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FEASIBILITY STUDY OF 105 MM M68 COMPOSITE BORE EVACUATOR

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The feasibility of fabricating a 105 MM M68 composite bore evacuator by the filament winding process has been demonstrated. Design and fabrication procedures for the manufacturing of this type of bore evacuator are presented in this report.

ACKNOWLEDGMENT

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INTRODUCTION

Rapid fire tank or closed-cab mounted guns (105 mm M68, 90 mm M41, 76 mm M32, 120 mm M58, 155 mm M185) have a tendency to discharge propellant gases into the cab when the breech is opened to receive the next round. This reverse flow impairs the crew's sight as well as breathing.

An effective measure used in the prevention of reverse flow is a bore evacuator. The evacuator is simply a gas reservoir that is attached to the gun tube. The operating principle is that when the pressure in the bore drops below that in the evacuator, which occurs after firing, the stored gas is drawn out toward the muzzle. The flow of gas from evacuator toward muzzle creates a partial vacuum into which clean air enters, thus flushing the bore and precluding reverse propellant gas flow into the gun compartment. Presently bore evacuators vary in weight from around 67 lbs (105 mm M68) to about 200 lbs (155 mm M185) and cost from \$350 (105 mm M68) to about \$800 (155 mm M185). Various machining, cutting and welding operations are performed in the fabrication of present bore evacuators. This report introduces a novel bore evacuator made of fiber glass/epoxy material which is expected to cut weight and cost by 67 and 50 percent respectively.

DESIGN

A typical bore evacuator consists of two axisymmetric transition zones as depicted in Figure 1. The composite concept consists of a cylindrical body bonded to two similar domes and reinforced by a filament wound overwrap (Figure 2). The procedures for tailoring the composite properties to a specific application are well understood. Computer programs "LAMCOMB", "TRNZNE", and "GEOD" described in Watervliet Technical Report WVT-TR-74014 have been employed in the design and programming of the filament winding machine used in the actual fabrication of the 105 mm M68 composite bore evacuator. Table 1 presents input and output of "TRNZNE", the composite elastic constants under input were obtained from "LAMCOMB".

From Table 1 one can clearly see that the concept is safe when a maximum internal pressure of 500 psi is considered.

Table 2 shows that for the max pressure the lap joint has a factor of safety 2. To this, additional safety is produced by the overwrap which will be discussed in the fabrication procedure.

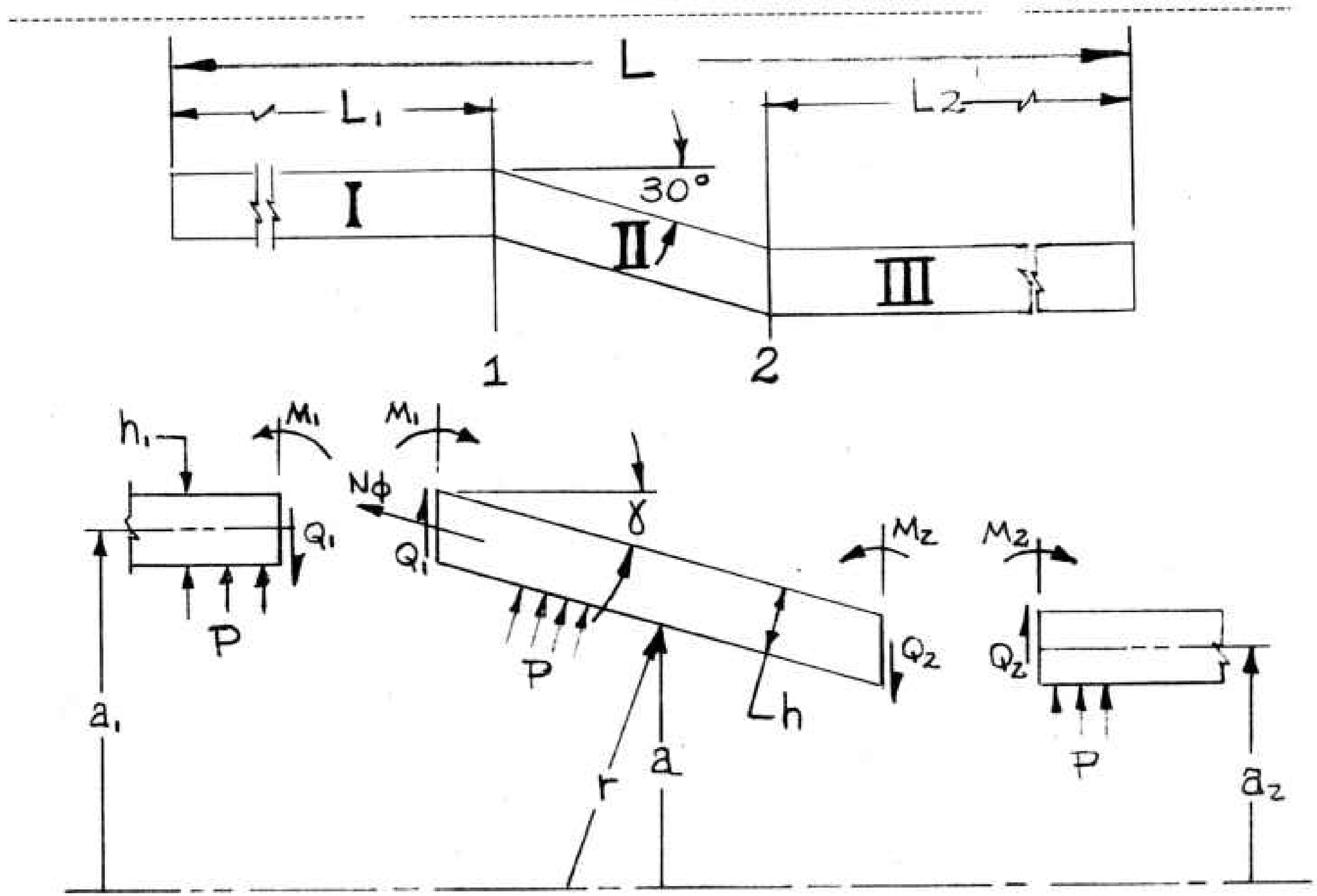


FIGURE 1. Schematic of a Typical Transition Zone.

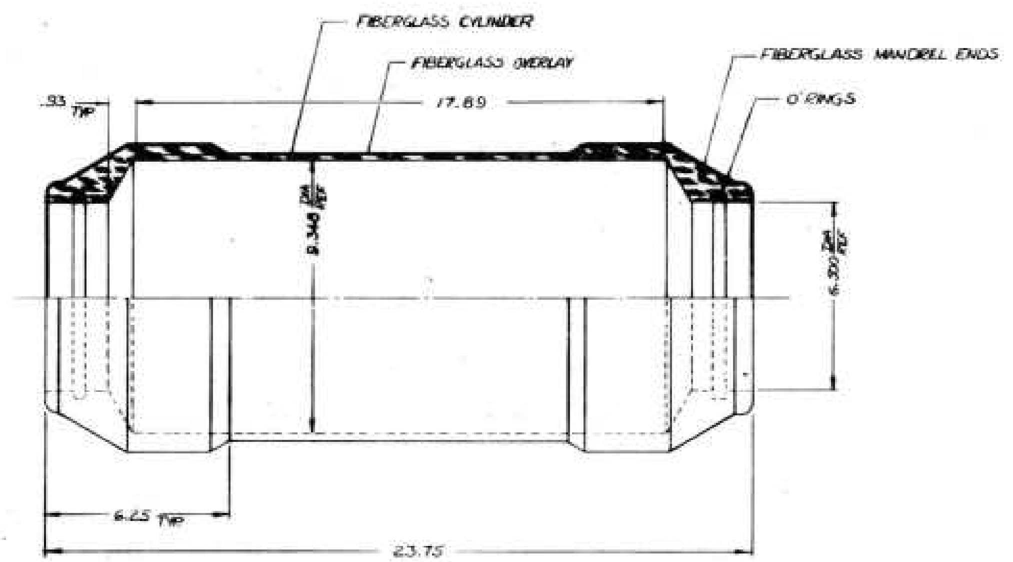


FIGURE 2. 105 mm M68 Composite Bore Evacuator.

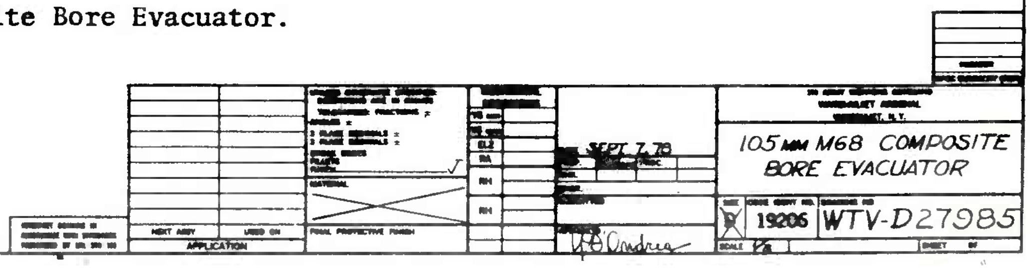


TABLE 1. TRNZNE RESULTS

INPUT:

	a in.	h in.	L in	E $x10^6$ psi	ν	D $x10^6$ psi	G $x10^6$	K	γ
1	4.987	.25	3	5.1	.475	.020	2.02	68%	30°
2	3.46	.376	.93	3.4	.5	.042	1.84		

*OUTPUT:

	W $x10^{-4}$	Θ $x10^{-6}$	M $x10^{-1}$	Q $x10^{-1}$	σ_c	σ_a	σ_{ab}	σ_{cb}	$\sigma_{eq.}$
1	-.176	.397	-.404	-.758	18	5.1	± 3.87	± 1.83	20
2	-.103	.015	.123	.728	10	0	± .5	± .25	10

a = axial; b = bending; c = circumferential; eq = equivalent
K = filament Volume ratio; D = Flexural Modulus; G = shear modulus
W = linear deflection; Θ = angular deflection; M = bending moment;
Q = shearing force
h = thickness; L = length of action; ν = poisson ratio

*All output is non-dimensionalized by dividing by the pressure "P".

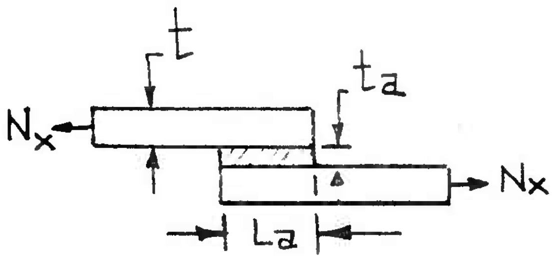
TABLE 2. LAP JOINT ANALYSIS (REF. 1)

$$f^{s}_{2,avg} = \frac{N_x}{L2} = 216 \text{ psi}$$

$$\bar{f}^{s}_{1,max} = \frac{1}{4}\,[\omega L_2(1+3\alpha)\,\frac{\cosh 2x}{\sinh \omega\, L2} + 3(1-\alpha)]f^{s}_{2,avg}$$

$$= \bar{K}\, f^{s}_{2,avg} = 13.6\, f^{s}_{2,avg}$$

$$= 2937.6$$



$$\text{then:}\quad F.S. = \frac{F^{su}_{2}}{\bar{f}^{s}_{2,max}} = \frac{5.5}{2.9} \simeq 2$$

<u>NOTE</u>

$$\alpha = 1 + \{1+2\sqrt{3}\,\tanh[\,\frac{L_2}{t}\,(\frac{3(1-\lambda_{xy})N_x}{2Ex\ t})^{1/2}]\} = .56$$

$$\omega = [\frac{2(1-\lambda_{xy})G_2}{Ex\ t_2\ t}]^{1/2} = 6.75$$

where

N_x = 646.6#/in

L_2 = 3"

t_2 = .002

G_2 = 75 Ksi

t = .25

E_x = 5.1 Msi

λ_{xy} = .225

F^{su}_{2} = 5500 psi

$\lambda_{xy} = \nu_{xy}\,\nu_{yx}$

a = adhesive

$f^{s}_{a,avg}$ = apparent shear stress in adhesive

$\bar{f}^{s}_{a,max}$ = theoretical shear stress in adhesive

F^{su}_{a} = ultimate shear stress strength in adhesive

---

[1]USAF's "Advanced Composite Design Guide," (Volume 2) AD 916-680, Jan. 1973.

FABRICATION

The fiber glass bore evacuator was fabricated in three stages using pre-preg S-glass/epoxy roving. The winding was accomplished on a servo-controlled, programmable filament winding machine explained in detail in Reference 2[2]. A constant tension of 6#/end was maintained as the winding tension.

Stage 1

This first operation called for the fabrication of the evacuator's end domes. This was accomplished on the mandrel shown in Figure 3. The dimensional and assembly drawings are shown in Figures 4 and 5.

The uniqueness of this winding operation lies in the fact that the evacuator's O-ring slots were wound into the end domes. A continuous winding program was developed from "GEOD", which enabled on each pass, the placement of the fibers along side, up-over-down, and along side the split rings shown in Figure 3. This type of construction results in a groove which has much greater integrity, than one-built-in with only hoop windings or one that is machined in after fabrication. In addition, this perturbed helical pattern provided the ± 45° angle, on the large diameter, needed for the bonding operation.

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[2] D'Andrea, G., Cullinan, R., "Development of: Design Analysis, Manufacturing, and Testing of the 81 mm XM73 Fiber Glass/Epoxy Recoilless Rifle," June 1974, WVT-TR-74014.

FIGURE 3. Evacuator's End Domes and Mandrel.

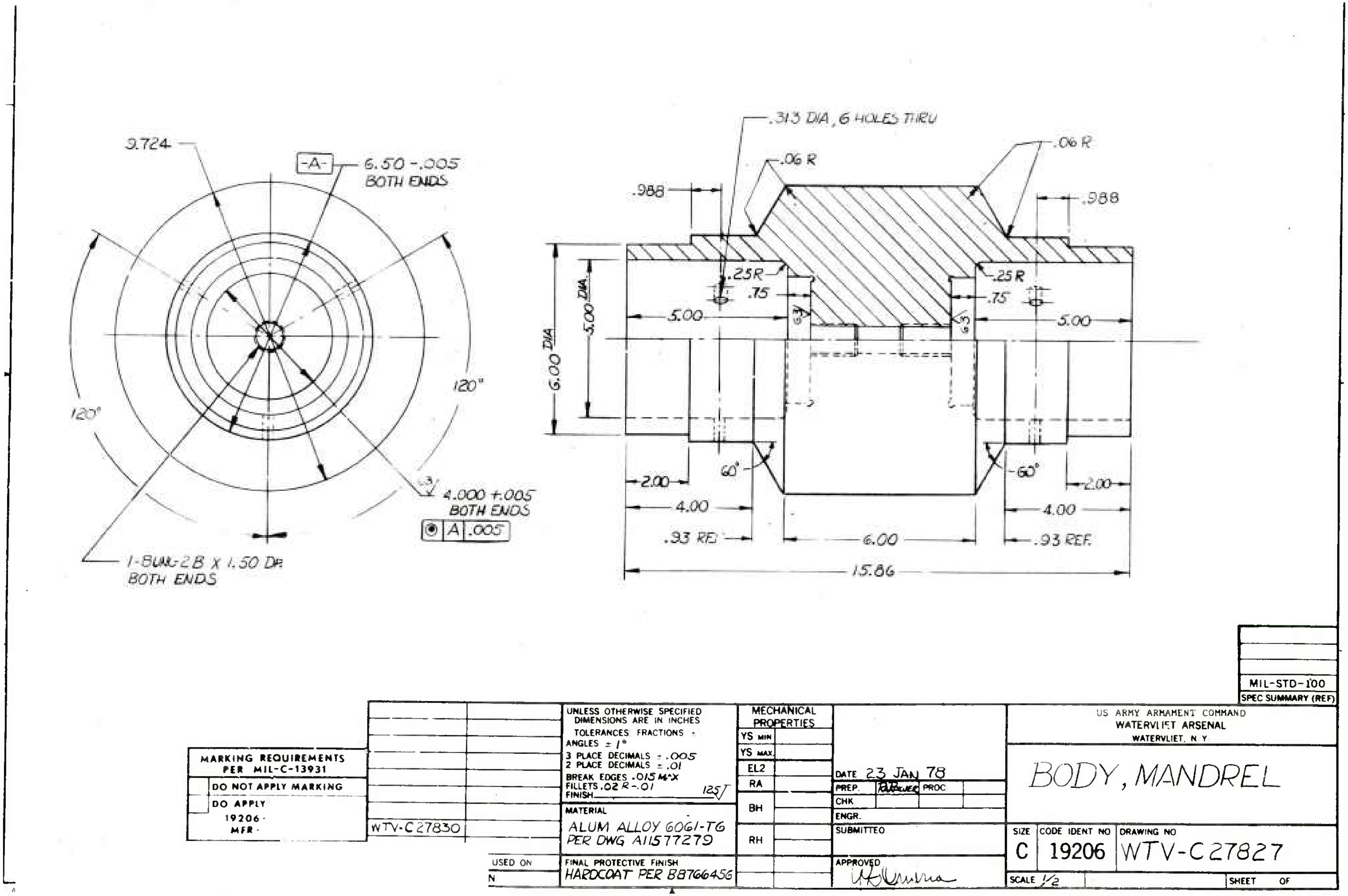


FIGURE 4. Mandrel Body of Evacuator's End Domes.

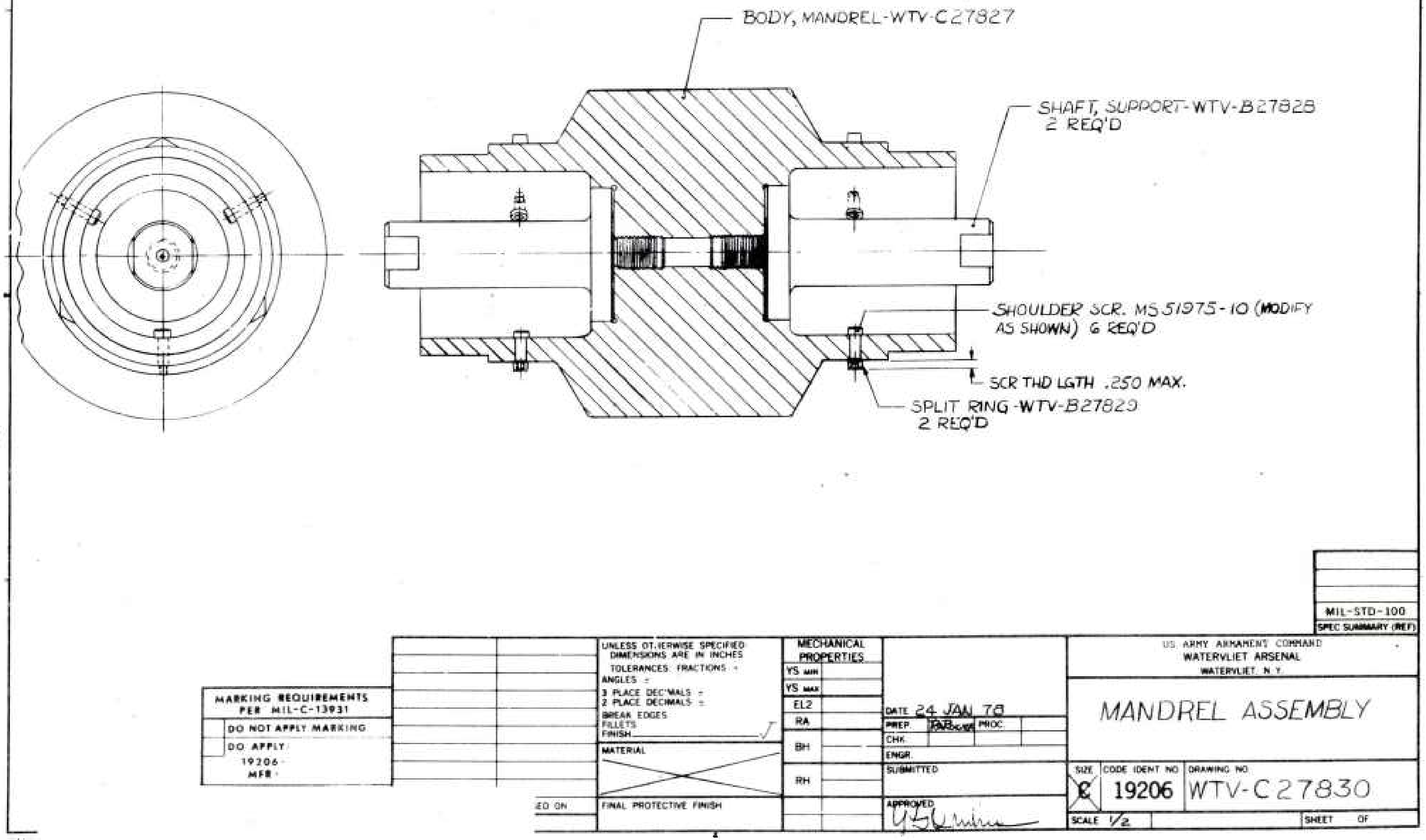


FIGURE 5. Mandrel Assembly of Evacuator's End Domes.

Figure 6 shows additional output which is received from "GEOD" along with every winding program. For this initial pattern, a schematic dimensional profile of the mandrel to be wound is shown in Figure 6a. Figure 6b shows the variation in the angle of wrap as the filament is wound along the length of the mandrel.

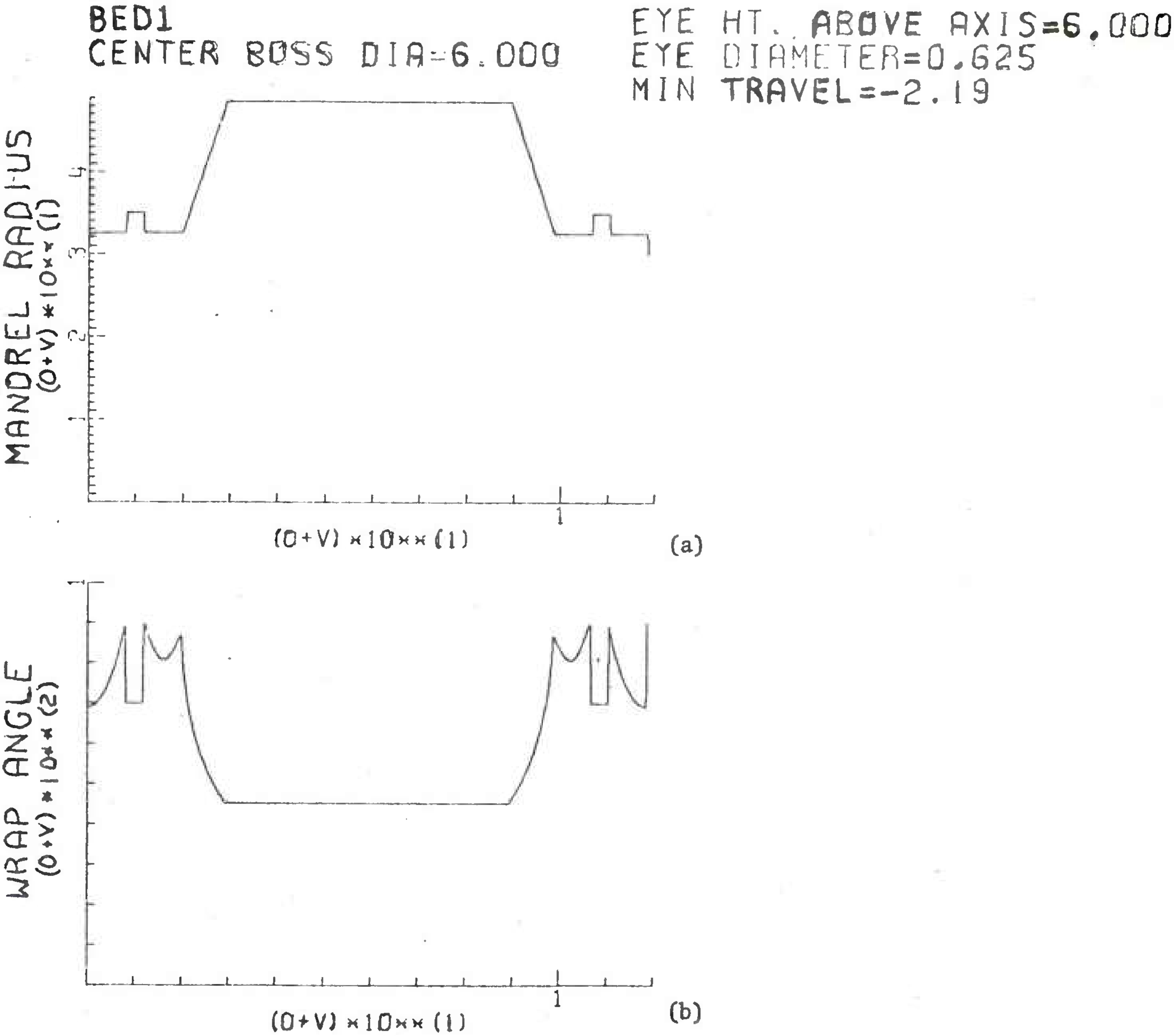
The actual fabrication procedure called for one complete helical pattern (2 layers). Hoop layers were then added on both sides in the area of split rings to provide an even thickness, .250" above the top of the split ring. An additional hoop layer was wound across the top of the large diameter.

A second helical winding program was developed to wrap the body of the mandrel. This concept is shown in Figure 7. Eleven helical patterns (22 layers) and a finishing hoop layer were wound to provide for a total thickness build-up of .250" at the large diameter.

Figure 8a shows the schematic of the initial windings, which now become mandrel dimensions for this second program. Figure 8b is the variation in the wrap angle as the item is wound.

The finish winding was rotated in the winder and gelled (200°F) for 2 hours. It was then placed in a 350°F oven for 3 hours to develop the final cure of the epoxy resin.

After cure and cooling, the fiberglass was finished machined at both ends and a parting cut was made in the center of the large diameter. This resulted in two mirror-image domes which then could be removed from the mandrel as shown in Figure 3.



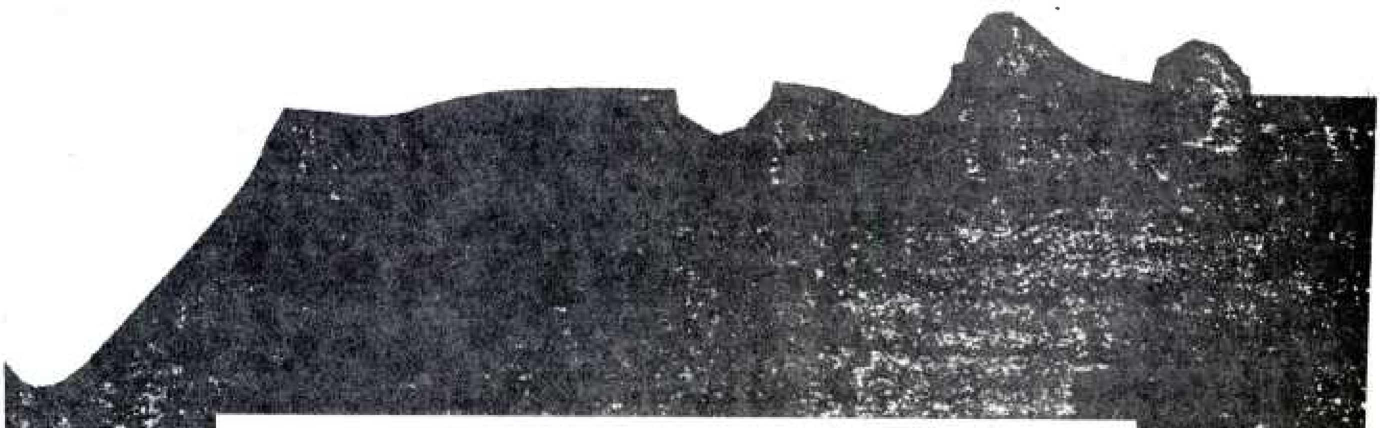
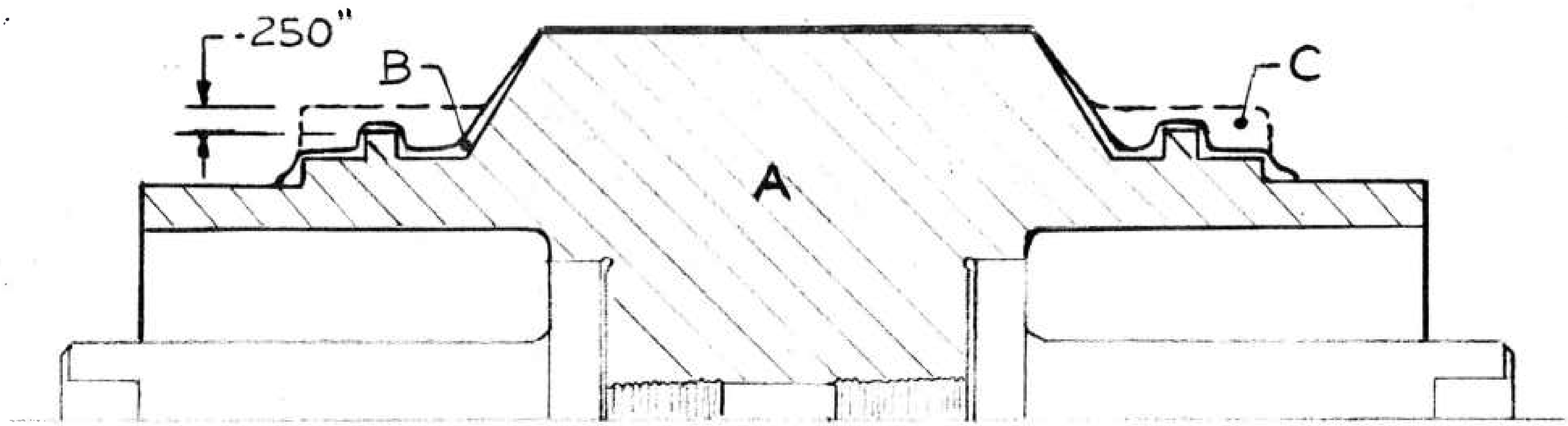


FIGURE 6. Output from GEOD (End Domes, First Stage).



A - ORIGINAL END DOME MANDREL

B - AFTER WINDING 1st HELIX PATTERN (BED1)

C - ADDITIONAL HOOP WINDING TO EVEN BOTH SIDES FOR THE WINDING OF BED2.

FIGURE 7. Winding Sequence (End Domes).

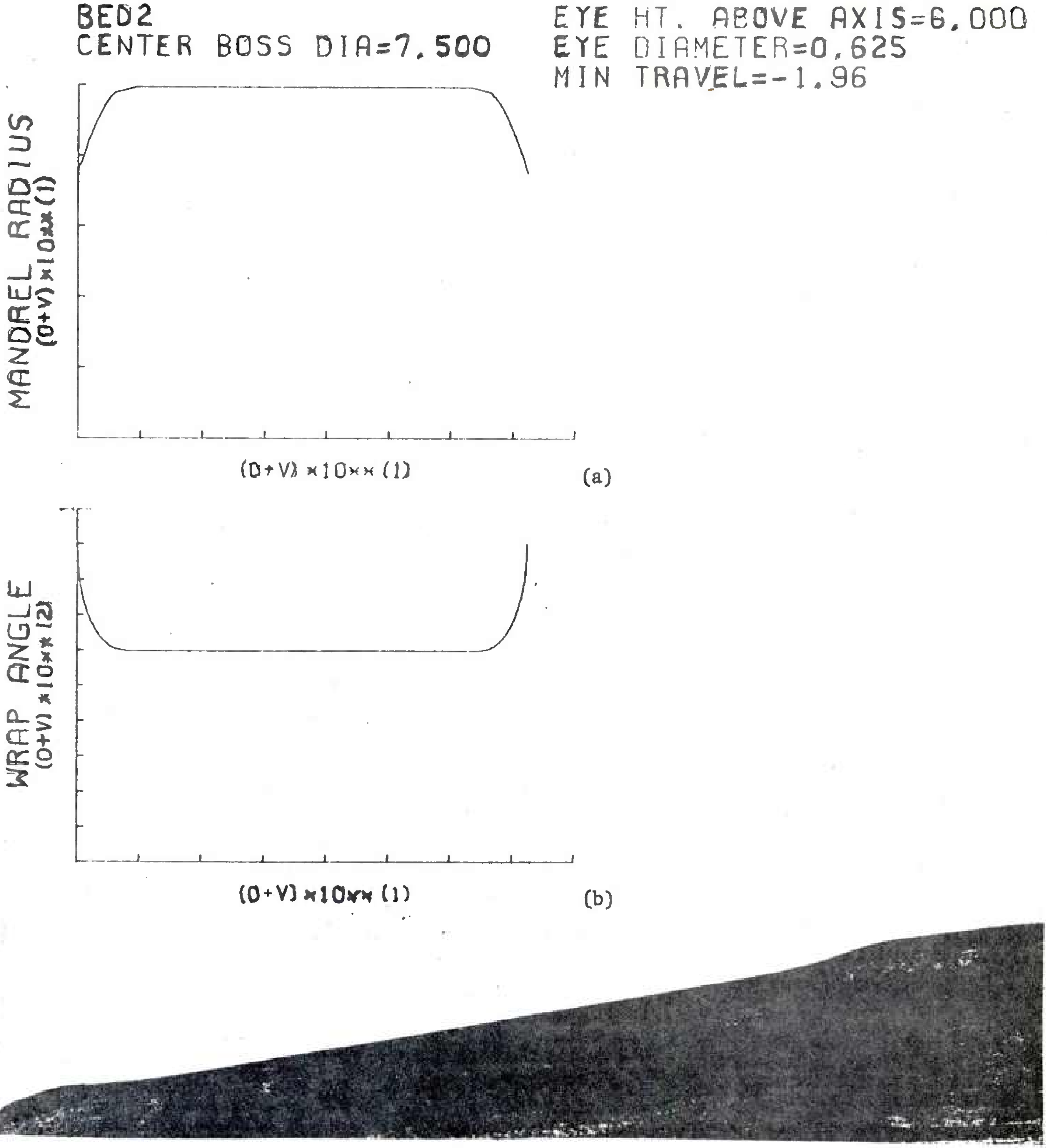


FIGURE 8. Output from GEOD (End Domes, Second Stage).

The mandrel design, as shown in Figures 4 and 5, called for three segments to make up the split ring. Each segment was held in place, on the mandrel, by internal screws. In order to remove the fiber glass domes, these screws were removed and the split ring came out with the dome. The individual segments were then removed from the inside of the fiberglass domes, each having a perfectly formed O-ring groove. This groove with an O-ring in place, can be seen inside of the freed dome shown in Figure 3.

Stage 2

This second operation involved the fabrication of the evacuator body. It called for the winding of a simple cylinder on the mandrel shown in Figure 9. The angle of wrap for this winding was ± 54°. Figure 10 gives the mandrel profile and the angle of wrap along the length of the cylinder.

Nine helical patterns (18 layers) were wound. In addition five hoop layers were interspaced to bring the cylinder to an O.D. of 9.730". The gelling and curing of the resin was carried out in the same manner as explained in Stage 1.

The cylinder was then machined to an O.D. of 9.714" for a length of 3.0" at each end. This value is .010" under the I.D.'s of the domes fabricated in Stage 1. This was to provide a .005" bond line between the domes and body. A slim cut was taken over the center portion to rough up the surface for future windings of Stage 3. Mandrel and cylinder are shown in Figure 11.

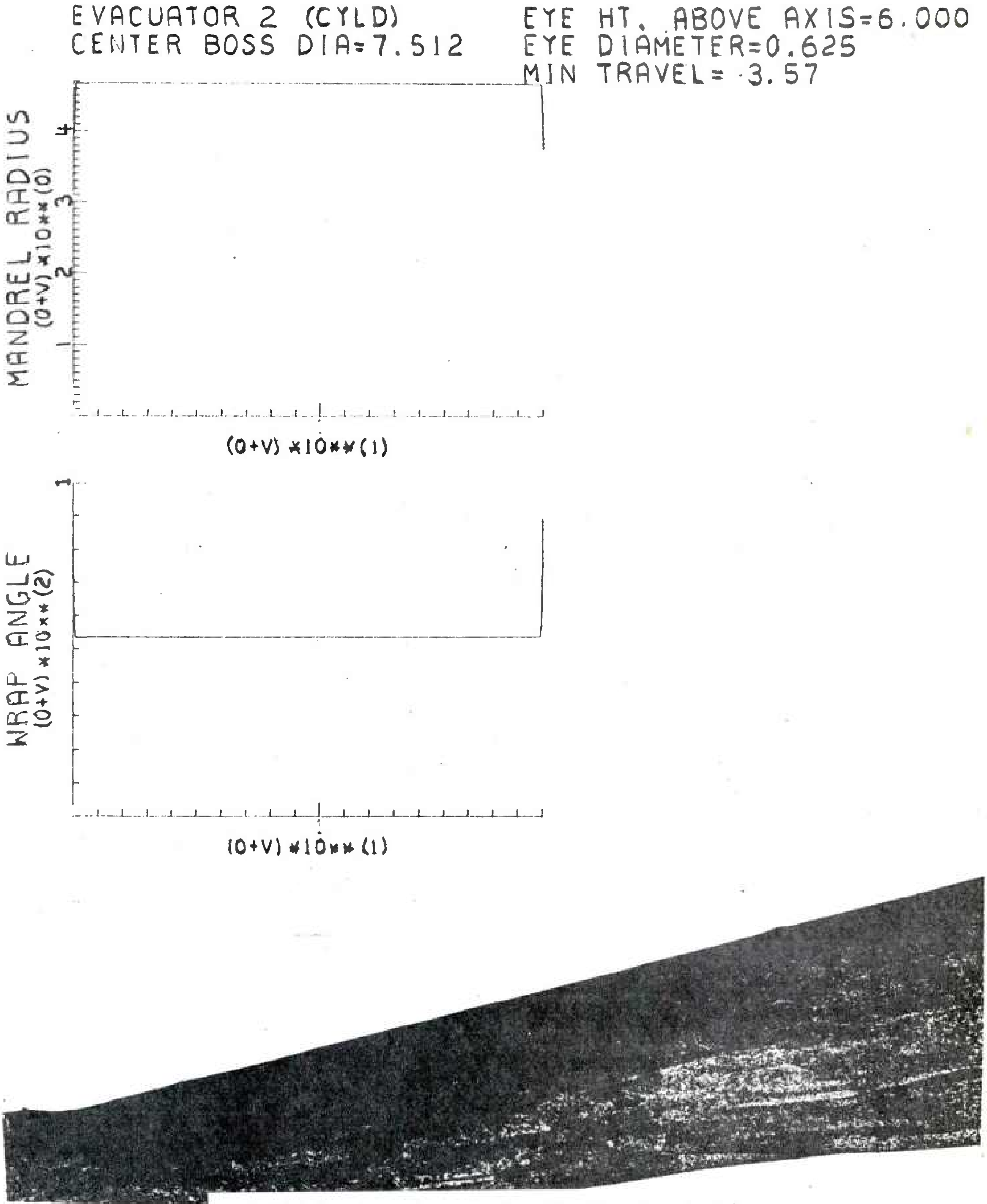


FIGURE 9. Output from GEOD (Cylindrical Body).

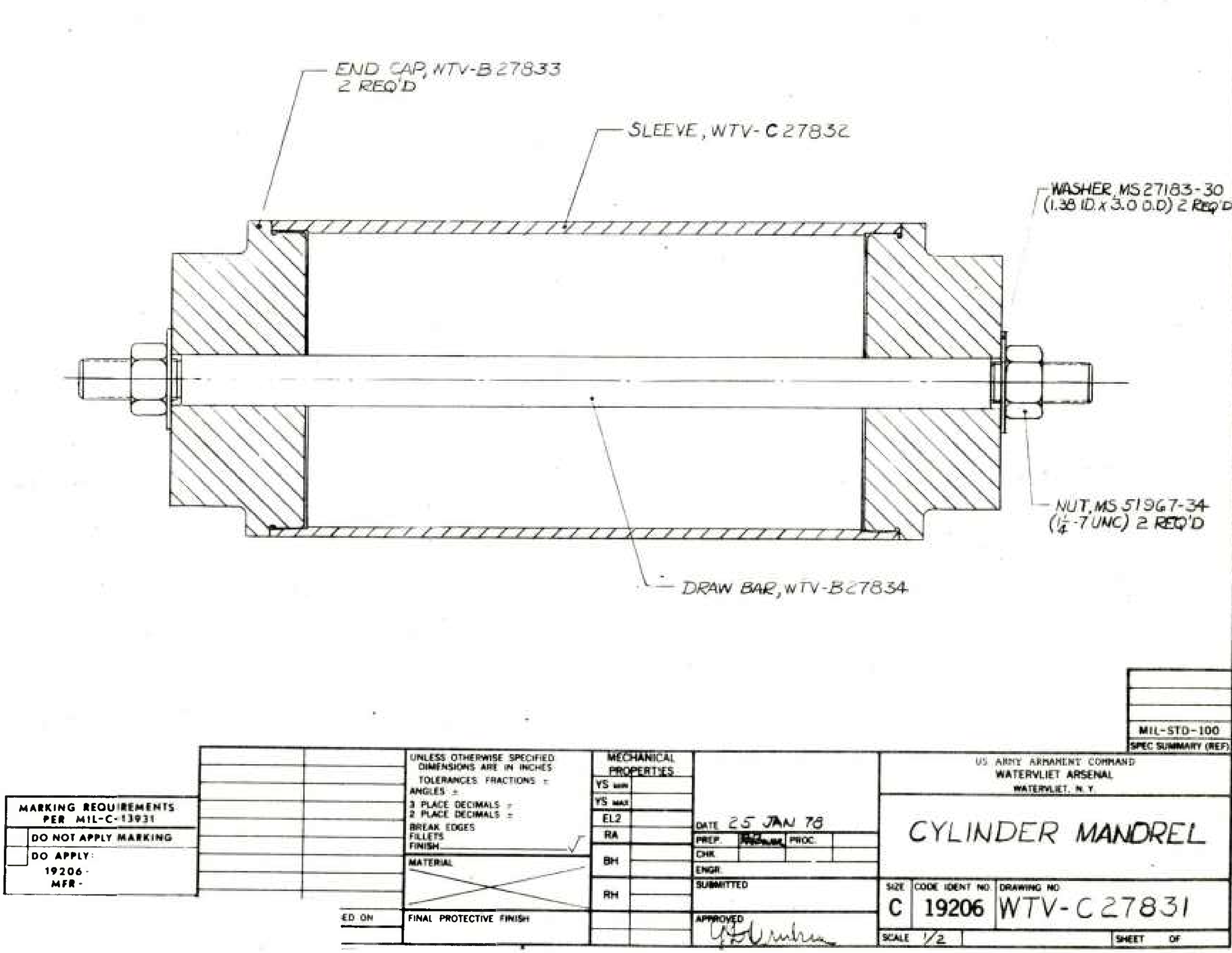


FIGURE 10. Evacuator's Cylinder Mandrel.

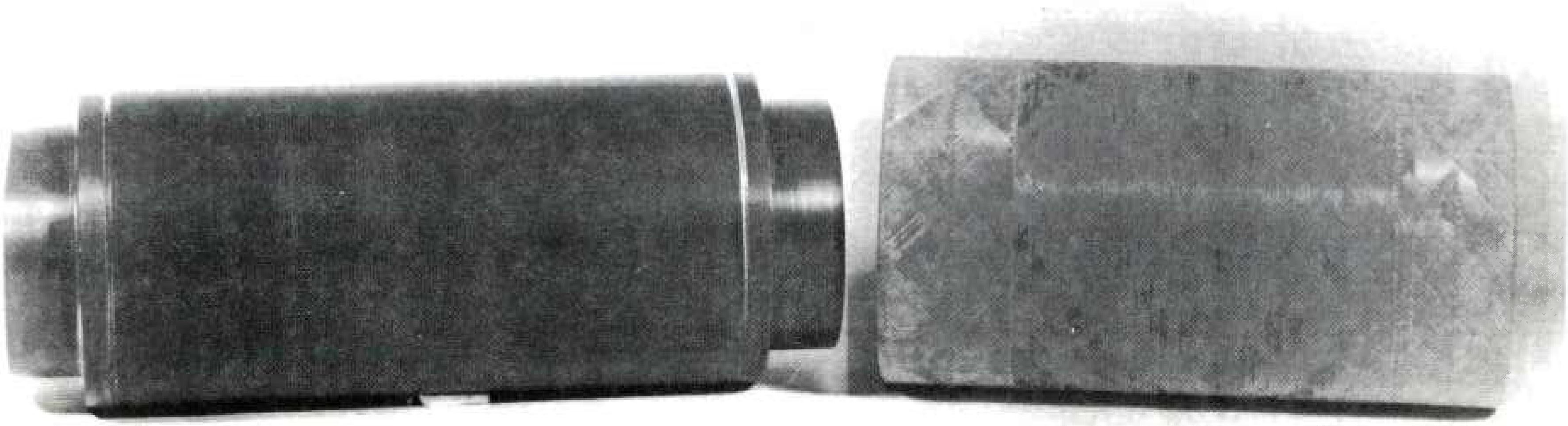


FIGURE 11. Evacuator's Cylindrical Body and Mandrel.

The end domes were then bonded to the cylinder with an epoxy/polyamide adhesive.

Stage 3

The final stage called for helical wrapping over the entire assembly. Although, as shown in the Design Section, the adhesive should be able to take the loads, this helical wrap was an additional safety factor and tied the structure together.

The bonded assembly from Stage 2 was placed on the mandrel shown in Figure 12. It was held in place on the mandrel by using actual O-rings in the O-ring groove. This provided enough friction to hold the assembly in place during winding.

Three helical patterns were wound over the entire assembly. Figure 13 shows the mandrel dimensions and the angles of wrap. The resin was gelled and cured as mentioned above.

The only machining required for this final end item was a finishing of the shoulders at both ends. A view of the final product is shown in Figure 14.

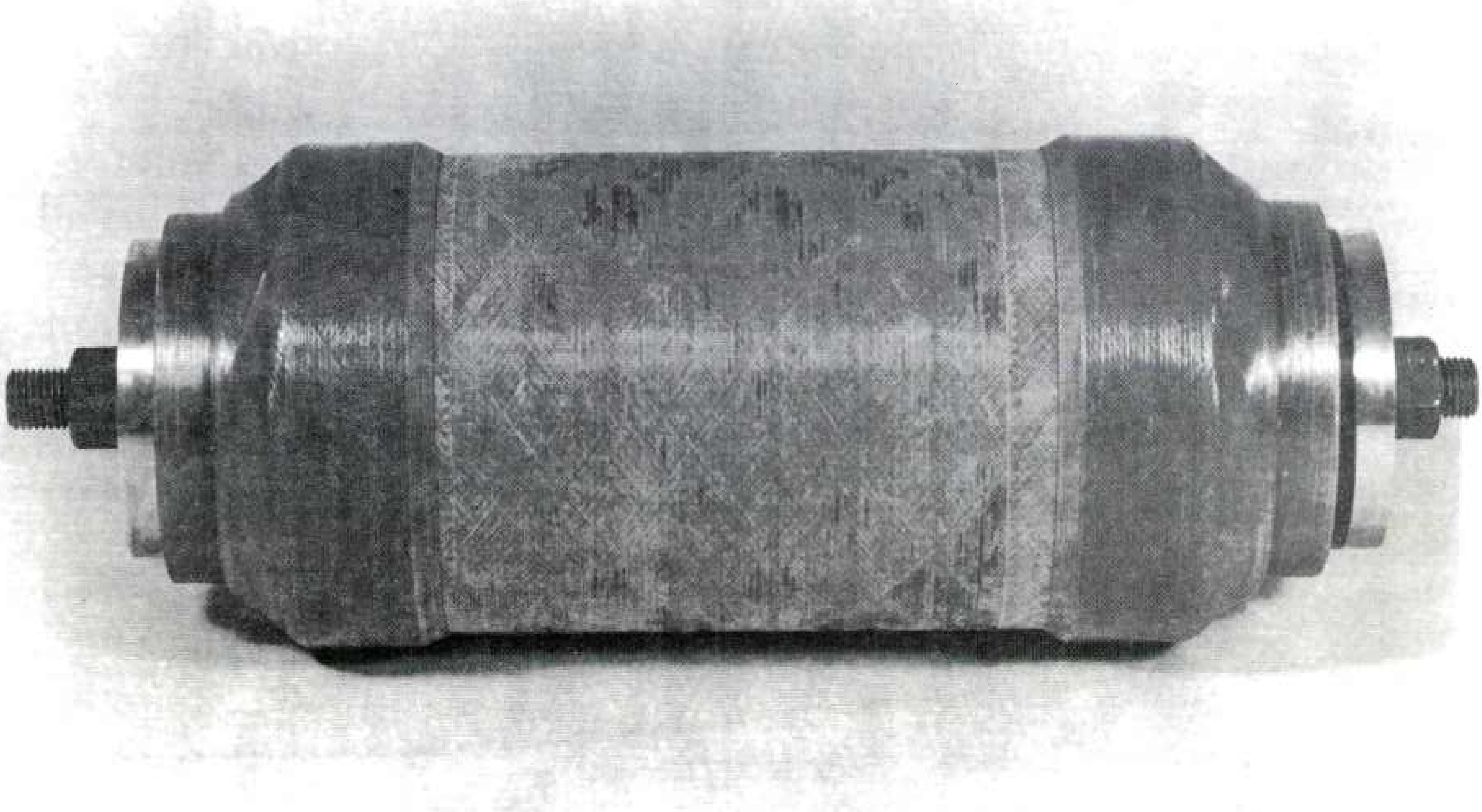


FIGURE 12. Bonding Assembly of Evacuator's End Domes and Cylindrical Body.

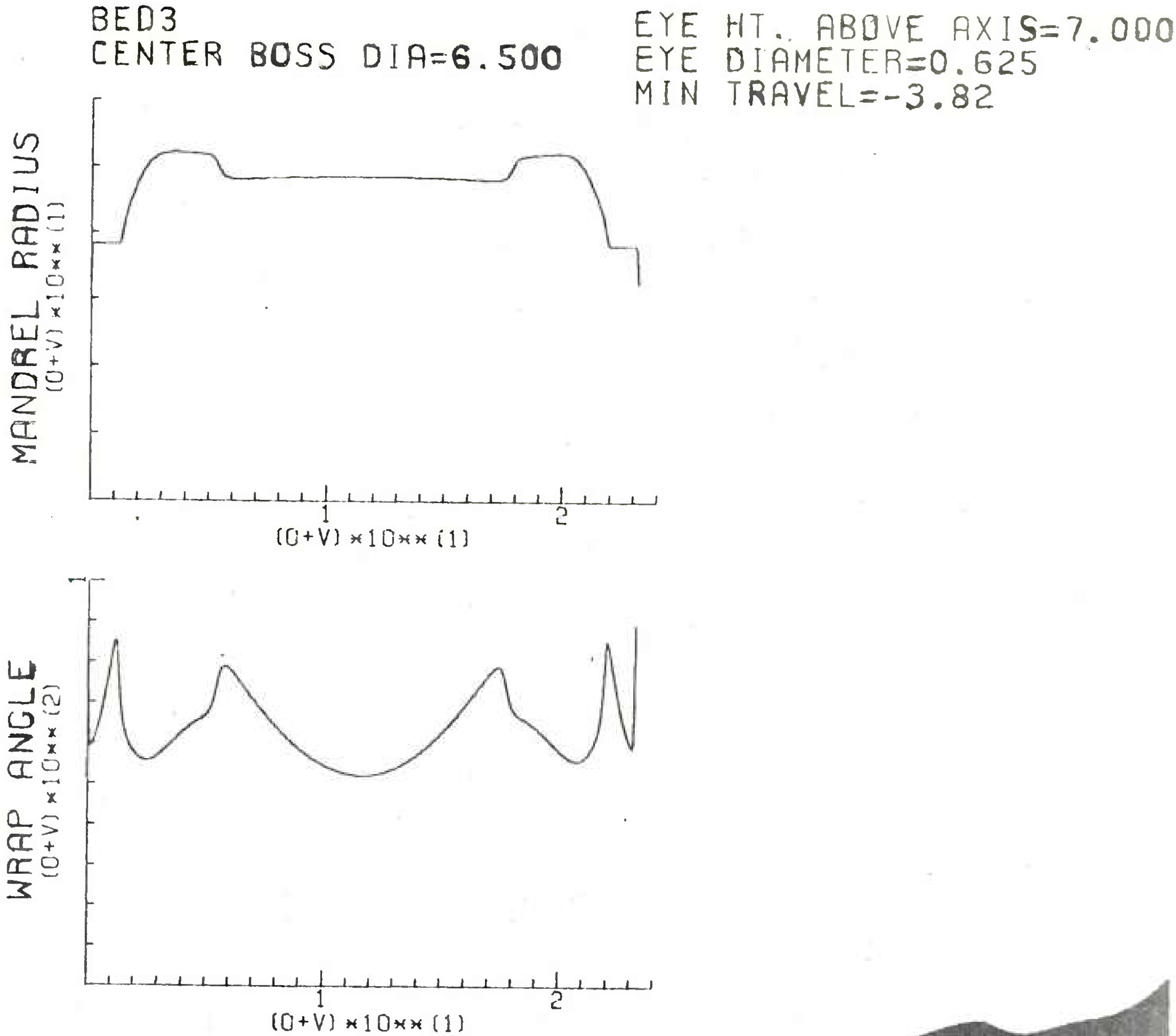


FIGURE 13. Output from GEOD to Overwrap Bonded Bore Evacuator

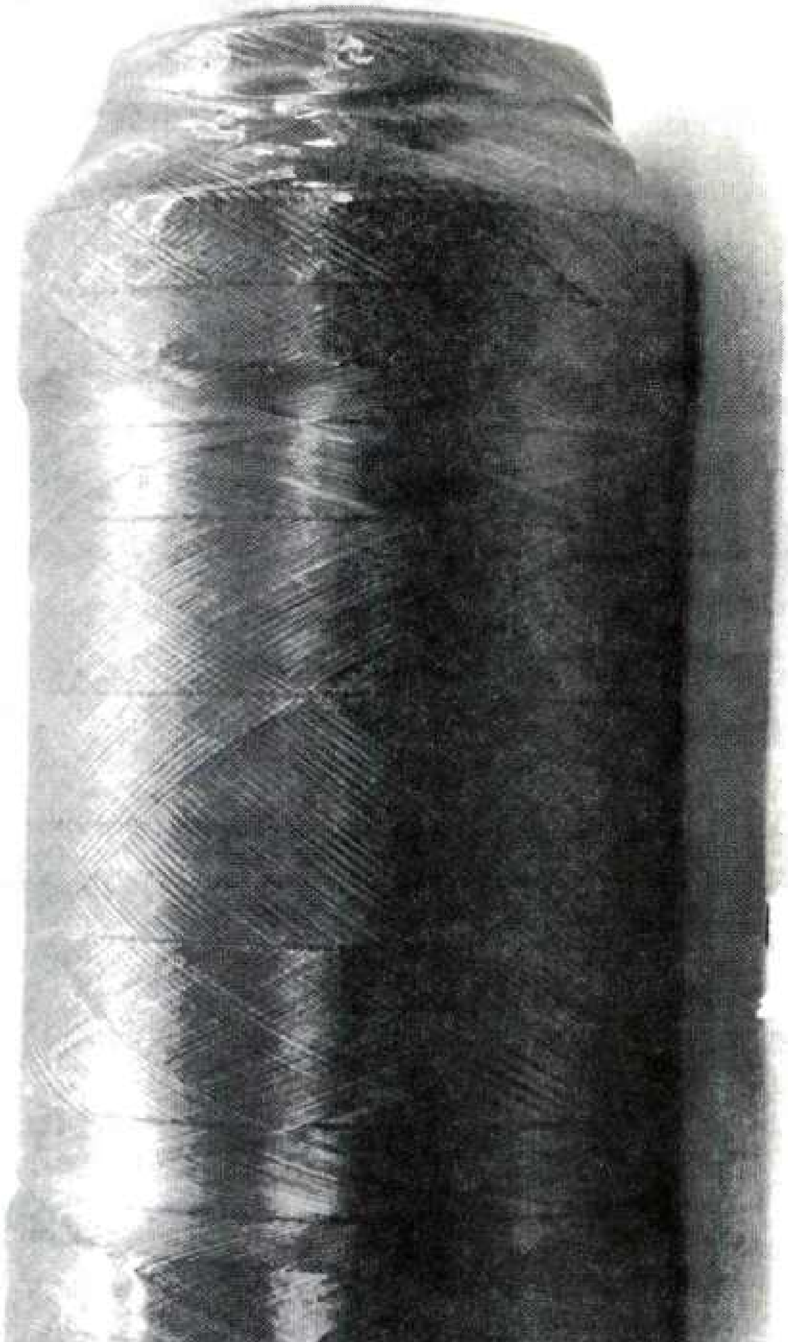


FIGURE 14. Finished 105 mm M68 Composite Bore Evacuator

CONCLUSIONS

1. The feasibility of fabricating a 105 mm M68 bore evacuator by the filament winding process has been demonstrated. Using a fiber glass/epoxy system, for equivalent strength, the estimated weight and cost savings as compared to a steel evacuator are 67% and 50% respectively. The developed design and fabrication methodology are adaptable to the spectrum of bore evacuators.

2. Materials analysis indicates acceptable resistance to the common weather and chemical environments such as: bore cleaner, diesel fuel, red oil, and propellant gases.

3. Previous tests conducted on a similar structure (105 mm thermal shroud[3]),indicate sufficient resistance to damage from (a) contact with trees and foilage under traveling modes and (b) rough handling during assembly and disassembly.

4. To complete the demonstration of the feasibility of a filament wound fiber glass/epoxy bore evacuator, firing tests should be performed to access:

1. Bore evacuator - tube surface gas leakage
2. Performance over operational temperature range
3. Effects of reduced mass on accuracy and dispersion

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[3] D'Andrea, G., et al, "105 mm M68 Thermal Shroud," November 1972, WVT-7249.

REFERENCES

1. USAF's "Advanced Composite Design Guide," (Volume 2) AD 916-680, January 1973.

2. D'Andrea, G., Cullinan, R., "Development of: Design Analysis, Manufacturing, and Testing of the 81 mm XM73 Fiber Glass/Epoxy Recoilless Rifle," June 1974, WVT-TR-74014.

3. D'Andrea, G., et al, "105 mm M68 Thermal Shroud," November 1972, WVT-7249.

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