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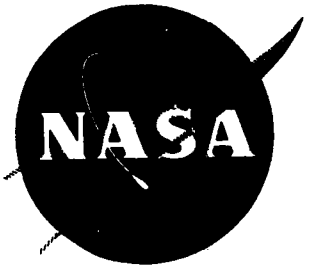


# PROCESS SPECIFICATION

# APPLICATION OF FOAM-IN-PLACE POLYURETHANE TO HIGH VOLTAGE DEVICES

by

C. J. Holzbauer

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Contract NAS 3-8905



TRW SYSTEMS GROUP, INC.
Redondo Beach, California

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CONTRACT NAS 3-8905

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PROCESS SPECIFICATION

APPLICATION OF FOAM-IN-PLACE POLYURETHANE
TO HIGH VOLTAGE DEVICES

1. SCOPE

This specification establishes the materials, procedures and controls to be used for encapsulating high voltage direct current electrical assemblies.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids form a part of this specification to the extent specified herein:

SPECIFICATIONS

Federal

| | |
|---|---|
| O-A-51 | Acetone, Technical |
| MIL-T-7003 | Trichloroethylene, Stabilized, Degreasing |
| TT-M-261 | Methyl Ethyl Ketone |

3. REQUIREMENTS

3.1 Health and Safety Precautions.

3.1.1 Toxicity. Many of the materials (solvents and foam material) used in this process are toxic if breathed or absorbed through the skin in excessive quantities. These materials can be used without hazard if the general precautions specified herein are observed.

3.1.1.1 Avoid contact of the solvents and foam components with the skin. Special care shall be taken to prevent contact with open breaks in the skin. Any areas of the skin that are contacted by these materials shall be washed immediately and thoroughly with soap and water.

3.1.1.2 If any material contaminates the eyes, flush immediately with copious quantities of water. Then obtain immediate medical attention.

3.1.1.3 After using any of the materials specified herein, wash the hands thoroughly with soap and water before smoking or eating.

3.1.2 Flammability. Many of the materials specified herein are flammable. No smoking or open flames shall be allowed within 25 feet of an operation where these materials are being used.

3.1.3 Ventilation. Good, general ventilation shall be provided in all work areas to prevent buildup of solvent vapor and toluene diisocyanate vapor. Mixing and application of the foam should be accomplished in an exhaust ventilated booth having a minimum face velocity of 100 feet per minute (fpm).

3.2 Materials.

The following materials, or approved equivalent, shall be used to assure satisfactory results for the foaming process established by this specification.

3.2.1 Foam Systems.

| | |
|---|---|
| CPR 23 Series | Manufactured and supplied by CPR Division of the Upjohn Co., 55 Alaska Ave., Torrance, California 90503. |
| Stafoam AA 600 Series | Manufactured and supplied by Polytron Dept., Olin-Mathieson Chemical Corp., 661 So. Tenth Street Richmond, California 94804 |

3.2.2 Mold Releases and Maskants.

| | |
|---|---|
| Waxes, Carnauba Base | Simoniz (Simoniz Wax Co.)<br>Johnson Paste Wax (Johnson Wax Co.)<br>Epowax (Furane Plastics, Inc., 4516 Brazil Street, Los Angeles California 90039). |
| Fluorocarbon Spray Release | MS-136, Miller-Stephenson Chemical Co. Los Angeles, California |
| Silicone Grease | DC-7, Dow Corning Corporation |
| Films | Polytetrafluoroethylene (*Teflon) - Commercial<br>Polyvinylchloride |

3.2.3 Cleaning Materials.

| | |
|---|---|
| Solvents | Methyl Ethyl Ketone (TT-M-261)<br>1,1,1 Trichloroethylene (O-T-636)<br>Trichlorotrifluoroethane (*Freon TF) - Commercial |
| Abrasives | Ajax Cleanser, Institutional Grade - Commercial<br>No. 80 Grit Aluminum Oxide - Commercial<br>No. 325 Grit Aluminum Oxide - Commercial |

* Trade name of E. I. Du Pont de Nemours.

| | |
|---|---|
| Sulfuric Acid (Specific Gravity 1.84) | Commercial |
| Sodium Dichromate | Commercial |

3.2.4 Equipment.

| | |
|---|---|
| Balance, Harvard | Ohaus Scale Corp. |
| Propeller-type Stirrer | High RPM, Motor or air driven (Commercial) |
| Circulating Air Oven | Capable of 210 ± 10°F |

3.3 Procedure.

3.3.1 Mold Preparation.

3.3.1.1 Cleaning. The mold surfaces shall be thoroughly cleaned and dried prior to application of mold release. Gross contamination of oils, greases, or particulate matter shall be removed by wiping with a clean cloth dampened in acetone, methyl ethyl ketone, Freon TF, or 1,1,1 Trichloroethylene. Immersion in the solvent accompanied by scrubbing with a cloth or brush is also acceptable. Following removal of the gross contaminants, vapor degrease the mold pieces in Freon TF or 1,1,1 Trichloroethylene. Parts shall be dried thoroughly (at room temperature or in a circulating air oven).

3.3.1.2 Mold Release Application. Apply two (2) coats of wax (3.2.2) or fluorocarbon release (3.2.2) to all mold surfaces to which the foam must not adhere. If wax is used, each of the two coats shall be buffed lightly to remove excess wax. Mold hardware (bolts, nuts, plugs, studs, etc.) are frequently more easily coated using the silicone grease or the fluorocarbon spray.

3.3.2 Electrical Assembly Preparation.

3.3.2.1 If any part of the assembly is separable from the assembly and yet is to be an integral part of the foamed assembly, that part shall be cleaned as specified in 3.3.1.1. In addition, if that part is aluminum and can be etched without damage, the part shall be etched for 5-10 minutes at 130-150°F in a solution of the following composition.

| | |
|---|---|
| Distilled Water | 30 parts by weight |
| Sulfuric Acid (Specific Gravity 1.84) | 10 parts by weight |
| Sodium Dichromate | 4 parts by weight |

CAUTION: The usual precautions for handling and using acids apply to the use of the sulfuric acid and the prepared solution.

Rinse thoroughly under running water and dry in a circulating air oven at 150°F. Handle cleaned parts only with clean cotton gloves or clean tongs.

3.3.2.2 If the separable part is not aluminum or would otherwise be damaged by etching but can be abrasively blasted, dry abrasive blast all surfaces to which the foam must adhere using No. 80 grit aluminum oxide. Remove all abrasive grit by blowing with clean, dry, oil-free air.

3.3.2.3 If the separable part cannot be abrasively blasted without damage, scrub the surfaces with a wet slurry of an abrasive cleaner, such as institutional grade Ajax or No. 325 grit aluminum oxide. Rinse clean under running water and air dry in an air-circulating oven at 150°F.

3.3.2.4 If none of the above cleaning procedures are appropriate, clean in accordance with the cleaning procedure specified for the electrical assembly (3.3.2.5).

3.3.2.5 The electrical assembly shall be thoroughly cleaned by vapor degreasing in Freon TF or 1,1,1 trichloroethylene. If the hot solvent is detrimental to any components, the next preferred cleaning method is ultrasonic cleaning in either solvent, followed by rinsing in clean solvent. Immersion and brush cleaning followed by rinsing in clean solvent is to be used only if the previous two methods cannot be used.

NOTE: After cleaning, all parts that are to be an integral part of the final assembly after foaming shall be protected from re-contamination. Handling of these parts shall be accomplished only with clean, dry cotton gloves or by using clean tongs (or tweezers, as appropriate).

3.3.3 Weigh the assembly that is to be embedded in foam and record the weight ($W_1$).

3.3.4 Assemble the mold and position the electrical assembly within the mold in the required location. Mask, mold release or otherwise protect (as appropriate) all terminals, feed-thru's, leads, etc., using materials specified in 3.2.2. Allow only the foam entry port and vents to remain open and unobstructed.

3.3.5 Foam Quantity Determination. The volume of free-space in the mold (V) shall be calculated from the mold dimensions and subtracting a volume allowance for the electronic assembly. A reasonably accurate volume of the assembly can be obtained at the time of cleaning (3.3.2.5) by liquid displacement method, using the cleaning solvent as the liquid. If the configuration of the mold is such as to make calculation of the mold volume difficult or tedious, the volume may be measured by liquid capacity at the time of mold cleaning (3.3.1.1).

3.3.5.1 Having determined the volume of free space (V) to be filled by the foam, the weight of mixed foam (W) required to achieve the specified density shall be calculated as follows:

$$V \times D \times 0.30 = W$$

Where V = volume (in cubic inches) to be filled by foam.
D = desired density (in pounds per cubic foot) of foam.
W = weight of foam required in grams.

3.3.6 Selection of Foam to be Used. The material to be used for foaming shall be selected in accordance with the specified density as follows:

| Foam Density Specified | Material to be Used |
|---|---|
| 6 lbs/ft$^3$ or less | CPR 23-2<br>Stafoam A-602 |
| 8-12 lbs/ft$^3$ | CPR 23-4<br>Stafoam A-604 |
| 14-20 lbs/ft$^3$ | CPR 23-8<br>Stafoam A-608 |

3.3.7 Pre-heat the mold and assembly, which at this point is ready for foaming, to 110-120°F and maintain at this temperature until just prior to introduction of the foam.

3.3.8 Foam Formulation, Preparation and Application.

3.3.8.1 Before proceeding, the method that will be used to introduce the proper quantity of foam into the mold must be selected. Either of the following two methods are acceptable.

3.3.8.1.1 Method 1. Just prior to proportioning and mixing the foam material, weigh the mold and assembly on a balance and add a balance weight equal to the weight of foam required (W), as determined in 3.3.5.1. When preparing the foam, use at least 20% more foam (1.2W) than required to be added to the mold. When adding foam (3.3.8.6), exactly W grams of foam can be added to the mold by noting when the weight of foam counterbalances the balance weight.

3.3.8.1.2 Method 2. When proportioning the quantity of foam, weigh and mix exactly 1.15W grams of foam. After mixing, pour the foam into the mold but do not scrape foam from the mixing container. Approximately 15% of the foam will adhere to the mixing container, thereby resulting in the desired quantity (W) in the mold.

3.3.8.2 The foam components shall be proportioned in accordance with the manufacturer instructions, with an allowable weight tolerance of $\pm$ 2%.

3.3.8.2.1 CPR 23 Series Foam.

3.3.8.2.1.1 Weigh the required quantity of Component T into an unwaxed paper container. (A metal, glass, polyethylene, or fluorocarbon container may be used but paper is recommended because of its disposable nature, making clean-up easier.) The volume of the container occupied by Component T shall be no more than one-quarter nor less than one-tenth of the total container volume.

3.3.8.2.1.2 Rapidly weigh the required quantity of Component R into the same container.

3.3.8.2.2 Stafoam AA-600 Series Foam.

3.3.8.2.2.1 Weigh the required quantity of Component T into an unwaxed paper container. (A metal, glass, ploye thylene or fluorocarbon container may be used but paper is recommended because of its disposable nature, making clean-up easier.) The volume of the container occupied by Component T shall be no more than one-quarter nor less than one-tenth of the total container volume.

3.3.8.2.2.2 Rapidly weigh the required quantity of Component T into the same container.

3.3.8.3 Thoroughly mix the two components at high RPM using a propeller-type stirrer, keeping the propeller blades submerged in the foam material at all times while mixing and moving the stirrer throughout the volume of the material (especially important at container bottom and sides to insure complete and thorough mixing). Mix for 45 seconds or until the first sign of foaming occurs (as evidenced by a whitening of the material), whichever occurs first.

3.3.8.4 Rapidly pour the mixed foam material into the pre-heated mold, distributing uniformly while pouring (3.3.8.1). It is important that material foam from bottom of mold (location opposite vents) through the assembly to the vents to insure a uniform product and prevent air entrapment which will result in large voids.

NOTE: To achieve a heavier-than-normal "skin" at any particular location, if desired, brush that area for 2 to 5 seconds with the foam material using a stiff bristle brush (such as an acid brush).

3.3.8.5 Immediately upon completion of pouring, position the cover on the foam entry port and secure.

3.3.9 Allow the mold assembly to remain undisturbed at room temperature for 10-20 minutes, then place in an air-circulating oven at 210 $\pm$ 10°F for 10 $\pm$1 hours to cure the foam.

3.3.10 After the oven cure, the mold shall be removed from the oven and permitted to cool naturally, without forced cooling, to room temperature.

3.3.11 When cool, remove mold and trim flash and vent sprues from the foamed part.

3.3.12 Weigh the foamed part and record the weight ($W_2$).

3.3.13 Cleanup.

3.3.13.1 Cleanup of foam spillage, mixing equipment, etc., should be accomplished as soon as practical after completion of pouring the foam in the mold. Clean by immersion and scrubbing using methyl ethyl ketone or acetone.

3.3.13.2 Flash and sprue removal from the foamed assembly may be accomplished by cutting with a sharp knife or similar instrument.

3.4 Workmanship. The foam-embedded assembly shall exhibit the following characteristics:

3.4.1 The prescribed volume of the assembly as specified on the engineering drawing shall be filled with foam.

3.4.2 The foam shall be of uniform cell size without cracks, delamination, or thickness.

3.4.3 The density of the foam shall be as specified on the engineering drawing. The tolerance on the density shall be $\pm$ 1/2 lb/ft$^3$ for densities of 4 lbs/ft$^3$ or less, and $\pm$ 15% for densities greater than 4 lbs/ft$^3$.

3.5 Rework. Rework shall be accomplished by cutting away the foam to expose the void (or component to be replaced). Refoaming shall be accomplished in accordance with the requirements of 3.3.4 and subsequent. Cleaning of an area to be refoamed shall be by cutting away the contaminated surface of foam; solvent cleaning shall not be used.

4. QUALITY ASSURANCE PROVISIONS

4.1 Process Control. The following operations shall be observed and/or verified by Quality Control.

4.1.1 Visually inspect interior surfaces (molding surfaces) of mold for contamination, including particulate and liquid (solvents).

4.1.2 Verify complete coverage of mold release on those surfaces which will contact foam.

4.1.3 Verify cleaning and drying of the assembly to be embedded in the foam.

4.1.4 Verify mold volume determination and calculation of foam weight required and actually used.

4.1.5 Verify preheating of mold and assembly before pouring of foam.

4.1.6 Witness and verify proper proportioning, mixing, and pouring of the foam.

4.1.7 Verify foam cure.

4.1.8 Verify that foam density of the foamed assembly is as specified on the engineering drawing. The density of the foam shall be calculated as follows:

$$\left(\frac{W_2 - W_1}{V}\right) \times 3.83 = D$$

$W_2$ = weight of foamed assembly, in grams (3.3.12)

$W_1$ = weight of assembly before foaming, in grams (3.3.3)

$V$ = volume of foam, in cubic inches (3.3.5)

$D$ = density, in pounds per cubic foot

4.2 Foam Quality. The molded foam shall be inspected for the workmanship requirements of 3.4.

5. PREPARATION FOR DELIVERY

5.1 Packaging. The foam-in-place assemblies shall be wrapped in polyethylene sheeting conforming to MIL-P-22035, Type I, Grades 1 through 3, or placed in bags fabricated from the sheeting. Openings shall be secured to prevent contamination. When transporting or shipping is required, the assemblies shall be placed in containers suitably constructed and with the contents padded to ensure safe delivery by common carrier to the destination.

5.2 Identification. Identification markings (part numbers, etc.) may be placed on the foam surface as long as the marking does not interfere with the function of the assembly and will withstand normal handling. No marking method which penetrates or pierces the foam surface is allowed.

6. NOTES

6.1 Intended Use. The procedures and materials specified in this document are intended to provide low-weight mechanical support and electrical insulation for electrical assemblies. These materials and procedures will provide insulation for high voltage direct current devices for use in the space environment.

6.2 Drawing Callout. In addition to the specification number and descriptive title, it is necessary that the desired density be specified on the drawing. Unless otherwise specified, the density tolerances are as specified in 3.4.3.

6.2.1 A careful review of the assembly drawing for materials and components should be made and additional notes should be incorporated on the drawing to prevent damage from the solvents and operations specified herein.

6.3 Precautionary Note. Although the foam materials called-out in this specification are chemically compatible with nearly all materials used in component and circuit fabrication, considerable heat may be liberated during the foaming process. It is desirable to determine experimentally the heat liberated for each design using a model prior to encapsulation of flight units to insure complete process (including thermal) compatibility.