ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICH.

FIFTH PROGRESS REPORT

TO

MATERIALS LABORATORY

WRIGHT AIR DEVELOPMENT CENTER

ON

EFFECT OF PRIOR CREEP ON MECHANICAL PROPERTIES OF AIRCRAFT STRUCTURAL METALS

by

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Project 2498

Air Force Contract No. AF33(616)-3368
Task No. 73605

February 9, 1957

SUMMARY

This report covers progress under Contract AF33(616)-3368 for the period from October 21, 1956 to February 9, 1957 on a study of the effects of prior creep on the short-time mechanical properties of three aircraft structural metals. The materials under study include: 2024-T86 aluminum alloy; C-110M titanium alloy; and 17-7PH precipitation hardening stainless steel.

During the period covered by this report a draft report summarizing the work accomplished during the first year of the contract was written for submission to the Wright Air Development Center. In addition, a brief paper outlining the scope of the investigation and including some preliminary results was presented at the Florida Conference on High-Speed Aerodynamics and Structures held at Gainsville, Florida, January 22 - 24, 1957.

Work accomplished during this period after the completion of the summary report included the establishment of a sampling procedure for the C-110M titanium alloy, preliminary tensile tests of C-110M at room temperature and initial creep tests at 700° and 800°F for this material.

The investigation of the 17-7PH(TH 1050 condition) was continued to cover the effects of variable amounts of total deformation in 100 hours at 800° or 900°F on the subsequent room temperature tensile properties. The data indicate that increased amounts of total deformation up to 2.25 percent result in increased strengths. However, the principal strengthening effect comes from the exposure to temperature alone.

INTRODUCTION

This report, the fifth progress report issued under Air Force Contract No. AF33(616)-3368, covers the period from October 21, 1956 to February 9, 1957.

The purpose of the investigation is to study the effects of elevated temperature prior-creep exposure on the mechanical properties of three aircraft structural sheet alloys.

The materials and temperature ranged under investigation include:

1. Aluminum alloy 2024-T86 at 350°, 400°, and 500°F
2. Titanium alloy C-110M at 650°, 700°, and 800°F
3. Stainless steel 17-7PH(TH 1050 condition) at 600°, 800°, and 900°F

Both stressed and unstressed exposures are to be carried out for times of 10, 50, or 100 hours. The stressed exposures are to be carried out to 0.5, 1.0, 2.0, and 3.0 percent total deformation where practicable. The total deformation is defined as all deformation, elastic and plastic, occurring during the application of the load and during the creep of the specimen at the testing stress and temperature.

Following these specified exposures, the materials are to be evaluated with respect to the following properties at both room temperature and the temperature of prior creep exposure: short-time tensile properties; short-time compression properties; tension-impact strength; and hardness at room temperature. Metallurgical studies will be carried out where significant effects are noted to explain their cause.

The test stresses for the nominal exposure conditions are determined from curves of stress versus time for a given total deformation, established for each material at each testing temperature. Replicate exposure tests were run for many of the conditions in order to ensure generality of the results. The basis for comparison is to be the normal properties of the unexposed material established through 9 or 10 tests of samples chosen randomly from the various sheets of material.

The test materials were procured as approximately 0.064-inch thick sheets. The test direction for the aluminum and stainless steel was specified to be the direction crosswise to the sheet rolling direction, while the titanium alloy is to be tested parallel to the rolling direction. The choice of testing direction was determined by a desire to test each material in its weaker direction.

The aluminum alloy 2024-T86 was furnished by the manufacturer in the cold worked and artifically aged condition, while the titanium alloy C-110M was furnished as hot rolled and annealed. The stainless steel 17-7PH was treated to the TH1050 condition at the University. This treatment consists of aging first at 1400° and then at 1050°F.

In the initial contract the principal test effort was assigned to the evaluation of the aluminum alloy.

Test Material, Specimen Preparation, Test Equipment and Procedures

Inasmuch as the test materials, specimen preparation, equipment, and procedures have been previously discussed in progress reports as they have been developed, this material will not be repeated here. A complete discussion of these topics has been included in the First Summary Report to be issued shortly.

One new topic, that of the sampling procedure for the C-110M titanium alloy, will be discussed since it is outside the scope of the First Summary Report.

Sampling Procedure for C-110M

The sampling procedure for the C-110M titanium alloy was designed to permit the most economical utilization of the material consistent with the specification that it be tested parallel to the sheet rolling direction.

Three sheets were arbitrarily selected to be tested. The sheets chosen were all 90 inches long; two were 36 inches wide, and the third was 34 inches wide. The general sampling scheme for an individual sheet is shown in Figure 1.

Each sheet was divided into one-inch wide strips running the length of the sheet. For the initial tests of the unexposed properties, strips, 1, 5, 9, etc, as indicated in Figure 1, were subdivided to provide a repeating sampling pattern over both the width and length of the sheet. The remainder of the strips were reserved for blanks for the specimens to be subjected to exposure prior to testing. Over the 90-inch length of the sheet, four sections or quarters of length were laid out. One end was designated the "A" end and its subsections labeled AA and AB, while the other end was designated the "C" end and its subsections labeled CC and CD. An individual specimen is identified by a number sequence designating the sheet number, section number, and strip number.

RESULTS AND DISCUSSION

Tensile Tests of C-110M Titanium Alloy

Tensile tests at room temperature were completed on nine specimens of the C-110M titanium alloy. Three specimens each were tested from the three sheets arbitrarily selected for exposure tests on this material. The results of these tests are summarized in Table 1. Also included in this table are the manufacturer's reported properties for this heat.

The data indicate that the properties of the material are fairly consistent from sheet to sheet. The scatter in properties within individual sheets is about the same as the over-all scatter, with the exception that the yield strength values for sheet 1 are a trifle lower than the values from sheets 2 and 3.

Also included in Table 1 are the manufacturer's reported properties for this heat and the typical properties for this material as given in the Rem-Cru Data Sheet on C-110M dated November 1, 1955.

The manufacturer's reported properties for this heat show a slightly higher strength and lower ductility than those determined at the University of Michigan. In addition, the spread between the tensile and yield strength was slightly less than found in the tests at the University.

Both sets of actual test results for this particular heat of material appear to well exceed the typical values reported in the Product Data Sheet on C-110M. This increased strength was accompanied by no essential sacrifice of ductility.

Creep Tests of C-110M Titanium Alloy

Creep tests have been initiated on samples of the C-110M titanium alloy in order to determine the stresses necessary for the attainment of the desired total deformations in the time periods at the temperatures specified for stressed exposure tests. The temperatures of testing include 650°, 700°, and 800°F and total deformations from 0.5 to 3 percent are to be covered for 10, 50, or 100 hours.

Two tests have been completed to date at 800° and one test at 700°F. The data are summarized in Table 2. The stresses used so far appear to be within the range desired for the stressed exposure tests. The 10,000 psi test at 800°F showed a continually decreasing creep rate with time over the entire time of testing--some 300 hours. The 25,000 psi test at 800°F reached a steady creep rate at about 70 hours.

Stressed Exposure Tests of 17-7PH

Previous reports have contained the results of tests of the effects of stressed exposure to 2-percent total deformation in 100 hours at temperatures between 600° and 900°F on the subsequent room temperature tensile properties of 17-7PH(TH1050 condition). The tests indicated that such exposures resulted in increased tensile and yield strength, with the maximum effect occurring at about 800-850°F.

Some test results are now available covering exposure for 100 hours at 800° or 900°F to a range of deformations prior to room temperature tensile tests. These data are summarized in Table 3 and plotted in Figure 2.

The indicated effects are:

1. Exposure to temperature alone (zero deformation ordinate of Figure 2) increased tensile and yield strengths and reduced elongation.

2. A prior deformation of 0.5 percent apparently reduced the increase in strength arising from unstressed exposure.

3. The tensile and yield strengths were of the same order of magnitude and possibly increased with increasing prior deformation for deformations larger than 0.5 percent. It is difficult, however, to be sure of the trends and magnitude of the effects due to the erratic changes with increasing deformation indicated by the data.

4. Additional exposures of specimens with subsequent tests at room temperature seem necessary to check both the trends and the maximum and minimum as indicated by the apparently erratic properties obtained to date.

5. The data obtained to date indicate no consistent difference in tensile and yield strengths for stressed exposure at 800° and 900°F. Elongations, however, were consistently higher following exposure at 900°F.

TABLE 1

Tensile Test Data at Room Temperature for C110M Titanium Alloy

Spec. No.	Ult. Tensile (psi)	0.2% offset Yield Strength (psi)	Elongation (%/2 in.)	Reduction of Area (%)	Modulus $E \times 10^6$ psi/in./in.
1A-9T	145,000	140,000	22.0	35.2	16.8
1AB-17T	144,000	139,000	24.0	32.4	16.0
1C-13T	152,000	144,000	21.5	30.2	16.8
Average	147,000	141,000	23.5	32.6	16.5
2A-28T	146,000	142,000	20.5	32.0	16.9
2C-5T	146,000	144,000	22.3	29.6	16.8
2C-20T	147,000	143,000	21.7	31.6	16.4
Average	146,333	143,000	21.5	31.1	16.7
3A-13T	147,000	145,000	21.5	30.8	16.4
3A-34T	151,000	147,000	22.5	33.3	16.6
3C-20T	146,000	142,000	22.7	26.4	15.8
Average	148,000	144,667	22.2	30.1	16.3
Average - 9 tests	146,211	142,889	22.4	31.3	16.5
Manufacturers reported properties for this heat *	149,400	147,200	15.0	----	----
Manufacturers typical properties for this alloy**	130,000	120,000	15.0	32.0	---

* Heat No. A1172600

** Rem Cru Data Sheet, November 1, 1955

TABLE 2

Creep Test Data for C110M Titanium Alloy

Test Temp. (°F)	Spec. No.	Stress (psi)	Load. Def. (%)	Time to Reach Indicated Total Deformation 0.5%	1.0%	2.0%	3.0%
700	1C-5T	50,000	.36	28	107.5	220	a
800	1A-24T	25,000	.182	4	11	27.5	46.5
	2C-1T	10,000	.009	52.5	295.5	a	---

a - test discontinued before reaching the deformation.

TABLE 3

Effect of Prior Creep-Exposure on Tensile Properties
of 17-7PH (TH 1050 Conditions)

Nominal Exposure Conditions			Actual Exposure Conditions				Subsequent Room Temperature Tensile Properties				
Temp (°F)	Time (hr)	Total Def. (%)	Spec. No.	Time (hr)	Stress (psi)	Total Def. (%)	Ult. Tensile Strength (psi)	0.2% offset Yield Strength (psi)	Elongation (% /2 inches)	Reduction of Area (%)	Modulus E x 10^6 psi/in./in.
800	100	0.5	3P-T5	100.0	59,000	0.48	208,000	204,000	3.8	17.6	30.3
	100	1.0	3H-T5	100.0	70,000	0.89	220,000	215,000	3.5	14.0	32.1
	100	2.0	2S-T6	102.1	81,000	1.88	227,000	222,000	4.2	15.8	30.2
	100	2.0	3P-T1	102.6	81,000	2.12	232,000	229,000	3.5	12.1	29.9
	100	3.0	3L-T2	100.0	85,000	2.45	218,000	214,000	2.2	20.2	30.1
900	100	0.5	3G-T5	100.0	37,000	0.47	204,000	196,000	4.5	17.6	29.2
	100	1.0	3A-T4	100.0	46,000	0.95	228,000	220,000	4.5	14.4	30.1
	100	2.0	2R-T1	100.0	49,000	1.55	214,000	209,000	6.5	16.7	29.9
	100	2.0	3G-T2	100.0	50,000	2.04	224,000	219,000	4.0	15.2	29.7
	100	2.0	1Q-T22	100.1	50,000	2.33	235,000	230,000	4.0	13.1	30.0
	100	3.0	3Q-T4	100.0	52,000	2.30	221,000	219,000	5.0	14.9	31.0

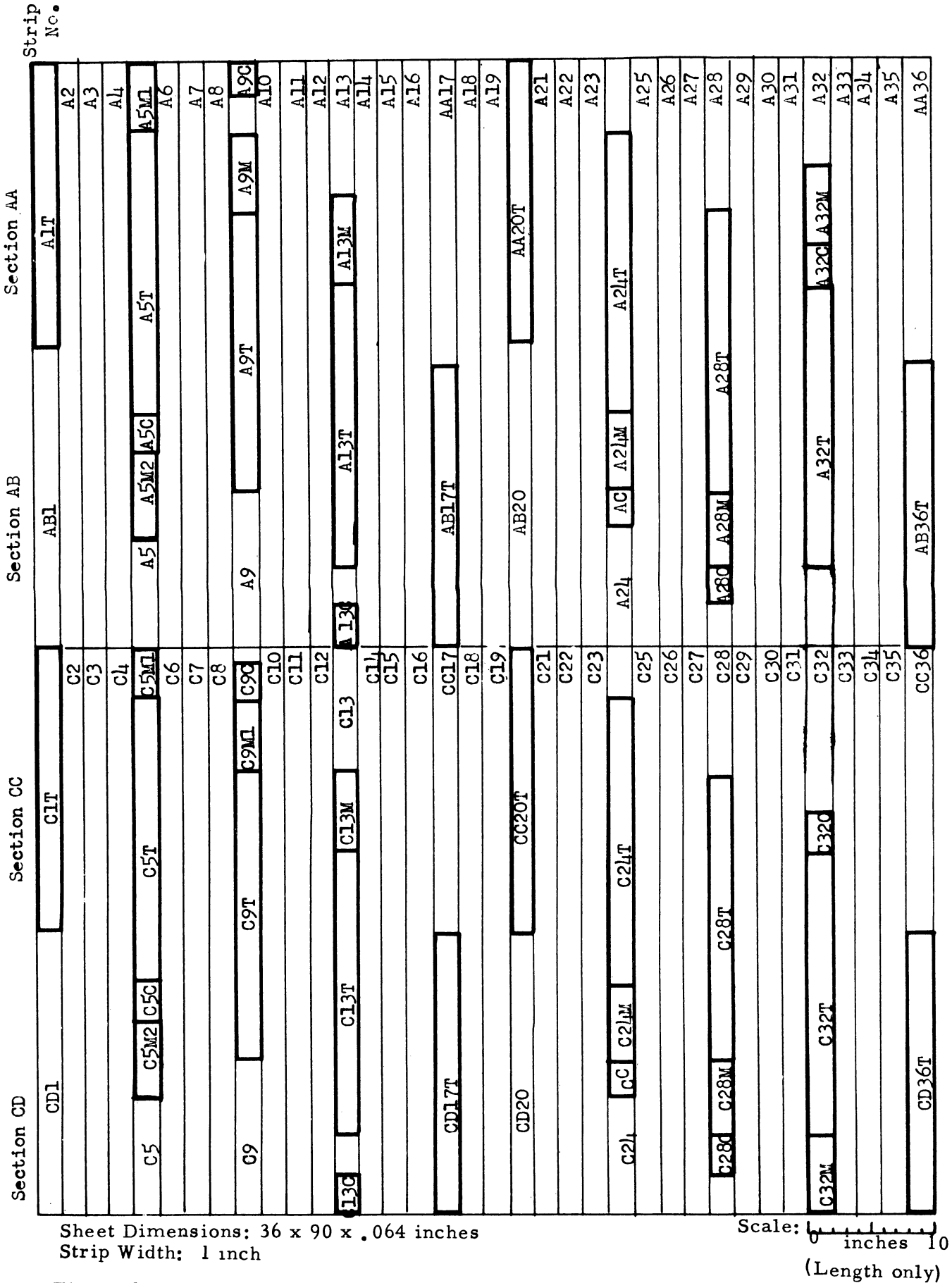

Figure 1, - Sampling Procedure for Sheets of C110M Titanium Alloy.

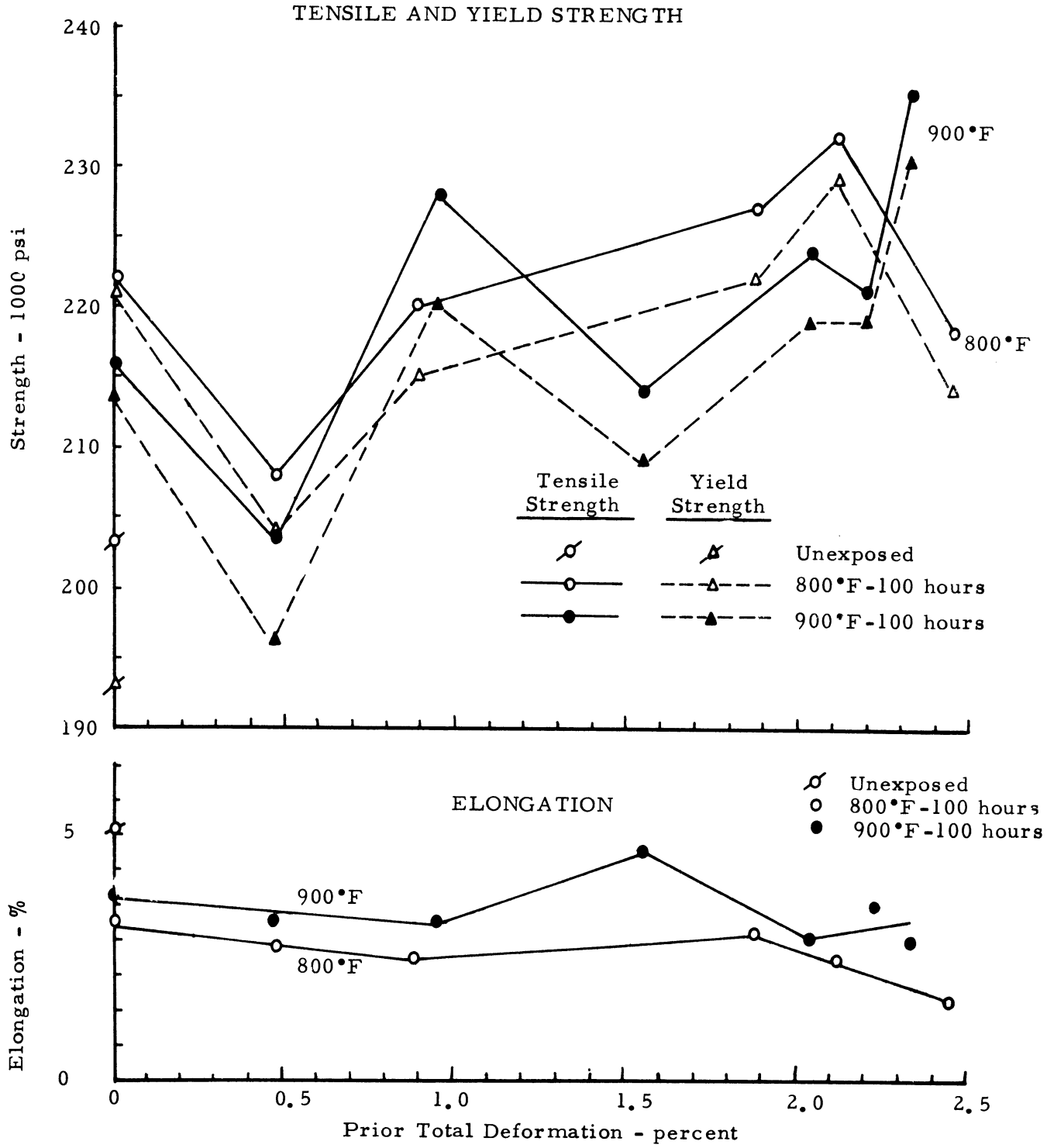

Figure 2. - Tensile Properties of 17-7PH(TH 1050) at Room Temperature After 100 Hours Prior Creep at 800° or 900°F.