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PROPERTIES OF XA78S ALUMINUM ALLOY SHEET, PLATE AND EXTRUSIONS

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WRIGHT AIR DEVELOPMENT CENTER
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FOREWORD

This report was prepared by the Metals Branch and was initiated under Project No. 7360, "Materials Analysis and Evaluation Techniques", Task No. 73605, "Design Data for Metals", formerly RDO No. 614-13, "Design and Evaluation Data for Structural Metals" and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with H. W. Zoeller and R. E. Wittman acting as project engineers.

This report covers period of work from September 1951 to April 1953.

ABSTRACT

The mechanical and metallurgical properties of XA78S aluminum alloy clad sheet, plate and extrusions have been evaluated in this work. Long time tests will be reported in a supplement to this work. The results when compared with the evaluation by other investigators, may lead to the acceptance of this alloy as an aircraft material. The XA78S aluminum alloy has approximately 10 percent greater strength than other high strength aluminum alloys. It has corrosion resistance, fatigue strength, microstructural characteristics, response to heat treatment and spot welding properties comparable to other commercial aluminum base alloys containing zinc, magnesium, and copper. This alloy offers greater resistance to bending therefore, the forming will be more difficult. As a result of this evaluation three specifications have been issued. The designations for XA78S, 75S and 24S aluminum alloys have been recently changed to X7178, 7075 and 2024, respectively.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. Whitmore

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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INTRODUCTION

A new high strength wrought aluminum alloy designated as XA78S has been developed by the Aluminum Company of America. The material investigated contained approximately 6.8 per cent zinc, 2.9 per cent magnesium, 2 per cent copper, 0.13 per cent chromium, 0.29 per cent silicon and 0.07 per cent iron. The alloy was reported by the producer to have a tensile strength approximately 10 per cent higher than the best commercial high strength wrought aluminum alloy in use today. This report presents the results of preliminary investigations made to determine various mechanical, metallurgical and corrosion resistant properties of XA78S clad sheets, bare plate and extrusions.

MATERIALS

A total of six clad sheets, two plates and two extrusions were obtained for testing. The sheet and plate material measured 48 x 72 inches. The thickness and temper of the sheets and plates were as follows:

0.032 inch thick sheet clad XA78S-0[1]

0.032 inch thick sheet clad XA78S-T6[2]

0.064 inch thick sheet clad XA78S-0

0.064 inch thick sheet clad XA78S-T6

0.125 inch thick sheet clad XA78S-0

0.125 inch thick sheet clad XA78S-T6

0.250 inch thick bare plate XA78S-T6

0.500 inch thick bare plate XA78S-T6

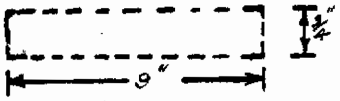
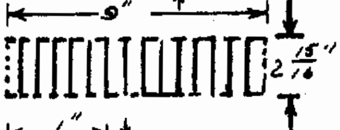
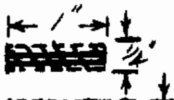
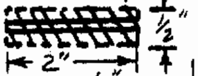
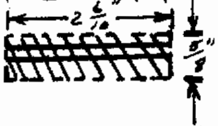
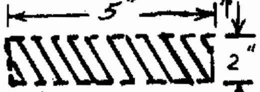
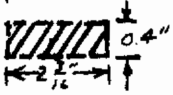
[1] -0 Annealed
[2] -T6 Solution heat treated and artificially aged

An extrusion having a hat cross section and an extrusion having approximately a rectangular cross section were received in four, twelve foot lengths. The hat extrusion was 3.5 inches wide, 1.5 inches high and had a wall thickness of 0.125 inch. The rectangular extrusion was 2.5 inches wide and 1.375 inches high and had round corners with radii of 0.25 inch. They were in the solution heat treated and artifically aged temper.

Strips were cut from the material in the longitudinal and transverse directions wherever possible. The location and identification of the test specimens are given in Table I and Figures 1 through 5.

TABLE I

IDENTIFICATION OF XA78S ALUMINUM SPECIMENS SHOWN IN FIGURES 1 THROUGH 4

Specimen Tested	Shape and size	Type	Sheets, Plates and Extrusions
TENSILE		Flat	0.032 - 0.500 inch thick Sheet & plate Hat shaped & bar extrusion
FATIGUE		Flat	Hat shaped extrusion
		Flat	0.032 inch thick sheet 0.064 inch thick sheet
		Flat	0.125 inch thick sheet 0.250 inch thick sheet
COMPRESSION		Round	0.250 inch thick plate
		Round	0.500 inch thick plate Bar extrusion
		Flat	0.064 inch thick sheet 0.125 inch thick sheet Hat shaped extrusion
SPOT WELDING		Shear Tensile	0.032 inch thick sheet 0.064 inch thick sheet
		Fatigue	0.032 inch thick sheet
		Corrosion	0.032 inch thick sheet
POTENTIAL MEASUREMENT		Bare & Clad	0.032 inch thick sheet 0.064 inch thick sheet 0.125 inch thick sheet
IMPACT		Charpy V Notched	0.500 inch thick plate Bar extrusion

As received sheets were 4 feet wide and 6 feet long
As received extrusions were in 12 foot sections

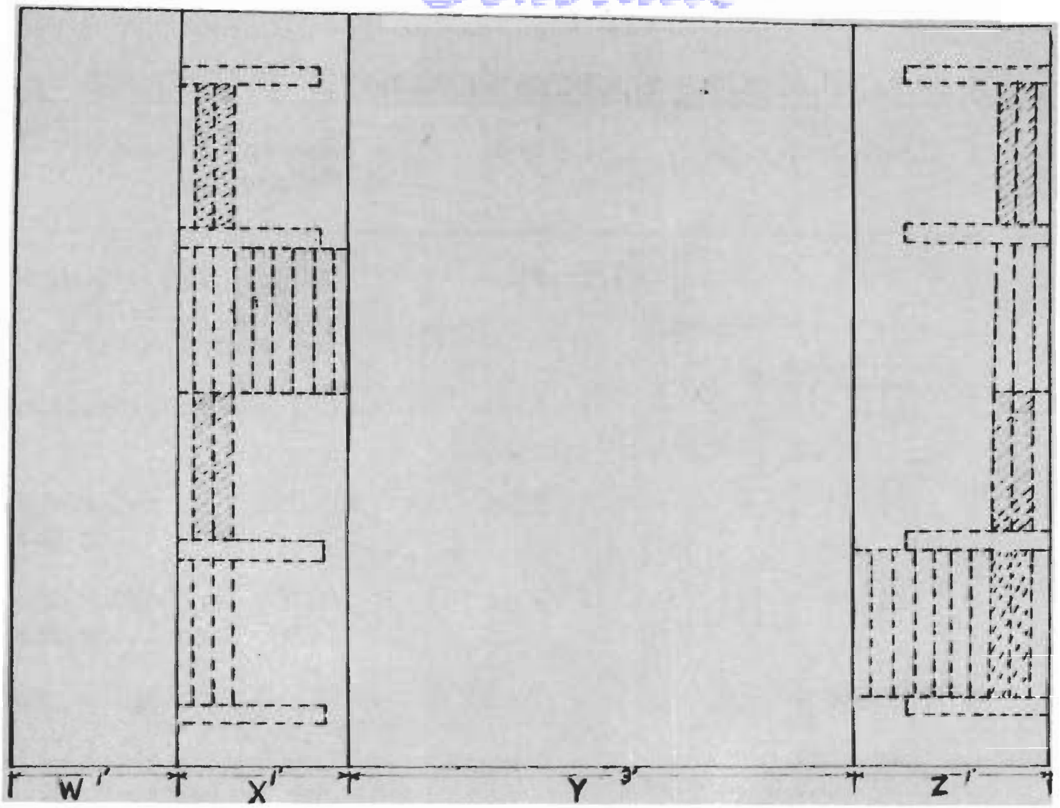


FIGURE 1-A CLAD XA78S-0 0.032 INCH THICK

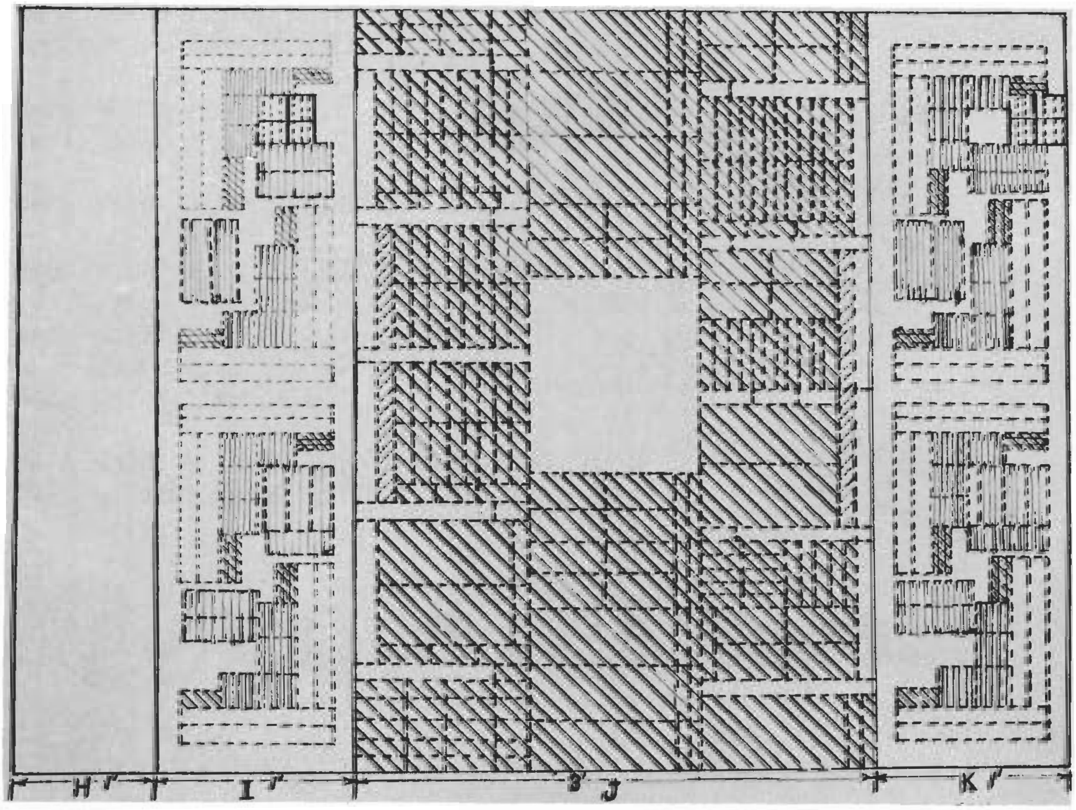


FIGURE 1-B CLAD XA78S-T6 0.032 INCH THICK

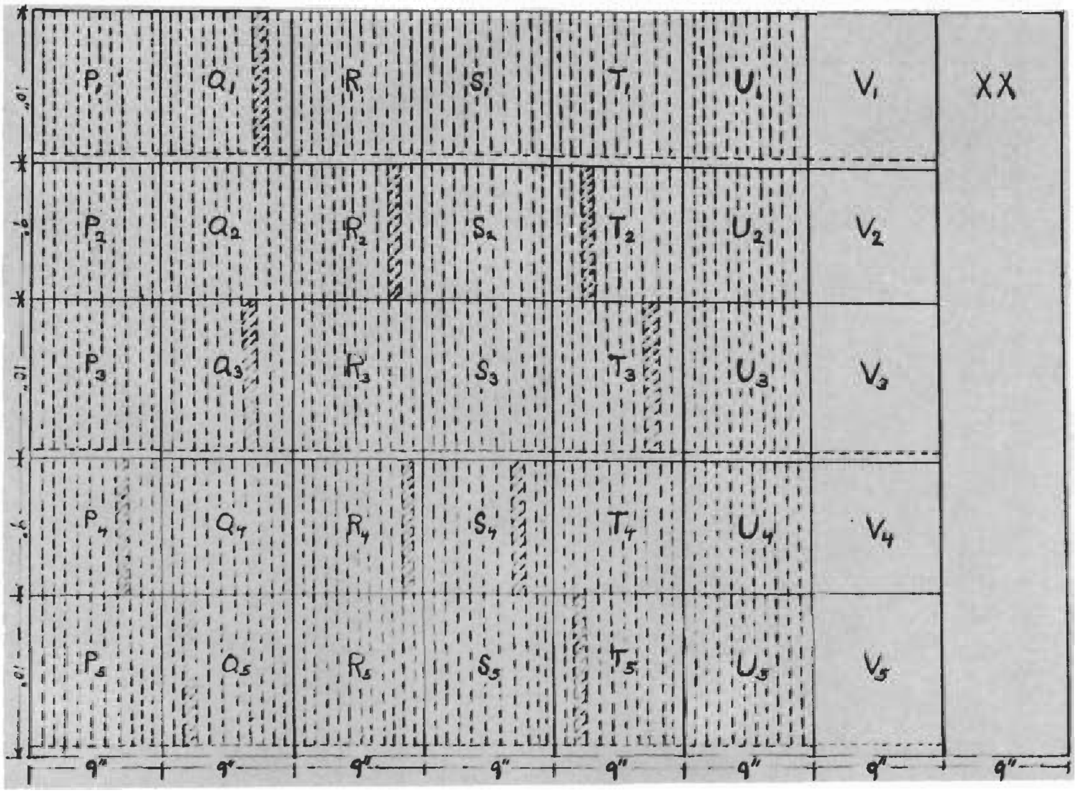


FIGURE 2-A CLAD XA78S-0 0.064 INCH THICK

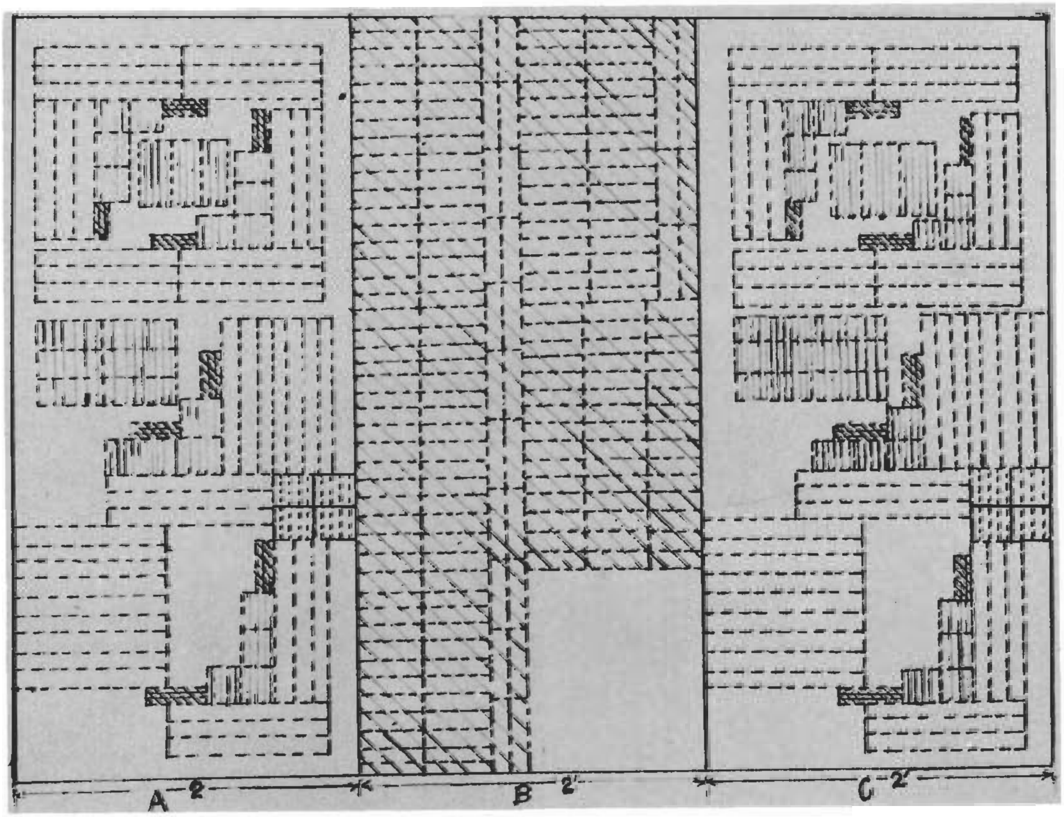


FIGURE 2-B CLAD XA78S-T6 0.064 INCH THICK

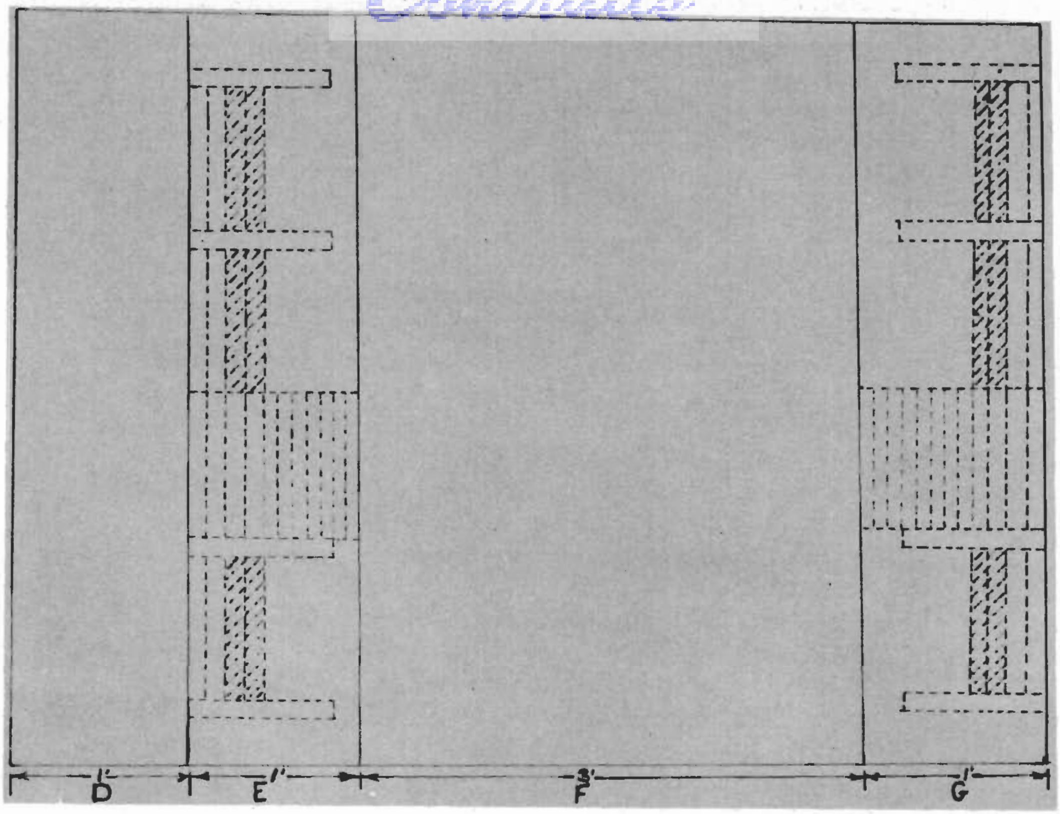


FIGURE 3-A CLAD XA78S-0 0.125 INCH THICK

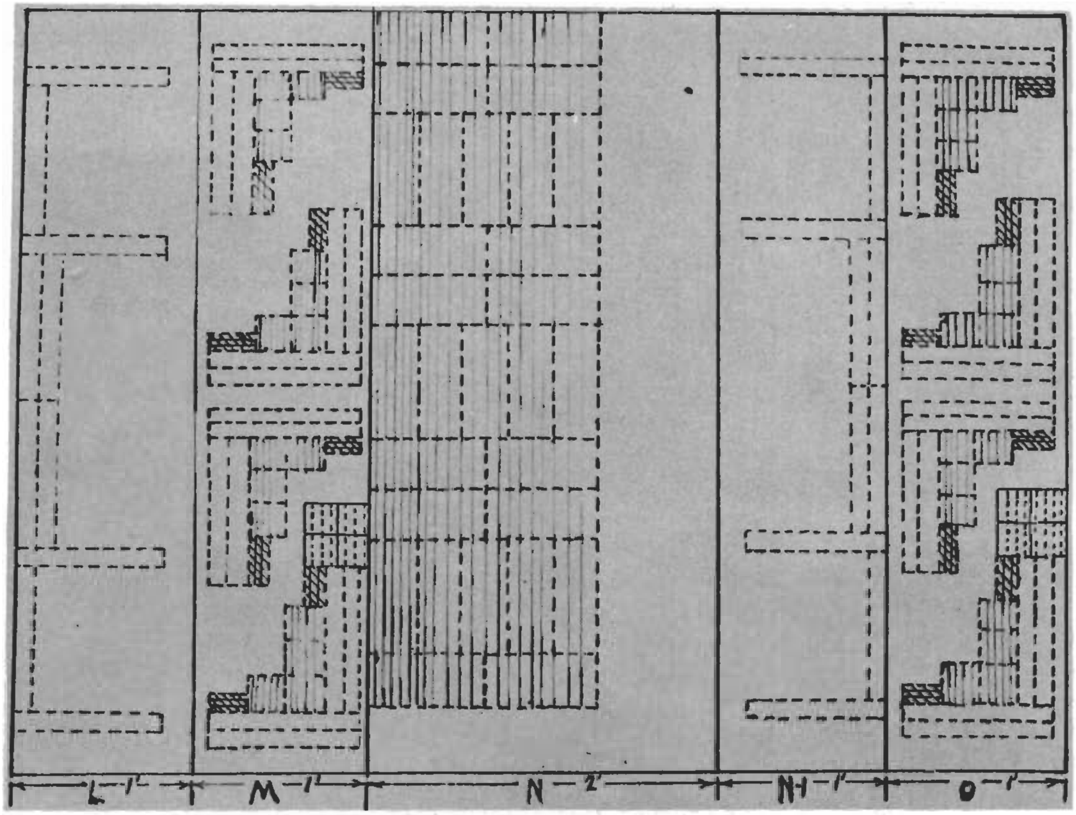


FIGURE 3-B CLAD XA78S-T6 0.125 INCH THICK

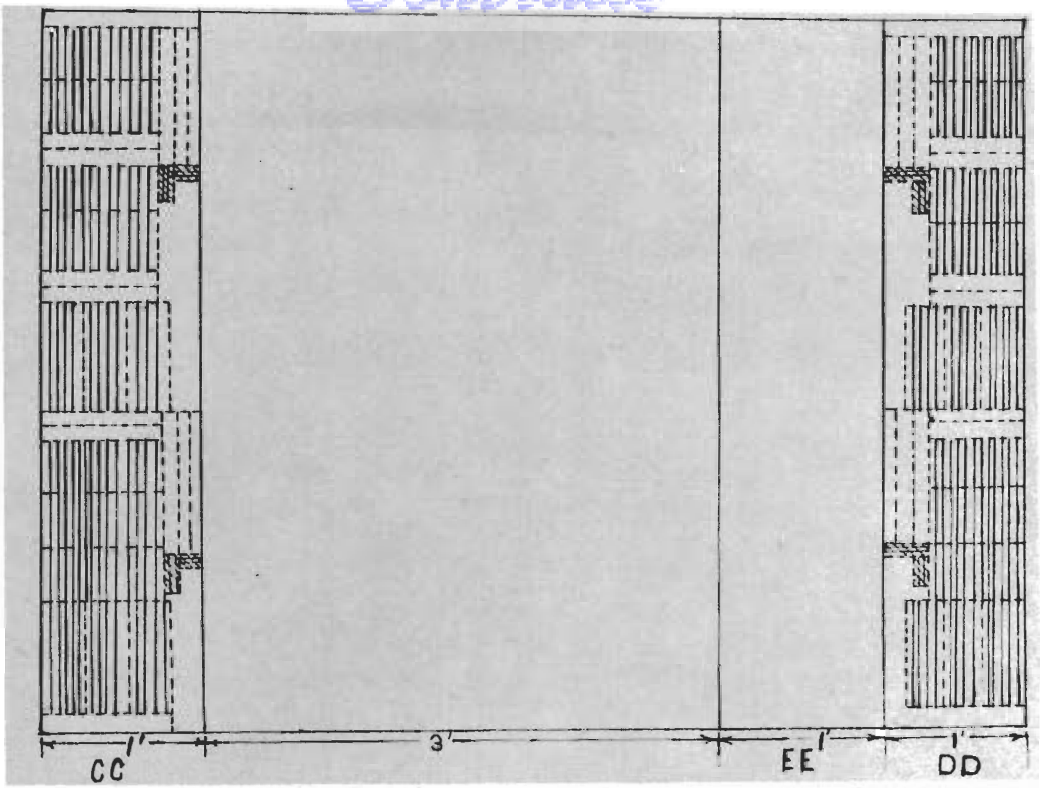


FIGURE 4-A BARE XA78S-T6 0.250 INCH THICK

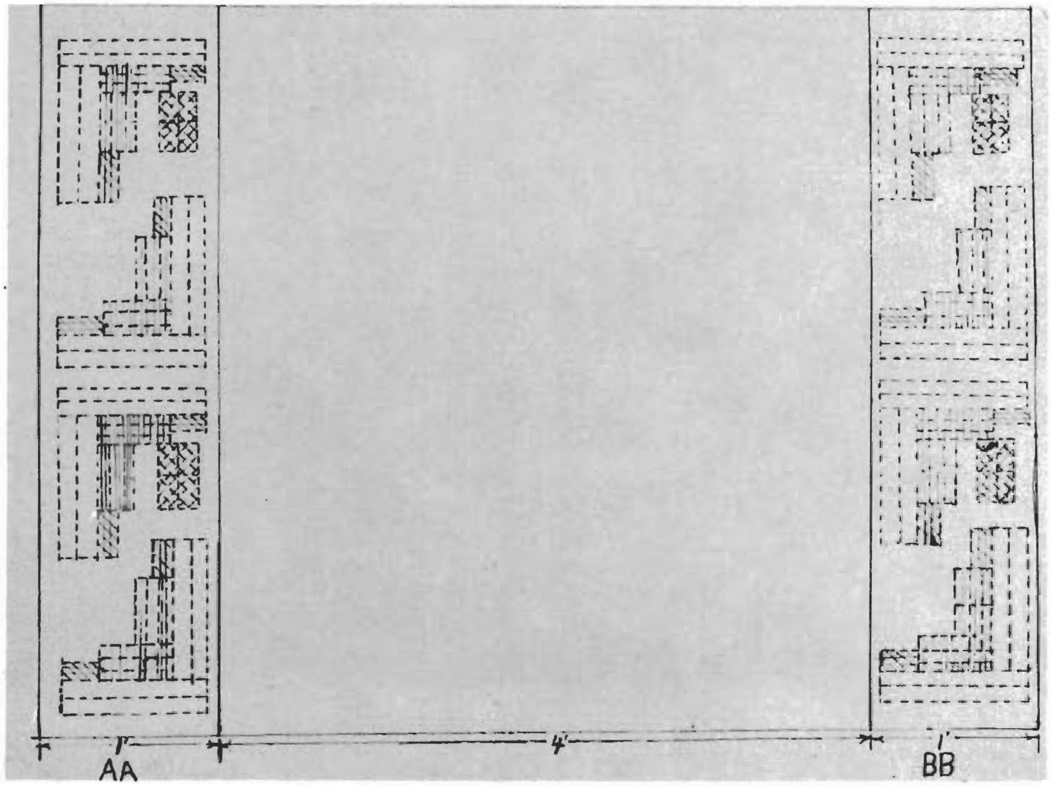


FIGURE 4-B BARE XA78S-T6 0.500 INCH THICK

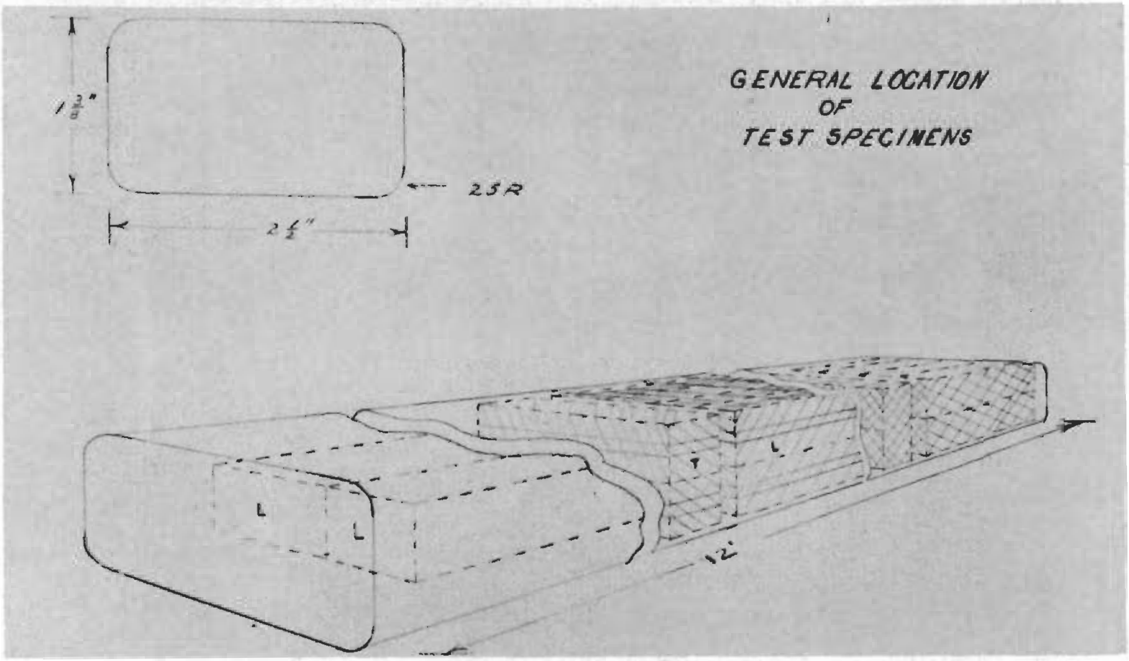


FIGURE 5-A XA78S-T6 ROUND CORNER BAR EXTRUSION DESIGN NO. 6178AM

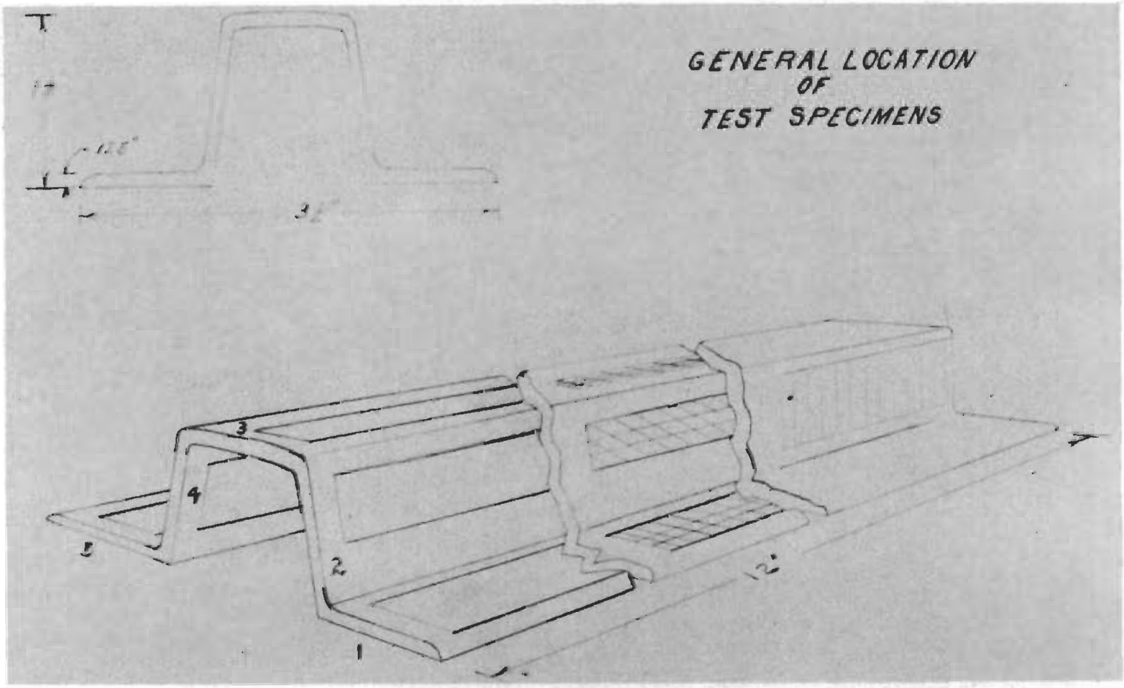


FIGURE 5-B XA78S-T6 HAT SHAPED EXTRUSION DESIGN NO. 11976

PROCEDURES AND RESULTS

Chemical Analysis

A chemical analysis was obtained for each sheet, plate and extruded sample received for this investigation. The results are listed in Table II.

The main alloying elements found in XA78S were zinc, magnesium, copper, and chromium with silicon and iron evidently being residual elements. Variations in the percentages of alloying elements were not great. However, in the extrusions the copper and magnesium were higher than in the other materials. The chromium content appears to be lower than normal for this type alloy. The amount of silicon present in the extruded materials was approximately 0.30 per cent higher than in the sheet and plate material.

The cladding used on the sheet was 72S which has a nominal composition of 99 per cent aluminum and 1 per cent zinc.

TABLE II

Chemical Composition of XA78S Aluminum Alloy Sheet, Plate and Extrusions

Type of Material	Elements Zn	Mg	Cu	Cr	Fe	Si
0.032 inch - Annealed sheet	7.08	2.88	1.84	0.13	0.08	0.09
0.032 inch - T6 sheet	6.61	2.82	1.96	0.13	0.08	0.08
0.064 inch - Annealed sheet	6.72	2.71	2.01	0.13	0.08	0.07
0.064 inch - T6 sheet	6.77	2.77	1.81	0.13	0.08	0.07
0.125 inch - Annealed sheet	6.78	2.84	1.88	0.13	0.08	0.09
0.125 inch - T6 sheet	6.94	2.83	1.99	0.13	0.08	0.09
0.250 inch - T6 plate	6.62	2.76	1.85	0.13	0.08	0.07
0.500 inch - T6 plate	6.68	2.72	1.82	0.13	0.08	0.07
Hat extrusion	6.76	2.90	2.01	0.13	0.03	0.50
Bar extrusion	6.90	2.99	2.26	0.16	0.03	0.33

Tensile Properties of Clad Sheet

Panels for tensile specimens were taken statistically from each clad sheet as shown in Figures 1 to 3. The legend for the type specimens is given in Table I. Each panel tested was represented by at least sixteen tensile samples, half from the transverse direction, and the remainder from the longitudinal direction. Standard two inch gage length specimens conforming to Specification QQ-M-151a, Type 5, were machined from the panels. A 20,000 pound capacity Tinius Olsen testing machine was used to determine the tensile properties. The deformations were obtained using an Olsen autographic extensometer and electronic recorder for the majority of tests. For the determination of moduli of elasticity, Tuckerman optical strain gages were used. Half of the specimens selected from each sheet were tested in the as received condition and the other half were heat treated in the laboratory, following the method recommended by the producer. The heat treatment consisted of heating the specimens to 870°F ± 10°F for twenty minutes for 0.032 inch thick sheet, thirty minutes for 0.064 inch thick sheet, and forty minutes for 0.125 inch thick sheet. After heating, the samples were immediately quenched in cold water. The specimens were naturally aged at room temperature for three days before artificial aging treatment. The material was artificially aged at 250°F for 24 hours.

The results of tensile tests on clad material are given in Table III. The averages of tests made on clad sheet, and the tentatively set minimum properties are shown in Tables IV and V, respectively. All of the tensile properties exceed the minimum values set by the producer.

The tensile yield strength for the mill heat treated sheet averaged 72,900 psi in the transverse direction and 73,600 in the longitudinal direction, with an elongation of approximately 10% in both directions. These results were some 8% over the tentative minimum values. The ultimate tensile strength of the material was essentially the same in both directions of rolling averaging 81,300 psi, which is 9% over the typical tensile strength of clad 75S-T6 aluminum alloy sheet. The modulus of elasticity for clad XA78S-T6 aluminum alloy sheet was essentially the same as the clad 75S-T6 aluminum alloy sheet, the primary modulus being 10.3×10^6 and the secondary modulus being 9.3×10^6.

The ultimate tensile strength of the material, heat treated in the laboratory, averaged 1,400 and 2,200 psi higher than the mill heat treated sheets in the transverse and longitudinal directions, respectively.

The ratio of the tensile yield to tensile ultimate was slightly greater in the longitudinal direction than in the transverse for both mill and laboratory heat treated materials. The mill heat-treated material, however, exhibited higher ratios than did that heat-treated in the laboratory in both directions. This ratio tended to increase as the sheet thickness increased and as the thickness increased a slight increase occurred in the yield and ultimate strengths for all conditions tested. In Table VI is presented the ratios of various properties for XA78S-T6. The same ratios for 75S-T6 aluminum alloy are presented for comparison. The tensile ratios for clad sheet are approximately the same for the two materials. The greatest difference is the ratio of the longitudinal yield strength to the transverse yield strength, with that of 75S-T6 being greater than XA78S-T6. Tensile values for 75S-T6 ratios were obtained from Reference 4.

Individual results obtained from the specimens in the different tempers, with the exception of the annealed material, were plotted in the form of a frequency curve as shown in Figure 6. The values are identified as the thickness of sheet, direction of rolling, and temper. All values fell within the relatively narrow range of 73,000 ± 4,000 psi for the yield strength, and 81,500 ± 3,500 psi in tensile strength. The elongation in all cases was 11±3 per cent. Typed stress-strain curves for the clad mill heat treated material are shown in Figure 7.

TABLE III

STRENGTH OF XA78S ALUMINUM ALLOY

Thickness of Sheet	Location of Specimen	Condition of Specimen Tested	Direction of Specimen	Yield Strength Psi	Tensile Strength Psi	Elongation % in 2 Inches
0.032	X-1	Mill Annealed[1]	Transverse	12,400	30,200	16
"	X-5	" "	"	12,600	29,900	16
"	Z-12	" "	"	12,800	30,400	16.5
"	Z-23	" "	"	11,900	30,300	16.5
"	X-2	" "	Longitudinal	12,300	30,300	16.5
"	X-3	" "	"	13,500	31,300	17.5
"	Z-11	" "	"	13,100	31,000	19.5
"	Z-13	" "	"	13,200	30,800	17.5
"	X-18	Heat treated at lab[2]	Transverse	71,400	81,800	11.5
"	X-22	" " " "	"	72,300	82,800	11.5
"	X-12	" " " "	"	72,000	82,600	11.0
"	Z-22	" " " "	"	71,800	81,400	11.0
"	X-8	" " " "	Longitudinal	71,600	82,500	12.5
"	X-10	" " " "	"	72,300	83,700	12.5
"	Z-18	" " " "	"	72,300	82,800	14.0
"	Z-20	" " " "	"	73,600	82,300	11.0
"	J-2	Mill Heat Treated[3]	Transverse	70,300	78,800	11
"	J-4	" " "	"	73,000	80,900	12.5
"	J-12	" " "	"	74,100	81,900	12.5
"	J-14	" " "	"	73,800	81,000	11
"	I-13	" " "	"	70,500	78,600	8
"	I-14	" " "	"	70,500	78,300	8.5
"	I-11	" " "	"	70,900	78,800	9
"	K-10	" " "	"	70,700	78,900	8.5
"	J-1	" " "	Longitudinal	70,900	79,500	11.5
"	J-3	" " "	"	71,100	79,900	10.5
"	J-11	" " "	"	73,900	81,500	10
"	J-13	" " "	"	71,400	79,800	11
"	K-5	" " "	"	72,700	80,300	9
"	I-1	" " "	"	73,300	79,500	10
"	K-2	" " "	"	73,300	79,400	10.5
"	I-2	" " "	"	73,300	79,300	9
"	J-6	Reheat treated[4]	Transverse	71,100	81,300	13.5
"	J-9	" "	"	70,500	80,900	14
"	J-16	" "	"	71,100	81,100	11.5
"	J-19	" "	"	71,000	80,900	12.5
"	J-8	" "	Longitudinal	71,300	81,200	13
"	J-10	" "	"	71,100	81,700	13
"	J-18	" "	"	71,700	81,600	13
"	J-20	" "	"	71,400	81,900	13.5
0.064	P_1-12	Mill Annealed	Transverse	14,000	31,700	18.5
"	Q_3-12	" "	"	12,900	30,700	19.5
"	R_1-13	" "	"	13,700	31,300	18
"	T_1-12	" "	"	14,200	32,900	19
"	P_1-11	" "	Longitudinal	14,700	32,300	19.5
"	R_1-10	" "	"	14,400	31,900	17.5
"	T_1-10	" "	"	14,200	31,900	19.5
"	V_1-10	" "	"	14,500	32,300	19.5
"	P_3-12	Heat treated at lab	Transverse	72,900	82,800	12
"	Q_3-12	" " " "	"	72,400	82,300	13
"	R_3-13	" " " "	"	73,400	82,000	12
"	T_3-12	" " " "	"	71,700	81,700	11.5
"	R_5-8	" " " "	Longitudinal	76,100	84,800	12.5
"	R_5-4	" " " "	"	73,100	83,700	13
"	S_5-5	" " " "	"	73,900	84,700	12.5
"	S_3-7	" " " "	"	73,800	81,700	12
"	A-3	Mill Heat treated	Transverse	72,900	83,000	10.5
"	A-6	" " "	"	72,600	82,500	11.0
"	C-3	" " "	"	72,400	81,500	9.5
"	C-6	" " "	"	71,400	81,300	10.0
"	A-13	" " "	"	73,200	82,200	9
"	C-17	" " "	"	71,200	80,500	10
"	C-26	" " "	"	72,900	82,500	10
"	A-27	" " "	"	75,300	83,500	10
"	C-8	" " "	Longitudinal	72,700	80,500	9.5
"	A-7	" " "	"	73,000	81,200	11.5
"	C-19	" " "	"	72,900	82,000	10
"	C-21	" " "	"	75,500	82,300	10.5
"	C-22	" " "	"	70,400	78,500	9
"	C-25	" " "	"	69,600	77,700	10
"	A-20	" " "	"	70,600	82,700	10
"	A-23	" " "	"	75,900	82,500	10
"	A-18	Reheat treated	Transverse	73,400	84,700	12
"	A-20	" "	"	73,500	84,200	11
"	C-16	" "	"	74,500	84,900	12
"	C-18	" "	"	74,500	85,000	12
"	A-39	" "	Longitudinal	73,000	83,100	12.5
"	A-37	" "	"	72,900	82,400	11.5
"	A-19	" "	"	73,300	83,600	12.5
"	A-21	" "	"	73,400	83,700	12
0.125	E-1	Mill Annealed	Transverse	15,100	32,100	18.5
"	E-6	" "	"	15,300	32,400	17.5
"	G-1	" "	"	15,100	32,800	20
"	G-6	" "	"	15,200	33,300	20.5
"	E-1	" "	Longitudinal	14,700	32,000	20
"	E-5	" "	"	15,300	31,200	19.5
"	C-19	" "	"	14,500	32,600	19.5
"	G-24	" "	"	15,300	31,900	18
"	E-21	Heat treated at lab	Transverse	72,900	83,600	11
"	E-26	" " " "	"	73,200	84,400	12.5
"	G-23	" " " "	"	73,400	84,400	11.5
"	G-28	" " " "	"	73,600	84,400	11.5
"	E-13	" " " "	Longitudinal	76,200	82,700	11.5
"	E-18	" " " "	"	75,900	82,300	13
"	G-32	" " " "	"	73,400	78,300	12
"	G-36	" " " "	"	75,800	82,400	12.5
"	M-2	Mill Heat Treated	Transverse	73,200	83,600	10.5
"	M-1	" " "	"	72,200	82,300	10
"	O-7	" " "	"	73,100	83,300	9
"	O-9	" " "	"	73,200	83,100	8
"	L-1	" " "	"	73,000	81,300	9.5
"	L-3	" " "	"	73,500	84,000	10
"	L-8[5]	" " "	"	73,900	84,400	11
"	N-1	" " "	"	74,300	81,200	11
"	M-3	" " "	Longitudinal	76,900	81,500	9.5
"	M-6	" " "	"	75,500	80,900	10
"	O-11	" " "	"	75,000	81,300	10
"	O-13	" " "	"	75,400	81,300	10
"	N-5	" " "	"	75,800	81,500	10
"	L-4	" " "	"	74,400	80,800	9
"	L-6	" " "	"	74,900	80,900	9.5
"	N-6[6]	" " "	"	76,200	81,900	10
"	M-7	Reheat treated	Transverse	74,800	85,200	12
"	M-9	" "	"	75,400	85,200	10
"	O-13	" "	"	74,600	85,000	10
"	O-16	" "	"	73,600	84,700	11.5
"	M-7	" "	Longitudinal	75,800	83,200	12.5
"	M-11	" "	"	75,700	83,800	12.5
"	O-14	" "	"	75,700	83,400	12
"	O-12	" "	"	75,400	82,900	11.5

NOTES:

1. Sheet delivered in annealed condition (clad XA78S-0). Tested as received.
2. Specimens from annealed sheet. Heat treated at Research Laboratory.
3. Sheet delivered in heat treated condition (clad XA78S-T6). Tested as received.
4. Specimens from heat treated sheet. Reheat treated at Research Laboratory.
5. Modulus of elasticity determined to be (PRI.) 10.3×10^6 (SEC.) 9.33×10^6.
6. Modulus of elasticity determined to be (PRL) 10.25×10^6 (SEC.) 9.31×10^6.

TABLE IV

SUMMARY OF TENSILE PROPERTIES OF CLAD XA78S

Sheet Thickness Inches	Yield Strength psi	Ultimate Strength psi	Elongation %	Yield Strength psi	Ultimate Strength psi	Elongation %
	Transverse			Longitudinal		
			Annealed O(1)			
.032	12,400	30,200	16.5	13,000	30,900	18.0
.064	13,700	31,700	19	14,400	32,100	19.0
.125	15,200	32,700	19	14,900	31,900	19
Avg.	13,800	31,500	18.5	14,100	31,600	18.5
		Heat Treated at Laboratory T6(2)				
.032	71,900	82,200	11.5	72,500	82,800	12.5
.064	72,600	82,200	12	74,200	83,700	12.5
.125	73,300	84,200	11.5	75,300	81,400	12
Avg.	72,600	82,900	11.5	74,000	82,600	12
		Mill Heat Treated T6(3)				
.032	71,800	79,500	10.5	72,500	80,200	10
.064	73,100	82,200	9.5	72,900	80,700	10
.125	73,700	83,900	10	75,300	81,300	10
Avg.	72,900	81,900	10	73,600	80,700	10
		Reheat Treated at Laboratory T6(4)				
.032	70,900	81,100	13	71,400	81,600	13
.064	74,000	84,700	12	72,900	83,200	12
.125	74,600	85,000	11	75,700	83,300	12
Avg.	73,200	83,600	12	73,300	83,100	12

NOTE:

(1) Sheet delivered in annealed condition (clad XA78S-O). Tested as received.

(2) Specimens from annealed sheet. Laboratory heat treated.

(3) Sheet delivered in heat treated condition (clad XA78S-T6). Tested as received.

(4) Specimens from heat treated sheet. Laboratory reheat treated.

TABLE V

TENTATIVE MINIMUM TENSILE PROPERTIES OF XA78S - SHEET AND PLATE

Alloy and Temper	Thickness Range in.	Minimum Tensile Strength psi	Minimum(2) Yield Strength psi	Elongation in 2 in. %
Bare XA78S-O	0.016 - 0.499	40,000(1)	21,000(1)	10
XA78S-T6	0.016 - 0.040	83,000	72,000	7
	0.041 - 0.499	84,000	73,000	8
Clad XA78S-O	0.016 - 0.499	36,000(1)	20,000(1)	10
XA78S-T6	0.016 - 0.040	76,000	66,000	7
	0.041 - 0.499	78,000	68,000	8

NOTE: (1) Maximum so specified to insure complete annealing.

(2) Offset = 0.2 per cent.

TABLE VI

RELATIONSHIP BETWEEN MECHANICAL PROPERTIES OF XA78S

Temper	Thickness Inches	$\frac{TS(W)}{TS(X)}^{(1)}$	$\frac{TYS(W)}{TS(W)}^{(1)}$	$\frac{TYS(X)}{TS(X)}$	$\frac{TYS(W)}{TYS(X)}$	$\frac{CYS(W)}{CYS(X)}^{(3)}$	$\frac{CYS(W)}{TYS(X)}$	$\frac{CYS(X)}{TYS(X)}$	$\frac{FS(W)}{TS(W)}^{(4)}$	$\frac{FS(X)}{TS(X)}$	$\frac{FS\ 10^5(W)}{TS(W)}$	$\frac{FS\ 10^5(X)}{TS(X)}$
Mill Annealed Clad Sheet	.032	1.02	0.42	0.41	1.05							
	.064	1.01	0.45	0.43	1.05							
	.125	0.98	0.47	0.46	0.98							
	Average	1.00	0.44	0.44	1.02							
Lab Heat Treated Clad Sheet	.032	1.01	0.88	0.88	1.01							
	.064	1.02	0.89	0.88	1.02							
	.125	0.97	0.93	0.86	1.04							
	Average	1.00	0.90	0.88	1.02							
Reheat Treated Clad Sheet	.032	1.01	0.88	0.88	1.01							
	.064	0.98	0.88	0.88	0.98							
	.125	0.98	0.91	0.88	1.01							
	Average	0.99	0.89	0.88	1.00							
Mill Heat Treated Clad Sheet	.032	1.00	0.88	0.90	0.99				0.20	0.19	0.38	0.36
	.064	0.99	0.90	0.89	1.00	0.93	1.06	1.15	0.20	0.18	0.35	0.32
	.125	0.98	0.93	0.88	1.03	0.96	1.05	1.13	0.16	0.14	0.31	0.28
	Average	0.99	0.91	0.89	1.01	0.94	1.05	1.14	0.19	0.17	0.35	0.32
Bare Plate	.250	0.99	0.94	0.88	1.05	0.96	1.00	1.11	0.22	0.22	0.40	0.40
	.500	1.04	0.92	0.89	1.07	0.95	1.02	1.16				
	Average	1.02	0.93	0.88	1.06	0.95	1.01	1.13				
Hat Extrusion	1.5x3.5		0.91				1.08		0.20		0.36	
Bar Extrusion	1.37x2.5		0.93			1.07	1.00					
					75S-T6							
Clad Sheet	0.015 to 0.500	1.00	0.92	0.88	1.04	0.94	0.97	1.07	0.17	0.16	0.37	0.37
Bare Sheet Plate	0.015 to 0.500	1.00	0.91	0.88	1.04	0.95	0.97	1.07	0.22	0.25	0.40	0.40

NOTES TO TABLE VI

(1) (W) = Longitudinal Direction, (X) = Transverse Direction,
T S = Ultimate Tensile Strength

(2) TYS = Tensile Yield Strength

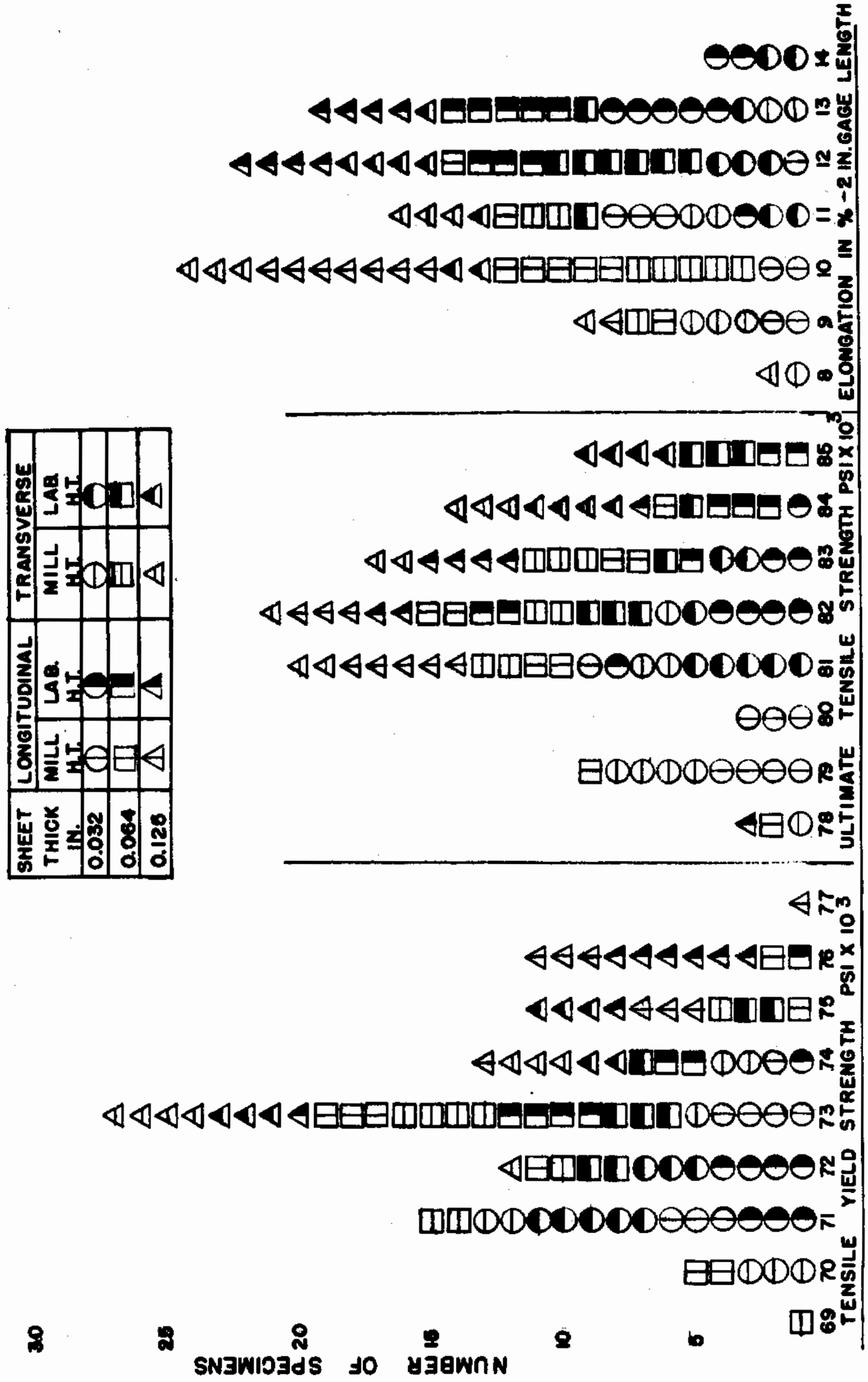
(3) CYS = Compressive Yield Strength

(4) FS = Fatigue Strength at $20x10^6$ Cycles

(5) FS = Fatigue Strength at 10^5 Cycles

FIGURE 6

FREQUENCY CURVE CLAD XA 78S-T6 ALLOY



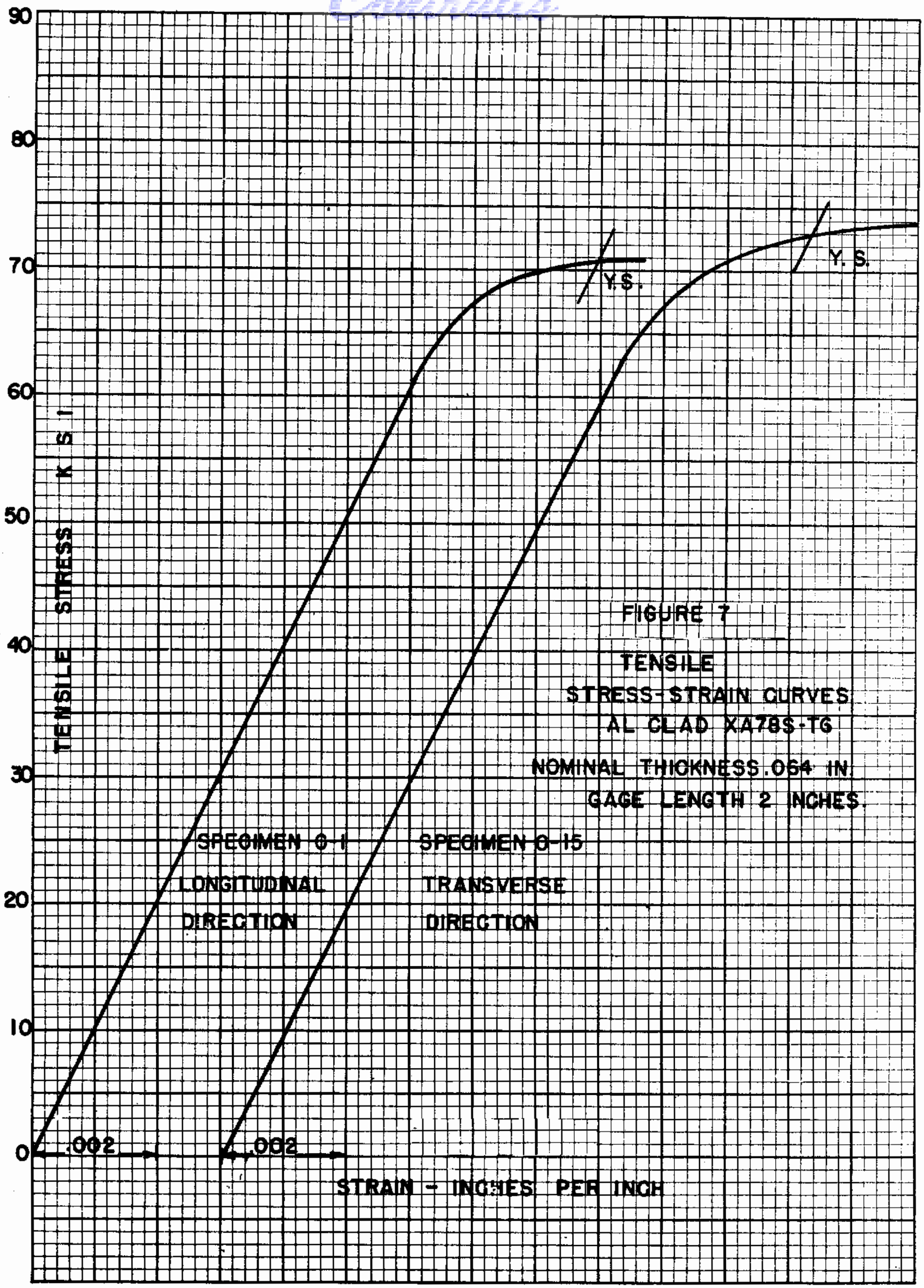


FIGURE 7

TENSILE
STRESS-STRAIN CURVES
AL CLAD XA78S-T6
NOMINAL THICKNESS .064 IN.
GAGE LENGTH 2 INCHES.

Tensile Properties of 0.250 and 0.500 Inch Bare Plate

Six tensile specimens, three in the longitudinal and three in the transverse direction, were tested from each mill heat treated panel examined. The tensile strengths were determined using standard specimens in a 60,000 lb capacity Baldwin-Southwark testing machine. The tensile yield strengths were obtained using a Templin autographic strain gage and recorder. The individual tensile results are given in Table VII.

The tensile yield strength for the 0.250 inch thick material averaged 81,800 psi in the longitudinal direction and 77,300 psi in the transverse direction. The ultimate tensile strength for the 0.250 inch plate was 87,500 psi for both directions of rolling. The ultimate tensile strength of the 0.500 inch plate averaged 87,200 psi in the transverse direction and was 90,600 psi in the longitudinal direction.

The average tensile ultimate and yield strengths for bare XA78S-T6 aluminum alloy were about ten percent above the corresponding average properties of 75S-T6 aluminum alloy. Typical stress-strain curves for the 0.500 inch material are given in Figure 8.

The average ratio of the tensile yield strength to tensile ultimate strength was slightly higher for the bare material than for the clad material in the longitudinal direction and the same as clad sheet in the transverse direction. This differed somewhat from 75S-T6 aluminum alloy in which the ratio of tensile yield to tensile ultimate in the longitudinal direction is slightly lower for the bare material than for the clad. The same ratio in the transverse directions for both materials was equal. Brinell hardness of the bare material, using 1000 kg load with a 10 mm. tungsten carbide ball, averaged 170 BHN.

TABLE VII

TENSILE PROPERTIES OF BARE XA78S-T6 PLATES

Specimen No.	Plate Thickness Inches	Direction of Specimen	Yield Stength psi	Ultimate Strength psi	Elongation %
CC-1	0.250	Longitudinal	79,300	86,000	11
CC-3	0.250	Longitudinal	82,600	87,800	13.5
CC-6(1)	0.250	Longitudinal	81,500	87,800	13.5
DD-4	0.250	Longitudinal	82,200	87,600	14
DD-5	0.250	Longitudinal	83,700	87,800	13.5
DD-6	0.250	Longitudinal	81,600	88,000	14
		Average	81,800	87,500	13
CC-7	0.250	Transverse	80,000	89,100	11.5
CC-8	0.250	Transverse	78,100	88,800	11.5
CC-10(2)	0.250	Transverse	79,600	88,500	10.5
DD-7	0.250	Transverse	75,200	86,400	9.0
DD-8	0.250	Transverse	76,900	88,200	9.0
DD-9	0.250	Transverse	75,700	86,700	11.0
		Average	77,300	88,000	10
AA-4	0.500	Longitudinal	83,200	90,200	12
AA-5	0.500	Longitudinal	83,000	90,200	12
AA-6	0.500	Longitudinal	83,500	90,400	12.5
BB-1	0.500	Longitudinal	84,000	91,200	13
BB-2	0.500	Longitudinal	83,700	90,700	13.5
BB-3	0.500	Longitudinal	83,900	91,100	11.5
		Average	83,400	90,600	12.5
AA-7	0.500	Transverse	76,200	85,700	12
AA-8	0.500	Transverse	77,000	86,400	11.5
AA-9	0.500	Transverse	76,100	85,800	12
BB-7	0.500	Transverse	78,700	88,500	13.5
BB-8	0.500	Transverse	78,500	88,300	12.5
BB-9	0.500	Transverse	78,600	88,300	13.5
		Average	77,500	87,200	12.5

NOTE:

(1) Modulus of Elasticity Determined to be 10.08X10^6

(2) Modulus of Elasticity Determined to be 10.06X10^6

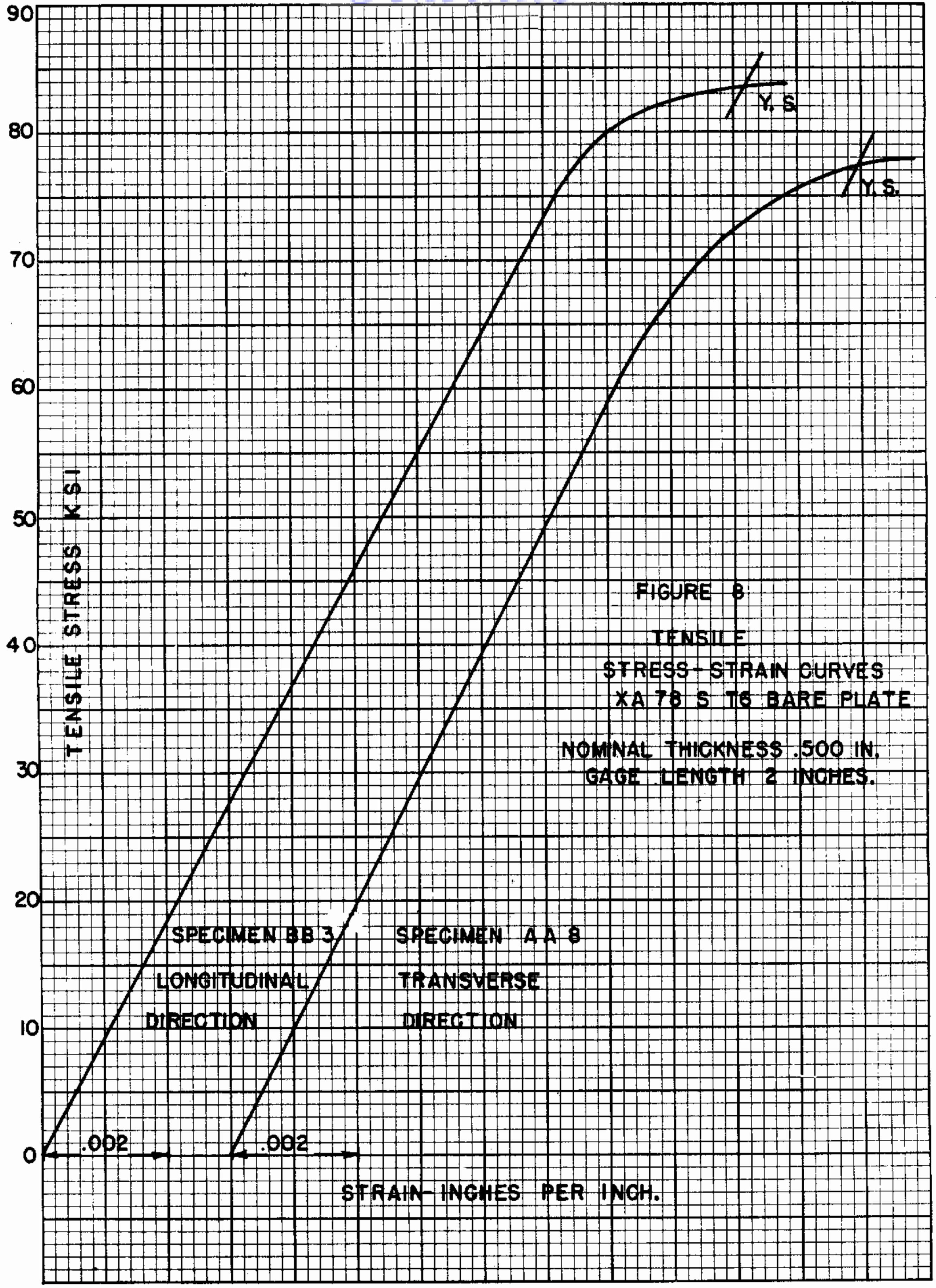


FIGURE 8

TENSILE
STRESS-STRAIN CURVES
XA 78 S T6 BARE PLATE

NOMINAL THICKNESS .500 IN.
GAGE LENGTH 2 INCHES.

Tensile Properties of Extrusions

Two types of extruded sections were subjected to tensile evaluation in the longitudinal direction only. These sections were hat shaped and round corner bar as shown in Figure 5. All specimens were standard types and were tested using the equipment described in the procedure for the XA78S-T6 aluminum alloy bare plate. Individual results are shown in Table VIII.

The tensile yield strength for the hat and bar sections averaged 89,200 psi and 93,300 psi, respectively and the ultimate tensile strength 98,000 psi and 100,400 psi, respectively. The tensile yield strengths of specimens from the sides of the hat extrusion were 4.5 percent lower and the ultimate tensile strengths 3 percent lower than for specimens taken from the flanges and top. The average values for both the extrusions were about 10 percent higher than for the bare plate in the longitudinal direction although the average ratio of the yield to ultimate strengths was essentially the same as for bare plate. The elongation over a two inch gage length averaged 10.0 percent for the hat section and 6.5 percent for the round corner bar. Specimens taken from the bar extrusion were round which may account for the lower percentage elongation. Stress-strain curves for these sections are shown in Figure 9.

Brinell hardness tests were conducted on both sections, the average readings being 170 B. H. N.

TABLE VIII

XA78S-T6 HAT & BAR EXTRUSIONS

TENSILE PROPERTIES

LONGITUDINAL DIRECTION

Extruded Section	Specimen Number	Specimen Location	Yield Strength psi	Tensile Strength psi	Per Cent Elong.	Brinell Hardness 1000kg/10mm
Hat-A	1A-1	Bottom	92400	100100	9.0	168
	2A-1	Side	86000	96200	11.0	160
	3A-1	Top	90300	99400	10.0	163
	4A-1	Side	87000	96000	11.0	159
	5A-1	Bottom	91900	99500	9.5	158
	1A-2	Bottom	90000	99500	10.0	169
	2A-2	Side	87200	97600	10.0	159
	3A-2	Top	90100	99800	10.5	161
	4A-2	Side	87900	96900	10.0	158
	5A-2	Bottom	91300	99700	10.0	159
	1A-3	Bottom	90700	99800	10.0	168
	2A-3	Side	86200	97400	11.0	156
	3A-3	Top	89100	99400	9.5	164
	4A-3	Side	86500	96500	9.5	150
	5A-3	Bottom	89800	98800	11.0	153
Hat-B	1B-1	Bottom	92100	99700	10.0	164
	2B-1	Side	89400	97600	10.0	160
	3B-1	Top	91600	99600	10.0	165
	4B-1	Side	87500	96700	10.0	158
	5B-1	Bottom	89600	97300	10.0	158
	1B-2	Bottom	91800	99500	10.0	164
	2B-2	Side	88700	96100	10.0	154
	3B-2	Top	91300	99200	9.5	162
	4B-2	Side	88200	97100	9.5	161
	5B-2	Bottom	90200	98000	9.5	159
	1B-3	Bottom	92500	99900	8.5	165
	2B-3	Side	89100	97400	10.0	157
	3B-3	Top	91800	99900	10.0	157
	4B-3	Side	87500	96400	10.0	160
	5B-3	Bottom	90800	98000	10.0	161
AVERAGE VALUES			89200	98000	10.0	160
Bar A	A1		92600	100200	6.5	
	A2		92000	99100	6.5	
	A3		92500	101200	7.0	
	A4		93500	100500	6.5	
	A5		94700	100800	5.5	
	A6		94500	100400	6.5	
AVERAGE VALUES			93300	100400	6.5	

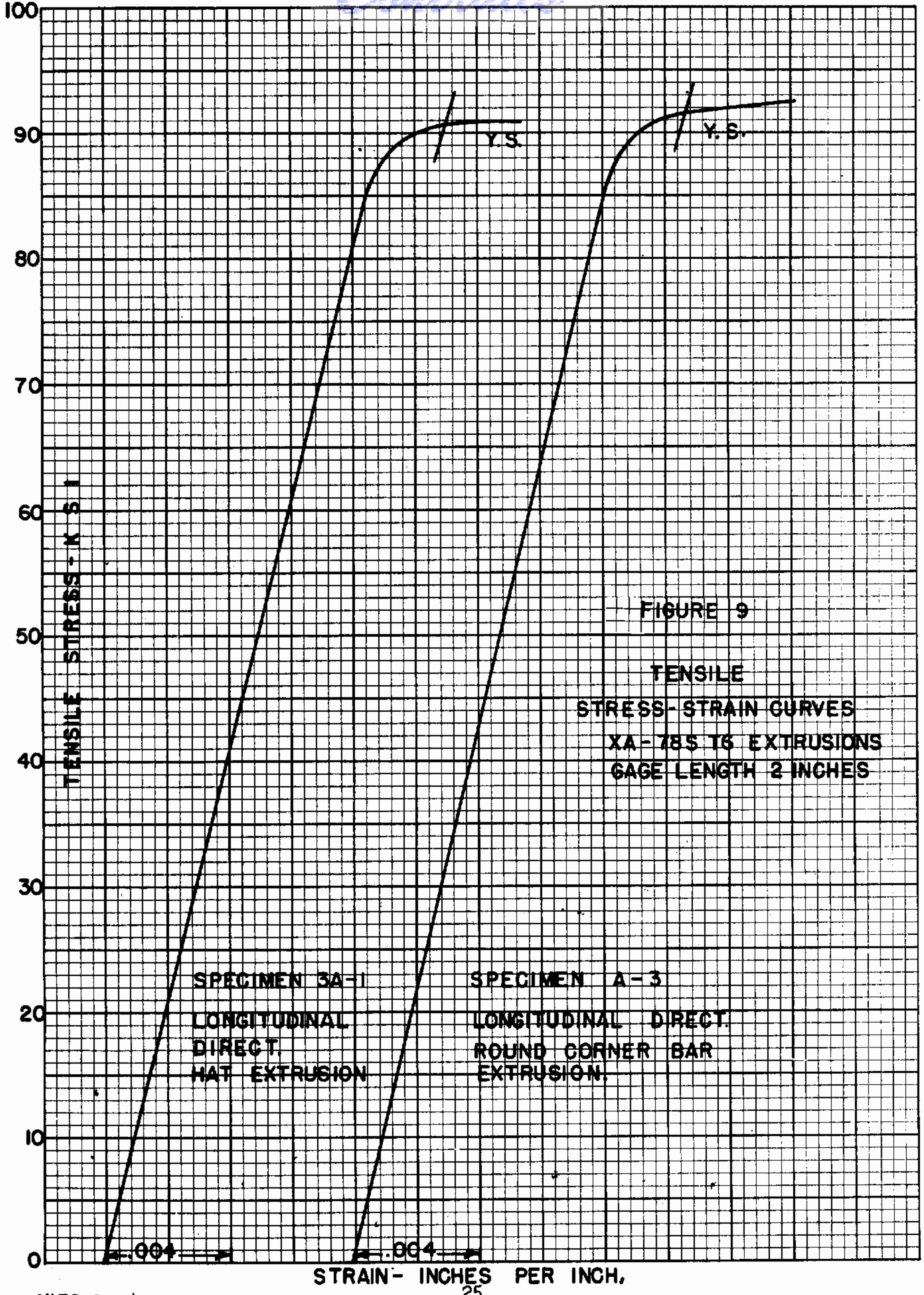


FIGURE 9

TENSILE
STRESS-STRAIN CURVES
XA-78S T6 EXTRUSIONS
GAGE LENGTH 2 INCHES

Compressive Properties of Clad Sheet, Bare Plate & Extrusions

Compressive specimens were taken from the mill heat treated materials in both directions of rolling with the exception of the hat extrusions. Tests on this section were conducted in the longitudinal direction only. A Montgomery-Templin compression jig and Templin extensometer were used to determine the yield strengths of standard flat specimens from the clad sheet and hat extrusion. Round specimens of the dimensions shown in Table I from the bare plate and hat extrusions were tested using a Southwark Peters averaging extensometer with the exception of the 0.250 inch material. Due to the short length of the specimens a special compression jig with a dial gage calibrated to 0.0001 inch was used to obtain the yield strength. The compressive yield strength was based on the stress at a 0.2% offset. Individual results are shown in Tables IX and X.

The 0.064 and 0.125 inch clad sheet had an average compressive yield strength of 84,100 psi in the transverse direction and 76,300 psi in the longitudinal direction. Difficulty was encountered in testing the 0.032 inch sheet and results are not presented at this time. The results of compression tests on the 0.500 inch bare plate were quite scattered, ranging from 77,400 psi to 92,000 psi in the transverse direction and 80,900 psi to 87,900 psi longitudinally. The individual specimens were etched after the tests to substantiate the direction of rolling. The average properties of the bare plate were determined to be 85,100 psi in the transverse and 83,300 psi in the longitudinal direction. The strength of the 0.500 inch plate was about the same in the transverse direction as for the 0.250 inch plate and was 3% higher in the longitudinal direction. As a comparison the average compressive yield strengths were about 6% and 1% higher than the tensile yield strengths for the clad and bare materials respectively in the longitudinal direction, and 14 and 10% higher respectively in the transverse direction. This differs from 75S-T6 for which the compressive yield strength in the longitudinal direction is less than the tensile yield strength and the compressive yield strength in the transverse direction is only 7% higher than the tensile yield strength. No difference is shown, however, between these ratios for bare and clad 75S-T6 material which were obtained from Reference 9.

An average of thirty tests on the hat extrusion, all in the longitudinal direction, gave a compressive yield strength of 96,200 psi. The strengths of individual specimens from the flanges and top of this section were 5.5% higher than those from the sides. Values obtained from the bar extrusion averaged 94,700 psi in the longitudinal direction and 88,800 psi in the transverse direction. The compressive yield strength of the hat extrusion averaged 8% over the tensile yield strength while the average compressive and tensile yield strengths of the bar extrusion were equal. The average strength of both extrusions was 10.5 per cent higher than the compressive yield strength of the bare plate.

Typical stress-strain compressive curves for the clad, bare and extruded material are presented in Figures 10, 11 and 12, respectively.

A comparison of the tensile ultimate, tensile yield and compressive yield properties of 75S-T6 and XA78S-T6 is shown in Figure 13.

TABLE IX

COMPRESSIVE PROPERTIES OF XA78S-T6 MILL HEAT TREATED SHEET AND PLATE

.064" Clad Sheet		.125" Clad Sheet		.250" Bare Plate		0.500 Bare Plate	
Specimen Number (Flat)	Yield Strength 0.2% Offset psi	Specimen Number (Flat)	Yield Strength 0.2% Offset psi	Specimen Number (Round)	Yield Strength 0.2% Offset psi	Specimen Number (Round)	Yield Strength 0.2% Offset psi
			Longitudinal Direction				
C25	72700	L18	81600	CC28	81000	AA46	80900
C26	75300	L19	79200	CC29	81200	AA47	85500
C27	74500	L22	77100	CC30	82900	AA48	87900
C28	78100	L23	82900	CC31	82600	AA49	82400
A25	79200	N18	79300			BB46	84400
A26	76900	N19	78000			BB47	86500
A27	82500	N22	79200				
A28	79600	N23	78000				
Average	77200	Average	79400	Average	81900	Average	84600
			Transverse Direction				
C29	79700	L26	84800	CC32	84000	AA50	79900
C30	81500	L28	84300	CC33	84400	AA51	77400
C31	82000	L29	78500	CC34	85500	AA52	88800
C32	83800	L31	84600	CC35	85700	AA53	90700
A29	84400	N26	81300			BB50	92000
A30	86100	N28	83200			BB51	87900
A31	87700	N29	83300			BB52	84400
A32	82800	N31	81300			BB53	81100
Average	83500	Average	82700	Average	84900	Average	85300

TABLE X

COMPRESSIVE PROPERTIES OF XA78S-T6 HAT & ROUND CORNER BAR EXTRUSIONS

HAT EXTRUSION (3.5" WIDE X 1.5" HIGH X .125" THICK)

LONGITUDINAL DIRECTION (FLAT SPECIMENS)

Specimen Location	Specimen Number	Yield Strength Psi	Specimen Location	Specimen Number	Yield Strength Psi
Bottom	1 A-1	102,400	Bottom	1 B-1	99,800
Side	2 A-1	95,400	Side	2 B-1	92,300
Top	3 A-1	98,500	Top	3 B-1	97,000
Side	4 A-1	94,300	Side	4 B-1	89,500
Bottom	5 A-1	98,000	Bottom	5 B-1	96,800
Bottom	1 A-2	99,100	Bottom	1 B-2	98,800
Side	2 A-2	93,900	Side	2 B-2	93,800
Top	3 A-2	100,000	Top	3 B-2	95,200
Side	4 A-2	96,700	Side	4 B-2	93,000
Bottom	5 A-2	101,300	Bottom	5 B-2	96,500
Bottom	1 A-3	97,700	Bottom	1 B-3	101,300
Side	2 A-3	92,700	Side	2 B-3	93,200
Top	3 A-3	98,800	Top	3 B-3	95,600
Side	4 A-3	91,400	Side	4 B-3	90,100
Bottom	5 A-3	96,900	Bottom	5 B-3	96,300
AVERAGE		97,100	AVERAGE		95,300

ROUND CORNER BAR (1.375" x 2.5" x .25" R)
ROUND SPECIMENS (0.500 Inch Diameter)

Longitudinal Direction		Transverse Direction	
A-1	96,900	A-1	88,300
A-2	92,900	A-2	89,300
A-3	91,400	A-3	89,400
A-4	97,900	A-4	88,400
A-5	98,500	A-5	87,800
A-6	90,500	A-6	89,900
AVERAGE	94,700	AVERAGE	88,800

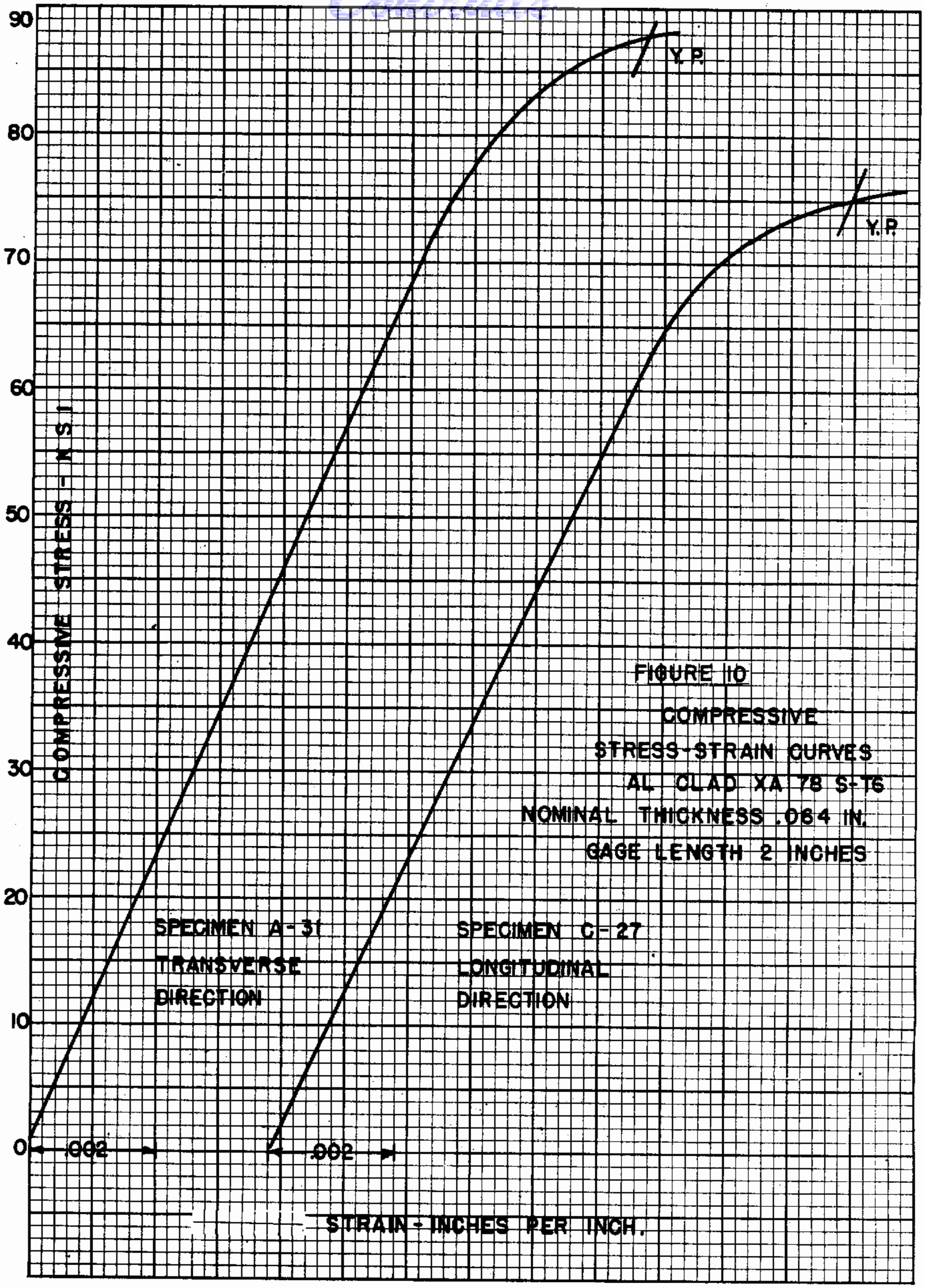


FIGURE 10

COMPRESSIVE
STRESS-STRAIN CURVES
AL CLAD XA 78 S-T6
NOMINAL THICKNESS .064 IN.
GAGE LENGTH 2 INCHES

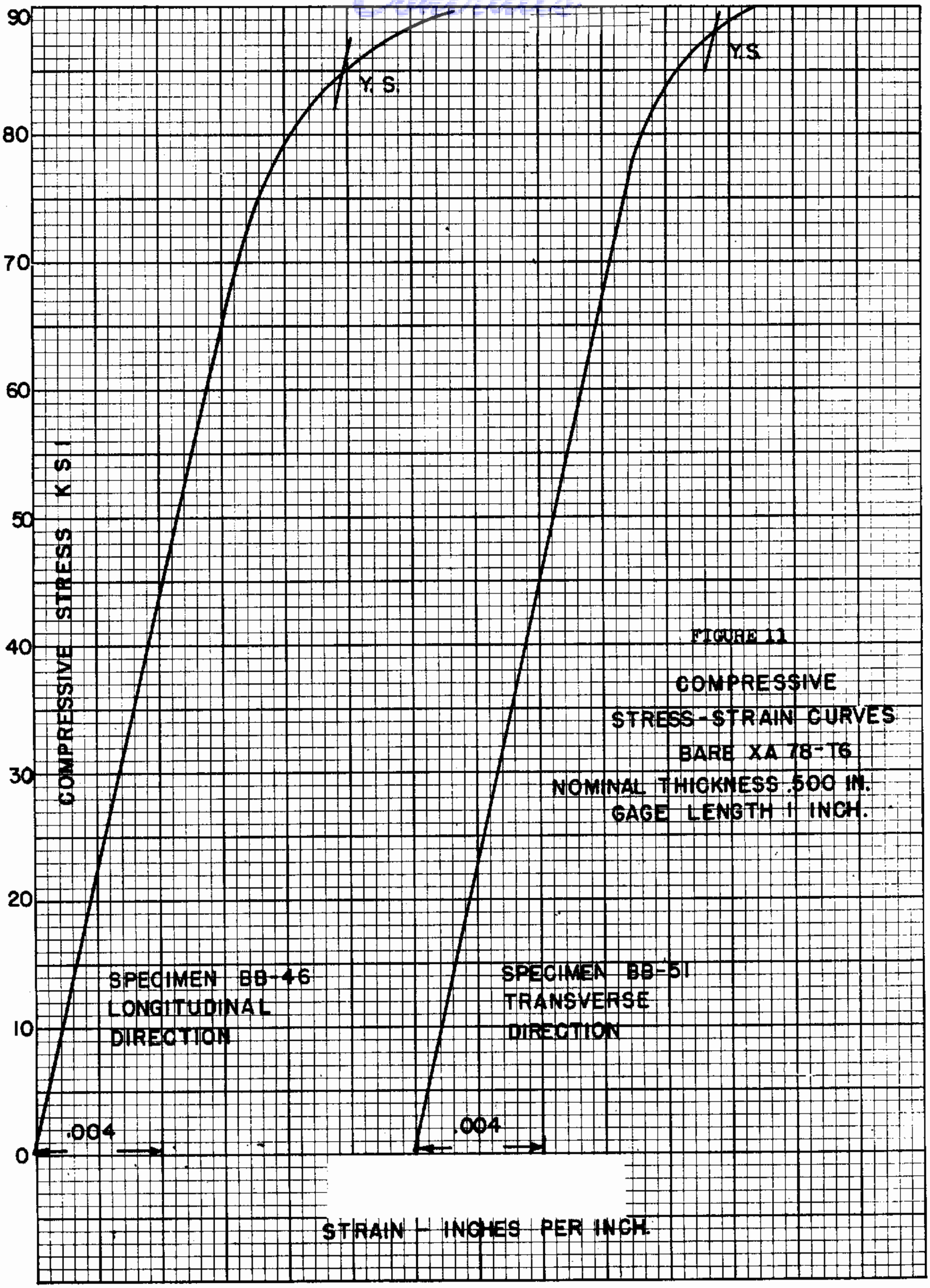


FIGURE 11

COMPRESSIVE
STRESS-STRAIN CURVES
BARE XA 78-T6
NOMINAL THICKNESS .500 IN.
GAGE LENGTH 1 INCH.

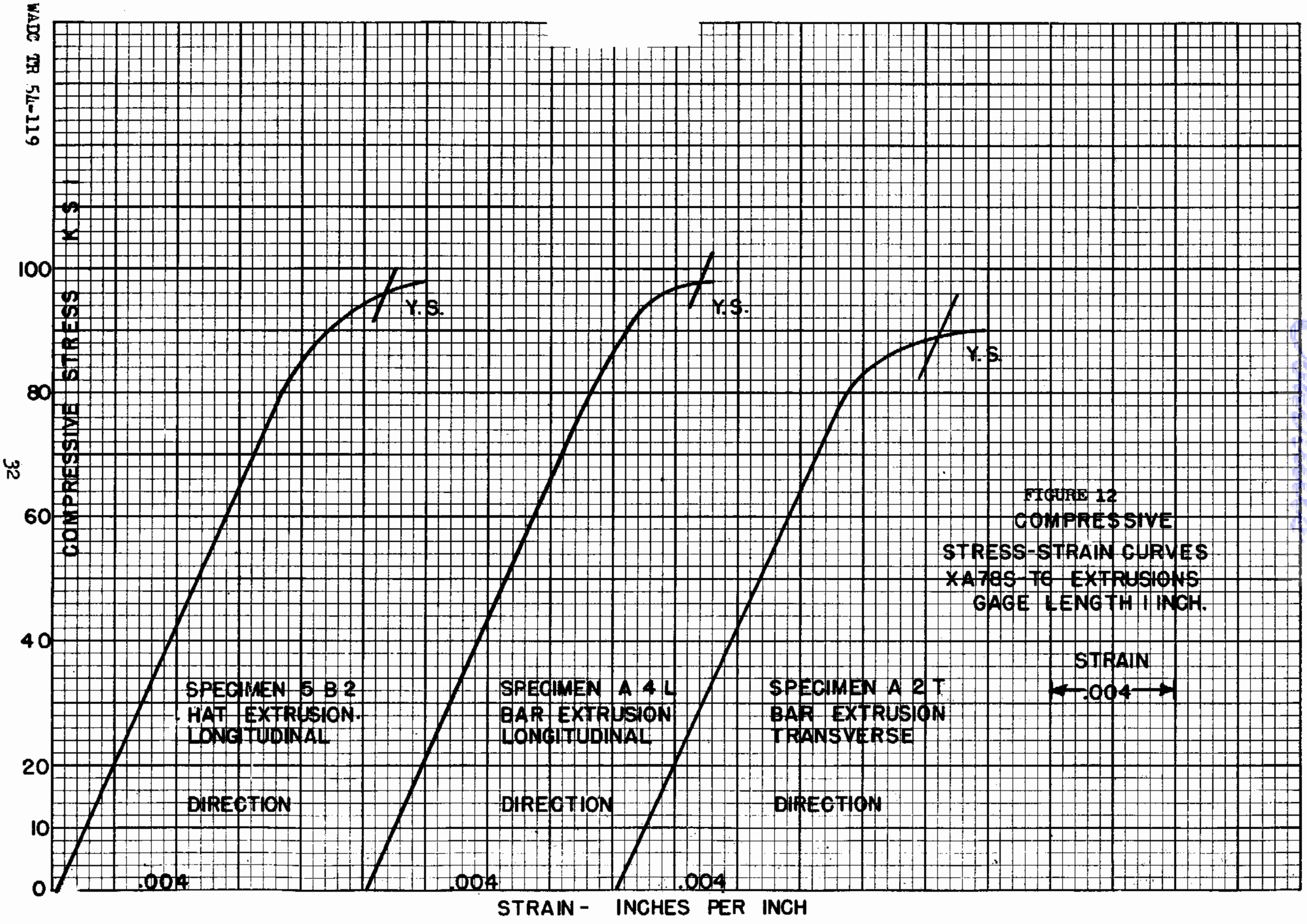


FIGURE 12
COMPRESSIVE
STRESS-STRAIN CURVES
XA78S-T6 EXTRUSIONS
GAGE LENGTH 1 INCH.

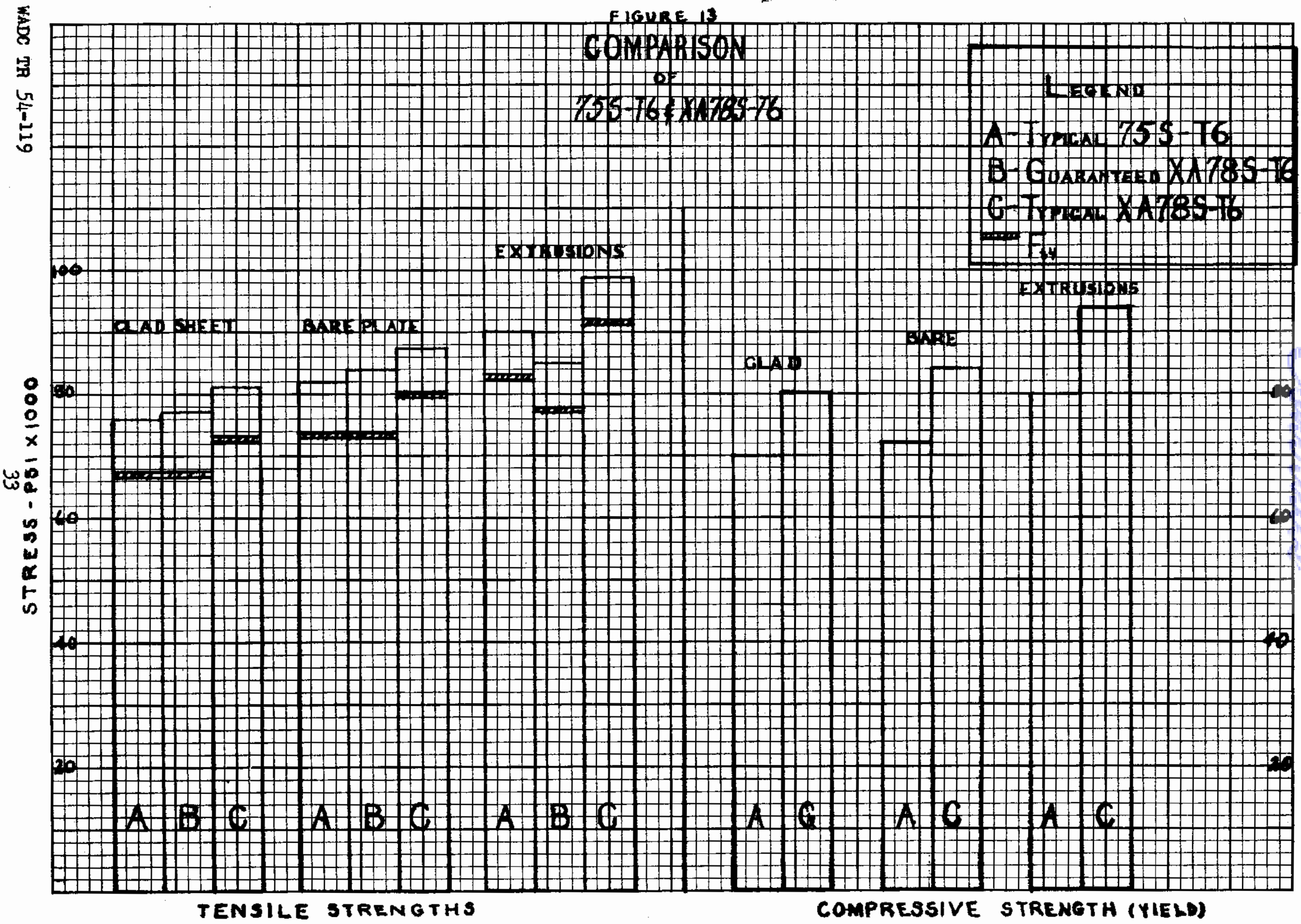


FIGURE 13
COMPARISON
OF
75S-T6 & XA78S-T6

Impact Properties

Standard Charpy V-notched specimens were taken in both the longitudinal and horizontal transverse directions from the XA78S-T6 0.500 inch bare plate and bar extrusion. Testing was carried out using a Tinius-Olsen impact combination type machine.

More energy was absorbed in the longitudinal direction for both materials. The results show very little scatter within each specimen group. The average amount of energy absorbed for the bare plate was 3.25 ft. lbs in the transverse direction and 4.5 ft. lbs. in the longitudinal direction. The bar extrusion averaged 1.90 ft lbs in the transverse direction and 5.40 ft. lbs. in the longitudinal direction. These latter results are lower than 75S-T6 extrusions which average approximately 7.5 and 3.0 ft. lbs. in the longitudinal and transverse directions respectively. The test results for XA78S-T6 are shown in Table XI.

Results of Brinell Hardness tests on all specimens taken from the bar extrusion gave values of 170 BHN in the horizontal transverse direction and 175 BHN in the horizontal longitudinal direction.

TABLE XI

IMPACT PROPERTIES OF XA78S-76 ALUMINUM ALLOY

Specimen Number	Specimen Direction	Energy Absorbed	Brinell Hardness 1000 kg/10mm
	Round Corner Bar Extrusion		
A1	Transverse	2.00	171
A2	Transverse	1.50	161
A3	Transverse	2.00	171
A4	Transverse	2.00	171
A5	Transverse	2.00	167
A6	Transverse	1.50	172
A7	Transverse	2.25	175
A8	Transverse	2.00	170
AVERAGE		1.90	170
A1	Longitudinal	4.00	177
A2	Longitudinal	5.50	175
A3	Longitudinal	5.00	173
A4	Longitudinal	5.25	175
A5	Longitudinal	6.25	177
A6	Longitudinal	6.50	176
A7	Longitudinal	5.75	176
A8	Longitudinal	5.00	175
AVERAGE		5.40	175
	0.500 Inch Thick Bar Plate		
T1	Transverse	3.5	
T2	Transverse	3.0	
T3	Transverse	3.0	
T4	Transverse	3.0	
T5	Transverse	3.0	
T6	Transverse	4.0	
AVERAGE		3.25	
L1	Longitudinal	5.0	
L2	Longitudinal	4.5	
L3	Longitudinal	4.0	
L4	Longitudinal	5.0	
L5	Longitudinal	4.0	
L6	Longitudinal	4.0	
AVERAGE		4.5	

Standard Charpy V notched specimens

Effect of Solution Time on the Mechanical Properties of XA78S

To determine the effect that the length of soaking time at solution temperature has on the physical properties, transverse tensile panels were taken from all three thicknesses of XA78S-O clad sheet. The samples were heat treated to 870°F ± 10°F and held at solution temperature for intervals of time ranging from 5 minutes to 2 hours. The test pieces were quenched in cold water and artificially aged at 250°F for 24 hours. Two specimens were tested representing each soaking period. Results of tests are given in Table XII.

Little variation was noted in the properties due to thickness of sheet or length of soaking time at solution temperature. Results indicated that soaking periods at solution temperatures from five minutes to one hour were sufficient for the alloy to develop maximum properties. A soaking period of 20 minutes for 0.032 inch thick sheet, 30 minutes for 0.064 inch thick sheet, and 40 minutes for 0.125 inch thick sheet (the soaking time used for 75S-T6) would probably be satisfactory for general use. Microscopic examination indicated that a slight diffusion of the constituents into the cladding occurred when the material was soaked for two hours. The diffusion in the thinner sheets was greater than in the thicker sheets.

TABLE XII

EFFECT OF SOLUTION TIME ON THE MECHANICAL PROPERTIES OF XA-78S ALLOY

Location of Specimen Used	Time at Temperature (Minutes)	Sheet Thickness Inches	Average Yield Strength Psi	Average Ultimate Strength Psi	Average Elong. Per Cent
Z-8, Z-9	5	.032	70,200	80,000	12.5
Z-10, Z-11	10	.032	70,600	80,400	13
Z-12, Z-13	20	.032	72,200	81,300	12.5
Z-20, Z-21	30	.032	72,100	82,900	12
Z-36, Z-37	40	.032	73,100	84,400	13.5
Z-38, Z-39	60	.032	72,000	81,900	12.5
Z-40, Z-41	120	.032	73,100	84,500	13.5
U_3-6, U_3-7	5	.064	72,800	81,000	12
U_3-9, U_3-10	10	.064	73,900	82,700	12
U_3-11, U_4-2	20	.064	73,800	83,100	13
U_4-4, U_4-5	30	.064	74,100	84,300	12
U_5-1, U_5-2	40	.064	74,700	84,200	14
U_5-3, U_5-5	60	.064	75,000	83,800	12.5
U_5-6, U_5-7	125	.064	74,800	84,700	13
E-13, E-14	5	.125	69,000	79,400	12
E-20, E-21	10	.125	73,200	83,900	13
E-15, E-16	20	.125	73,200	83,300	11.5
E-17, E-18	30	.125	72,400	83,300	12.5
G-15, G-16	40	.125	73,400	84,900	12.5
G-13, G-14	60	.125	74,600	86,400	13
G-11, G-12	120	.125	73,300	85,900	11.5

Clad XA78S-0 Sheet. Transverse specimens
Solution treatment 870°F for time shown above
Artificially aged at 250°F for 24 hours

Natural Aging

Natural aging characteristics of XA78S aluminum alloy were studied as a possible aid in solving the forming problems. Transverse specimens were taken from the 0.064 inch thick clad sheet. They were heat treated at 870°F ± 10°F for 30 minutes and cold water quenched. The samples were naturally aged at room temperature for periods varying from 10 minutes to 3,600 hours before testing. Two or more specimens were tested to represent each aging period. The results of natural aging tests are given in Table XIII and Figure 14.

The properties began to increase immediately after quenching. The yield strength increased rather slowly during the first hour and then increased rapidly for the first three days, after which a definite slowing down of the aging process occurred. After aging 1000 hours the tensile strength exceeded the tentative minimum value desired by the producer. At that time the yield strength was only 54,000 psi, which was far below the minimum expected for heat treated and aged material.

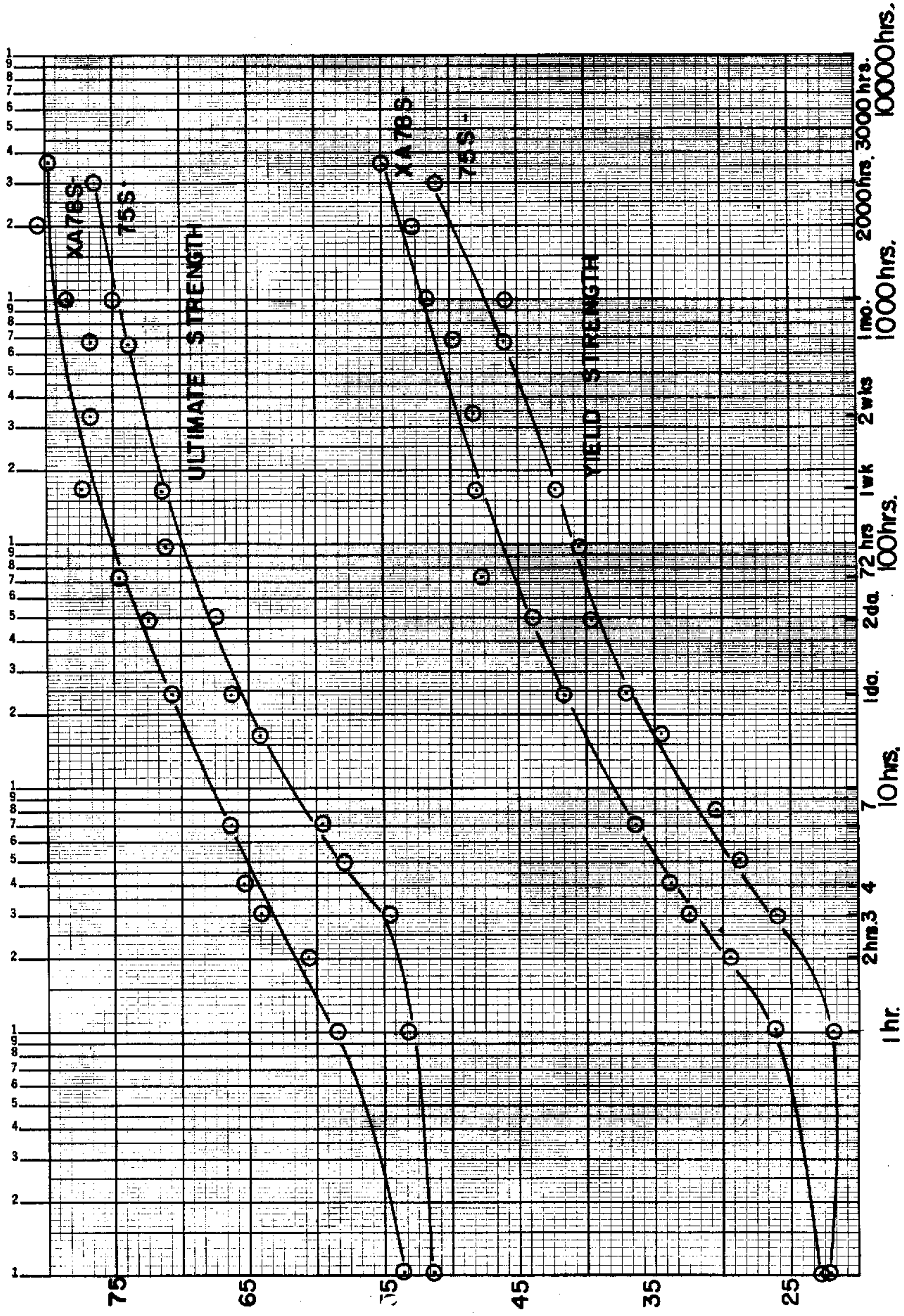
The natural aging properties for 75S, obtained from USAF Technical Report 5129, were also plotted on Figure 14 for comparison. XA78S aluminum alloy age hardened more rapidly immediately after quench than did the 75S material.

TABLE XIII

EFFECT OF NATURAL AGING ON THE TENSILE PROPERTIES OF CLAD XA78S ALLOY

Location of Specimen Used	Aging Time	Average Yield Strength psi	Average Tensile Strength psi	Average Elongation % in 2 inches
P_3-6, P_3-7, P_4-9, P_4-11	0.2 hour	22,900	53,700	22
P_3-10, P_4-2, P_4-10, P_5-2	1 hour	26,600	58,500	21
P_4-3, P_4-4, T_1-4, T_1-5	2 hour	29,500	60,700	21
$P_5$8, P_5-10, T_1-3 T_5-1	3 hour	32,700	64,300	20
P_5-3, P_5-4, T_4-4 T_4-9	4 hour	33,800	65,400	19
P_5-8, P_5-9, T_1-8, T_1-9	7 hour	36,400	66,200	19
P_2-3, P_2-5, T_2-9, T_3-10	16 hour	41,000	70,200	19
P_5-10, P_5-11, T_1-6, T_5-2	24 hour 1 day	41,700	70,800	20
P_2-7, P_2-8, S_3-2, S_4-6	48 hour 2 day	43,900	72,800	21
S_2-3, S_2-4	72 hour 3 day	48,300	74,700	21
S_5-2, S_3-5	168 hour 1 wk	48,400	77,300	19
S_1-4, S_3-6	336 hour 2 wk	48,400	76,600	20
S_5-2, S_2-6	672 hour 1 mo.	49,800	76,700	19
S_4-5, S_2-7	1000 hour	51,700	78,100	19.5
S_3-9, S_3-10	2000 hour	53,700	80,700	19
S_4-1, S_4-3	3600 hour	55,000	79,700	17.5

Clad XA78S-O sheet material 0.064 inch thick. Transverse specimens Solution heat treated 870°F ± 10°F, for 30 minutes, cold water quenched. Held at room temperature for time shown above before testing.



EFFECT OF NATURAL AGING ON CLAD XA78S & 75S AL. ALLOY

FIGURE 14

Artificial Aging - Constant Aging Treatment

The producer of XA78S aluminum alloy recommended an artificial aging treatment of 250°F for 24 hours, similar to that used extensively for 75S. In order to verify this aging treatment, specimens were taken from the 0.064 inch thick clad XA78S-0 sheet shown in Figure 2 and were numbered in accordance with the nomenclature given in that figure. They were solution heat treated at 870°F for 30 minutes and quenched in cold water. After the panels had been aged at room temperature for a minimum of two days, artificial aging was carried out at temperatures which varied from 225°F to 325°F in steps of 25°F. For each aging temperature the period of time at temperature was arbitrarily varied from 1 hour to 96 hours. The results of the artificial aging treatments are given in Table XIV and Figure 15.

The properties shown for zero aging time in Figure 15 are those of samples which were held at room temperature for 72 hours before testing. At 225°F the aging rate was slow. The desired minimum yield strength of 68,000 psi was not reached until after 16 hours. The properties of test pieces aged at 250°F increased with time up to 48 hours. As the temperature increased, the aging rate became more rapid. At 275°F the desired minimum values were reached in 3 hours, while at 300°F they were exceeded after the first hour. Time of aging in excess of 4 hours at 300°F and 325°F resulted in a decrease in properties.

The artificial aging tests indicated that the best constant aging treatment was at 250°F for 24 hours. On the sheet material tested in this work, longer holding time at 250°F gave even higher strengths but did not improve ductility.

TABLE XIV

Effect of Constant Artificial Aging on Tensile Properties

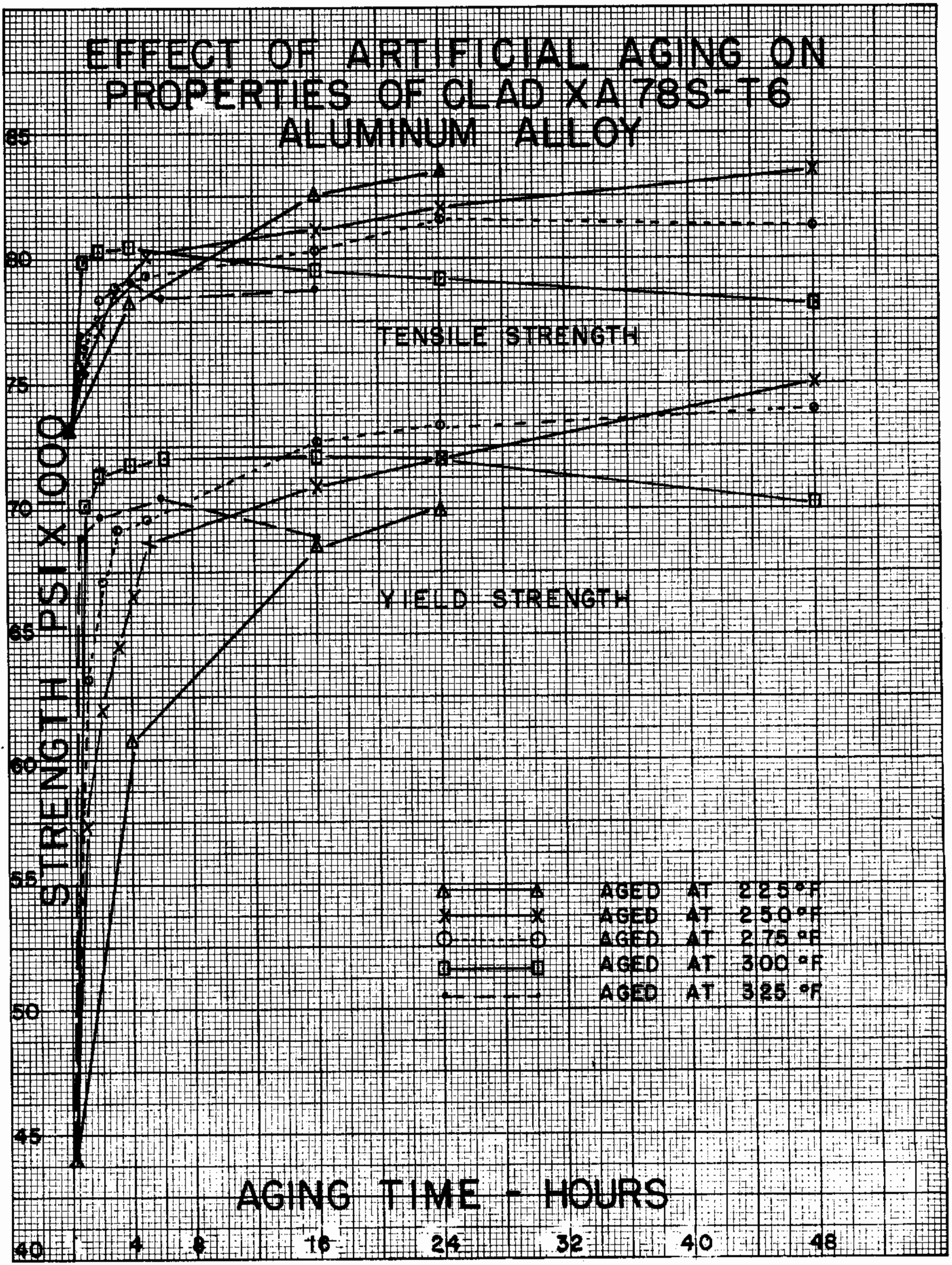
Location of Specimens Used	Aging Treatment Temperature Degree F	Aging Treatment Time Hours	Average Yield Strength psi	Average Ultimate Strength psi	Average Elongation % in 2 Inches
U_5-5, U_5-6	225°F	4 hrs	60,700	78,200	15
U_5-7, U_5-8	225°F	16 hrs	68,200	82,500	14
U_5-9, U_5-10	225°F	24 hrs	69,900	83,400	14
Q_1-5, Q_1-6	250°F	1 hr	57,300	75,600	16
Q_1-3, Q_1-4	250°F	2 hrs	62,200	77,200	14
Q_1-8, Q_1-9	250°F	3 hrs	64,600	78,600	14
Q_2-8, Q_2-9	250°F	4 hrs	66,600	80,400	14.5
Q_2-10, Q_2-11	250°F	5 hrs	68,700	80,100	13.5
Q_2-4, Q_2-5	250°F	16 hrs	70,900	81,200	12
Q_2-1, Q_2-2	250°F	24 hrs	72,000	82,000	13
Q_4-10, Q_5-2	250°F	48 hrs	75,000	83,500	12
Q_2-3, Q_2-7	250°F	96 hrs	74,000	82,500	10.5
Q_3-3, Q_3-4	275°F	1 hr	63,200	76,400	13.5
Q_3-2, Q_3-5	275°F	2 hrs	67,200	78,300	13
$Q_3$6, Q_3-7	275°F	3 hrs	69,200	78,900	13
Q_3-10, Q_3-11	275°F	5 hrs	69,600	79,300	12
Q_4-4, Q_4-6	275°F	16 hrs	72,700	80,300	11
Q_4-2, Q_4-3	275°F	24 hrs	74,000	81,300	11
Q_4-7, Q_4-9	275°F	48 hrs	70,900	78,800	11

TABLE XIV (CONT'D)

Location of Specimens Used	Aging Treatment Temperature Degree F	Time Hours	Average Yield Strength psi	Average Ultimate Strength psi	Average Elongation % in 2 Inches
T_2-1, T_2-6	300°F	1 hr	70,100	80,000	13
T_2-7, T_2-8	300°F	2 hrs	71,300	80,300	12
T_5-10, T_5-11	300°F	4 hrs	71,700	79,800	11.5
T_2-8, T_2-9	300°F	6 hrs	72,000	79,800	10
T_2-6, T_2-7	300°F	16 hrs	72,200	79,500	9.5
T_4-10, T_4-11	300°F	24 hrs	71,700	79,100	10
T_4-1, T_4-2	300°F	48 hrs	70,200	78,100	10
T_5-5, T_5-6	325°F	1 hr	68,800	77,400	11
T_5-7, T_5-8	325°F	2 hrs	69,600	77,400	10
T_5-9, T_5-10	325°F	4 hrs	71,300	79,100	10.5
T_3-4, T_3-6	325°F	6 hrs	70,300	78,500	10.5
T_3-8, T_3-9	325°F	16 hrs	68,500	78,800	10

Clad XA78S-O sheet material 0.064 inch thick sheet. Transverse specimens, solution heat treated 870°F ± 10°F for 30 minutes, quenched in cold water. Aged at room temperature for 3 days before artificial aging conducted as shown above.

FIGURE 15


EFFECT OF ARTIFICIAL AGING ON
PROPERTIES OF CLAD XA78S-T6
ALUMINUM ALLOY
STRENGTH PSI X 1000
85
80
75
70
65
60
55
50
45
40
TENSILE STRENGTH
YIELD STRENGTH
AGED AT 225 °F
AGED AT 250 °F
AGED AT 275 °F
AGED AT 300 °F
AGED AT 325 °F
AGING TIME - HOURS
4
8
16
24
32
40
48

Artificial Aging - Interrupted Aging Treatment

A series of short time artificial aging treatments was investigated to determine if shorter aging periods could produce physical properties which were comparable to the constant aging treatments. A relatively low temperature was used to start the aging cycle and a higher temperature was employed to complete the cycle. Transverse specimens were taken from the 0.064 inch thick clad XA78S-D aluminum alloy sheet material. They were solution heat treated at 870°F for 30 minutes, quenched in cold water and aged at room temperature for 3 days. The initial artificial aging cycle was started at temperatures varying from 212°F to 250°F for periods of 3 to 4 hours. They were allowed to cool to room temperature before final aging at temperatures ranging from 300°F to 325°F for periods of 2 to 8 hours. The results are given in Table XV and Figure 16.

The interrupted aging treatments produced strength properties which exceeded the minimum values of 68,000 psi yield strength and 78,000 psi ultimate tensile strength while some of them had properties which approached the properties of normally aged material. The results were lower in samples initially aged at 212°F than they were at 250°F. The combination of the highest ultimate strength and yield strength was obtained in the test pieces which were initially aged at 250°F for 4 hours and finally aged at 300°F for 4 hours. The combination of time and temperature treatments near that aging cycle resulted in similar properties. Elongation in all cases was between 10 per cent and 12 per cent.

TABLE XV

EFFECT OF VARIOUS INTERRUPTED AGING TREATMENTS ON CLAD XA78S SHEET

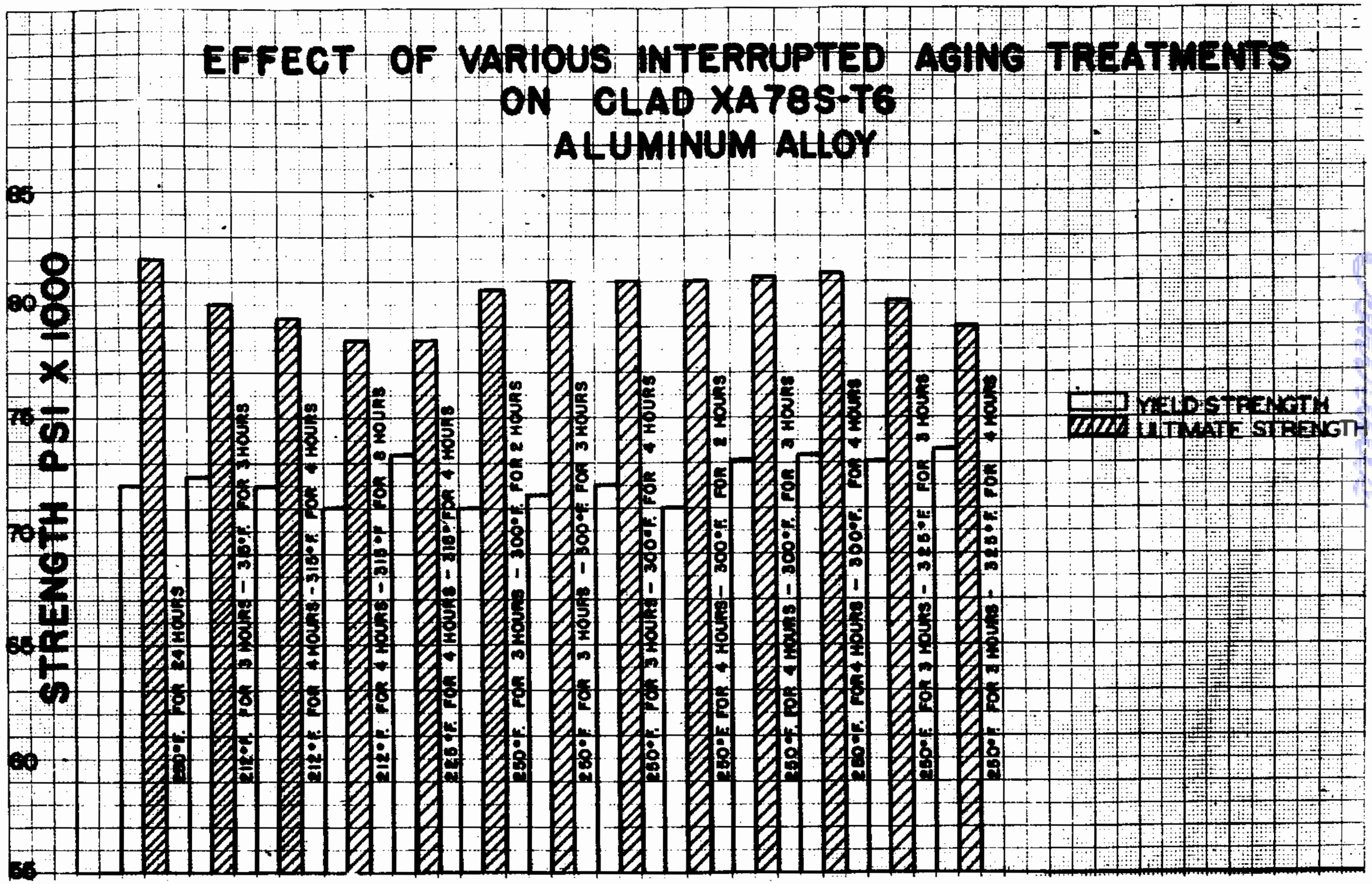
Location of Specimens Used	AGING TREATMENT				Average Yield Strength psi	Average Ultimate Strength psi	Average Elongation % in 2 inches
	Initial Temperature Degrees F	Initial Time Hrs	Final Time Degrees F	Final Time Hrs			
U_3-2, U_3-3	212°F	3 hrs	315°F	3 hrs	72,300	80,100	11
U_4-11, U_5-1	212°F	4 hrs	315°F	4 hrs	71,900	79,400	11
U_5-3, U_5-4	212°F	4 hrs	315°F	8 hrs	71,100	78,400	10
U_2-3, U_5-2	225°F	4 hrs	315°F	4 hrs	73,600	78,600	11
U_1-1, U_1-2	250°F	3 hrs	300°F	2 hrs	71,200	80,600	11
U_1-4, U_1-7	250°F	3 hrs	300°F	3 hrs	71,700	80,900	11
U_1-8, U_1-9	250°F	3 hrs	300°F	4 hrs	72,200	80,900	11
U_2-1, U_2-2	250°F	4 hrs	300°F	2 hrs	71,500	81,100	12
U_2-4, U_2-5	250°F	4 hrs	300°F	3 hrs	72,900	81,200	11
U_2-6, U_2-7	250°F	4 hrs	300°F	4 hrs	73,500	81,400	12
U_2-8, U_2-9	250°F	3 hrs	325°F	3 hrs	73,100	80,300	10
U_2-11, U_3-1	250°F	3 hrs	325°F	4 hrs	73,600	78,600	11
	250°F	24 hrs			72,000	82,000	13

Clad XA78S-0 sheet material 0.064 inch thick. Transverse specimens

Solution treated 870°F ± 10°F for 30 minutes cold water quenched.

Aged at room temperature for 3 days before artificial aging as shown above.

FIGURE 16



EFFECT OF VARIOUS INTERRUPTED AGING TREATMENTS ON CLAD XA78S-T6 ALUMINUM ALLOY

Effect of Delay Between Quench and Artificial Aging on Mechanical Properties

To observe if delay periods between the quenching operation and artificial aging treatment affects the mechanical properties, a delay quench curve was made. Transverse tensile panels were taken from 0.064 inch thick annealed sheet. They were solution heat treated at 870°F for 30 minutes and quenched in cold water. The samples were artificially aged at 250°F for 24 hours, after intervals of natural aging at room temperatures ranging up to three months. The results are given in Table XVI and Figure 17.

The highest mechanical properties were obtained in solution heat treated and quenched material which was artificially aged immediately after quenching. Little variation was noted in the properties when delays up to 1300 hours occurred between quenching and artificial aging treatment. The minimum tensile strength was reached after seven hours delay, and the minimum tensile yield strength after four hours delay. The strengths were then only 1900 psi below the highest results obtained when the alloy was artificially aged immediately after quenching. A slight decline in the properties was indicated in the material when delays greater than five weeks occurred. No particular variation in microstructure was observed as a result of the delays between quenching and artificial aging.

TABLE XVI

EFFECT OF DELAY BETWEEN QUENCH AND ARTIFICIAL AGING ON TENSILE PROPERTIES OF ALCLAD XA78S ALLOY

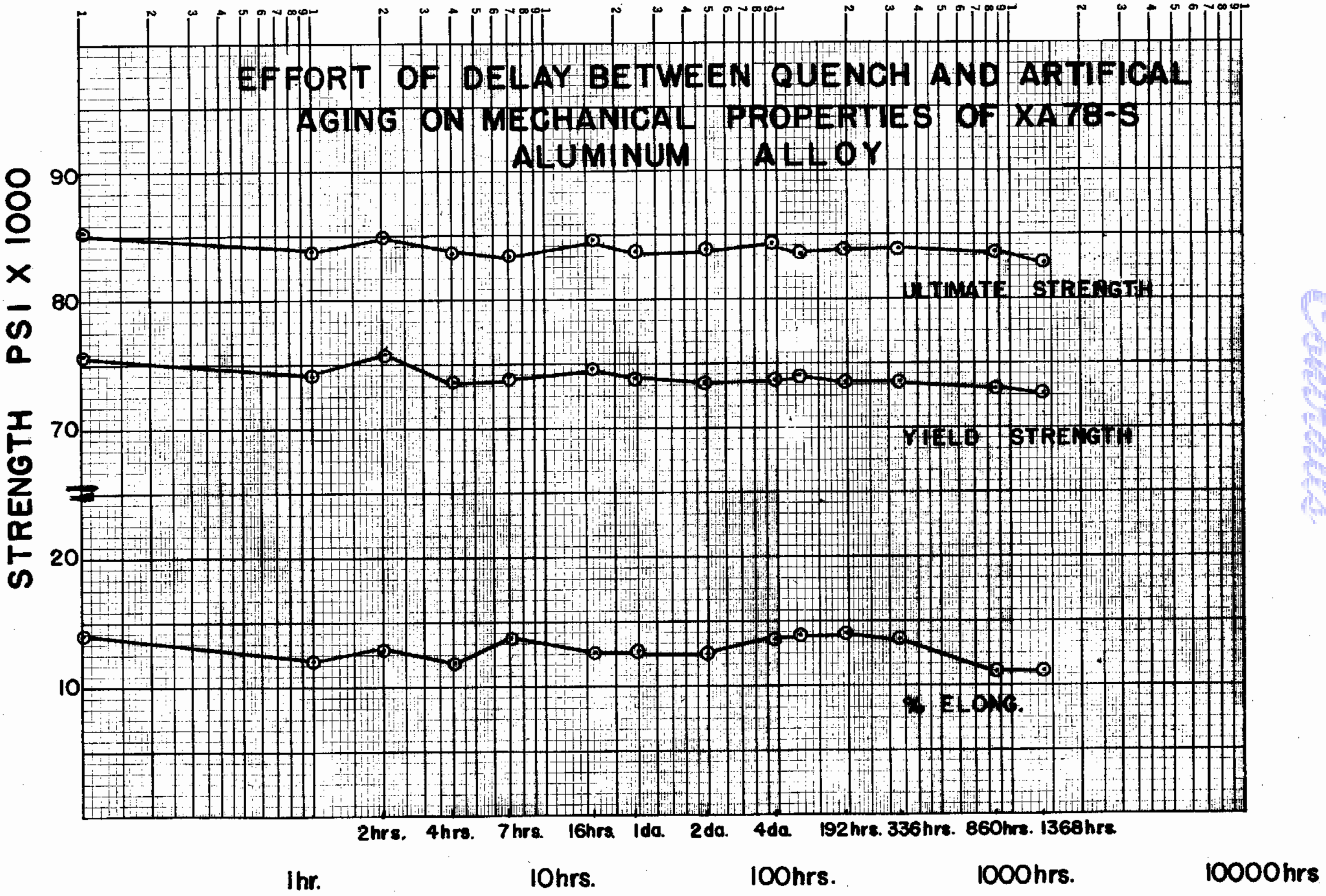
Location of Specimens Used	Delay between Quench and Age	Average Yield Strength psi	Average Tensile Strength psi	Average Elongation % in 2 Inches
R_2-8, R_2-11	None	75,200	85,100	14
R_1-2, R_1-3	1 hr	74,100	83,800	12.5
R_2-5, R_2-4	2 hr	75,600	84,600	13.5
R_1-7, R_2-1	4 hr	73,300	83,700	12
R_2-6, R_2-7	7 hr	73,600	83,200	13.5
R_3-9, R_3-8	16 hrs	74,600	84,500	12.5
R_4-1, R_4-2	24 hrs	73,400	83,600	12.5
R_1-4, R_1-5	48 hrs	73,400	83,500	12.5
R_3-1, R_3-2	96 hrs	73,400	84,200	13.5
R_4-4, R_4-6	124 hrs	74,000	83,500	13.5
R_2-9, R_3-5	192 hrs	73,800	83,900	14
R_4-7, R_4-8	336 hrs	73,400	83,700	12.5
R_3-11, R_1-6	860 hrs	73,400	83,300	11
R_4-10, R_4-3	1368 hrs	72,200	82,800	11

Clad XA78S-0 aluminum alloy sheet, 0.064 inch thick, transverse specimens.

Solution heat treated 870°F ± 10°F for 30 minutes, cold water quenched.

After quenching held at room temperature for time shown above before artificial aging.

FIGURE 17


EFFORT OF DELAY BETWEEN QUENCH AND ARTIFICAL
AGING ON MECHANICAL PROPERTIES OF XA78-S
ALUMINUM ALLOY
ULTIMATE STRENGTH
YIELD STRENGTH
% ELONG.
STRENGTH PSI X 1000
90
80
70
20
10
2hrs.
4hrs.
7hrs.
16hrs.
1da.
2da.
4da.
192hrs.
336hrs.
860hrs.
1368hrs.
1hr.
10hrs.
100hrs.
1000hrs.
10000hrs

Effect of Slow Quench on the Mechanical Properties of XA78S

To investigate the effect which the rate of quench has on the mechanical properties, transverse panels were selected from the 0.064 inch thick XA78S-0 sheet. They were solution heat treated at 870°F±10°F for 30 minutes. The first specimens were quenched in cold water as rapidly as possible. Other test pieces were delayed at intervals ranging from 5 seconds to one minute before quenching. The alloy was then artificially aged at 250°F for 24 hours, after natural aging at room temperature for three days. Each delay period was represented by two samples.

The mechanical properties are given in Table XVII and Figure 18. The results obtained from the materials immediately quenched were the highest. A definite decline in the properties was not observed until after delays greater than twenty seconds. As the delay periods increased the decrease in the properties was more rapid. An increase in the strengths was observed between the delay of 45 seconds and 55 seconds. A second series of specimens was tested and resulted in similar behavior. Susceptibility to intergranular corrosion was not observed in alloy samples which were held in air for thirty seconds before quenching. Accelerated intergranular corrosion tests were made in accordance with the provisions of Specification MIL-H-6088.

The temperature of the alloy at time of quench was determined with a portable contact pyrometer. Samples similar to the type used in this investigation were heated to 870°F. When removed from the furnace the head of the pyrometer was placed on the flat surface of the sample. Temperature readings were recorded at intervals of 5 seconds.

The results are shown in the form of a curve in Figure 18. No accurate temperature was obtained for the first 10 seconds of cooling.

TABLE XVII

EFFECT OF DELAY QUENCH ON MECHANICAL PROPERTIES

Location of Specimens Used	Time Delayed Seconds	Average Yield Strength	Average Ultimate Strength	Average Elongation % in 2 inches
	1.8 Sec.	74,600	83,200	12.5
S_3-9, S_3-10	5 Sec.	73,900	83,000	11.5
S_4-8, S_4-9	10 Sec.	73,200	82,500	12
S_1-1, S_1-2	20 Sec.	72,900	81,800	12
S_1-3, S_1-5	30 Sec.	70,700	80,100	11.5
S_1-7, S_1-9	35 Sec.	68,600	76,100	11.5
P_1-1, P_1-3				
S_4-1, S_4-2	40 Sec.	60,300	71,900	11
P_1-4, P_1-7				
S_2-11, S_3-2	45 Sec.	55,500	67,900	11
P_1-2, P_1-10				
S_1-8, S_2-2	50 Sec.	61,800	72,300	11
P_2-2, P_2-3				
S_3-1, S_2-9	60 Sec.	44,500	60,500	11.5
P_2-3, P_2-5				
S_2-6, S_2-2	Air Cooled	22,700	46,600	16

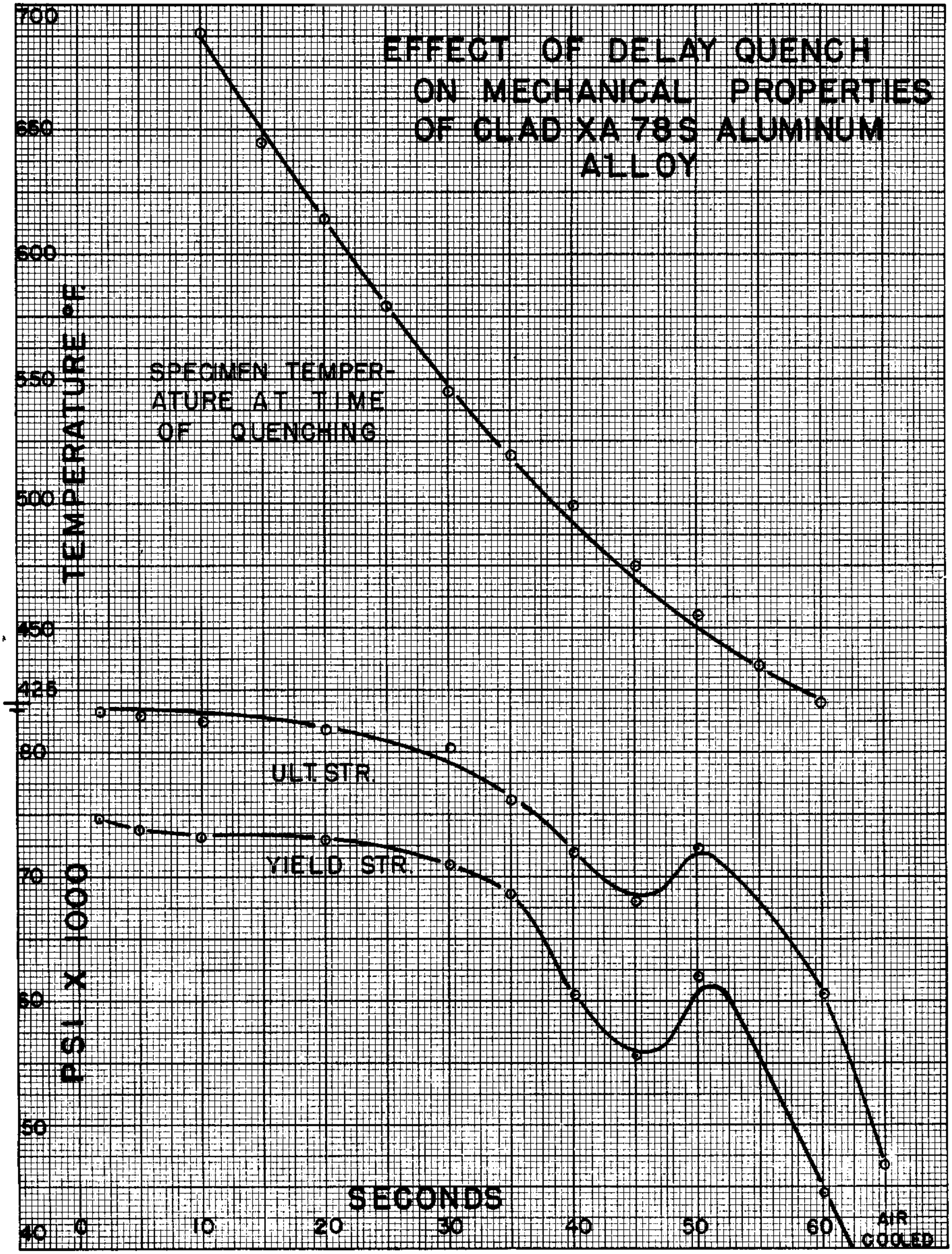
Clad XA78S-0 sheet material, 0.064 inch thick, transverse specimens.

Solution heat treated 870°F ± 18°F for 30 minutes, cold water quenched.

Delayed at room temperature for time shown above before quenching.

Artificially aged at 250°F for 24 hours.

FIGURE 18


EFFECT OF DELAY QUENCH ON MECHANICAL PROPERTIES OF CLAD XA 78 S ALUMINUM ALLOY
TEMPERATURE °F
700
650
600
550
500
450
425
SPECIMEN TEMPERATURE AT TIME OF QUENCHING
PSI X 1000
80
70
60
50
40
ULT. STR.
YIELD STR.
SECONDS
0
10
20
30
40
50
60
AIR COOLED

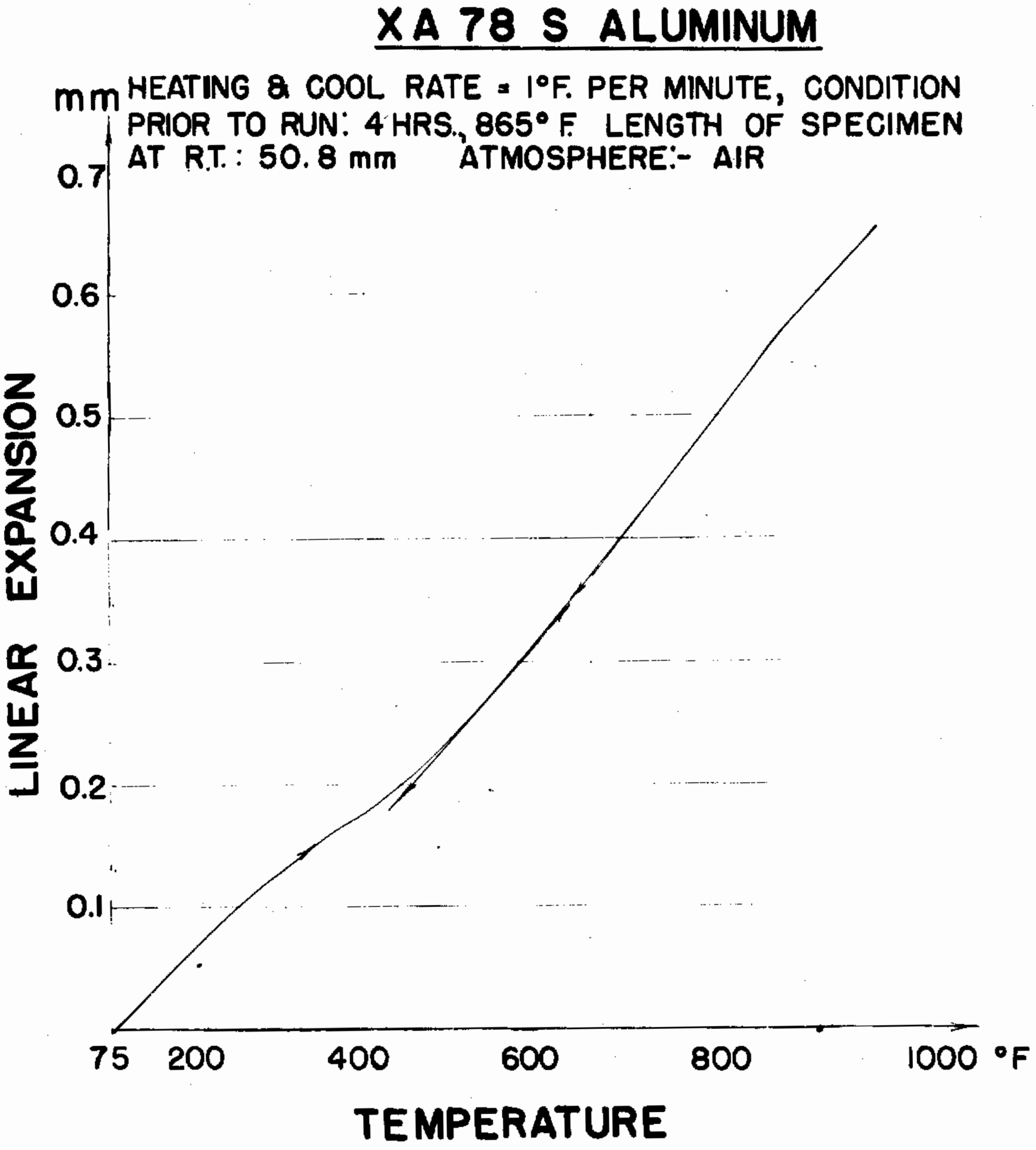
Dilatometer Measurements

The range over which precipitation occurs and degree of thermal expansion in XA78S aluminum alloy were determined in a Lietz dilatometer instrument. Round samples 0.185 inch in diameter by 2 inches long were machined from panel CC shown in Figure 4.

One of the test samples was solution heat treated 870°F ± 10° for 30 minutes and quenched in cold water. Immediately after quenching the specimen was placed in the dilatometer with a sample of pure aluminum of similar size. A light beam and an optical system were so arranged in the instrument that, as the pure aluminum samples expanded the light beam moved along the abscissa onto a film, and as the XA78S aluminum alloy samples expanded the light beam moved along the ordinate. Thus, if the two metals expanded at the same rate, a straight line at a 45 degree angle would have been recorded on the film. Small changes in the difference of the rate of expansion cause the recording line to vary slightly from a straight line. Heat was applied so that the temperature increased at the rate of 1°F per minute. Figure 19 shows the heating and cooling curves for the solution heat treated specimen. The heating curve indicates that the normal expansion rate slowed down between the temperatures 200°F and 450°F. The decrease in the curve was significant in that precipitation occurred within that range. A slight change was revealed somewhere near 850°F which indicated a major phase near that temperature. The curves of a fully annealed specimen are shown in Figure 20. Due to the absence of precipitation in the annealed condition the curves almost coincided with each other. The phase change at approximately 850°F was also noted in this test. A mill heat treated sample tested in the dilatometer showed no evidence of precipitation other than that which might have been due to over aging. Excessive creep and collapse of the sample at approximately 1010°F was revealed as shown in Figure 21.

FIGURE 19

DILATOMETER MEASUREMENTS - SOLUTION TREATED CONDITION



28235-P

FIGURE 20

DILATOMETER MEASUREMENTS - FULLY ANNEALED CONDITION

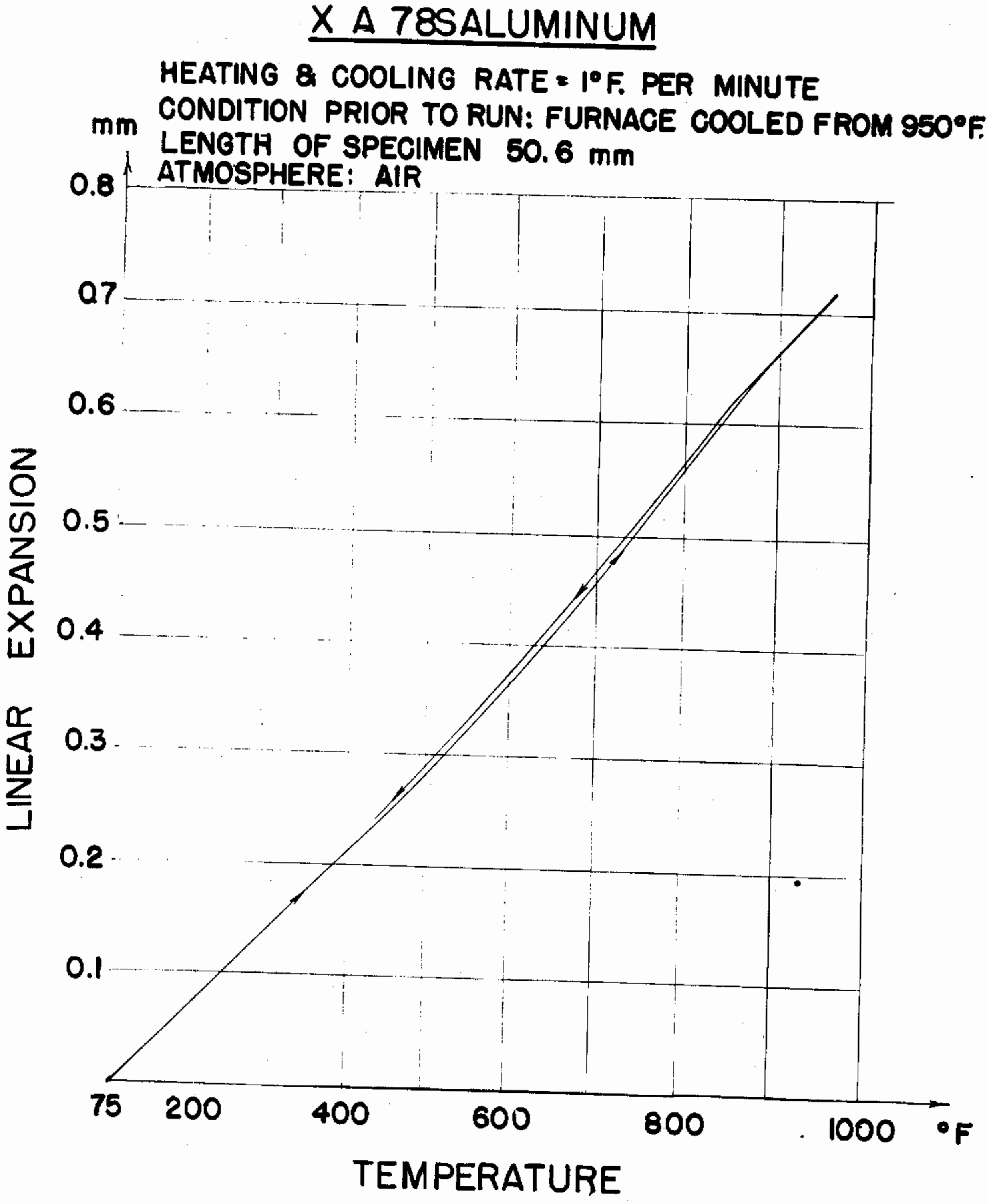


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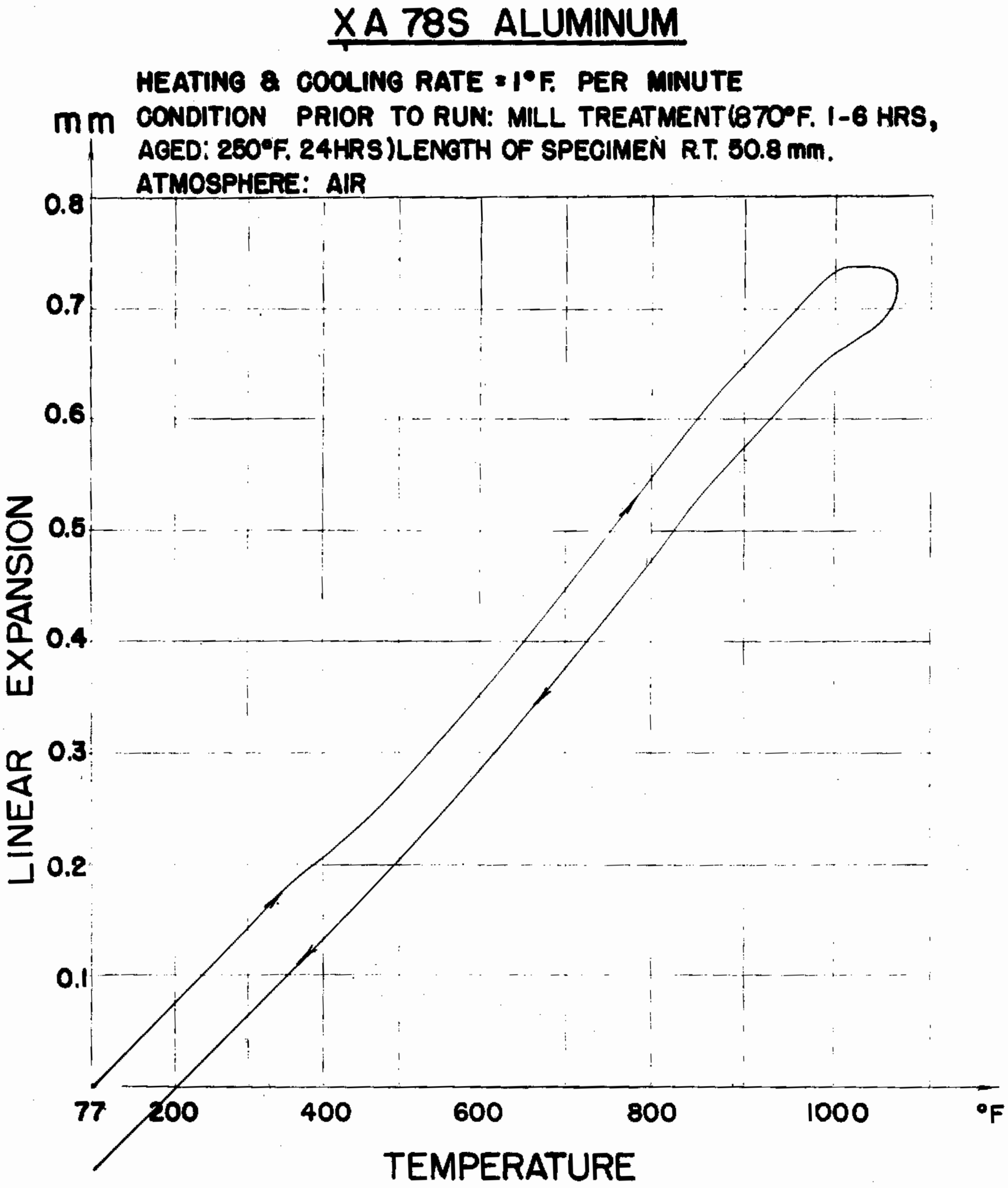
FIGURE 21

DILATOMETER MEASUREMENTS - SOLUTION TREATED & AGED CONDITION



28237-P

Potential Measurements

Potential measurements were made on strips cut from laboratory and mill heat treated sheet material. The specimens were given various heat treatments in pairs, after which the cladding was machined from one of the samples of each pair.

The specimens were abraded with No. 240 grit alundum paper, cleaned with 100% methanol and rinsed with distilled water. Wax was applied to the edges and upper portion of the strips to eliminate edge and water line effects. This left a metal area about 1 1/2 by 3/4 inch on each side of the specimen exposed to the corrosive solution.

The potential measurements were made with a saturated calomel electrode and a corrosive solution of the following: 58.45 grams of C.P. sodium chloride, 9.1 milliliters of 30 per cent hydrogen peroxide, made up to one liter with distilled water. A Leeds and Northrop vacuum tube potentiometer No. 7663-A1 was used to measure the potential difference between the metal specimen and the calomel half cell.

The measurements were begun immediately after the samples were immersed in the solution and continued at ten minute intervals for one hour, and thereafter at one hour intervals for five hours. Steady readings were usually obtained in one hour. The temperature of the corrosive solution was controlled at 23° centigrade.

The results of the potential measurements are given in Table XVIII. The specimens with proper heat treatments either at the mill or laboratory, showed the greatest potential difference between the clad and bare sheet. Extended periods of soaking during solution treatment decreased the potential difference between the core and the cladding of the 0.032 inch thick specimens. This was probably caused by diffusion of the core constitutents into the cladding. Slow cooling of the panels after solution treatment also decreased the potential difference between the cladding and core by shifting the core potential in the anodic direction.

TABLE XVIII

CORROSION POTENTIALS OF

CLAD XA78S ALUMINUM ALLOY

Location of Specimen Used	Thickness of Sheet	Condition of Sheet	Surface Condition	Potential^{x} MV	Diff. MV
K-8 I-8	0.032	Mill heat treated	Clad Bare	880^{xx} 730	150
A-6, A-10	0.064	Mill heat treated	Clad Bare	870 745	125
L-8, L-4	0.125	Mill heat treated	Clad Bare	855 730	125
X-3, X-4	0.032	870°F 20 min., cold water quench, aged 250°F 24 hrs.	Clad Bare	880 740	140
X-16, X-17	0.032	870°F 60 min., cold water quench, aged 250°F 24 hrs.	Clad Bare	880 740	140
X-24, X-25	0.032	870°F 2 hrs, cold water quench, aged 250°F 24 hrs.	Clad Bare	880 740	140
X-31, X-32	0.032	870°F 4 hrs, cold water quench, aged 250°F 24 hrs.	Clad Bare	840 770	70
X-42, X-43	0.032	870°F 30 min., air colled, aged 250°F 24 hrs.	Clad Bare	860 815	50
Q_1-9, R_2-10	0.064	870°F 30 min., cold water quench, aged 250°F 24 hrs.	Clad Bare	855 735	120
T_2-4, Q_3-8	0.064	870°F 60 min., cold water quench, aged 250°F 24 hrs.	Clad Bare	850 735	115
T_3-9, Q_5-3	0.064	870°F 2 hrs, cold water quench, aged 250°F 24 hrs.	Clad Bare	860 735	125
T_3-9, P_4-8	0.064	870°F 30 min., Air cooled aged at 250°F 24 hrs.	Clad Bare	850 820	30
E-4, G-29	0.125	870°F 40 min., cold water quench, aged 250°F 24 hrs.	Clad Bare	860 740	120

TABLE XVIII CONTINUED

Location of Specimen Used	Thickness of Sheet	Condition of sheet	Surface Condition	Potential[x] MV	Diff. MV
E-9, G-34	0.125	870°F 80 min., cold water quench, aged 250°F 24 hrs.	Clad Bare	855 735	120
E-25, 0.125	0.125	870°F 40 min., air cooled aged at 250°F 24 hrs.	Clad Bare	855 830	25

x Millivolts negative to a saturated calomel electrode.

xx Values reported to nearest 5 millivolts.

Intergranular Corrosion

Two thicknesses of XA78S-T6 material were used to test for susceptibility to intergranular corrosion. Panels, each six inches by one inch, were taken from clad 0.064 inch thick sheet and bare 0.250 inch thick plate. The cladding was removed from the 0.064 inch specimens by machining. Two samples from each thickness were tested representing the mill heat treated temper. Six other specimens from each series were solution heat treated at 870°F for forty minutes. Half of the strips were cold water quenched and the other half cooled in air. They were naturally aged at room temperature for three days before artificial aging at 250°F for 24 hours. The specimens were properly cleaned, then corroded by immersion in sodium chloride and hydrogen peroxide solution for six hours in accordance with Specification MIL-H-6088 paragraph 5.5.3. A cross-section was prepared from each of the corroded samples for microscopic examination.

No evidence of intergranular attack was detected in either the water quenched or air cooled specimens. All the corroded specimens revealed slight areas of surface pitting.

Metal to Metal Adhesions

Tensile tests were conducted to determine the advisability of using XA78S-T6 clad sheet in conjunction with metal to metal adhesives. Several specimens from the clad 0.064 inch thick sheet in the transverse direction were heated and then subjected to a salt spray bath for 30 days. Specification QQ-M-151a procedures were followed. One group was treated for 30 minutes at 300°F, another group for 2 hours at 300°F and a final group for 30 minutes at 350°F. The tensile properties for this material before and after salt spray corrosion exposure tests are shown in Table XIX. The results of heating alone show a very slight drop in the tensile properties, averaging one to two percent with no significata change in elongation. The effect of the 30 day salt spray after heating upon the strength of the alloy was also negligible. From these data it can be seen that the strength properties of XA78S-T clad sheet would not be affected to any significant extent when adhesive bonded upon these time and temperature conditions.

TABLE XIX

PROPERTIES OF MILL HEAT TREATED CLAD XA78S-T6, .064 In. THICK SHEET WHEN SUBJECTED TO HEAT TREATING AND A THIRTY DAY SALT SPRAY TRANSVERSE DIRECTION

Specimen Number	Yield Strength psi	Ultimate Strength psi	Per Cent Elongation in 2 inches	Specimen Number	Yield Strength Psi	Ultimate Strength psi	Per Cent Elongation in 2 inches
	MILL HEAT TREATED				30 DAY SALT SPRAY ONLY		
A76	72,900	82,000	10.0	C51	70,600	78,900	9.0
A78	72,600	81,500	9.0	C52	70,000	78,500	9.5
C76	71,400	80,500	9.0	C53	70,500	78,200	8.5
C77	72,200	81,300	9.0	C54	74,100	81,800	10.0
Average	72,300	81,300	9.0	Average	71,300	79,400	9.2
	30 Minutes at 300°				30 Min. at 300° and 30 Day Salt Spray Bath		
A53	75,500	82,100	11.5	A51	76,300	82,500	11.0
A54	75,100	81,500	9.5	A52	75,800	82,500	11.0
A55	75,300	81,900	11.0	C63	73,700	80,900	11.0
A56	75,000	81,500	9.5	C64	73,000	80,300	10.5
Average	75,200	81,800	10.4	Average	74,700	81,300	10.9
	30 Minutes at 350°				30 Min. at 350° and 30 Day Salt Spray Bath		
C60	72,000	79,800	11.0	C55	70,800	78,800	9.5
C61	72,000	79,500	9.5	C56	72,300	70,100	9.5
C62	71,900	80,200	9.5	C57	72,000	79,700	10
C59	71,800	79,400	11.0	C58	72,200	79,900	11
Average	71,900	79,800	10.2	Average	71,800	79,300	10.0
	2 Hours at 399°				2 Hours at 300° and 30 Salt Spray		
A64	72,000	79,100	7	A57	71,800	79,300	10
A68	71,700	79,800	10	A59	71,800	79,100	11
A69	71,300	79,100	9	A62	69,900	77,500	9.5
A70	72,000	80,000	11	A63	71,400	78,100	7
Average	71,800	79,500	9.2	Average	71,200	78,500	9.4

XA78S-T6 Fatigue Properties

Fatigue strengths were determined for the following XA78S-T6 products:

Bare plate 0.250 inch thick
Bare plate 0.500 inch thick
Clad sheet 0.032 inch thick
Clad sheet 0.064 inch thick
Clad sheet 0.125 inch thick
Hat-shaped extrusion 0.125 inch thick
Extrusion 1-3/6 in x 2-1/2 in.

Rotating beam, cantilever bending and axial loading fatigue tests were made, however, all test methods were not used on each shape of material. Following are the test procedures used on the various shapes of material.

ROTATING BEAM

Rotating beam tests were conducted on specimens from a 0.500 in. rolled plate and from a 1-3/8 in x 2-1/2 in. extrusion. Material from the plate was tested both longitudinal and transverse to the rolling direction in both notched and unnotched conditions. Material from the extrusion was tested in the longitudinal direction only in the notched and unnotched conditions. The tests were made in R. R. Moore type rotating beam fatigue machines at 10,000 rpm. Notched specimens had a stress concentration factor of 2.6. Fatigue strengths at 20 x 10^6 and 500 x 10^6 cycles are shown in Table XX. S-N diagrams obtained for the plate material are shown in Figure 23; those for the extrusion are shown in Figure 28.

CANTILEVER REVERSED BENDING

Material from the 0.250 in. bare plate, the 0.125 in. hat-shaped extrusion and clad sheet in the 0.032 in., 0.064 in. and 0.125 in. nominal thicknesses were tested in reversed cantilever bending. Tests were made in both the longitudinal and transverse directions, except for the hat-shaped extrusions, which was tested in the longitudinal direction only. All test were made in Krouse Plate Bending Cantilever fatigue machines at 1725 rpm. Specimens were of the Krouse uniform strength type. Fatigue strengths at 20 x 10^6 cycles for all cantilever bending tests are shown in Table XX. S-N diagrams obtained in cantilever bending tests are shown in Figure 22 and Figures 24 thru 27.

AXIAL LOADING

The 1-3/8 in. x 2-1/2 in. extrusion was tested axially in both completely reversed and zero to maximum tension loading. Tests were made on round notched and unnotched specimens in the longitudinal direction. Notched specimens had a stress concentration factor of 3.0. Testing was done in a 6-Ton Schenck axial loading fatigue machine. Fatigue strengths at 20 x 10^6 cycles for this material are shown in Table XX. S-N diagrams are shown in Figure 31.

Clad sheets, 0.032 in. and 0.125 in. nominal thickness, were tested in zero to maximum tensile axial loading. Tests were made both longitudinal and transverse to the rolling direction. These tests were done in a 2 Ton Schenck axial loading fatigue machine. Fatigue strengths at 20 x 10^6 and 50 x 10^6 cycles for the 0.032 in. sheet and at 20 x 10^6 cycles for the 0.125 in. sheet are shown in Table XX. S-N diagrams are shown in Figures 29 and 30.

Discussion of Results

In general, the fatigue properties of XA78S-T6 were equal to or higher than those of other high strength aluminum alloys. Since the static mechanical properties of this alloy exceed those of 75S-T6, the strongest aluminum alloy in present use, a comparison of the fatigue strengths of these two alloys would reveal any advantage in fatigue strength which might be gained by using the new alloy. However available data on 75S-T6 products cover a wide range of fatigue strength values and a quantitative comparison is not practical except where comparable tests have been made using the same testing techniques, specimen shapes, finishes and testing machines etc. Comparable rotating beam tests on XA78S-T6 and 75S-T6 in the unnotched condition show fatigue strengths of 22,500 psi and 21,000 psi, respectively, at 500 x 10^6 cycles. For the 0.064 in. alclad material tested in reversed sheet bending, the fatigue strengths at 20 x 10^6 cycles were 16,500 psi and 14,500 psi for the XA78S-T6 alloy longitudinal and transverse, respectively, while comparable tests on alclad 75S-T6 gave fatigue strengths of 13,500 psi and 12,500 psi for the longitudinal and transverse directions, respectively. These are the only comparable tests made on the same thicknesses of the two alloys.

Available data on extrusions of the two alloys were made from specimens taken from different sized and shaped extrusions so are not strictly comparable. However, data furnished by the Aluminum Research Laboratory of the Aluminum Company of America on various 75S-T6 products show a wide scatter band of test results for these products. The S-N curves for XA78S-T6 rotating beam tests for both the 0.500 inch plate and the extrusion fall in the upper part of the scatter band of the 75S-T6 fatigue data. This indicates that the rotating beam fatigue strengths of the two XA78S-T6 products are, at least, as good as those of 75S-T6 products. The notched rotating beam fatigue strengths at 500 x 10^6 cycles were 11,500 psi and 10,500 psi for the longitudinal and transverse plate material, respectively. The extrusion had a notched fatigue strength of 13,500 psi in the longitudinal direction. These notched fatigue strengths are within the range of values reported for similar 75S-T6 products.

The fatigue strength of the 1-3/8 in. x 2-1/2 in. extrusion in reversed axial loading was 23,500 psi at 20 x 10^6 cycles; in zero to maximum tensile loading it was 29,000 psi. The latter fatigue strength is approximately 7% lower than values reported for 75S-T6 products. The notched fatigue strengths in axial loading were in the same range as those reported for the 75S-T6 alloy for the same stress concentration factor ($K_t = 3.0$).

The axial fatigue strength for the 0.032 in. alclad sheet in zero to maximum tensile loading was 16,500 psi for both the longitudinal and transverse directions. Fatigue strengths for the 0.125 in. alclad sheet were 14,000 psi and 12,500 psi for the longitudinal and transverse directions, respectively. These fatigue strengths appear to be low based on fatigue strengths obtained for the same material in reversed cantilever bending. No comparable fatigue test data are available on alclad 75S-T6 sheet.

TABLE XX

FATIGUE STRENGTH OF XA78S-T6

Material	Direction	Type of Loading	Type of Specimen	Fatigue Strength psi at $20x10^6$	at $500x10^6$ cycles	S-N Diagram
Bare Plate .250 in.	Longitudinal	Cantilever Bending Reversed	Unnotched	19,500	———	Fig. 22
Bare Plate .250 in.	Transverse	Cantilever Bending Reversed	Unnotched	19,500	———	Fig. 22
Bare Plate .500 in.	Longitudinal	Rotating Beam	Unnotched	29,000	22,500	Fig. 23
Bare Plate .500 in.	Transverse	Rotating Beam	Unnotched	30,000	24,000	Fig. 23
Bare Plate .500 in.	Longitudinal	Rotating Beam	Notched	13,500	11,500	Fig. 23
Bare Plate .500 in.	Transverse	Rotating Beam	Notched	13,000	10,500	Fig. 23
Alclad Sheet .032 in.	Longitudinal	Cantilever Bending Reversed	Unnotched	15,500	———	Fig. 24
Alclad Sheet .032 in.	Transverse	Cantilever Bending Reversed	Unnotched	15,500	———	Fig. 24
Alclad Sheet .064 in.	Longitudinal	Cantilever Bending Reversed	Unnotched	16,500	———	Fig. 25
Alclad Sheet .064 in.	Transverse	Cantilever Bending Reversed	Unnotched	14,500	———	Fig. 25
Alclad Sheet .125 in.	Longitudinal	Cantilever Bending Reversed	Unnotched	13,000	———	Fig. 26
Alclad Sheet .125 in.	Transverse	Cantilever Bending Reversed	Unnotched	11,500	———	Fig. 26
Hat-Shaped Extrusion .100 thick	Longitudinal	Cantilever Bending Reversed	Unnotched	20,000	———	Fig. 27
Extrusion 1-5/8 x 2-3/8 in.	Longitudinal	Rotating Beam	Unnotched	25,000	22,000	Fig. 28
Extrusion 1-5/8 x 2-3/8 in.	Longitudinal	Rotating Beam	Notched	13,500	12,000	Fig. 28
Alclad Sheet .032 in.	Longitudinal	Axial Load. 0 to max.	Unnotched	16,500	15,500 (1)	Fig. 29
Alclad Sheet .032 in.	Transverse	Axial Load. 0 to max.	Unnotched	16,500	15,500 (1)	Fig. 29
Alclad Sheet .125 in.	Longitudinal	Axial Load. 0 to max.	Unnotched	14,000	———	Fig. 30
Alclad Sheet .125 in.	Transverse	Axial Load. 0 to max.	Unnotched	12,500	———	Fig. 30
Extrusion 1-5/8 x 2-3/8 in.	Longitudinal	Axial Load. Reversed	Unnotched Round	23,500	———	Fig. 31
Extrusion 1-5/8 x 2-3/8 in.	Longitudinal	Axial Load. Reversed	Notched Round	9,500	———	Fig. 31
Extrusion 1-5/8 x 2-3/8 in.	Longitudinal	Axial Load. 0 to max.	Unnotched Round	29,000	———	Fig. 31
Extrusion 1-5/8 x 2-3/8 in.	Longitudinal	Axial Load. 0 to max.	Notched	14,000	———	Fig. 31

(1) Fatigue strength at $50x10^6$ cycles

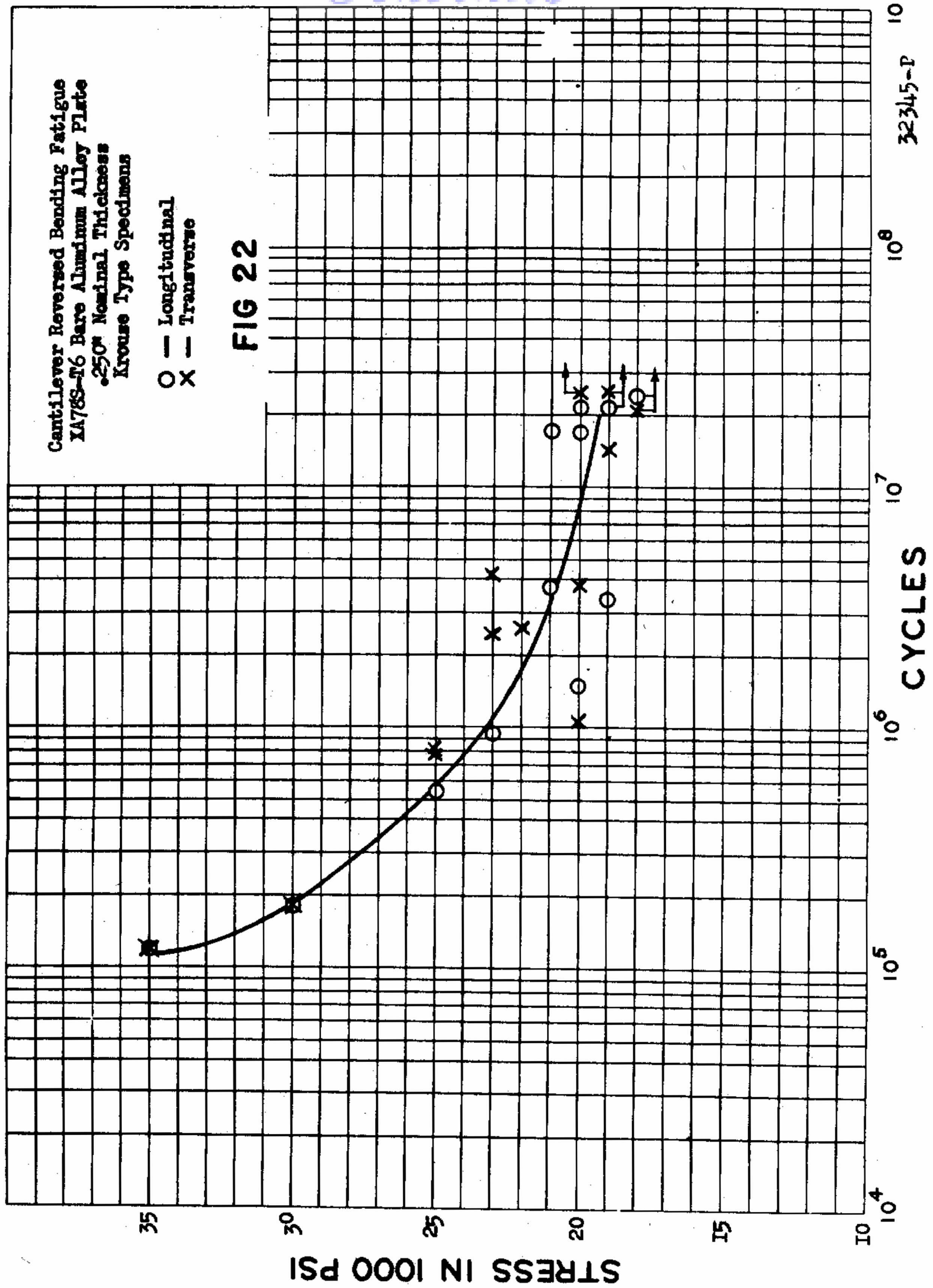


FIG 22

Cantilever Reversed Bending Fatigue
XA78S-T6 Bare Aluminum Alloy Plate
.250" Nominal Thickness
Krouse Type Specimens

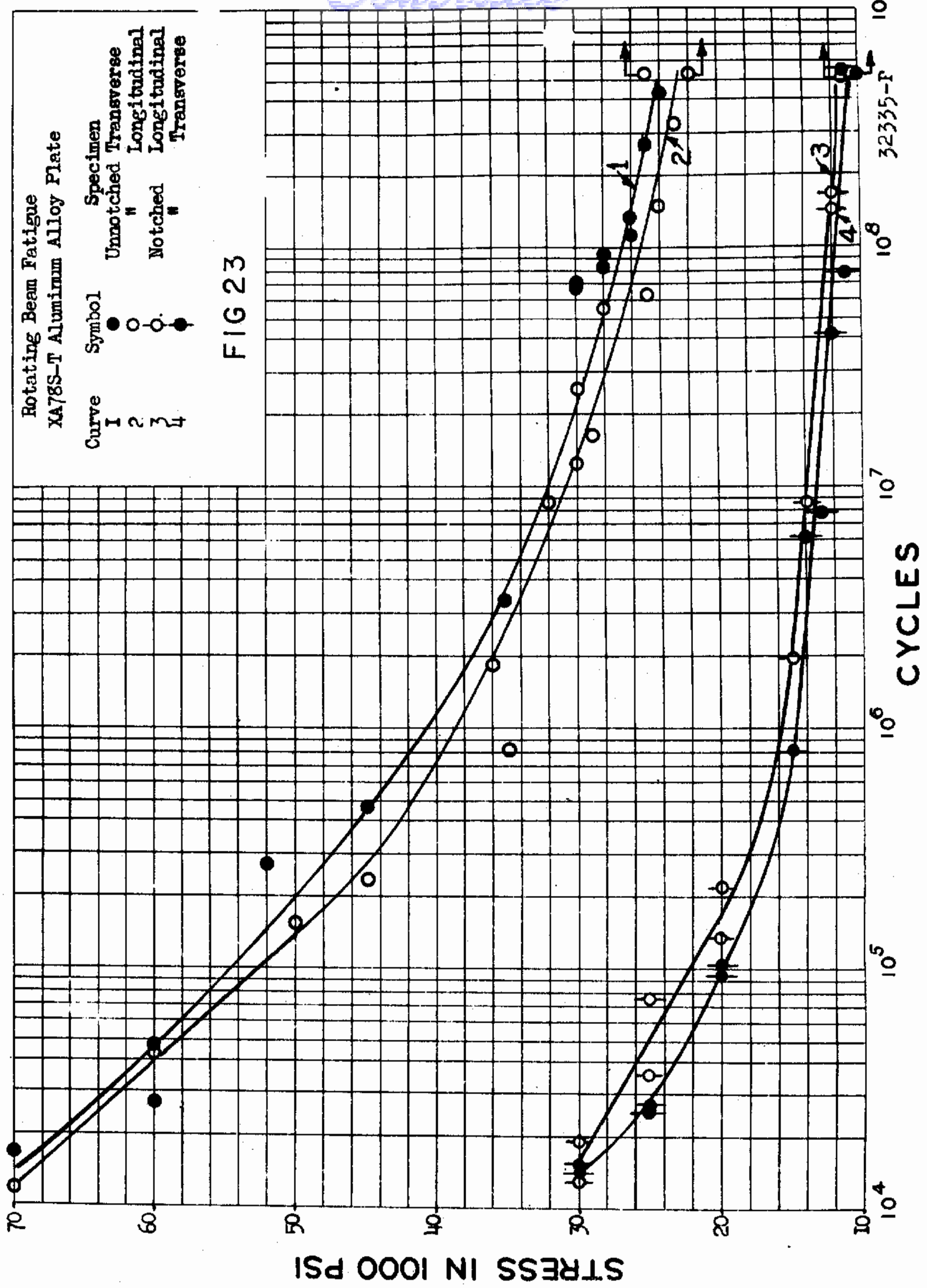

Rotating Beam Fatigue
XA78S-T Aluminum Alloy Plate
Curve Symbol Specimen
1 ● Unnotched Transverse
2 ○ " Longitudinal
3 -○- Notched Longitudinal
4 -●- " Transverse
1
2
3
4
STRESS IN 1000 PSI
70
60
50
40
30
20
10
CYCLES
10^4
10^5
10^6
10^7
10^8
10
32335-F

FIG 23

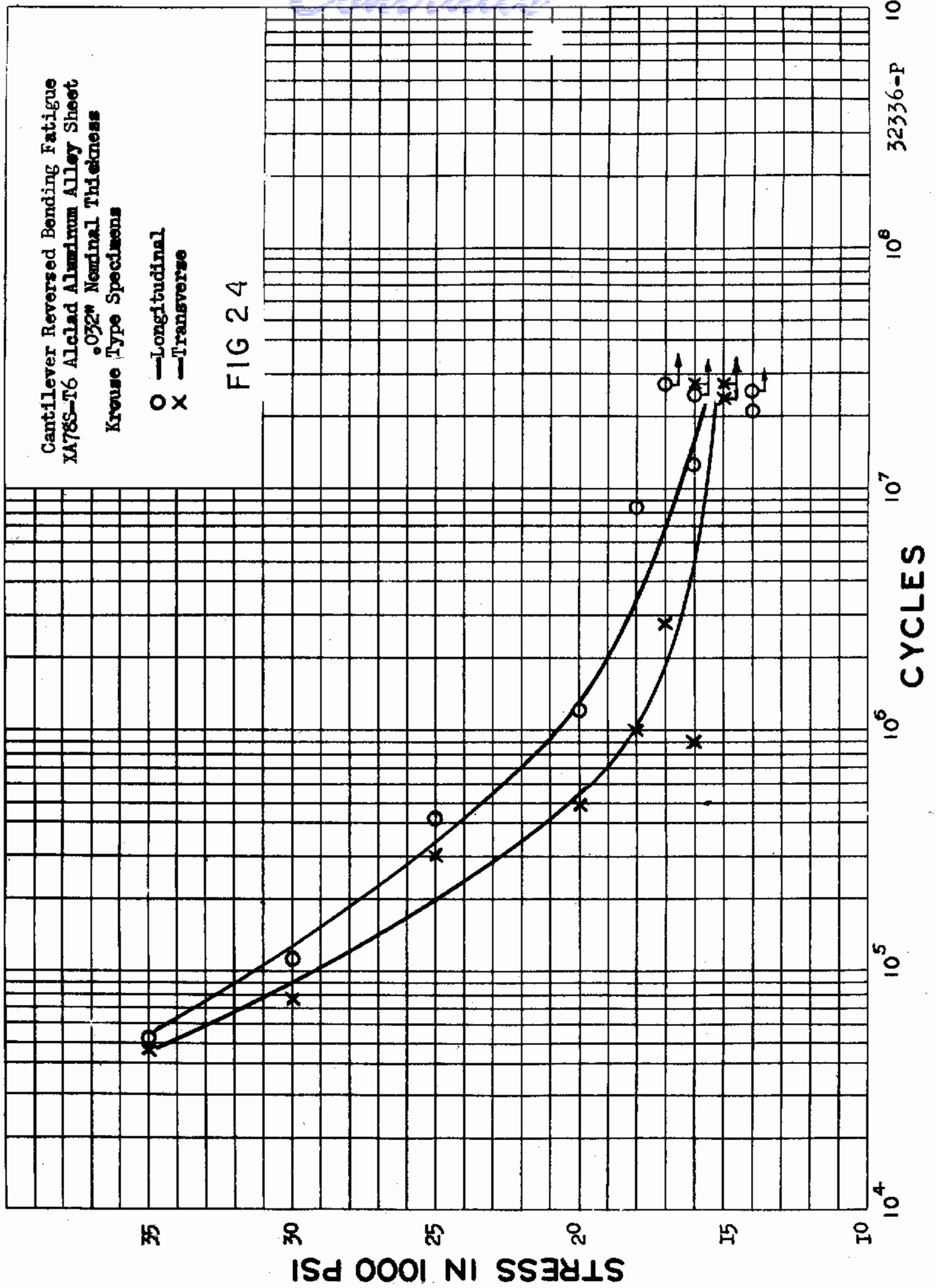
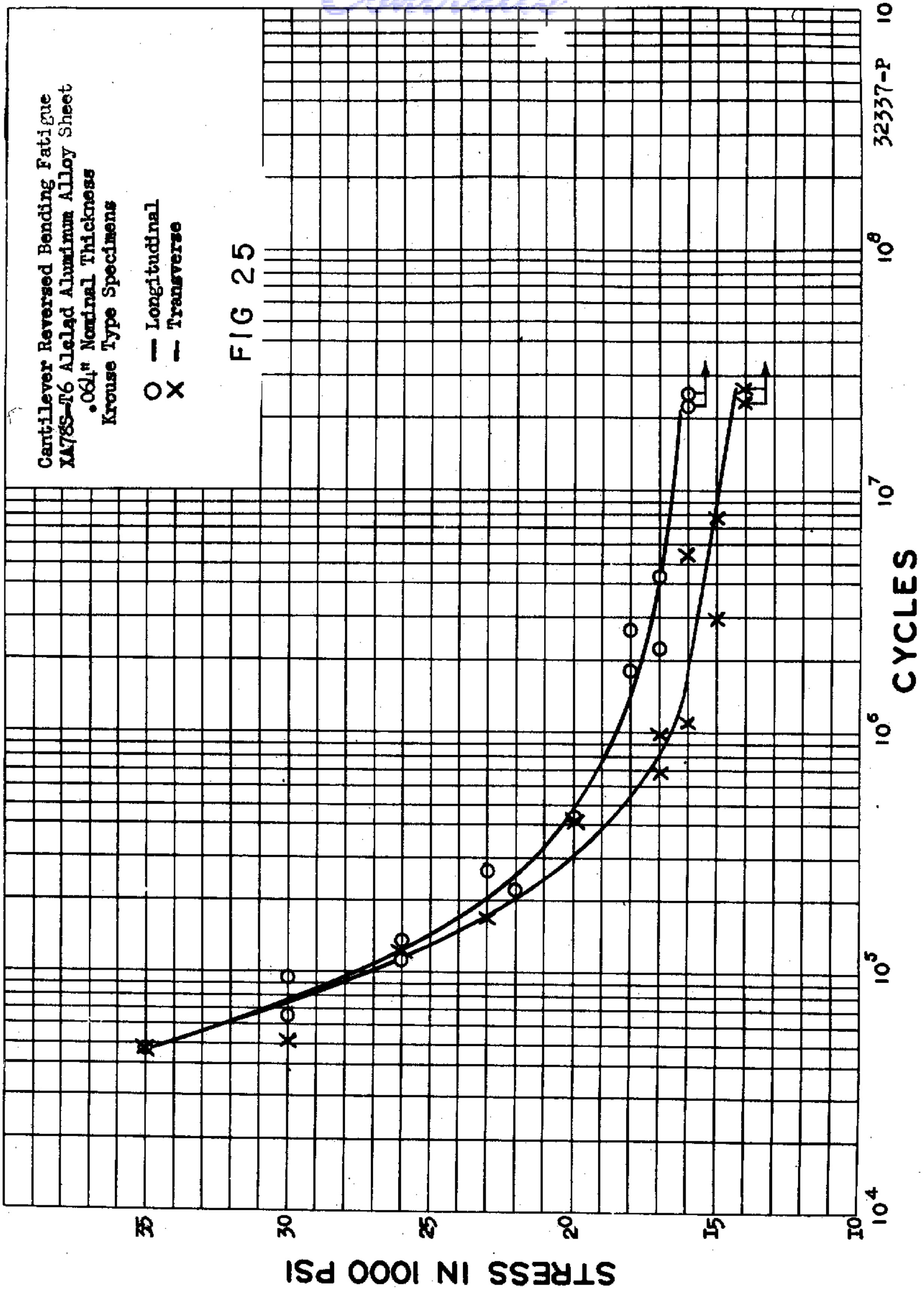


FIG 24

Cantilever Reversed Bending Fatigue
XA78S-T6 Alclad Aluminum Alloy Sheet
.032" Nominal Thickness
Krouse Type Specimens



Cantilever Reversed Bending Fatigue
XA78S-T6 Alclad Aluminum Alloy Sheet
.064" Nominal Thickness
Krouse Type Specimens

FIG 25

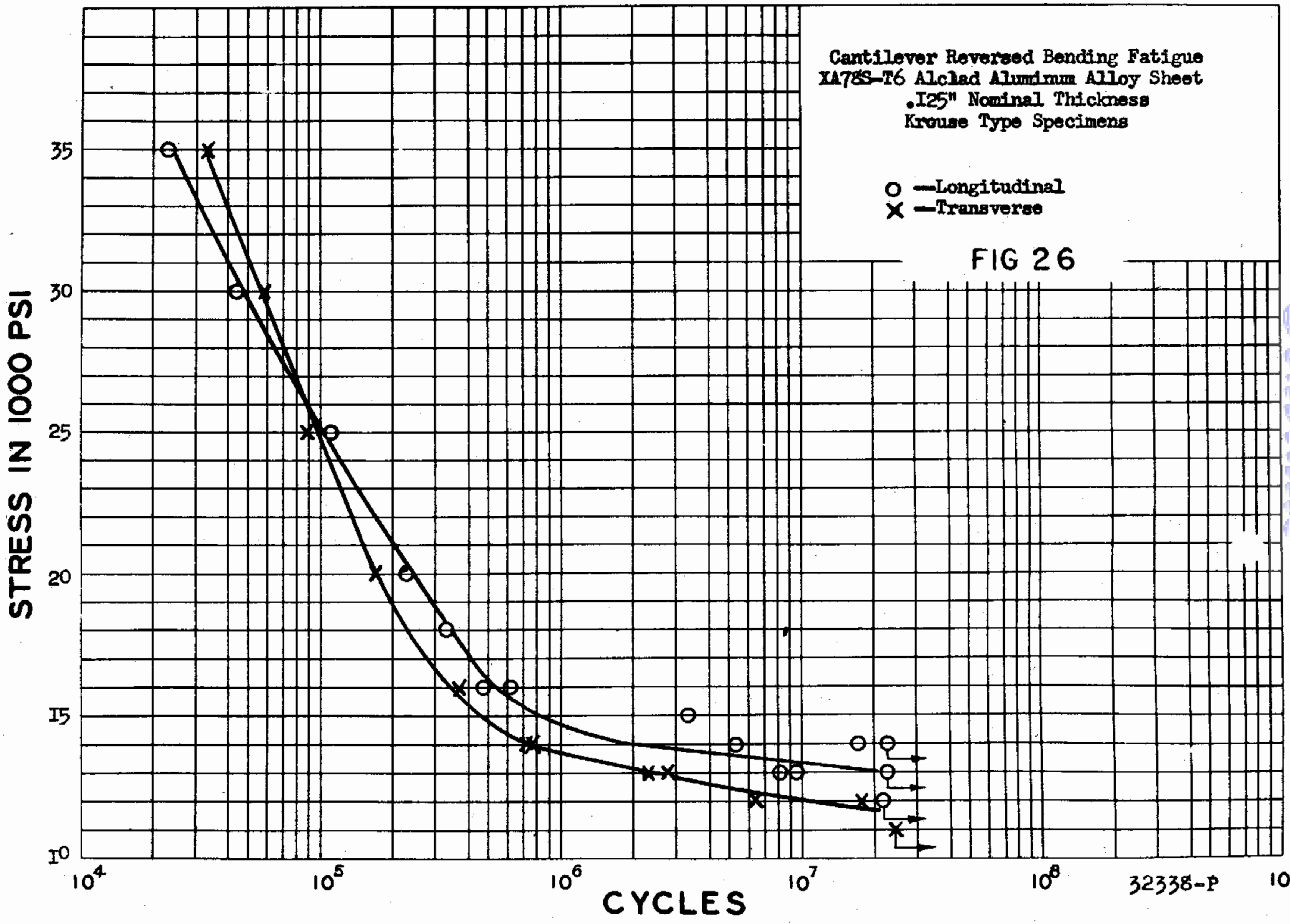
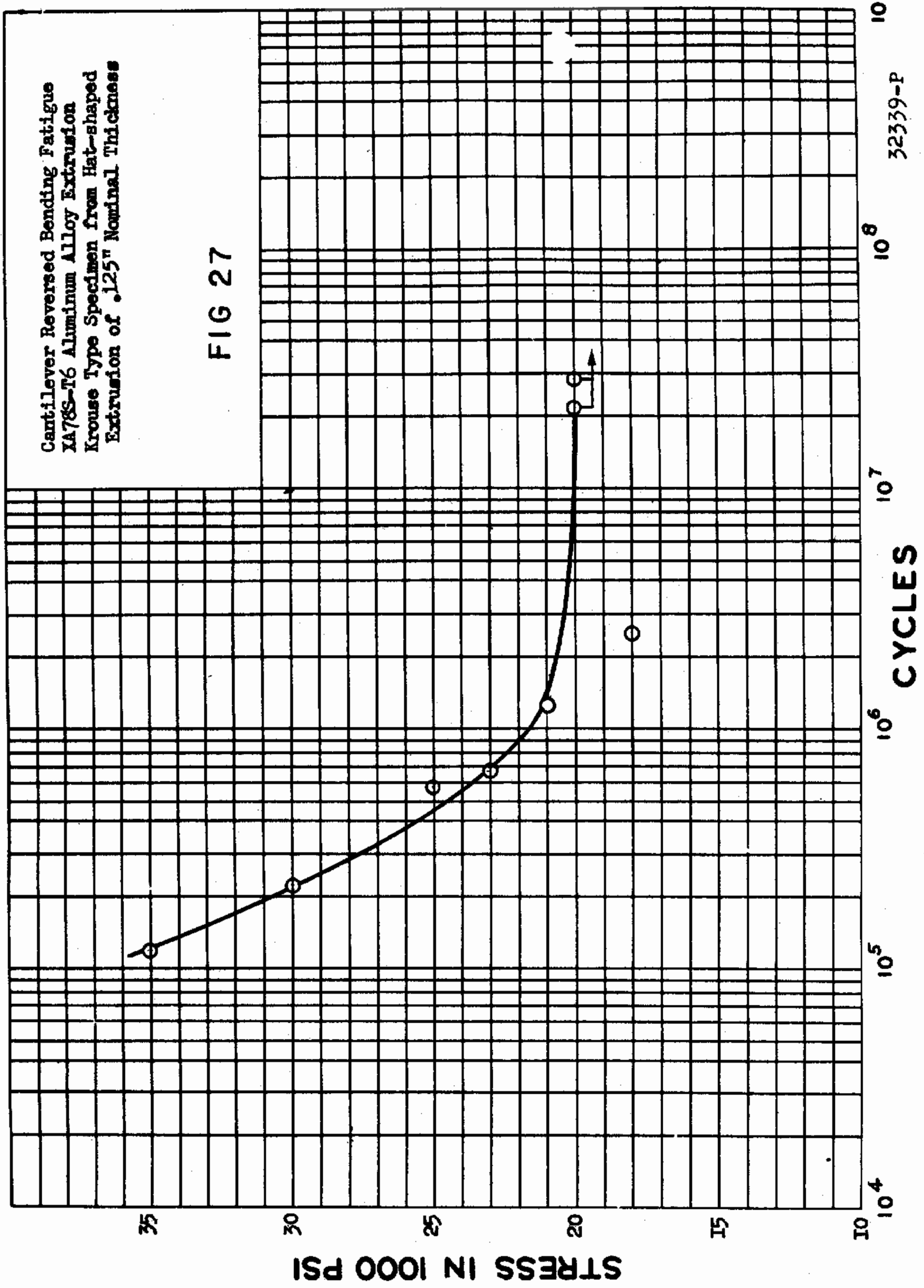


FIG 26

Cantilever Reversed Bending Fatigue
XA78S-T6 Alclad Aluminum Alloy Sheet
.125" Nominal Thickness
Krouse Type Specimens



Cantilever Reversed Bending Fatigue
XA78S-T6 Aluminum Alloy Extrusion
Krouse Type Specimen from Hat-shaped
Extrusion of .125" Nominal Thickness

FIG 27

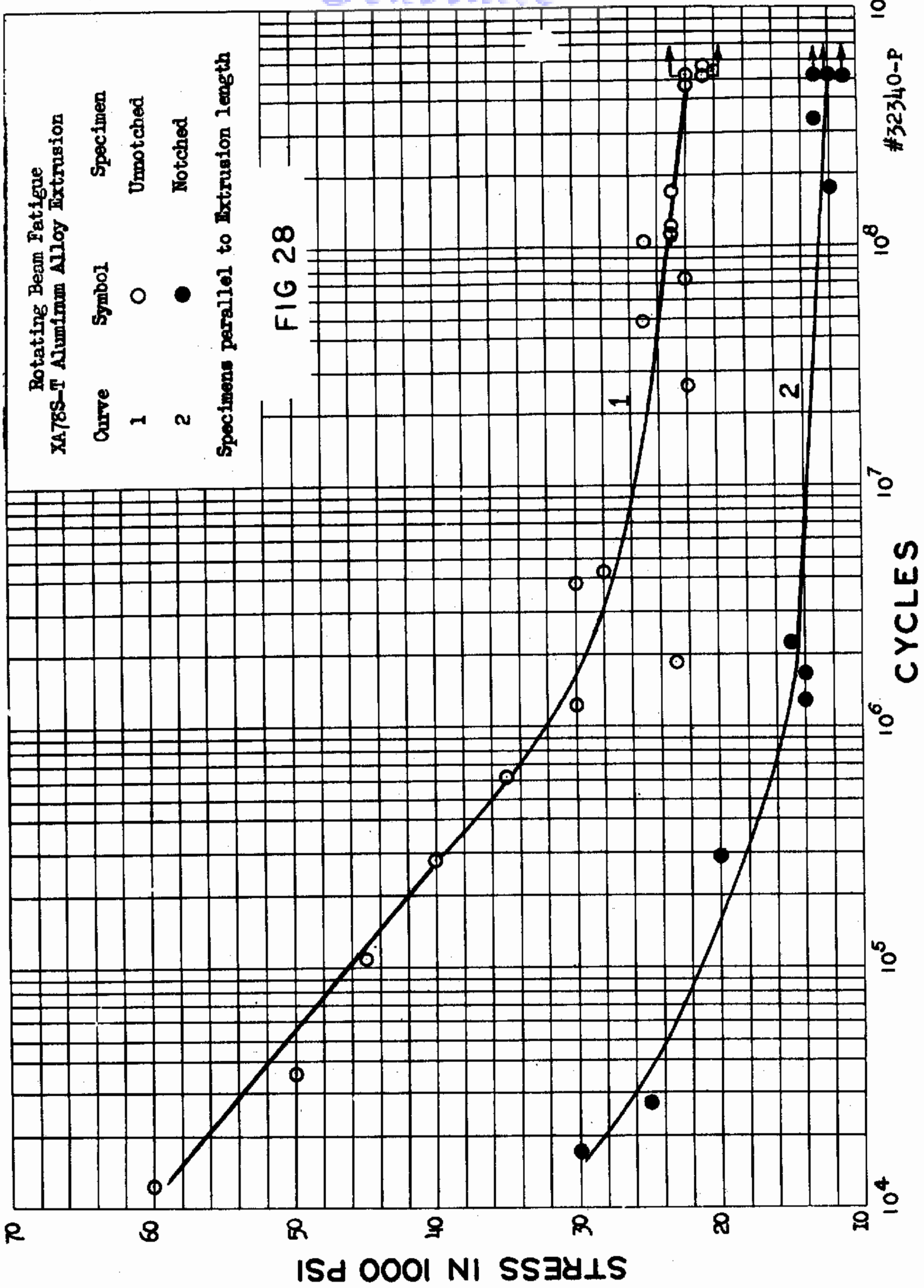
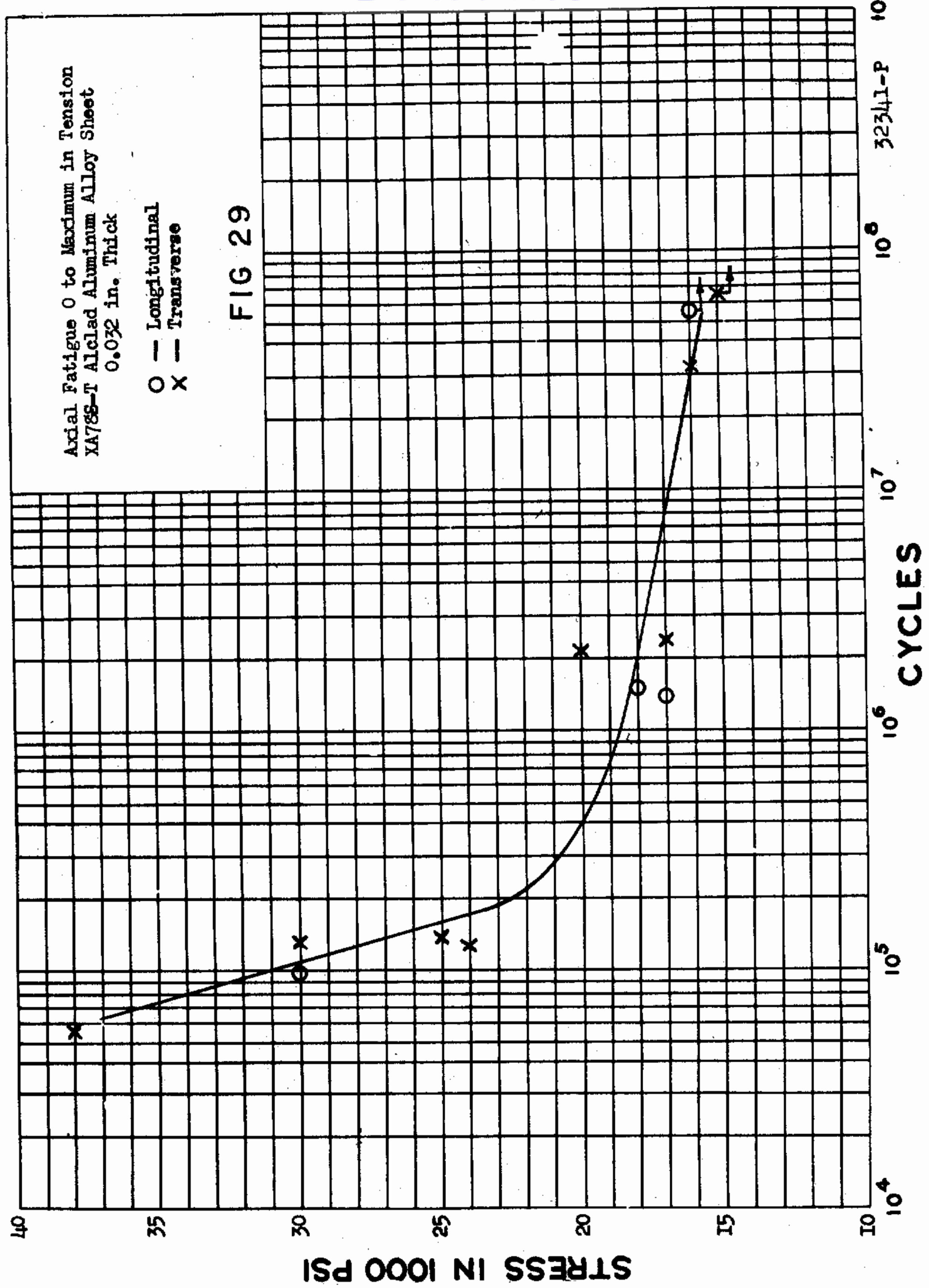
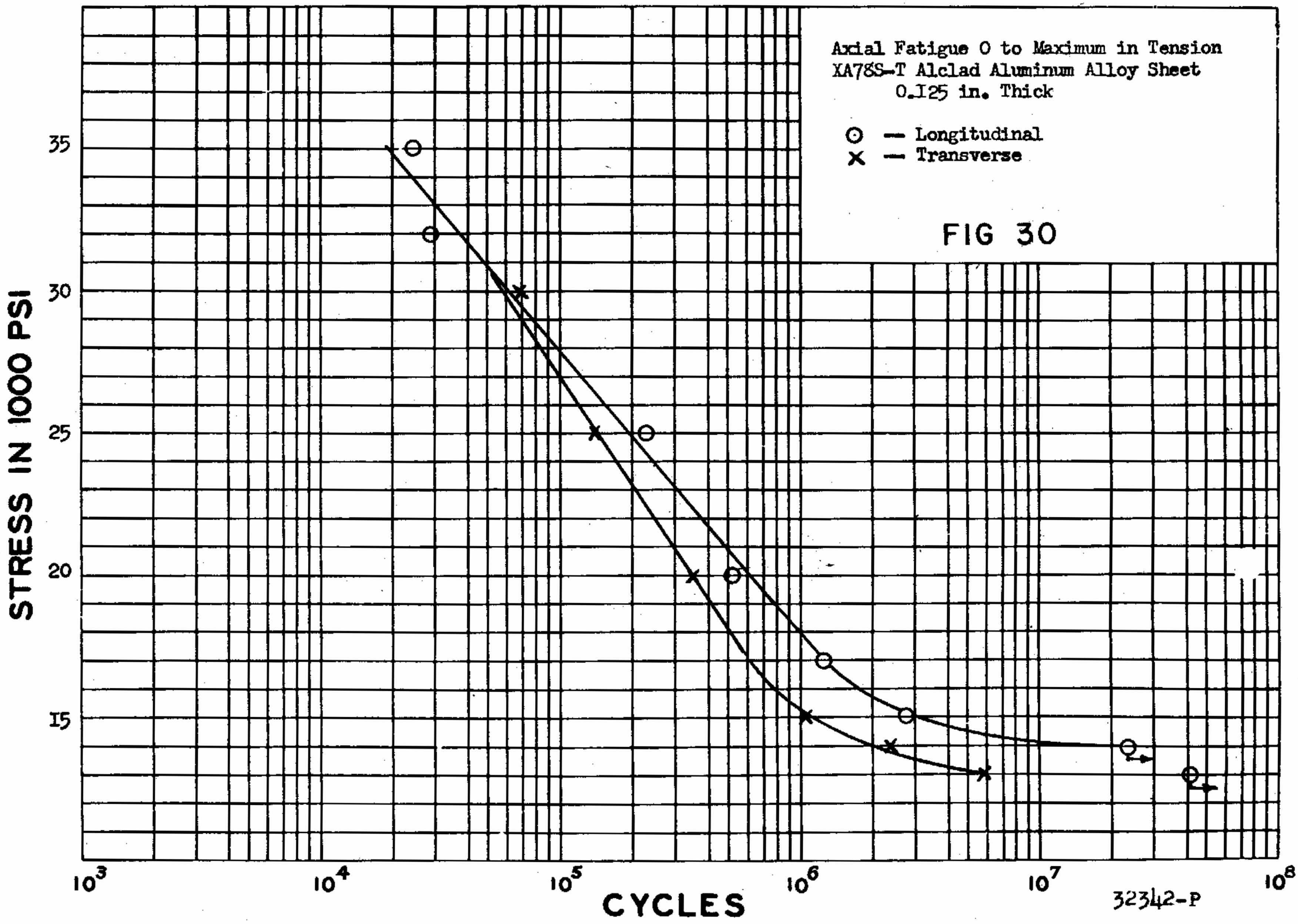

Rotating Beam Fatigue
XA78S-T Aluminum Alloy Extrusion
Curve
Symbol
Specimen
1
○
Unnotched
2
●
Notched
Specimens parallel to Extrusion length
1
2
STRESS IN 1000 PSI
70
60
50
40
30
20
10
CYCLES
10^4
10^5
10^6
10^7
10^8
10
#32340-P

FIG 28



Axial Fatigue 0 to Maximum in Tension
XA78S-T Alclad Aluminum Alloy Sheet
0.032 in. Thick

FIG 29



Axial Fatigue 0 to Maximum in Tension
XA78S-T Alclad Aluminum Alloy Sheet
0.125 in. Thick

FIG 30

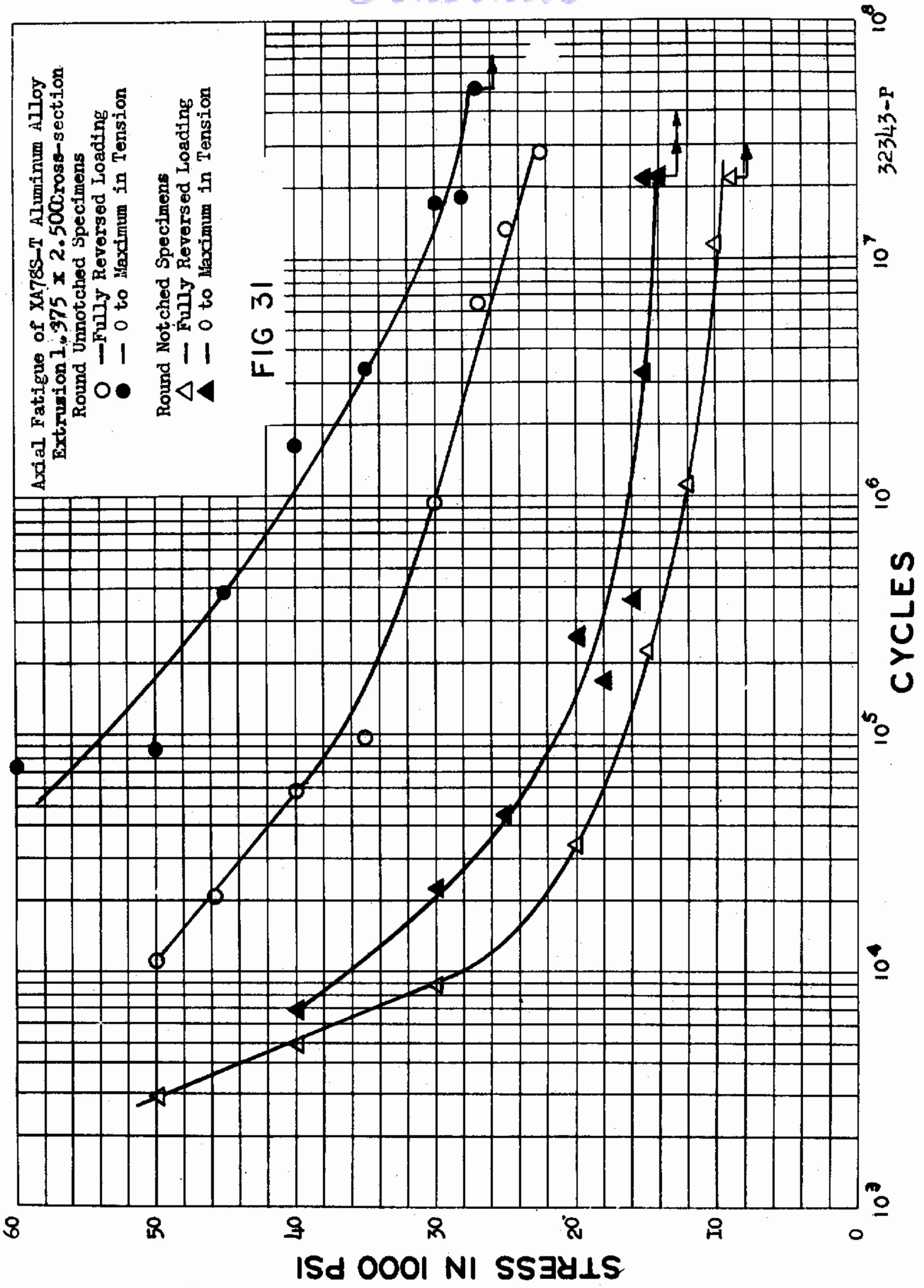

Axial Fatigue of XA78S-T Aluminum Alloy
Extrusion 1.375 x 2.500 Cross-section
Round Unnotched Specimens
○ — Fully Reversed Loading
● — 0 to Maximum in Tension
Round Notched Specimens
△ — Fully Reversed Loading
▲ — 0 to Maximum in Tension
STRESS IN 1000 PSI
0
10
20
30
40
50
60
CYCLES
10^3
10^4
10^5
10^6
10^7
10^8
32343-P

FIG 31

Spot Welding Properties 78S-T6

The spot welding characteristics investigated in XA78S-T6 aluminum alloy sheets were tensile and shear strength, weld ductility, fatigue properties, and effect of corrosion on the welded area. The material was welded at Materials Laboratory, Directorate of Research, using a Taylor-Winfield Spotwelder, Type H. W. P. 33-302. This equipment was of the electrostatic stored energy type.

Preliminary tests were made on a number of sample specimens to determine the proper settings to use in spot welding XA78S-T6. The settings found to be most suitable, and those used in this investigation, were 2700 volts and 360 mfd. for 0.032-in. thick sheet, and 2600 volts and 1680 mfd. for 0.064-in. thick sheet. They will be referred to in this section of the report as normal settings. To compare spot welding properties of XA78S-T6 alloy with those of other aluminum alloys, similar specimens were made for each type of test from both 24S-T3 and 75S-T6 aluminum alloy sheets. In order to avoid possible variations due to chemical cleaning, the surface oxide on all specimens was removed with a rotary wire brush before spot welding.

Standard single-spot specimens for tension and shear tests were made from 0.032 inch sheet, Panel J in Figure 1, and 0.064 inch sheet, Panel B in Figure 2. A U-type tension specimen was used to test the 0.032 in. sheet, but because the 0.064 inch sheet of XA78S-T6 alloy could not be bent in the form of a U without fracturing, a cross-tension specimen was substituted for the U-type. Typical illustration of test specimens before and after fracture are shown in Figures 27 and 28. Two series of the tension and shear samples were made from 0.032 in. thick sheet; one series was welded at the normal voltage setting, and the other at a slightly higher voltage setting. Capacitance on both series was maintained at normal settings. Samples spot welded at the higher settings were used for comparison purposes. The 0.064-in. strips were welded using the normal settings.

Double-spot specimens for shear tests, four-spot specimens for fatigue tests, and ten-spot specimens for corrosion tests were made from the 0.032-in. thick sheet. The double-spot and the fatigue specimens were welded at the normal settings, using a 1/2-in. spacing between the welds. Fatigue tests were made in a fatigue machine in which the load was varied from zero to the maximum with no reversal of stress. Four sets of ten spot corrosion specimens were made from each of the alloys, using a one-inch weld spacing. Two sets were welded at normal voltage settings and two at 2750 volts and 480 mfd. The higher settings were employed to induce overheating and probable cracking. Cracking would produce the most unfavorable conditions from a corrosion standpoint. One set of specimens at each machine setting was exposed to a salt spray atmosphere for 240 hours, while the remaining sets were left unexposed and reserved for comparison purposes.

All specimens were aged at room temperature for 72 hours or more after welding, as tests indicate that the shear strength of the welded joint increased from 10 to 20 percent after three to five days of natural aging.

Results of the U-tension and shear tests are given in Table XXI, and the results of shear tests on double spot and corrosion plates are given in Table XXII. The average shear strength of spot welds made in XA78S-T6 was adequately above the average requirements listed in Military Specification MIL-W-6860. As determined by results of U-tension tests given in Table XXI, the ductility of spot welds in 0.032-in. thick XA78S-T6 sheet welded at normal voltage settings, compares favorable with the other two materials, but at higher voltage settings, the ductility was reduced substantially. From Table XXI, tests made on 0.064-in. thick sheet indicate that at this thickness, spot welds in XA78S-T6 are considerably less ductile than those in either 24S-T3 and 75S-T6. Results in Table XXII of physical tests conducted on the corroded specimens revealed that shear strength of the spot weld joints were unaffected by salt spray exposure. Results of fatigue tests are listed in Table XXIII and Figure 34. XA78S-T6 aluminum alloy has comparatively good spot weld fatigue strength with respect to 24S-T3 and 75S-T6 alloys.

Metallurgical examination of sections across the spot weld showed the fused nugget in each alloy to be of suitable size and grain structure. Weld diameter and penetration of the fusion zone were in compliance with specification requirements. Typical sections through spot welds in each alloy are shown in Figure 35.

TABLE XXI

TENSILE STRENGTHS OF SINGLE SPOT-WELDED ALUMINUM ALLOYS

	Welder Setting	Sheet Thickness	Tip Pressure	Tip Radius	24S-T	75S-T	XA 78S-T
U-Tension Tensile Strength (lbs)	2700 v 360 mf	0.032 in	1000 lb	3 in	155	149	158
U-Tension Tensile Strength (lbs)	2800 v 360 mf	0.032 in	1000 lb	3 in	159	143	115
Tension-Shear Strength (lbs)	2700 360 mf	0.032 in	1000 lb	3 in	494	539	490
Tension-Shear Strength (lbs)	2800 v 360 mf	0.032 in	1000 lb	3 in	594	516	520
Cross-Tension Strength (lbs)	2600 v 1680 mf	0.064 in	1900 lb	4 in	473	404	302
Tension-Shear Strength (lbs)	2600 v 1680 mf	0.064 in	1900 lb	4 in	1112	1121	1237

The above values are the averages of several tests made on similar specimens.

They represent the total load in pounds required to pull apart the welded specimens.

TABLE XXII

TENSILE STRENGTHS OF SPOT-WELDED ALUMINUM ALLOYS

	Welder Setting	Sheet Thickness	Tip Pressure	Tip Radius	Spot Spacing	24S-T	75S-T	XA78S-T
Shear Strength per Spot of 10-Spot Corrosion Plates (Unexposed) (lbs)	2700 v 360 mf	0.032 in	1000 lb	3 in	1/2 in	422	526	497
Shear Strength per Spot of 10-Spot Corrosion Plates (Exposed) (lbs)	2700 v 360 mf	0.032 in	1000 lb	3 in	1/2 in	423	499	541
Shear strength per Spot of 10-Spot Corrosion Plates (unexposed) (lbs)	2750 v 480 mf	0.032 in	1000 lb	3 in	1/2 in	616	575	490
Shear Strength per Spot of 10-Spot Corrosion Plates (Exposed) (lbs)	2750 v 480 mf	0.032 in	1000 lb	3 in	1/2 in	681	575	604
Shear Strength of Double-spot Specimens (lbs)	2700 v 360 mf	0.032 in	1000 lb	3 in	1/2 in	748	831	850

The above values are the averages of several tests made on similar specimens. They represent the total load in pounds required to pull apart each spot of the 10-spot corrosion plates and the double-spot joint itself in the two-spot specimens.

TABLE XXIII

FATIGUE TEST OF SPOT WELD JOINTS

Alloy	Load (1) lbs	Cycles	Remarks
XA78S-T6	400	59,500	Failed
XA78S-T6	300	148,300	Failed
XA78S-T6	200	1,320,300	Failed
XA78S-T6	200	616,600	Failed
XA78S-T6	150	3,436,500	Failed
XA78S-T6	140	945,200	Failed
XA78S-T6	140	10,941,900	Did not fail
75S-T6	400	72,800	Failed
75S-T6	300	165,300	Failed
75S-T6	200	659,700	Failed
75S-T6	175	1,299,900	Failed
75S-T6	160	1,482,300	Failed
75S-T6	150	10,845,300	Did not fail
24S-T3	420	150,000	Failed
24S-T3	300	584,700	Failed
24S-T3	200	1,510,600	Failed
24S-T3	175	4,864,800	Failed
24S-T3	160	14,492,000	Did not fail

(1) Axial loading 0 to maximum loading.

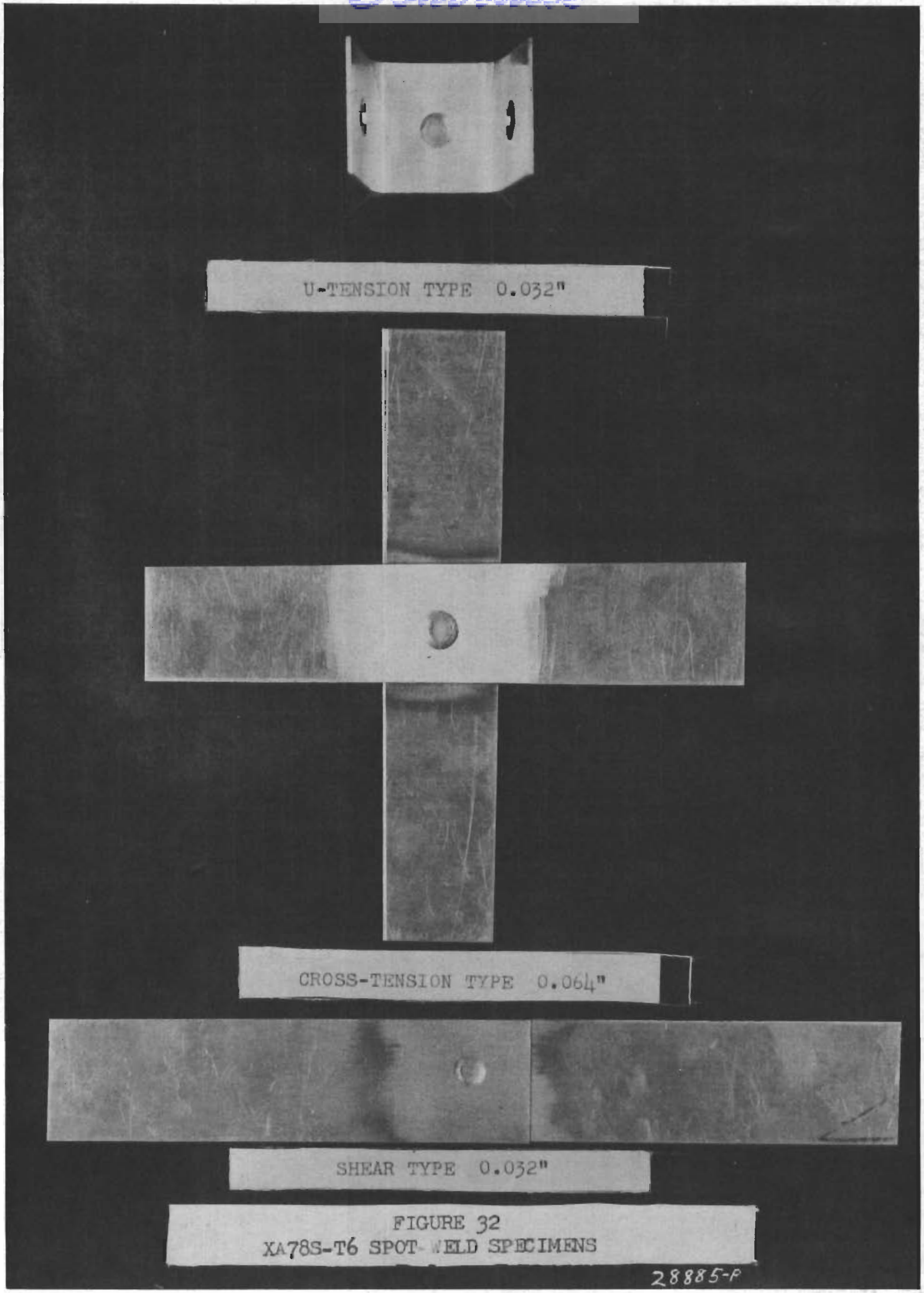


FIGURE 32
XA78S-T6 SPOT-WELD SPECIMENS

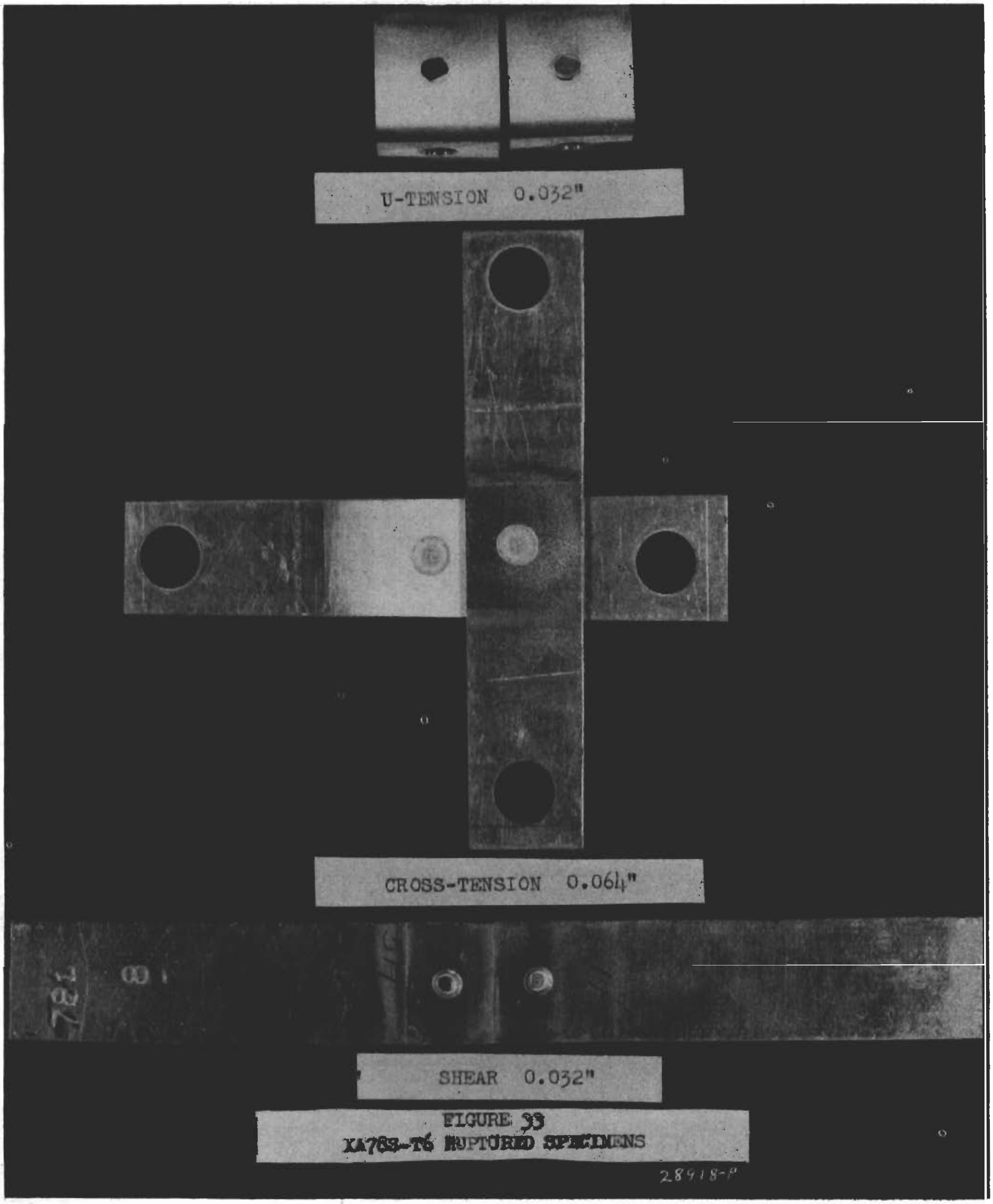


FIGURE 33
XA78S-T6 RUPTURED SPECIMENS

28918-P

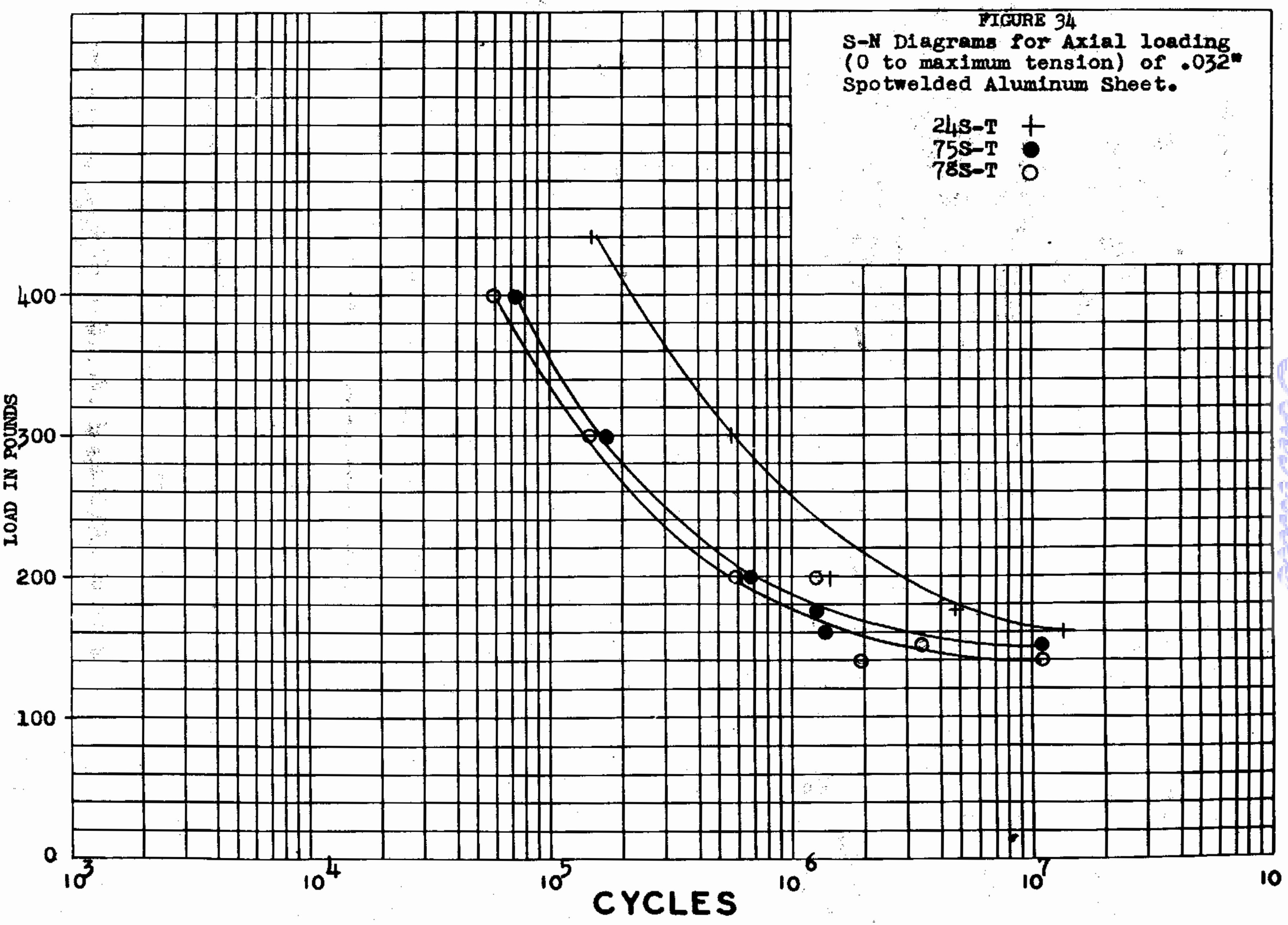
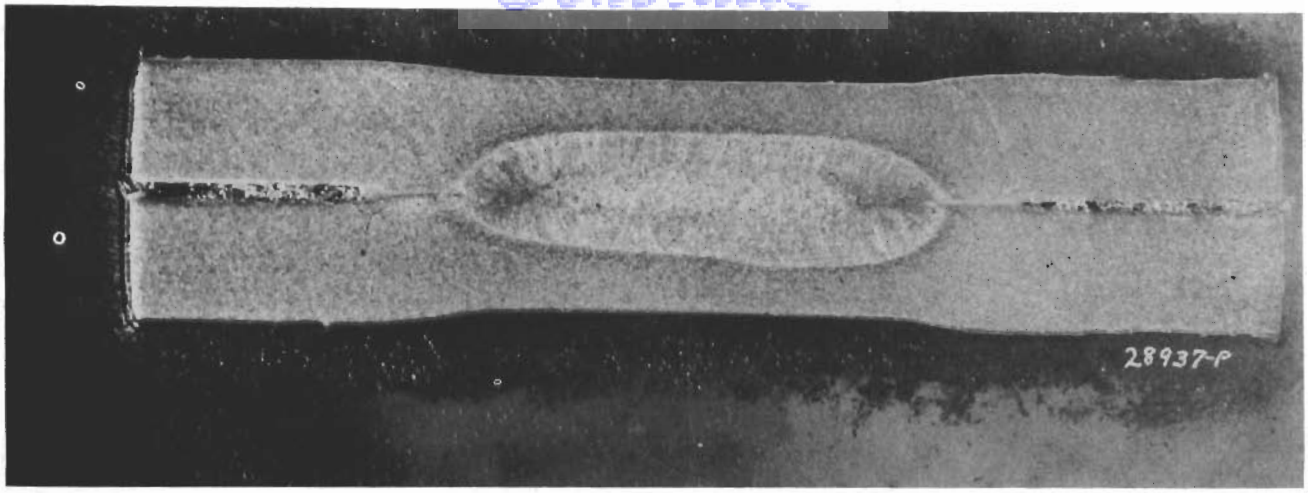
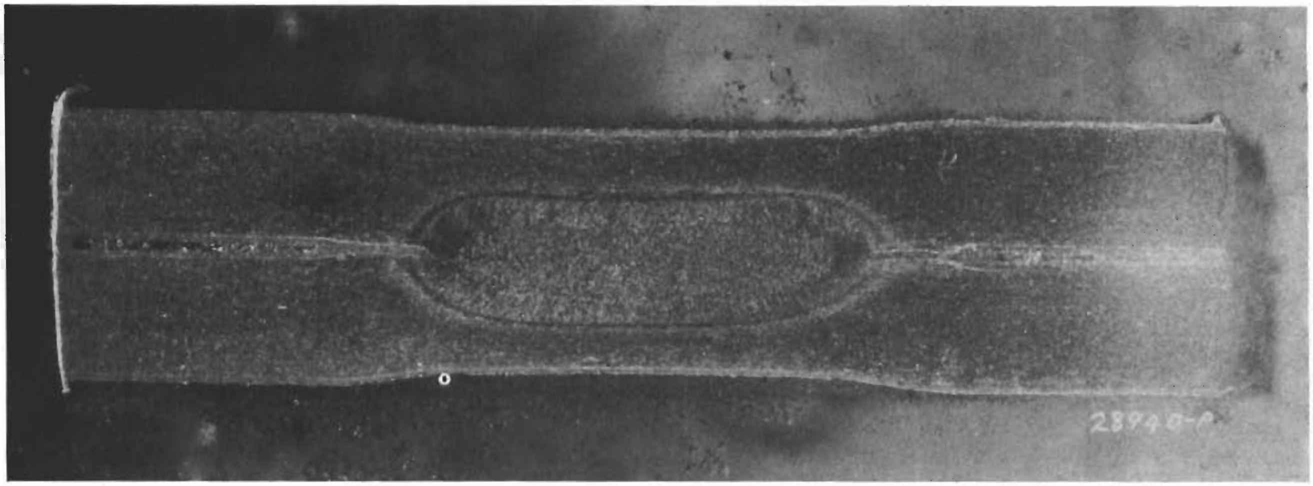


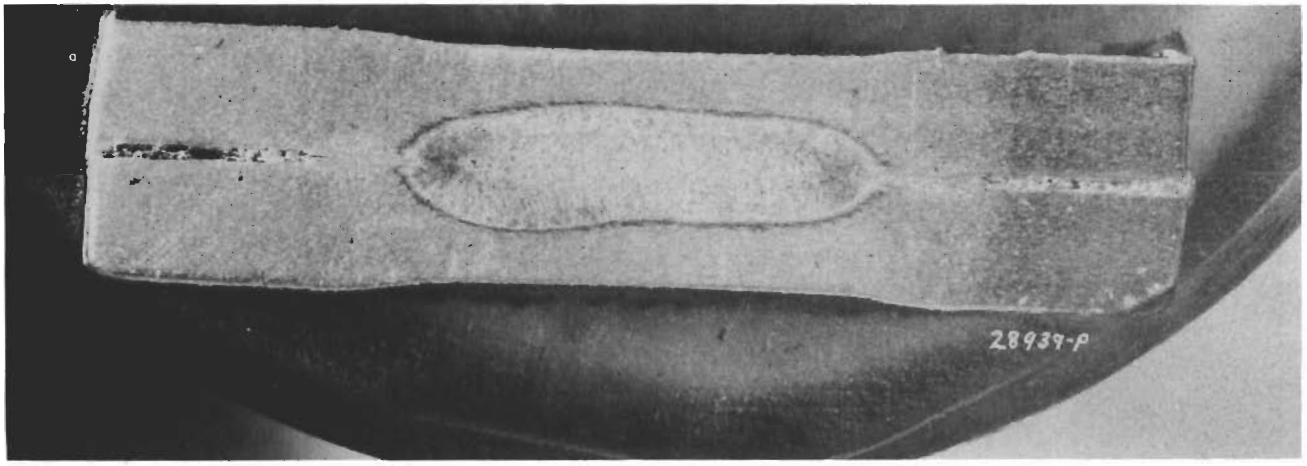
FIGURE 34
S-N Diagrams for Axial loading
(0 to maximum tension) of .032"
Spotwelded Aluminum Sheet.



24S-T3 0.064 INCH



75S-T6 0.064 INCH



XA78S-T6 0.064 INCH

FIGURE 35 SECTIONS THROUGH SPOT WELDS IN HIGH STRENGTH ALUMINUM ALLOYS

Magn 10x Etch: Keller's Reag.

Bend Properties

Bend tests were made on sheets of various thickness. The purposes were to determine the minimum radius over which the sheet could be bent 180 degree without showing cracks and to determine the number of times the material could be bent to 90°, over a radius 4 times the sheet thickness. Samples were taken from the annealed and heat treated sheet material in the longitudinal and transverse directions. The bending was performed by securing one end of the strip in a vise and manually bending over a rod having the proper radius for that bend. The results are shown in Table XXIV.

The annealed material was bent through 180° on itself without fracturing. The number of 90° reverse bends which the 0.032 inch thick sheet withstood was 16 in the transverse direction and 22 in the longitudinal direction. The 0.064 inch thick sheet endured 6 reverse bends in the transverse direction and 8 in the longitudinal direction while the 0.125 inch thick sheet withstood 4 and 6 reversals, respectively.

The solution heat treated and artificially aged material appeared to be more brittle than other aluminum, zinc, magnesium and copper based alloys. The minimum bend radius for the 0.032 inch thick transverse specimens was 3T, for the 0.064 inch thick samples was 3-1/2T, while the 0.125 inch thick sheet material was 4T. The 0.064 and 0.125 test strips failed after one reversal.

TABLE XXIV

BEND PROPERTIES OF CLAD XA78S - ALLOY IN ANNEALED AND T6 TEMPER

Sheet Thickness Inches	Condition of Material	Minimum Radius to Make 180° Bend		No. of Repeated 90° Bends Over Radius or 4T	
		Transverse (1)	Longitudinal (2)	Transverse	Longitudinal
0.032	Annealed	0T	0T	16	22
0.064	Annealed	0T	0T	6	8
0.125	Annealed	0T	0T	4	6
0.032	Mill Heat Treated	3T	2-1/2T	3	4
0.064	Mill Heat Treated	3-1/2T	3T	1	1
0.125	Mill Heat Treated	4T	3T	1	1

(1) Transverse - Axis of bend parallel to direction of rolling.

(2) Longitudinal-Axis of bend normal to direction of rolling.

Cladding Examination

Microscopic examination was conducted to determine the thickness of the cladding on the sheet material submitted and the diffusion of the core constituents into the cladding caused by reheating at solution treatment temperatures. Panels, 3 inches square were taken from all thickness of clad XA78S-T6 sheet. They were solution heat treated at 870°F for varying periods, quenched in cold water and aged at 250°F for 24 hours. Metallographic specimens were prepared from each sheet in the mill heat treated temper, as well as from the panels which were resolution heat treated and aged in the laboratory. All specimens were examined at 100 diameters magnification. The results are shown in Table XXV.

The average thickness of the cladding was approximately 4 percent of the thickness of the sheet. The values shown for the mill heat treated samples represent the average thickness. In examining the test pieces which were reheat treated in the laboratory, an attempt was made to determine the closest approach of the core constituents to the surface of the specimen. Since the distinction between the diffused phase and the cladding was not sharp the results shown in Table XXV must be considered to be approximate.

TABLE XXV

THICKNESS OF CLADDING ON CLAD XA78S-T6 SHEETS

Location of Specimen Used	Gage of Sheet Inches	Solution Heat Treatment	Thickness of Undiffused Cladding Inches	Amount of Diffusion Inches
I-50	0.032	MILL HEAT TREATED	0.0014	
I-52	0.032	870°F for 30 minutes	0.0013	0.0001
K-50	0.032	870°F for 60 minutes	0.0011	0.0003
K-52	0.032	870°F for 2 hours	0.0010	0.0004
K-53	0.032	870°F for 4 hours	0.0008	0.0006
A-77	0.064	MILL HEAT TREATED	0.0028	
A-79	0.064	870°F for 30 minutes	0.0028	
A-80	0.064	870°F for 60 minutes	0.0028	
C-78	0.064	870°F for 2 hours	0.0024	0.0004
C-81	0.064	870°F for 4 hours	0.0023	0.0005
M-41	0.125	MILL HEAT TREATED	0.0058	
M-42	0.125	870°F for 40 minutes	0.0056	.0002
O-41	0.125	870°F for 2 hours	0.0056	.0002
O-43	0.125	870°F for 4 hours	0.0054	.0004
O-44	0.125	870°F for 6 hours	0.0052	.0006

Microscopic Characteristics

Microscopic study of XA78S - Aluminum Alloy was made in order to distinguish the microstructure of the alloy in different tempers and to observe the constituents. In the annealed sheet, as shown in Figure 36, most of the hardening constituents, zinc-magnesium, are out of solution and appear in the matrix as many small particles. The microstructure revealed that recrystallization occurred and the effects of plastic deformation, resulting from cold work, had been relieved. The arrangement and size of the constituents in the annealed samples are shown in Figure 37.

When the material is solution heat treated, the principal alloying constituents are dissolved in the solid solution matrix. By quenching the material rapidly from the heat treating temperature, the soluble alloying elements are retained in solid solution. Left scattered in the matrix are a few particles of insoluble Mg_2Si and the constituents containing chromium, iron, and manganese. Figure 38 shows the microstructure of XA78S-W type alloy immediately after a solution heat treatment quench.

Good strengths in this material were obtained through the use of precipitation heat treatment. The precipitation heat treatment probably resulted in the formation of submicroscopic precipitated particles which strengthen and harden the matrix. A difference in grain contrast between the heat treated and artificially aged material was noted in the structures illustrated by Figures 38 and 39. The microstructure of the clad aluminum alloy and the XA78S-T core are shown in Figure 40. Slight diffusion of cladding was observed at the diffusion zone.

XA78S material was also furnished as extrusions. The microstructure of the shapes varied depending on metal flow during extrusion process. Figure 41 shows the microstructure of a heat treated and artificially aged round corner bar extrusion. Micro etched cross sections of extrusions will be presented in the supplementary work.

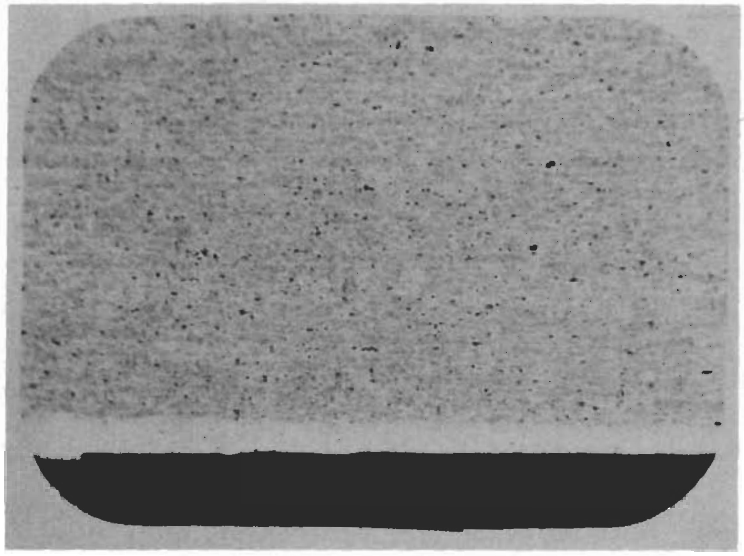


FIG 36 PLATE 27955-M

MAGN 100x DIAM ETCH Keller

REMARKS:

XA78S-0 clad 0.032 inch thick sheet in longitudinal direction. Most of hardening constituents are out of solution and appear in the matrix as many small particles. Annealing has relieved effects of plastic deformation.

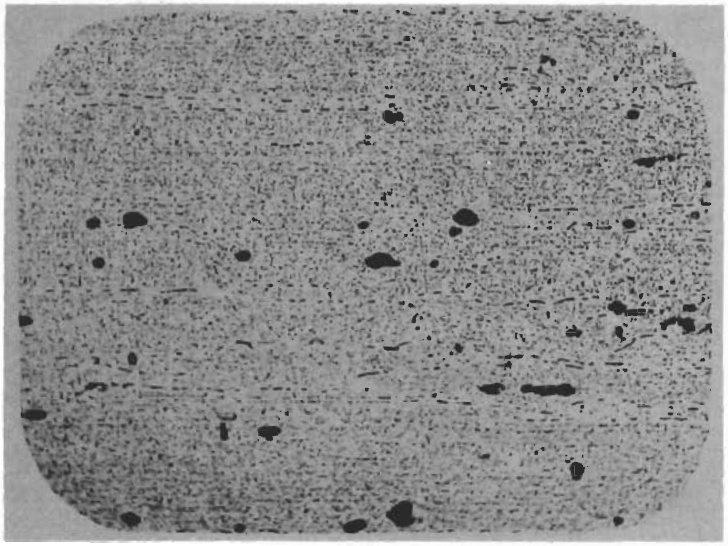


FIG 37 PLATE 28866-M

MAGN 500x DIAM ETCH Keller

REMARKS:

XA78S-0 clad 0.064 inch thick sheet showing size and arrangement of constituents in the core of this material.

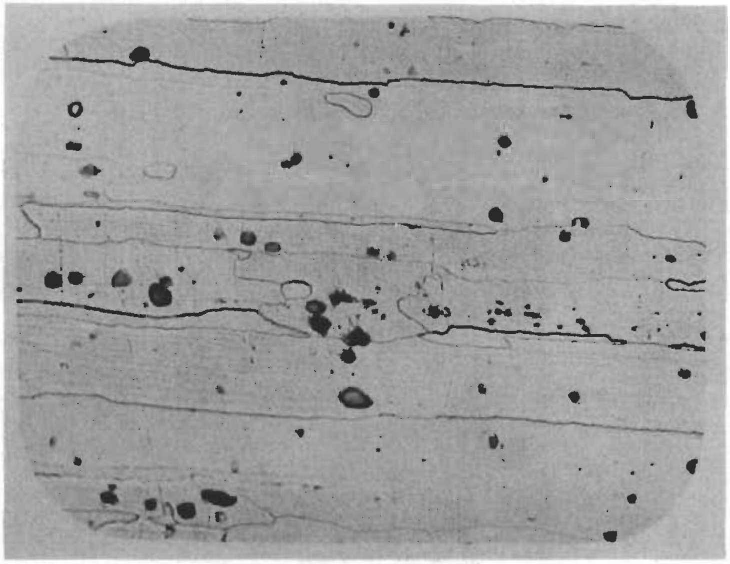


FIG 38 PLATE 28867-M

MAGN 500x DIAM ETCH Keller

REMARKS:

XA78S-W bare 0.250 inch thick plate. Structure was that of a solid solution with a few particles of insoluable constituent appearing in the matrix. The material has been recrystallized and has developed well defined grain boundaries. The photomicrograph was obtained two hours after solution heat treatment.

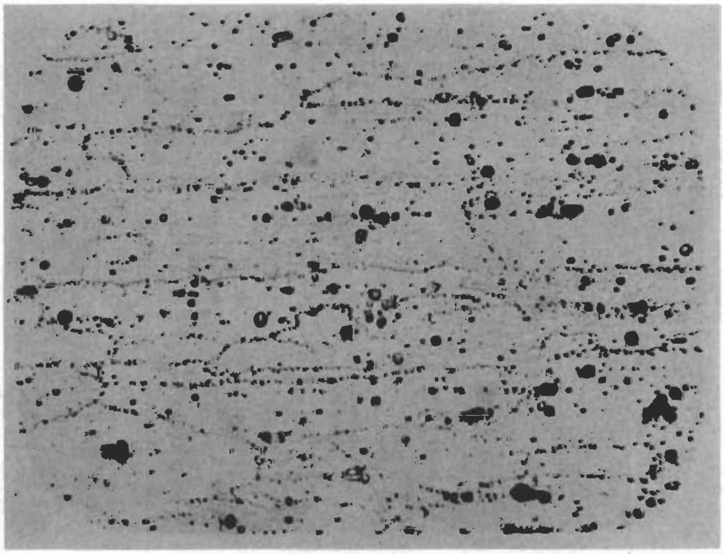


FIG 39 PLATE 28872-M

MAGN 500x DIAM ETCH Keller

REMARKS:

XA78S-T6 clad 0.125 inch thick sheet, showing distribution and size of constituents in the core material.

FIG 40 PLATE 28916-M

MAGN 100x DIAM ETCH Keller

REMARKS:

XA78S-T6 clad 0.125 inch thick sheet. Etching differentiates between cladding and core. Diffusion zone, resulting from migration of the alloying element into the cladding, is evident. Particles scattered through the core are Mg_3Si and the chromium bearing constituents. —

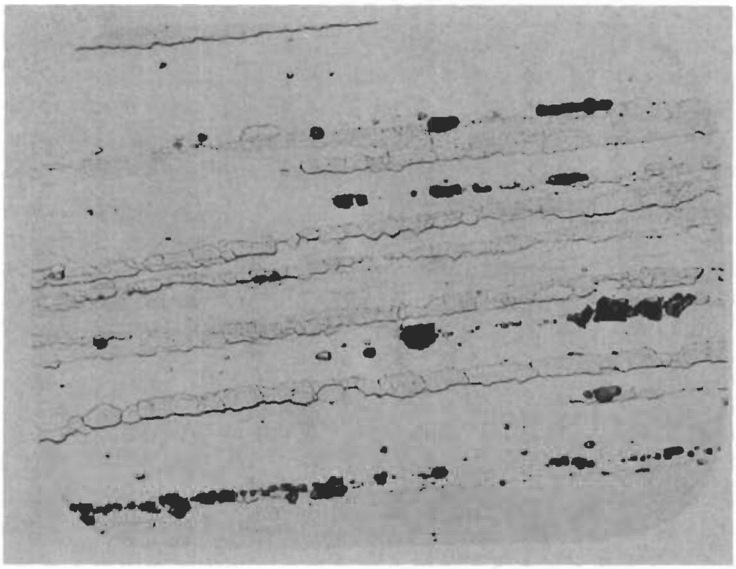


FIG 41 PLATE 28868-M

MAGN 500x DIAM ETCH Keller

REMARKS:

XA78S-T6 round corner bar extrusion. Structure is similar to extruded 75S-T6 aluminum alloy. It contains particles of chromium bearing constituent.

CONCLUSIONS

The chemical composition of XA78S - aluminum alloy sheet and plate material investigated was 6.8% zinc, 2.8% magnesium, 1.90% copper, 0.13% chromium, 0.08% silicon, and 0.07% iron. The composition of the extrusions was 6.9% zinc, 2.9% magnesium, 2.1% copper, 0.14% chromium, 0.42% silicon and 0.03% iron. The cladding used on the sheet was 72S.

The alloy developed high physical properties both in the mill heat treated and laboratory heat treated condition. The tensile strength, tensile yield strength and compressive yield strength of the material averaged approximately 10% higher than the corresponding properties of other high strength aluminum alloys.

The average mechanical properties of the clad sheet material were 81,300 psi ultimate tensile strength, 72,300 psi tensile yield strength, 80,500 psi compressive yield strength with 11.5% elongation in 2 inches. The lower properties obtained in any single test made in this program for the clad alloy were 77,800 psi ultimate tensile strength, 69,600 psi tensile yield strength, 72,700 psi compressive yield strength with 8% elongation.

The average properties of the bare plate material were 88,300 psi ultimate tensile strength, 80,000 psi tensile yield strength, 83,800 psi compressive yield strength with 12.5% elongation in 2 inches. The lowest properties obtained in any single test made in this investigation for the base material were 85,700 psi ultimate tensile strength, 75,200 psi tensile yield strength, 72,700 psi compressive yield strength with 9% elongation.

The properties of the extruded sections investigated were 18% above the producers suggested minimum properties. The ultimate tensile strength averaged 99,200 psi, the tensile yield 90,000 psi, the compressive yield 96,000 psi with 10% elongation. The lowest properties obtained from any single test taken from the extruded sections were 96,000 psi ultimate tensile strength, 86,000 psi tensile yield strength, 87,300 psi compressive yield strength with 8.5% elongation.

The unnotched fatigue strengths of Clad XA78S-T6 sheets at 20 x 10^6 cycles were 15 to 18% higher than similar clad sheets of 75S-T6. In bare sheets and extrusions the two alloys had approximately the same fatigue strengths.

The soaking time for solution heat treatment of XA78S material was similar to that required for 75S material as given in the military heat treat Specification MIL-H-6088. Since it has a higher alloying content than 75S, temperatures above 880°F should be avoided in both sheet and extruded material. Excessive soaking time will result in diffusion of core alloying constituents into the clad material.

Artificial aging is necessary to develop optimum mechanical properties. The best constant aging treatment was 250°F for 24 hours, while the best interrupted aging cycle was 250°F for 4 hours followed by 300°F for 4 hours.

As in the case of other high strength aluminum alloys, XA78S-W age hardens at room temperature. Natural aging induced approximately the same ultimate tensile strength properties as were obtained through artificial aging within 2,000 hours. However, the yield strength at that time was much lower than would be obtained by artificial aging and it is doubtful if maximum yield strength could be attained by natural aging.

Sound spot welds can be made in XA78S-T6 aluminum alloy. The results of this investigation indicate that spot welds have very nearly the same strength but lower ductility than those in 24S-T3 aluminum alloy. The physical properties of spot welds in 75S-T6 and XA78S-T6 are approximately the same, but spot welds in both these alloys are less ductile and have lower fatigue strength than those made in 24S-T3.

The potential measurements showed a potential difference of 115 to 150 millivolts between the core and cladding of the properly heat treated sheet material. Improper heat treatments, such as extended soaking periods and slow cooling rates, lowered the potential differences by shifting the potential in the anodic direction.

The material is more difficult to bend and form than other high strength aluminum alloys. Larger bend radii are required, therefore, forming operations will be more difficult than for other aluminum alloys. It may be performed while the material is in the W-condition, however, due to the natural aging characteristics forming of the alloy should be accomplished as soon as possible after quenching. Bending in the heat treated and aged condition is difficult and causes localized strain within the grains of the alloy.

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ACTION TAKEN

Three specifications, MIL-A-9180 (USAF), MIL-A-9183 (USAF) and MIL-A-9186 (USAF) have been written and issued for United States Air Force use of XA78S aluminum alloy clad sheet and plate, bare sheet and plate, and extruded material.

CONTENT OF PART II OF TECHNICAL REPORT

Test results of other investigations such as tensile notched sensitivity, fatigue axial loading and rotating beam notched and unnotched, stress corrosion, shear, and bearing, along with rechecks already reported will be included in Part II to this technical report.