NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The information furnished herewith is made available for study upon the understanding that the Government's proprietary interests in and relating thereto shall not be impaired. It is desired that the Judge Advocate (WCJ), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, be promptly notified of any apparent conflict between the Government's proprietary interests and those of others.

WADC TECHNICAL REPORT 57-150
Part II

EFFECT OF PRIOR CREEP ON MECHANICAL PROPERTIES OF AIRCRAFT STRUCTURAL METALS

Part II: - 17-7PH Alloy (TH 1050 Condition)

Jeremy V. Gluck
Howard R. Voorhees
James W. Freeman

Engineering Research Institute
The University of Michigan

November 1957

Materials Laboratory
Contract No. AF 33(616)-3368
Supplement No. 1(57-850)
Project No. 7360

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This report was prepared by the Engineering Research Institute of the University of Michigan under USAF Contract No. AF 33(616)-3368. The contract was initiated under Task No. 73605, with Mr. E. L. Horne acting as project engineer for the Materials Laboratory, Directorate of Laboratories, Wright Air Development Center.

This report covers work conducted from January 10, 1957 to November 9, 1957.

The research is identified in the records of the Engineering Research Institute as Project No. 2498.

ABSTRACT

A study was carried out of the effect of exposure to elevated-temperature creep conditions on subsequent mechanical properties of aircraft structural metals. The present report considers a precipitation hardening stainless steel, 17-7PH (TH 1050 condition). Exposures were conducted for times of 10, 50, or 100 hours either unstressed or at stresses giving up to 3-percent total deformation at temperatures between 600° and 900°F.

Following the exposures, short-time tensile, compression, or tension-impact tests were run at either room temperature or the temperature of exposure. The principal effects found were a loss in ductility in tensile tests and a substantial loss in compression yield strength after exposure to creep at 600°F. In general, remarkably little change in the other mechanical properties was found as a result of exposure to creep, with any such changes primarily confined to increases in strength.

PUBLICATION REVIEW

This report has been reviewed and is approved

FOR THE COMMANDER:

R. R. KENNEDY
Chief, Metals Branch
Materials Laboratory

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

An investigation was carried out to determine the effects of prior creep-exposure on short-time mechanical properties of 17-7PH (TH 1050 condition) precipitation hardening stainless steel sheet. When alloys are exposed to high temperatures, the possibility always exists that structural changes can be introduced which will adversely affect the properties for subsequent service. In addition the creep process itself might damage the metal as well as accelerate the temperature induced structural changes. Very little information is available on the subject. Results of the type presented, therefore, serve the double purpose of providing specific data for 17-7PH alloy and of building up information on the basic principles involved. The latter is important because future aircraft structures will be increasingly exposed to creep conditions during part of their operating cycles. These exposures must, however, not alter the short-time mechanical strength, ductility and shock resistance of the materials of construction to the extent that they will not be able to meet subsequent service requirements. This is particularly important for ability to withstand thermal stresses which will occur during subsequent cooling and reheating and for the high intensity loads of short duration associated with aircraft operation.

The data presented for 17-7PH steel were obtained as part of a research program covering three alloys of the types used in aircraft structures in sheet form. A previous report (Ref. 1) presented similar information for an aluminum alloy, 2024-T86 and some preliminary data for the 17-7PH sheet. A future report will present the data for a titanium alloy, C110M. The research has been carried out under sponsorship of the Materials Laboratory, Directorate of Laboratories, Wright Air Development Center, U. S. Air Force under Contract AF 33(616)-3368.

"Manuscript released by authors on January 27, 1958 for publication as a WADC Technical Report."

EXPERIMENTAL PROGRAM

To accomplish the objectives of this program three primary exposure temperatures were selected for the studies of 17-7PH (TH 1050 condition): 600°, 800°, and 900°F. Time periods of 10, 50, and 100 hours were selected for the exposure of test specimens either at zero stress or stresses selected to give 0.5, 1.0, 2.0, and 3.0 percent total deformation in the time intervals. Total deformation is defined as all deformation (both elastic and short-time plastic strain) occurring during the application of the load plus the creep deformation of the specimen under the given conditions of stress and temperature.

Of the four variables involved in such exposure; time, temperature, stress, and total deformation, only three can be chosen independently. In this investigation the stresses were fixed at those values which, on the average, would give the desired total deformations. Inherent scatter in creep properties causes actual deformations for some specimens to be greater or less than the desired nominal value. A sufficient number of tests were run to cover this effect.

Stresses to produce the desired nominal amounts of deformation were selected from plots of stress versus time for a given total deformation established from survey tests at each of the primary test temperatures. Time-elongation data were obtained for all specimens and all correlations of residual properties are presented in terms of the actual deformation. The deformation data are presented as total loading deformation, plastic deformation during loading (if any), creep deformation and total deformation.

After the exposure period, the following tests were carried out.:

1. Tensile tests at room temperature and the exposure temperature.

2. Compression tests at the same temperatures.

3. Tension-impact tests at the same temperatures on notched and unnotched specimens.

4. Hardness determination at room temperature.

Temperatures both intermediate to or below the three principal testing temperatures were used for additional survey tests which consisted of exposure to a nominal 2 percent total deformation in 100 hours followed by a room temperature tensile test. In addition to the above, some cold bend testing was also carried out.

In all cases test specimens were selected at random. Properties of specimens subjected to creep exposure were compared with the average properties established for the unexposed material by a series of from five to ten replicate tests intended to define the normal scatter in the given property. In addition, for a number of the creep-exposure conditions, duplicate exposures were run to gain more confidence in the results.

Testing of the 17-7PH alloy was carried out in the direction crosswise to the sheet rolling direction. This is believed to be the nominally weaker direction of this material.

TEST MATERIAL

Sixteen sheets of the 17-7PH precipitation hardening stainless steel were purchased from the Armco Steel Corporation. All sheets were from their Heat number 55651. The material was supplied in sheets 0.064-inches thick by 36 inches by 120 inches in No. 2D finish and in Condition A. Condition A consists of an annealing treatment carried out at 1925°F followed by air cooling. The certified chemical analysis furnished by the producer was within the nominal composition limits for the alloy:

Element	Nominal (percent)	Actual (percent)
Carbon	0.09 Max	0.072
Manganese	1.00 Max	0.55
Phosphorus	0.04 Max	0.018
Sulfur	0.03 Max	0.011
Silicon	1.00 Max	0.33
Chromium	16.00-18.00	17.03
Nickel	6.50- 7.50	7.25
Aluminum	0.75- 1.50	1.28
Iron	Balance	Balance

Heat treatment to the TH 1050 condition was carried out at the University using the following sequence on bundles of six one-inch wide specimen blanks.

1. Condition A material heated in air for 1-1/2 hours at 1400±10°F,
2. Air cooled in 10 minutes to approximately 500°F,
3. Quenched in 60°F water,
4. Held 8-12 hours at 60°F,
5. Aged 1-1/2 hours at 1050±10°F, then air cooled.

This treatment is a refinement of that ordinarily specified for the material. (Ref. 2). It was adopted to aid in obtaining a closer degree of uniformity than required by the usual commercial treatment specifications. The 8-12 hours holding at 60°F before the final aging treatment was largely for convenience in scheduling the use of available furnaces.

TEST SPECIMENS

The preparation of test specimens from the sheet stock involved two considerations. The first was to obtain random sampling of the specimen blanks from the sheet stock; and the second was the design and machining of the specimens themselves.

SAMPLING PROCEDURE

In an investigation of the scope of the present one the sampling procedure for test specimens is doubly important. First, a reliable set of base properties is essential to provide a reference point from which to measure possible property changes resulting from creep exposure, and second, it is important that the exposure samples be representative of the test stock.

A number of possible sources of scatter in properties exist even in well produced sheet material. Among these variations can be slight differences in chemical analysis or mill practice, such as point-to-point differences in the amount of reduction, segregation carried through from the ingot, or differing thermal history. These variations can result in heat-to-heat differences, sheet-to-sheet differences, or differences within a single sheet.

In the present investigation, it was not felt to be feasible to include possible heat-to-heat variations. Thus, all material procured for each alloy was taken from a single heat. However, it was felt to be essential that any variations between sheets and within a given sheet be recognized.

Six sheets were arbitrarily selected for providing test specimens. It was desired that any given specimen be readily identifiable according to its original location in the test sheets. Figures 1 and 2 illustrate the sampling scheme for the 17-7PH stainless steel. As these figures indicate, each sheet of material was divided into a number of modules or panels over the length of the sheet. Within each panel the specimen blanks were arranged in a pattern across the width of the sheet. Repetitions of the panel extended the sampling over the length of the sheet. The panels were five to seven inches wide and the specimen blanks were one inch wide. As each strip was sheared, a code number was stamped on it identifying the sheet number, panel number, and specimen position within the panel -- in that order. Thus, the specimen labeled 3D-T2 indicates a tensile specimen from the second strip of panel D in sheet 3.

SPECIMEN PREPARATION

Dimensions of the various test specimens that were machined from the one-inch wide specimen blanks are shown in Figures 3 and 4. All specimens for the tests of the mechanical properties were designed so that they could be machined from the creep specimens following the desired exposure. For the exposure tests themselves, the width of the gage section of the specimen was machined 0.030 inches over the 0.5 inch nominal width. This procedure permitted the measurement of the properties of the material itself unaffected by the particular edge effects, if any, associated with the prior exposure of the specimen.

For ease in machining, jigs were constructed so that five or six specimens could be made at the same time. The specimens were milled to rough dimensions. The shoulder radii and gage sections were then ground to finished dimensions.

The notched tension-impact specimen was prepared to the major dimensions using standard procedures. Following this, a flat-bottomed V-groove was ground into each edge of the specimen. During this operation the specimen was held in a special fixture so that the location of the notches could be accurately controlled. Next, the center of each flat was nicked with a sharp grinding wheel. Finally, the nicked flat was lapped to the final gauge width and root radius, using a lapping compound and a phosphor bronze wire whose radius was slightly under the final radius desired for the notch. For the notch prepared to the dimensions indicated in Figure 4 the theoretical stress concentration factor, K_t is equal to 4.2.

The notched tension-impact test was added to the program after the dimensions for unnotched specimens had been established. The notch geometry adopted was that which had been previously chosen for notched-specimen rupture tests in another research program being conducted for the Materials Laboratory. The width was thus not the same for smooth and notched specimens used in the present program. This fact should be of little consequence since the desired comparison is not between different types of specimens, but between like specimens with different histories of prior creep exposure.

TEST EQUIPMENT

The test equipment utilized in this investigation may be divided into two categories: the creep-rupture equipment used to produce the desired exposures either with or without stress; and the equipment for the subsequent tensile, compression, or tension-impact tests.

EXPOSURE-TEST EQUIPMENT

The creep-rupture tests and elevated-temperature exposure tests, either stressed or unstressed, were carried out in individual University of Michigan creep-testing machines. In these units the stress is applied to the specimen by a dead load acting through a third class lever system. The specimen is held by a gripping system that includes universal joints at either end in order to provide uni-axial loading. The specimen is heated by a wire-wound resistance furnace fitting over the specimen assembly.

Strain measurements are accomplished by a modified Martens optical extensometer system. Pairs of extensometer bars are attached to collars which are pinned through holes in the shoulder sections of the test specimen or clamped directly on the specimen gage section. Extensometer attachment to the specimen shoulder necessitates the use of correction factors in order to obtain the true deformation of the gage section of the specimen.

The extensometer bars extend from the bottom of the furnace and are spring clamped (over a cylindrical pin) against machined flats on the bottom specimen holder. Sandwiched between the sets of extensometer bars are the stems of small mirrors. Differential movement of the top and bottom sets of bars causes the mirrors to rotate. A fixed illuminated scale and a telescope fitted with cross hairs are mounted about five feet from the mirrors. As the specimen elongates, a very small movement of the extensometer bars results in a large change in the reflected scale reading observed through the telescope. The factor for converting the observed movement to absolute deformation has been computed from the geometry of the system and checked experimentally. The dimensions of the system used at the University of Michigan permit detection of a specimen elongation of about 10 millionths of an inch.

TENSILE AND COMPRESSION TEST EQUIPMENT

The tensile and compression tests were carried out in a Baldwin-Southwark hydraulic tensile machine equipped with a strain pacer. The holders for the tensile tests were the same type as used for creep testing, while a special fixture was constructed for the compression tests.

For elevated-temperature tests a wire-wound resistance furnace was constructed with a 5-inch diameter core. This larger-than-usual core was necessary to accommodate the extensometer assembly and compression fixture. The difficulties in obtaining temperature distribution over the specimen gage length in such a furnace with a high ratio of core diameter to length were minimized by providing a closer spacing of furnace windings at the bottom of the furnace.

The basic design of the compression test fixture was adapted from that of Flanigan, et. al. (Ref. 3) plus several modifications suggested in a report (Ref. 4) from the Titanium Metallurgical Laboratory at Battelle Memorial Institute on compression testing techniques. The fixture consists of a base, a pair of adjustable guide blocks, a loading ram, and a cylindrical head to position the loading ram. The results of Kotchanik, et. al., were cited (Ref. 4) to show that values of compressive modulus (slope of the stress strain curve) were independent of supporting force when the guide blocks contained off-set grooves. Accordingly, a set of grooves off-set from each other were machined into the surface of the guide blocks. The unit is shown in Figure 5 assembled for testing.

The base and guide blocks were made from H-40 steel and the loading ram from 17-22A(V) steel hardened to Rockwell "C" 40. The purpose of the guide blocks is to constrain the specimen from lateral buckling during the test. A pair of set screws provides the means for adjustment of the movable guide block.

RECORDING EXTENSOMETER SYSTEM FOR TENSION AND COMPRESSION TESTS

The tensile machine was equipped with an O. S. Peters automatic stress-strain recording system to permit a continuous plot of the test results. This recording system also included a strain pacer which permitted accurate control of strain rates.

The O. S. Peters recording system employs a linear variable transformer (or microformer) to detect deformations.

To permit the use of the microformer for elevated temperature testing, an auxiliary extensometer unit was constructed to transfer specimen motion outside the furnace using an averaging linkage.

The system is shown in Figure 5 set up for a compression test. The specimen is gripped by screws made of heat-resistant alloy and tipped with tungsten carbide inserts. Motion of these screws is transmitted by pairs of flat extensometer bars made of 17-7PH alloy. At the lower ends of these bars are two cross pieces--one attached to a rod and the other containing a tube. The ends of the cross pieces are grooved to fit pins brazed to the lower ends of the extensometer bars. This joint acts in much the same manner as a knife edge. A spring maintains the seat of the pin in the cross piece. Finally, the microformer pickup is attached to the rod and tube.

Also essential to this system is the open frame that forms the base for the compression test set-up and which is drilled and tapped at each end so that it can be included in the specimen gripping assembly for tensile tests. The purpose of this frame is to permit the attachment of the microformer to the rod and tube on the center line of the compression or tension axis.

TENSION-IMPACT TEST EQUIPMENT

An existing Olsen impact testing machine was modified to permit carrying out tension-impact tests on sheet specimens. The modifications included construction of pairs of specimen-holding jaws that could be attached to the pendulum of the impact machine, and extension of the striking surfaces so that the impact occurred at the maximum downward point of the pendulum swing. In addition, it was necessary to re-calibrate the scale of the machine to obtain true values of impact strength under the test conditions employed.

The specimen-holding jaws were modified from the design of Muhlenbruch (Ref. 5) and are illustrated in Figure 6. The grip assembly was made to screw into a holding assembly fixed to the pendulum head. The specimen itself is held in the split grip sections. A cavity was machined into one side of the split grip to accommodate the specimen. The other half of the split grip has a plane surface and is fixed into position by an indexing pin located at the back end of the grip. The two halves of each grip are locked together by a snap ring. Stiffening rods fixed to the front holder and allowed to "float" in holes in the rear holder reduce the bending tendency of the assembly as the pendulum falls. The striker, which is screwed onto the rear holder provides the necessary tension-impact loading as it hits the striking plates of the machine. Since the shoulder dimensions of the notched specimens were different from those of the smooth specimens a set of jaws was constructed for each type of test.

The impact data can not be read directly from the scale of the machine because of the added weight of the grips and because the rear portion of the grips fall from the head immediately after the impact blow. The calibration procedure to account for these factors was given previously. (Ref. 1).

Elevated temperature tension-impact tests reported in the First Summary Report, (Ref. 1) were run by first heating the specimen assembly in a separate furnace and then attaching it to the pendulum. This procedure was time-consuming and clumsy, necessitating compensation for the time delays involved. However, fairly consistent values of impact energy could be obtained in this way.

An improvement of this procedure was accomplished by the construction of a small split furnace that just fits around the specimen grips. The unit assembled for operation is illustrated in Figure 7. When the test temperature is attained, the furnace is opened like a book and removed from the specimen assembly, and the pendulum latch released.

The furnace itself consists of a split transite box about 4 inches square by 6 inches long, the halves of which are hinged. The heating elements are contained in a pair of drilled-out fire bricks which form the core of the furnace. The inner furnace liner was fabricated from sheet stainless steel. The heating elements consist of four 285-watt and four 90-watt cartridge heaters inserted in the furnace annulus parallel to the core. A provision is made for varying the longitudinal position of the heating elements in order to ensure proper temperature distribution. The 90-watt heaters are wired through a controller to provide on-off control, while the 285-watt heaters are on continuously. The power input to both sets of heaters is controlled by a Variac. This allows close control to be obtained at any desired temperature level. At temperatures up to 900°F it has been possible to obtain specimen temperature variations of less than 3°F over the gage length.

BEND TEST EQUIPMENT

The fixtures for conducting cold bend tests were adapted from a design presented by Craighead, et. al. (Ref. 6) and consist of a female test anvil and a set of male "V" indenters. The test consists of bending strip samples (the same dimensions as a compression specimen) to a 75° "V" over successively smaller radii until cracking is visible to the naked eye. The test anvil contains a 75° V-shaped cavity one-inch wide at the top. A 1/16-inch wide slot was machined into the bottom of the cavity. The indenters were also machined to a 75° angle, with the apexes of the individual indenters machined to various radii ranging in graduated steps from a 1/2-inch radius to 1/64-inch radius. Both the anvil and the indenters were made of hardened tool steel.

TEST PROCEDURES

Wherever applicable, ASTM Recommended Practices were adhered to in test procedures. Other testing details followed practices developed through experience at the University of Michigan.

Specimen temperatures for all elevated-temperature tests were measured with chromel-alumel thermocouples wired to the gage section. All thermocouple beads were shielded from direct furnace radiation by a wrapping of asbestos cord.

In order to limit the holding time at the start of a test, furnaces were preheated within 50°F of the desired final temperature before specimens were placed into them. The temperature distribution over the entire gage section could be brought to within ±3°F of the nominal test temperature in a time period of no more than four hours. For the creep-exposure tests, an elapsed time of four hours between placing the specimen in the furnace and application of the load was adopted to provide uniformity of testing procedures.

CREEP-EXPOSURE TEST PROCEDURE

For each creep test, three thermocouples were used, one in the center and one at each end of the gage section. The modified Martens extensometer system described previously was used to measure the deformation both during load application and during the ensuing creep period.

At the end of the 10, 50, or 100 hour exposure period a final extensometer reading was taken and the power to the furnace turned off. Experience has shown that cooling the specimen with the load in place minimizes property changes of the type associated with creep "recovery." For the tests carried out under no load, i.e., temperature exposure only, the same general scheme was used. All the steps of a normal creep test were followed with the exception of the loading. The two duplicate specimens for each unstressed exposure were wired together and run in the same unit at the same time. The slight additional thickness of the material had no detectable effect on the temperature distribution within the furnace.

In the initial tests to determine time-deformation data of 17-7PH alloy, the extensometer bars were suspended from pins through the specimen shoulders. The procedure for calculating the effective gage length in this instance was previously presented in detail (Ref. 1). For creep-exposures where more limited amounts of deformation were encountered the extensometer bars were attached to collars clamped directly onto the specimen gage section and no correction was necessary.

Gage section attachment of collars is satisfactory where specimen necking is small. Comparisons of results obtained with shoulder attachment of bars indicated this practice would be satisfactory in the present investigation.

TENSION AND COMPRESSION TESTS

The tensile test procedure with respect to temperature level and distribution was the same as that described for creep-exposure with the exception that two thermocouples rather than three were mounted on the gage section of the specimen. This was necessary in order not to interfere with the extensometer assembly mounted on the gage section. With reasonable care it was found possible to attain a temperature distribution of 2-3°F over the gage length of the specimen mounted in the large core diameter furnace used for these tests.

Due to the manner in which the specimen was gripped in the fixture, it was not possible to mount thermocouples directly on the compression specimens. For actual compression tests, the temperature measurements were taken from couples mounted at the base of the cylinder at the upper end of the fixture and the support block at the lower end of the fixture. With suitable shunting of the furnace winding it was possible to obtain a distribution of 3°F over the fixture. The validity of this method of temperature measurement was checked by comparing the readings from the external couples with the readings from a set of three couples that had been spot welded to the edges of a dummy specimen of 17-7PH alloy. The correlation between the dummy and the external couples was good.

For the room temperature tension tests the microformer strain follower was mounted directly on the specimen gage section, while at elevated temperatures the extensometer assembly was used in conjunction with the strain follower.

The tests were run at a strain rate of 0.005 inches per inch per minute with the aid of the strain pacer. Interchangeable "rod and tube" and "tube and rod" extensometer fixtures permitted operation of the recording system in the proper direction for pacing regardless of whether the test was in tension or compression. The test data were recorded in the form of a curve of load versus deformation. From this curve were calculated the 0.2 percent offset yield strength and the slope of the elastic portion (elastic modulus). The maximum load observed from the recorder trace was used to calculate the ultimate tensile strength. Measurements of elongation and reduction of area were made from the fractured specimen.

Because of the clearances that existed in the fixture, it was necessary to use a gage length of 1.7 inches for the compression tests. After accurately setting the gage length with the aid of a jig, the holding screws were tightened until it was certain that the tungsten carbide tips had achieved a tight grip on the specimen. A light coating of Molykote lubricant was applied to the specimen, the entire assembly placed in the opened compression fixture, and the top of the fixture was then set in place and screwed down.

According to Kotchanik, et. al. (Ref. 4) compressive yield strength values obtained from this type of fixture have a critical relationship to the supporting force. Consequently, a torque wrench was used to tighten the specimen guide blocks. A force of from 2 to 4 inch pounds was found to give consistent results.

After the fixture was closed, the assembly was set on the pedestal and placed under the cross head of the tensile machine as shown in Figure 5. Finally, the strain follower was attached to the rod and tube of the extensometer and the recording system zeroed. The load application was continued until a marked change in slope was observed in the recorder trace. From the trace, the slope of the elastic portion (compressive modulus) and the 0.2 percent offset yield strength were determined.

TENSION-IMPACT TEST PROCEDURE

Prior to assembling the specimen in the tension-impact test holding grips, measurements were made of the shoulder-to-shoulder distance and the cross sectional area of the specimen gage section.

The actual running of the test consisted of screwing the grip assembly to the holder at the back of the pendulum head which had been previously raised to the fixed initial height. The latch holding the specimen was then released and the head allowed to fall between the striking surfaces. The height to which the indicating disc rose after the impact was read from the scale of the machine and this value converted to energy absorbed upon impact. Measurements of specimen elongation and reduction of area after impact were made on a number of specimens. Although these data are reported, significance of reduction of area for sheet specimens is questionable.

In elevated temperature tests, when the proper temperature had been attained, the furnace was opened, removed from the specimen assembly and the pendulum latch released. Figure 7 shows the equipment assembled for such a test. The interval from removal of the furnace to the fracture of the specimen was less than five seconds.

METALLOGRAPHIC EXAMINATIONS

Conventional techniques of mounting, grinding, polishing and etching were followed in preparing specimens for metallographic examination.

The samples were first mounted in bakelite and then wet ground in order to remove any disturbed metal. The rough polishing steps were carried out successively on 240-, 400-, and 600-mesh silicon carbide paper on a rotating lap. The paper was lubricated with water throughout these steps.

Finish polishing was accomplished with acqueous media of Linde "A" and Linde "B" polishing compounds on rotating laps covered with "Microcloth."

The polished samples were then etched with Marble's Reagent or with a special reagent developed at the University of Michigan for the examination of heat-resistant materials.

The composition of Marble's Reagent follows:

$CuSo_4$	20 gm
conc H Cl	100 ml
H_2O	100 ml

The composition of the special etch developed at the University is the following:

<u>No. 4 Etch</u>

29% $CuCl_2$ in H_2O
36% Glacial Acetic Acid
23% HCl
5% H_2SO_4
7% $HCrO_4$

Hardness measurements were taken using a Rockwell "C" scale. Five or six impressions were made on the shoulders and gage section of the exposed specimens. Average values were reported. Measurements taken on fractured samples were made well back from the fracture in order to avoid spurious results due to an excessively thin sample. The nominal thickness of the material was well within the limits of reliability of the Rockwell "C" scale.

BEND TEST PROCEDURE

Cold bend tests were conducted in the tensile machine utilizing the compression head. The sample used was identical to the compression sample. The procedure consisted in bending the sample over the largest radius and then examining it. If no cracks visible to the naked eye were found, the next smallest indenter was used, and so forth, until visible cracks were observed.

EXPERIMENTAL RESULTS

Curves of stress versus time for total deformation were first established to define the stresses to be used for the creep-exposure tests. The specimens were then exposed under the specified conditions and subjected to tensile, compression, and tension-impact tests at room temperature or the exposure temperature. In addition, hardness determinations, some bend tests and metallographic studies were carried out.

Properties of the specimens following exposure are related graphically to the amount of prior creep, temperature or time of exposure. Consistent trends in these curves were taken as significant property changes. The conditions used to evaluate base properties were inadequate to fix realistic confidence limits by statistical methods. Under this condition the information provided from simple trends is probably as effective as that which would be gained using the statistical approximations which would have been necessary under the limitations of evaluation of base properties.

In plots showing the effect of prior creep, both the unexposed properties and properties after unstressed exposure are indicated on the zero deformation axis.

In all tabulations the specimen is described both by the nominal-exposure conditions and the actual-exposure conditions including the actual deformations of the specimen.

All correlations have been made in terms of the actual deformations obtained in the tests. The complete time-elongation data obtained permitted the separation of the deformation into its various components. In a few cases, plastic deformation was obtained during loading and this has been noted in the tabulations. Generally, the amount of this deformation was small. The major portion of the plastic deformation during testing comes from creep at the testing temperature and stress. This component, designated the creep deformation, was obtained by subtracting the total loading deformation from the total deformation at the end of the test. Where sufficient differences were obtained, the residual properties were plotted with respect to both the total deformation and the creep deformation.

ESTABLISHMENT OF EXPOSURE STRESSES

Curves of stress versus time to reach a given total deformation were determined to define stresses for the creep-exposure tests. Tests at 600°, 800°, and 900°F were conducted and allowed to run until rupture. The rupture times and fracture ductility are an additional indication of the uniformity of the material and test procedures.

The results of these tests are summarized in Table 1. The data include the loading deformation and the time required to reach the total deformations of interest between 0.5 and 3.0 percent. Elongation and reduction of area values are reported although it should be recognized that reduction of area data for sheet specimens is frequently difficult to measure reliably.

The curves of stress versus time to reach total deformations of 0.5, 1.0, 2.0, and 3.0 percent at each of the test temperatures are plotted in Figure 8, together with a curve of the rupture life. The nominal stresses for the required exposure conditions were determined by the intersections of the total deformation curves with the ordinates at 10, 50, or 100 hours. These stresses are tabulated with the exposure test data for the various specimens.

Generally the slopes of the total deformation curves follow the slope of the rupture curve at the same temperature. At 600°F low stresses were required in order not to exceed 0.5 percent total deformation on loading and the curve was drawn from the results of only two tests. Four or more points were available for the construction of the other curves. Rupture times and elongations on rupture showed good consistency at 800° and 900°F but exhibited some scatter at 600°F.

Hardness determinations on the rupture samples following the completion of testing are also included in Table 1. Moderate increases in hardness were obtained from exposure to time, stress and temperature. The differences between the three exposure temperatures were slight and probably not significant.

BASE PROPERTIES BEFORE CREEP EXPOSURE

Tensile, compression, and tension-impact tests were conducted on randomly selected specimens in order to establish an average strength of the as-treated material at both room temperature and the temperatures for creep-exposure tests and subsequent mechanical tests. Samples were taken from each of three sheets and the results are presented as the average values within sheets and the average of all tests at the particular test temperature. The averages of all tests were used as the basis for comparison to determine the effect, if any, of the exposure to temperature or to temperature and stress.

The individual test values and averaged properties for each sheet are presented in order to indicate the possible variations within individual sheets. In considering these values it should be recognized that the location of the sample, specimen preparation, heat treatment variations and testing conditions all could influence results from individual tests. Rigorous statistical evaluations were not used because all variables, particularly the interrelationship of heat-treatment group and the sheet from which the specimens were taken, were not adequately covered to fix realistic confidence limits. The average properties are, therefore, used in the balance of the report to relate initial properties to properties after exposure.

Tensile Properties

The results of tensile tests at room temperature, 600°, 800°, and 900°F are summarized in Table 2. A plot showing the effect of test temperature on the average short-time mechanical properties is presented in Figure 9. Typical stress-strain curves are plotted in Figure 10.

In the room-temperature test results specimens 1L-T1, 1L-T2, 1L-T3, and 1L-T4 are treated as one test for the purpose of computing the average values. This was done since the four specimens were not only adjacent in the original sheet but heat treated in the same bundle. These results indicate the high degree of reproducibility of properties over a small area of the material and for a single batch of heat-treated specimens. Treating them as one test for the purpose of computing average values reduces the bias inherent when grossly unequal sample sizes and different heat-treatment lots are used.

Both the ultimate tensile and yield strengths showed a similar decrease with increasing temperature (Fig. 9). A slight decrease in elongation from the values at room temperature was observed at 600°F, while at 800° and 900°F there was a substantial increase in elongation. The reduction of area data showed a similar trend (Table 2).

The modulus values included in Table 2 were computed from the slopes of the stress-strain curves. Consequently, they should not be regarded as precision determinations of the modulus but are included only for comparative purposes.

Compression Properties

The results of compression tests are presented in Table 3 and plotted in Figure 9 as a function of temperature. Typical stress-strain curves are presented in Figure 11.

At room temperature and 600°F the compression yield strength was some 12-15 percent higher than the corresponding tensile yield strength and above the ultimate tensile strength. However, the deterioration in compression yield strength with temperature was greater at 800° and 900°F and it fell to about the value of the tensile strength at the higher temperatures. Indicated modulus values in compression were slightly higher than those obtained in tension.

Tension-Impact Properties

Tension-impact tests were run on both smooth and notched specimens. The data are summarized in Tables 4 and 5 and plotted as a function of temperature in Figure 9.

Smooth Specimens. The results of tension-impact tests at room temperature, 600°, 800°, and 900°F on smooth specimens are summarized in Table 4. The tension-impact strength decreased with test temperature up to 800°F and then increased at 900°F. The scatter between extreme values within individual sheets was greater than the scatter between the sheets themselves, with the data showing somewhat greater consistency at the higher testing temperatures. Elongation and reduction of area values showed little change with test temperature. A slight decrease in ductility may have occurred at 900°F.

Notched Specimens. The notched specimen tension-impact test results are summarized in Table 5 and plotted in Figure 9. At room temperature the notched specimens showed a greater scatter than did the smooth specimens. However, the limited number of elevated-temperature tests exhibited fairly good agreement. In general, the effect of notching the samples was to reduce the tension-impact strength significantly. It should be noted incidentally that the cross-sectional area at the base of the notch is about 25 percent greater than the gage-section area of the smooth samples. Slight variations in the notches may account for the scatter in the room-temperature results.

In contrast to the smooth-specimen tests, the notched tests indicated little or no temperature dependence on tension-impact strength. There may have been a slight increase in strength at 900°F corresponding to that occurring in the tests of smooth specimens. Perhaps the specimen geometry rather than the material controlled the notched tension-impact strength. As mentioned previously the theoretical stress concentration factor for the notch was 4.2.

TENSILE PROPERTIES AND HARDNESS VALUES AFTER EXPOSURE

Tensile tests were conducted on samples exposed without stress to establish the influence of temperature and time alone on tensile properties. The tests after exposure to the required amounts of creep then show the added effects of creep.

Tensile tests were conducted at room temperature after all conditions of exposure. In addition, tests were also run at the same temperature as was used in the exposure.

Unstressed Exposure

Room-Temperature Tests. Room-temperature tensile tests following unstressed exposure showed significant results depending principally on the temperature of exposure. As Table 6 and Figure 12 indicate, exposure at 600°F had no particular effect on the tensile properties, with negligible effects also noted for 10-hours exposure at 800° and 900°F. The longer exposures at 800° and 900°F did result in a moderate significant increase in tensile and yield strength. The elongation data show little change although they move consistently in the opposite direction from the changes in strength. Hardness data are consistent with the changes in strength. For the longer times and higher temperatures the scatter in residual properties for the duplicate exposure conditions was fairly small. Scatter was somewhat more pronounced for the specimens exposed at 600°F.

Elevated-Temperature Tests. The data indicate a very little, if any, change in strength with exposure time for samples exposed at 600° and 800°F and a slight increase in strength for the samples exposed at 900°F for 100 hours (Table 7 and Fig. 13). With the exception of the 10 and 50-hour exposures at 600°F, the agreement between duplicate tests was very close. Moderate losses in ductility occurred in the samples exposed for 100 hours at 800° and 900°F and tested at these temperature, while the samples tested at 600°F appeared to be unaffected.

Creep Exposure

Specimens were exposed to nominal total deformations between 0.5 and 3.0 percent at the primary test temperatures of 600°, 800°, and 900°F. Initially, at least two specimens each were exposed to a nominal total deformation of 2 percent at 400°, 500°, 650°, 700°, 750°, and 850°F to verify that the primary test temperatures properly covered the range of effects.

Room-Temperature Tests. The test results, Table 8, are shown graphically for each exposure time and temperature by Figures 14, 15, and 16. In each figure both the creep deformations and the total deformations are indicated. Figure 17 summarizes the results for the three primary test temperatures and permits a comparison of the effect of exposure time and total deformation on the residual properties. Finally, Figure 18 shows the effects of exposure temperature on the properties of materials exposed for 100 hours either unstressed or stressed to produce a nominal total deformation of 2 percent in 100 hours. This figure includes the results of tests of samples given stressed exposures at temperatures below or intermediate to the principal exposure temperatures.

Increased amounts of prior creep at 600°F, Figure 14, resulted in an increase in tensile and yield strength following all time periods of exposure. Exposure for 100 hours resulted in a leveling off or decrease after more than 1.5-percent deformation. A significant reduction in ductility was noted after exposure to deformations of the order of 1 percent. From the original elongation of about 7 percent for the as-treated material, the elongation leveled out at about 2 percent.

The changes in properties are related in Figure 14 to both the creep deformation and the total deformation which includes the elastic deformation and plastic deformation, if any, from applying the load as well as the subsequent creep deformation. It will be noted that this simply resulted in the property change curves being shifted by the difference between the two deformations. In those cases where the deformation during loading represented practically all the deformation, the changes in properties were hardly significant even in 100 hours. Consequently, it appears that the creep deformation was mainly responsible for the observed changes in properties.

Prior creep at 800°F, Figure 15, resulted in some increase in strength for 10 hours exposure. However, prior creep for 50 and 100 hours did not appear to increase the tensile and yield strengths much beyond that due to exposure to temperature alone. Some reduction in ductility resulted for samples pre-crept at 800°F with little influence from time of exposure. The elongation values fell to about 3.5 percent in this instance. The data were considerably more erratic than at 600°F and no conclusions based on creep versus total deformation effects could be derived.

Prior creep at 900°F, Figure 16, resulted in trends in properties which were somewhat difficult to interpret. For both 10 and 50 hours prior creep there apparently were maximum increases in strength at intermediate deformations followed by a drop in strength to about the level of the unexposed material for deformations of about 2-3 percent. The results for samples given prior creep for 100 hours at 900°F indicated that the deformation caused little change in strength beyond that due to the exposure to temperature alone. The erratic nature of the data raises some question as to whether there was any real effect of creep on the strength properties. The severe drop in ductility observed at the lower temperatures was not encountered following the 900°F exposures. Again, the data did not permit separation of creep deformation versus total deformation effects. The summary of the room-temperature test results presented in Figure 17 indicates an increase in tensile and yield strength with increased prior creep for all time periods at 600° and for 10-hours exposure at 800° and 900°F. For 50 and 100-hours exposure at 800°F, the principal changes in properties appear to be due to temperature alone, while the 900°F results indicate a possible drop-off in strength at the longer times and greater amounts of prior deformation. Elongation values underwent a substantial drop following creep at 600° and possibly some decrease after creep at 800°F. Creep at 900°F caused little change.

Figure 17 also indicates that the time of exposure was of minor importance compared to the temperature and amount of creep.

A better understanding of the influence of prior creep on the tensile and hardness properties at room temperature can be obtained from Figure 18. This figure shows the properties after exposure at temperatures from 400° to 900°F for 100 hours and a nominal total deformation of 2 percent. The figure shows that:

1. Exposure to temperature alone at 800° and 900°F caused an increase in tensile and yield strength; but not when the exposure temperature was 600°F.

2. When the material was also exposed to sufficient stress to cause about 2-percent total deformation there were increases in strength for all temperatures of exposure with the largest increases occurring at 600° to 850°F. The increases were greater for yield than for tensile strength.

3. The most important effect revealed by Figure 18 is the reduction in elongation caused by stressed exposure in the middle of the temperature range investigated. The tests carried out at 600°F indicated that the effect occurs at total deformations greater than 1 percent (Figure 14). As Figure 18 shows, the adverse effect occurs in the range from 500° to 700°F and is a maximum at about 600°F. At 800°F and above, the elongation values were about the same for stressed or unstresses exposure. The loss of ductility was accompanied by a fairly large increase in the yield strength.

4. The hardness data indicate a possible minimum after exposure at about 600°F.

Representative stress-strain curves obtained in room-temperature tests following prior creep-exposure are presented in Figure 19.

Elevated-Temperature Tests. Some increases in 600°F tensile and yield strength resulted from prior creep up to about 2 percent for the three time periods considered. (See Table 9 and Fig. 20). The increase in yield strength was more definite than for tensile strength. As the 100-hour data indicate, larger amounts of deformation probably do not cause as much increase in strength. Ductility decreased to fairly low values as the result of prior creep. The data also suggest that the creep deformation caused the changes rather than total deformation. Both of these latter two effects were noted in the influence on properties at room temperature.

Prior creep at 800°F, Figure 21, resulted in relatively little effect on 800°F tensile properties. Some increase in tensile and yield strength may have occurred for 50 or 100-hours exposure, although this is questionable. Elongation values may have been increased by intermediate amounts of creep in 50 and 100 hours.

Prior creep at 900°F had very little effect on the 900°F tensile properties, Figure 22.

Figure 23 summarizes the results of the elevated-temperature tensile tests following prior creep and illustrates that significant changes were confined to 600°F. What changes that do occur in the 800° and 900°F are inconsistent and appear to be no greater than the effects of exposure to temperature alone. At 600°F, the tensile strength, and particularly the yield strength were increased by prior creep up to about 3 percent. Beyond this point some decrease may occur. The effect of prior creep time appears to be negligible.

Representative stress-strain curves for these tests are plotted in Figure 24.

COMPRESSION PROPERTIES AFTER EXPOSURE

Compression tests at room temperature or the temperature of exposure were conducted on specimens given stressed or unstressed exposure for 10, 50, or 100 hours at 600°, 800°, or 900°F. The property evaluated in these tests was the 0.2-percent-offset yield strength. Modulus values computed from the slopes of the stress strain curves are also reported. Correlations were based on both the total deformation and the creep deformation.

Unstressed Exposure

Unstressed exposure was found to cause little change in either the room temperature or elevated-temperature compression properties of 17-7PH.

Room Temperature. The results of room-temperature compression tests on specimens given unstressed exposure are summarized in Table 10 and plotted in Figure 25. A fair degree of scatter was encountered in these tests and it was necessary to expose three specimens at several of the exposure conditions rather than the usual two. However, even this expedient did not completely clarify the test results and some question still remains concerning the true effects.

Average values indicate that unstressed exposure for periods up to 100 hour at 800° and 900°F had little or no effect on the room-temperature compression yield strength. Exposure for 10 or 100 hours at 600°F apparently resulted in a loss of strength up to 20 percent of the base value. However, the 50-hour exposure at this temperature apparently had little effect. No explanation was found for this inconsistency.

Elevated Temperature. The results of compression tests conducted at the exposure temperature following unstressed exposure are summarized in Table 11 and plotted in Figure 26. Due to excessive variation encountered between the first two tests exposed for 10 hours at 600° and 900°F an additional test was carried out.

The 600° and 800°F compression yield strengths were little affected by the time of prior exposure. There may have been a slight decrease after the 10-hour exposure. A slight increase in strength may have resulted at 900°F.

Creep Exposure

The effects of prior creep on compression yield strength were fairly large for the 600°F exposure, but somewhat inconsistent for the 800° and 900°F exposure. In contrast to the tensile test results, the significant effects were confined principally to losses in strength.

Room Temperature . Room-temperature compression tests following prior creep are summarized in Table 12. Individual plots summarizing the test results obtained from each of the exposure temperatures are presented in Figures 27, 28, and 29, while a summary of the effect of prior creep on the residual compression strength is presented in Figure 30.

Prior creep at 600°F caused a fairly substantial drop in the compression yield strength. As Figure 30 brings out, the effect was about the same regardless of the time period. A reduction in the compression yield strength of as much as 30 percent from the base value was noted for deformations greater than about 1-2 percent. Scatter in the results of unstressed exposure tests tends to make the origin of the curves somewhat uncertain. The drop in strength with increased amounts of prior creep at 600°F appears, however, to be fairly well established. Again creep appeared to be a controlling factor in the change in properties at 600°F.

As Figures 28 and 29 indicate, scatter in the test data made the establishment of trends very difficult for exposure to creep at 800° and 900°F. Deviations from the base value of not more than 10-12 percent were the rule and the direction of change showed little consistency. This was especially evident in the 50 and 100-hour data for prior creep at 800°F and the 10-hour data for prior creep at 900°F. In fact, most of the tests points fall within the range of yield strengths for the as-treated material, Table 3. It is quite likely, therefore, that there is no particular effect of prior creep at 800° and 900°F on the room-temperature compression strength or if there is an effect, it is masked by the inherent scatter of the material. The reduction in strength from exposure at 600°F, on the other hand, appears to be quite genuine and falls well outside the normal scatter of the material, as is illustrated by the summary, Figure 30.

Typical stress-strain curves from these tests are presented in Figure 31.

Elevated Temperature. The test data for specimens compression tested at the exposure temperature following prior creep are summarized in Table 13 and Figures 32, 33, 34, and 35.

Similar to the case of the room-temperature tests, a considerable drop in the 600°F compressive yield strength was caused by prior creep at 600°F, Figure 32. The strength dropped precipitously for total deformations greater than 1 percent, leveling off at values up to 40 percent below the base strength. Figure 35 indicates that the time of exposure had a minor effect, the principal cause being the amount of prior deformation in the material. Again, creep deformation appeared to be the controlling factor in property changes at 600°F.

The 800°F compression yield strength appeared to undergo a moderate decline with increasing prior creep, Figure 36. However, the decrease was limited to about 15 percent of the base value. The change in properties, if any, that occurred at 900°F was as much due to exposure to temperature alone as to prior deformation. Again there is very little indicate of a significant change in properties from prior creep at 800°F and 900°F. As Figure 35 shows, however, there was a significant loss in strength at 600°F.

Typical stress-strain curves for these tests are presented in Figure 36.

TENSION-IMPACT PROPERTIES AFTER EXPOSURE

Tension-impact tests at room temperature or the temperature of exposure were run on samples subjected to stressed or unstressed exposure at 600°, 800°, or 900°F. A notched specimen tension-impact test was evaluated on samples that had been given 50 hours stressed exposure. Smooth specimens were tested for the conditions of 10 or 100-hours exposure and for all the tests following unstressed exposure.

Unstressed Exposure

Specimens were exposed for 10, 50, or 100 hours at 600°, 800°, or 900°F and then machined to smooth specimens for tension-impact testing at room temperature or the exposure temperature. The room-temperature test results are summarized in Table 14 and plotted in Figure 37. The elevated-temperature results are summarized in Table 15 and plotted in Figure 38.

Room Temperature. Smooth specimen tension-impact strength at room temperature following unstressed exposure may have increased slightly with increased exposure time at 600° and 800°F, Figure 37. Exposure at 900°F for 10 hours caused a substantial increase in tension-impact strength, which then dropped off for the 50 and 100-hours exposure. The strength following 100-hours exposure at 900°F fell slightly below the corresponding 600° and 800°F values. Elongation values tended to follow the trends in tension-impact strength.

The behavior of room-temperature tension-impact strength following unstressed exposure was similar to the behavior of the tensile strength, Figure 13. However, the maximum in strength occurred earlier and the drop-off for the 900°F exposures was more rapid for the tension-impact.

Elevated Temperature. Figure 38 shows that tension-impact properties at the elevated temperature following unstressed exposure behaved in a manner similar to the corresponding room-temperature tests. The 600° and 800°F tests showed moderate or inconsequential effects. However, the 900°F tests revealed the same sharp rise in strength for the 10-hours exposure followed by a drop for the longer exposure times. Elongation values again behaved in much the same manner as the tension-impact strengths.

Creep Exposure

Specimens subjected to prior creep for 10 or 100 hours at 600°, 800°, or 900°F were tested as smooth tension-impact specimens at room temperature or the exposure temperature. The creep specimens subjected 50-hours prior creep were tested as notched tension-impact specimens at room temperature or the exposure temperature.

Room Temperature. Room-temperature tests of smooth specimens following prior creep showed some effects in spite of a considerable amount of scatter. The notched tests, on the other hand, showed little effect and exhibited better consistency. (See Tables 16 and 18 and Figure 39).

Because of the scatter in the smooth specimen test results it was not deemed feasible to try to separate the effects by separate curves for 10 or 100 hours. For this reason comparisons of the results on the basis of creep and total deformations are not included in this plot.

The data indicate that declines in smooth specimen tension-impact strength tend to occur with increased amounts of prior creep. Test scatter makes it difficult to establish the influence of temperature of exposure. The notched specimens tested after exposure at 600° or 800°F showed little, or no decrease with increased prior creep although the specimens tested after 800°F exposure all fell well below the base value for the material. The notched tests for specimens exposed at 900°F appeared to follow the same trend as the smooth-bar tests. It is entirely possible, that the presumed effects indicated for the smooth-specimen tests at 600° and 800°F are not genuine. The scatter in data points makes correlations of the test results difficult and a case could be made for the construction of horizontal correlation lines for these temperatures, thus indicating no effect of prior creep.

Elongation values show some decline with prior creep, Table 16.

Elevated Temperature. A slight decrease in impact strength with increased prior creep was found in the 600°F tests, while the 800°F tests showed virtually no effect. (See Table 17 and Fig. 40). At 900°F the initial increase caused by 10 hours unstressed exposure was rapidly dissipated by the effect of deformation, similar to the case of the room-temperature tests. This was shown by the smooth-specimen tests and the tests on the notched specimens following 50-hours exposure indicate a possible similar effect. The smooth specimen data following 100-hour exposure at 900°F showed very little or no effect of prior creep on properties.

Elongation values, Table 17, for all tests were low and showed no particularly consistent effect beyond possibly some reduction from the base condition.

BEND-TEST RESULTS

Bend tests at room temperature were run on specimens in the as-treated condition and after 10, 50, or 100-hours exposure (unstressed) at 800°F. The results of these tests are tabulated below:

Specimen	Exposure Condition	Bend Radius At Which Cracking Occurred
1J-X1	Unexposed	1/4-inch
1N-X1	Unexposed	1/4-inch
2C-X1	Unexposed	1/4-inch
2L-X1	Unexposed	1/2-inch
3K-X1	Unexposed	3/8-inch
3T-X1	Unexposed	1/4-inch
2L-X10	800°F--10 hours	3/8-inch
2K-X10	800°F--10 hours	1/2-inch
1N-X1	800°F--50 hours	3/8-inch
1J-X10	800°F--50 hours	1/4-inch
2C-X1	800°F--100 hours	1/2-inch
3T-X10	800°F--100 hours	3/8-inch

As the data indicate, slight decreases in bend properties were noted for 10 or 100-hours exposure at 800°F. The elongations obtained from room-temperature tensile tests following the same exposure conditions showed a small but consistent decrease with time of exposure, Figure 12. The elongations in room-temperature tension-impact tests following similar exposure showed a slight increase for 10-hours exposure which remained the same for the 50-hours exposure, followed by a further slight increase at 100 hours. (Fig. 37).

Further bend tests were not carried out due to the limitations of the bend-test fixture. Cracking over the 1/2-inch bend radius indentor was occurring after exposure. This was the largest radius which could be used with the fixture. Bending over larger radii would have been necessary to define bend properties for the samples, especially for those given stressed exposure. This would have required preparation of a larger bend tester.

METALLOGRAPHIC EXAMINATION

A limited metallographic examination revealed little, if any, effect of exposure on microstructure. There was not sufficient time to cover all test conditions or to incorporate the use of other techniques such as x-ray diffraction examination or electron microscopy.

Photomicrographs of samples before or after stressed or unstressed exposure are presented in Figures 41-44, all taken at 1000X magnification. Figure 41 illustrates the material as-treated to the TH 1050 condition. Figure 42 shows a sample after 100-hours unstressed exposure at 800°F, while Figure 43 shows a sample after 555 hours at 800°F and 90,000 psi. Figure 44 is a specimen after 100-hours unstressed exposure at 900°F. As these figures show, there was little discernable effect on microstructure at 1000X magnification from the exposure to temperature or to temperature and stress. This does not rule out the possibility that more refined techniques or complete examination would reveal significant effects.

DISCUSSION

For most of the conditions of testing remarkably little change in the mechanical properties of 17-7PH (TH 1050 condition) resulted from exposure to temperatures of 600°, 800°, and 900°F for time periods up to 100 hours and creep up to 3 percent. The major changes found were a decrease in ductility in tensile tests and a loss in compression yield strength after exposure to creep at about 600°F. Changes observed in other properties at room temperature or at the exposure temperature were relatively small and in most cases were hardly outside the scatter of the data.

The effects of temperature and exposure stress on the room temperature elongation or room temperature compression yield strength are shown in Figure 45 and 46 respectively. These figures, prepared for an exposure time of 10 hours, indicate the range of exposure stresses causing loss in subsequent properties. The limiting exposure conditions indicated by dashed lines, are the 10-hour rupture strengths at the various exposure temperatures.

The correlations of tensile and yield strength with exposure conditions often showed trends in the properties as a result of exposure which indicated a real effect on properties. This was perhaps most evident as an increase in tensile and yield strength at room temperature after exposure above 600°F for 50 and 100 hours. The increase in strength tended to be larger the more the deformation, up to 2-percent total deformation. In no case, however, was there a pronounced decrease in tensile strength or in tension-impact properties.

In those cases where the changes in mechanical properties were relatively small, it was difficult to determine whether trends were real or simply the result of scatter in properties. The changes were generally at most only slightly more than the range in values established for the original stock. Secondly, there often was considerable variation between duplicate or triplicate specimens. It was impractical to conduct sufficient tests for each exposure condition to establish the range in properties. If the uncertainty due to variation in properties had not been present, the absence of large changes in properties as a result of creep exposure might have been evident with much less testing.

The cause of scatter in properties was not determined. Some variation was certainly due to location of specimens within sheets and between sheets. Probably some variation also occurred between the groups of specimens heat treated at different times. Testing-condition variations could also have been involved. The limited data available did indicate a high degree of reproducibility of tensile properties at room temperature for adjacent specimens heat treated in one group.

The tension-impact tests did not disclose evidence of low-impact strength or even much change as a result of exposure to creep. The indications are, therefore, that no severe embrittlement to rapidly applied loads was produced by creep exposure. The bend-test results were rather limited but did tend to show a loss in bend ductility. This occurred for exposure at 800°F for which little evidence of change in tensile-test ductility or tension-impact characteristics was found. The possibility remains, however, that more extensive bend testing would have shown a significant deterioration as a result of prior-creep exposure.

The data appear to indicate that creep at 600°F was necessary for loss in ductility, the increases in tensile and yield strengths, and the losses in compression yield strength. Such changes as did occur after exposure at 800° and 900°F seemed to be more a function of temperature and time of exposure and were influenced very little by creep. The cause for this was not evident from the results. Certainly there was little change in properties after exposure at 600°F even in 100 hours unless appreciable creep occurred.

The structural studies were not sufficiently complete to explain any of the observed effects. In general, little change in structure or hardness would be expected in view of the relatively small changes in properties. A more detailed study might give some explanation for the loss in ductility and compression yield strength after creep at about 600°F.

It should be recognized that the data obtained were limited to one heat of material with one heat treatment. However, sufficient tests were run to make fairly certain that the temperatures of exposure adequately covered the range from 600° to 900°F.

CONCLUSIONS

Exposure of 17-7PH (TH 1050 condition) sheet to creep at about 600°F for total deformations up to 3 percent in 100 hours resulted in a loss in ductility in tensile tests and a substantial loss in compression yield strength. This occurred for tests at room temperature and at 600°F. Yield and ultimate strengths from tension tests and tension-impact properties were not greatly changed.

Exposure to creep at 800° and 900°F had relatively little effect on mechanical properties. Such changes as did occur generally showed an increase in properties. In no case was there any indication of a serious loss in mechanical properties. This included tension-impact tests on both smooth and notched specimens.

Creep appeared to be required for the loss in ductility and compression yield strength during exposure at 600°F. Unstressed material or material which underwent little creep showed little change in these properties.

In general, the results reflected remarkably little change in mechanical properties as a result of exposure to creep at 600° to 900°F.

REFERENCES

1. Gluck, J. V., Voorhees, H. R., and Freeman, J. W., "Effect of Prior Creep on Mechanical Properties of Aircraft Structural Metals," WADC Technical Report 57-150, January 1957.

2. Armco Steel Corp., Product Data Bulletin on Armco 17-7PH Steel, March 1, 1954.

3. Flanigan, A. E., Tedsen, L. F., Dorn, J. E. "Compressive Properties of Aluminum Alloy Sheet At Elevated Temperatures," Proceedings A.S.T.M., Vol. 46, pages 951-967, (1946).

4. Hyler, W. S., "An Evaluation of Compression-Testing Techniques for Determining Elevated Temperature Properties of Titanium Sheet," Titanium Metallurgical Laboratory, Battelle Memorial Insitute, TML Report No. 43, pages 21, A-13 (June 8, 1956).

5. Muhlenbruch, C. W., "A Tension-Impact Test for Sheet Materials," A.S.T.M. Bulletin No. 196, page 43, February 1954.

6. Craighead, C. M., Simmons, O. W. and Eastwood, L. W., "Titanium Binary Alloys," Transactions AIME, Vol. 188, March 1950, Journal of Metals, p. 489.

TABLE 1

RUPTURE AND TOTAL DEFORMATION DATA FOR 17-7PH ALLOY (TH 1050 CONDITION)

Spec. No.	Test Temp. (°F)	Stress (psi)	Rupture Time (hours)	Elongation (% in 1 inch)	Reduction of Area (%)	Hardness after test (R"C")	Loading Def. (%)	Time to Reach Indicated Total Deformation - hours 0.5%	1.0%	2.0%	3.0%
1K-T5	600	180,000	0.1	4.0	13.1	44.4	---	---	---	---	---
1K-T2		180,000	broke on loading	4.0	0	42.3	---	---	---	---	---
1U-T1		175,000	15.1	10.0	17.5	45.5	0.80	---	0.05	1.6	4.1
1C-T3		170,000	11.9	7.0	15.0	44.7	0.75	---	0.4	2.5	5.7
1G-T1		170,000	42.6	9.0	20.5	45.8	0.72	---	4.0	4.6	12.0
1L-T6		165,000	98.8	12.5	20.5	44.3	0.69	---	0.6	17.5	32.0
1C-T5		160,000	661.2	16.5	26.0	47.7	0.64	---	8.5	71.0	152.0
2E-T1		150,000	stopped at 2515.2 hrs.	---	---	---	0.59	---	46.0	330.0	675.0
2E-T5		125,000	stopped at 1893.3 hrs.	---	---	---	0.52	---	2000.0*	---	---
2C-T6		115,000	stopped at 119 hrs.	---	---	44.0	0.44	75.0	---	---	---
1G-T5	800	105,000	37.3	22.0	37.0	46.3	0.47	0.05	0.3	0.8	1.3
3A-T6		100,000	61±3	43.0	44.0	46.8	0.41	0.1	1.9	6.4	10.2
1U-T3		100,000	107±5	32.0	44.0	46.0	0.41	0.1	2.3	8.5	16.0
1C-T4		95,000	179.1	26.0	36.5	47.2	0.38	0.4	4.0	14.0	25.5
1U-T4		90,000	555.6	37.5	48.5	48.2	0.35	0.5	8.0	29.0	52.0
1Q-T25		70,000	stopped at 1936.7 hrs.	---	---	---	0.26	7.0	90.0	850.0	---
3P-T5		59,000	stopped at 100 hrs.	---	---	44.6	0.23	115.0*	---	---	---
1U-T5	900	75,000	19.8	31.0	46.5	46.9	0.32	0.10	1.0	2.9	4.6
1K-T4		70,000	29.1	28.0	49.0	46.1	0.29	0.20	1.2	3.4	5.7
1K-T6		70,000	56.7	38.5	52.8	45.9	0.30	0.25	1.4	4.6	7.7
1L-T5		70,000	24.5	29.8	48.6	45.6	0.31	0.15	0.8	2.4	4.3
1C-T2		70,000	28.4	32.2	47.2	46.8	0.30	0.17	1.1	3.2	5.2
1K-T3		60,000	152.2	33.0	65.0	45.7	0.26	0.8	4.4	13.5	24.4
1G-T4		55,000	323.6	43.0	51.0	46.8	0.24	1.5	5.0	23.0	45.5
1C-T2		50,000	699.1	40.0	49.5	46.4	0.21	4.0	17.0	76.0	134.0
3G-T5		37,000	stopped at 100 hrs.	---	---	44.1	0.14	120.0*	---	---	---

* Estimated

TABLE 2

TENSILE DATA FOR 17-7PH ALLOY (TH 1050 CONDITION)

Test Temp (°F)	Spec. No.	Ult. Tensile Strength (psi)	0.2% Offset Yield Strength (psi)	Elongation (%/2 inches)	Reduction of Area (%)	Modulus, E 10^6 (psi)	Hardness (R"C")
room	1C-T1	212,000	204,000	4.2	16.9	29.0	43.9
	(1L-T1	209,000	195,500	6.0	13.9	28.8	42.8
	* (1L-T2	214,000	195,000	5.5	14.3	29.0	43.5
	(1L-T3	216,000	209,000	5.6	9.8	28.7	43.8
	(1L-T4	215,000	208,000	4.5	13.4	28.6	44.9
	1U-T2	211,000	206,000	4.0	17.9	28.6	43.4
	Average	211,333	203,690	4.7	14.4	28.8	43.7
	2J-T3	197,000	183,500	9.0	19.4	27.6	43.4
	2N-T3	187,000	173,000	8.8	21.7	29.3	42.3
	Average	192,000	178,250	8.9	20.6	28.4	42.8
	3G-T1	201,000	195,000	7.8	18.7	28.2	45.1
	3Q-T1	202,000	194,000	7.2	20.8	29.2	44.3
	Average	201,500	194,500	7.5	19.8	28.7	44.7
	Average of "7" Tests	203,000	193,910	6.7	20.5	28.7	43.8
600	1G-T3	179,600	168,500	4.0	12.6	28.1	
	1P-T22	175,300	169,500	5.8	17.2	28.2	
	1P-T26	163,600	158,900	5.0	15.0	27.9	
	Average	172,833	165,633	4.9	14.9	28.1	
	2E-T2	183,000	168,700	4.5	16.1	29.3	
	2J-T4	156,900	148,000	5.2	14.8	27.4	
	2S-T4	186,900	179,000	5.2	16.1	27.2	
	Average	175,600	165,233	5.0	15.7	28.0	
	3A-T3	157,100	147,900	2.5	16.4	29.4	
	3P-T3	186,000	178,600	6.2	15.2	27.9	
	3P-T4	159,200	150,000	4.5	12.5	28.6	
	Average	167,433	158,833	4.4	14.7	28.6	
	Average - 9 Tests	171,989	163,233	4.8	15.1	28.2	
800	1P-T25	150,000	136,000	13.7	30.6	27.6	
	2E-T3	148,000	138,000	15.5	28.8	26.0	
	2J-T2	153,000	146,000	11.0	21.0	23.7	
	2R-T4	148,000	138,000	10.8	26.8	23.6	
	Average	149,667	140,667	12.4	25.5	24.4	
	3F-T5	148,000	138,000	12.8	29.2	23.0	
	3P-T2	147,000	137,000	9.5	27.9	24.8	
	3B-T6	140,000	132,000	9.3	23.5	22.2	
	Average	145,000	135,667	10.5	26.9	23.3	
	Average - 3 Sheets	148,223	137,444	12.2	27.6	25.1	
	Avg. -7 tests	147,710	137,857	11.8	26.8	24.4	
900	1K-T1	118,200	109,100	17.5	38.6	20.9	
	1Q-T24	123,000	111,000	21.3	39.2	21.7	
	Average	120,800	110,500	18.4	38.9	21.3	
	2J-T1	125,000	112,000	32.3	43.0	21.6	
	2S-T5	129,000	118,000	11.5	35.5	21.4	
	Average	127,000	115,000	21.9	39.2	21.5	
	3B-T7	117,300	109,000	17.5	38.6	21.0	
	3L-T3	121,500	109,000	16.5	41.0	22.2	
	3Q-T2	123,000	112,000	20.5	38.3	22.5	
	Average	120,600	111,000	18.2	39.3	21.9	
	Average - 3 Sheets	122,800	112,133	19.8	39.1	21.6	
	Avg. -7 tests	122,295	111,444	19.6	39.2	21.6	

* treated as one test -- 4 specimens immediately adjacent in original sheet and heat treated in a single bundle

TABLE 3

COMPRESSION TEST DATA

FOR 17-7PH (TH 1050 CONDITION)

Test Temp (°F)	Spec. No.	0.2% Offset Yield Strength (psi)	Modulus, E 10^6 (psi)
room	1C-C44	242,000	29.5
	1C-C4	235,000	30.1
	1C-C22	228,000	29.6
	1U-C4	226,000	29.6
	Average	232,750	29.7
	2J-C44	195,000	29.6
	2E-C2	206,000	30.1
	Average	200,500	29.8
	3L-C6	205,000	29.8
	3L-C4	234,000	29.6
	3L-C44	216,000	30.3
	Average	220,777	29.8
	Average - 9 tests	220,667	29.8
600	1U-X2	184,000	25.6
	1T-X44	182,000	26.2
	Average	183,000	25.9
	2C-X2	190,000	25.8
	2T-X2	190,000	25.8
	Average	190,000	25.8
	3D-X2	181,000	26.2
	3R-X44	187,500	26.2
	3K-X2	184,000	26.2
	Average	184,167	26.2
	Average - 7 tests	185,500	26.0
800	1D-X44	146,000	24.4
	1N-X44	149,000	24.4
	1U-X44	148,000	24.4
	Average	147,667	24.4
	2U-X44	144,000	24.7
	2G-X2	144,000	24.7
	2A-X44	146,000	23.8
	Average	144,667	24.4
	3K-X44	146,200	25.4
	3T-X44	147,000	24.4
	3D-X44	151,000	24.8
	Average	148,067	24.9
	Average - 9 tests	146,800	24.6
900	1N-X2	107,000	23.0
	1T-X3	112,000	23.1
	1T-X2	114,000	23.1
	Average	111,000	23.1
	2C-X44	110,000	23.0
	2U-X2	117,500	23.5
	2L-X2	119,000	22.6
	Average	115,500	23.0
	3D-X3	112,000	23.2
	3R-X2	115,500	23.0
	3T-X2	118,000	23.2
	Average	115,133	23.1
	Average - 9 tests	113,877	23.1

TABLE 4

TENSION-IMPACT TEST DATA FOR

SMOOTH SPECIMENS OF 17-7PH (TH 1050 CONDITION)

Test Temp (°F)	Spec. No.	Tension-Impact Strength (ft-lb)	Elongation (%)	Reduction of Area (%)
room	1C-M5	35	--	--
	1C-M6	37	--	--
	1C-M1	45	--	--
	1D-X14	70	7.5	22.4
	Average	47		
	2A-X5	41	2.0	17.4
	2E-M1	62	--	--
	2J-M1	48	--	--
	2J-M2	41	--	--
	2L-X5	62	3.0	15.0
	2U-X5	64	2.5	15.3
	Average	53		
	3F-M4	33	--	--
	3L-M2	52	--	--
	3L-M5	52	--	--
	Average	46		
	Average - 13 tests	49	~3.8	~17.0
600	4C-T2	45	3.5	17.9
	4L-T3	37	3.5	16.2
	4R-T5-1	57	2.5	20.0
	Average	46	3.2	18.0
	5E-5T-1	39	3.0	--
	5N-5T-2	37	3.8	16.4
	5U-T4-1	31	3.5	18.4
	Average	36	3.4	17.4
	6A-T2-3	31	2.5	16.4
	6J-T5-2	43	3.3	15.1
	6R-T4	41	3.5	16.7
	Average	38	3.1	16.1
	Average - 9 tests	40.1	3.2	17.2
800	4C-T2-1	30	2.5	14.8
	4L-T3-2	31	2.0	15.8
	4R-5T-3	26	2.5	17.2
	Average	29	2.3	15.9
	5E-5T-3	24	2.5	15.0
	5N-5T-1	33	3.0	15.3
	5U-4T-2	29	2.0	17.6
	Average	29	2.5	16.0
	6A-2T-2	31	2.5	--
	6J-5T-1	32	2.5	18.0
	6R-4T-2	33	2.5	24.1
	Average	32	2.5	22.0
	Average - 9 tests	29.9	2.4	17.3
900	4C-2T-3	37	2.2	18.7
	4L-3T-1	44	1.5	2.0
	4R-5T-2	49	3.5	6.8
	Average	43	2.4	9.2
	5E-5T-2	42	1.0	5.6
	5N-5T-3	34	3.5	16.5
	5U-4T-3	39	3.0	16.0
	Average	38	2.5	12.7
	6A-2T-1	45	1.5	8.2
	6J-5T-3	54	3.0	14.9
	6R-4T-3	50	3.0	15.8
	Average	50	2.5	12.9
	Average - 9 tests	43.8	2.5	11.6

TABLE 5

TENSION-IMPACT TEST DATA FOR

NOTCHED SPECIMENS OF 17-7PH (TH 1050 CONDITION)

Test Temp (°F)	Spec. No.	Tension-Impact Strength (ft-lb)	Elongation (%)	Reduction of Area (%)
room	1G-M5	32	--	--
	1G-M2	8	--	--
	1U-M2	16	--	--
	1U-M4	12	--	--
	Average	17		
	2E-M4	28	0.5	2.8
	2E-M6	36	--	--
	2N-M4	45	--	--
	2N-M5	9	--	--
	2N-M6	29	0.5	1.8
	Average	29		
	3F-M5	36	--	--
	3F-M6	49	--	--
	3L-M1	46	--	--
	3L-M6	28	0.5	2.8
	Average	40		
	Average - 13 tests	28	~0.5	~2.5
600	1U-M5	29	0.5	0.9
	2E-M5	29	0.5	0.6
	Average	29	0.5	0.8
800	1G-M1	28	nil	nil
	1U-M6	30	0.5	2.8
	Average	29	0.2	1.4
900	2N-M2	34	nil	0.1
	2J-M4	28	1.0	1.7
	Average	31	0.5	0.9

TABLE 6

EFFECT OF UNSTRESSED EXPOSURE ON ROOM TEMPERATURE TENSILE PROPERTIES

OF 17-7PH (TH 1050 CONDITION)

Spec. No.	Exposure Conditions Temp (°F)	Stress (psi)	Time (hrs)	Total Def. (%)	Room Temperature Tensile Properties After Exposure: Ult. Tensile Strength (psi)	0.2% Offset Yield Strength (psi)	Elongation (%/2 inches)	Reduction of Area (%)	E (10^6 psi/in./in.)	Hardness (R"C")
Average Properties - 3 sheets - As treated					203,000	193,910	6.7	20.5	28.7	43.8
2E-T4	600	None	10	None	192,000	183,000	8.5	20.0	30.2	40.9
3P-T3	600	None	10	None	209,000	203,000	6.5	19.7	30.4	43.4
			Average		200,500	193,000	7.5	19.8	30.3	42.2
1P-T21	600	None	50	None	193,000	186,000	10.5	18.3	30.4	42.0
3L-T5	600	None	50	None	187,000	180,000	9.0	22.6	31.2	41.6
			Average		190,000	183,000	9.8	20.5	30.8	41.8
2N-T4	600	None	100	None	192,500	184,200	8.0	18.4	29.4	42.5
3A-T1	600	None	100	None	212,000	206,000	7.5	19.4	29.8	45.8
			Average		202,250	195,100	7.8	18.9	29.1	45.3
3H-T1	800	None	10	None	201,000	195,000	7.5	18.7	30.8	43.8
2R-T3	800	None	10	None	192,000	187,000	5.0	16.9	29.8	41.9
			Average		196,500	191,000	6.2	17.8	30.3	42.8
2S-T2	800	None	50	None	218,000	213,000	4.9	15.1	31.2	43.6
1Q-T23	800	None	50	None	220,000	215,000	6.0	17.9	30.4	45.5
			Average		219,000	214,000	5.4	16.5	30.8	44.6
3G-T6	800	None	100.0	None	222,000	216,000	4.0	17.9	29.8	47.4
2N-T2	800	None	100.0	None	222,500	216,000	5.0	17.3	30.2	48.2
			Average		222,250	216,000	4.5	17.6	30.0	47.8
1P-T23	900	None	10	None	205,500	200,000	6.5	17.2	30.2	43.1
3A-T5	900	None	10	None	206,500	201,000	5.0	18.2	30.8	44.2
			Average		206,000	200,500	5.8	17.7	30.5	43.6
2S-T1	900	None	50	None	230,000	224,000	3.5	14.1	30.9	46.2
3H-T6	900	None	50	None	234,000	228,500	5.0	13.7	30.6	47.0
			Average		232,000	226,500	4.2	13.9	30.8	46.6
3P-T6	900	None	100.0	None	222,000	215,000	4.5	8.4	30.4	46.2
2N-T5	900	None	100.0	None	220,000	213,000	6.0	17.1	28.8	47.0
			Average		221,000	214,000	5.2	12.8	29.6	46.6

TABLE 7

EFFECT OF UNSTRESSED EXPOSURE ON ELEVATED TEMPERATURE TENSILE PROPERTIES

OF 17-7PH (TH 1050 CONDITION)

Exposure Conditions		Tensile Properties After Exposure							
Exposure Temp (°F)	Exposure Time (hrs)	Test Temp (°F)	Spec. No.	Ult. Tensile Strength (psi)	0.2% Offset Yield Strength (psi)	Elongation (%/2 inches)	Reduction of Area (%)	Modulus, E 10^6 (psi)	Hardness (R"C"*)
Not exposed		600	Average	171,989	163,233	4.8	15.1	28.2	43.8
600	10	600	1D-T3	159,000	151,000	5.5	15.2	25.4	42.0
	10	600	3U-T1	180,000	177,000	4.8	13.9	26.0	43.7
			Average	169,500	164,000	5.2	14.0	25.7	42.8
	50	600	2U-T3	148,000	139,500	6.5	19.6	26.0	39.4
	50	600	3E-T2	187,000	177,000	4.5	16.5	25.4	46.5
	50	600	5P-T1	160,000	152,000	5.0	15.1	25.5	40.1
			Average	165,000	156,167	5.3	17.1	25.6	42.0
	100	600	1J-T3	159,000	148,000	1.8	19.7	26.4	40.9
	100	600	2U-T6	161,000	153,000	5.0	18.3	25.8	42.1
			Average	160,000	150,500	3.4	19.0	26.1	41.5
Not exposed		800	Average	147,700	137,857	11.8	26.8	24.4	43.8
800	10	800	1A-T5	147,000	136,000	10.5	27.1	24.4	44.9
	10	800	2C-T4	153,000	75,700 (a)	15.0	28.7	25.0	47.6
			Average	150,000	136,000	12.8	27.9	24.7	46.2
	50	800	1N-T5	151,000	144,000	11.0	24.5	23.4	45.9
	50	800	3N-T2	158,000	149,000	7.5	18.7	24.0	45.7
			Average	154,500	146,500	9.2	21.6	23.7	45.8
	100	800	1T-T6	150,000	140,000	7.5	21.0	24.5	43.5
	100	800	2C-T5	154,000	141,000	8.0	21.8	25.2	45.5
			Average	152,000	140,500	7.8	21.4	24.8	44.5
Not exposed		900	Average	122,295	111,444	19.6	39.2	21.6	43.8
900	10	900	1F-T5	127,000	116,000	25.0	41.0	22.8	46.9
	10	900	3K-T3	126,000	117,000	17.3	35.2	22.2	45.9
			Average	126,500	116,500	21.2	38.1	22.5	46.4
	50	900	2C-T3	130,000	119,000	15.0	27.8	22.2	44.0
	50	900	3U-T5	122,000	115,000	18.5	37.3	23.1	47.9
			Average	126,000	117,000	16.8	32.6	22.6	45.9
	100	900	1T-T1	133,000	125,000	11.3	25.2	21.5	44.4
	100	900	3T-T2	132,500	122,000	10.3	27.2	22.4	44.7
			Average	132,750	123,500	10.8	26.2	22.0	44.6

(a) omitted from average
* Rockwell "C" hardness at room temperature

TABLE 8

EFFECT OF PRIOR CREEP-EXPOSURE ON ROOM TEMPERATURE

TENSILE PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Nominal Exposure Conditions			Actual Exposure Conditions							Room Temperature Tensile Properties After Exposure					
Temp (°F)	Time (hrs)	Total Def. (%)	Spec. No.	Time (hrs)	Stress (psi)	Load Def. (Total)(%)	Load. Def. (Plastic)(%)	Creep Def. (%)	Total Def. (%)	Ult. Tensile Strength (psi)	0.2% Offset Yield Strength (psi)	Elongation (%/2 inches)	Reduction of Area (%)	Modulus, E 10^6 (psi)	Hardness (R"C")
600	10	0.5	2U-T5	10.0	118,000	0.43	nil	0.02	0.45	186,500	179,000	5.5	20.5	29.6	41.1
			2K-T1	10.1	118,000	0.43	nil	0.02	0.45	198,000	190,000	6.8	19.5	27.9	42.1
	10	1.0	3D-T6	10.0	159,000	0.69	0.14	0.35	1.04	210,000	210,000	4.0	16.3	29.7	45.0
			5S-T6	10.0	159,000	0.74	0.18	0.87	1.61	208,000	208,000	2.5	15.1	29.0	42.5
	10	2.0	1D-T6	10.0	167,000	0.77	0.19	0.99	1.76	211,000	211,000	2.3	13.3	28.0	43.3
			2T-T5	--	167,000	rupture on load.			--	--	--	--	--	--	--
	10	3.0	2G-T4	10.2	173,000	0.98	0.37	1.53	2.51	227,000	227,000	2.0	11.2	28.5	44.7
			3R-T6		173,000	rupture at 6.5 hours.			--	--	--	--	--	--	--
	50	0.5	1D-T5	50.1	116,000	0.43	nil	0.06	0.49	205,000	195,000	7.0	16.7	30.0	45.1
	50	1.0	3K-T2	50.2	150,000	0.54	0.05	0.32	0.86	205,000	205,000	3.2	13.8	29.2	44.2
			6N-T1	50.6	150,000	0.61	0.08	0.51	1.12	213,000	213,000	2.0	13.5	29.4	43.8
	50	2.0	2A-T3	--	160,000	rupture on load.			--	--	--	--	--	--	--
			2B-T4	50.0	160,000	0.66	0.11	0.84	1.50	220,000	220,000	2.0	10.3	29.0	46.1
	50	3.0	3T-T5	50.0	164,000	0.63	0.06	1.18	1.81	216,000	216,000	2.2	10.5	29.9	44.0
			5L-T2	50.0	165,000	0.75	0.17	3.41	4.16	(228,000+)	228,000	1.5	9.3	43.9	--
	100	0.5	3D-T1	100.0	114,500	0.39	nil	0.05	0.44	191,500	186,000	9.8	17.2	29.6	45.0
			2B-T5	100.0	114,500	0.41	nil	0.04	0.45	210,000	202,000	6.5	15.6	30.4	45.6
	100	1.0	1D-T4	99.9	146,000	0.55	0.04	0.31	0.86	218,000	218,000	3.0	10.7	29.2	42.9
	100	2.0	2N-T1	100.5	157,000	0.60	0.05	1.28	1.88	223,000	223,000	1.5	13.7	29.4	--
			3Q-T7	104.9	157,000	0.64	0.09	3.20	3.84	209,000	--	2.0	8.6	30.3	41.1
			3H-T4	--	157,000	rupture at 17.8 hours			--	--	--	--	--	--	--
			1P-T24	99.9	157,000	0.64	0.09	4.66	5.30	217,500	188,500	2.0	5.8	28.9	42.8
	100	3.0	2C-T1	100.0	161,000	0.74	0.18	3.68	4.42	218,000	218,000	1.8	6.3	29.0	43.9
800	10	0.5	3K-T6	10.2	70,000	0.29	0.01	0.13	0.52	212,000	206,500	4.3	13.1	29.8	42.6
			2M-T2	10.0	70,000	0.28	nil	0.12	0.50	216,000	208,000	4.3	13.4	29.8	45.6
	10	1.0	2G-T5	10.2	88,000	0.36	0.01	0.68	1.04	191,500	188,000	6.5	16.6	30.2	41.1
			3J-T2	11.6	98,000	0.35	nil	0.65	1.00	229,000	226,000	3.5	13.3	28.2	46.9
	10	2.0	1J-T6	10.0	98,000	0.35	nil	1.86	2.21	208,000	207,000	3.5	16.5	28.4	45.5
			2K-T2	11.6	98,000	0.41	nil	1.58	1.99	217,000	214,000	3.5	13.3	29.6	44.4
	10	3.0	3R-T5	10.0	101,000	0.42	nil	2.08	2.55	234,000	222,000	3.0	14.2	30.2	48.7
	50	0.5	1N-T1	50.0	62,000	0.23	nil	0.15	0.48	187,000	174,000	9.5	17.0	29.4	42.3
			4G-T1	49.9	62,000	0.24	nil	0.28	0.52	218,000	212,000	5.0	16.7	28.0	45.7
	50	1.0	2A-T1	50.0	75,000	0.32	0.02	0.64	0.96	221,000	207,000	9.5	16.6	29.5	47.4
			4J-T4	50.0	75,000	0.28	nil	0.50	0.78	211,000	203,000	6.8	15.1	29.9	45.9
	50	2.0	3R-T2	50.0	86,000	0.35	0.01	1.43	1.78	172,000	171,000	3.0	16.4	29.2	45.0
			2K-T6	50.0	86,000	0.35	0.01	1.81	2.16	227,000	224,000	3.5	14.7	30.0	45.0
	50	3.0	1J-T4	50.1	91,000	0.33	nil	2.77	3.10	216,000	212,000	3.5	17.0	29.6	46.9
	100	0.5	3P-T5	100.0	59,000	0.23	nil	0.15	0.48	208,000	204,000	3.8	17.6	30.3	--
			2B-T3	100.0	59,000	0.22	nil	0.34	0.56	233,000	230,000	4.5	12.7	30.3	47.5
	100	1.0	3H-T5	100.0	70,000	0.27	nil	0.62	0.89	220,000	215,000	3.5	14.0	32.1	--
			1F-T6	99.9	70,000	0.26	nil	0.65	0.91	236,000	231,000	4.0	13.8	30.0	46.8
	100	2.0	3P-T1	102.6	81,000	0.31	nil	1.81	2.12	233,000	229,000	3.5	12.1	29.9	46.7
			2S-T6	102.1	81,000	0.32	nil	1.56	1.88	227,000	222,000	4.2	15.8	30.2	46.7
	100	3.0	3L-T2	100.0	85,000	0.32	nil	2.13	2.45	218,000	214,000	2.2	20.2	30.1	--

TABLE 8 (Continued)

EFFECT OF PRIOR CREEP-EXPOSURE ON ROOM TEMPERATURE

TENSILE PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Nominal Exposure Conditions: Temp (°F)	Time (hrs)	Total Def. (%)	Spec. No.	Actual Exposure Conditions: Time (hrs)	Stress (psi)	Load Def. (Total)(%)	Load Def. (Plastic)(%)	Creep Def. (%)	Total Def. (%)	Room Temperature Tensile Properties After Exposure: Ult. Tensile Strength (psi)	0.2% Offset Yield Strength (psi)	Elongation (%/2 inches)	Reduction of Area (%)	Modulus, E 10^6 (psi)	Hardness (R"C")
900	10	0.5	2L-T6	10.1	46,000	0.21	nil	0.36	0.57	228,000	218,000	2.2	3.6	30.3	46.3
			1M-T2	10.0	46,000	0.19	nil	0.38	0.57	204,000	198,000	8.2	19.2	30.0	45.0
	10	1.0	1J-T2	10.1	55,000	0.24	nil	0.89	1.13	215,000	207,000	4.0	15.2	29.9	44.0
	10	2.0	3K-T1	10.0	62,000	0.28	nil	2.03	2.31	221,500	219,000	3.5	12.7	29.4	47.0
			5N-T2	10.0	62,000	0.25	nil	1.56	1.81	222,000	217,000	5.0	14.9	30.1	44.7
	10	3.0	1N-T6	10.1	68,000	0.27	nil	3.09	3.36	201,000	195,000	4.8	17.6	29.2	43.1
	50	0.5	2U-T4	50.0	40,000	0.17	nil	0.45	0.62	235,000	228,000	7.0	9.8	30.0	48.4
			3J-T3	50.0	40,000	0.15	nil	0.54	0.69	240,000	237,000	5.5	11.3	29.3	48.0
	50	1.0	2A-T2	50.0	48,500	0.20	nil	0.91	1.11	200,000	191,500	9.8	18.0	29.4	44.3
	50	2.0	1D-T2	49.9	54,000	0.29	0.04	1.48	1.77	205,000	197,000	6.8	17.0	29.2	47.5
			3S-T4	50.4	52,000	0.23	nil	1.41	1.64	224,000	222,000	4.5	14.8	30.2	46.0
	50	3.0	3R-T1	50.0	56,000	0.25	nil	2.15	2.40	195,000	189,000	8.0	19.6	30.0	43.0
	100	0.5	3G-T5	100.0	37,000	0.14	nil	0.33	0.47	204,000	196,000	4.5	17.6	29.2	--
	100	1.0	2M-T1	100.0	46,000	0.19	nil	1.51	1.70	227,000	222,000	3.5	17.2	30.0	45.6
			3A-T4	100.0	46,000	0.25	0.03	0.74	0.99	228,000	220,000	4.5	14.4	30.1	46.0
			2K-T5	100.0	46,000	0.19	nil	1.63	1.82	238,000	218,000	3.3	10.2	30.4	47.8
			2R-T1	100.0	49,000	0.19	nil	1.36	1.55	214,000	209,000	6.5	16.7	29.9	45.3
		2.0	3G-T2	100.1	50,000	0.22	nil	1.82	2.04	224,000	219,000	4.0	15.2	29.7	46.8
			1Q-T22	100.0	50,000	0.20	nil	2.13	2.33	235,000	230,000	4.0	13.1	30.0	48.1
	100	3.0	1H-T1	100.1	52,000	0.26	0.02	3.30	3.56	223,000	222,000	3.5	14.5	29.0	46.2
			3Q-T4	100.0	52,000	0.23	nil	2.07	2.30	221,000	219,000	5.0	14.9	31.0	--

SPECIMENS EXPOSED AT TEMPERATURES EITHER BELOW OR

INTERMEDIATE TO THE PRINCIPAL TEST CONDITIONS

Nominal Exposure Conditions: Temp (°F)	Time (hrs)	Total Def. (%)	Spec. No.	Actual Exposure Conditions: Time (hrs)	Stress (psi)	Load Def. (Total)(%)	Load Def. (Plastic)(%)	Creep Def. (%)	Total Def. (%)	Room Temperature Tensile Properties After Exposure: Ult. Tensile Strength (psi)	0.2% Offset Yield Strength (psi)	Elongation (% /2 inches)	Reduction of Area (%)	Modulus, E 10^6 (psi)	Hardness (R"C")
400	100	1.0-2.0	6A-T4	100.0	180,000	0.73	0.16	0.08	0.81	207,000	207,000	6.3	17.2	29.2	45.4
			4T-T5	100.0	183,000	1.42	0.48	0.22	1.64	206,000	206,000	4.0	16.7	29.0	44.9
500	100	1.0-2.0	5P-T4	100.0	170,000	0.78	0.17	0.24	1.02	204,000	204,000	4.0	18.5	30.2	45.7
			6G-T5	100.0	175,000	0.97	0.46	0.88	1.85	216,000	216,000	2.5	12.1	28.0	46.0
650	100	2.0	2S-T3	105.0	137,000	0.52	0.05	1.36	1.88	215,000	215,000	2.5	12.5	30.4	43.5
			3B-T4	100.1	137,000	0.59	0.05	2.09	2.68	206,000	206,000	2.5	14.0	31.8	41.7
700	100	2.0	2R-T6	100.2	118,000	0.47	0.02	1.34	1.81	211,000	210,000	4.0	17.7	29.6	--
			3G-T3	100.7	118,000	0.41	0.05	1.19	1.60	218,500	218,000	3.0	16.0	30.8	44.9
			3Q-T5	188.9	118,000	0.48	0.06	2.43	2.91	208,000	206,000	2.7	15.4	30.4	43.9
			2R-T2	100.1	120,000	0.52	nil	2.14	2.66	219,000	218,000	2.2	13.7	30.6	--
			3Q-T6	100.0	120,000	0.46	0.02	1.50	1.96	220,000	219,000	3.5	13.8	29.6	--
750	100	2.0	2J-T5	100.0	101,000	0.41	0.02	1.49	1.92	222,000	220,000	3.0	17.0	29.7	44.2
			3B-T3	100.0	101,000	0.34	0.02	1.37	1.71	218,000	217,000	4.5	16.7	30.0	46.1
850	100	2.0	2R-T5	100.0	66,000	0.26	nil	1.48	1.74	235,000	230,000	5.0	13.4	30.8	46.1
			3H-T3	100.1	66,000	0.29	nil	1.80	2.09	231,000	228,000	4.2	14.3	30.0	47.6

TABLE 9

EFFECT OF PRIOR CREEP-EXPOSURE ON ELEVATED TEMPERATURE

TENSILE PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Nominal Exposure Conditions			Actual Exposure Conditions							Tensile Properties After Exposure						
Temp (°F)	Time (hrs)	Total Def. (%)	Spec. No.	Time (hrs)	Stress (psi)	Load Def. (Total)(%)	Load Def. (Plastic)(%)	Creep Def. (%)	Total Def. (%)	Test Temp (°F)	Ult. Tensile Strength (psi)	0.2% Offset Yield Strength (psi)	Elongation (%/2 inches)	Reduction of Area (%)	Modulus, E 10^6 (psi)	Hardness (R"C"*)
600	10	0.5	1T-T3	10.0	118,000	0.44	nil	0.03	0.47	600	172,000	159,000	4.3	14.9	26.1	42.2
		1.0	2L-T3	9.9	159,000	0.78	0.23	1.09	1.87	600	169,000	138,000	2.5	17.5	25.2	42.3
			6G-T6	10.0	159,000	0.68	0.13	0.41	1.09	600	178,000	177,000	2.5	11.8	24.0	44.3
		2.0	2M-T3	10.5	167,000	0.72	0.13	0.75	1.47	600	179,000	178,000	3.0	14.3	27.7	16.0
		3.0	1A-T6	10.3	173,000	0.82	0.21	2.23	3.05	600	185,000	182,000	2.7	11.8	26.0	47.1
	50	0.5	2L-T4	51.0	116,000	0.43	nil	0.03	0.46	600	177,000	171,000	3.5	14.8	25.2	43.0
			6R-T2	50.0	116,000	0.39	nil	0.03	0.42	600	184,000	173,000	5.0	10.4	27.3	46.2
		1.0	2H-T3	50.0	150,000	0.64	0.11	0.75	1.39	600	168,000	168,000	3.0	16.6	25.9	40.9
			1T-T4	50.0	150,000	0.54	0.02	0.28	0.82	600	192,000	180,000	6.8	13.6	26.0	43.9
		2.0	3T-T4	50.0	160,000	0.69	0.12	1.09	1.78	600	180,000	--	2.3	10.3	26.2	43.4
		3.0	2T-T3	50.0	164,000	0.68	0.10	1.57	2.25	600	185,000	185,000	2.0	10.5	25.4	42.6
	100	0.5	2L-T1	100.2	114,500	0.42	nil	0.06	0.48	600	167,000	155,000	3.8	15.0	24.4	41.9
		1.0	3R-T4	100.0	146,000	0.65	0.14	0.78	1.43	600	169,500	169,500	2.3	13.4	28.6	41.2
		2.0	1T-T2	100.4	157,000	0.76	0.21	3.29	4.05	600	176,000	171,000	1.8	7.8	26.0	41.4
			4T-T1	100.0	157,000	0.67	0.12	1.49	2.16	600	176,000	176,000	1.0	12.4	25.6	42.4
		3.0	3D-T5	100.0	161,000	0.68	0.11	2.02	2.70	600	185,000	185,000	1.5	9.8	25.6	42.7
800	10	0.5	1T-T5	10.1	70,000	0.27	nil	0.20	0.47	800	148,000	136,000	9.3	24.0	23.4	43.7
		1.0	3T-T3	10.2	88,000	0.33	nil	0.54	0.87	800	143,000	133,000	13.0	24.8	23.0	43.2
			1S-T1	10.0	88,000	0.35	nil	0.62	0.97	800	152,000	144,000	14.0	26.0	24.5	45.6
		2.0	2A-T5	10.2	98,000	0.37	nil	1.51	1.88	800	151,000	143,000	9.5	24.4	24.4	46.0
		3.0	1N-T3	10.1	101,000	0.38	nil	2.04	2.42	800	141,000	141,000	6.5	19.9	25.0	42.0
			5L-T6	10.0	102,000	0.40	nil	2.32	2.72	800	145,000	139,000	7.5	20.0	25.6	41.7
	50	0.5	3D-T3	50.0	62,000	0.25	nil	0.28	0.53	800	144,500	135,000	11.0	24.5	24.1	43.5
		1.0	2A-T4	51.4	75,000	0.29	nil	0.71	1.00	800	155,000	145,000	8.8	20.3	23.3	47.8
			5K-T6	50.0	81,000	0.29	nil	1.10	1.39	800	152,000	144,000	10.0	23.3	27.9	44.1
		2.0	4C-T4	50.0	86,000	0.32	nil	1.27	1.59	800	151,000	144,000	15.0	29.3	23.6	16.9
			2L-T5	50.0	86,000	0.33	nil	1.57	1.90	800	152,000	143,000	15.0	25.8	23.4	43.5
		3.0	3T-T6	50.0	91,000	0.36	nil	2.44	2.80	800	159,000	137,000	12.0	23.3	23.6	47.7
	100	0.5	1N-T2	100.0	59,000	0.24	nil	0.29	0.53	800	156,000	136,000	8.3	22.2	23.8	45.9
		1.0	3E-T4	100.0	70,000	0.32	0.04	0.25	0.57	800	172,000	154,000	15.0	27.1	24.3	47.6
			2T-T6	99.9	70,000	0.26	nil	0.47	0.83	800	149,000	140,000	16.8	27.7	22.6	47.6
		2.0	3T-T1	100.0	81,000	0.32	nil	1.76	2.08	800	144,000	137,000	14.8	28.8	23.3	46.5
			6Q-T6	100.0	81,000	0.30	nil	1.54	1.84	800	165,000	147,000	12.0	22.3	25.4	47.1
		3.0	2G-T1	100.1	85,000	0.35	0.01	2.12	2.47	800	147,000	139,500	7.8	14.6	24.2	42.8
900	10	0.5	1N-T4	10.1	46,000	0.18	nil	0.30	0.48	900	118,000	104,000	21.5	39.0	22.4	42.6
		1.0	6K-T6	10.0	55,000	0.20	nil	0.45	0.65	900	128,000	120,000	21.3	36.4	25.2	46.4
			2T-T2	10.0	55,000	0.24	nil	0.75	0.99	900	121,000	111,000	20.0	34.6	21.0	41.0
			5D-T3	10.0	55,000	0.24	nil	0.70	0.94	900	130,000	129,000	19.5	38.9	23.9	45.7
		2.0	3R-T3	10.9	62,000	0.27	nil	1.43	1.70	900	122,000	115,000	16.5	25.2	22.0	42.8
		3.0	2G-T6	10.1	68,000	0.31	nil	2.41	2.80	900	125,000	117,000	14.5	31.3	21.3	43.9
	50	0.5	2L-T2	50.0	40,000	0.16	nil	0.54	0.70	900	131,000	117,000	12.5	22.4	22.8	45.3
		1.0	3K-T5	50.1	48,500	0.22	nil	1.00	1.22	900	132,000	121,000	25.1	35.6	21.9	44.9
		2.0	2C-T2	50.0	52,000	0.25	0.01	1.50	..75	900	132,000	120,000	22.6	34.4	21.9	45.9
			1R-T6	50.0	52,000	0.22	nil	1.59	1.81	900	135,000	128,000	11.8	24.4	23.2	46.0
		3.0	3D-T2	51.4	56,000	0.26	nil	2.41	2.67	900	134,000	107,000	15.0	28.0	22.0	43.6
	100	0.5	1D-T1	100.2	37,000	0.16	nil	0.43	0.59	900	132,000	119,000	17.8	28.4	23.0	45.6
		1.0	2G-T3	100.0	46,000	0.20	nil	1.13	1.33	900	129,000	118,000	14.3	20.8	22.2	45.4
		2.0	3K-T4	100.0	50,000	0.22	nil	1.72	1.94	900	126,000	113,000	17.5	33.6	21.8	44.0
			1R-T2	100.1	50,000	0.21	nil	1.88	2.09	900	132,000	119,000	15.0	30.6	24.4	44.1
		3.0	1J-T1	100.0	52,000	0.24	nil	2.73	2.97	900	129,000	115,000	15.0	29.8	22.1	43.2

* Rockwell "C" hardness at room temperature.

TABLE 10

EFFECT OF UNSTRESSED EXPOSURE ON ROOM TEMPERATURE

COMPRESSION PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Nominal Exposure Conditions		Compression Properties After Exposure			
Exposure Temp (°F)	Exposure Time (hrs)	Test Temp (°F)	Spec. No.	0.2% Offset Yield Strength (psi)	Compression Modulus, E 10^6 (psi)
Not exposed			Average	220,667	29.8
600	10	room	1D-X33	183,000	29.5
	10	room	2T-X44	231,000	30.3
	10	room	2U-X3	192,000	28.4
			Average	202,000	29.4
	50	room	2G-X44	218,000	30.0
	50	room	3K-X3	224,000	29.4
			Average	221,000	29.7
	100	room	1N-M71	177,000	28.9
	100	room	2G-X33	176,000	30.0
	100	room	1D-X13	193,000	29.7
			Average	182,000	29.5
800	10	room	2U-M74	226,000	28.8
	10	room	3R-X33	227,000	28.6
			Average	226,500	28.7
	50	room	1T-X33	202,000	30.3
	50	room	2L-X33	219,000	30.0
	50	room	2A-X11	242,000	28.0
			Average	221,000	29.4
	100	room	3A-X33	195,000	29.4
	100	room	3K-X33	228,000	30.0
	100	room	3R-X11	246,000	30.4
			Average	223,000	29.9
900	10	room	1N-M72	194,000	28.8
	10	room	2L-X3	223,000	29.3
	10	room	2A-X1	232,000	29.3
			Average	216,333	29.1
	50	room	2G-X3	212,000	30.0
	50	room	3T-X33	233,000	30.2
			Average	222,500	30.1
	100	room	1N-X3	235,000	29.6
	100	room	2T-X33	210,000	30.8
	100	room	3R-X1	238,000	29.8
			Average	227,667	30.1

TABLE 11

EFFECT OF UNSTRESSED EXPOSURE ON ELEVATED TEMPERATURE COMPRESSION PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Exposure Conditions		Compression Properties After Exposure			
Exposure Temp (°F)	Exposure Time (hrs)	Test Temp (°F)	Spec. No.	0.2% Offset Yield Strength (psi)	Compression Modulus, E 10^6 (psi)
Not exposed		600	Average	185,500	26.0
600	10	600	1N-M76	147,000	25.3
	10	600	2U-M73	183,000	27.2
	10	600	3D-X33	149,000	26.5
			Average	159,667	26.3
	50	600	1J-X3	184,000	26.5
	50	600	2U-M72	174,000	26.5
			Average	179,000	26.5
	100	600	2A-X3	173,000	26.9
	100	600	3T-X3	176,000	26.5
			Average	174,500	26.7
Not exposed		800	Average	146,800	24.6
800	10	800	1N-M75	133,000	24.4
	10	800	2U-M75	142,000	26.8
			Average	137,500	25.6
	50	800	2U-M76	152,000	24.4
	50	800	3R-X3	150,000	24.3
			Average	151,000	24.4
	100	800	1N-M7	148,000	24.2
	100	800	2C-X33	149,000	24.4
			Average	148,500	24.3
Not exposed		900	Average	113,877	23.1
	10	900	1N-X33	121,000	22.6
	10	900	2U-X33	95,500	22.7
	10	900	2L-X44	136,000	22.8
			Average	117,500	22.7
	50	900	1J-X33	130,000	22.7
	50	900	2C-X3	128,000	21.2
			Average	129,000	22.0
	100	900	1N-M74	117,000	21.2
	100	900	2U-M71	127,000	22.0
			Average	122,000	21.6

TABLE 12

EFFECT OF PRIOR CREEP-EXPOSURE ON ROOM TEMPERATURE

COMPRESSION PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Nominal Exposure Conditions			Actual Exposure Conditions								Compression Properties After Exposure		
Temp (°F)	Time (hrs)	Total Def. (%)	Spec. No.	Time (hrs)	Temp (°F)	Stress (psi)	Load Def. (Total)(%)	Load Def. (Plastic)(%)	Creep Def. (%)	Total Def. (%)	Test Temp (°F)	0.2% Offset Yield Strength (psi)	Compression Modulus, E 10^6 (psi)
600	10	0.5	1H-T6	10.0	600	118,000	0.43	nil	0.02	0.45	room	218,000	30.3
			4L-T6	10.0	600	116,000	0.35	nil	0.02	0.37	room	204,000	29.0
		1.0	3J-T5	10.0	600	159,000	0.79	0.22	0.20	0.99	room	197,000	29.9
			5B-T3	10.0	600	159,000	0.64	0.08	0.33	0.97	room	161,500	28.2
		2.0	1F-T3	10.0	600	167,000	0.64	0.06	0.72	1.36	room	165,000	29.9
	50	0.5	1H-T2	50.0	600	116,000	0.44	nil	0.04	0.48	room	210,000	29.0
		1.0	3N-T3	50.0	600	150,000	0.58	0.06	0.27	0.85	room	200,000	29.4
			5E-T3	50.1	600	150,000	0.60	0.08	0.52	1.12	room	161,000	28.9
		2.0	2F-T7	51.0	600	160,000	0.63	0.07	1.26	1.89	room	152,000	29.5
		3.0	1R-T1	50.0	600	164,000	0.78	0.20	4.22	5.30	room	138,000	28.4
	100	0.5	2T-T4	100.0	600	114,500	0.41	nil	0.04	0.45	room	224,000	29.9
		1.0	2U-T1	100.0	600	146,000	0.56	0.04	0.64	1.20	room	157,000	28.9
			6G-T2	100.0	600	146,000	0.65	0.14	0.78	1.43	room	146,000	28.6
		2.0	3H-T7	100.0	600	157,000	0.66	0.11	1.22	1.88	room	163,000	30.1
		3.0	1S-T3	100.1	600	161,000	0.68	0.12	1.80	2.48	room	176,000	28.6
			5K-T1	100.0	600	161,000	0.69	0.13	2.37	4.06	room	140,000	30.5
800	10	0.5	1F-T1	10.0	800	70,000	0.27	nil	0.18	0.45	room	238,000	29.9
			5D-T2	10.0	800	70,000	0.25	nil	0.18	0.43	room	212,000	30.0
		1.0	3N-T4	10.0	800	88,000	0.37	0.02	0.62	0.99	room	226,000	29.0
		2.0	1S-T2	10.1	800	98,000	0.37	nil	1.12	1.49	room	202,000	30.0
		3.0	2F-T3	10.0	800	101,000	0.41	nil	1.69	2.10	room	202,000	30.0
			6N-T6	10.0	800	102,000	0.42	0.01	2.06	2.48	room	199,000	30.0
	50	0.5	2B-T6	50.0	800	62,000	0.22	nil	0.30	0.52	room	237,000	30.1
			1F-T4	50.4	800	62,000	0.22	nil	0.26	0.48	room	250,000	29.4
		1.0	1A-T4	50.7	800	75,000	0.30	nil	0.65	0.95	room	226,000	30.0
		2.0	3J-T6	50.5	800	86,000	0.32	nil	1.32	1.64	room	238,000	29.9
			2H-T2	50.1	800	86,000	0.34	nil	1.35	1.69	room	195,000	29.2
		3.0	3U-T2	50.6	800	91,000	0.36	nil	2.64	3.00	room	240,000	28.6
			4J-T6	50.0	800	91,000	0.38	0.02	3.40	3.78	room	204,000	29.8
	100	0.5	2G-T2	99.9	800	59,000	0.23	nil	0.31	0.54	room	214,000	29.9
		1.0	2U-T2	100.0	800	70,000	0.27	nil	0.55	0.82	room	202,000	30.1
			5B-T1	100.0	800	70,000	0.28	nil	0.70	0.98	room	197,000	29.0
		2.0	3L-T1	100.0	800	81,000	0.37	0.04	1.45	1.82	room	218,000	30.0
			6N-T2	100.0	800	81,000	0.33	0.01	1.64	1.97	room	200,000	30.0
		3.0	1A-T2	100.0	800	85,000	0.35	0.01	2.20	2.55	room	237,000	29.6
			6A-T3	100.0	800	85,000	0.34	nil	1.95	2.29	room	224,000	29.7
900	10	0.5	1A-T1	10.1	900	46,000	0.18	nil	0.37	0.55	room	240,000	29.4
		1.0	2F-T5	10.0	900	55,000	0.23	nil	1.01	1.24	room	236,000	29.5
		2.0	3N-T6	10.0	900	62,000	0.26	nil	2.00	2.26	room	232,000	30.0
			6J-T1	10.0	900	68,000	0.29	0.02	2.18	2.47	room	203,000	29.3
		3.0	1S-T4	10.1	900	68,000	0.31	nil	4.74	5.05	room	230,000	29.0
			2H-T6	10.0	900	68,000	0.33	0.01	2.75	3.08	room	190,000	29.8
	50	0.5	1A-T3	50.0	900	40,000	0.17	nil	0.44	0.61	room	242,000	29.4
		1.0	3U-T4	50.0	900	48,500	0.22	nil	1.35	1.57	room	241,000	30.0
			2D-T1	50.0	900	48,500	0.21	nil	0.99	1.20	room	212,000	30.1
		2.0	1H-T5	50.0	900	52,000	0.22	nil	1.64	1.86	room	232,000	29.3
			6E-T1	49.9	900	52,000	0.21	nil	1.68	1.89	room	230,000	30.4
		3.0	2F-T6	50.0	900	56,000	0.22	nil	1.93	3.15	room	228,000	28.6
	100	0.5	2A-T6	100.0	900	37,000	0.16	nil	0.52	0.68	room	245,000	30.0
		1.0	3D-T4	100.0	900	46,000	0.19	nil	1.06	1.25	room	245,000	30.2
			6B-T1	100.0	900	46,000	0.21	nil	0.84	1.05	room	242,000	29.2
		2.0	1J-T5	100.1	900	50,000	0.23	nil	1.83	2.06	room	217,000	29.8
			6B-T3	100.0	900	53,000	0.23	nil	2.66	2.89	room	231,000	29.4
		3.0	2T-T1	100.0	900	52,000	0.24	nil	1.58	1.82	room	200,000	29.4
			1B-T3	100.0	900	52,000	0.24	nil	1.95	2.19	room	206,000	30.0

TABLE 13

EFFECT OF PRIOR CREEP-EXPOSURE ON ELEVATED TEMPERATURE

COMPRESSION PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Nominal Exposure Conditions			Actual Exposure Conditions								Compression Properties After Exposure		
np ')	Time (hrs)	Total Def. (%)	Spec. No.	Time (hrs)	Temp (°F)	Stress (psi)	Load Def. (Total)(%)	Load Def. (Plastic)(%)	Creep Def. (%)	Total Def. (%)	Test Temp (°F)	0.2% Offset Yield Strength (psi)	Compression Modulus, E 10^6 (psi)
	10	0.5	3M-T1	10.0	600	118,000	0.44	0.03	0.02	0.46	600	159,000	26.4
		1.0	1R-T3	10.0	600	159,000	0.68	0.13	0.55	1.23	600	127,000	25.6
		2.0	4J-T1	10.0	600	167,000	0.95	0.36	2.42	3.37	600	114,000	26.0
			5H-T2	10.0	600	167,000	0.78	0.19	1.26	2.04	600	120,000	25.0
	50	0.5	3M-T4	50.0	600	116,000	0.44	0.03	0.03	0.47	600	170,000	25.3
		1.0	6M-T6	50.0	600	150,000	0.56	0.03	0.33	0.89	600	157,000	25.9
		2.0	3S-T5	50.0	600	160,000	0.58	0.02	1.10	1.68	600	114,000	25.8
		3.0	1M-T4	18.9	600	164,000	1.05	0.43	6.00	7.05	600	107,000	24.6
	100	0.5	3E-T1	100.0	600	114,500	0.42	0.02	0.02	0.44	600	188,500	26.5
		1.0	2B-T1	99.9	600	146,000	0.58	0.07	0.61	1.19	600	135,000	25.4
		2.0	3J-T1	119.0	600	157,000	0.62	0.07	0.97	1.59	600	127,000	25.9
		3.0	1S-T6	100.0	600	161,000	0.68	0.11	2.48	3.16	600	123,000	25.8
	10	0.5	4C-T6	10.0	800	70,000	0.25	nil	0.20	0.45	800	139,000	24.0
		1.0	1R-T5	10.0	800	88,000	0.32	nil	0.50	0.82	800	130,000	24.6
			6A-T1	10.0	800	88,000	0.36	nil	0.61	0.97	800	127,000	23.2
		2.0	3S-T3	10.0	800	98,000	0.35	nil	1.16	1.51	800	132,000	24.4
		3.0	2D-T3	10.0	800	101,000	0.41	nil	1.59	2.00	800	129,000	24.8
	50	0.5	1R-T4	50.0	800	62,000	0.25	nil	0.33	0.58	800	147,000	24.4
		1.0	3S-T6	49.9	800	75,000	0.28	nil	0.56	0.84	800	142,000	24.0
		2.0	6K-T2	50.1	800	86,000	0.37	0.03	1.85	2.22	800	137,000	24.0
		3.0	1M-T5	50.2	800	91,000	0.36	nil	3.59	3.95	800	129,000	23.7
			5K-T2	50.1	800	91,000	0.36	nil	2.06	2.42	800	127,000	24.0
	100	0.5	3N-T5	105.6	800	59,000	0.22	nil	0.32	0.54	800	146,000	24.8
		1.0	1F-T2	105.2	800	70,000	0.27	nil	0.68	0.95	800	154,000	23.5
			5K-T3	100.0	800	70,000	0.24	nil	0.45	0.69	800	149,000	24.4
		2.0	2F-T1	100.0	800	81,000	0.31	nil	1.35	1.66	800	139,000	25.4
		3.0	3U-T6	100.0	800	85,000	0.34	nil	2.04	2.36	800	138,500	24.3
	10	0.5	3J-T4	10.0	900	46,000	0.22	nil	0.52	0.74	900	117,000	22.9
			1H-T4	10.1	900	46,000	0.19	nil	0.25	0.54	900	112,000	23.4
		1.0	1B-T2	10.0	900	55,000	0.25	nil	1.76	1.01	900	123,000	21.6
			2BT	10.0	900	50,000	0.24	nil	0.66	0.90	900	102,000	23.4
			3E-T6	10.0	900	52,000	0.21	nil	0.64	0.85	900	114,000	21.5
		2.0	6A-T6	10.0	900	62,000	0.27	nil	1.68	1.95	900	117,000	23.0
		3.0	5B-T6	10.0	900	68,000	0.29	nil	2.77	3.06	900	116,000	22.6
	50	0.5	4L-T1	49.9	900	40,000	0.21	nil	0.41	0.62	900	134,500	22.1
		1.0	1B-T1	50.0	900	48,500	0.20	nil	0.95	1.15	900	133,000	23.1
		2.0	3M-T3	50.1	900	52,000	0.24	nil	1.26	1.50	900	135,000	22.6
			4G-T4	50.0	900	52,000	0.24	nil	1.57	1.81	900	114,000	23.2
		3.0	6R-T6	50.4	900	56,000	0.26	nil	3.47	3.73	900	128,000	23.5
	100	0.5	3E-T3	100.0	900	37,000	0.14	nil	0.56	0.70	900	120,500	22.9
		1.0	1S-T5	100.0	900	46,000	0.26	0.05	6.09	6.35	900	108,000	22.4
		2.0	2F-T2	100.1	900	50,000	0.22	nil	2.05	2.27	900	115,000	23.4
		3.0	1H-T3	100.0	900	52,000	0.22	nil	3.57	3.79	900	114,000	21.9

TABLE 14

EFFECT OF UNSTRESSED EXPOSURE ON ROOM TEMPERATURE

SMOOTH-BAR TENSION-IMPACT PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Exposure Conditions			Tension-Impact Properties After Exposure			
Temp (°F)	Time (hrs)	Spec. No.	Test Temp (°F)	Tension-Impact Strength (ft-lb)	Elongation (%)	Reduction of Area (%)
600	10.0	1T-X5	room	53	3.5	14.8
	10.0	2T-X22	room	58	8.5	26.5
	Average			56	6.0	20.7
	50.0	2A-X22	room	64	7.5	26.2
	50.0	3T-X4	room	50	4.5	25.4
	Average			57	6.0	25.8
	100.0	1T-X22	room	66	10.0	27.9
	100.0	3K-X4	room	55	4.3	20.8
	Average			60	7.2	14.4
800	10.0	2U-X22	room	66	7.3	22.6
	10.0	3R-X5	room	58	3.8	15.5
	Average			62	5.6	19.0
	50.0	1J-X5	room	50	2.0	11.4
	50.0	2L-X22	room	68	8.0	20.8
	Average			59	5.0	16.1
	100.0	2G-X22	room	66	7.5	24.9
	100.0	3R-X4	room	60	5.0	20.1
	Average			63	6.2	22.5
900	10.0	2G-X4	room	77	8.5	24.8
	10.0	3K-X22	room	70	6.5	22.4
	Average			74	7.5	23.6
	50.0	1N-X22	room	64	5.3	25.2
	50.0	3D-X4	room	68	5.0	21.7
	Average			66	5.2	23.4
	100.0	1N-X5	room	56	2.0	14.3
	100.0	2C-X22	room	57	4.0	22.6
	Average			56	3.0	18.4

TABLE 15

EFFECT OF UNSTRESSED EXPOSURE ON ELEVATED TEMPERATURE SMOOTH-BAR TENSION-IMPACT PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Nominal Exposure Conditions						
Temp (°F)	Time (hrs)	Spec. No.	Test Temp (°F)	Tension-Impact Strength (ft-lb)	Elongation (%)	Reduction of Area (%)
600	10.0	2T-X4	600	36	3.5	17.9
	10.0	1D-X2L	600	64	4.0	20.7
		Average		50	3.8	19.3
	50.0	2L-X4	600	35	3.5	19.1
	50.0	3D-X22	600	35	4.0	29.1
		Average		35	3.8	24.1
	100.0	1D-X5	600	42	3.0	16.9
	100.0	3D-X5	600	39	3.5	21.5
		Average		40	3.2	19.2
800	10.0	1N-X4	800	35	3.5	17.3
	10.0	3K-X5	800	29	2.5	15.1
		Average		32	3.0	16.2
	50.0	1J-X4	800	26	3.0	20.8
	50.0	2G-X5	800	32	3.0	15.0
		Average		29	3.0	17.9
	100.0	2T-X5	800	33	2.5	18.1
	100.0	3T-X22	800	32	4.0	18.2
		Average		32	3.2	18.2
900	10.0	1J-X22	900	56	4.0	11.1
	10.0	3K-X22	900	70	4.0	9.0
		Average		63	4.0	10.0
	50.0	2C-X4	900	35	1.5	10.5
	50.0	3T-X5	900	35	2.5	15.0
		Average		35	2.0	12.2
	100.0	1T-X4	900	48	4.0	20.2
	100.0	2U-X4	900	29	2.0	11.4
		Average		38	3.0	15.8

TABLE 16

EFFECT OF PRIOR CREEP-EXPOSURE ON ROOM TEMPERATURE

SMOOTH-BAR TENSION-IMPACT PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Nominal Exposure Conditions			Actual Exposure Conditions								Tension-Impact Properties After Exposure			
Temp (°F)	Time (hrs)	Total Def. (%)	Spec. No.	Time (hrs)	Temp (°F)	Stress (psi)	Load Def. (Total)(%)	Load Def. (Plastic)(%)	Creep Def. (%)	Total Def. (%)	Test Temp (°F)	Tension-Impact Strength (ft-lb)	Elongation (%/2 inches)	Reduction of Area (%)
600	10	0.5	4Q-T6	10.0	600	118,000	0.40	nil	0.02	0.42	room	49	2.8	17.3
		1.0	5E-T2	10.0	600	159,000	0.64	0.08	0.40	1.04	room	32	1.5	14.3
		2.0	6M-T3	10.0	600	167,000	0.72	0.13	1.09	1.81	room	32	1.8	17.3
			4F-T7	10.1	600	164,000	0.72	0.14	0.94	1.66	room	50	2.5	13.5
		3.0	4A-T2	10.0	600	173,000	0.76	0.15	1.51	2.27	room	56	2.0	13.6
	100	0.5	2H-T4	100.3	600	114,500	0.39	nil	0.06	0.45	room	45	2.5	17.9
		1.0	6M-T2	100.1	600	146,000	0.60	0.08	0.89	1.49	room	42	1.3	16.5
		2.0	5U-T6	100.0	600	157,000	0.74	0.19	3.80	4.54	room	50	1.5	13.7
			4F-T3	100.0	600	157,000	0.60	0.05	0.97	1.57	room	35	1.5	12.9
		3.0	3S-T2	100.3	600	161,000	0.72	0.15	1.82	2.54	room	51	1.0	14.3
800	10	0.5	5E-T1	10.0	800	70,000	0.27	nil	0.22	0.49	room	50	3.5	17.3
			4M-T3	10.0	800	70,000	0.24	nil	0.22	0.46	room	66	4.5	18.2
		1.0	5L-T3	10.0	800	88,000	0.32	nil	0.46	0.78	room	38	2.5	16.5
		2.0	4M-T4	10.0	800	98,000	0.41	0.02	1.09	1.52	room	52	3.5	17.4
			5U-T7	10.0	800	97,925	0.38	nil	2.06	2.44	room	47	2.0	15.0
		3.0	6J-T3	10.0	800	101,000	0.39	nil	2.01	2.40	room	43	2.5	14.4
			4F-T2	10.0	800	101,000	0.41	nil	1.69	2.10	room	52	2.3	13.1
	100	0.5	2D-T2	100.0	800	59,000	0.22	nil	0.29	0.51	room	34	3.0	7.5
			5K-T4	100.0	800	59,000	0.22	nil	0.30	0.52	room	53	2.5	14.9
		1.0	5H-T6	100.0	800	70,000	0.29	nil	0.65	0.94	room	62	3.5	15.5
			4Q-T1	101.9	800	70,000	0.20	nil	0.60	0.80	room	62	3.0	15.7
		2.0	3M-T6	100.1	800	81,000	0.32	nil	1.28	1.60	room	45	2.5	15.0
		3.0	5H-T3	100.0	800	85,000	0.35	nil	2.07	2.42	room	37	1.8	15.0
			1M-T1	100.0	800	85,000	0.34	nil	1.93	2.27	room	52	3.0	14.3
			4A-T3	100.0	800	86,000	0.25	nil	2.30	2.55	room	52	2.3	12.9
900	10	0.5	5E-T6	10.0	900	46,000	0.18	nil	0.22	0.40	room	51	3.0	15.0
		1.0	4R-T4	10.0	900	55,000	0.22	nil	0.66	0.88	room	62	3.5	17.3
			5L-T4	10.0	900	55,000	0.22	nil	0.87	1.09	room	41	1.5	14.4
		2.0	6K-T1	10.0	900	62,000	0.24	nil	1.40	1.64	room	51	3.0	16.5
		3.0	5N-T3	10.0	900	68,000	0.31	nil	2.93	3.24	room	43	3.0	15.0
			6K-T4	10.0	900	68,000	0.32	nil	4.78	5.10	room	51	1.5	9.9
	100	0.5	6E-T2	100.0	900	37,000	0.16	nil	0.44	0.60	room	33	2.3	11.3
		1.0	3M-T5	100.0	900	46,000	0.19	nil	0.90	1.09	room	36	1.5	13.4
		2.0	1M-T3	100.1	900	50,000	0.24	nil	1.51	1.75	room	54	4.0	17.3
			4Q-T2	100.0	900	50,000	0.22	nil	2.45	2.67	room	64	3.0	16.3
		3.0	2H-T1	100.1	900	52,000	0.37	0.12	1.91	2.28	room	33	2.3	10.5

TABLE 17

EFFECT OF PRIOR CREEP-EXPOSURE ON ELEVATED TEMPERATURE

SMOOTH-BAR TENSION-IMPACT PROPERTIES OF 17-7PH (TH 1050 CONDITION)

Nominal Exposure Conditions				Actual Exposure Conditions							Tension-Impact Properties After Exposure			
Temp (°F)	Time (hrs)	Total Def. (°F)	Spec. No.	Time (hrs)	Temp (°F)	Stress (psi)	Load Def. (Total)(%)	Load Def. (Plastic)(%)	Creep Def. (%)	Total Def. (%)	Test Temp (°F)	Tension-Impact Strength (ft-lb)	Elongation (%/ 2 inches)	Reduction of Area (%)
600	10	0.5	6N-T3	10.0	600	118,000	0.40	nil	0.01	0.41	600	34	3.0	17.3
		1.0	5D-T4	10.0	600	159,000	0.61	0.05	0.43	1.03	600	40	4.0	15.7
		2.0	4F-T6	10.0	600	167,720	0.93	0.33	3.97	4.90	600	31	1.8	16.0
	100	0.5	4M-T6	100.0	600	114,500	0.43	0.03	0.05	0.48	600	41	3.5	17.9
		1.0	5P-T6	100.0	600	146,000	0.57	0.06	0.61	1.18	600	28	2.3	15.8
		2.0	6R-T1	100.0	600	157,000	0.70	0.15	4.40	5.10	600	54	1.0	19.2
		3.0	4F-T4	100.0	600	161,000	0.74	0.17	3.70	4.44	600	28	1.5	19.8
800	10	0.5	4R-T6	10.0	800	70,000	0.22	nil	0.22	0.44	800	32	3.5	17.3
		1.0	5P-T2	10.0	800	88,000	0.33	nil	0.61	0.94	800	28	3.0	13.5
		2.0	5S-T3	10.0	800	98,000	0.38	nil	1.94	2.32	800	32	3.0	23.5
	100	0.5	5N-T1	100.0	800	59,000	0.21	nil	0.28	0.49	800	33	2.0	18.4
		1.0	6M-T1	100.0	800	70,000	0.28	nil	0.52	0.80	800	28	3.0	12.8
		2.0	6Q-T3	100.0	800	81,000	0.32	nil	1.28	1.60	800	45	2.5	14.4
		3.0	4A-T6	100.0	800	85,000	0.32	nil	1.81	2.13	800	30	2.5	15.4
900	10	0.5	4A-T4	10.0	900	46,000	0.20	nil	0.35	0.55	900	31	2.5	17.3
		1.0	5U-T3	10.0	900	55,000	0.21	nil	0.69	0.90	900	45	3.0	15.0
		2.0	6Q-T1	10.0	900	62,000	0.28	nil	1.28	1.56	900	38	3.0	12.0
		3.0	5B-T2	10.0	900	68,000	0.30	nil	2.80	3.10	900	32	3.3	14.3
	100	0.5	4C-T1	100.0	900	37,000	0.15	nil	0.49	0.64	900	30	1.0	4.3
		1.0	5N-T6	100.0	900	46,000	0.17	nil	0.82	0.99	900	28	2.3	15.8
		2.0	6K-T3	100.0	900	50,000	0.27	0.05	2.07	2.34	900	33	2.5	12.1
		3.0	5L-T1	100.0	900	52,000	0.20	nil	1.73	1.93	900	32	2.0	12.8

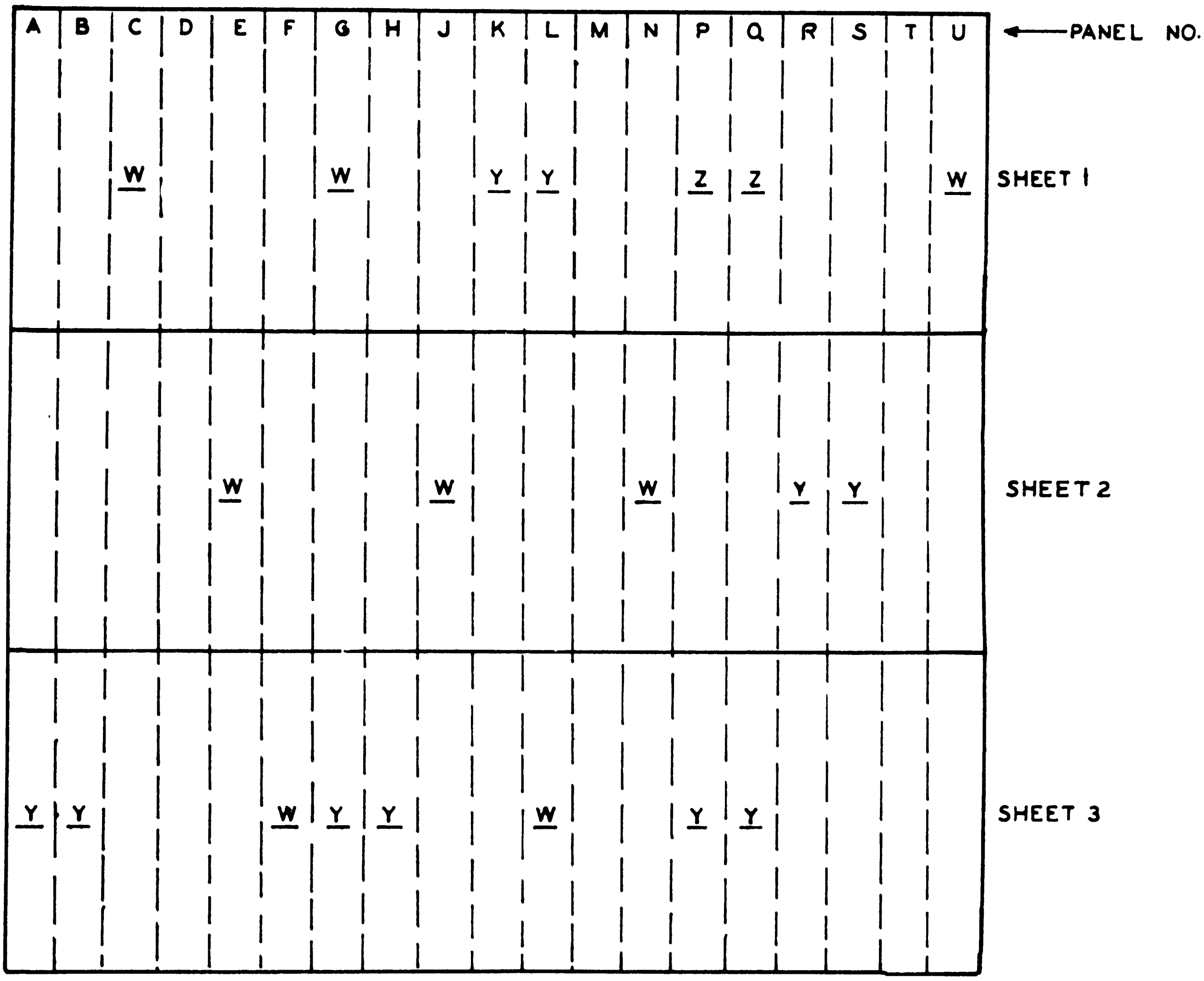
TABLE 18

EFFECT OF FIFTY HOURS PRIOR CREEP EXPOSURE ON NOTCHED SPECIMENS

TENSION-IMPACT PROPERTIES OF 17-7PH (TH 1050 CONDITION)

AT ROOM TEMPERATURE ON ELEVATED TEMPERATURE

			Actual Exposure Conditions								Notched Specimen Tension-Impact Properties After Exposure			
Temp (°F)	Time (hrs)	Total Def. (%)	Spec. No.	Time (hrs)	Temp (°F)	Stress (psi)	Load Def. (Total)(%)	Load Def. (Plastic)(%)	Creep Def. (%)	Total Def. (%)	Test Temp (°F)	Tension-Impact Strength (ft-lb)	Elongation (%)	Reduction of Area (%)
600	50	0.5	2D-T4	50.1	600	116,000	0.43	0.02	0.02	0.45	room	21	1.0	1.0
		1.0	6B-T6	50.1	600	150,000	0.62	0.09	0.33	0.95	room	33	nil	1.9
		2.0	6G-T3	50.1	600	160,000	0.70	0.14	2.66	3.36	room	29	1.8	1.3
		3.0	5B-T5	50.0	600	164,000	0.66	0.09	1.63	2.29	room	29	nil	nil
		0.5	4Q-T4	50.1	600	116,000	0.45	0.04	0.03	0.48	600	33	0.5	0.9
		1.0	5S-T1	49.9	600	150,000	0.63	0.10	0.73	1.36	600	30	1.0	1.8
		2.0	4R-T4	50.0	600	160,719	0.71	0.14	2.57	3.28	600	29	0.5	1.9
800	50	0.5	3S-T1	50.0	800	62,000	0.23	nil	0.25	0.48	room	15	nil	nil
		1.0	1M-T6	50.1	800	75,000	0.30	nil	0.68	0.98	room	18	0.5	1.8
		2.0	6E-T6	50.0	800	86,000	0.35	0.01	1.50	1.85	room	18	nil	1.9
		3.0	2H-T5	50.0	800	91,000	0.37	0.01	3.20	3.57	room	17	1.0	1.9
		0.5	4T-T6	51.3	800	62,000	0.21	nil	0.23	0.44	800	31	0.5	0.9
		1.0	6N-T7	51.3	800	75,000	0.30	nil	0.57	0.87	800	10	nil	nil
		2.0	6E-T3	51.3	800	86,000	0.31	nil	1.28	1.59	800	40	0.5	1.9
		3.0	5U-T2	50.0	800	91,000	0.33	nil	2.49	2.82	800	33	0.5	2.8
900	50	0.5	2D-T6	50.2	900	40,000	0.17	nil	0.43	0.60	room	20	1.0	2.8
		1.0	5H-T1	50.2	900	48,500	0.20	nil	0.81	1.01	room	33	0.5	1.9
		2.0	6Q-T2	50.3	900	52,000	0.21	nil	1.34	1.55	room	19	0.8	1.9
		3.0	3M-T2	50.0	900	56,000	0.23	nil	2.13	2.36	room	14	1.0	1.6
		0.5	6G-T1	50.0	900	40,000	0.36	0.18	0.46	0.82	900	33	0.5	0.9
		1.0	4G-T6	50.0	900	48,500	0.20	nil	0.95	1.15	900	39	0.5	1.9
		2.0	6R-T3	50.0	900	52,000	0.24	nil	1.80	2.04	900	35	0.5	0.9
		3.0	5P-T3	50.0	900	56,000	0.26	nil	3.02	3.28	900	32	nil	1.0



Sheet Dimensions: 36 x 120 x 0.064 inches
Panel Width: 6-1/4 to 6-1/2 inches
Sheet Designation: 1, 2, 3, etc.
Panel Designation: A, B, C, etc.
Panel Location Code: 1A, 3L, etc. (Sheet No. - Panel No.)
Specimen Blank Sampling Scheme: W, Y, or Z (see Figure 2)

Figure 1. - Panel Sampling Scheme for Sheets of 17-7PH Stainless Steel.

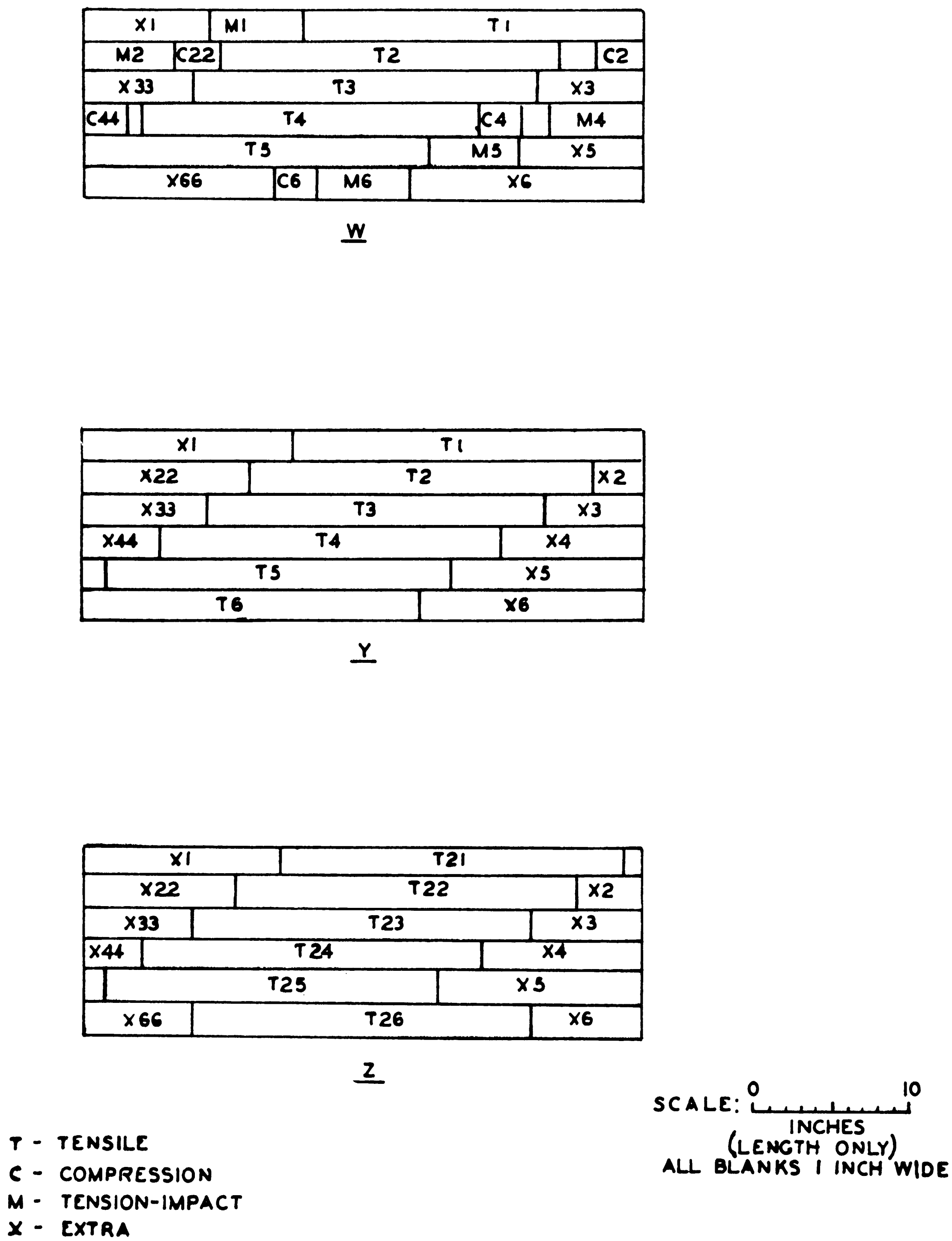


Figure 2. - Specimen Blank Sampling Schemes for Panels of 17-7PH Stainless Steel Sheet.

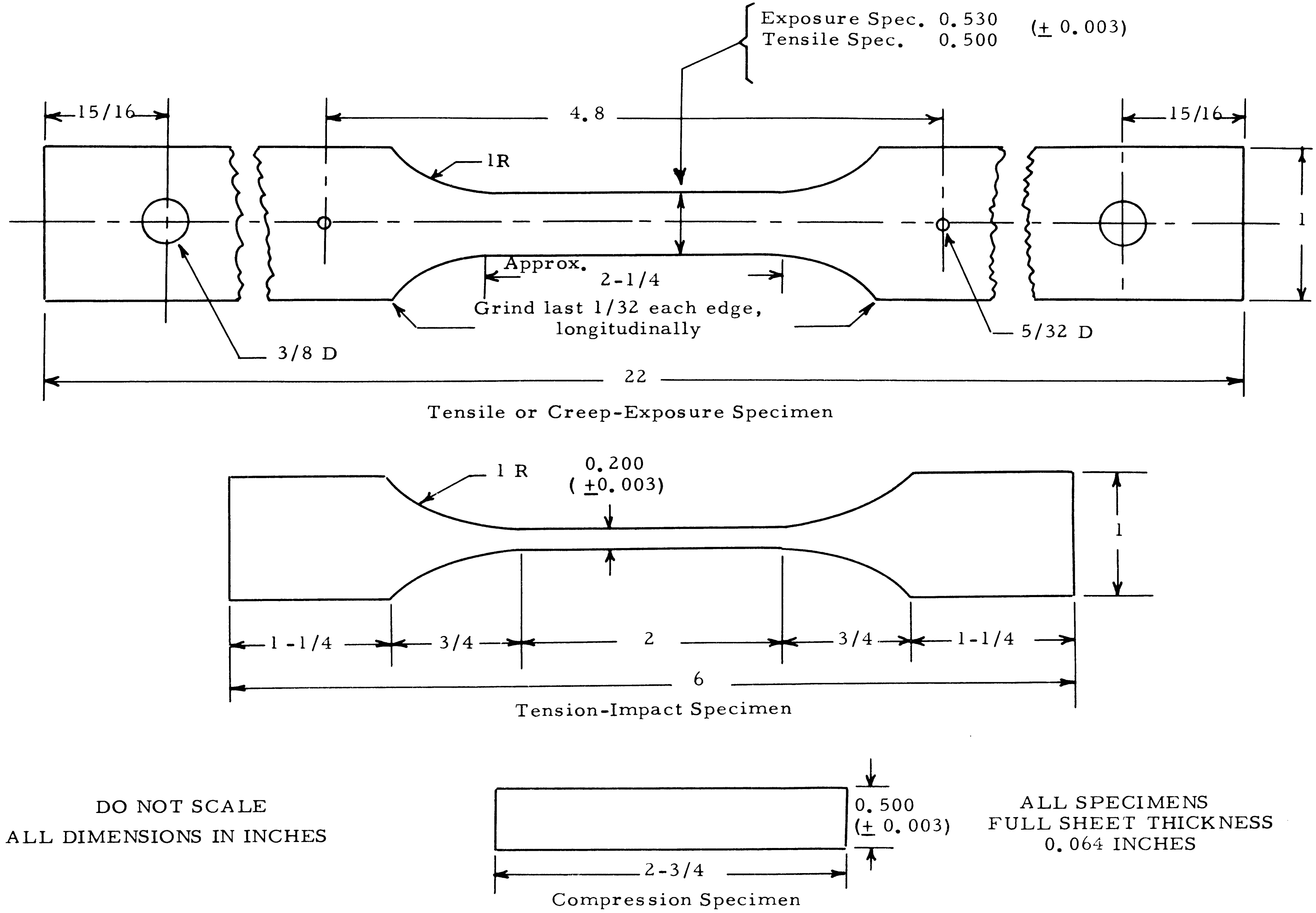


Figure 3. - Details of Test Specimens (Tension-Impact and Compression Specimens Designed to be Cut from Creep Specimens after Exposure).

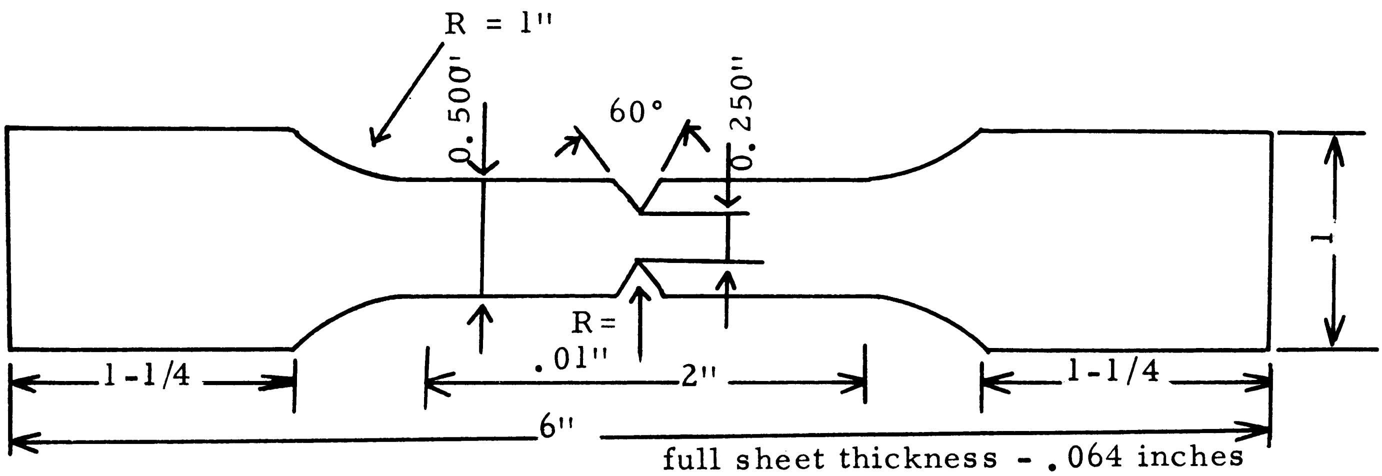


Figure 4. - Design of Notched Tension-Impact Specimen.

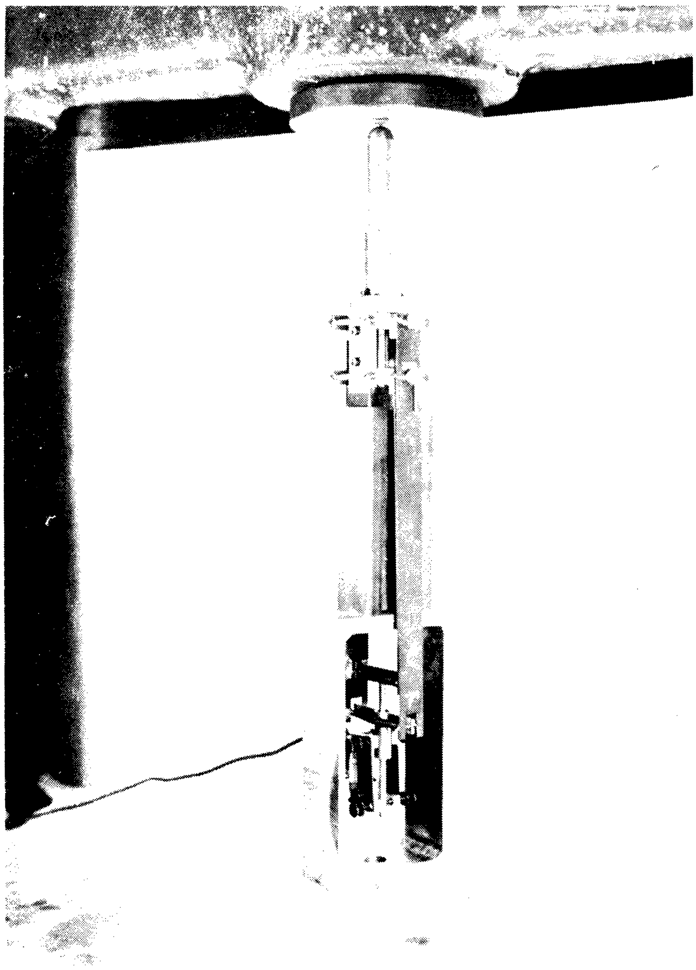


Figure 5. - Compression Fixture Assembled for Testing with Averaging Extensometer in Place.

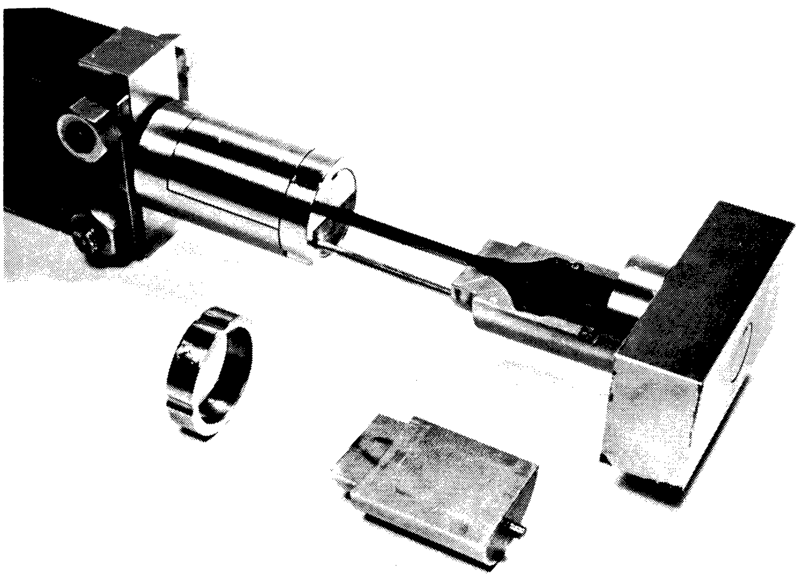


Figure 6. - Tension-Impact Specimen and Gripping Assembly for Smooth Specimens.

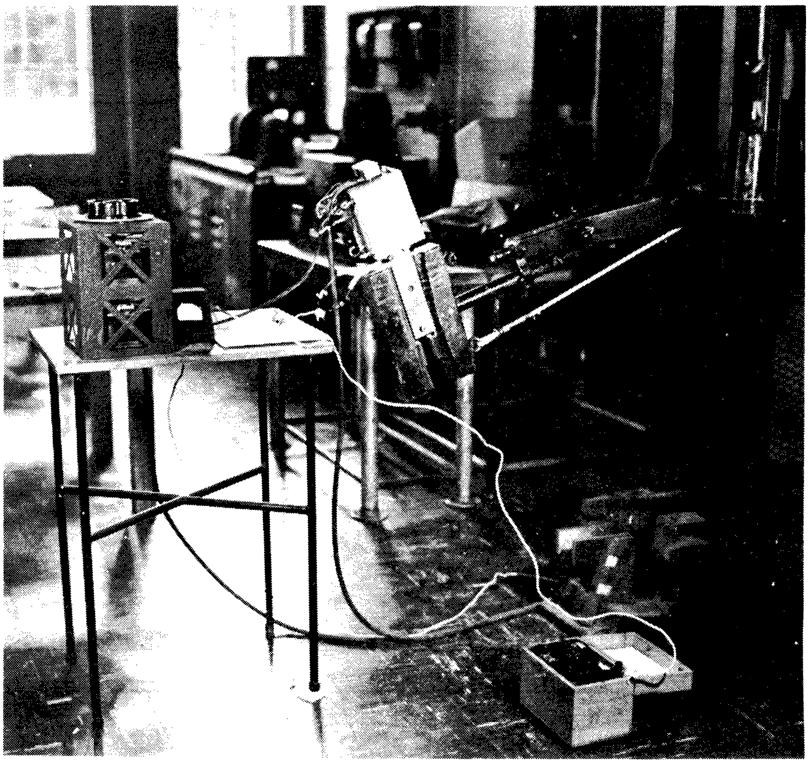


Figure 7. - Tension-Impact Test Equipment Showing Removable Furnace In Place.

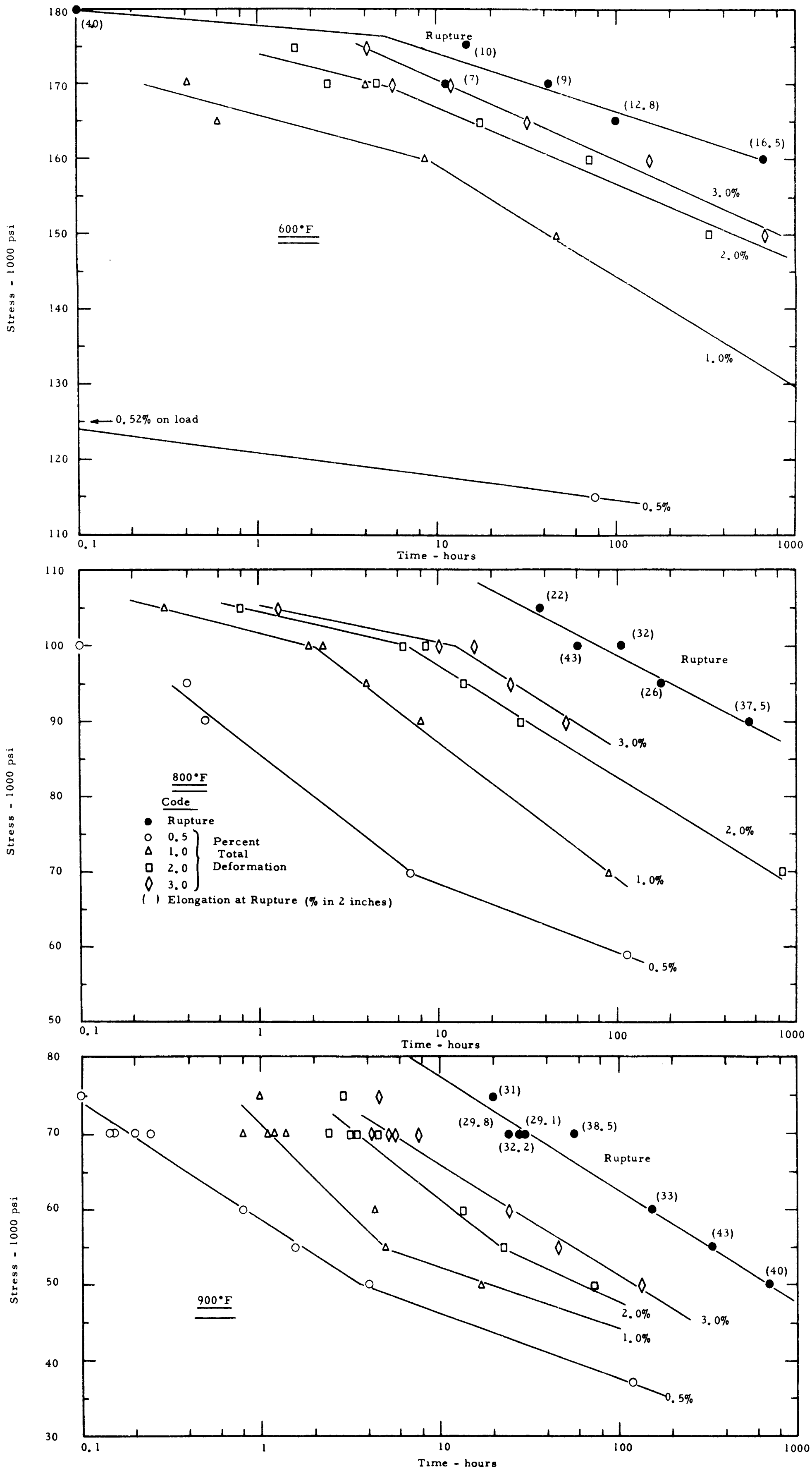


Figure 8. - Stress-Rupture Time and Stress-Time for Total Deformation Curves for 17-7PH (TH 1050 Condition) at 600°, 800°, and 900°F.

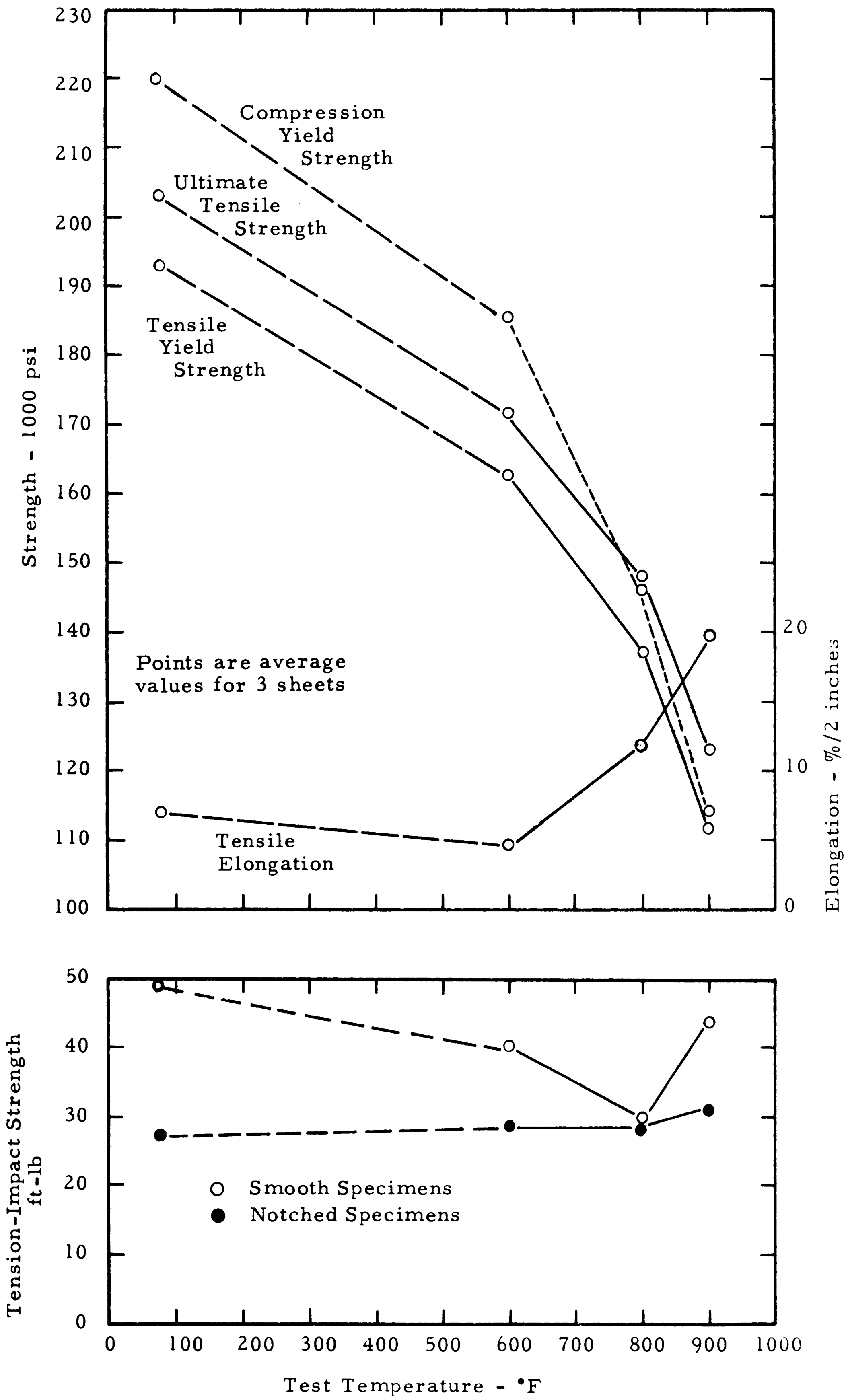


Figure 9. - Effect of Test Temperature on Short-Time Mechanical Properties of 17-7PH (TH 1050 Condition).

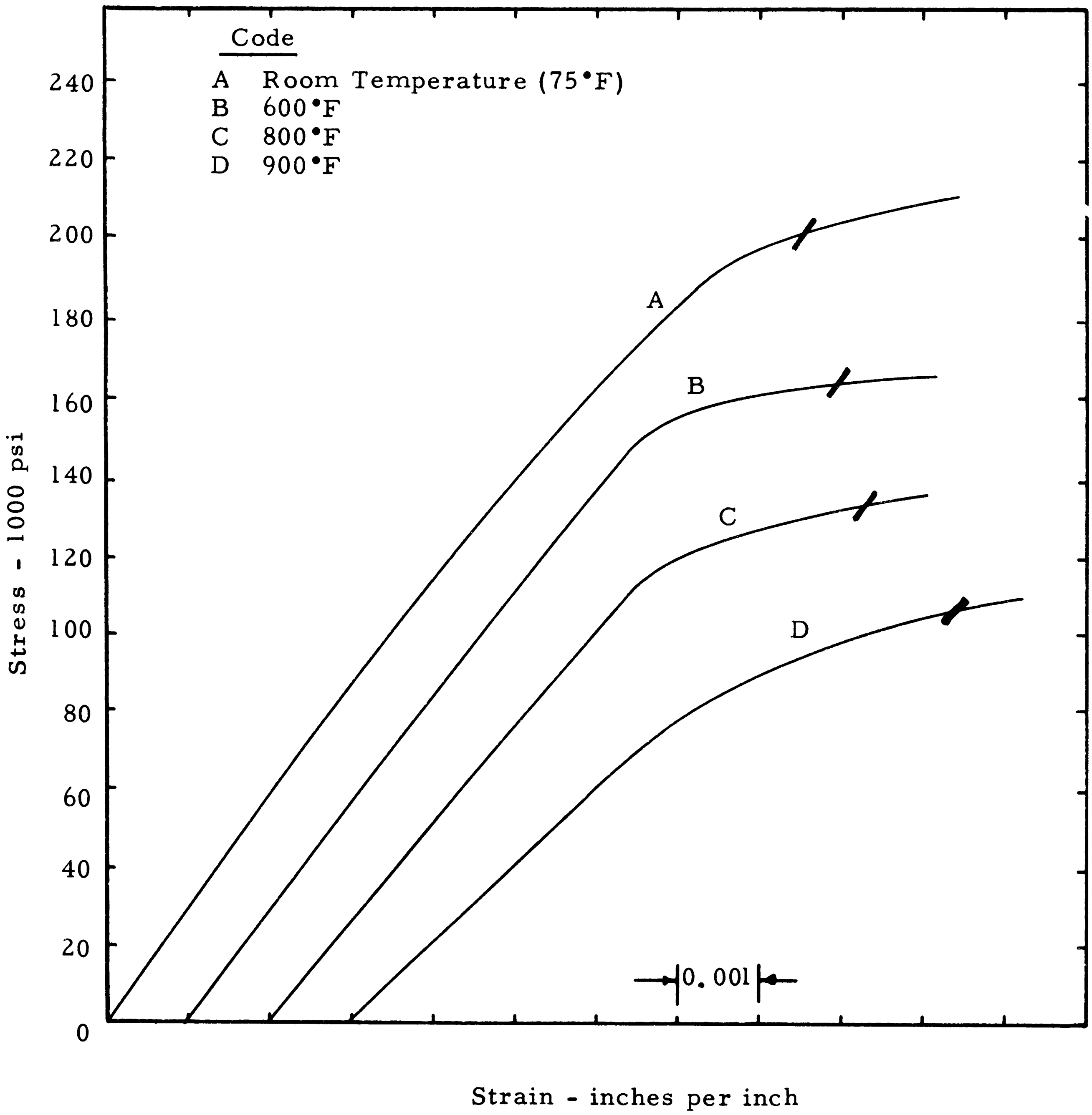


Figure 10. - Representative Tensile Test Stress-Strain Curves for 17-7PH (TH 1050 Condition) as Heat Treated.

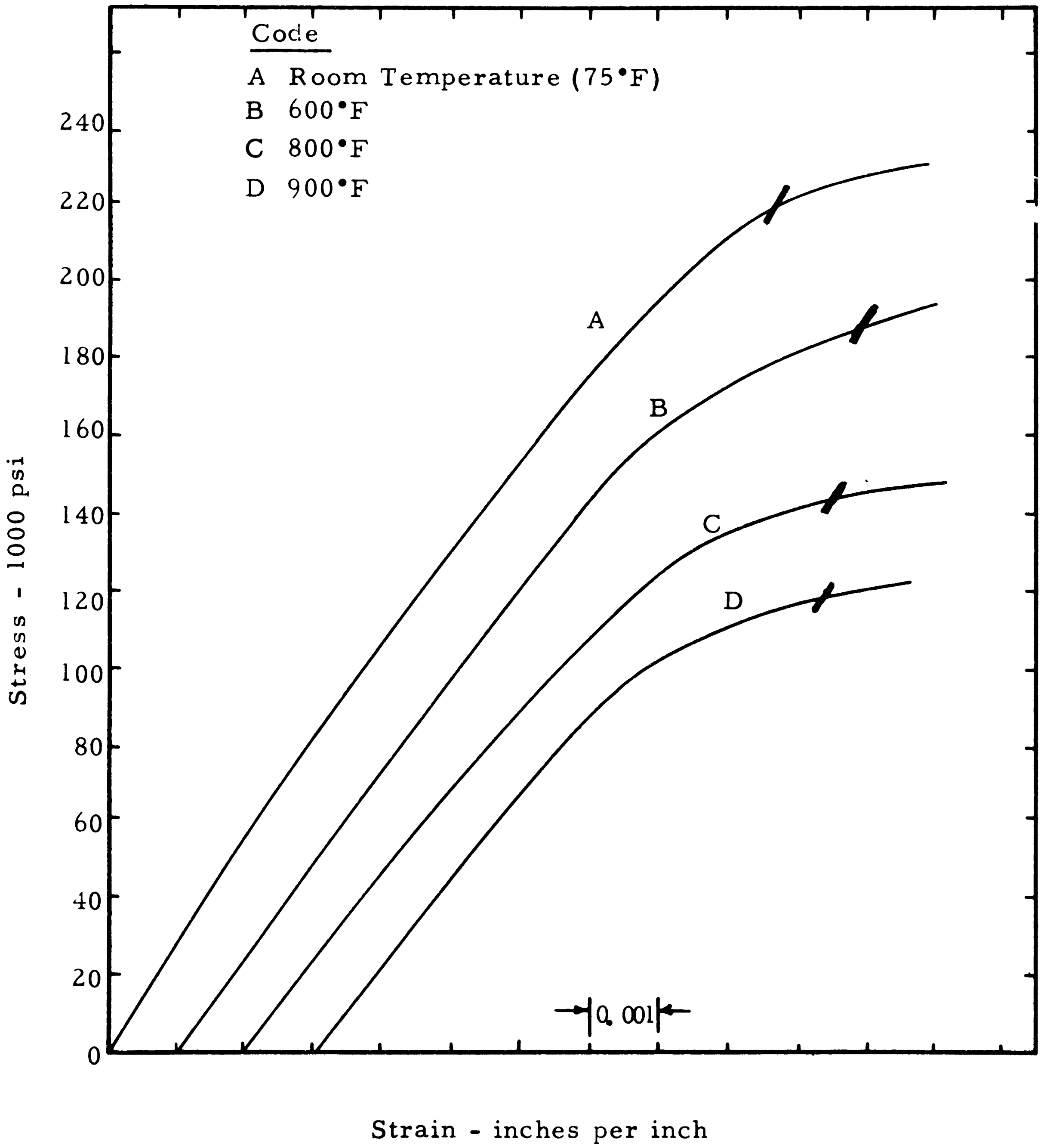


Figure 11. - Representative Compression Test Stress-Strain Curves for 17-7PH (TH 1050 Condition) as Heat Treated.

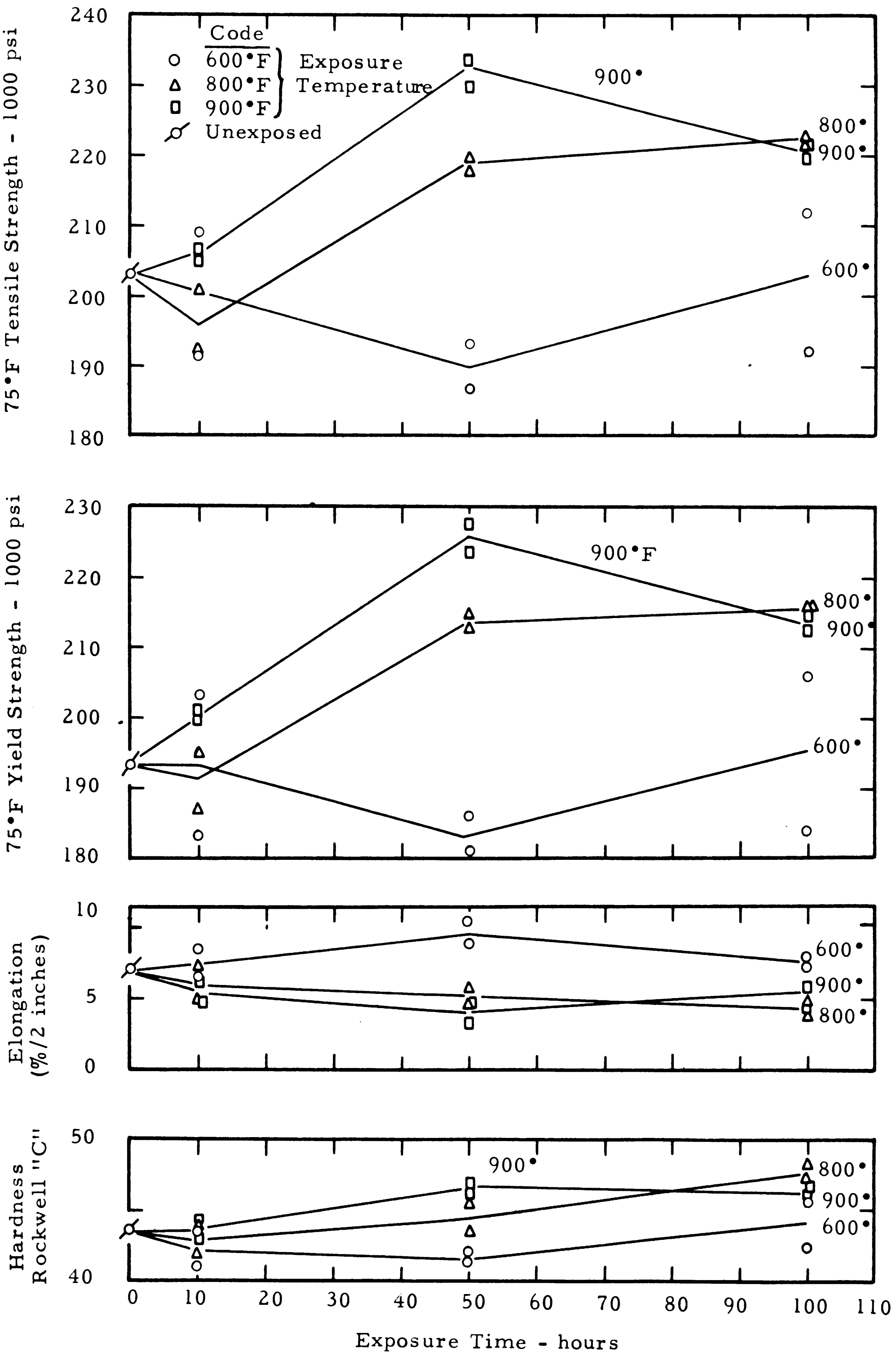


Figure 12. - Effect of Unstressed Exposure at 600°, 800°, or 900°F on Room Temperature Tensile Properties of 17-7PH (TH 1050 Condition).

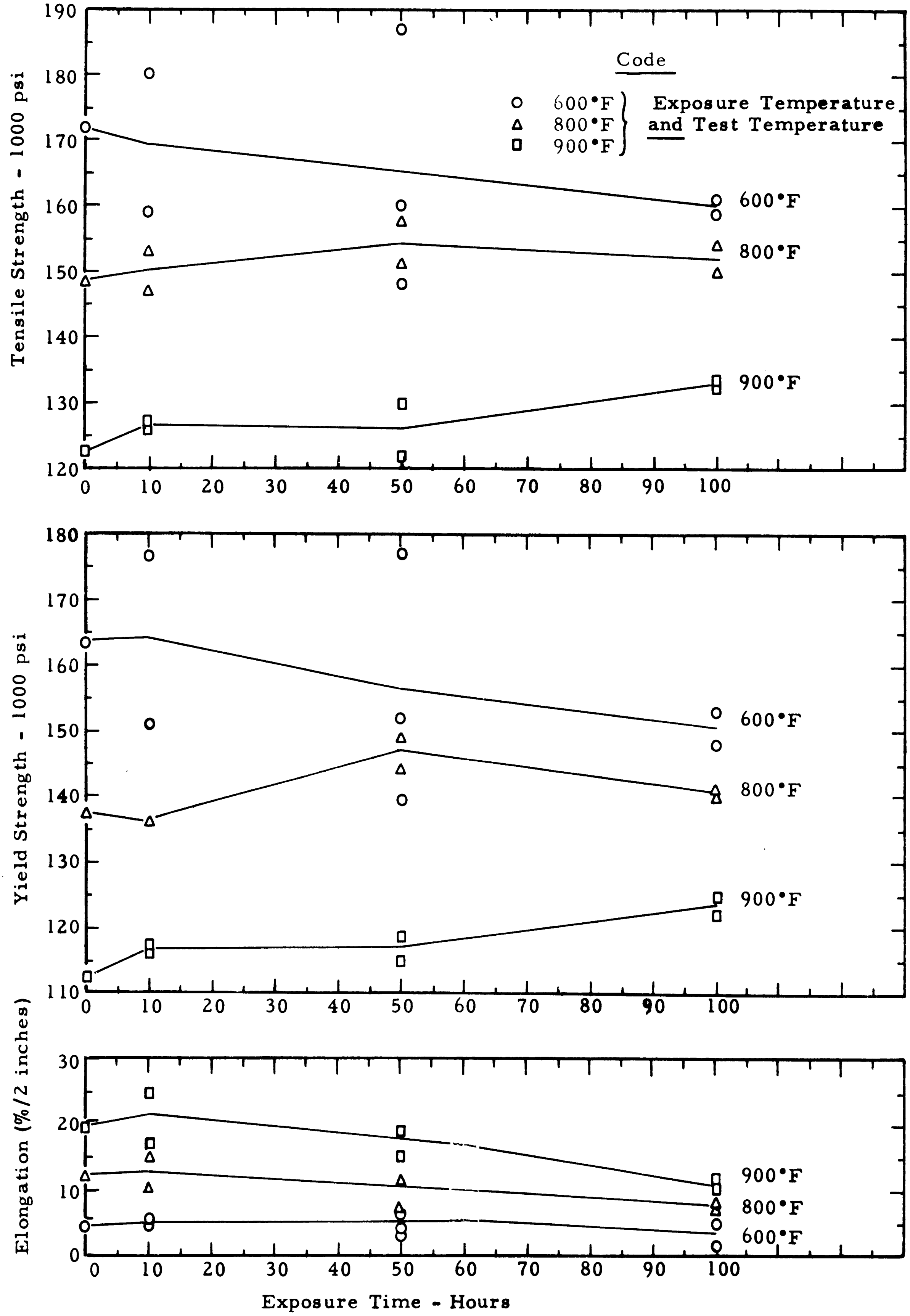


Figure 13. - Effect of Unstressed Exposure at 600°, 800°, and 900°F on Elevated Temperature Tensile Properties of 17-7PH (TH 1050 Condition).

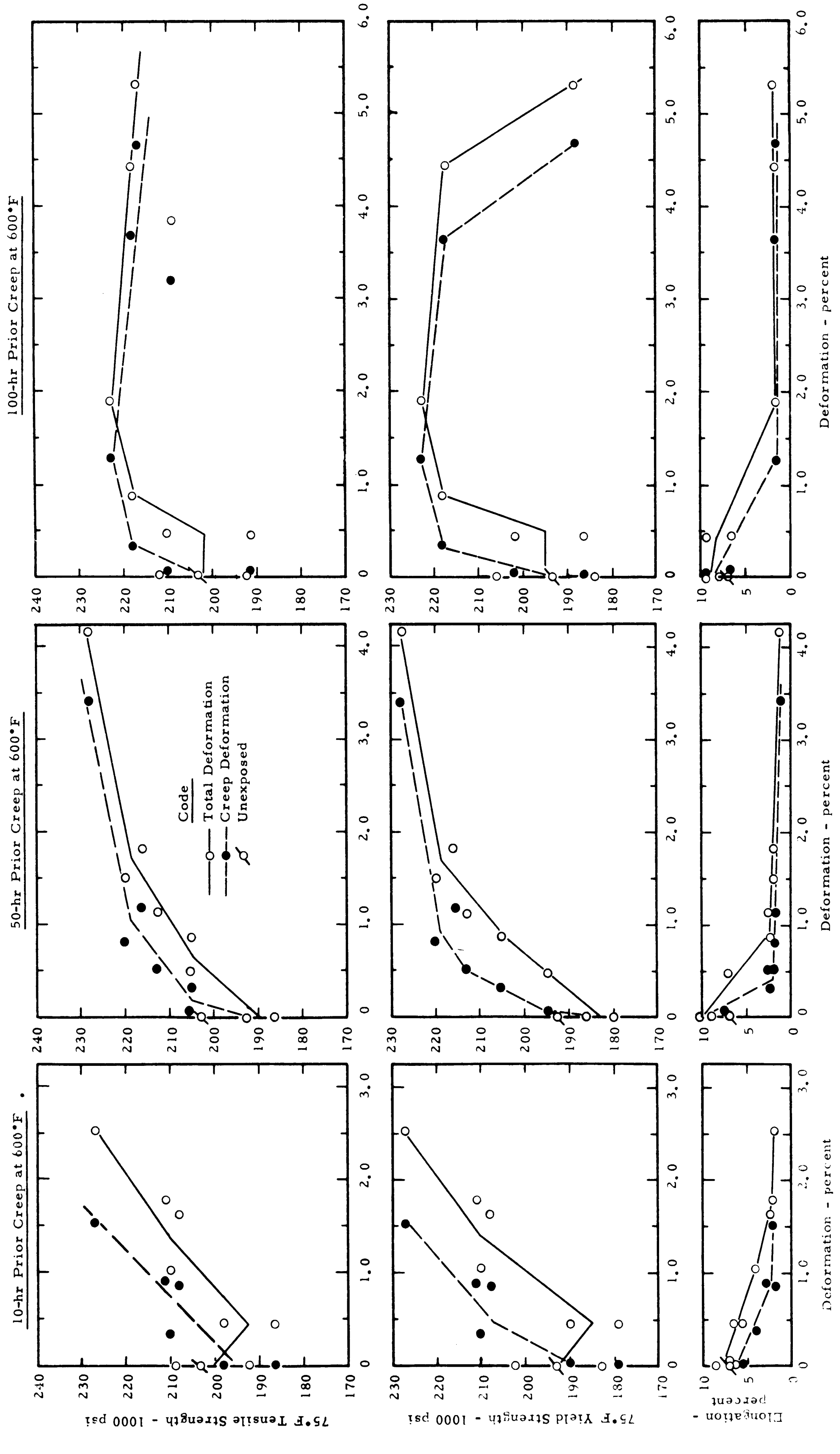


Figure 14. - Effect of Prior Creep Exposure at 600°F for 10, 50 or 100 Hours on Room Temperature Tensile Properties of 17-7PH (TH 1050 Condition).

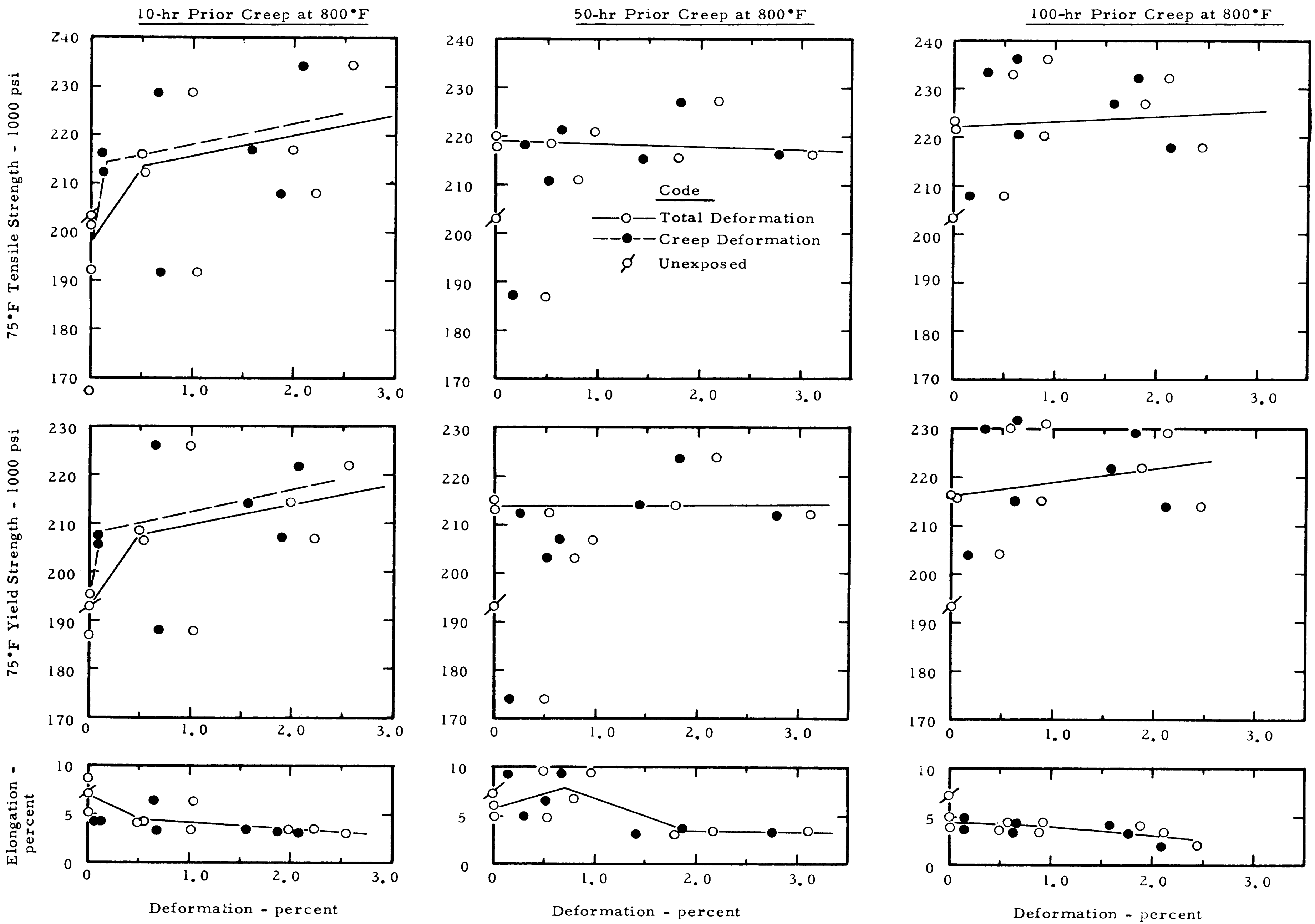


Figure 15. - Effect of Prior Creep Exposure at 800°F for 10, 50 or 100 Hours on Room Temperature Tensile Properties of 17-7PH (TH 1050 Condition).

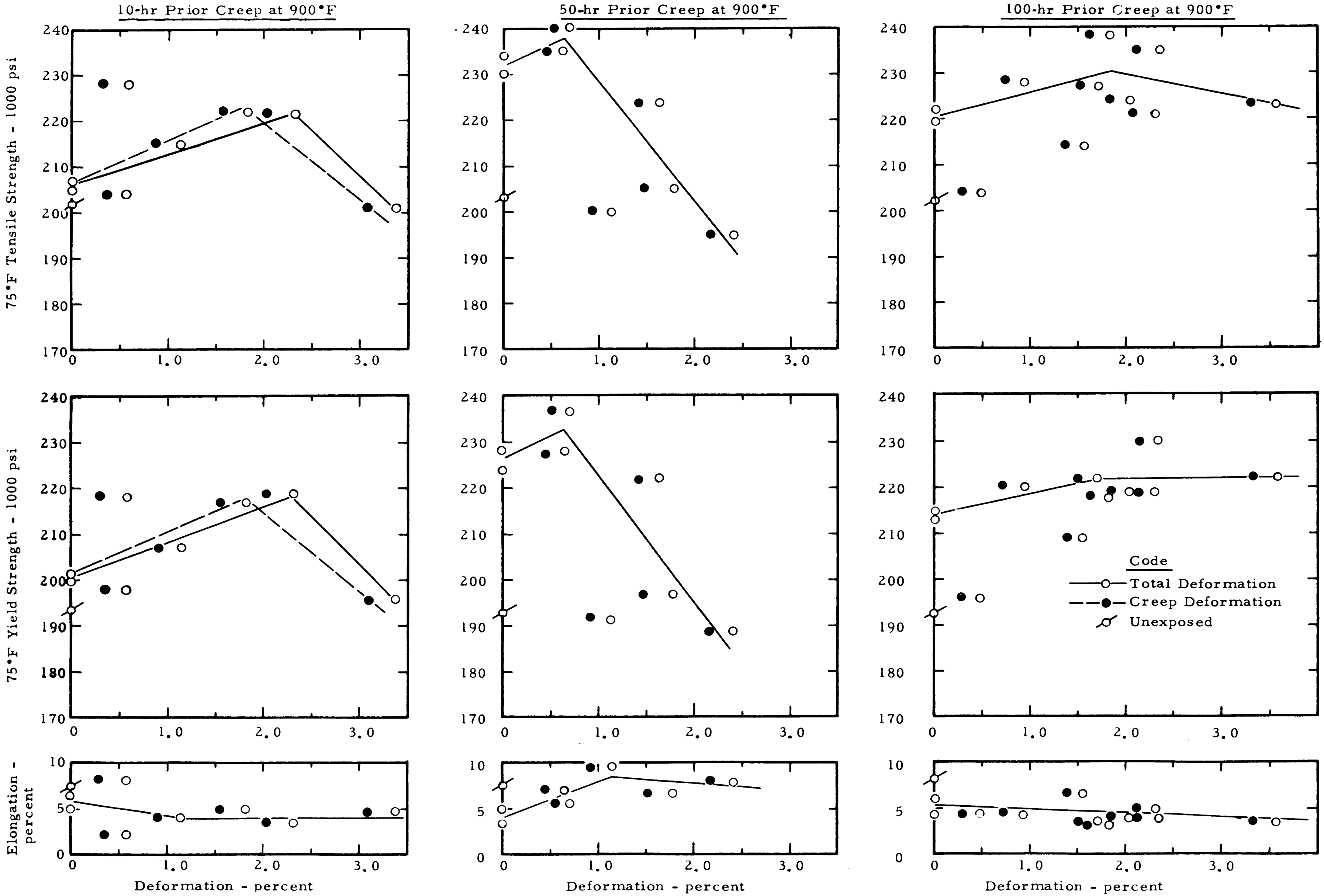


Figure 16. - Effect of Prior Creep Exposure at 900°F for 10, 50, or 100 Hours on Room Temperature Tensile Properties of 17-7PH (TH 1050 Condition).

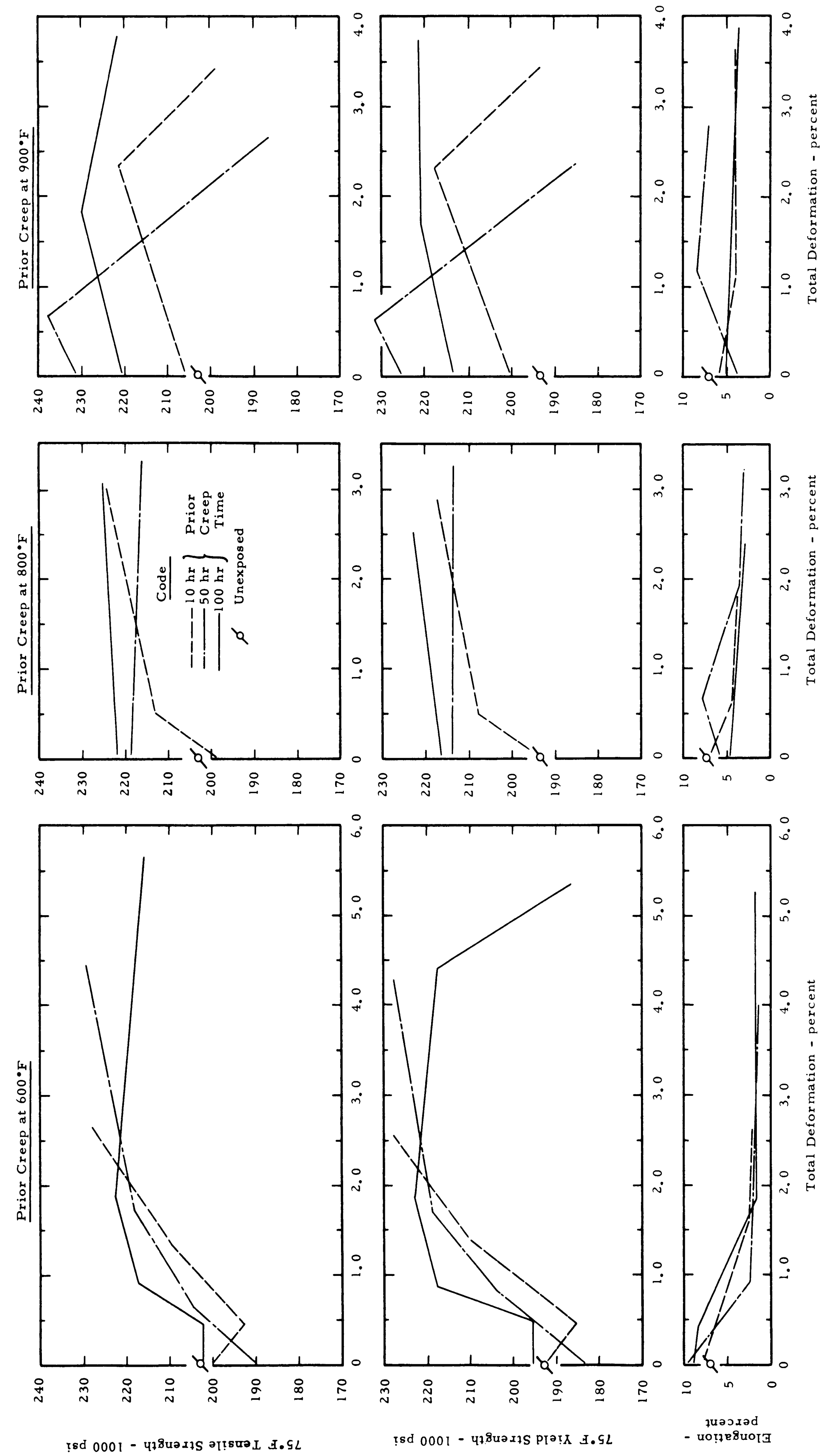


Figure 17. - Summary of Effect of Prior Creep Exposure at 600°, 800°, or 900°F on Room Temperature Tensile Properties of 17-7PH (TH 1050 Condition).

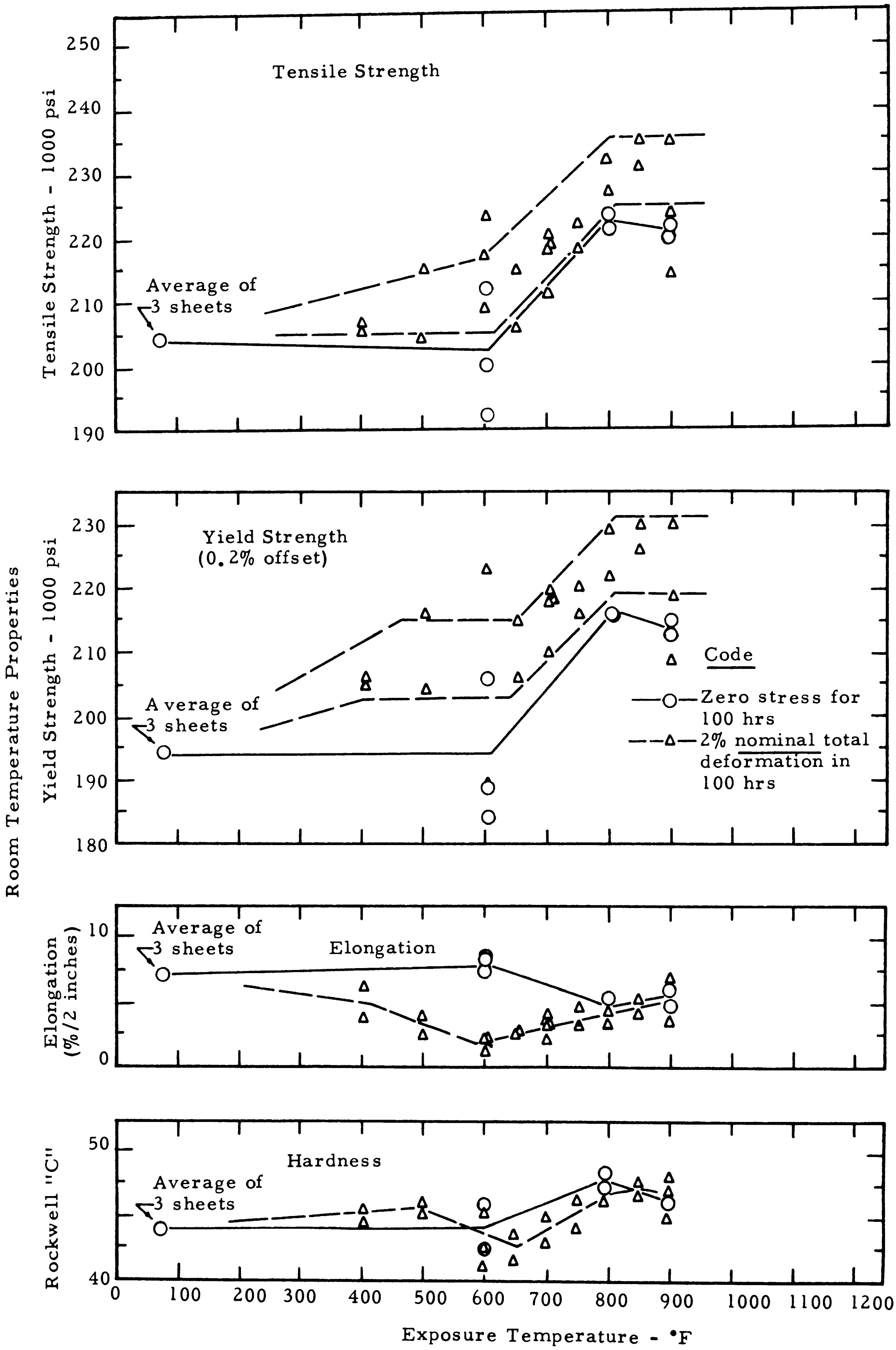
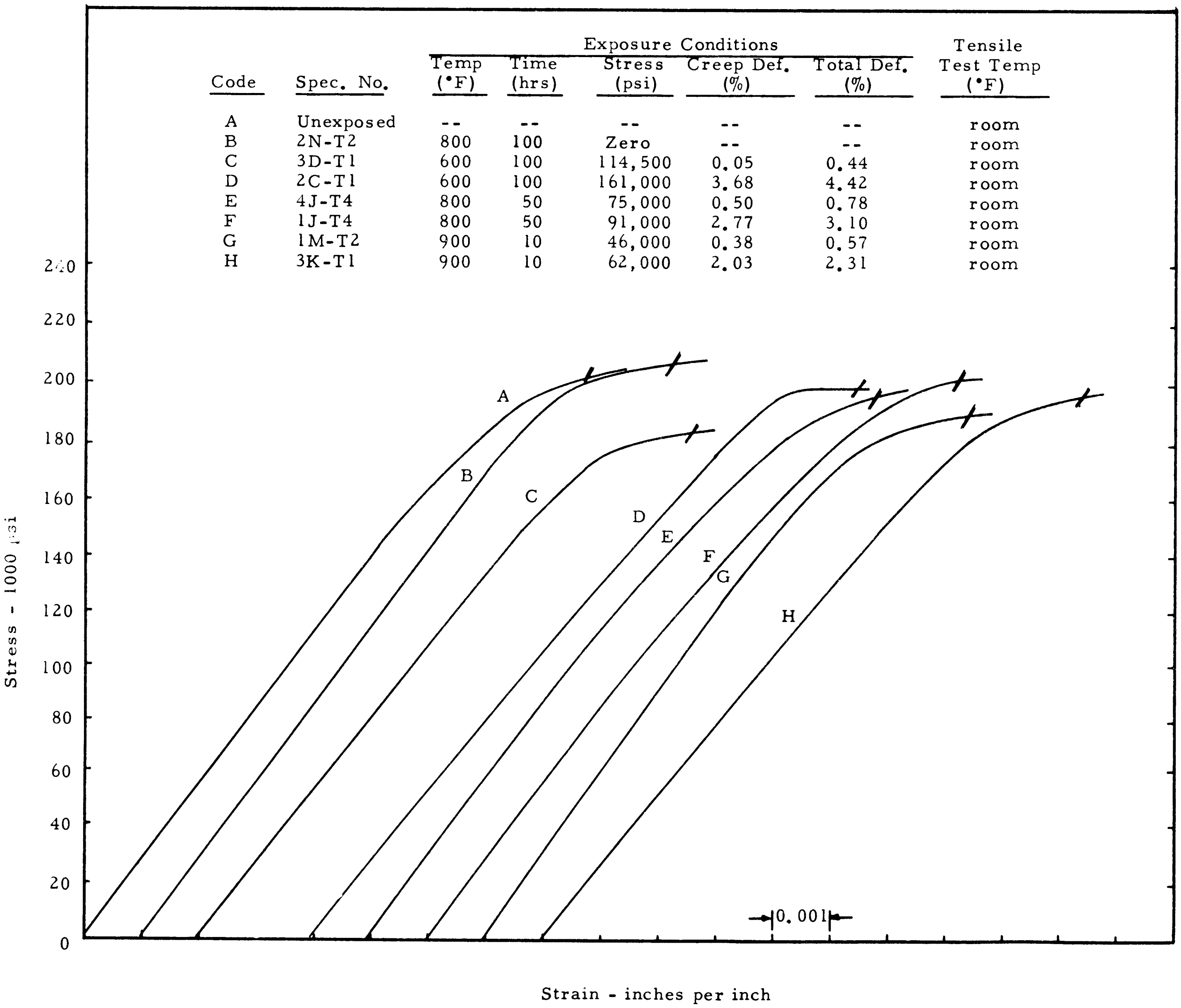


Figure 18. - Effect of 100 Hours Exposure Either Unstressed or to Two Percent Nominal Total Deformation on Room Temperature Tensile Properties of 17-7PH (TH 1050 Condition).



Code	Spec. No.	Exposure Conditions: Temp (°F)	Time (hrs)	Stress (psi)	Creep Def. (%)	Total Def. (%)	Tensile Test Temp (°F)
A	Unexposed	--	--	--	--	--	room
B	2N-T2	800	100	Zero	--	--	room
C	3D-T1	600	100	114,500	0.05	0.44	room
D	2C-T1	600	100	161,000	3.68	4.42	room
E	4J-T4	800	50	75,000	0.50	0.78	room
F	1J-T4	800	50	91,000	2.77	3.10	room
G	1M-T2	900	10	46,000	0.38	0.57	room
H	3K-T1	900	10	62,000	2.03	2.31	room

Figure 19. - Representative Room Temperature Tensile Test Stress-Strain Curves for 17-7PH (TH 1050 Condition) After Prior Creep Exposure.

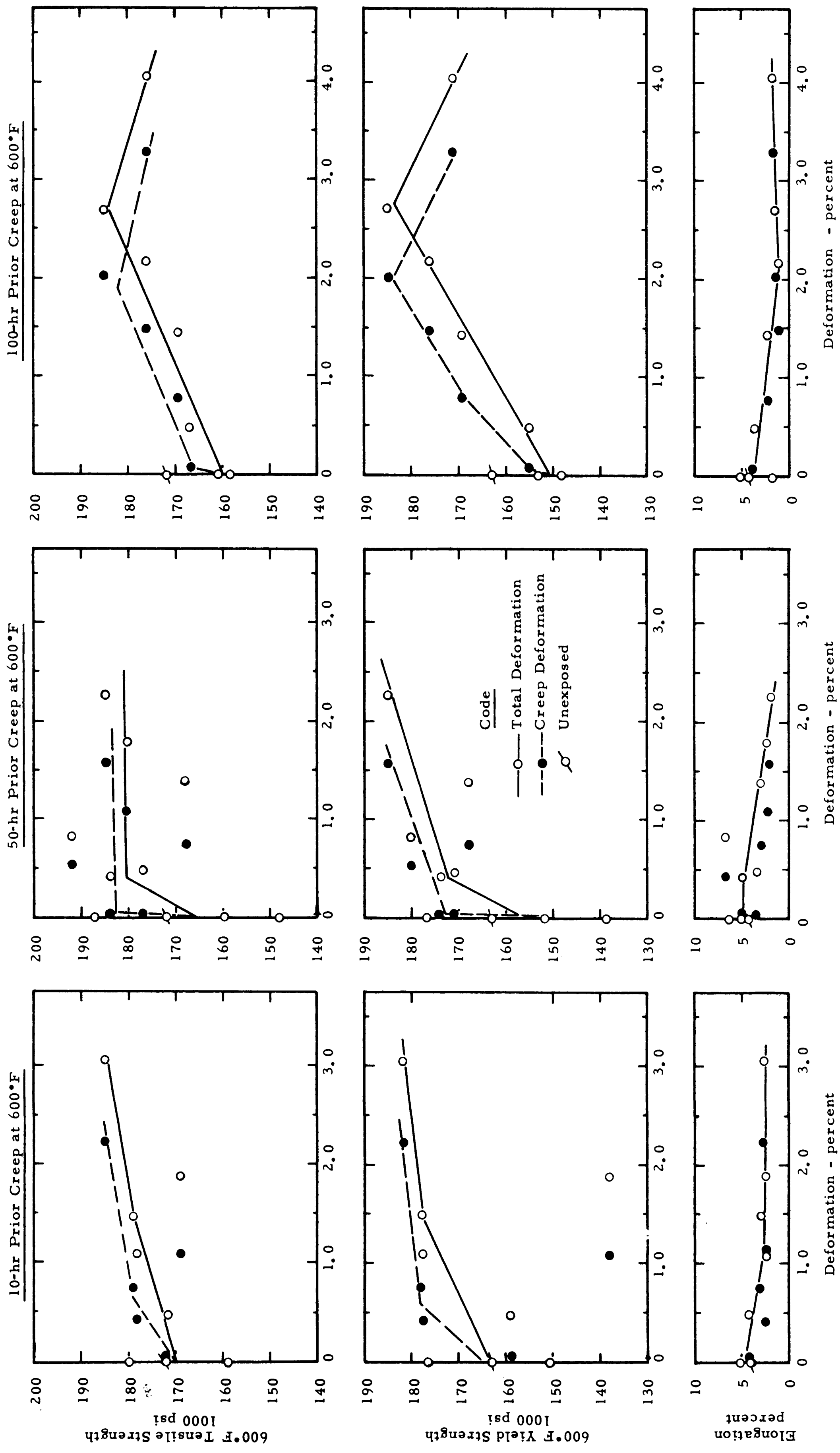


Figure 20. - Effect of Prior Creep Exposure at 600°F for 10, 50, or 100 Hours on 600°F Tensile Properties of 17-7PH (TH 1050 Condition).

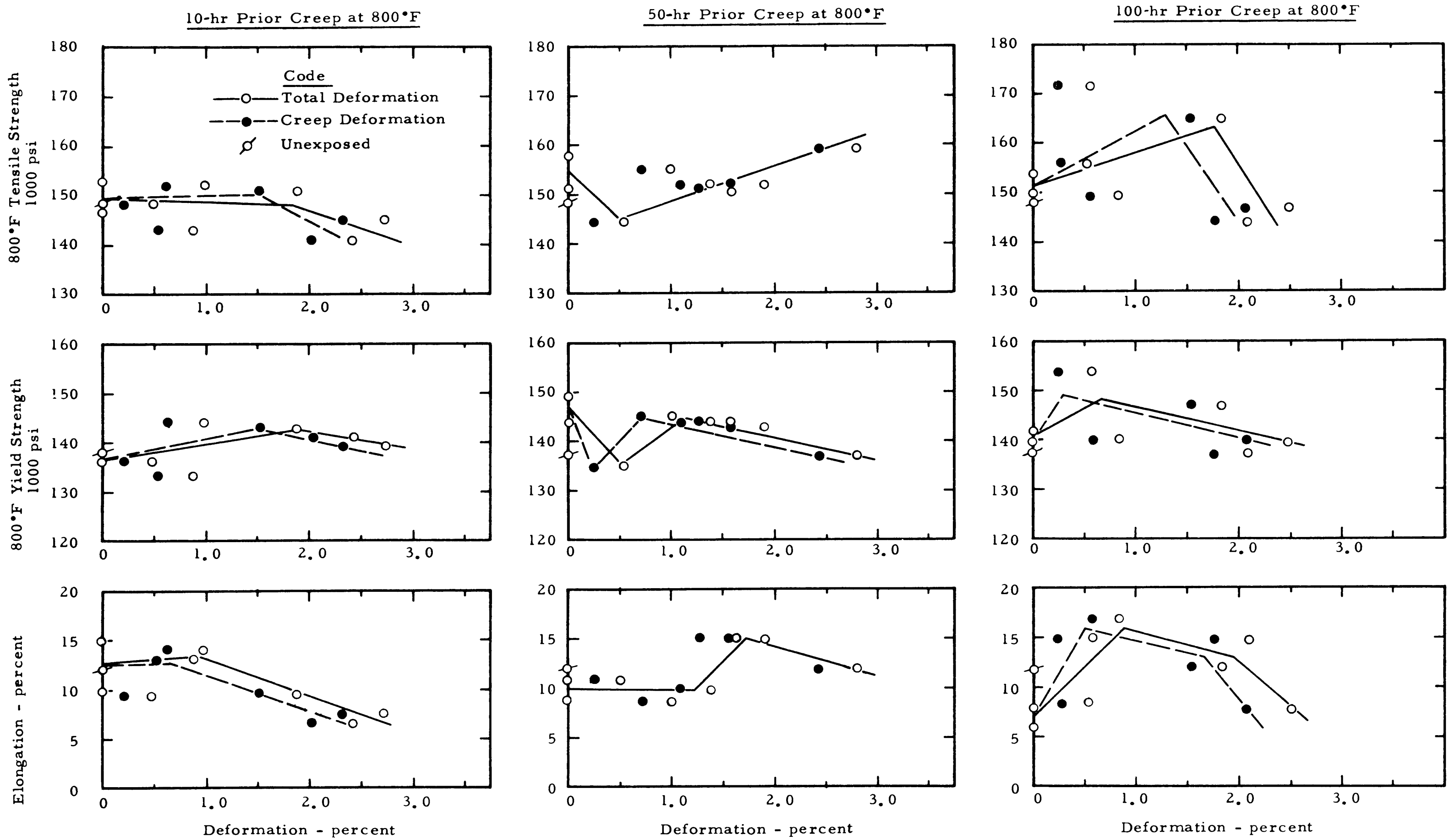


Figure 21. - Effect of Prior Creep Exposure at 800°F for 10, 50, or 100 Hourson 800°F Tensile Properties of 17-7PH (TH 1050 Condition).

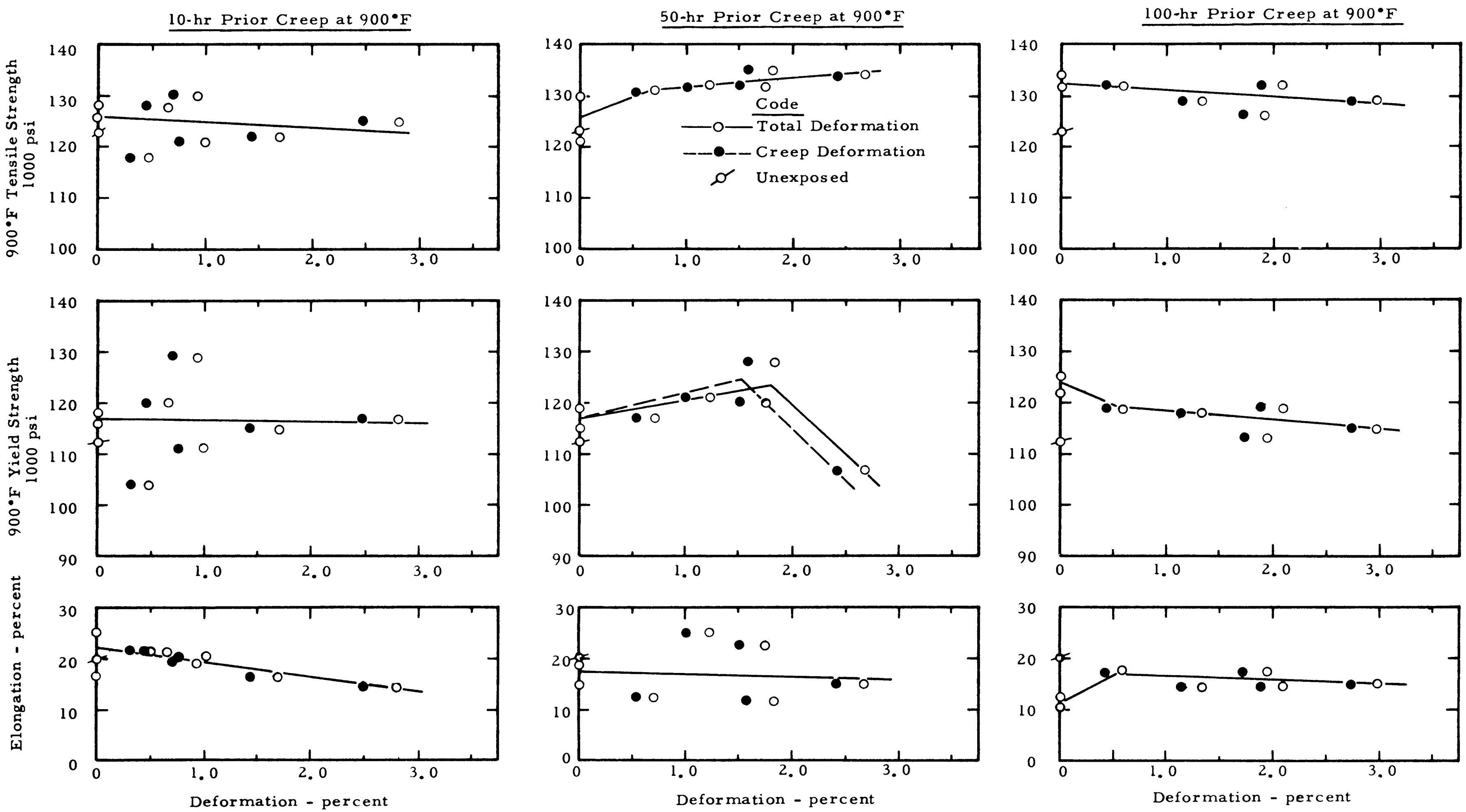


Figure 22. - Effect of Prior Creep Exposure at 900°F for 10, 50, or 100 Hours on 900°F Tensile Properties of 17-7PH (TH 1050 Condition).

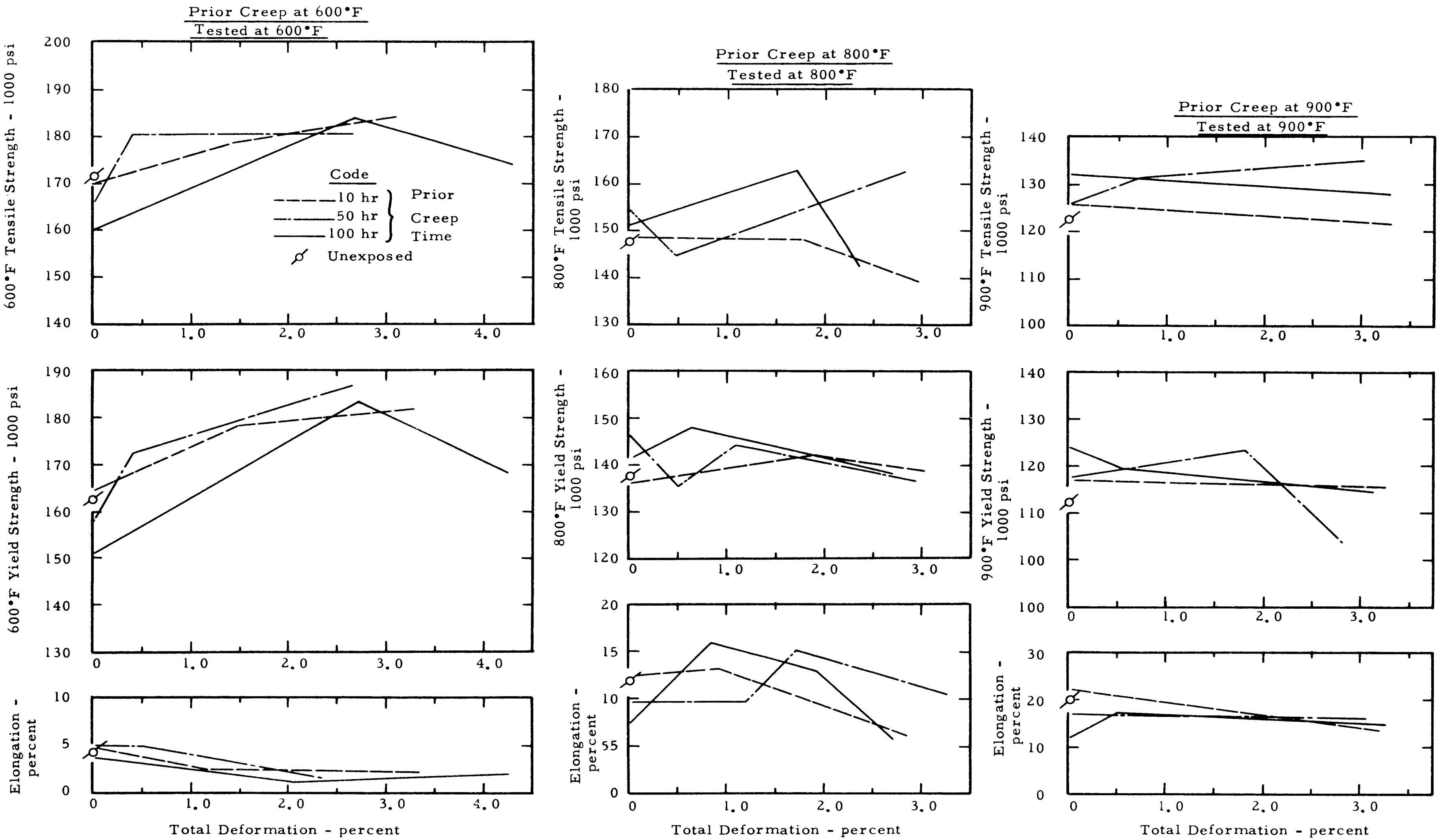


Figure 23. - Summary of Effect of Prior Creep Exposure at 600°, 800°, or 900°F on Tensile Properties of 17-7PH (TH 1050 Condition) at Exposure Temperature.

		Exposure Conditions					Tensile
Code	Spec. No.	Temp (°F)	Time (hrs)	Stress (psi)	Creep Def. (%)	Total Def. (%)	Test Temp (°F)
A	Unexposed	--	--	--	--	--	600
B	1J-T3	600	100	Zero	--	--	600
C	2L-T1	600	100	114,500	0.06	0.48	600
D	3D-T5	600	100	161,000	2.02	2.70	600
E	Unexposed	--	--	--	--	--	800
F	3N-T2	800	50	Zero	--	--	800
G	5K-T6	800	50	81,000	1.10	1.39	800
H	3T-T6	800	50	91,000	2.44	2.80	800
I	Unexposed	--	--	--	--	--	900
J	1F-T5	900	10	Zero	--	--	900
K	2G-T6	900	10	68,000	2.41	2.80	900
L	1R-T2	900	100	50,000	1.88	2.09	900

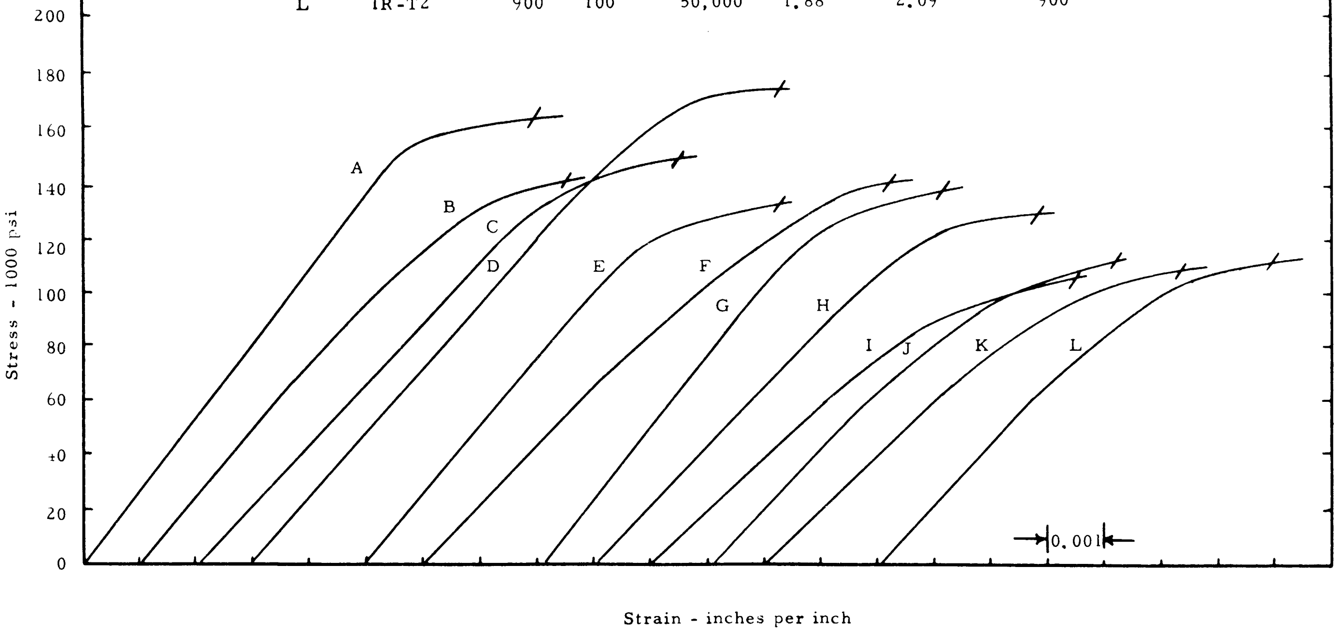


Figure 24. - Representative Tensile Test Stress-Strain Curves at Elevated Temperature for 17-7PH (TH 1050 Condition) Given Prior Creep Exposure.

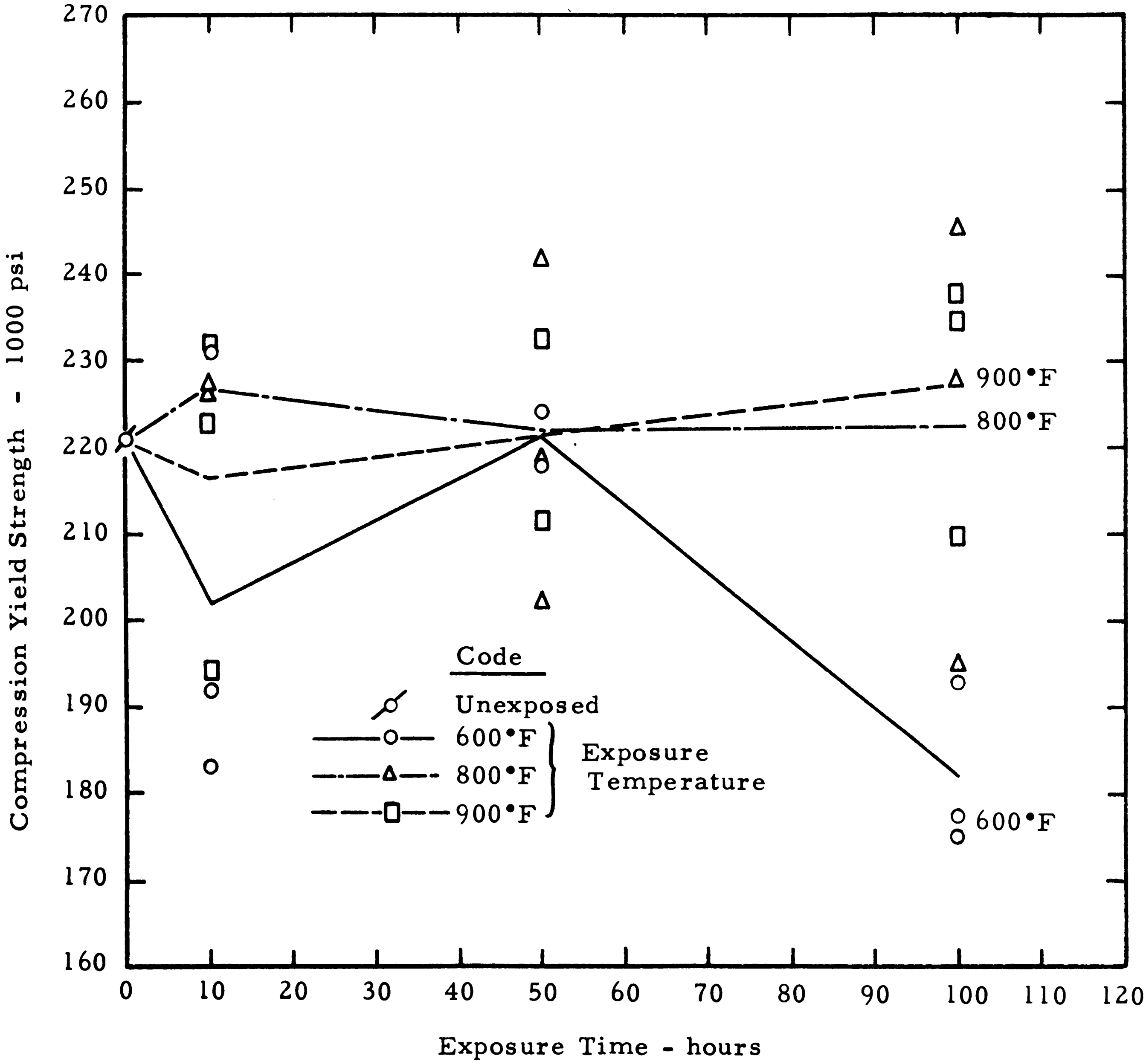


Figure 25. - Effect of Unstressed Exposure on Room Temperature Compression Yield Strength of 17-7PH (TH 1050 Condition).

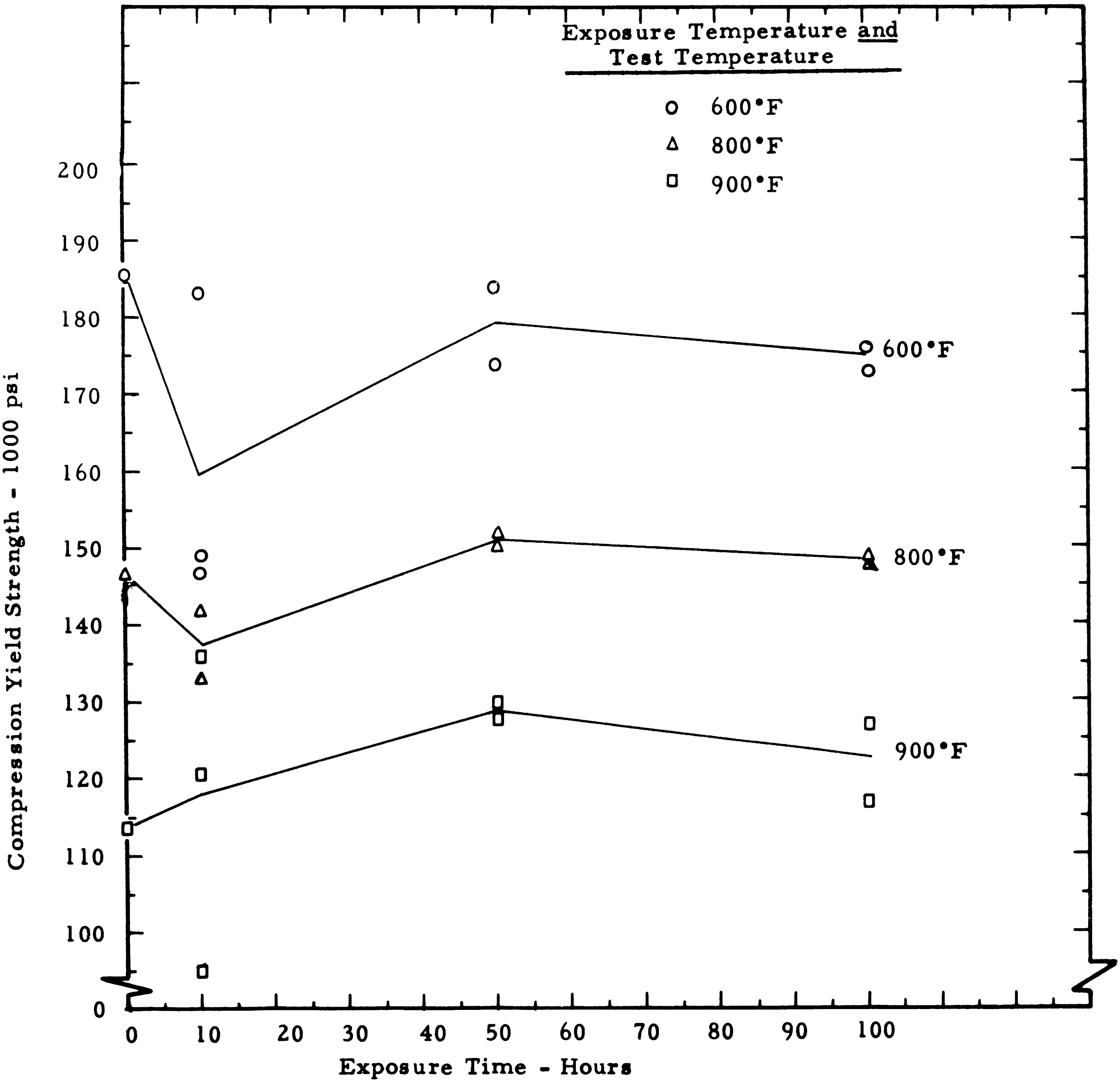


Figure 26. - Effect of Unstressed Exposure on Elevated Temperature Compression Yield Strength of 17-7PH (TH 1050 Condition).

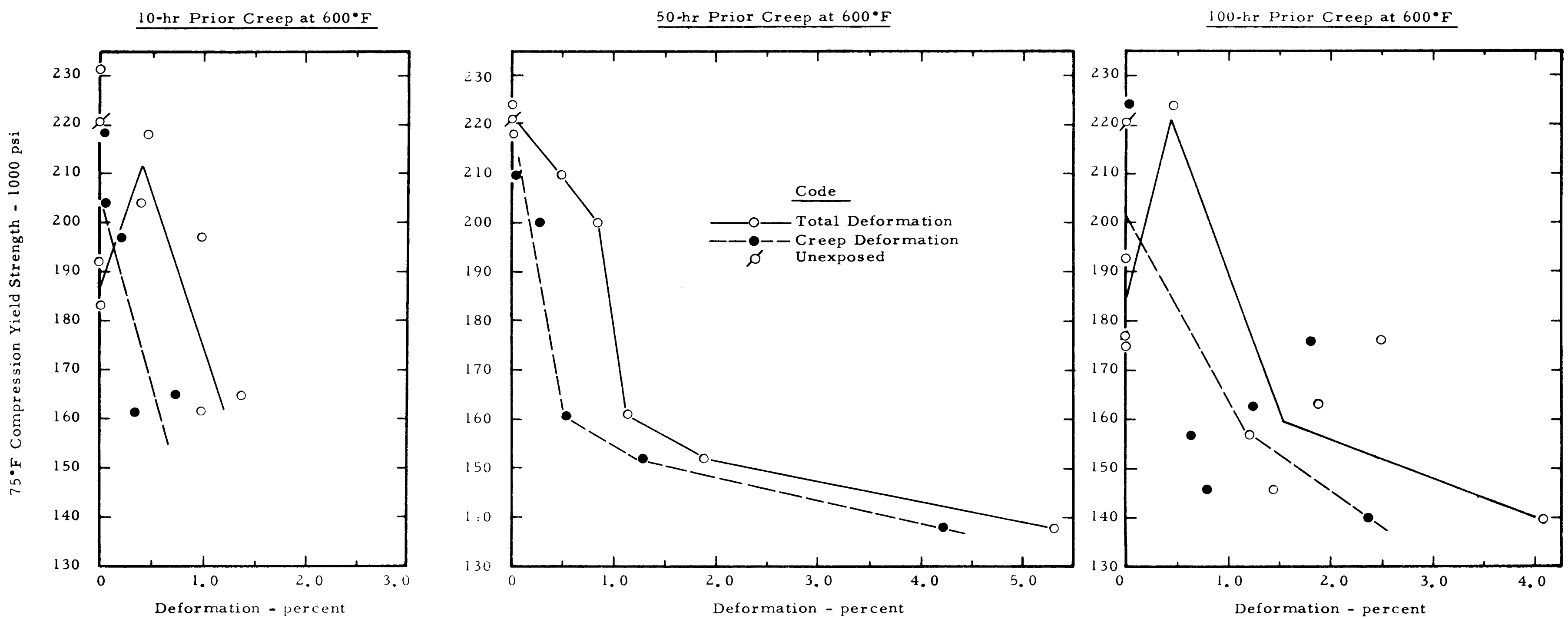


Figure 27. - Effect of Prior Creep at 600°F for 10, 50, or 100 Hours on Room Temperature Compression Yield Strength of 17-7PH (TH 1050 Condition).

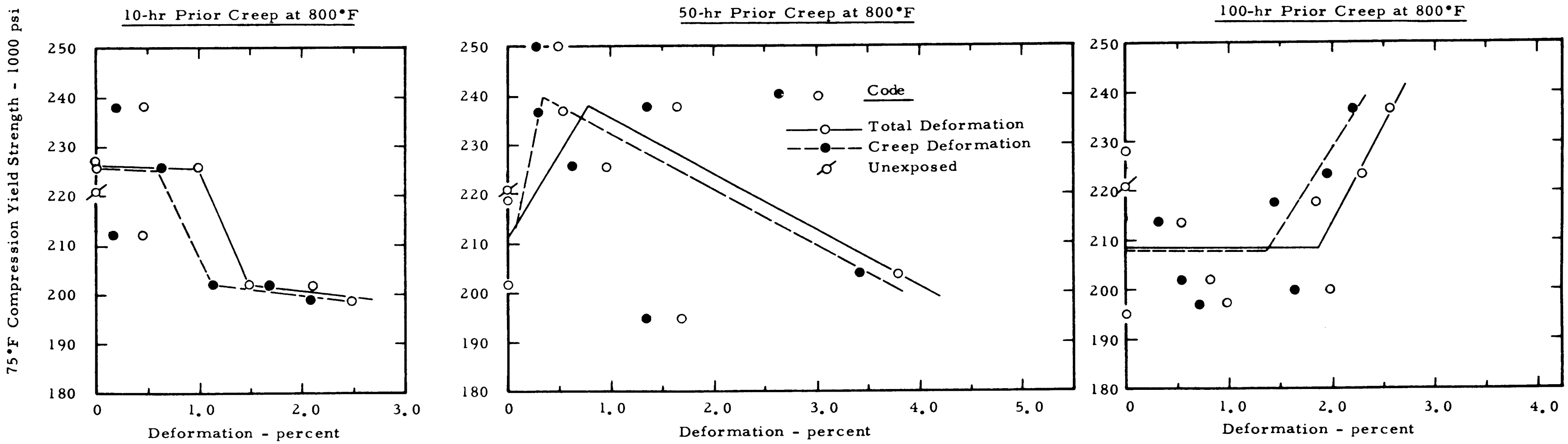


Figure 28. - Effect of Prior Creep at 800°F for 10, 50, or 100 Hours on Room Temperature Compression Yield Strength of 17-7PH (TH 1050 Condition).

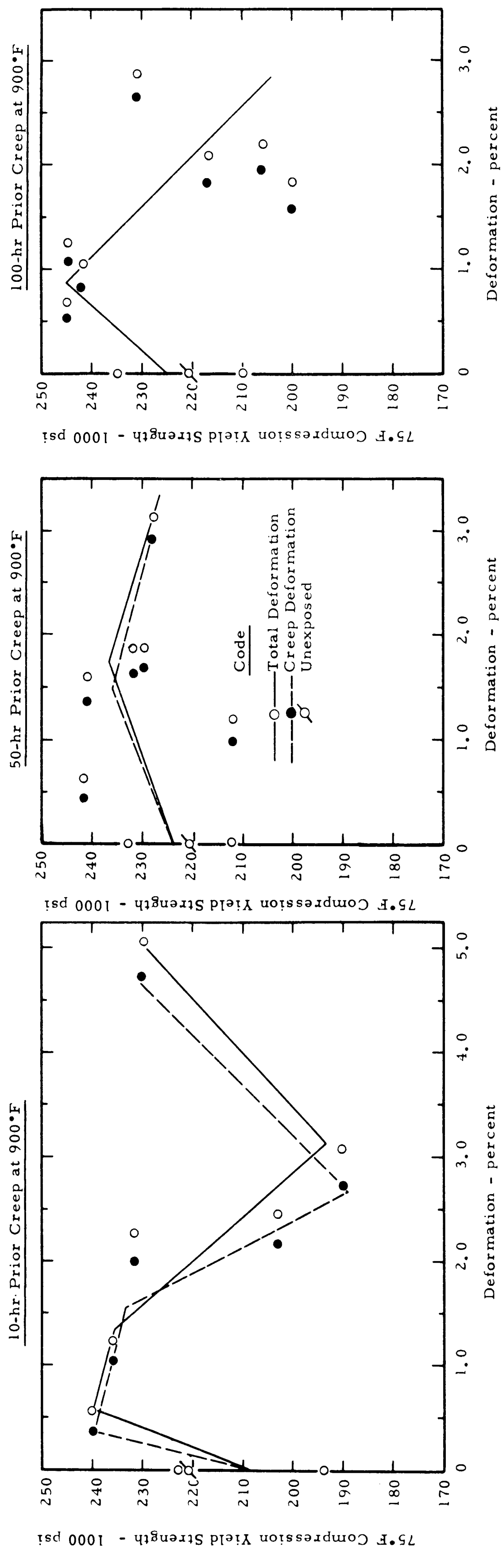


Figure 29. - Effect of Prior Creep at 900°F for 10, 50, or 100 Hours on Room Temperature Compression Yield Strength of 17-7PH (TH 1050 Condition).

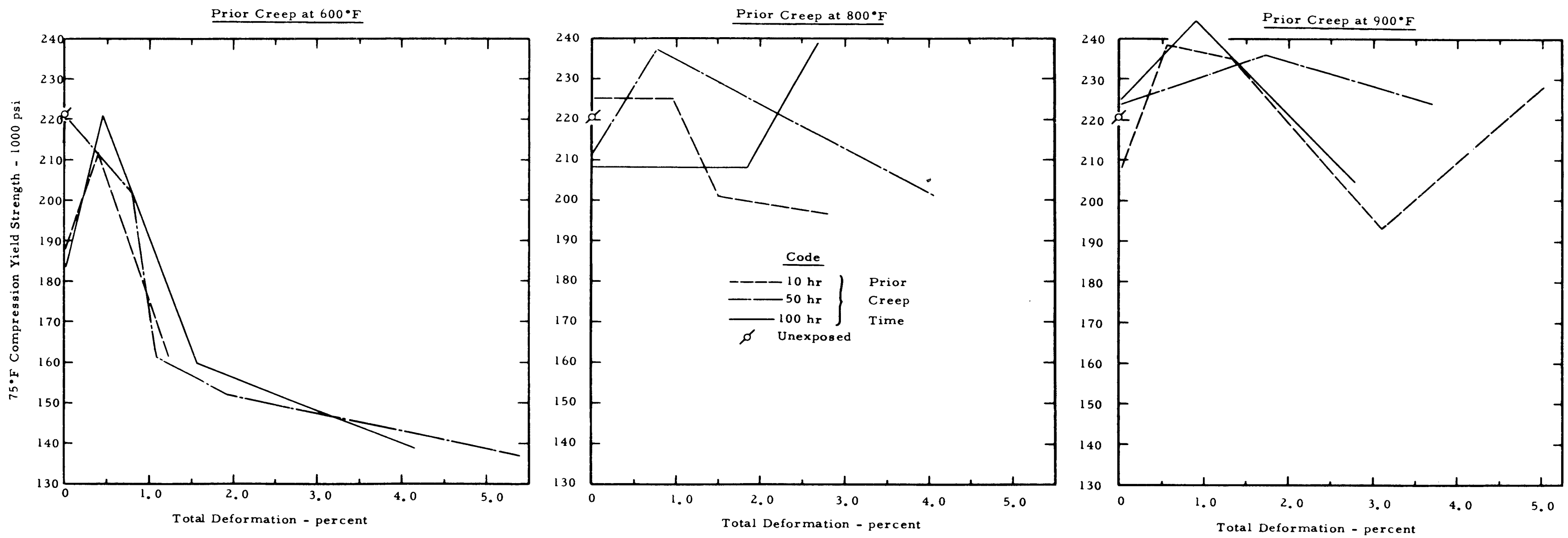


Figure 30. - Summary of Effect of Prior Creep Exposure at 600°, 800°, or 900°F on Room Temperature Compression Yield Strength of 17-7PH (TH 1050 Condition).

Code	Spec. No.	Exposure Conditions Temp (°F)	Time (hrs)	Stress (psi)	Creep Def. (%)	Total Def. (%)	Compression Test Temp (°F)
A	Unexposed	--	--	--	--	--	room
B	1N-M71	600	100	Zero	--	--	room
C	6G-T2	600	100	146,000	0.78	1.43	room
D	2L-X33	800	50	Zero	--	--	room
E	1A-T4	800	50	75,000	0.65	0.95	room
F	5B-T1	800	100	70,000	0.70	0.98	room
G	2L-X3	900	10	Zero	--	--	room
H	1A-T1	900	10	46,000	0.37	0.55	room
I	1A-T3	900	50	40,000	0.44	0.61	room
J	6E-T1	900	50	52,000	1.68	1.89	room
K	2T-T1	900	100	52,000	1.58	1.82	room

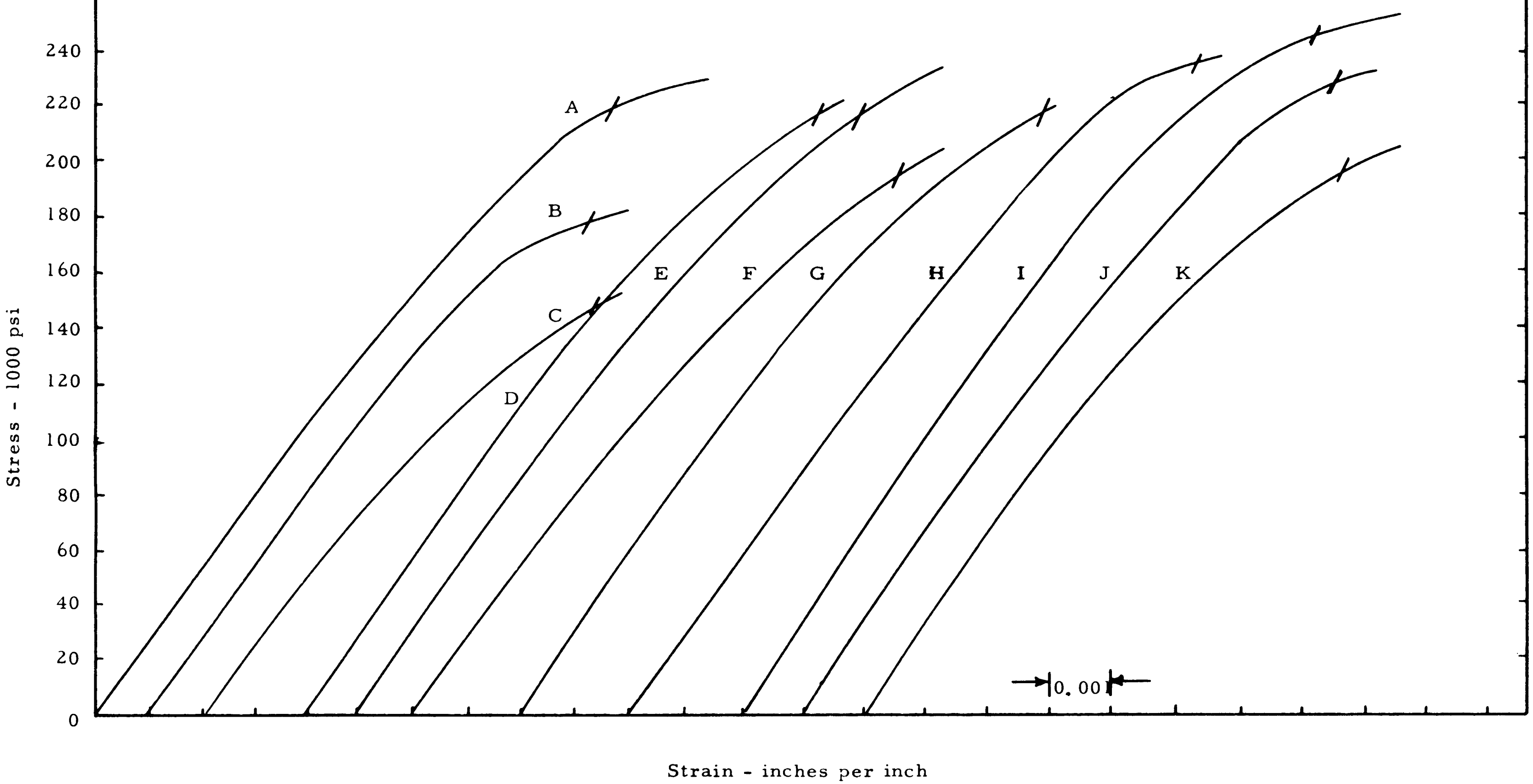


Figure 31. - Representative Room Temperature Compression Test Stress-Strain for 17-7PH (TH 1050 Condition) After Prior Creep Exposure.

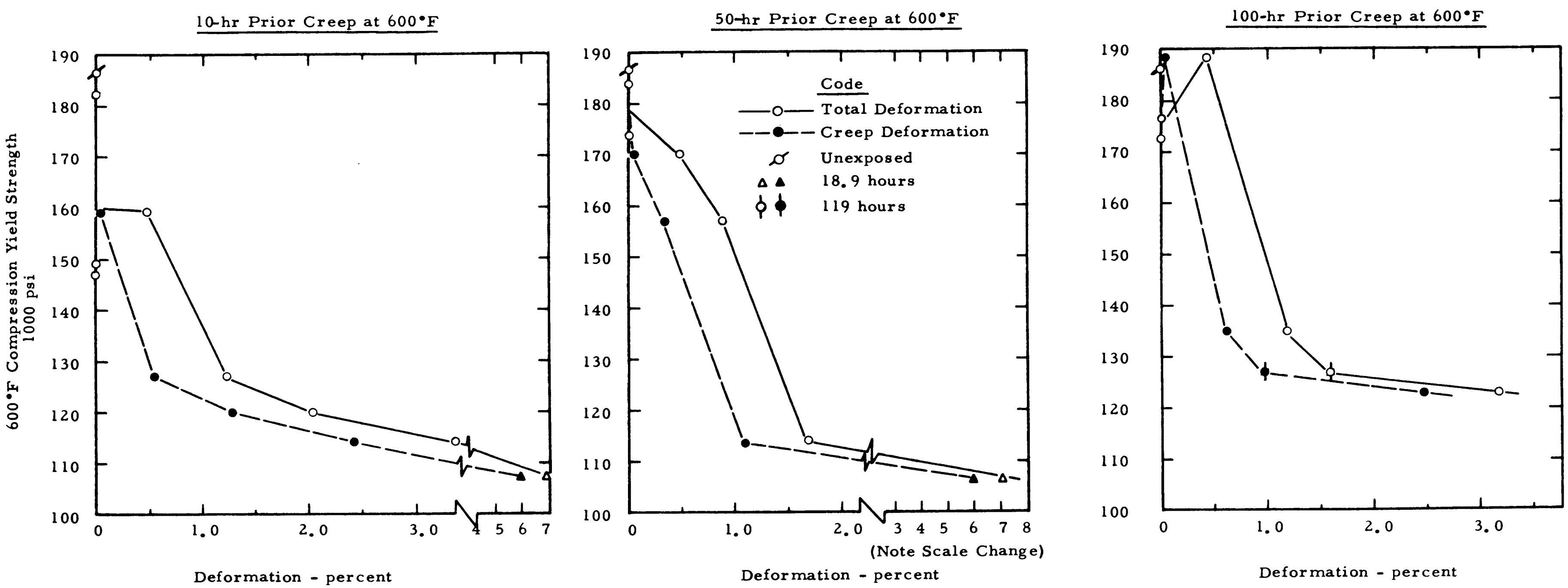


Figure 32. - Effect of Prior Creep at 600°F for 10, 50, or 100 Hours on 600°F Compression Yield Strength of 17-7PH (TH 1050 Condition).

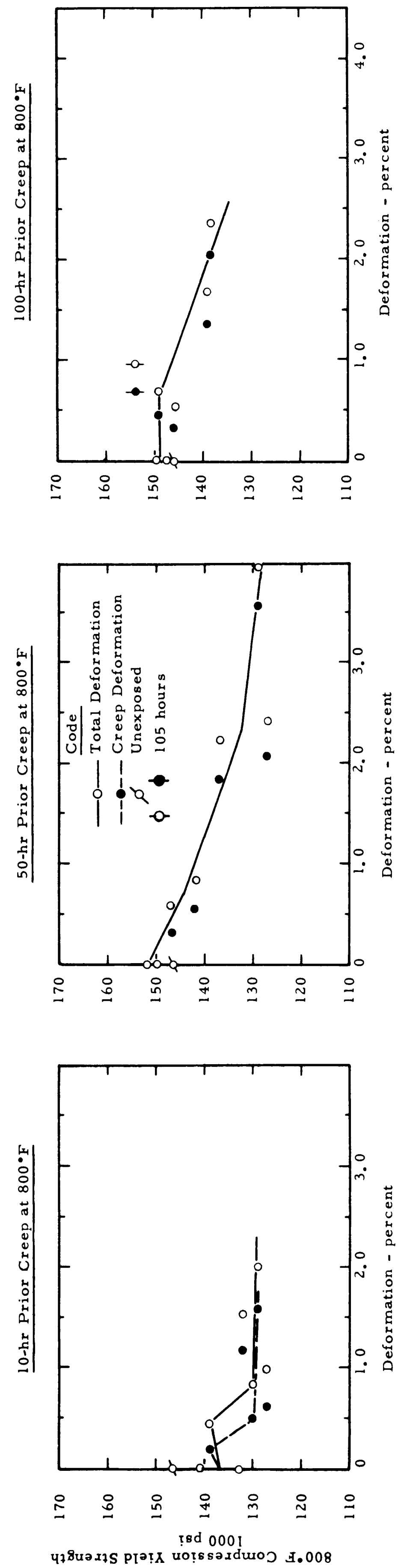


Figure 33. - Effect of Prior Creep at 800°F for 10, 50, or 100 Hours on 800°F Compression Yield Strength of 17-7PH (TH 1050 Condition).

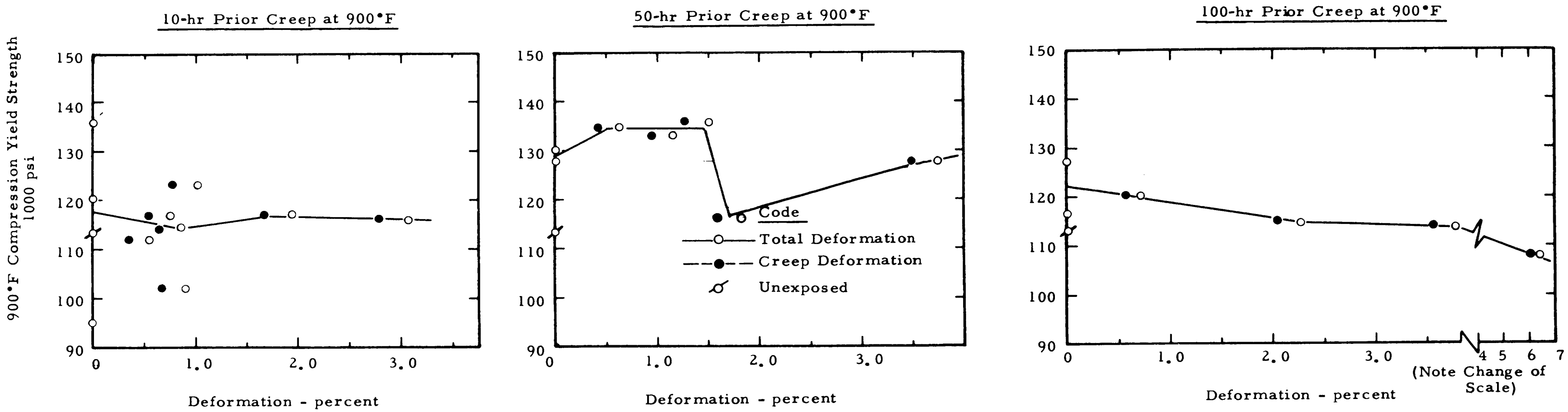


Figure 34. - Effect of Prior Creep at 900°F for 10, 50, or 100 Hours on 900°F Compression Yield Strength of 17-7PH (TH 1050 Condition).

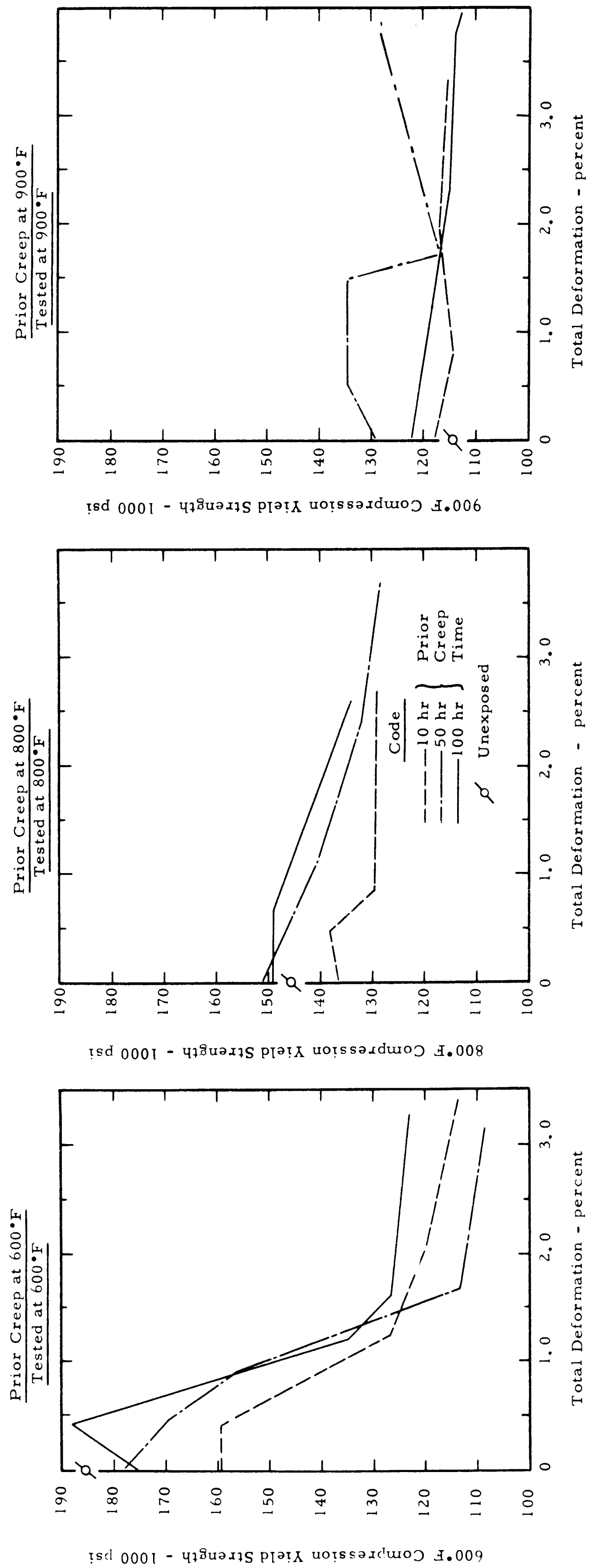
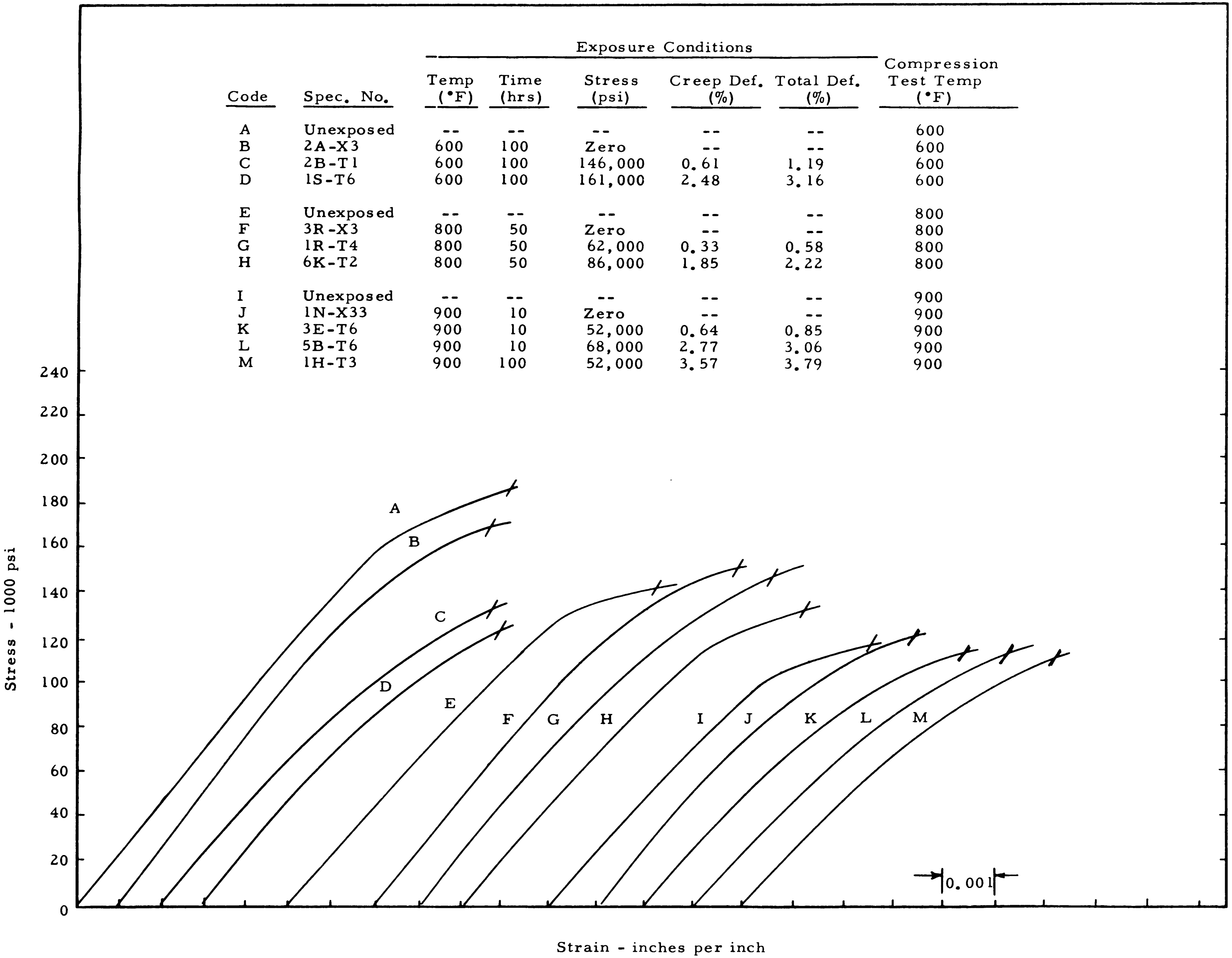


Figure 35. - Summary of Effect of Prior Creep Exposure at 600°, 800°, or 900°F on Elevated Temperature Compression Yield Strength of 17-7PH (TH 1050 Condition).



Code	Spec. No.	Exposure Conditions: Temp (°F)	Time (hrs)	Stress (psi)	Creep Def. (%)	Total Def. (%)	Compression Test Temp (°F)
A	Unexposed	--	--	--	--	--	600
B	2A-X3	600	100	Zero	--	--	600
C	2B-T1	600	100	146,000	0.61	1.19	600
D	1S-T6	600	100	161,000	2.48	3.16	600
E	Unexposed	--	--	--	--	--	800
F	3R-X3	800	50	Zero	--	--	800
G	1R-T4	800	50	62,000	0.33	0.58	800
H	6K-T2	800	50	86,000	1.85	2.22	800
I	Unexposed	--	--	--	--	--	900
J	1N-X33	900	10	Zero	--	--	900
K	3E-T6	900	10	52,000	0.64	0.85	900
L	5B-T6	900	10	68,000	2.77	3.06	900
M	1H-T3	900	100	52,000	3.57	3.79	900

Figure 36. - Representative Compression Test Stress-Strain Curves at Elevated Temperature for 17-7PH (TH 1050 Condition) After Prior Creep Exposure.

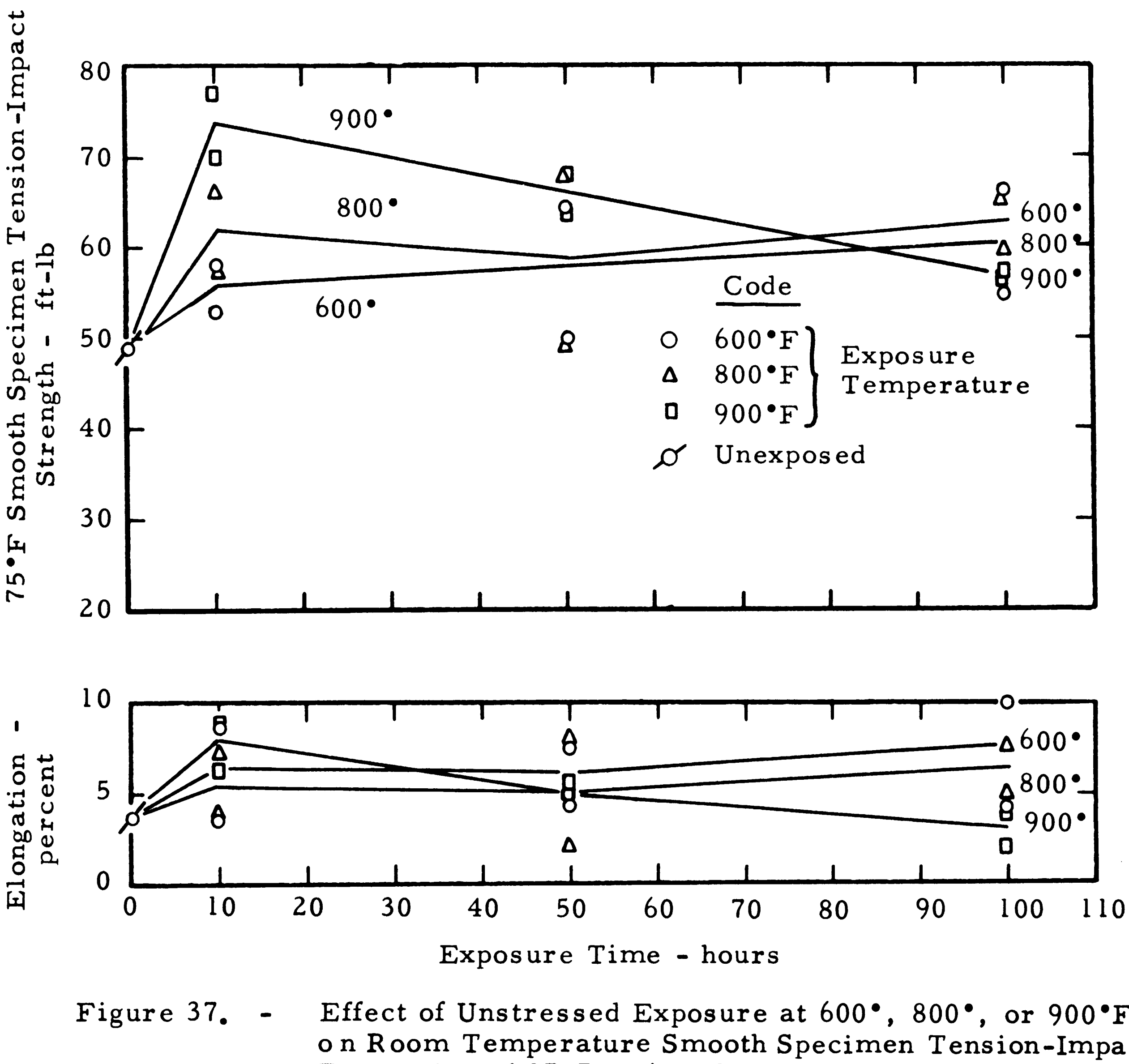


Figure 37. - Effect of Unstressed Exposure at 600°, 800°, or 900°F on Room Temperature Smooth Specimen Tension-Impact Properties of 17-7PH (TH 1050 Condition).

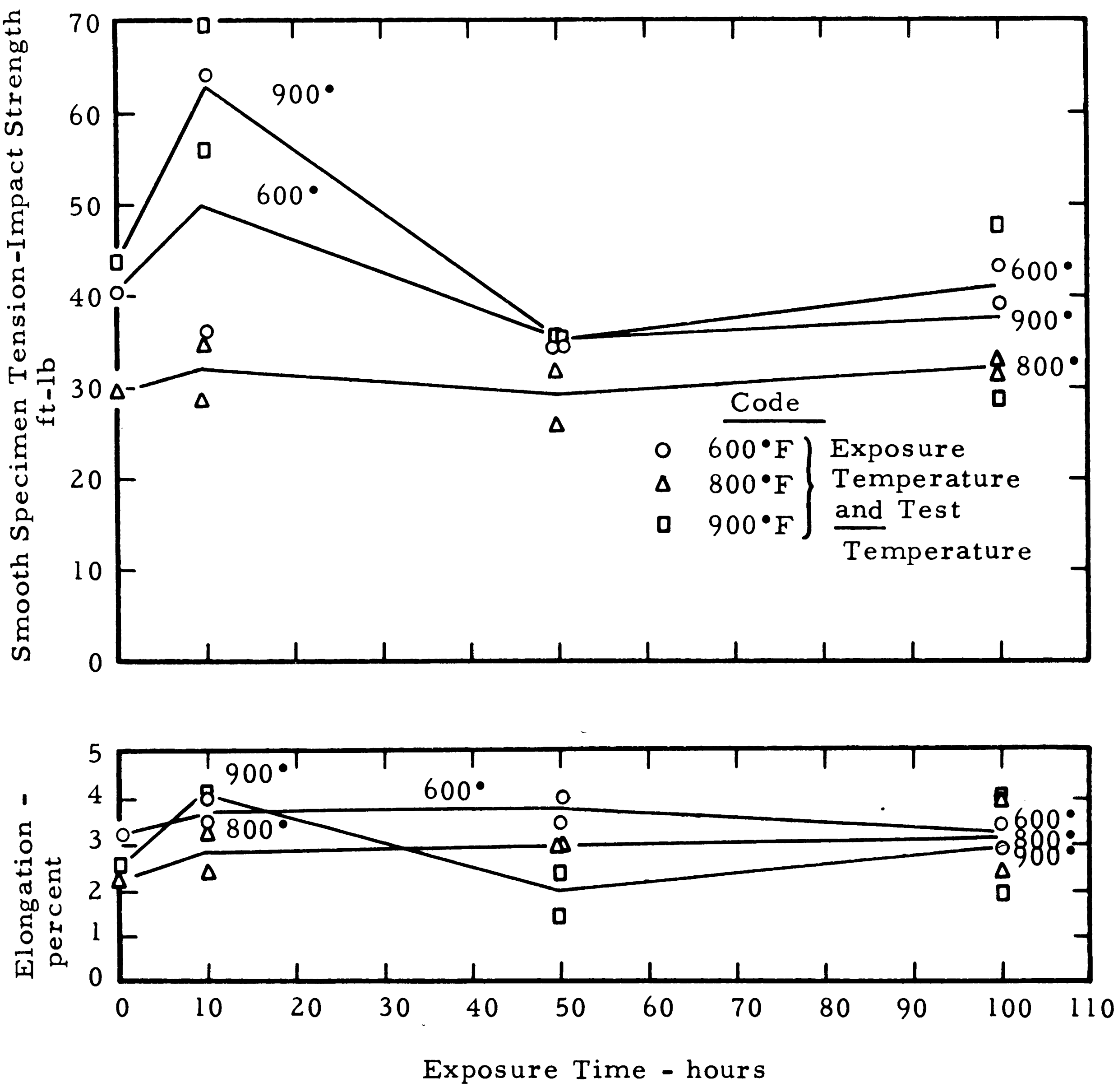


Figure 38. - Effect of Unstressed Exposure at 600°, 800°, or 900°F on Elevated Temperature Smooth Specimen Tension-Impact Properties of 17-7PH (TH 1050 Condition).

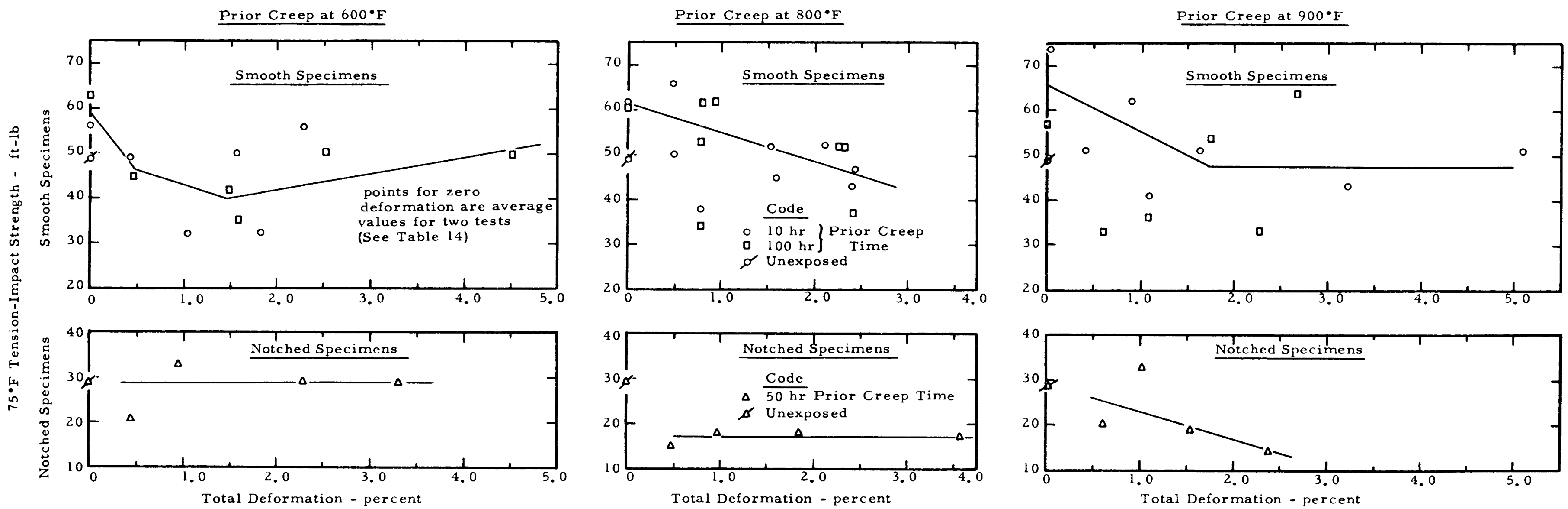


Figure 39. - Effect of Prior Creep Exposure at 600°, 800°, or 900°F on Smooth Specimen and Notched Specimen Tension-Impact Properties of 17-7PH (TH 1050 Condition) at Room Temperature.

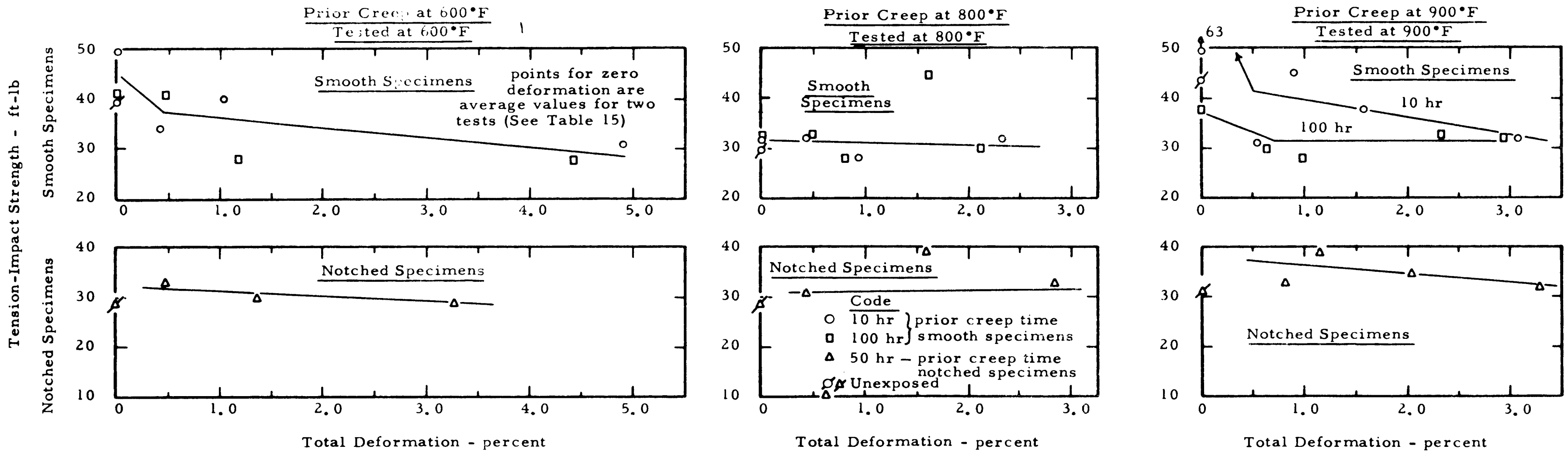


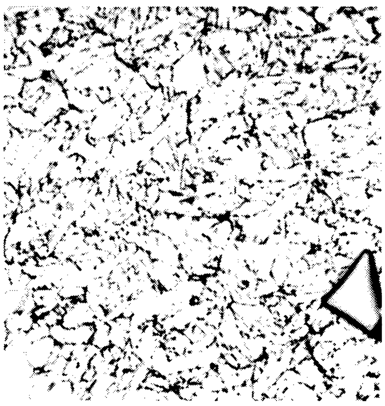
Figure 40. - Effect of Prior Creep Exposure at 600°, 800°, or 900°F on Smooth Specimen and Notched Specimen Tension-Impact Properties of 17-7PH (TH 1050 Condition) at Elevated Temperature.

Marble's Reagent X1000

Figure 41. - 17-7PH (TH 1050 Condition) As Treated

Marble's Reagent X1000

Figure 42. - 17-7PH (TH 1050 Condition) Exposed 100 Hours at 800°F (no stress)



No. 4 Etch X1000

Figure 43. - 17-7PH (TH 1050 Condition) Exposed 555 Hours at 800°F and 90,000 psi

Marble's Reagent X1000

Figure 44. - 17-7PH (TH 1050 Condition) Exposed 100 Hours at 900°F (no stress)

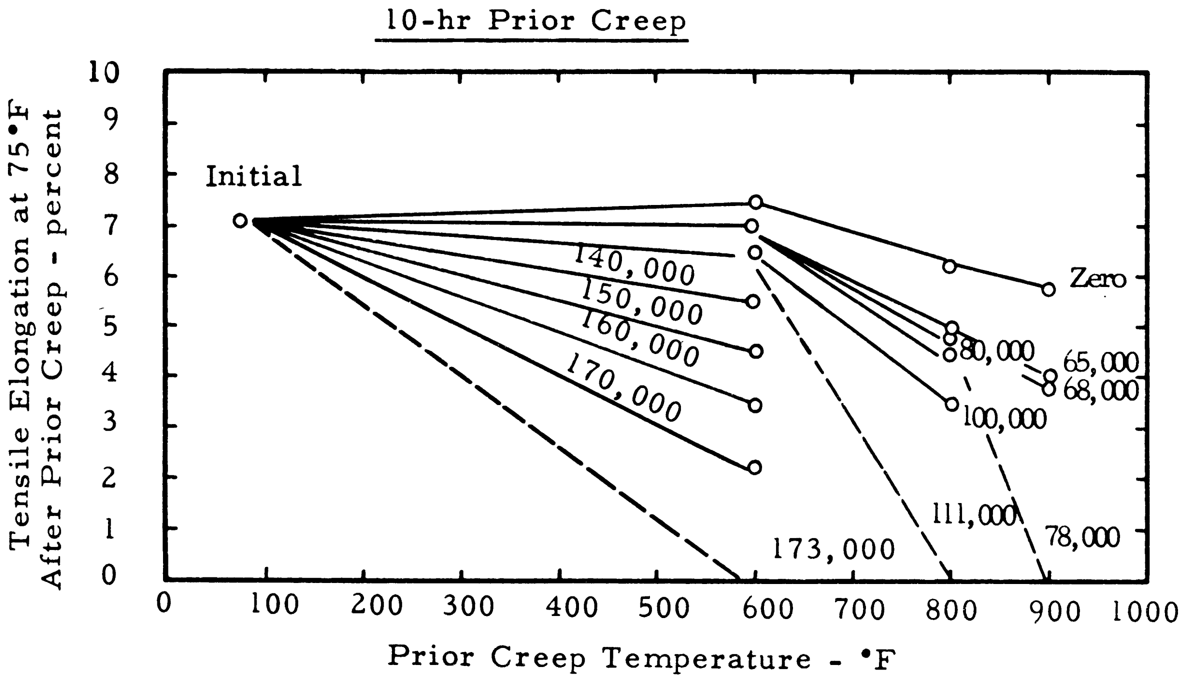


Figure 45. - Effect of Exposure Temperature and Stress on Subsequent Room Temperature Tensile Elongation of 17-7PH (TH 1050 Condition) Subjected to 10 Hours Prior Creep-Exposure.

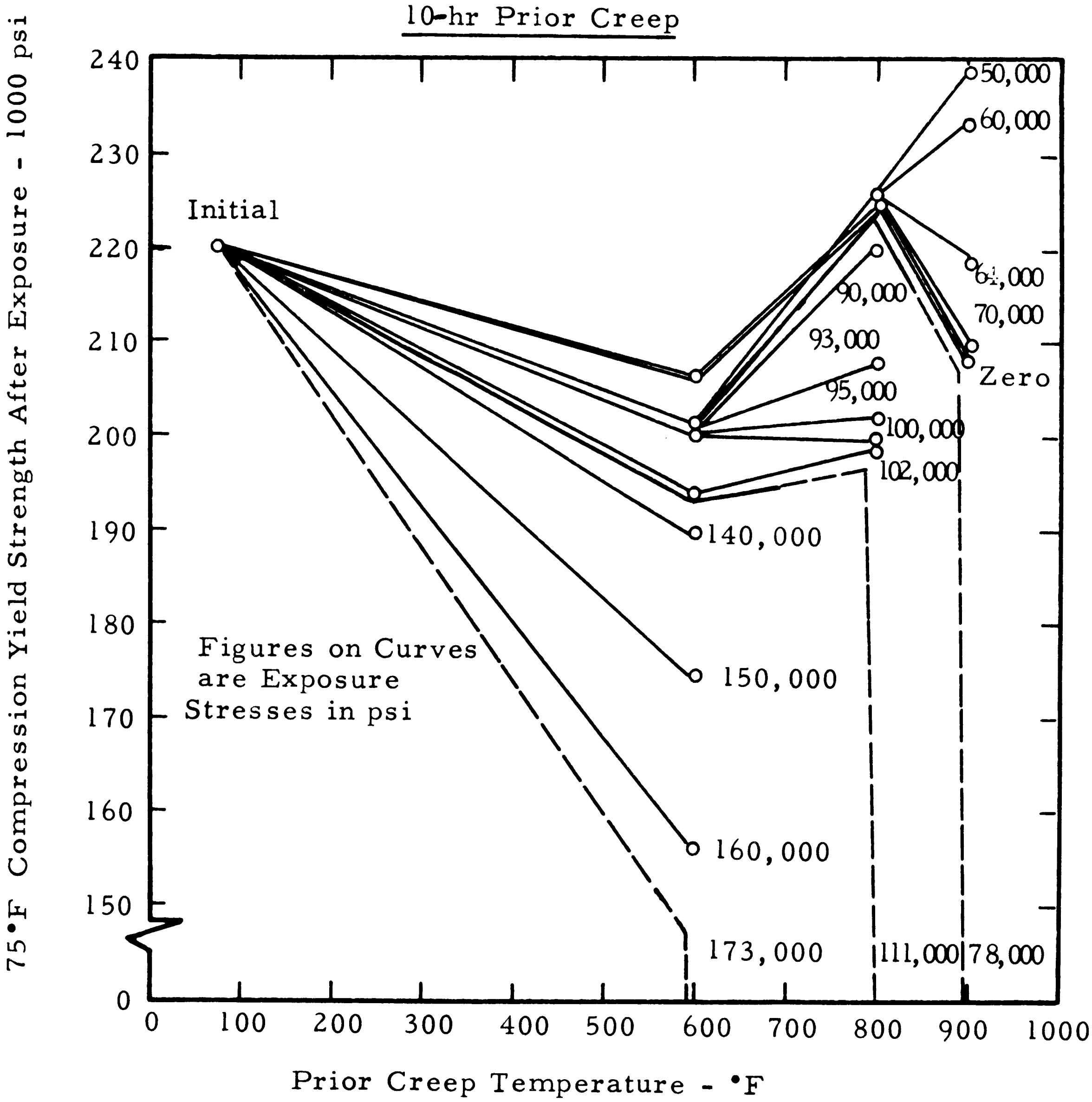


Figure 46. - Effect of Exposure Temperature and Stress on Subsequent Room Temperature Compression Yield Strength of 17-7PH (TH 1050 Condition) Subjected to 10 Hours Prior Creep-Exposure.