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FINAL REPORT ON LOW COST ABLATIVE HEAT SHIELDS FOR SPACE SHUTTLES

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FOREWORD

This document, final report on Low Cost Ablative Heat Shields for Space Shuttles, is a contractual requirement of the program performed for the National Aeronautics and Space Administration at Langley Research Center under Contract NASI-9944. The program was conducted by the Production Engineering and Product Development Group for the Missile Insulation and Plastic Department, of the Aerospace and Defense Products Division of The B.F.Goodrich Company, Akron, Ohio, between May and December, 1970.

Mr. C. M. Pittman of the Materials Division, Langley Research Center, Hampton, Virginia, was the technical representative for the project.

ABSTRACT

Two ablative material compositions were used to fabricate two flat and two curved two-foot by four-foot by two-inch thick low density ablative panels.

The panels consist of a non-metallic honeycomb reinforcement matrix, bonded to a non-metallic face sheet attachment surface, and filled with ablator material.

Several unique techniques and processes were used in the program, these include hydraulic press and high pressure autoclave "Cookie Cut" loading, controlled thickness sequence loading under vacuum bag--Atmospheric pressure by use of a flexible barrier curtain, and high pressure autoclave final loading and curing to net panel size.

Cost estimates are included for production lots of 1, 10 and 100 panels in various shapes and sizes.

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ILLUSTRATIONS

FINAL REPORT ON LOW COST ABLATIVE

HEAT SHIELDS FOR SPACE SHUTTLES

By Production Engineering and
Product Development Department, Missile
Insulation and Plastics Group,
Aerospace and Defense Products
A Division of The B.F.Goodrich Company

SUMMARY

The major objectives of the program were two-fold:

1. To develop low cost methods of producing elastomer-Microballoon ablative material heat shields for space shuttle use; then produce and deliver two flat and two curved ablative heat shields, two feet by four feet by two inches thick, of the following ablative material compositions:

   (a) 20 percent elastomer, 80 percent Microballoons

   (b) 67 percent elastomer, 33 percent Microballoons

2. To establish realistic cost estimating data on optimum developed processes and techniques for ship set production quantities of various shapes and sizes of ablative shields.

Program schedule was originally planned as (1) Material and Fabrication Development to be followed by (2) Production of contractual requirements in two foot by four foot by two inch ablative shields. This schedule was revised and Material Development and Reproducibility testing continued throughout the entire program.

The ablation shield composite density requirements were met in both the 13 to 17 lb/ft^3, 20 percent elastomer, 80 percent Microballoon and the 25 to 30 lb/ft^3, 67 percent elastomer, 33 percent Microballoon ablative filler compositions.

INTRODUCTION

The era of the space shuttle as a reusable logistic vehicle has created a requirement for ablative heat shield material with reliable shield efficiency, combined with low replacement cost, for economic feasibility of flight vehicle reuse.

The objective of this project, is the development of processes and equipment for production of four prototype low density ablation shield test panels. These processes and equipment are to be applicable to ultimate low cost, large scale production of ablation heat shields using an elastomeric system composed of liquid silicone resin and phenolic Microballoons as a filler for non-metallic honeycomb.

A thin non-metallic face sheet, bonded to the honeycomb provides an attachment base for assembly to the surface areas of the shuttle vehicle requiring aerodynamic heating insulation.

An efficient ablation heat shield with a high reliability factor produced with this elastomer system must be manufactured under controlled processes designed to adequately prepare the silicone resin and Microballoon mix for a consistant and reproducible cure and cured density after loading into the honeycomb reinforcement. The handling and loading processes of the elastomeric mix must also present a controllable and reproducible method, insuring minimal variations in panel density over the total panel area, while being applicable to either flat or contoured panel shapes.

Another project objective is to establish cost data necessary to furnish realistic cost estimates for the large quantities of both flat and contoured ablation shield panel material required for each space shuttle orbiter flight.

PROGRAM APPROACH

The major technical effort on the program was directed at the development of optimum material mixing, loading, and curing techniques compatable to the current ablative shield requirements, and capable of downstream scale up to the larger and more complex ablative shield shape requirements of the Space Shuttle Orbiter Flight Program.

The development and refinement of processes and techniques was accomplished in a sub-scale test panel production effort as the initial phase of program activity.

During the development panel production effort, several process changes, influenced by faulty or degraded component material preventing reproducibility of processes, required time consuming duplication of subscale test panel production and testing.

At the conclusion of the test panel effort, the final revised and optimized processes and techniques were then applied to the production of the deliverable ablation material panels and plugs.

DEVELOPMENT

A program for development production of sub-scale 12-inch x 12-inch x 1½ and 2-inch test panels was established as the basis for evaluation of all phases of elastomeric filler preparation processes, panel fabrication techniques and final cure cycles.

The sub-scale test panels also furnished sample material for physical test data study to establish optimum processes required for final panel production and cost data relating to those processes.

Early development work on the 12 x 12 sub-scale panels indicated process and technique problems in the areas of mixing, resin distribution, primer wetting, loading techniques, and compaction processes for panel reproducibility and minimal local area density variance after cure.

These problem areas were resolved by additional process development and 12 x 12 development panel production and evaluation.

A major contributor to non-reproducibility of fabrication processes was found to be the primer used on the honeycomb matrix prior to loading and the Microballoon filler prior to resin mixing. Deleting the primer from the Microballoon preparation prior to elastomer-Microballoon mixing and substitution of a solvent extended Sylgard 182 resin prime coat for the honeycomb matrix prior to loading has solved the reproducility problem and has not degraded finished panel material physical properties.

This change is attractive cost-wise by reduction of ablation material primer, mixing, and drying costs.

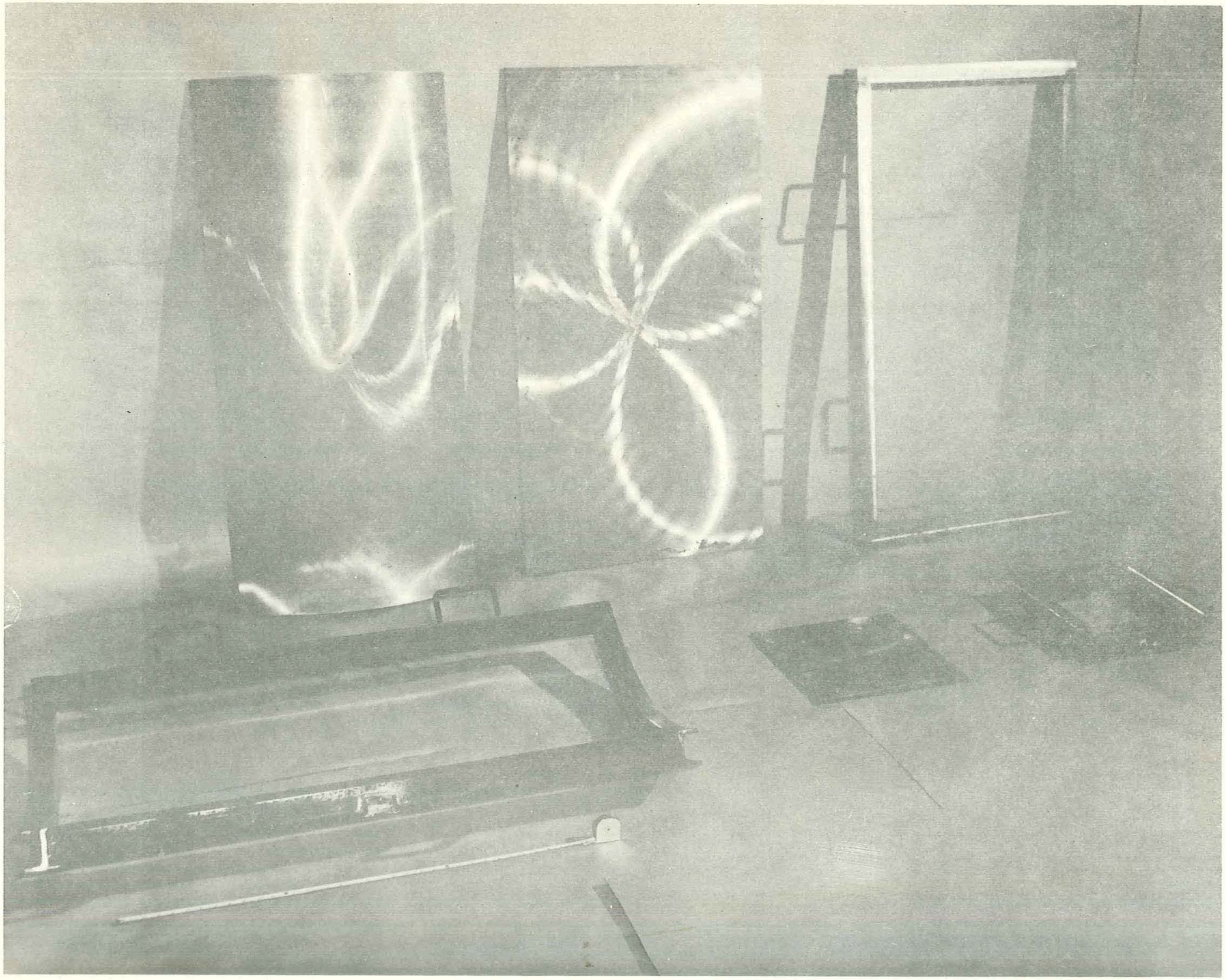
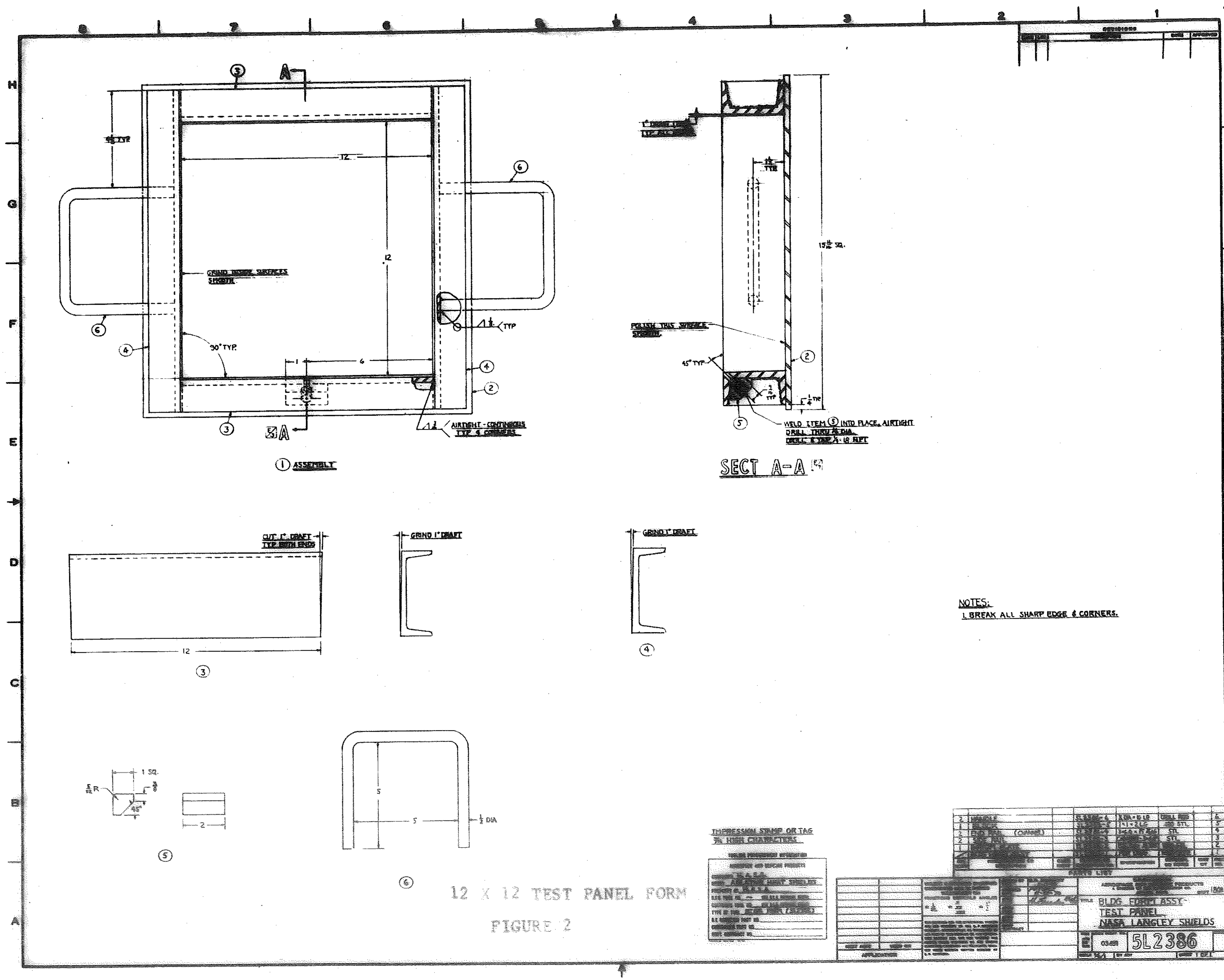
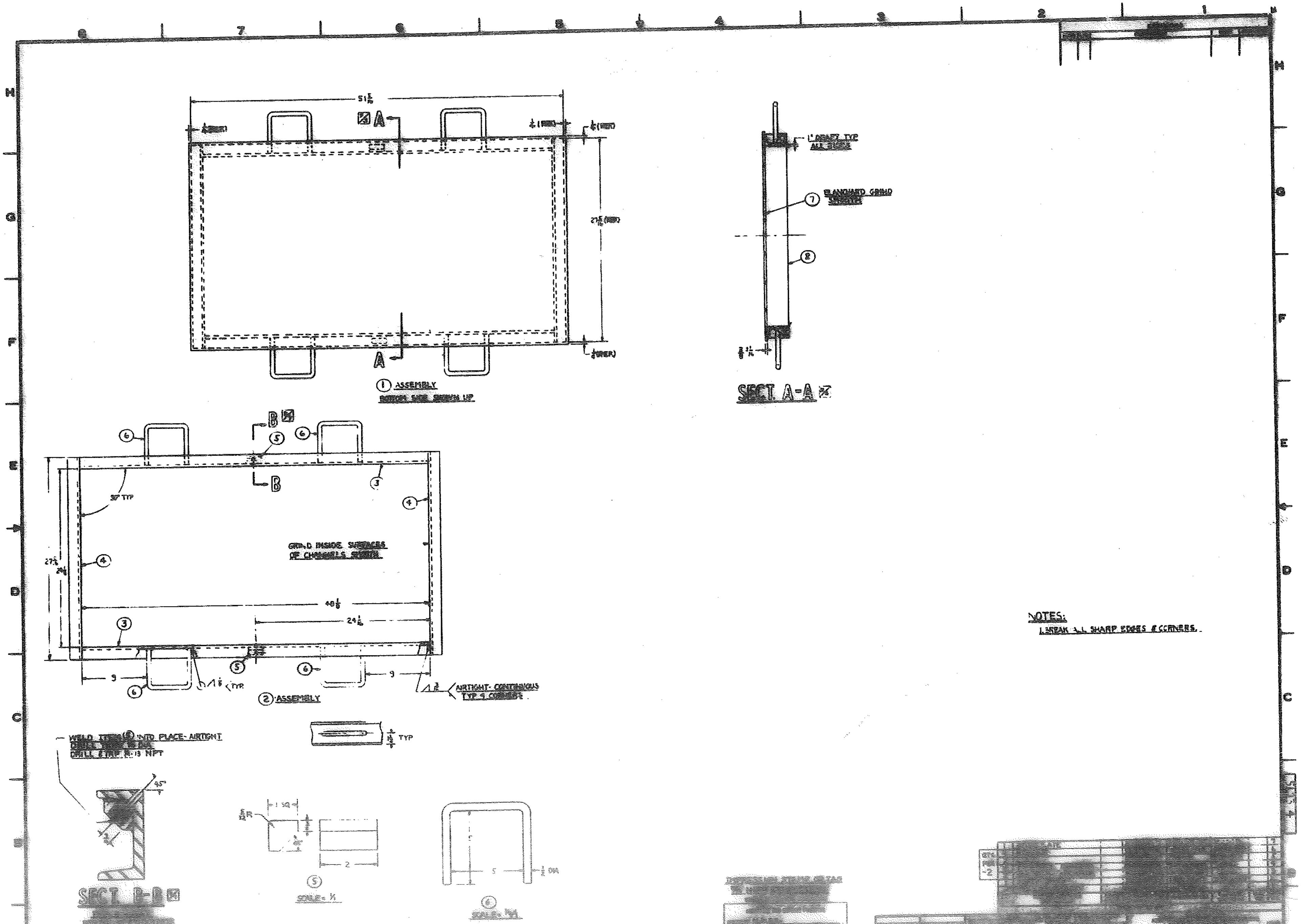


Figure 1
Building and Cure Form Tooling
12 inch x 12 inch x 3 inch Sub-scale Test Panel Form
2 ft. x 4 ft. x 3 inch Production Flat Panel Form
2 ft. x 4 ft. x 3 inch Production Curved Panel Form



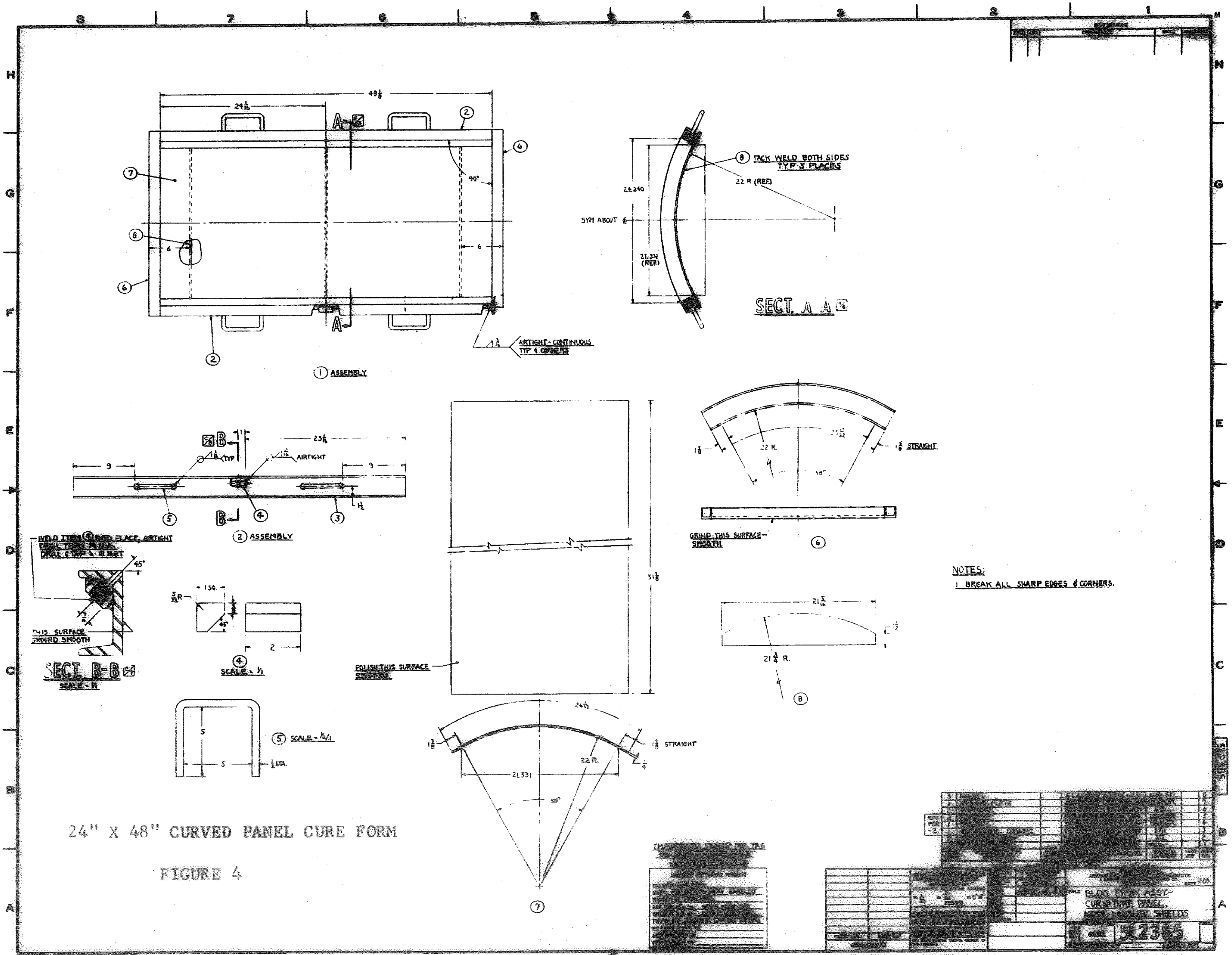
12 X 12 TEST PANEL FORM

FIGURE 2



24 X 48 FLAT PANEL CURE FORM

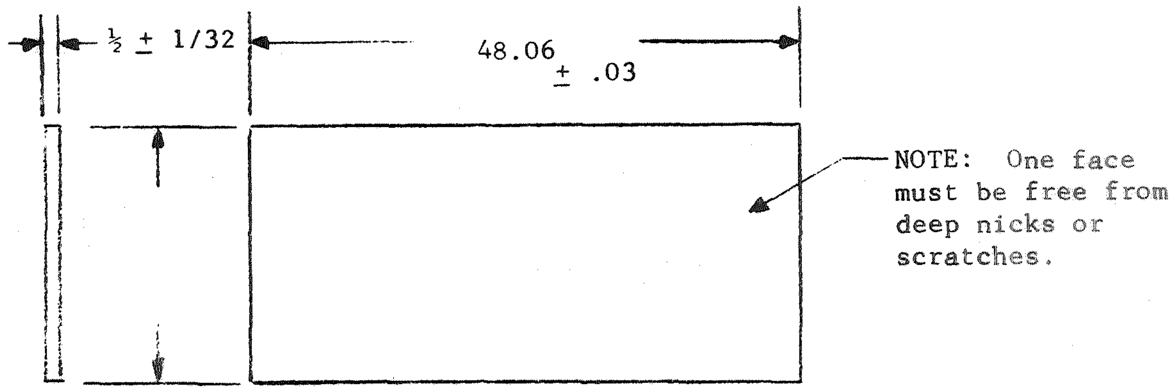
FIGURE 3



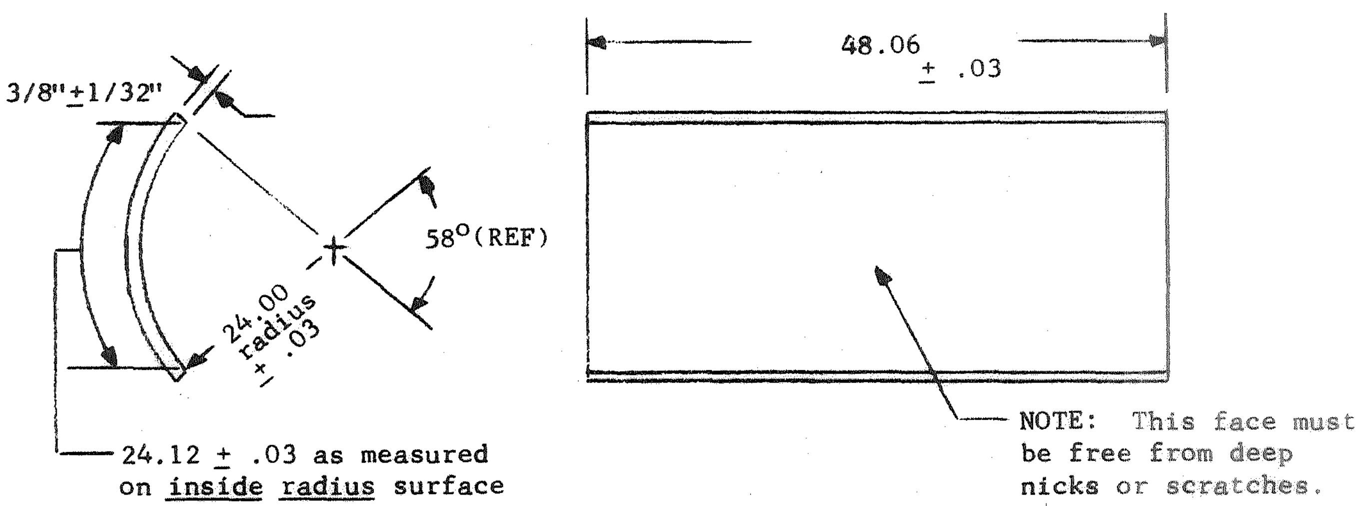
24" X 48" CURVED PANEL CURE FORM

FIGURE 4

NASA PANELS -- PROJECT 996

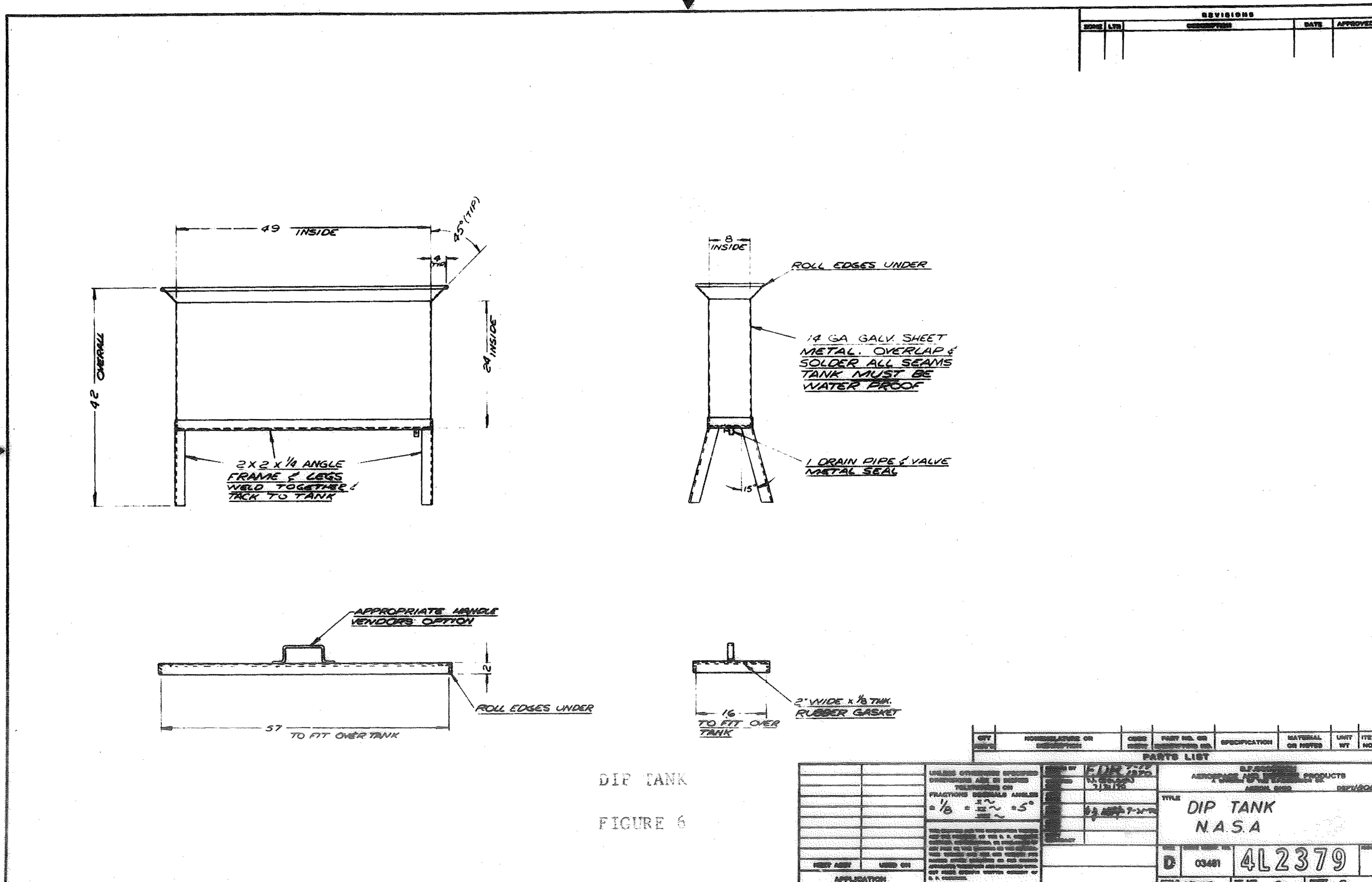


Item (1), Flat Panel Cover Plate, 6061 Aluminum, Break Sharp Corners



Item (2) Curved Panel Cover Plate, 6061 Aluminum-Break Sharp Corners

FIGURE 5



DIP TANK

FIGURE 6

TESTING

A. Raw Materials

All materials used in preparing ablative insulation were tested upon receipt to verify conformance with manufacturers' specifications. Tests were those applicable to the specific material.

1. Face Sheet

Supplier: U.S. Polymeric Inc.

Designation: EC-201 - Fiberglass prepreg.

Description: 50" Volan A treated style 181 glass fabric impregnated with phenolic resin.

Procedure	Supplier Data	B.F.G.
% Resin FTMS406-7061 3 hrs. @ 1200°F	34.3%	34.7%
% Volatiles 20 min. @ 325°F	5.8	6.0
% Flow 15 psi - 325°F	16.5	16.3

2. Microballoons

Supplier: Union Carbide Corporation

Designation: BJO-0930

Description: Hollow phenolic resin spheres.

Procedure	Supplier Data	B.F.G.
Density	.21-25 gm/cc 52 gm/500 cc	47
Particle size	0.2% on 40 mesh	0
Micro-		4.8-122 microns Avg. 51.7 microns Broken 7.2 %
Moisture Content 2 hrs. @ 220°F	4.0 max.	3.8%

A. Raw Materials (Cont'd)

3. Resin

Supplier: Dow Corning

Designation: Sylgard 182

Description: Colorless silicone resin plus catalyst.

Procedure	Supplier Data	B.F.G.
Specific Gravity ASTM-D-297	1.05 ± 0.03	1.04
Viscosity Brookfield Viscometer RVF #2 Spindle @ 2 RPM.	4000 - 6500	4350
Cure using 10% catalyst - 4 hr. @ 250°F		
Durometer ASTM-D-2240	35	40
Ultimate tensile ASTM-D-412	800	723
Ultimate elongation ASTM-D-412	100	90
Pot life @ room temperature FTMS 406 - Method 1021	8 hrs.	

4. Primer

Supplier: Dow Corning

Designation: XZ-8-5066

Description: Water White Liquid

Procedure	Supplier Data	B.F.G.
% Solids 16 hr. @ 150°F	10%	10.85
Specific Gravity FTMS 141a Method 4183	0.97	0.99
Viscosity Centistokes	3	
Infrared trace		Attached

5. Adhesive

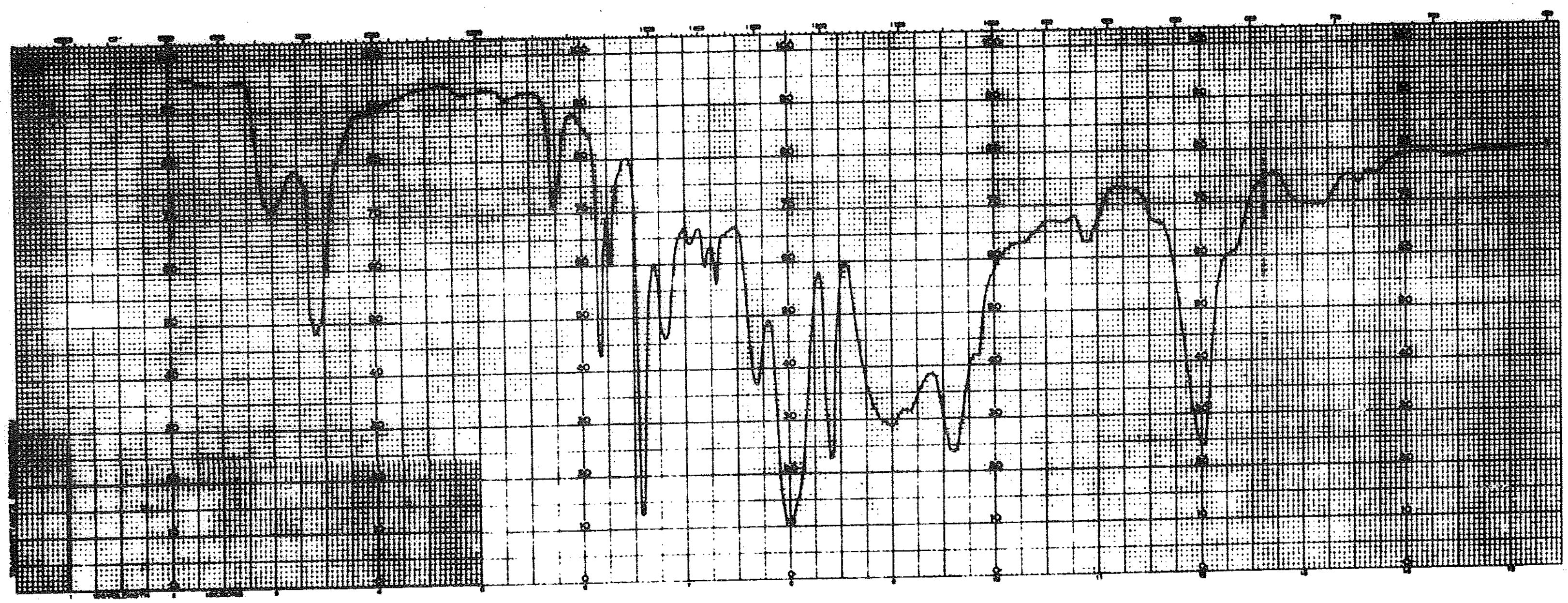
Supplier: B.F.Goodrich Company

Designation: Plastilok 729

Description: Flexible structural bonding adhesive

Procedure	B.F.G.
Weight	.03 lb/ft^2
Work life at room temperature	15 days
Tack life at room temperature	5 days
Storage temperature	0°F

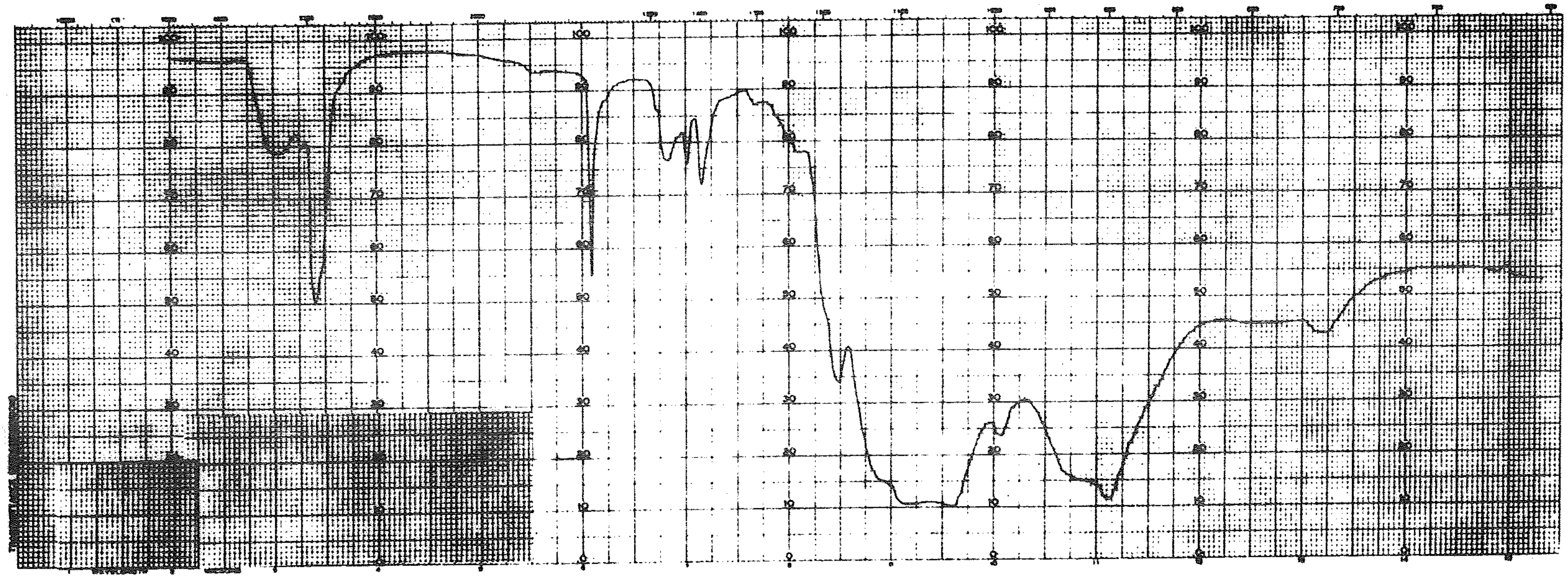
Cure cycle 35 min. rise + 60 min. @ 350°F under 15-45 psi



INFRARED SPECTRUM
DOW CORNING PRIMER XZ-8-5066
CAST ON SODIUM CHLORIDE

This trace is used for material identification and to compare lot-to-lot uniformity of the material.

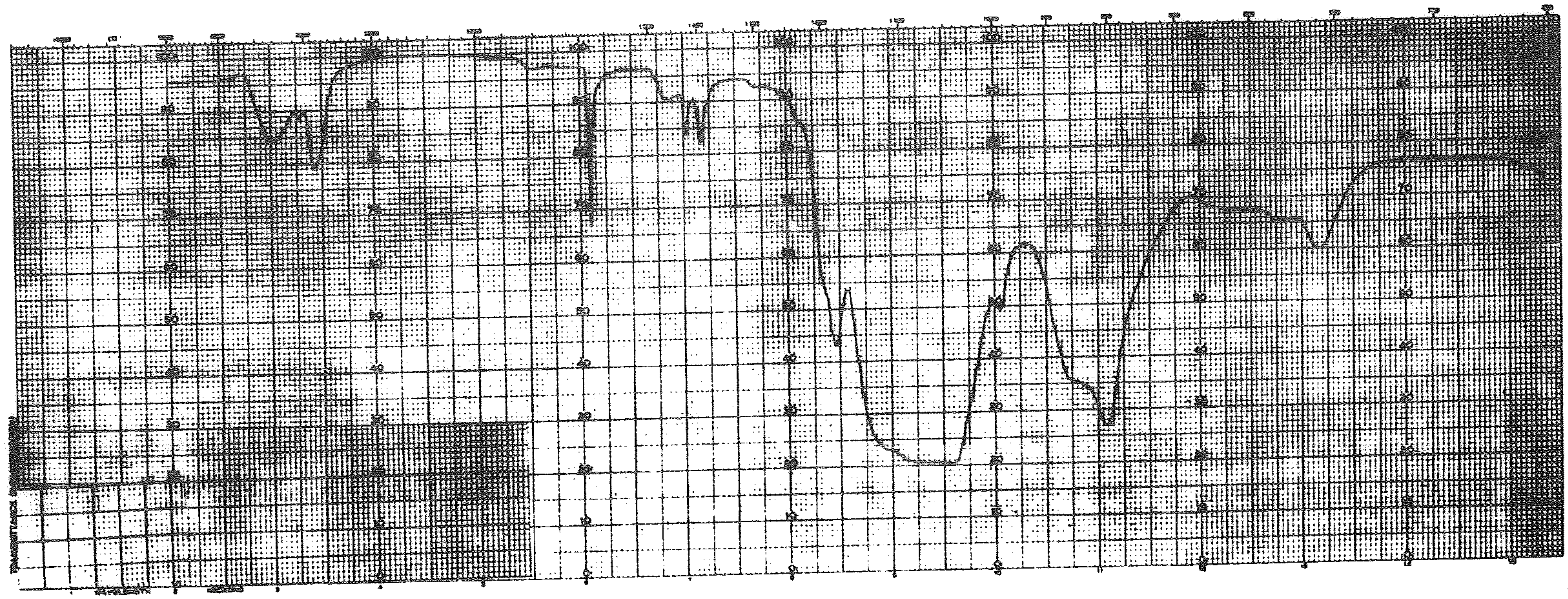
FIGURE 7



INFRARED SPECTRUM
DOW CORNING PRIMER 92-019
CAST ON SODIUM CHLORIDE

This trace is used for material identification.

FIGURE 8



INFRARED SPECTRUM
DOW CORNING SYLGARD PRIMER
CAST ON SODIUM CHLORIDE

This trace is used for material identification.

FIGURE 9

Physical Test Data - Plastilock 729 - .085 lbs. sq. ft./supported

1. Metal to metal lap shear strength. 2024 T-81 aluminum - .064" thick.

Test Temperature	Typical Average Values Primed	Typical Average Values No prime
- 67°F	2639 psi	2869
75°F	3160	2924
225°F	4827	4550
350°F	3709	3424
380°F	3257	2929
400°F		2773
425°F		2056
450°F		1006

2. Flatwise tension. 2024 T-81 facings. 5052 aluminum core - one-eighth inch size - non-perforated.

Test Temperature	Typical Average Values No prime
- 67°F	1410 psi
75°F	1415 psi
225°F	1205 psi
350°F	960 psi
380°F	950 psi

3. Sandwich peel - 2024 T-3 .020" gauge aluminum skins. 5052 aluminum core - 1/4" cell size.

Test Temperature	Typical Average Values No prime
- 67°F	29 in.lbs./3"
75°F	37 in.lbs./3"
225°F	40 in.lbs./3"
350°F	33 in.lbs./3"
380°F	36 in.lbs./3"

4. 90° Peel. .020" gauge, 2024 T-3 aluminum bonded to .064" gauge 2024 T-3 backing - 1" wide strips.

Test Temperature	Typical Average Values No prime
- 67°F	13 lbs./in.
R.T.	17 lbs./in.
225°F	22 lbs./in.
350°F	23 lbs./in.
380°F	24 lbs./in.

5. Short Beam. 3" x 8" beam flexure. 2024 T-81, .064" skins, 5052 core 1/8" cell size, 1/2" high.

Test Temperature	Typical Average Values No prime
- 67°F	2662 lbs.
R.T.	2665 lbs.
225°F	2550 lbs.
350°F	2300 lbs.
380°F	2076 lbs.

A. Raw Materials (Cont'd)

6. Honeycomb

Supplier: Hexcel Corporation

Designation: HRP - 3/8 GF12-2.6 to meet Mil C 8073 A

Description: Glass fabric impregnated with heat resistant phenolic resin.

Compressive stress ASTM-D-695 - 160 psi

1" x 1" x 2" specimens tested at .05 in/min.

7. Calking Compound

Supplier: Schnee-Morehead

Designation: # 5120-C

Description: 3/8" x 3/16" Cream colored coil.

No Tests.

8. Cure Blanket

a. Supplier: E.I. duPont

Designation: Tedlar - 3 mil.

Description: 50" wide clear plastic sheet.

No Tests.

b. Supplier: B.F.Goodrich Company

Designation:	60923	65060
Description:	.100" thick butyl	.030" thick Neoprene

No Tests.

9. Solvent

Supplier: Phillips Petroleum Company

Designation: Hexane, normal

Description: Water white liquid.

Boiling range initial 57°C - final 73°C

B. RESIN MICROBALLOON MIXES

Preliminary testing of resin-Microballoon mixes was carried out to evaluate mixing methods, primers and solvent effects. Two tests were used for evaluation. Density was tested per ASTM-D-1622. Compressive stress was tested per ASTM-D-695 using 1" x 1" x 1" cubes tested at .05 inches/minutes.

Ten (10) percent resin - 90 percent Microballoons.

Compressive Stress		
Transversal	Longitudinal	Density
156 psi	177 psi	10.2 lb/ft^3
156	165	10.0
165	223	11.0
145	159	9.8
200	174	10.2
164 average	180 psi	10.2

MIXING AND PRIMER EVALUATION

Drum Tumbling

Mixing was accomplished by adding ten percent by weight of catalized resin to 90 percent by weight of primed Microballoons and tumbling in a drum for 2 hours.

The mix was cast into blocks and cured 16 hours at 250°F under a vacuum of 25-29 inches of mercury.

This series of samples contained no solvent; therefore, most of the resin ended up coating the drum. Longer tumbling times may have improved the resin dispersion, but pot life limitations made the use of this method impractical for large panels.

Primers evaluated were Dow Corning Sylgard Primer, 92-019, and XZ-8-5066. The first two primers differ primarily in that 92-019 contains a fluorescent dye for color identification. This similarity is evident from the infrared traces, Figures 8 and 9, which contain identical peaks. Both primers contain 5 percent solids. The only sample which held together was the sample using XZ-8-5066 primer on the Microballoons. The XZ-8-5066 primer is an epoxy derivative of a silicone as shown by the infrared trace, Figure 7. The definite peaks in the trace at 6.3 microns, 8.0 microns, 9.6 microns, 10.9 microns, and 12.1 microns characterize an epoxy type material. The broad band between 9 and 10 microns characterizes a silicone base material. The sample using XZ-8-5066 primed Microballoons had a density of 8.95 lb/ft^3 and a compressive strength of 35 psi.

Air Stirrer

A laboratory air stirrer was used to mix primed Microballoons with catalized resin diluted with hexane. This method accomplished the necessary mixing in 10 minutes, but the solvent had to be removed before the samples were cured. Air drying was used to remove the hexane. Samples were spread on a table 1/2" thick and allowed to dry at room temperature.

The dried mix was loaded into test blocks and cured 16 hours @ 250°F under a vacuum of 25-29 inches of mercury.

The XZ-8-5066 primer again proved superior to the other two primers yielding samples of 10.3 lb/ft^3 density with compressive strength values as high as 176 psi when it was used with 100 percent primer and 200 percent hexane. These percentages are based upon the weight of Microballoons.

A series of samples was mixed at the 67 percent catalized resin - 33 percent primed Microballoon ratio using an air stirrer and stirring 5 minutes. This series proved that hexane was not required to produce this mix. Density ranged from 25.3 to 27.2 lb/ft^3 and compressive stress varied from 400 psi to 700 psi based on primer variations. All samples in this series used XZ-8-5066.

TEST DATA

DRUM TUMBLED SAMPLES 10% RESIN

SAMPLE	MICROBALLOONS PRIMED WITH	% PRIMER	% HEXANE	DENSITY	COMPRESSIVE STRESS
A-1	92-019	100		9.07	
A-2	92-019	150		10.02	
B-1	XZ-8-5066	50		8.95	36 psi
C-1	Sylgard	100		9.85	
C-2	Sylgard	150		10.18	

AIR STIRRER 10% RESIN

SAMPLE	MICROBALLOONS PRIMED WITH	% PRIMER	% HEXANE	DENSITY	COMPRESSIVE STRESS
B-2	XZ-8-5066	50	100	10.21	36
B-3	XZ-8-5066	50	200	10.19	27
B-4	XZ-8-5066	100	100	10.02	161
B-5	XZ-8-5066	100	200	10.27	176
B-6	XZ-8-5066	100	300	11.02	103
A-1	92-019	200	100	10.59	11
A-2	92-019	200	200	11.08	26
B-10	XZ-8-5066	100	200	10.20	13
C-1	Sylgard	200*	100	---	
C-2	Sylgard	200*	200	---	
	20% Resin				
D-1	XZ-8-5066	100	200	14.52	24

*Primer baked 1 hour @ 70°C before resin addition

TEST PANELS

All usable test panels were evaluated for density, compressive stress, and shear strength.

Density was tested per ASTM D 1622. Samples were cut from the 12" x 12" panel, weighed and measured.

Compressive stress was measured by ASTM Method D 695 using 1" x 1" samples. Other compressive stress tests were obtained by pressing a 1" x 1" aluminum block into a 2" x 2" sample. This latter method was used when filler was lost from the edges of samples during machining.

The test equipment is shown in Figure 17. The compressive stress test was used to compare the strength of the filled honeycomb with the strength of the same honeycomb as received and to evaluate the relative quality of the test samples. All samples were tested in the T direction--the thickness of the honeycomb. Sample S-8 was also tested in the L-longitudinal and W-width directions. All samples showed improved strength over the original 160 psi obtained on unfilled honeycomb in the T direction. This improvement of from 162 percent to 415 percent is due to the stiffening effect of the filler and is an additional indicator that properly compacted and cured material has been produced, or can be produced from the sampled mix of material.

Shear strength was measured by the plate shear method of Mil Std 401. Samples were reduced in width to one-inch to accomodate the 200 pound maximum load capacity of the TM Instron tester. This test is shown in Figure 19. Tested samples are shown in Figure 20.

Filled honeycomb samples were bonded to the metal shear plates using Hysol 907 quick setting adhesive.

The shear test samples all failed at the adhesive-honeycomb interface. This test again demonstrates the stiffening effect of loading the honeycomb. The failures at the interface show that the filling in the samples is cured and bonded to the honeycomb. Uncured filling or unbonded material yeilds a 45 degree angle break in the honeycomb due to buckling.

MIXING FOR LOW DENSITY 12-INCH BY 12-INCH by 2-INCH TEST PANELS

Dow Corning primers 92-019, XZ-8-5066, and Sylgard primer were evaluated at a concentration of 100% and 150% using 90% Microballoon-10% resin systems. The mixing was performed as follows:

1. Microballoons placed in glass tube and primer passed through Microballoons with the aid of a vacuum.

2. Samples removed from tubes and dried for 30 minutes at room temperature.

3. Primed Microballoons placed in quart can with 10% resin added over the Microballoons.

4. Can was sealed and placed on roller mill for two hours.

The use of a roller mill proved to be inadequate for resin dispersion. The rolling action caused the resin to coat the sides of the container. Dilution of the resin with 200% Hexane showed no noticable improvement in dispersion.

Proper resin dispersion was accomplished by placing the primed Microballoons in a stainless-steel beaker, adding the resin diluted with 200% Hexane, and mixing system with an air stirrer.

A one-cubic inch sample was made from each mix and cured 16 hours at 250°F. The samples were then tested for compressive strength. The use of Dow Corning primer XZ-8-5066 at a concentration of 100% provided the best compressive strength sample.

Since material requirements were much greater for 12" x 12" test panels compared to the one-cubic inch samples, a one gallon capacity Ross Mixer was used for 12" x 12" panels.

The dilution of the resin was cut from 200% to 100% Hexane.

Four (4) individual mixes were made to provide the quantity of material necessary for one 12" x 12" panel with optimum density of 15 lbs./ft^3.

The first six 12" x 12" test panels that were made were 90% Microballoon - 10% resin composition.

The mixing procedure was as follows:

1. One-hundred and seventy grams of BJO-0930 Microballoons placed in mixer with 170 grams of Dow Corning XZ-8-5066 primer poured over Microballoons.

2. Mixed for ten minutes.

3. Removed from mixer, spread out to 1/2" thick layer and dried for three (3) hours at room temperature.

4. Nineteen grams of resin (containing 10% catalyst) were diluted with 170 grams of Hexane. Mixed five minutes by hand.

5. Primed Microballoons placed in mixer with diluted resin added over Microballoons. (Ref. Figure 11)

6. Mixed for 15 minutes.

7. The contents were removed from the mixer, spread out to 1/2" thick layer, and dried one hour at room temperature.

8. The above procedure was repeated three additional times.

9. Mixing was done the same day that the panels were fabricated and cured. The four batches were combined and loaded into the honeycomb.

The remaining low density 12" x 12" test panels that were mixed were 80% Microballoons - 20% resin combination. The first 80% Microballoon - 20% resin 12" x 12" panel that was dried showed a loss of 5% below the initial calculated weight. This loss in weight was due to additional volatiles lost during cure. An increase of 5% in Microballoons and resin solve this problem.

Various methods were tried to reduce the drying time for the primer and resin, such as under vacuum, but the method which yielded the best panel still remained room temperature drying (2 hours minimum for primer and one hour for resin).

MIXING FOR HIGH DENSITY 12 INCH BY 12 INCH BY 2 INCH TEST PANELS

A one-gallon capacity Ross Mixer was used for the mixing of high density test panel material. Two high density test panels were made. The mixing procedure for each is as follows:

High Density Test Panel No. HD-1

1. One-hundred and eighty grams of BJO-0930 Microballoons were placed in mixer with 170 grams of Dow Corning XZ-8-5066 primer poured over the Microballoons.

2. Mixed for 10 minutes.

3. Contents removed from mixer, spread out to 1/2" thick layer, and dried for two hours at room temperature.

4. Three-hundred and sixty-five grams of resin (10% catalyst) were diluted with 170 grams of Hexane and hand stirred for five minutes.

5. Primed Microballoons placed in mixer with diluted resin added over Microballoons. (Ref. Figure 11)

6. Mixed for 15 minutes.

7. The contents were removed from mixer, spread out to 1/2" thick layer and dried one hour at room temperature.

8. The above procedure was repeated three additional times in order to obtain the quantity of material needed for a 12" x 12" test panel.

9. Material was placed in polyethylene bag and refrigerated at -4°F until needed.

High Density Test Panel No. HD-2

The only variation between this mix and the first mix was that the use of Hexane to disperse the resin was deleted. Acceptable resin dispersion was obtained without the use of Hexane.

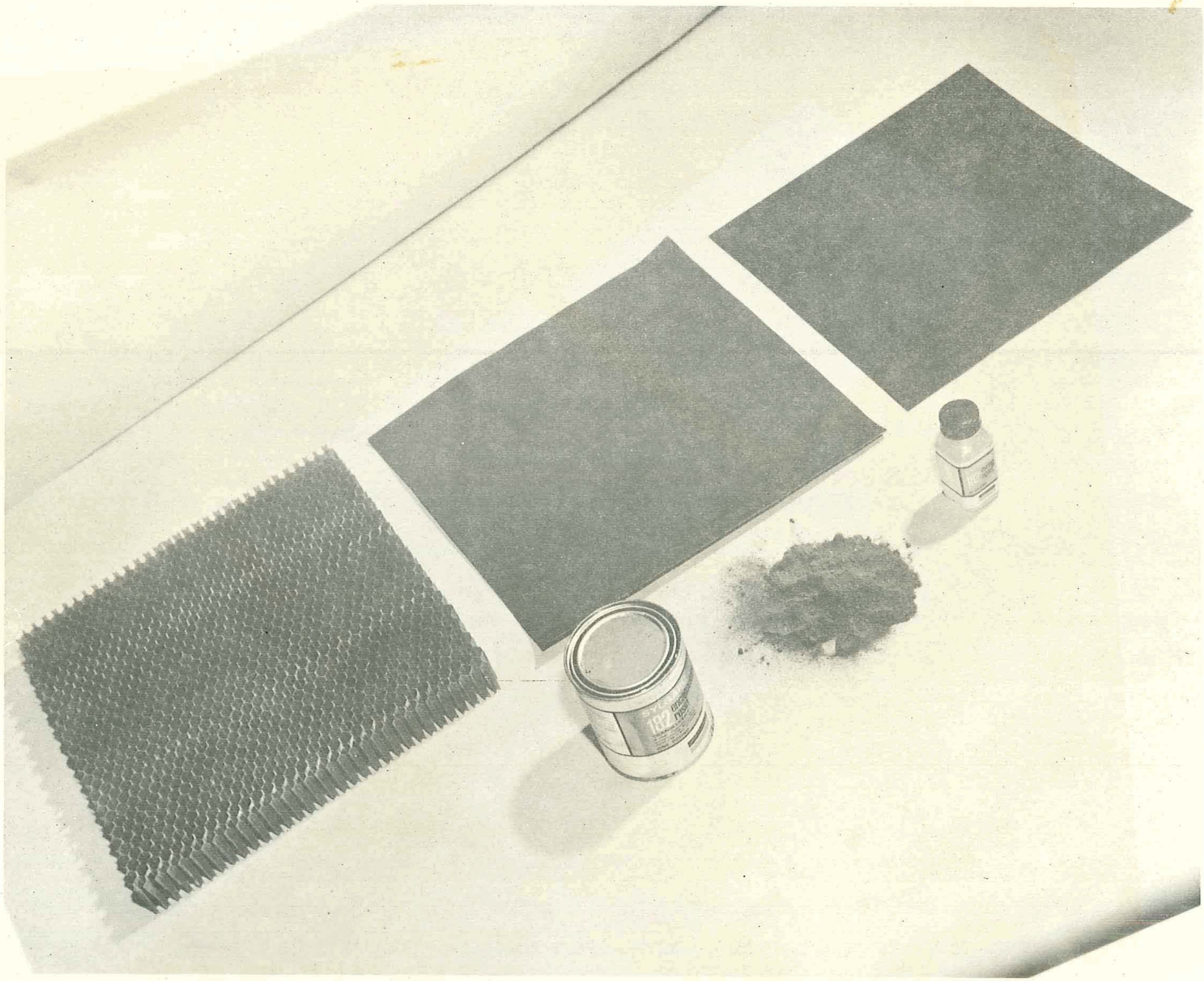


FIGURE 10
Sub-scale Ablation Panel Materials
Honeycomb, Face Sheet Plies,
Resin, Microballoons, and Resin Catalyst.

FIGURE 11
Ross Mixer, 1 Gallon Capacity

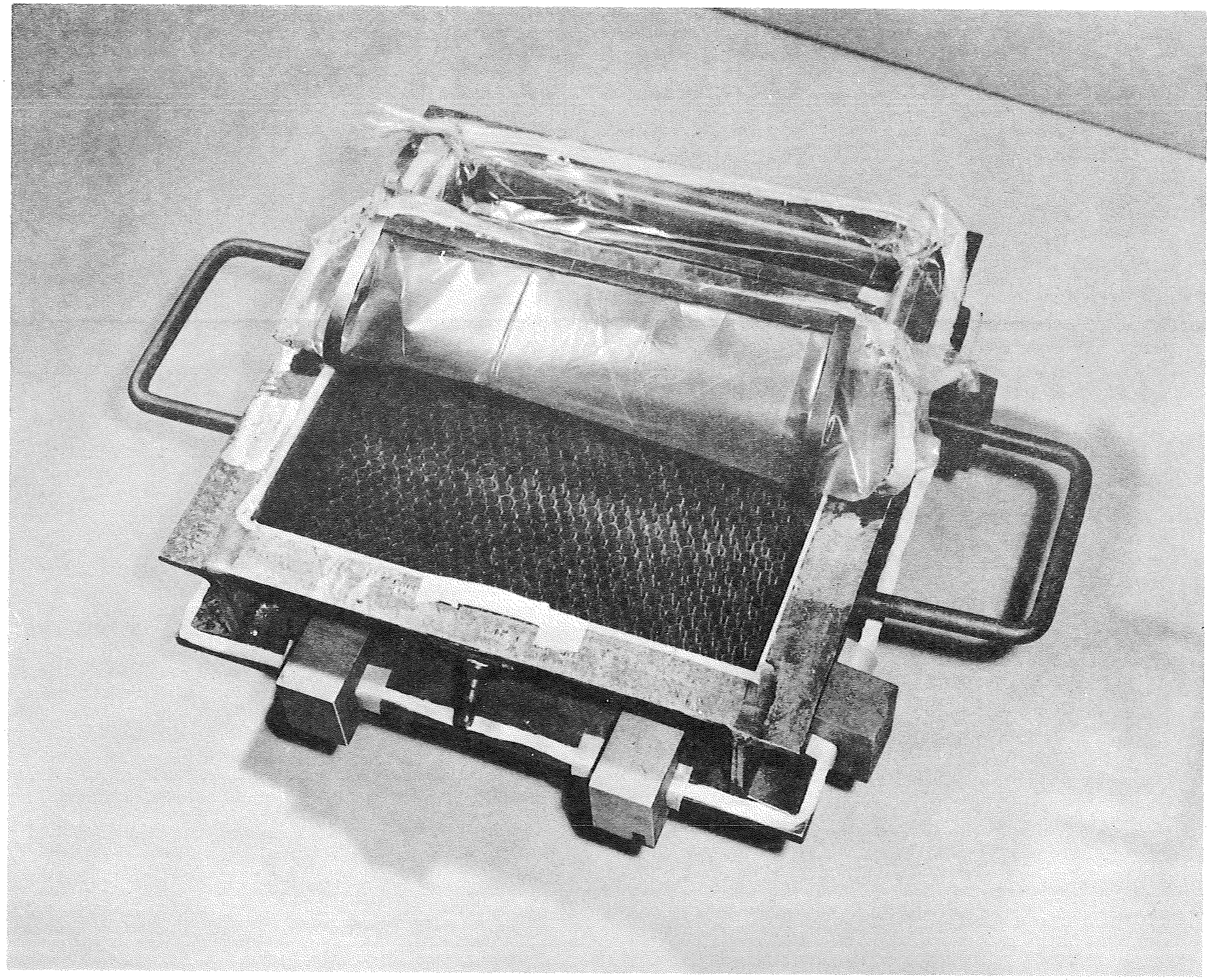


FIGURE 12

Sub-scale Cure Form, with
Honeycomb - Face Skin Assembly
Partially Bagged for Bond Cure

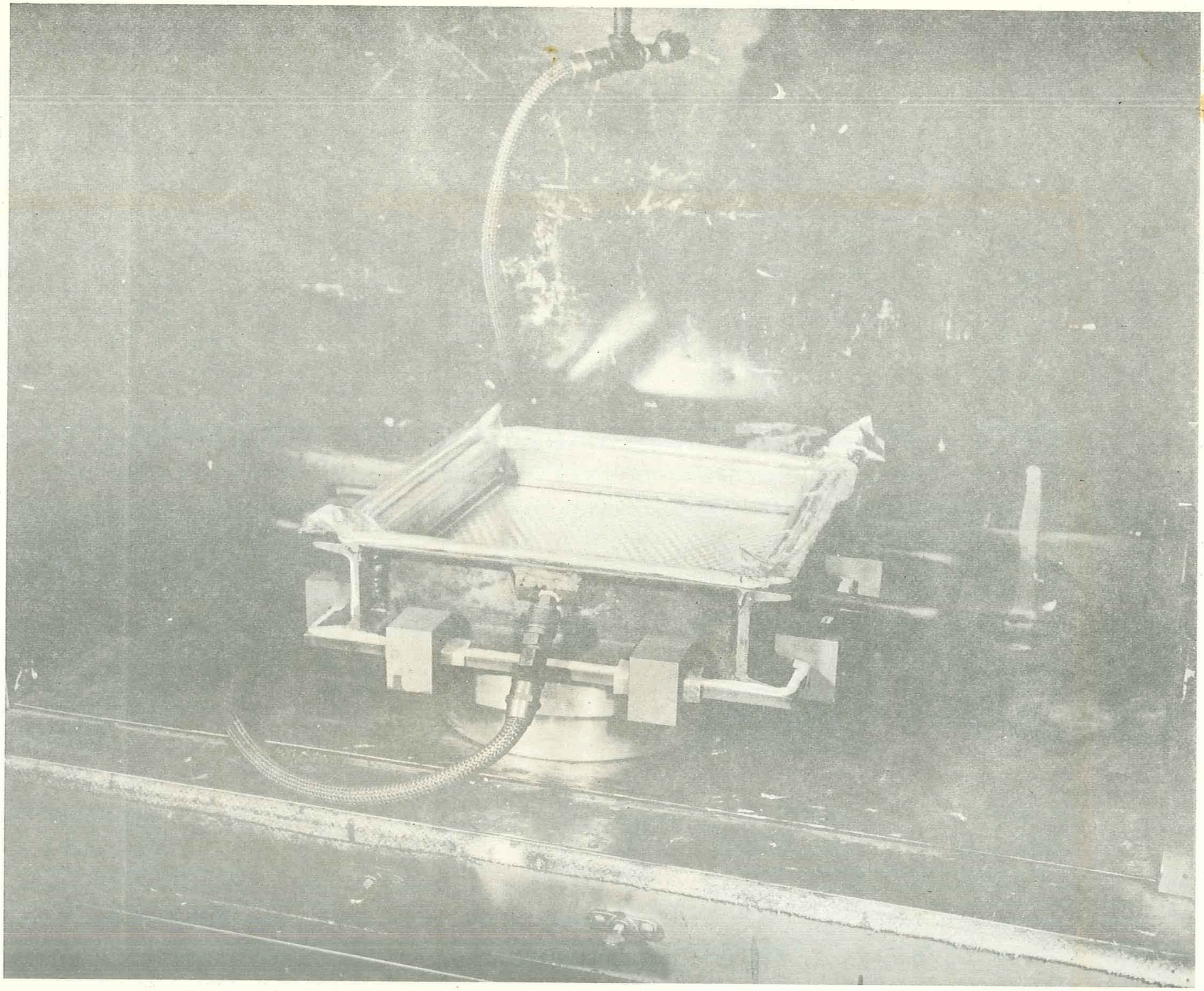


FIGURE 13
Sub-scale Cure Form, with Honeycomb - Face Skin Bonded in Place, Ready For Removal From Vacuum Equipped Cure Oven.

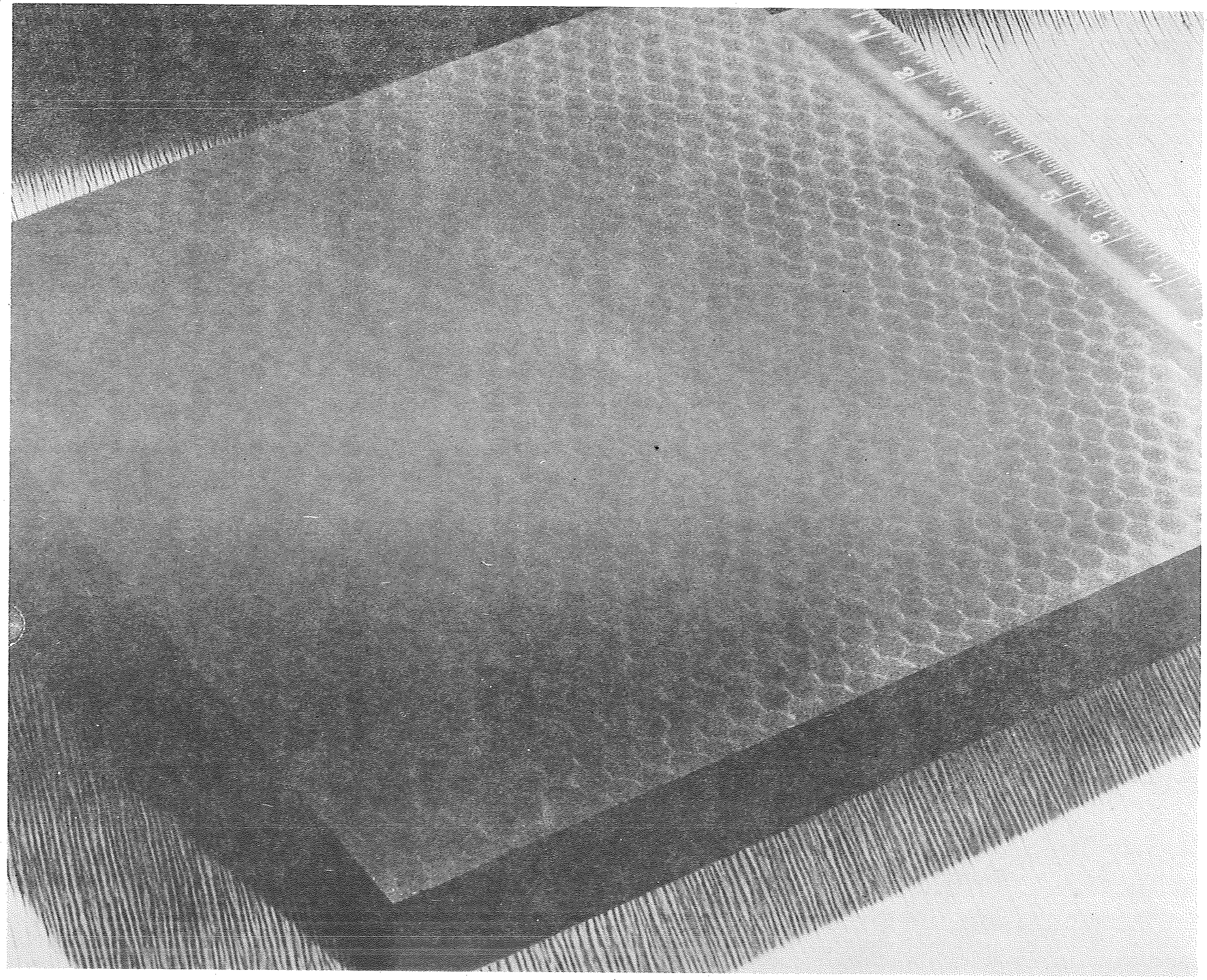


FIGURE 14
Cured 12 inch x 12 inch sub-scale ablation test panel No. S-4
10 Percent Elastomer, 90 Percent Microballoons

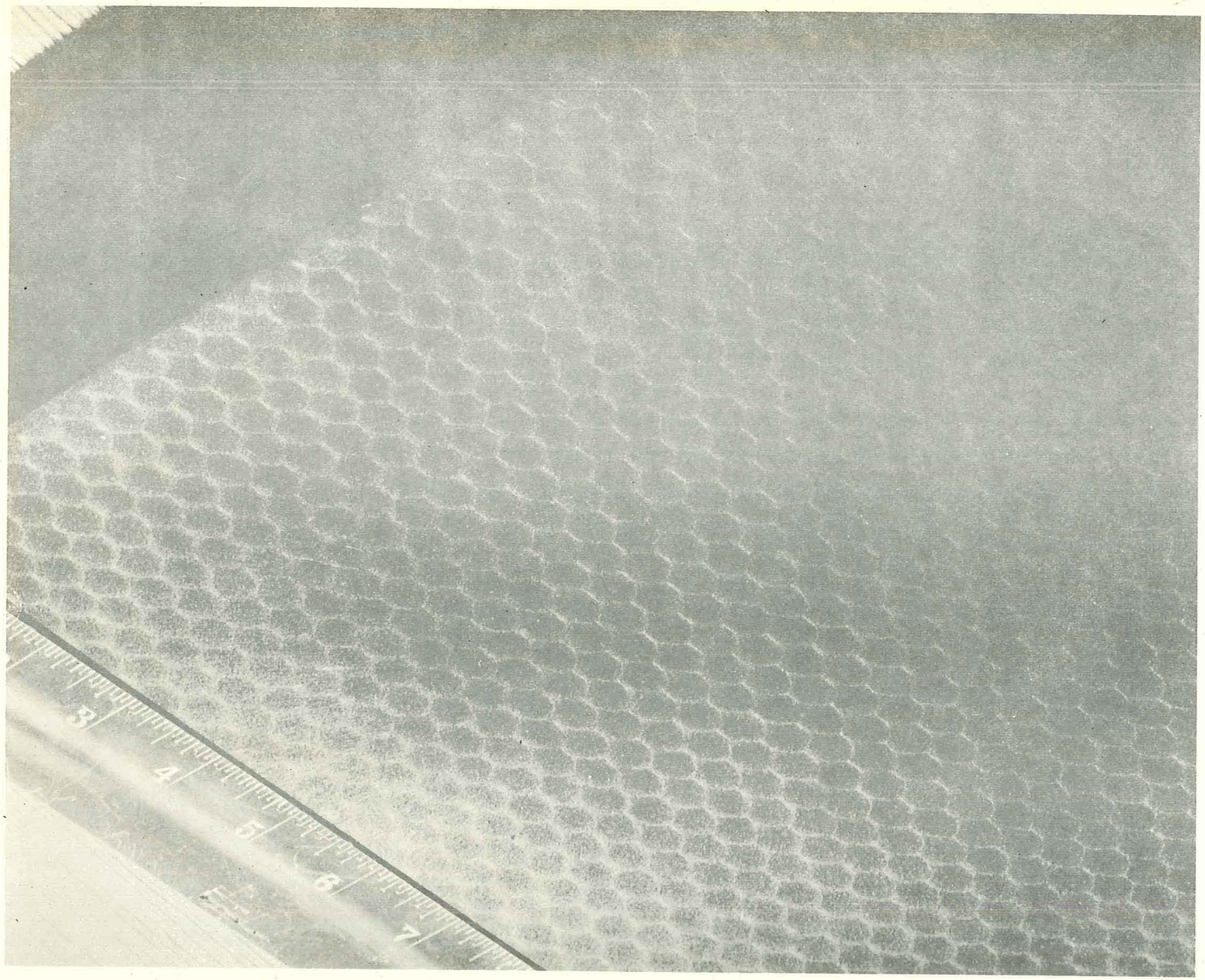
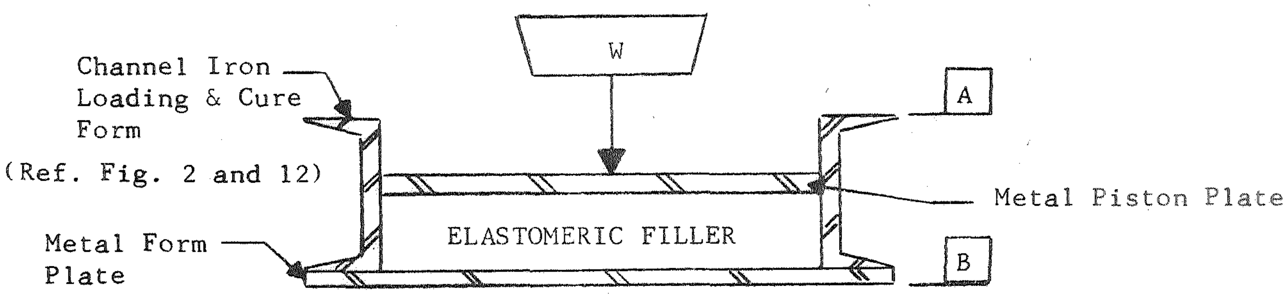


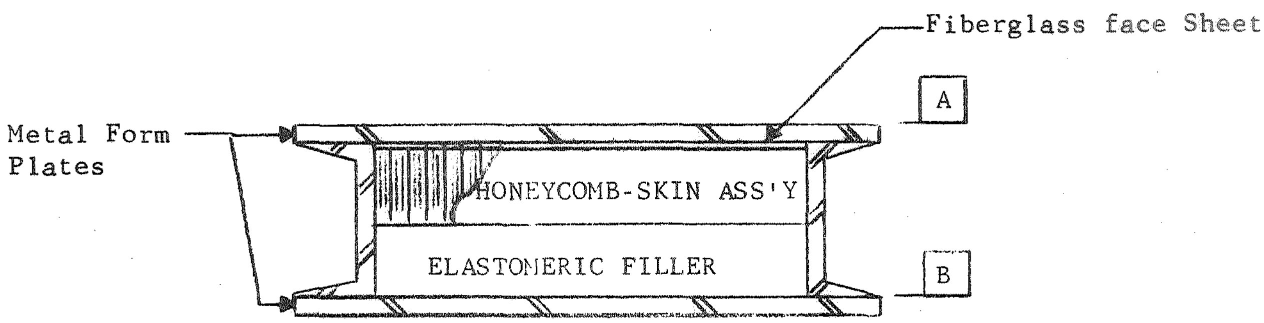
FIGURE 15
Sub-scale Test Panel No. S-4, Enlarged View

DEVELOPMENT WORK:
12 INCH X 12 INCH X 2 INCH TEST PANELS

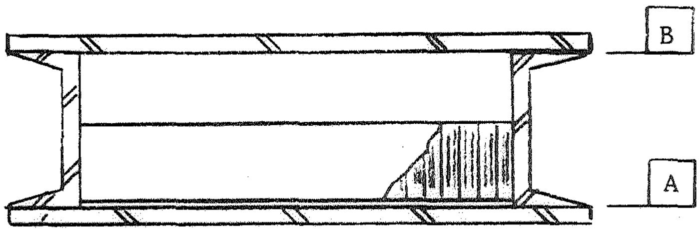
Initial Test Panel Loading, Using Vacuum Pressure Only



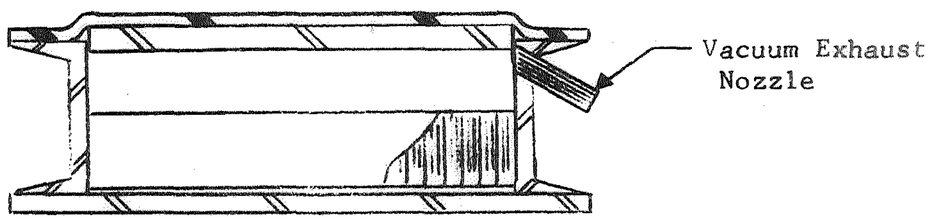
(1) Filled and doctor bar leveled resin-Microballoon filler, lightly compacted in cure form, under weight and piston plate.



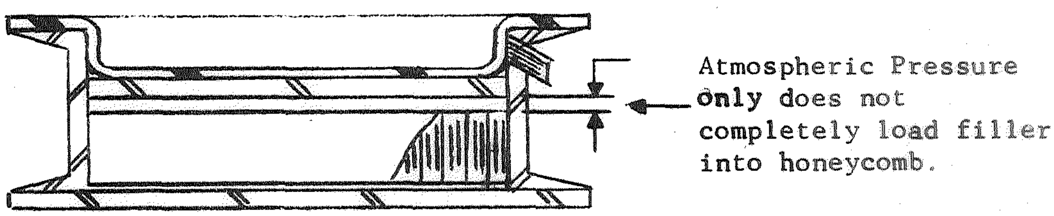
(2) Piston plate removed and primed honeycomb with bonded face plate placed on top of lightly compacted filler material in cure form with top plate in place.



(3) Cure form inverted, placing leveled and lightly compacted filler on top of honeycomb.



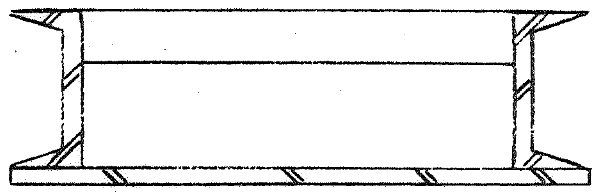
(4) Loading Cover plate removed, piston plate in place over filler material, vacuum bag and exhaust nozzle installed. Ready for application of vacuum pressure at 25-28".



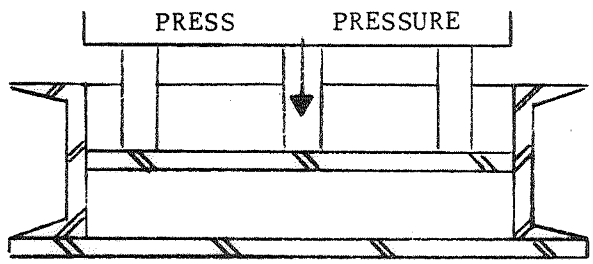
(5) Application of 25"-28" vacuum permits atmospheric pressure to force piston plate down, forcing resin Microballoon load into primed honeycomb.

(6) Unit as is in item (5) above then cured, under full vacuum, for 16 hours at 250°F.

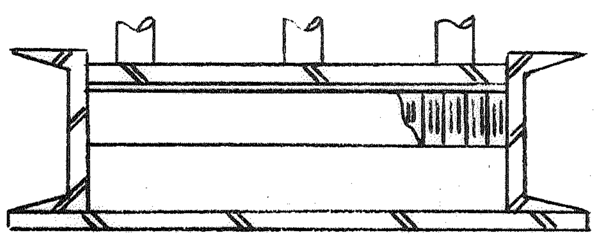
Hydraulic Press Loading Development Work



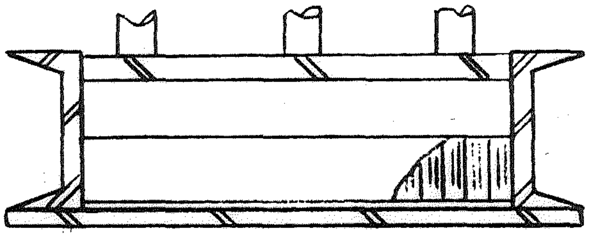
(1) Loaded and Doctor bar leveled resin-Microballoon mix.



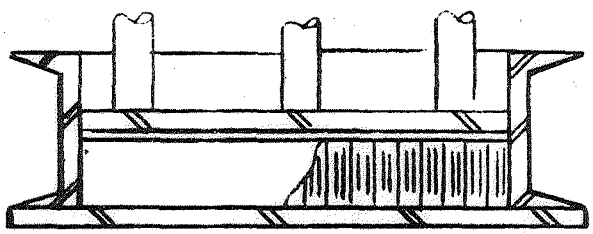
(2) Compacted resin-Microballoon mix.



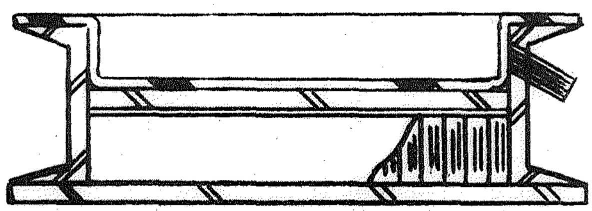
(3) Primed honeycomb in place over partially compacted resin-Microballoon mix.



(3A) Loaded form may be inverted.

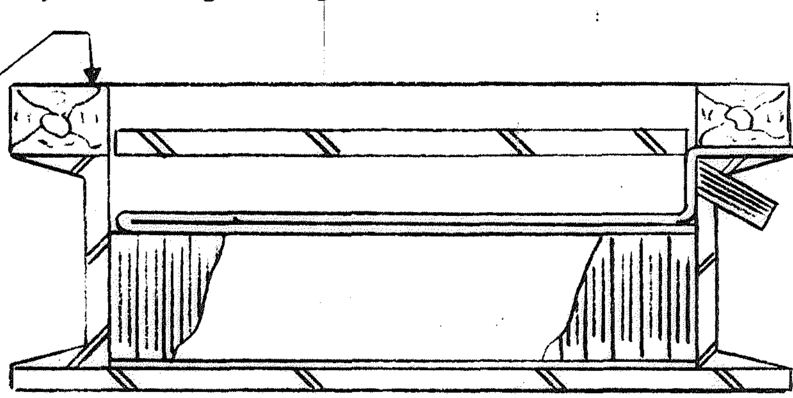


(4) Primed honeycomb pressed into leveled and compacted resin-Microballoon mix. Performed in hydraulic press at 160 to 175 psi, from either (3) or (3A) above configuration.



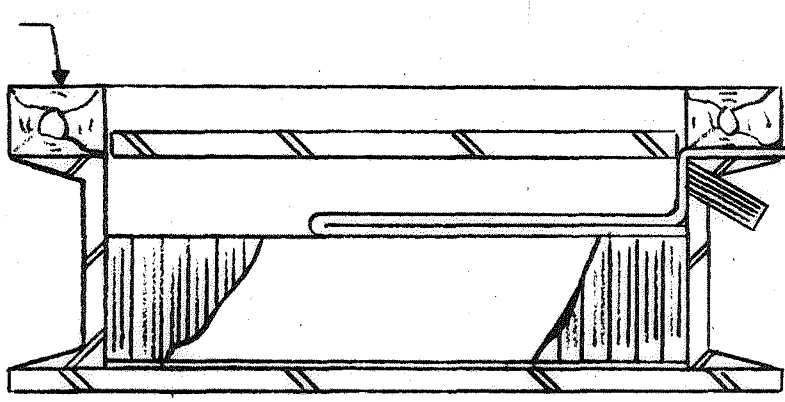
(5) Vacuum bagged and cured. Full line vacuum -- 25-28" applied to part during cure. (Ref. Fig. 15 and 16)

Final loading method, applicable to flat and curved panels: This method provides the capability of handling large volume loading by permitting partial loading of primed honeycomb in controlled density sequential layer filling, using a portion of the total load in each loading sequence.

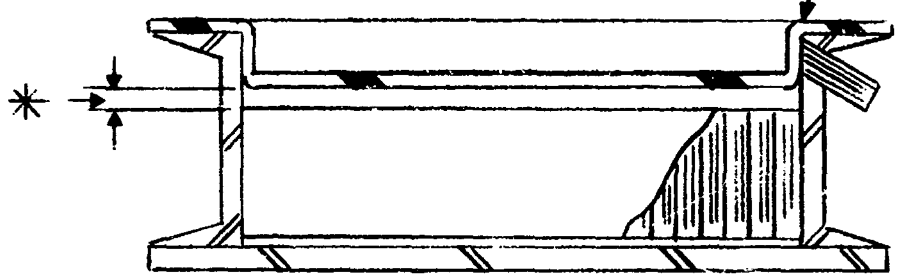


The loading and curing form, with primed honeycomb resting on bottom form plate, teflon-fiberglass barrier curtain in place, and partial resin-Microballoon load spread and doctor bar leveled in place on top of barrier curtain. A metal piston plate then covers the spread and leveled filler material.

Approximately 25% of complete load used per sequence.



Teflon-fiberglass barrier curtain shown partially withdrawn, piston plate slightly compressing and holding filler material in place during complete curtain withdrawal, and prior to installation of thin rubber vacuum bag. Vacuum exhaust applied to bagged sealed assembly causing piston plate to force partial filler load into honeycomb.

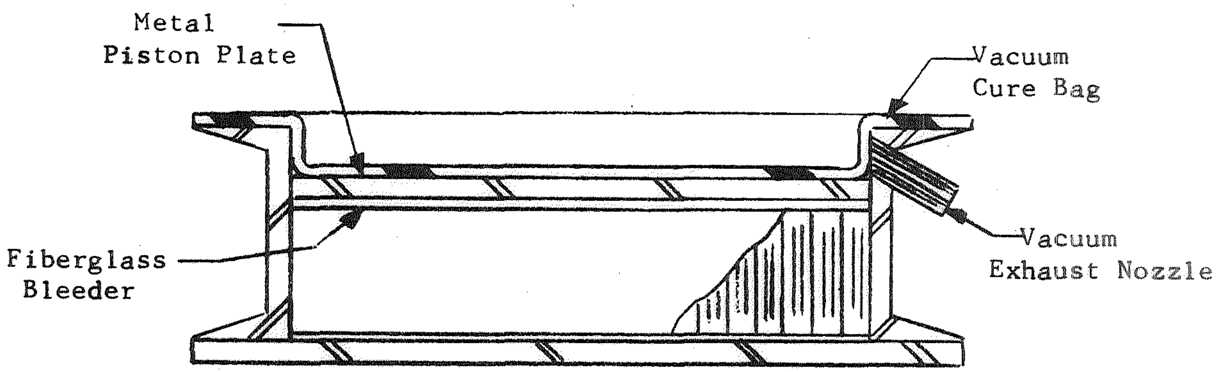


After fourth loading operation, (*Note vacuum pressure will not force last portion of total load completely into honeycomb) metal piston plate is removed and vacuum bag replaced directly over resin-Microballoon load.

The bagged cure form and panel assembly is then placed into an autoclave, vacuum lines attached, vacuum applied, and the autoclave pressurized to 150-160 psi, and held at 150-160 psi for five (5) minutes, pressure is then released by blowing down the autoclave. This completes the filling operation to the top surface of the honeycomb reinforcement.

The bagged cure for - panel assembly is then removed and the top surface of the honeycomb-filler panel is examined for any low spots, (i.e. indented cell top surface) low spots indicating low density cell core filling.

Any low core areas noted are filled by scrapping off any high spots noted (or slight amount of additional filler added).



The metal piston plate is replaced over a fine weave fiberglass bleeder cloth covering the honeycomb panel, elastomeric cure bag applied, and part placed in autoclave, vacuum line attached, vacuum applied and autoclave pressurized to 150-160 psi and held for five (5) minutes, then blown down to 50 $\pm$ 5 psi and held at 50 $\pm$ 5 psi for entire cure cycle.

The cure cycles established by 12" x 12" development panel cure evaluation are as follows:

A - Low Density Elastomeric Filler

16 Hrs. @ 250 ^{o}F, 25-28" Vacuum and

50 psi Autoclave pressure.

B - High Density Elastomeric Filler

24 Hrs. @ 180 ^{o}F, 25-28" Vacuum and

50 psi Autoclave pressure.

DEVELOPMENT TEST PANEL FABRICATION AND COMMENTS

PANEL NO.	ELAST-OMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
S-1	10/90	50 percent of face sheet sanded and solvent cleaned, remaining 50% solvent cleaned only. HC bonded to fiberglass face sheet under vacuum pressure only. MB and HC primed with XZ-8-5066 primer. MB and resin mixed in one gallon Ross Mixer. 4 batch mix. 4 step loading on top of HC, using bag and vacuum pressure to fill HC cells.	1. Cure and adhesion of Plastilock 729 bonded face skin good in both sanded and non-sanded areas, sanding is not required for good face skin adhesion. 2. HC was not filled to face skin and approx. 3/4 inch of elastomer thickness did not enter HC but cured on top of HC. 3. Elastomer mix cure -- good.	Poor fill Not Checked.
S-2	10/90	Same priming resin mix and loading procedure as S-1 above, with 200 lb. weight applied for loading pressure in addition to vacuum pressure prior to vacuum bag cure.	1. MB-resin mix filling only slightly improved; approx. ½" of mix did not enter HC and cured on top of HC. 2. Elastomer mix cure and adhesion -- good.	Poor fill Not Checked.
S-3	10/90	A porous fiberglass-phenolic veil was prepared for the HC face sheet. The priming, mixing, and loading operations same as S-1 and 2 above, except 50 psi air pressure applied to bagged panel assembly prior to vacuum bag cure.	1. Slight improvement in HC filling, approx. ¼" of elastomer did not enter HC and cured on top of HC. 2. Elastomer mix cure and adhesion -- good.	Poor fill Not Checked.
S-4	10/90	HC with face sheet bonded in place primed with XZ-8-5066 primer. MB primed and mixed in 4 batches, each batch air dried one hour, then all batches blended together. The elastomer mix load was placed into the cure form, distributed and leveled. The HC-face sheet assembly, with face sheet up, was then	1. 150 psi, hydraulic press pressure produced a smooth "Cookie Cut" entry of the HC into the elastomer mix down to preset stops. 2. Spring back of elastomer mix after vacuum cure very slight.	16.5 lb/ft^3

(continued)

PANEL NO.	ELAST-OMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
S-4	10/90	placed on top of the elastomer mix load. The assembly then placed in a hydraulic press for "Cookie Cut" entry of the HC into the elastomer mix. Vacuum bag pressure cure.	3. HC filling was good to face sheet. 4. Good cure and adhesion.	
S-5	10/90	Elastomer priming and mixing reduced from 4 to 3 batches for load requirements. HC face sheet assembly "Cookie Cut" into leveled load mix @ 150 psi in hydraulic press, same as S-4 vacuum bag cure.	1. HC filled to top of face sheet. 2. Slight top surface spring back of elastomer mix fill noted. 3. Good elastomer mix cure and adhesion.	14.1 lbs/ft^3
S-6	10/90	Elastomer mix preform test, same mix priming and mixing procedure as S-5. Mix load placed in loading and cure form, then compressed to cure height @ 150 psi, pressure released and load vacuum bagged and cured under 25/28" vac. for 3¼ hrs. @ 250°F. After cooldown the preformed load showed some surface cracking due to shrinkage. HC-face skin assembly then "Cookie Cut" into preformed load, part bagged and vacuum cured for 16 hours @ 250° F.	1. Preformed elastomer mix load could not be handled as a briquet after partial cure. 2. Surface cracks noted after partial cure did not knit during final cure. 3. Force required to enter HC into partial cured preform crushed HC resulting in only partial entry of HC into preform.	---
S-7	20/80	Resin-Microballoon mix ratio revised to 20 percent resin, 80 percent Microballoons elastomer mix - 3 batch process, same priming and mixing as S-5 except for mix ratio. Loading procedure-hydraulic press, 150 psi "Cookie Cut" into total load. 25 to 28" vacuum pressure, bag cure 16 hrs. @ 250°F.	1. Slight load spring back noted on panel top surface after loading. 2. Approx. 1/16" material not entered into H.C. after vacuum cure, sanded off with good finish. 3. Cells well filled to top of face sheet. 4. Good Cure and adhesion.	15.62 lbs/ft^3

PANEL NO.	ELASTOMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
		NOTE: Test panels S-1 through S-7 inclusive were produced using 1½ inch thick nylon-phenolic honeycomb, on hand prior to delivery of the Hexcel HRP - 3/8-GF12 - 2.6 x 2.0" material ordered for the program.		
S-8	20/80	Reproducibility check on fabrication processes used for S-7, with 2" fiberglass honeycomb matrix, elastomer mix, 3 batch process same as S-7. Cure form filled with 50 percent of total load, leveled and HC-face skin assembly "Cookie Cut" into elastomer mix @ 150 psi press pressure against stops. Partial filled panel removed, remaining half of load placed into form and process repeated. Panel assembly bagged and vacuum cured 16 hrs. @ 250°F.	1. 1/8" of "Spring back" cured elastomer noted on top of panel after cure. 2. Vacuum pressure - 25 to 28", appears to be inadequate to restrain the elastomer filler in required volume-compression during panel cure. 3. Sectioned panel shows good filling to top of face sheet with some indication of lower density fill at top of face sheet. 4. Elastomer mix cure and adhesion to HC matrix -- good.	15.25 lb/ft^3
S-9	20/80	Autoclave loading and cure based on fabrication of S-8, with the following process variations: 1. Initial 50% of elastomer mix load forced into HC-face skin assembly by hand pressure. 2. Remaining 50 percent of filler placed into loading and cure form, leveled and the half filled HC-face skin assembly placed (continued)	1. Faulty autoclave pressure controller caused slow rise to 150 psi for this cure. 2. Panel shows top (open cell) surface cracks, indicating either insufficient cure at 50 psi, permitting filler spring back and cracking during vacuum pressure only - oven final cure, or partial resin cure prior to total compaction due to	

PANEL NO.	ELAST-OMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
S-9	20/80	on top. 3. Metal piston plate placed over top of face skin, then total assembly vacuum bagged for cure. 4. Vacuum bagged part placed in autoclave, 25-28" vacuum applied to bagged part. Autoclave pressurized to 150/160 psi and pressure to be held for one minute then reduced to 50 psi. 5. Panel cured one hour @ 250°F, full vacuum, 50 psi pressure, dry air cure, then cooled down @ 30°/hour to 190°F. 6. Autoclave pressure removed, part removed from autoclave and circulating dry air oven cured, under 25-28" vacuum for 12 hours @ 250°F. Cooldown @ 30°/hour to 100°F.	slow pressure rise. 3. Filling of matrix appears good; cure questionable.	---
S-10	20/80	Autoclave cure cycle and pressure cure test for elastomer mix. No honeycomb-face sheet assembly used. 150/160 psi forming pressure held for five minutes, then reduced to 50 psi and held for: Step Cure cycle - 1 hour @ 150°F 1 hour @ 175°F 1 hour @ 212°F Cooldown @ 30°F/hr to 150°F, then panel removed and debagged.	1. Panel shows severe cracking, due to excessive shrinkage without matrix support. 2. Cure - Fair. 3. Suspect possible condition of excess volatiles in elastomer mix at time of loading. 4. Due to cracks, etc., final cure was not applied.	No Matrix, Not Checked

PANEL NO.	ELAST-OMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
S-11	20/80	Elastomer mix preparation and autoclave-oven cure cycle test: 1. Same elastomer mix preparation as S-9 and S-10 except mix vacuum dried one hour instead of 2 hours air dry. 2. Loading of honeycomb-face skin assembly same as S-9 except 150/160 psi autoclave filling pressure held for five minutes before reduction to 50 psi hold cure pressure. Circulating dry air autoclave cure cycle @ 50 psi pressure after filling: One hour @ 150°F One hour @ 175° F One hour @ 212° F Four hour cooldown to 100°F under full vacuum and 50 psi autoclave pressure. Final Cure: Circulating dry air oven cure, part vacuum bagged for 25-28" vacuum. 16 hours @ 250°F, with drift cooldown to room temperature.	1. Elastomer mix cured flush to top surface of honeycomb, good surface appearance; no cracking. 2. Filling good to top of face sheet. 3. Cure and adhesion to matrix - good. 4. Overall panel density after autoclave cure, prior to final cure -- 17.25 lb/ft^3.	15.8 lb/ft^3

PANEL NO.	ELASTOMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
S-12	20/80	Repeat of S-11 fabrication except Microballoons primed with XZ-8-5066 primer were allowed to air dry sixteen hours @ room temperature prior to resin mixing. Final elastomer mix air dried for one hour and vacuum dried for one hour. Autoclave cure; same as S-11. Final cure: Part bagged, full vacuum 25 to 28" -- six hours @ 250°F in circulating air oven.	1. Elastomer mix cured flush to top of honeycomb, good surface appearance. 2. Sectioned panel shows fair filling, some HC cells lack approximately 1/16" of solid fill to face sheet. 3. Good cure and adhesion. 4. Total panel density after autoclave cure, prior to final cure was 17.32 lb/ft^3.	16.0 lb/ft^3
S-13	20/80	"No Cure" panel loading trial for removable flexible barrier curtain sequence loading. Primed Microballoon filler, without resin used for this test. Honeycomb-face sheet assembly was placed into bottom of loading cure form with open cell face up. The folded over barrier curtain placed on top of the honeycomb and a partial filler load distributed and leveled on top of the curtain. A metal plate then placed on the top of the leveled filler and the curtain withdrawn, permitting load access to honeycomb for filling. Initial portion of load, up to 50 percent was filled by hand pressure on metal plate. Final portion of load required 150 psi hydraulic press pressure to force filler flush to matrix surface.	1. No cure required. 2. Removable curtain system worked good, no removal problems. 3. Loading, into top of honeycomb matrix cells, with partial loading operation, was quickly accomplished with apparent even filling.	

PANEL NO.	ELASTOMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
S-14	20/80	Elastomer mix preparation same as S-11 except primed Microballoons and primed Microballoon-resin mixes were both dried in a stainless steel container with forced air circulation. Filling and loading, using barrier curtain. Autoclave cure, same as S-11.	1. Cure - fair. 2. Elastomer adhesion to XZ-8-5066 primed honeycomb - poor 3. Elastomer mix appeared to have shrunk approximately 1/32" below top surface of honeycomb.	---
S-15	20/80	Stored-refirgerated elastomer mix test. Microballoon-primer mix table air dried for 2 hours @ room temperature. Primed Microballoon-resin mix table air dried for one hour @ room temperature. Final mix stored in sealed poly bags @ $10^{o}F$ for 72 hours prior to loading and curing. Panel filled in a four step process using the barrier curtain method, filling into top of honeycomb, and applying 25-28" vacuum pressure force to load filler into honeycomb on each filling operation. Metal piston plate placed over loaded panel and unit bagged for autoclave pressure final fill and cure operation. (continued)	1. Elastomer mix cure and adhesion to honeycomb - good. 2. Sectioned panel shows good cell fill. 3. Refrigerated storage offers method of accomplishing large mix requirement panel production.	14.6 lb/ft^3

PANEL NO.	ELAST-OMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
S-15	20/80	Autoclave pressure final fill operation: pressurize bagged part, under 25-28" vacuum, to 150/160 psi. Hold at pressure for 5 minutes, then reduce pressure to 50 psi and hold. Autoclave step cure cycle: (Rise times not included) One hour @ 150°F One hour @ 175°F One hour @ 212°F Two hours @ 250°F Four hour cooldown to 130°F @ 30°/hr., under full vacuum and 50 psi pressure.		
P-1	20/80	Full size 2 ft by 4 ft by 2.0" cured test panel. Thirty-two batches were mixed in the one gallon Ross Mixer and stored at 10°F for completion of panel loading. Same mixing and drying procedure as S-15. Four step curtain loading,with vacuum assist on last two steps, and final loading under autoclave pressure same as S-15. Autoclave cure cycle: Part bagged and held at 25-28" vacuum, 50 psi autoclave pressure. (continued)	1. Elastomer mix cure and adhesion to honeycomb - good. 2. Edge fill not complete around outer edge of panel. 3. Sectioned panel shows some voids in cell spaces at top of face skin. 4. Sectioned panel spot area density checks show range of 15.35 lb/ft^3 to 18.35 lb/ft^3, indicates need for improved distribution method for large panel	17.06 lb/ft^3

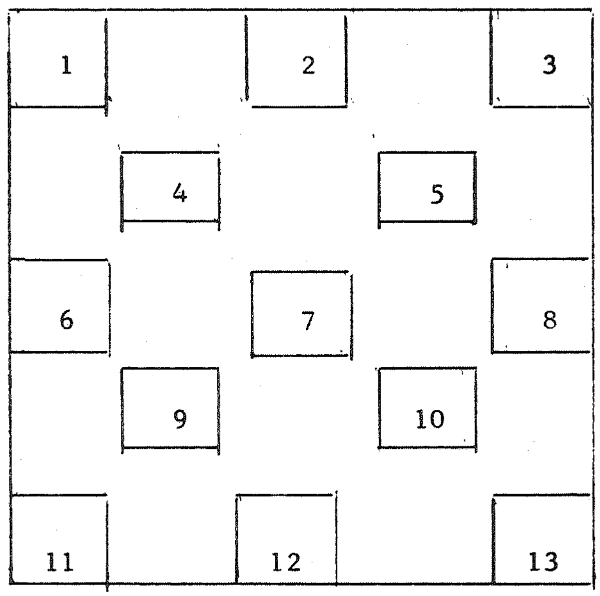
PANEL NO.	ELAST-OMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
P-1	20/80	One hour @ 200°F Four hours @ 250°F Remove 50 psi pressure, holding 25-28" vacuum on part. Twelve hours @ 250°F Drift cooldown, under vacuum to room temp.		
S-16	20/80	Proof panel for 30 gallon production mix, processed in 50 gallon Pony Mixer. Honey-comb matrix edges preloaded prior to placement in loading form for curtain method loading and filling. Cure -- same as P-1.	1. Elastomer mix cure and adhesion to honeycomb - good. 2. Overall panel density low, indicating excessive volatile loss from calculated panel load weight with this mix. 3. Sectioned panel shows approx. ¼" lack of fill at bottom of cells throughout panel.	12.9 lb/ft^3
S-17	20/80	Repeat of S-16, with 16% increase in load weight to cover volatile loss in cure.	1. Elastomer mix cure and adhesion to honeycomb - good. 2. Panel edge and surface appearance - good. 3. Sectioned panel shows good cell filling to face sheet.	14.9 lbs/ft^3
S-18	20/80	Nomex honeycomb test panel same processes as S-17.	1. Nomex honeycomb crushed under loading pressure conditions.	15.9
S-19	20/80	Repeat of S-18 - Nomex honeycomb test panel.	1. Nomex honeycomb again crushed under minimal load pressure conditions.	16.6

PANEL NO.	ELASTOMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
HD-1	67/33	High density mix test panel. Honeycomb only no face sheet used. Elastomer load mixed in four equal batches using one gallon Ross Mixer. Mixed batches were very wet, indicating solvent not necessary for resin dispersion curtain loading and filling method with final fill under autoclave pressure. Cure same as P-1.	1. Material seemed to load easier than 20/80 mix. 2. Good cure and adhesion to honeycomb. 3. During cure, resin appears to have settled out of mix to create a porous resin skin at base of panel.	32.14
HD-2	67/33	High density mix test panel. Same mix and mix procedure as HD-1 except Hexane solvent deleted. Loading and cure same as HD-1.	1. Mixing procedure not affected by removing solvent from mix. 2. Elastomer mix handled well in loading. 3. Cured panel appearance good, no evidence of excessive resin settling. 4. Adhesion to honeycomb - good. 5. Sectioned panel shows good filling to top of face sheet.	32.6 lbs/ft^3
HD-3	67/33	Factory batch 30 gallon high density mix proof panel. Loading and cure same as HD-1.	1. Elastomer mix handled well in loading process. 2. Cured panel appearance - good, no evidence of excessive resin settling. 3. Elastomer mix cure and adhesion-good.	29.7 lb/ft^3

PANEL NO.	ELASTOMER MIX RATIO	FABRICATION PROCESS COMMENTS; PRIMING, LOADING, AND CURE VARIABLES	PANEL EVALUATION, COMMENTS	12" x 12" PANEL OVERALL DENSITY
S-20	20/80	Cure check panel for 20/80-30 gallon production batch mix. This elastomer mix cured and checked in panel S-16 at time of batch mixing failed to cure up in the initial 2 ft x 4 ft x 2 inch production flat panel.	1. Elastomer material cure - poor, very crumbly and putty-like. 2. No adhesion to honeycomb. 3. Same condition cure as large production panel.	18.1 lbs/ft^3
S-21	20/80	Proof panel for elastomer mix with XZ-8-5066 primer deleted, mixed in one gallon Ross Mixer. Honeycomb primed with Hexane solvent extended Sylgard 182 resin and air dried 2 hours at room temperature. Cure same as P-1.	1. Panel surface appearance - good. 2. Elastomer cure and adhesion - good.	
S-22	20/80	30 gallon factory mix proof panel. XZ-8-5066 priming of Microballoons deleted. Honeycomb primed with solvent extended Sylgard 182 resin, air dried two hours curtain method step filled and loaded. Final fill and cure same as P-1.	1. Panel surface appearance - good. 2. Elastomer mix cure and adhesion to honeycomb - good.	13.6 lbs/ft^3

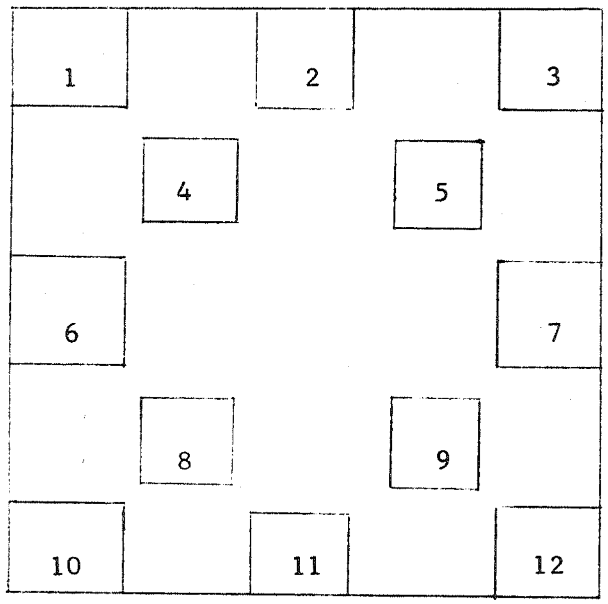
TEST PANEL S-4

SEGMENTED AS SHOWN



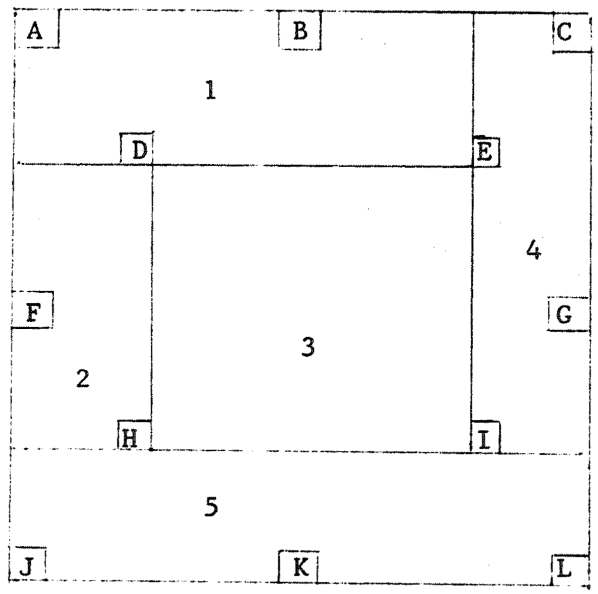
	Density of each segment
S-4-1	13.80 lb/ft^3
2	14.23
3	14.42
4	14.85
5	14.21
6	14.31
7	14.65
8	14.44
9	14.77
10	14.59
11	14.19
12	14.92
13	14.27

TEST PANEL S-5
SEGMENTED AS SHOWN



	Density of each segment
S-5-1	13.85 lb/ft^3
2	14.24
3	14.48
4	14.65
5	14.45
6	15.15
7	13.85
8	14.02
9	13.65
10	13.94
11	14.46
12	13.22
Average	14.16

TEST PANEL S-8
SEGMENTED AS SHOWN

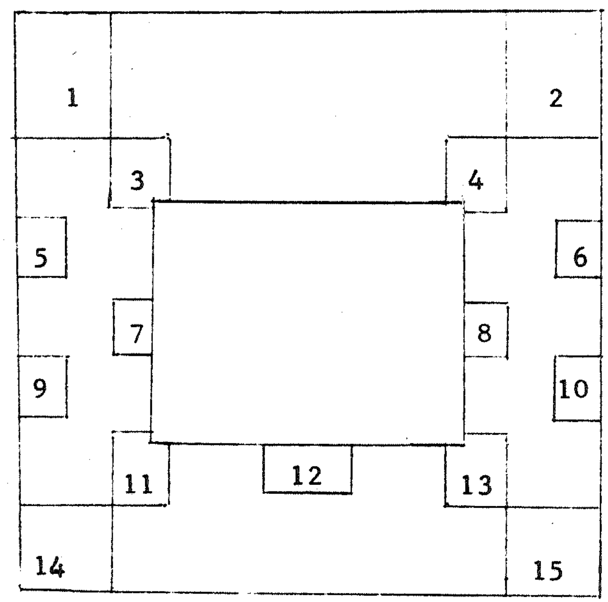


	Density of each segment
S-8-1	15.00 lb/ft^3
2	15.41
3	15.21
4	15.42
5	15.36

	Top	Middle	Bottom (Face Sheet Removed)
S-8-A	15.55	15.31	12.79x
B	16.19	14.34	13.95x
C	14.54	13.72x	13.41x
D	14.70	13.89	11.50
E	15.52	13.90	12.50x
F	15.82	14.58	13.02x
G	16.30	14.30	12.60x
H	15.51	14.22	14.02
I	14.93x	14.75x	12.00
J	15.28x	15.40x	14.02x
K	17.56	14.95x	12.48x
L	16.25x	16.67x	14.58x

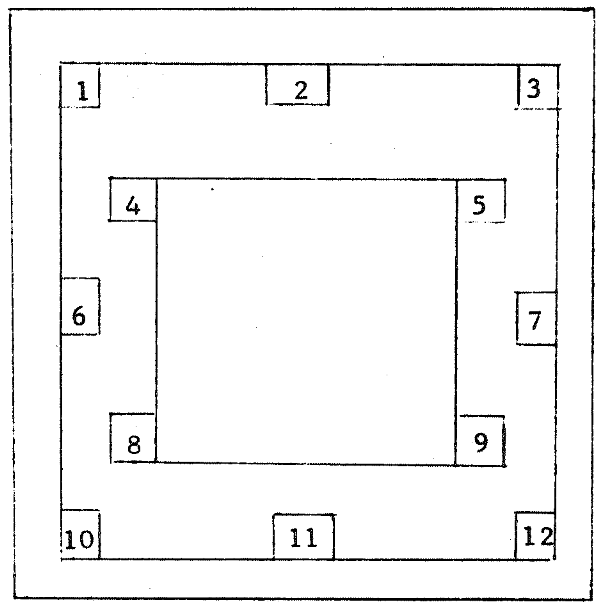
x Material was lost due to cutting. Samples are lower than if all material had remained in the honeycomb.

TEST PANEL S-12
SEGMENTED AS SHOWN



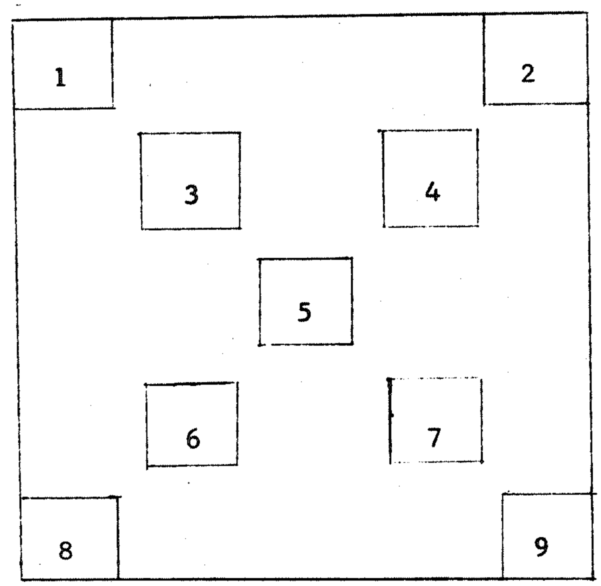
	Density of each segment
S-12-1	16.00
2	15.52
3	16.34
4	16.20
5	17.05
6	15.76
7	16.77
8	15.87
9	16.55
10	Discarded
11	16.23
12	16.21
13	15.67
14	15.70
15	15.82

TEST PANEL S-15
SEGMENTED AS SHOWN



	Density of each segment
S-15-1	14.70 lb/ft^3
2	14.17
3	14.56
4	13.44
5	14.52
6	13.89
7	14.72
8	14.56
9	14.95
10	14.92
11	15.23
12	15.02

TEST PANEL S-18
SEGMENTED AS SHOWN



	Density of each segment
S-18-1	15.81
2	16.38
3	15.85
4	15.82
5	15.61
6	16.10
7	15.81
8	16.08
9	15.84

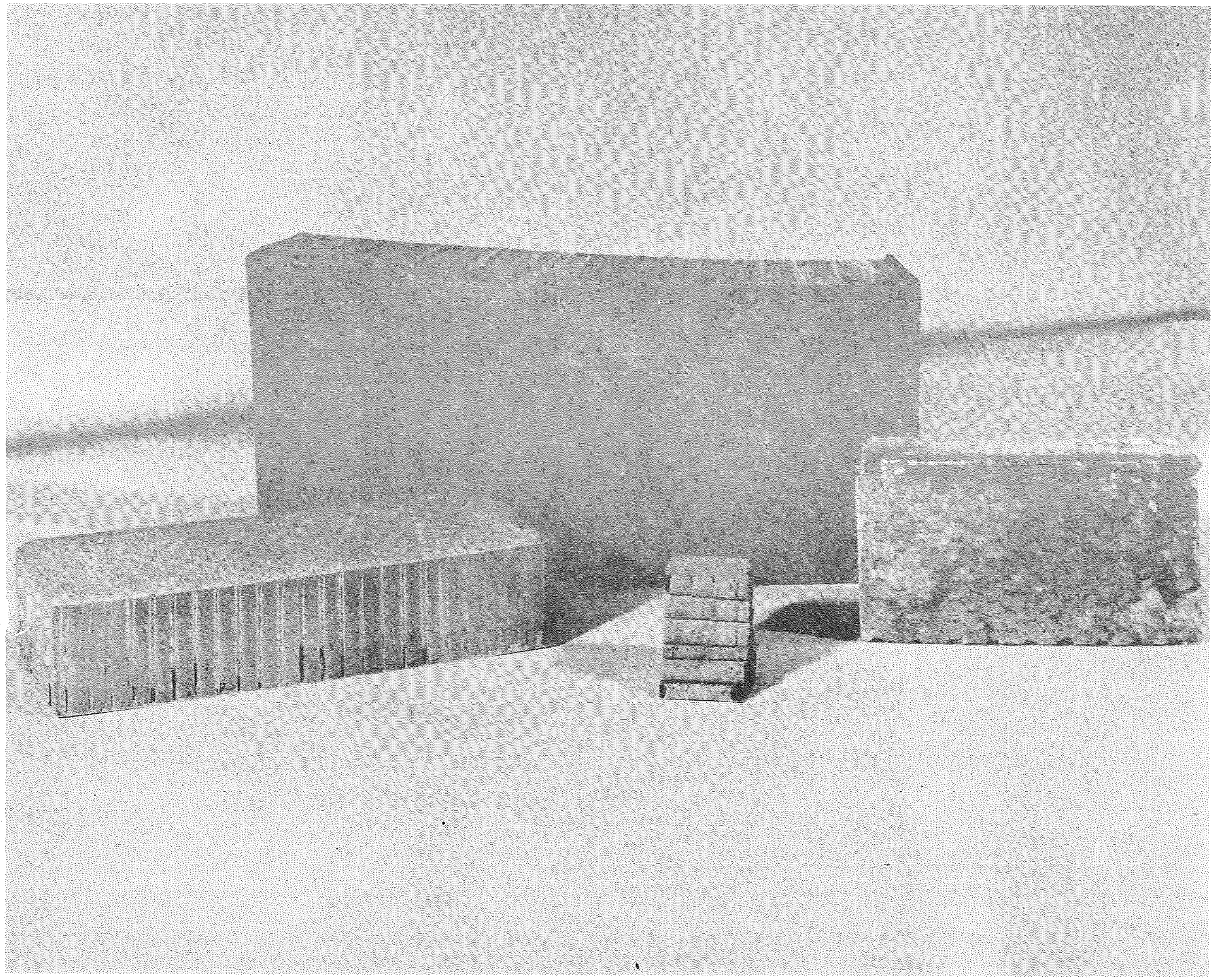


FIGURE 16
Sub-scale and Full scale test panel specimens
Elastomer 20 percent, Microballoons 80 percent

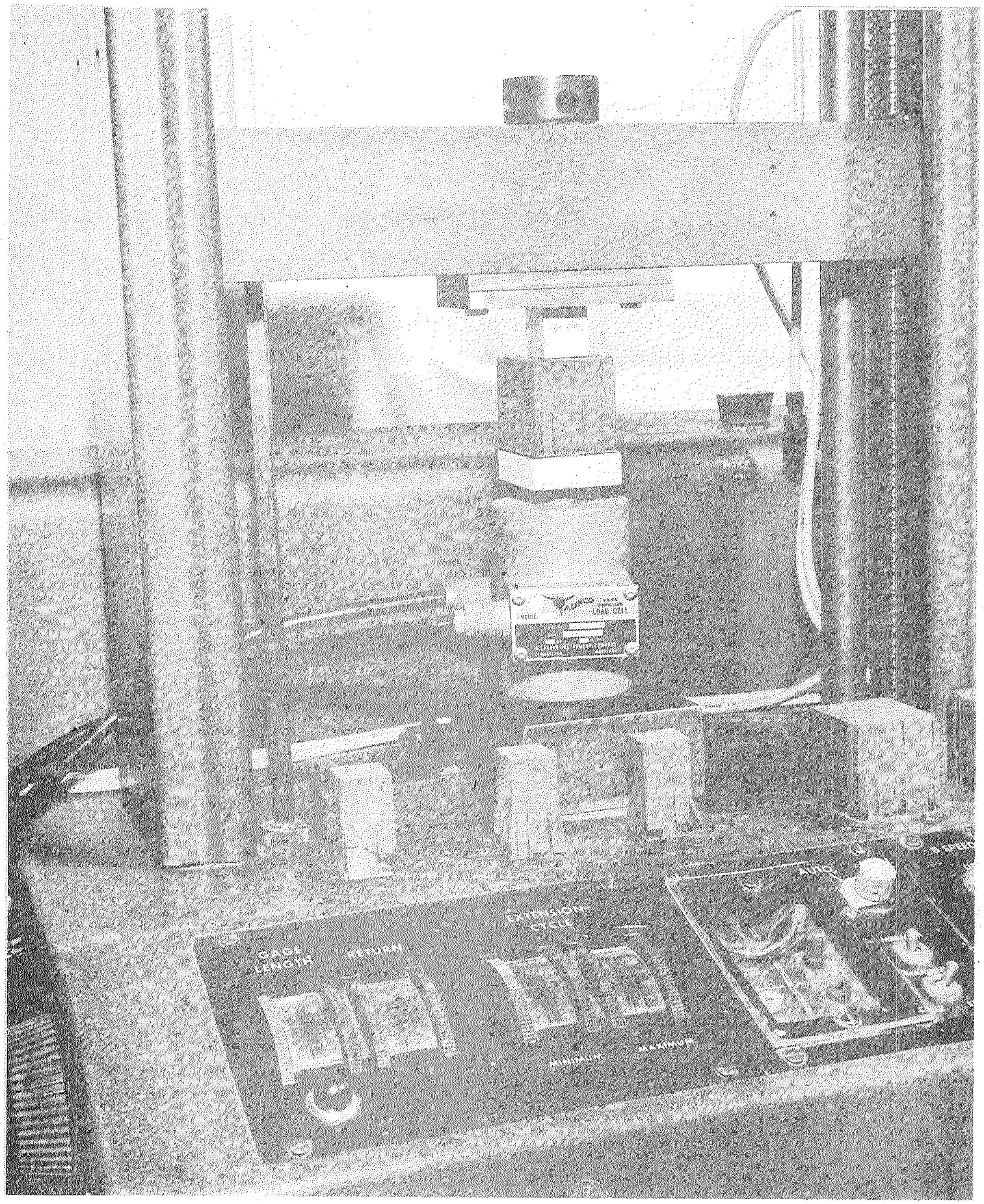


FIGURE 17
Ablation Material Compression Testing in Instron Unit
1 inch x 1 inch x 2 inch and 2 inch Cube Speciments

DEVELOPMENT TEST PANELS

Compressive Stress

(Ref. Fig. 17)

SAMPLE	TYPE PLUNGER	SAMPLE AREA STRESS	PSI
S-3	Flat plate	1.00	400
S-4	Flat plate	1.00 in^2	260
S-4	Flat plate	1.00 in^2	300
S-4	1" x 1" block	4.00	410
S-5	1" x 1" block	4.00	460
S-8-T	1" x 1" block	4.00	590
S-8-L	1" x 1" block	4.00	144
S-8-W	1" x 1" block	4.00	180
S-12	1" x 1" block	4.00	600
S-15	1" x 1" block	4.00	550
S-16	1" x 1" block	4.00	480
S-17	1" x 1" block	4.00	662
S-21	Flat plate	1.00	292
S-21	Post cure 4 hr @ $300^{\circ}F$	1.00	294
S-22	Flat plate	1.00	350
2" x 2' x 4'	Curved panel 1" x 1"	4.00	440
2" x 2' x 4'	Curved panel flat plate	1.00	292
HD-1	1" x 1"	4.00	387
HD-2	1" x 1"	4.00	348

FIGURE 18
Ablation Material Shear Test

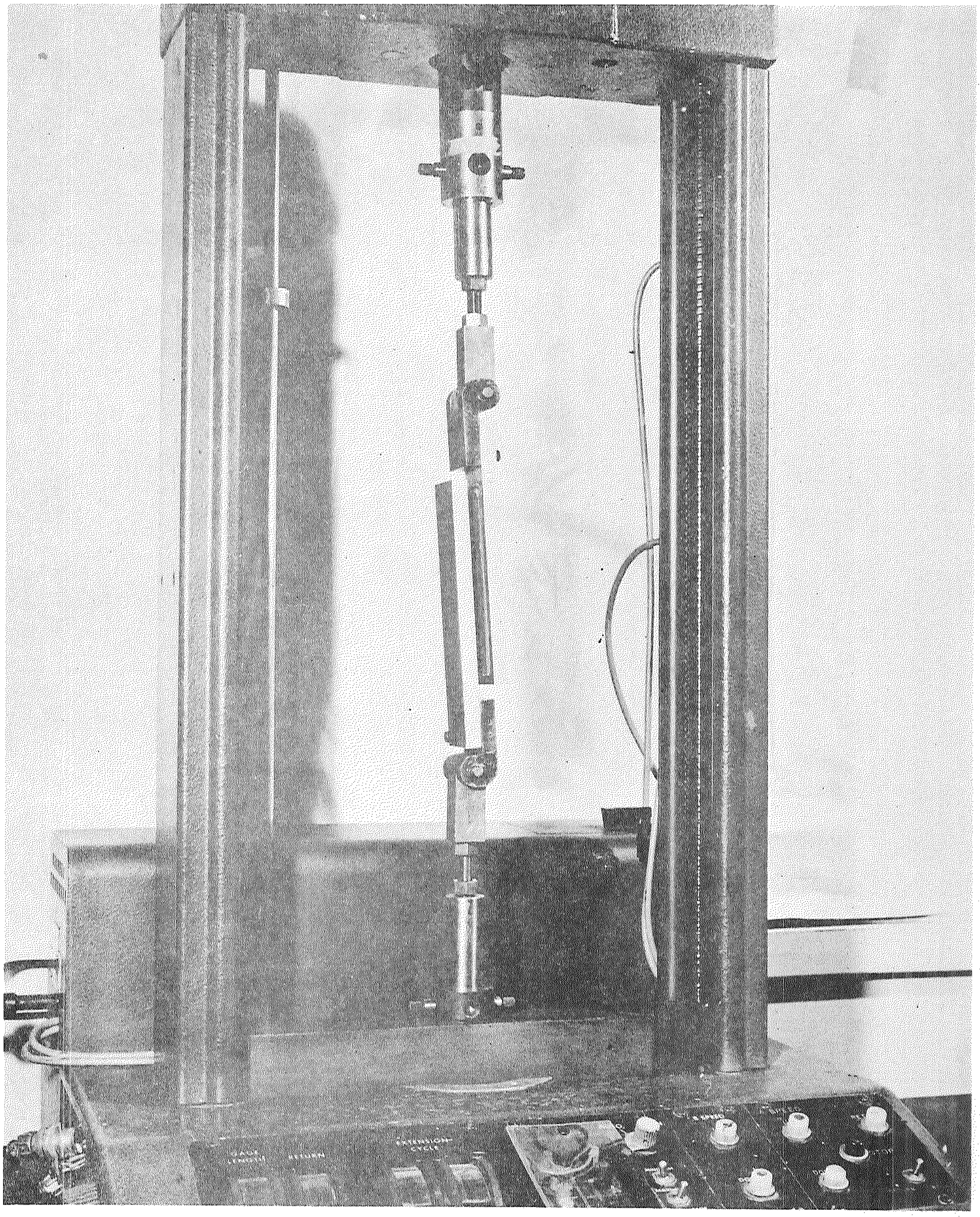


FIGURE 18
Ablation Material Shear Test

DEVELOPMENT TEST SAMPLES

Plate Shear

(Ref. Fig. 18 and 19)

SAMPLE	SHEAR STRESS
S-5	70 psi
S-7	80 psi
S-17	70 psi
S-22	210 psi
2" x 2' x 4' curved panel	100 psi
HD-2	80 psi

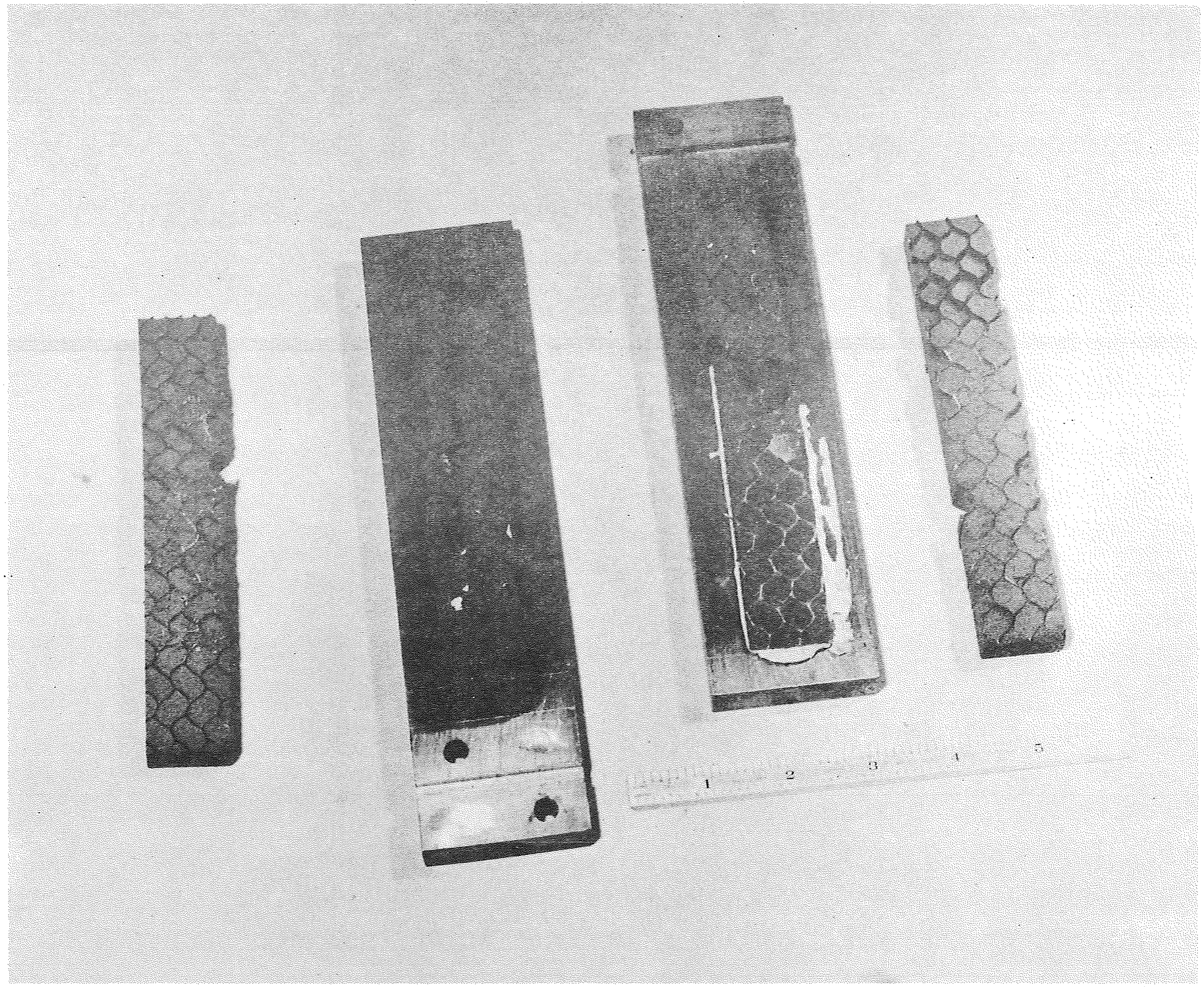
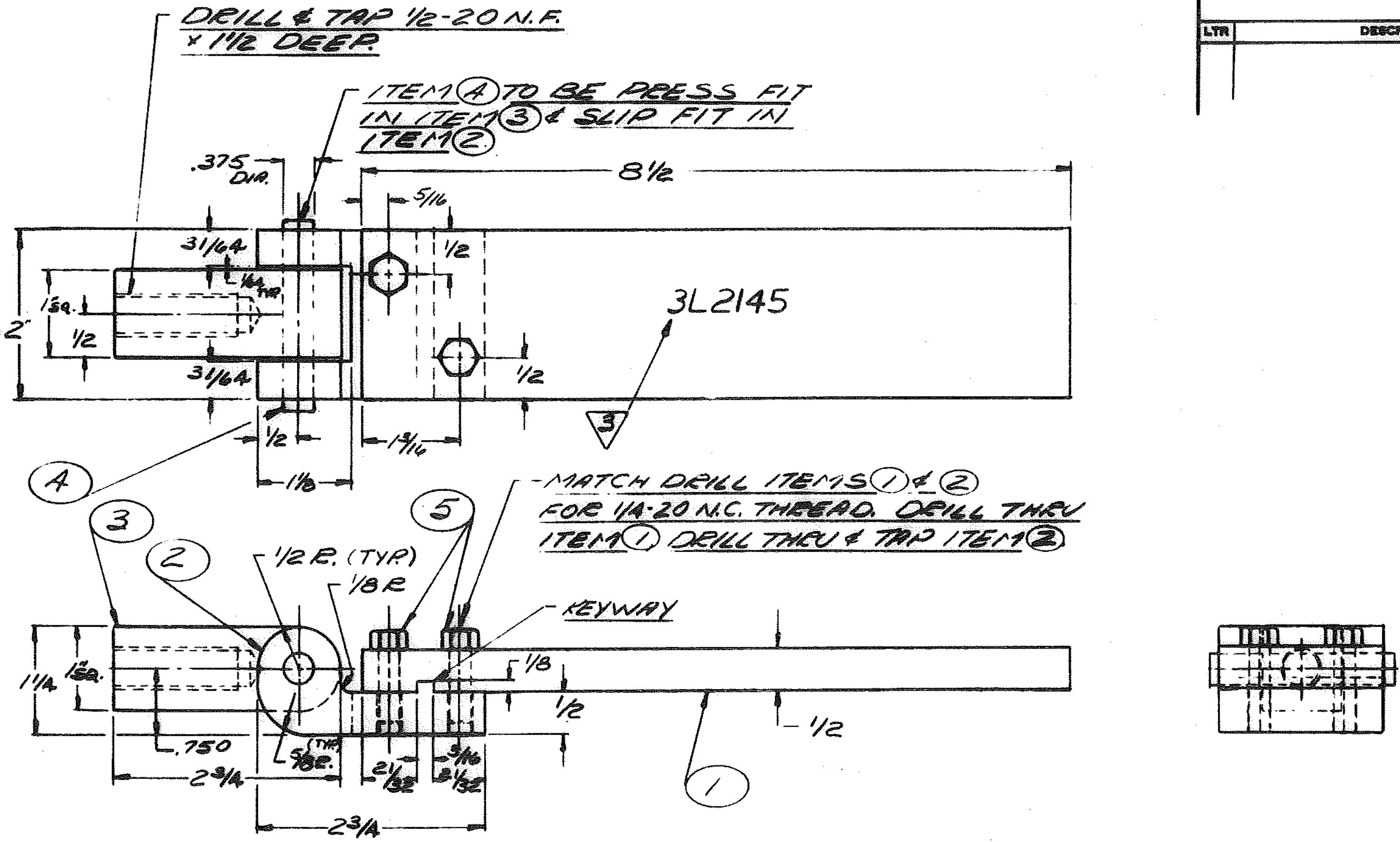


FIGURE 19
Ablation Material Shear Test Specimens

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



NOTES:

1. MATERIAL: STEEL 1020 OR EQUIVALENT.
2. REMOVE BURRS & BREAK ALL SHARP EDGES.
3. IMPRESSION STAMP IN SPECIFIED AREA "3L2145" 1/4 ± 1/16 HIGH x 1/64 DEEP.
4. TWO UNITS REQUIRED TO MAKE ONE TEST FIXTURE ASSEMBLY.

QTY REQ'D	NOMENCLATURE OR DESCRIPTION	CODE IDENT	PART NO. OR IDENTIFYING NO.	SPECIFICATION	MATERIAL OR NOTES	UNIT WT	ITEM NO.
2	HEX. BOLT		1/4-20 N.C.		STEEL		5
1	PIN .375 DIA.		3L2145-A		STEEL		4
1	FITTING SWIVEL		3L2145-3		STEEL		3
1	FITTING FLANGE		3L2145-2		STEEL		2
1	FACE PLATE		3L2145-1		STEEL		1
	TEST UNITS		3L2145				

PARTS LIST

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES ± 1/64 ± .X ~ ± .XX ~ ±~ .XXX .010

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DRAWN BY R.J. SCHNICK
CHECKED J.C. KALK
CONTRACT

B.F. GOODRICH AEROSPACE AND DEFENSE PRODUCTS A DIVISION OF THE B.F. GOODRICH CO. AKRON, OHIO DEPT 1808

TITLE PANEL SHEAR TEST UNIT NASA PROJECT-996

SIZE C CODE IDENT. NO. 03481 3L2145

SCALE FULL WT ACT SHEET 1 OF 1

3L2145

SHEAR TEST FIXTURE

FIGURE 20

ABLATIVE PLUGS

Development

Sub-scale 12 inch x 12 inch panel material was used for development production of ablative plugs by a lathe rough turning and grinding operation.

Ablation material problems, particularly adhesion, with the original 10-90 mix, made machining difficult for production of plugs without ablation material separation from honeycomb or complete loss of a section of ablation material by actual fallout. No problems occurred in machining the 67-33 material plugs. A single cavity plug mold was designed and obtained for net size plug molding development. A simple tube plug cutter with 3/8" hex head centering device was produced to provide a symetrical single cell honeycomb matrix for the molded plugs.

The single cavity mold (3L2145) cavity was loaded with a calculated weight of microballoon-resin mix, the mix load then compressed to approximately cured height by assembling the mold top-plunger into the cavity and hand pressure closing, then removing the mold top. The precut symetrical honeycomb matrix is then placed into the cavity, on top of the preformed and compacted filler material; the mold is closed to register "Cookie Cutting" the honeycomb matrix into the pre-compacted filler, and the plug cured with the standard production cure cycle.

After cure cooldown, the plug is pressed out of the cavity using the cavity base plug and a pin through the knock-out hole. (Ref. Fig. 21)

This procedure successfully produced satisfactory plugs with excellent honeycomb matrix centering in both 10-90 and 67-33 mix ablation material fillers; however, due to rejection percentages of 10-90 mix plugs for signs of or actual delamination of filler from honeycomb, this method was tabled for further investigation of the "rough core cutout-final machined plug".

The NASA change of program scope from 10-90 to 20-80 low density ablation mix resulted in a material more suitable for good machining and this method of plug production was established for both 20-80 and 67-33 mix plugs.

Production

Trim material from production panels or 12 x 12 development panels of acceptable density and cure is rough cut to an oversize diameter plug using a conventional two lip hollow steel tube plug cutter.

Production (Cont'd)

These rough cut diameter plugs are quickly ground to specified diameter in a lathe equipped with a tool post grinder unit and a collet chuck for holding purposes.

The 13 to 17 lb/ft^3 and 25 to 30 lb/ft^3 density ablation plugs furnished with the production panels were produced by this method.

Comments

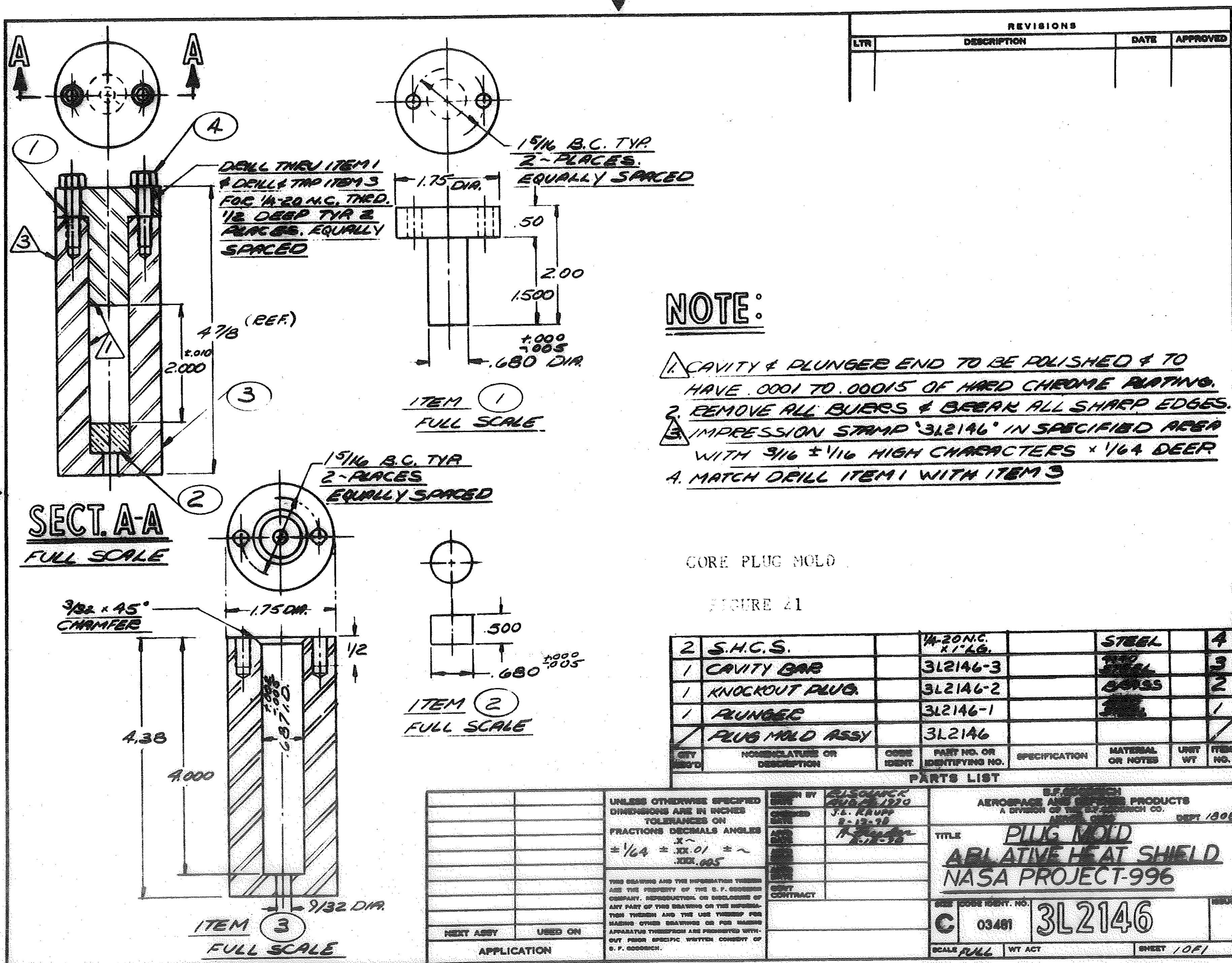
The process of net size molding; particularly with use of a multiple cavity mold, offers definite cost advantage when large quantities of plugs are considered. Further investigation of mold design for improved part release (i.e. slight cavity draft, teflon liner, or improved mold release agents) from a matched metal mold is recommended.

MOLDED PLUGS 20/80 RESIN/MICROBALLOON RATIO

	Weight Grams	Density lb/ft^3	Compressive Stress psi
1	2.91	14.75	458
2	2.92	14.8	366
3	2.92	14.8	544
4 S/N-1	2.77	14.1	
5	2.94	14.96	474
6	3.00	15.29	
7 S/N-2	2.90	14.1	
8 S/N-3	2.95	14.35	
9 S/N-4	2.96	13.94	
10 S/N-5	3.15	14.35	
11 S/N-6	2.89	14.46	
12	2.90	14.76	
13	2.93	14.92	
14 (90/10 mix)	---	---	
15	2.86	14.56	
16	2.89	14.71	

MOLDED PLUGS 67/33 RESIN/MICROBALLOON RATIO

1	5.44	27.69
2	5.22	26.57
3	5.31	27.03
4	5.60	28.28
HD-2-1	6.22	34.1
-2	6.16	33.7
-3	6.14	33.5
-4	6.23	34.1
-5	6.07	33.5
-6	5.91	32.6
-7	5.98	32.8



CORE PLUG MOLD

FIGURE 41

MACHINED PLUGS

(Delivered with Production Panel Sets)

20/80 Mix	Plug Density Lbs/ft^3	20/80 Mix	Plug Density Lbs/ft^3
Plug No. 1	14.33	Plug No. 7	13.85
2	14.04	8	13.96
3	13.92	9	14.30
4	13.84	10	13.52
5	14.42	11	14.03
6	14.25	12	13.78

67/33 Mix	Plug Density Lbs/ft^3	67/33 Mix	Plug Density Lbs/ft^3
Plug No. 1	29.58	Plug No. 7	31.53
2	30.81	8	30.92
3	31.44	9	29.63
4	30.04	10	32.01
5	31.95	11	30.40
6	30.76	12	31.44

FACTORY MIXING FOR LOW DENSITY 2' x 4' FLAT AND CURVED PANELS

A 50 gallon capacity Pony mixer was used for the first and second factory mixes. The third factory mix was done in a 50 gallon capacity Ross Mixer. Each 50 gallon mix provided the quantity of material for two 2' x 4' panels and one 12" x 12" test panel.

Mixing was as follows:

Factory Mix 1

1. 28.58 pounds of BJO-0390 Microballoons was placed in mixer with 27 pounds of Dow Corning XZ-8-5066 primer poured over the Microballoons.
2. Mixed for twenty minutes.
3. Contents were removed from mixer, spread out to ½" thick layer, and dried for two hours at room temperature.
4. 7.18 pounds of resin (10% catalyst) were premixed for ten minutes with an air stirrer.
5. The resin was approximately divided in half, and each diluted with four gallons of Hexane to aid resin dispersion. Each mixed for 10 minutes with air stirrer and hand stirred before addition to Microballoons.
6. Primed Microballoons placed in mixer with resin added over Microballoons.
7. Mixed for twenty minutes.
8. Removed from mixer, spread out to 1/2" thick layer and dried for one hour at room temperature.
9. Final mix placed in double polyethylene bags and refrigerated at 40°F until fabrication of panel.

Factory Mix 2

The only variations between the first and second factory mix were:

1. The primer was dried one additional hour for a total of three hours at room temperature to remove the volatiles.

Factory mix 2 (Cont'd)

2. Resin was diluted by 12 gallons of Hexane as compared to 8 gallons in the first factory mix.

Factory Mix 3

1. 28.58 pounds of BJO-0930 Microballoons were placed in Ross Mixer. (NOTE: Primer and primer mixing deleted.)

2. 7.18 pounds of resin (10% catalyst) were premixed for 10 minutes with an air stirrer.

3. The resin was divided approximately in fourths and each diluted with 4 gallons of Hexane (total of 16 gallons Hexane). Each mixed for ten minutes with air stirrer and hand stirred before addition to Microballoons.

4. Resin poured over Microballoons and mixed for twenty minutes.

5. Because of the 16 gallons of Hexane that was used, an additional hour of mixing was required for rapid evaporation of solvent.

6. Removed from mixer, spread out to 1/2" thick layer, and dried for twenty minutes at room temperature.

7. Finished material placed in double polyethylene bag and refrigerated at 40°F until needed.

MIXING OF HIGH DENSITY MATERIAL FOR 2' x 4' FLAT AND CURVED PANELS

One factory mix was made of high density material. The use of a 50 gallon Ross Mixer provided enough material for two 2' x 4' panels and one 12" x 12" test panel, each with a density of 29 lbs/ft^3.

Mixing was as follows:

1. 24.23 pounds of resin (10% catalyst) was divided approximately in half. Each half was air stirred for five minutes and hand stirred before addition to mixer.

3. One-half of the total resin was poured over the Microballoons.

4. Mixed for five minutes.

5. The sides and paddles of the mixer were scraped to remove a resin buildup.

6. The second half of the resin was added to the mixer.

7. Mixed for ten minutes.

8. The sides and paddles of the mixer were again scraped to remove resin buildup.

9. Mixed for additional 30 minutes with air circulation in mixer.

10. Contents removed from mixer, bagged, and refrigerated at 40°F until needed.

FABRICATION PROCEDURE

Adhesive Bond Assembly of Fiberglass-phenolic Honeycomb and Fiberglass-phenolic Face Sheet

Preparation

1. Clean cure frame and bottom cover plate with alcohol and clean rag, assemble frame and plate.

2. Spray contact surfaces with MS-122 release agent.

3. Remove plastilock adhesive film from refrigerated storage, allow film to warm up to room temperature.

4. Clean bonding surface of honeycomb and face sheet with M.E.K., and clean rag. Allow to air dry at room temperature.

Assembly

1. Place face sheet on flat surface, with bonding face up. Apply size cut sheet of plastilock film to surface of face sheet, work out trapped air bubbles with clean rubber stitcher roller.

2. Place face sheet into cure frame with plastilock coated surface up.

3. Place honeycomb into cure frame, with cleaned surface on top of Plastilock film - face sheet buildup. Press down on top surface area of honeycomb, using hand pressure only.

4. Place 5 mil. Mylar film sheet over top surface of honeycomb.

5. Place 3" wide, cured rubber caul strips around top edges of buildup. Tape into place with masking tape.

6. Cover vacuum exhaust port with two ply pad of 181 fiberglass bleeder cloth.

7. Apply continuous strip of sealing putty around top flange of cure form. Locate cured rubber cure bag over frame, seal bag to cure frame by hand pressure over sealing putty on flange area. (Ref. Fig. 13)

8. Clamp bag edge holding bars in place to hold down edges during cure.

Cure

NOTE: Flat panel units are cured under 25 to 28 inches vacuum pressure only, using a circulating hot air oven. Curved panels are dry air cured in an autoclave, under 25-28 inches vacuum and 30 psi ± 5 psi autoclave pressure for positive curved bond area cure contact.

Apply vacuum to cure frame, check system for vacuum leaks. Repair and recheck if required.

1. Place cure frame assembly into circulating hot air oven (or circulating hot air autoclave).

2. Apply 25-28 inches vacuum (and 30 psi autoclave pressure).

3. Set temperature controls for 350°F ± 10°F at 45 minutes rise time.

4. Cure for 75 minutes ± 15 minutes @ 350°F.

5. Cooldown to room temperature under full vacuum (and 30 psi pressure if autoclave cure).

6. Debag; remove bonded honeycomb-face sheet assembly.

7. Visually check bond line at base of honeycomb cells, if bonded 100 percent, aside for following operations.

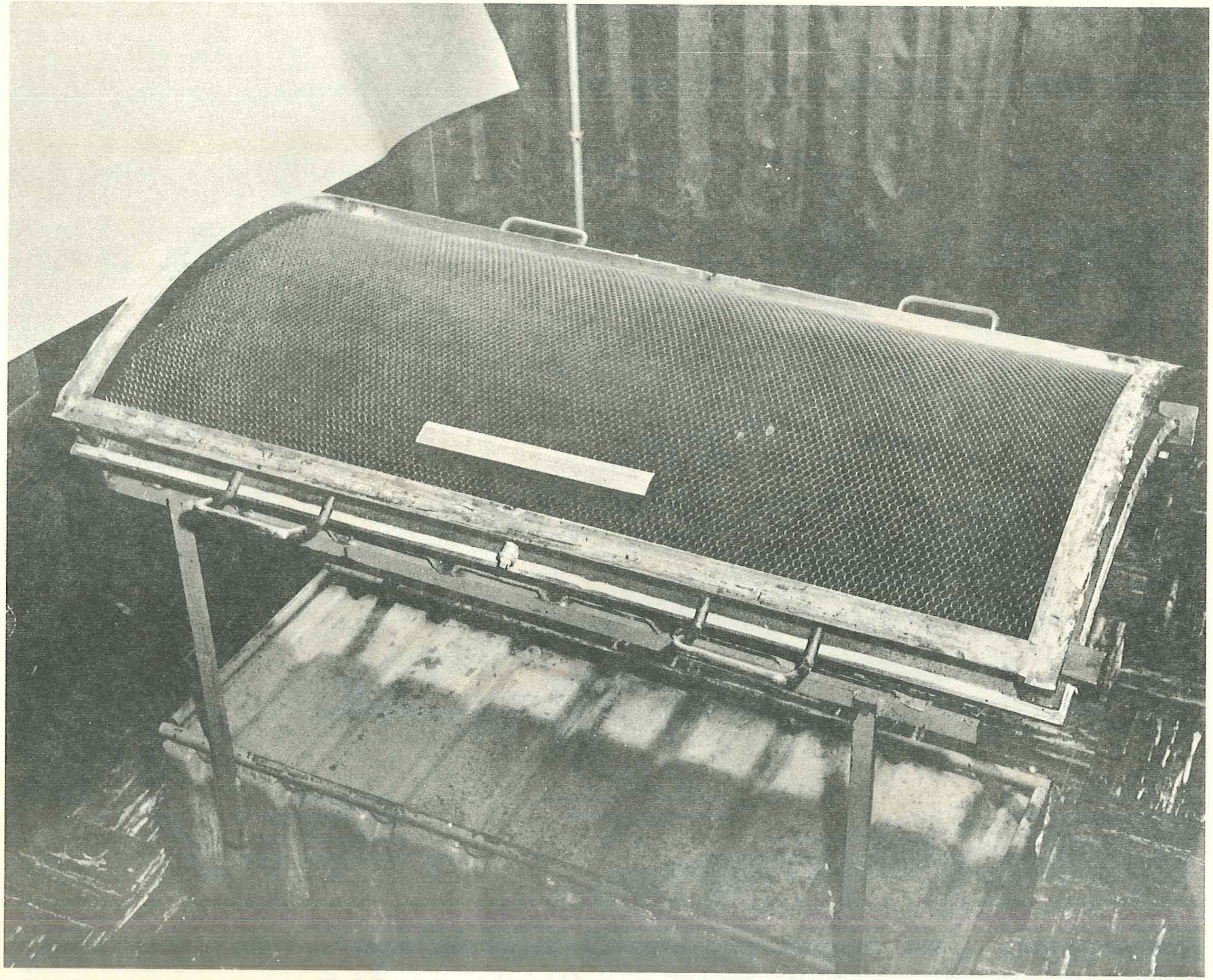


FIGURE 22
Curved Panel Loading and Cure Form
With Honeycomb - Face Sheet Assembly
In place for Loading

LOADING AND FILLING

Honeycomb Matrix Preparation

1. Mix 400 grams of 182-A resin with 40 grams of 182-B catalyst and dilute with 1600 grams of hexane. Mix thoroughly.

2. Pour the mixture into a shallow pan large enough to accomodate a 2" x 24" x 48" honeycomb panel with the base sheet attached.

3. Place the honeycomb (H.C.) panel in a pan with the base sheet side up. DO NOT SUBMERGE OVER THE BASE SHEET.

4. Lift the panel up, support and allow the excess to run off for 10-15 minutes.

5. Place the panel on an absorbent material for several minutes. Reverse, and allow to air dry for 45-60 minutes.

6. Return the mix to a sealed container for future use.

Prepare Cure Form and Honeycomb Matrix

1. Clean cure form by wiping with a clean cloth saturated with ethanol. Air dry.

2. Spray a light coating of MS-122 release agent on the cure form cavity surfaces. Mask off flange areas to prevent contamination.

3. Secure the frame to the plate with clamps.

4. Apply sealing putty at the lower edge of the frame and frame base. Press tightly into place.

5. Manually spatula elastomer mix into partial cells around the outer edge of the honeycomb.

6. Place edge-filled primed honeycomb-face sheet assembly into the cure frame with open cells facing up.

7. Position the loading curtain over the honeycomb, with overhang extending over the frame edge.

8. Place wood frame loading extension over the cure frame edges and clamp into place.

Loading and Filling, 80/20 Microballoon-Elastomer Mix

1. Divide total panel fill load of 80/20 mix into four (4) equal parts.

2. Distribute one-fourth of the mix load onto the loading curtain and disperse/debulk by chopping with a .03-inch thick metal strip, cut to fit the width of the jig.

3. Cover the mix layer with one ply of coarse fiberglass bleeder cloth.

4. Place an aluminum cover plate on top of the fiberglass cloth.

5. Withdraw the loading curtain and remove the wood extension frame.

6. Seal the plastic vacuum bag to the flange edges of the cure form with a sealing putty, and apply 25/28 inches of vacuum to assembly--forcing the elastomer mix into the honeycomb. Filling can be assisted by hand or light roller pressure on top surface of vacuum bag.

7. Repeat steps No. 2 through 6 inclusive for three additional filling cycles.

8. After the fourth filling cycle and vacuum application, chop and level the layer of elastomer mix not compressed into the honeycomb matrix, using the .03-inch thick metal strip.

9. Apply a single ply cover of coarse fiberglass bleeder to the face of the elastomer mix - honeycomb assembly. Place cured rubber caul strips around the top outer edge of the cover plate to prevent vacuum bag bridging.

10. Bag cure form - panel assembly for final filling, using 1/8-inch thick cured butyl vacuum bag sealed with a strip putty. Check assembly for vacuum leaks and place assembly into autoclave.

11. Pressurize autoclave to 150 psi and hold at 150 psi for five (5) minutes with 25 to 28 inches vacuum on bagged assembly; then remove pressure.

12. Remove panel - cure form assembly from the autoclave; strip back vacuum bag, lift off cover plate and examine filled honeycomb surface. Level off any indicated high spots and fill any indented or low fill areas with excess material removed from high spots.

13. Place fiberglass covered aluminum cover plate over panel assembly; replace and reseal 1/8-inch thick cured butyl vacuum bag. Place clamped bars around outer edges of vacuum bag and check system for vacuum leaks.

Loading and Filling, 67/33 Microballoon-Elastomer Mix

1. Divide total panel fill load into three equal parts.

2. Distribute one-third of panel mix onto loading curtain, level and debulk by hand leveling and chopping action using .03-inch thick metal strip.

3. Cover mix layer with one ply of coarse fiberglass bleeder cloth.

4. Place aluminum cover plate on top of fiberglass cloth.

5. Withdraw loading curtain and remove wood extension frame, the leveled and lightly compacted layer of elastomer mix remaining on the top surface of the honeycomb.

6. Apply hand pressure to elastomer mix, using a pressure block over entire surface, pressing mix into honeycomb.

7. Repeat steps No. 2 through 6 inclusive for two additional filling operations. The third filling operation will not completely compress the elastomer mix into honeycomb; hand level and redistribute where necessary.

8. Place one ply of fiberglass bleeder cloth over elastomer mix - panel assembly.

9. Place aluminum cover plate on top of bleeder cloth.

10. Place cured rubber caul strips around outer edges of aluminum cover plate.

11. Bag cure form - panel assembly for final filling, using 1/8-inch thick cured butyl vacuum bag sealed with strip putty. Check assembly for vacuum leaks and place assembly into autoclave.

12. Pressurize autoclave to 150 psi and hold at 150 psi for five minutes with 25-28 inches vacuum on bagged assembly, then remove pressure.

13. Remove panel - cure form assembly from autoclave; strip back vacuum bag, lift off cover plate and fiberglass cover ply and examine filled honeycomb surface. Level off any indicated high spots and fill any indented or low fill areas with excess material removed from high spots.

14. Cover surface of panel with one ply of .002 gauge release agent coated mylar film, then place the aluminum cover plate, pre-covered with a teflon coated glass bleeder cloth, over the mylar film.

15. Replace and reseal the 1/8-inch thick cured butyl vacuum cure bag. Place clamp bars around edges of vacuum bag and check for vacuum leaks.

PANEL CURE

Cure - 80/20 Microballoon - Elastomer Mix

1. Place vacuum bagged cure form - panel assembly into circulating dry air cure autoclave.

2. Pressurize autoclave to 50 psi and apply 25-28 inches vacuum to bagged panel, check for vaccum leaks, remove and repair leaks if necessary, then repeat leak check.

3. Cure bagged panel assembly @ 250°F, 25-28 inches vacuum, 50 psi autoclave pressure for sixteen hours.

4. Shutdown autoclave steam heat input. Blow down 50 psi pressure, and allow part to drift cooldown to room temperature under 25-28 inches of vacuum at heat loss rate of autoclave, approximately 30°F/hr.

5. Remove vacuum when part reaches room temperature; remove assembly from autoclave.

6. Remove vacuum bag and cover plate from the part; trim and remove any existing edge flash.

7. Remove the cured panel from the cure form.

Cure - 67/33 Microballoon-Elastomer Mix

1. Place vacuum bagged cure form - panel assembly into circulating dry air cure autoclave.

2. Pressurize autoclave to 50 psi, 25-28 inches vacuum on bagged part. Check system for vacuum leaks, remove and repair if necessary, then repeat leak checks.

3. Cure bagged panel assembly @ 180°F, 25 to 28 inches vacuum, 50 psi autoclave pressure for 24 hours.

4. Shutdown autoclave steam heat input, blow down 50 psi pressure, and allow part to drift cooldown to room temperature under 25-28 inches of vacuum at heat loss rate of autoclave, approximately 30°F/hr.

5. Remove vacuum when part reaches room temperature, remove assembly from autoclave.

6. Remove vacuum bag, cover plate, and cover film from part, trim and remove any existing edge flash.

7. Remove cured panel from cure form.

DELIVERED PANEL DENSITIES

ITEM NO.		PANEL DENSITY LB/FT^3
	<u>20 Percent Resin, 80 Percent Microballoon Mix</u>	
1	2 ft. x 4 ft. by 2 inch flat panel	14.54
2	2 ft. by 4 ft. by 2 inch curved panel	15.64
	<u>67 Percent Resin, 33 Percent Microballoon Mix</u>	
1	2 ft. by 4 ft. by 2 inch flat panel	29.96
2	2 ft. by 38 inch by 2 inch curved panel	29.05

RECOMMENDATIONS

Program effort and results in panel fabrication, reproducibility, and final cost indicate improvement of panel fabrication, reproducibility, and cost would result from further investigation of the following areas:

A. MATERIALS:

1. Use of thixotropic additives for prevention of resin settling in the 67 percent resin, 33 percent Microballoon mix.

2. Improved matrix or use of larger cell size honeycomb.

3. Evaluation of improved primer materials.

4. Effect of moisture on material cure and cured material physical properties.

B. PROCESSES:

1. Optimum cure and post cure cycles.

2. Optimum 20/80 mix batch size to minimize percentage of solvent required for mixing.

3. Improved solvent reduction/removal from 20 percent resin, 80 percent Microballoon batch after mixing.

4. Repair techniques for large and small area repair.

5. Protective surface coatings, for prevention of moisture pickup and handling damage.

C. EQUIPMENT:

1. "O" ring or expendable rubber gasket seal vacuum loading and cure forms.

2. Fabric reinforced elastomer bag presses for "half mold" filling and curing operations using hydraulic or pneumatic bag pressure devices. Would accommodate multiple radius

C. EQUIPMENT (CONT'D):

contoured shapes at minimum tooling costs.

3. Automated filling, leveling, and compacting equipment.

D. QUALITY CONTROL:

1. Standardized molded briquet or proof panel tests for factory large volume batch mix qualification prior to use for panel production.

2. Reliable low cost "Core Fill" inspection for cured panels.

QUALITY CONTROL

The quality control effort during the development phase of this program was directed at estabishing inspection criteria for the various phases of fabrication. These criteria will be used in the design of the quality and inspection systems for future production contracts. This basically includes the following steps:

1. Receiving inspection of all raw materials used in the fabrication process.

2. In-process inspection of fabrication and curing operations.

3. Final visual inspection of the fabricated assembly.

4. Inspect, using appropriate NDT method, for delaminations, voids and lack of bond.

5. Inspect protective packaging, paperwork and packing prior to shipment.

Several NDT methods are available to evaluate delaminations, voids and lack of bond. These are: radiographic, neutron radiography, liquid crystal and laser holography. These methods would have to be studied and evaluated on the merits of their performance in determining the extent of the anomolies found versus the actual panel condition.

FABRICATION AND PROJECTED FABRICATION COSTS

The finalized processes and processing costs used for fabrication of the required flat and curved configuration ablation panels are detailed in the following cost write-up.

Fabrication tooling for the full size panels was designed for multi-purpose use in view of the program requirement of one panel only in each of two configurations and two elastomer mix densities.

Completed Panel Tooling and Cost

Item	Cost
Flat loading and cure frame with bottom and cover plates*	$ 887.00
Curved loading and cure frame with bottom and cover plates.*	1124.00
Dip Tank	389.00

*Tooling also used for honeycomb-face skin bonding operation.

The following projected costs for increased quantities of various sized ablation panels are based on fabrication processes developed for this program. They include reduced costs in areas of improved processes, tooling, and tooling utilization made possible by increased production quantities.

MATERIAL COSTS

2 FT. BY 4 FT. BY 2 INCH
PRODUCTION ABLATIVE PANELS

I T E M	COSTS*
1. Elastomeric 20 percent, Microballoons 80 percent	
(a) Flat panel - 2' x 4' x 2"	
1) HRP - 3/8 - GF12 x 2.6 Hexcel honeycomb. Flat 24" x 48" x 2.00".	$140.00
2) 181 Fiberglass - EC201 phenolic resin prepreg x 50" wide x 48" long. 36% Resin solids.	12.70
3) Microballoons, Union Carbide Company No. BJO-0930 x 17.6 lbs.	37.49
4) Silicone resin, Dow Corning Sylgard 182 x 0.40 lbs.	2.18
5) Silicone resin catalyst, Dow Corning Sylgard 182 x 0.04 lbs.	.22
6) Solvent, hexane, six gallons	1.14
7) Adhesive film, plastilock No. 729, 2' x 4'.	1.92
8) Miscellaneous, Tedlar release film, bleeder cloth, sealing putty, release agent, etc.	2.50
	$198.15
(b) Curved Panel - 2' x 4' x 2"	
1) HRP - 3/8 - GF12 x 2.6 Hexcel honeycomb, 24" width curved to 24" outer surface radius x 48" long x 2.00" thick.	$155.47
2) 181 Fiberglass - EC201 phenolic resin, prepreg x 50" wide x 48" long, 36% Resin solids.	12.70
3) Microballoons, Union Carbide Company No. BJO-0930 x 17.6 lbs.	37.49

*10% Natural Waste added.

I T E M	COSTS*
(b) <u>Curved Panel-2' x 4' x 2" (Cont'd)</u>	
4) Silicone Resin, Dow Corning Sylgard 182 x 0.40 lbs.	$ 2.18
5) Silicone Resin Catalyst, Dow Corning Sylgard 182 x 0.04 lbs.	.22
6) Solvent, hexane, six gallons	1.14
7) Adhesive film, plastilock No. 729, 2' x 4'.	1.92
8) Miscellaneous, Tedlar release film, bleeder cloth, sealing putty, release agent, etc.	2.50
	$213.62
2. <u>Elastomer 67, percent, Microballoons 33 percent</u>	
(a) <u>Flat panel - 2' x 4' x 2"</u>	
1) HRP - 3/8 - GF12 x 2.6 Hexcel honeycomb flat, 24" x 48" x 2".	$140.00
2) 181 Fiberglass - EC201 phenolic, etc.	12.70
3) Microballoons, Union Carbide Company No. BJO-0930 x 12.76 lbs.	27.18
4) Silicone resin, Dow Corning Sylgard 182 x 23.6 lbs.	128.62
5) Silicone resin catalyst, Dow Corning Sylgard 182 x 2.36 lbs.	12.86
6) Adhesive film, plastilock No. 729, 2' x 4'.	1.92
7) Miscellaneous, Tedlar release film, bleeder cloth, sealing putty, release agent, etc.	2.50
	$325.78
(b) <u>Curved Panel - 2' x 4' x 2"</u>	
1) HRP - 3/8 - GF12 x 2.6 Hexcel honeycomb, curved, 2' x 4' x 2".	$155.47
2) 181 Fiberglass - EC201 phenolic resin, prepreg x 50" wide x 48" long. 36% Resin solids.	12.70
3) Microballoons, Union Carbide Company No. BJO-0930 x 17.6 lbs.	37.49

*10% Natural Waste added.

I T E M	COSTS*
(b) Curved Panel - 2' x 4' x 2" (Cont'd)	
4) Silicone Resin, Dow Corning Sylgard 182 x 23.6 lbs.	$128.62
5) Silicone Resin Catalyst, Dow Corning Sylgard 182 x 2.36 lbs.	12.86
6) Adhesive film, Plastilock No. 729, 2' x 4'.	1.92
7) Miscellaneous, Tedlar release film, bleeder cloth, sealing putty, release agent, etc.	2.50
	$351.56

*10% Natural Waste added.

FABRICATION HOURS PER COMPLETED PANEL

80 PERCENT MICROBALLOON - 20 PERCENT ELASTOMER MIX
PANEL SIZE: 2 FT. BY 4 FT. BY 2.0 INCHES, FLAT PANEL

O P E R A T I O N	HOURS
1. Material Preparation	
Resin-Microballoon mixing	4.0
Drying	1.5
Storage	0.5
2. Face Skin Preparation and Cure	
Layup two plies	1.4
Bag and Cure	5.0
Trim	0.4
3. Honeycomb Preparation and Face Skin Bonding	
Skin and Plastilock preparation	2.2
Bag and Cure	3.6
Strip Bag and Remove Part and Visual Inspect Bond	1.4
4. Resin Mix Filling and Compacting	
Setup Cure Form	1.2
Load, Level, Bag and Compact	4.0
Final Fill - Autoclave	1.2
5. Bag and Cure - Autoclave	
Assemble Top Plate and Bag	2.0
Cure	2.0
Remove From Cure	1.0
Repair Edges	4.4
Visual and Dimensional Inspection and Density Check	1.2
6. Drilling	
Layout and Core drill six 11/16 dia. holes.	3.0
7. Furnish Six 11/16 Diameter Core Plugs.	3.0
8. Package	1.0
9. Engineering Follow-up	16.0
10. Technician Follow-up	24.0

FABRICATION HOURS PER COMPLETED PANEL

80 PERCENT MICROBALLOON - 20 PERCENT ELASTOMER MIX
PANEL SIZE: 2 FT. BY 4 FT. BY 2.0 INCHES, CURVED PANEL

O P E R A T I O N	HOURS
1. Material Preparation	
Resin - Microballoon mixing	4.0
Drying	1.5
Storage	0.5
2. Face Skin Preparation and Cure	
Layup Two plies	1.4
Bag and cure	5.0
Trim	0.6
3. Honeycomb Preparation and Face Skin Bonding	
Skin and Plastilock preparation	2.6
Bag and cure	4.0
Strip bag and remove part, and visual inspect bond.	1.8
4. Resin Mix Filling and Compacting	
Setup cure form	1.4
Load, level, bag and compact	5.0
Final fill - autoclave	1.4
5. Bag and Cure - Autoclave	
Assemble top plate and bag	2.0
Cure	2.0
Remove from cure	1.0
Repair edges	5.2
Visual and dimensional inspection and Density check	1.2
6. Drilling	
Layout and core drill six 11/16 dia. holes.	3.0
7. Furnish Six 11/16 Diameter Core Plugs	3.0
8. Package	1.0
9. Engineering Follow-up	16.0
10. Technician Follow-up	24.0

FABRICATION HOURS PER COMPLETED PANEL

33 PERCENT MICROBALLOON - 67 PERCENT ELASTOMER MIX
PANEL SIZE: 2 FT. BY 4 FT. BY 2.0 INCHES, FLAT PANEL

O P E R A T I O N	HOURS
1. Material Preparation	
Resin - Microballoon mixing	4.0
Drying	0.5
Storage	0.5
2. Face Skin Preparation and Cure	
Layup two plies	1.4
Bag and Cure	5.0
Trim	0.4
3. Honeycomb Preparation and Face Skin Bonding	
Skin and Plastilock preparation	2.2
Bag and Cure	3.6
Strip bag and remove part, and visual inspect bond.	1.4
4. Resin Mix Filling and Compacting	
Setup cure form	1.2
Load, level, bag and compact	5.0
Final fill - autoclave	1.2
5. Bag and Cure - Autoclave	
Assemble top plate and bag	2.0
Cure	2.4
Remove from cure	1.0
Repair edges	4.4
Visual and dimensional inspection and Density check	1.2
6. Drilling	
Layout and core drill six 11/16 dia. holes.	3.0
7. Furnish Six 11/16 Diameter Core Plugs	3.0
8. Package	1.0
9. Engineering Follow-up	16.0
10. Technician Follow-up	24.0

FABRICATION HOURS PER COMPLETED PANEL

33 PERCENT MICROBALLOON - 67 PERCENT ELASTOMER MIX
PANEL SIZE: 2 FT. BY 4 FT. BY 2.0 INCHES, CURVED PANEL

O P E R A T I O N	HOURS
1. Material Preparation	
Resin - Microballoon mixing	4.0
Drying	0.5
Storage	0.5
2. Face Skin Preparation and Cure	
Layup two plies	1.4
Bag and cure	5.0
Trim	0.4
3. Honeycomb Preparation and Face Skin Bonding	
Skin and Plastilock preparation	2.6
Bag and cure	4.0
Strip bag and remove part, and visual inspect bond	1.8
4. Resin Mix Filling and Compacting	
Setup cure form	1.4
Load, level, bag and compact	6.0
Final fill - autoclave	1.4
5. Bag and Cure - Autoclave	
Assemble top plate and bag	2.0
Cure	2.4
Remove from cure	1.0
Repair edges	5.2
Visual and dimensional inspection and Density check	1.2
6. Drilling	
Layout and core drill six 11/16 dia. holes.	3.0
7. Furnish Six 11/16 Diameter Core Plugs	3.0
8. Package	1.0
9. Engineering Follow-up	16.0
10. Technician Follow-up	24.0

FABRICATION COSTS PER COMPLETED PANEL

PANEL COMPOSITION AND CONFIGURATION	1 PANEL
A. 20 Percent Elastomer, 80 Percent Microballoons	
Flat Panel 2 ft. x 4 ft. x 2.0 inches	$1644
Curved Panel 2 ft. x 4 ft. x 2.0 inches	$1734
B. 67 Percent Elastomer, 33 Percent Microballoons	
Flat Panel 2 ft. x 4 ft. x 2.0 inches	$1861
Curved Panel 2 ft. x 4 ft. x 2.0 inches	$1969

PRODUCTION QUANTITY EFFECT

PROJECTED FABRICATION COST PER PANEL

PANEL COMPOSITION AND CONFIGURATION	COST PER PANEL	
	10 PANELS	100 PANELS
A. 80 Percent Microballoons, 20 Percent Elastomer 2 ft. by 4 ft. x 2.0 inch panels		
1. Flat Panel	$687	$539
2. Curved Panel	$764	$608
B. 33 Percent Microballoons 67 Percent Elastomer 2 ft. by 4 ft. by 2.0 inches		
1. Flat Panel	$892	$735
2. Curved Panel	$985	$821

PRODUCT FLIGHT UNIT MATERIAL COSTS
PROJECTED ON 8000 FT^2/FLIGHT UNIT--FLAT PANEL CONFIGURATION

MATERIAL	FLIGHT UNIT REQUIREMENTS	1 FLIGHT	10 FLIGHTS	100 FLIGHTS
A. <u>Elastomer 20 Percent, Microballoons 80 Percent</u>				
1) HRP - 3/8-GF12-2.6 honeycomb.	8000 Ft^2 @ $6.30/$Ft^2$		$ 5.42	
2) Fiberglass-phenolic prepreg	1800 yd^2 @ $2.02/$yd^2$		1.97	$ 1.96
3) Adhesive film, Plastilock 729	900 yd^2 @ $ .24/yd^2			
4) U/C BJO-0930 Microballoons	17600 lbs. @ .95/lb.			
5) Elastomer, Sylgard 182	4400 lbs. @$5.20/lb.		Estimate 4.60	Estimate 4.40
6) Catalyst, Sylgard 182	440 lbs. @ $5.20/lb.		Estimate 4.60	Estimate 4.40
7) Solvent, Hexane	6000 gal. @ .23/gal.			
8) Misc. release films, bag stock bleeder, release agents, tape, etc.	8000 Ft^2 @ $1.25/$Ft^2$ Total	$10,000	$10,000	$ 10,000
	Sub Total	107,520	97,486	96,500
	+ Defective	26,880*	19,497**	14,475***
	Total	134,400	116,983	110,975
B. <u>Elastomer 67 Percent, Microballoons 33 Percent</u>				
1) HRP - 3/8-GF12-2.6 honeycomb.	8000 Ft^2 @ $6.30/$Ft^2$		5.42	
2) Fiberglass phenlic prepreg	1800 yd^2 @ $2.02/$yd^2$		1.97	1.96
3) Adhesive film, Plastilock 729	900 yd^2 @ $ .24/yd^2			
4) U/C BJO-0930 Microballoons	12700 lbs. @ .98/lb.		.95	
5) Elastomer, Sylgard 182	24000 lbs. @ $5.00/lb. Estimate		Estimate 4.50	Estimate 4.00
6) Catalyst, Sylgard 182	2400 lbs. @ $5.00/lb. Estimate		Estimate 4.50	Estimate 4.00
7) Misc. release films, bag stock bleeder, release agent, tape, etc.	8000 Ft^2 @ $1.25/$Ft^2$ Total	$10,000	$10,000	$ 10,000
	Sub Total	208,698	187,987	174,769
	+ Defective	52,175*	37,597**	26,215***
	Total	260,873	225,584	200,984

<u>NOTES</u>

1) * 25% Defective added
2) ** 20% Defective added
3) *** 15% Defective added

SIZE VARIATION EFFECT

PROJECTED FABRICATION COST PER PANEL

PANEL COMPOSITION AND CONFIGURATION	COST PER PANEL		
	1 PANEL	10 PANELS	100 PANELS
A. 20 Percent Elastomer, 80 Percent Microballoons			
1. Flat Panel			
(a) 3 ft. x 5 ft. x 2.0 inches	$ 964	$ 758	$ 633
(b) 4 ft. x 6 ft. x 2.0 inches	1244	1007	852
B. 67 Percent Elastomer, 33 Percent Microballoons			
1. Flat Panel			
(a) 3 ft. x 5 ft. x 2.0 inches	$1319	$1094	$ 960
(b) 4 ft. x 6 ft. x 2.0 inches	1802	1529	1356

CONFIGURATION EFFECT
PROJECTED COST PER PANEL
2 FT. BY 4 FT. BY 2.0 INCH DOUBLE CURVATURE PANELS

PANEL COMPOSITION	COST PER PANEL		
	1 PANEL	10 PANELS	100 PANELS
67 Percent Elastomer, 33 Percent Microballoons	$2110	$1874	$1413

SUMMARY COST TABLE
UNIT SELLING PRICES (EXCLUDING FEE)

PANEL CONFIGURATION	QUANTITY	COST ($/Ft^2)	
		LOW DENSITY ELASTOMER	HIGH DENSITY ELASTOMER
2' x 4' x 2" Flat	1	$206.00	$233.00
	10	86.00	112.00
	100	67.00	92.00
2' x 4' x 2" Curved	1	$217.00	$246.00
	10	96.00	123.00
	100	76.00	103.00
3' x 5' x 2" Flat	1	$ 64.00	$ 88.00
	10	51.00	73.00
	100	42.00	64.00
4' x 6' x 2" Flat	1	$ 52.00	$ 75.00
	10	42.00	64.00
	100	36.00	57.00
2' x 4' x 2" Double-Curvature	1	---	$264.00
	10	---	234.00
	100	---	177.00

RESULTS AND DISCUSSION

ABLATION PANEL AND PLUG PRODUCTION

Panel and plug production for deliverable items required by program contract was approached in accordance with guide line processes and techniques established in the sub-scale panel development phase of the program.

Work on the lower density elastomer mix ablation material received major attention from the start of the program since it was reasoned that this material would present more difficult mixing and fabrication technique development.

Initial production panel effort was hampered by non-reporducibility of scaled-up factory mixes of 20/80 mix ablator. Cure inconsistancies occurred at previously established cure pressure and temperature-time cycles.

Factory batch mix No. 1, a scaled-up 50 gallon material mix, was found to have poor ablator material adhesion in the initial sub-scale proof panel cured for the batch mix evaluation. This condition was verified in a second sub-scale panel under controlled conditions and the batch mix was discarded.

Factory batch mix No. 2, a scaled-up 50 gallon material mix, with revised mixing procedures was then processed and a sub-scale proof panel fabricated and cured. The sub-scale proof panel indicated improved ablator material cure and adhesion properties and a 2' x 4' x 2.0 inch panel was then fabricated from the batch mix. This full size production panel autoclave cured sixteen hours at 250^{o}F, indicated a marked lack of cure and extremely poor Microballoon-resin adhesion. An additional cure of twelve hours at 250^{o}F in a circulating dry air oven did not change the ablator material cure condition and the panel was scrapped.

A cure test using the elastomer-catalyst combination only resulted in a satisfactory cure, as did a cure test using non-primed Microballoon-catalyzed resin mix. With this evidence that the primer was apparently reacting as a cure and cure adhesion inhibitor, a sub-scale 12" x 12" x 2.0 inch test panel was produced deleting the primer on both the Microballoons and the honeycomb matrix. The honeycomb matrix was prepared by priming with a solvent extended resin-cure agent mix and air dried prior to panel fabrication. The cure and adhesion test results on this sub-scale proof panel were good and factory mix No. 3 was prepared for production of the deliverable 20/80 composition hardware.

The 20/80 composition 2 ft x 4 ft x 2.0 inch flat panel was processed without problems, resulting in an acceptable cure panel meeting specification density. The 2 ft x 4 ft x 2.0 inch 20/80 composition curved panel was then fabricated and processed. This panel, about 2 hours into autoclave cure, developed a vacuum seal leak.

The cure was stopped, autoclave opened and the bagged part was found to have a damaged bag and a localized burn area on one edge, located 10 inches in from the end of the panel. The damaged panel area, three inches long by two and one-half inches wide, was cut out down to the face sheet and a new section of honeycomb matrix bonded in place. The replaced honeycomb was filled with the calculated density volume of Microballoon resin mix, the panel re-bagged and cured sixteen hours at 250°F under 25-28" vacuum and 50 psi autoclave pressure. The panel and repair area cure looked good; some edge repairs were required.

The twelve cylindrical 20/80 composition plugs required for the two panels were rough cored and final machined from the No. 3 factory mix batch sub-scale proof panel.

The scaled up high density, 67 percent resin-33 percent Microballoon mix, was processed in a 50 gallon Ross Mixer and refrigerated at 40°F in sealed poly bags until required for panel fabrication.

The proof panel for this factory batch mix exhibited good cure and appearance. The 67/33 composition 2 ft x 4 ft x 2.0 inch flat panel was then fabricated and processed through final cure. A faulty steam controller on the cure autoclave extended the 180°F cure time on this panel, resulting in panel warpage after cure.

This panel also required some minor surface repair.

The 67/33 composition 2 ft x 4 ft x 2.0 inch curved panel was then fabricated and processed through final cure.

After 16 hours 2 180°F autoclave dry air cure it was noted that the elastomer top surface felt tacky and undercured.

The panel was then post-cured for 16 hours @ 250°F in a circulating dry air oven. The post-cured panel exhibited a satisfactory degree of cure and required some top surface and edge repair.

Panel top surface repairs, for each of the two density elastomer mixes, were required to replace small local areas of uncured elastomer mix. This condition, not noticed to any degree in sub-scale panel production, has not been satisfactorily explained by material or process analysis.

Some edge areas required repair due to elastomer mix adhesion to the release agent coated cure form surface; this could be eliminated by a teflon coating on form panel contact surfaces in the "net size" panel molding approach.

Issue 1727 — APPENDIX A AMMENDMENTS

KDA:bbw

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 1

1. AMENDMENT/MODIFICATION NO. 1

2. EFFECTIVE DATE 7/2/70

3. REQUISITION/PURCHASE REQUEST NO. Not Applicable

4. PROJECT NO. (If applicable)

5. ISSUED BY CODE
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23365

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS CODE FACILITY CODE
(Street, city, county, state, and ZIP Code)
The B. F. Goodrich Company
Aerospace and Defense Products Division
500 South Main Street
Akron, Ohio 44318

8. ☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. NAS1-9944
DATED 4/28/70 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS
☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.
Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:
(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)
Not Applicable

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS
(a) ☒ This Change Order is issued pursuant to Clause 39, Changes, of the General Provisions
The Changes set forth in block 12 are made to the above numbered contract/order.
(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.
(c) ☐ This Supplemental Agreement is entered into pursuant to authority of ______
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

I. Part II, Statement of Work, paragraph 4.a. of the Contract Schedule, is hereby changed to read:

"a. Elastomer - 10%, Microballoons - 90% or Elastomer - 20%, Microballoons - 80%, 13 lb/ft^3 $\leq$ Density $\leq$ 17 lb/ft^3."

II. There shall be no change in cost, fee or period of performance as a result of this change.

RECEIVED JUL 13 1970 Accessories & Plastics Sales Dept.

JUL 10 1970

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS requested TO SIGN THIS DOCUMENT AND RETURN 1 copy TO ISSUING OFFICE acknowledging receipt thereof.

14. NAME OF CONTRACTOR/OFFEROR
BY ______ (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY [signature] (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)

16. DATE SIGNED

18. NAME OF CONTRACTING OFFICER (Type or print) LEON W. FITCHETT

19. DATE SIGNED 7/2/70

30-101-f-p

U.S. GOVERNMENT PRINTING OFFICE : 1968 O—330-000

CONTRACTOR'S COPY

KDA:bw 1724

STANDARD FORM 30, JULY 1966 GENERAL SERVICES ADMINISTRATION FED. PROC. REG. (41 CFR) 1-16.101	AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT	PAGE 1 OF 2

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
2	JUL 28 1970	Not Applicable	

5. ISSUED BY CODE

National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23365

6. ADMINISTERED BY (If other than block 5) CODE

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) CODE FACILITY CODE

The B. F. Goodrich Company
Aerospace and Defense Products Division
500 South Main Street
Akron, Ohio 44318

8. ☐ AMENDMENT OF SOLICITATION NO. ____ DATED ____ (See block 9)

☒ MODIFICATION OF CONTRACT/ORDER NO. NAS1-9944 DATED 4/28/70 (See block 11)

AUG 3 1970

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

Not Applicable

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ____
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Clause 34, Excusable Delays, of the General Provisions
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

JUL 21 1970

I. Part III, Period and Place of Performance, paragraph A, is changed to read as follows:

"A. The period of performance shall be seven (7) months from the date of this contract, inclusive of the submission of the final report."

II. Part IV, Reports, subparagraph C.8, the last sentence is changed to read:

"The Contractor shall submit the required approval copies of the final report five (5) months from the date of the contract."

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR The B.F.Goodrich Company BY (Signature of person authorized to sign)		17. UNITED STATES OF AMERICA BY (Signature of Contracting Officer)	
15. NAME AND TITLE OF SIGNER (Type or print) R. L. Delagrange Supervisor, Government Contracts	16. DATE SIGNED 7/24/70	18. NAME OF CONTRACTING OFFICER (Type or print) LEON W. FITCHETT	19. DATE SIGNED JUL 28 1970

30-101-f-p

CONTRACTOR'S COPY

U.S. GOVERNMENT PRINTING OFFICE : 1966 O—250-045

III. Part VI, <u>Delivery, Inspection, and Acceptance</u>, subparagraph A, item 1, is changed to read under "From Date of Contract" to "$5\frac{1}{2}$ months" in lieu of "$4\frac{1}{2}$ months."

IV. There shall be no change in the estimated cost or fixed fee as a result of this modification.

CONTRACTOR'S COPY

KLA:bbw

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 2

1. AMENDMENT/MODIFICATION NO. 3
2. EFFECTIVE DATE NOV 3 1970
3. REQUISITION/PURCHASE REQUEST NO. Not Applicable
4. PROJECT NO. (If applicable)

5. ISSUED BY CODE
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23365

6. ADMINISTERED BY (If other than block 5) CODE

RECEIVED NOV 10 1970 Accessories & Plastics Sales Dept.

NOV 9 1970 Akron, Ohio

7. CONTRACTOR NAME AND ADDRESS CODE FACILITY CODE
(Street, city, county, state, and ZIP Code)
The B. F. Goodrich Company
Aerospace and Defense Products Division
500 South Main Street
Akron, Ohio 44318

8. ☐ AMENDMENT OF SOLICITATION NO.
DATED (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. NAS1-9944
DATED 4/28/70 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

Not Applicable

cc: Oliver Hirist, DCASO 11-18-70

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ____
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of Part IX, Notice of Delay, of the Contract Schedule
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

OCT 20 1970

I. Part II, Period of Performance, paragraph A is changed to read as follows:

"A. The period of performance shall be eight and one-half ($8\frac{1}{2}$) months from the date of this contract, inclusive of the submission of the final report."

II. Part IV, Reports, subparagraph C.8, the last sentence is changed to read:

"C.8. The Contractor shall submit the required approval copies of the final report six and one-half ($6\frac{1}{2}$) months from the date of the contract."

III. Part VI, Delivery, Inspection, and Acceptance, subparagraph A, item 1 is changed to read under "From Date of Contract" to seven (7) months in lieu of five and one-half ($5\frac{1}{2}$) months.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR The B.F. Goodrich Company
BY (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)
J. T. Gleason
Government Contracts Administrator

16. DATE SIGNED 10/27/70

18. NAME OF CONTRACTING OFFICER (Type or print)
FRANK V. MOORE

19. DATE SIGNED NOV 3 1970

30-101-4-p

U.S. GOVERNMENT PRINTING OFFICE

CONTRACTOR'S COPY NOV 3 1970

IV. There shall be no change in the estimated cost or fixed fee as a result of this modification.