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Interim Summary Report

SCREENING PROGRAM
ON
SUPERALLOYS FOR TRISONIC TRANSPORT

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SCREENING PROGRAM
ON
SUPERALLOYS FOR TRISONIC TRANSPORT

INTRODUCTION

This report is provided as an interim summary of the evaluation of superalloys in sheet form being conducted at Michigan as part of the Screening Program for Materials for the Trisonic Transport. These data represent the results of the program being used cooperatively by several laboratories for preliminary survey of the candidate materials. This screening program includes the following tests for all materials, using samples from both the longitudinal and transverse direction of the sheet:

1) Tensile tests using both unnotched samples and samples with sharp-edge notches at each of the following temperatures:

a) -110°F
b) 75°F
c) 350°F
d) 650°F
e) 800°F

2) Tensile tests at 75° and 650°F after exposure in air for 1000 hours at 650°F under 40,000 psi. Exposure is made using unnotched and notched samples from both the longitudinal and transverse direction of the sheet.

The unnotched samples in most cases had a reduced section 0.5-inch wide by 2.0-inches long. The only exception to this was required by the narrow sheet obtained for AM350 alloy. This material required that the transverse unnotched samples be made with a reduced section 0.375-inch wide by 1.75-inches long. The ASTM sharp-edge notch sample was used for all notched testing.

The screening program on superalloys is intended to determine the upper temperature limit of usefulness for the most promising alloys. Accordingly, as the preliminary screening above is completed, some materials are to be subjected to further study. This will involve both tensile testing at higher temperatures and an increase in the exposure temperature, still using an exposure for 1000 hours under 40,000 psi.

The data obtained from the test program include the following:

1) Ultimate tensile strength, 0.2-percent offset yield strength, and elongation from unnotched samples
2) Net section tensile strength for samples with sharp-edge notches
3) The ratio of the tensile strength with a notched sample to the tensile strength of an unnotched sample (hereafter referred to as "notched tensile strength ratio", or "N/S ratio").

EXPERIMENTAL MATERIALS

The experimental program to date has included work on the following materials in the form of 0.025-inch sheet:

1) Rene' 41, annealed (Heat R217)
2) Rene' 41, cold worked 20 percent and 35 percent (Heat R-216)
3) N155, cold worked 40 percent and 65 percent (Heat M-5623)
4) A286, cold worked 30 percent and 80 percent (Heat ______)
5) L605, cold worked 25 percent and 45 percent (Heat L1842)
6) D979, cold worked 30 percent and 50 percent (Heat W23211)
7) AM350 CRT air melted (Heat 89746)

In addition to the above alloys, Waspaloy is to be included in the program.

The heat numbers and reported chemical compositions of the first six materials listed are included in Table I. Composition has not been reported for the AM350.

The Rene' 41 alloy was obtained from the General Electric Company Metallurgical Products Department. All three conditions of the alloy were produced on a hand mill providing sheet 36-inches wide.

Items (3) - (6) above were obtained through the NASA Lewis Research Center from the Wallingford Steel Company. These were produced on a strip mill as 12-inch wide strip.

AM350 alloy was included in the program to serve as a base-line material for comparison of data among the cooperating laboratories. It was provided by the Allegheny Ludlum Research Laboratory as 6.5-inch wide strip from a small hand mill.

The N155 and L605 were tested in the as-rolled condition. Various aging treatments were studied for the cold worked Rene' 41, A286, and D979 alloys. These materials were then subjected to the screening program using the aging treatment deemed optimum on the basis of preliminary testing. The annealed Rene' 41 was given the standard age for the alloy. The AM350 was tempered for 3 hours at 850°F. The heat treatments used are given in the respective tables for each alloy.

RESULTS

The relative properties of the materials before exposure are presented, followed by a detailed presentation of the properties of each material as a function of test temperature. The effects of exposure for 1000 hours under 40,000 psi at 650°F are then discussed for those materials on which exposures have been completed. Finally, the effects of exposure at 800° and 1000°F on Rene' 41 alloy are given, and proposed exposures for other materials are discussed.

Properties Before Exposure

The notched tensile strength ratio as a function of the ultimate tensile strength and yield strength at 75°, 650°, and 800°F are given by figures 1 and 2 using the available data for all materials. Since there is some variation in density among the materials and because the ratio of tensile strength to density has general utility, the relation of the N/S ratio to this parameter is shown by figure 3. As will be discussed in detail later, exposure generally did not change the properties significantly. Therefore, the correlations of figures 1 through 3 provide an adequate presentation of the relative strengths of the several alloys. These figures indicate the following:

1) Marked increases in strength were obtained by cold working the alloys. This was true both for the alloys which were tested in the as-rolled condition, as well as for the Ti + Al bearing alloys which were aged to enhance the properties after cold working.

2) The increase in strength from cold working was generally accompanied by a reduced N/S ratio. An exception to this generality was present in the Rene' 41 data at all three testing temperatures, and in the N155 data from longitudinal samples tested at 650°F.

3) For a given strength level, there is a considerable spread among the N/S ratios for the various alloys; or, vice versa, a considerable variation exists among the strength values at a given value of N/S ratio.

4) The relation between N/S ratio and strength was generally the same for both the longitudinal and transverse directions in the sheets except for N155 alloy cold reduced 65 percent in which the transverse direction had a lower N/S ratio than the longitudinal direction at 75° and 650°F. At 800°F, both of the conditions of N155 had transverse N/S ratios lower than the longitudinal ratios.

The study of the general trends and relative properties of the various materials at a given temperature should be accompanied by a more detailed consideration of the properties of each individual alloy as a function of test temperature. The data for each alloy (tables II through VII) are presented graphically in figures 4 through 15. The data presently available indicate the following:

1) Both the strength and N/S ratio decreased with increasing test temperature. In all cases where tests were conducted, both values were either higher in tests at -110°F or nearly the same as tests at 75°F. The values at room temperature were higher than those at 650° or 800°F.

2) Except when large cold reductions were introduced, there was relatively little difference between longitudinal and transverse specimens.

3) Elongations generally decreased with increasing test temperature if there was any appreciable change.

4) Cold reductions increased strength and reduced ductility. This was true for the as-cold rolled materials and for the nickel-base Ti + Al bearing alloys which were aged after cold work. The increase in strength was accompanied by a decrease in N/S ratio, as previously discussed.

Properties After Exposure at 650°F

Although the exposure testing is not complete for all materials, some data are available for all alloys except AM350. These data (tables II - VI and figs. 4 through 11, and 13) indicate the following:

1) Exposure for 1000 hours at 650°F under 40,000 psi did not significantly decrease strength at room temperature or at 650°F in any case. The data for Rene' 41 alloy at -110°F after exposure indicated no changes in strength.

2) Two of the alloys, N155 and L605, showed fairly large increases in strength (figs. 7 through 10) as a result of exposure at 650°F. Both ultimate and yield strengths were increased with the extent of the increase being much greater in tests at room temperature than at 650°F. Also, the increases were greater for the heavier cold worked material (figs. 8 and 10) than for the material with the lower amount of cold work (figs. 7 and 9).

3) The N/S ratio generally remained unaffected by exposure at 650°F. Most cases in which changes occurred indicated an increase in N/S ratio. N155 and L605 alloys, for which the strength increased with exposure, showed some decrease in N/S ratio. Comparison of these data with the trends given in figures 1 and 2, however, shows that the decrease in N/S ratio was actually less for the strength change involved than would be indicated by the curves.

4) Exposure at 650°F had little effect on elongation except for Rene' 41 alloy which showed some decrease in elongation from the exposure.

Properties After Exposure at Temperatures above 650°F

To date, only Rene' 41 alloy annealed and aged has been evaluated after exposure at higher temperatures than 650°F. Exposures have been made with Rene' 41 for 1000 hours under 40,000 psi at 800° and 1000°F with subsequent tensile tests at 75°F and at the exposure temperature. As was the case for this alloy after exposure at 650°F, these higher temperature exposures had little effect on strength or N/S ratio (table II and fig. 4). Exposure at 1000°F may have slightly reduced the N/S ratio at 1000°F. Exposure at 800° and 1000°F did not reduce ductility as much as the exposure at 650°F.

On the basis of the relations between strength and N/S ratio (figs. 1 through 3), the decision has been made to extend the screening program to higher exposure temperatures as follows:

1) Rene' 41 annealed and aged - screen at 1200°F;
2) A286 cold reduced 30 percent and aged - screen at 1000°F
3) L605 cold reduced 25 percent - screen at 1000°F
4) Either Rene' 41 cold reduced 35 percent and aged, or D979 cold reduced 50 percent and aged pending results of tests presently in progress - screen at 1000°F.

DISCUSSION

No attempt has been made to draw conclusions from the data for two reasons. Firstly, there has not yet been a clear delineation of the proper way to interpret the data. Required levels of strength or N/S ratio have not been established. Secondly, there are many other factors, such as fabricability, availability, cost, elastic modulus, and thermal expansion which should also be considered in the final selection of materials when a basis for evaluation of the screening test data is established.

A considerable amount of exposure testing at 650°F is still in progress. This will be completed. The decision has been made, however, to limit all testing after exposure to room temperature and the exposure temperature. No tests will be made at -110°F after exposure. In addition, the program has further been limited by omitting tests at 350°F on unexposed material.

In a few cases, the influence of heat treatment is receiving further study. If promising combinations of properties are obtained, they will be added to the screening program. Waspaloy will be tested when the material becomes available.

TABLE I

CHEMICAL COMPOSITIONS OF EXPERIMENTAL MATERIALS

Alloy	Heat Number	Chemical Composition (weight percent)															
		C	Si	Mn	Cr	Ni	Co	Mo	Ti	Al	Cb+Ta	W	Fe	V	P	S	B
Rene' 41	R-217	.09	.07	.06	18.97	Bal	11.20	9.75	3.20	1.50	---	---	<.30	---	---	.006	.0045
Rene' 41	R-216	.10	.06	.06	18.48	Bal	10.43	9.37	3.19	1.42	---	---	2.20	---	---	.007	.0047
N155	M-5623	.11	.72	1.61	22.14	19.91	19.50	3.22	---	---	1.21	2.40	Bal	---	.017	.011	---
A286	---	.057	.60	1.10	15.22	24.86	---	1.24	2.12	.23	---	---	Bal	.33	.028	.007	.0015
L605	L-1842	.09	.65	1.34	20.37	9.60	Bal	---	---	---	---	14.49	1.98	---	.009	.010	---
D979	W23211	.078	.15	.18	15.02	43.97	---	4.06	3.04	1.02	---	3.57	Bal	---	.007	.006	.12

TABLE II

TENSILE TEST RESULTS

RENE' 41 ALLOY

(Density - 0.298 lb/in^3)

					Tensile Properties(c)					
					Unnotched				Notched	
Cold Reduction (percent)	Aging Treatment	(a) Exposure Temp (°F)	Test Temp (°F)	(b) Direction	Ultimate Strength (1000 psi)	Ultimate/Density (1000 in.)	Yield Strength (1000 psi)	Elong. (%)	Tensile Strength (1000 psi)	Notch Ratio
0	16hr-1400°F	None	-110	L	222	745	162	25	186	.84
		650	-110	L	217	729	166	17	183	.84
		None	-110	T	219	735	159	27	179	.82
		650	-110	T	203	682	164	10	178	.88
		None	75	L	204	685	154	22	172	.84
		650	75	L	196	658	155	16	170	.88
		800	75	L	186	624	156	11	169	.91
		1000	75	L	203	682	157	24	166	.82
		None	75	T	204	685	154	23	171	.83
		650	75	T	195	655	152	13	162	.83
		800	75	T	201	675	154	25	169	.84
		1000	75	T	201	675	---	19	159	.79
		None	350	L	196	658	145	27	158	.81
		None	350	T	193	648	141	25	151	.78
		None	650	L	184	618	145	25	154	.84
		650	650	L	183	614	142	19	156	.85
		None	650	T	191	641	147	21	157	.82
		650	650	T	180	604	143	14	148	.82
		None	800	L	179	601	139	26	156	.87
		800	800	L	174	584	134	18	145	.83
		None	800	T	182	611	143	25	150	.82
		800	800	T	175	588	132	24	134	.76
		None	1000	L	175	588	133	24	148	.85
		1000	1000	L	179	601	145	16	121	.68
		None	1000	T	178	598	138	20	145	.81
		1000	1000	T	176	591	136	19	131	.74
20	16hr-1400°F	None	-110	L	247	830	214	14	221	.90
		None	-110	T	244	819	209	14	190	.78
		None	75	L	229	769	208	10	205	.89
		650	75	L	230	772	205	12	196	.85
		None	75	T	225	755	200	10	181	.80
		None	650	L	215	722	190	11	160	.74
		650	650	L	213	715	189	11	160	.75
		None	650	T	209	702	188	12	132	.63
		650	650	T	208	698	185	11	166	.80
		None	800	L	213	715	192	13	126	.59
35	2hr-1500°F	None	75	L	249	836	230	8	196	.79
		650	75	L	246	826	230	9	---	---
		None	75	T	237	795	216	7	182	.77
		None	650	L	229	769	210	7	138	.60
		650	650	L	229	769	213	6	160	.70
		None	650	T	222	745	200	8	155	.70
		650	650	T	221	742	200	7	158	.72
		None	800	L	221	742	210	6	142	.64
		None	800	T	217	729	196	6	142	.63

a) Exposure for 1000 hours under 40,000 psi at the indicated temperature
b) L - Longitudinal; T - Transverse
c) "Ultimate/Density" - ratio of ultimate strength to density; "Yield Strength" - 0.2-percent offset yield; "Elong." - elongation in 2 inches; "Notched Tensile Strength" - tensile strength of sample with sharp edge notches; "Notch Ratio" - ratio of Notched Tensile Strength to Ultimate Strength.

TABLE III

TENSILE TEST RESULTS

N155 ALLOY

(Density - 0.298 lb/in^3)

Cold Reduction (percent)	Aging Treatment	(a) Exposure Temp (°F)	Test Temp (°F)	(b) Direction	Tensile Properties(c) Unnotched Ultimate Strength (1000 psi)	Ultimate / Density (1000 in.)	Yield Strength (1000 psi)	Elong. (%)	Notched Tensile Strength (1000 psi)	Notch Ratio
40	None	None	-110	L	216	725	180	12	213	.99
		None	-110	T	222	745	185	10	194	.87
		None	75	L	188	631	167	7	183	.97
		650	75	L	205	688	189	4.5	196	.96
		None	75	T	190	638	159	8	168	.88
		650	75	T	210	705	183	6	164	.78
		None	350	L	173	581	150	2.5	160	.92
		None	350	T	178	598	158	3.5	118	.66
		None	650	L	168	564	151	1.5	110	.65
		650	650	L	170	571	155	2.0	131	.77
		None	650	T	175	588	154	2.5	114	.65
		650	650	T	179	601	158	2.5	102	.57
		None	800	L	166	557	150	2.5	127	.76
		None	800	T	173	581	147	2.0	97	.56
65	None	None	-110	L	247	830	210	6.0	212	.86
		None	-110	T	264	886	227	7.5	164	.62
		None	75	L	217	729	185	4.0	186	.86
		650	75	L	244	819	224	2.0	180	.74
		None	75	T	232	779	187	5.0	115	.50
		650	75	T	259	870	227	2.5	122	.47
		None	350	L	201	675	165	2.5	154	.77
		None	350	T	215	722	177	3.0	107	.50
		None	650	L	198	665	176	2.0	144	.73
		650	650	L	207	695	188	2.0	118	.59
		None	650	T	213	715	186	2.0	88	.41
		650	650	T	221	742	199	2.0	91	.41
		None	800	L	201	675	174	1.5	118	.59
		None	800	T	213	715	185	1.5	69	.32

a) Exposure for 1000 hours under 40,000 psi at tne indicated temperature
b) L - Longitudinal; T - Transverse
c) "Ultimate/Density" - ratio of ultimate strength to density; "Yield Strength" - 0.2-percent offset yield; "Elong." - elongation in 2 inches; "Notched Tensile Strength" - tensile strength of sample with sharp edge notches; "Notch Ratio" - ratio of Notched Tensile Strength to Ultimate Strength.

TABLE IV

TENSILE TEST RESULTS

L605 ALLOY

(Density - 0.332 lb/in^3)

Cold Reduction (percent)	Aging Treatment	Exposure Temp (°F)(a)	Test Temp (°F)	Direction(b)	Tensile Properties(c) Unnotched Ultimate Strength (1000 psi)	Ultimate/Density (1000 in.)	Yield Strength (1000 psi)	Elong. (%)	Notched Tensile Strength (1000 psi)	Notch Ratio
25	None	None	-110	L	234	705	154	15	197	.84
		None	-110	T	240	723	187	10	197	.82
		None	75	L	208	626	154	12	176	.85
		650	75	L	215	648	172	9	200	.93
		None	75	T	213	642	163	9	174	.82
		650	75	T	230	693	197	9	209	.91
		None	350	L	194	584	133	16	153	.79
		None	350	T	197	594	150	9	152	.77
		None	650	L	186	560	143	15	164	.88
		650	650	L	188	566	147	8	155	.82
		None	650	T	192	578	158	8	142	.74
		650	650	T	197	594	167	6	155	.79
		None	800	L	184	554	140	7	143	.78
		None	800	T	196	591	162	5	130	.66
45	None	None	-110	L	291	877	211	3.0	157	.54
		None	-110	T	305	919	230	4.5	140	.46
		None	75	L	264	795	182	2.5	146	.55
		650	75	L	290	874	247	2.0	156	.54
		None	75	T	276	831	192	4.0	137	.50
		650	75	T	302	910	258	3.0	127	.42
		None	350	L	250	753	182	2.5	128	.51
		None	350	T	263	792	202	4.0	124	.47
		None	650	L	251	756	193	2.0	118	.47
		650	650	L	257	774	214	2.3	154	.60
		None	650	T	262	789	208	2.5	130	.50
		650	650	T	264	795	213	2.8	97	.37
		None	800	L	249	750	203	2.0	144	.58
		None	800	T	260	783	221	2.0	107	.41

a) Exposure for 1000 hours under 40,000 psi at the indicated temperature
b) L - Longitudinal; T - Transverse
c) "Ultimate/Density" - ratio of ultimate strength to density; "Yield Strength" - 0.2-percent offset yield; "Elong." - elongation in 2 inches; "Notched Tensile Strength" - tensile strength of sample with sharp edge notches; "Notch Ratio" - ratio of Notched Tensile Strength to Ultimate Strength.

TABLE V

TENSILE TEST RESULTS

D979 ALLOY

(Density - 0. 296 lb/in^3)

					Tensile Properties[c]					
					Unnotched				Notched	
Cold Reduction (percent)	Aging Treatment	(a) Exposure Temp (°F)	Test Temp (°F)	(b) Direction	Ultimate Strength (1000 psi)	Ultimate/Density (1000 in.)	Yield Strength (1000 psi)	Elong. (%)	Notched Tensile Strength (1000 psi)	Notch Ratio
30	16hr-1200°F	None	75	L	222	750	198	7.0	211	.95
		None	75	T	216	730	182	8.0	197	.91
		None	350	L	212	716	196	4.5	182	.86
		None	650	L	211	714	198	3.0	164	.78
		650	650	L	202	683	190	4.3	190	.94
		None	650	T	195	659	174	5.0	146	.75
		650	650	T	194	656	168	4.5	151	.78
		None	800	L	199	673	188	3.5	144	.72
		None	800	T	192	649	168	4.5	150	.78
50	16hr-1100°F	None	75	L	273	923	257	1.8	178	.65
		None	75	T	262	886	238	3.8	190	.72
		None	650	L	244	825	239	1.5	143	.61
		None	650	T	237	801	213	2.5	123	.52

a) Exposure for 1000 hours under 40,000 psi at the indicated temperature
b) L - Longitudinal; T - Transverse
c) "Ultimate/Density" - ratio of ultimate strength to density; "Yield Strength" - 0.2-percent offset yield; "Elong." - elongation in 2 inches; "Notched Tensile Strength" - tensile strength of sample with sharp edge notches; "Notch Ratio" - ratio of Notched Tensile Strength to Ultimate Strength.

TABLE VI

TENSILE TEST RESULTS

A286 ALLOY

(Density - 0. 288 lb/in^3)

					Tensile Properties[c]					
					Unnotched				Notched	
Cold Reduction (percent)	Aging Treatment	(a) Exposure Temp (°F)	Test Temp (°F)	(b) Direction	Ultimate Strength (1000 psi)	Ultimate/Density (1000 in.)	Yield Strength (1000 psi)	Elong. (%)	Notched Tensile Strength (1000 psi)	Notch Ratio
30	16hr-1300°F	None	-110	L	202	701	169	14	189	.94
		None	75	L	185	642	163	11	180	.97
		None	75	T	181	628	154	10	180	.99
		650	75	T	182	632	157	11	174	.95
		None	650	L	166	576	151	6	123	.74
		650	650	L	167	580	158	6	143	.86
		None	650	T	167	580	147	6	121	.72
		650	650	T	166	576	151	7	123	.74
		None	800	L	162	563	145	5	116	.71
		None	800	T	163	566	146	5	115	.71
80	16hr-1100°F	None	75	L	239	830	230	2.8	143	.60
		None	75	T	263	913	250	3.8	140	.53
		None	650	T	230	798	216	2.5	83	.36

a) Exposure for 1000 hours under 40,000 psi at the indicated temperature
b) L - Longitudinal; T - Transverse
c) "Ultimate/Density" - ratio of ultimate strength to density; "Yield Strength" - 0.2-percent offset yield; "Elong." - elongation in 2 inches; "Notched Tensile Strength" - tensile strength of sample with sharp edge notches; "Notch Ratio" - ratio of Notched Tensile Strength to Ultimate Strength.

TABLE VII

TENSILE TEST RESULTS

AM350 ALLOY

(Density - 0.282 lb/in^3)

Cold Reduction (percent)	Aging Treatment	Exposure Temp (°F) [a]	Test Temp (°F)	Direction [b]	Tensile Properties [c]					
					Unnotched				Notched Tensile Strength (1000 psi)	Notch Ratio
					Ultimate Strength (1000 psi)	Ultimate/Density (1000 in.)	Yield Strength (1000 psi)	Elong. (%)		
(20-30)	3hr- 850°F	None	75	L	199	706	164	23	217	1.09
		None	75	T	205	727	174	20[d]	204	1.00
		None	650	L	174	617	148	6	162	.93
		None	650	T	176	624	141	4[d]	156	.89

a) Exposure for 1000 hours under 40,000 psi at the indicated temperature

b) L - Longitudinal; T - Transverse

c) "Ultimate/Density" - ratio of ultimate strength to density; "Yield Strength" - 0.2-percent offset yield; "Elong." - elongation in 2 inches; "Notched Tensile Strength" - tensile strength of sample with sharp edge notches; "Notch Ratio" - ratio of Notched Tensile Strength to Ultimate Strength.

d) Elongation in 1.75 inches

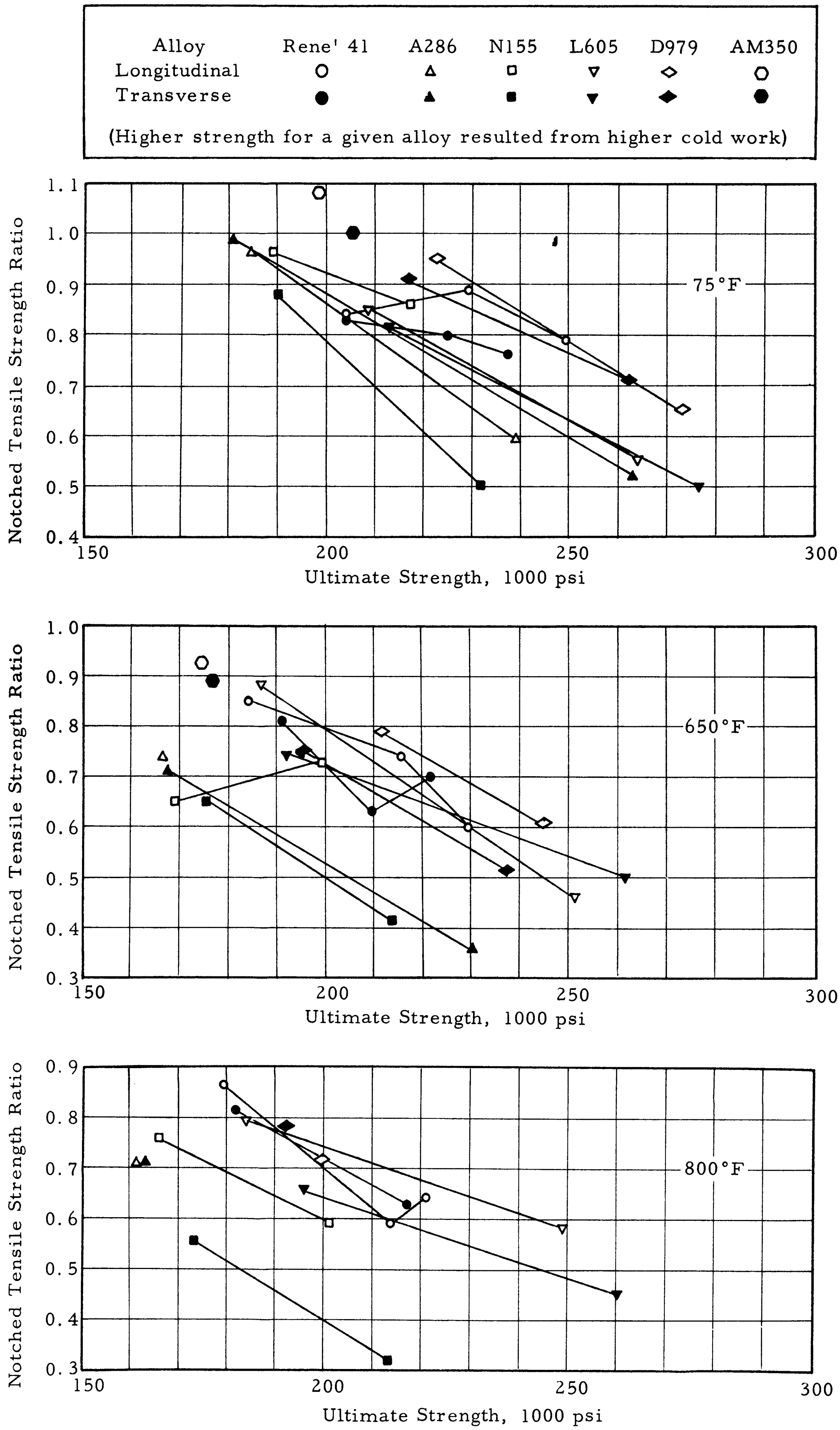


Figure 1 . Ratio of sharp notch strength to tensile strength as a function of the tensile strength for the indicated materials at 75°, 650°, and 800°F.

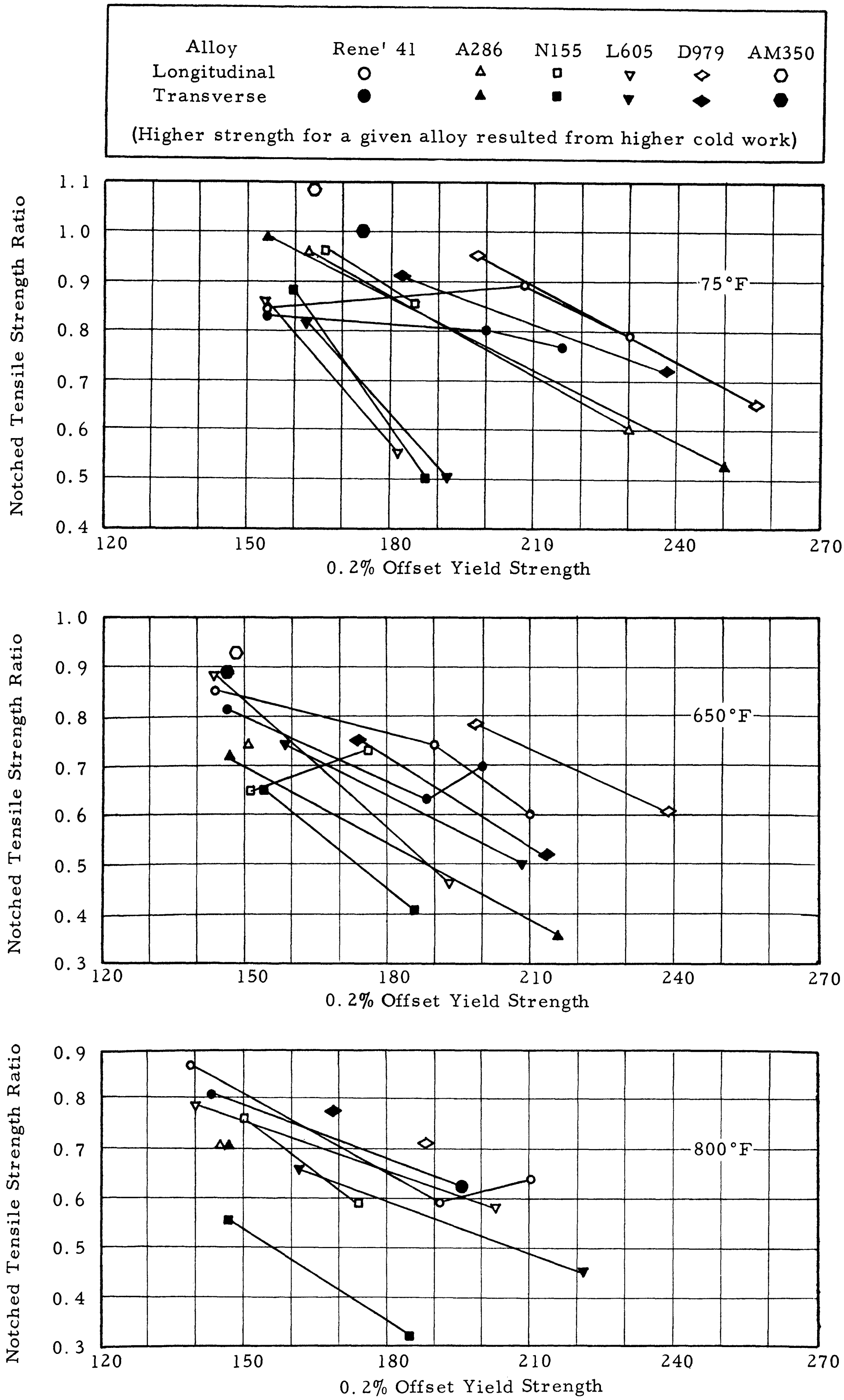


Figure 2. Ratio of sharp notch strength to tensile strength as a function of the 0.2 percent offset yield strength for the indicated materials at 75°, 650°, and 800°F

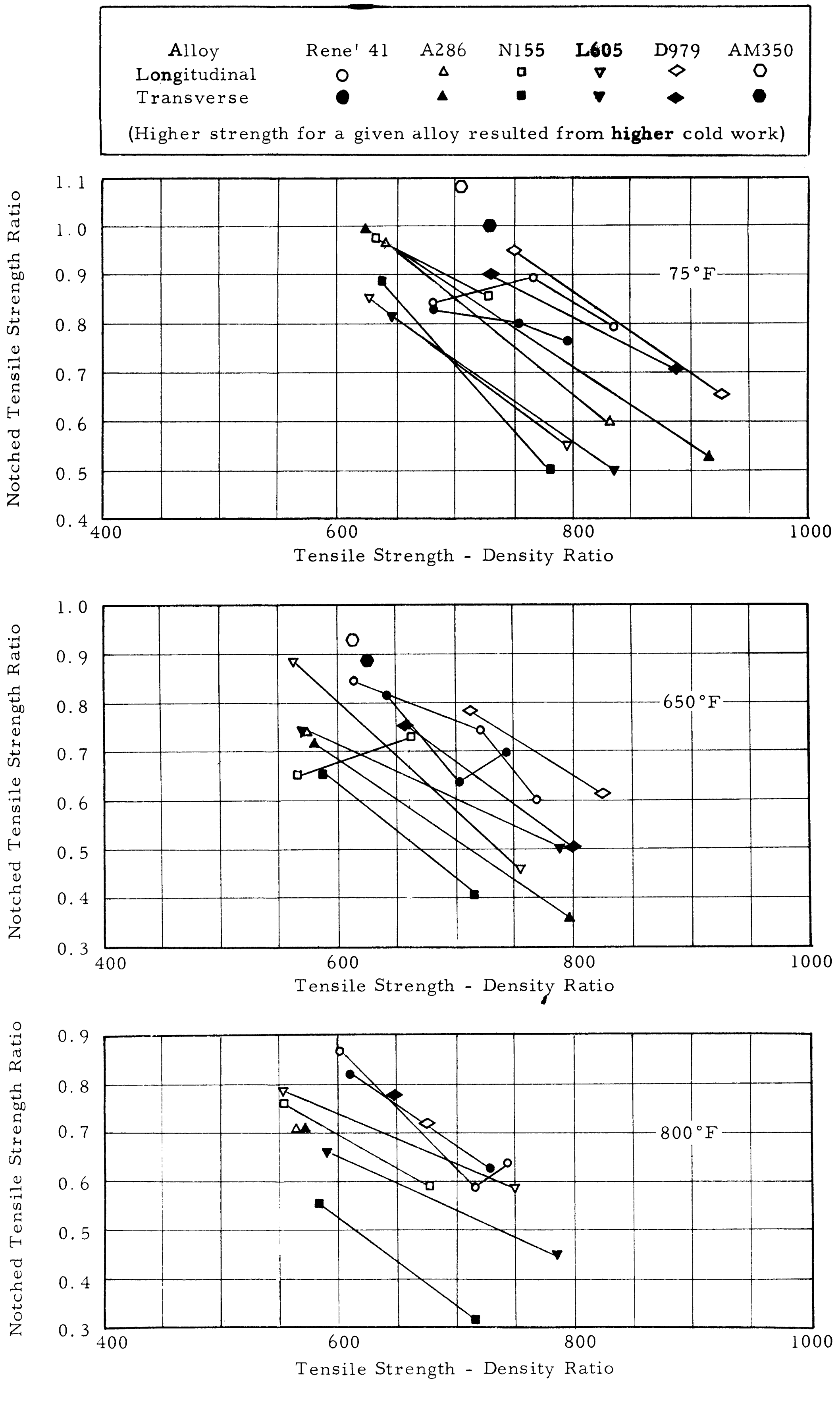
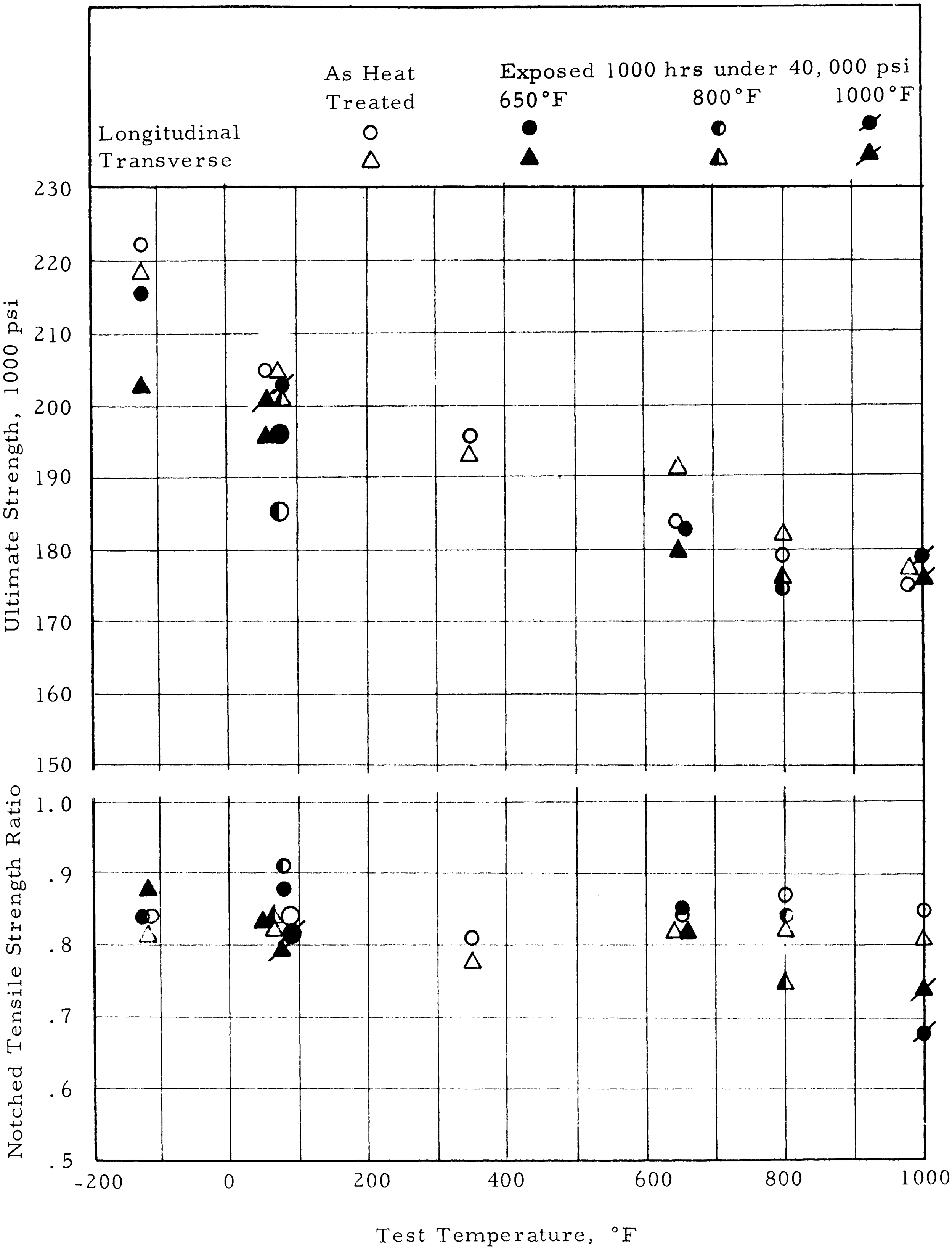
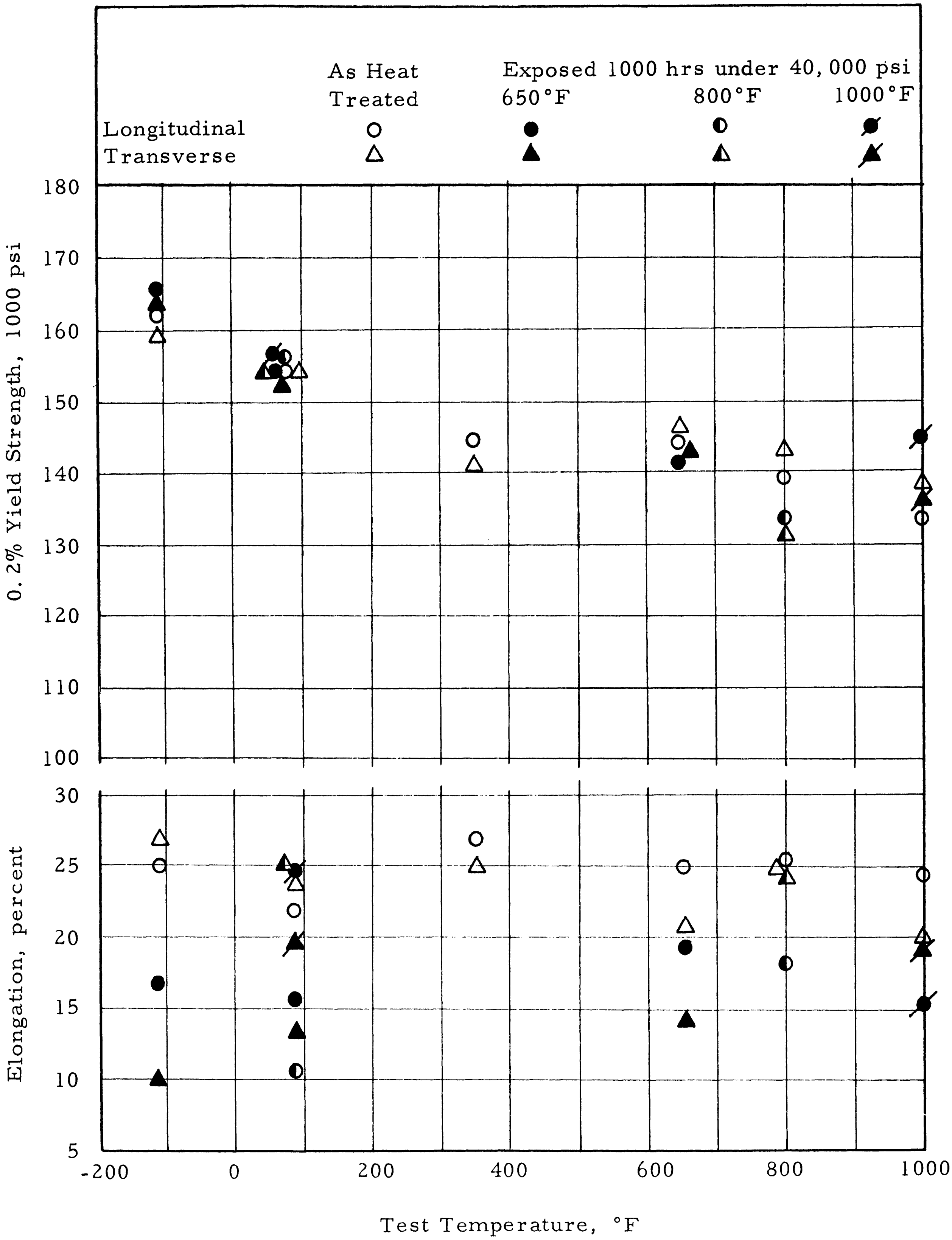


Figure 3. Ratio of sharp notch strength to tensile strength as a function of the tensile strength-density ratio for the indicated materials at 75°, 650°, and 800°F.



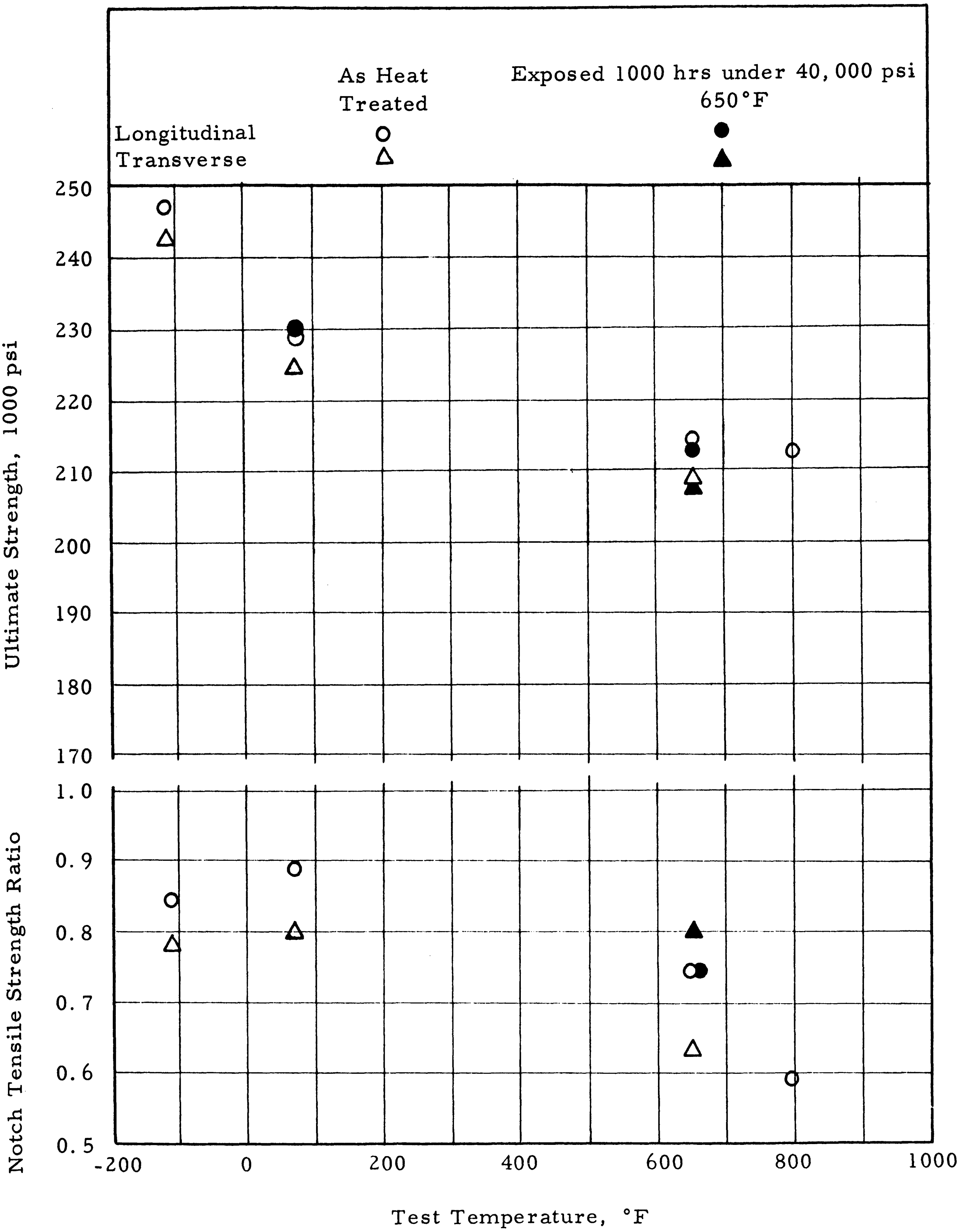
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 4. Tensile properties as a function of test temperature for Rene' 41 alloy annealed and aged 16 hours at 1400°F. Material was tested both as-heat treated and after creep exposure.



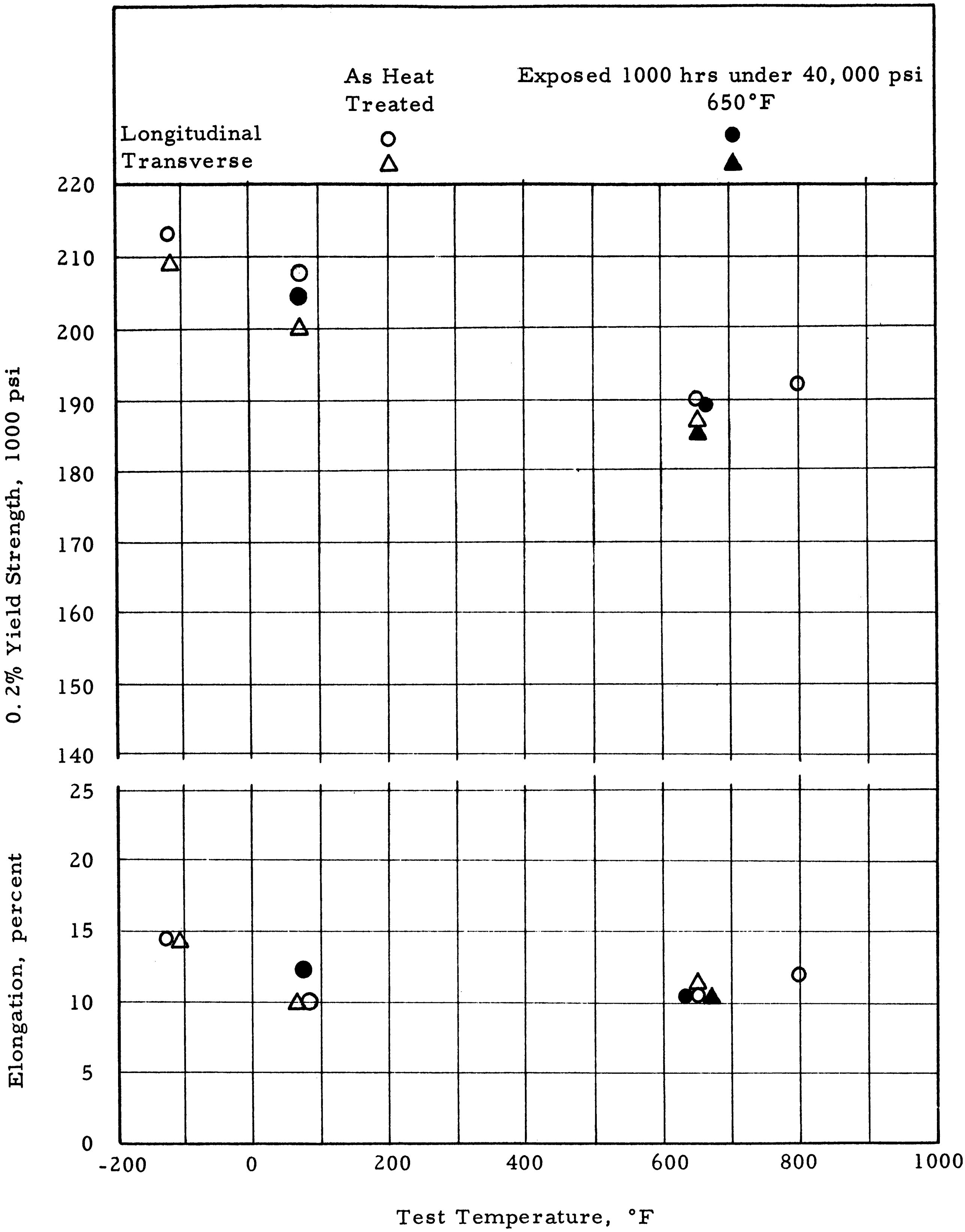
(b) 0.2-percent offset yield strength and elongation

Figure 4 (Concluded). Tensile properties as a function of test temperature for Rene' 41 alloy annealed and aged 16 hours at 1400°F. Material was tested both as-heat treated and after creep exposure.



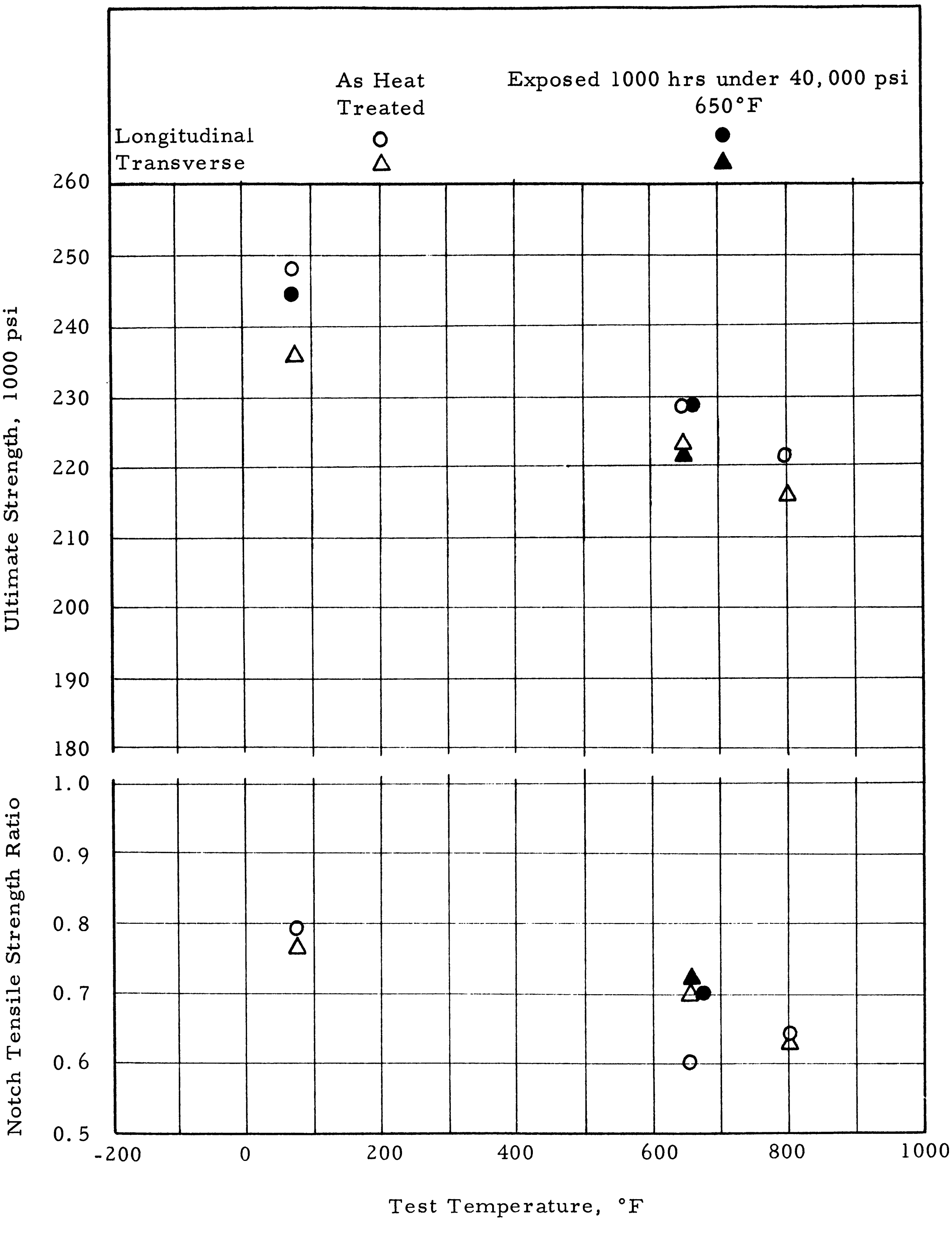
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 5. Tensile properties as a function of test temperature for Rene' 41 alloy cold reduced 20 percent and aged 16 hours at 1400°F. Material was tested both as-heat treated and after creep exposure.



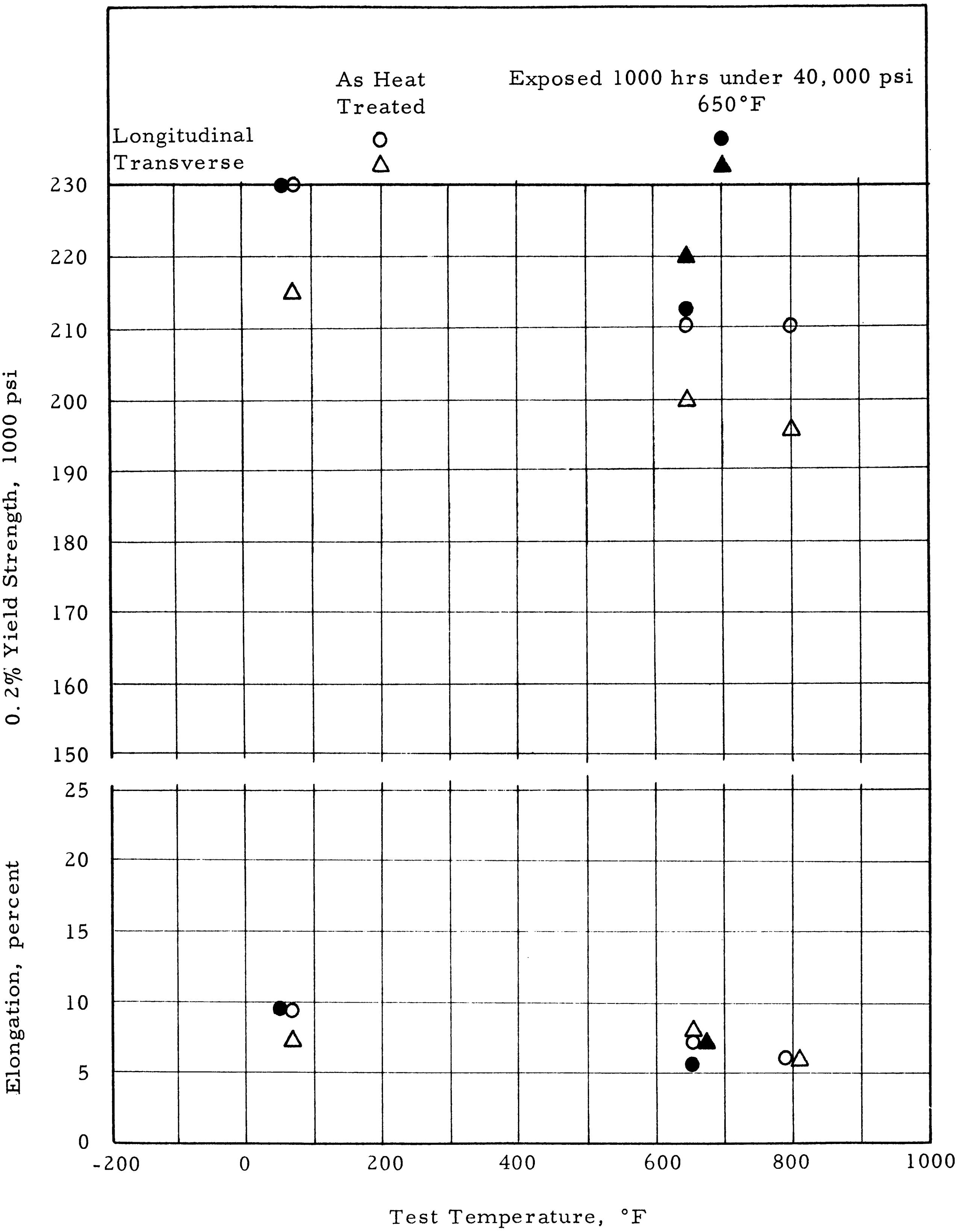
(b) 0.2-percent offset yield strength and elongation

Figure 5 (Concluded). Tensile properties as a function of test temperature for Rene' 41 alloy cold reduced 20 percent and aged 16 hours at 1400°F. Material was tested both as-heat treated and after creep exposure.



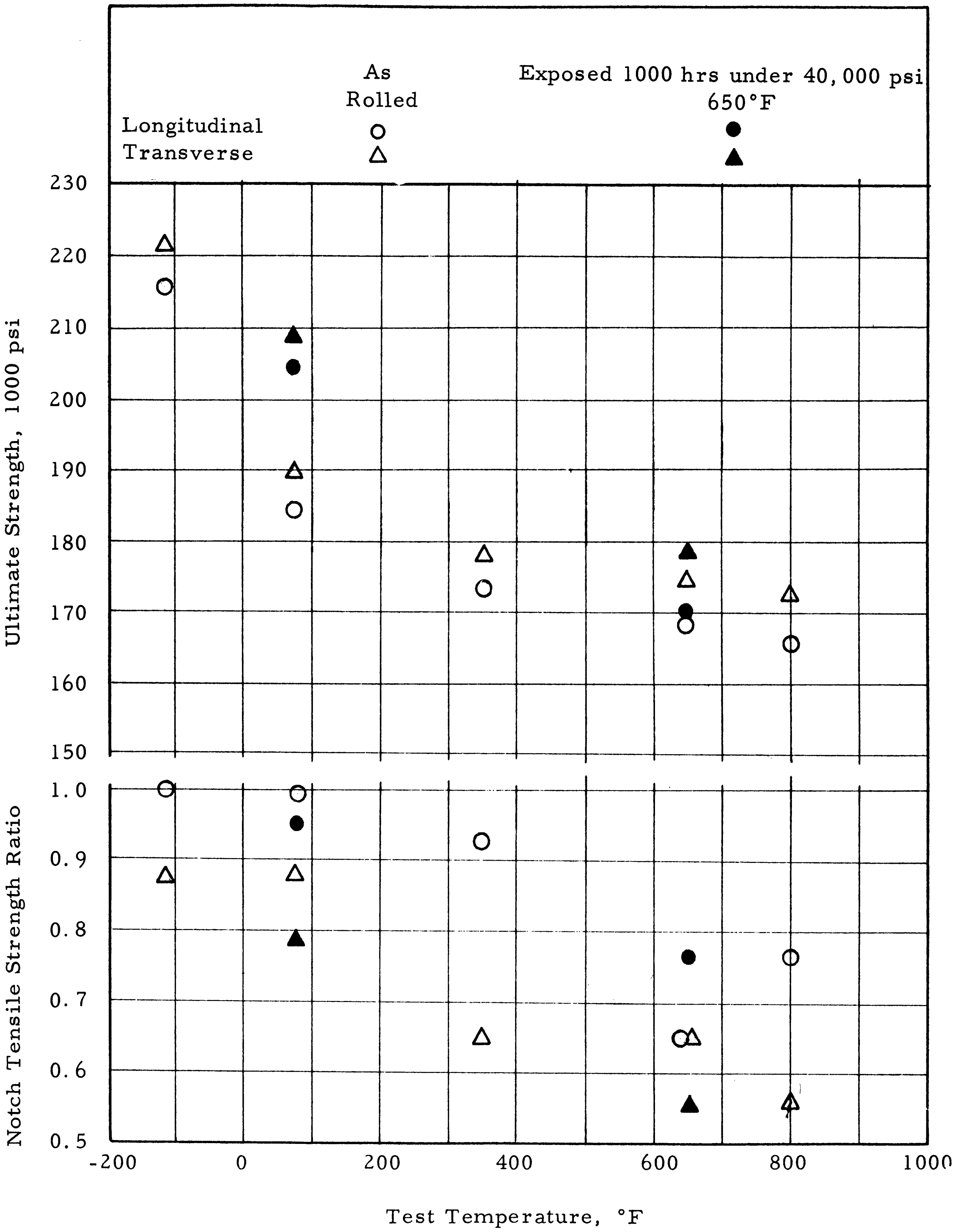
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 6. Tensile properties as a function of test temperature for Rene' 41 alloy cold reduced 35 percent and aged 2 hours at 1500°F. Material was tested both as-heat treated and after creep exposure.



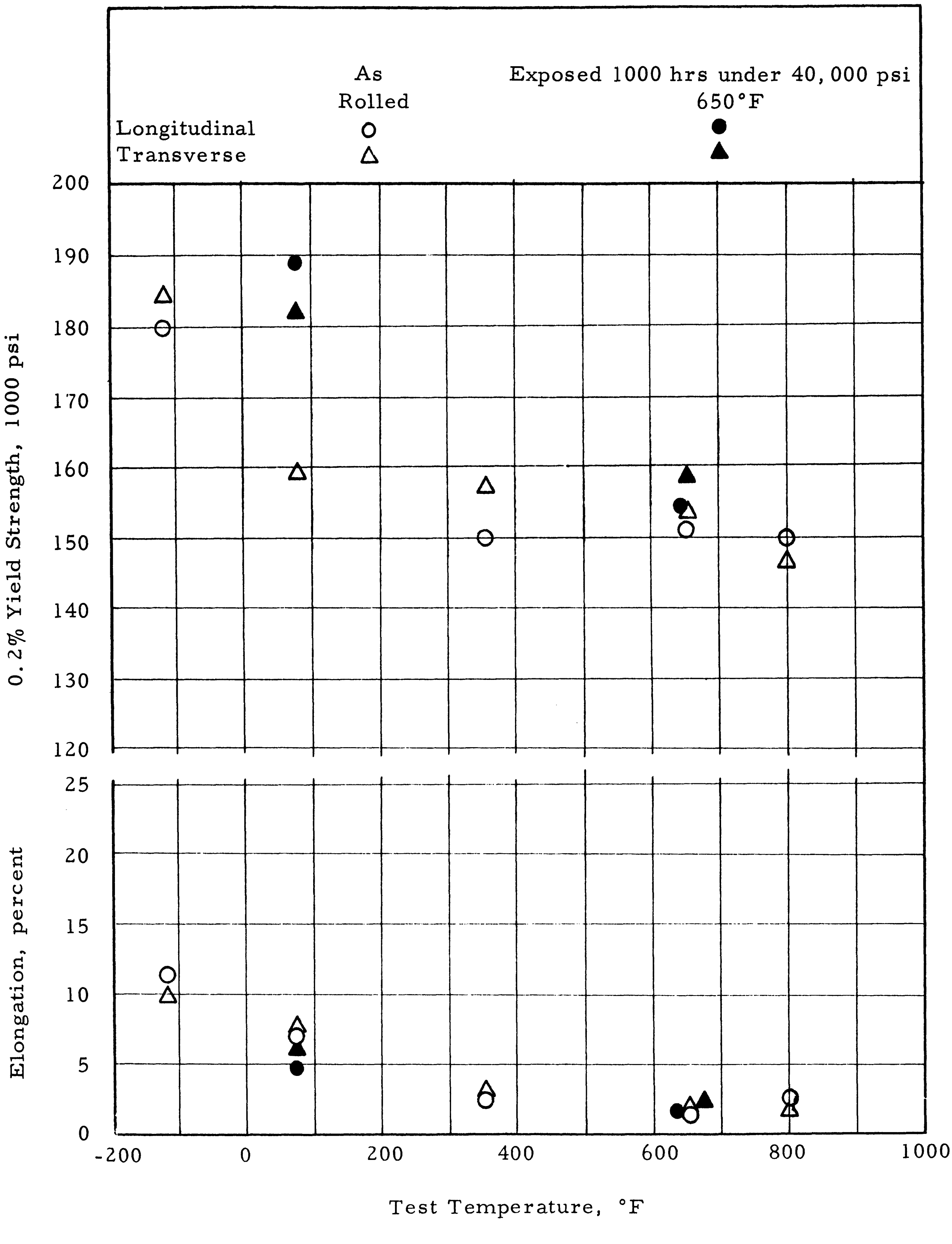
(b) 0.2-percent offset yield strength and elongation

Figure 6 (Concluded). Tensile properties as a function of test temperature for Rene' 41 alloy cold reduced 35 percent and aged 2 hours at 1500°F. Material was tested both as-heat treated and after creep exposure.



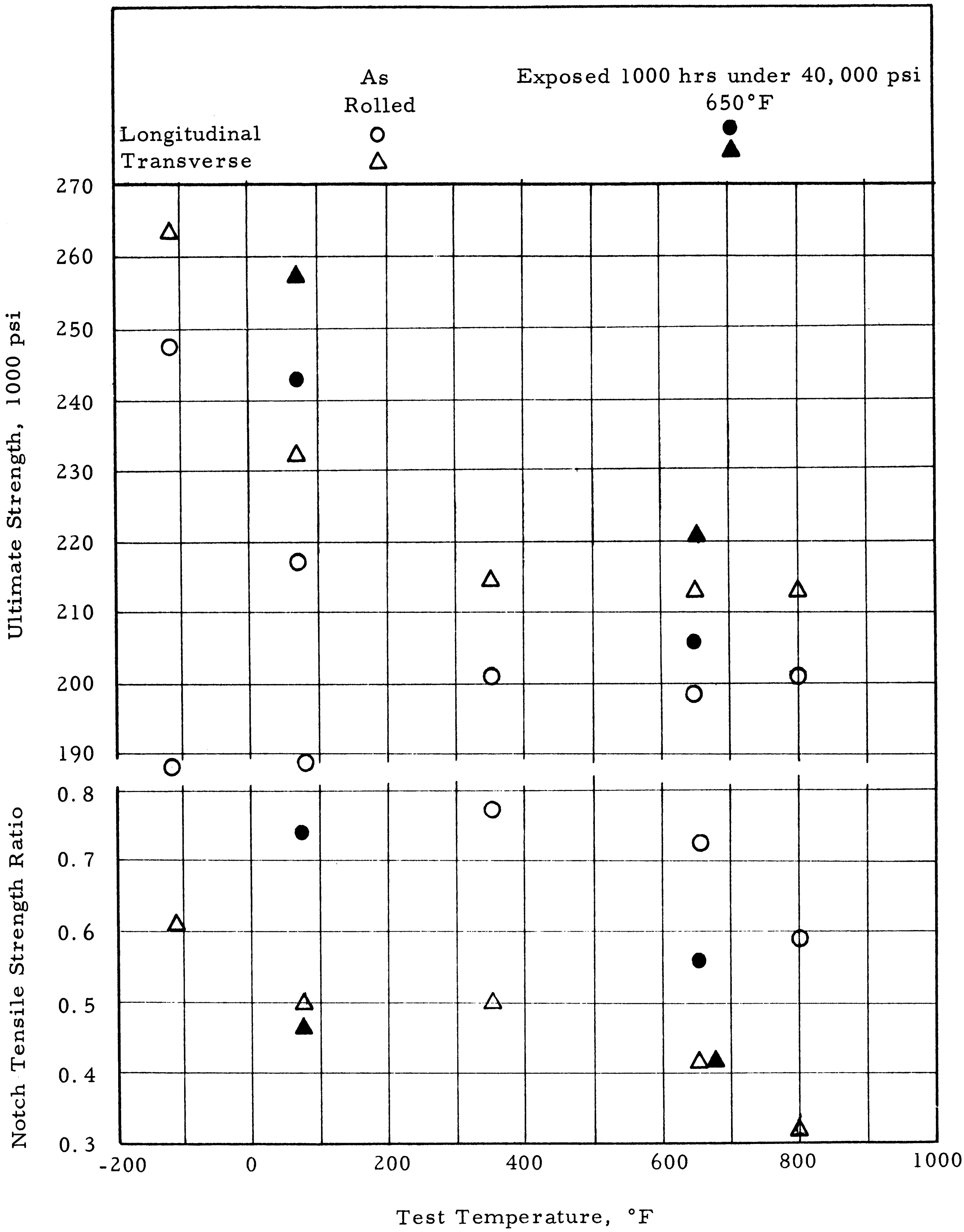
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 7. Tensile properties as a function of test temperature for N155 alloy cold reduced 40 percent. Material was tested both as-rolled and after creep exposure.



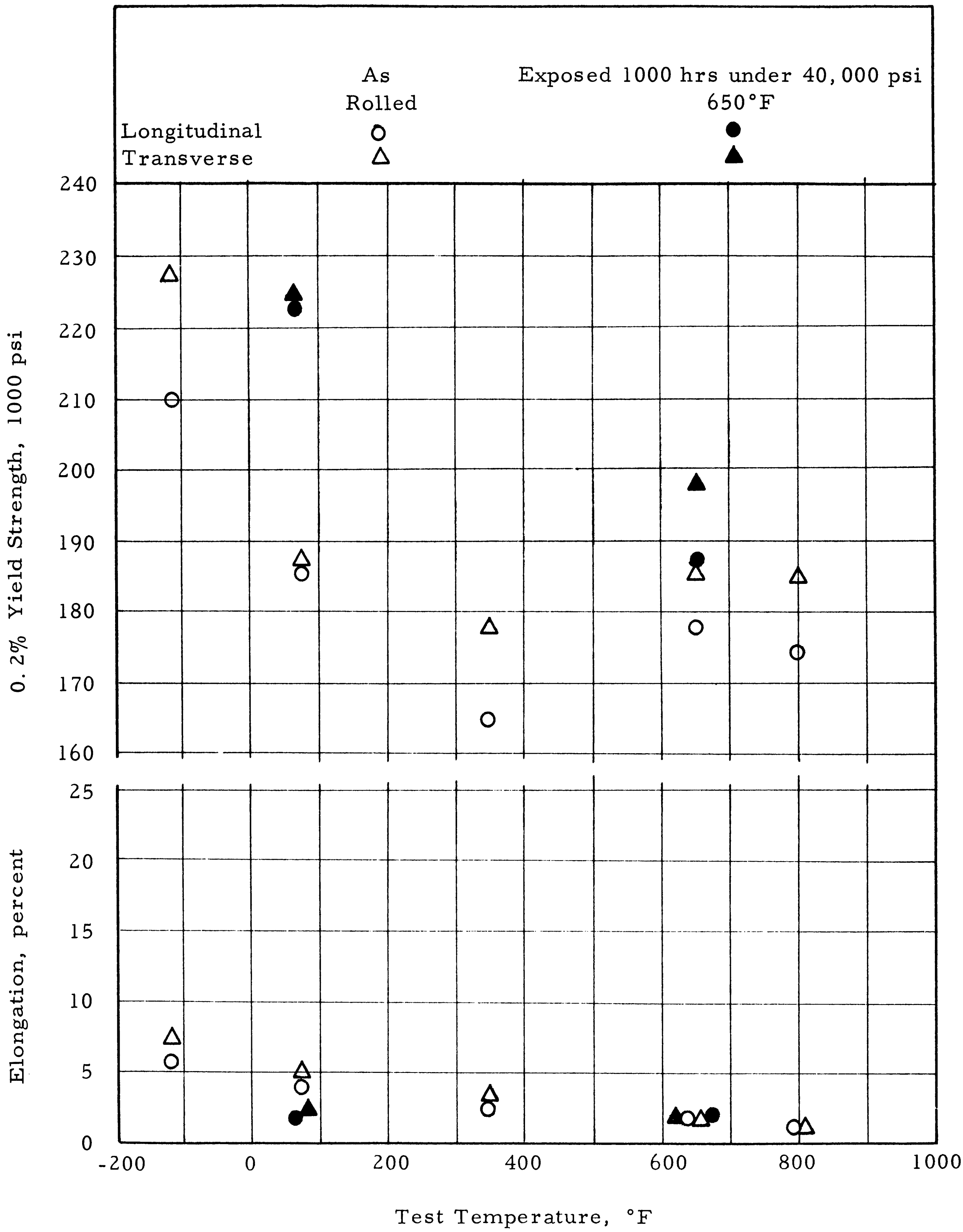
(b) 0.2-percent offset yield strength and elongation

Figure 7 (Concluded). Tensile properties as a function of test temperature for N155 alloy cold reduced 40 percent. Material was tested both as-rolled and after creep exposure.



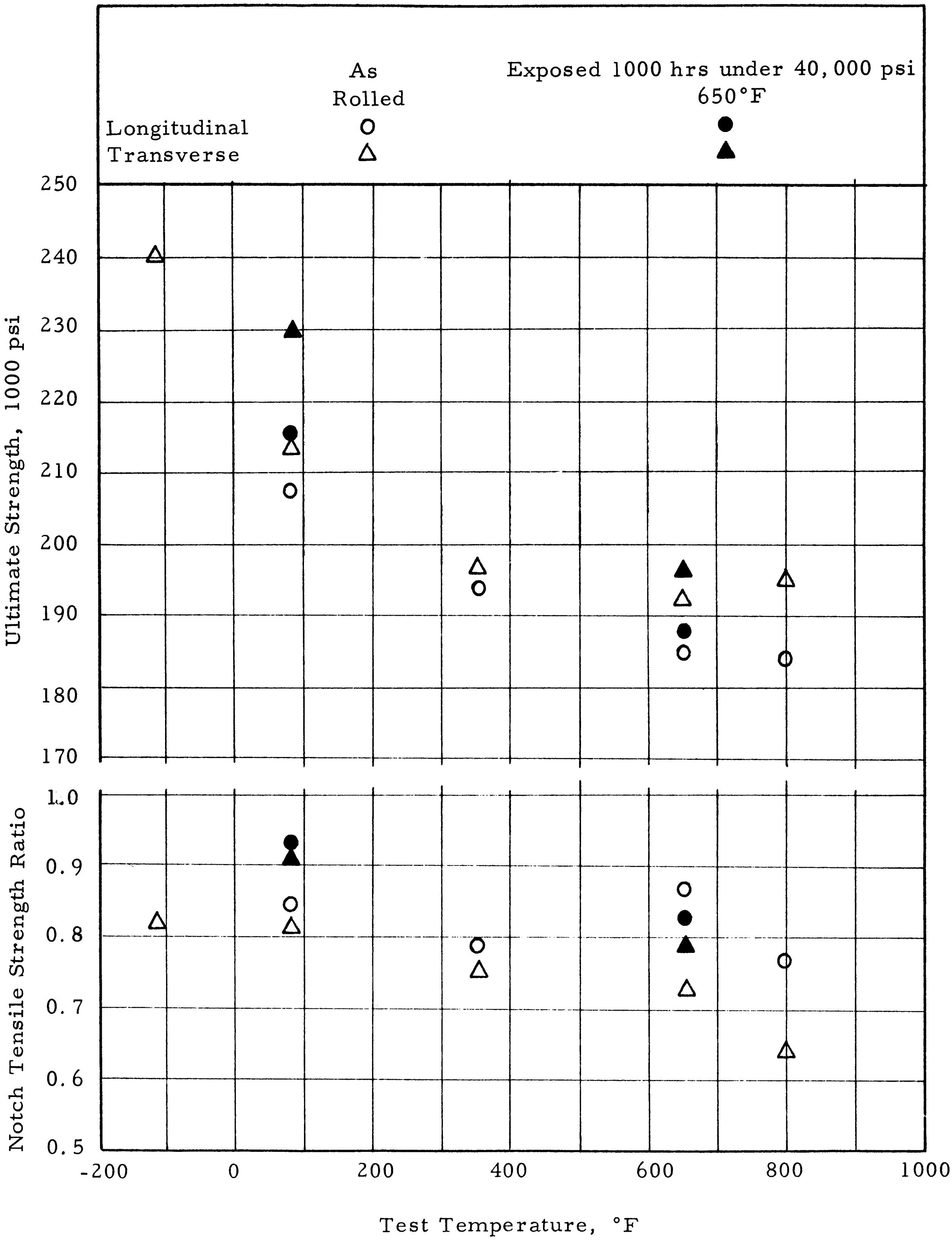
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 8. Tensile properties as a function of test temperature for N155 alloy cold reduced 65 percent. Material was tested both as-rolled and after creep exposure.



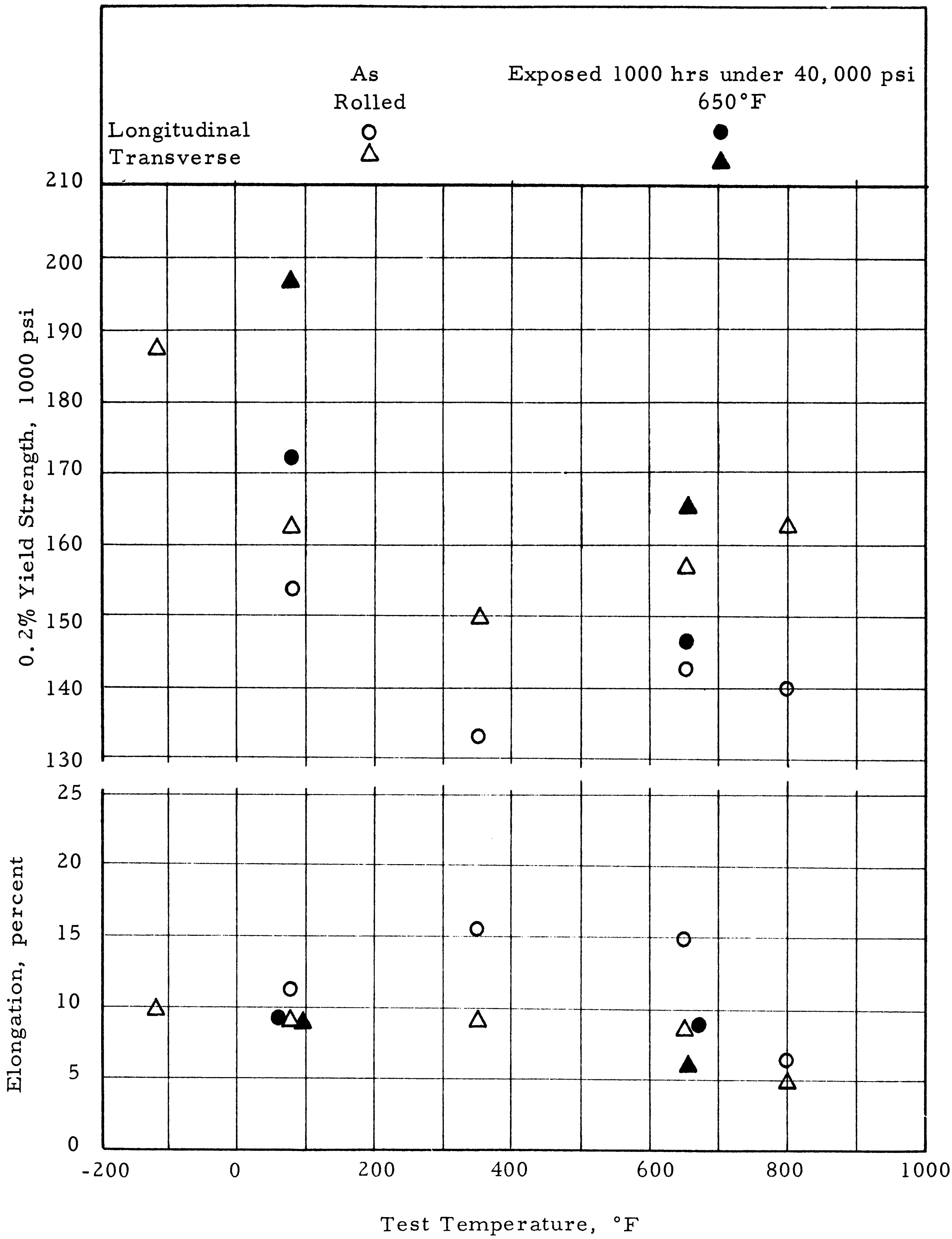
(b) 0.2-percent offset yield strength and elongation

Figure 8 (Concluded). Tensile properties as a function of test temperature for N155 alloy cold reduced 65 percent. Material was tested both as-rolled and after creep exposure.



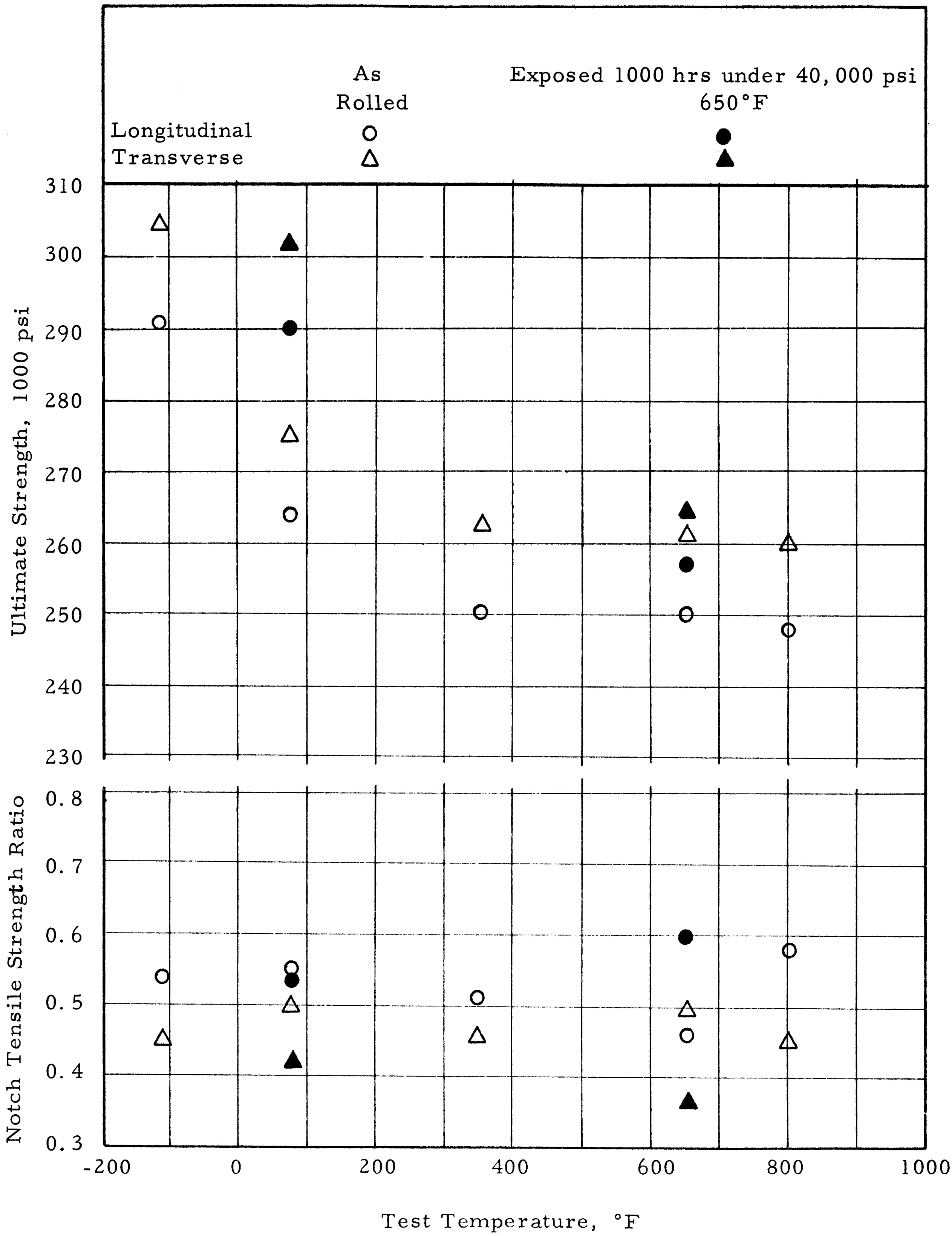
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 9. Tensile properties as a function of test temperature for L605 alloy cold reduced 25 percent. Material was tested both as-rolled and after creep exposure.



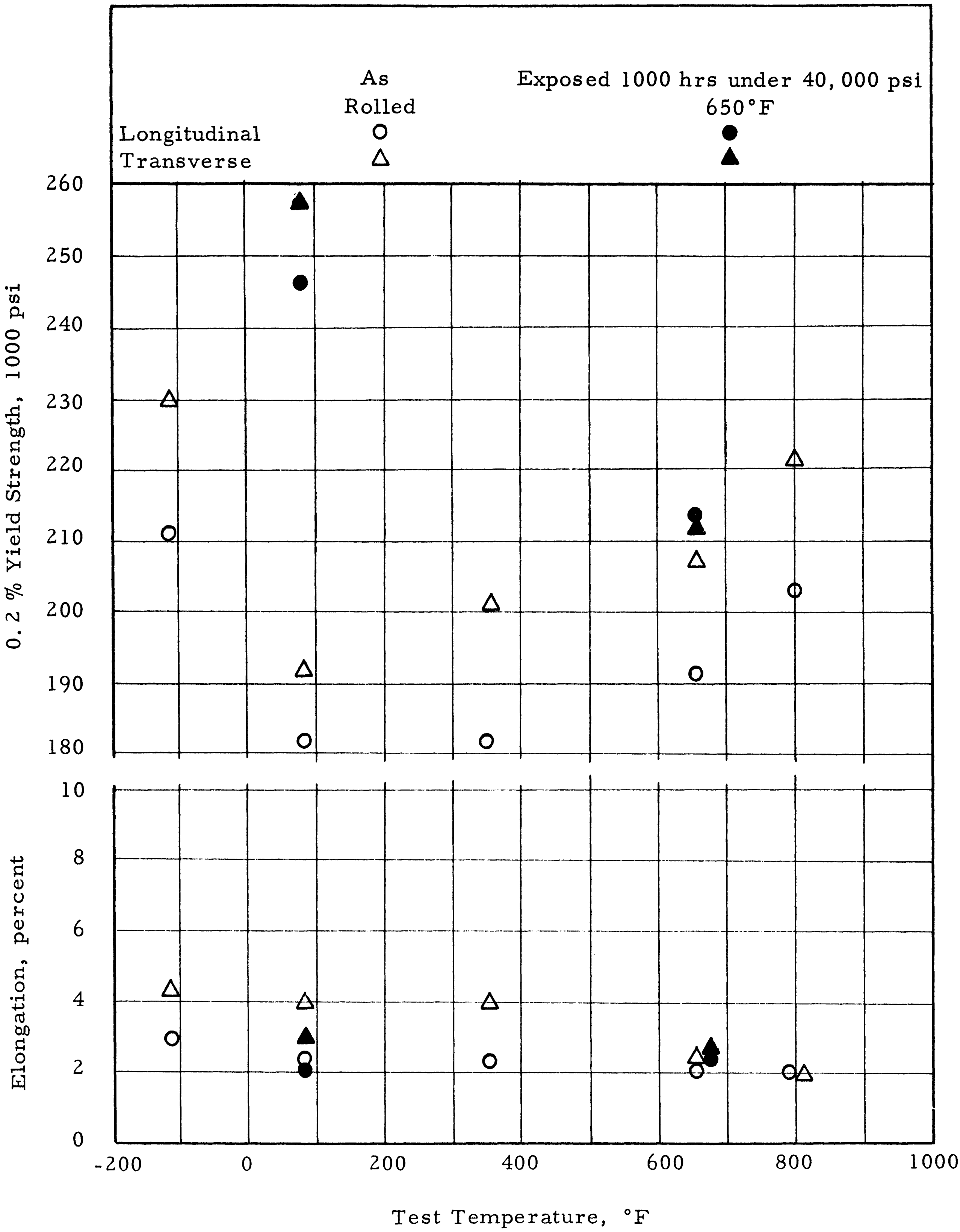
(b) 0.2-percent offset yield strength and elongation

Figure 9 (Concluded). Tensile properties as a function of test temperature for L605 alloy cold reduced 25 percent. Material was tested both as-rolled and after creep exposure.



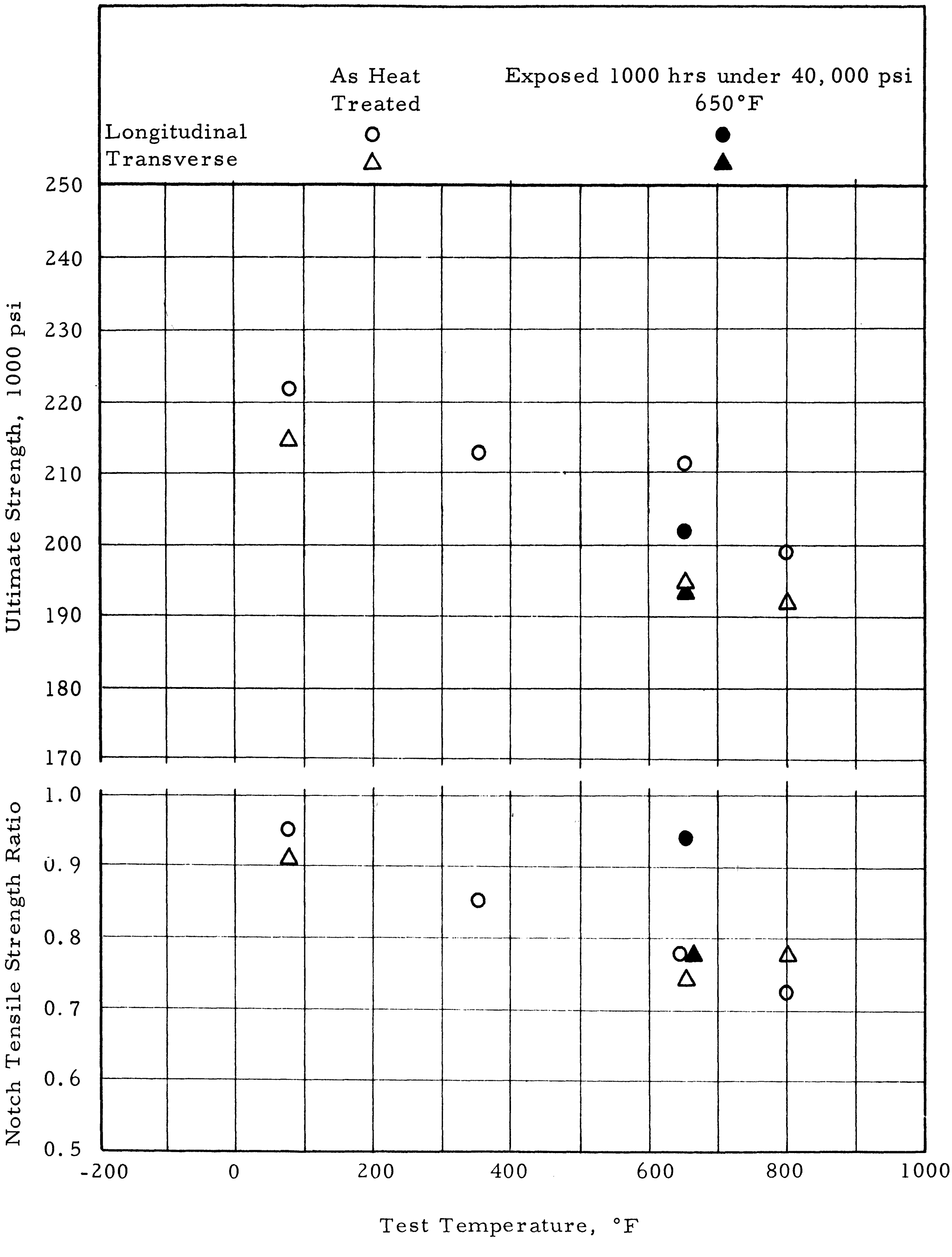
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 10. Tensile properties as a function of test temperature for L605 alloy cold reduced 45 percent. Material was tested both as-rolled and after creep exposure.



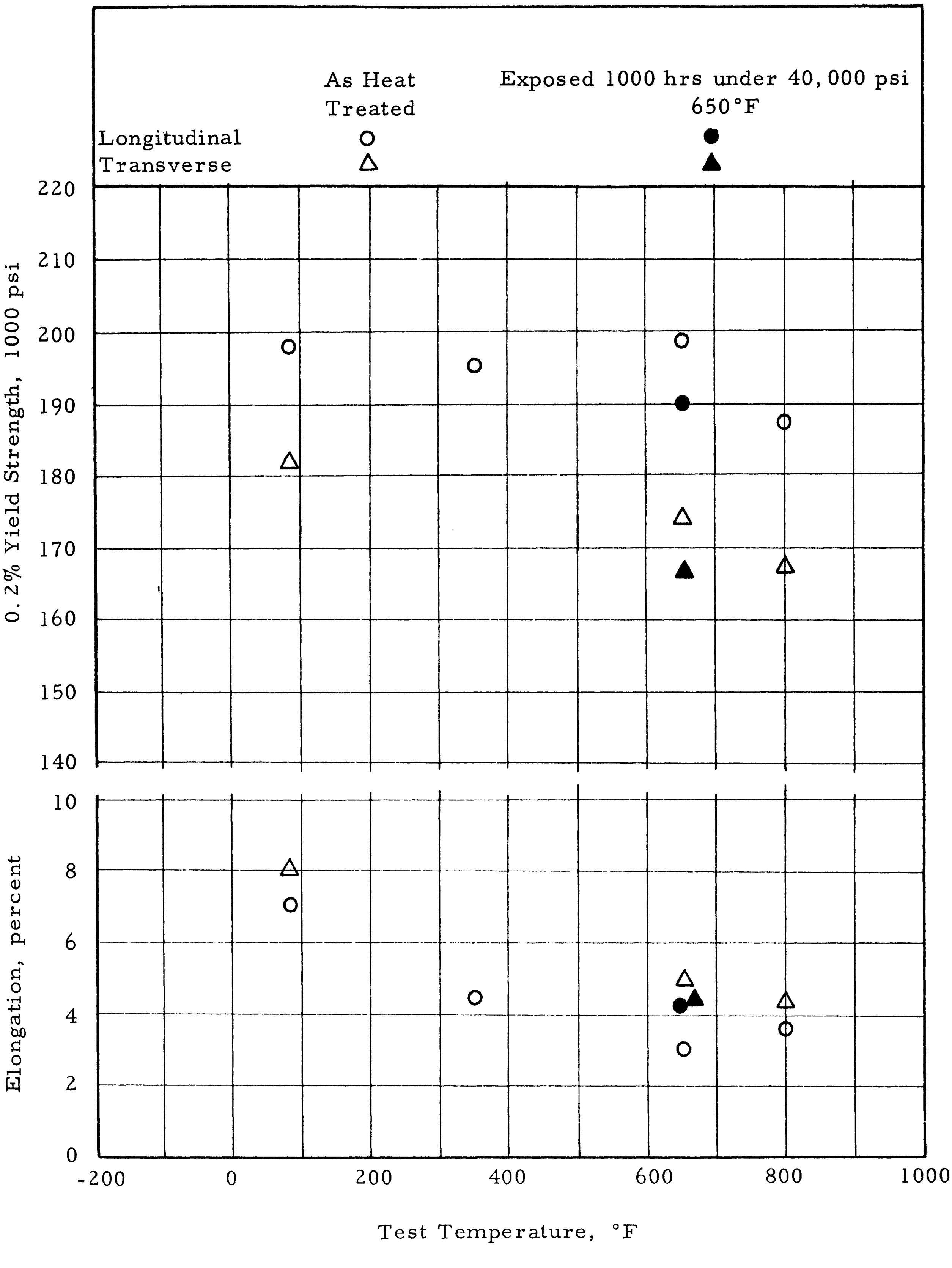
(b) 0.2-percent offset yield strength and elongation

Figure 10(Concluded). Tensile properties as a function of test temperature for L605 alloy cold reduced 45 percent. Material was tested both as-rolled and after creep exposure.



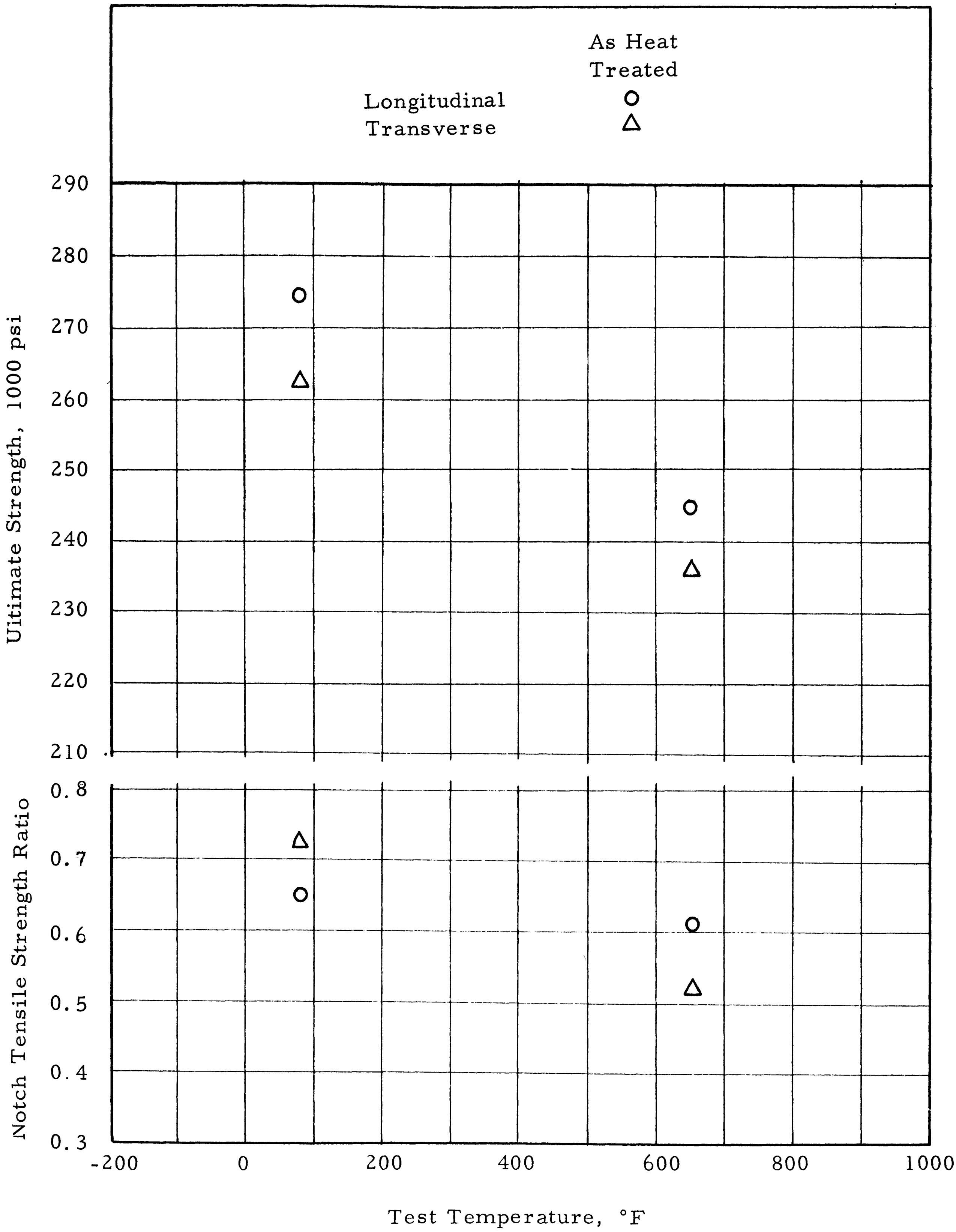
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 11. Tensile properties as a function of test temperature for D979 alloy cold reduced 30 percent and aged 16 hours at 1200°F. Material was tested both as-heat treated and after creep exposure.



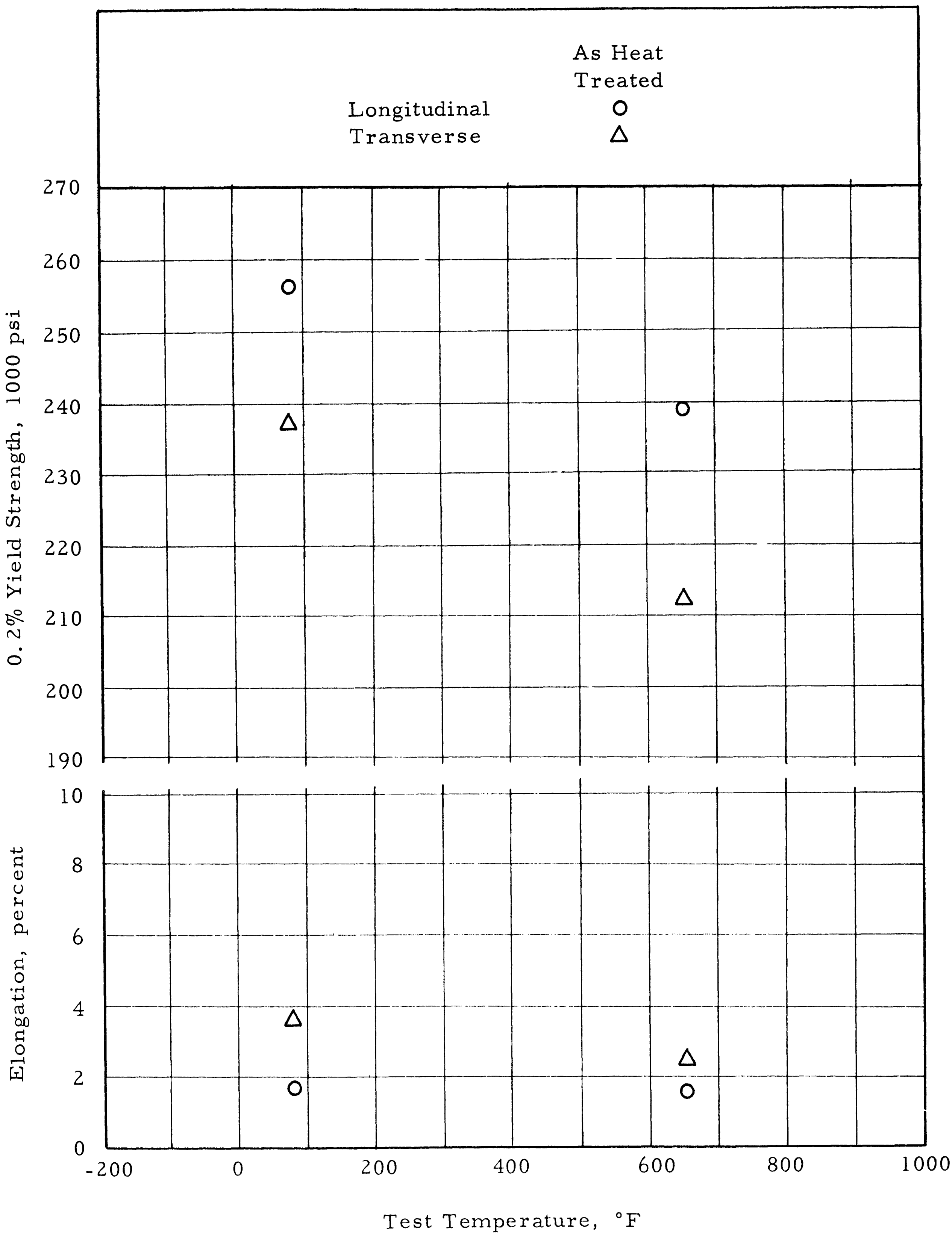
(b) 0.2-percent offset yield strength and elongation

Figure 11(Concluded). Tensile properties as a function of test temperature for D979 alloy cold reduced 30 percent and aged 16 hours at 1200°F. Material was tested both as-heat treated and after creep exposure.



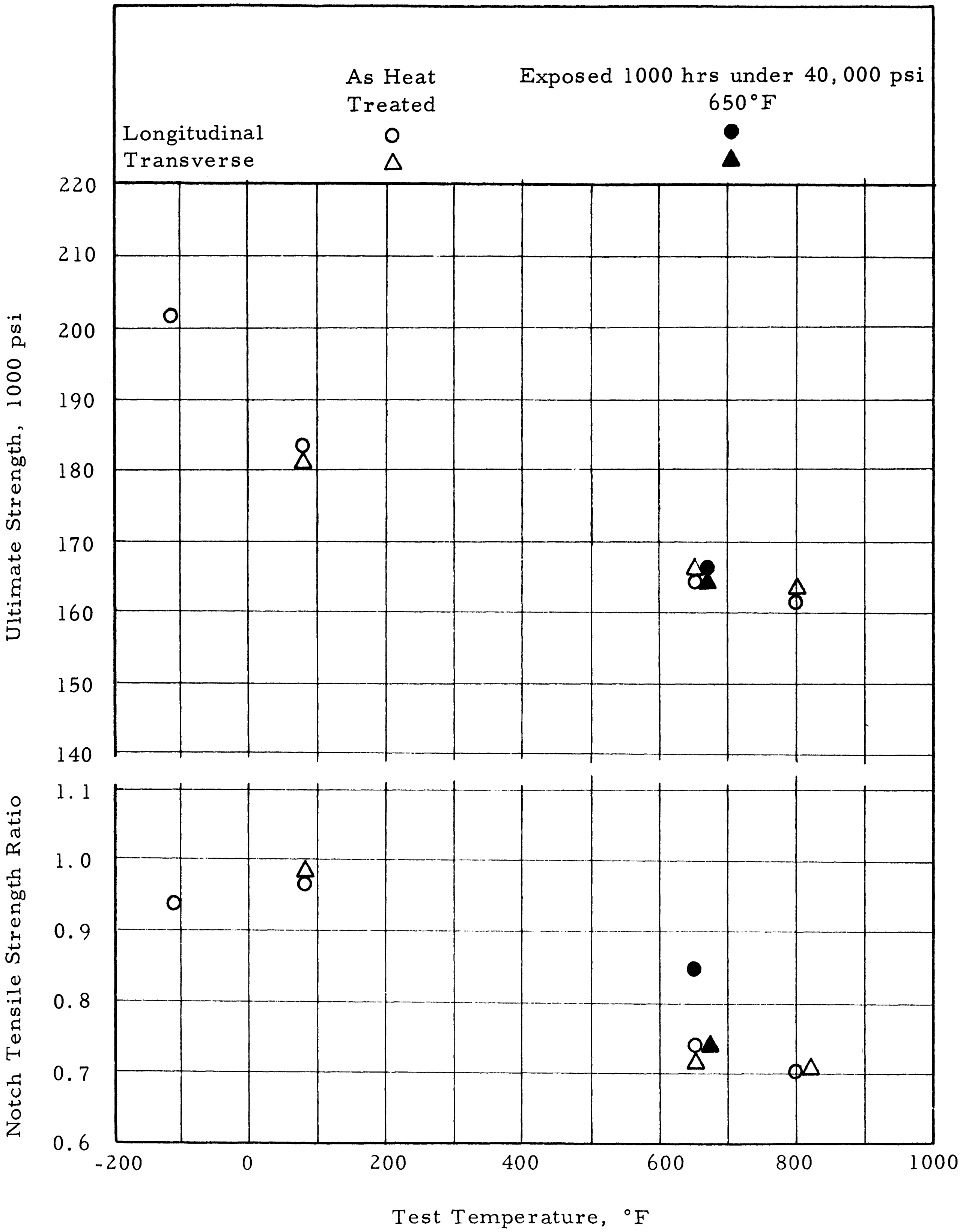
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 12. Tensile properties as a function of test temperature for D979 alloy cold reduced 50 percent and aged 16 hours at 1100°F.



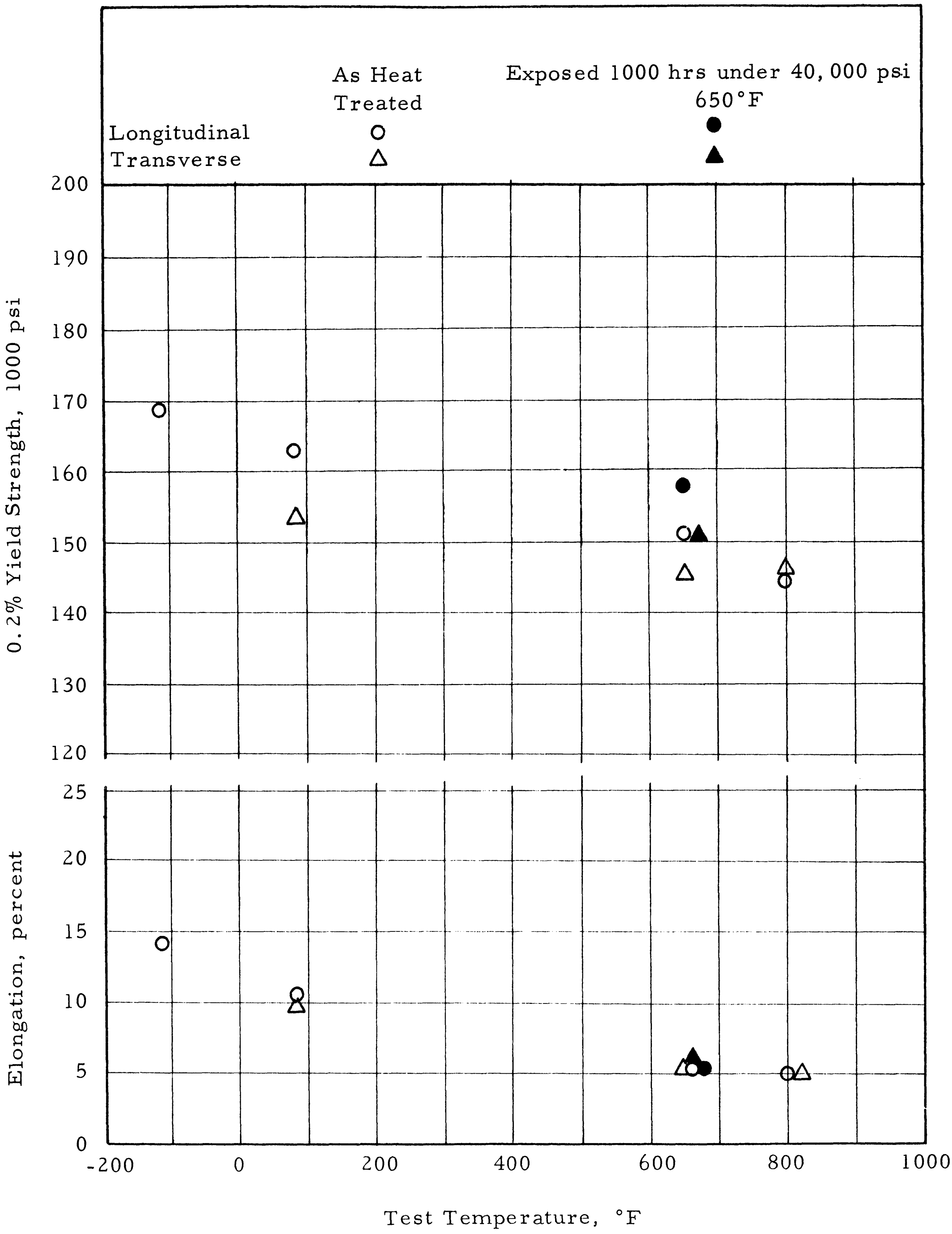
(b) 0.2-percent offset yield strength and elongation

Figure 12 (Concluded). Tensile properties as a function of test temperature for D979 alloy cold reduced 50 percent and aged 16 hours at 1100°F.



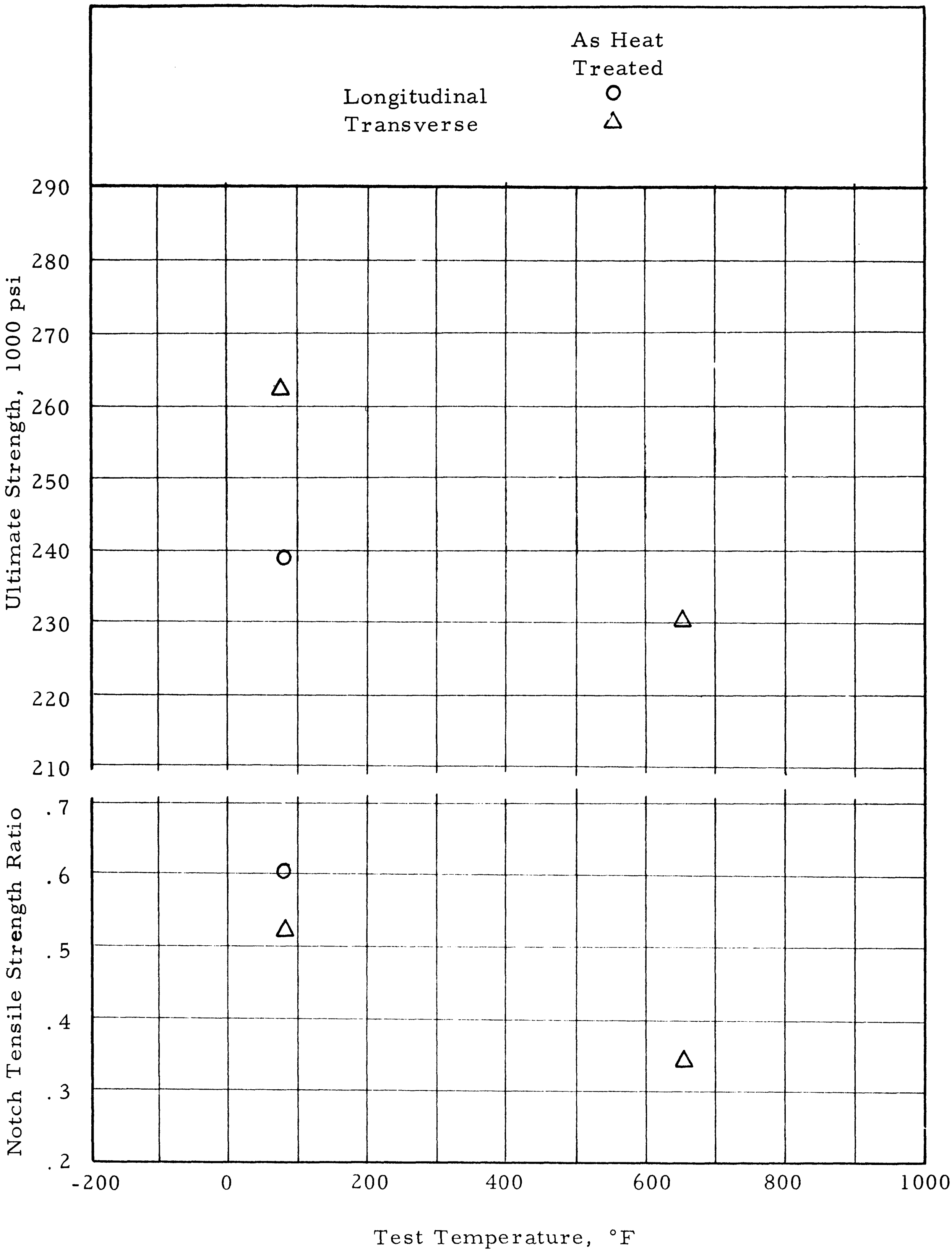
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 13. Tensile properties as a function of test temperature for A286 alloy cold reduced 30 percent and aged 16 hours at 1300°F. Material was tested both as-heat treated and after creep exposure.



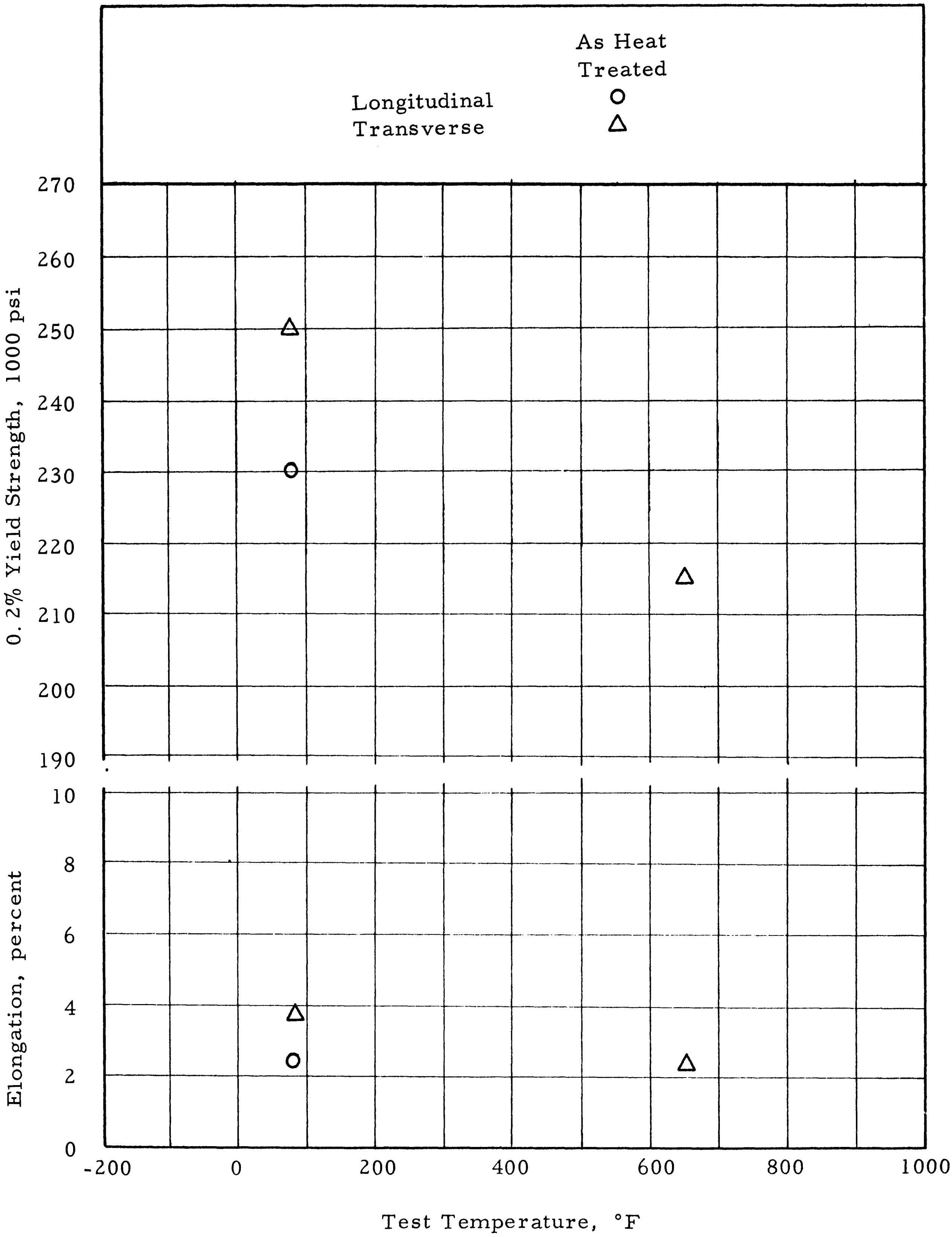
(b) 0.2-percent offset yield strength and elongation

Figure 13 (Concluded). Tensile properties as a function of test temperature for A286 alloy cold reduced 30 percent and aged 16 hours at 1300°F. Material was tested both as-heat treated and after creep exposure.



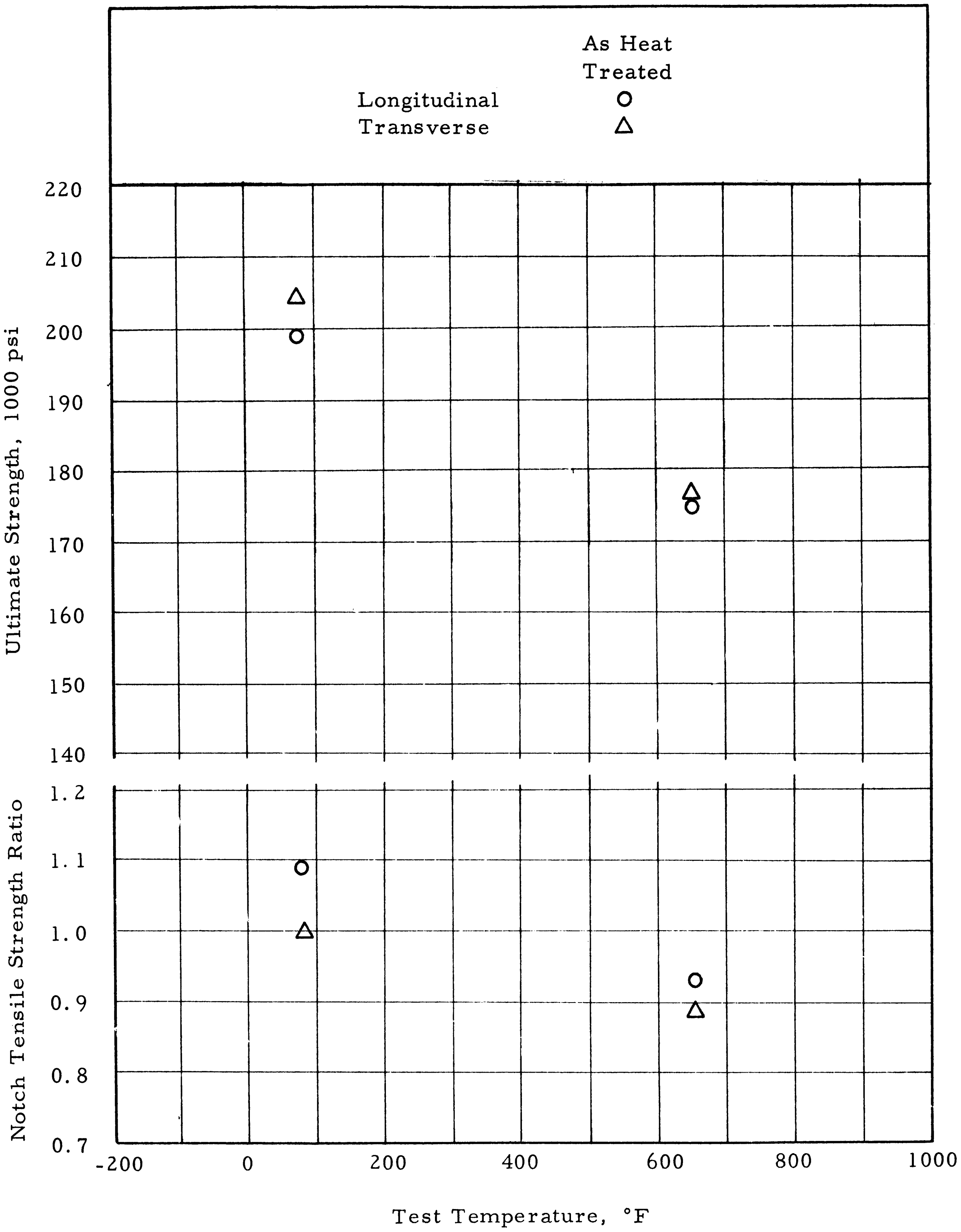
(a) Ultimate tensile strength and notch tensile strength ratio

Figure 14. Tensile properties as a function of test temperature for A286 alloy cold reduced 80 percent and aged 16 hours at 1100°F.



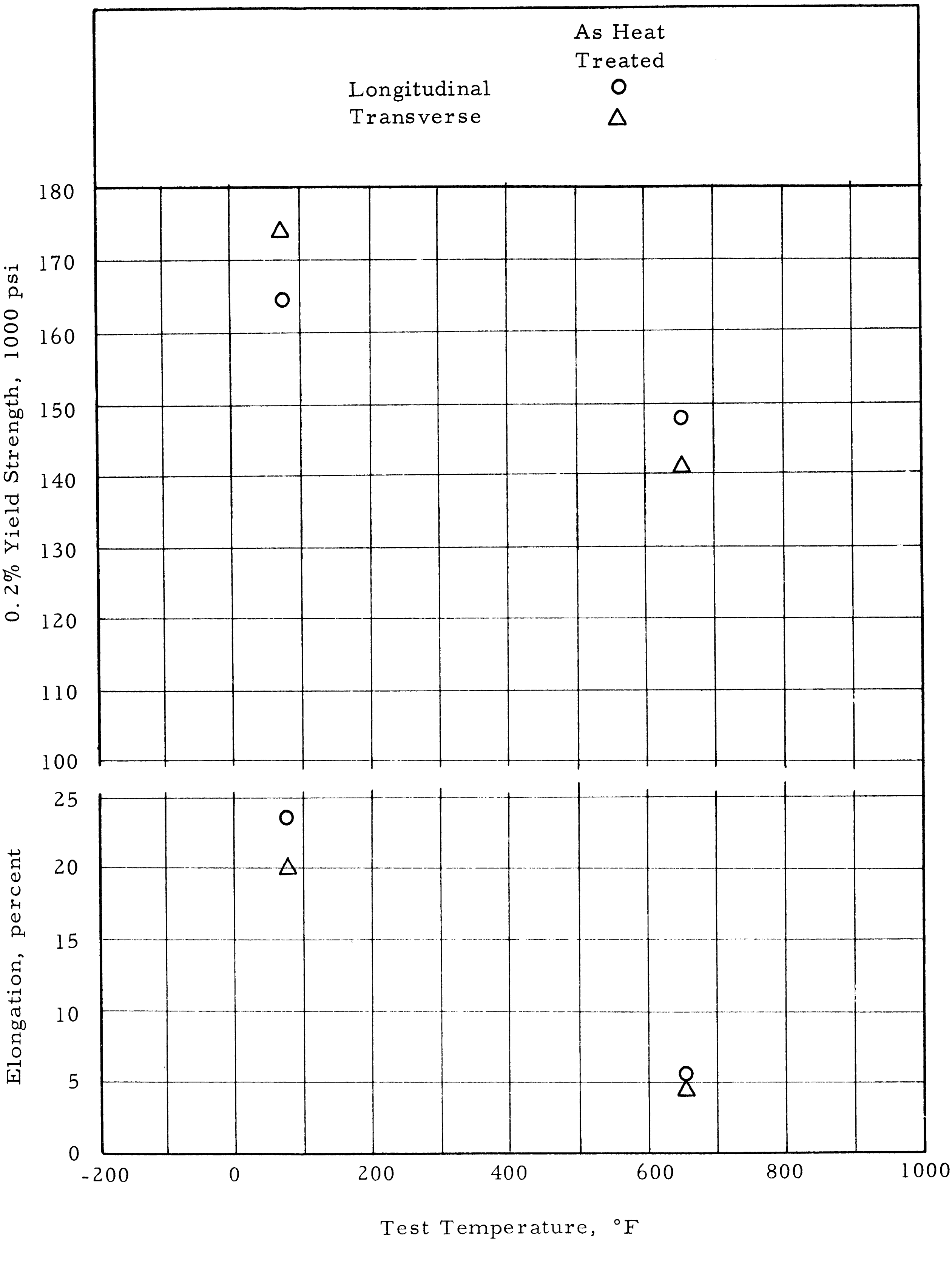
(b) 0.2-percent offset yield strength and elongation

Figure 14 (Concluded). Tensile properties as a function of test temperature for A286 alloy cold reduced 80 percent and aged 16 hours at 1100°F.



(a) Ultimate tensile strength and notch tensile strength ratio

Figure 15. Tensile properties as a function of test temperature for AM350 alloy in the CRT condition.



(b) 0.2-percent offset yield strength and elongation

Figure 15 (Continued). Tensile properties as a function of test temperature for AM350 alloy in the CRT condition.