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SECTION 490

REPORT GD/A-AKM64-038

PROCEDURE FOR APPLYING REFLECTIVE VAPOR BARRIER TO POLYURETHANE FOAM INSULATION PANELS

MD PROJECT REPORT
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ABSTRACT

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This report describes a development program to implement the results of an earlier program to improve the Centaur forward bulkhead insulation system.

This project has resulted in the successful process development and installation of an improved reflective vapor barrier system. A reflective aluminized film, formed and bonded to the polyurethane foam insulation panels, minimizes the inherent growth characteristics of the foam when the foam panels are subjected to sunlight, heat, and high humidity.

Standard resin adhesives were used; oven post-cure and a machining operation have minimized the problem of foam expansion during the forming operation; overforming the films should minimize effects of elastic memory.

This project resulted in an improvement in the reliability of the Centaur insulation system.

author

Copies of this report are available on request to Technical Services, Section 490-3, Extension 671.

TITLE

PROCEDURE FOR APPLYING REFLECTIVE VAPOR BARRIER TO POLYURETHANE FOAM INSULATION PANELS

OBJECTIVE

To develop manufacturing methods for covering the Centaur forward bulkhead foam insulation panels with a reflective vapor barrier of aluminized film.

INTRODUCTION

This project was initiated to develop manufacturing methods for implementing the results of previous development work (Report No. AOA62-0013, Centaur Forward Bulkhead Insulation Test Program) which determined a satisfactory system of insulating the Centaur forward bulkhead with rigid polyurethane foam.

Report No. AOA62-0013 describes the polyurethane foam used on AC-1 through AC-5 bulkheads as erratic and dimensionally unstable even at ambient temperatures. Some of the foam panels swelled to such an extent that the panels bulged out away from the Centaur bulkhead skin and ruptured the bond area between the foam and stainless steel fuel tank wall. This ruptured area caused a void to be formed which filled with air. The air became liquid air when cryogenic fuel was pumped into the tank. This cryo-pumping action rendered the insulation properties of the foam useless in these unbonded areas and some of the panels had to be removed and replaced.

INTRODUCTION (contd)

During the development stage of work on task AOA62-0013 it was found that a reflective vapor barrier of thin (.001-inch) plastic film bonded to the foam panels minimized or eliminated the swelling action of the foam. Because of the stabilizing action of this film on the foam it was decided to incorporate this system on a production Centaur bulkhead. The project described in this report was therefore initiated to develop methods of applying aluminized plastic film (Mylar) to full sized production foam panels.

CONCLUSIONS

1. Aluminized films can be formed and bonded successfully to polyurethane foam panels using standard resin adhesives.

2. The film used in this program had an elastic memory and tended to flatten out after a part has been formed. Over-development of the contour of the part should improve shape stability.

3. The Freon-blown polyurethane foam used on this project expanded as much as 22% during the forming operation. This action has now been minimized by an oven post-cure and a machining operation.

RECOMMENDATIONS

1. Several aluminized films, purported to have less memory and more elongation, should be evaluated to minimize spring back and distortion.

2. A program should be initiated to improve the present 55-72277-29 and -33 BNTO's (Bonding Tools) to allow parts to be made in an overformed condition. This should minimize the distortion of finished parts due to film memory and foam warpage. The parts should also be stored in a contoured holding fixture prior to installation on missile bulkhead.

3. A program should be initiated by engineering to evaluate foams which have a lower heat distortion index such as some of those mentioned in Manufacturing Development Report AN62AMR-4087 (Evaluation of Urethane Foam Panels).

4. A program should be started to develop an acceptable procedure for improving the stability of the rigid polyurethane foam used on the Centaur forward bulkheads. The stabilizing work done to date has greatly improved the stability characteristics of the foam, but optimum post-cure cycles and machining tolerances have not been established.

5. If heated metal dies are used to form or bond polyurethane foam, it is recommended that steam heat be used. The use of steam will speed up the entire process.

DISCUSSION

BACKGROUND INFORMATION ON RESULTS OF PREVIOUS FOAM PANEL TESTING (AOA62-0013).

An 18-inch diameter stainless steel test bulkhead was made and insulated with Freon-Blown foam panels. Some of the panels were covered with the aluminum paint coating used on Centaur AC-1 through AC-5, some were covered with an aluminized film (Dupont Mylar) and some were covered with unaluminized film (Dupont FEP). This bulkhead was subjected to sunlight and relatively high humidity as well as being filled and emptied of LH_2 about 12 times.

Figures 1 and 2 show the test bulkhead before being subjected to above stated environments. Panels 2 of Fig. 1 were covered with an unaluminized film. Panels 3 of Fig. 1 were covered with an aluminized film and panels 5 of Fig. 2 were painted with the aluminum paint used on Centaur AC-1 through AC-5.

FIGURE 1. 18" DIAMETER BULKHEAD BEFORE TESTING
(Panel No. 2 is unaluminized film covered and Panel No. 3 is aluminized film covered)

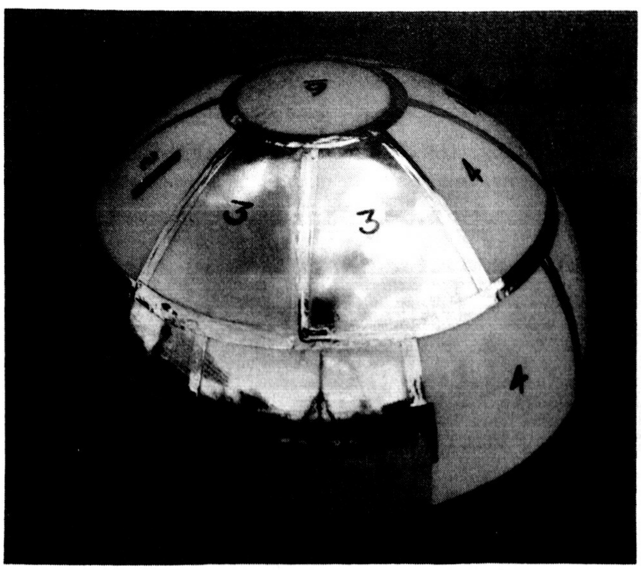
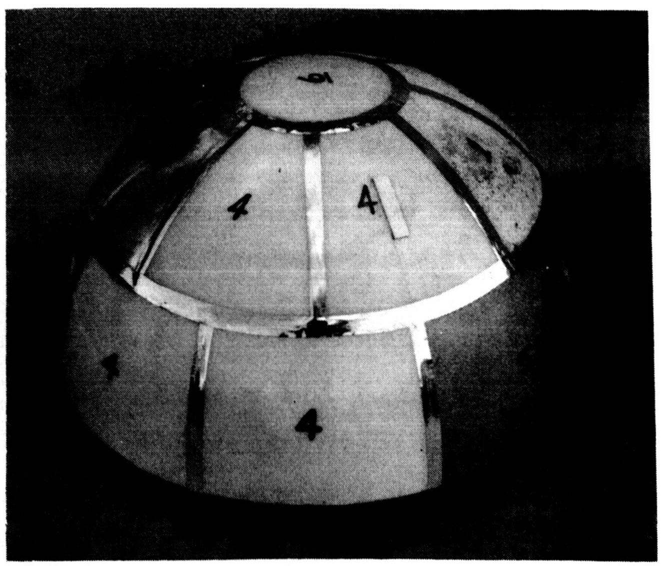


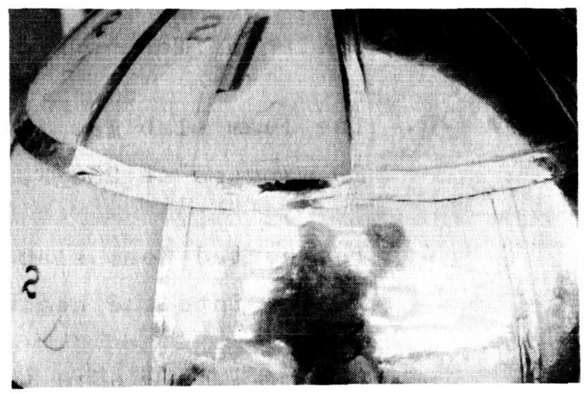
FIGURE 2. 18" DIAMETER BULKHEAD BEFORE TESTING
(Panel No. 5 is aluminum paint coated)



DISCUSSION (contd)

The foam panels formed a smooth and continuous contour on the test tank before being cycled in the various mentioned environments. This can be especially seen on Panel 2 of Fig. 1 by observing the smooth contour of foam and metal angle.

FIGURE 3. ALUMINIZED FILM COVERING AFTER TESTING

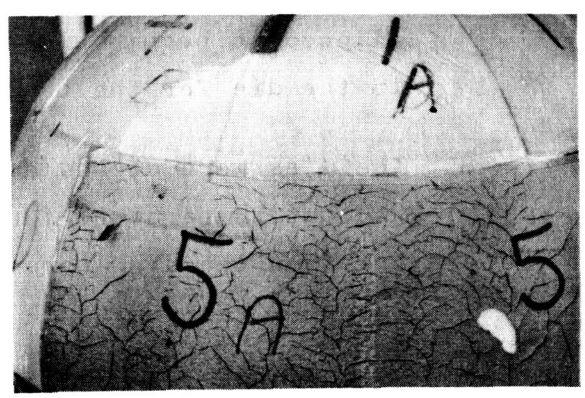


Excessive foam swelling can be observed on Panel 2 of Fig. 3 around the angle and at the bottom of the panel. Panel 3 of Fig. 3 shows the aluminized film covered panels to be still intact with no appreciable swelling.

Figure 4 shows how the aluminum paint fractured and chipped away from the foam leaving very little vapor barrier protection and thus impairing the radiation qualities of the paint.

These tests showed the importance of applying the aluminized film to the foam panels to prevent foam distortion.

FIGURE 4. ALUMINUM PAINT COATING AFTER TESTING



Another test bulkhead was prepared using a CO_2-blown foam in place of the Freon-blown foam. Test results showed the foam to be very stable even without the aluminized film covering. The first part of the Development Program included this foam.

DISCUSSION (contd)

The procedures developed for forming the CO_2 blown foam and bonding it to the aluminized film were as follows:

1. Matched aluminum male and female dies were made and installed in a heated platen press. The press temperature was set at 340°F ± 10°F.

2. A slab of foam was cut to fit the opening of the die.

3. The foam slab was inserted in an oven and heated for 10 to 20 minutes at 250°F.

4. The heated foam slab was removed from the oven and immediately placed into the heated dies which were then closed.

5. The dies were held in the closed position for 10 minutes then reduced to room temperature by a water cooling system in the dies. The parts were then removed.

6. A sheet of aluminized Mylar film was inserted into the female part of the die and vacuum formed to fit the cavity.

7. The Mylar and foam surfaces were coated with an adhesive (Applied Plastic Company, 1252 System). The adhesive was allowed to become almost tack-free before placing the foam in the die for the bonding operation.

8. The dies were closed and heated to 220°F. They were held at that temperature for approximately 30 minutes at 220°F and then the dies were water cooled to below 100°F before removing the parts.

Since the small aluminum test dies produced very successful parts the following full sized prototype tool was made.

DISCUSSION (contd)

FABRICATION AND OPERATION OF FULL SIZED CAST ALUMINUM PROTOTYPE FORMING AND BONDING DIE

A large cast aluminum tool was made similar to the small test tool. The tool was made to produce the 55-72277-33 panel. The contoured parts of the tool were sand cast in aluminum and ground to shape. They were then machined flat on the bottom sides and grooves were machined into the tool to serve as a water jacket. A base plate was bonded to the male and female section with Bloomingdale Rubber Company's FM 1000 adhesive film. The bond was accomplished in a large heated platen press at 50 psi and 350°F for 1-1/2 hours.

The sequence of operation in producing a foamed panel was the same as listed for the small test tool.

Prototype Tool Problems:

The following problems were encountered in the operation of the large aluminum prototype tool that were not apparent in fabricating the small parts.

1. The sand-cast aluminum prototype dies developed slight leaks due to porosity in the castings. Most of these leaks were closed by welding, and it was determined that this problem would not exist when the production dies were made.

2. The foam forming and cure time cycles were excessive. The aluminum dies were mounted in an electrically heated platen press. It took onehour to uniformly heat the dies to 340°F by conduction from the press platens. The total foam forming cycle was two hours based on a one-hour die heat-up time, a 1/2-hour foam forming cycle, and a 1/2-hour die cooling cycle.

The fabrication time cycle could be accelerated by heating the die with steam, but a steam facility was not available.

Prototype Foam Problems:

While the Manufacturing Development Section was developing the processes for fabricating the foam parts, the Engineering Department was attempting to find an acceptable CO_2 blown foam. It was finally resolved, after much testing, that acceptable CO_2 blown foam could not be obtained in time to fit into the production schedule for Centaur AC-6. Plans for using the CO_2 blown foam were abandoned in favor of using the original Freon-blown foam with the aluminized film added. It was also decided to eliminate the matched metal dies in favor of high temperature plastic tools which would be used for forming and bonding with an oven-cure cycle instead of using a heated platen press. Doing this would save the cost of more expensive metal dies, and also oven facilities are more available at GD/A than heated platen presses.

Prototype Plastic Tool Fabrication For Forming and Bonding Foam:

FIGURE 5. PROTOTYPE FORMING & BONDING TOOL

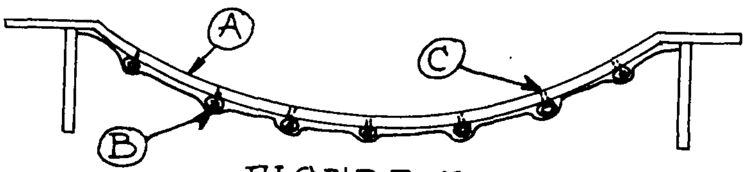


FIGURE 5

A prototype plastic vacuum forming and bonding tool was made to replace the aluminum dies (Fig. 5). This tool was similar to the metal die except it did not have a water cooling jacket. This tool was a high temperature epoxy laminate (A), with a series of 1/4-inch copper tube vacuum lines (B) bonded to the back side with additional layers of laminate. Holes (C) were drilled (No. 60) from the inside of the mold through the laminate and into the copper vacuum tubes to provide the vacuum necessary to form the aluminized film.

DISCUSSION (contd)

Prototype Part Fabrication Using Plastic Forming and Bonding Tool:

A piece of aluminized Mylar was layed across the tool (Fig. 6) opening and a vacuum ring was positioned over the film and clamped tightly around the periphery of the tool (Fig. 7). The tool, with Mylar in place, was then placed in an oven set at 450°F. After the tool had been in the oven for about three minutes, vacuum was applied through the vacuum tubes. This drew the Mylar film tightly against the inside shape of the tool. The tool was removed from the oven (Fig. 8) and the Mylar cleaned with alcohol while vacuum was maintained to hold the film in position. An epoxy/versamid adhesive was applied to the Mylar and foam slab by brush (Fig. 9).

FIGURE 6. VACUUM TOOL AND ALUMINIZED FILM

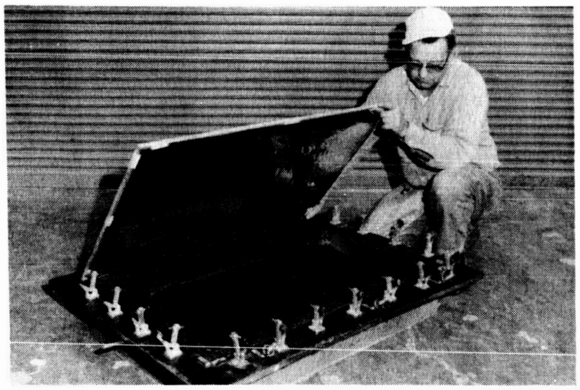


FIGURE 7. POSITIONING OF ALUMINIZED FILM AND VACUUM RING

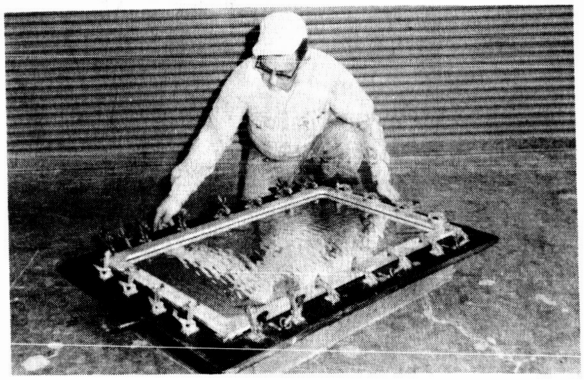


FIGURE 8. REMOVAL OF FORMED FILM FROM OVEN

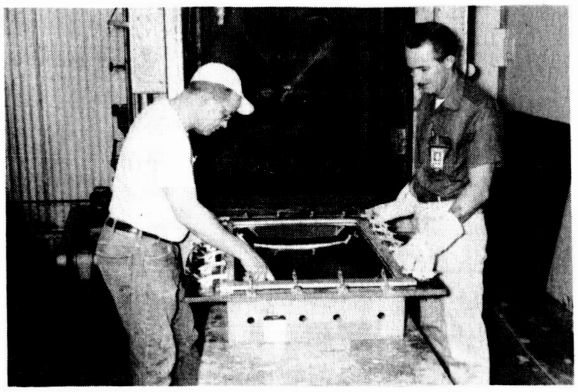
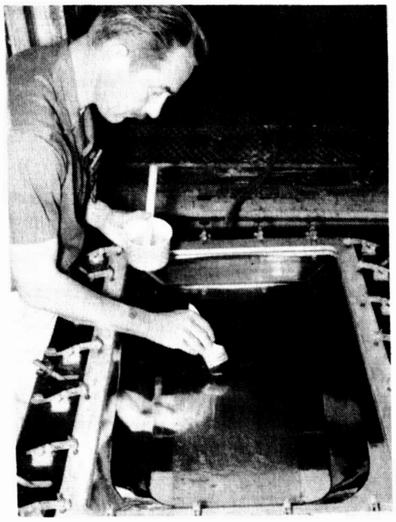


FIGURE 9. APPLICATION OF ADHESIVE



The foam was positioned over the film in the tool and the pressure bag was applied (Fig. 10) to force the foam firmly against the film until the adhesive cured. The pressure in the bag was set at 3.5 psi (Fig. 11). Following an oven cure of 150°F $\pm$ 10°F for one hour, the tool was cooled to room temperature and the finished part removed, trimmed, and packaged (Fig. 12). Figure 13 shows the three different panel configurations which make up the Centaur forward bulkhead insulation. There are 56 aluminized film covered panels in all. There are eight of the Fig. 13 (A) panels, 36 of the Fig. 13 (B) panels, and 12 of the Fig. 13 (C) panels.

FIGURE 10. INSTALLATION OF FOAM AND PRESSURE BAG

FIGURE 11. PRESSURE ADJUSTMENT ON BONDING TOOL

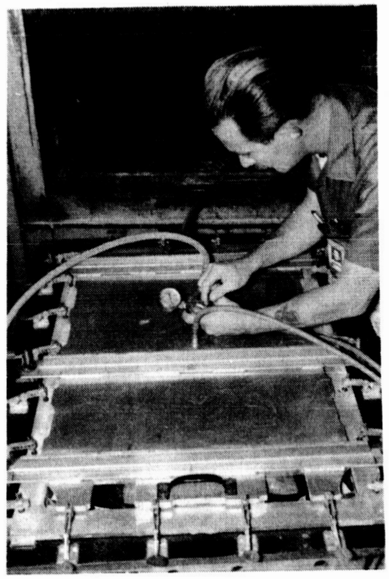


FIGURE 12. FINISHED PART BEING PACKAGED

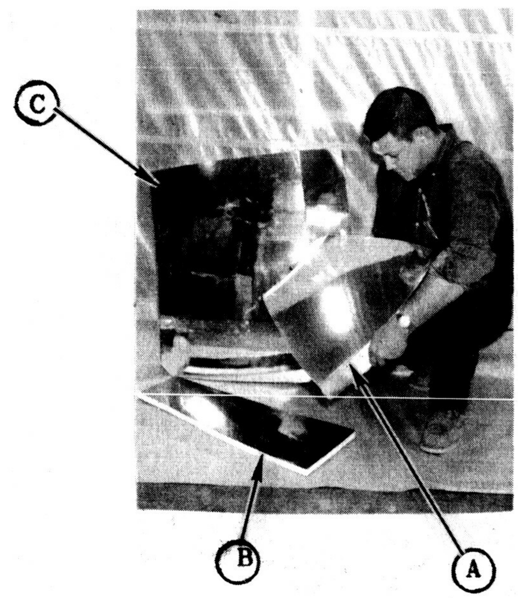


FIGURE 13. THE THREE DIFFERENT CONFIGURATIONS MAKE UP THE CENTAUR FORWARD BULKHEAD INSULATION (System of 56 parts)

Prototype Foam Panel Distortion Problems:

All of the parts made in the prototype mold had a tendency to flatten out (spring-back between 20 to 30 percent) depending on how long the part was cured in the oven during adhesive bonding and how long the part was in the bonding tool prior to removal. To alleviate this condition, the prototype forming and bonding tool was temporarily altered by adding an insert to the tool. This insert formed a more acute angle in the beveled area and thereby caused the film to be slightly overformed. The insert was removed following this overforming operation and the overformed film was placed in the net shape tool. The overformed film shape returned to approximately the tool shape. A panel was made using this system and the resultant part had less spring-back than one made without overforming, but due to the urgent need for parts for AC-6 it was decided to proceed without an overforming operation. It was felt that spring-back would not be too serious a problem because the foam panels were quite flexible and would be pressed tightly against the metal of the forward bulkhead by vacuum pressure during the bonding operation. During actual installation the main difficulty due to panel distortion was encountered in trimming and fitting the panels to each other on the bulkhead prior to the bonding operation. Having parts exactly to contour would make the trim and fit operation much easier.

PRODUCTION DEVELOPMENT WORK AND FABRICATION OF PRODUCTION PANELS FOR AC-6

The tool design department prepared the sketches of the forming and bonding tools and the plastic tooling shop fabricated the tools. The tools were made similar to the prototype tool except that the vacuum system consisted of a chamber instead of copper tubes. This provided a greater vacuum volume which accelerated the film forming cycle.

After the tools were fabricated it was found that the vacuum system leaked through the epoxy fiberglass laminate. The leaks were sealed by heating the tools to 250°F and painting the edges of the tools with an epoxy adhesive while vacuum was applied. This sucked the resin into the laminate thereby sealing the leaks. A 50/50 mix of epoxy (Shell 828 Epoxy) and hardener (General Mills Versamid 125) were used.

Production Pressure Bag Fabrication and Operation:

The prototype and production pressure bags were made using a room temperature vulcanizing silicone rubber (General Electric RTV-60) reinforced with one layer of 181-style fiberglass. They were made by the wet layup method on a flat table. The periphery of each bag was sewn and the exposed threads were coated with a brush coat of silicone rubber. The 55-72277-31 pressure bag was used in making about 20 production parts before leaks developed around the periphery due to peeling action caused by the 3 to 5 psi internal bag pressure.

A rubber manufacturer was contacted to make the pressure bags. It developed that the manufacturer could not produce a bag capable of test pressures to 15 psi, so the pressure pad pressure system was devised.

Pressure Pad System and Operation:

A pressure pad was fabricated using a wet layup of epoxy and fiberglass. The resin system was the same as that used for the forming and bonding tools. The laminate was about 1/4-inch thick and contoured to fit the shape of the forming tool. The side of the pressure pad which pressed against the rigid foam during the bonding operation was lined with a one-inch thickness of flexible polyurethane foam. Weights equal to about 2 to 5 psi were added to provide the bonding pressure.

The remainder of the first ship set of 56 parts was made using pressure pads and weights. The weights were eliminated at the start of the second ship set fabrication program and replaced by vacuuming the pressure pad against the foam. This system produced a grainy textured appearance on the film side of the panel but ensured good parts with a minimum amount of resin needed to bond the film to the foam.

DISCUSSION (contd)

Foam Panel Fabrication:

When section 490 started work on the first ship set the foam panels had already been heat-formed to shape on the tools used to fabricate all of the Centaur forward bulkhead insulation panels prior to AC-6. Some of these panels varied in thickness as much as 22 percent after heat forming. Due to the urgency of the program it was decided to pick the best of these formed panels for production parts. The majority of the picked panels were over .90-inch but under 1.00-inch thick. The B/P tolerance was set at .87 to .90 inches. The large (55-72277-29) panel is the most critical because the aft end of this panel feathers out in an area where a tank fabrication jig fits. If the -29 panels are too thick in that area the jig will not slip over them.

About 75 percent of the AC-6 missile set was completed before it was found that the foam could be stabilized somewhat by curing the flat foam slabs at 200°F for one hour followed by machining them to B/P tolerances. It is felt that variations in post cure time and temperatures could be developed to stabilize this foam to within an acceptable percentage of less than 5 percent growth.

Resin System:

The resin system used on the production parts was changed from the epoxy system used on the prototypes to another similar system in order to reduce viscosity. (Shell 815 epoxy 60 parts, and 40 parts of General Mills Versamid 140). This provided a resin system which allowed the resin to flow more easily and thereby push out entrapped air faster. It was found advantageous to use as little resin as possible with this system.

DISCUSSION (contd)

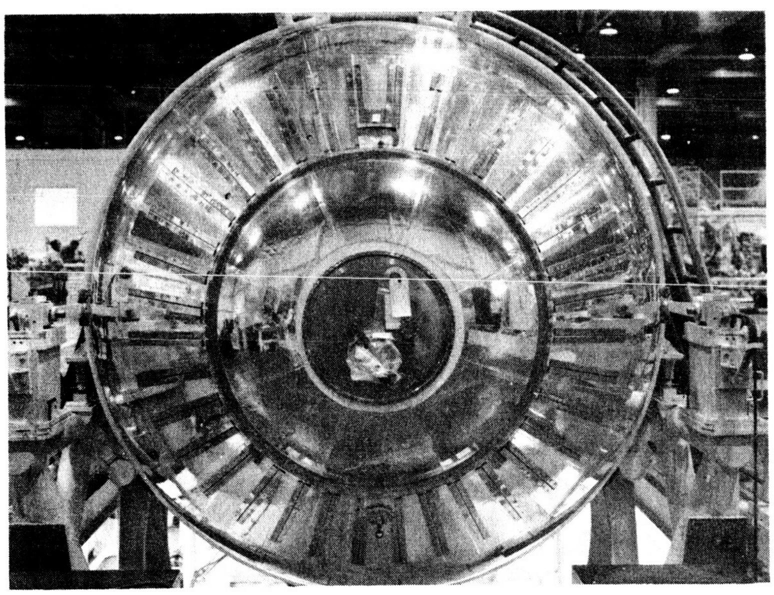
Mylar Forming and Bonding:

The procedures for forming and bonding the aluminized Mylar film to the foam are the same as those that were used for bonding the prototype parts (see pages 8 through 10).

RESULTS

This project has resulted in the fabrication and installation of 56 insulation panels on the Atlas/Centaur AC-6 forward bulkhead.

FIGURE 14. AC-6 INSULATION COMPLETED



STATUS

Follow-on work is now in progress to investigate:

- improvement of the film forming process
- improvement of the adhesive cure cycle
- a holding fixture (hold parts to shape)
- use of films having greater elongation and less memory
- overforming

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