TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 840

TENSILE AND PACK COMPRESSIVE TESTS OF SOME SHEETS OF ALUMINUM ALLOY, 1025 CARBON STEEL, AND CHROMIUM-NICKEL STEEL

By C. S. Atchison and James A. Miller
National Bureau of Standards

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SUMMARY

Tensile and compressive stress-strain curves, stress-deviation curves, and secant modulus-stress curves are given for longitudinal and transverse specimens of 17S-T, 24S-T, and 24S-RT aluminum-alloy sheet in thicknesses from 0.032 to 0.081 inch, 1025 carbon steel sheet in thicknesses of 0.054 and 0.120 inch, and chromium-nickel steel sheet in thicknesses from 0.020 to 0.0275 inch.

Significant differences were found between the tensile and the compressive stress-strain curves, and also the corresponding corollary curves; similarly, differences were found between the curves for the longitudinal and transverse directions. These differences are of particular importance in considering the compressive strength of aircraft structures made of thin sheet. They are explored further for the case of compression by giving tangent modulus-stress curves in longitudinal and transverse compression and dimensionless curves of the ratio of tangent modulus to Young's modulus and of the ratio of reduced modulus for a rectangular section to Young's modulus, both plotted against the ratio of stress to secant yield strength.

INTRODUCTION

A knowledge of the tensile and the compressive properties of thin sheet metal is essential for the efficient design of many parts of aircraft structures. The compressive properties are of particular importance because the design of most of these structures is dictated by compressive rather than tensile strength.

A serious difficulty in obtaining the compressive properties of thin sheet metal is the tendency of the sheet to buckle at a stress well below the yield strength. This difficulty is overcome to a large extent by the pack method developed in recent years at the National Bureau of Standards with the support of the National Advisory Committee for Aeronautics and the Bureau of Aeronautics, Navy Department (references 1 and 2). Preliminary tests of a number of sheet materials used in aircraft showed that large differences may exist between the tensile and compressive properties. There were also appreciable differences for specimens taken lengthwise of the sheet and those taken crosswise.

For this reason it seemed desirable to obtain the tensile and compressive properties of sheet metals used in aircraft, to evaluate these differences, and to provide an experimental background for a study and classification of stress-strain data. The National Advisory Committee for Aeronautics accordingly requested the National Bureau of Standards to carry out such an investigation.

The present paper gives the results of tensile and pack compressive tests on specimens taken from some aluminum alloy and steel sheets in the direction of the length of the sheet and in the direction of the width. These results are presented for purposes of comparison rather than for use as typical properties of the materials. It is hoped that a continuation of this study will result in obtaining parameters or analytical expressions that will provide a better description of the stress-strain relationship of some of these materials than those in use at present.

MATERIAL

The description of the sheet materials is given in table I. The sheets having as their source NACA were surplus sheets from other investigations for the National Advisory Committee for Aeronautics (references 3, 4, and 5). The sheets having as their source Navy Department were materials submitted from time to time by the Bureau of Aeronautics, Navy Department, for mechanical tests. The authors take this opportunity to thank the Navy Department for permission to include this material in the present paper.

Table II gives the chemical composition of the chromium-nickel steel as supplied by the manufacturers.

TENSILE TESTS

The tensile specimens were taken from each sheet in the lengthwise direction (longitudinal) and crosswise (transverse). They were type 5 specimens described in reference 6 and complied with specifications in reference 7.

The tensile specimens were tested in beam and poise, screw type, testing machines. They were held in Templin grips.

The strain was measured by a pair of Tuckerman 2-inch optical strain gages. These gages were attached to opposite faces of the reduced section when the specimen was under an initial load.

The tensile stress-strain curves are shown in figures 1 to 20. The figure numbers correspond to the sheet numbers. The origin for each curve was obtained from an extrapolation to zero stress by a least-square line fitted by factorial moments (reference 8).

The stress-deviation curves were obtained by the method proposed by Tuckerman (reference 9). For each sheet the trail modulus was the experimental value of Young's modulus in longitudinal tension.

The secant modulus-stress curves were plotted from secant moduli obtained by dividing each value of stress by the corresponding value of strain.

The results of the tensile tests and the tensile properties prescribed in current Navy Department specifications are given in table III.

The experimental value of Young's modulus for each specimen from the aluminum alloys, from the carbon steel, and also for each transverse specimen from the chromium-nickel steels was taken as the slope of a least-square straight line fitted to the lower portion of the stress-strain curve. For each longitudinal specimen from the chromium-nickel steels, the value of Young's modulus was taken as the slope of a least-square parabola at the origin.

The yield strengths by the offset method were obtained from the stress-strain curves and the experimental values of Young's modulus given in table III.

The yield strengths by the extension-under-load method were obtained from the stress-strain curves and the values given in table III of strain prescribed in the specifications for the extension-under-load method.

Sheets 1 to 13, comprising the aluminum alloys and the carbon steel, complied with the tensile requirements in current specifications. Sheets 14, 15, and 16 of chromium-nickel steel passed current tensile specification requirements for 1/4-hard, 1/2-hard, and 3/4-hard temper, respectively, and are considered as such in this report. Sheets 17, 18, 19, and 20, of chromium-nickel steel passed current tensile specification requirements for full-hard temper with the exception that the elongation value for sheet 17 was 3.0 percent, not the prescribed 4.0 percent. These sheets are considered as full-hard temper in this report.

PACK COMPRESSIVE TESTS

The compressive tests of the aluminum alloy and the carbon steel sheets were made by the pack method described in reference 1. The compressive tests of the chromium-nickel steel sheets were made in accordance with the extension of the pack method described in reference 2.

The specimens for the packs were taken from each sheet in the longitudinal direction and in the transverse direction. The number of specimens in each pack is given in table IV.

The packs were tested in a vertical, fluid-support, Bourdon-tube, hydraulic-type, universal testing machine of 100 kips capacity.

The strain was measured by a pair of Tuckerman 1-inch optical strain gages. These gages were attached on each side of the pack to the edge of the middle specimen when the pack was under an initial load.

The compressive stress-strain curves, the stress-deviation curves, and the secant modulus-stress curves are shown in the figures.

The tangent modulus-stress curves were faired through a number of points, each being an arbitrarily selected value of tangent modulus plotted against the corresponding value of stress. Each value of stress was obtained on the stress-strain or the stress-deviation curve by moving a straight-edge, oriented to correspond to the given value of tangent modulus, into tangency with the curve.

In order to facilitate the comparison of the shapes of the tangent-modulus curves for the different materials, nondimensional tangent modulus-stress curves are also shown. These curves were plotted from values obtained by dividing the tangent moduli by Young's modulus and by dividing the stresses by the yield strength, secant method The yield strength, secant method (after Osgood, reference 10) was selected so that the nondimensional curves could be used for materials the compressive stress-strain curves of which are affinely related to any of the stress-strain curves obtained from these sheets.

The reduced modulus-stress curves for a rectangular cross section are also shown as nondimensional curves. These curves were plotted from values obtained by dividing the reduced moduli by Young's modulus and by dividing the stresses by the yield strength, secant method. The reduced modulus for a rectangular section (reference 11) is given by the following formula:

$$E_r = \frac{4\ E\ E_\sigma}{\left(\sqrt{E} + \sqrt{E_\sigma}\right)^2}$$

where

E_r = reduced modulus

E = Young's modulus

E_σ = tangent modulus

The results of the compressive tests are given in table IV.

Young's modulus for each specimen was taken as the slope of a least-square straight line fitted to the lower portion of the stress-strain curve.

The yield strengths, offset method, were obtained from the stress-strain curves and the experimental values of Young's modulus given in table IV.

The yield strengths, secant method, were obtained from the stress-strain curves and the values of secant modulus* given in table IV.

For sheets 1 to 13, comprising the aluminum alloys and carbon steel, the values of compressive yield strength, both longitudinal and transverse, were greater than the specified minimum values for tensile yield strength.

For sheets 14 to 19, of chromium-nickel steels, the longitudinal compressive yield strengths were less than the specified tensile yield strengths. The transverse compressive yield strengths, however, were greater than the specified values. For sheet 20 of chromium-nickel steel, the values of compressive yield strength, both in the longitudinal direction and in the transverse direction, were greater than the specified tensile yield strength for the full-hard temper. For the convenience of readers interested in the compressive properties of the chromium-nickel steels, the information supplied by the manufacturers regarding the chemical composition of sheets 14 to 20 is given in table II.

CONCLUSIONS

The materials considered in this report passed current tensile specification requirements with the exception of a longitudinal elongation value from one sheet. Since the tensile properties usually exceeded the specified minimum values by large amounts, the results cannot be considered as representative of material just meeting specifications.

For the aluminum alloys the yield strengths as determined either by the offset method or by the extension-under-load method were nearly the same for each tensile specimen. Likewise, the yield strengths as determined by the offset method and by the secant method were nearly

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*The values of secant modulus were obtained, as suggested by Osgood in reference 12, by multiplying Young's modulus by a constant for the material so chosen that, for a tensile specimen just passing specifications, the yield strength obtained by the secant method would be equal to the specified minimum yield strength.

the same for each pack. The closest agreement of yield strengths was between the transverse tensile and the longitudinal compressive values; the difference did not exceed 5.2 percent. In each case there was an appreciable difference in the shapes of the curves even when there was little difference between yield strengths.

For the carbons steels, the longitudinal yield strengths were nearly the same in tension and in compression and the transverse yield strengths were nearly the same. There were, however, marked differences in the yield strength with direction.

In the case of the chromium-nickel steels, the differences between the tensile and compressive properties and between the compressive properties in the two directions were especially pronounced. Owing to the gradual curvature of the stress-strain curves and the differences between the experimental values and the specification values for Young's modulus and yield strength, the values for yield strength obtained by the extension-under-load method differed from those obtained by the offset method by amounts up to 9 percent. With the exception of the yield strength of the stress-relieved specimen, which was well above the minimum value specified for tensile yield strength, the longitudinal compressive yield strengths obtained by the secant method were lower than the corresponding values obtained by the offset method by amounts up to 26 percent. This difference was ascribed to the gradual curvature of the stress-strain curves and to the lack of correspondence between the longitudinal compressive yield strengths and the values specified for the tensile yield strengths. On the other hand, the yield strengths for the transverse packs were above those specified for the longitudinal tensile specimens and the values obtained by the secant method were higher than those obtained by the offset method.

The results given in this paper emphasize the need for further consideration of definitions of yield strength for materials with gradually curving stress-strain curves.

In general, the appreciable differences in the shapes of the longitudinal tensile, the transverse tensile, the longitudinal compressive, and the transverse compressive stress-strain curves and their corollary curves suggest that they cannot be used interchangeably in precise design.

National Bureau of Standards,
Washington, D. C., October 20, 1941.

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TABLE I.- DESCRIPTION OF MATERIALS TESTED

Sheet	Description	Nominal thickness of sheet (in.)	Source	Navy specifications	
				When material was acquired	Current
1	Aluminum alloy 17S-T	0.032	NACA	47A3b	47A3c
2	----------do----------	.051	-----do-----	-------do-------	-----do-----
3	Aluminum alloy 24S-T	.032	Navy Dept.	47A10	47A10d
4	----------do----------	.064	-----do-----	-------do-------	-----do-----
5	----------do----------	.081	-----do-----	-------do-------	-----do-----
6	Aluminum alloy 24S-RT	.032	NACA	47A10INT	-----do-----
7	----------do----------	.032	Navy Dept.	47A10a	-----do-----
8	----------do----------	.051	NACA	47A10INT	-----do-----
9	----------do----------	.064	Navy Dept.	47A10a	-----do-----
10	----------do----------	.081	NACA	47A10INT	-----do-----
11	----------do----------	.081	Navy Dept.	47A10a	-----do-----
12	1025 carbon steel	.054	NACA	47S17a	AN-QQ-S-651
13	----------do----------	.120	-----do-----	-------do-------	-----do-----
14	Chromium-nickel steel	.020	Navy Dept.	47S21	47S21a
15	----------do----------	.020	-----do-----	-------do-------	-----do-----
16	----------do----------	.020	-----do-----	-------do-------	-----do-----
17	----------do----------	.020	-----do-----	-------do-------	-----do-----
18	----------do----------	.020	-----do-----	-------do-------	-----do-----
19	----------do----------	.024	-----do-----	-------do-------	-----do-----
20	----------do----------	.0275	-----do-----	-------do-------	-----do-----

TABLE II

CHEMICAL COMPOSITION OF CHROMIUM-NICKEL STEELS,

AS SUPPLIED BY THE MANUFACTURERS

Sheet	Carbon (percent)	Manganese (percent)	Chromium (percent)	Nickel (percent)
14	0.11	0.76	17.8	7.8
15	.10	.72	17.4	7.5
16	.13	.63	17.5	7.3
17	.08	.35	18.4	8.0
18	.13	.34	17.0	7.0
19	.13	.38	17.1	7.2
[a]20	.12	.47	17.96	7.01

[a]The manufacturer of sheet 20 stated that it had a stress-relieving heat treatment after cold rolling.

TABLE III.- RESULTS OF TENSILE TESTS

Sheet	Material	Nominal thickness of sheet (in.)	Direction	Specification values: Strain prescribed for yield strength, extension under load	Specification values: Young's modulus (kips/sq in.)	Specification values: Minimum yield strength (kips/sq in.)	Specification values: Minimum tensile strength (kips/sq in.)	Specification values: Minimum elongation in 2 inches (percent)	Test results: Young's modulus (kips/sq in.)	Test results: Yield strength, Offset method, offset = 0.2 percent (kips/sq in.)	Test results: Yield strength, Extension under load method (kips/sq in.)	Test results: Tensile strength (kips/sq in.)	Test results: Elongation in 2 inches (percent)
1	Aluminum alloy 17S-T	0.032	Longitudinal	0.0052	[a]10,000	32.0	55.0	18.0	10,400	40.1	40.0	56.7	20.5
			Transverse	.0052	10,000	32.0	55.0	18.0	10,300	34.6	34.4	57.8	19.0
2	---do---	.051	Longitudinal	.0052	10,000	32.0	55.0	18.0	10,330	41.6	41.4	60.7	20.5
			Transverse	.0052	10,000	32.0	55.0	18.0	10,370	36.2	35.8	59.3	20.5
3	Aluminum alloy 24S-T	.032	Longitudinal	.0060	10,000	40.0	62.0	15.0	10,500	55.2	54.7	70.4	18.0
			Transverse	.0060	10,000	40.0	62.0	15.0	10,300	48.1	47.0	67.7	19.0
4	---do---	.064	Longitudinal	.0060	10,000	40.0	62.0	17.0	10,500	52.1	51.8	69.3	19.5
			Transverse	.0060	10,000	40.0	62.0	17.0	10,490	45.8	45.1	68.3	19.0
5	---do---	.081	Longitudinal	.0060	10,000	40.0	62.0	17.0	10,480	53.1	52.8	70.8	19.0
			Transverse	.0060	10,000	40.0	62.0	17.0	10,420	44.1	43.6	66.1	18.5
6	Aluminum alloy 24S-RT	.032	Longitudinal	.0070	10,000	50.0	65.0	11.0	10,500	61.6	61.5	73.5	17.5
			Transverse	.0070	10,000	50.0	65.0	11.0	10,560	54.2	54.0	71.5	16.5
7	---do---	.032	Longitudinal	.0070	10,000	50.0	65.0	11.0	10,410	65.6	65.2	76.2	13.5
			Transverse	.0070	10,000	50.0	65.0	11.0	10,520	56.6	55.9	74.7	14.5
8	---do---	.051	Longitudinal	.0070	10,000	50.0	65.0	12.0	10,440	63.0	62.5	74.3	16.0
			Transverse	.0070	10,000	50.0	65.0	12.0	10,520	56.5	55.8	73.0	15.5
9	---do---	.064	Longitudinal	.0070	10,000	50.0	65.0	12.0	10,450	63.4	62.6	75.0	15.0
			Transverse	.0070	10,000	50.0	65.0	12.0	10,510	56.6	55.6	72.4	15.0
10	---do---	.081	Longitudinal	.0070	10,000	50.0	65.0	12.0	10,440	63.8	63.2	74.8	16.5
			Transverse	.0070	10,000	50.0	65.0	12.0	10,590	56.4	55.6	72.7	15.0
11	---do---	.081	Longitudinal	.0070	10,000	50.0	65.0	12.0	10,470	63.8	63.4	74.7	15.5
			Transverse	.0070	10,000	50.0	65.0	12.0	10,460	56.2	55.4	72.2	15.5
12	1025 carbon steel	.064	Longitudinal	.0042	[b]30,000	36.0	55.0	11.0	30,060	61.6	61.6	78.1	20.0
			Transverse	.0042	30,000	36.0	55.0	11.0	31,620	64.1	64.1	77.6	20.0
13	---do---	.120	Longitudinal	.0042	30,000	36.0	55.0	16.0	30,370	52.6	52.6	69.7	24.0
			Transverse	.0042	30,000	36.0	55.0	14.0	31,140	56.1	56.1	71.6	22.5
14	Chromium-nickel steel	.050	Longitudinal	[c].00488	26,000	75.0	125.0	25.0	28,190	106.4	97.9	174.3	33.5
			Transverse	(d)	(d)	(d)	(d)	(d)	28,790	96.6	93.1	173.3	32.0
15	---do---	.020	Longitudinal	[c].00623	26,000	110.0	150.0	10.0	28,540	125.2	123.8	154.0	27.5
			Transverse	(d)	(d)	(d)	(d)	(d)	29,070	121.1	121.7	157.4	22.0
16	---do---	.020	Longitudinal	[c].00719	26,000	135.0	175.0	5.0	27,760	142.6	143.0	182.2	22.5
			Transverse	(d)	(d)	(d)	(d)	(d)	28,640	137.4	140.6	193.2	20.5
17	---do---	.020	Longitudinal	[c].00738	26,000	140.0	185.0	4.0	25,770	173.9	157.5	199.2	3.0
			Transverse	(d)	(d)	(d)	(d)	(d)	29,010	162.7	150.3	204.1	6.5
18	---do---	.020	Longitudinal	[c].00738	26,000	140.0	185.0	4.0	27,240	176.5	162.2	204.3	17.0
			Transverse	(d)	(d)	(d)	(d)	(d)	29,060	160.2	158.8	211.7	11.5
19	---do---	.024	Longitudinal	[c].00738	26,000	140.0	185.0	4.0	27,260	158.8	153.8	186.6	18.5
			Transverse	(d)	(d)	(d)	(d)	(d)	29,000	149.7	151.8	193.0	17.5
20	---do---	.0275	Longitudinal	[c].00738	26,000	140.0	185.0	4.0	27,230	169.3	160.5	197.7	14.0
			Transverse	(d)	(d)	(d)	(d)	(d)	31,030	180.4	175.5	204.5	11.0

[a]Computed from specified yield strength, specified extension under load and an offset of 0.2 percent.

[b]Computed from specified yield strength, specified extension under load and an offset of 0.3 percent.

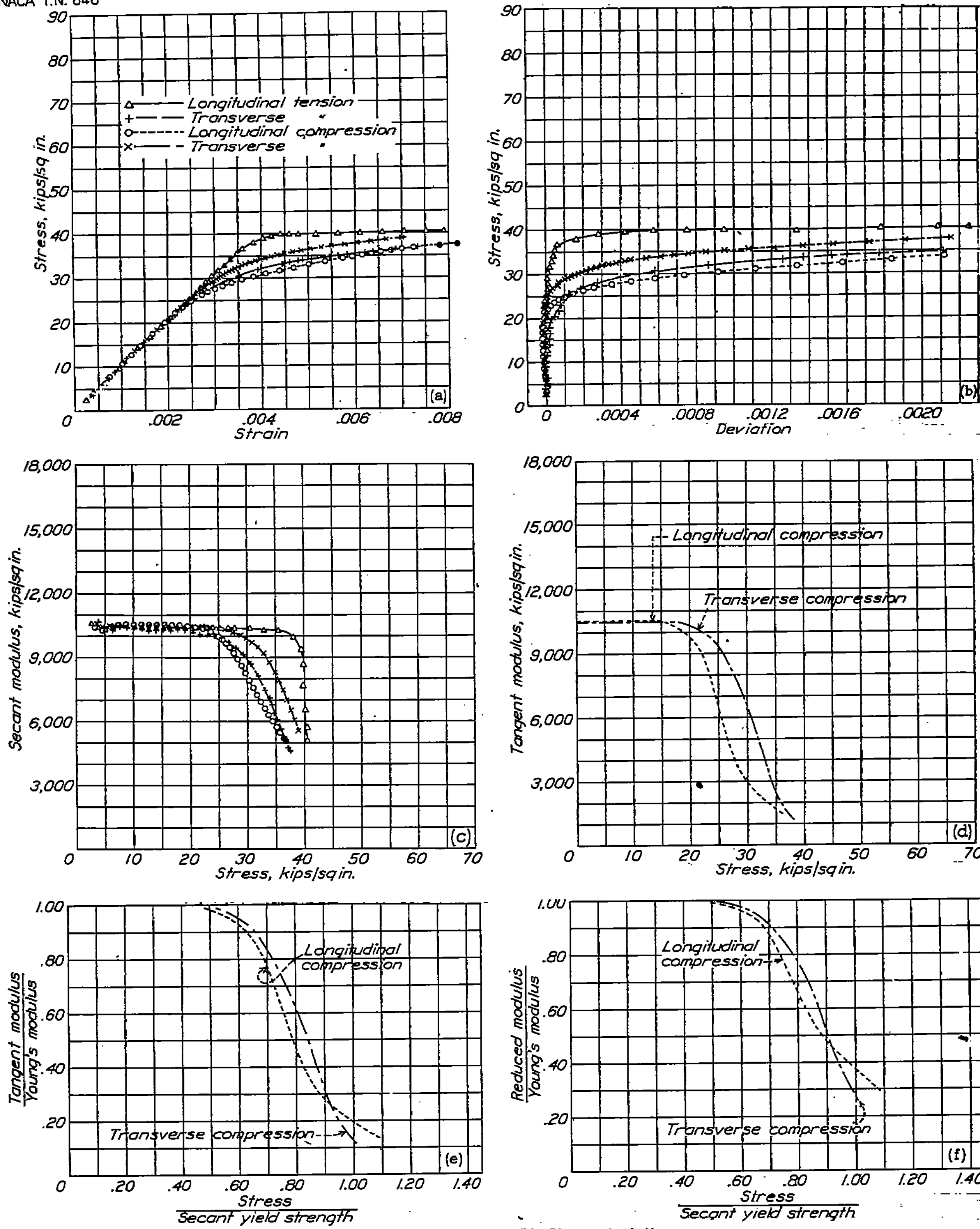
[c]Computed in conformity with the value of Young's modulus prescribed in current specification.

[d]The current specification applies only to longitudinal specimens. When required, the value prescribed for the longitudinal specimen was used for the transverse specimen.

TABLE IV.- RESULTS OF PACK COMPRESSIVE TESTS

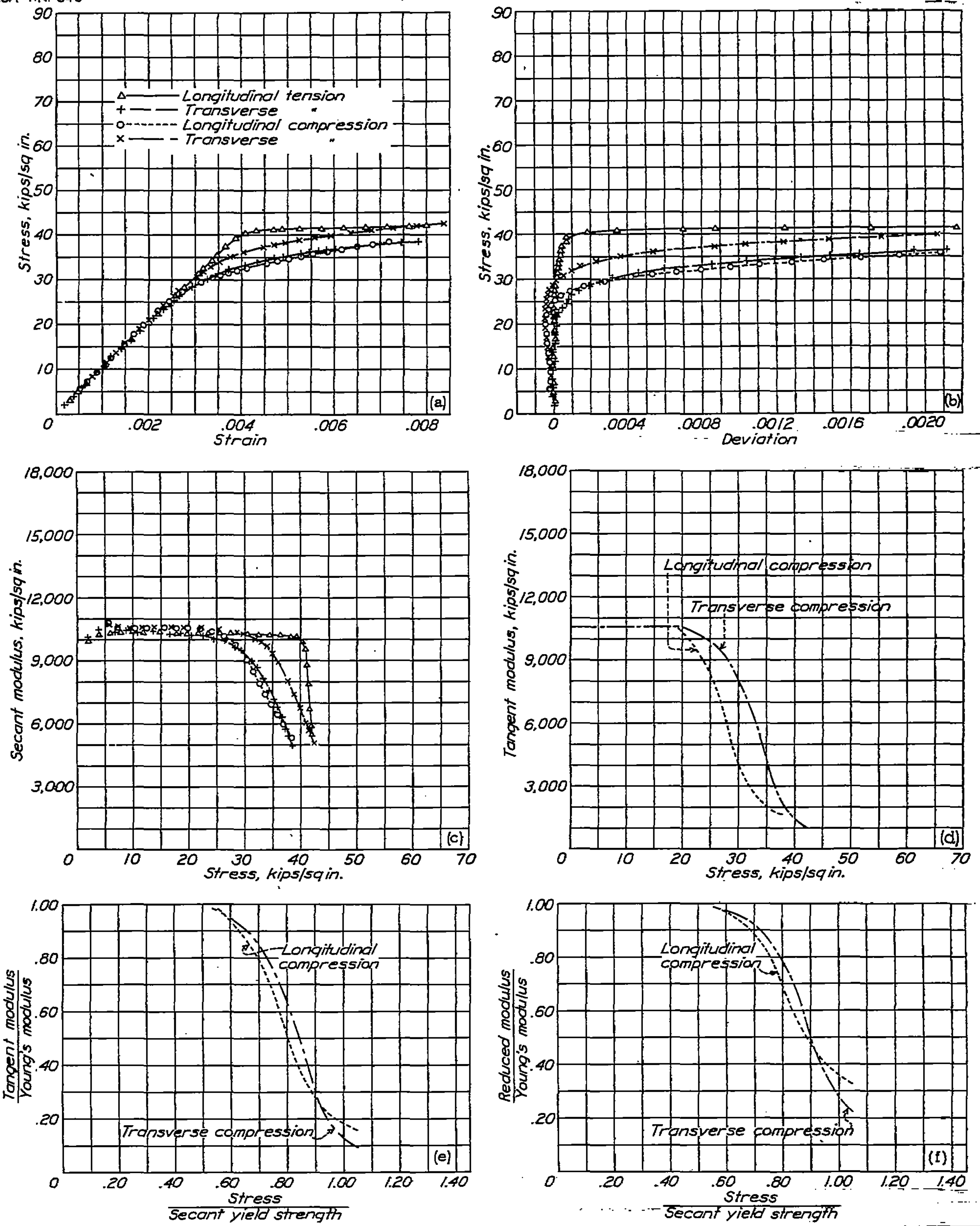
Sheet	Material	Nominal thickness of sheet (in.)	Direction	Number of specimens in a pack	Young's modulus (kips/sq in.)	Secant modulus (kips/sq in.)	Yield strength: Offset method, offset = 0.2 percent (kips/sq in.)	Yield strength: Secant method (kips/sq in.)
1	Aluminum alloy 17S-T	0.032	Longitudinal	13	10,530	6,480	33.4	33.3
			Transverse	13	10,460	6,440	37.4	37.7
2	----------do----------	.051	Longitudinal	5	10,570	6,510	35.4	35.6
			Transverse	5	10,580	6,510	39.6	40.2
3	Aluminum alloy 24S-T	.032	Longitudinal	13	10,680	7,120	46.5	47.1
			Transverse	13	10,620	7,080	50.4	51.1
4	----------do----------	.064	Longitudinal	5	10,650	7,100	44.0	44.3
			Transverse	5	10,710	7,140	49.1	49.7
5	----------do----------	.081	Longitudinal	5	10,610	7,080	43.3	43.6
			Transverse	5	10,650	7,100	47.8	48.3
6	Aluminum alloy 24S-RT	.032	Longitudinal	13	10,800	7,720	51.4	51.1
			Transverse	13	10,750	7,680	57.5	57.8
7	----------do----------	.032	Longitudinal	13	10,840	7,740	55.7	55.9
			Transverse	17	10,760	7,680	[a]61.4	[a]61.9
8	----------do----------	.051	Longitudinal	7	10,680	7,630	53.8	53.9
			Transverse	7	10,730	7,670	59.2	59.7
9	----------do----------	.064	Longitudinal	7	10,750	7,680	55.1	55.3
			Transverse	7	10,770	7,700	60.4	61.0
10	----------do----------	.081	Longitudinal	5	10,720	7,660	53.6	53.7
			Transverse	5	10,760	7,680	60.2	60.8
11	----------do----------	.081	Longitudinal	5	10,720	7,660	54.0	54.1
			Transverse	5	10,740	7,680	60.2	60.8
12	1025 carbon steel	.064	Longitudinal	5	30,780	8,780	59.7	59.6
			Transverse	5	32,660	9,330	63.6	63.6
13	----------do----------	.120	Longitudinal	5	31,310	8,940	52.0	52.3
			Transverse	5	31,790	9,080	56.1	56.3
14	Chromium-nickel steel	.020	Longitudinal	31	28,070	16,580	73.5	70.3
			Transverse	31	28,980	17,110	121.8	134.9
15	----------do----------	.020	Longitudinal	31	28,100	19,080	72.5	59.1
			Transverse	31	29,260	19,860	136.7	139.8
16	----------do----------	.020	Longitudinal	31	27,610	19,930	83.4	61.6
			Transverse	31	28,990	20,930	165.4	169.7
17	----------do----------	.020	Longitudinal	31	26,120	19,040	97.9	81.7
			Transverse	31	29,660	21,630	191.2	199.1
18	----------do----------	.020	Longitudinal	31	27,370	19,950	111.0	95.4
			Transverse	31	29,260	21,330	197.5	208.2
19	----------do----------	.024	Longitudinal	25	27,290	19,900	91.4	75.0
			Transverse	25	29,310	21,370	181.0	186.7
20	----------do----------	.0275	Longitudinal	23	27,600	20,120	161.6	164.9
			Transverse	23	31,580	23,020	202.2	207.7

[a]Buckled at 61.0 kips/sq in. stress, yield strength obtained by extrapolation.



(a) Stress-strain curves.
(b) Stress-deviation curves.
(c) Secant modulus-stress curves.
(d) Tangent modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

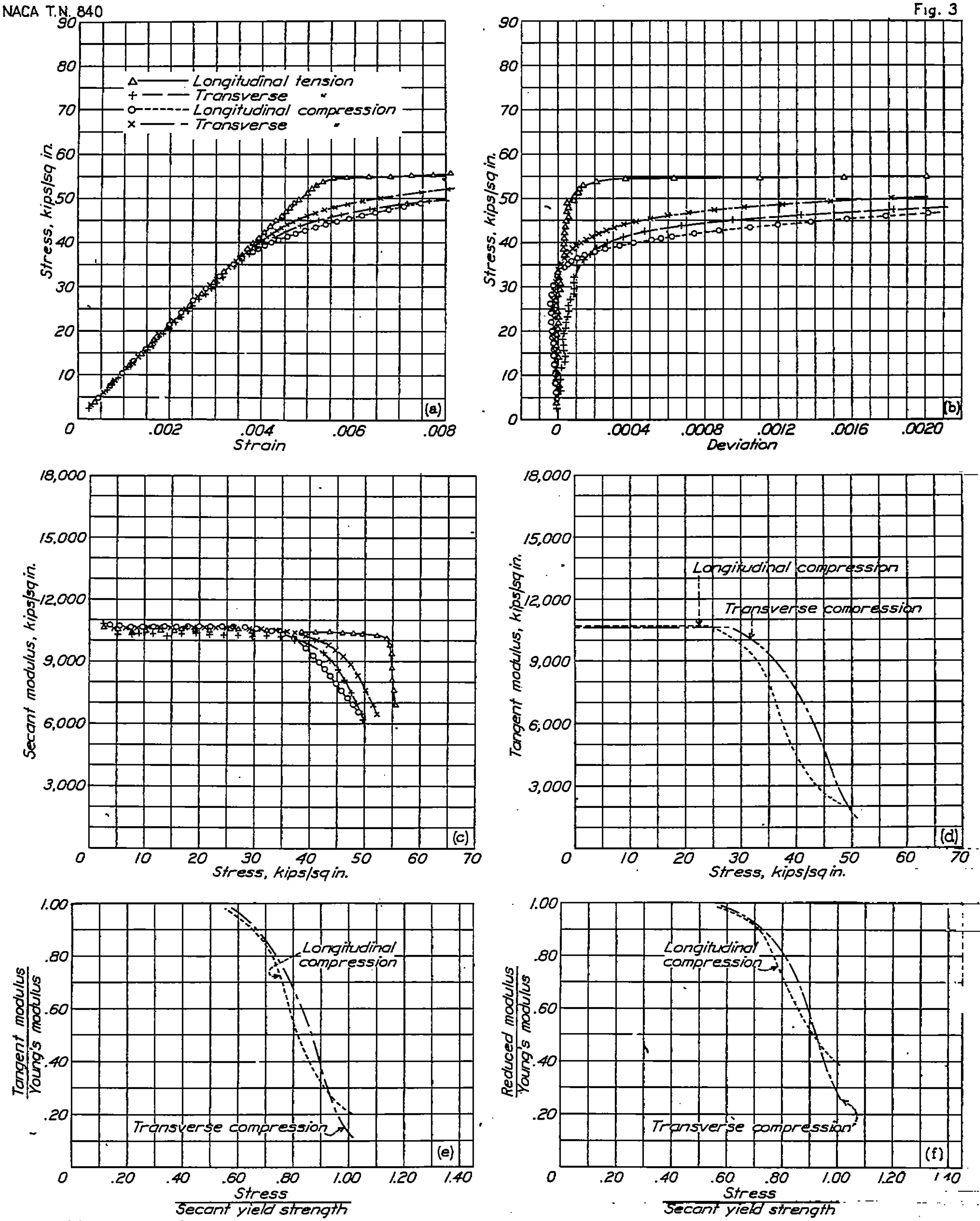
Figure 1.- Sheet 1. Aluminum alloy 17S-T; thickness, 0.032 inch.



(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.

(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

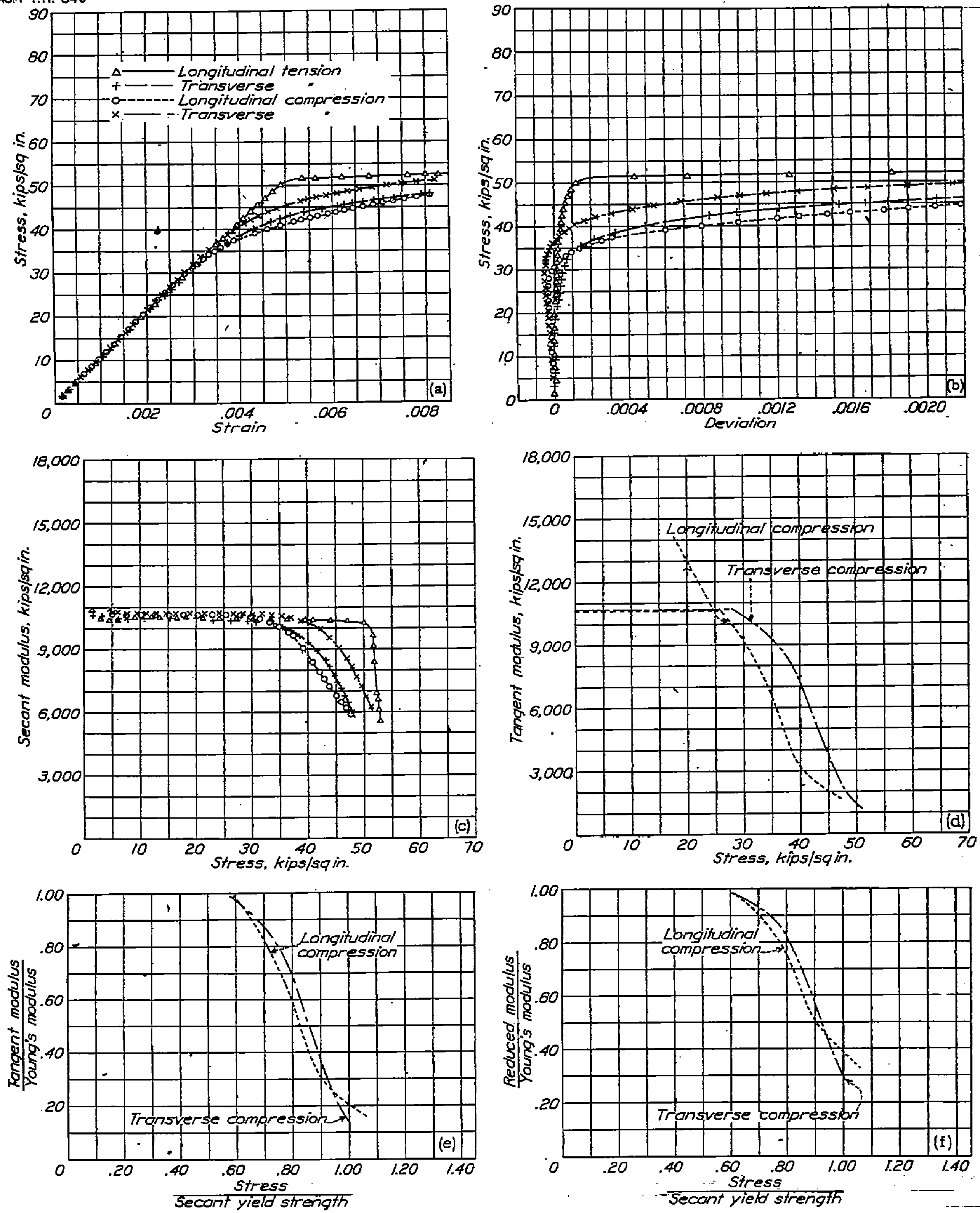
Figure 2.- Sheet 2. Aluminum alloy 17S-T; thickness, 0.051 inch.



(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.

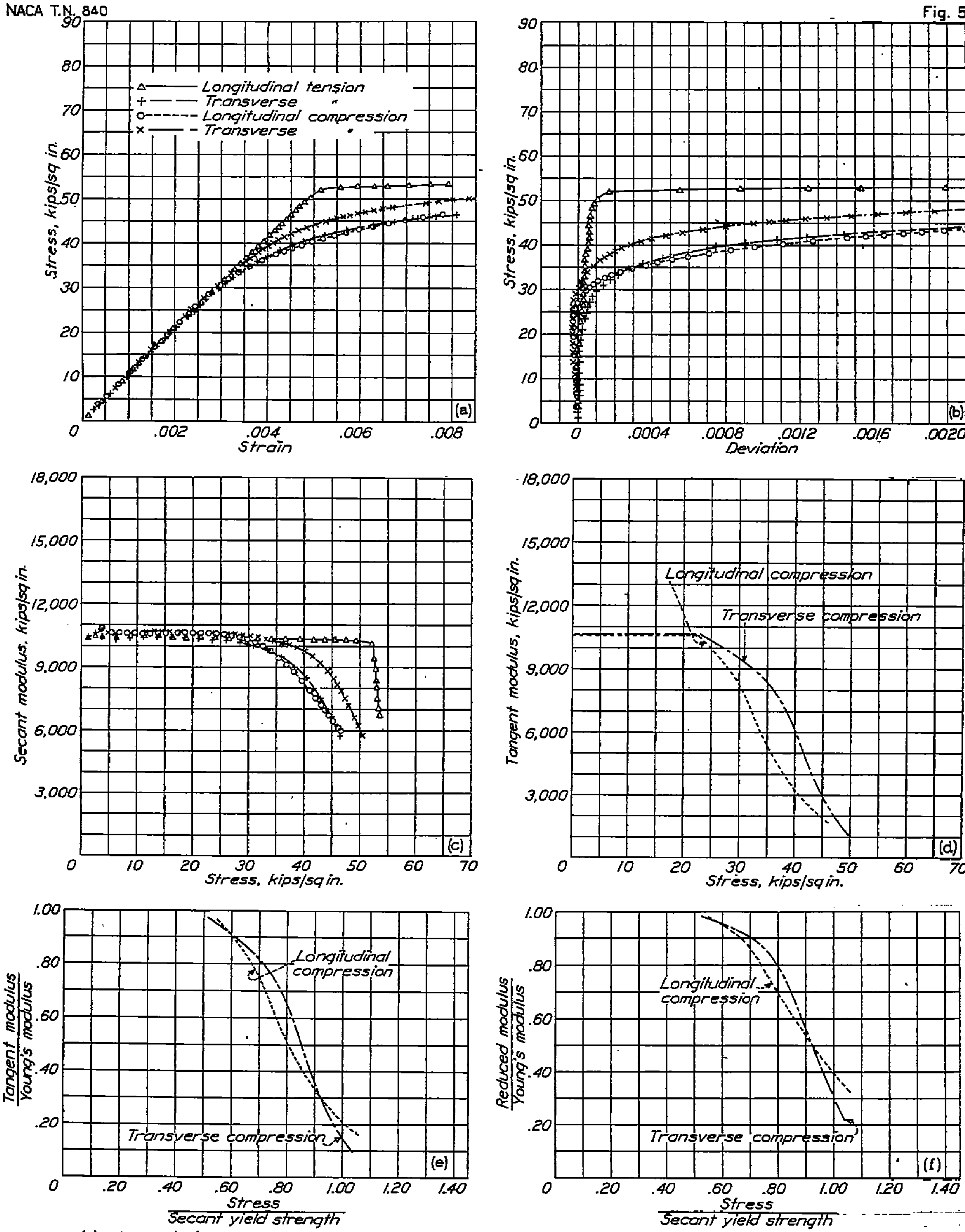
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 3.- Sheet 3. Aluminum alloy 24S-T; thickness, 0.032 inch.



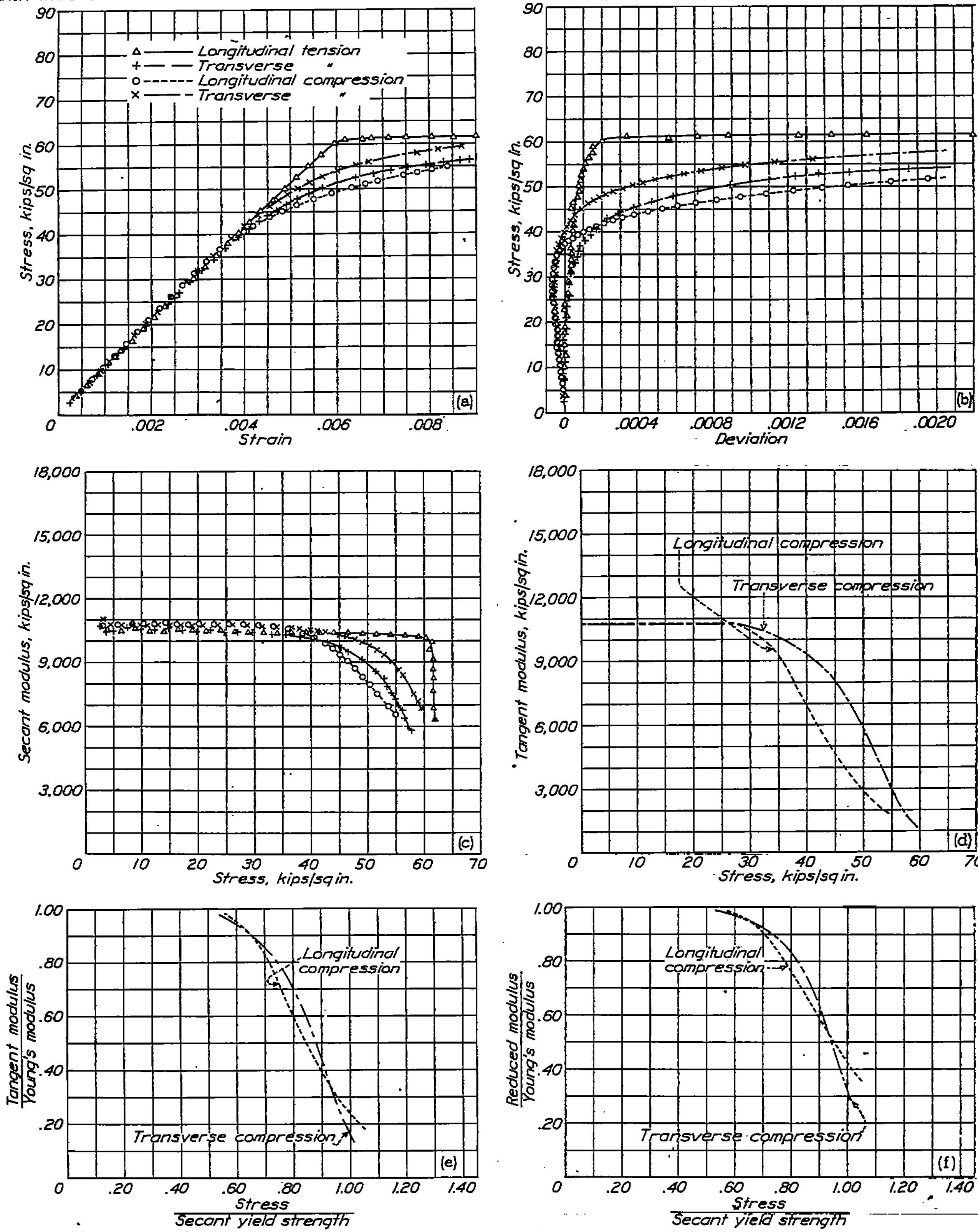
(a) Stress-strain curves.
(b) Stress-deviation curves.
(c) Secant modulus-stress curves.
(d) Tangent modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 4.- Sheet 4. Aluminum alloy 24S-T; thickness, 0.064 inch.



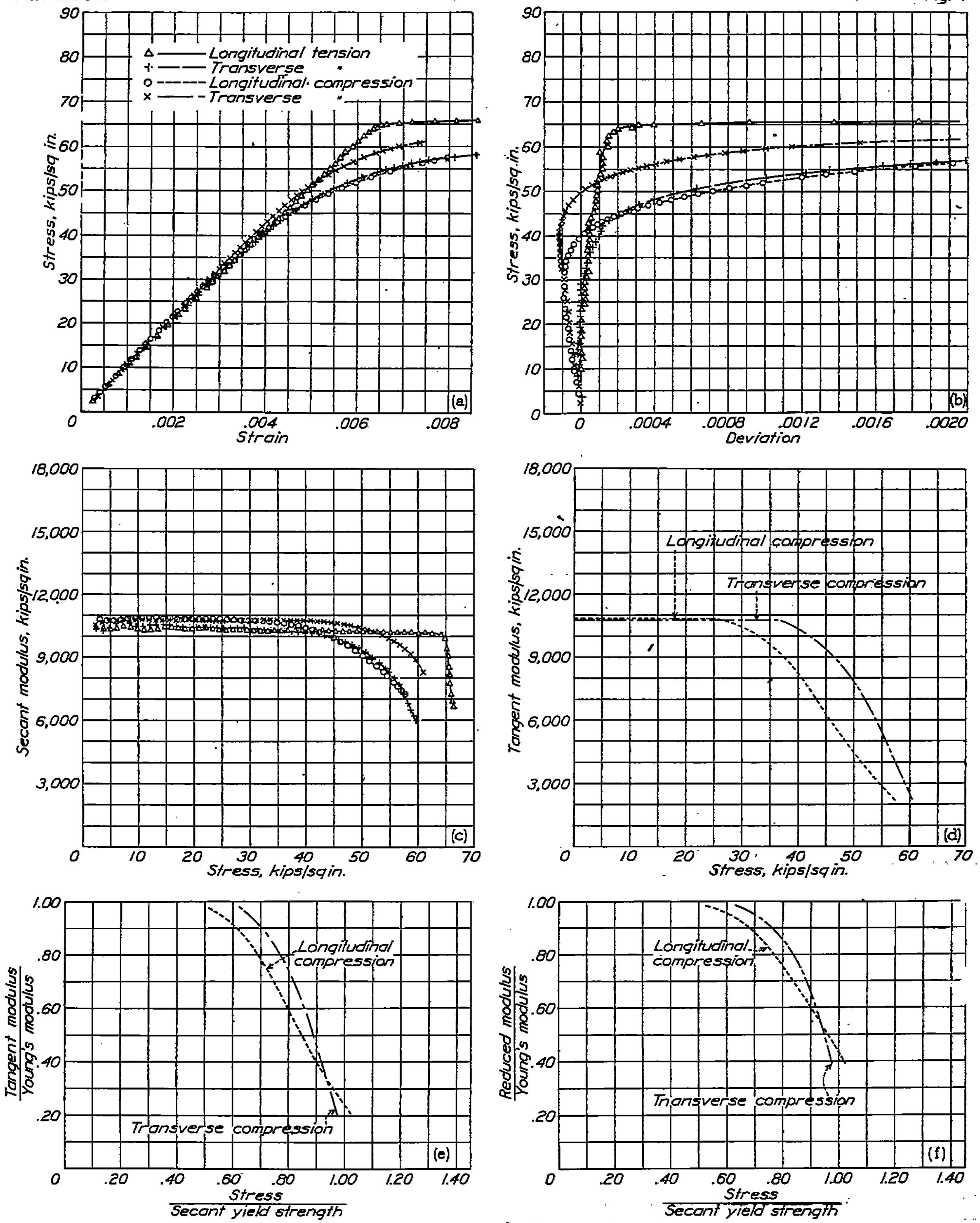
(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 5.- Sheet 5. Aluminum alloy 24S-T; thickness, 0.081 inch.



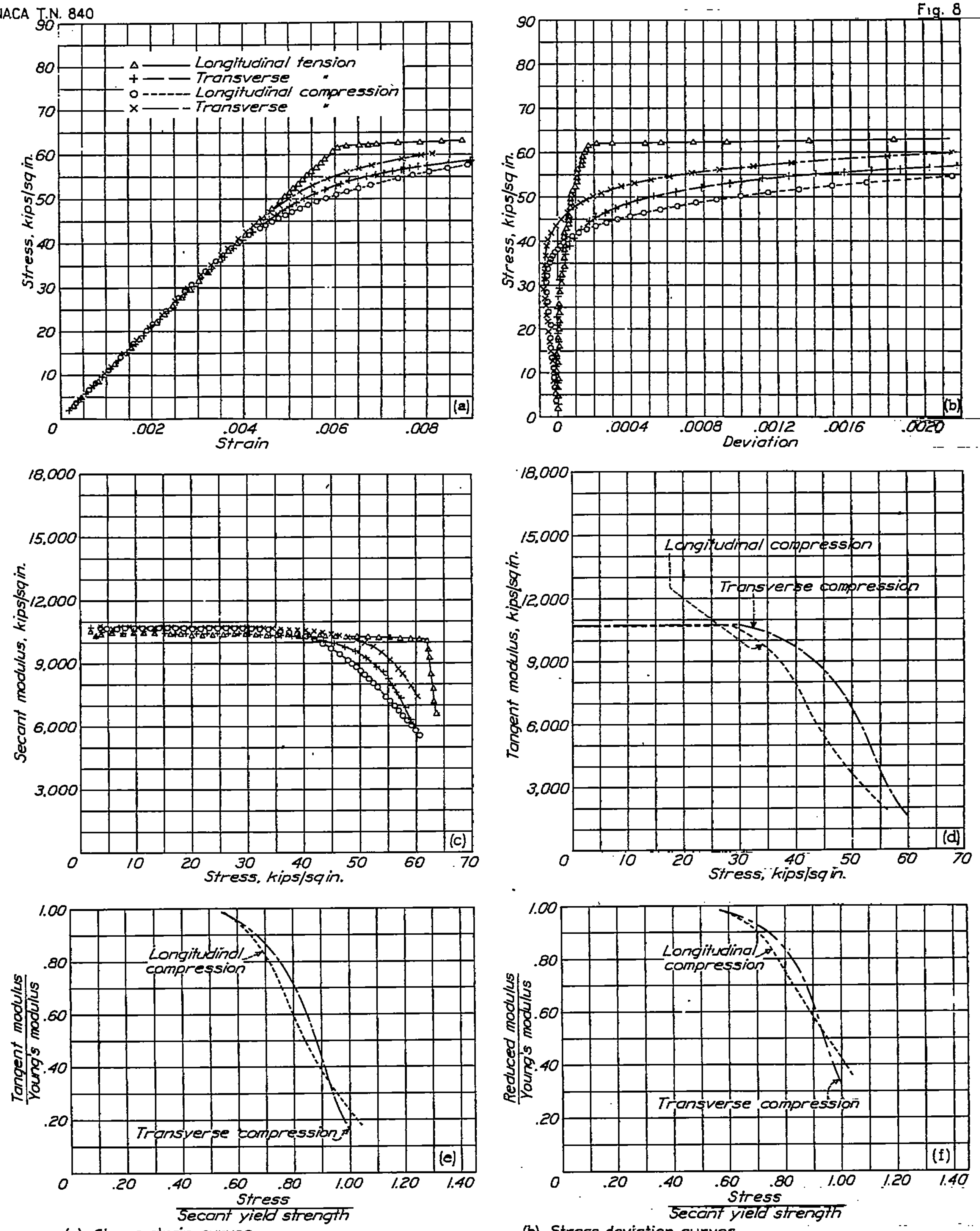
(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 6.- Sheet 6. Aluminum alloy 24S-RT; thickness, 0.032 inch.



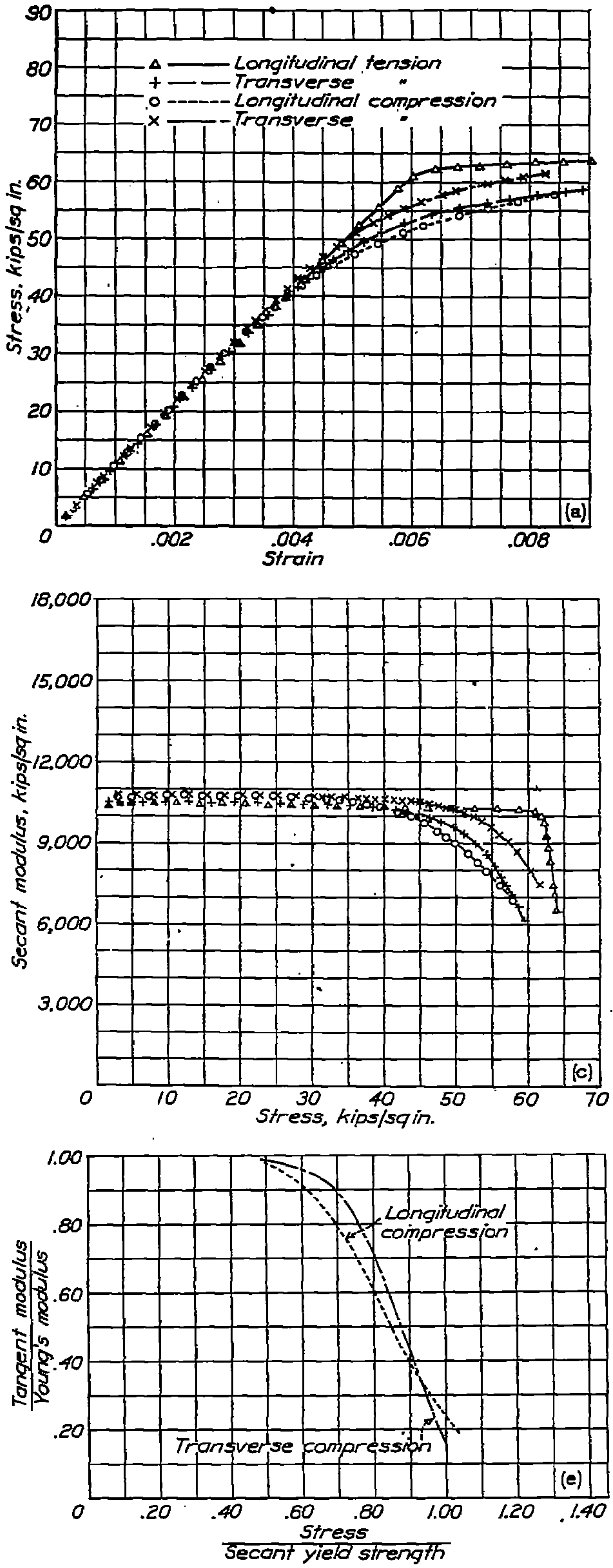
(a) Stress-strain curves.
(b) Stress-deviation curves.
(c) Secant modulus-stress curves.
(d) Tangent modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 7.- Sheet 7. Aluminum alloy 24S-RT; thickness, 0.032 inch.



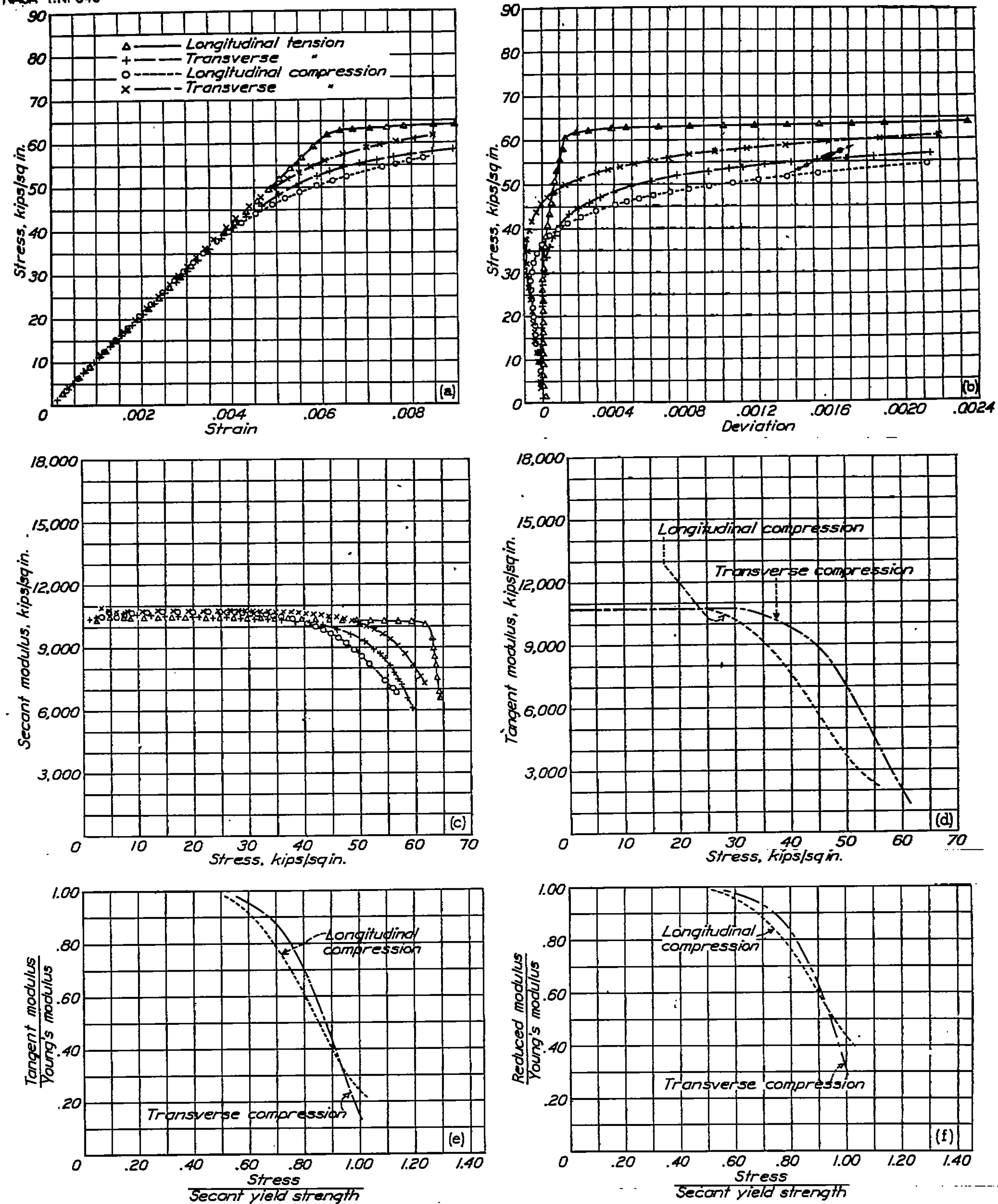
(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 8.- Sheet 8. Aluminum alloy 24S-RT; thickness, 0.051 inch.



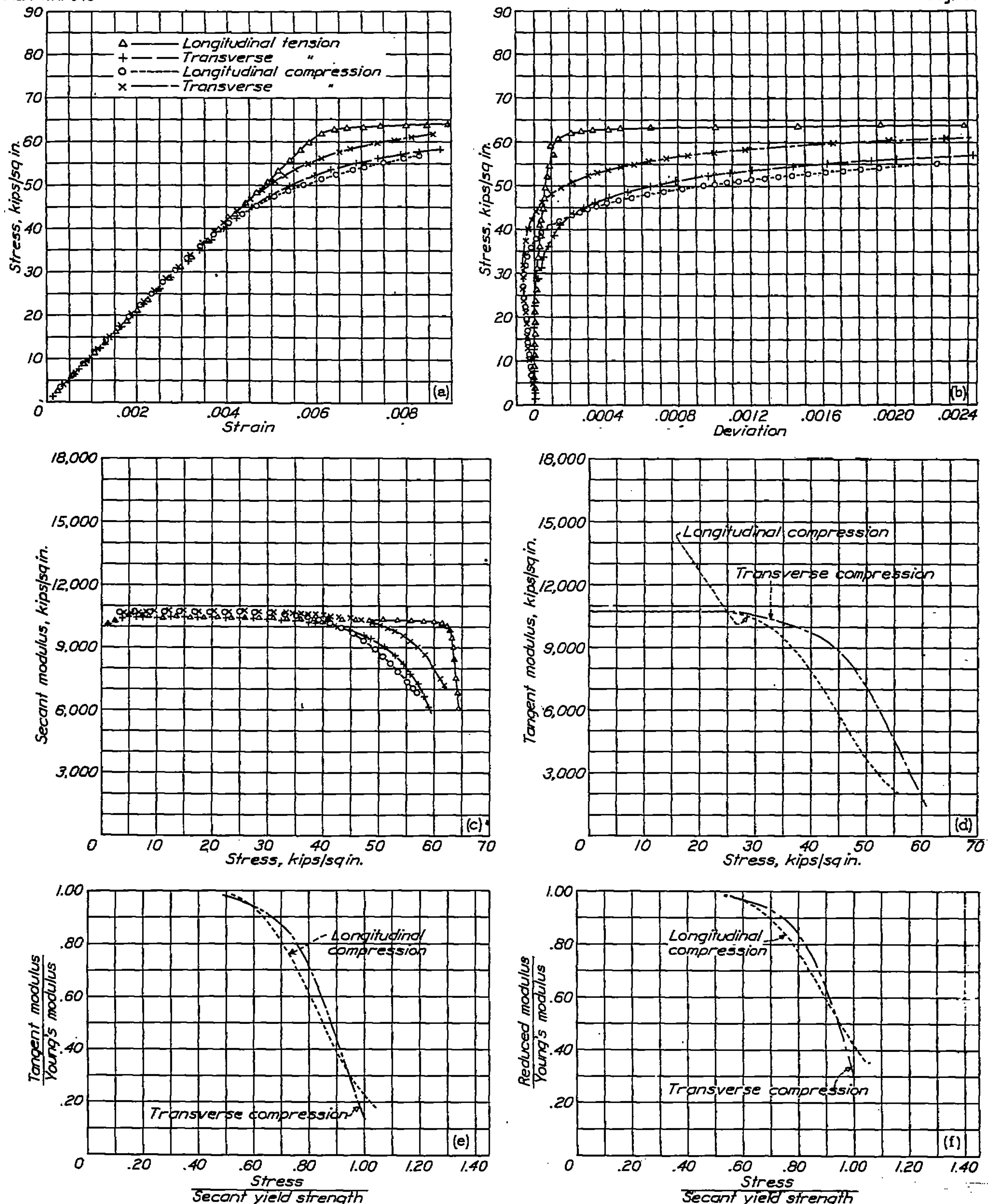
(a) Stress-strain curves.
(b) Stress-deviation curves.
(c) Secant modulus-stress curves.
(d) Tangent modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 9.- Sheet 9. Aluminum alloy 24S-RT; thickness, 0.064 inch.



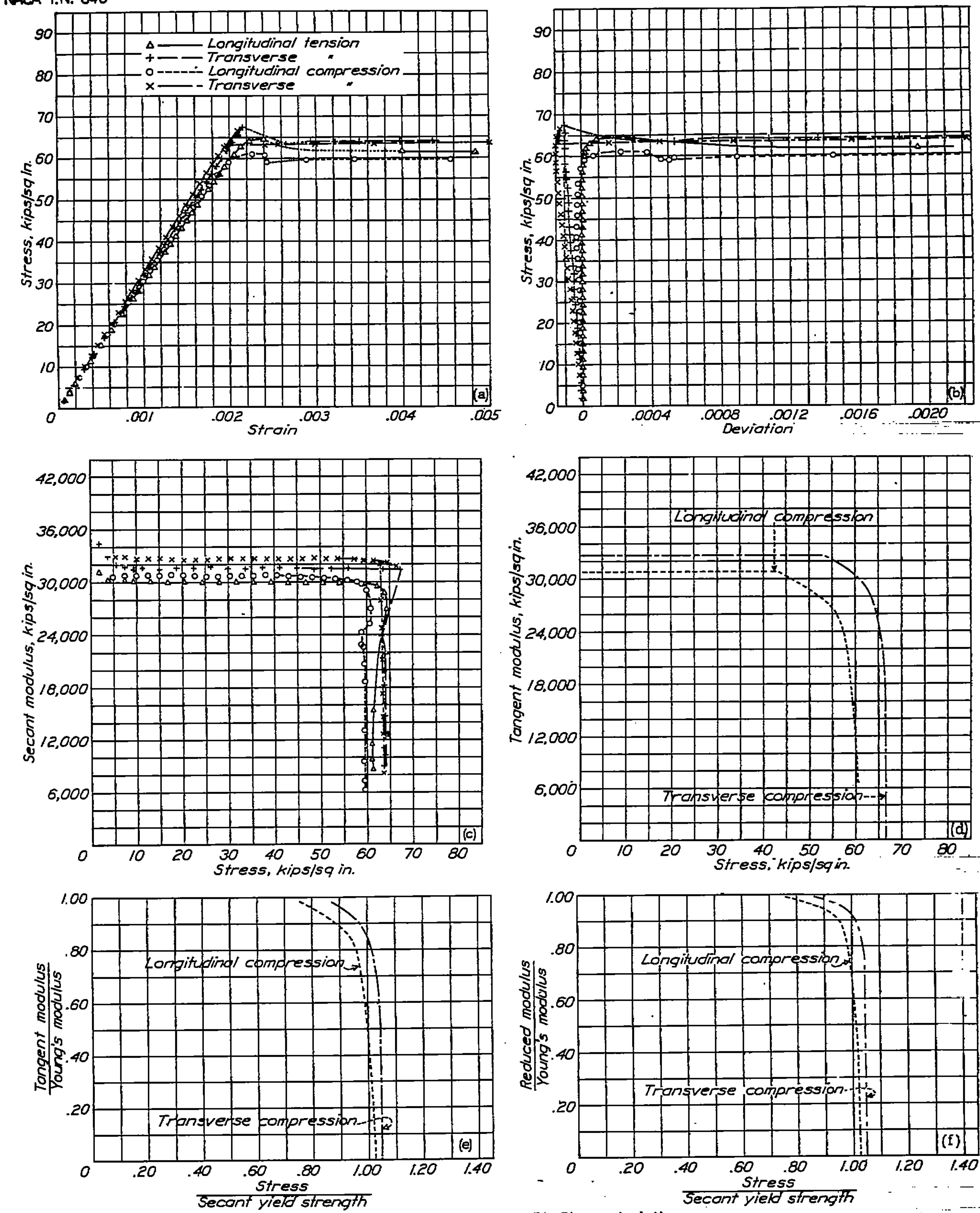
(a) Stress-strain curves.
(b) Stress-deviation curves.
(c) Secant modulus-stress curves.
(d) Tangent modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 10.- Sheet 10. Aluminum alloy 24S-RT; thickness, 0.081 inch.



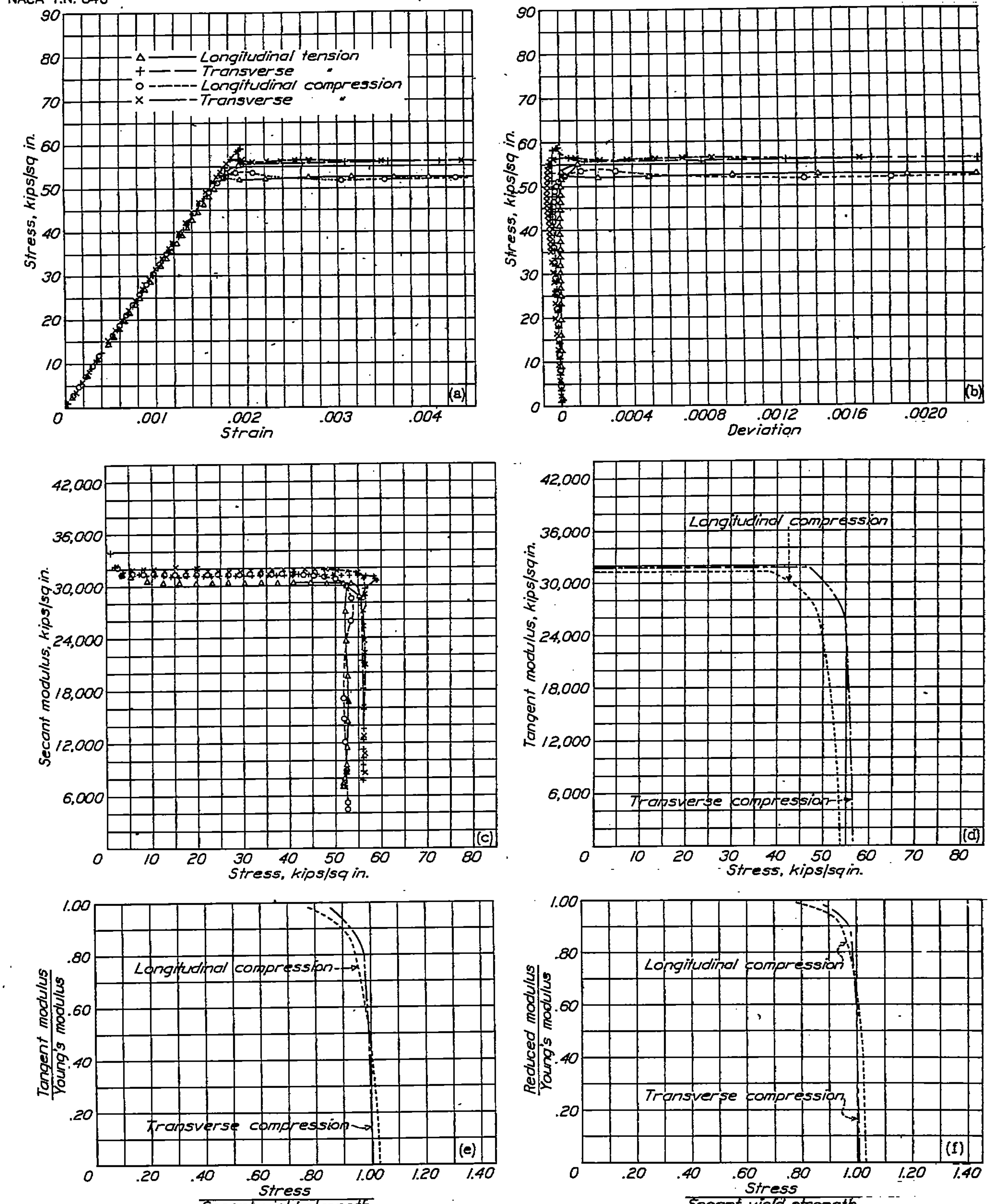
(a) Stress-strain curves.
(b) Stress-deviation curves.
(c) Secant modulus-stress curves.
(d) Tangent modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 11.- Sheet 11. Aluminum alloy 24S-RT; thickness, 0.081 inch.



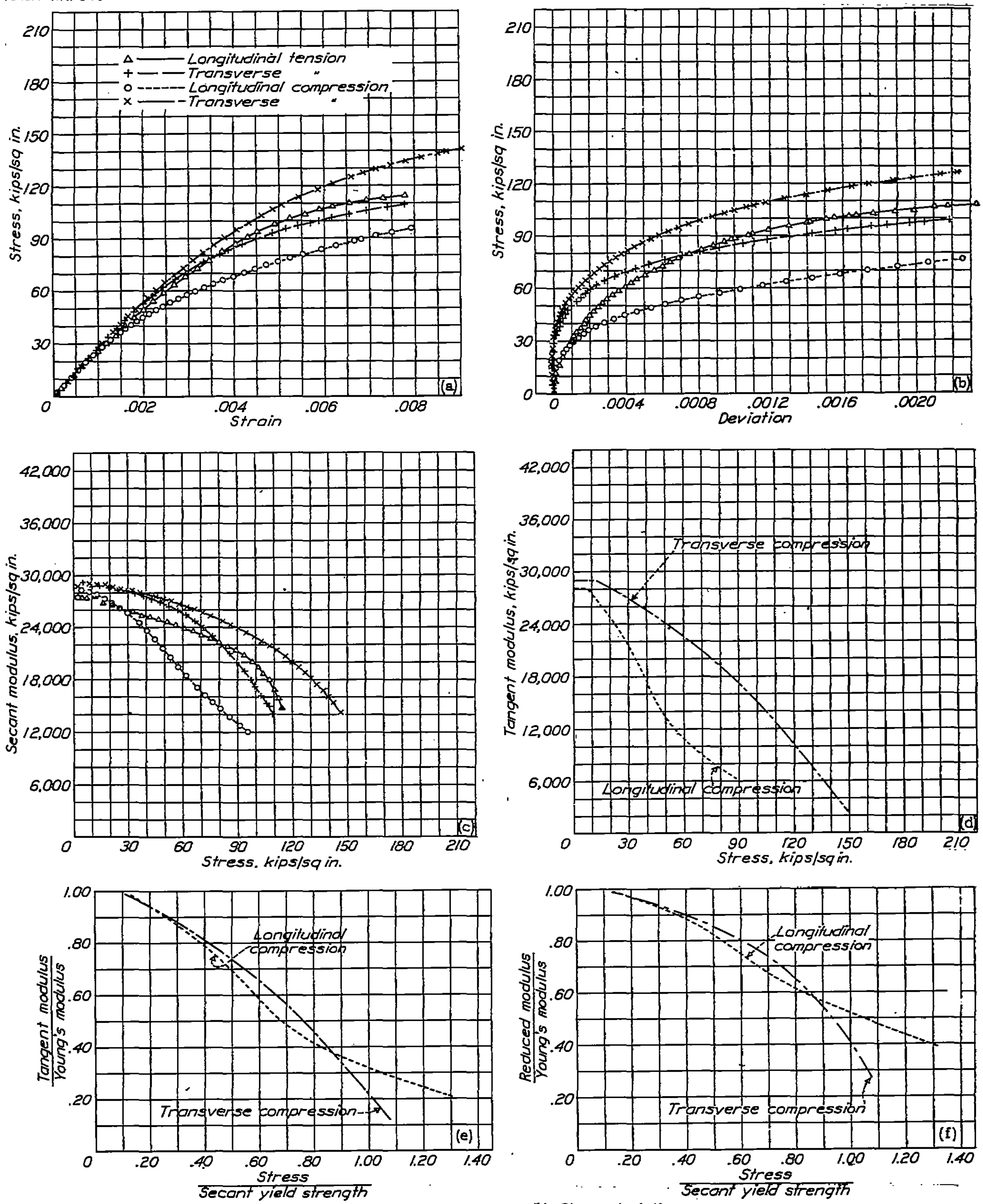
(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 12.- Sheet 12. 1025 carbon steel; thickness, 0.054 inch.



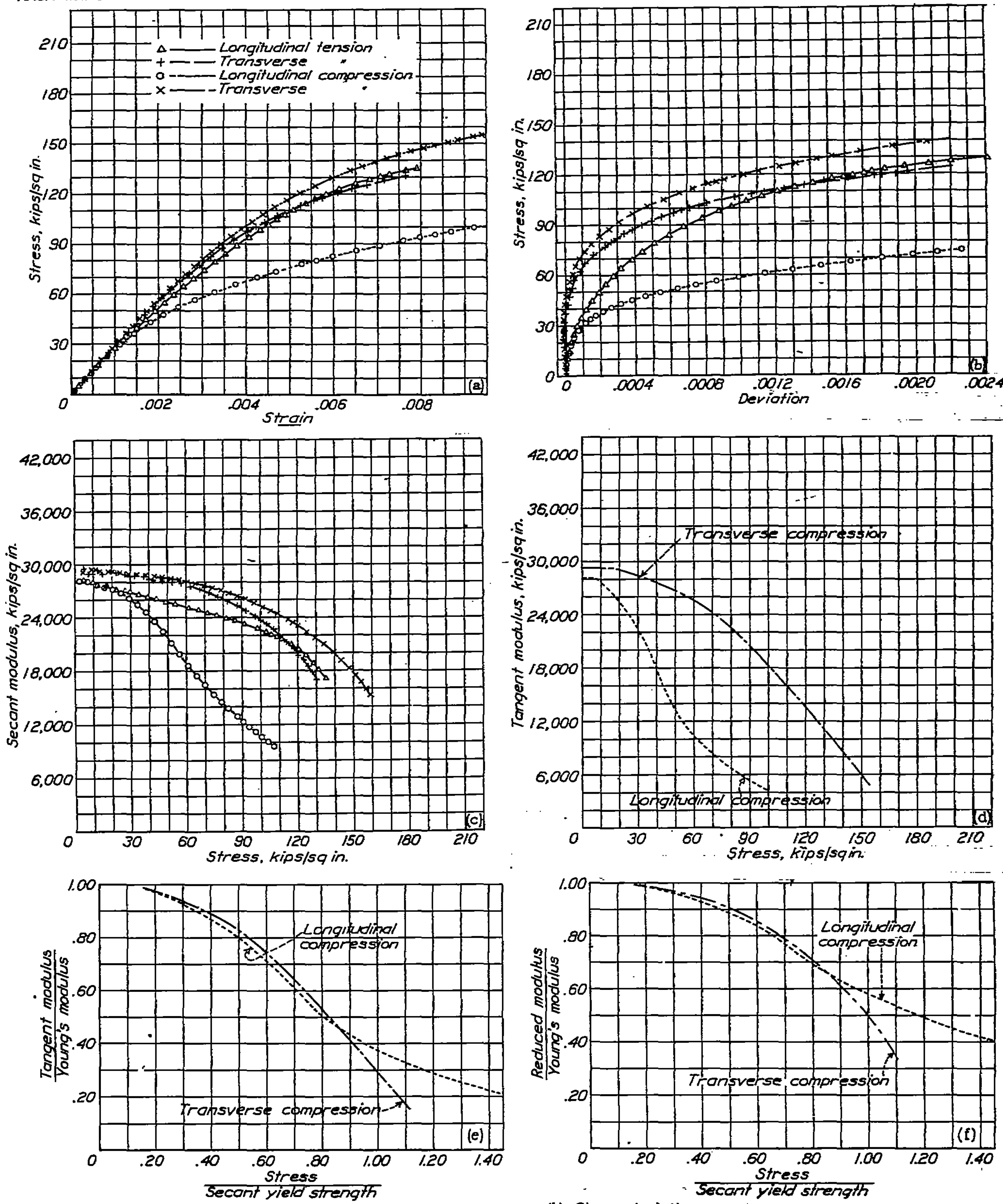
(a) Stress-strain curves.
(b) Stress-deviation curves.
(c) Secant modulus-stress curves.
(d) Tangent modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 13.- Sheet 13. 1025 carbon steel; thickness, 0.120 inch.



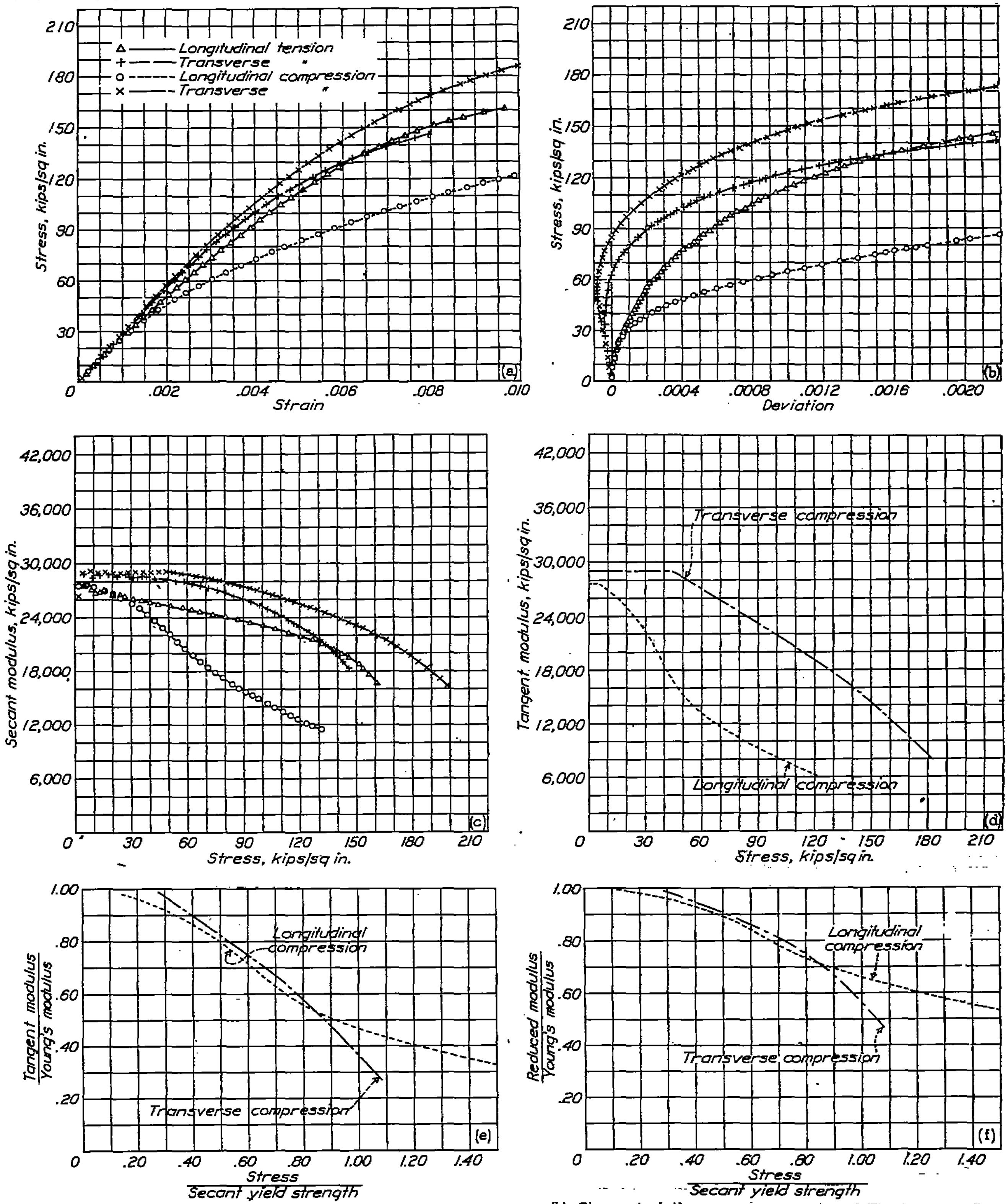
(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 14.- Sheet 14, Chromium-nickel steel 1/4 hard; thickness, 0.020 inch.



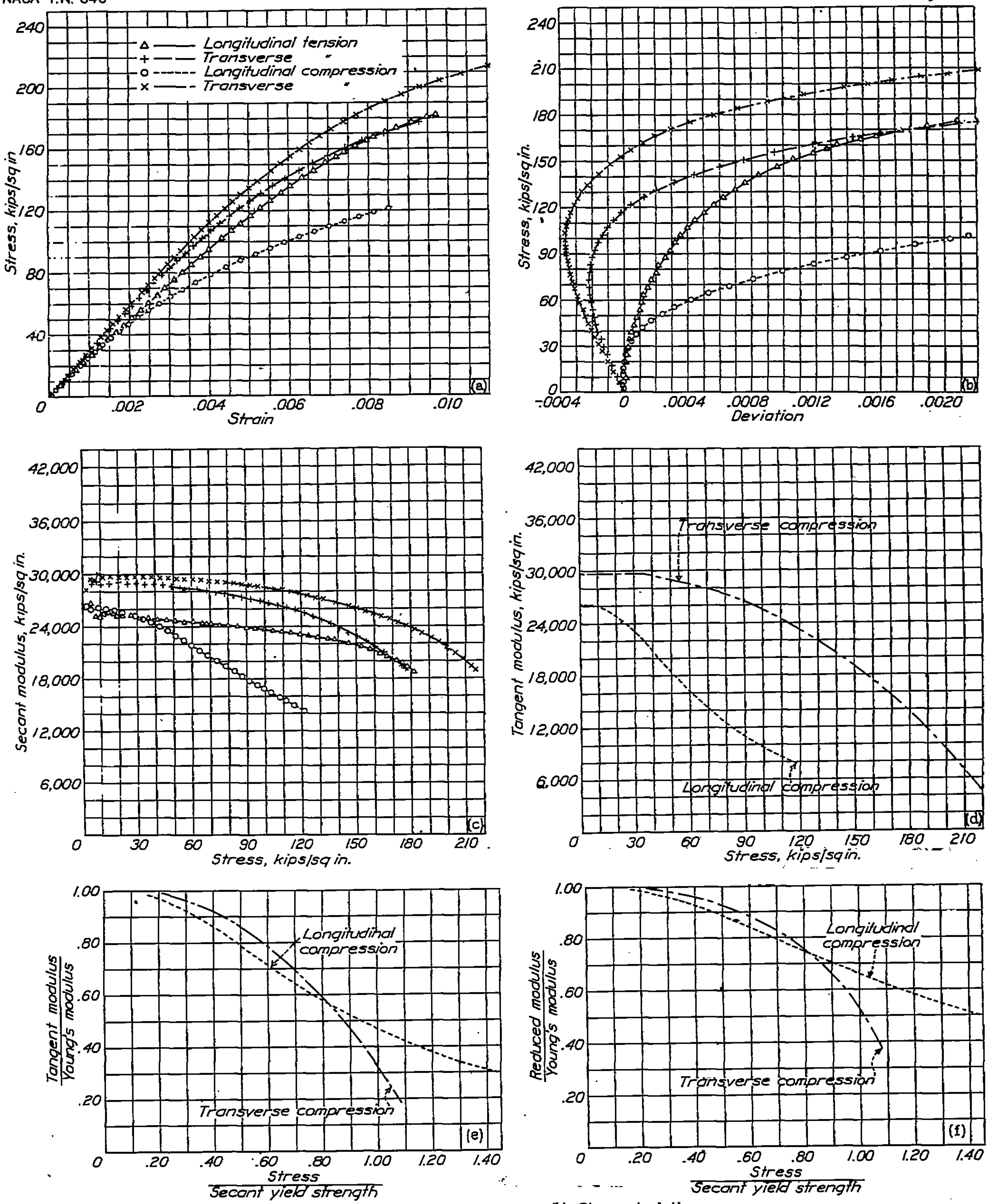
(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 15.- Sheet 15. Chromium-nickel steel 1/2 hard; thickness, 0.020 inch.



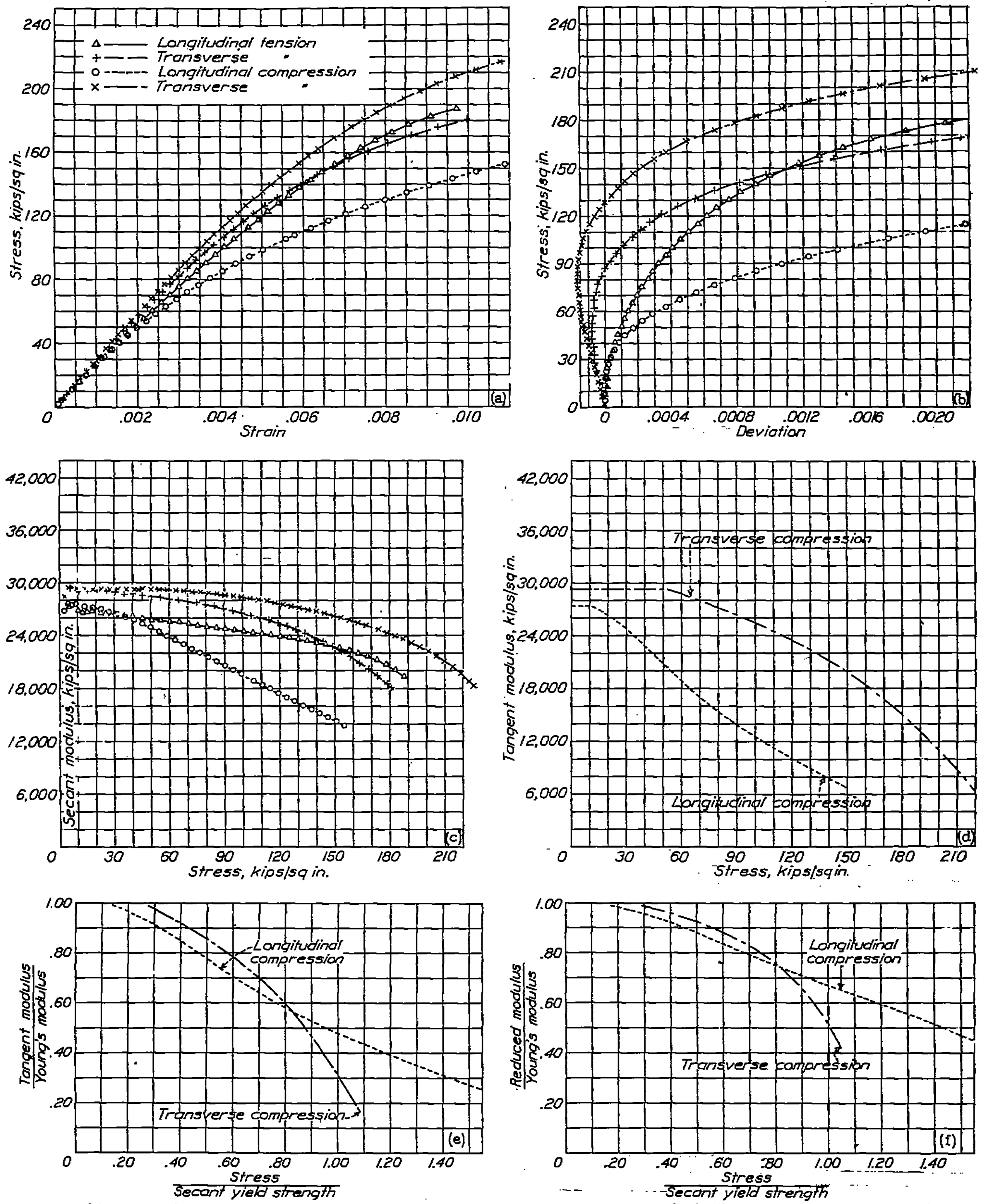
(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 16.- Sheet 16. Chromium-nickel steel 3/4 hard; thickness, 0.020 inch.



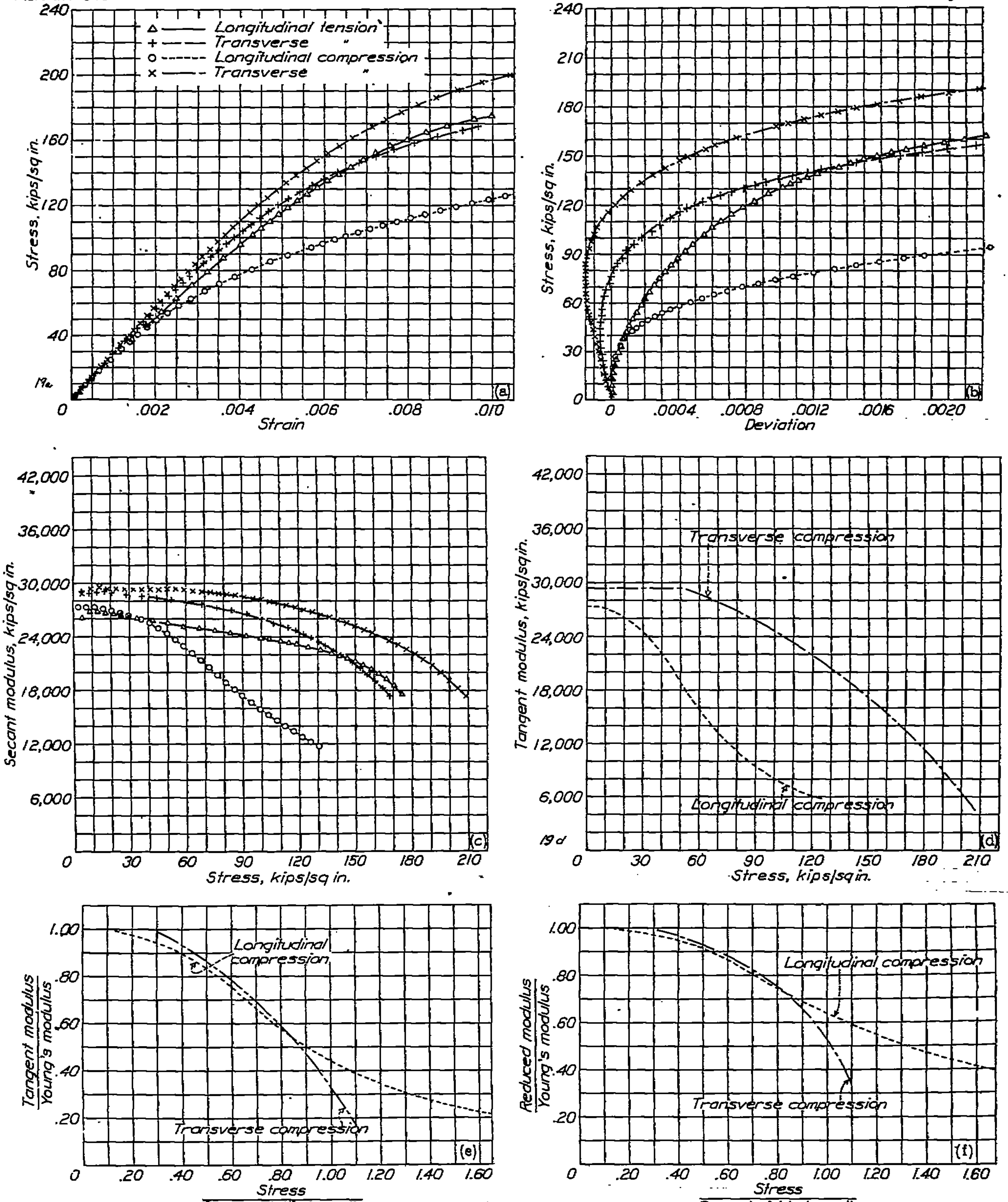
(a) Stress-strain curves.
(b) Stress-deviation curves.
(c) Secant modulus-stress curves.
(d) Tangent modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 17.- Sheet 17. Chromium-nickel steel full hard; thickness, 0.020 inch.



(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

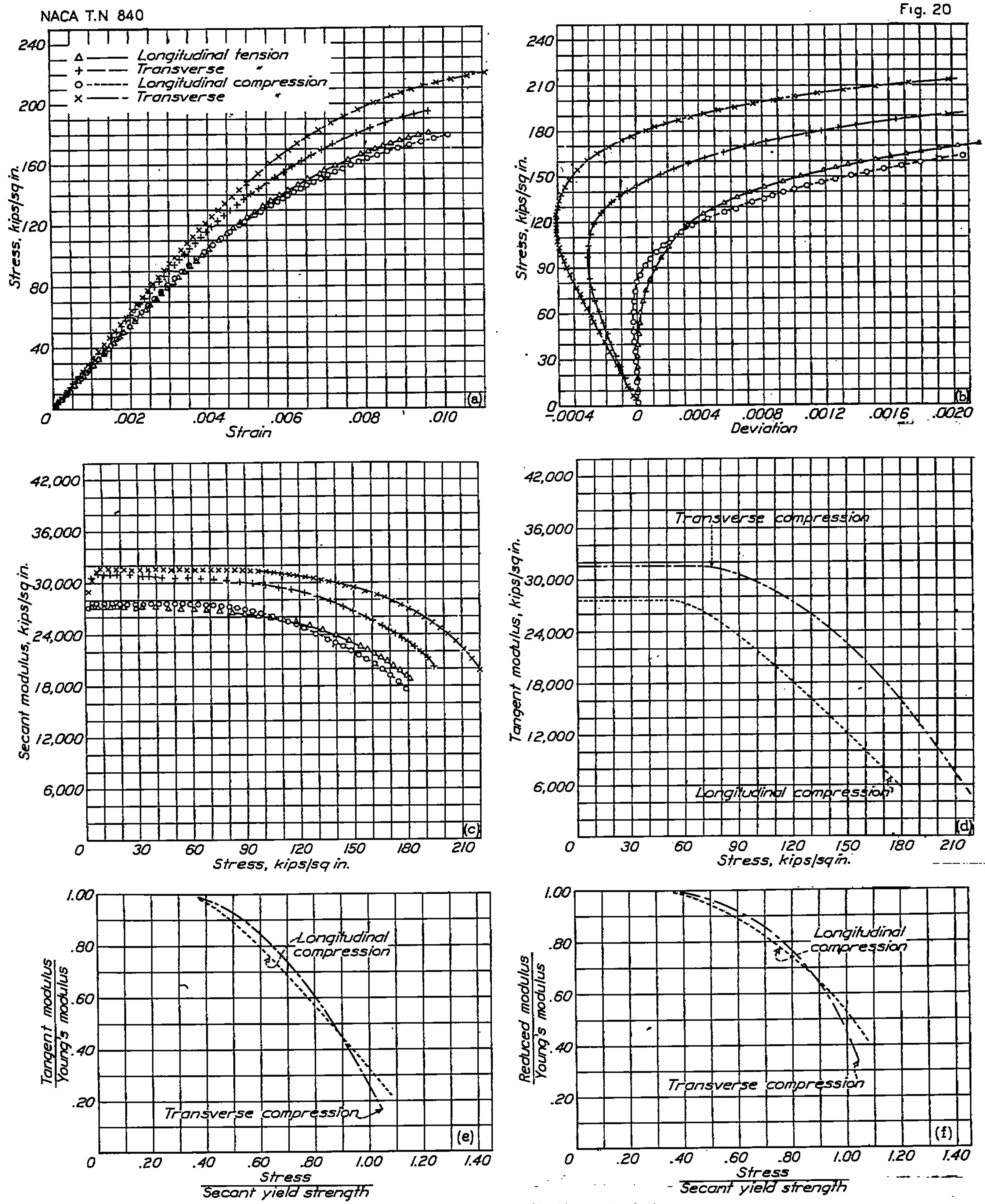
Figure 18.- Sheet 18. Chromium-nickel steel full hard; thickness, 0.020 inch.



(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.

(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 19.- Sheet 19. Chromium-nickel steel full hard; thickness, 0.024 inch.



(a) Stress-strain curves.
(c) Secant modulus-stress curves.
(e) Nondimensional tangent modulus-stress curves.
(b) Stress-deviation curves.
(d) Tangent modulus-stress curves.
(f) Nondimensional reduced modulus-stress curves.

Figure 20.- Sheet 20. Chromium-nickel steel full hard; thickness, 0.0275 inch.

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REVISION none

ORIG. AGENCY NO. TN-840

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AUTHOR(S): Atchinson, C. S.; Miller, James A.

ORIGINATING AGENCY: National Advisory Committee for Aeronautics, Washington, D. C.

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Feb '42	Restr.	U.S.	Eng.	32	tables, graphs

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P1116 Strength (Mechanics)

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Steel, Aluminum Alloys

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