SUMMARY

This report covers progress under Contract AF33(616)-3368, for the period from June 21, 1956 to August 20, 1956 on a study of the effects of prior creep on the short-time mechanical properties of three aircraft sheet metals. The materials under study are: 2024-T86 aluminum alloy; C110M titanium alloy; and 17-7PH (TH1050) precipitation hardening stainless steel.

Tests of stressed exposure of 17-7PH to give two percent total deformation in 100 hours in the temperature range from 600° to 900°F indicate that the tensile and yield strengths at room temperature are increased over those for the material given unstressed exposure for the same time period. The material given unstressed exposure had previously been shown to be increased in strength over the as-treated condition. The effect of stressed exposure appears to be most marked at 800° to 850°F.

Tests have been completed of the scatter in room temperature tensile, compression, and tension-impact properties of the 2024-T86 aluminum alloy. In addition, room temperature tensile properties have been determined for specimens previously held for times up to 100 hours at temperatures between 350° and 500°F. The results indicate that the strength decreased as either the time or temperature of exposure was increased.

INTRODUCTION

This report, the third bi-monthly progress report to be issued under Air Force Contract No. AF33(616)-3368, covers the period from June 21, 1956 to August 20, 1956.

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

The materials under investigation are the following:

1. An aluminum alloy, 2024-T86, from 350 to 500°F
2. A titanium alloy, Rem Cru C110M, from 650 to 800°F
3. A precipitation hardening stainless steel, Armco 17-7PH (TH1050) from 600° to 900°F.

The exposures are to be carried out both stressed and unstressed for times up to 100 hours. The range of deformations to be considered for stressed exposure tests is from 0.5 percent to 3.0 percent.

Following the specified exposures the materials are to be evaluated with respect to the following properties at both room temperature and the temperature of exposure; short-time tensile properties, tension-impact strength, short-time compression properties, and hardness.

The net change in these properties with respect to the properties of the as-treated materials is considered a measure of the stability of the material and an aid in defining the operating limits for design purposes. Where significant effects are noted, metallographic studies will be carried out.

TESTING PROGRAM

The present investigation is a study of the effects of stressed or unstressed exposure to time and temperature on the mechanical properties of three aircraft structural sheet metals. In the Introduction it was noted that time periods up to one hundred hours and total deformations up to three percent were to be studied.

Total deformation is considered to be all deformation occurring during the application of the load and during creep of the specimen at the testing temperature and stress. Because of the large number of tests contemplated to be run, it was decided to fix the time, stress, and temperature of testing. Consequently, one must accept the deformation obtained, realizing that it might vary somewhat from the nominally specified value. In order to minimize such variations, the testing stresses are determined from curves of stress versus time for a given total deformation that are established for each material at each testing temperature.

Therefore, the over-all testing program included two preliminary steps with each material before the exposure tests could be run or evaluated properly. First, the scatter in properties of the as-treated material must be determined at each testing temperature, and second, the total deformation curves must be established.

Three primary testing temperatures were selected for each material. They are the following:

a.	2024-T86	350°, 400°, 500°F
b.	C110M	650°, 700°, 800°F
c.	17-7PH	600°, 800°, 900°F

The exposure time periods were fixed at 10, 50, and 100 hours, and the exposures were to be carried out at zero stress and at the stresses resulting in

0.5, 1.0, 2.0, and 3.0 percent total deformation in the three time intervals previously mentioned.

The aluminum and titanium alloys are to be tested in the conditions as received from the manufacturers. The C110M titanium alloy is furnished as hot-rolled and annealed and the 2024-T86 aluminum alloy is furnished in the cold worked and artificially aged condition. The stainless steel, 17-7PH, is to be tested in the TH 1050 condition, a double aging treatment carried out at 1400° and then 1050°F, which is to be performed at the University.

All the materials are to be procured as approximately 0.064-inch thick sheet. The aluminum and the stainless steel alloys are to be tested in the direction crosswise to the sheet rolling direction, while the titanium alloy is to be tested in the direction parallel to the rolling direction.

After the completion of the exposures the following tests are to be carried out:

1. Tensile tests at both room temperature and the exposure temperature
2. Compression tests at the same temperatures
3. Tension-impact tests at the same temperatures
4. Hardness tests at room temperature. Where deemed useful, metallographic examination will be made.

Correlation of the data will be made with respect to the conditions of exposure, the basis of comparison to be the properties of the unexposed material. In addition to the establishment of the scatter of the normal properties of each material, care will be taken that the specimens for exposure testing will be taken randomly from the test material.

The current contract contemplates emphasis of the testing effort to be placed on the evaluation of the aluminum alloy.

In the case of the stainless steel, a survey will be made on the effects of prior creep to two percent total deformation in 100 hours on the room temperature tensile properties. These exposures will be carried out at 50°F temperature intervals between 600° and 900°F.

TEST MATERIALS

To date, the aluminum alloy and the stainless steel have been received, while the titanium alloy remains on order with delivery promised about September 1, 1956. The specifications of the materials follow:

2024-T86 Aluminum Alloy

Nineteen Al-clad sheets of the aluminum alloy, 2024-T86, were received from the Kaiser Aluminum and Chemical Corporation. The sheet dimensions were 0.065-inches thick by 48 inches wide by 72 inches long.

Although the heat number of the material was not specified, a certified inspection report was received from the producer stating that the composition of the material shipped to the University was within the nominal limits for this material. These are the following:

Element	Range (percent)
Copper	3.8-4.9
Manganese	0.3-0.9
Magnesium	1.2-1.8
Silicon	0.50 Max
Iron	0.50 Max
Chromium	0.25 Max
Zinc	0.10 Max
Others	0.15 Max
Aluminum	Balance

The T86 condition of this material is a cold working and aging treatment carried out by the producer. It consists of the following steps:

1. Solution treatment: 910-930°F, quench in cold water
2. Cold work: approximately 5.5 percent reduction
3. Aged: 370-380°F

Armco 17-7PH Stainless Steel

Sixteen sheets of the 17-7PH precipitation hardening stainless steel were received from the Armco Steel Corporation. 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 this alloy. These are the following:

Element	Nominal (percent)	Actual (heat 55651)
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- 7.75	7.25
Aluminum	0.75- 1.50	1.28
Iron	Balance	Balance

The TH 1050 condition was achieved by using the following treatment:

1. Condition A material heated in air for 1-1/2 hours at 1400°F
2. Air Cool 10 minutes to approximately 500°F
3. Quench in 60°F water
4. Hold 8-12 hours at 60°F
5. Age 1-1/2 hours at 1050°F, then air cool.

This treatment is a refinement of that specified by Armco. It was adopted to insure a closer degree of control and uniformity than required by the usual commercial treatment specifications.

C110M Titanium Alloy

The C110M titanium alloy remains on order from the Rem-Cru Titanium Corporation. The alloy is a binary containing from 7-9 percent manganese, the balance being titanium. The material is to be procured in the annealed condition as 0.064-inch thick sheet.

SPECIMEN PREPARATION

A sampling procedure was set up in order to randomize the results with respect to both sheet-to-sheet variations in properties and the variations within an individual sheet. Because of the different as-received sheet sizes of the aluminum and stainless steel alloys, the physical details of the sampling schemes differed although the principle was the same for each.

Three sheets were arbitrarily selected for initial tests on scatter of tensile properties and on creep characteristics. Each sheet was divided into panels approximately 5 inches wide, and the panels themselves subdivided so that the 1-inch wide specimen blanks represented various positions across the width of the sheets. The panels represented sampling over the length of the sheet. Each specimen was labeled with a code number indicating sheet number, panel number, and specimen position within the panel.

The sheet and panels sampling schemes for the aluminum alloy are indicated in Figure 1 and those for the 17-7PH alloy are indicated in Figures 2 and 3. Reference to these diagrams permits the establishment of the location of any of the test specimens cited in the section on Results and Discussion.

The dimensions of the various test specimens are indicated in Figure 4. The specimens were designed so that they could be cut from creep specimens following the desired exposure.

In order that the practice for machining the subsequent test specimens be uniform, the creep or exposure specimens are made with a gage section width of 0.530 inches. Following exposures to creep, either the edges are ground to the 0.500-inch width of the tensile test specimen or the tension-impact or compression specimen is machined. In this way the final tests measure the properties of the sheet material itself and not the particular specimen's edge effects.

TEST EQUIPMENT

Discussions of the equipment used for creep-exposure tests, tensile tests, and tension-impact tests were included in the first two progress reports. These will not be repeated here. In the period covered by this report the compression testing equipment was completed and operated for room-temperature tests of the aluminum alloy. In addition, the furnace for elevated temperature testing was completed and studies of its temperature distribution in conjunction with the various testing fixtures were initiated. These studies are not sufficiently complete to warrant discussion at the present time.

Compression-Test Equipment

The compression-test fixture was adapted from that of Flanigan et al (ref. 1) and is shown in Figure 5. The fixture consists of a steel base, a pair of adjustable guide blocks, and a loading ram. The base and guide blocks were made from H-40 steel and the loading ram from 17-22 AV steel hardened to Rockwell "C" 40. The base of the fixture is the stationary loading surface while the ram provides the compression force as it is actuated by the cross head of a Baldwin Southwark Hydraulic Tensile Test Machine. The guide blocks constrain the specimen from lateral buckling during the test. A pair of set screws provides the means for adjustment of the moveable guide block.

The extension of the specimen is transmitted by a rod and tube type of extensometer which is attached to the edges of the specimen. The extensometer screws are made of N-155 heat-resistant alloy with tungsten carbide tips set into the points of the screws. The remainder of the fixture is made of 18-8 stainless steel. Figure 6 shows the extensometer assembly fastened to a compression specimen. An O. S. Peters microformer is attached to the bottom part of the extensometer. In this manner a stress-strain curve can be recorded automatically for a compression test in much the same was as it is for a tensile test.

The complete compression test assembly is shown in Figure 7. The fixture is placed on a pedestal having a groove to accommodate the extensometer rod and tube assembly.

TEST PROCEDURES

Compression Test Procedure

The operation of a compression test at room temperature is relatively simple. Following the measurement of the test specimen, the extensometer is attached using a gage section of about 1.7 inches. The holding screws are tightened until it is certain that the tungsten carbide tips have achieved a tight grip on the specimen. A light coating of Molykote lubricant is placed on the surface of the specimen and the entire assembly is placed in the opened compression fixture. The top of the fixture is screwed down, the guide block is tightened with a light pressure on the set screws and the loading ram is then set in place. The entire assembly on top of its pedestal is then placed under the cross head of the tensile machine. Finally, the microformer strain follower is attached to the rod and tube and the recording system is zeroed. The load is applied at the tensile machine setting that gives a strain rate of 0.005 inches per inch per minute in a tensile test. (This was necessary since the strain pacer cannot be operated in reverse). The load is applied until a definite yielding can be observed in the recorder trace. From the recorder trace, the compressive modulus and 0.2 percent offset yield strength are determined.

RESULTS AND DISCUSSION

Stressed Exposure Tests---17-7PH Alloy

As indicated in the section on Testing Program (Page 2), the initial phase of the evaluation of the 17-7PH alloy consists of a survey of the effect of stressed exposure to two percent total deformation in 100 hours on the room temperature tensile properties. The temperatures considered are in 50°F increments from 600° to 900°F.

Results obtained to date from this study are summarized in Table 1. Also included in Table 1 are the results of tests of the effects of 100 hours unstressed exposure at 600°, 800°, and 900°F. Plots of tensile strength, yield strength, and elongation versus exposure temperature for both the stressed and unstressed conditions are presented in Figure 8. The duplicate tests for each exposure condition have not all been completed, however, the available results indicate that the effect of stressed exposure is to further increase the tensile and yield strength over the levels produced by unstressed exposure. As Figure 8 indicates, the maximum effects for both stressed and unstressed exposure occur in the neighborhood of 800-850°F.

Based on the average of two tests, 100 hours unstressed exposure at 600°F resulted in little change in room-temperature strength and ductility. Exposure at 800°F resulted in a significant increase in the strength, while the 900°F exposure resulted in a slight drop in strength from the 800°F values.

Stress exposure to two percent total deformation in 100 hours in the same temperature range resulted in increased room-temperature strength for each exposure temperature. The maximum increase in tensile strength for unstressed exposure over the as-treated condition was approximately 19,000 psi while the maximum increase found to date for stressed exposure was about 32,000 psi.

These changes represented an increase in the order of 10-15 percent over the as-treated value. Accompanying the increased tensile and yield strengths was a decrease in the ductility as measured by the elongation. At the lower end of the range of exposure temperature the stressed samples showed lower ductilities than the unstressed, while the values tended to converge for exposures at 800° and 900°F.

Since the data are not complete, especially at the lower temperatures of stressed exposure, further detailed discussion of the results does not appear to be warranted. One effect should be noted. That is, the effect of exposure seems to reduce the spread between the tensile and yield strengths. Furthermore, this effect is more marked for the stressed conditions than for the unstressed conditions. For the as-treated condition the spread between the tensile and yield strength represents about 5 percent of the tensile strength, while for the unstressed exposures the spread is reduced to 3 percent of the tensile strength and for the stressed condition the value is of the order of only one percent of the tensile strength. Thus, at higher levels of tensile strength the relative spread between the tensile and yield strength decreases with increasing severity of exposure conditions.

Tensile-Test Results---2024-T86 Alloy

The results of tensile tests at room temperature on the as-treated condition of the 2024-T86 aluminum alloy are presented in Table 2. Ten specimens were tested, representing material from varying locations within three sheets. The purpose of these tests was to establish a base condition for comparison of the effects of exposure.

The results show close agreement in properties for all the test specimens. The variation in properties between sheets is negligible as are the variations within the sheets themselves.

Compression Test Results---2024-T86 Alloy

The results of 10 compression tests run at room temperature on samples of the 2024-T86 aluminum alloy are presented in Table 3. The data reported are the 0.2 percent offset yield strength and the elastic modulus as computed from the slope of the stress-strain curve. The values for compressive yield strength show a bit more scatter than do the values for tension yield strength reported above and are almost 5000 psi higher. The modulus values show fairly good agreement, both within themselves and in comparison with the tension modulus.

Tension-Impact Test Results---2024-T86 Alloy

The results of 10 tension-impact tests at room temperature on the 2024-T86 aluminum alloy are reported in Table 4. The results show an average absorption of energy upon fracture of 18.2 ft-lbs.

Exposure Test Results---2024-T86 Alloy

The results of eighteen tests of the effects of unstressed exposure to elevated temperature on the room temperature tensile properties of the 2024-T86 aluminum alloy are reported in Table 5. The exposures were run for 10, 50, and 100 hours at temperatures of 350°, 400°, and 500°F. Two specimens from different sheets were run for each exposure condition. Plots of tensile and yield strength versus exposure time for each temperature are presented in Figure 9. These data show that increasing time and temperature of exposure resulted in a decrease in strength. As Table 5 indicates, the effect of exposure conditions on the ductility properties is slight and does not appear to be significant.

All conditions of exposure resulted in some decrease in strength although the decrease was moderate for times up to 100 hours at 350°F. Ten hours at 400°F had a slightly greater adverse effect than did 100 hours at 350°F, and the strength fell off rapidly for further increases in time and temperature. The most severe condition of exposure, 100 hours at 500°F, resulted in a loss in strength of over 30 percent from the as-treated value, however, 50 hours at this temperature did not appear to have any greater effect than did 10 hours which resulted in a loss of some 18 percent of the as-treated strength.

Creep-Rupture Tests---2024-T86 Alloy

Creep-rupture tests at 350°, 400°, and 500°F are in progress on samples of the 2024-T86 aluminum alloy. The purpose of these tests is to establish curves of stress versus time to reach the total deformations required for the stressed exposure tests of this material. The data obtained to date are summarized in Table 6 and plotted in Figure 10.

Most of the tests have been run with the extensometer collars mounted on the shoulders of the specimen. Mounting the collars directly on the gage section may not be too practical because of the danger of inadvertently notching the specimen due to its softness. In one case premature failure occurred at a collar mounted on the gage section.

As discussed in the Second Progress Report, (ref. 2), the mounting of the extensometer collars at the shanks of the specimen necessitates the introduction of a correction factor to account for the deformation of the fillets and shanks. This factor is calculated from the specimen geometry and a curve of stress versus minimum creep expressed in arbitrary units. The calculation of the effective gage length was discussed in detail in the Second Progress Report and will not be repeated here.

The data were complete enough to permit calculation of the effective gage length for creep of 2024-T86 at 500°F. This was found to be the shoulder-to shoulder distance minus 0.90 inches. The total deformations calculated with this factor are included in Table 6 and plotted in Figure 10. The data for 350° and 400°F are not yet sufficiently complete to permit calculation of the effective gage lengths for creep at these temperatures.

The curves of stress versus rupture time for this material are consistent and appear to be in line with the uniformity in properties of the material as revealed by the room-temperature tests of the short-time mechanical properties. The values of elongation on rupture are low at 350° and 400°F and it may prove to be difficult to produce the total deformations of up to 3 percent desired for the stressed exposure tests.

FUTURE WORK

During the next two-month period the tests of mechanical properties will be expanded to include tests at elevated temperature. This will include scatter tests of the normal properties at elevated temperatures and also the tests on samples given exposures.

The program of creep-rupture testing of 2024-T86 will be continued until the total deformation curves covering desired stressed exposure conditions have been established.

The creep-exposure tests of 17-7PH to give 2 percent total deformation in 100 hours will be completed. Following this, the emphasis of stressed exposure tests will be shifted to the 2024-T86 aluminum alloy.

REFERENCES

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

2. Gluck, Voorhees, Freeman, "Second Progress Report to Materials Laboratory, WADC" on Contract AF33(616)-3368, "Effect of Prior Creep on Mechanical Properties of Aircraft Structural Metals," page 15-17.

Table 1

Effect of Stressed or Unstressed Exposure on Room Temperature Tensile Properties of

17-7PH Alloy (TH 1050 Condition)

	Exposure Conditions				Room Temperature Tensile Properties					
Spec. Loc.	Temp (°F)	Stress (psi)	Time (hr)	Total Def. (%)	Ult. Tensile (psi)	0.2% offset Yield (psi)	Elongation (% - 2 in)	Reduction of Area (%)	E (10^6 psi)	Hardness R"C"
Average Properties - 3 sheets - As treated					203,100	193,050	7.1	18.2	28.6	43.7
2N-T4	600	none	100.0	none	192,500	184,200	8.0	18.4	29.4	42.5
3A-T1	"	"	"	"	212,000	206,000	7.5	19.4	28.8	45.8
			Average		202,250	195,100	7.8	18.9	29.1	44.2
2N-T1	600	157,000	100.5	1.89	223,000	(223,000)	1.5	13.7	29.4	45.3
							2.0	8.6	30.3	
*2E-T5	"	125,000	1893.0	0.95	231,000	230,000	3.5	13.9	30.6	
2S-T3	650	137,000	105.0	1.87	215,000	215,000	2.5	12.5	30.4	
2R-T6	700	118,000	100.2	1.82	211,000	210,000	4.0	17.7	29.6	42.8
*2R-T2	"	120,000	100.1	2.54	219,000	218,000	2.2	13.7	30.6	
2J-T5	750	101,000	100.0	1.94	222,000	220,000	3.0	17.0	29.7	44.2
3B-T3	"	"	"	1.62	218,000	217,000	4.5	16.7	30.0	
			Average	1.78	220,000	218,500	3.7	16.3	29.8	
3G-T6	800	none	100.0	none	222,000	216,000	4.0	17.9	29.8	47.4
2N-T2	"	"	"	"	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
3P-T1	800	81,000	102.6	2.12	232,000	229,000	3.5	12.1	29.9	46.7
2S-T6	"	"	102.1	1.88	227,000	222,000	4.2	15.8	30.2	46.7
			Average	2.00	229,500	225,500	3.8	14.0	30.1	46.7
2R-T5	850	66,000	100.0	1.99	235,000	230,000	5.0	13.4	30.8	
3P-T6	900	none	100.0	none	222,000	215,000	4.5	8.4	30.4	46.2
2N-T5	"	"	"	"	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
3A-T4	"	46,000	100.0	0.95	228,000	220,000	4.5	14.4	30.1	46.0
3G-T2	"	50,000	"	2.04	224,000	219,000	4.0	15.2	29.7	

* Data included for comparative purposes only; test conditions not otherwise applicable.

Table 2

Room Temperature Tensile Test Data

2024-T86 Alloy

Spec. Loc.	Ult. Tensile (psi)	0.2% offset Yield (psi)	Elongation (% - 2 in)	Reduction of Area (%)	$E \times 10^6$ psi	Hardness R"B"
2P-T5	75,000	70,100	10.2	12.9	10.7	82.5
2C-T2	75,800	70,900	7.2	12.7	10.9	82.0
2J-T3	76,100	70,800	8.0	8.9	11.0	79.7
Average	75,633	70,600	8.5	11.5	10.9	81.4
3E-T1	74,500	69,400	8.0	19.0	10.4	79.5
3L-T3	75,400	70,800	7.2	13.6	11.3	79.1
3L-T5	76,000	70,600	6.2	8.9	11.0	80.8
3E-T2	76,400	70,600	7.5	11.3	10.6	80.0
Average	75,575	70,350	7.2	13.2	10.8	79.8
4A-T5	75,200	70,000	8.0	8.6	10.7	79.9
4M-T3	77,500	72,000	7.5	10.6	10.9	78.9
4G-T2	75,000	70,400	8.0	12.2	10.7	80.8
Average	75,900	70,800	7.8	10.4	10.7	79.9
Average - 10 tests	75,690	70,560	7.8	11.9	10.8	80.3

Table 3

Room Temperature Compression Test Data

2024-T86 Alloy

Spec. Loc.	0.2% offset Yield Strength (psi)	Modulus E x 10^6
2P-C4	74,100	10.7
2C-C1	77,800	10.2
2J-C4	76,000	10.5
2J-C3	73,000	10.2
Average	75,250	10.4
3E-C1	77,800	10.6
3E-C4	75,800	10.4
3L-C4	79,600	11.1
Average	77,730	10.7
4M-C3	69,200	10.6
4A-C2	72,600	10.1
4G-C3	76,100	10.1
Average	72,630	10.3
Average - 10 tests	75,200	10.4

Table 4

Room Temperature Tension-Impact Test Data

2024-T86 Alloy

Spec. Loc.	Energy Absorbed (ft-lb)	Elongation (%)	Reduction of Area (%)
2C-M22	20	7.5	7.0
2J-M2	19	6.5	13.7
2P-M22	16	5.5	9.3
Average	18.3	6.5	10.0
3E-M2	18	6.5	12.4
3E-M44	21	5.0	11.7
3L-M4	18	5.8	16.3
Average	19.0	5.8	13.4
4A-M2	20	4.5	11.6
4G-M22	14	4.0	6.2
4G-M4	20	7.5	13.7
4M-M4	16	5.2	9.2
Average	17.5	5.3	10.2
Average - 10 tests	18.2	5.8	11.2

Table 5

Effect of Unstressed Exposure on Room Temperature Tensile Properties

2024-T86 Alloy

Temp °F	Time hr	Spec. No.	Ult. Tensile (psi)	0.2% offset Yield (psi)	Elongation (% - 2 in.)	Reduction of Area (%)	$E \times 10^6$ psi
350	10.0	2J-T1	74,900	69,000	7.5	9.2	10.9
	10.0	4A-T2	75,400	69,500	8.2	13.8	10.1
			75,150	69,250	7.8	11.8	10.5
	50.0	2P-T1	73,300	66,100	7.5	9.9	11.0
	50.0	4G-T3	74,500	65,900	7.5	8.1	10.8
			73,900	66,000	7.5	9.0	10.9
	100.0	2P-T3	71,600	63,500	7.5	11.1	10.8
	100.0	4M-T1	71,500	63,200	7.0	11.0	10.8
			71,550	63,350	7.2	11.0	10.8
400	10.0	2P-T2	71,600	63,900	6.5	15.3	11.0
	10.0	4G-T1	71,200	63,300	6.5	12.3	11.0
			71,400	63,600	6.5	13.8	11.0
	50.0	3E-T4	67,000	56,900	7.5	12.9	11.0
	50.0	4M-T2	66,600	56,500	7.5	11.4	11.3
			66,800	56,700	7.5	12.2	11.2
	100.0	2C-T3	64,500	53,800	7.5	12.1	10.7
	100.0	3L-T1	64,300	53,800	7.5	13.0	11.3
			64,400	53,800	7.5	12.6	11.0

Table 5 (continued)

Temp °F	Time hr	Spec. No.	Ult. Tensile (psi)	0.2% offset Yield (psi)	Elongation (% - 2 in.)	Reduction of Area (%)	$E \times 10^6$ psi
500	10.0	2P-T11	62,500	50,100	7.0	10.0	10.6
	10.0	3E-T3	61,500	49,300	7.0	12.6	10.4
			62,000	49,700	7.0	11.3	10.5
	50.0	2C-T4	62,400	50,300	7.5	10.0	10.8
	50.0	4G-T4	59,900	48,500	7.0	11.7	10.6
			61,150	49,400	7.2	10.8	10.7
	100.0	3L-T4	51,500	37,000	7.0	13.0	10.9
	100.0	4A-T3	52,100	38,800	6.5	13.6	10.6
			51,800	37,900	6.8	13.3	10.8

Table 6

Rupture and Total Deformation Data

2024-T86 Alloy

Spec. Loc.	Test Temp (°F)	Stress (psi)	Rupture Time (hours)	Elongation (% - 1 inch)	Reduction of Area (%)	Loading Def (%)	Time to Reach Indicated Total Deformation (hours) 0.5%	1.0%	2.0%	3.0%
3L-T11	350	45,000	24.5	4.2	9.2					
4A-T4		40,000	in progress							
2C-T1		35,000	481.2	2.8	4.1					
2P-T4	400	40,000	6.6	7.0	14.4					
4M-T11		35,000	28.1	2.0	1.6					
2C-T5		30,000	83.1	4.0	6.6					
3E-T11		30,000	(51.5)a	1.5	4.6					
2J-T5		25,000	in progress							
4G-T5		20,000	in progress							
3L-T2	500	25,000	1.7	7.0	20.4	.34	.06	.51	1.05	1.5
4G-T11		20,000	11+2	11.0	27.4	.27	.60	2.60	----	---
2J-T11		19,000	22.8	9.2	13.1	.22	2.20	7.90	----	---
2C-T11		15,000	113.1	9.2	16.3	.16	11.10	42.40	----	---
4A-T11		10,000	in progress							

a) premature failure at collar; collar on gage section in this instance

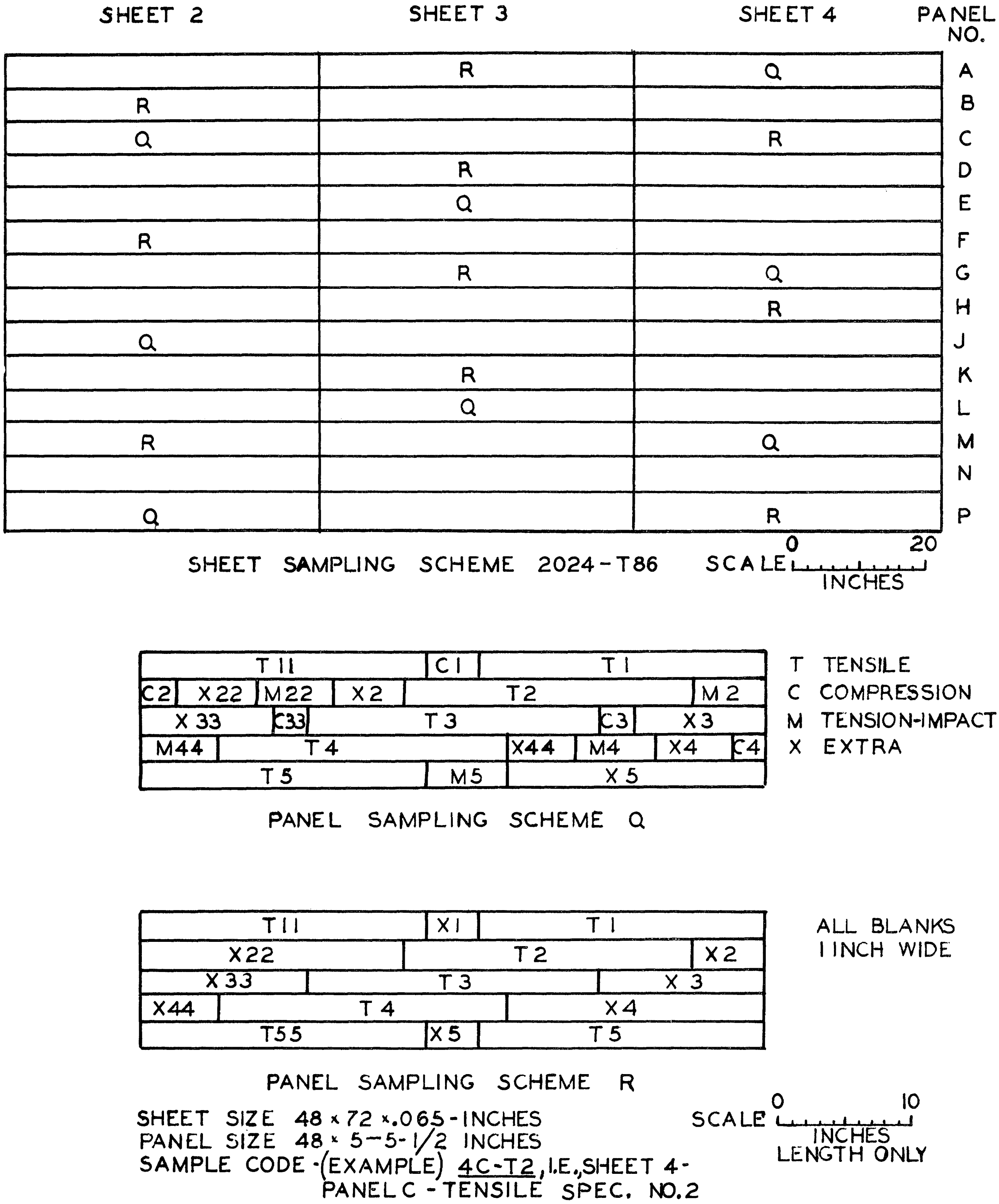
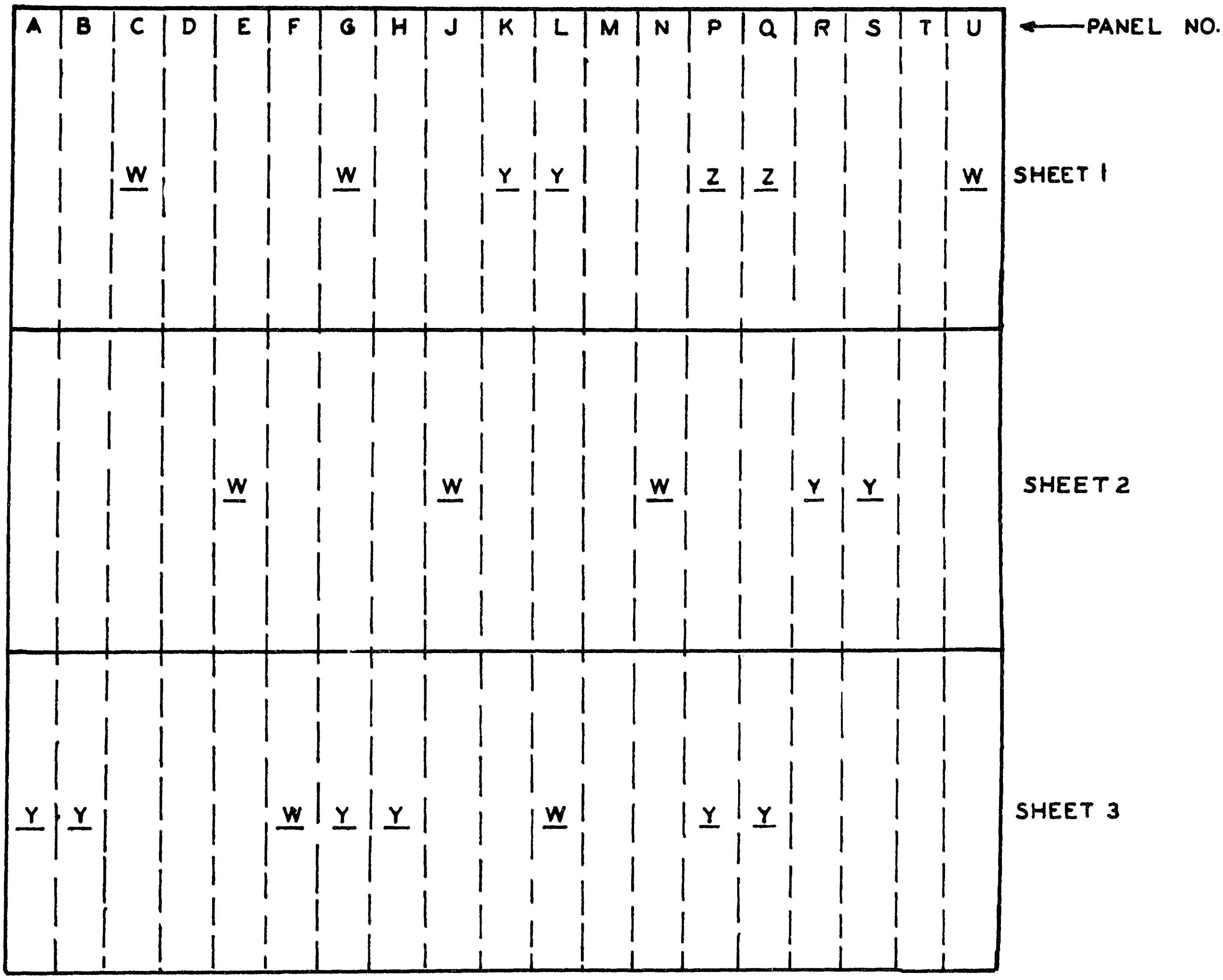


Figure 1. - Sampling Procedure for sheets of 2024-T86 aluminum alloy



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 3)

Figure 2. - Panel sampling scheme for sheets of 17-7PH stainless steel sheet

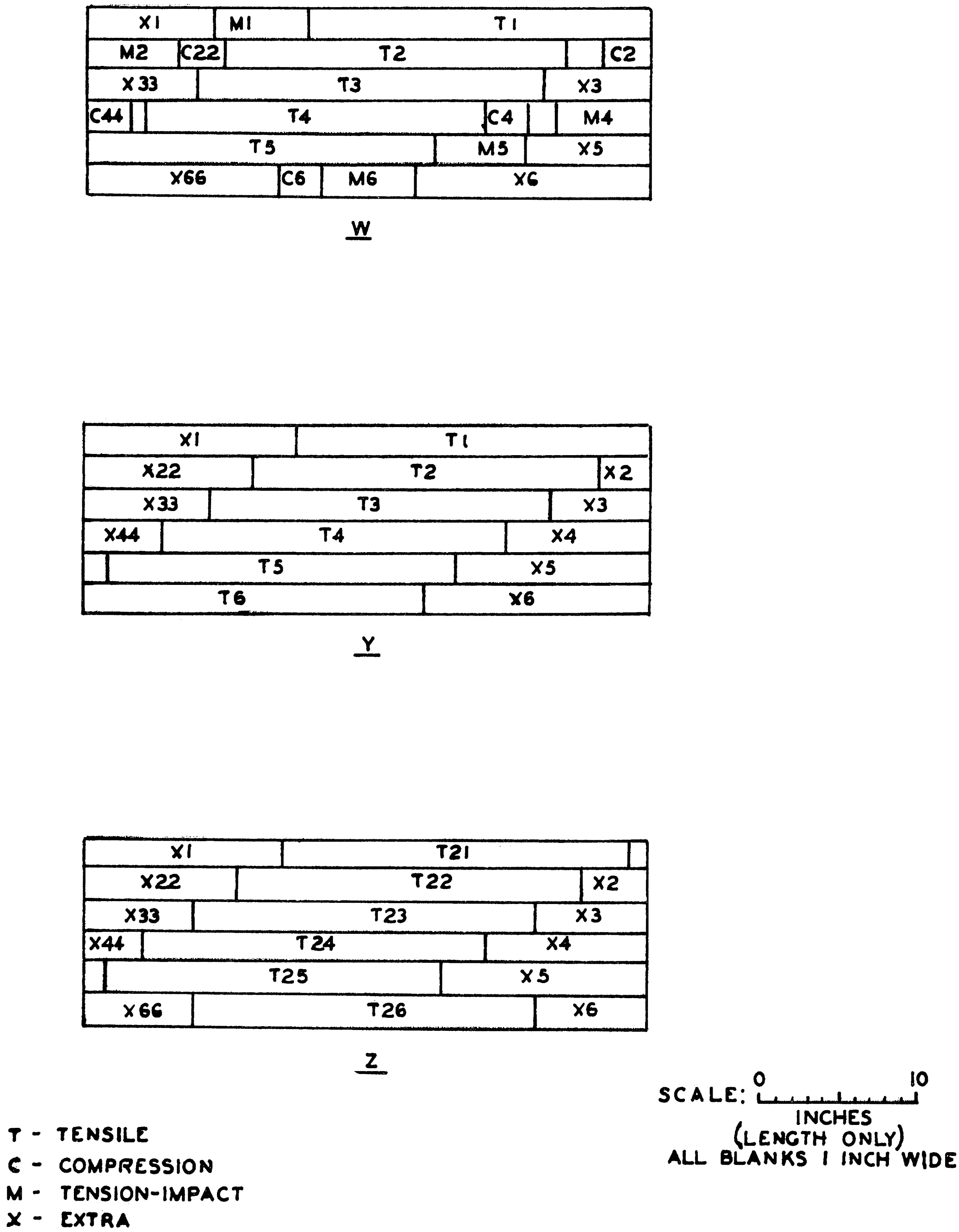


Figure 3. - Specimen blank sampling schemes for panels of 17-7PH stainless steel sheet

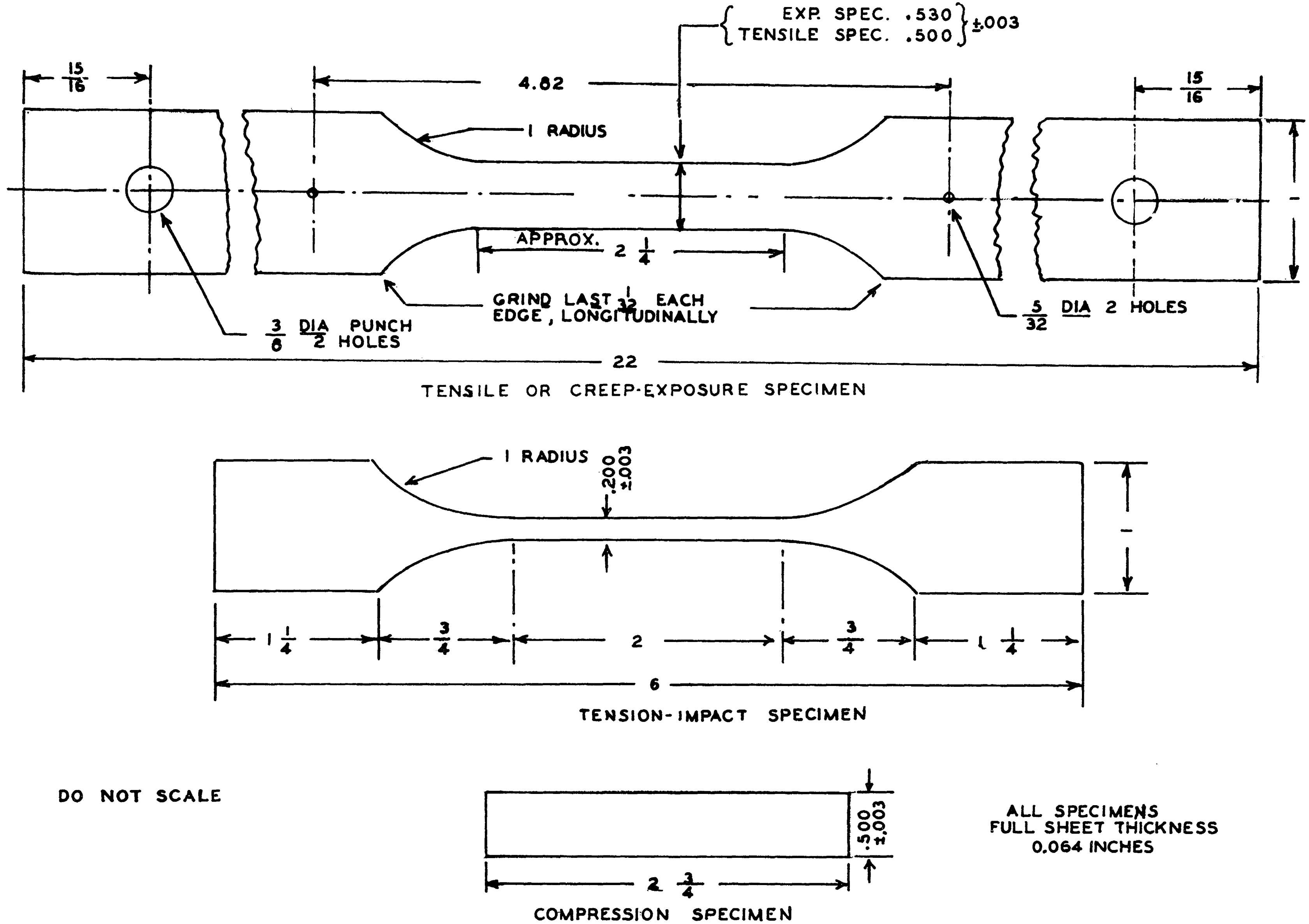


Figure 4. - Details of Test Specimens (Tension-Impact and Compression Specimens Designed to be Cut from Creep Specimens after Exposure).

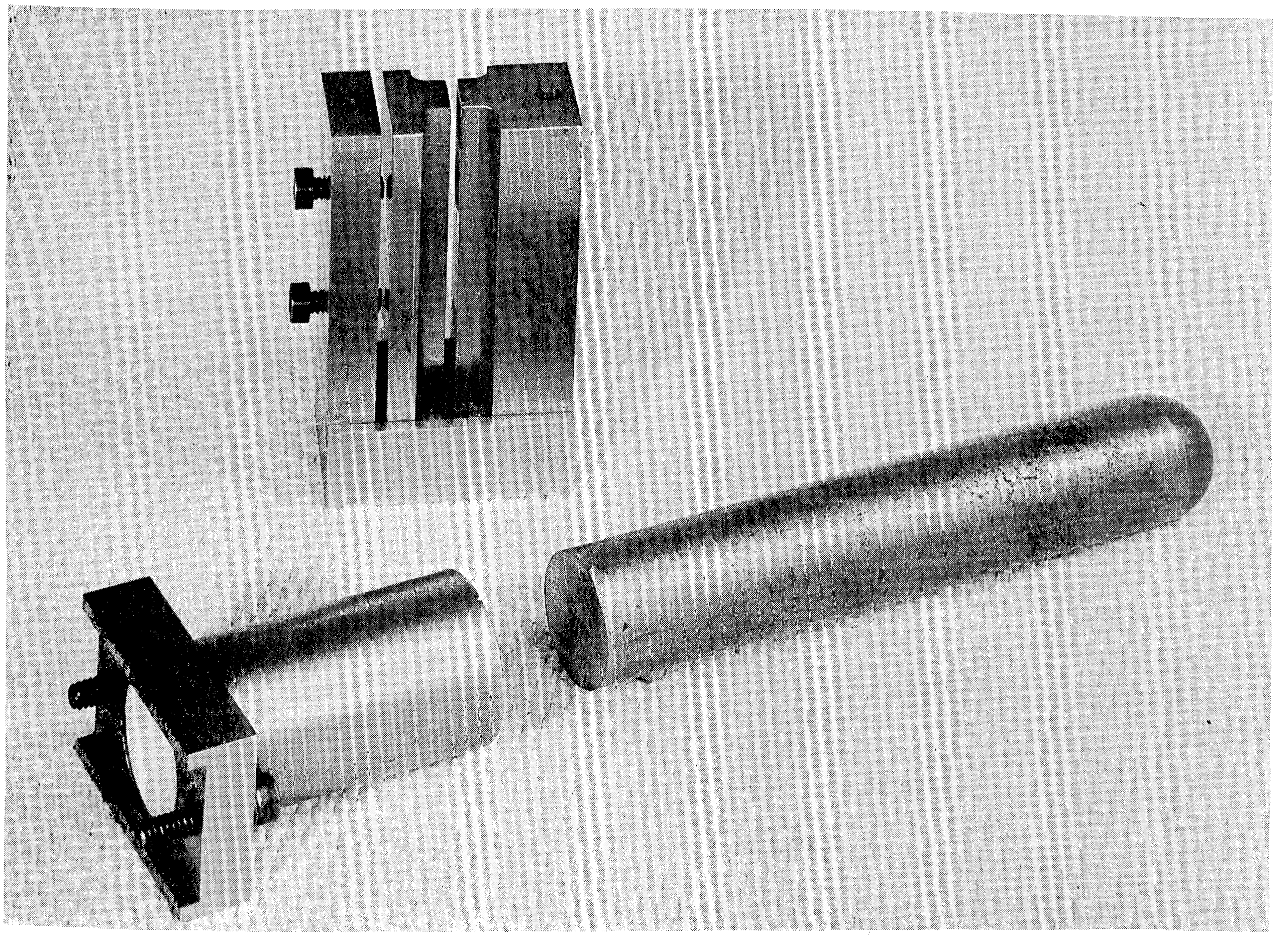


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Figure 5. - Compression test fixture

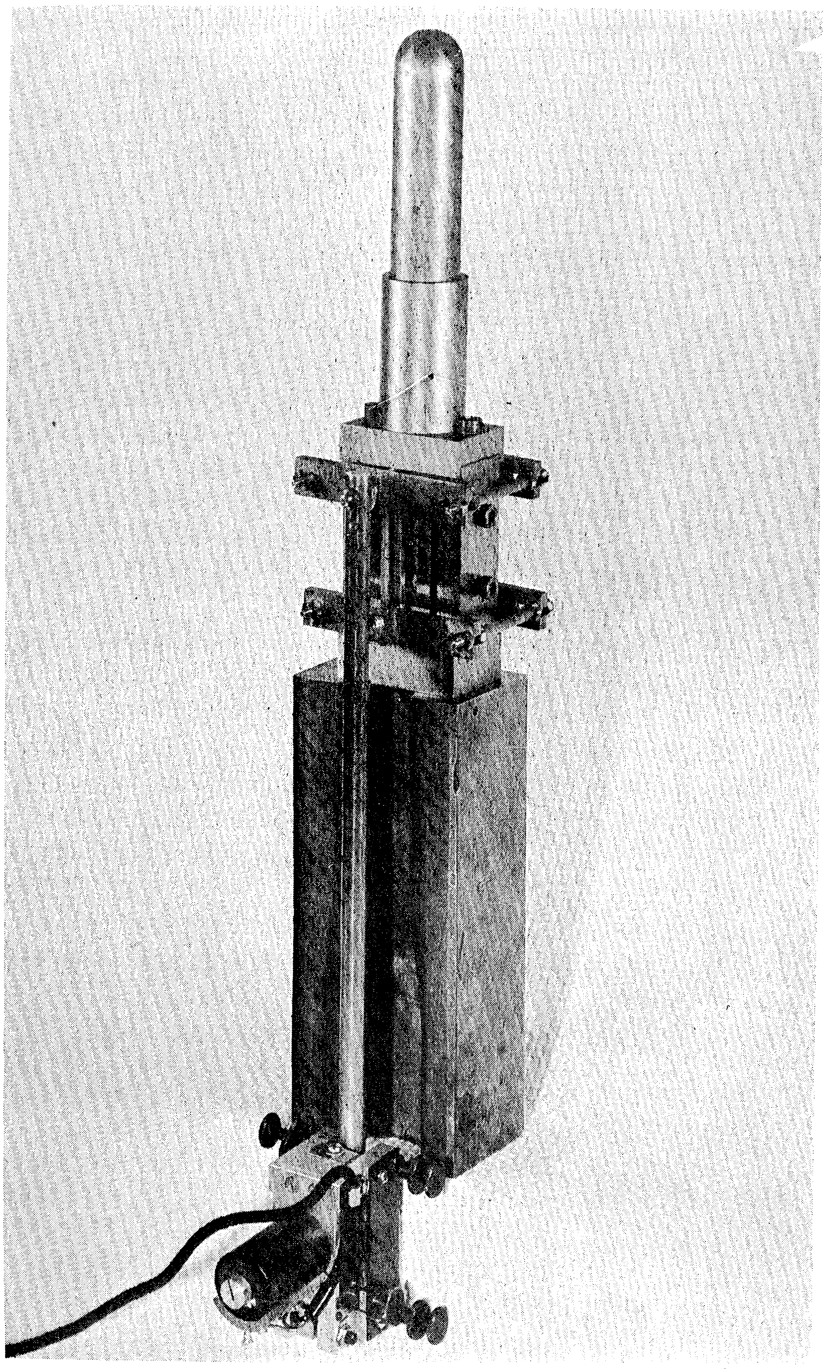

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Figure 7. - Compression test equipment assembled for operation

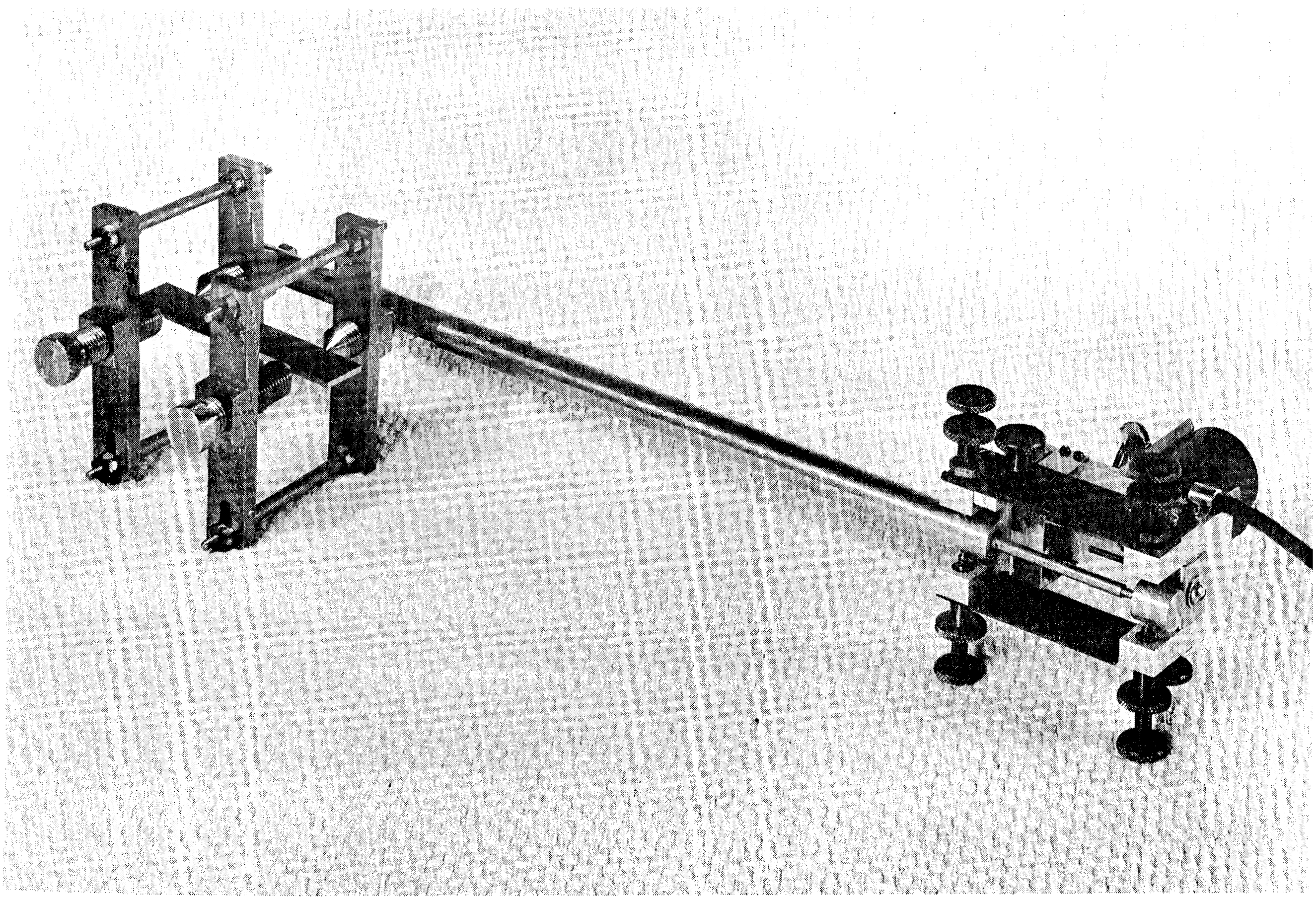

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Figure 6. - Rod and tube extensometer fixture

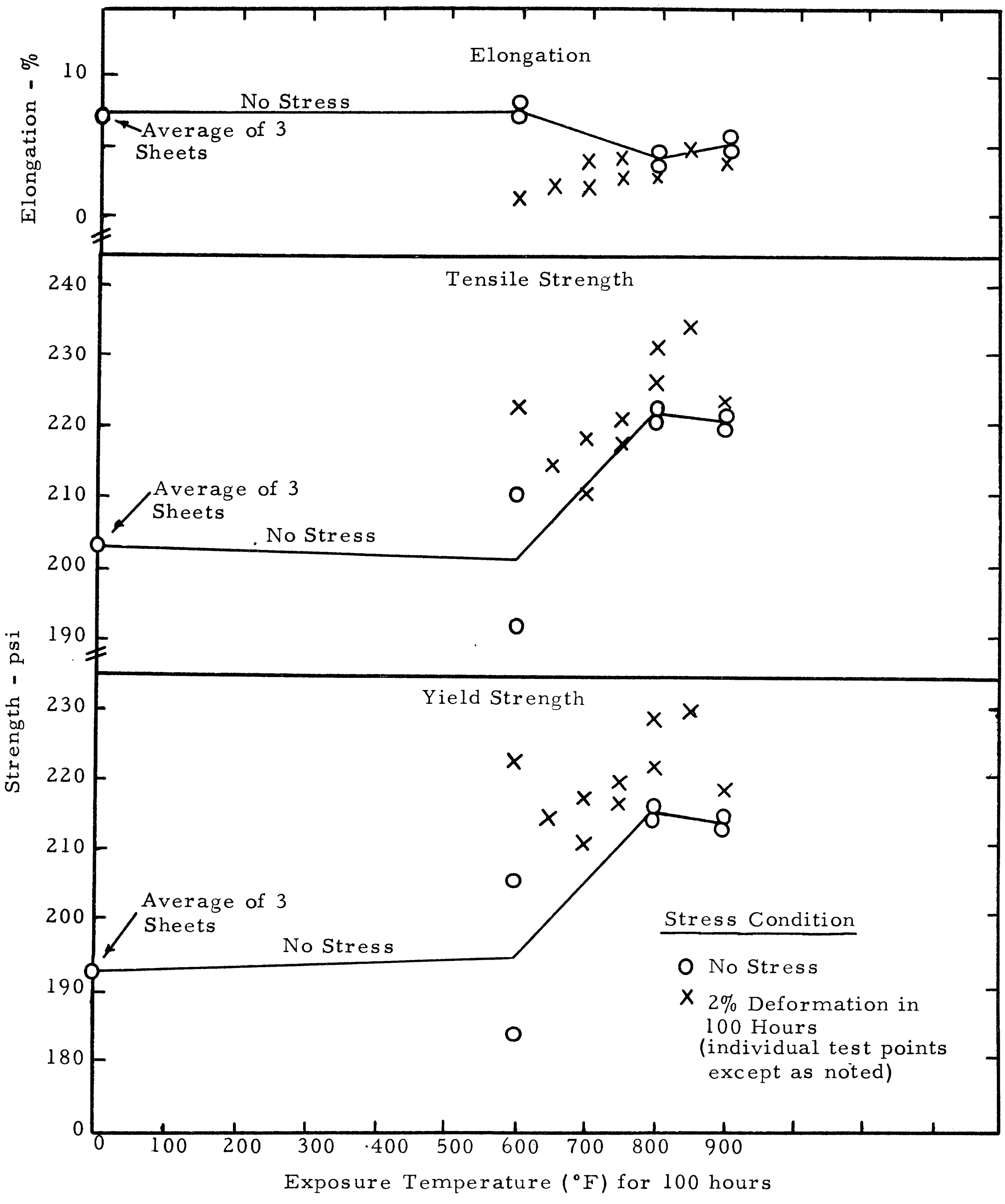

Figure 8. - Effects of 100 hours unstressed exposure or 100 hours stressed exposure to 2% total deformation on room temperature tensile properties of 17-7PH Alloy (TH 1050 Condition)

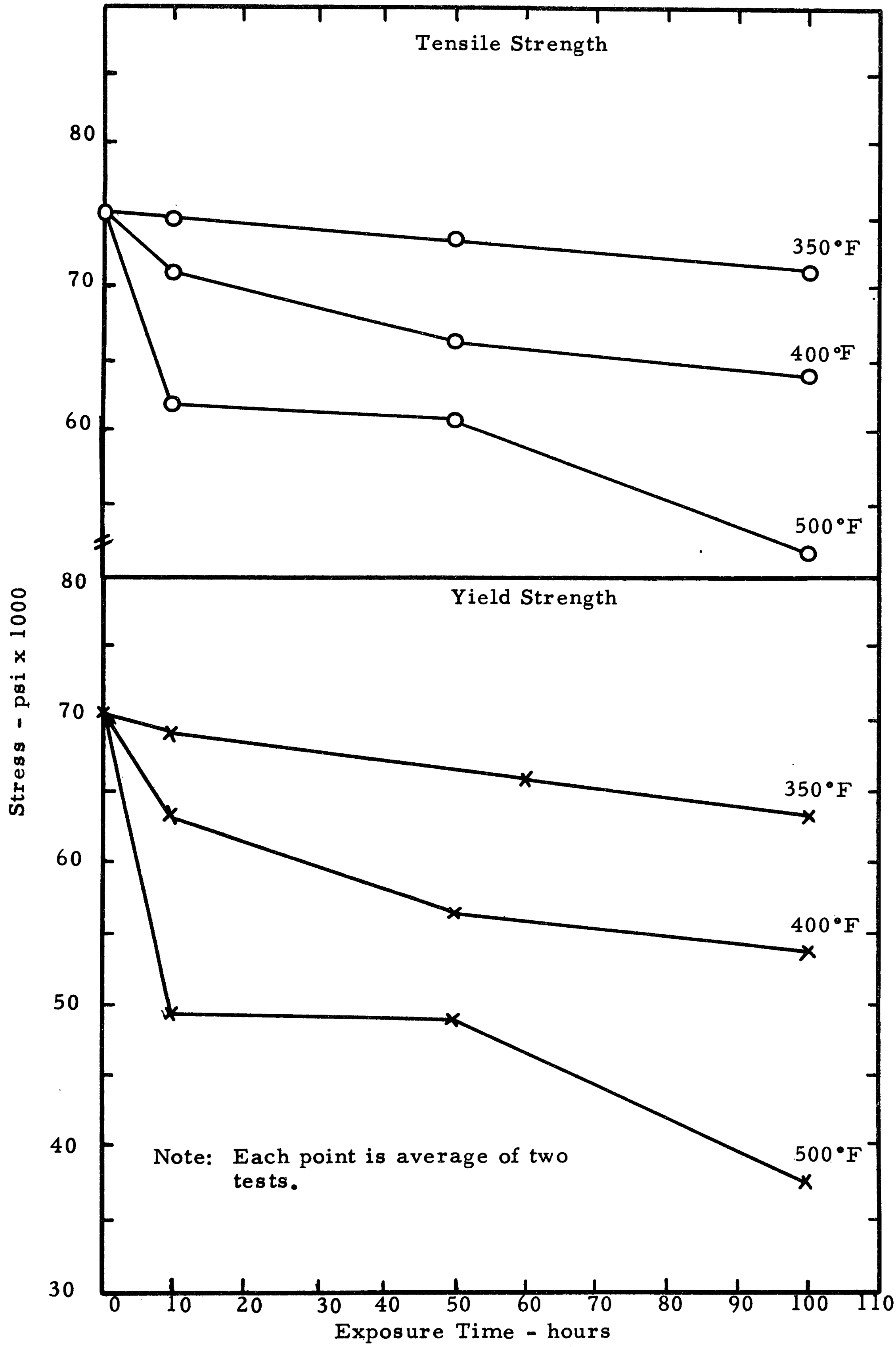

Figure 9. - Effect of unstressed exposure on room temperature tensile and yield strength of 2024-T86 Aluminum Alloy.

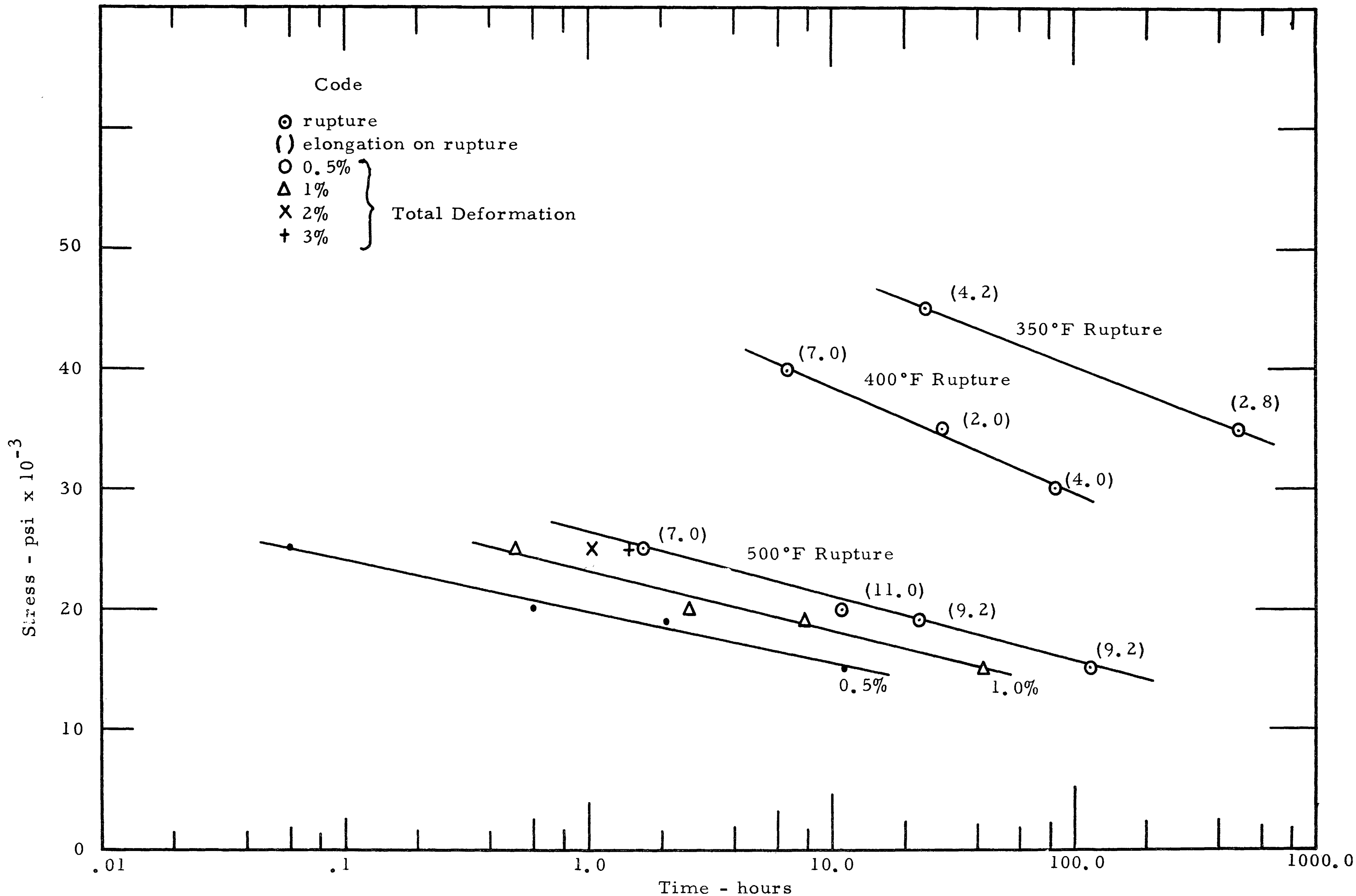

Figure 10. - Time for rupture and specified total deformation at 350°, 400°, and 500°F for 2024-T86 Aluminum Alloy