NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 4075

TENSILE STRESS-STRAIN PROPERTIES OF 17-7 PH AND AM 350 STAINLESS-STEEL SHEET AT ELEVATED TEMPERATURES

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SUMMARY

Tensile stress-strain test results are presented for 17-7 PH stainless-steel sheet in the Condition TH 1,050 and for AM 350 stainless-steel sheet in the double-aged condition for temperatures from room temperature to 1,300° F. Stress-strain curves and data for yield and ultimate stresses, Young's modulus, and elongation are given in tabular and graphical form. A comparison is made between the tensile properties and the compressive properties of NACA Technical Note 4074.

INTRODUCTION

Two precipitation-hardening stainless steels, 17-7 PH and AM 350, show promise as aircraft structural materials for elevated-temperature use. In addition to high strength and satisfactory ductility in the heat-treated condition, these materials are corrosion resistant and can be easily worked in the annealed condition. Conventional short-time elevated-temperature data from various sources for these stainless steels and other selected alloys are given in reference 1.

In the present investigation, short-time elevated-temperature tensile data were obtained for 17-7 PH and AM 350 stainless-steel sheet from the same sample material for which the compressive properties were determined in reference 2. The 17-7 PH was in the Condition TH 1,050 and the AM 350 was double aged. The tensile stress-strain curves and the tensile properties are given herein for temperatures up to 1,300° F. A comparison with the compressive properties is included.

MATERIALS AND SPECIMENS

The 17-7 PH stainless-steel sheet material was furnished by the Armco Steel Corporation. The specimens were cut in the with-grain direction from three annealed 0.05-inch-thick sheets measuring 48 by 96 inches. After being machined, the specimens were heat-treated to Condition TH 1,050 $\left(1\frac{1}{2}\right.$ hours at 1,400° F, air cooled to below 60° F within $1\frac{1}{2}$ hours, $1\frac{1}{2}$ hours at 1,050° F, and air cooled$\left.\right)$.

The AM 350 stainless-steel sheet was furnished by the Allegheny Ludlum Steel Corporation. The specimens were cut in the with-grain direction from one single 0.063-inch-thick annealed sheet measuring 22 by 45 inches. After being machined these specimens were hardened by double aging $\left(1\frac{1}{2}\right.$ hours at 1,350° F, air cooled, $1\frac{1}{2}$ hours at 850° F, and air cooled$\left.\right)$.

The specimen dimensions for both materials are given in figure 1. The nominal chemical composition and the minimum room-temperature properties may be found in tables I and II of this report.

TEST PROCEDURE

Conventional tensile stress-strain tests were performed at room and elevated temperatures. The equipment and procedure were essentially the same as described in reference 3. The specimens were exposed to the test temperature for 1/2 hour and then loaded to failure at a strain rate of 0.002 per minute. A stress-strain curve and a strain-time curve for each test were recorded simultaneously on an autographic recorder. The strain-time curve was used to control the strain rate during the test. The temperature variations during the exposure period were within ±10° F and during the test within ±5° F of the desired test temperature. Several tests at room temperature were conducted with Tuckerman optical strain gages to determine Young's modulus more accurately.

RESULTS AND DISCUSSION

The results of the tensile stress-strain tests of 17-7 PH and AM 350 stainless steels are given in tables III and IV and are illustrated in figures 2 to 6.

The stress-strain curves for room and elevated temperatures are shown in figure 2 for 17-7 PH and in figure 3 for AM 350. The 0.2-percent-offset yield stress is indicated by a tick mark on each curve. The shapes of the stress-strain curves for the two materials are rather different. The stress-strain curves of 17-7 PH cease to be linear at relatively low stresses whereas those of AM 350 are linear over a considerable portion of the curve below yield, at least up to 800° F.

The variation of the yield and ultimate tensile stresses with temperature for 17-7 PH is shown in figure 4. The yield and ultimate stresses for 17-7 PH decrease slowly with temperature to about 700° F after which a rapid decrease occurs. The yield stress is within 10 percent of the ultimate stress over the entire temperature range except at 1,200° F. The ultimate stress is slightly higher and the yield stress is appreciably higher at room temperature than the minimum values given in reference 4 (table II). At elevated temperatures, the ultimate tensile stress is about the same as those given by the producer (refs. 1 and 4) up to about 700° F; the yield stress, however, is appreciably higher than that reported in references 1 and 4.

The variation of the yield and ultimate stresses with temperature for AM 350 is shown in figure 5. The ultimate stress is maintained up to about 800° F after which a rapid decrease occurs. The yield stress decreases slowly up to about 900° F after which it drops rapidly. The yield stress is appreciably less than the ultimate stress over most of the temperature range. Both the yield and ultimate stresses are considerably greater at room temperature than the corresponding minimum values given by the producer (table II). At elevated temperatures, the yield and ultimate stresses, although slightly higher, follow closely the results given by the producer (refs. 1 and 5).

The ultimate stresses for 17-7 PH and AM 350 are about the same at room temperature (see figs. 4 and 5) but AM 350 has considerably greater strength above 400° F. The yield stress for 17-7 PH, however, is considerably greater than that for AM 350 up to about 800° F. Above 800° F, both the yield and ultimate stresses for AM 350 are superior to those for 17-7 PH.

The variation of Young's modulus with temperature is shown in figure 6 for 17-7 PH and AM 350 stainless steel. As the data correlate satisfactorily with a single curve, the variation of the modulus with temperatures obtained in these tests is the same for both materials. The present data are also in good agreement with the producer's results for AM 350 (ref. 5) and also with the compressive data of reference 2. Within the existing scatter of the data, the variation of Young's modulus with temperature appears to be about the same in tension and compression for both materials.

A comparison of the tensile and compressive yield stresses from room temperature to 1,200° F for 17-7 PH and AM 350 is made in figures 7 and 8, respectively. The compressive data were taken from reference 2. The compressive yield stress for 17-7 PH (fig. 7) is about 8 percent greater than the tensile yield stress over the entire temperature range. For AM 350 (fig. 8), the compressive yield stress is about 6 percent higher than the tensile yield stress. It should be noted that the compressive data used are only for specimens cut from the same sheets and in the same grain direction as the tensile specimens of the present report.

CONCLUDING REMARKS

Tensile stress-strain tests of 17-7 PH (Condition TH 1,050) and AM 350 (double aged) stainless-steel sheet indicate that these materials retain a large part of their room-temperature strength up to about 700° F and 800° F, respectively. At room temperature, the ultimate stress for these materials is about the same, but the yield stress for AM 350 is appreciably less than that for 17-7 PH. Above 800° F, however, AM 350 has greater strength than 17-7 PH.

The compressive yield stresses for 17-7 PH and AM 350 are slightly greater than the corresponding tensile yield stresses over the entire temperature range. The variation of Young's modulus with temperature is the same for both materials for both tension and compression.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 27, 1957.

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1. Favor, Ronald J., Achbach, William P., and Hyler, Walter S.: Materials-Property-Design Criteria for Metals. Pt. 5 - The Conventional Short-Time, Elevated-Temperature Properties of Selected Stainless Steels and Super Alloys. WADC Tech. Rep. 55-150 Pt. 5 (Battelle Memorial Inst. Contract No. AF 33(616)-2303, Project No. 7360), Wright Air Dev. Center, U. S. Air Force, Dec. 1956.

2. Stein, Bland A.: Compressive Stress-Strain Properties of 17-7 PH and AM 350 Stainless-Steel Sheet at Elevated Temperatures. NACA TN 4074, 1957.

3. Hughes, Philip J., Inge, John E., and Prosser, Stanley B.: Tensile and Compressive Stress-Strain Properties of Some High-Strength Sheet Alloys at Elevated Temperatures. NACA TN 3315, 1954.

4. Anon.: Armco Precipitation Hardening Stainless Steels. Product Data Bulletin, Armco Steel Corp. (Middletown, Ohio), Mar. 1, 1954.

5. Anon.: Engineering Properties of Precipitation Hardening Alloy - AM 350 (Sheet or Strip Form). Allegheny Ludlum Steel Corp. (Pittsburg, Pa.).

TABLE I

CHEMICAL COMPOSITION OF 17-7 PH AND AM 350 STAINLESS STEELS

[All values in percent]

Element	17-7 PH (a)	AM 350 (b)
Chromium	16.00 to 18.00	16.0 to 17.0
Nickel	6.50 to 7.75	4.0 to 5.0
Aluminum	0.75 to 1.50	
Molybdenum . . .		2.50 to 3.25
Carbon	0.09 maximum	0.08 to 0.12
Manganese . . .	1.00 maximum	0.50 to 1.25
Nitrogen		0.07 to 0.13
Silicon	1.00 maximum	0.50 maximum
Phosphorus . . .	0.04 maximum	0.04 maximum
Sulfur	0.03 maximum	0.03 maximum

[a]Reference 4.
[b]Obtained from Allegheny Ludlum Steel Corporation.

TABLE II

PRODUCER'S MINIMUM ROOM-TEMPERATURE TENSILE PROPERTIES FOR

17-7 PH AND AM 350 STAINLESS-STEEL SHEET

	17-7 PH, Condition TH 1,050 (a)	AM 350, double aged (b)
Yield stress, ksi	150	125
Ultimate stress, ksi	180	160
Elongation in 2 inches, percent . .	6	12

[a]Reference 4.
[b]Obtained from Allegheny Ludlum Steel Corporation.

TABLE III

TENSILE STRESS-STRAIN TEST RESULTS FOR 0.05-INCH-THICK 17-7 PH STAINLESS-STEEL SHEET HEAT-TREATED TO CONDITION TH 1,050 AFTER 1/2-HOUR TEMPERATURE EXPOSURE FOR A STRAIN RATE OF 0.002 PER MINUTE

Temperature, °F	Yield stress, ksi	Ultimate stress, ksi	Young's modulus, psi	Elongation in 2 inches, percent
[a]Room temperature	169	186	30.0×10^6	[b]5.5
Room temperature	168	185	32.2	7.5
[a]Room temperature	171	187	30.0	8.5
200	165	176	29.6	8.5
300	162	172	28.9	[b]6.0
400	159	167	28.0	[b]2.0
500	154	163	27.7	4.0
600	148	159	26.0	4.0
600	146	161	29.1	4.0
700	140	144	25.6	7.5
800	118	123	26.9	[b]5.0
900	88.9	93.0	23.4	25
1,000	59.3	60.5	21.2	[b]26
1,100	33.8	35.7	17.1	[b]32
1,200	18.0	24.8	11.0	[b]29
1,200	19.7	25.6	11.8	35

[a]Tuckerman optical strain gages.
[b]Broke outside gage length.

TABLE IV

TENSILE STRESS-STRAIN TEST RESULTS FOR 0.063-INCH-THICK DOUBLE-AGED AM 350 STAINLESS-STEEL SHEET AFTER 1/2-HOUR TEMPERATURE EXPOSURE FOR A STRAIN RATE OF 0.002 PER MINUTE

Temperature, °F	Yield stress, ksi	Ultimate stress, ksi	Young's modulus, psi	Elongation in 2 inches, percent
Room temperature	154	182	31.5×10^6	10.5
Room temperature	152	182	30.9	14.5
[a]Room temperature	-----	-----	30.9	----
290	137	170	29.8	10
470	128	169	28.2	8
500	126	168	27.9	7
545	131	171	26.7	9
610	129	171.5	27.8	4
700	122	173	25.4	5.5
700	122	176	26.5	7.5
780	117	171.6	26.0	8
800	119	168	25.5	9.5
900	107	146	25.4	[b]3.5
1,000	86.1	115	22.6	3
1,000	-----	115	21.6	2
1,000	81.8	-----	20.1	1.5
1,100	56.6	65.9	17.7	3
1,200	31.5	39.7	13.3	19
1,300	20.4	27.6	10.3	18.5

[a]Tuckerman optical strain gages.
[b]Broke outside gage length.

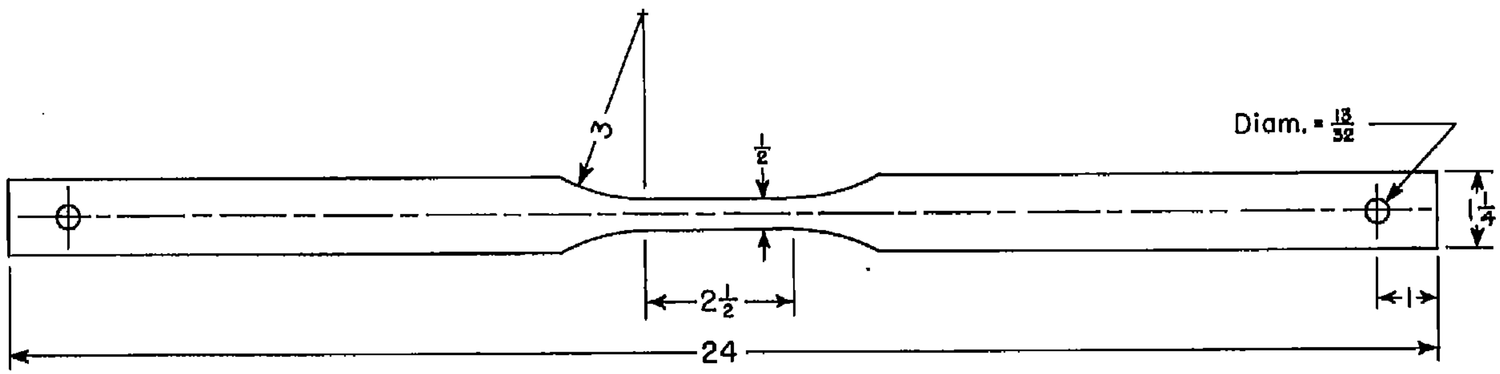

Figure 1.- Tensile test specimen for elevated-temperature stress-strain tests. (All dimensions are in inches.)

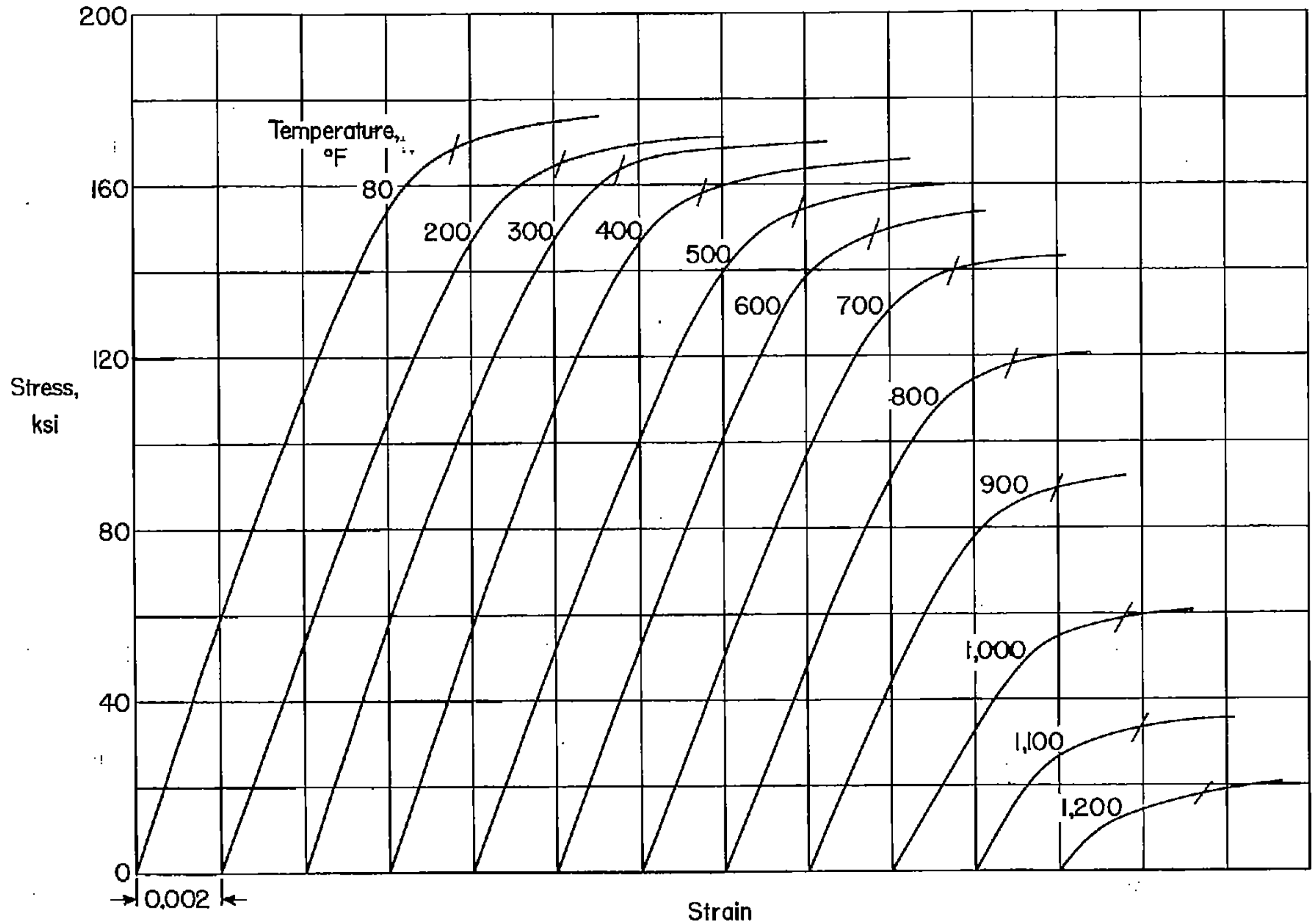

Figure 2.- Tensile stress-strain curves for 17-7 PH stainless-steel sheet in Condition TH 1,050, after 1/2-hour temperature exposure, for a strain rate of 0.002 per minute. The tick marks indicate 0.2-percent-offset yield stresses.

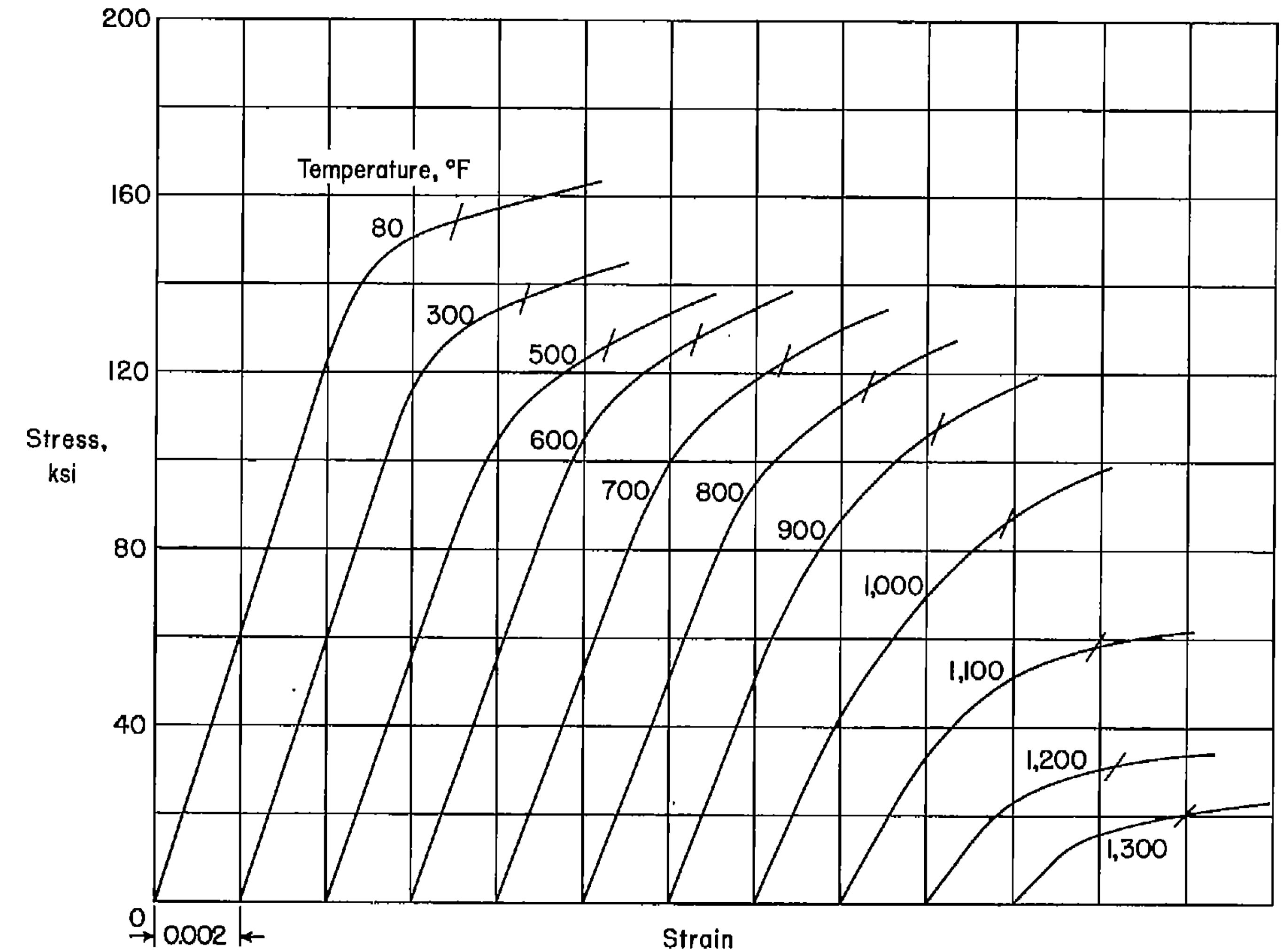

Figure 3.- Tensile stress-strain curves for double-aged AM 350 stainless-steel sheet, after 1/2-hour temperature exposure, for a strain rate of 0.002 per minute. The tick marks indicate 0.2-percent-offset yield stresses.

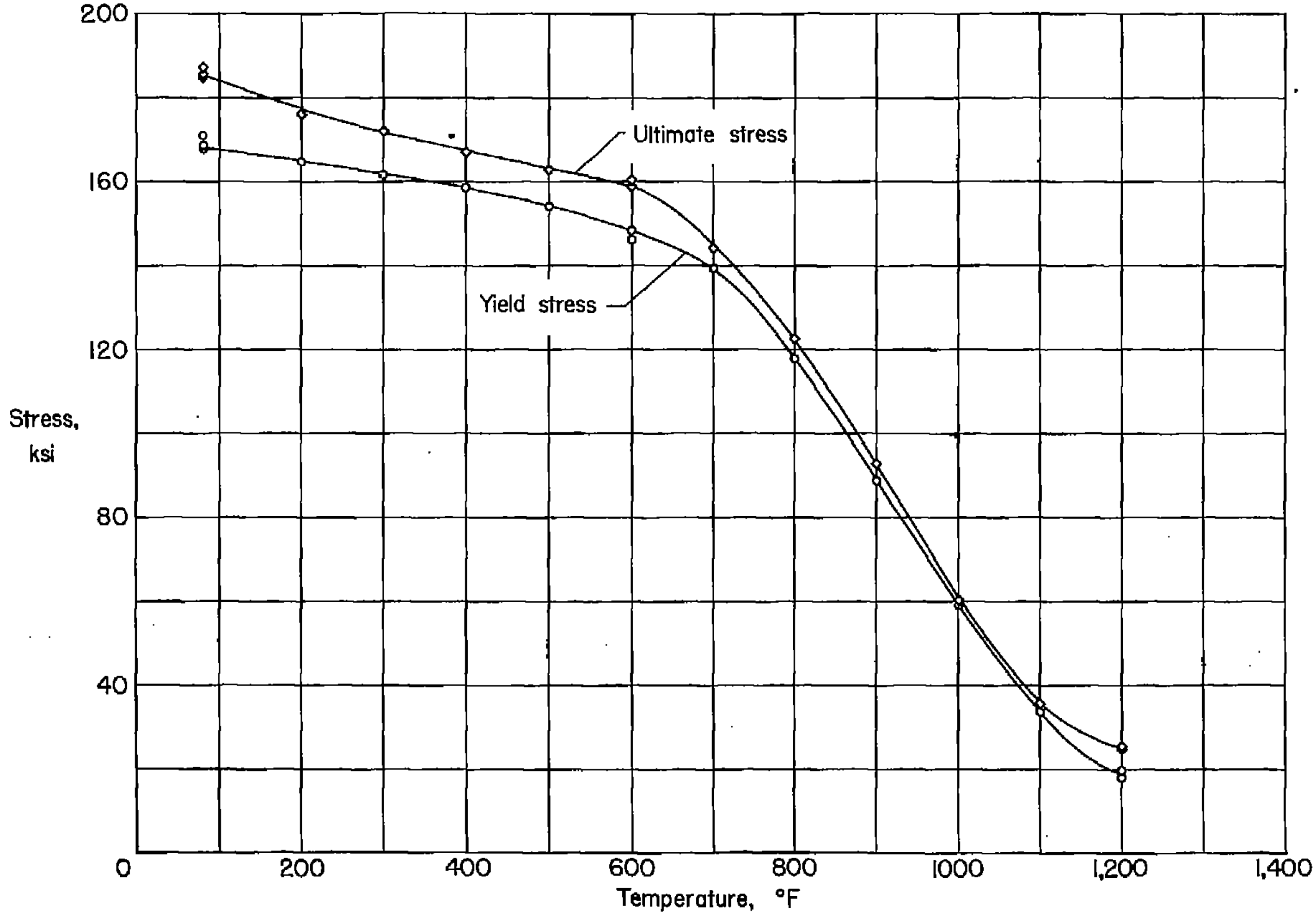

Figure 4.- Tensile yield and ultimate stresses at elevated temperatures for 17-7 PH stainless-steel sheet in Condition TH 1,050, after 1/2-hour temperature exposure, for a strain rate of 0.002 per minute. Yield stresses are for 0.2-percent offset.

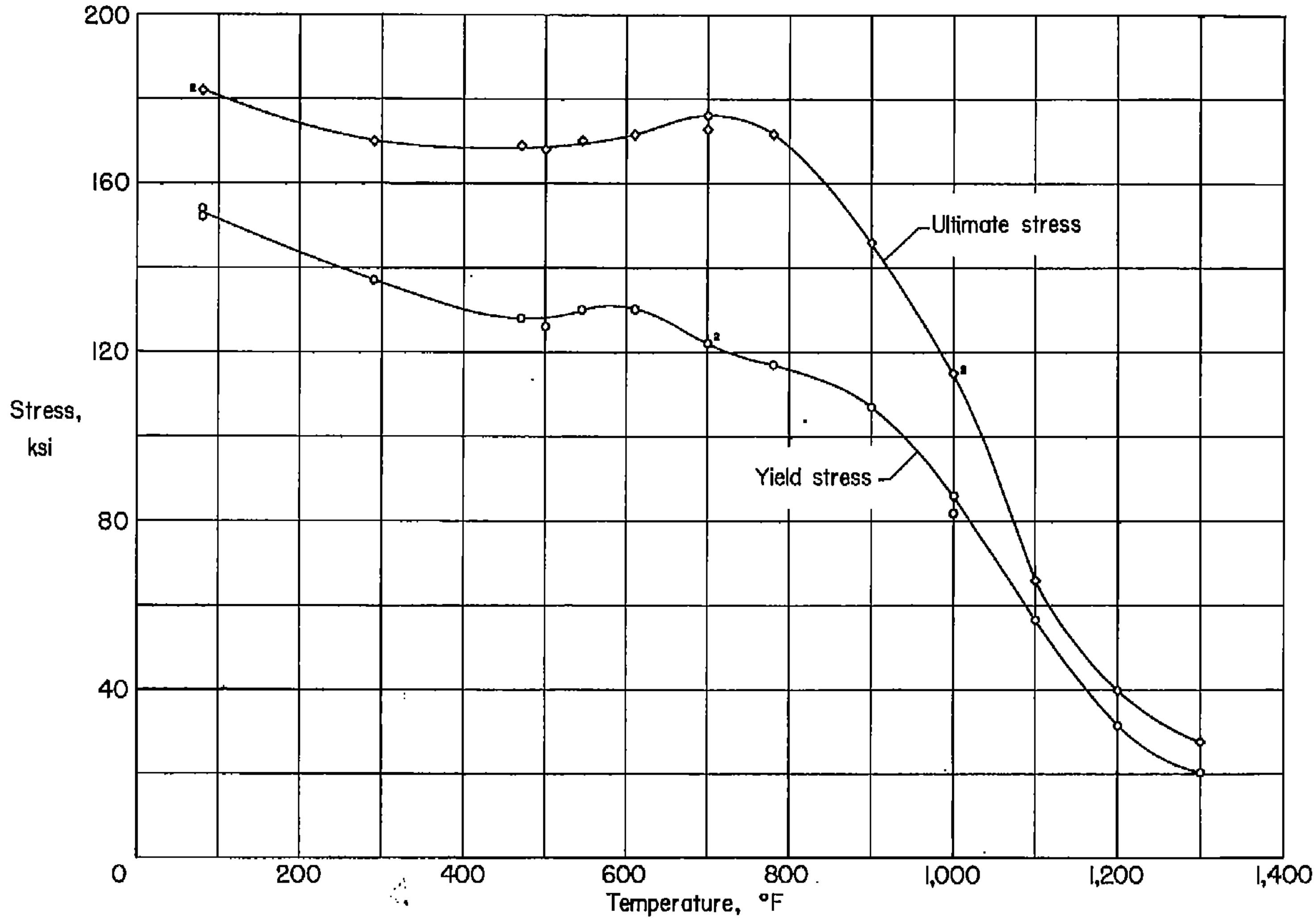

Figure 5.- Tensile yield and ultimate stresses at elevated temperatures for double-aged AM 350 stainless-steel sheet, after 1/2-hour temperature exposure, for a strain rate of 0.002 per minute. Yield stresses are for 0.2-percent offset.

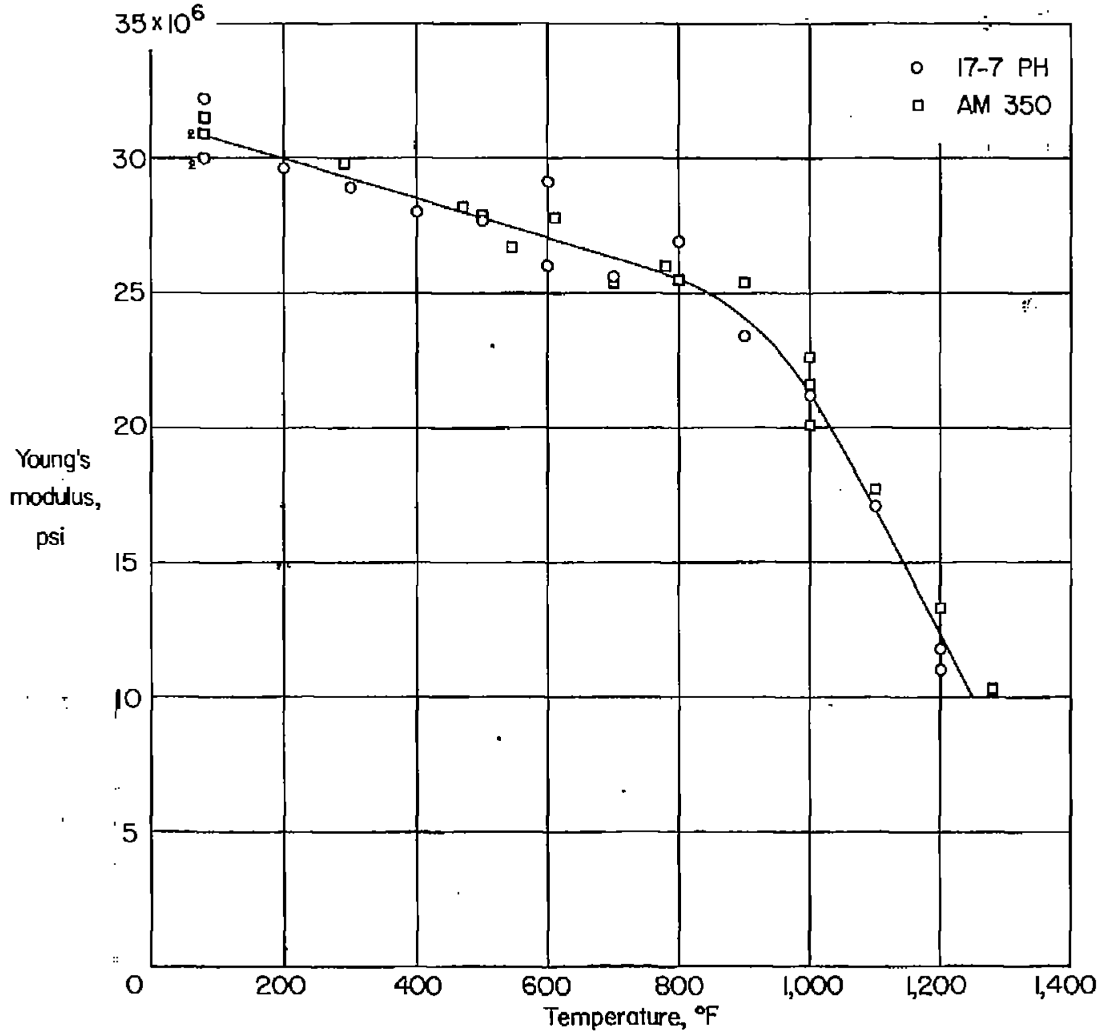

Figure 6.- Young's modulus for 17-7 PH (Condition TH 1,050) and double-aged AM 350 stainless-steel sheet at elevated temperatures after 1/2-hour exposure.

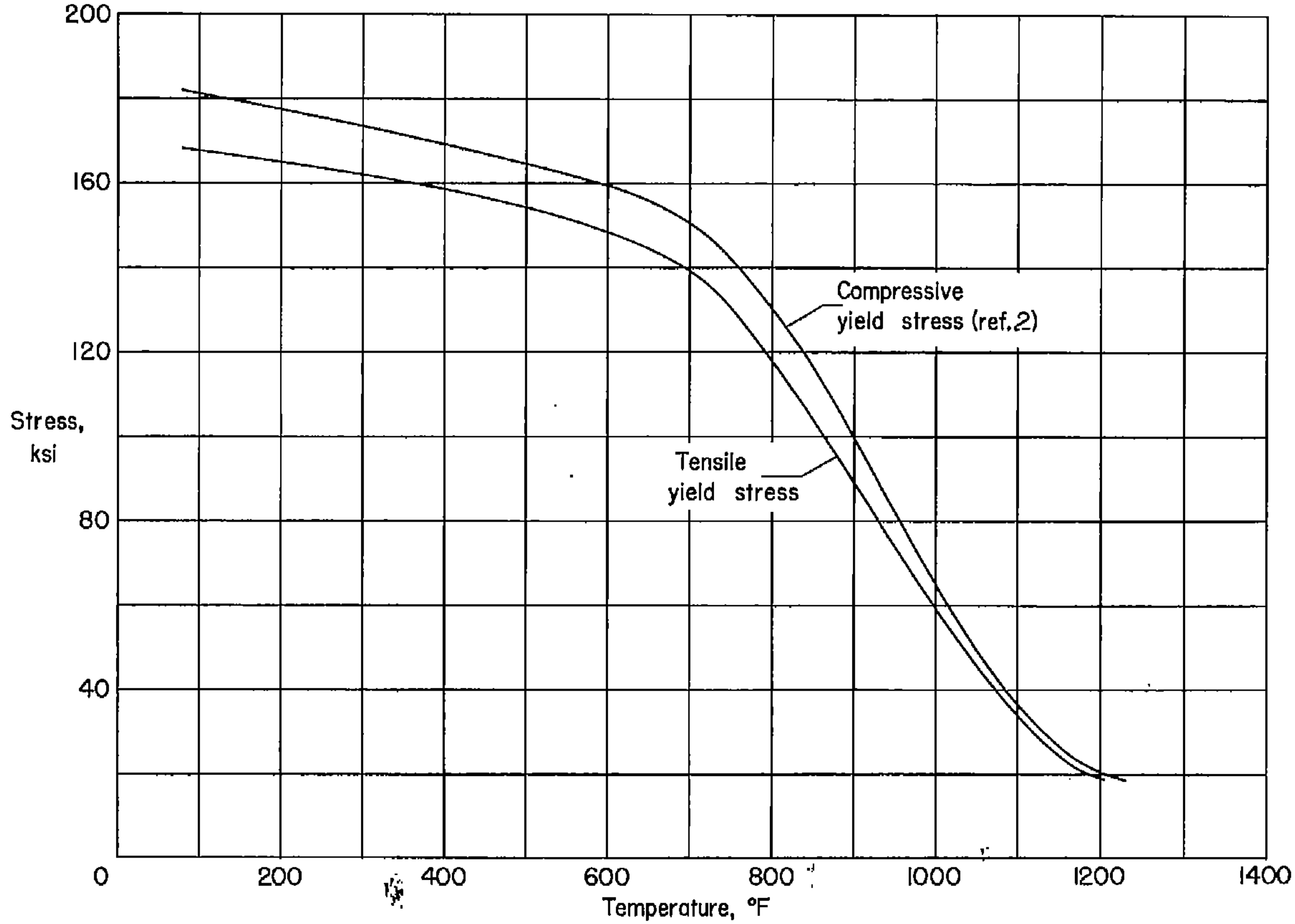

Figure 7.- Comparison of tensile and compressive yield stresses at elevated temperatures for 17-7 PH stainless-steel sheet in Condition TH 1,050, after 1/2-hour temperature exposure, for a strain rate of 0.002 per minute. Yield stresses are for 0.2-percent offset.

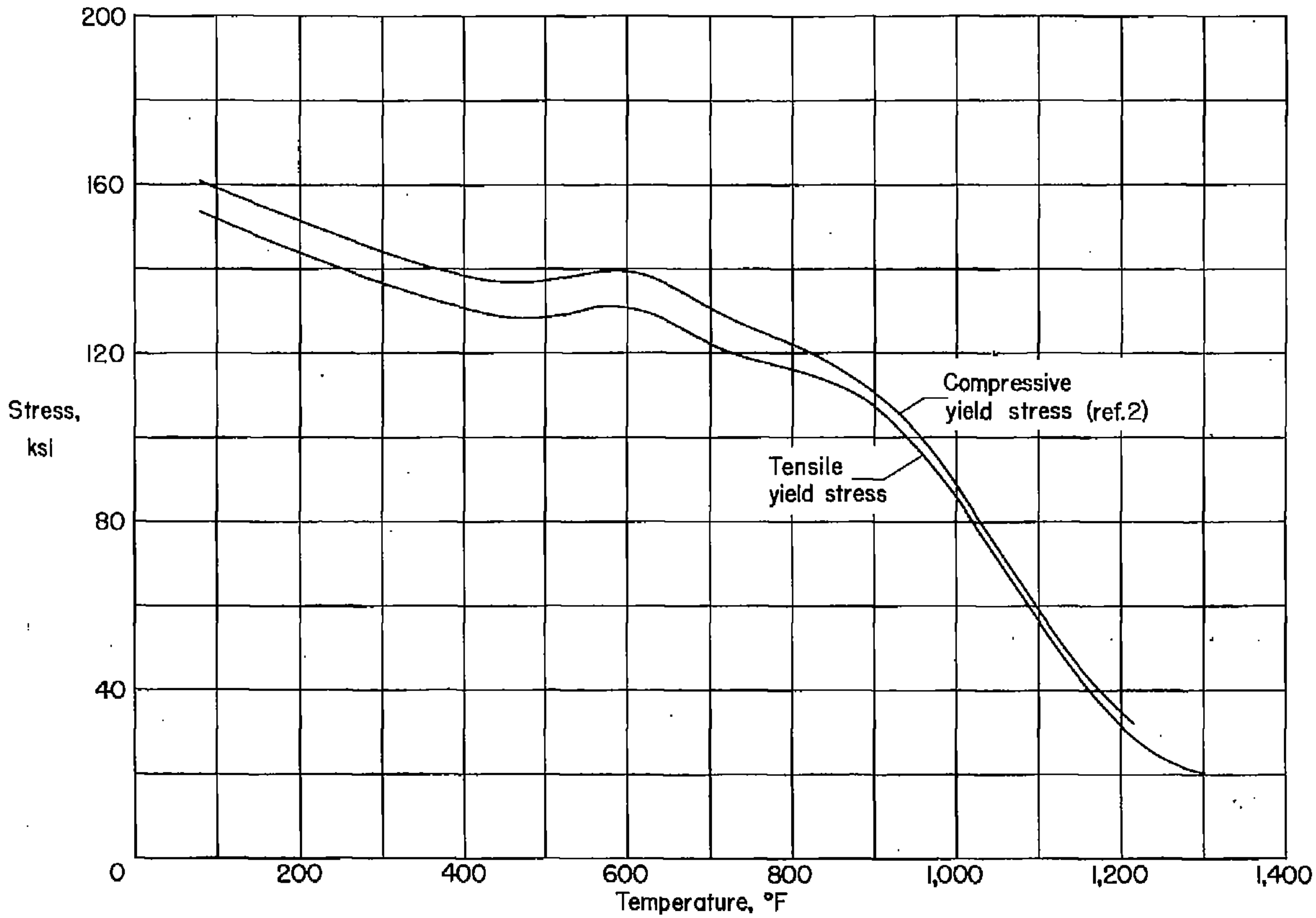

Figure 8.- Comparison of tensile and compressive yield stresses at elevated temperatures for double-aged AM 350 stainless-steel sheet, after 1/2-hour temperature exposure, for a strain rate of 0.002 per minute. Yield stresses are for 0.2-percent offset.

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