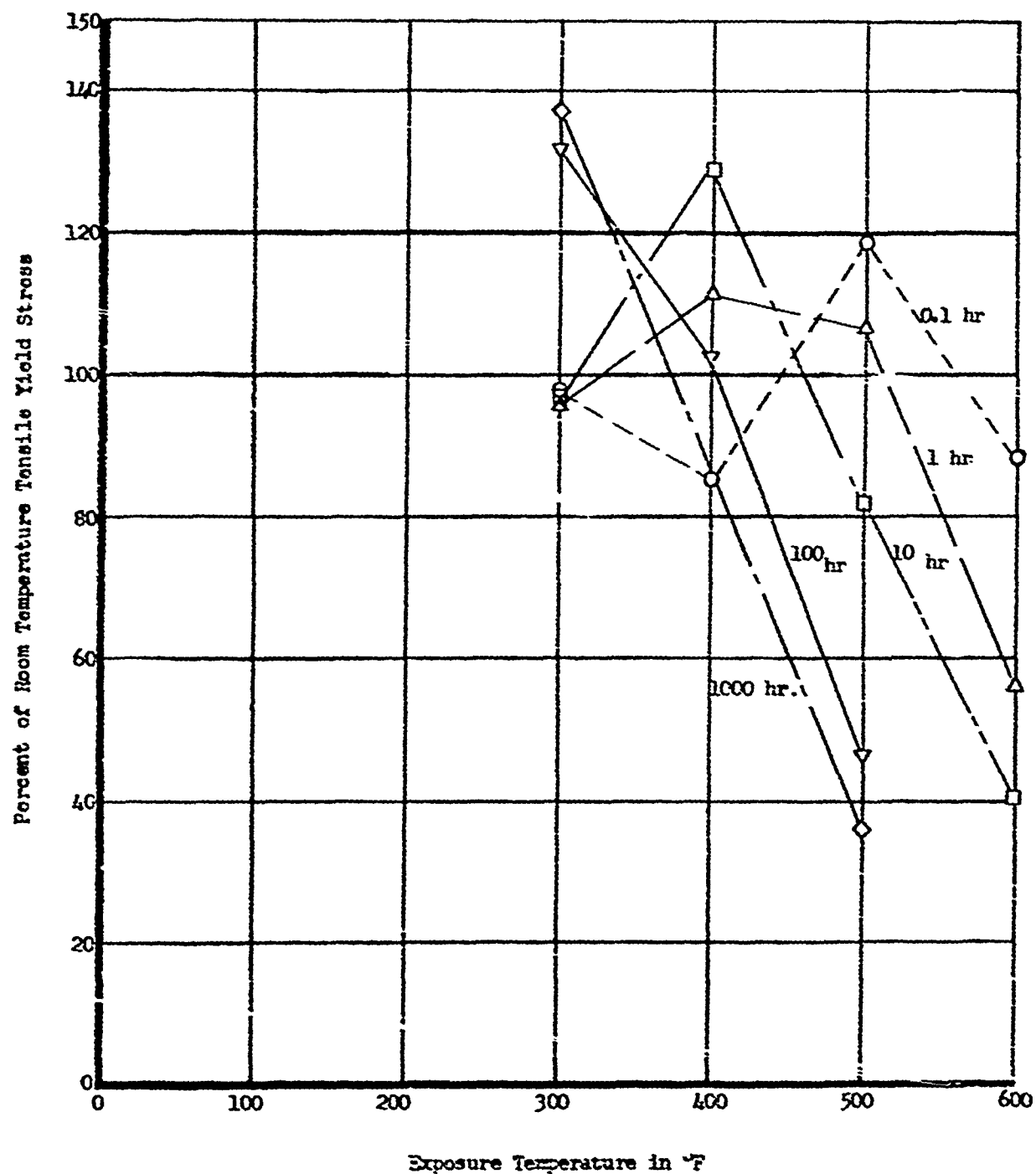


Figure 4L Tensile Yield Stress of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

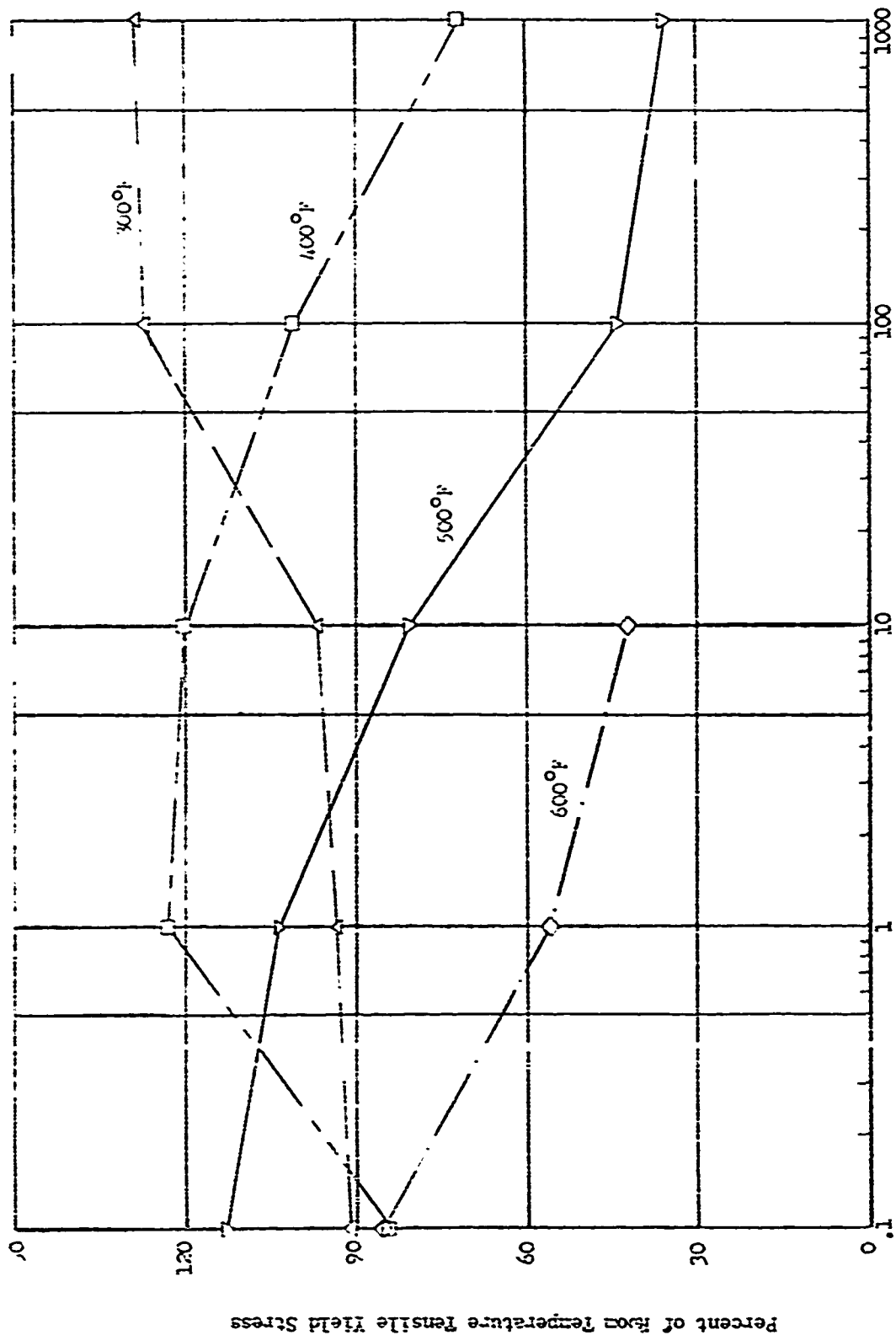


Figure 42. Tensile Yield Stress in Tension of 2024-T3 Clad Sheet at 2000°F After Exposure to Elevated Temperatures

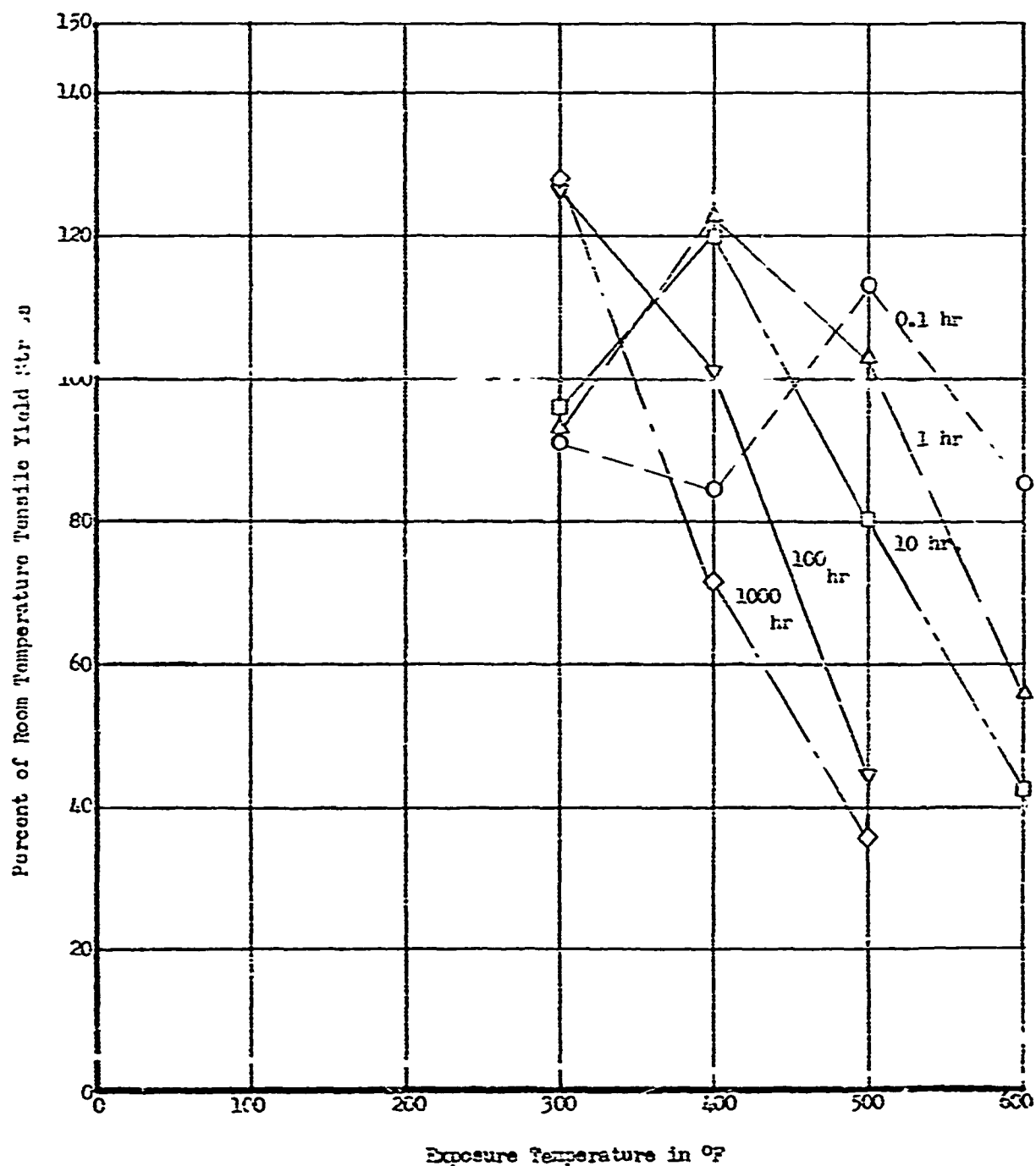


Figure 43.

Tensile Yield Stress of 2024-T3 Clad Sheet at 200°F
After Exposure to Elevated Temperatures

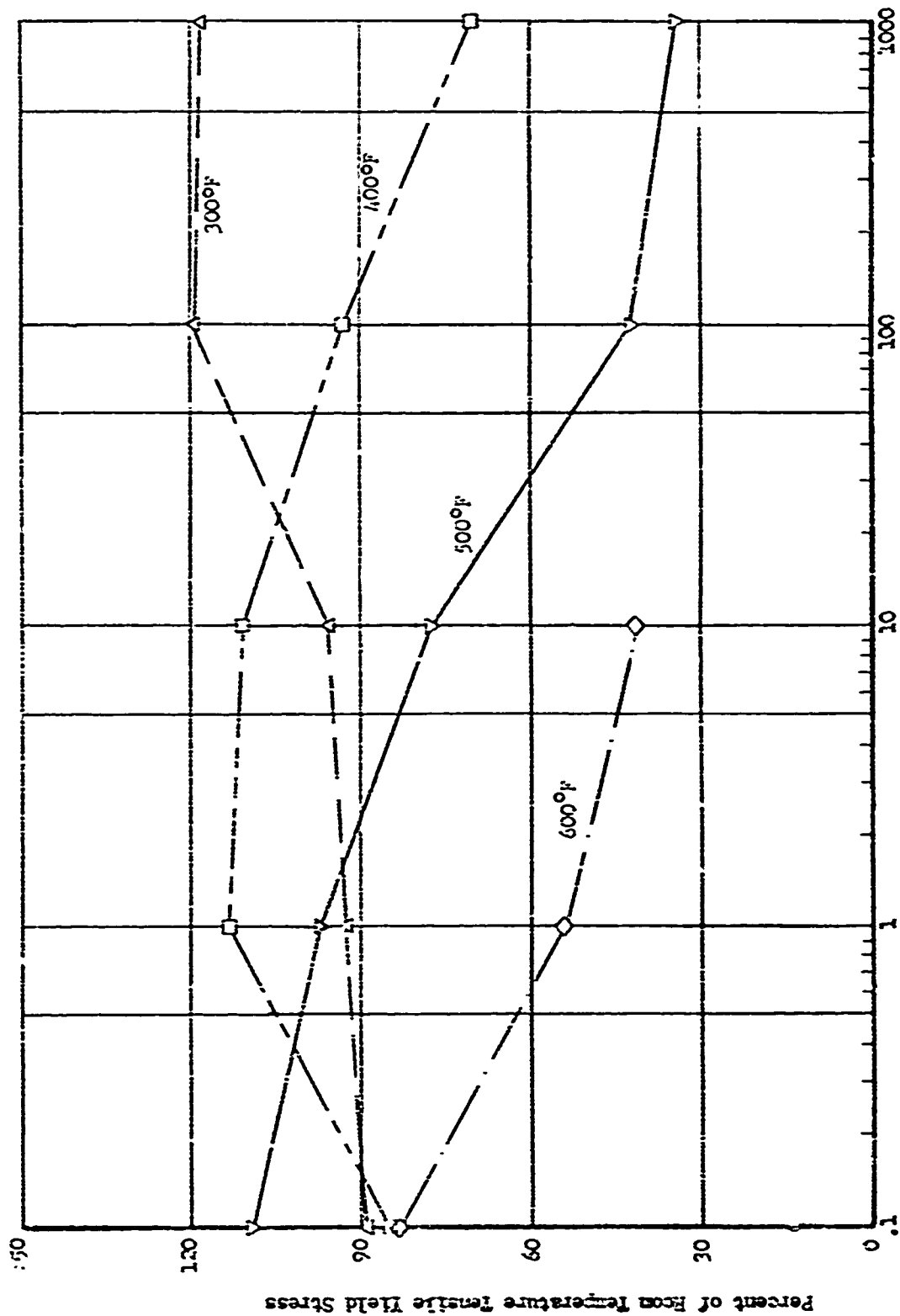


Figure 11. Tensile Yield Stress in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

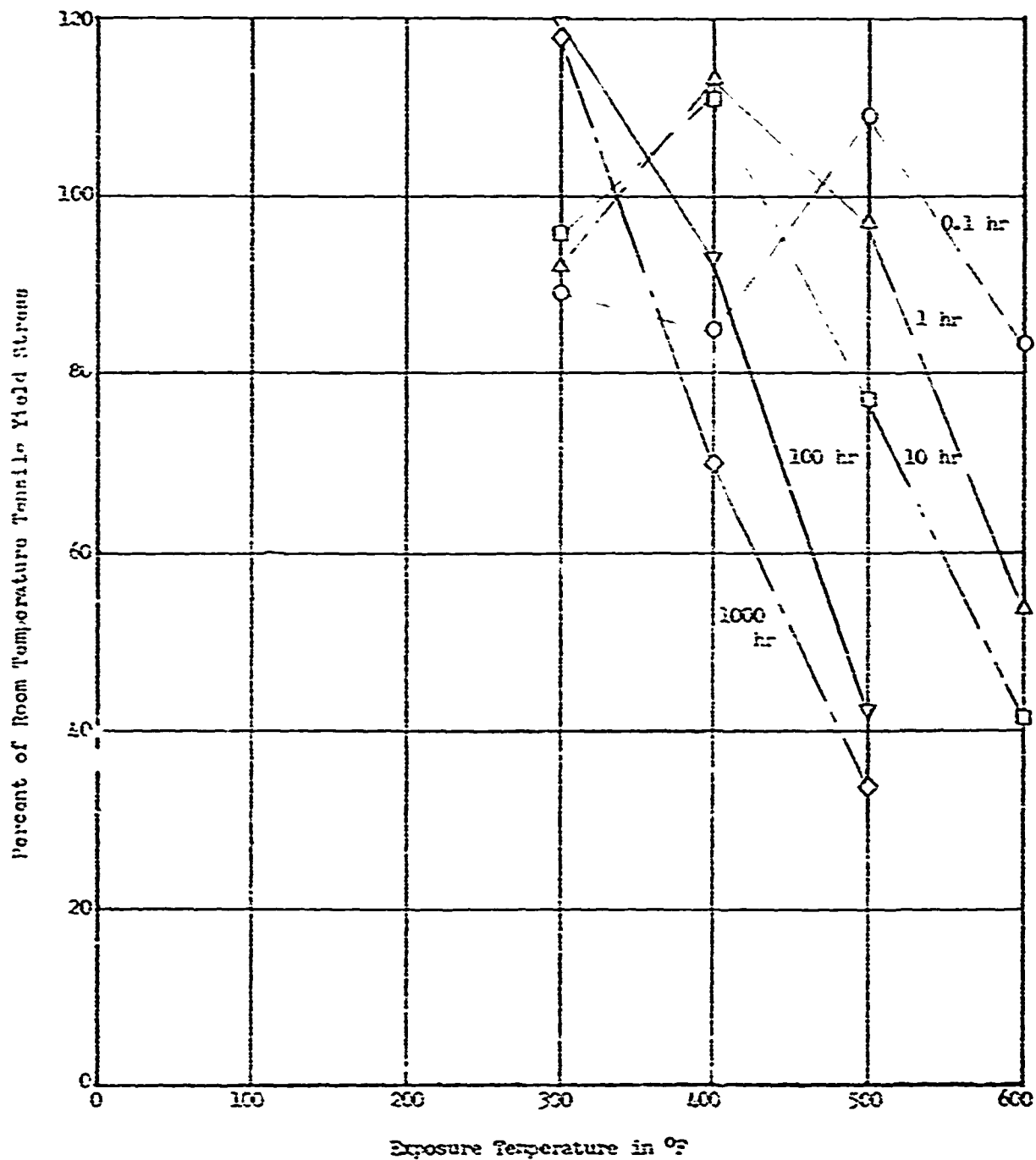


Figure 45. Tensile Yield Stress of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

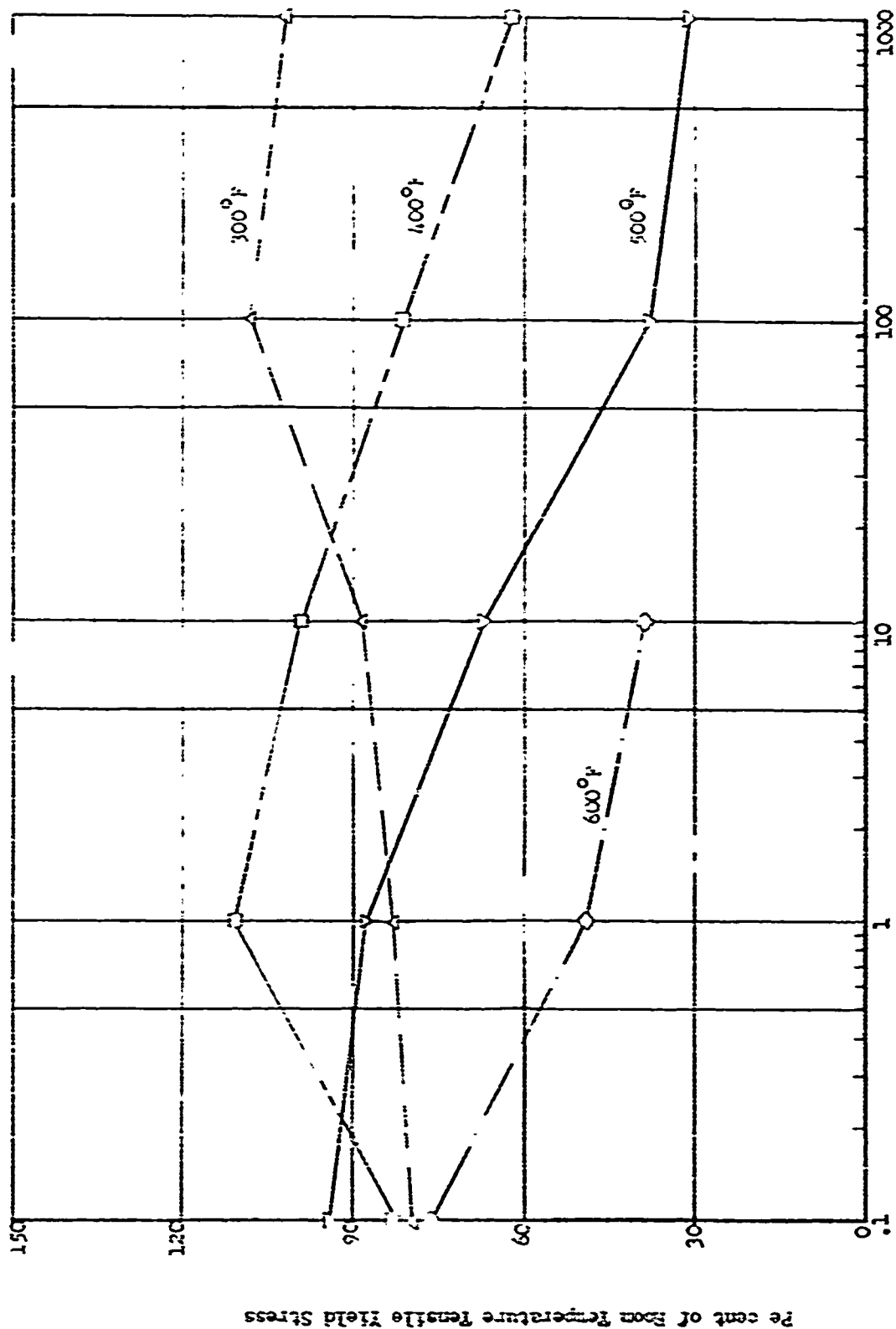


Figure 46. Tensile Yield Stress in Tension of 2024-T3 Clad Sheet at 100°F After Exposure to Elevated Temperatures

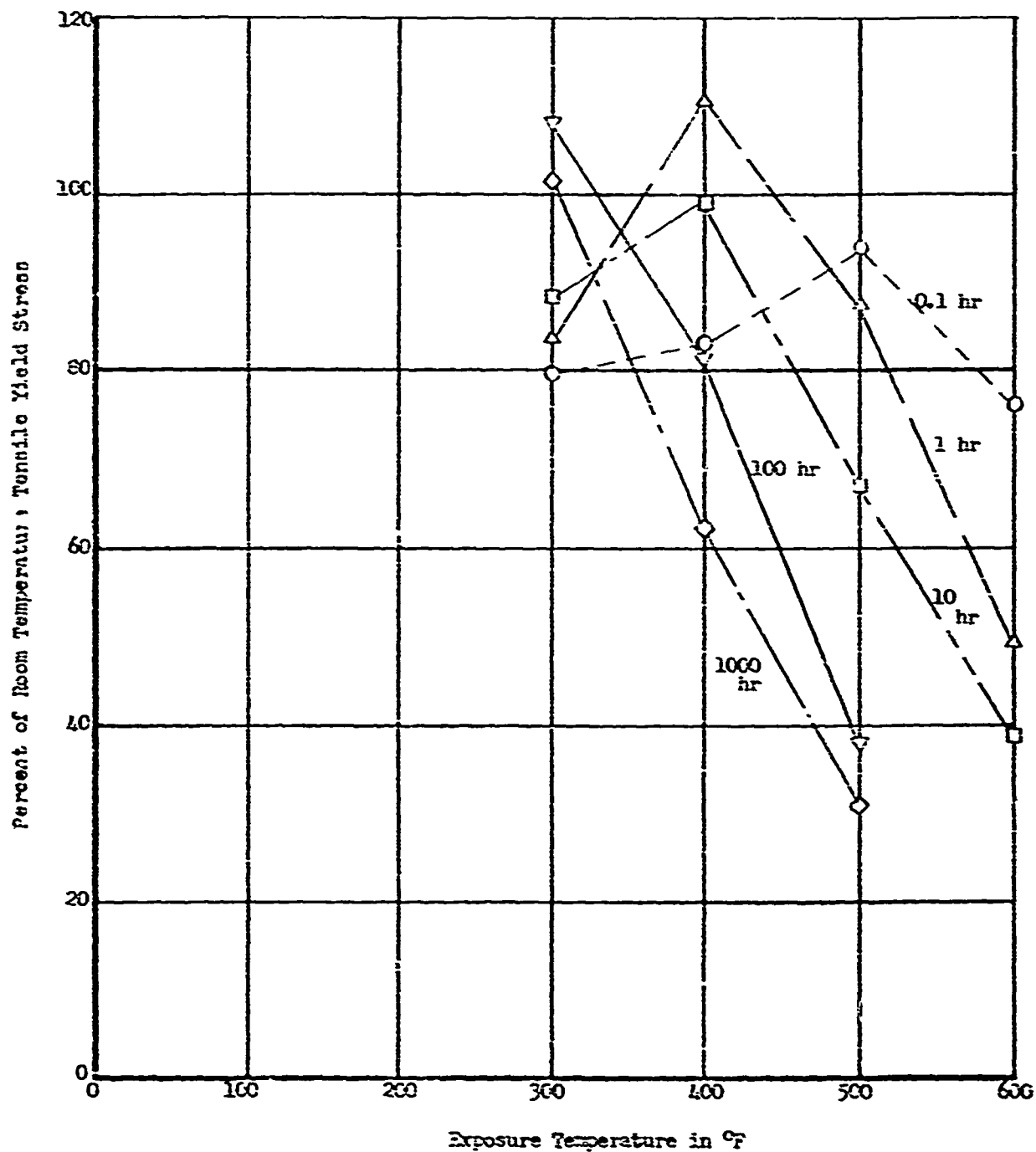


Figure 47.

Tensile Yield Stress of 2024-T3 Clad Sheet at 400°F
After Exposure to Elevated Temperatures

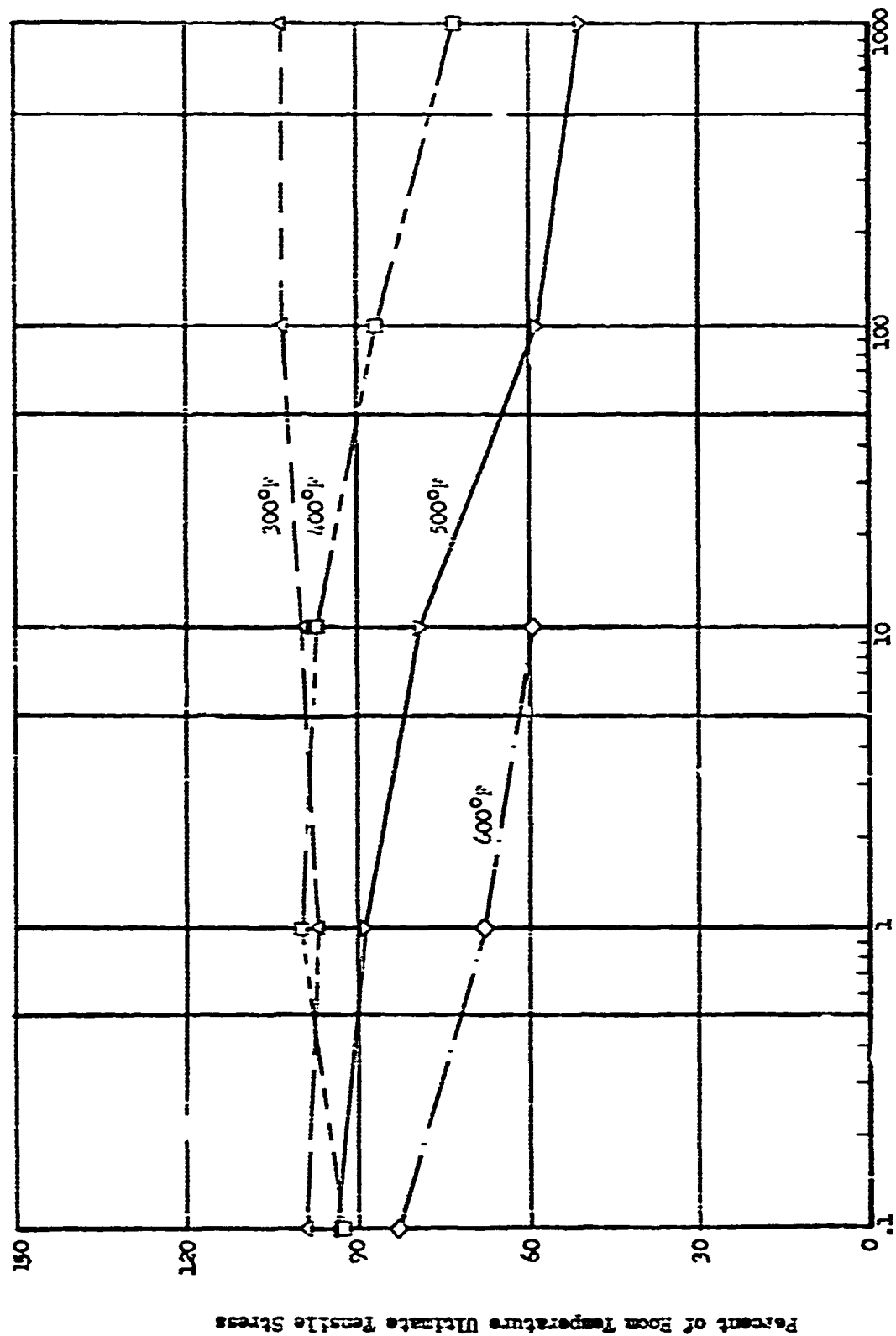


Figure 48. Ultimate Tensile Stress of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

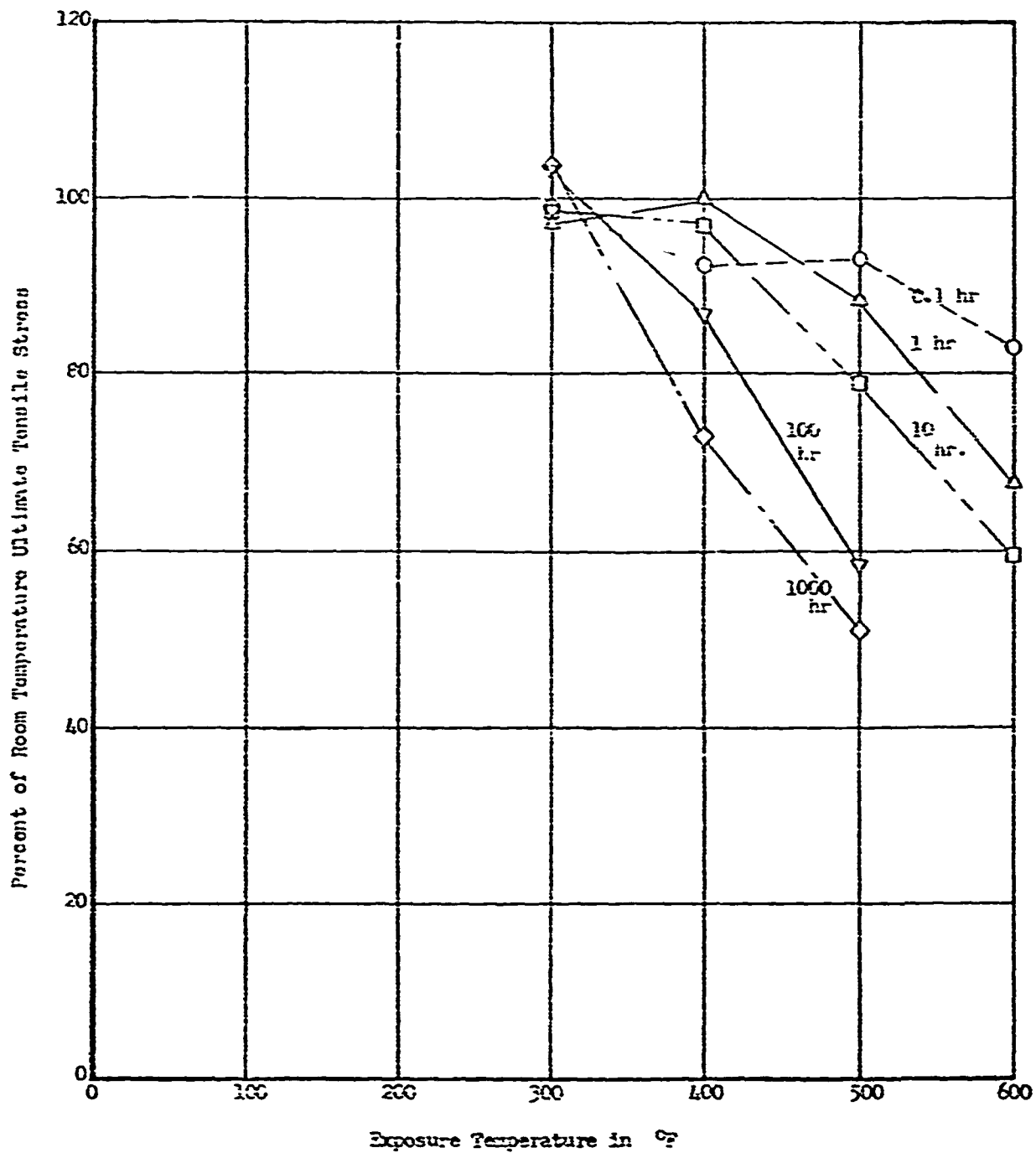


Figure 49. Ultimate Tensile Stress of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

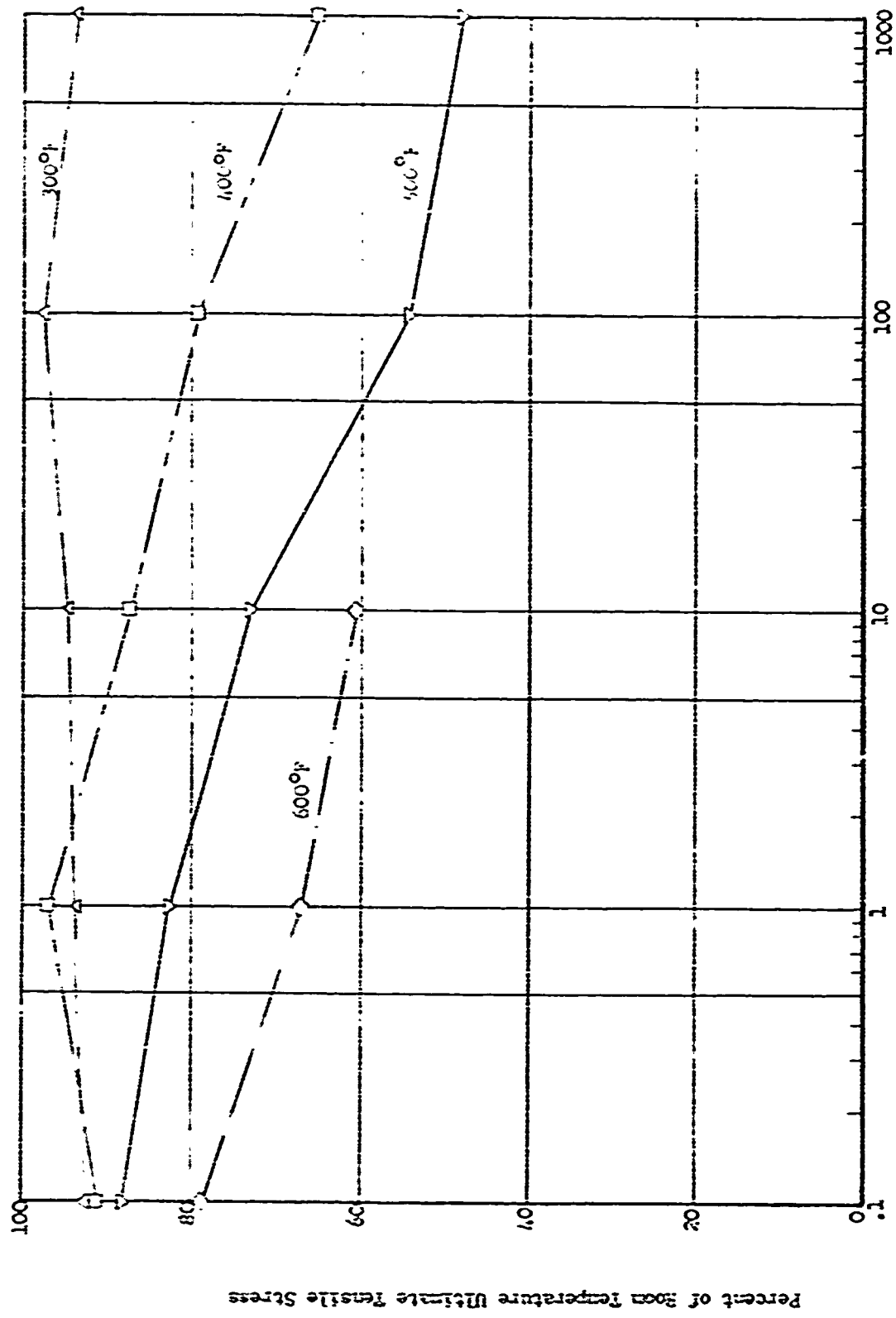


Figure 50. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

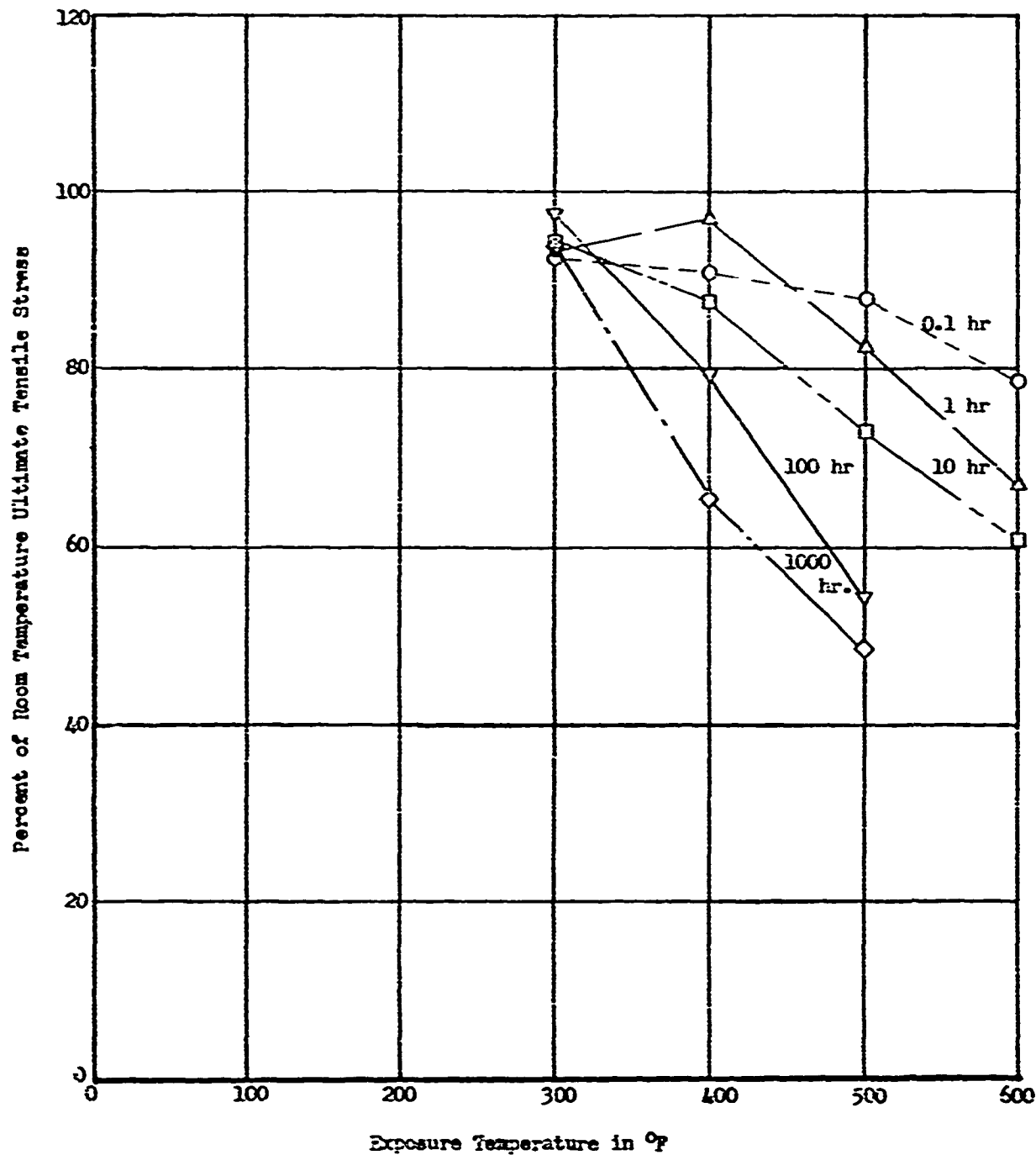


Figure 51. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

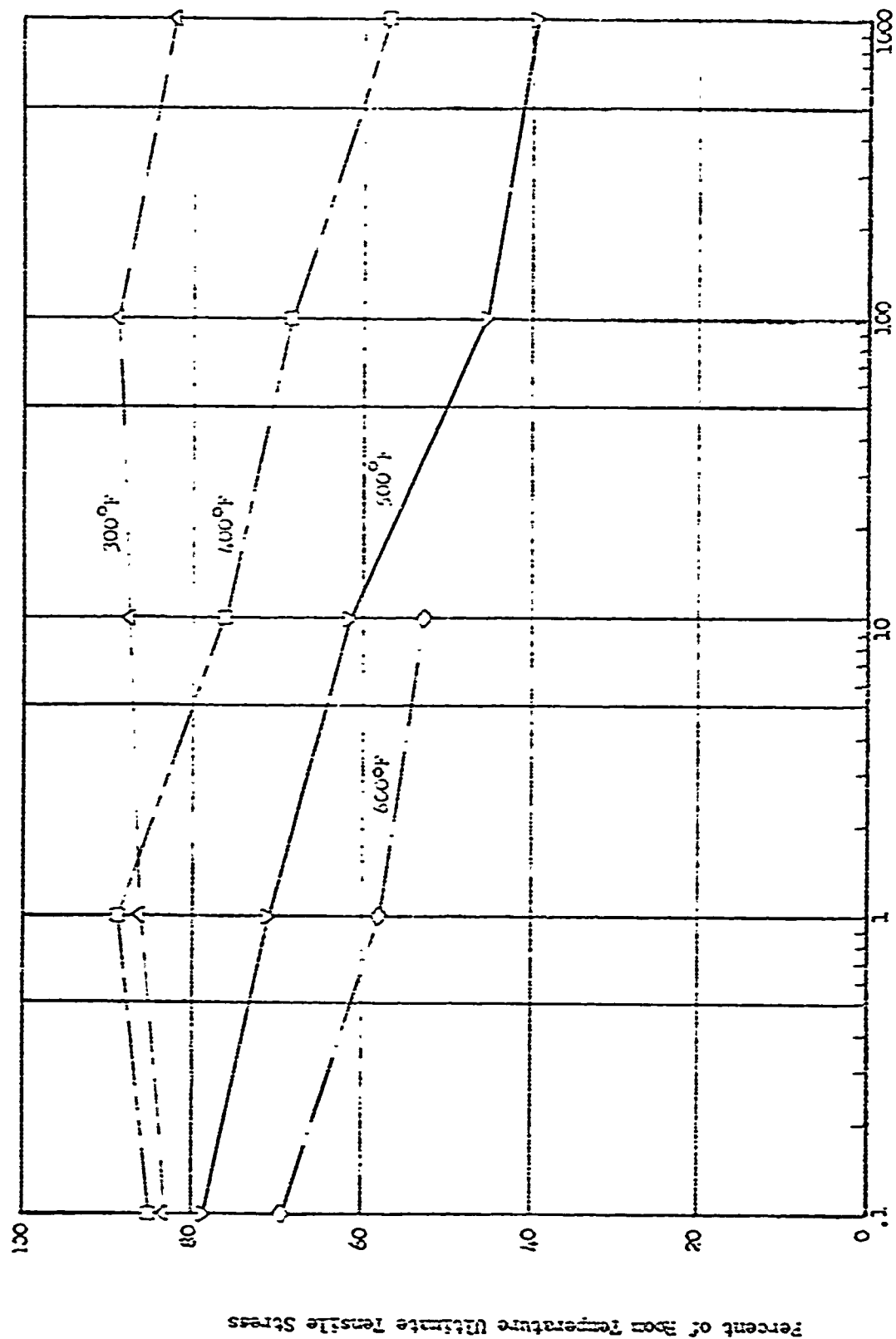


Figure 52. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

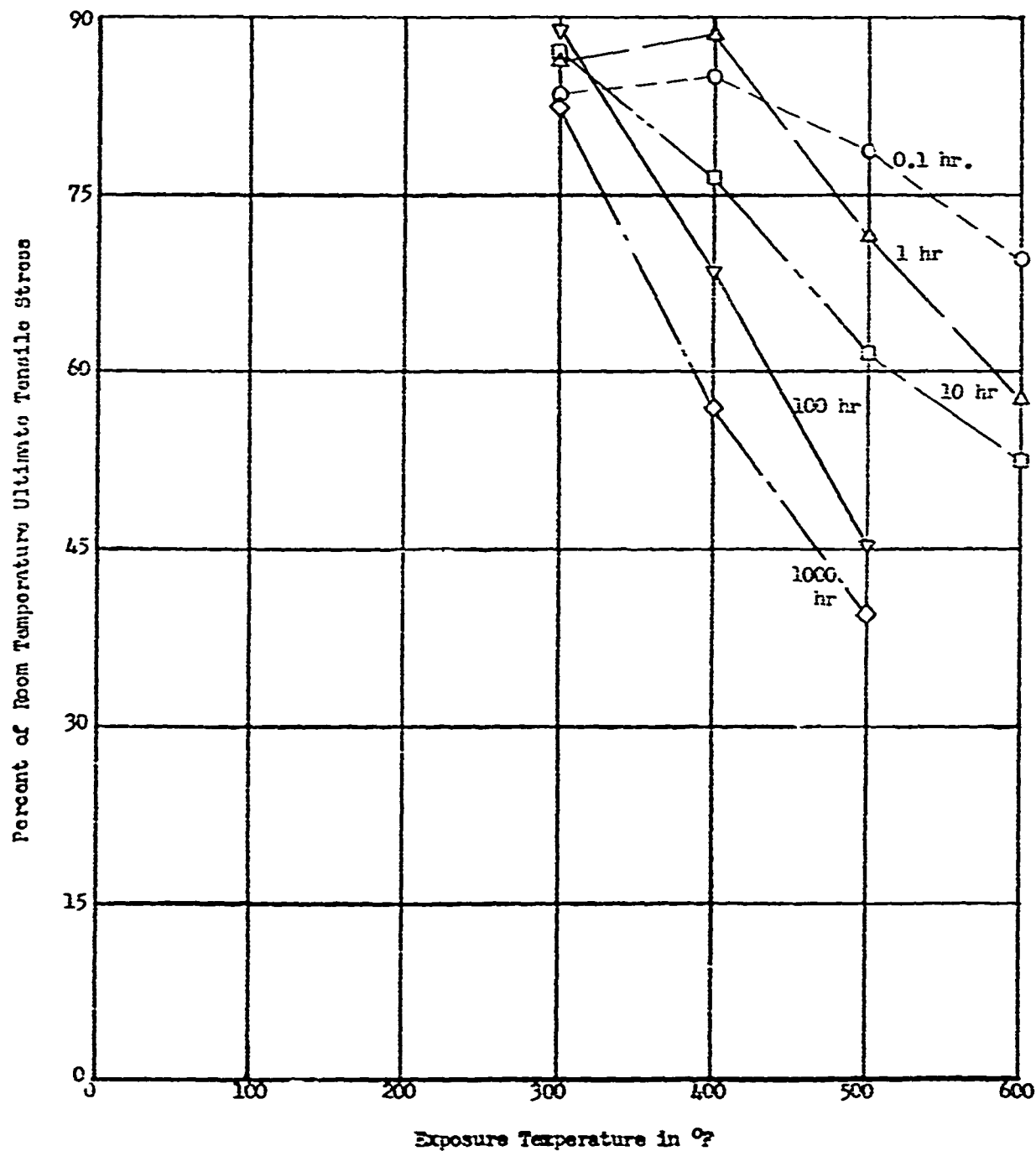


Figure 53. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

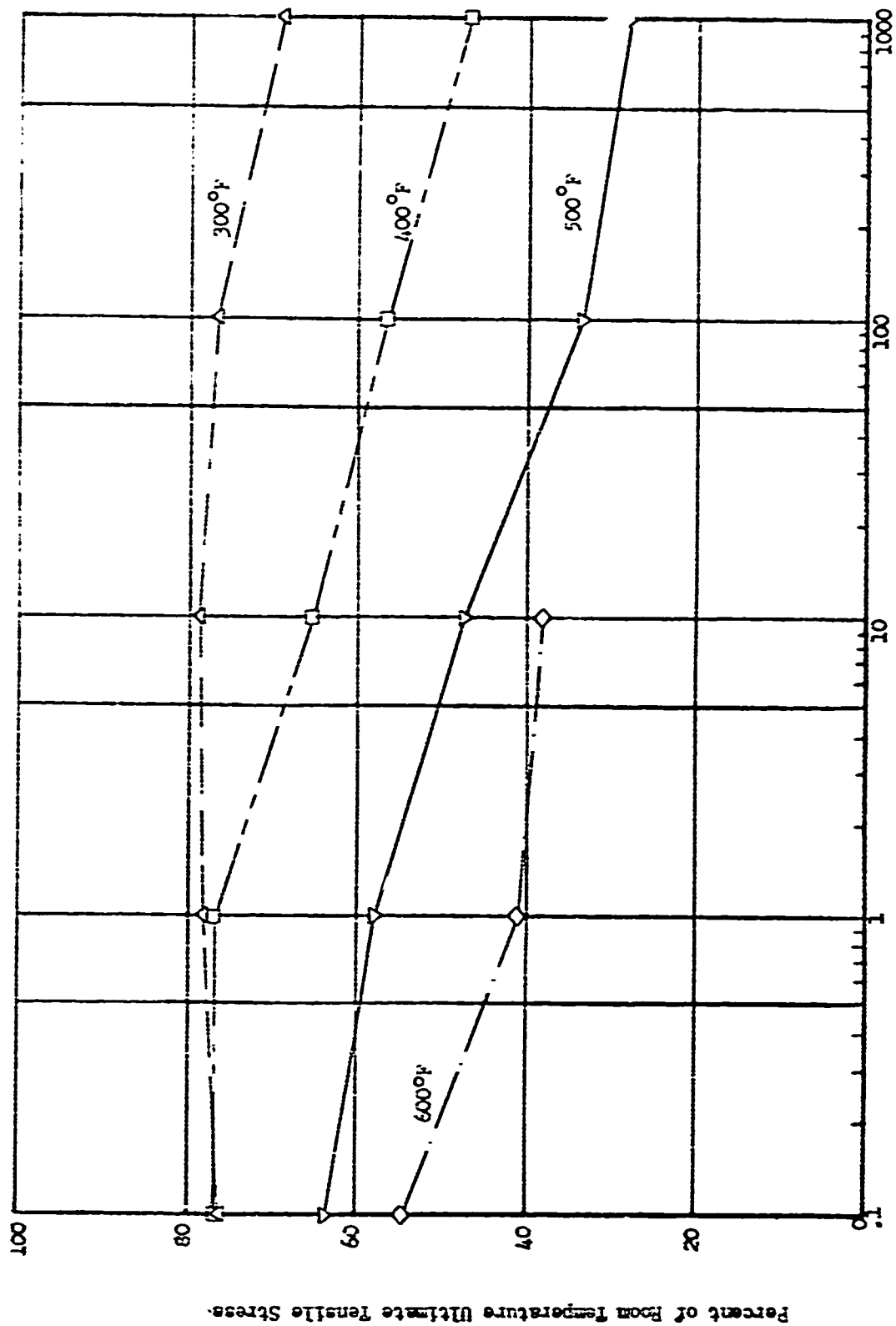


Figure 54. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

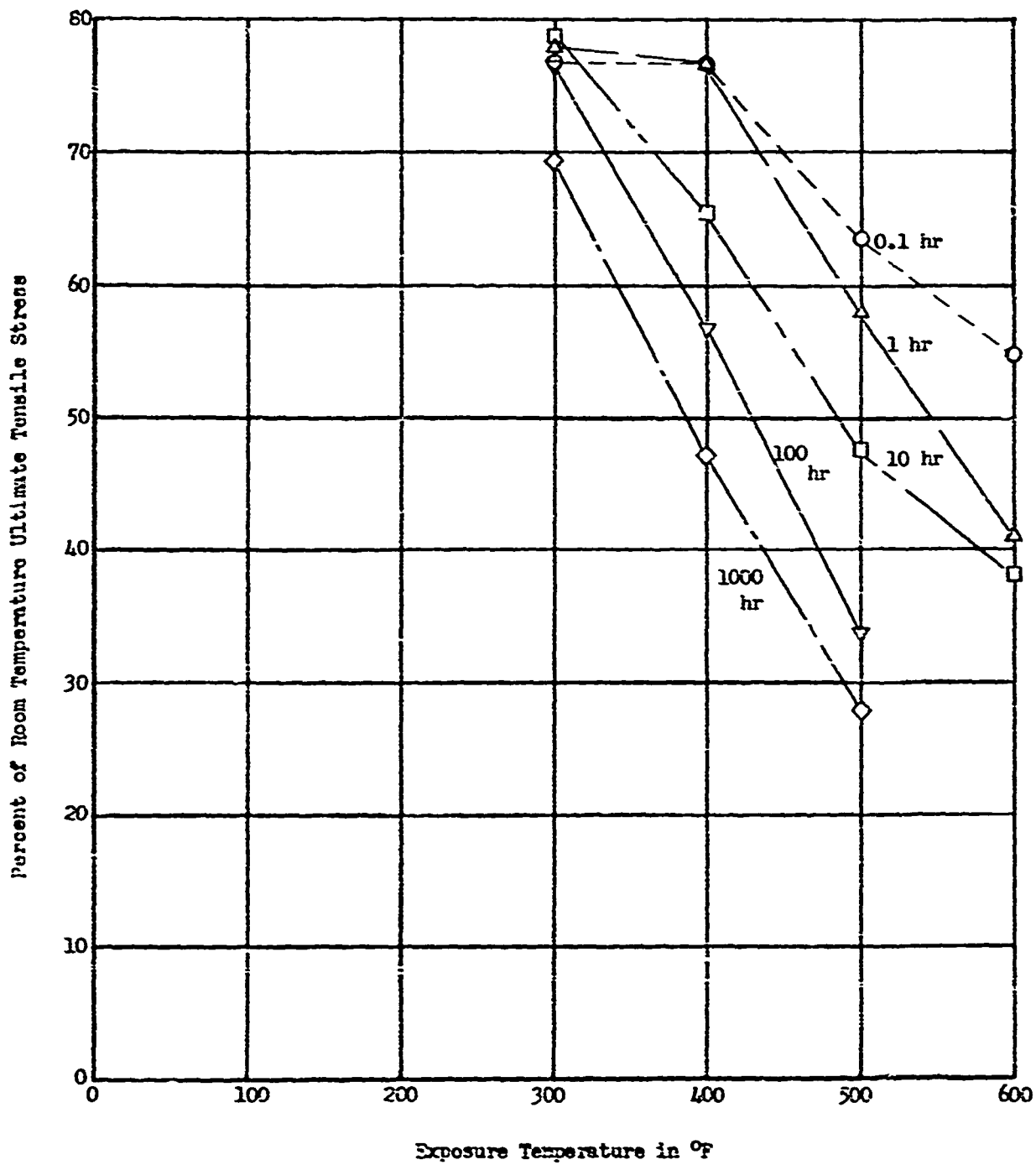


Figure 55. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

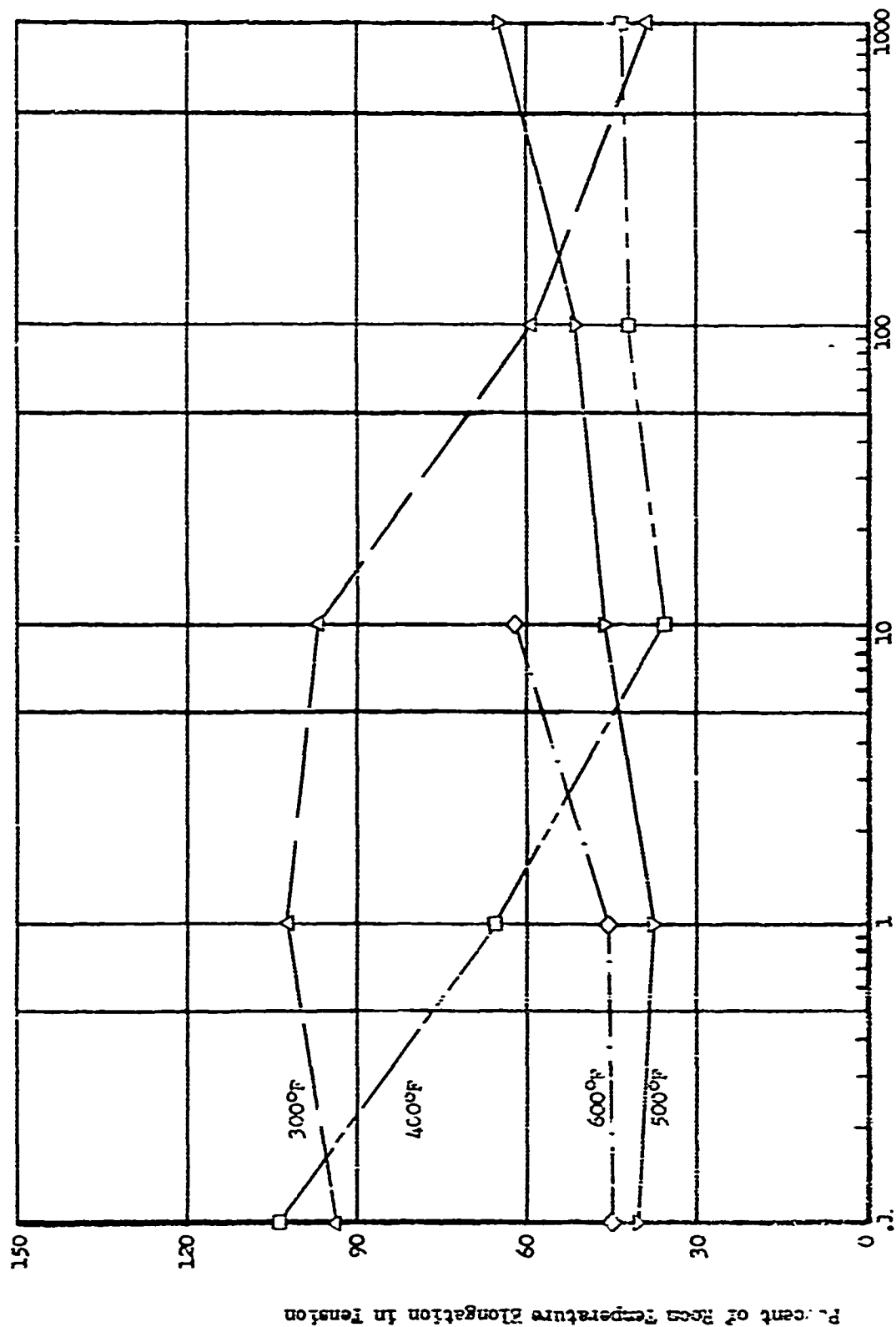


Figure 56. Elongation in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

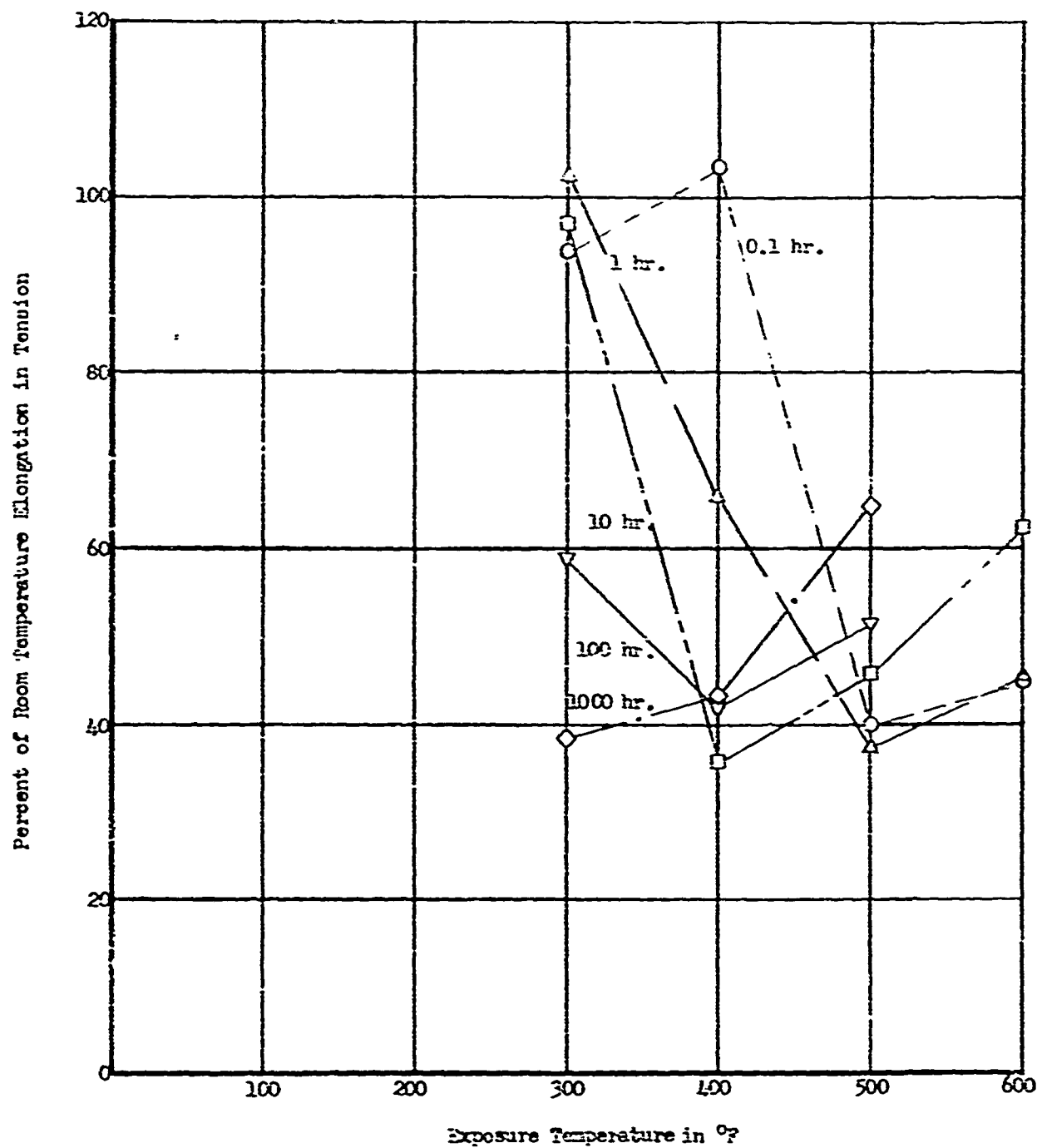


Figure 57. Elongation in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

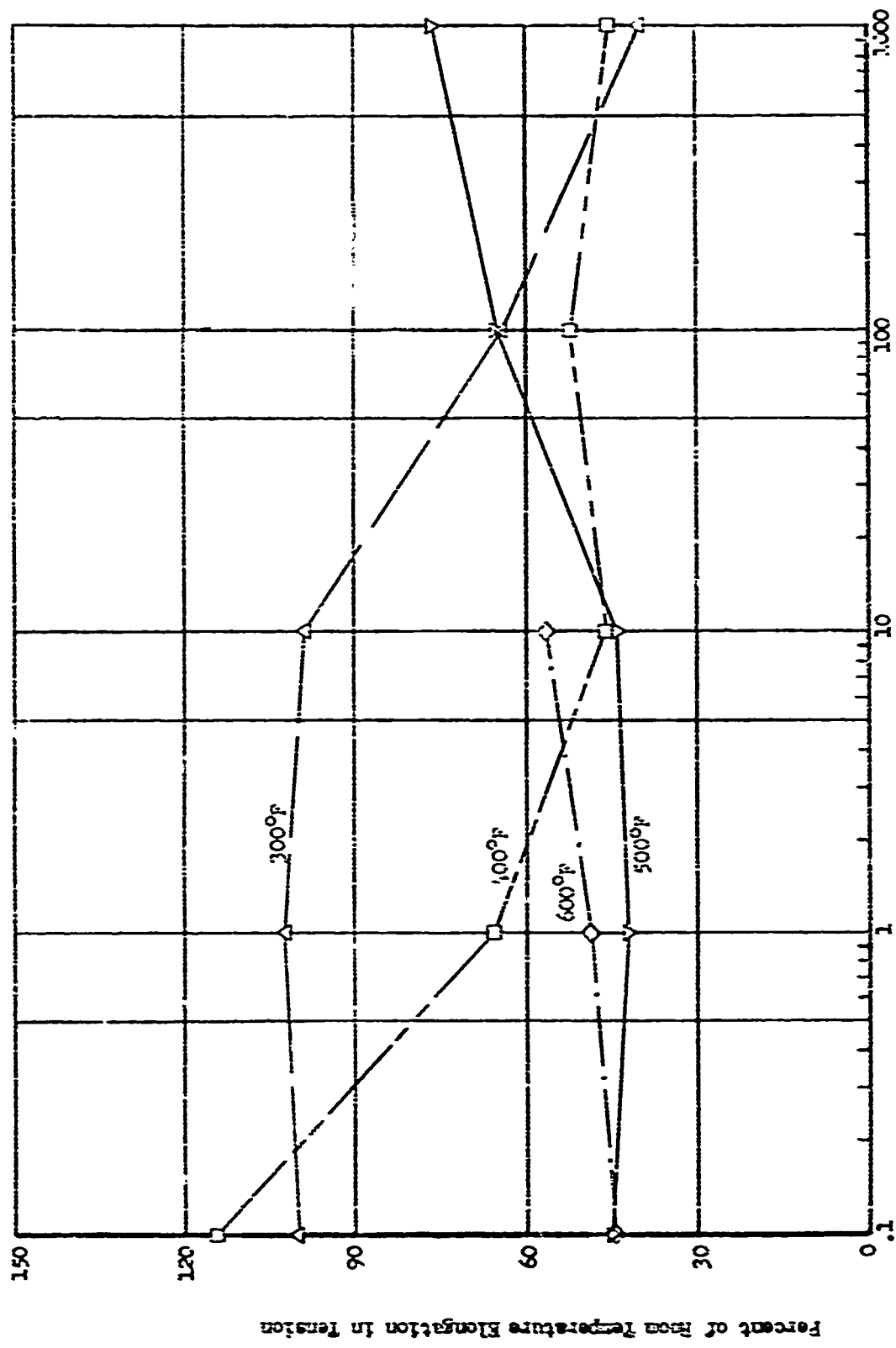


Figure 58. Elongation in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

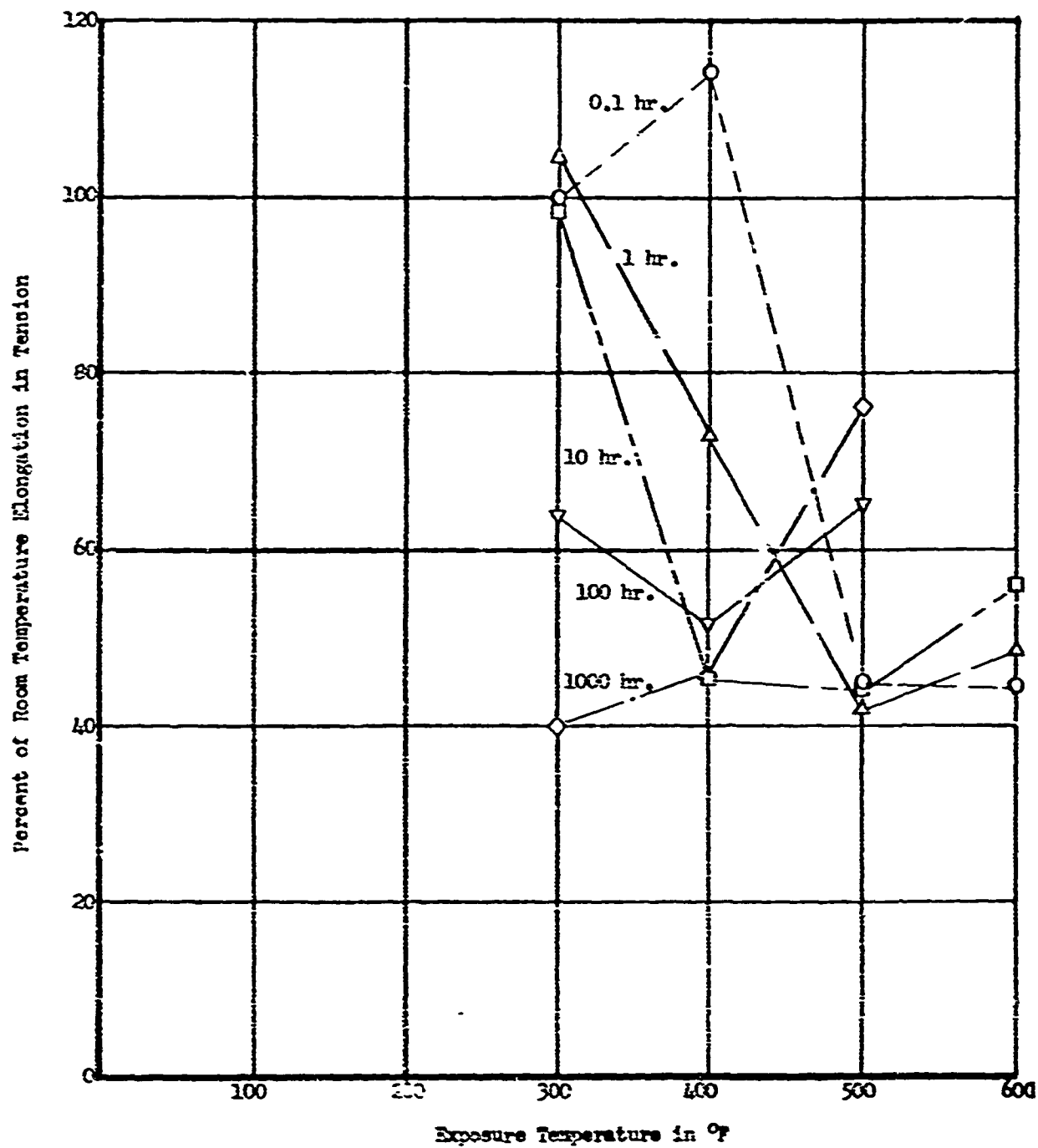


Figure 59.

Elongation in Tension of 2024-T3 Clad Sheet at 200°F
After Exposure to Elevated Temperatures

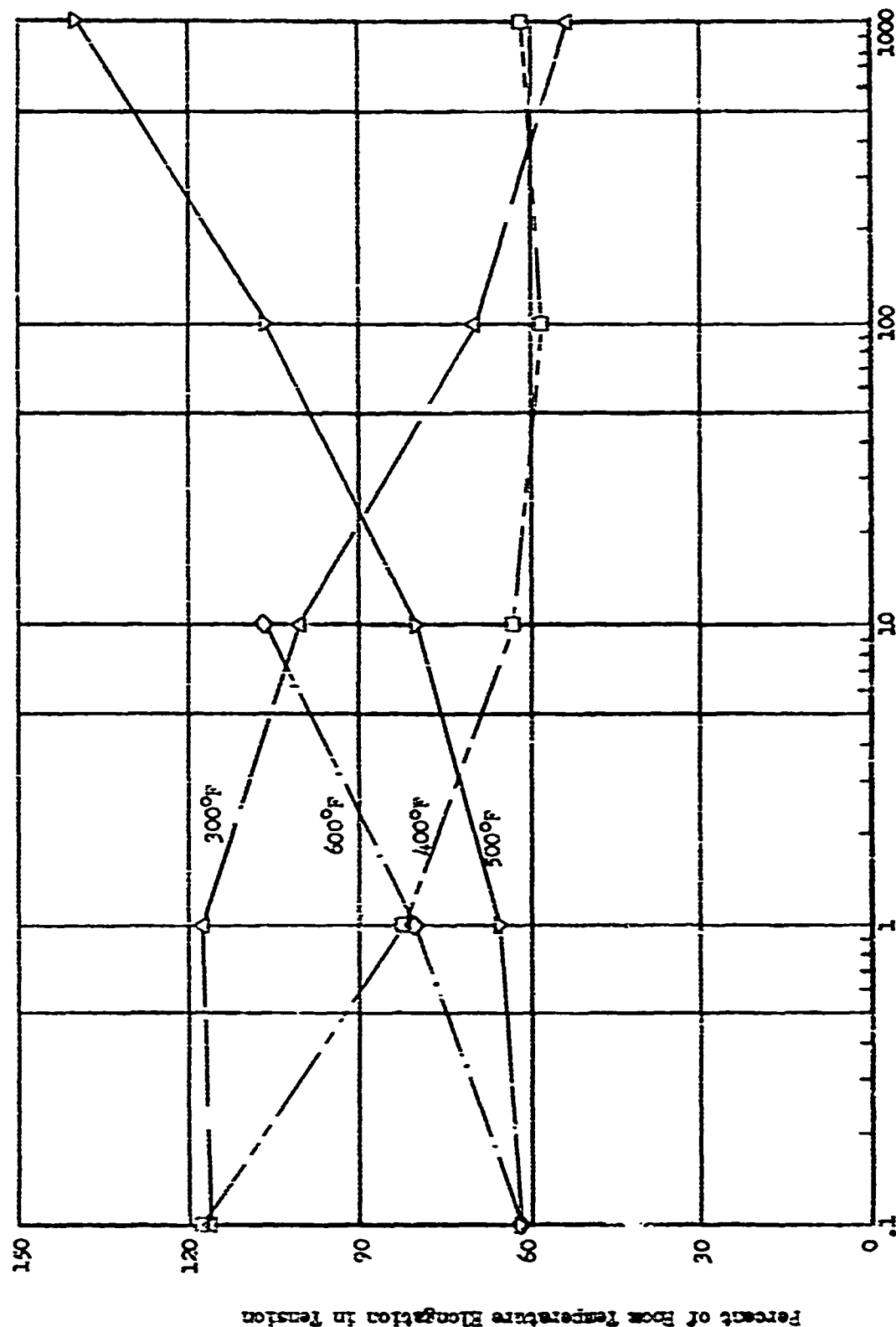


Figure 60.
Elongation in Tension of 2024-T3 Clad Sheet at 300°F After Exposure
to Elevated Temperatures

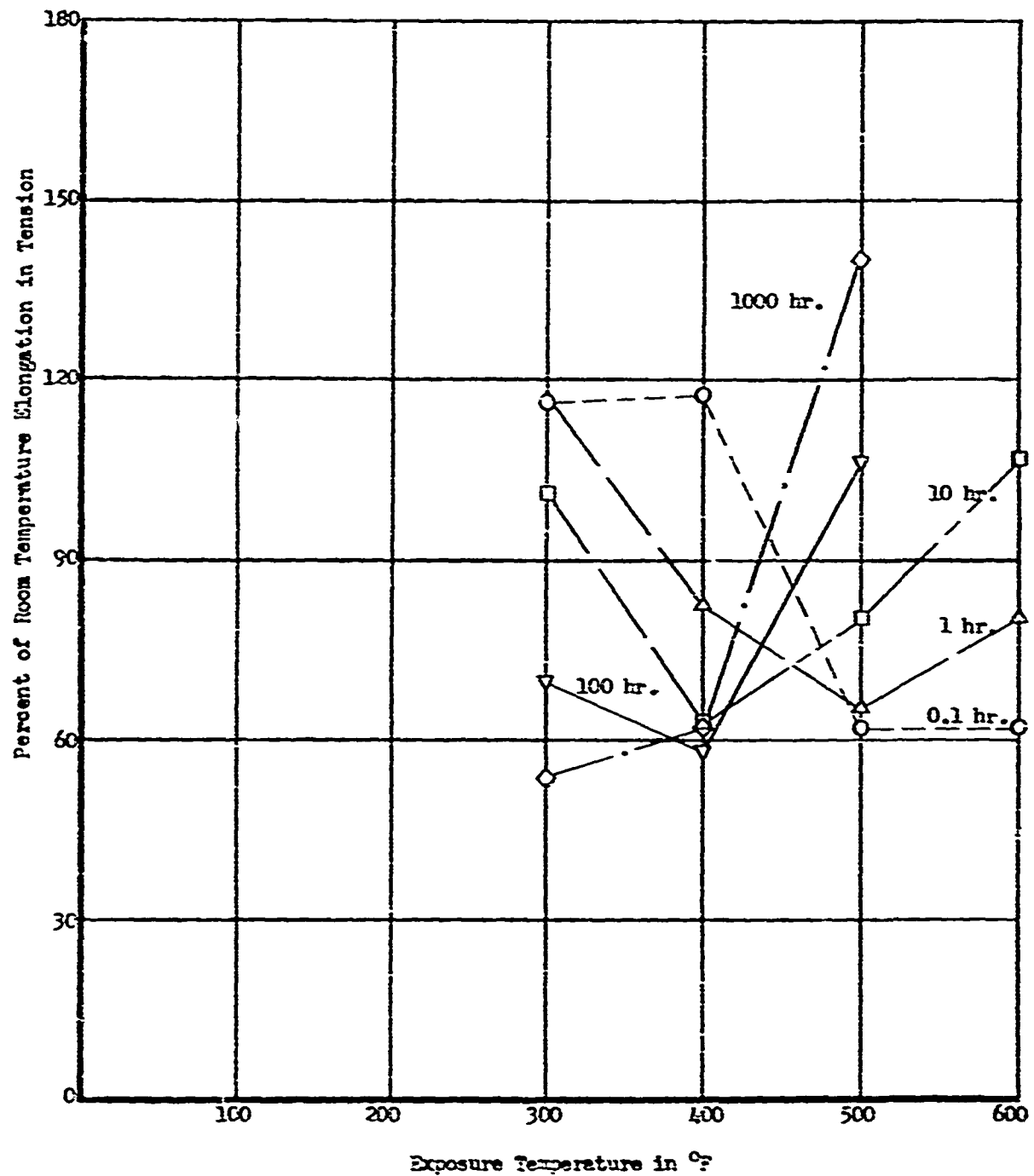


Figure 61.

Elongation in Tension of 2024-T3 Clad Sheet at 300°F
After Exposure to Elevated Temperatures

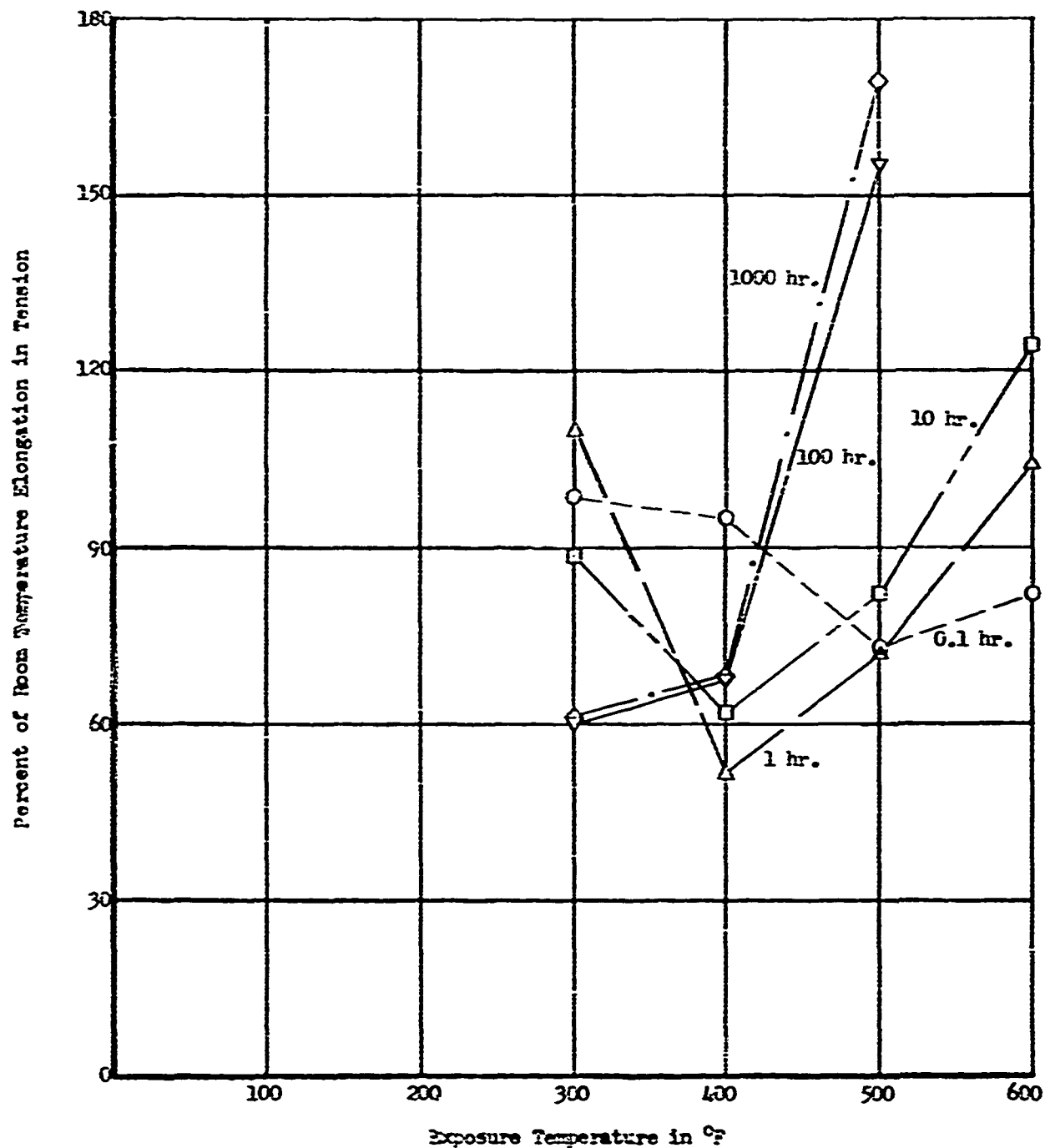


Figure 62.

Elongation in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

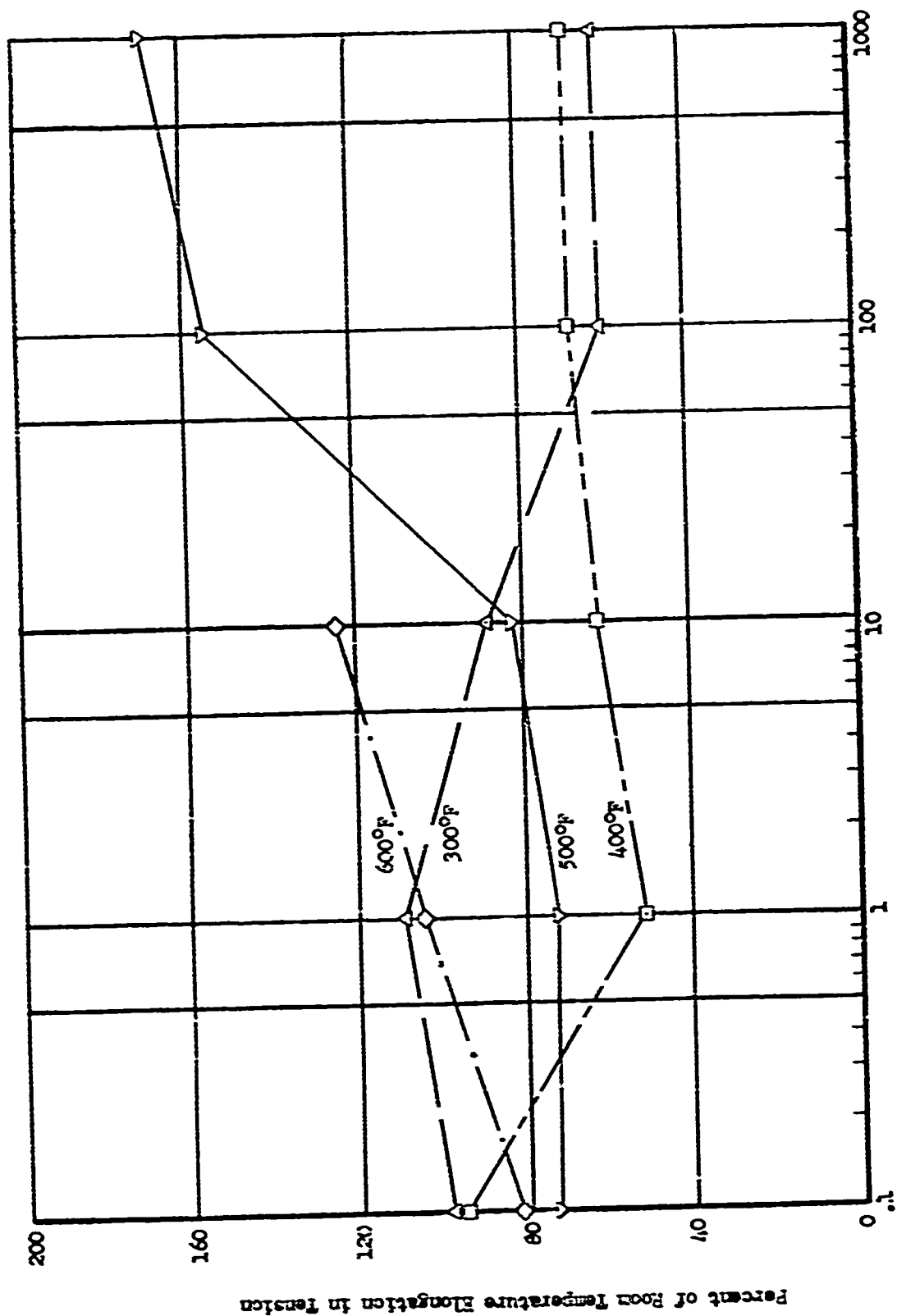


Figure 63.
Elongation in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

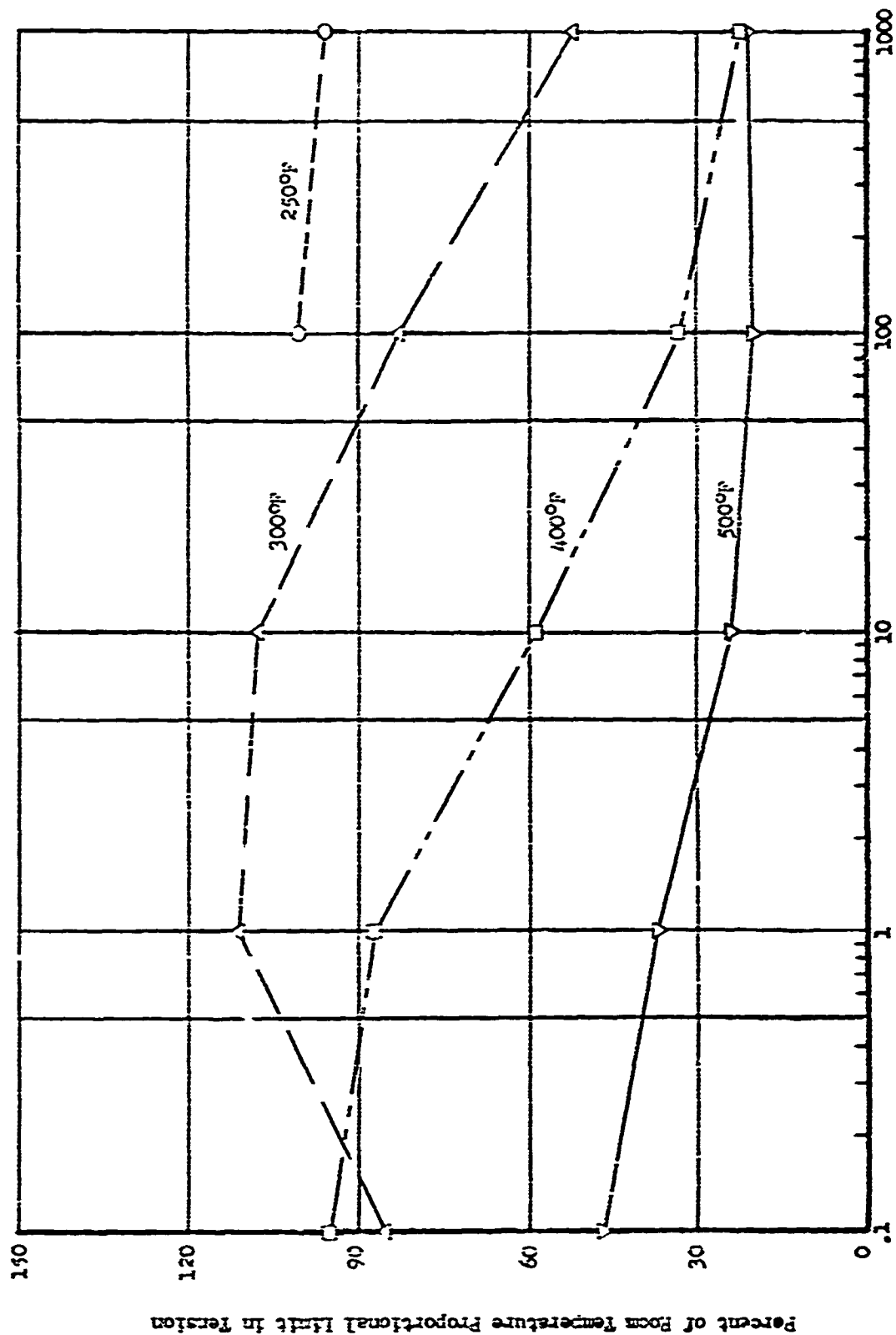


Figure 64. Proportional Limit in Tension of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

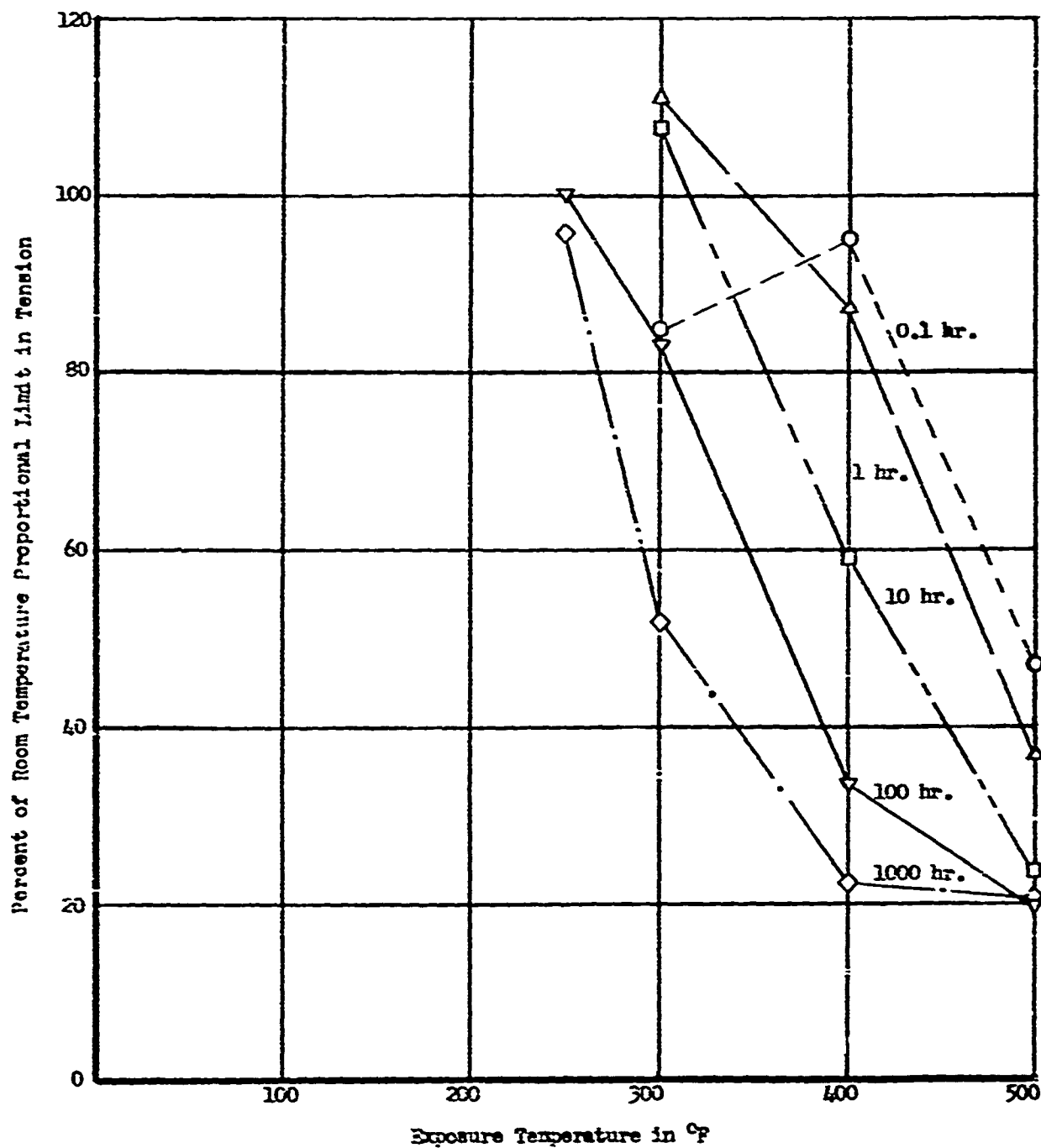


Figure 65.

Proportional Limit in Tension of 7075-T6 Clad Sheet
at Room Temperature After Exposure to Elevated Temperatures

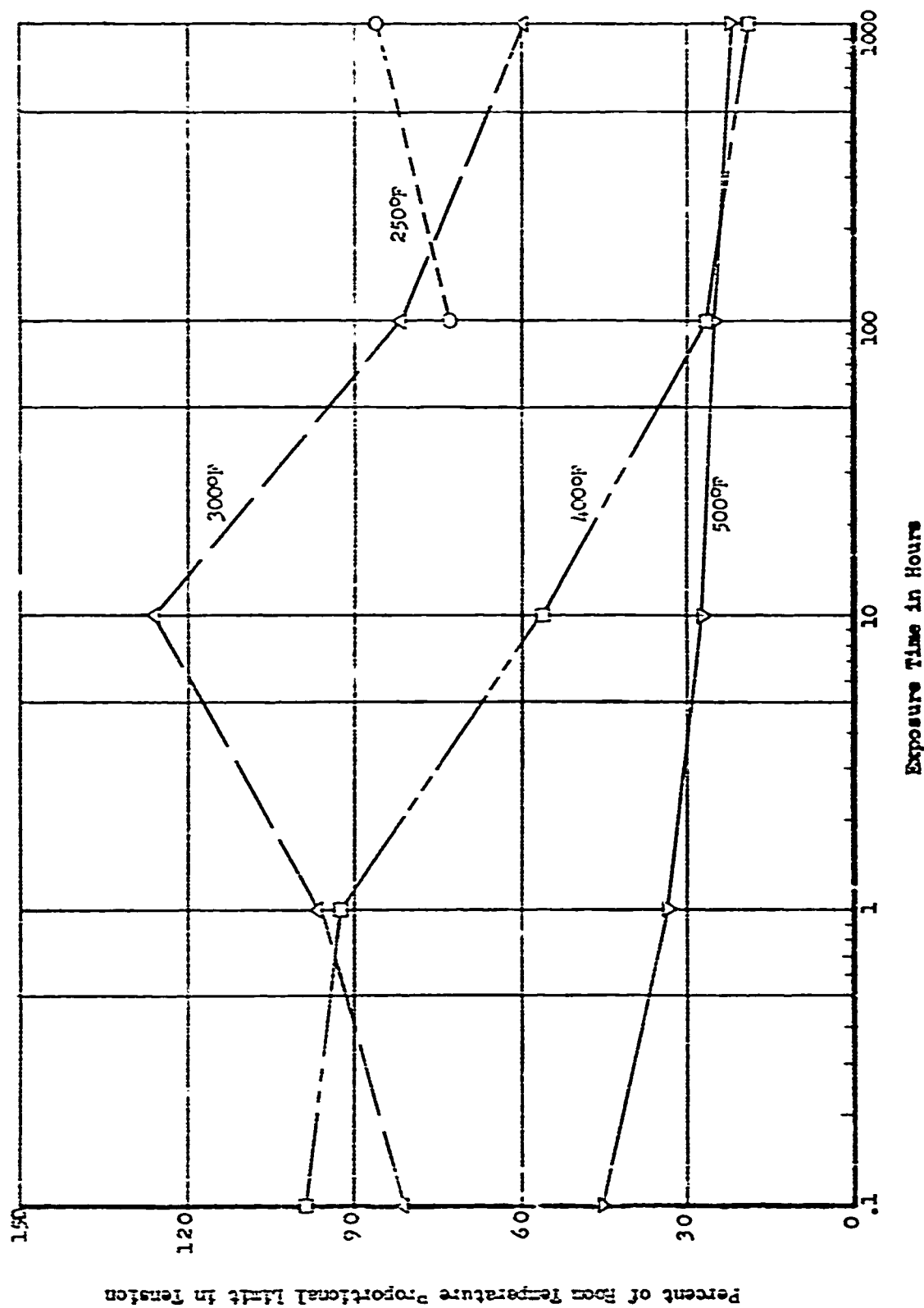


Figure 66. Proportional Limit in Tension of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

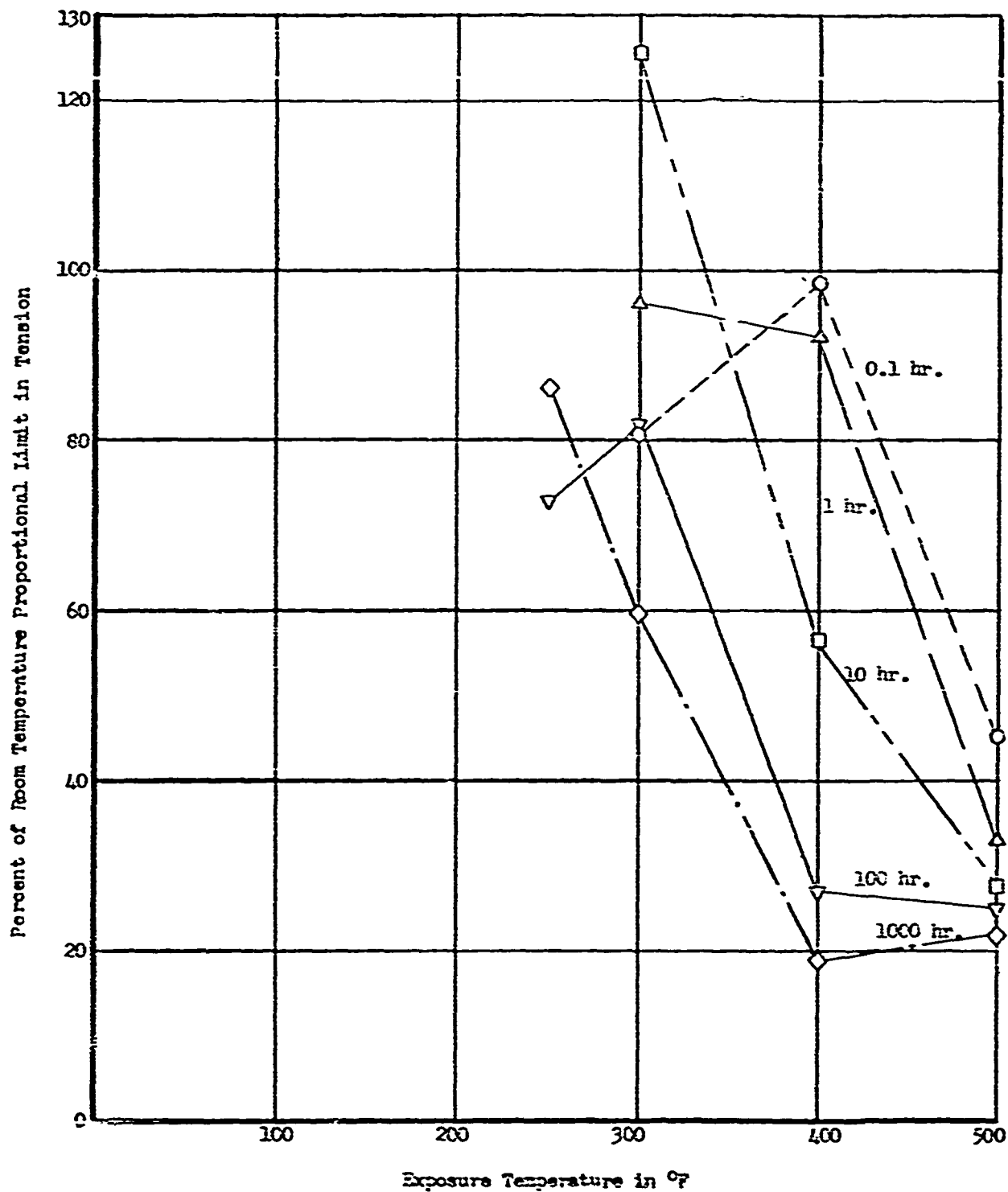


Figure 67.

Proportional Limit in Tension of 7075-T6 Clad Sheet
at 200°F After Exposure to Elevated Temperatures

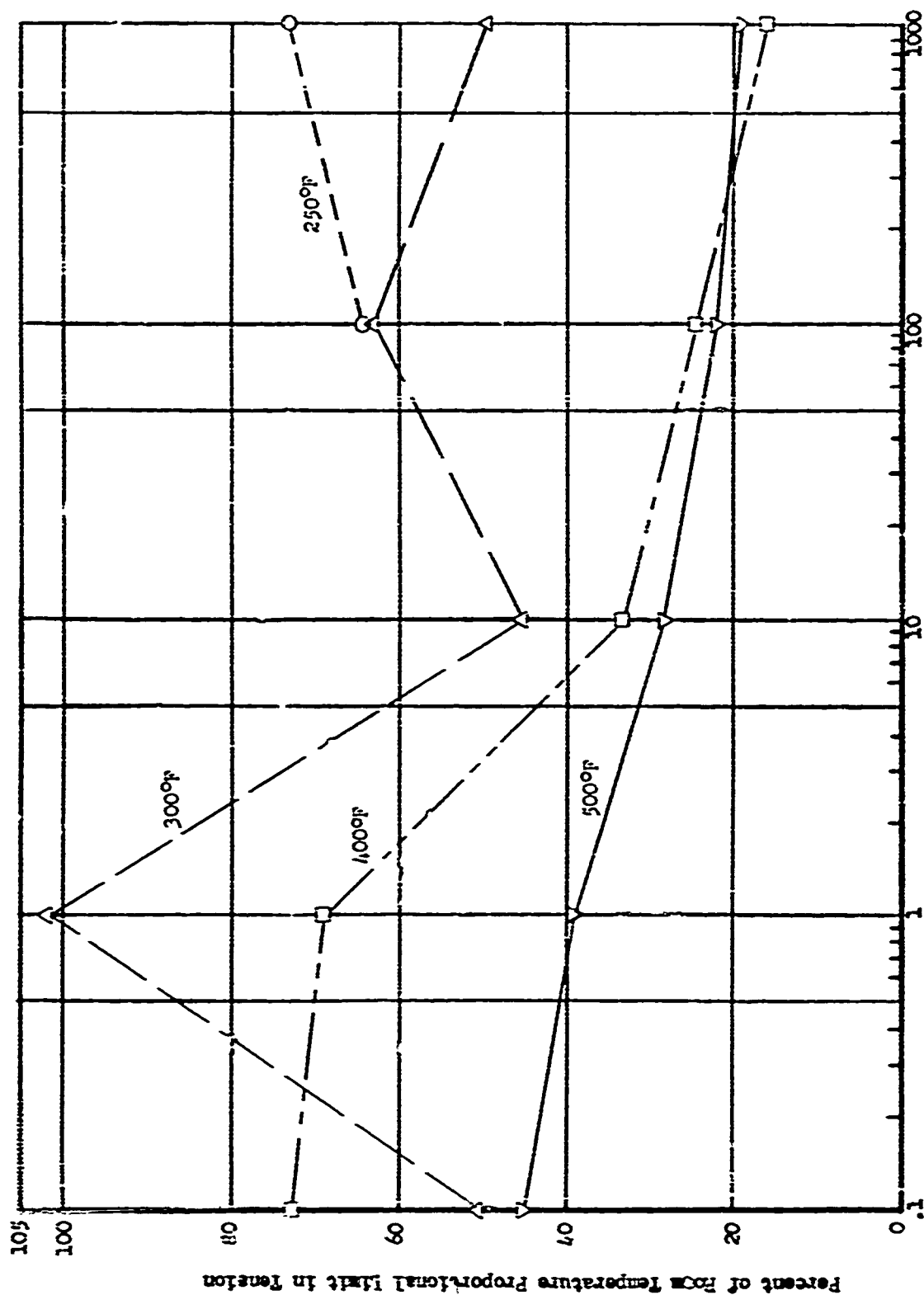


Figure 68.
Proportional Limit in Tension of 7075-T6 Clad
Sheet at 300°F After Exposure to Elevated Temperatures

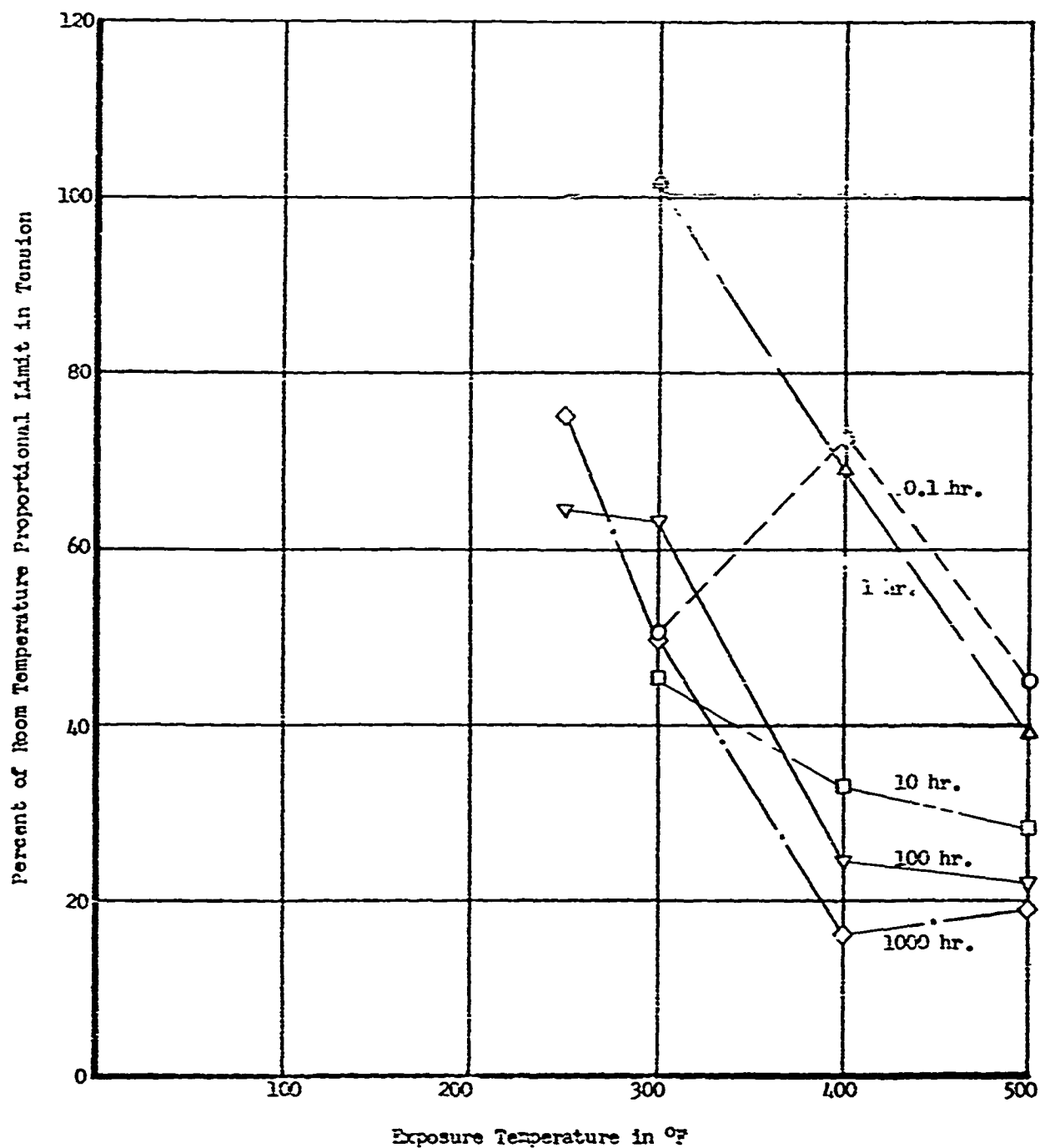


Figure 69.

Proportional Limit in Tension of 7075-T6 Clad Sheet
at 300°F After Exposure to Elevated Temperatures

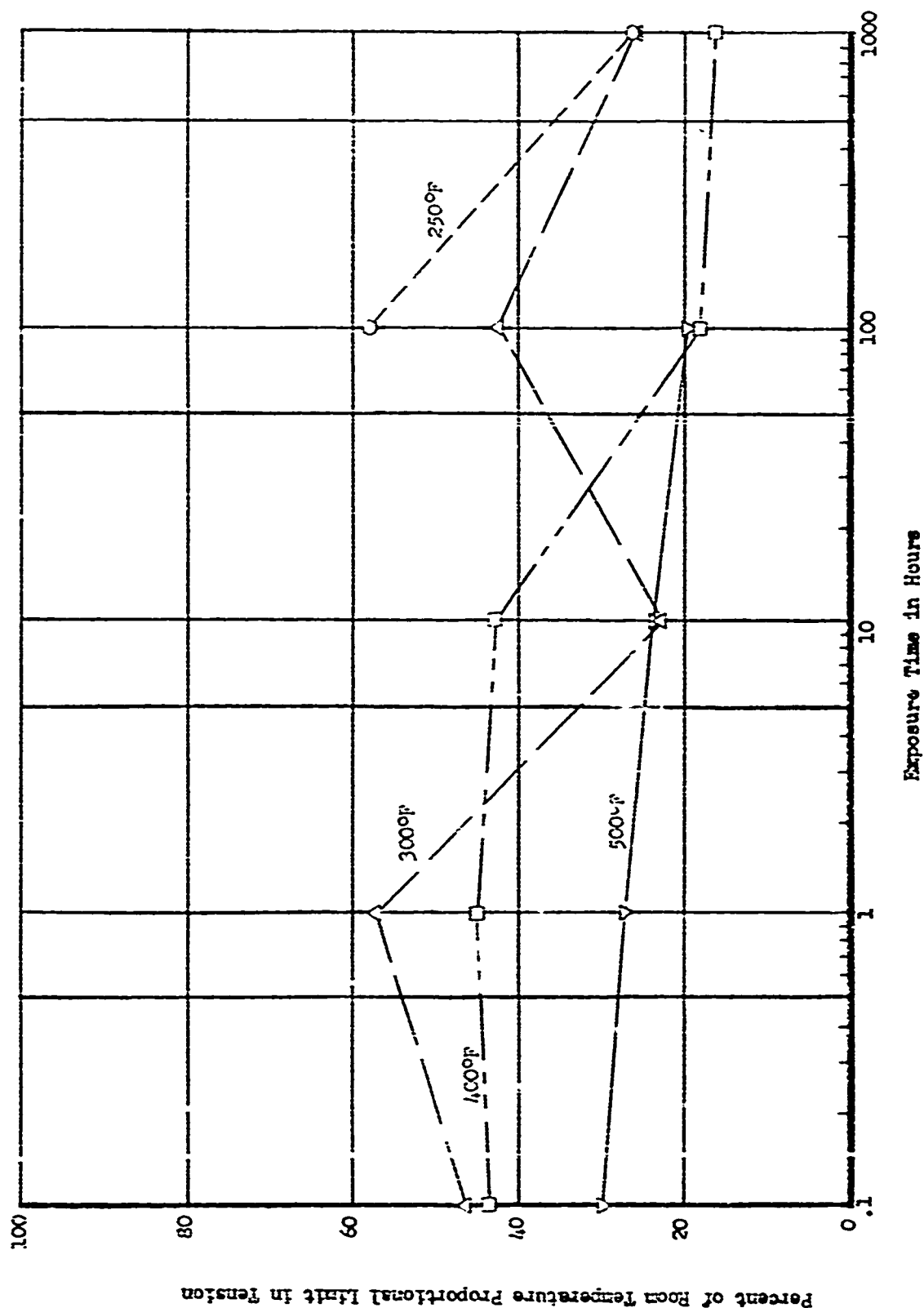


Figure 70.
Proportional Limit in Tension of 7075-T6 Clad
Sheet at 400°F After Exposure to Elevated Temperatures

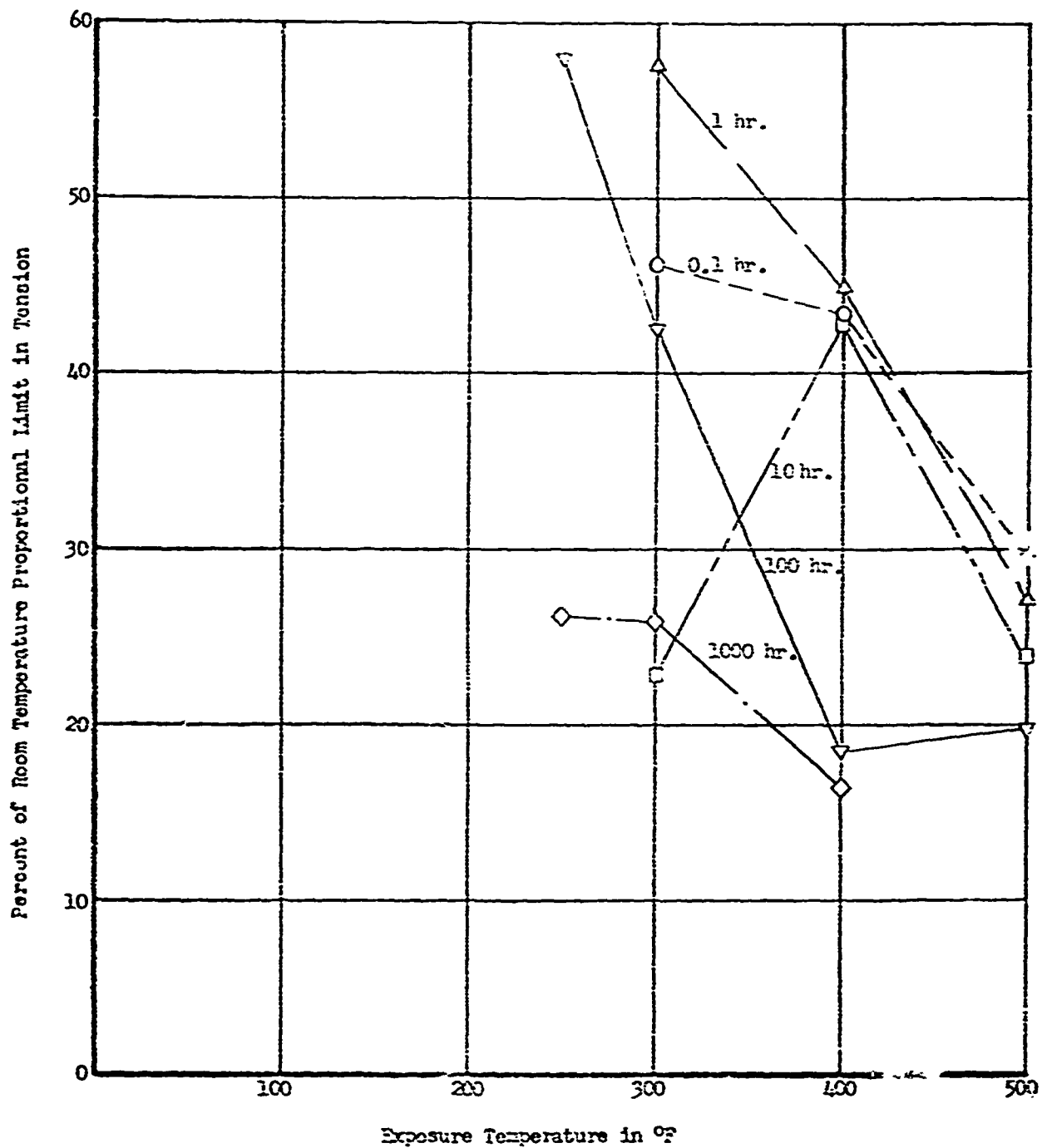


Figure 71.

Proportional Limit in Tension of 7075-T6 Clad
Sheet at 400°F After Exposure to Elevated Temperatures

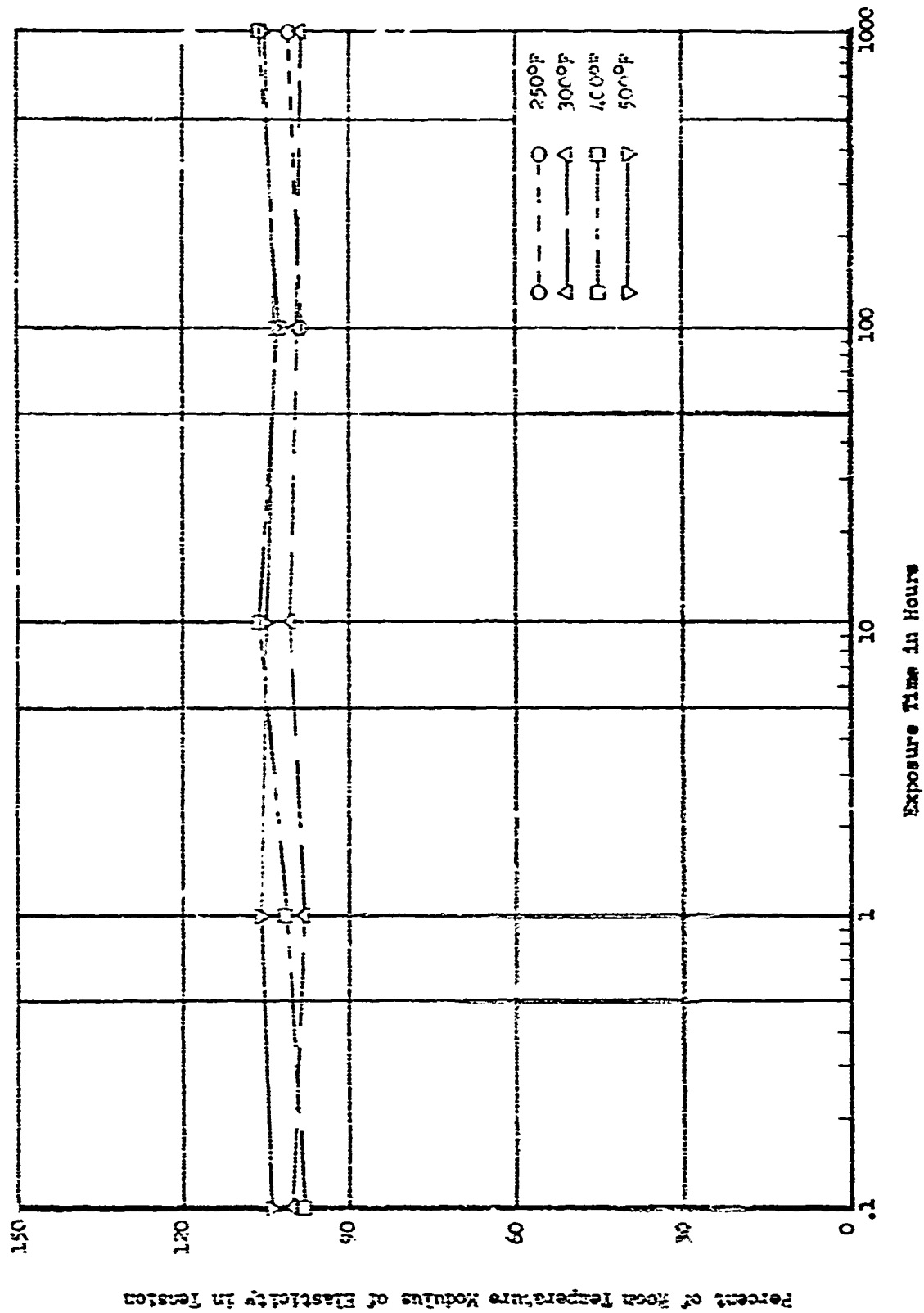


Figure 72. Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

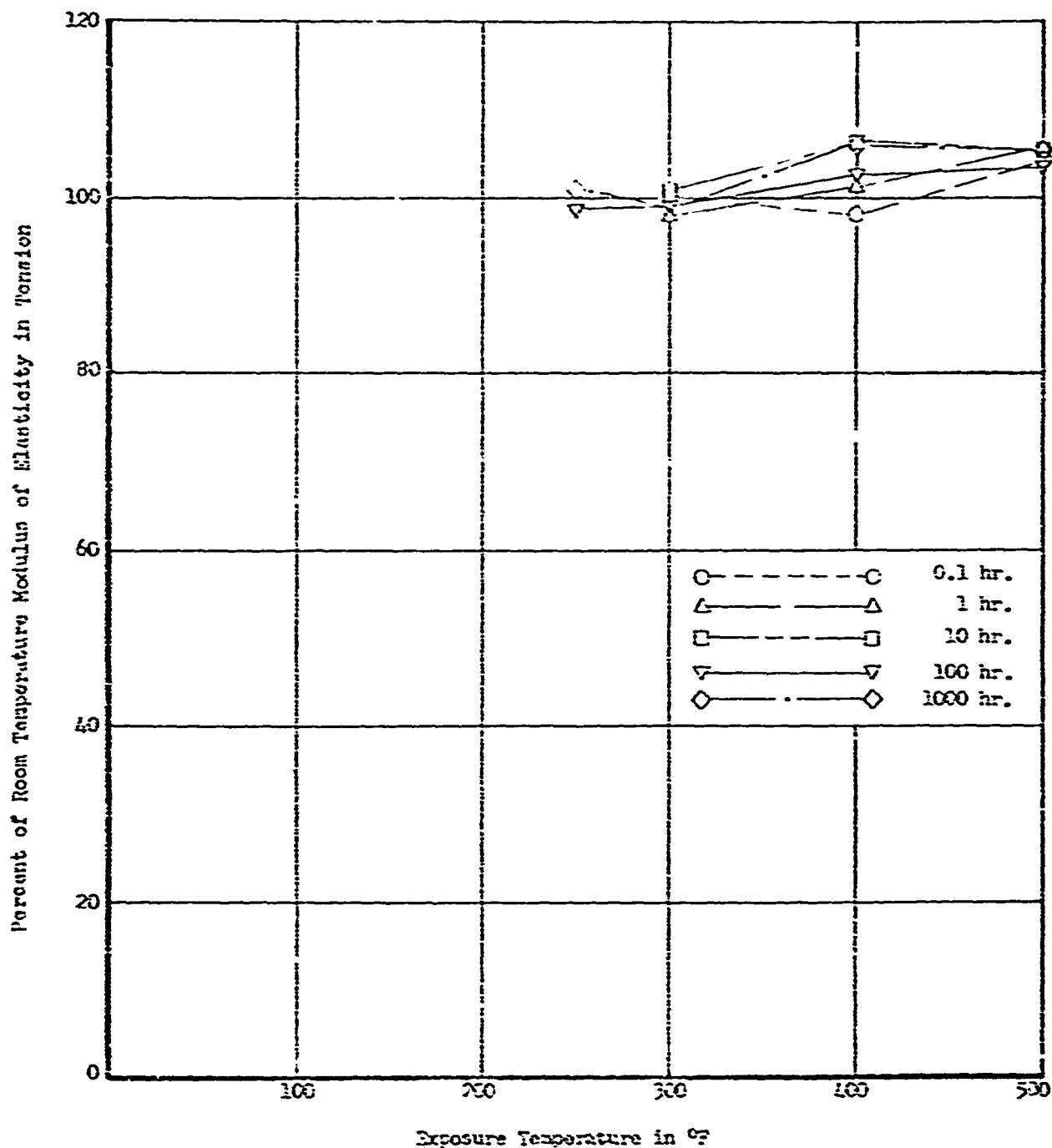


Figure 73.

Modulus of Elasticity in Tension of 7075-76 Clad Sheet
at Room Temperature After Exposure to Elevated Temperatures

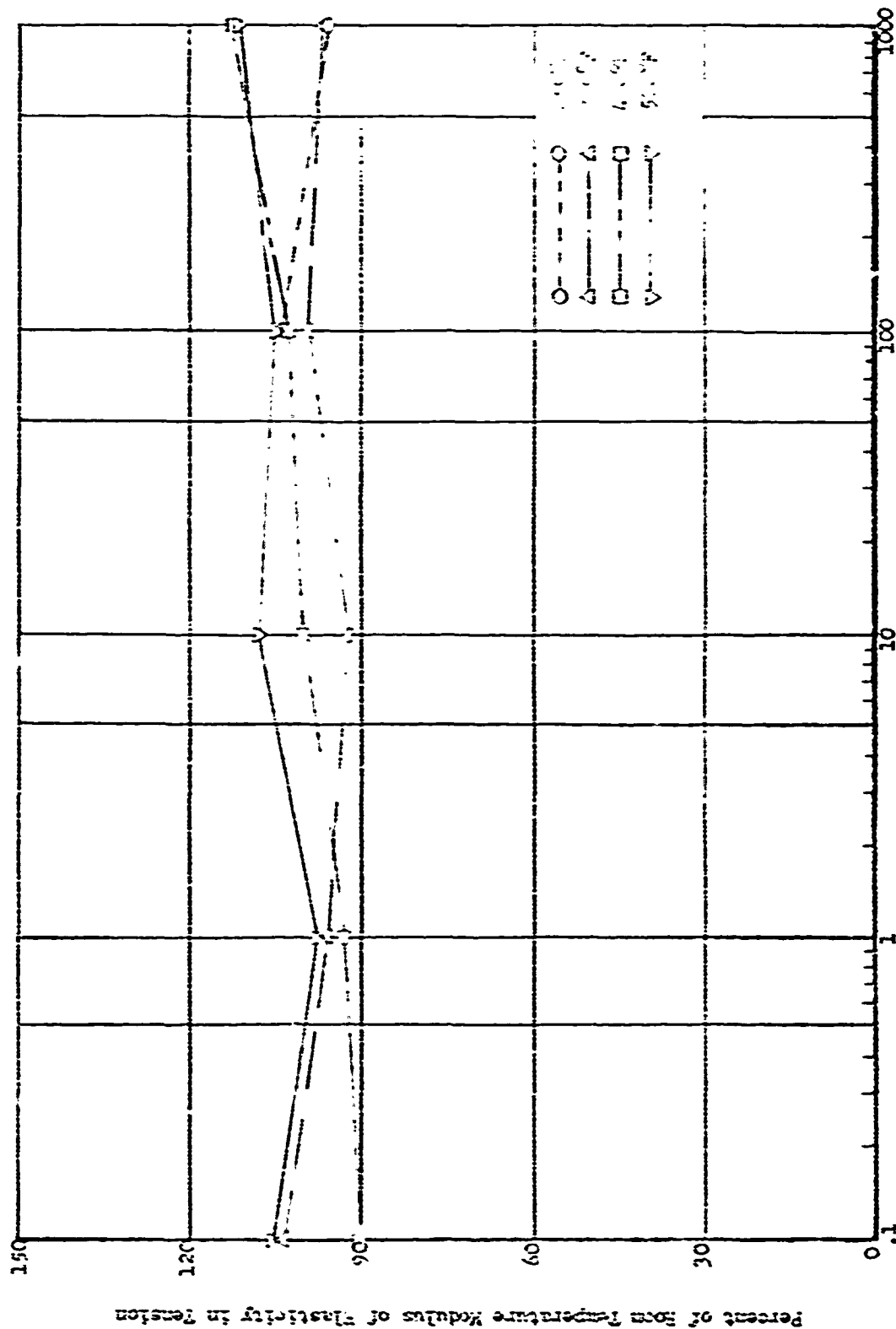


Figure 7/4.

Modulus of Elasticity in Tension of 7075-T6 Clad
Shunt at 200°F After Exposure to Elevated Temperatures

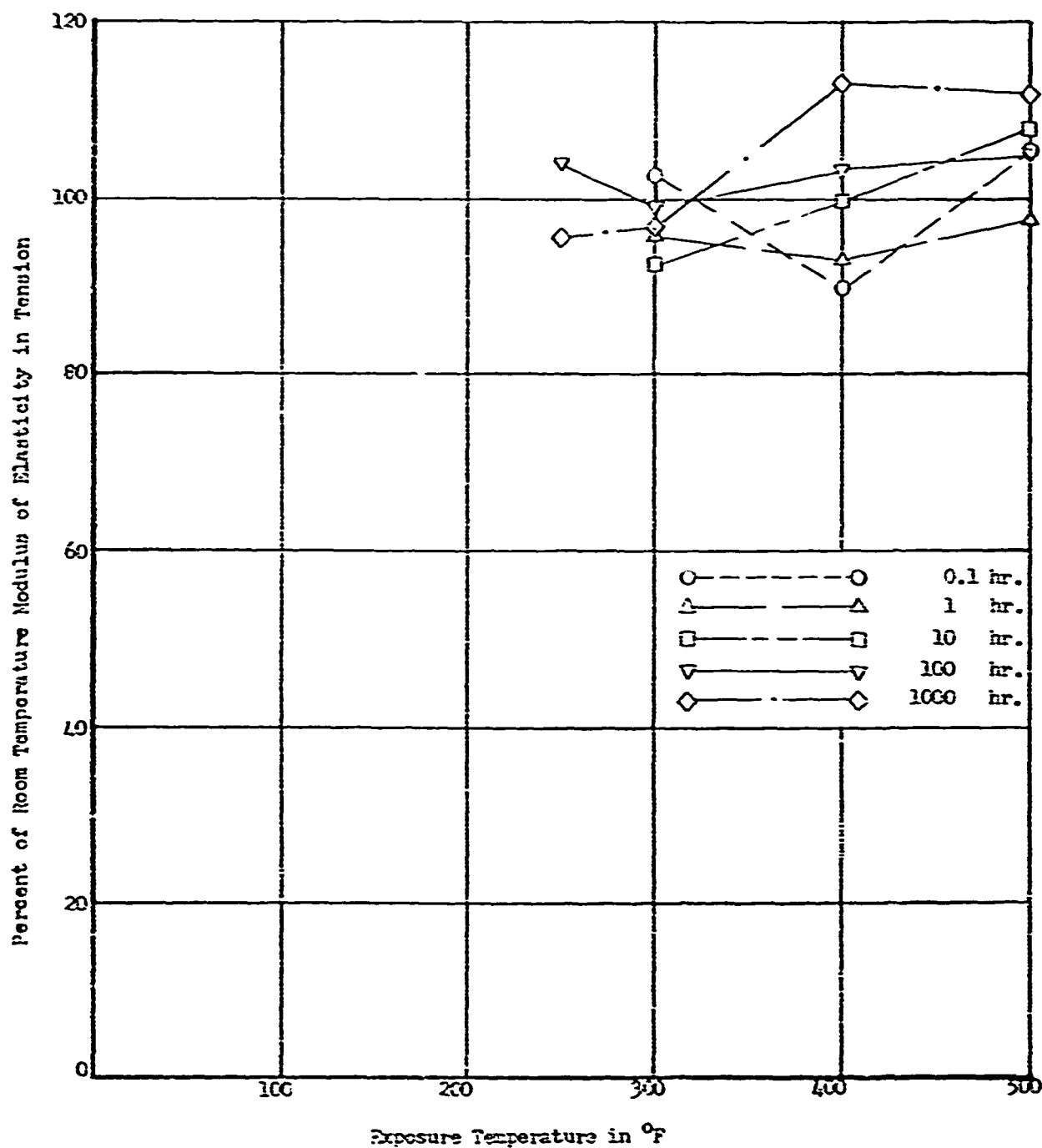


Figure 75. Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

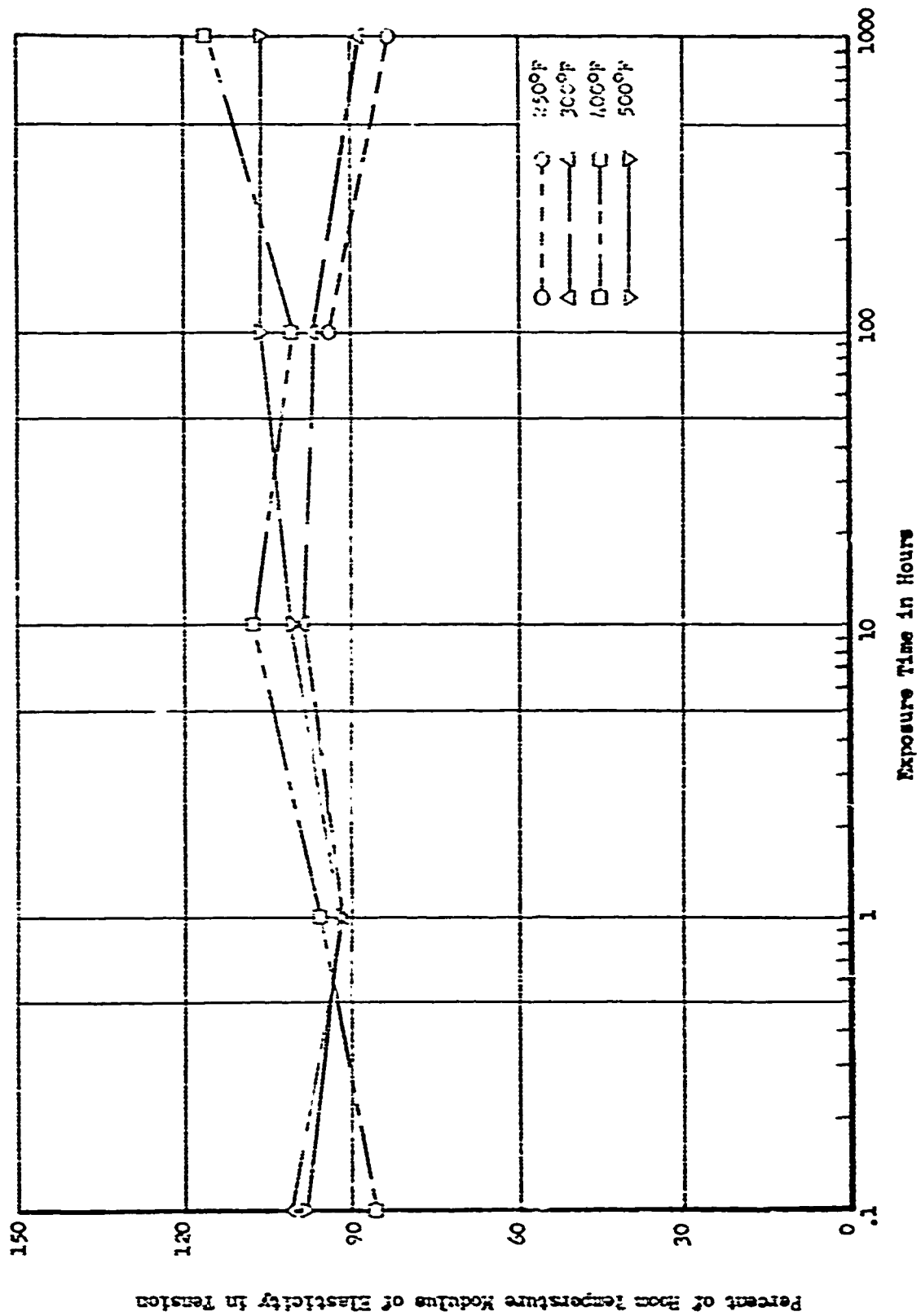


Figure 76.
Modulus of Elasticity in Tension of 7075-T6 Clad
Sheet at 300°F After Exposure to Elevated Temperatures

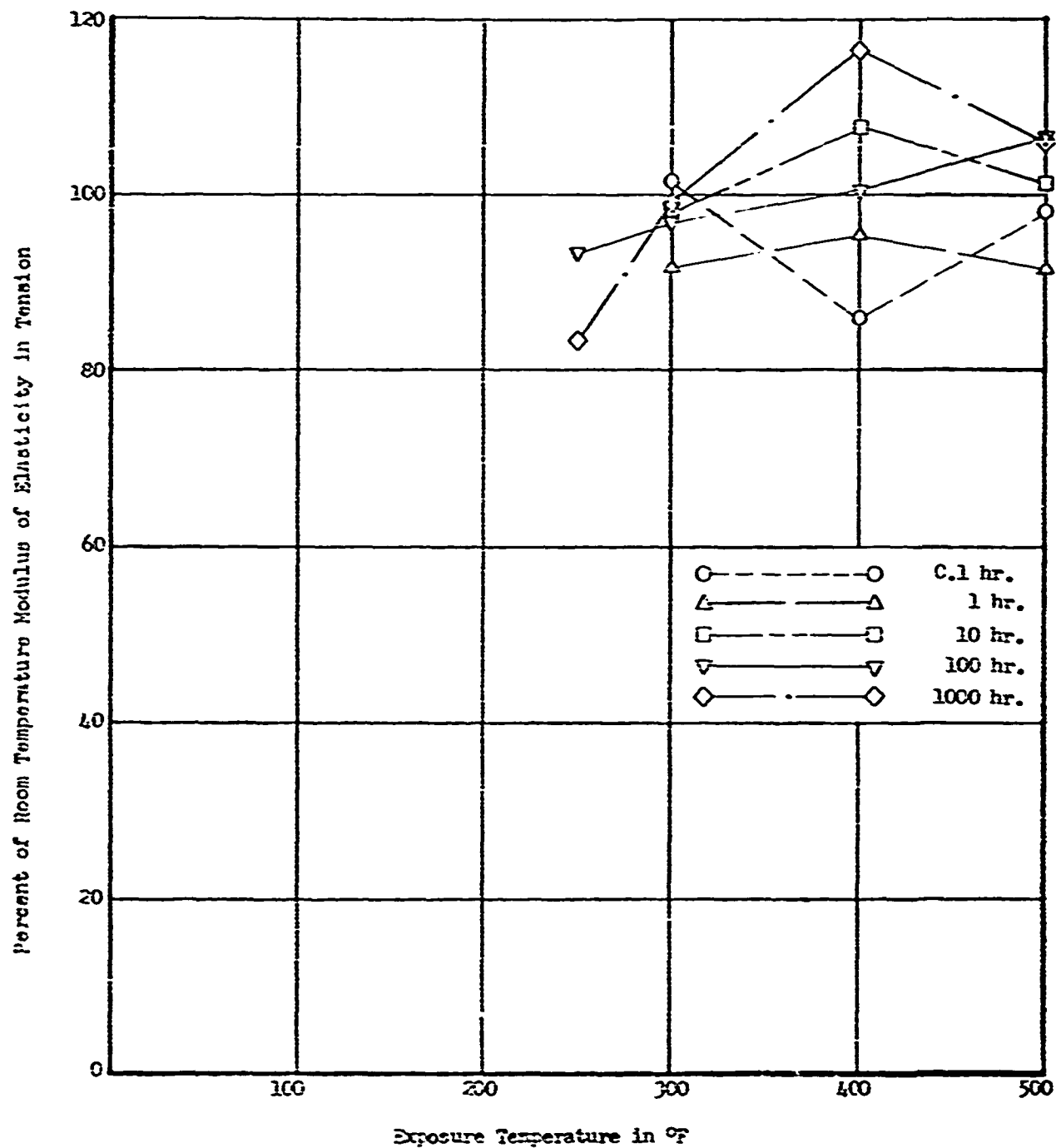


Figure 77.

Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

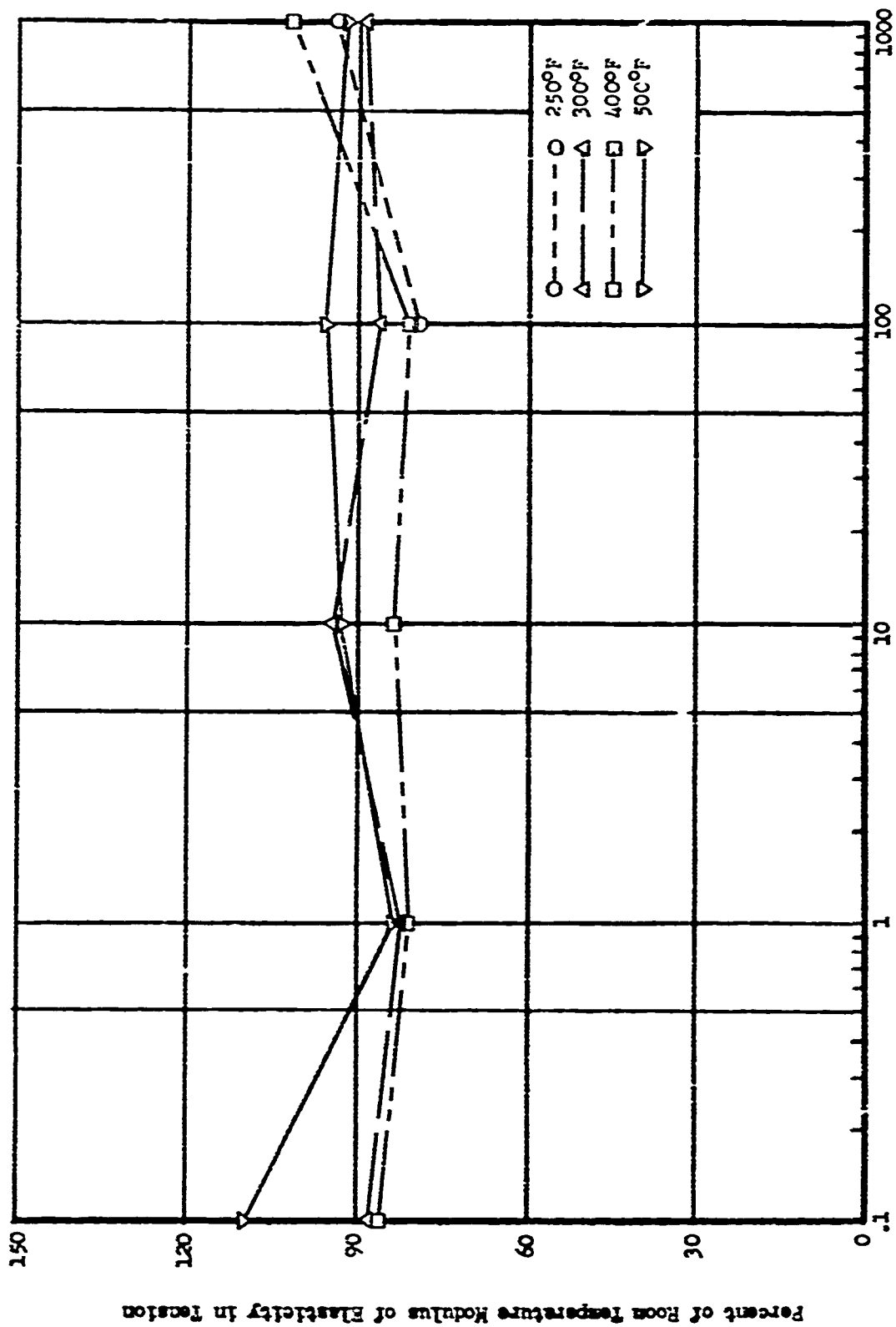


Figure 78.

Modulus of Elasticity in Tension of 7075-T6 Clad

Sheet at 400°F After Exposure to Elevated Temperatures

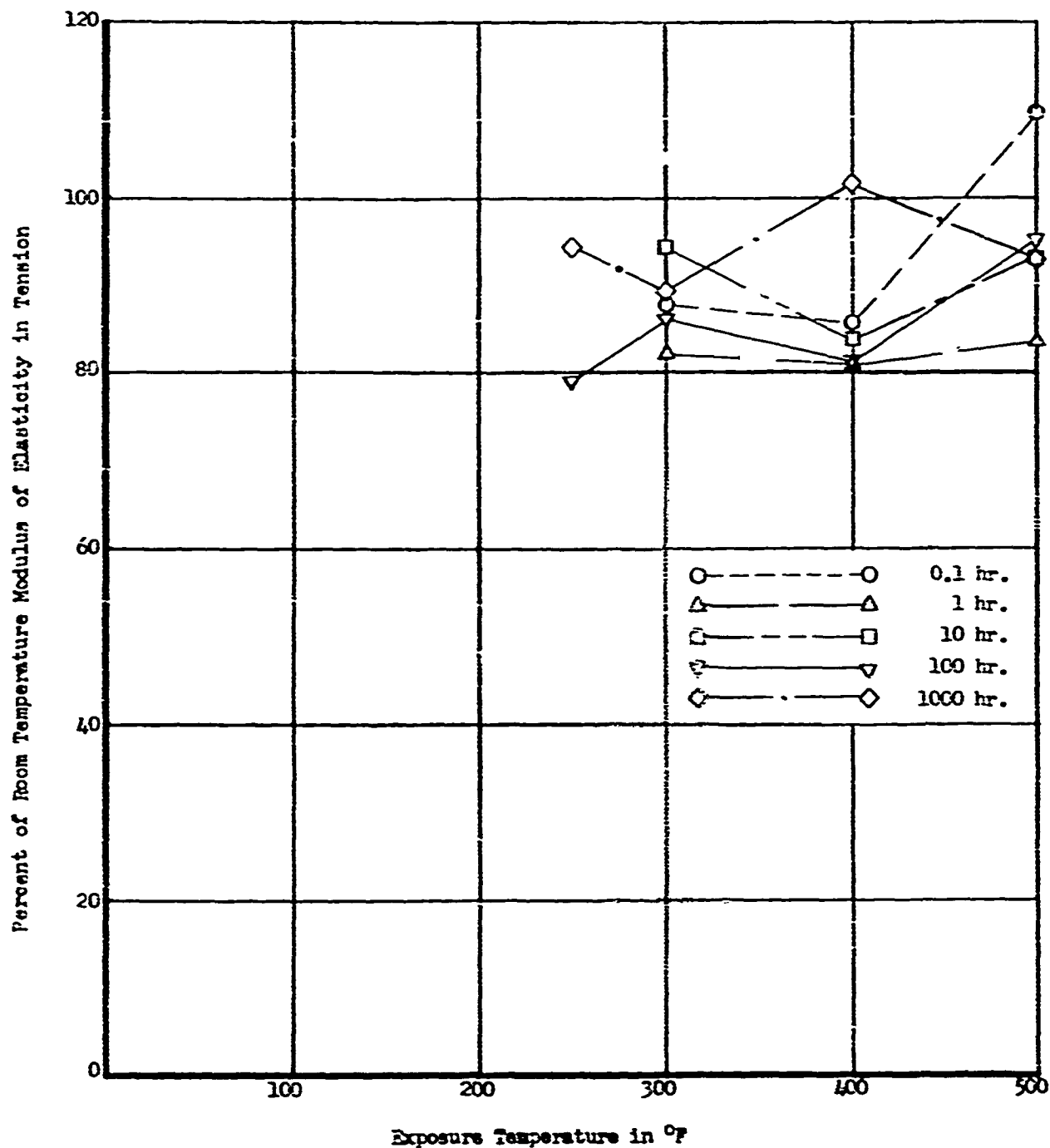


Figure 79.

Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

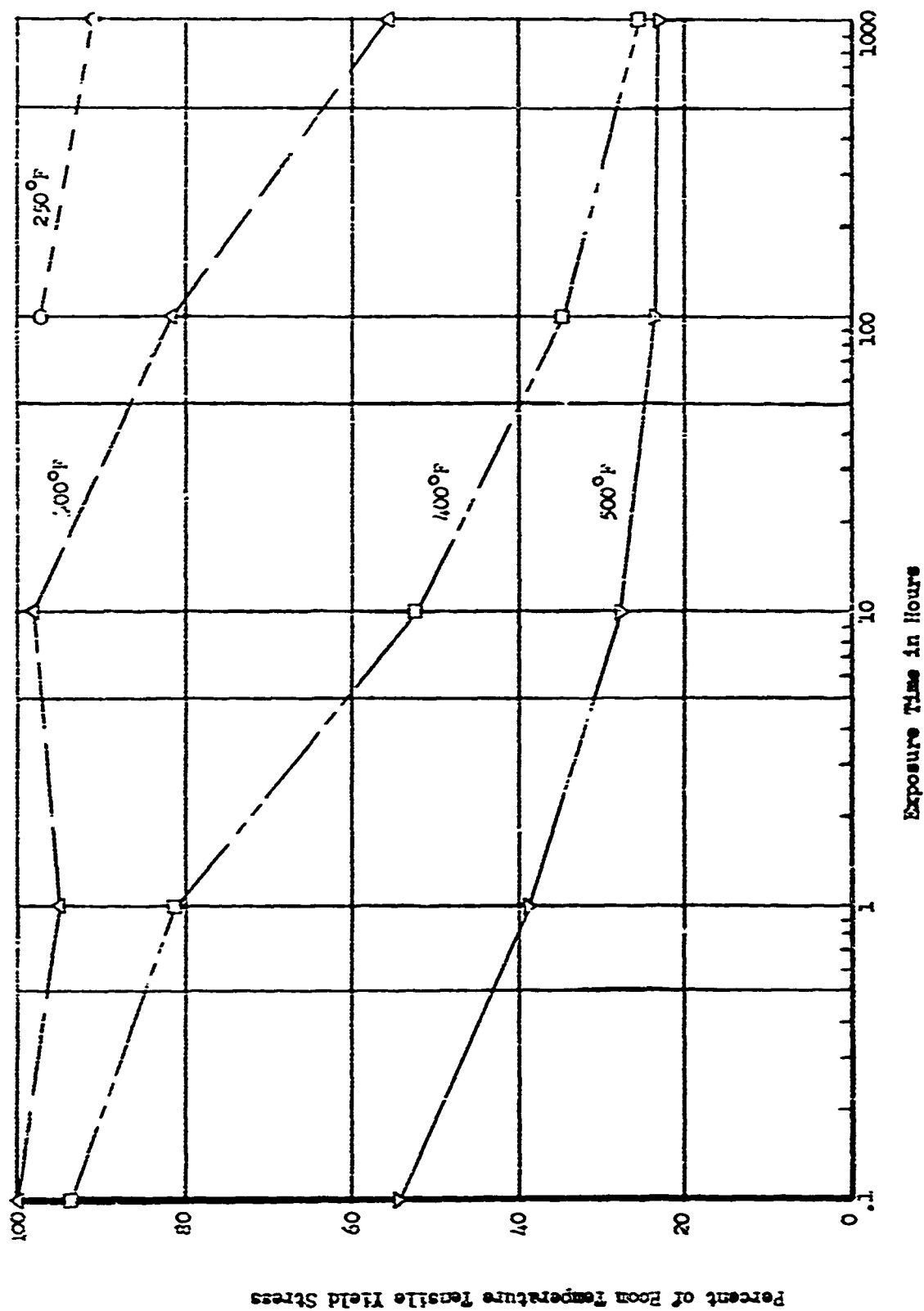


Figure 80. Tensile Yield Stress of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

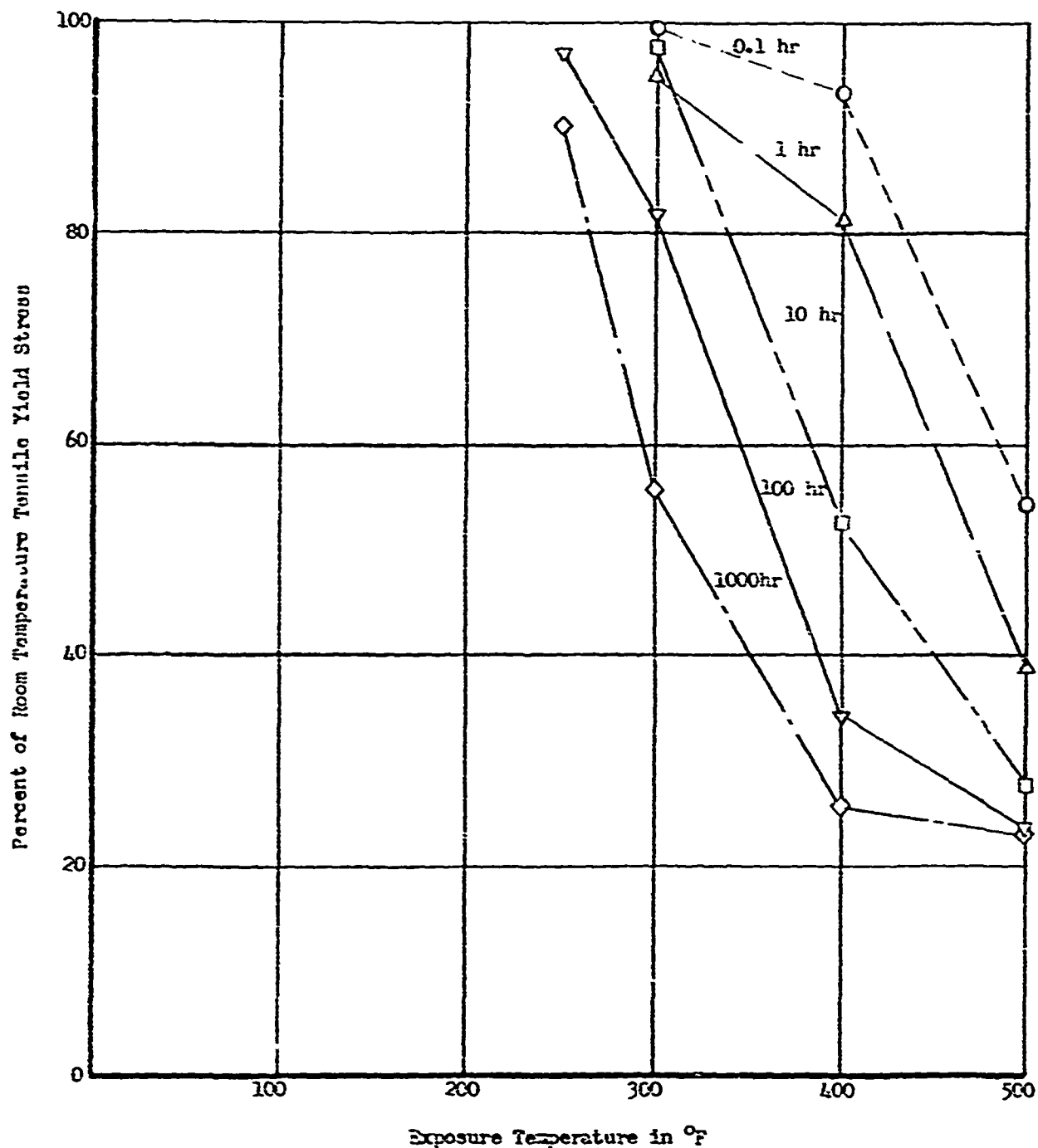


Figure 81.

Tensile Yield Stress of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

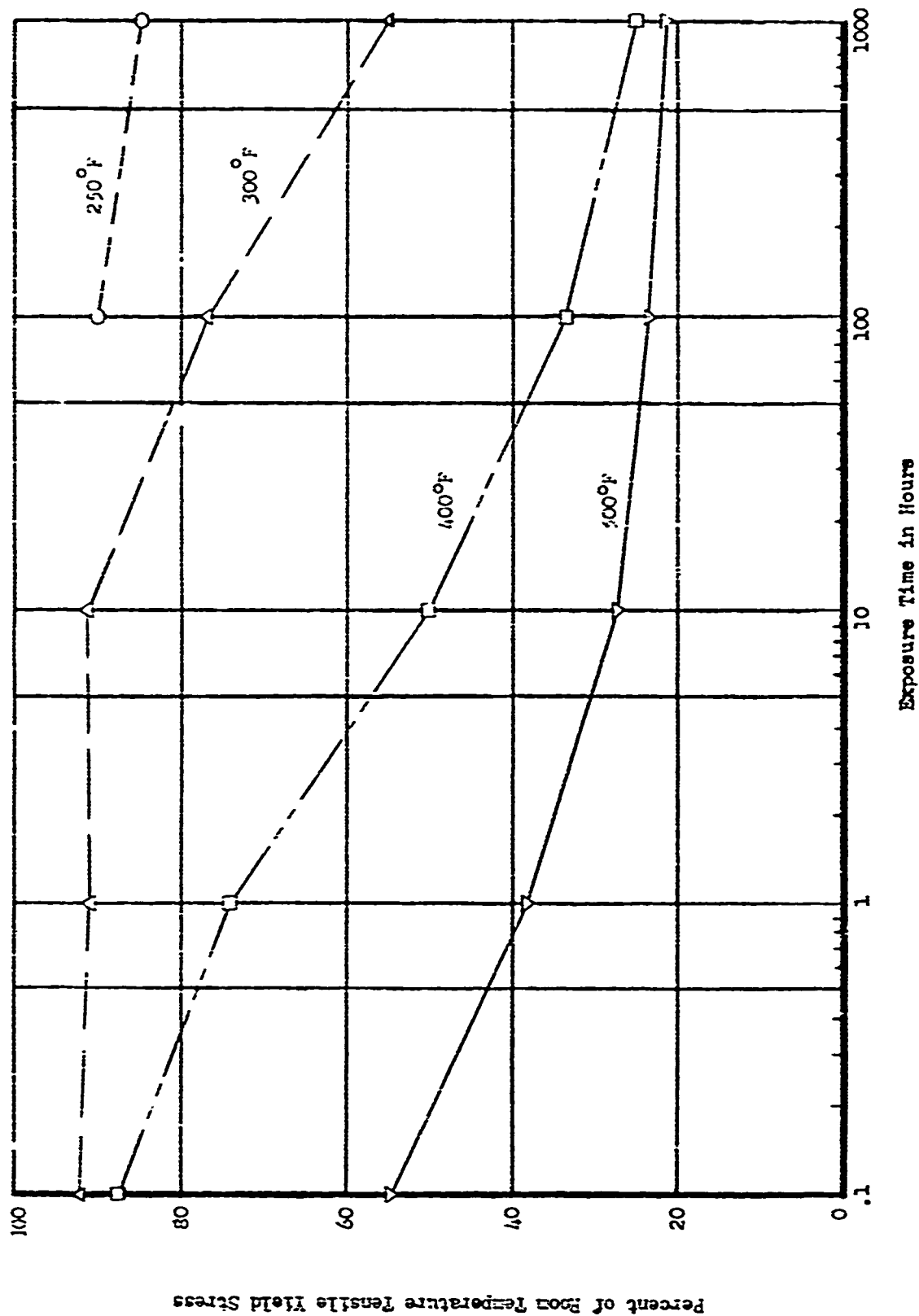


Figure 82. Tensile Yield Stress of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

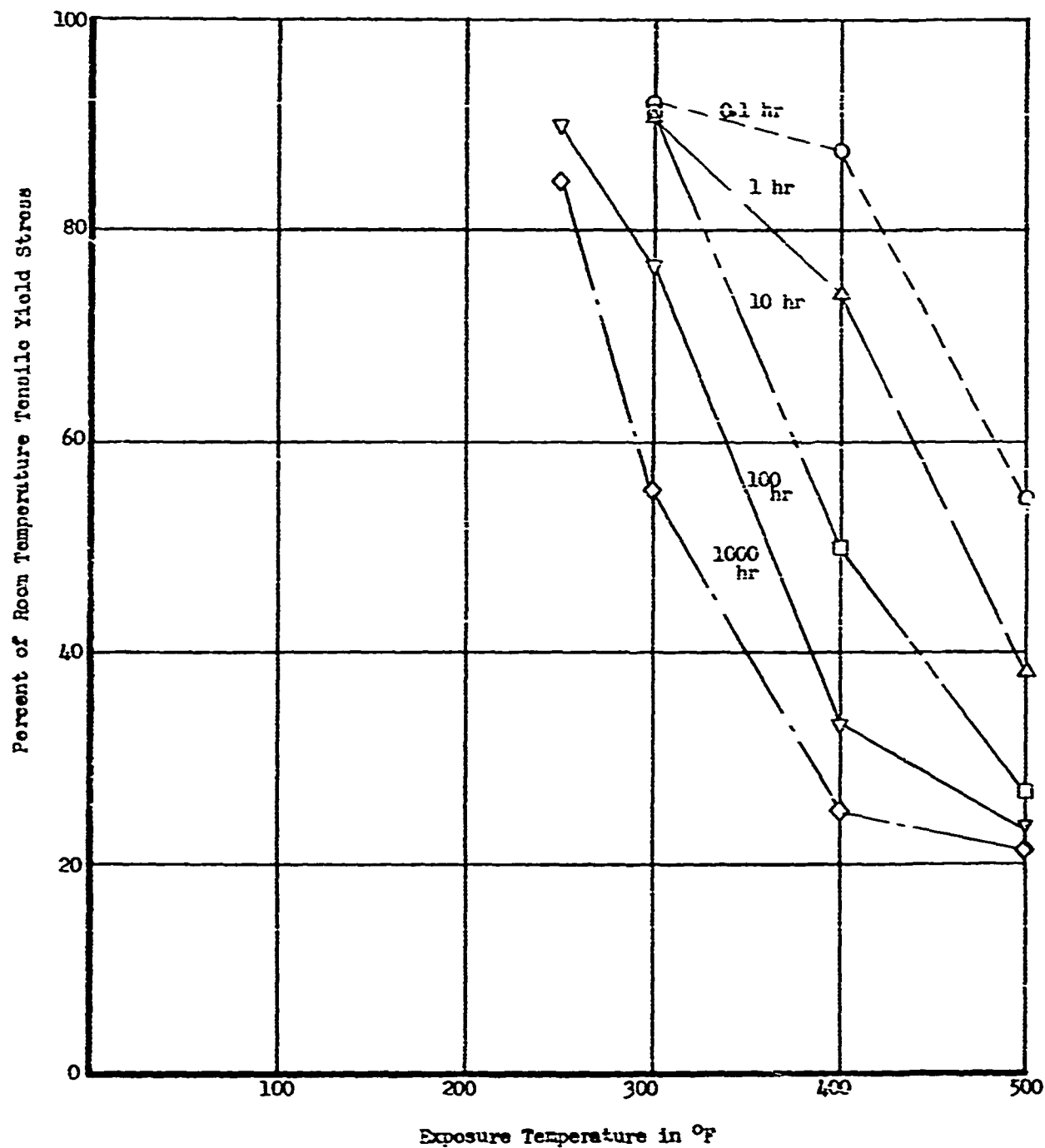


Figure 83.

Tensile Yield Stress of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

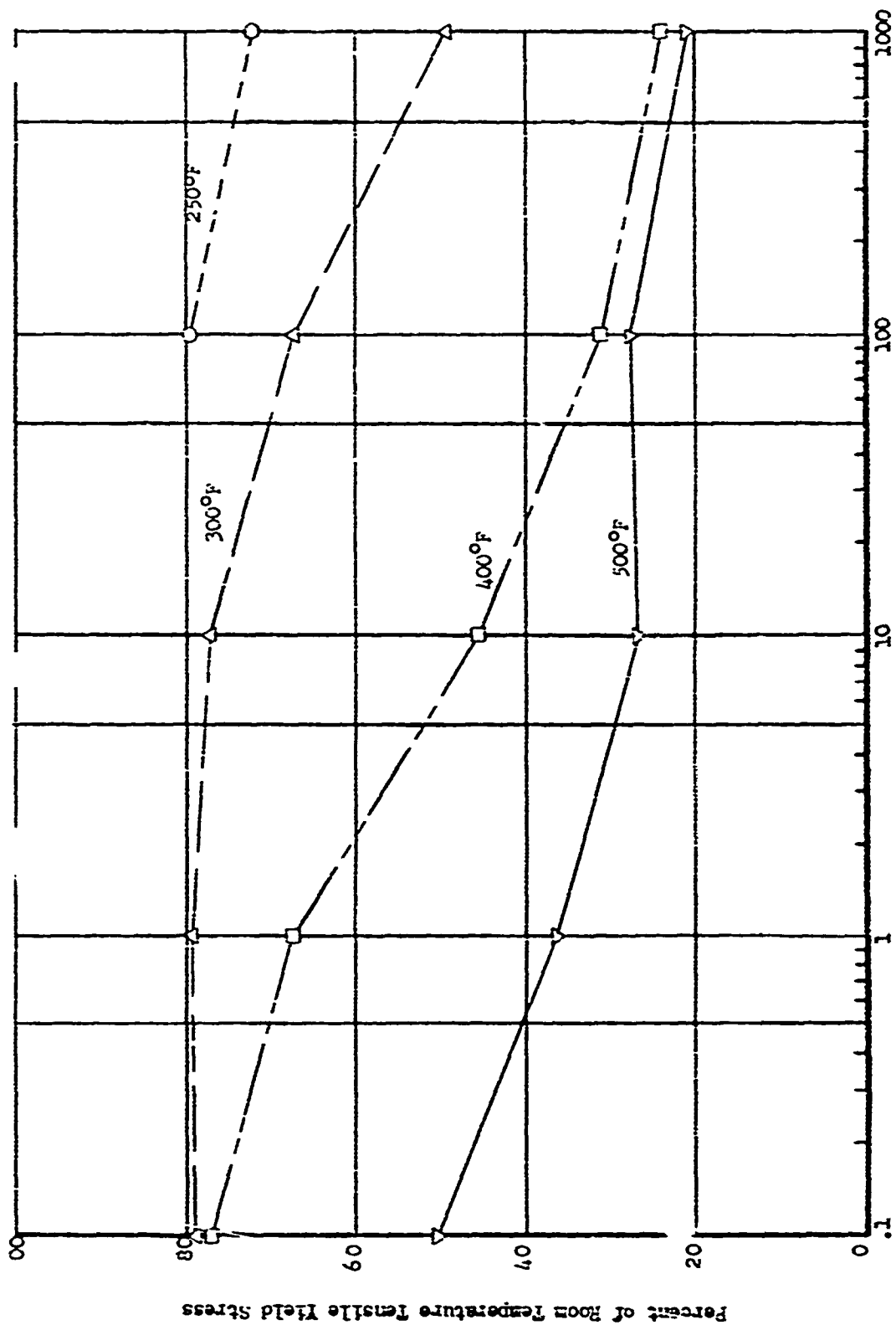


Figure 84.
Tensile Yield Stress of 7075-T6 Clad Sheet at
300°F After Exposure to Elevated Temperatures

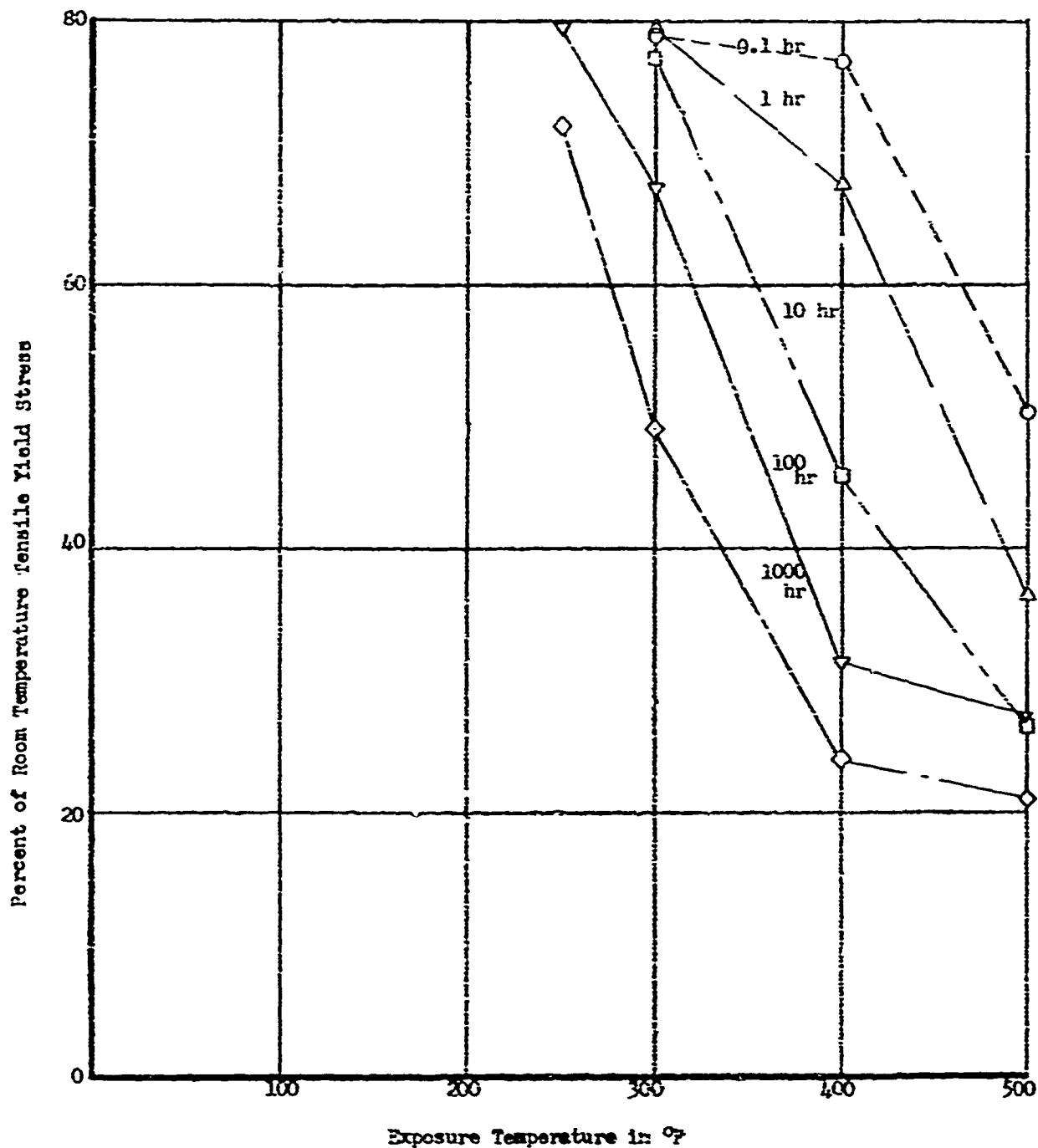


Figure 85.

Tensile Yield Stress of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

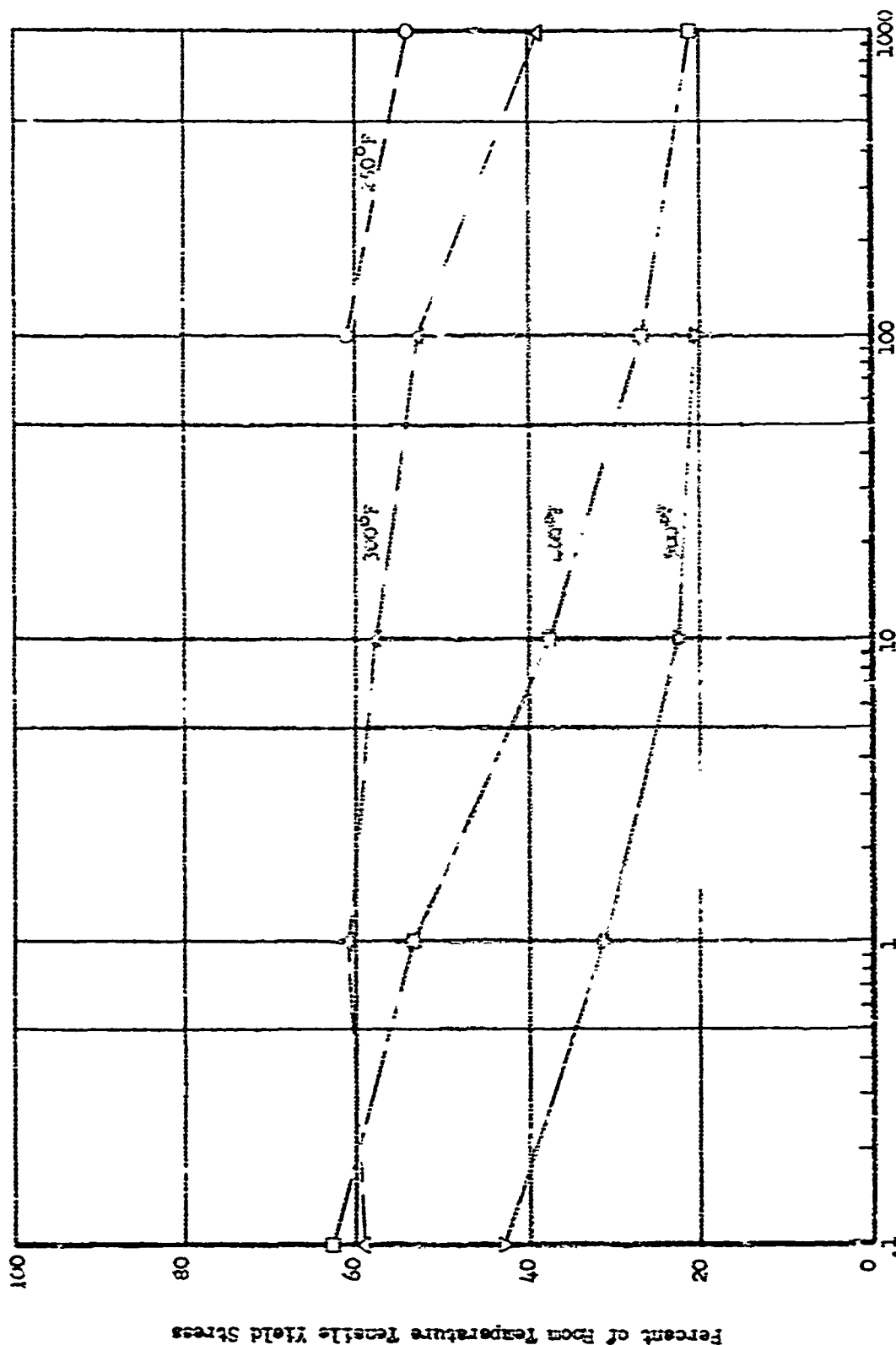


Figure 86. Tensile Yield Stress of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperature

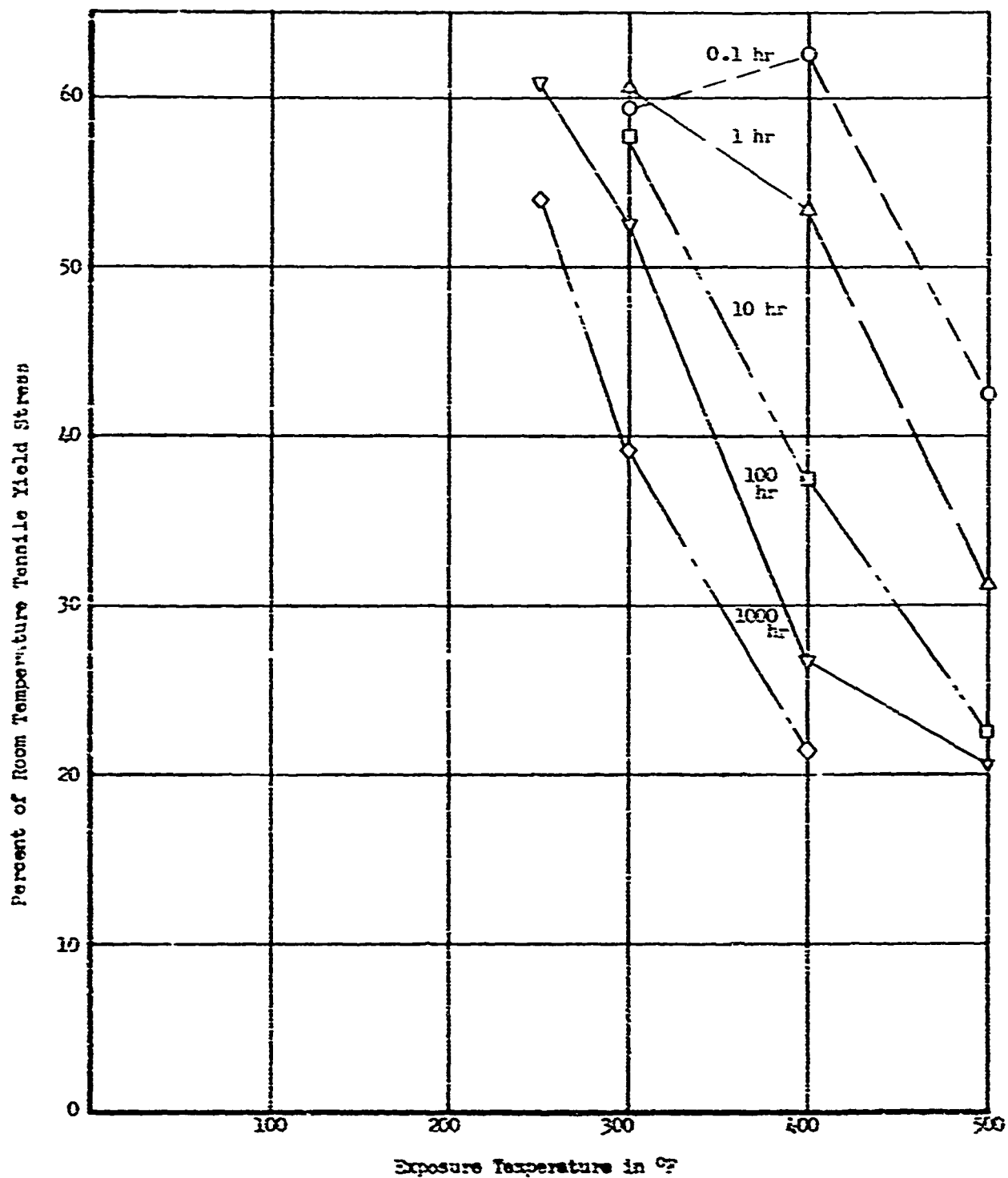


Figure 37.

Tensile Yield Stress of 7075-T6 Clad Sheet
at 400°F After Exposure to Elevated Temperatures

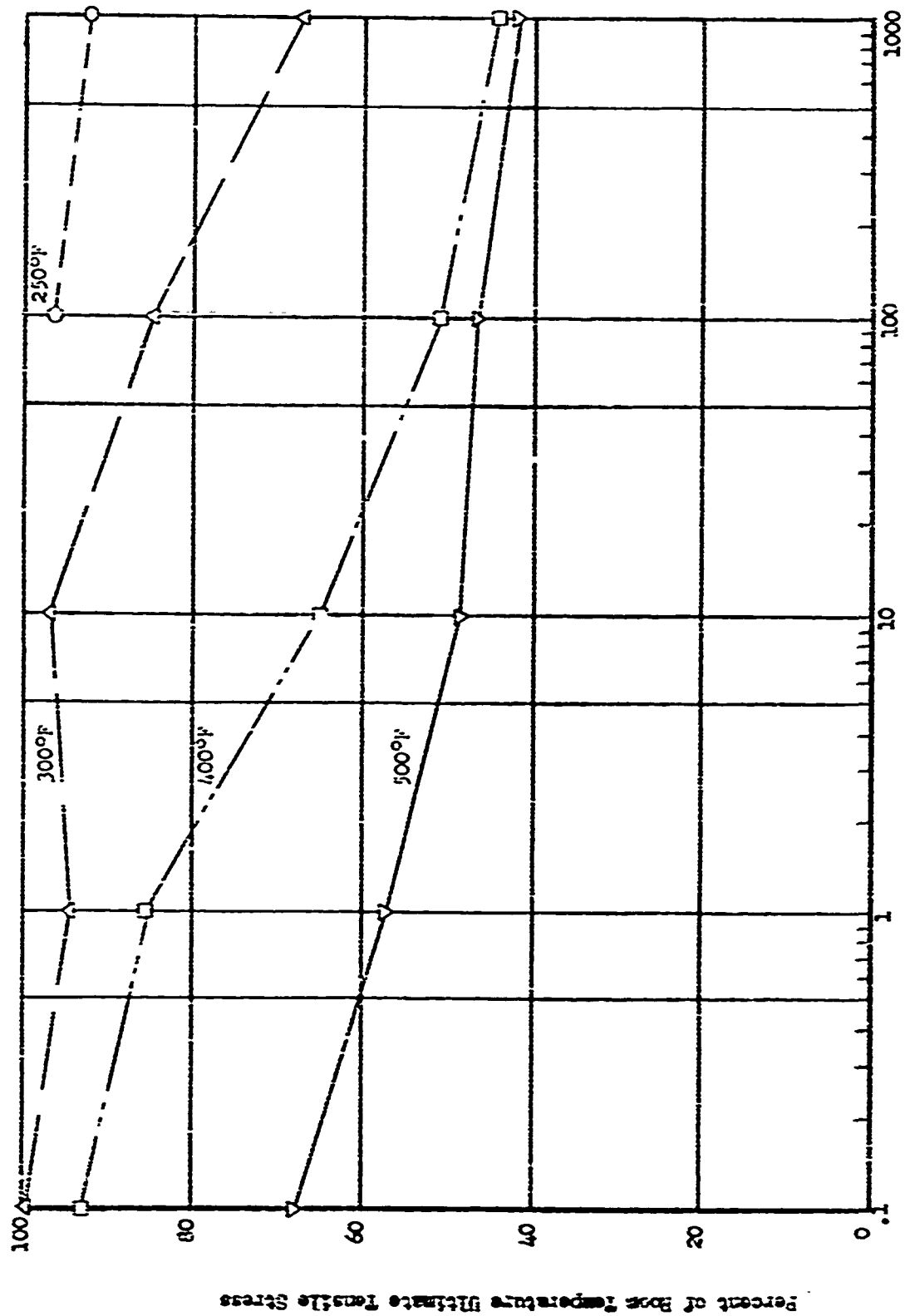


Figure 88. Ultimate Tensile Stress of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

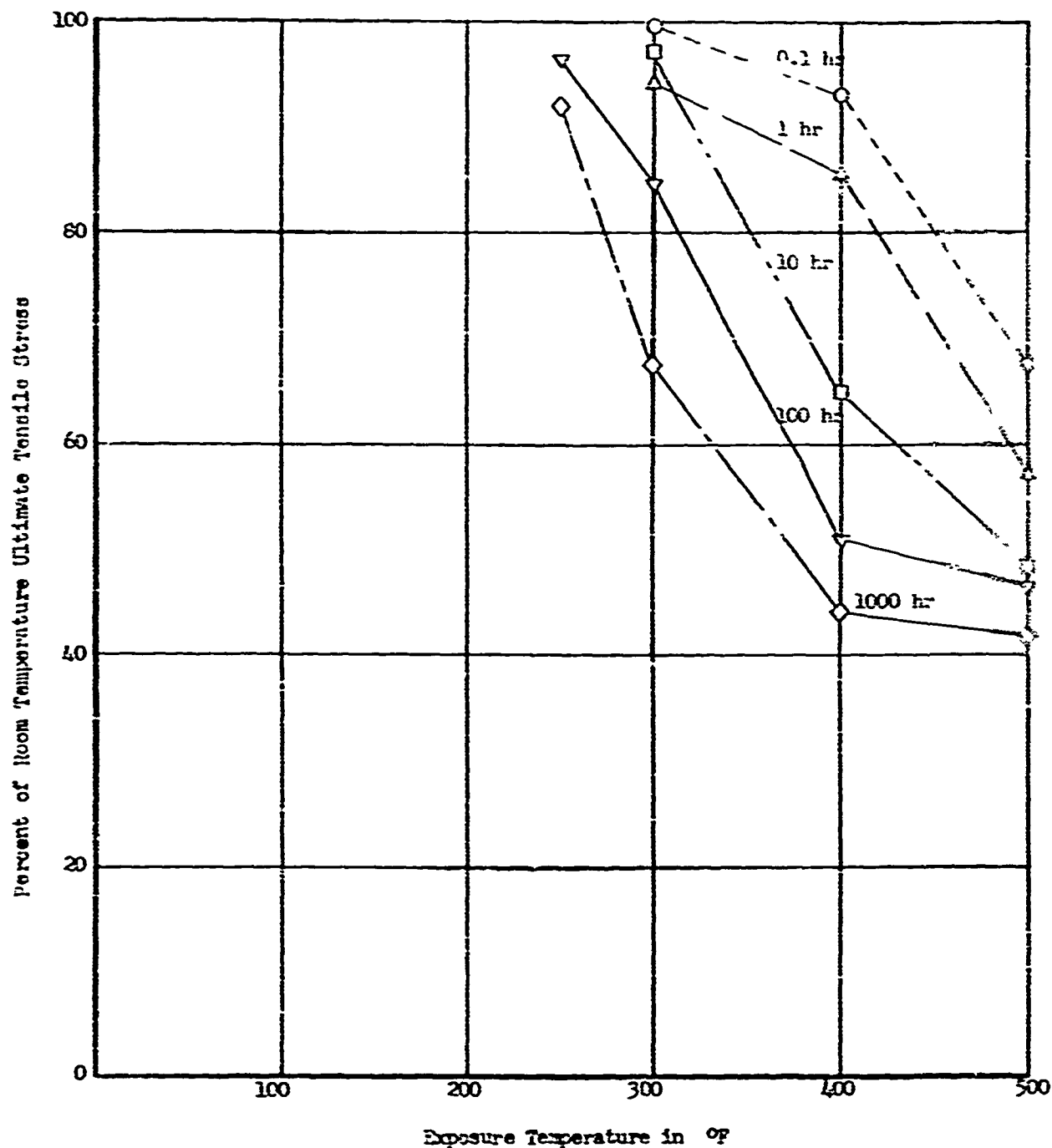


Figure 89. Ultimate Tensile Stress of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

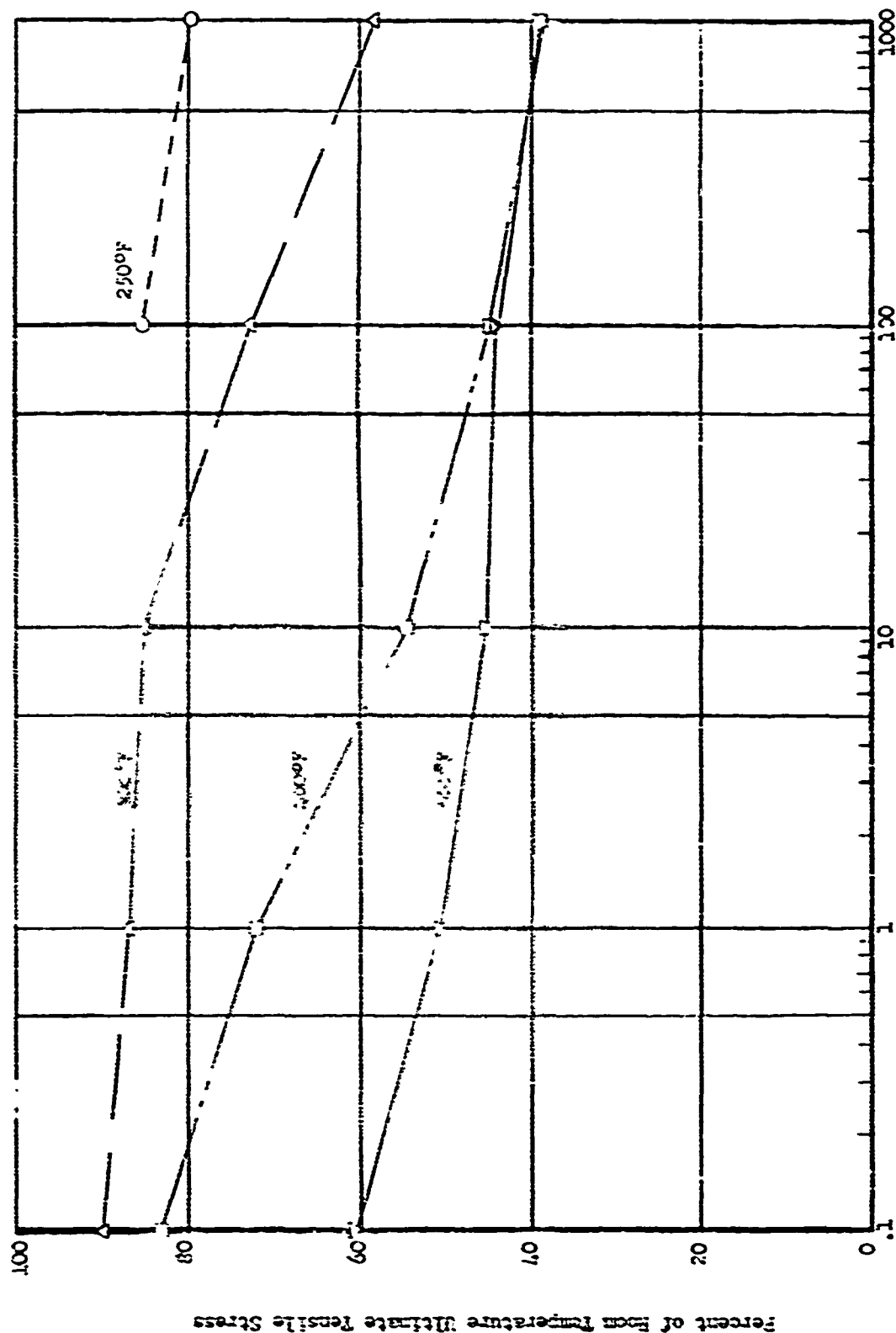


Figure 90. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

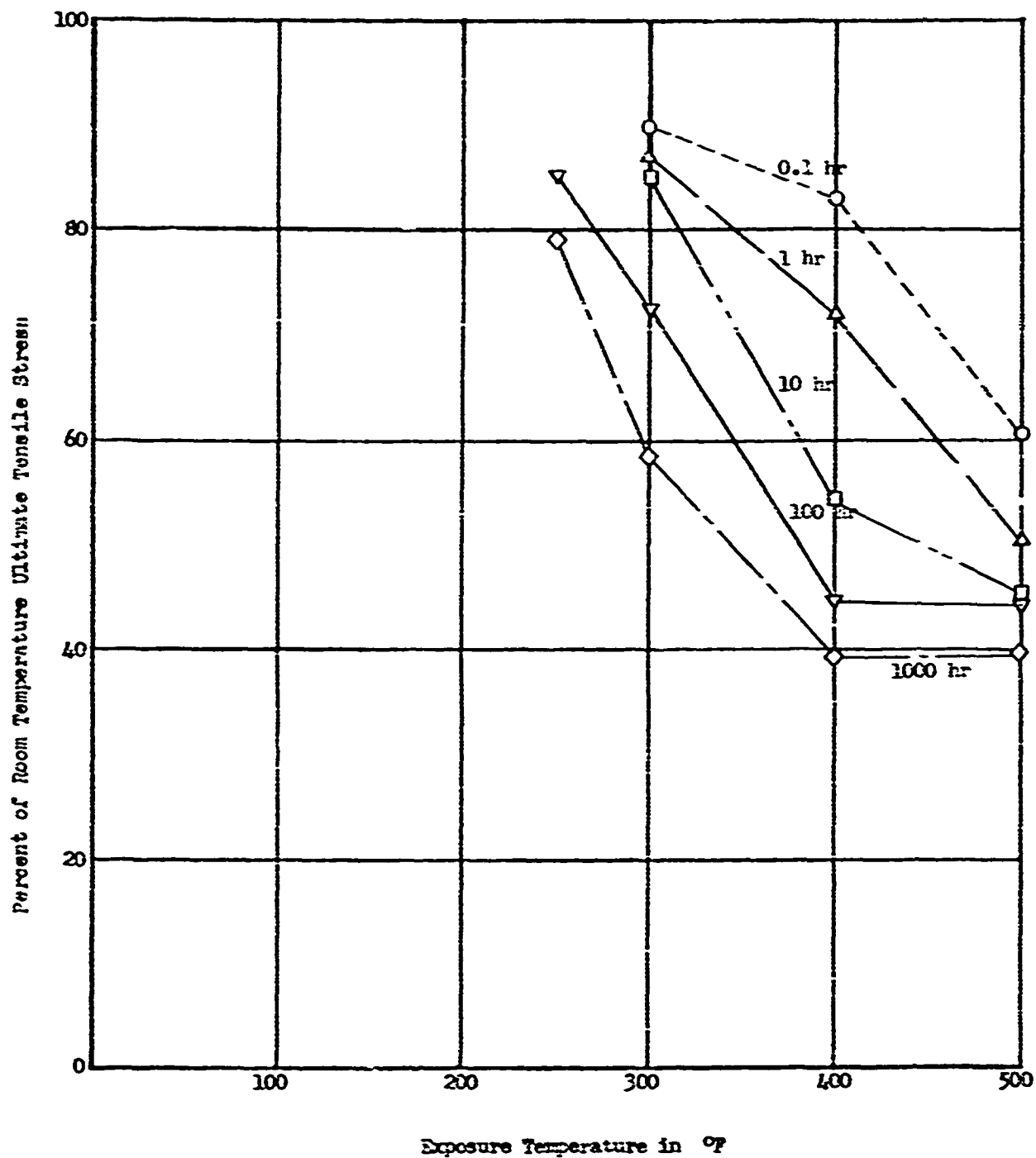


Figure 91. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

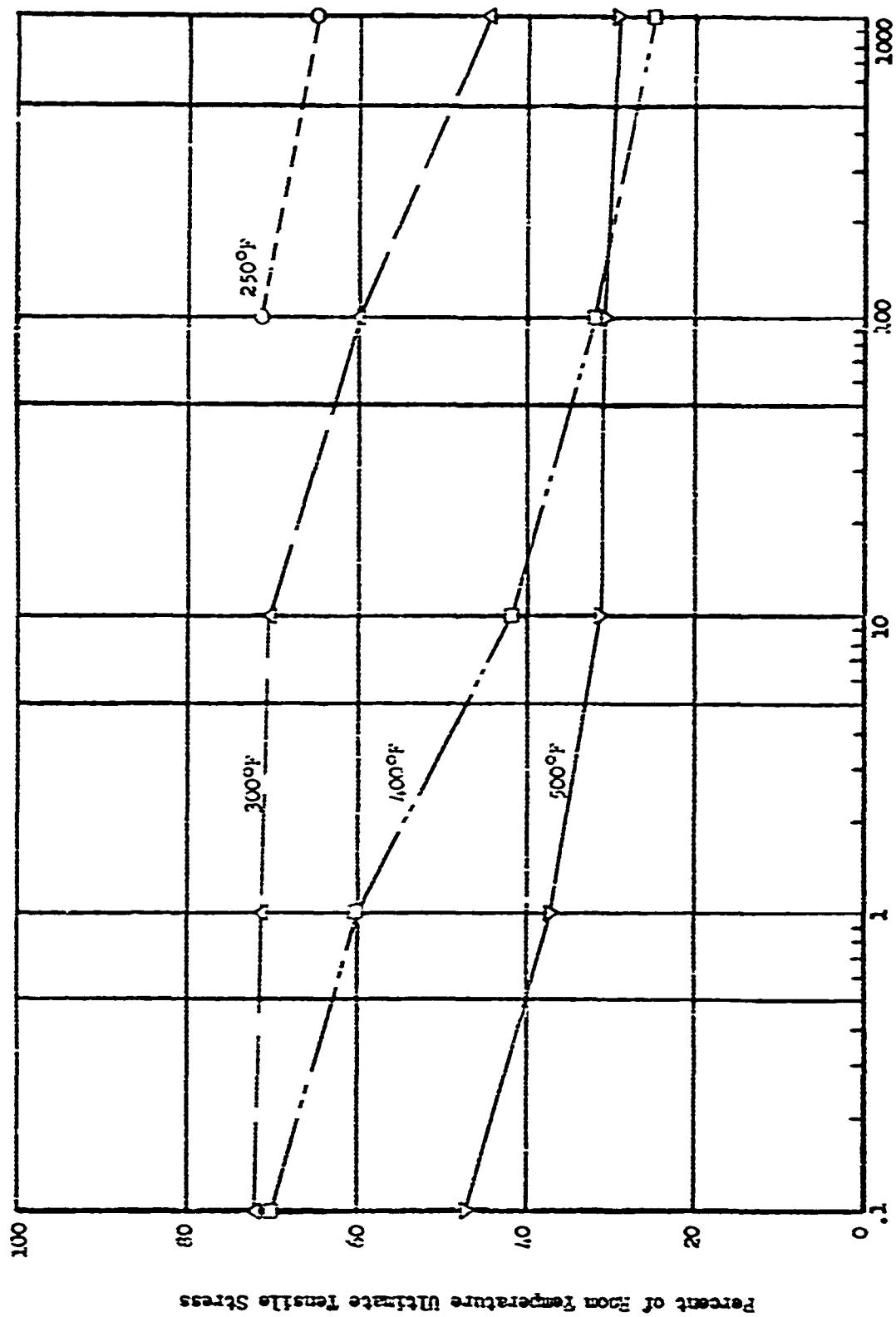


Figure 92. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

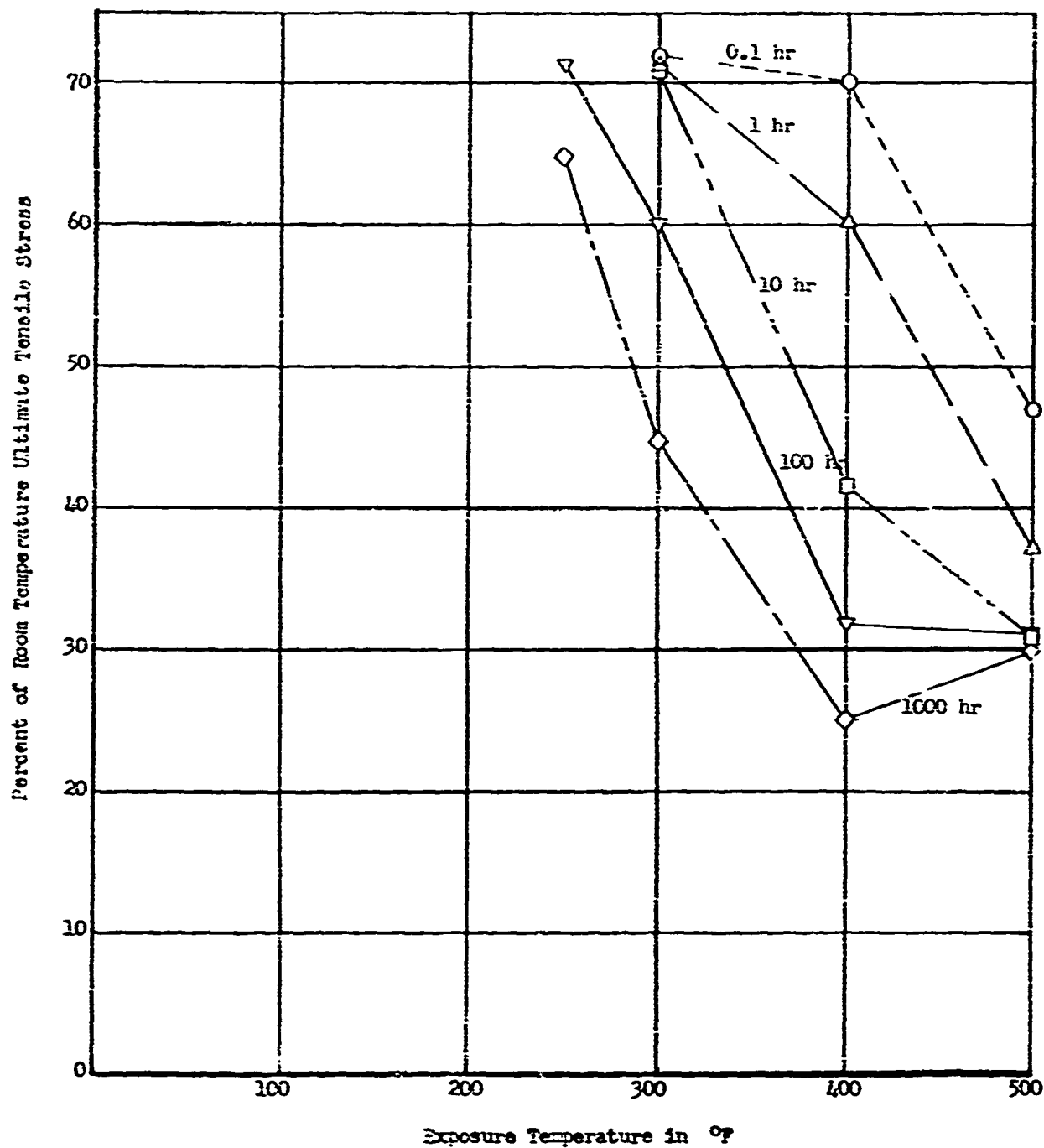


Figure 93. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

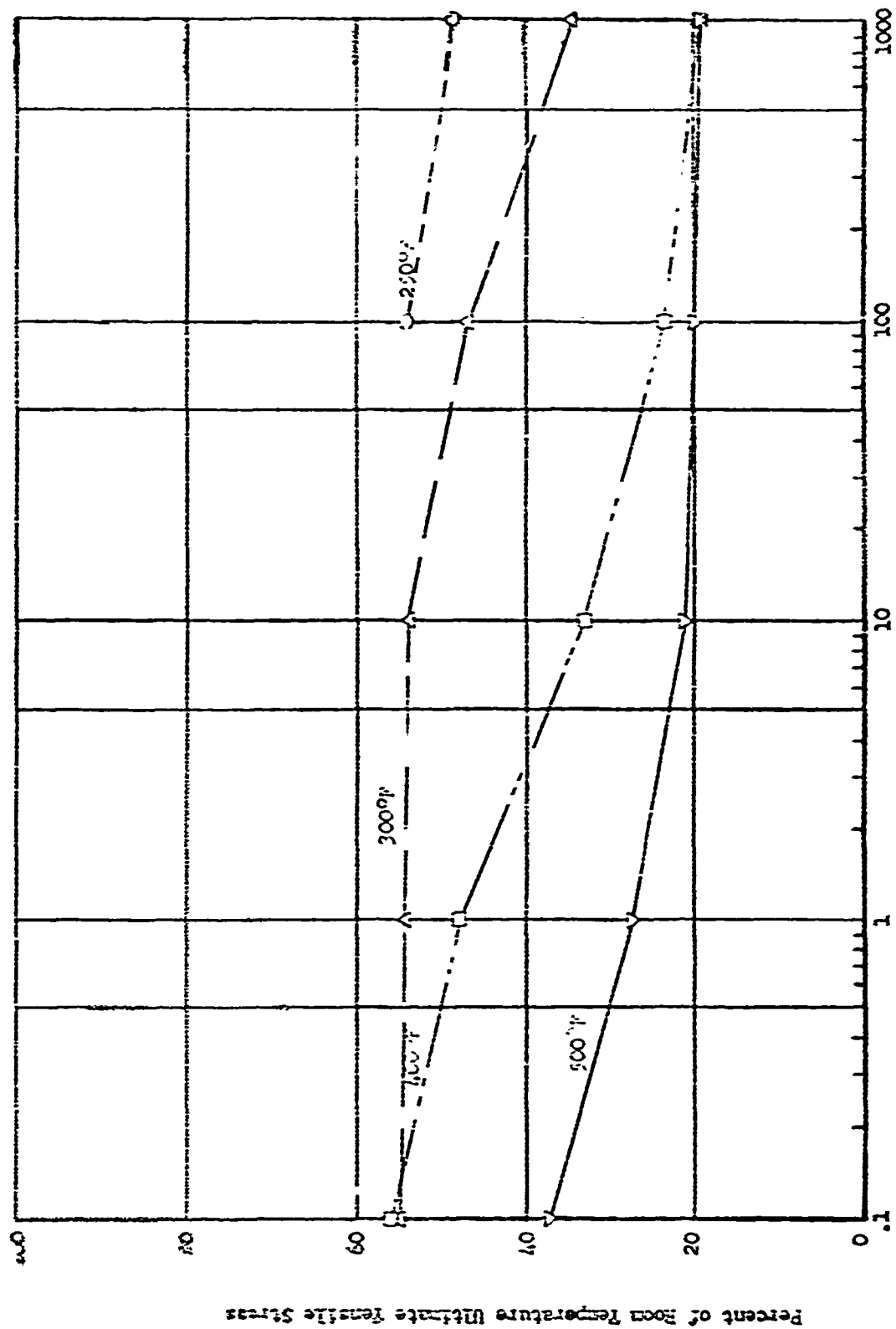


Figure 94. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

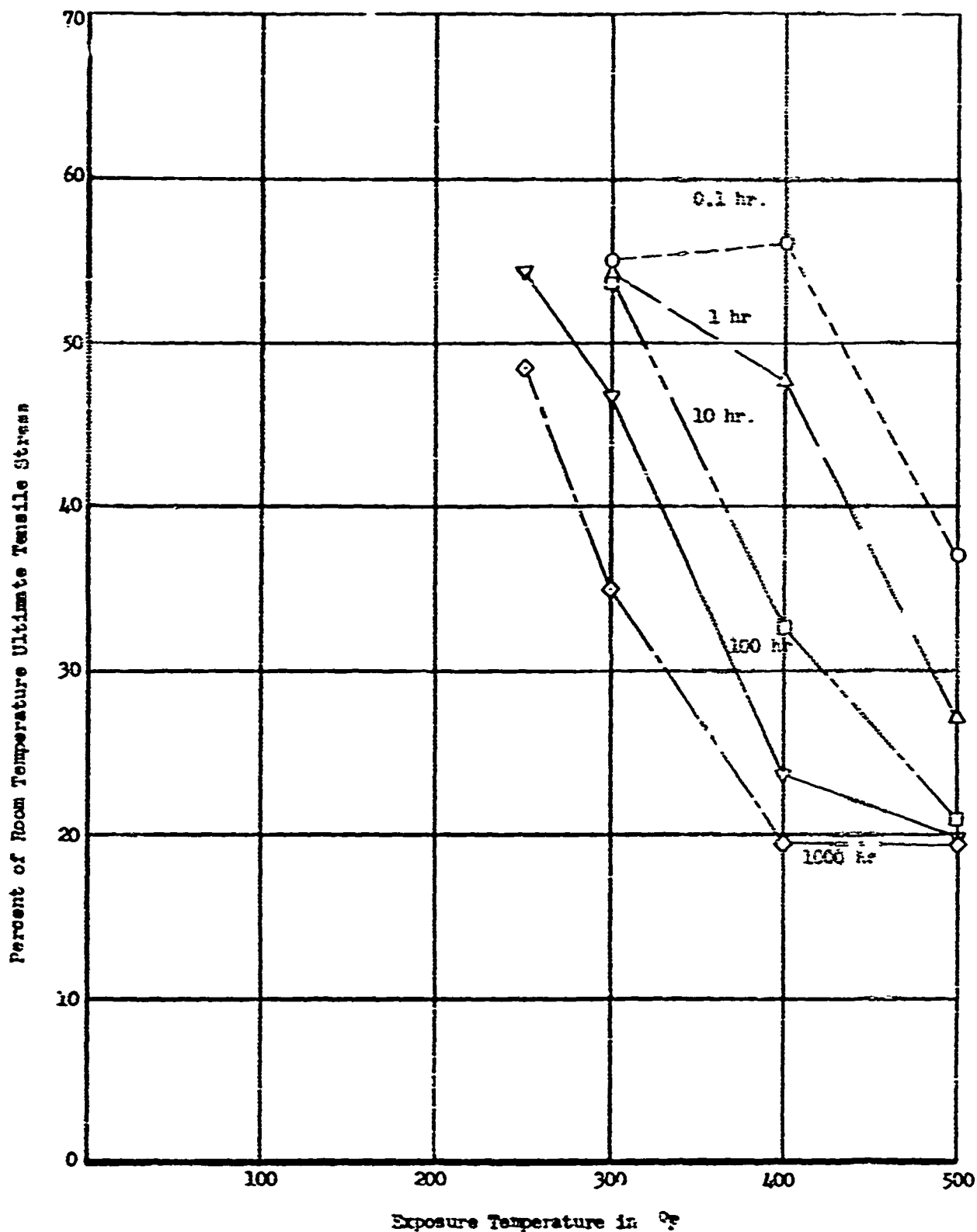


Figure 95. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

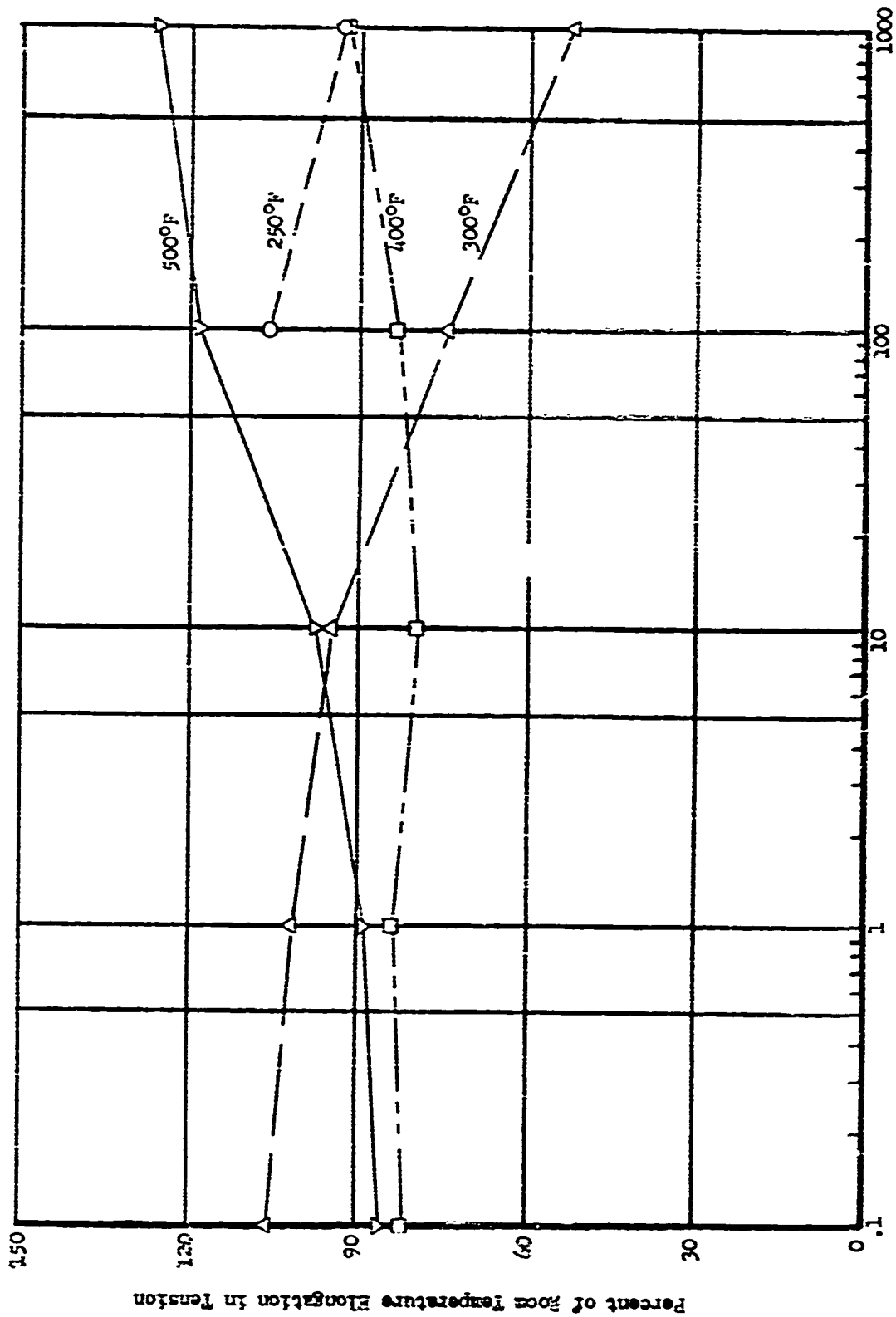


Figure 96.
Elongation in Tension of 7075-T6 Clad
Sheet at Room Temperature After Exposure to Elevated Temperatures

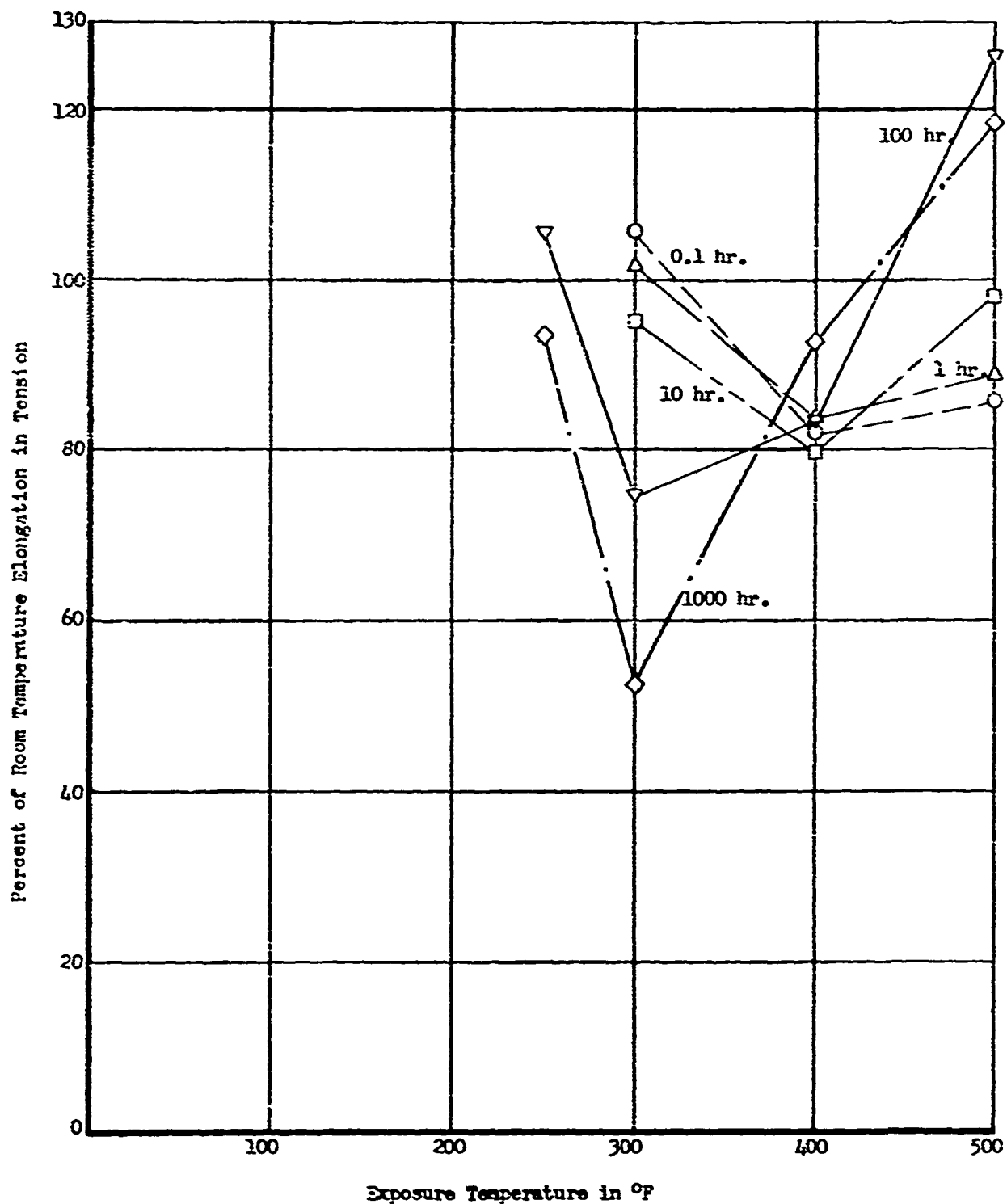


Figure 97.

Elongation in Tension of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

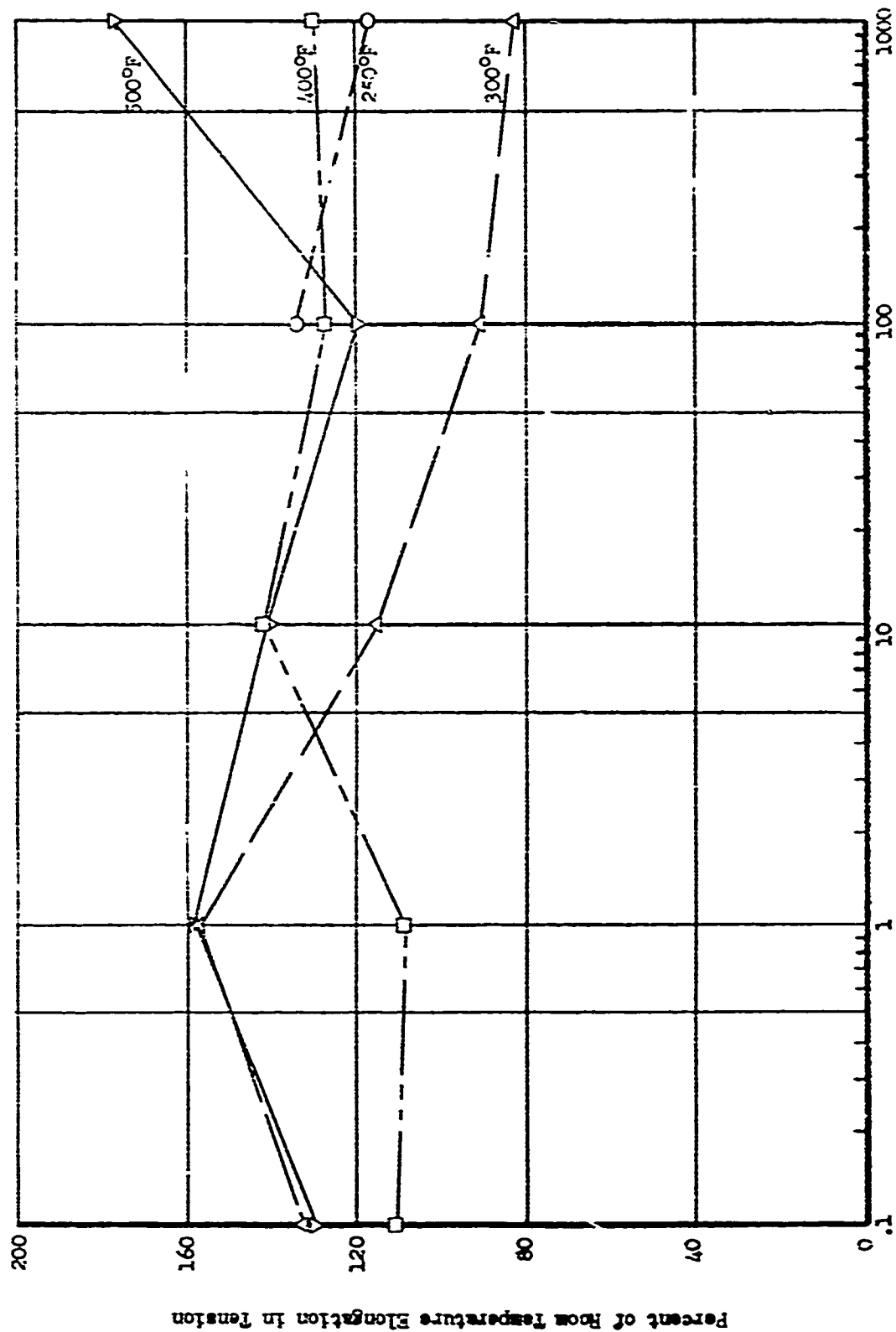


Figure 98.
Elongation in Tension of 7075-T6 Clad Sheet
at 200°F After Exposure to Elevated Temperatures

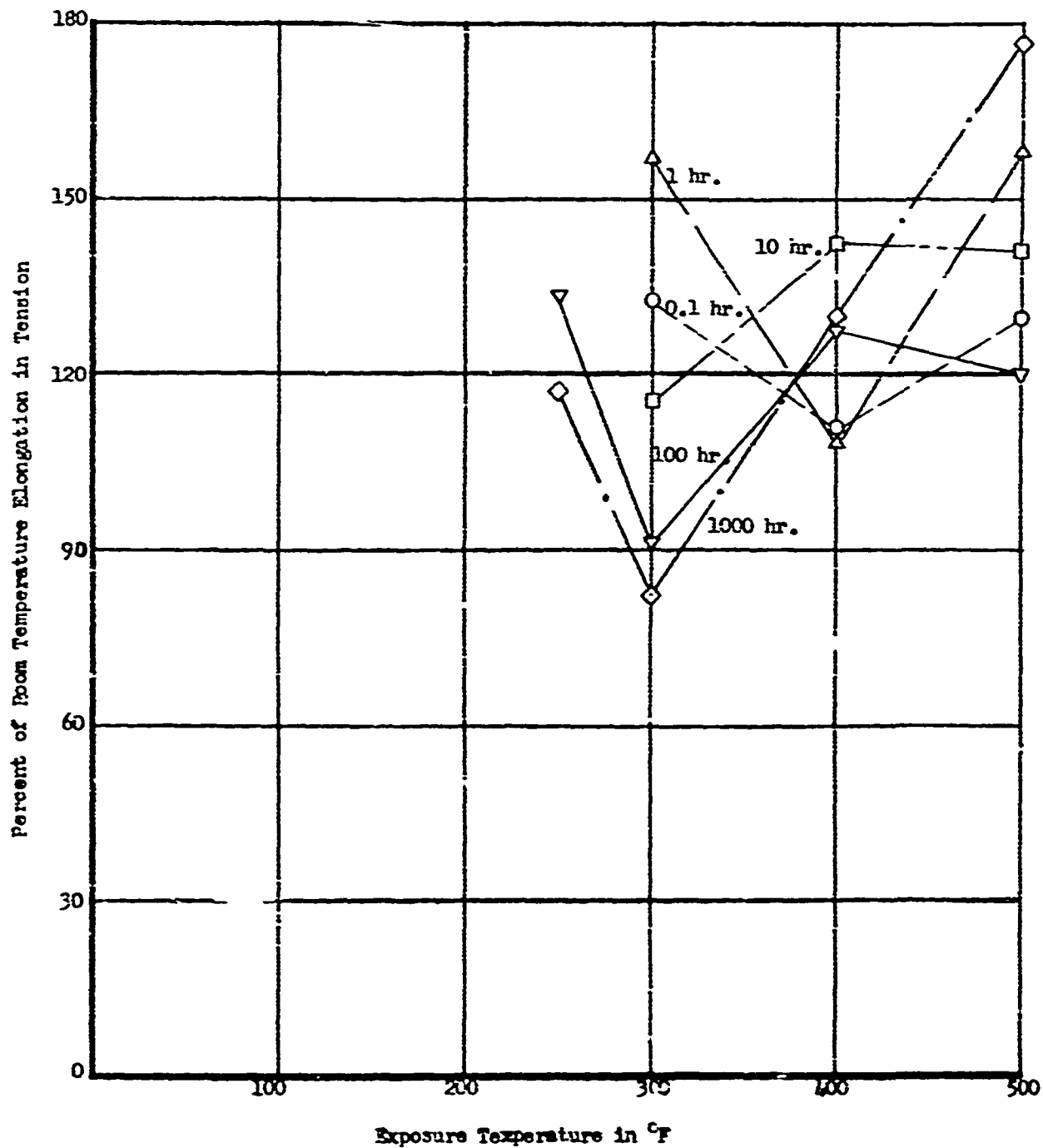


Figure 99. Elongation in Tension of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

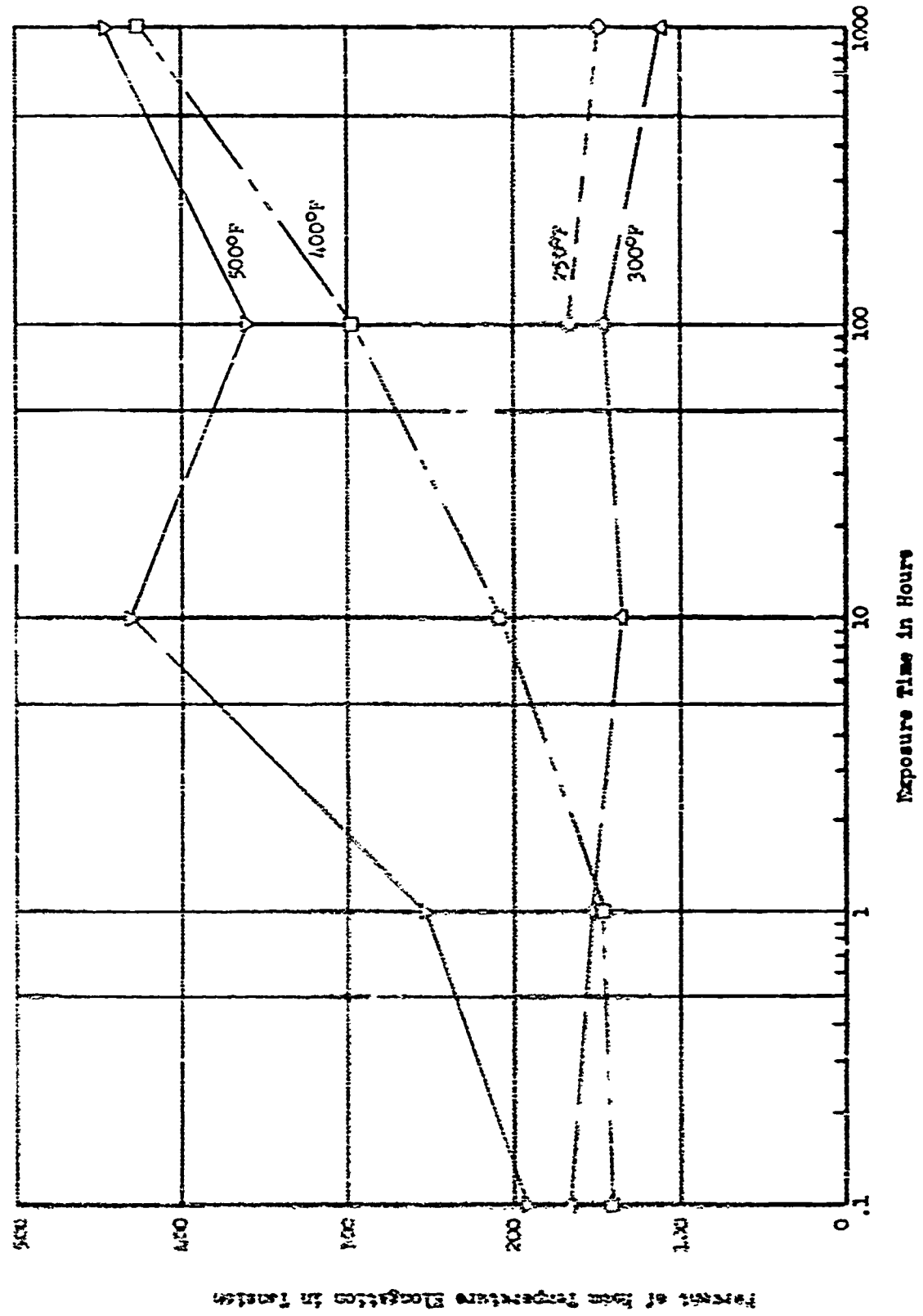


Figure 100. Elongation in Tension of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

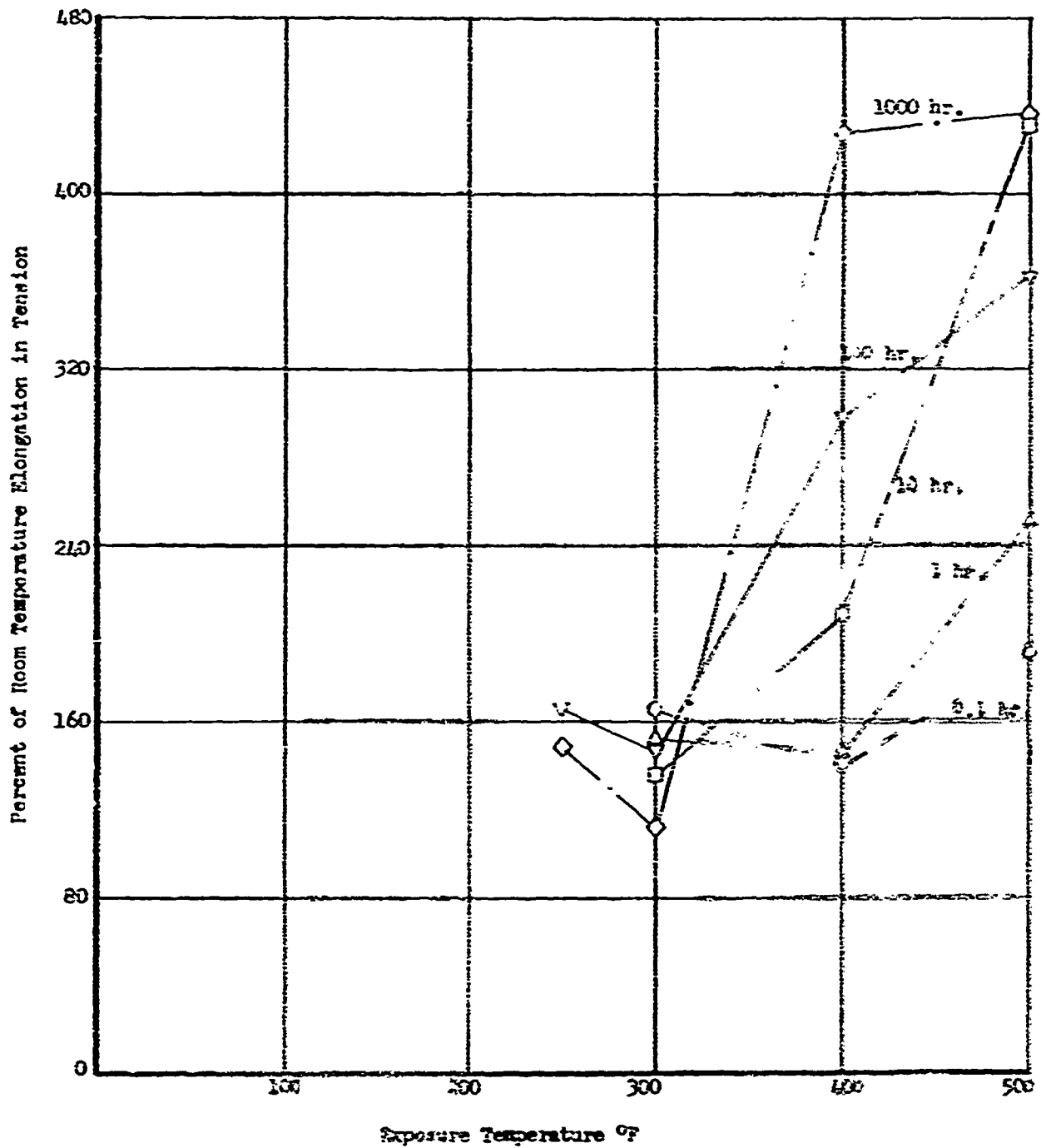


Figure 101.

Elongation in Tension of 7075-T6 Clad Sheet
at 100°F After Exposure to Elevated Temperatures

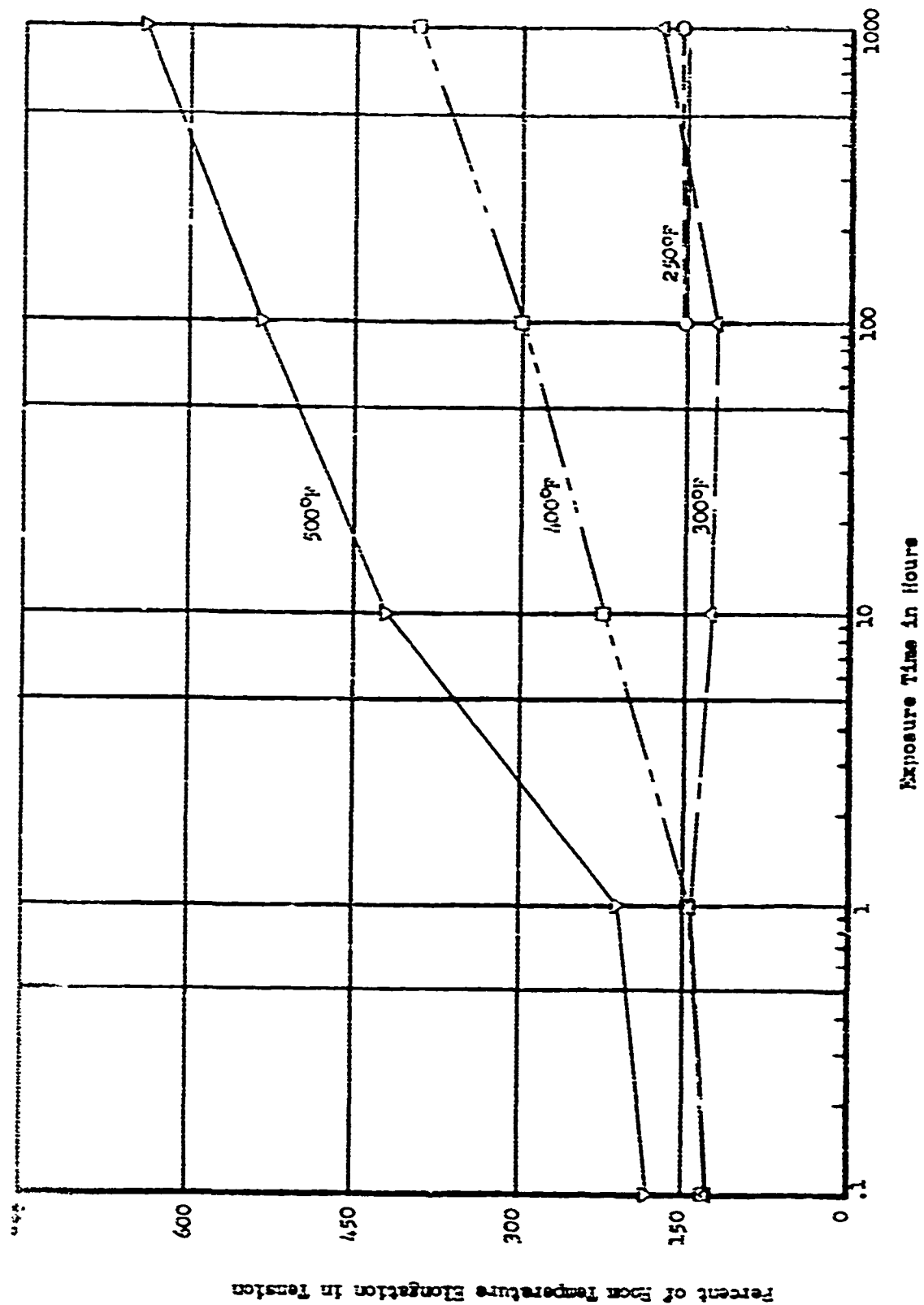


Figure 102. Elongation in Tension of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

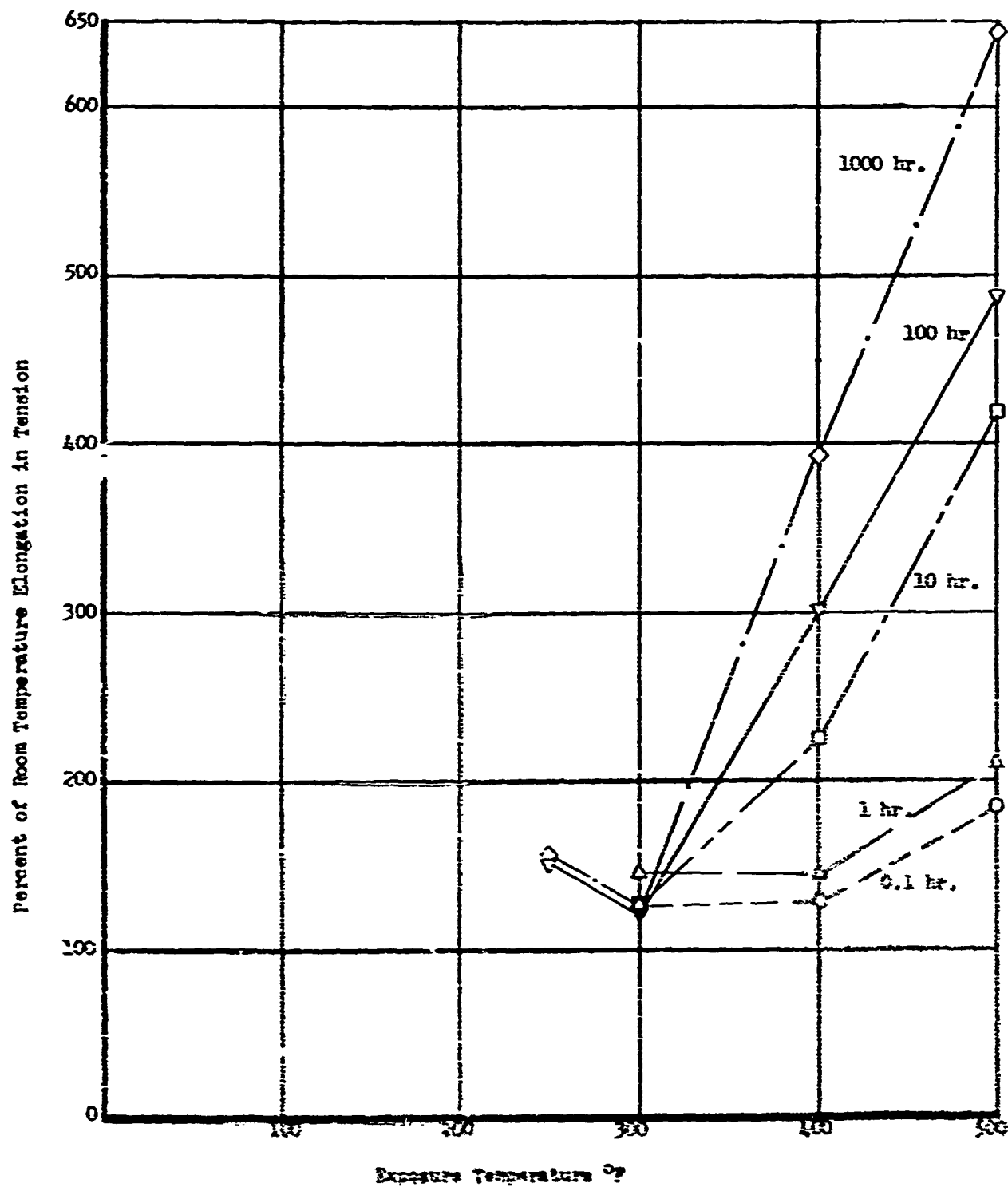


Figure 103.

Elongation in Tension of 7075-T6 Clad Sheet
at 400°F After Exposure to Elevated Temperatures

TABLE XVII

Tensile Properties of 2024-T3 Alclad Sheet at Room and Elevated
Temperature after Exposure at Elevated Temperatures

Exposure Temperature of	Exposure Time Hours	Testing Tempera- ture of	Average Percent of Room Temperature Properties				
			Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
--	--	200	90.44	101.03	93.82	95.25	45.0
--	--	300	79.12	97.12	92.83	94.49	116.50
--	--	400	71.92	97.01	77.59	75.79	72.50
500	0.1	R.T.(1)	100.7	101.0	93.0	93.1	93.8
300	0.1	200	92.7	99.7	91.1	92.4	100.1
300	0.1	300	95.0	93.6	89.2	93.4	116.3
300	0.1	400	87.2	94.3	79.5	75.6	93.5
400	0.1	R.T.(1)	52.8	100.0	85.3	92.5	103.5
400	0.1	200	68.9	95.5	84.5	91.0	114.2
400	0.1	300	89.3	95.4	85.0	95.0	117.5
400	0.1	400	100.3	80.0	83.2	75.7	95.0
500(2)	0.1	R.T.	159.7	93.6	119.3	92.9	40.0
500	0.1	200	151.3	94.2	113.2	93.1	44.8
500	0.1	300	130.6	95.0	109.2	73.7	52.1
500	0.1	400	94.8	92.0	93.9	63.6	72.6
600	0.1	R.T.	100.3	97.5	83.2	82.9	44.7
600	0.1	200	121.4	90.9	85.6	73.7	44.3
600	0.1	300	99.4	98.7	83.4	69.4	61.9
600	0.1	400	94.0	90.0	76.1	54.7	81.9
300	1.0	R.T.	110.2	93.5	95.5	96.8	102.4
300	1.0	200	140.3	95.9	93.5	93.1	104.7
300	1.0	300	135.1	93.4	92.1	85.2	117.6
300	1.0	400	132.5	82.9	83.5	73.2	109.8
400(2)	1.0	R.T.	190.4	98.2	124.4	100.3	65.7
400	1.0	200	213.4	95.1	123.3	95.9	72.9
400	1.0	300	210.5	77.2	113.2	93.6	32.4
400(2)	1.0	400	150.0	95.1	110.9	76.4	51.8
500	1.0	R.T.	147.6	95.0	105.9	83.7	37.3
500	1.0	200	135.6	95.6	103.3	82.6	41.9
500	1.0	300	114.5	71.2	97.0	71.4	55.5
500	1.0	400	75.3	71.6	87.7	57.3	71.9
600	1.0	R.T.	55.9	78.5	55.4	67.7	45.3
600	1.0	200	54.0	82.3	56.1	55.9	45.3
600	1.0	300	60.7	84.1	54.0	57.5	30.5
600	1.0	400	60.2	80.2	49.3	41.1	104.0

TABLE XVII (Cont'd)
Tensile Properties of 2024-T3 Alclad Sheet at Room and Elevated
Temperature after Exposure at Elevated Temperatures

Exposure Temperature °F	Exposure Time Hours	Testin- g Temper- ature °F	Average Percent of Room Temperature Properties				
			Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
300	10.0	R.T.(1)	119.6	99.4	97.0	98.6	96.6
300	10.0	200	115.1	101.9	96.8	94.2	98.6
300	10.0	300	104.9	95.6	95.5	97.3	100.9
300	10.0	400	105.5	98.8	73.7	78.7	88.6
400	10.0	R.T.	158.1	102.6	123.8	96.6	35.6
400	10.0	200	177.9	93.4	120.3	87.6	45.4
400	10.0	300	157.1	95.6	110.6	76.3	62.9
400	10.0	400	105.4	91.1	99.1	65.5	61.5
500	10.0	R.T.	98.9	99.8	82.1	78.9	45.7
500	10.0	200	100.4	96.7	80.5	72.9	44.0
500	10.0	300	91.4	89.6	77.4	61.1	80.3
500	10.0	400	87.4	85.7	65.8	47.5	91.9
600	10.0	R.T.	44.7	95.2	40.8	59.4	62.2
600	10.0	200	48.5	102.7	42.3	69.7	55.3
600	10.0	300	53.0	102.2	41.4	52.4	105.7
600	10.0	400	52.5	86.8	38.5	39.2	124.4
700	100.0	R.T.	124.3	99.7	151.9	123.1	58.9
700	100.0	200	175.0	99.9	126.5	97.6	53.7
700	100.0	300	152.6	99.4	119.5	89.8	59.5
700	100.0	400	154.6	79.3	102.2	76.8	60.0
800	101.0	R.T.	128.1	94.2	102.5	86.7	41.8
800	101.0	200	134.3	89.3	101.1	79.5	51.5
800	101.0	300	125.5	83.0	95.1	69.5	58.2
800	101.0	400	94.4	81.4	81.2	55.6	67.5
900	100.0	R.T.	57.4	99.1	45.6	58.4	51.3
900	100.0	200	60.5	96.4	44.3	54.3	65.1
900	100.0	300	54.4	91.2	42.5	45.2	105.3
900	100.0	400	51.1	82.4	39.1	33.5	155.2
1000	1000.0	R.T.	124.7	101.7	137.5	123.5	38.5
1000	1000.0	200	117.4	97.2	125.0	93.6	40.0
1000	1000.0	300	94.8	98.5	117.7	82.4	53.5
1000	1000.0	400	72.7	94.1	101.8	69.2	61.0
1000	1000.0	R.T.	72.3(3)	99.3(3)	75.1(3)	73.0	43.3
1000	1000.0	200	48.8	105.5	71.2	65.4	45.3
1000	1000.0	300	52.0	94.3	69.8	55.8	61.6
1000	1000.0	400	29.9	104.5	62.3	45.9	68.0
1000	1000.0	R.T.	31.6	100.6	36.0	50.9	64.8
1000	1000.0	200	41.6	96.7	34.7	48.2	76.2
1000	1000.0	300	32.5	100.3	33.2	39.5	140.0
1000	1000.0	400	28.3	100.4	30.2	27.9	158.9

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

(2) The percentages corresponding to these exposure temperatures are indicative of original data plus that obtained from repeat specimens.

(3) This value represents one specimen only.

TABLE XVIII

Tensile Properties of 7075-T6 Alclad Sheet at Room and Elevated Temperatures after Exposure at Elevated Temperatures

Exposure Temperature °F	Exposure Time Hours	Testing Temperature °F	Average Percent of Room Temperature Properties				
			Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
--	--	200	119.09	97.55	96.49	90.95	115.04
--	--	300	105.94	93.11	83.73	74.05	137.59
--	--	400	51.41	93.11	60.10	55.13	101.50
300	0.1	R.T.(1)	95.6	100.2	99.8	99.7	105.8
300(2)	0.1	200	90.6	102.5	92.0	89.7	132.5
300	0.1	300	50.4	101.0	73.8	72.1	165.3
300	0.1	400	46.2	97.7	59.2	55.0	126.9
400	0.1	R.T.	94.9	98.0	93.4	92.9	92.0
400	0.1	200	98.4	99.9	87.7	83.1	110.8
400	0.1	300	72.8	85.9	77.1	70.0	140.6
400	0.1	400	43.3	85.7	52.5	55.0	128.5
500	0.1	R.T.	95.6	104.5	94.3	87.8	85.8
500	0.1	200	95.2	105.3	94.5	90.5	129.7
500	0.1	300	45.0	98.1	50.5	46.9	191.4
500	0.1	400	29.7	109.6	42.6	37.0	183.3
300	1.0	R.T.	111.1	97.9	94.0	94.4	101.7
300	1.0	200	91.1	95.8	90.7	85.0	156.0
300	1.0	300	101.9	91.7	79.5	71.3	152.5
300	1.0	400	57.4	82.2	60.8	54.3	145.8
400	1.0	R.T.	87.3	101.4	81.4	85.5	83.0
400	1.0	200	92.3	93.0	74.1	72.0	108.5
400	1.0	300	60.3	95.5	67.5	60.2	146.2
400	1.0	400	44.2	81.1	53.3	47.7	143.0
500	1.0	R.T.	96.5	105.8	93.6	87.1	84.7
500	1.0	200	93.1	97.7	88.2	80.5	154.3
500	1.0	300	79.1	91.7	68.5	57.3	251.0
500	1.0	400	57.1	85.8	51.2	47.1	210.0
300	10.0	R.T.	107.6	100.5	97.8	97.0	94.9
300	10.0	200	125.4	92.4	91.1	85.0	114.4
300	10.0	300	42.4	98.3	77.2	70.3	135.1
300	10.0	400	22.0	94.3	57.7	53.8	126.0
400	10.0	R.T.	88.8	106.3	82.2	84.0	79.7
400	10.0	200	84.4	99.0	49.0	54.4	142.3
400	10.0	300	33.2	107.3	43.6	41.6	208.1
400	10.0	400	47.7	83.3	37.5	32.3	224.4
500	10.0	R.T.	23.8	103.6	27.7	48.4	98.0
500	10.0	200	27.3	107.7	25.7	45.5	140.2
500	10.0	300	25.3	101.0	24.0	31.3	43.12
500	10.0	400	23.7	93.1	22.3	20.2	419.1

TABLE XVIII (Cont'd.)

Tensile Properties of 7075-T6 Alclad Sheet at Room and Elevated Temperatures after Exposure to Elevated Temperatures

Exposure Temperature °F	Exposure Time Hours	Testing Temperature °F	Average Percent of Room Temperature Properties				
			Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
250	100.0	R.T.(1)	100.1	98.6	97.2	96.4	105.6
250	100.0	200	72.7	103.9	89.9	85.4	133.6
250	100.0	300	64.3	93.5	79.6	71.3	166.4
250	100.0	400	57.2	79.0	60.9	54.3	151.7
300	100.0	R.T.	83.0	96.9	81.7	84.7	74.5
300	100.0	200	41.8	99.2	76.6	72.7	91.0
300	100.0	300	43.1	96.6	67.3	60.0	144.6
300	100.0	400	42.5	86.2	52.6	46.6	121.4
400	101.0	R.T.	33.3	102.4	34.4	50.9	83.6
400(2)	101.0	200	26.2	103.1	33.3	45.1	127.1
400	101.0	300	24.4	100.6	31.2	31.8	297.7
400	101.0	400	18.3	60.9	26.7	23.6	300.7
500	100.0	R.T.	19.7	103.3	23.6	46.5	118.4
500	100.0	200	75.0	105.0	23.7	44.1	120.0
500	100.0	300	23.2	106.1	27.4	31.3	351.6
500	100.0	400	19.7	75.2	20.4	19.9	436.4
250	1000.0	R.T.	74.7	101.0	90.4	92.2	93.5
250	1000.0	200	66.2	99.3	84.6	79.2	117.1
250	1000.0	300	75.1	81.6	72.0	64.9	148.0
250	1000.0	400	26.2	74.4	54.0	48.4	156.1
300	1000.0	R.T.	51.8	99.1	55.9	67.4	52.5
300	1000.0	200	59.4	46.7	55.3	58.4	82.5
300	1000.0	300	49.4	69.1	49.1	44.7	111.5
300	1000.0	400	25.7	68.9	39.2	34.9	124.0
400	1000.0	R.T.	22.2	106.1	25.6	44.1	92.5
400	1000.0	200	18.8	112.6	25.1	39.4	130.1
400	1000.0	300	16.0	116.2	24.0	25.1	27.1
400	1000.0	400	16.3	101.6	21.4	19.4	391.7
500	1000.0	R.T.	20.9	105.4	23.2	41.8	126.0
500	1000.0	200	21.9	111.8	21.5	39.5	176.5
500	1000.0	300	18.8	105.9	20.9	29.3	446.2
500	1000.0	400	22.5(3)	92.3(3)	19.1(3)	19.3	642.3

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

(2) The percentages corresponding to these exposure temperatures are indicative of original data plus that obtained from retest specimens.

(3) This value represents two specimens only.

TABLE X-1

Properties of 2024-T3 and 7075-T6 Alclad Sheet at Room and Elevated Temperatures after a Sequence of Exposures at Elevated Temperatures

Sequence of Exposure Time & Temperature First Second Third Fourth Exposure Exposure Exposure Exposure 1000 Hrs. 1000 Hrs. 1000 Hrs. 1000 Hrs.				Testing Temperature °F	Average Percent of Room Temperature Properties				
					Proportional Limit	Modulus of Elasticity	Tensile Yield Strength	Tensile Ultimate Strength	Elongation
2024-T3 Alclad Sheet Properties									
100	100	--	--	R.T. (1)	104.5	99.0	150.5	87.5	35.4
100	100	--	--	200	138.8	58.7	103.2	60.5	48.3
100	100	--	--	300	127.1	89.6	95.4	68.8	69.5
100	100	--	--	400	104.2	84.7	83.7	57.7	69.0
100	100	100	--	R.T.	125.4	96.3	106.7	87.8	44.3
100	100	100	--	200	143.8	66.3	103.6	60.4	49.3
100	100	100	--	300	112.9	88.7	93.1	68.2	64.0
100	100	100	--	400	174.0	77.8	91.3	56.7	76.4
500	500	--	--	R.T.	52.7	93.6	60.2	66.3	42.9
500	500	--	--	200	54.4	95.3	56.3	61.8	49.6
500	500	--	--	300	47.6	94.0	53.5	50.8	68.3
500	500	--	--	400	40.5	87.7	48.8	38.4	87.8
500	500	500	--	R.T.	54.0	95.9	56.4	62.1	45.8
500	500	500	--	200	43.1	102.8	51.2	54.2	52.8
500	500	500	--	300	35.8	111.7	49.4	44.4	78.0
500	500	500	--	400	38.4	98.7	46.4	37.3	82.1
500	500	500	500	R.T.	38.3	98.1	46.4	43.1	51.9
500	500	500	500	200	38.5	97.3	44.4	37.4	62.5
500	500	500	500	300	35.1	91.3	44.3	49.4	79.3
500	500	500	500	400	36.2	91.1	47.7	49.7	60.3
7075-T6 Alclad Sheet Properties									
100	100	--	--	R.T. (1)	50.3	85.9	77.8	84.1	90.1
100	100	--	--	200	77.7	82.3	75.4	73.0	115.6
100	100	--	--	300	69.6	76.0	68.2	58.6	155.7
100	100	--	--	400	40.7	88.7	52.4	46.3	161.0
100	100	100	--	R.T.	62.9	95.8	73.4	85.2	80.0
100	100	100	--	200	84.1	99.0	76.9	72.7	100.7
100	100	100	--	300	66.7	91.6	66.5	59.8	130.4
100	100	100	--	400	44.5	90.0	53.1	46.7	145.5
500	500	--	--	R.T.	30.5	106.7	37.5	34.1	79.7
500	500	--	--	200	34.8	97.5	37.0	36.9	153.1
500	500	--	--	300	27.2	100.0	34.7	33.3	275.0
500	500	--	--	400	21.0	109.8	29.3	28.4	271.9
500	500	500	--	R.T.	27.0	114.6	38.7	34.7	83.6
500	500	500	--	200	13.4	97.3	37.7	45.7	146.1
500	500	500	--	300	29.8	109.3	35.0	33.1	260.2
500	500	500	--	400	22.4	95.0	29.1	25.1	231.6
500	500	500	500	R.T.	11.2	125.4	38.4	31.4	85.6
500	500	500	500	200	18.0	103.7	34.9	34.0	148.0
500	500	500	500	300	20.1	94.7	34.1	31.1	256.0
500	500	500	500	400	21.7	94.0	29.0	24.0	236.0

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-80°F.

TABLE IX

Tensile Properties of 2024-T3 and 7075-T6 Alclad Sheet at Room and Elevated Temperatures after an Additional Sequence of Exposures at elevated Temperatures.

Sequential Exposure Time and Temperature				Testing Temperature °F	Average Percent of Room Temperature Properties				
First	Second	Third	Fourth		Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
2024-T3 Alclad Sheet Properties									
1.0Hr	5.0Hrs	30.0Hrs	219.0Hrs						
405°F	420°F	375°F	330°F	R. T. (1)	168.3	102.2	127.2	99.0	38.9
465	420	375	330	200	137.0	101.6	117.7	88.9	49.0
465	420	375	330	300	126.1	100.5	108.9	76.5	60.6
465	420	375	330	400	98.9	99.4	95.9	64.7	67.6
1.0Hr	4.6Hrs	25.2Hrs	164.0Hrs						
510°F	465°F	420°F	375°F	R. T.	164.3	100.9	101.6	86.4	43.4
510	465	420	375	200	106.1	96.7	92.0	75.4	52.1
510	465	420	375	300	130.3	94.3	83.8	63.1	43.4
510	465	420	375	400	109.4	88.3	74.6	52.1	48.1
1.0Hr	4.3Hrs	21.5Hrs	126.1Hrs						
555°F	510°F	465°F	420°F	R. T.	85.6	99.3	68.2	69.4	51.1
555	510	465	420	200	77.6	96.4	65.3	60.5	42.5
555	510	465	420	300	83.1	96.2	61.1	52.0	42.4
555	510	465	420	400	79.2	94.9	55.4	50.7	31.5
1.0Hr	4.3Hrs	14.6Hrs	99.6Hrs						
600°F	555°F	510°F	465°F	R. T.	71.4	98.9	51.7	51.1	34.1
600	555	510	465	200	67.5	96.1	43.3	52.0	27.1
600	555	510	465	300	55.9	95.1	33.5	44.4	31.1
600	555	510	465	400	48.5	89.8	39.2	33.4	20.1
7075-T6 Alclad Sheet Properties									
1.0Hr	4.0Hrs	27.6Hrs	141.7Hrs						
340°F	340°F	300°F	260°F	R. T.	76.41	101.18	80.77	82.13	90.0
340	340	300	260	200	101.79	99.48	79.17	72.17	118.33
340	340	300	260	300	107.82	97.82	72.94	62.45	147.50
340	340	300	260	400	86.74	95.04	54.35	60.38	131.66
1.0Hr	4.0Hrs	21.4Hrs	145.1Hrs						
400°F	340°F	340°F	300°F	R. T.	55.9	99.8	56.2	63.6	94.4
420	340	340	300	200	57.9	101.4	53.7	55.1	126.6
420	340	340	300	300	48.3	97.7	49.4	43.8	185.5
420	340	340	300	400	32.2	104.3	38.3	33.8	161.1
1.0Hrs	4.0Hrs	2.2Hrs	113.4Hrs						
460°F	400°F	380°F	340°F	R. T.	39.9	102.3	41.8	54.7	75.7
460	400	380	340	200	42.4	104.3	41.4	47.9	121.2
460	400	380	340	300	34.9	98.9	34.7	34.7	136.9
460	400	380	340	400	35.5	90.4	30.8	28.0	197.7
1.0Hr	4.0Hrs	17.5Hrs	90.5Hrs						
500°F	460°F	420°F	380°F	R. T.	33.2	101.3	34.8	48.2	88.3
500	460	420	380	200	33.7	103.4	29.6	43.4	137.1
500	460	420	380	300	28.0	97.1	27.0	30.1	143.9
500	460	420	380	400	26.2	97.1	24.1	22.0	171.1

(1) R. T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

TABLE XXI

ROOM TEMPERATURE ROCKWELL HARDNESS OF .064 GAGE 2024-T3 ALCLAD
SHEET AFTER VARIOUS TEMPERATURE-TIME EXPOSURE CONDITIONS

Specimen Number	Yield Strength psi	Ultimate Strength psi	R _B	Hardness R _H
2A1	15380	33860		96.5
2A2	15670	34710		95.9
2A3	15560	34440		97.0
2C29	51730	67030	78.0	
2C30	51560	68280	77.4	
2C31	46850	60410	65.1	
2C32	46860	60380	65.8	
2C33	47150	60440	66.4	
2D7	25630	46560	40.4	103.8
2D8	24760	45770	39.1	103.1
2D9	24290	45450	38.2	103.3
2E7	37930	63320	70.6	
2E8	38050	63370	71.0	
2E9	38050	63320	69.5	
2F9	50000	62040	70.9	
2F10	49070	61800	68.6	
2G9	39060	56090	61.5	110.9
2G10	39340	55960	60.0	111.0
2G11	39870	55900	58.0	110.9
2J1	18120	39660	23.4	98.9
2J4	17690	39340	25.8	98.9
2J5	17590	39820	23.0	97.6
2K4	36010	52830	54.8	109.1
2K5	35940	52810	54.1	109.6
2K6	35830	52650	55.1	109.3
2L4	56830	65530	74.9	
2L5	56680	65530	74.9	
2L6	56270	65370	74.0	
2M4	21010	40640	27.6	102.5
2M5	20060	38740	26.3	103.0
2M6	19940	39260	24.1	101.1
2N5	46590	59440	68.0	
2N6	46630	59360	67.4	
2N7	46930	59510	68.5	
2P6	59820	71170	79.6	
2P7	59630	70950	80.8	
2P8	59230	70770	79.7	
2V1	33790	49850		117.0
2V2	--	49540		108.7
2V3	--	49690		106.2
2W1	46260	59500	67.3	109.4
2W2	46570	59500	68.5	
2W3	47660	60120	68.7	

TABLE XXI (Cont'd)

Room Temperature Rockwell Hardness of .064 Gage 2024-T3 Alclad Sheet After Various Temperature-Time Exposure Conditions

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness R _B	R _H
2X1	46900	59440	66.0	
2X2	47630	59910	67.8	
2X3	49610	60490	68.2	
2Y12	42300	66460	69.4	
2Z1	61540	68920	77.0	
2Z2	61460	69350	76.9	
2Z3	61680	69690	78.3	
2AA1	27160	45370	35.6	105.6
2AA2	26700	45170	40.0	104.3
2AA3	26180	45300	34.0	105.6
2BB1	27430	44670		103.1
2BB2	25690	43080		102.8
2BB3	24140	41510		101.8
2CC1	27390	44190	39.0	104.3
2CC2	27290	44340	41.5	104.9
2CC3	25630	43750	40.2	104.1
2DD2	41650	65850	68.3	
2DD3	41570	66820	68.8	
2EE1	41240	66360	69.0	
2EE2	41730	66670	69.4	
2EE3	41390	67230	70.1	
2HH1	30230	47210	41.6	106.7
2HH2	29970	47050	42.1	106.7
2HH3	30160	47340	42.2	107.0
2II1	23300	43210	15.9	99.3
2II2	22600	41950	14.9	97.7
2II3	21740	41300	16.6	99.1
2JJ1	56720	67500	70.3	114.3
2JJ2	55630	66720	70.6	114.4
2JJ3	55510	66980	71.1	114.4
2KK1	44450	59530	60.1	111.4
2KK2	44110	58920	59.3	112.0
2KK3	43310	58690	58.4	112.0
2AC1	42830	66470	71.0	
2AC2	43550	66510	70.9	
2BC1	42970	67500	71.2	
2BC2	43300	67450	71.1	
2CC1	43770	68230	71.8	
2CC2	44100	68010	71.4	
2DC1	44220	67340	71.5	
2DC2	44030	68240	71.5	
2EC1	44550	68540	71.6	
2EC2	44530	68590	71.4	
2FC2	44700	68540	71.7	
2GC1	44250	67550	70.3	
2GC2	44380	67500	69.4	

TABLE XXI (Cont'd)

Room Temperature Rockwell Hardness of .064 Gage 2024-T3 Alclad Sheet After
Various Temperature-Time Exposure Conditions

Specimen Number	Yield Strength psi	Ultimate Strength psi	R _B	Hardness R _H
2HC1	44380	67810		112.5
2HC2	44080	67910	70.2	
2IC1	44980	68810	71.3	
2IC2	44670	68970	71.6	
2JC1	43610	66510	69.8	
2JC2	43610	66670	70.2	
2KC1	43690	66620	69.5	
2KC2	43830	67280	70.0	
2LC1	43940	67550	72.2	
2LC2	43960	67790	70.9	
2MC1	43830	67750	70.9	
2MC2	43400	67790	70.9	
2NC1	44750	68670	69.7	
2NC2	44460	68460	71.2	
2OC1	45220	69980	71.5	
2OC2	45120	69140	71.3	
2PC1	45500	69560	71.4	
2PC2	44780	68100	70.1	
2QC1	45120	68210		112.0
2QC2	44920	68310		113.3

TABLE XXII

ROOM TEMPERATURE ROCKWELL HARDNESS OF .064 GAGE 7075-T6 ALCLAD SHEET AFTER
VARIOUS TEMPERATURE-TIME EXPOSURE CONDITIONS

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness	
			R _p	R _H
7A1	14050	32840		92.6
7A2	13980	32300		92.3
7A3	14200	32790		91.3
7C34	54060	65910	73.3	115.8
7C35	53770	65900	74.6	115.5
7D21	54370	66340	72.4	114.8
7D22	25570	44140	37.3	105.1
7D23	25650	44160	35.6	104.8
7D28	25820	44240	36.2	104.9
7F38	62540	72640	77.6	
7F39	62700	72800	79.5	
7F40	62700	72830	78.6	
7G6	36170	53380	55.5	110.0
7H1	36130	53550	56.1	110.4
7H2	35970	51610	53.6	109.6
7I4	65600	76910	81.0	
7I5	65820	77160	79.3	
7I6	65500	77000	80.5	
7K7	63220	74840	80.3	
7K8	63690	75640	79.1	116.3
7L1	63060	71340	81.5	
7M6	18330	37780		97.8
7M8	18430	37580		98.0
7O4	64080	75000	81.0	
7P1	66020	76210	81.5	116.6
7P11	65760	76210	81.2	
7P12	23310	40190		102.0
7P13	23310	40030		102.3
7Q1	35060	50650	55.0	109.4
7Q2	35110	50810	53.7	109.5
7Q3	34790	50320	53.8	109.1
7R2	56010	66610	75.6	
7R3	55950	66610	74.9	
7R4	55710	66510	73.5	
7U3	67340	76560	81.9	
7U4	67340	76560	82.3	
7U5	67500	76720	81.0	
7V4	54660	65970	74.1	
7V5	55350	66670	75.3	
7W3	53260	64540	74.4	
7W4	53630	64950	74.0	
7W5	55290	66190	73.4	

TABLE XIII (Cont'd)

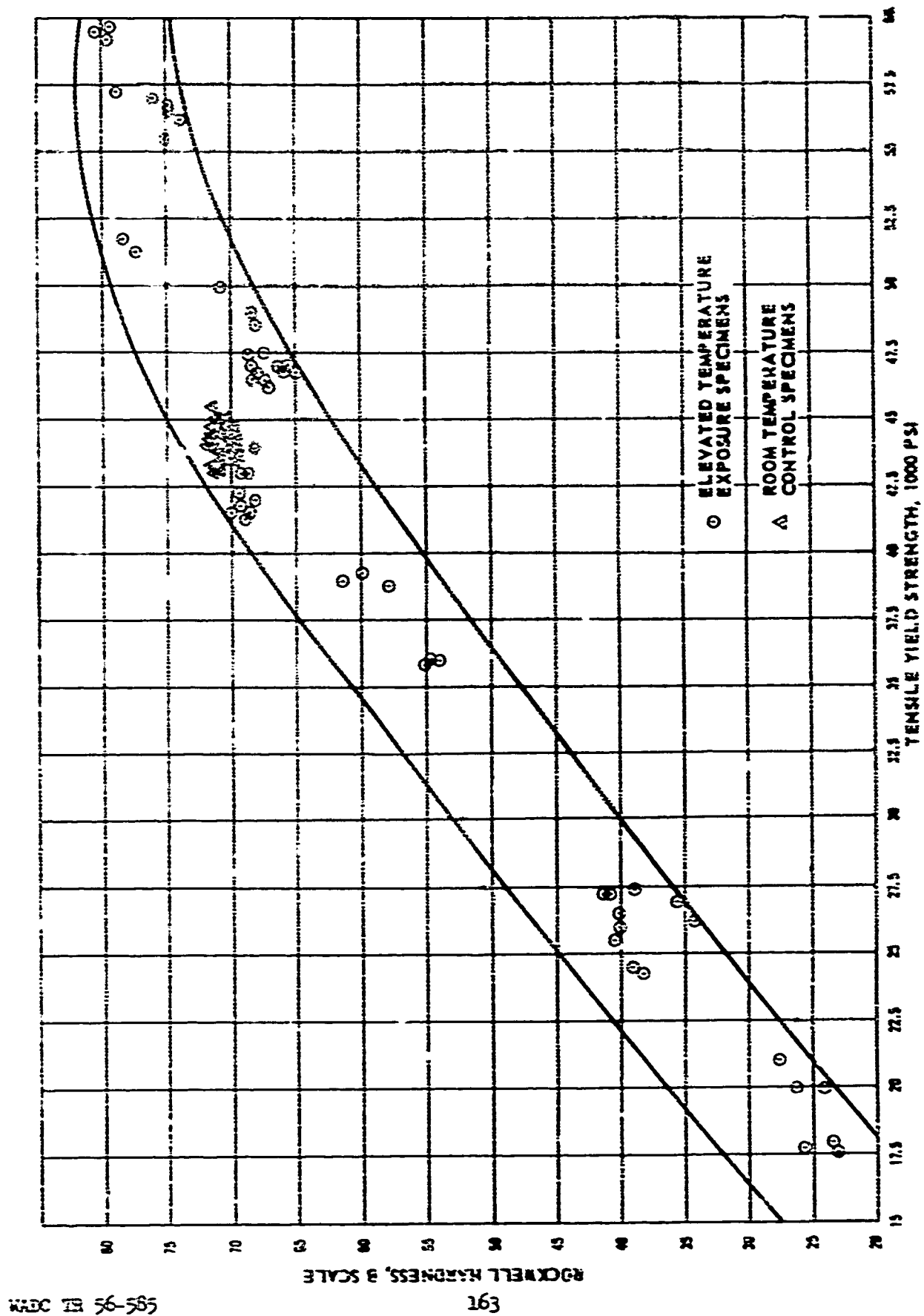
Room Temperature Rockwell Hardness of .064 Gage 7075-T6 Alclad Sheet After
Various Temperature-Time Exposure Conditions

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness R _p	Hardness R _H
7A3	20100	37580		96.8
7A9	17800	37740		96.9
7A10	17700	37500		97.0
7A11	17270	34760		95.7
7A2	17650	34920		95.4
7A3	17410	34650		93.0
7Z1		72900	83.7	
7Z2	61610	72740	81.4	
7Z3	62020	72440	80.4	
7AA1	25450	42680	33.4	103.8
7AA2	25840	43120	33.8	104.3
7AA3	25770	43060	33.2	103.7
7BB1	26700	42720		102.1
7BB2	26500	42930		104.0
7BB3	26590	42930		103.7
7CC1	26530	42280	28.3	103.6
7CC2	26350	42470	30.6	102.7
7CC3	26200	42330	26.6	103.7
7DD1			31.2	116.4
7DD2			30.9	116.2
7EE1	37820	52220	59.6	111.0
7EE2	38170	52370	59.5	110.3
7EE3	38660	52500	59.6	110.3
7FF1	15450	35670		94.4
7FF2	15290	35190		95.0
7FF3	15190	35130		94.6
7GG1	20350	36790	23.0	101.1
7GG2	20690	37260	15.8	101.1
7GG3	20630	37190	20.3	101.0
7HH1	27270	43450	41.9	106.0
7HH2	27520	43460	39.5	106.1
7HH3	27340	43450	39.5	106.3
7II1	52340	68990	80.0	106.0
7II2	62150	68040	81.5	105.5
7II3	61830	69400	81.6	106.4
7JJ1	38880	52540	57.2	110.6
7JJ2	38690	52670	55.0	111.0
7JJ3	38400	52510	54.9	110.6
7AC2	66720	78310	83.2	
7BC1	66500	77450	83.4	
7BC2	65890	77710	82.5	
7CC1	66010	76970	80.8	
7CC2	66050	76850	81.8	

TABLE XXII (Cont'd)

ROOM TEMPERATURE ROCKWELL HARDNESS OF .064 GAGE 7075-T6 ALCLAD SHEET AFTER
VARIOUS TEMPERATURE-TIME EXPOSURE CONDITIONS

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness R ₃₀	R _H
7DC1	66240	77330	91.4	
7DC2	65720	77650	82.4	
7EC1	66940	78550	90.6	
7EC2	66720	77920	91.3	
7FC1	67590	78500	90.3	
7FC2	66550	78130	90.3	
7GC1	66820	77380	80.4	
7GC2	66450	77900	79.8	
7EC1	66880	78130	91.1	
7EC2	66020	77880	82.3	
7IC1	65890	77860	79.0	
7IC2	65640	76610	79.9	
7JC1	67250	77850	83.0	
7JC2	67250	77850	82.0	
7KC1	67900	78230	90.6	
7KC2	66940	78500	81.7	
7LC1	66500	78320	91.2	
7MC1	65320	77440	92.2	
7PC1	67470	78690	83.5	
7PC2	67420	78760	83.8	
7QC2	67040	77920	83.2	
7RC2	67850	78520	83.8	
7SC1	67420	79520	91.8	
7SC2	68310	79420	91.5	
7TC1	68210	78430	80.8	
7TC2	68690	78750	81.3	
7UC1	69400	79500	81.3	
7UC2	69240	79500	81.0	



585-05 H. 17M

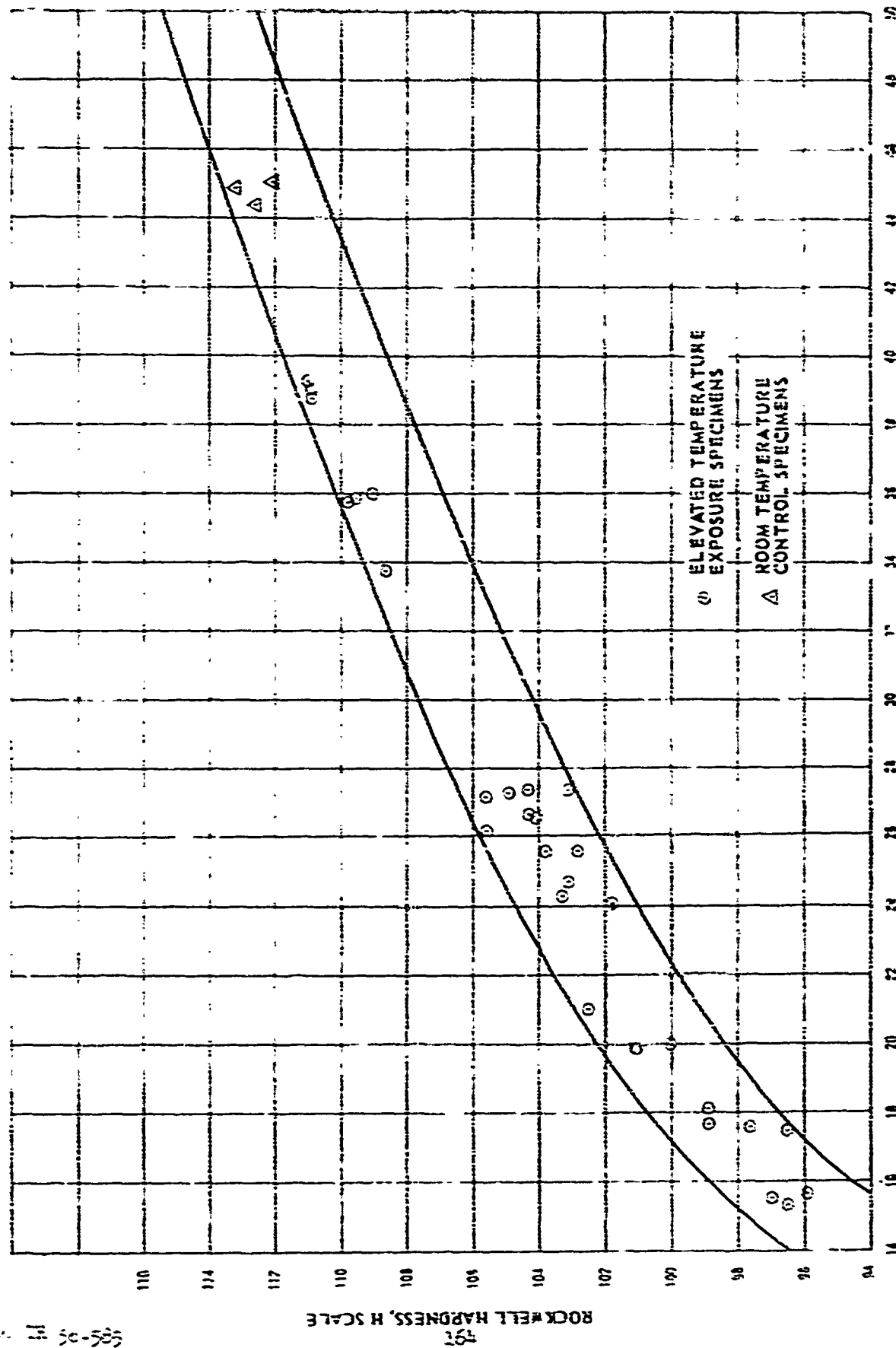


FIGURE 105 ROCKWELL HARDNESS VERSUS TENSILE YIELD STRENGTH OF 2024-T3 ALUMINUM ALLOY

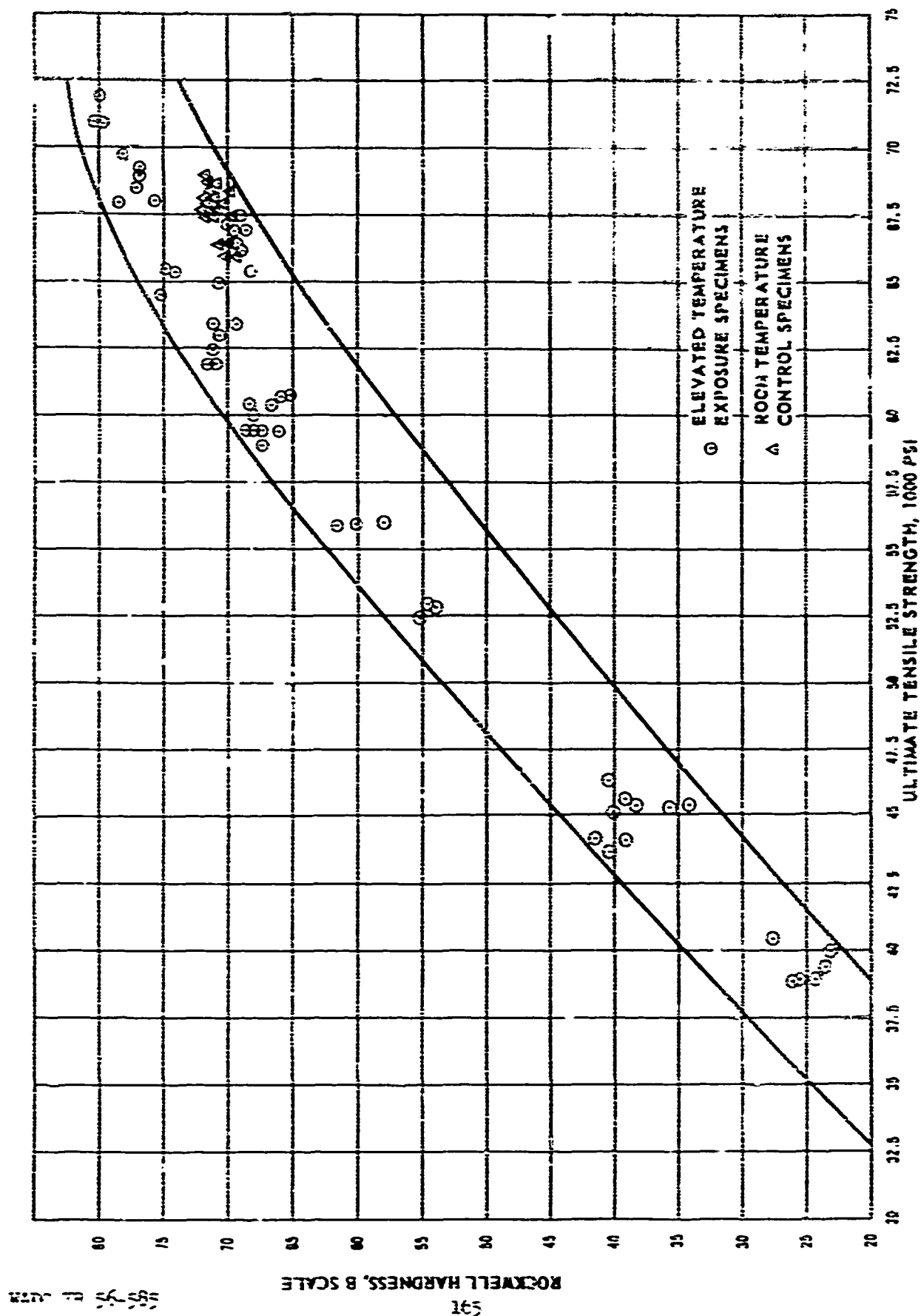


FIGURE 106 ROCKWELL B VERSUS ULTIMATE TENSILE STRENGTH FOR 2024-T3 ALUMINUM ALLOY

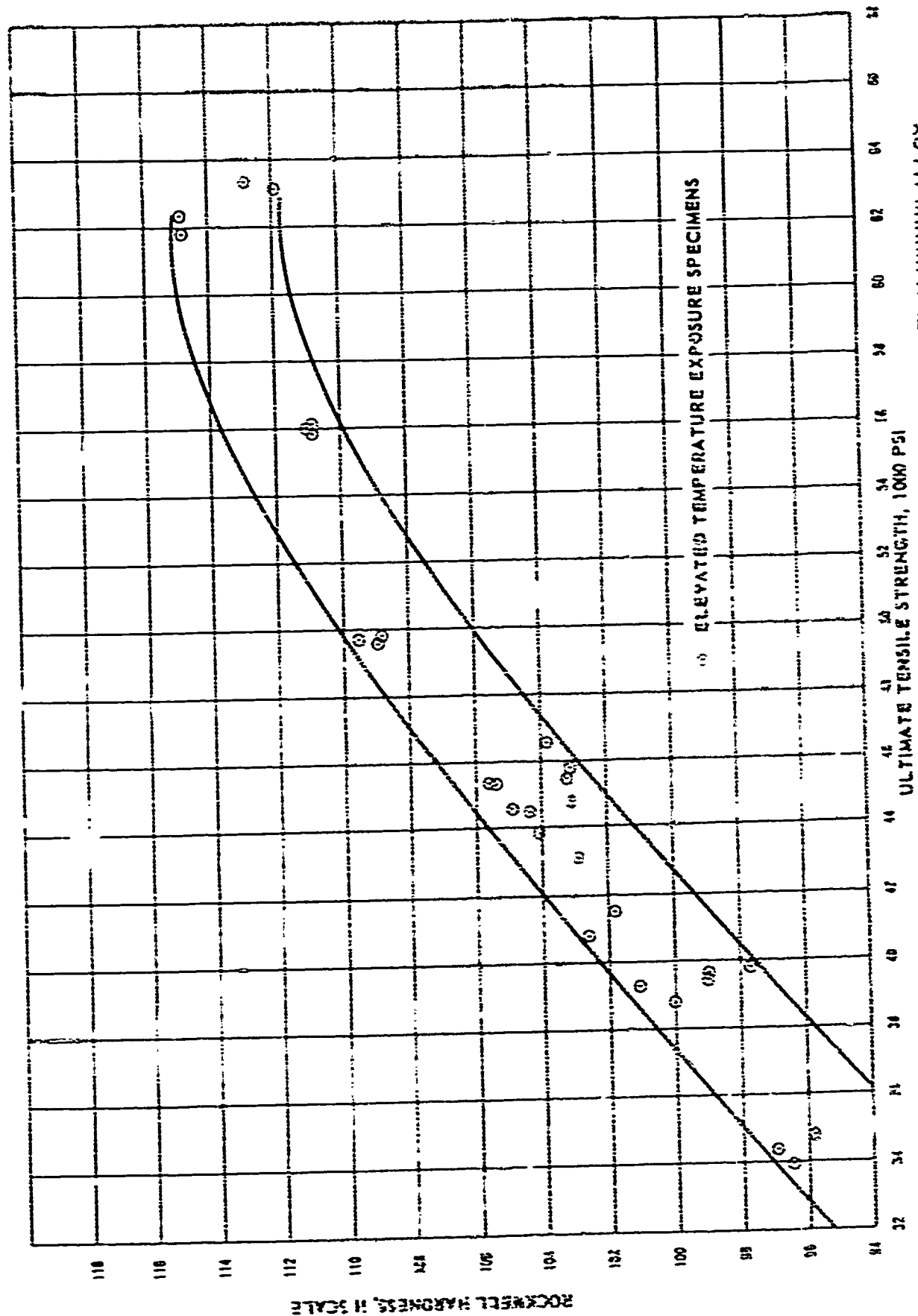
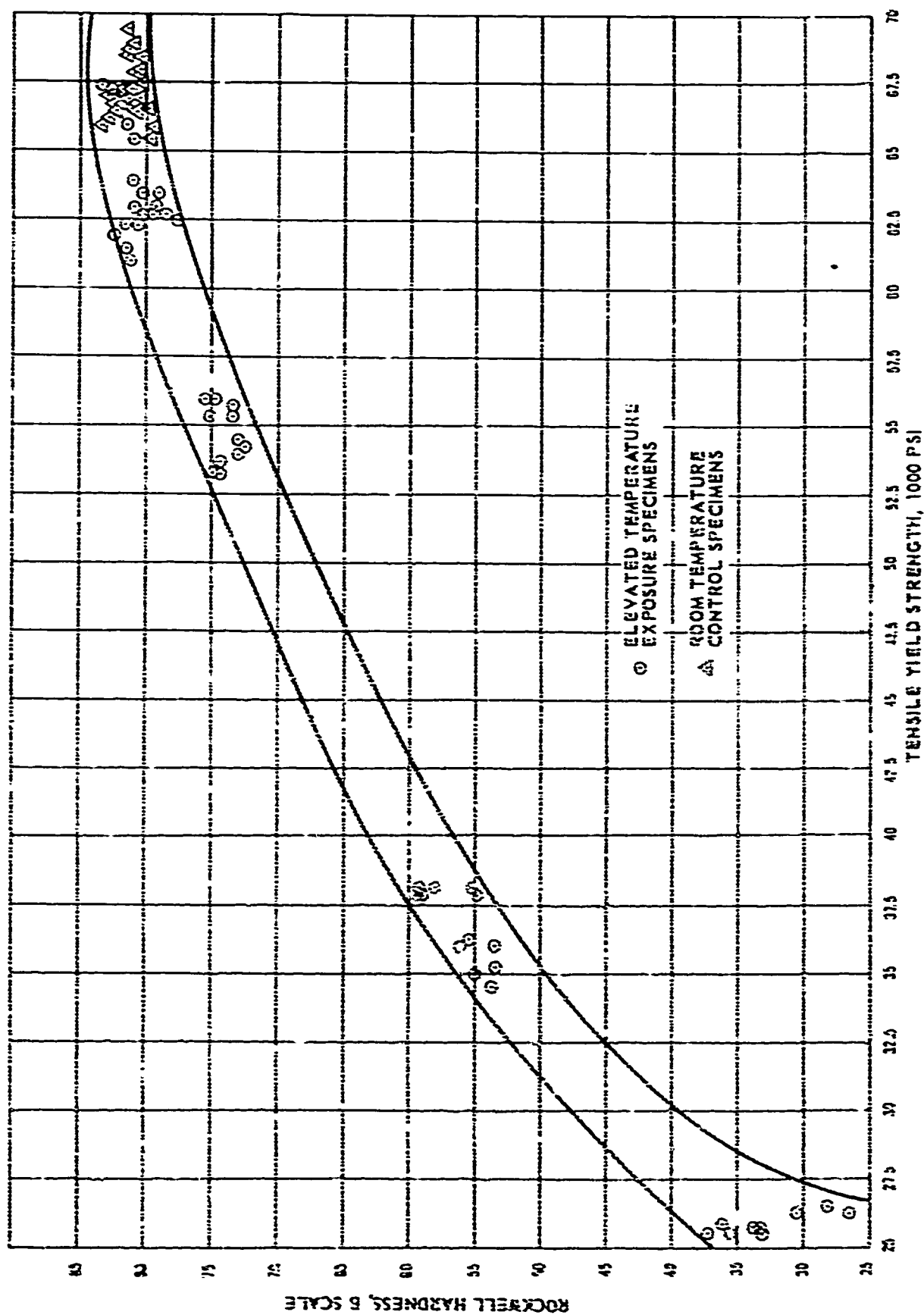


FIGURE 107 ROCKWELL H VERSUS ULTIMATE TENSILE STRENGTH FOR 2024-T3 ALUMINUM ALLOY



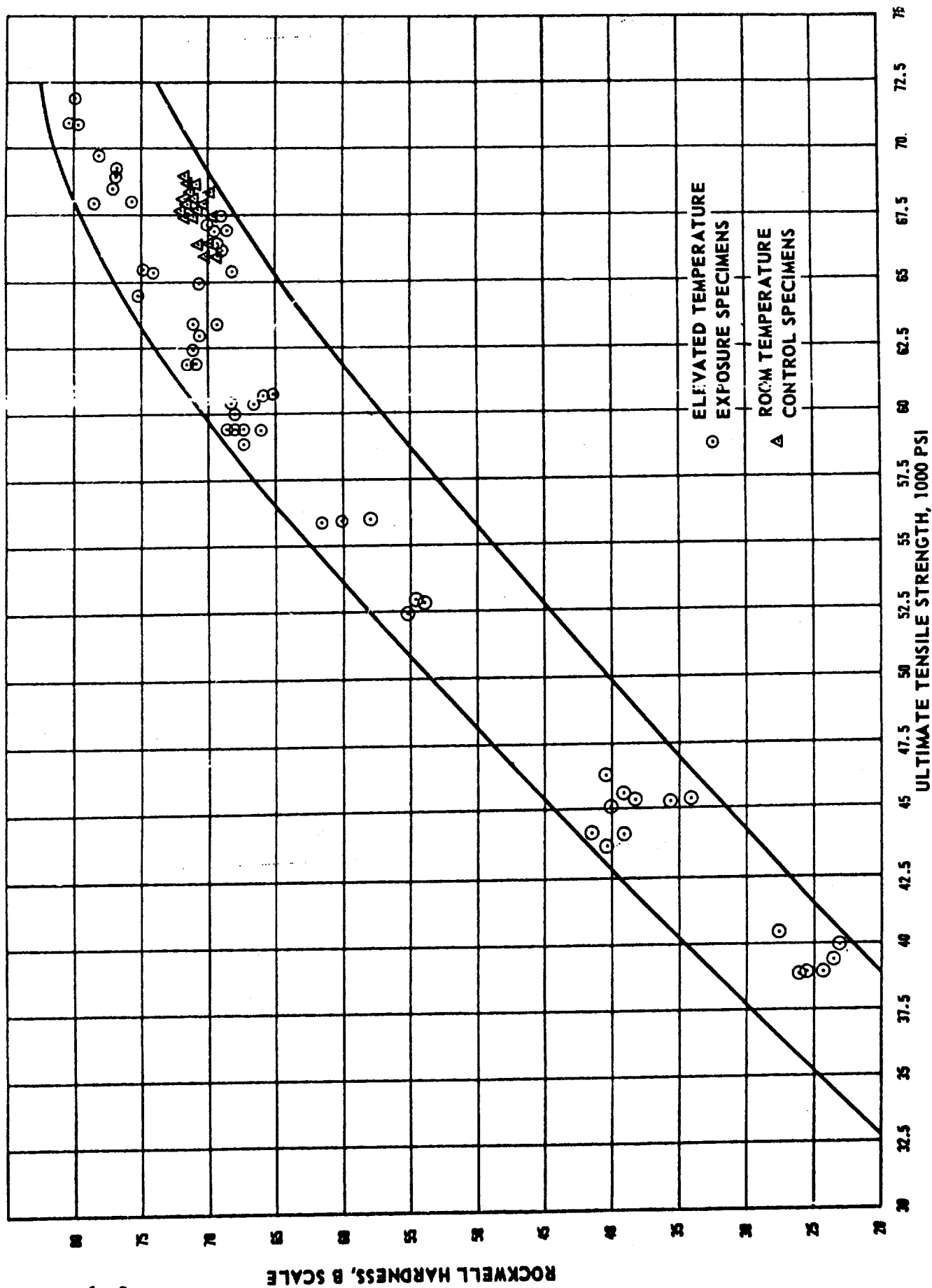


FIGURE 106 ROCKWELL B VERSUS ULTIMATE TENSILE STRENGTH FOR 2024-T3 ALUMINUM ALLOY

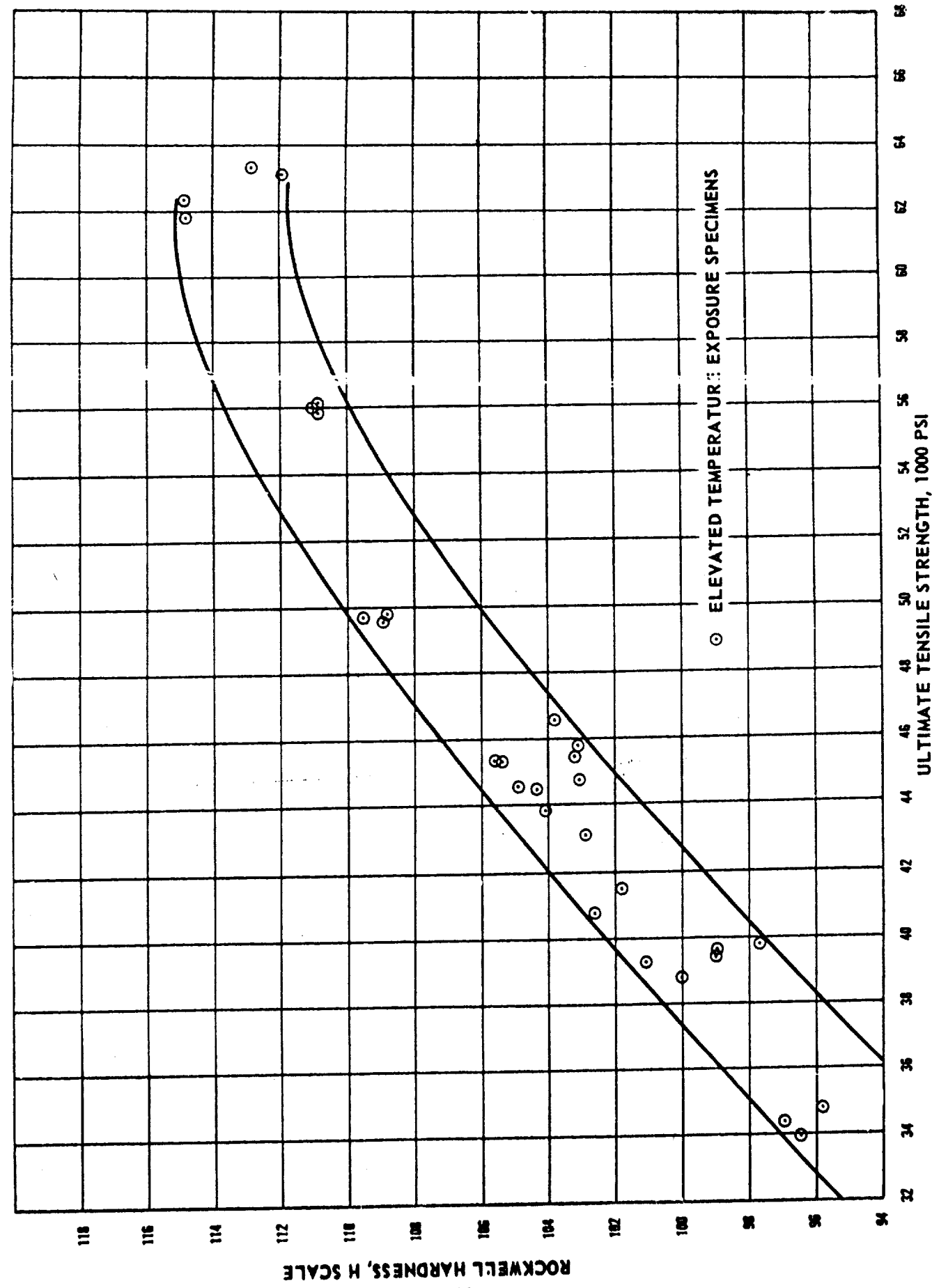


FIGURE 107 ROCKWELL H VERSUS ULTIMATE TENSILE STRENGTH FOR 2024-T3 ALUMINUM ALLOY

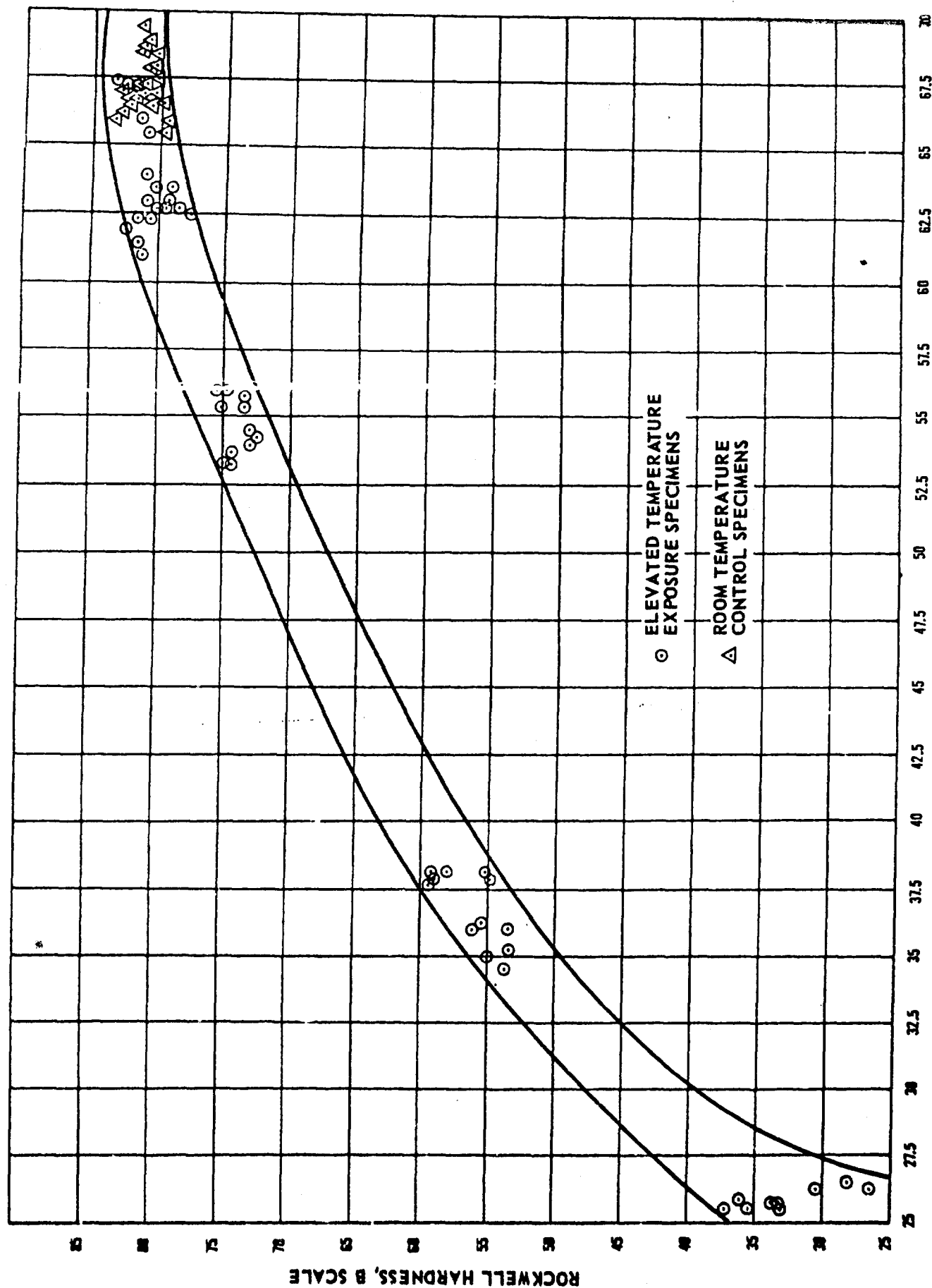


FIGURE 108 ROCKWELL HARDNESS VERSUS TENSILE YIELD STRENGTH OF 7075-T6 ALUMINUM ALLOY

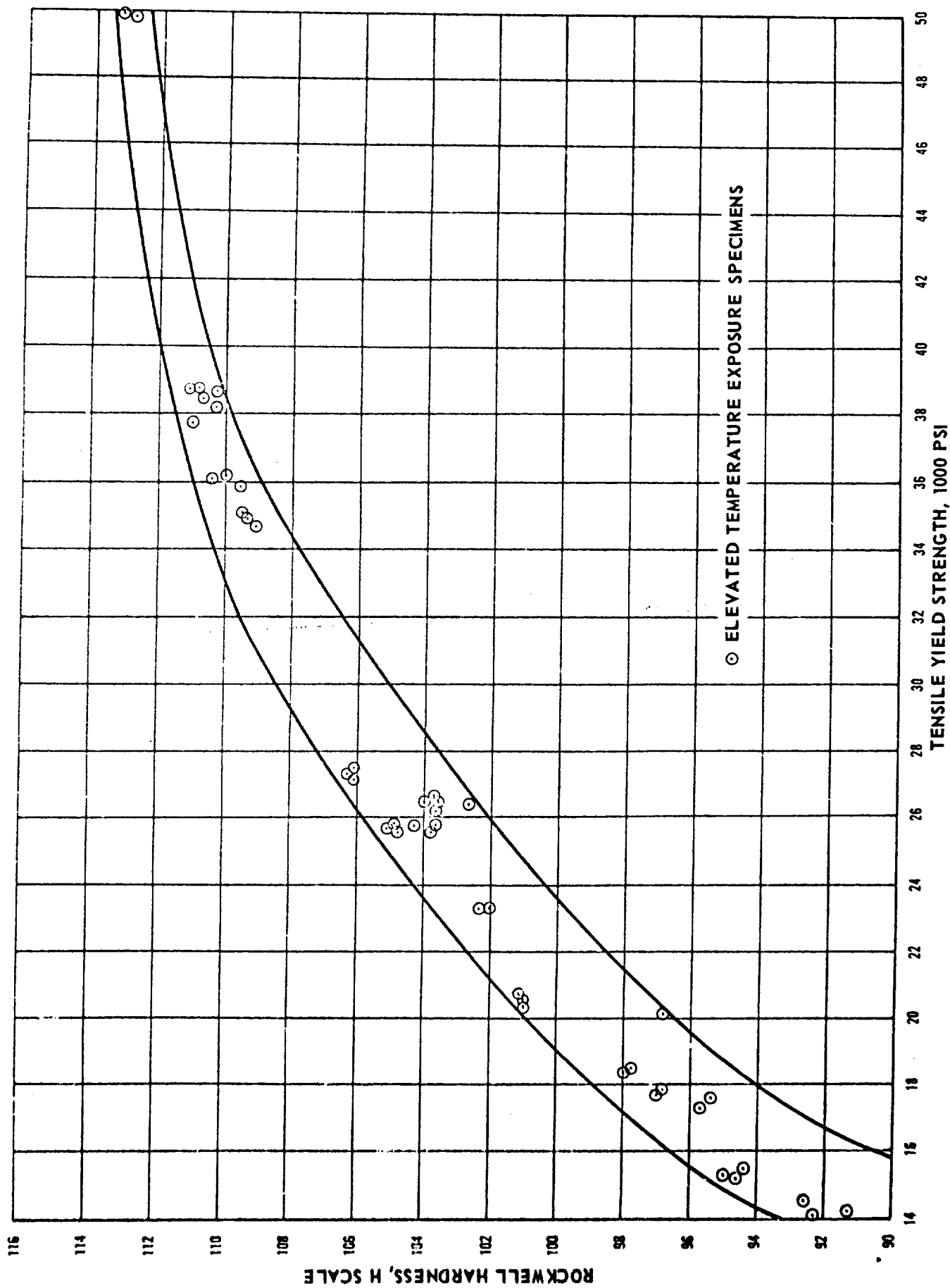


FIGURE 109 ROCKWELL HARDNESS VERSUS TENSILE YIELD STRENGTH OF 7075-T6 ALUMINUM ALLOY

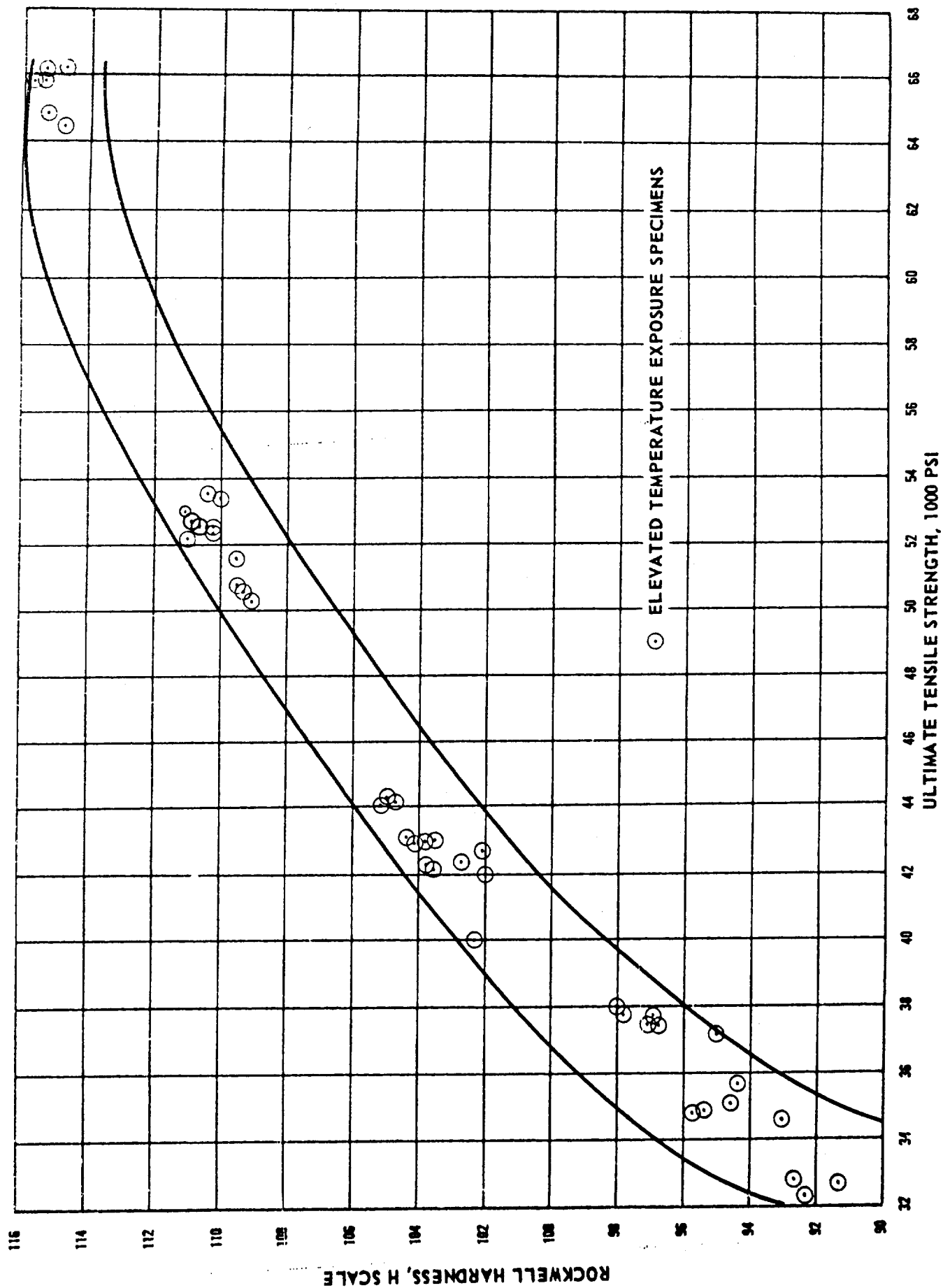


TABLE XIII

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 0.1 AND 1.0 HOUR EXPOSURE AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temperature °F	Exposure Time hrs.	Testing Temperature °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Ave. Elong. % in 2"	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
233 1	-	-	200	20060	22610	9.59	9.81	44310	44220	63850	63990	19.0	19.0	.0050	.069
233 2	-	-	200	22530		9.85		43830		63890		19.0	19.0	.0046	.069
233 3	-	-	200	25250		10.00		44530		64220		19.0		.0047	.069
233 4	-	-	300	22990	19780	9.46	9.43	41820	41540	56940	56760	22.5	23.3	.0045	.069
233 5	-	-	300	17330		9.41		41260		56590		22.5		.0047	.069
233 6	-	-	300	19020		9.41		41540		56760		25.0		.0040	.069
233 7	-	-	400	16310		9.41		35070		51080		15.0		.0044	.069
233 8	-	-	400	17690	17980	9.59	9.42	33850	34720	50920	50920	15.0	14.5	.0044	.069
233 9	-	-	400	19930		9.26		35230		50770		13.5		.0042	.069
23 9	300	0.1	R.T. (1)	17190		10.34		42970		67810		18.5		.0055	.067
23 10	300	0.1	R.T.	23750	21280	11.60	10.65	44060	43340	67190	67270	20.0	19.7	.0041	.067
23 11	300	0.1	R.T.	22900		10.00		42990		66820		20.5		.0046	.067
23 12	300	0.1	200	20310		10.23		41410		62970		19.0		.0047	.067
21 2	300	0.1	200	17240	18210	10.25	10.32	38870	40300	63010	62610	20.0	20.2	.0052	.067
21 3	300	0.1	200	17080		10.47		40620		61850		21.5		.0050	.067
21 3	300	0.1	300	18650	17640	10.18	10.17	39810	39970	57370	57490	24.0	23.6	.0051	.067
21 4	300	0.1	300	18080		10.21		40000		57550		24.5		.0050	.067
21 5	300	0.1	300	16200		10.11		40090		57550		22.5		.0049	.067
21 6	300	0.1	400	16820	16950	9.77	9.68	35380	35320	52520	52190	20.0	19.8	.0050	.067
21 7	300	0.1	400	15520		9.72		35580		52510		20.0		.0052	.067
21 2	300	0.1	400	16720		9.55		35000		51560		19.0		.0051	.067
23 7	400	0.1	R.T.	15050	14500	10.33	10.47	37930	38010	63320	63400	19.5	20.7	.0054	.061
23 8	400	0.1	R.T.	15720		10.53		38050		63370		21.0		.0054	.061
23 9	400	0.1	R.T.	12740		10.56		38050		63520		21.5		.0054	.061
23 11	400	0.1	200	16410	16420	10.08	9.94	37500	37670	62190	62440	23.0	22.8	.0047	.067
23 12	400	0.1	200	16410		9.98		37810		62500		23.0		.0050	.067
27 7	400	0.1	200	16450		9.77		37700		62620		22.5		.0050	.067
27 1	400	0.1	300	21090	22720	10.50	9.86	37810	38020	58280	58400	23.5	23.5	.0048	.075
27 2	400	0.1	300	26170		9.32		38320		58410		24.0		.0061	.075
27 3	400	0.1	300	20900		9.75		37940		58520		23.0		.0044	.075
27 4	400	0.1	400	25700	25320	8.22	8.27	37380	37190	52650	52700	19.5	19.0	.0052	.061
27 5	400	0.1	400	25000		8.44		36800		52640		19.0		.0054	.061
27 6	400	0.1	400	23860		8.14		37380		52800		18.5		.0054	.061

TABLE XXIII (Cont'd)

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER 0.1 AND 1.0 HOUR EXPOSURE AT ELEVATED TEMPERATURES

500	2F 6	R.T.	(2)	32580	(2)	10.08	49540	62120	62090	8.0	.0051
500	2F 9	R.T.	34880	32580	(2)	10.08	49540	62040	62090	8.0	.0050
500	2F 10	R.T.	30280	38690	10.26	9.80	55600	61800	64700	8.0	.0051
500	2T 1(3)	R.T.	39440	38690	9.86	9.80	55590	64750	64700	8.0	.0051
500	2T 2(3)	R.T.	38940		9.74		55610	64640		7.5	.0053
500	2F 11	200	37540	35530	10.00	9.78	50310	59810	59850	9.0	.0050
500	2G 1	200	36760		9.37		51400	59810	59850	8.5	.0053
500	2G 2	200	32300		9.96		51400	59940		8.5	.0049
500	2G 3	300	28190	29300	10.28	9.88	48290	52960	52960	12.0	.0047
500	2G 4	300	34420		9.56		48440	53120	53120	11.8	.0047
500	2G 5	300	25000		9.79		48440	53280		11.5	.0046
500	2G 6	400	20000	21260	8.94	9.57	40780	42340	42340	12.5	.0050
500	2G 7	400	20960		9.38		41930	43170	42980	15.5	.0051
500	2G 8	400	22810		10.38		42190	43440		13.5	.0048
600	2G 9	R.T.	20310	22500	10.40	10.14	39060	56090	56090	8.5	.0048
600	2G 10	R.T.	25860		9.81		39340	55960	55950	8.5	.0048
600	2G 11	R.T.	21320		10.22		38870	55800		8.5	.0046
600	2G 12	200	26970	26510	9.26	9.54	38330	53630	53630	9.0	.0046
600	2E 1	200	26260		9.48		37580	53300	53360	9.0	.0047
600	2E 2	200	25310		9.88		37740	53150		9.0	.0046
600	2E 3	300	19650	21090	10.49	10.41	36640	46860	47080	13.0	.0050
600	2E 4	300	20940		10.62		37190	47190	47080	12.5	.0060
600	2E 5	300	22500		10.12		36880	47190		13.5	.0054
600	2E 6	400	19530	19880	9.52	9.49	33590	37190	37090	17.0	.0053
600	2E 7	400	20060		9.66		33490	36730	37090	17.5	.0047
600	2E 8	400	20060		9.29		33950	37350		17.0	.0047
400	2C 28	R.T.	(2)		(2)			68280		15.5	.0045
400	2C 29	R.T.	34430	35650	9.69	9.76	51790	67930	68160	16.0	.0050
400	2C 30	R.T.	36880		9.84		51560	68280		16.0	.0050
400	2T 3(3)	R.T.	37930	40100	9.67	9.67	57120	67800	67960	11.0	.0053
400	2T 4(3)	R.T.	42260		9.67		57210	68110		10.5	.0053
400	2B 17	200	38440		9.08		52340	65000		15.5	.0020
400	2B 18	200	37240	38280	9.22	9.14	53610	65200	65390	15.5	.0020
400	2B 19	200	39180		9.12		53610	65990		15.0	.0020
400	2B 20	300	40160	37760	8.06	8.20	49100	60000	59770	16.0	.0060
400	2B 21	300	36610		8.23		49200	59840	59770	19.5	.0064
400	2B 22	300	36610		8.31		49200	59470		16.5	.0069
400	2C 25	400	(2)	27850	(2)	8.45	(2)	52720	52270	12.0	.0045
400	2C 26	400	(2)		(2)			52050	52270	11.0	.0050</

TABLE XIII (Cont'd)
RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 0.1 AND 1.0 HOUR EXPOSURE AT ELEVATED TEMPERATURES

2C 34	500	1.0	200	29590	9.47	45570	56170	9.0	.0092	.054
2C 35	500	1.0	200	29680	9.62	45710	56510	8.5	.0075	.054
2C 36	500	1.0	200	29340	9.85	44950	56150	9.0	.0075	.054
2D 1	500	1.0	300	25870	9.22	42590	48270	14.5	.0060	.043
2D 2	500	1.0	300	29000	8.95	42790	48430	14.5	.0060	.043
2D 3	500	1.0	300	28320	8.88	43040	48580	11.0	.0060	.043
2D 4	500	1.0	400	22800	9.06	37420	39310	14.5	.0060	.038
2D 5	500	1.0	400	15310	9.00	37190	39060	16.0	.0062	.038
2D 6	500	1.0	400	17350	9.10	37540	39270	13.5	.0056	.038
2D 7	600	1.0	R.T.	15310	9.63	25630	46560	9.0	.0054	.054
2D 8	600	1.0	R.T.	13790	9.80	24760	45770	9.5	.0050	.054
2D 9	600	1.0	R.T.	12230	9.80	24290	45450	9.0	.0050	.054
2D 10	600	1.0	200	17390	8.68	24840	45340	10.0	.0061	.054
2D 11	600	1.0	200	14870	8.77	25160	45730	9.5	.0068	.054
2D 12	600	1.0	200	14260	9.02	24290	45140	10.0	.0053	.054
2E 1	600	1.0	300	15530	8.68	24530	39750	15.5	.0053	.054
2E 2	600	1.0	300	14130	8.96	24070	39600	16.0	.0053	.054
2E 3	600	1.0	300	12420	9.36	23600	39600	17.0	.0053	.054
2E 4	600	1.0	400	14490	8.20	22120	28190	21.5	.0054	.054
2E 5	600	1.0	400	12660	8.48	21880	27810	21.0	.0053	.054
2E 6	600	1.0	400	15050	8.46	21940	28530	20.0	.0048	.054

- (1) R.T. designates room temperature. Actual temperature was not measured but is known to be in the range 60-85°F.
- (2) Autographic strain recorder curve was unsatisfactory for determining subject properties.
- (3) Retest specimens to fulfill requirement of at least three good specimens per testing condition.

TABLE XIV

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 10.0 AND 100.0 HOURS EXPOSURE AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temperature °F	Exposure Time Hrs.	Testing Temperature °F	Proportional Limit psi	Average Proportional Limit	Modulus of Elasticity, 10 ⁶ psi	Average Modulus of Elasticity, 10 ⁶ psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. 2" in. 2" %	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./in.
2L 4	400	10.0	R.T. (1)	27170		10.42		56830		65530		7.0	.0050	.081
2L 5	400	10.0	R.T.	23290	25260	10.65	10.51	56480	56590	65530	65480	7.5	.0051	.081
2L 6	400	10.0	R.T.	25310		10.45		56270		65370		7.5	.0051	.081
2L 7	400	10.0	200	31690		9.37	9.56	52620	52880	59230	59340	9.0	.0053	.075
2L 8	400	10.0	200	33180	32530	9.94		53090		59110		9.5	.0050	.075
2L 9	400	10.0	200	32710		9.41		52920		59380		9.5	.0054	.075
2L 10	400	10.0	300	27780		9.73	9.59	49230		52010		13.0	.0039	.075
2L 11	400	10.0	300	21140	25070	9.62		48610	48610	51700	51650	12.5	.0046	.075
2L 12	400	10.0	300	21300		9.44		47990		51240		12.5	.0048	.075
2E 1	400	10.0	400	20000		9.38	9.37	43380		44460		11.5	.0045	.075
2E 2	400	10.0	400	20550	20210	9.39		43100	43240	44170	44370	13.0	.0046	.075
2E 3	400	10.0	400	20090		9.36		43250		44480		11.5	.0050	.075
2E 4	500	10.0	R.T. (1)	21230		9.92		36010		52830		8.5	.0036	.054
2E 5	500	10.0	R.T.	20000	19970	10.12	10.14	35940	35930	52810	52760	9.0	.0037	.054
2E 6	500	10.0	R.T.	18690		10.37		35830		52650		8.5	.0036	.054
2E 7	500	10.0	200	20340		9.48	9.82	35250	35230	48760	48810	8.0	.0036	.061
2E 8	500	10.0	200	20650	20260	10.49		35250		48760		8.0	.0035	.061
2E 9	500	10.0	200	19780		9.50		35200		48910		9.5	.0037	.061
2E 10	500	10.0	300	17860		9.54	9.10	33540		41300		15.0	.0048	.067
2E 11	500	10.0	300	19630	18450	8.93		33860	33850	41120	41240	15.0	.0048	.067
2E 12	500	10.0	300	17860		8.84		34160		41300		16.5	.0047	.067
2L 1	500	10.0	400	14350		8.81	8.78	29500		32140		16.5	.0049	.075
2L 2	500	10.0	400	17190	15980	8.54		29530	29360	32340	32170	17.0	.0050	.075
2L 3	500	10.0	400	16410		9.01		29060		32030		17.0	.0048	.075
2J 1	600	10.0	R.T. (1)	8333		10.06		18120		39660		11.5	.0064	.067
2J 4	600	10.0	R.T.	9231	8560	9.33	9.70	17690	17800	39380	39620	11.5	.0061	.067
2J 5	600	10.0	R.T.	8117		9.73		17590		39820		13.0	.0061	.067
2J 7	600	10.0	200	9875		10.36	10.46	18530		40470		11.01	.0051	.067
2J 8	600	10.0	200	8916	9284	10.81		18420	18460	40400	40390	10.5	.0052	.067
2J 9	600	10.0	200	9062		10.21		18440		40310		11.0	.0051	.067
2J 10	600	10.0	300	11250		10.42	10.42	18440		34840		20.0	.0043	.054
2J 11	600	10.0	300	9467	10150	10.13		17870	18070	34800	34860	21.0	.0043	.054
2J 12	600	10.0	300	9737		10.70		17900		34950		21.0	.0048	.054

SECRET
TO THE PRESIDENT OF THE UNITED STATES
FROM THE SECRETARY OF DEFENSE
SUBJECT: [REDACTED]
DATE: [REDACTED]

2024	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1925	1924	1923	1922	1921	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1895	1894	1893	1892	1891	1890	1889	1888	1887	1886	1885	1884	1883	1882	1881	1880	1879	1878	1877	1876	1875	1874	1873	1872	1871	1870	1869	1868	1867	1866	1865	1864	1863	1862	1861	1860	1859	1858	1857	1856	1855	1854	1853	1852	1851	1850	1849	1848	1847	1846	1845	1844	1843	1842	1841	1840	1839	1838	1837	1836	1835	1834	1833	1832	1831	1830	1829	1828	1827	1826	1825	1824	1823	1822	1821	1820	1819	1818	1817	1816	1815	1814	1813	1812	1811	1810	1809	1808	1807	1806	1805	1804	1803	1802	1801	1800	1799	1798	1797	1796	1795	1794	1793	1792	1791	1790	1789	1788	1787	1786	1785	1784	1783	1782	1781	1780	1779	1778	1777	1776	1775	1774	1773	1772	1771	1770	1769	1768	1767	1766	1765	1764	1763	1762	1761	1760	1759	1758	1757	1756	1755	1754	1753	1752	1751	1750	1749	1748	1747	1746	1745	1744	1743	1742	1741	1740	1739	1738	1737	1736	1735	1734	1733	1732	1731	1730	1729	1728	1727	1726	1725	1724	1723	1722	1721	1720	1719	1718	1717	1716	1715	1714	1713	1712	1711	1710	1709	1708	1707	1706	1705	1704	1703	1702	1701	1700	1699	1698	1697	1696	1695	1694	1693	1692	1691	1690	1689	1688	1687	1686	1685	1684	1683	1682	1681	1680	1679	1678	1677	1676	1675	1674	1673	1672	1671	1670	1669	1668	1667	1666	1665	1664	1663	1662	1661	1660	1659	1658	1657	1656	1655	1654	1653	1652	1651	1650	1649	1648	1647	1646	1645	1644	1643	1642	1641	1640	1639	1638	1637	1636	1635	1634	1633	1632	1631	1630	1629	1628	1627	1626	1625	1624	1623	1622	1621	1620	1619	1618	1617	1616	1615	1614	1613	1612	1611	1610	1609	1608	1607	1606	1605	1604	1603	1602	1601	1600	1599	1598	1597	1596	1595	1594	1593	1592	1591	1590	1589	1588	1587	1586	1585	1584	1583	1582	1581	1580	1579	1578	1577	1576	1575	1574	1573	1572	1571	1570	1569	1568	1567	1566	1565	1564	1563	1562	1561	1560	1559	1558	1557	1556	1555	1554	1553	1552	1551	1550	1549	1548	1547	1546	1545	1544	1543	1542	1541	1540	1539	1538	1537	1536	1535	1534	1533	1532	1531	1530	1529	1528	1527	1526	1525	1524	1523	1522	1521	1520	1519	1518	1517	1516	1515	1514	1513	1512	1511	1510	1509	1508	1507	1506	1505	1504	1503	1502	1501	1500	1499	1498	1497	1496	1495	1494	1493	1492	1491	1490	1489	1488	1487	1486	1485	1484	1483	1482	1481	1480	1479	1478	1477	1476	1475	1474	1473	1472	1471	1470	1469	1468	1467	1466	1465	1464	1463	1462	1461	1460	1459	1458	1457	1456	1455	1454	1453	1452	1451	1450	1449	1448	1447	1446	1445	1444	1443	1442	1441	1440	1439	1438	1437	1436	1435	1434	1433	1432	1431	1430	1429	1428	1427	1426	1425	1424	1423	1422	1421	1420	1419	1418	1417	1416	1415	1414	1413	1412	1411	1410	1409	1408	1407	1406	1405	1404	1403	1402	1401	1400	1399	1398	1397	1396	1395	1394	1393	1392	1391	1390	1389	1388	1387	1386	1385	1384	1383	1382	1381	1380	1379	1378	1377	1376	1375	1374	1373	1372	1371	1370	1369	1368	1367	1366	1365	1364	1363	1362	1361	1360	1359	1358	1357	1356	1355	1354	1353	1352	1351	1350	1349	1348	1347	1346	1345	1344	1343	1342	1341	1340	1339	1338	1337	1336	1335	1334	1333	1332	1331	1330	1329	1328	1327	1326	1325	1324	1323	1322	1321	1320	1319	1318	1317	1316	1315	1314	1313	1312	1311	1310	1309	1308	1307	1306	1305	1304	1303	1302	1301	1300	1299	1298	1297	1296	1295	1294	1293	1292	1291	1290	1289	1288	1287	1286	1285	1284	1283	1282	1281	1280	1279	1278	1277	1276	1275	1274	1273	1272	1271	1270	1269	1268	1267	1266	1265	1264	1263	1262	1261	1260	1259	1258	1257	1256	1255	1254	1253	1252	1251	1250	1249	1248	1247	1246	1245	1244	1243	1242	1241	1240	1239	1238	1237	1236	1235	1234	1233	1232	1231	1230	1229	1228	1227	1226	1225	1224	1223	1222	1221	1220	1219	1218	1217	1216	1215	1214	1213	1212	1211	1210	1209	1208	1207	1206	1205	1204	1203	1202	1201	1200	1199	1198	1197	1196	1195	1194	1193	1192	1191	1190	1189	1188	1187	1186	1185	1184	1183	1182	1181	1180	1179	1178	1177	1176	1175	1174	1173	1172	1171	1170	1169	1168	1167	1166	1165	1164	1163	1162	1161	1160	1159	1158	1157	1156	1155	1154	1153	1152	1151	1150	1149	1148	1147	1146	1145	1144	1143	1142	1141	1140	1139	1138	1137	1136	1135	1134	1133	1132	1131	1130	1129	1128	1127	1126	1125	1124	1123	1122	1121	1120	1119	1118	1117	1116	1115	1114	1113	1112	1111	1110	1109	1108	1107	1106	1105	1104	1103	1102	1101	1100	1099	1098	1097	1096	1095	1094	1093	1092	1091	1090	1089	1088	1087	1086	1085	1084	1083	1082	1081	1080	1079	1078	1077	1076	1075	1074	1073	1072	1071	1070	1069	1068	1067	1066	1065	1064	1063	1062	1061	1060	1059	1058	1057	1056	1055	1054	1053	1052	1051	1050	1049	1048	1047	1046	1045	1044	1043	1042	1041	1040	1039	1038	1037	1036	1035	1034	1033	1032	1031	1030	1029	1028	1027	1026	1025	1024	1023	1022	1021	1020	1019	1018	1017	1016	1015	1014	1013	1012	1011	1010	1009	1008	1007	1006	1005	1004	1003	1002	1001	1000	999	998	997	996	995	994	993	992	991	990	989	988	987	986	985	984	983	982	981	980	979	978	977	976	975	974	973	972	971	970	969	968	967	966	965	964	963	962	961	960	959	958	957	956	955	954	953	952	951	950	949	948	947	946	945	944	943	942	941	940	939	938	937	936	935	934	933	932	931	930	929	928	927	926	925	924	923	922	921	920	919	918	917	916	915	914	913	912	911	910	909	908	907	906	905	904	903	902	901	900	899	898	897	896	895	894	893	892	891	890	889	888	887	886	885	884	883	882	881	880	879	878	877	876	875	874	873	872	871	870	869	868	867	866	865	864	863	862	861	860	859	858	857	856	855	854	853	852	851	850	849	848	847	846	845	844	843	842	841	840	839	838	837	836	835	834	833	832	831	830	829	828	827	826	825	824	823	822	821	820	819	818	817	816	815	814	813	812	811	810	809	808	807	806	805	804	803	802	801	800	799	798	797	796	795	794	793	792	791	790	789	788	787	786	785	784	783	782	781	780	779	778	777	776	775	774	773	772	771	770	769	768	767	766	765	764	763	762	761	760	759	758	757	756	755	754	753	752	751	750	749	748	747	746	745	744	743	742	741	740	739	738	737	736	735	734	733	732	731	730	729	728	727	726	725	724	723	722	721	720	719	718	717	716	715	714	713	712	711	710	709	708	707	706	705	704	703	702	701	700	699	698	697	696	695	694	693	692	691	690	689	688	687	686	685	684	683	682	681	680	679	678	677	676	675	674	673	672	671	670	669	668	667	666	665	664	663	662	661	660	659	658	657	656	655	654	653	652	651	650	649	648	647	646	645	644	643	642	641	640	639	638	637	636	635	634	633	632	631	630	629	628	627	626	625	624	623	622	621	620	619	618	617	616	615	614	613	612	611	610	609	608	607	606	6
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- 1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-80°F.
- 2) Autographic recorder curve was unsatisfactory for determining subject properties.
- 3) Due to testing emergency, test was delayed one hour.

RESULTS OF TENSILE TESTS OF 2024-T3 ALUMINUM AT ROOM AND ELEVATED TEMPERATURES
AFTER 1000 HOURS EXPOSURE AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temperature °F	Exposure Time Hrs.	Testing Temperature °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10 ⁶ psi	Average Modulus of Elasticity 10 ⁶ psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Ave. Elong. in 2"	Strain Rate Sec./in./min.	Head Travel in Plastic Range in./min.
21 1	300	1000.0	R.T. (1)	38460	38510	9.59	9.79	61540	61630	68920	68920	8.0	7.7	.0055	.081
21 2	300	1000.0	R.T.	38700		9.55		61460		69350		7.5		.0038	.081
21 3	300	1000.0	R.T.	39380		10.23		61880		69670		7.5		.0037	.081
21 4	300	1000.0	200	39480	34860	9.26	9.36	57360	57380	62580	62610	8.0	8.0	.0054	.081
21 5	300	1000.0	200	35360		9.35		57450		62610		8.0		.0056	.081
21 6	300	1000.0	200	29730		9.98		57320		62650		8.0		.0056	.081
21 7	300	1000.0	300	23320	25770	9.72	9.19	52590	52750	55340	55200	10.5	10.7	.0033	.081
21 8	300	1000.0	300	29140		9.15		52910		55210		10.5		.0056	.081
21 9	300	1000.0	300	24850		9.99		52760		55060		11.0		.0057	.081
21 10	300	1000.0	400	21010		9.20		45410		46180		13.0		.0049	.069
21 11	300	1000.0	400	26150	23670	9.00	9.06	45690	45620	46310	46320	11.5	12.2	.0051	.069
21 12	300	1000.0	400	23850		8.97		45750		46460		12.0		.0050	.069
21 1	400	1000.0	R.T.	21230	21230	9.79	9.79	33790	33790	49850	49690	9.5	8.8	.0049	.081
21 2	400	1000.0	R.T.	(2)		(2)		(2)		49540		8.5		.0046	.081
21 3	400	1000.0	R.T.	(2)		(2)		(2)		49690		8.5		.0048	.081
21 4	400	1000.0	200	16110	12970	9.81	9.92	32220	32150	44230	44530	9.0	9.2	.0045	.071
21 5	400	1000.0	200	11430		10.35		31400		44060		9.5		.0046	.071
21 6	400	1000.0	200	11370		9.61		32890		45290		9.0		.0048	.071
21 7	400	1000.0	300	13760	13820	9.59	9.56	31040	31300	38530	38630	15.5	12.5	.0043	.081
21 8	400	1000.0	300	13860		9.93		31940		39200		11.0		.0043	.081
21 9	400	1000.0	300	13850		9.17		30920		38150		11.0		.0048	.081
21 10	400	1000.0	400	13190	13550	9.83	10.28	27700	27920	31600	31990	13.0	13.8	.0050	.081
21 11	400	1000.0	400	13930		9.93		27650		31730		13.0		.0048	.081
21 12	400	1000.0	400	13540		11.10		28400		32460		15.5		.0048	.081
21 1	500	1000.0	R.T.	6860	7420	9.49	10.11	15380	15540	33850	34340	12.5	12.5	.0044	.075
21 2	500	1000.0	R.T.	7320		11.16		15670		34710		11.5		.0046	.075
21 3	500	1000.0	R.T.	8090		9.67		15560		34440		13.5		.0050	.075
21 4	500	1000.0	200	9430	9490	9.07	8.71	15250	15420	32440	32500	15.0	14.7	.0045	.075
21 5	500	1000.0	200	9520		8.23		15680		32540		15.0		.0045	.075
21 6	500	1000.0	200	9450		8.82		15400		32540		14.0		.0035	.075
21 7	500	1000.0	300	8010	7511	10.08	10.96	14300	14660	26190	26630	27.0	27.0	.0044	.075
21 8	500	1000.0	300	7940		9.85		14580		26470		32.0		.0026	.075
21 10	500	1000.0	300	6570		12.96		15100		27710		22.0		.0023	.075
21 11	500	1000.0	400	6456	6070	11.07	11.10	13890	13360	19650	18850	27.0	33.8	.0025	.075
21 12	500	1000.0	400	6120		11.12		13400		19210		28.5		.0025	.075
21 13	500	1000.0	400	5640		11.11		12790		17690		46.0		.0026	.075

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

(2) Autographic strain recorder curve was unsatisfactory for determining subject properties.

TABLE XVI

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER A SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

Specimen No.	Sequential Exposure Time & Temp.				Average Proportional Limit	Modulus of Elasticity	Average Yield Strength	Ultimate Strength	Average Elong. % in 2"	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
	First of	Second of	Third of	Fourth of							
	10 Hrs.	100 Hrs.	1000 Hrs.	Temp. of	psi	10 ⁶ psi	psi	psi			
Z1 1	500	400	-	R.T. (1)	21030	10.50	46260	59500	8.0	.0054	.054
Z1 2	500	400	-	R.T.	20400	10.43	46570	59500	7.5	.0054	.054
Z1 3	500	400	-	R.T.	28040	10.31	47660	60120	8.0	.0053	.054
Z1 4	500	400	-	200	28500	9.88	45950	55140	10.0	.0057	.054
Z1 5	500	400	-	200	31330	9.09	45670	54500	9.5	.0062	.054
Z1 6	500	400	-	200	32450	8.99	45810	54970	10.0	.0064	.054
Z1 7	500	400	-	300	28000	9.42	42310	46920	16.0	.0057	.050
Z1 8	500	400	-	300	28140	9.28	42660	47400	13.5	.0058	.050
Z1 9	500	400	-	300	28350	9.55	42070	46650	13.0	.0058	.050
Z1 10	500	400	-	400	23450	8.70	37230	39540	13.5	.0058	.050
Z1 11	500	400	-	400	21010	9.30	37120	39420	15.5	.0057	.050
Z1 12	500	400	-	400	24850	8.67	37120	39110	13.0	.0058	.050
Z1 1	500	400	300	R.T.	23990	10.79	46900	59440	9.5	.0036	.054
Z1 2	500	400	300	R.T.	28790	10.24	47830	59910	9.0	.0035	.054
Z1 3	500	400	300	R.T.	30560	10.25	48610	60490	8.5	.0035	.054
Z1 4	500	400	300	200	32970	9.49	46900	55260	10.0	.0045	.067
Z1 5	500	400	300	200	30220	9.84	46170	54600	10.0	.0044	.067
Z1 6	500	400	300	200	32110	9.36	46300	54780	10.0	.0045	.067
Z1 7	500	400	300	300	23650	9.71	42000	46770	12.5	.0047	.067
Z1 8	500	400	300	300	27150	9.73	42180	46930	13.5	.0055	.067
Z1 9	500	400	300	300	24070	9.35	40830	46020	13.0	.0055	.067
Z1 10	500	400	300	400	65690	8.29	36700	38680	15.5	.0057	.067
Z1 11	500	400	300	400	25310	8.42	36200	38500	17.0	.0058	.067
Z1 12	500	400	300	400	24690	8.57	36350	38960	14.0	.0060	.067
Z1 1	600	500	-	R.T.	15430	9.00	27160	45370	8.5	.0037	.071
Z1 2	600	500	-	R.T.	14950	10.75	26700	45170	8.5	.0047	.061
Z1 3	600	500	-	R.T.	14730	9.17	26180	45300	9.5	.0045	.061
Z1 4	600	500	-	200	17080	9.32	25160	42080	10.0	.0043	.061
Z1 5	600	500	-	200	15310	9.61	25130	42500	10.0	.0043	.061
Z1 6	600	500	-	200	14060	9.57	24770	42110	10.5	.0050	.061
Z1 7	600	500	-	300	15110	9.42	23990	34890	13.5	.0044	.061
Z1 8	600	500	-	300	11590	9.64	23200	34330	14.5	.0050	.061
Z1 9	600	500	-	300	14160	9.06	24130	34840	14.0	.0043	.061
Z1 10	600	500	-	400	12580	8.65	21540	26100	21.0	.0044	.061
Z1 11	600	500	-	400	11430	8.73	21750	26350	16.0	.0044	.061
Z1 12	600	500	-	400	10560	8.85	21740	26240	17.0	.0043	.061

TABLE XVI (Cont'd)

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER A SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

228 1	600	500	400	-	R.T.	16460	15600	9.69	27130	44670	43090	9.5	.069
228 2	600	500	400	-	R.T.	16190		9.60	25760	43080		10.2	.069
228 3	600	500	400	-	R.T.	16110		10.05	24110	41510		10.5	.069
228 4	600	500	400	-	200	10030		10.93	23560	38210		12.0	.069
228 5	600	500	400	-	200	13920	12450	9.68	23330	37960		11.5	.069
228 6	600	500	400	-	200	13400		9.91	23230	37770		11.0	.069
228 7	600	500	400	-	300	11720		9.79	23010	32360		14.5	.069
228 8	600	500	400	-	300	10020		11.63	23280	32820		15.5	.069
228 9	600	500	400	-	300	9230		11.73	21360	31120		21.0	.069
228 10	600	500	400	-	400	11300		9.57	20710	25510		21.0	.069
228 11	600	500	400	-	400	9780	11210	10.06	20960	25780		15.0	.069
228 12	600	500	400	-	400	12530		9.66	21860	26520		17.5	.069
228 1	600	500	400	300	R.T.	14460		9.60	27390	44190		10.5	.061
228 2	600	500	400	300	R.T.	7030	9670	10.00	27280	44340		11.0	.061
228 3	600	500	400	300	R.T.	7530		9.27	26630	43750		11.0	.061
228 4	600	500	400	300	200	11410		10.34	25380	38910		13.0	.061
228 5	600	500	400	300	200	11220	12440	8.52	25110	38790		13.0	.061
228 6	600	500	400	300	200	14690		9.81	25220	38060		13.0	.061
228 7	600	500	400	300	300	16040		9.58	24920	34060		15.5	.061
228 8	600	500	400	300	300	15220	15510	8.77	23910	33080		18.0	.061
228 9	600	500	400	300	300	15280		8.54	23980	33080		16.0	.061
228 10	600	500	400	300	400	11590		9.10	23510	27260		19.5	.061
228 11	600	500	400	300	400	14210	12560	8.92	21580	26550		14.0	.061
228 12	600	500	400	300	400	11620		8.79	21530	26890		16.5	.061

(1) H designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER AN ADDITIONAL SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

Specimen Number	Sequential Exposure Time and Temperature				Testing Temperature by	Proportional Limit		Average Modulus of Elasticity		Average Yield Strength		Average Ultimate Strength		Avg. Elong. in 2"	Strain Rate Head Travel	
	First	Second	Third	Fourth		Limit	psi	psi	psi	psi	psi	psi	psi		in./in./min.	Below Yield
21J 1	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	219 Hrs. 330°F	R.T. (1)	35000	10.31	56720	67500	7.5	.0051	.054				
21J 2	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	R.T.	38120	10.00	55630	66720	7.5	.0050	.066				
21J 3	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	R.T.	33960	9.71	55610	66980	8.0	.0048	.065				
21J 4	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	200	29530	10.31	52500	60470	9.5	.0050	.072				
21J 5	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	200	28340	9.65	52340	59280	10.0	.0050	.068				
21J 6	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	200	29520	9.90	52010	59880	9.5	.0052	.060				
21J 7	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	300	26390	9.49	47840	51850	12.5	.0048	.054				
21J 8	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	300	27160	10.03	48300	52160	11.5	.0050	.062				
21J 9	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	300	26690	10.00	47680	51540	12.0	.0052	.073				
21J 10	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	400	25540	10.00	42310	43540	12.5	.0050	.067				
21J 11	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	400	20250	9.61	42520	43480	13.0	.0050	.068				
21J 12	1.0 Hr. 165°F	2.0 Hrs. 165°F	30.0 Hrs. 165°F	330 330	400	17130	9.58	41900	43300	13.0	.0050	.059				
21K 1	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	164.0 Hrs. 375°F	R.T.	27130	10.02	44460	59330	8.5	.0050	.040				
21K 2	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	R.T.	27070	9.71	44110	58920	8.5	.0048	.042				
21K 3	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	R.T.	23400	10.46	43310	56690	8.5	.0048	.037				
21K 4	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	200	23240	9.98	40380	51280	9.5	.0046	.074				
21K 5	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	200	23950	10.23	39480	50650	9.5	.0051	.074				
21K 6	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	200	25080	9.54	39640	50650	10.5	.0051	.063				
21K 7	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	300	20810	9.41	36930	43230	12.0	.0042	.060				
21K 8	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	300	17790	10.19	35920	42070	12.0	.0053	.067				
21K 9	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	300	20230	9.43	35920	42070	12.0	.0054	.071				
21K 10	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	400	16940	8.79	31930	34520	13.5	.0053	.067				
21K 11	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	400	15920	9.23	32640	35510	13.0	.0050	.064				
21K 12	1.0 Hr. 165°F	1.6 Hrs. 165°F	25.2 Hrs. 165°F	375 375	400	16560	9.16	32320	35190	12.0	.0054	.067				
21L 1	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	126.1 Hrs. 120°F	R.T.	17080	9.83	30880	47210	10.0	.0055	.038				
21L 2	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	R.T.	15060	9.65	29970	47050	10.0	.0060	.057				
21L 3	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	R.T.	13910	10.23	30160	47340	10.0	.0051	.048				
21L 4	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	200	16250	9.21	29100	42720	11.5	.0066	.065				
21L 5	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	200	145	9.89	28820	42680	12.0	.0058	.056				
21L 6	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	200	16610	9.73	28730	42590	11.5	.0054	.064				
21L 7	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	300	17180	8.75	26720	35000	16.5	.0050	.061				
21L 8	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	300	10840	9.89	27190	35620	15.0	.0051	.066				
21L 9	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	300	16560	10.12	27130	35330	17.0	.0058	.050				
21L 10	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	400	13080	8.56	23210	27260	11.5	.0050	.048				
21L 11	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	400	13640	10.39	24160	29470	15.5	.0050	.050				
21L 12	1.0 Hr. 165°F	1.3 Hrs. 165°F	21.5 Hrs. 165°F	120 120	400	15890	9.45	27700	30220	16.0	.0058	.062				

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER AN ADDITIONAL SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

[illegible]

7) Z.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

TABLE XVIII
RESULTS OF TENSILE TESTS OF TTT-TOCALUMINUM AT ROOM AND ELEVATED TEMPERATURES
AFTER 0.1 AND 1.0 HOUR EXPOSURES AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temperature of	Exposure Time Hrs.	Testing Temperature of	Proportional Limit psi	Average Proportional Limit	Modulus of Elasticity 10^5 psi	Average Modulus of Elasticity 10^5 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. in 2" %	Ave. Elong. in 2" %	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
T11	-	-	200	37500		8.60		62340		68990		16.0		.0054	.069
T12	-	-	200	37690	36050	9.02	8.79	62180	62120	68310	68810	16.3	15.7	.0047	.069
T13	-	-	200	38960		8.75		61830		69400		15.0		.0031	.069
T14	-	-	300	32130		8.49		54220		56720		17.5		.0051	.069
T15	-	-	300	32870	32370	8.25	8.38	54060	52910	55560	56720	17.0	18.3	.0047	.069
T16	-	-	300	32120		8.41		53440		55870		20.0		.0051	.069
T17	-	-	400	18680		7.95		37580		41110		6.5		.0045	.069
T18	-	-	400	18070	18590	9.05	7.93	38420	38670	41870	41760	15.0	13.5	.0045	.069
T19	-	-	400	19020		7.75		40000		42000		19.0		.0052	.069
T21	300	0.1	R.T. (1)	37580		9.25		65600		75910		12.5		.0040	.067
T22	300	0.1	R.T.	38820	37930	9.25	9.25	65820	65510	77160	77020	13.0	12.7	.0040	.067
T23	300	0.1	R.T.	37330		9.26		65500		77000		12.5		.0040	.067
T27	300	0.1	200	34240		8.94		59870		66310		15.0		.0051	.067
T28	300	0.1	200	29270	31760	9.82	9.38	60760	60320	69150	68760	15.5	16.2	.0047	.067
T29	300	0.1	200	(2)		(2)		(2)		68830		16.0		.0042	.067
T31	300	0.1	200	29960		9.42		61850		70510		15.5		.0051	.067
T32	300	0.1	200	29730	27860	9.33	9.38	62030	61950	70410	70460	15.0	15.3	.0050	.067
T33	300	0.1	300	18730		9.37		52700		56350		19.5		.0048	.067
T34	300	0.1	300	16770	19580	9.06	9.38	52850	52910	56330	56520	18.5	20.3	.0050	.067
T35	300	0.1	300	23240		9.72		52800		56830		23.0		.0048	.067
T36	300	0.1	400	15020		8.14		39300		42430		14.5		.0053	.067
T37	300	0.1	400	19080	10460	8.10	8.17	40460	39930	43420	43100	15.5	15.5	.0053	.067
T38	300	0.1	400	19270		8.28		40030		43410		16.5		.0054	.067
T39	400	0.1	R.T.	41530		9.20		62540		72640		10.5		.0058	.067
T40	400	0.1	R.T.	41530	41940	9.20	9.20	62700	62640	72800	72730	10.5	10.5	.0071	.067
T41	400	0.1	R.T.	42760		9.21		62700		72830		10.5		.0073	.067
T42	400	0.1	200	39940		8.74		58790		65180		13.5		.0068	.067
T43	400	0.1	200	41720	42060	8.40	8.45	58440	58690	64810	64980	15.0	14.0	.0075	.067
T44	400	0.1	200	44330		8.20		58840		64930		13.5		.0075	.067
T45	400	0.1	300	28800		7.93		51940		54690		16.0		.0075	.067
T46	400	0.1	300	32730	29330	8.40	8.08	51700	51830	54150	54510	18.0	17.3	.0075	.067
T47	400	0.1	300	25460		8.18		51750		54710		17.0		.0076	.067

TABLE XVIII (Cont'd)
RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 0.1 AND 1.0 HOUR EXPOSURES AT ELEVATED TEMPERATURES

T2	5	400	0.1	25480	24000	5.70	7.40	11610	41840	12250	43510	11.5	.054
T2	6	400	0.1	28950		7.52		12280		12890		16.0	.054
T2	7	400	0.1	16880		7.98		41610		13730		17.0	.051
T2	8	500	0.1	18650		9.54		35170		51350		11.0	.0054
T2	1	500	0.1	19520	19280	9.29	9.55	35130	35090	53550	52840	11.0	.0054
T2	2	500	0.1	19280		9.83		35970		51610		10.5	.0053
T2	3	500	0.1	17680		8.97		35330		47110		17.5	.0051
T2	4	500	0.1	20540	18950	9.00	9.52	35130	35300	47160	47210	15.5	.0051
T2	5	500	0.1	18550		10.60		35350		47420		17.0	.0051
T2	6	500	0.1	19170		9.32		33550		36740		25.0	.0055
T2	7	500	0.1	18790	15970	8.95	8.87	33340	33420	35620	36630	22.5	.0054
T2	8	500	0.1	18670		8.74		33280		35530		26.0	.0054
T2	1	500	0.1	13580		10.83		29310		28910		19.5	.0046
T2	2	500	0.1	11530	13160	9.47	10.12	27710	27930	28340	28530	27.0	.0047
T2	3	500	0.1	14390		10.33		27950		28520		19.5	.0041
T2	7	300	1.0	38990		9.10		63220		74840		13.0	.0050
T2	8	300	1.0	37660	38400	9.33	9.17	63690	63320	75640	75940	12.0	.0050
T2	1	300	1.0	38850		9.10		63060		71340		12.0	.0050
T2	5	300	1.0	35830		8.71		59550		57830		18.5	.0050
T2	6	300	1.0	27940	31340	9.44	9.03	59210	59490	67940	68020	17.0	.0051
T2	7	300	1.0	30260		9.10		59710		68310		20.0	.0050
T2	8	300	1.0	31330		8.71		51900		55240		17.0	.0047
T2	1	300	1.0	31250	30980	8.80	8.73	51760	51810	55290	55370	17.0	.0052
T2	2	300	1.0	30350		8.71		51760		55590		20.0	.0051
T2	3	300	1.0	17680		7.83		33550		42200		18.5	.0050
T2	4	300	1.0	16450	17160	8.00	7.85	32160	33370	42170	42030	16.0	.0050
T2	5	300	1.0	17350		7.75		33010		41720		17.0	.0052
T2	8	400	1.0	38150		9.08		54050		65910		10.0	.0050
T2	1	400	1.0	35820	35010	9.15	9.31	53770	54060	65900	66050	10.5	.0050
T2	2	400	1.0	32040		9.71		54370		66340		10.5	.0050
T2	15	200	1.0	34920		8.40		49180		55570		11.5	.0055
T2	17	200	1.0	27100	30680	9.13	8.82	49190	49400	55840	55850	11.5	.0055
T2	19	200	1.0	30030		8.95		49840		56170		13.5	.0052
T2	13	300	1.0	24920		9.49		44340		45120		19.5	.0055
T2	14	300	1.0	21310	22920	9.00	9.06	45410	44390	47050	46680	17.0	.0055
T2	15	300	1.0	22530		8.71		45230		46880		20.5	.0057
T2	19	400	1.0	16450		7.67		35340		36970		21.0	.0050
T2	20	400	1.0	15030	15990	7.84	7.59	35620	35470	37090	36880	17.5	.0051
T2	22	400	1.0	15500		7.26		35460		36600		17.0	.0051

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- (1) T_{∞} designation from temperature, actual temperature was not measured but was known to be in the range 15-20°C.
- (2) Autotransitive strain recorder gave unsatisfactory for determining subject properties.
- (3) Test of "stimulus to subject" method of at least three terminals for testing condition.

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Specimen No.	Exposure Temp. °C	Exposure Time Hrs.	Testing Temp. °C	Average Proportional Limit psi	Average Modulus of Elasticity 10 ⁶ psi	Average Yield Strength psi	Average Ultimate Strength psi	Average Elong. %	Average Reduction of Area %	Strain Rate in./in./min.	Head Travel in Plastic Region in./min.
70	200	10.0	N.T. (1)	34000	9.48	61000	75000	12.0	0.0035		0.61
71	200	10.0	N.T.	35200	9.40	62000	76000	12.0	0.001		0.61
72	200	10.0	N.T.	36370	9.33	63700	76000	12.0	0.0039		0.61
73	200	10.0	200	42000	8.46	61000	66000	13.5	0.0032		0.75
74	200	10.0	200	42000	8.33	61700	67300	13.0	0.0035		0.75
75	200	10.0	200	41000	8.06	61000	67370	16.5	0.0038		0.75
76	200	10.0	200	16500	9.63	58000	57700	10.0	0.0017		0.75
77	200	10.0	200	17000	9.10	58000	55300	15.5	0.0018		0.75
78	200	10.0	200	15000	8.94	51000	51700	19.5	0.0049		0.75
79	200	10.0	400	7600	8.00	56000	62000	16.0	0.0032		0.75
80	200	10.0	400	7200	8.04	55000	60700	16.0	0.0033		0.75
81	200	10.0	400	6010	8.27	55000	62300	17.5	0.0033		0.75
82	400	10.0	N.T.	10000	9.73	30000	30000	9.5	0.001		0.61
83	400	10.0	N.T.	10500	10.10	31100	30300	10.5	0.0020		0.61
84	400	10.0	N.T.	10000	9.70	30700	30380	9.5	0.0031		0.61
85	400	10.0	200	10700	9.12	33300	40000	10.0	0.001		0.75
86	400	10.0	200	10400	9.21	33600	40000	10.0	0.001		0.75
87	400	10.0	200	10000	9.41	33000	42100	10.5	0.001		0.75
88	400	10.0	200	11400	9.82	30000	38000	21.5	0.010		0.75
89	400	10.0	200	9370	10.16	30000	38170	23.0	0.0049		0.75
90	400	10.0	200	9600	9.81	30000	38000	23.0	0.014		0.75
91	400	10.0	400	12000	7.70	30000	38000	33.5	0.003		0.75
92	400	10.0	400	13000	7.80	29100	38170	24.5	0.0030		0.75
93	400	10.0	400	12000	7.69	28000	35000	25.0	0.0031		0.75
94	200	10.0	N.T.	7000	10.66	10000	37700	12.0	0.0050		0.61
95	200	10.0	N.T.	7200	10.30	10000	37000	12.5	0.004		0.61
96	200	10.0	N.T.	9100	9.32	10000	37000	13.0	0.0040		0.61
97	200	10.0	N.T.	11000	9.92	20000	37000	11.0	0.0014		0.61
98	200	10.0	N.T.	8300	9.15	17000	37100	13.0	0.0049		0.61
99	200	10.0	400	10000	9.12	17000	35000	13.5	0.0049		0.61

TABLE XIX (Cont'd)
RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 10 AND 100 HOURS EXPOSURE AT ELEVATED TEMPERATURES

7075-T6	1	500	10.0	200	7878	7930	10.72	10.31	18100	18250	25050	17.0	.0019	.051
7075-T6	2	500	10.0	200	8350		10.45		18330		25050	17.5	.0017	.051
7075-T6	3	500	10.0	200	7556		9.75		18330		25050	17.5	.0050	.051
7075-T6	4	500	10.0	200	10410		9.49		17820		25760	14.5	.0015	.053
7075-T6	5	500	10.0	200	9810	10020	9.49	9.42	17630	17270	25600	14.5	.0048	.059
7075-T6	6	500	10.0	200	9840		9.29		16950		25560	15.5	.0018	.059
7075-T6	7	500	10.0	300	9678		8.64		17560		25750	51.0	.0050	.075
7075-T6	8	500	10.0	300	10510	9860	9.35	8.98	17570	17580	24030	19.0	.0051	.075
7075-T6	9	500	10.0	300	9395		8.95		17510		24280	57.5	.0019	.075
7075-T6	10	500	10.0	300	9630	9980	9.37	9.51	16950	16980	24510	47.0	.0015	.059
7075-T6	11	500	10.0	300	8630		9.97		17040		24600	48.0	.0045	.059
7075-T6	12	500	10.0	300	8650		9.19		16870		24650	42.0	.0018	.059
7075-T6	13	500	10.0	400	7860	7300	8.36	8.42	14940	14940	16250	47.5	.0015	.059
7075-T6	14	500	10.0	400	7290		8.99		14980		16310	46.5	.0048	.059
7075-T6	15	500	10.0	400	6750		7.91		14910		16260	50.5	.0018	.059
7075-T6	16	500	10.0	400	10450	9904	7.52	7.44	15400	15550	16410	55.0	.0053	.075
7075-T6	17	500	10.0	400	(4)		(4)		(4)		(4)	(4)	.0053	.075
7075-T6	18	500	10.0	400	9717		7.35		15700		16580	57.0	.0053	.075
7075-T6	19	250	100.0	R.T.	45940	46820	8.85	8.90	67340	67390	75550	14.0	.0033	.051
7075-T6	20	250	100.0	R.T.	46090		8.97		67340		76550	12.0	.0051	.051
7075-T6	21	250	100.0	R.T.	48440		8.87		67300		76720	13.5	.0051	.051
7075-T6	22	250	100.0	200	38440	34010	9.20	9.38	62500	62550	67970	15.0	.0051	.051
7075-T6	23	250	100.0	200	34060		9.46		62190		67970	18.0	.0051	.051
7075-T6	24	250	100.0	200	29530		9.47		62190		67810	17.0	.0050	.051
7075-T6	25	250	100.0	300	30090	30090	8.51	8.44	55780	55170	56830	21.5	.0058	.051
7075-T6	26	250	100.0	300	28210		8.45		54860		56580	18.5	.0018	.051
7075-T6	27	250	100.0	300	31980		8.35		54860		56580	22.5	.0052	.051
7075-T6	28	250	100.0	400	28900	27060	6.99	7.17	41690	41510	42950	19.0	.0058	.057
7075-T6	29	250	100.0	400	28660		6.96		41720		42580	18.5	.0052	.057
7075-T6	30	250	100.0	400	25720		7.55		42590		42950	18.5	.0048	.057
7075-T6	31	300	100.0	R.T.	37600	37200	8.71	8.71	56010	55990	66610	11.0	.0050	.055
7075-T6	32	300	100.0	R.T.	37500		8.68		55950		66610	11.0	.0051	.055
7075-T6	33	300	100.0	R.T.	36510		8.74		55710		66510	10.5	.0051	.055
7075-T6	34	300	100.0	200	36740	36660	8.47	8.73	52300	52150	56870	13.0	.0050	.051
7075-T6	35	300	100.0	200	36380		8.88		52500		57100	12.5	.0050	.051
7075-T6	36	300	100.0	200	35560		8.63		52560		57210	12.0	.0049	.051
7075-T6	37	300	100.0	300	27970	28570	8.84	8.53	45250	45280	47540	24.0	.0056	.075
7075-T6	38	300	100.0	300	28550		9.15		46220		47540	16.0	.0049	.075
7075-T6	39	300	100.0	300	28590		8.74		45060		47160	19.5	.0049	.075

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER 10 AND 100 HOURS EXPOSURE AT ELEVATED TEMPERATURES

(1) 3.7. designates room temperature. Actual temperature was not measured but was known to be in the range $60 - 85^{\circ}\text{F}$.

(2) Autographic strain recorder curve was unsatisfactory for determining sub-ject properties.

(3) Excess specimens to fulfill requirement of at least three good specimens per testing condition.

(4) Pin joint hole defective. Unable to perform testing.

TABLE XXI

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 1000 HOURS EXPOSURE AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temperature of	Exposure Time Hrs.	Testing Temperature of	Proportional Limit	Average Modulus of Elasticity, 10 ⁶ psi	Average Yield Strength, psi	Average Ultimate Strength, psi	Ave. Elong. in 2"	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
72 1	250	1000.0	R.T. (1)	(2)	(2)	61510	72900	11.5	.0048	.071
72 2	250	1000.0	R.T.	9.41	9.06	61820	72740	11.5	.0046	.071
72 3	250	1000.0	R.T.	8.71		62020	72840	11.5	.0048	.071
72 4	250	1000.0	200	8.50	8.57	57930	62450	14.5	.0049	.071
72 5	250	1000.0	200	8.51		57330	62180	13.0	.0051	.071
72 6	250	1000.0	200	8.71		58070	62740	15.0	.0051	.071
72 7	250	1000.0	300	7.59	7.50	49680	51280	17.0	.0051	.071
72 8	250	1000.0	300	7.59		47920	51280	16.0	.0050	.071
72 9	250	1000.0	300	7.32		50003	51110	21.5	.0053	.071
72 10	250	1000.0	400	8.56	8.47	36470	38220	21.0	.0050	.069
72 11	250	1000.0	400	8.50		36710	38130	17.0	.0050	.069
72 12	250	1000.0	400	8.36		37510	38170	19.5	.0050	.069
72 1	300	1000.0	R.T.	9.44	9.32	37820	52270	10.5	.0061	.081
72 2	300	1000.0	R.T.	9.17		38170	52370	10.5	.0061	.081
72 3	300	1000.0	R.T.	9.35		38660	52500	10.5	.0059	.081
72 4	300	1000.0	200	9.41	9.09	37740	45410	17.0	.0061	.081
72 5	300	1000.0	200	8.71		37740	45280	16.0	.0053	.081
72 6	300	1000.0	200	9.15		37850	45430	16.5	.0056	.081
72 7	300	1000.0	300	9.02	8.38	33440	34340	20.0	.0070	.081
72 8	300	1000.0	300	8.50		33340	34650	21.5	.0056	.081
72 9	300	1000.0	300	8.60		33650	34920	25.5	.0054	.081
72 10	300	1000.0	400	8.15	8.36	27220	27540	28.0	.0053	.069
72 11	300	1000.0	400	8.69		26670	27020	22.0	.0051	.069
72 12	300	1000.0	400	8.24		26440	26800	24.5	.0051	.069
72 1	400	1000.0	R.T.	10.58	9.55	17270	31760	12.5	.0053	.081
72 2	400	1000.0	R.T.	9.33		17650	34920	12.0	.0051	.081
72 3	400	1000.0	R.T.	8.76		17410	34650	12.5	.0053	.081

TABLE XXI (Cont'd)
RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 1000 HOURS EXPOSURE AT ELEVATED TEMPERATURES

7T 4	400	1000.0	200	7630	8660	10.05	15930	31050	17.0	.0051
7T 5	400	1000.0	200	8280		10.22	17110	31080	17.5	.071
7T 6	400	1000.0	200	9470		10.12	17260	31080	17.5	.071
7T 7	400	1000.0	300	7410	7280	10.50	16130	21160	21.0	.081
7T 8	400	1000.0	300	7140		10.11	16430	21380	23.5	.081
7T 9	400	1000.0	300	7370		10.77	16260	21350	23.0	.081
7T 10	400	1000.0	400	7600		9.67	11530	15120	19.5	.081
7T 11	400	1000.0	400	6250	7330	9.65	11170	15180	21.5	.081
7T 12	400	1000.0	400	8130		9.11	11670	15350	25.5	.081
7A 1	500	1000.0	R.T.	7320		10.15	14050	32810	13.5	.061
7A 2	500	1000.0	R.T.	5480	7330	10.11	13930	32300	14.0	.075
7A 3	500	1000.0	R.T.	8350		9.31	11200	32790	16.0	.075
7A 4	500	1000.0	200	8600		11.12	14530	30510	21.0	.075
7A 5	500	1000.0	200	5980	7970	10.21	11520	34550	20.0	.075
7A 6	500	1000.0	200	8330		10.69	11290	30220	20.0	.075
7A 7	500	1000.0	300	6720		10.74	13970	22320	16.5	.075
7A 8	500	1000.0	300	7700	6930	8.15	13860	22850	28.0	.075
7B 1	500	1000.0	300	6360		10.66	13970	22630	26.0	.075
7B 2	500	1000.0	400	(2)	7180	(2)	(2)	11590	31.5	.075
7B 3	500	1000.0	400	8430		8.89	12930	15180	26.5	.075
7B 4	500	1000.0	400	6340		8.60	12530	11770	22.6	.075

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-80°F.

(2) Autographic strain recorder curve was unsatisfactory for determining subject properties.

TABLE XXXI

RESULTS OF TENSILE TESTS OF 7075-T6 ALUMINUM RIBBON AT ROOM AND ELEVATED TEMPERATURES AFTER A SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

Specimen No.	Sequential Exposure Time & Temp.				Average Proportional Limit, psi	Modulus of Elasticity, 10 ⁶ psi	Average Modulus of Elasticity, 10 ⁶ psi	Average Yield Strength, psi	Ultimate Strength, psi	Average Ultimate Strength, psi	Ave. Elong. % in 2"	Strain Rate, in./in./min.	Head Travel in Plastic Range, in./min.
	1-2 Hr. 100° F.	3rd 100° F.	Fourth 1000 Hr. 100° F.	Testing Proportional Limit, psi									
7V 1	400	-	-	H.T. (1)	37260	8.82	8.77	53940	65120	53940	11.0	.0070	.061
7V 2	400	-	-	H.T.	37160	8.75	8.75	54660	65970	54660	10.5	.0060	.061
7V 3	400	-	-	H.T.	38040	8.73	8.73	55350	66070	55350	11.5	.0060	.061
7V 4	400	-	-	200	36820	8.17	8.10	53310	59040	53310	13.5	.0058	.061
7V 5	400	-	-	200	39800	8.01	8.01	52800	56850	52800	14.5	.0060	.061
7V 6	400	-	-	400	34830	8.55	8.55	51500	56850	51500	14.5	.0071	.061
7V 7	400	-	-	300	32090	7.38	7.38	45530	46330	45530	20.0	.0076	.061
7V 8	400	-	-	300	32960	7.82	7.82	44970	45510	44970	19.0	.0071	.061
7V 9	400	-	-	300	33630	7.30	7.30	45450	46020	45450	20.0	.0066	.061
7V 10	400	-	-	400	37413	8.04	8.04	53100	57140	53100	20.0	.0076	.075
7V 11	400	-	-	400	36100	8.04	8.04	51900	56110	51900	21.0	.0071	.061
7V 12	400	-	-	400	37360	8.04	8.04	52730	57530	52730	23.0	.0076	.061
7V 13	400	-	-	H.T.	37400	8.61	8.61	54000	64540	54000	10.5	.0071	.054
7V 14	400	-	-	H.T.	35850	8.79	8.79	54000	64950	54000	11.0	.0085	.054
7V 15	400	-	-	H.T.	37360	8.60	8.60	53300	66190	53300	11.0	.0071	.054
7V 16	400	-	-	200	37170	8.64	8.64	52730	57530	52730	14.5	.0066	.054
7V 17	400	-	-	200	38160	9.21	9.21	53300	57210	53300	14.0	.0066	.054
7V 18	400	-	-	200	37560	9.01	9.01	51940	56690	51940	13.5	.0066	.054
7V 19	400	-	-	300	31580	8.04	8.04	45320	46200	45320	16.5	.0071	.054
7V 20	400	-	-	300	28370	8.62	8.62	46970	45890	46970	19.5	.0069	.054
7V 21	400	-	-	300	29210	8.22	8.22	45650	46530	45650	17.0	.0071	.054
7V 22	400	-	-	400	21350	7.68	7.68	36260	36950	36260	19.5	.0076	.054
7V 23	400	-	-	400	23410	8.54	8.54	36230	36710	36230	21.0	.0071	.054
7V 24	400	-	-	400	19590	8.72	8.72	33670	36350	33670	18.0	.0071	.054
7V 25	400	-	-	H.T.	32660	10.24	9.81	25480	42880	25480	10.0	.0057	.061
7V 26	400	-	-	H.T.	14690	9.61	9.61	23840	43120	23840	10.0	.0347	.069
7V 27	400	-	-	H.T.	14570	9.27	9.27	25750	43060	25750	10.5	.0042	.069
7V 28	400	-	-	200	15300	8.91	8.91	23310	37190	23310	20.5	.0047	.069
7V 29	400	-	-	200	17540	8.40	8.40	25460	37280	25460	20.5	.0045	.069
7V 30	400	-	-	200	15830	9.16	9.16	25460	37300	25460	18.0	.0046	.069

[illegible]

7AA 7	500	400	-	-	100	14410	122700	9.23 8.68 9.67	9.19	21880 23750 23770	231000	27340 26620 26140	43.5 35.0 27.0	35.2	.063 .069 .064
7AA 8	500	400	-	-	100	13910									.069
7AA 9	500	400	-	-	100	11160									.069
7AA 10	500	400	-	-	100	8950		8.68		19970	20110	20160	15.0		.069
7AA 11	500	400	-	-	100	10790	9650	10.84 11.16	10.09	20350	20110	20150 20310	36.5 33.0	36.8	.069 .069 .069
7AA 12	500	400	-	-	100	9650									.069
7BB 1	500	400	-	-	100	10640		10.79	10.77	26700	26600	42750	11.0		.069
7BB 2	500	400	-	-	100	12950	127700	11.45 10.59		26500	26600	42950	10.5	10.7	.069 .069 .069
7BB 3	500	400	-	-	100	16750									.069
7BB 4	500	400	-	-	100	16450	157900	9.52 8.47 9.45	9.15	26010 25950 25790	21910	16640 16380 16500	16.0 18.0 18.5	18.7	.069 .069 .069
7BB 5	500	400	-	-	100	16990									.069
7BB 6	500	400	-	-	100	13990									.069
7BB 7	500	400	-	-	100	14350	14100	10.03 11.33 10.75	10.27	26050 26050 26150	26070	26350 26450 26450	36.0 37.0 29.0	33.3	.069 .069 .069
7BB 8	500	400	-	-	100	14290									.069
7BB 9	500	400	-	-	100	13710									.069
7BB 10	500	400	-	-	100	9940	10660	8.97 8.58 9.25	8.73	20160 20130 20940	20040	20260 20130 20800	36.5 31.0 31.0	32.2	.071 .071 .071
7BB 11	500	400	-	-	100	11420									.071
7BB 12	500	400	-	-	100	13650									.071
7CC 1	500	400	250	250	100	13910	13460	10.26 11.83 12.02	11.37	26550 26350 26200	26360	42280 42470 42350	10.5 11.5 10.5	10.7	.061 .069 .067
7CC 2	500	400	250	250	100	16250									.061
7CC 3	500	400	250	250	100	16610									.069
7CC 4	500	400	250	250	100	15290	15940	9.38 9.68 9.16	9.41	25320 25350 25260	25300	35740 35810 35560	12.0 17.0 20.5	18.5	.069 .069 .069
7CC 5	500	400	250	250	100	16850									.069
7CC 6	500	400	250	250	100	16250									.069
7CC 7	500	400	250	250	100	16750	14110	8.40 8.79 8.63	8.61	25300 25390 25510	25400	25740 25750 25690	34.0 32.5 27.5	32.0	.069 .069 .069
7CC 8	500	400	250	250	100	16750									.069
7CC 9	500	400	250	250	100	16750									.069
7CC 10	500	400	250	250	100	16750									.069
7CC 11	500	400	250	250	100	16750	9650	8.17 8.23 9.22	8.54	19750 19940 19970	19890	19910 20030 20030	30.0 36.0 36.5	29.5	.069 .069 .069
7CC 12	500	400	250	250	100	8150									.069

(???) N.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60 - 85°F

TABLE XIII

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER AN ADDITIONAL SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

RESULTS OF TENSILE TESTS OF 7075-T6 ALUMINUM SHEET AT ROOM AND LOW TEMPERATURES																		
Specimen Number	Sequential Exposure Time and Temperature				Testing Temperature	Proportional Limit		Average Elasticity Modulus of		Average Yield Strength		Ultimate Strength		Avg. Elong. in 2"	Strain Rate Head Travel Below Yield in Plastic Range			
	First	Second	Third	Fourth		Limit	psi	X 10 ⁶ psi	X 10 ⁶ psi	psi	psi	psi	psi		in./in./min.	in./in./min.		
7075 1	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	R.T. (1)	15000	14060	10.03	10.03	53870	53810	66130	66030	11.0	.0055	.074		
7075 2	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	R.T.	15080	14060	10.08	10.08	53970	53810	65820	66030	10.5	.0044	.18		
7075 3	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	R.T.	12100	14060	10.43	10.43	53560	53810	66150	66030	10.5	.0051	.054		
7075 4	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	200	20190	18730	9.88	9.88	52650	52790	57490	57690	15.0	.0048	.042		
7075 5	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	200	17000	18730	10.31	10.31	52640	52790	57660	57690	14.5	.0050	.050		
7075 6	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	200	18990	18730	9.92	9.92	53070	52790	57930	57690	13.0	.0054	.055		
7075 7	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	23810	19840	9.56	9.56	47780	48620	49080	49970	19.5	.0048	.054		
7075 8	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	16330	19840	9.75	9.75	49300	48620	50590	49970	17.5	.0050	.065		
7075 9	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	19380	19840	10.25	10.25	48770	48620	50230	49970	16.0	.0050	.050		
7075 10	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	400	13980	15960	9.46	9.46	37720	38900	39510	40310	16.5	.0049	.046		
7075 11	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	400	14930	15960	10.03	10.03	39110	38900	40570	40310	15.5	.0052	.056		
7075 12	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	400	18970	15960	9.29	9.29	39880	38900	40850	40310	15.5	.0048	.045		
7075 1	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	R.T.	24280	22350	9.36	9.36	38880	38880	52540	52640	11.0	.0050	.040		
7075 2	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	R.T.	23090	22350	8.94	8.94	38690	38880	52670	52640	10.6	.0054	.051		
7075 3	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	R.T.	20220	22350	9.12	9.12	38400	38880	52510	52640	10.5	.0051	.054		
7075 4	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	200	24340	23350	9.47	9.47	35520	35970	44110	44410	16.5	.0054	.048		
7075 5	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	200	22770	23350	9.27	9.27	35970	35970	44110	44410	15.0	.0054	.055		
7075 6	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	22430	23350	9.27	9.27	37020	35970	44550	44410	15.0	.0054	.055		
7075 7	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	20420	19440	8.95	8.95	33760	34070	34880	34690	24.5	.0058	.048		
7075 8	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	16930	19440	9.19	9.19	35550	34070	34840	34690	23.5	.0053	.052		
7075 9	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	20970	19440	8.71	8.71	32900	34070	34350	34690	23.0	.0053	.054		
7075 10	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	400	13710	12990	9.84	9.84	26930	26370	27580	27120	20.0	.0056	.057		
7075 11	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	400	13180	12990	9.22	9.22	26210	26370	26890	27120	23.0	.0050	.055		
7075 12	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	400	12090	12990	9.59	9.59	25970	26370	26930	27120	19.0	.0050	.052		
7075 1	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	R.T.	13380	14540	9.29	9.29	27270	27380	43450	43450	10.0	.0046	.069		
7075 2	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	R.T.	17550	14540	9.06	9.06	27520	27380	43460	43450	10.0	.0048	.069		
7075 3	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	R.T.	12690	14540	9.53	9.53	27340	27380	43450	43450	10.0	.0050	.069		
7075 4	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	200	12350	14540	9.83	9.83	26770	26890	37300	37090	16.0	.0051	.069		
7075 5	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	200	12350	14540	9.31	9.31	26600	26890	36950	37090	16.0	.0050	.069		
7075 6	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	200	18580	14540	9.27	9.27	27320	26890	36910	37090	16.0	.0048	.069		
7075 7	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	11170	12720	9.38	9.38	29000	29220	26360	26860	20.0	.0046	.069		
7075 8	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	13160	12720	8.80	8.80	25170	29220	27080	26860	20.0	.0051	.069		
7075 9	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	300	13280	12720	8.75	8.75	29480	29220	27140	26860	38.0	.0051	.069		
7075 10	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	400	11790	12990	8.37	8.37	21590	21490	21670	21610	25.0	.0051	.069		
7075 11	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	400	13550	12990	8.13	8.13	21390	21490	21520	21610	27.5	.0048	.069		
7075 12	1.0 Hr. 300°F	1.8 Hr. 300°F	21.6 Hr. 300°F	121.7 Hr. 260°F	400	13600	12990	8.19	8.19	21590	21490	21650	21610	26.0	.0049	.069		

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER AN ADDITIONAL SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

	1.0 Hr.	4.0 Hrs.	17.5 Hrs.	90.5 Hrs.	R.T.	12260	9.22	20350	36790	12.0	.0057
TGS 1	500°F	460°F	420°F	380°F	R.T.	11000	9.04	20560	37260	11.0	.0057
TGS 2	500	460	420	380	R.T.	12810	8.91	20630	37190	11.5	.0056
TGS 3	500	460	420	380							
TLL 1	500	460	420	380	200	15920	8.54	20700	34080	20.5	.0060
TLL 2	500	460	420	380	200	17190	8.86	21500	34550	20.5	.0056
TLL 3	500	460	420	380	200	15170	8.73	20930	34340	20.0	.0058
TGS 7	500	460	420	380	300	9880	8.77	19350	23060	44.0	.0052
TGS 8	500	460	420	380	300	9940	8.62	19410	23320	45.0	.0057
TGS 9	500	460	420	380	300	10650	8.64	19630	23520	45.0	.0051
TGS 10	500	460	420	380	400	10900	8.02	16880	17070	44.0	.0050
TGS 11	500	460	420	380	400	8730	8.98	16840	17030	50.0	.0050
TGS 12	500	460	420	380	400	9540	8.60	16970	17120	46.5	.0046

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

(2) Malfunction of tensile test equipment and test could not be performed.

TABLE XXXIII
 HCCB TEMPERATURE TENSILE TEST RESULTS OF 2024-T3 ALCLAD SHEET
 FOR COMPARISON WITH EXTRUDED TEMPERATURE RESULTS

Specimen No.	Proportional Limit	Average Proportional Limit	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength	Average Yield Strength	Ultimate Strength	Average Ultimate Strength	Elongation % in 2"	Average Elongation	Strain Rate Yield in./in./min.	Head Travel in Plastic Range in./min.
2AC 1	(1)	22800	(1)	10.05	42830	43190	64170	67490	18.5	19.3	(2)	(2)
2AC 2	22800		10.05		43550		64510		20.0		(2)	(2)
2BC 1	20420	17910	10.03	10.62	42970	43140	67500	67400	21.0	21.0	(2)	(2)
2BC 2	19560		10.60		43300		67450		21.0		(2)	(2)
2CC 1	17130	21410	10.20	9.98	43770	43940	65530	64120	22.0	21.0	(2)	(2)
2CC 2	24090		9.76		44100		65510		21.0		(2)	(2)
2DC 1	26090	21210	9.52	9.88	44220	44130	67340	67790	19.5	20.3	.0050	.061
2DC 2	23330		10.23		44030		67310		21.0		.0050	.061
2EC 1	21920	23090	10.24	10.43	44550	44510	64510	64570	20.0	20.0	.0048	.061
2EC 2	21230		10.36		44550		64590		20.0		.0046	.061
2FC 1	23040	25150	10.37	10.31	44710	44720	68890	64720	20.0	20.0	.0030	.064
2FC 2	26090		10.10		44700		68510		20.0		.0032	.064
2GC 1	24520	22430	10.27	10.40	44350	44350	67550	67530	19.0	19.0	.0030	.048
2GC 2	22710		10.53		44380		67500		19.0		.0030	.048
2HC 1	22070	21140	10.46	10.34	44380	44230	67810	67860	19.5	21.0	.0032	.075
2HC 2	26250		10.61		44080		67910		22.5		.0030	.075
2IC 1	20040	18570	10.10	10.31	44980	44850	68810	64890	19.5	20.3	.0042	.067
2IC 2	17080		10.52		44670		68970		21.0		.0038	.067
2JC 1	18050	19160	10.14	10.19	43610	43610	65510	65590	19.5	19.5	.0034	.086
2JC 2	19170		10.24		43610		66070		19.0		.0032	.086
2KC 1	21230	20180	9.96	10.16	43690	43760	64630	64950	19.0	19.5	.0034	.086
2KC 2	19140		10.35		43850		67280		19.5		.0031	.086
2LC 1	18120	18290	10.31	10.24	43740	43950	67350	67670	21.0	20.5	.0030	.086
2LC 2	18770		10.18		43960		67800		20.0		.0033	.086
2MC 1	19140	19400	10.36	10.29	43850	43620	67750	67780	19.0	19.5	.0033	.086
2MC 2	14810		10.22		43100		67790		20.0		.0033	.086
2NC 1	23150	21190	10.25	10.42	44750	44600	68670	64560	19.5	19.8	.0033	.086
2NC 2	19250		10.68		44460		68460		20.0		.0037	.086

TABLE XXXIII (cont'd)
ROCK TEMPERATURE TRENCH TEST RESULTS OF 4084-T3 ALUMINUM BORE FOR COMPARISON
WITH ESTIMATED TEMPERATURE DISTRIBUTION

201 1	20170	22070	10.41	10.12	43220	45170	48700	49000	20.0	.0041	.006
202 2	21770		10.43		43120		49100		21.0	.0041	.006
211 1	22320	22000	10.32	10.24	43500	45100	49500		21.0	.0041	.006
212 2	21670		10.17		44700		49100		21.5	.0041	.006
213 1	21150	21000	10.31	10.12	43120	45020	48210		20.0	.0040	.006
214 2	22720		10.52		44920		49100		20.0	.0041	.006
215 1	22670	22600	10.21	10.19	43400	45100	49100		21.0	.0040	.006
216 2	22500		10.17		43400		49100		20.5	.0040	.006
217 1	22610	24010	10.32	10.32	44300	44300	49100		18.0	.0040	.006
218 2	21910	21000	10.44	10.42	44100	44300	49100		20.0	.0040	.006
219 1	20120		10.10		44320		49100		20.0	.0041	.006
220 2	22570	22070	10.33	10.39	44300	44300	49100		21.5	.0041	.006
221 1	23100	24000	10.42	9.87	44600	44700	49100		19.0	.0040	.006
222 2	21700		9.51		44910		49100		21.5	.0041	.006
223 1	22150	22100	10.47	10.51	44400	44400	49100		20.5	.0040	.006
224 2	22170		10.56		44300		49100		20.0	.0040	.006
225 1	24300	23500	11.00	10.40	45000	44700	49100		20.5	.0041	.006
226 2	20400		10.60		44400		49100		20.0	.0040	.006
227 1	22100	20400	9.72	9.82	43900	43500	49100		20.0	.0040	.006
228 2	18450		9.91		43200		49100		20.0	.0040	.006
229 1	20500	24000	9.64	9.63	44000	44000	49100		20.5	.0040	.006
230 2	30490		9.64		44000		49100		19.5	.0040	.006
231 1	27170	24000	9.90	9.97	44700	44700	49100		20.0	.0040	.006
232 2	29000		10.04		44200		49100		21.0	.0040	.006
233 1	27410	24000	9.87	9.89	45000	45000	49100		21.5	.0040	.006
234 2	20300		9.91		45000		49100		21.0	.0040	.006
235 1	24950	24000	9.91	9.89	45000	45000	49100		22.0	.0040	.006
236 2	30390		9.70		45000		49100		19.5	.0040	.006
237 1	16520	16000	9.72	9.91	43900	43900	49100		19.5	.0040	.006
238 2	15100		10.11		43000		49100		19.0	.0040	.006
239 1	21300	19000	10.00	9.89	43000	43000	49100		22.5	.0040	.006
240 2	10140		9.75		43000		49100		21.5	.0040	.006
241 1	24700	24000	9.71	9.72	43500	43500	49100		20.0	.0040	.006
242 2	25590		9.71		43500		49100		20.0	.0040	.006
243 1	19000	17000	9.79	9.97	43500	43500	49100		19.0	.0040	.006
244 2	16700		10.16		43000		49100		20.0	.0040	.006
245 1	20100	19000	10.07	9.95	43500	43500	49100		20.5	.0040	.006
246 2	18600		9.84		43000		49100		20.0	.0040	.006
247 1	19100	21200	9.94	9.77	43000	43000	49100		19.5	.0040	.006
248 2	25310		9.64		44100		49100		20.0	.0040	.006
249 1	16000	15000	12.21	10.24	43000	43000	49100		19.0	.0040	.006
250 2	12400		12.21		43000		49100		18.0	.0040	.006

TABLE XXIV
ROOM TEMPERATURE TENSILE TEST RESULTS OF 7075-T6 ALCLAD SHEET
FOR COMPARISON WITH ELEVATED TEMPERATURE RESULTS

Specimen No.	Proportional Limit, psi	Average Proportional Limit, psi	Modulus of Elasticity, 10 ⁶ psi	Average Modulus of Elasticity, 10 ⁶ psi	Yield Strength, psi	Average Yield Strength, psi	Ultimate Strength, psi	Average Ultimate Strength, psi	Elongation, in. in 2"	Average Elongation, in. in 2"	Strain Rate, in./in./min.	Reduction of Area, %
70C 1	31150	35350	9.58	9.36	67050	68080	77110	76710	11.5	11.7	(2)	(2)
70C 2	31350		9.11		65720		76310		11.5		(2)	(2)
70C 1	32050	35250	9.45	9.18	65500	66700	76550	77580	13.5	13.7	(2)	(2)
70C 2	30750		9.50		65550		76110		13.5		(2)	(2)
70C 1	35250	31750	8.92	9.12	66510	65500	76970	76910	12.0	12.2	(2)	(2)
70C 2	37450		9.51		65080		76950		13.5		(2)	(2)
70C 1	36950	35590	9.45	9.31	66240	65460	77330	77430	10.5	11.5	(2)	(2)
70C 2	44210		9.16		65720		77650		12.5		(2)	(2)
70C 1	42100	35070	9.40	9.30	65940	65950	76550	76240	12.0	12.3	(2)	(2)
70C 2	30350		9.79		65720		77280		12.5		(2)	(2)
70C 1	43970	44130	9.37	9.33	67590	67000	78530	78350	13.0	13.1	(2)	(2)
70C 2	42540		9.18		65550		78110		13.5		(2)	(2)
70C 1	32240	30270	9.31	9.40	66200	66300	77320	77690	12.0	12.2	(2)	(2)
70C 2	41290		9.15		66150		77300		12.5		(2)	(2)
70C 1	42470	41890	9.71	9.04	66300	66450	78130	78300	13.0	12.7	(2)	(2)
70C 2	41340		9.54		65020		77600		12.5		(2)	(2)
70C 1	42530	44290	9.32	9.23	65850	65760	77850	77230	12.0	12.0	(2)	(2)
70C 2	45960		9.14		65540		78610		12.0		(2)	(2)
70C 1	40320	41290	9.29	9.29	67250	67250	77350	77850	12.0	12.3	(2)	(2)
70C 2	41770		9.29		67250		77850		12.5		(2)	(2)
70C 1	37100	35650	9.20	9.32	67900	67420	78230	78350	12.5	12.3	(2)	(2)
70C 2	34200		9.11		66940		78500		12.0		(2)	(2)
70C 1	34790	36510	9.42	9.18	65500	65610	78320	78320	12.0	11.8	(2)	(2)
70C 2	30420		9.54		64720		78380		11.5		(2)	(2)
70C 1	30840	29870	9.18	9.56	65320	64960	77440	77350	12.0	11.8	(2)	(2)
70C 2	28900		9.65		646104		77270		11.5		(2)	(2)
70C 1	33930	35920	9.40	9.27	66560	66340	77600	77430	11.0	11.3	(2)	(2)
70C 2	37900		9.15		66130		77260		11.5		(2)	(2)

TABLE XXIV (Cont'd.)

ROOM TEMPERATURE TENSILE TEST RESULTS OF 7075-T6 ALCLAD SHEET FOR COMPARISON
WITH ELEVATED TEMPERATURE RESULTS

70C 1	32150	30990	9.37	9.38	55110	65290	76530	76890	11.5	12.0	.0026
70C 2	29840		9.37		65480		77260		12.5		.0026
70C 1	34460	33710	9.31	9.33	67470	67490	78690	78740	13.0	13.0	.0053
70C 2	32960		9.36		67520		78780		13.0		.0053
70C 1	31920	30810	9.24	9.26	66940	66990	77850	77890	12.5	12.3	.0053
70C 2	29710		9.29		67040		77920		12.0		.0052
70C 1	45950	45177	9.41	9.47	68280	68060	78960	78740	13.0	13.2	.0060
70C 2	44390		9.53		67850		78520		13.5		.0060
70C 1	34680	37440	9.76	9.53	67420	68120	79520	79470	14.0	14.2	.0058
70C 2	40190		9.30		68810		79420		14.5		.0063
70C 1	41690	44500	8.93	8.80	68210	68450	78430	78590	14.5	14.5	.0063
70C 2	47920		8.57		68690		78750		14.5		.0061
70C 1	46840	46760	9.04	9.03	69400	69320	79500	79500	12.5	12.5	.0062
70C 2	46690		9.03		69240		79500		12.5		.0057
70C 1	47100	46700	9.13	9.08	68550	68490	78870	78940	11.5	12.2	.0058
70C 2	46310		9.02		68430		79210		13.0		.0059
70C 1	42770	44550	9.15	9.05	68010	68110	78620	78610	14.0	13.5	.0061
70C 2	46330		8.95		68210		78590		13.0		1.0061
70C 1	48330	48680	9.20	9.07	68390	68140	78710	78650	13.0	13.3	.0080
70C 2	43030		8.94		67880		78590		13.5		.0080
70C 1	45830	46060	9.03	9.00	68170	68170	78940	78860	13.5	13.3	.0053
70C 2	46300		8.96		68170		78780		13.0		.0050
70C 1	46310	46240	9.14	8.97	68110	68370	78850	78880	12.0	12.3	.0048
70C 2	46170		8.80		68630		78910		12.5		.0048
70C 1	45940	45560	9.10	9.12	68750	68590	79530	79450	12.5	12.8	.0048
70C 2	45780		9.27		68440		79380		13.0		.0046
70C 1	46760	47260	9.29	9.22	69260	68790	79770	79870	13.0	12.8	.0046
70C 2	47760		9.15		68330		79970		12.5		.0046
70C 1	45990	46550	9.16	9.06	68590	68560	79330	79450	13.0	12.5	.0048
70C 2	47120		8.97		68530		79230		12.0		.0048
70C 1	29750	30800	9.07	9.04	66300	66430	77690	77780	11.5	11.5	.0054
70C 2	31850		9.00		66560		77870		11.5		.0051
70C 1	41010	40180	9.13	9.40	62450	68320	78550	77640	12.5	12.5	.0051
70C 2	37340		9.61		68200		76740		12.5		.0051
70C 1	37020	36930	8.82	8.78	64620	65010	75540	75930	12.5	12.5	.0051
70C 2	36770		8.74		65390		76310		12.5		.0051
70C 1	34640	35280	9.06	8.94	66930	66670	77120	76870	12.5	13.0	.0051
70C 2	37780		8.82		66410		76620		13.5		.0050

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1. Acoustic load strain curve exhibited a continuous curve. Primary modulus, secondary modulus, or proportional limit could not be determined.
2. Strain and head travel rates were not determined on the first tests performed. From standard laboratory practice, it is estimated that these tests were performed at .004 in./min. strain rate within elastic region and .04 in./min. head travel from yield to fracture.
3. Head travel rate adjusting dial on tensile machine was out of calibration during these tests.