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**TENSILE AND TENSILE-FATIGUE PROPERTIES OF TRANSPARENT
ENCLOSURE ATTACHMENTS FOR AIRCRAFT**

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SWEDLOW PLASTICS COMPANY

APRIL 1953

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FOREWORD

This report was prepared by Swedlow Plastics Company under Air Force Contract Number AF 33 (038)-22456. The work was administered under the Special Projects Branch, Aircraft Laboratory, Wright Air Development Center, with Captain F. M. Cooper acting as project engineer. The project was identified by RDO No. 453-303 "Development of Stronger and More Fatigue Resistant Attachments for Transparent Materials".

ABSTRACT

Fifteen types of edge attachments, eight for monolithic acrylic material and seven for laminated acrylic material were designed, fabricated and tested for tensile strength at room temperature and -65°F , and in tensile-fatigue at room temperature. Thirteen of these types were designed using MIL-P-6886 acrylic material and two were designed using MIL-P-5425 acrylic material.

Though ultimate tensile strengths vary widely depending on design and materials used in the attaching edge, it appears that the tensile-fatigue limit in all cases where good engineering design practices are maintained approaches one pound per mil thickness per inch of width of MIL-P-6886 transparent acrylic material at 500,000 cycles. Although MIL-P-5425 acrylic material appears to have a slightly greater endurance limit, insufficient data are available to definitely draw such a conclusion.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

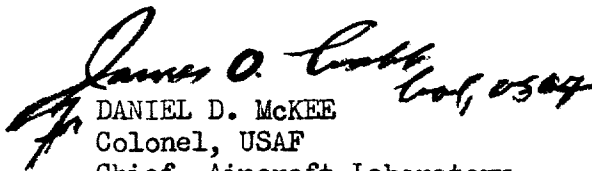

DANIEL D. McKEE
Colonel, USAF
Chief, Aircraft Laboratory
Directorate of Laboratories

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TENSILE AND TENSILE-FATIGUE PROPERTIES OF TRANSPARENT

ENCLOSURE ATTACHMENTS FOR AIRCRAFT

Late in World War II it became apparent that transparent enclosures for aircraft could no longer be attached by the simple means previously used in unpressurized craft. This realization induced a general reaction toward edge reinforcement in the technical sections of all concerns involved. Solutions to the problem were in many cases independently evolved and consequently many types of attaching edges appeared.

The basic purposes for this attaching edge were threefold:

1. To increase bearing strength.
2. To prevent the inception of fracture in the body of the transparent material.
3. To prevent propagation of fracture from the attaching edge into the body of the transparent material.

The direction of attack to achieve these purposes has been universally similar in that some attaching edge has been cemented to the transparent enclosure. The materials used for this purpose have varied widely and include cast acrylic reinforcing strips, rubber extrusions, stainless wire screen - acrylic laminates, square woven Fiberglas cloth-acrylic laminates, and free Nylon loops. More recent innovations have included new weaves of glass cloth as satin weaves and unidirectional weaves built into acrylic laminates and many synthetic fiber acrylic laminates, most notably Orlon and Dacron.

This report covers engineering data sponsored and financed by Wright-Development Center, Wright-Patterson Air Force Base, Dayton, Ohio, on tensile strength and tensile-fatigue of fifteen edge attachment designs (see Appendix II, Page 14 through 29). These designs are similar to six which have been in actual use in the past several years. However, they have been arbitrarily adapted to both monolithic and laminated acrylic sheets as well as to standard caliper transparent stock to reduce the number of variables. Monolithic designs are all adapted to transparent material .312 inch thick, and laminated designs are all adapted to .500 inch laminated material consisting of two outside skins of acrylic sheet .150 inches thick, with a center ply of polyvinyl butyral .200 inches thick. All designs were developed using MIL-P-6886 transparent material except STS-022 and STS-023 (Appendix II, Page 28 and 29) in which MIL-P-5425 transparent material was used. Otherwise these two designs were duplicates of STS-001A and STS-002 respectively.

Forty two specimens of each of the fifteen designs were fabricated for test purposes in thirteen inch long panels and the specimens were cut and finished from the panels. Materials used in the fabrication of these specimens are described in Appendix I, Page 12 and 13.

All tensile and tensile-fatigue tests were conducted on rigid attaching edge specimens in bearing on two evenly spaced 1/4 inch pins (see Figure 1, Page 5). The Nylon loop types were tested with a lateral locking pin in a slot simulating actual frame installation.

Ultimate tensile strengths were determined for each of these designs at both 70°F. $\pm$ 5°F. and -65°F. +0°F. - 5°F.

Table 1 shows these values as averages of 10 specimens in each case. The wide variation in these average values is due to the original design strength and the comparison of the specimen design with the corresponding ultimate tensile makes apparent the reasons for corresponding high and low values. The erratic increase or decrease due to thermal depression may be of design interest but will not be discussed in this report. Tensile test details and data are in Appendix III, Page 30 through 35.

TABLE 1

AVERAGE TENSILE STRENGTHS

DESIGN	TENSILE STRENGTH IN LBS. PER INCH OF WIDTH AT		INCREASE (+) OR DECREASE (-) AT -65°F.	
	+70°F. $\pm$ 5°F.	-65°F. +0°F. -5°F.	Lbs/inch	Percentage
STS-001A	1379	1728	+ 348	+ 39.9
STS-002	1771	2201	+ 430	+ 24.3
STS-003A	913	1019	+ 106	+ 11.6
STS-004A	1391	1362	- 29	- 2.1
STS-005	598	773	+ 175	+ 29.3
STS-007	331	800	+ 469	+141.6
STS-008	630	605	- 25	- 4.0
STS-009	628	769	+ 151	+ 22.5
STS-010	1076	1148	+ 72	+ 6.7
STS-012	1222	1533	+ 311	+ 25.5
STS-013	1803	1416	- 387	- 21.5
STS-014A	1491	1605	+ 114	+ 7.6
STS-015	1467	2041	+ 574	+ 39.1
STS-022	1522	2052	+ 550	+ 36.4
STS-023	1206	2771	+1565	+129.7

Equipment for tensile-fatigue testing was specially designed and constructed to meet the requirements of this program. The design requirements were as follows:

1. Load accuracy to $\pm$ 1%.
2. Elongation from 0 to 10% in a 10 inch specimen.
3. All loads in the positive or tensile direction with a minimum load in each cycle of zero pounds.
4. Adjustable maximum load in each cycle from 100 lbs. to 5,000 lbs.
5. Cycling rate of approximately 15 cycles per minute.
6. An even division within the cycle between (a) at rest, or zero load, (b) apply stress, (c) maintain stress, (d) decrease stress.

The design finally evolved to meet these requirements was a simple beam mechanism with a variable fulcrum. Load accuracy was maintained through careful design, accurate calibration and careful operational techniques. Elongation variations were made possible by the use of a variable cam drive. Stress was applied by dead weight application at the aft end of the simple beam through a

cam operated rocker arm. As the dead weight came to rest on a platform, no compressive load was applied to the specimen. Cycling rate was arrived at by a simple mechanical speed reduction to the drive cam. Item 5 above posed a difficult problem in that normal fatigue cycles follow a sine wave pattern. The equipment design for this program arrived at four even quadrants of cycle in the following manner. The "at rest" position was maintained at no load by resting the dead weight load on a tray. In the second quadrant stress was applied by lifting the dead weight on a restrained helical spring calibrated to support slightly more than the dead weight. Stress was maintained by lifting and suspending the dead weight load. Stress was decreased by resting the weight on a tray and decreasing the spring tension to zero. Figures 1, 2, and 3, on Pages 5 and 6 show the equipment at work.

Fatigue data is reported herein as ultimate load in pounds per inch of attaching edge. Detailed results are given in Appendix IV, Page 36 through 55. Table 2 below shows a tabulated comparison of fatigue results.

TABLE 2

SPECIMEN NUMBER	TENSILE-FATIGUE AT AMBIENT TEMPERATURE (75°F. $\pm$ 5°F.) FATIGUE STRENGTH IN LBS. PER INCH OF ATTACHING EDGE AT:			
	1,000 Cycles	10,000 Cycles	100,000 Cycles	500,000 Cycles(Est)
STS-001A	825	645	485	420
STS-002	790	555	420	370
STS-003A	495	350	245	220
STS-004A	740	520	335	270
STS-005	405	345	300	300
STS-007	230	200	175	150
STS-008	500	450	410	380
STS-009	415	340	265	210
STS-010	530	360	320	310
STS-012	590	425	330	310
STS-013	680	460	365	340
STS-014A	790	575	450	420
STS-015	760	525	360	320
STS-022	850	650	560	540
STS-023	740	585	450	410

Several conclusions emerge from the fatigue data as evolved. All rigid attachments show a steep decline of fatigue strength. Nylon attachments STS-005, STS-007, STS-008, and STS-009, though they do not have a high initial strength, show a very flat fatigue decline as compared to the rigid designs. Fiberglass-acrylic attaching edges to MIL-P-6886 acrylic sheet in general show a typical slope of loss and appear to approach an endurance limit of approximately 300 lbs. per inch of width. Since all specimens are designed on either .312" thick monolithic sheet or .300" acrylic sheet in one half inch laminated stock this value seems to approach 1 pound per mil thickness of the transparent sheet.

For identical designs and a difference only in the acrylic sheet a rather interesting comparison can be made between STS-001A and STS-002, (MIL-P-6886) and their equivalents, STS-022 and STS-023 (MIL-P-5425). Initial strengths are somewhat at variance but fatigue strength at 1,000 cycles and again at 10,000 cycles

are almost identical for the monolithic designs (STS-001A and STS-022) and for the laminated designs (STS-002 and STS-023). However, beyond this point MIL-P-5425 sheet shows definitely super characteristics.

Tensile-fatigue tests were started at -65°F . on specimens STS-001A, STS-002, and STS-003. Results showed an amazing similarity between room temperature and depressed temperature data, with the cold temperature fatigue essentially strengths parallel to, but higher than the room temperature fatigue strengths (Figure 31, Page 38, Figure 33, Page 40 and Figure 35, Page 42).

It was decided that should this be the case all the way through, further pursuit along this line would not be worth the relatively great amount of time and effort involved, particularly in view of the fact that the information evolved would be of little or no value insofar as edge attachment designs is concerned.

To prove this apparent relation it was decided to pick a design where cold temperature ultimate tensile strength was materially less than room temperature tensile. STS-013 seemed to fit this description nicely since it shows a 21.5% loss in tensile strength at -65°F . (Table 1, Page 2).

Tensile-fatigue data as developed on STS-013 (Figure 44, Page 51) shows the fatigue strengths at room temperature and at -65°F . equal at approximately 40 cycles, and the predicted relation of higher values at cold temperatures thereafter. This probably indicates an unbalanced condition of internal stress in this design at depressed temperatures.

Cold fatigue work was discontinued at this point for the reasons outlined above.

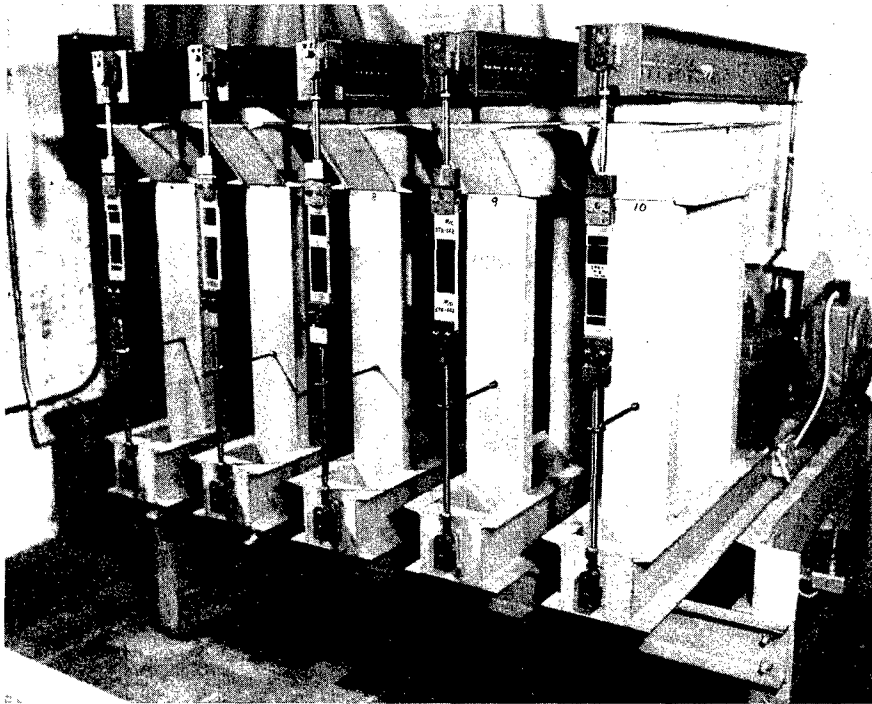


Figure 1. Tensile-fatigue units six to ten showing specimens in test position in the specimens grips.

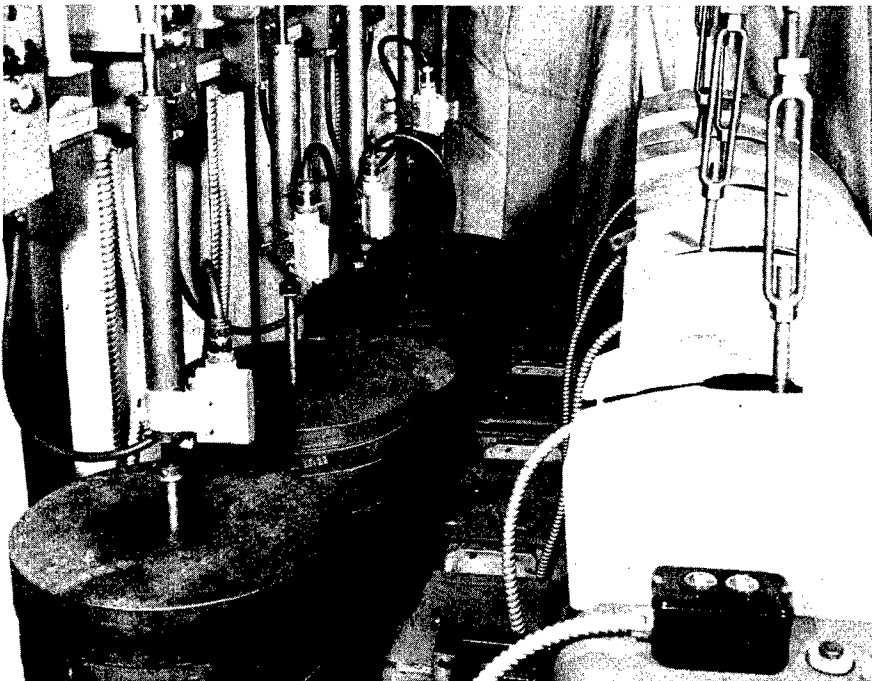


Figure 2. The operating and control end of the tensile-fatigue unit six to ten showing dead weight loads and rock arm assembly.

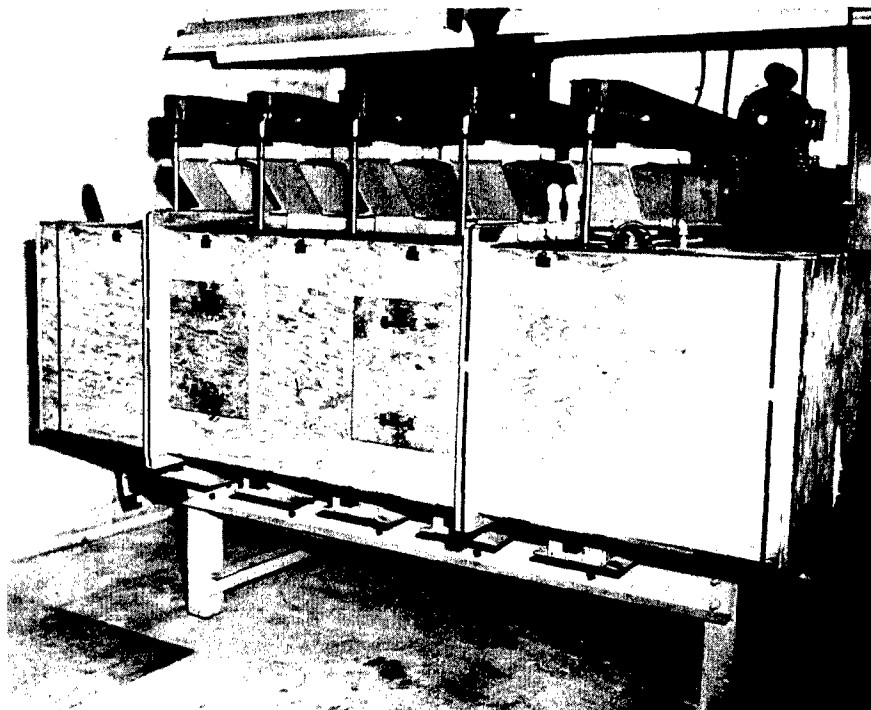


Figure 3. Tensile-fatigue units one to five showing cold chamber.

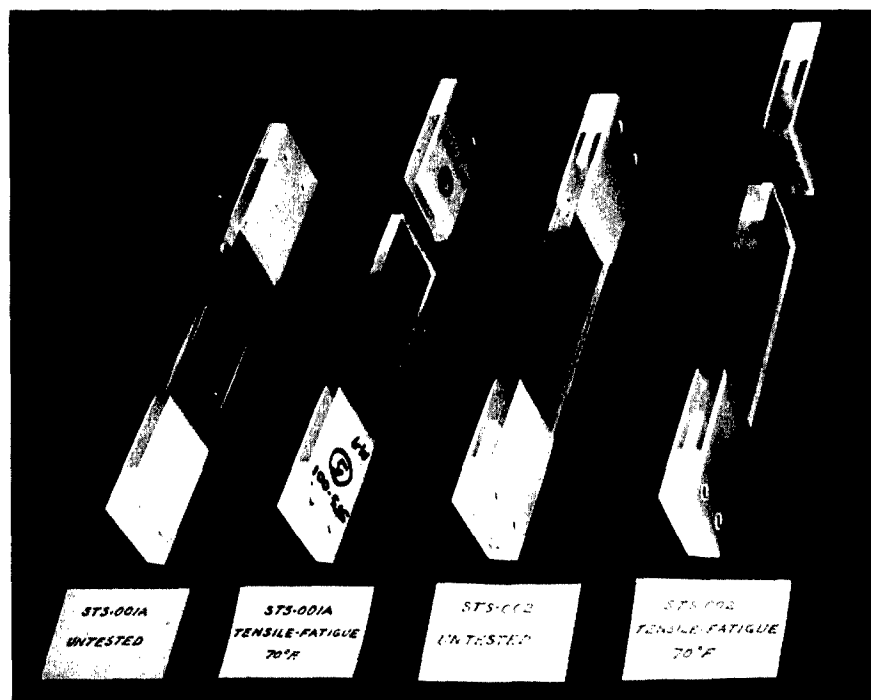


Figure 4. Test specimens.

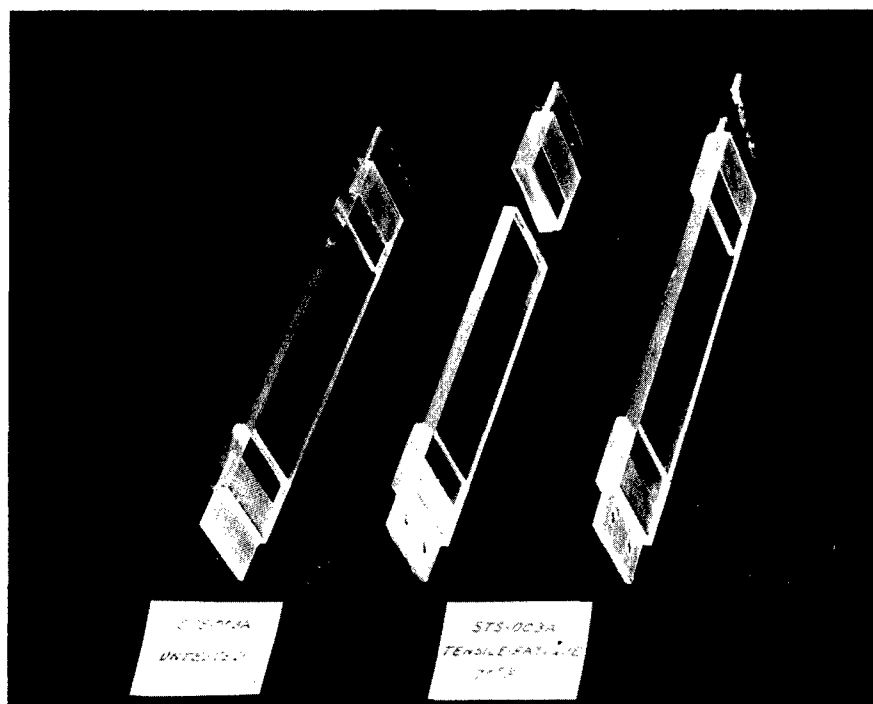


Figure 5. Test Specimens.

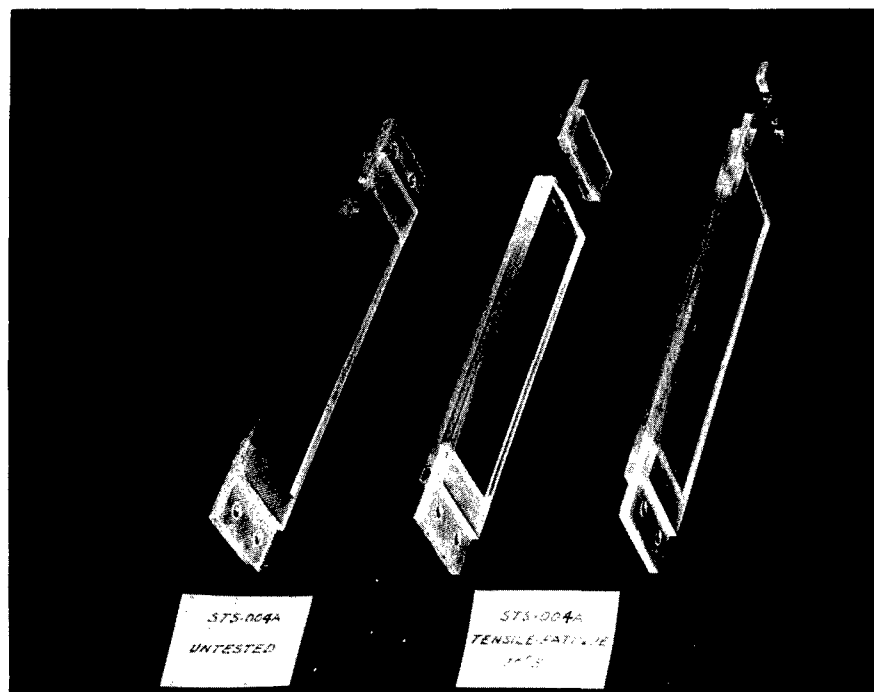


Figure 6. Test Specimens.

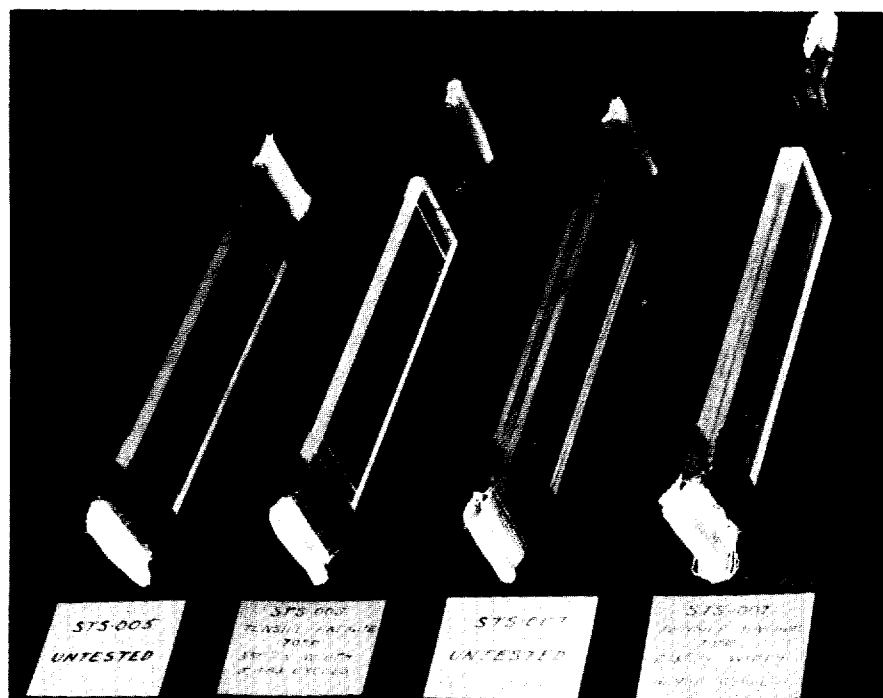


Figure 7. Test Specimens.

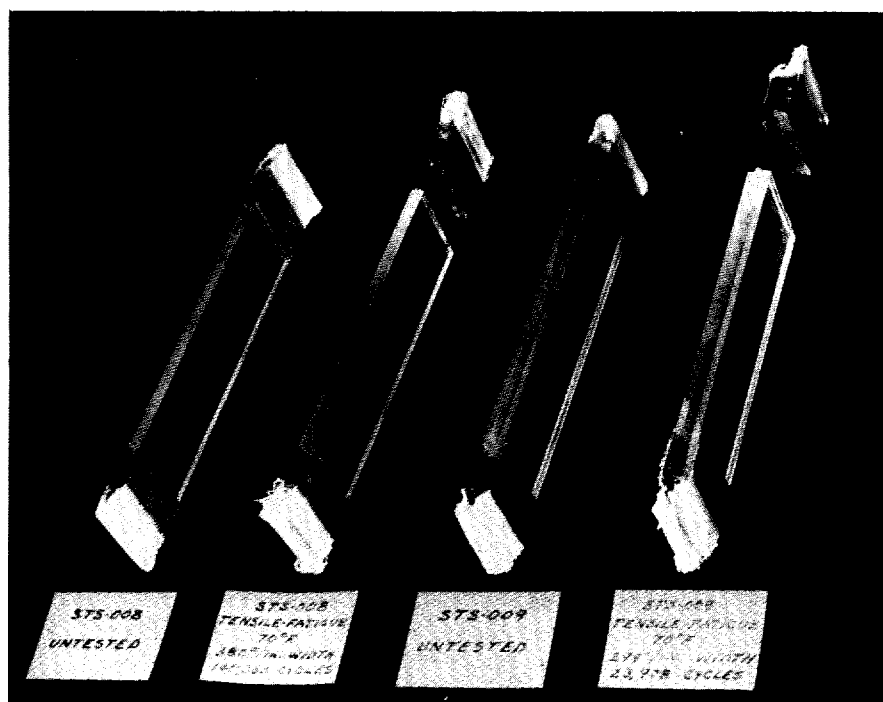


Figure 8. Test Specimens.

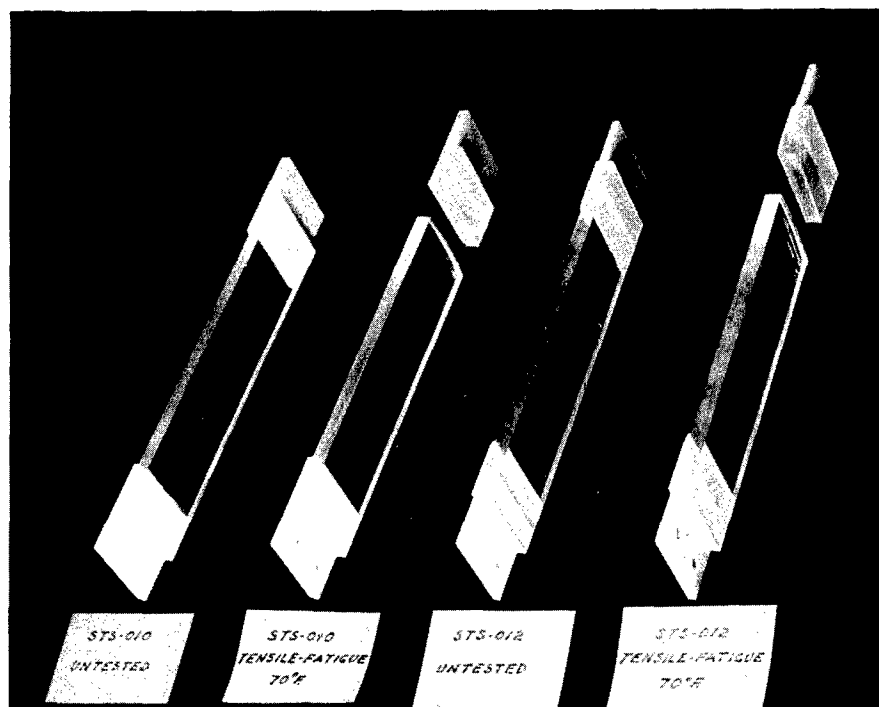


Figure 9. Test Specimens.

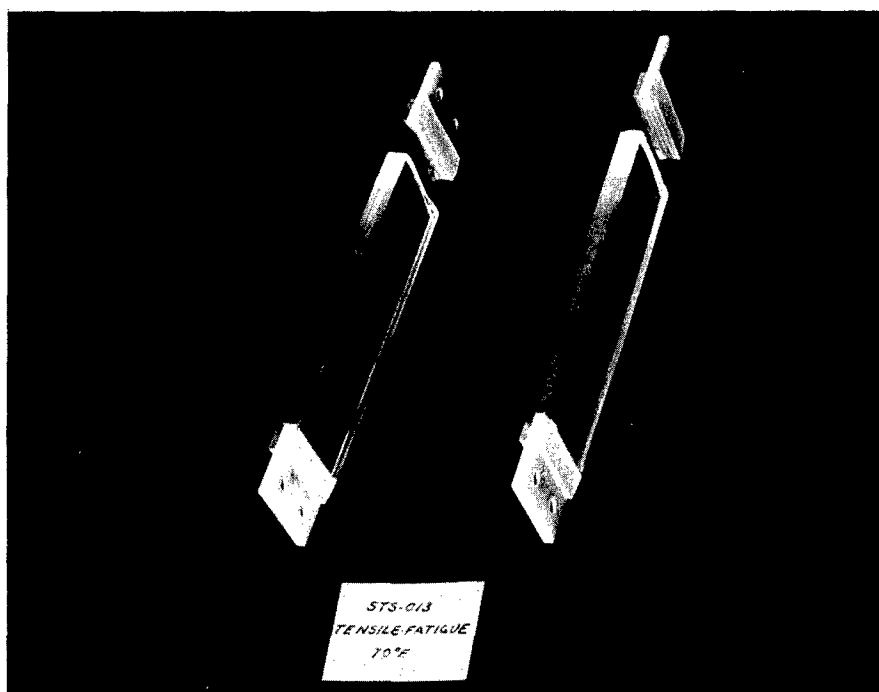


Figure 10. Test Specimens.

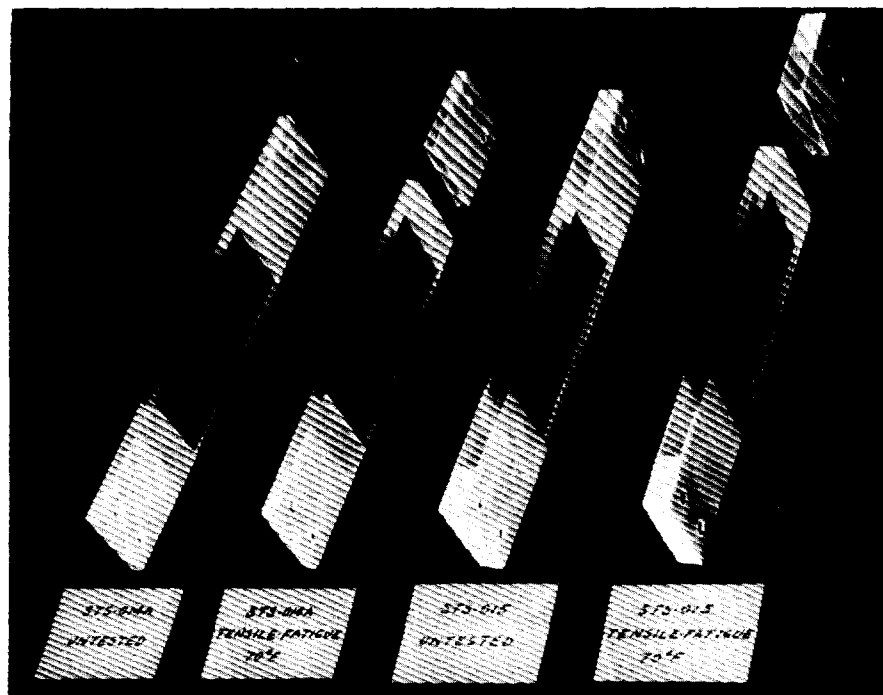


Figure 11. Test Specimens.

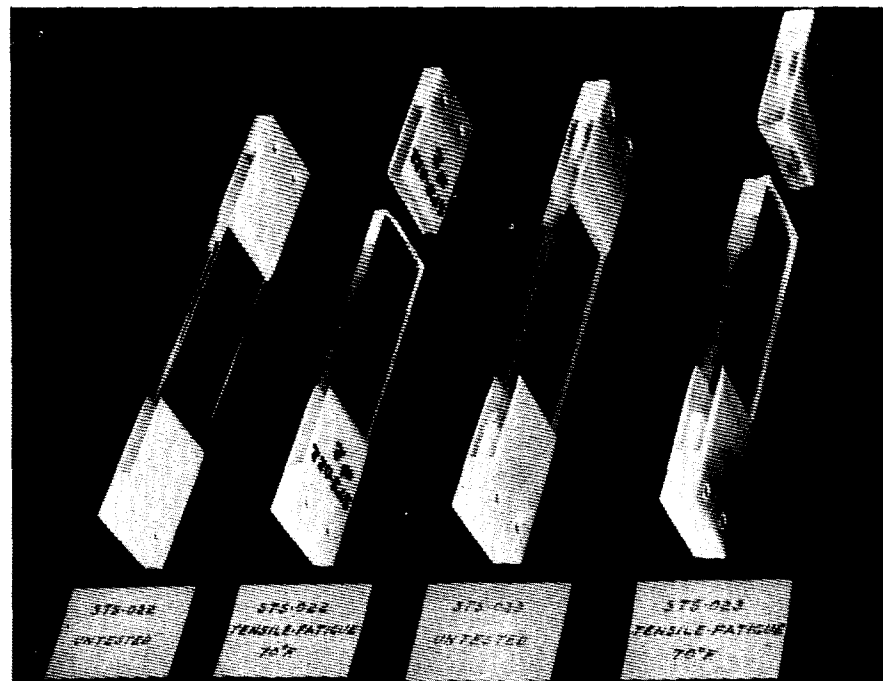


Figure 12. Test Specimens.

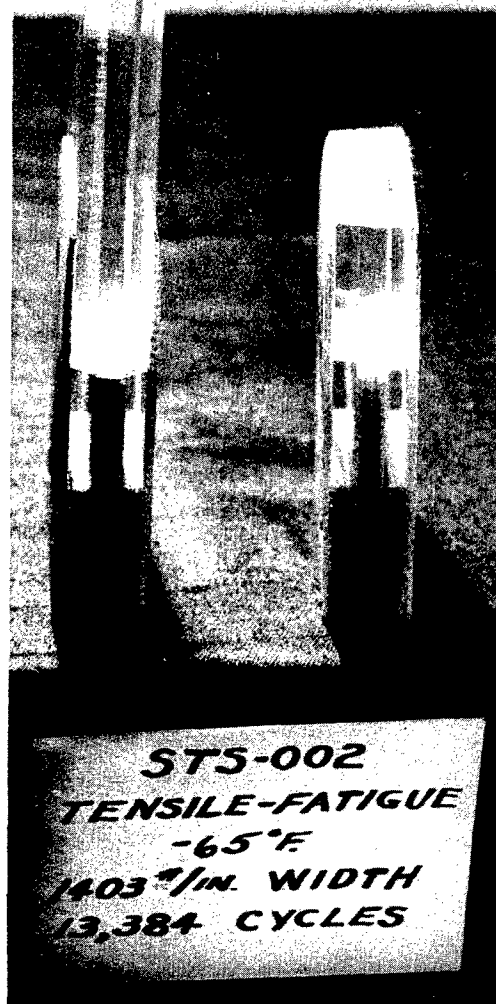


Figure 13.

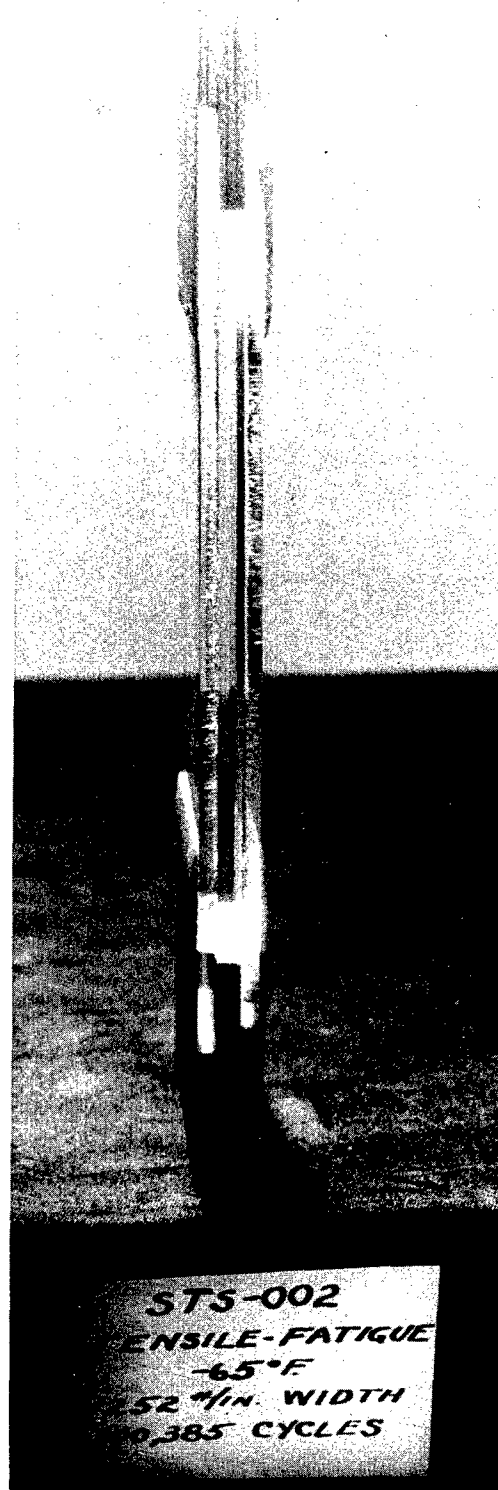


Figure 14.

Figure 13 and Figure 14 show typical fatigue fracture and craze originating from the butyral layer after long cycling at relatively high loads for laminated specimens.

APPENDIX I

MATERIAL SPECIFICATIONS

Monolithic cast acrylic sheet per specification MIL-P-6886
(.312"; 1/16"; 3/16").

Source: Rohm & Haas, Knoxville, Tennessee.

Monolithic cast acrylic sheet per specification MIL-P-5425, (.312").

Source: Rohm & Haas, Knoxville, Tennessee.

Laminated cast acrylic sheet per BMS 8-4 (.50"). Surface sheets .15"
Polyvinyl butyral innerlayer sheet .20".

Source: Pittsburgh Plate Glass Company, Creighton, Penna.

Laminated cast acrylic sheet per BMS 8-4 (.50") with the exception
that the surface sheets conform to specification MIL-P-5425. Sur-
face sheets .15". Polyvinyl butyral innerlayer sheet .20".

Source: Pittsburgh Plate Glass Company, Creighton, Penna.

Fiberglas fabric, X-27-14 (Owens-Corning, finish 14).

Source: Coast Manufacturing Company, Livermore, California.

Physical characteristics:

Plain weave

17 x 17

Yarn, 150 3/3

Thickness, .016"

Minimum Breaking Strength, Warp, 375 lbs/sq. inch.

Minimum Breaking Strength, Fill, 375 lbs/sq. inch.

Weight, 12.73 oz/sq. yard.

Fiberglas fabric, ECC-11-128-14 (Owens-Corning, finish 14).

Source: Coast Manufacturing Company, Livermore, California.

Physical characteristics:

Plain weave

42 x 32

Yarn, 225 1/3

Thickness, .007"

Minimum Breaking Strength, Warp, 250 lbs/sq. inch.

Minimum Breaking Strength, Fill, 200 lbs/sq. inch.

Weight, 6.07 oz/sq. yard.

Stainless steel 30 mesh wire, 0.013" thickness.

Source: The Ludlow-Saylor Wire Company, St. Louis, Missouri.

Finished Nylon Duck, SN-5.

Source: Wellington Sears, Shawmut, Alabama.

Physical characteristics:

3 x 4 basket weave

58 1/2 x 58

Thickness, .0375"

Maximum Breaking Strength, Warp, 1169 lbs/sq. inch.

Maximum Breaking Strength, Fill, 1177 lbs/sq. inch.

Weight, 18.30 oz/sq. yard.

Fiberglas - Acrylic Laminate.

Source: Manufactured by Swedlow Plastics Company, 6986 Bandini Boulevard, Los Angeles 22, California, as press cured acrylic resin bonded Fiberglas laminate.

Stainless Steel Mesh - Acrylic Laminate.

Source: Manufactured by Swedlow Plastics Company, Los Angeles, California, as press cured acrylic resin bonded stainless steel mesh (Ludlow-Saylor Wire Company).

S-33 Precoating cement.

Source: Swedlow Plastics Company, Los Angeles, California

Characteristics:

Methylmethacrylate polymer thickened chlorinated solvent cement.

S-47-BS Cement.

Source: Swedlow Plastics Company, Los Angeles, California

Characteristics:

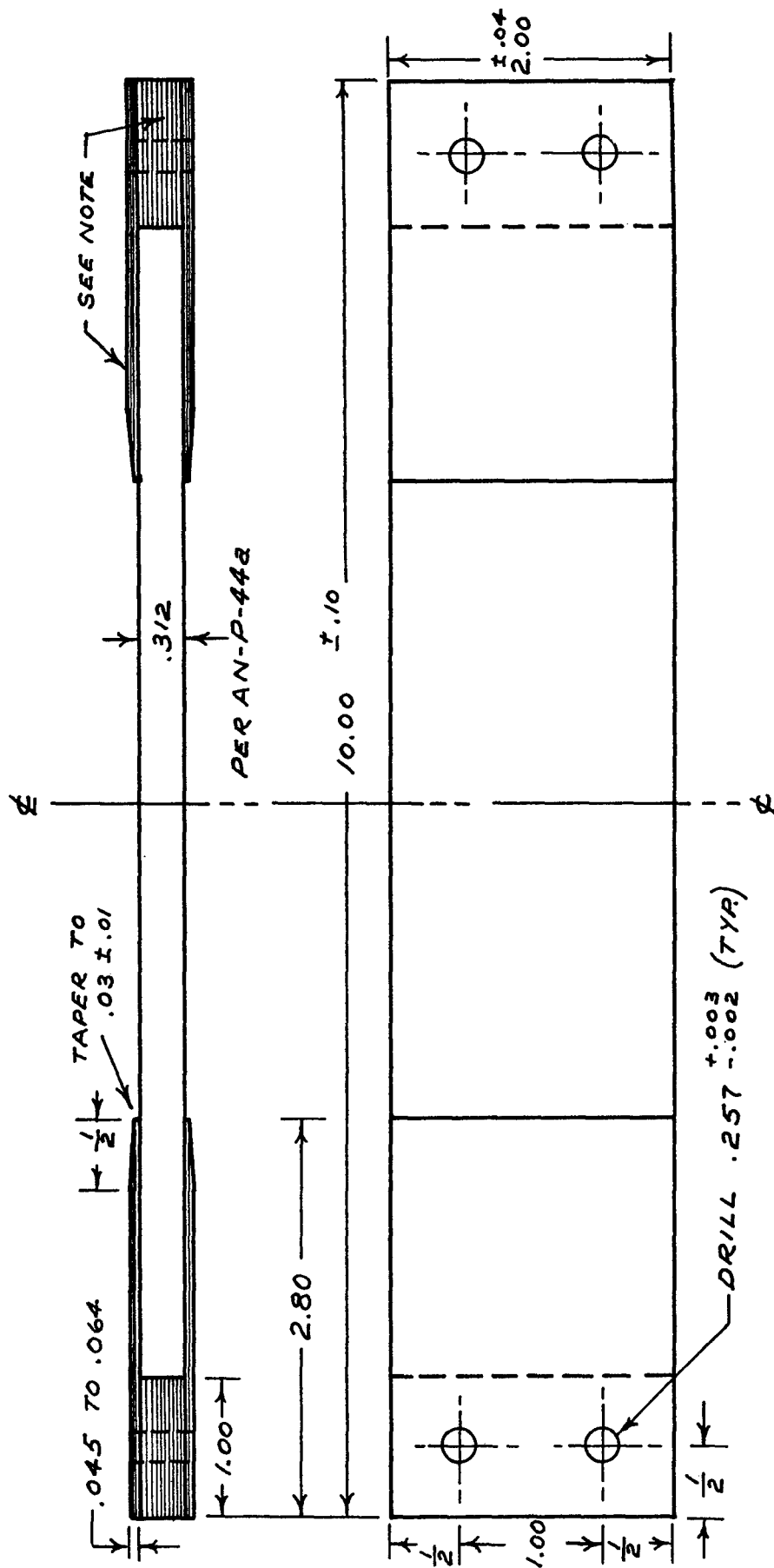
Totally reactive thickened methylmethacrylate syrup catalyzed to induce polymerization either by ultraviolet irradiation or by heat.

Penacolite XG-1500-2.

Source: Koppers Company, Inc., Chemical Division, Pittsburgh, Pa.

APPENDIX II

TRANSPARENT ENCLOSURE EDGE ATTACHMENT DESIGNS



NOTE:
X-27-14 ACRYLIC LAMINATE EARS & BUTT-BLOCK.

TOLERANCES:

FRACTIONAL ± $\frac{1}{32}$

DECIMAL .XX ± .030

.XXX ± .010

Figure 15.

D-47 TYPE EDGE		ATTACHMENT-MONOLITHIC	
STS-001A		FULL	
DRAWN	R. D. LIGGETT	5/15/51	5/15/51
CHECKED	P. Noyes	6/13/51	6/13/51
APPROVED	<i>[Signature]</i>	6/13/51	6/13/51

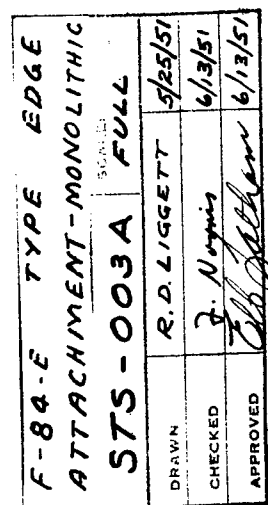
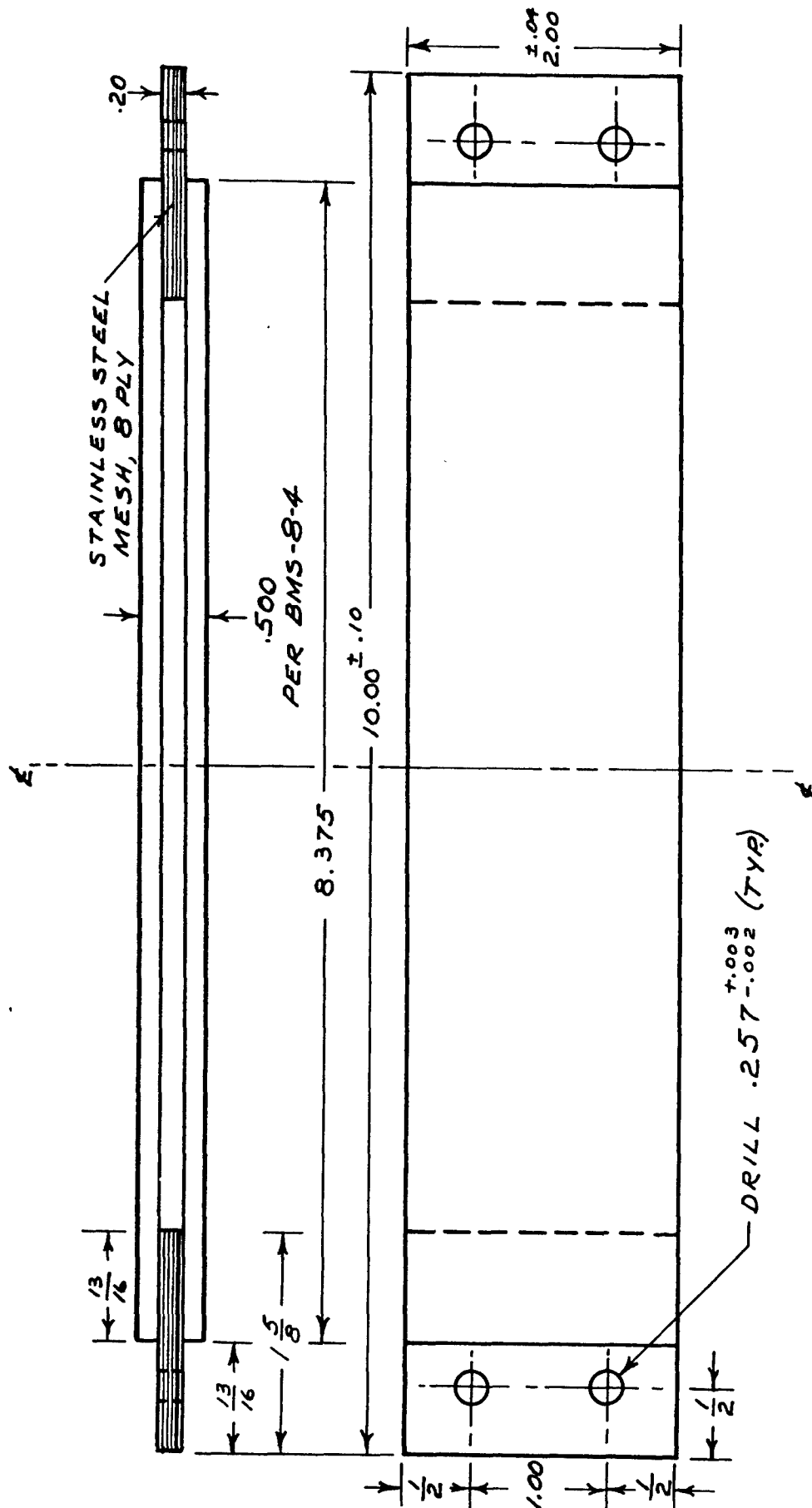


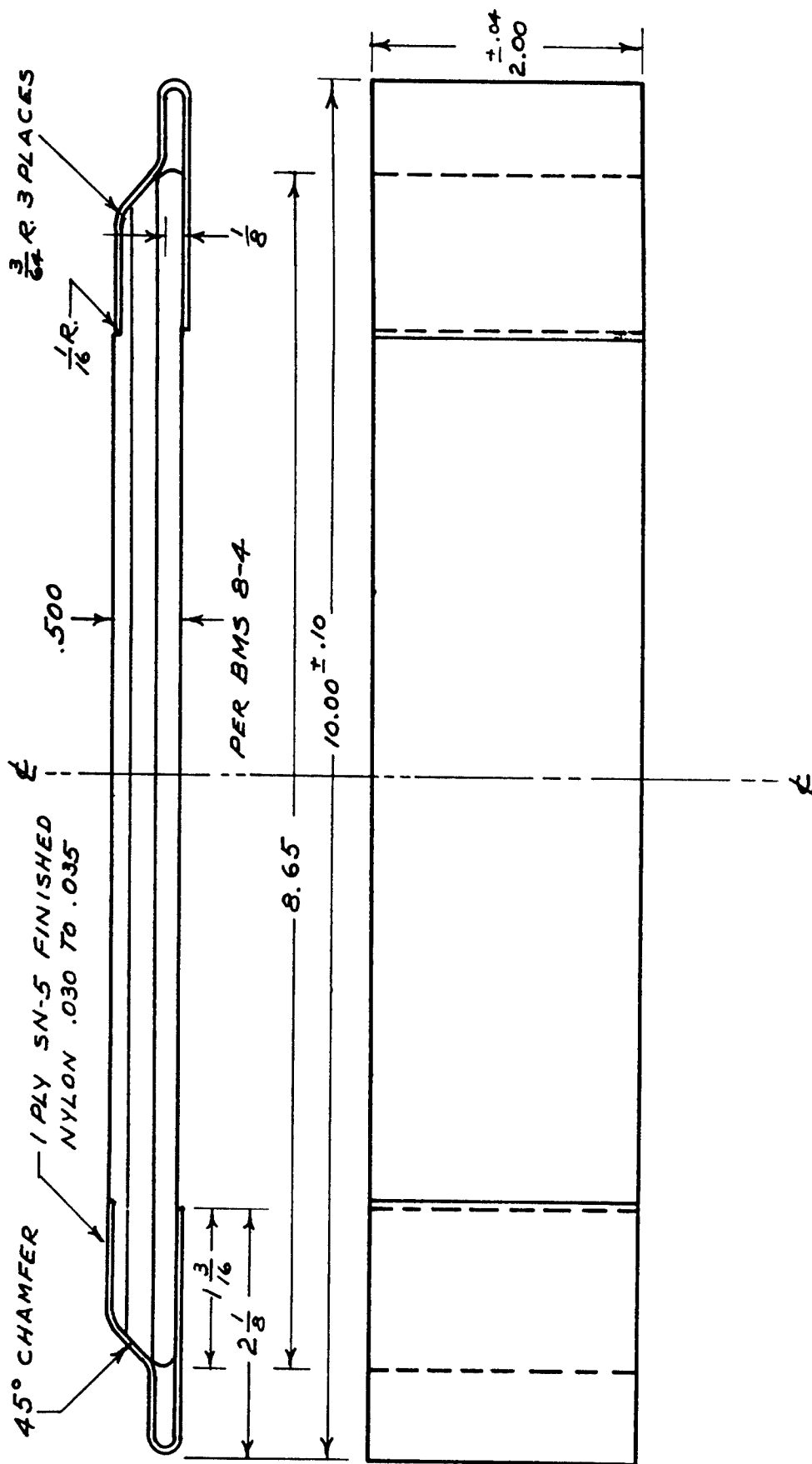
Figure 17.



TOLERANCES:
 FRACTIONAL $\pm \frac{1}{32}$
 DECIMAL .XX $\pm .030$
 .XXX $\pm .010$

Figure 18.

F-84-E TYPE EDGE		ATTACHMENT-LAMINATED	
STS-004A		FULL	
DRAWN	R. D. LIGGETT	5/28/51	
CHECKED	F. Noyes	6/13/51	
APPROVED	Ed. J. Latham	6/13/51	



TOLERANCES:

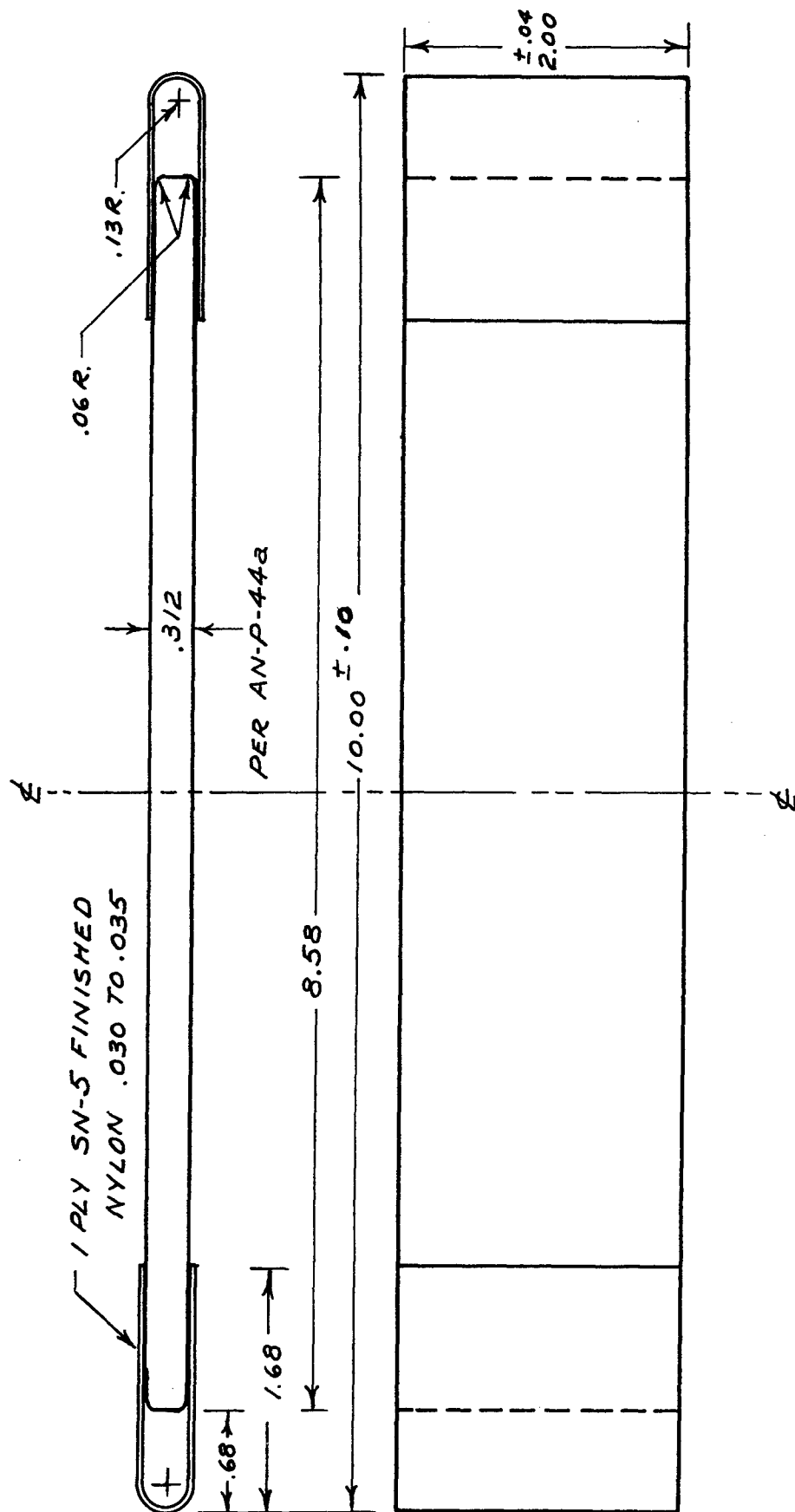
FRACTIONAL $\pm \frac{1}{32}$

DECIMAL .XX $\pm$.030

.XXX $\pm$.010

F-86A TYPE EDGE			SCALE: FULL
ATTACHMENT-LAMINATED			
STS-007			
DRAWN	R. D. LIGGETT	5/24/51	
CHECKED	F. Noyes	6/13/51	
APPROVED	Ed. J. J. J.	6/13/51	

Figure 20.



TOLERANCES:

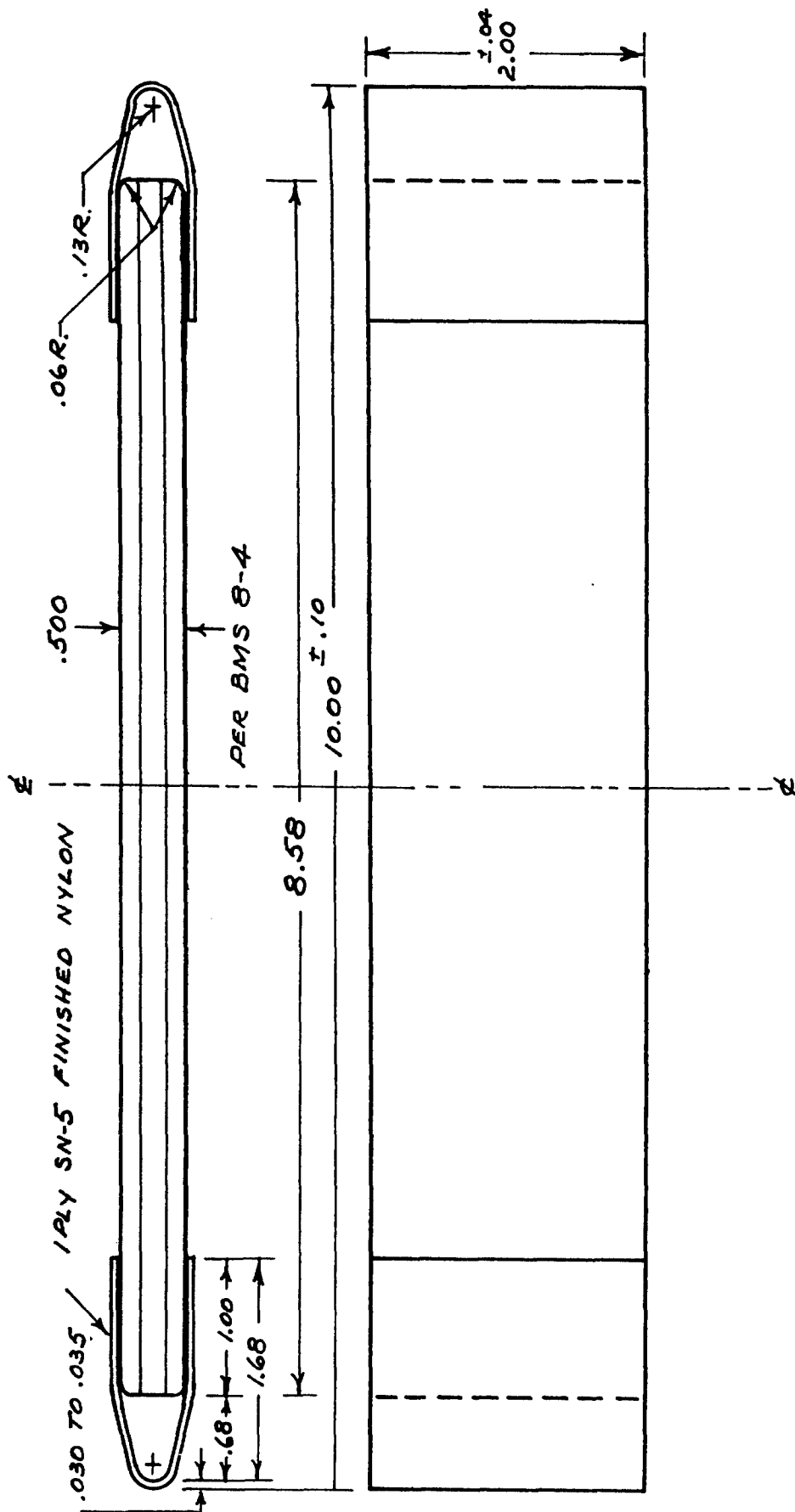
FRACTIONAL $\pm \frac{1}{32}$

DECIMAL .XX $\pm .030$

.XXX $\pm .010$

F-89 TYPE EDGE		SCALE	
ATTACHMENT-MONOLITHIC		FULL	
ST5-008			
DRAWN	R. D. LIGGETT	5/18/51	
CHECKED	F. N. Wiggins	6/13/51	
APPROVED	E. B. J. H. H. H.	6/13/51	

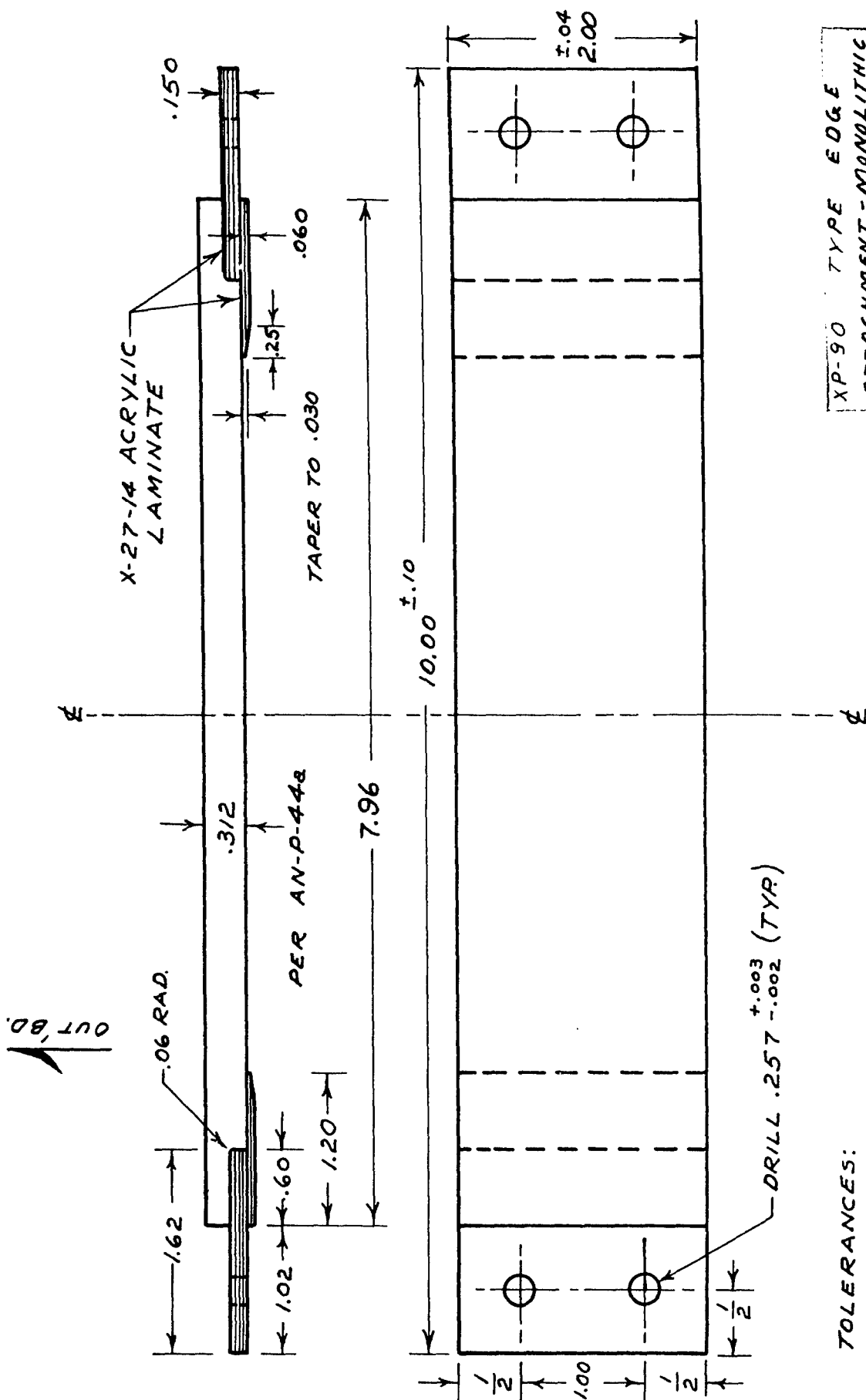
Figure 21.



TOLERANCES:
 FRACTIONAL $\pm \frac{1}{32}$
 DECIMAL $.XX \pm .030$
 $.XXX \pm .010$

F-89	TYPE	EDGE
ATTACHMENT-LAMINATED		
STS-009	FULL	
DRAWN	R.O. LIGGETT	5/24/51
CHECKED	F. Nagels	6/13/51
APPROVED	Elly J. J. J.	6/13/51

Figure 22.

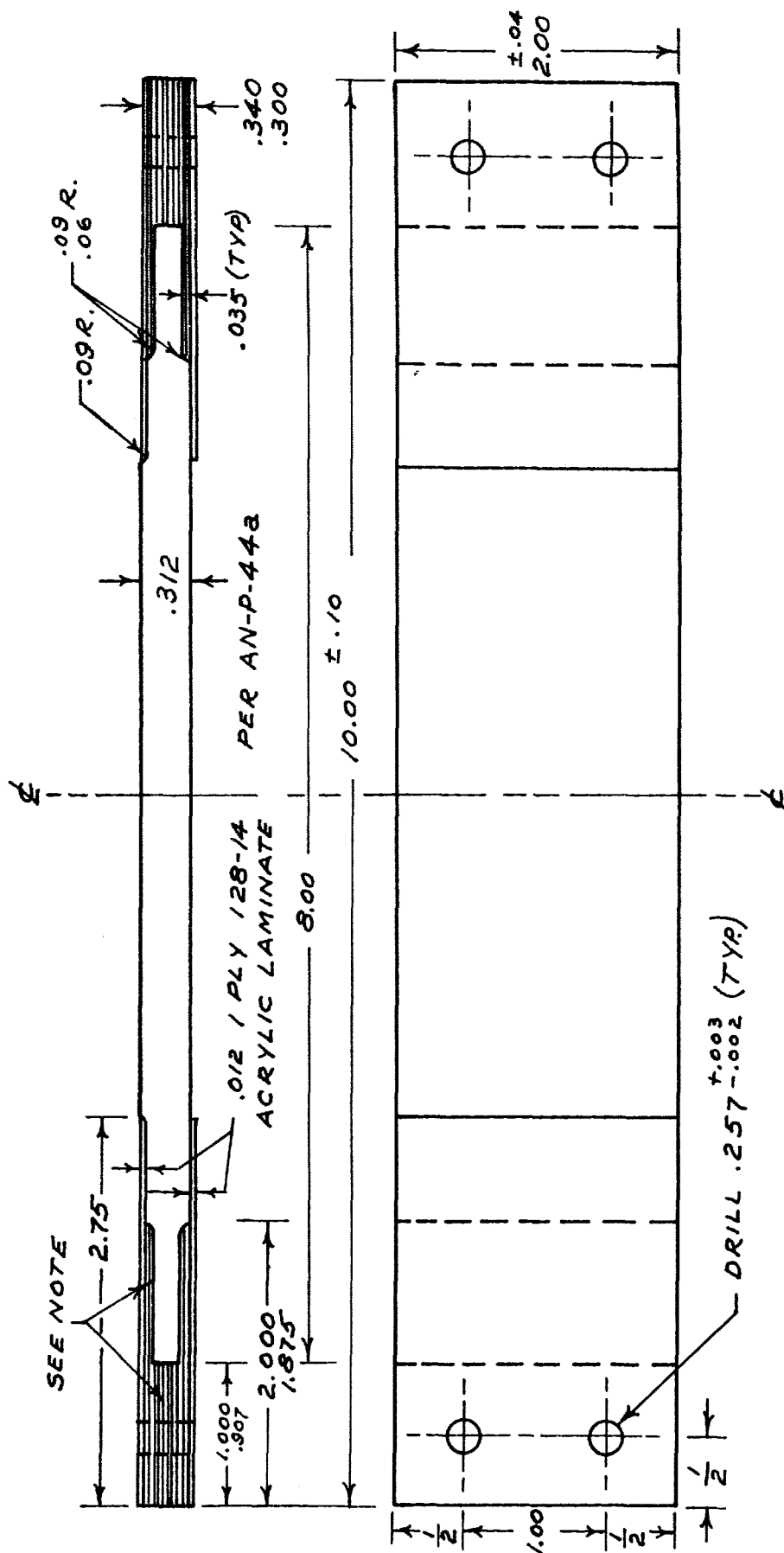


TOLERANCES:

FRACTIONAL	DECIMAL
$\frac{1}{32}$	.XX $\pm .030$
	.XXX $\pm .010$

XP-90	TYPE	EDGE
ATTACHMENT	MONOLITHIC	
STS - 012	FULL	
DESIGN	R. D. LIGGETT	6/4/51
INSPECTED	F. N. ...	6/13/51
APPROVED	...	

Figure 24.



NOTE:
EARS & BUTT-BLOCK TO BE
X-27-14 ACRYLIC LAMINATE.

TOLERANCES:

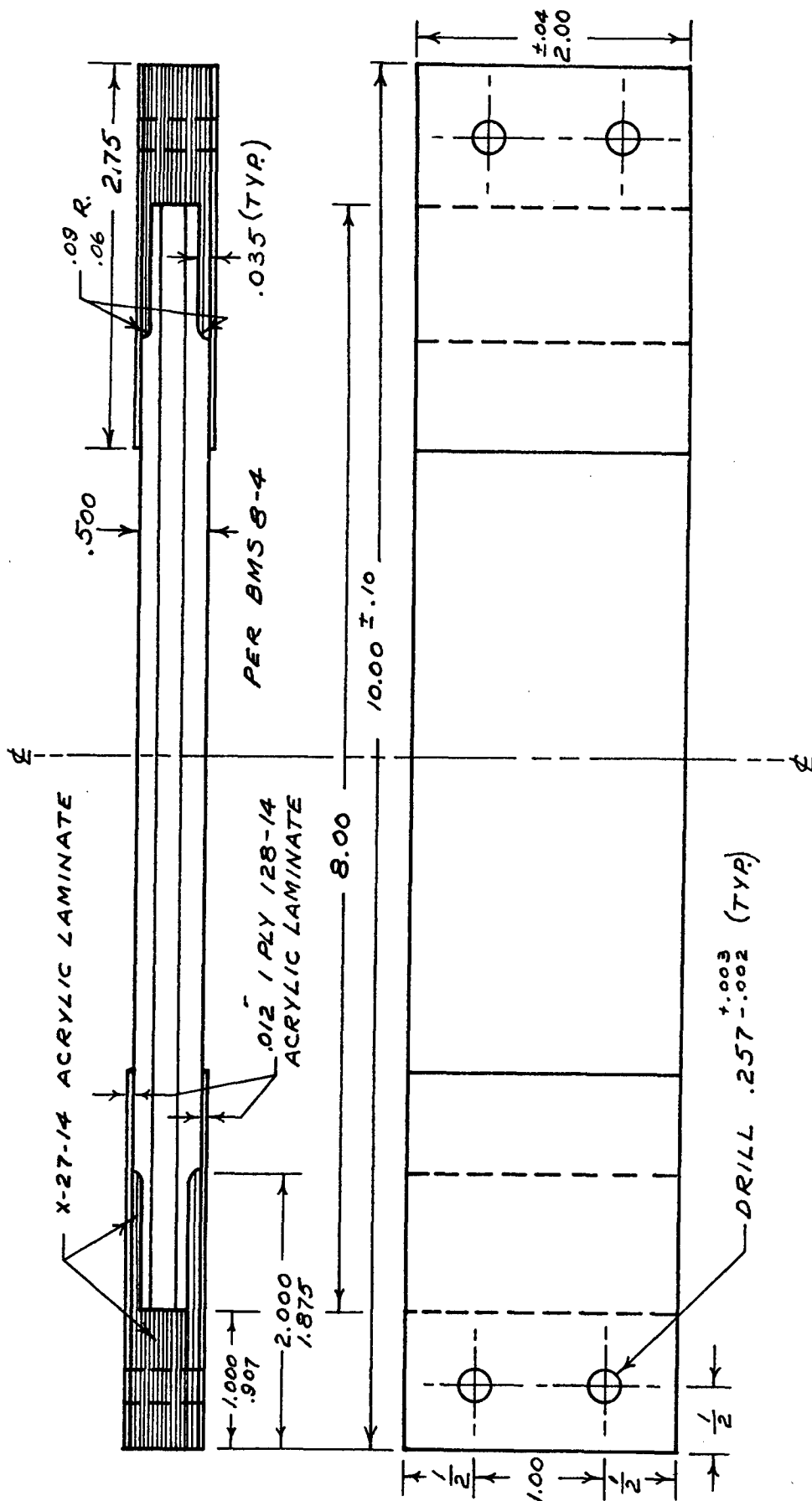
FRACTIONAL $\pm \frac{1}{32}$

DECIMAL .XX $\pm .030$

.XXX $\pm .010$

Figure 26.

F-94 TYPE EDGE		ATTACHMENT - MONOLITHIC	
STS-014A		FULL	
DESIGNED	R.D. LIGGETT	5/15/51	
CHECKED	F. Norris	6/13/51	
APPROVED		6/13/51	

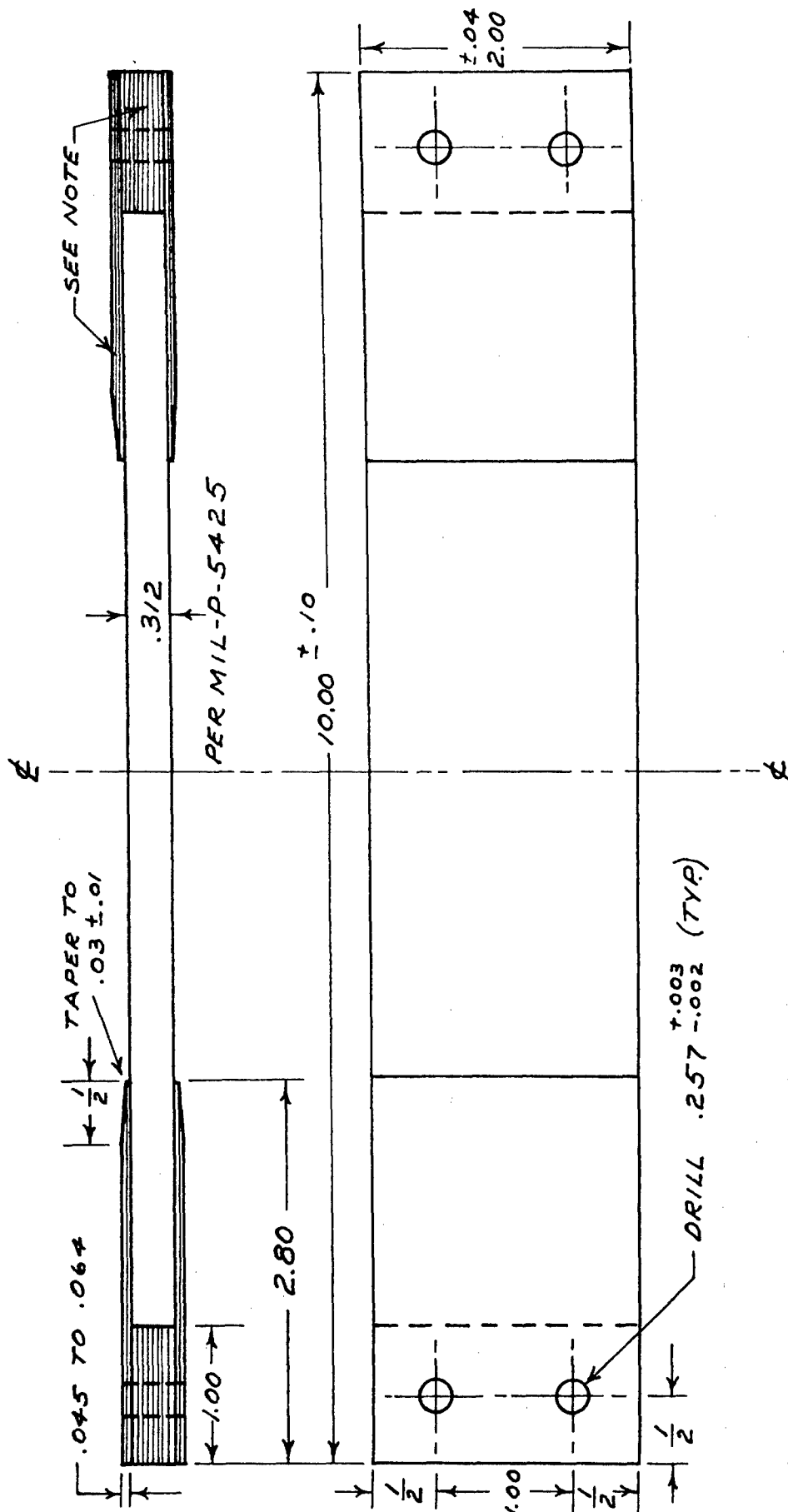


TOLERANCES:

FRACTIONAL	DECIMAL
$\frac{1}{32}$	.XX ± .030
	.XXX ± .010

F-94-C TYPE EDGE	
ATTACHMENT-LAMINATED	
STS-015	
DRAWN	R.D. LIGGETT
CHECKED	F. Norgis
APPROVED	J. L. Latham
	SCALE: FULL
	5/18/51
	6/13/51
	6/13/51

Figure 27.



NOTE:
X-27-14 ACRYLIC EARS & BUTT-BLOCK

TOLERANCES:

FRACTIONAL $\pm \frac{1}{32}$

DECIMAL .XX $\pm .030$

.XXX $\pm .010$

Figure 28.

B-47 TYPE EDGE		ATTACHMENT - MONOLITHIC	
STS-022		FULL	
DRAWN	R. D. LIGGETT	7/31/51	
CHECKED	F. N. Noyes	8/1/51	
APPROVED	W. J. Johnson	8/1/51	

APPENDIX III

TENSILE TEST DETAILS

Tensile test performed at 70°F. $\pm$ 5°F. were conducted on a Dillon Tensile Tester, (Hercules Model K). This machine is operated with a mechanical power drive. The dynamometer indicator is calibrated regularly by the Los Angeles County Department of Weights and Measures using a dead weight method of calibration. Tensile tests performed at -65°F. $\pm$ 0°F. -5°F. were conducted on a Baldwin Universal Tester maintained as commercial testing equipment by Triplett and Barton Incorporated, 831 No. Lake Street, Burbank, California.

In all cases the testing was conducted using a grip which roughly simulated actual frame installation. In the case of rigid attaching ends the specimen was tested in bearing on two 1/4" pins at each end. The Nylon loop type attachments were tested with the loop locked around a 1/4" lateral pin in a slot simulating frame installation.

Tensile test procedures were per ASTM D-628-49T and the rate of pull was .25" per minute.

In the following tabulated test results all specimens ruptured in the acrylic sheet at the inner edge of the attachment unless otherwise noted.

--STS-001A (75°F)--					--STS-001A (-65°F)--			
Spec. No.	Width	Thick ness	Lbs. Pulled	Lbs/inch of Width	Width	Thick ness	Lbs. Pulled	Lbs/inch of Width
1	1.986	.309	3400	1715	2.003	.301	3175	1585
2	1.991	.295	3000	1505	2.000	.303	3260	1630
3	2.012	.301	2550	1268	1.997	.306	3795	1900
4	2.002	.300	2500	1250	1.999	.311	3560	1781
5	2.000	.300	2500	1250	2.008	.323	4265	2124
6	2.007	.298	2500	1243	2.006	.298	2915	1453
7	2.006	.302	2750	1370	2.012	.307	3415	1697
8	1.992	.306	2450	1230	2.008	.309	3565	1775
9	1.995	.323	3050	1530	2.014	.302	3180	1579
10	2.000	.311	2850	<u>1425</u>	2.006	.309	3515	<u>1752</u>
Average				1379	Average 1728			

--STS-002 (75°F)--

Spec. No.	Width	Thick-ness	Lbs. Pulled	Lbs/inch of Width
1	2.004	.517	2750	1370
2	2.000	.517	3500	1750
3	2.006	.516	4000	1990
4	2.009	.510	4600	2290
5	2.004	.520	3150	1570
6	2.008	.518	3100	1542
7	1.985	.516	3695	1860
8	2.005	.514	3450	1720
9	2.007	.516	3700	1840
10	2.000	.515	3550	1775
Average				1771

--STS-002 (-65°F)--

Width	Thick-ness	Lbs. Pulled	Lbs/inch of Width
2.003	.526	4515	2254
2.004	.521	3825	1909
2.003	.531	4400	2197
2.003	.522	5035	2514
1.960	.515	4025	2054
2.002	.523	4600	2298
2.002	.531	3925	1961
2.002	.527	4050	2023
2.001	.515	4480	2239
2.001	.531	5130	2564
Average			2201

--STS-003A (75°F)--

1	2.002	.314	1800	900
2	2.008	.315	1650	823
3	2.005	.318	1850	922
4	2.010	.319	1650	820
5	2.007	.316	1700	848
6	2.006	.313	1850	921
7	2.007	.317	2050	1022
8	1.999	.313	1850	925
9	1.992	.306	1950	980
10	2.004	.318	1950	970
Average				913

Specimen No.2 failed in bearing.

--STS-003A (-65°F)--

2.000	.311	2675	1338
2.007	.315	2415	1203
2.009	.325	1990	991
2.009	.325	1700	846
2.013	.309	2190	1088
2.006	.316	1820	907
2.002	.326	1995	997
2.006	.321	1890	942
2.005	.319	1980	988
1.999	.315	1790	895
Average			1019

All specimens failed in bearing.

--STS-004A (75°F)--

1	2.011	.510	2700	1342
2	2.004	.512	3050	1520
3	2.002	.508	2850	1425
4	2.004	.507	2350	1172
5	2.004	.512	2950	1472
6	2.009	.507	2650	1320
7	2.000	.509	2700	1350
8	2.001	.514	2800	1400
9	2.003	.512	--	--
10	1.992	.513	2850	1432
11	2.000	.508	2950	1475
Average				1391

All specimens failed in bearing except specimen No.4 which ruptured acrylic sheet at the inner edge of the tongue.

--STS-004A (-65°F)--

2.025	.517	2200	1086
2.007	.513	3095	1542
2.018	.519	2960	1467
2.011	.510	2375	1181
2.015	.517	2875	1427
2.014	.511	2800	1390
2.011	.533	2945	1464
2.003	.512	1500	749*
2.015	.511	2435	1208
2.015	.517	3005	1491
Average			1362

All specimens failed in bearing.

--STS-005 (75°F)--

Spec. No.	Width	Thick- ness	Lbs. Pulled	Lbs/inch of Width
1	1.995	.312	1250	627
2	1.985	.302	985	497
3	1.981	.307	1100	555
4	1.982	.309	1200	605
5	1.997	.303	1225	615
6	1.982	.311	1250	630
7	1.992	.303	1300	653
8	1.995	.303	1225	615
9	1.992	.303	1150	578
10	1.998	.309	1200	<u>600</u>

Average 598

Specimen No.1 ruptured the Nylon Cloth at the lower edge of the acrylic.

--STS-005 (-65°F)--

Width	Thick- ness	Lbs. Pulled	Lbs/inch of Width
1.999	.334	1500	750
1.998	.323	1440	721
1.999	.331	1440	720
1.996	.339	1485	744
1.952	.339	1425	730
1.999	.306	1385	693
2.000	.323	1545	773
1.998	.330	1410	706
2.000	.338	1510	755
1.998	.312	1465	<u>733</u>

Average 733

--STS-007 (75°F)--

1	2.004	.523	600	299
2	1.999	.520	600	300
3	1.999	.528	775	388
4	1.999	.518	700	350
5	2.000	.531	760	380
6	2.001	.524	525	262
7	2.000	.522	600	300
8	1.997	.521	575	288
9	2.000	.530	760	380
10	1.996	.523	720	<u>361</u>

Average 331

In every case the acrylic rupture originated from the face rout.

--STS-007 (-65°F)--

1.994	.533	1685	845
1.998	.534	1665	833
1.997	.514	1640	821
1.995	.517	1600	832
1.997	.513	1590	796
1.993	.511	1485	745
1.995	.509	1555	779
1.998	.510	1625	813
1.995	.524	1440	722
1.997	.527	1620	<u>811</u>

Average 800

--STS-008 (75°F)--

1	1.998	.306	1200	601
2	1.980	.307	1225	618
3	1.985	.306	1250	630
4	1.992	.306	1250	628
5	1.994	.306	1235	619
6	2.000	.304	1275	638
7	1.998	.306	1300	650
8	1.998	.303	1300	650
9	1.997	.306	1250	626
10	1.993	.306	1275	<u>640</u>

Average 630

Items 1 through 7 and item 9 failed cement line between Nylon and acrylic sheet. Item 8 ruptured acrylic above the attach. Item 10 failed in the Nylon cloth.

--STS-008 (-65°F)--

1.990	.326	1285	646
1.980	.292	1375	694
1.991	.330	1375	691
1.997	.320	1250	626
1.995	.321	1170	586
1.993	.331	1070	537
2.000	.331	1070	535
1.998	.332	1200	601
1.996	.344	1000	501
1.933	.292	1215	<u>629</u>

Average 605

All specimens failed in shear between Nylon and acrylic sheet.

--STS-009 (75°F)--

Spec. No.	Width	Thick-ness	Lbs. Pulled	Lbs/inch of Width
1	2.003	.300	1270	634
2	2.000	.300	1270	635
3	2.004	.300	1340	668
4	2.003	.300	1270	634
5	2.003	.300	1220	609
6	2.002	.300	1220	610
7	2.003	.300	1270	634
8	2.000	.300	1270	635
9	2.001	.300	1080	540
10	2.006	.300	1365	680

Average 628

In all specimens the acrylic face sheets under the cemented part of the loop cracked and shattered; then bond failed.

--STS-009 (-65°F)--

Width	Thick-ness	Lbs. Pulled	Lbs/inch of Width
1.996	.501	1550	777
2.002	.504	1515	757
2.003	.507	1510	754
1.998	.505	1490	746
1.997	.507	1585	794
1.999	.517	1600	800
1.997	.506	1520	761
1.998	.525	1490	746
2.000	.518	1520	760
1.996	.500	1595	799

Average 769

All specimens failed the Nylon cloth.

--STS-010 (75°F)--

1	1.992	.326	2000	1003
2	1.992	.331	2050	1028
3	1.993	.318	2200	1105
4	1.992	.326	1850	928
5	1.985	.318	2500	1260
6	1.985	.323	2350	1184
7	1.985	.326	1750	882
8	1.987	.318	2450	1233
9	1.987	.318	2300	1158
10	1.987	.323	1950	982

Average 1076

--STS-010 (-65°F)--

2.002	.333	2400	1199
2.002	.340	2665	1331
2.000	.308	2150	1075
1.996	.312	2405	1205
1.995	.309	1930	967
2.002	.332	2475	1236
1.998	.320	1940	971
2.000	.318	2100	1050
1.987	.332	2355	1185
1.991	.331	2515	1263

Average 1148

--STS-012 (75°F)--

1	2.005	.306	2650	1322
2	2.005	.309	2600	1297
3	1.997	.299	2350	1177
4	1.997	.297	2350	1177
5	2.003	.308	2480	1238
6	1.999	.303	2250	1125
7	2.005	.311	2480	1237
8	2.000	.300	2480	1240
9	2.003	.298	2384	1190
10	2.004	.298	2432	1213

Average 1222

--STS-012 (-65°F)--

1.996	.330	3210	1608
1.997	.343	3050	1527
2.001	.333	2955	1477
1.992	.335	3055	1534
1.990	.340	3050	1533
1.995	.337	3265	1637
1.997	.339	3260	1632
1.987	.333	3110	1565
1.993	.342	2700	1355
2.004	.342	2920	1457

Average 1533

--STS-013 (75°F)--

Spec. No.	Width	Thick-ness	Lbs. Pulled	Lbs/inch of Width
1	1.999	.523	3705	1853
2	1.990	.521	3935	1977
3	1.995	.524	4035	2022
4	2.001	.522	3110	1555
5	2.004	.524	3790	1890
6	1.990	.509	3355	1686
7	2.000	.512	3550	1775
8	2.003	.511	3450	1772
9	1.990	.498	3450	1732
10	2.005	.514	3650	1820

Average 1803

In specimens 2, 7, and 10 the Fiberglas laminate failed in bearing.

--STS-013 (-65°F)--

Width	Thick-ness	Lbs. Pulled	Lbs/inch of Width
2.000	.510	3400	1700
1.981	.493	2895	1462
1.999	.503	2700	1351
1.996	.498	2730	1368
2.000	.497	2865	1433
1.995	.497	2665	1336
1.998	.502	2865	1434
2.000	.503	2615	1308
2.000	.496	2860	1430
2.005	.475	2675	1334

Average 1416

--STS-014A (75°F)--

1	1.997	.313	3210	1607
2	2.002	.295	3210	1604
3	1.975	.314	2965	1502
4	1.999	.315	3110	1555
5	1.994	.315	3210	1610
6	1.992	.296	2965	1488
7	2.000	.297	2565	1283
8	1.985	.295	2575	1297
9	2.001	.314	2870	1435
10	2.004	.313	3065	1530

Average 1491

--STS-014A (-65°F)--

1.987	.294	3200	1611
1.985	.309	4120	2076
1.992	.327	2775	1393
1.995	.336	3250	1629
1.997	.337	3225	1615
1.983	.335	3150	1589
1.998	.333	3245	1624
1.996	.338	3495	1751
1.995	.331	2560	1283
1.998	.325	3350	1677

Average 1605

--STS-015 (75°F)--

1	2.004	.514	2480	1237
2	1.998	.515	2480	1241
3	2.002	.517	2720	1358
4	2.003	.493	3115	1555
5	2.001	.510	2870	1434
6	2.003	.502	3110	1552
7	2.009	.500	2820	1404
8	2.000	.509	3450	1725
9	2.008	.512	3210	1599
10	1.996	.508	3115	1560

Average 1467

--STS-015 (-65°F)--

1.997	.517	4025	2016
2.005	.527	3755	1873
1.998	.531	4225	2115
2.005	.494	4730	2359
1.998	.496	3630	1817
2.000	.512	4390	2195
1.999	.529	3710	1856
1.996	.530	4250	2129
2.009	.518	3940	1961
2.004	.529	3790	1891

Average 2041

--STS-022 (75°F)--

<u>Spec. No.</u>	<u>Width</u>	<u>Thick- ness</u>	<u>Lbs. Pulled</u>	<u>Lbs./inch of Width</u>
1	2.001	.288	2720	1359
2	1.995	.302	2965	1486
3	2.002	.289	3060	1528
4	1.997	.297	3545	1775
5	2.003	.285	2670	1332
6	2.000	.285	2625	1313
7	2.003	.301	3400	1697
8	1.991	.297	3200	1607
9	2.005	.307	3075	1533
10	2.003	.313	3000	<u>1497</u>
Average				1512

--STS-022 (-65°F)--

<u>Width</u>	<u>Thick- ness</u>	<u>Lbs. Pulled</u>	<u>Lbs./inch of Width</u>
2.001	.318	4600	2299
2.002	.285	3740	1868
2.001	.293	4050	2014
2.002	.290	3710	1853
1.998	.319	3710	1857
2.003	.321	4540	2267
2.002	.292	3800	1898
2.003	.330	4680	2336
2.005	.322	4650	2319
2.001	.336	3615	<u>1807</u>
Average			2052

--STS-023 (75°F)--

<u>Spec. No.</u>	<u>Width</u>	<u>Thick- ness</u>	<u>Lbs. Pulled</u>	<u>Lbs./inch of Width</u>
1	2.002	.514	2460	1228
2	1.998	.520	3240	1622
3	2.001	.504	2200	1100
4	2.001	.504	2510	1255
5	2.004	.506	2430	1213
6	2.009	.507	2280	1135
7	2.004	.504	1985	990
8	2.000	.508	2600	1300
9	1.998	.502	2135	1068
10	2.006	.505	2300	<u>1147</u>
Average				1206

--STS-023 (-65°F)--

<u>Width</u>	<u>Thick- ness</u>	<u>Lbs. Pulled</u>	<u>Lbs./inch of Width</u>
2.003	.512	5495	2743
2.004	.519	5115	2552
2.003	.521	5590	2791
2.003	.509	5850	2921
2.003	.521	5775	2883
2.001	.500	5525	2761
1.998	.520	5565	2785
1.998	.520	5320	2663
1.995	.504	5575	2795
1.998	.511	5620	<u>2813</u>
Average			2771

APPENDIX IV

TENSILE-FATIGUE DATA

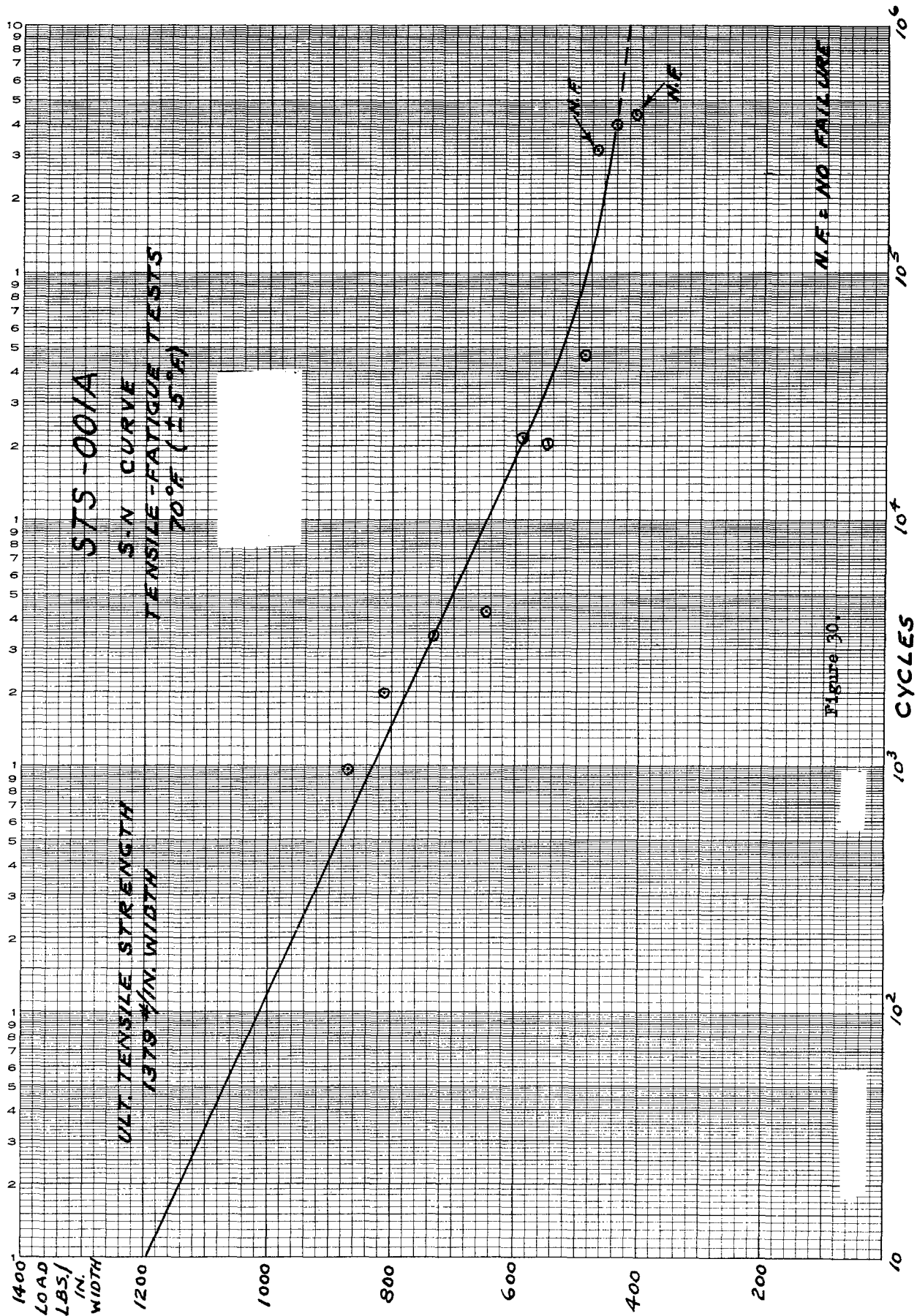
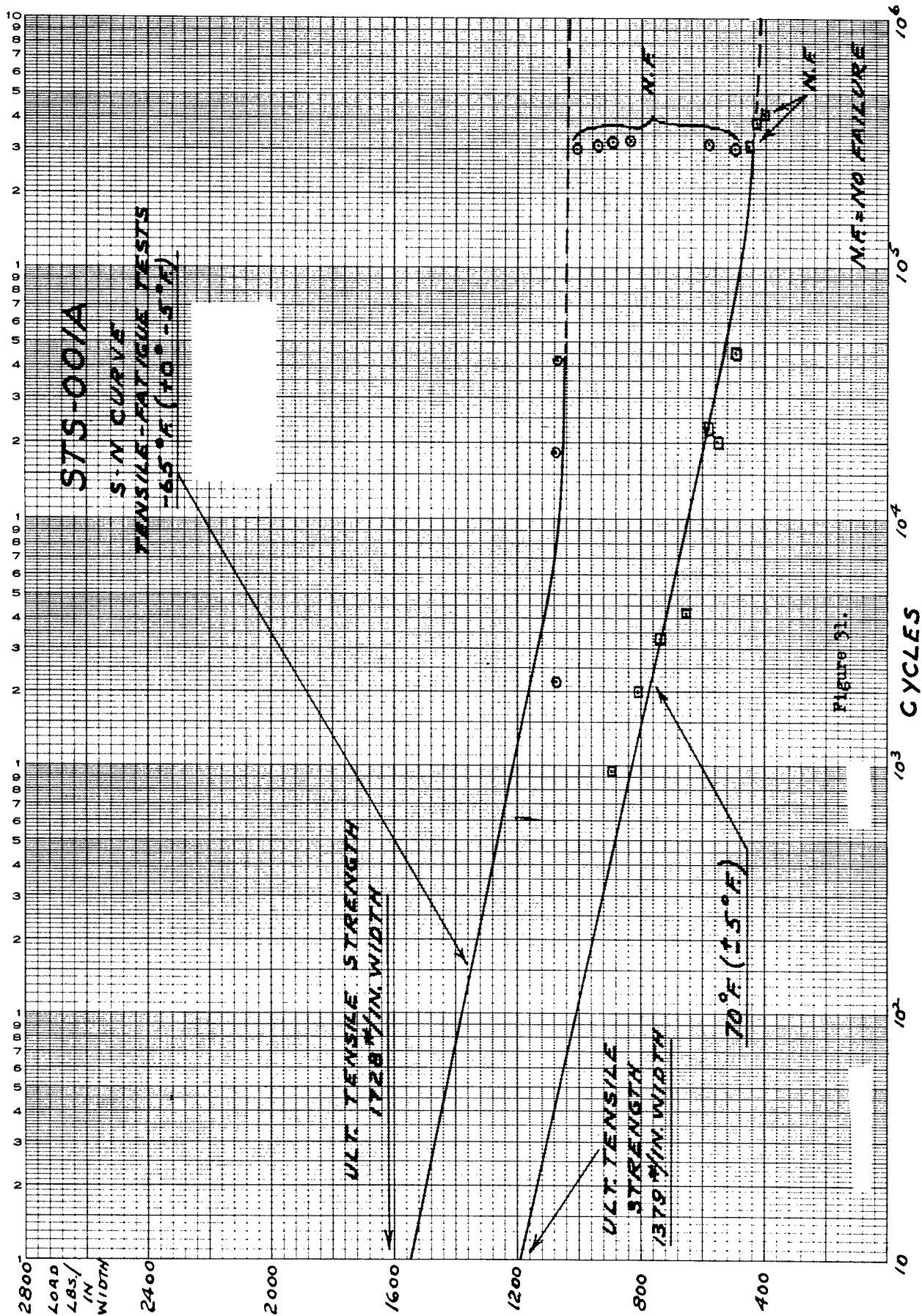


Figure 30.



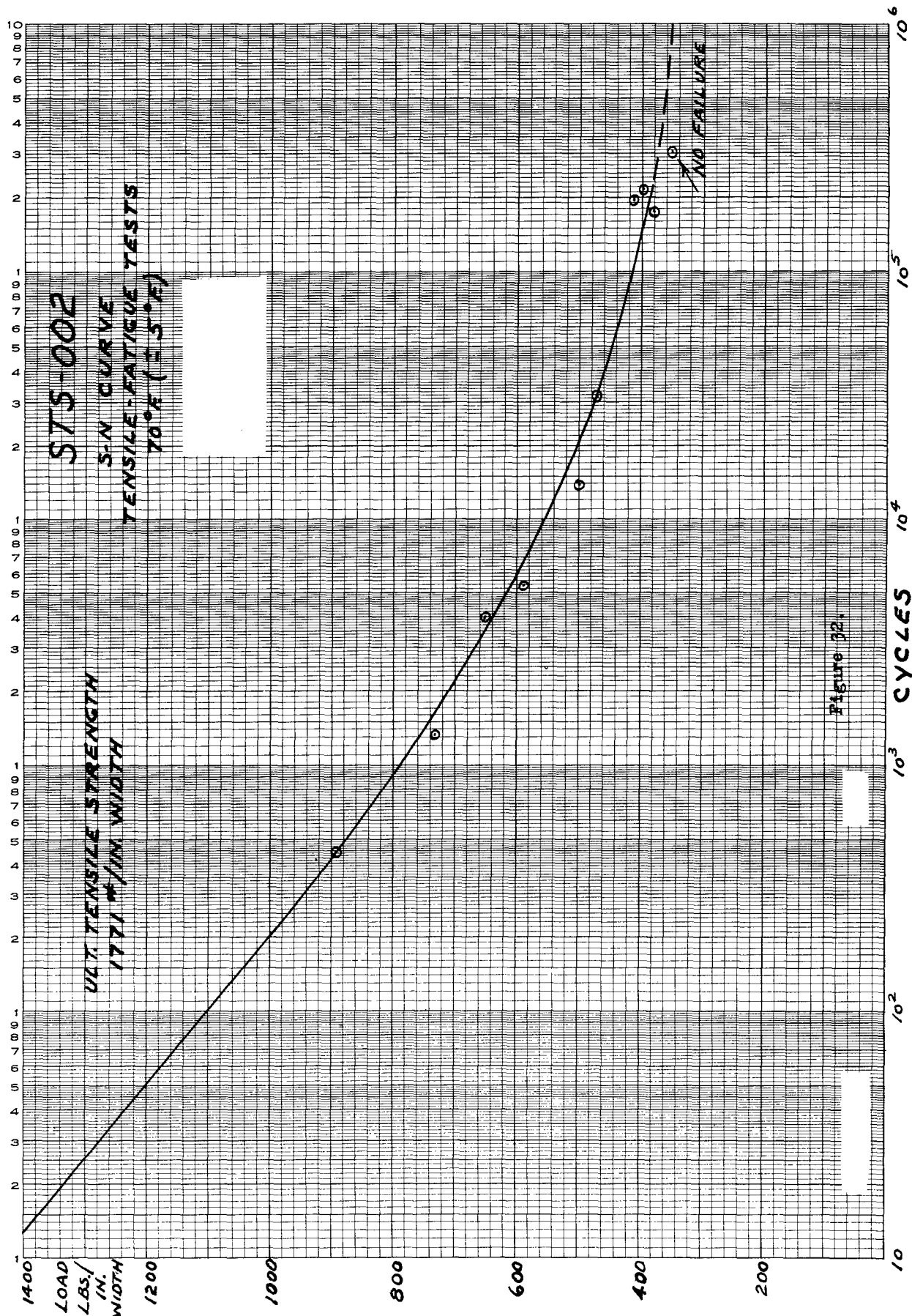


Figure 32.

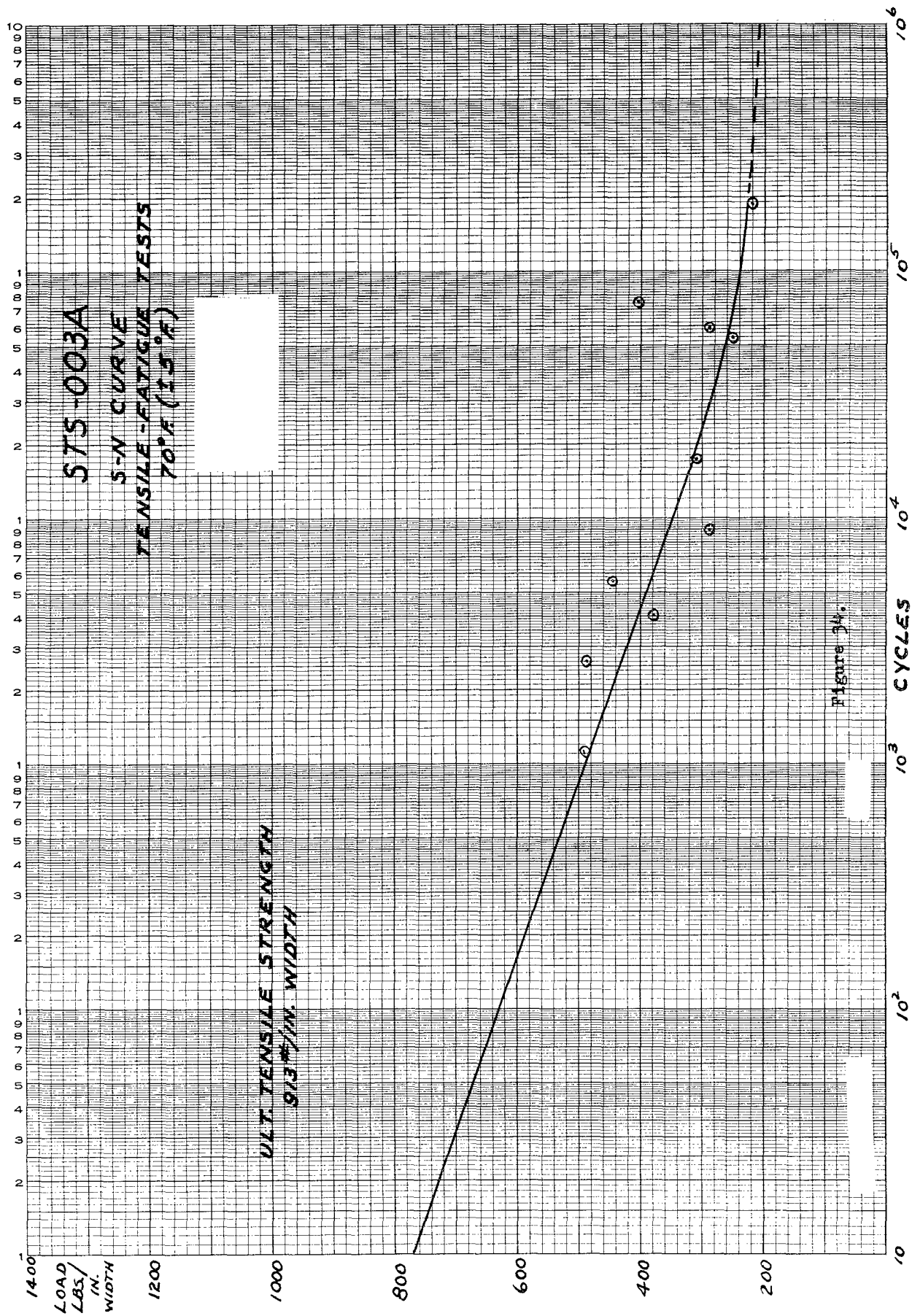


Figure 34.

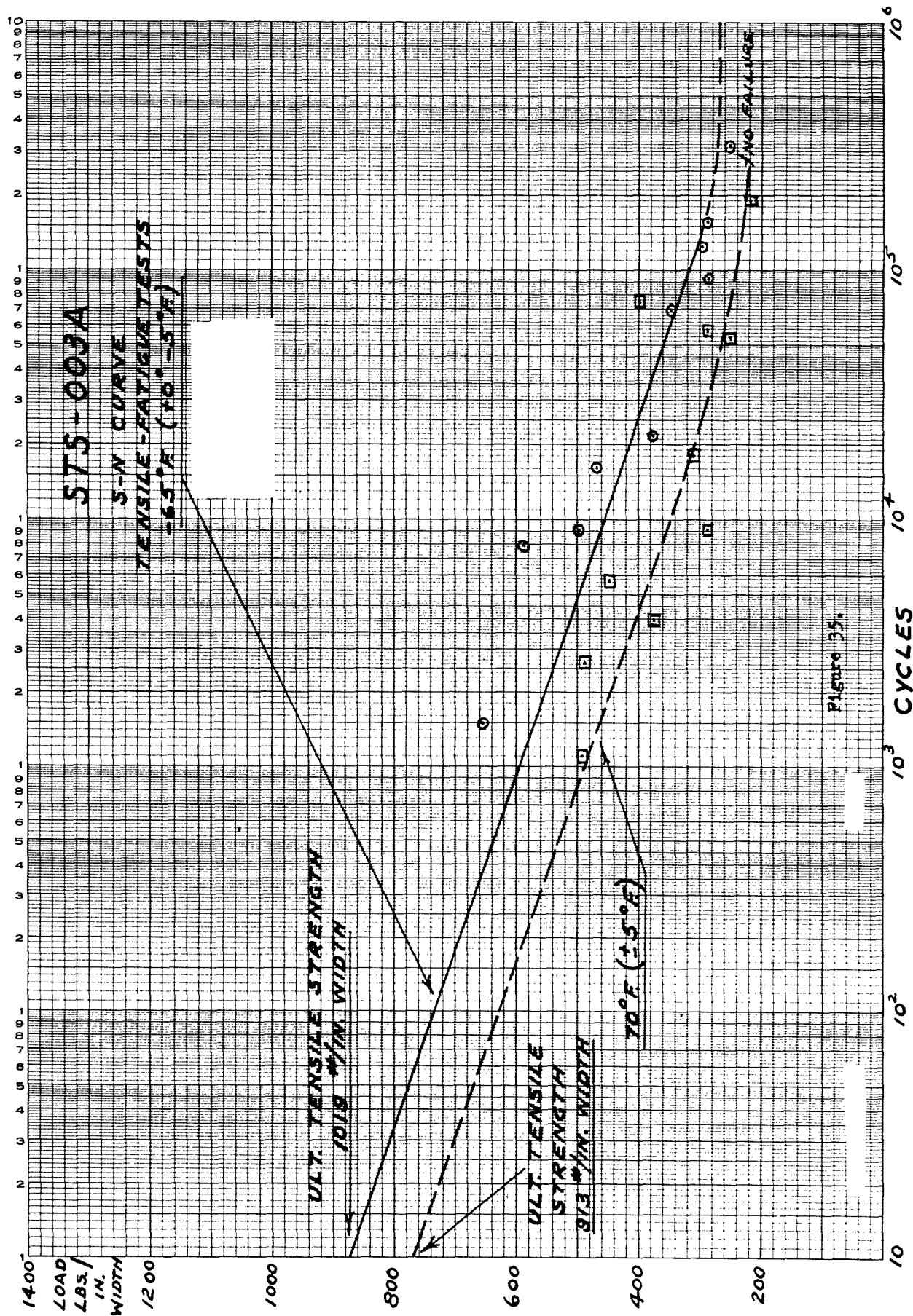
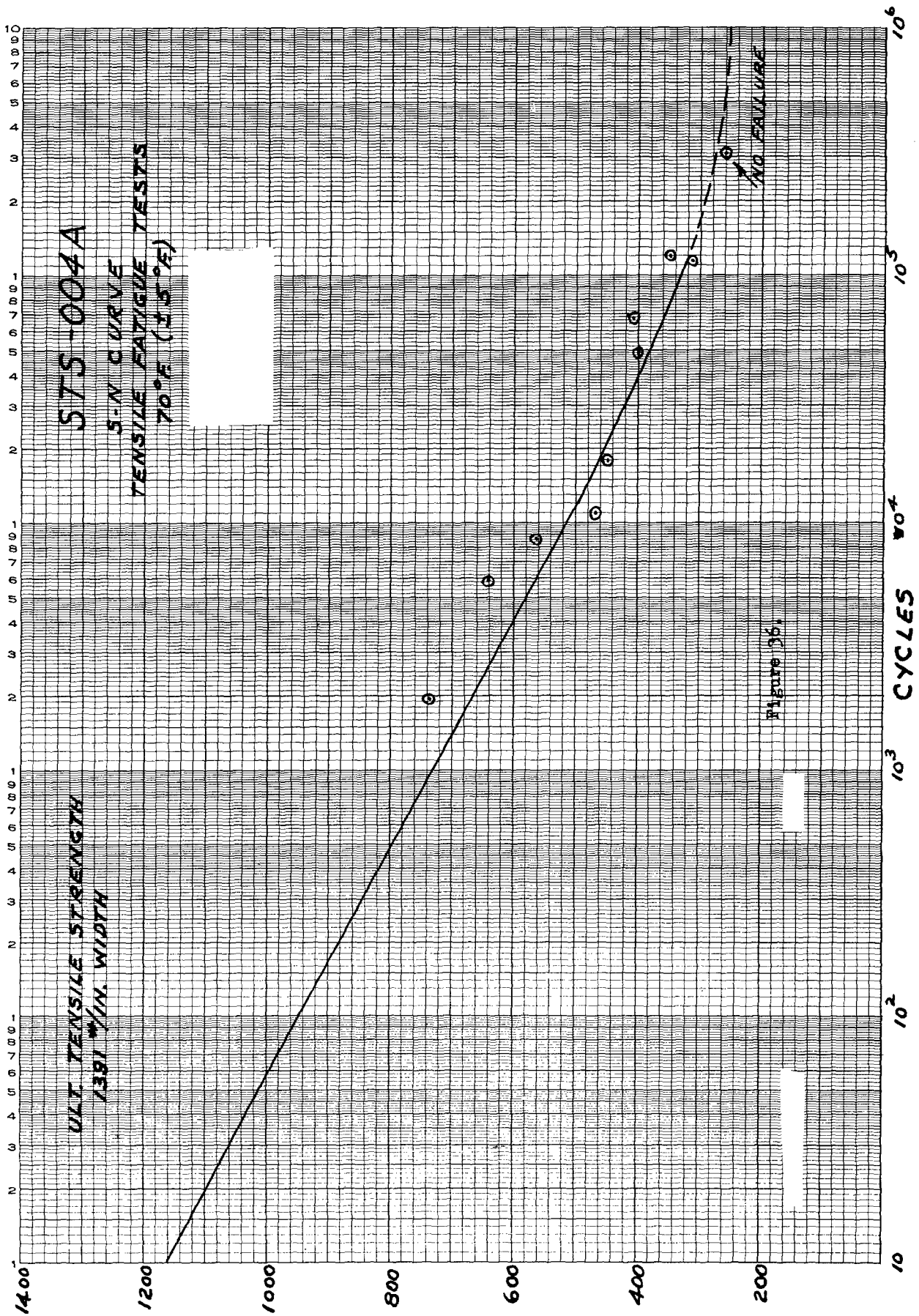
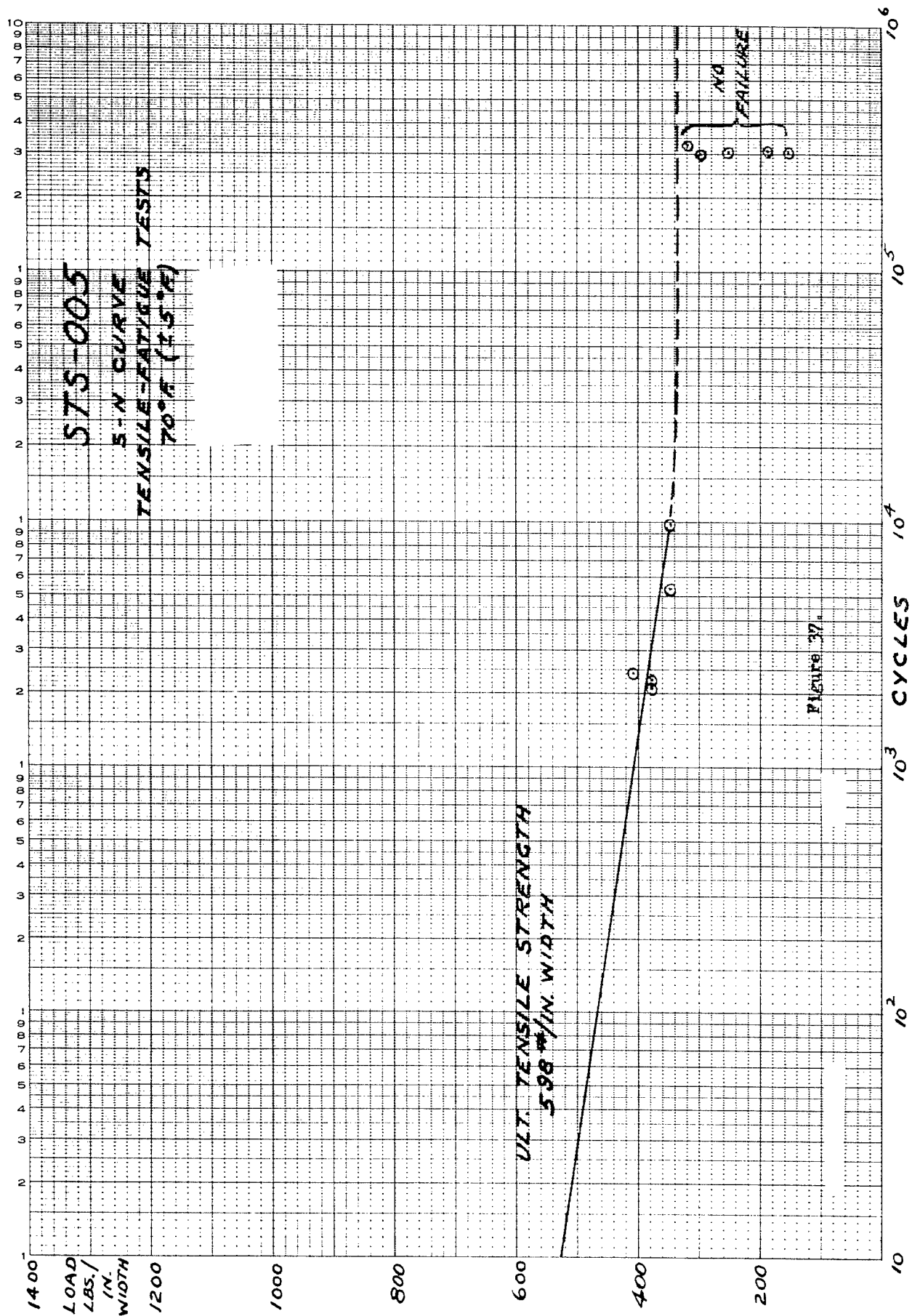
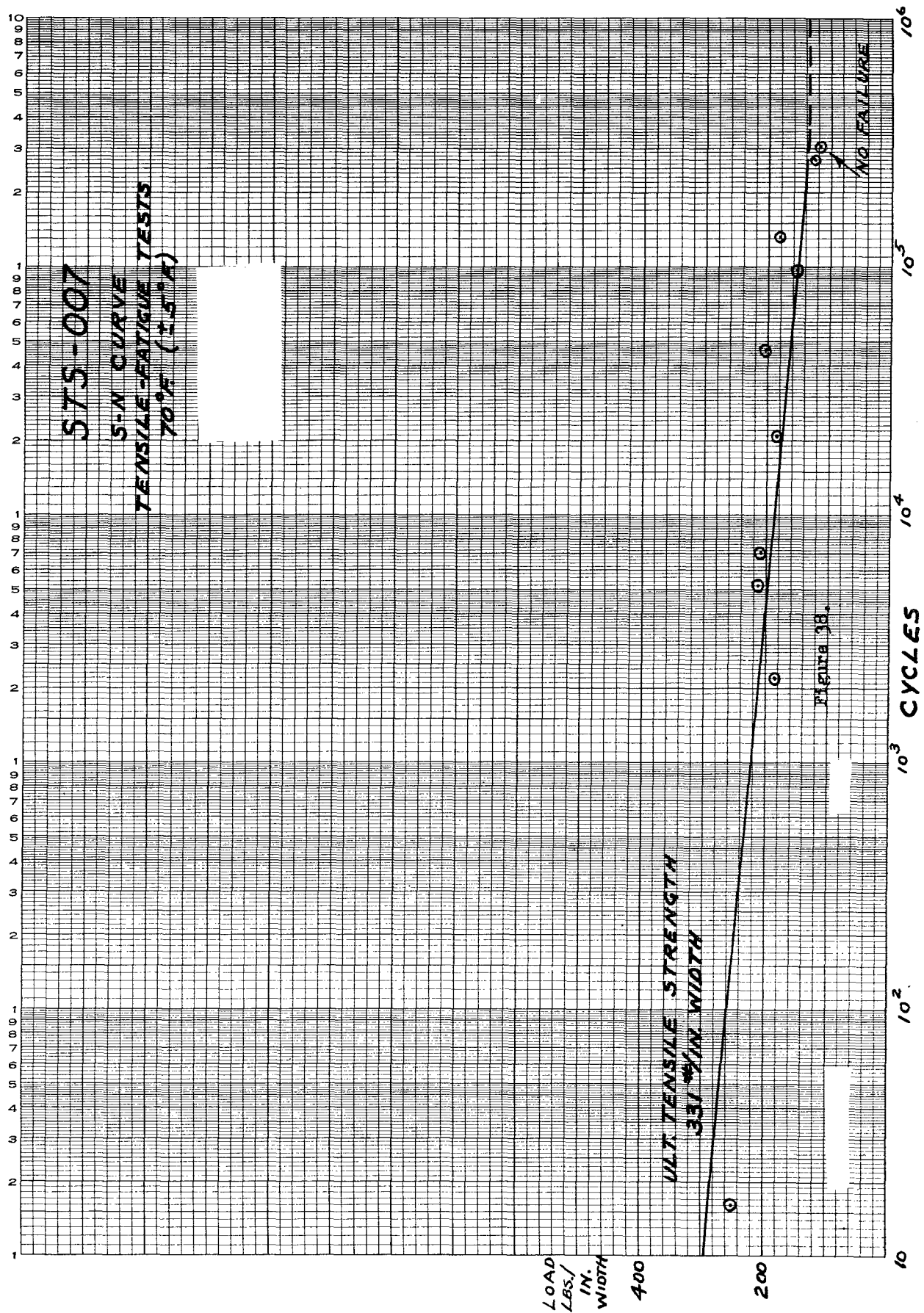


Figure 35.







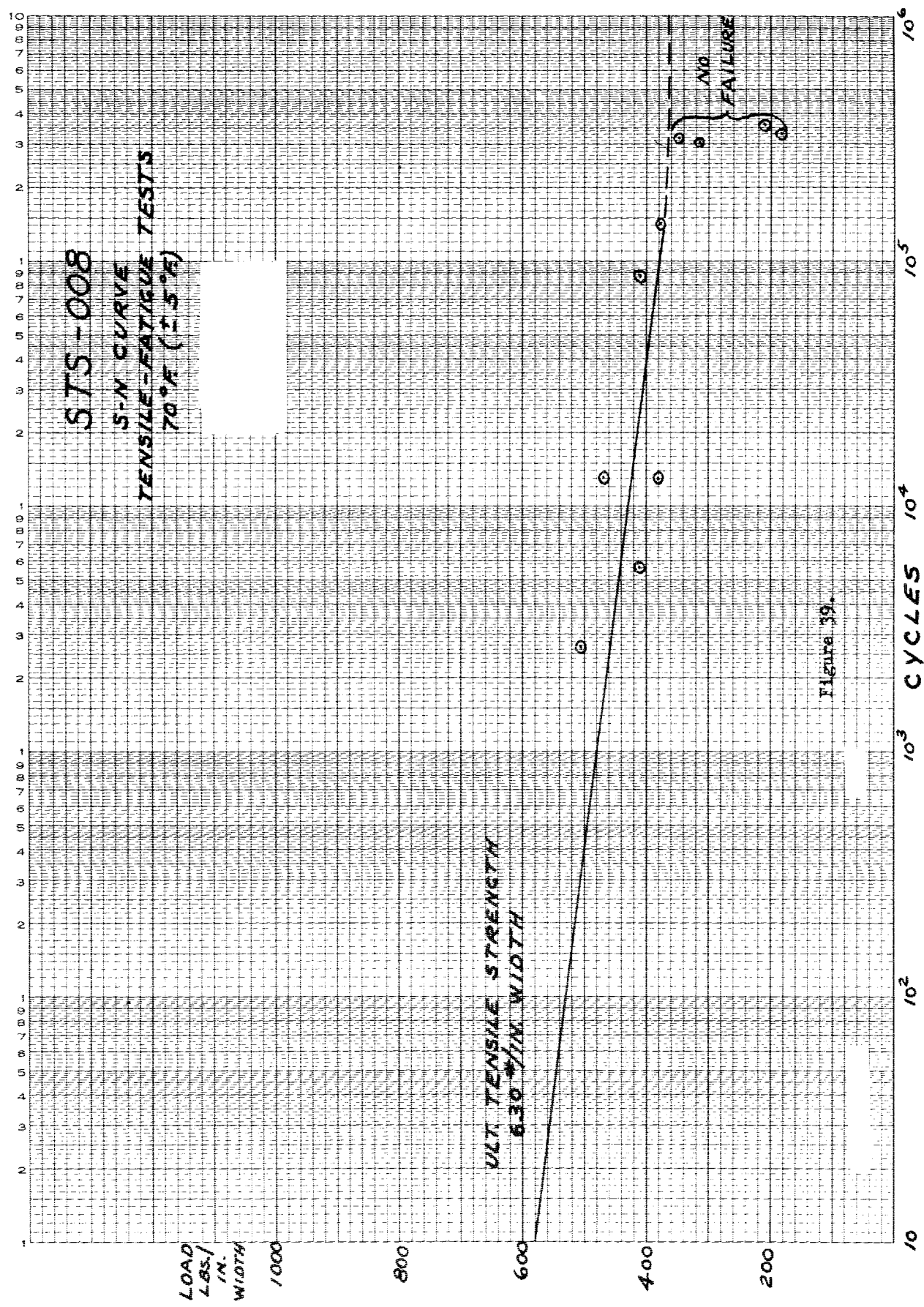


Figure 39.

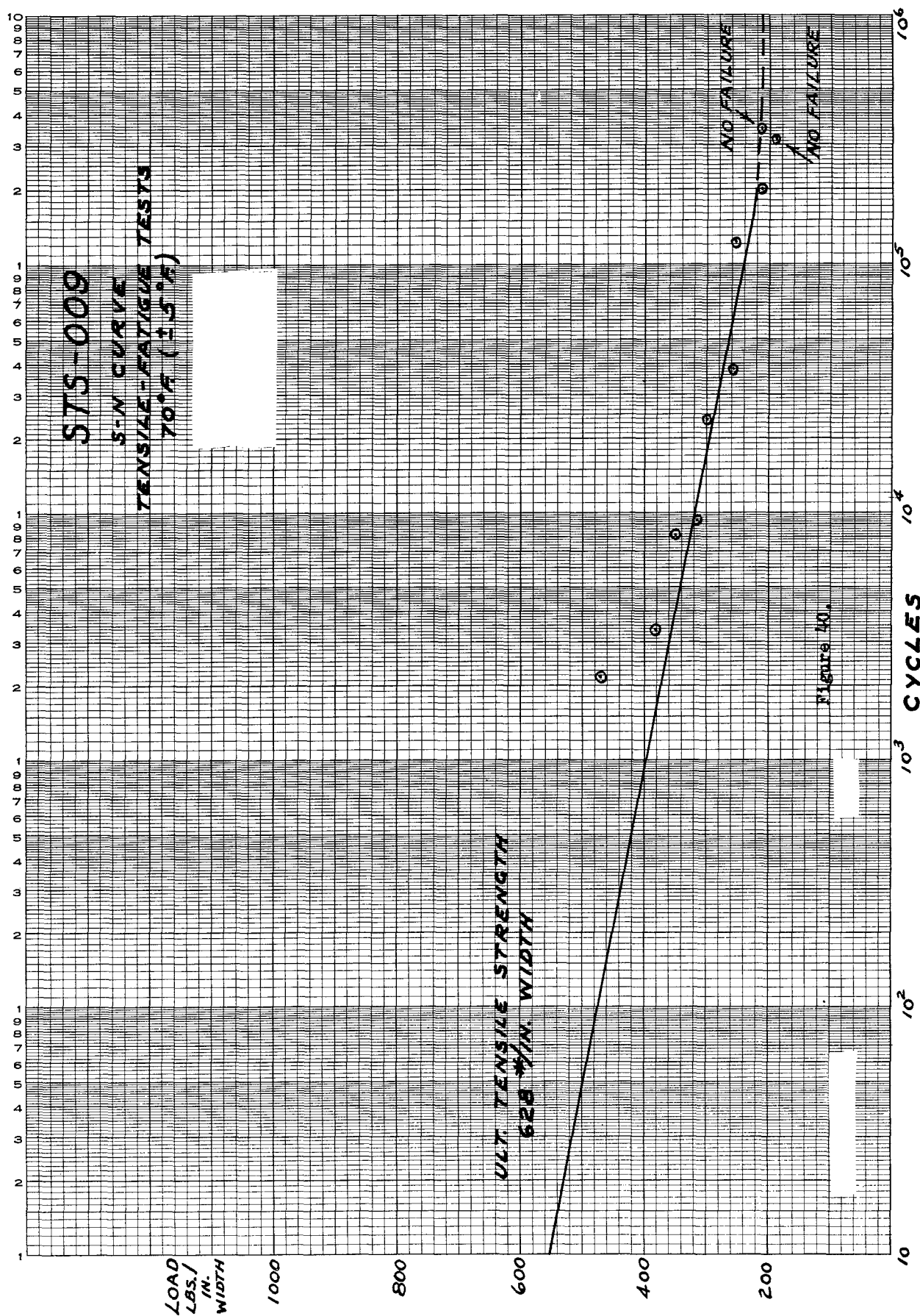
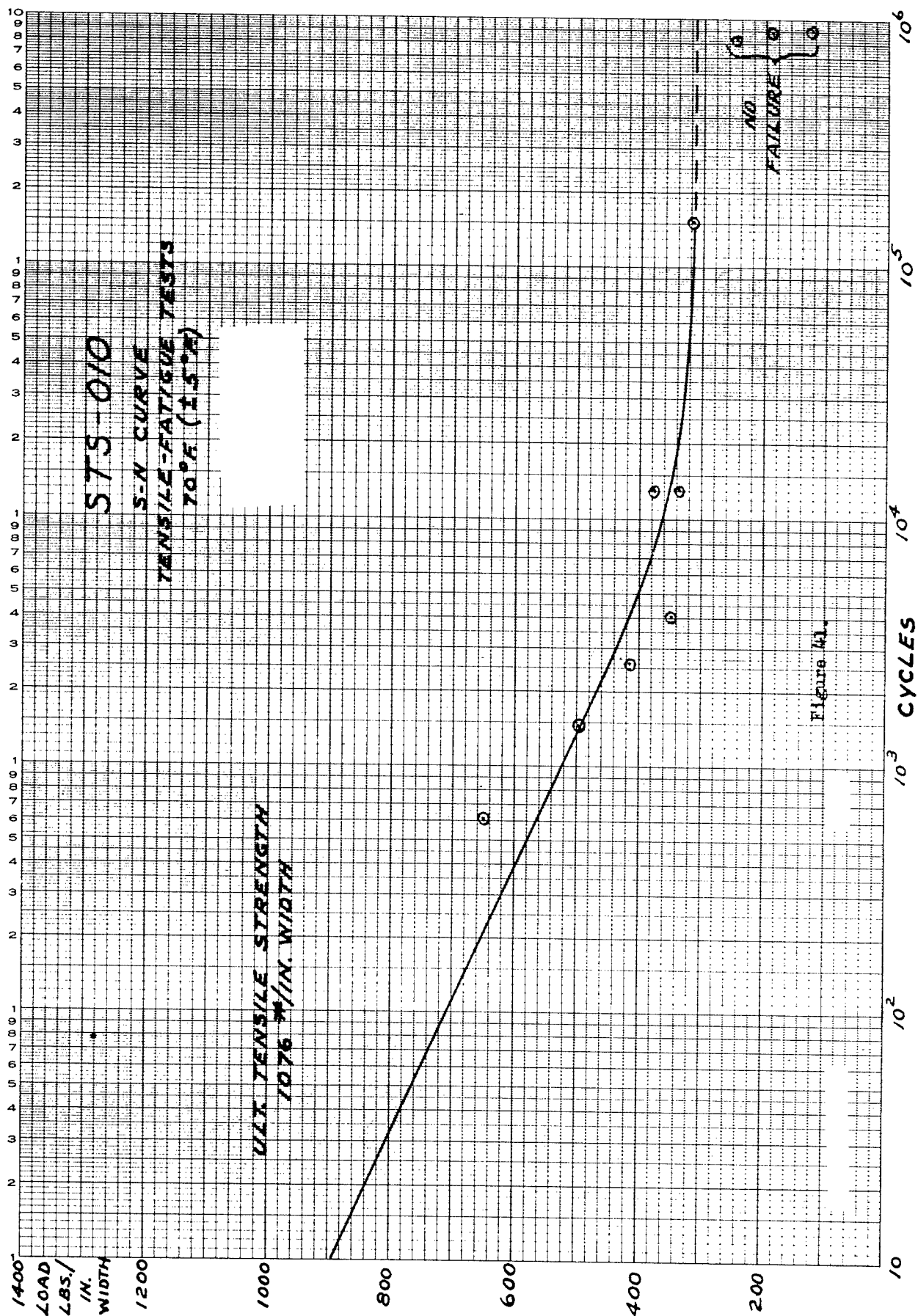
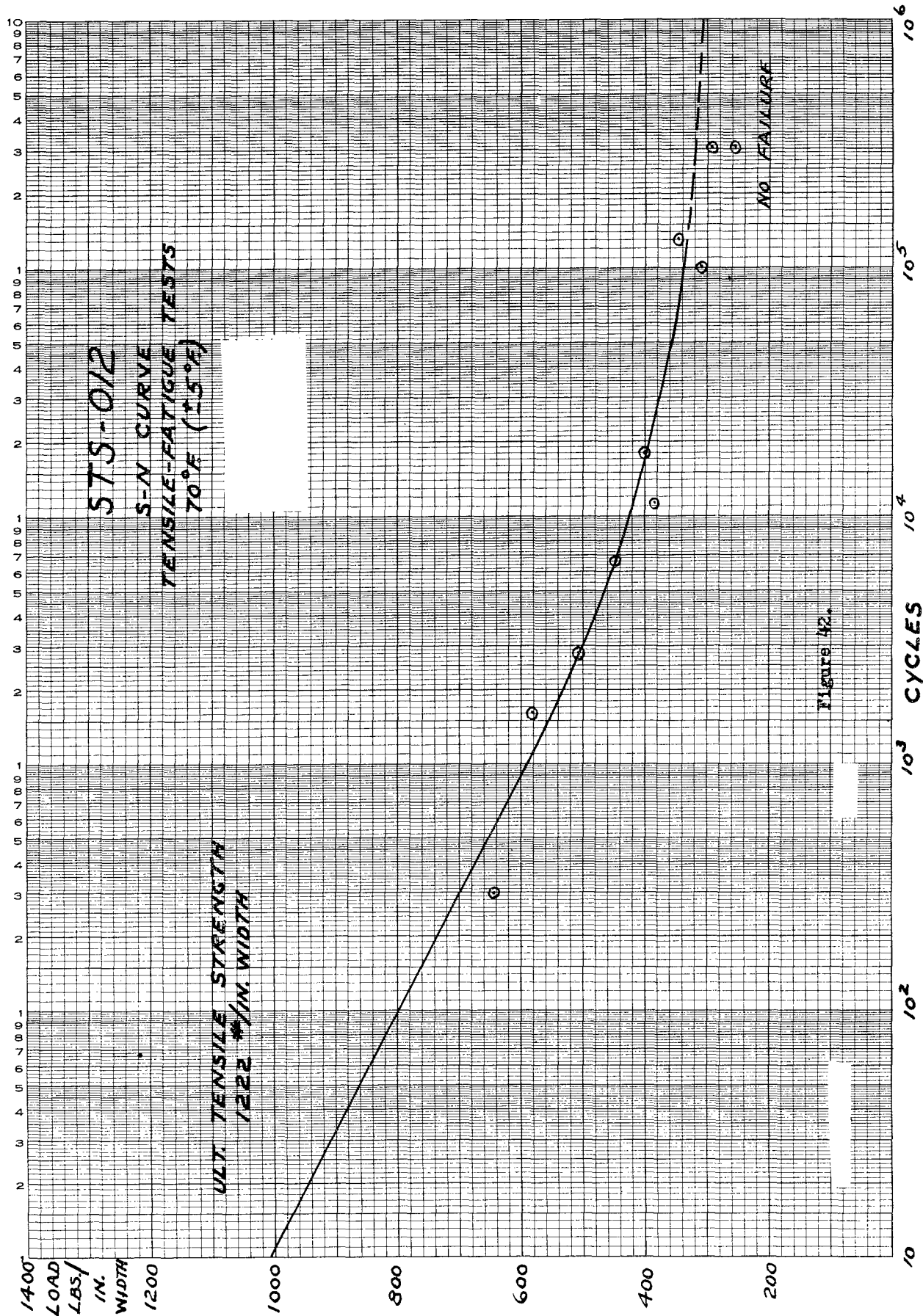


Figure 40.





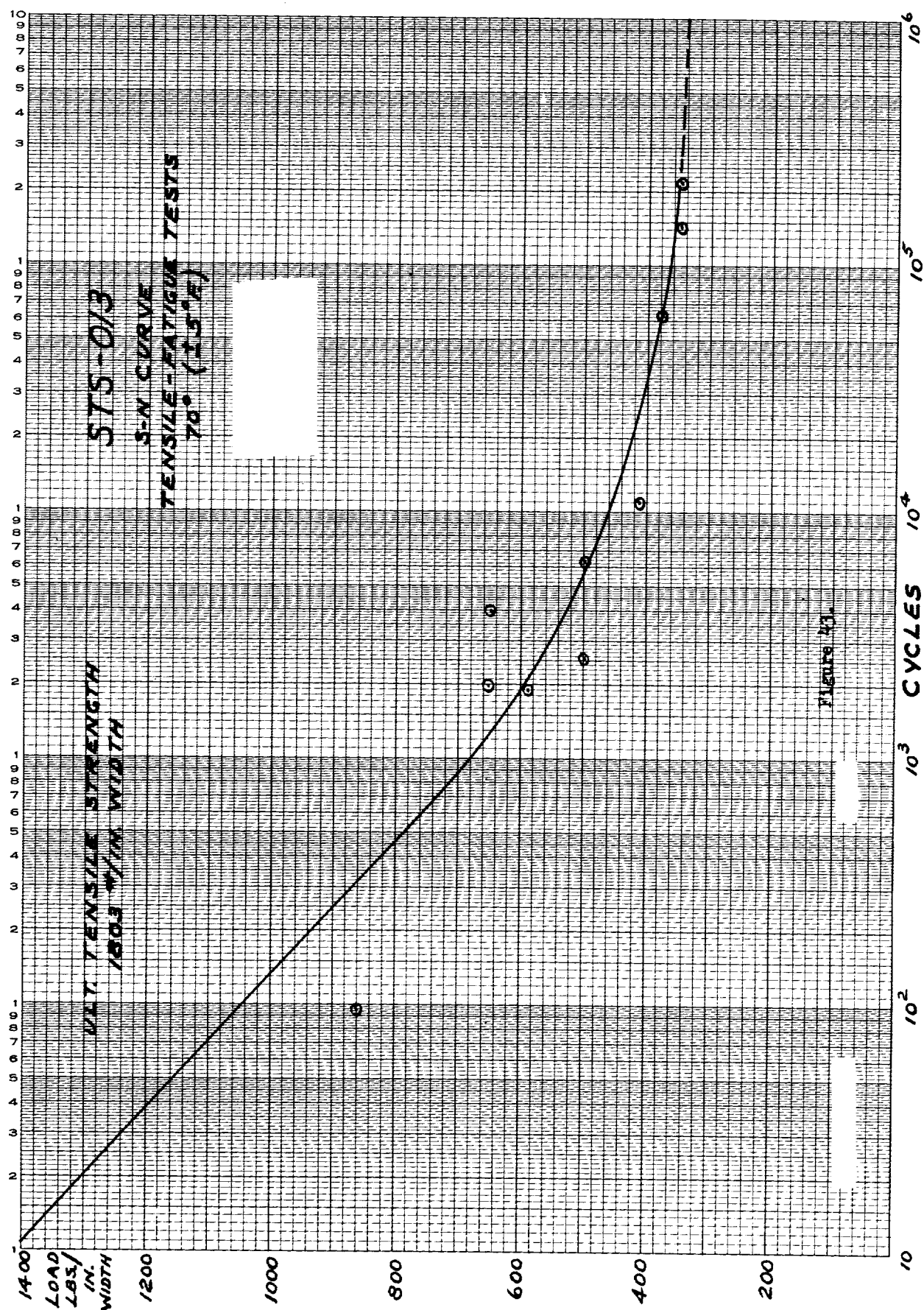


Figure 43.

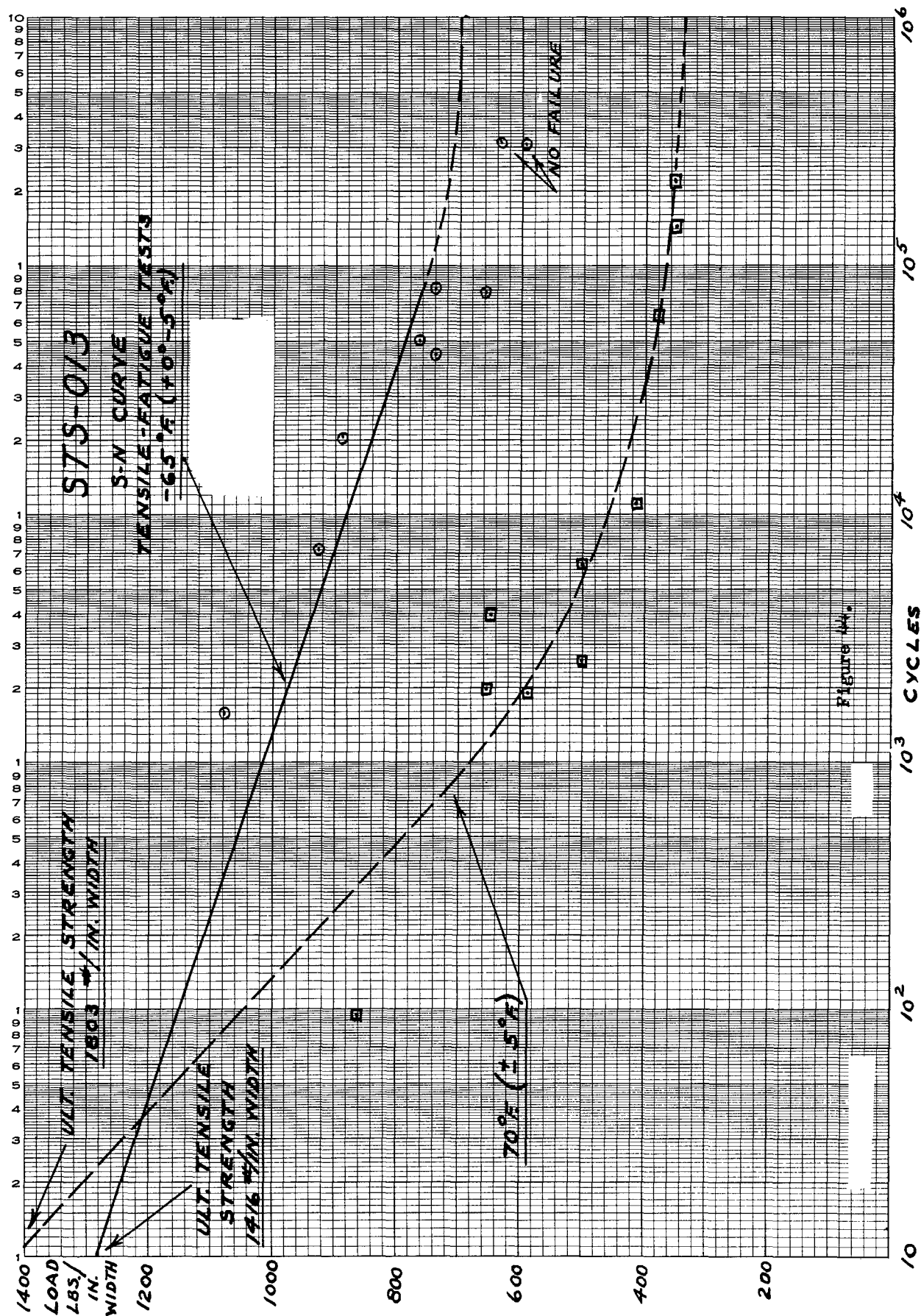


Figure 44.

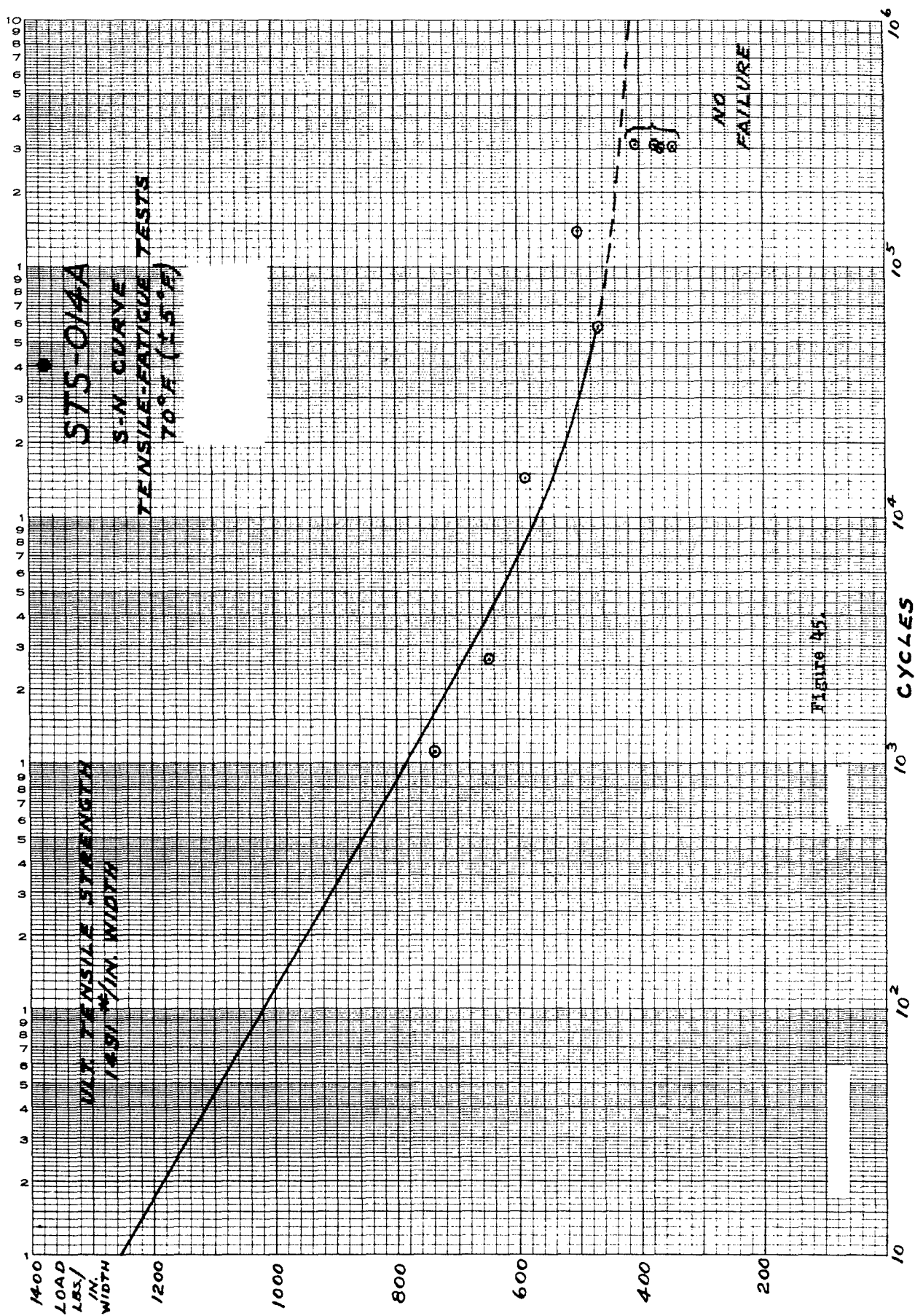


FIGURE 45.

