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A METHOD OF FABRICATING A FOAM PLASTIC SHELTER

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PACIFIC MISSILE RANGE

Point Mugu, California

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SUMMARY

This report provides the results of a project conducted to develop for the Pacific Missile Range a disposable lightweight shelter to withstand a variety of climatic environments throughout the world.

The method that was developed, a field-expandable polyurethane foam sprayed over a reusable inflated mold, successfully meets the project requirements. Information is given on necessary materials and procedures to fabricate the shelter.

INTRODUCTION

The Pacific Missile Range (PMR) Satellite Geophysics Office provides operations management for worldwide research and development for the geodetic satellite tracking network and furnishes support to the Department of Defense Geophysics Program. To operate such a satellite tracking system poses unique logistics problems, among which is the initial transportation of shelters to remote locations. Some of these locations offer no shore facilities to off-load vessels, and others are in uninhabited parts of the world with no roads or other means of convenient access. It is therefore desirable to have materials that are lightweight and compact enough to be airlifted to a site.

To implement the assigned task of the Geophysics Office, it was essential to provide a number of disposable insulated shelters adequate for housing expensive geophysics instrumentation and two operators for a period of 6 weeks. Accordingly, Project TC/05 was established by PMR on 11 May 1967 to develop a prototype shelter to meet project requirements.

This report describes the design, selection of materials, and construction of a shelter to meet the project requirements: to withstand climatic environments that encompass polar, tropic, and desert areas.

Literature Survey and Background Information

A literature survey was conducted to ascertain whether any military or commercial shelter technology would meet the needs of the program. Requirements gave the range of temperatures from -50° to 125°F, with snow, wind, rain, and other phenomena prevalent in areas where geophysics observation stations might be needed. These requirements appeared to eliminate tentage and other similar structures designed for temporary shelter. The literature described a variety of practices that consisted of transporting prefabricated structures or conventional building materials, with trained personnel to erect the shelters. Serious and unacceptable drawbacks to this practice are high initial cost and shipping volume, and excessive on-site labor. In addition, it was noted that various departments of the Army, Navy, and Air Force have developed designs for special-purpose buildings by application of low-bulk materials such as polyurethane, which may be expanded on-site to form structural panels by incorporating the material as a core between fiberglass reinforced plastic facings. The structural panels may be assembled into buildings in the field. The use of transportable molds for polyurethane foam panels has already demonstrated the practicality of on-site fabrication.

All of these and other building concepts noted in the literature were of considerable interst, but it was felt that the best approach to the problem would be a urethane foam sprayed over a shell structure (a mold).

MATERIAL, EQUIPMENT, AND METHODS

To avoid logistics problems associated with shipment of prefabricated plastic or other shell structures noted in the literature, the decision was made to construct the shelter in the field and to provide the major building components in the form of fabric, sheeting, or liquid foam materials that have low cubage and are logistically desirable. To accomplish this, an igloo-shaped shelter 8 feet in diameter and 8 feet high was designed to accommodate two men and the instrumentation.

For the prototype, a plywood frame was made for fabricating the mold (figure 1). The mold is made from adhesively-bonded nylon fabric that folds into a compact package when not in use. The bonded seams of the mold are spray-coated with a neoprene sealant to ensure airtightness, the mold is unfolded, and the bottom is temporarily secured with metal staples to a 10-foot-diameter base. (The base is shown in figure 2.) The mold is then inflated with low-pressure compressed air and the prefabricated plywood insulated door and window frames are taped in place on the mold (figure 3). Foam mold release is sprayed onto the mold before the foam is applied to ensure ease of mold removal once the foam has set.

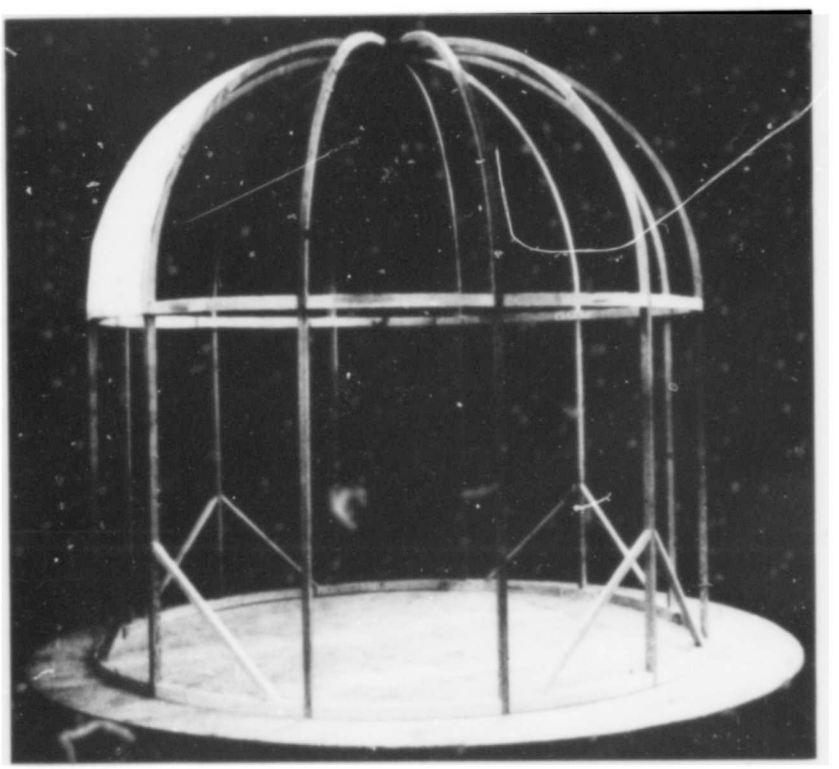

Figure 1. Plywood Form for Inflatable Mold.

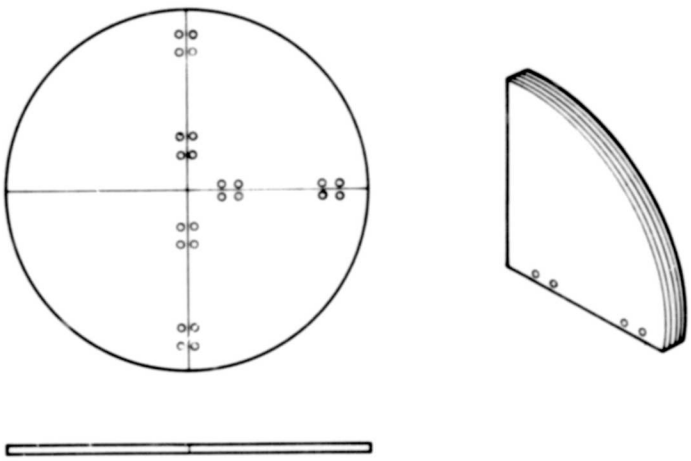

Figure 2. Plywood Base.

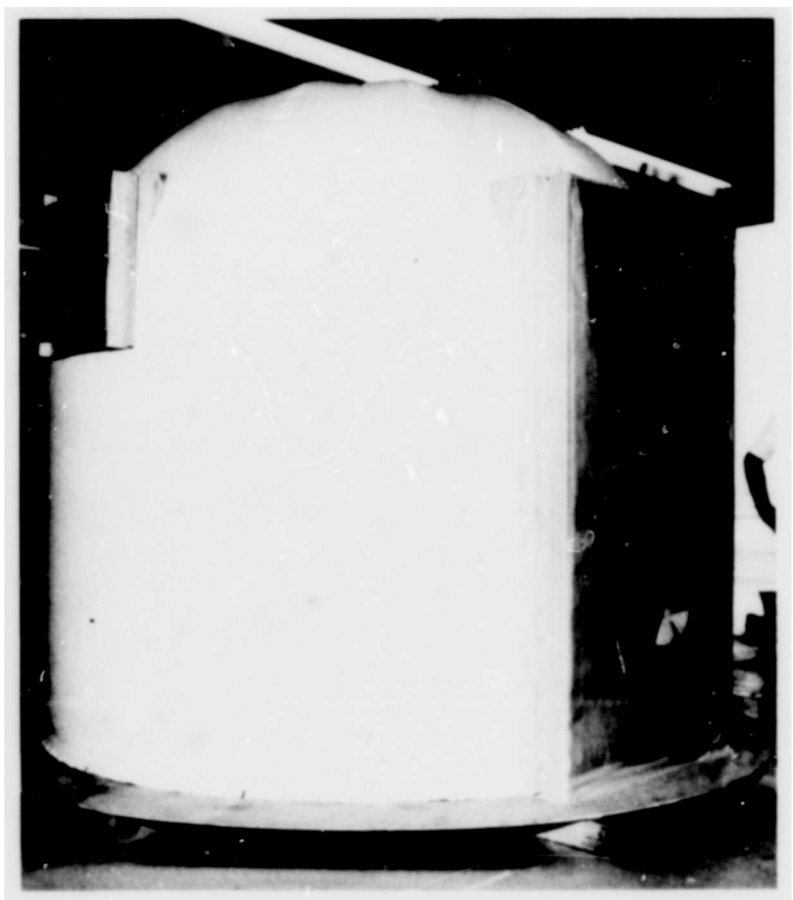

Figure 3. Door and Window Frames Installed.

There are some safety measures to observe when the foam is sprayed onto the structure: The di-polyisocyanates used in the manufacture of polyurethanes are mucous irritants and lacrimators; it is therefore advisable for persons directly exposed to fumes during the spraying operation to wear respirators if the spraying is done in an enclosed area. When the foam has set and formed the finished structure, it is completely free of irritants and toxics.

The urethane foam is sprayed onto the mold from 5-gallon cans of plastic and accelerator. The spray gun (described in table 1) was operated from the shop's compressed air supply. Thirty-five cubic feet of air per minute was used at 75 pounds per square inch. A portable air compressor could be used for processing in the field.

Table 1. Materials Needed for Plastic Foam Shelter

Item	Description	Source
Equipment		
Foam gun	Static mix gun with rotary positive displacement. Weight: 2 pounds.	The Upjohn Company, CPR Division, 550 Alaska Avenue, Torrance, California 90503
Stapling machine	Tacker staple. Gun type Federal Specification GGG-T-206, Stock No. 9Q-5120-889-1796	General Services Administration, Federal Supply Catalog, August 1967
Staples	Federal Stock No. 9Z-5315-889-2602.	General Services Administration, Federal Supply Catalog, August 1967
Hardware		
Door hinges	3 by 3 inches, No. 804, Federal Stock No. 92-5340-231-2L41	General Services Administration, Federal Supply Catalog, August 1967
Door latch	Item 1303B, catalog No. 71	McMaster Carr Co., 9601 John Street, Los Angeles, California
Ventilator	Type L Air-X-Houster, 6-inch size with insect screen.	Haldman, Inc. 2845 Supply Avenue, Los Angeles, California
Materials		
Inflatable mold fabric	"Hypalon" white nylon fabric, No. 72-014. Weight: 12 ounces per square yard. 54 inches wide.	E. I. du Pont de Nemours & Co., Industrial Fabrics Section, 200 South Garfield Avenue, Los Angeles, California
Plywood	Military Specification MIL-P-6070, Type I exterior, fully waterproof bond.	
Door insulation	Styrofoam No. 22 packaged boards, 1 by 12 by 36 inches.	Dow Chemical Company, 900 Wilshire Boulevard, Los Angeles 17, California
Window glazing	1 8-inch acrylic sheet stock, Federal Specification MIL-P-5425, finish A, Stock No. G-9330-292-9810.	General Services Administration, Federal supply Catalog, August 1967
Nylon fabric cement	Type 5149 cement with activator	E. I. du Pont de Nemours & Co., Industrial Fabrics Section, 200 South Garfield Avenue, Los Angeles, California
Inflatable mold sealant	Gaco No. N-700, white liquid neoprene coating.	Chemical Proof Corporation, 12049 Regent Street, Downey, California
Mold sealant thinner	Xylol thinner.	Chemical Proof Corporation, 12049 Regent Street, Downey, California
Foam mold release	CPR-MR-250 urethane mold release.	The Upjohn Company, CPR Division, 550 Alaska Avenue, Torrance, California 90503
Foam system	Isonate system, CPR 385	The Upjohn Company, CPR Division, 550 Alaska Avenue, Torrance, California 90503

In this prototype, the average thickness of the foam is 2 inches, except around the door and window frames, where additional foam was sprayed to securely lock the frames in place (figure 4). Three or four 5-gallon cans of foam components are needed for an average-size structure. Physical and chemical properties of the foam are given in table 2.

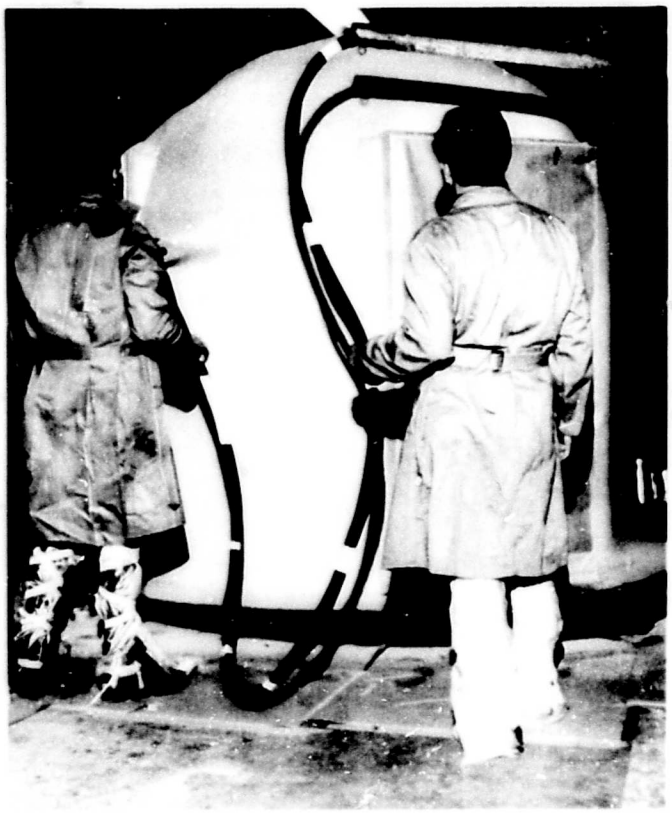

Figure 4. Door and Window Frames Locked in Place With Plastic Foam.

After a curing time of 1 hour, the nylon mold is deflated and removed through the door opening. The inflatable mold can be used many times; ease of removal is assured by use of the foam mold release.

Door, Window, and Ventilator

Installation of shelter hardware, that consists of an insulated door with fittings, acrylic window, and ventilator, is accomplished in a short time with simple hand tools. The finished shelter is shown in figure 5.

The door is a composite sandwich structure of 1/8-inch plywood facings over a styrofoam plastic core. This design provides thermal insulation to prevent heat leakage through the door. Configurations of the door and window are shown in figure 6. The ventilator is described in table 1, which also lists other items needed to build a plastic foam shelter, and gives procurement sources.

Table 2. Properties of Isonate System CPR 385 Foam as Cited by Manufacturer

CPR 385 is a nonburning, PAPI- (polymethylene, polyphenyl isocyanate) based polyether, fluorocarbon, blown-foam spray system.

	Test Temperature (Degrees Fahrenheit)	ASTM* Method	Test Units and Values	
Physical Properties				
Nominal Density	74	D1622	2 lbs/ft^3	
Compressive Strength				
Parallel[1]	74	D1621	26 psi	
Perpendicular	74	D1621	14 psi	
Compressive Modulus				
Parallel	74	D1621	700 psi	
Perpendicular	74	D1621	320 psi	
		D1623		
Tensile Strength				
Parallel	74	D1623	45 psi	
Perpendicular	74	D1623	25 psi	
Shear Strength				
Parallel	74	C273	23 psi	
K Factor	74	C177	Btu/ft^2 Hr $^\circ$F/in	0.11 to 0.14
Flame Resistance	74	D1693	NA (not applicable)	nonburning
Water Absorption	74	D2127	0.02 lb/ft^2	
Dimensional Stability (28 days) (net change in volume)	160	D2126	6%	
Chemical Properties				
Viscosity, Component A	77	D1638	250 cps	
Specific Gravity	77	D1638	NA	1.24
Viscosity, Component B	77	D1638	500 cps	
Specific Gravity	77	D1638	NA	1.20
Ratios: Parts by weight (total mix equals 100 parts)				
Component A				50
Component B				50
Processing				
Cure Time				1 hr**
Cure Temperature				65°F **

[1] Properties measured in direction of rise
* American Society for Testing Materials
** Other cure times and temperatures have not been determined

Options to Design

A foam structure can be any reasonable shape or size, and rooms can be added as needed.

Although the floor used in the shelter described is rather thin plywood, the floor can be a composite, of the same material as the door, if more insulation is required. The floor can also be of foam; the foam can be smoothed before it hardens.

Electrical wiring can easily be laid in a foam structure. The uninsulated wiring can be taped where needed, then covered with foam; the foam is an excellent insulator. Piping can be laid the same way.

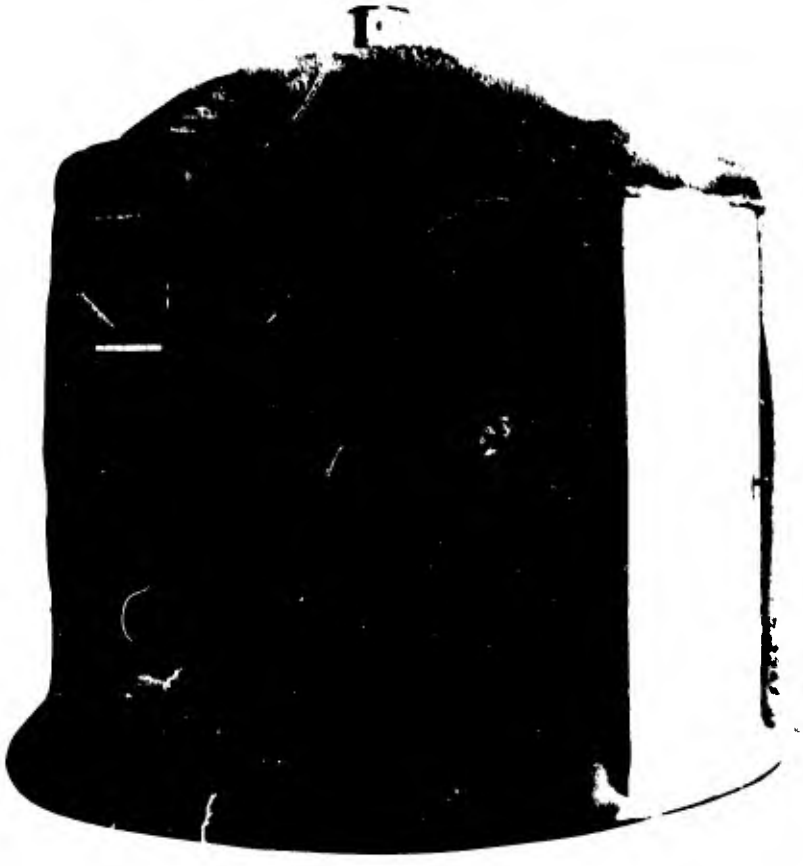

Figure 5. Completed Shelter.

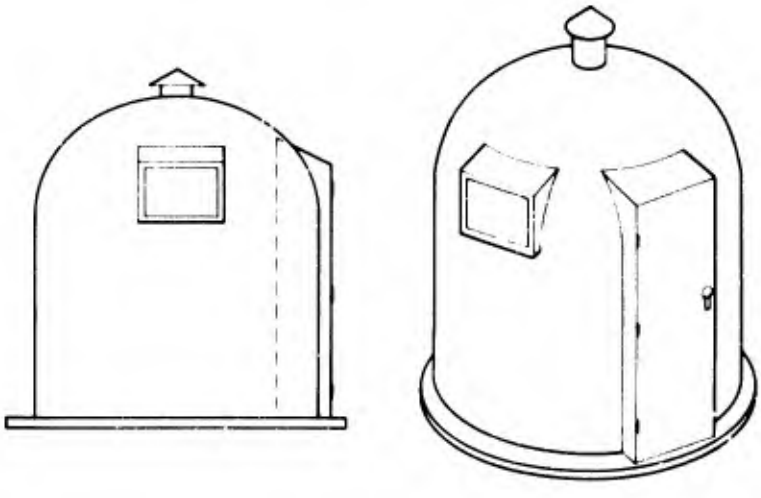

Figure 6. Door and Window Configurations.

DISCUSSION

The practical application of the construction method described in this document depends to a large extent on the processing environment. In temperate climates where spraying operations can be initiated at temperatures of about 70°F, very satifactory results may be obtained. According to the manufacturer's processing literature, the optimum temperatures of the foam components "A" and "B" are 90° and 75°F, respectively. However, the present shelter was sprayed at a temperature of approximately 65°F, with excellent results. The measured specific gravity of the cured foam was 1.8 pounds per cubic foot, which is slightly less than the normal density of 2.0 pounds per cubic foot as described in the manufacturer's literature.

Several characteristics of the polyurethane foam must be considered before open-air spraying. For example, before the spraying operation in cold environments, it would be necessary to heat the foam components and the hose that conveys the foam from the mixing chamber to the spray gun. In addition, a strong wind will affect the atomization and direction of the foam spray. It is therefore advisable to shield the spraying area from the wind with a tarpaulin, or a similar protection. Environmental temperature limitations for processing are not known.

The specific foam formula selected for the shelter was based on its resistance to moisture absorption and fungal deterioration. The foam is also one of the most effective thermal insulating materials known and the 2-inch-thick layer on the shelter provides effective control of temperatures in the -30° to -60°F range. Additionally, the foam is non-flammable.

CONCLUSIONS

1. It is estimated that the developed foam plastic shelter has the potential to reduce Satellite Geophysics Program transportation costs by an impressive factor.

2. A method of fabricating a disposable shelter by applying foam plastic on a reusable inflatable mold has been successfully demonstrated.

3. Field tests are required to evaluate the shelter under extreme environmental conditions.

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13 ABSTRACT

This report contains a description of the plastic foam shelter designed to meet the need for satellite geophysics observation stations located throughout the world. The shelter was designed for the Pacific Missile Range Satellite Geophysics Office.

Shelter materials can be airlifted to the site where the shelter is to be erected. The shelter meets requirements for a structure that can comfortably house men and equipment in polar, tropic, and desert environments.

Information is given on necessary materials and procedures to fabricate the shelter.

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