NASA CR 72125

260-IN.-DIA MOTOR FEASIBILITY DEMONSTRATION PROGRAM

Volume VI: 260-SL Motor Nozzle and Exit Cone Assemblies

Book 2: Figures & Appendixes

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NO. NAS3-6284

AEROJET-GENERAL CORPORATION

SACRAMENTO, CALIFORNIA

N67-30895 (ACCESSION NUMBER)
(THRU)
497 (PAGES)
1 (CODE)
28 (CATEGORY)
(NASA CR OR TMX OR AD NUMBER)
FACILITY FORM 602

NASA CR 72125

FINAL PHASE REPORT

260-IN.-DIA MOTOR FEASIBILITY DEMONSTRATION PROGRAM

Volume VI

260-SL MOTOR NOZZLE AND EXIT CONE ASSEMBLIES

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8 April 1966

Contract No. NAS3-6284

Technical Management
NASA Lewis Research Center
Cleveland, Ohio

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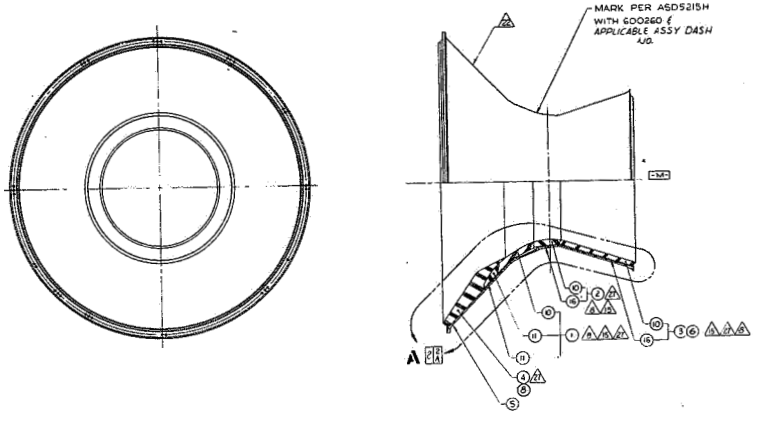
REVISIONS				
LTR	ZONE	DESCRIPTION	DATE	APPROVED
A		SEE "A" CHG ADCN INC	[illegible]	[illegible]
B		SEE "B" CHG ADCN INC	[illegible]	[illegible]
C		SEE "C" CHG ADCN INC	[illegible]	[illegible]
D		SEE "D" CHG DCN	[illegible]	[illegible]
E		SEE "E" CHG ADCN INC	[illegible]	[illegible]
F		SEE "F" CHG ADCN INC	[illegible]	[illegible]
G		SEE "G" CHG ADCN INC	[illegible]	[illegible]
H		SEE DCN	[illegible]	[illegible]
J		SECURITY CLASSIFICATION DOWNGRADED TO UNCLASSIFIED BY AUTHORITY OF DD 254 DATED 6-28-68 SEE DCN.	18 JUL 68	[illegible]

NOTES:

1. REMOVE ALL BURRS AND SHARP EDGES EQUIVALENT TO .005 -.015 R UNLESS OTHERWISE SPECIFIED.
2. INTERPRET DRAWING PER STANDARDS PRESCRIBED IN MIL-D-70327.
3. SURFACE ROUGHNESS 125/ UNLESS OTHERWISE SPECIFIED.
4. [-M-] IS DEFINED AS A STRAIGHT LINE CONNECTING THE CENTERS OF [-A-] AND [-B-].
5. WHEN PART IS REFERENCED TO A STANDARD TEMPERATURE OF 68° F AND WITH [-A-] AND [-B-] RESTRAINED TO DRAWING TOLERANCES, ALL OTHER DIMENSIONS SHALL BE WITHIN DRAWING TOLERANCES.

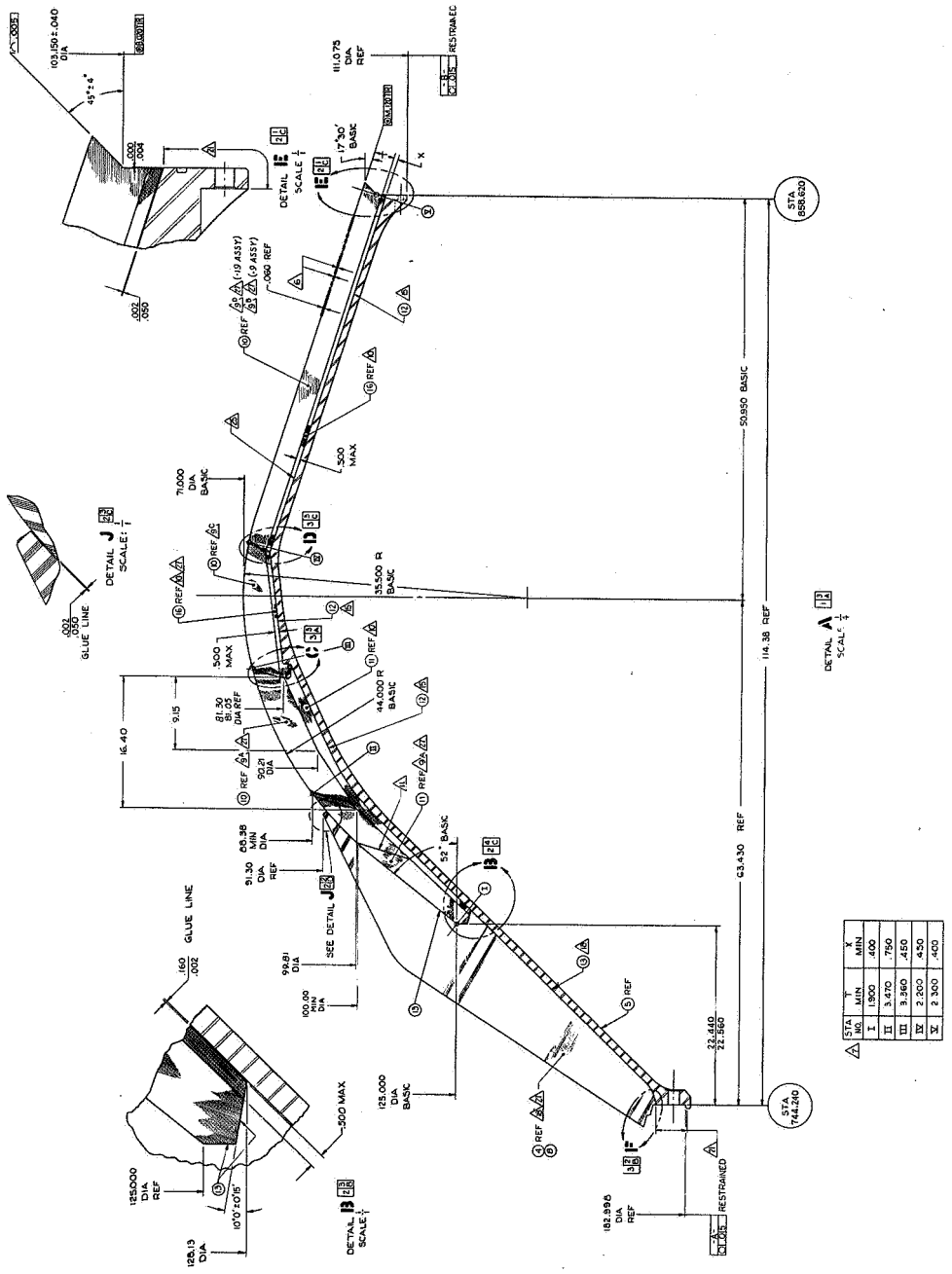
6. CONTOUR MAY VARY WITHIN .030 EITHER SIDE OF BASIC WITH MAXIMUM SLOPE VARIATION NOT TO EXCEED .005 INCH PER INCH.
7. DIMENSIONS MEASURED NORMAL TO INSIDE SURFACE.
8. MOLD IN ACCORDANCE TO AGC-36413 AT 1,000 PSI HYDROCLAVE PRESSURE.
9. LAMINATE ORIENTATION TO BE:
   A. 75° TO 85° HALF ANGLE WITH RESPECT TO CENTER LINE NOZZLE.
   B. 15° TO 25° HALF ANGLE WITH RESPECT TO CENTER LINE NOZZLE.
   C. 60° TO 70° HALF ANGLE WITH RESPECT TO CENTER LINE NOZZLE.
   D. 30° TO 40° AS WRAPPED HALF ANGLE WITH RESPECT TO CENTER LINE NOZZLE.
10. TAPE TO BE WRAPPED PARALLEL TO EXTERIOR SURFACE OF INNER PART.
11. SURFACE TO COINCIDE WITHIN 0.010" OF ADJACENT LAMINATES.
12. REMOVED.
13. LUBRICATE PACKING WITH MIL-L-4343 LUBRICATING GREASE.
14. INSTALLED PACKING I.D. STRETCH TO BE FROM 1 TO 3%.
15. INSTALL INSERTS USING AGC-34151, TYPE II ADHESIVE. PROCESS AND CURE AT 180° MAXIMUM CURE TEMPERATURE PER AGC-36422.
16. FILL GAP WITH AGC-34076, CLASS 5 SEALING COMPOUND.
17. THIS AREA TO BE FREE OF ADHESIVE AND AGC-34076 SEALING COMPOUND
18. INSTALL INSULATION USING AGC-34151 TYPE III OR TYPE IV ADHESIVE IN ACCORDANCE TO AGC-36422 AND AGC APPROVED PROCESS. MAXIMUM CURE TEMPERATURE TO BE 180°F.
19. LEAK TEST PER AGC-36425 IN ACCORDANCE TO AGC-36422.
20. ALL METAL SURFACES TO BE PROTECTED FROM CORROSION DURING FABRICATION, SHIPPING, AND STORAGE.
21. APPLY MIL-C-16173, GRADE 3 CORROSION PREVENTIVE COMPOUND PER AGC-36234.
22. TOUCH UP ALL BARE EXTERIOR SURFACES WITH PRIMER PER AGC-36072.
23. HANDLING RINGS REQUIRED DURING FABRICATION, HANDLING, SHIPPING, AND AT NEXT ASSEMBLY TO MAINTAIN [-A-] AND [-B-] TO DRAWING TOLERANCES AT ALL TIMES. CONFIGURATION SUBJECT TO AGC APPROVAL.
24. METHOD OF PRESERVATION PER MIL-P-116, METHOD II. SUB-METHOD SUBJECT TO AGC APPROVAL.
25. APPLY AGC-34345 TYPE II PRIMER TO ALL INTERIOR SURFACES OF NOZZLE SHELL PER AGC-36422.
26. SURFACE CLEANING, COMPONENT FITTING, PRIMING, AND BONDING PROCESS CONTROL AND PROCESSING SHALL BE IN ACCORDANCE TO AGC-36422.
27. DURING INSTALLATION AND BONDING OF THE INSERTS TO THE SHELL, A UNIFORM PRESSURE NOT TO EXCEED 50 PSI IS PERMITTED.
28. APPLY .002 INCH MINIMUM THICKNESS OF AGC-34345, TYPE II, PRIMER TO ALL EXPOSED PHENOLIC SURFACES AFTER FINAL ASSEMBLY. END FACE COATING THICKNESS SHALL NOT EXCEED .005. CURE AT ROOM TEMPERATURE FOR SIX HOURS MINIMUM.



											PRIMER COLOR "V"		MIL-P-8585					19
21	AR		AR								CORROSION PREVENTIVE COMPOUND		MIL-C-16173 GRADE 3					18
20	AR		AR															17
		AR		AR	AR						MOLDING TAPE, SILICA CLOTH	TYPE II	AGC-34116		1	1 A		16
12	AR		AR								LUBRICATING GREASE		MIL-L-4343					15
25	AR		AR								PRIMER	TYPE II	AGC-34345					14
16	AR		AR								ADHESIVE	TYPE III OR TYPE IV	AGC-34151					13
16	AR		AR								ADHESIVE	TYPE II	AGC-34151		2	2 C		12
					AR						[illegible] TAPE, [illegible]	TYPE I	AGC-34312		1	3 A		11
		AR		AR	AR	AR					MOLDING TAPE [illegible]	TYPE I	AGC-34106		1	3 A		10
	AR		AR								SEALING COMPOUND	SILICONE RUBBER	AGC-34076 CLASS 5		3	2 B		9
27	1									600303-3	INSULATION				1	1 A		8
	3		3								PACKING .275 ± .006 CROSS SECTION DIA	CLASS I GRADE 60	MIL-R-6855					7
11	1									-7	INSERT, THROAT EXTENSION				1	3 A		6
	1		1							600259-1	SHELL				1	13 A		5
17										600303-1	INSULATION				1	3 A		4
17			1							-5	INSERT, THROAT EXTENSION				1	2 A		3
17	1		1							-3	INSERT, THROAT				1	2 A		2
17	1		1							-1	INSERT, ENTRANCE				1	2 A		1
	-19	-7	-9	-5	-3	-1	SYM	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	NO. REQ'D	SYM	CODE IDENT NO.

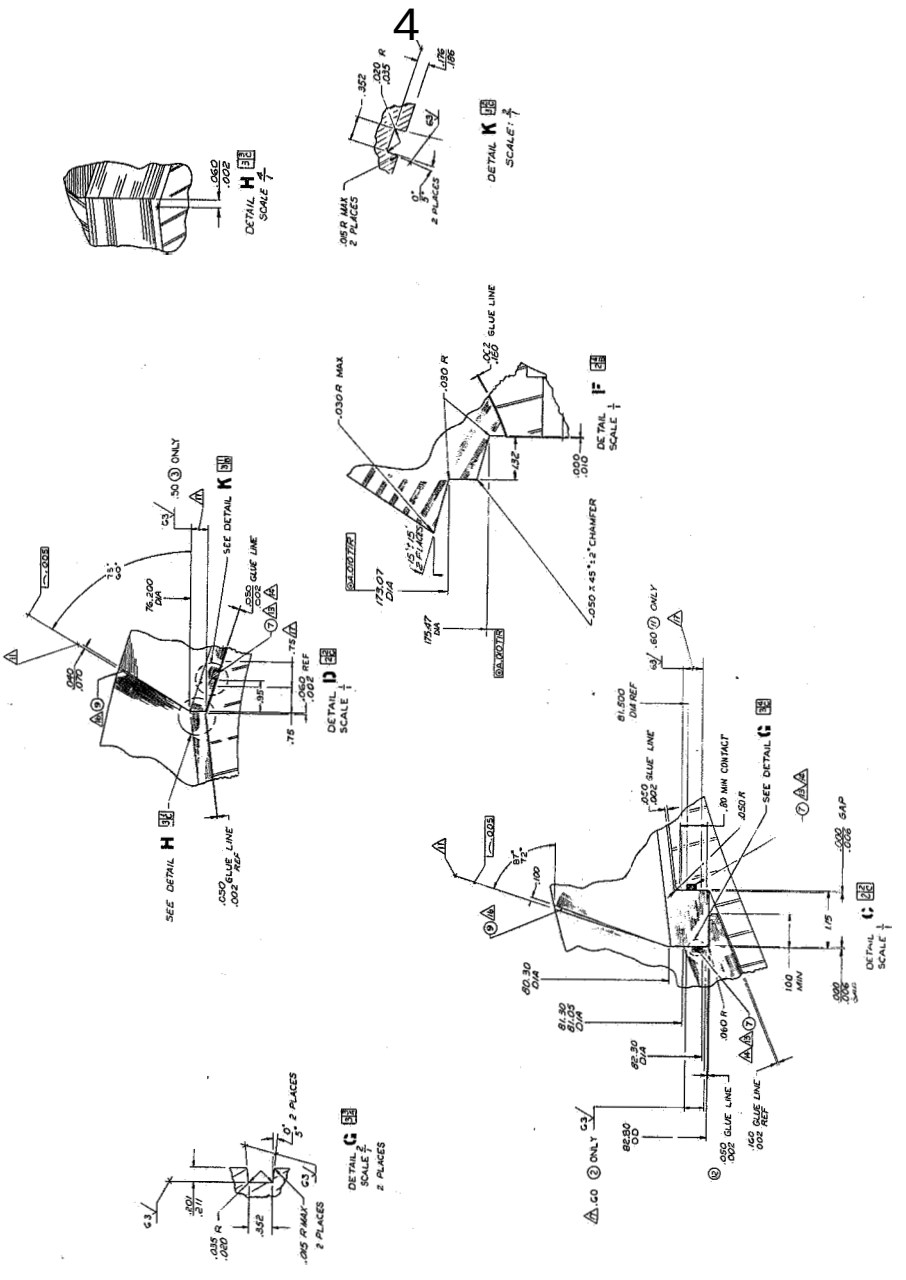
Figure 1, Sheet 1 of 3

260-SL Nozzle Assembly Drawing



260-SL Nozzle Assembly Drawing

Figure 1, Sheet 2 of 3



260-SL Nozzle Assembly Drawing

Figure 1, Sheet 3 of 3

NOTES:

1 REMOVE ALL BURRS AND SHARP EDGES EQUIVALENT TO .005 +.015 R UNLESS OTHERWISE SPECIFIED.

2 INTERPRET DRAWING PER STANDARDS PRESCRIBED IN MIL-D-70327.

3 SURFACE ROUGHNESS 125/ UNLESS OTHERWISE SPECIFIED.

4 -N- IS DEFINED AS A STRAIGHT LINE CONNECTING THE CENTERS OF -A- AND -N- ; -D- IS DEFINED AS A PLANE PASSING THROUGH THE CENTERS OF -N- AND -K- .

5 WHEN PART IS REFERENCED TO A STANDARD TEMPERATURE OF 68° F. WITH -A- AND -N- RESTRAINED TO DRAWING TOLERANCE, ALL OTHER FEATURES SHALL BE WITHIN DRAWING TOLERANCE.

6 EXCEPT AS OTHERWISE NOTED, MAXIMUM SLOPE VARIATION NOT TO EXCEED .005 INCH PER INCH.

7 DIMENSIONS "T" AND "X" ARE MEASURED NORMAL TO INSIDE SURFACE.

8 MAXIMUM PERMISSIBLE MISMATCH WITH INSIDE SURFACE OF PN 600260.

9 THIS SURFACE TO ALLOW .040 TO .070 GAP WITH MATING SURFACE OF PN 600260.

10 ALL FILLET AND CORNER RADII TO BE SMOOTH. NO STEPS OR MISMATCH PERMITTED.

11 ULTRASONIC INSPECT ALL FORGINGS PER AGC-36163, CLASS II.

12 LAMINATE ORIENTATION TO BE PARALLEL TO CENTER LINE OF EXIT CONE ±3° AS SHOWN.
A. FORWARD AND AFT INSERT LAMINATE ORIENTATION TO MATCH WITHIN 0°30' AT JOINT LINE.
B. JOINT LINE TO COINCIDE WITHIN 0°15' OF ADJACENT LAMINATES OF -1 PART.
C. COMPOSITE LAMINATE TO BE WRAPPED AND VACUUM BAG CURED PER AGC-36413.

13 BOND JOINT PER NOTE 13 OR USE RESIN SYSTEM OF INSERT MATERIAL.

14 TAPE TO BE WRAPPED PARALLEL TO EXTERIOR OF INNER PARTS AND PROCESSED PER 12F.

15 TIG WELD PER AGC-36073 USING WELDING WIRE PER AGC-44039. WELD GROOVE DESIGN SUBJECT TO AGC APPROVAL.

16 GIRTH BUTT WELDS PERMITTED TO JOIN FACINGS AND DOUBLERS INTO CONTINUOUS AXIAL STRIPS.
A. PERMISSIBLE WELD CROWN TO BE 0.001 TO 0.005 INCH ON INSIDE AND OUTSIDE SURFACES. REMOVE EXCESS WELD CROWN BY GRINDING. GRIND MARKS TO BE TRANSVERSE TO LONGITUDINAL AXIS OF EXIT CONE.
B. TOTAL ALLOWABLE MISMATCH OF WELDED SECTION NOT TO EXCEED 10% OF MINIMUM MATERIAL THICKNESS (90% CONTINUOUS MEMBRANE).
C. EACH GORE SHAPED FACING AND DOUBLER TO BE CONTINUOUS AND OF A HOMOGENEOUS STRUCTURE IN THE AXIAL DIRECTION.

17 HEAT TREAT -15,-17,-21, AND -23 PER MIL-S-25043 TO CONDITION TH1050, 150,000 PSI MINIMUM 0.2% OFFSET YIELD STRENGTH AFTER WELDING.

18 WHEN OF WELDED CONSTRUCTION, TIG WELD PER AGC-36073. FILLER WIRE PER AGC-34013. WELD GROOVE DESIGN SUBJECT TO AGC APPROVAL.
A. LONGITUDINAL WELDS:
1. LOCATION OF WELDS TO BE EQUALLY SPACED WITHIN .30 INCHES.
2. TOTAL ALLOWABLE MISMATCH OF WELDED SECTIONS NOT TO EXCEED 5% OF MINIMUM THICKNESS (95% CONTINUOUS MEMBRANE).
3. PERMISSIBLE WELD CROWN OF .020/.002 INCH ON INSIDE AND OUTSIDE SURFACES.
B. GIRTH WELDS:
1. TOTAL ALLOWABLE MISMATCH OF WELDED SECTIONS NOT TO EXCEED 10% OF MINIMUM MATERIAL THICKNESS (90% CONTINUOUS MEMBRANE).
2. PERMISSIBLE WELD CROWN OF .040/.002 INCH ON INSIDE AND OUTSIDE SURFACE.
C. REMOVE EXCESS WELD CROWN BY GRINDING. GRIND MARKS TO BE TRANSVERSE TO LONGITUDINAL CENTER LINE.

19 WELD REPAIR:
A. PRIOR TO HEAT TREAT REPAIR WELDS PER AGC-36073. NO DEFECTS SHALL BE REPAIRED MORE THAN THREE TIMES.
B. WELD REPAIR AFTER HEAT TREAT SUBJECT TO AGC APPROVAL.

20 NORMALIZE -11 AND -13 PER MIL-H-6875. MINIMUM ACCEPTABLE TENSILE YIELD STRENGTH AT 0.2% OFFSET TO BE 55,000 PSI.

21 MAGNETIC PARTICLE INSPECT ALL STEEL PARTS PER AGC-32116 AFTER HEAT TREATMENT AND FINAL MACHINE.

22 RADIOGRAPHIC INSPECT ALL WELDS ON STEEL PARTS BEFORE AND AFTER HEAT TREATMENT PER AGC-36069 AND INTERPRET PER AGC-13860, TABLE I, CLASS I.

23 ASSEMBLE STRUCTURAL SHELL TO INSERT ASSEMBLY IN ACCORDANCE TO AGC-36400. CURE PRESSURE T. [illegible] HG WITH INTERNAL [illegible]

24 LUBRICATE PACKING WITH MIL-L-4343 LUBRICATING GREASE.

25 INSTALLED PACKING INSIDE DIAMETER STRETCH TO BE 1 TO 3%.

26 FILL CAVITIES WITH CORFIL 615 IN ACCORDANCE WITH AGC-36400.

27 BOND WITH AGC-34151 TYPE II ADHESIVE AND CURE PER AGC-36180 AT ROOM TEMPERATURE.

28 LUBRICATE THREADS AND UNDER HEAD WITH MIL-T-5544 THREAD COMPOUND.

29 TORQUE TO:
A. 20 25 INCH POUNDS.
B. 250 320 INCH POUNDS.

30 LEAK TEST PER AGC-36425 IN ACCORDANCE TO AGC-36400.

31 REMOVED.

32 ALL METAL SURFACES TO BE PROTECTED FROM CORROSION DURING FABRICATION, SHIPPING AND STORAGE.

33 APPLY PRIMER TO ALL EXPOSED METAL SURFACES PER AGC-36072 UNLESS OTHERWISE SPECIFIED.

34 APPLY MIL-D-16173 GRADE 3 CORROSION PREVENTIVE COMPOUND PER AGC-36234.

35 CHEMICAL TREATMENT PER MIL-C-5541.

36 HANDLING RINGS REQUIRED DURING FABRICATION, HANDLING, SHIPPING AND AT NEXT ASSEMBLY TO MAINTAIN -A- AND -B- TO DRAWING TOLERANCES AT ALL TIMES. CONFIGURATION SUBJECT TO AGC APPROVAL.

37 METHOD OF PRESERVATION PER MIL-P-116, METHOD II. SUB-METHOD SUBJECT TO AGC APPROVAL.

38 THIS AREA TO BE FREE OF ADHESIVE.

39 FINAL MACHINE AFTER HEAT TREATMENT.

40 ADHESIVE FILM NO. 75-25 MAY BE SUBSTITUTED FOR AGC-34323 ADHESIVE FILM.

41 PARTS -11 AND -13 SHALL EITHER BE PROTECTED WITH PRIMER PER AGC-34345 WITHIN 4 HOURS AFTER CLEANING OR SHALL BE BONDED WITH ADHESIVE WITHIN 8 HOURS AFTER CLEANING. THE SURFACE WHEN INSPECTED PER MIL-P-116 SHALL NOT BE CONTAMINATED OR SHOW EVIDENCE OF RUST JUST PRIOR TO BONDING.

42 AGC-34345 TYPE I PRIMER MAY BE OMITTED ON PARTS -15,-17, -21 AND -23 PROVIDED THE METHOD OF PROTECTION AND THE ALLOWABLE ELAPSED TIME BETWEEN CLEANING AND BONDING IS APPROVED BY AEROJET GENERAL CORPORATION.

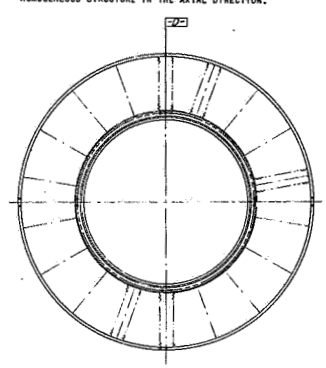
43 APPLY .002 INCH MINIMUM THICKNESS OF AGC-34345 TYPE II PRIMER TO ALL EXPOSED PHENOLIC REINFORCED FABRIC SURFACES AFTER FINAL ASSEMBLY. END FACE COATING THICKNESS SHALL NOT EXCEED .005. CURE AT ROOM TEMPERATURE FOR 6 HOURS MINIMUM.

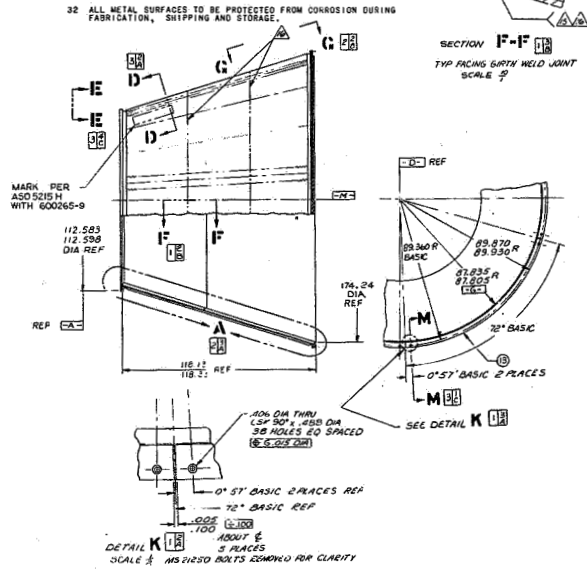
44 INTEGRITY OF HONEYCOMB STRUCTURE TO BE DETERMINED PER AGC APPROVED TREPAN TEST METHOD.

45 APPLY AGC-34238 CORK SHEET WITHIN THIS SURFACE PER AGC-36394 EXCEPT PARAGRAPH 3.7.2 POTTING OF CORK VOIDS, SHALL BE CHANGED TO: ANY VOIDS AT THE BUTT JOINTS SHALL BE POTTED WITH POTTING COMPOUND IN ACCORDANCE WITH AGC-34308, AGC-34151, TYPE II, ADHESIVE MAY BE SUBSTITUTED FOR AGC-34310 ADHESIVE.

REVISIONS			
SYM	SHEET	DESCRIPTION	DATE	APPROVED
A	SEE "A" CHG DCN		[illegible]	[illegible]
B	SEE "B" CHG ADCN		—	[illegible]
C	SEE "C" CHG DCN		[illegible]	[illegible]
D	SEE "D" CHG ADCN INC		[illegible]	[illegible]
E	SEE "E" CHG ADCN INC		[illegible]	[illegible]
F	SEE "F" CHG ADCN INC		[illegible]	[illegible]
G	SEE DCN		[illegible]	[illegible]
H	SEE DCN		[illegible]	[illegible]
J	SECURITY CLASSIFICATION DOWNGRADED TO UNCLASSIFIED BY AUTHORITY OF DD250 DATED 5-28-63 SEE DCN.		[illegible]	[illegible]
K	SEE "K" CHG DCN		[illegible]	[illegible]
L	SEE DCN		[illegible]	[illegible]
M	SEE DCN		[illegible]	[illegible]

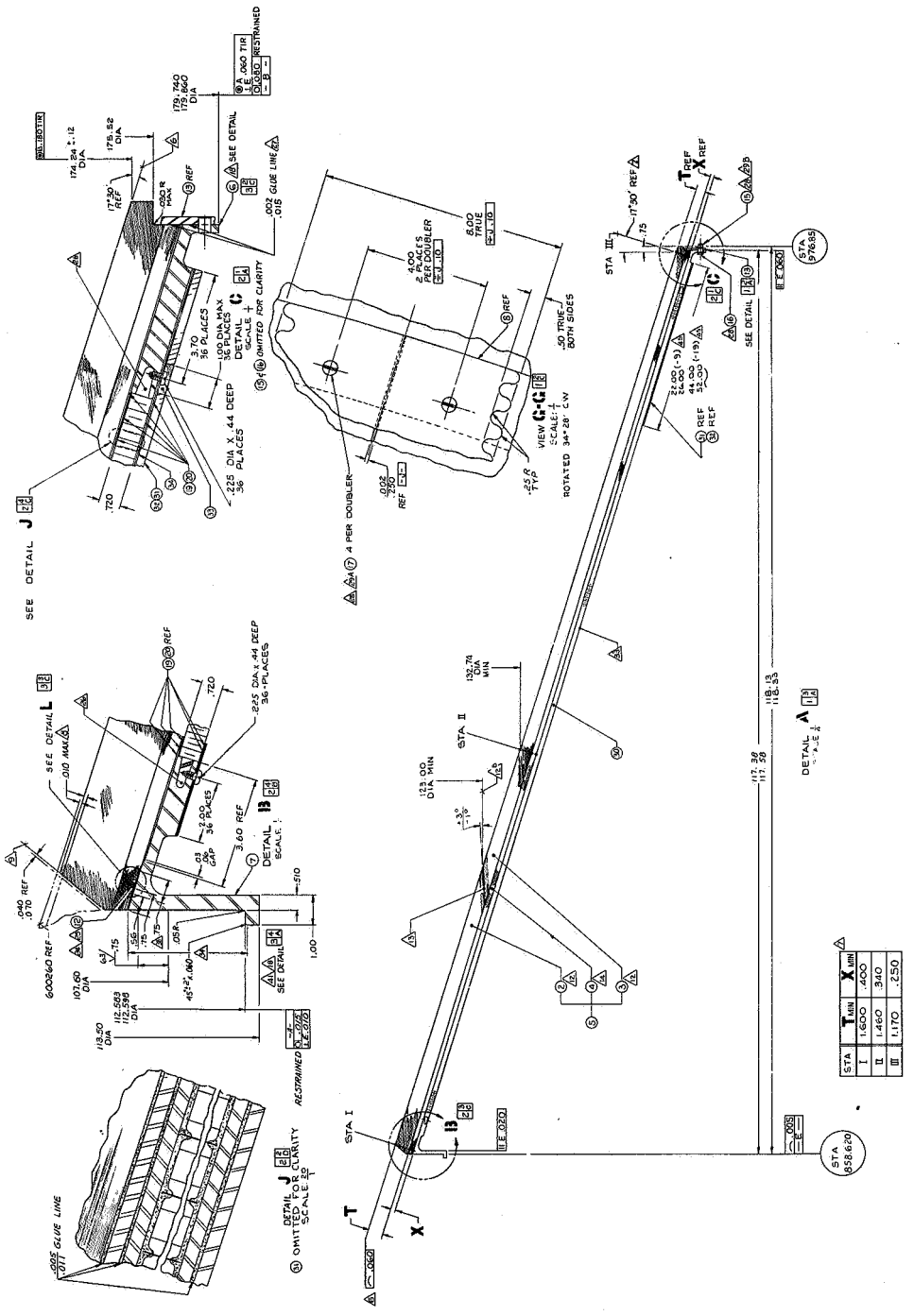
43	AR	AR				ADHESIVE, CORK BONDING		AGC-34310	2	34
43	AR	AR				POTTING COMPOUND		AGC-34308	2	33
43	AR	AR				CLOTHING, PROTECTIVE, CORK		AGC-34305	2	32
43	AR	AR				CORK, SHEET - .25 THK		AGC-34238	2	31
	AR	AR				CORE MATERIAL 6.0 LB - .50" (NOM)	ALUMINUM	MIL-C-7438	2	30
43	AR	AR				PRIMER, TYPE II		AGC-34345		29
43	AR	AR	0154C			CORFIL 615				28
43	AR	AR				WIRE - FILLER		AGC-34013		27
43	AR	AR				WIRE, WELDING, 17-7 PH		AGC-44039		26
43	AR	AR				CORROSION PREVENTIVE COMPOUND GRADE 3		MIL-C-16173		25
43	AR	AR				LUBRICATING GREASE		MIL-L-4343		24
43	AR	AR				THREAD COMPOUND, ANTI-SEIZE GRAPHITE - PETROLATUM		MIL-T-5544		23
43	AR	AR				PRIMER COLOR Y		MIL-P-6585		22
43 43	AR	AR				ADHESIVE, TYPE II		AGC-34151		21
43 43	AR	AR				ADHESIVE FILM		AGC-34323		20
43 43	AR	AR				PRIMER	TYPE I	AGC-34345		19
43	AR	AR	0404			ADHESIVE FILM 75-25				18
	72	72			MS 24621-58	SCREW			2	17
	196	196			MS 21042-6	NUT			4	16
	196	196			MS 21250 (NOM)	BOLT			24	15
										14
43	5	5			-27	RING, RETAINER	7075-T6 AL ALLOY	QQ-A-225	2	13
43	1	1			-25	PACKING - 2.5 ± 2.00% CROSS SECTIONAL DIA. CLASS 2 GRADE		MIL-P-6855	2	12
43	18	18			-23	FACING - OUTER	6Al 4V TI 17-7 PH	MIL-S-6Al-4V	3	11
43	18	18			-21	FACING - INNER			3	10
43	18	18			-17	FACING - INSERT	COND TH 1050		3	9
43	18	18			-15	DOUBLER			3	8
43	1	1			-13	FLANGE - FWD	4130 STL	MIL-S-5059 CL 1 MIL-S-5059 CL A	2	7
43	1	1			-11	FLANGE - AFT			2	6
	1	1			-7	INSERT 1000Y			2	5
		1			-5	REINFORCEMENT - INSERT	METALLIC TAPE LAMINATE TYPE II	AGC-34312	2	4
		1			-3	INSERT - AFT			2	3
		1			-1	INSERT - FWD	MACHINE TAPE LAMINATE TYPE II	AGC-34306	2	2
										1
SYM	7	8	SYM	ZONE	TOTAL ON SUBSYSTEM NO.	DESCRIPTION OR DESIGNATION	MATERIAL	SPECIFICATION	UNIT WT.	SYM	PART NO.





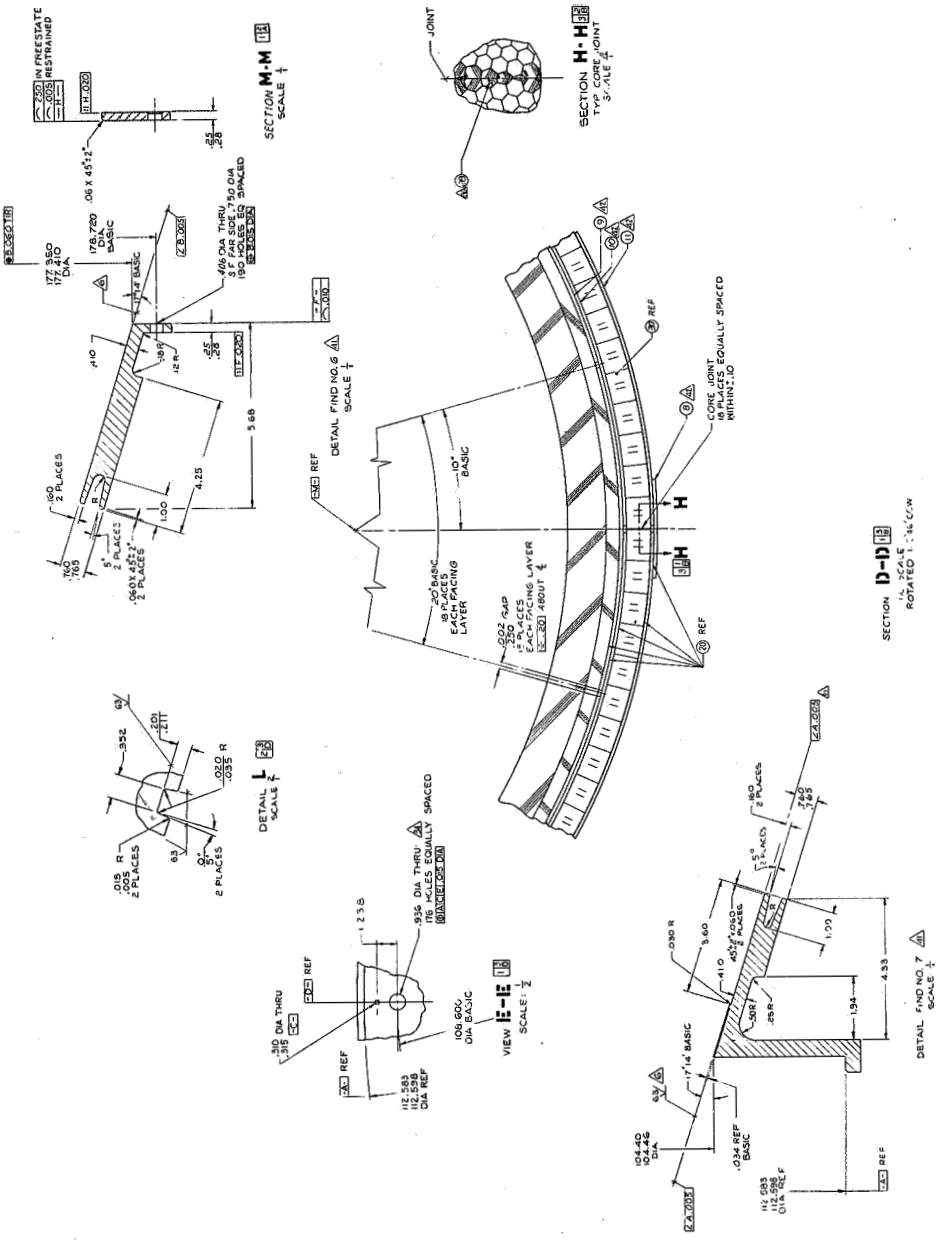
260-SL Nozzle Exit Cone Drawing

Figure 2, Sheet 1 of 3



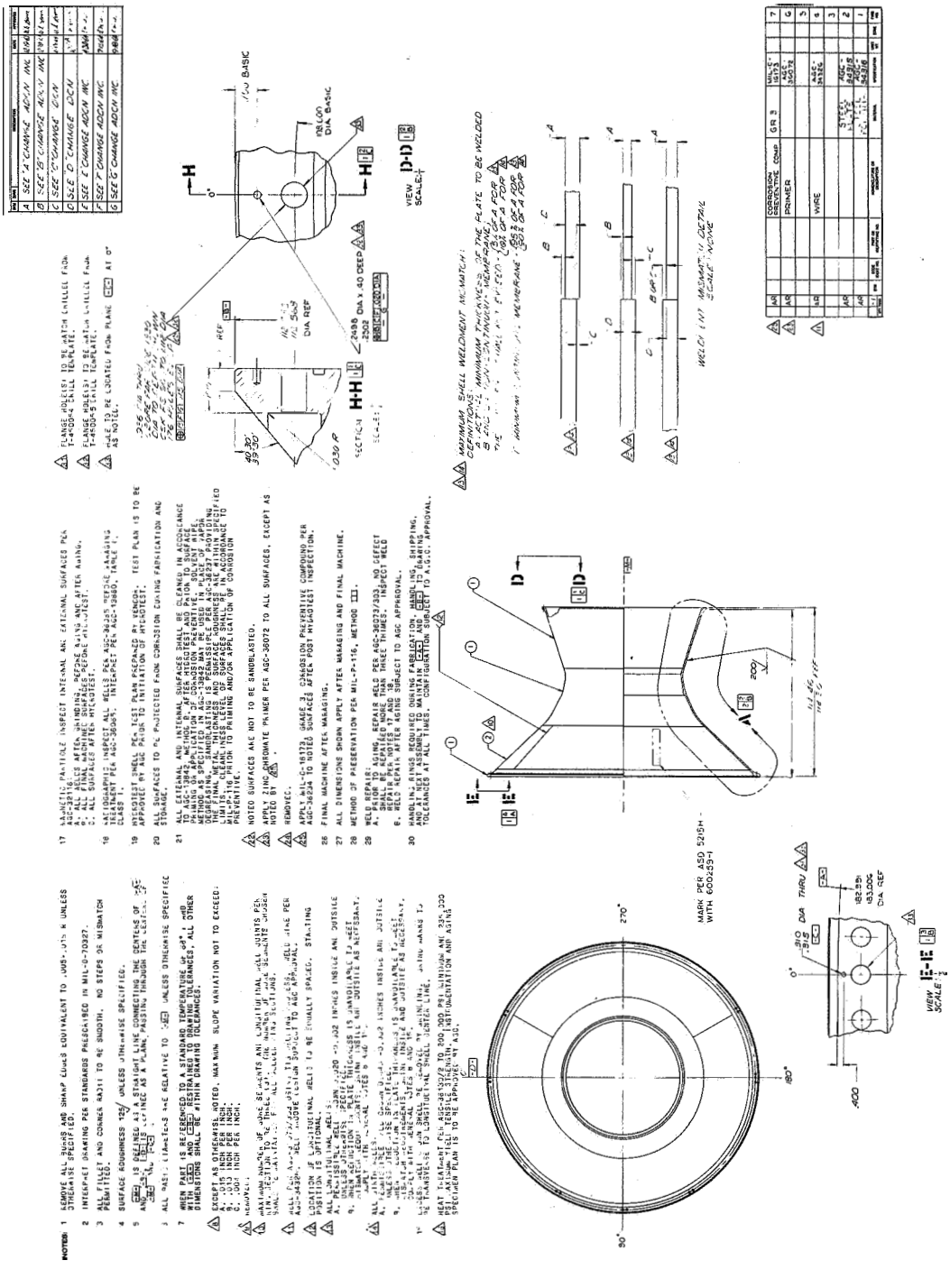
260-SL Nozzle Exit Cone Drawing

Figure 2, Sheet 2 of 3



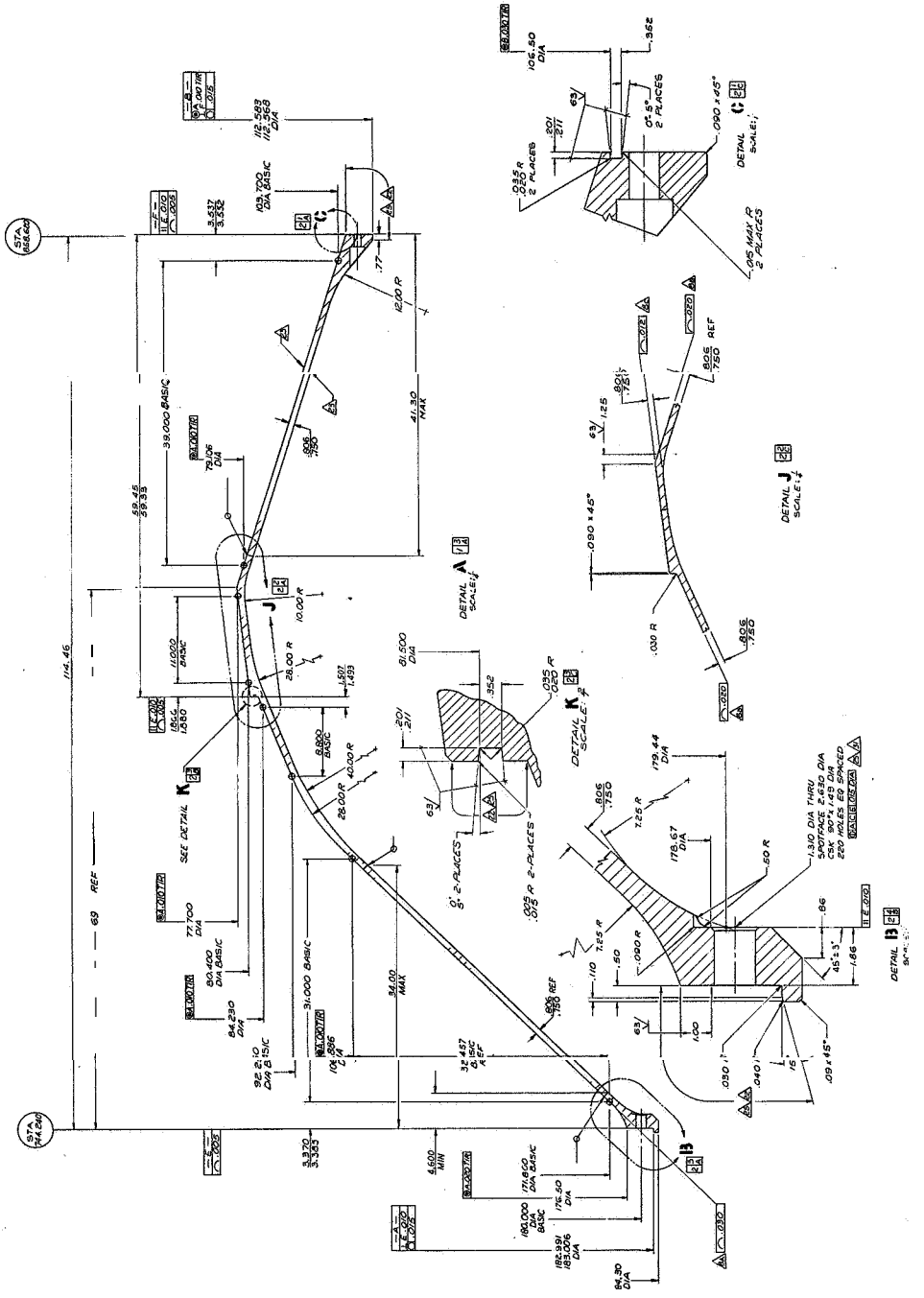
260-SL Nozzle Exit Cone Drawing

Figure 2, Sheet 3 of 3



260-SL Nozzle Shell Drawing

Figure 3, Sheet 1 of 2



260-SL Nozzle Shell Drawing

Figure 3, Sheet 2 of 2

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED
A		SEE "A" CHG ADCN	2-14-64	[illegible]
B		SEE "B" CHG ADCN	2-27-64	[illegible]
C		SEE "C" CHG DCN	11-6-64	[illegible]
D		SEE INCORP ADCN		
E		SEE INCORP ADCN		
F		SECURITY CLASSIFICATION DOWNGRADED TO UNCLASSIFIED BY AUTHORITY OF DD254 DATED 6-28-65. SEE DCN	8-3-65	[illegible]

NOTES:

1. REMOVE ALL BURRS AND SHARP EDGES EQUIVALENT TO .005 -.015 R UNLESS OTHERWISE SPECIFIED.
2. INTERPRET DRAWING PER STANDARDS PRESCRIBED IN MIL-D-70327.
3. SURFACE ROUGHNESS 125√ UNLESS OTHERWISE SPECIFIED.
4. -A- IS DEFINED AS A STRAIGHT LINE CONNECTING THE CENTERS OF -A- AND -B-.
5. WHEN PART IS REFERENCED TO A STANDARD TEMPERATURE OF 68° F WITH -A- AND -B- RESTRAINED TO DRAWING TOLERANCE, ALL OTHER FEATURES SHALL BE WITHIN TOLERANCE.
6. CONTOUR MAY VARY WITHIN .030 EITHER SIDE OF BASIC WITH MAXIMUM SLOPE VARIATION NOT TO EXCEED .005 INCH PER INCH.
7. DIMENSIONS MEASURED NORMAL TO INSIDE SURFACE.
8. MOLD IN ACCORDANCE TO AGC-36413 AT 1,000 PSI HYDROCLAVE PRESSURE.
9. LAMINATE ORIENTATION TO BE:
   A. 72° TO 87° HALF ANGLE WITH RESPECT TO CENTER LINE NOZZLE.
   B. -1° TO +3° HALF ANGLE WITH RESPECT TO CENTER LINE NOZZLE.
   C. 60° TO 75° HALF ANGLE WITH RESPECT TO CENTER LINE NOZZLE.
10. TAPE TO BE WRAPPED PARALLEL TO EXTERIOR SURFACE OF INNER PART.
11. SURFACE TO COINCIDE WITHIN 0° 15' OF ADJACENT LAMINATES.
12. APPLY AG. 34345, TYPE II PRIMER PER AGC-36422 TO ALL INTERIOR SURFACES OF SHELL.
13. LUBRICATE PACKING WITH MIL-L-4343 LUBRICATING GREASE.
14. INSTALLED PACKING ID STRETCH TO BE FROM 1 TO 3%.
15. INSTALL INSERTS USING AGC-34151, TYPE II ADHESIVE, PROCESS AND CURE AT 180°F MAXIMUM CURE TEMPERATURE PER AGC-36422.
16. FILL GAP WITH AGC-34076, CLASS 5 SEALING COMPOUND.
17. THIS AREA TO BE FREE OF ADHESIVE AND AGC-34076 SEALING COMPOUND.
18. INSTALL INSULATION USING AGC-34151 TYPE III OR IV ADHESIVE IN ACCORDANCE WITH AGC-36422 MAXIMUM CURE TEMPERATURE TO BE 180°F.
19. LEAK TEST PER AGC-36425 IN ACCORDANCE WITH AGC-36422.
20. ALL METAL SURFACES TO BE PROTECTED FROM CORROSION DURING FABRICATION, SHIPPING AND STORAGE.
21. APPLY MIL-C-16173, GRADE 3 CORROSION PREVENTIVE COMPOUND PER AGC-36234.
22. TOUCH UP ALL BARE EXTERIOR SURFACES WITH PRIMER PER AGC-36072.
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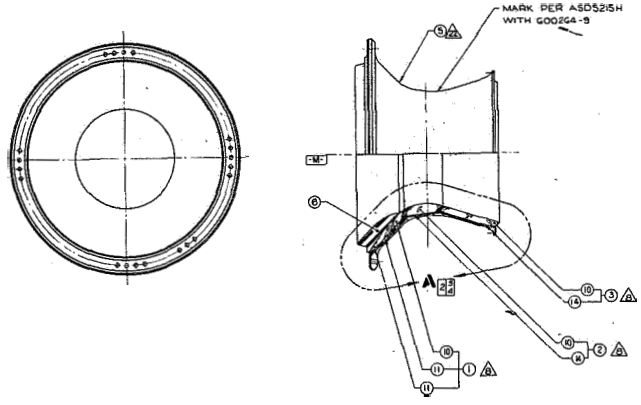
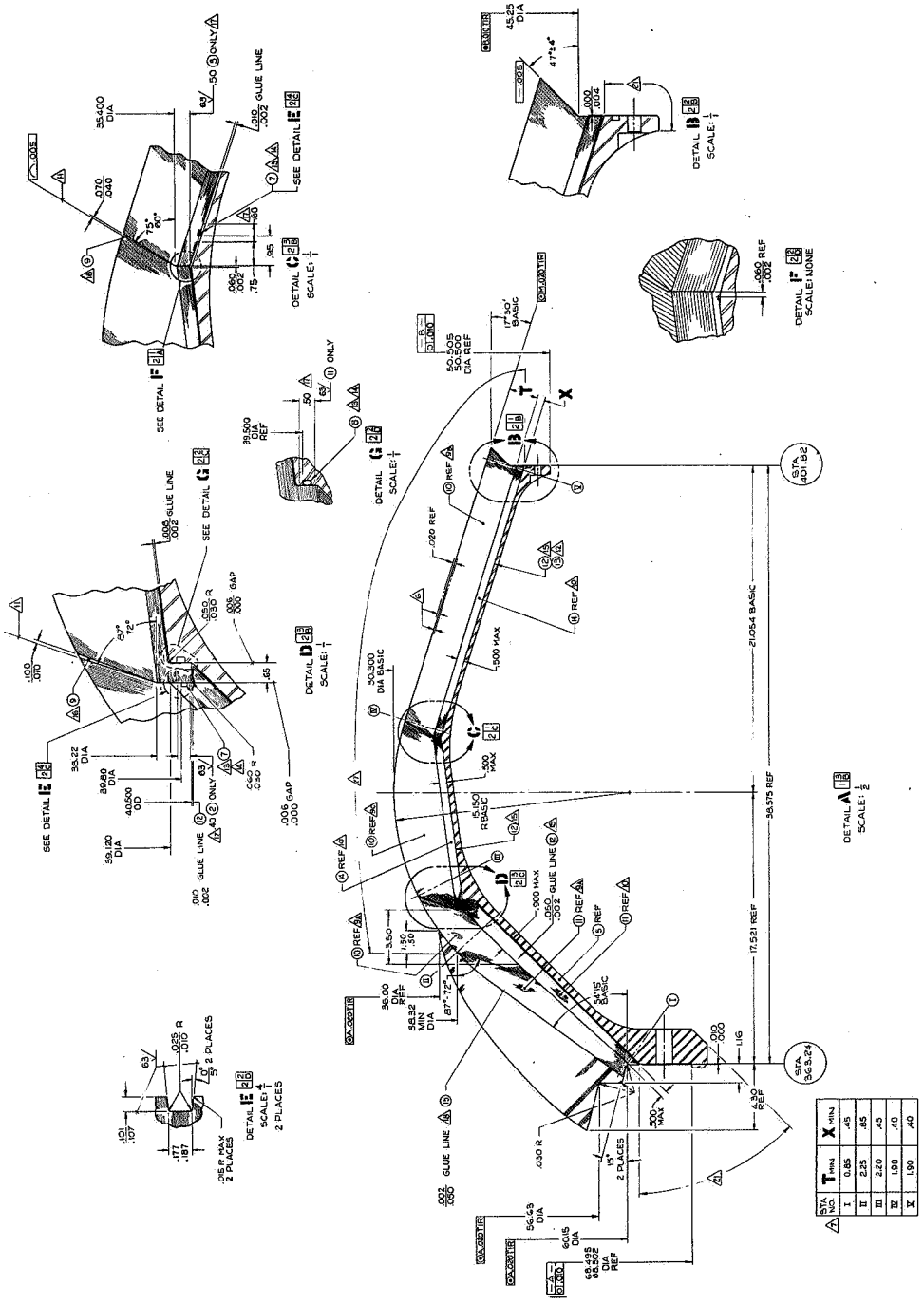
26. CURING INSTALLATION AND BONDING OF THE INSERTS TO THE SHELL A UNIFORM PRESSURE NOT TO EXCEED 50 PSI IS PERMITTED.
27. APPLY A .002 MIN THICK BRUSH OR SPRAY COAT OF AGC-34345, TYPE II PRIMER TO ALL EXPOSED MACHINED PHENOLIC REINFORCED FABRIC SURFACES AND INTERNAL INSULATION AS SHOWN AFTER FINAL ASSEMBLY OF COMPONENT. END FACE COATING THICKNESS SHALL NOT EXCEED .005. CURE AT ROOM TEMPERATURE. SEE NOTE 28.
28. EPON 826 MIXED WITH CURING AGENT "U" PER MANUFACTURERS (CODE IDENT NO. 86961) DIRECTIONS, IS AN ACCEPTABLE ALTERNATE MATERIAL.



22	AR							PRIMER COLOR Y		MIL-P-8585					20
21	AR							CORR PREVENTIVE COMPOUND	GRADE 3	MIL-C-16173					19
															18
															17
13	AR							LUBRICATING GREASE		MIL-L-4343					16
15	AR							ADHESIVE	TYPE III OR IV	AGC-34151		2			15
	AR	AR	AR					MOLDING TAPE, IMPREGNATED SILICA FABRIC BIAS CUT, TYPE II		AGC-34312					14
12	AR							PRIMER	TYPE II	AGC-34345		2			13
12	AR							ADHESIVE	TYPE II	AGC-34151		2			12
		AR	AR	AR				MOLDING TAPE IMPREGNATED SILICA FABRIC BIAS CUT TYPE I		AGC-34312		1			11
		AR	AR	AR				MOLDING TAPE IMPREGNATED CACHLINEN, BIAS CUT TYPE I		AGC-34306		1			10
	AR							SEALING COMPOUND	SILICONE RUBBER	AGC 34076 CLASS 5		2			9
	1							PACKING .209 ± .005 CROSS SECTIONAL DIA	CLASS 1 GRADE 60	MIL-R-6855		2			8
	2							PACKING .139 ± .004 CROSS SECTIONAL DIA	CLASS 1 GRADE 60	MIL-R-6855		2			7
	1						600304-1	INSULATION, INTERNAL				1			6
	1						G00263-1	SHELL				1			5
															4
	1						-5	INSERT, THROAT EXTENSION				1			3
	1						-3	INSERT, THROAT				1			2
	1						-1	INSERT, ENTRANCE				1			1
	-91-S-3-1-1														
	SYM							DESCRIPTION	MATERIAL	SPECIFICATION					

Figure 4, Sheet 1 of 2

120-SS-1 Nozzle Assembly Drawing



DIA NO	T MIN	X MIN
I	0.85	.45
II	2.25	.85
III	2.20	.45
IV	1.90	.40
V	1.90	.40

120-SS-1 Nozzle Assembly Drawing

Figure 4, **Sheet** 2 **of** 2

REV	DATE	DESCRIPTION	DATE	APPROVED
A		SEE A CHANGE ADCN		
B		SEE B CHANGE ADCN INC		
C		SEE C CHANGE ADCN INC		
D		SEE D CHANGE ADCN INC		
E		SEE E CHANGE DCN		
F		SEE INCORP ADCN		
G		SEE INCORP ADCN		
H		SECURITY CLASSIFICATION DOWNGRADED TO UNCLASSIFIED BY AUTHORITY OF DD 254 DATED 6-25-65 SEE DCN		

NOTES:

1 REMOVE ALL BURRS AND SHARP EDGES EQUIVALENT TO .005/ .015 R UNLESS OTHERWISE SPECIFIED.

2 INTERPRET DRAWING PER STANDARDS PRESCRIBED IN MIL-D-70327.

3 SURFACE ROUGHNESS 125/ UNLESS OTHERWISE SPECIFIED.

4 DATUM AXIS [-H-] IS DEFINED AS A STRAIGHT LINE CONNECTING THE CENTERS OF DIAMETERS [-A-] AND [-B-].

5 WHEN PART IS REFERENCED TO A STANDARD TEMPERATURE OF 68°F, WITH [-A-] AND [-B-] RESTRAINED TO DRAWING TOLERANCE, ALL OTHER FEATURES SHALL BE WITHIN DRAWING TOLERANCE.

6 MAXIMUM PERMISSIBLE SLOPE VARIATION NOT TO EXCEED .005 IN/IN.

7 ALL METAL SURFACES TO BE PROTECTED FROM CORROSION DURING FABRICATION, SHIPPING AND STORAGE.

8 LUBRICATE PACKING WITH MIL-L-4343 LUBRICATING GREASE.

9 METHOD OF PRESERVATION PER MIL-P-116, METHOD II. SUB-METHOD SUBJECT TO AGC APPROVAL.

10 MAXIMUM PERMISSIBLE MISMATCH WITH INSIDE SURFACE OF P N 600264.

11 LEAK TEST PER AGC-36400.

12 FILL THIS CAVITY WITH CORFIL 615 PER AGC-36400.

13 ASSEMBLE STRUCTUAL SHELL TO INSERT ASSEMBLY IN ACCORDANCE TO AGC-36400. CURE PRESSURE SHALL BE 13 ±2 PSI.

14 DIMENSIONS "T" AND "X" ARE MEASURED NORMAL TO INSIDE SURFACE.

15 LAMINATE ORIENTATION TO BE PARALLEL TO CENTER LINE OF CONE WITHIN -1° TO +3° AS SHOWN.
A. FORWARD AND AFT INSERT LAMINATE ORIENTATION TO MATCH WITHIN 0°30' AT JOINT LINE.
B. JOINT LINE TO COINCIDE WITHIN 0°15' OF ADJACENT LAMINATES.
C. COMPOSITE LAMINATES TO BE BAGGED AND VACUUM BAG CURED IN ACCORDANCE TO AGC-36413.

16 ALL DIMENSIONS SHOWN ARE AFTER FINAL MACHINING.

17 TAPE TO BE WRAPPED PARALLEL TO EXTERIOR OF INNER PARTS AND PROGRESSED PER NOTE 6.

18 APPLY ZINC CHROMATE PRIMER TO ALL EXPOSED METAL SURFACES PER AGC-36072 UNLESS OTHERWISE SPECIFIED.

19 ALL FILLET AND CORNER RADII TO BE SMOOTH. NO STEPS OR MISMATCH PERMITTED.

20 LUBRICATE BOLT THREADS AND UNDER HEAD WITH MIL-T-5544 ANTI-SEIZE COMPOUND. TORQUE BOLTS TO 100 ±20 INCH POUNDS.

21 LUBRICATE SCREW THREADS WITH MIL-T-5544 ANTI-SEIZE COMPOUND. TORQUE SCREWS TO 20 ±5 INCH POUNDS.

22 BOND WITH AGC-34151 TYPE II ADHESIVE AND CURE PER AGC-36160 AT 160° F OR LESS.

23 BOND JOINT PER NOTE 22 OR USE RESIN SYSTEM OF INSERT MATERIAL.

24 APPLY MIL-C-16173 GRADE 3 CORROSION PREVENTIVE COMPOUND PER AGC-36234.

25 GIRTH WELDS PERMITTED TO JOIN FACINGS AND DOUBLERS INTO CONTINUOUS AXIAL STRIPS.
A. PERMISSIBLE WELD CROWN OF .001/.005 ON INSIDE AND OUTSIDE SURFACES. REMOVE EXCESS WELD CROWN BY GRINDING. GRIND MARKS TO BE TRANSVERSE TO LONGITUDINAL AXIS OF EXIT CONE.
B. TOTAL ALLOWABLE MISMATCH OF WELDED SECTIONS NOT TO EXCEED 10% OF MINIMUM MATERIAL THICKNESS (90% CONTINUOUS MEMBRANE).
C. EACH GORE SHAPED FACING AND DOUBLER TO BE CONTINUOUS AND OF HOMOGENEOUS STRUCTURE IN THE AXIAL DIRECTION.

26 INSTALLED PACKING INSIDE DIAMETER STRETCH TO BE 1 TO 3%.

27 TIG WELD PER AGC-36073 USING WELDING WIRE PER AGC-44039. WELD GROOVE DESIGN SUBJECT TO AGC APPROVAL.

28 SOLUTION HEAT TREAT -15, -17, -25, AND -27 PER MIL-S-25043 TO CONDITION TH1050, 150,000 PSI MINIMUM 0.2% OFFSET YIELD STRENGTH AFTER WELDING.

29 WHEN OF WELDED CONSTRUCTION, TIG WELD PER AGC-36073. FILLER WIRE PER AGC-44013. WELD GROOVE DESIGN SUBJECT TO AGC APPROVAL.
A. LONGITUDINAL WELDS:
1. LOCATION OF WELDS TO BE EQUALLY SPACED WITHIN .30 .
2. TOTAL ALLOWABLE MISMATCH OF WELDED SECTIONS NOT TO EXCEED 5% OF MINIMUM THICKNESS (95% CONTINUOUS MEMBRANE).
3. PERMISSIBLE WELD CROWN OF .020/.002 ON INSIDE AND OUTSIDE SURFACES.
B. GIRTH WELDS:
1. TOTAL ALLOWABLE MISMATCH OF WELDED SECTIONS NOT TO EXCEED 10% OF MINIMUM MATERIAL THICKNESS (90% CONTINUOUS MEMBRANE).
2. PERMISSIBLE WELD CROWN OF .040/.002 ON INSIDE AND OUTSIDE SURFACES.
C. REMOVE EXCESS WELD CROWN BY GRINDING. GRIND MARKS TO BE TRANSVERSE TO LONGITUDINAL CENTER LINE.

30 THIS SURFACE TO ALLOW .040 TO .070 GAP WITH MATING SURFACE OF P N 600264.

31 MAGNETIC PARTICLE INSPECT ALL STEEL PARTS PER AGC-32116 AFTER HEAT TREATMENT AND FINAL MACHINE.

32 RADIOGRAPHIC INSPECT ALL WELDS ON STEEL PARTS BEFORE AND AFTER HEAT TREATMENT PER AGC-36065 AND INTERPRET PER AGC-13860 TABLE I, CLASS I.

33 ULTRASONIC INSPECT ALL FORGINGS PER AGC-36163, CLASS II.

34 WELD REPAIR:
A. PRIOR TO HEAT TREAT REPAIR WELDS PER AGC-36073. NO DEFECT SHALL BE REPAIRED MORE THAN THREE TIMES.
B. WELD REPAIR AFTER HEAT TREAT SUBJECT TO AGC APPROVAL.

35 NORMALIZE -11 AND -13 PER MIL-H-6875. MINIMUM ACCEPTABLE TENSILE YIELD STRENGTH AT 0.2% OFFSET TO BE 55,000 PSI.

36 HANDLING SLINGS REQUIRED DURING FABRICATION, HANDLING, SHIPPING, AND AT NEXT ASSEMBLY TO MAINTAIN [-A-] AND [-B-] TO DRAWING TOLERANCES AT ALL TIMES. CONFIGURATION SUBJECT TO AGC APPROVAL.

37 ADHESIVE FILM NO. 75-25 MAY BE SUBSTITUTED FOR AGC-34323 ADHESIVE FILM.

38 PARTS -11, -13 AND -23 SHALL EITHER BE PROTECTED WITH PRIMER PER AGC-34345 WITHIN FOUR HOURS AFTER CLEANING OR SHALL BE BONDED WITH ADHESIVE WITHIN EIGHT HOURS AFTER CLEANING. THE SURFACE CLEANLINESS WHEN INSPECTED PER MIL-P-116 SHALL NOT BE CONTAMINATED OR SHOW EVIDENCE OF RUST JUST PRIOR TO BONDING.

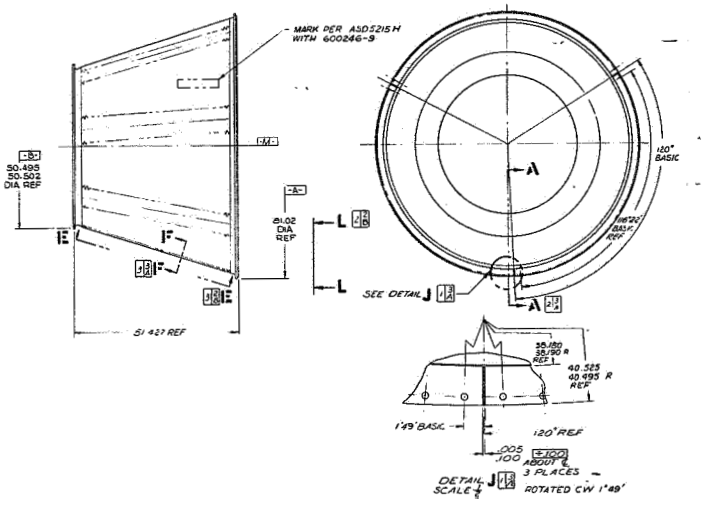
39 AGC-34345 TYPE I PRIMER MAY BE OMITTED ON PARTS -15, -17, -25 AND -27 PROVIDED THE METHOD OF PROTECTION AND THE ALLOWABLE ELAPSED TIME BETWEEN CLEANING AND BONDING IS APPROVED BY AGC.

40 PACKAGING AND MARKING OF ASSEMBLY FOR SHIPMENT SHALL BE IN ACCORDANCE WITH AGC-36447.

41 APPLY A .002 MIN THICK BRUSH OR SPRAY COAT OF AGC-34345, TYPE II PRIMER TO ALL EXPOSED MACHINED PHENOLIC FABRIC REINFORCED INTERNAL AND END FACE SURFACES AFTER FINAL ASSEMBLY OF COMPONENT. END FACE COATING THICKNESS SHALL NOT EXCEED .005. CURE AT ROOM TEMPERATURE. SEE NOTE 43.

42 EPON 828 MIXED WITH CURING AGENT "U" PER MANUFACTURERS (CODE IDENT NO. 86861) DIRECTIONS, IS AN ACCEPTABLE ALTERNATE MATERIAL.

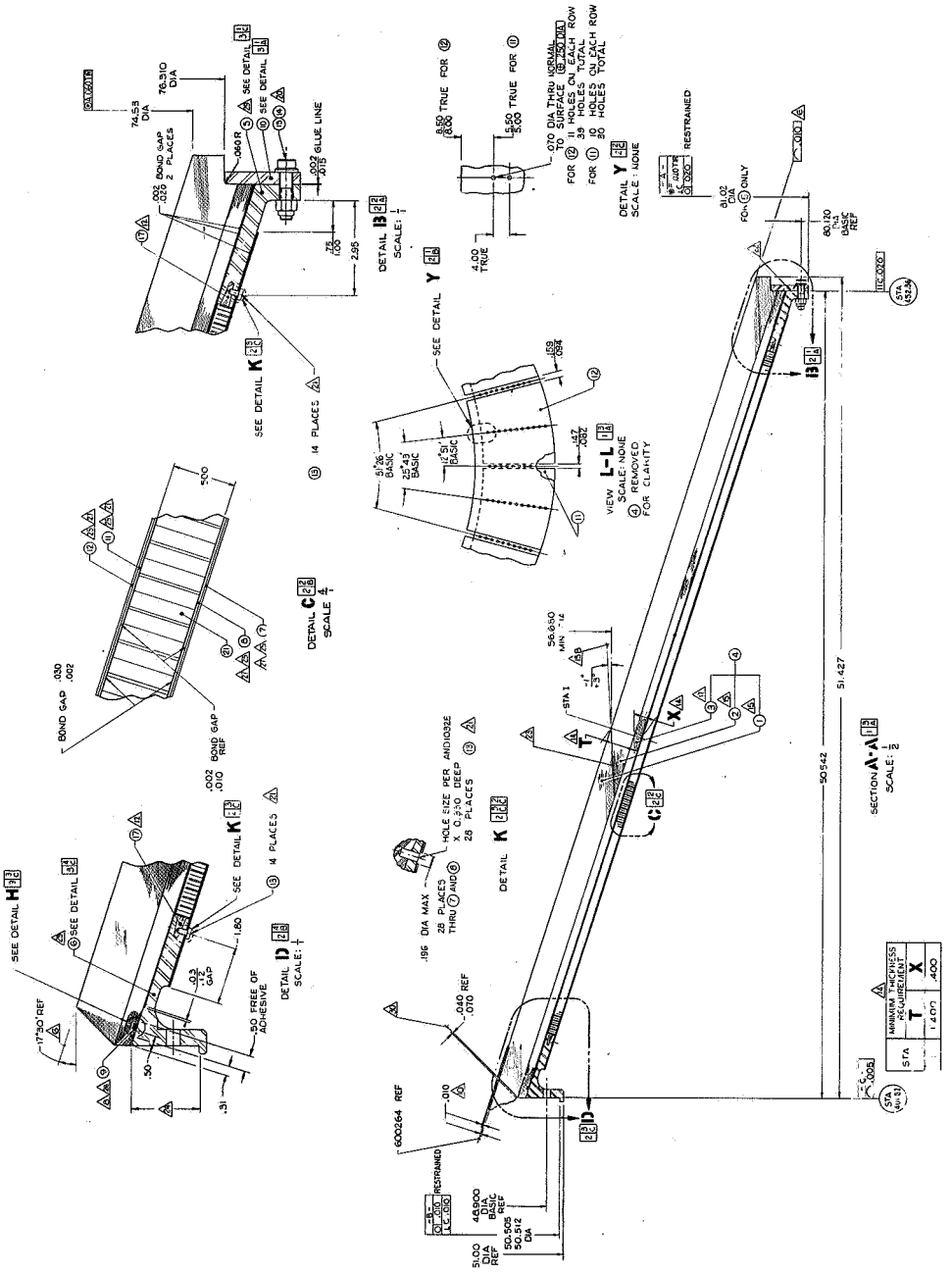
43 TREPAN TEST STRUCTURAL INTEGRITY OF HONEYCOMB STRUCTURE PER AGC APPROVED METHOD.



41, 42	AR				PRIMER	TYPE II	AGC-34345			31
37	AR		84961		ADHESIVE FILM	75-25				30
24	AR				WELD WIRE		AGC-34013			29
27	AR				WELD WIRE	17-7PH	AGC-44039			28
24	AR				CORROSION PREVENTIVE	GRADE 3	MIL-C-16173			27
8	AR				LUBRICATING GREASE		MIL-L-4343			26
21, 43	AR				ANTI-SEIZE COMPOUND		MIL-T-5544			25
18	AR				PRIMER, COLOR "Y"		MIL-P-8585			24
22	AR				ADHESIVE	TYPE II	AGC-34151			23
37, 38	AR				ADHESIVE FILM		AGC-34323	3	A	22
	AR				CORE MATERIAL 60-76-30P(60003)	ALUMINUM	MIL-C-7438	2	B	21
										20
										19
41, 39	AR				PRIMER	TYPE I	AGC-34345	3	A	18
37	AR		07542		ADHESIVE FOAM	CORFIL 615				17
										16
	99			143 90318.8	BOLT			2	1	15
	99			MS 21042-6	NUT			2	1	14
	98			MS 24632-42	SCREW			2	1	13
	7			-27	FACING-INSERT	.018 THK 17-7PH	MIL-S-25043	2	1	12
	7			-25	FACING-INNER	COND TH1050		2	1	11
	3			-23	RETAINING RING	440 STEEL COND N	MIL-S-18129	2	1	10
40	1			-21	PACKING - .139±.004 CROSS SECTIONAL DIA	CLASS I SILICONE	MIL-R-6855	2	1	9
	7			-17	FACING-OUTER	.018 THK 17-7PH	MIL-S-25043	2	1	8
	7			-15	DOUBLER	COND TH1050		2	1	7
35, 36	1			-13	FLANGE-FWD	4130 STEEL	MIL-S-6758 CLASS 1 OR 2 AS STATED ABOVE	2	1	6
35, 36	1			-11	FLANGE-AFT			2	1	5
	1			-7	INSERT ASSY			2	1	4
		1		-5	REINFORCEMENT-INSERT	MOLDING TAPE, SILICA FABRIC	AGC-34312	1	1	3
		1		-3	INSERT-AFT		TYPE II	1	1	2
		1		-1	INSERT-FWD	MOLDING TAPE, SILICA FABRIC	AGC-34312 TYPE II	1	1	1
-9,-7 OR LESS	QTY				PART OR MATERIAL NO.	SPECIFICATION OR DESCRIPTION (CAST OR CONTINUED)	MATERIAL			

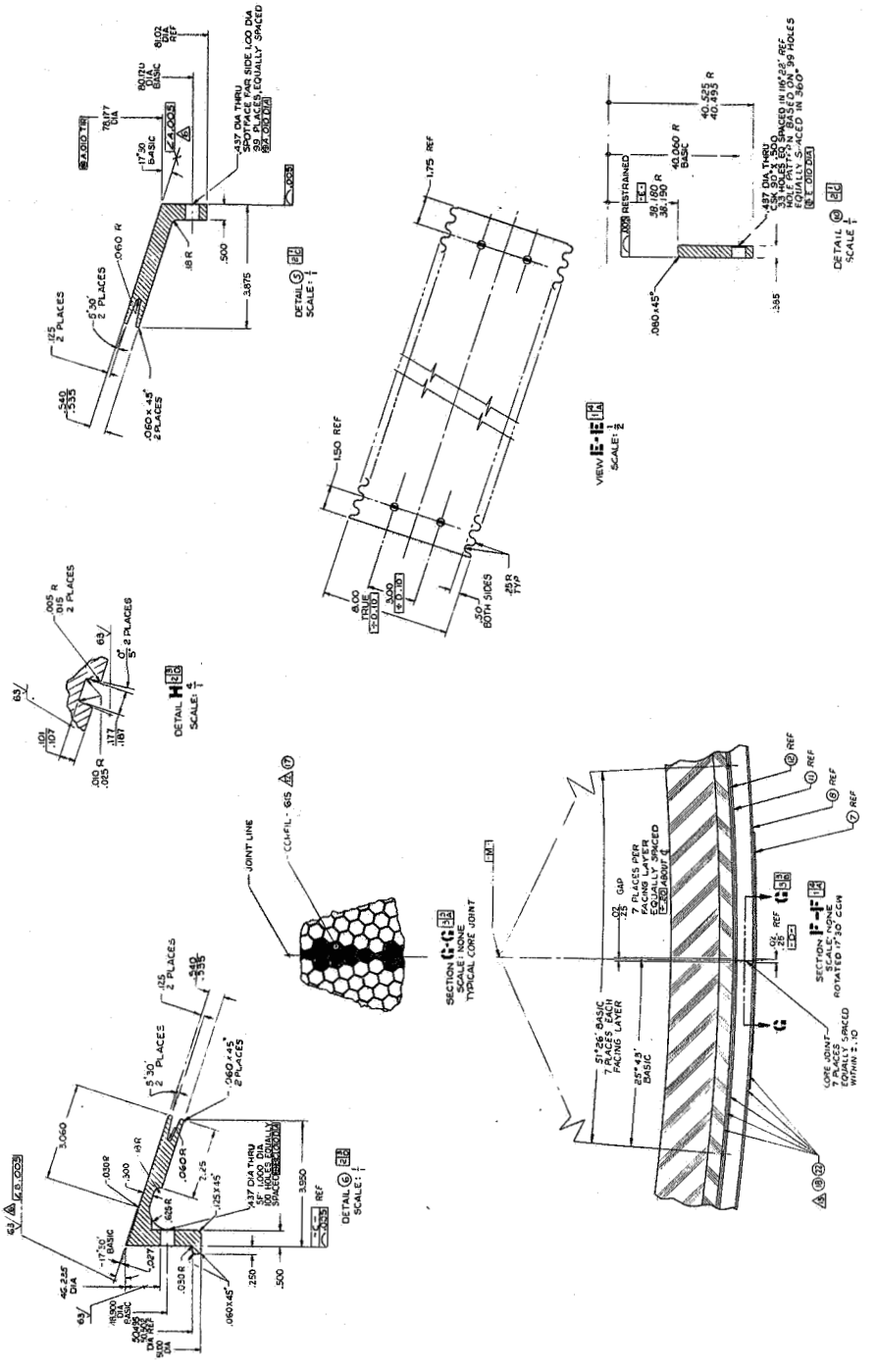
120-SS-1 Nozzle Exit Cone Drawing

Figure 5, Sheet 1 of 3



120-SS-1 Nozzle Exit Cone Drawing

Figure 5, Sheet 2 of 3



120-SS-1 Nozzle Exit Cone Drawing

Figure 5, Sheet 3 of 3

REVISIONS			
ZONE	ZONE	DESCRIPTION	DATE / APPROVED
A		SEE A CHG DCN	[illegible]
B		SEE "B" CHG DCN	[illegible]
C		SEE "C" CHANGE ADCN INC	[illegible]
D		SEE "D" CHANGE DCN	[illegible]

NOTES: 1 REMOVE ALL BURRS AND SHARP EDGES EQUIVALENT TO .005 - .015 R UNLESS OTHERWISE SPECIFIED.

2 INTERPRET DRAWING PER STANDARDS PRESCRIBED IN MIL-D-70327.

3 ALL FILLET AND CORNER RADII TO BE SMOOTH. NO STEPS OR MISMATCH PERMITTED.

4 SURFACE ROUGHNESS 125/ UNLESS OTHERWISE SPECIFIED.

5 -M- IS DEFINED AS A STRAIGHT LINE CONNECTING THE CENTERS OF -B- AND -C- .

6 ALL BASIC DIAMETERS RELATIVE TO -M- .

7 REMOVED

8 REMOVED

9 MACHINE DIMENSIONS TO BE WITHIN TOLERANCE WHEN REFERENCED TO A STANDARD TEMPERATURE OF 68° F.

10 FINAL MACHINE AFTER MARAGING.

11 ALL SURFACE CONTOUR CHANGES WITHIN THE TOLERANCE ZONE MUST NOT EXCEED .005 IN/IN SLOPE.

12 ALL DIMENSIONS SHOWN APPLY AFTER MARAGING AND FINAL MACHINE.

13 ALL EXTERNAL AND INTERNAL SURFACES SHALL BE CLEANED IN ACCORDANCE WITH AGC-13842 AS APPLICABLE, METHOD 3. PRIOR TO SURFACE PRIMING OR APPLICATION OF CORROSION PREVENTIVE. SOLVENT WIPE PER AGC-13842 MAY BE USED IN PLACE OF VAPOR DEGREASING. SANDBLASTING IS PERMISSIBLE PER AGC-36237 PROVIDING THE FINAL METAL THICKNESS AND SURFACE ROUGHNESS ARE WITHIN SPECIFIED LIMITS. CLEANLINESS LEVEL OF SURFACE SHALL BE IN ACCORDANCE TO MIL-P-116. PRIOR TO PRIMING AND/OR APPLICATION OF CORROSION PREVENTIVE.

14 REMOVED.

15 REMOVED.

16 WELD PER AGC-36073/303, USING T.I.G. WELDING PROCESS. WELD WIRE PER AGC-34326. WELD GROOVE DESIGN SUBJECT TO A.G.C. APPROVAL.

17 ALL BIRTH WELDS:
1. PERMISSIBLE WELD CROWN OF .04-.002 INSIDE AND OUTSIDE. REMOVE EXCESS WELD DEPOSIT BY GRINDING.
2. WHEN REDUCTION IN FORGING THICKNESS IS UNAVOIDABLE TO MEET MISMATCH REQUIREMENTS, GRIND INSIDE AND OUTSIDE AS NECESSARY. COMPLY WITH GENERAL NOTE 17

18 REMOVED

19 HEAT TREAT PER AGC-36130/2 TO 290,000 PSI MINIMUM AND 235,000 PSI MAXIMUM YIELD TENSILE STRENGTH. INSTRUMENTATION AND MARAGING SPECIMEN PLAN IS TO BE APPROVED BY AGC.

20 MAGNETIC PARTICLE INSPECT EXTERIOR AND INTERIOR SURFACES PER AGC-32116:
A. ALL FINAL MACHINE SURFACES.
B. ALL WELDS AFTER GRINDING, BEFORE MARAGING AND AFTER MARAGING.

21 RADIOGRAPHIC INSPECT ALL WELDS, EXTERIOR AND INTERIOR, BEFORE AND AFTER MARAGING TREATMENT PER AGC-36065. INTERPRET PER AGC-13860, TABLE I, CLASS 1.

22 WELD REPAIR:
A. PRIOR TO MARAGING REPAIR WELD PER AGC-36073/303. NO DEFECT SHALL BE REPAIRED MORE THAN THREE TIMES. INSPECT WELD REPAIR PER NOTES 20 AND 21.
B. WELD REPAIR AFTER MARAGING SUBJECT TO AGC APPROVAL.

23 ALL SURFACES TO BE PROTECTED FROM CORROSION DURING FABRICATION AND STORAGE.

24 APPLY ZINC CHROMATE PRIMER PER AGC-36072 TO ALL EXTERNAL AND INTERNAL SURFACES, EXCEPT AS NOTED BY 25 .

25 APPLY CORROSION PREVENTIVE MIL-C-16173 GRADE 1, PER AGC-36234 TO ALL SURFACES NOTED.

26 REMOVED.

27 PROTECT NOTED SURFACES PER AGC-36237 WHEN SANDBLASTING.

28 METHODS OF PRESERVATION PER MIL-P-116, METHOD III.

29 DRILL THESE HOLES USING CHAMBER TO NOZZLE MASTER DRILL FIXTURE.

30 REMOVED

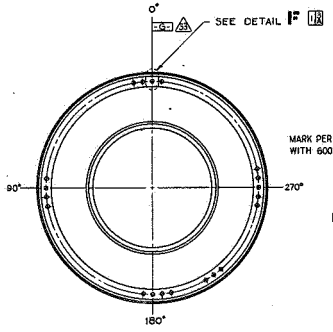
31 THESE DIAMETERS MAY BE RESTRAINED TO TRUE SHAPE FOR INSPECTION.

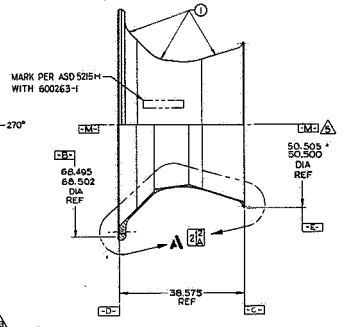
32 HANDLING RINGS REQUIRED DURING FABRICATION, HANDLING, SHIPPING, AND AT NEXT ASSEMBLY TO MAINTAIN -B- AND -C- TO DRAWING TOLERANCES AT ALL TIMES. CONFIGURATION SUBJECT TO AGC APPROVAL.

33 -G- IS DEFINED AS A PLANE PASSING THROUGH CENTERS OF INDEX HOLE AND DATUM -B- .

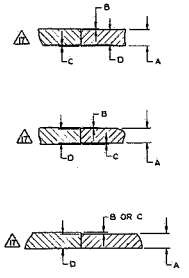
34 PROCESS DIMENSIONS DO NOT INSPECT.

35 THE NOZZLE SHELL STEEL SHALL CONFORM TO THE FOLLOWING SPECIFICATION: FORGINGS - AGC-34316.

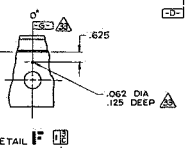




MAXIMUM SHELL WELDMENT MISMATCH DEFINITIONS: 17
A = ACTUAL MINIMUM THICKNESS OF THE FORGING TO BE WELDED
B AND C = NON-CONTINUOUS MEMBRANE.
THE SUM (B + C) SHALL NOT EXCEED 10% OF A
D = MINIMUM CONTINUOUS MEMBRANE — 80% OF A



WELDMENT MISMATCH DETAIL
SCALE 1/1

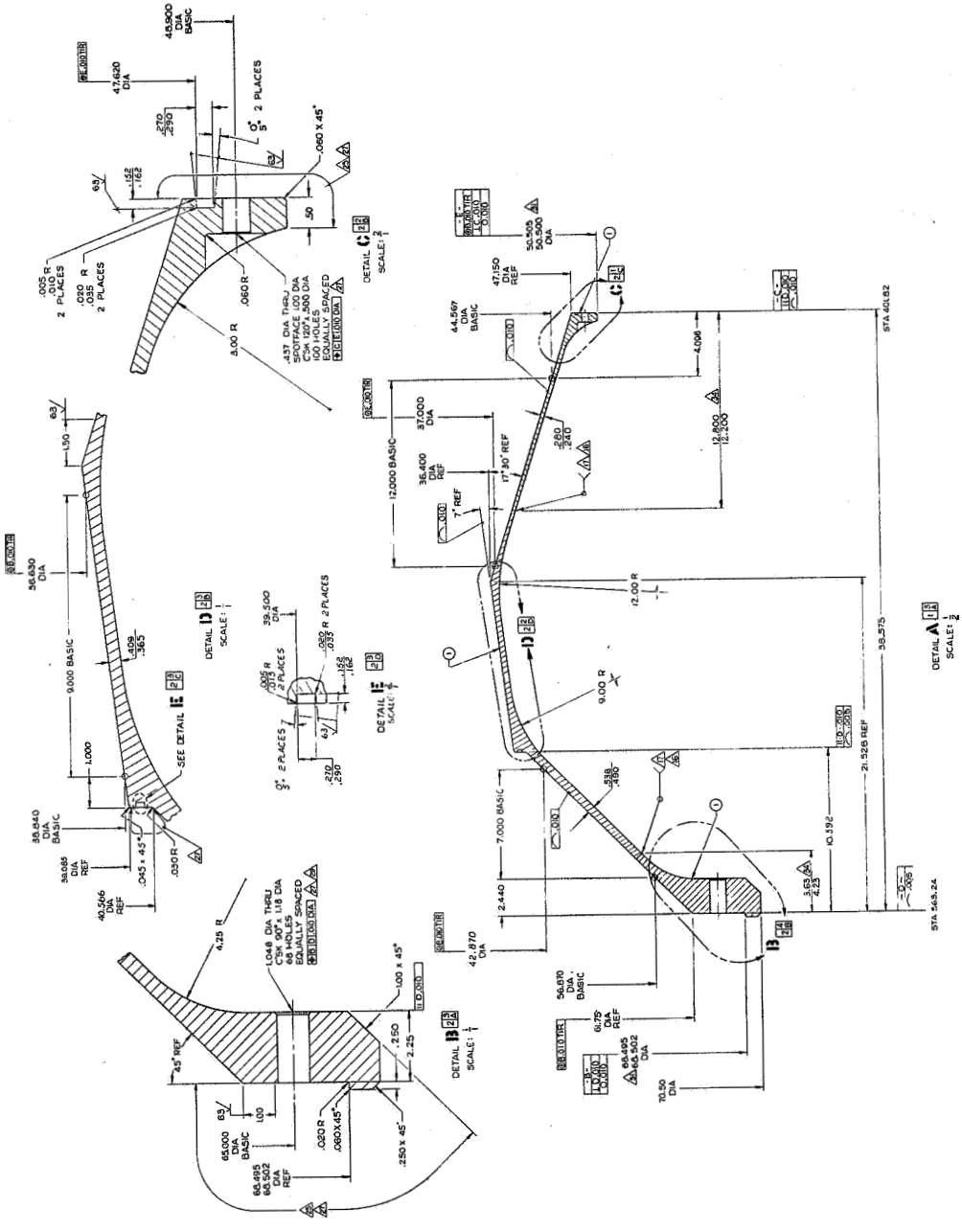


DETAIL F 12
SCALE: 1/2

ZONE	QTY	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	UNIT WT.	ZONE	ITEM NO.
									8
									7
25	AR			CORROSION PREVENTIVE COMP	GR 1	MIL-C-16173			6
24	AR			DRIVER - COLOR Y		MIL-P 8585			5
									4
16	AR			FILLER WIRE		AGC-34326			3
									2
35	3				FORGING STEEL	AGC-34316			1

Figure 6, Sheet 1 of 2

120-SS-1 Nozzle Shell Drawing



120 S-1 Nozzle Shell Drawing

Figure 6, Sheet 2 of 2

REVISIONS			
SYM	ZONE	DESCRIPTION	DATE
A		SEE A CHANGE ADCN INC	11-14
B		SEE B CHANGE ADCN INC	11-14
C		SEE C CHANGE ADCN INC	2-24
D		SEE D CHANGE ADCN INC	5-15
E		SEE E CHANGE DCN	1-13
F		SEE F CHANGE ADCN INC	4-20
G		SEE G CHANGE DCN	1-20

NOTES:

1 INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED IN MIL-D-70327.

2 SURFACE ROUGHNESS 125 UNLESS OTHERWISE SPECIFIED.

3 REMOVED.

4 BOND USING ADHESIVE PER AGC-34151 TYPE II. PREPARE PRIMED METAL SURFACES PER AGC-36180. PREPARE PLASTIC SURFACES PER AGC-13842, METHOD C. CURE PER AGC-36180. IF AN6-13A BOLT AND NAS1022N8 NUT ARE IN PLACE DURING BONDING OF RETAINER RING TO SHELL AND EXIT CONE INSERT THEN ANTI-SEIZE COMPOUND SHOULD BE APPLIED TO NUT AND BOLT SUCH THAT THEY CAN BE EASILY REMOVED (WITHOUT DAMAGING NOZZLE) AFTER BONDING AND FINAL MACHINING.

5 MACHINE ENDS OF EXIT CONE INSERT TO MATE WITH SHELL, RETAINER RING, AND THROAT INSERT WITHIN GAPS SHOWN IN DETAILS D AND E.

6 MACHINE INSIDE CONTOUR OF EXIT CONE INSERT, THROAT INSERT, AND ENTRANCE CAP. INSERT IS TO BE WITHIN .005 OF THE BASIC CONTOUR AND THE SLOPE VARIATION IS NOT TO EXCEED .005 IN/IN.

7 BOND INSULATION TO SHELL AND ENTRANCE CAP INSERT WITH EPON 948 ADHESIVE. PREPARE MATING SURFACE OF ENTRANCE CAP INSERT PER AGC-13842, METHOD C. INSULATION PER AGC-13842 METHOD B AND SHELL PER AGC-36180. CURE AT 180° F OR LESS, METHOD SUBJECT TO AGC APPROVAL.

8 FILL GAP VOID FREE WITH SEALING COMPOUND AGC-34076 CLASS 5 PRIOR TO BONDING INTO ASSEMBLY.

9 LUBRICATE BOLT THREADS WITH ANTI-SEIZE COMPOUND AND TORQUE TO 100 ±25 INCH-POUNDS. TORQUE IN A SEQUENCE PATTERN PER ASD5226.

10 METHOD OF PRESERVATION PER MIL-P-116, METHOD III.

11 LUBRICATE PACKING WITH LUBRICATING GREASE. PACKING, GROOVE AND SURFACE CONTACTING PACKING TO BE FREE OF SEALING COMPOUND AND ADHERIVE.

12 LEAK CHECK ASSEMBLED NOZZLE INSERT BONDS AND FILLED GAPS PER AGC-36425. TEST PLAN TO BE SUBMITTED FOR A.G.C. APPROVAL.

13 EPON 948 AND EPON 948.2 MAY BE USED INTERCHANGEABLY FOR SECONDARY BONDING OF INSULATION.

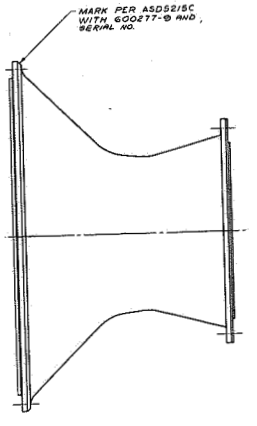
14 REMOVE ALL BURRS AND SHARP EDGES EQUIVALENT TO .004-.015 R UNLESS OTHERWISE SPECIFIED.

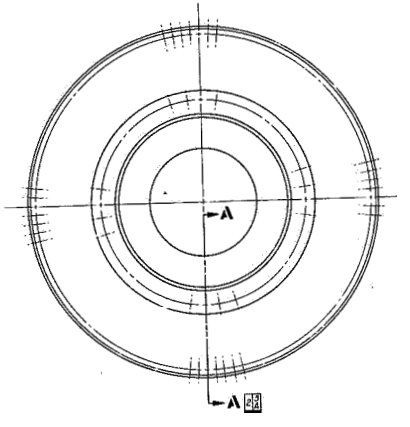
15 ALL METAL SURFACES TO BE PROTECTED FROM CORROSION DURING FABRICATION, SHIPPING AND STORAGE.

16 APPLY MIL-C-16173, GRADE 3, CORROSION PREVENTIVE COMPOUND PER AGC-36234 TO SURFACES NOTED.

17 REFINISH DAMAGED PRIMER PER AGC-36072 ON ALL EXTERIOR SURFACES PRIOR TO SHIPMENT.

18 DURING INSTALLATION AND BONDING OF THE INSERTS TO THE SHELL, A UNIFORM PRESSURE NOT TO EXCEED 50 PSI IS PERMITTED.

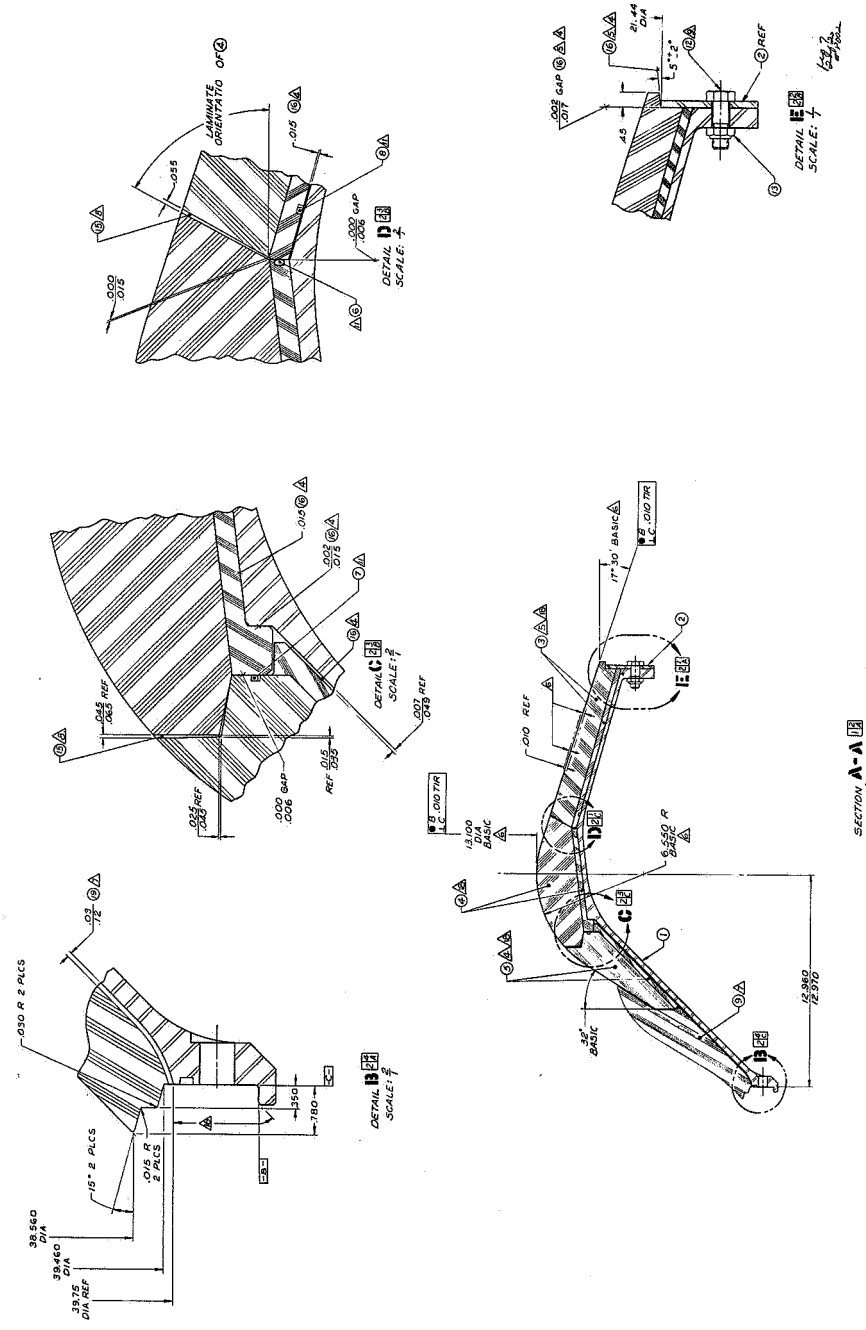




	AR			PRIMER ZINC CHROMATE	COLOR T	MIL-P-8585		21
	AR			CORR. PREVENTIVE COMPOUND	GRADE 3	MIL-C-16173		20
13	AR	5696		ADHESIVE	EPON 948			19
	AR			ANTI-SEIZE COMPOUND		MIL-T-5544		18
	AR			LUBRICATING GREASE		MIL-L-6343		17
	AR			ADHESIVE	TYPE II	AGC-34151		16
	AR			SEALING COMPOUND	CLASS 5	AGC-34076		15
								14
	42		NAS 1022N8	NUT				13
	42		AN6-13A	BOLT				12
								11
								10
	1		600298-1	INSULATION			2	9
	1		600281-5	PACKING			2	8
	1		600281-3	PACKING			2	7
	1		600281-1	PACKING			2	6
	1		600279-1	INSERT, ENTRANCE CAP			2	5
	1		600278-1	INSERT, THROAT			2	4
	1		600274-1	INSERT, EXIT CONE			2	3
	1		600273-1	RING, RETAINER			2	2
	1		600272-1	SHELL			2	1
QTY REQD	PER	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	PART NO.	CODE	FIG. NO.

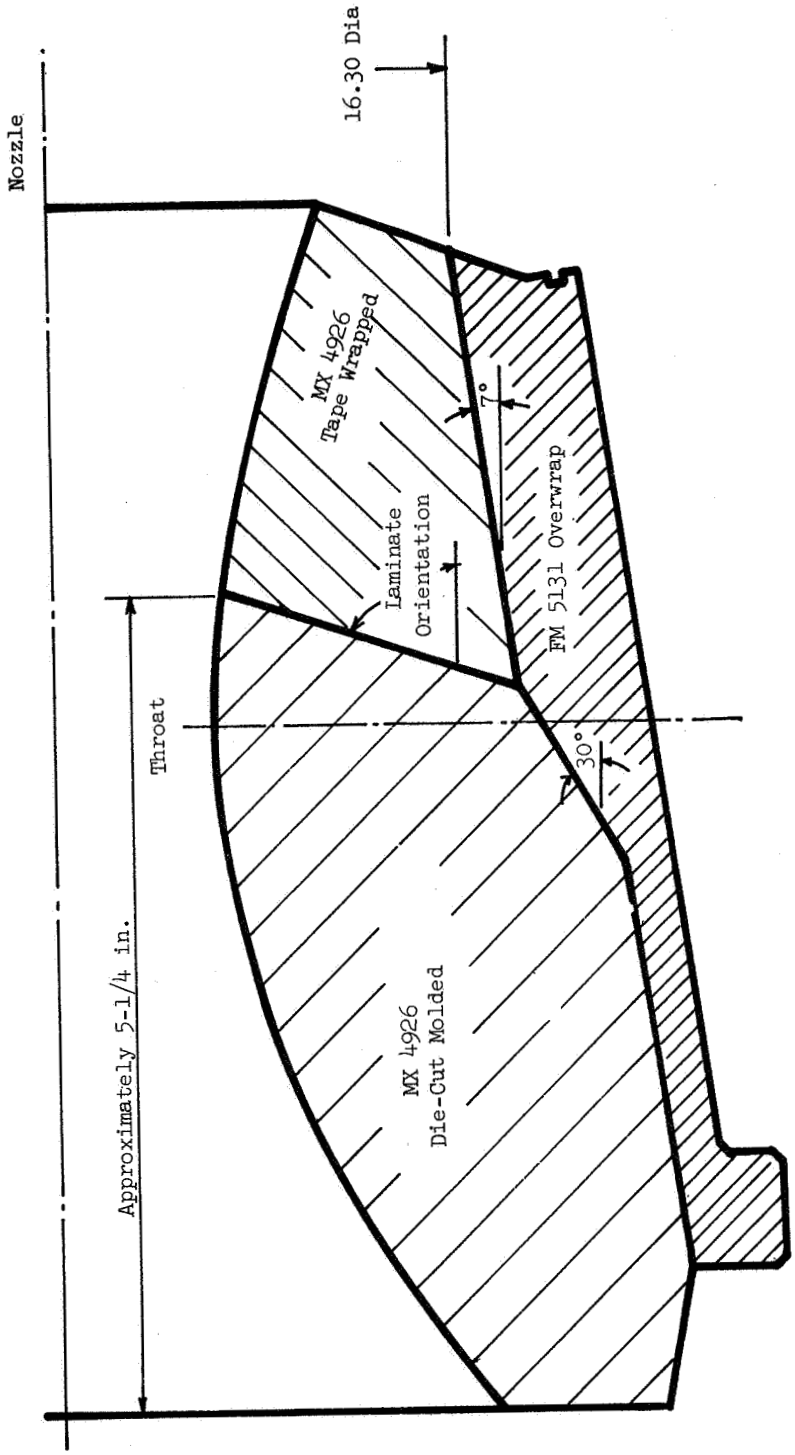
44-SS Nozzle Assembly Drawing

Figure 7, Sheet 1 of 2



44-SS Nozzle Assembly Drawing

Figure 7, Sheet 2 of 2



3-SS-3 zz4 Throat Insert

Figure 8

NOTES:

1 REMOVE ALL BURRS AND SHARP EDGES EQUIVALENT TO .005 -.015 R.

2 INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327.

3 ALL FILLET AND CORNER RADII TO BE SMOOTH. NO STEPS OR MISMATCH PERMITTED.

4 ALL DIMENSIONS SHOWN ARE AFTER HEAT TREATMENT AND FINAL MACHINING.

5 ALL MACHINED DIMENSIONS TO BE WITHIN TOLERANCE WHEN REFERENCED TO A STANDARD TEMPERATURE OF 68°F.

6 MAXIMUM PERMISSIBLE SLOPE VARIATION OF ALL SURFACES NOT TO EXCEED .020 IN/IN UNLESS OTHERWISE SPECIFIED.

7 MAXIMUM PERMISSIBLE SLOPE VARIATION TO BE .010 IN/IN.

8 ALL SURFACES TO BE PROTECTED FROM CORROSION DURING FABRICATION.

9 SURFACE ROUGHNESS 125/ UNLESS OTHERWISE SPECIFIED.

10 MAGNETIC PARTICLE INSPECT ALL FINAL MACHINED SURFACES BEFORE HYDROTEST AND COMPLETE SHELL AFTER HYDROTEST PER AGC-36235.

11 HYDROTEST SHELL TO 600 ±5 PSIG PER TEST PLAN PREPARED BY VENDOR. TEST PLAN IS TO BE APPROVED BY AGC PRIOR TO INITIATION OF HYDROTEST.

12 CLEAN AND DEGREASE PER MIL-P-116 PROCESS C-1 AND AS NOTED BELOW:
A. SANDBLASTING PER AGC-36237 IS PERMISSIBLE PROVIDING THE FINAL METAL THICKNESS AND SURFACE ROUGHNESS REMAIN WITHIN THE SPECIFIED VALUES.
B. PROTECT NOTED MACHINE SURFACES PER AGC-36237 WHEN SANDBLASTING.

13 APPLY ZINC CHROMATE PRIMER PER AGC-36072 TO ALL EXTERNAL SURFACES EXCEPT AS NOTED BY 14 AND 18 AFTER POST HYDROTEST INSPECTION.

14 APPLY CORROSION PREVENTIVE PER AGC-36234 TO SURFACES NOTED AFTER HYDROTEST INSPECTION.

15 METHOD OF PRESERVATION PER MIL-P-116, METHOD III.

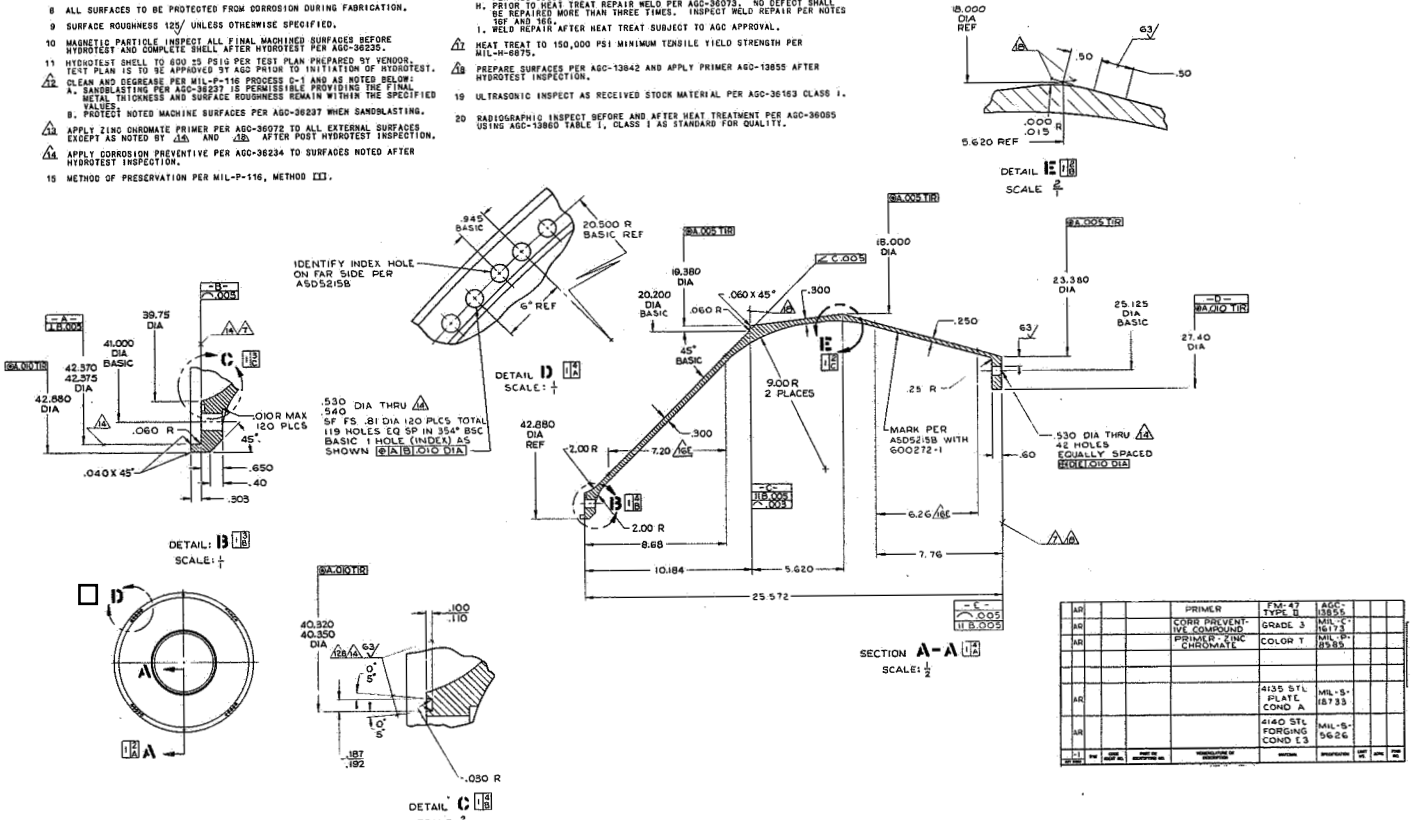
16 METHOD OF FABRICATION IS OPTIONAL SUBJECT TO AGC APPROVAL. CONICAL SECTIONS MAY BE FORGED OR ROLLED AND WELDED PLATE. BOLT RINGS MAY BE FORGED OR RINGS CUT FROM PLATE. HOWEVER, IF WELDING TECHNIQUES ARE USED THE FOLLOWING WELD NOTES APPLY:
A. WELD PER AGC-36073, USING WELD ROD PER MIL-R-5632 CLASS 2.
B. LOCATION OF LONGITUDINAL WELDS IN SHELL TO BE EQUALLY SPACED STAGGERED IN RELATION TO ADJOINING LONGITUDINAL WELDS.
C. GIRTH WELDS:
TOTAL ALLOWABLE MISMATCH OF WELDED SECTIONS NOT TO EXCEED 10% OF MINIMUM MATERIAL THICKNESS (90% CONTINUOUS MEMBRANE). PERMISSIBLE WELD CROWN OF .040 -.000 OUTSIDE AND .005 -.000 INSIDE. REMOVE EXCESS WELD DEPOSIT BY GRINDING. GRIND MARKS TO BE TRANSVERSE TO SHELL AXIS.
D. LONGITUDINAL WELDS:
TOTAL ALLOWABLE MISMATCH OF WELDED SECTIONS NOT TO EXCEED 5% OF MINIMUM MATERIAL THICKNESS (95% CONTINUOUS MEMBRANE). PERMISSIBLE WELD CROWN OF .020 -.002 OUTSIDE AND .005 -.000 INSIDE. REMOVE EXCESS WELD DEPOSIT BY GRINDING. GRIND MARKS TO BE TRANSVERSE TO SHELL AXIS.
E. PERMISSIBLE WELD AREA.
F. MAGNETIC PARTICLE INSPECT ALL WELDS AFTER GRINDING, BEFORE AND AFTER HEAT TREATMENT PER AGC-36235.
G. RADIOGRAPHIC INSPECT ALL WELDS BEFORE AND AFTER HEAT TREATMENT PER AGC-36085 AND INTERPRET PER AGC-13860, TABLE I, CLASS 1.
H. PRIOR TO HEAT TREAT REPAIR WELD PER AGC-36073. NO DEFECT SHALL BE REPAIRED MORE THAN THREE TIMES. INSPECT WELD REPAIR PER NOTES 16F AND 16G.
I. WELD REPAIR AFTER HEAT TREAT SUBJECT TO AGC APPROVAL.

17 HEAT TREAT TO 150,000 PSI MINIMUM TENSILE YIELD STRENGTH PER MIL-H-6875.

18 PREPARE SURFACES PER AGC-13842 AND APPLY PRIMER AGC-13855 AFTER HYDROTEST INSPECTION.

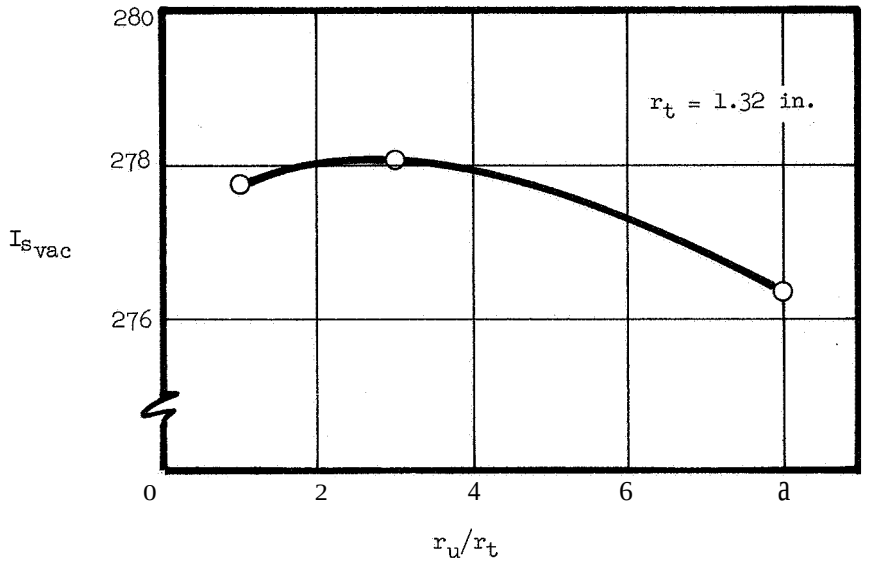
19 ULTRASONIC INSPECT AS RECEIVED STOCK MATERIAL PER AGC-36163 CLASS 1.

20 RADIOGRAPHIC INSPECT BEFORE AND AFTER HEAT TREATMENT PER AGC-36085 USING AGC-13860 TABLE I, CLASS I AS STANDARD FOR QUALITY.

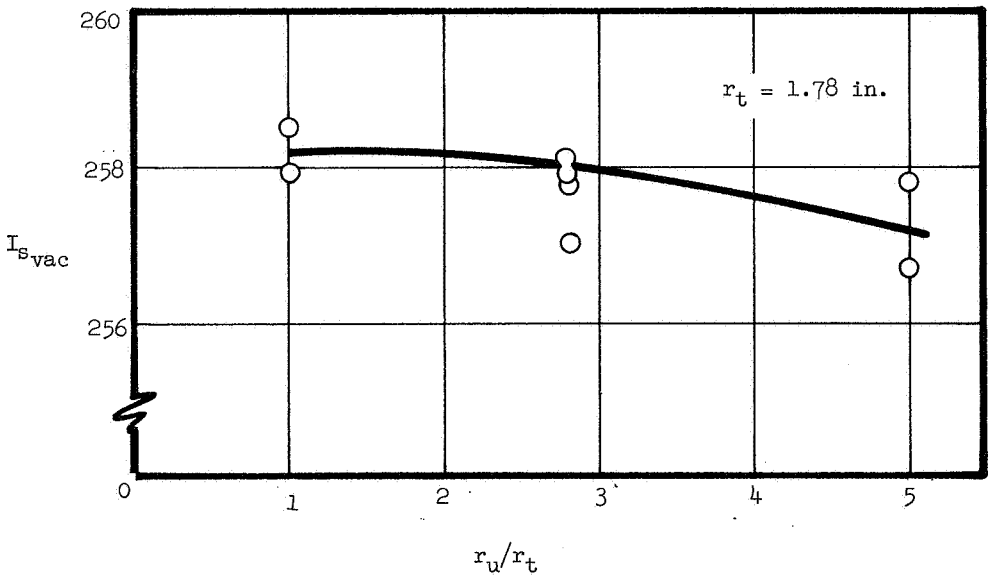


44-SS Nozzle Shell Drawing

Figure 9



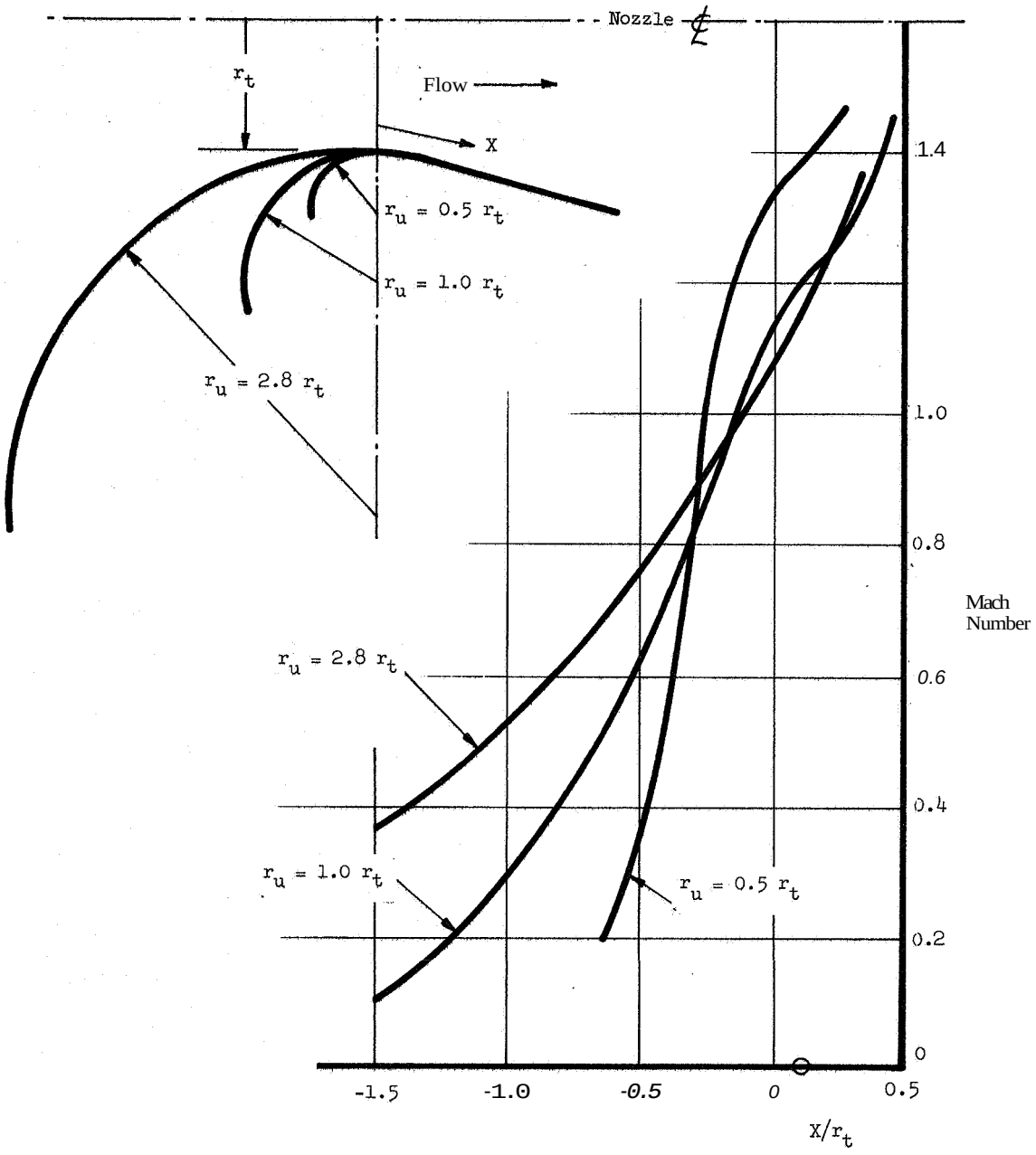
(a)



(b)

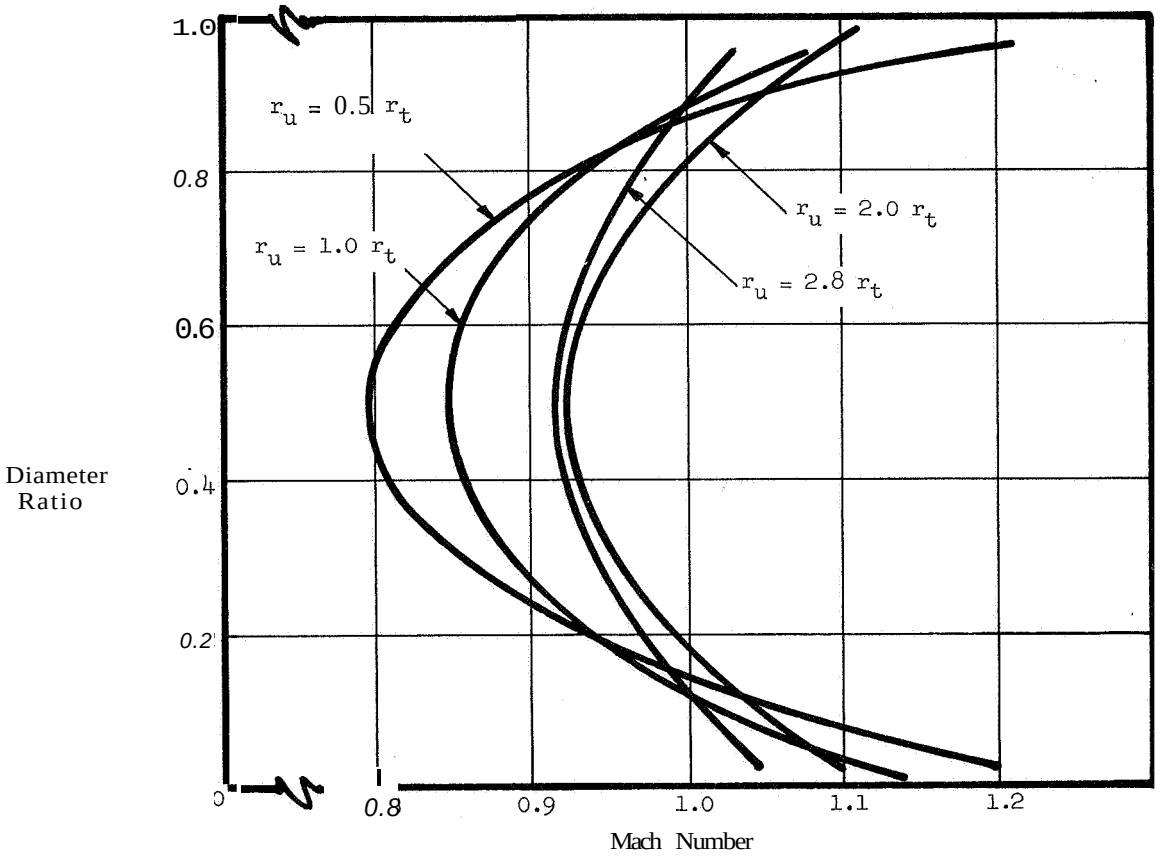
Effects of Upstream Wall Radius Ratio on Vacuum Specific Impulse

Figure 10



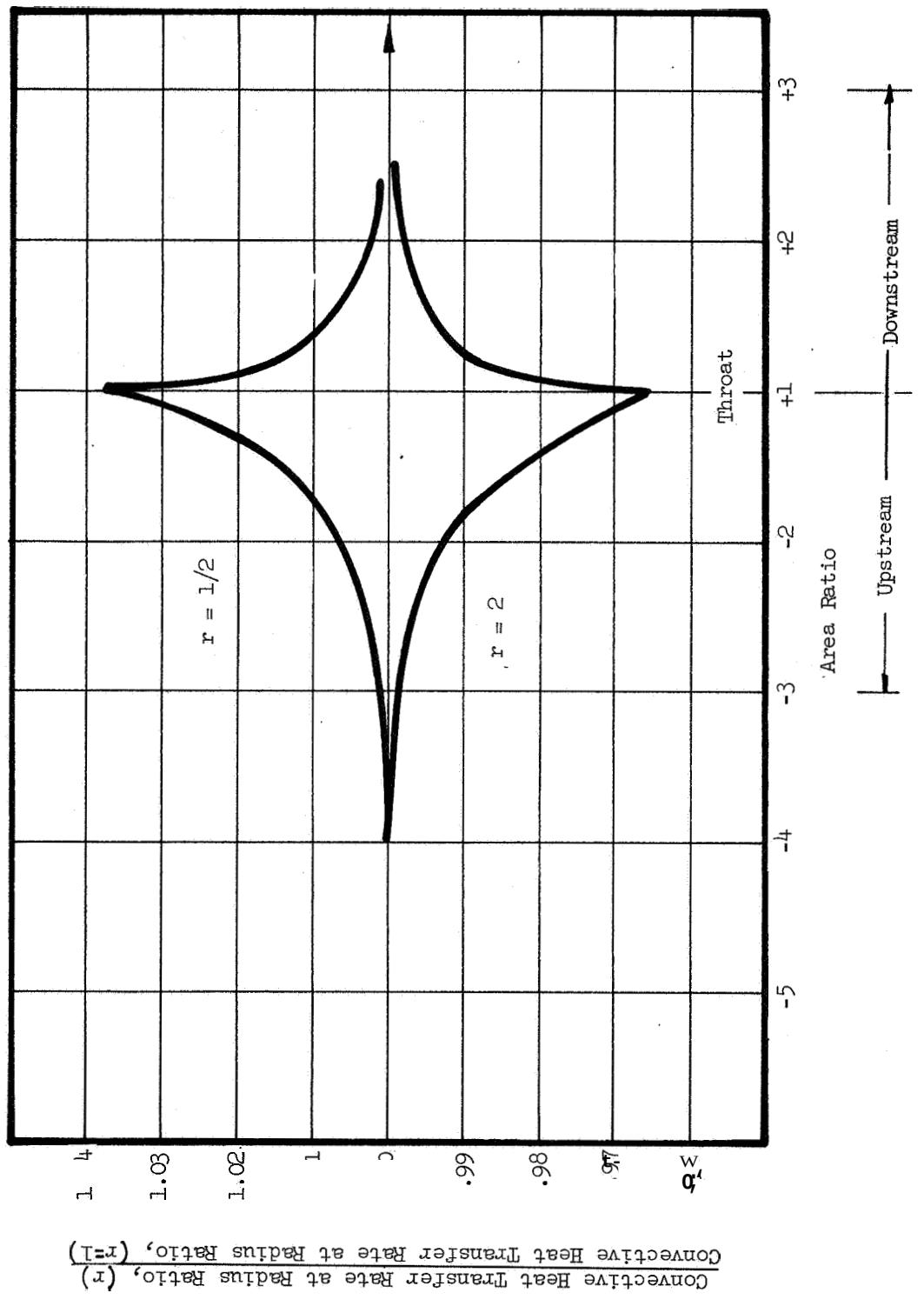
Effects of **Upstream** Wall Radius **Ratio** on Nozzle Entrance Wall Mach **Number** Distribution

Figure 11



Effects of Upstream Wall Radius Ratio on Nozzle Throat Wall Mach Number Distribution

Figure 12



Ratio of Heat-Transfer Coefficients as a Function of Nozzle Area Ratio

Figure 13

Material	Tape Orientation, Degrees	Initial Throat dia, in.	Final Throat dia	Chamber Temp., °F	Avg Chamber Press. psia	Burn. Dur., sec	Nozzle Area Ratio	Avg Surf. Recess. Rate mil/sec	Char Depth in.	Remarks
Silica Cloth										
MX-2600	0-10	7.0	7.63	5760	500	128	3.4	3.1	---	
MX-2600	67	1.25	1.51	5760	450	78	4.0	3.2	---	
MX-2646	0-10	2.7	3.0	5760	500	24	2.0 3.0	7.0 2.1	--- ---	
MX-2646	0-10	2.7	2.94	5760	500	24	2.0 3.0	7.8 2.9	--- ---	
(CTL) Refrasil	0	17.0	17.36	5415	457	60.1	2.0	10.0	---	
Refrasil	0	25.90	26.08	5500	539	45.7	2.0	12.0	---	
Refrasil	0	25.75	26.08	5620	547	67.1	2.0	13.4	---	
Refrasil	0	28.40	29.50	5980	572	88.1	2.0	16.2	---	TVC liq. inj.
MX-2641	0	14.7	15.99	5700	415	134.0	2.7 6.0	5.6 1.0	---	
FM-XA-0-34-2	0	18.4	19.01	5700	455	124.6	2.9 7.0	7.4 0.3	---	
MX-2625	Random	1.25	1.55	5760	450	78.0	2.6	2.8	---	
MX-2625	Molded	4.71	---	5430	551	45.0	1.4	6.7	---	
MX-2625	Molded	4.33	---	5500	550	60.0	7.5 2.0	6.25 9.5	---	
AVCO X-2001	90	3.25	4.10	5700	488	23.5	1.0	18.0	---	
AVCO X-2010	0	6.40	8.85	5980	464	117.0	5.0 9.0	8.0 7.0	---	TVC tar
FM-5067	0	6.85	7.06	5660	563	94.2	4.74 7.0	9.0 6.0	---	
FM-XOA-34-2	0	14.7	15.13	5700	464	134	2.8 4.5 7.0	5.5 2.0 0.5	---	
Silica	15 Initial 0 Final	21.0	21.55	5380	573	122.8	1.5 3.0 6.0	7.9 4.7 1.2	---	
FM-XA-0-34-2	0	24.0	24.38	5700	545	78.8	3.0	4.5	---	

Experimental Data on Nozzle Materials

Figure 14, Sheet 1 of 4

Material	Tape Orientation Degrees	Initial Throat dia, in.	Final Throat, dia	Chamber Temp., °F	Avg Chamber Press., dia	Burn. Dur., sec	Nozzle Area Ratio	Avg Surf. Recess. Rate mil/sec	Char Depth in.	Remarks
Graphite Cloth										
MX-4551	45-75	4.0	4.210	5500	557	17.8	1	5.9	.25	Tubular throat
FM-5064	45-75	4.0	4.293	5500	532	18.3	1	8.0	.28	Tubular throat.
FM-5064	67	2.7	2.94	5760	500	24.0	1	5.05	.55	
FM-5064	---	4.392	5.287	5500	407	66.7	1	6.63	---	
FM-5064	---	5.277	6.511	5500	428	114.9	1	5.37	---	
FM-5064	0	6.85	7.06	5860	563	94.2	2.37	7.40	---	
MX-4551	90	14.70	15.99	5700	415	134.0	1	4.80	---	Tubular throat (12" lg.)
MX-4551	30-45	14.70	15.99	5700	415	134.0	1.7 1.25	1.85 3.6	---	
MX-4551	30	24.0	24.38	5700	545	78.7	1.27 2.40	4.0 1.0	---	
MX-4551	67	1.25	1.59	5760	450	78.0	1	2.16	.73	
MX-4551	67	1.25	1.51	5760	450	78.0	1	1.67	.70	
MX-4551	30	18.4	15.01	5700	555	124.6	1.7 2.2	3.1 1.9	--- ---	
FM-5014G	67	7.0	7.63	5760	500	128.0	1	2.45	---	
FM-5014G	67	1.25	1.655	5760	450	78.0	1	2.59	.77	
FM-50146	---	4.392	5.298	5500	373	68.1	1	6.66	---	
FM-5014G	30	14.7	15.13	5700	460	134.0	1.5 2.5	1.7 1.1	--- ---	
N4024 (Narmco)	67	1.25	1.45	5760	450	76.0	1	1.26	.65	
N4024 (Narmco)	Random	2.70	3.0	5760	500	24.0	1	6.25	.55	
N4024 (Narmco)	45	2.70	2.97	5760	500	24.0	1	5.55	.45	

Experimental Data on Nozzle Materials

Figure 14, Sheet 2 of 4

Material	Tape Orientation Degrees	Initial Throat dia. in.	Final Throat dia	Chamber Temp., °F	Avg Chamber Press., dia	Burn. Dur., sec	Nozzle Area Ratio	Avg. Surf Recess. Rate mil/sec	Char Depth in.	Remarks
Carbon Cloth										
MX-4926	67	1.25	1.625	5760	450	78	1	2.40	0.64	
MX-4034	67	1.25	1.694	5760	450	78	1	2.85	0.71	
FM-5063	67	2.70	3.530	5760	500	24	1	17.30	0.65	Severe spalling
FM-5055	30	4.388	5.130	5500	373	72.3	1	5.14	---	
AVCO X2006	90	3.25	3.560	5700	600	23.7	1	6.50	---	
AVCO X2006	90	6.4	8.850	5980	464	117.0	1	10.5	---	Jet tabs
MX-4926	90	2.75	---	6010	500	34.0	2.34	3.0	---	
MX-4926	0	8.6	---	5900	475	60.0	6.5	2.3	.32	
FM-5065	Molded	8.6	---	5900	475	60.0	6.5	2.16	.37	
m-4926	45-75	4.0	4.178	5700	525	19.3	1	4.6	.25	Tubular throat
FM-5063	45-75	4.0	4.214	5700	548	18.4	1	5.8	.20	Tubular throat
AVCO X2006	90	4.0	4.205	5700	547	18.3	1	5.6	.35	Tubular throat
FM-5014G	45	12.64	---	5900	700	32.0	2.5	3.3	.45	Large gouge
m-4926	45	12.64	---	5900	700	31.0	2.5 3.0	3.22 1.61	.45	
MX-4926	0	9.63	---	5900	542	57.1	6.98	1.03	---	Delaminations and waviness
MX-4926	0	9.63	---	5900	460	55.9	6.85 9.85	1.32 0.74	---	Gouges around TVC injector parts
FM-5065	Molded	9.63	---	5900	542	57.1	2.44 5.55	0.86 1.035	---	Severe spalling
FM-5065	Molded	9.63	---	5900	460	55.9	2.52 6.10	0.88 1.32	---	Severe spalling
MX-4926	0	9.63	---	5900	488	61.1				

Experimental **Data** on Nozzle Materials

Figure 14, Sheet **3** of 4

Material	Tape Orientation Degrees	Initial Throat dia, in.	Final Throat, dia	Chamber Temp., °F	Avg Chamber Press.psia	Burn. Dur., sec	Nozzle Area Ratio	Avg Surf. Recess. Rate mil/sec	Char Depth in.	Remarks
N4024 (Narmco)	67	2.70	2.97	5760	500	24.0	1	5.62	.60	
N4024 (Narmco)	87	2.70	2.99	5760	500	24.0	1	6.10	.60	
AGX-G-79	67	2.70	2.92	5760	500	24.0	1	4.5	.65	
MX-2630A	Molded	9.63	---	5900	525	59.3	2.7 6.1	3.6 1.6	---	
MX-2630A	Molded	9.63	---	5900	498	58.0	3.1	3.0	---	Erratic surf. recession
MX-2630A	Molded and Holes Drilled	9.63	---	5900	472	64.0	3.1	3.0	---	Erratic surf. recession
FM-5014G	0	9.63	---	5900	494	56.5	2.7	2.48	---	
FM-5014G	0	9.63	---	5900	506	59.0	2.6 5.5	1.70 1.02	---	
FM-5014G	0	9.63	---	5900	445	66.0	1.83 2.50	3.80 1.82	---	Delaminations and blisters
FM-5014G	0	9.63	---	5900	442	66.6	1.80	5.10	---	Delaminations and blisters

Experimental Data on Nozzle Materials

Figure 14, Sheet 4 of 4

Vendor	Trade Name	Type of Cloth	Resin
U. S. Polymeric	FM 5014G	Graphite (NCC)	Phenolic
U. S. Polymeric	FM 5055	Carbon (HITCO)	Phenolic
U, S. Polymeric	FM 5063	Carbon (HITCO)	Phenolic
U. S. Polymeric	FM 5072	Carbon (NCC)	Phenolic
U. S. Polymeric	FM 5055/5131	Carbon/Silica	Phenolic
Narmco	N-4024	Graphite (NCC)	Phenolic
Narmco	N-4034	Carbon (HITCO)	Phenolic
Narmco	Nehrglo	Carbon (Graphite Special)	Phenolic
Fiberite	MX 4551	Graphite (NCC)	Phenolic
Fiberite	MX 4926	Carbon (HITCO)	Phenolic
Fiberite	DEN 438A	Carbon (NCC)	Epoxy Novolac
Coast	9-P055-3	Graphite (NCC)	Phenolic

Reinforced Plastics Evaluated in MERM Tests

Figure 15

Material Designation	Type	Initial Design Pressure, psia	Surface Recession Rate, mil/sec Maximum	Average
N-4034	Carbon	600	7.6	4.61
FM-5063	Carbon	600	7.7	3.58
N-4024	Graphite	600	8.0	3.68
MX-4926	Carbon	600	8.5	3.66
MX-4551	Graphite	600	9.0	3.26
FM-5014G	Graphite	600	9.0	3.55
FM-5072	Carbon	600	9.2	2.89
FM-5063	Carbon	600	9.8	4.87
FM-5055	Carbon	600	10.9	4.52
FM-5055/5131	Carbon/Silica	600	12.3	7.12
MX 4926	Carbon	400	4.3	2.65
FM-5072	Carbon	400	4.6	2.30
Nehrglo	Carbon	400	5.4	3.44
MX-4551	Graphite	400	5.8	2.46
9-PO55-3	Graphite	400	7.2	3.51
FM-5063	Carbon	400	7.4	3.25
FM-5055	Carbon	400	7.4	3.80
N-4034	Carbon	400	8.3	3.23
FM-5014G	Graphite	400	8.9	2.96
DEN-438	Carbon	400	9.5	3.53
N-4024	Graphite	400	Chunking	3.12
FM-5055/5131	Carbon/Silica	400	11.3	6.65

Test Conditions:
Propellant - P32; Flame Temperature - 5680°F
Initial Throat Dia - 0.604 in. for 600-psia design chamber pressure
0.710 in. for 400-psia design chamber pressure

Maximum and Average Surface Recession Rates of Reinforced Plastics Tested in MERM's

Figure 16

Instantaneous Pressure, psi	Surface Recession Rate, mil/sec*											
	MX-4551	FM-5055	MX-4926	FM-5014G	N-4034	N-4024	Nehrglo	FM-5063	FM-5072	DEN 438	FM-5131 FM-5055	9-P005-3
600	8.8---	--- ---	8.4 ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---
50	6.6- -	10.7 --	8.2 - -	--- ---	— - -	- - - -	- - - -	--- ---	--- ---	--- ---	--- ---	--- ---
50	8.0- -	10.6 - -	7.7 - -	--- ---	- - - -	8.0 - -	- - - -	7.6 ---	--- ---	--- ---	13.1 ---	--- ---
40	7.6- -	10.0 - -	7.2 --	5 —	--- ---	7.0 ---	7.6 —	7.4 ---	9.0 ---	--- ---	13.0 ---	--- ---
00	4 -	8.4 - -	6.6 --	7 ---	--- ---	5.8 ---	7.3 ---	5.8 ---	5.8,4.6	--- ---	13.0 - -	--- ---
350	5.5---	8.4 ---	6.0,4.4	6.6,8.4	9.7,8.2	4.6 ---	6.9 ---	4.8,6.6	5.0,4.2	--- 9.5	13.0 —	--- ---
300	4.6,5.8	7.2,7.3	5.3,4.1	4.8,6.6	8.8,6.8	4.0 ---	6.3,5.4	4.2,6.0	4.0,3.6	--- 7.4	10.2,11.0	— 7
25	3.2,4.0	5.6 .4	4.2,3.7	3 ,5 5	7.2,4.4	3.2,6.6	5.6,5.1	3.3,5.2	3.2,3.0	--- 5.0	4 0	— 5.0
00	1.9,1.9	4.4,4.8	3.0,3.4	2.2 1	.1,3.3	2 4 3	435 .1	2.6,4.4	2.2,2.2	--- 3.2	8	- - 3.5
150	1.2,1.2	3.3,3 5	1.9,3.0	1 4,2.9	4.7,2.4	1.8,2.4	2.8,2.3	2.0,2.6	1.2,1.7	--- 2.0	5.2,6.2	- - 2.4
00	--- ---	2.2,2.6	-- 2	--- ---	2 8,- -	- - 1.6	1.6,1.0	--- 2.0	--- ---	--- 1.0	4.6,3.6	- - 2.0

*First recession rate from 600-psia chamber-pressure test
Second recession rate from 400-psia chamber-pressure test

Figure 17

Instantaneous Surface Recession Rates of Reinforced Plastics in MERM's

A = Data from AGC Report No. 453, 6 December 1962
B = Data generated by the material supplier (u)

Commercial Number	Reinforcement Type	Reinforcement Source	Reinforcement Spec.	Resin Type	Resin Source	Resin Spec.	Orientation	Specific Gravity	Tensile Strength ll to Plies	Tensile Modulus ll to Plies X 10^6	Compressive Strength Strength	Compressive Strength Modulus	Shear Strength		Flexural Strength Strength	Flexural Strength Modulus X 10^6	Note
MX 4926	Carbon Fabric	Hitco CCA-1		SC1008 Phenolic	Monsanto	MIL-R-9299	E	1.44	15,300	1.90	32,400	2.0	14,700	---	30,700	2.1	
							F		21,600	1.90	64,200	1.6	3,800	---	30,400	2.1	A
							L				42,600	2.0	14,600				
FM 5072	Carbon Fabric	Nat'l Carbon VCK		91LD Phenolic Modified	U.S.P.	MIL-R-9299		1.40	15,200	---	18,100		---	---	30,000	2.2	
								---	---	---	31,400	---	---	---	---	---	B
								---	---	---	---	---	---	---	---	---	
FM 5063	Carbon Fabric	Nat'l Carbon VKC		U.S.P. 39 Phenolic	U.S.P.		E	1.51	21,400	3.1	30,100	---	1,140	---	32,100	3.04	
							F		---	---	50,300	---	---		---	---	B
							L		---	---	---	---			---	---	
FM 5914C	Carbon Fabric	Hitco CCA-1		91LD Phenolic Modified	U.S.P.	MIL-R-9299	E	1.52	10,500	2.7	30,800	2.5	15,500	---	28,400	2.8	
							F		16,200	2.6	73,200	1.9	2,500		25,800	2.5	A
							L		---	---	36,100	2.6	17,200		---	---	
MX 4551	Graphite Fabric	Nat'l Carbon WCA		Polamide Phenolic (Nylon)		None	E	1.44	7,200	1.2	15,500	1.2	19,000	---	14,000	1.3	
							F		6,300	1.30	30,200	0.9	2,600		12,100	1.3	A
							L		---	---	14,200	1.4	8,000				
MX 4500	Graphite Fabric	Nat'l Carbon WCA		SC1008 Phenolic	Monsanto		E	1.35	14,000	1.3	10,000	---	---	---	18,000	1.50	
							F		---	---	---	---	---	---	---	---	
							L		---	---	---	---	---	---	---	---	
FM 5014G	Graphite Fabric	Nat'l Carbon WCA		91LD Phenolic Modified			E	1.43	9,400	2.1	18,800	1.0	10,100	---	17,800	1.70	
							F		14,200	5.9	42,900	1.2	2,600		16,800	1.60	A
							L		---	---	17,700	1.8	10,300		---		
MX 2600	Silica Fabric	Siltemp 84 or Hitco C-100-48		SC1008 Phenolic			E	1.74	13,000	1.5	18,000	---	2,500	---	20,000	1.75	
							F	---	---	---	---	---	---		---	---	B
							L	---	---	---	---	---	---		---	---	
MX 2646	Silica Fabric	Siltemp 84 or Hitco C-100-48		Polyamide Phenolic (Nylon)			E	1.78	15,900	4.6	59,900	3.3	17,200		25,900	3.6	
							F		14,100	4.0	76,800	2.4	7,800		26,300	3.5	A
							L		---	---	65,900	3.3	18,400		---	---	
FM 5131	Silica Fabric	Hitco C-100-48		Polyamide Phenolic (Nylon)			E	1.70 min.	16,000	2.5	34,000	---	---	---	24,000	1.72	
							F	---	---	---	---	---	---		---	---	B
							L	---	---	---	---	---	---		---	---	
FM 5067	Silica Fabric	Hitco C-100-48					E	1.74	11,600	---	52,200	---	---	---	20,100	2.6	
							F										
							L										

E = Edgewise
F = Flatwise per Report #453
L = Lengthwise

Room Temperature Properties of Carbon and Silica Cloth Materials

Figure 18, Sheet 1 of 2

Commercial Number	Thermal Properties: Therm BTU/Ft^2 *F/In.	Thermal Properties: vity Test p. °F	Thermal Properties: Specific Heat Value	Thermal Properties: Specific Heat Test Temp. °F	Thermal Properties: Linear Coeff. of Thermal Expansion ⊥ to Plies x 10^{-6}	Thermal Properties: Linear Coeff. of Thermal Expansion ∥ to Plies x 10^{-6}	Laminate Hardness B-Barcol R-Rockwell	B Stage Material rties: Resin Content % By Wt.	B Stage Material rties: Filler Content % By Wt.	B Stage Material rties: Relief. (Fabric) % By Wt.	B Stage Material rties: Volatile % By Wt.	B Stage Material rties: Resin Flow % By Wt.	Note
MX 4926		300	.29	150	50	6.5	---	31.5-36.5	4-8	55.5-64.5	4.7	---	B
FM 5072	3.8	---	---	---	---	---	Barcol -73	34 ± 3	12-16	---	4 Max	4-12	B
FM 5063	4.3	200	.23	---		3.17	---	34 ± 3	12-16	44-54		4-12	B
FM 5014C	5-4	200	.24	---	---	---	---	34 ± 3	12-16	44-54	Max	4-12	B
MX 4551	5.8 5.6	300 500	.23	150	20.8	[illegible]	Rockwell B 25	33-37	---	---	-6	---	B
MX 4500	5.8 5.7	300 500	.23	---	45.5		Rockwell B 25	30-34					B
FM 5014G	5.8	200	.23	---				34 ± 3	12-1[illegible]	44-54		4-12	B
MX 2600	2.8	300	.22		25		Rockwell B 55-65	29-33	6-10	57-65		---	B
MX 2646			.24		50		Barcol 60-70	18-22	0	73-80		---	B
FM 5131			---	---	---		---	---	--	---		---	B
FM 5067			.24	200	---		---	33 ± 4		65 ± 4			B

Room Temperature Properties of Carbon and Silica Cloth Materials

Figure 18, Sheet 2 of 2

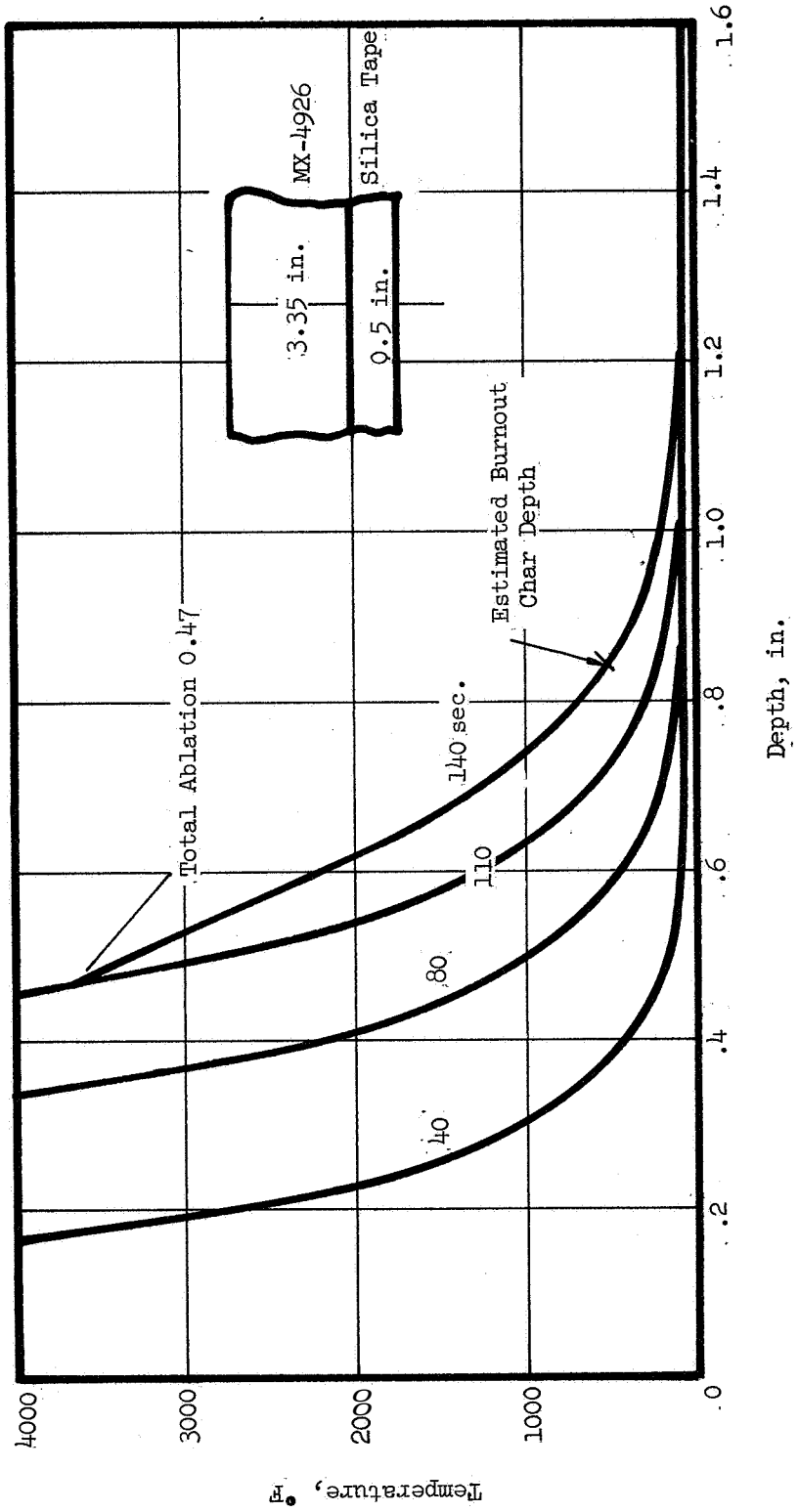
Nozzle	Component	Material	Type of Stress	Margin of Safety+
260-SL	Nozzle Shell (chamber-Nozzle Attachment Joint)	Maraging 18%-Nickel Steel	Tensile between holes	0.339
260-SL	Throat Nozzle Insert	Silica Cloth and Phenolic (FM-5131)	Bond shear	0.120
260-SL	Exit Cone			
	Honeycomb Facings	17-7 PH Stainless Steel	Hoop tension	0.030
	Forward Fitting	AISI 4130	Bending in flange	High
120-SS	Nozzle Shell	Maraging 18%-Nickel Steel	Hoop tension	0.780
120-ss	Entrance Cap Nozzle Insert	Silica Cloth and Phenolic (MX-2646)	Hoop tension	1.200
120-ss	Exit Cone Honeycomb Facings	17-7 PH (TH 1050) Stainless Steel	Hoop tension	0.660
44-ss	Nozzle Shell	AISI 4340 Steel	Tension	0.300
44-ss	Entrance Cap Nozzle Insert	Silica Cloth and Phenolic (MX-2646)	Bond shear	1.200

* All loads are for static firing condition

$$\text{Margin of Safety} = \frac{\text{Allowable Stress}}{\text{Design Stress}} - 1$$

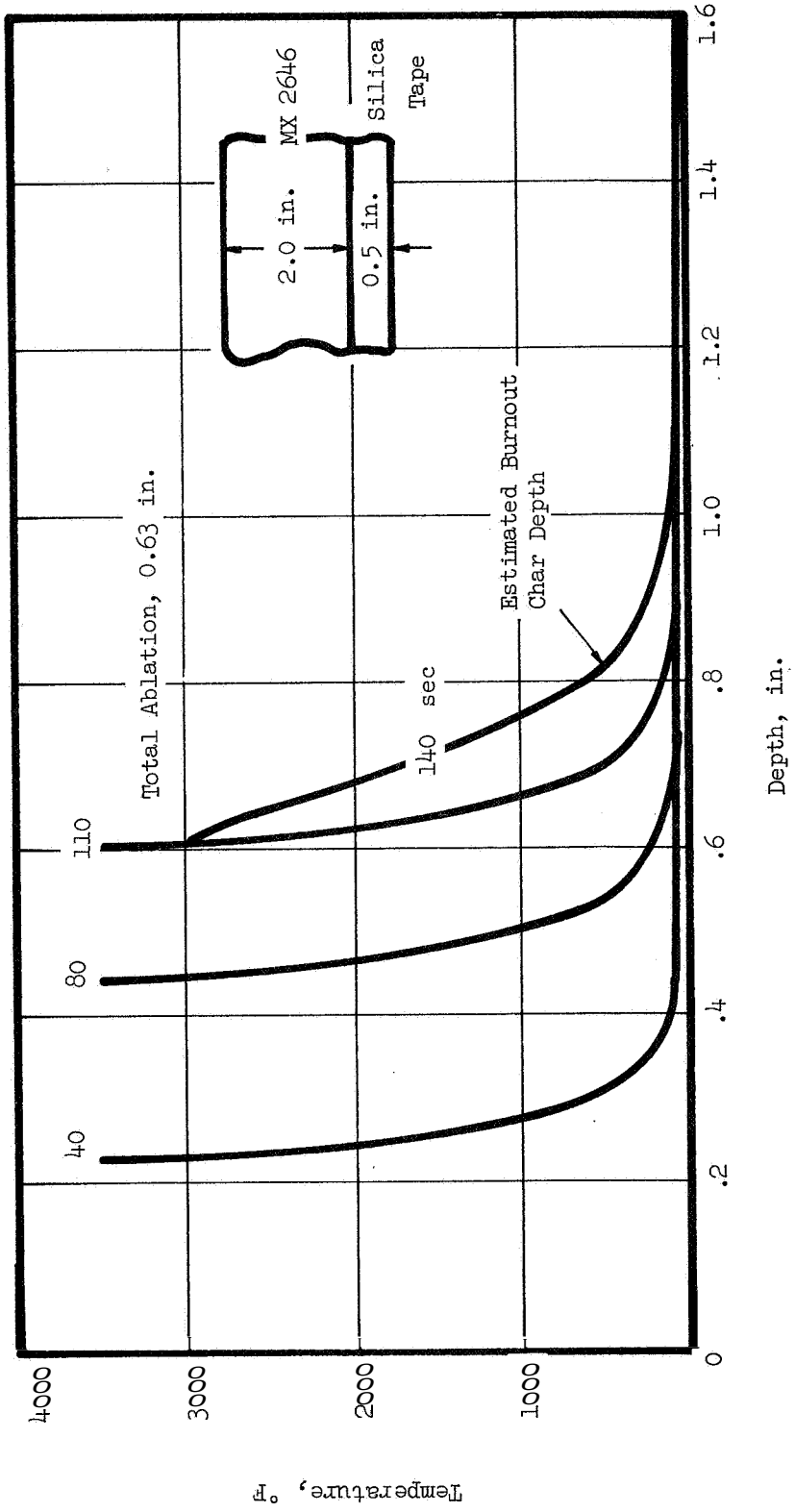
Minimum Margins of Safety for Nozzle Components

Figure 19



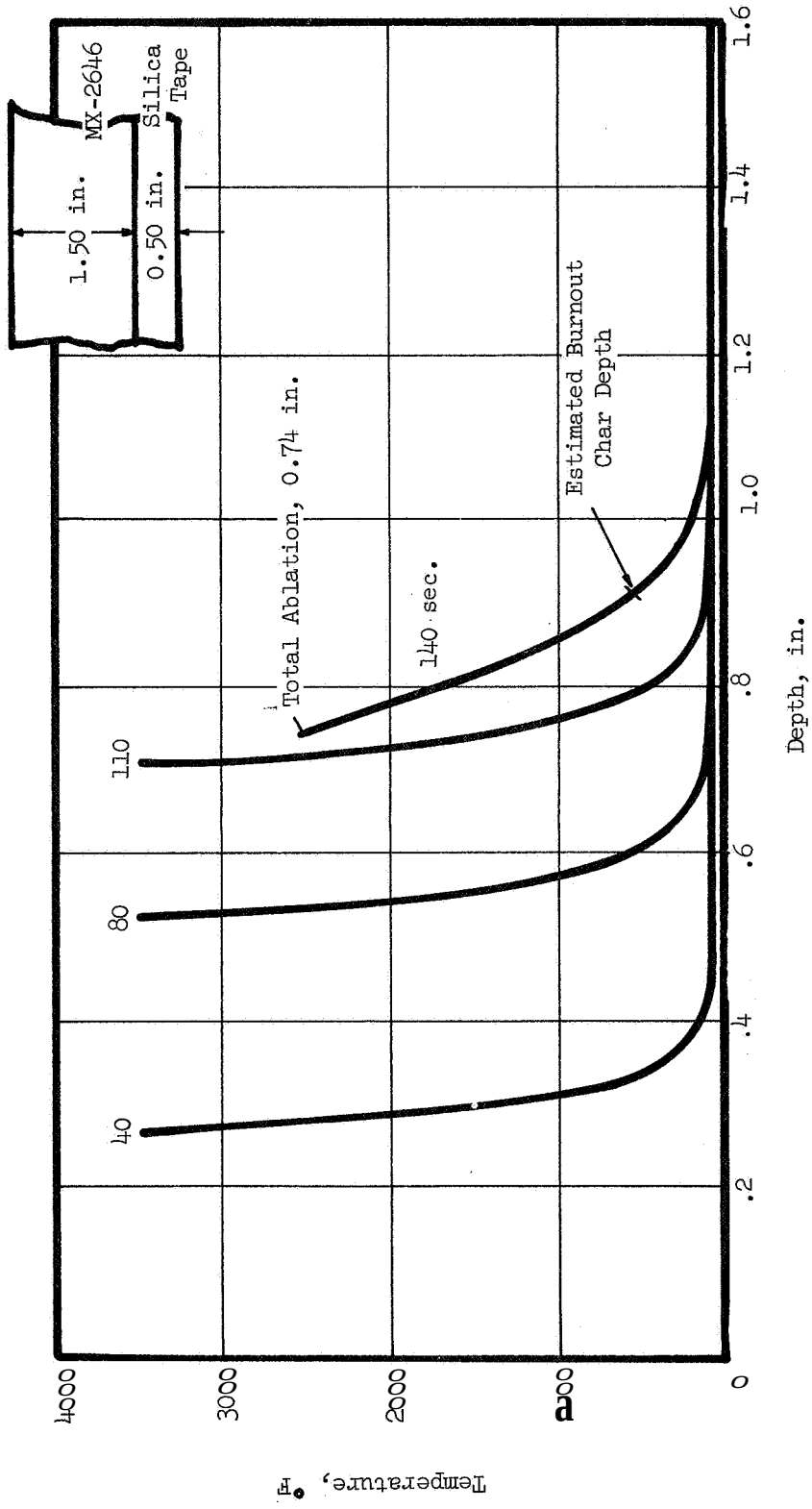
Temperature Profiles at the Throat of the 260-SL-1 Nozzle

Figure 20



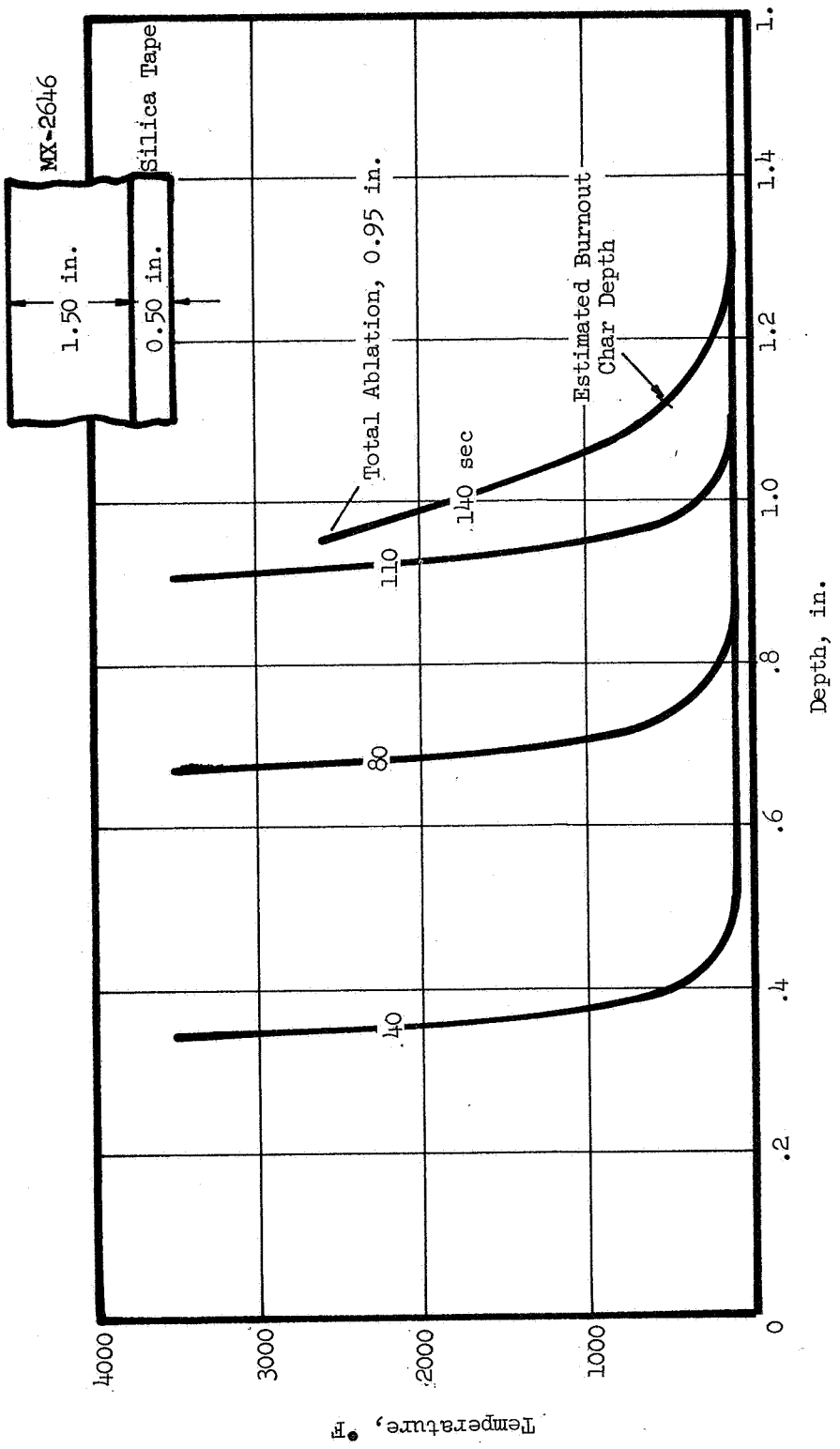
Temperature Profiles Upstream of the Throat of the 260-SL-1 Nozzle,
Area Ratio = 3.1:1

Figure 21



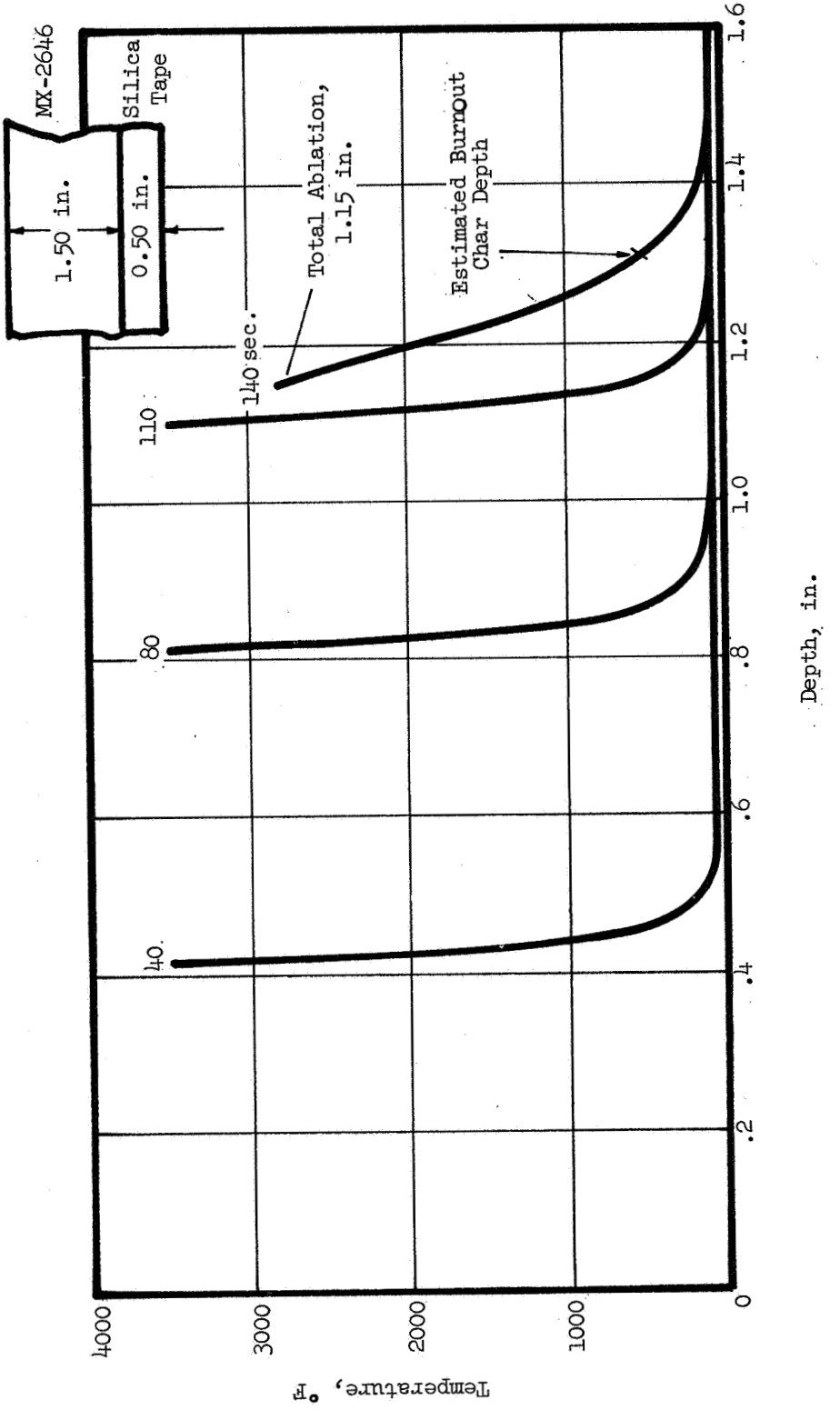
Temperature Profiles Upstream of the Throat of the 260-SL-1 Nozzle, Area Ratio = 2.58:1

Figure 22



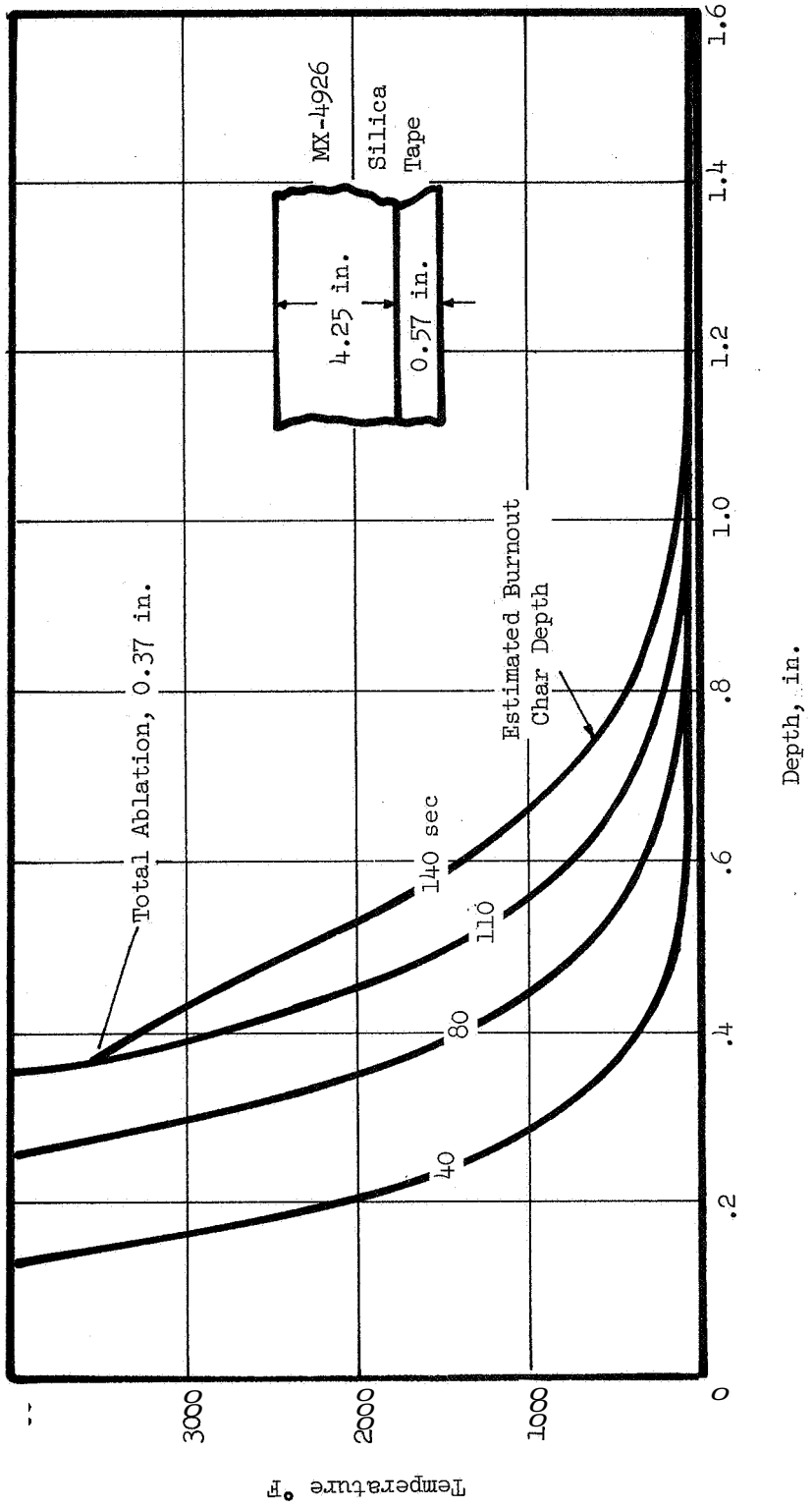
Temperature Profiles Upstream of the Throat of 260-SL-1 Nozzle,
Area Ratio = 1.98:1

Figure 23



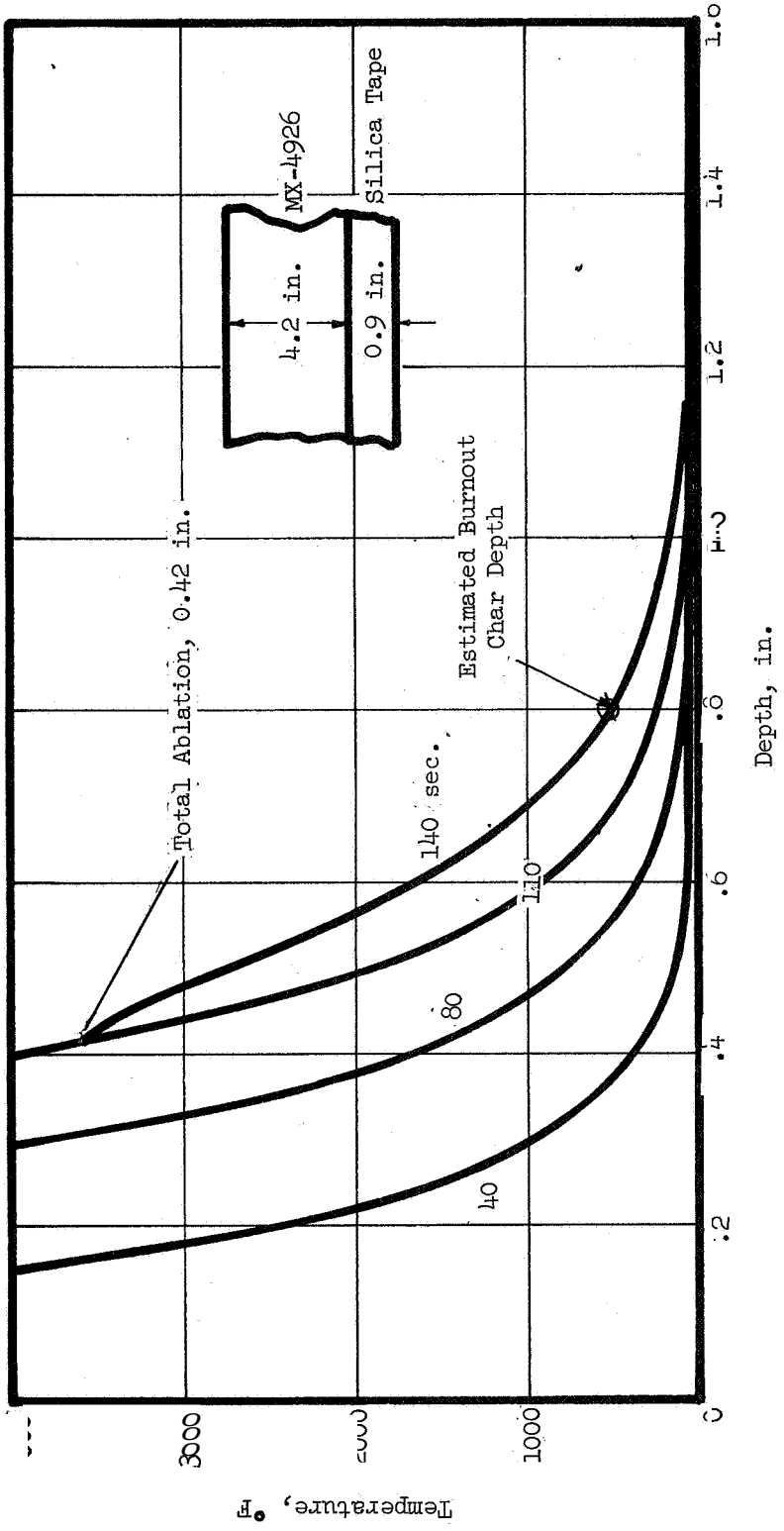
Temperature Profiles Upstream of the Throat of 260-SL-1 Nozzle, Area Ratio = 1.60:1

Figure 24



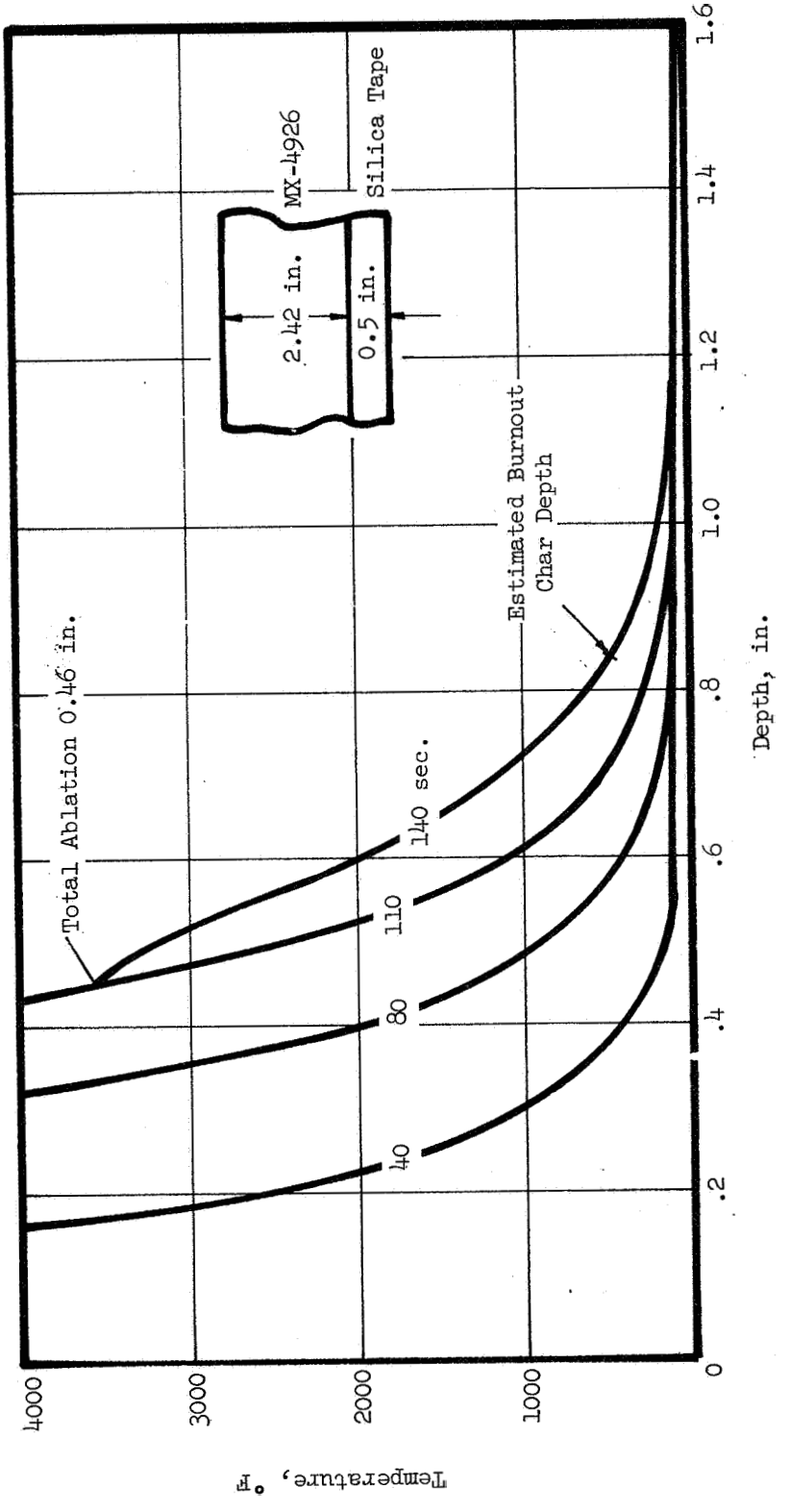
Temperature Profiles Upstream of the Throat of the 260-SL-1 Nozzle,
Area Ratio = 1.4:1

Figure 25



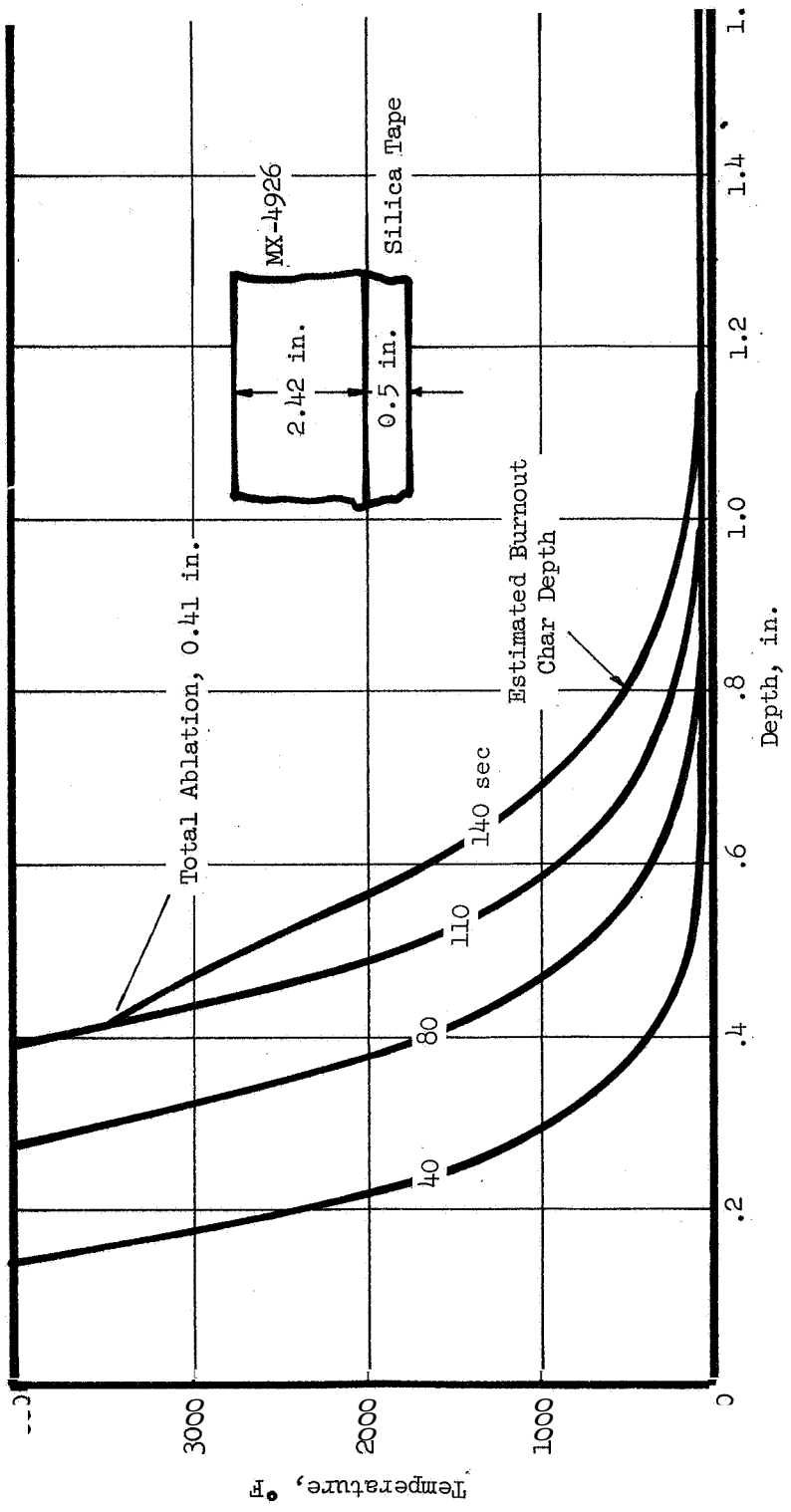
Temperature Profiles Upstream of the Throat of the 260-SL-1 Nozzle,
Area Ratio = 1.22:1

Figure 26



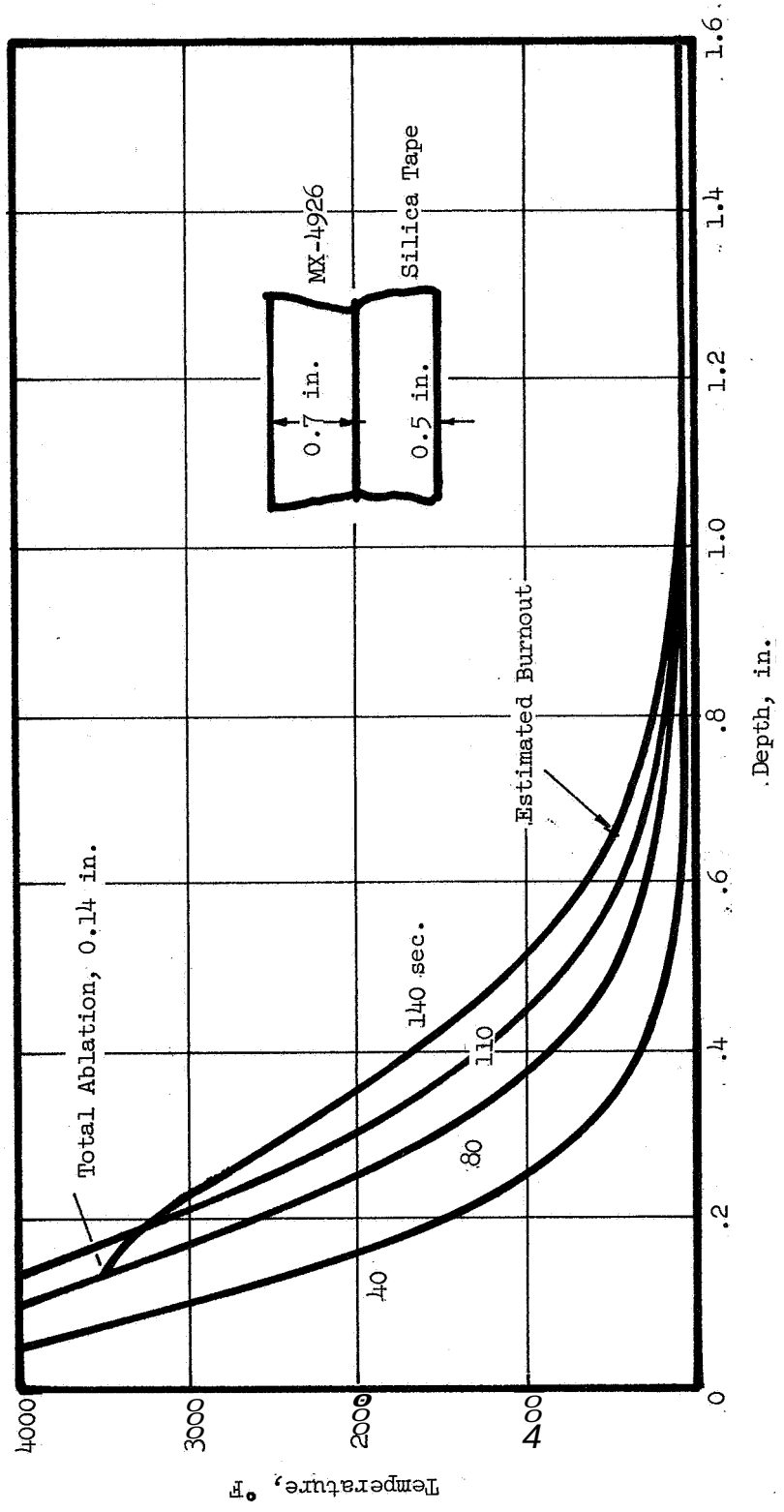
Temperature Profiles Upstream of the Throat Station of the 260-SL-1
Nozzle, Area Ratio = 1.085:1

Figure 27



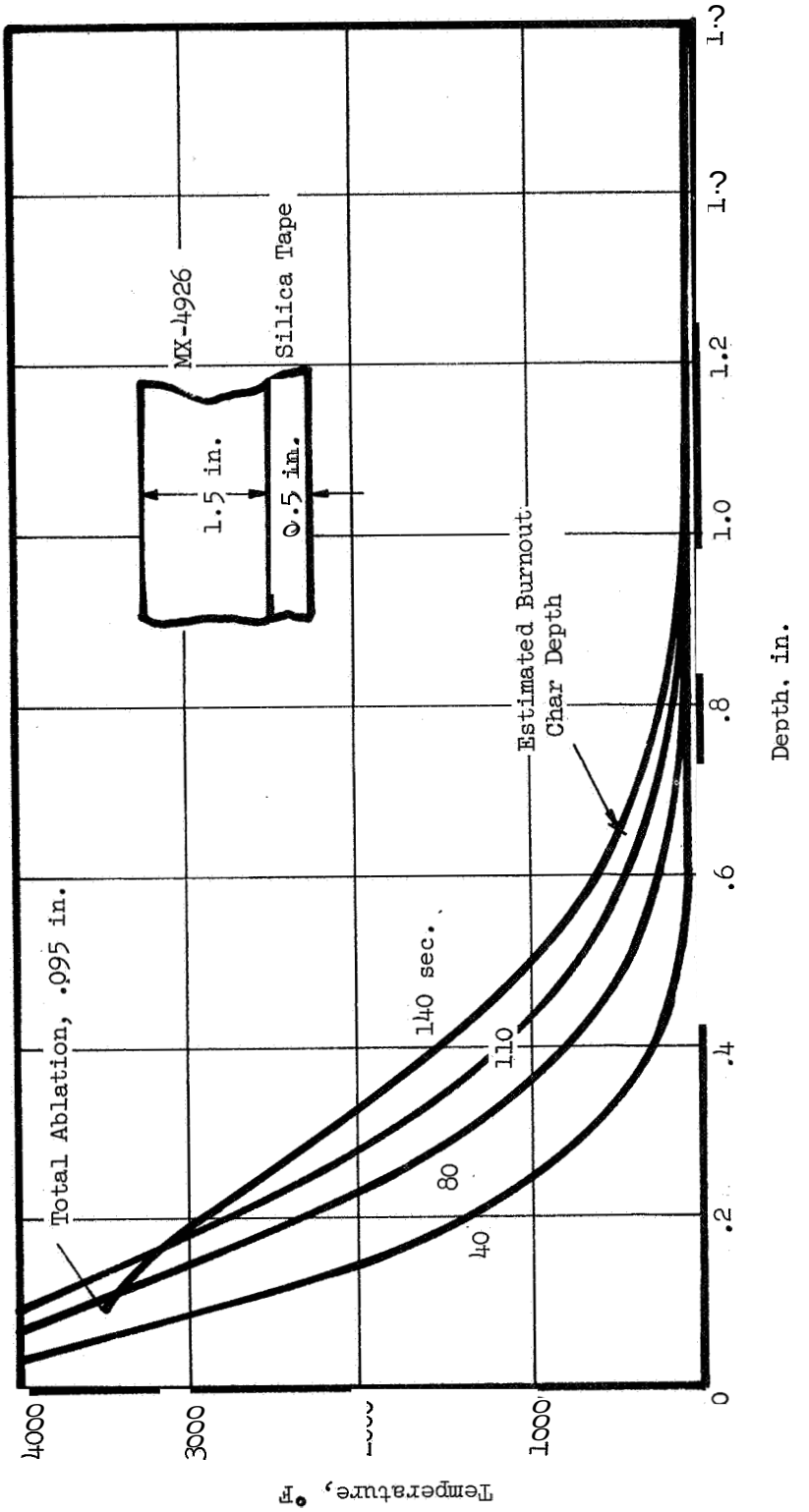
Temperature Profiles Downstream of the Throat of the 260-SL-1 Nozzle,
Area Ratio = 1.1:1

Figure *28*



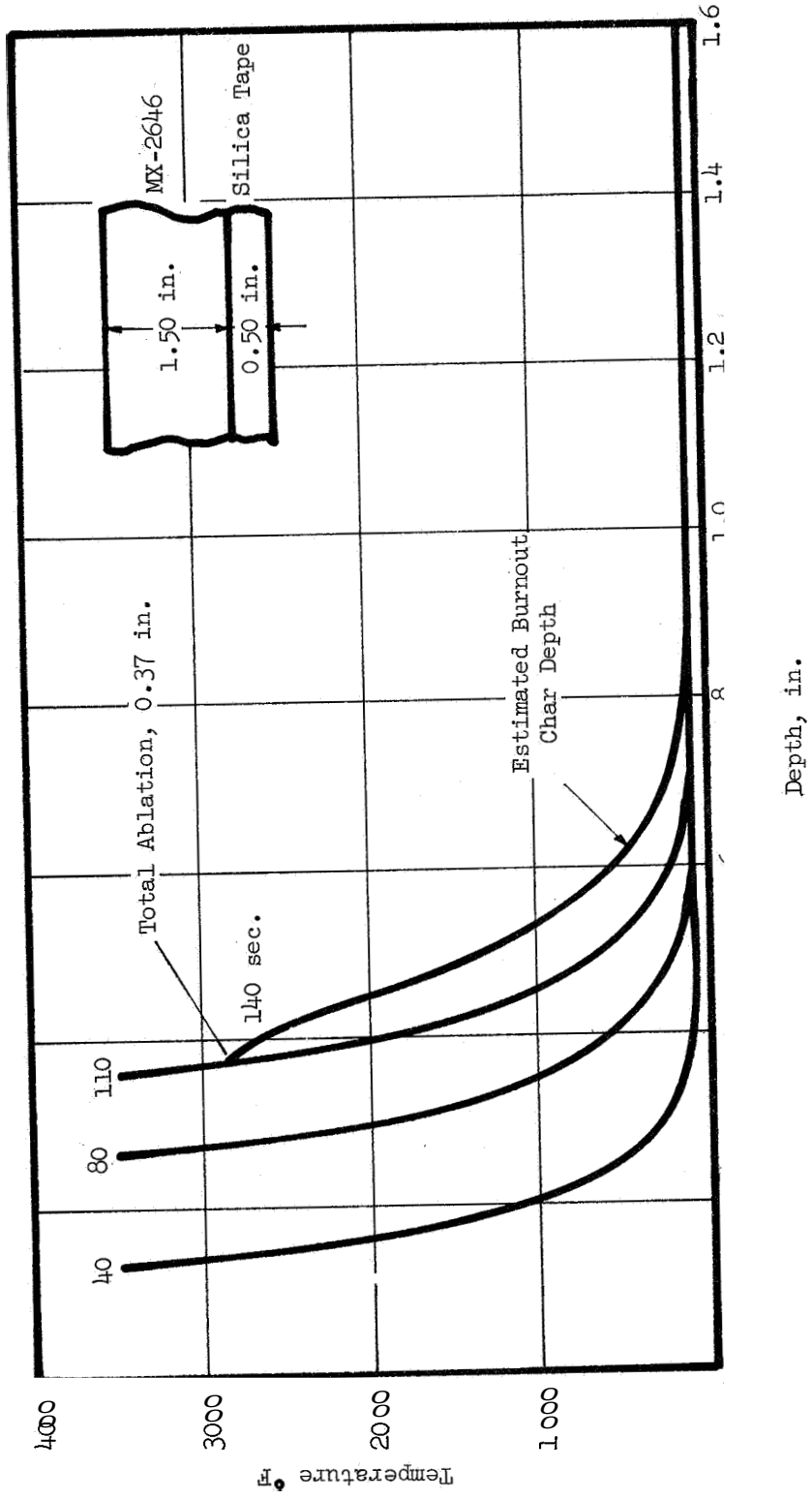
Temperature Profiles Downstream of the Throat of the 260-SL-1 Nozzle, Area Ratio = 2.5:1

Figure 29



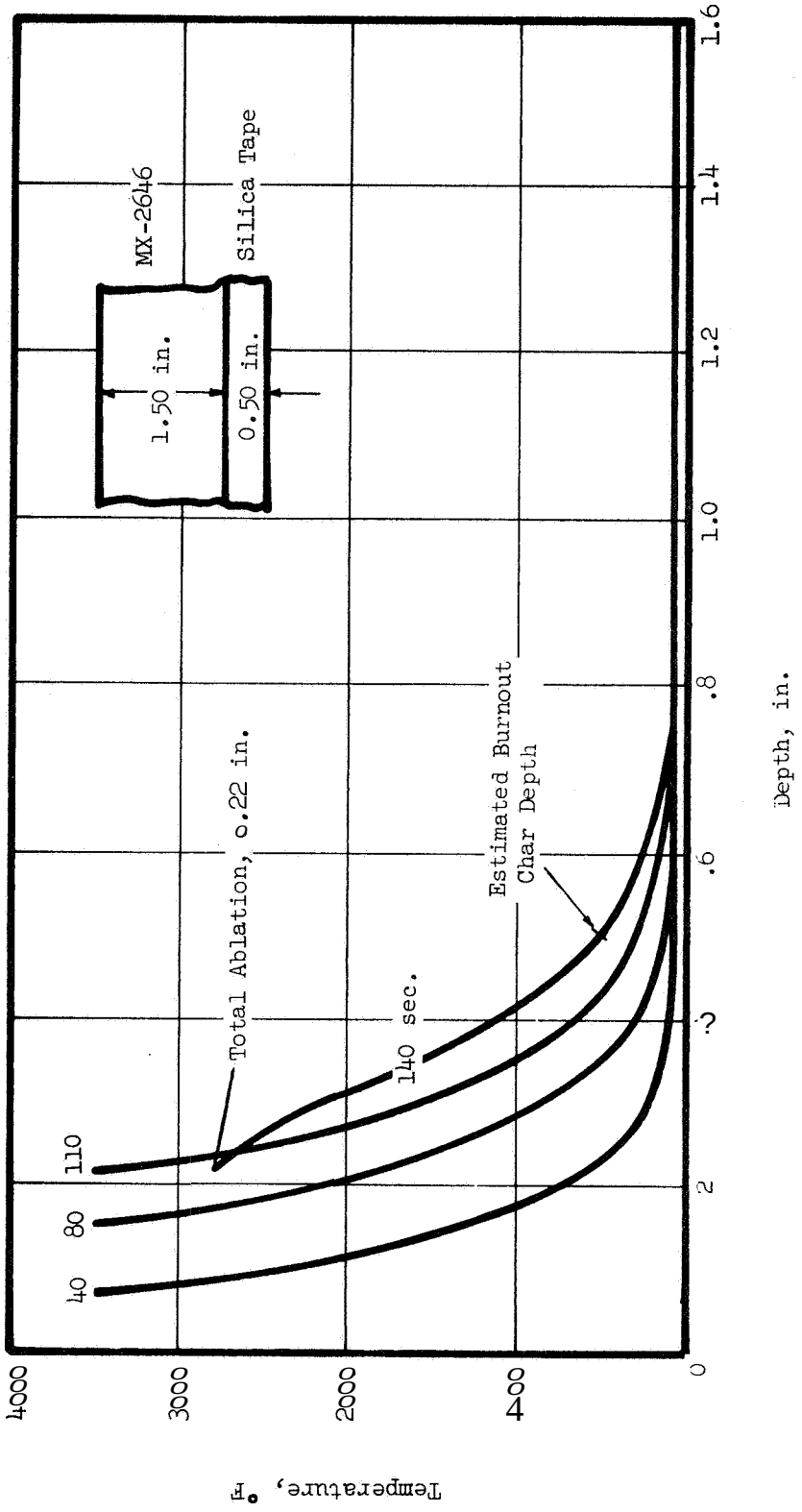
Temperature Profiles Downstream of the Throat of the 260-SL-1 Nozzle, Area Ratio = 3.37:1

Figure 30



Temperature Profiles Downstream of the Throat of the 260-SL-1 Nozzle,
Area Ratio = 3.78:1

Figure 31



Temperature Profi Downstream of the Throat of 260-SL-1 Nozzle,
Area Ratio - 6.0:1

Figure 32

Materials (Average Properties)	MX-4926	MX-2646
Density, lb/cu ft	90	112
Specific heat, Btu/lb°F	0.28	0.25
Thermal conductivity, Btu/hr ft°F	0.34	0.19
Effective ablation temperature, °F	4,040	3,540
Effective higher heat of ablation, Btu/lb	12,100	3,970

Table of Thermal Properties

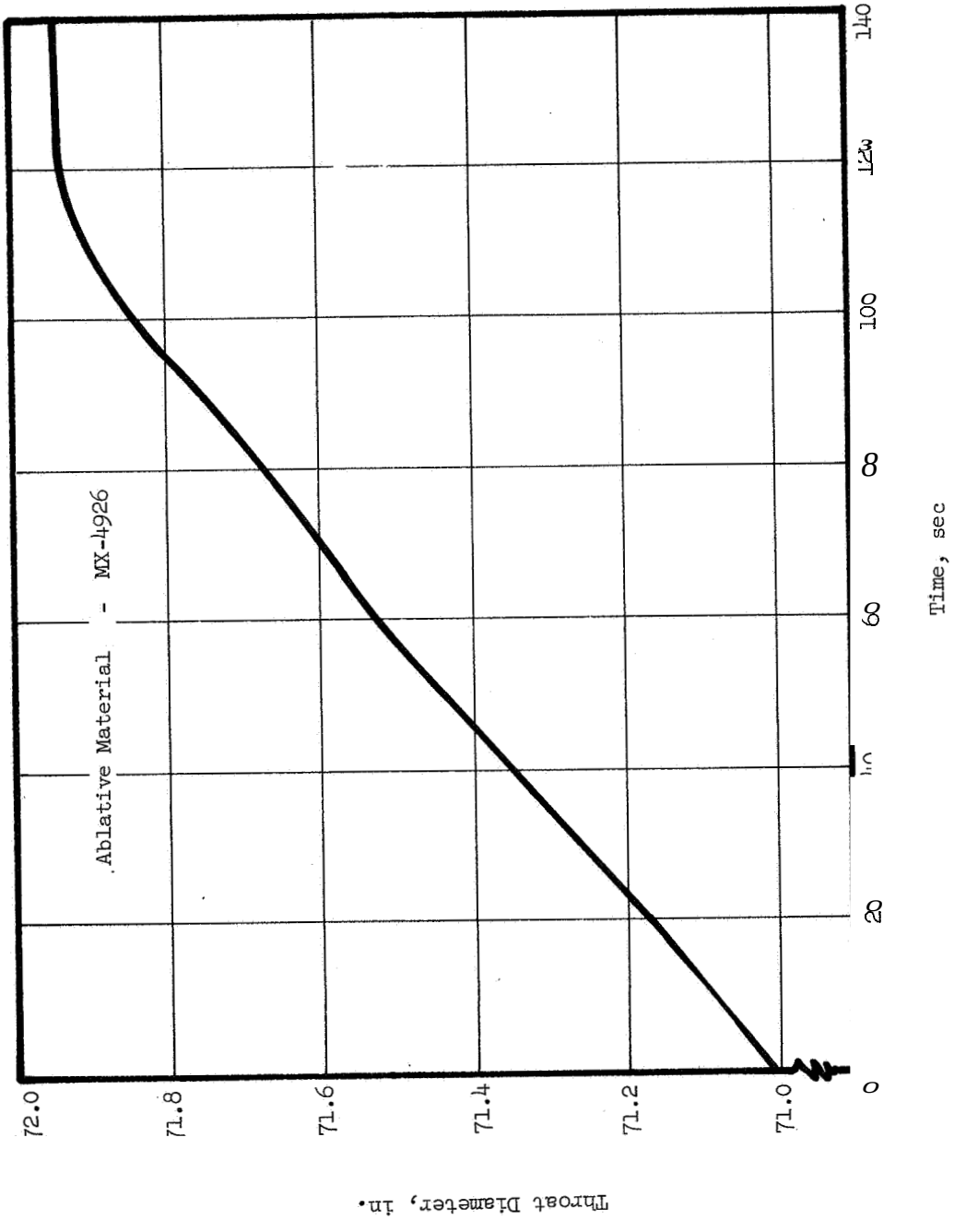
Figure 33

Area Ratio	Material	Ablation Depth (In.) *	Char Depth (In.) *	100° Depth (In.) *
3.1	MX-2646	.63	.82	1.02
2.58	MX-2646	.74	.92	1.12
1.98	MX-2646	.95	1.12	1.29
1.6	MX-2646	1.15	1.31	1.49
1.41	MX-4926	.37	.78	1.15
1.22	MX-4926	.42	.81	1.17
1.085	MX-4926	.46	.83	1.19
1.0	MX-4926	.47	.85	1.2
1.1	MX-4926	.41	.81	1.17
2.5	MX-4926	.14	.66	1.1
3.37	MX-4926	.095	.65	1.1
3.78	MX-2646	.37	.61	.85
6.0	MX-2646	.22	.51	.8

* Depth Normal to Original Plastic Surface

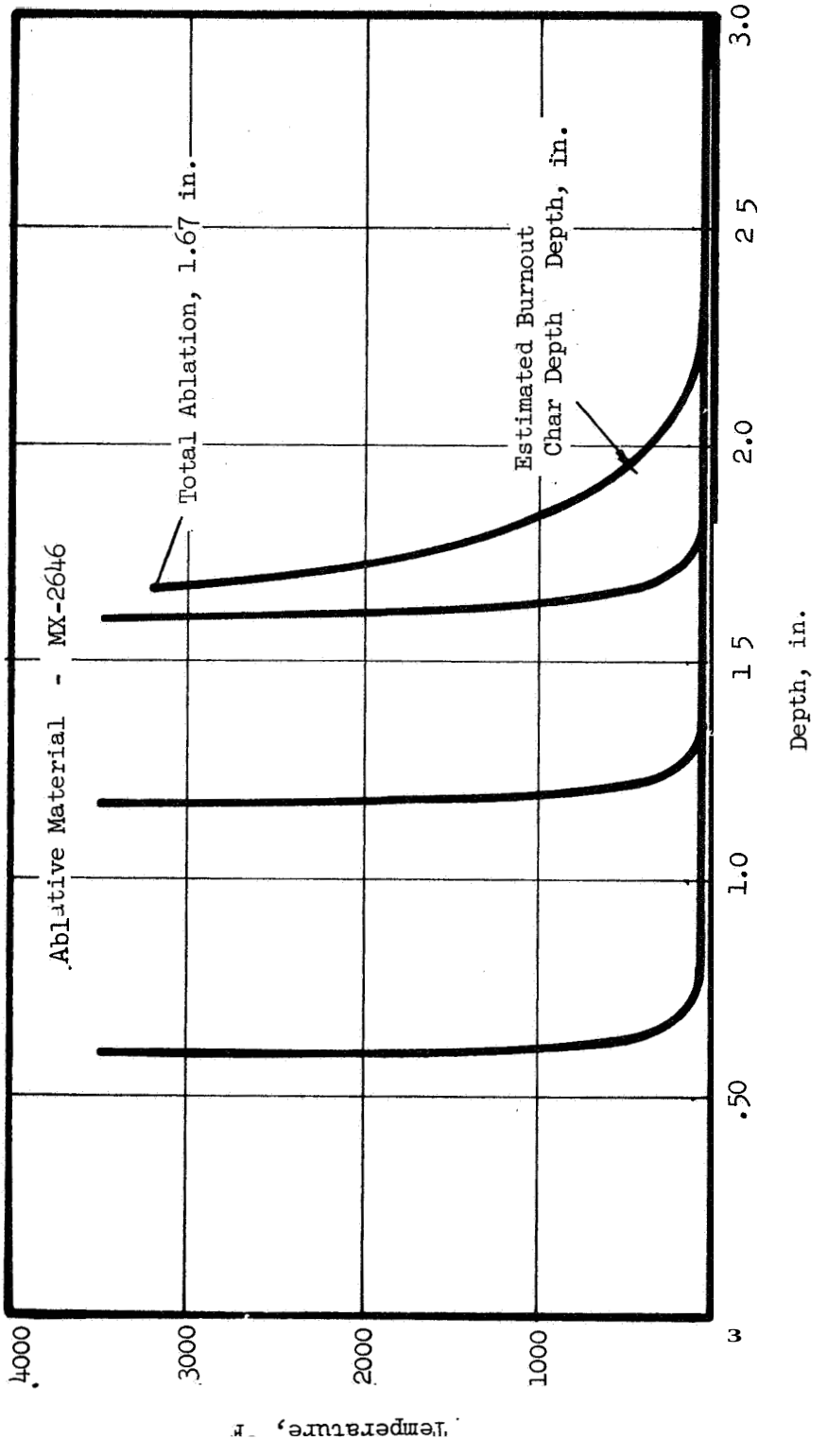
Summary of Predicted Burnout Dimensions, 260-SL Nozzle

Figure 34



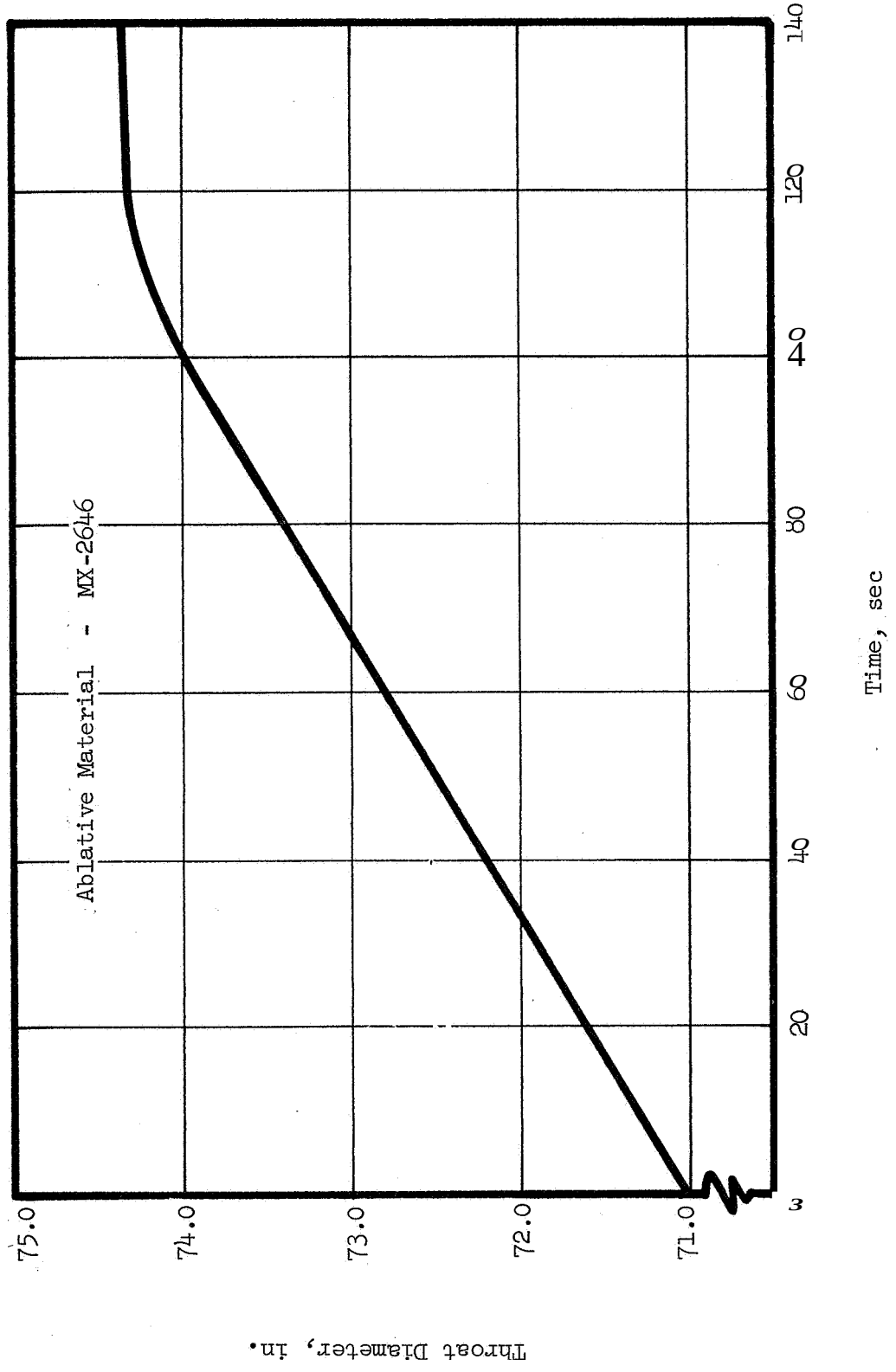
Throat Diameter Variation with Time, 260-SL-1 Nozzle

Figure 35



Thermal Response of a Typical Silica Cloth Phenolic to the 260-SL-1 Throat Environment

Figure 36



Throat Variation versus Time for a Typical Silica C4th Phenolic in a 260-SL-1 Nozzle

Figure 37

	Surface Recession Rate, mil/sec				
	MERM		260-SL		
Material	Max.	Ave.	Max.	Ave.	Nom.
Nerghlo	6.6	3.75	2.55	1.8	1.8
MX-4551	9.0	4.05	3.6	2.1	1.8
FM-5072	7.4	3.90	3.15	1.9	2.0
MX-4926	8.3	3.93	3.8	2.15	2.0
FM-5063	6.35	4.65	3.2	2.1	2.2
*DEN 438	7.3	4.36	3.65	2.35	2.35
FM-5014G	8.6	5.25	3.6	2.4	2.35
FM-5055	9.6	7.01	3.9	3.2	3.4
5055/5161	14.5	7.83	6.5	4.2	4.1

*Recession rates of all materials except DEN 438 are results of 600 psia chamber tests. DEN 438 results are based on 400 psia chamber tests.

Approximate Recession Rates of Reinforced Plastics for 260-in. Nozzle with D_t = 66.4 in.

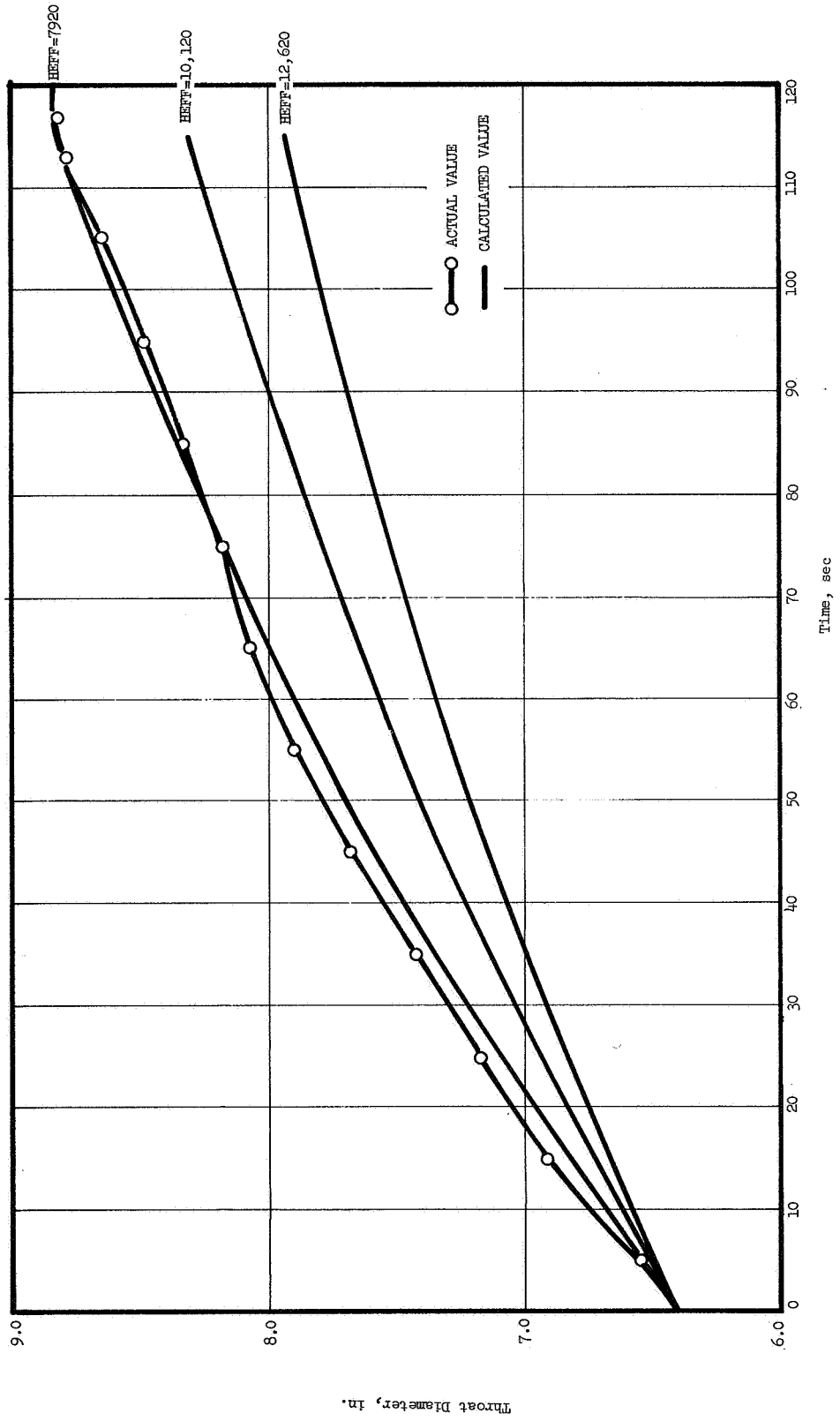
Figure 38

Material	Motor	Actual Recession Rate, mil/sec	Actual Area Ratio	Projected Recession Rate at 60.1 Nozzle Throat, mil/sec	Remarks
MX 4926 (Carbon)	Adv. Polaris SEF-3	3.30	2.5	4.38	
MX 4926 (Carbon)	UTC TM3A	4.60	10	3.00	Tubular throat
MX 4926 (Carbon)	[illegible] 86	3.0	3.4	3.54	
MX 4926 (Carbon)	TAPCO S/[illegible]	7.25	10	2.45	End-burning grain
MX 4926 (Carbon)	MERM	8.6	10	3.85	End-burning grain
MX 4926 (Carbon)	[illegible] TR-[illegible] (Minuteman)	1.32 0.74	6.5 9.5	5.46 6.69	Liquid injection TVC used in this section
MX 4926 (Carbon)	[illegible] TW-7 (Minuteman)	1.03	9.8	4.82	Liquid injection TVC used in this section
FM 5014G (Graphite)	52 TW-[illegible] (Minuteman)	2.48	27	7.66	
FM 5014G (Graphite)	[illegible] [illegible]Z (Minuteman)	1.70 1.02	26 55	3.00 3.93	
FM 5014G (Graphite)	54 FW-2 (Minuteman)	3.80	1.83	4.85	Liquid injection TVC located far downstream of this section
FM 5014G (Graphite)	52 FW-5 (Minuteman)	5.10	1.0	5.54	

Recession rates are corrected to throat station conditions and projected to the [illegible] motor nozzle throat conditions by the approximate

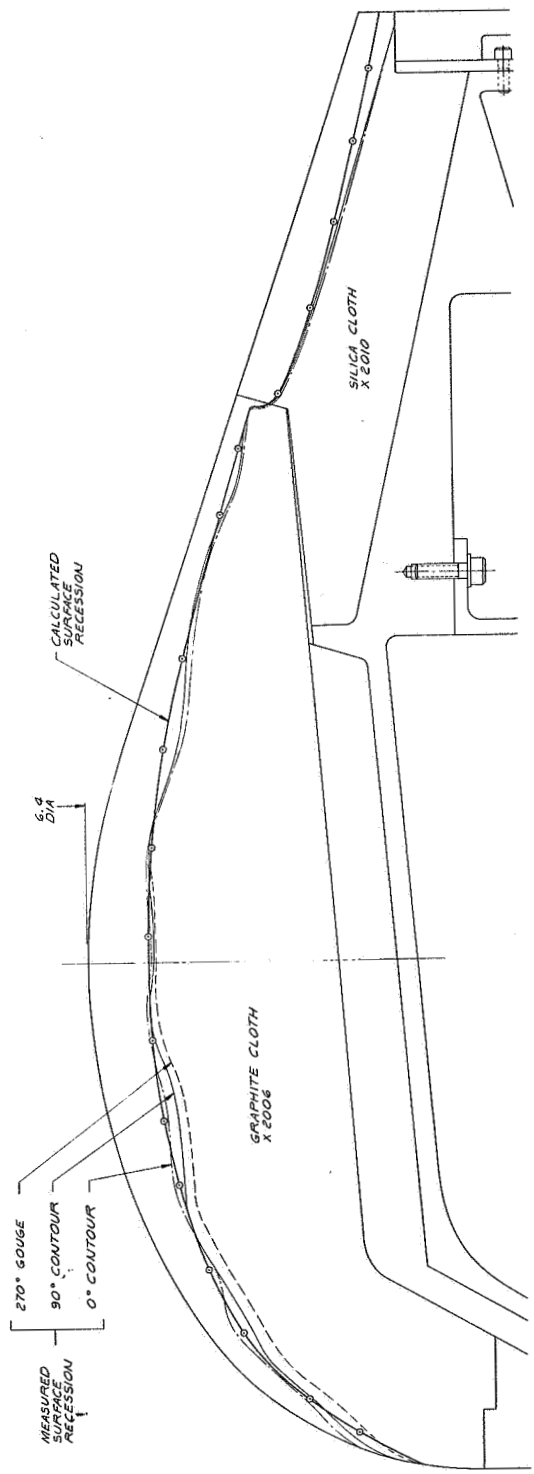
Figure 39

Projected Surface Recession Rates of Carbon Cloth Phenolic (MX 4926) and Graphite Cloth Phenolic (FM 5014G) for the 260-in.-dia Motor



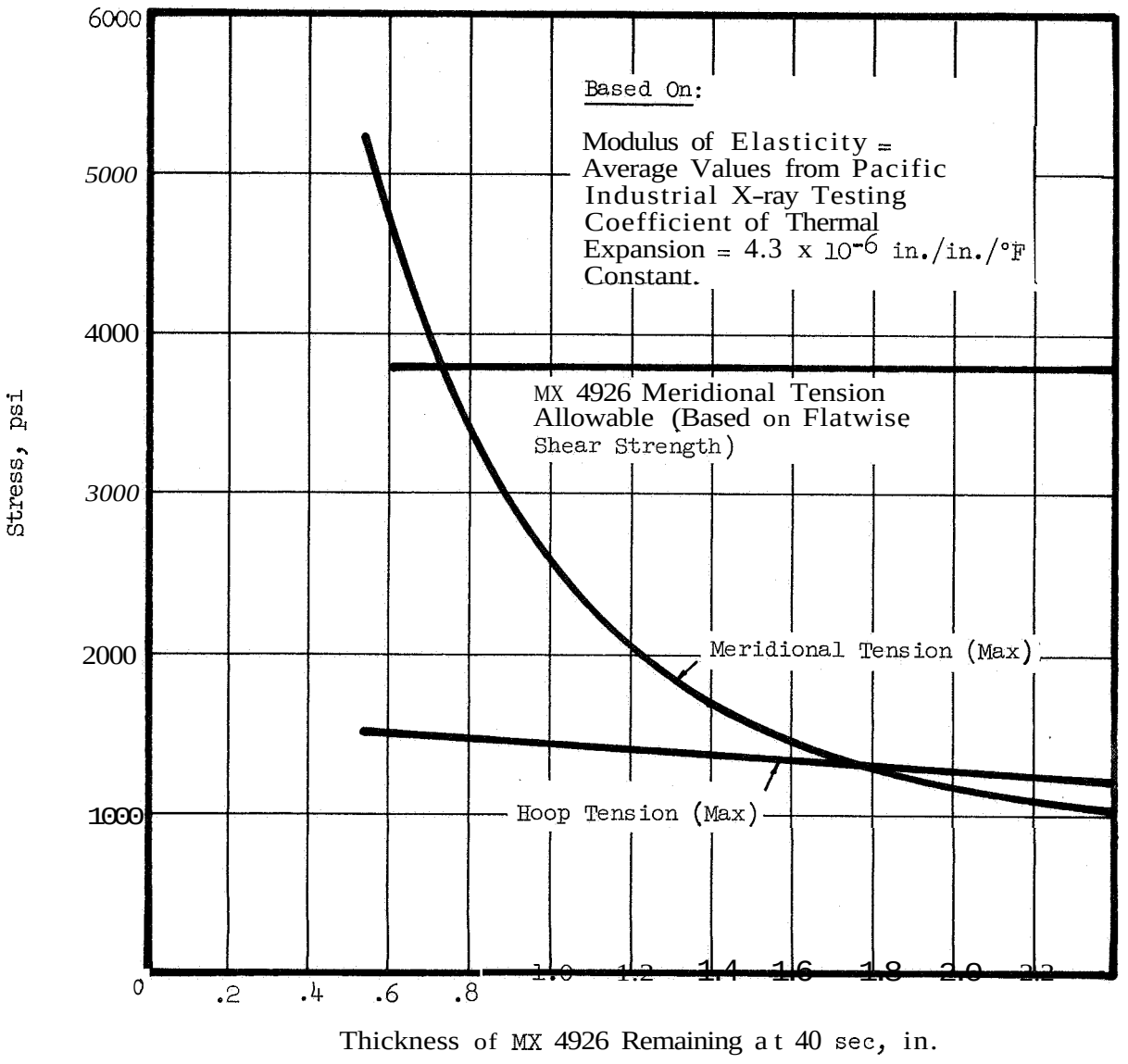
54-SS-2 Throat Diameter as a Function of Firing Time

Figure 40



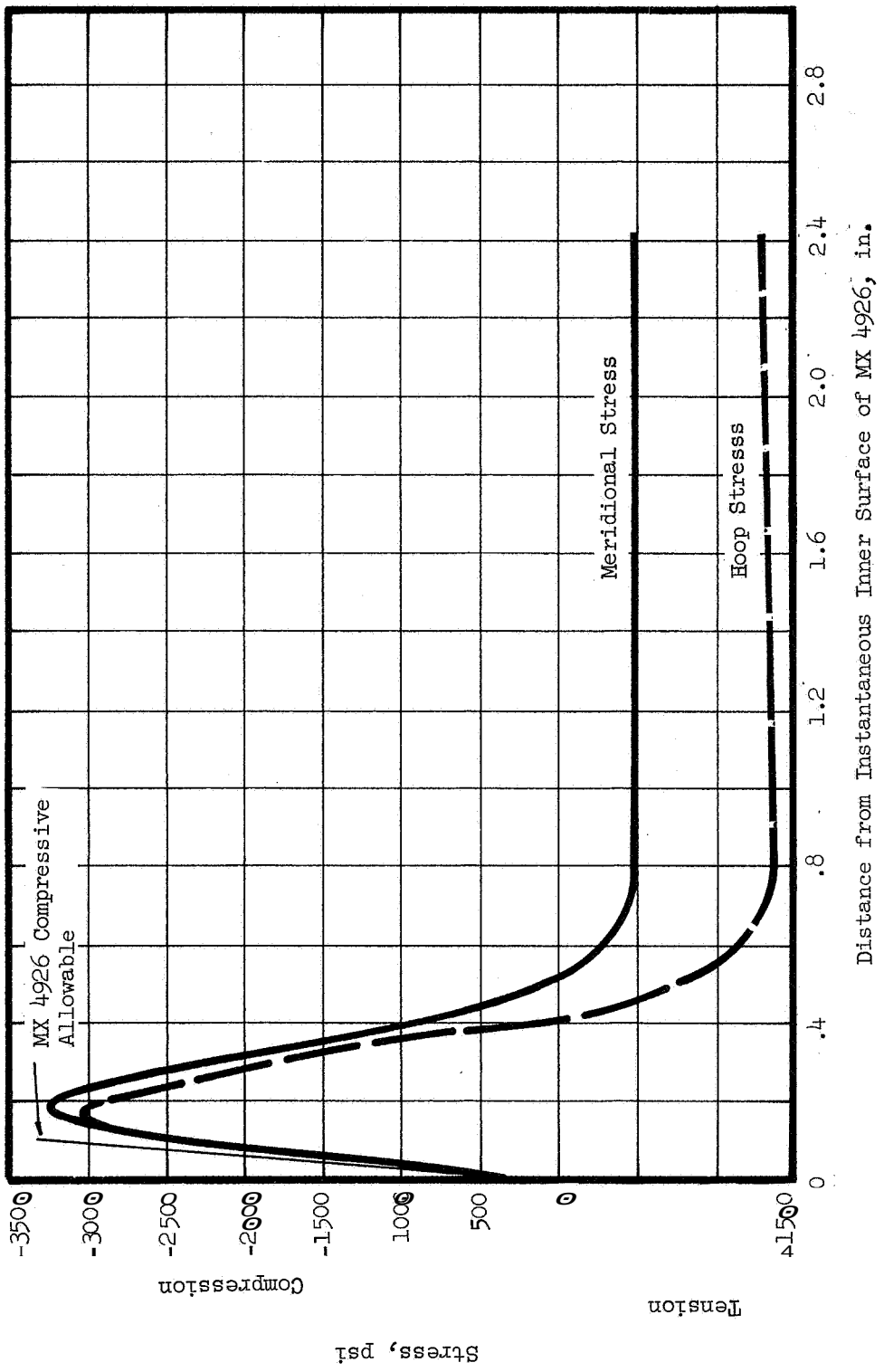
Sketch of 54-SS-2 Throat Showing Calculated and Measured Post Fired Surface Recession

Figure 41



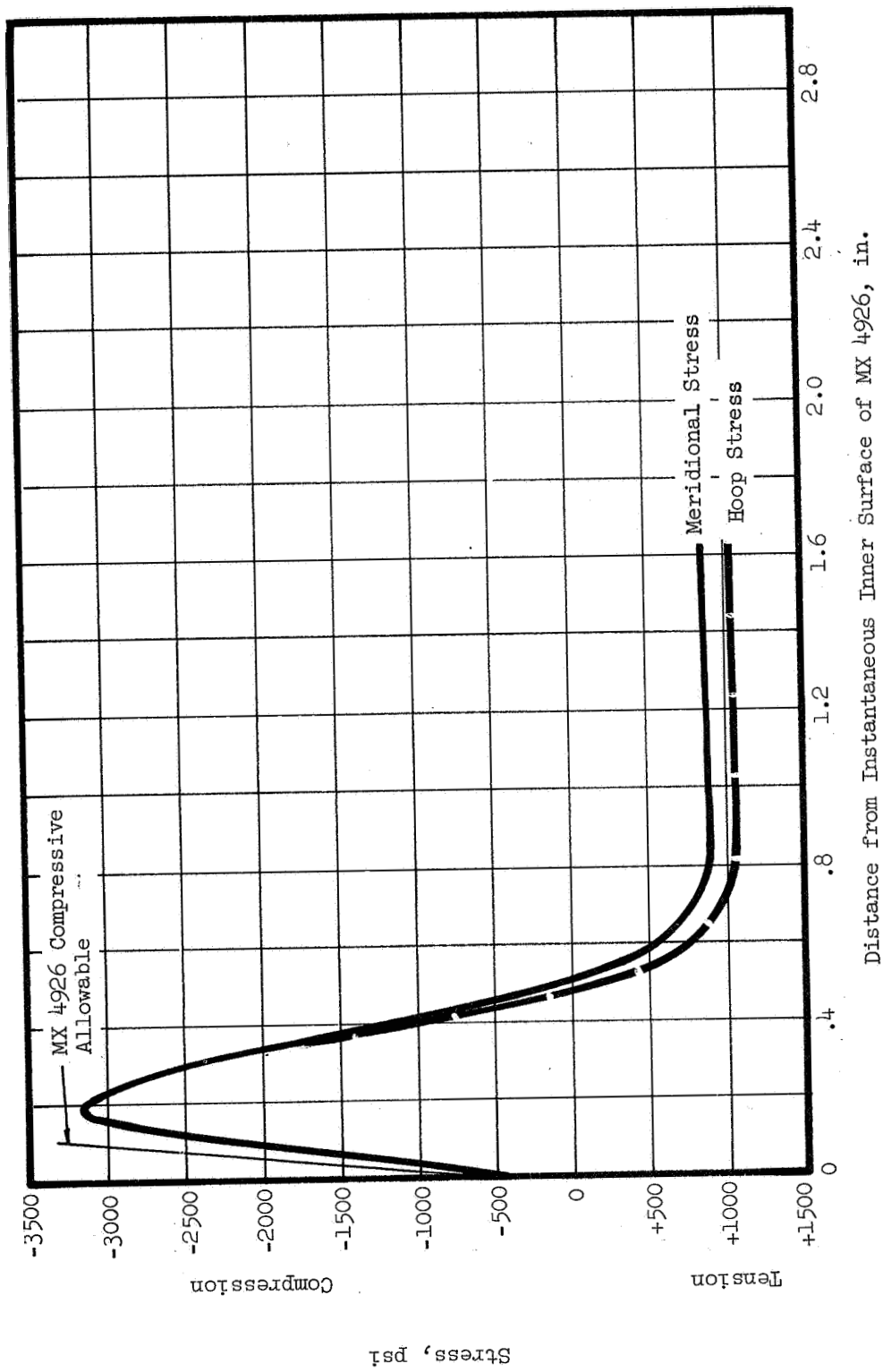
Stress vs Thickness of MX-4926 Remaining at 40 sec, 260-SL Nozzle, Area Ratio = 1.1:1

Figure 42



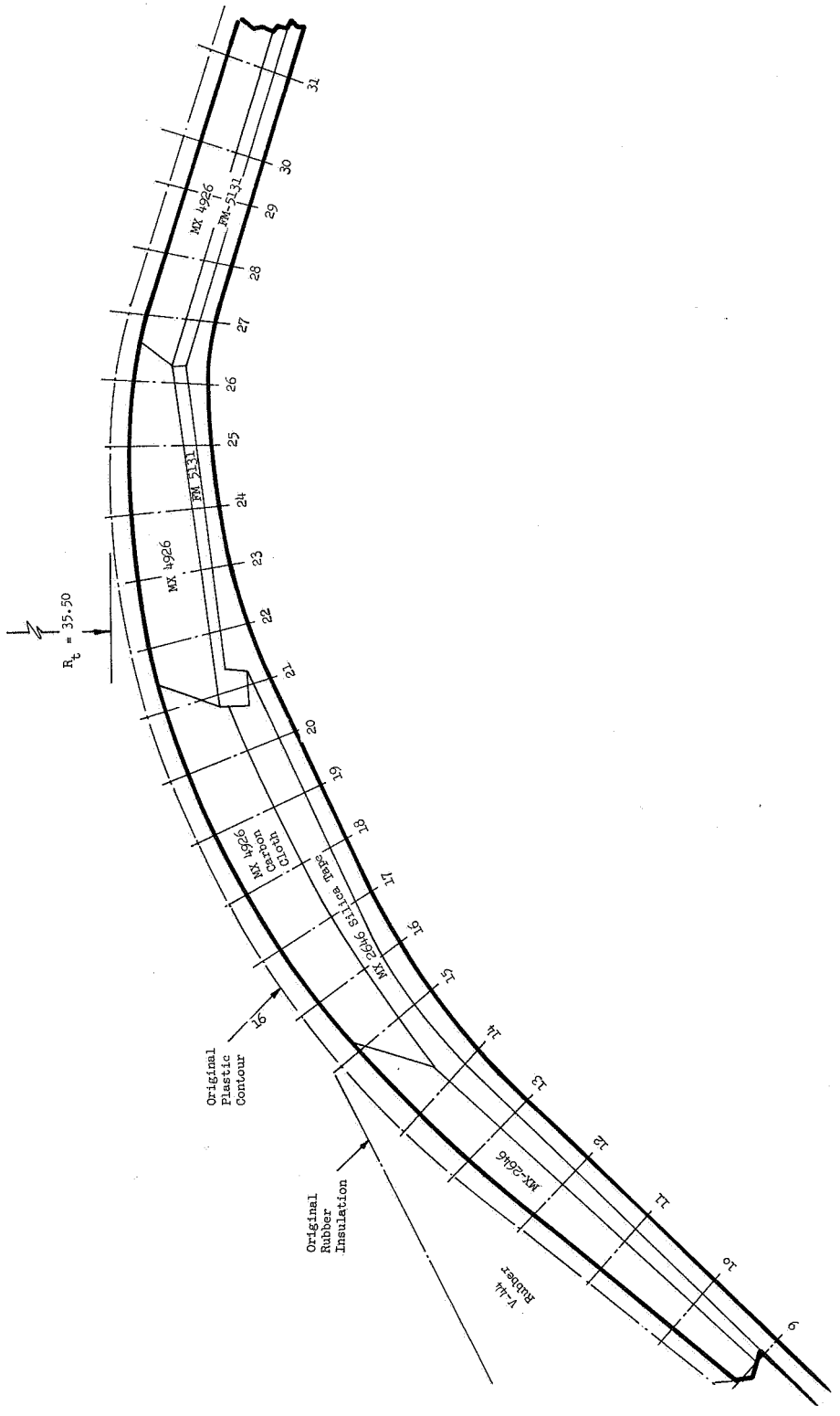
Stress Profile at Throat Station at 110 sec, 260-SL Motor Nozzle

Figure 43



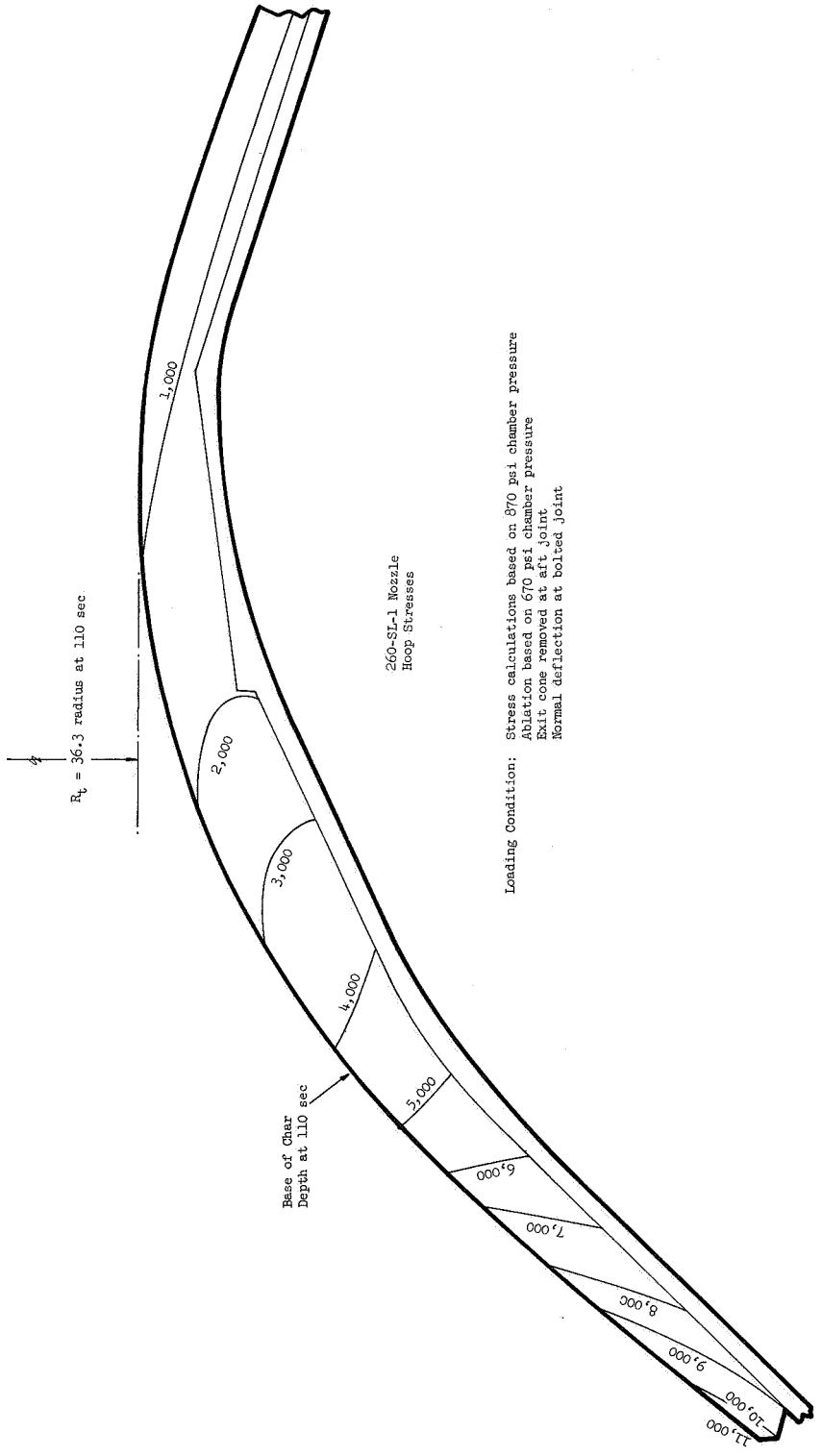
Stress Profile at Aft End of Throat Insert at 110 sec, 260-SL Nozzle

Figure 44



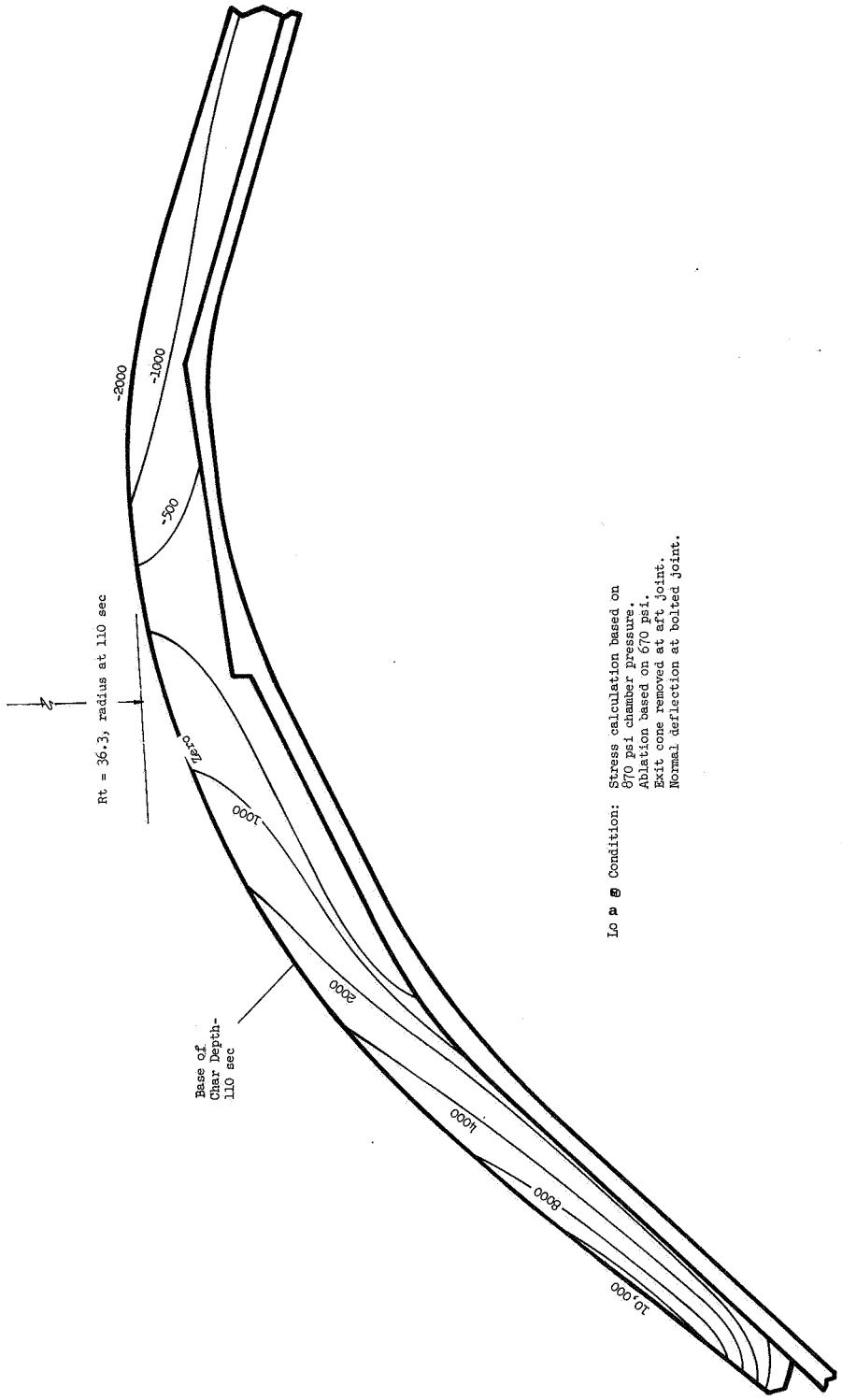
260-SL Nozzle Geometry and Stations of Stress Calculations

Figure 45



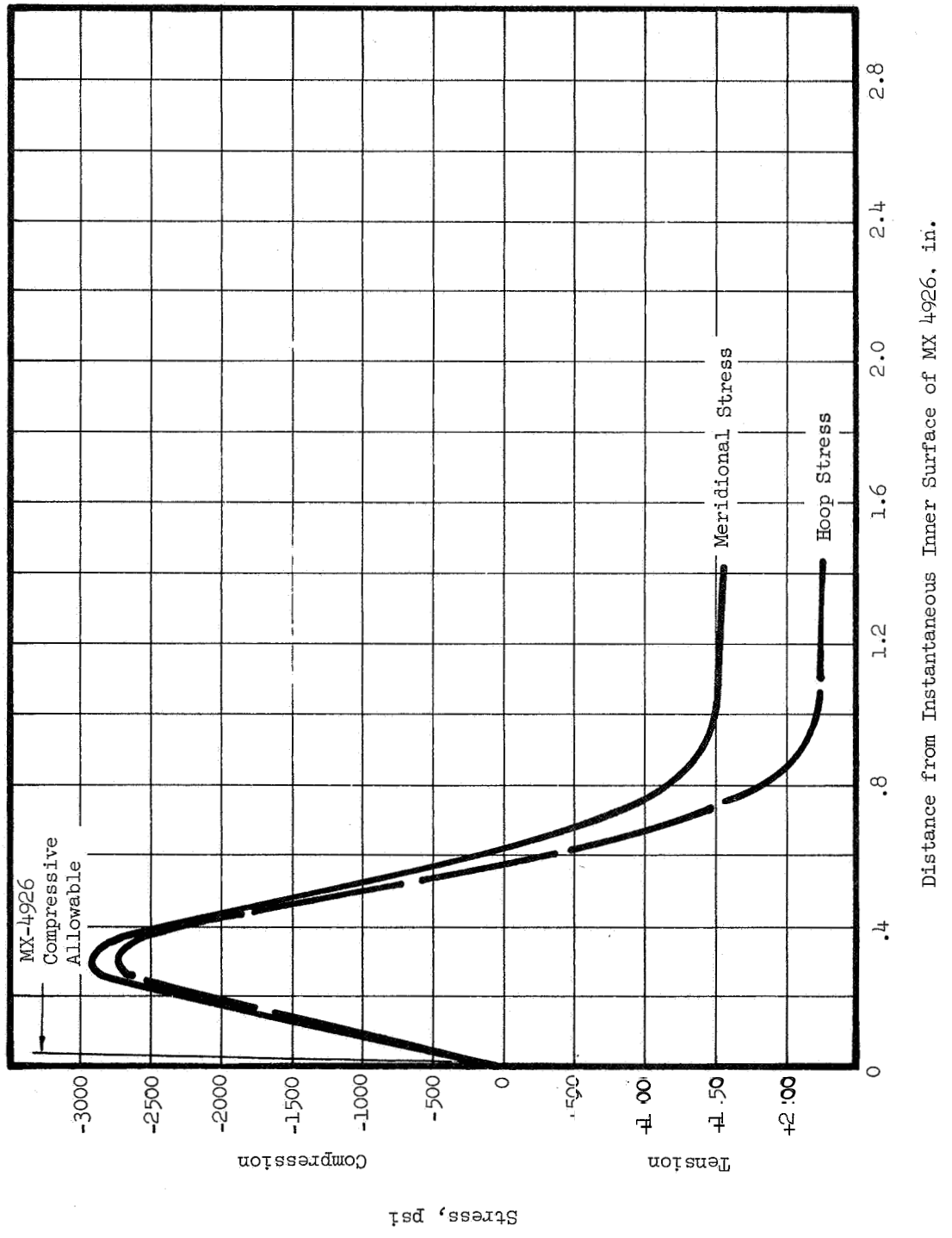
Hoop Stresses in 260-SL Nozzle

Figure 46



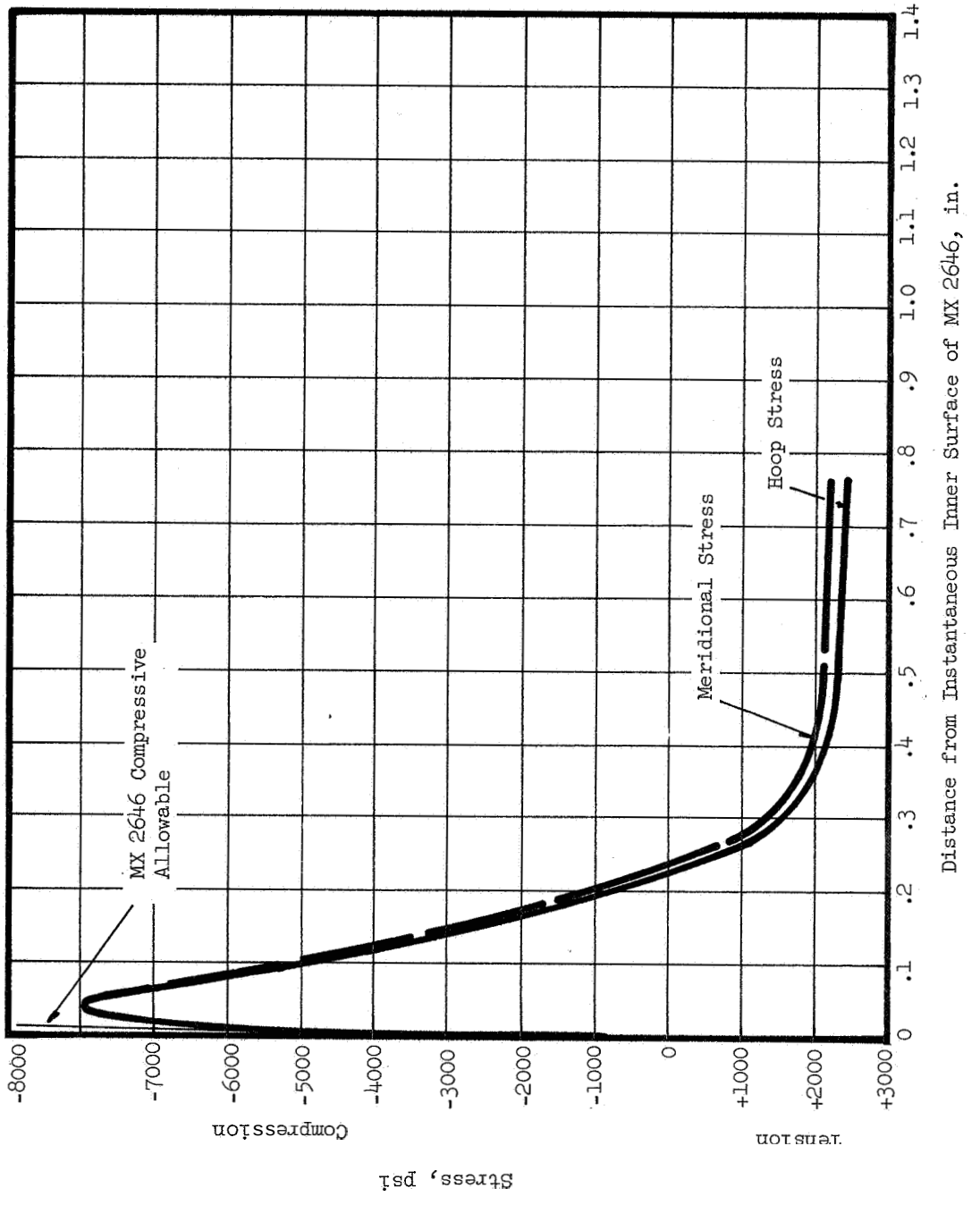
Meridional Stresses in 260-SL Nozz 4

Figure 47



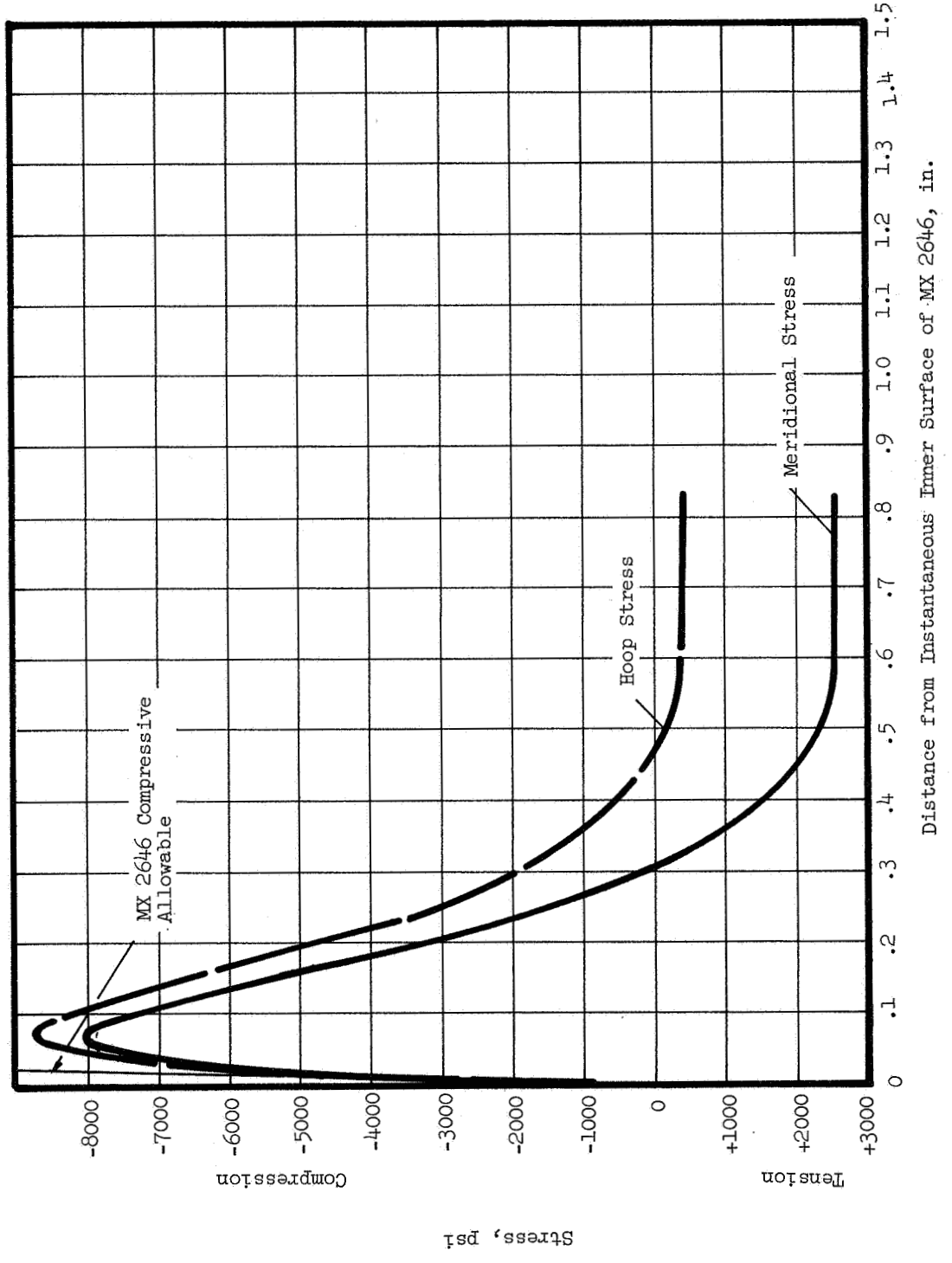
Stress Profile in Exit Cone Insert at 110 sec, Area Ratio = 2.5:1, 260-SL Nozzle

Figure 48



Stress Profile in Exit Insert at 110 sec, Area Ratio = 3.78:1, 260-SL Nozzle

Figure 49



Stress Profile in Exit Cone Insert at 110 sec, Area Ratio = 6.0:1, 260-SL Nozzle

Figure 50

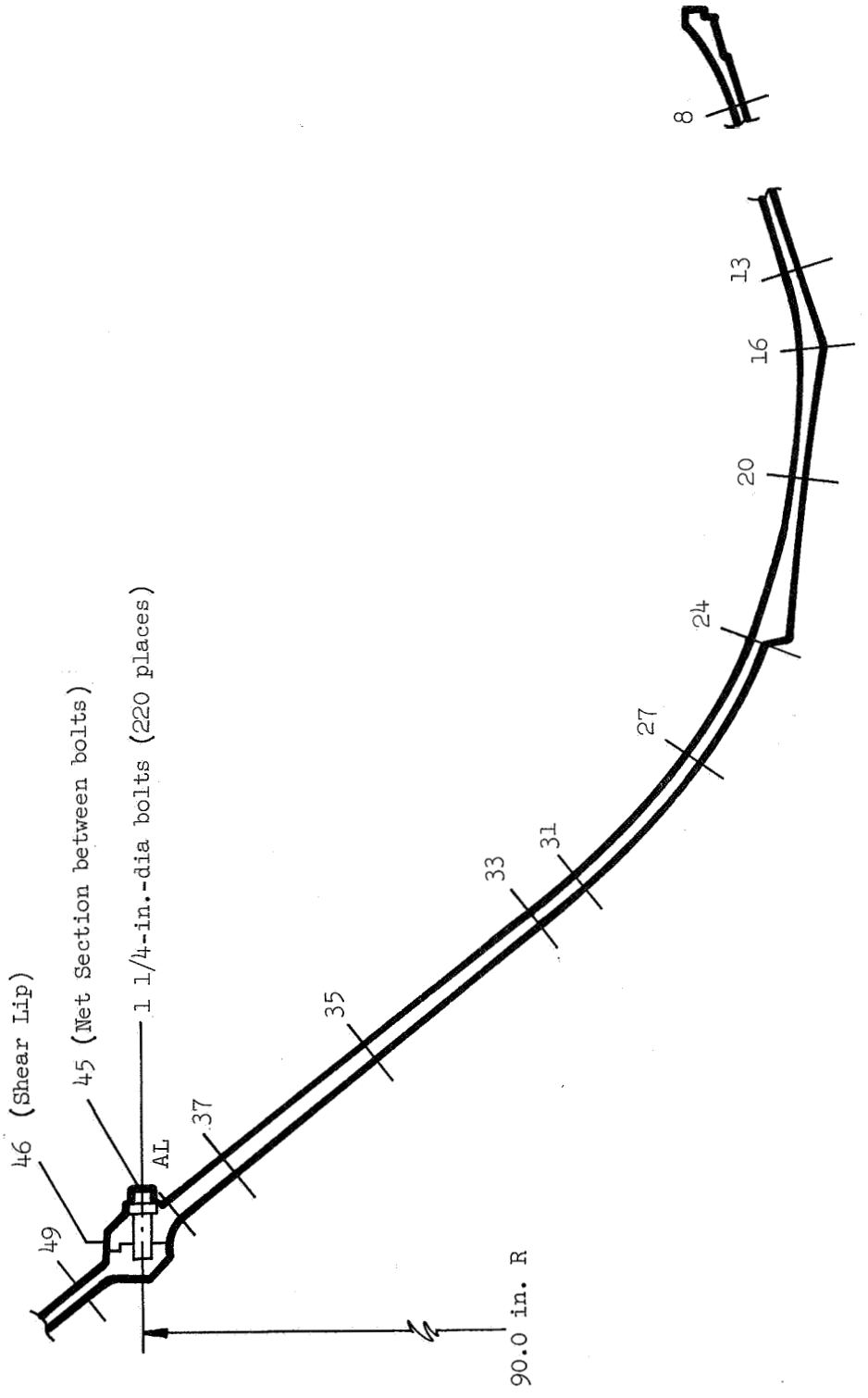
C t	(in.)	(in.)	Stresses, psi					Margin of Safety
			Meridional Outer	Meridional Inner	Hoop Outer	Hoop Inner	Allowable	
49	.550	93.70	9910	156800	55000	99100	190000	.212
AL	1.650	88.40	16220	48030	71010	80550		1.359
37	.750	80.02	91120	42340	130980	116340		.451
35	.750	67.62	54870	58220	113100	114110		.665
33	.750	55.22	49780	40960	110060	107410		.726
31	.920	51.30	51960	14960	115030	103930		.652
27	.750	46.17	23010	37530	76550	80910		1.348
24	.750	41.85	28720	24430	60510	59220		2.140
20	.750	39.85	15450	31280	66580	71330		1.664
16	1.000	39.30	47140	-12920	90030	72020		1.110
13	.750	40.30	21870	26340	68450	69790		1.722
8	.820	51.25	73450	-18100	67340	39870	190000	1.587
			CHAMBER-NOZZLE ATTACHMENT JOINT					
45			Max. Stress-Net Section Between Holes t = 149000 psi				200000	.339
46			Shear [illegible] s n Sh[illegible] r Lip s = 62 [illegible]				119000	.916
			1-1/4-in.-dia Bolts Pretension Load P_T = 128000 lb				213310 lb	.666

NOTES:

1. The solution for the above stresses was based on a condition of 871 psi chamber pressure with a reduction of 5,110,000 lb in the meridional load due to the thrust.

Structural Analysis Summary, Nozzle Shell, 260-SL-1 Motor

Figure 51



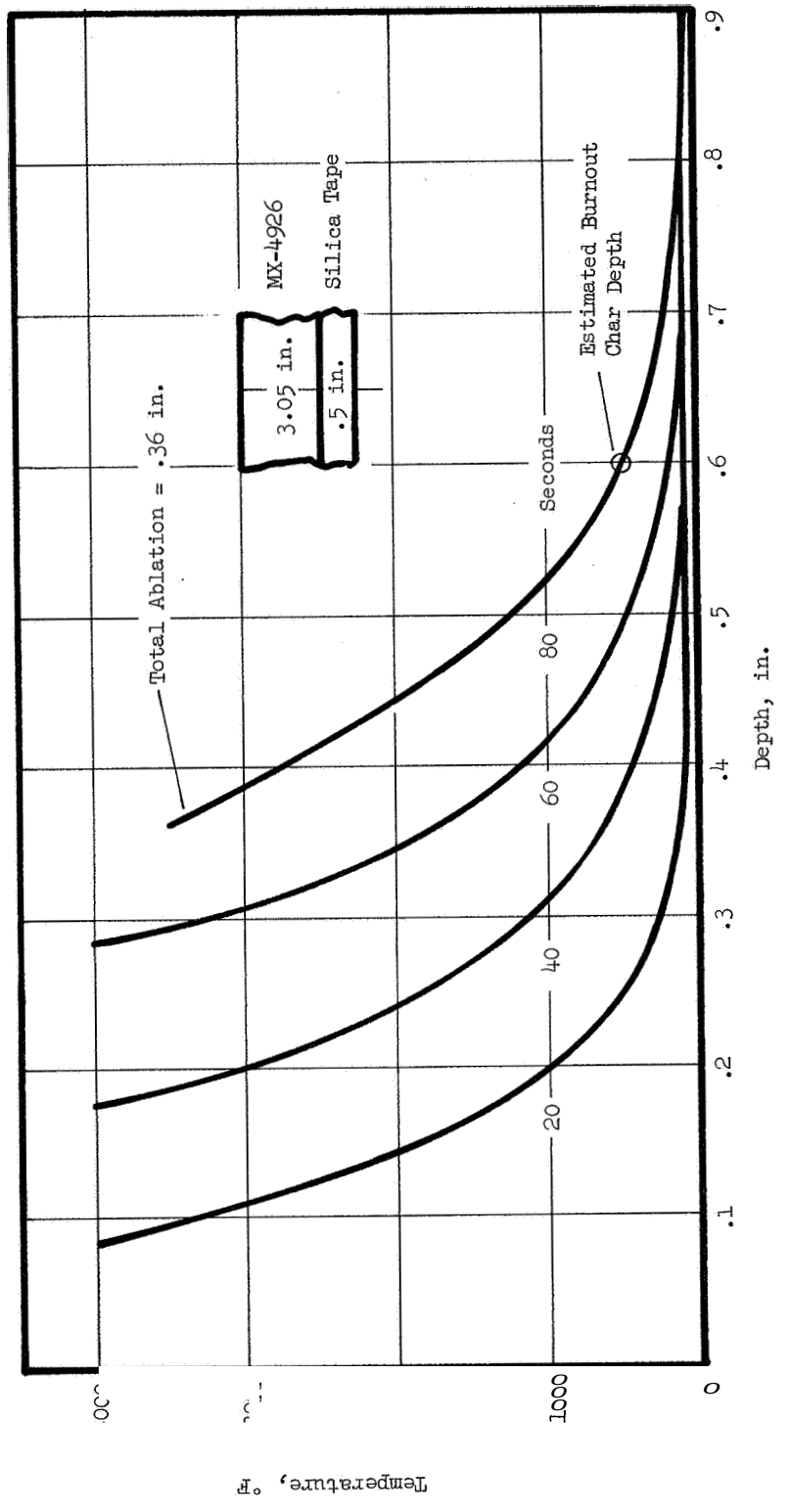
260-SL Nozzle Shell Station Considered in Stress Analysis

Figure 52

Time, sec	Chamber Pressure, psia	Heat Transfer Coefficient, Btu/sq ft sec °F
0	460	0.284
10	535	0.320
25	500	0.304
67	710	0.402
71	610	0.357
72.5	175	0,132
80	Ambient	0

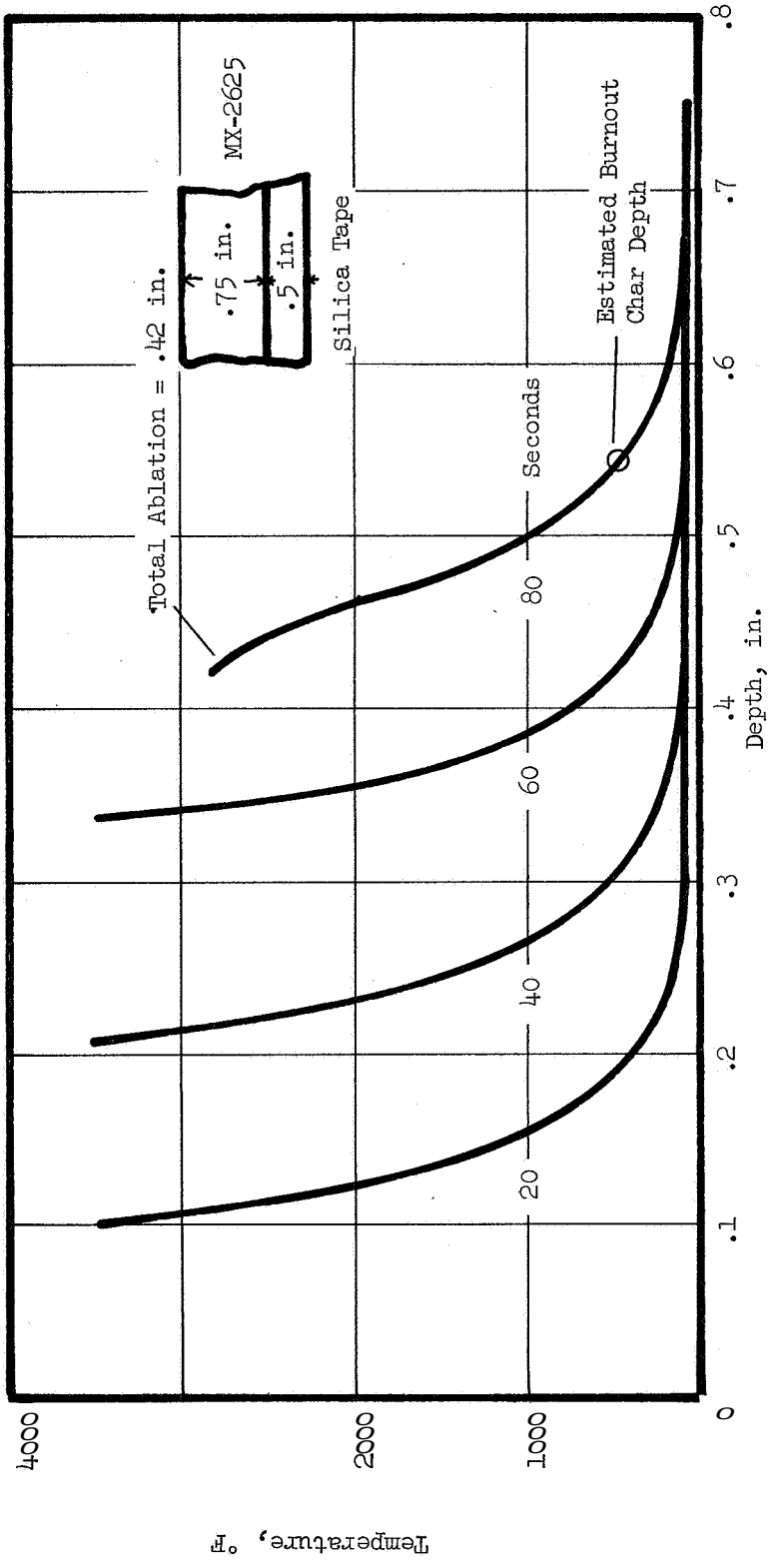
Calculated Throat Heat Transfer Coefficients, 120-SS Motor Nozzle

Figure' 53



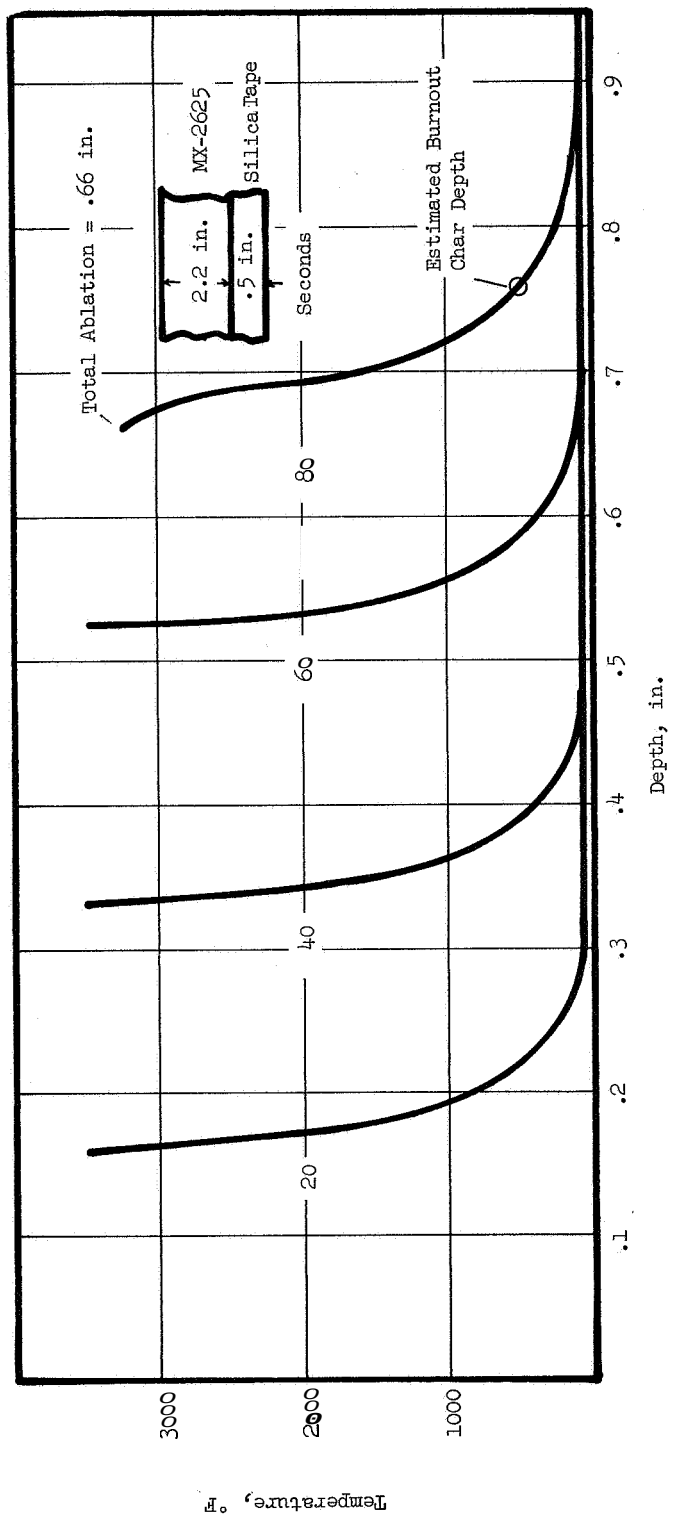
Temperature Profiles at the Throat of the 120-in.-dia Motor

Figure 54



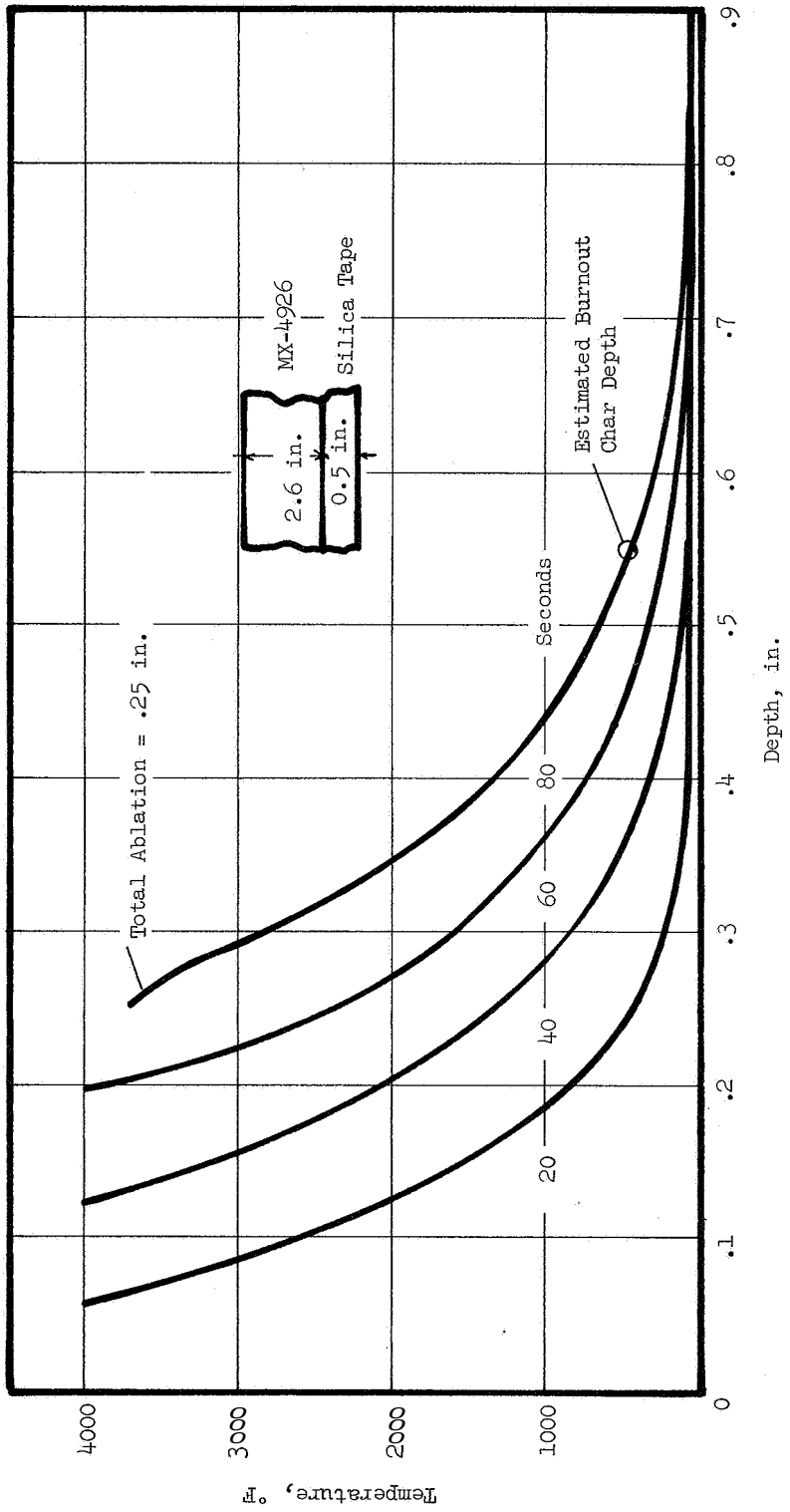
Temperature Profiles Upstream of the Throat of the 120-in.-dia Motor, Area Ratio = 3.66:1

Figure 55



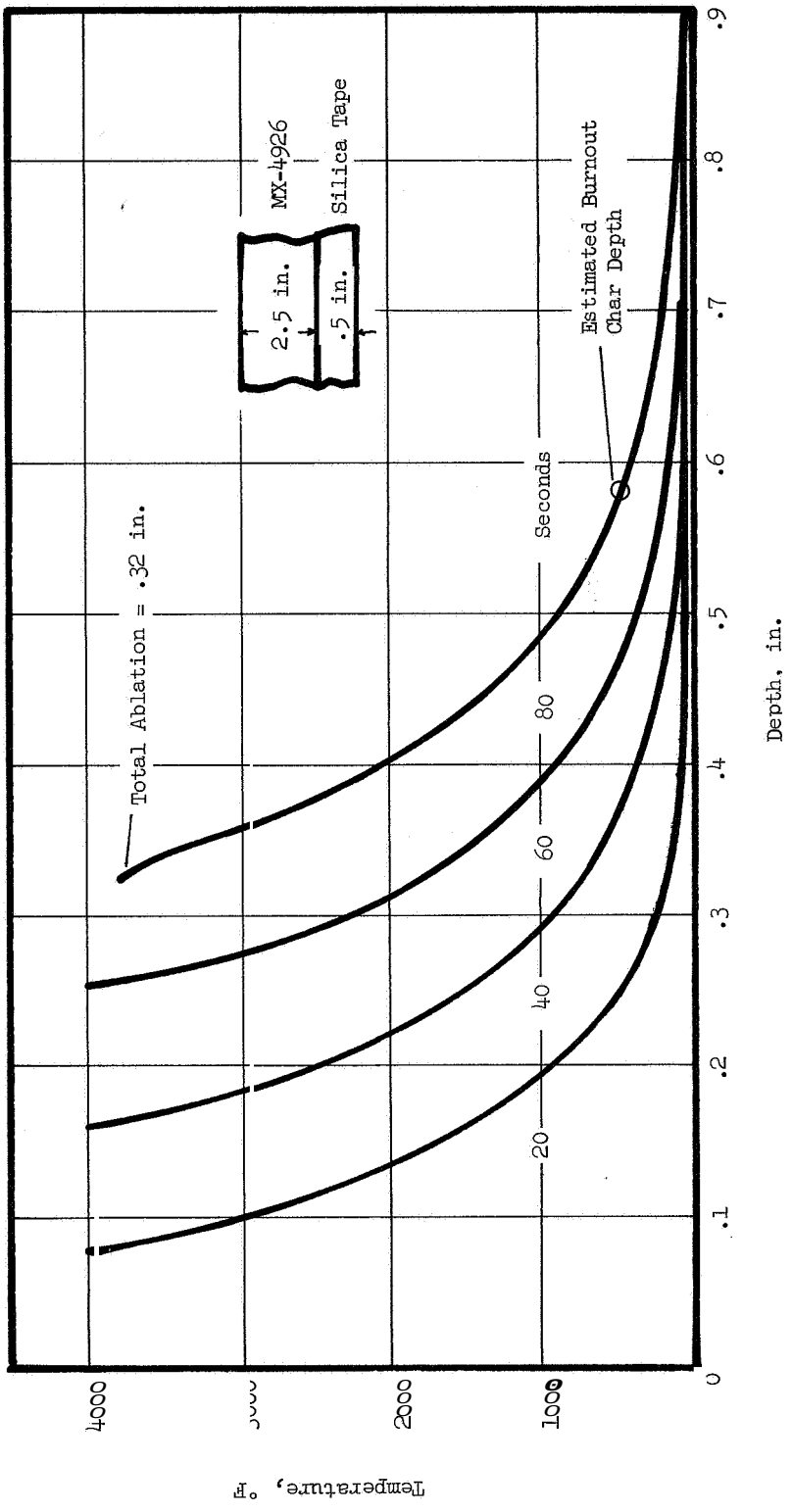
Temperature Profiles Upstream of the Throat of the 120-in.-dia Motor, Area Ratio = 2.66:1

Figure 56



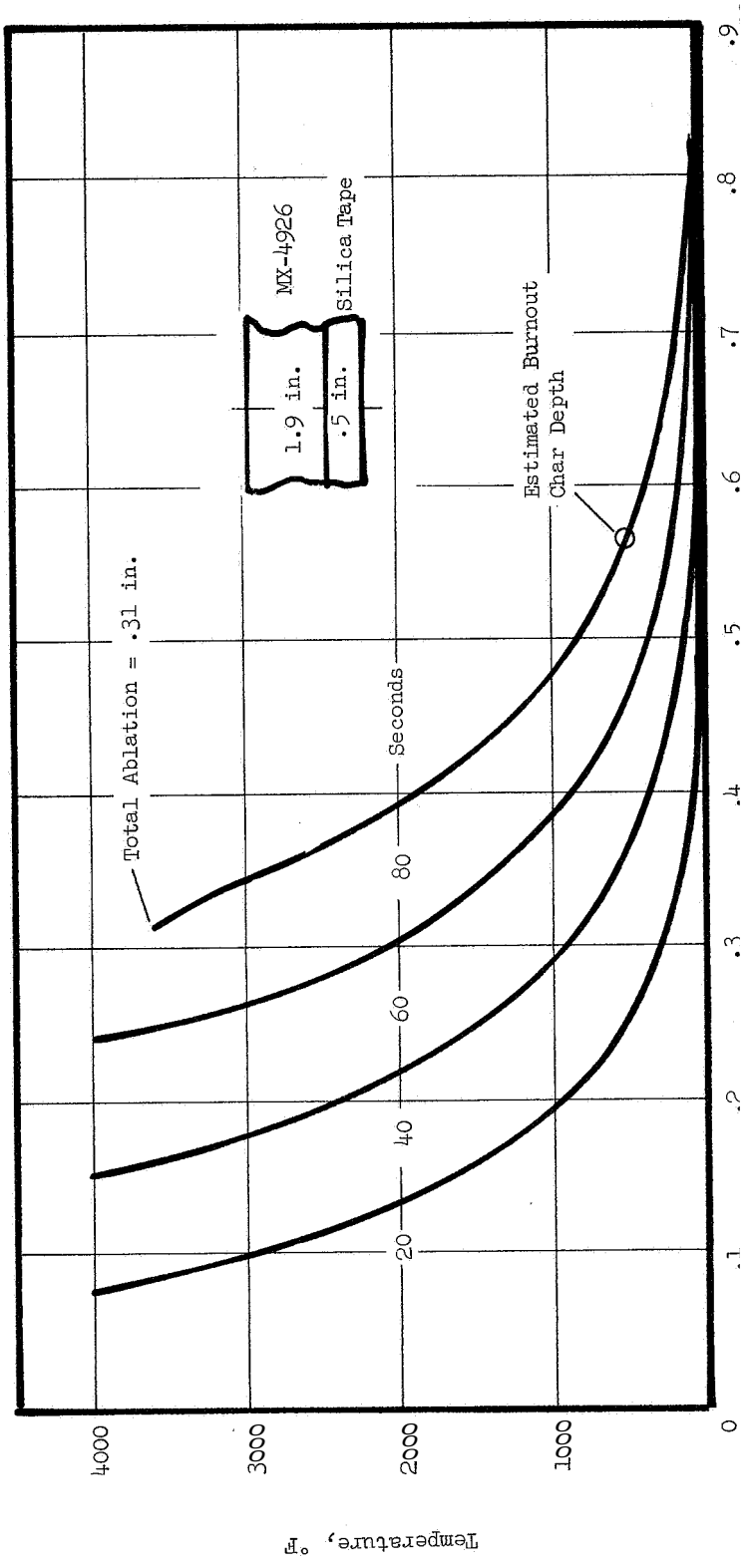
Temperature Profiles Upstream of the Throat of the 120-in.-dia Motor, Area Ratio = 1.6:1

Figure 57



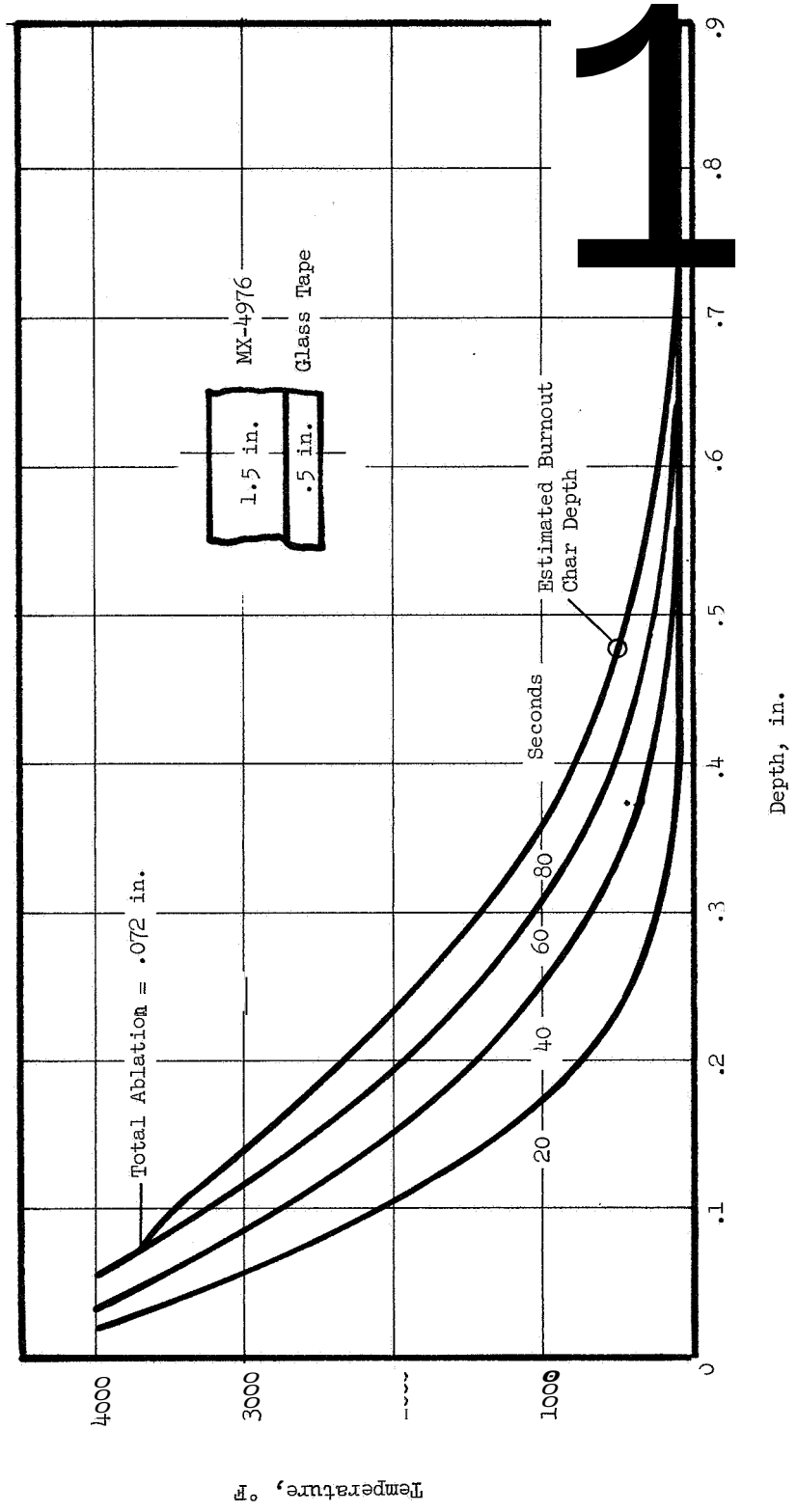
Temperature Profiles Upstream of the Throat of the 120-in.-dia Motor, Area Ratio = 1.20:1

Figure 58



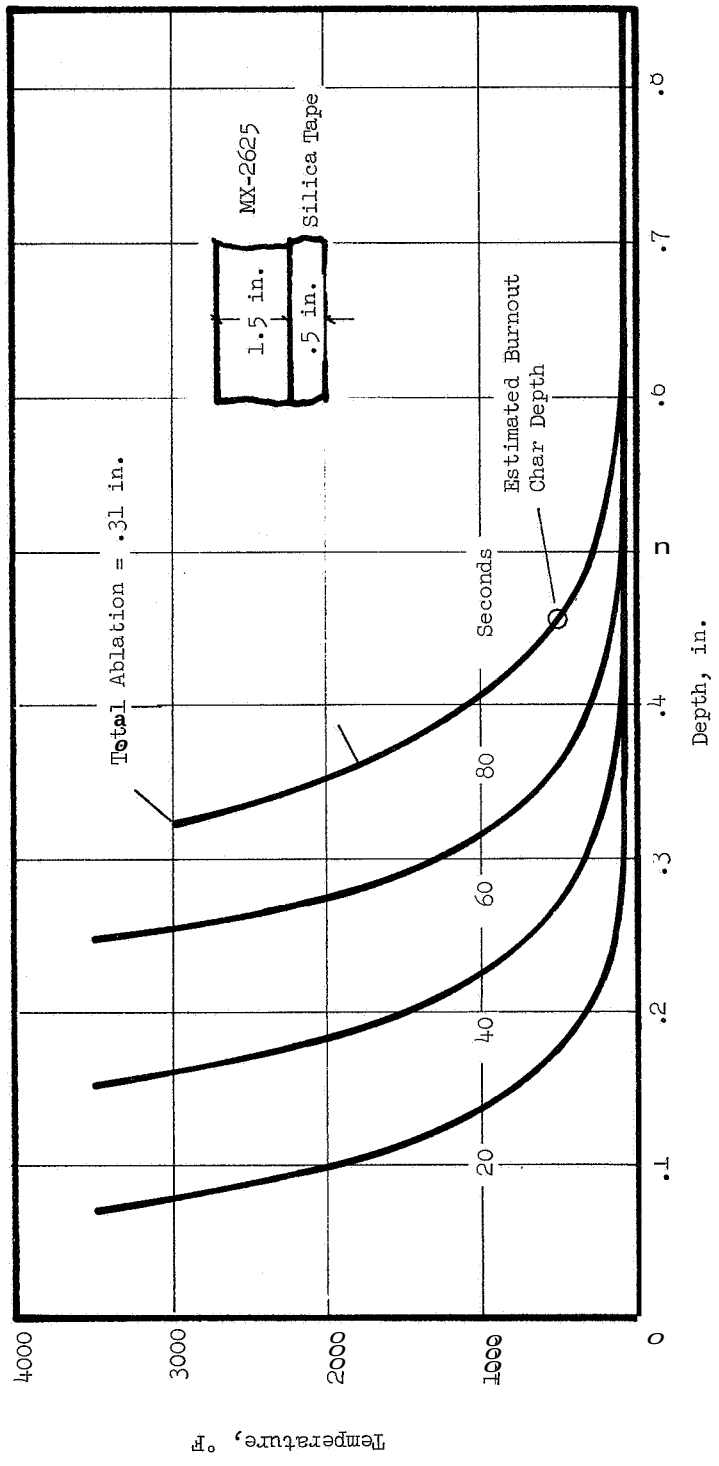
Temperature Profiles Downstream of the Throat of the 120-in.-dia Motor, Area Ratio = 1.1:1

Figure 59



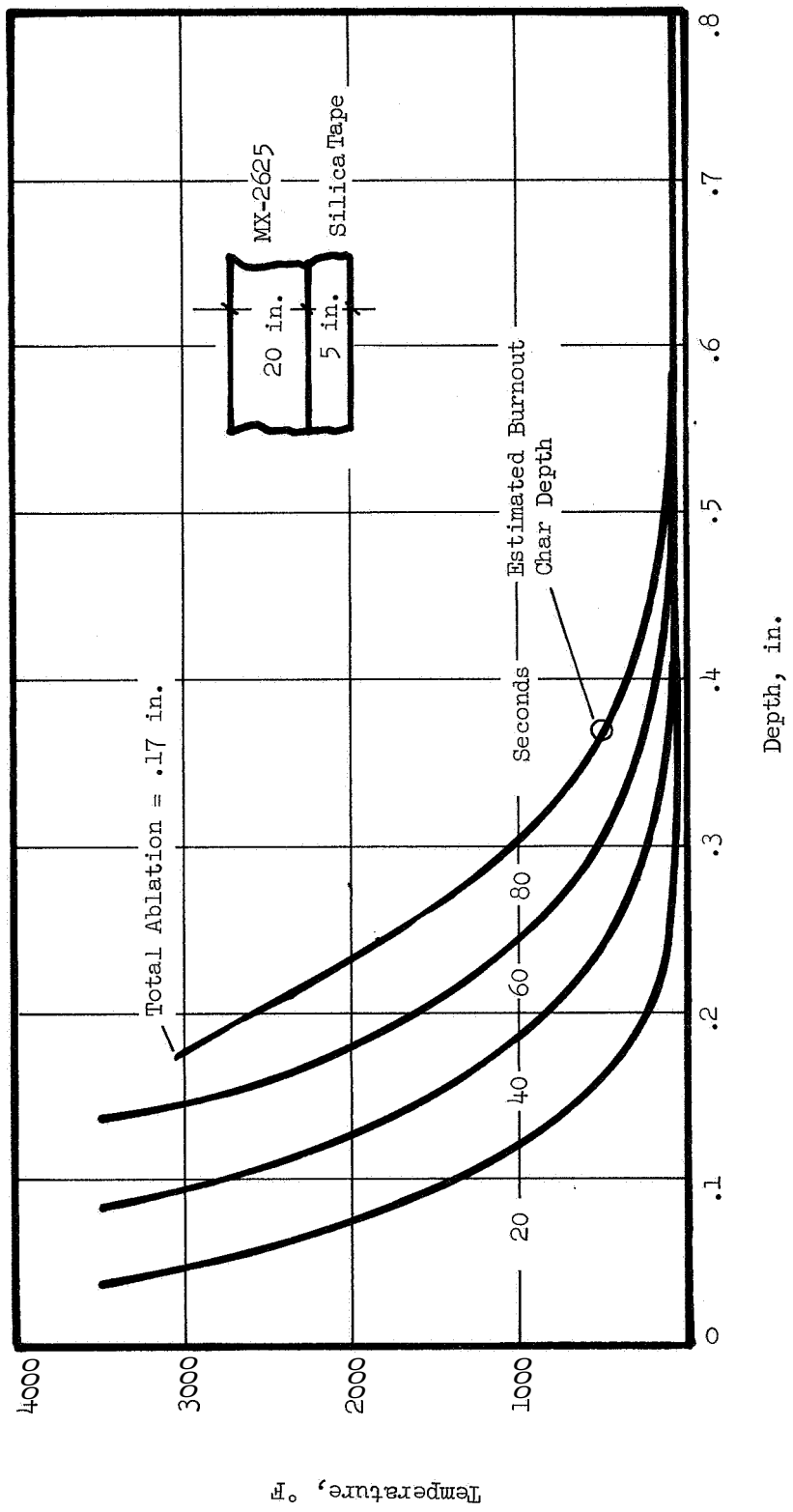
Temperature Profiles Downstream of the Throat of the 120-in.-dia Motor, Area Ratio = 3.4:1

Figure *60*



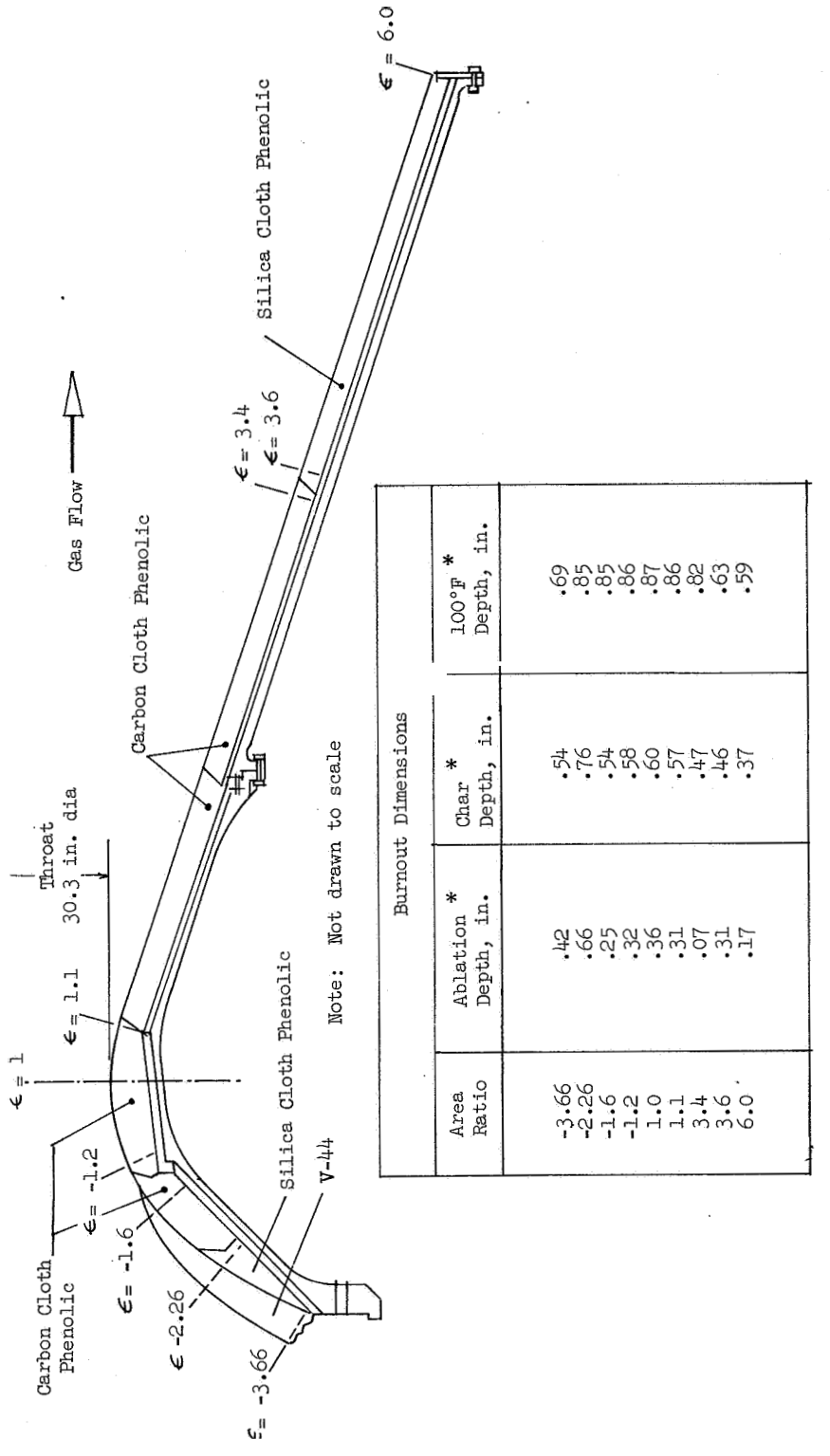
Temperature Profiles Downstream of the Throat of the 120-in.-dia Motor. Area Ratio = 3.6:1

Figure 61



Temperature Profiles Downstream of the Throat of the 120-in.-dia Motor, Area Ratio = 6.0:1

Figure 62

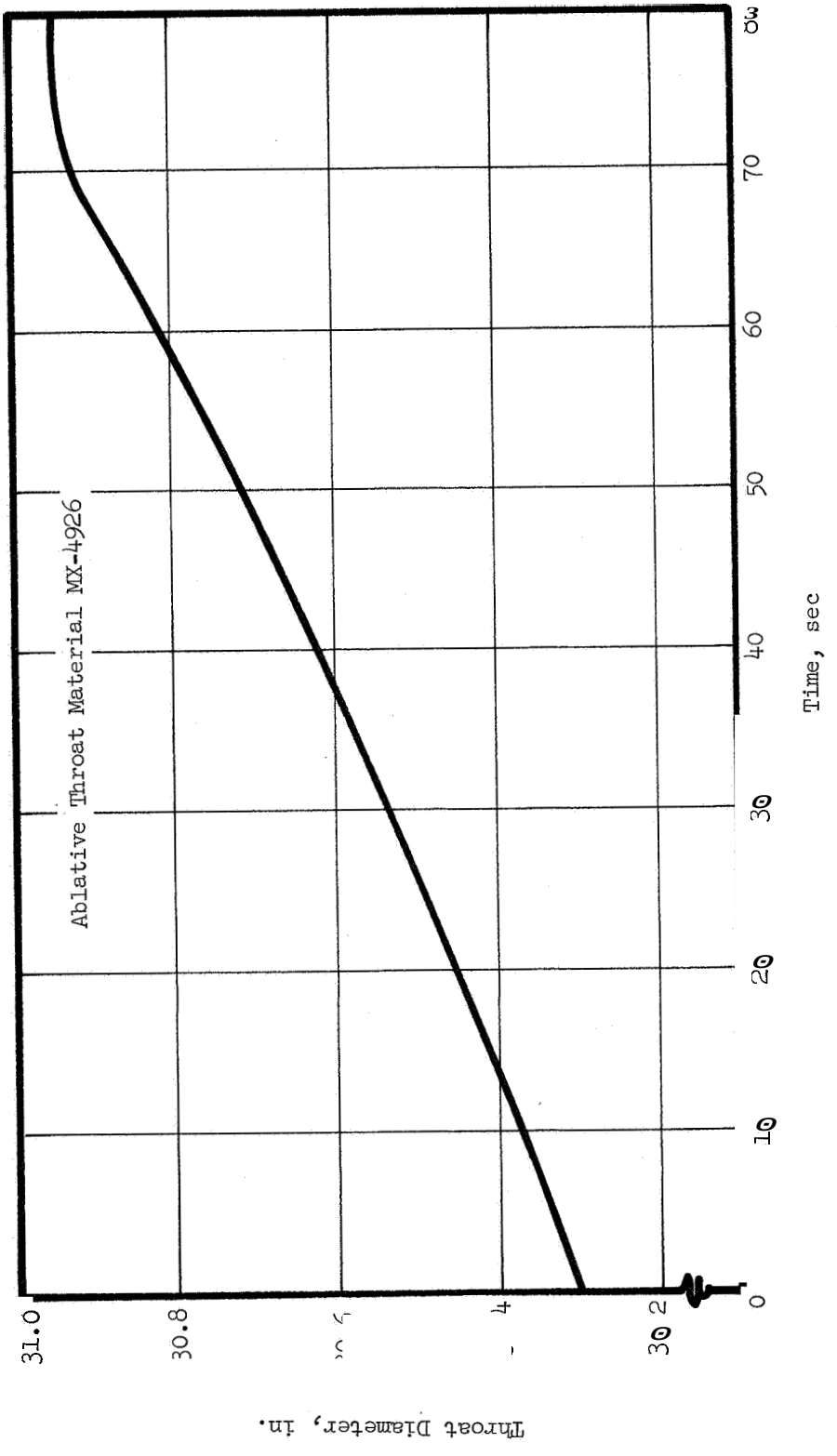


Burnout Dimensions			
Area Ratio	Ablation * Depth, in.	Char * Depth, in.	100°F * Depth, in.
-3.66	.42	.54	.69
-2.26	.66	.76	.85
-1.6	.25	.54	.85
-1.2	.32	.58	.86
1.0	.36	.60	.87
1.1	.31	.57	.86
3.4	.07	.47	.82
3.6	.31	.46	.63
6.0	.17	.37	.59

*Depth Below Original Plastic Contour

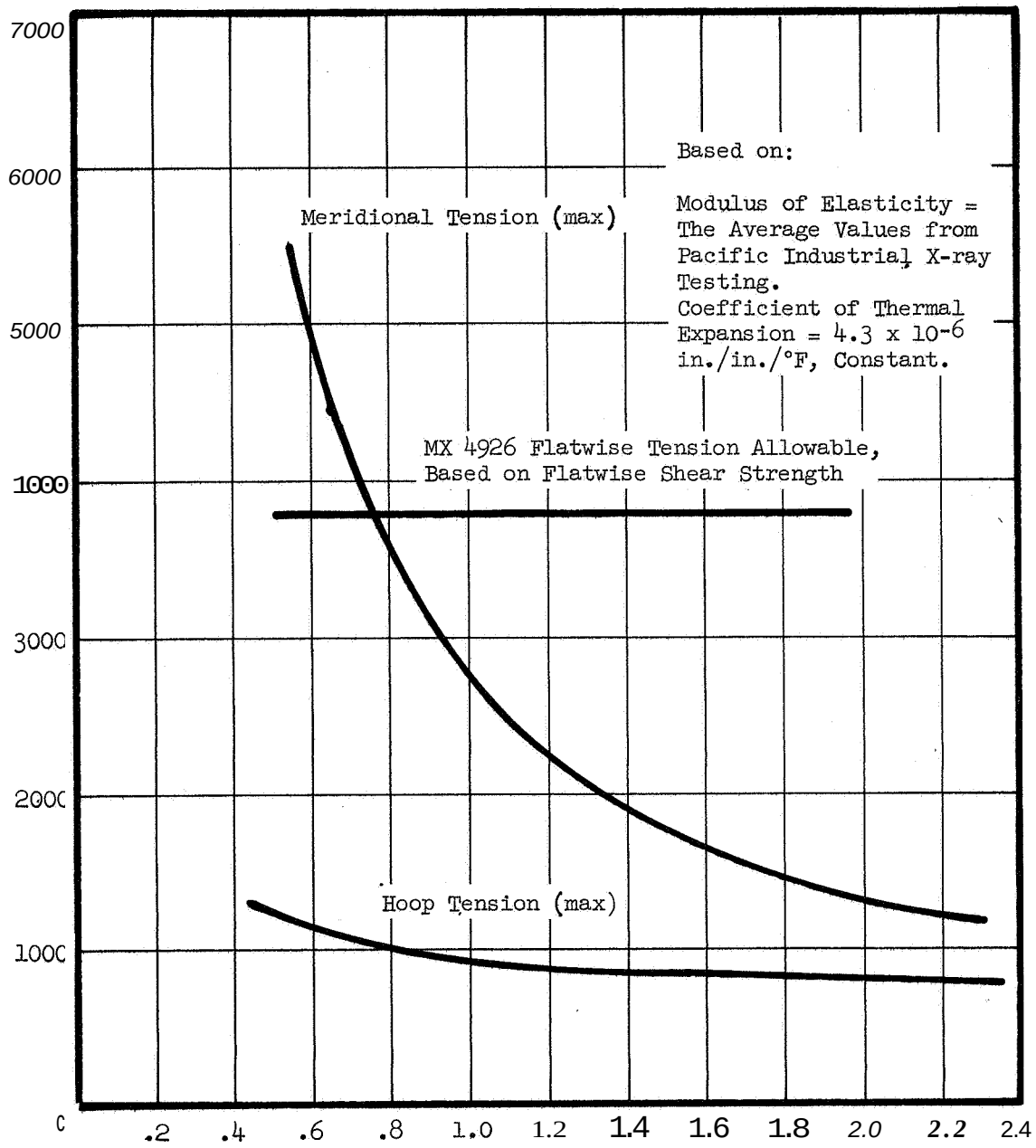
Summary of Predicted Surface Recession, Char and 100°F Isotherm, 120-SS-1 Nozzle

Figure 63



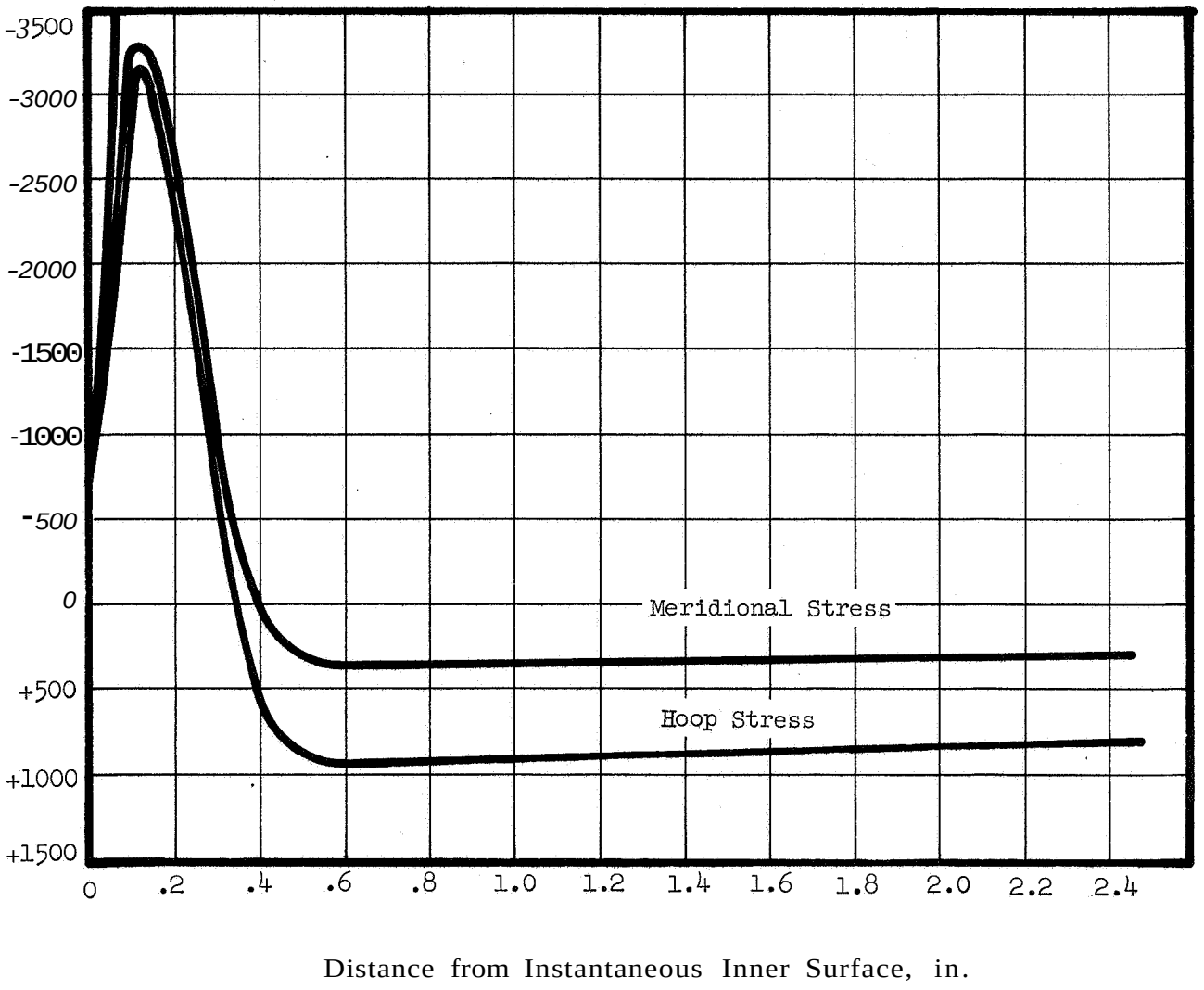
120-in. Motor Throat Diameter Variation with Time

Figure 64



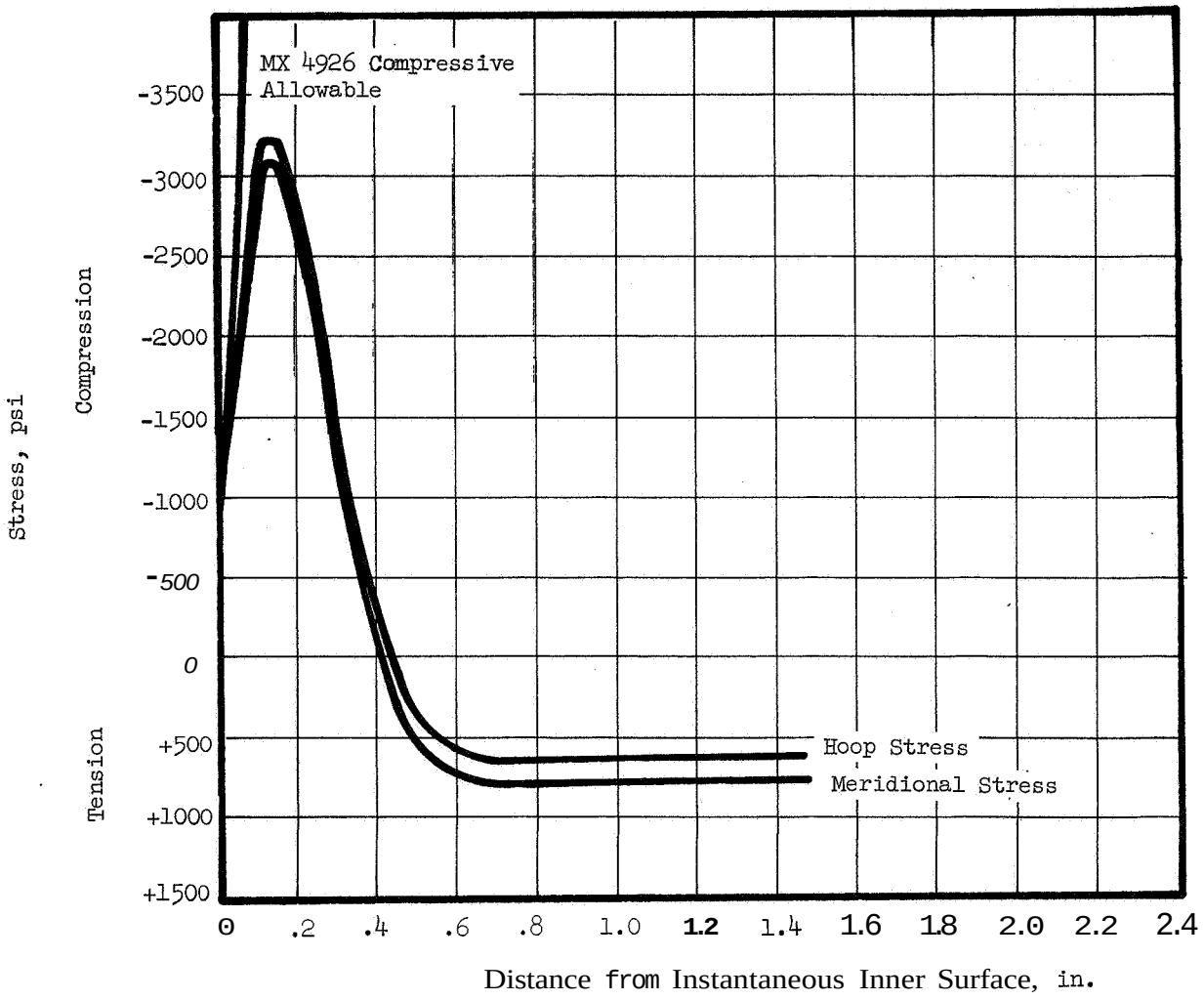
Maximum Hoop and Meridional Tension Stress vs Thickness of MX 4926 Remaining at 60 sec, 4.0 in. Aft of Throat Station, EO-SS Motor Nozzle

Figure 65



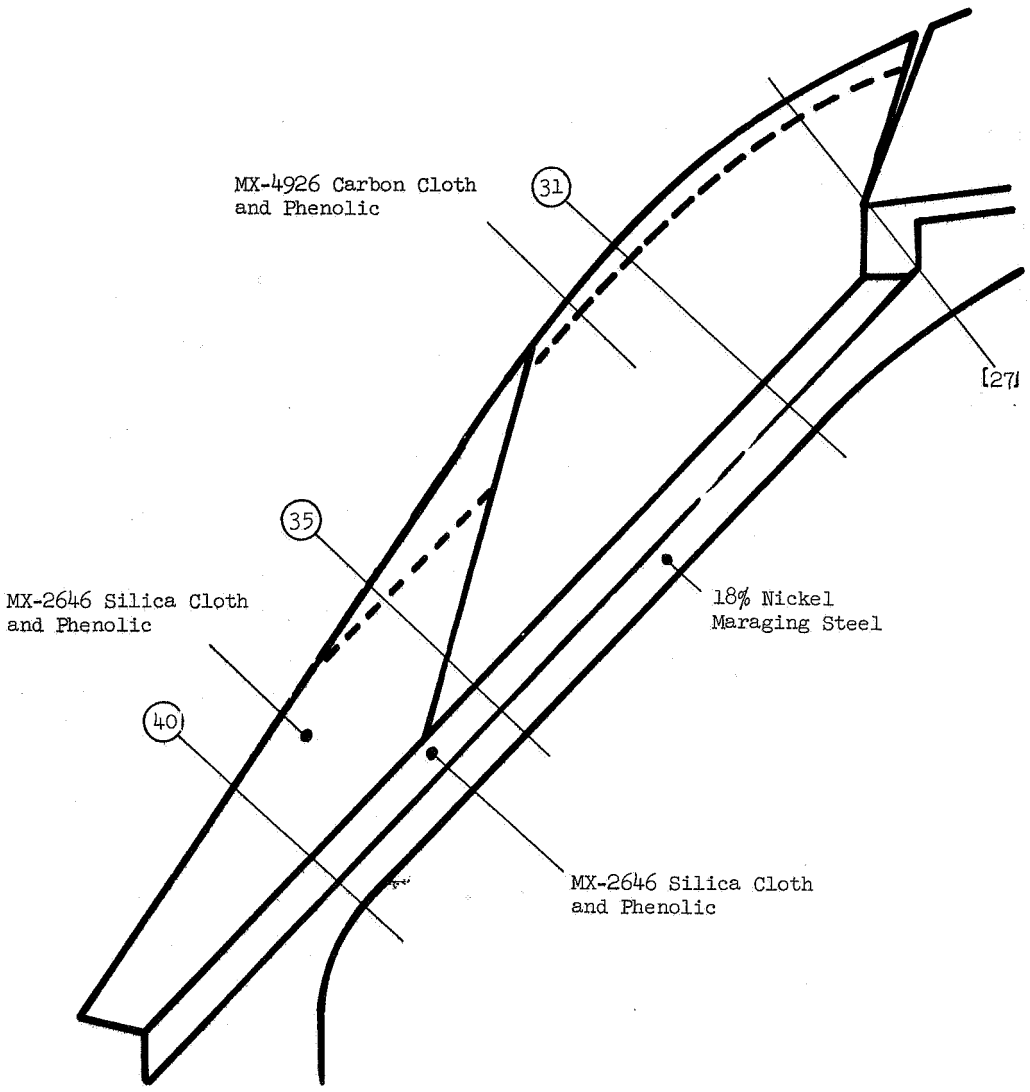
Throat Stress Profile, MX 4926 at 60 sec, 120-SS Motor Nozzle

Figure 66



Stress Profile 4.0 in. Aft of Throat Station, MX 4926 at 60 sec, 120-SS Motor Nozzle

Figure 67

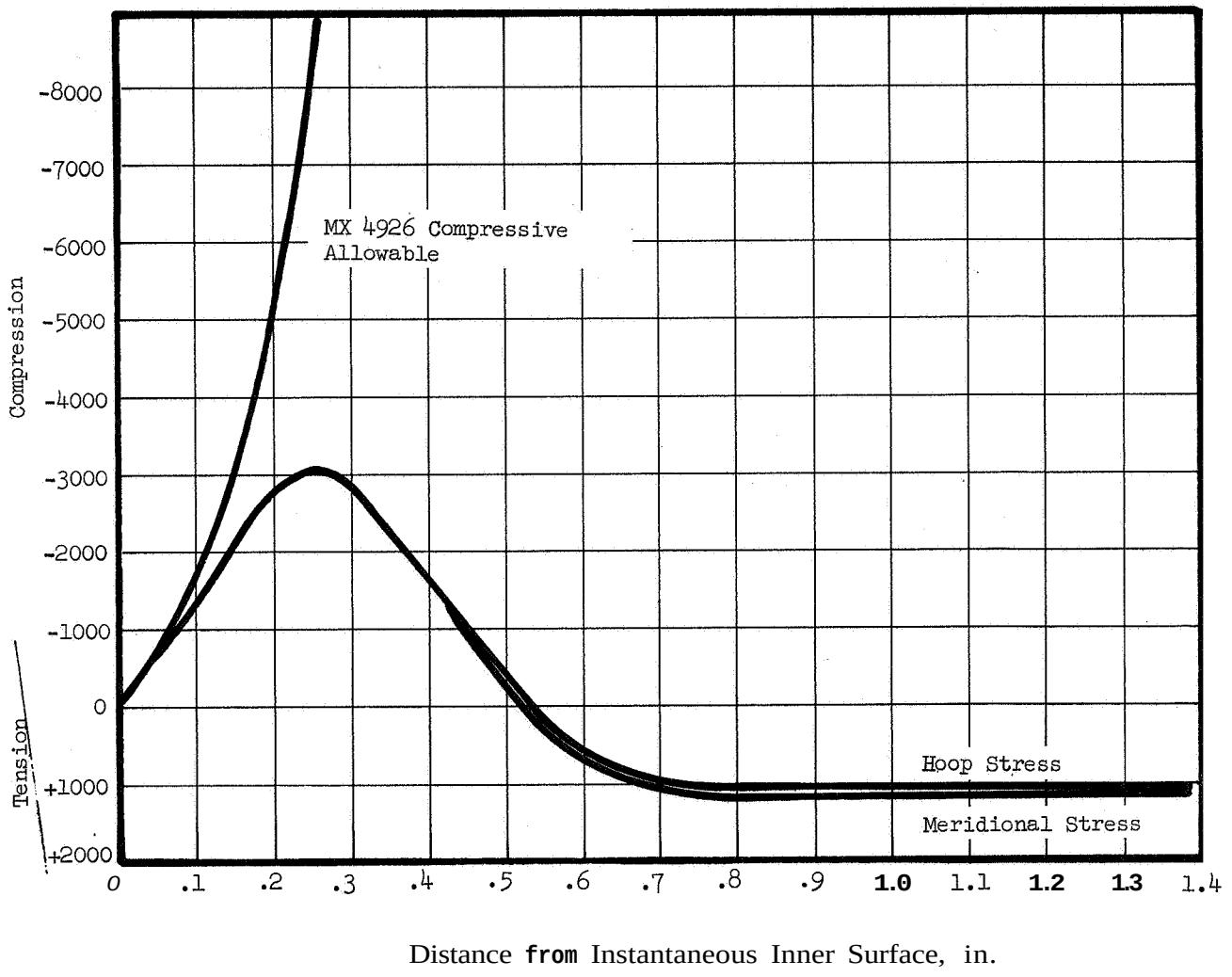


Station	Meridional Inner Stress, psi	Meridional M.S.	Hoop Inner Stress, psi	Hoop M.S.
31	114	High*	6,065	1.62
35	-419	High	7,230	1.20
40	912	High	6,632	1.40

*Margin of Safety, MS, is greater than 10.0

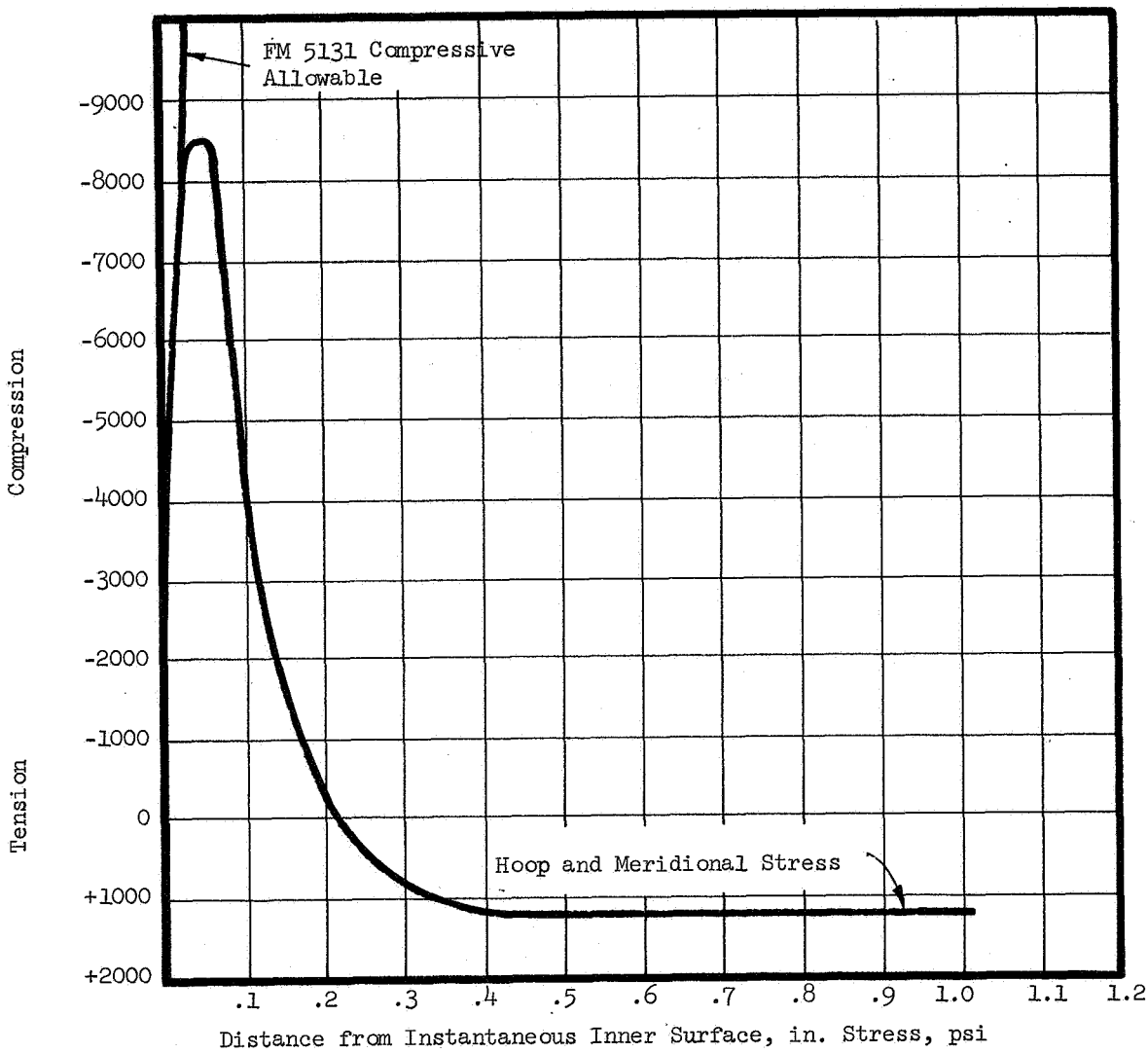
Hoop and Meridional Stresses in Entrance **Cap** Insert, EO-SS Nozzle

Figure *68*



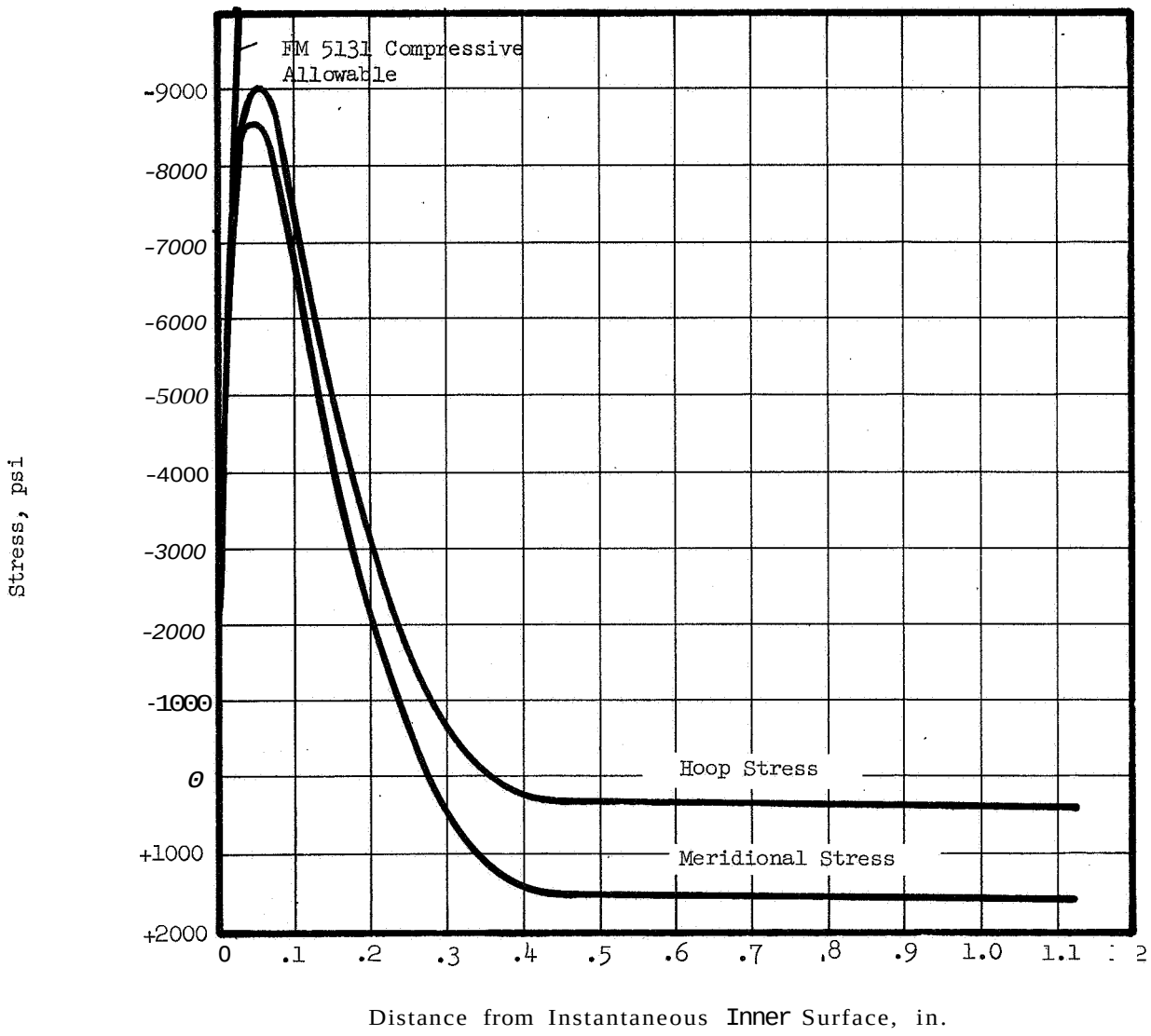
Stress Profile at Exit Cone, Area Ratio 3.4:1, MX 4926 at 60 sec,
EO-SS Motor Nozzle

Figure 69



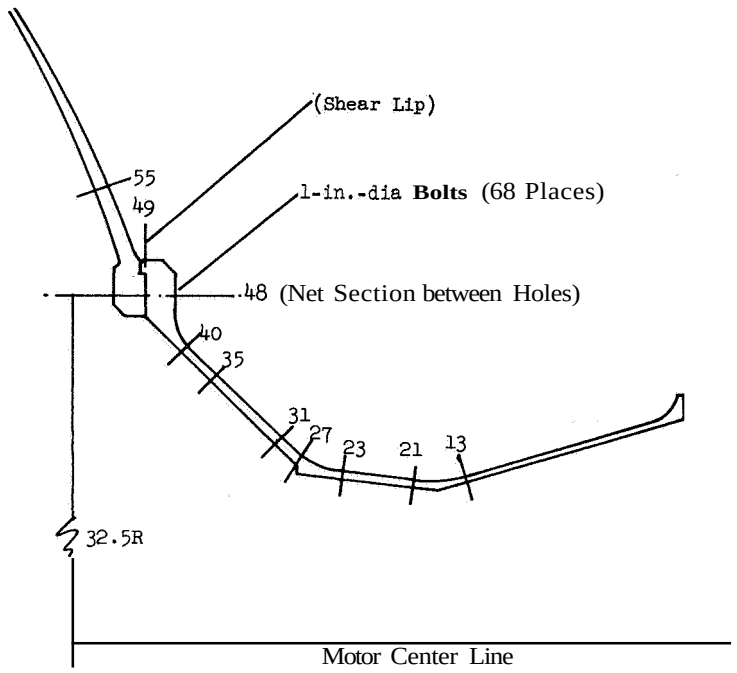
Stress Profile at Exit Cone, Area Ratio = 3.6:1, FM-5131 at 60 sec, 120-SS Motor Nozzle

Figure 70



Stress Profile at Exit Cone, Area Ratio = 6.0:1, FM-5131 at 60 sec, 120-SS motor Nozzle

Figure 71



Nozzle Shell

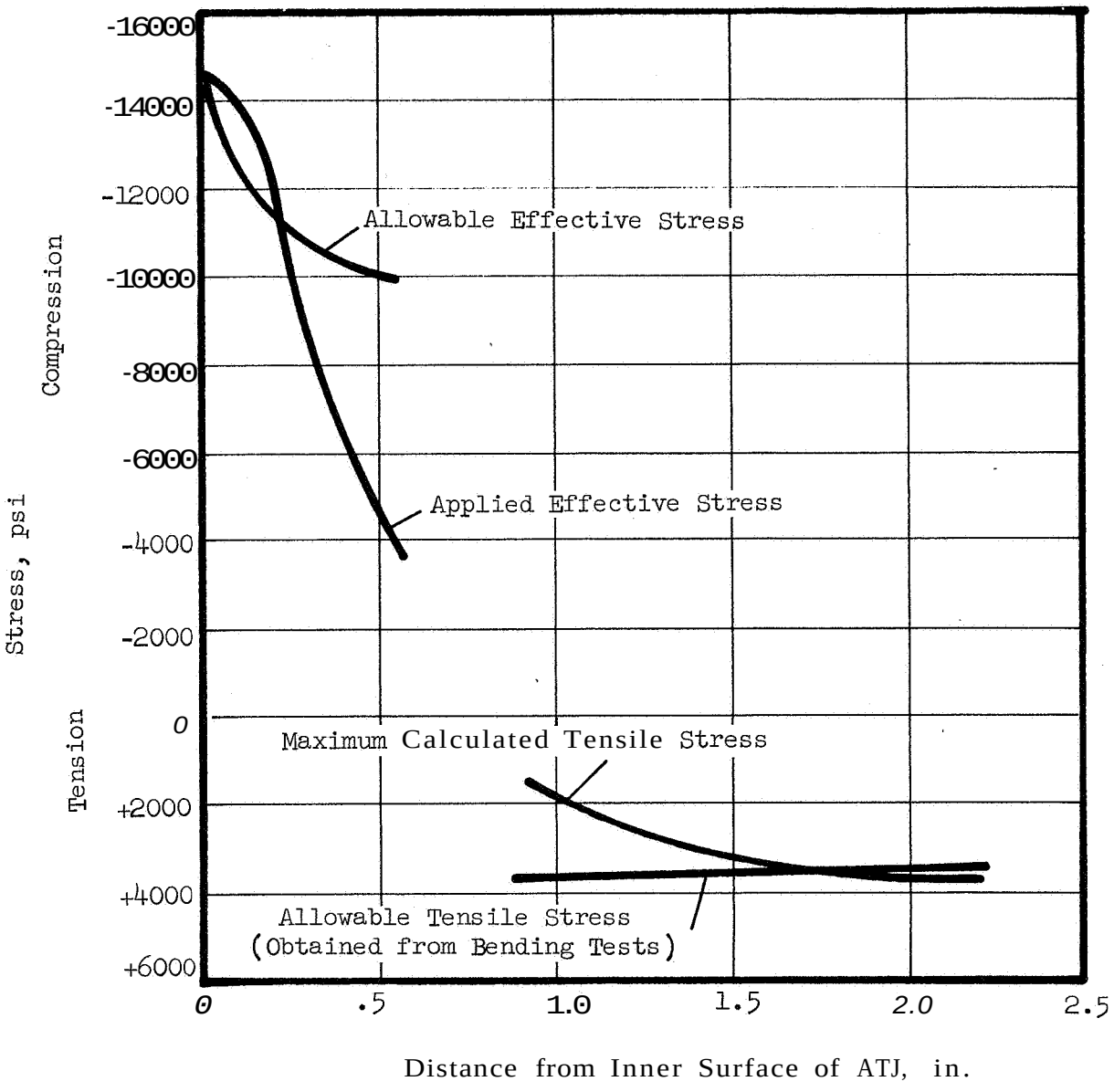
Location	t, in.	R, in.	Meridional Outer	Meridional Inner	Hoop	Hoop Inner	Allowable	Margin of Safety
13	.25	19.03	70630	4180	106710	86770	190,000	.78
21	.365	18.66	27110	22150	63180	61700		2.00
23	.38	19.31	-11270	13350	31720	39100		3.85
27	.80	20.42	-7740	12680	42710	48840		2.89
31	.49	21.80	8060	8260	56820	56870		2.34
35	.49	26.03	30120	4680	74780	67150		1.54
40	.53	28.32	25940	16400	65590	63130		1.87
55	.615	40.50	88650	29190	66990	49150	190,000	1.14

CHAMBER-NOZZLE **ATTACHMENT** JOINT

48	2.22	**Maximum** Stress - Net Section Between Holes $_t$ = 59710 psi	200,000	2.34
49	.77	Shear Stress at Shear Lip $_s$ = 44770 psi	119,000	1.65
		1 in. Dia. Bolts Pretension Load Q_{PT} = 69683 lb	116,138 lb	.66

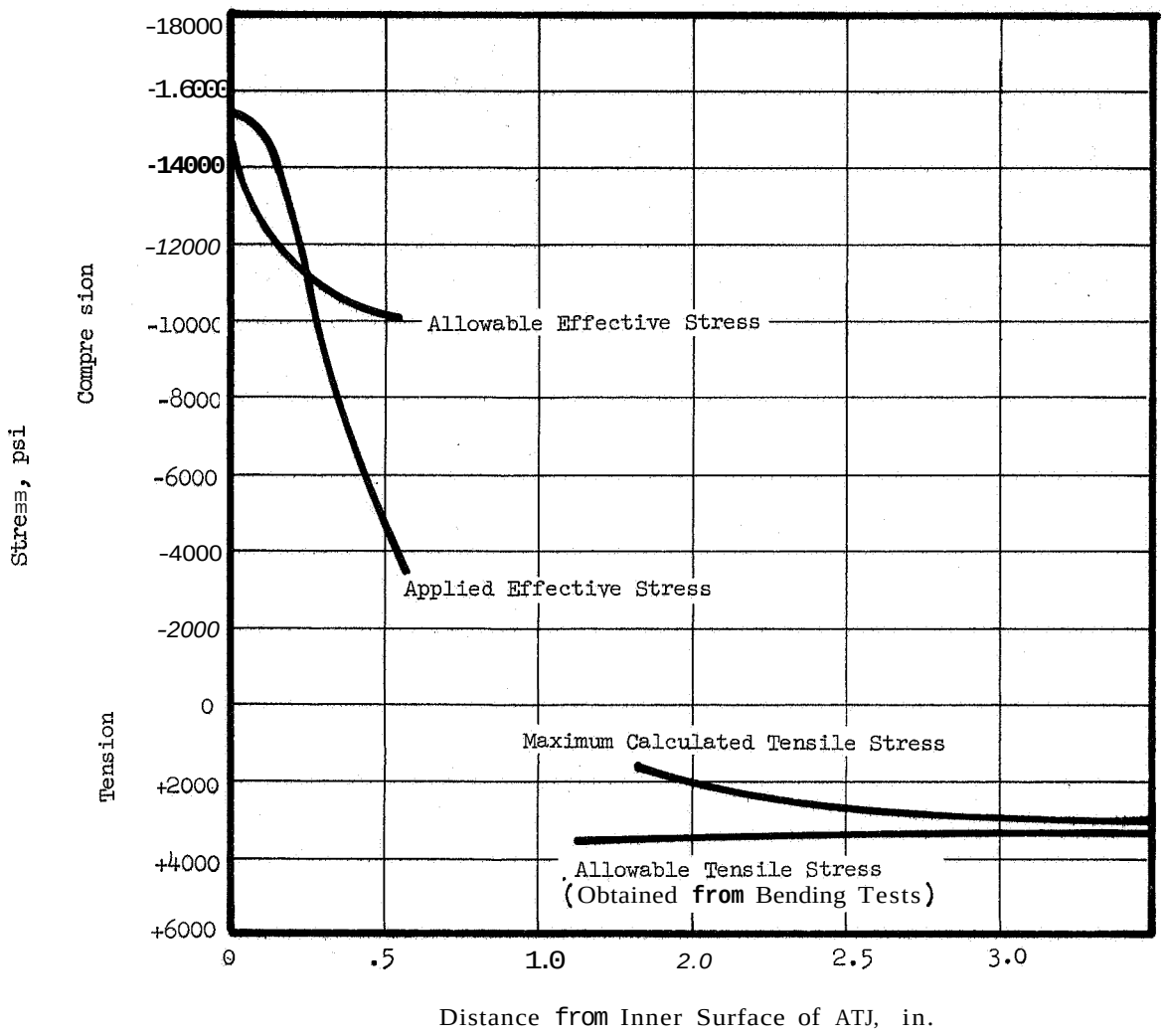
Margins of Safety **for** 120-SS **Nozzle Shell**

Figure 72



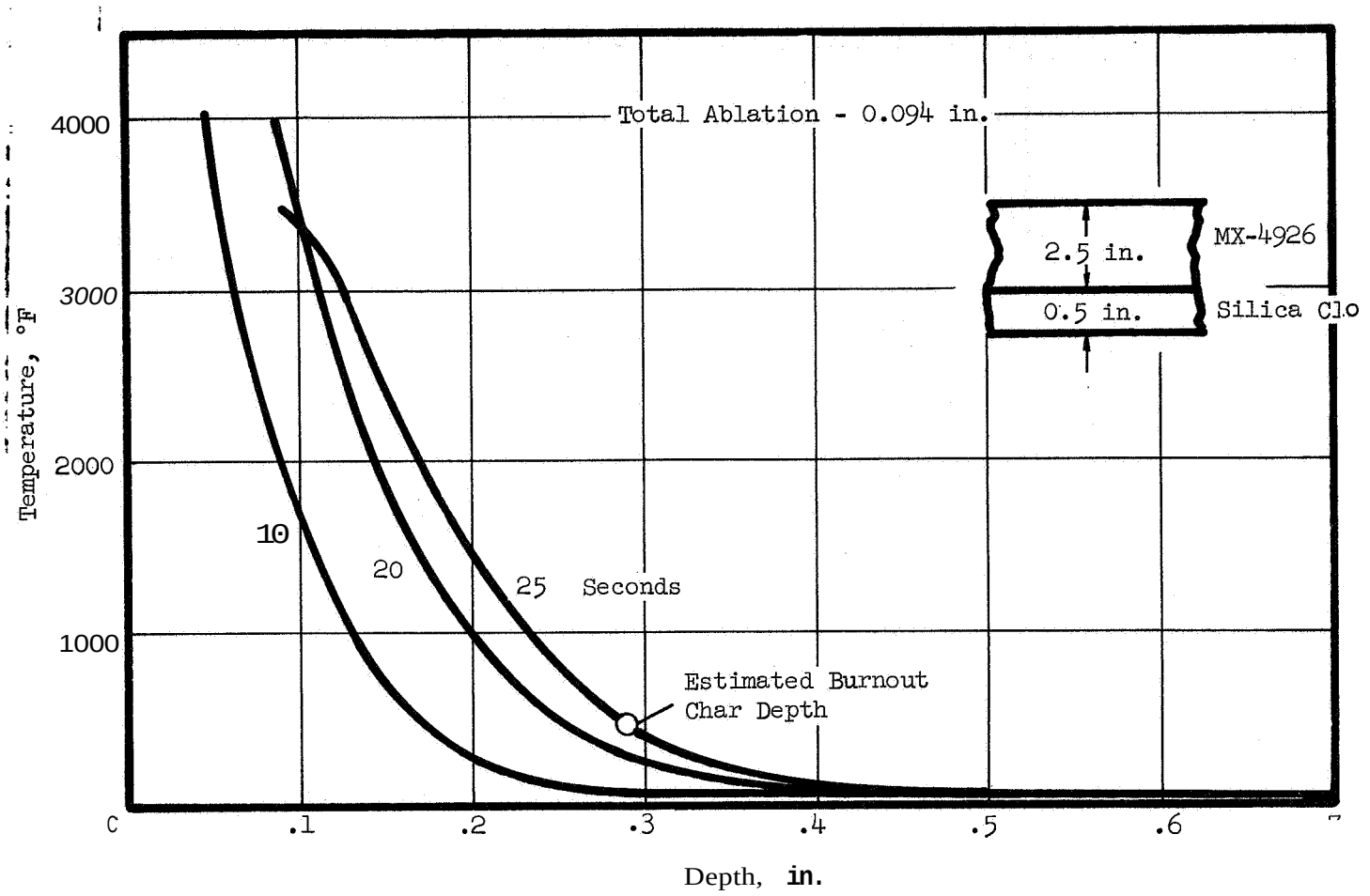
Thermal Stresses in the Aft End of an ATJ Monolithic Graphite Throat after 19 sec Firing Duration, 44-SS Motor

Figure 73



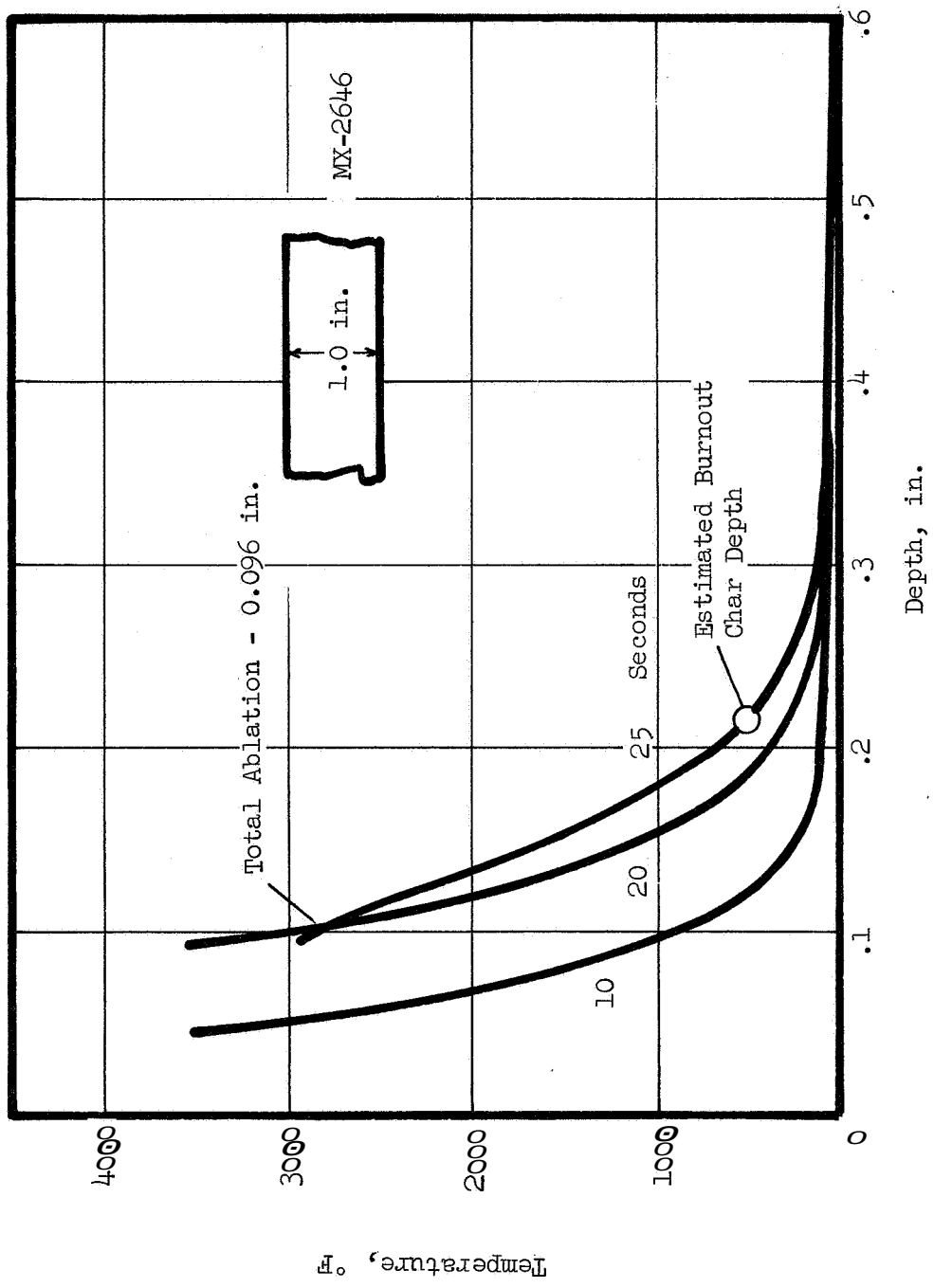
Thermal Stresses at Throat, Station of ATJ Monolithic Graphite Throat after 19 sec Firing Duration, 44-SS Motor

Figure 74



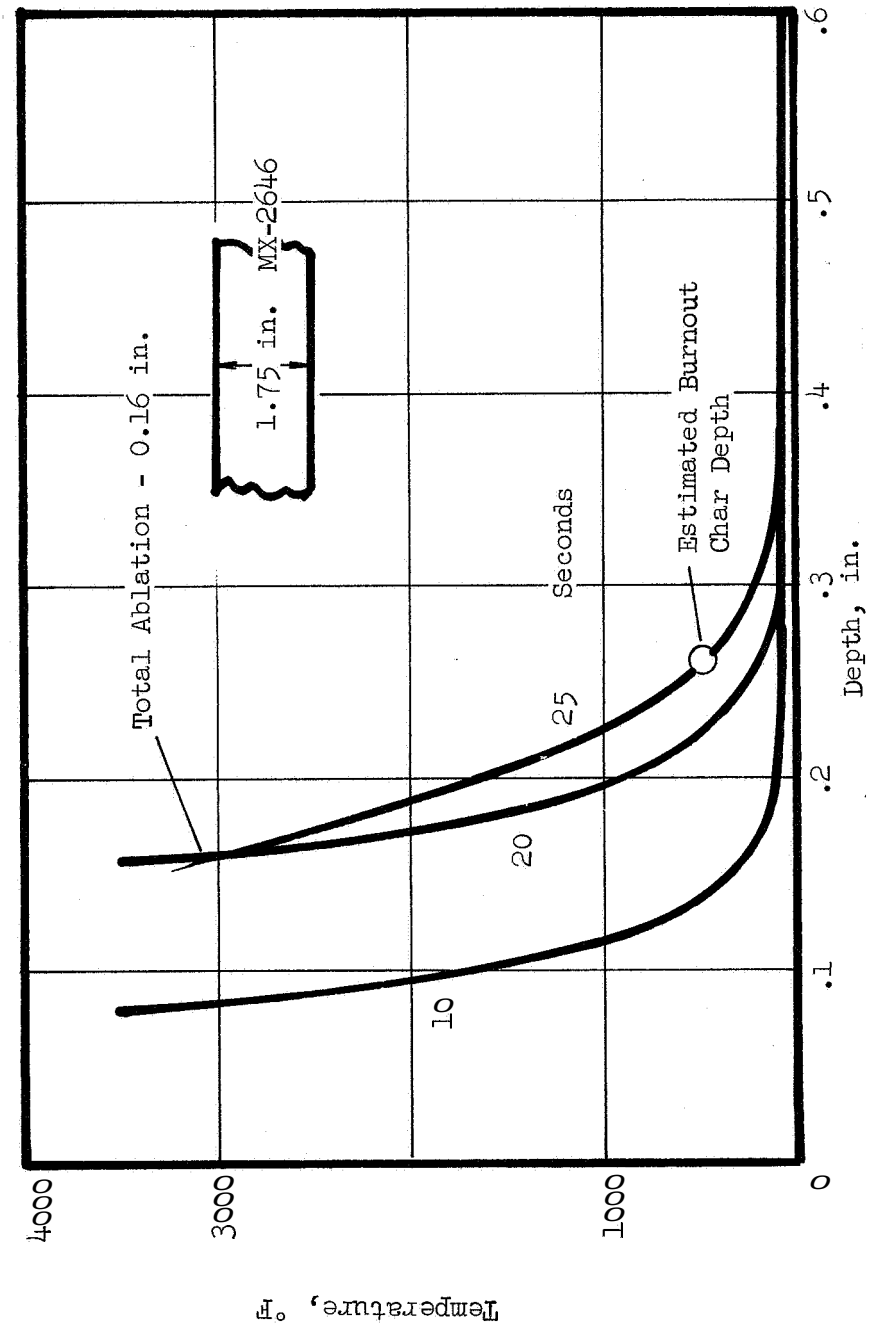
Temperature Profiles at the **Throat** for the 44-in.-dia **Motor**

Figure 75



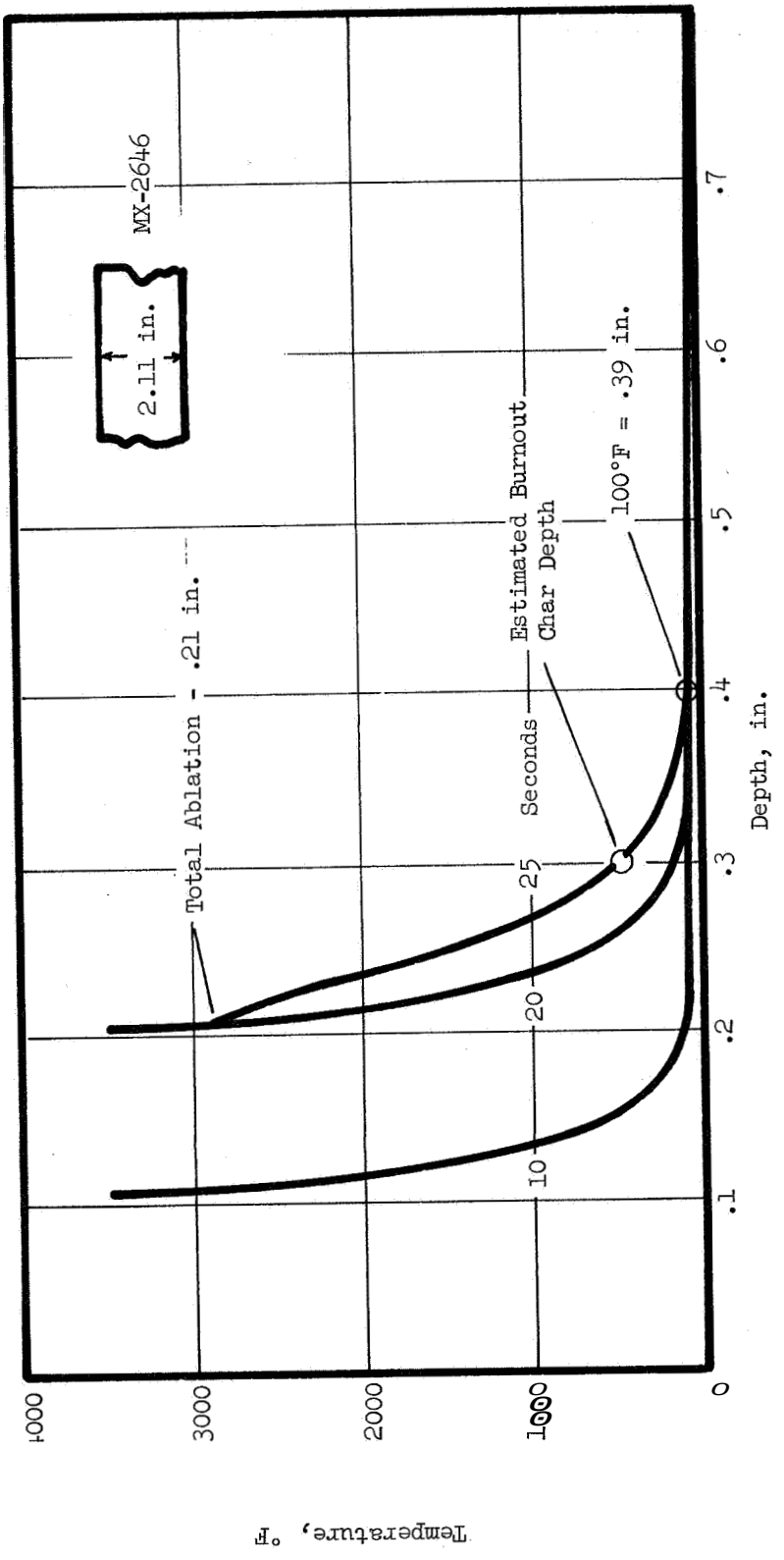
Temperature Profiles Upstream of the Throat for the 44-in.-dia Motor (Area Ratio - 4.0:1)

Figure 76



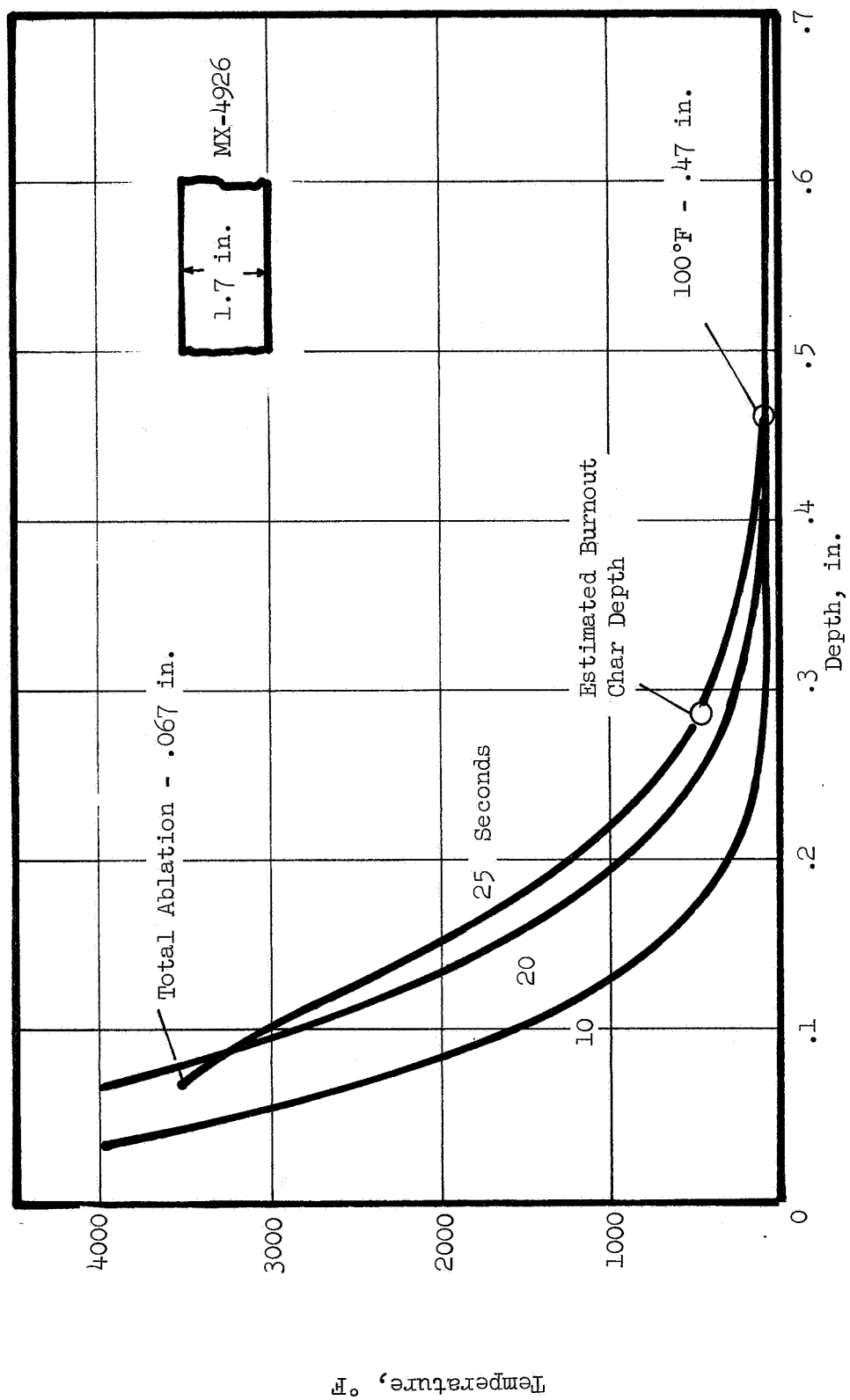
Temperature Profiles Upstream of the Throat for the 44-in.-dia Motor (Area Ratio = 2.4:1)

Figure 77



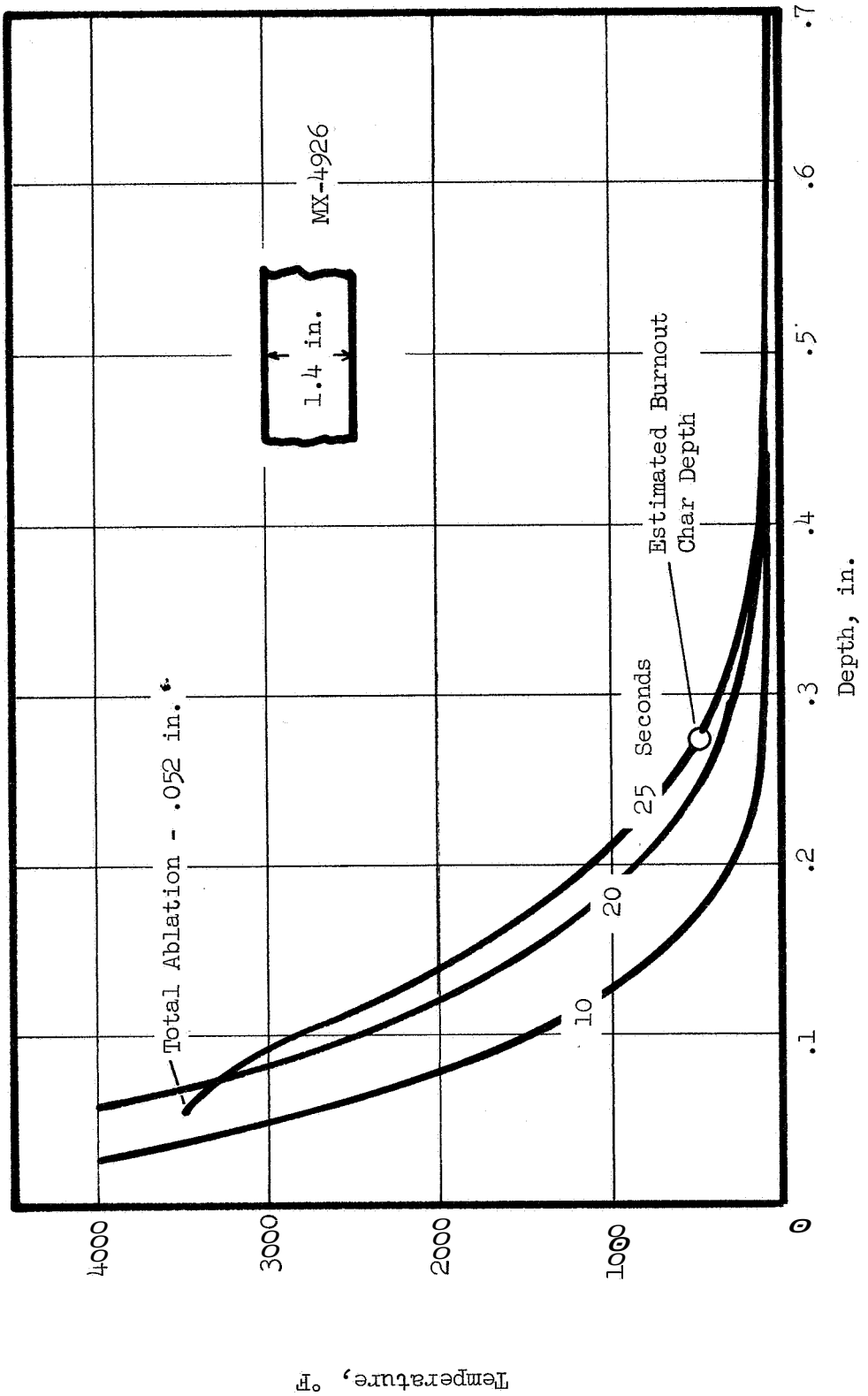
Temperature Profiles Upstream of the Throat for the 44-in.-dia Motor (Area Ratio = 1.8:1)

Figure 78



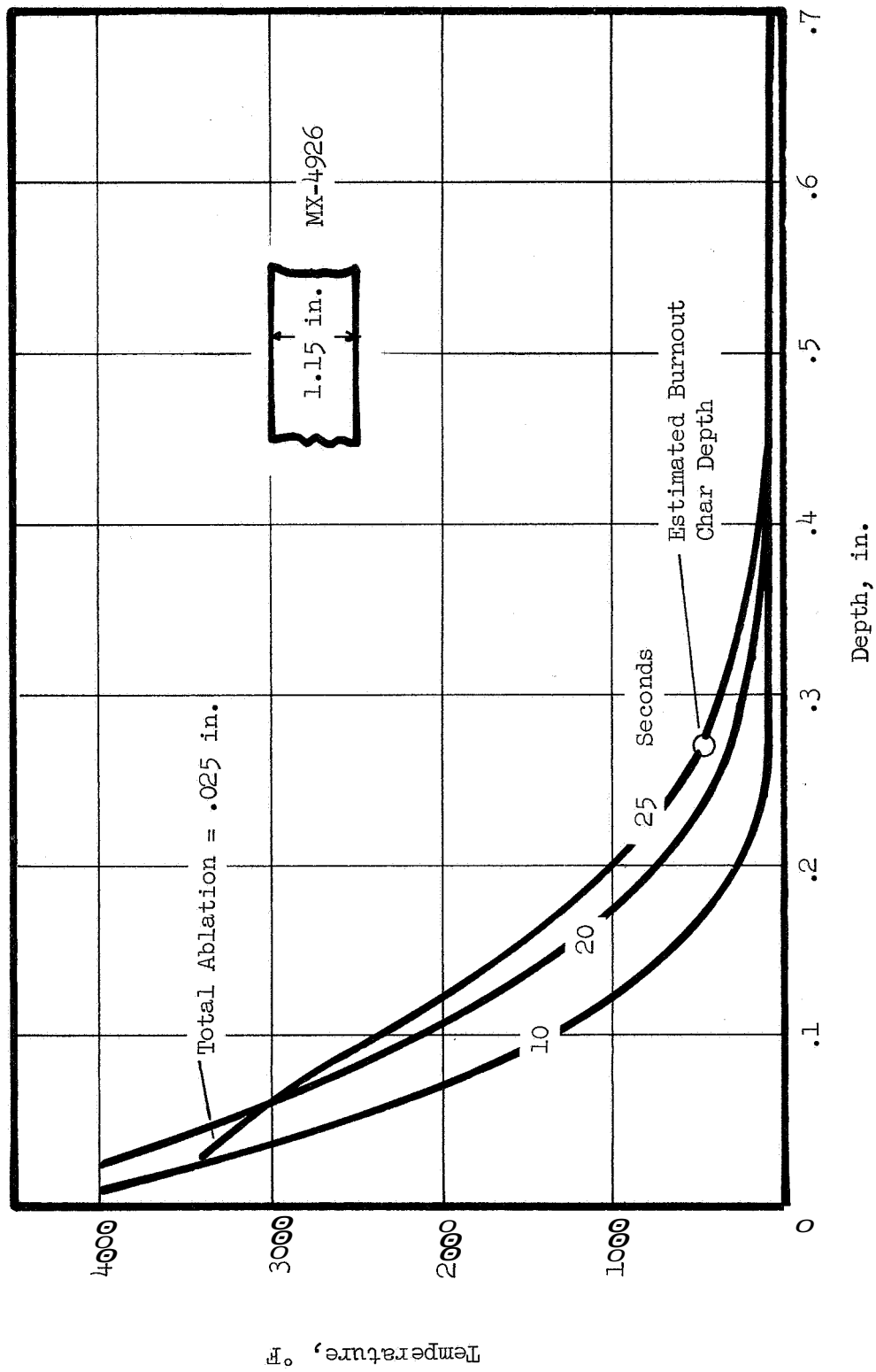
Temperature Profiles Upstream of the Throat f the 44-in.-dia
Motor (Area Ratio = 1.5:1

Figure 79



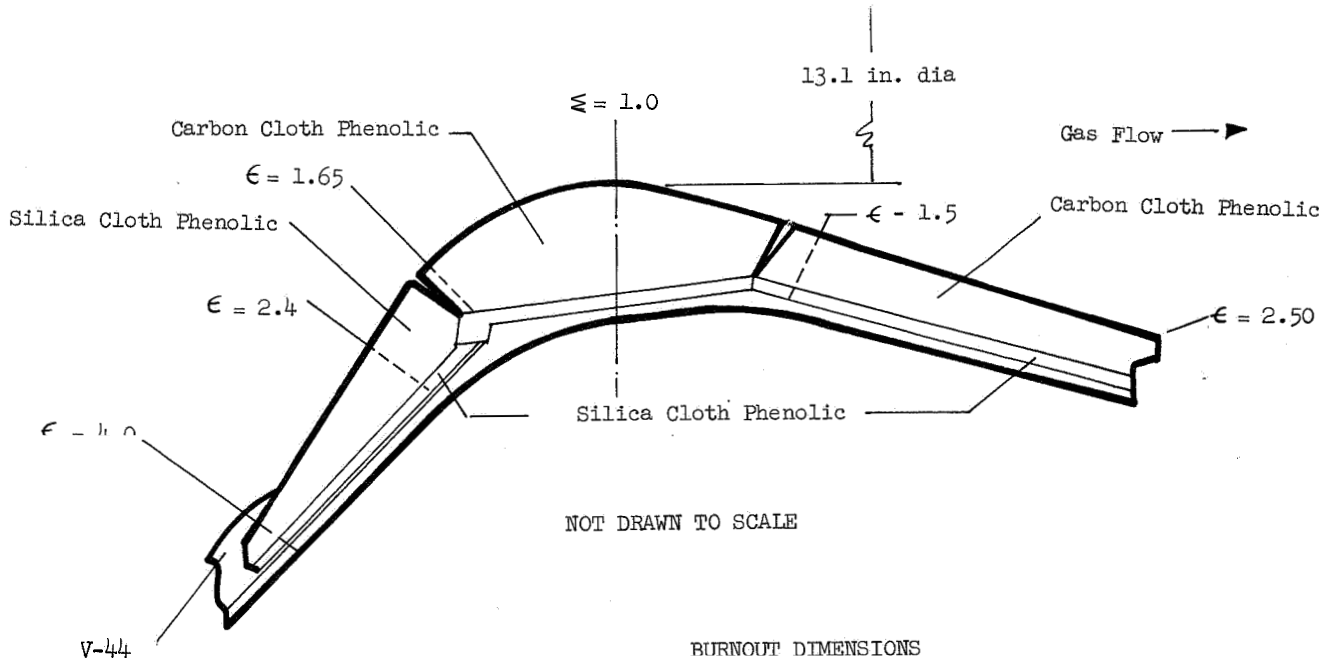
Temperature Profiles Downstream of the Throat for the 44-in.-dia Motor (Area Ratio = 1.5:1)

Figure 80



Temperature Profile Downstream of the Throat for the 14-in.-dia
Motor (Area Ratio = 2.45:1)

Figure 81



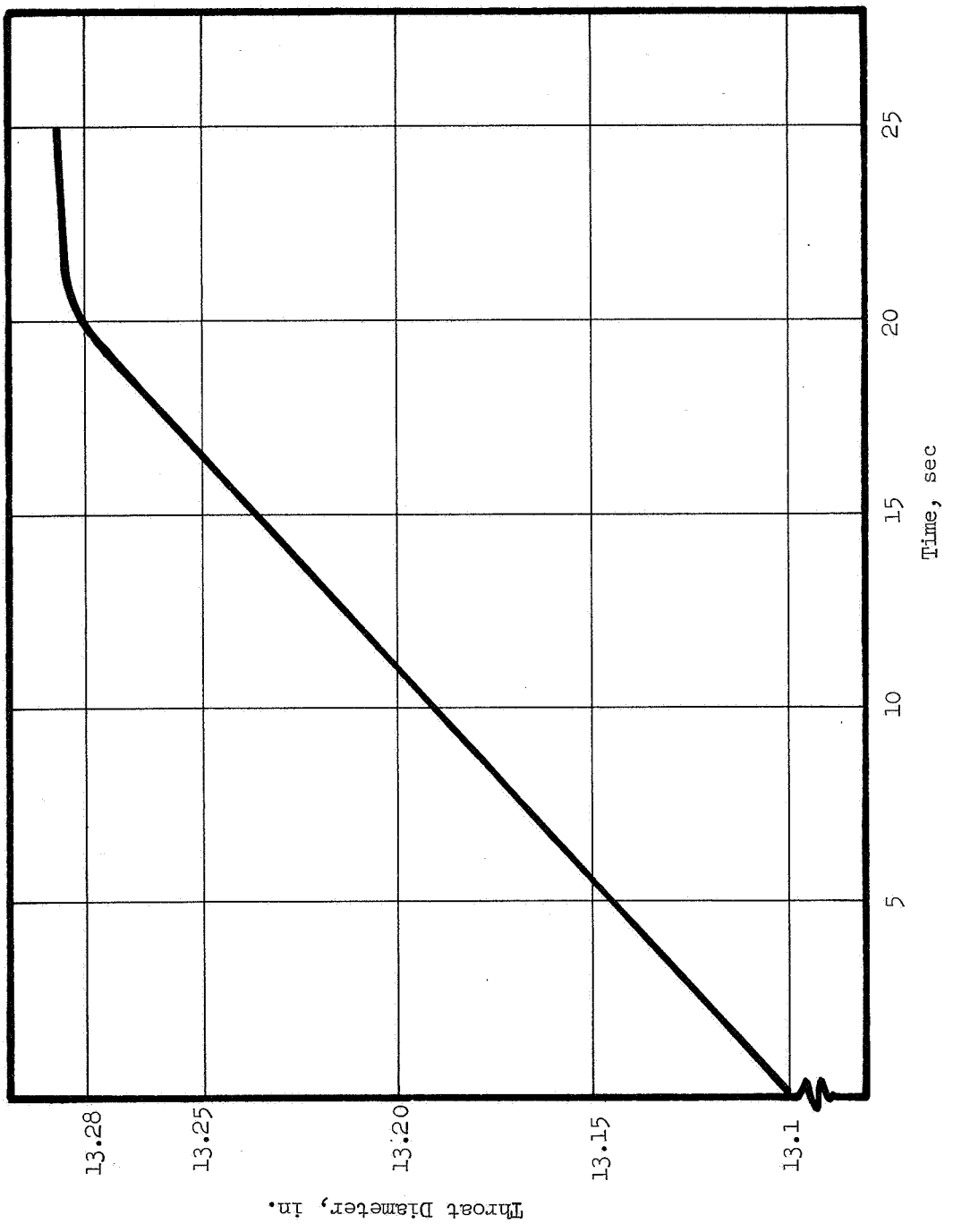
BURNOUT DIMENSIONS

Area* Ratio	Material	Ablation** Depth, in.	Char** Depth, in.	100°F ** Depth, in.
-4.0	MX 2625	.099	.21	.34
-2.4	MX 2625	.16	.27	.37
-1.65	MX 4926	.061	.28	.47
1.0	MX 4926	.094	.29	.47
+1.5	MX 4926	.052	.28	.47
+2.45	MX 4926	.025	.27	.46

* Area Ratios Refer to Original Plastic Contour
**Depth Below Original Contour

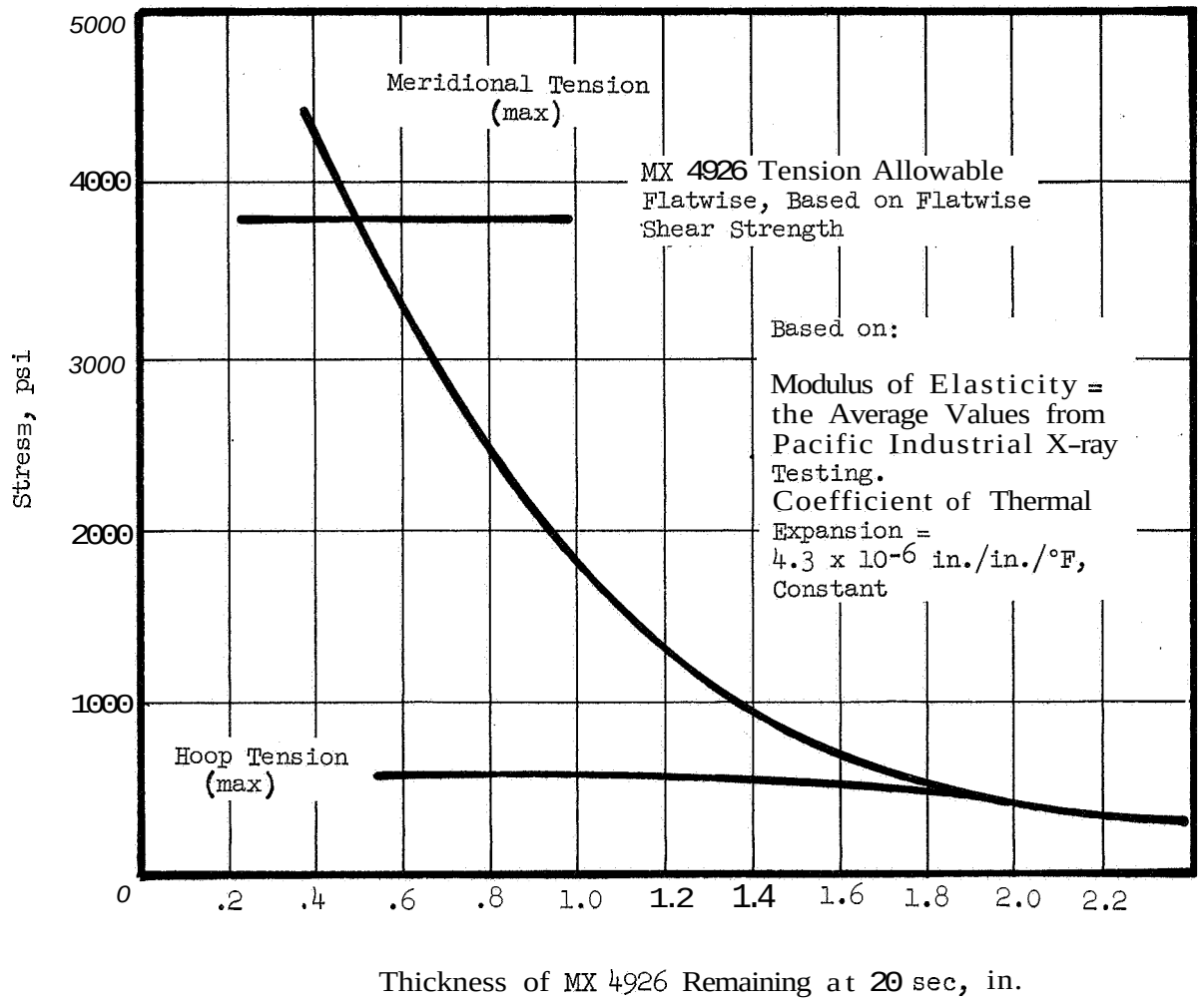
Summary of Predicted Ablation, Char, and 100°F Isotherm, 44-SS Motor Nozzle

Figure 82



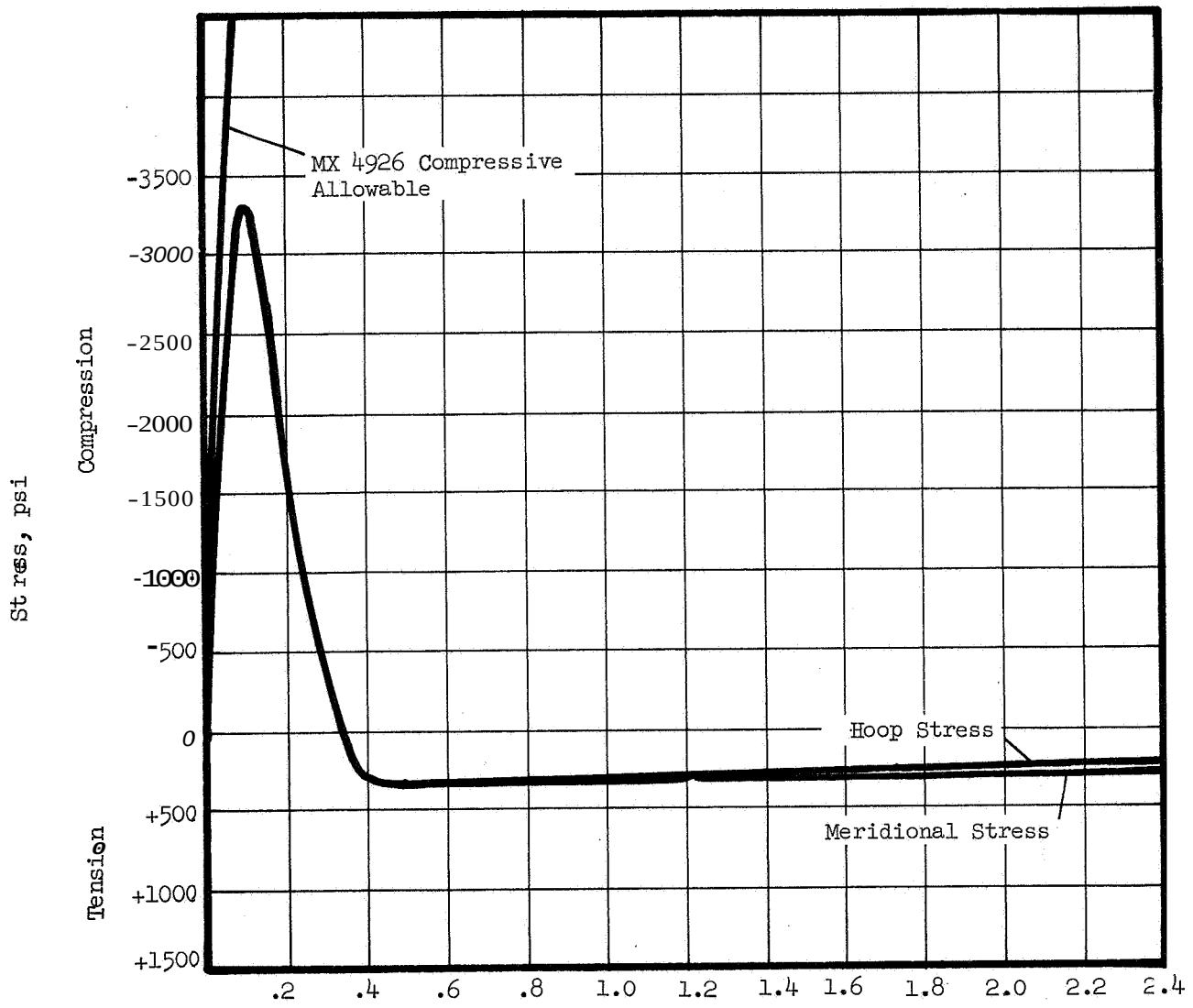
Throat Diameter vs Time for the 44-in. Motor

Figure 83



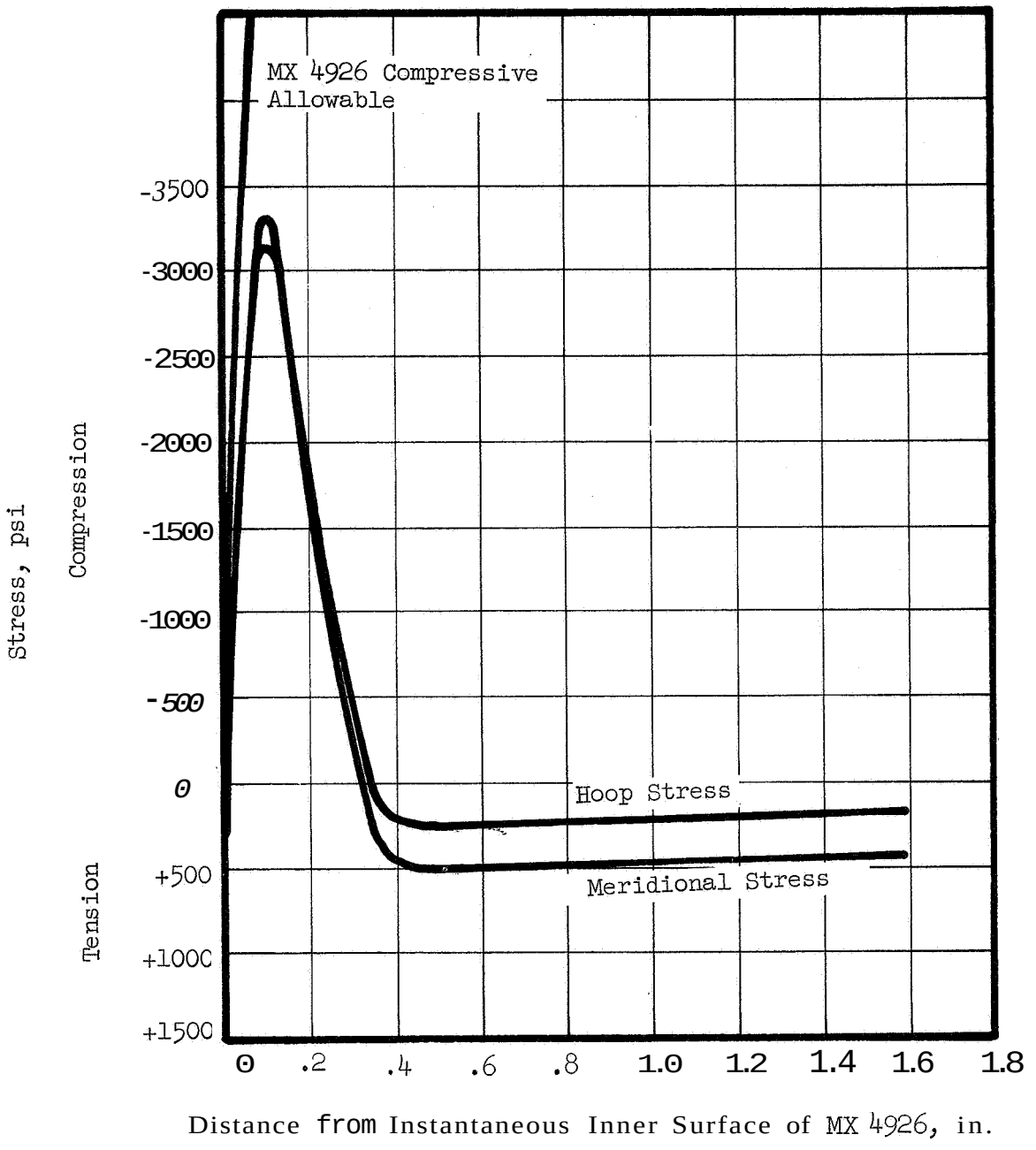
Hoop and Meridional Stresses vs MX 4926 Throat Thickness Remaining at 20 sec Firing Duration, 44-SS Motor

Figure 84



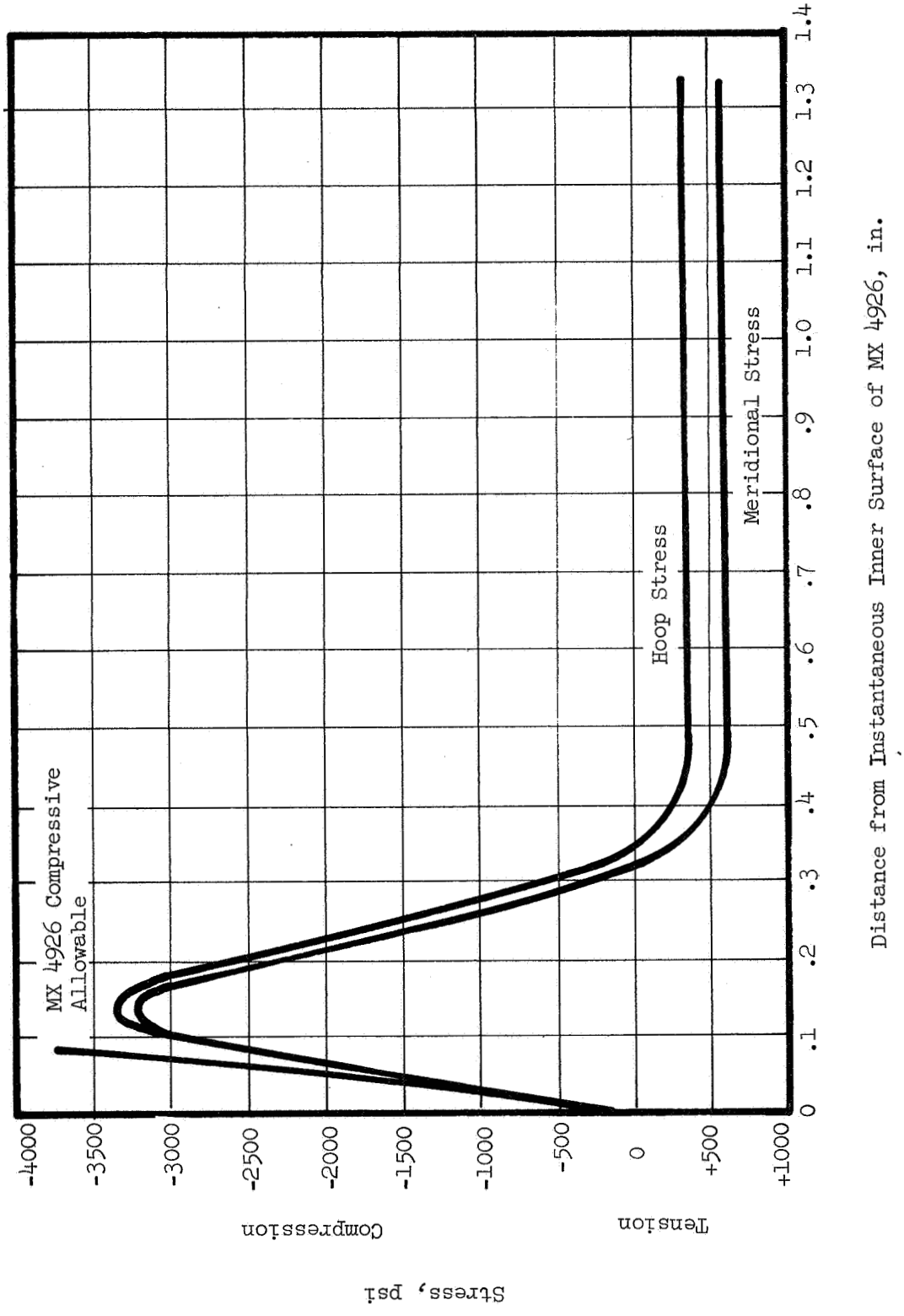
Throat Insert Thermal Stresses at 20 sec Firing Duration, 44-SS Motor Nozzle

Figure 85



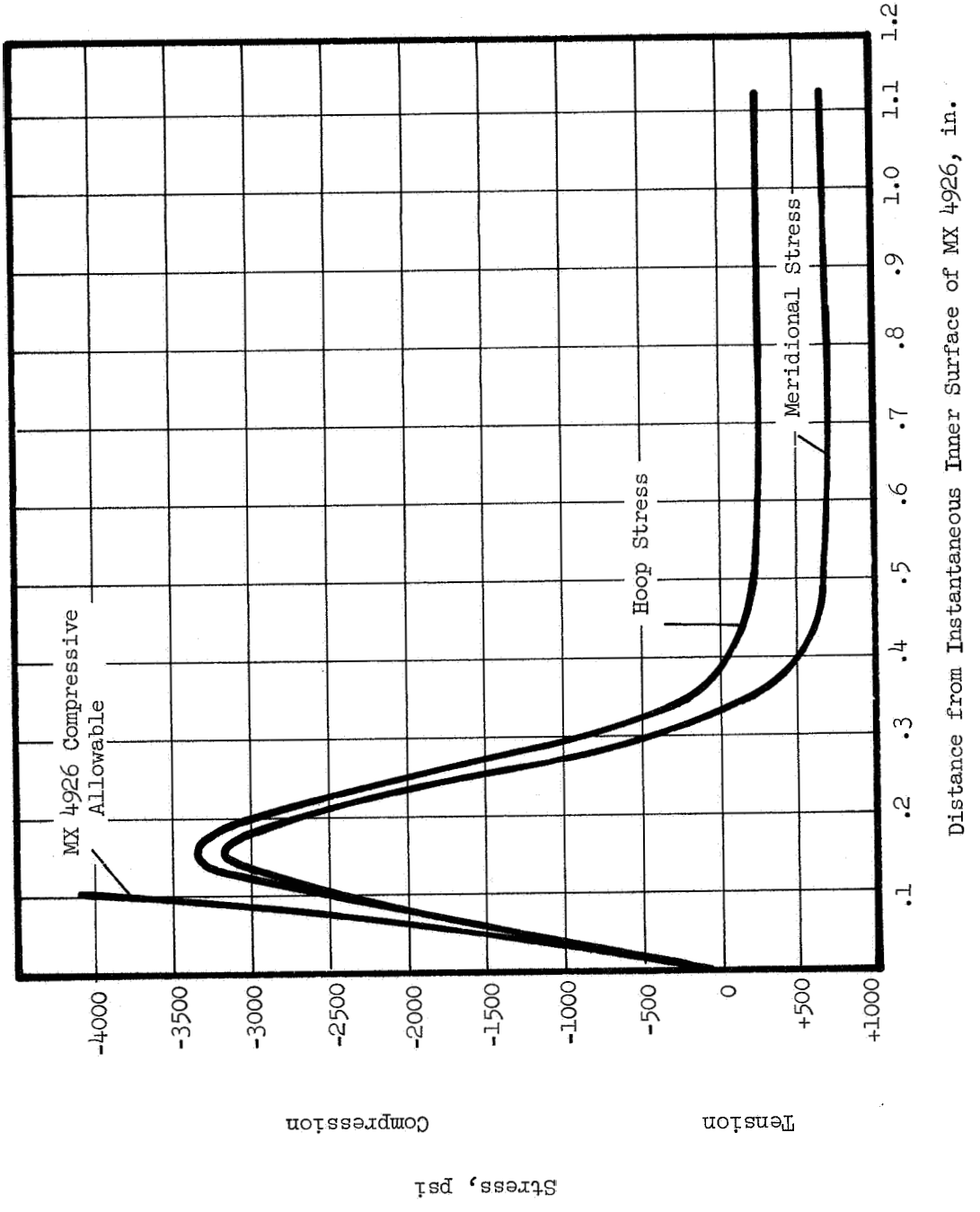
Thermal Stresses at Aft End of Throat Insert at 20 sec Firing Duration, 44-SS Motor Nozzle

Figure 86



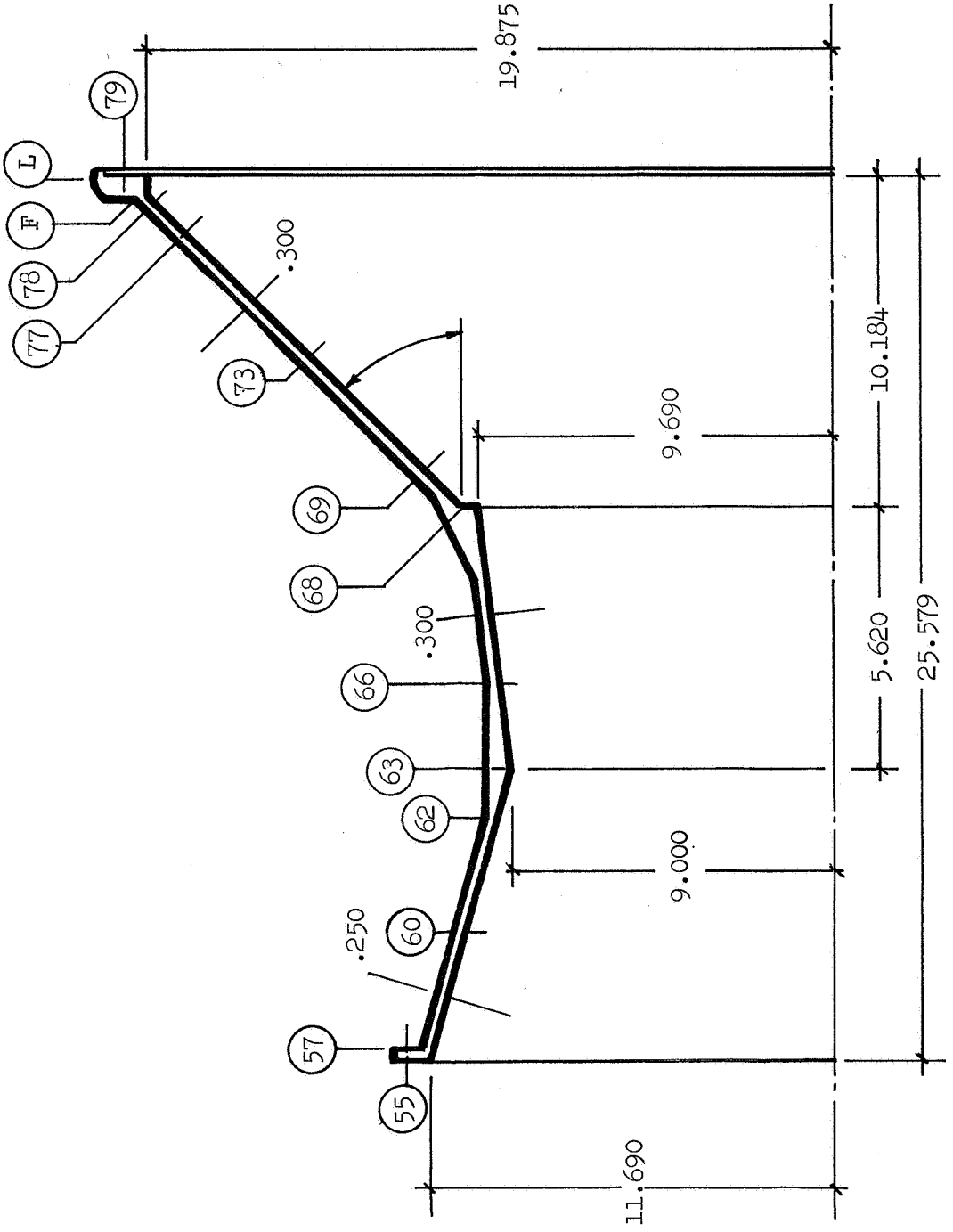
Exit Cone Liner Stress Profile at Area Ratio = 1.5:1 at 20 sec Duration,
44-SS Motor Nozzle

Figure 87



Exit Cone Liner Stress Profile at Area Ratio = 2.45:1 at 20 sec Duration, 44-SS Motor Nozzle

Figure 88



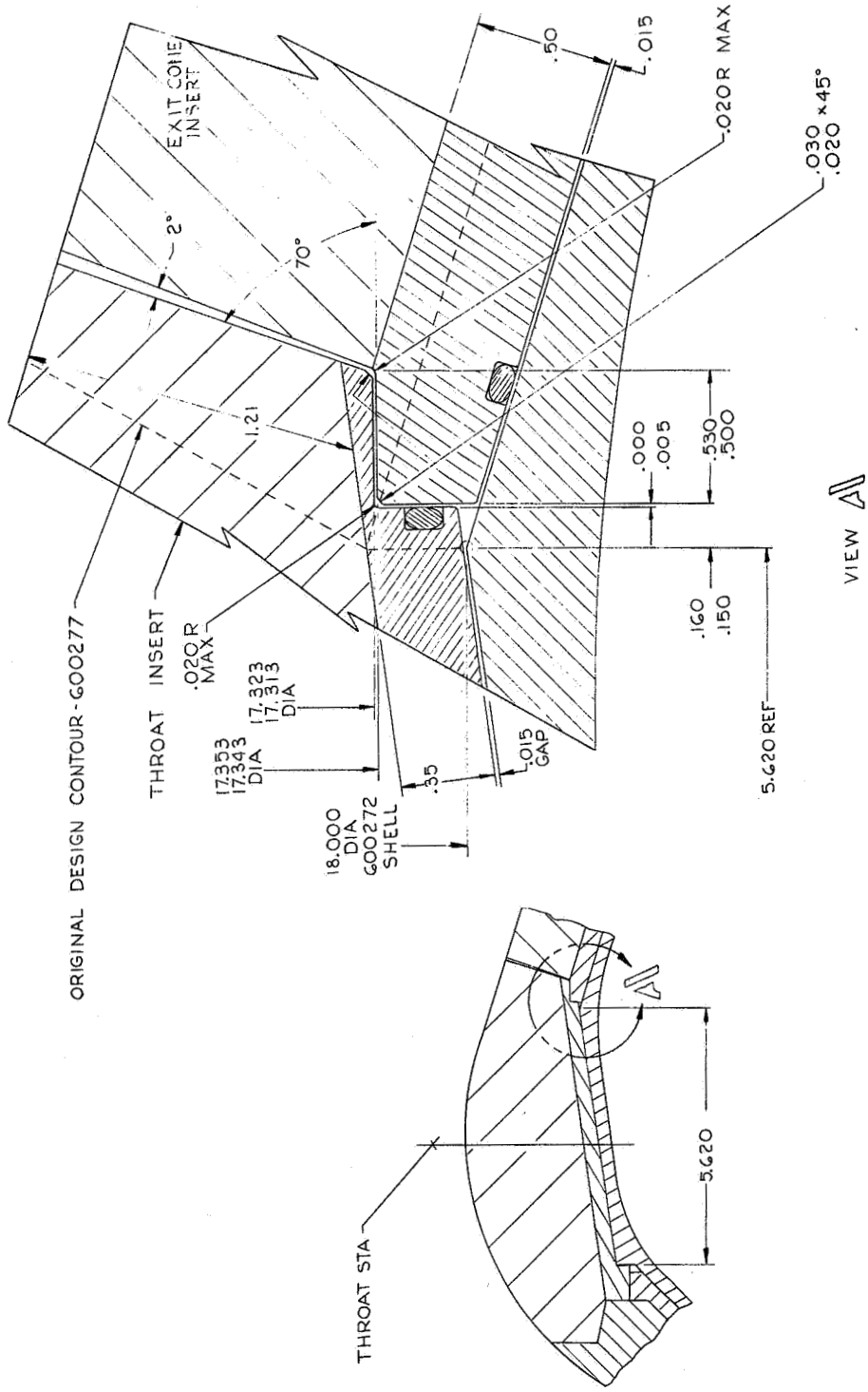
Locations of Stress Analysis of the 44-SS Nozzle Shell

Figure 89

Location	R, in.	t, in.	Stresses, psi Merid Outer	Merid Inner	Hoop Outer	Hoop Inner	Allowable	M.S.
57	11.65	.250	-78,711	115,391	-29,573	28,658	150,000	.300
60	10.41	.250	19,279	16,180	37,514	36,585		2.999
62	9.54	.250	17,887	13,946	36,067	34,884		3.159
63	9.22	.450	16,277	395	36,495	31,731		3.110
66	9.60	.400	- 1,376	21,038	19,599	26,324		4.698
68	10.45	.600	1,766	16,129	30,127	34,435		3,356
69	11.52	.300	35,335	8,090	50,757	42,584		1.955
73	15.34	.300	29,867	29,717	62,310	62,265		1.407
77	19.34	.300	60,476	12,214	45,088	30,610		1.480
78	19.59	,300	51,561	21,066	35,819	26,669		1.909
F	19.77	.410	29,594	22,459	24,183	22,024		4.069
			EXIT CONE FLANGE					
55	.57		Maximum Stress Net Section Between Holes, f_t		71,545 psi		150,000	1.096
			Retainer Ring Bolts Pretension Load Hydrostatic Test Condition, Q_{PT}		22,334 lbf		37,224	,667
			NOZZLE SHELL - CHAMBER ATTACHMENT JOINT					
79	.640		Maximum Stress Net Section Between Holes, f_t		95,730 psi		150,000	.567
L	.25		Shear Lip - Shear Stress, F_s		25,928 psi		-	High
			Bending Stress, f_b		93,340 psi		150,000	.607
			Chamber-Nozzle Bolts (Dwg. No. 1-330015) Pretension Load, Q_{PT}		10,967 lb		18,278	.667

Structural Analysis Summary, Nozzle Shell, 44-in.-dia Motor

Figure 90



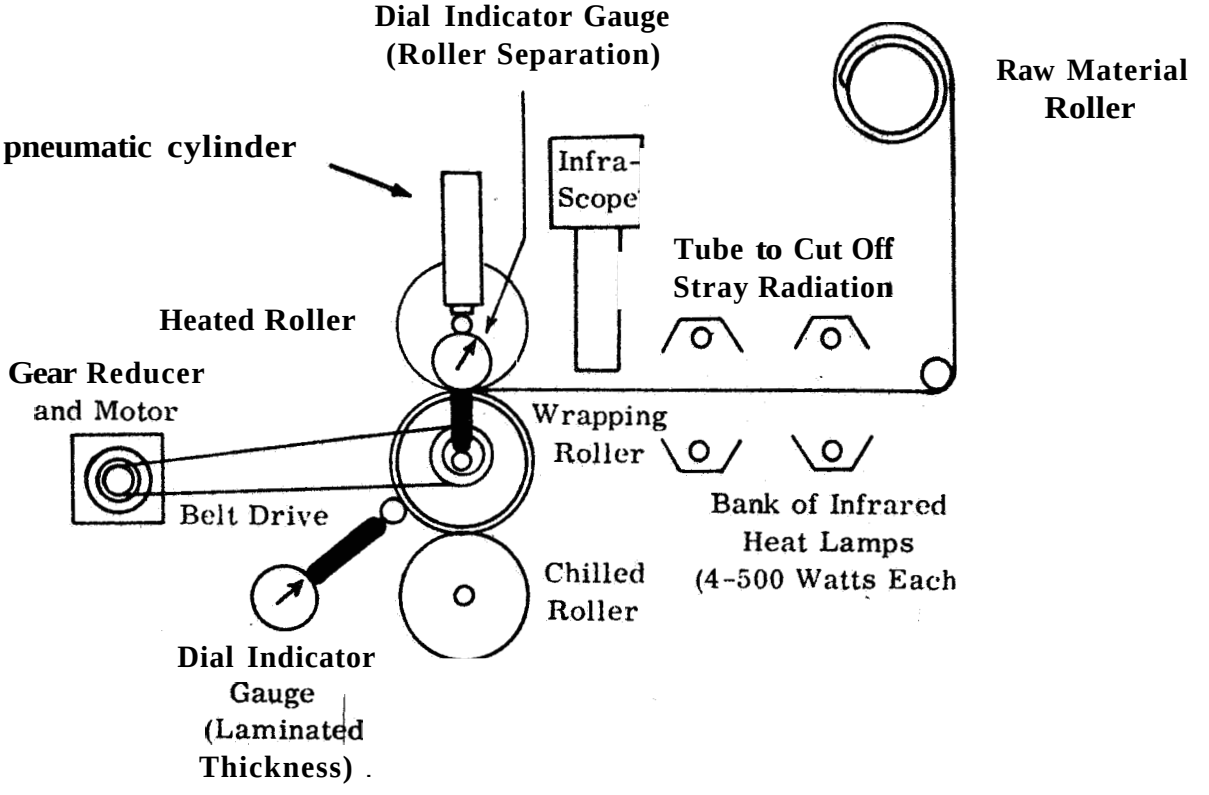
44-SS-1 Nozzle Throat to Exit Cone Insert Interface

Figure 91

Material	Volatile Content, %	Resin Solids, %	Laminate Flow
MX-4926	4 to 7	31 to 37	2 to 7
FM-5131	3 to 6	28 to 34	6 to 15
MX-2646	2 to 5	18 to 23	0 to 3

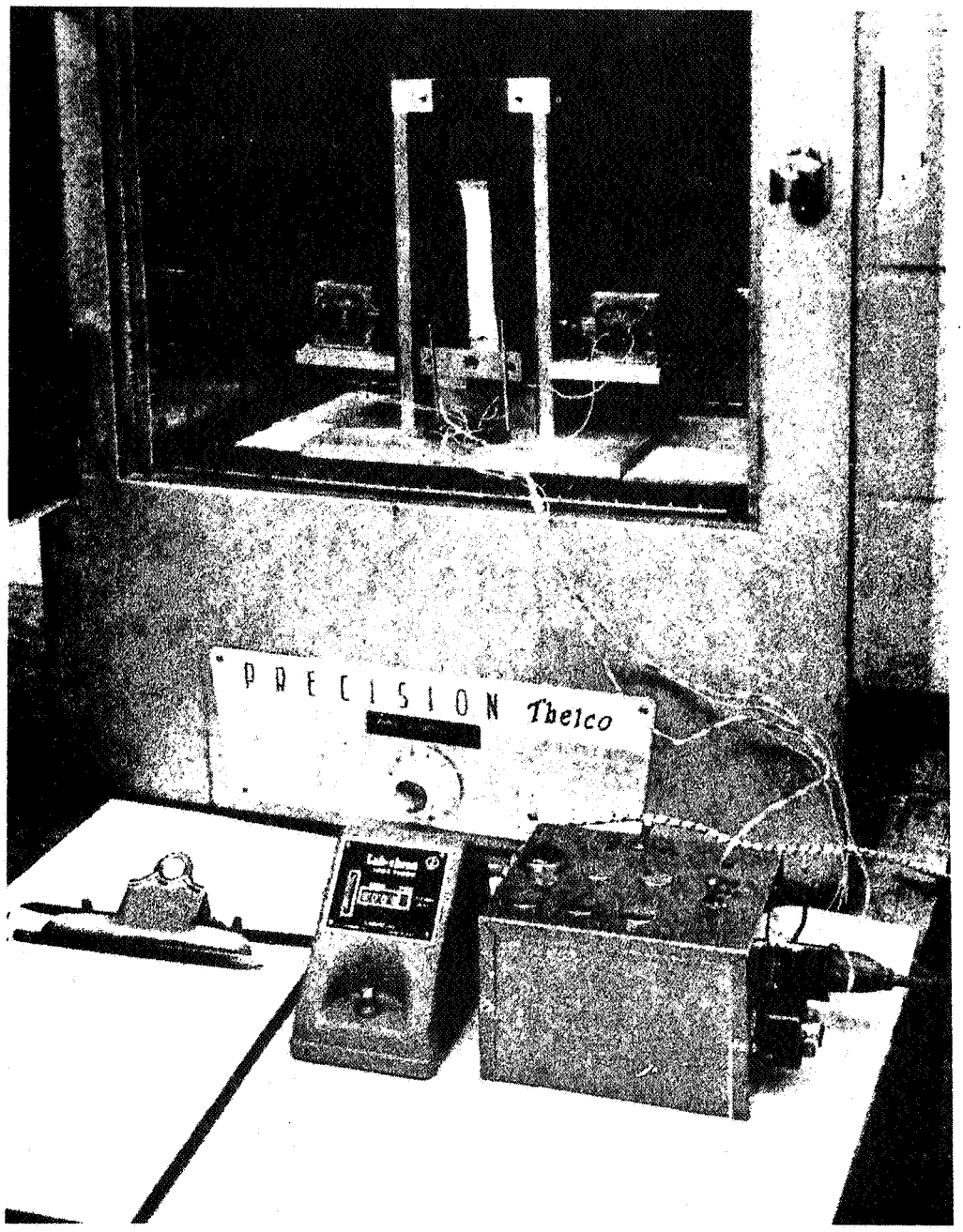
Raw Material Specifications

Figure 92



Schematic of Three Roll Tape Wrapping Stand

Figure 93



Formability Test Equipment

Figure 94

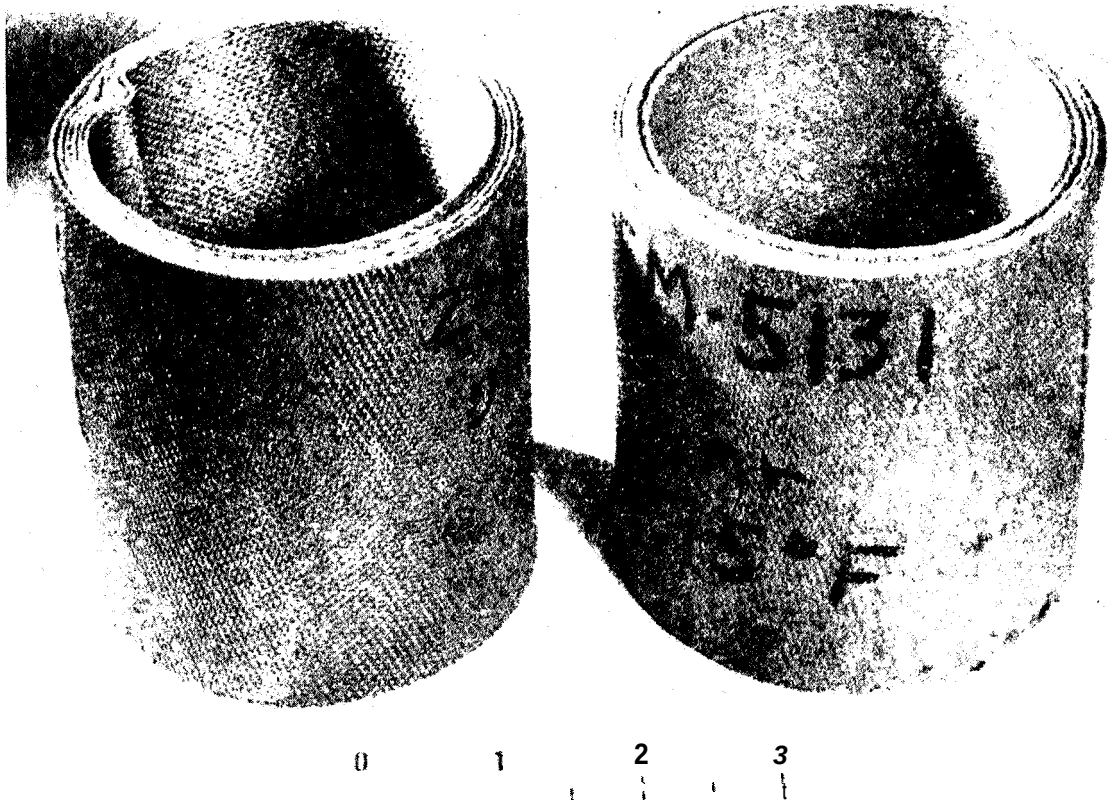
Material Purchased with 1.30 to 1.50 IRPI Index Values

Material	Volatile Content, %	Resin Solids, %	IRPI Index	300°F Gel Time, sec	Viscosity Index	Chang Index	Laminate Flow, %
FM-5131 Lot G-2816-28	4.18	31.6	1.50 (1)	92	---	15.9	9.7
MX-2646 Lot S-829-2A	2.85	21.3	---	---	---	36.0	(2)
MX-4926 Lot S-527	4.3	35.2	---	102	---	28.8	5.8
Material Purchased to 1.0 Max. IRPI Index Values							
MX-2646 Lot A-108	3.10	20.15	---	---	2.5	---	0.0
FM-5131 Lot G-3161	4.31	32.30	0.818 (1)	---	2.7	---	11.4
MX-4926 Lot S-883	6.79	35.41	0.817 (1)	---	---	30.1	14.1
MX-4926 Lot A-226	5.66	30.35	0.99 (3)	---	2.5	---	13.1

(1) Fiberite IRPI Method 1-2
(2) MX-2646 does not respond to the flow test.
(3) Fiberite IRPI Method 1-3

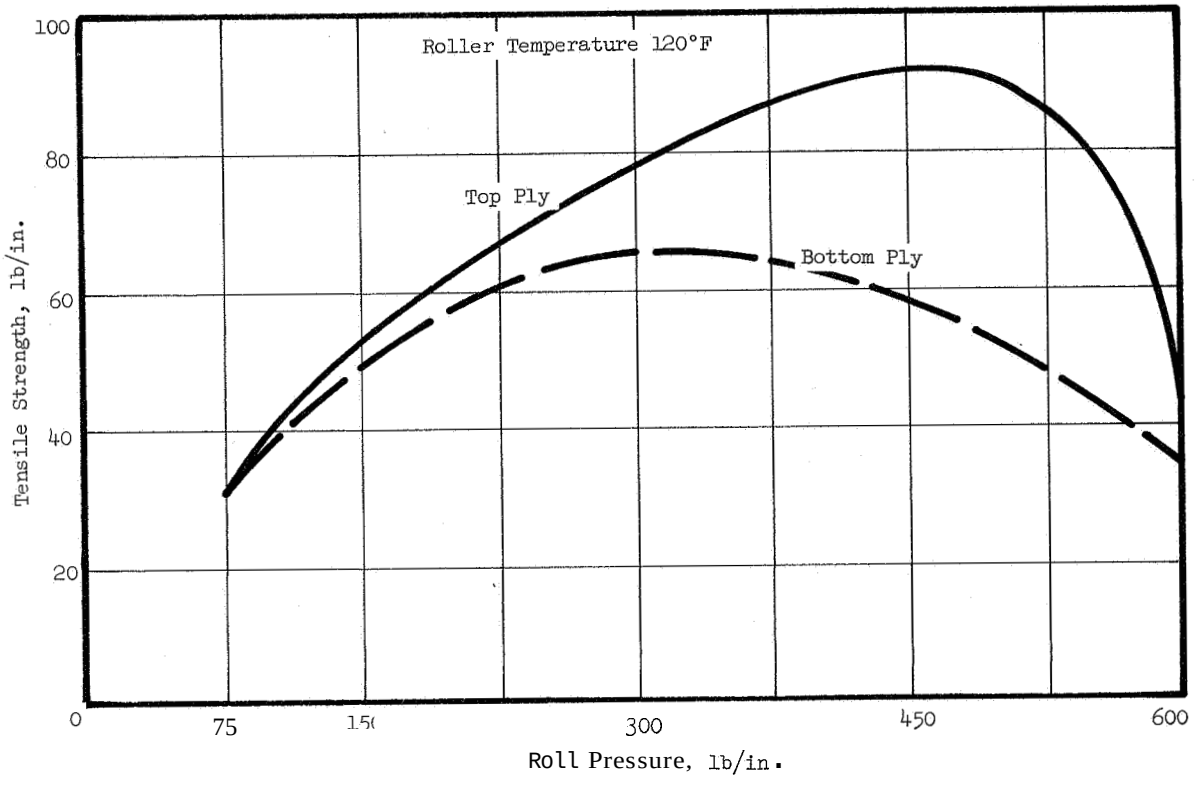
Raw Material Properties

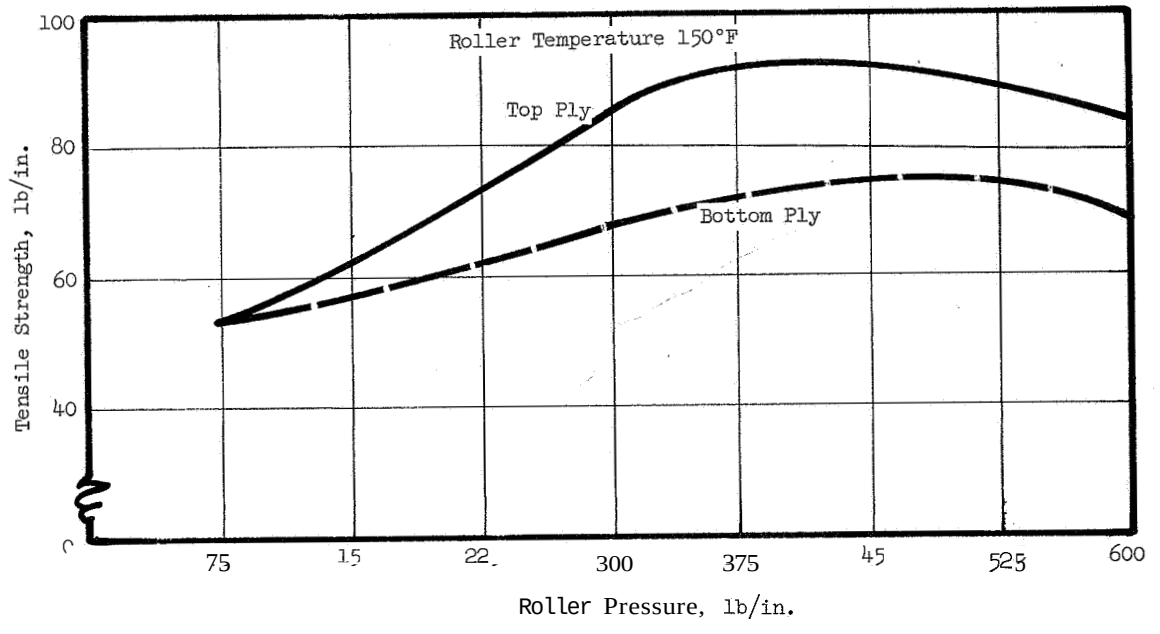
Figure 95



Cylindrical Specimen Wound on TRW Three Roll Tape Wrapping Test Stand

Figure 96





Tensile Strength of B-Staged MX-4926 vs Roller Pressure

Figure 97

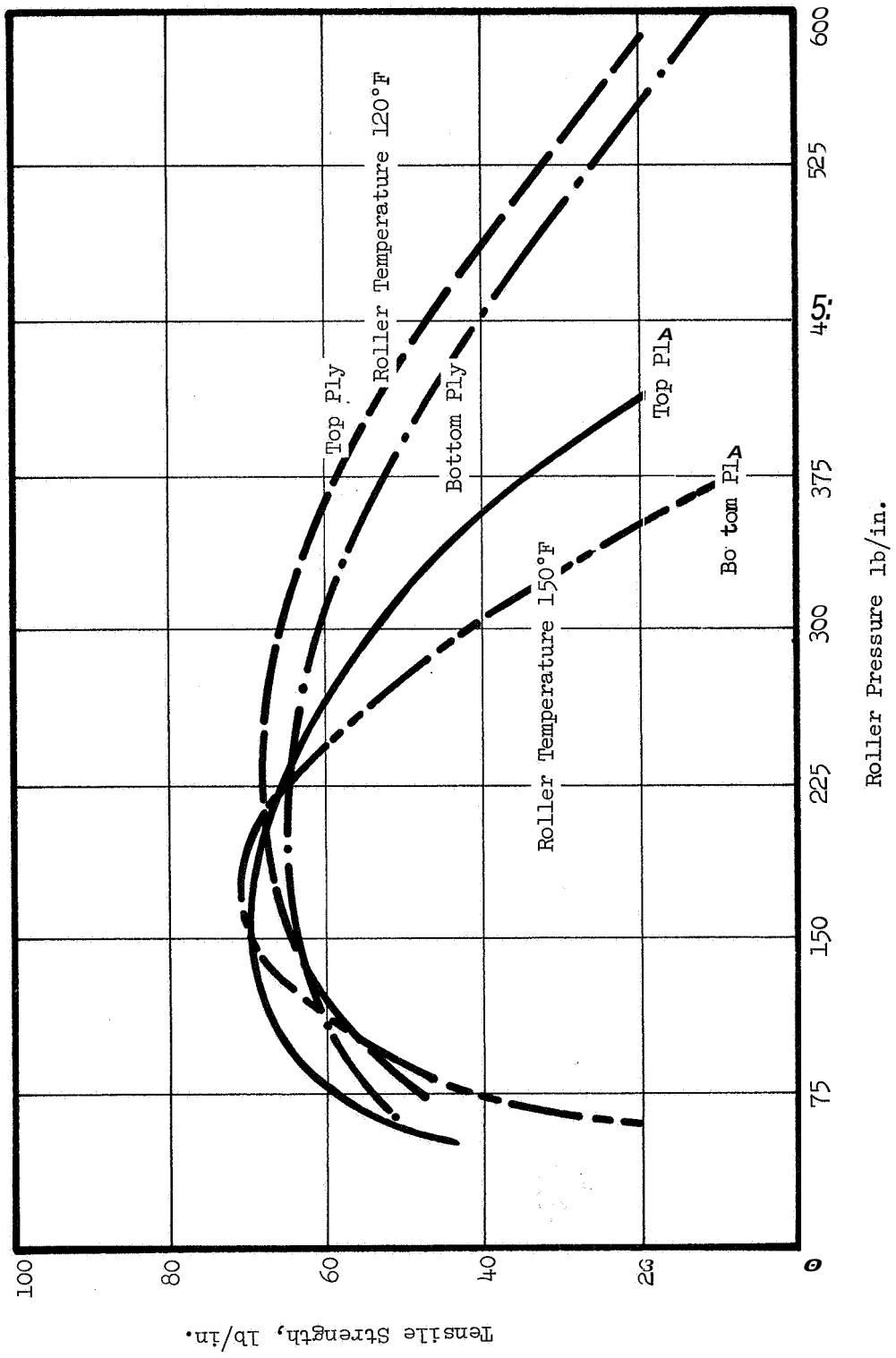
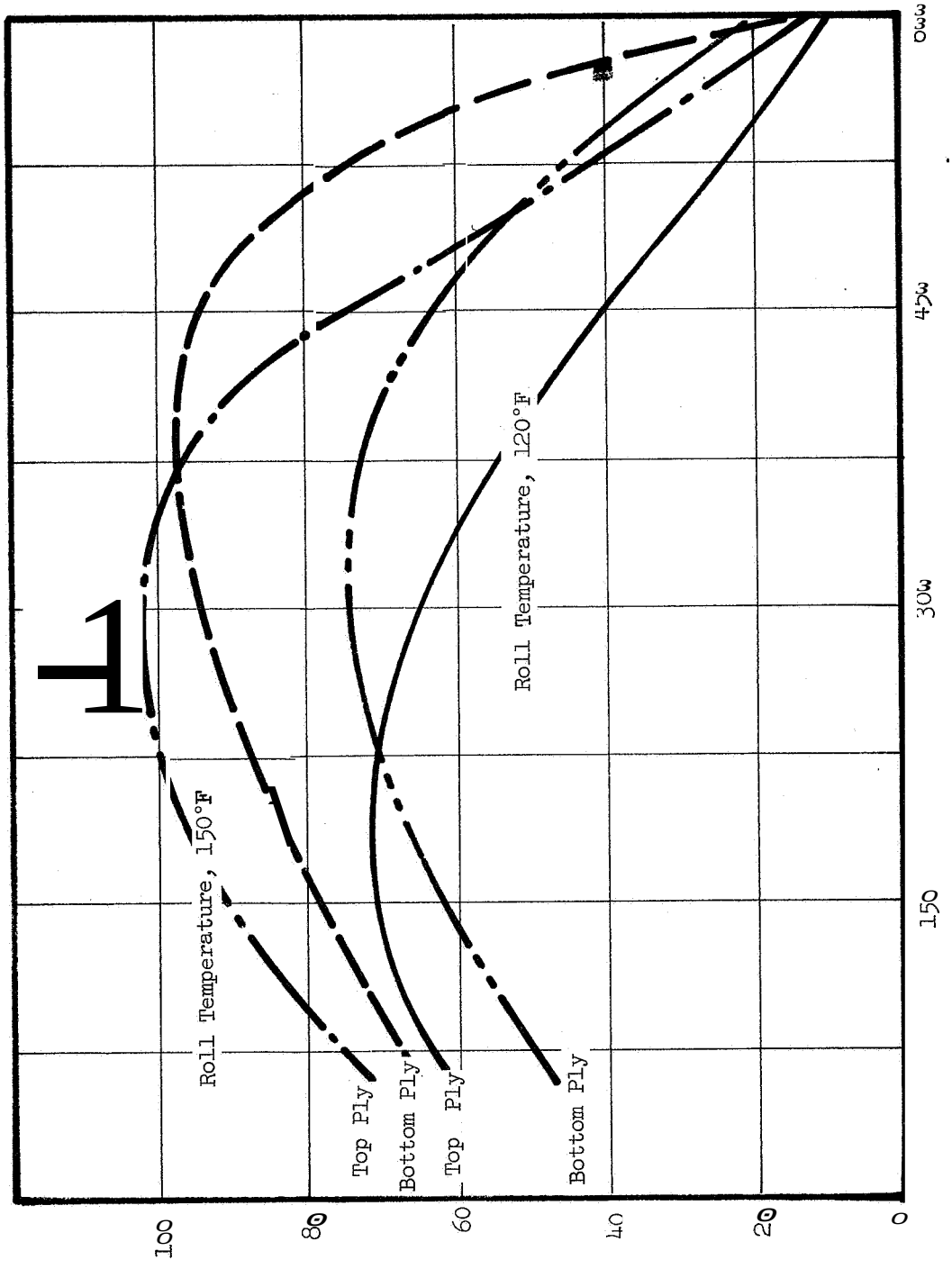


Figure 98

Tensile Strength of B-Staged FM-5131 vs Roller Pressure



Tensile Strength of B-Staged MX-2646 vs Roller Pressure

Figure 99

Material	Volatile Content, %	Resin Solids, %	Infrared Poly Index	Gel Time @ 300°F, sec	Viscosity Index	Chang Index
FM-5131 Lot G-2816-28	4.18	31.60	1.50	92	----	15.9
MX-2646 Lot S-829-2A	2.85	21.30	----	----	----	36.0
MX-4926 Lot S-527	4.3	35.2	----	102	----	28.8
MX-2646* Lot A-108	3.10	20.15	----	----	2.5	----
FM-5131* Lot G-3161	4.31	32.3	0.818	----	2.7	----
MX-4926* Lot S-883	6.79	35.41	8.817	----	----	30.1
MX-4926* Lot A-226	5.66	30.35	0.99	----	2.5	----

* Green Material (Special)

As-Received Material Properties

Figure 100

FM-5131

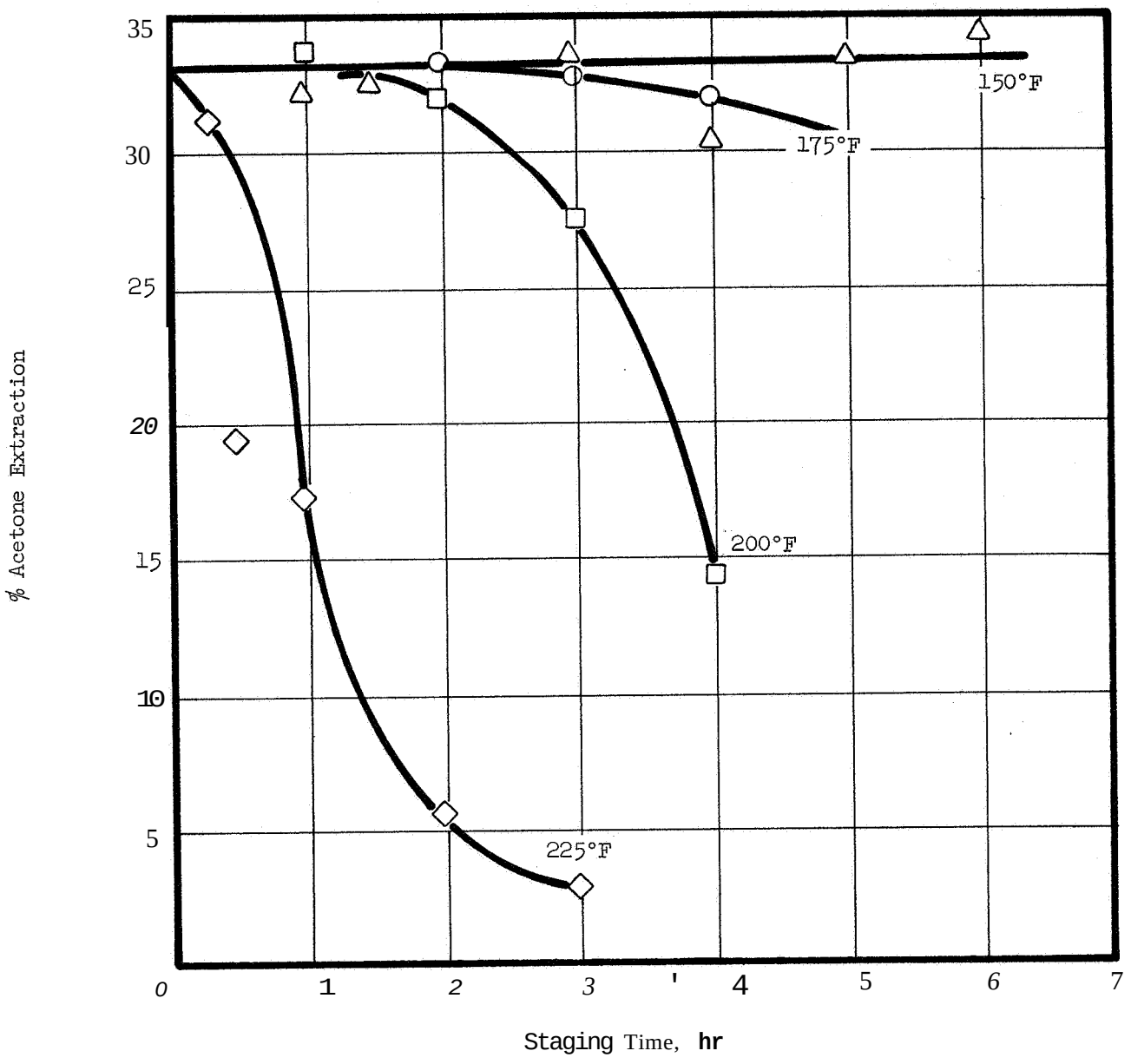
Temp. °F	Gel-Tim - Seconds Triplicate Results		
325	67	72	74
300	67	78	79
275	77	78	84
250	112	120	123
225	206	212	214
200	362	467	---

MX-4926

325	77	79	89
300	92	100	106
275	152	154	160
250	281	284	294
225	446	454	470

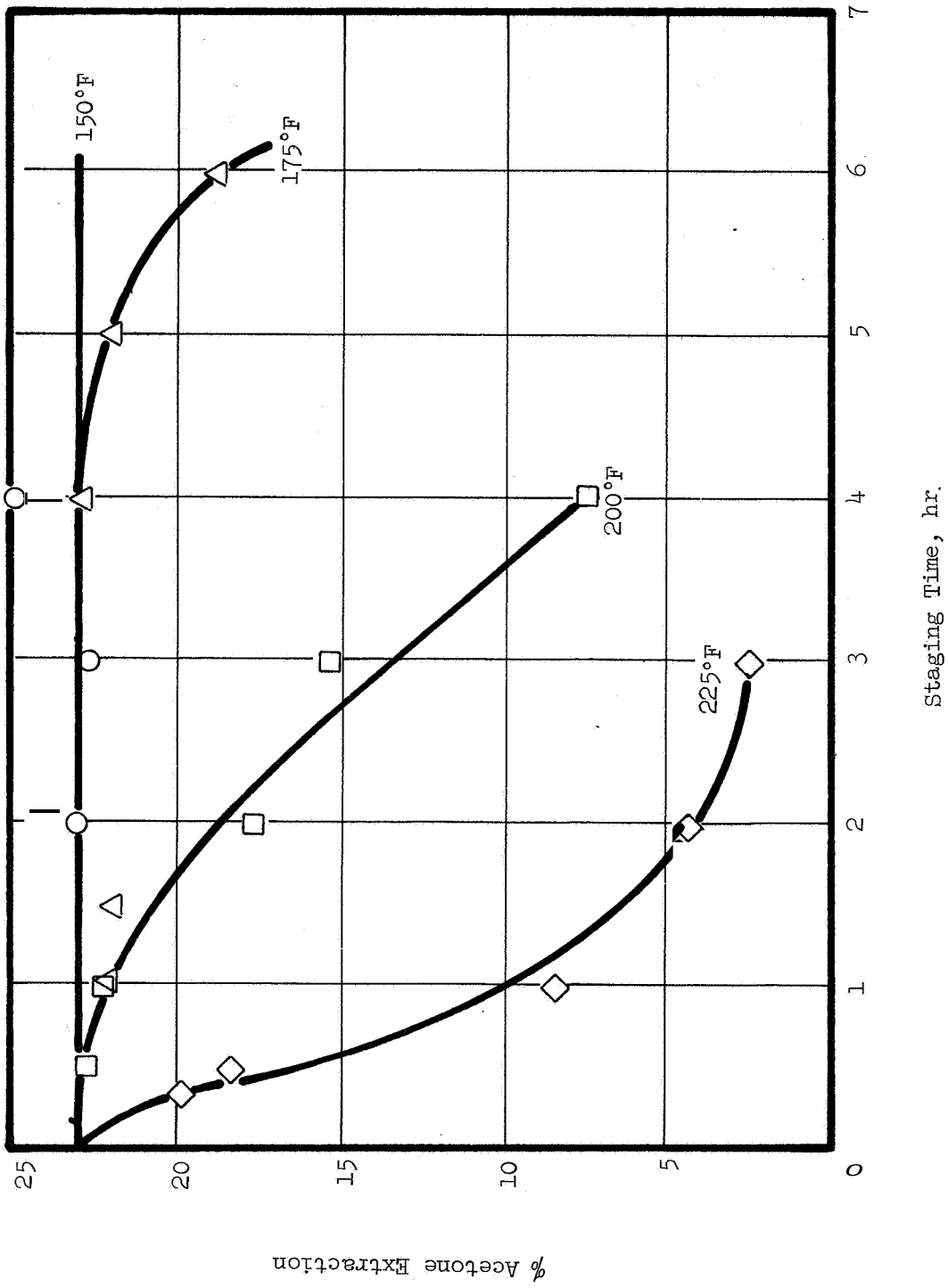
Gel Time vs Temperature for FM-5131 and MX-4926

Figure 101



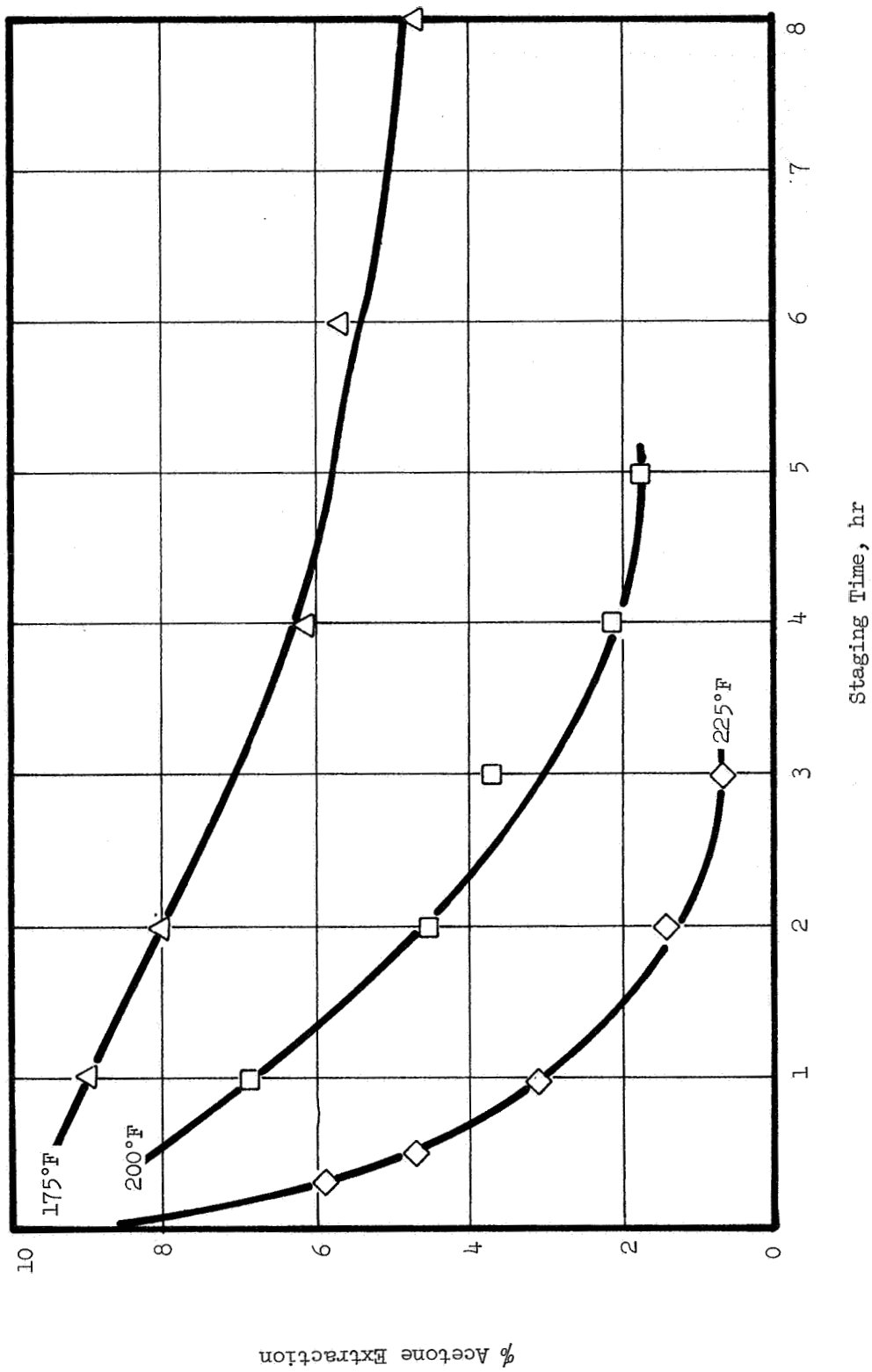
MX 4926 Acetone Extraction vs Staging Time and Temperature
as Received Resin Content - 35.2%

Figure 102



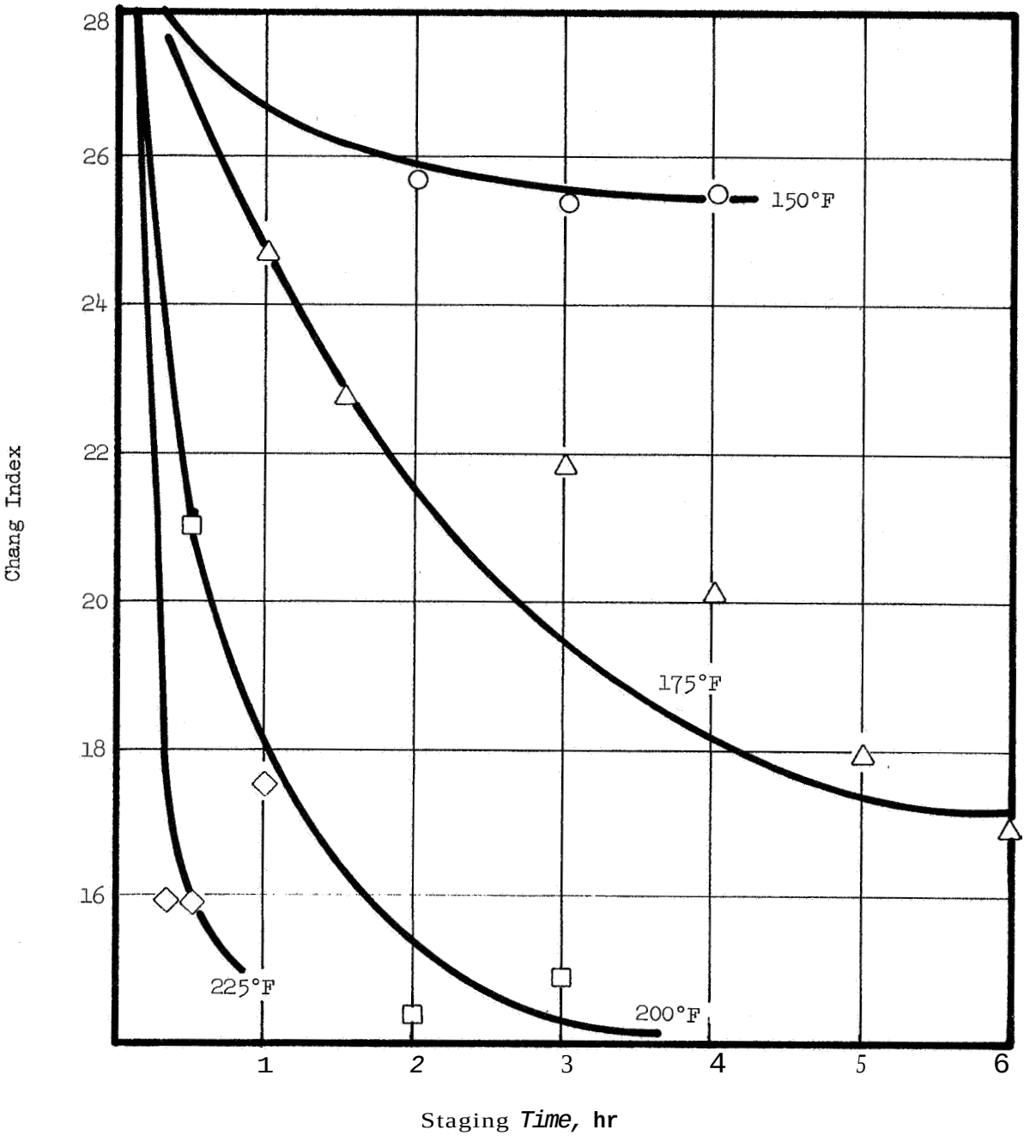
FM 5131 Acetone Extraction vs Staging Time and Temperature as Received Resin Content - 31.6%

Figure 103



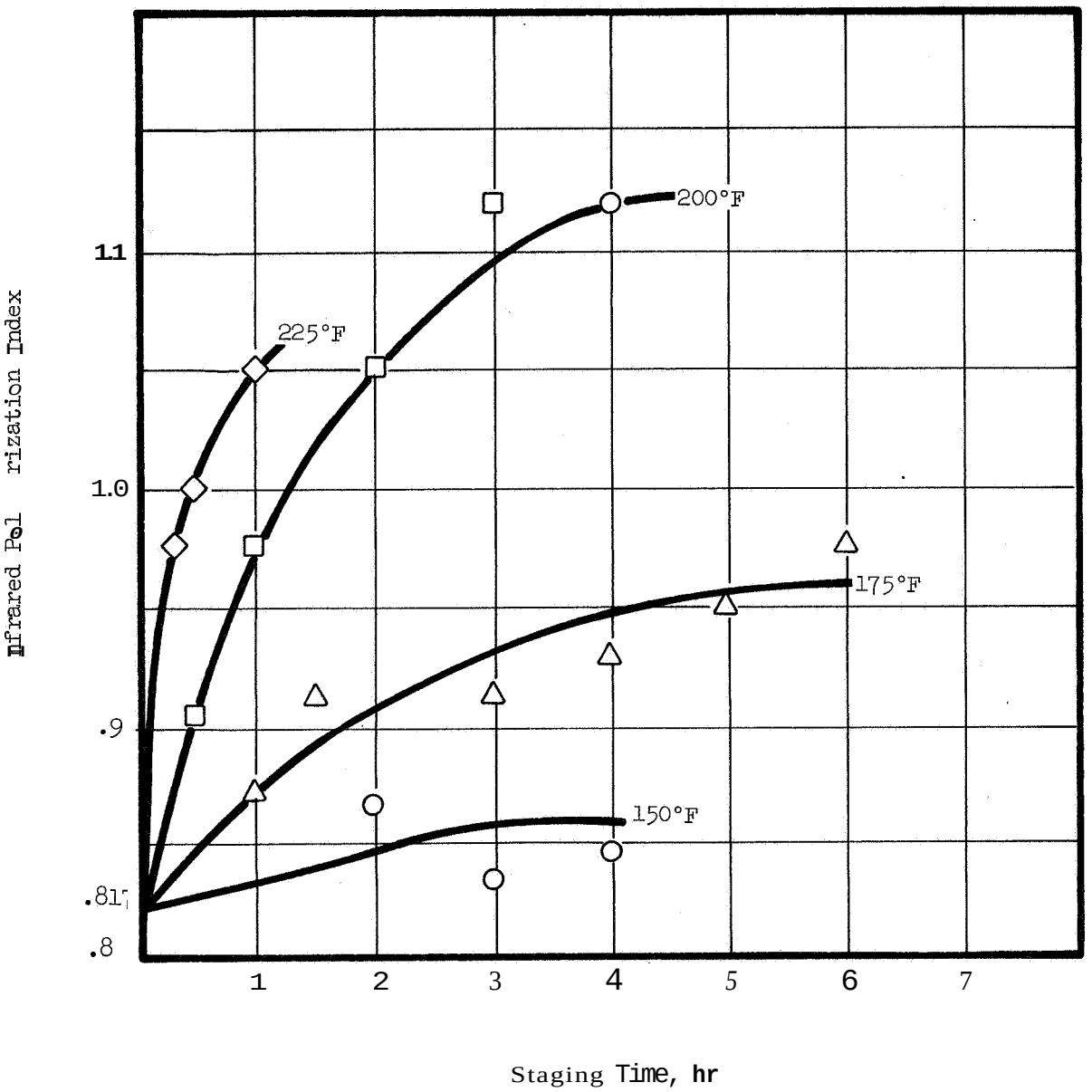
MX-2646 Acetone Extraction vs Staging Time and Temperature as Received Resin Content - 21.3%

Figure 104



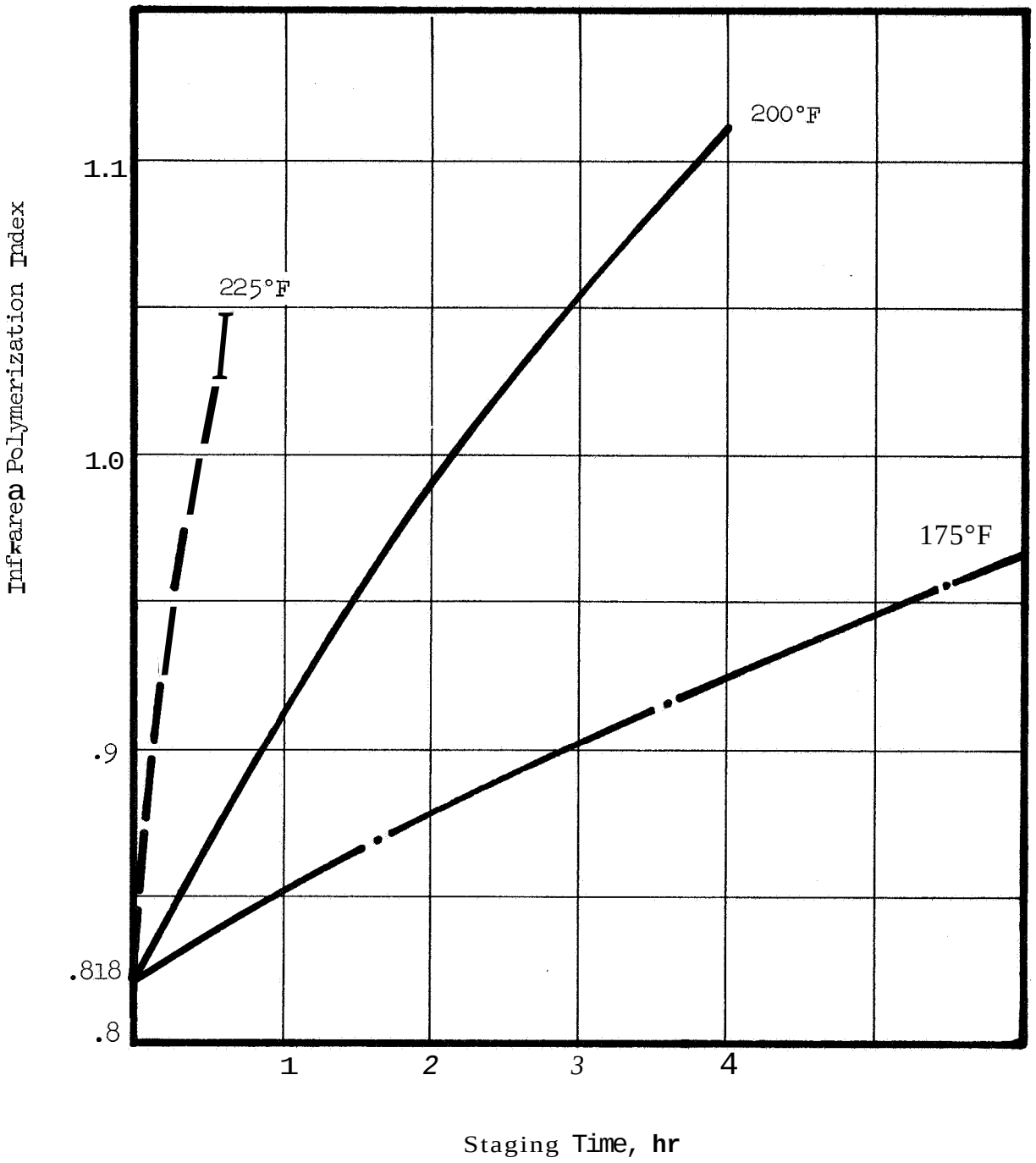
MX 4926 Chang Index vs Staging Time and Temperature

Figure 105



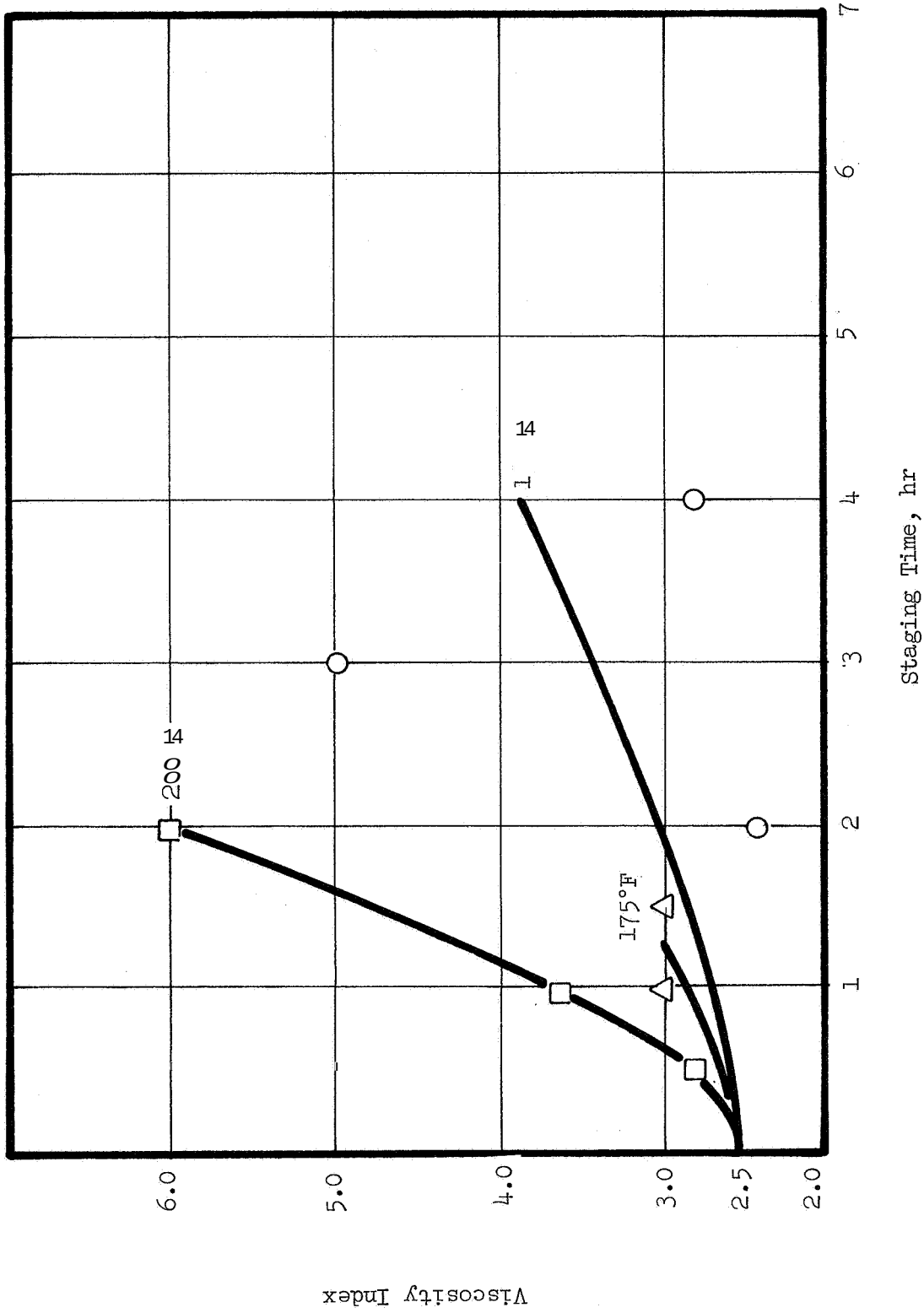
MX 4926 Infrared Polymerization Index vs Staging Time and Temperature

Figure 106



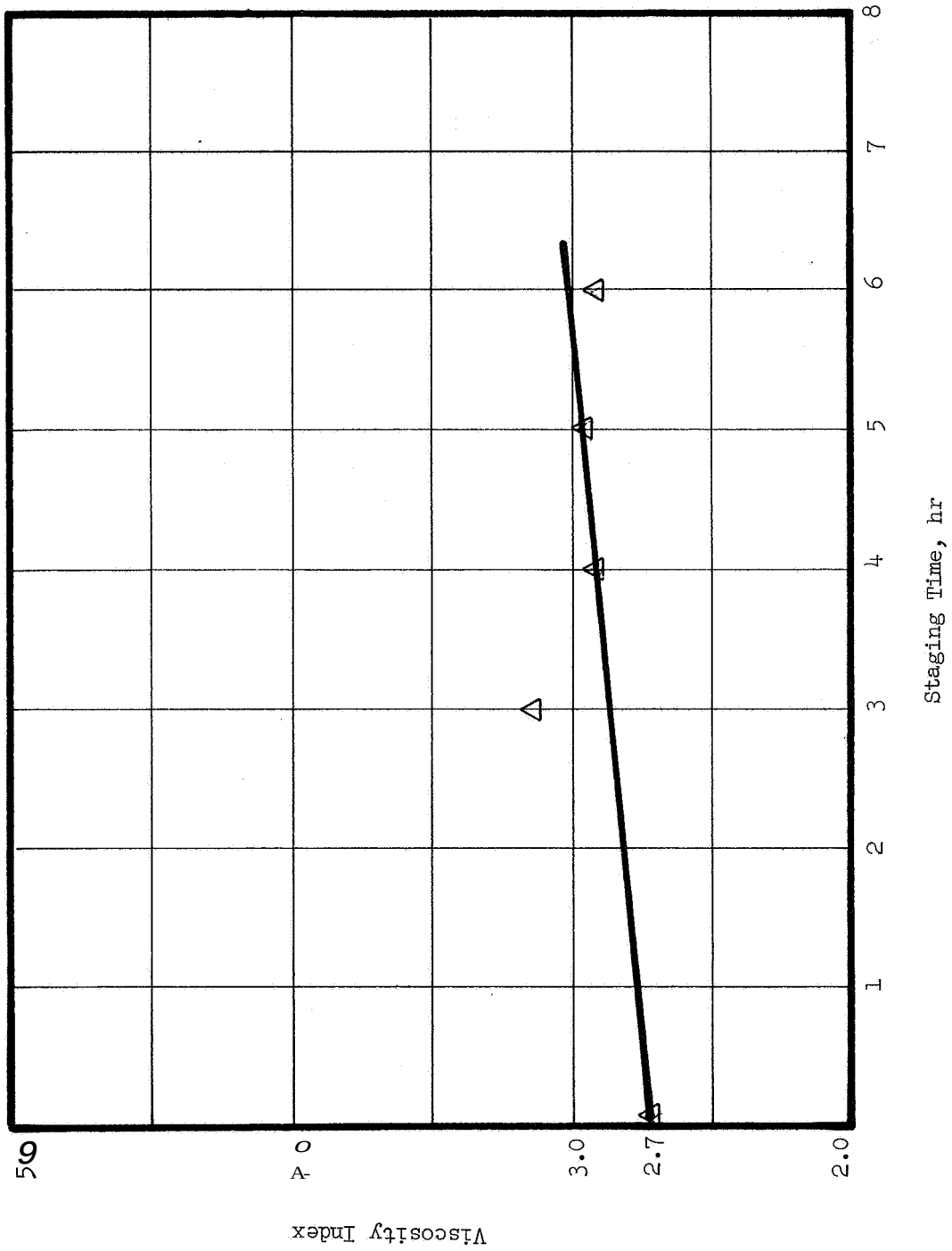
HM 5131 Infrared Polymerization Index vs Staging Time and Temperature

Figure 107



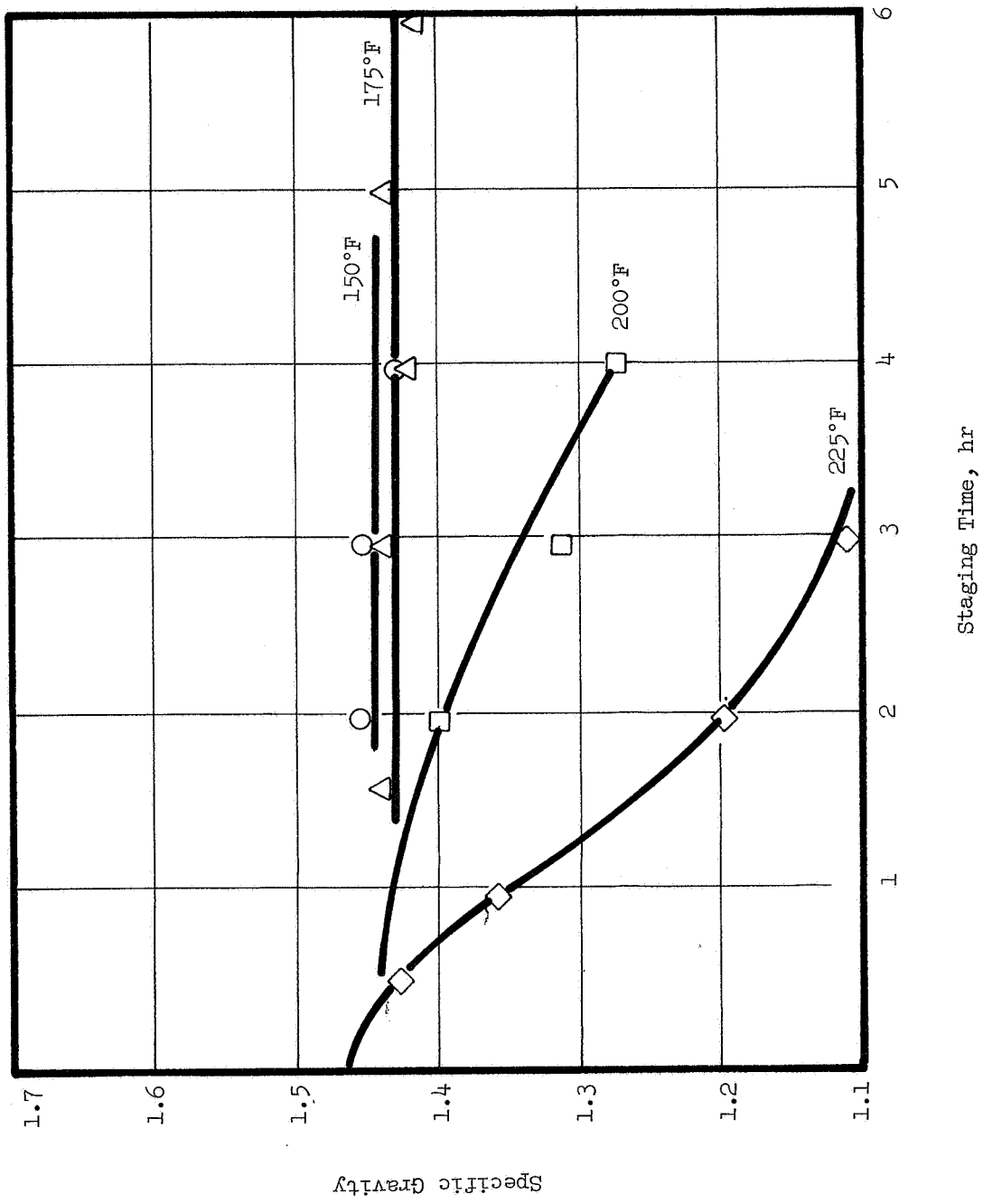
MX 4926 Viscosity Index vs Staging Time and Temperature

Figure 108



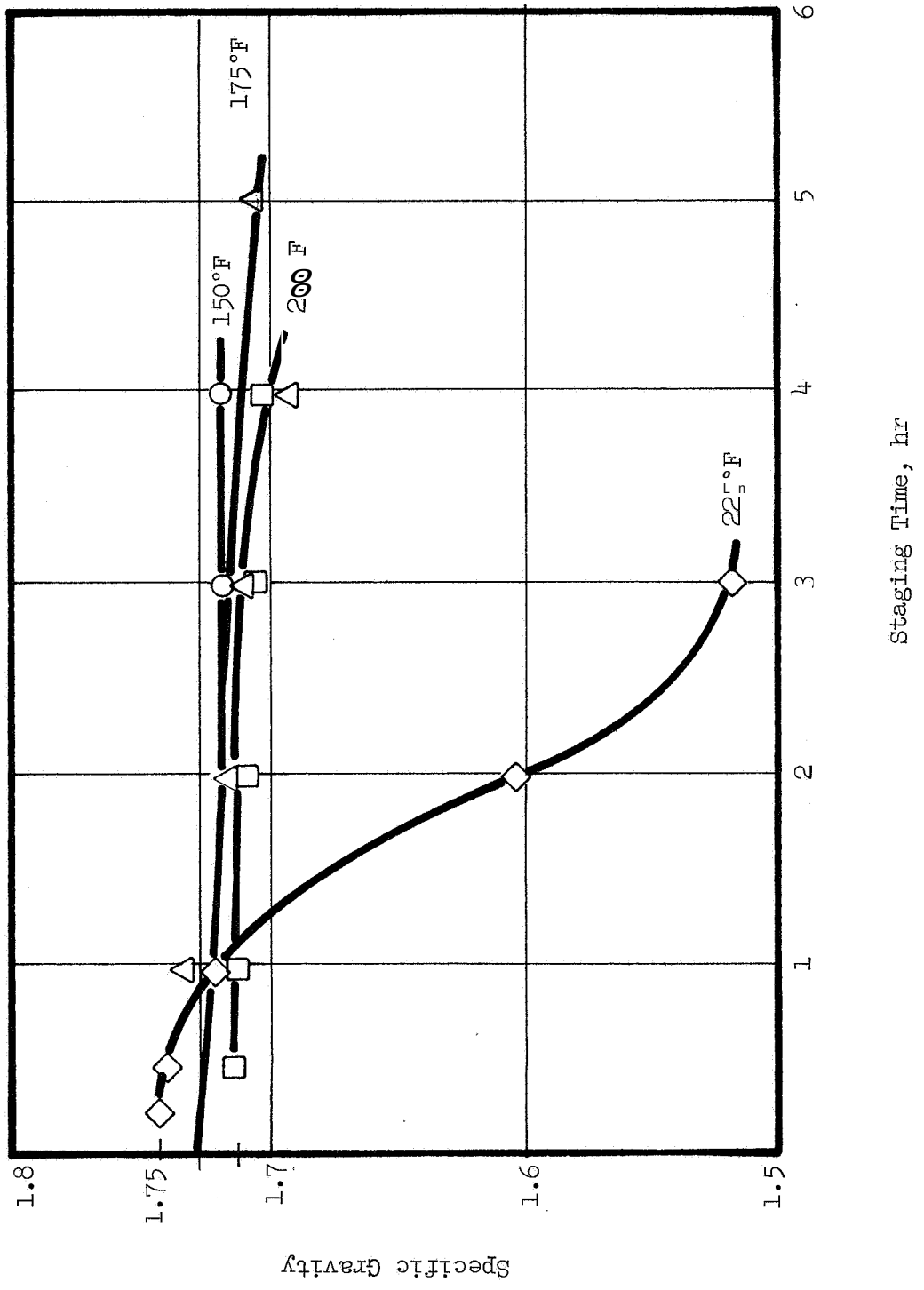
FM 5131 Viscosity Index vs Staging Time at 175°F

Figure 109



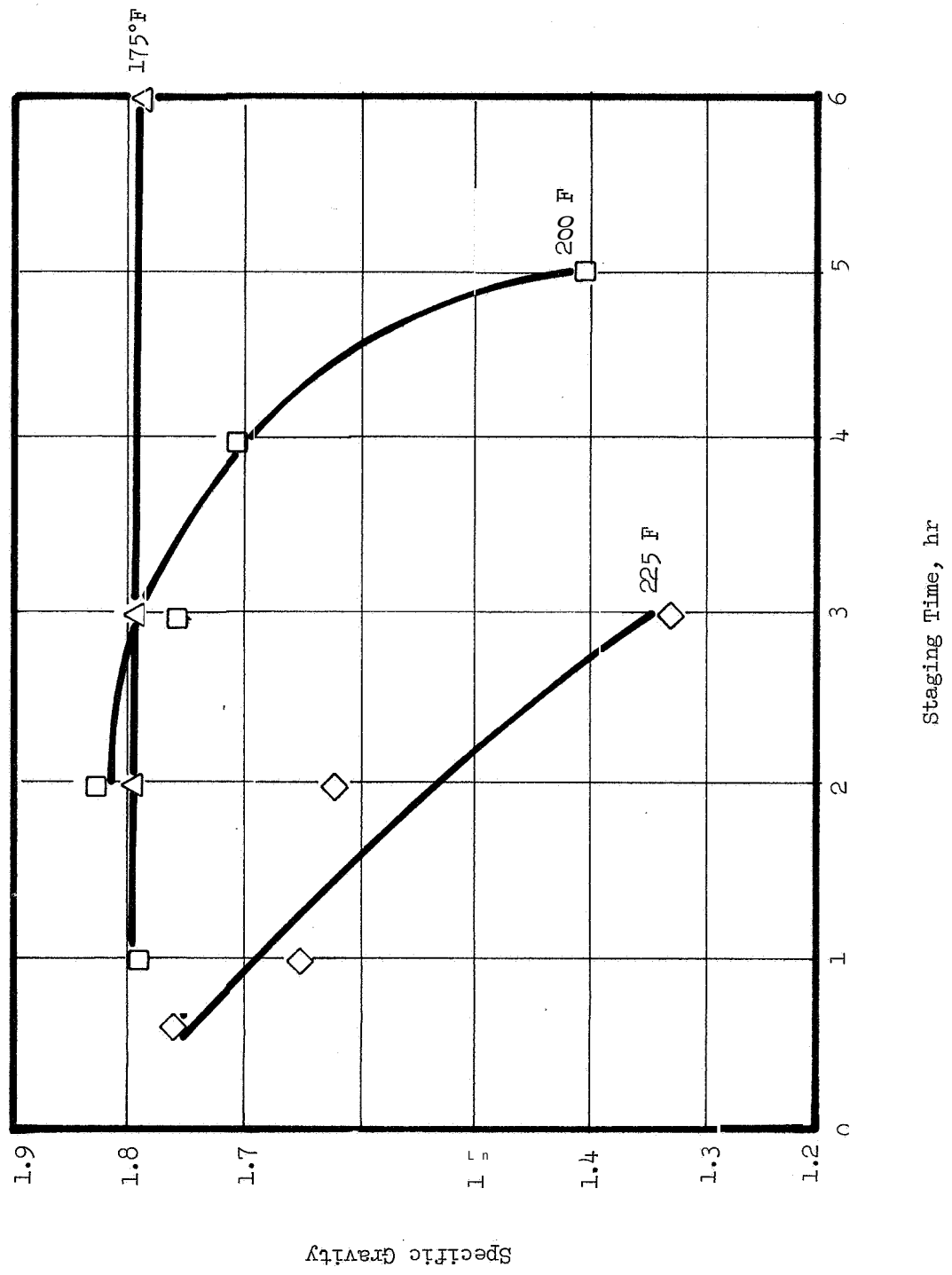
MX 4926 Specific Gravity vs Time and Temperature

Figure 110



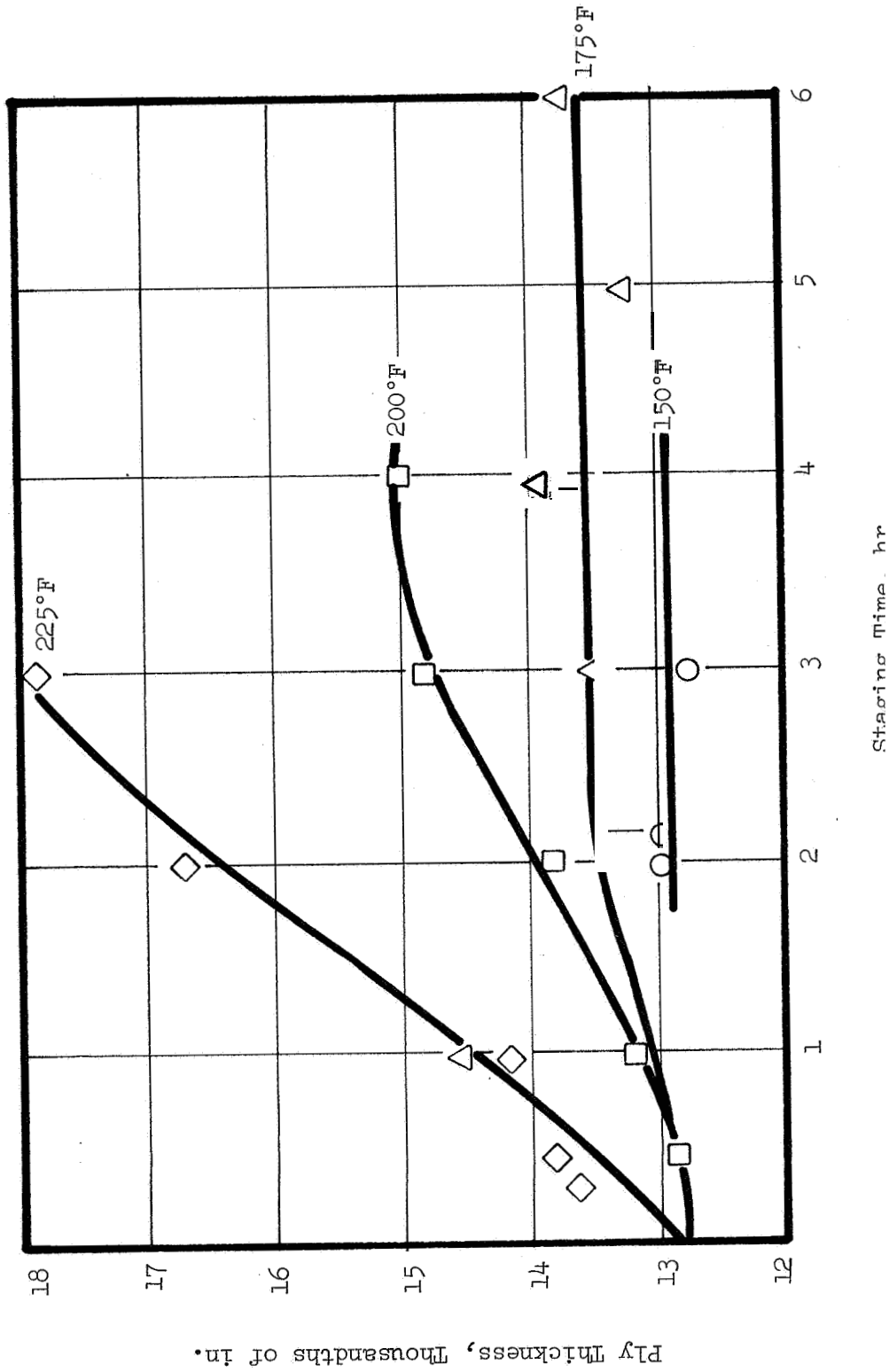
FM 5131 Specific Gravity vs Staging Time and Temperature

Figure 111



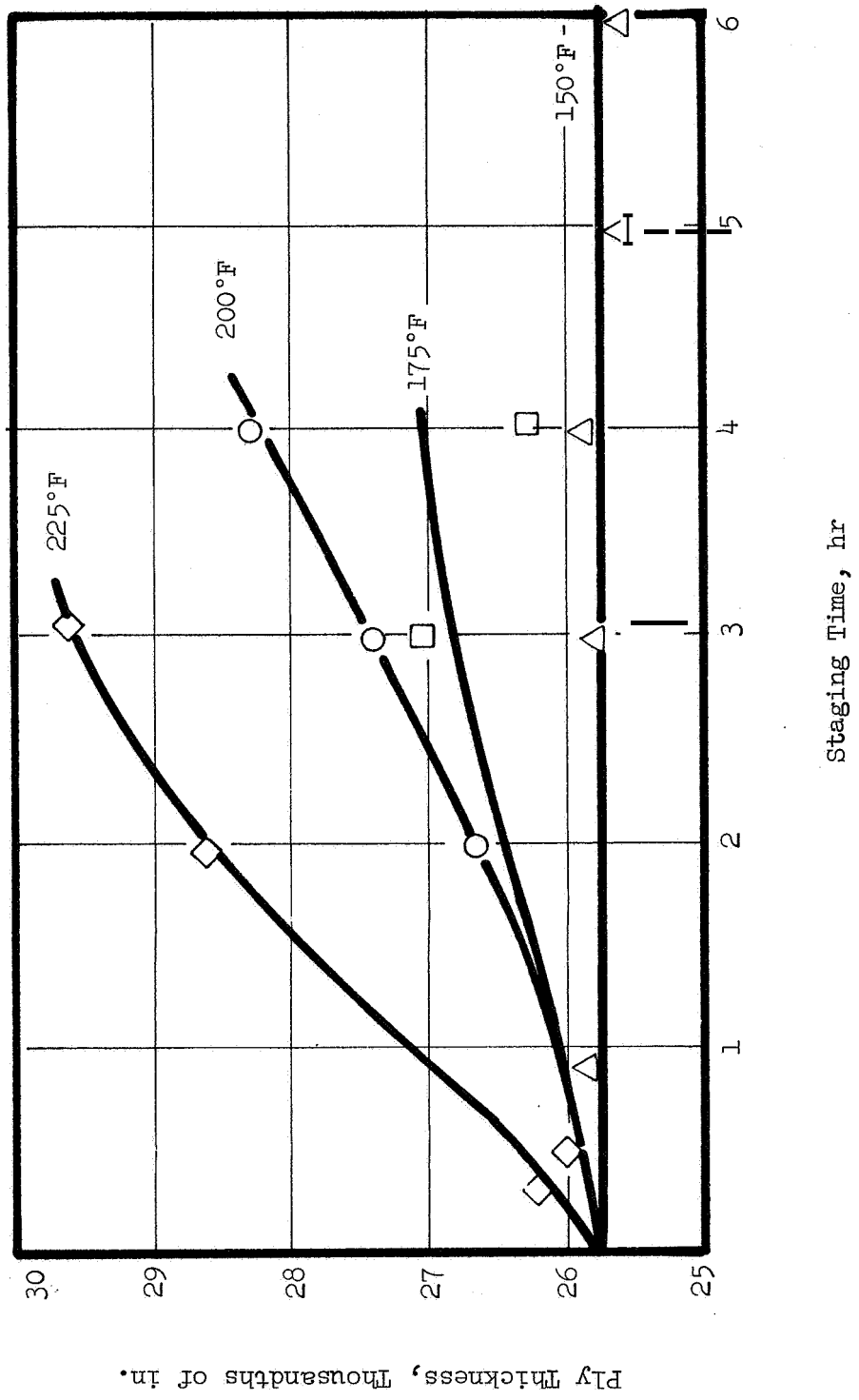
Specific Gravity vs Staging Time for MX 2646

Figure 112



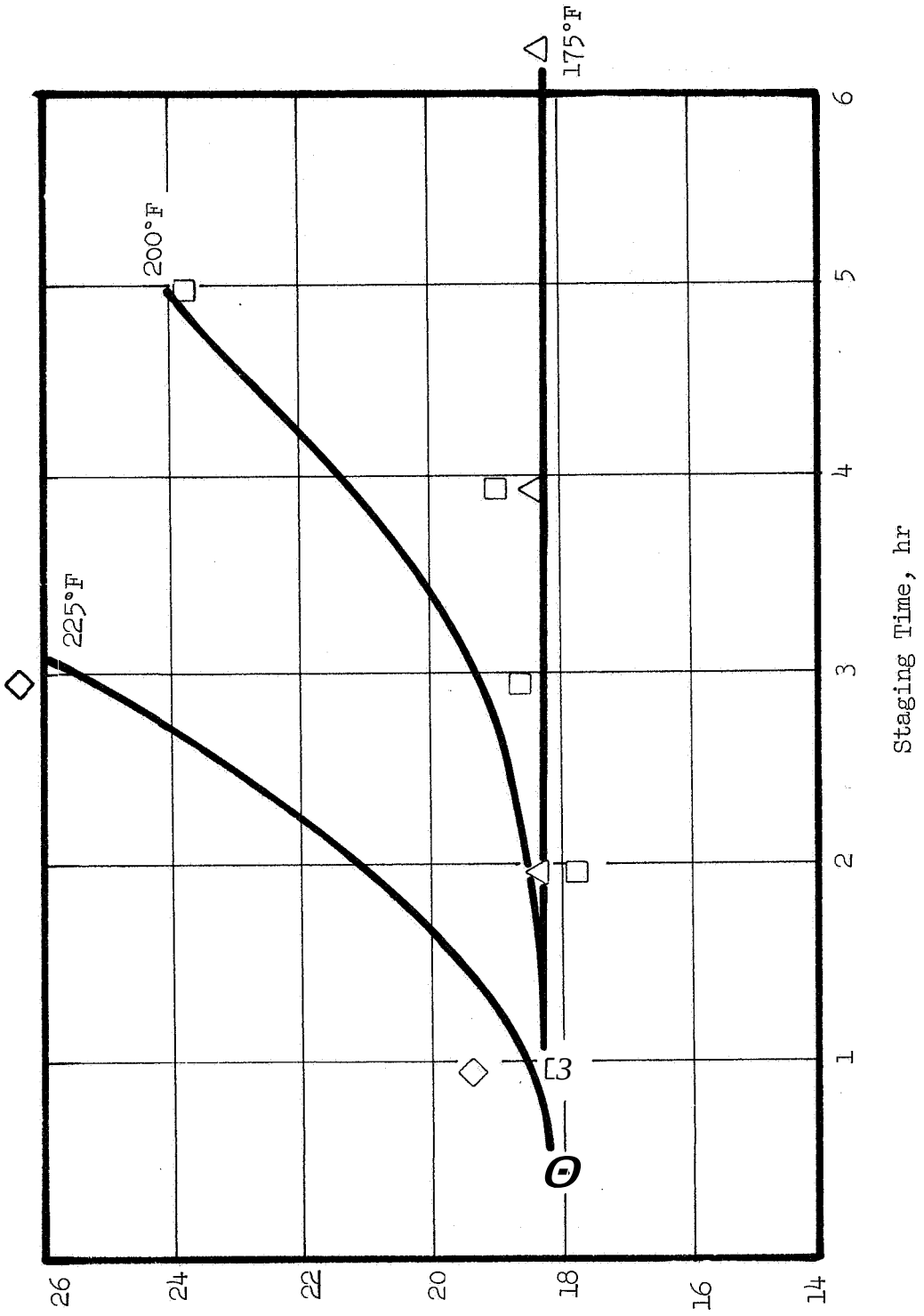
MX-4926 Ply Thickness vs Staging Time and Temperature

Figure 113



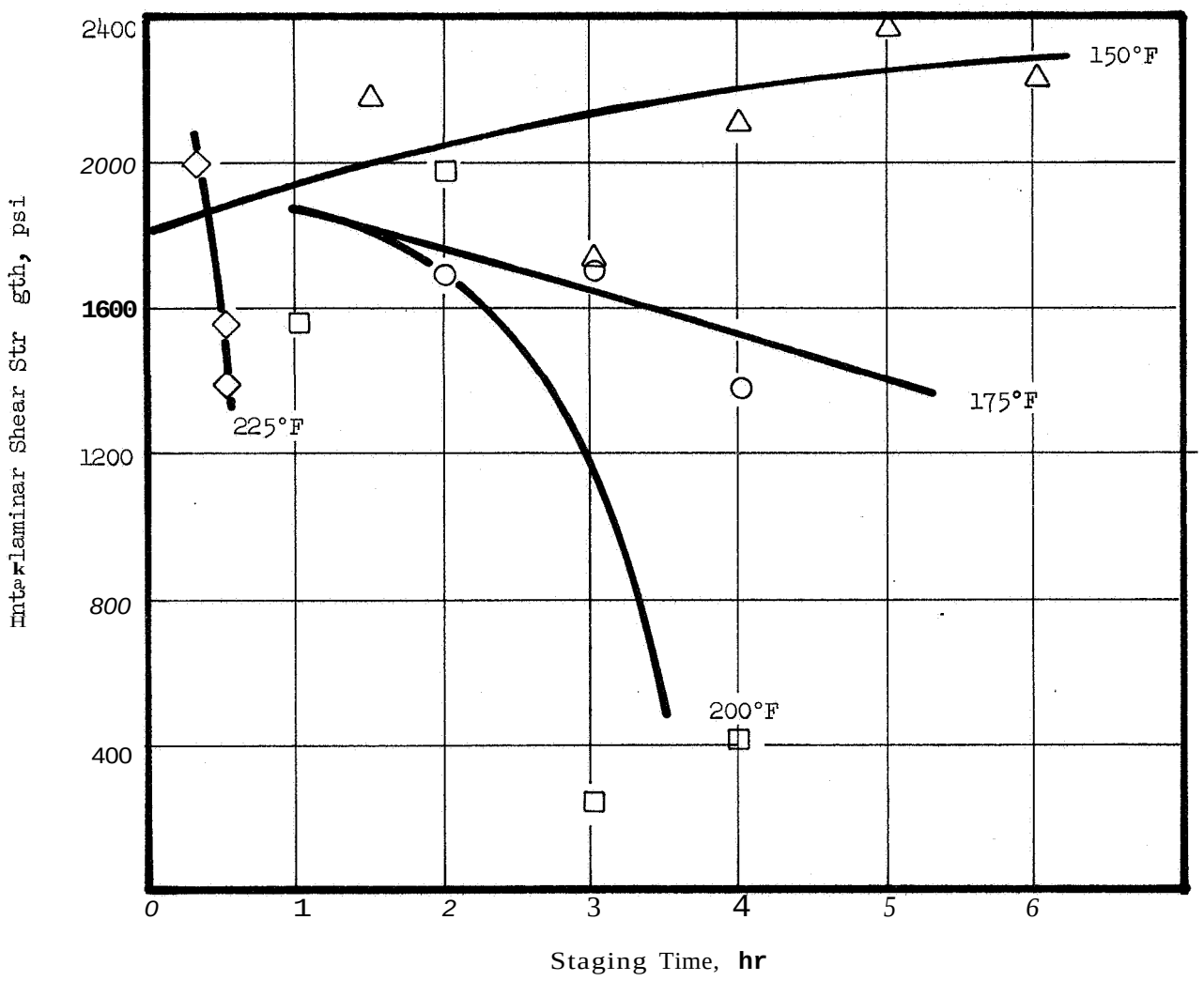
FM-5131 Ply-Thickness vs Staging Time and Temperature

Figure 114



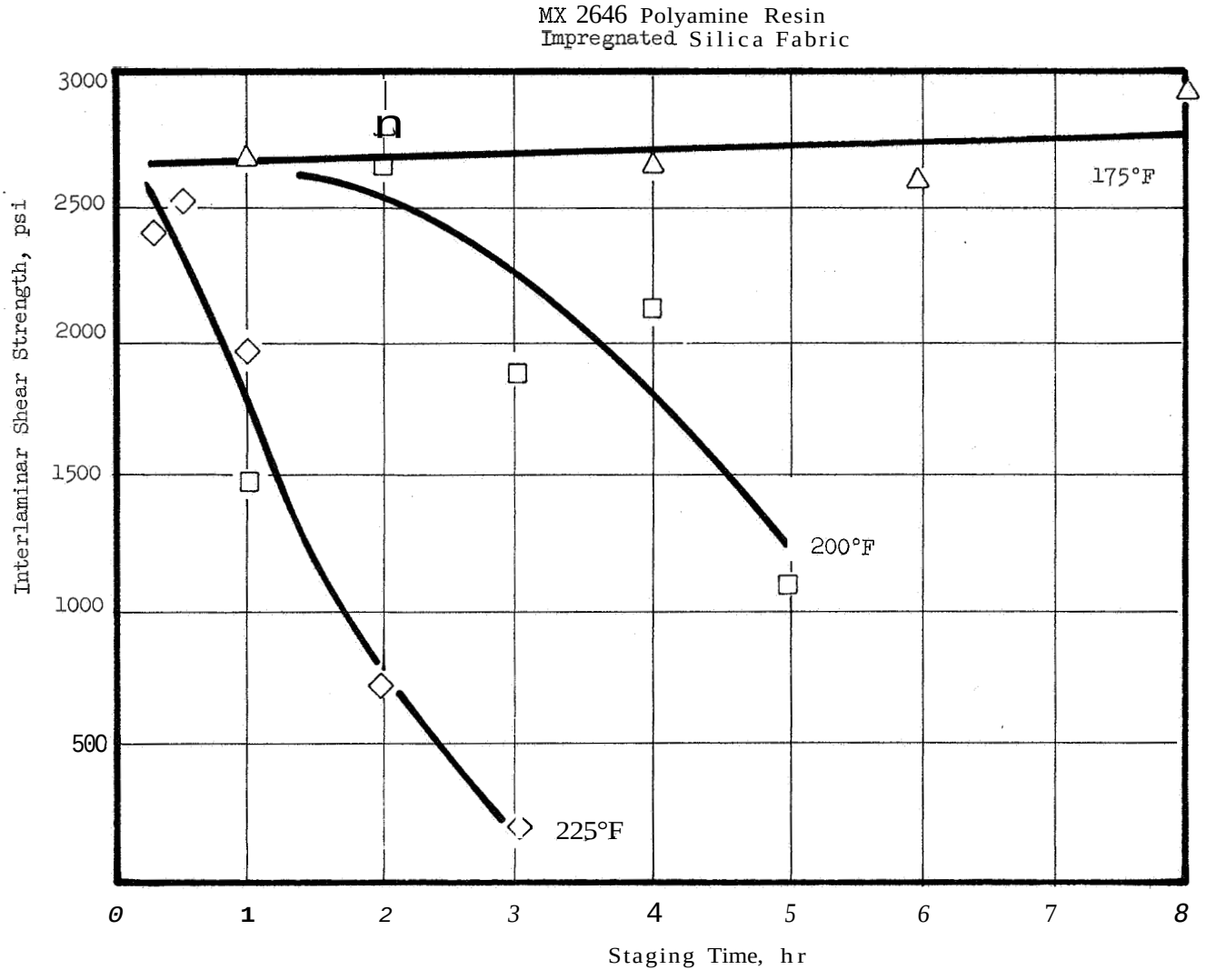
MX-2646 Ply Thickness vs Staging Time and Temperature

Figure 115



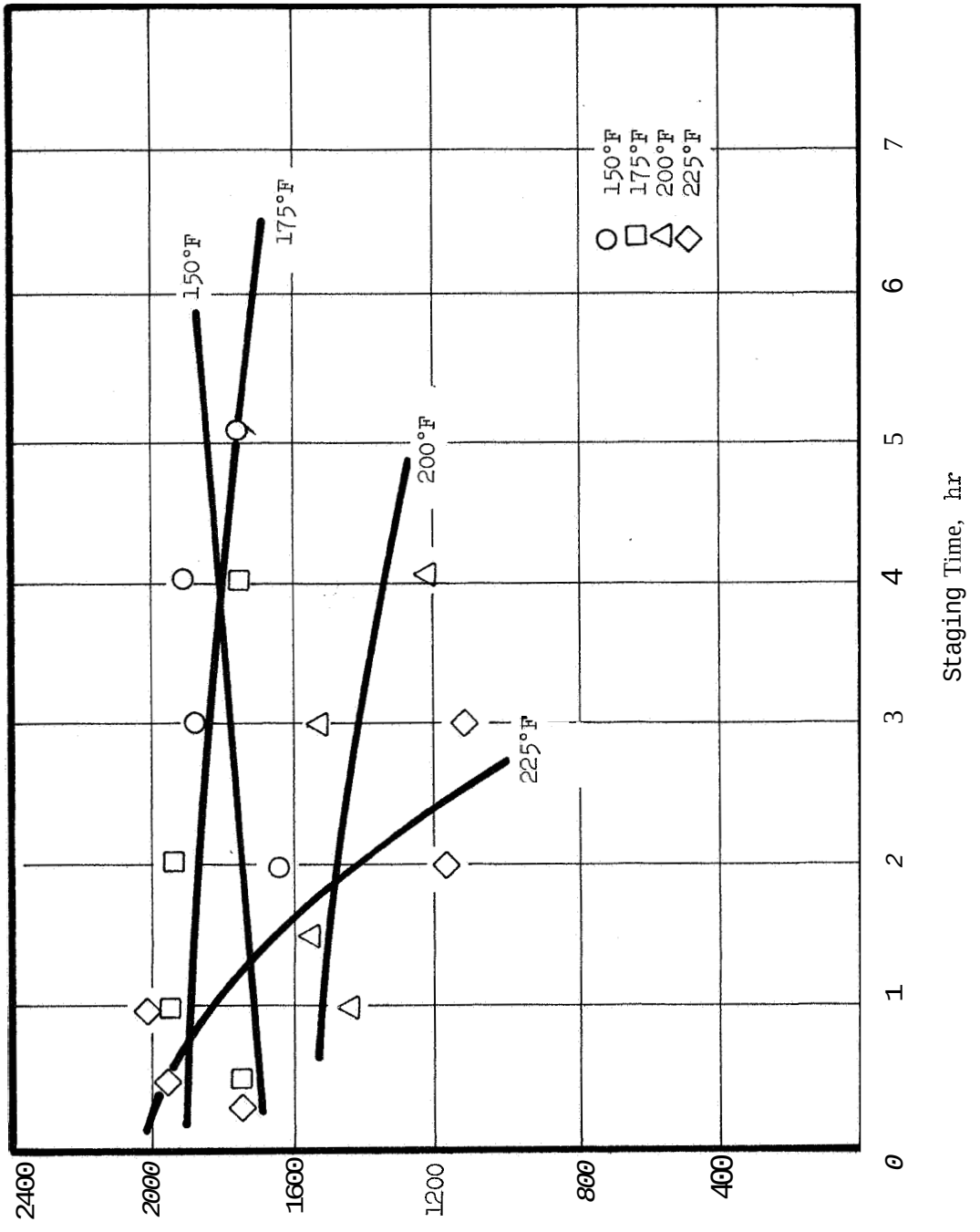
Interlaminar Shear vs Staging Time, MX 4926 Phenolic Resin Impregnated Carbon Fabric

Figure 116



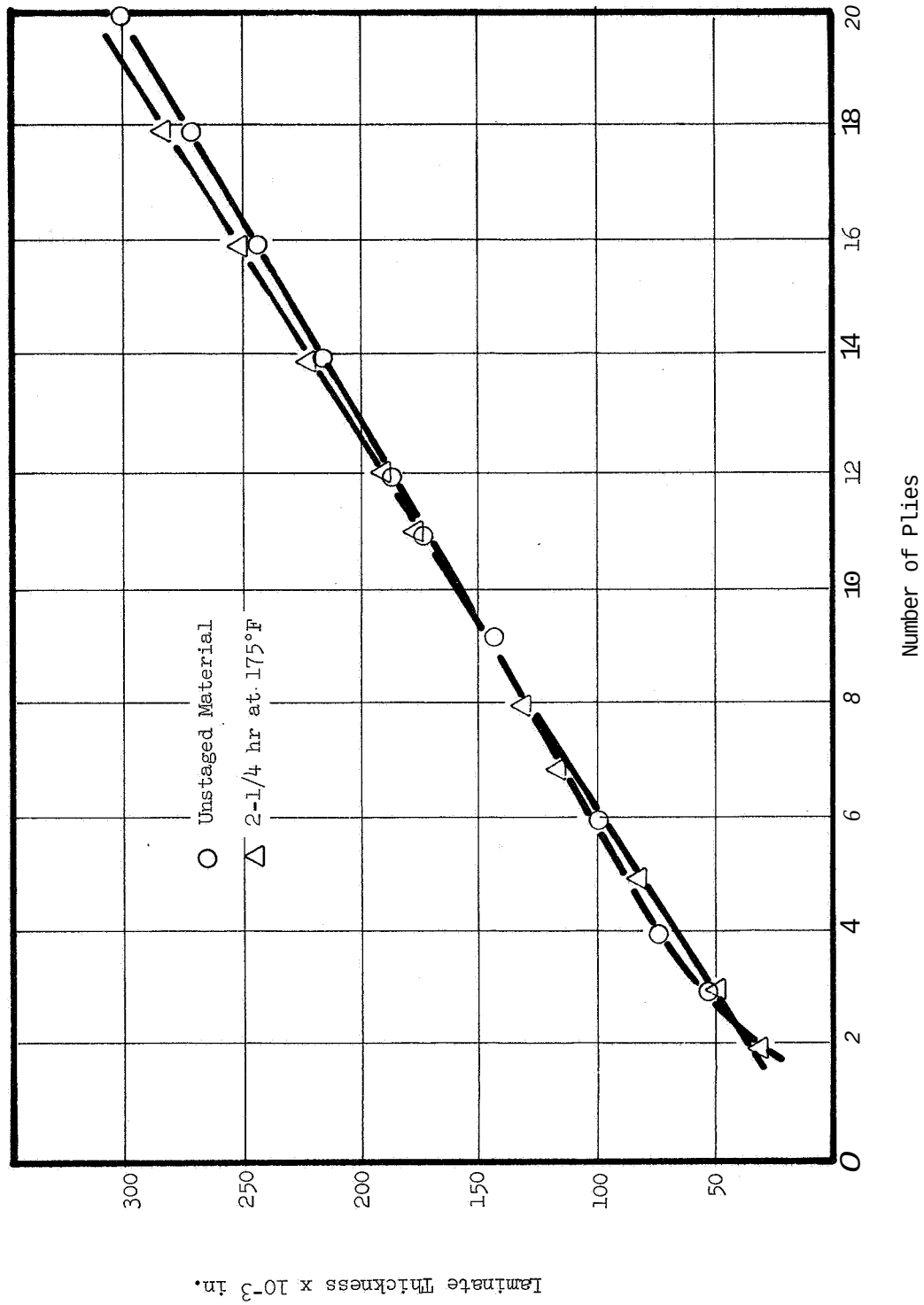
Interlaminar Shear Strength vs Staging Time, MX 2646
Polyamine Resin Impregnated Silica Fabric

Figure 117



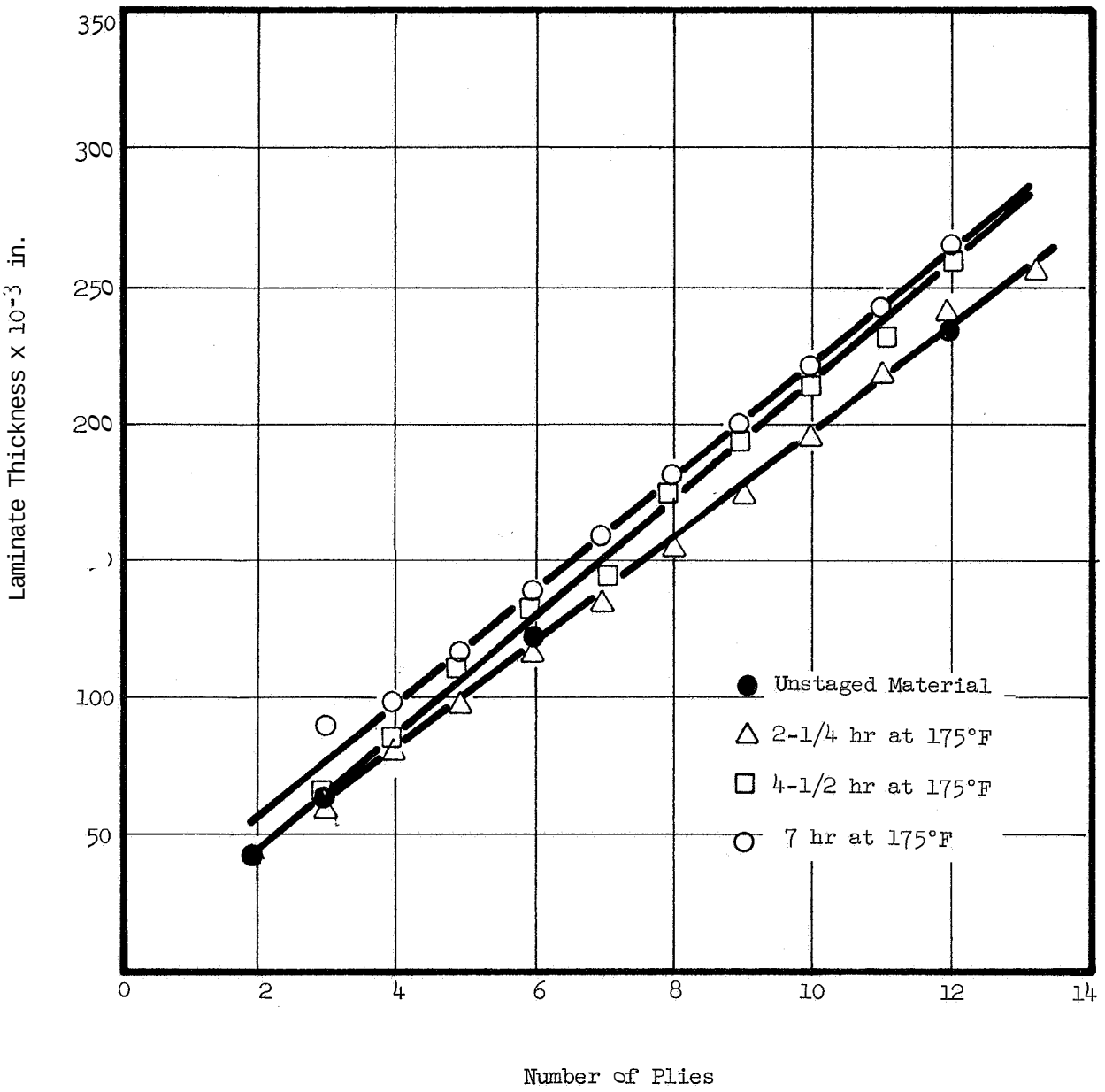
Interlaminar Shear Strength vs Staging Time, FM 5131 Phenolic Resin Impregnated Silica Fabric

Figure 118



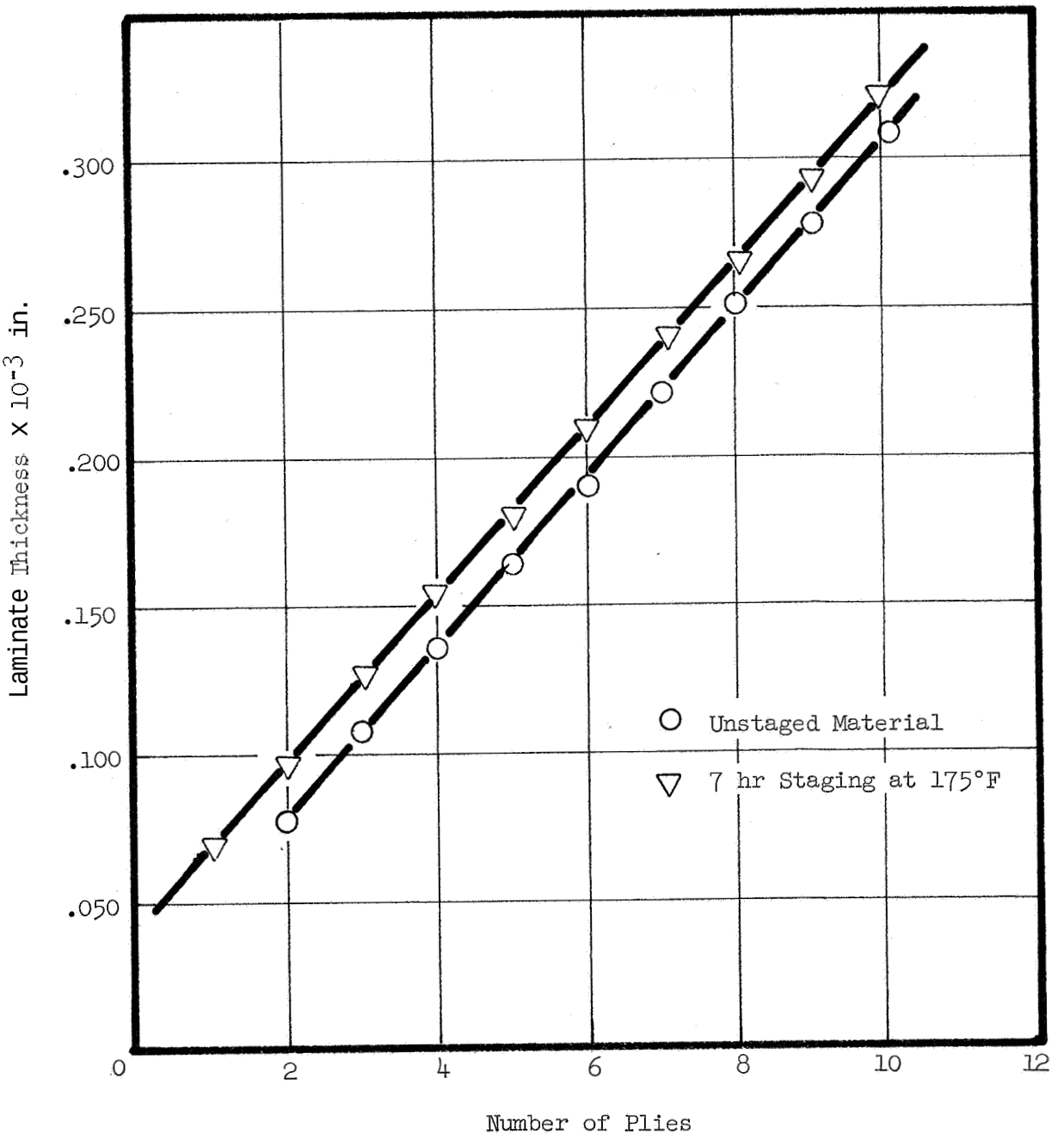
Number of Plies vs Total Thickness for Staged and Unstaged MX-4926

Figure 119



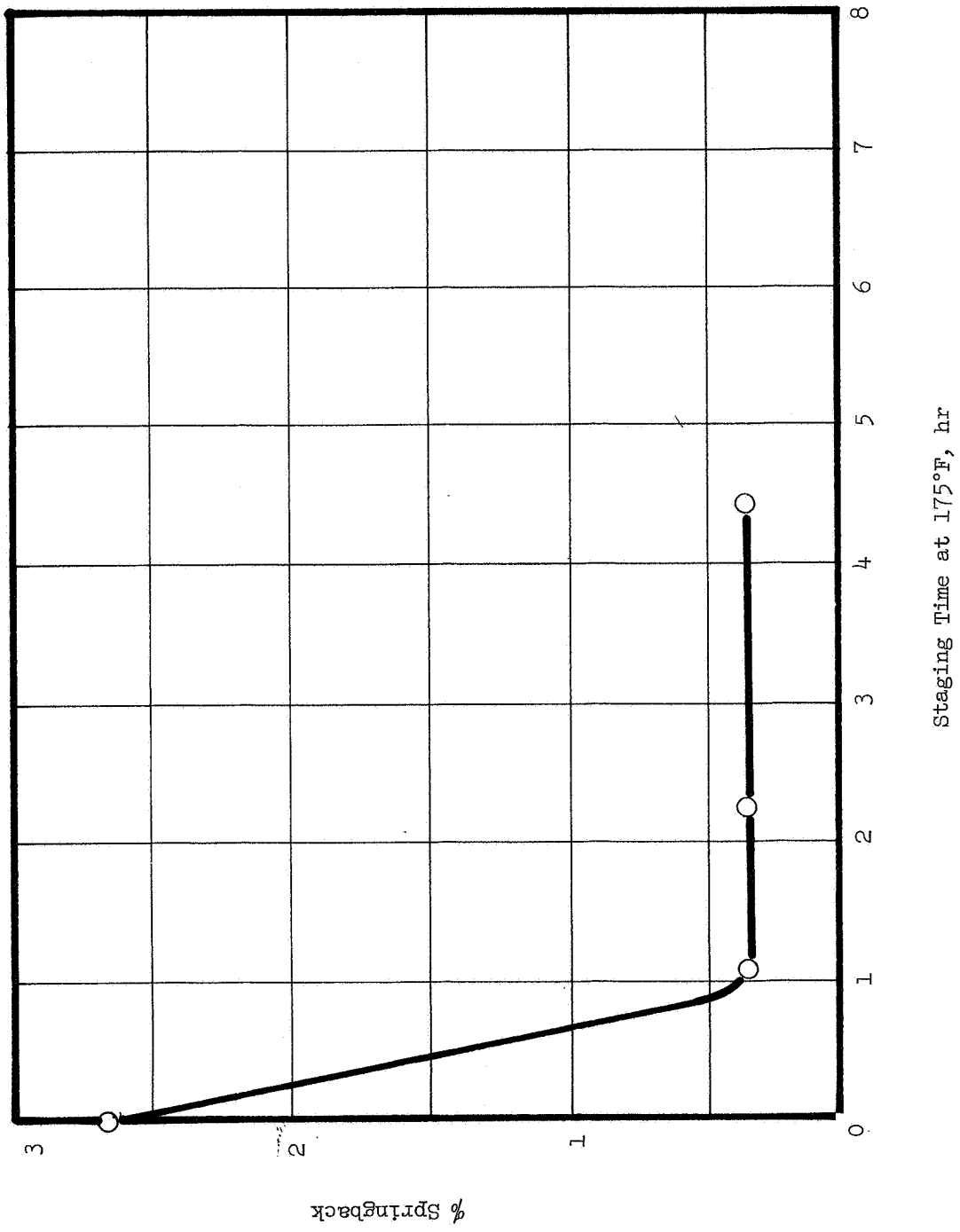
Number of Plies vs Laminate Thickness for Staged and Unstaged MX-2646

Figure 120



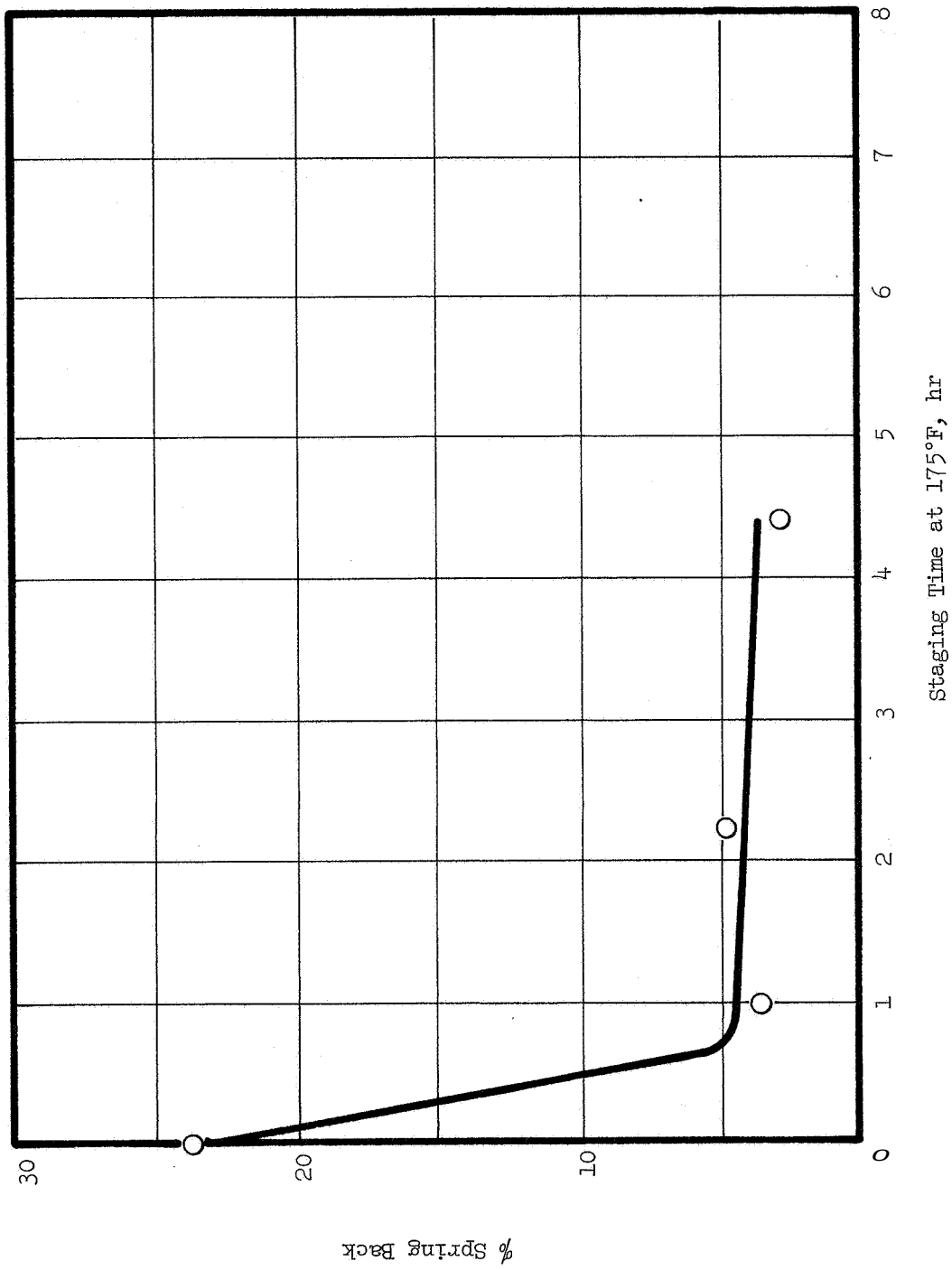
Number of Plies vs Total Thickness for Staged and Unstaged FM-313.

Figure 121



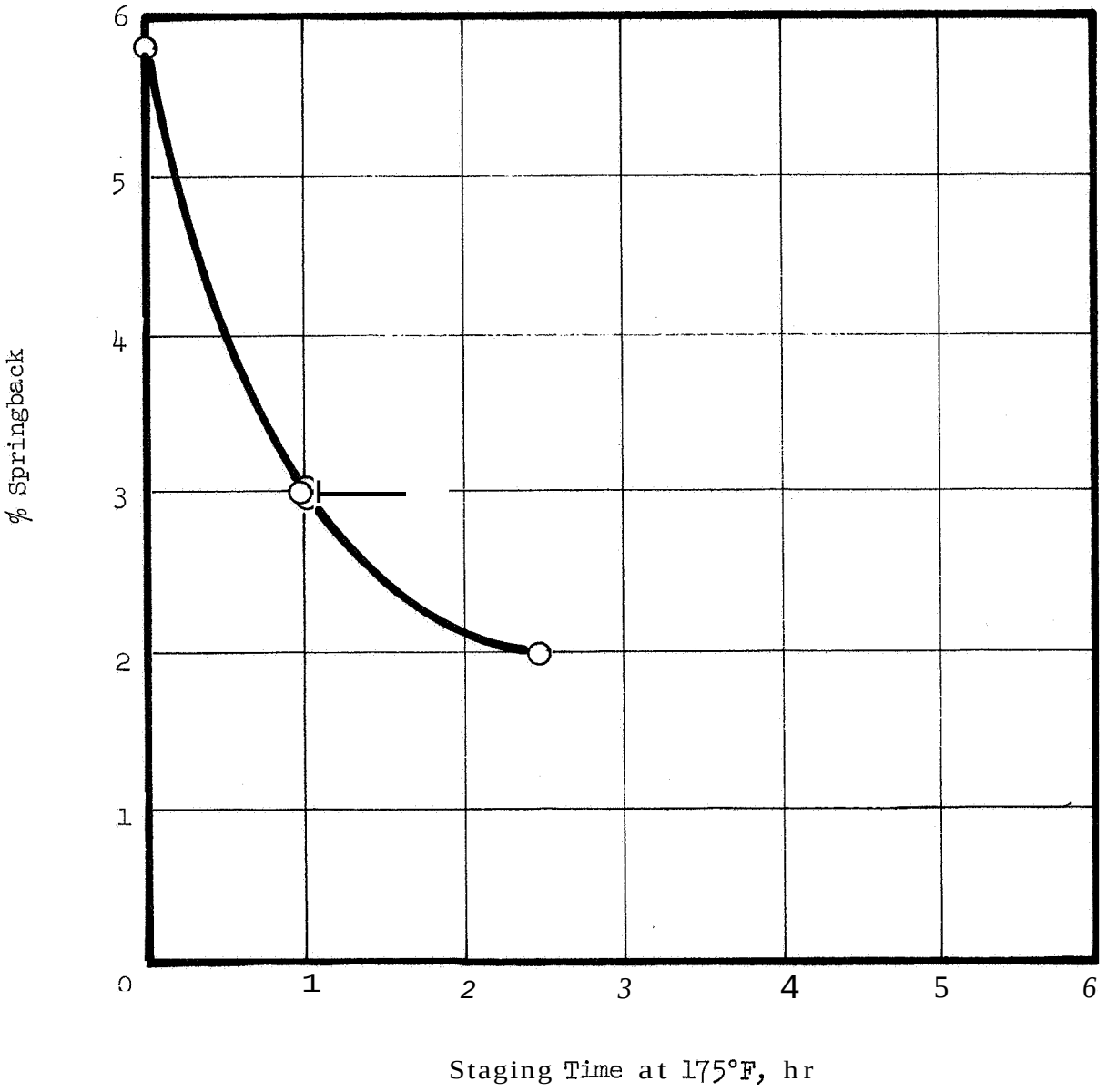
FM 5131 Springback vs Staging Time

Figure *122*



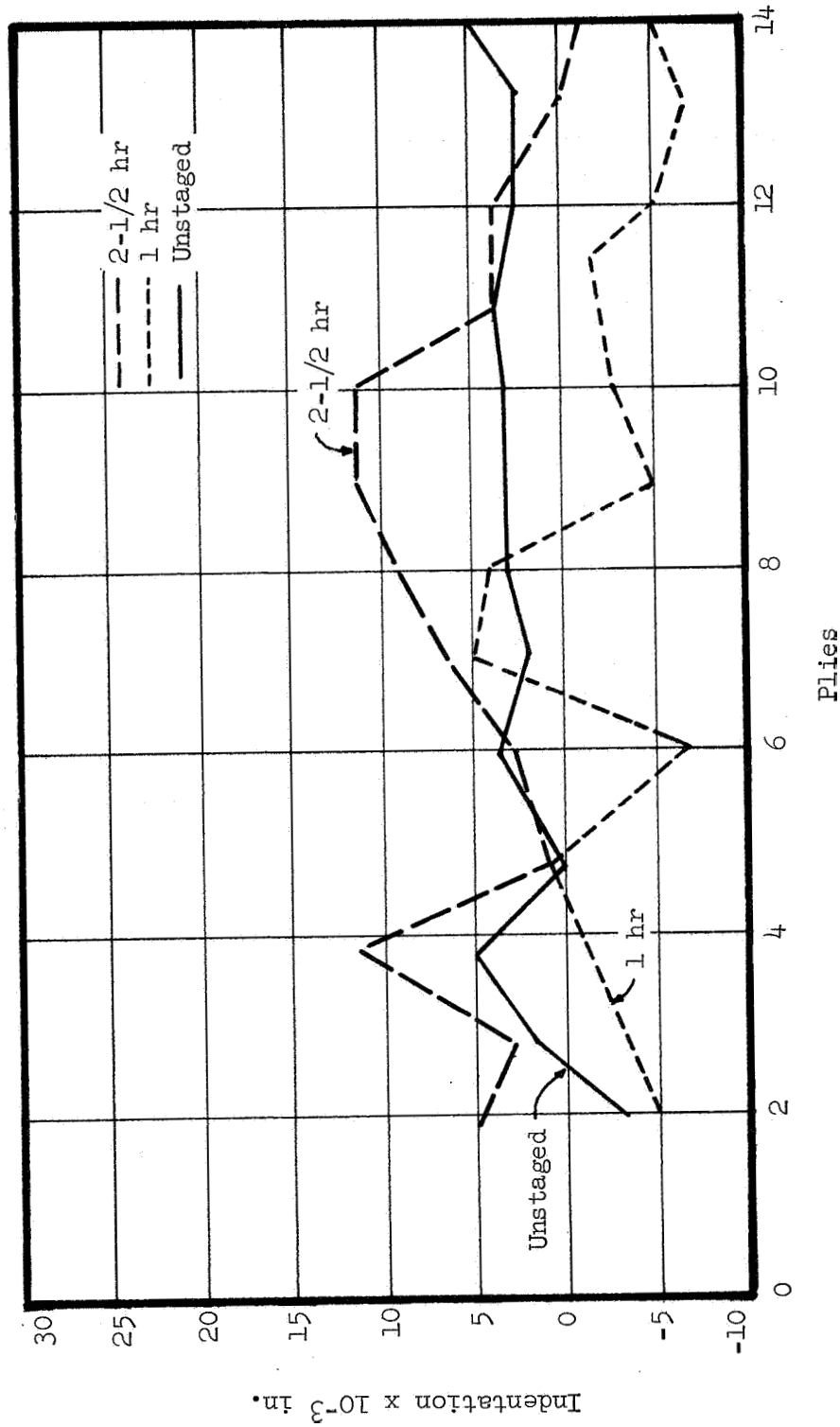
MX-2646 Springback vs Staging Time

Figure 123



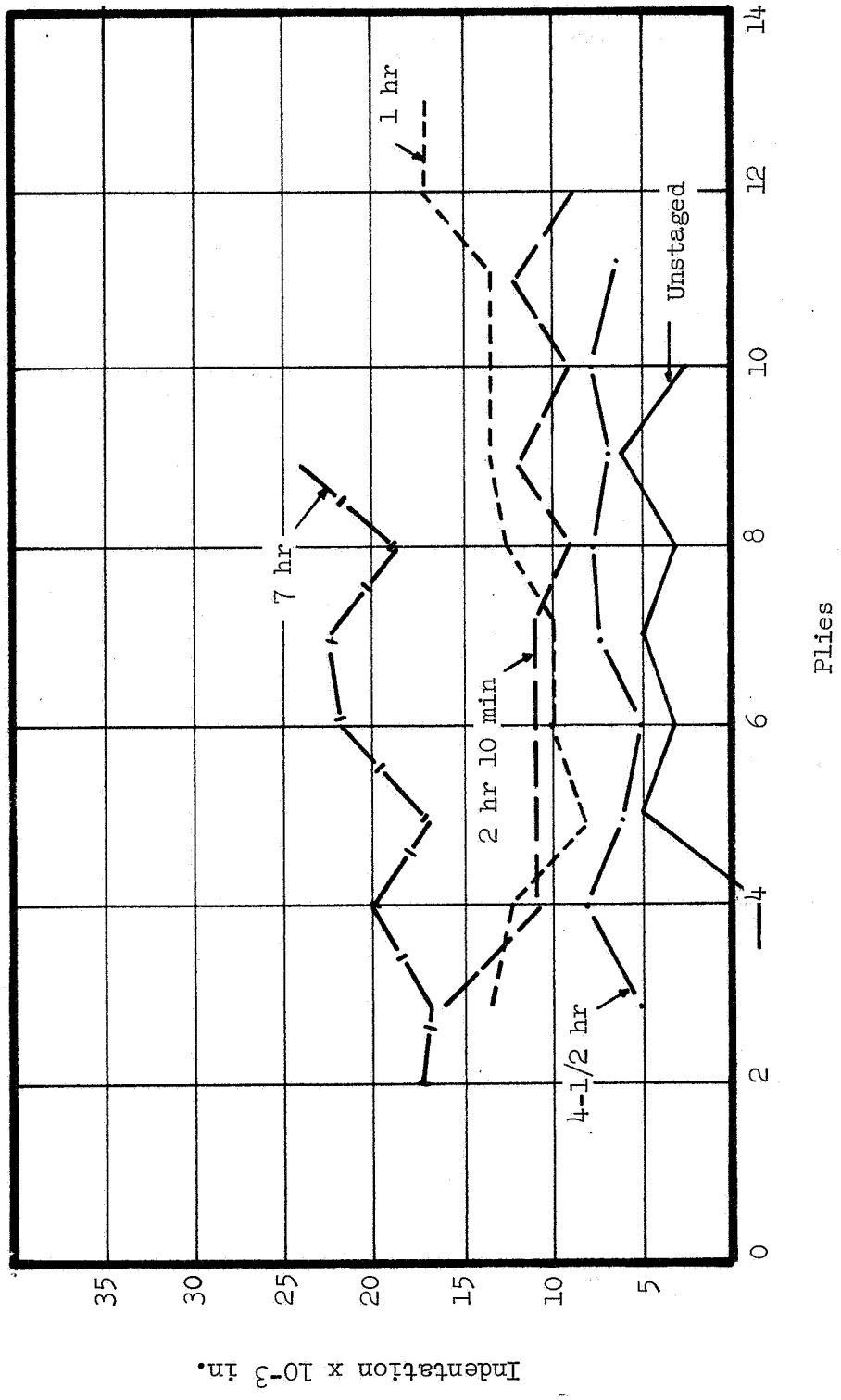
MX-4926 Springback vs Staging Time

Figure 124



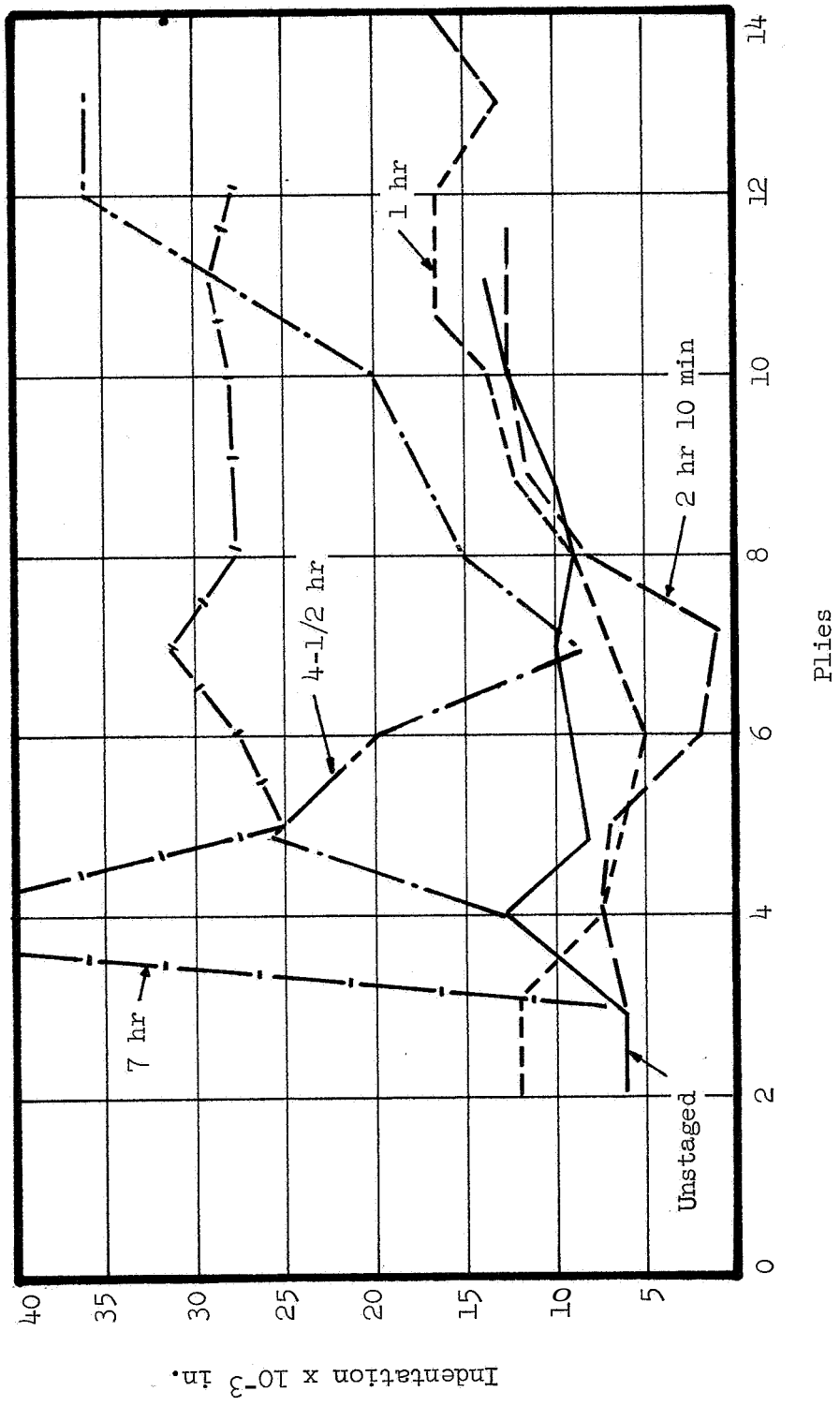
Roller Indentation During Debulking for MX 4926 Staged at 175°F

Figure 125



Roller Indentation During Debulking for FM 5131 Staged at 175°F

Figure 126



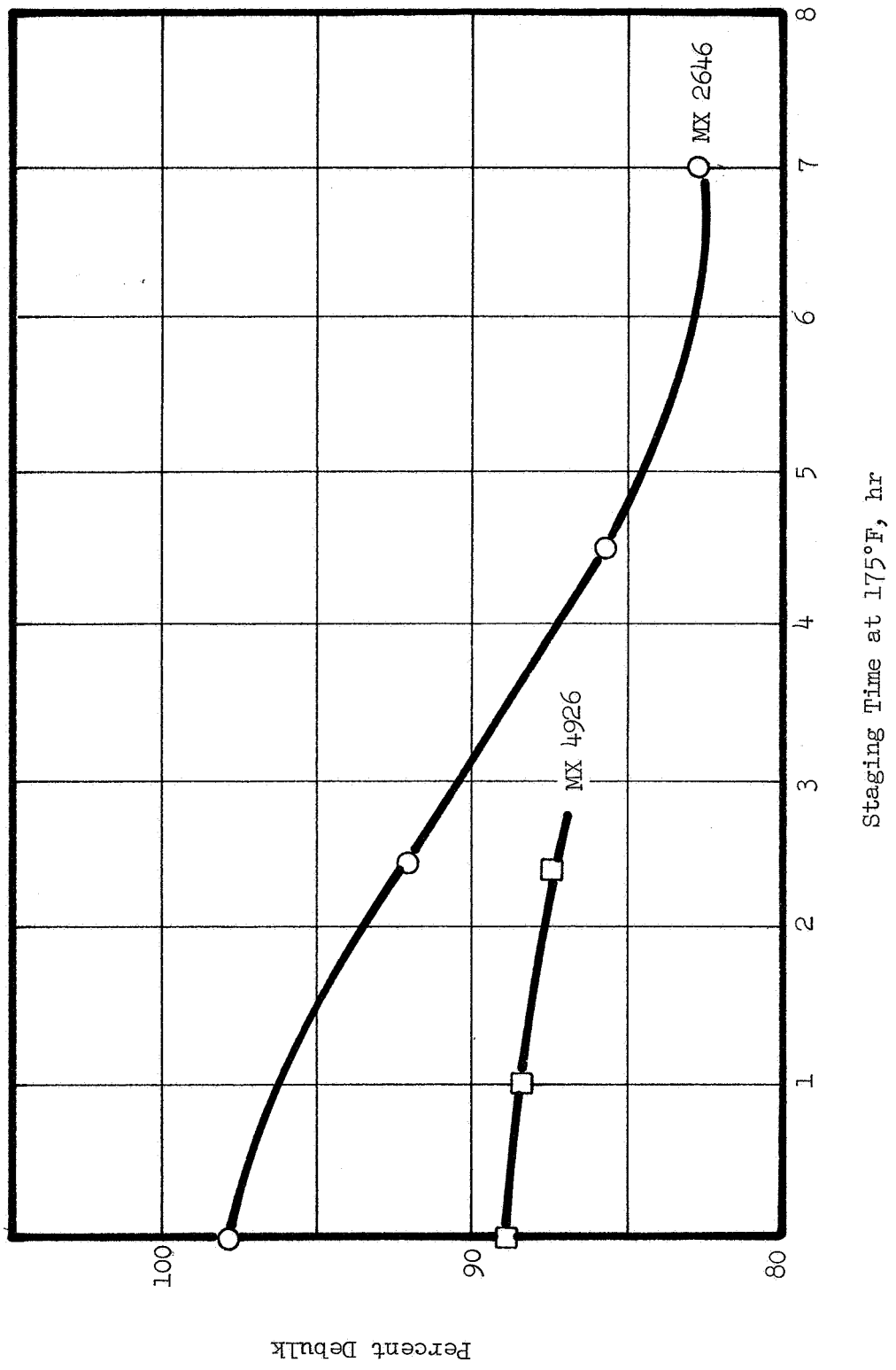
Roller Indentation During Debulking for MX 2646 Staged at 175°F

Figure 127

Material	Staging Time @ 175°F, Hr.	Shore D Hardness
FM-5131	0	40
	1	56
	2	72
	$4\frac{1}{2}$	81
	7	80
MX-2646	0	40
	1	48
	$2\frac{1}{2}$	53
	$4\frac{1}{2}$	57
MX-4926	0	63
	1	78
	$2\frac{1}{2}$	79

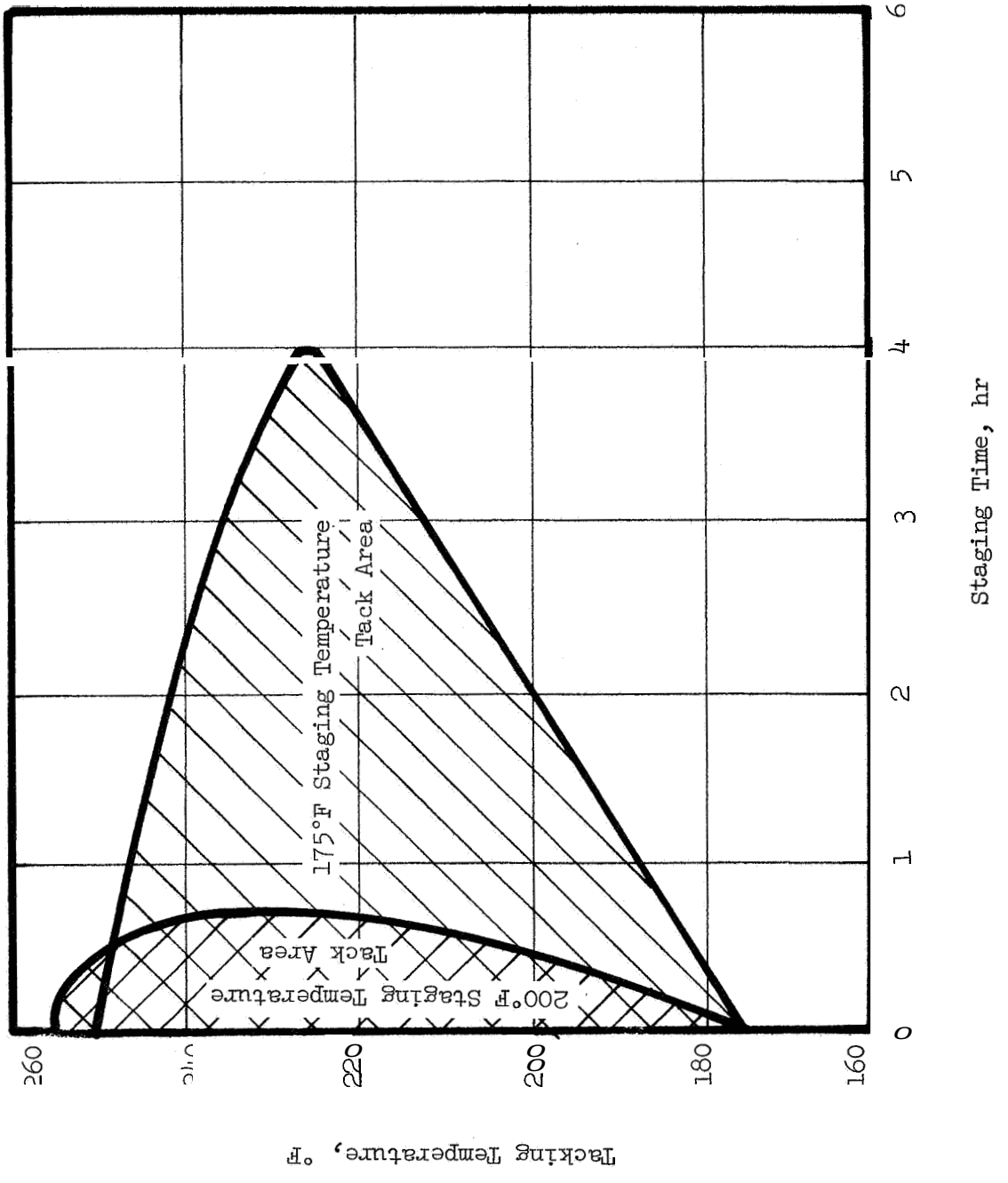
Shore D Hardness of Staged Material Tape Wrapped on Cylindrical Mandrel

Figure 128



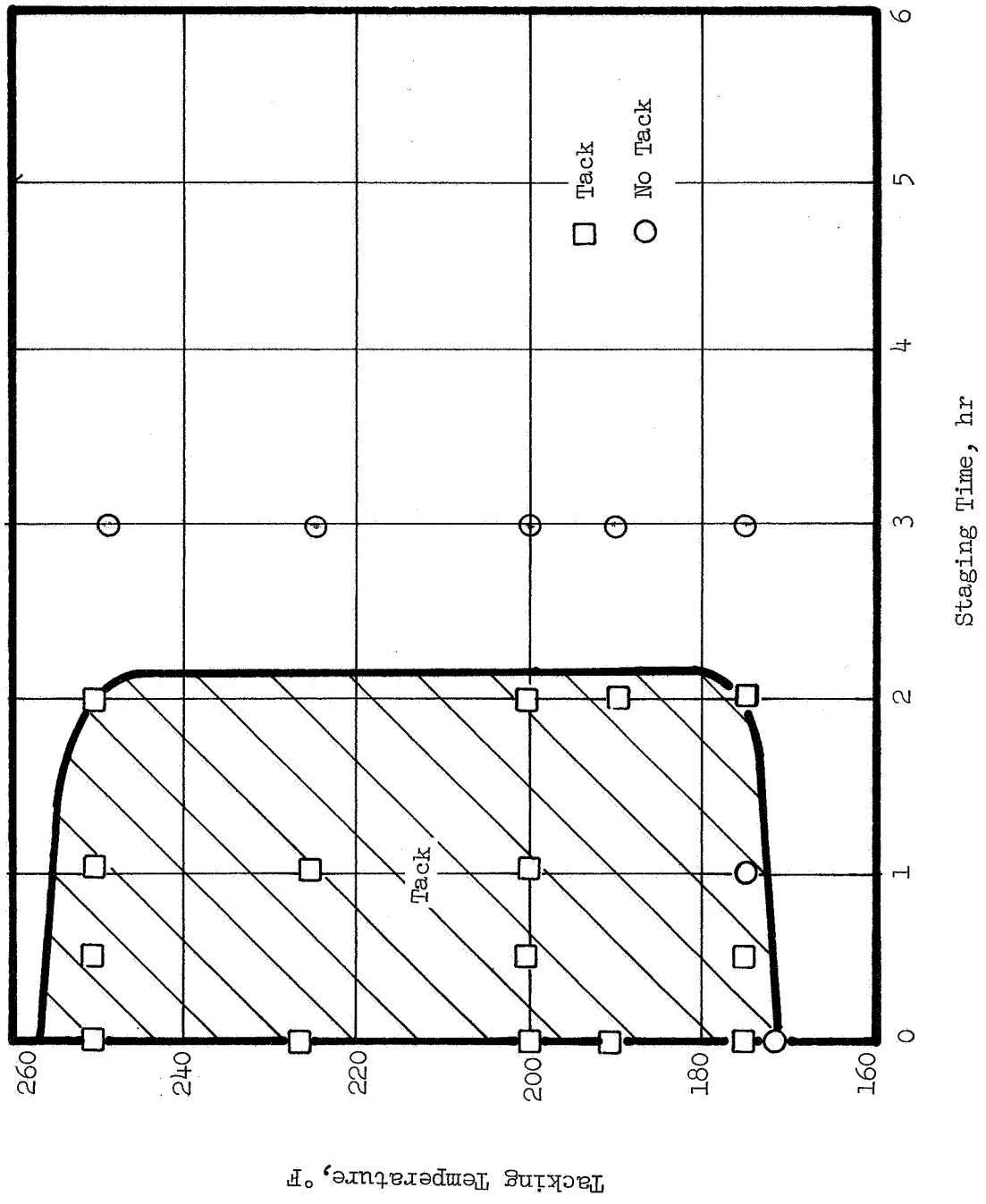
Percent Debulk vs Staging Time at 175°F

Figure 129



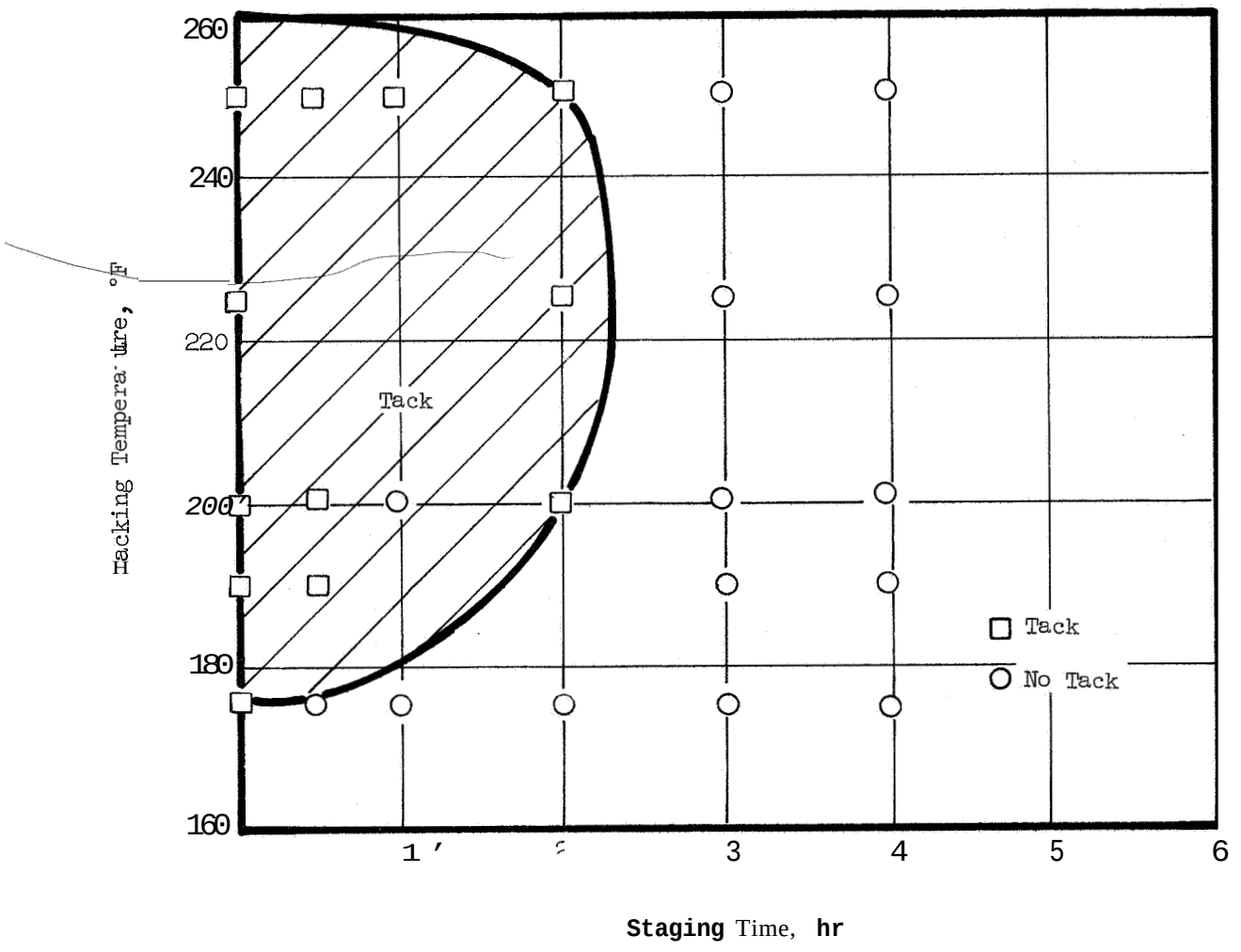
Tacking Temperature vs Time, MX-4926 Staged at 175 and 200°F

Figure 130



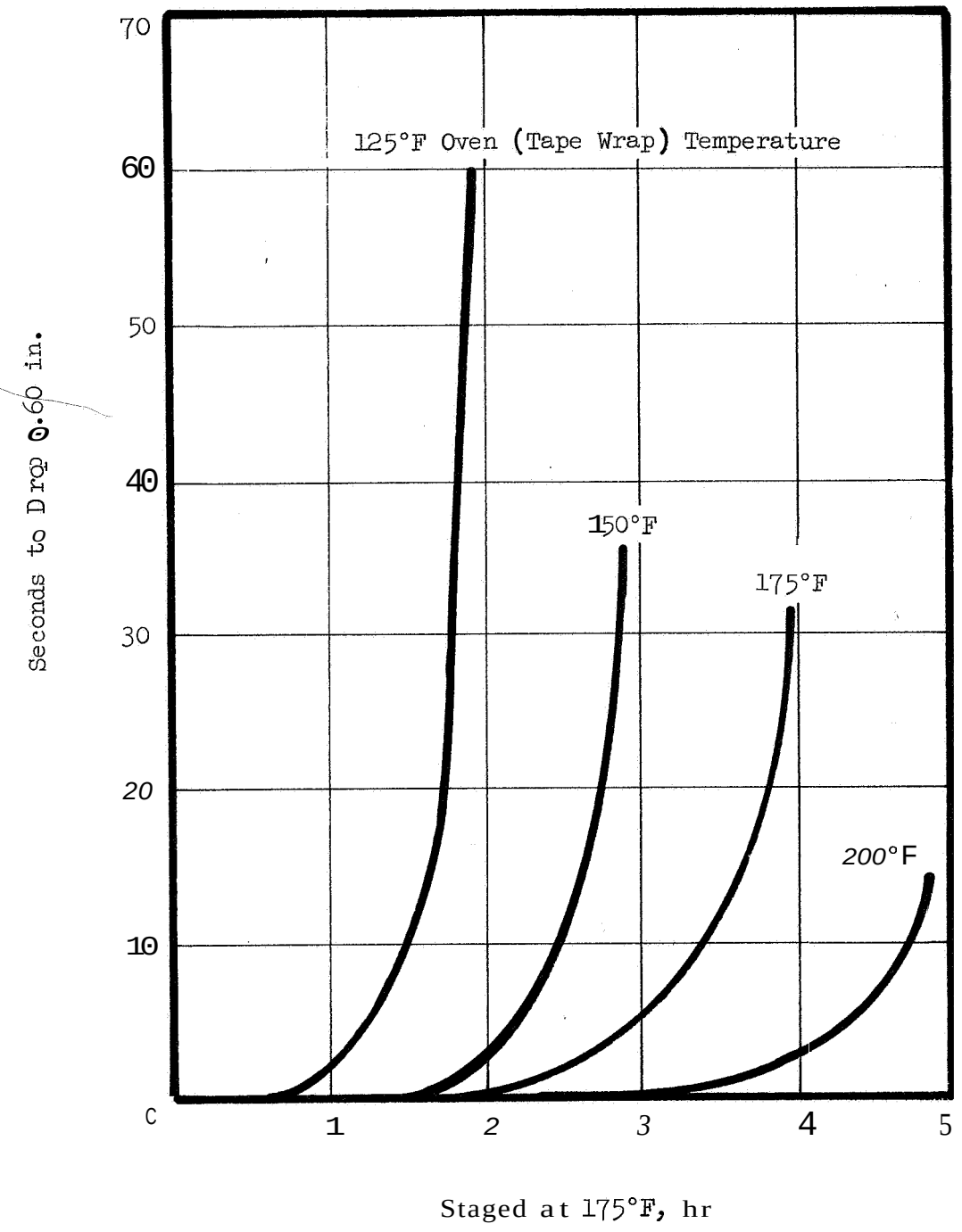
Tacking Temperature vs Staging Time, FM-5131 Staged at 200°F

Figure 131



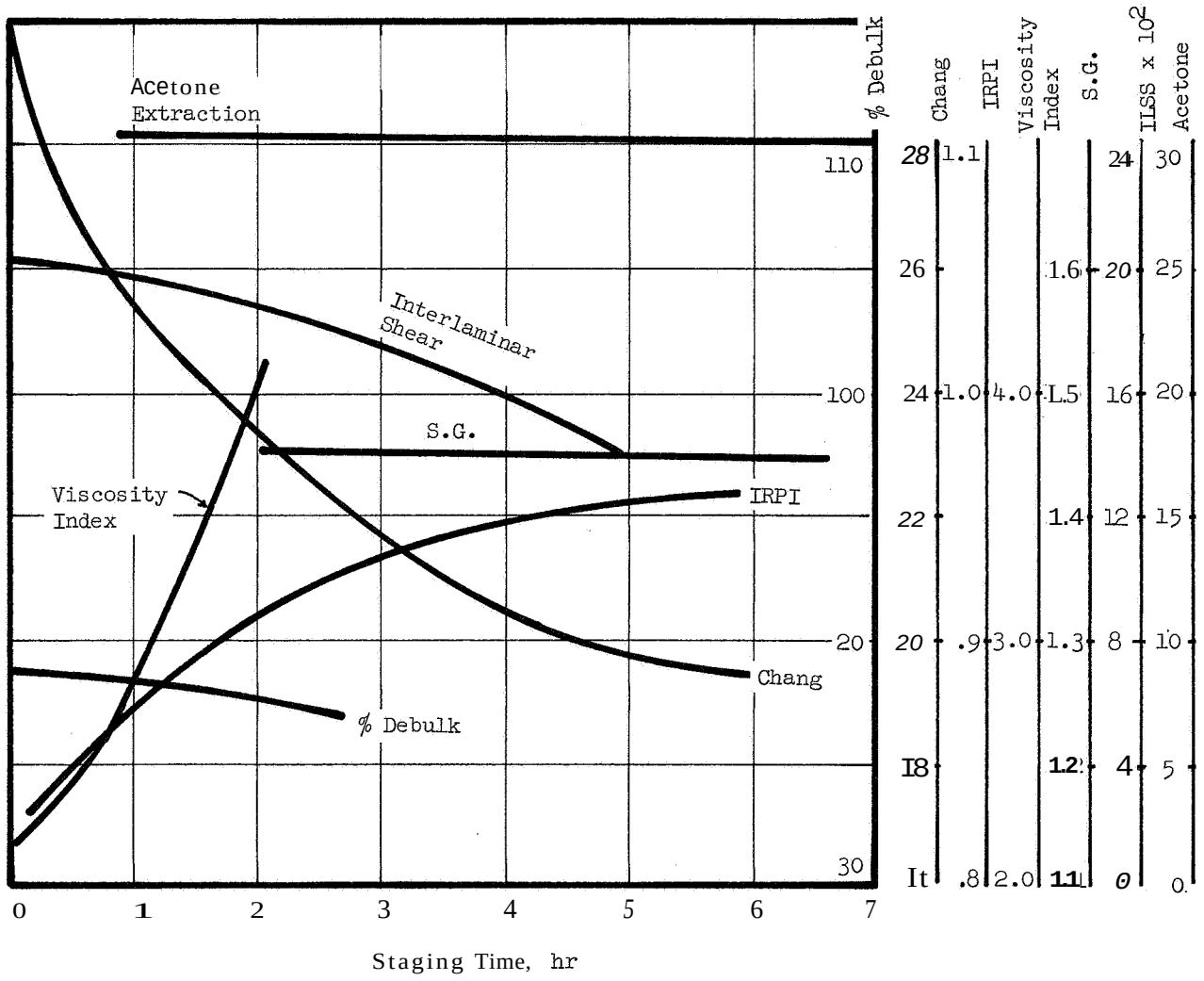
Tacking Temperature vs Staging Time, MX-2646 Staged at 200°F

Figure 132



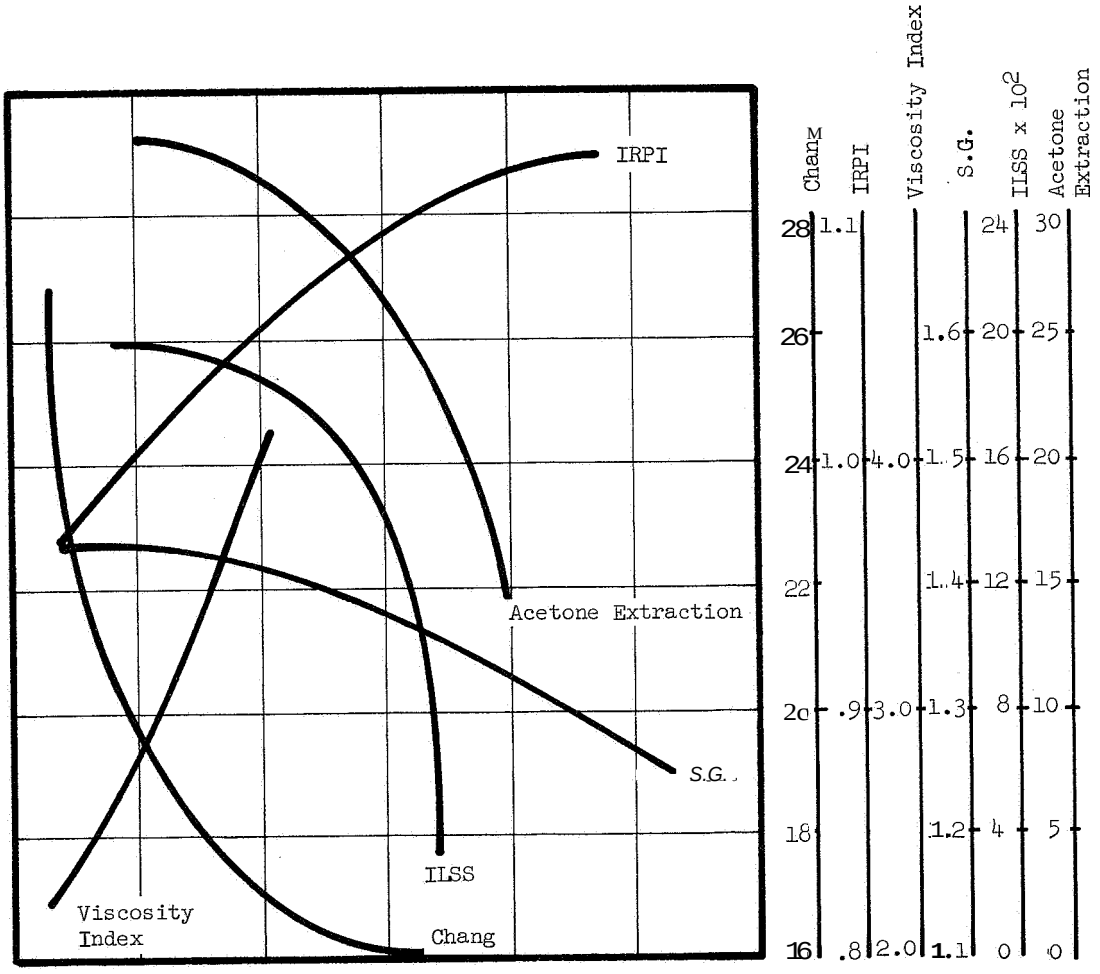
Deformation of MX-4926 Staged at 175°F, Time to Fall 0.600 in. at Various Oven (Tape Wrap) Temperatures

Figure 133



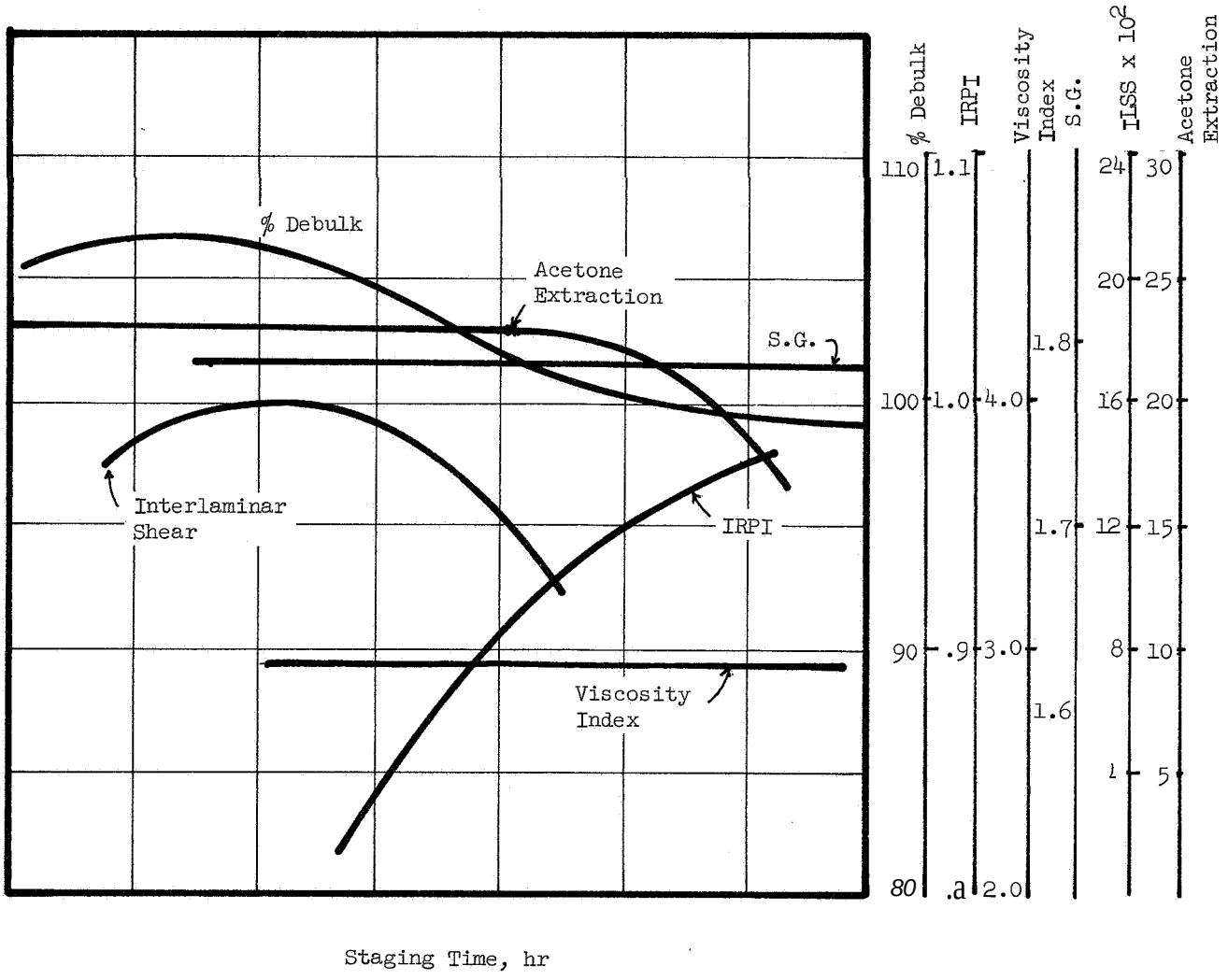
Various Prepreg Properties vs Staging Time, MX-4926, 175°F Staging Temperature

Figure 134



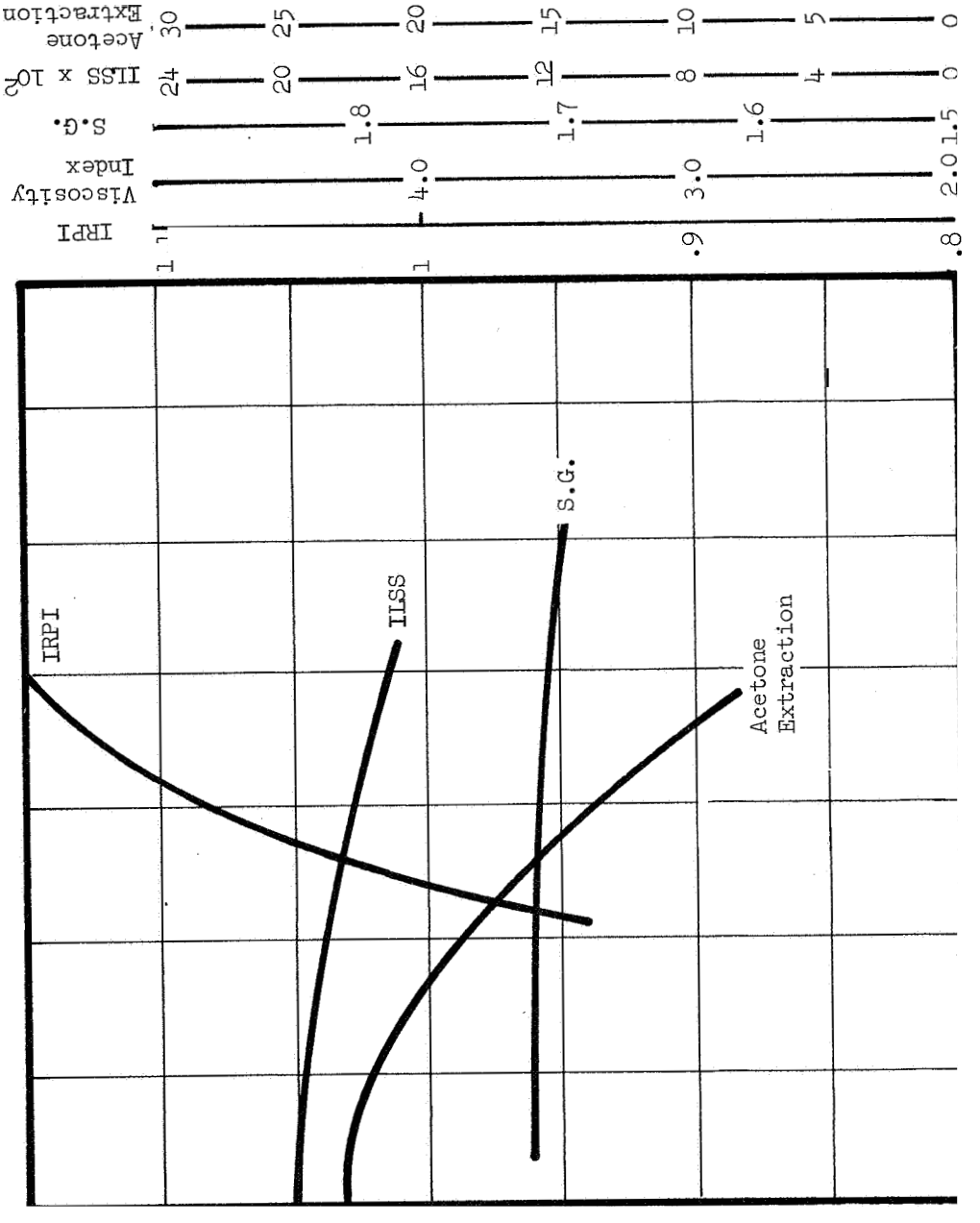
Various Prepreg Properties vs Staging Time, MX-4926, 200°F Staging Temperature

Figure 135



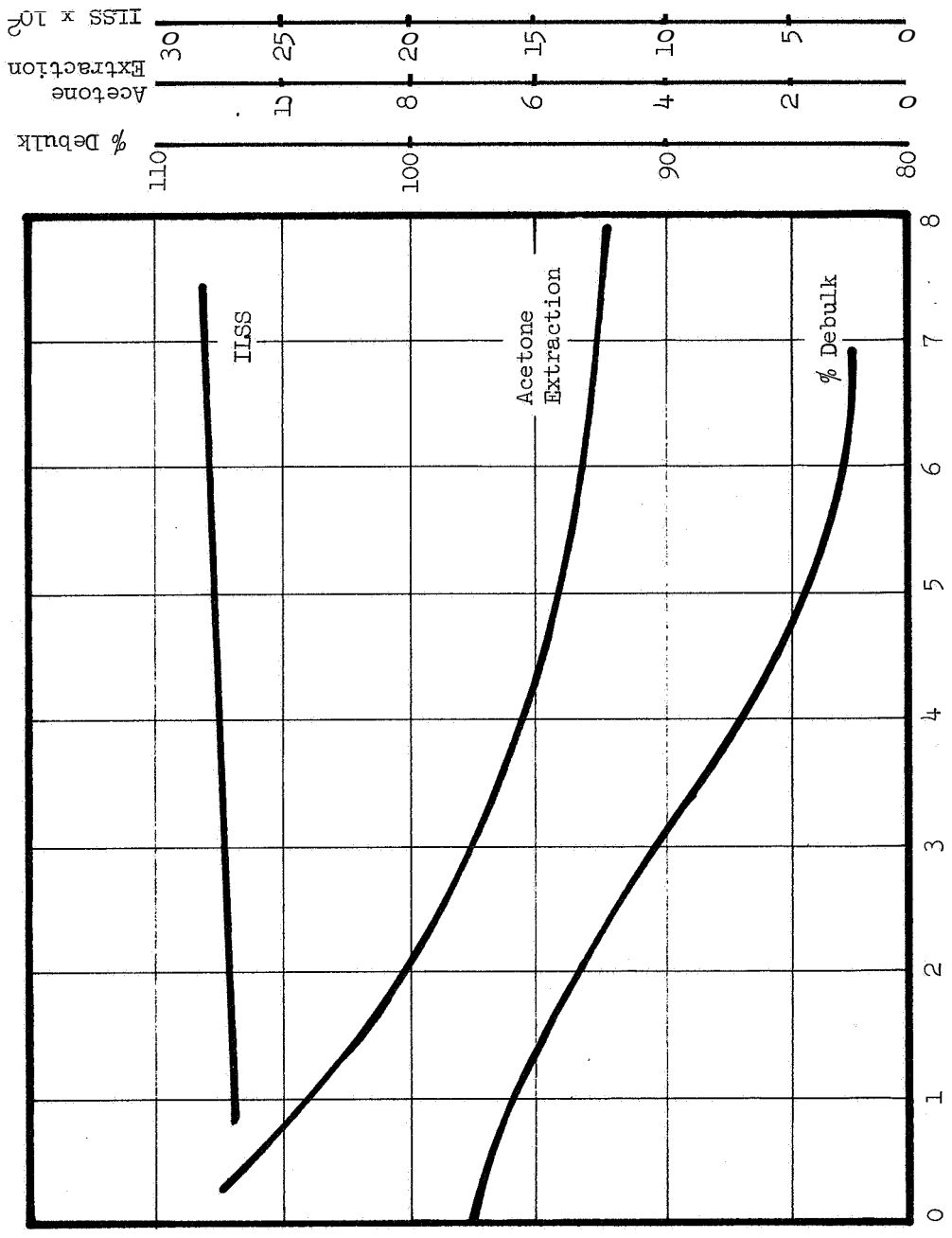
Various Prepreg Properties vs Staging Time, FM-5131, 175°F Staging Temperature

Figure 136



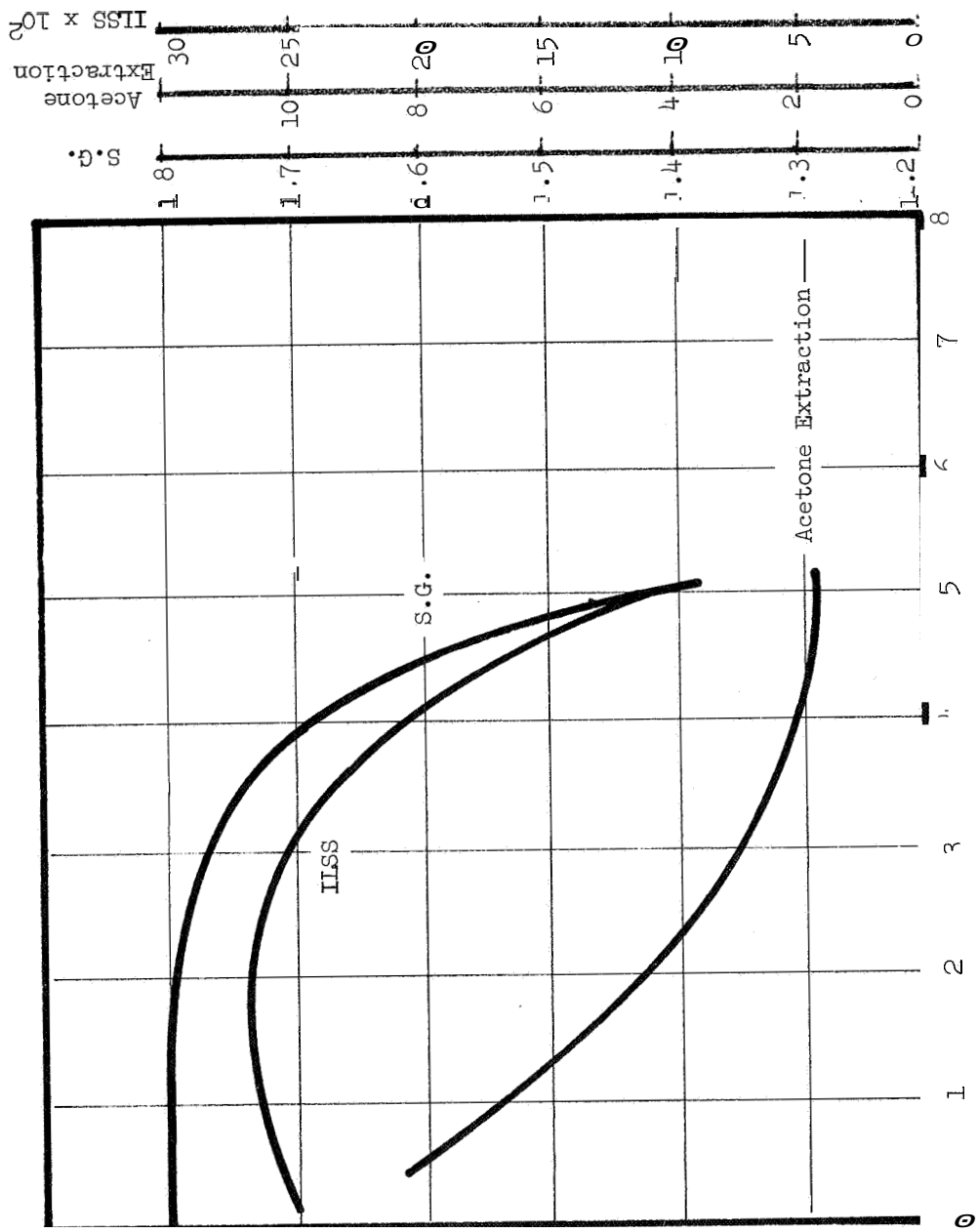
Various Prepreg Properties vs Staging Time, FM-5131, 200°F Staging Temperature

Figure 137



Various Prepreg Properties vs Staging Time, MX-2646, 175°F Staging Temperature

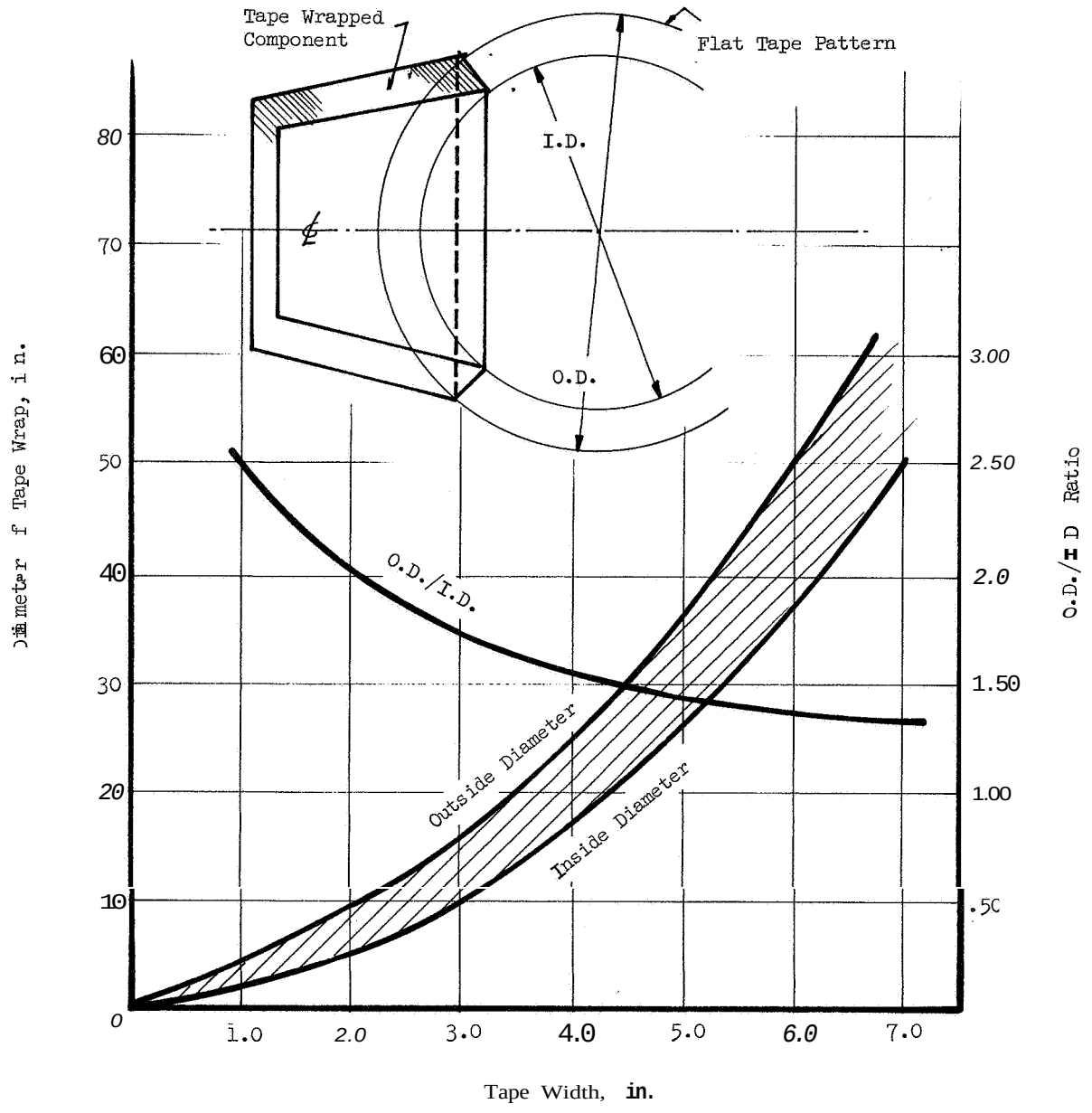
Figure 138



Staging Time, hr

Various Prepreg Properties vs Staging Time, MX-2646, 200°F Staging Temperature

Figure 139



Tape Wrap Diameter vs Tape Width for 45° Bias Carbon Fabric

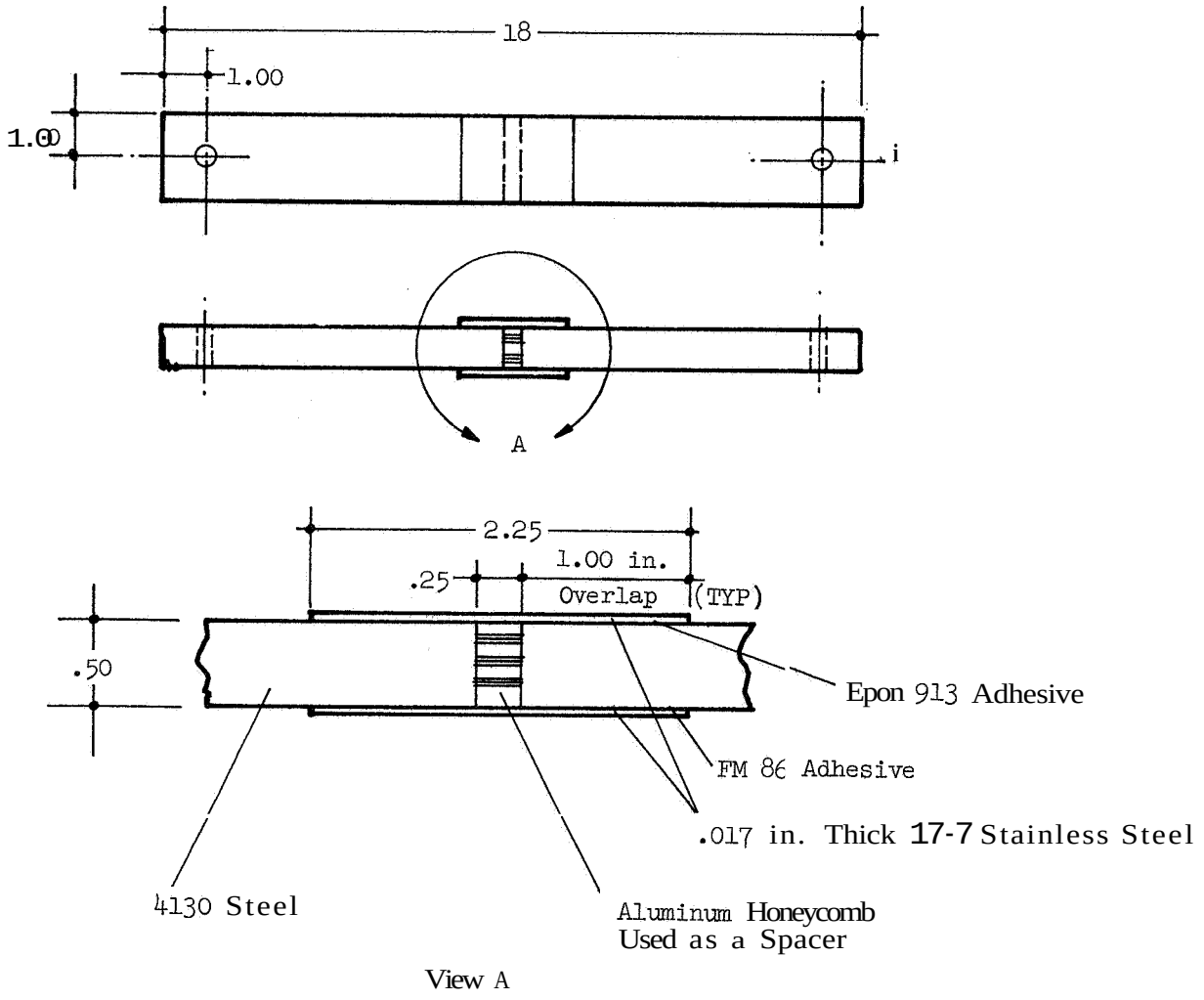
Figure 140

Low-Temperature Curing Adhesives	CURE SCHEDULE NO. 1 Tensile Strength and Mode of Failure	CURE SCHEDULE NO. 2 Tensile Strength and Mode of Failure	CURE SCHEDULE NO. 3 Tensile Strength and Mode of Failure
A. Epon 940 (Shell Chemical Co.)	Cured at room temperature	Cured 16 hr at 110°F	Cured 24 hr at 110°F
Specimen A	Panels fabricated but not tested because of low values obtained on Cure Schedule No. 3	Panels fabricated but not tested because of low values obtained on Cure Schedule No. 3	120 psi Core Adhesion 100%
Specimen B			132 psi Core Adhesion 100%
Specimen C			101 psi Core Adhesion 100%
Average			118 psi
B. Epon 940 (Shell Chemical Co.)	Cured 2 hr at 190°F	Cured 3 hr at 190°F	Cured 4 hr at 190°F
Specimen A	635 psi Cohesive 95% Core Rupture 5%	765 psi Cohesive 70% Core Adhesion 3%	335 psi Cohesive 40% Core Adhesion 60%
Specimen B	700 psi Cohesive 90% Core Rupture 10%	680 psi Cohesive 60% Core Adhesion 4%	570 psi Cohesive 75% Core Adhesion 25%
Specimen C	525 psi Cohesive 25% Core Rupture 75%	590 psi Cohesive 70% Core Adhesion 3%	650 psi Cohesive 80% Core Adhesion 20%
Average	620 psi	680 psi	520 psi
C. FM-86 (Blooming-Dale Rubber Co.)	Cured 4 hr at 160°F	Cured 6 hr at 4 °F	Cured 8 hr at 160°F
Specimen A	712 psi Cohesive 90% Face Adhesion 10%	930 psi Cohesive 100%	970 psi Cohesive 10%
Specimen B	805 psi Cohesive 90% Face Adhesion 10%	----------Damaged	1080 psi Cohesive 10%
Specimen C	758 psi Cohesive 95% Face Adhesion 5%	990 psi Cohesive 100%	995 psi Cohesive 95%, Core Rupture 5%
Average	758 psi	960 psi	1015 psi
High Temperature Curing Adhesives			
A. Metalbond 400 (Narmco Mat'ls Inc.)	Cured 1 hr at 350 F	Cured 2 hr at 350°F	Cured 3 hr at 350°F
Specimen A	500 psi Core Adhesion 100%	Panels Fabricated but not tested. Replaced by AF-110 Adhesive	Panels fabricated but not tested. Replaced by AF-110 Adhesive
Specimen B	540 psi Core Adhesion 90% Skin Adhesion 10%		
Specimen C	--- Bond to Loading block failed		
Average	520 psi		
B. AF-110 (3M Co.)	Cured 1 hr at 350 F	Cured 2 hr at 350°F	Cured 3 hr at 350°F
Specimen A	925 psi Bond to Loading Block Failed	990 psi Cohesive 5% Core Rupture 95%	1030 psi Core Rupture 100%
Specimen B	690 psi Core Rupture 85% Core Adhesion 10% Skin Adhesion 5%	935 psi Cohesive 10% Core Rupture 90%	1015 psi Core Rupture 95% Cohesive 5%
Specimen C	1055 psi Core Rupture 60%	935 psi Cohesive 15% Core Rupture 85%	950 Core Rupture 95% Cohesive 5%
Average	890 psi	965 psi	1000 psi
C. FM-1000 (Blooming-Dale Rubber Co.	Cured 1 hr at 340°F	Cured 2 hr at 340°F	Cured 3 hr at 340°F
Specimen A	550 Core Adhesion 50% Skin Adhesion 50%	535 Core Adhesion 60% Skin Adhesion 40%	525 Core Adhesion 100%
Specimen B	530 Core Adhesion 50% Skin Adhesion 50%	500 Core Adhesion 50% Skin Adhesion 50%	515 Core Adhesion 100%
Specimen C	510 Core Adhesion 50% Skin Adhesion 50%	450 Core Adhesion 90% Skin Adhesion 10%	485 Core Adhesion 100%
Average	530 psi	495 psi	510 psi

Specimens were bonded with 5 to 10 psi pressure

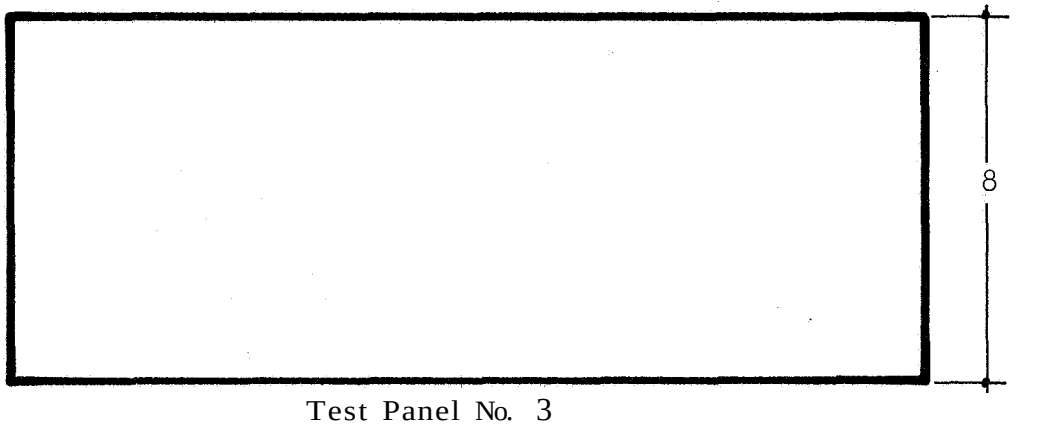
Flatwise Tensile Strength of Adhesives

Figure 141

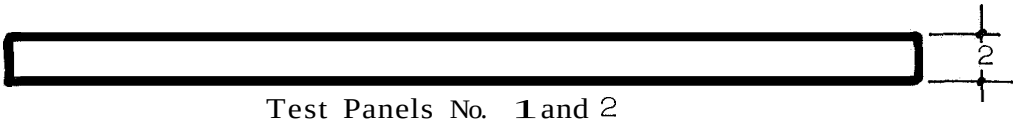


Exit Cone Attachment Ring-to-Honeycomb-Bond Test Specimen

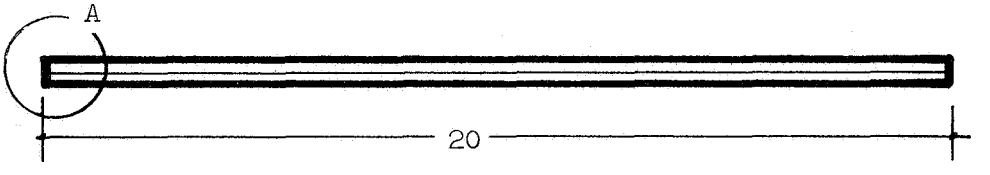
Figure 142

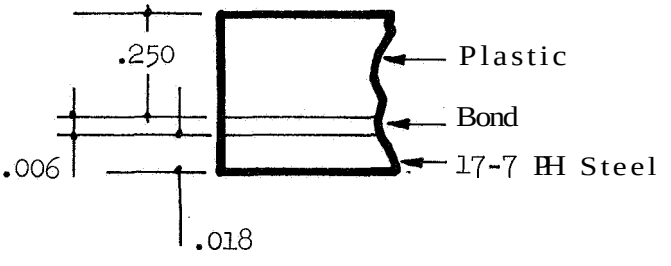


Test Panel No. 3



Test Panels No. 1 and 2

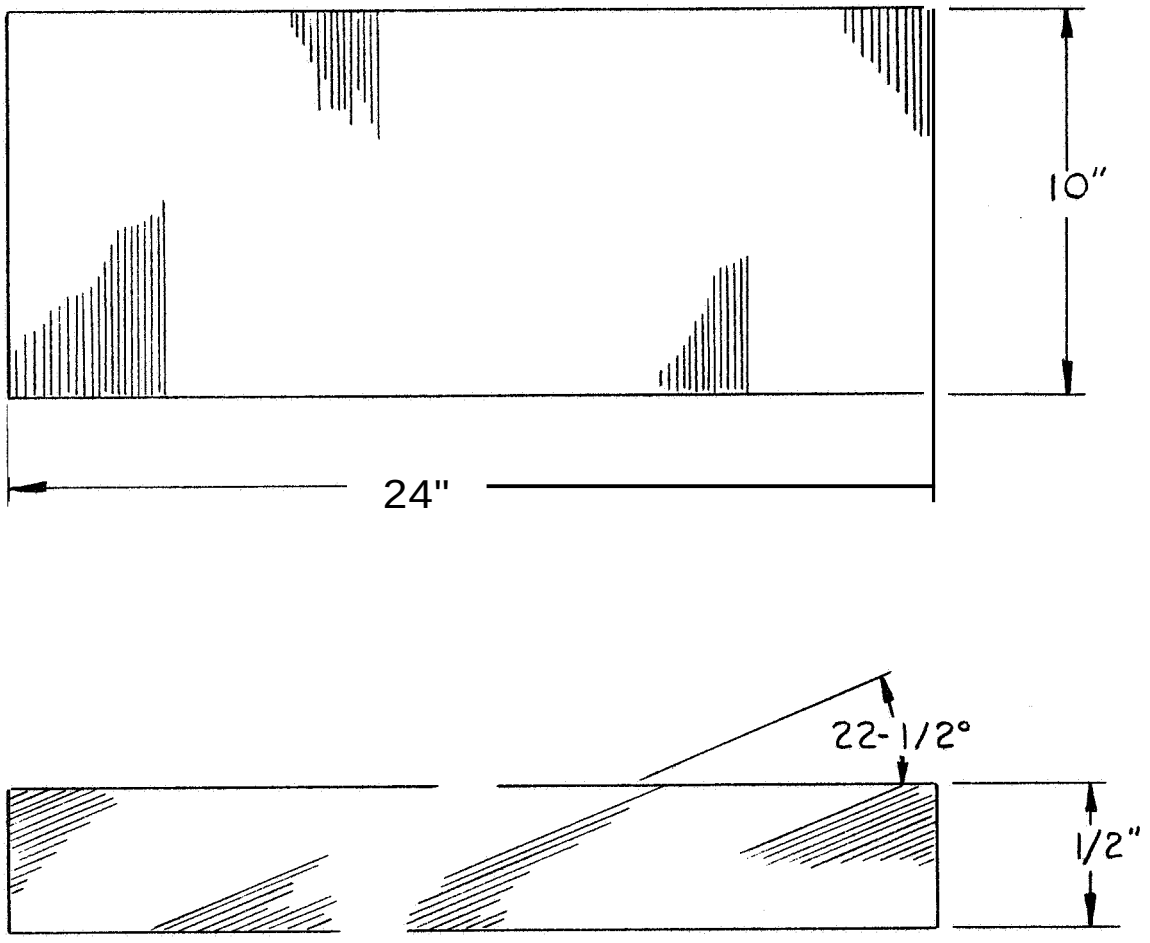




Detail A

Test Panels for Thermal Stress Measurements

Figure 143



Oriented Plastic Test Panels Prepared for Stress Analysis
Between Ablative Liner and Honeycomb Skins

Figure 144

Flatwise Tensill-e Strength
(Specimens Tested per ASTM C 297-55)

Specimen No.	Stress, psi	Mode of Failure
1	700	Cohesive 90%, Core Rupture 10%
2	-	Broke before test
3	185	Cohesive 90%
4	280	Cohesive 100%
5	740	Cohesive 100%
6	470	Cohesive 85%
7	300	Cohesive 100%
8	270	Cohesive 80%
9	240	Cohesive 80%
10	550	Cohesive 80%
11	700	Cohesive 95%
12	375	Cohesive 90%
Average	435	

Flexural Strength
(3 by 8 in. Specimens, 6 in. Span. Loading at 2 - One-Quarter Span Points)
Core Ribbon Direction Normal to Beam

Specimen No.	Flexural Strength (Total Load), lb
1	810
2	1150
3	1130
4	1080
5	1120
6	1070
Average	1060

Core Ribbon Direction Parallel to Beam

1	1490
2	1490
3	1530
4	1560
5	1450
6	1430
Average	1490

Mechanical Properties of Honeycomb Vacuum Bonded with FM-86 Adhesive

Figure 145

17-7 PH, TH-1050 skins bonded to 1/4" cell aluminum core. Bond line temperature raised to 180°F in 120 minutes and then cured 4 hours at 180°F. Pressure - 25-27" Of Hg.

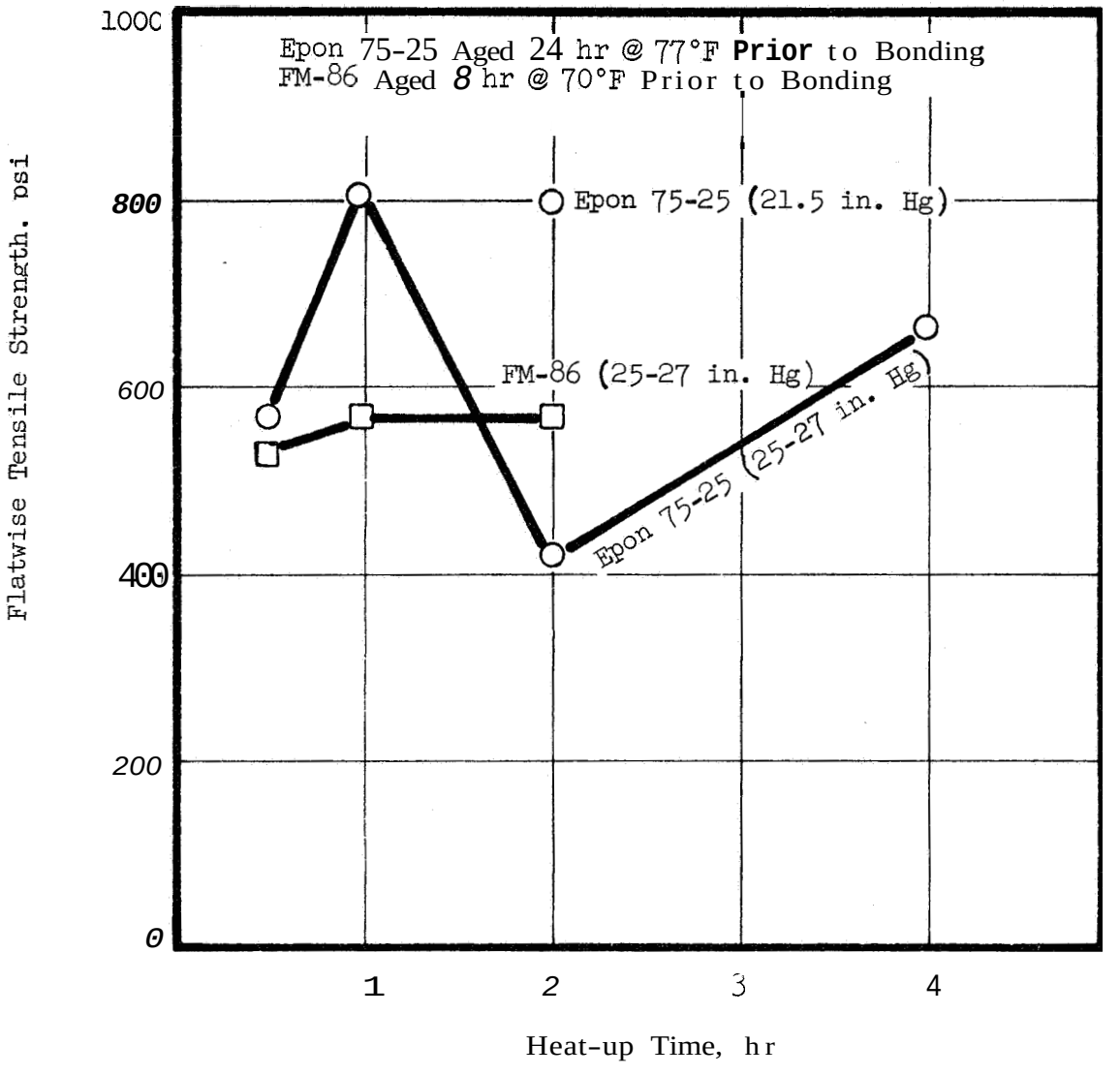
Specimen	Adhesive Exposure Time*, hr	Stress	Mode of Failure
1A	4-8	695 psi	Cohesive 100%
2A		720 psi	Cohesive 100%
3A		705 psi	Cohesive 100%
Average		705 psi	
1B	24	370 psi	**
2B		500 psi	**
3B		630 psi	Cohesive 100%
Average		500 psi	
1C	48	860 psi	Cohesive 100%
2c		820 psi	Cohesive 100%
3C		620 psi	Cohesive 100%
Average		765 psi	
1D	72	--	Specimen broke before test
2D		795 psi	Cohesive 100%
3D		770 psi	Cohesive 100%
Average		780 psi	

*Adhesive exposure time at 75°F prior to bonding

**The adhesive had flowed about 1/8 in. up the core and the fillet was thin or nonexistent. There also was a lack of adhesive left on the skin.

Flatwise Tensile Strength of **Epon** 75-25

Figure 146



Effect of Heat-up Time to 180°F and Vacuum Pressure on Strength of Adhesive

Figure 147

Specimen	Panel	Stress, psi	Mode of Failure
1	3	695	Cohesive and core
2	7	745	Loading block
3	6	810	Loading block
4	4	905	Core failure
5	2	485	Misaligned block
6	1	840	Core failure
7	5	745	Loading block
	Average	745	

Trepan Specimens Taken from the 120-SS Nozzle Exit Cone

Figure 148

Specimen		Flatwise Tensile Strength, psi	Mode of Failure
Bonded at 180°F 3 hr		700	Cohesive 90%, Core Rupture 10%
			Broke before test
		185	Cohesive 90%, Core Adhesion 10%
		280	Cohesive 100%
		740	Cohesive 100%
		470	Cohesive 85%, Core Adhesion 15%
		300	Cohesive 100%
		270	Cohesive 80%, Core Adhesion 20%
		240	Cohesive 80%, Core Adhesion 20%
		550	Cohesive 80%, Core Adhesion 20%
		700	Cohesive 95%, Core Adhesion 5%
		375	Cohesive 90%, Core Adhesion 10%
	Average	435	
3 heat cycles of 3 hr at 180°F		415	Cohesive 70%, Core Adhesion 30%
		---	Broke before test
		390	Cohesive 100%
	Average	400	
4 heat cycles of 3 hr at 180°F		625	Cohesive 90%, Core Adhesion 10%
		625	Cohesive 95%, Core Adhesion 5%
		360	Cohesive 65%, Core Adhesion 35%
	Average	535	

Effect of Heat Cycles on FM-86 Bond Strength of Vacuum Cured Panels

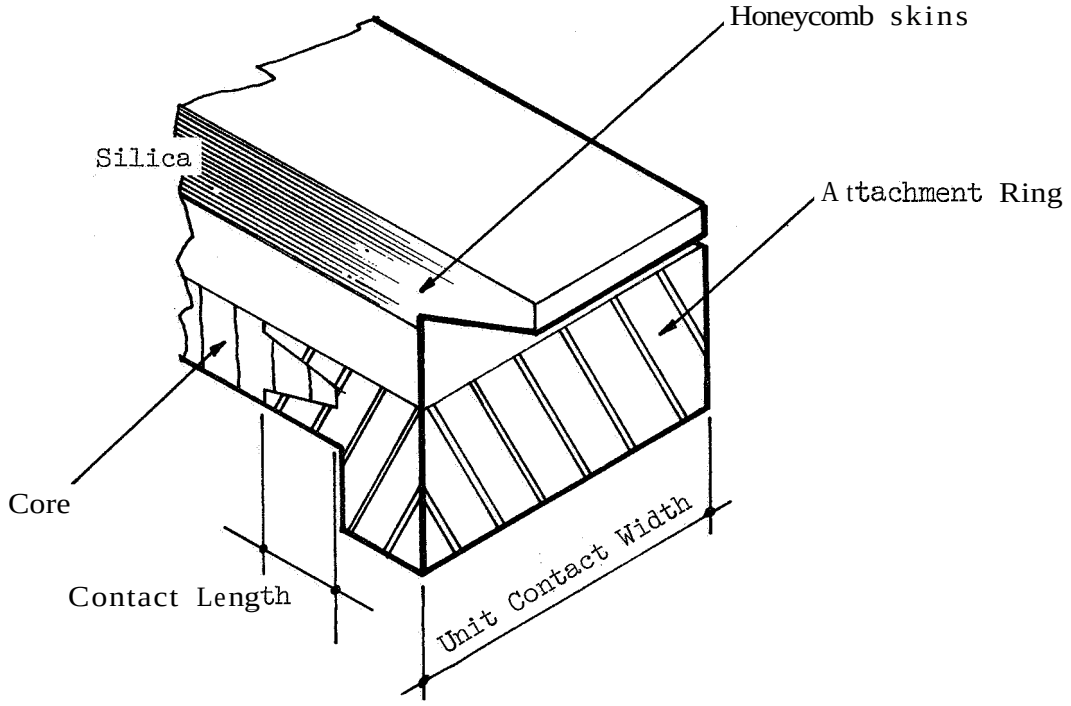
Figure 149

Adhesive Exposure Time at 70°F, hr	Average Flatwise Tensile Strength of Specimens, psi
1	584
2	846
4	1032
6	867
8	969
10	852
12	850
14	434

Note: Panels cured 2 hours at 190° ± 10°F at 90 psi bonding pressure (not contained in a vacuum bag).

Pot Life of FM-86 Adhesive

Figure 150



Schematic of Exit Cone Attachment Ring-to-Honeycomb Sandwich

Figure 151

Adhesive Compressive Strength (ASTM 695), psi

Specimen No.	Epon 913	Epon 933
1	9200	10,000
2	8900	9,000
3	9100	9,900
4	8900	10,000
5	9100	9,400
6	9400	9,400
Average	9100	9,650

Adhesive Tensile Strength and Elongation (ASTM-D638)

Specimen No.	Tensile, psi		Elongation,%	
	913	933	913	933
1	3400*	6000	--	9.9
2	5000	6800	--	11.4
3	5100	7200	--	12.8
4	5300	5860	--	8.9
5	5000	5940	--	9.2
6	5100	5590	--	7.8
Average	5100	6230	--	10.0

*This value omitted from average.

Adhesive Block Shear Strength (~~ASTM-D732~~), psi

Specimen No.	Epon 913	Epon 933
1	5500	6900
2	5900	6700
3	5800	6700
4	5900	5700
5	5800	5600
6	6000	5700
Average	5815	6215

Properties of Plastic to Metal Adhesives

Figure 152

a

Cured 3 hr at 180°F

Specimen No.*	Lap Stress—, psi	Mode of Failure
1A	1040	Tensile break in plastic
5A	1070	Tensile break in plastic
6A	1300	Tensile break in plastic
7A	1310	Tensile break in plastic

Cured 6 hr at 180°F

Specimen No.*	Lap Stress—, psi	Mode of Failure
1B	1550	Tensile break in plastic
2B	1450	Tensile break in plastic
3B	1520	Tensile break in plastic
4B	1320	Tensile break in plastic
5B	1020	Tensile break in plastic
6B	1160	Tensile break in plastic
7B	1510	Tensile break in plastic

* Data from specimens 2A, 3A, and 4A are erroneous
**Shear stress in lap at time of plastic failure

Lap Shear Tests of FM-5131 Bonded to 17-7 Stainless Steel with Epon 913 Adhesive (1/2-in. Lap)

Figure 153

Specimen	Failure	Load, lb	Area, sq in.	Stress, lb/sq in.
No primer				
1	Cohesive	1670	0.50	3340
2	"	1610	0.50	3220
3	"	1510	0.50	3020
4	"	1470	0.50	2940
5	"	1630	0.50	3260
6	"	1690	0.50	3380
7	"	1670	0.50	3340
			Average	3215
With primer				
1	Adhesive 10%	1430	0.50	2860
2	" 20%	1450	0.50	2900
3	" 10%	1490	0.50	2980
4	" 10%	1500	0.50	3000
5	" 20%	1550	0.50	3100
6	" 5%	1550	0.50	3100
7	" 15%	1530	0.50	3060
			Average	3000

NOTE: All specimens cured 3 hr at 180°F.

Lap Shear Tests of 17-7PH Stainless Steel Primed with Fuller 162-Y-22 and Bonded with Epon 913 Adhesive

Figure 154

One-quarter in. Gen-Gard V-44 Bonded to Primed Steel Plate

Time	70°F	80°F	100°F
8 hr	Not cured	Not cured	Not cured
12 hr	Not cured	Not cured	Not cured
18 hr	Not cured	Not cured	25 lb/in.
24 hr	Not cured	Not cured	45 lb/in.*
			37 lb/in.
48 hr	30 lb/in.	33 lb/in.	55 lb/in.
	25 lb/in.	27 lb/in.	50 lb/in.
72 hr	43 lb/in.	93 lb/in.	68 lb/in.
	32 lb/in.	83 lb/in.	50 lb/in.
1 wk	73 lb/in.	100 lb/in.	92 lb/in.
		90 lb/in.	60 lb/in.

*First value is initial maximum pull
Second value is leveling off pull

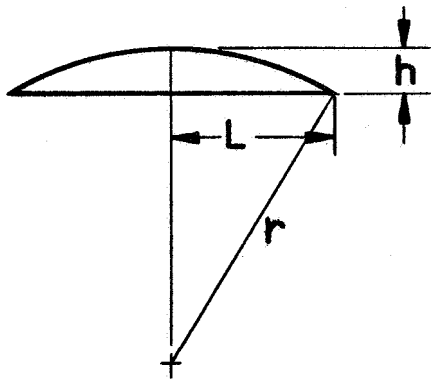
Epon 948 Peel Strength at Various Cure Cycles

Figure 155

Glue Line Thickness, in.	Failure	Load, lb	Area, sq in.		Stress lb/sq in.
0.006	Steel	2400	0.938		2560
		2650			2830
		2700			2880
		2300			2450
		2850			3040
		2650			2830
0.006	Steel	2350	0.938		2510
				Avg.	2730
0.033	Steel	2600	0.938		2770
		2350			2500
		2350			2500
		2750			2930
		2500			2660
		2500			2660
0.033	Steel	2900	0.938		3090
				Avg.	2730
0.037	Steel	2420	0.938		2580
		1950			2080
		2000			2130
		2200			2350
		1650			1760
	Adhesive	1400			1500
0.037	Adhesive	1320	0.938		1410
				Avg.	1970
0.120	Adhesive	1080	0.938		1150
		1090			1165
		840			895
		1040			1110
		1120			1190
		1160			1240
0.120	Adhesive	1030	0.938		1100
				Avg.	1120
0.205	Adhesive	155	0.938		165
		170			180
		180			190
		160			170
		160			170
		114			120
0.205	Adhesive	95			100
				Avg.	155

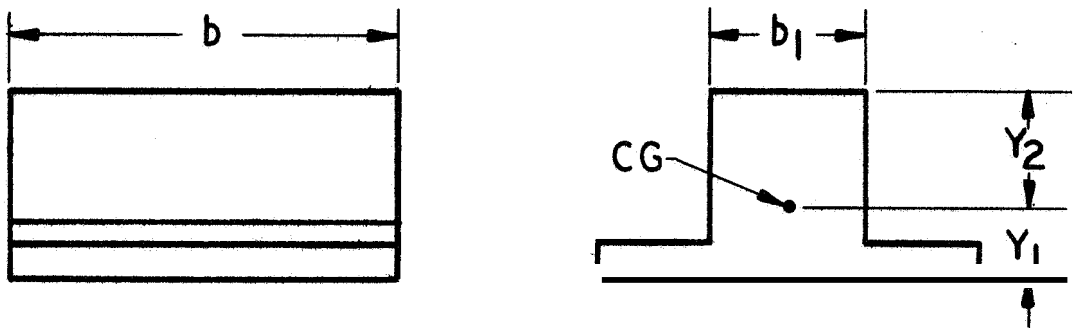
Effect of Glue Line Thickness on Bond Strength of 17-7 PH Stainless Steel Bonded with Epon 913

Figure 156



Radius of Curvature

Figure 157



Equivalent Steel Section

Figure 158

Panel No.	h* (in.)	r* (in.)	Steel (psi)	Plastic (psi)
1	0.0175	4167	+ 558	- 99
2	0.0185	2703	+ 860	- 153
3	0.048	1042	- 2233	+ 398

*See Figure 157 for definition of term.

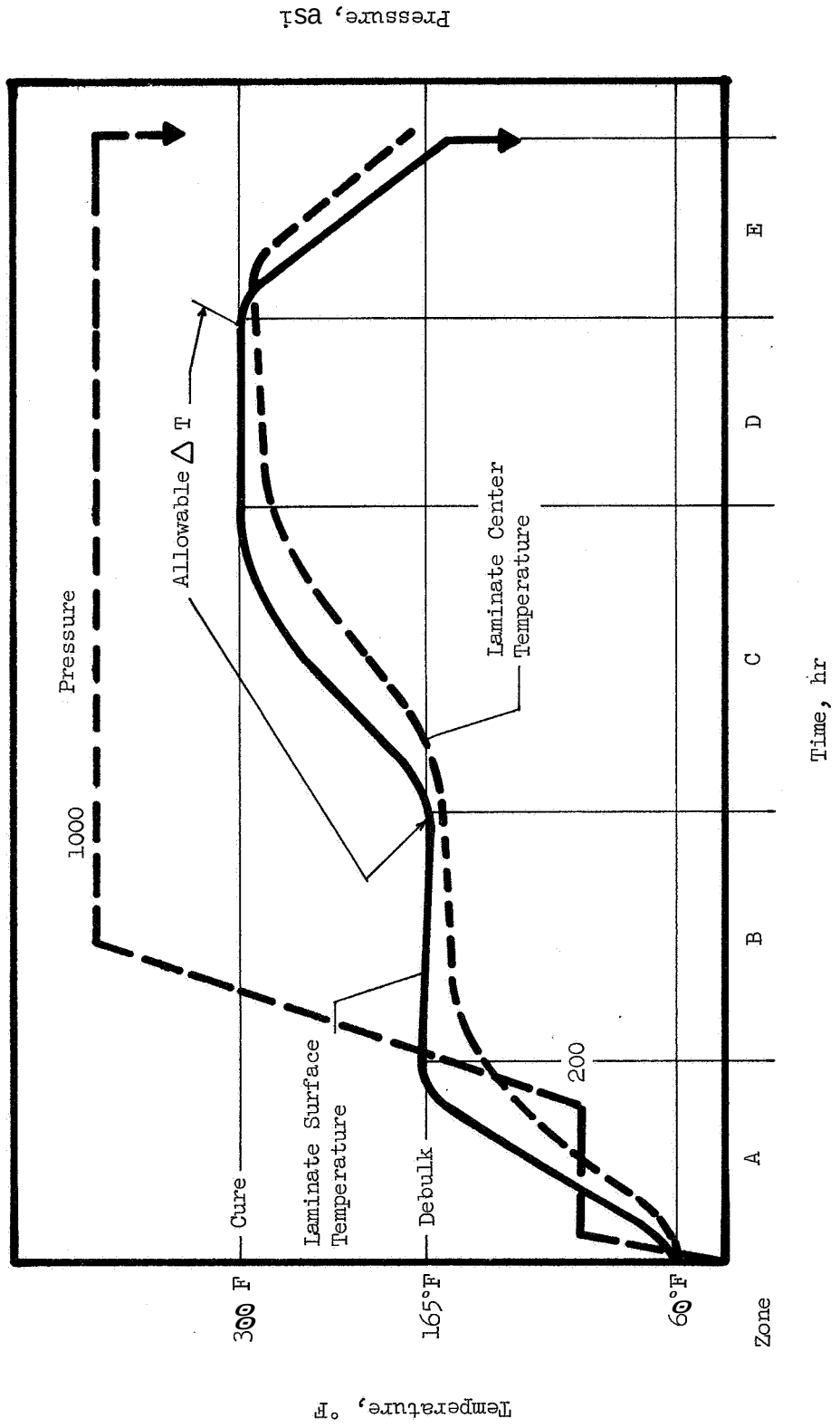
Bending Stresses in Test Panels

Figure 159

Property	Specification	MX-4926	FM-5131
Resin Solids, %	TAP-DAP-117	35.2	34.9
Volatile Content, %	TAP-DAP-102A	6.65	3.76
Degree of Polymerization, %	TAP-DAP-104A	13.0	27.2
Material Thickness, in.	-	0.029 to 0.031	0.037
Infrared Index	Fiberite Method I-3	1.06	1.454
Gel Time, sec	(See Subtask III)	174 & 182	120 & 144
Flow, %	TAP-DAP-105A	7.9	15.1
Tack, lbs	TAP-DAP-115A	10 Plus	10 Plus
Formability (Drape)	TAP-DAP-114	Acceptable	Acceptable
Acetone Extraction, %	ASTM-D-494	30.8	25.40

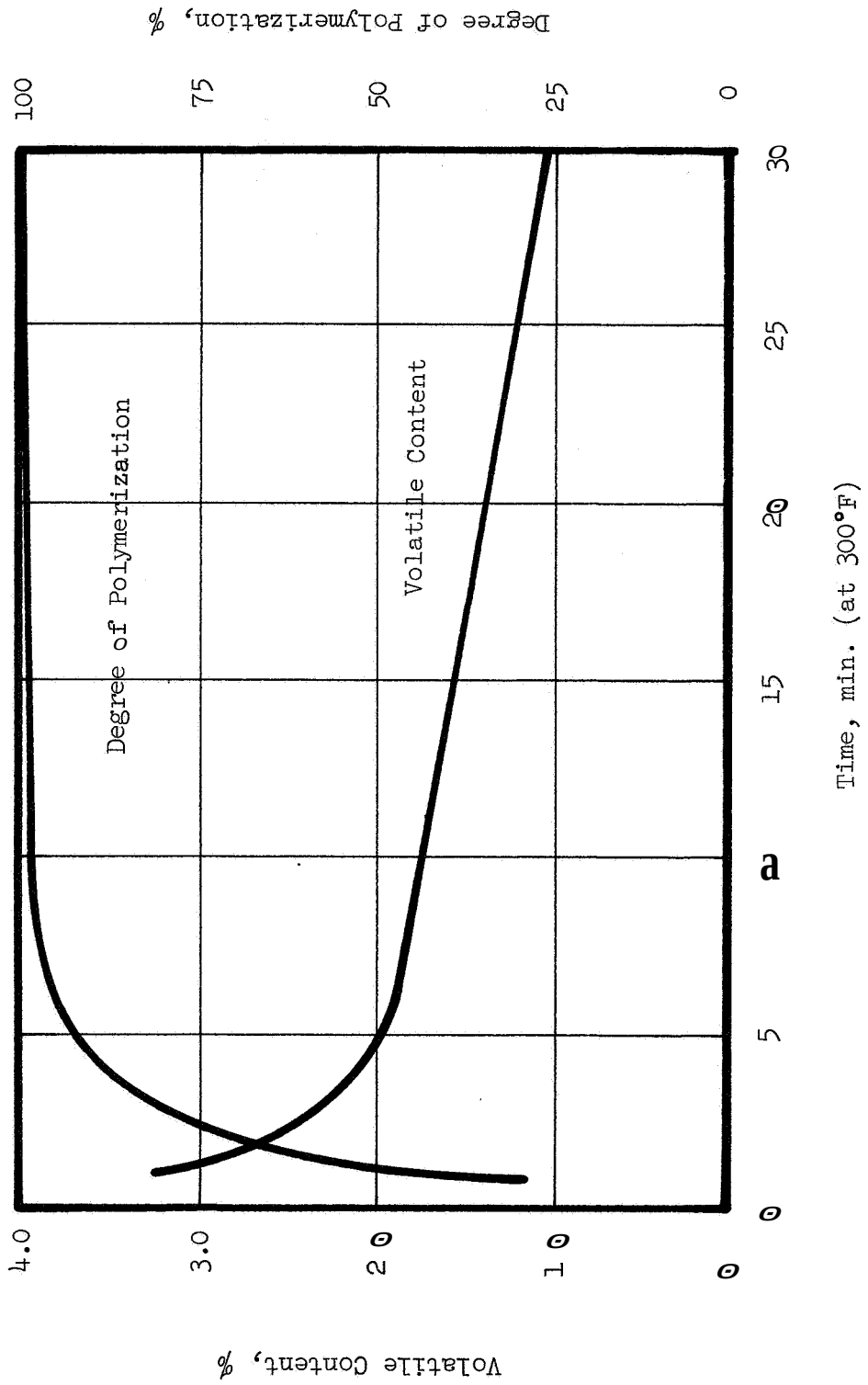
Properties of MX-4926 and FM-5131 Used for Subtask III

Figure 160



Preliminary Cure Cycle

Figure 161



Degree of Polymerization and Volatile Content of P926 at 300°F

Figure 162

Section	Temperature Gradient °F	Specific Gravity	Acetone Extractables, %	Thickness, in.	Volatile Content %	DMF * Extraction, %	Degree of Polymerization, %
A	179-164	1.39	35.30	0.970	3.69	39.40	2.7
B	175-164	1.38	35.90	0.077	3.86	40.20	1.0
C	164-158	1.35	37.20	0.981	4.23	36.50	0.0
D	158-150	1.33	33.60	0.975	3.88	43.80	7.3

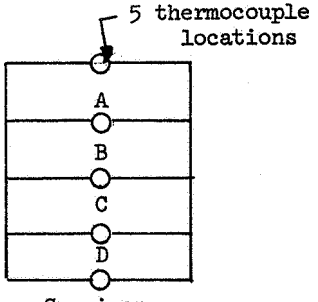
Reference Data

100% molded density: 1.43

Raw material acetone extractable content, 34.1%

Raw material resin solids content, 36.3%

*DMF - DiMethyl Formamide



Specimen Configuration

Figure 163

Densification Study Results, Specimen No. 1, MX-4926
Separated in Four 70 Ply Segments (A, B, C, and D)

Segment	Temperature Gradient °F	Specific Gravity	Acetone Extractables, %	Thickness, in.	Volatile Content %	DMF * Extraction, %	Degree of Polymerization %
A	312-262	1.44	0.40	0.919	2.75	6.42/7.66	98.9
B	262-230	1.44	5.91	0.941	2.41	38.90	83.7
C	230-208	1.42	7.14	0.942	1.84	38.60	80.3
D	208-180	1.38	18.72	0.951	0.40	40.40	48.4

Reference Data

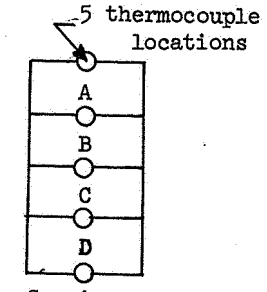
100% molded density, 1.44

Raw material acetone extractable content, 34.1%

Laminate total thickness, 3.750 inches

Raw material resin solids content, 36.3%

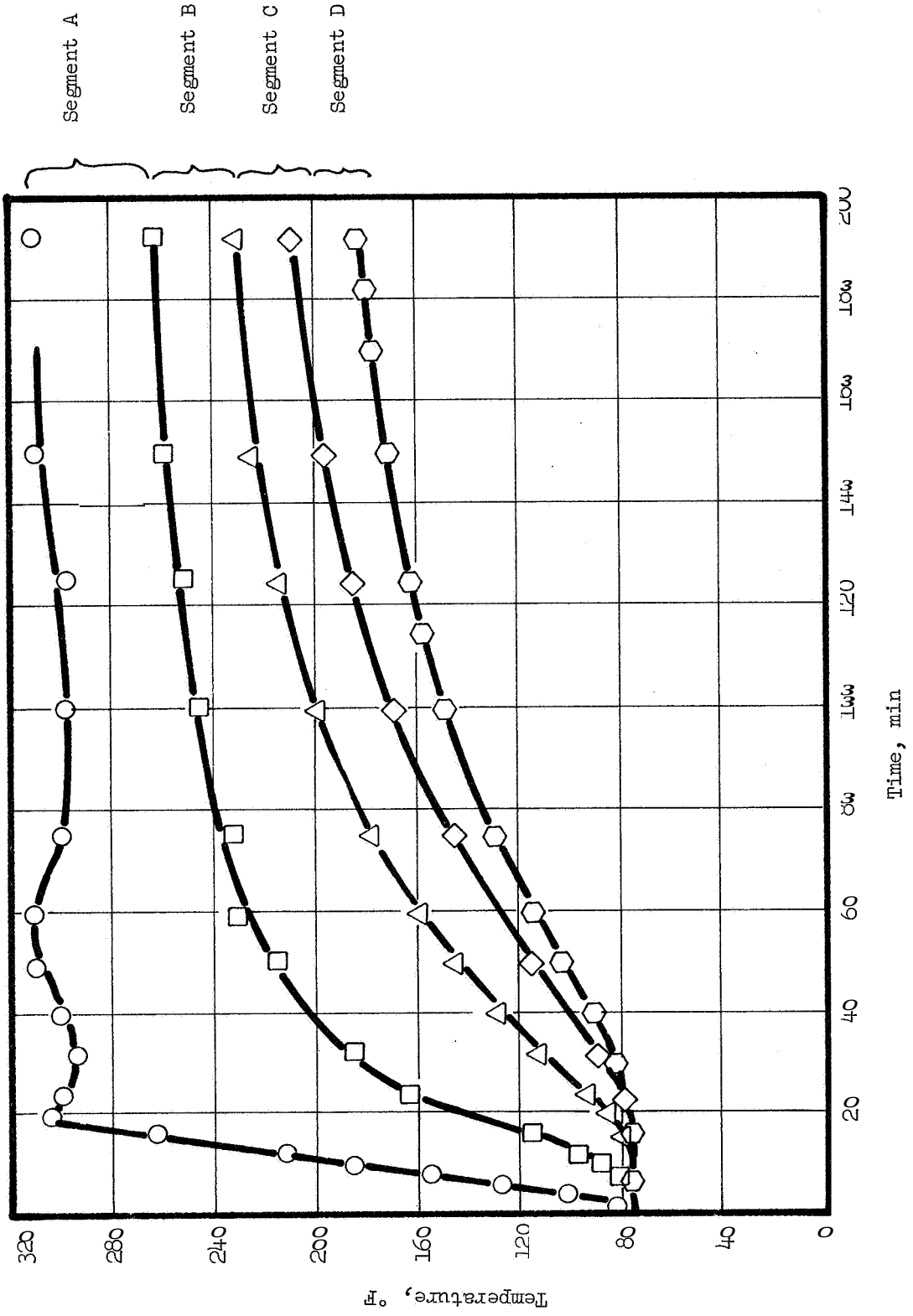
* DMF - DiMethyl Formamide



Specimen Configuration

Densification Study Results, Specimen No 2, MX-4926

Figure 164



Temperature Gradients, Specimen No. 2, MX-4926 Carbon Phenolic

Figure 165

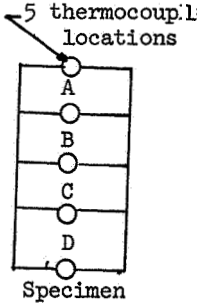
Segment	Temperature Gradient °F	Specific Gravity	Acetone Extractables, %	Thickness, in.	Volatile Content %	Resin Solids, %	Degree of Polymerization %
A	180-165	1.65	23.20	0.486	3.84	33.75	31.2
B	165-149	1.63	26.80	0.505	3.62	34.90	23.2
C	149-136	1.63	26.80	0.505	3.62	34.90	23.2
D	136-125	1.64	26.65	0.504	3.53	34.30	22.3

Reference Data

100% molded density: 1.65 - 1.68

Raw material: Acetone extractable content, 25.40%; volatile content 3.76%; resin solids 34.90%

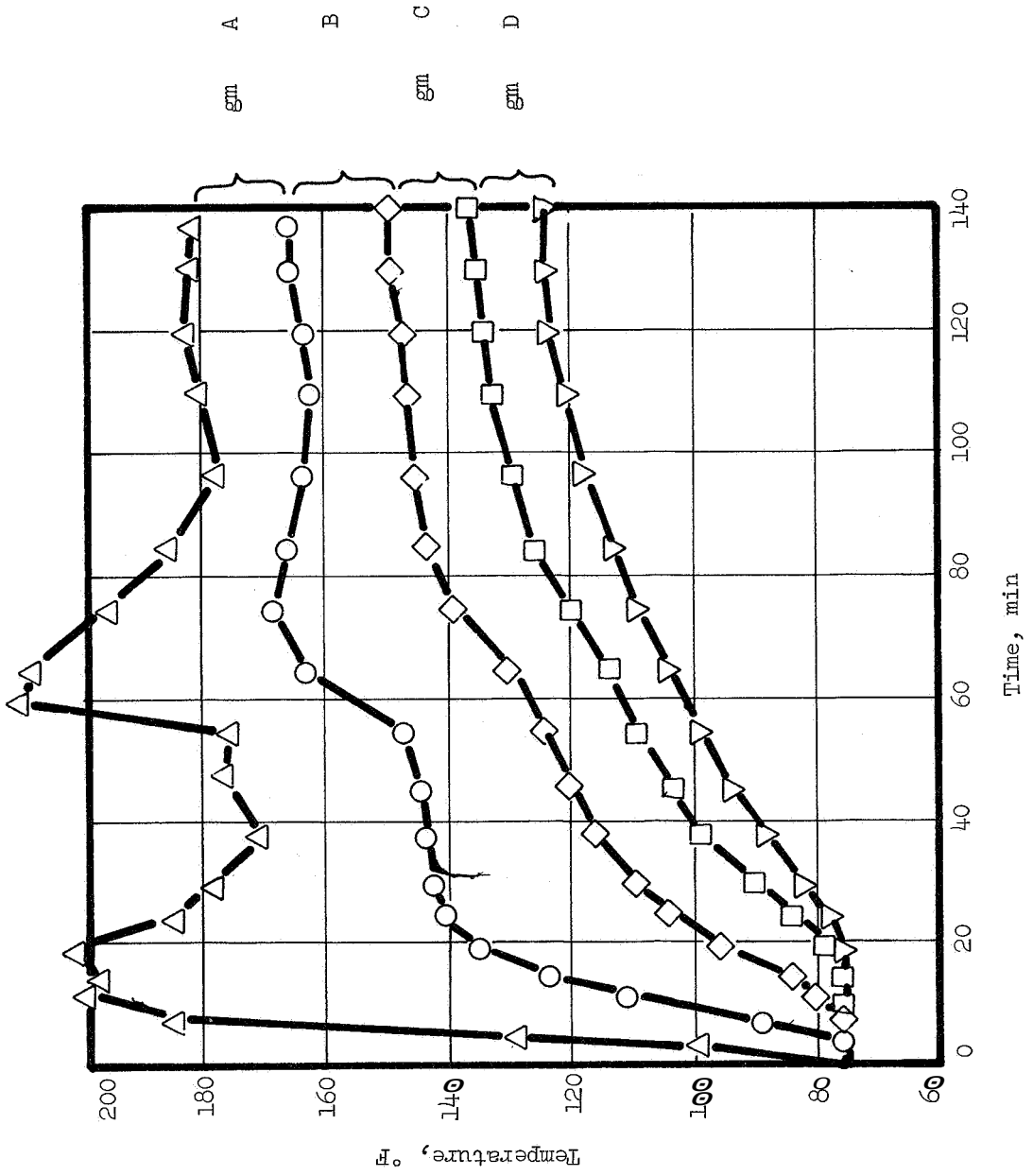
Laminate total thickness, 2.11 inches



Specimen Configuration

Densification Study Results, Specimen No. 3, FM-5131

Figure 166



Temperature Gradients, Specimen No. 3, FM-5131 Silica Phenolic

Figure 167

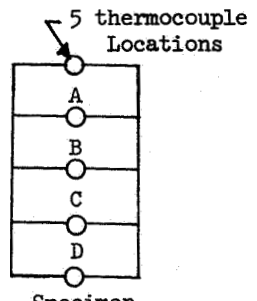
Segment	Temperature Gradient °F	Specific Gravity	Acetone Extractables, %	Thickness, in.	Volatile Content %	Resin Solids, %	Degree of Polymerization %
A	304-274	1.70	1.60	0.487	2.20	33.10	95.16
B	274-243	1.71	4.00	0.512	2.87	35.50	88.73
C	243-210	1.[illegible]	9.57	0.513	3.21	34.10	71.95
D	210-180	1.66	17.10	0.530	3.72	35.20	51.50

Reference Data

Raw material density: 1.65 - 1.68

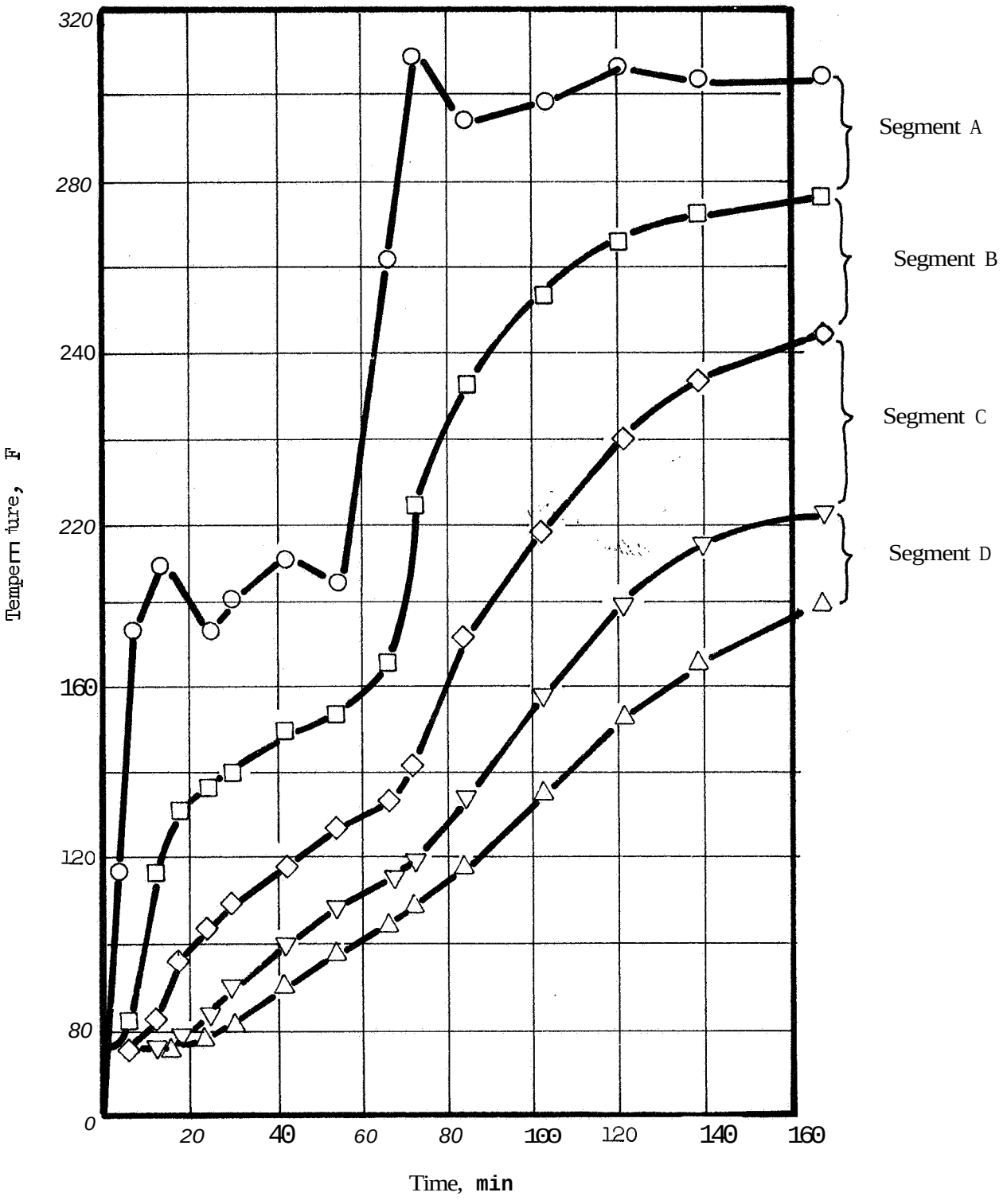
Raw material acetone extractable content: 25.40%

Laminate total thickness: 2.042 inches



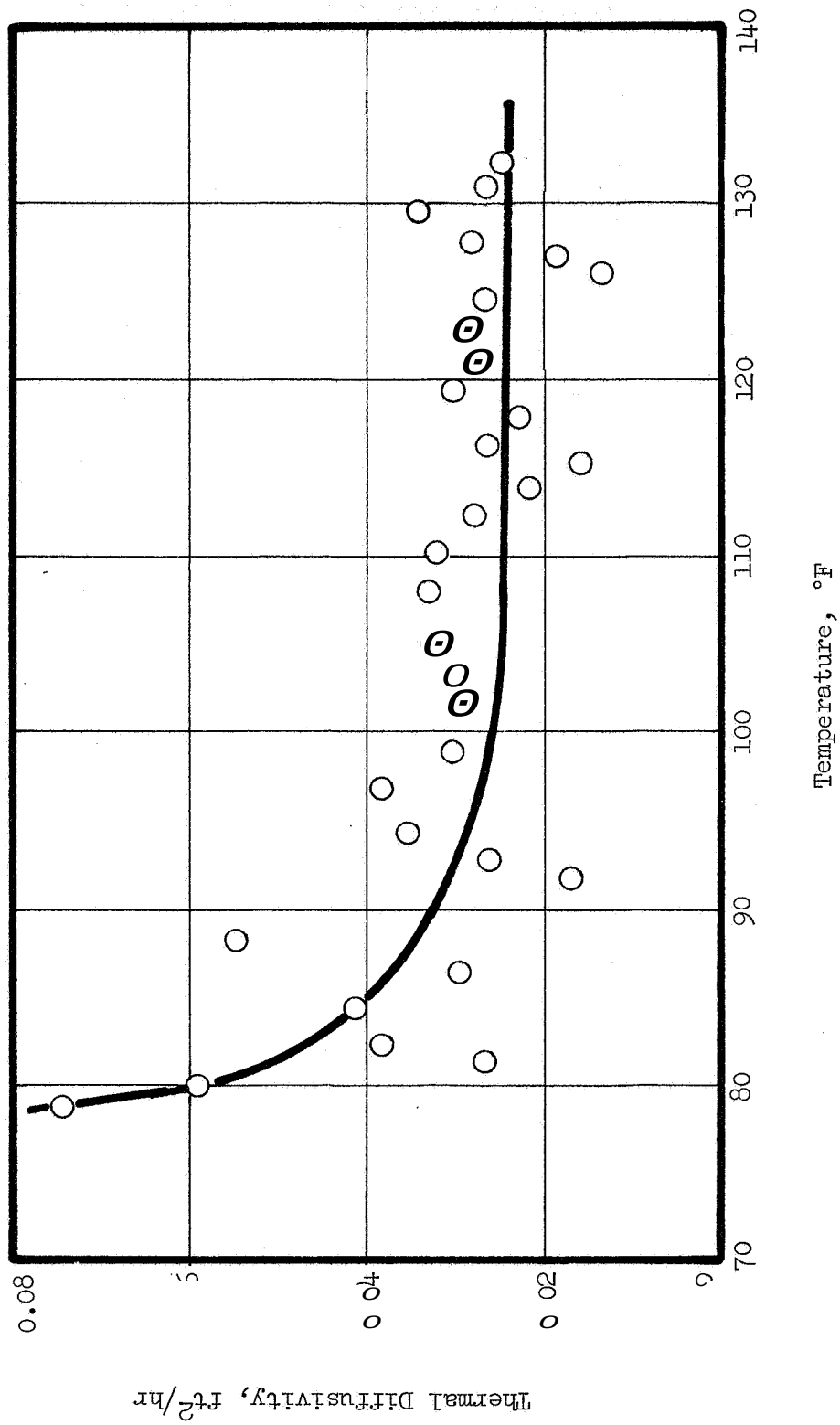
Specimen Configuration

Densification Study Results, Specimen No. 4, FM 5131



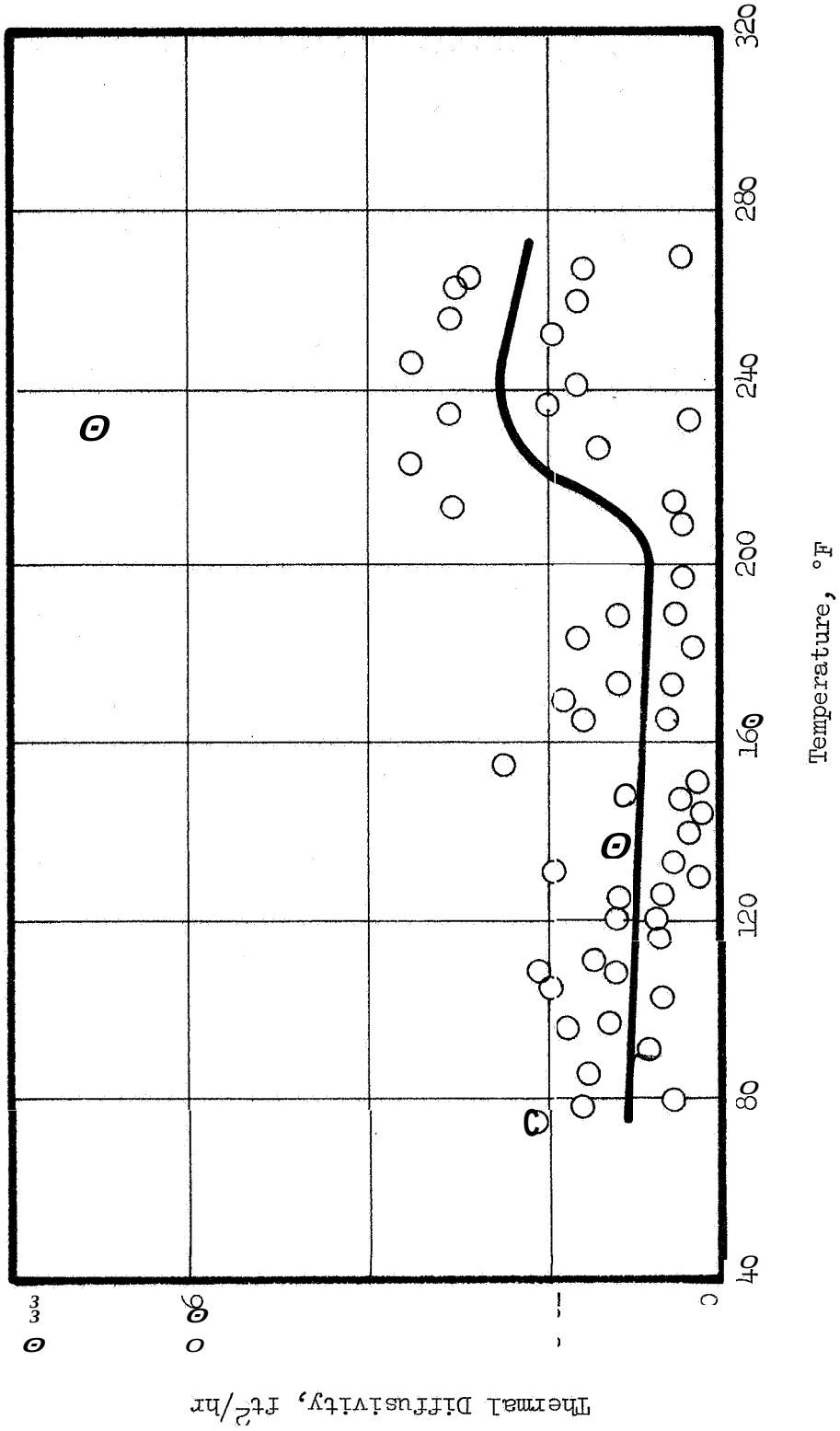
Temperature Gradients, Specimen No. 4, FM-5131 Silica Phenolic

Figure 169



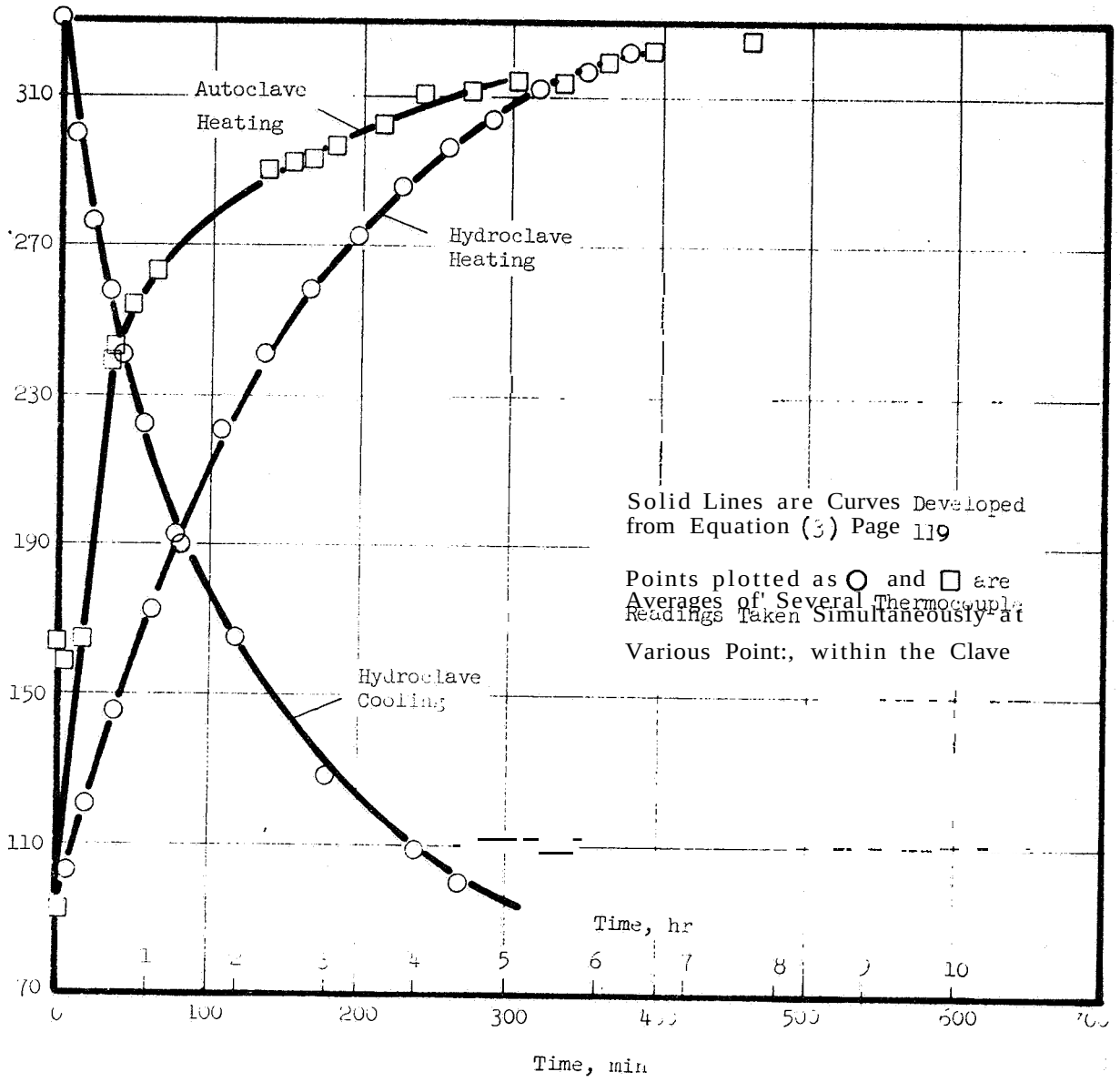
Thermal Diffusivity of MX 4926 Carbon Phenolic as a Function of Temperature

Figure 170



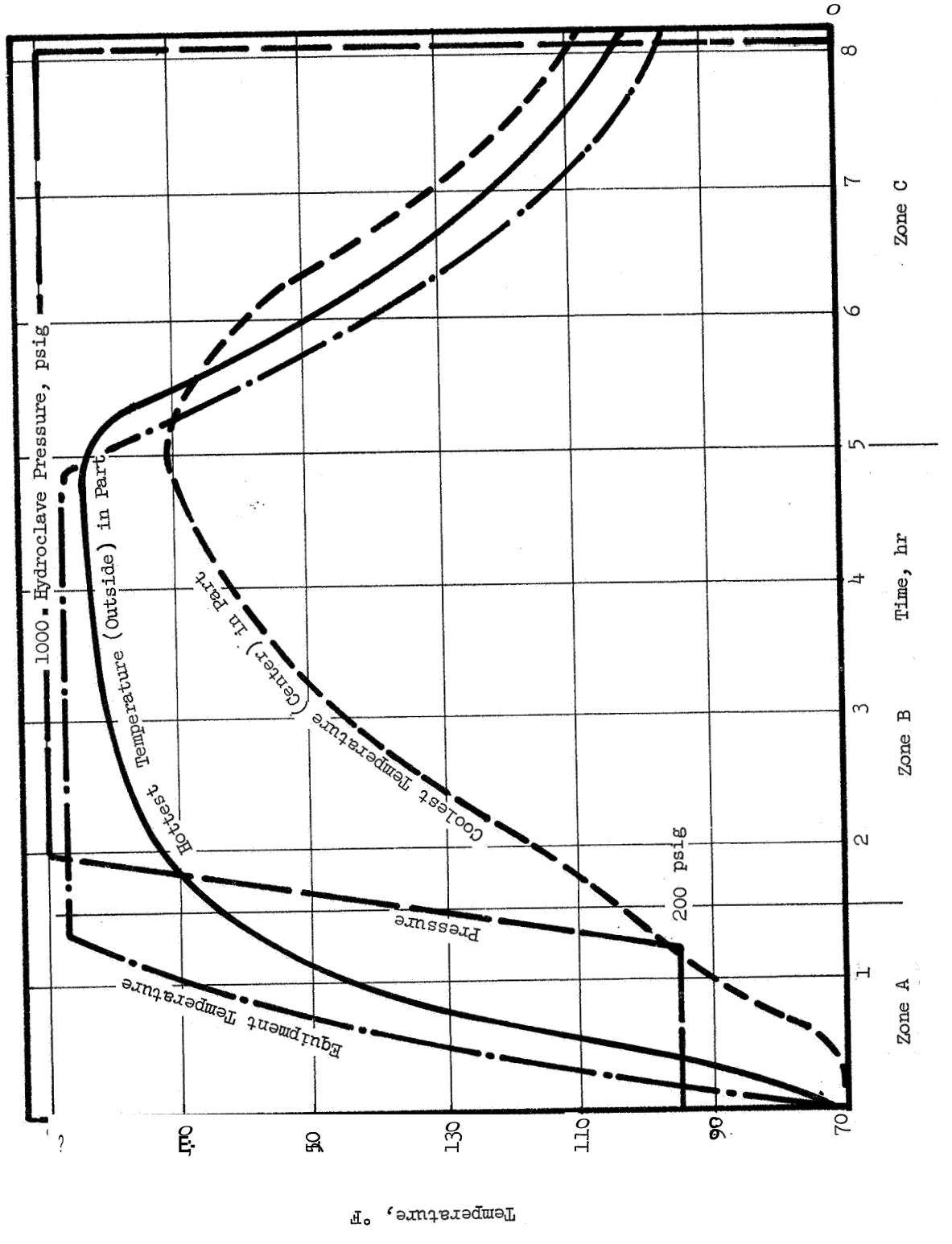
Thermal Diffusivity of FM-5131 Silica Phenolic as a Function of Temperature

Figure 171



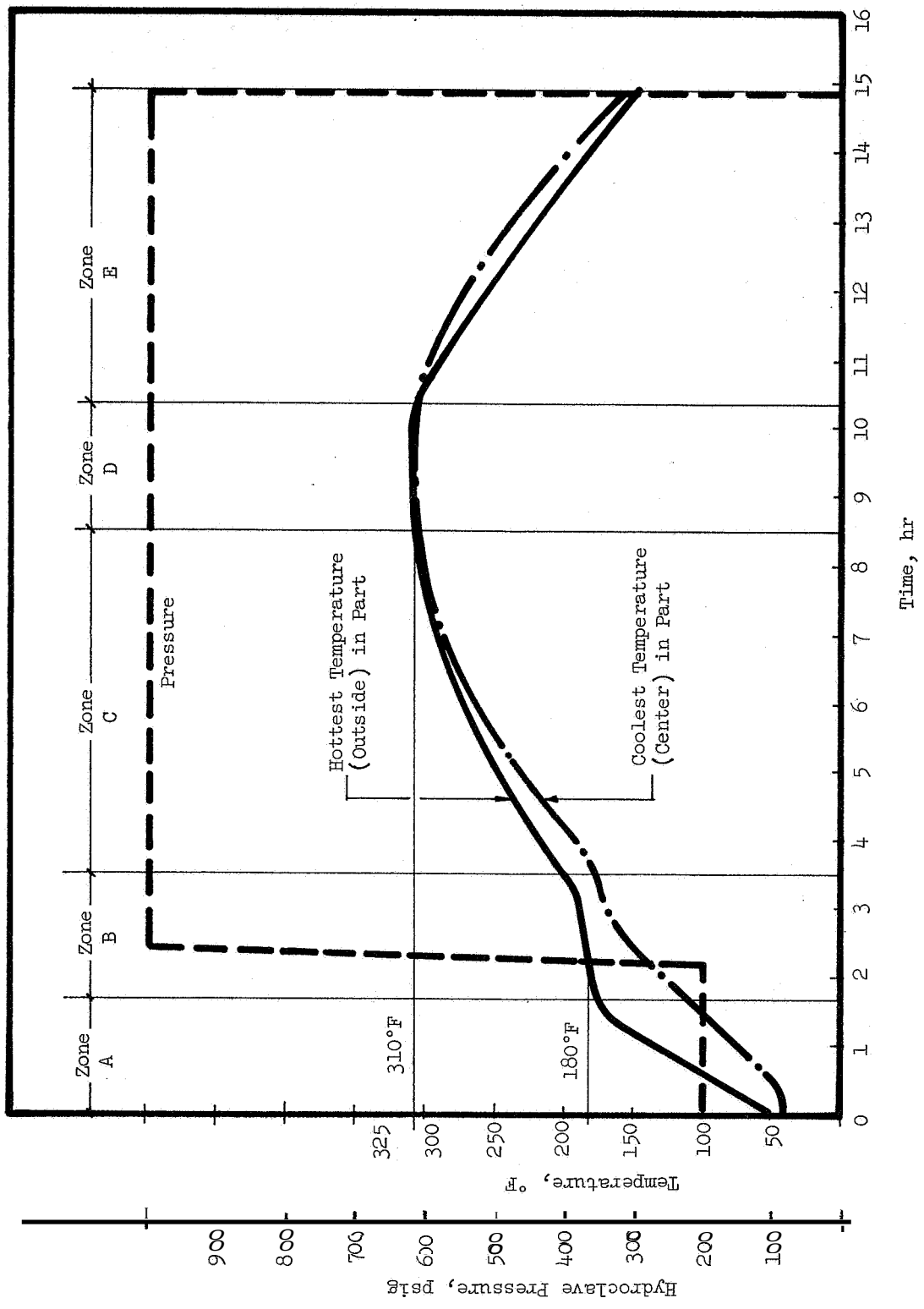
Temperature Response of TRW 130-in. Hydroclave - Autoclave

Figure 172



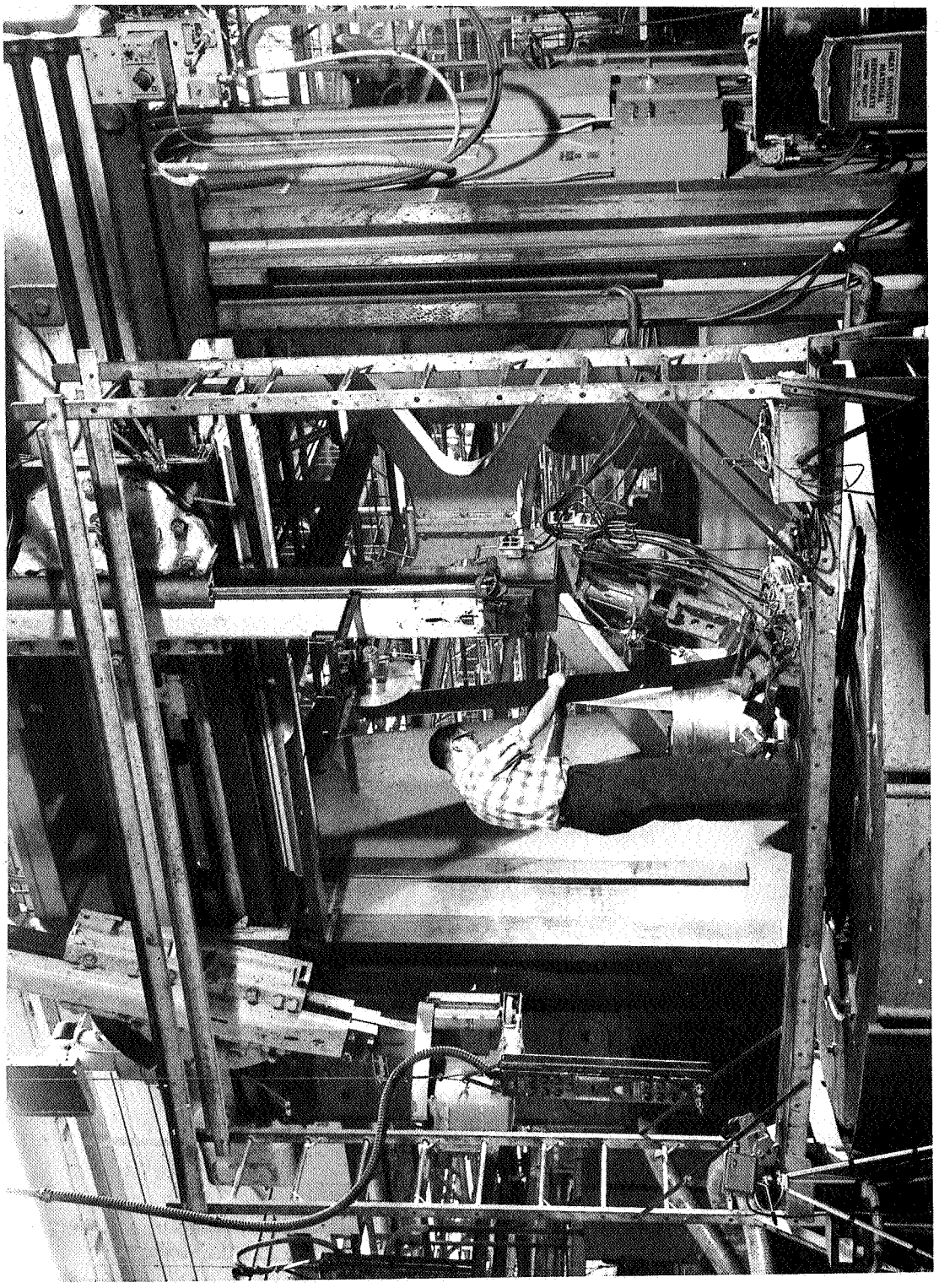
Predicted Preform C 4 for 120-SS Nozzle Half-Length Throat

Figure 173



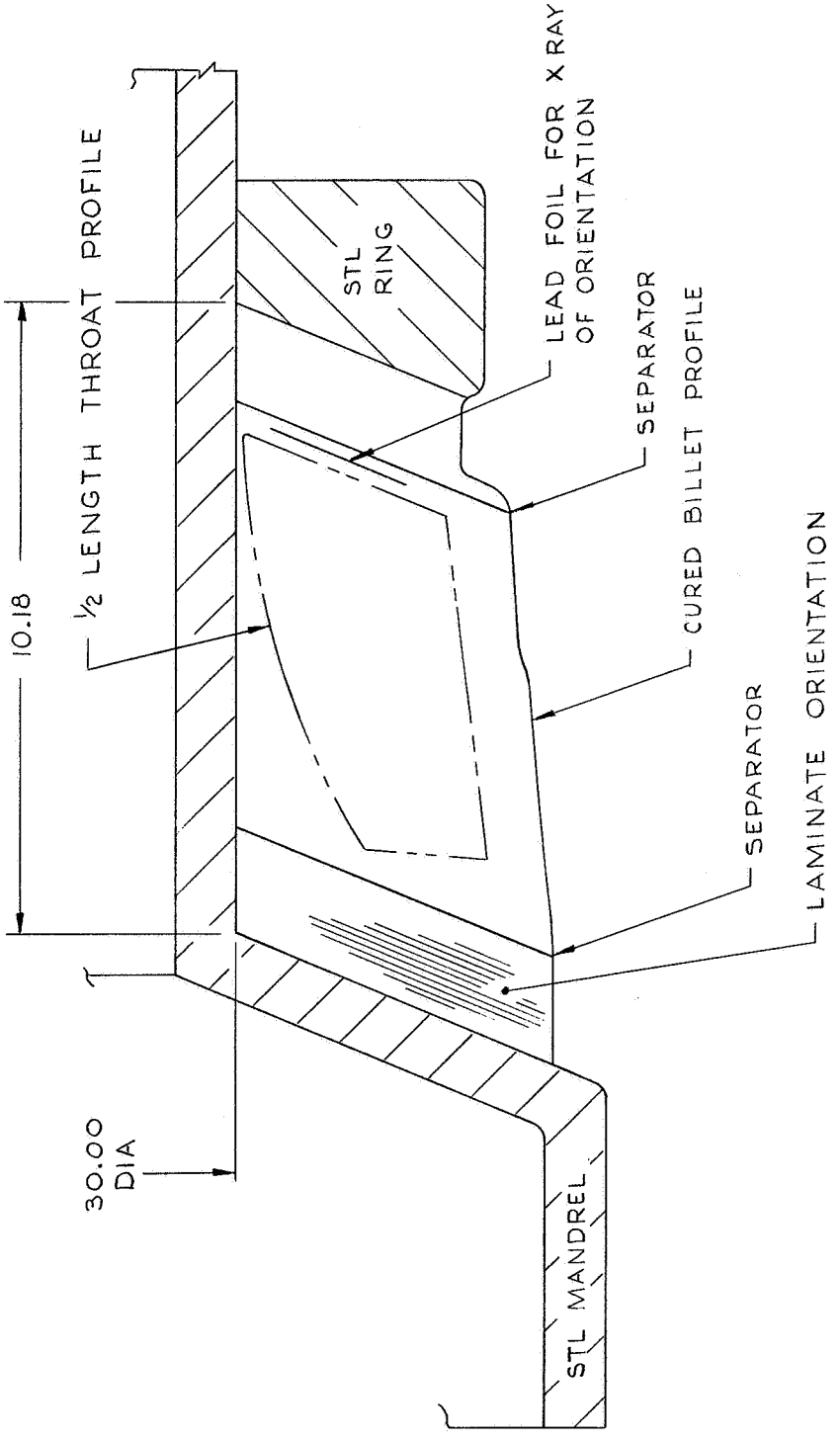
Predicted Cure Cycle for 120-SS Half-Length Throat

Figure 174



Wrapping the 120-SS Half-Length Throat on a 144-in. Betts Vertical Turret Lathe

Figure 175



Fabrication Sketch of 120-SS Half-Length Throat

Figure 176

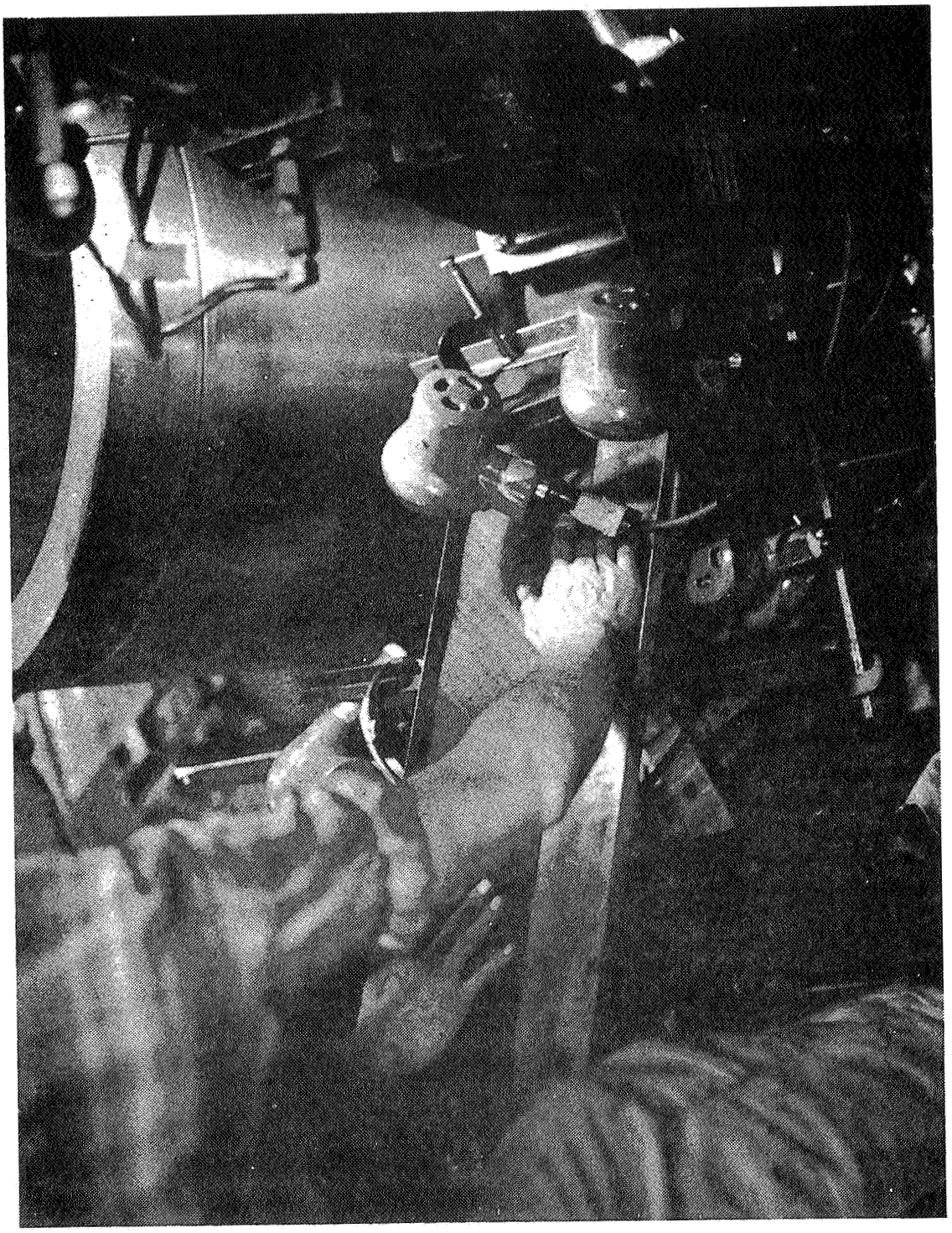
120 SS Xalf Length Throat

Material	MX 4926									FM 5131
Lot No	A220									G3133
Roll No	1	2	3	4	5	10	13	22	27	1
Raw Material Properties										
Tape Width, in.	4		5 5	5.5	Broad Goods	Broad Goods	5.0	5.5	5.25	18.0
Resin Content, %	33.0	36.2	35.5	36.2	35.5	32.5	35.4	33.6	36.4	31.0
Volatile Content %	4.6	4 5	46	4 5	46	4 5	4 8	46	4.7	4 3
Flow, %	2.7	4 3	4 3	4 3	4 3	2.0	4 3	3 5	5 0	10 3
Viscosity Index		2.1*		2.1 *			2.1 *		2.2	2 7
Tack lb		8.4 *		- -			8.4 *		- -	15 0
Drape lb		8 5 *		- -			8 5		- -	- -
IRPI Index		1.17 *		- -			- -		- -	- -
Molded Laminate Properties										
Specific Gravity		1 45		1 48	1 48		1 5*		1.54	1 79
Flexural Strength psi		42,000		44 500 *			42,000*		41.200	20,400
Flexural Modulus, psi		3,240,000		---			3,240,000*		---	2,430,000

* Average Value for all the rolls

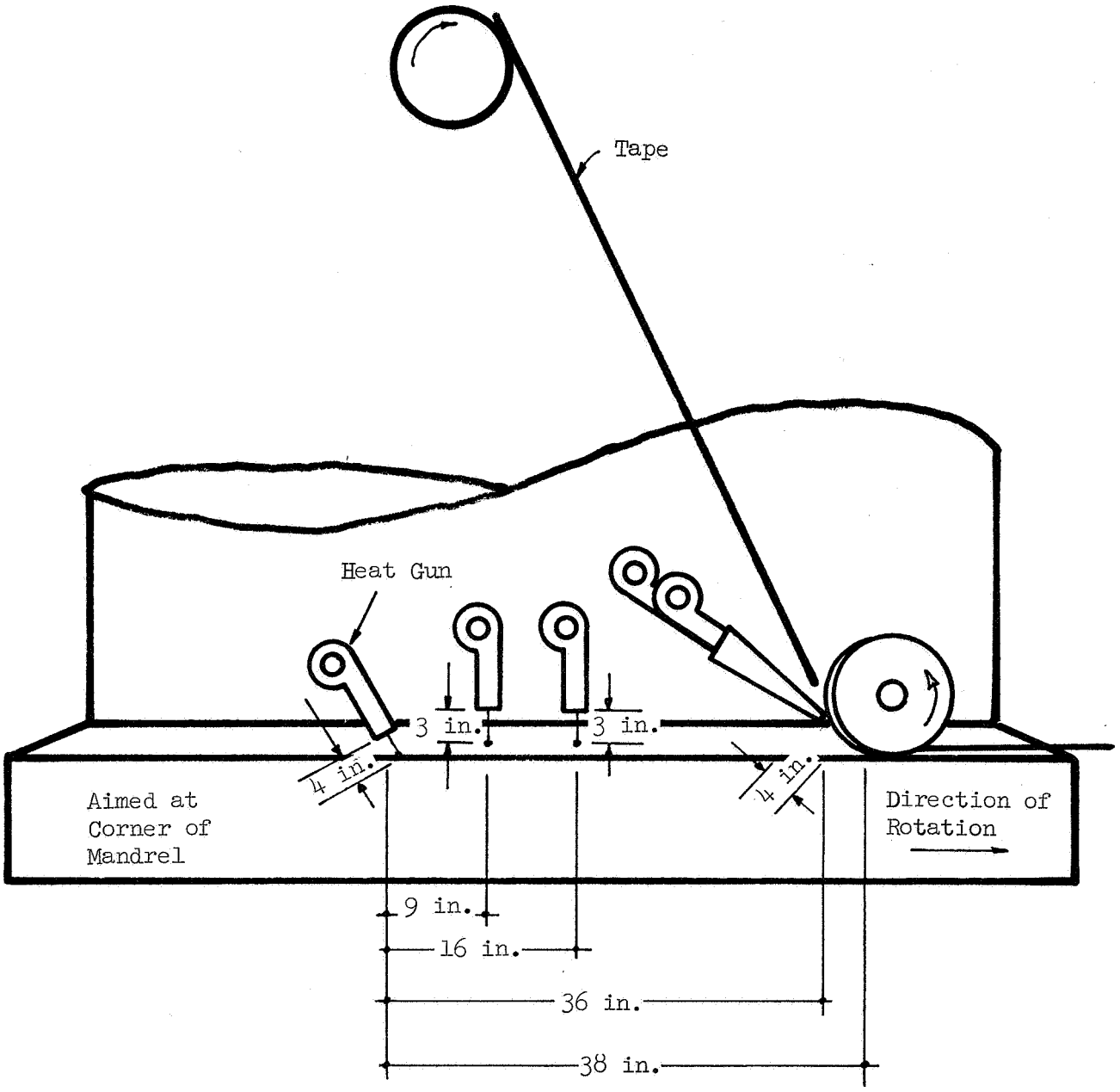
As-Received Material Properties of Raw Material and Cured Laminates

Figure 177



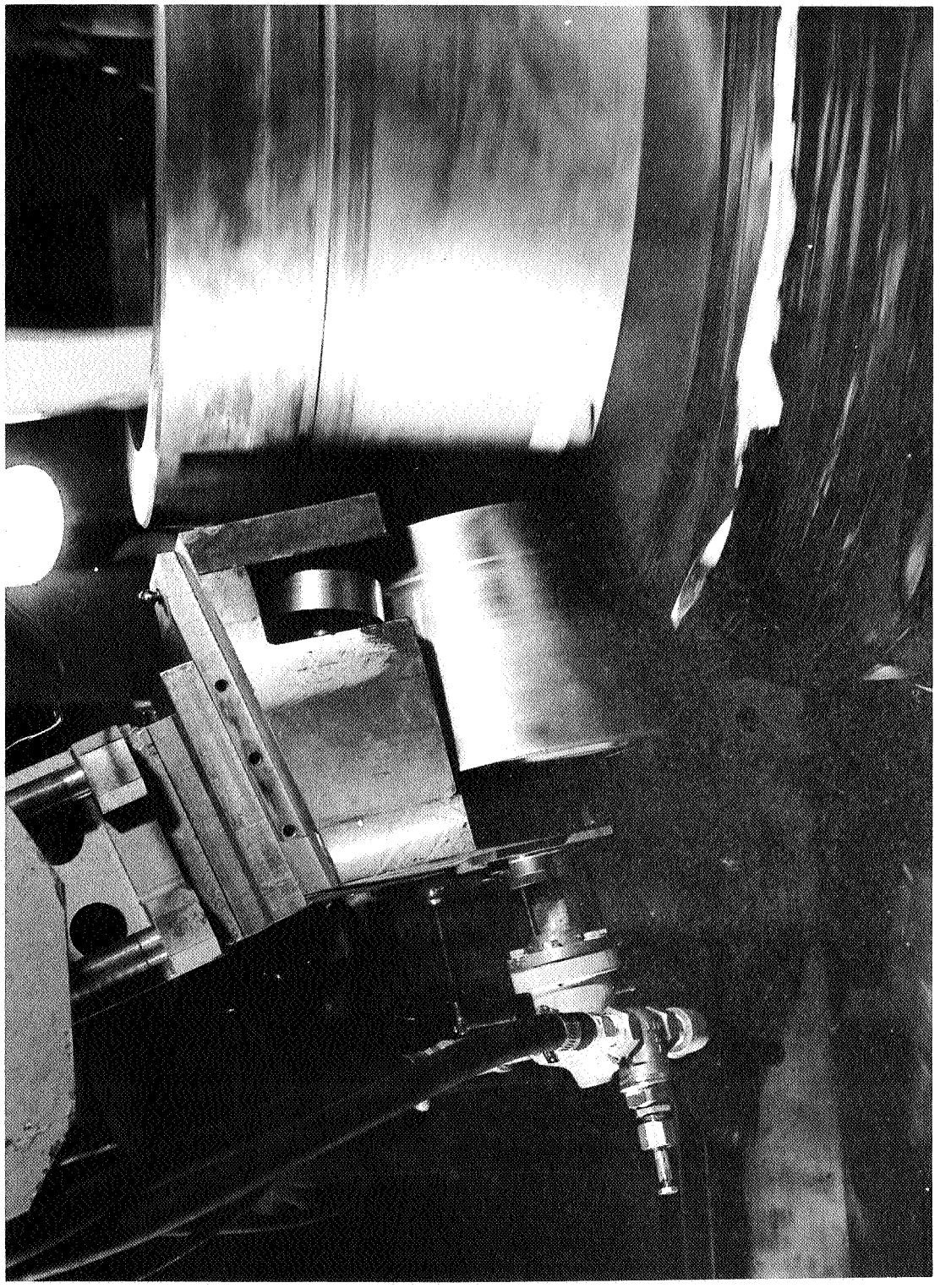
Experimenting with Chute to Feed MX-4926 to Debulking Roller

Figure 178



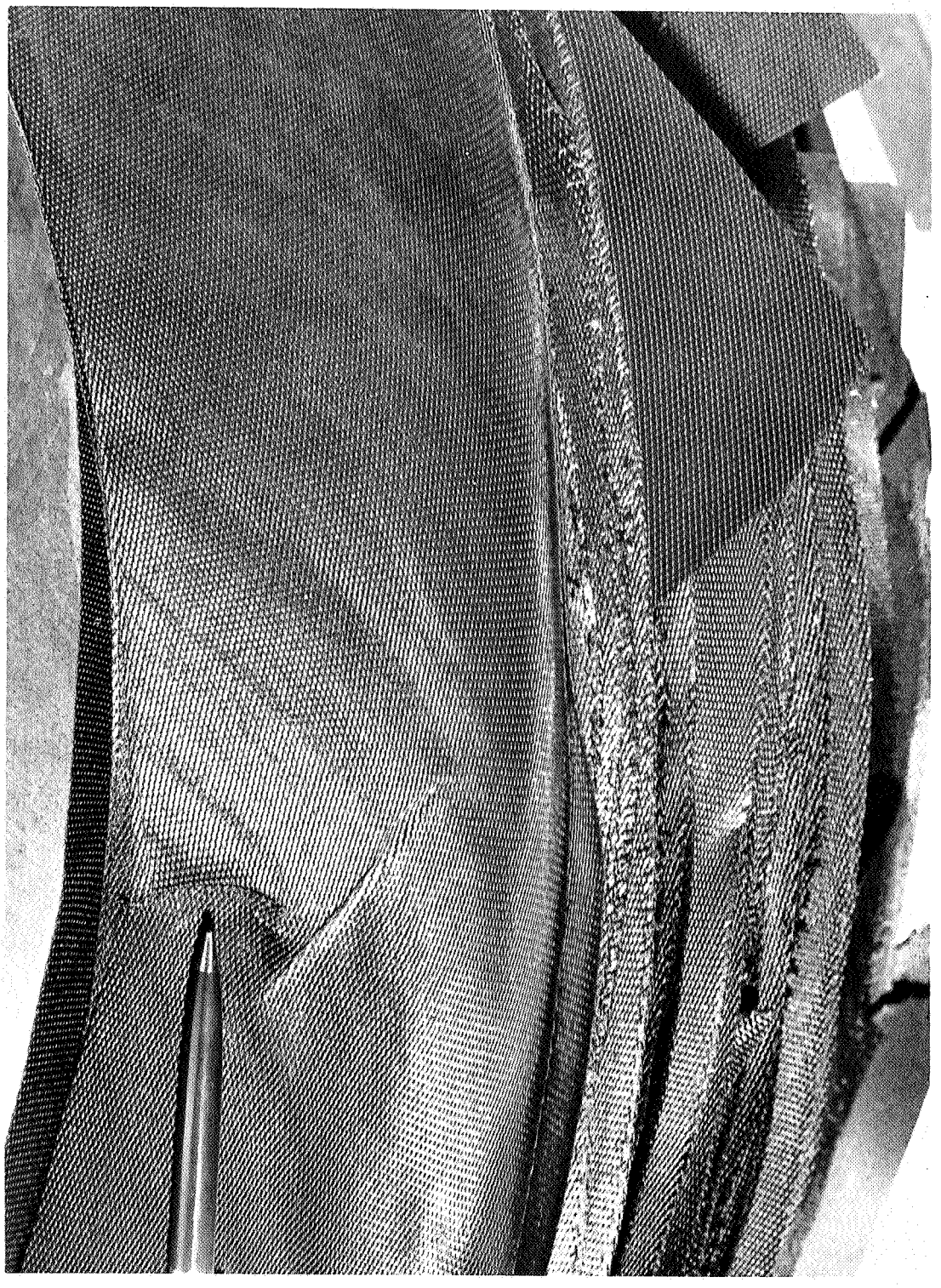
Typical Heat Gun **Array**

Figure 179



Applying Tape with Conical Debulking Roller

Figure 180



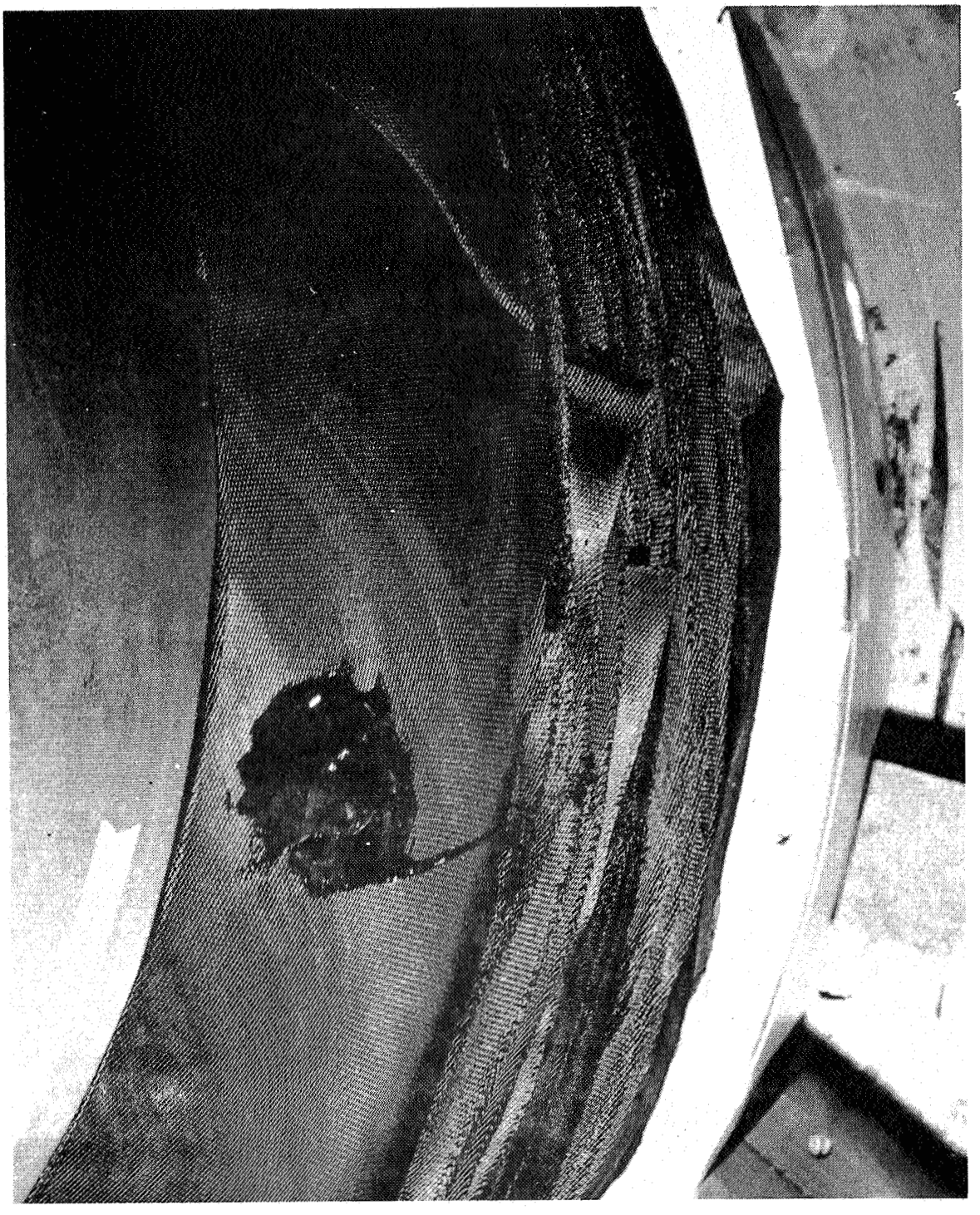
Typical Wrinkle Resulting from Excessive Tape Width with Respect to Mandrel Diameter

Figure 181

Parameter	Scheduled Value Tape Width, in. 4	5	5-1/4	5-1/2	Achieved Value Tape Width, in. 4	5	5-1/4	5-1/2
Roller Pressure, lb/in. width	300	300	300	300	188	150	90	230
Roller Temperature, °F	260	260	260	260	*	*	*	*
Tape Temperature, °F	280	280	280	280	130/145	120/135	140/150	230/250
Mass Temperature, °F	140	140	140	140	130/145	120/135	140/150	150/160
Mandrel Temperature, °F	140	140	140	140	100/110	105/110	100	105/110
Tape Weight, lb	21.3	57.7	36.6	128.8	17.2	39.9	27.6	95.7
Tape Thickness, in	-	-	-	-	.024/.025	.023/.025	.024/.026	.026/.027
Lay-up Thickness, in.	1.187	2.5	1.5	5.0	1.187	2.5	1.5	5.0
Number of Plies	70	146	88	292	65	117	77	250

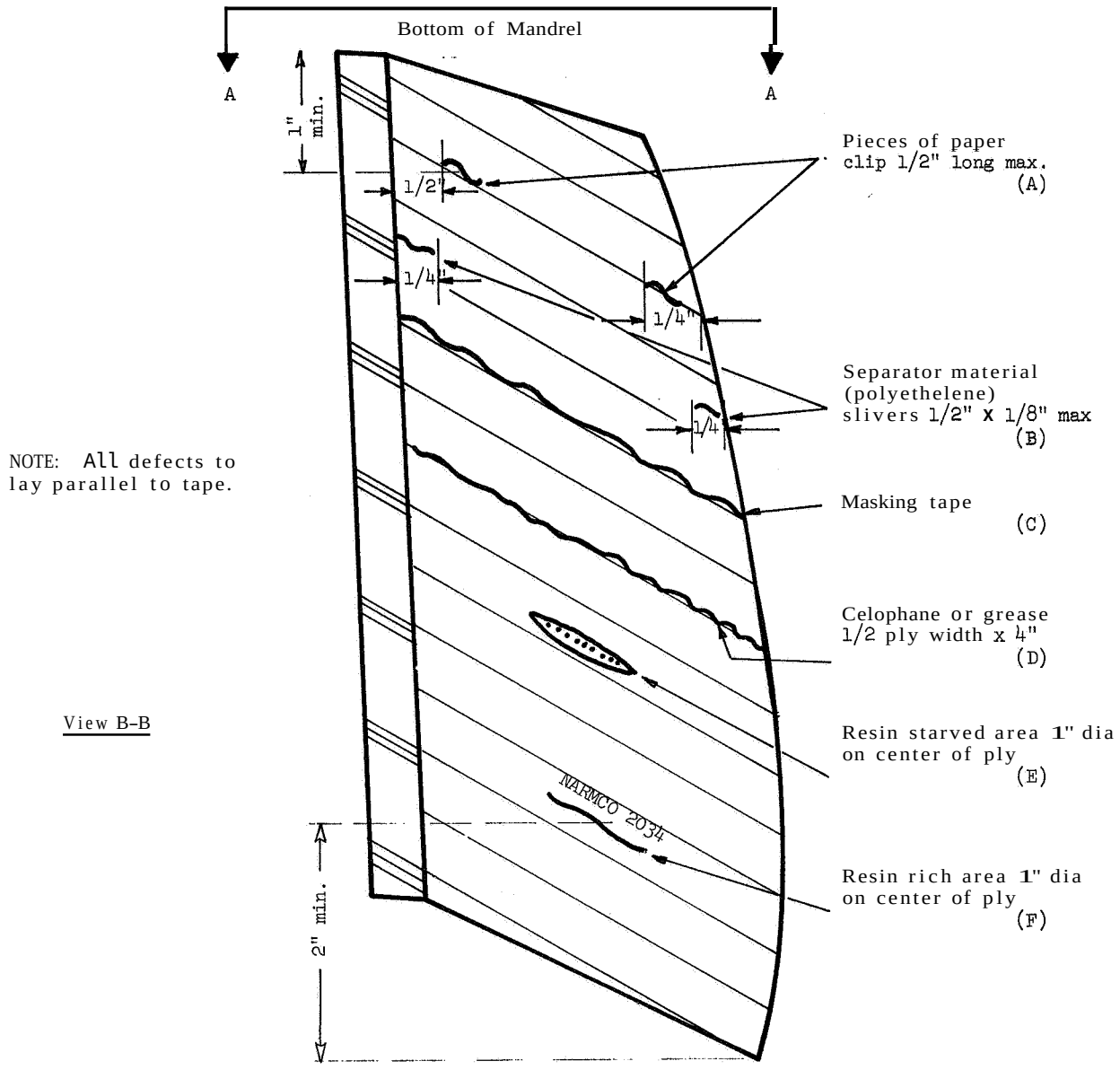
MX-4926 Tape Wrapping Parameters, 120-3S Half-Length Throat

Figure 182



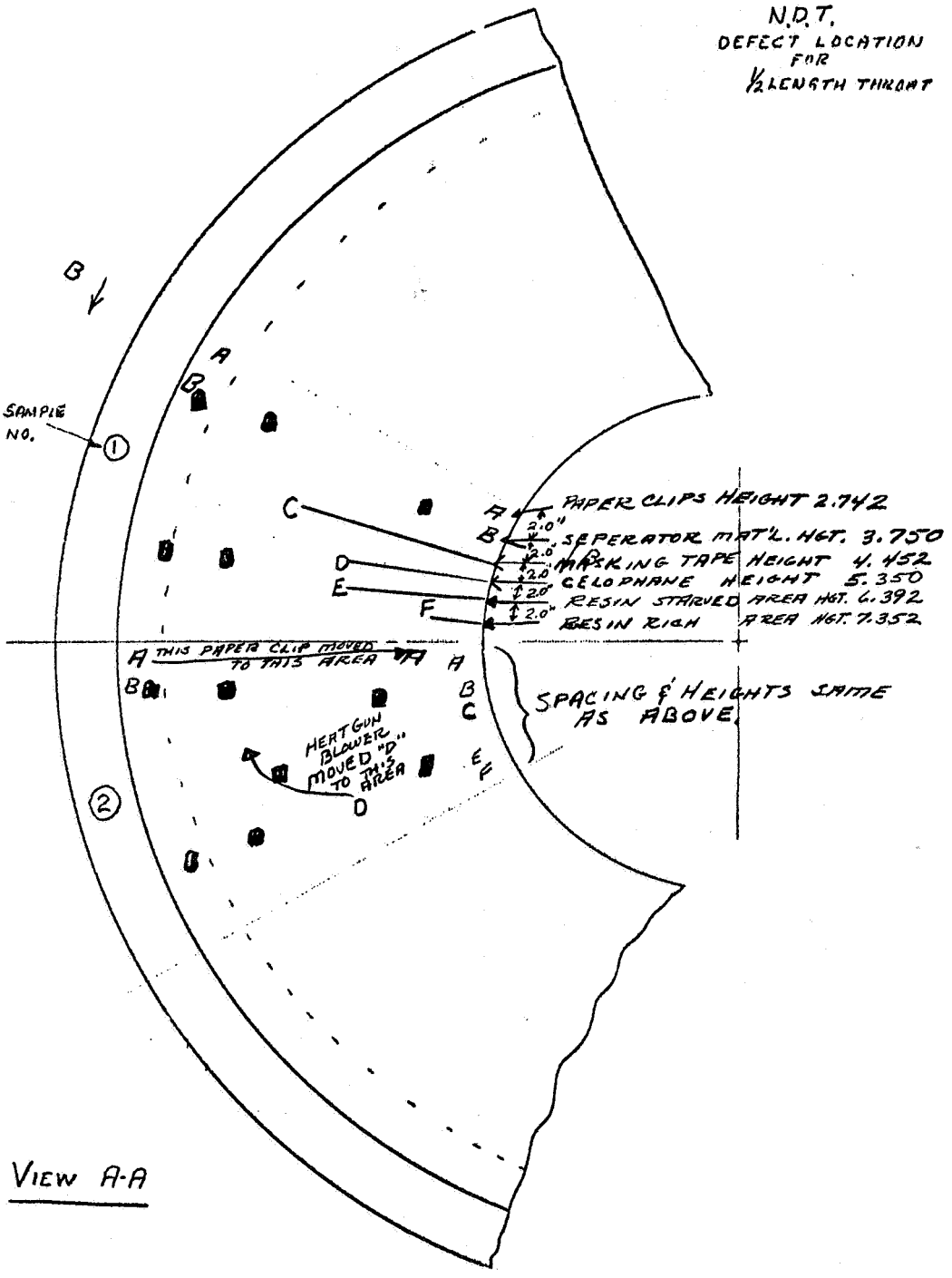
Introduction of Resin to Provide Resin Rich Area for X-Ray Evaluation

Figure 183



Defect Location

Figure 184



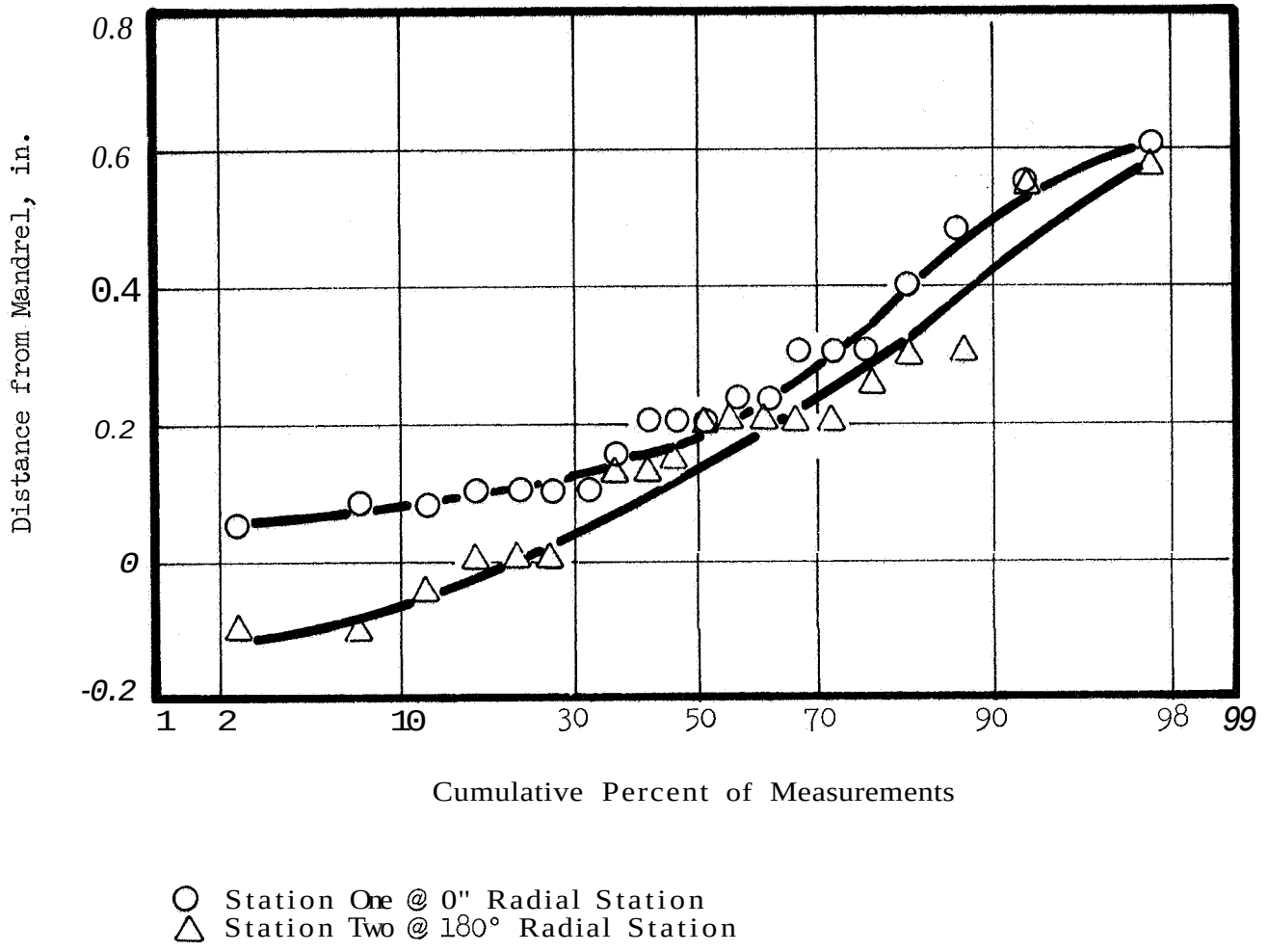
Defect Location

Figure 185

Tape Width, in,	Tape Thickness, in.	% Debulk	Cumulative Number of Plies Applied
5-1/2	0.022	59	58
	0.016	81	67
	0.017	77	85
	0.019	69	93
	0.019	69	117
	0.021	62	139
	0.020	65	189
	0.019	69	207
	0.019	69	223
	0.019	69	243
5-1/4	0.015	87	314
5	0.023	57	393
5	0.019	68	417
5	0.015	87	443
4	0.017	77	509

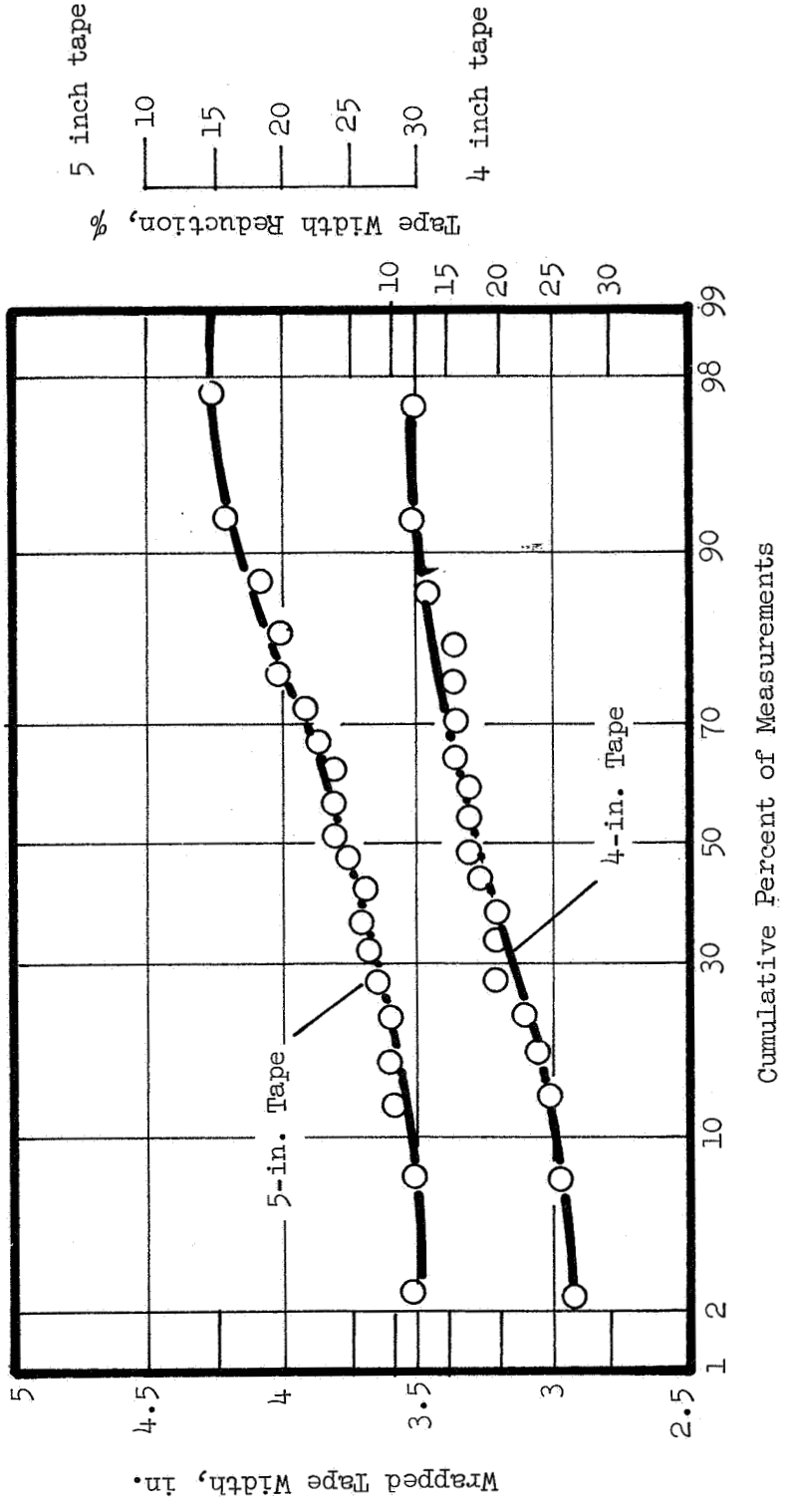
Debulk Achieved on MX-4926 Based on Ply Thickness

Figure 186



Distance Between Mandrel and 5-in.-Wide MX 4926 Tape, 320-SS
Half-Length Throat

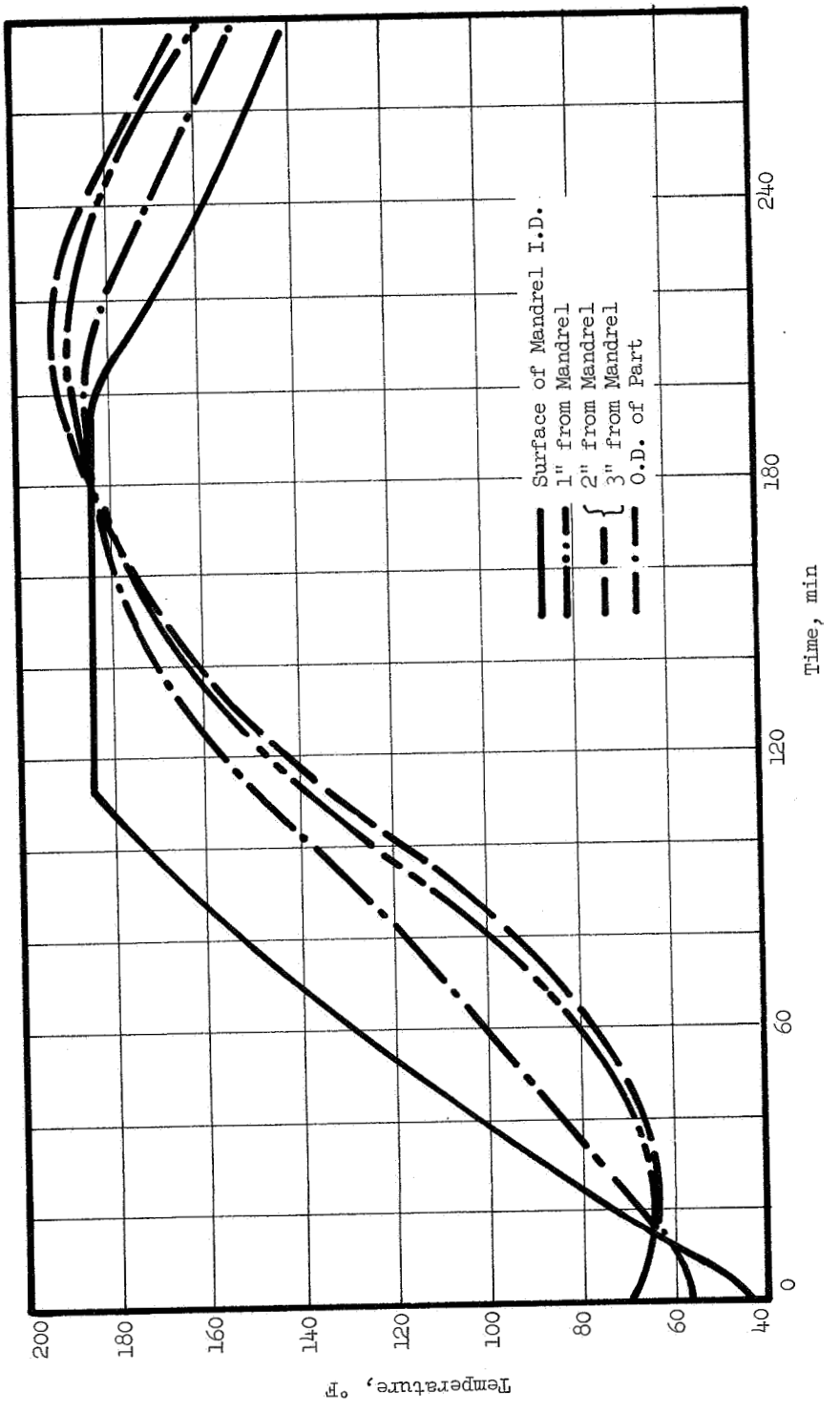
Figure 187



Numbers at Right Show Tape Necking in Percent of Original Width

Distribution of MX-4926 Carbon Phenolic Wrapped Tape Widths During Fabrication of 120-SS Half-Length Throat

Figure 188



Actual Preform Cycle - Temperature vs Time, 120-SS Half-Length Throat

Figure 189

Parameter	Scheduled	Achieved
Roller Pressure, lb/in. width	300	300 to 496
Roller Temperature, "F	260	Cooled with 60-70°F water
Tape Temperature, °F	280	-
Mass Temperature, °F	140	90 to 100
Mandrel Temperature, °F	140	80 to 100
Tape Weight, lb	68.1	116.0
Tape Thickness, in.	-	0.036 to 0.038
Number of Plies	29	60

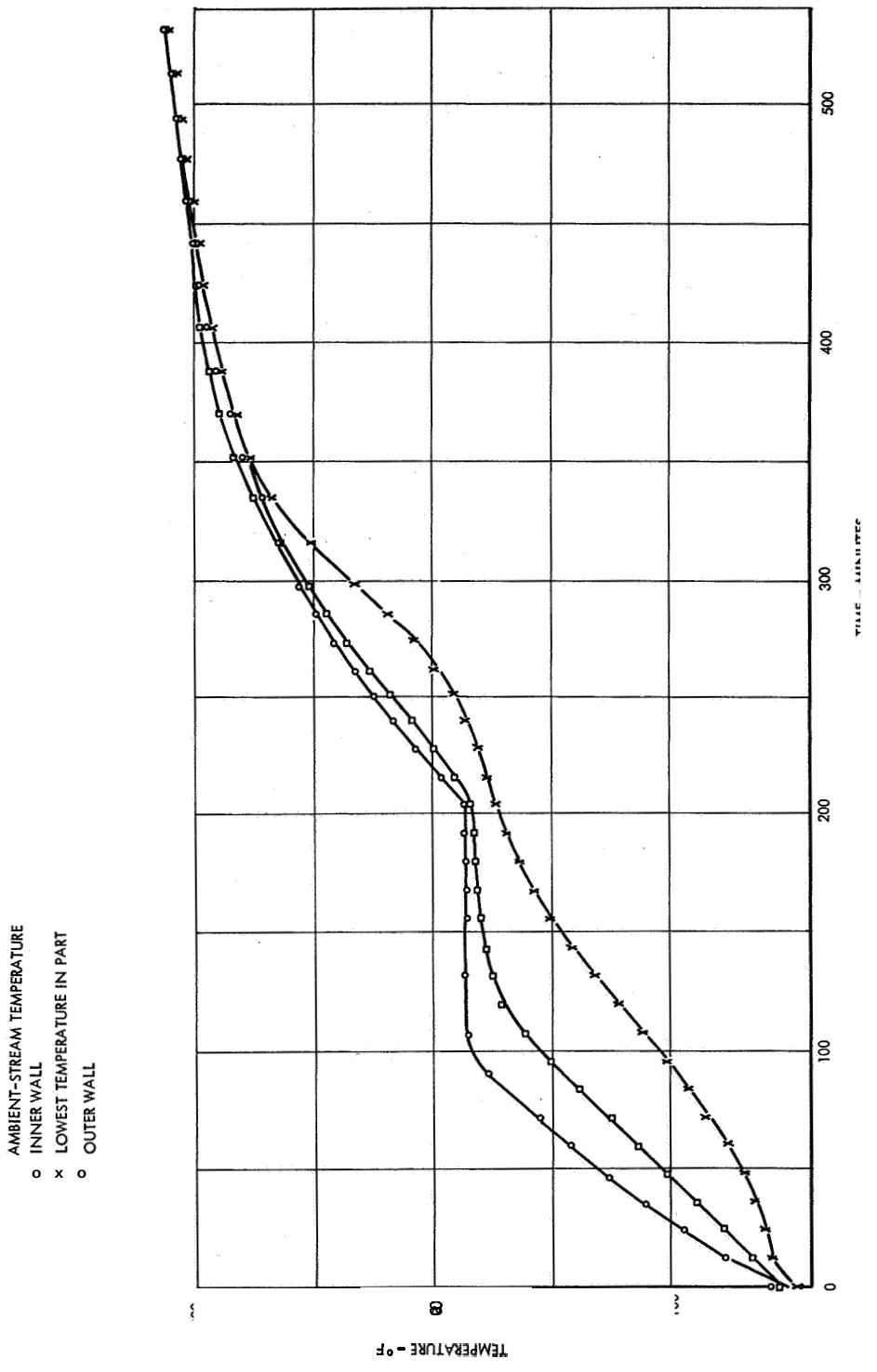
FM-5131 Tape Wrapping Parameters, EO-SS Half-Length Throat, 1-1/2 and 2 in. Tape Widths

Figure 190

Tape Thickness, in.	% Debulk
0.021	--
0.035	74
0.034	77
0.025	--
0.034	77
0.024	--
0.022	--
0.030	87
0.034	77
0.031	84
0.021	--
0.024	--
0.030	87
0.026	--
0.030	87
0.032	81
0.026	--
0.024	--
0.028	93
0.028	93
0.030	87

Debulk Achieved on FM-5131 Based on Ply Thickness

Figure 191



Actual 120-S1 Half-Length Throat Cure Cycle

Figure 192

Test	Aft Test Ring Carbon Results	Aft Test Ring Carbon Remarks (*)	Aft Test Ring Silica Results	Forward Test Ring Carbon Results	Forward Test Ring Carbon Remarks (*)	Forward Test Ring Silica Results
Microtensile	21400	35°-		25200	0°-OGL	
	23100	35°-OGL		24600	0°-OGL	
	23300	30°-ADF				
ASIM D-1708	23600	35°-OGL		19400	45°-ADF	
Modified	25900	30°-OGL				
	26100	30°-OGL		21200	45°-	
	22800	30°-OGL		21400	15°-ADF	
	19300	20"-ADF		14600	85°-OGL	
Interlaminar Shear	5920	10°-15°	2630	4860	75°	2590
	5510	20°-25°	2820	4560	0°	3110
Federal Test Standard	5200	20°	2650	4400	3-4"	2340
406 Method 1042	5550	20°-25°	2380	5920	15°	2560
Modified	4430	15°	2650	4090	0°	3350 (**)
	5440	15°	2550	4450	0"	2560
Edgewise Compression				40200	SI-2 DIAG	
	34100	15"-SI		39400	SI-1 DIAG	
	35900			36400	SI-2 DIAG	
ASTM-D-695	37800			31400	SI-2 DIAG	
	34900					
	39300			36400	1 DIAG	
Specific Gravity	1.44		1.74	1.45		1.74
	1.44		1.74	1.48		1.74
	1.44		1.74	1.48		1.74
Federal Test Standard	1.44		1.74	1.48		1.74
406 Method 5011	1.44		1.74	1.48		1.74
	1.44		1.74	1.47		1.74
Volatile Content	2.27		2.41	2.03		2.57
	2.03		2.43	1.73		2.61
TAP-DAP-122	2.09		2.50	1.95		2.62
Acetone Extractables	0.19		0.14	0.14		0.17
	0.20		0.17	0.17		0.18
ASTM-D-494	0.20		0.14	0.13		0.14

* OGL; broke outside gage length. ADF; axial diagonal fracture.
SI-2 DIAG, sheared interlaminarly with 2 diagonals.
Degrees in remarks column are estimates of departure from required specimen orientation.

** Specimen which was 90 degrees out of orientation.

Physical Properties Obtained from Test Ring Specimens, EO-SS
Half-Length Throat

Figure 193

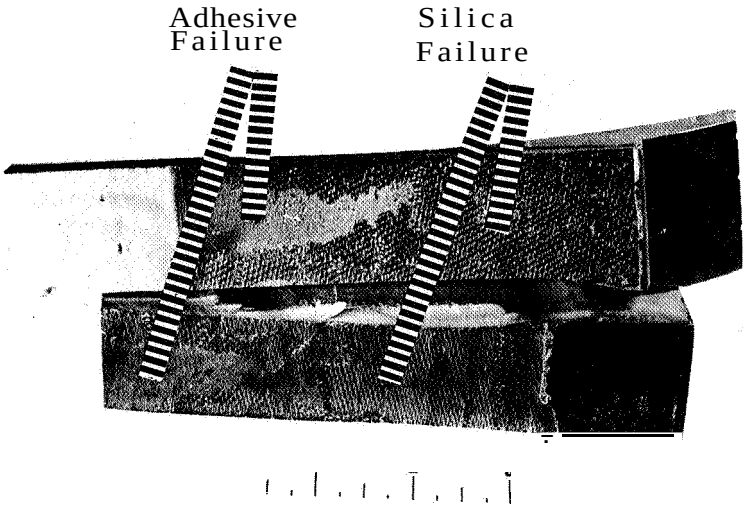


Figure 194. Separation of Bond Joint of Steel Shell to Half-Length Throat

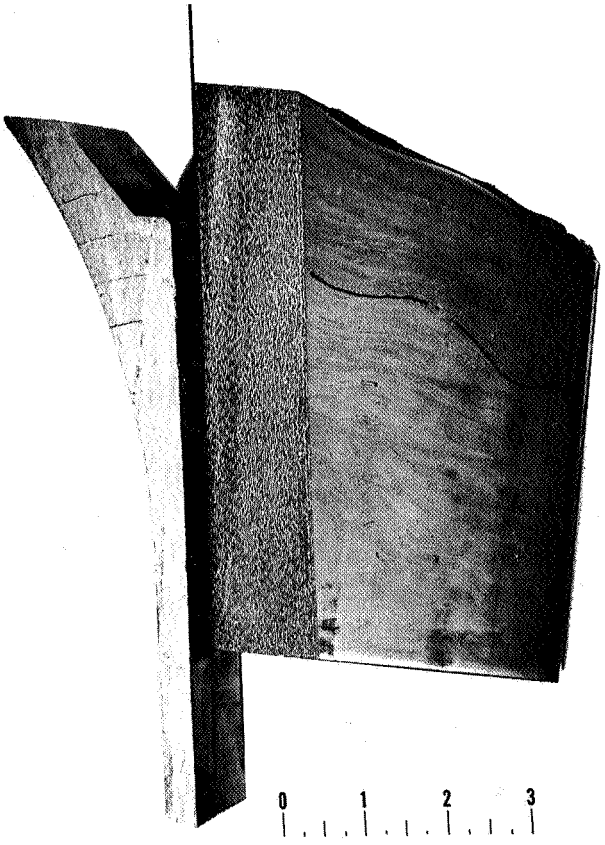


Figure 195. Half-Length Throat Cross-Section

Figure 194 and Figure 195

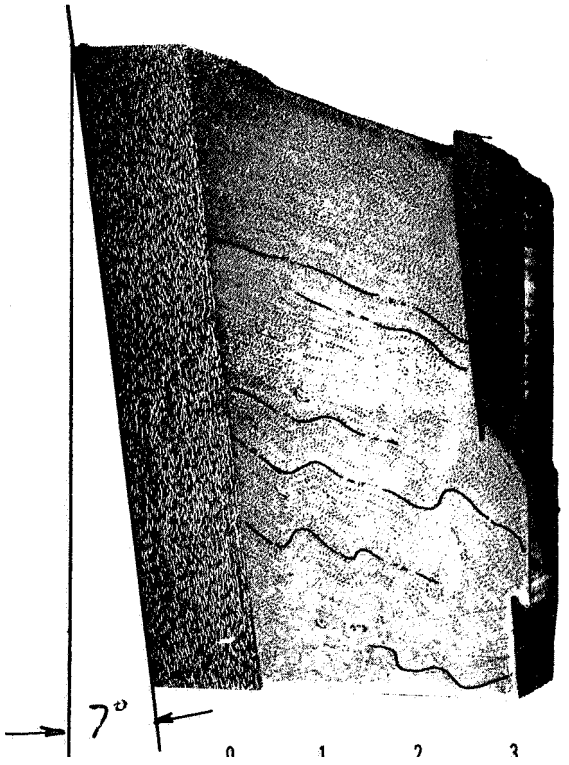


Figure 196. Half-Length Throat Cross-Section

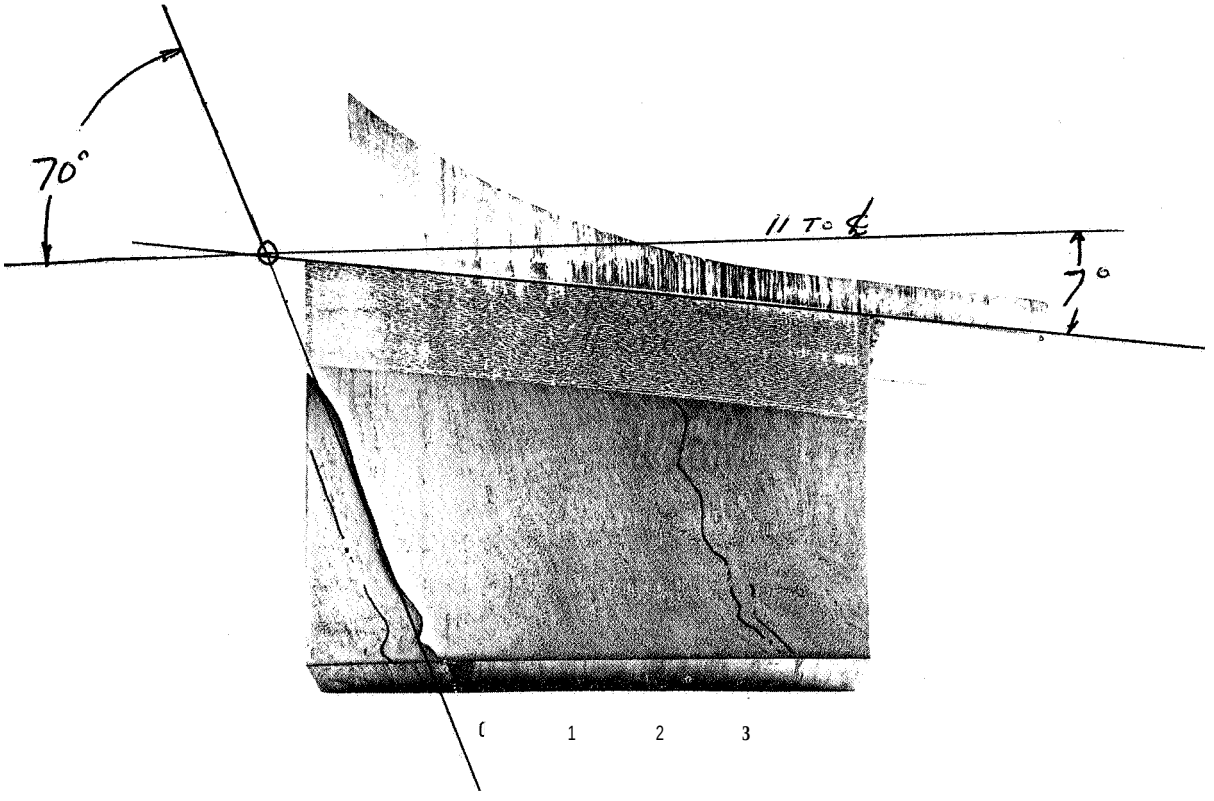
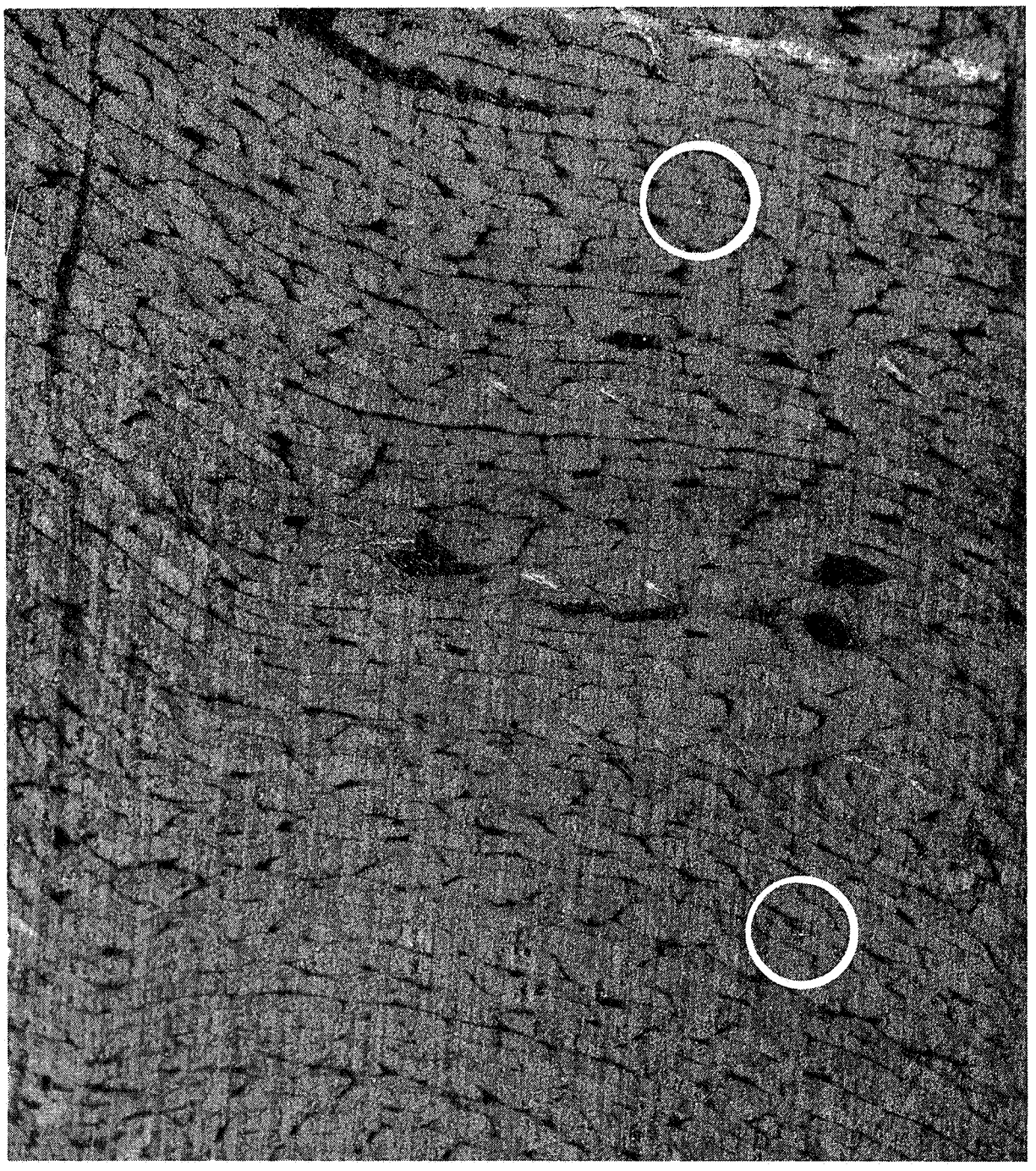


Figure 197. Half-Length Throat Cross-Section

Figure 196 and Figure 197



Cross-Section of Half-Length Throat (Mag. 10X)

Figure 198

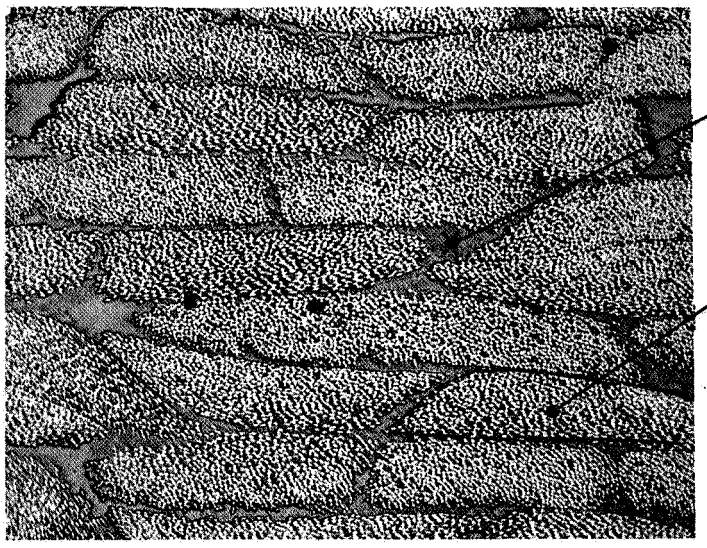


Figure 199. Cross-Section of Half-Length Throat Showing Ruptured Fiber Bundles (Mag. 50X)

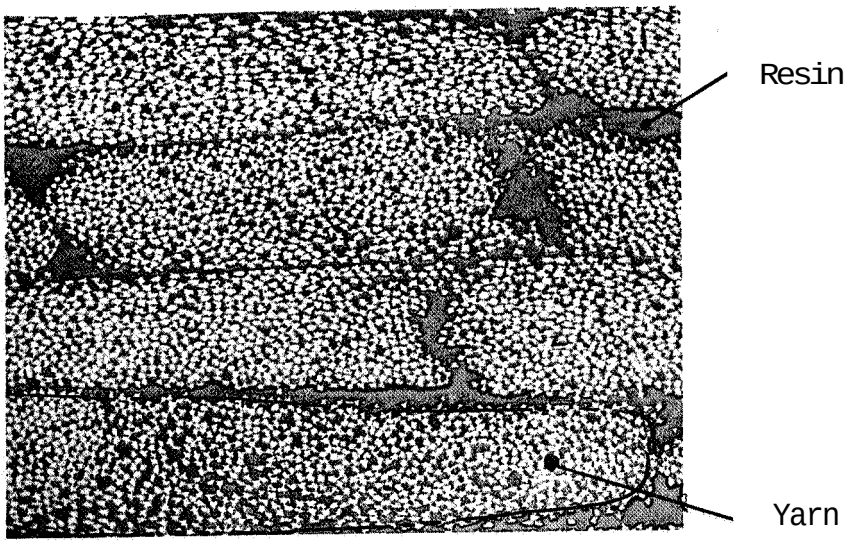


Figure 200. Ruptured Fiber Bundles (Mag. 100X)

Figure 199 and Figure 200

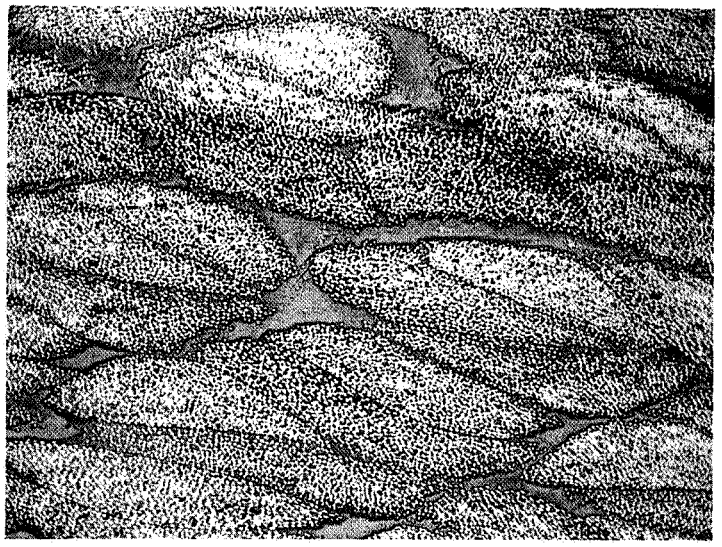


Figure 201. Normal Fiber Bundles (Mag. 50X) Sectioned Through Bias Weave

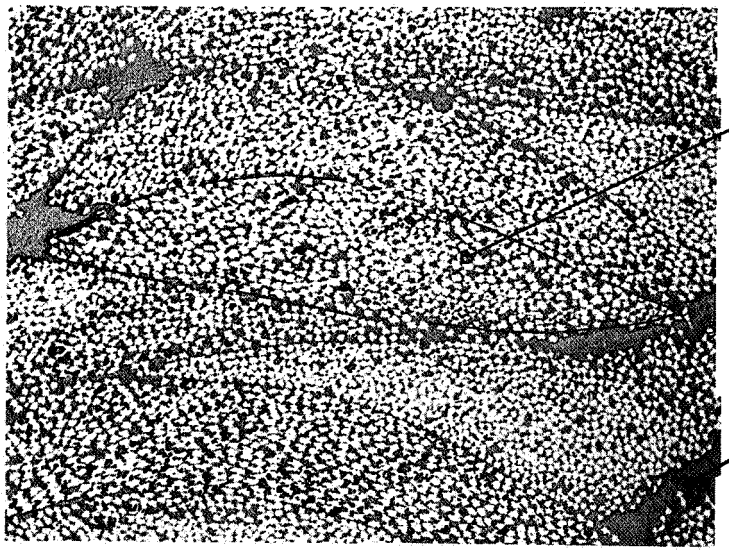
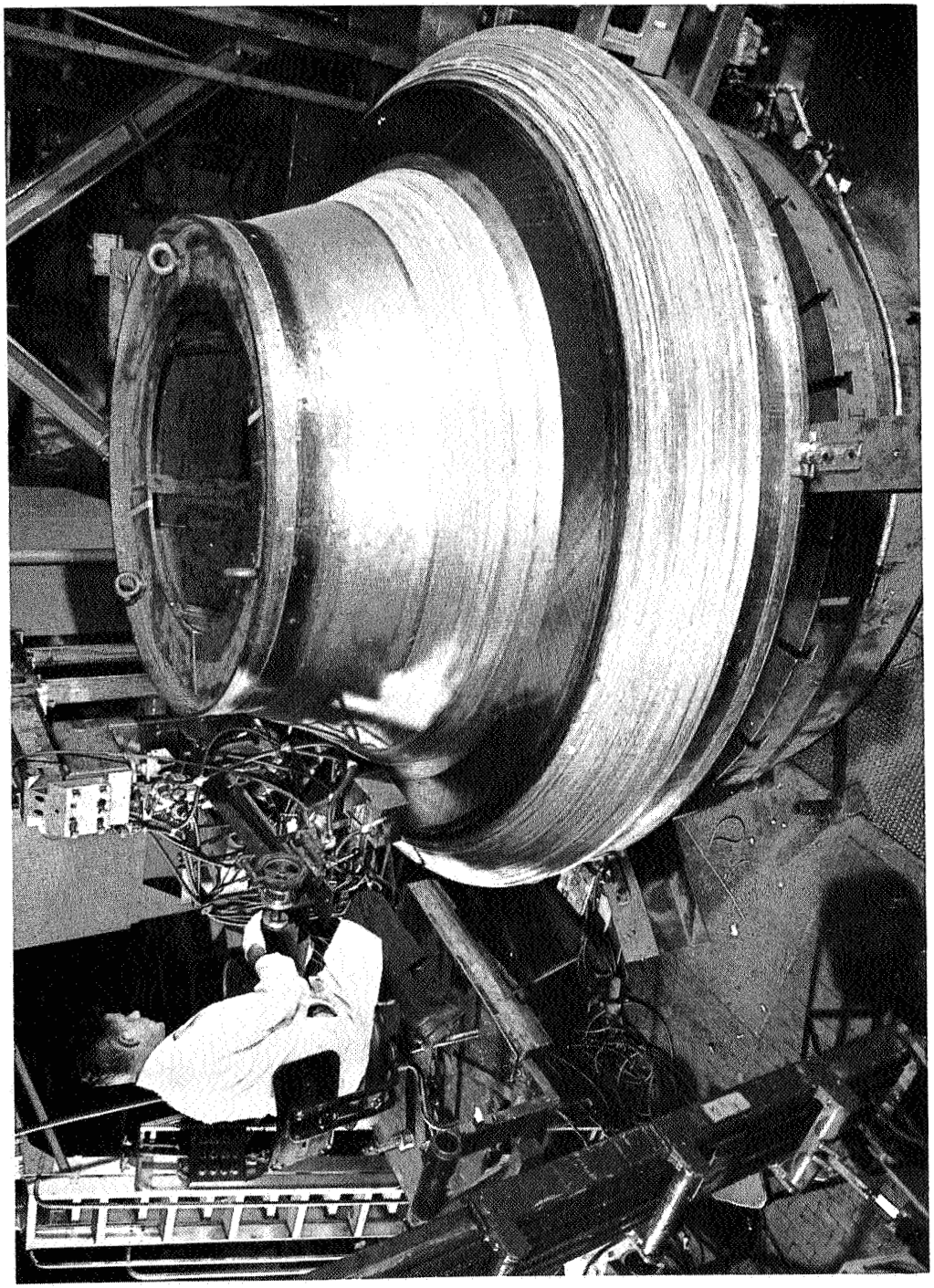


Figure 202. Normal Fiber Bundles (Mag. 100X) Sectioned Through Bias Weave

Figure 201 and Figure 202



Wrapping 260-SL-1 Nozz 4 Entrance Insert

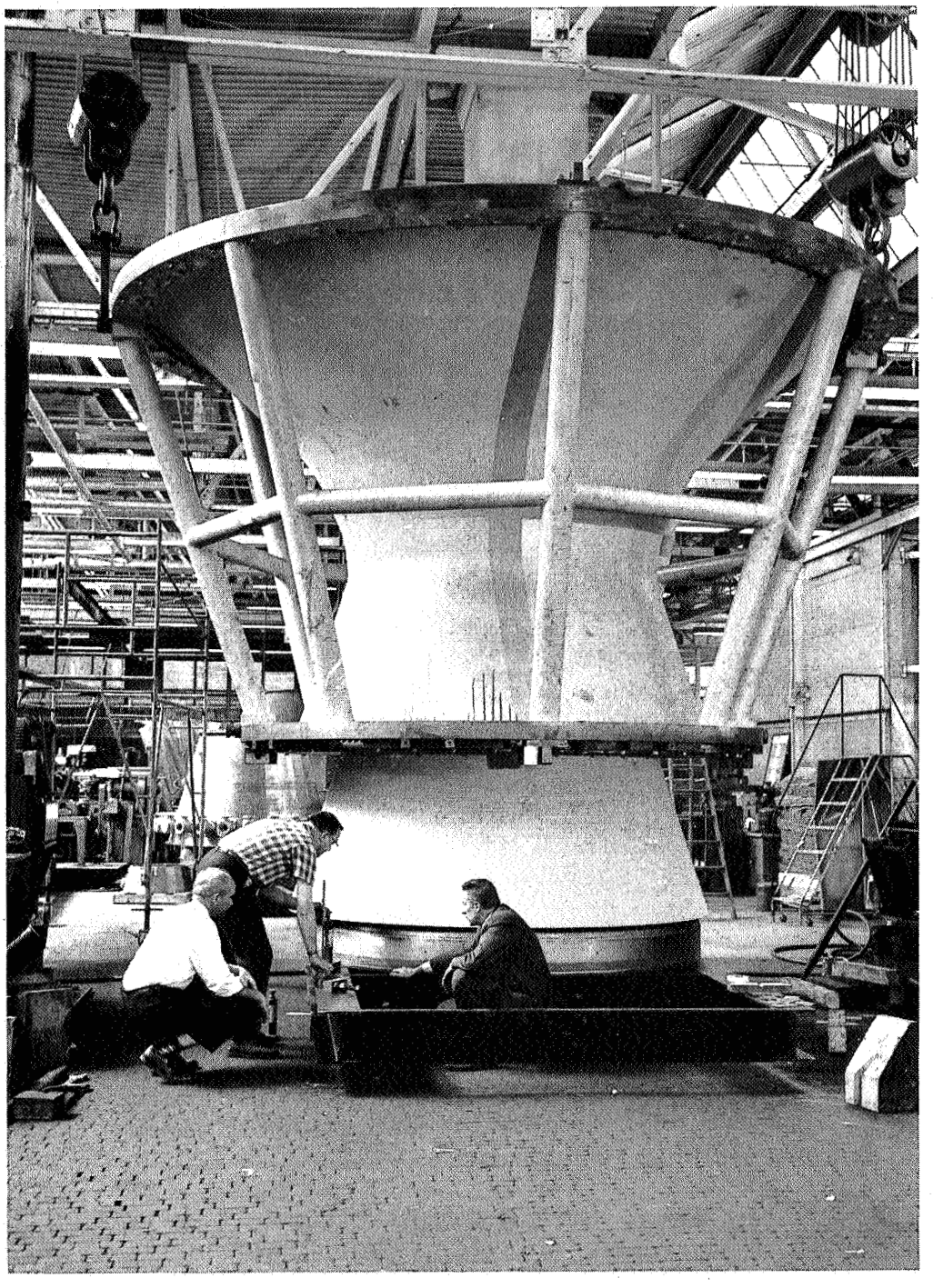
Figure 203

Vacuum Bagging 260-SL-1 Nozzle Entrance Insert

Figure 204

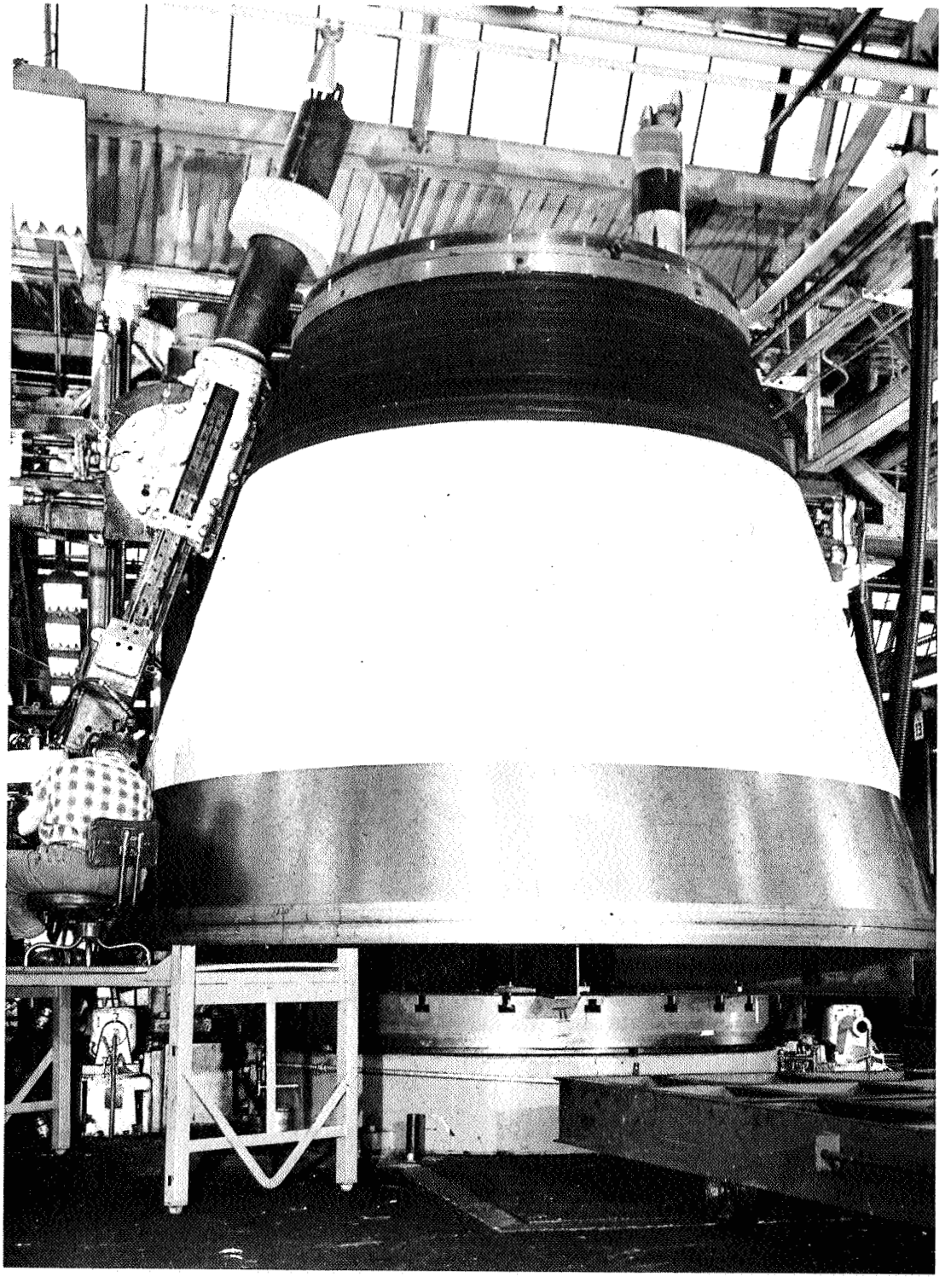
Final Machining of 260-SL-1 Nozzle Insulation

Figure 205



Dry-Fit of 260-SL-1 Throat Extension Insert to Nozzle Shell

Figure 206

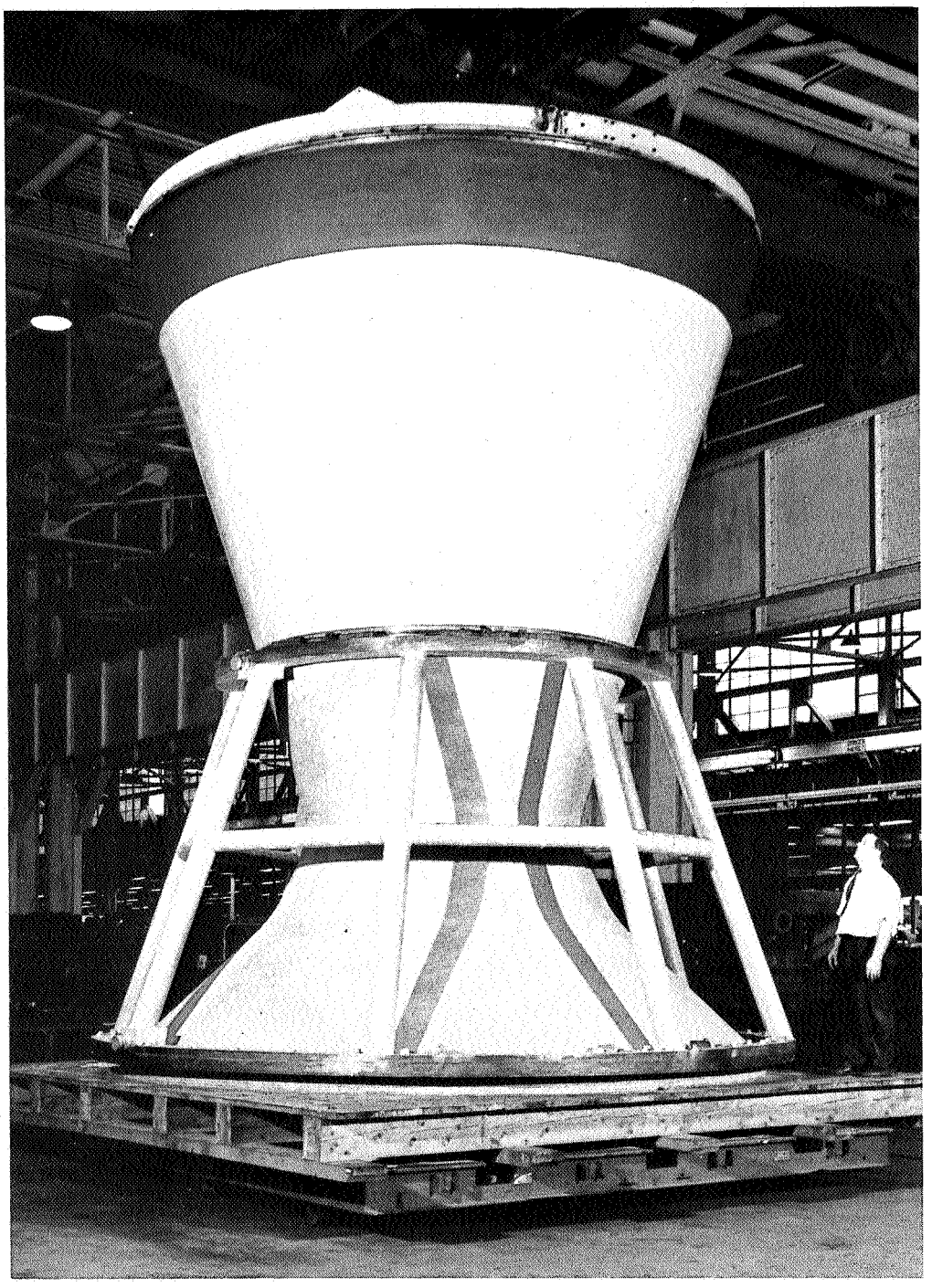


Tape Wrapping 260-SL-1 Exit Cone Liner

Figure 207

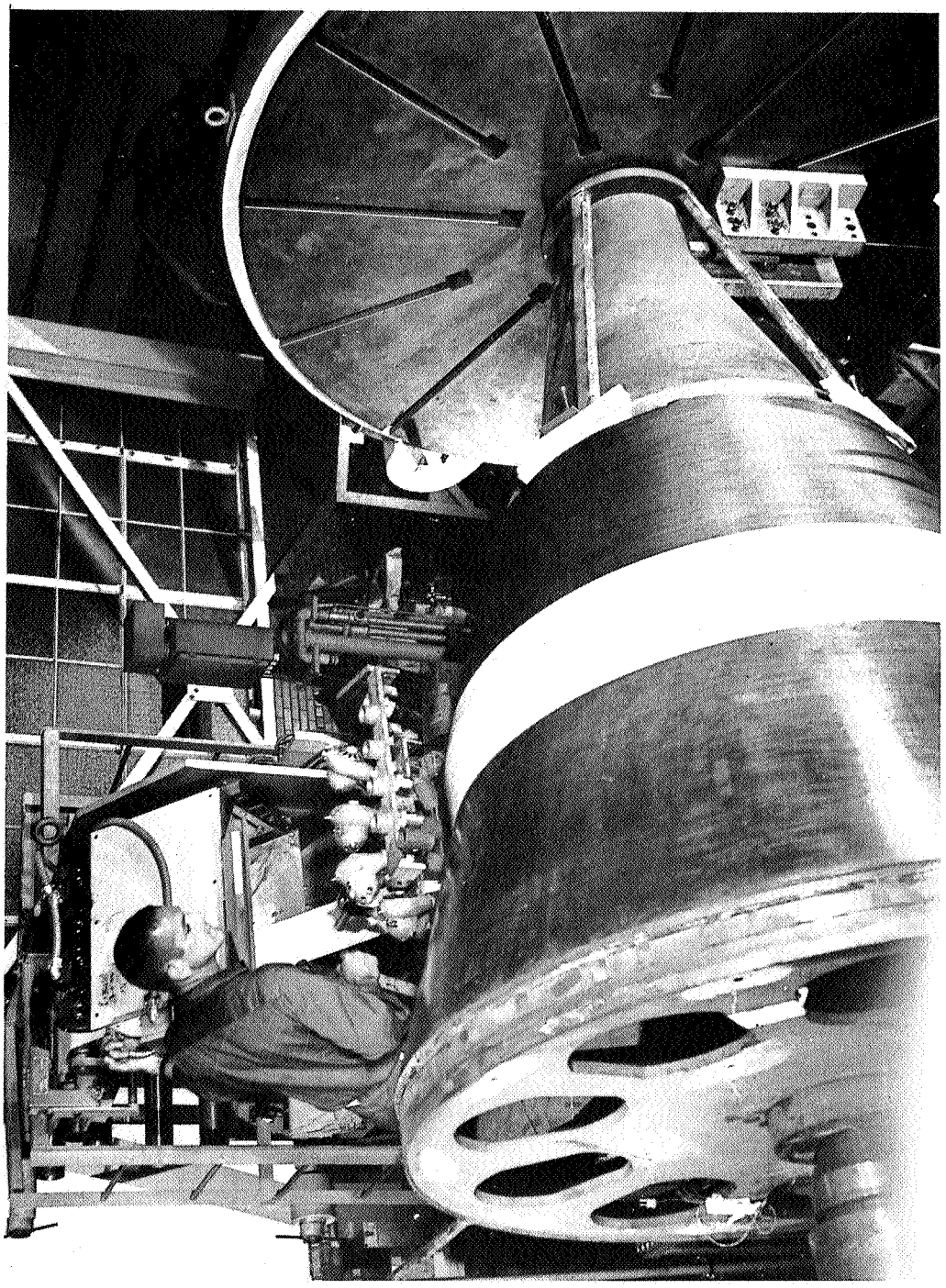
Installation of **Metal** Strips for Nylon Tension **Wrap** Operation

Figure *208*



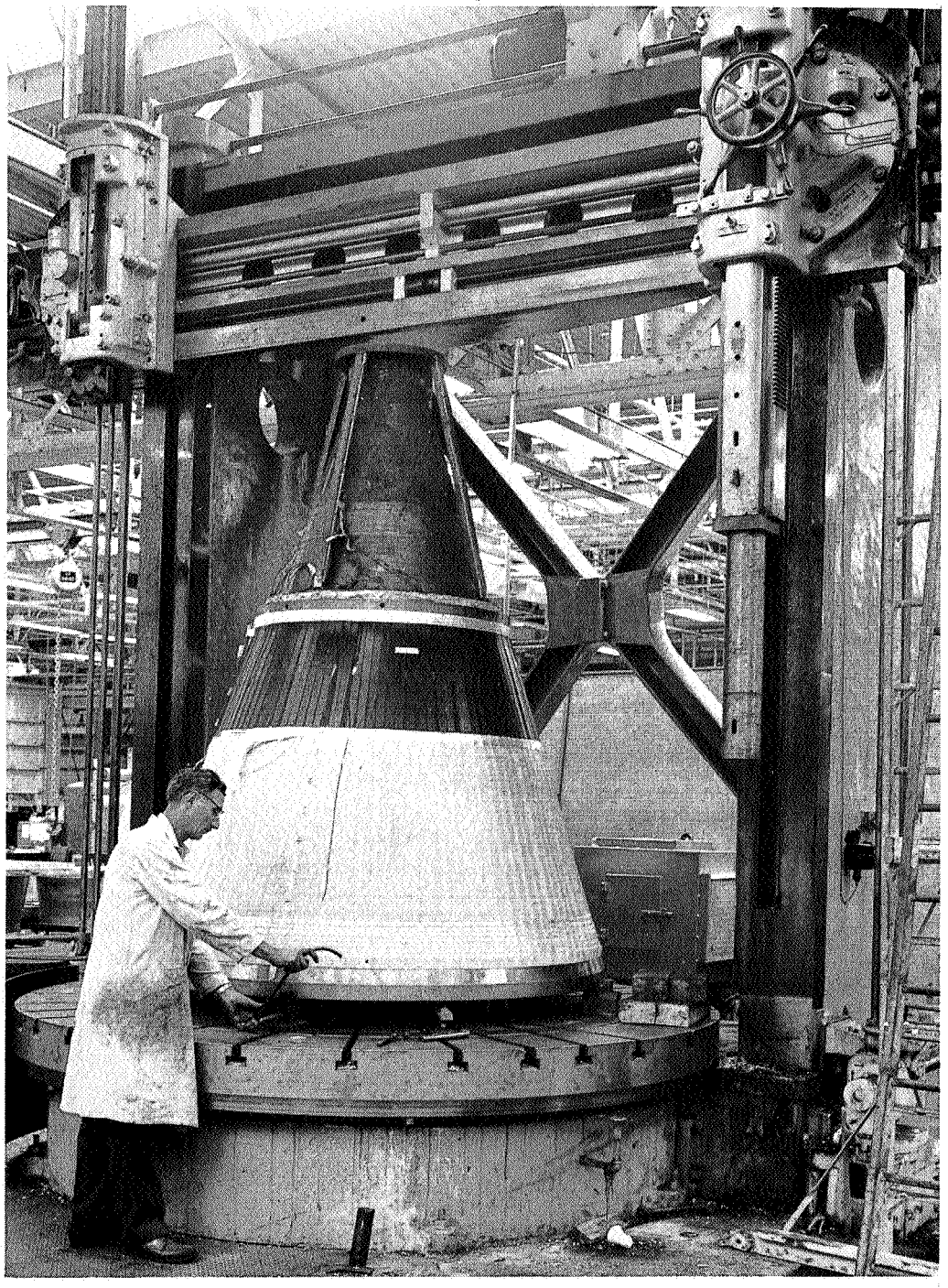
Trial Assembly of 260-SL-1 Nozzle and Exit Cone

Figure 209



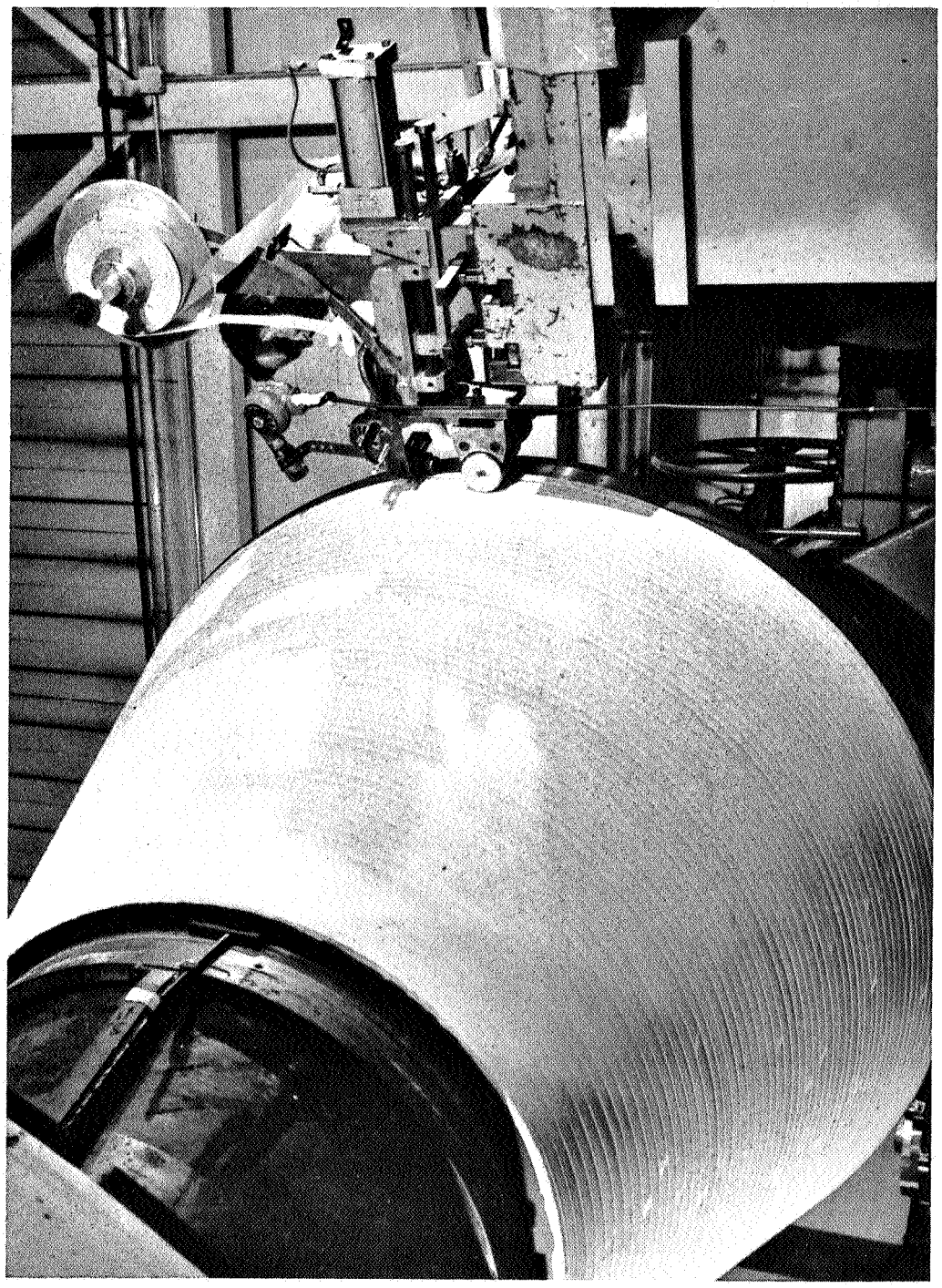
Wrapping 120-SS-1 Exit Cone Liner

Figure 210



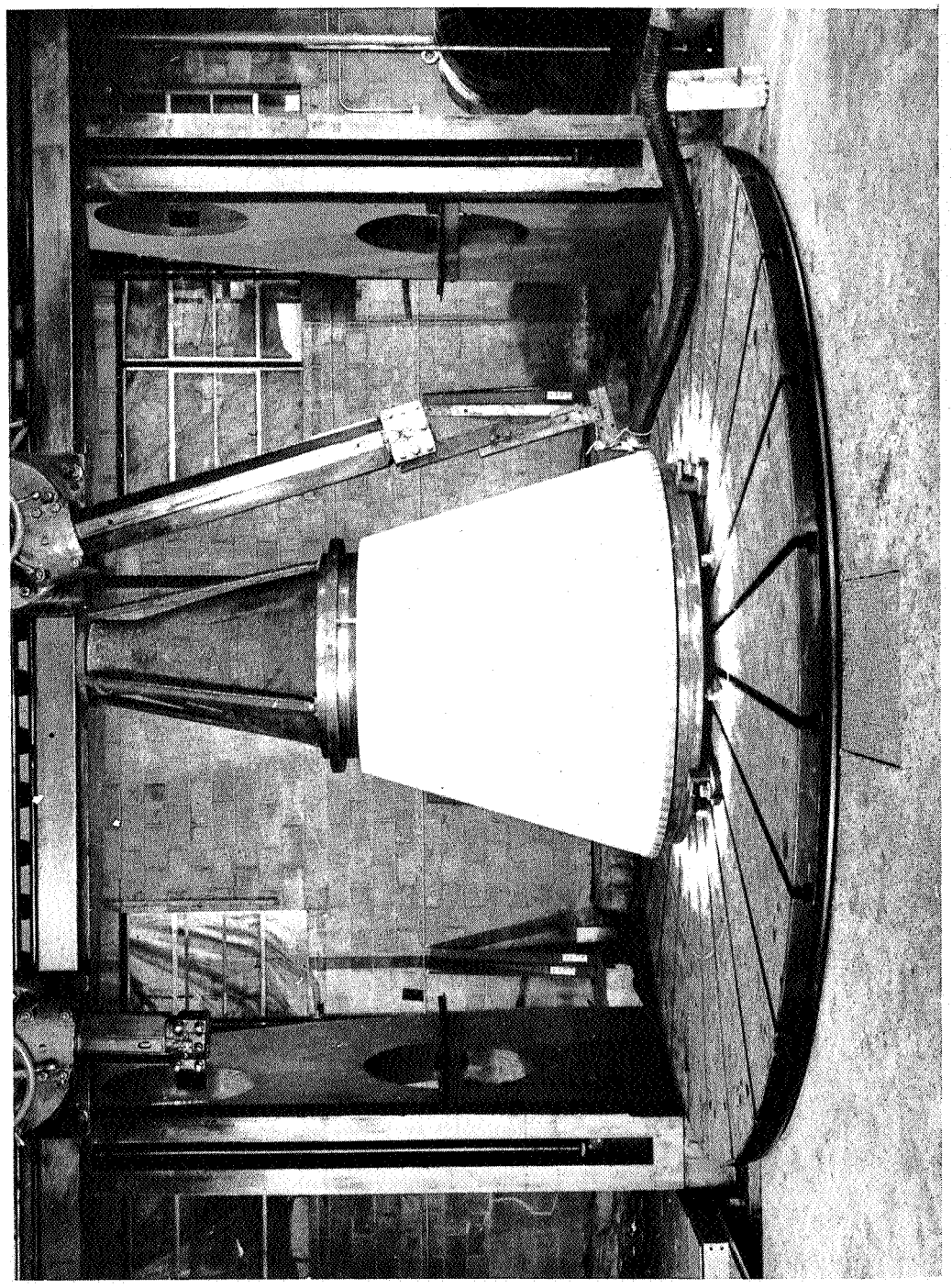
120-SS-1 Exit Cone Liner After Preform Cure

Figure 211



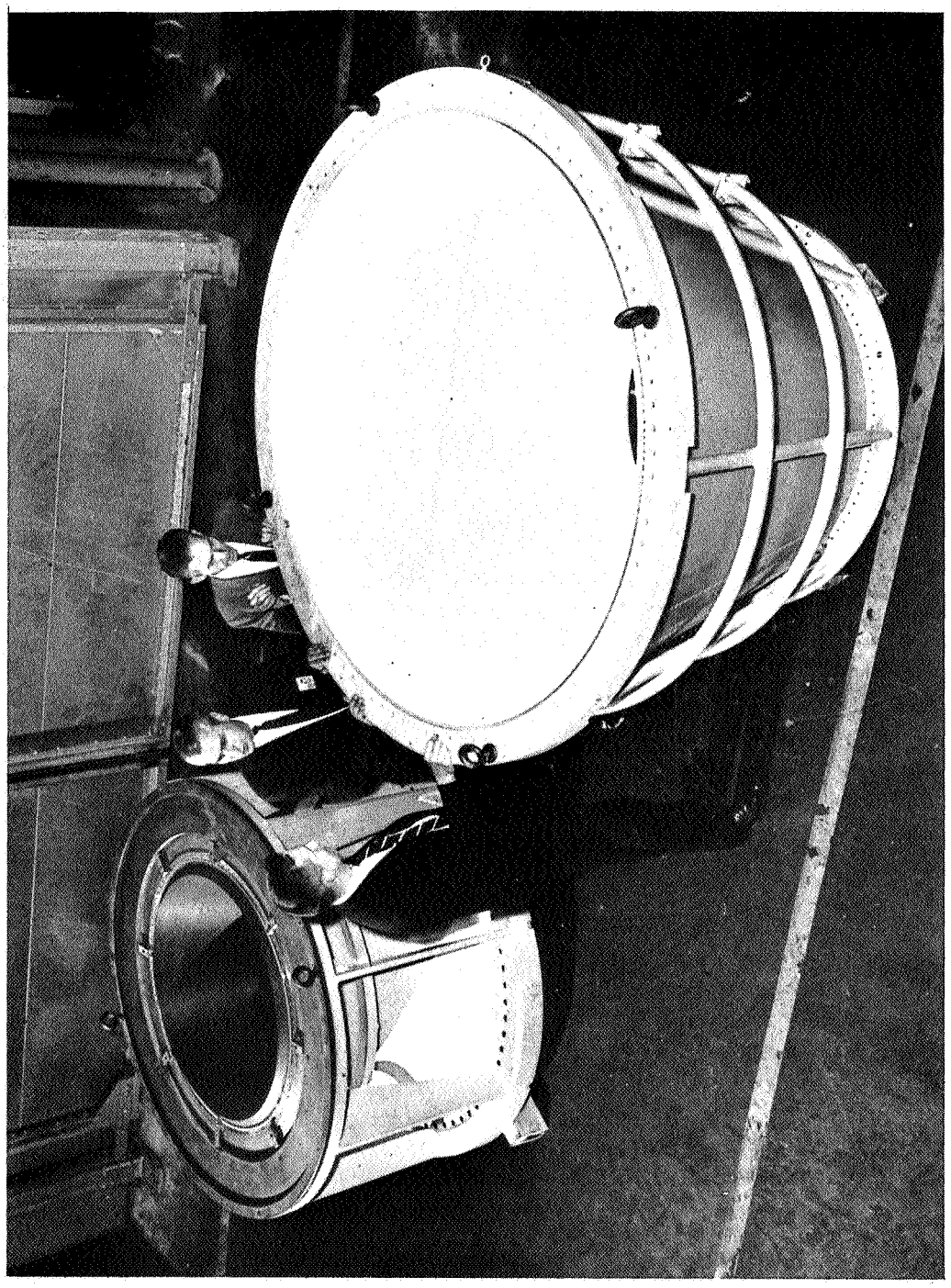
Silica Tape Overwrap on 120-SS-1 Exit Cone Liner

Figure 212



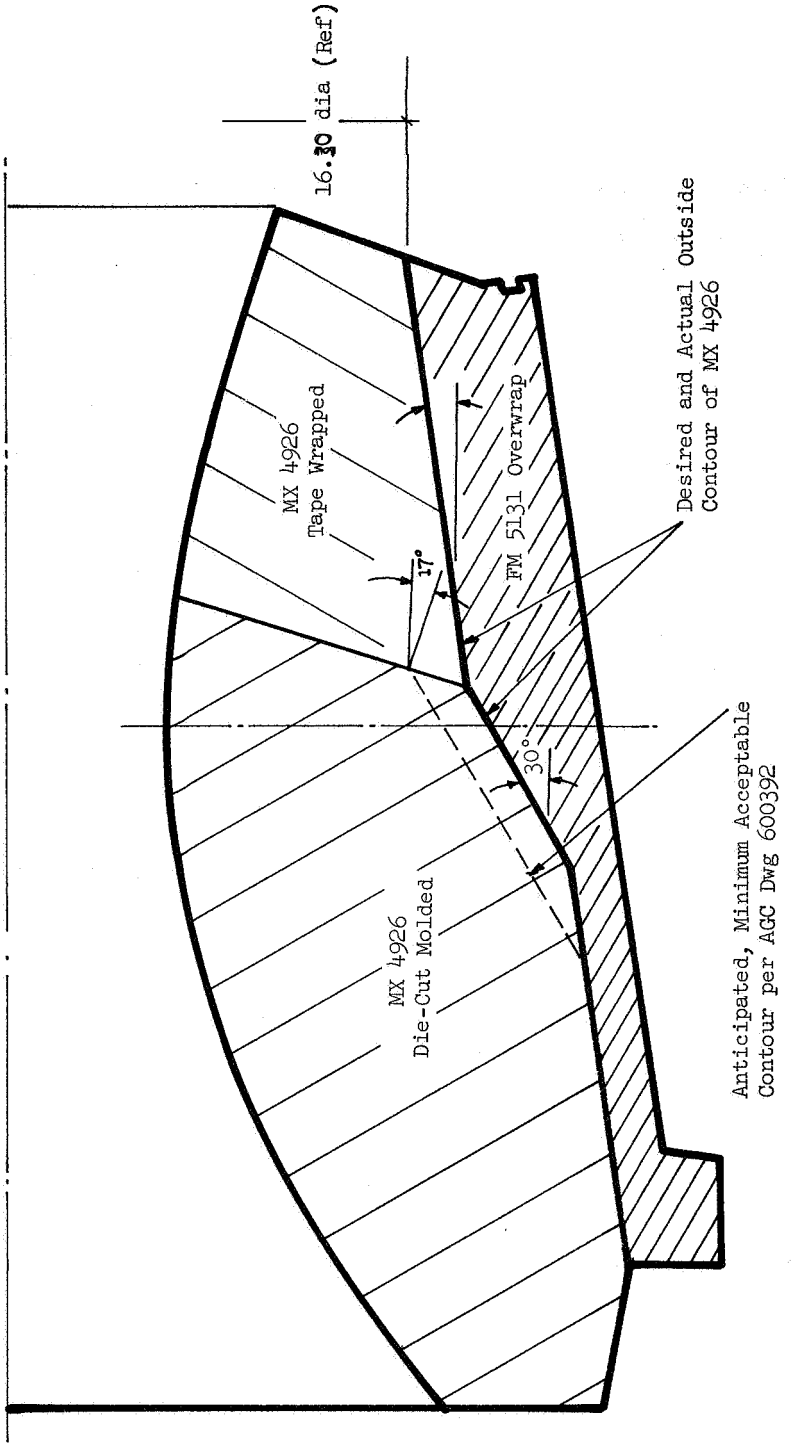
Final Machining of 120-SS-1 Exit Cone Liner Overwrap

Figure 213



Completed 120-SS-1 Nozzle and Exit Cone Assemblies in Handling Fixtures

Figure 214



Throat Insert, 44-SS-3 Motor Nozzle

Figure 215

After Preforming of Inner Wrap*

Property	MX-4926	MX-2646
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.42 1.42	1.55 1.56
Acetone Extractables per ASTM-D-494-46, %	27.10 27.25 27.30 27.70	5.50 6.20 5.37 5.39
Volatiles per TAP-DAP-102A, Dust, %	3.22 3.18 3.11 3.18	3.37 3.41 3.36 3.39

After Final Cure

Property	Specification Requirements	Aft Test Ring Inner Wrap MX-4926	Aft Test Ring Over Wrap MX-2646	Fwd Test Ring Inner Wrap MX-2646
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.38 min. for MX-4926 1.75 min. for MX-2646	1.45 1.45 1.45	1.80 1.80 1.80	1.77 1.79 1.78
Acetone Extractables per ASTM-D-494-46, %	1% max.	0.15 0.14 0.14	0.15 0.11 0.15	0.04 0.06 0.04
Interlaminar Shear per Fed. Test Method Std. 406, psi	1000 psi min.	2,800 3,400 3,150	3,250 3,400 3,600	3,350 4,050 2,650
Interlaminar Shear per Fed. Test Method Std. 406, psi	1000 psi min.	Interface Between Inner Wrap and Over Wrap 3,700 4,200 4,000		
Volatiles per TAP-DAP-122, %	3% max.	2.73 2.65 2.77	0.94 0.99 1.00	1.68 1.35 1.46
Microtensile per ASTM-D-1708, psi	Report Only	19,300 20,900 15,600	17,250 15,800 16,400	14,650 15,950 18,350

*No specification requirements for preform test specimens.

Entrance Insert Properties from End Ring Test Specimens, 260-SL-1 Nozzle

Figure 216

After Preforming of Inner Wrap*

Property	MX-4926
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.45 1.44
Acetone Extractables per ASTM-D-494-46, %	18.95 21.38
Volatiles per TAP-DAP-102A, Dust, %	2.33 2.30

After Final Cure

Property	Specification Requirements	Aft Test Ring Inner Wrap MX-4926	Aft Test Ring Over Wrap FM-5131	Fwd Test Ring Inner Wrap MX-4926	Fwd Test Ring Over Wrap FM-5131
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.38 Min. for MX-4926 1.68 Min. for FM-5131	1.44 1.44 1.44	1.72 1.71 1.72	1.44 1.46 1.43	1.73 1.72 1.73
Acetone Extractables per ASTM-D-494-46, %	1% Max.	0.11 0.04 0.10	0.12 0.10 0.10	0.06 0.04 0.06	0.11 0.16 0.11
Interlaminar Shear per Fed. Test Method Std 406, Method 1042, psi	1000 Psi Min.	3,500 3,800	2,100 2,200 2,600	2,620 3,810	2,410 1,840
Interlaminar Shear per Fed. Test Method Std. 406, Method 1042, psi	1000 Psi Min.	Interface Between Innerwrap and Overwrap 2,100 2,400 2,700		Interface Between Innerwrap and Overwrap 1,750 1,660	
Volatiles per TAP-DAP-122, %	3% Max.	1.59 1.66 1.70	2.97 2.97 2.89	2.16 2.13 2.21	3.05 3.11 3.16
Microtensile per ASTM-D-1708, psi	Report Only	15,800 12,300 13,600	13,000 12,200 14,450	14,690 16,240 15,300	8,040 8,530 11,370

* No specification requirements for preform test specimens.

Throat Insert Properties from End Ring Test Specimens, 260-SL-1 Nozzle

Figure 217

After Preform of Inner Wrap*

Property	MX-4926
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.43 1.43 1.43
Acetone Extractables per ASTM-D-494-46, %	25.4
Volatiles per TAP-DAP-102A, Dust, %	4.91

After Final Cure

Property	Specification Requirements	Aft Test Ring Inner Wrap MX-4926	Fwd Test Ring Inner Wrap MX-4926	Fwd Test Ring Over Wrap FM-5131
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.38 Min. for MX-4926 1.68 Min. for FM-5131	1.45 1.44 1.45	1.45 1.46 1.45	1.73 1.73 1.73
Acetone Extractables per ASTM-D-494-46 (%)	1% Max.	0.07 0.04 0.05	0.21 0.15 0.13	0.21 0.23 0.14
Interlaminar Shear per Fed. Test Method Std. 406, Method 1042 (Psi)	1000 Psi Min.	1,900 2,800	2,300 2,400	1,700 1,600
Interlaminar Shear per Fed. Test Method Std. 406, Method 1042 (Psi)	1000 Psi Min.		Interface Between Inner Wrap and Over Wrap 2,200 1,700	
Volatiles per TAP-DAP-122 (%)	3% Max.	1.64 1.67 1.57	2.04 2.06 2.06	3.22 3.20 3.21 3.24 3.28 3.21
Microtensile per ASTM-D-1708 (Psi)	Report Only	15,900 15,300 16,900	15,700 14,400 15,700	9,600 8,900 9,500

* No specification requirements for preform test specimens.

Throat Extension Insert Properties from End Ring Test Specimens, 260-SL-1 Nozzle

Figure 218

Property	Specification REquirements	Aft Test Ring Inner Wrap FM-5131	Aft Test Ring Over Wrap FM-5131	Fwd Test Ring Inner Wrap MX-4926	Fwd Test Ring Over Wrap FM-5131
Specific Gravity per Fed, Test Method Std. 406, Method 5011	1.38 Min. for MX-4926 1.68 Min. for FM-5131	1.75 1.75 1.75	1.75 1.75 1.75	1.37 1.37 1.37	1.70 1.70 1.71
Acetone Extractables per ASTM-D-49-46, %	1% Max.	0.14 0.15 0.20	0.13 0.06 0.09	0.07 0.24 0.22	0.10 0.08 0.14
Interlaminar Shear per Fed. Test Method Std. 406, Method 1042, psi	1000 Psi Min.	1,460 1,550 1,430	1,900 1,700 1,800	2,500 2,200 2,800	2,000 2,000 2,000
Interlaminar Shear per Fed. Test Method Std. 406, Method 1042, psi	1000 Psi Min.	Interface Between Innerwrap and Overwrap 1,700 1,800		Interface Between Innerwrap and Overwrap 2,000 2,300 2,000	
Volatiles per TAP-DAP-122, %	3% Max.	2.89 2,83 2.86	2.93 2.91 2.95	2.39 2.04 2.14	2.66 2.70 2.71
Microtensile per ASTM-D-1708, psi	Report Only	12,030 15,600 13,310	9,600 9,000 d,200	10,700 5,400 11,800	26,400 20,400 25,700

Exit Cone Insert Properties from End Ring Test Specimens after Final Cure, 260-SL-1 Nozzle

Figure 219

Component Properties after Final Cure from Test Specimens

Test Conducted	Specification Limits	Aft Test Ring Inner Wrap MX-4926	Aft Test Ring Over Wrap MX-2646	Fwd Test Ring Inner Wrap MX-2646
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.38 min for MX-4926; 1.75 min. for MX-2646	1.45 1.45 1.45	1.78 1.80 1.79	1.80 1.81 1.81
Acetone Extractables per ASTM-D-494-46, %	1% max	0.08 0.11 0.08	0.07 0.06 0.06	0.16 0.08 0.05
Interlaminar Shear (208489) per Fed. Test Method Std. 406, psi	1000 psi min	2,980 2,550 2,810	2,700 3,100 3,300	-- 3,300 3,100
Interlaminar Shear (208489) per Fed. Test Method Std. 406, psi	1000 psi min	Interface Between Inner Wrap and Over Wrap 2,100 2,400 2,600		
Volatile (208491) per TAP-DAP-122, %	3% max	2.71 2.68 2.48	1.38 1.70 1.51	1.72 1.67 1.70
Microtensile (208488) per ASTM-D-1708, psi	Report only	17,700 13,400	17,600 14,200 18,100 18,200	12,700 19,600 17,100

Entrance Insert Properties from End Ring Test Specimens, 260-SL-2 Nozzle

Figure 220

Component Properties after Final Cure from Test Specimens

Test Conducted	Specification Limits	Aft Test Ring		Fwd Test Ring	
		Inner Wrap MX-4926	Over Wrap FM-5131	Inner Wrap MX-4926	Over Wrap FM-5131
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.38 min for MX-4926 1.68 min for FM-5131	1.45 1.45 1.45	1.74 1.74 1.74	1.45 1.44 1.45	1.75 1.75 1.75
Acetone Extractables per ASTM-D-494-46, %	1% max	0.19 0.16 0.16	0.11 0.07 0.11	0.09 0.17 0.11	0.19 0.13 0.12
Interlaminar Shear (208489) per Fed. Test Method Std. 406, Method 1042, psi	1000 psi min	2,500 1,500 5,900	1,600 i, 500 1,800	5,020 1,310 5,600	1,410 1,240 1,380
Interlaminar Shear (208489) per Fed. Test Method Std. 406, Method 1042, psi	1000 psi min	Interface Between Inner Wrap and Over Wrap 2,000 1,700 1,500		Interface Between Inner Wrap and Over Wrap 1,480 1,830 1,660	
Volatiles (208491) per TAP-DAP-122, %	3% max	2.20 2.07 2.20	2.83 2.87 2.84	2.14 2.04 2.03	2.84 2.79 2.80
Microtensile (208488) per ASTM-D-1708, psi	Report only	16,300 15,500 14,000	9,300 4,300 4,600	17,100 12,700 14,900	9,900 8,900 io,900

Throat Insert Properties from End Ring Test Specimens, 260-SL-2 Nozzle

Figure 221

Component Properties after Final Cure from Test Specimens

Test Conducted	Specification Limits	Aft Test Ring Inner Wrap MX-4926	Fwd Test Ring Inner Wrap MX-4926	Fwd Test Ring Over Wrap FM-5131
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.38 min for MX-4926 1.68 min for FM-5131	1.44 1.44 1.44	1.45 1.45 1.45	1.73 1.73 1.73
Acetone Extractables per ASTM-D-494-46, %	1% max	0.24 0.19 0.20	0.12 0.11 0.18	0.25 0.25 0.14
Interlaminar Shear (208489) per Fed. Test Method Std. 406, Method 1042, psi	1000 psi min	3,300 3,500	2,720 2,360 2,570	1,410 1.470 2,040
Interlaminar Shear (208489) per Fed. Test Method Std. 406, Method 1042, psi	1000 psi min		Interface Between Inner Wrap and Over Wrap 2,400 2,510 2,400	
Volatiles (208491) per TAP-DAP-122, %	3% max	1.93 1.94 1.94	1.93 2.10 2.02	3.28 3.31 3.30
Microtensile (208488) per ASTM-D-1708, psi	Report only	13,600 13,500 12,100	15,500 15,900 15,600	10,200 10,400 10,700

Throat Extension Insert Properties from End Ring Test Specimens, 260-SL-2 Nozzle

Figure 222

Component Properties after Final Cure from Test Specimens

Test Conducted	Specification Limits	Aft Test Ring Inner Wrap FM-5131	Aft Test Ring Over Wrap FM-5131	Fwd Test Ring Inner Wrap MX-4926	Fwd Test Ring Over Wrap FM-5131
Specific Gravity per Fed. Test Method Std. 406, Method 5011	1.38 min for MX-4926 1.68 min for FM-5131	1.71 1.71 1.70	1.71 1.70 1.72	1.42 1.41 1.42	1.71 1.72 1.71
Acetone Extractables per ASTM-D-494-46, %	1% max	0.12 0.14 0.15	0.10 0.11 0.10	0.02 0.11 0.09	0.06 0.07 0.09
Interlaminar Shear (208489) per Fed. Test Method Std. 406, Method 1042, psi	1000 psi min	1,230 1,280 1,140		2,620 1,510 2,200	1,270 1,290 970
Interlaminar Shear (208489) per Fed. Test Method Std. 406, Method 1042, psi	1000 psi min	Interface Between Inner Wrap and Over Wrap 1,020 1,320		Interface Between Inner Wrap and Over Wrap 1,700 2,000 1,960	
Volatiles (208491) per TAP-DAP-122, %	3% max	3.36 3.24 3.26	3.13 3.26 3.13	2.60 2.53 2.62	3.11 3.06 3.06
Microtensile (208488) per ASTM-D-1708, psi	Report only	8,300 7,900 7,500		21,400 18,800 23,100	10,100 7,400 9,000

Exit Cone Insert Properties from End Ring Test Specimens, 260-SL-2 Nozzle

Figure 223

Component	Non-Destructive Inspection	Discrepancy	Disposition
Entrance Insert	Radiographic and Ultrasonic	The inner (oriented) wrap is delaminated at the interface between carbon and silica materials. The separation extends from the overwrap interface radially inward approximately 1-1/4 in. which is approximately half the innerwrap ply thickness, and is continuous around the full 360° circumference of the insert.	No effect on insert performance is anticipated. Since the innerwrap-to-overwrap bond shows no defects, structural integrity is unimpaired; since the separation does not extend to the surface exposed to exhaust gas flow, there will be no effect on surface recession.
Throat Insert	Radiographic and Ultrasonic	Several delaminations exist in the carbon inner (oriented) wrap. The largest separation is located axially 3 in. aft of the aft face of the insert retention lip, extends radially through the full thickness of the carbon, and covers 340° of circumference. The plane of separation changes in at least five places. Five smaller delaminations exist in the area 4-1/2 to 7 in. aft of the aft face of the insert retention lip, all extending radially inward from the overwrap interface by varying amounts up to 1/2 the thickness of the carbon plies. Some delamination exists at every angular position over the full 360° circumference of the insert.	No effect on insert performance is anticipated. The innerwrap-to-overwrap bond shows no defects and will thus provide retention of the innerwrap as designed. At the eroding surface, negligible local increase in material loss may occur at the separation; the condition is comparable to the area of joints between inserts and no local effect has been obtained in such joints of nozzles tested in subscale motors.
Throat Extension Insert	Radiographic and Ultrasonic	No discrepancies.	
Exit Cone Liner	Ultrasonic, Radiographic, Alcohol Penetrat: c Check	Two delaminations exist in the carbon inner (parallel-to-centerline) wrap near the forward end of the liner, described as follows: 1) This separation is visible at the forward face of the liner 13/16 in. radially inward from the interface between the innerwrap and overwrap. Ultrasonic inspection indicates the separation extends across the full ply thickness of 2.4 in. and covers the full 360° of circumference. Alcohol penetration check from the forward end shows penetration to the interior surface over approximately 10° of circumference. 2) A separation extending from the interior surface at a plane 7 in. aft of the forward end of the liner, extending outward along the plies, a distance of 1-1/2 to 3 in., and covering the full 360° of circumference.	Repair by filling the delamination at the liner end face with Epon 919 resin mixed with catalyst B. Cut a groove in the forward face of the liner 0.100 in. wide at surface approximately 0.040 depth. Separately vacuum bag the forward end face and a minimum of 8 in. of the interior at the forward end. Bleed resin into both of the evacuated bags. Upon completion of resin application, no filling of the separation extending through the liner from the end face could be detected with ultrasonic inspection. However, the initial forward end portion cannot be checked since ultrasonic inspection is effective only perpendicular to the surface of transducer application. Visual inspection indicates continuous fill of the groove cut in the forward face. Analysis of loads during firing indicates 228 lb maximum loading from differential pressure. Lap shear panels bonded with the same Epon 919 resin used for liner repair and cured at ambient temperature, indicated 3000-psi average lap tensile shear strength. With the delamination sealed by filling of the groove and potted on assembly to the nozzle, adequate retention of the separated portion is provided. Analysis of erosion expected if the separated portion is ejected at the start of firing indicates no overheating should occur beyond the overwrap interface at this limit condition. After resin fill, ultrasonic inspection of the second delamination originating at the interior surface indicates separation over approximately 180° of circumference indicating some filling of this separation with Epon 919 was achieved. Since the laminate at this point extends to the overwrap and there are no defects in overwrap-to-innerwrap bond, normal retention of this portion is afforded, and no adverse effect will result from the separation.

Summary of Non-Destructive Inspection of Plastic Components, 260-SL-1 Nozzle and Exit Cone Assemblies

Figure 224

Bond Joint	Bond Line Gap, in.	Avg. Bond Shear Strength, psi	Ultrasonic Inspection	Axial Gap, in.
Throat Insert to Nozzle Shell	.010 to .015	3573	One grid area 9% unbonded; less than 1/2% of total area is unbonded.	Throat insert to shell face, .003 to .011 in.
Entrance Insert to Nozzle Shell	.022 to .087	2875	One grid area 8.5% unbonded; approximately 1/2% of total area is unbonded.	Throat to inlet inserts; approximately .002 to .003 in.
Throat Extension Insert to Nozzle Shell	.010 to .023	33 [illegible]	One area of 16 sq in. plus several small areas; approximately 1/2% of total area is unbonded.	Throat to throat extension inserts, 0.023 to 0.028 in.
Insulation to Nozzle Shell	.026 to .096	1002	0.1% unbonded	Insulation to entrance insert, 0.010 to 0.040 in.
Insulation to Entrance Insert	.085 to .275	1002	Not detectable with ultrasonics	

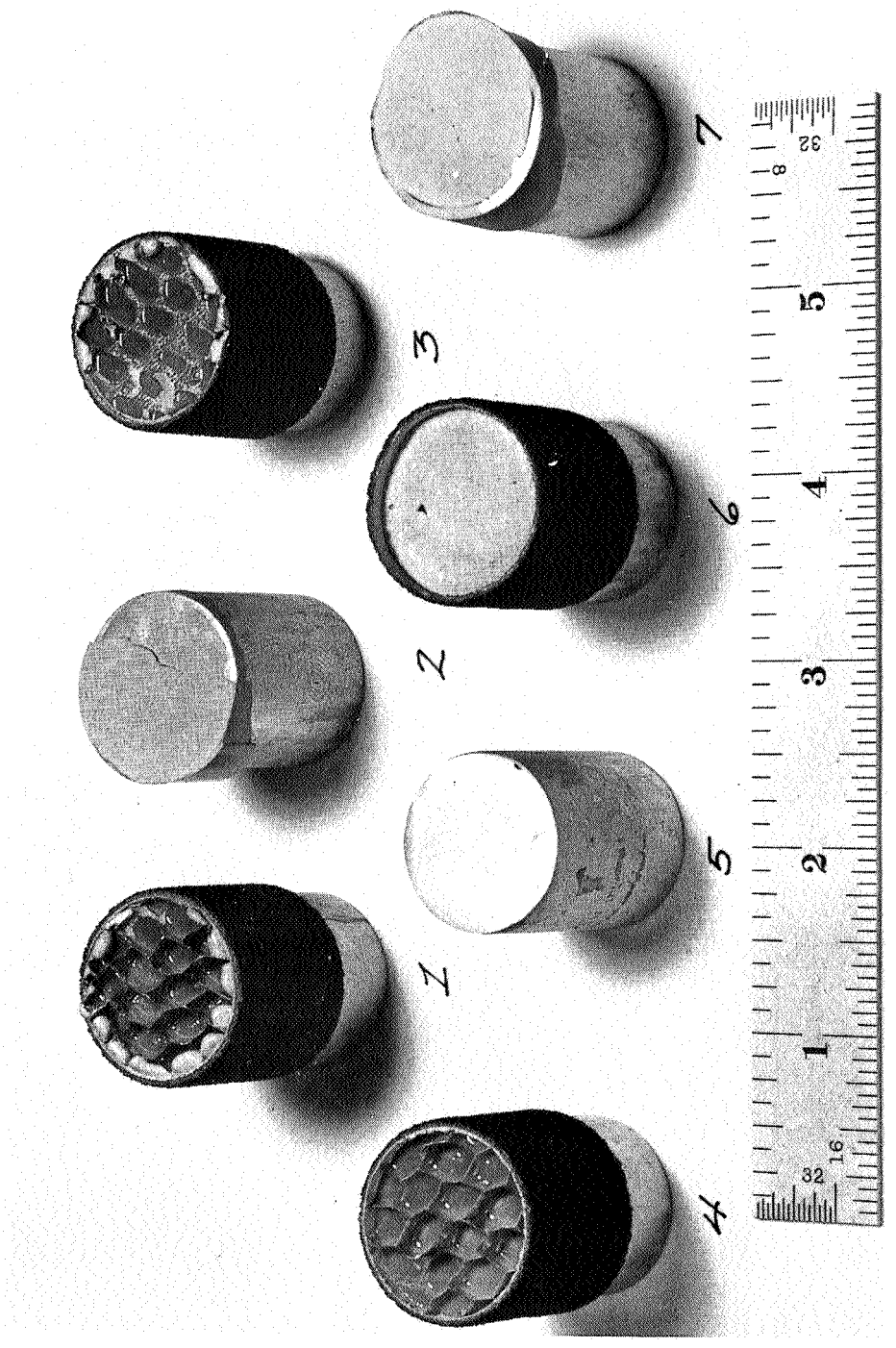
Bonding Process Summary of Nozzle Assembly, 260-SL-1 Nozzle

Figure 225

Bond Joint	Bond Line Gap, in.	Average Bond Shear Strength, psi	Ultrasonic Inspection	Axial Gap, in.
Throat Insert to Nozzle Shell	0.009 to 0.027	3138	No indications.	Throat insert to shell face, 0.0035 to 0.0115 in.
Entrance Insert to Nozzle Shell	0.045 to 0.156	3240	One area 3.5 by 6 in., less than 0.5% is unbonded.	Throat to inlet inserts, 0.007 to 0.021 in.
Throat Extension Insert to Nozzle Shell	0.013 to 0.033	3042	One area 1 by 2.5 in., less than 0.5% is unbonded.	Throat to throat extension inserts, 0.000 to 0.006 in.
Insulation to Nozzle Shell	0.021 to 0.14	1455, 1236	Less than 0.5% is unbonded.	Insulation to entrance insert, 0.022 to 0.090 in.
Insulation to Entrance Insert	0.034 to 0.171	1455, 1236	Not detectable with ultrasonics.	

Bonding Process Summary of Nozzle Assembly, 260-SL-2 Nozzle

Figure 226



Trepan Test Specimens of 260-SL-1 Exit Cone

Figure 227

Bond Joint	Bond Line Gap, in.	Bond Shear Strength, psi	Ultrasonic Inspection
Inner doubler to exit cone liner (Epon 913)	0.003 to 0.011	Primed - 2283 avg. Unprimed - 3488 avg.	Unbonding in several areas near aft end, totaling approximately 6% of surface. Repaired by drilling doublers and injecting Epon 913. No ultrasonic indications after repair.
Forward flange to exit cone (Epon 913)	0.012 to 0.023	Primed to Unprimed - 3036 avg.	No defects
Aft flange to exit cone (Epon 913)	0.008 to 0.049	Primed to Unprimed - 2383 avg.	No defects
Honeycomb to inner facings (FM 75-25)	0.008 to 0.011	Six trepan tests; High 1001, Low 581; 897 avg.	Not detectable with ultrasonics
Honeycomb to outer facings (FM 75-25)	0.008 to 0.011	18 trepan tests High 1001, Low 323; 585 avg.	Not detectable with ultrasonics
Outer doublers to outer skin (FM 75-25)	0.008 to 0.011	Primed - 1787 avg	No defe ts

Exit Cone Bonding Process Summary, 260-SL-1 Nozzle

Figure 228

Bond Joint	Bondline Thickness, in.	Average Bond Shear Strength, psi	Ultrasonic Inspection
Inner Doublers to Plastic	0.017 - 0.027	1540, 1829 (first cure) 1500, 2000 (third cure)	Doubler No. 3: One indication at 7-3/4 in. from edge and 52-1/2 in. from aft end 1/2 in. wide x 1-1/2 in. long. One indication at 19 in. from edge and 33-3/8 in. from aft end 1/2 in. wide x 2 in. long.
Aft Flange to Inner Doublers (Epon 913)	0.022 - 0.062	3240 first cure) 1928 [second cure)	From 0° (TDC) to 90° CCW (looking aft) signal above optimum bond by maximum of 20% over 3-1/4 in. bond at thickest cross-sectional area of ring.
Inner Facing to Inner Doublers (Epon 955)	0.007 - 0.013	851, 1664 (first cure) 1574, 1843 (second cure)	Not Applicable.
Honeycomb Core to Inner	0.007 - 0.013	851, 1664 (first cure) 1574, 1843 (second cure) Trepan - 715 Flatwise Tensile: 657 (first cure) 717 (second cure)	Not Applicable.
Outer Facing to Honeycomb Core (Epon 955)	0.007 - 0.013	1006, 1388 Trepan - 729 Flatwise Tensile: 798	Nonstandard Areas: Fanel No. 2: 14 in. from fwd flange 3 in. from left doubler area 2-1/2 in. x 1/2 in., 46.5 in. from fwd flange 3 in. from left doubler area 1 in. x 2 in., 57.5 in. from fwd flange 3 in. from left doubler area 1 in. x 2-1/2 in. Panel No. 3: 70 in. from fwd flange 3 in. from left doubler area 24 in. x 1/2 in. intermittent. Fanel No. 11: 5 in. from flange 2 in. from left doubler area 3 in. x 1/2 in. Fanel No. 14: 40.5 in. from flange 3 in. from left doubler. Area d in. x 1/2 intennettent.
Forward Flange to Inner Doubler (Epon 913)	0.008 - 0.030	2397	No Indication.
Forward Flange to Plastic Liner (Won 913)	0.012 - 0.040	2397	NO Indication.
Outer Facings to Forward Flange (Epon 955)	0.007 - 0.013	1006, 1388	No Indication.
Outer Facings to Aft Flanges (Epon 955)	0.007 - 0.013	1006, 1388	No Indication.
Outer Doublers to Outer Facings (Epon 955)	0.007 - 0.013	1006, 1388	Nonstandard Areas: Doubler No. 2: 27.5 in. from flange 1 in. from left end of doubler 2-1/4 in. x 1/2 in. area. Doubler No. 3: 19 in. from flange 1 in. from left end of doubler 1 in. x 1/2 in. area. 21.5 in. from flange 1 in. from left end of doubler 2-1/2 in. x 1/2 in. area. 43 in. from flange 1 in. from left end of doubler 1 x 1/2 in. area Doubler No. 5: 44.5 in. from flange 2 in. from left end of doubler 2 in. x 2-1/2 in. area.

Exit Cone Bonding Process Summary, 260-SL-2 Nozzle

Figure 229

Property	Specification Requirements MX-2646	Specification Requirements MX-4926	Ultimate Properties from Laboratory Tests (1000-psi Mold Pressure) MX-2646	Ultimate Properties from Laboratory Tests (1000-psi Mold Pressure) MX-4926	MX-2646 Innerwrap	MX-4926 Innerwrap	MX-2646 Overwrap	MX-2646/ MX-4926 Interface
Interlaminar Shear, psi	1,000 min.	1,000 min	---	---	2,690 2,940	2,020 2,970	4,320 3,710	1,360 4,480
Acetone Extraction, %	1.0 max	1.0 max	5 max	5 max	.08	.13	.09	N/A
Specific Gravity	1.75 min	1.38 min	0.78 min	1.45 min	1.78 1.77	1.44 1.44	1.80 1.77	N/A
Volatile Content, %	3 max	3 max	---	---	2.04	1.53	---	N/A

Properties of Cured Entrance Insert from End Ring Test Specimens, 120-SS-1 Nozzle

Figure 230

Property	FM-5131 Outerwrap Specification Requirement	FM-5131 Outerwrap Test Value	MX-4926 Innerwrap Specification Requirement	MX-4926 Innerwrap Test Value
Specific Gravity	1.68	1.73	1.38	1.45
Interlaminar Shear, psi	1000	2.240 2.260	1000	1.220 840 3.970
Volatiles, %	≤ Maximum	2.04 2.31	≤ Maximum	---
Edgewise Compression, psi	Not Required	21,100 24,800	Not Required	36,500 35,800
Flexural Strength, psi	16,000*	18,000 17,700	30,000*	40,700
Acetone Extraction, %	1 Maximum	0.18	1 Maximum	0.14
Laminate Orientation, degrees	60 to 70	66.29	60 to 75	66.29

*Not required for cured part acceptance, only a material procurement requirement

Properties of Cured Throat Insert from End Ring Test Specimens, 120-SS-1 Nozzle

Figure 231

Property	MX-4926 Innerwrap Specification Requirement	MX-4926 Innerwrap Actual	FM-5131 Outerwrap Specification Requirement	FM-5131 Outerwrap Actual	Interface MX-4926 and FM-5131
Specific Gravity	1.38	1.45 1.45	1.68	1.71 1.71	Not Applicable
Interlaminar Shear, psi	1000 min	2,510 2,880	1000 min	2,760 2,640	3,600 2,750
Volatile, %	3 max	1.94 1.95	3 max	-	Not Applicable
Edgewise Compression, psi	Not Required	55,600 57,700	Not Required	15,400 15,300	Not Applicable
Flexural Strength, psi	30,000 min*	40,300 34,200	16,000 min*	22,400 23,400	Not Applicable
Acetone Extraction, %	1 max	0.08 0.10	1 max	0.07 0.08	Not Applicable

*Not required for cured part acceptance, only a material procurement requirement.

Properties of Cured Throat Extension Insert from End Ring Test Specimens, 120-SS-1 Nozzle

	MK-4926		FM-5131 Outer Overwrap	Interface Bond Between MX-4926 and FM-5131	1000 psi Press Molding Typical Yawes*	
	Inner I D	Inner O D			MX-4926	FM-5131
Interlaminar Shear, psi	3,700 2,500	3,000 1,900	2,500 2,400	1,800 2,200	3,700 -	- -
Compressive Strength, psi (Edge Compression)	27,900 22,400	33,000 35,000	14,900 15,300	Not Applicable	-	15,000 18,000
Tensile Strength, psi (Micro Specimen)	15,300 6,100	12,300 16,700	9,200 6,800	Not Applicable	18,000	12,000 to 15,000
Specific Gravity	1.34 1.34	1.34 1.34	1.70	Not Applicable	1.4 min.	1.73
Acetone Extractibles, %	- -	0.22 0.21	- -	Not Applicable	.5	.5
Volatile Content, % (Ratio of Wt Loss to Initial Wt of Laminate)	- -	2.30 2.15	- -	Not Applicable	-	-

*Data presented for comparison of the nylon tension wrapped and molded 120-SS exit cone to a typical platen pressure test panel data.

Physical and Chemical Properties of Exit Cone Forward Test Ring, 120-SS-1 Motor

Figure 233

Property	Inner Wrap I D Under Strap	Inner Wrap I D Between Straps	Inner Wrap O.D Under Straps	Inner Wrap O.D Between Straps	Outer Wrap Under Strap	Outer Wrap Between Straps	Interface Bond Between FM-5131 and FM-5131	TRW/AGC Reqmt's FM-5131	1000 psi Press Mold Typical Values FM-5131
Interlaminar Shear, psi	2,200 1,800	1,800 2,300	2,100 2,100	2,000 2,300	1,400 1,500	1,300 1,300	2,200 1,900	1,000	
Compressive Strength, psi (Edge compression)	22,500 22,200	18,000 23,000	21,200 20,200	20,700 19,800	12,800 13,900	13,100 14,400	N/A	Not Req'd	15,000 18,000
Tensile Strength, psi (Micro Tensile)	11,800 13,100	12,500 13,200	13,200 12,300	13,800 13,000	6,200 5,000	6,200 6,100	N/A	Not Req'd	12,000 15,000
Specific Gravity	1.72 1.72	1.72 1.72	1.74 1.74	1.74 1.74	1.74 1.74	1.73 1.73	N/A	1.58 min	1.73
Acetone Extractible, %	.12		.11		.16	.14	N/A	1% max	5
Volatile Content, %	2.87 - 2.84				-		N/A	3% max	-

Figure 234

Physical and Chemical Properties of Exit Cone Aft Test Ring, 120-SS-1 Motor

	Specimen No. 1		Specimen No. 2		Specimen No. 3	
	Tensile Strength, psi	Modulus Elasticity, psi	Tensile Strength, psi	Modulus Elasticity, psi	Tensile Strength, psi	ulus icity, si
Hoop Direction Entrance Insert Forward Test Ring Silica (MX-2646)	17,600	3.32×10^6	17,100	3.05×10^6	17,100	- x 10^6
Hoop Direction Entrance Insert Aft Test Ring Carbon (MX-4926)	14,600	3 04 x 10^6	13,600	2.60×10^6	13 90	2 52 x 10^6
Meridional Direction Entrance Insert 120SS Fired Component Silica (MX-2646)	7,870	3.29×10^6	7,580	2.63×10^6	8,160	2.83×10^6
Hoop Direction Throat Insert Test Ring Carbon (MX-4926)	15,800	3.28×10^6	19,700	2.74×10^6	17,400	2 79 x 10^6

Ablative Materials Property Data from 120-SS-1 Motor Components

Figure 235

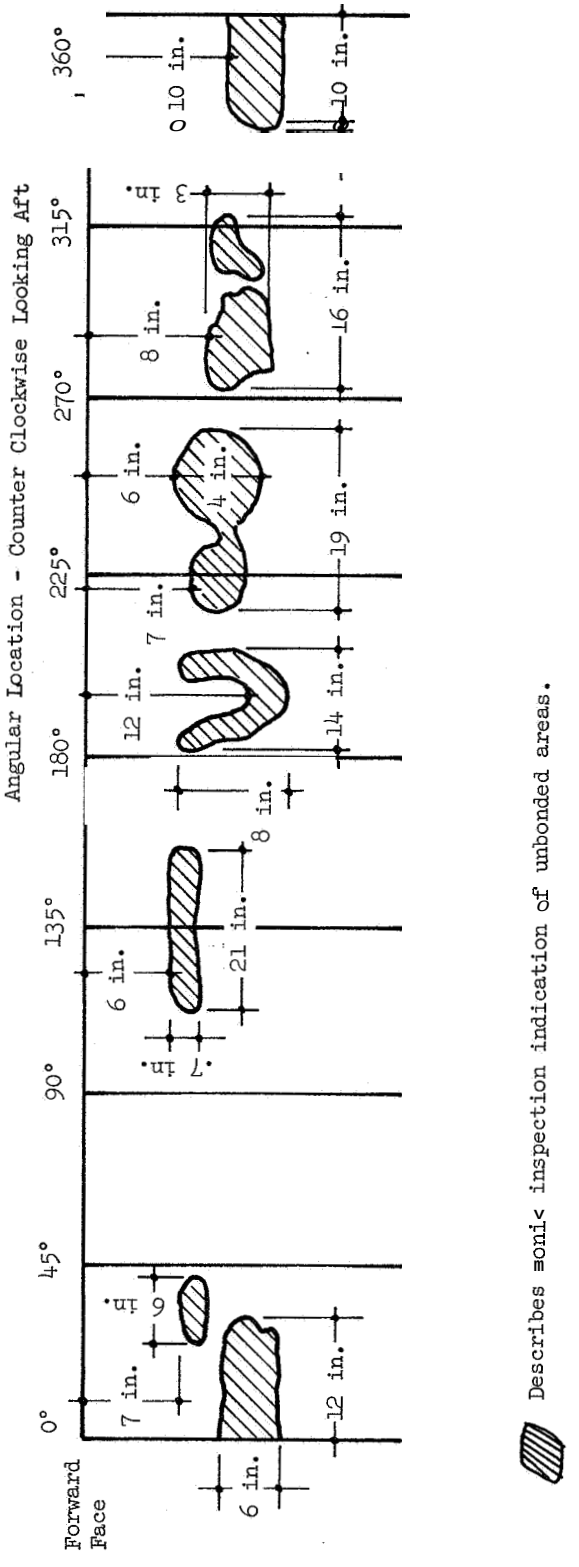


Figure 236

Prefire Ultrasonic Inspection of the 120-SS Entrance Inlet, Epon 913 Bond to the Nozzle Shell

Component Assembly	Gap Requirement, in.	Actual, in.	Remarks
Insulation Nozzle to Shell	.002 - .050	.014 - .070	Accepted by Aerojet Engineering Review Board
Exit Cone Insert to Nozzle Throat Extension Insert	.040 - .070	.000 - .050	Accepted by Aerojet Engineering Review Board
Entrance Insert to Shell	.020 - .050	.041 - .050	
Entrance Insert to "O" Ring Groove	.000 - .006	.001 - .002	
Entrance Insert to Throat Insert	.002 - .010	.002 - .003	
Throat Insert to Shell	.002 - .008	.006 - .008	
Throat Insert to Shell Shoulder	.000 - .006	.006	
Throat Insert to "O" Ring Groove	.000 - .006	.005 - .006	
Throat Extention to Shell	.002 - .010	.004 - .008	

Bond Gap Inspection Data, 120-SS-1 Nozzle

Figure 237

In-Process Test	Requirement, psi	Actual, psi	Test Represents
Lap Shear, steel to steel with Epon 948 cured at 135°F for 24 hr	--	844 avg.	Bonding of rubber insulation to shell
Lap Shear, steel to steel with Epon 913 cured at 140°F for 7 hr	2100 min.	2219 avg.	Bonding of entrance insert to shell
Lap Shear, steel to steel with Epon 913 cured at 140°F for 7 hr	2100 min.	3780 avg.	Bonding throat insert to shell

In Process Specimen Test Results, 120-3S-1 Nozzle

Figure 238

Plug No.	Relative Location on Assy Panel No.	Location	Test Requirement	Test Result	Mode of Failure
1	3	Middle	300 psi min	696 psi	Cohesive failure
2	7	Bottom	↓	745 psi	Pull-plug bond failure
3	6	Middle	↓	810 psi	Pull-plug bond failure
4	4	Top	↓	907 psi	Core failure
5	2	Middle	↓	486 psi	Adhesive failure
6	1	Bottom	↓	842 psi	Core failure
7	5	Top	↓	745 psi	Pull-plug failure

Exit < e Trepan Test Data, Motor 120-SS-1

Figure 239

Test Panel	Lap Shear Requirement	Lap Shear Actual	Flatwise Tensile Requirement	Flatwise Tensile Actual
Steel to steel with Epon 913; 4 hr cure at 180°F	2000 psi min avg	3201 psi avg	-	-
Steel to steel with Epon 75-25; 4 hr cure at 180°F	2000 psi min avg	2930 psi min	-	-
Honeycomb to steel with Epon 75-25; 4 hr cure at 180°F	-	-	400 psi min avg	555 psi avg

Exit Cone Bond Test Data, Motor 120-SS-1

Figure. 240

Property	Specification Requirements	Extrance Insert		Throat Insert		Exit Cone Insert	
		MX-2646 Liner	MX-2646 Overwrap	MX-4926 Liner	FM-5131 Overwrap	MX-4926 Liner	FM-5131 Overwrap
Acetone Extractables, %	1.0 max.	0.29	0.27	0.19	0.23	0.12	0.25
Specific Gravity	MX-2[illegible]4[illegible] 1 75 min.	1.78	1.78				
	MX-492[illegible], 1 [illegible]8 min.			1.45		1.46	
	FM-5131 1.6[illegible] min.				1.73		1.72
Interlaminar Shear, psi	1000 min.	3,600	*	3,850	1,170	4,843, 4,331	1,26[illegible] 1,472
R sin Soli[illegible], %	MX-2[illegible]4[illegible] 18 23	22.70	22.20				
	MX-4926, 31.5-37			38.6		35.22	
	FM-5131, 29.5-35				[illegible]4.2		34.1
Vol tile[illegible] %	2.0 max.	.89	*	1.8[illegible]	*	2 55	2.26

*Insufficient material to obtain test specimen.

Cured Physical Properties from End Ring Test Specimens, 44-SS-1 Nozzle

Figure 241

Property	Specifications Requirements	Entrance Insert		Throat Insert		Exit Cone Insert	
		MX-2646 Liner	MX-2646 Overwrap	MX-4926 Liner	FM-5131 Overwrap	MX-4926 Liner	FM-5131 Overwrap
Acetone Extractables, %	1.0 max	0.15	0.15	0.10	0.21	0.15	0.25
Specific Gravity	MX-2646, 1.75 min	1.78	1.79				
	MX-4926, 1.38 min			1.46		1.45	
	FM-5131, 1.68 min				1.73		1.74
Interlaminar Shear, psi	1000 min.	4710, 3920	4190, 4150	4750, 4780	3320, 3190	1780, 1830	*
Resin Solids, %	MX-2646, 18-23	21.10	21.20				
	MX-4926, 31.5-37			36.70		35-39	
	FM-5131, 29.5-35				33.9		32.6
Volatiles, %	2.0 max	1.15	*	1.94	3.33	2.00	*

*Insufficient material to obtain test specimen.

Cured Physical Properties from End Ring Test Specimens,
44-SS-2 Nozzle

Figure 242

Property	Specification Requirements	Entrance Insert		Throat Insert			Exit Cone Insert	
		MX-2646 Liner	MX-2646 Overwrap	MX-4926 Liner		FM-5131 Overwrap	MX-4926 Liner	FM-5131 Overwrap
				Die Molded	Tape Wrapped			
Acetone Extractables, %	1.0 max.	63, 65	63, 63	.80, .11	.11, .08, .22	.13, .13, .24	.10, .11	.23, .16
Specific Gravity	MX-2646, 1.75 min.	1.73, 1.79	1.77, 1.80					
	MX-4926, 1 38 min			1.45, 1.45	1.41 1.43		1.45, 1.45	
	FM-5131, 1.68 min.					1.72, 1.72		1.72, 1.71
Interlaminar Shear, psi	1000 min.	3800, 3900	3500, 4000	2240, 2860	*	*	3770	2140, 2260
Resin Solids, %	MX-2646, 18-23	23 0	22.9					
	MX-4926, 31 5 37			39.7	38 , 37 , 38		35.94	
	FM-5131 29 5-35					32.7, 32.7, 33.0		35.0
Volatiles, %	2.0 max.	2.18, 2.04	*	2.76, 2.72	2.57, 2.53, 2.52	2.55, 2.52, 2.61	1.95, 1.93	*

*Insufficient Material to Obtain Test Specimens

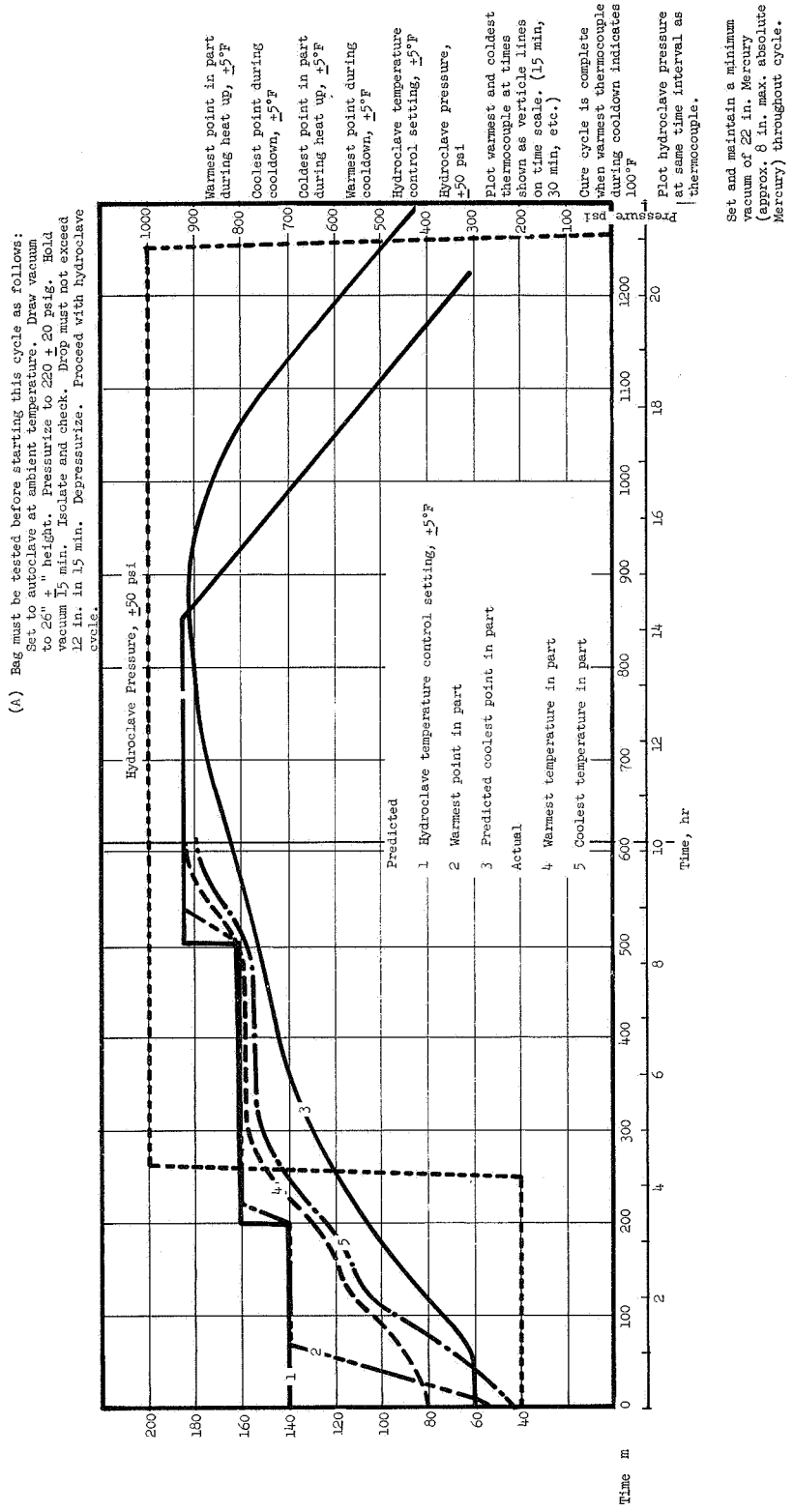
Cured Physical Properties from End Ring Test Specimens, 44-SS-3 Nozzle

Figure 243

Bond Joint	44-SS-1 Nozzle		44-SS-2 Nozzle		44-SS-3 Nozzle		
	Bondline Gap, in.	Ultrasonic Inspection	Bondline Gap, in.	Ultrasonic Inspection	Bondline Gap, in.	Avg. Bond Shear Strength,	Ultrasonic Inspection
Throat Insert to Nozzle Shell	.011 to .014	No unbonding detected	.010 to .015	No unbonding detected	.018 to .022	3444	No unbonding detected
Entrance Insert to Nozzle Shell	.026 to .043	Three unbonded areas 1-3/4 by 2-1/2, 5-1/4 by 1-1/4, and 6-1/2 by 1/2 in. less than 1% of total area unbonded	.03 to .06	Less than 1% of total area is unbonded	.017 to .032	3085	No unbonding detected
Exit Cone Insert to Nozzle Shell	.01 to .015	No unbonding detected	.010 to .05	Less than 1% of total area is unbonded	.008 to .012	---	Two unbonded areas; 4.2 by 3.6 and 3.6 by 1.8 in. less than 1/2% of total areas
Insulation to Nozzle Shell	.025 to .19	One area 3 by 2 in. from forward flange	.017 to .15	Unbonded areas less than 1/2% of total area	.045 to .05	1013	No unbonding detected
Insulation to Entrance Insert	.027 to .12	No unbonding detected	.020 to .075		.032 to .055	1103	No unbonding detected

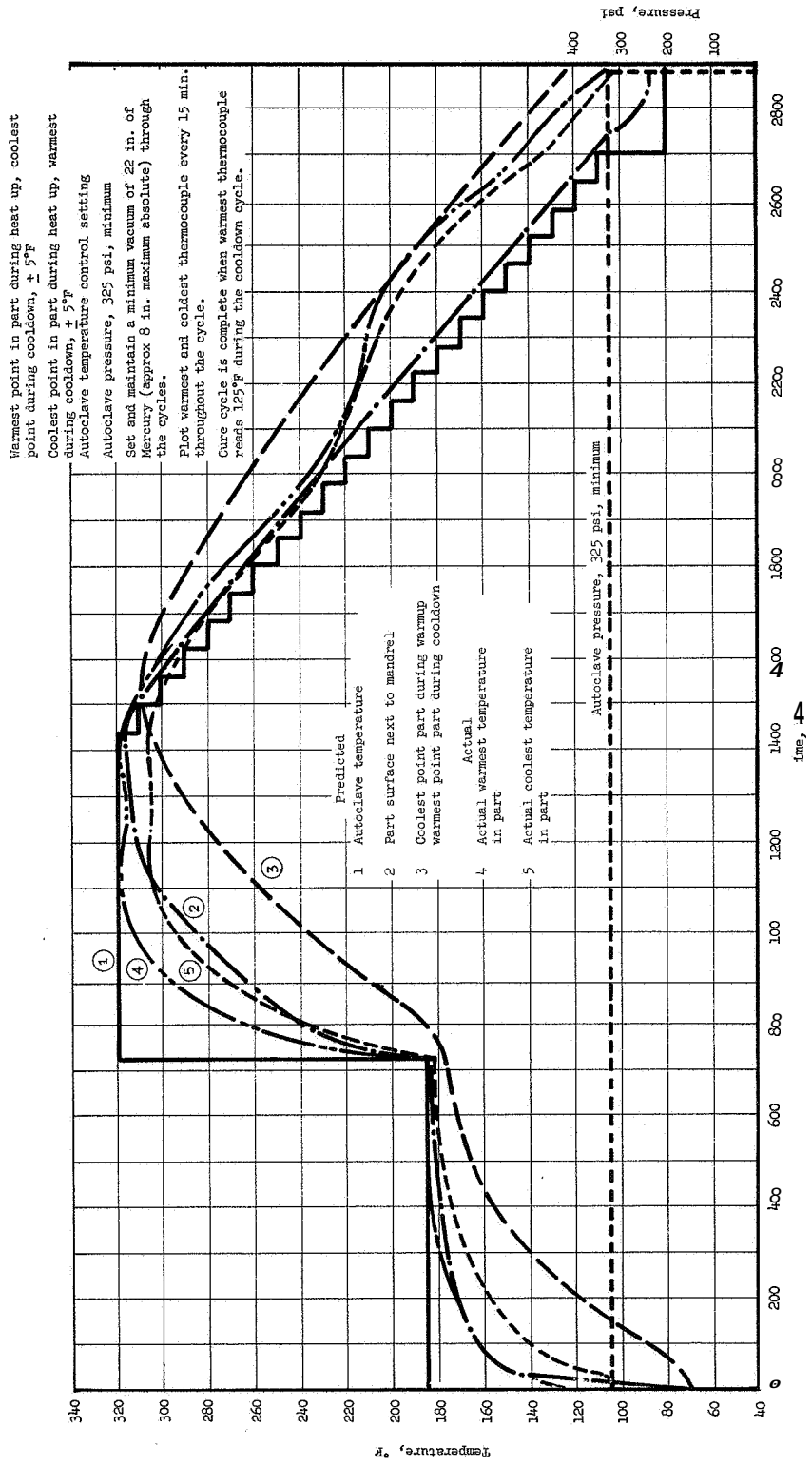
Figure 244

Bonding Inspection Summary of 44-SS Nozzle Assembly



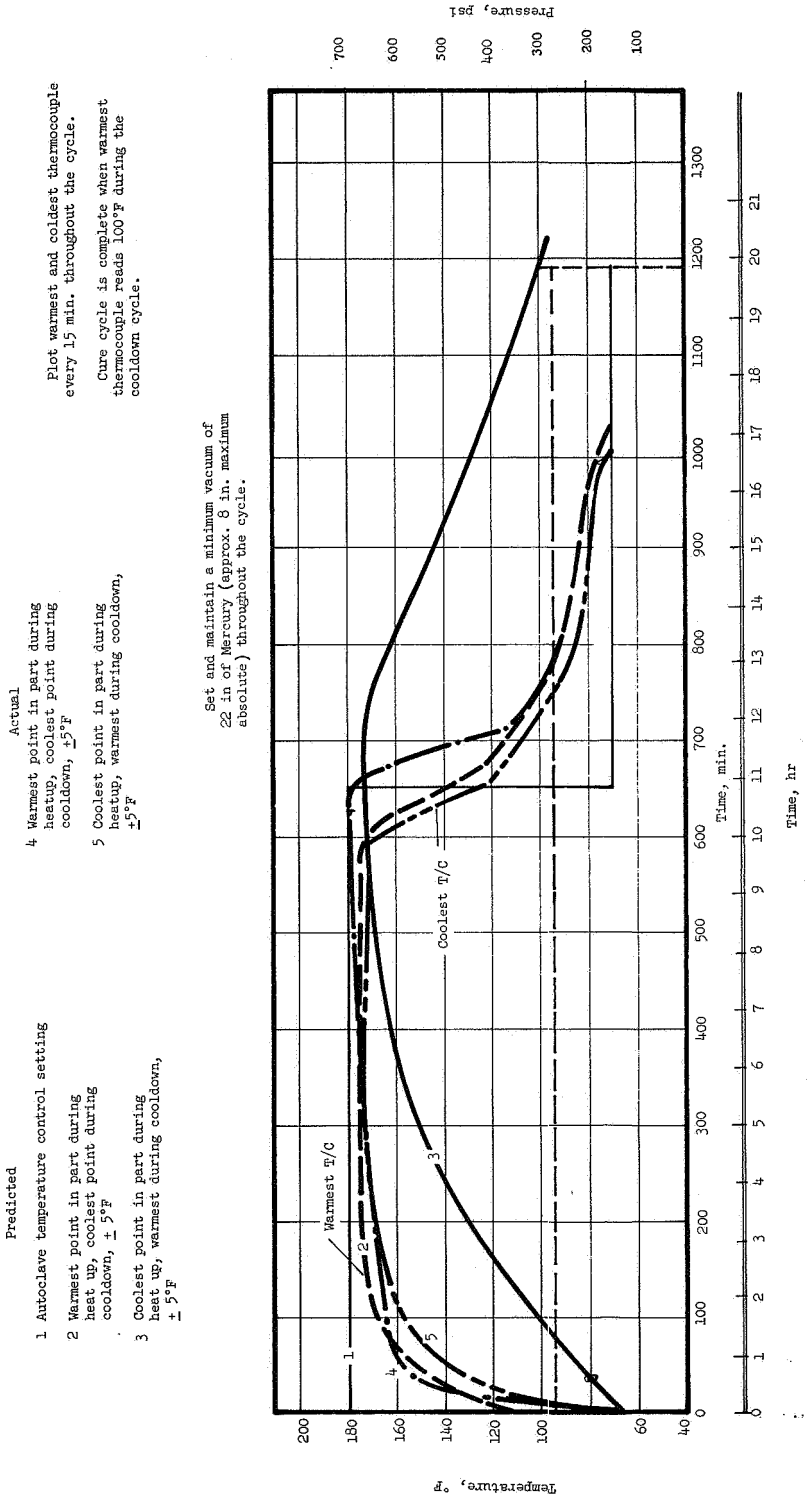
Inlet Insert, Hydroclave Preform Cycle, 260-SL-1 Nozzle

Figure 245



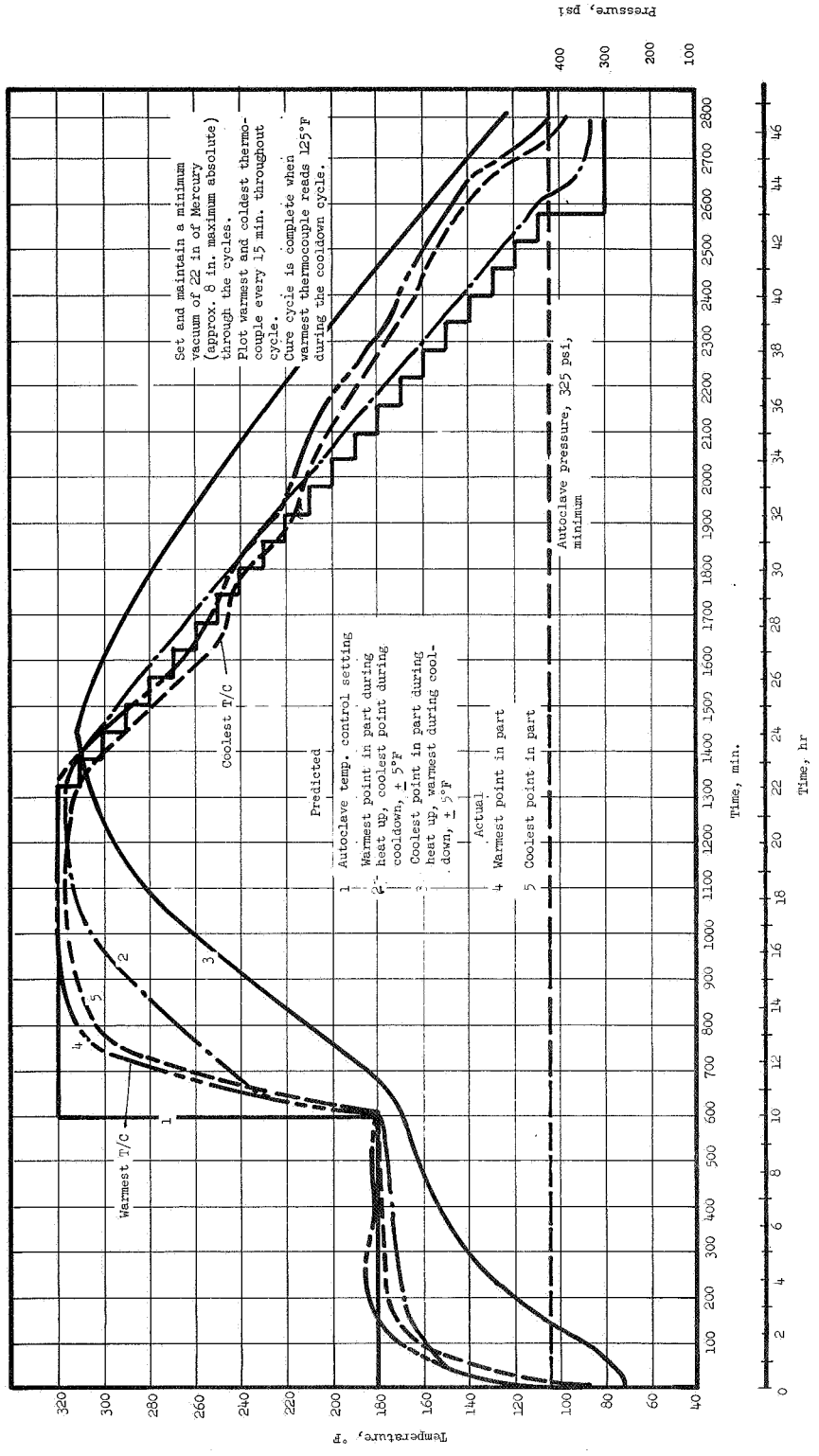
Entrance Insert, Autoclave Final Cure Cycle, 260-SL-1 zzle

Figure 246



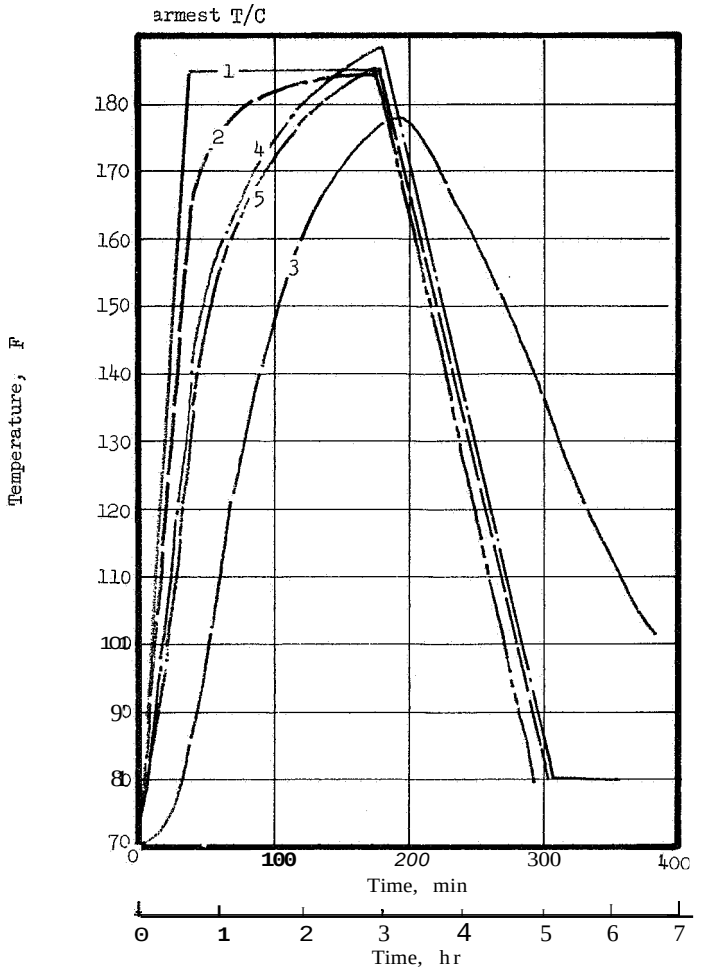
Throat Insert, Autoclave Preform CX-4, 260-SL-1 Nozzle

Figure 247



Throat Insert Autoclave, Final Cure Cycle, 260-SL-1 Nozzle

Figure 248



1. Install in autoclave. Connect vacuum and dead end gage. Draw vacuum. Isolate and check. 3 in. drop in 20 min is permissible. Repair if needed.
2. Connect TC's to recorder leads having the same number.
3. Close clave. Pressurize to 300 psi ± 10 psi. Recheck vacuum. 5 in. drop in 20 min. permissible.
4. Set autoclave temperature to 185°F. When coldest TC reaches 175°F, hold for 60 min.
5. Cool to 135°F maximum at the rate of 50°F per hour.

Predicted

1 Autoclave emperature

2 Mandrel side of part (warmest)

3 Coolest part point during warmup; warmest during cooldown

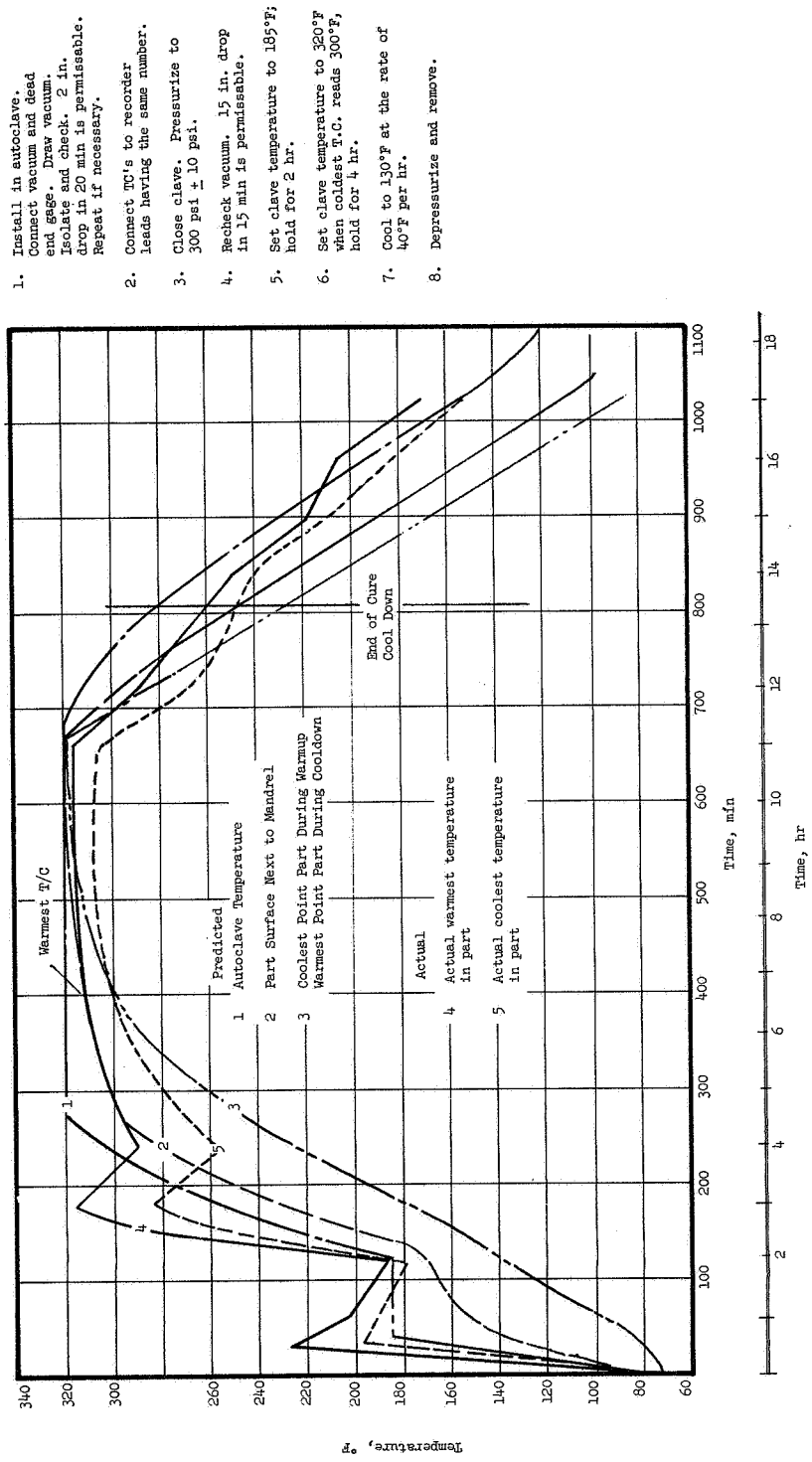
Actual

4 Warmest point in part

5 Coolest point in part

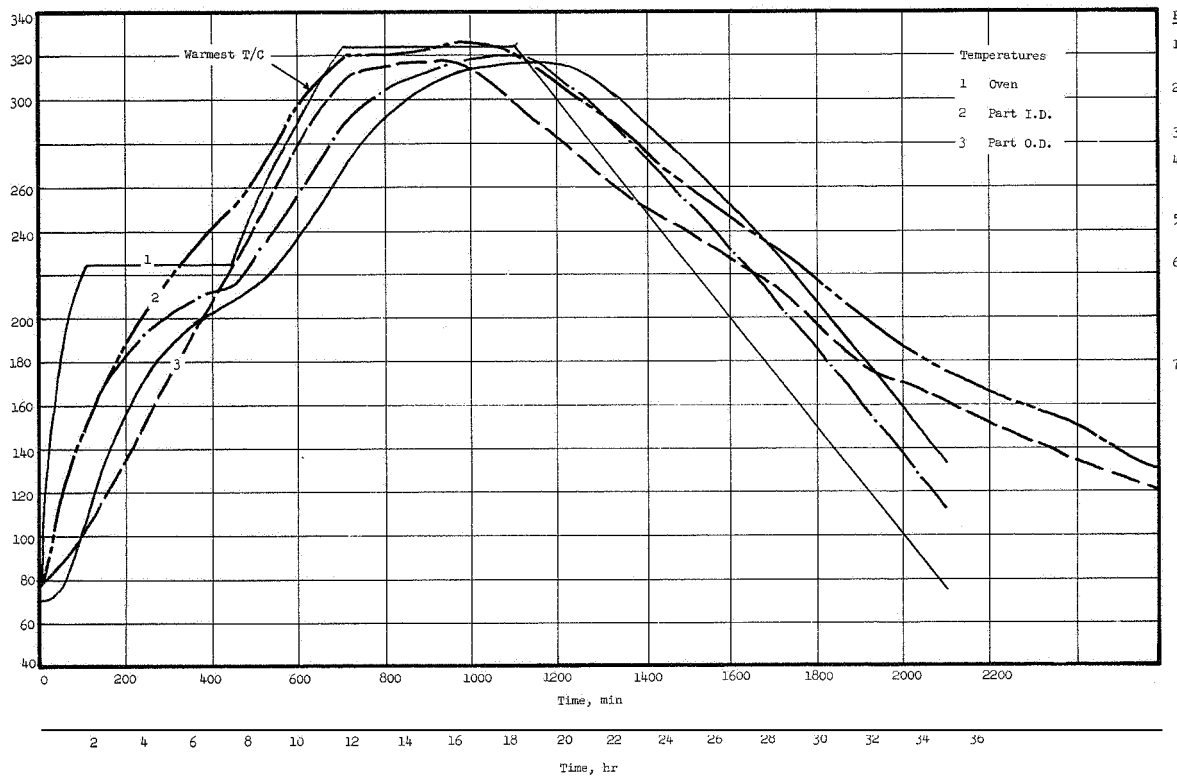
Throat Extension Insert, Preform Cycle, 260-SL-1 Nozzle

Figure 249



Throat Extension Insert, Final Autoclave Cure, 260-SL-1 Nozzle

Figure 250



PROCEDURE

1. Close oven doors and start all recording equipment.
2. Set vacuum for (15 ± 2) in. of Mercury.
3. Set oven for 225°F. Turn on oven.
4. When warmest thermocouple reaches 180°F, set vacuum at $(25 \pm^{5}_{1})$ in. of Mercury.
5. When the coldest thermocouple reaches (215 ± 5) °F, set oven for 325°F.
6. Record vacuum gage reading every 15 min. It is not necessary to plot this curve. Record the readings on the warmest and coolest thermocouples every 15 min. for the first five hr and every 30 min. thereafter.
7. After the coldest thermocouple has been above 300°F for four hr, begin the cooldown. Set oven for 75°F. The object is to cool the oven 15 Farenheit degrees every hr.

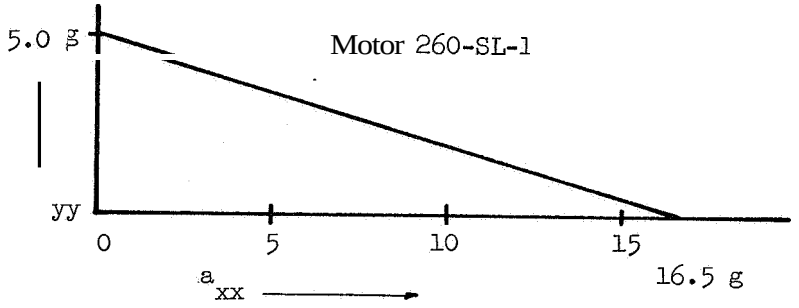
   The only method for adjusting the cooldown rate is opening or closing the oven door.

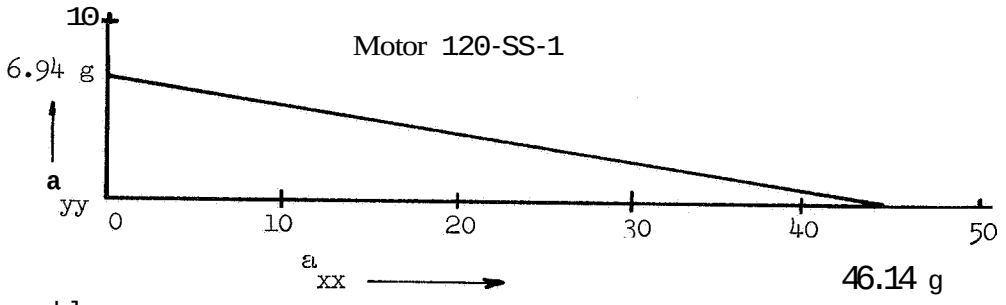
   At no time should the difference in temperature between the warmest and coolest thermocouples exceed 50 Farenheit degrees. If this difference does exceed 50 degrees, the oven door should be closed immediately and the oven turned off.

Figure 251

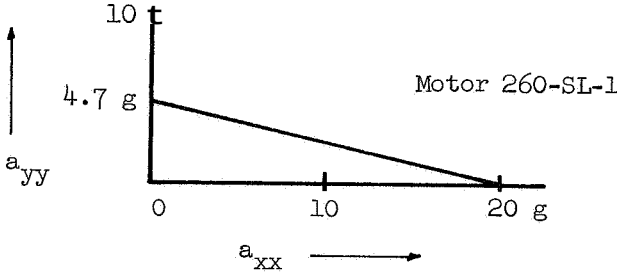
Exit Cone Insert, Final Cure Cycle, 260-SL-1 Nozzle

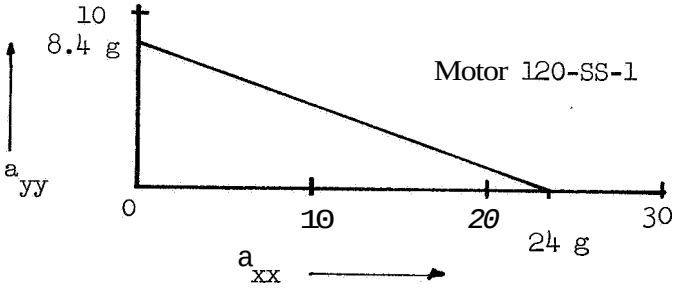
Exit Cone Assembly





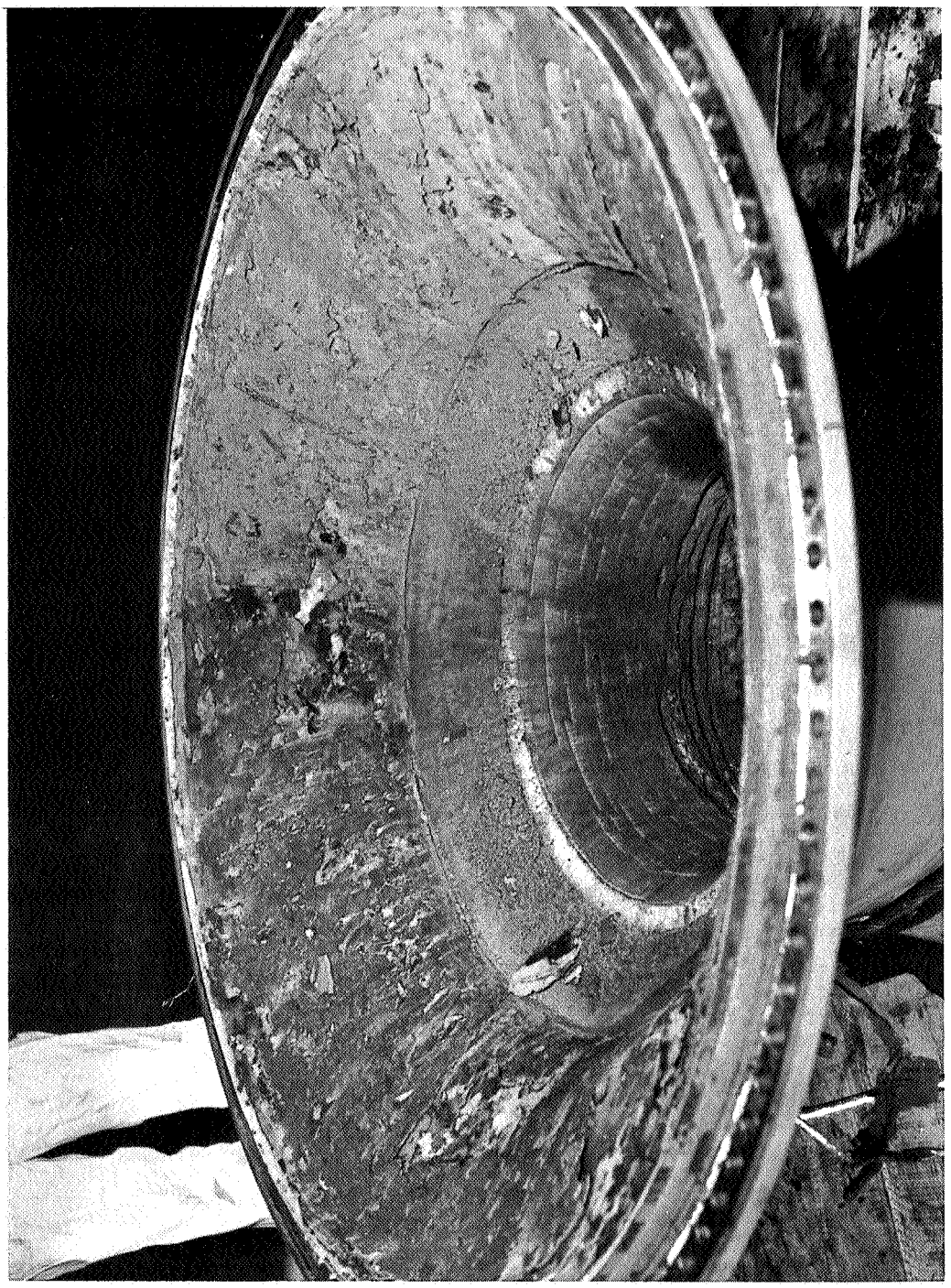
Nozzle Assembly





Handling Envelopes for the 260-SL-1 and 120-SS-I Motor Nozzles and Exit Cones

Figure 252

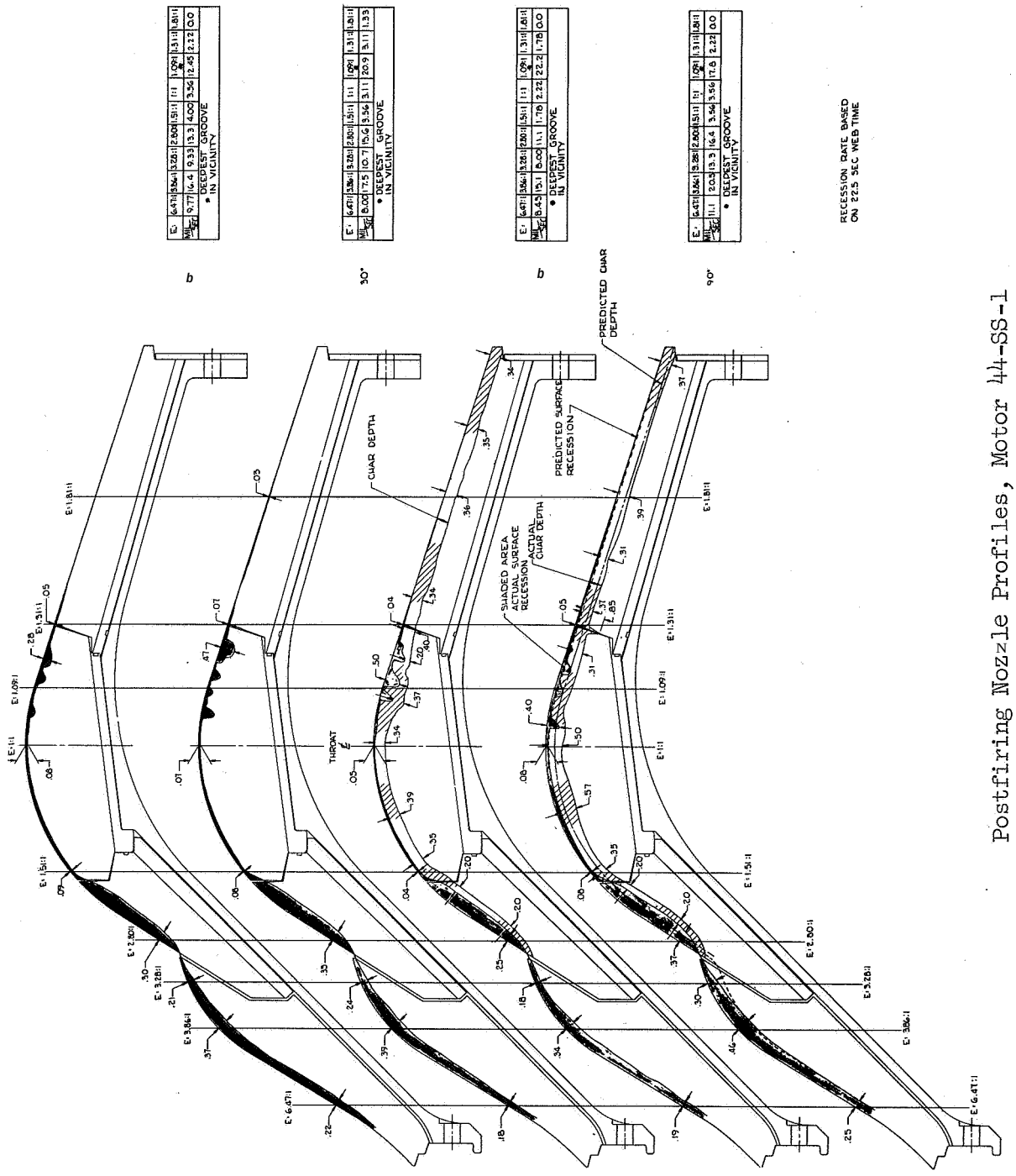


Posttest View of 44 S-1 zzle Throat Insert

Figure 253

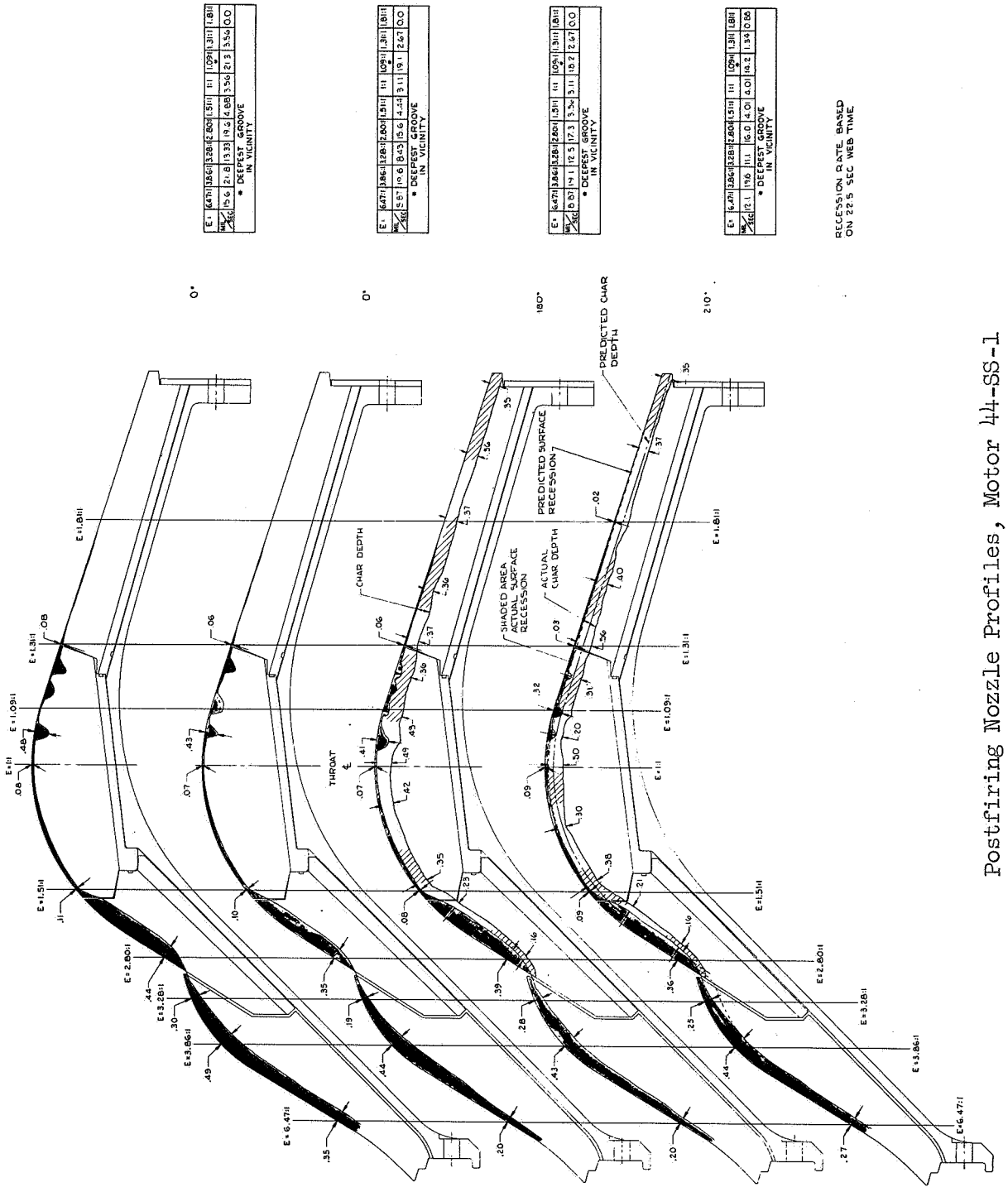
Posttest View of 44-SS-1 Nozzle Throat Insert

Figure 254



Postfiring Nozzle Profiles, Motor 44-SS-1

Figure 255, Sheet 1 of 3



Postfiring Nozzle Profiles, Motor 44-SS-1

Figure 255, Sheet 2 of 3

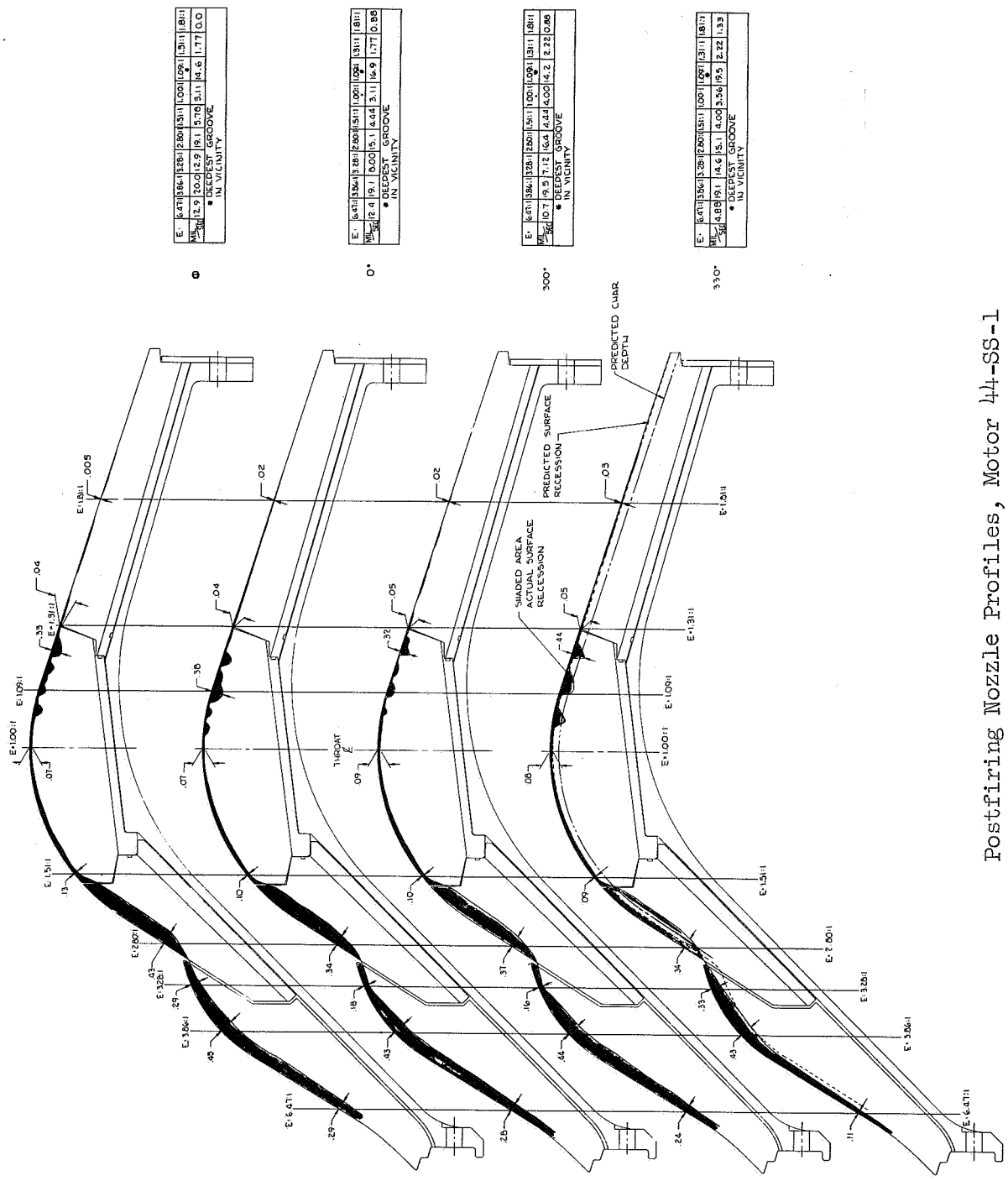


Figure 255, Sheet 3 of 3

Area Ratio	Material	SURFACE RECESSION, IN. 'Radial: Locations, Degrees 0	30	60	90	120	150	180	210	240	270	300	330	Predicted
-6.47	V-44	.22	.18	.19	.25	.35	.20	.20	.27	.29	.28	.24	.11	.18
-3.86	V-44	.37	e39	.34	.46	.49	e44	e43	.44	p45	e43	.44	a43	48
-3.28	V-44	.21	.24	.18	.30	.30	.19	.28	.25	.29	.18	.16	.33	.60
-2.80	MX-2646	e30	.35	.25	.37	e44	.35	.39	.36	.43	.34	.37	e34	.15
-1.51	MX-4926	.09	.08	e04	.08	.11	.10	.08	.09	.13	.10	.10	.09	07
10	MX-4926	.08	.07	.05	.08	.08	.07	.07	.09	p07	.07	.09	.08	.094
1.09*	MX-4926	.28	.47	.50	.40	e48	e43	e41	.32	.33	.38	.32	.44	.085
1.31	MX-4926	.05	.07	.04	.05	.08	.06	.06	.03	e04	.04	.05	.05	.07
181	MX-4926	0	.03	0	0	0	0	0	.02	.005	.02	.02	.03	.04
250	MX-4926	0	0	0	0	0	0	0	0	0	0	0	0	e025

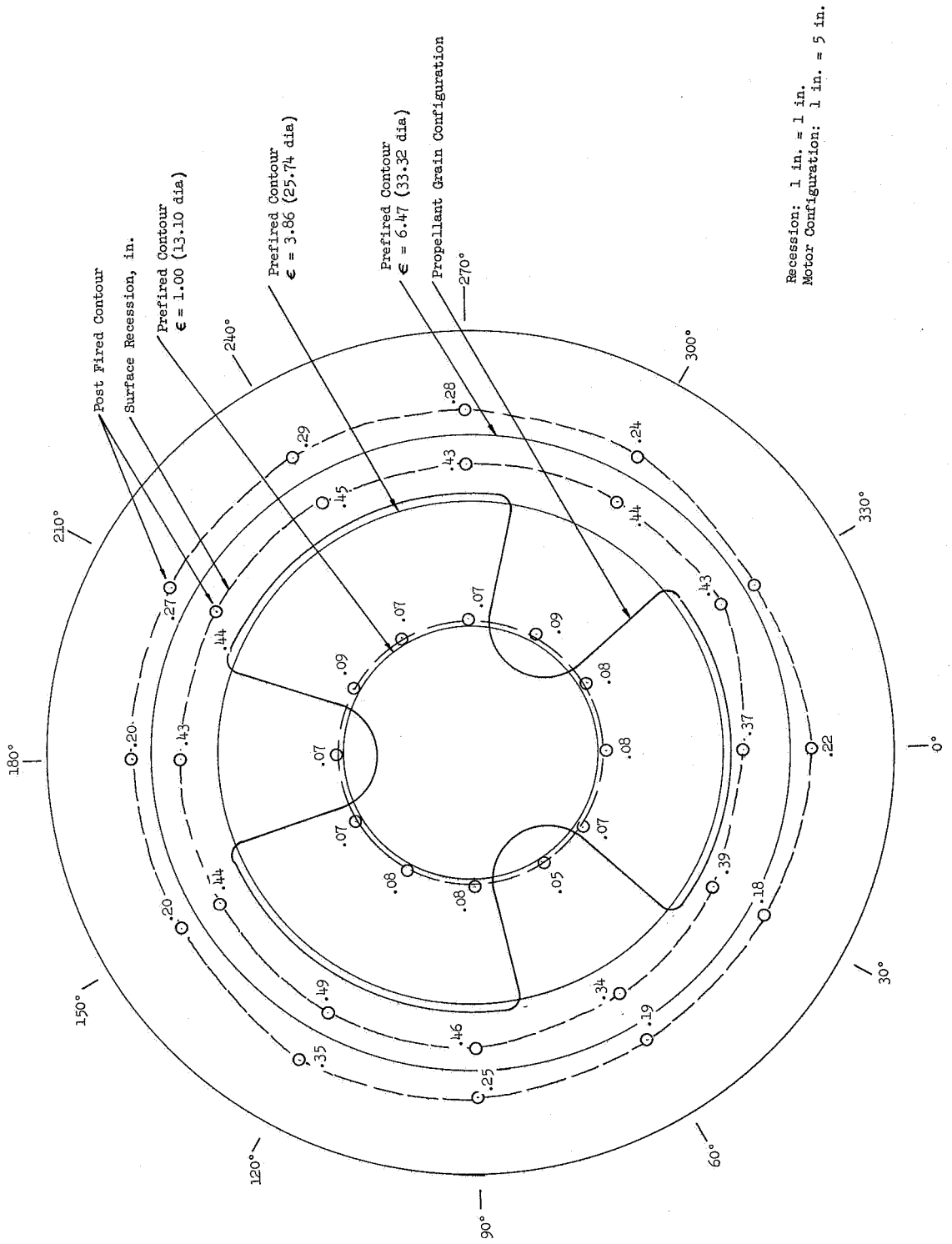
*Deepest Groove in Vicinity.

Nozzle Surface Recession at Various Radial ana Axial Locations, 44-SS-1 Motor

Figure 256

Sectional View of AP-SS-1 Nozzle

Figure 257



Radial Plot of Recession in 44-SS-1 Entrance Insulation

Figure 258

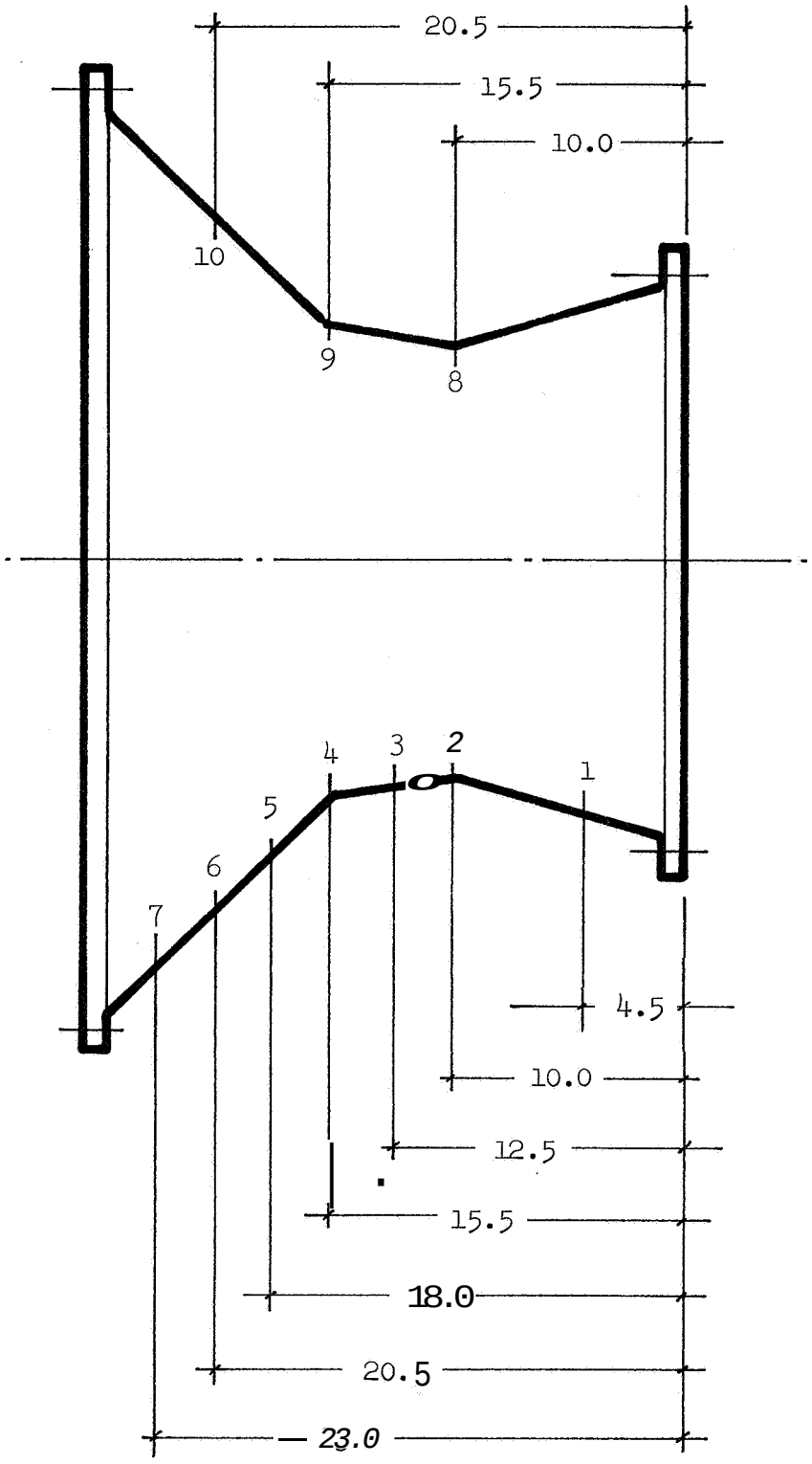
Area Ratio	Material	Char Depth, in. Actual* Radial Location, Degrees 60	90	180	210	Avg	Predicted
-2.80	MX2646	.20	.20	.16	.16	.18	.12
-1.51	MX4926	.35	.35	.35	.38	.36	.22
1.0	"	.34	.50	.49	.50	.46	.20
1.31	"	.34	.37	.37	.56	.41	.22
1.81	"	.36	.39	.37	.40	.38	.24
2.50	"	.34	.37	.35	.35	.35	.25

*Char depth measured *only* at 60, 90, 180 and 210°.

Nozzle Char Depth, 44-SS-1 **Motor**

Figure *259*

a



Thermocouple Locations on Nozzle, Motor 44-SS-1

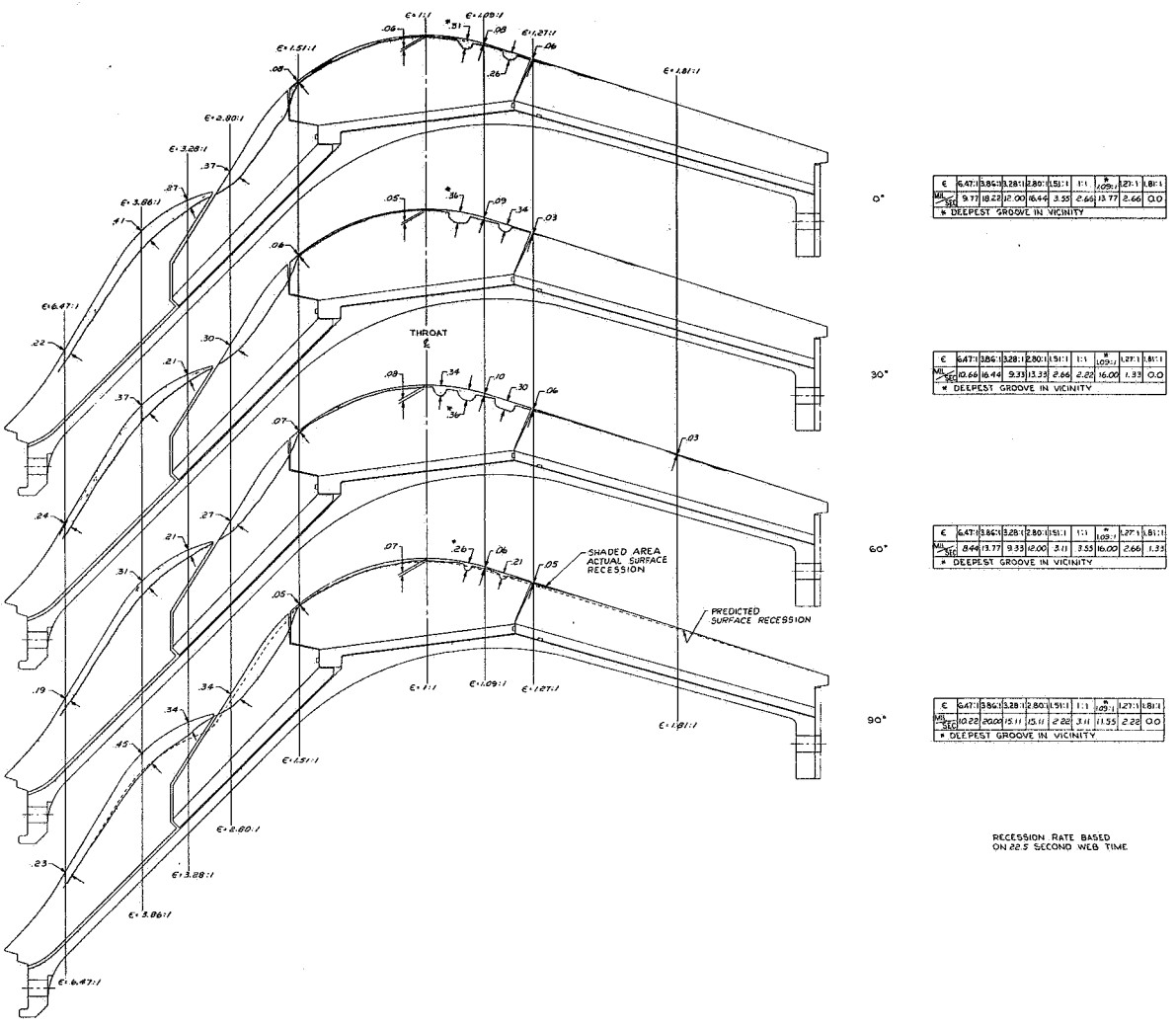
Figure 260

Thermocouple Number	Time, sec	0	10	20	24.8*	30	35
		Temperature, °F					
1		83	85	92	94	96	96
2		84	86	93	95	96	97
3		84	85	96	97	97	98
4		83	85	90	91	92	91
5		84	86	95	97	99	99
6		85	87	95	98	100	100
7		83	86	97	99	101	102
8		81	82	83	83	83	83
9		82	83	83	84	84	83
10		83	83	84	86	86	87

*End of *action* time

Time-Temperature Summary of Nozzle Shell Thermocouples, Motor 44-SS-1

Figure 261



ε	6.47:1	3.86:1	3.28:1	2.80:1	1.51:1	1:1	*1.09:1	1.27:1	1.81:1
MIL/SEC	9.77	18.22	12.00	16.44	3.55	2.66	13.77	2.66	0.0

* DEEPEST GROOVE IN VICINITY

ε	6.47:1	3.86:1	3.28:1	2.80:1	1.51:1	1:1	*1.09:1	1.27:1	1.81:1
MIL/SEC	10.66	16.44	9.33	13.33	2.66	2.22	16.00	1.33	0.0

* DEEPEST GROOVE IN VICINITY

ε	6.47:1	3.86:1	3.28:1	2.80:1	1.51:1	1:1	*1.09:1	1.27:1	1.81:1
MIL/SEC	8.44	13.77	9.33	12.00	3.11	3.55	16.00	2.66	1.33

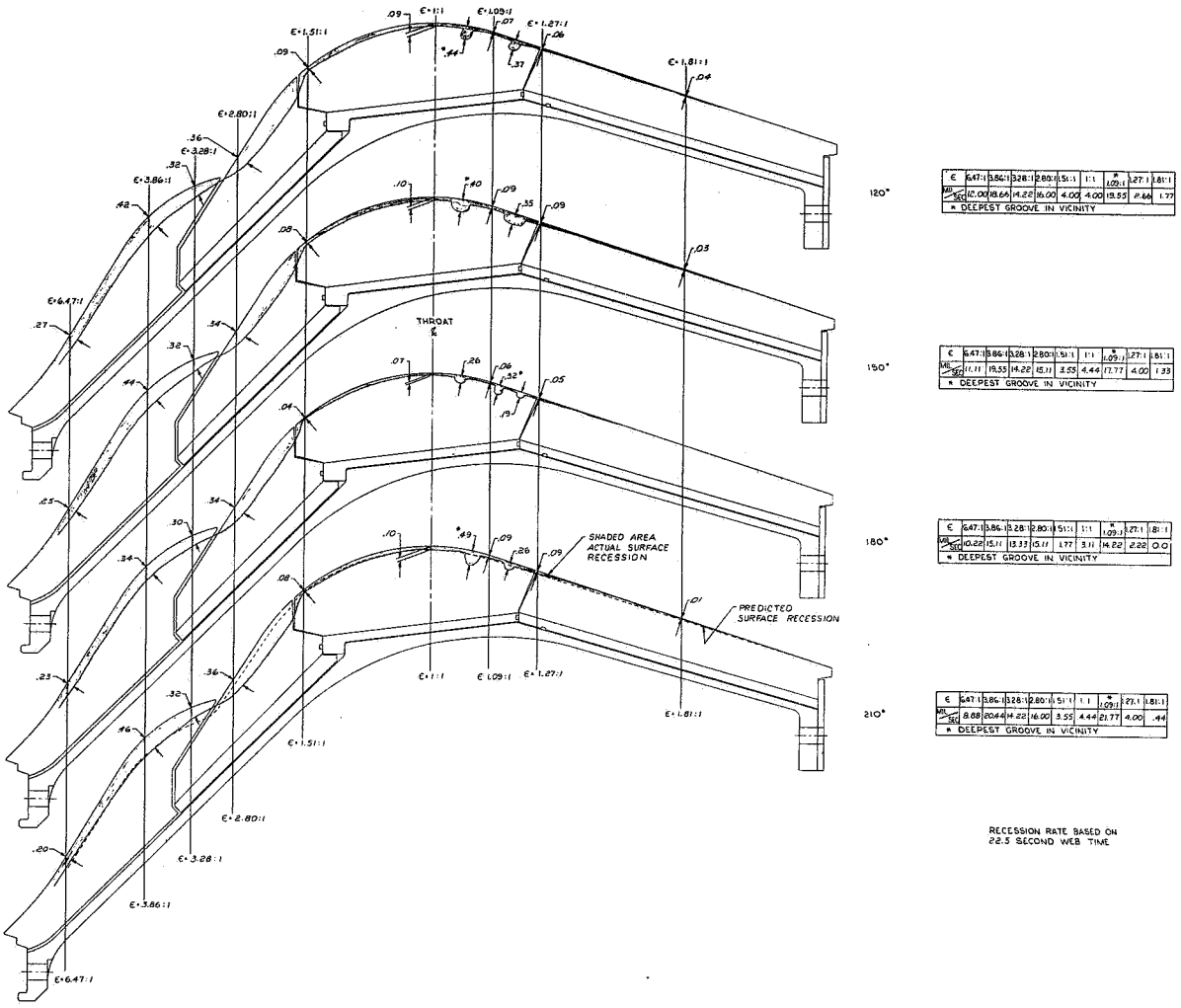
* DEEPEST GROOVE IN VICINITY

ε	6.47:1	3.86:1	3.28:1	2.80:1	1.51:1	1:1	*1.09:1	1.27:1	1.81:1
MIL/SEC	10.22	20.00	15.11	15.11	2.22	3.11	11.55	2.22	0.0

* DEEPEST GROOVE IN VICINITY

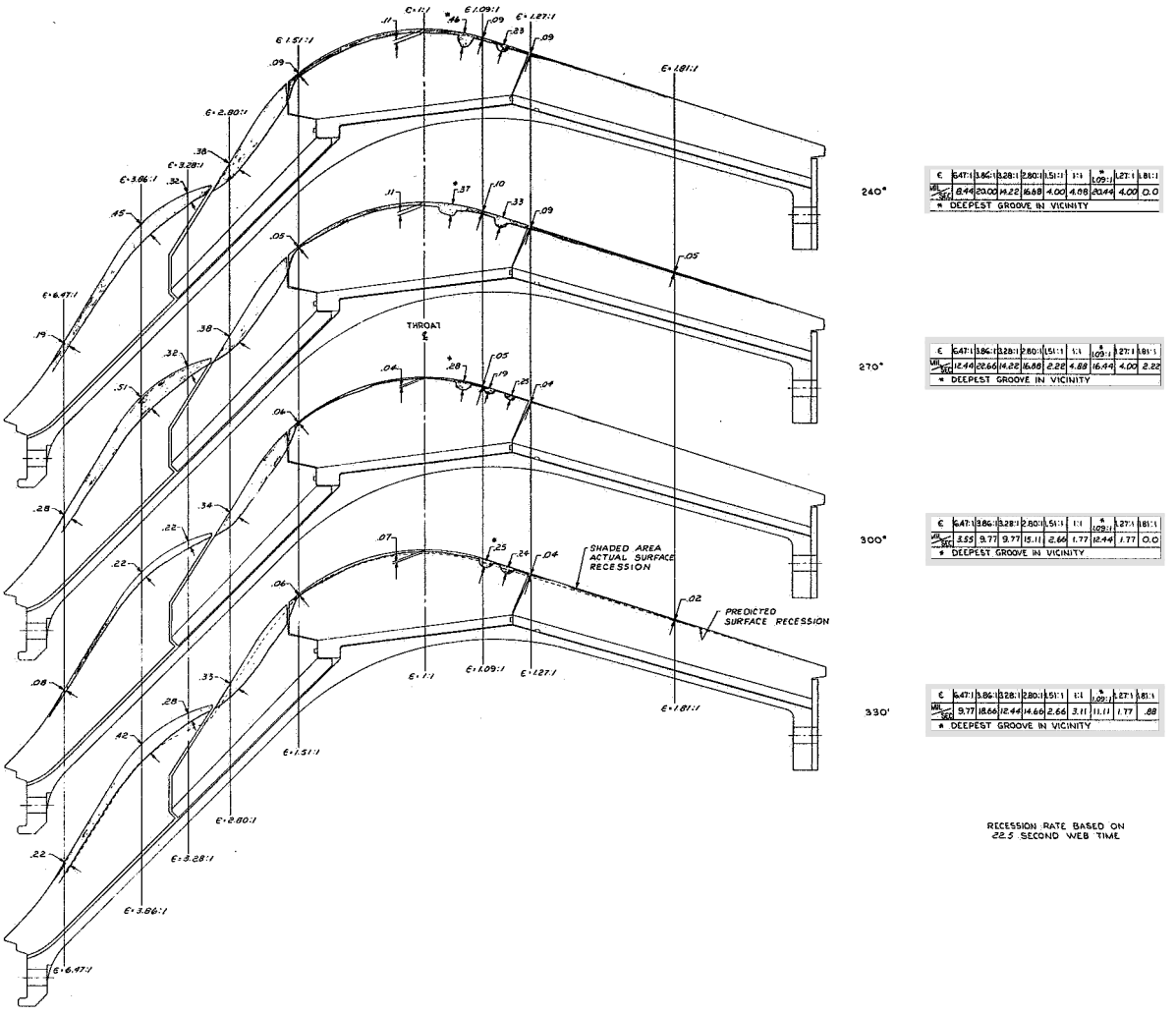
Postfiring Nozzle Profiles, **Motor** 44-SS-2

Figure 262, Sheet 1 of 3



Postfiring Nozzle Profiles, Motor 44-SS-2

Figure 262, Sheet 2 of 3



Postfiring Nozzle Profiles, Motor 44-SS-2

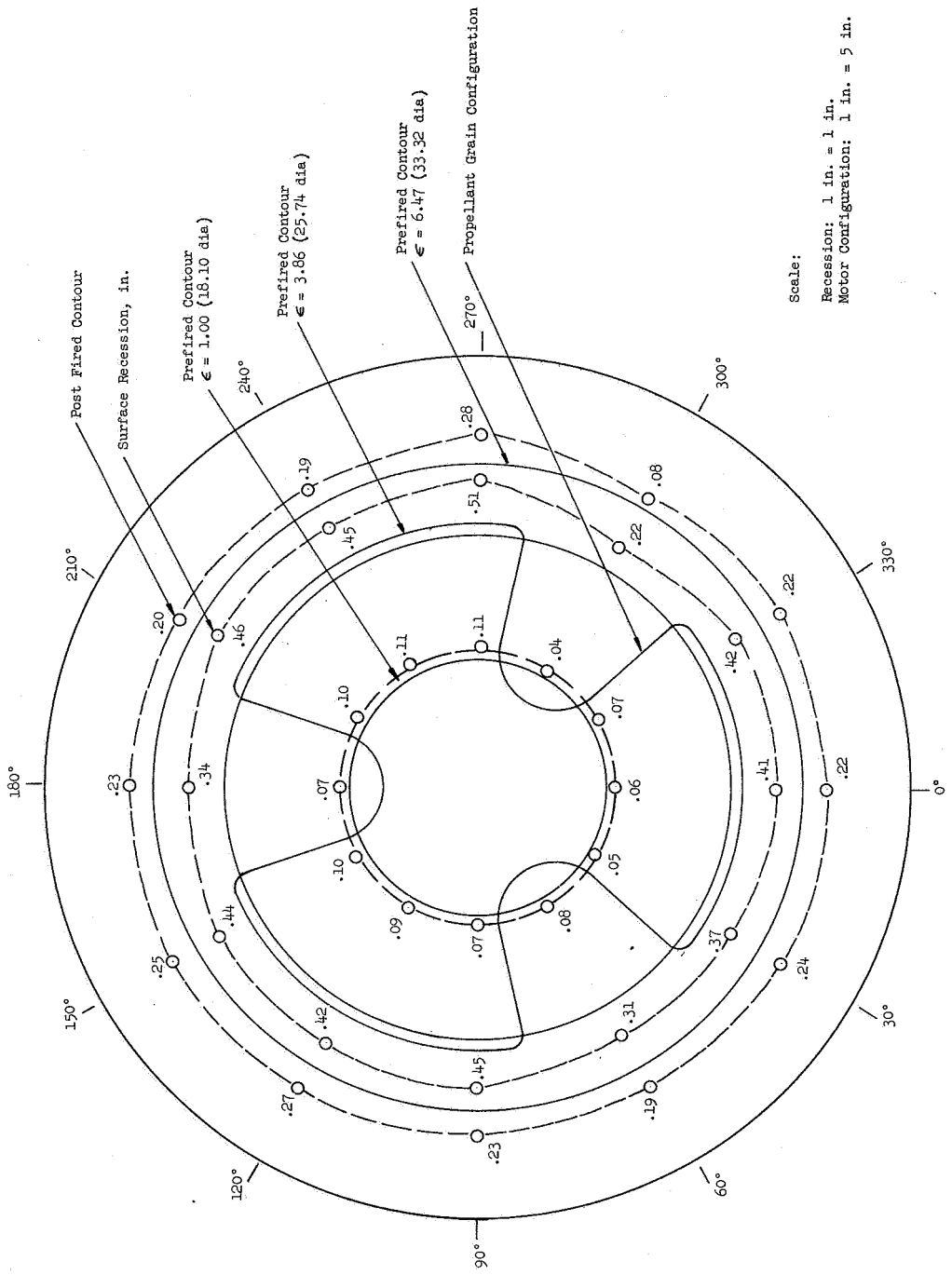
Figure 262, Sheet 3 of 3

Area Ratio	Material	SURFACE RECESSION, IN. Radial Location, Degrees 0	30	60	90	120	150	180	210	240	270	300	330	Predicted
[illegible] 47	V-44	.22	.24	.19	.23	27	.25	.23	.20	19	.28	.08	.22	.18
3.83	V-44	.41	.07	.31	.45	42	44	.34	.43	.45	.51	.22	.42	.28
[illegible]3 28	V-44	27	.21	.21	34	.32	32	30	.2	.32	.32	.22	.28	8
2.80	MX-2343	.37	30	27	.34	.33	34	.34	.33	.38	.38	.34	.33	.15
1.51	MX-4923	.08	.03	.07	.05	49	.08	.04	48	.09	.05	.06	.03	.07
1.0	MX-4923	.03	45	.08	.07	.09	.10	.07	.10	.11	.11	.04	.07	.07
1.09*	MX-[illegible]23	.31	.23	.33	.23	.44	.20	32	49	43	.37	.28	.25	685
1.27	MX-[illegible]23	96	.03	.03	.05	.03	96	.05	.09	49	.09	.04	.04	.07
1.81	MX-[illegible]23	0	0	.03	0	.04	.03	0	.01	0	.05	0	.02	.04
2.50	MX-42 23	0	0	0	0	0	0	0	0	0	0	0	0	.025

*Deepest groove in vicinity.

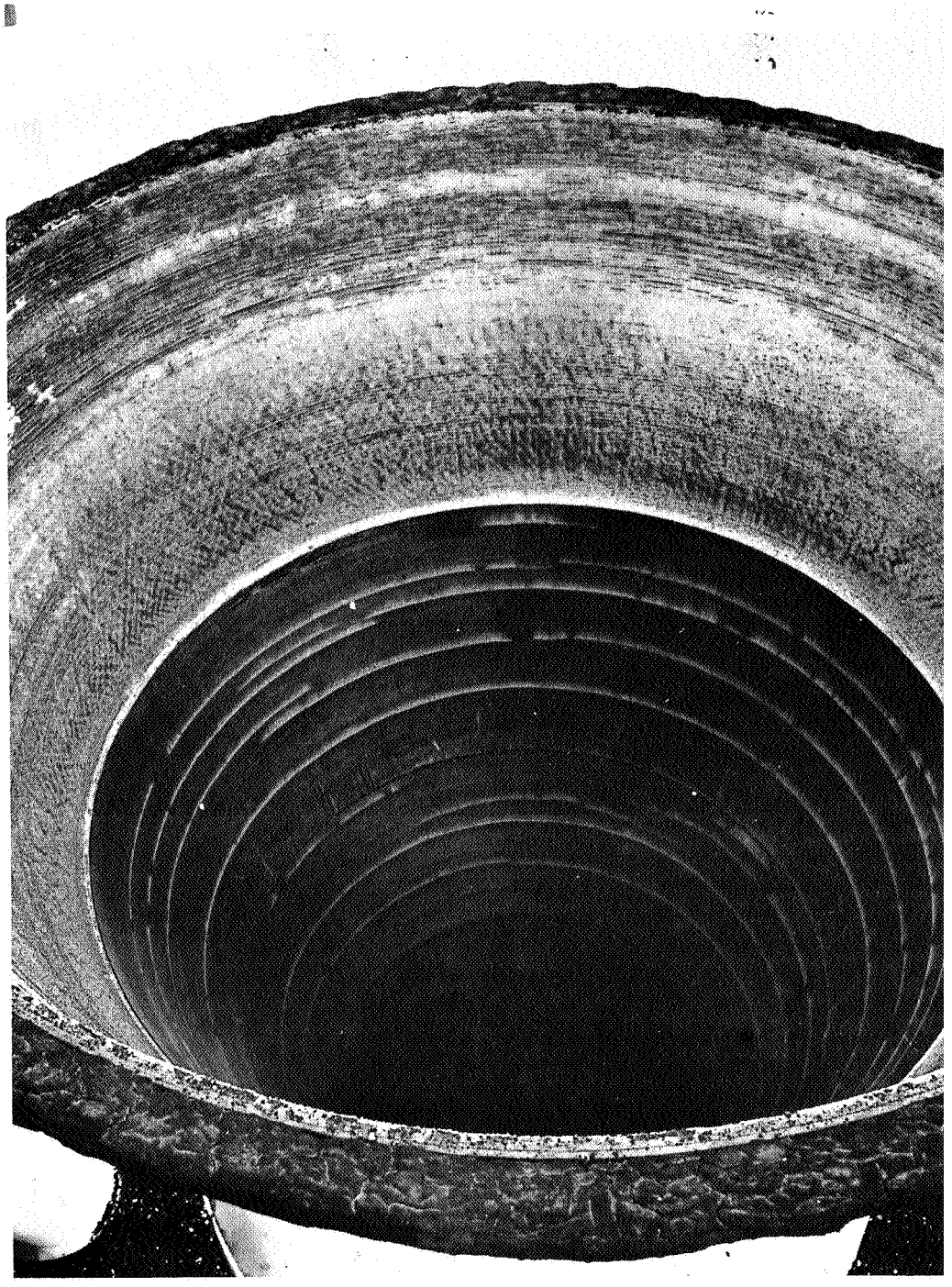
Nozzle Surface Recession at Various Radial and Axial Locations, 44-SS-2 Motor

Figure 263



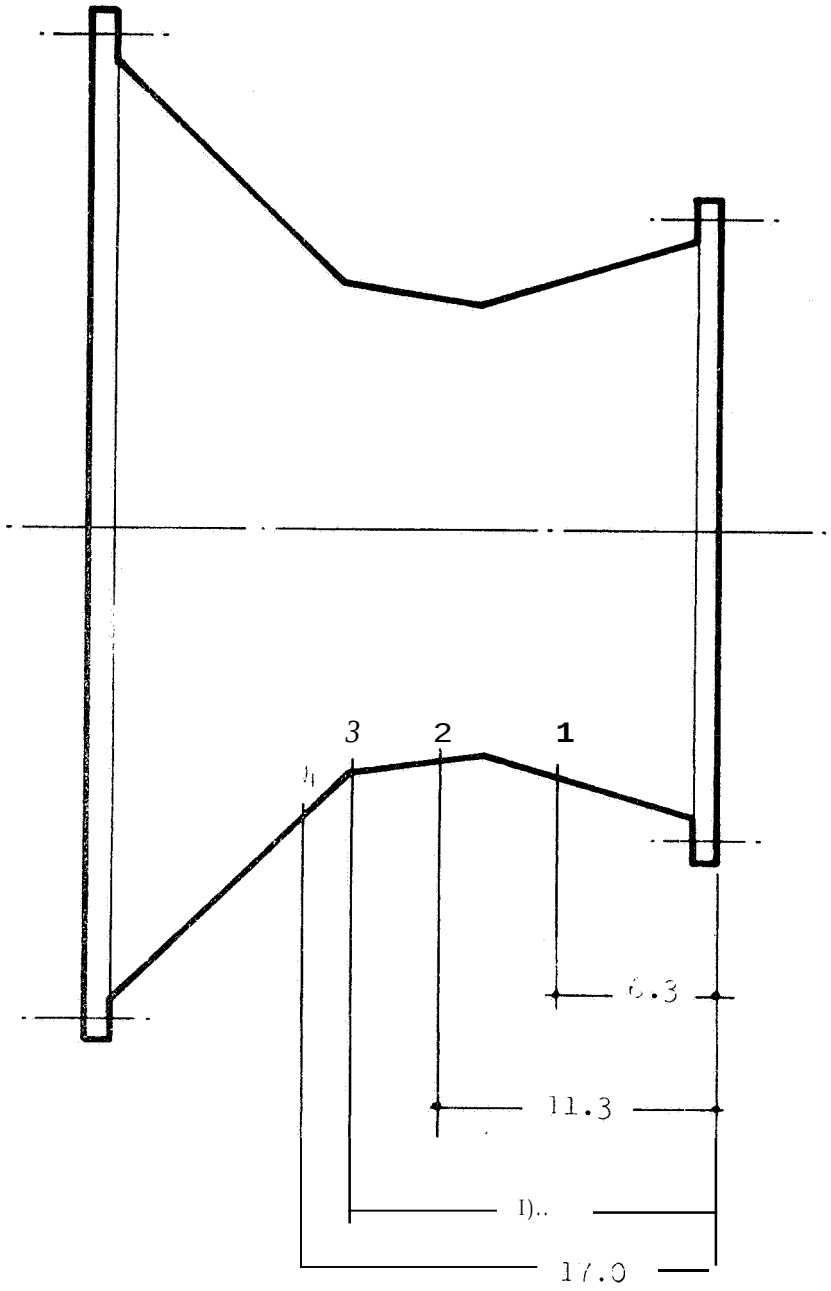
Radial Plot of Recession in 44-SS-2 Entrance Insulation

Figure 264



Postfiring View of Nozzle Throat, Motor 44-SS-2

Figure 265



Nozzle Thermocouple Locations, Motor 44-SS-2

Figure 266

Thermocouple No.	Time, sec	Temperature, °F 0	10	20	24.7*	30	36
1		81	82	81	82	82	83
2		82	82	82	82	82	82
3		83	83	84	84	84	85
4		83	83	83	83	83	83

*End of action time

Figure 267

Time-Temperature Summary of Nozzle Shell Thermocouples, Motor 44-SS-2

Posttest View, Nozzle Entrance, Motor 44-SS-3

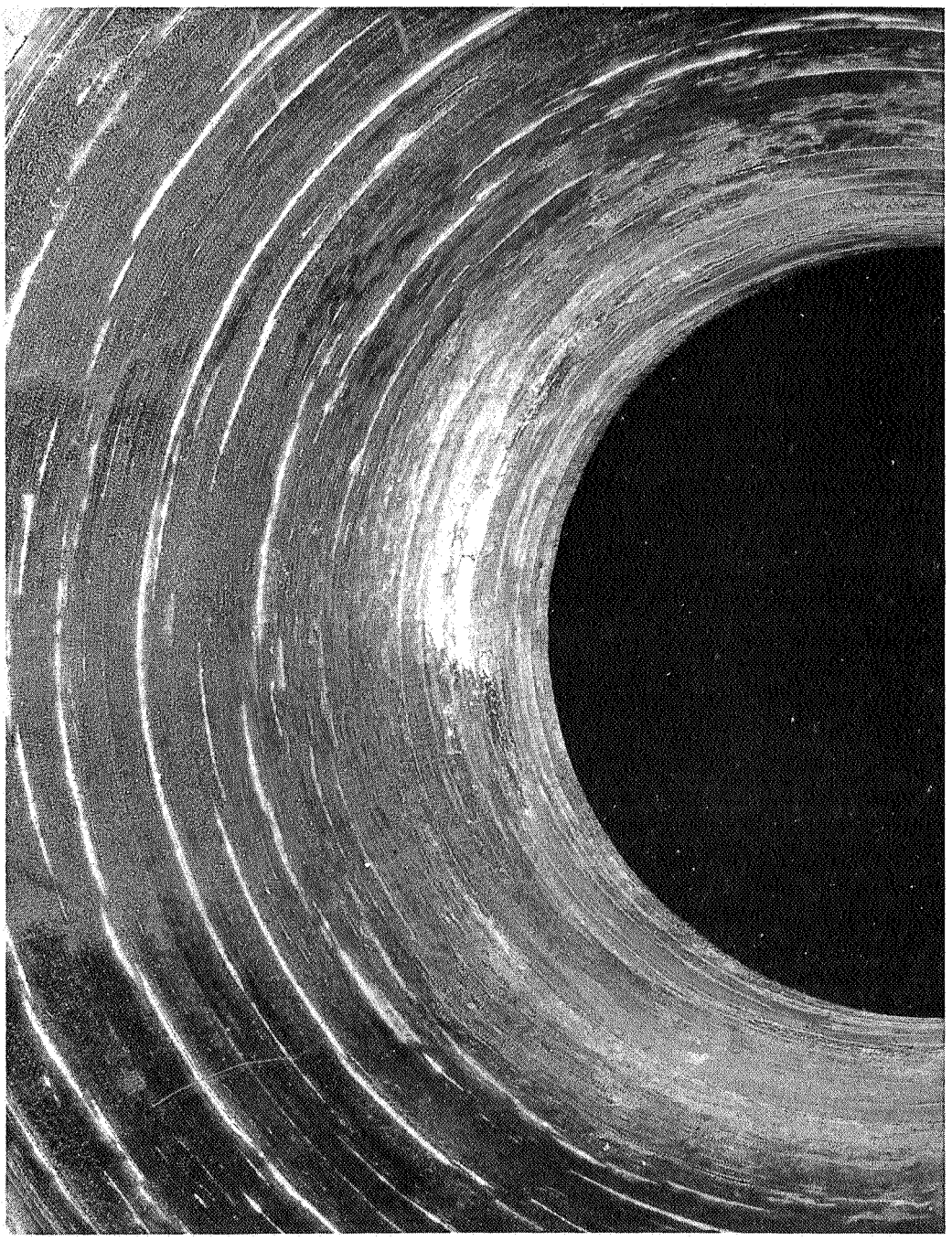
Figure 268

Posttest View, Nozzle Entrance, Motor 44-SS-3

Figure 269

Posttest View, Nozzle Exit Cone, Motor 44-SS-3

Figure 270

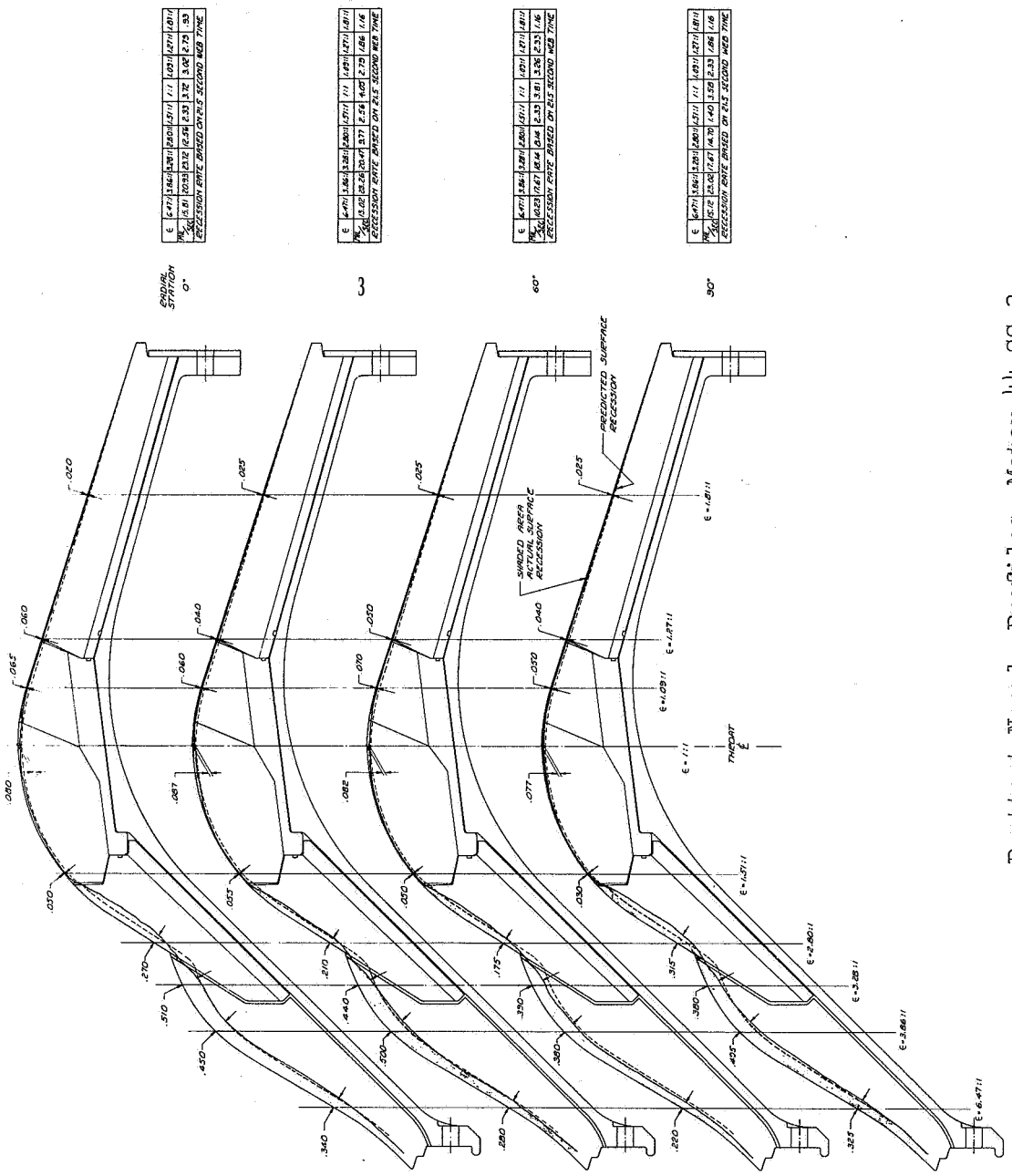


Posttest View, Nozzle Throat and Exit Cone, Motor 44-SS-3

Figure 271

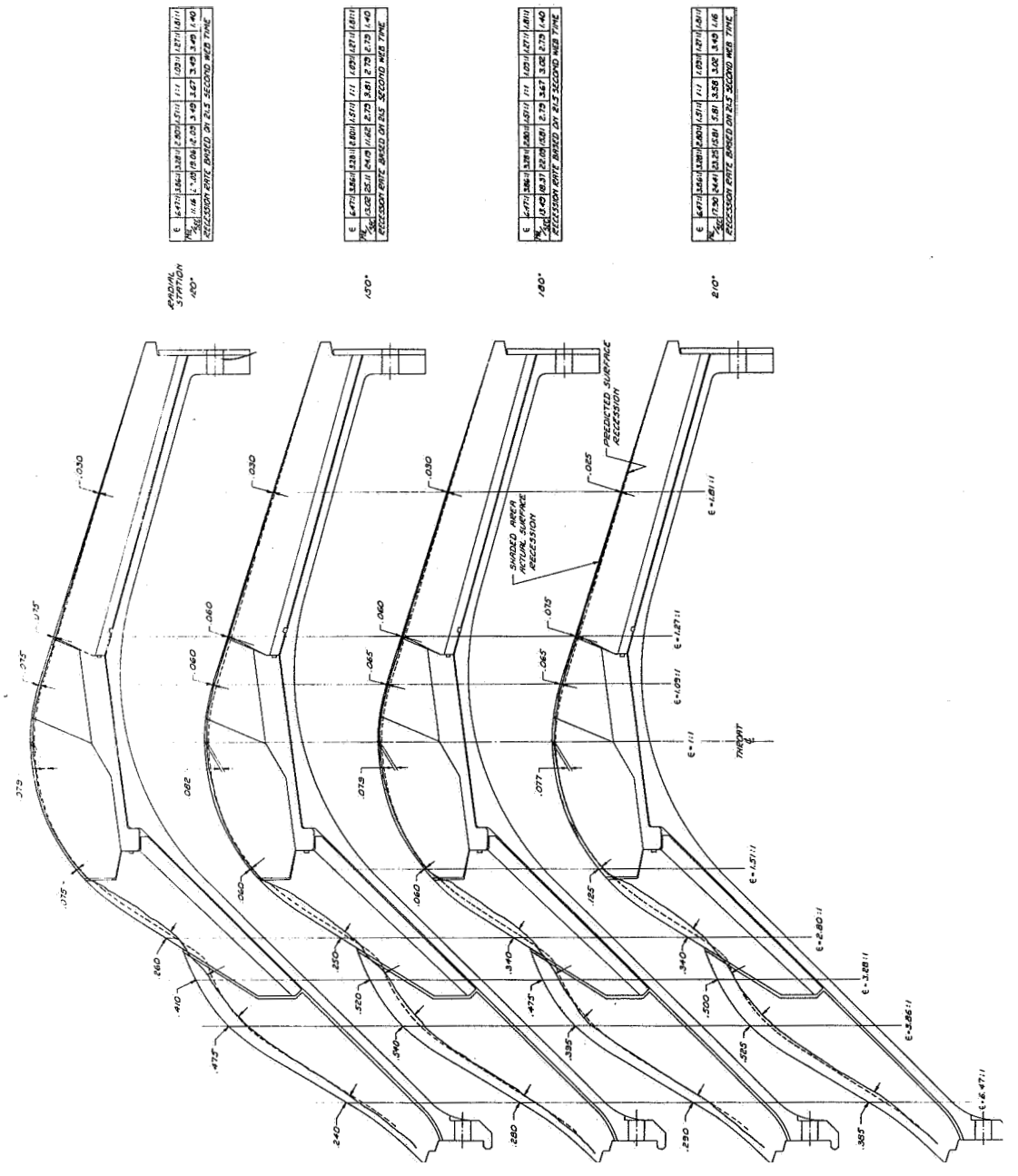
Posttest Aft View of Throat, 44-SS-3 Motor Nozzle

Figure 272



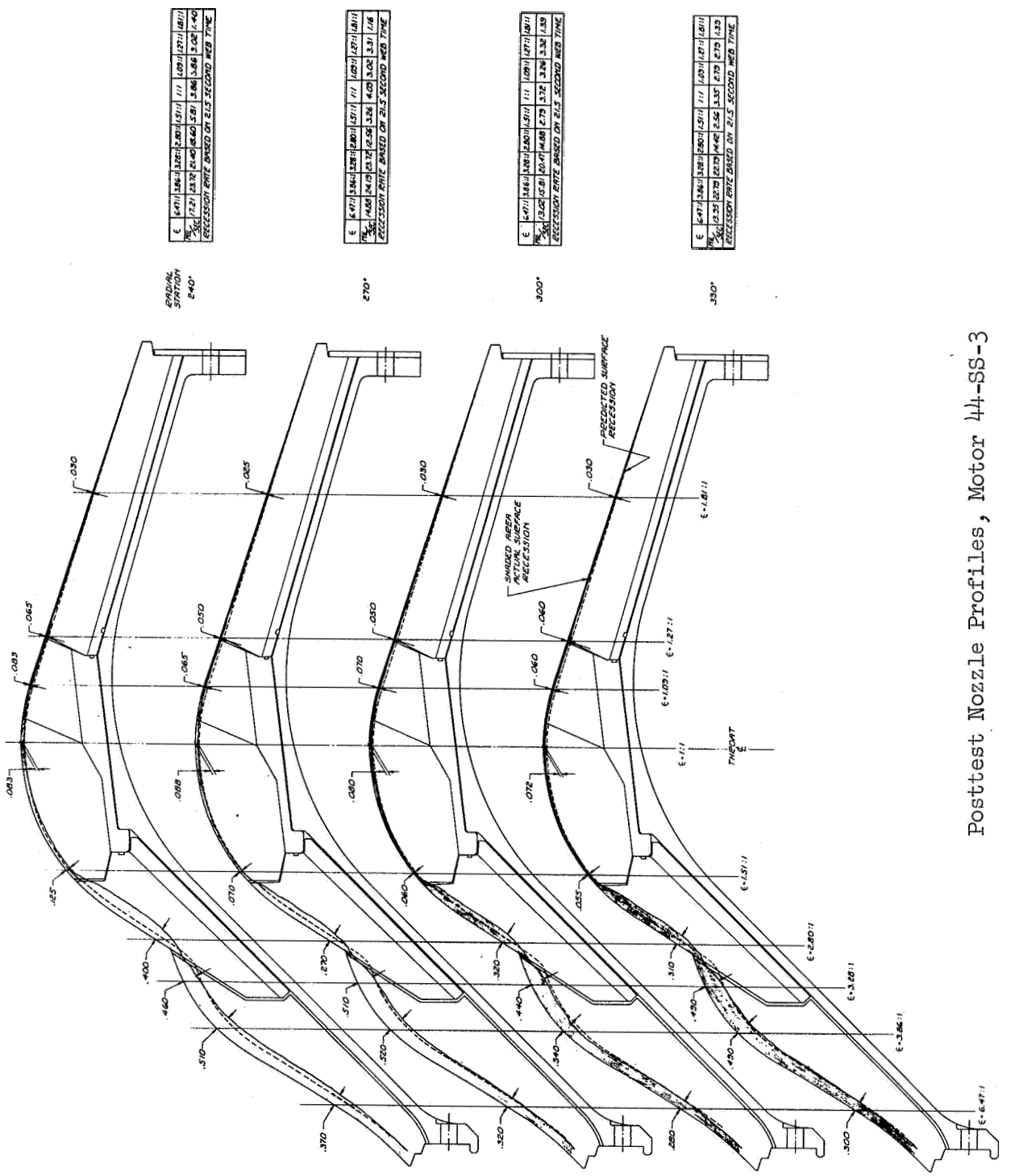
Posttest Nozzle Profiles, Motor 44-SS-3

Figure 273, Sheet **1** of 3



Posttest Nozzle Profiles, Motor 44

Figure *273*, Sheet *2* of *3*



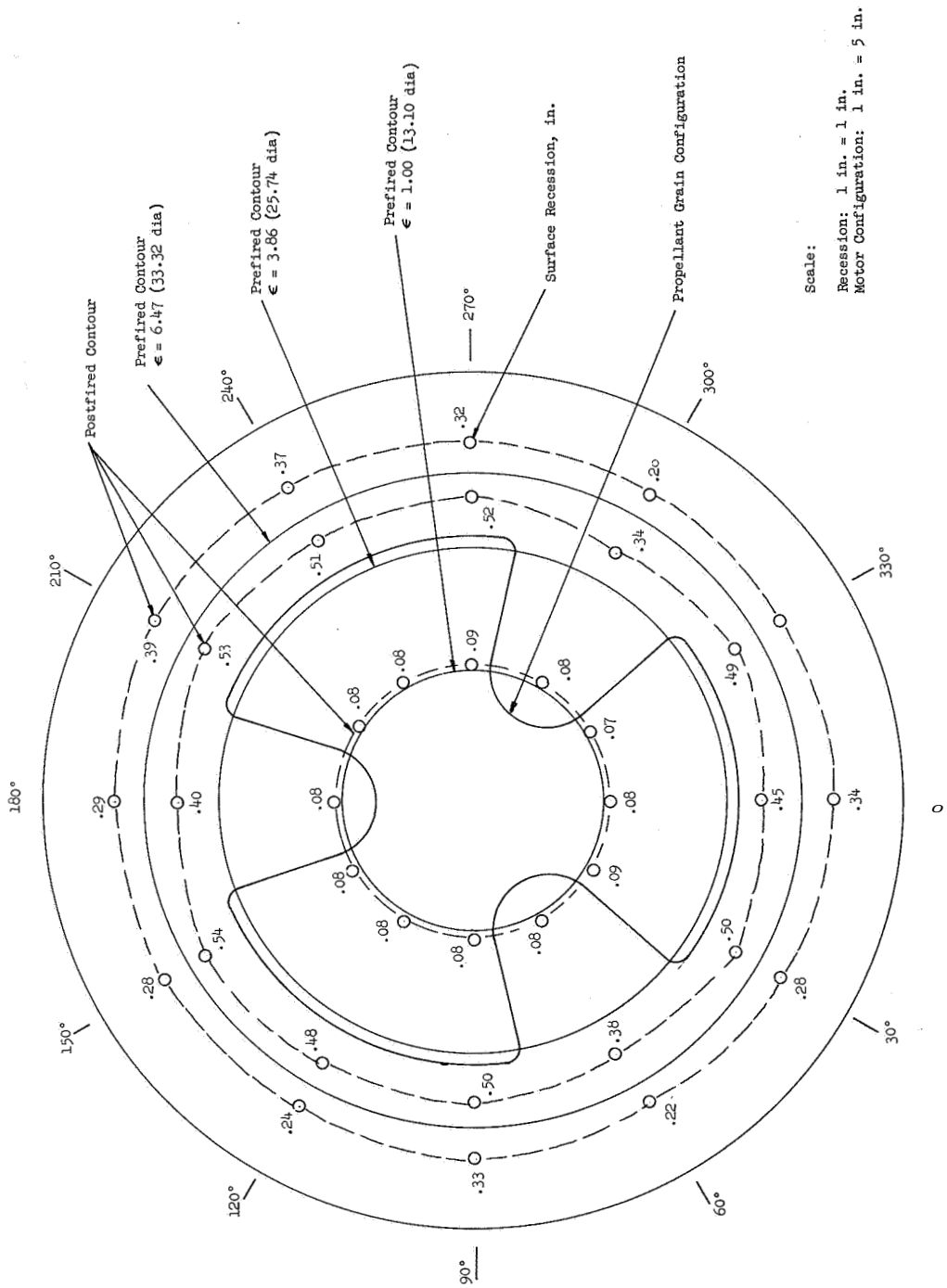
Posttest Nozzle Profiles, Motor 44-SS-3

Figure 273, Sheet 3 of 3

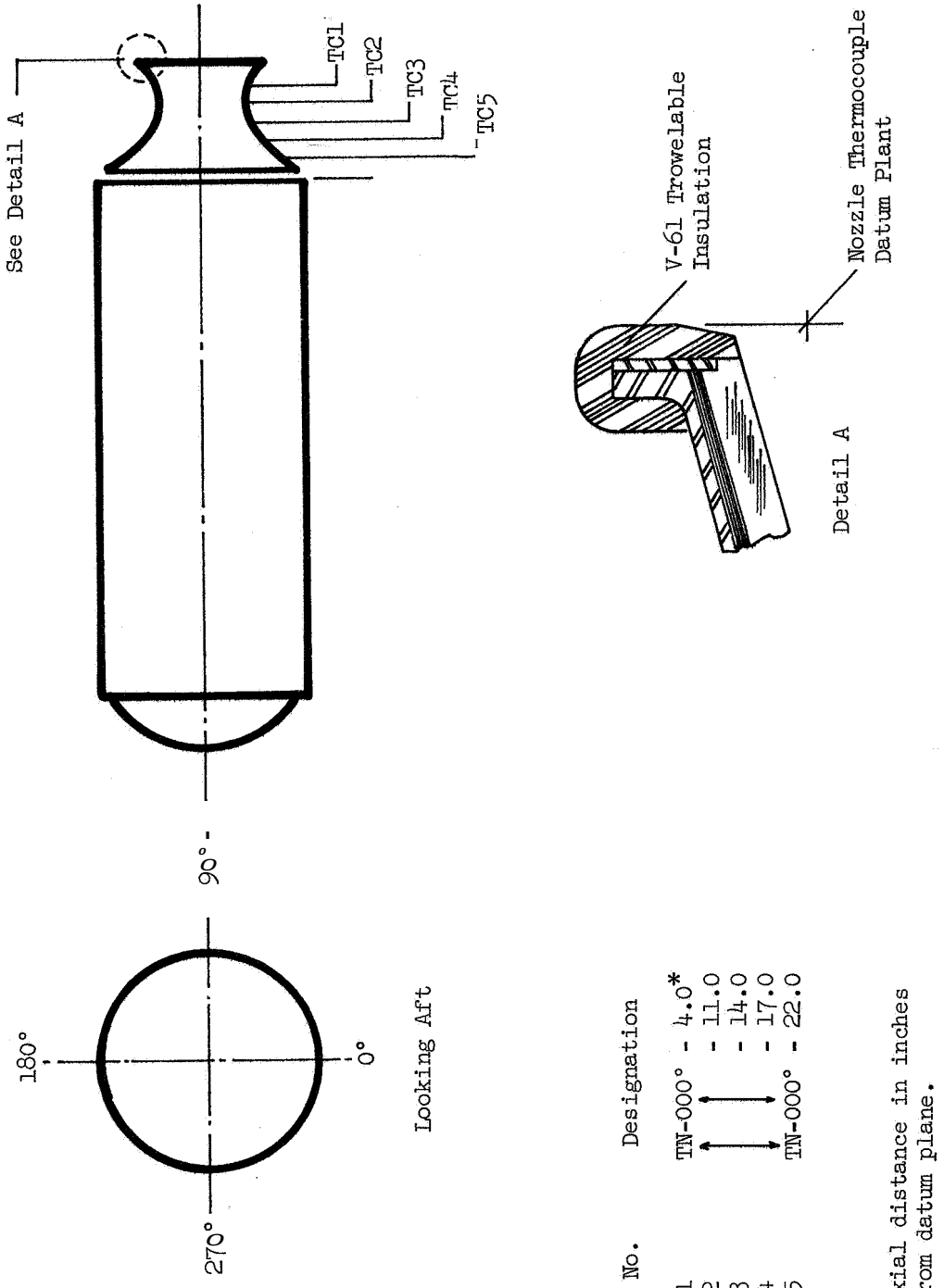
Area Ratio	Material	SURFACE RECESSION, IN. Radial Location, Degrees 0	30	60	90	120	150	180	210	240	270	300	330	Predicted
-6.47	V-44	.04	.28	.22	.33	.24	.28	.29	.39	.37	.32	.28	.30	.18
-3.86	V-44	.43	.30	.38	.50	.48	.34	.40	.53	.51	.52	.	.49	.48
-3.28	V-44	.31	.44	.39	.38	.41	.52	.48	.50	.46	.51	.44	.49	.60
-2.80	MX-2646	.27	.21	.18	.32	.26	.23	.34	.34	.40	.27	.32	.31	.15
-1.51	MX-4926	.05	.06	.03	.03	.08	.06	.06	.13	.02	.07	.06	.06	.07
1.0	MX-4926	.08	.09	.08	.08	.08	.08	.08	.08	.08	.09	.08	.07	.094
1.09	MX-4926	.07	.06	.07	.05	.08	.06	.07	.07	.08	.07	.07	.06	.085
1.27	MX-4926	.06	.04	.05	.04	.08	.06	.06	.08	.07	.05	.05	.08	.07
1.81	MX-4926	.02	.03	.03	.03	.03	.03	.03	.04	.03	.03	.03	.03	.04
2.00	MX-4926	0	0	0	0	0	0	0	0	0	0	0	0	.025

Nozzle Surface Recession at Various Radial and Axial Locations, PP-SS-3 Motor

Figure 274



Radial Plot of Recession in 44-SS-3 Entrance Insulation



Nozzle Thermocouple Locations, Motor 44-SS-2

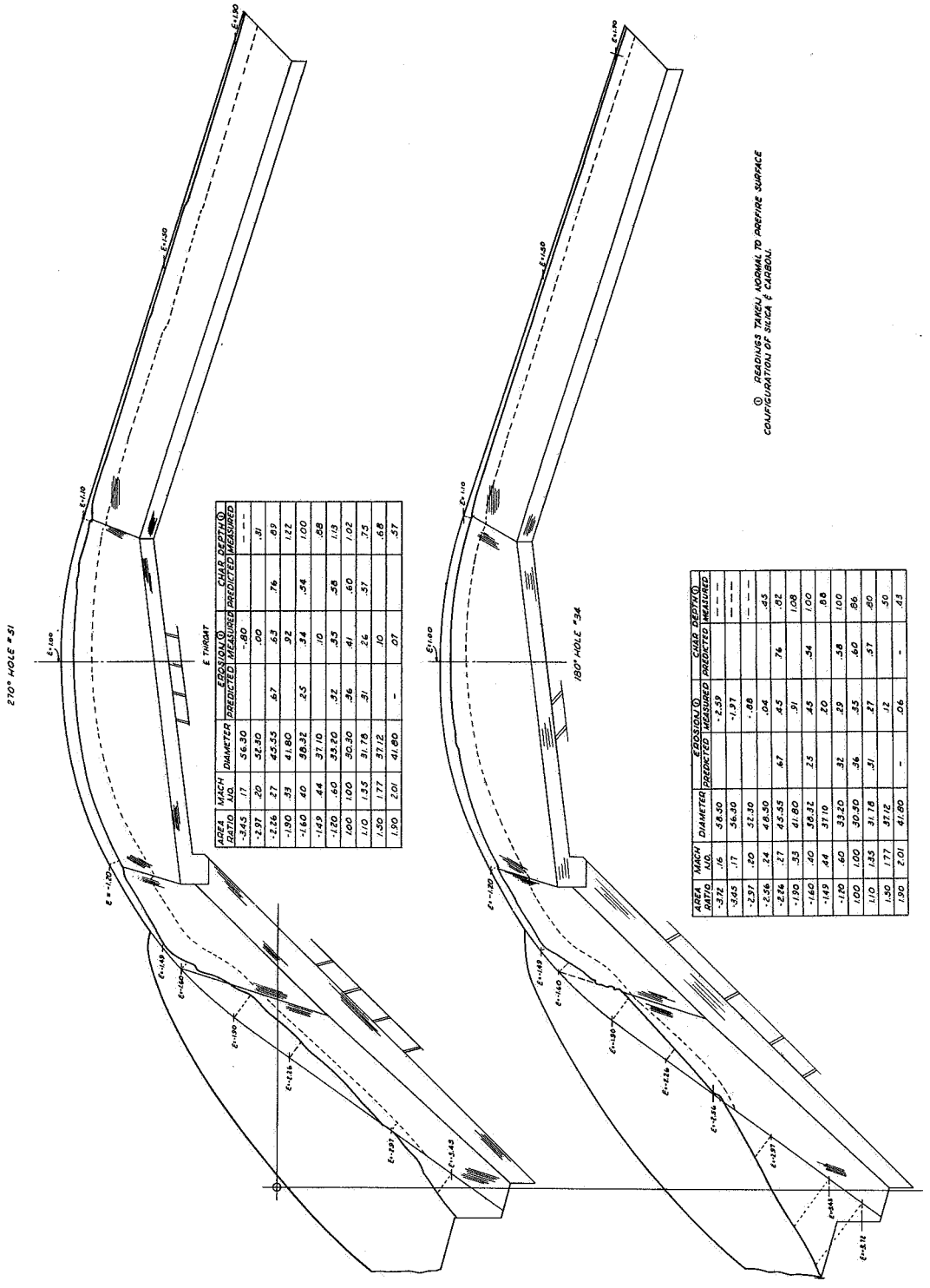
Figure 276

Thermocouple Number	Time sec	0	10	20	23.2 *	30	40	50	60	70	80	90	100	110
1		68	68	70	70	70	71	73	74	75	76	76	76	77
2		69	69	69	70	71	72	73	75	76	77	77	78	78
3		69	69	70	71	71	73	74	75	77	77	77	77	77
4		69	69	70	71	72	73	75	76	76	77	78	78	78
5		69	69	70	71	72	74	77	80	82	84	85	86	86

*End of action time

Figure 277

Time-Temperature Summary of Nozzle Shell Thermocouples, Motor 44-SS-3

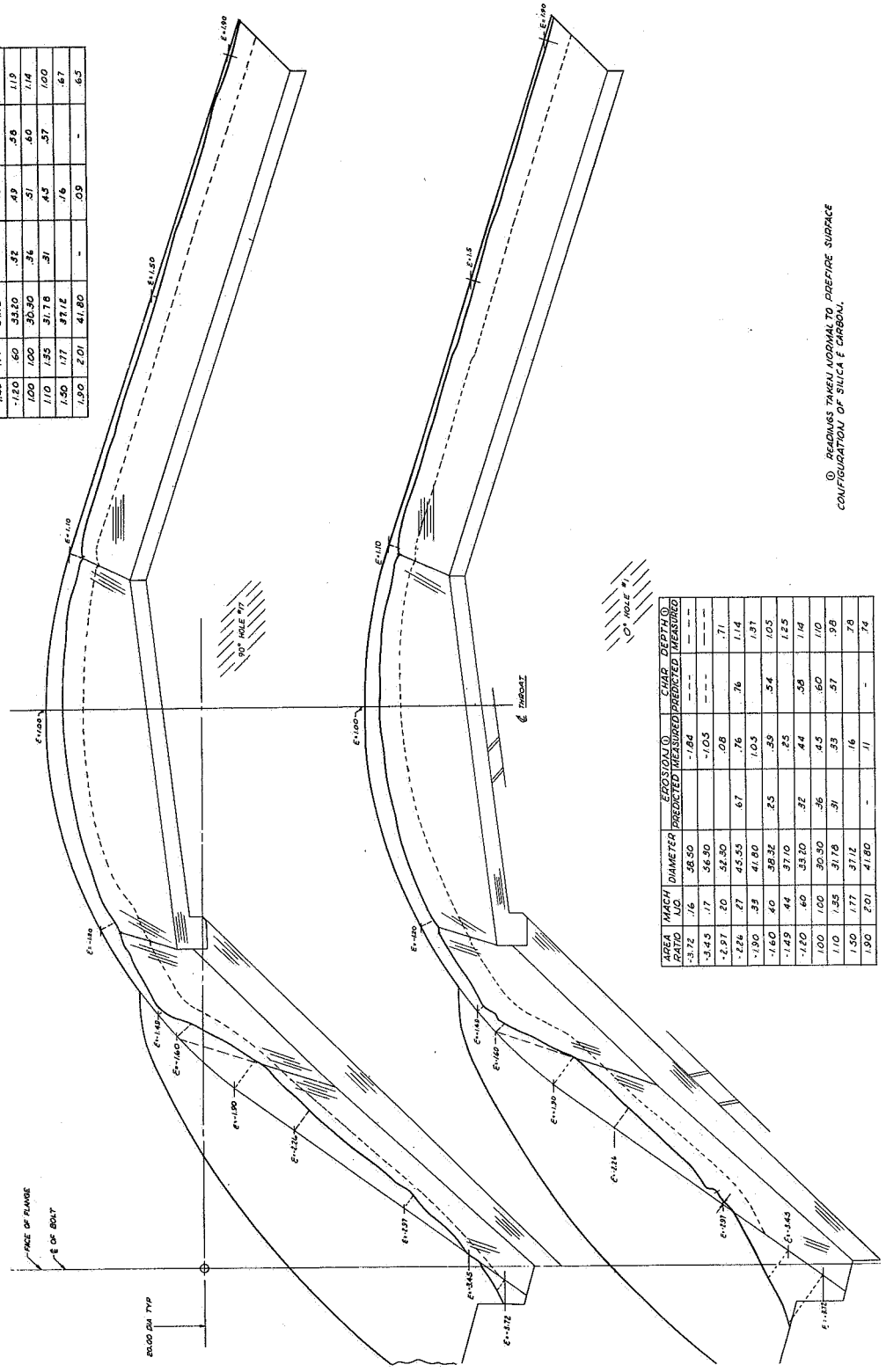


AREA RATIO	MACH NO.	DIAMETER	EROSION ① PREDICTED	EROSION ① MEASURED	CHAR DEPTH ① PREDICTED	CHAR DEPTH ① MEASURED
-3.45	.17	56.30		.80		— — —
-2.97	.20	52.30		.00		.31
-2.56	.27	45.55	.67	.63	.76	.89
-1.90	.33	41.80		.92		1.22
-1.60	.40	38.32	.25	.34	.54	1.00
-1.49	.44	37.10		.10		.88
-1.20	.60	33.20	.32	.35	.55	1.19
1.00	1.00	30.30	.36	.41	.60	1.02
1.10	1.35	31.18	.31	.26	.57	.75
1.30	1.77	37.12		.10		.68
1.90	2.01	41.80	-	.07		.37

AREA RATIO	MACH NO.	DIAMETER	EROSION ① PREDICTED	EROSION ① MEASURED	CHAR DEPTH ① PREDICTED	CHAR DEPTH ① MEASURED
-3.72	.16	58.30		-2.59		— — —
-3.45	.17	56.30		-1.37		— — —
-2.97	.20	52.30		-.88		— — —
-2.56	.24	48.50		.04		.45
-2.56	.27	45.55	.67	.45	.76	.82
-1.90	.33	41.80		.31		1.08
-1.60	.40	38.32	.25	.45	.54	1.00
-1.49	.44	37.10		.20		.88
-1.20	.60	33.20	.32	.29	.58	1.00
1.00	1.00	30.30	.36	.35	.60	.86
1.10	1.35	31.18	.31	.27	.57	.80
1.30	1.77	37.12		.12		.50
1.90	2.01	41.80	-	.06	-	.43

Erosion Profiles of 120-SS-1 Nozzle Assembly

Figure 278, Sheet 1 of 4

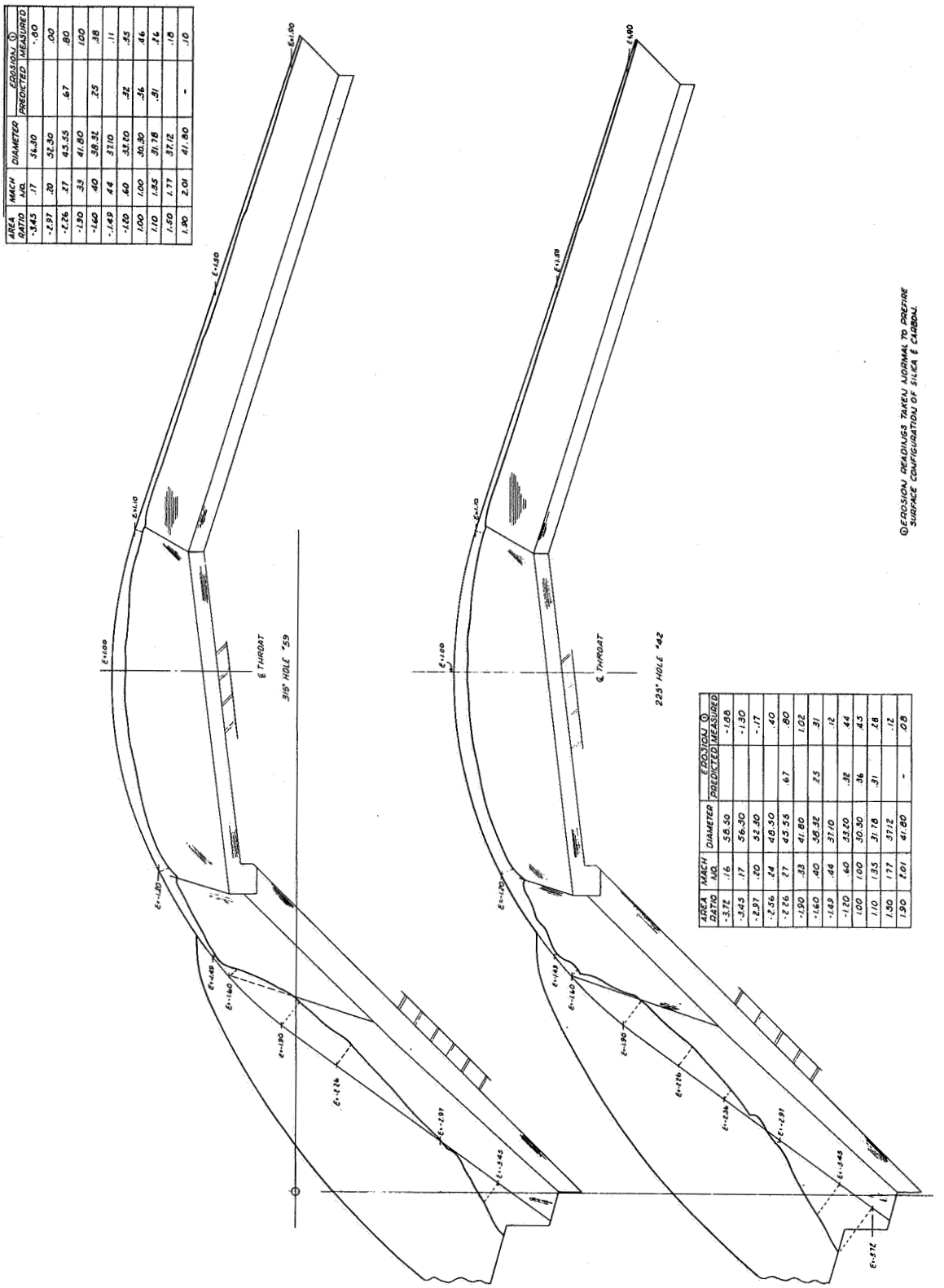


AREA RATIO	MACH NO.	DIAMETER	EROSION ① PREDICTED	EROSION ① MEASURED	CHAR DEPTH ① PREDICTED	CHAR DEPTH ① MEASURED
-3.72	.16	38.50		-.62		
-3.45	.17	36.30		.00		.32
-2.97	.20	32.30		.50		.72
-2.26	.27	45.55	.67	.80	.76	1.16
-1.30	.33	41.80		1.09		1.41
-1.60	.40	38.32	.25	.60	.54	1.09
-1.49	.44	37.10		.18		.88
-1.20	.60	33.20	.32	.49	.58	1.19
1.00	1.00	30.30	.36	.51	.60	1.14
1.10	1.35	31.78	.31	.45	.57	1.00
1.30	1.77	37.12		.16		.67
1.90	2.01	41.80	-	.09	-	.65

AREA RATIO	MACH NO.	DIAMETER	EROSION ① PREDICTED	EROSION ① MEASURED	CHAR DEPTH ① PREDICTED	CHAR DEPTH ① MEASURED
-3.72	.16	38.50		-.84	---	---
-3.45	.17	36.30		-1.05	---	---
-2.97	.20	32.30		.08		.71
-2.26	.27	45.55	.67	.76	.76	1.14
-1.30	.33	41.80		1.03		1.31
-1.60	.40	38.32	.25	.39	.54	1.05
-1.49	.44	37.10		.25		1.25
-1.20	.60	33.20	.32	.44	.58	1.14
1.00	1.00	30.30	.36	.45	.60	1.10
1.10	1.35	31.78	.31	.33	.57	.98
1.30	1.77	37.12		.16		.78
1.90	2.01	41.80	-	.11	-	.74

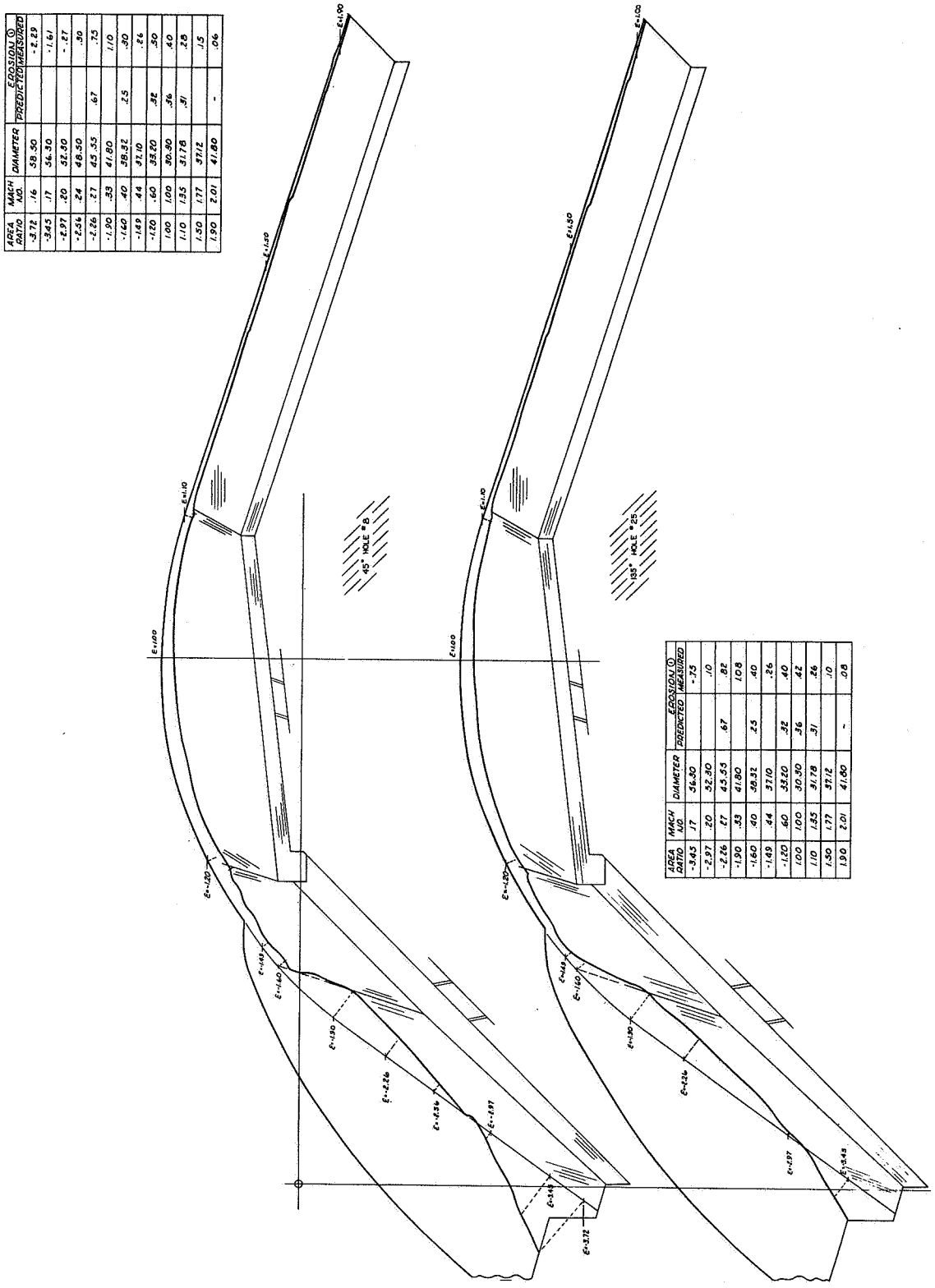
Erosion Profiles of 120-SS-1 Nozzle Assembly

Figure *278,* Sheet *2* **of** 4



Erosi Profi4s of 120-SS-1 Nozz4 Assembly

Figure *278*, **Sheet** 3 ***of*** 4



AREA RATIO	MACH NO.	DIAMETER	EROSION ⊙ PREDICTED	EROSION ⊙ MEASURED
-3.72	.16	58.50		-2.29
-3.45	.17	56.30		-1.61
-2.97	.20	52.30		-.27
-2.56	.24	48.50		.30
-2.26	.27	45.55	.67	.75
-1.90	.33	41.80		1.10
-1.60	.40	38.32	2.5	.20
-1.49	.44	37.10		.26
-1.20	.60	33.20	.32	.50
1.00	1.00	30.50	.36	.40
1.10	1.35	31.78	.31	.28
1.50	1.77	37.12		.15
1.90	2.01	41.80	-	.06

AREA RATIO	MACH NO.	DIAMETER	EROSION ⊙ PREDICTED	EROSION ⊙ MEASURED
-3.45	.17	56.30		-.73
-2.97	.20	52.30		.10
-2.26	.27	45.55	.67	.82
-1.90	.33	41.80		1.08
-1.60	.40	38.32	2.5	.40
-1.49	.44	37.10		.26
-1.20	.60	33.20	.32	.40
1.00	1.00	30.50	.36	.42
1.10	1.35	31.78	.31	.26
1.50	1.77	37.12		.10
1.90	2.01	41.80	-	.08

Erosion Profiles of 120-SS-1 Nozzle Assembly

Figure 278, Sheet 4 of 4

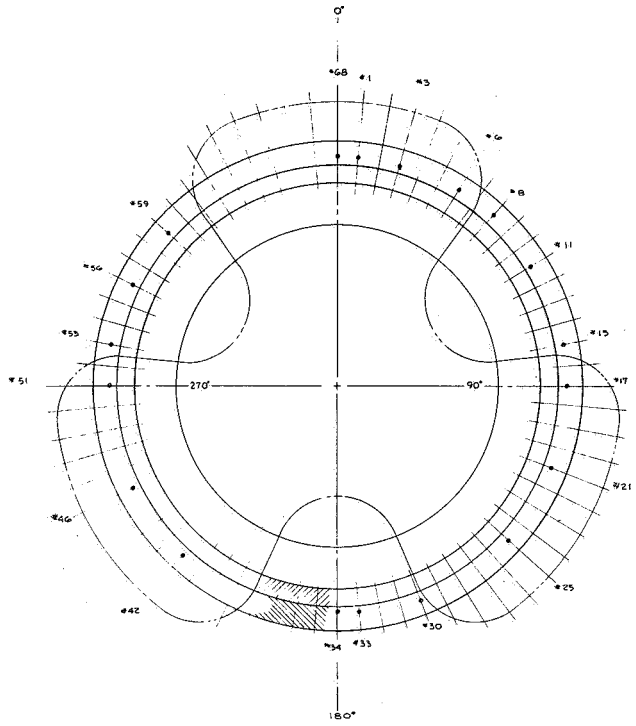
Location - Hole No./Orientation

Area Ratio	Material	11 58°	3 16°	5 26.5°	21 11°	33 175°	46 244°	56 296°	68 0°	8 45°	17 90°	25 135°	34 180°	42 225°	51 270°	59 315°	Avg.	Predicted*
2.26	MX-2646	.66	.90	1.04	.84	.72	.88	.87	.76	.75	.80	.82	.45	.80	.63	.80	.78	.67
1.60	MX-4926	.21	.31	.58	.29	.18	.38	.28	.39	.30	.60	.40	.45	.28	.34	.38	.36	.254
1.20	MX-4926	.50	.43	.47	.48	.26	.58	.36	.44	.50	.49	.40	.29	.44	.35	.35	.42	.324
1.00	MX-4926	.35	.43	.56	.42	.36	.51	.36	.45	.40	.51	.42	.35	.45	.41	.46	.43	.365
1.10	MX-4926	.29	.27	.38	.20	.31	.31	.23	.33	.28	.45	.26	.27	.28	.26	.26	.29	.314
1.90	MX-4926	.04	.10	.06	.07	.07	.09	.02	.11	.06	.09	.08	.06	.08	.07	.10	.07	--

*Corrected to actual 120-SS motor pressure and duration.

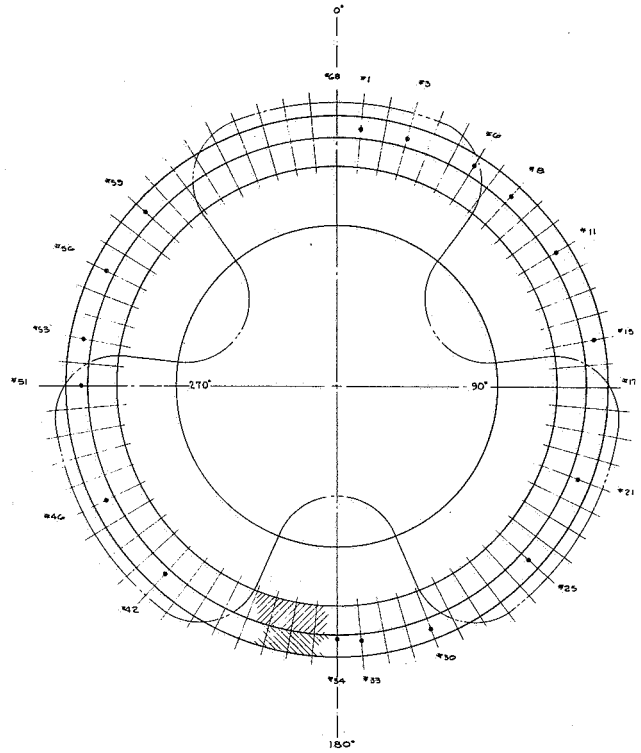
Recession Depths of 120-SS-1 Nozzle Entrance Section

Figure 279



SECTION D-D

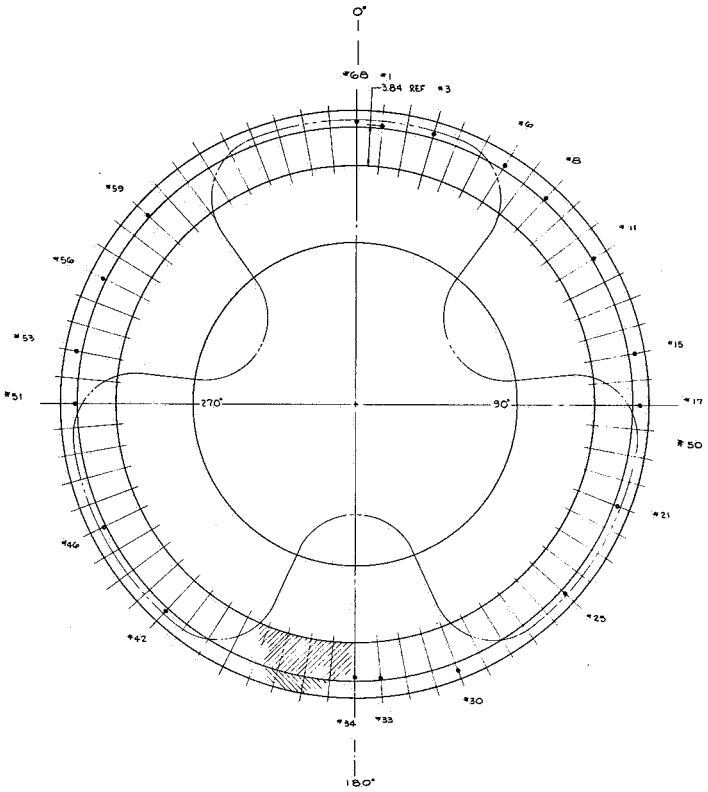
HOLE Nº	EROSION HEIGHT		
1	2.45	33	2.25
3	2.40	34	2.15
6	2.64	42	2.42
8	2.60	46	2.35
11	2.20	51	2.35
15	2.55	53	2.66
17	2.58	56	2.40
21	2.40	59	2.35
25	2.56	68	2.52
30	2.50		



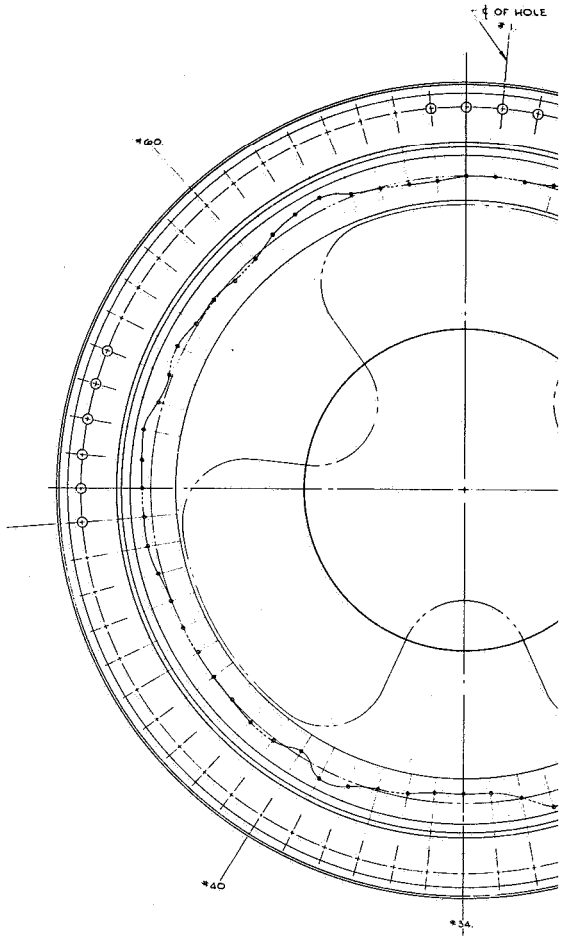
SECTION C-C

HOLE NR.	EROSION HEIGHT		
1	3.50	33	3.37
3	3.63	34	3.17
6	3.72	42	3.35
8	3.63	46	3.54
11	3.56	51	3.40
15	3.84	53	3.60
17	3.60	56	3.59
21	3.58	59	3.60
25	3.61	68	3.77
30	3.75		

280-1



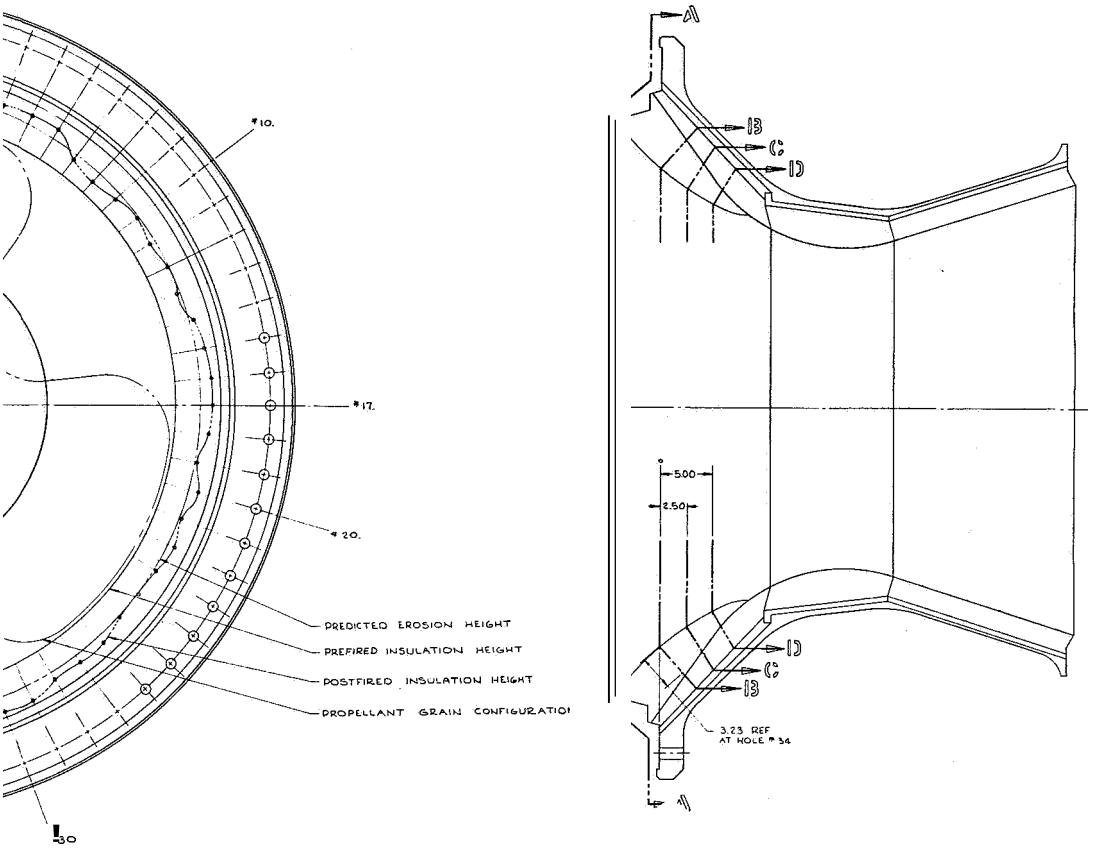
SECTION B B



VIEW - A.

HOLE NR.	EROSION HEIGHT		
1	3.84	33	3.55
3	4.08	34	3.23
6	4.06	42	3.97
8	3.80	46	3.85
11	3.75	51	3.75
15	4.20	53	4.13
17	4.20	56	3.95
21	4.03	59	3.88
25	4.12	68	4.13
30	4.35		

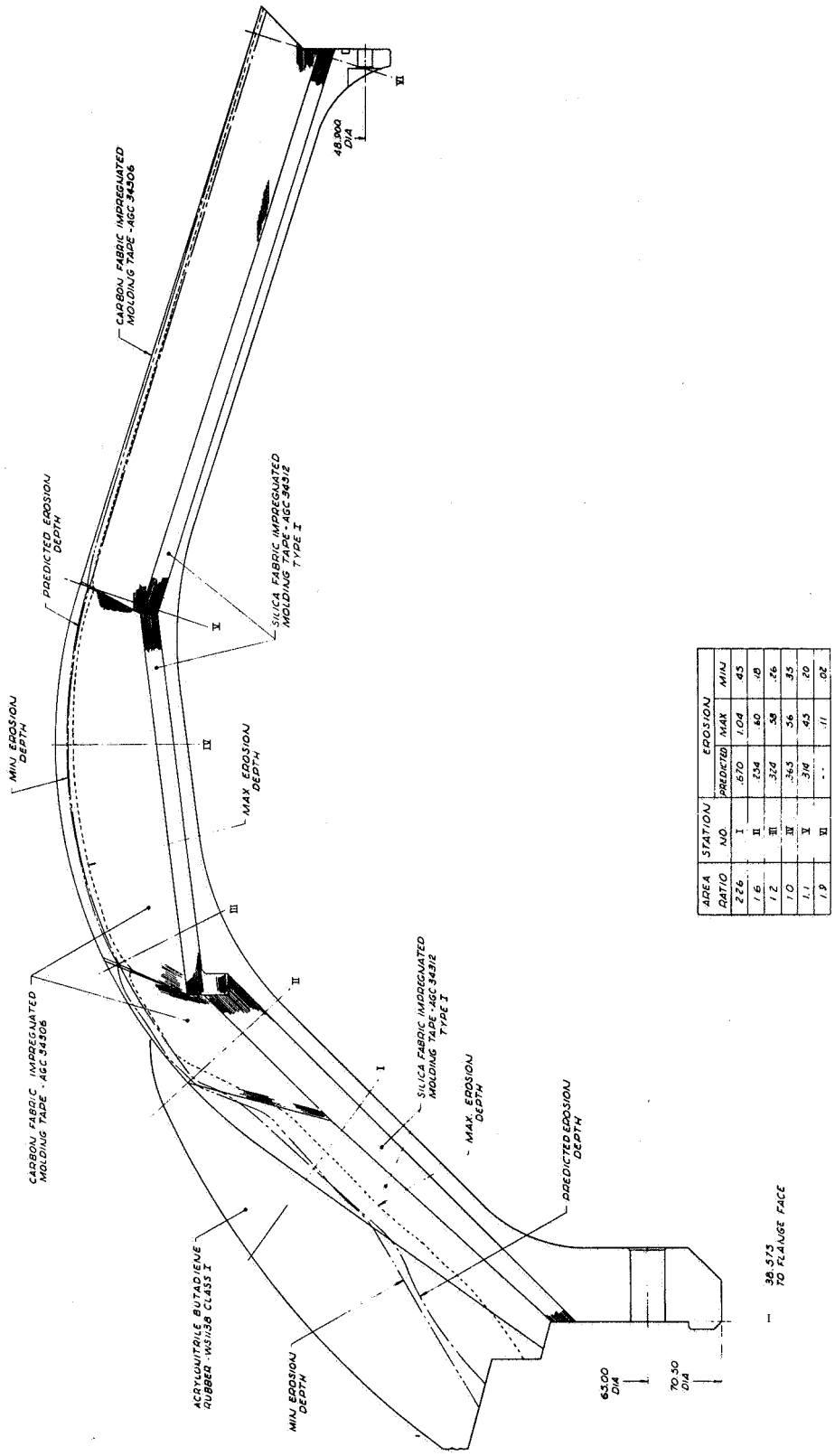
HOLE NR.	EROSION HEIGHT								
1	2.38	11	1.72	21	2.50	31	3.80	41	2.44
2	2.32	12	2.18	22	3.00	32	2.25	42	2.50
3	2.56	13	1.98	23	2.50	33	1.44	43	2.18
4	3.06	14	2.75	24	2.44	34	1.38	44	2.16
5	3.25	15	3.12	25	2.42	35	1.31	45	2.14
6	3.32	16	3.44	26	3.12	36	1.88	46	2.32
7	1.80	17	3.50	27	3.18	37	2.12	47	2.44
8	1.38	18	3.18	28	3.10	38	2.75	48	2.75
9	1.68	19	2.50	29	3.88	39	3.25	49	3.12
10	2.12	20	3.25	30	3.75	40	1.72	50	3.06



51	3.12	61	2.88
52	3.32	62	3.32
53	3.50	63	3.44
54	2.75	64	2.50
55	2.62	65	2.26
56	3.00	66	1.98
57	2.44	67	1.92
58	2.50	68	2.38
59	2.00		
60	2.18		

Erosion Contour of 120-SS-1 Nozzle Entrance Section

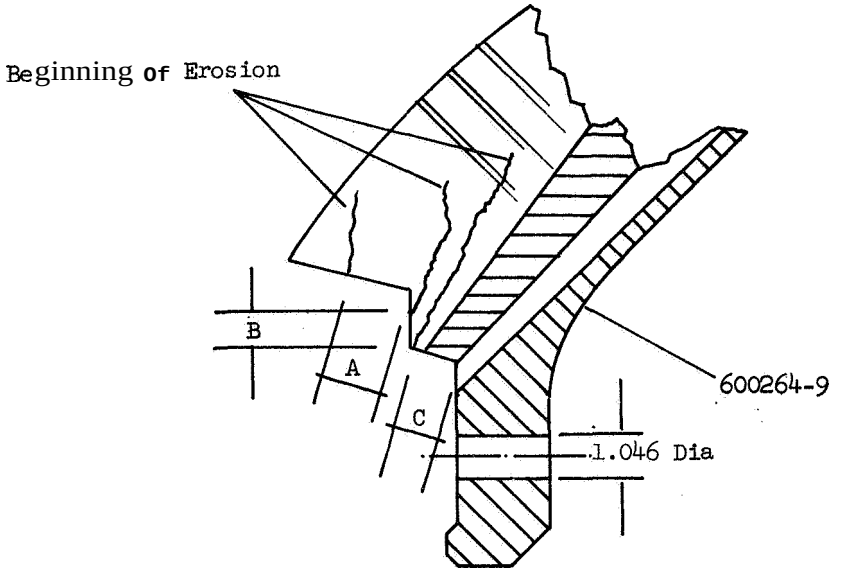
Figure 280-3



AREA RATIO	STATION NO.	EROSION PREDICTED	EROSION MAX	EROSION MIN
226	I	.670	1.04	.45
16	II	.234	.40	.18
12	III	.324	.58	.26
7.0	IV	.363	.56	.35
1.1	V	.314	.45	.20
1.9	VI	-	.11	.02

Erosion Contour of 120-SS-1 Nozzle Assembly

Figure 281



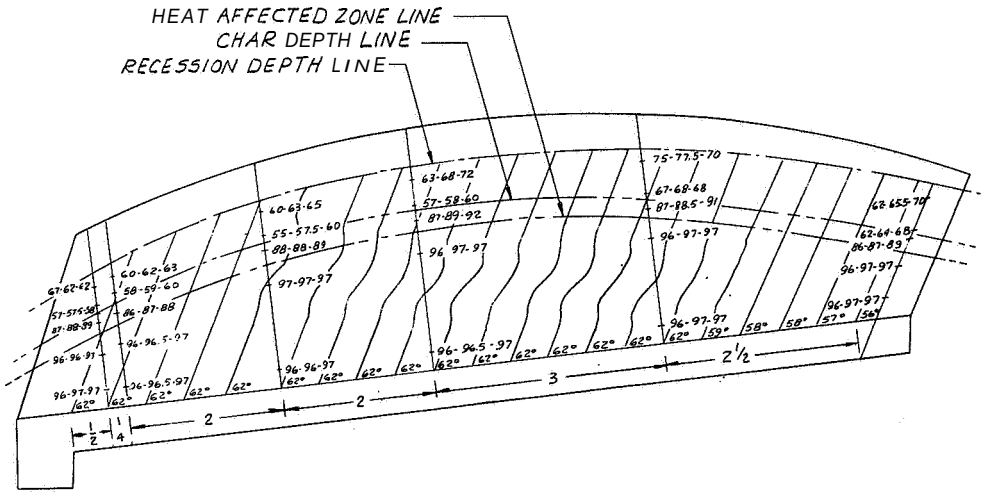
Dimensions A, B, and C, were taken from the center line of each 1.046-in.-dia hole.

Hole No.	Dimension A	Dimension B	Dimension C	Hole No.	Dimension A	Dimension B	Dimension C	Hole No.	Dimension e	Dimension B	Dimension C
1	.680			24	.610			47	.650		
2	.750			25	.660			48	.320		
3	.500			26		1.310		49		1.330	
4		1.460		27		1.260		50		1.480	
5		1.110		28		1.400		51		1.350	
6		1.060		29			1.120	52		1.050	
7	1.300			30		.100		53		.700	
8	1.720			31		.050		54	.300		
9	1.400			32	.800			55	.450		
10	.960			33	1.700			56	.030		
11	1.350			34	1.730			57	.660		
12	.900			35	1.810			58	.540		
13	1.100			36	1.220			59	1.090		
14	.300			37	.950			60	.850		
15		1.300		38	.300			61	.150		
16		.800		39		1.200		62		.960	
17		.600		40	1.400			63		.850	
18		1.250		41	.600			64	.560		
19	.540			42	.580			65	.780		
20		1.100		43	.860			66	1.100		
21	.550			44	.900			67	1.130		
22	.050			45	.910			68	.680		
23	.500			46	.750						

Posttest 120-SS-1 Nozzle Erosion Pattern of V-44 Insulation

Figure 282

NOTES: 1. SNORE D **READINGS** ARE MIN, AVE, & MAX.
LOCATIONS **OF** SHORE READINGS ON PLOT
LINES ARE AVERAGE.



Posttest Hardness Plot and Laminate Orientation of **120-SS-1**
Nozzle Throat

Figure 283

NOTES: 1. SHORE D READINGS ARE MIN, AVE, & MAX. LOCATIONS
READINGS ON PLOT LINES ARE AVERAGE.

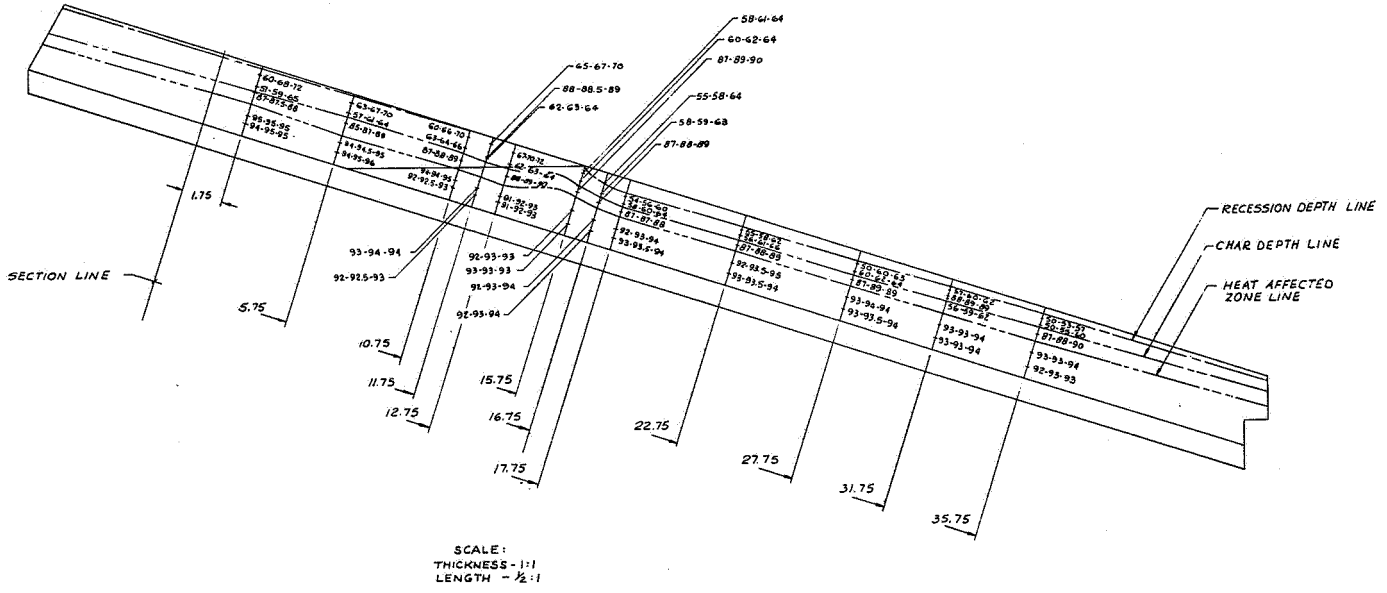


Figure 284

Shore D Hardness Readings of 120-SS-1 Exit Cone Assembly

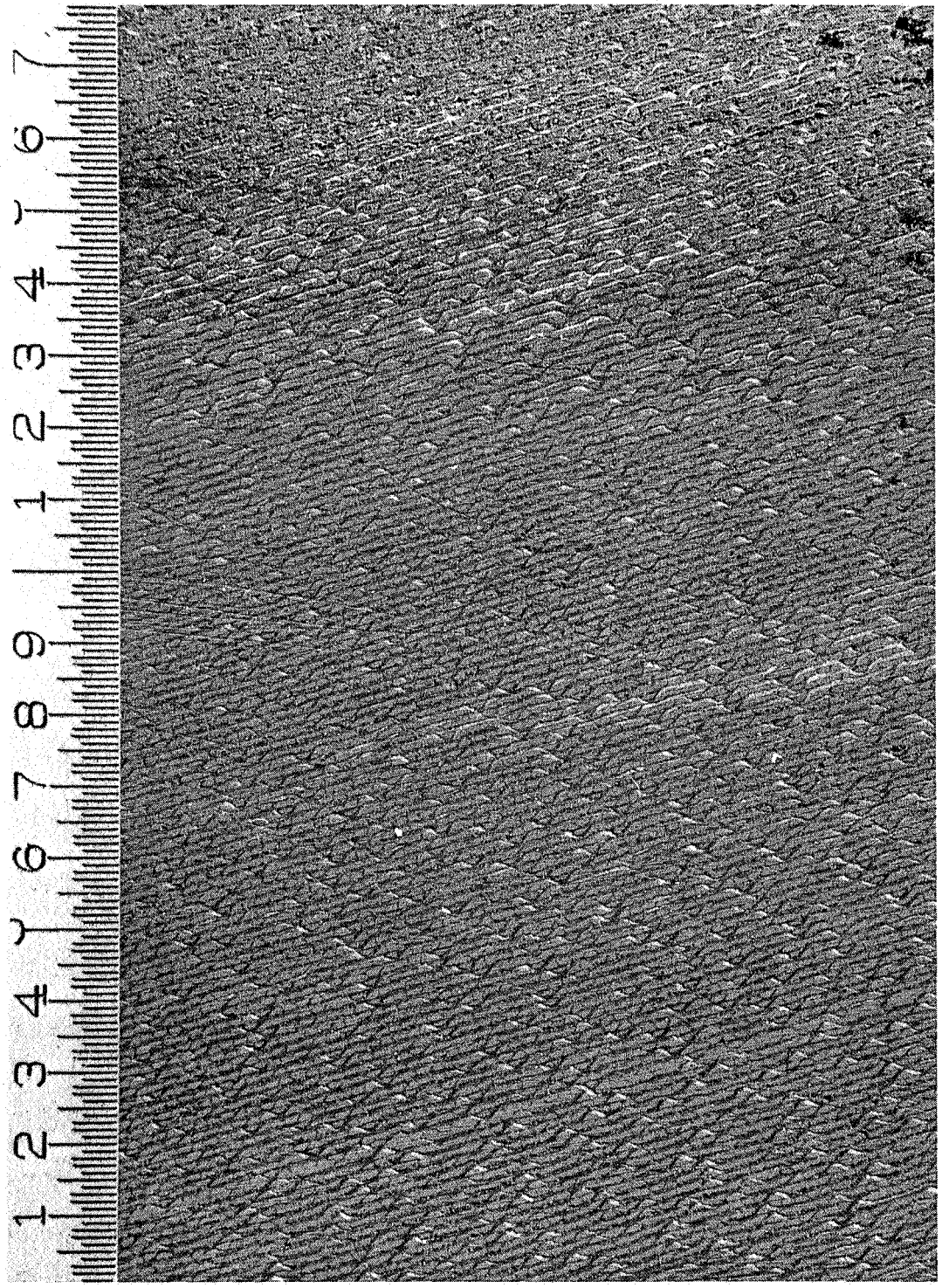
	Location, Degrees	Material	Volatiles, %	Density, lb/cu.in.	Interlaminar Shear, psi
Inlet	0	Silica	0.60	0.066	5,100
	180	Silica	0.69	0.065	4,310
	90	Carbon	2.08	0.051	2,660
	180	Carbon	1.95	0.052	3,210
	270	Carbon	2.28	0.052	2,840
	180	Silica/Carbon	-	-	1,900
*	270	Silica/Carbon	-	-	2,840
Throat	0	Carbon	1.70	0.050	3,990
	180	Carbon	2.26	0.050	1,840
	270	Carbon	1.30	0.051	1,850
Throat Extension	0	Carbon	2.25	0.052	2,530
	90	Carbon	2.00	0.052	2,660
	180	Carbon	2.00	0.051	2,400
Exit Cone	90	Silica	2.38	0.060	1,970
	180	Silica	1.90	0.060	2,660
	270	Silica	2.72	0.060	2,290
	90	Carbon	1.62	0.050	4,060
	180	Carbon	1.86	0.050	3,400
**	270	Carbon	2.00	0.050	2,090

* Only 2 specimens of the silica and silica/carbon interface were available for interlaminar shear due to lack of material thickness.

**Interlaminar shear specimens at the silica/carbon interface were unobtainable due to the post-force material separation.

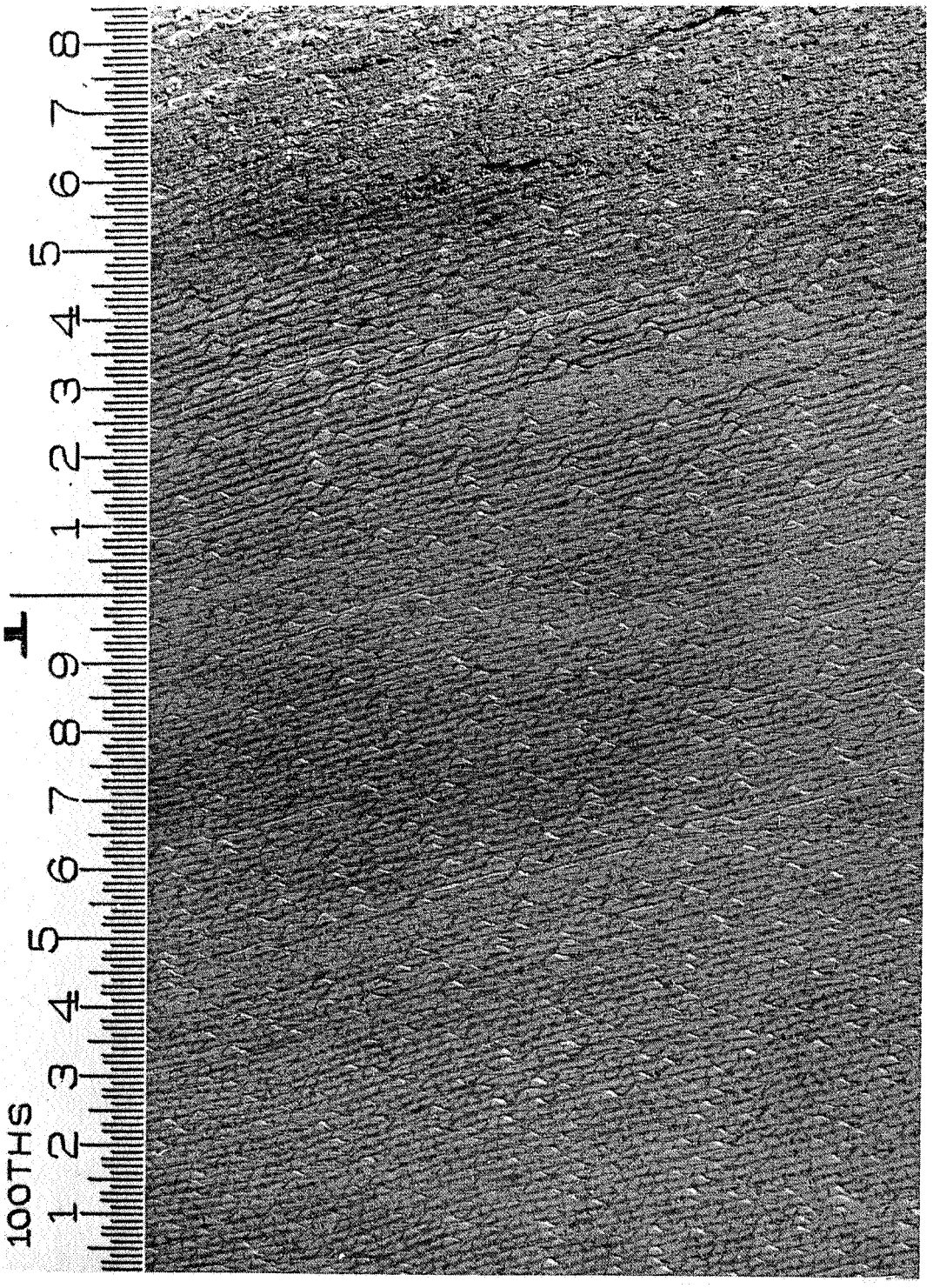
Figure 285

Physical Property Test Results, Post-Fired 120-SS-1 Nozzle Components



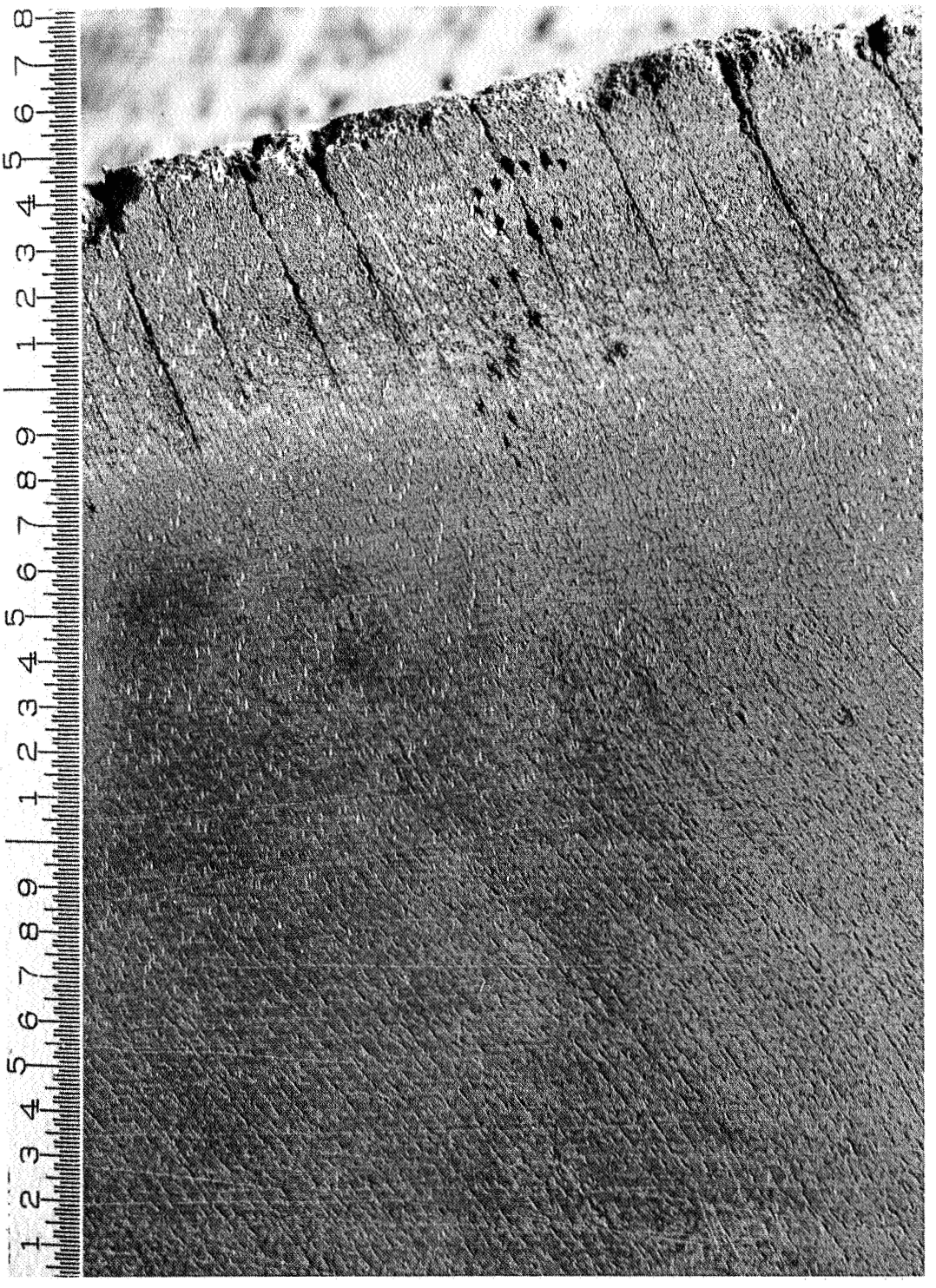
Forward Section of the Nozzle Throat Extension Insert, Motor 120-SS-1

Figure 286



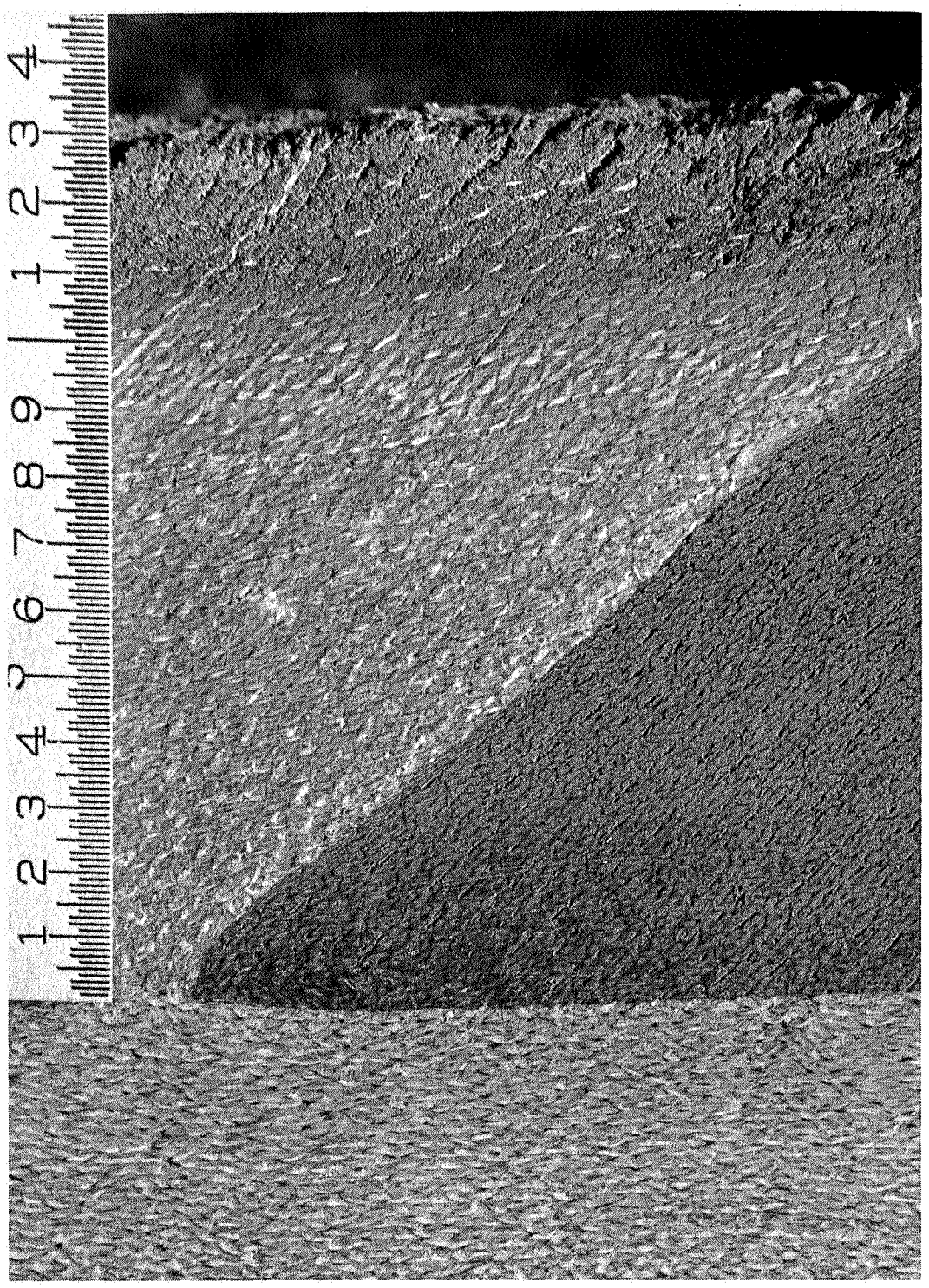
Aft Section of the Nozzle Throat Extension Insert, Motor 120-SS-1

Figure *287*



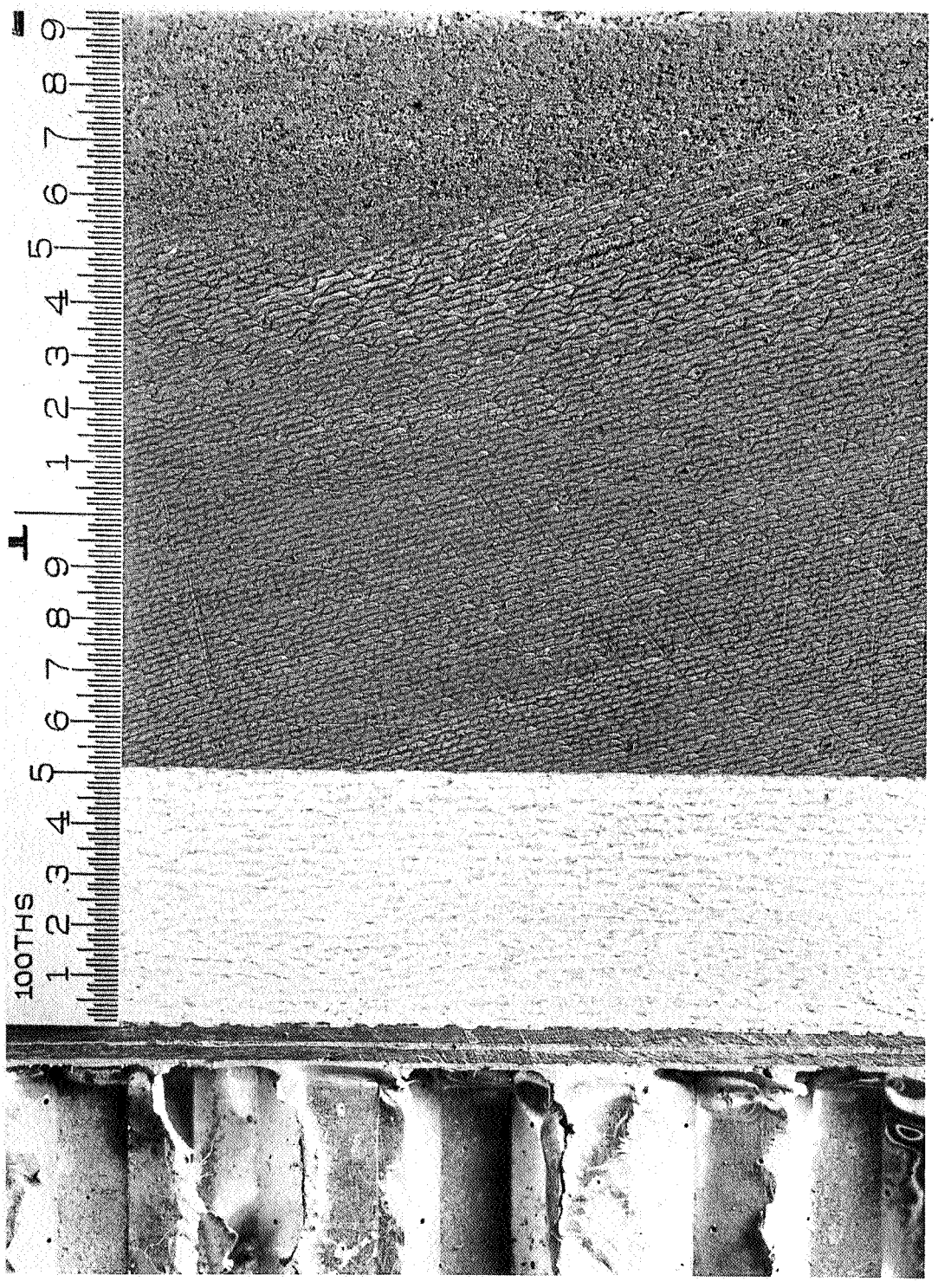
Aft Section of the Nozzle Throat Insert, Motor 120-SS-1

Figure 288



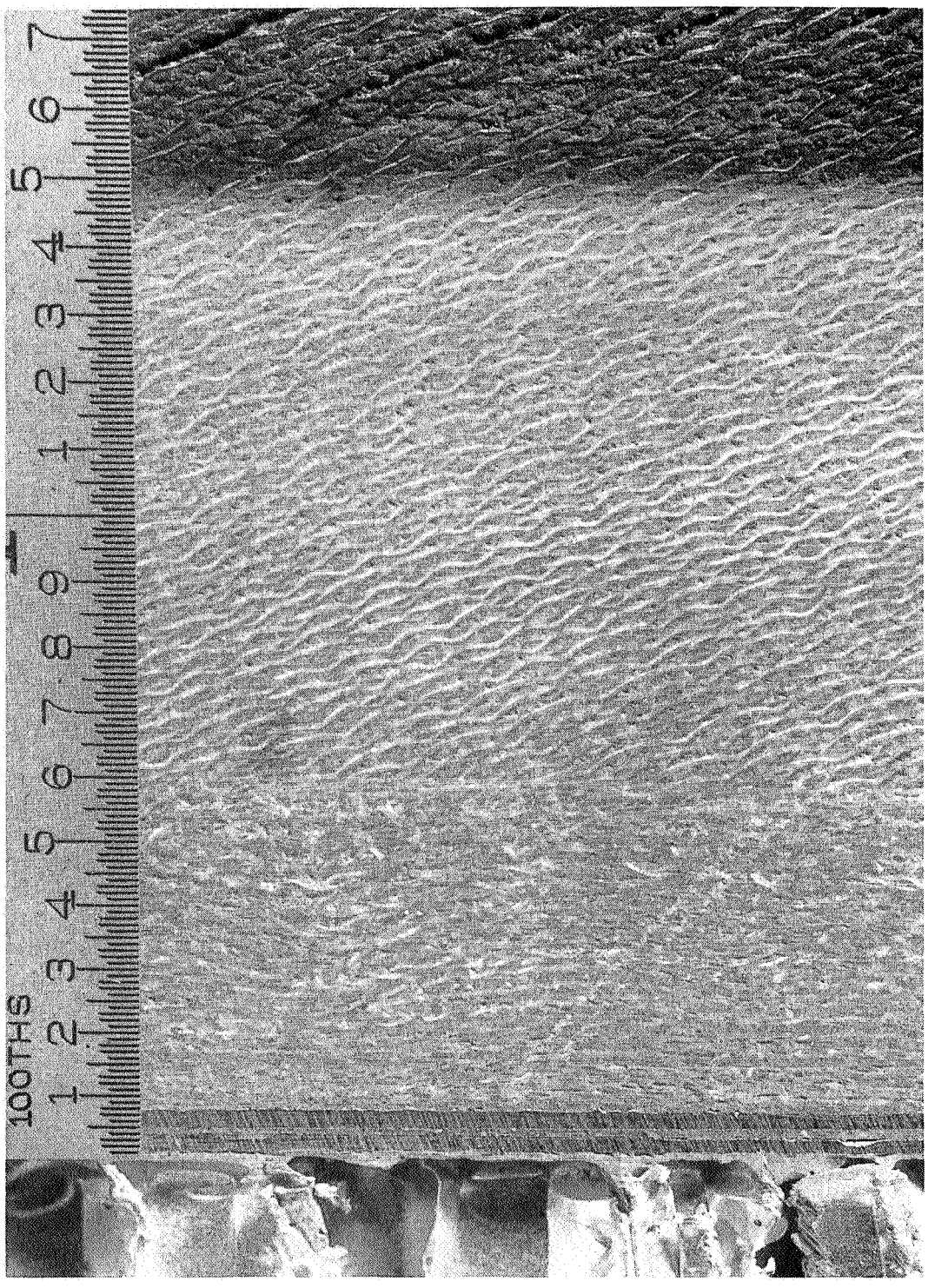
Section of the Nozzle Entrance Insert, Motor 120-SS-1

Figure 289



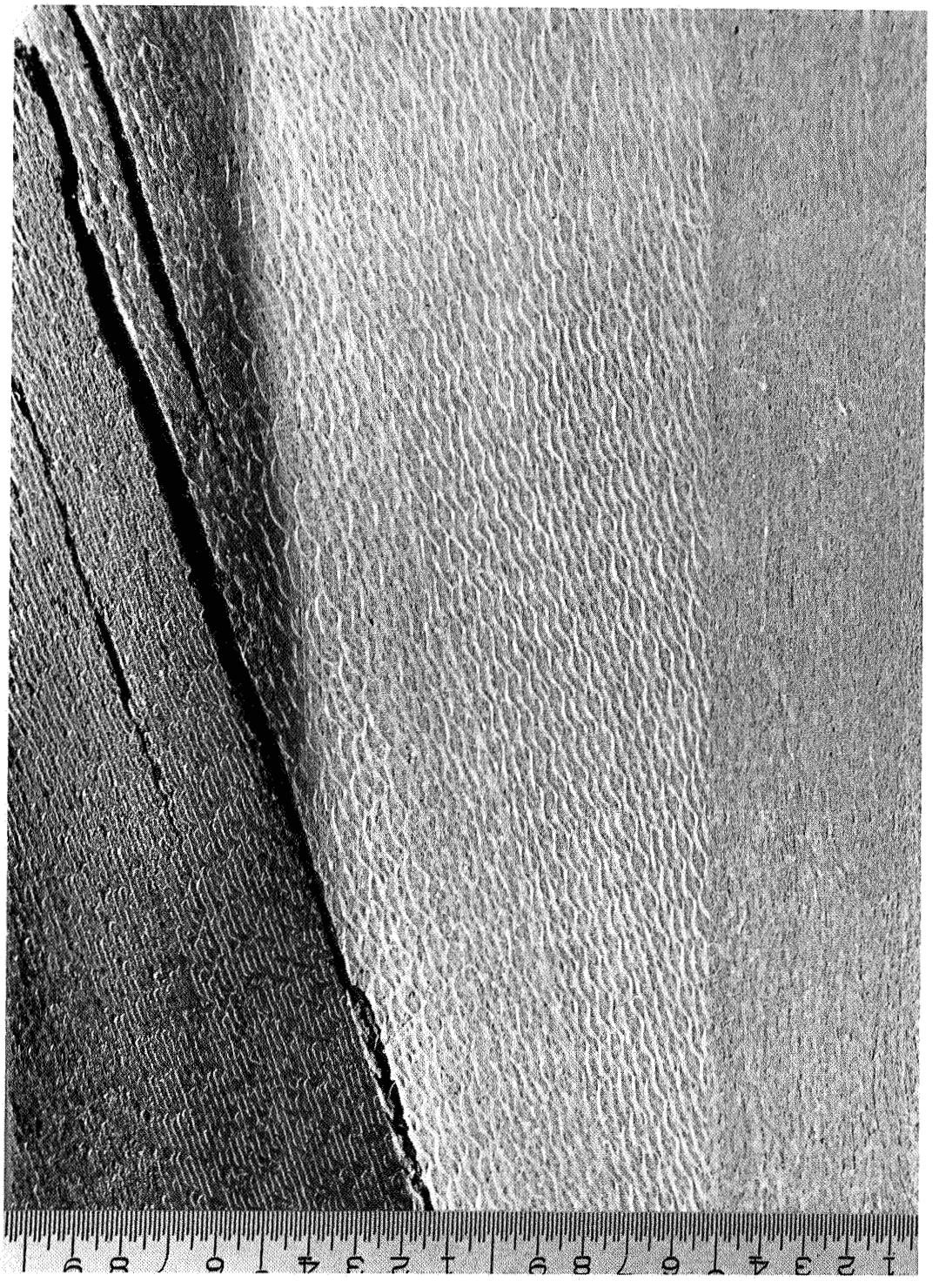
Forward Section of the Exit C Liner, Motor 120-SS-1

Figure 290



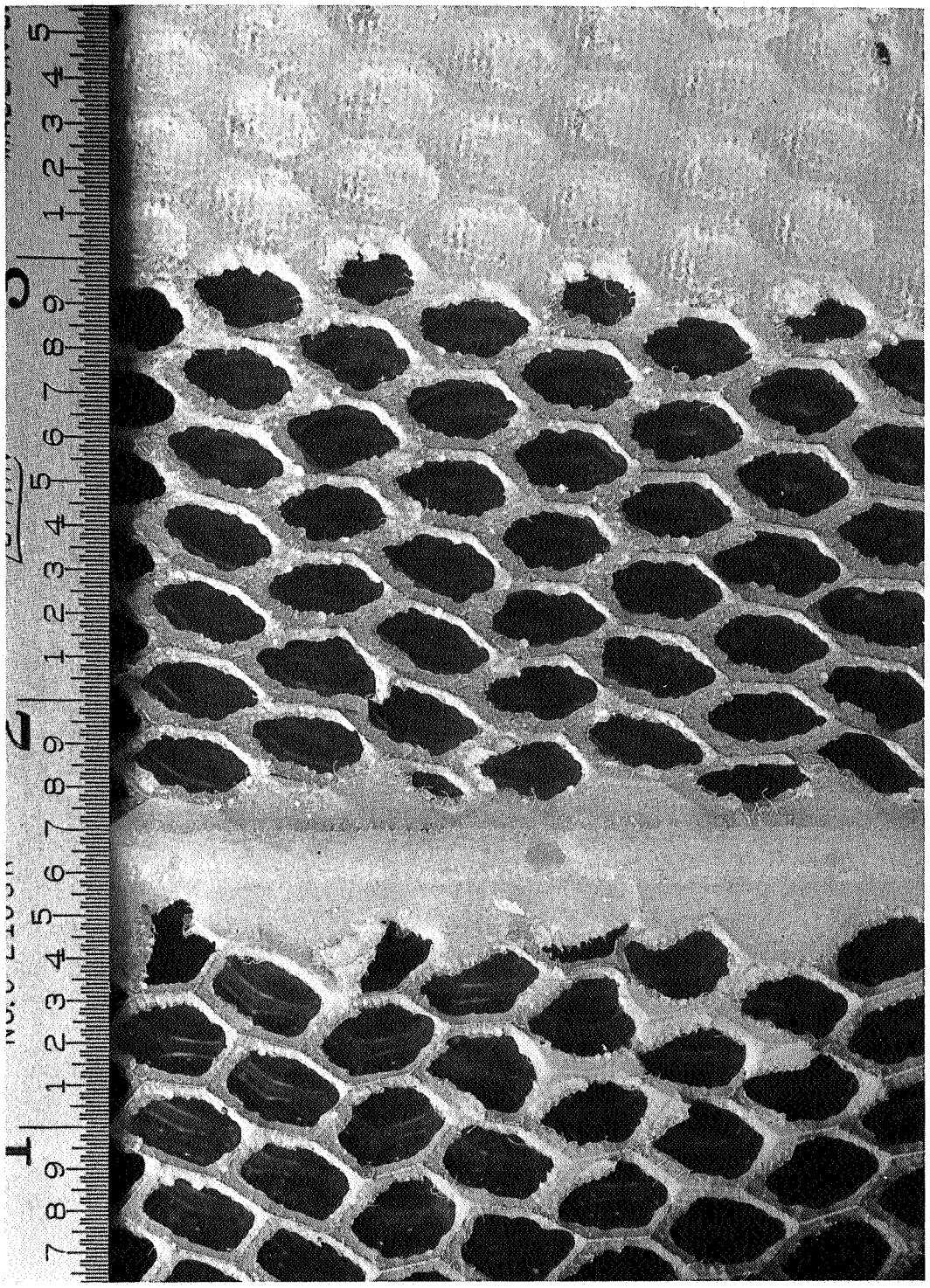
Aft Section of the Exit Cone Liner, Motor 120-SS-1

Figure 291



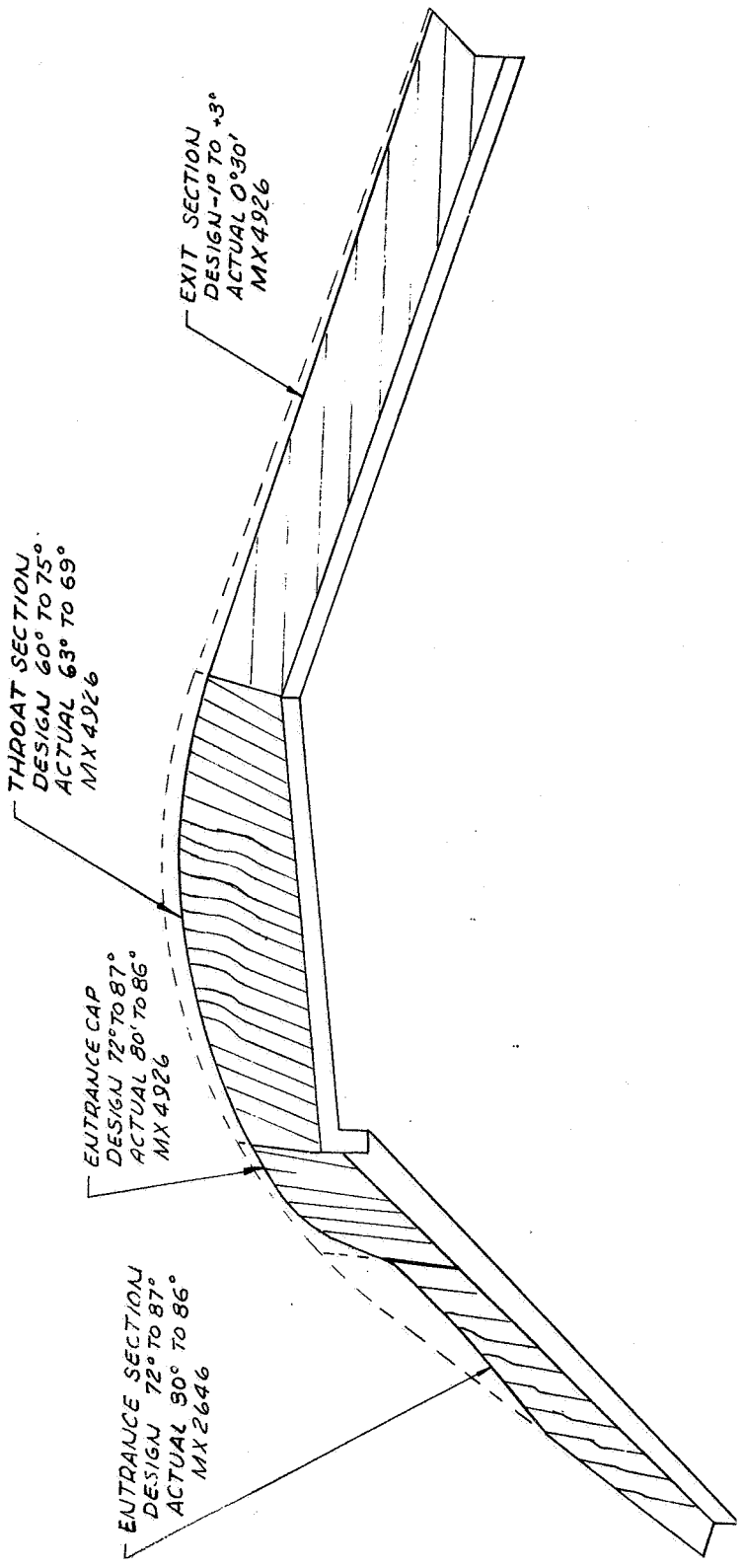
Section of the Exit Cone Liner, Motor 120-SS-1

Figure 292



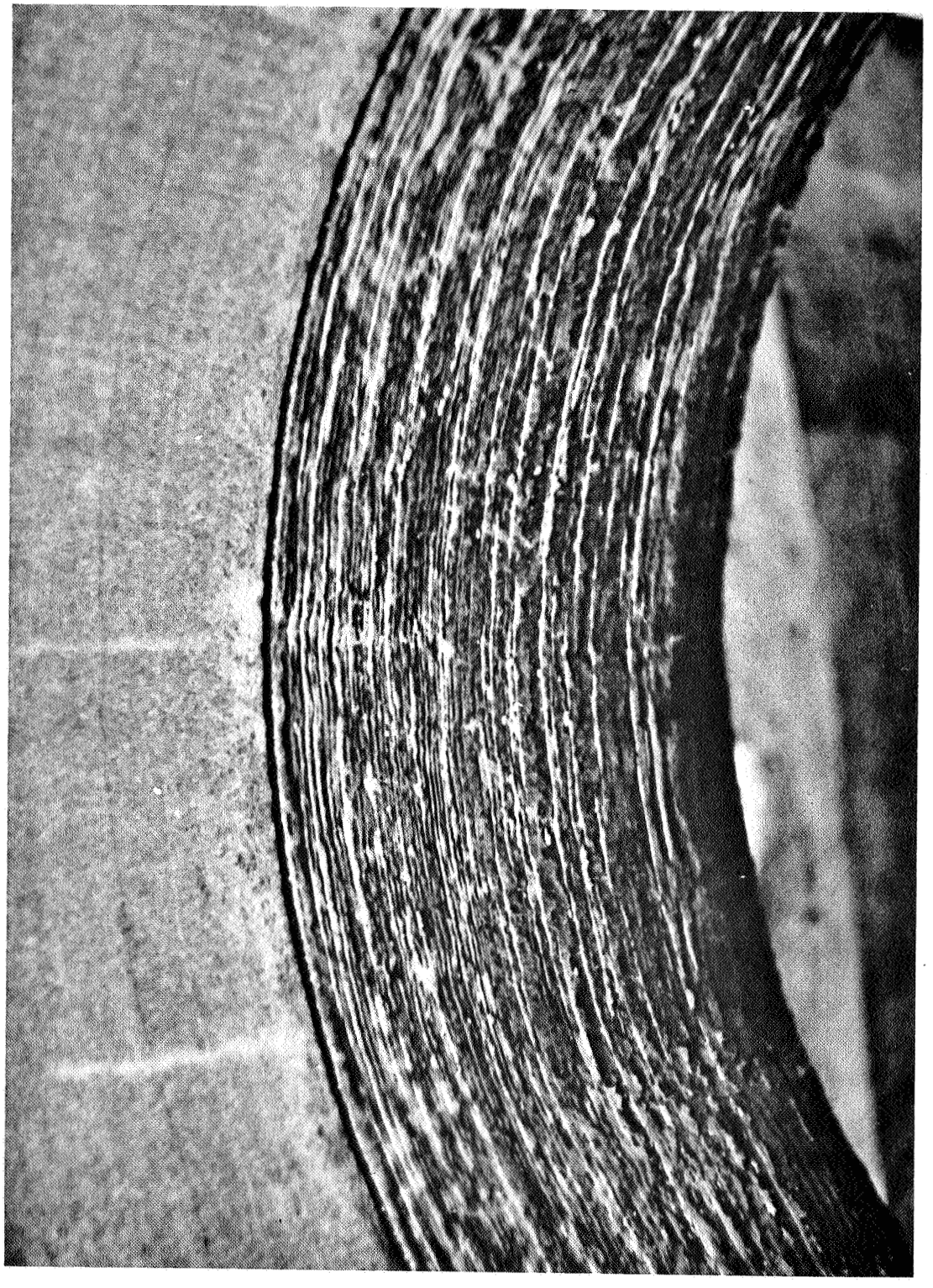
Section of the Honeycomb Core of the Exit Cone, Motor 120-SS-1

Figure 293



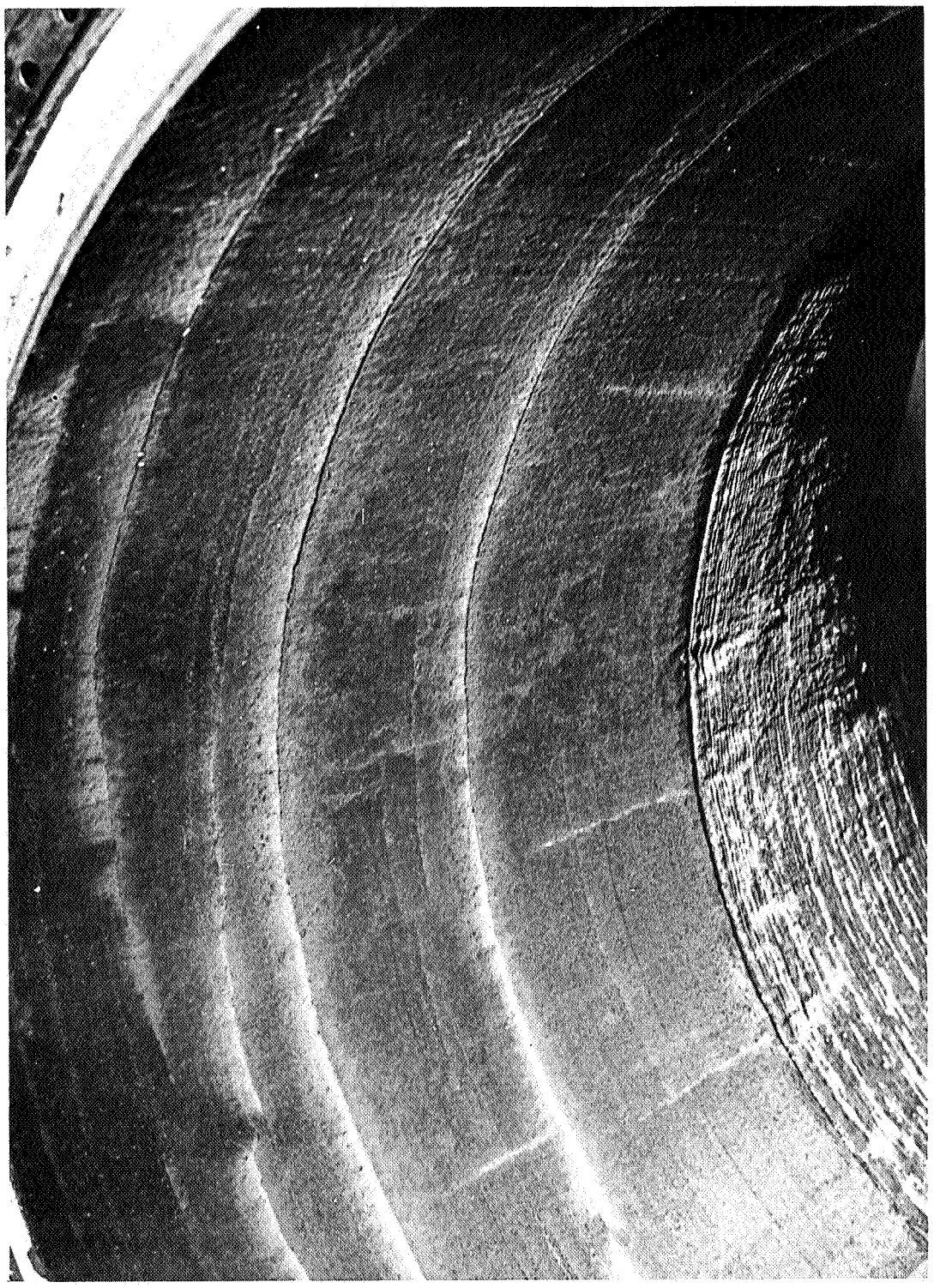
Tape Wrap Orientation of 120-IS-1 Nozzle Assembly

Figure 294



Posttest View of 120-SS Nozzle Throat Insert

Figure 295



Posttest View of 120-SS-1 Throat Extension Insert

Figure 296

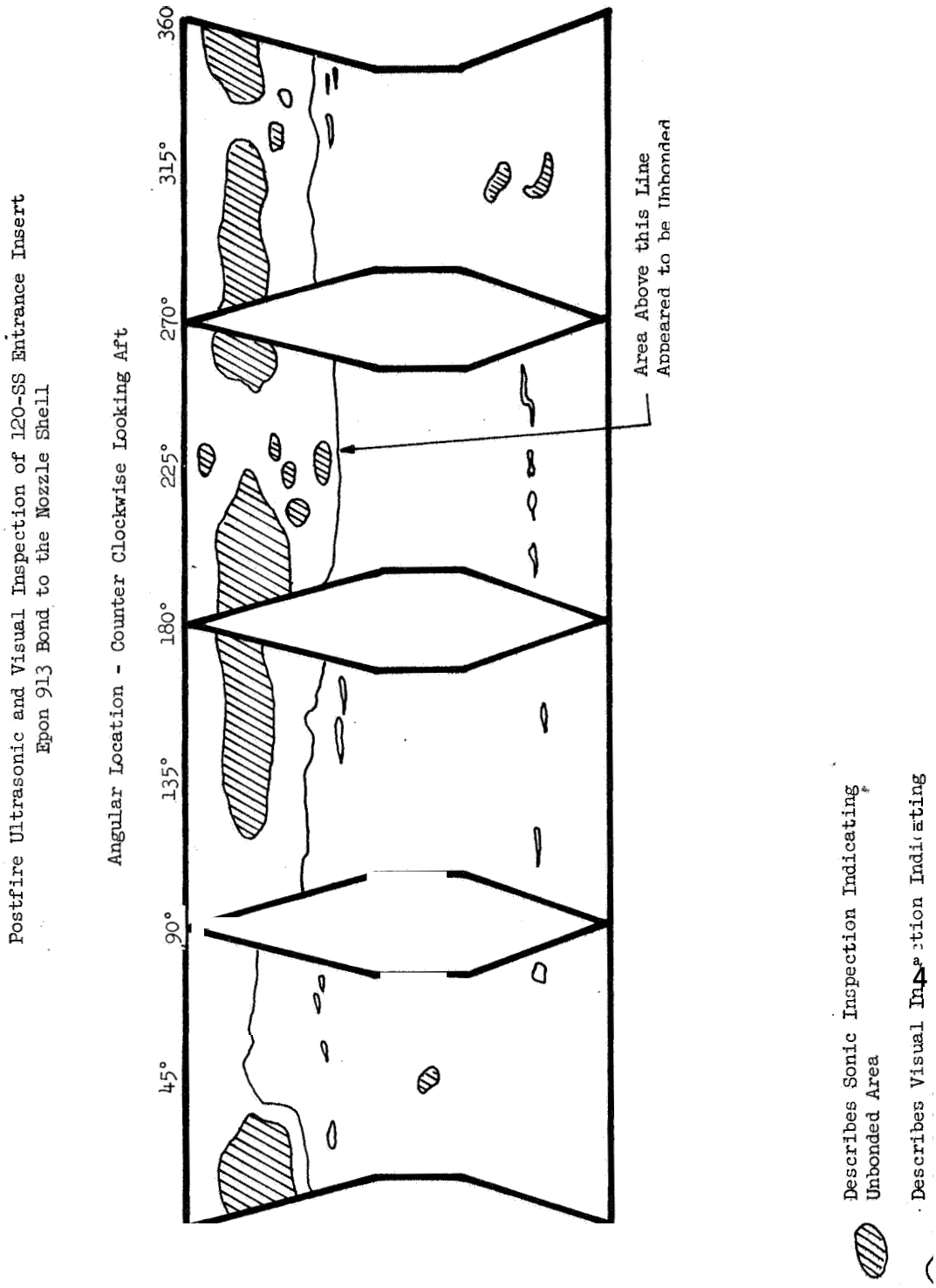
Area Ratio	Material	Predicted Ablation Depth in.	Predicted Recession Rate mil/sec (1)	Predicted Recession Rate mil/sec (2)	Actual (Average) Ablation Depth in.	Actual (Average) Recession Rate mil/sec (1)	Actual (Average) Recession Rate mil/sec (2)
2.26	MX-2646	.67	8.5	7.4	.78	9.9	8.7
1.6	MX-4926	.254	3.2	2.8	.36	4.6	4.0
1.2	↓	.324	4.1	3.6	.42	5.3	4.7
1.0	↓	.365	4.6	4.05	.43	5.4	4.8
1.1	↓	.314	4.0	3.5	.30	3.8	3.2
3.4	MX-4926	.071	0.9	0.8	+.01	-	-
3.6	FM-5131	.314	4.0	3.5	.31	3.9	3.5
6.0	FM-5131	.172	2.2	1.9	.05	0.63	0.56

(1) Calculation based on 79 seconds corresponding to motor pressure drop to 250 psia.

(2) Calculation based on motor action time of 90 seconds.

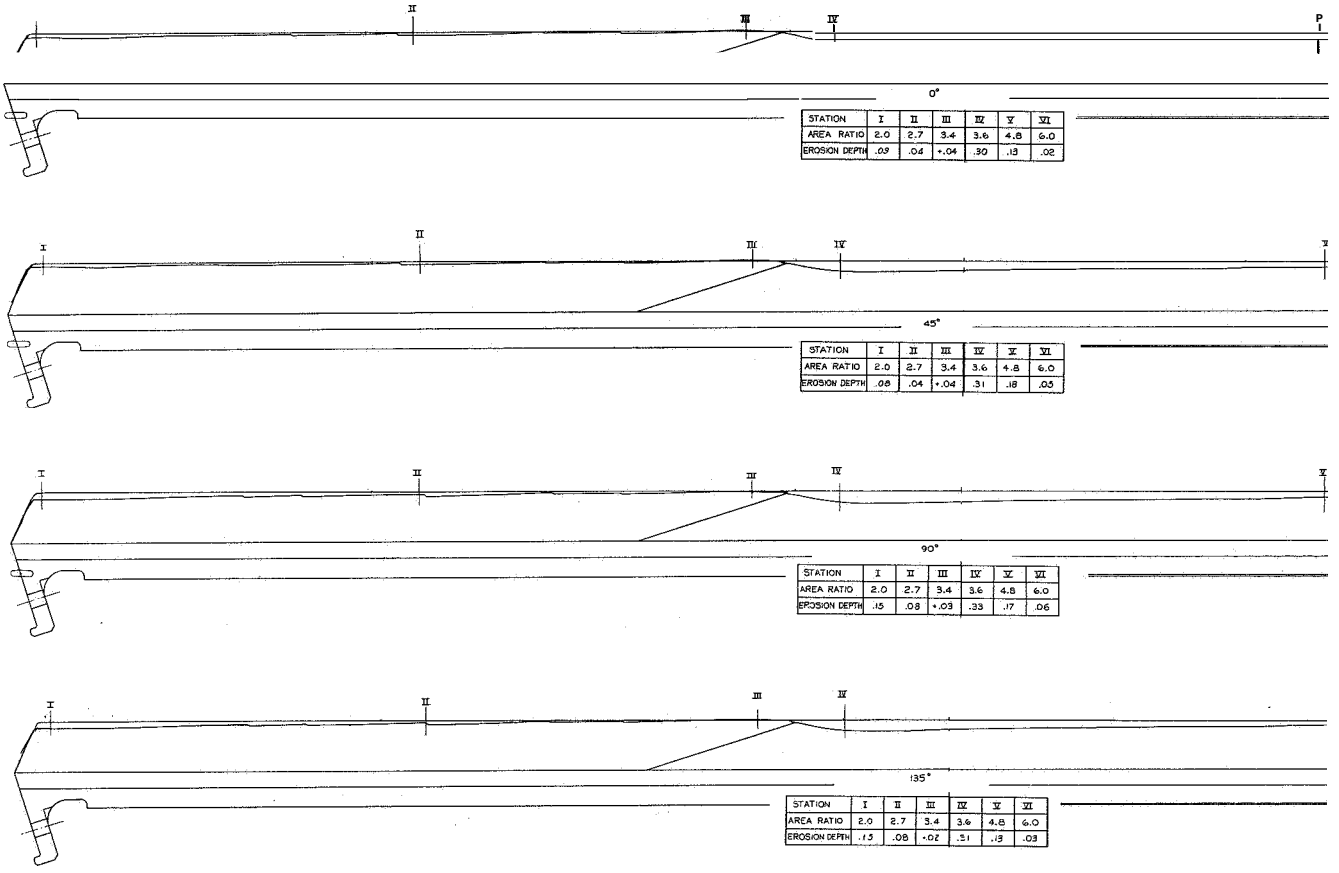
Recession Rates of 120-SS-1 Nozzle Assembly

Figure 297



Postfire Ultrasonic and Visual Inspection of 120-SS Entrance Insert
Epon 913 Bond to the Nozzle Shell

Figure 298

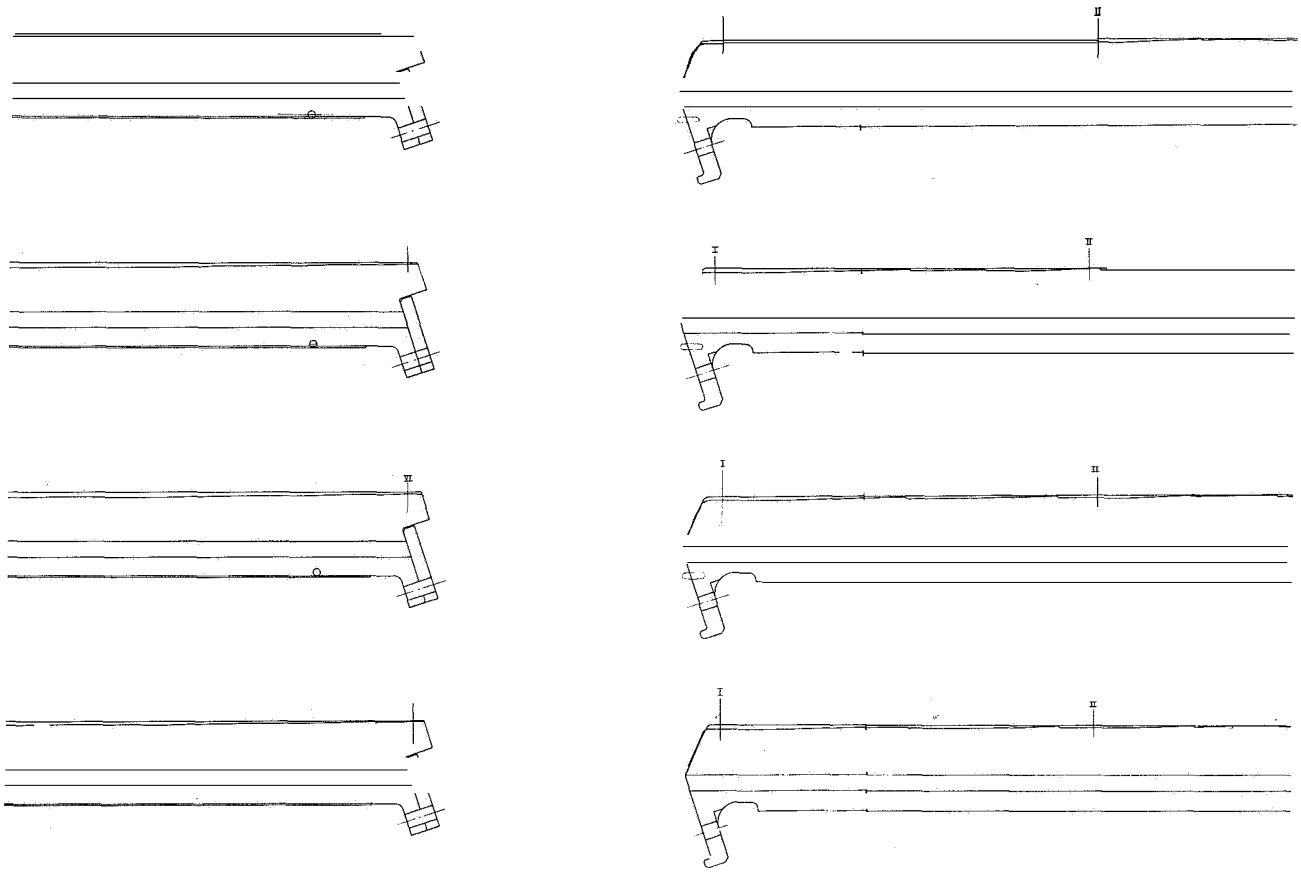


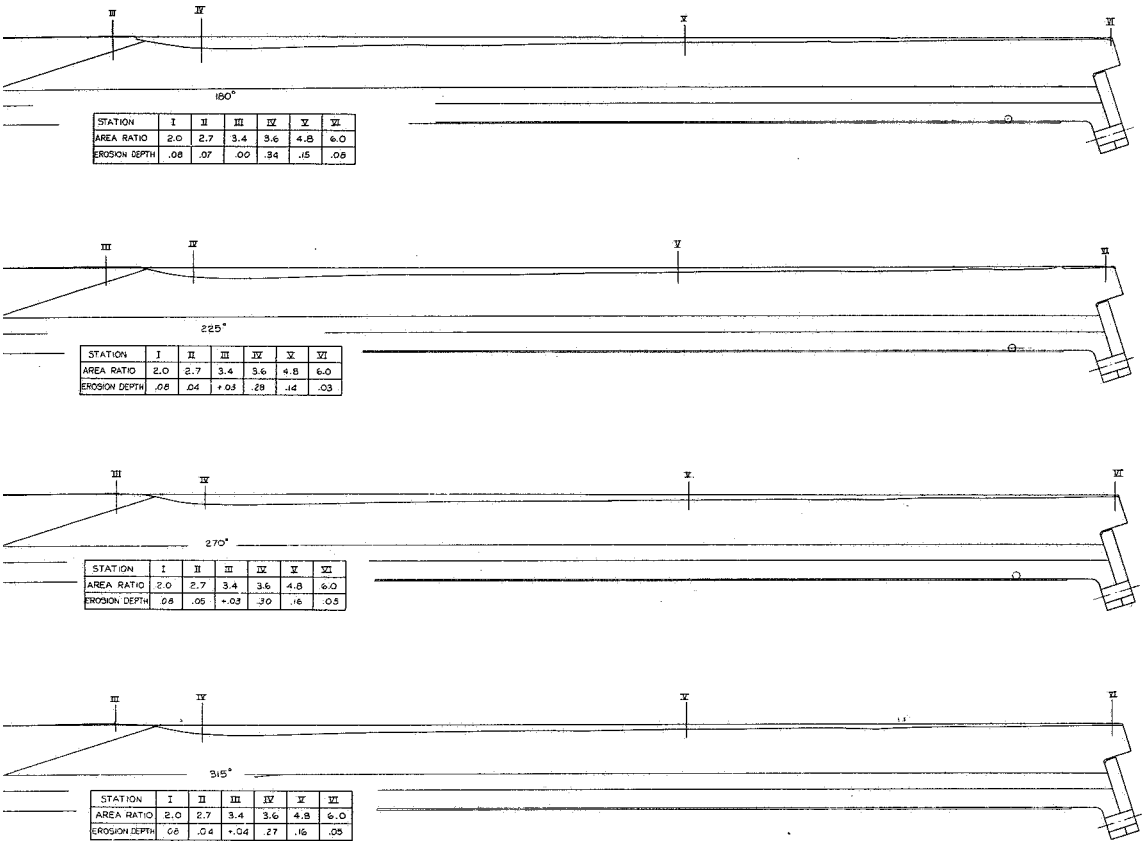
STATION	I	II	III	IV	V	VI
AREA RATIO	2.0	2.7	3.4	3.6	4.8	6.0
EROSION DEPTH	.09	.04	+.04	.30	.13	.02

STATION	I	II	III	IV	V	VI
AREA RATIO	2.0	2.7	3.4	3.6	4.8	6.0
EROSION DEPTH	.08	.04	+.04	.31	.18	.05

STATION	I	II	III	IV	V	VI
AREA RATIO	2.0	2.7	3.4	3.6	4.8	6.0
EROSION DEPTH	.15	.08	+.03	.33	.17	.06

STATION	I	II	III	IV	V	VI
AREA RATIO	2.0	2.7	3.4	3.6	4.8	6.0
EROSION DEPTH	.13	.08	+.02	.31	.13	.03


II
I
II
I
II
I
II



STATION	I	II	III	IV	V	VI
AREA RATIO	2.0	2.7	3.4	3.6	4.8	6.0
EROSION DEPTH	.08	.07	.00	.34	.15	.08

STATION	I	II	III	IV	V	VI
AREA RATIO	2.0	2.7	3.4	3.6	4.8	6.0
EROSION DEPTH	.08	.04	+.03	.28	.14	.03

STATION	I	II	III	IV	V	VI
AREA RATIO	2.0	2.7	3.4	3.6	4.8	6.0
EROSION DEPTH	.08	.05	+.03	.30	.16	.05

STATION	I	II	III	IV	V	VI
AREA RATIO	2.0	2.7	3.4	3.6	4.8	6.0
EROSION DEPTH	.08	.04	+.04	.27	.16	.05

Erosion Profiles of 120-SS-1 Exit Cone Assembly

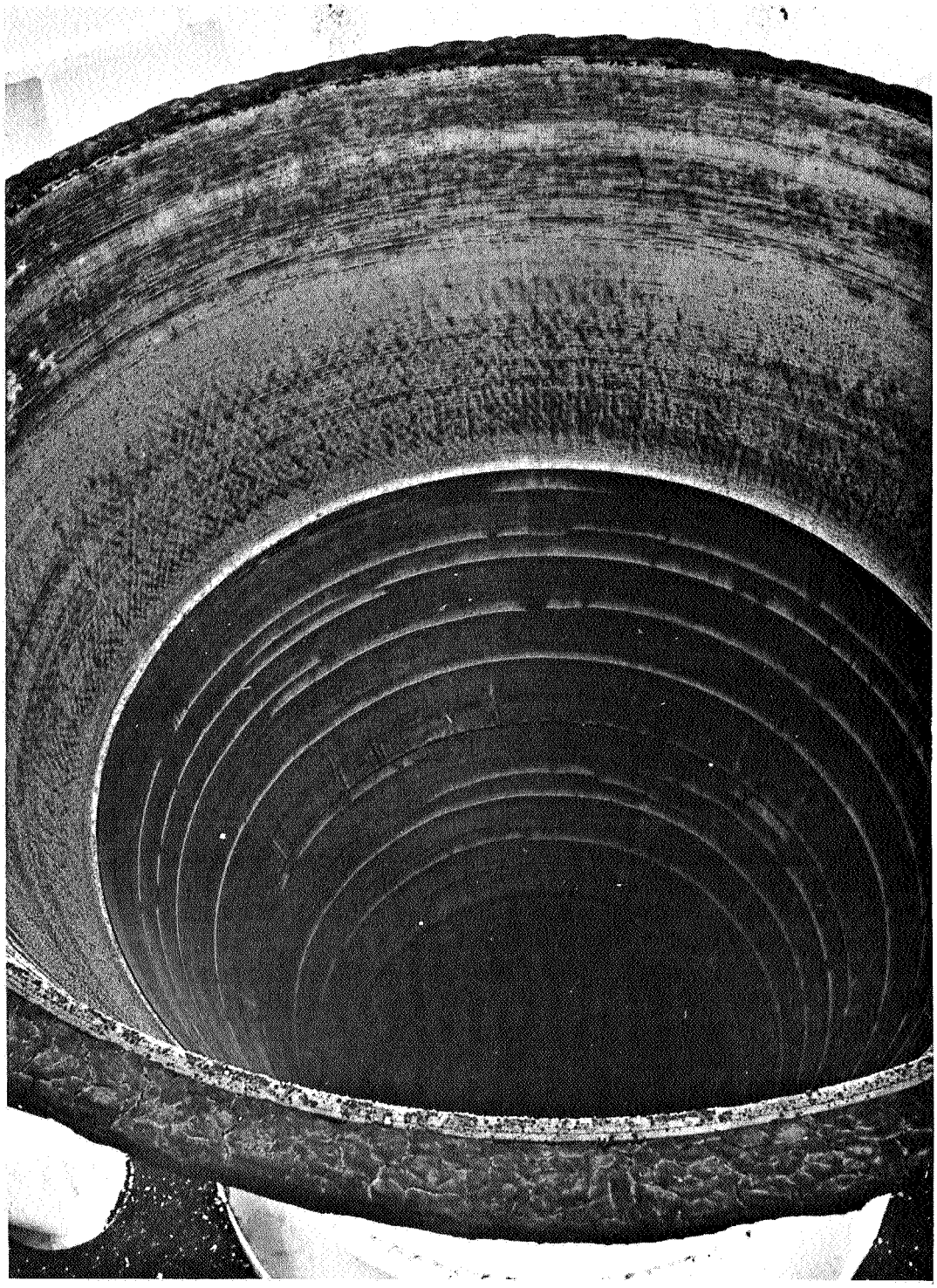
Figure 299-3

Exit Cone Erosion Depth

Area Ratio	Material	Location 0°	45°	90°	135°	180°	225°	270°	315°	Average	Predicted*
2.0	MX-4926	.09	.08	.15	.15	.08	.08	.06	.08	.10	-
2.7	MX-4926	.04	.04	.08	.08	.07	.04	.05	.04	.06	-
3.4	MX-4926	+.04	+.04	-.03	+.02	+.00	-.03	+.03	+.04	+.01	.071
3.6	FM-5131	.30	.31	.33	.31	.34	.28	.30	.27	.31	.304
4.8	FM-5131	.13	.18	.17	.13	.15	.14	.16	.16	.15	-
64	FM-5131	.02	.05	.06	.03	.08	.03	.05	.05	.05	.172

*Corrected to actual 120-SS motor pressure and duration.

Recession Depths of 120-SS-1 Exit Cone

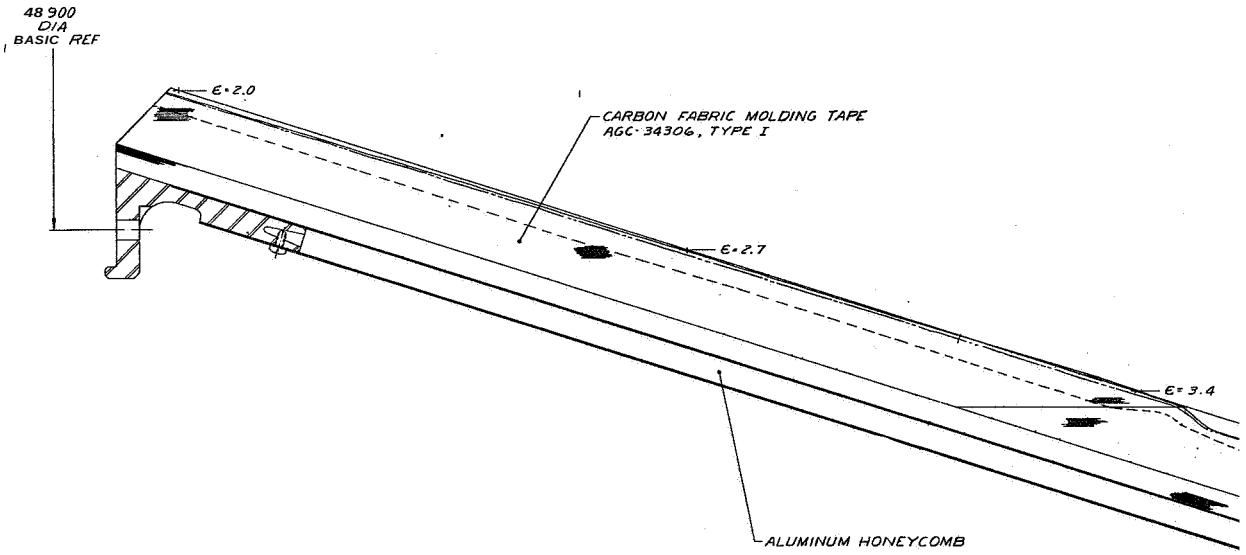


Posttest View of 120-SS-1 Exit Cone

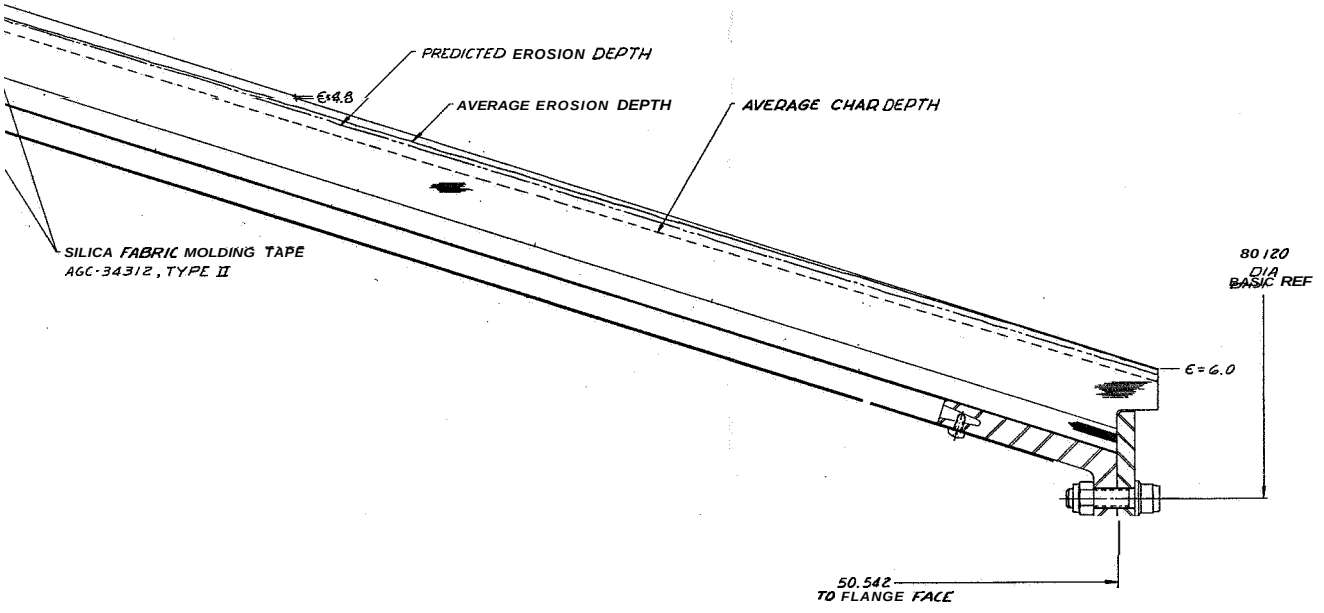
Figure 301

Posttest View of 120-SS-1 Exit Cone

Figure 302

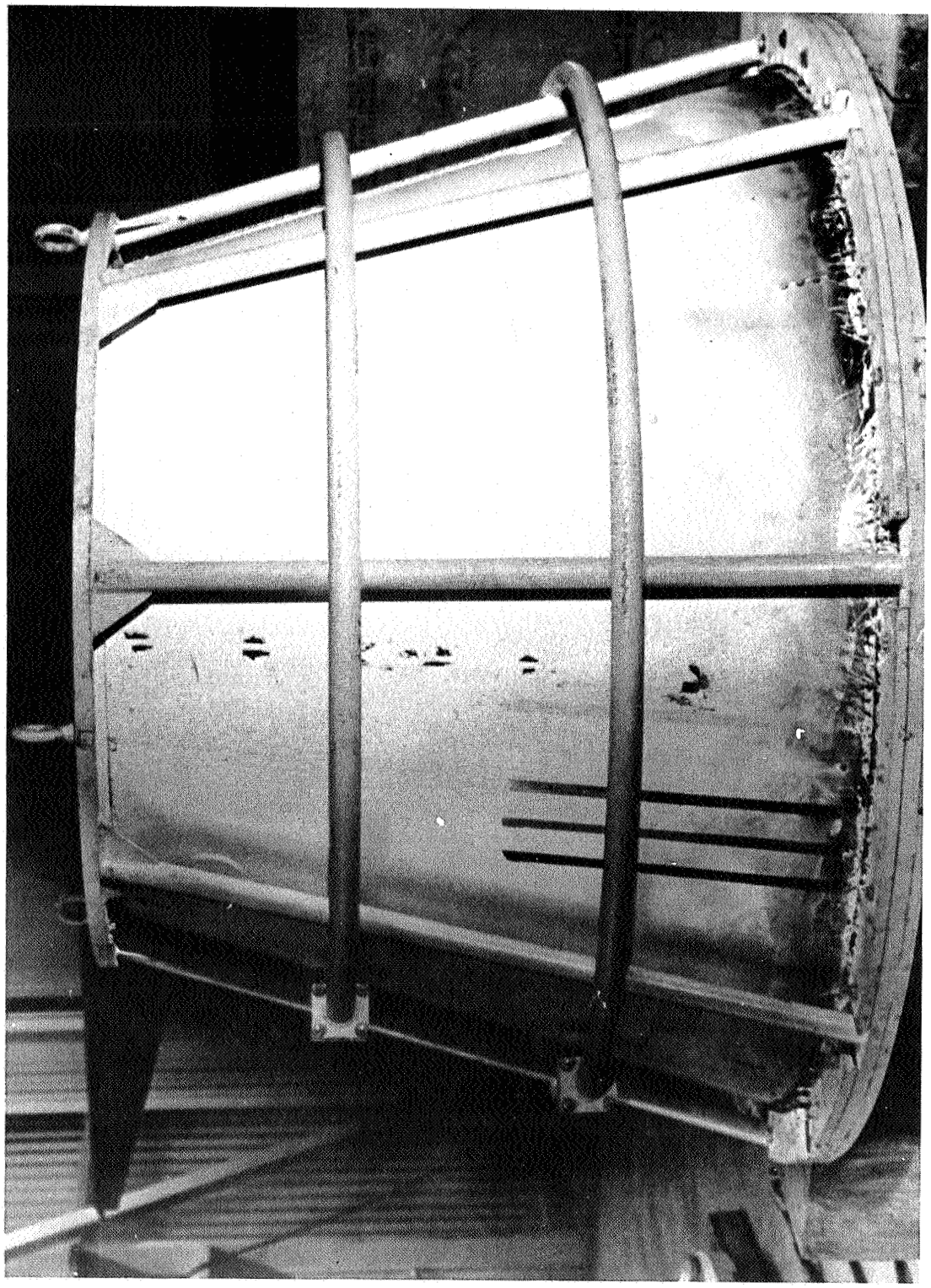


AREA RATIO	EROSION		CUAR DEPTH	
	PREDICTED	AVERAGE	PREDICTED	AVERAGE
2 0	--	.10	--	50
2 7	--	.06	--	.50
3 4	071	+.01	.47	.45
3.6	314	.31	44	57
4.8	--	.15	--	.50
6.0	.172	05	.37	28



Erosion Contour of 120-SS-1 Exit Cone

Figure 303-2



Posttest View of 120-SS-1 Exit Cone

Figure 304

Posttest External View of 120-SS-1 Exit Cone

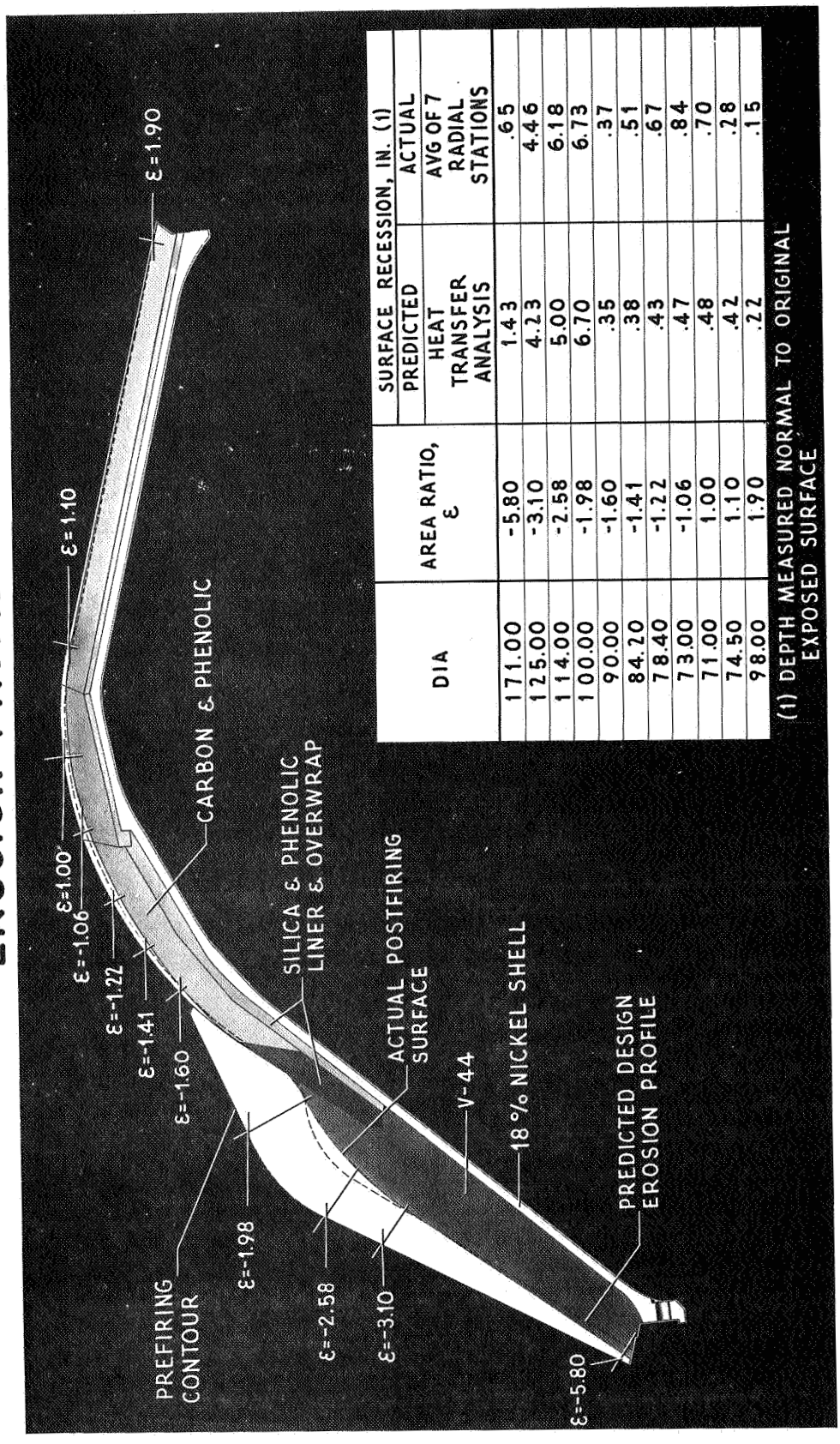
Figure 305

		Predicted Surface Recession. in.(*)		Actual Surface Recession. in.(*)									
				Radial Location, degrees									
Area Ratio	Material	Based on Heat Transfer Analysis	Based on Avg 120-SS-data	0	60	120	180	220	240	300	Avg	Min	Max
-5.80	V-44	1.43(**)	1.82	0.58	0.98	0.65	0.44	0.68	0.56	0.64	0.65	0.44	0.98
-3.10	V-44	4.23(**)	5.50	3.78	4.35	4.76	4.45	4.62	4.35	4.89	4.46	3.78	4.89
-2.58	V-44	5.00(**)	6.50	5.72	5.70	6.62	5.83	6.49	6.60	6.28	6.18	5.70	6.62
-1.98	V-44 and MX-2646	6.70(**)	8.71	6.46	6.48	7.55	5.75	8.95	6.48	5.42	6.73	5.42	8.95
-1.60	MX-4926	0.35	0.45	0.15	0.28	0.44	0.45	0.39	0.45	0.42	0.37	0.15	0.45
-1.41	MX-4926	0.38	0.51	0.54	0.41	0.41	0.55	0.60	0.62	0.45	0.51	0.41	0.62
-1.22	MX-4926	0.43	0.53	0.68	0.52	0.78	0.60	0.78	0.77	0.54	0.67	0.52	0.78
-1.06	MX-4926	0.47	0.54	0.89	0.75	0.97	0.77	0.79	0.92	0.78	0.84	0.75	0.97
1.00	MX-4926	0.48	0.55	0.67	0.62	0.77	0.62	0.80	0.77	0.62	0.70	0.62	0.80
1.10	MX-4926	0.42	0.42	0.25	0.23	0.26	0.23	0.28	0.41	0.30	0.28	0.23	0.41
1.90	MX-4926	0.22	0.22	0.19	0.15	0.16	0.11	0.15	0.15	0.15	0.15	0.11	0.19
2.00	MX-4926	0.20	0.20	0.16	0.09	0.18	0.16	-	0.16	0.17	0.15	0.09	0.18
2.50	MX-4926	0.14	0.14	0.10	0.14	0.11	0.12	-	0.06	0.09	0.10	0.06	0.14
3.28	FM-5131	0.47	0.47	0.62	0.60	0.61	0.63	-	0.59	0.60	0.60	0.59	0.63
3.78	FM-5131	0.40	0.40	0.45	0.50	0.45	0.51	-	0.42	0.45	0.46	0.42	0.51
6.00	FM-5131	0.23	0.23	+.14(#)	0.18	0.05	0.12	-	0.07	0.15	0.07	+.14	0.18

* Depth measured normal to original exposed surface.
** V-44 recession based on empirical large motor data.
\# Char surface expanded beyond original contour.

Surface Recession of 260-SL-1 Nozzle

Figure 306

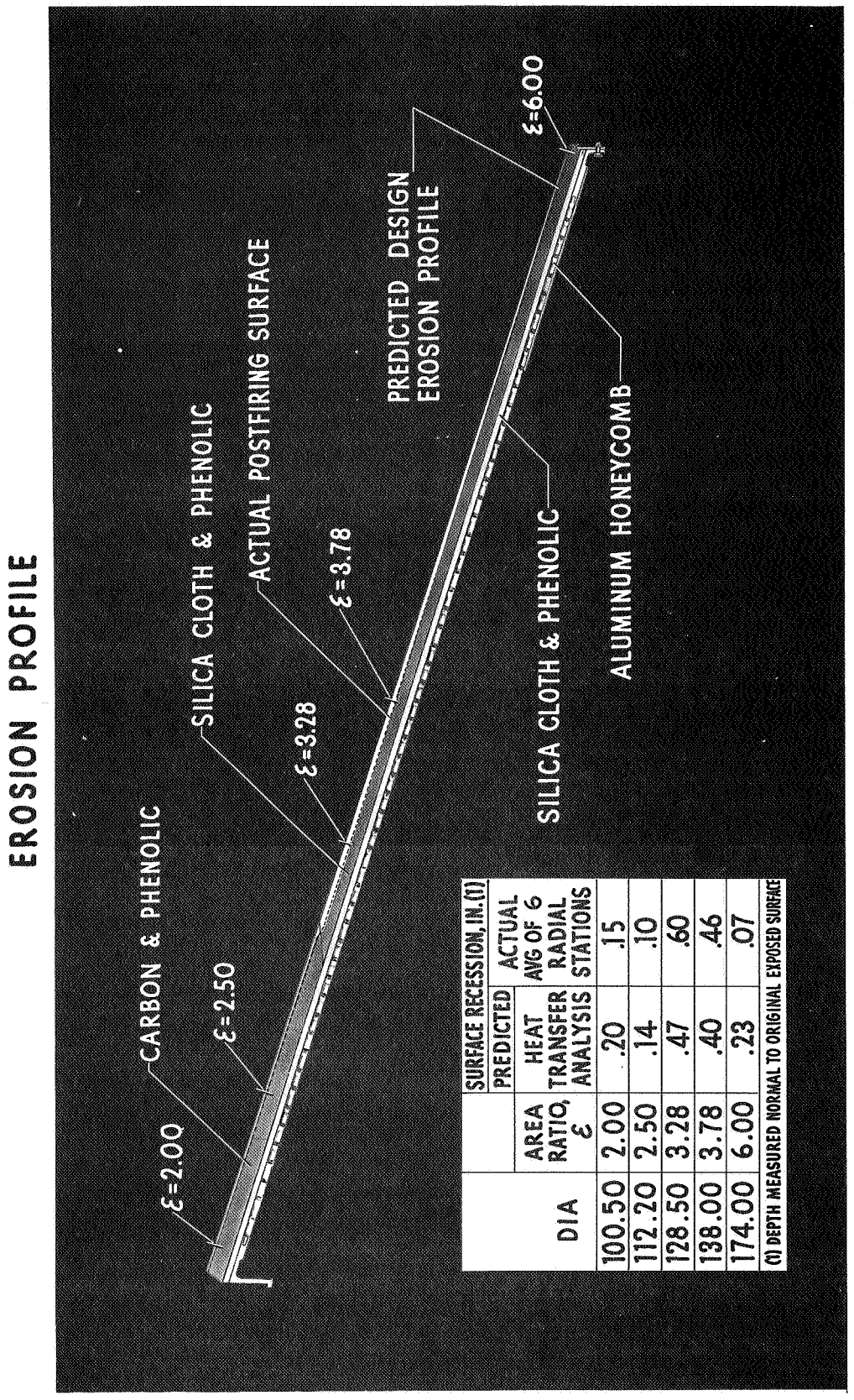


DIA	AREA RATIO, ε	SURFACE RECESSION, IN. (1) PREDICTED HEAT TRANSFER ANALYSIS	SURFACE RECESSION, IN. (1) ACTUAL AVG OF 7 RADIAL STATIONS
171.00	-5.80	1.43	.65
125.00	-3.10	4.23	4.46
114.00	-2.58	5.00	6.18
100.00	-1.98	6.70	6.73
90.00	-1.60	.35	.37
84.20	-1.41	.38	.51
78.40	-1.22	.43	.67
73.00	-1.06	.47	.84
71.00	1.00	.48	.70
74.50	1.10	.42	.28
98.00	1.90	.22	.15

(1) DEPTH MEASURED NORMAL TO ORIGINAL EXPOSED SURFACE

Figure 307

Surface Recession of 260-SL-1 Nozz 4

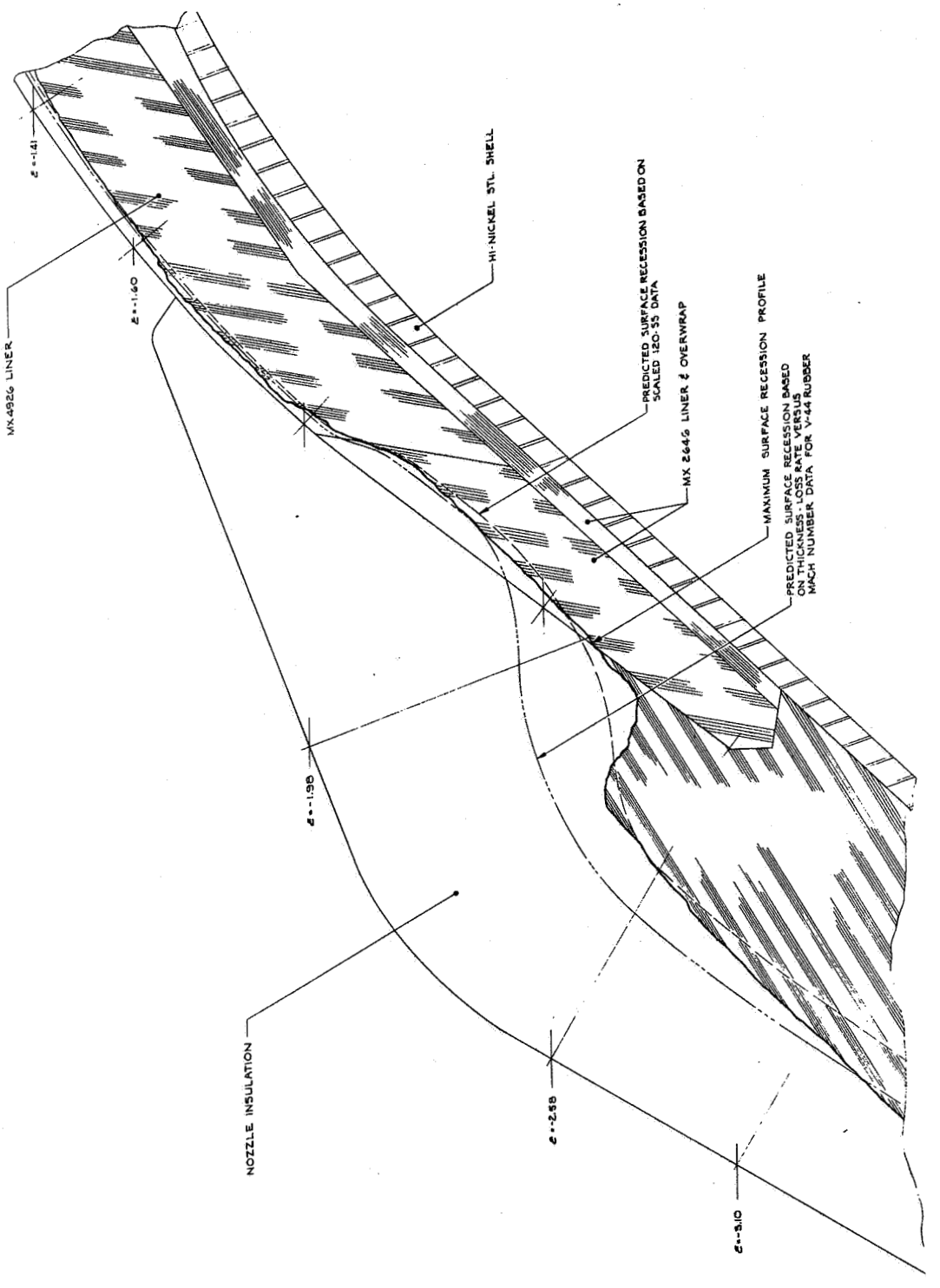


DIA	AREA RATIO, ε	SURFACE RECESSION, IN. (1) PREDICTED HEAT TRANSFER ANALYSIS	ACTUAL AVG OF 6 RADIAL STATIONS
100.50	2.00	.20	.15
112.20	2.50	.14	.10
128.50	3.28	.47	.60
138.00	3.78	.40	.46
174.00	6.00	.23	.07

(1) DEPTH MEASURED NORMAL TO ORIGINAL EXPOSED SURFACE

Figure 308

Surface Recession of 260-SL-1 Exit Cone

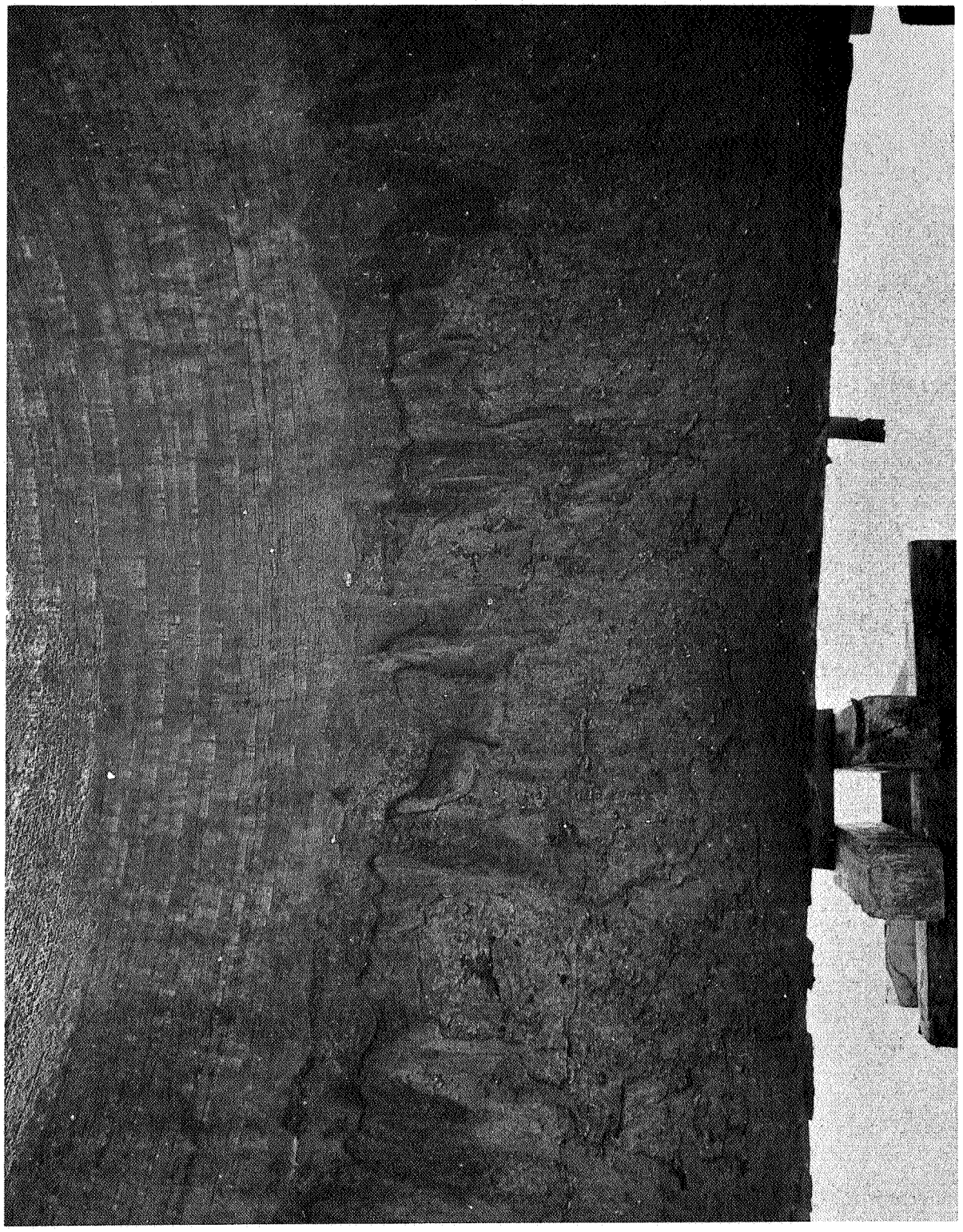


Maximum Erosion Profile of 260-SL-1 Nozzle Insulation

Figure 309

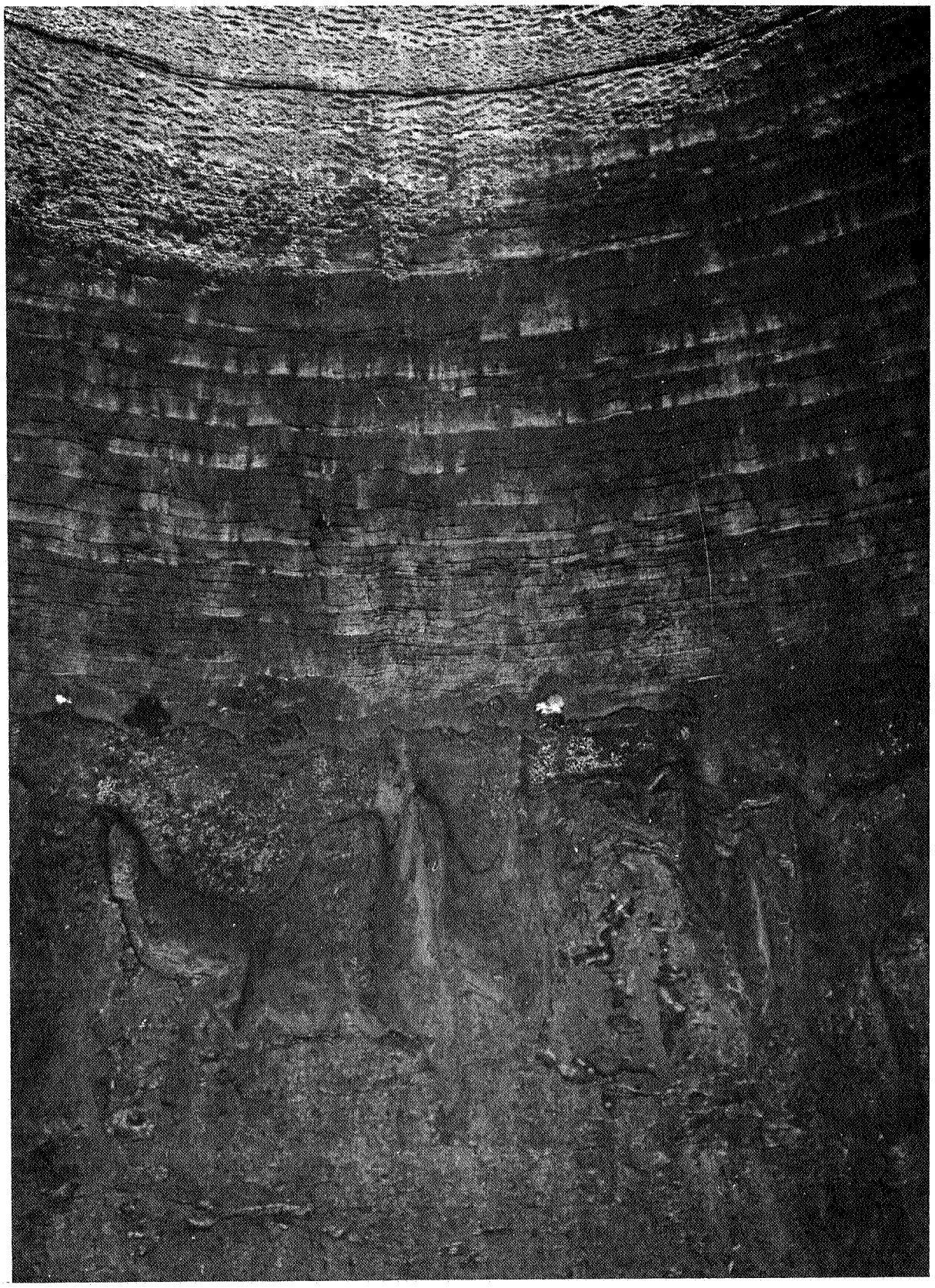
Posttest of 260-SL-1 Nozzle Insulation

Figure 310



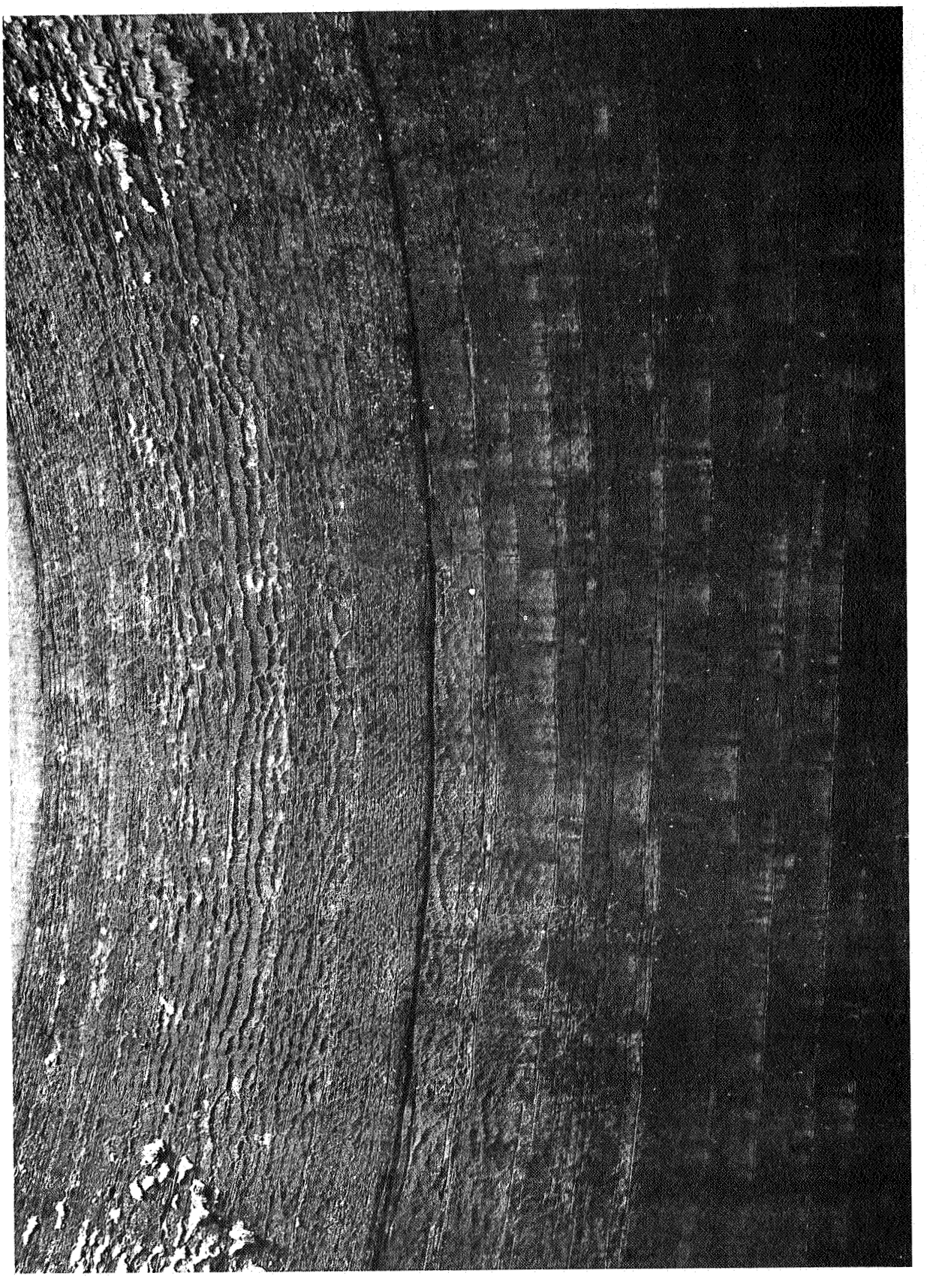
Posttest View of 260-SL-1 Nozzle Inlet Insulation

Figure 311



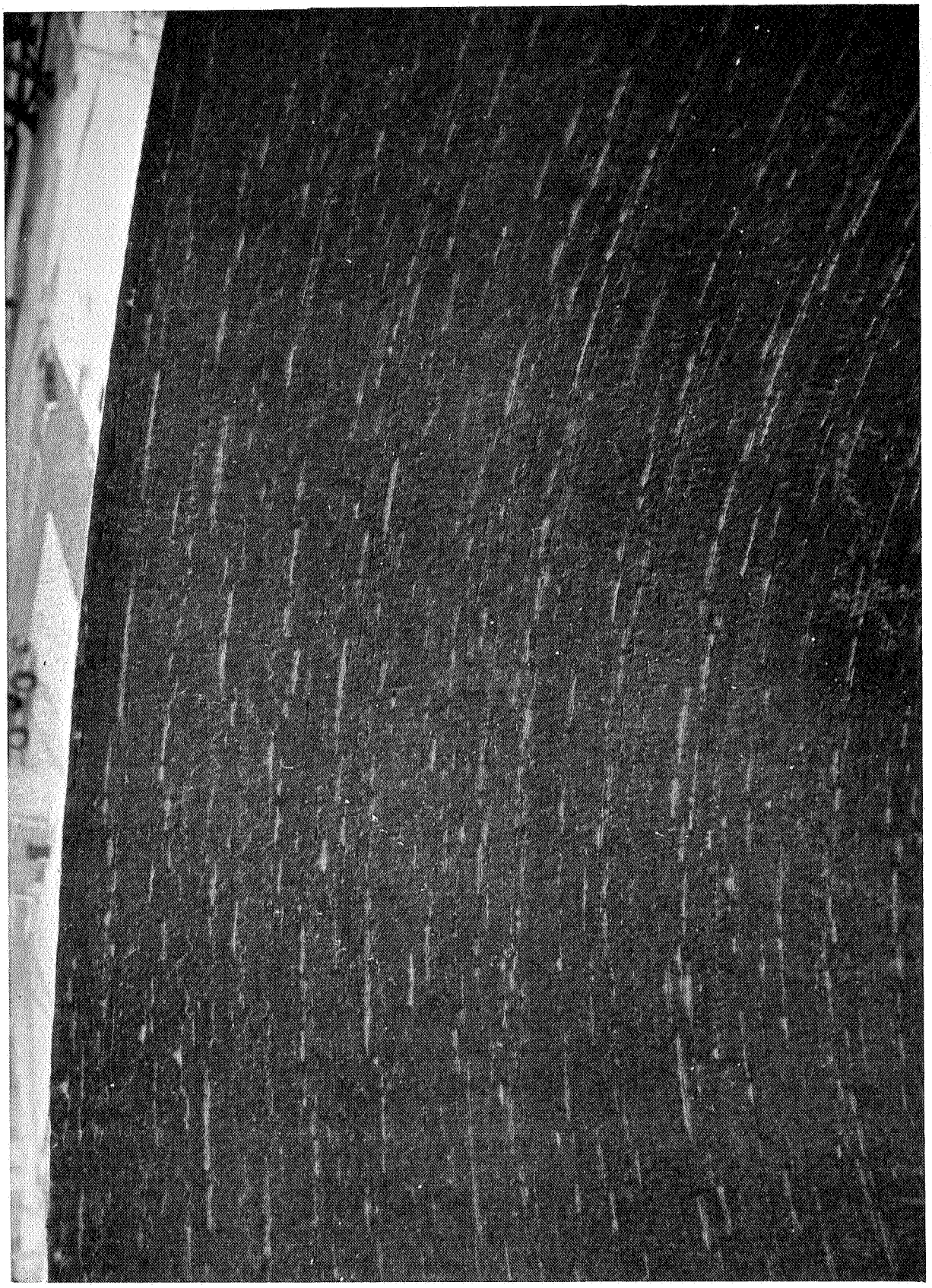
Posttest **View of** 260-SL-1 Nozzle Entrance Insert

Figure 312



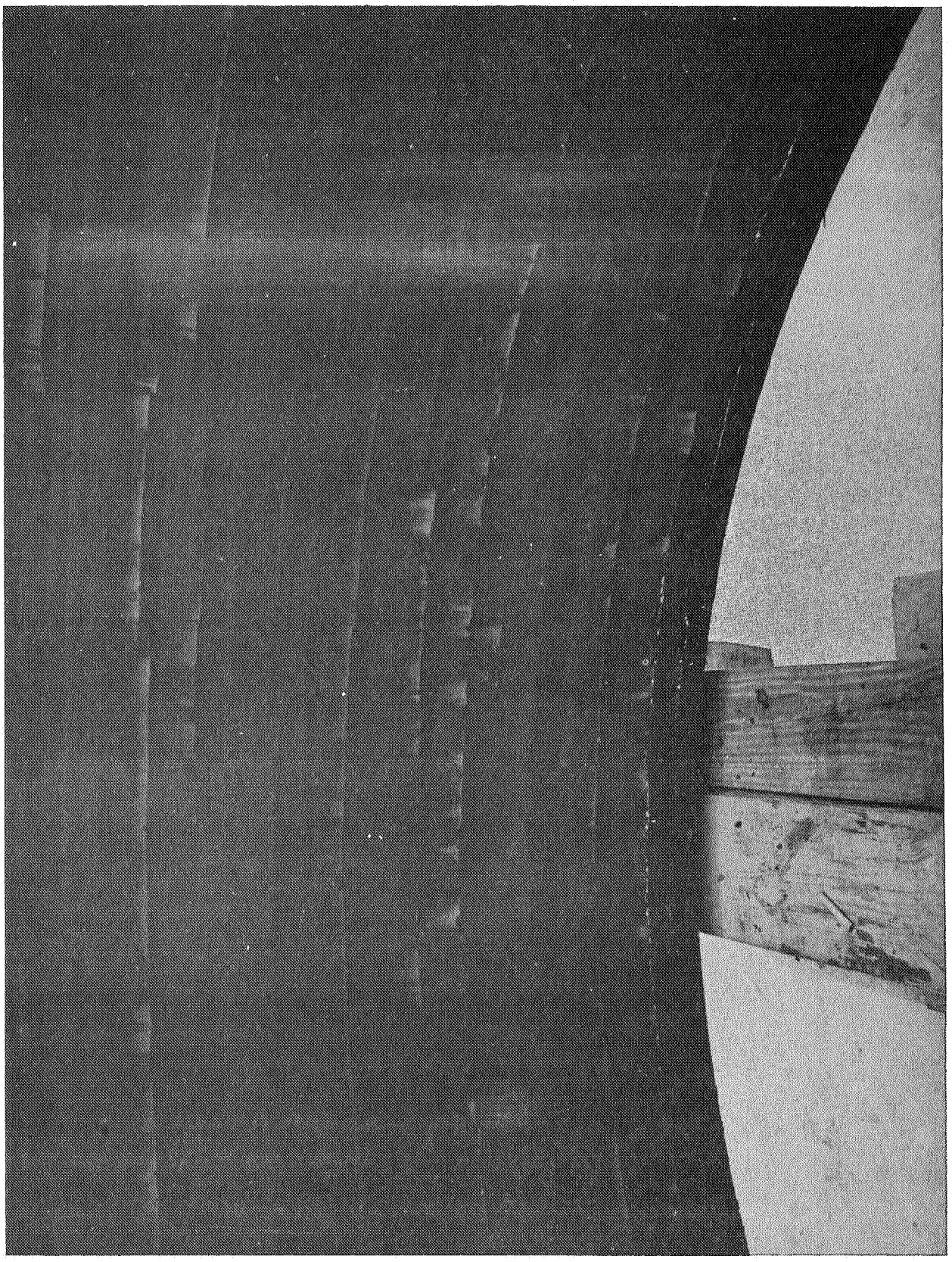
Posttest View of 2820-SL-1 Nozzle Throat Insert

Figure 313



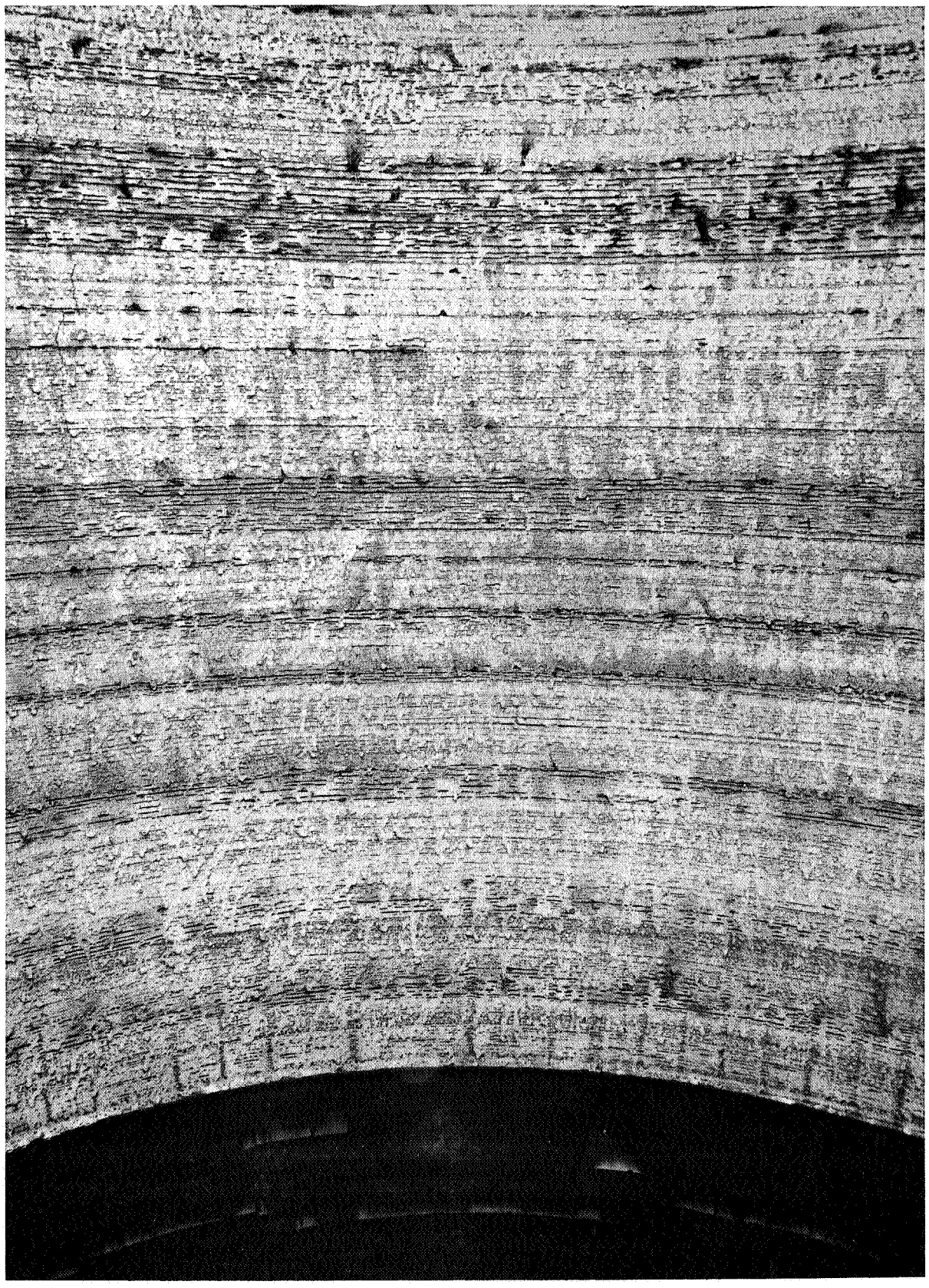
Posttest View of 260-SL-1 Nozzle Throat Extension Insert

Figure 314



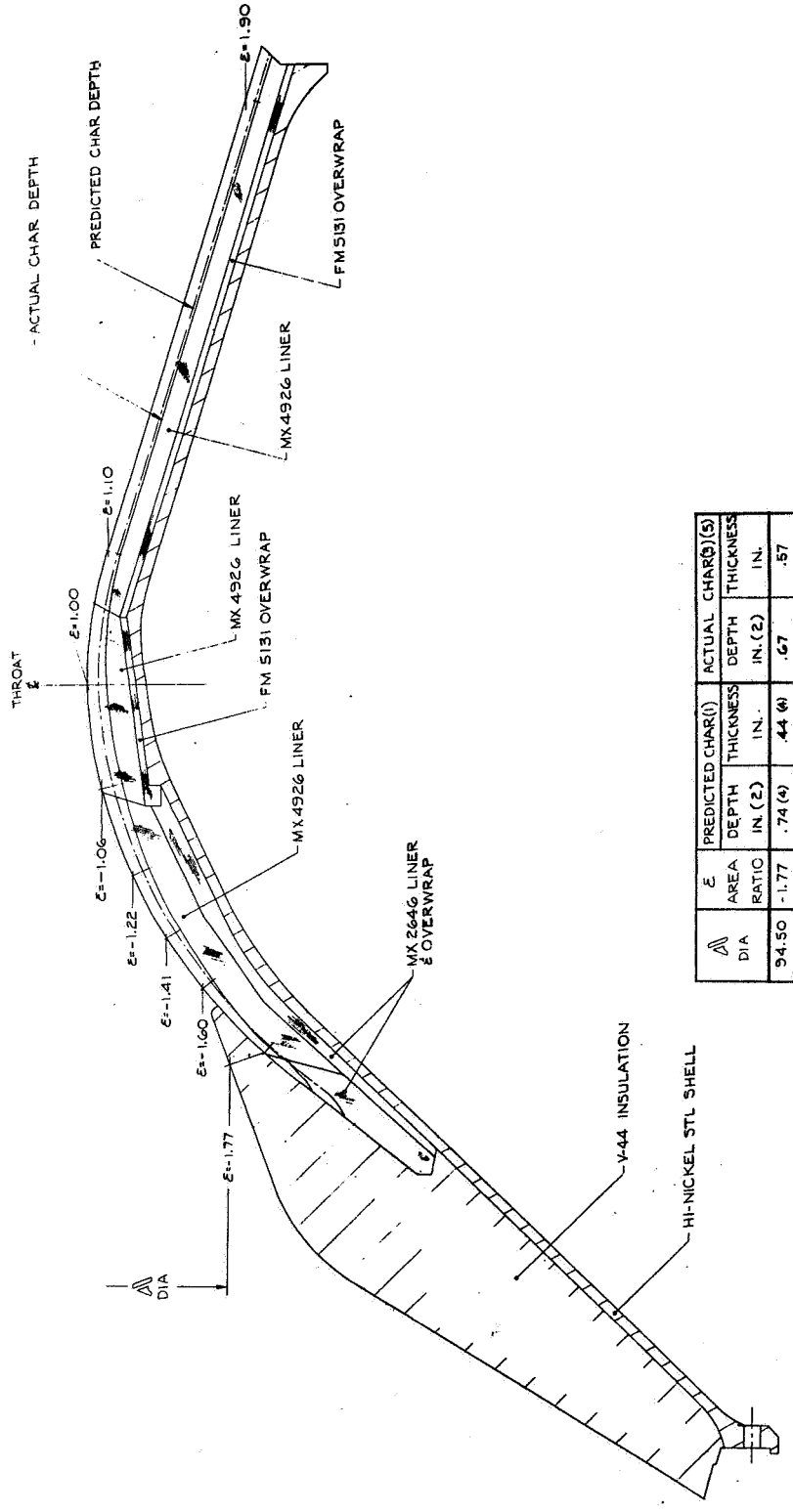
Posttest View of 260-SL-1 Exit Cone, Carbon Cloth 3a Phenolic

Figure 315



Posttest View of 260-SL-1 Exit Cone, Silica Cloth and Phenolic

Figure 316

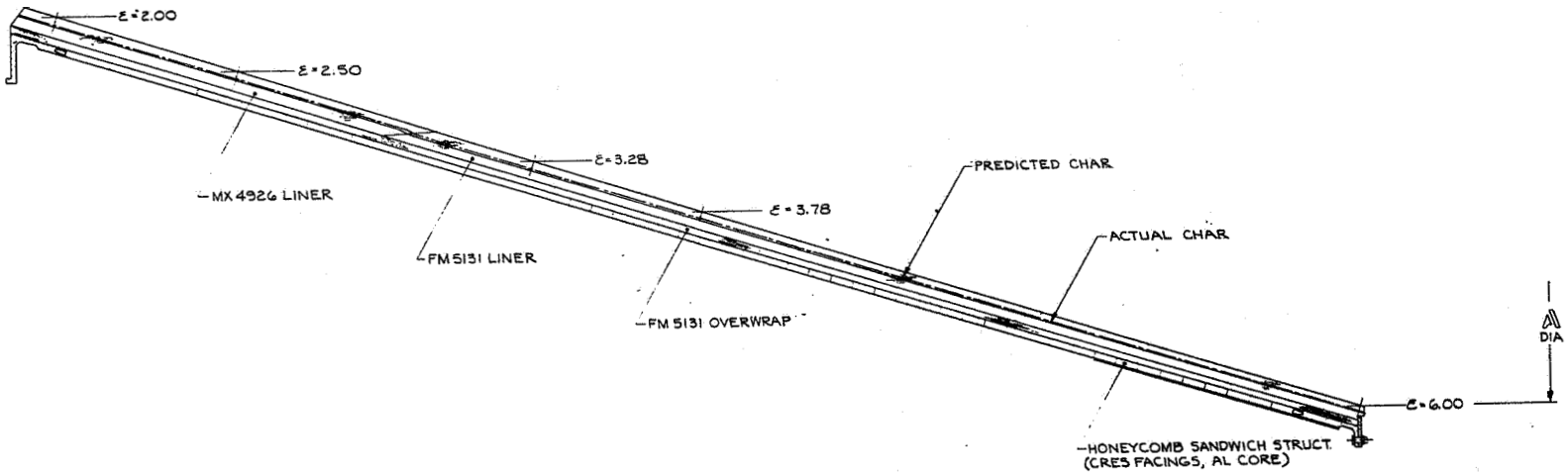


DIA	ε AREA RATIO	PREDICTED CHAR(1) DEPTH IN. (2)	PREDICTED CHAR(1) THICKNESS IN.	ACTUAL CHAR(3)(5) DEPTH IN. (2)	ACTUAL CHAR(3)(5) THICKNESS IN.
94.50	1.77	.74 (4)	.44 (4)	.67	.57
90.00	1.60	.78	.43	.97	.70
84.20	1.41	.80	.42	1.35	.85
78.40	1.22	.83	.40	1.50	.80
73.00	1.06	.86	.39	1.77	.85
71.00	1.00	.87	.39	1.53	.85
74.50	1.10	.82	.40	1.05	.80
98.00	1.90	.79	.57	1.05	.85

(1) BASED ON 140 SECONDS
(2) DEPTH MEASURED NORMAL TO ORIGINAL EXPOSED SURFACE
(3) QUENCH STARTED AT 247 SECONDS.
(4) ASSUMING NO V-44 PRESENT
(5) MEASUREMENTS TAKEN AT 0° STATION ONLY

Char Depth of 260-SL-1 Nozzle

Figure 317



DIA	ε AREA RATIO	PREDICTED CHAR(1)		ACTUAL CHAR(3)(4)	
		DEPTH IN. (2)	THICKNESS IN.	DEPTH IN. (2)	THICKNESS IN.
100.50	2.00	.77	.57	.88	.75
112.20	2.50	.66	.52	.85	.75
128.50	3.28	.71	.24	.88	.42
138.00	3.78	.62	.22	.74	.42
174.00	6.00	.52	.19	.58	.40

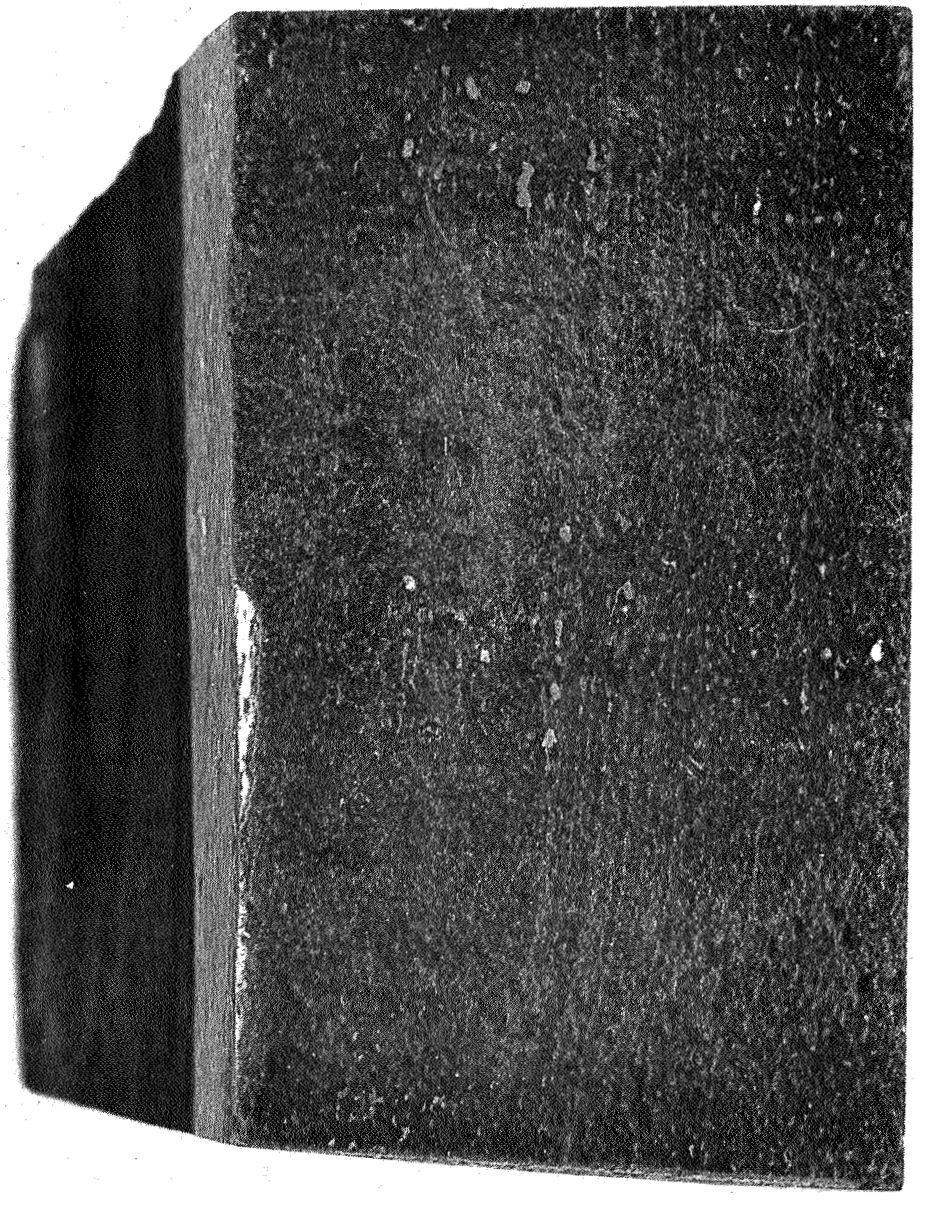
(1) BASED ON 140 SECONDS.
(2) DEPTH MEASURED NORMAL TO ORIGINAL SURFACE.
(3) QUENCH STARTED AT 247 SECONDS.
(4) MEASUREMENTS TAKEN AT 0° STATION ONLY

Figure 318

Char Depth of 260-SL-1 Exit Cone

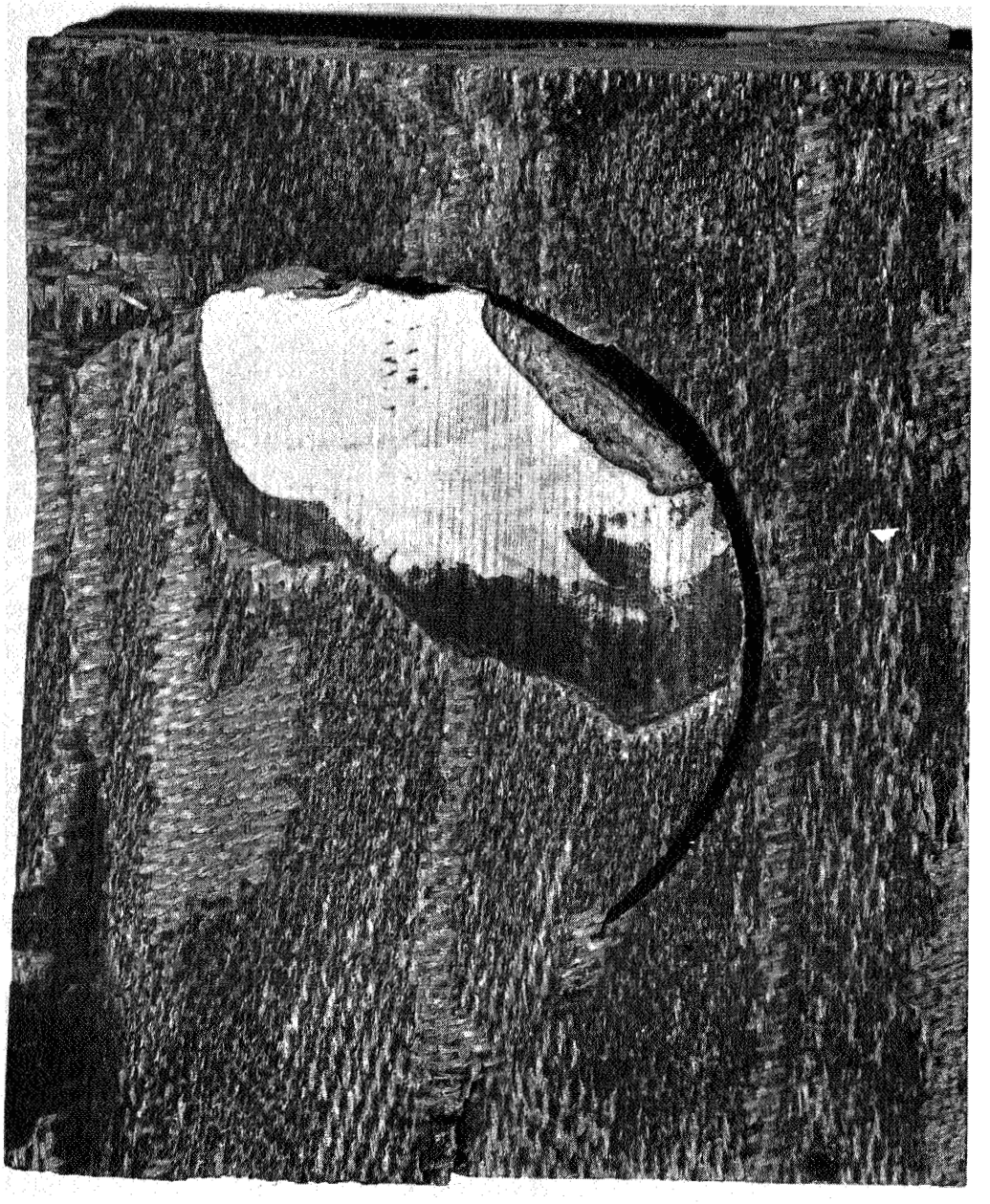
Posttest View of 260-SL-1 Exit Cone Exterior

Figure 319



Bonda Surface of 2ξ0-ML-1 Nozzle Shell to Plastic Insert

Figure 320



Unbonded Surface of 260-SL-1 Nozzle Shell to Plastic Insert

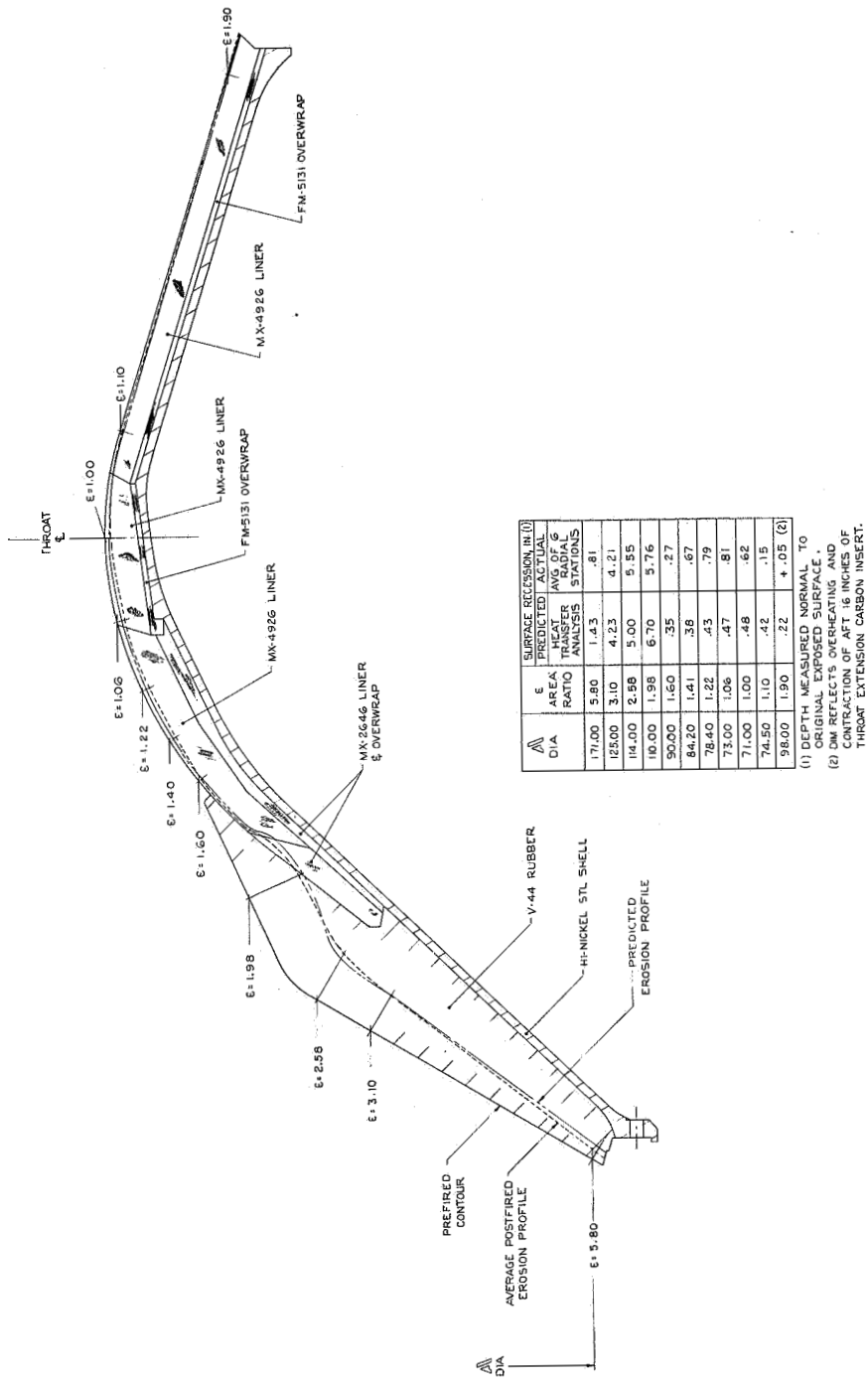
Figure 321

Area Ratio	Material	Predicted Surface Recession, in.* Based on Heat Transfer Analysis	Predicted Surface Recession, in.* Based on Avg 260-SL-1 Data	Actual Surface Recession, in.* Radial Location, degrees 0	60	120	180	240	300	Avg	Min	Max
-5.80	V-44	1.43**	0.65	0.79	0.83	0.85	0.92	0.85	0.63	0.81	0.63	0.92
-3.10	V-44	4.23**	4.46	4.14	3.87	4.14	4.40	4.20	4.55	4.22	3.87	4.55
-2.58	V-44	5.00**	6.18	5.98	4.94	5.30	5.63	5.44	5.98	5.55	4.94	5.98
-1.98	V-44 and MX-2646	6.70**	6.73	6.50	5.22	5.40	5.73	5.58	6.12	5.76	5.22	6.50
-1.60	MX-4926	0.35	0.37	0.33	0.27	0.36	0.20	0.14	0.32	0.27	0.14	0.36
-1.41	MX-4926	0.38	0.51	0.74	0.67	0.72	0.55	0.59	0.77	0.67	0.55	0.77
-1.22	MX-4926	0.43	0.67	0.85	0.76	0.88	0.68	0.67	0.87	0.79	0.67	0.88
-1.06	MX-4926	0.47	0.84	0.81	0.81	0.81	0.80	0.75	0.91	0.82	0.75	0.91
1.00	MX-4926	0.48	0.70	0.56	0.59	0.56	0.67	0.59	0.71	0.61	0.56	0.71
1.10	MX-4926	0.42	0.28	0.17	0.13	0.09	0.11	0.25	0.17	0.15	0.09	0.25

* Depth measured normal to original exposed surface.
**V-44 recession based on empirical large motor data

Surface Recession of 260-SL-2 Motor Nozzle

Figure 322

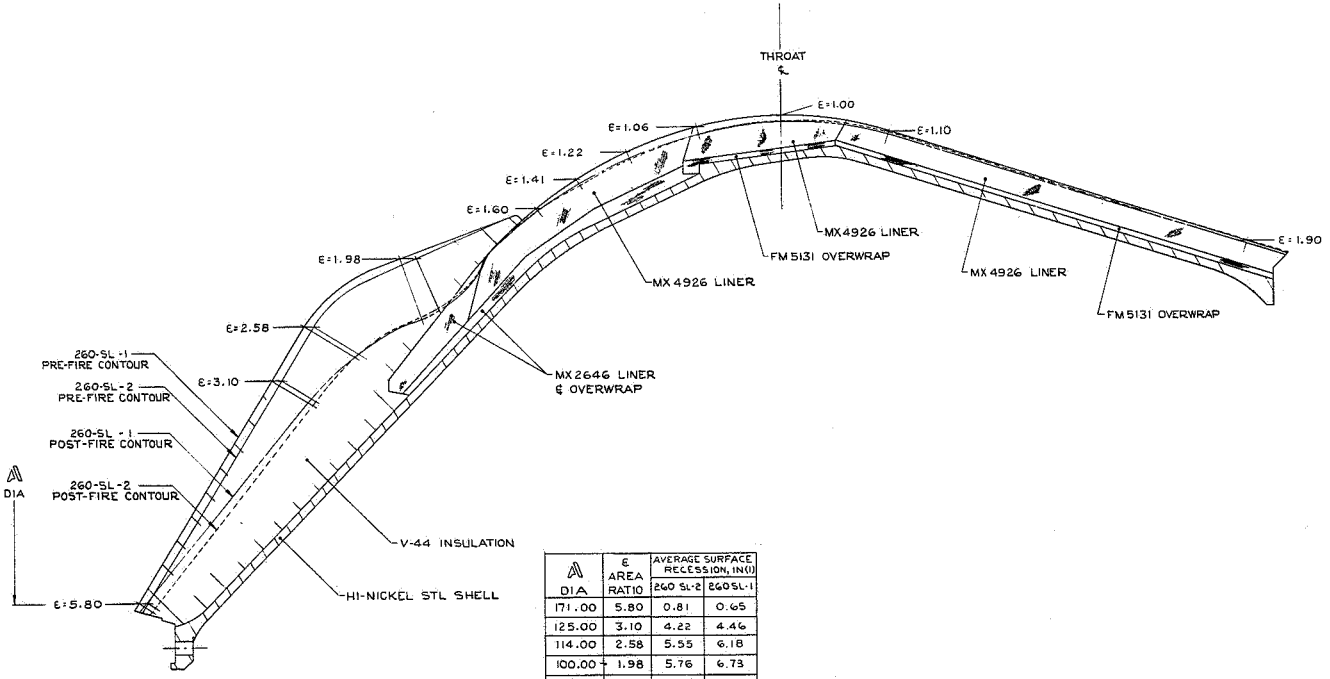


DIA	ε AREA RATIO	SURFACE RECESSION, IN (1) PREDICTED HEAT TRANSFER ANALYSIS	ACTUAL AVG OF 6 RADIAL STATIONS
171.00	5.80	1.43	.81
125.00	3.10	4.23	4.21
114.00	2.58	5.00	5.55
110.00	1.98	6.70	5.76
90.00	1.60	.35	.27
84.20	1.41	.38	.67
78.40	1.22	.43	.79
73.00	1.06	.47	.81
71.00	1.00	.48	.62
74.50	1.10	.42	.15
98.00	1.90	.22	+ .05 (2)

(1) DEPTH MEASURED NORMAL TO ORIGINAL EXPOSED SURFACE.
(2) DIM REFLECTS OVERHEATING AND CONTRACTION OF AFT 16 INCHES OF THROAT EXTENSION CARBON INSERT.

Nozzle Surface Recession Profile, Motor 260-SL-2

Figure 323



DIA	ε AREA RATIO	AVERAGE SURFACE RECESSION, IN(1)	
		260 SL-2	260 SL-1
171.00	5.80	0.81	0.65
125.00	3.10	4.22	4.46
114.00	2.58	5.55	6.18
100.00	1.98	5.76	6.73
90.00	1.60	0.27	0.37
84.20	1.41	0.67	0.51
78.40	1.22	0.79	0.67
73.00	1.06	0.82	0.84
71.00	1.00	0.61	0.70
74.50	1.10	0.15	0.28
98.00	1.90	+.01(2)	0.15

(1) DEPTH MEASURED NORMAL TO ORIGINAL EXPOSED SURFACE, ACTUAL AVG OF 6 RADIAL STATIONS.
(2) DIM REFLECTS OVERHEATING AND CONTRACTION OF AFT 16 INCHES OF THROAT EXTENSION CARBON INSERT.

Nozzle Surface Recession Profiles, Motor 260-SL-1 and -2

Figure 324

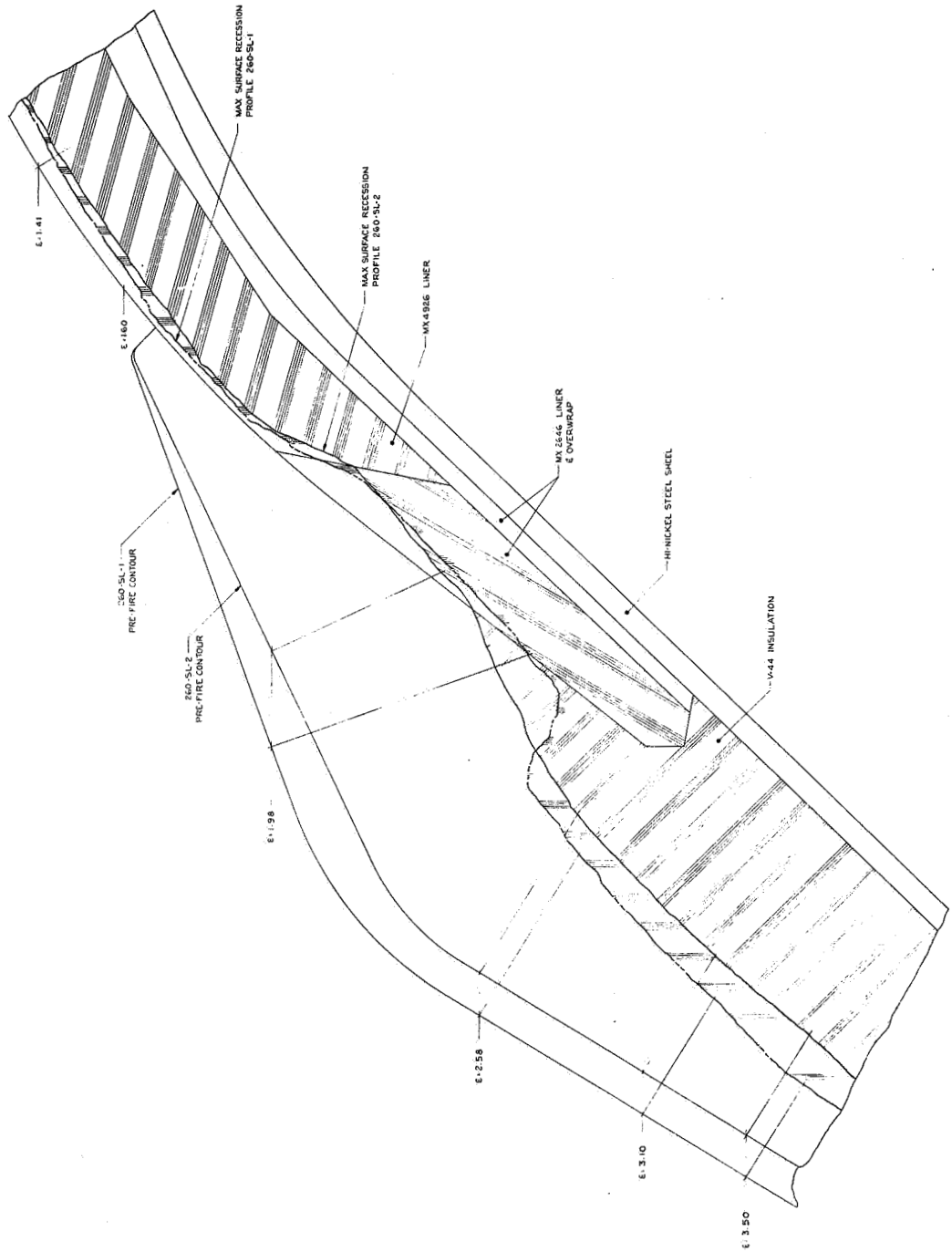
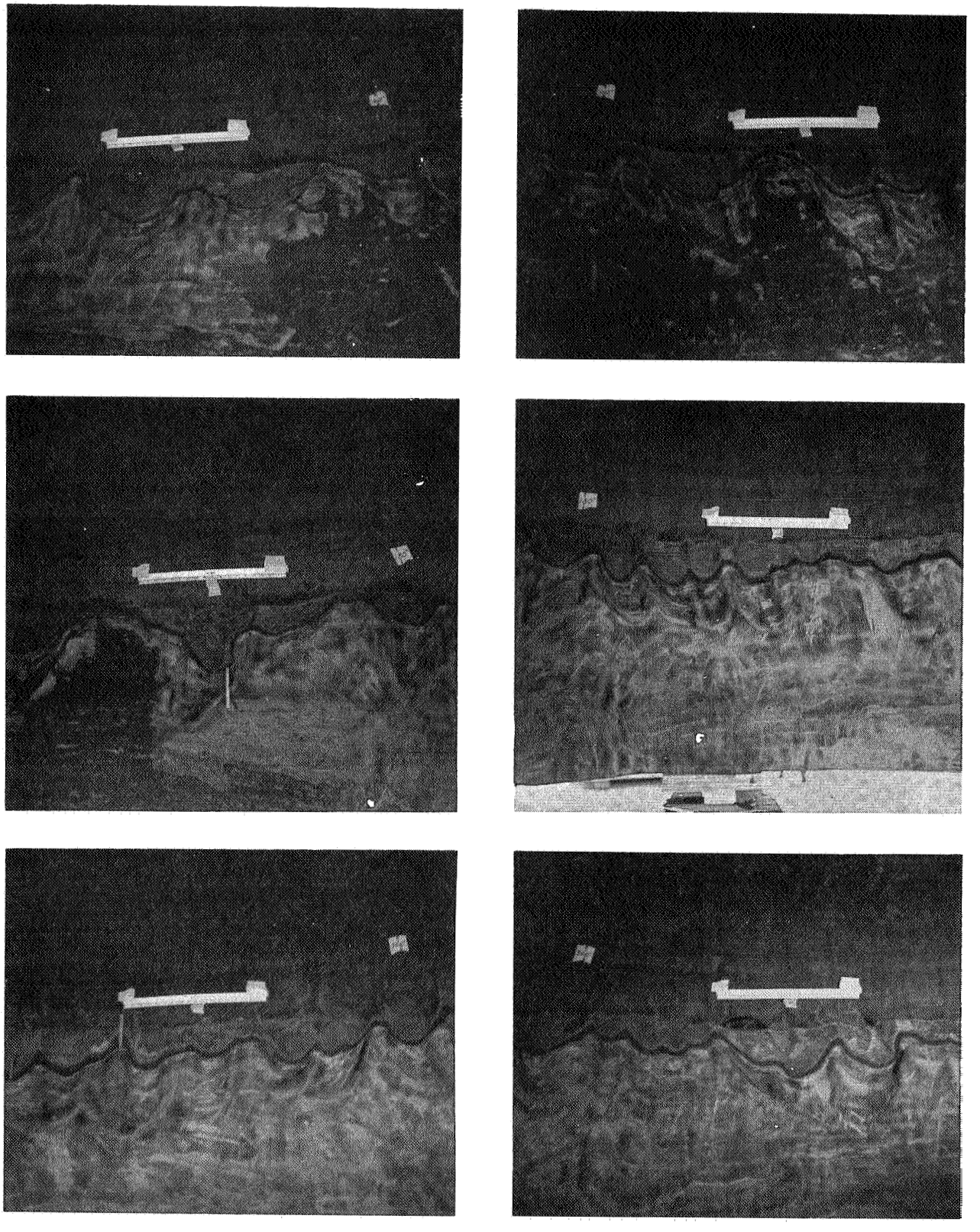


Figure 325

Nozzle Insulation Erosion Profile, Motor 260-SL-2



Posttest View of Nozzle Entrance Insulation, Motor 260-SL-2

Figure 326

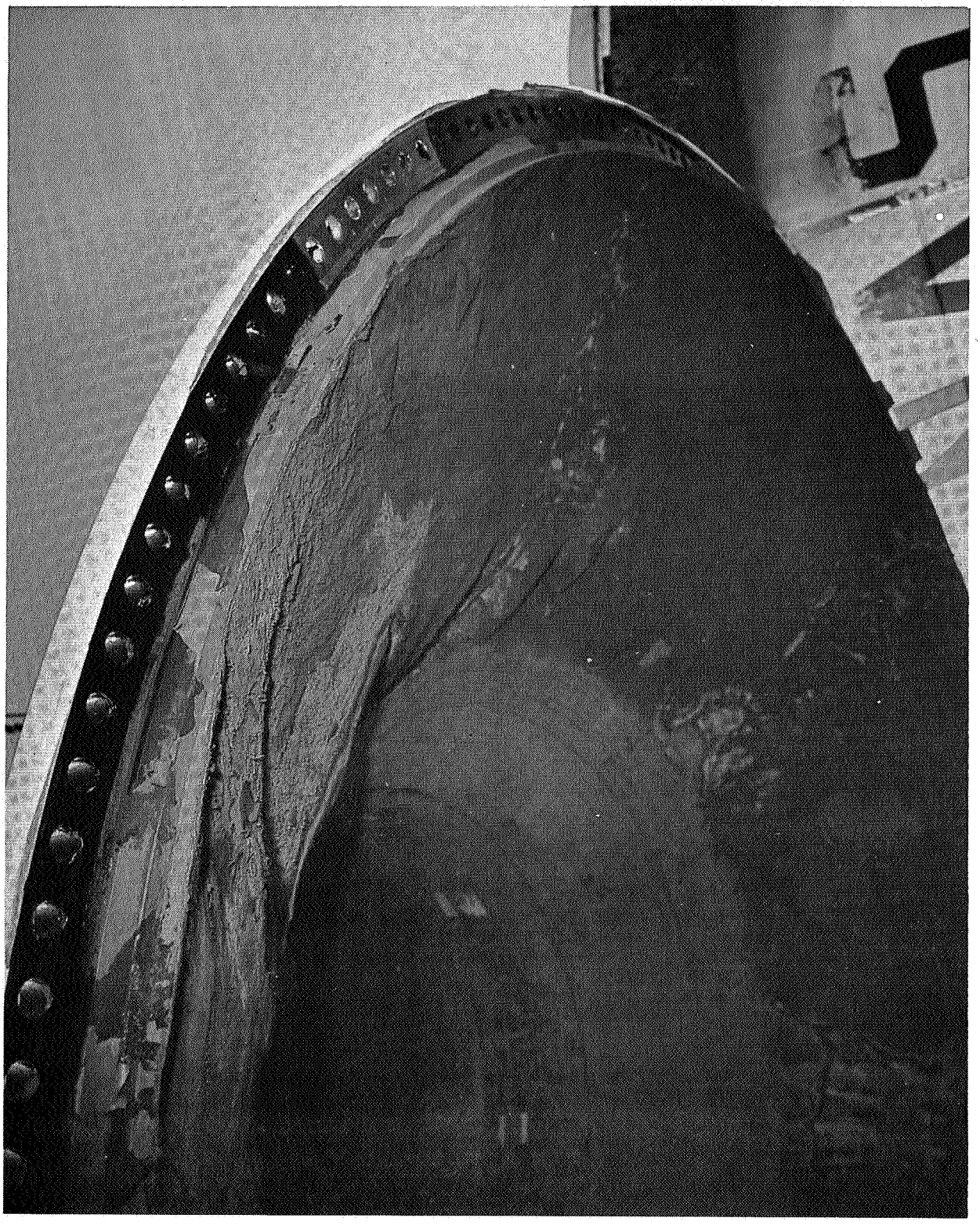
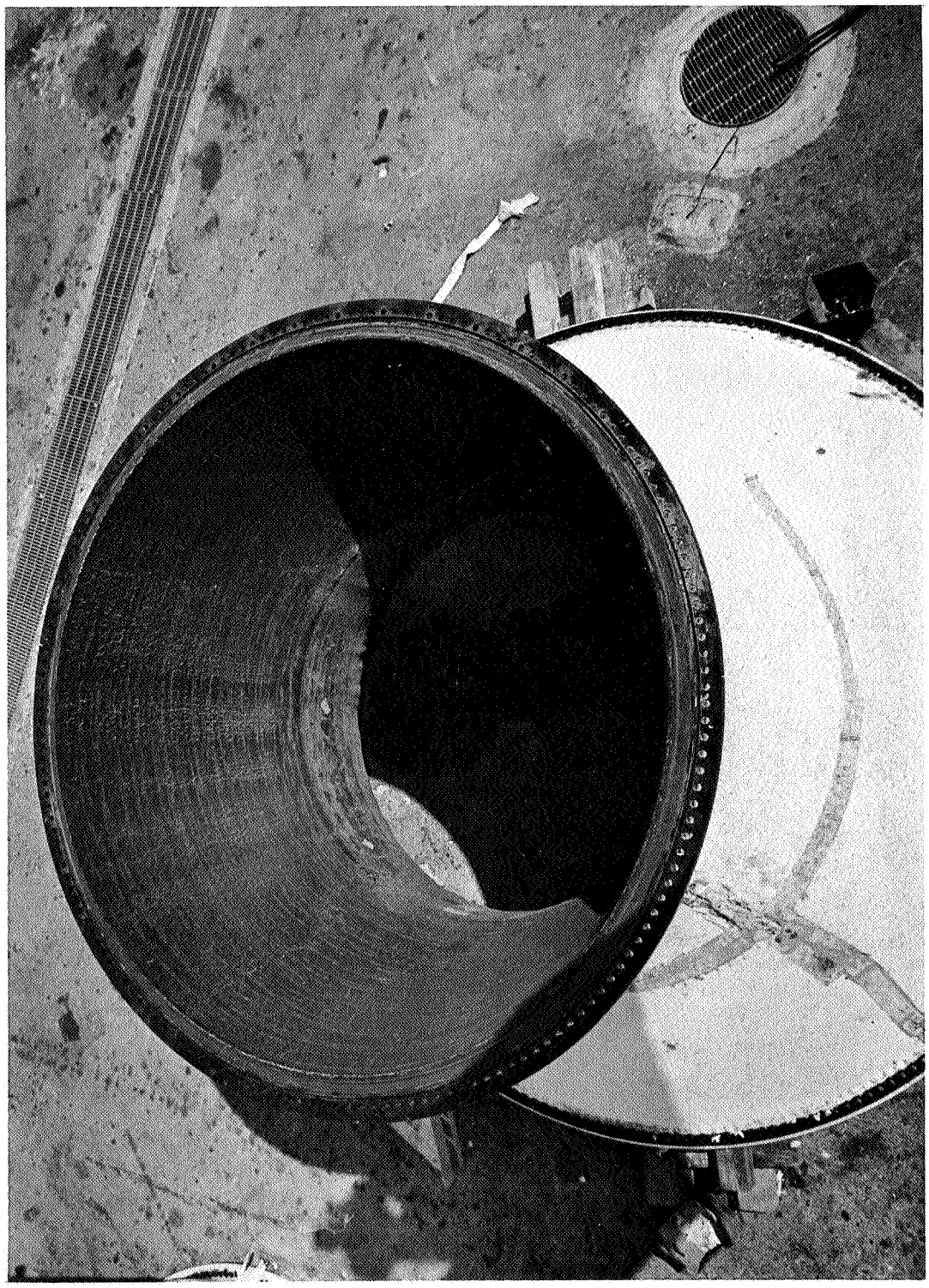


Figure 327

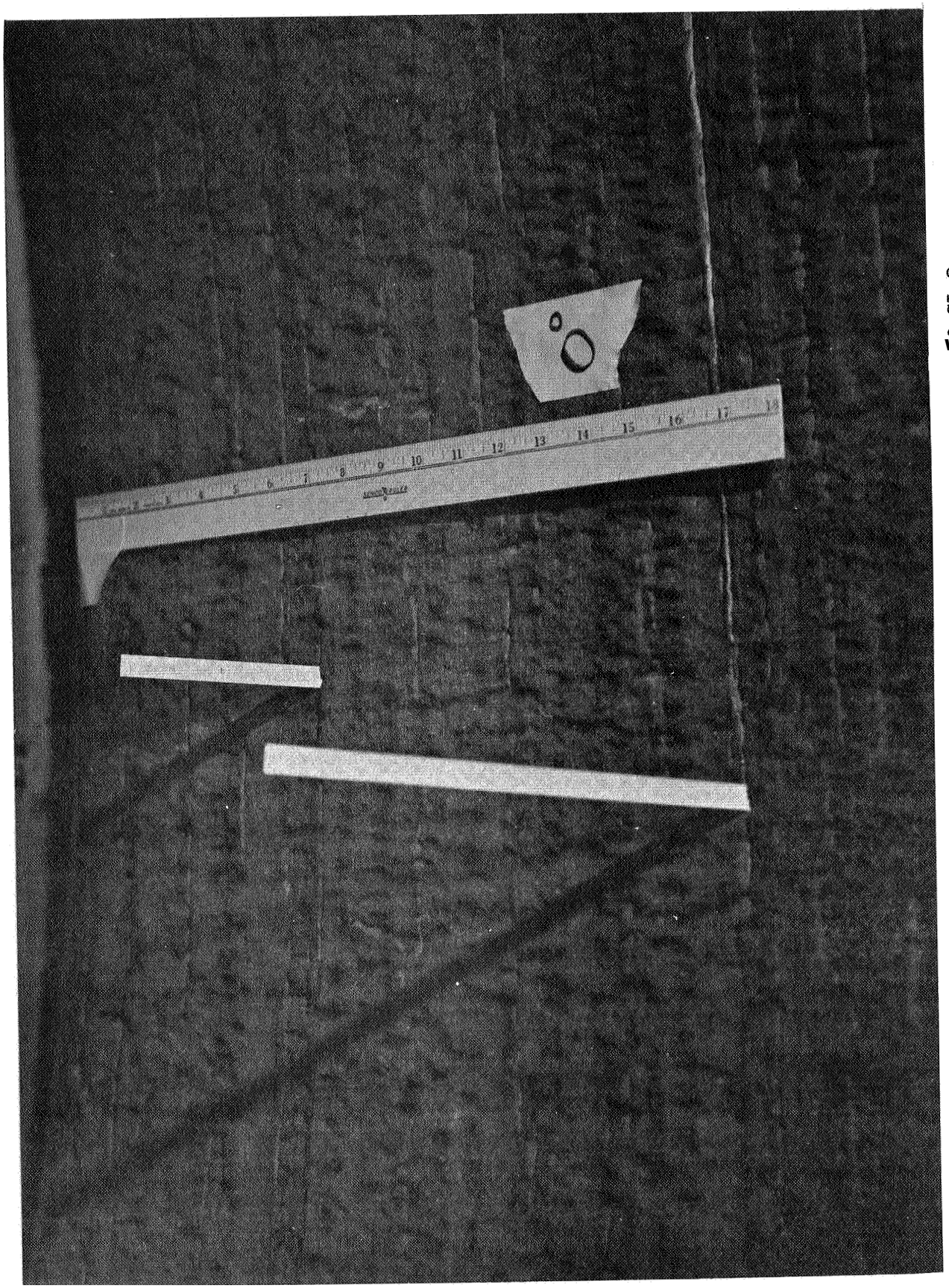


Posttest View of Nozzle Throat Insert, Motor 260-SL-2

Figure 328

Posttest View of Nozzle Throat Insert Surface, Test 260-SE-2

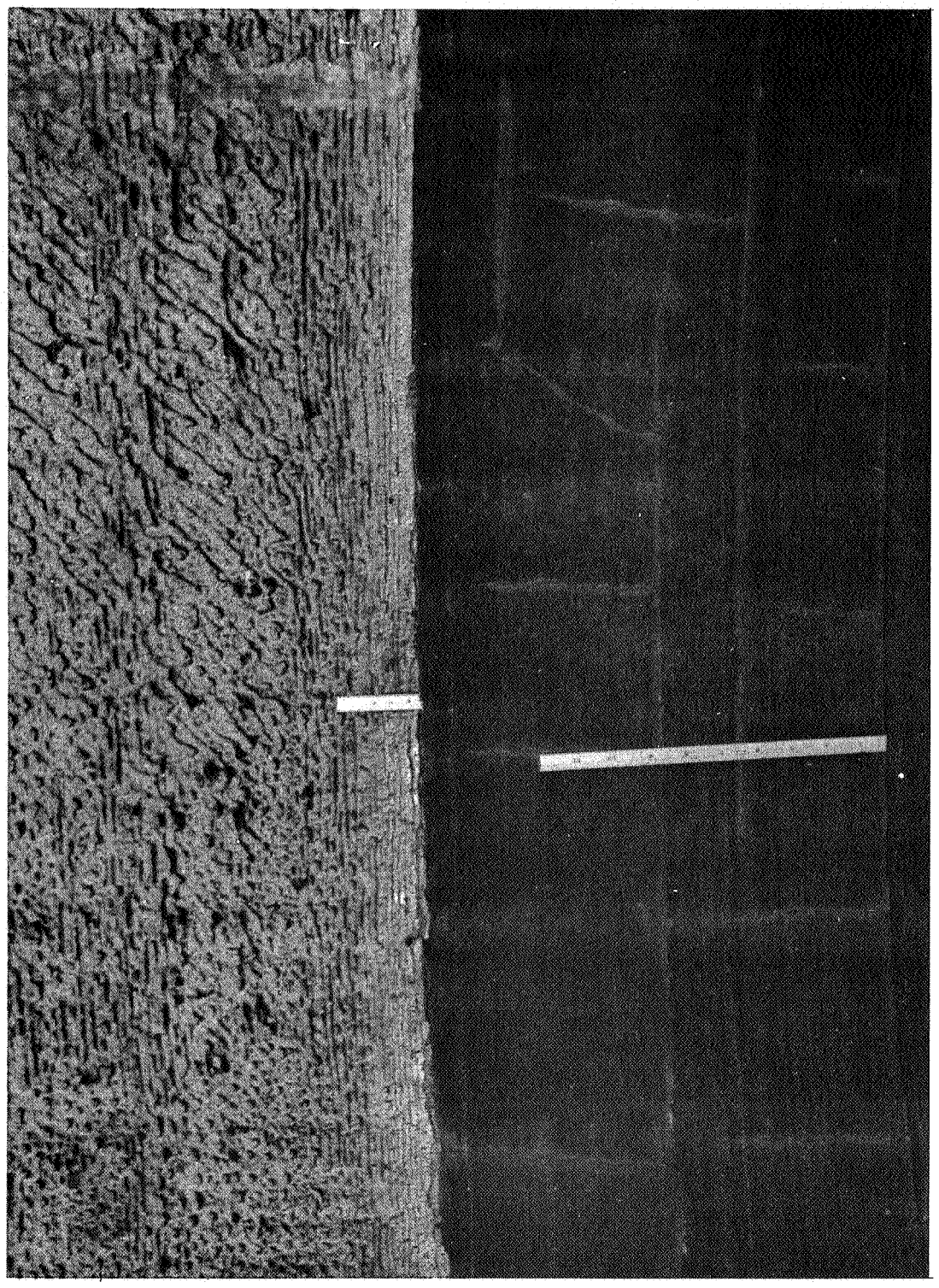
Figure 329



Posttest View of Nozzle Throat Extension Insert, Motor 2W0-SL-2

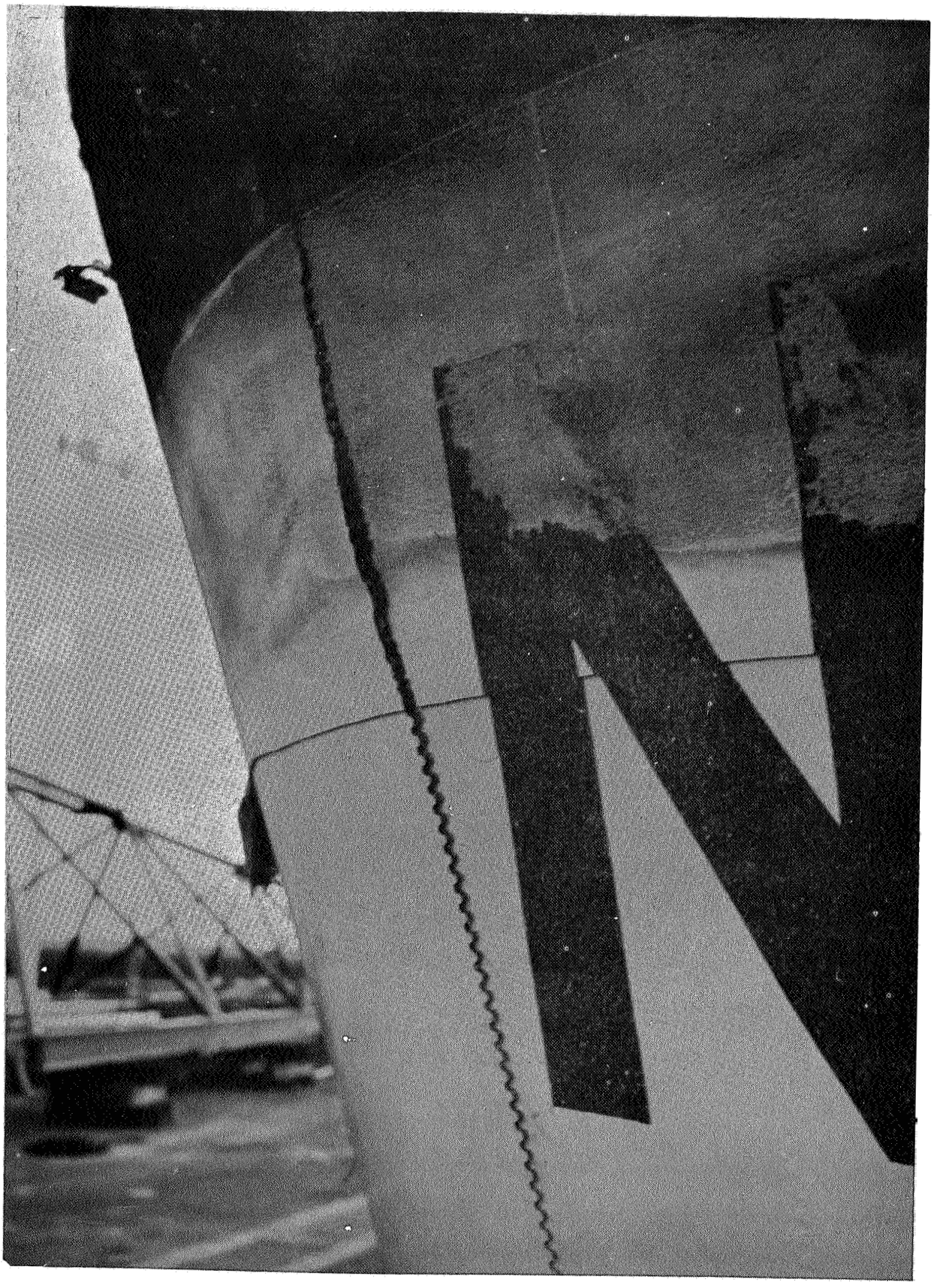
Figure 330

Figure 331



Posttest View of Exit Cone Ablation Surface, Motor 260-SL-2

Figure 332



Posttest View of Exit Cone Exterior, Motor 260-SL-2
Figure 333

Report NASA CR 72125

Appendix A

Ablative Material Property Procedures

QUALITY CONTROL

FIBERITE TEST METHOD 1-3

DEGREE OF ADVANCEMENT OF PHENOLIC "B" STAGED MATERIAL BY INFRA-RED ANALYSIS UTILIZING ZERO POINT BASE LINE

I EQUIPMENT:

1. Double beam Infra-Red Spectrophotometer.
2. Matched sealed Na Cl cells 0.20 mm path length or variable path wedge cell.

II EQUIPMENT SPECIFICATIONS:

1. Spectrophotometer must be balanced in accordance with manufacturer's procedure before operation.
2. Io and noise scans must be run at one (1) week intervals to assure proper operation of the instrument.
3. Cell used will be marked to assure the reference cell will always be used in the reference beam and the sample cell will always be used in the analytical beam.
4. A spectrum will be scanned at one week intervals with acetone in both cells to assure that the cells are in proper operating condition. The spectrum obtained shall not vary more than $\pm$ 3% transmission over the range of 9.0 to 15.0 microns.

III INSTRUMENT SETTINGS:

1. The instrument shall be set for double beam operation.
2. Slit program "Normal"
3. Scanning rate .. 1.0 microns/min. max.
4. Recording paper Linear transmission paper

IV SAMPLE PREPARATION:

1. Obtain a representative sample of prepreg material and cut it into ½ x ½ inch squares. Weigh 6.0 grams of material and dissolve it in 36 milliliters of spectro grade acetone.* Extract for a minimum of 10 minutes with intermittent stirring.
2. Filter the extract through fluted high retention filter paper. Collect the filtrate in a clean beaker.
3. Rinse the reference and sample cells three times with spectro grade acetone. Flush each cell with dry nitrogen. Fill the reference cell with spectro grade acetone. Fill the sample cell with extract.
4. Balance the spectrophotometer and set at 12.2 microns. Insert the sample and reference cells. If the transmission is greater than 45% adjust the concentration of the remaining solution by evaporating acetone at room temperature. If the transmission is less than 40% adjust the concentration of the remaining solution by diluting with spectro grade acetone.
5. Fill the sample cell with extract of correct concentration and scan the spectrum from 8.0 to 15.0 microns.

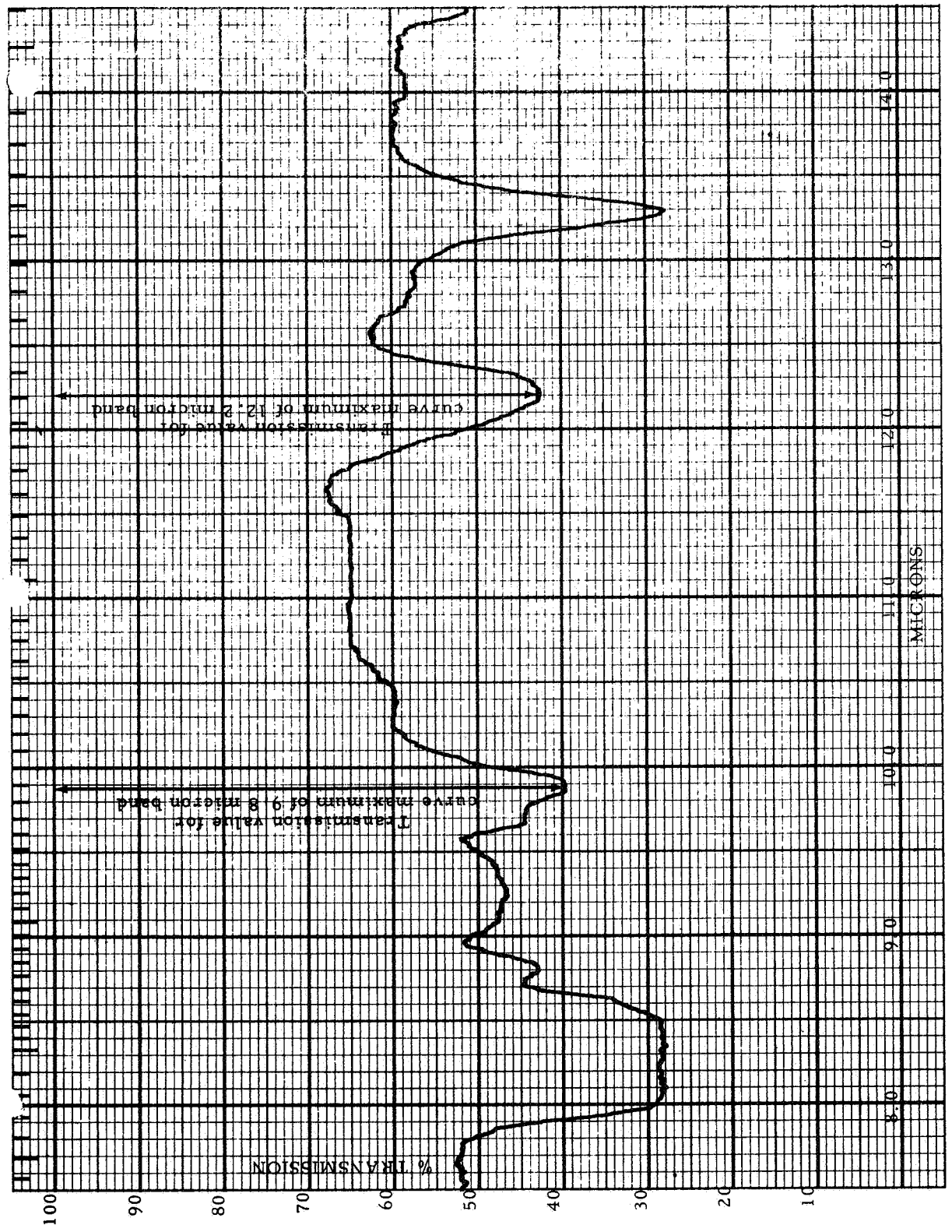
V DETERMINATION OF IRPI

1. Remove the spectrum from the instrument and determine the transmission values at the curve maximum of the 9.8 micron band and of the 12.2 micron band as illustrated on the spectrum on the reverse side.
2. Convert these transmission values to absorbance values as follows: absorbance = Log (1/transmission).
3. The IRPI value is calculated as follows:

$$\text{IRPI} = \frac{\text{absorbance values of the 12.2 micron band}}{\text{absorbance values of the 9.8 micron band}}$$

*Double distilled CP Acetone may be used.

APRIL, 1964


% TRANSMISSION
100
90
80
70
60
50
40
30
20
10
8.0
9.0
10.0
11.0
12.0
13.0
14.0
MICRONS
Transmission value for curve maximum of 9.8 micron band
Transmission value for curve maximum of 12.2 micron band

POLYMERIC Chemicals, Inc.

SANTA ANA, CALIF., P.O. BOX 2187, PHONE 549-1101 • STAMFORD, CONN., P.O. BOX 546, DAVIS 4-7545 • UTRECHT, HOLLAND

TEST METHOD CTM-5
DECREE OF CURE
BY CHANG'S INDEX

ABLATIVE HANDBOOK SECTION 3

1.0 Scope

1.1 This method describes a procedure for an arbitrary measure of the relative degree of cure, advancement, or polymerization of liquid resins or prepregs.

2.0 Equipment

2.1 duret, 50 ml.
2.2 Analytical balance
2.3 Triple bean balance
2.4 Distilled water
2.5 Acetone
2.6 Pipet, 25 ml.
2.7 Aluminum dish, 1.5 gm., 2-3/8 inch diameter, 5/8 inch deep
2.8 Hypodermic syringes, 2 ml., 10 ml., 30 ml. with delivery needles
2.9 Oven, forced air
2.10 Desiccator
2.11 Filter paper, Whatman Nos. 41, 42
2.12 Fritted glass filtering crucibles, medium, fine
2.13 Flasks, 125 ml. erlenmeyer

3.0 Sample Size

3.1 Liquid resins
3.1.1 10 grams for resins between 50% and 100% solids
3.1.2 20 grams for resins between 30% and 50% solids
3.1.3 .For resins near 20% solids, measure solids according to the method of paragraph 4.2 and proceed to paragraph 4.3.
3.2 Prepreg materials
3.2.1 15 grams for materials of between 40% and 56% dry resin content
3.2.2 20 grams for materials of between 30% and 40% dry resin content

4.0 Procedure

4.1 Preparation of Intermediate Solutions

TEST METHOD CTM-5

4.0 Procedure - (Cont'd.)

4.1.1 Prepare duplicate solutions

4.1.2 Liquid Resins - Mix in a flask the appropriate sample size weighed on the triple beam balance, with about 50 ml. of acetone. Determine the resin solids of mixture according to the method of paragraph 4.2.

4.1.3 Prepreg Materials - Soak the appropriate sample size, chopped to about 1/2" x 1/2" and weighed in a flask on the triple beam balance, with 50 ml. of acetone for 15 minutes minimum. Swirl occasionally. Filter the extracted material through No. 41 or 42 filter paper. If the material contains fine filler, thorough filtration may require the use of a medium or fine fritted glass filtration crucible. Determine the resin solids of the solution according to the method of paragraph 4.2.

4.2 Determination of Resin Solids of Intermediate Solutions

4.2.1 Weigh on the analytical balance by difference from a 2 ml. syringe, 2 ml. of intermediate solution (or liquid resin of paragraph 3.1.3). Discharge the solution into a tared aluminum solids dish. Dry in a 275°F. forced air oven for 30 minutes. Cool in a desiccator. Reweigh on the analytical balance.

4.2.2 Calculate resins solids of the intermediate solutions as follows:

$$\% \text{ Solids} = \frac{\text{Final weight of dish} - \text{Initial weight of dish}}{\text{2 ml. sample weight}} \times 100$$

4.2.3 For highest precision, intermediate solution should be in range of 10% to 20% solids.

4.2.4 Solids should be run in triplicate and agree within .3% of the average of three determinations.

4.3 Preparation of Final Solution at 4.0% Resin Solids

4.3.1 Calculate W_1, weight in grams of intermediate solution to be used, as follows:

$$W_1 = \frac{160}{\text{\% resin solids from par. 4.2.2}}$$

Calculate W_2, weight of acetone to be used, as follows:

$$W_2 = 40 - W_1$$

NON-METALLIC MATERIALS DEVELOPMENT DEPARTMENT	Thompson Ramo Wooldridge Inc. 23555 Euclid Avenue Cleveland 17, Ohio	TAP DAP-117 SHEET 1 OF 2 ISSUED 4-10-63 REVISED

DEVELOPMENT ANALYTICAL PROCEDURE

RESIN SOLIDS BY DMF EXTRACTION

1.0 PURPOSE:

1.1 The purpose of this procedure is to determine the resin solids content of carbon and graphite reinforced phenolic raw materials and preforms by means of extraction with N,N - dimethylformamide.

2.0 EQUIPMENT:

21 Extraction Apparatus, Modified Underwriter's Form.

2.2 Extraction Thimbles, Paper, Double Thickness, 80 x 22 mm.

23 Electric Hot Plate.

2.4 Filter Paper.

2.5 Analytical Balance.

26 Aluminum Drying Mshes.

2e7 Drying Oven.

2.8 Desiccator.

3.0 SAMPLE:

3.1 A 0.5 ± 0.05 gm sample shall be used for each test. Duplicate tests are required for reporting results.

4.0 PROCEDURE:

&l Determine volatile content of material per TAP-DAP-102.

4.2 Precondition thimbles by rinsing for a minimum of 3 minutes in DMF and drying for 1 hour at 350°F. Cool in desiccator to room temperature.

4.3 Weigh 0.5 ± 0.05 gn sample (fresh material, not "devoled" sample) to the nearest .0001 gm onto filter paper. Fold over paper and place into 22 x 80 mm extraction thimble.

4.4 Plaoe thimble containing sample into extraction apparatus. Add 50 ml DMF filling the thimble and pouring the remainder into the flask.

Thompson Ramo Wooldridge Inc.

TPFC-1968

TAP-DAP-117
SHEET 2 OF 2
ISSUED 4-10-63
REVISED

Turn on hot plate and condenser, and adjust heat so as effect 15 - 20 reflux changes per hour. Continue to reflux for 4 hours.

4.5 Disassemble extraction apparatus and pour extracted solution into a previously tared aluminum drying dish. Dry at 325°F to constant weight in an air-circulating oven.

5.0 CALCULATIONS:

5.1 Resin Solids:

$$\% RS = \frac{(W_2)\ (100)}{W_1\left(1 - \frac{\%Vols}{100}\right)}$$

Where W_1 is the original wt. of sample
W_2 is the wt of the dry resin extract.

6.0 WORT:

6.1 The average of two determinations shall be reported as the percent resin solids.

6.2 The range of values shall not be more than 1.0 percentage point in repeated tests.

Prepared by: E. S. Davis
E. S. Davis
Non-Metallic Materials Development

Approved by: WEW intre
W. E. Winters, Supvr.
Non-Metallic Materials Development

Thompson Ramo Wooldridge Inc.

TAPCO GROUP Non-Metallic Materials Development Department	Thompson Ramo Wooldridge Inc. 23555 Euclid Avenue Cleveland 17, Ohio DEVELOPMENT ANALYTICAL PROCEDURE	TAP- DAP-116 SHEET 1 OF 1 ISSUED 4-3-63 REVISED

BARCOL HARDNESS

1.0 PURPOSE:

1.1 This method describes a procedure for determining the hardness of plastic materials using a Barcol Impressor.

2.0 EQUIPMENT:

2.1 Barcol Impressor, Model GYZJ-934 , Barber Coleman Co.,Rockford, Illinois.

2.2 Calibration Disc

3.0 SAMPLE:

3.1 Five determinations are made on a single sample, of at least 3 square inches in area and 1/8 inch thick.

4.0 PROCEDURE:

4.1 Conduct all tests at 75°F ± 15°F.

4.2 Check the Barcol Impressor using the calibration disc to see that it is accurate.

4.3 At five randomly selected points, test the hardness by firmly pressing the hardness tester onto the sample.

5.0 REPORTING:

5.1 Report the average of five dial readings as the Barcol Hardness of the sample.

5.2 The range of readings should not exceed 10 units.

Prepared by: E. S. Davis
E. S. Davis
Non-Metallic Materials
Development Department

Approved by: W E Winters
W. E. Winters, Supvr.
Non-Metallic Materials
Development Department

Thompson Ramo Wooldridge Inc.

TAPCO GROUP NON-METALLIC MATERIALS DEVELOPMENT DEPARTMENT	Thompson Ramo Wooldridge Inc. 23555 Euclid Avenue Cleveland 17, Ohio DEVELOPMENT ANALYTICAL PROCEDURE	TAP DAP-105A SHEET 1 OF 2 ISSUED 4-12-60 REVISED 4-10-63

LAMINAR FLOW
(VOLATILE-FREE)

1.0 **PURPOSE:**

1.1 The purpose of this procedure is to determine the laminating characteristics of phenolic preimpregnated materials by means of resin flow properties on a volatile-free basis.

2.0 **EQUIPMENT:**

2.1 Aluminum Foil

2.2 Balance, centigram

2.3 Carver 10-ton Laboratory Press, with thermostatically controlled platens, or equivalent.

2.4 Paper cutter

3.0 **SAMPLE:**

3.1 A representative 50 gram sample of prepreg material, cut into 4 ± 1/32" squares, is used. This quantity will be sufficient for duplicate tests.

4.0 **PROCEDURE:**

4.1 Using paper cutter or template and sharp knife, cut out sufficient 4" x 4" panels to make two 25 ± 3 gram samples.

4.2 Weigh sample to the nearest .01 gram. (W_1) Place between two sheets of aluminum foil approximately 6" x 8", and weigh sample and foil to the nearest .01 gm. (W_2)

NOTE: If the sample tends to stick to the foil after wring, it is permissible to use a non-volatile mold release agent, such as Miller-Stephenson's MS-112 on the foil. Such agents may be used only under conditions such that they do not undergo a weight loss of greater than .005 grams.

4.3 Preheat press platens to 300 ± 5°F. Place sample and foil into press, taking care that the edges of all panels remain properly aligned. Apply 200 ± 5 psi (3200 ± 80 lbs.) and hold for 3 minutes. Hold a pressure of 200 ± 20 psi for another 7 minutes and then release. Remove sample and cool in a desiccator, Weigh sample with foil to the nearest .01 gm. (W_3)

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TAP-DAP-105A
SHEET 2 OF 2
ISSUED 4-12-60
REVISED 4-10-62

4.4 Remove aluminum foil and resin flash, trimming the sample to its original 4" x 4" size. Care must be taken not to remove any reinforcing fibers. Weigh final laminate to the nearest .01 gm. (W_4)

5.0 **CALCULATIONS:**

5.1 The percent Resin Flow is calculated as

$$\% \text{ Flow} = \frac{\left[W_1-(W_2-W_3)-W_4\right]\ (100)}{W_1-(W_2-W_3)}$$

6.0 **REPORT:**

6.1 Report the average of two determinations as the percent resin flow.

62 The range of values obtained in successive determinations should be no greater than 1.5 percentage point, nor shall it exceed 15% of the median value.

Prepared by: E. S. Davis
E. S. Davis
Non-Metallic Materials
Development

Approved by: W E Winters
W. E. Winters, Suprv.
Non-Metallic Materials
Development

Thompson Ramo Wooldridge Inc.

TAPCO GROUP Non-Metallic Materials Development Department	Thompson Ramo Wooldridge Inc. 23555 Euclid Avenue Cleveland 17, Ohio DEVELOPMENT ANALYTICAL PROCEDURE	TAP DAP-104A SHEET 1 OF 3 ISSUED 4-15-60 REVISED 3-29-63

ACETONE EXTRACTION OF SOLUBLE MATERIAL
IN PHENOLIC PLASTIC MATERIALS

1.0 PURPOSE: This method is used in determining the amount of acetone-soluble material in molded or laminated phenolic products. Acetone extraction should be considered only as a quantitative expression of a property normally associated with the degree of cure Tor molded and laminated phenolic products, and should be used only as a comparative test for measuring degree of cure since it la affected by: (1) Nature of resin and filler, (2) Lubricant, (3) Molding temperatures, (4) Length of cure, (5) Thickness of the section from which sample is taken, (6) Nature of molded piece, (7) Technique ueed in molding, (8) Distribution of fines in the material to be extracted, and (9) Method of grinding specimens.

2.0 EQUIPMENT REQUIRED:

21 For breaking up a specimen - A drill press or a file is used.

2.2 Sieves - One set of U. S. standard sieves consisting of a cowr, a 40-mesh sieve, a 140 mesh sieve, and a receiving pan is used.

2.3 Sample bottle - A number of 2 to 4 ounce air-tight glass bottle containers, one for each sample under test.

2.4 Extraction apparatus - Modified underwriters form - Specified for ASTM test, D494, C.R.C. Catalog No. 12-3920.

2.5 Extraction thimbles - Whatman extraction single thickness thimbles, 80 mm x 22 mm.

2.6 Drying dishes - Aluminum foil dishes 2.25" in diameter, and 0.75" in height or higher.

27 Heating unit - An electric bot plate on which a proper temperature can be maintained.

2.8 Analytical Balance

2.9 Drying own - Any type of oven can be used in which a temperature of 50° ± 2°C can be maintained, providing the oven hay sufficient draft. An electrically heated oven should not be used unless it is exceedingly well ventilated as the acetone fumes are liabile tu come in contact with the heated coils and cause an explosion.

2.10 Extraction solvent - Acetone, reagent grade

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3.0 **SAMPLE:**

3.1 **Sample Size:**

3.1.1 On raw materials and preforms the sample size shall be 0.5 ± .05 gm per test.

3.1.2 On finished parts the sample size shall be 1.0 ± .05 gm per test.

3.2 **Preparation of Sample:**

3.2.1 Raw materials shall be diced into pieces of no greater site than 1/2" square.

3.2.2 Preforms shall be drilled or machined to form particles no greater than 1/4" in any dimension. No particles small enough to pass a 140 mesh screen shall be used.

3.2.3 Finished parts shall be drilled or machined to form a particle size of between 40 and 140 mesh.

3.2.4 In all cases, extreme care must be taken that the sample preparation method used does not heat the material sufficiently to increase its degree of cure.

3.3 The sample shall be kept in an airtight bottle to prevent absorption of moisture from the air.

4.0 **PROCEDURE:**

4.1 Accurately weigh sample into a tared, open texture, quantitative filter paper, 1.2 to 15 cm in diameter. Place the filter paper containing the sample in a standard, single thickness, extration thimble, 80 by 22 mm. Fold over the filter paper so that none of the sample can float oat.

&.2 Extraction - Place the thimble containing the weighed sample into the siphon in such a way that the outlet at the bottom is not plugged. Place the condenser and the siphon in the extraction flask and add 50 ml of C.P. acetone.

Start the water through the condenser and adjust the heat on tbe hot plate so that the siphon fills and empties between 15 and 20 times per hour. This rate is carefully maintained and the sample is extracted for 4 hoare minimum. After the siphon empties, remove the flask and pour the contents into a weighed dish. The flask is rinsed with acetone three times and the washings added to the extracted liquid in the dish.

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4.3 Drying - Place the dish in a well-ventilated drying oven maintained at a temperature of 105° ± 2°C and dry the sample to a constant weight. Between dryings, keep the dish in a desiccator to prevent absorption of moisture.

5.0 CALCULATIONS:

5.1 Percent Acetone soluble material $= \frac{\text{(Weight of dish + extract) - (Weight of dish)}}{\text{(Weight of Sample}} \times 100$

5.2 Percent Uncured Resin in material based on resin solids $= \frac{\text{(Percent acetone soluble material)}}{\text{(Percent Resin Solids)}} \times 100$

5.3 Degree of Polymerization = 100% - % Uncured Resin

5.4 Example: Lot 212
Sample Weights

Sample Wt = 4.982		Resin Solids	30.1
Extract Wt = 1.400		Volatiles	3.75

5.4.1 Correction for volatiles in sample weight (4.982) (.0375) = .187

$$\begin{array}{r} 4.982 \\ -0.187 \\ \hline 4.795 \end{array}$$

5.4.2 Percent Acetone Soluble $= \frac{1.400}{4.795} \times 100 = 29.2\%$

5.4.2 Percent Acetone Soluble Solids $= \frac{29.2}{30.1} \times 100 = 97\%$

5.4.4 Degree of Polymerization = 100% - 97% = 3%

6.0 REPORT:

6.1 Percent acetone extractable material (5.1)

6.2 Degree of Polymerization (5.3).

7.0 References:

ASTM, Method D494-46
Federal Specification L-P-406b, Method 7021.

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TAPCO GROUP MATERIALS ENGINEERING DEPARTMENT	Thompson Ramo Wooldridge Inc. 23555 Euclid Avenue Cleveland 17, Ohio	TAP-DAP-103 A SHEET 1 OF 2 ISSUED 2-22-60 REVISED 1-5-62

ANALYTICAL PROCEDURE
RESIN SOLID CONTENT OF RESIN IMPREGNATED MATERIALS

1. Purpose:

1.1 To determine the total resin solid content of impregnated materials in either the "B" or the "C" stags.

2. Equipment Required:

A. Analytical balance
B. Crucible - porcelain crucibles - coors size 1 or larger
C. Desiccator
D. Air-circulating oven
E. Muffle furnace

3. Preparation of Sample and Sample Size:

3.1 Sample balk material.

32 Examine acquired specimen to obtain a representative sample.

3.3 Use 3 to 5 grams for sample size. A minimum of 3 samples required for each lot or batch of material teated.

4. Procedure:

4.1 Place the samples in porcelain crucibles previously ignited at 1550°F ± 50°F and brought to a constant weight.

4.1.1 If percent volatile content is also to he determined, weigh to the newest 0.1 milligram (W_1).

12 Dry the samples in an air-circulating oven at 325°F for 20 minutes, cool in a desiccator and reweigh to obtain original wight (W_2).

4.2.1 "C" stage material need not be dried.

h.3 Burn out resin in muffle furnace for 4 hours at 900°F. Cool in a desiccator and reweigh (W_3).

4.3.1 "C" stage materials are heated for 8 hours and weighed. Reheat for 2 hours and check for constant weight.

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5. **Calculations:**

5.1 Percent volatile content = $\frac{W_1 - W_2 \times 100}{W_1}$

W_1 = original weight, uncured material
W_2 = weight of material after 20 minutes at 325°F

5.2 Percent resin solids = $\frac{W_2 - W_3 \times 100}{W_2}$

W_2 = weight of material after 20 minutes at 325°F
W_3 = weight of ash

6. **Procedure for Determining Percent Resin Solids in Asbestos Reinforcement Material:**

6.1 Follow Steps 4.1 and 4.2.

6.2 Burn out resin for 4 hours at 900°F (this prevents the resin from carbonizing) and then for 1 hour at 1525°F ± 25°F (this eliminates water of crystallization from chrysotile asbestos). Cool in a desiccator and weigh.

6.3 **Calculations:**

6.3.1 Percent resin solids = $100 - \frac{(W_3 \times 100)}{(W_2 \times .86)}$

W_3 = weight of ash
W_2 = original weight, weight of material after 20 minutes at 325°F

(.86 in above formula is correction factor for water of crystallization of chrysotile asbestos)

7. **Notes:**

7.1 The above procedures are not applicable for carbon reinforcement material.

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TAPCO GROUP MATERIALS ENGINEERING DEPARTMENT	Thompson Ramo Wooldridge Inc. 23555 Euclid Avenue Cleveland 17, Ohio	TAP DAP-102A SHEET 1 OF 2 ISSUED 2-22-60 REVISED 3-5-62

ANALYTICAL PROCEDURE
VOLATILE CONTENT OF RESIN IMPREGNATED MATERIALS

1. **Purpose:**

1.1 To determine the percent of volatile matter in resin impregnated materials.

1.2 This method can also be used as an integral part of TAP-DAP-103A - Resin Solid Content of Resin Impregnated Materials.

2. **Equipment Required:**

A. Analytical balance
B. Crucible - porcelain crucible - coors size 1 or larger
C. Desiccator
D. Air-circulating oven

3. **Preparation of Samples and Sample Size:**

3.1 A representative sample is taken of approximately 20 grams of material in the "B" stage. The sample is kept in an air-tight container to prevent loss of volatiles.

3.2 Use 3 to 5 grams for sample size. A minimum of 3 samples required for each lot or batch of material tested.

4. **Procedure:**

4.1 Place the samples in porcelain crucibles, previously ignited at 1550°F ± 50°F and brought to a constant weight, and weigh to the nearest 0.1 milligram (W_1).

4.2 Dry the samples in an air-circulating oven at 325°F for 20 minutes, cool in a desiccator and reweigh (W_2).

5. **Calculations:**

5.1 Percent volatile content = $\frac{W_1 - W_2 \times 100}{W_1}$

W_1 = original weight, uncured material
W_2 = weight of material after 20 minutes at 325°F

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6. Notes:

6.1 The volatile content determination is based on complete resin cure. In some instances, for special impregnated material, it may be necessary *to* extend the drying time.

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ANALYTICAL PROCEDURE

Specific Gravity of Molded and Laminated Plastics

1.0 Purpose:

1.1 To determine the specific gravity of solid reinforced plastic materials in the cured state.

2.0 Equipment Required:

2.1 Analytical Balance with specific gravity bridge.

3.0 Preparation of specimen:

3.1 Prepare a sample to an appropriate size and representative of a critical area in the final product.

3.2 Samples must be prepared with smooth sides and edges to prohibit air entrapment.

3.3 Sample weight met be between 1 to 5 grams.

4.0 Procedure:

4.1 The analytical balance is first tared with a piece of fine wire suspended from the hook of one of the pan supports.

L.2 Attach the sample and weigh to the nearest 0.1 mg. This is the weight in air or "a" weight.

4.3 Immerse the sample while suspended by the wire into freshly boiled distilled water at 73°F (±4°F), and weigh to the nearest 0.1 mg. This is weight "b", the uncorrected weight in water.

4.4 Remove the ample and reweigh the wire while suspended at the same level in the water. This is weight "c", or the loss in weight of the wire on immersion.

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5.0 **Calculation:**

5.1 *For* water as the immersing medium the calculation is:

$$SP/Gr.\ (73.4/73.4°F.) = \frac{a}{a - b - c}$$

a = Weight in grams in air.
b = Uncorrected weight in grams of sample in water.
c = Loss in weight, in grams, of wire in water.

6.0 **Requirements:**

6.1 The plastic material must be wet by the water but not affected by it in any manner. If the plastic material is affected by water use the procedure outlined in Federal Specification L-P-406b, Method 5012.

6.2 *The* plastic material must have a higher density than the water.

7.0 **References:**

ASTM, Method D-792-50
Federal Specification L-P-406b, Method 5011.

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TAPCO GROUP MATERIALS ENGINEERING DEPARTMENT	Thompson Ramo Wooldridge Inc. 23555 Euclid Avenue Cleveland 17, Ohio DEVELOPMENT ANALYTICAL PROCEDURE	TAP-DAP-120 SHEET 1 OF 4 ISSUED 5-20-63 REVISED

1.0 APPLICATION: This specification describes a method for determining the viscosity number of prepreg materials by mans of the kinematic viscosity and the refractive index of a solution of the prepreg resin in DMF (N,N - Dimethylformamide). The viscosity number is an expression of the degree of advancement of the resin.

2.0 MATERIALS AND EQUIPMENT:

2.1 Abbe-3L Refractometer, Bausch & Lomb, Rochester, N. Y.

2.2 Constant Temperature Bath, 77°F, Fisher unitized or Equivalent, Fisher Scientific Company, Pittsburgh, Pennsylvania.

2.3 Ubbelohde Viscometer, No. UBC, Size UB, Cannon Instrument Company, State College, Pennsylvania.

2.4 Timer, Second Model, Lab-Chron #1400, or Equivalent, Labline, Inc., Chicago, Illinois.

2.5 Filter Paper, Whatman #41.

2.6 Filter Discs, Millipore, Type OHWP 04700, Millipore Filter Company, Bedford, Massachusetts,

2.7 Filter Holder, Millipore, # XX15 04700, Millipore Filter Company, Bedford, Massachusetts.

28 Flasks, Erlenmeyer, 250 ml, wide mouth.

2.9 Flasks, Erlenmeyer, with ground glass stoppers, 125 ml.

2.10 Shaker, Utility, Precision Scientific, Chicago, Illinois, or Equivalent

2.11 Funnels, Filtering

2.12 Pump, Vacuum, Chemical Rubber Company, Cleveland, Ohio.

2.13 Vials, Snap Cap, 12 drams, Chemical Rubber Company, Cleveland, Ohio,

2.u Pipette, 50 ml.

2.15 DMF (N-N, Dimethylformamide) Eastman #5870 or Equivalent.

2.16 Acetone, Eastman #297 or equivalent.

2.17 Benzene, Eastman # P777 or equivalent.

2.18 Petroleum Ether, Baker #9268 or equivalent.

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2.19 Cotton **Balls,** Johnson and Johnson, or equivalent.

2.20 Flask, Filtering, with Sidearm, 4000 ml.

3.0 **PROCEDURE PUR** EXTRACTION OF **RESIN**:

3.1 Cut the prepreg material to be tested into 1/2" x 1/21' squares.

3.2 **Weigh** out 20.0 - 24.0 gms of the material into a **250 ml.** Erlenmeyer **flask.** If the resin content is **below** 35%, use a 30.0 gm **sample.**

3.3 Pipette 50 ml of DMF into the flask containing the sample.

3.h Agitate the mixture for 10 minutes on a laboratory shaker.

3.5 **Filter** the solution through **a** #41 Whatman Filter Paper, **and** oollect **in** the **125 ml** glass stoppered flasks. If **the** solution **is** not clear, refilter through **a** Millipore **OHWP** ***Oh700*** filter using the Millipore glass filter apparatus. When using the Millipore glass filter, collect the filtrate in a 12 **dram** vial suspended below the stem of the filter apparatus by means of **a** wire basket. Any particles still suspended **in** the solution after filtering through the Millipore will **be** too **small** to interfere with the viscosity determination.

4.0 PROCEDURE FOR REFRACTIVE INDEX DETERMINATION:

4.1 Before using the Abbe-3L Refractometer, the operator should read the reference manual supplied with the instrument to familiarize himself with the construction, operation, and care of **the** instrument.

4.2 Clean the prisms with successive wipes of acetone, benzene, **and** petroleum ether using cotton swabs. Do not use dry cotton on the prisms.

4.3 Adjust the temperature of the constant temperature bath to 77° ± 0.1°F and circulate through the refractometer.

4.4 Apply the sample solution to the prisms, close the prisms and set the refractometer scale to approximately 1.4550/

4.5 Adjust the compensator dial until there is **sharp** division between the upper light portion of the field and lower **dark** portion.

4.6 Bring this division line to the intersection of the cross hair lines.

4.7 Read the refractive **index** by depressing the scale illuminator switch. **If** the refractive index of the solution is above 1.4610, dilute the solution with a few milliliters of DMF. Repeat until the refractive

index is in the range of 1.4480 to 1.4610. If the refractive index of the solution is below 1.4480, it will be necessary to add a few more grama of the prepreg material and repeat the 10 minute agitation and filtration.

4.8 Report the refractive index and the temperature.

5.0 PROCEDURE FUR KINEMATIC VISCOSITY DETERMINATIONS:

5.1 Clean the Ubbelohde Viscosity tubes using successive rinses of acetone and benzene. Dry thoroughly.

5.2 Adjust the temperature of the bath to 77" ± 0.1°F.

5.3 Add the DMF-resin solution to the viscometer until the level is between the two blue lines on the large chamber.

5.4 Allow the solution 10 minutes to come to equilibrium temperature.

5.5 Draw the solution up through the capillary tube using vacuum. Do not allow bubbles to form in the rising liquid. Bring the upper level of the solution into the small, upper bulb, above the top, blue, reference line.

5.6 Release the vacuum and allow the solution to pass down through the capillary tube. When the solution miniscus passes the upper reference line start the timer. When the miniscus passes the lower blue line stop the timer and record the time in seconds. If the time is less than 200 seconds, the viscometer size is too large and a smaller Viscosity range viscometer should be used. If the time is greater than 1000 seconds, a larger range viscometer is needed,

5.7 Draw out the solution from the viscometer using vacuum and clean the viscometer with several rinses of acetone and benzene. Be sure the vacuum pump is properly trapped to prevent solvents entering the pump.

5.8 Calculate the viscosity of the solution in centistokes by multiplying the viscometer calibration constant by the number of seconds necessary for the solution to pass between the two reference lines.

5.9 Report the Viscometer Number, the Viscometer Calibration Constant, the time in seconds of the run, the viscosity, and the temperature of the bath.

6.0 PROCEDURE FUR THE DETERMINATION OF VISCOSITY NUMBER:

6.1 Refer to Figure, 1, the General Viscosity Chart.

6.2 Find the point of intersection of the refractive index and the kinematic viscosity.

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6.3 **Follow the closest diagonal band, to this point of intersection, and read off the viscosity number. Report as Viscosity Index Number.**

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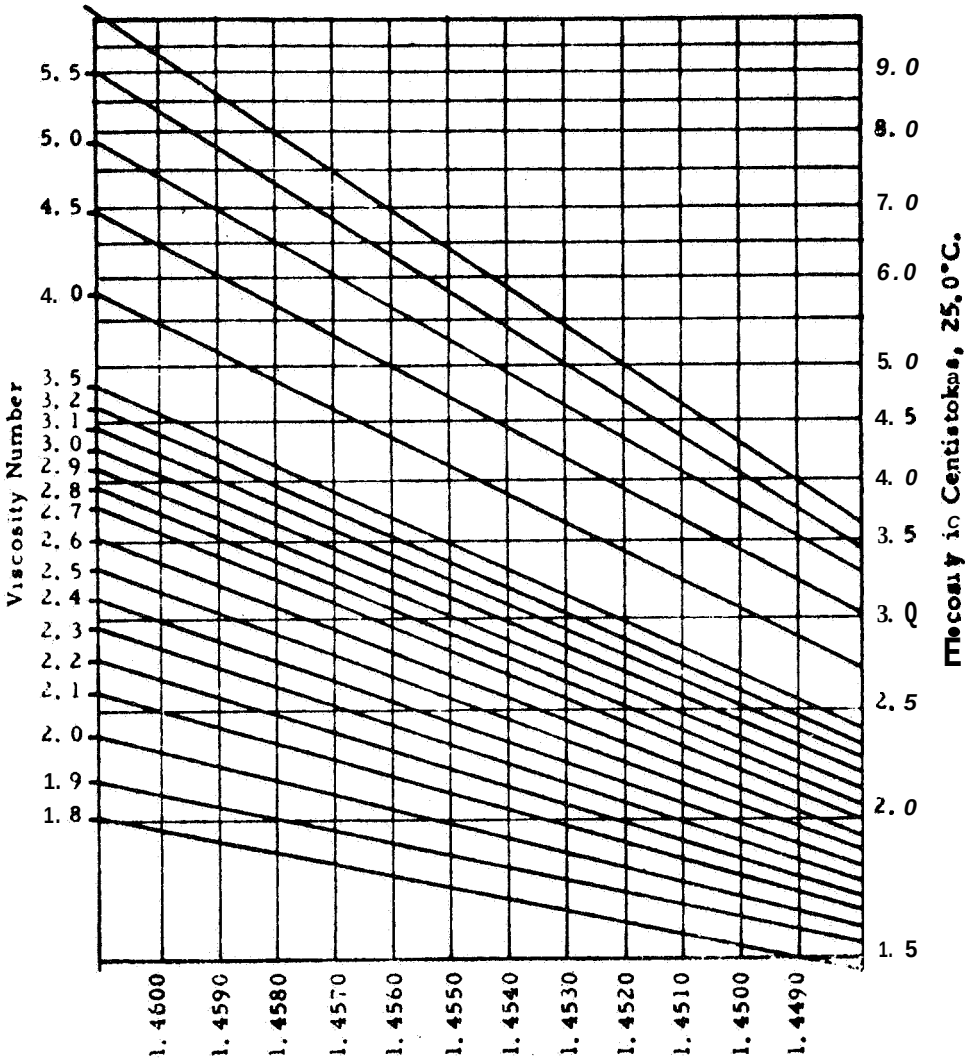

FIGURE 1 Refractive Index, *25. O'C.*
General Viscosity Number Chart

ELECTROMECHANICAL DIVISION MATERIALS TECHNOLOGY DEPARTMENT	**TRW** THOMPSON RAMO WOOLDRIOGE INC. 23555 EUCLID AVENUE • CLEVELAND, OHIO 44117 DETAILED ANALYTICAL PROCEDURE	TAP- DAP-115A SHEET 1 OF 2 ISSUED 1-17-64 REVISED 6-15-64

TACK OF PHENOLIC PREIMPREGNATED LAMINATING MATERIALS

1. PURPOSE:

1.1 The purpose of this procedure is to determine the tape wrapping characteristics of phenolic preimpregnated straight tapes and broadgoods.

2. EQUIPMENT:

2.1 Pneumatic splicing press with round, aluminum contact foot 1 inch in diameter and capable of applying 50 ± 5 pound load.

2.2 Heater, parallel plates with opening of 0.070" to 0.125" a d capability of controlling ± 5°F at 200°F.

2.3 Carbon steel strips 8" x 1" x 22 gauge,

2.4 Paper cutter.

2.5 Scott tensile tester, Model L6 with 2-speed dr ve.

2.6 Sling psychrometer.

3. SAMPLE:

3.1 For each test, two strips 4" ± 1/16 x 1" ± 1/32 are cut from a representative sanple. The 4" dimension shall be in the warp direction.

4. PROCEDURE:

4.1 Using a paper cutter, cut two strips of material 4" ± 1/16 x 1" + 1/32. Material shall have been stored in a sealed container at 75°F ± 8°F for 2-3 hours before cutting.

4.2 Place strips on an 8" x 1" steel sheet so that they overlap exactly 1". (Room in which test is performed shall be controlled to 75°F ± 8°F.)

4.3 Insert specimen mounted on steel strip between heated plates maintained at 200°F ± 5°F, such that the overlapped section is at the center of the heated space. Heat for 60 ± 2 seconds,

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4.4 Remove specimen from heater and immediately place in splice press. Lower weight gently and press for 1 minute ± 5 seconds. Remove specimen from press and from steel strip. NOTE: Time to transfer from heater to splice press shall not exceed 5 seconds,

4.5 Test on Scott Tensile Tester within 15 minutes of having made splice, Test in tensile-shear at an extension rate of 2 inches/min. Load specimen to failure and record load to nearest 0.1 of a pound.

4 4.6 Perform test in duplicate.

4.7 Measure and record the relative humidity in the room where the test was performed. This shall be done by duplicate tests with the sling psychrometer,

5. RECOXDS:

5.1 Record both tack values and the average to the nearest 0.1 of a pound,

5.2 Record room temperature.

5.3 Record relative humidity in room where material is cut, spliced, and tested,

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MATERIALS APPLICATION	TRW THOMPSON RAMO WOOLDRIDGE INC. 23555 EUCLID AVENUE • CLEVELAND, OHIO 44117	TAP- DAP-114 SHEET 1 OF 1 ISSUED 1-10-64 REVISED
NON-METALLIC MATERIALS	DEVELOPMENT ANALYTICAL PROCEDURE	

DRAPE OF PHENOLIC PREIMPREGNATED LAMINATING MATERIALS

1.0 **PURPOSE:**

1.1 The purpose of this procedure is to determine the "drapeability" of prepreg strips of material over a 1 inch diameter rod in order to establish the ability of the material to be handled during fabrication without breaking or loss of resin.

200 **EQUIPMENT:**

201 Steel rod 1" diameter and 6" long.

202 Bench Vise.

3.0 PROCEDURE:

3.1 Specimen: Straight or bias tape 2" wide by approximately 10" long. Specimen to be free of splices, breaks, or obvious weaving defects.

3.2 Conditions: Room and material temperature to be 70° - 80°F.

3.3 Holding specimen at both ends bend rapidly 180° around 1" rod.

4.0 **ACCEPTANCE CRITERIA:**

4.1 Material when tested shall not split, flake resin, crack, or break.

4.2 Material not meeting the above requirements will be cause for rejection.

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Report NASA CR 72125

APPENDIX B

TEST PROCEDURE AND EQUIPMENT USED FOR DETERMINING DENSIFICATION AND HEAT TRANSFER CHARACTERISTICS OF THICK ABLATIVE LAMINATES

Report NASA CR 72125
Appendix B

TEST PROCEDURE AND EQUIPMENT USED FOR DETERMINING DENSLFICATION AND HEAT TRANSFER CHARACTERISTICS OF THICK ABLATIVE LAMINATES

Test specimens were made by assembling approximately 280 plies of 4-in.-dia ablative material into a cylindrical billet. The plies were separated into four segments (A, B, C and D) of approximately 70 plies each with teflon film separators to permit insertion of thermcouples for recording of temperature gradients and to facilitate disassembly of the segments after the densification test, Density and aceton extraction testa were then conducted on the segments.

A special die, shown in Figure 1, was used for the molding test. The inside walls of the die were insulated with a transite tube and the bottom of the die was made of copper to permit the transfer of heat from the bottom surface of the die upward through the laminate. The laminate was cooled by circulating water through coiled tubing near the copper base of the die.

Directional heating was provided to the molding cavity by a bank of eight 200 watt electrical resistance elements mounted into the bottom platen. The resistors were thermostatically controlled by two-time-proportional, on-and-off circuit breakers. A thick asbestos-phenolic base was used to contain the copper base and coils, and to support the cylinder and laminate during molding.

The densification of the test sample was determined by dial indicator readings measuring the closure of the dies at intervals of 100 sec during the compaction and at 500 to 1000 sec thereafter.

The laminate test specimen, the special die, and related equipment are shown in Figures 2 and 3.

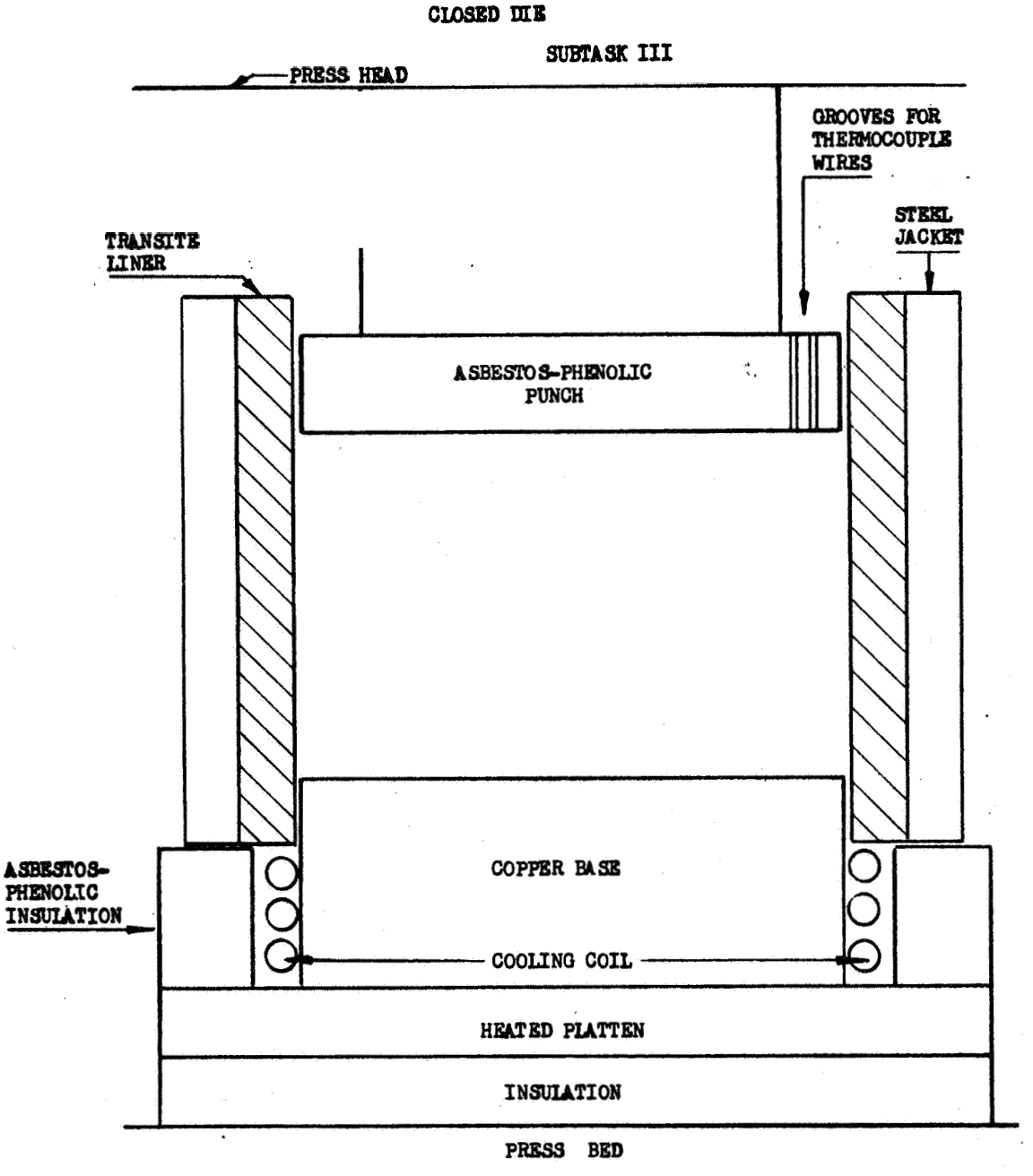
CLOSED DIE
SUBTASK III
PRESS HEAD
GROOVES FOR THERMOCOUPLE WIRES
STEEL JACKET
TRANSITE LINER
ASBESTOS-PHENOLIC PUNCH
COPPER BASE
ASBESTOS-PHENOLIC INSULATION
COOLING COIL
HEATED PLATTEN
INSULATION
PRESS BED

Figure 1

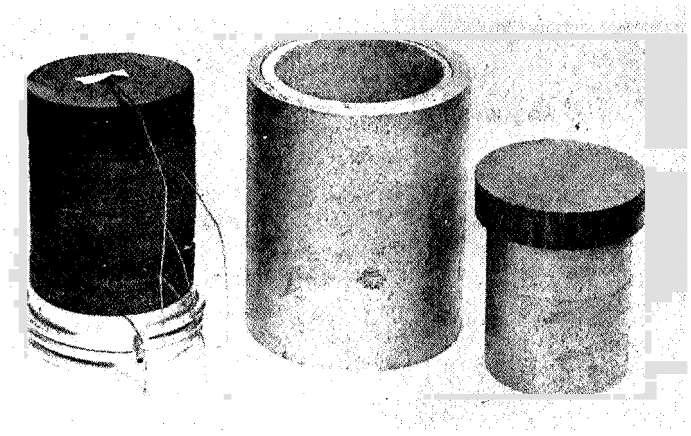

Figure 2

Closed die and instrumented thick laminate for densification and heat transfer studies.

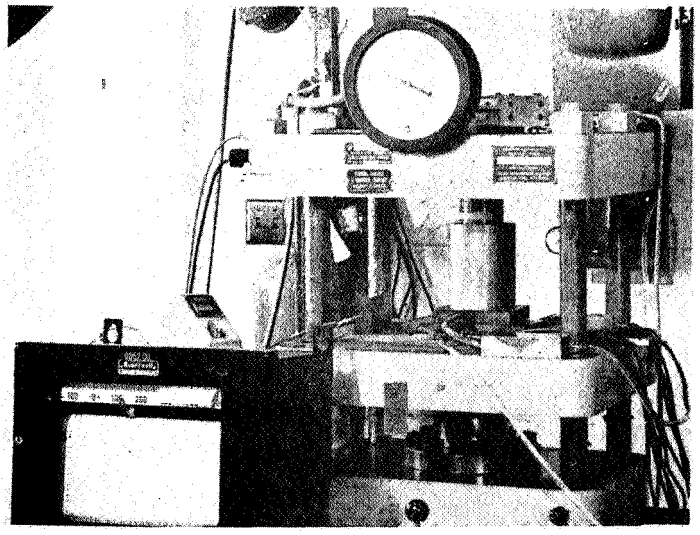

Figure 3

Laminate and die mounted in plastics press with 16 channel recorder and dial indicator.