VIRON

A DIVISION OF GEOPHYSICS CORPORATION OF AMERICA

7585 VIRON ROAD N. E. MINNEAPOLIS, MINNESOTA 55432

VIRON DIVISION
Geophysics Corporation of America
7585 Viron Road, N.E.
Minneapolis, Minnesota

MODIFICATION AND APPLICATION OF GELATIN FOR RIGIDIZATION OF EXPANDABLE HONEYCOMB STRUCTURES

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Approved By

Ivan W. Russell
Technical Project Manager

ABSTRACT

This sixth monthly progress report covers the period from 22 November to 22 December 1964 and describes the efforts and accomplishments on the Modification and Application of Gelatin for Rigidization of Expandable Honeycomb Structures. This study is being conducted under the direction of the Aeronautical Systems Division, Air Force Systems Command, U.S. Air Force, Wright-Patterson Air Force Base, Ohio. Mr. Fred W. Forbes, Wright-Patterson Air Force Base, is the cognizant program monitor.

This progress report has been authored by Nels S. Hanssen of the Viron Division, Geophysics Corporation of America, Minneapolis, Minnesota.

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SECTION I

INTRODUCTION

The Air Force Aero-Propulsion Laboratory in cooperation with the Air Force Materials Laboratory demonstrated the feasibility of utilizing gelatin as a rigidization media for expandable structures. That work was done as an in-house study. Further work under Contract AF33(616)-8483 produced some promising structural properties and space applicability information for gelatin. Under Contract AF33(657)-10409, the Air Force Aero-Propulsion Laboratory demonstrated the high strength to weight advantages of expandable honeycomb substrate fabrics.

The original objective of this study was to apply gelatin to space and terrestrial structures which consist of sandwich type structural materials. These particular structures are space shelters and solar energy concentrators. The above objective incorporated a three fold task; (1) Improving the existing gelatin rigidization system and selecting a suitable plasticizer system, (2) Chemical modification of gelatin for vapor phase rigidization, and (3) Application of gelatin (natural and modified) to sandwich type structures. In aggrement with a redirection of effort, further efforts on this contract will be divert to improving application techniques of a plasticizer boil-off gelatin system to space structures.

SECTION II

GELATIN APPLICATION

A. Accomplishments

Accomplishments during this reporting period can be summarized as follows:

1. Gelatin formulations were screened.
2. A satisfactory gelatin formulation was selected.
3. Flexibility retention of reflexibilized laminates was studied.
4. Eight inch solar collectors were vacuum cured.
5. Eight inch model shelters were vacuum cured.
6. A two foot solar collector was rigidized.
7. Several 3-1/2 foot shelters were assembled for impregnation and vacuum rigidization.

B. Experimental Work

Efforts of the sixth reporting period to develop gelatin for rigidization of expandable structures have been directed toward the following areas:

1. Screening for a stable gelatin formulation.
2. Selection of a satisfactory gelatin formulation.
3. Flexibility retention of laminates.
4. Vacuum cure of 8 inch collectors.
5. Vacuum cure of a 2 foot collector.
6. Vacuum cure of eight inch model shelters.

1. Screening For Stable Gelatin Formulations:

Several gelatin solutions were prepared according to formulations received from Monsanto Research Corporation. The formulas tested were as follows:

Formula	Parts By Weight 1	2	3
Gelatin	17.25	20.00	19
Water	69.00	60	74
Urea			4.3
Polyacrylic Acid			1.9
Formamide	13.75	20	

Solutions 1 and 2 gelled and became rubbery when cooled to room temperature. The mixture in formula 3 was heated for 16 hours at 140°F as was suggested but also gelled at room temperature.

2. Final Gelatin Formula

The gelatin formulation for rigidifying solar collectors and shelters was selected on the basis of:

a. Ease of formulating

b. Gelatin solid content

c. Viscosity

d. Ease of Vacuum impregnation

e. Flexibility retention of laminates

g. Room temperature viscosity stability

h. Good strength characteristics

The formula was suggested by Swift and Company and was slightly modified with respect to gelatin/liquidifier/solvent ratios by Viron. The formula was as follows:

	Parts By Weight
Gelatin	30.0
Water	38.5
2 - Chloroethanol	24.5
Methyl-butynol	7.0
	100.0

3. **Flexibility Retention**

The reflexibilized nylon and Raypan laminates discussed in Progress Report No. 5, page 6, were packaged in Scotch-Pak and after approximately 30 days, no change in flexibility was noted. These laminates will be rerigidized at a later time. Solvent removal will be completed in a shorter time because the gelatin/solvent ratio became much higher, i.e. 77 to 13 for the Raypan and 82/18 for the nylon after reflexibilizing.

4. **Vacuum Cure of Eight Inch Solar Collectors**

Two eight inch collectors were assembled and rigidized as outlined in Progress Report No. 5, page 6, except the flexible bonding layers were sprayed on the Mylar instead of being brushed. Very good cures were obtained in 4 hours at an average pressure of 16 microns Hg. The weight ratios of the fabric/gelatin solids/solvent, before and after cure, were as follows:

	Weight Ratios Fabric	Gelatin	Solvents
Before Cure	1	1	2.30
After Cure	1	1	0.18

The reflective surface of these collectors was poor. The structural material could not be stretched uniformly while being bonded and the flexible bonding layers were very thin.

Another approach taken to fabricate an 8 inch collector was to impregnate a preformed composite with the gelatin solution, rigidize it in a vacuum, and bond the rigid backing to a reflective surface with a flexible bonding layer. The gelatin was then reflexibilized with water and again vacuum cured. A poor bond resulted because the curved surfaces did not match. Another collector will be made by first reflexibilizing the cured gelatin impregnated structural material and then bonding it to the reflective surface. This will eliminate entrapped air and allow the surfaces to match. An experiment is in progress to learn the effect of bonding reflexibilized fabric to the epoxy.

5. Rigidization of a Two Foot Collector

A two foot solar collector was fabricated on a 28 inch diameter fixture equipped with a lowering ring. Assembly of the various components was performed in the manner described below:

a. A .001 inch aluminized Mylar film tailored from 16 gores was placed in an assembly fixture and pressurized.

b. The pressurized film was sprayed with four coats of a flexible epoxy. The fourth coat served to bond the nylon structural material.

c. The gored nylon structural material was mechanically lowered onto the tacky bonding layer with a uniform pressure force over the fabric to remove wrinkles in the fabric. The gelatin solution was uniformly distributed into the nylon fabric by vacuum impregnation.

d. The collector was cured in a 5 foot vacuum chamber for 17-1/2 hours at an average pressure of 0.5 mm Hg. After 2-1/2 hours, the collector had only partially rigidified, and vacuum cure was continued over night. After 17-1/2 hours, the gelatin seemed fully cured, but the internal pressure against the Mylar had dropped causing numerous wrinkles in the film. Another collector was started which will be assembled at a different skin stress.

6. Vacuum Cure of 8 Inch Model Shelters

Two 8 inch model shelters fabricated from Raypan and impregnated with the Swift gelatin formulation were vacuum cured with good results. Both models inflated fully during the first cure cycle and became very rigid.

The models were reflexibilized by suspending them over boiling water. During this process some gelatin was lost which resulted in a poorer inflation of the structures during the second cure cycle. The data in Table I show that the gelatin loss was about 50% for the first model.

The second model which had a nylon liner was impregnated with less gelatin. This model more fully inflated during the second cure cycle and according to the data in Table 2, retained most of its gelatin during reflexibilizing.

It is likely that a lessor amount of gelatin could have been used for Model 2 since the rigidity in each case seemed equal although the final cure of Model 1 resulted in a lower gelatin content.

Since a gelatin/solvent ratio of about 1/.10 seems necessary for rigidization, a method of determining rate of cure can be devised by plotting the amount of solvent in the sample vs time for a given structure.

	Fabric		Gelatin Solids	Solvents
Before cure	.99		1.0	2.30
After cure	.99		1.0	.03
Fabric/gelatin	49.5	/	50.5	
Average pressure was 20 microns for 16 hours				
After reflexibilizing	2.84		1.0	1.12
After second cure	2.84		1.0	.10
Fabric/gelatin	74	/	26	
Average pressure was 1mm Hg for 5 hours				

TABLE 1

WEIGHT RATIOS OF SHELTER MATERIALS
DURING VARIOUS STAGES OF FABRICATION, MODEL 1

Time in Vacuum	Fabric	Gelatin Solids	Solvents
0		1.0	2.30
2	1.73	1.0	1.58
4	1.73	1.0	0.85
6	1.73	1.0	0.47
8	1.73	1.0	0.25
10	1.73	1.0	0.16
12	1.73	1.0	0.12
Fabric/gelatin	63/37		
Average Pressure was 15 microns			
After reflexibilizing	2.01	1.0	0.66
After second cure	2.01	1.0	0.11
Fabric/gelatin	67/33		
Average Pressure was 1mm Hg for 4 hours			

TABLE 2

WEIGHT RATIOS OF SHELTER MATERIALS
DURING VARIOUS STAGES OF FABRICATION, MODEL 2

SECTION III

ANTICIPATED EFFORT

1. Flexibility retention of impregnated fabrics will be examined.
2. Two foot solar collectors will be cured, reflexibilized, and recured.
3. Three and one half foot shelters will be cured, reflexibilized, and recured.
4. The effect of bonding reflexibilized fabric to the epoxy will be determend.
5. A special structural fabric will be designed for one 3-1/2 foot shelter.
6. Work will be started to fabricate the end items for rigidization at Wright-Patterson Air Force Base.