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Experimental Guidelines for the Design of Turbine Rotor Fragment Containment Rings

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FINAL

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16. Abstract

Results of experimentation to determine design guidelines for turbine rotor fragment containment rings are presented in this report. The project consisted of two tasks. Task 1 was an investigation of the containment characteristics of cloth rings. Task 2 determined the engine casing thickness required for single and triple blade containment. This effort was conducted as part of the overall Rotor Fragment Protection Program.

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PREFACE

This report has been prepared by the Naval Air Propulsion Center (NAPC), Trenton, New Jersey, under National Aeronautics and Space Administration (NASA) Defense Purchase Request C41581-B Modification No. 10 from the Lewis Research Center, NASA, Cleveland, Ohio 44135, and by direction of the Federal Aviation Administration. Mr. Robert Johns and Dr. Chris Chamis of the Lewis Research Center served as program monitors. Their contributions and help during this program are greatly appreciated. The authors would like to thank the Boeing Military Airplane Development Organization, a part of the Boeing Aerospace Company, for conceptual and analytical support in the fabrication of the cloth containment rings.

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EXECUTIVE SUMMARY

The experimental program supporting parametric studies of rotor fragment containment was developed and conducted by the Naval Air Propulsion Center (NAPC) under National Aeronautics and Space Administration (NASA) sponsorship. The formal reporting of this program was sponsored by the Federal Aviation Administration Technical Center (FAA) because of the relevance of the information to propulsion safety. The program objective was to develop guidelines for the design of optimum weight containment rings for gas turbine engine rotor fragments.

The test program being reported consisted of two tasks. Task 1 was an investigation of the containment of rotor sectors by cloth rings. Task 2 determined the engine casing thickness required for single and triple blade containment.

One phase of Task 1 was an investigation of the capabilities of Kevlar fabric as a lightweight containment device as opposed to 4130 steel which was reported in reference 2. Another phase of Task 1 was to compare the containment performance of rings manufactured from ballistic nylon fabric to rings manufactured from Kevlar 29 fabric. Task 1 consisted of a series of rotor fragment containment experiments in which rotors were modified to fail at their respective design speeds into three, pie-shaped fragments. These fragments impacted rings made from aluminum mandrels wrapped with either Kevlar 29 fabric or ballistic nylon fabric. The results of these rotor containment experiments indicated that Kevlar is superior to nylon but still considered inadequate for containing rotor fragments.

The objective of Task 2 was to determine the minimum engine casing thickness required to contain single and triple blade failures. This task consisted of a series of blade containment experiments in which Pratt & Whitney JT3D and JT8D turbine blades were modified to fail at 100 percent design speed and generate single and triple blade fragments. These fragments impacted steel rings whose radial thickness was varied until fragment(s) containment was achieved. The results of these experiments indicated that the minimum engine casing thickness required to contain a single JT8D blade is 0.187 inch and to contain a single JT3D blade is 0.250 inch. The test results showed that a minimum casing thickness of 0.375 inch is required to contain either a JT3D or JT8D triple blade failure. The results attained in Task 2 can be used as a model for containment devices used in any military or commercial aircraft having engines comparable in size to the JT3D or JT8D.

INTRODUCTION

The Rotor Fragment Protection Program was sponsored by National Aeronautics and Space Administration (NASA) and conducted by Naval Air Propulsion Center (NAPC). Formal reporting of the program was sponsored by the Federal Aviation Administration (FAA) Technical Center because of the relevance of the information to propulsion safety. The objective of the program was to develop guidelines for the design of lightweight devices that will be used on aircraft to protect passengers and the aircraft structure from lethal and devasting fragments generated by failure of gas turbine engine rotating components.

Previous reports published by NAPC in conjunction with NASA which document the progress of this program are listed as references 1 through 7.

This report presents the results of a parametric test program that was conducted to provide guidelines for the design of gas turbine rotor fragment containment rings.

METHOD OF TEST

Task 1. Test results presented in this report were obtained using basically the same equipment and techniques described in references 4 and 5. Figure 1 shows a typical test installation. The test procedure was as follows. The test rotor, modified to fail and produce particular shaped fragments at a specified speed, is connected to the air-drive turbine by an arbor. The containment ring under test is freely suspended by guide wires and is concentrically positioned around the test rotor. The axial, midsection of the ring is positioned to coincide with the test rotor's plane of rotation, and radial tip clearance between the rotor and ring is maintained at 0.50 inch (1.27 centimeters). The spin chamber is evacuated to 10 millimeters (mm) Hg pressure in order to reduce the aerodynamic drag on the test rotor and thus reduce the power required to accelerate the rotor to its failure speed. In order to record the fragment release speed, an impact-triggering strip is fixed to the inner diameter of the containment ring. When the fragment is released and makes contact with the inner surface of the ring, the low voltage signal of the triggering strip is interrupted, indicating the time of failure which is correlated to the speed at that time. The containment criterion for the turbine rotor fragment containment tests of Task 1 was as follows: The cloth ring is an acceptable turbine rotor fragment containment system if the fragments do not penetrate the outer layer of cloth.

Task 2. The blade containment experiments performed in Task 2 were conducted in a containment chamber that is 4 feet in diameter and 1 foot high. The test rotor, modified to release single or triple blade fragments, is connected to the air-drive turbine by an arbor. The test containment ring is placed at the bottom of the containment chamber and is concentrically positioned around the test rotor. The axial midsection of the ring is positioned to coincide with the test rotor's plane of rotation. The containment chamber is evacuated to 0.5 mm Hg pressure in order to reduce the aerodynamic drag on the test rotor and thus the power required to accelerate the rotor to its designed 100 percent speed. In order to record the blade release speed, an accelerometer, which detects vibrations in the chamber, is affixed to the chamber lid. The shock that is produced by the blade failure is detected by the accelerometer indicating the time of failure which is correlated to the speed of that time.

The containment criteria for the turbine blade containment tests of Task 2 were as follows: The engine casing is acceptable for blade containment if the damage from rotor blade failures is contained by the engine case; i.e., without causing significant rupture or hazardous distortion of the engine casing and/or the expulsion of blades through or beyond the perimeter of the engine case or shield.

DESCRIPTION OF TEST AND DISCUSSION

Task 1. Table 1 lists the rotor fragment containment experiments that were conducted to investigate containment capabilities of cloth rings. It also describes the materials used and the conditions of each experiment.

Four containment experiments were conducted to investigate the performance of Kevlar® 29 fabric as a lightweight containment device as opposed to 4130 steel. In three of these experiments, the General Electric T58 engine power turbine rotors were modified to fail at design operating speed into three equal pie-shaped fragments. In the fourth containment experiment, a General Electric T58 engine power turbine rotor was modified to fail at 100 percent design speed into six equal pie-shaped fragments. These experiments aided in the development of the final design configuration of cloth containment rings which was then used in the rotor fragment containment evaluations comparing the containment performance of rings manufactured with ballistic nylon to those manufactured with Kevlar 29. Eight of these nylon versus Kevlar rotor fragment containment tests were conducted using Curtiss-Wright J65 turbine rotors (figure 2) modified to fail at design speed into three equal pie-shaped fragments (figure 3).

The fragments from these rotor containment tests impacted containment rings made from lightweight aluminum drums, 1/32 inch thick, wrapped with either Kevlar 29 or ballistic nylon fabric. The material was folded on the bias and stitched with one, two, and three rows of Kevlar or nylon thread to give the best energy absorption capability. Figures A-1 through A-5 of the appendix define the Kevlar and nylon containment ring manufacturing technique. This technique was developed by the Boeing Company, who fabricated and wrapped the Kevlar containment rings used in the first eight rotor fragment tests (see figure 4). In the last four containment tests (three ballistic nylon tests and one Kevlar 29 test), the containment rings were manufactured by the Pioneer Parachute Company and wrapped by NAPC personnel. An example of the NAPC wrapping process is shown in figure 5. Once wrapped, the cloth containment rings can be seen in figures 6 and 7. A brief summany of the cloth containment ring characteristics is presented in figure 8.

Results of the rotor fragment containment experiments conducted in Task 1 are shown in table 1. In the Kevlar 29 evaluation experiments, only one of four General Electric T58 turbine rotors was contained. In the kevlar 29 versus ballistic nylon experiments, only two Kevlar 29 rings contained the fragments generated by a Curtiss-Wright J65 turbine failure and none of the ballistic nylon rings contained the fragments. Figures 9 and 10 are examples of the nylon and Kevlar fabric damage after uncontained failures. The results of these cloth containment ring tests indicated that Kevlar 29 is superior to ballistic nylon, but both are considered inadequate for rotor containment.

Task 2. Table 2 lists the blade containment experiments that were conducted to determine the minimum engine casing thickness required for single and triple blade containment. This table also describes the materials used and the conditions of each experiment.

To determine the minimum engine casing thickness, a series of blade containment experiments was conducted. In these containment experiments, blades from fully bladed JT3D (second stage) and JT8D (first stage) low pressure turbine rotors were modified to fail at 100 percent design speed (6850 and 8800 revolutions per minute (rpm) respectively) and impact containment rings of various thickness (figure 11) made from A-286 steel. (JT3D and JT8D rotors were chosen as representative of large turbine rotors in use today.) The blade containment experiment results reported herein were generated by single and triple blade releases. Single blade release is accomplished by appropriate notching of a blade causing it to fail at the rotor's 100 percent design speed. Figure 12 shows a single blade notch configuration. Triple blade release is accomplished by modifying the rotor, as shown in figure 13, causing three blades to separate from the rotor at 100 percent design speed. Several preliminary tests were conducted, using 304 stainless steel containment rings, to verify the appropriate blade notching configuration to be used in achieving blade release at design speed.

The actual blade containment experiments used containment rings made from A-286 steel with an axial length of 9 inches. The radial thickness of the containment rings was varied from 0.140 inch to 0.387 inch. To optimize testing and reduce cost, a test scheme (figure 14) was developed. This test scheme was designed as follows: An arbitrary ring thickness was chosen, based on engineering judgement, as the starting point, and a containment test was conducted. If containment was achieved, the containment ring thickness would be reduced and another blade containment test would be conducted. If containment was not achieved, the containment ring thickness would be increased for the next containment test. This process was continued until containment was achieved. The results of these blade containment experiments are presented in matrix form in figure 15. These results indicate that the minimum engine casing thickness required to contain a single JT8D blade is 0.187 inch and to contain a single JT3D blade is 0.250 inch. The minimum engine casing thickness required to contain three blades from either a JT3D or JT8D rotor is 0.375 inch.

Using this test data, a simplified formula has been devised whereby the thickness of the containment ring required to contain fragments of specified energy may be estimated. Since the blade containment tests were conducted with containment rings made from A-286 steel, the formula is valid only for this ring material. It is expected that variations in ring material can be expressed by changes in the formula constants. The formula is

$$t = .0014E^{.48}$$

where t = thickness of the A-286 steel containment ring, inches
E = kinetic energy of the fragment, in-lbs.

Figure 16 shows the test data points plotted as fragment energy versus containment ring thickness. The solid line in figure 16 is a plot generated from the formula above. It is being used as a conservative approximation of the minimum thickness required for an A-286 steel containment ring to be successful at the corresponding fragment energy. However, due to the limited number of test specimens used in developing this formula, exact containment ring thickness should not be derived from this relationship.

CONCLUSIONS

Task 1. Neither Kevlar® 29 nor ballistic nylon fabrics are adequate for rotor containment. However, Kevlar 29 did perform better than ballistic nylon in these tests.

Task 2. The minimum engine casing thickness required to contain a JT8D single blade failure is 0.187 inch and to contain a JT3D single blade failure is 0.25 inch. Both the JT8D and JT3D experiments required a minimum casing thickness of 0.375 inch for triple blade containment. Since the JT8D and JT3D turbine rotors are representative of most large turbine engine designs used in commercial aircraft, the results of this testing can be generalized for any turbine engine having blade fragment energies comparable to the JT8D and JT3D turbine blades.

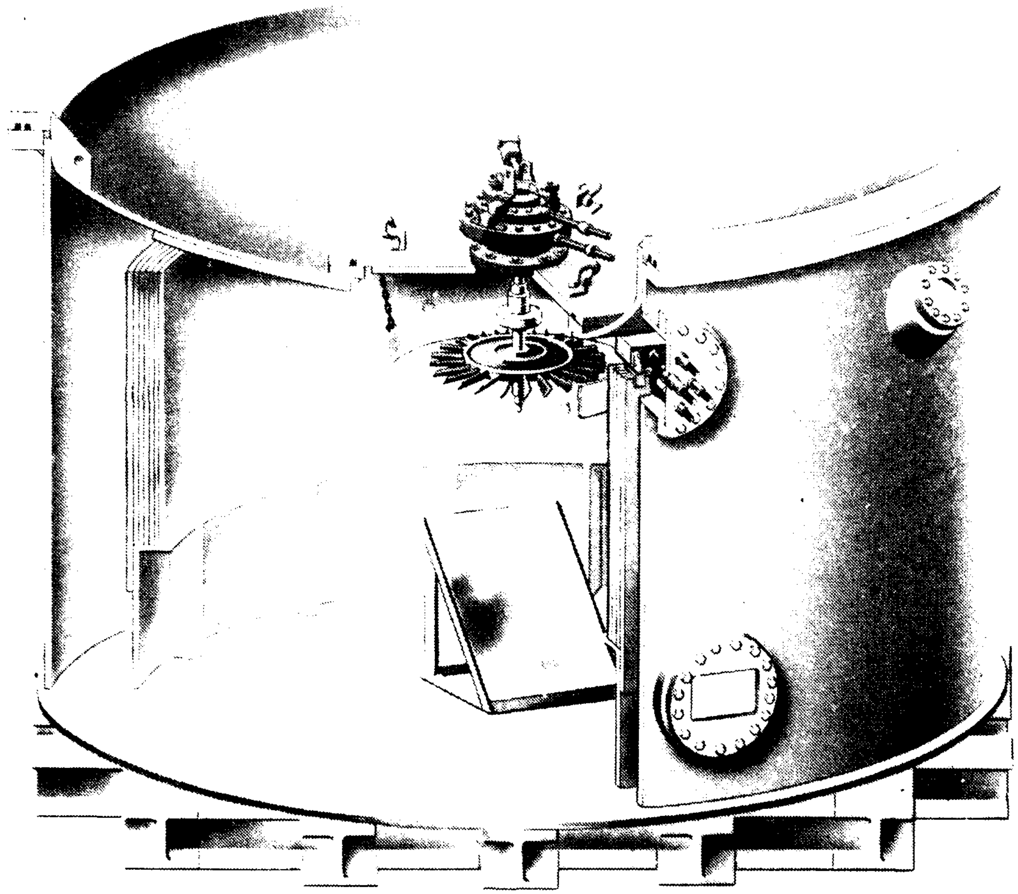
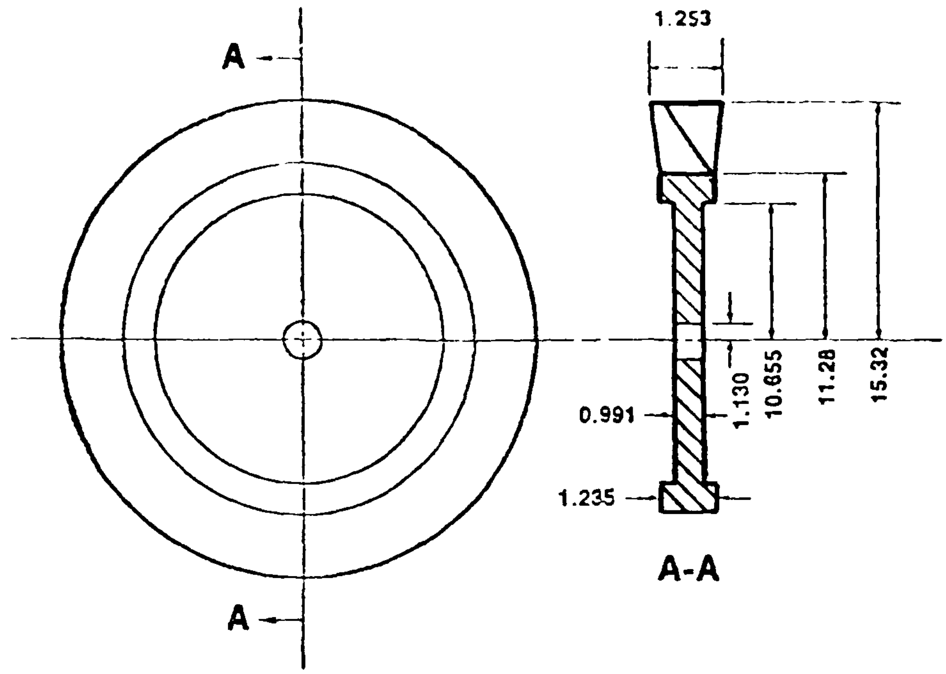


FIGURE 1. TEST SETUP FOR TASK 1



TYPE ROTOR : J-65 SECOND STAGE TURBINE (MODIFIED, UNSLOTTED)

ROTOR WEIGHT : 128 LBS (APPROX.)

ROTOR INERTIA : 9410 LB-IN^2 (NOMINAL)

	DISK	BLADES
MATERIAL :	17-22A FERRITIC STEELS	INCONEL 700
PROPERTIES :		
SU	142K PSI	148.5K PSI
SY	128.5K PSI	132K PSI
EU	18%	18%
HD	311 BHN	311 BHN

FIGURE 2. J65 TURBINE ROTOR CHARACTERISTICS

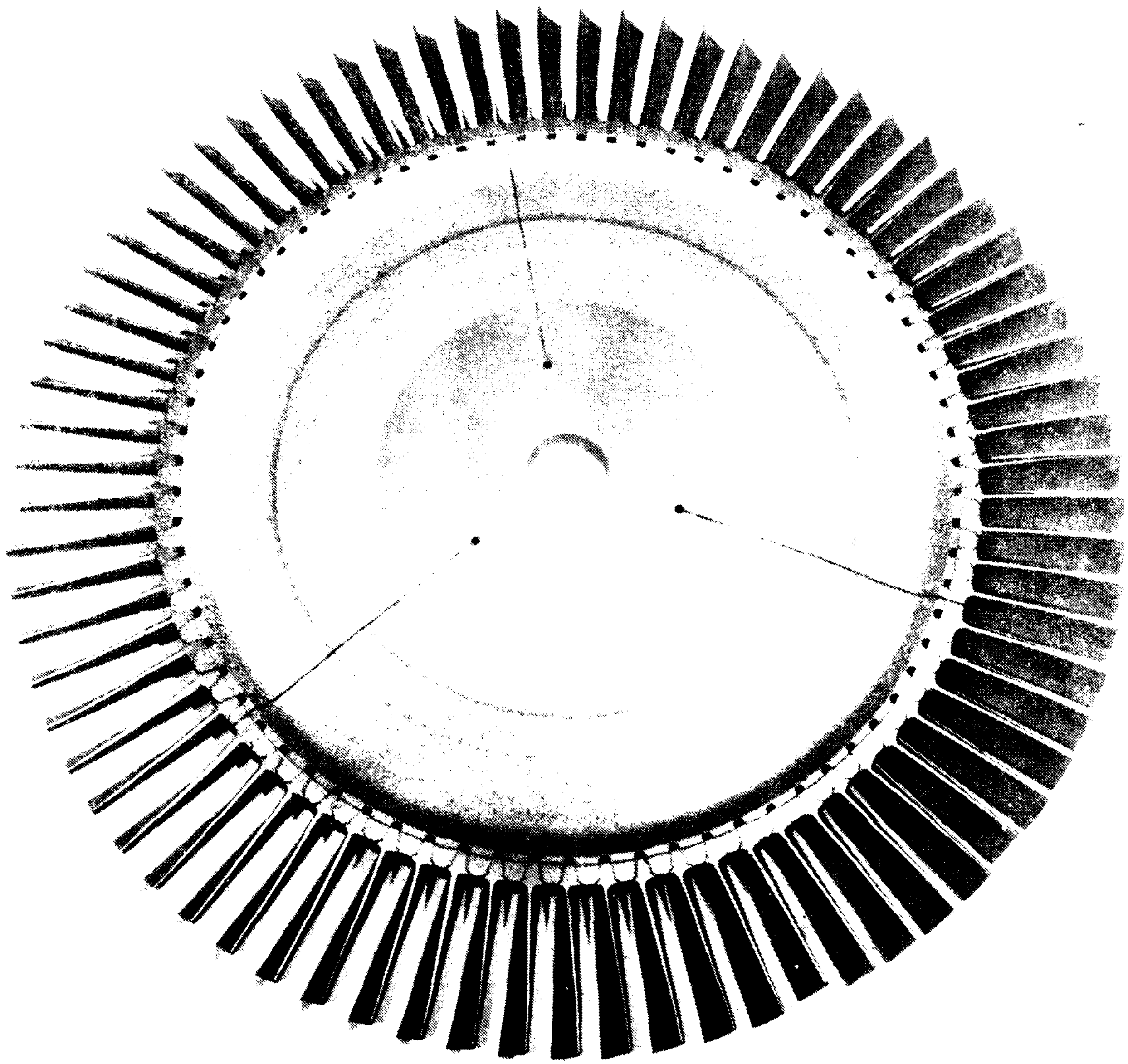


FIGURE 3. J65 ROTOR MODIFIED

T58 Rotors

Kevlar - Boeing - Four (4) Tests

1. No. 215 - 06/14/76 - Three (3) Fragments - Partial Containment
2. No. 218 - 09/02/76 - Three (3) Fragments - Contained
3. No. 219 - 10/19/76 - Six (6) Fragments - Not Containment
4. No. 220 - 12/07/76 - Three (3) Fragments - Partial Containment

J65 Rotors

Kevlar - Boeing - Four (4) Tests

1. No. 221 - 02/16/77 - Three (3) Fragments - Contained
2. No. 222 - 04/27/77 - Three (3) Fragments - Contained
3. No. 226 - 09/01/77 - Three (3) Fragments - Not Contained
4. No. 229 - 11/07/77 - Three (3) Fragments - Not Contained

Nylon - Pioneer Parachute Company - Three (3) Tests

1. No. 241 - 12/12/80 - Three (3) Fragments - Not Contained
2. No. 243 - 01/30/81 - Three (3) Fragments - Not Contained
3. No. 244 - 02/02/81 - Three (3) Fragments - Not Contained

Kevlar - Pioneer Parachute Company - One (1) Test

1. No. 245 - 02/04/81 - Three (3) Fragments - Not Contained

FIGURE 4. KEVLAR-NYLON TESTS

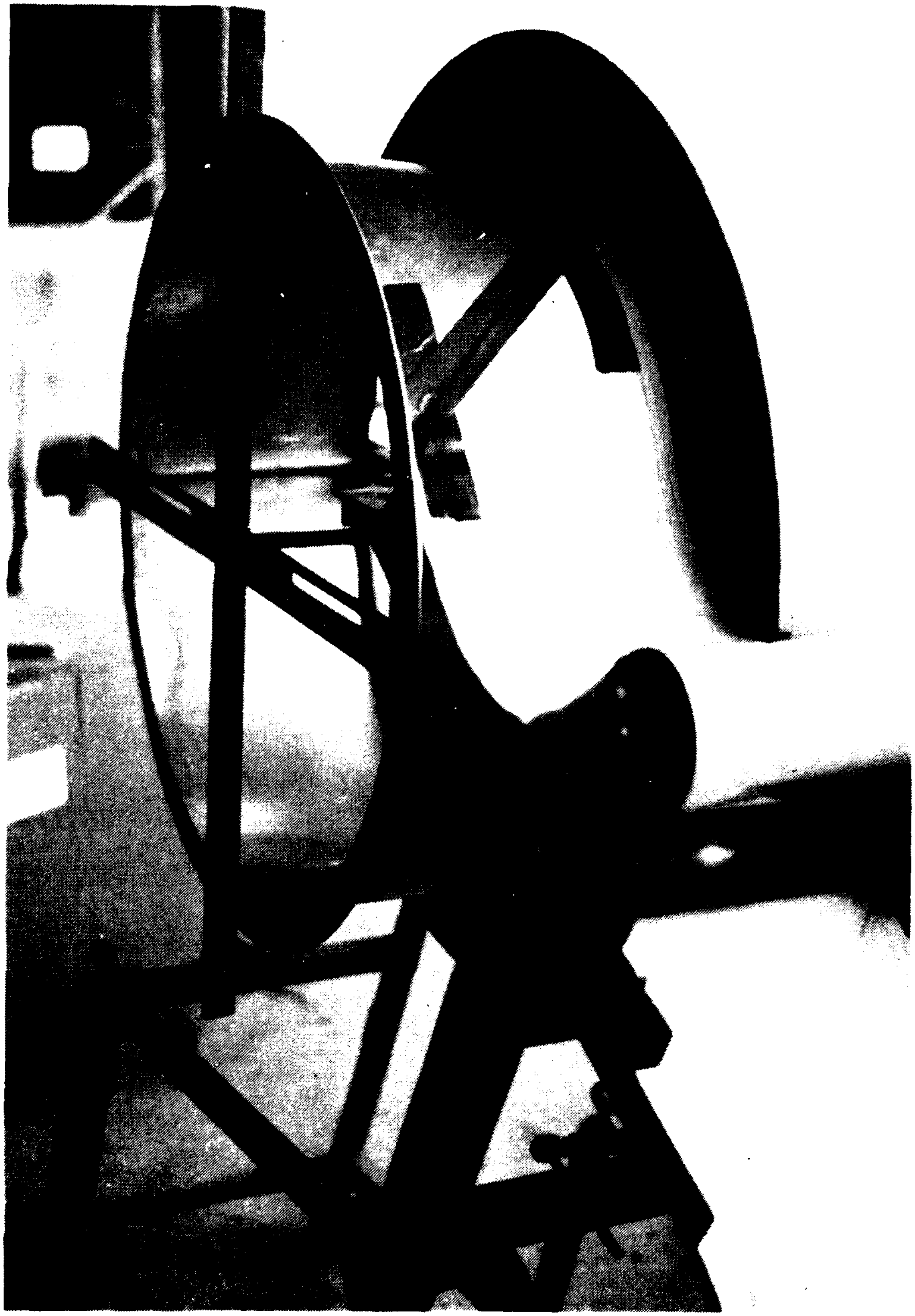


FIGURE 5. NAPC WRAPPING PROCESS

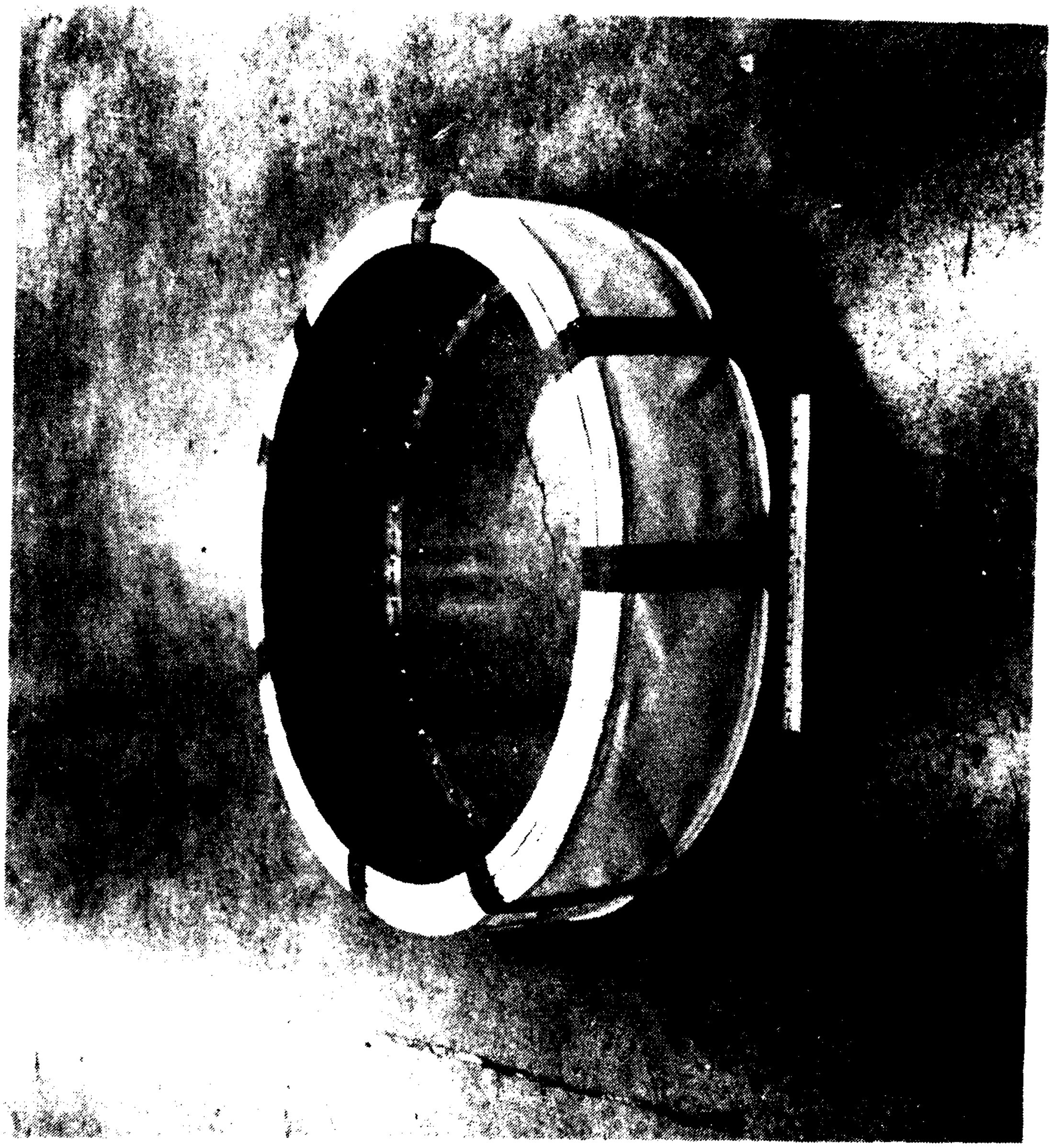


FIGURE 6. KEVLAR CONTAINMENT RING

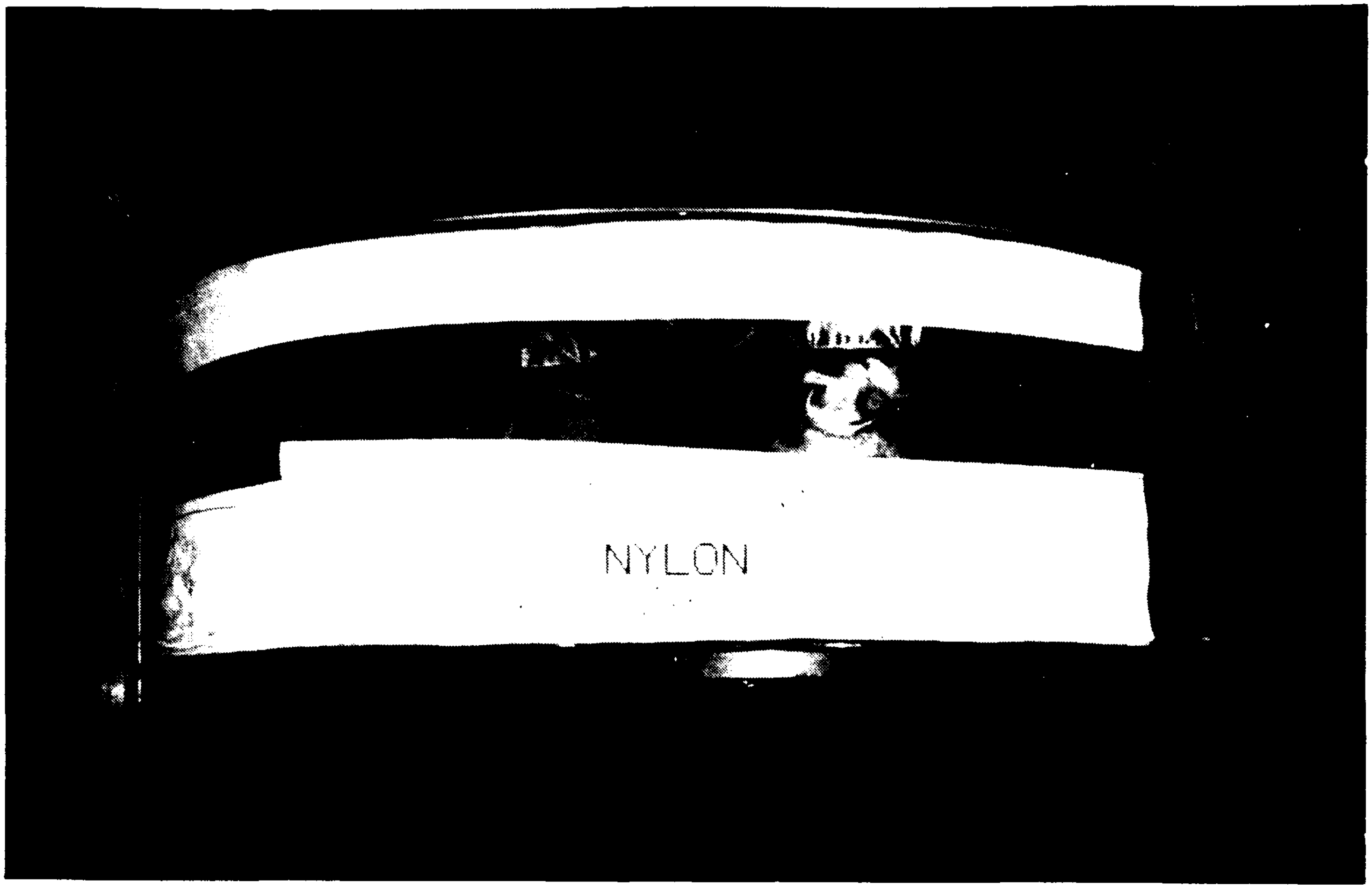


FIGURE 7. NYLON CONTAINMENT RING

MATERIAL	BALLISTIC NYLON	KEVLAR 29
ID	32"	32"
AXIAL LENGTH	12.5"	9"-12"
WEIGHT	65 LBS	55-71 LBS

FIGURE 8. CONTAINMENT RING CHARACTERISTICS

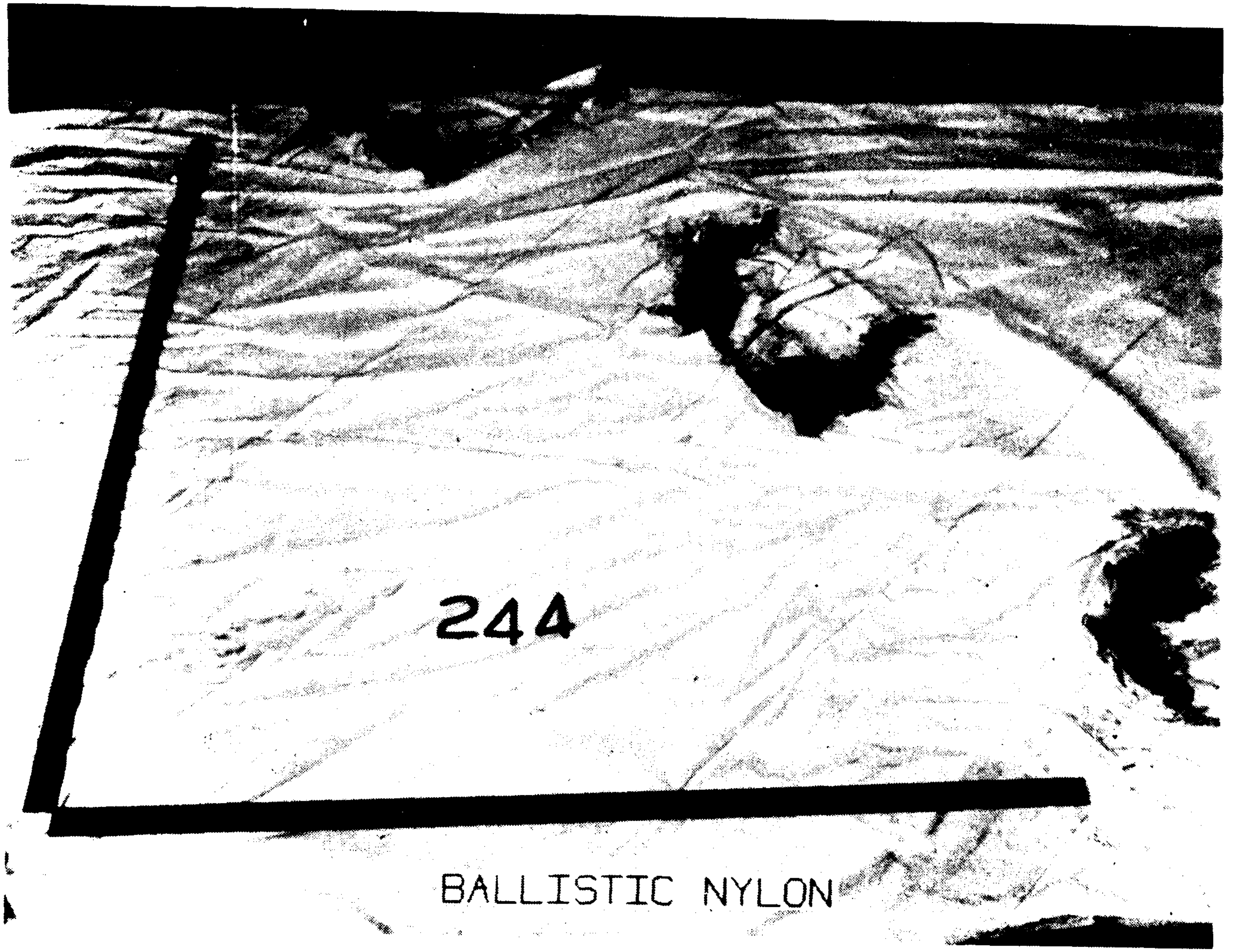
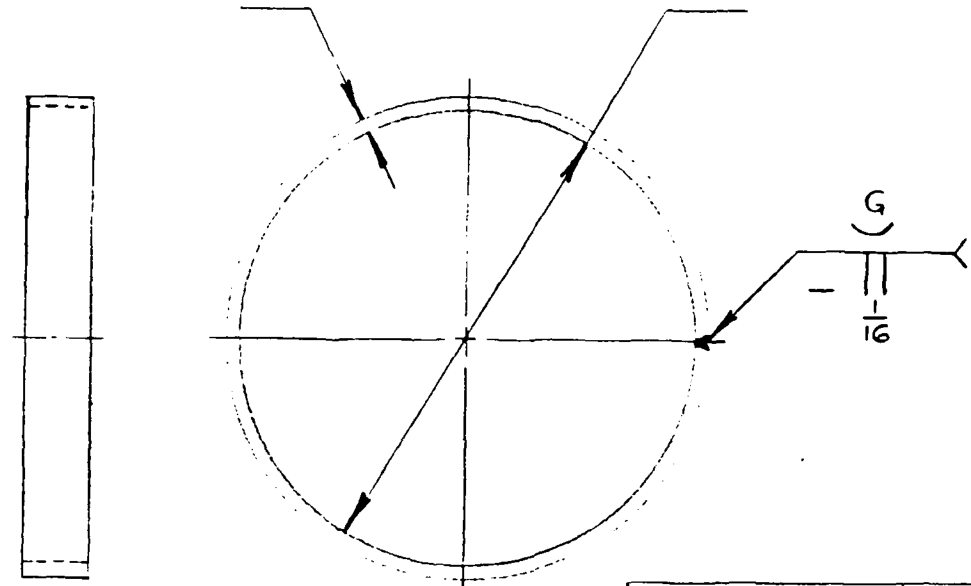


FIGURE 9. BALLISTIC NYLON UNCONTAINED FAILURE

FIGURE 10. KEVLAR 29 UNCONTAINED FAILURE



CONTAINMENT RING

MATERIAL:-
SHEET STEEL A286.
CORROSION AND HEAT
RESISTANT
(AEROSPACE MATERIAL
SPECIFICATION-AMS5525C)

CODE	THICK-NESS	AXIAL LENGTH	LENGTH
A	.140	9"	
B	.187	9"	
C	.250	9"	
D	.375	9"	

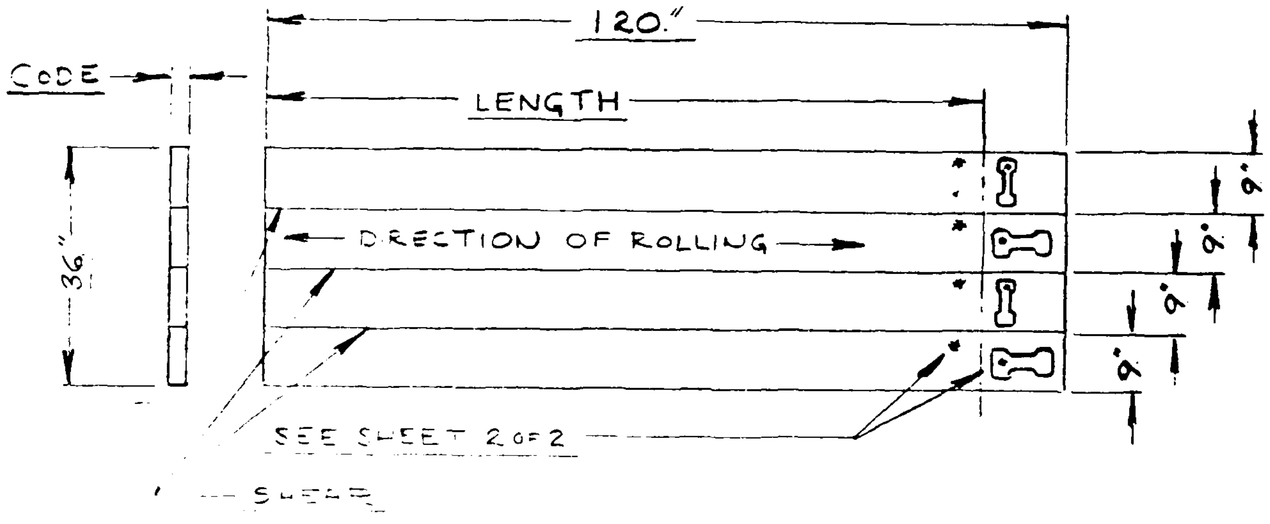
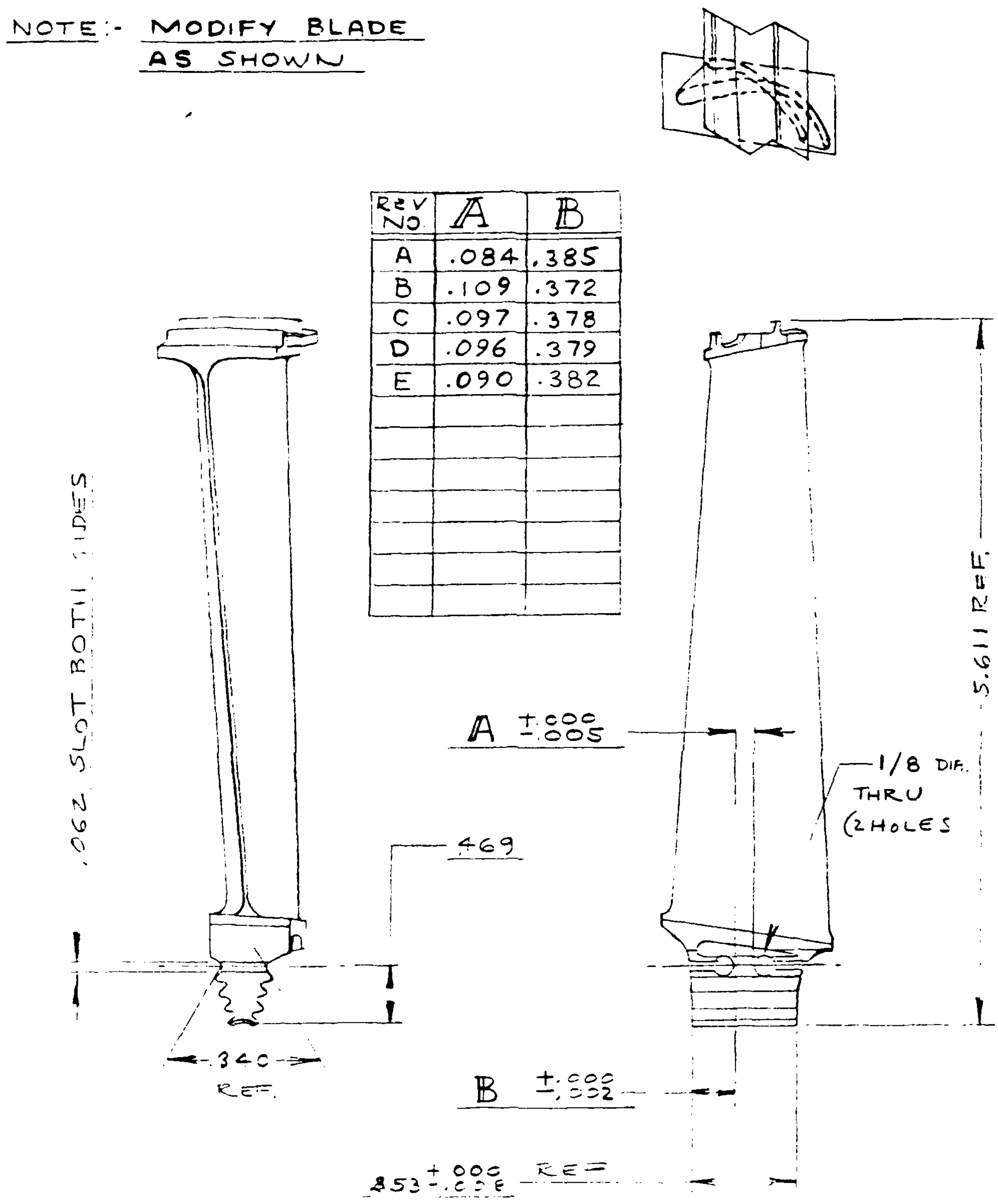


FIGURE 11. CONTAINMENT RING DESIGN



REV NO.	A	B
A	.084	.385
B	.109	.372
C	.097	.378
D	.096	.379
E	.090	.382

FIGURE 12. SINGLE BLADE MODIFICATION

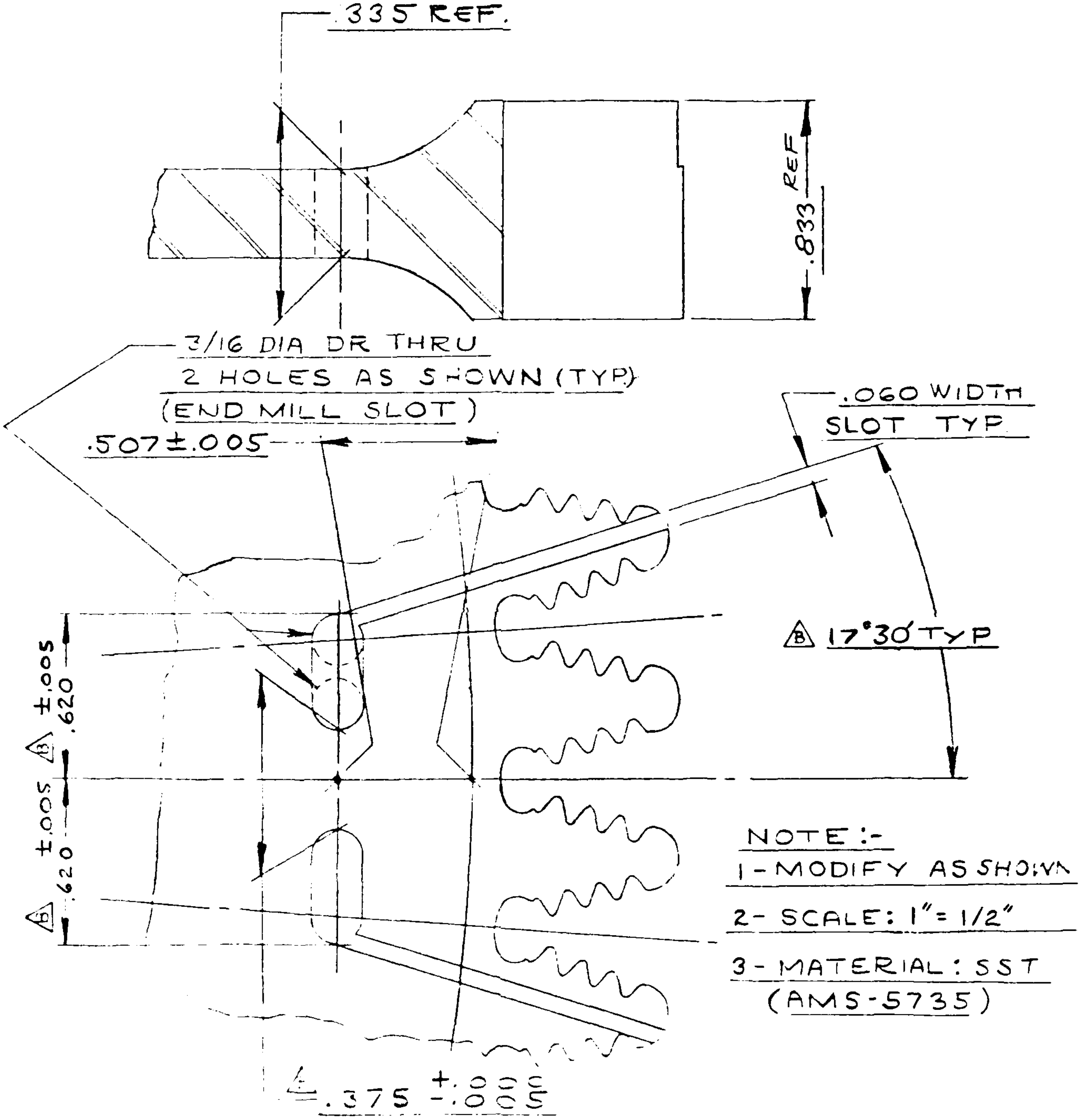
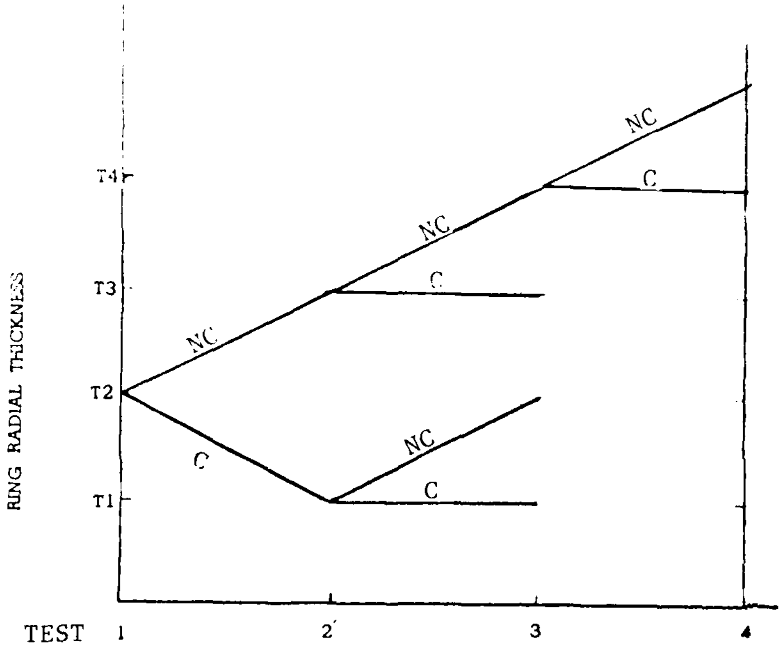


FIGURE 13. TRIPLE BLADE MODIFICATION



C - Contained
NC - Not Contained

FIGURE 14. TEST SCHEME FOR TASK 2

RING RADIAL THICKNESS (inches)	JT3D		JT8D	
	SB	TB	SB	TB
.140	NC		NC	
.187	NC C		C	
.250	C	NC		NC
.375		C		C

SB - Single Blade
TB - Triple Blade
C - Contained
NC - Not Contained

FIGURE 15. TEST MATRIX FOR TASK 2

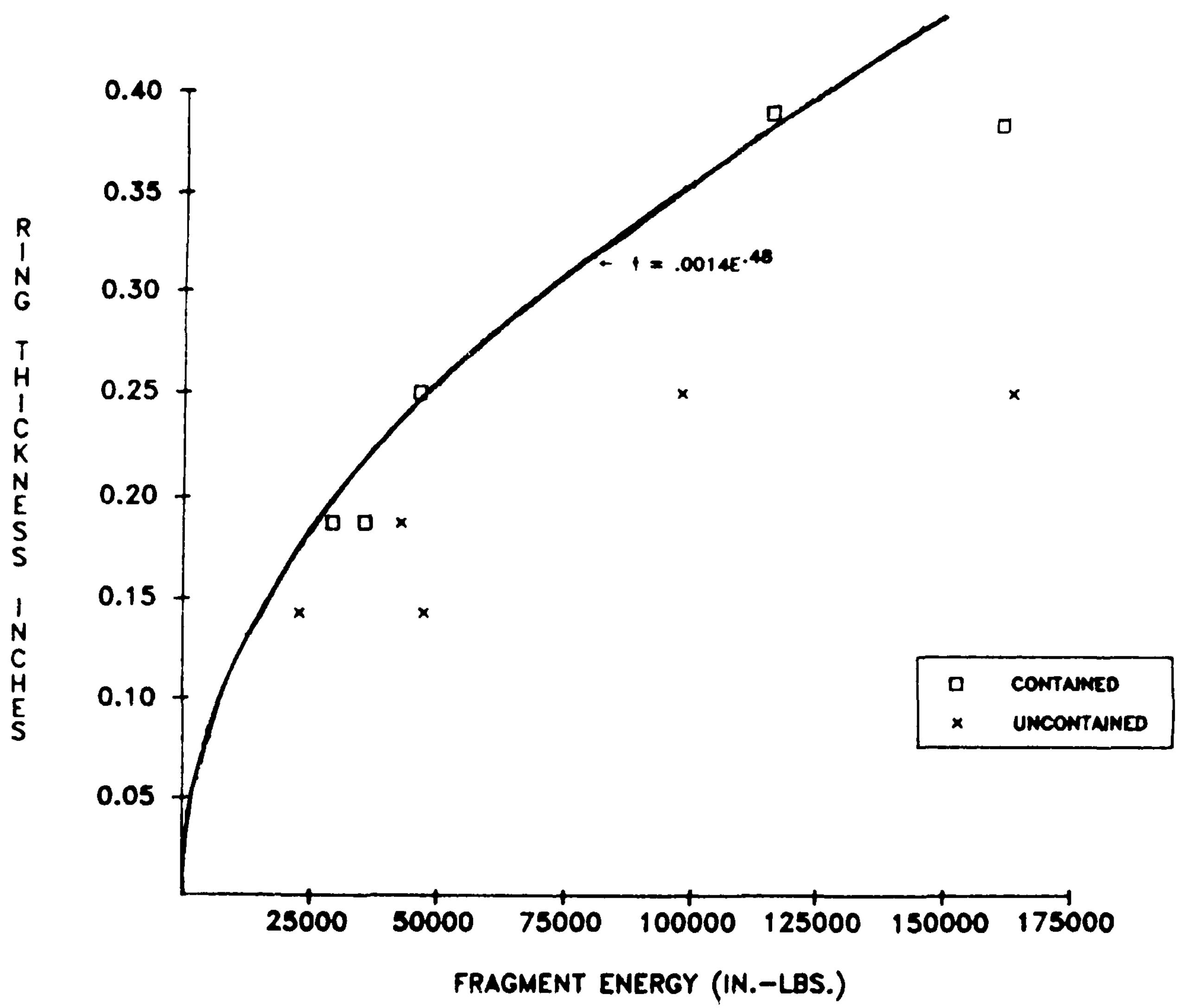


FIGURE 16. FRAGMENT ENERGY VERSUS CONTAINMENT RING THICKNESS

TABLE 1. ROTOR FRAGMENT CONTAINMENT EXPERIMENTS

TEST NO.	DATE	TYPE TEST	ROTOR/DISK TYPE	MATERIAL	DIAMETER INCHES	NO. OF FRAGMENTS	SPEED (RPM)	ENERGY (IN-LBS)	CONTAINMENT/CONTROL CONFIG-URATION	MATERIAL	ID INCHES	THICKNESS INCHES	AXIAL LENGTH INCHES	WEIGHT LBS	RESULTS
215	[illegible]/14/76	RB (1)	TURBINE ROTOR (3)	A-286	14.0	3	19055	851020	RING	KEVLAR (5)	15.0	UNDETERMINED	6.0	5.40	PARTIALLY CONTAINED
218	[illegible]/2/76	RB	TURBINE ROTOR (3)	A-286	14.0	3	20549	989709	RING	KEVLAR (5)	15.4375	UNDETERMINED	6.0	6.659	CONTAINED
219	10/19/76	RB	TURBINE ROTOR (3)	A-286	14.0	6	20605	995111	RING	KEVLAR (5)	15.375	UNDETERMINED	6.109	5.250	NOT CONTAINED
220	12/[illegible]/76	RB	TURBINE ROTOR (3)	A-286	14.0	3	19649	904913	RING	KEVLAR (5)	15.375	UNDETERMINED	6.125	4.75	PARTIALLY CONTAINED
221	2/16/77	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8080	8726768	RING	KEVLAR (5)	32.4	2.5	9.0	57.50	CONTAINED
222	[illegible]/2[illegible]/77	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8272	9036194	RING	KEVLAR (5)	32.125	2.75	12.0	71.47	CONTAINED
226	9/1/77	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8000	8554816	RING	KEVLAR (5)	32.312	2.2	11.0	55.5	NOT CONTAINED
229	11/7/77	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	7960	8469482	RING	KEVLAR (5)	32.375	2.5	12.0	58.5	NOT CONTAINED
241	12/12/80	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8200	8987904	RING	NYLON (7)	32.25	2.5	12.5	65	NOT CONTAINED
243	1/30/81	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	7734	901353	RING	NYLON (7)	31.3125	2.1875	12.5	65	NOT CONTAINED
244	2/2/81	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8300	9 38900	RING	NYLON (7)	31.3125	2.1875	12.5	66	NOT CONTAINED
245	2/4/81	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	7583	7670243	RING	KEVLAR (6)	31.3125	16.5 WRAPS	12.5	65	NOT CONTAINED

DATA COMPILATION FOOTNOTES FOR TABLES 1 AND 2:

(1) Rotor Burst. (2) Blade Burst.

(3) Turbine Rotor T58 Engine, Axial Flow Power Turbine Rotor Tip to Hub Ratio = 2.147, Blade Material: SEL, Rotor Material: A-286 (Figures 1 to 6).

(4) Turbine Rotor Curtiss-Wright J65 Second Stage, Axial Flow.
(5) Kevlar ring fabricated and wrapped by Boeing Company.
(6) Kevlar ring fabricated by Pioneer Parachute Company and wrapped by Navy.
(7) Nylon ring fabricated by Pioneer Parachute Company.

(8) Turbine Rotor Pratt & Whitney JT3D LPT-2, Axial Flow Turbine, Rotor Tip to Hub Ratio = 1.666, Blade Material: AMS 5382, Rotor Material: PWA 1003

(9) Turbine Rotor Pratt & Whitney JT8D LPT-1, Axial Flow Turbine, Rotor Tip to Hub Ratio = 1.458, Blade Material: AMS 5391 (INCONEL 713C), Rotor Material: AMS 5735 (A-286)

TABLE 2. BLADE CONTAINMENT EXPERIMENTS

TEST NO.	DATE	TYPE TEST	ROTOR/DISK						CONTAINMENT/CONTROL						RESULTS
			TYPE	MATERIAL	DIAMETER INCHES	NO. OF FRAGMENTS	SPEED (RPM)	ENERGY (IN-LBS)	CONFIG-URATION	MATERIAL	ID INCHES	THICKNESS INCHES	AXIAL LENGTH INCHES	WEIGHT LBS	
• 236	[illegible]/15/80	88 (2)	JT3D LPT2 (8)	PWA 1003	34.9375	1	7152	50803	FLANGED RING	ALUMINUM	36	1/32	7	3	NOT APPLICABLE
• 237	8/2/80	88	JT3D LPT2	PWA 1003	34.9375	1	6450	41319	FLANGED RING	ALUMINUM	36	1/32	7	3	NOT APPLICABLE
• 238	7/2/80	88	JT3D LPT2	PWA 1003	34.9375	1	6000	35755	—	—	—	—	—	—	NOT APPLICABLE
• 239	[illegible]	88	JT3D LPT2	PWA 1003	34.9375	1	6300	39419	—	—	—	—	—	—	NOT APPLICABLE
• 240	10/1/80	88	JT3D LPT2	PWA 1003	34.9375	1	6492	41860	—	—	—	—	—	—	NOT APPLICABLE
• 242	1/12/81	88	JT3D LPT2	PWA 1003	34.9375	1	7169	49373	RING	304 STAINLESS STEEL	35.05	.390	9	112	NOT APPLICABLE
246	7/14/81	88	JT3D LPT2	PWA 1003	34.94	1	6145	36275	RING	A-286	35.05	.187	9	55	CONTAINED
248	8/9/81	88	JT3D LPT2	PWA 1003	34.94	1	7020	47337	RING	A-286	35.05	.140	9	39	NOT CONTAINED
249	10/9/81	88	JT3D LPT2	PWA 1003	34.9375	1	6736	43580	RING	A-286	35.05	.187	9	54	NOT CONTAINED
250	10/21/81	88	JT3D LPT2	PWA 1003	34.9375	1	6942	46295	RING	A-286	35.05	.250	9	70	CONTAINED
• 251	12/11/81	88	JT3D LPT-2	PWA 1003	34.9375	3	7245	174900	RING	304 STAINLESS STEEL	35.05	.390	99	112	NOT APPLICABLE
• 252	7/27/82	88	JT8D LPT-1 (9)	A-286	27.35	1	•7600	19739	RING	304 STAINLESS STEEL	28	393	9	56.54	NOT APPLICABLE
• 253	8/26/82	88	JT8D LPT-1	A-286	27.35	1	9900	33494	RING	304 STAINLESS STEEL	28	393	9	56.54	NOT APPLICABLE
• 254	9/13/82	88	JT8D LPT-1	A-286	27.35	1	9024	27830	RING	304 STAINLESS STEEL	28	.393	9	56.54	NOT APPLICABLE
256	11/[illegible]/82	88	JT8D LPT-1	A-286	27.35	1	9360	29916	RING	A-286	28	187	9	40	CONTAINED
257	2/10/83	88	JT8D LPT-1	A-286	27.35	1	8290	23406	RING	A-286	28	140	9	32.5	NOT CONTAINED
258	4/7/83	88	JT8D LPT-1	A-286	27.35	3	8200	98945	RING	A-286	28	.250	9	55	NOT CONTAINED
259	7/1/83	88	JT8D LPT-1	A-286	27.35	3	8808	116219	RING	A-286	28	.390	9	89.5	CONTAINED
260	12/14/83	88	JT3D LPT-2	PWA 1003	34.9375	3	6907	163479	RING	A-286	35.05	244	9	69.5	NOT CONTAINED
261	5/20/84	88	JT3D LPT-2	PWA 1003	34.9375	3	6805	161250	RING	A-286	35.05	.304	9	110.5	CONTAINED

• Indicates preliminary test

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APPENDIX A

CLOTH CONTAINMENT RINGS MANUFACTURING TECHNIQUE

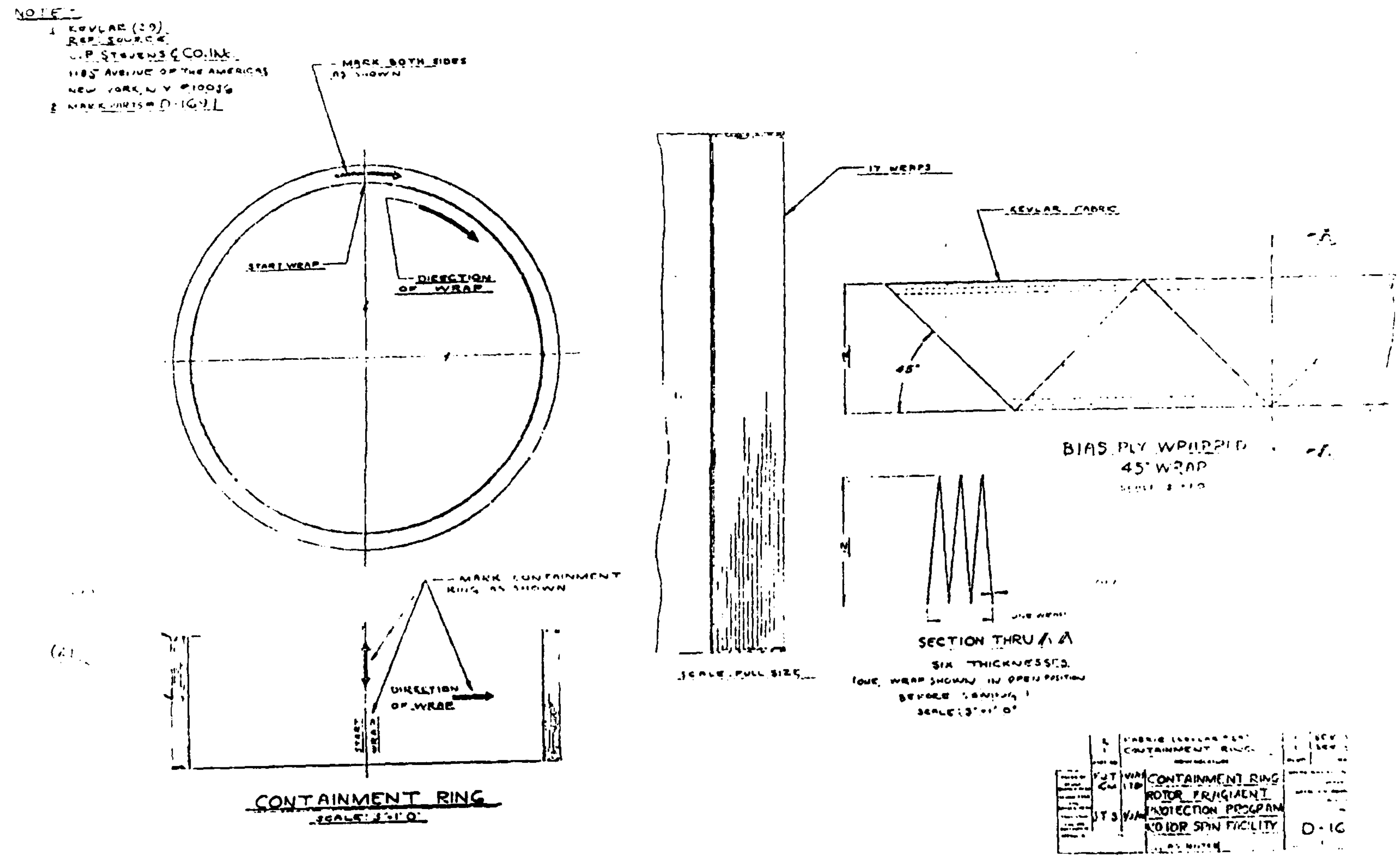

FIGURE A-1. KEVLAR CONTAINMENT RING MANUFACTURING DRAWING (1 OF 3)

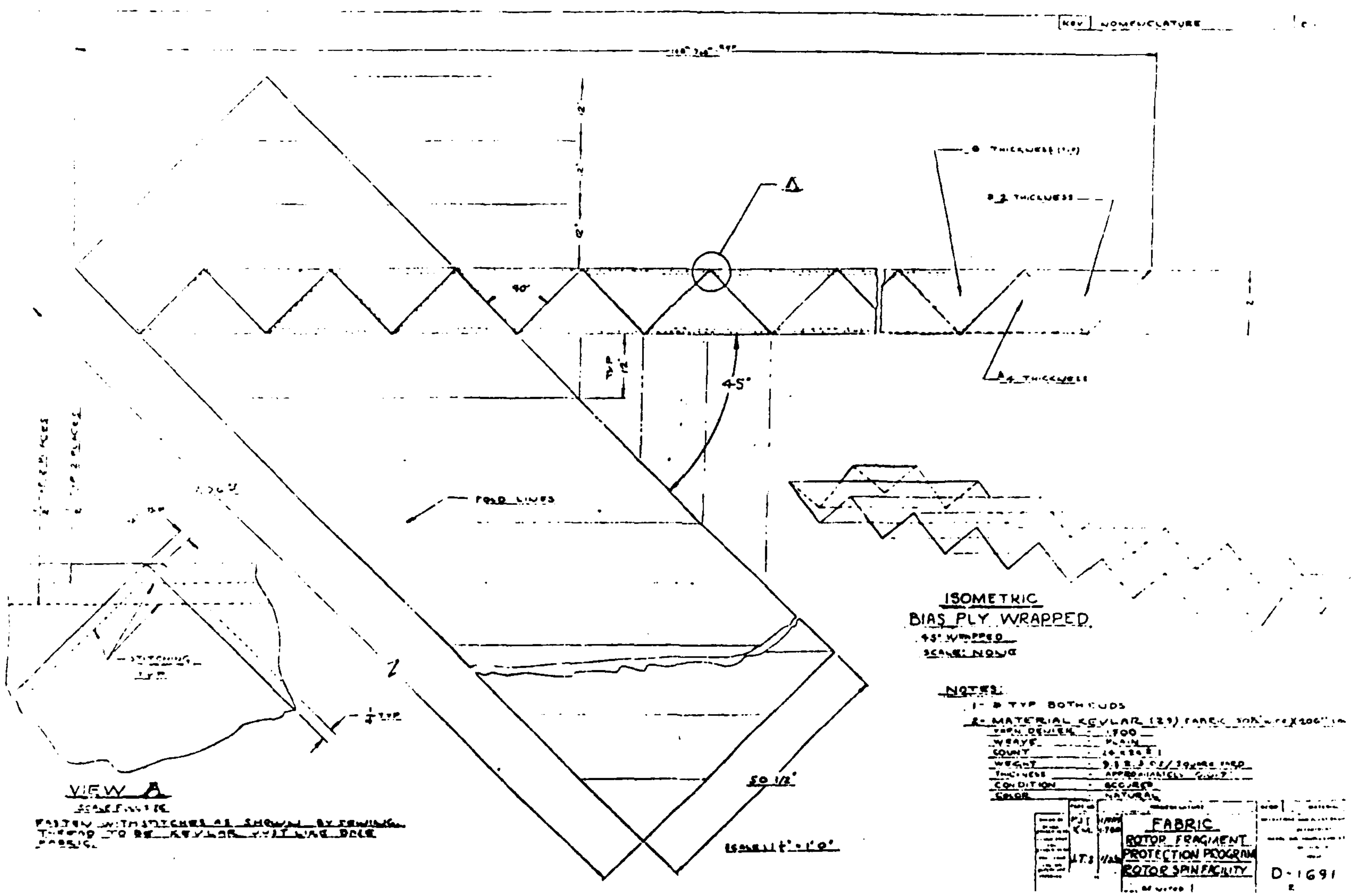

FIGURE A-2. KEVLAR CONTAINMENT RING MANUFACTURING DRAWING (2 OF 3)

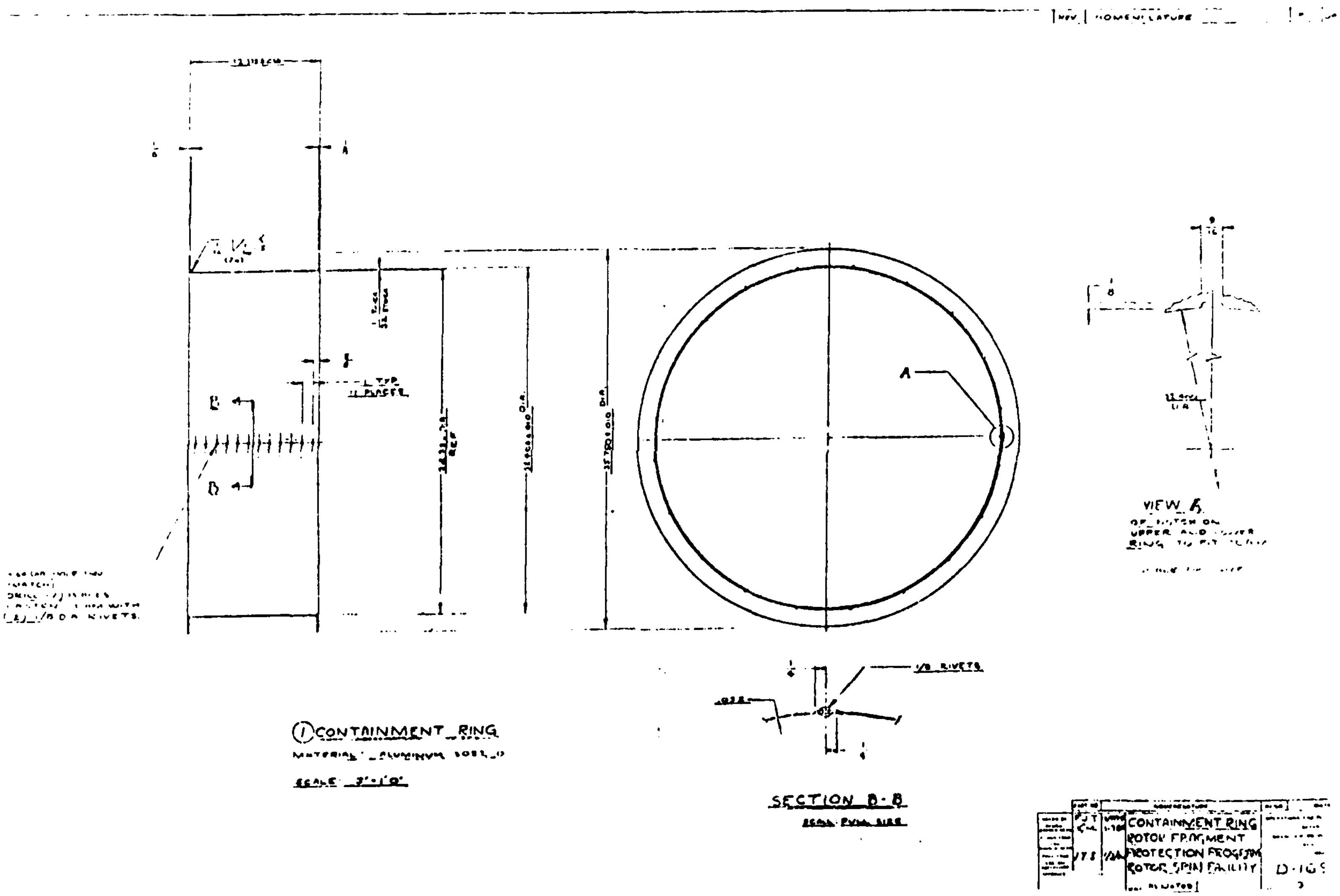

FIGURE A-3. KEVLAR CONTAINMENT RING MANUFACTURING DRAWING (3 OF 3)

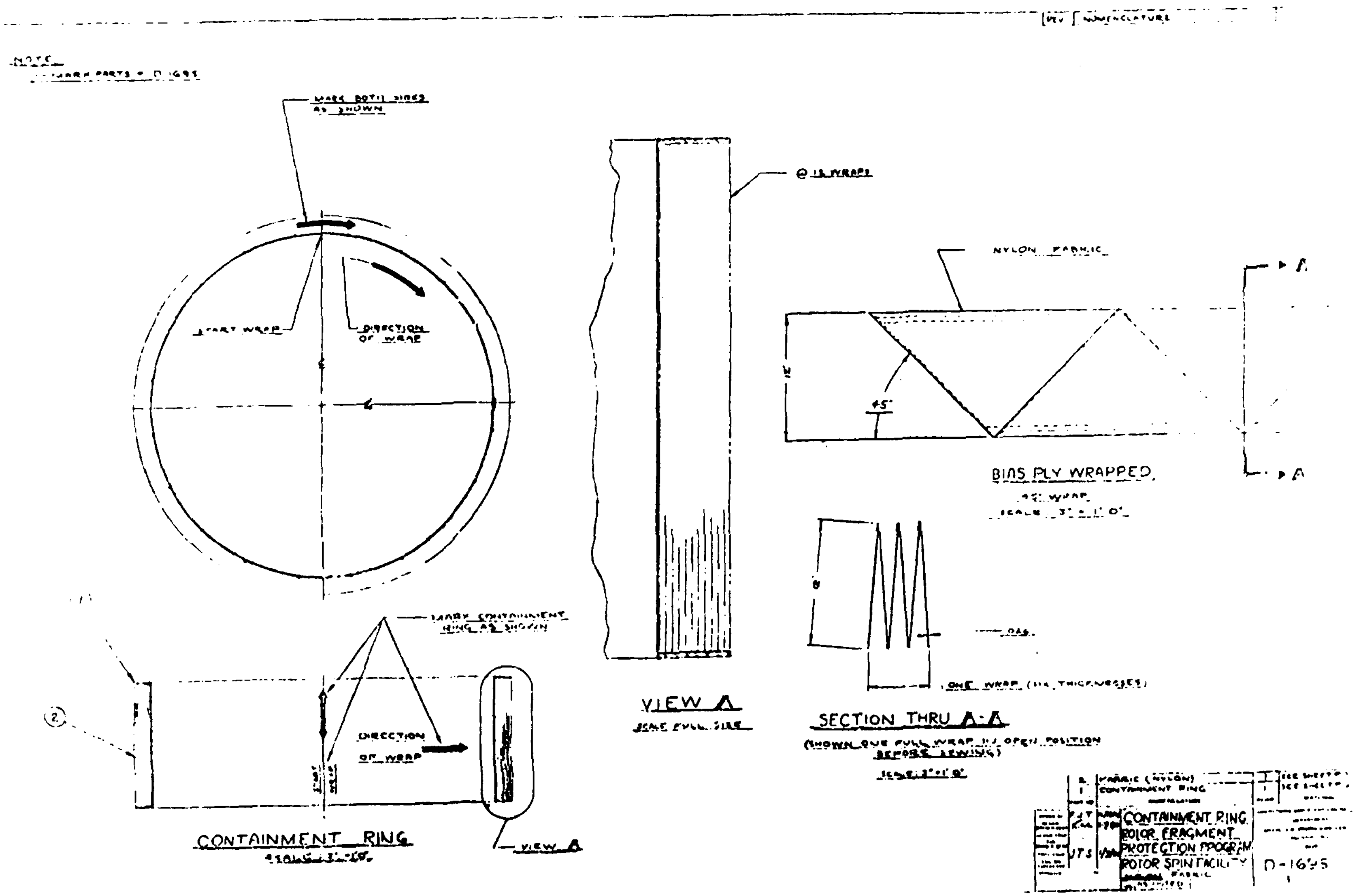

FIGURE A-4. NYLON CONTAINMENT RING MANUFACTURING DRAWING (1 OF 3)

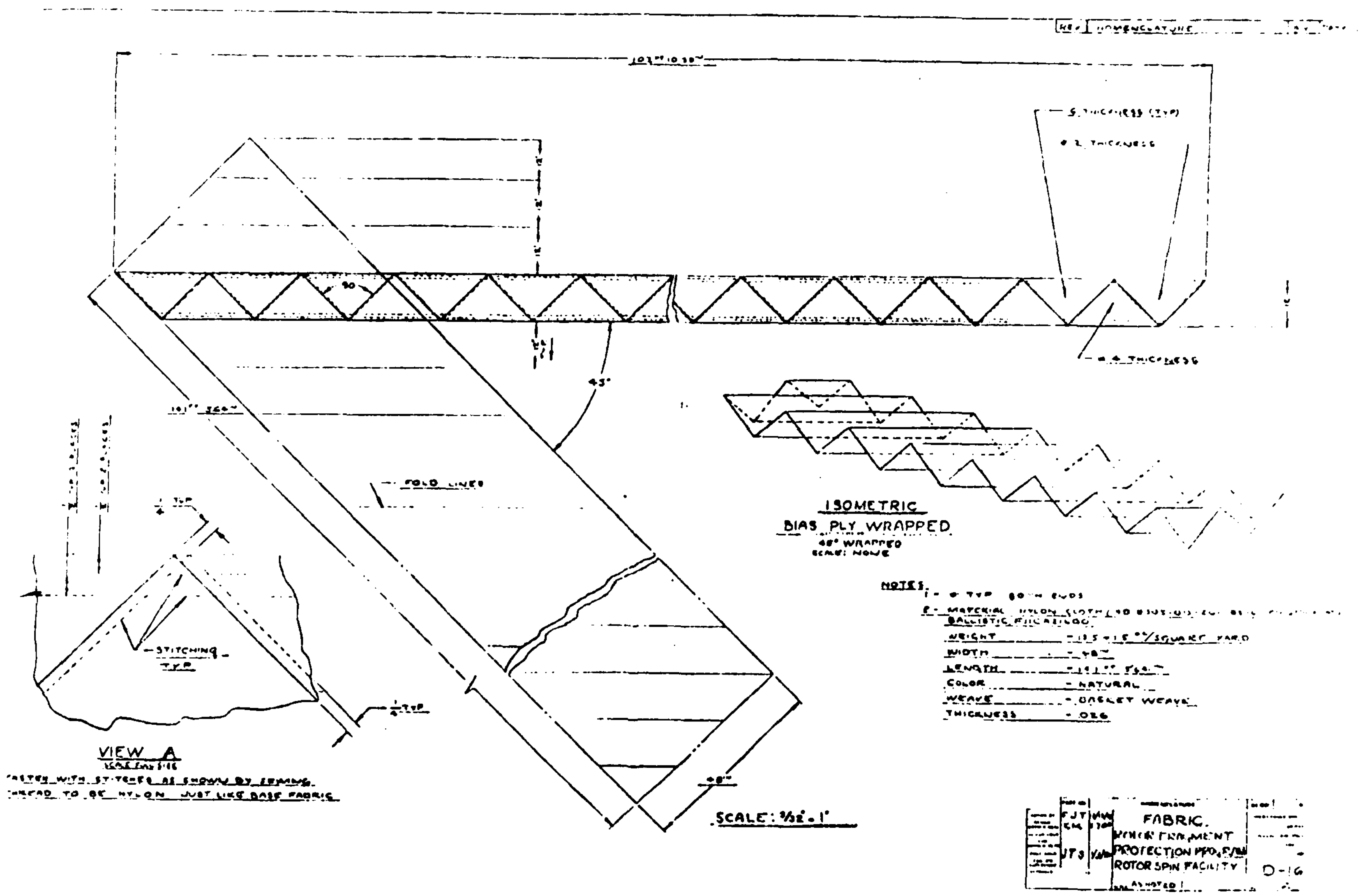

FIGURE A-5. NYLON CONTAINMENT RING MANUFACTURING DRAWING (2 OF 3)

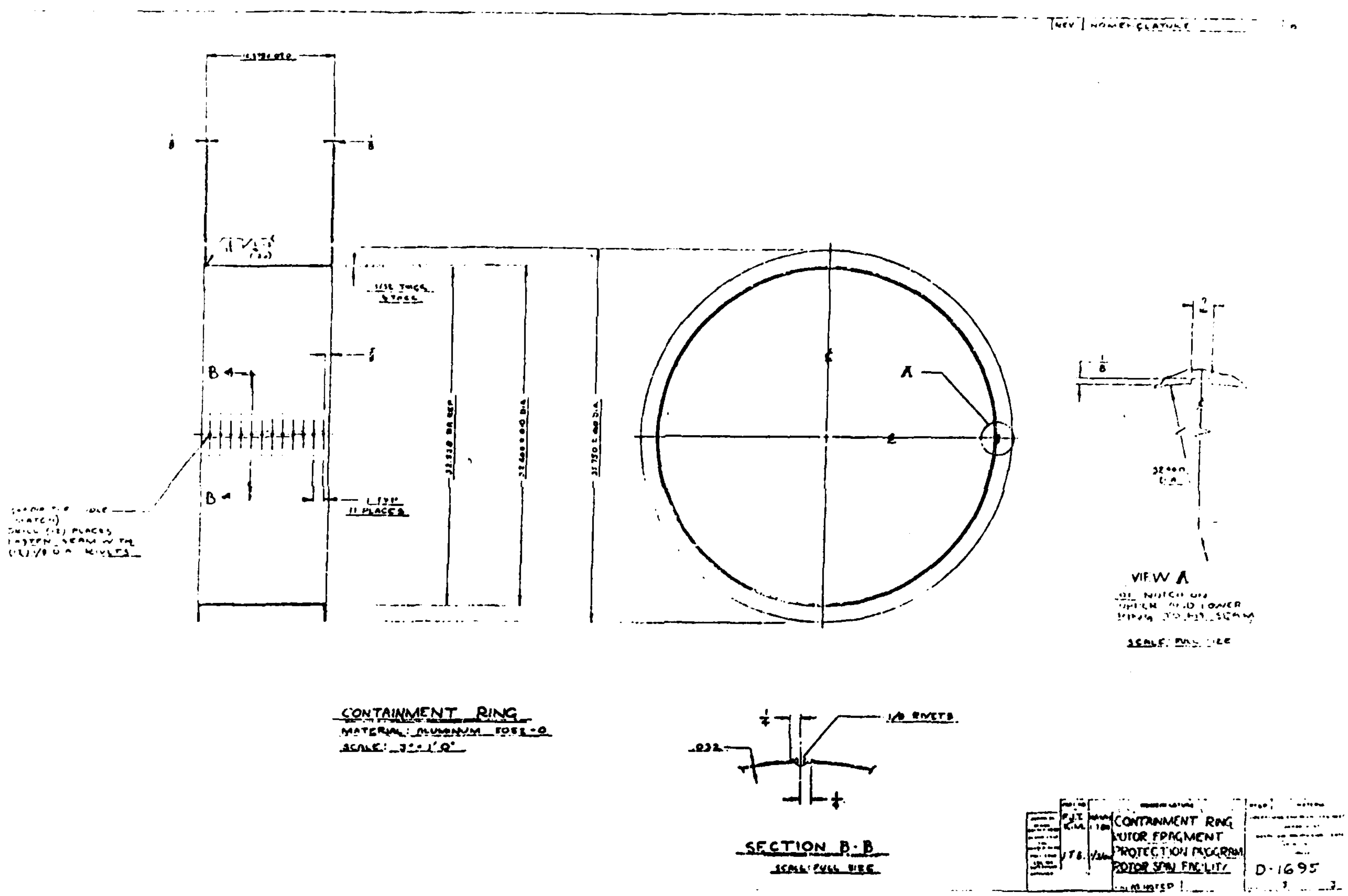

FIGURE A-6. NYLON CONTAINMENT RING MANUFACTURING DRAWING (3 OF 3)

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