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TECHNICAL REPORT TL-77-4

EFFECTS OF PROOF TESTING AND  
TEMPERATURE/HUMIDITY ON A  
CANDIDATE VIPER MOTOR  
CASE MATERIAL

**U.S. ARMY  
MISSILE  
RESEARCH  
AND  
DEVELOPMENT  
COMMAND**

Ground Equipment and Missile Structures Directorate  
Technology Laboratory

21 March 1977

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TECHNICAL REPORT TL-77-4

**EFFECTS OF PROOF TESTING AND TEMPERATURE/HUMIDITY  
ON A CANDIDATE VIPER MOTOR CASE MATERIAL**

R. J. Thompson, O. C. Fruchtnicht, and J. B. Cobb

**DA Project No. 1X66462D072  
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Technology Laboratory  
US Army Missile Research and Development Command  
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## I. INTRODUCTION

In most man-rated weapon systems, a 100% proof test of motor case components is a requirement. This is supposed to insure that critically-flawed parts are detected. In the case of filament wound motor cases, however, the proof test induces crazing of the matrix material which permanently alters some of the composite's properties, such as transverse stiffness and water vapor permeability.

The work presented in this report is directed to determining the effect proof testing has on the strength degradation of S-2 glass pressure vessels subjected to 95% relative humidity at 140°F for up to 16 weeks.

## II. MATERIAL TESTED AND SPECIMEN FABRICATION

The fiberglass composite system in this study is identical to the one currently planned for use in the Viper motor case. The roving was a 750 yd/lb "S-2" glass with an epoxy compatible finish. The resin system was Epotuf 37-139, Epotuf 37-624, EMI-24, and UCCA1100 in the ratios 100/84/2/1.6, respectively. The cure schedule was 1-1/2 hours at 275°F, 1 hour at 325°F, and 1 hour at 400°F.

The pressure vessel specimen was configured with a nominal inside diameter of 3 in., a cylindrical length of 5 in., and integral geodesic isotenoid domes on each end. The polar adapters were machined from 7075-T6 aluminum alloy.

A washout mandrel machined from common block salt was used for each vessel. Polar adapters were bonded to the mandrel ends with room temperature vulcanizing silicone rubber. Following cure of this rubber, the mandrel was spray-coated with a dispersion of silicone rubber. This coating formed the liner/bladder for the vessel. The mandrel (Figure 1) was then ready for wet winding.

The following winding sequence was used on the specimens. One layer of 34-deg helix, with a band advance of 0.10 in. using two rovings (750 yd/lb) was applied in a single circuit pattern. Following this, a layer of hoop windings was applied using a bandwidth of 0.20 in.

Following cure, the washout mandrel was removed with hot flowing water. This process lasted approximately 2 hours.

The loading and vessel construction was such that a hoop type failure (Figure 2) resulted. This was intentional in order to reduce scatter in the data resulting from mixed failure modes.

A completed typical vessel is shown in Figure 3.

### III. TEST PLAN

The test plan, as finally adopted, was limited in scope due to the time involved. Data were required within a 6-month period. To meet this schedule, 200 vessels were the maximum that could be fabricated and tested in this time frame.

Each test group consisted of a population of 16 vessels. This sample size was chosen so that statistically reliable distribution could be obtained.

Sixteen virgin vessels (i.e., not proof-tested and/or degraded) were pressurized to burst at a rate of 250 psi/sec using water as the pressurizing medium. This group of controls had a mean burst level of 3850 psi and a coefficient of variation (CV) of 3.3%.

Taking 75% of the mean burst level, i.e., 2890 psi, established the proof pressure level. Proof tests were conducted on eight groups. The proof pressure level was reached in approximately 5 sec, held for an additional 10 sec, and the released.

To separate the effect of possible strength loss due to proof testing and the loss due to combined effects of proof testing and subsequent environmental degradation, one group was burst immediately after proof testing. Three additional proof tested groups were placed in an environmental chamber (140°F and 95% relative humidity) for periods of 2, 6, and 16 weeks.

Two additional proof-tested groups were painted with a phenolic paint primer (Rinsid Mason 128A D061) and then placed in the chamber for periods of 2 and 16 weeks.

The final two proof-tested groups were placed in 0.040-in. thick fiberglass cylinders. The ends of the cylinders were sealed with 0.080-in. thick polyethelene end caps sealed with a silicone rubber. Figure 4 shows a typical specimen of this type. These specimens were subsequently placed in the environmental chamber for 2 and 16 weeks.

Three groups of virgin (not proofed) vessels were also placed in the chamber as a control group for the 2-, 6-, and 16-week aging.

### IV. RESULTS AND DISCUSSION

Mean burst pressure for the proof-tested but unaged vessels was 3880 psi compared to 3850 psi for the control group. The CV of both groups were identical. From these data it is evident that proof testing, as conducted in this study, has no measurable detrimental effect.

Groups were removed from environmental conditioning and tested the same day. All groups were tested at ambient temperature.

Four groups were conditioned for 2 weeks. The control group (no proof test) showed a 3.3% increase in burst strength with a CV of 2.2%. The bare proof-tested group gave a 10% decline in strength to 3480 psi with a CV of 5.6%. The proofed and painted group had the least loss, 4.6% to 3700 psi and CV of 4.6%.

The group sealed in the fiberglass tubes had a mean burst pressure of 3520 psi and a CV of 4.0%. This indicates that the tube offers little protection from the environment.

Only two groups were included for 6 weeks aging. The control group (no proof test) had dropped to a mean of 3200 psi with CV = 4.9%. The proof-tested group fell to 2850 psi with a CV of 4.4%.

All four types of specimens were tested after 16 weeks conditioning. There was a marked change in appearance of all vessels except the ones sealed in the fiberglass tubes. The uncoated and coated vessels are shown in Figures 5 and 6. The nonproofed group had a mean burst of 2780 psi or a 28% decline. The base proof-tested group was again the lowest at 2550 psi; however, the coated vessels were not much different at 2630 psi, each had the same CV of 3.5%. The group sealed in the fiberglass tube had lost 29% of its strength which indicates some degree of protection. All results are tabulated in Table 1.

## V. CONCLUSIONS

A biaxially-stressed filament wound pressure vessel has been developed and produced in quantities by the Ground Equipment and Missile Structures Directorate and has been demonstrated to be a very reproducible test specimen for materials characterization.

Burst strengths of these vessels as a function of time in an environment of 140°F and 95% relative humidity have been presented.

The combined effects of resin-crazing (proof testing) and environmental degradation is shown to be more severe although not to the extent that proof testing of fiberglass structures should be ruled out. Also, it has been determined that the Rinsid-Mason phenolic primer offers little protection from water vapor. The fiberglass tube does offer some degree of protection.

TABLE 1. TEST RESULTS

Exposure Time in 140°F, 95% Relative Humidity (week)	Burst Pressures (psig)			
	Group A (No Proof)	Group B (Proof Tested)	Group C (Proof Tested and Sealed in Tube)	Group D (Proof Tested and Painted)
0	3850 CV* = 3.3%	3880 CV = 3.3%	-	-
2	3980 CV = 2.2%	3480 CV = 5.6%	3520 CV = 4.0%	3700 CV = 4.6%
6	3200 CV = 4.9%	2850 CV = 4.4%	-	-
16	2780 CV = 3.9%	2500 CV = 3.5%	2750 CV = 3.5%	2630 CV = 3.4%

\*Coefficient of variation.



Figure 1. Finished mandrel.



Figure 2. Typical failure mode.

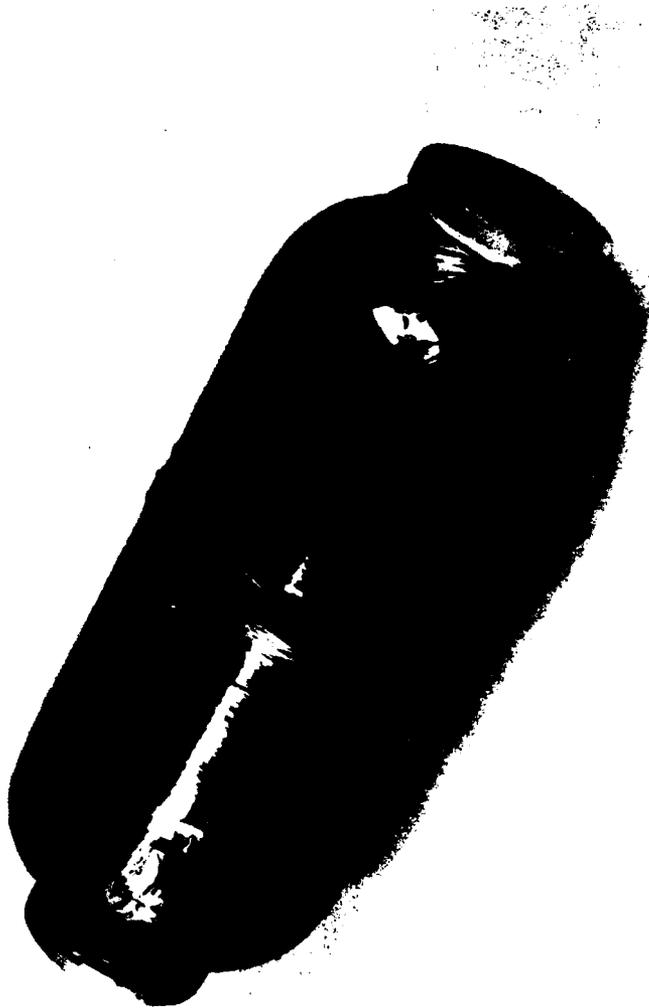


Figure 3. Finished vessel.

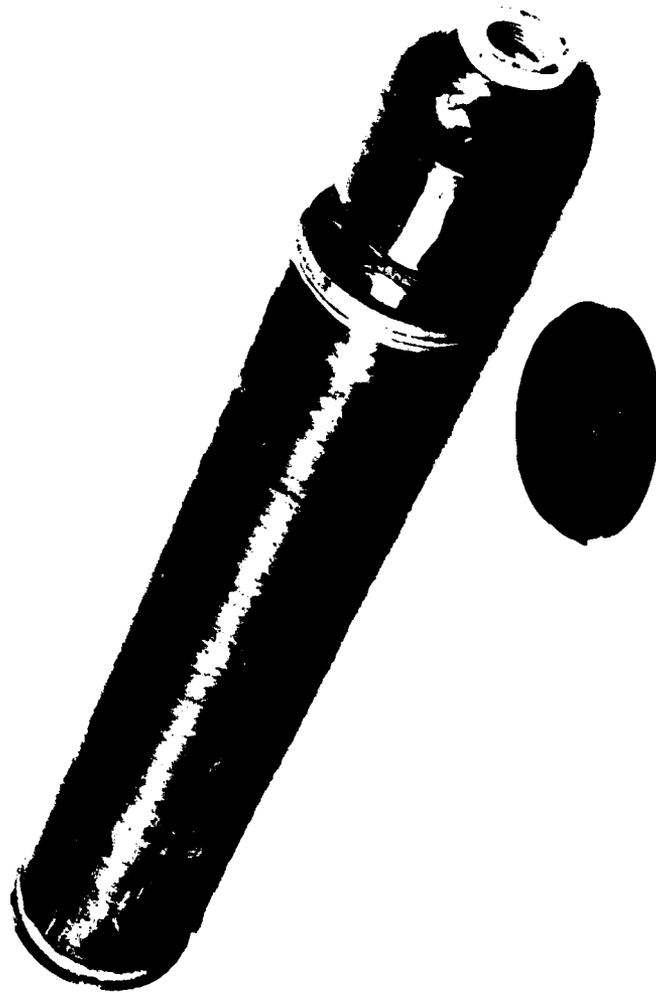


Figure 4. Fiberglass tube and vessel.



Figure 5. Aged uncoated vessel.

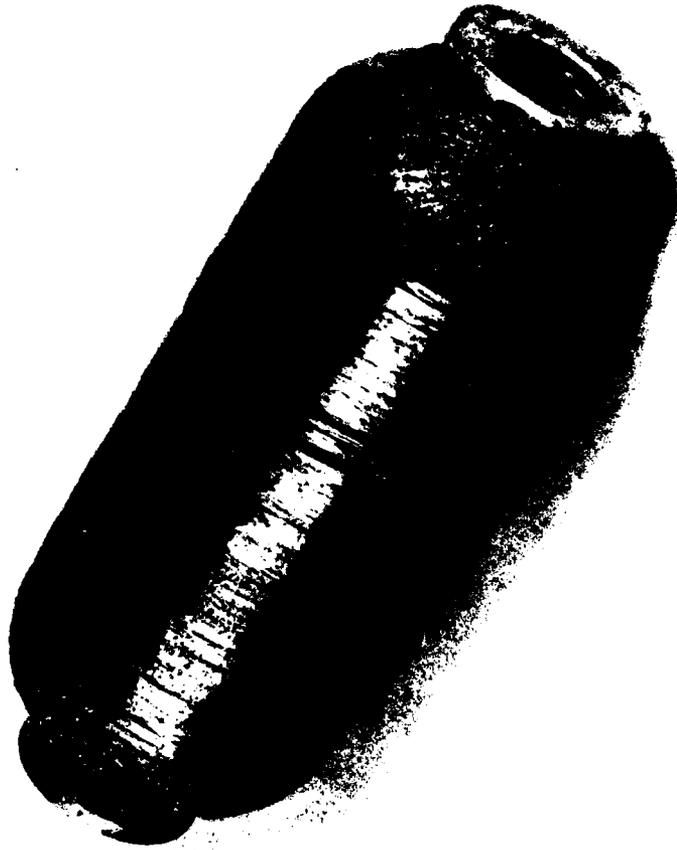


Figure 6. Aged coated vessel.

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