EMERSON & CUMING, INC.
Dielectric Materials Division
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DEVELOPMENT OF INORGANIC NON-FLAMMABLE SPACECRAFT POTTING, ENCAPSULATING, AND CONFORMAL COATING COMPOUNDS

by

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FOREWORD

A research study on the development of a potting and encapsulating compound and a conformal coating all based principally on inorganic materials has been performed under Contract Number NAS-9-8749, Manned Spacecraft Center, Houston, Texas.

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ABSTRACT

Four compounds, non-flammable in oxygen, were developed, two of which were potting compounds and two were coatings. Of the two potting compounds, one is completely inorganic, and the other about 80% inorganic. Glass microballoons were incorporated to make the products repairable and to reduce density. In both formulations, a volatile solvent was found necessary. Removal of the solvent by evaporation left a porous structure that required a sealer coat. Some of the electrical properties under conditions of high humidity did not meet the requirements of the work statement. It was felt that this was due to the porosity.

A conformal coating based on a brominated polyester was developed which was not porous, but which was not as readily repairable as the potting compound. It passed the majority of the requirements.

SECTION I

INTRODUCTION

Emerson & Cuming, Inc. was awarded a contract to conduct a program for the development of an inorganic non-flammable potting compound and conformal coating for use inside a manned spacecraft. Emerson & Cuming, Inc. presently offers completely inorganic castable ceramic encapsulants, and is therefore not unfamiliar with materials of this nature. These products have specific gravity around 2.5, and cannot be removed for the repair or replacement of a defective unit. Low specific gravity and easy repairability were among the properties sought in the potting compounds to be developed.

Past experience had demonstrated that the incorporation of glass microballoons (Eccospheres) not only reduced the density of formulations containing them, but in certain instances made these systems easily repairable. A system that is completely inorganic is ideal from the non-flammability point of view. It was obvious from the start, however, that the rigidity and porosity of such a system might leave something to be desired. It was also predicted from its chemical nature that adhesion would not be good and its electrical properties would deteriorate in humid air.

An organic binder should lead to considerable improvements in these last two properties, but might not give acceptable behavior when subjected to the oxygen flammability test.

The program was divided into two main sections: a) development of potting compounds and conformal coating, and b) the preparation of test samples and execution of the specified tests. Two potting compounds have been developed that can be used without undue difficulties: one of these is an all inorganic system, the other is largely inorganic, but contains an organic binder. A coating was required to seal the porosity of both of these potting compounds. Approximately thirty (30) observations and tests of widely varying complexity were required on each potting compound and on the conformal coating.

SECTION II

SUMMARY

Work was done to develop a potting compound with particular emphasis on materials that are non-flammable in oxygen.

Two approches were carried out: one, a totally inorganic composition, the other an inorganic material bonded together with a small amount of organic polymer. The former is based on a technology disclosed in U. S. Patent 2, 914, 413 and already being used at Emerson & Cuming, Inc. under license from Pennsalt Chemical Company. For the latter approach the use of a fluorinated elastomer was investigated. The formulation included glass microballoons to provide low density and repairability, and asbestos fiber to provide strength and a path for solvent release, and to reduce shrinkage. Several combinations were investigated to balance strength and shrinkage, and to eliminate voids in the cured material. This required the right balance of glass microballoons and asbestos fiber, as well as solvent system and resin.

Because both the completely inorganic potting compound, and that based on a fluoroelastomer were porous after cure, it was necessary that they be sealed. Taking advantage of what was learned in developing the potting compound, a sealer coat was prepared based on a solvent solution of a fluoroelastomer together with an alumina filler. Several coats were required with a primer applied before each coat.

The conformal coating was a highly filled brominated polyester containing no solvent or unreactive material. In order to avoid possible porosity, it was decided to avoid a solvent system. An epoxy system with a low enough viscosity to permit 75% to 80% filler is well known. But the highly brominated fire retardant systems are much too high in viscosity. Some are solids.

SECTION III

CONCLUSIONS

1. No completely satisfactory potting compound that passed all requirements of the contract was developed during this work.

2. The conformal coating developed in this work is considered acceptable in most respects, but does not meet all the requirements as set forth in the contract.

3. With the organic binders that are readily available, and that can be formulated to yield non-flammable compositions, most are solids or very viscous liquids. In order to incorporate high percentages of inorganic fillers, it is necessary to apply the binders as solutions. After curing a porous encapsulant results, which requires a sealer coat to keep out moisture.

4. Although polytetra fluoroethylene will burn in oxygen, as will fluorinated elastomers, the flammability of the latter can be dramatically reduced by use of a high content of inorganic filler.

5. A highly filled brominated epoxy burns vigorously under the same conditions that fluorinated elastomers do not burn.

6. A completely inorganic encapsulant which relies on the gelling of a silica sol to bond the inorganic particles together results in a porous structure being formed, since water must be eliminated.

7. The totally inorganic composition, QC-15, has poorer electrical properties then the system consisting of inorganic solids bonded together with fluoroelastomer--formulation 1015. All electrical tests except for dielectric constant, power factor and dielectric strength were carried out on samples that had three sealer coats.

8. The physical characteristics of the potting compounds and conformal coating are generally as required by the work statement of the contract.

9. Of the two potting compounds, the 1015 formulation is superior to the totally inorganic QC-15 formulation.

10. Many of the electrical failures are due to moisture passing through the sealer coat.

11. Both potting compounds failed in properties which one might expect to be affected by the porosity and/or low density of the compounds. These properties included moisture resistance, dielectric strength, and tensile properties.

SECTION IV

RECOMMENDATIONS

1. It is recommended that any further work on the development of potting compounds that are largely inorganic be concentrated on the use of fluoroelastomers as the binder.

2. It is further recommended that the substitution of a reinforcing filler for some of the glass microballoons be made to improve the deficient mechanical properties.

3. It is also recommended that further work on the fluoroelastomer based potting compounds explore ways of improving moisture resistance of the sealer coat.

4. It is recommended that no further consideration be given to the completely inorganic system based on the technology used in this work.

SECTION V

EXPERIMENTAL RESULTS

A. MATERIALS FORMULATION

1. Survey of Materials

In order to achieve non-flammability in oxygen of the potting compound, materials can be used that do not burn in oxygen. Inorganic oxides, silicates, glasses and most minerals, for example, fall into this category. The technology used in certain of the Eccoceram products offered by Emerson & Cuming, Inc. provides a means of curing inorganic materials to rigid solids. This technology is described in U. S. Patent 2, 914, 413, Nov. 24, 1959, assigned to Pennsalt Chemicals Corp. and available under license. (Ref. 1). In essence a small amount of powdered sodium silicate is mixed with a finely divided inert material. A silica sol, such as DuPont's Ludox, is mixed in to give a mass of paste-like consistency. This can be poured or formed, depending on the amount of Ludox used, and allowed to stand at room temperature to set. In the presence of the small amount of sodium silicate, the Ludox gels and thereby binds the mass together somewhat like the setting of cement. After this occurs, heat can be applied to remove water.

Since the products of this technology would probably not meet some of the requirements for the potting compound, the use of certain organic binders was indicated. Most polymers that might serve as binders, however, are flammable in air, as well as oxygen.

Ideally a potting compound is made from a low viscosity material that can be polymerized by an addition reaction to a thermoset material. Epoxies, polyesters, urethanes, and some silicones are among the classes that could be used. Of the epoxies, polyesters, urethanes, and silicones, many have fire retardant properties, usually produced by the addition of a halogen, preferably bromine, to the molecule. Such materials will burn when exposed to a flame in air, but will not of themselves support combustion in air for more than a few seconds. Probably all would burn vigorously in oxygen.

Besides the non-flammable characteristic, a maximum allowable cure temperature of 150°F is required for protection of encapsulated components. (See Paragraph B. 1 3. 3. 4 of this report.) This requirement eliminated some possible candidates.

One consideration in selecting materials was that they be readily available at reasonable cost. Carboxy nitroso rubber was developed by Thiokol Chemicals Corporation (Ref. 2, & Ref. 3), and is offered in both liquid and solid forms. The liquid CNR cured with dicyclopentadiene dioxide curing agent is suggested as a potting compound. Cost of the liquid is $1,025. per pound.

Work was done for the Air Force by Hooker Chemical Company on a non-flammable perfluoroalkylene triazine. (Ref. 4). The cured material is said not to burn even in 30 psi oxygen. Cure is effected with a tetraphenyl tin catalyst, but cure temperatures substantially above 150°F are required.

Celanese Chemical Company has done some work on a polybenzimidazol polymer that does not burn in 6 psi oxygen. Their work was concerned with the production of a fiber. After spinning the fiber it must be cured in the 500°F - 600°F range. A telephone discussion with a member of the Celanese technical staff working on the project failed to reveal any way of making a potting compound from this material that could be cured at 150°F.

Skybond 700 produced by Monsanto Company (Ref. 6) is a polyimide. It is useful for coating, but also requires a high temperature cure.

Owens - Illinois Glass Company offers a product called Glass Resin which is alleged to be non-flammable in oxygen. A coating of Glass Resin with an asbestos filler on a 1015 substrate was ignited with a Teflon coated wire in 16.5 psia oxygen, and burned with a bright flame.

Horizons, Inc. developed a material derived from phosphonitrilic chloride that does not burn in oxygen. (Ref. 5). Coatings based on this polymer might be useful, but none was available with which to experiment in the time available. Work on similar polymers was sponsored by the U.S. Air Force at W. R. Grace in 1963 and 1964 (Ref. 6).

A series of fluoroelastomers offered by E. I. Dupont de Nemours under the name Viton and by the 3 M Company under the name Fluorel offered some advantages. A variety of polymers essentially identical chemically, but of different molecular weights, are available commercially in the $10 - $15 per pound range. They can be cured at 150°F with aliphatic polyamines such as diethylene triamine (DETA).

The Shell Chemical Company offers a material, tradenamed Eposand, which is based on an epoxy resin. The exact composition is proprietary, but the basic idea appeared to offer possibilities for making a non-flammable potting compound. Two solvent solutions are supplied and prior to use are mixed in a 1 : 1 ratio. A filler may be mixed in at this point in an amount sufficient to give a material with a putty-like consistency. One solution contains an epoxy resin, and the other an amine hardener. The solvent mixture used is such that as the hardener and epoxy resin react, the product becomes insoluble in the solvent mix and plates out on the filler. As further cure takes place, the filler particles are bonded together in spite of the fact that solvent is present. The solid composite so formed can be heated or vacuum treated to remove solvent. A system such as this, contains a very high proportion of inorganic filler, and can be cured at room temperature. It appeared that this approach could be applied to a brominated epoxy and result in a non-flammable composite.

With the materials available from which to make a potting and encapsulating compound that would not burn in oxygen, it appeared that a solvent or volatile carrier would have to be used. Although potting compounds ideally contain no volatile materials, there seemed to be no other way. The inclusion of a volatile material in the potting compound meant that after removal of this constituent, the potting compound would be porous. In order to protect the encapsulated part from the intrusion of moisture, a sealer coat was required for the potting compound and this, too, had to be non-flammable in oxygen.

Two other requirements of the contract - namely, a maximum specific gravity of 1.1, and the ability to dig out the potting compound for repair work - strongly indicated the desirability of using Eccospheres - glass microballoons - as a filler.

2. Formulation of Potting Compounds

a. Eposand

Eposand solutions were obtained from Shell as a two part system. Equal parts of each were mixed, and 325 mesh silica added in the following proportions:

20 grams Part A Eposand
20 grams Part B Eposand
120 grams 325 mesh silica

This mix was allowed to stand overnight to set to a rigid composite. The solvent was then removed by heating in air at 150°F, and finally in vacuum at 150°F.

A preliminary check of flammability was carried out in air with a gas-oxygen flame. The sample burned and did not extinguish on removal of the flame.

The Shell Chemical Company was approached and agreed to prepare an Eposand system based on a brominated epoxy. In the interim, before this material arrived, efforts were made without success at Emerson & Cuming, Inc. to prepare a system of this type using an epoxy resin based on tetrabrom bisphenol A. The brominated epoxy from the Shell Chemical Company contained 15% bromine. The Eposand casting prepared as shown above also burned in air when exposed to a gas-oxygen flame. A sample was cast in an aluminum dish with a piece of etched 20 gage Teflon coated copper wire embedded in it. After curing and evaporating all solvent, this was tested in a 16.5 psi oxygen atmosphere. It burst into flame when the Teflon coated wire was electrically overloaded. Further work with this formulation was therefore discontinued.

b. Fluoroelastomers

Of the commercially available polymers that have essentially no hydrogen, the fluoroelastomers - Fluorel from 3 M Company and Viton from E. I. Dupont de Nemours & Co., Inc., offer certain advantages. Unlike Teflon they are easily soluble in ketones and esters and can be cross-linked at a relatively low temperature with polyamines.

It was necessary to make the potting compound somewhat thixotropic to prevent separation of the fillers from the liquid during potting. The use of vibration to pack the material in place was found to be very helpful. Since, after curing the material would be porous, it was decided to use asbestos fibers not only to produce a thixotropic mix, and keep the fillers evenly dispersed but also to add strength to the cured piece and aid in solvent removal.

One of the major problems encountered in the development of the formulation was the formation of voids or bubbles within the casting during cure. Several factors were found to contribute to this problem.

A comparison was made between Fluorel No. 2141 and Viton A as the binder in the formulation. The bubble formation was about the same with each resin, but shrinkage was less with Fluorel than with the same formulation of Viton A. On this basis Fluorel was selected for further experimentation.

For the removal of solvent from a casting, it was felt that acetone would be the best choice, since it is a ketone with the lowest boiling point. However, it proved to be so volatile, that a skin formed rapidly on the surface of a casting preventing air bubbles from escaping at the surface. A mixture of methyl ethyl ketone (MEK) and methyl isobutyl ketone (MIBK) was selected. The MIBK was found to retard evaporation so that air bubbles could rise more readily to the top of the casting and escape.

TABLE 1
EXPERIMENTAL POTTING COMPOUND FORMULATIONS

	Parts by Weight Formulation No.			
	207	1015	0021	1512
20% Fluorel 2141 in MEK	48	48	48	48
20% Fluorel 2141 in MIBK	12	12	12	12
25% DETA in MEK	2.5	2.5	2.5	2.5
Asbestos (Powminco Grade 25 PM)	20	10	0	15
Eccospheres R	7	15	21	12
Oncor 23 A	5	5	5	5
MgO	2	2	2	2

In pouring these formulations into a cavity, it is advantageous to vibrate the potting compound into it. Tapping the container on a bench top, or the use of a Syntron Vibrator attached to a wooden platform are effective. Obviously the latter is preferred. The vibration assists in keeping the potting compound fluid enough so that air bubbles that are trapped in the material during pouring can rise to the surface.

The ease of elimination of bubbles depends on the amount of asbestos fiber present. Formula 207 had large bubbles that were not eliminated under vibration, due to the relatively high percentage of asbestos fiber. Formula 0021 with no asbestos fiber had virtually no bubbles, but was so weak as to be useless. Formula 1015 was selected as the best compromise.

Viton C-10, another of the group of fluoroelastomers from E. I. Dupont de Nemours, Inc., was evaluated in place of the Fluorel 2141 in the 1015 Formulation, and found to be superior with respect to the ease with which bubbles were eliminated. Its shrinkage was a little greater than Fluorel in the 1015 Formulation, but not as great as Viton A. The final formulation was therefore made with Viton C-10 in place of Fluorel 2141 as shown in the following table.

TABLE 2
FINAL FORMULATION, 1015A OF POTTING COMPOUND BASED ON A FLUOROELASTOMER

20% Viton C-10 in MEK	48
20% Viton C-10 in MIBK	12
25% DETA in MEK	2.5
Asbestos fibers (Powminco Grade 25 PM)	10
Eccospheres R	15
Oncor 23A	5
Mg O	2

Procedure for Preparation of Formulation 1015 -- Materials Used

A 20% solution of Viton C-10 in methyl ethyl ketone or methyl isobutyl ketone can be made up by allowing 20 parts of Viton C-10 to stand in a bottle with 80 parts of MEK, while occasionally shaking the bottle. The use of a Waring blender will accomplish the same result faster.

Powminco Asbestos Grade 25PM from Powhatan Mining Co.
Maglite Y Magnesium Oxide from Merck & Company
Oncor 23 a Antimony Oxide from National Lead Company
Eccospheres R - glass microballoons

To make 100 parts by weight of potting compound 1015, the following procedure is recommended.

Mix 52 parts of the 20% MEK solution of Viton C-10 with 12 parts of the 20% MIBK solution of Viton C-10. Using a power stirrer, add 11 parts of the asbestos fiber, 5.5 parts of Oncor 23 A and 2.2 parts of Maglite Y. Stir until the solids are thoroughly wet out. When the asbestos and magnesium oxide are added to the liquid part of the system, the surface of the solid does not become wet instantaneously with the liquid. Stirring of the mix for a short period of time (one minute for 200 g of mix) insures that the solids become thoroughly wet. Then add 16.5 parts of Eccospheres R, and stir at a slow speed until a smooth mix is obtained.

The Eccospheres can be increased or decreased plus or minus 20% to adjust the viscosity of the mix to any desired level. High shear mixing at this stage should be avoided. Otherwise, some Eccospheres may be broken.

Prior to use, mix in 2.7 parts of a 25% solution of DETA in MEK to 100 parts of the 1015 formulation.

c. Ceramic Potting Compound

Emerson & Cuming, Inc. has offered totally inorganic compositions for potting for several years now. Eccoceram QC is based on a technology disclosed in U. S. Patent 2,914,413 assigned to Pennsalt Chemicals Corporation.

Using this technology, a composition was made up of Eccospheres R, 325 mesh silica and sodium silicate powder SS-65 from Pennsalt Chemical Co. After mixing together crudely, the powder was passed through a 20 mesh screen. Any lumps of powder were broken up with a brush till they passed through the screen. Asbestos fibers were then added, and the mixture blended thoroughly. The powder was mixed with Ludox, a 30% solids silica aquasol produced by E. I. Dupont de Nemours, Inc., and then cast into a mold. The mold is preferably enclosed, for example, in a polyethylene bag to prevent water evaporation from the surface. Within 24 hours the entire mass sets to a rigid solid. The mold was removed from the polyethylene bag and the water allowed to evaporate.

The use of Eccospheres was dictated by the requirement that the encapsulation should be repairable. In a comparison of Eccospheres R and Eccospheres SI, the former were found to give a stronger piece.

Originally no asbestos fiber was used, but the need for improved strength dictated its use. Again a compromise on the amount of asbestos was necessary. Large amounts of asbestos gave good strength, but prevented bubble release.

TABLE 3
QC - 15 FORMULATION

	Parts by weight
Asbestos Fiber	10
Eccospheres R	20
Silica (-325 mesh)	30
Sodium Silicate SS-65 Powder	4
Ludox AS	60 - 100

The amount of Ludox AS depends on how pourable the mix must be.

Procedure for the Preparation of Formulation QC - 15 -- Materials Used

Powminco Asbestos Fiber Grade 25 PM from Powhatan Mining Co.
Eccospheres R from Emerson & Cuming, Inc.
Silica(-325 mesh) from Whittaker, Clark and Daniels, Inc.
Sodium Silicate Powder SS-65 from Pennsalt Chemical Co.
Ludox AS(silica aquasol) from E. I. Dupont de Nemours

Twenty parts of Eccospheres R, 30 parts of silica(-325 mesh) and 4 parts of ground sodium silicate SS-65 are mixed together. The mixture is then passed through a 20 mesh screen to make sure that no lumps of sodium silicate or Eccospheres are present. Add to the screened mix, 10 parts by weight of asbestos fiber. This is then thoroughly blended to a homogeneous mix.

When ready for use, add Ludox to the desired consistency. If the mix is too pasty, some difficulty will be experienced in elimination of air bubbles.

3. a. Sealer Coat FTA-3

Since both the 1015 and QC-15 potting compound formulations resulted in porous castings after curing, due to the use of a volatile liquid, a sealer coat was required. The coating was to be on the surface of the casting, and was to exclude moisture from the casting. Because Fluorel 2141 forms a higher viscosity solution in ketones than does Viton A or C-10 at the same solids level, it was selected. In addition, work performed earlier had demonstrated that the fluoroelastomers could be formulated not to burn with a flame in oxygen.

A 20% Fluorel solution in methyl ethyl ketone was made up, and to this was added magnesium oxide and tabular alumina, in the amounts shown below:

TABLE 4
FORMULATION OF SEALER COAT FTA-3

Ingredient	Parts by weight
20% solution of Fluorel 2141 in MEK	200
MgO Maglite Y from Merck and Co.	7
Tabular alumina(-325 mesh)from Alcoa Co.	140

These materials are ball milled together for 1 - 2 hours. The mix is then ready for packaging. Prior to use, 2. 5 parts of a 25% solution of diethylene triamine in MEK are added to 100 parts of the coating material.

After cure, the coating consists of 22% cross-linked fluoroelastomer and 78% inorganic solids.

In the development of the coatings, samples were made in which the amount of tabular alumina was varied. Cakes of the 1015 formulation with the Teflon coated wire embedded in them were coated and tested in the oxygen atmosphere. In this series, the inorganic solids were 88%, 84%, 78% and 74% of the total. The first three of these did not ignite in the oxygen atmosphere, while the one with 74% inorganic solids did burn. Since the 78% sample had the lowest viscosity of those that did not ignite, it was selected.

Prior to application of the sealer coat over the 1015 or QC-15 formulations, or over itself, a primer coat of Chemlok 607 (produced by Hughson Chemical Co.) was applied.

Studies were carried out using the insulation resistance tests to determine the number of coatings that should be applied. A predetermined number of coatings was applied to the potting compound in an insulation resistance box. After cure the insulation resistance was measured. The sample was then placed in a 95% RH chamber for 48 hours, after which the insulation resistance was measured. It was determined that to get a satisfactory result at least three coatings had to be applied. Three coats were later applied to the test samples for many of the electrical measurements, as noted in the text.

Because the potting compounds are porous, the sealer coat is necessary. The sealer coat itself, however, contains a solvent, which can penetrate into the potting compound. In the course of removing these solvents, paths may be created through which moisture can penetrate This may partially explain some of the unsatisfactory results that were obtained later when the moisture resistance tests were run with temperature and humidity cycling.

b. Conformal Coating - MRTA-5

It was felt that the conformal coating should not be a solvent solution, because of the possibility of porosity. A low viscosity 100% reactive system that had fire retardant properties was found in a product from the Marco Division of W. R. Grace Company, namely a brominated polyester MR-670. The company would not disclose the percent bromine. This system will cure at room temperature when catalyzed with MEK peroxide and a cobalt naphthenate accelerator.

Profitting by the experience on the sealer coat, tabular alumina was used as the filler. The viscosity of the polyester is 770 centipoise at room temperature, so that a very high loading of filler can be added while still maintaining flowability. A series of experiments were run, which demonstrated that at a filler loading of about 77% or above, the coating would not burn in an oxygen atmosphere. Tests were made on discs measuring 6 cm in diameter by one cm thick with a Teflon coated 20 gage wire embedded in it as an ignition source. Ignition of the wire was made with the Teflon coated wires under the sample.

The conformal Coating is made up as follows:

100 parts of MR-670
340 parts of -325 mesh tabular alumina (Alcoa)
0.1 parts of cobalt naphthenate 6%

To 100 parts MR-670, add 340 parts of -325 mesh tabular alumina and 0.1 part of cobalt naphthenate, and mix on a Hobart or similar mixer for 10 minutes. Prior to use, 1 gram of MEK peroxide is mixed in to give a uniform blend. This will have a usable pot life of about one hour.

B. TESTING

On the following pages are presented the results of the tests and observations run on the potting compounds and the conformal coating. To preclude the necessity of referring back and forth to the work statement in Appendix 1. We have listed the test name, test number and the specified performance requirement. If the reader wishes more detail on the test, he will find it in Appendix 1.

NOTE: The paragraph numbers correspond to those used in the work statement.

1. Potting Compounds - Physical Characteristics

3.3.1 Appearance

The as-poured and cured compounds shall be homogeneous and free from lumps and coarse particles and voids.

The materials as received from the vendor may have some tendency for the filler to settle. Before use, the container contents should be stirred to disperse the filler homogeneously throughout the mix. There are no coarse gritty particles. In some formulations there are asbestos fibers, which could be regarded as coarse. These, however, are intended to be in the formulation.

3.3.2 Application

Potting and encapsulating compounds shall be capable of being readily applied by an injection or extrusion gun.

Formulations 1015 and QC-15 are both capable of application through a hypodermic syringe, or caulking gun.

The sealer coat can be applied by brush or dip. It cannot be applied by spray.

3.3.3 Application Life

The compound shall be suitable for application for a minimum of 60 minutes.

Formulation 1015 has an application life of several hours, if kept covered. Formulation QC-15 has an application life of at least one hour.

The sealer coat has an application life of several hours, if kept covered.

3.3.4 Curing Time

The cure time to obtain optimum properties shall not exceed 7 days at room temperature and 50% humidity. Elevated temperatures up to 150°F may be used to accelerate the cure time.

The curing time for both encapsulants and the sealer coat are well within the seven days. Temperatures up to 150°F are beneficial not only for speeding this up, but also for removing solvent.

3.3.5 Storage Life

The uncured compounds shall be capable of meeting the requirements of this statement of work for 6 months when stored below 70°F.

All materials prepared and submitted under this contract have storage lives of at least six months when stored at 70°F or below in unopened containers. The precaution mentioned earlier of mixing the contents of the container to a uniform consistency before catalyzing must be observed.

3.3.6 Repair and Rework

The cured compounds must be capable of being removed either mechanically or chemically, without damaging wiring, solder joints, or electronic components.

The potting compounds, 1015 and QC-15, were formulated to be mechanically removed. Even with several sealer coats they can be cut off, or dug out from a casting.

In applying a patch to the 1015, a primer coat of Chemlok 607 is necessary. The QC-15 should be painted with Ludox AS immediately prior to applying a patch.

2. Potting Compounds - Performance Characteristics

3.3.7 Temperature Rating

The compounds shall retain useful physical and electrical properties from 0°F to +250°F, as verified by the insulation resistance.

Insulation resistance shall be measured at 0°F and 250°F.

NOTE: Paragraph 4.4.3.5 of Appendix C calls for insulation resistance at room temperature and 100°C.

Insulation resistance tests were run at room temperature, then 0°F, then 250°F and finally on these same samples at room temperature again. The 1015 and QC-15 formulations were given three sealer coats before running these tests.

The three samples of 1015 gave the following insulation resistance readings:

TABLE 5

Insulation Resistance on Three Samples of 1015 Potting Compound

Sample No.	Test Temp.	Spec. Minimum-ohms	Insulation Resistance, ohms No. 1	No. 2	No. 3
1	72°F	$1x10^{11}$	$3.0x10^{11}$	$4.6x10^{11}$	$6.0x10^{11}$
2	72°F	$1x10^{11}$	$2.0x10^{12}$	$2.0x10^{12}$	$2.5x10^{12}$
3	72°F	$1x10^{11}$	$0.9x10^{12}$	$1.0x10^{12}$	$0.6x10^{12}$
Average			$1.06x10^{12}$	$1.15x10^{12}$	$1.23x10^{12}$
1	0°F	none given	$1.5x10^{9}$	$1.3x10^{9}$	$2.0x10^{9}$
2	0°F	none given	$1.5x10^{10}$	$4.0x10^{9}$	$0.7x10^{10}$
3	0°F	none given	$2.0x10^{10}$	$2.0x10^{10}$	$1.0x10^{10}$
Average			$1.22x10^{10}$	$0.82x10^{10}$	$0.63x10^{10}$
1	250°F	$7.5x10^{8}$*	$2.5x10^{6}$	$4.0x10^{6}$	$4.0x10^{6}$
2	250°F	$7.5x10^{8}$	$7.0x10^{8}$	$6.0x10^{8}$	$8.0x10^{8}$
3	250°F	$7.5x10^{8}$	$7.0x10^{7}$	$8.0x10^{7}$	$5.0x10^{7}$
Average			$2.58x10^{8}$	$2.28x10^{8}$	$2.85x10^{8}$
1	72°F	$1x10^{11}$	$4.0x10^{11}$	$5.0x10^{11}$	$4.0x10^{11}$
2	72°F	$1x10^{11}$	$1.4x10^{12}$	$0.7x10^{12}$	$1.3x10^{12}$
3	72°F	$1x10^{11}$	$1.1x10^{12}$	$1.0x10^{12}$	$0.7x10^{12}$
Average			$0.97x10^{12}$	$0.73x10^{12}$	$0.80x10^{12}$

* Specification minimum is $7.5x10^{8}$ ohms at 200°F.

The second 72°F measurements are essentially the same as those obtained before exposure to 0°F and 250°F.

The three samples of QC-15 gave the following insulation resistance values with measurements at each temperature in the order shown.

TABLE 6

Insulation Resistance of Three Samples of QC-15 Potting Compound

Sample No.	Test Temp.	Spec. Minimum-ohms	Insulation Resistance No. 1	No. 2	No. 3
1	72°F	$1x10^{11}$	$2.0x10^{10}$	$1.3x10^{10}$	$5.0x10^{10}$
2	72°F		$4.0x10^{10}$	$1.2x10^{10}$	$4.0x10^{10}$
3	72°F		$2.2x10^{10}$	$2.3x10^{11}$	$4.0x10^{10}$
Average			$2.7x10^{10}$	$1.2x10^{11}$	$4.7x10^{10}$
1	250°F	none given	$5.0x10^{7}$	$1.3x10^{8}$	$2.0x10^{7}$
2	250°F	none given	$10.0x10^{7}$	$0.9x10^{8}$	$2.0x10^{8}$
3	250°F	none given	$3.0x10^{7}$	$3.5x10^{8}$	$6.0x10^{7}$
Average			$6.0x10^{7}$	$1.9x10^{8}$	$0.9x10^{8}$
1	0°F	$7.5x10^{8}$	$4.0x10^{12}$	$1.5x10^{12}$	$0.5x10^{12}$
2	0°F	$7.5x10^{8}$	$4.0x10^{12}$	$0.7x10^{12}$	$0.6x10^{12}$
3	0°F	$7.5x10^{8}$	$1.2x10^{12}$	$0.9x10^{12}$	$0.4x10^{12}$
Average			$3.1x10^{12}$	$1.0x10^{12}$	$0.5x10^{12}$
1	72°F	$1x10^{11}$	$4.0x10^{11}$	$0.8x10^{11}$	$0.95x10^{11}$
2	72°F	$1x10^{11}$	$1.5x10^{11}$	$5.0x10^{11}$	$0.7x10^{11}$
3	72°F	$1x10^{11}$	$0.7x10^{11}$	$10.0x10^{11}$	$2.0x10^{11}$
Average			$2.1x10^{11}$	$5.3x10^{11}$	$1.2x10^{11}$

3.3.8 Hardness Rating

No stated limits.

The hardness of the 1015 formulation with three sealer coats is 30 to 35 Shore D. The hardness of the QC-15 formulation with three sealer coats is 65 Shore D.

3.4.1 Flammability

Candidate potting materials and encapsulating compounds shall be self-extinguishing immediately after wire fusion, with no further evidence of degradation by combustion in a 6.2 psia oxygen or 16.5 psia oxygen when subjected to Test No. 5, SN-P-0003 of Appendix A in work statement. See Appendix 1.

Three Bendix pygmy plugs were potted with the 1015 formulation, and each given three sealer coats. These were tested for flammability in 16.5 psia oxygen according to Test No. 5, SN-P-0003, Appendix A. The wire ignited in each case and burned down to the coating on the plug, and then went out. No further burning or glowing occurred.

The same formulation with no coating will burn with a glow, although there is no flame.

Similarly, three Bendix plugs were potted with the QC-15 formulation, and then given three sealer coats. When tested for flammability in 16.5 psia, the Teflon coated wire ignited, and burned down to the coating, and then went out. No further burning or glowing occurred.

3.4.2 Outgassing

> As a screening test, the total organics expressed as pentane equivalents evolved from any of the candidate potting, coating or encapsulating materials shall not exceed 100 micrograms per gram of sample, when tested at 5.0 psia oxygen and 200°F in accordance with Test No. 7, Appendix A. Outgassed carbon monoxide shall not exceed 25 micrograms per gram when tested in accordance with the same test. Quantification of outgassed products and accurate weight loss data in 5 psia oxygen are required prior to final MSC acceptance of candidate materials. MSC acceptance shall be predicated upon the requirements that none of the outgassed products shall constitute a toxic hazard to the crew (from Exhibit A, Page 4 of Work Statement).
>
> The specification limits for total organics expressed as pentane equivalents is 100 micrograms per gram of test sample.
>
> Carbon monoxide shall not exceed 25 micrograms per gram of sample.

The outgassing was run at White Sands on Formulation 1015 with three sealer coats, and Formulation QC-15 with 3 sealer coats. The following results were obtained.

The total organics and carbon monoxide for Formulation 1015 was 10 micrograms per gram, which is well within the specification limits. An infrared scan of the gases showed ethylene and TF Freon. The only sources of organic material in the 1015 formulation is the Viton C-10, methyl ethyl ketone and methyl isobutyl ketone used as solvents. One might speculate on the origin of the ethylene, but it is certainly not formed by any very straightforward mechanism. The presence of TF Freon is even more difficult to explain, since TF Freon contains chlorine. The carbon monoxide was 5.4 micrograms per gram also well within the specification limits.

The QC-15 sample coated with the same sealer coating as used on the 1015 samples show 81 micrograms per gram of total organics, and 1.6 micrograms per gram of carbon monoxide. An infrared scan detected methanol, ethylene and methyl ethyl ketone. The ketone is one of the solvents used in the sealer coat, but there is no straightforward explanation for the presence of either methanol or ethylene.

3.4.3 Odor

> The average odor rating of all candidate materials must not exceed 2.0, when tested at 5.0 psia oxygen and 200°F in accordance with Test No. 6, Appendix A (from Exhibit A, Page 5 of Work Statement).

The same samples used in the preceding test for outgassing were tested at White Sands with the following results.

With no dilution the 1015 sample was rated 1.7, which is within the specification.

The QC-15 sample was not tested for odor because the total organics over the sample was 2,152 ppm. Since the QC-15 without the sealer coat is completely inorganic, it is concluded that all of the organics come from the sealer coat. Why this high concentration of organic vapors was found with the QC-15, but not with the 1015 sample is not explained. Both samples have the same sealer coat.

3.4.4 Vacuum Volatility

> The rate of weight loss in 1×10^{-4} torr at 250°F shall stabilize within 6 hours, and the continuing rate of weight loss shall not exceed 0.02 percent per hour when measured continuously in vacuum with an in-situ microbalance. The rate of weight loss shall continue to decrease with time.
>
> There shall be no visible condensate deposited on a glass slide maintained at least 100°F below the test temperature and located in close proximity to the test specimen within the vacuum chamber. The total weight loss for the initial 24 hour period shall not exceed 1.0 percent.
>
> An additional vacuum volatility test specimen shall be prepared per MSFC-SPEC-202A, Paragraph 4.4.3.11 (see Appendix C) for potting compounds. Upon completion of 24 hour vacuum testing, there shall be no apparent visual degradation, and the compounds shall withstand the required 200 megohm moisture resistance tests of Paragraph 3.4.7, Appendix C, for potting compounds (from Exhibit A, Page 5 of the Work Statement.)

Tests were run at NASA Manned Spacecraft Center In Houston, except that the insulation resistance samples were returned to Emerson & Cuming, Inc. for the moisture resistance test. These samples were subjected to the moisture resistance test of Paragraph 3.4.7 at Associated Testing Laboratories, Inc. Insulation resistance was measured at Emerson & Cuming, Inc. and at Associated Testing Laboratories, Inc. before exposure to the moisture resistance test. After exposure, insulation resistance was measured at Associated Testing Laboratories, Inc. Each sample had three sealer coats on the top surface.

Insulation resistance tests run at 75°F at Emerson & Cuming, Inc. after exposure to vacuum of 10^{-4} at 250°F, and before exposure to the moisture resistance test, and at Associated Testing Laboratories, Inc. before and after exposure to high humidity are shown in Table 7. The same samples were also run at 212°F at Associated Testing Laboratories, Inc. prior to exposure to moisture resistance tests. The results of these tests are shown in Table 7.

The weight loss of the 1015 potting compound formulation at 1×10^{-4} torr and 250°F was 0.59% in six hours. The weight loss during the seventh hour was .015% and less per hour thereafter. This is within the specification limit of .02%.

The weight loss of the QC-15 potting compound under the same test conditions was 0.426% in the first six hours. The weight loss during the seventh hour was .027%. Not until the ninth hour did the rate of weight loss go below 0.02%.

No condensation from the above materials was apparent on the glass slide installed in the system.

Copies of the weight loss tables and graphs from the NASA White Sands Test Facility are shown in Appendix 2.

TABLE 7

Insulation Resistance of Sample exposed to 10^{-4} torr.

Material	Before*	After*	Test Temp.	Test Station
QC-15	6.5×10^8		24°C	Emerson & Cuming
	1.8×10^8		24°C	" "
	1.4×10^9		24°C	" "
Average	7.4×10^8			
	1.5×10^9	$< 1.0 \times 10^6$	24°C	Associated Testing Lab.
	3.1×10^6	$< 1.0 \times 10^6$	24°C	" " "
	1.1×10^7	$< 1.0 \times 10^6$	24°C	" " "
Average	5.0×10^8	$< 1.0 \times 10^6$		
	3.8×10^5	$< 1.0 \times 10^6$	100°C	Associated Testing Lab
	3.7×10^5	$< 1.0 \times 10^6$	100°C	" " "
	4.6×10^5	$< 1.0 \times 10^6$	100°C	" " "
Average	4.0×10^5	$< 1.0 \times 10^6$		
1015	5.0×10^{11}		24°C	Emerson & Cuming
	3.0×10^{11}		24°C	" "
	3.0×10^{11}		24°C	" "
Average	3.7×10^{11}			
	5.5×10^{10}	7.8×10^6	24°C	Associated Testing Lab
	3.9×10^{10}	5.2×10^6	24°C	" " "
	3.0×10^{10}	3.6×10^6	24°C	" " "
Average	4.1×10^{10}	5.5×10^6		
	1.9×10^8	1.6×10^6	100°C	" " "
	1.3×10^8	1.3×10^6	100°C	" " "
	1.6×10^8	3.7×10^6	100°C	" " "
Average	1.6×10^8	2.2×10^6		

* Insulation resistance in ohms before and after exposure to high humidity.

Both materials failed the vacuum volatility test, because both materials failed to pass the moisture resistance portion of the test.

3.4.7 Moisture Resistance

The insulation resistance of specimens prepared as specified in 4.3.3.5 shall be 200 megohms or 2×10^8 ohms minimum when tested as specified in 4.4.3.11 (from Appendix C, Page 5 of Work Statement).

These tests were carried out by Associated Testing Laboratories, Inc. Three samples of Formulation 1015 each with three sealer coats, and three samples of QC-15 formulation each with three sealer coats were tested. Test results are shown in Table VI.

TABLE 8

Insulation resistance in ohms of 1015 and QC-15 after 5 temperature and humidity cycles.

Material	Sample No.	Position A	Position B	Position C
1015	1	6.6×10^{7}	1.6×10^{8}	1.7×10^{7}
	2	7.0×10^{8}	8.0×10^{8}	8.5×10^{8}
	3	2.9×10^{8}	2.4×10^{8}	1.2×10^{8}
	Average	3.5×10^{8}	4.0×10^{8}	3.3×10^{8}
QC-15	4	2.5×10^{5}	1.8×10^{5}	1.7×10^{5}
	5	No reading	5.0×10^{5}	1.7×10^{5}
	6	1.8×10^{5}	7.4×10^{5}	3.0×10^{5}
	Average	2.1×10^{5}	4.7×10^{5}	2.1×10^{5}

The 1015 samples are on the average just acceptable. The QC-15 samples fail to pass the minimum specification in all cases.

4.4.3.1 Dielectric Constant and Power Factor

Specification Limits: K' 5.0 pf 0.09. The dielectric constant and power factor of Formulation 1015 were determined at 1 MHz.

TABLE 9

Dielectric Constant and Power Factor of Potting Compounds

Material	Sample No.	K'	pf
1015	A	1.50	0.022
	B	1.40	0.020
	C	1.38	0.017
QC-15	A	1.99	0.051
	B	1.92	0.048
	C	2.01	0.050

The values for both dielectric constant and power factor are well within the specification limits. If it appears desirable in order to enhance some other property, the density of each of these materials can be significantly increased without exceeding the specification limits for dielectric constant and power factor.

4.4.3.2 Dielectric Strength

Specification Limit: 500 volts/mil of thickness minimum.

Five discs each of Formulations 1015 and QC-15 were prepared for the determination of dielectric strength at environmental Testing Corporation.

All samples were 50 mils thick. The following values were obtained for breakdown voltage in volts/mil.

TABLE 11

Dielectric Strength of Potting Compounds.

1015		QC-15	
Sample No. 1	160 v/mil	Sample No. 1	20
Sample No. 2	120	Sample No. 2	20
Sample No. 3	100	Sample No. 3	20
Sample No. 4	100	Sample No. 4	20
Sample No. 5	100	Sample No. 5	20

No samples reached the required level of dielectric strength.

4.4.3.3 Volume and Surface Resistivity

Specification Limits: $\rho_v = 1 \times 10^{12}$ ohms-cm

$\rho_s = 1 \times 10^{12}$ ohms-cm

The volume and surface resistivities of Formulation 1015 and QC-15 were determined. The 1015 and QC-15 had three sealer coats, since in use they will have the sealer coat.

TABLE 12

Volume and Surface Resistivities of Potting Compounds.

Formulation 1015

	ρ_v	ρ_s
Sample No. 1	1.79×10^{12} ohm-cm	3.81×10^{12} ohm-cm
Sample No. 2	4.78×10^{12} ohm-cm	3.85×10^{11} ohm-cm
Sample No. 3	1.64×10^{12} ohm-cm	3.89×10^{11} ohm-cm

Formulation QC-15

	ρ_v	ρ_s
Sample No. 1	8.67×10^{10} ohm-cm	8.92×10^{10} ohm-cm
Sample No. 2	9.51×10^{10} ohm-cm	8.11×10^{10} ohm-cm
Sample No. 3	8.78×10^{10} ohm-cm	1.45×10^{10} ohm-cm

Formulation 1015 meets the requirements set for volume and surface resistivities. Formulation QC-15 fails in both properties.

4.4.3.4 Arc Resistance

Specification Limit: 45 seconds minimum.

Arc resistance of 1015 and QC-15 each with three sealer coats was measured at Electrical Testing Laboratories in New York City.

The following results were obtained with Formulations 1015 and QC-15.

TABLE 13

Are Resistance of Potting Compounds.

1015		QC-15	
Sample No. 1	124 seconds	Sample No. 1	133 seconds
Sample No. 2	122 seconds	Sample No. 2	129 seconds
Sample No. 3	123 seconds	Sample No. 3	129 seconds

Both materials meet requirements of the specification.

4.4.3.6 High Potential

The specification limit is no breakdown.

Three samples of Formulation 1015 each with three sealer coats, and three samples of QC-15 each with 3 sealer coats were subjected to the high potential test by Associated Testing Laboratories, Inc.

There were no breakdowns.

4.4.3.7 Low Temperature Flexibility

It was agreed that this test would not be run.

4.4.3.8 Temperature Resistance

The volume resistivity shall be determined in accordance with Paragraph 4.4.3.3, except the testing shall be conducted at $100 \pm 1°C$ after a conditioning period of 30 minutes at the test temperature to determine conformance to 3.5 (from Appendix C, Page 9 of Work Statement).

Specification Limits: 1×10^9 ohm-cm minimum.

Three samples of Formulation 1015 each with three sealer coats and three samples of QC-15 each with three sealer coats, were tested for temperature resistance at 100°C.

TABLE 14

Temperature Resistance of Potting Compounds as Indicated by Volume Resistivity at 100°C.

Formulation 1015

	Volume Resistivity - ρ_v
Sample No. 1	1.16×10^{10} ohm-cm
Sample No. 2	0.96×10^{10} ohm-cm
Sample No. 3	1.13×10^{10} ohm-cm

Formulation QC-15

	Volume Resistivity - ρ_v
Sample No. 1	2.35×10^{10} ohm-cm
Sample No. 2	1.74×10^{10} ohm-cm
Sample No. 3	2.65×10^{10} ohm-cm

Both the 1015 and QC-15 samples exceeded the minimum requirements called for.

4.4.3.9 Fungus Resistance

Specification Limit: No evidence of support of fungus growth.

Samples of Formulation 1015 and Formulation QC-15, and the sealer coat on 1015 and QC-15 were tested for support of fungus at Associated Testing Laboratories, Inc. These tests showed no sign of either potting compound supporting fungus growth. The sealer coat, however, exhibited a small amount of fungus growth. There is no obvious explanation for this, since the 1015 potting compound and the sealer coat are both based on a fluoroelastomer cured with DETA.

4.4.3.10 Tear Strength

It was agreed that this test would not be performed.

4.4.3.11 Moisture Resistance

This was covered under Paragraph 3.4.7.

4.4.3.12 Tensile Strength or Elongation

Specification Limit: 2500 psi Min.

The tensile strength of the 1015 formulation was run on uncoated samples with the following results:

TABLE 15

Tensile Strength of Potting Compound 1015 Formulation

	Tensile, psi
Sample No. 1	90.0
Sample No. 2	70.9
Sample No. 3	85.4
Sample No. 4	74.8
Sample No. 5	86.9
Average	81.6

The QC-15 samples could not be measured, because they are so brittle that they broke in the tensile machine clamp.

The tensile strength is far below the specified minimum. With this type of system, some improvement in tensile strength might be expected through additional study. In our opinion, however, such an improved product would still be an order of magnitude below the prescribed minimum.

It should be pointed out, however, that there are materials, which are used for encapsulating electronic components, and which will withstand very high G forces, but which have tensile strengths in the 100 - 200 psi range.

4.4.3.13 Shrinkage

Specification Limit: 3% Max.

The shrinkage was determined on Formulation 1015 and on Formulation QC-15 without the sealer coat.

% Shrinkage of 1015 = 7.3%

% Shrinkage of QC-15 = 9.3%

4.4.3.14 Compression Set

It was agreed that this test would not be run.

4.4.3.15 Resistance to Ozone

It was agreed that this test would not be performed.

4.4.4.1 Non-Volatile Content

The non-volatile content of 1015 has been found to be 47.8%. The non-volatile content of QC-15 will vary somewhat with the mixture, but will be about 65%. Essentially all of the volatile material in QC-15 is the water contained in the Ludox that is used.

4.4.4.2 Viscosity

Specification Limits: 100 - 450 poises

Viscosities were measured with a Brookfield viscometer at 10 RPM with No. 7 spindle.

Viscosity at 24°C of Formulation 1015 after addition of catalyst is 45 poises. Viscosity of Formulation QC-15 at 24°C varies depending on the amount of Ludox that is added. The range is 15 - 20 poises.

4.4.4.3 Specific Gravity

The specific gravity of cured Formulation 1015 is 0.36. The specific gravity of QC-15 is 0.81.

4.4.4.6.1 Adhesion to Metal

Specification Limit: 15 lbs./inch minimum

Samples of Formulation 1015 were prepared using a primer coat of Chemlok 607 on the metal. The samples prepared with Formulation QC-15 required that the canvas be soaked in Ludox prior to application of the QC-15.

These samples were sent to Acton Environmental Testing Laboratory. The following is a quotation from their report "the 3 samples were prepared for adhesion testing . . . However, two samples crumbled too badly to grip properly, and the third separated from the metal base during preparation for testing".

Since this test was designed to be run on a flexible material and both 1015 and QC-15 are rigid; it is not surprising that all attempts at running this test were unsuccessful.

In order to obtain adhesion to metal data on 1015 and QC-15 it was decided to test the lap shear strength according to ASTM 1002. The lap shear strength of 1015 was found to be 110 psi on all samples run. Attempts to make lap shear samples using QC-15 were unsuccessful.

3.4.5.3 Bond Strength to Etched Wire

The bond strength to etched Teflon coated wire of Formulation 1015, Formulation QC-15 and the conformal coating was determined with the following results:

1015	7.06 lbs.
QC-15	8.56 lbs.
MRTA-15	8.50 lbs.

3.4.5.4 Patch Potting Adherence

The specification minimum is 2.0×10^8 ohms.

Samples of Formulation 1015 and QC-15 were dug out partially from the insulation resistance box. The 1015 was primed with Chemlok 607, and then repotted with freshly mixed 1015 over the cured material. The QC-15 sample was similarly dug out. The surface was painted with Ludox, and freshly mixed QC-15 vibrated into the cavity.

After curing these samples, three sealer coats were applied to each sample curing each before applying the next one. The moisture resistance test and insulation resistance were run at Associated Testing Laboratories, Inc.

Following are the insulation resistance measurements at 24°C and at 100°C.

TABLE 16

Insulation Resistance of Potting Compounds after Patch Potting.

At 24°C:

Formulation 1015

Sample No. 10	9.0×10^7;	5.2×10^7;	1.2×10^8 ohms
Sample No. 11	8.0×10^5;	3.8×10^5;	2.1×10^5 ohms
Sample No. 12	4.1×10^6;	7.6×10^6	1.4×10^6 ohms
Average	3.2×10^7	2.0×10^7	4.1×10^7

Formulation QC-15

Sample No. 13	1.1×10^5;	2.7×10^5;	10^5 ohms
Sample No. 14	1.6×10^5;	1.4×10^5;	10^5 ohms
Sample No. 15	1.0×10^5;	1.6×10^5;	1.5×10^5 ohms
Average	1.2×10^5	1.9×10^5	1.0×10^5

At 100°C:

Formulation 1015

Sample No. 10	1.4×10^7;	1.4×10^7;	2.1×10^7 ohms
Sample No. 11	1.8×10^6;	9.0×10^5;	1.3×10^6 ohms
Sample No. 12	1.9×10^7;	2.6×10^7;	3.0×10^7 ohms
Average	1.1×10^7	1.4×10^7	1.7×10^7 ohms

Formulation QC-15

Sample No. 13	1.5×10^5;	1.6×10^5;	1.3×10^5 ohms
Sample No. 14	2.1×10^5;	2.0×10^5;	1.9×10^5 ohms
Sample No. 15	1.5×10^5;	1.1×10^5;	2.3×10^5 ohms
Average	1.7×10^5	1.6×10^5	1.8×10^5 ohms

Neither Formulation 1015 nor QC-15 with three sealer coats meets the minimum specification, although the 1015 formulation is considerably better than the QC-15 material.

3. Conformal Coating - Physical Characteristics (as described in Exhibit A of the Work Statement)

3.3.1 Appearance.

The as-poured and cured compound shall be homogeneous and free from lumps and coarse particles and voids.

The conformal coating will have some tendency for the filler to settle. This must be stirred back in to give a uniform mix prior to use.

3.3.2 Application

Conformal coatings shall be capable of being applied by brush, spray, dipping, or thin casting temperature.

The conformal coating can be applied by brush or dip. It cannot be sprayed.

3.3.3 Application Life

The compound shall be suitable for application for a maximum of 60 minutes.

The conformal coating has an application life of about 60 minutes. This is controlled by the amount of accelerator used. The material as supplied has 0.1% cobalt naphthenate accelerator, which is the amount required to give a 60 minute pot life after addition of catalyst.

3.3.4 Curing Time

The curing time to obtain optimum properties shall not exceed 7 days at room temperature and 50 percent maximum humidity. Elevated temperatures up to 150°F may be used to accelerate the cure time.

The conformal coating can be cured in 6 - 8 hours at room temperature.

3.3.5 Storage Life

The uncured compounds shall be capable of meeting the requirements of this statement of work for 6 months when stored below 70°F.

The storage life of the conformal coating is 6 months at 70°F in unopened containers. Mixing immediately prior to use is necessary.

3.3.6 Repair and Rework

The cured compounds must be capable of being removed, either mechanically or chemically, without damaging wiring, solder joints, or electronic components. The adherence of patch potting to previously applied potting must be adequate to withstand the 200 megohm moisture resistance tests of Paragraph 3.4.5.4.

The conformal coating contains no Eccospheres to provide easier removability. It, therefore, must be chemically stripped. Eccostrip 93 or Eccostrip 94 as supplied by Emerson & Cuming, Inc. have been shown to attack the coating. It is not at all practical, however, to try to strip the resin out of an insulation resistance box. As a coating it can be repaired, but it cannot be repaired if there is any appreciable depth to dig through.

4. Conformal Coating - Performance Characteristics (see Exhibit A and Appendix D of Work Statement)

3.3.7 Temperature Rating

The compounds shall retain useful physical and electrical properties from 0°F to +250°F, as verified by the insulation resistance.

The insulation resistance was run at room temperature 0°F, 250°F, and finally at room temperature again. The specification limit is 1×10^{11} at room temperature and 7.5×10^{8} at 100°C.

TABLE 17

Insulation Resistance of Conformal Coating

MRTA-5 at Room Temperature and Elevated Temperature

Sample No.	Insulation Resistance (ohms) at 72°F	250°F	0°F	72°F
7	2×10^{13}	0.7×10^{10}	2×10^{13}	2×10^{13}
	2×10^{13}	0.58×10^{10}	2×10^{13}	2×10^{13}
	2×10^{13}	0.54×10^{10}	2×10^{13}	2×10^{13}
8	2×10^{13}	0.38×10^{10}	2×10^{13}	2×10^{13}
	2×10^{13}	0.3×10^{10}	2×10^{13}	2×10^{13}
	2×10^{13}	0.45×10^{10}	2×10^{13}	2×10^{13}
9	2×10^{13}	0.40×10^{10}	2×10^{13}	2×10^{13}
	2×10^{13}	0.34×10^{10}	2×10^{13}	2×10^{13}
	2×10^{13}	0.44×10^{10}	2×10^{13}	2×10^{13}

3.3.8 Hardness Rating

The hardness of fully cured compounds shall be measured and submitted for NASA-MSC approval.

The hardness of the conformal coating is 85 to 90 Shore D. The specification limits are 80 to 90 Shore A.

3.4.1 Flammability

Candidate conformal coatings shall be self-extinguishing immediately after wire fusion, with no further evidence of degradation by combustion in 6.2 psia oxygen or 16.5 psia oxygen when subjected to the electrical overload Test No. 1, Appendix B.

Three samples of the conformal coating on an eight lug terminal block were tested for flammability in 16.5 psia oxygen. The Teflon insulation on the lead wires ignited, burned down to the coating, and went out without igniting the coating in all cases.

3.4.2 Outgassing

The total organics expressed as pentane equivalents shall not exceed 100 micrograms per gram of sample. Outgassed CO shall not exceed 25 micrograms per gram of sample.

The outgassing tests were run on a casting of the MRTA-5 coating.

The outgassed carbon monoxide was 2.4 micrograms per gram. The total organics outgassed was 7.5 micrograms per gram. Both of these values are within acceptable limits.

3.4.3 Odor

The average odor rating of all candidate materials must not exceed 2.0, when tested at 5.0 psia oxygen and 200°F in accordance with Test No. 6, Appendix A.

The samples used in the outgassing tests were also tested at White Sands for odor with the following results:

The odor rating with no dilution was 1.7 which is within the specification limits.

3.4.4 Vacuum Volatility

The rate of weight loss in 1×10^{-4} torr at 250°F shall stabilize within 6 hours, and the continuing rate of weight loss shall not exceed 0.02 percent per hour when measured continuously in vacuum with in-situ microbalance. The rate of weight loss shall continue to decrease with time.

There shall be no visible condensate deposited on a glass slide maintained at least 100°F below the test temperature and located in close proximity to the test specimen within the cavuum chamber. The total weight loss for the initial 24 hour period shall not exceed 1.0 percent.

An additional vacuum volatility test specimen shall be prepared per MSFC-SPEC-393A, Paragraph 4.5.2.10 (see Appendix D) for conformal coatings. Upon completion of 24 hour vacuum testing, there shall be no apparent visual degradation, and the compounds shall withstand the required 200 megohm moisture resistance tests of Paragraph 3.4.6, Appendix D, for conformal coatings.

Tests were run at the Manned Spacecraft Center in Houston except that the insulation resistance samples were returned to Emerson & Cuming, Inc. for the moisture resistance test.

Insulation resistance measurements were conducted at Associated Testing Laboratories, Inc. before and after exposure to the condition of the moisture resistance test.

TABLE 18

Insulation resistance of the conformal coating MRTA-5 as it is affected by exposure of the material to high vacuum.

Before exposure, and tested at 24°C :

1.5×10^{11} 7.0×10^{10} 1.0×10^{11} Ave. = 1.07×10^{11} ohms

Before exposure, and tested at 100°C :

7.0×10^{10} 5.0×10^{10} 6.5×10^{10} Ave. = 6.17×10^{10} ohms

After exposure, and tested at 24°C :

2.3×10^{6} 1.1×10^{6} 2.6×10^{6} Ave. = 2.0×10^{6} ohms

After exposure, and tested at 100°C :

1.0×10^{7} 1.2×10^{8} 1.2×10^{8} Ave. = 8.3×10^{7} ohms

The weight loss of the MRTA-5 conformal coating exposed to a vacuum of 1×10^{-4} torr at 250°F for 25 hours was .090%.

No condensation from the above materials was apparent on the glass slide installed in the system.

Copies of the weight loss tables and graphs from the NASA White Sands Test Facility are shown in Appendix 2.

3.4.5 and 4.5.2.8 Fungus Resistance

The compound shall show no evidence of deterioration when subjected to fungus growth as encountered in tropical climates.

Fungus resistance tests run on MRTA-5 by Associated Testing Laboratories, Inc. indicate that this material will support fungus growth. The basic resin is a brominated polyester, but the supplier would not disclose anything more about the constitution of the material. It is, therefore, not possible to comment on what constituent is supporting the fungus growth. Growth was slight, but was present on the test sample.

3.4.6 Moisture Resistance

When tested as specified in 4.5.2.10, the insulation resistance of specimens prepared as specified in 4.5.2.5 shall be 200 megohms minimum. (2×10^8 ohms)

Three samples of the conformal coating were tested, at Associated Testing Laboratories, Inc., after 5 cycles to 71°C and 95% relative humidity, with the following results:

TABLE 19

Effect of moisture on the insulation resistance of the conformal coating.

At 24 ± 1°C :

Sample No. 1	8.3×10^7 ;	8.5×10^7 ;	9.4×10^7	ohms
Sample No. 2	5.5×10^6 ;	6.0×10^6 ;	9.9×10^6	ohms
Sample No. 3	1.9×10^{10};	1.9×10^{10} ;	1.8×10^{10}	ohms

At 100 ± 1°C :

Sample No. 1	1.3×10^7 ;	1.3×10^7 ;	6.6×10^7	ohms
Sample No. 2	1.9×10^{10} ;	2.0×10^{10} ;	2.4×10^{10}	ohms
Sample No. 3	2.2×10^{10} ;	2.4×10^{10} ;	2.6×10^{10}	ohms

Of the three samples tested, one passed this test when measured at 24°C and two passed when measured at 100°C.

The tests on the following pages are called for by the specification and are described in Appendix D of the Work Statement.

4.5.2.1 Dielectric Constant and Dissipation Factor

Specification Limits: K' = 5.0 Max. pf = 0.09 Max.

The dielectric constant and power factor of the conformal coating MRTA-5 were measured at 1 MHz.

TABLE 20

Dielectric constant and power factor of conformal coating.

	K'	pf
Sample A	4.94	0.0088
Sample B	4.72	0.0077
Sample C	4.71	0.0074

4.5.2.2 Dielectric Strength

Specification Limit: 500 volts/mil of thickness

Five discs, 50 mils thick, were prepared for measurement at Acton Environmental Testing Corporation. Three samples withstood 20 kv; one failed at 20 kv, another failed at 18 kv.

4.5.2.3 Volume and Surface Resistivity

Specification Limits: $_{v}$ = 10^{12} ohm-cm Minimum
$_{s}$ = 10^{12} ohm-cm Minimum

The volume and surface resistivities of the conformal coating MRTA-5 were determined:

TABLE 21

Volume and surface resistivity of conformal coating.

Sample No. 1	5.59×10^{14}	8.10×10^{14}
Sample No. 2	4.28×10^{14}	2.03×10^{14}
Sample No. 3	4.39×10^{14}	2.03×10^{14}

The conformal coating is well within the specification limits.

4.5.2.4 Arc Resistance

Specification Limit: 45 seconds Minimum

The arc resistance of the conformal coating was measured at Electrical Testing Laboratories, Inc. Three samples were tested with the following results:

TABLE 22

Are resistance of conformal coating.

MRTA-5 Sample	Time to Track
No. 7	212 seconds
No. 8	214 seconds
No. 9	215 seconds

The arc resistance of the material is excellent and is well above the specification minimum.

4.4.3.5 Insulation Resistance

The insulation resistance of the conformal coating was determined as described previously under moisture resistance.

Specification Limits: 1.0×10^{11} ohms at 24°C
7.5×10^{8} ohms at 120°C

TABLE 23

Insulation resistance of conformal coating at 24°C and 120°C.

At 24°C :

Sample No.	1	5.5×10^{11}	4.5×10^{11}	2.0×10^{11} ohms
Sample No.	2	1.6×10^{12}	1.4×10^{12}	1.4×10^{12} ohms
Sample No.	3	0.7×10^{12}	1.0×10^{12}	1.4×10^{12} ohms

At 120°C :

Sample No.	1	6.0×10^{9}	5.0×10^{9}	6.0×10^{9} ohms
Sample No.	2	4.0×10^{9}	5.5×10^{9}	6.0×10^{9} ohms
Sample No.	3	4.5×10^{9}	4.5×10^{9}	5.0×10^{9} ohms

The insulation resistance is above the specification minimum.

4.5.2.6 High Potential

Specification Limit: no breakdown

Three samples of the conformal coating were subjected to the high potential test by Associated Testing Laboratories, Inc.

There were no breakdowns.

4.5.2.7 Temperature Resistance

The volume resistivity shall be determined after a conditioning period of 30 minutes at 121° $\pm$ 1°C.

Specification Limit: 10^{9} ohm-cm Minimum

Three samples of MRTA-5 were tested for temperature resistance as described.

TABLE 24

Volume resistivity of the conformal coating at 121°C.

	Volume Resistivity
Sample No. 1	6.23×10^{13} ohm-cm
Sample No. 2	3.77×10^{13} ohm-cm
Sample No. 3	6.56×10^{12} ohm-cm

The volume resistivity is substantially above the specification minimum.

4.5.2.9 See comments under tear strength for the potting compounds.

4.5.2.10 The moisture resistance - see Page 35.

4.5.2.11 Tensile Strength or Elongation

The tensile strength shall be 1400 psi Minimum.

The tensile strength of the conformal coating MRTA-5 was determined with the following results:

Sample No. 1	3179 psi
Sample No. 2	4157 psi
Sample No. 3	2647 psi

Obviously anything of the nature of MRTA-5 will have essentially no elongation.

4.5.2.12 Shrinkage

Specification Limit: 3% Maximum

% Shrinkage of MRTA-5 = 4.4%

4.5.2.13 Compression Set

It was agreed that this test would not be run.

Viscosity

The viscosity of the conformal coating MRTA-5 at 24°C is 1440 poises.

Specification Limit: 250 poises Maximum

The material exceed the specification maximum for viscosity.

4. 5. 3. 5. 1 Adhesion to Metal

Specification Limit: 15 lbs. /inch

This test was designed for use on a flexible material and, therefore, attempts to apply it to MRTA-5 were unsuccessful. In order to obtain adhesion to metal data it was decided to run lap shear strength according to ASTM 1002, however MRTA-5 is too brittle to successfully make and cut the necessary samples.

4. 5. 3. 2 Specific Gravity

The test specimen shall be tested in accordance with Method 14011 of Standard FED-STD-601 to determine conformance to 3. 5.

Specification Limit: 1. 2 Maximum

Specific gravity of cured MRTA-5 is 2. 53.

TABLE 25 summarizes the results of the tests run on the two potting compounds with the sealer coat, as well as the test runs on the conformal coating. When a material fails a given test, we have given a number to indicate the extent of the failure. If the reader is interested in more detail, he should refer to the text.

TABLE 25

Summary of Tests on Potting Compound with Sealer Coat and on Conformal Coating

	QC-15	1015-	MRTA-5
3.3.1 Appearance	Pass	Pass	Pass
3.3.2 Application	Pass	Pass	Pass
3.3.3 Application Life	Pass	Pass	Pass
3.3.4 Curing Time	Pass	Pass	Pass
3.3.5 Storage Life	Pass	Pass	Pass
3.3.6 Repair & rework	Pass	Pass	Pass
3.3.7 Temp. rating	Fail 1	Fail 1	Pass
4.4.3.5 Insulation resist.	Pass	Pass	Pass
3.3.8 Hardness	Pass	Pass	?
3.4.1 Flammability	Pass	Pass	Pass
3.4.2 Outgassing	Pass	Pass	Pass
3.4.3 Odor	Fail 3	Pass	Pass
3.4.4 Vacuum volatility	Fail 3	Fail 3	Fail 3
3.4.7 Moisture resist.	Fail 3	Pass	Fail 1
4.4.3.1 Dielectric const. & power factor	Pass	Pass	Pass
4.4.3.2 Dielectric strength	Fail 3	Fail 3	Fail 1
4.4.3.3 Volume & resistivity	Fail 2	Pass	Pass

		QC-15	1015-	MRTA-5
4.4.3.4	Arc Resist.	Pass	Pass	Pass
4.4.3.6	High Potential	Pass	Pass	Pass
4.4.3.7	Low temp. flexibility	NA	NA	NA
4.4.3.8	Temp. resistance	Pass	Pass	Pass
4.4.3.9	Fungus Resistance	Pass	Pass	Fail 1
4.4.3.10	Tear strength	NA	NA	NA
4.4.3.12	Tensile strength	Fail 3	Fail 3	Pass
4.4.3.13	Shrinkage	Fail 2	Fail 2	Fail 1
4.4.3.14	Compression set	NA	NA	NA
4.4.3.15	Ozone resist.	NA	NA	NA
4.4.4.1	Non vol. content	Determined	Determined	
4.4.4.2	Viscosity	Determined	Determined	Determined
4.4.4.3	SP. gravity	Pass	Pass	Fail 2
4.4.4.6.1	Adhesion to metal	Fail 3	Fail 3	Fail 3
3.4.5.3	Bond strength to ethed wr.	Fail 2	Fail 2	
3.4.5.4	Patch Potting adhesive	Fail 3	Fail 1	

Notes

1.) N.A. - Not applicable

2.) Where materials failed, the degree of failure is indicated by the number following the word "fail" 1 = almost passed
2 = definite failure
3 = failed by wide margin

For further details, see text of report.

SECTION VI

INSTRUCTIONS FOR USE OF MATERIALS

A. INSTRUCTIONS FOR THE USE OF POTTING COMPOUND 1015

CAUTION: Use in well ventilated area and avoid flame, this material contains flammable solvents.

1. Thoroughly mix Part A in its original container. Use a lifting motion as well as stirring motion to insure complete mixing of the entire contents.

2. Weigh out the required quantity of Part A. Add 2.7 parts of Part B per 100 parts of Part A. (by weight). Mix thoroughly. Unused portions of both Part A and Part B should be covered immediately to prevent loss of solvent. Also mixed material should be covered when not in use. As stated on P 13, the application life after addition of catalyst is several hours.

3. The material can be applied by pouring, caulking gun or hypodermic syringe depending on the size and configuration of the mold. Regardless of the application technique, vibration will be necessary to remove air and improve the flow of the potting compound. After application is complete, vibration should be continued as long as air bubbles rise to the surface. Do not attempt to use vacuum to remove air bubbles, this will result in large voids created by solvent vapor.

4. Castings should be cured overnight at 120°F (49°C) and then 24 hours in vacuum oven at 135°F (58°C) to be sure all of the solvent has been removed. For very large castings, longer time, particularly under vacuum, may be necessary. The precise procedure must be determined by experiment.

5. Castings of this material should be sealed with the sealer coat.

B. INSTRUCTIONS FOR THE USE OF POTTING COMPOUND QC-15

1. If Part A is lumpy, the lumps must be broken up. This can be accomplished by pushing the powder through a 20 mesh screen with a paint brush. After all the lumps are broken up, the asbestos fibers left on the screen should be returned to the mixture.

2. Weigh out the required amount of Part A and add Part B (100 - 160 parts of parts of Part B to 100 parts of Part A). 120 parts of Part B per 100 parts of Part A is usually optimum. Mix thoroughly. The consistency of the mixture should be such that it will flow under vibration and can readily be spread with a spatula. It should not flow readily without vibration. Too much Part B increases shrinkage and cracking; too little makes it difficult to remove trapped air.

3. This potting compound can be applied by pouring, caulking gun or hypodermic syringe depending on the size and configuration of the mold. Vibration is necessary during application to make the potting compound flow and to remove trapped air. Vibration should continue as long as air bubbles rise to the surface.

4. Cure for at least 24 hours at room temperature in a sealed container such as a plastic bag. Remove from the container and allow to dry for at least 24 hours at room temperature and 24 hours at 150°F. Drying of QC-15 should not be rushed too much as this will cause the castings to crack. Large sized castings may require a slower drying cycle. No problems would be expected in volumes of 200cc or less. If trouble is encountered in the setting and drying times, these periods should be lengthened. Experimentation will be necessary to determine how great an increase in time is required to give acceptable properties.

5. All castings of QC-15 should be coated with sealer coat.

C. INSTRUCTIONS FOR THE USE OF SEAL COAT FTA-3

Sealer coat should be used as a moisture barrier on all castings made with either potting compound 1015 or potting compound QC-15.

CAUTION: Use in well ventilated area and avoid flame. This material contains flammable solvents.

1. For best results, when coating either potting compound, large flat areas should first be abraded with coarse sandpaper. In any case, the surface should be primed with Chemlok 607 (Hughson Chemical Co.). A coat of Chemlok 607 is applied and allowed to dry (ca. 30 minutes at room temperature or 10 minutes at 150°F).

   Caution: Chemlok 607 contains methanol, exercise reasonable care to avoid skin and eye contact; avoid prolonged or repeated inhalation of vapors and avoid ingestion. Keep away from flame.

2. Thoroughly mix Part A in its original container. Weigh out the desired quantity of Part A. Add 2.5 parts of Part B to 100 parts of Part A.

3. The sealer coat may be applied by brushing or dipping. As much material should be applied with each coat as possible without running.

4. After applying a coat of sealer, the part should be left at room temperature for about an hour, then cured at 120°F (49°C) for at least 4 hours before the next coat is applied.

5. At least three coats of sealer are recommended for use with 1015 and QC-15. It is necessary to prime with Chemlok 607 before each coat of sealer. More than three coats may be used where required.

6. After the final coat, cure overnight at 120°F (49°C) and then in the vacuum oven at 150°F for 24 hours to be sure all solvent has been removed.

D. INSTRUCTIONS FOR THE USE OF MRTA-5 COATING COMPOUND

1. Completely mix the entire contents of the shipping container. Power mix until a smooth mixture of uniform consistency is obtained. High shear power mixing is permissible.

2. Weigh out the required amount of MRTA-5 and add Catalyst 7 - 0.23 parts of Catalyst 7 to 100 parts of MRTA-5. If it is not convenient to weigh out the Catalyst 7, approximately 40 drops equals 1 gram, a dropper may be calibrated for greater accuracy. Again mix thoroughly.

3. MRTA-5 is best applied by troweling under vibration. The vibration should be continued until a smooth surface is obtained and no more air bubbles rise to the surface.

4. This material will have a usable pot life of about 60 minutes and will cure within 5 hours at room temperature.

5. The cure time of MRTA-5 can be reduced by addition of up to 0.15% cobalt naphthenate to the mix. However, it should be remembered that this will also greatly reduce the pot life.

SECTION VII

REFERENCES

L. 1. U. S. Patent 2,914,413 Robert Mercer assigned to Pennsalt Chemical Corporation.

2. Elastomeric and Compliant Materials for Liquid Rocket Fuel and Oxidizer Application by W. R. Sheehan, N. B. Levine and J. Green of the Reaction Motors Division of Thiokol Chemical Corp., Technical Report ML-TDR-64-107.

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4. Perfluoro alkylene triazine Elastomeric Polymers by E. Dorfman and W. E. Emerson of Hooker Chemical Corp. under AF Materials Laboratory Contract AF-33 (615) 1636 Reports of August 1965, February 1967 and May 1968.

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6. "Phosphonitrile Shows Commercial Promise" Anon., Chem. & Eng. News, January 13, 1969 p. 34.

7. Phosphonitrilic Laminating Resin by J. M. Maselli, T. Bieniek, R. M. Nurch, A. Kawam, R. G. Rice of W. R. Grace & Co. Technical Report AFML-65-314, June 1967.

8. Letter dated, June 26, 1969 from R. R. Tillett of NASA White Sands Test Facility to Nonmetallic Materials Information Center in Houston.

APPENDIX 1

Statement of work and pertinent test methods for development of a nonflammable spacecraft potting and encapsulating compound, and a conformal coating compound.

EXHIBIT "A"
STATEMENT OF WORK

NONFLAMMABLE SPACECRAFT POTTING

ENCAPSULATING, AND CONFORMAL COATING COMPOUNDS

TABLE OF CONTENTS

1.0 Introduction

The presently available polymeric potting, encapsulating, and conformal coating compounds, although suited to their conventional applications in ambient air, do not provide adequate flame safety for use in the cabin oxygen environment of manned spacecraft. The primary flame propagation hazard is associated with the relatively large surface areas of conformal coatings which are required to provide dielectric protection and moisture-proof terminations for spacecraft wire harnesses at terminal strips and circuit breaker panels. Only slightly less serious is the combustibility of present electrical connector potting compounds used in the pure oxygen atmosphere. Encapsulating compounds may be classed as less critical, since they are normally used in sealed components and are protected from direct contact with ambient oxygen.

The flammability of these present compounds requires that they be encapsulated with relatively thick layers of inorganic coatings which may be brittle, tend to flake and crack, add substantial weight, and hamper any wiring rework required.

2.0 Objectives

It is required that new potting, coating, and encapsulating compounds be developed which will not sustain flame when subjected to the special oxygen flammability tests described in this statement of work. These compounds must not evolve toxic gases at elevated temperatures, and the toxicity of pyrolysis products must be minimal. They must exhibit low volatility at operating temperatures in both 5 psia nominal oxygen atmosphere and vacuum. See requirements of paragraph 3.4.

Additional requirements described in this statement of work include the usual stringent electrical and physical properties, high bond strength to etched Teflon and Kapton wire, and ease of repair and rework.

A desirable goal is to obtain a clear or transparent potting and coating compound to allow post-fabrication inspection.

3.0 Technical Requirements

3.1 Approach

The requirements of nonflammability, low volatility, and low toxicity of pyrolysis products may be achieved by any of the standardized techniques, by unique and hitherto unproven methods, or by any combination thereof. The study should include investigation of conventional flame inhibition techniques such as addition of halogen bearing compounds singly or in synergistic combination with other components such as antimony trioxide, with special emphasis on anticipated volatility/toxicity problems. The use of nontoxic inorganic fillers as flame retardant "heat sinks," and organometallic curing agents should also be considered.

3.2 Materials

3.2.1 Basic Compounds - Any materials inherently possessing adequate electrical and physical properties may be considered. A detailed literature search and compilation of state-of-the-art test data is required to justify the proposed ultimate choice or choices as a starting point for the development program.

3.2.2 Primers - The use of a primer for potting, encapsulating, and/or conformal coatings, to improve the adhesion to the base structure is permitted, provided the composite primer and basic compound successfully pass all tests of paragraph 3.4.

3.2.3 Toxicity - Any potentially toxic materials associated with the processing or handling of the compounds shall be identified, and appropriate safety precautions shall be recommended.

3.2.4 Clarity - It is desirable for the cured product to be as transparent as possible to allow post-fabrication inspection for bubbles or voids. No special pigments or color additives shall be used.

3.3. Performance and Product Characteristics

3.3.1 Appearance - The as-poured and cured compounds shall be homogenous and free from lumps and coarse particles and voids.

3.3.2 Application - Potting and encapsulating compounds shall be capable of being readily applied by an injection or extrusion gun. Conformal coatings shall be capable of being applied by brush, spray, dipping, or thin casting temperature.

3.3.3 Application Life - The compound shall be suitable for application for a minimum of 60 minutes.

3.3.4 Curing Time - The curing time to obtain optimum properties shall not exceed 7 days at room temperature and 50 percent maximum humidity. Elevated temperatures up to 150°F may be used to accelerate the cure time.

3.3.5 Storage Life - The uncured compounds shall be capable of meeting the requirements of this statement of work for 6 months when stored below 70°F.

3.3.6 Repair and Rework - The cured compounds must be capable of being removed, either mechanically or chemically, without damaging wiring, solder joints, or electronic components. The adherence of patch

potting to previously applied potting must be adequate to withstand the 200 megohm moisture resistance tests of paragraph 3.4.5.4.

3.3.7 Temperature Rating - The compounds shall retain useful physical and electrical properties from 0°F to +250°F, as verified by the insulation resistance and low temperature flexibility tests of paragraph 3.4.5.

3.3.8 Hardness Rating - The hardness of fully cured compounds shall be measured and submitted for NASA-MSC approval.

3.4 Properties and Test Requirements

3.4.1 Flammability - Candidate potting materials and encapsulating compounds shall be self-extinguishing immediately after wire fusion, with no further evidence of degradation by combustion in a 6.2 psia oxygen or 16.5 psia oxygen when subjected to Test No. 5, SN-P-0003 (Appendix A). Candidate conformal coatings shall be self-extinguishing immediately after wire fusion, with no further evidence of degradation by combustion in 6.2 psia oxygen or 16.5 psia oxygen when subjected to the electrical overload Test No. 1, Appendix B.

Quantitative and qualitative analyses of chamber products evolved during pyrolysis are required, using the techniques of Test No. 6, Appendix A, as a minimum.

3.4.2 Outgassing - As a screening test, the total organics expressed as pentane equivalents evolved from any of the candidate potting, coating, or encapsulating materials shall not exceed 100 micrograms per gram of sample, when tested at 5.0 psia oxygen and 200°F in accordance with Test No. 7, Appendix A. Outgassed carbon monoxide shall not exceed

25 micrograms per gram when tested in accordance with the same test. Quantification of outgassed products and accurate weight loss data in 5 psia oxygen are required prior to final MSC acceptance of candidate materials. MSC acceptance shall be predicated upon the requirement that none of the outgassed products shall constitute a toxic hazard to the crew.

3.4.3 Odor - The average odor rating of all candidate materials must not exceed 2.0, when tested at 5.0 psia oxygen and 200°F in accordance with Test No. 6, Appendix A.

3.4.4 Vacuum Volatility - The rate of weight loss in $1X10^{-4}$ Torr at 250°F shall stabilize within 6 hours, and the continuing rate of weight loss shall not exceed 0.02 percent per hour when measured continuously in vacuum with an in-situ microbalance. The rate of weight loss shall continue to decrease with time.

There shall be no visible condensate deposited on a glass slide maintained at least 100°F below the test temperature and located in close proximity to the test specimen within the vacuum chamber. The total weight loss for the initial 24-hour period shall not exceed 1.0 percent.

An additional vacuum volatility test specimen shall be prepared per MSFC-SPEC-202A, paragraph 4.4.3.11 (See Appendix C) for potting compounds, and per MSFC-SPEC-393A, paragraph 4.5.2.10 (See Appendix D) for conformal coatings. Upon completion of 24-hour vacuum testing, there shall be no apparent visual degradation, and the compounds shall withstand the required 200 megohm moisture resistance

tests of paragraph 3.4.7, Appendix C, for potting compounds, and paragraph 3.4.6, Appendix D, for conformal coatings.

3.4.5 Physical and Electrical Properties

3.4.5.1 Potting and Encapsulating Compounds - Candidate potting and encapsulating compounds shall be tested in accordance with the requirements for Type III compounds per MSFC-SPEC-202A, paragraphs 3.4.5 - 3.5 (See Appendix C), except the adhesive bond strength requirements to PVC and Neoprene are deleted. Testing procedures are in accordance with paragraph 4.4., Appendix C, except delete paragraphs 4.4.4.6.2 and 4.4.4.6.3. Test results shall be submitted for NASA-MSC review and final approval.

3.4.5.2 Conformal Coatings - Candidate conformal coatings shall be tested in accordance with the requirements for Type I compounds per MSFC-SPEC-393A, paragraphs 3.4.5 - 3.5 (See Appendix D). Testing procedures are in accordance with paragraph 4.5, Appendix D. Test results shall be submitted for NASA-MSC review and approval.

3.4.5.3 Bond Strength to Etched Wire - The bond strength of both potting and conformal coating compounds to etched Teflon and Kapton wire must exceed ten (10) pounds pull-out, and the failure must be cohesive (in the compound) rather than adhesive (at the wire-compound interface), when tested per Test No. 2, Appendix B.

3.4.5.4 Patch Potting Adherence - The adherence of patch potting or coating material to previously applied compounds must be adequate to withstand the 200 megohm moisture resistance tests of paragraph 3.4.7, Appendix C, for potting compounds, and paragraph 3.4.6,

Appendix D, for conformal coatings. The test samples shall be prepared with the required electrodes encapsulated by the applicable candidate compound. The upper portion of the cured compound shall be removed to a depth of at least one inch (1.00"), exposing both electrodes, to demonstrate compliance with paragraph 3.3.6. Patch potting or coating shall then be applied to replace the original compound, in accordance with the recommended process. The moisture resistance test shall be conducted on the "repaired" specimen to demonstrate dielectric integrity of the repair.

APPENDIX A

DNA-0002

Procedures and Requirements for the Flammability and Offgassing Evaluation of Spacecraft Non-metallic Materials

Test 5

Test 6

Test 7

Test 17

TEST NO. 5
ELECTRICAL CONNECTOR POTTING
FLAMMABILITY TEST

1.0 PURPOSE

This test evaluates the flammability characteristics of spacecraft potting compounds in a specific gas atmosphere environment. It is designed to simulate a short circuit or dielectric breakdown on current carrying wires, or connector contacts within the potting used to environmentaly seal electrical connectors.

2.0 TEST CONDITIONS - PRESSURES AND ATMOSPHERE

The test pressure and gas mixture conditions for the pertinent materials category shall be designated by the requirements for each program.

3.0 TEST DISCIPLINE

3.1 Each test shall be directed by the cognizant Test Engineer or his appointed alternate.

3.2 Approval of the test shall be indicated at the end of the test procedure by the signatures of the responsible Test Engineer. Entires transcribed to the test data sheets will also be verified by the Test Engineer.

4.0 CRITERIA OF ACCEPTABILITY

Connector potting material shall not be capable of sustaining combustion in the designated test atmosphere following removal of the ignition source with current overloads up to the melting point of the electrical wire conductor.

5.0 TEST EQUIPMENT

5.1 Test Chamber - Test chamber shall have sufficient volume to ensure complete combustion of the potting compound specimen and shall be suitably constructed and protected to ensure safe operation. A window or viewing port for visual observations shall be provided. A test chamber shall contain inlets for vacuum, source of power for wire overload, air, oxygen, and gas mixture. A horizontal sample holder and a central connector mount shall be included and positioned within the test chamber. See Figure 1.

5.2 Pressure Gauge - The pressure gauge shall be capable of measuring absolute pressure with an accuracy of ± 0.1 Torr.

5.3 Gas Supply - The gas shall be commercially available conforming to appropriate specifications.

5.4 Sample Holder and Connector Mount - The sample holder shall consist of two horizontally mounted electrical connections (bolt with knurled nuts) spaced 12 inches apart. The electrical terminals shall be connected to the ignition power source. A central connector consisting of a vertical panel drilled to receive a horizontal Bendix PT07 Jam Nut Receptacle or equivalent shall be provided.

5.5 Ignition Source - An external power supply shall be provided which is capable of providing a large steady DC current so that a very high temperature will be achieved quickly. The power source must be capable of supplying 100 amperes of current through a 18 AWG fourteen inch long wire.

6.0 SAMPLE PREPARATION

6.1 Prepare three (3) samples for each candidate potting compound per paragraphs 6.2 through 6.8 below.

6.2 Verify material identifications as one of the items below:

6.2.1 Manufacturer's Certification

6.2.2 NASA Certification

6.2.3 Contractor Certification

6.2.4 Definite Identification not available

6.3 A fourteen inch (14") length of AWG 18 white teflon insulated wire (MIL -W-16878, Type E, or MIL -W-22759, Type MS21985) shall be prepared as follows:

6.3.1 Form a "U" bend in the middle of the wire and etch the center 4 inch per MSC Specification Q-3.

6.3.2 Strip one half inch insulation from each end.

6.3.3 Cut the wire in half such that two inches of etched insulation remains on the unstripped end of each seven inch length.

6.4 Obtain a Bendix Pygmy PT06CP-18-11P Straight Plug or equivalent. Strip 1/4" from the end of each 7" wire prepared per 6.3. Crimp one 7" wire to contact K and the second 7" wire to adjacent contact L.

6.5 Crimp nine (9) etched white AWG 20 Teflon insulated wires, each 3" long, in the remaining contacts.

6.6 Place the potting boot on the connector and fill with the candidate potting compound, per the manufacturer's instructions. Ensure that the potting compound is within recommended shelf life. Ensure that all steps are followed exactly as they would be in flight hardware, including cleaning and priming of connector rear insert for bondability, degassing potting compound, proper humidity control, etc.

6.7 Cure per applicable user's procedure or manufacturer's recommended time/temperature for optimum properties.

6.8 Remove potting boot.

7.0 CENTRAL CONNECTOR PREPARATION

7.1 Prepare three (3) Central Connectors per paragraphs 7.2 through 7.5 below.

7.2 Obtain a Bendix Pygmy PT07CP-18-11S Jam Nut Receptacle or equivalent. Crimp a short AWG 16 Teflon insulated jumper between contact K and contact L.

7.3 Place the potting boot on the connector and fill with the compound to be tested.

7.4 Cure per manufacturer's instruction.

7.5 Remove potting boot.

8.0 TEST PROCEDURE

The procedure shall be carried out in the following sequences:

8.1 The sample prepared per Paragraph 6.0 shall be mounted in the sample holder by locking the PT06CP plug to the PT07CP receptacle which has been placed in the vertical panel provided for it, and fastened with a threaded locknut. The stripped ends of the 7 inch lengths of wire crimped into the plug shall be fastened to the current supply terminals of the sample holder.

8.2 The test chamber shall be evacuated to a pressure of 1 Torr and repressurized to the test pressure with oxygen. Allow the chamber to stand for one minute. A leak is indicated if an increase in test chamber pressure of 1 Torr is observed during one minute after the vacuum pump is closed off from the system. The system shall be brought to atmospheric pressure and the leak corrected before any additional tests are carried out. Repeat the above procedure.

8.3 After the test chamber has been stabilized at the test pressure, soak the specimens ten minutes. Apply a current of 55 amperes to the wire. If ignition or considerable degradation is not obtained in one minute, the current shall be increased by 5 amperes (i.e., from 55 to 60 and 60 to 65, etc.) until such time as the wire fails or ignition occurs. If the wire fails, voltage shall remain applied to the open wire until it is positively established that current does not flow by bridging the gap to adjacent conductors.

8.4 Three samples of each potting compound shall be tested. The failure of any one sample to meet the criteria of Paragraph 3.0 shall be cause for rejection of that compound.

9.0 REPORT

The following test data and pertinent information concerning the materials shall be reported:

9.1 Name and positive identification (para. 6.2) of the material

9.2 Vendor designation and vendor.

9.3 Usage, quantity, and surface area in the spacecraft.

9.4 Test pressure and test atmosphere.

9.5 Results of each test including combustion phenomena if ignition occurs.

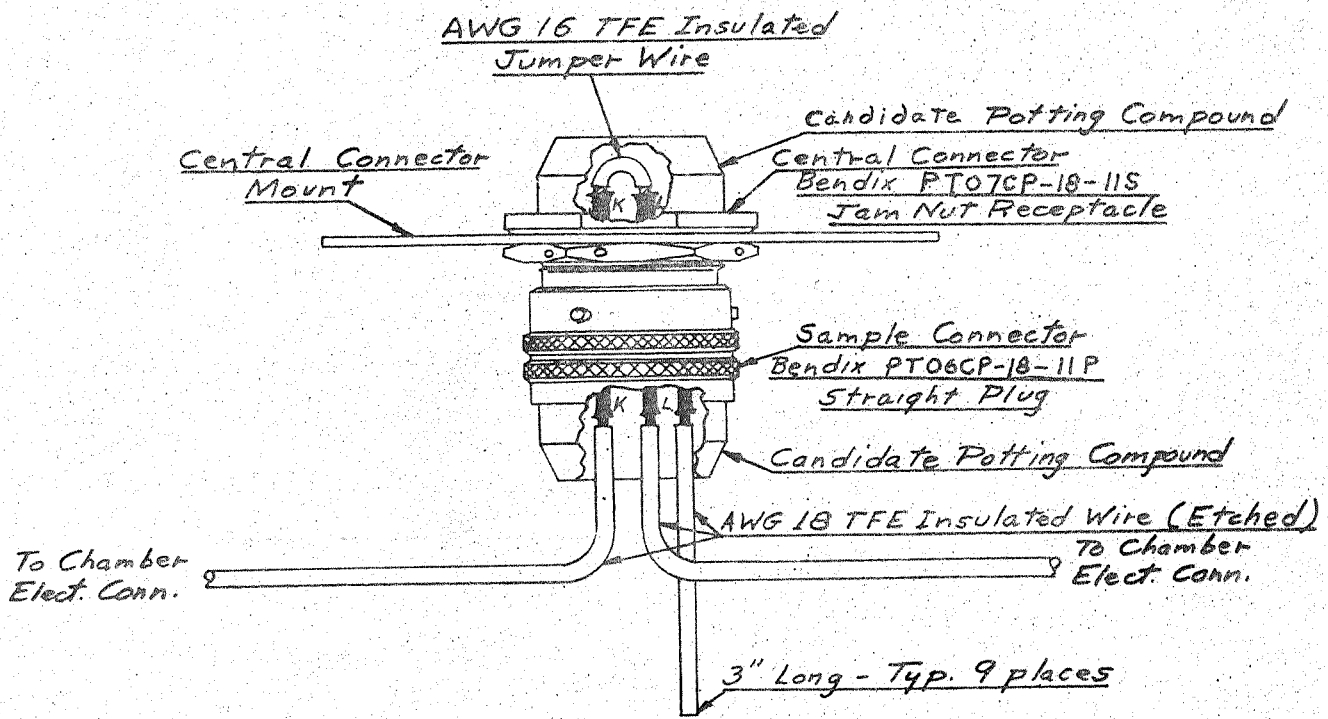
9.6 Date of test.

9.7 Test number.

9.8 Identity of the testing agency.

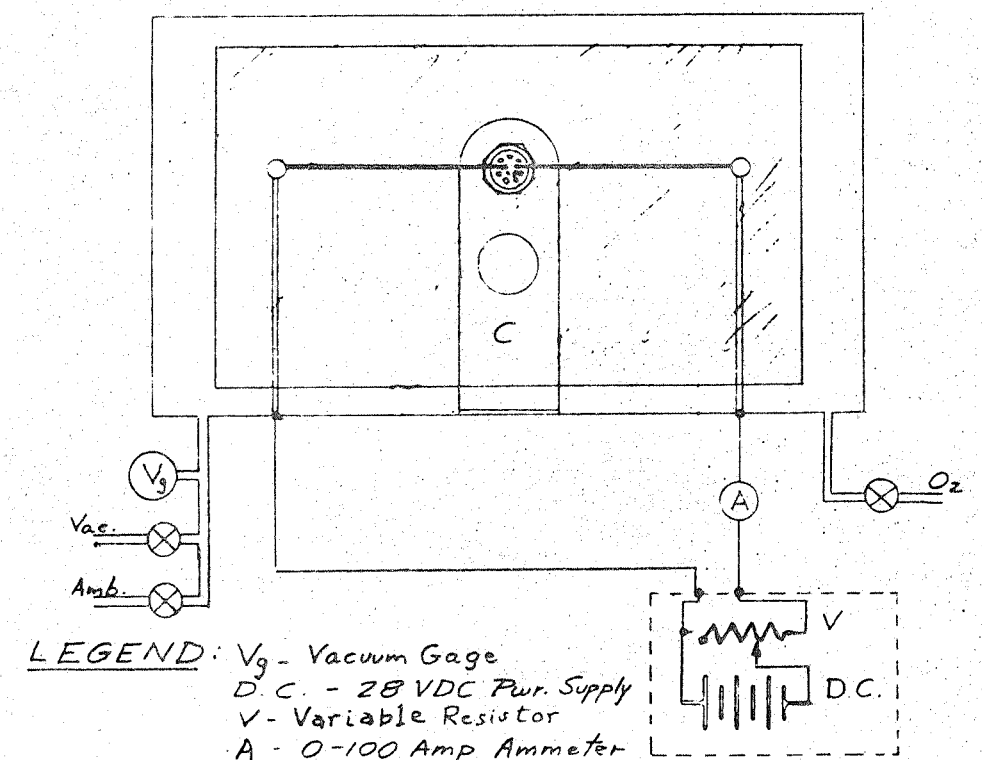
9.9 Names & signature of Test Coordinator.

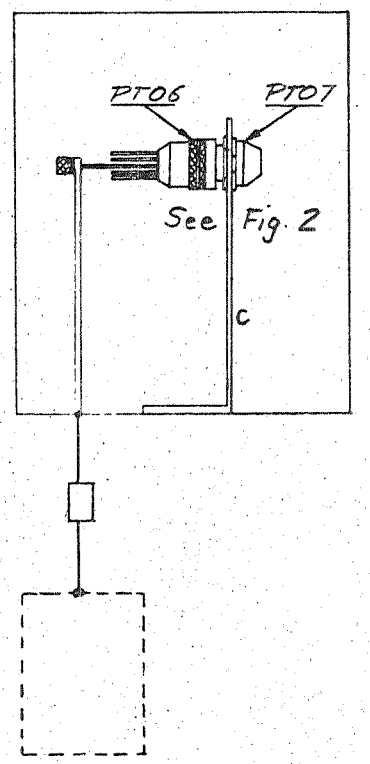
FIG. 2 SAMPLE CONFIGURATION



AWW
9-13-66

FIG. 1 POTTING FLAMMABILITY TEST EQUIPMENT SCHEMATIC





LEGEND: V_g - Vacuum Gage
D.C. - 28 VDC Pwr. Supply
V - Variable Resistor
A - 0-100 Amp Ammeter

C - Central Connector Mount
PT06 - Bendix PT06-CP-18-11P Straight Plug
PT07 - Bendix PT07-CP-18-11S Jam Nut Receptacle

AWW
9-13-66

TEST NO. 6
DETERMINATION OF ORGANIC OFFGASSING PRODUCTS AND CARBON MONOXIDE

NOTE: This test will not be conducted prior to applicable flammability tests nor will it be conducted on materials which have failed a flammability test unless specifically requested.

1.0 PURPOSE

This procedure establishes the criteria for a screening test, which will determine the suitability of nonmetallic materials for use in the space vehicle crew compartment environments. The criteria is established with respect to production by out-gassing of potentially toxic or objectionable volatiles. The volatiles are separated into two categories: Carbon Monoxide and Total Organics.

2.0 TEST CONDITIONS - PRESSURES & ATMOSPHERE

The test pressure and gas mixture conditions for the pertinent materials category shall be designated by the requirements for each program.

3.0 CRITERIA OF ACCEPTABILITY

3.1 The reporting laboratories shall report total organics as micrograms per gram (μg/g) of sample material using methane as a standard.

3.2 The maximum allowable level of total organics in the tested configuration shall not exceed 100 micrograms of total organics per gram of sample.

3.3 Carbon monoxide shall be reported as the number of micrograms produced by one gram of sample material.

3.4 The maximum allowable level of carbon monoxide in the tested configuration shall not exceed 25 micrograms of carbon monoxide per gram of sample.

4.0 TEST DISCIPLINE

4.1 Each test shall be directed by the cognizant test engineer or his appointed alternate.

4.2 Approval of the test shall be indicated at the end of the test procedure by the signatures of the responsible test engineer. Entries transcribed to the test data sheets will be also verified by the test engineer.

5.0 TEST EQUIPMENT

5.1 Test Chamber - The test chamber shall have a minimum main chamber volume of two liters. It shall have a configuration and be fabricated of materials which allow ready cleaning. A thermometer or thermocouple and pressure gauge for temperature and pressure determination, respectively, shall be included in the test chamber. The chamber shall be connected to a manifold system to permit evacuation, pressure readings, gas introduction, and sample withdrawal. An alternate system would be to connect the chamber directly to a gas chromatograph and/or mass spectrometer for the gas analyses.

5.2 Heating Source - The oven shall maintain constant temperature control over the test chamber to ±5°F. The temperature during sample exposures shall be recorded.

5.3 Vacuum Pump - The vacuum pump shall be capable of producing a vacuum less than one Torr.

5.4 Analytical Equipment - The analytical equipment shall consist of the following types of equipment and any other instruments which the tester desires to use efficiently to evaluate offgassing products.

5.4.1 Gas Chromatograph System - Recorder, thermal conductivity and hydrogen flame ionization detectors. The columns shall have the capability of separating light organic and inorganic gases, organic sulfides and mercaptans, halogenated hydrocarbons, representative aliphatic and aromatic hydrocarbons including aldehydes, ketones, alcohols, and esters. The hydrogen flame ionization detector has greater sensitivity to organic materials. Conversely, because of the flame ionization detector's lack of sensitivity to the inorganic compounds listed above, the thermal conductivity detector is used for their identification.

5.4.2 Recording Infrared Spectrophotometer capable of analyzing 3 microliters (3 µl) or less of liquid with accessories which include an infrared gas cell with 10m path length.

5.4.3 Mass Spectrometer

5.4.4 Electron Capture Detector

5.4.5 Trapping System suitable for trapping and transfer of microliter quantities of liquid from the gas chromatograph to the infrared spectrophotometer or mass spectrometer. A direct G. C. mass spectrometer connection can replace the trapping system if desired.

5.4.6 Gas Sampling System suitable for transfer of measured volumes of gas samples from the test chamber to the gas chromatograph.

5.4.7 Calibration Gas Samples as required to quantify detector sensitivity and readout. These may be bought from a manufacturer or made up in the laboratory.

6.0 PREPARATION OF TEST EQUIPMENT

6.1 Prior to loading of sample into a container, the container shall be loaded to test pressure with test atmosphere, heated at 155° ± 5° F for 24 hours, and the gas analyzed for total organics and carbon monoxide. The container shall be certified clean for use if the total organics value is 5 ppm by volume methane or less over the test atmosphere and the carbon monoxide value is 5 ppm by volume or less. After use, the container shall be reused without cleaning if the sample values are equal to or less than the above. If not, the container shall be heated and purged with air or nitrogen by some convenient method, such as a heat gun with blower, loaded to test pressure with test atmosphere, and tested to the above specifications.

6.2 Leak Check - The test system shall not increase in pressure more than one Torr. while remaining at a reduced pressure of one Torr for a time period of one hour.

7.0 PRETEST PROCEDURE

7.1 Verify material identification as one of the following:

7.1.1 Manufacturer's certification

7.1.2 NASA certification

7.1.3 Contractor certification

7.1.4 Definite identification not available

8.0 TEST SPECIMENS

8.1 All the materials tested in the program shall be classified into four categories; surface, volume, weight, or specialized items.

8.2 Samples based on Surface

This classification is defined as all those materials that are essentially two-dimensional. This would include films, fabrics, coatings, finishes, inks, primers, adhesives, thin film lubricants, tapes, and electrical insulating material.

The sample tested shall have a surface area of 46.5 ± 2.5 square inches per liter of test container. Coatings, finishings, etc. shall be coated on clean aluminum substrate of 0.020 ± 0.01 inch thickness. Material thickness, curing process, and method of application shall be in accordance with the manufacturer's recommendations. Material may be coated on both sides of the aluminum panel. Tapes and other similar materials with an adhesive surface shall be fastened to a similar aluminum panel. In all cases, only the outer surface of a material on the aluminum panel is counted in the surface area determinations. Films, fabrics, and similar materials shall be cut to give 46.5 ± 2.5 square inches surface area. Since these materials are two-surfaced in use, both the top and bottom surface shall be counted in determining total surface area. Heat shrinkable tubing shall be applied and shrunk to simulate actual use configuration.

8.3 Samples based on Volume

This classification is defined as all those materials having an indefinite volume but having a large real surface area due to surface convolutions or matting. These shall include foams and other blown or foamed materials and insulation padding.

Samples of these materials shall be cut to a thickness of 0.50 ± 0.05 inches unless the existing thickness is less than 0.40 inches. In this case, the existing thickness shall be used. The material shall be cut to such a size as to give 7.75 ± .75 square inches of total surface per liter of test container volume. All surface, tops, bottoms, and sides shall be used to compute total surface area. In cases where the natural thickness is such that the material cut would be too large to be placed into the container, two or more pieces may be cut as long as the total surface area requirement is met.

8.4 Samples based on Weight

This classification is defined as all those materials having a definite bulk and not falling into the volume classification. This shall include potting compounds, molding compounds, cast or formed objects, solid wires, and thick plastics. Liquids that are not used or applied as coatings or thin films shall be included.

The samples shall be used as much as possible in the supplied configuration and cut to give 5.0 ± 0.25 grams per liter of test container. Potted or molded materials shall be prepared and cured per manufacturer's directions and cut to weight. Liquids shall be placed in an aluminum dish 2.25 ± 0.25 inches in diameter. Sample weight shall be 5.0 ± 0.25 grams per liter.

8.5 Specialized Items

It must be recognized that some materials will not meet the above classifications and must be specially handled. This will most often occur with non-homogeneous materials. These cases will be tested in the manner designated by the Test Engineer. The manner of testing and sample preparation shall be fully reported.

9.0 PROCEDURE

9.1 Purge the test chamber until the minimum test atmosphere concentration is 95 percent and begin heating. Bring the chamber to 155° ± 5°F and adjust the chamber pressure to test pressure.

9.2 After twenty-four hours, check the test gas for contaminants with the gas chromatograph. Proceed to 9.3 if the total contamination is less than 5.0 ppm by volume over the test atmosphere. If the contamination exceeds the above value, the test chamber shall be flushed and rechecked after an additional twenty-four hours. This procedure shall be continued until the contamination is below the specific level of 5 ppm. If the gassing contamination continues indefinitely, revision of the test chamber is indicated.

9.3 Place a clean weighed specimen prepared per Section 8.0 in the test chamber.

9.3.1 The chamber shall be evacuated through a liquid nitrogen trap to below one Torr. The chamber shall then be closed off and the test gas, filtered through a 5X Molecular Sieve, bled into the chamber to test pressure. The conditions of exposure are held at 155° ± 5° F for a total period of 72 hours. Following the designated exposure period, the chamber is brought to room temperature. After the final gas samples are taken, the test specimen is removed from the chamber and weighed. The gases are then analyzed for the following:

9.3.1.1 Total organics expressed as methane equivalents.

9.3.1.2 Outgassing components exceeding 10 µg/g including but not limited to the following: HCN, Benzene, Xylene, MEK, Chloroform, n-Butanol, Dichloromethane, 1-4 Dioxane, Formaldehyde, Trichloroethylene, HCL, Ammonia, Hydrogen Fluoride, Carbonyl Fluoride and Silicon Tetra-fluoride. Condensates in the cold trap may be recovered as gas and likewise analyzed and plotted.

9.3.1.3 Quantity of carbon monoxide evolved.

9.4 Determination of Total Organics - The gas chromatograph with the proper columns, Beckman Total Hydrocarbon Analyzer or an equivalent instrument may be used for the determination.

9.5 Outgassing components, including those listed in 9.3.1.2, that exceed 10 µg/g shall be identified and recorded in the reporting format.

9.6 Determination of Carbon Monoxide - The carbon monoxide content of the evolved gases shall be determined under Section 9.4 above by utilizing an appropriate separation and analytical technique having the sensitivity to detect within 0.5 µg/g CO.

9.7 All charts and data are to be retained in the event further identification or evaluation is necessary.

10.0 REPORTING DATA

10.1 The following test data and pertinent information concerning the material tested shall be reported:

10.1.1 Name and positive identification of the material (paragraph 7.1)

10.1.2 Vendor designation and vendor

10.1.3 Usage, and surface area in the spacecraft

10.1.4 Weight and size - length, width and thickness of sample tested

10.1.5 Test pressure and atmosphere

10.1.6 Results of tests

10.1.6.1 Carbon monoxide in micrograms per gram

10.1.6.2 Total organics in micrograms per gram

10.1.6.3 Identity of organics greater than 10 micrograms/gm

10.1.6.4 Weight loss, percent.

10.1.7 Name and number of test procedure

10.1.8 Date of test

10.1.9 Test number

10.1.10 Identity of the testing agency

10.1.11 Name and signature of test coordinator.

TEST NO. 7
ODOR TEST

1.0 PURPOSE

These procedures are designed to eliminate unsuitable materials from use in the habitable area of spacecraft. A material that fails these requirements shall not be used.

2.0 TEST CONDITIONS - PRESSURES AND ATMOSPHERE

The test pressure and gas atmosphere conditions for the pertinent materials category shall be designated by the requirements for each program.

3.0 ODOR CRITERIA

3.1 Selection of Test Panel for Odor Evaluation - The test conductor shall establish a pool of qualified personnel.

3.1.1 Members of the pool shall be male and each member be capable of detecting seven basic odors from the following solutions:

Primary Odor	Standard Compound	Amount Dilution in Water
Ethereal	1, 2 - dichoroethane	0.4 ml in 500 ml
Camphoraceous	1, 8 - cineole	5µl in 500 ml
Musky	15 - hydroxypentadecanoic acid lactone	1 mg in 1,000 ml
Floral	1 - methyl-1-ethyl-2-phenyl propanol-1	0.075 ml in 500 ml
Minty	menthone (dl)	2µl in 333 ml
Pungent	formic acid	25 ml of 90 percent solution in 500 ml

Putrid (methyl disulphide) methyl dithiomethane 1µl in 10,000 ml

3.1.2 Members of the pool shall be given three odorless solutions along with the seven primary standards for the detection of odor.

3.1.3 The solutions shall be freshly prepared once a month or as needed.

3.1.4 The established pool for odor evaluation shall be requalified every three months.

3.1.5 A panel of five or ten members shall be selected from the pool for odor evaluations. In the event that the test panel consists of five members, each member shall evaluate each sample twice for odor.

3.1.6 Odor panel members should receive a nose and throat examination by a medical staff prior to, and after, each odor test session.

3.1.7 Members of the pool shall not participate on the panel if their sense of smell is affected in any manner.

3.1.8 At least one of the seven basic odors shall be presented to the panel members as a standard for sensing odor prior to evaluation of odors from any sample material.

3.1.9 Panel members shall not be permitted to see the material or to know the gas sample being evaluated for odor, nor to see the ratings of the other panelists.

3.1.10 Odor evaluations on sample materials shall be performed in a suitable room, free from extraneous odors.

3.1.11 Odor evaluations shall be performed on every new bottle of oxygen or gas used for the tests.

3.3 Odor Evaluation - Each panel member shall evaluate the odor of a sample according to the following scale:

Members Rating	Test Conductor's Rating
Undetectable	0
Barely detectable	1
Easily detectable	2
Objectionable	3
Irritating	4

3.3.1 A total score of 25 or less, for the sum of ten odor evaluations of any sample material by the panel members, signifies the material passes the odor test. A total score above 25 at any dilution signifies that the material fails.

4.0 TEST DISCIPLINE

4.1 All materials shall have been tested for carbon monoxide content and total organics before being subjected to the odor test. If a material has over 25 micrograms/gram of carbon monoxide, or over 100 micrograms/gram of total organics, no odor test shall be performed. If the offgassing products above 10 μg/g are analyzed and are judged by the appropriate space medicine division to be noxious, this fact shall be noted on the test report, and no odor test need be performed.

4.2 Each test shall be directed by the cognizant test engineer or his appointed alternate.

4.3 Approval of the test shall be indicated at the end of the test procedure by the signature of the responsible Test Engineer. Entries transcribed to the test data sheets will also be verified by the Test Engineer.

5.0 TEST EQUIPMENT

5.1 Test Chamber - The test chamber shall be made of pyrex glass and its internal volume shall be two liters minimum. The test chamber shall have the following:

5.1.1 A gas tight removable cover.

5.1.2 A sampling valve.

5.1.3 A sampling port capable of being sealed with a septum.

A laboratory vacuum dessicator may be utilized as a test chamber.

5.2 Oven - The oven shall be capable of providing a constant temperature of 200°F.

5.3 Test Gas Supply - The test gas shall be commercially available & conform to the appropriate specifications. Suitable equipment for transferring gas to test chamber shall be used.

5.4 Sample Transfer Equipment - Glass syringes, of 30 cc minimum capacity, shall be used for measuring and transferring the sample atmospheres from the test chambers to panel members face mask.

5.5 Pressure Gauge - The pressure gauge shall be capable of measuring absolute pressures to within ± 0.1 Torr accuracy.

5.6 Olfactometer - The olfactometer shall consist of a mask made of odorless flexible material which can be applied to a panel member's face.

5.7 All odor testing equipment shall be nonproducers of odor and carbon monoxide, under test conditions set forth under Section 8.0.

6.0 PRETEST PROCEDURE

6.1 Verify material identification as one of the items below:

6.1.1 Manufacturer's certification

6.1.2 NASA certification

6.1.3 Contractor certification

6.1.4 Definite identification not available

7.0 TEST SPECIMENS PREPARATION

7.1 All the materials tested shall be classified into four catagories; surface, volume, weight, or specialized items.

7.2 Samples based on Surface

This classification is defined as all those materials that are essentially two-dimensional. This would include films, fabrics, coatings, finishes, inks, primers, adhesives, thin film lubricants, tapes, and electrical insulating material.

The sample tested shall have a surface area of 46.5 ± 2.5 square inches per liter of test container. Coatings, finishings, etc. shall be coated on clean aluminum substrate of 0.020 ± 0.01 inch thickness. Material thickness, curing process, and method of application shall be in accordance with the manufacturer's recommendations. Material may be coated on both sides of the aluminum panel. Tapes and other similar materials with an adhesive surface shall be fastened to a similar aluminum panel. In all cases, only the outer surface of a material on the aluminum panel is counted in the surface area determinations. Films, fabrics, and similar materials shall be cut to give 46.5 ± 2.5 square inches surface area. Since these materials are two-surfaced in use, both the top and bottom surface shall be counted in determining total surface area. Heat shrinkable tubing shall be applied and shrunk to simulate actual use configuration.

7.3 Samples based on Volume

This classification is defined as all those materials having a definite volume but having a large real surface area due to surface convolutions or matting. These shall include foams and other blown or foamed materials and insulation padding.

Samples of these materials shall be cut to a thickness of 0.50 ± 0.05 inches unless the existing thickness is less than 0.40 inches. In this case, the existing thickness shall be used. The material shall be cut to such a size as to give 7.75 ± 0.75 square inches of total surface per liter of test container volume. All surface, tops, bottoms, and sides shall be used to compute total surface area. In cases where the natural thickness is such that the material cut would be too large to be placed into the container, two or more pieces may be cut as long as the total surface area requirement is met.

7.4 Samples based on Weight

This classification is defined as well as all those materials having a definite bulk and not falling into the volume classification. This shall include potting compounds, molding compounds, cast or formed objects, solid wires, and thick plastics. Liquids that are not used or applied as coatings or thin films shall be included.

The samples shall be used as much as possible in the supplied configuration and cut to give 5.0 ± 0.25 grams per liter of test container. Potted or molded materials shall be prepared and cured per manufacturer's directions and cut to weight. Liquids shall be placed in an aluminum dish 2.25 ± 0.25 inches in diameter. Sample weight shall be 5.0 ± 0.25 grams per liter.

7.5 Specialized Items

It must be recognized that some materials will not meet the above classifications and must be specially handled. This will most often occur with non-homogeneous materials. These cases will be tested in the manner designated by the test engineer in charge. The manner of testing and sample preparation shall be fully reported.

8.0 TEST CONDITIONS

8.1 The atmosphere and pressure in the test chamber at the start of exposure shall be that specified for each program.

8.2 The sample materials shall be heated at test temperature of 155° ± 5°F for a test duration of at least 72 hours.

8.3 Leak Check - The test system shall not increase in pressure more than one Torr. while remaining at a reduced pressure of one torr for a time period of one hour.

8.4 Odor evaluations shall be started within three hours of the conclusion of the thermal treatment.

8.5 All measuring equipment shall have the proper calibration stickers.

8.6 All equipment shall be cleaned in accordance with commonly accepted laboratory practices and shall be given a distilled water rinse and oven-dried at a minimum temperature of 200° F. The equipment shall be free of extraneous odors.

9.0 TEST PROCEDURE

The procedure shall be conducted in the following order.

9.1 Sample materials shall be prepared according to the conditions outlined under sample preparation in Section 7.0.

9.2 After placing the sample material in the test chamber, the chamber shall be evacuated to one Torr. or less. The test chamber shall then be pressurized to test pressure and test atmosphere.

9.3 The test chamber shall be exposed to a temperature of 155 ± 5°F in an oven for a time period of at least 72 hours, allowing time for initial warm-up.

9.4 Following the isothermal exposure, the test chamber shall be removed from the oven and allowed to return to room temperature.

9.5 The pressure in the test chamber shall be measured and recorded.

9.6 Observation of distillable residues on interior chamber walls shall be made and recorded.

9.7 The test chamber shall be pressurized to one atmosphere with test gas and a sampling septum installed.

9.8 Odor Test - Known volumes of sample atmosphere shall be extracted from the test chamber by means of a syringe and diluted with fresh gas in the following proportions:

9.8.1 One part of sample atmosphere to 29 parts of test gas.

9.8.2 One part of sample atmosphere to 9 parts of test gas.

9.8.3 No dilution, or as drawn from the flask.

9.8.4 A material that fails the criterion at any of the above dilutions shall terminate additional testing. Testing shall begin with the greatest dilution and progress toward no dilution.

10.0 REPORTING

Unless otherwise specified, the following test data and pertinent information concerning the materials shall be reported.

10.1 Name and positive identification (para. 6.0) of material.

10.2 Vendor designation and vendor.

10.3 Total rating numbers determined by the panel members.

10.4 Definition of the odor as interpreted by each panel member.

10.5 Status of the material as a result of the test.

10.6 Name and number of the test procedure.

10.7 Test pressure, atmosphere, and temperature.

10.8 Date of test.

10.9 Identity of the testing agency.

10.10 Name and signature of test coordinator.

SUPPLEMENTARY TEST NO. 17
GUIDELINES FOR SIMULATED PANEL AND ASSEMBLY FLAMMABILITY TESTS

1.0 PURPOSE

This procedure describes the method for determining the combustion characteristics, particularly the propagation rate, of a number of different size and areas of nonmetallic materials of similar or different types which make up a functional assembly, subsystem or system in the spacecraft. The sizes and areas of the materials are such that the materials fall into Category B of the Nonmetallic Materials Selection Guidelines and Test Requirements.

(Each item usually requires a specifically developed procedure. Guidelines for establishing the parameters of the test follow.)

2.0 OBJECTIVE

The objective of fire tests on assemblies is to determine the behavior of the assembly under the particular test conditions, and at the same time to furnish data which can be basis for the formulation of generalized fire models for the simulation of many different fire situations. In this fashion, a limited number of well instrumented fire tests on assemblies can lead to the ability to predict fire hazard situations for assemblies under a variety of conditions. The generation of this type of ability would simplify the problem of designing and assessing the reliability of manned spacecraft to a large extent. Each test, then, should be designed to be complete not only of itself, but also as a part of the overall picture of a model of the potential fire situation in the entire spacecraft.

3.0 TEST GUIDELINES

In general, two modes of ignition must be considered:

1. Ignition from an internal source, i.e., wire overload or short circuit.

2. Ignition from an external source, i.e., a flame or fire propagated from another nearby burning entity.

Naturally, the effects of burning of the assembly must be considered in light of its influence on the spacecraft external to the assembly, as well as the effects of the fire internal to the assembly.

The information desired as a result of the fire tests is:

A. Temperature distribution within the assembly.

B. Initial point of ignition.

C. Total heat generated.

D. Increase in pressure in the chamber.

E. Flame propagation paths within the assembly.

F. Heat transport paths away from the assembly.

G. Plume characteristics (temperature, size, shape).

H. Characteristics of burning (sparks, burning rate, drips, etc.)

I. Quantity and composition of combustion product gases.

The steps in the overall test program to obtain this information are as follows:

A. Define or select the test assembly. This should be a portion of the spacecraft which is a meaningful and convenient package for fire hazard testing and analysis. The portion selected shall be that definable area vulnerable to a potential fire.

B. Perform a fire hazard analysis on the test assembly.

   1. Material inventory

   2. Configuration analysis

   3. Thermal analysis

C. Design the fire test to produce the required information. The experimental design will be based on the fire hazard analysis.

D. Write detailed test procedure.

E. Conduct the test.

F. Report and evaluate the results.

G. Make recommendations.

2.2 Specific Guidelines

A. Test Conditions

1. Configuration and materials of the test assembly will duplicate exactly the flight article.

2. Test assembly (combustion element) will be oriented in the test chamber as it will be in the operational spacecraft at launch.

3. The test chamber volume will be sufficient to accomodate the largest assembly to be tested with adequate space around the assembly to allow observation of the extent of projection of burning pieces due to sputtering and expansion of gases internal to the burning mass.

4. For checking out an assembly mounted in a completed spacecraft, the test assembly must be identical to the one in the spacecraft. However, to demonstrate the feasibility of overcoating the flight assembly with a fire retardant compound and, thereby, render a retrofit unnecessary, the test assembly must be coated with the same fire retardant material and then tested for compliance with the flammability requirements.

5. The test assembly will be operational prior to and during the test and will be tested for operation after the test.

   a. The worst case, mode of operation, determined by the fire hazard analysis, will be selected.

   b. The test assembly will be in operation prior to the test until steady state conditions are reached.

6. For assemblies containing substitute materials or new designs, the test configuration need not be operational unless economically feasible. Only the nonmetallic materials shall be configured as in the flight article. Expensive components may be simulated, but the basic material, geometry and mass of the components must be the same as in the flight assembly.

7. All thermal interfaces will be simulated

   a. Cold plates

   b. Structure

   c. Convection due to the cabin fan

   d. Cabin radiation characteristics

8. Environment

a. Test chamber atmosphere temperature will be 75°F at start of test.

b. Atmosphere pressure per program requirements.

c. Gas mixture added to chamber at normal spacecraft addition rate (during testing).

9. Instrumentation

Instrumentation requirements for each test assembly will be determined on an individual basis as part of the overall combustion hazard analysis.

a. Temperature Measurements

Temperatures will be continuously recorded during testing.

(1) Temperature measuring and recording equipment will have response times equal to or greater than the rate of change of the location being measured as predicted by thermal calculations.

(2) Locations of temperature measurement devices will depend on the configuration of the assembly being tested. These should provide:

(a) A complete temperature profile of the assembly

(b) Location of ignition sites

(3) Measure ambient gas temperature.

(4) Measure chamber wall temperature.

b. Heat Flux Measurements

Measure radiant and total heat flux in all directions from the panel by the use of fast response calorimeters such as asymptotic types or equivalent.

c. Pressure Measurement

Continuously measure and record the chamber gas pressure.

d. Determine quantity and composition of combustion gas generated. Suggest GC, mass spectrometry methods.

B. Procedure

1. Test procedures or plans will be written and documented prior to each test.

2. Each test procedure will receive the approval of cognizant NASA/MSC personnel prior to test.

3. Ignition

Ignition will be accomplished at appropriate sites (determined by combustion hazard analysis) and will simulate the following fire conditions depending on most likely ignition means determined by the hazard analysis.

a. Momentary heat source

b. Ignition source with continuous heat input (internal)

c. External heat input

A rationale justifying selection of ignition point and means will accompany each test report.

C. Instrument Calibration

1. Standards

Secondary reference standards will be certified against primary reference standards maintained by the NBS. The type of standard and frequency of calibration shall be approved by the RASPO section.

2. Calibration Frequency

Test chamber control and indicating instrumentation shall normally be calibrated monthly against secondary standards. Test item measuring instrumentation shall be calibrated against secondary standards prior to any test.

3. Invalidation

Modification, repairs or changes shall invalidate the previous calibration and the instrumentation shall be recalibrated prior to reuse.

D. Post Test Inspection

The following comparable before and after test data will be obtained.

1. Color still photographs
2. Weight of individual materials
3. Operational characteristics
4. Visual inspection

3.0 TEST REVIEW AND APPROVAL

Specific test plans prepared for panel and assembly tests will be submitted by contractor and GFE organizations for MSC review, prior to the initiation of testing. The responsible test organization should commence test article configuration and instrumentation immediately. If MSC response is not received in 10 working days, test programs may be initiated and test plan approval assured.

APPENDIX B

SPECIAL TEST

TEST NO. 2

BOND STRENGTH TO ETCHED TEFLON AND KAPTON WIRE

1.0 PURPOSE

This test is designed to evaluate the bondability of the candidate potting, encapsulating, and conformal coating compounds to etched TFE Teflon wire insulation and FEP Teflon dispersion-coated Kapton wire insulation.

2.0 CRITERIA OF ACCEPTABILITY

Compounds shall fail in cohesive shear at no less than ten (10) pounds load, when the wiring they are encapsulating is subjected to a standardized tensile test. Adhesive failures allowing the wire to pull out of the compound are indicative of inadequate etching, and require retesting.

3.0 TEST EQUIPMENT

3.1 Tensile Tester, Instron, or equal.

3.2 Sample Holder, per Figure 1.

4.0 SAMPLE PREPARATION

4.1 The following wire insulations shall be used in testing each compound:

4.1.1 Three (3) samples of TFE Teflon insulated AWG 20 hookup wire, per MIL-W-22759, Type MS 21985. Each sample shall consist of five (5) wires, 24" long.

4.1.2 Three (3) samples of FEP Teflon overcoated Kapton insulated AWG 20 hookup wire, per MIL-W-81381/1 (AS). Each sample shall consist of five (5) wires, 24" long.

4.2 The wiring specimens of 4.1 shall be etched per MSC-SPEC-Q-3 (Appendix D).

4.3 The etched specimens shall be encapsulated in the sample holder of Figure 1, using the candidate compounds. The samples shall be cured, using recommended cure time/temperature cycle.

5.0 TEST PROCEDURE

5.1 Insert a pin through the hole in the bottom of the sample holder and attach to a clevis at the lower crosshead of the tensile tester.

5.2 Attach the wires under test to a lug provided at the upper crosshead.

5.3 Assure that clevises/lugs are attached to the tensile tester crossheads with spherically seated bolts to assure alignment of the force along the wire axis.

5.4 Set the moving crosshead speed at one inch per minute free head travel.

5.5 Conduct the test, assuring that the test wires are pulled completely free of the candidate compound.

6.0 RESULTS

6.1 Report the highest load carried by the wire under test as the ultimate load, for the three samples of each of the wire insulations of paragraph 4.1.

6.2 Report whether each specimen failed cohesively or adhesively.

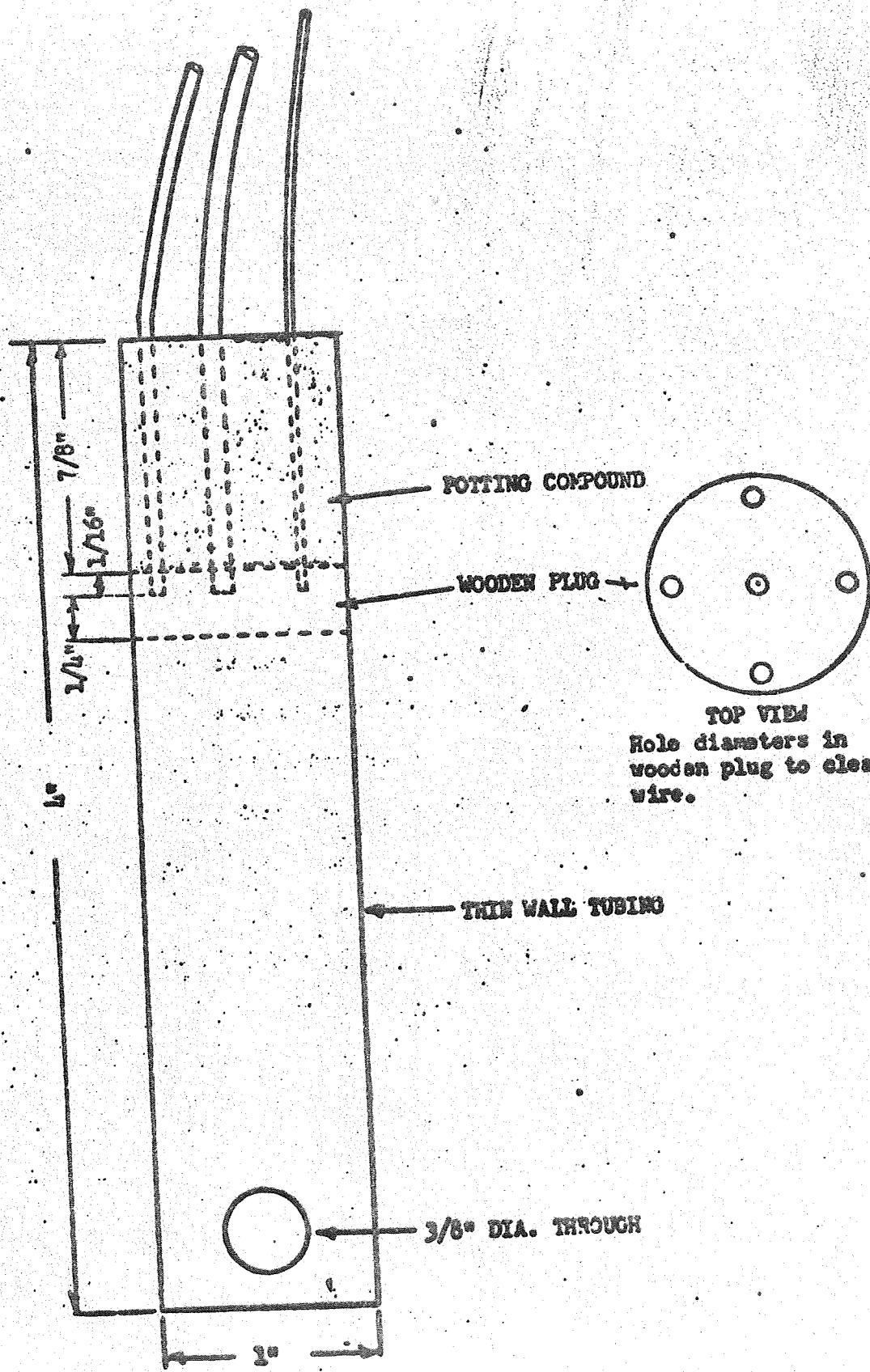


FIGURE 1 SAMPLE HOLDER CROSS-SECTION SHOWING METHOD OF POTTING WIRE SAMPLES FOR TENSILE TEST

APPENDIX C

MSFC-SPEC-202A

COMPOUND, POTTING AND MOLDING, ELASTOMERIC

December 11,1964

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPECIFICATION

COMPOUND, POTTING AND MOLDING, ELASTOMERIC

This specification has been approved by the George C Marshall Space Flight Center (MSFC) and is mandatory for use by MSFC and associated contractors.

1. SCOPE

1.1 Scope. - This specification establishes the requirements for a high temperature resistant, flexible, elastomeric, potting and molding compound for encapsulating connectors, printed circuit board, and components.

1.2 Classification. - Elastomeric potting and molding compounds shall be of the following types, as specified (see 6.2):

Type I - Hardness rating 45 - 60 Shore A (see table I).

Type II - Hardness rating 61 - 75 Shore A (see table I).

Type III - Hardness rating 76 - 99 Shore A (see table I)

2. APPLICABLE DOCUMENTS

2.1 The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposals shall apply.

SPECIFICATIONS

Federal

QQ-A-287	Aluminum Alloy Plate and Sheet, Alclad 7075.

TT-M-261	Methyl Ethyl-Ketone (for Use in Organic Coatings).

Military

MIL-R-3065	Rubber, Fabricated Parts.
MIL-E-5272	Environmental Testing, Aeronautical and Associated Equipment, General Specification for.
MIL-I-7444	Insulation Sleeving, Electrical, Flexible.

STANDARDS

Federal

Federal Test Method Standard No. 601	Rubber, Sampling and Testing (Test Method).

PROCEDURES

George C. Marshall Space Flight Center

MSFC-PROC-186	Potting and Molding Cable Assemblies, Using Polyurethane, Procedure for.

PUBLICATIONS

National Aeronautics and Space Administration

NPC 200-2	Quality Program Provisions for Space System Contractors.
NPC 200-3	Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. - The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposals shall apply.

American Society of Testing and Materials

D149	Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies.
D150	A-C Capacitance, Dielectric Constant, and Loss Characteristics of Electrical Insulating Materials.
D257	Electrical Resistance of Insulating Materials.
D395	Compression Set of Vulcanized Rubber.
D495	High-Voltage, Low-Current Arc Resistance of Solid Electrical Insulating Materials.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Phildelphia 3, Pa.)

3. REQUIREMENTS

3.1 Qualification. - The compound furnished under this specification shall be a product that has been tested, and passed the qualification tests specified herein, and has been listed on or approved for listing on the applicable qualified products list.

3.2 Samples.

3.2.1 Qualification sample. - The qualification sample shall meet all requirements of this specification (see 6.3).

3.2.2 Preproduction sample. - The preproduction sample, when required, shall meet all requirements of this specification (see 6.2).

3.3 Materials. - The compound covered by this specification shall be formulated from a chemically curing, synthetic elastomeric compound and such other ingredients necessary to produce a product to high quality

suitable for the purpose intended. The compound shall be supplied in two-part kits or premixed, degassed, and frozen. The compound may be supplied as a three part kit when the addition of a colorant is required.

3.3.1 Primer. - The use of a primer, to improve the adhesion of the molding compound to the base structure, is permitted. The primer shall be from the same manufacturer as the molding compound with which it is used and shall be applied in strict accordance with the manufacturer's recommendations.

3.3.2 Toxicity. - The compound shall contain no benzene, chlorinated solvents, or other highly toxic materials, either initially or as a product of the curing reaction.

3.3.3 Nonvolatile content. - The minimum nonvolatile content of the compound shall be 99 percent by weight.

3.3.4 Color additives. - Colors may be added if the electrical and physical properties are not reduced below the requirements of this specification.

3.4 Performance and product characterisitcs.

3.4.1 Appearance. - The compound shall be homogeneous and free from lumps and coarse particles. A skin is permissible on the base compound of two-part kits, but the skin shall be removed and discarded before mixing. There shall be no separation of pigment which cannot be readily dispersed.

3.4.2 Application. - The molding compound shall be capable of being readily applied by an injection or extrustion gun as specified in Procedure MSFC-PROC-186.

3.4.2.1 Application life. - The compound shall be suitable for application for a minimum of 60 minutes.

3.4.3 Curing time. - Cure shall be in accordance with the manufacturers instructions, except the curing time of the compound shall not exceed 7 days maximum at 24 $\pm$ 2 degrees Celsius (^{o}C), or 16 hours maximum at 82 $\pm$ 2^{o}C.

3.4.4 Storage life. - The premixed compound shall be capable of meeting the requirements of this specification when stored at minus 29 $\pm$ 2^{o}C for 7 days after receipt. The two-part compound shall be capable of meeting the requirements of this specification for 6 months when stored below 25 $\pm$ 2^{o}C.

3.4.5 Low temperature flexibility. - The compound shall not crack or separate from the test specimen when subjected to a temperature of minus 55°C for a minimum of 4 hours and tested as specified in 4.4.3.7.

3.4.6 Fungus resistance. - The compound shall show no evidence of support to fungus growth when subjected to actively growing fungi cultures.

3.4.7 Moisture resistance. - The insulation resistance of specimens prepared as specified in 4.3.3.5 shall be 200 megohms minimum when tested as specified in 4.4.3.11.

3.4.8 Ozone resistance. - The compound shall show no evidence of cracking when exposed for 7 days to an ozone concentration of 50 ± 3 parts per 100 million parts of air at 38 ± 1°C.

3.5 Physical properties. - The compound shall meet the requirements specified in table I when tested in accordance with the applicable test methods of section 4.

3.6 Product marking. - The compound shall be marked as specified in 5.3.

4. QUALITY ASSURANCE PROVISIONS

4.1 The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the procuring activity, that are covered by an inspection or quality control plan as required by the applicable NASA Quality Publication NPC 200-2 or NPC 200-3 as referenced in the contract (see 6.2). Unless otherwise specified, the inspection plan as required by NASA Quality Publication NPC 200-3 shall be submitted for review with the supplier's bid or proposal. Inspection and test records shall be kept complete and upon request made available to the procuring activity or its designated representative in accordance with NASA Quality Publication NPC 200-2, NPC 200-3, or other provisions of the contract or procurement document. The procuring activity, or its designated representative, reserves the right to perform any or all of the inspections set forth in the specification to assure that the end item conforms to the prescribed requirements.

4.2 Samples.

4.2.1 Qualification sample. - The qualification sample shall consist of at least 10 twenty ounce kits and 24 six ounce frozen cartridges representative of the identical material and manufacturing process that is used in production.

Table I. Physical properties*

Properties	Requirements
Dielectric constant	5.0 maximum
Power factor	0.09 maximum
Dielectric strength (50 mils)	500 volts/mil thickness maximum
Volume resistivity (ambient)	1×10^{12} ohms/centimeter minimum
Surface resistivity	1×10^{12} ohms minimum
Arc resistance	45 seconds minimum
Insulation resistance (ambient)	100,000 megohms minimum
Insulation resistance (100°C)	750 megohms minimum
High potential resistance (60 cps/minute)	No breakdown
Temperature resistance (100°C)	1×10^{9} ohms/centimeter minimum
Tear strength	Type I - 100 lbs/in. minimum Type II - 150/lbs/in. minimum Type III - 250 lbs/in. minimum
Tensile strength	Type I - 1,000 psi minimum Type II - 2,000 psi minimum Type III - 2,500 psi minimum
Elongation	Type I - 500% minimum Type II - 400% minimum Type III - 300% minimum
Shrinkage	3% maximum
Hardness (after full cure)	Type I - 45 - 60 Shore A Type II - 61 - 76 Shore A Type III - 76 - 99 Shore A
Compression set	Type I - 35% maximum Type II - 35% maximum Type III - 35% maximum
Viscosity (24°C) (freshly mixed from two-part kits)	Not less than 100 nor more than 300 poises
Viscosity (24°C) (freshly thawed when premixed and frozen)	Not less than 100 nor more than 450 poises
Adhesion bond strength (metal)	15 pounds/inch minimum
Adhesion bond strength (PVC)	15 pounds/inch minimum
Adhesion bond strength (neoprene)	15 pounds/inch minimum
Specific gravity	1.1 maximum

* Requirements for types II and III are the same as type I unless otherwise noted.

4.2.2 Preproduction sample. - When preproduction tests are required, the preproduction sample shall consist of at least 10 twenty fluid ounce kits and 24 six ounce frozen cartridges representative of the identical material and manufacturing process to be used in production. Performance test data shall be included with the preproduction sample submitted for approval. Preproduction sample examinations and tests shall be performed by the contractor under MSFC surveillance or as directed by the procuring activity, at the installation designated by the contract or order (see 6.2).

4.2.2.1 Preproduction sample rejection. - If any specimen of the preproduction sample fails to meet the requirements of any inspection specified herein, the preproduction sample shall be rejected. Before a new preproduction sample is submitted, a detailed report shall be forwarded to the procuring activity covering the rejection and the action taken to prevent recurrences of the defect causing failure. A reworked preproduction sample shall not be submitted. Production lots will not be considered for acceptance until the preproduction sample has been approved.

4.2.3 Acceptance inspection. - The acceptance sample shall be selected at random from each batch submitted for MSFC acceptance at any one time. The acceptance sample shall consist of a minimum of one kit or frozen cartridge from each of the batches submitted.

4.2.3.1 Acceptance inspection rejection. - If the acceptance sample fails any inspection specified herein, the entire batch represented by the sample shall be rejected. Before the rejected batch can be resubmitted for acceptance, a detailed report shall be forwarded to the procuring activity covering the rejections and the action taken to prevent recurrence of the defect causing failure. The defect causing failure and the corrective action taken will be the basis for permitting resubmittal. Any reworked batch must be accompanied by a detailed report concerning previous rejection and corrective action taken.

4.3 Examinations. - The compound shall be examined to determine conformance to 3.4.1 and 3.4.2. When ready for shipment, the compound shall be examined to determine conformance to the packaging, packing, and marking requirements of section 5.

4.4 Test procedure.

4.4.1 Test conditions.

4.4.1.1 Standard conditions. - Standard conditions are defined as $24 \pm 2^{\circ}C$ and 50 ± 5 percent relative humidity. Unless otherwise specified, tests shall be conducted at standard conditions.

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4.4.1.2 Thawing conditions. - The premixed frozen cartridges of molding compound shall be thawed for 30 minutes in a 49 + 1°C water bath or heating block when taken from a storage temperature of minus 29°C prior to testing.

4.4.1.3 Mixing and degassing. - When the material is supplied in two parts, the curing agent may partially crystallize. It is permissible to warm the curing agent in accordance with the manufacturer's recommendation, except the temperature shall not exceed 93 + 2°C and the curing agent shall not require more than 60 minutes to completely liquify, and become smooth and uniform without any crystallization or graininess when returned to 24°C after heating. Place the curing agent and the base compound in a clean dry metal or glass container having approximately twice the volume of the material. Mix the curing agent and the base compound thoroughly and degas at a pressure of less than 5 milliliters of mercury. The material shall be agitated or vibrated during degassing to break foam. Degas until foaming subsides. The time required to degas a one-pint quantity shall not exceed twenty minutes.

4.4.2 Qualification tests. - The qualification tests shall consist of all the tests specified herein.

4.4.3 Preproduction tests. - The preproduction tests, when required, shall consist of all the acceptance tests specified herein and the following tests. The items submitted to these tests shall be considered unserviceable but may be retained for examination by the procuring activity.

4.4.3.1 Dielectric constant and power factor. - Three disc specimens, 2 inches in diameter and 0.125 inch thick, shall be cured at standard conditions. Tests shall be conducted in accordance with ASTM method D150. The specimen shall be tested at 1 megacycle and at the standard test conditions (see 4.4.1) to determine conformance to 3.5.

4.4.3.2 Dielectric strength. - Five disc specimens, 4 inches in diameter and 50 mils thick, shall be prepared as specified in 4.4.1. The test shall be conducted in accordance with ASTM method D149.

4.4.3.3 Volume and surface resistivity. - Three disc specimens, 4 inches in diameter and 0.125 inch thick, shall be prepared as specified in 4.4.1. Tests shall be conducted in accordance with ASTM method D257 using a General Radio type 544B bridge, or equivalent instrument, with a test voltage of 500 volts. Readings shall be made after application of current. Calculations necessary for volume and surface resistivity shall be made using the approximate ASTM formulas for effective areas and effective perimeter. All specimens shall conform to the requirements of 3.5.

4.4.3.4 Arc resistance. - Three disc specimens, 4 inches in diameter and 1/8 inch thick shall be prepared as specified in 4.4.1. Tests shall be conducted in accordance with ASTM method D495 at a temperature of 24 ± 2°C. and 50 ± 5 percent relative humidity to determine conformance to 3.5. The surface of the test specimen shall be smooth and free from dust or other contamination.

4.4.3.5 Insulation resistance. - Three test specimens shall have dimensions as specified in figure 1. The mold in which the specimens are cast shall provide for the accurate spacing of brass rod electrodes. The electrodes shall be 0.125 inch in diameter and approximately 3 inches long. The electrodes shall be inserted at the opposite end of the cylindrical specimen in such a manner that 1.50 inches of the length of each pair is embedded in compound. Measurements shall be made by the megohm bridge using a potential of 500 volts. Electrification time shall not exceed 2 minutes. Tests shall be conducted at 24 and 100 ± 1°C after a conditioning period of 30 minutes at test temperature to determine conformance to 3.5.

4.4.3.6 High potential. - Test specimens as specified in 4.4.3.5 shall be utilized for this test. A potential of 1,000 volts root mean square, 60 cycles per second shall be applied between all contacts, for a period of 1 minute. The test voltage shall be applied gradually at the rate of 500 volts each second to determine conformance to 3.5.

4.4.3.7 Low temperature flexibility. - Three test specimens of aluminum alloy, measuring 1 by 6 by 0.032 inches conforming to Specification QQ-A-287 will be used for the test. The recommended primer (see 3.3.1) shall be applied to one side of the test specimens, then a quantity of compound shall be mixed and applied over the primer in a manner which will produce cured coatings with a thickness of 0.050 inch to 0.066 inch, leaving 1 inch at each end of the test specimens uncoated. The test specimens shall be inserted in a flexibility jig as shown in figures 2 and 3, so that the uncoated side will contact the contour block and the weight will contact only the uncoated end of the test specimens. The flexibility jig and test specimens shall be subjected to a conditioning temperature of minus 55 ± 1°C for 4 hours. After the specified conditioning, the specimens shall then be bent around the curved portion of the flexibility test jig by releasing the fastening hook. The test specimens shall be removed and examined to determine conformance to 3.5.

4.4.3.8 Temperature resistance. - The volume resistivity shall be determined in accordance with paragraph 4.4.3.3, except the testing shall be conducted at 100 ± 1°C after a conditioning period of 30 minutes at the test temperature to determine conformance to 3.5.

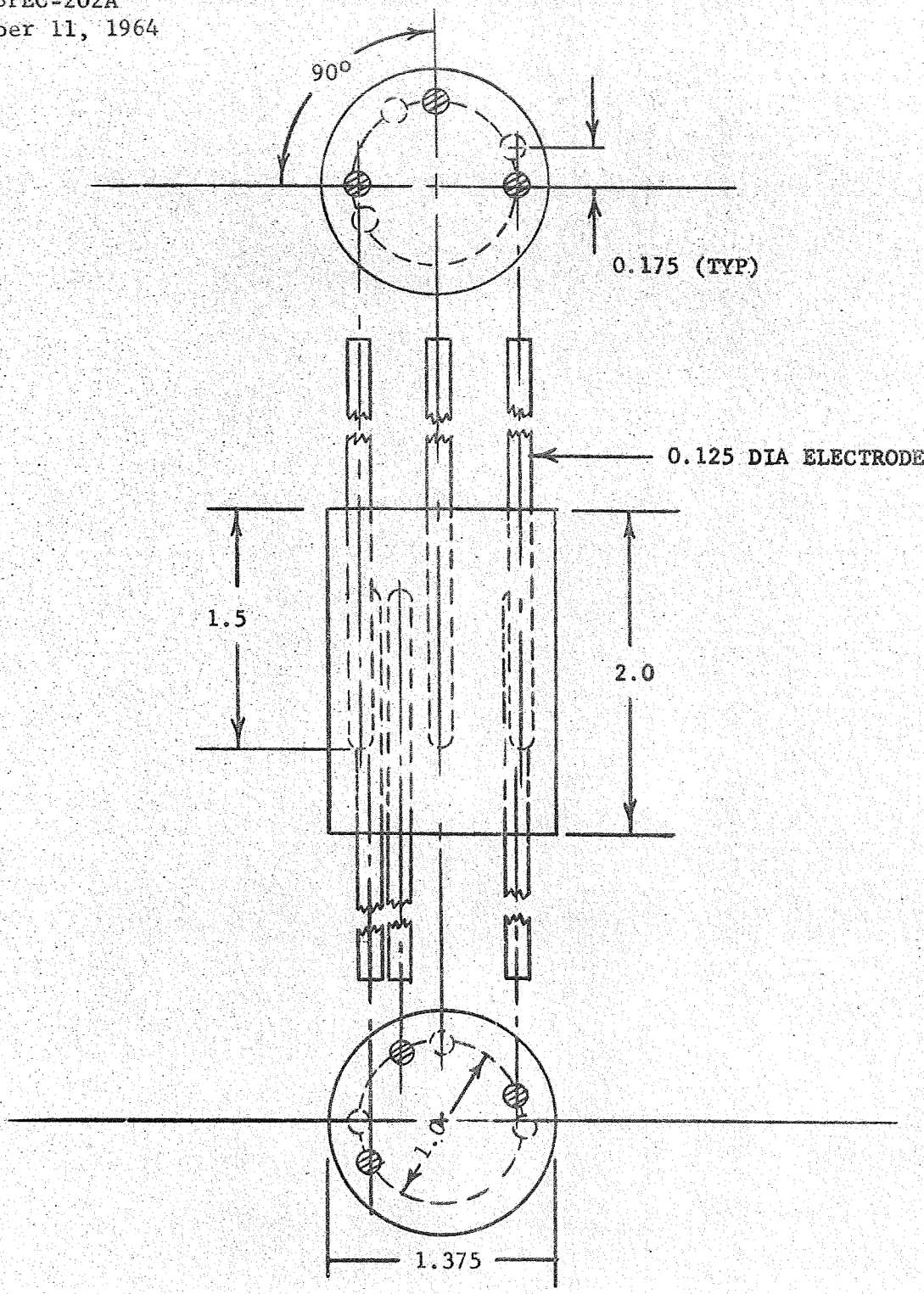

Figure 1. Insulation resistance test specimen.

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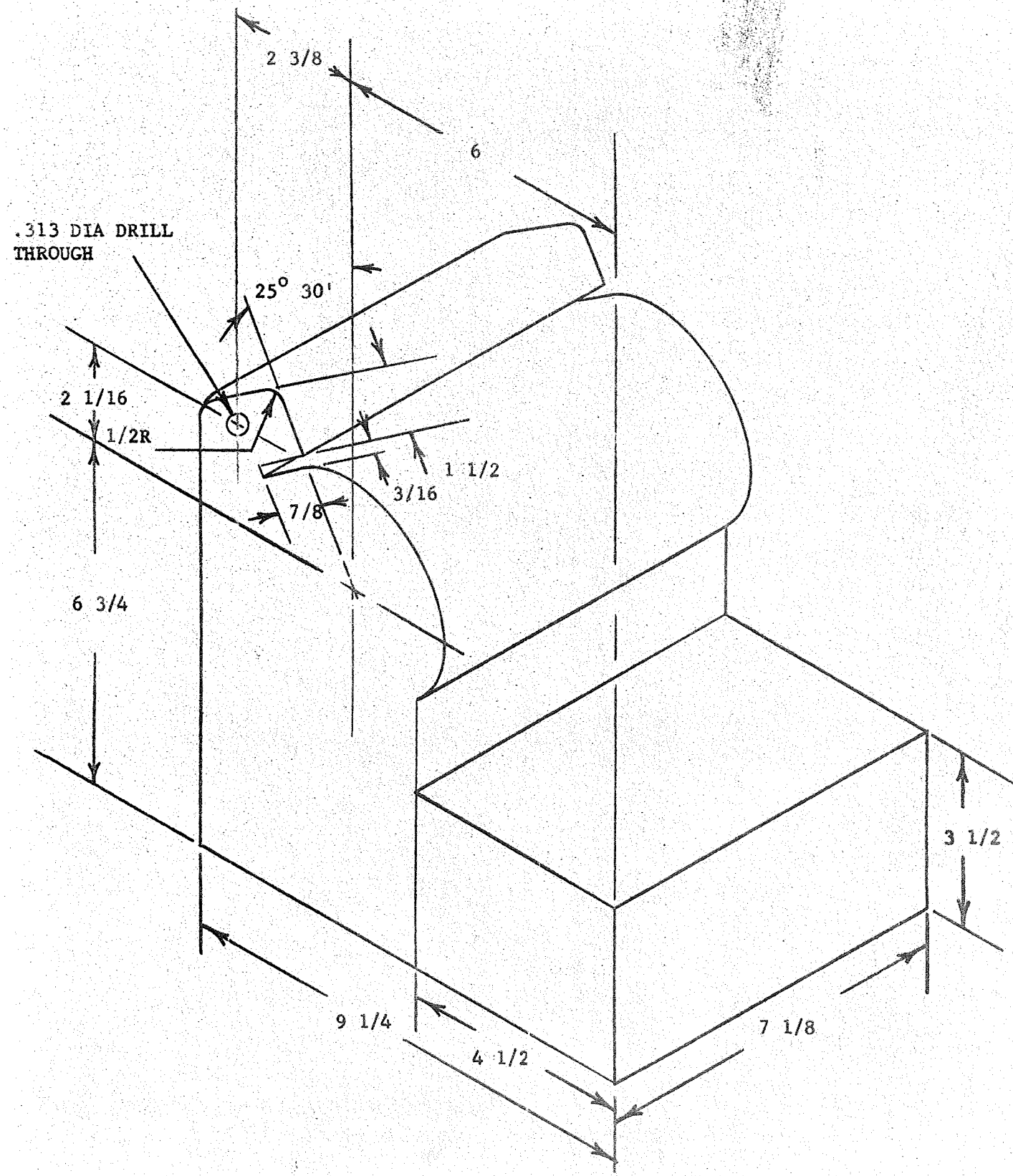

Figure 2. Contour block.

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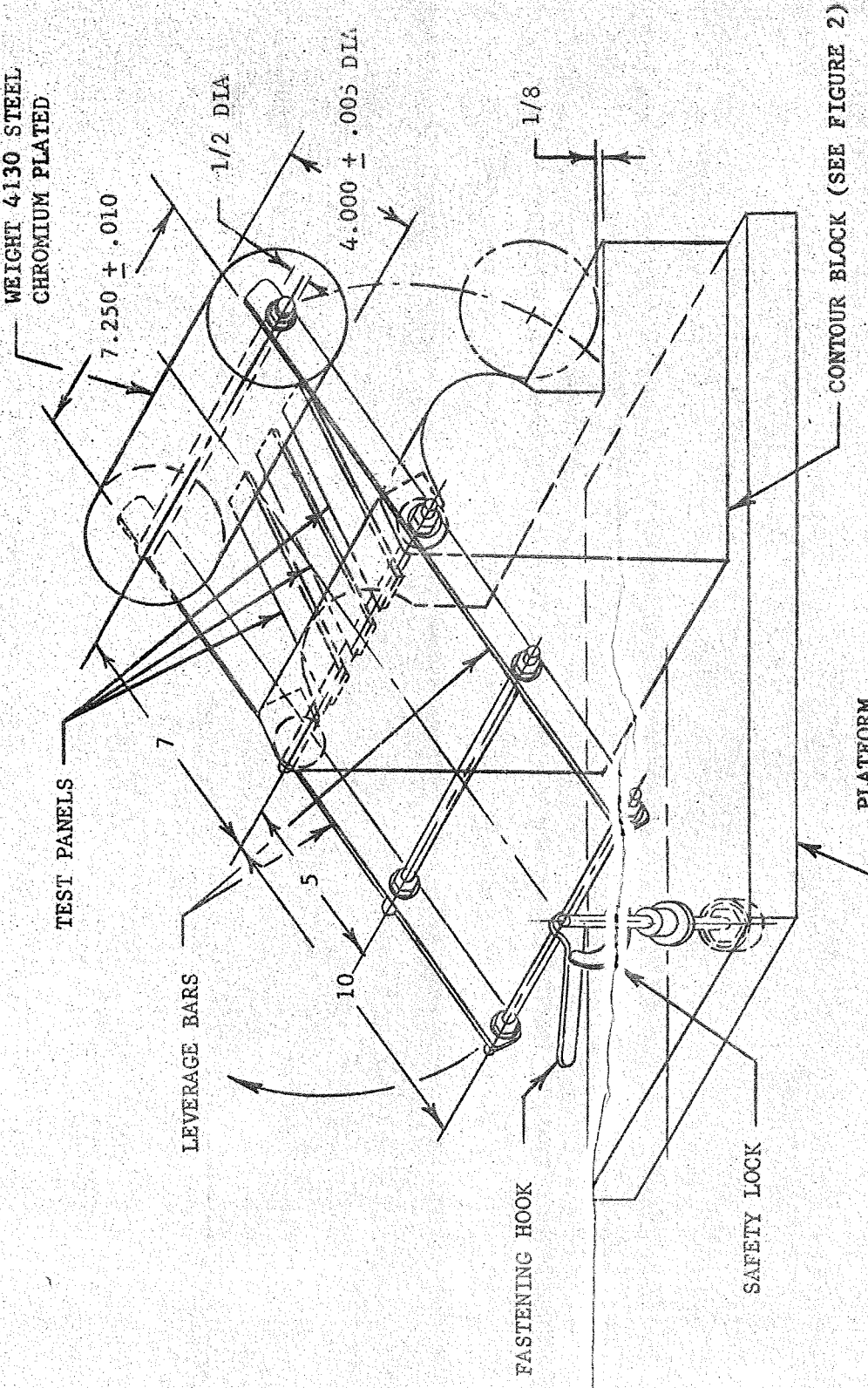

Figure 3. Low temperature flexibility apparatus.

4.4.3.9 Fungus resistance. - The test specimen shall be tested in accordance with procedure I of Specification MIL-E-5272 to determine conformance to 3.4.6.

4.4.3.10 Tear strength. - Test specimens cured in accordance with manufacturer's instructions shall be subjected to the tear resistance tests in accordance with method 4211 of Federal Test Method Standard Number 601 to determine conformance to 3.5. The test specimens shall be cut with a model C die. An optional method of preparing the tear strength test specimen shall be direct molding that will result with exact dimensions of the specimen cut with a model C die.

4.4.3.11 Moisture resistance. - Three test specimens cast for insulation resistance shall have dimensions as specified in figure 1. The mold in which the specimens are cast shall provide for the accurate spacing of brass rod electrodes. The electrodes shall be 0.125 inch diameter and approximately 3 inches long. They shall be inserted at the opposite end of the rectangular specimen in such a manner that 1.50 inches of the length of each pair shall be spaced 0.050 $\pm$ 0.010 inch apart. Four pairs of electrodes shall be spaced at least 0.750 inch apart. The specimens shall be placed in a humidity chamber at 24 $\pm$ 1°C. The chamber temperature shall be raised uniformly to 71 $\pm$ 1°C during a two hour period maintaining 95 percent relative humidity. These conditions shall be maintained for six hours. During the next 16 hour period, the temperature of the chamber shall drop at a uniform rate to 26 $\pm$ 1°C. This shall constitute one cycle. A test shall consist of five complete cycles after which the test specimen shall be tested as specified in 4.4.3.5 to determine conformance to 3.4.7.

4.4.3.12 Tensile strength or elongation. - The tensile strength or elongation testing shall be in accordance with method 4111 of Federal Test Method Standard Number 601. The dumbbell specimens shall be cut from the cast sheets of the molding compound cured for 16 hours at 82 $\pm$ 2°C. The procedure for determining elongation shall be in accordance with method 4121 of Federal Test Method Standard Number 601 to determine conformance to 3.5.

4.4.3.13 Shrinkage. - A cubical mold, approximately 1.0 inch on each side and having an open top shall be utilized for the test. The volume at 23 $\pm$ 1°C shall be determined. Mixed compound shall be cast into the mold, and cured in accordance with the manufacturer's instructions. The specimen shall then be cooled, examined and its volume at 23 $\pm$ 1°C determined by the water displacement method. The percent shrinkage shall be calculated as follows:

$$\text{Percent shrinkage} = \frac{V_1 - V_2}{V_1} \times 100$$

V_1 = Volume of the mold and

V_2 = Final volume of component

4.4.3.14 Compression set. - The compound shall be tested in accordance with ASTM D395, Method B, except the standard test specimen shall be prepared by direct molding of the circular disc 0.500 inch thick and 1.129 inches in diameter using a suitable mold. The compression employed shall be 20 percent for all hardness.

4.4.3.15 Resistance to ozone. - Five test specimens 1 inch wide by 4 inches long by 0.075 to 0.089 inches thick, shall be prepared as specified in 4.4.1. Bench marks shall be made 1 inch apart centered perpendicular to the length of the specimen. The specimens shall be mounted in a suitable frame which can be adjusted in such a manner that the specimens will be tensioned sufficiently that 1 inch bench marks will be separate to 1.250 inches. The frame and specimens shall be exposed for 7 days to an ozone concentration of 50 $\pm$ 3 parts per 100 million parts air at 38 $\pm$ 1°C. At the end of the exposure time the specimens shall be examined under a 7 power magnifier to determine conformance to 3.4.3.

4.4.3.16 Storage life.

4.4.3.16.1 Two-part kits. - The two-part kits shall be subjected to all examinations and tests specified herein after being stored for 6 months at a temperature below 26 $\pm$ 2°C to determine conformance to 3.4.4.

4.4.3.16.2 Frozen compound. - The frozen premixed compound shall be subjected to all examinations and tests specified herein after being stored for 7 days at minus 28 $\pm$ 1°C to determine conformance to 3.4.4.

4.4.4 Acceptance tests.

4.4.4.1 Nonvolatile content. - Fresh molding compound shall be transferred immediately to tared containers 1.750 inches in diameter and 1.250 inches deep (Central Scientific number 44356, aluminum culture dish, or an approved equal). The compound shall be leveled even with the top of the dish. The dish shall be weighed. The dish shall then be exposed to 82 $\pm$ 1°C for 24 $\pm$ 1 hours. The samples shall then be removed from the oven and allowed to cool to room temperature. The dish shall then be weighed to determine conformance to 3.3.3. Percent nonvolatile content equals the weight of compound after heating times 100 divided by the weight of compound before heating.

4.4.4.2 Viscosity. - Viscosity determinations on the base material with the addition of a curing agent shall be made with the Brookfield Viscosimeter, Model RVF, with a number 7 spindle, operated at 10 revolutions per minute or with approved equivalent equipment. The base material and the viscosimeter shall be at a uniform temperature of 24 ± 2°C during the test. The base material shall be thoroughly stirred immediately before testing. Readings shall be taken when the pointer first assumes a steady position after release of the clutch to determine conformance to 3.5.

4.4.4.3 Specific gravity. - The test specimen shall be tested in accordance with method 14011 of Federal Test Method Standard Number 601 to determine conformance to 3.5.

4.4.4.4 Application life.

4.4.4.4.1 Two-part material. - A 250 gram sample of mixed compound shall be used to determine application life, which shall commence at the end of the mixing period. A standard one-half pint can with its retaining flange removed shall be utilized for testing in conjunction with a Brookfield Viscosimeter, Model RVF, equipped with a number 7 spindle and operated at 10 revolutions per minute. Consistency shall be determined at the end of a 50 minute period. Supplemental readings shall be made at 10 minute intervals until a reading of 1,000 poises is attained which shall be considered as the end of the application life test. The spindle shall not be drawn from the material during the test. Readings shall be taken when the pointer on the viscosimeter dial first assumes a steady position after a minimum of three revolutions to determine conformance to 3.5.

4.4.4.4.2 Premixed, frozen compound. - A 6 fluid ounce compound cartridge thawed in accordance with 4.4.1.2 shall be equipped with a 4 inch nozzle having a 0.125 ± 0.005 inch orfice. The gun and material shall be maintained at a standard condition throughout the test. The gun shall be attached to a constant air supply of 75 ± 5 pounds per square inch. From 2 to 3 inches of material shall be extruded initially to fill the nozzle and clear any entrapped air. Material will be extruded into a suitable container and application life determined as specified in 4.4.4.4.1.

4.4.4.5 Hardness. - The hardness tests shall be performed in accordance with method 3021 of Federal Test Method Standard Number 601 to determine conformance to 3.5.

4.4.4.6 Adhesion.

4.4.4.6.1 Metal test specimens. - A 3 by 6 approximately 0.0625 inch aluminum alloy panel conforming to Specification QQ-A-287 shall be cleaned with a solvent such as methyl-ethyl-ketone conforming to Specification TT-M-261. Clean cotton gauze sponges shall be used to wipe the wet solvent from the surfaces to avoid redeposit of contaminants. The cleaned surfaces shall be primed with a thin coat of primer recommended by the molding compound manufacturer, and allowed to dry in accordance with the manufacturer's recommendations, but not to exceed 60 minutes. A 0.125 inch coating of the molding compound shall be applied to the primed metal panel. A 3 by 6 inch area of a 3 by 12 inch strip of cotton duck sheeting shall be intimately coated on one side with molding compound and placed on the panel, leaving a loose end approximately 6 inches in length. The panel shall be cured for 16 hours at 82 $\pm$ 2°C. Two 1 inch wide strips shall be cut through the compound and fabric to the panel surface and extended the full length of the loose end of the fabric. The edge of the panel shall not be used as one edge of the test strip.

4.4.4.6.2 Rubber test specimens. - A 1.50 by 0.075 inch thick (nominal) rubber specimen qualified to Specification MIL-R-3065, SC 615 shall be buffed with a suitable abrasive to clean the surface. The method of abrasion shall assure complete breaking of the surfaces to be primed. Loose dust shall be removed by blowing off with clean dry air and wiping the surfaces with the primer recommended by the molding compound manufacturer. A thin coat of the same primer shall be applied and allowed to dry in accordance with the manufacturer's instructions, but not to exceed 60 minutes. The primed rubber shall be placed primed side down on the mold (see figure 4) and secured in place with masking tape. The assembled mold shall be placed rubber side down on a flat surface and the cavity shall be completely filled with the molding compound to a slight crown. A metal panel cleaned and primed shall be placed on top of the mold. The test specimen shall be cured with the rubber sides down for 16 hours at 82 $\pm$ 2°C and then allowed to cool at least 12 hours at room temperature prior to testing.

4.4.4.6.3 Vinyl test specimen. - A 6 inch sample of vinyl tubing conforming to Specification MIL-I-7444, 0.50 inch in diameter or larger shall be split lengthwise and the surface to the vinyl tubing to primed shall be made tacky by applying methyl-ethyl-ketone conforming to Specification TT-M-261 before prime application. The surfaces shall then be coated with a primer recommended by the molding compound manufacturer and allowed to become tack-free. The test specimen shall then be prepared in the same manner as the rubber specimen in paragraph 4.4.4.6.2.

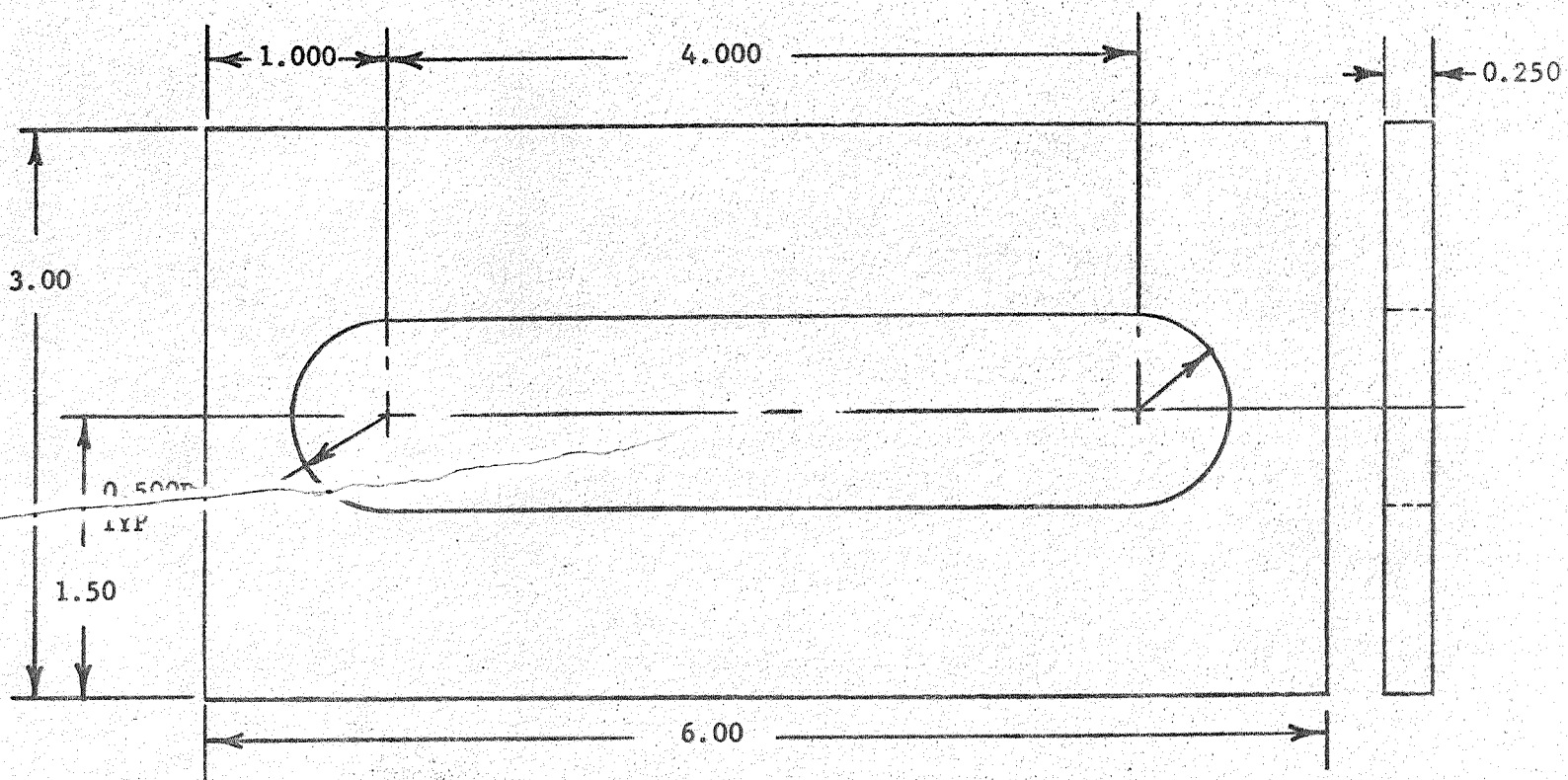

Figure 4. Adhesion test setup.

4.4.4.6.4 Test method. - The test specimens prepared as specified in 4.4.4.6.1 through 4.4.4.6.3 shall be tested in accordance with method 8031 of Federal Test Method Standard Number 601, except that a 180 degree pull and a jaw separation rate of 2 ± 0.125 inch per minute shall be used to determine conformance to 3.5.

5. PREPARATION FOR DELIVERY

5.1 Two-part kits. - The base compound and curing agent shall be packaged in individual containers. The ratio of the quantity contained in the base compound container to the quantity contained in the curing agent container shall be the same as the recommended mixing ratio of the base compound and curing agent.

5.1.2 Frozen compound. - The frozen compound shall be premixed, degassed, and packaged in 5, 6, or 12 ounce Pyles Industries Model 950C Polyethylene Cartridges, or approved equal, complete with plunger and cartridge cap.

5.2 Packing. - All exterior shipping containers in the shipment shall contain the same number of the type of unit packages. Shipping containers shall be of uniform size and shall be so designed as to insure that damage is prevented during handling and shipping. Frozen shipments shall be packed in a manner that will prevent thawing or other damage during transit.

5.3 Marking.

5.3.1 Base compound containers. - Each base compound container shall be durably and legibly marked with the following information:

(a) Title, number, and date of this specification.

(b) Classification (see 1.2).

(c) Manufacturer's name and address.

(d) Manufacturer's product designation.

(e) Manufacturer's batch designation.

(f) Manufacturer's batch designation for the curing agent that the base compound is to be used with.

(g) Stock number.

(h) Date of manufacture.

(i) Contract number.

(j) Quantity contained.

5.3.2 Curing agent container. - Each curing agent container shall be durably and legibly marked with the following information:

(a) Manufacturer's name and address.

(b) Manufacturer's product designation.

(c) Manufacturer's batch designation.

(d) Manufacturer's batch designation for the base compound that the curing agent is to be used with.

(e) Date of manufacture.

5.3.3 Frozen cartridges. - Each frozen cartridge shall be durably and legibly marked with the following information:

(a) Title, number, and date of this specification.

(b) Classification (see 1.2).

(c) Manufacturer's name and address.

(d) Manufacturer's product designation.

(e) Manufacturer's batch designation.

(f) Stock number.

(g) Date of manufacture.

(h) Contract number.

(i) Quantity contained.

5.3.4 Exterior shipping containers. - Each exterior shipping container shall be legibly and durably marked with adequate instructions to insure that damage during handling and shipping is prevented. Instructions for handling to prevent thawing during transit from manufacturer to procuring activity and storage after receiving shall be marked on all exterior shipping containers for frozen cartridges.

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6. NOTES

6.1 Intended use. - This specification is intended for use in qualifying elastomeric compounds (for potting and molding) to be used in space vehicle and associated equipment.

6.2 Ordering data. - Procurement documents should specify the following:

(a) Title, number, and date of this specification.

(b) Type of elastomeric compound.

(c) Whether a preproduction sample is required (see 3.2.2).

(d) Where preproduction or tests are to be performed (see 4.2.2).

(e) Applicable quality publication (see 4.1).

6.3 Provisions for qualification. - With respect to products requiring qualification, awards will be made only for such products as have, prior to the bid opening date, been tested and approved for inclusion in the applicable qualified products list whether or not such products have actually been so listed by that date. The attention of suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the procuring activity tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. Requests for information pertaining to qualification of products covered by this specification should be addressed to:

Chief, Electrical Equipment Section
Electrical Systems Integration Division
Astrionics Laboratory
George C. Marshall Space Flight Center
Huntsville, Alabama

Notice. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be

regarded by implication or otherwise as in any manner licensing the holder or any other person, corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodian:

NASA - George C. Marshall Space Flight Center

Preparing activity:

George C. Marshall Space Flight Center

APPENDIX D

MSFC-SPEC-393A
Amendment 1

COMPOUND, PRINTED CIRCUIT BOARD
CONFORMAL COATING, ELASTOMERIC

and

MSFC-SPEC-393A
October 9, 1964

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPECIFICATION

COMPOUND, PRINTED CIRCUIT BOARD CONFORMAL COATING, ELASTOMERIC

The amendment forms a part of George C. Marshall Space Flight Center (MSFC) Specification MSFC-SPEC-393A, dated April 19, 1965, and has been approved by MSFC and is available for use by MSFC and associated contractors.

(1) Page 8, paragraph 4.5.1.3, line 4: Change "60 degrees C" to read "93 $\pm$ 6 degrees C."

Custodian:	Preparing activity:
NASA - George C. Marshall Space Flight Center	George C. Marshall Space Flight Center

MSFC-SPEC-393A
April 19, 1965
SUPERSEDING
MSFC-SPEC-393
October 9, 1964

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPECIFICATION

COMPOUND, PRINTED CIRCUIT BOARD, CONFORMAL COATING, ELASTOMERIC

This specification has been approved by the George C. Marshall Space Flight Center (MSFC) and is mandatory for use by MSFC and associated contractors.

1. SCOPE

1.1 Scope. - This specification establishes the requirements for a high temperature resistant, flexible, elastomeric compound for conformal coatings, printed circuit boards, and components.

1.2 Classification. - Coating compound shall be of the following type:

Type I - Physical properties shall be as specified in table I.

NOTE

Additional types will be added when qualified by MSFC.

2. APPLICABLE DOCUMENTS

2.1 The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or request for proposals shall apply.

SPECIFICATIONS

Federal

QQ-A-287 Aluminum Alloy Plate and Sheet, Alclad 7075.

TT-M-261	Methyl-Ethyl-Ketone (for Use in Organic Coatings).
TT-X-916	Xylene (for Use in Organic Coatings).

Military

MIL-E-463	Ethyl Alcohol (for Ordnance Use).
MIL-C-5015	Connectors, Electric, "AN" Type.
MIL-E-5272	Environmental Testing, Aeronautical and Associated Equipment, General Specification for.
MIL-A-6091	Alcohol, Ethyl, Specially Denatured, Aircraft.
MIL-I-8660	Insulating and Sealing Compound, Electrical.
MIL-I-10428	Isopropyl Alcohol, Technical.

George C. Marshall Space Flight Center

MSFC-SPEC-377	Plastic Sheet, Laminated, Copper-Clad (for Printed Wiring), Specification for.

STANDARDS

Federal

FED-STD-406	Plastics, Methods of Testing.
FED-STD-601	Rubber, Sampling and Testing.

PROCEDURES

George C. Marshall Space Flight Center

MSFC-PROC-293	Coating, Conformal (Polyurethane), Printed Circuit Assemblies, Procedure for.

PUBLICATIONS

National Aeronautics and Space Administration (NASA)

NPC 200-2	Quality Program Provisions for Space System Contractors.
NPC 200-3	Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. - The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposals shall apply.

American Society for Testing and Materials (ASTM)

ASTM D150-59T	Methods of Test for A-C Capacitance, Dielectric Constant, and Loss Characteristics of Electrical Insulating Materials.
ASTM D257-61	Methods of Test for Electrical Resistance of Insulating Materials.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia 3, Pennsylvania.)

3. REQUIREMENTS

3.1 Qualification. - The compounds furnished according to this specification shall be a product that has been tested, has passed the the qualification tests specified herein, and has been listed on or approved for listing on the applicable qualified products list.

3.2 Samples.

3.2.1 Qualification. - The qualification sample shall be capable of meeting the requirements of this specification (see 6.3).

3.2.2 Preproduction. - The preproduction sample, when required (see 6.2), shall be capable of meeting all the requirements of this specification.

3.2.3 Quality assurance. - The quality assurance sample, when required (see 6.2), shall be capable of meeting all the requirements of this specification.

3.3 Materials. - The compound covered by this specification shall be formulated from a chemically curing, synthetic, elastomeric compound. The compound shall be supplied in two-part kits or premixed, degassed, frozen cartridges.

3.3.1 Primer. - The use of a primer, to improve adhesion of the coating compound to the base structure, is permitted. The primer shall be from the same manufacturer as the coating compound with which it is used and shall be applied in strict accordance with the manufacturer's recommendations.

3.3.2 Toxicity. - The compound shall contain no benzene, chlorinated solvents, or other highly toxic materials, either initially or as a product of the curing reaction.

3.3.3 Nonvolatile content. - The minimum nonvolatile content of the compound shall be 99 percent by weight.

3.4 Performance and product characteristics.

3.4.1 Appearance. - The compound shall be homogeneous and free from lumps and coarse particles. The base compound of two-part kits shall not solidify at 16 degrees Celsius (C) or above. A skin is permissible on the base compound of two-part kits, but the skin shall be removed and discarded before mixing. There shall be no separation of pigment which cannot be readily redispersed.

3.4.2 Application. - The coating compound shall be capable of being readily applied by a spray gun as specified in Procedure MSFC-PROC-293.

3.4.2.1 Application life. - The compound shall be suitable for application for a minimum of 60 minutes.

3.4.3 Curing time. - The curing time of the compound shall be 7 days maximum at 24 $\pm$ 3 degrees C, or 16 hours maximum at 82 $\pm$ 3 degrees C.

3.4.4 Storage life. - The premixed compound shall be capable of meeting the requirements of this specification when stored at minus 29 degrees C for 7 days after mixing. The two-part compound shall be capable of meeting the requirements of this specification when stored for 6 months at 27 degrees C maximum.

3.4.5 Fungus resistance. - The compound shall show no evidence of deterioration when subjected to fungus growth as encountered in tropical climates.

3.4.6 Moisture resistance. - When tested as specified in 4.5.2.10, the insulation resistance of specimens preprared as specified in 4.5.2.5 shall be 200 megohms minimum.

3.5 Physical properties. - The compound shall meet the requirements specified in table I when tested in accordance with the applicable test methods of section 4.

3.6 Product marking. - The compound shall be marked as specified in 5.3.

3.7 Corrosion on metal parts. - The parts shall show no evidence of corrosion when in contact with the conformal coating material.

4. QUALITY ASSURANCE PROVISIONS

4.1 The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to MSFC that are covered by the applicable NASA Quality Publication NPC 200-2 or NPC 200-3 as referenced in the contract (see 6.2). Unless otherwise specified, the inspection plan as required by NASA Quality Publication NPC 200-3 shall be submitted for review with the supplier's bid or proposal. Inspection and test records shall be kept complete and, upon request, made available to the procuring activity or its designated representative in accordance with NASA Quality Publication NPC 200-2, NPC 200-3, or other provisions of the contract or procurement document. The procuring activity, or its designated representative, reserves the right to perform any or all of the inspections set forth in the specification to assure that the end item conforms to the prescribed requirements.

4.2 Samples.

4.2.1 Qualification. - The qualification sample shall consist of at least 100 fluid ounces in 5 or more kits and if packed in frozen cartridges twelve 6-ounce kits representative of the identical material and manufacturing processes to be used in production.

Table I. Physical properties

Properties	Requirements - Type I
Dielectric constant	5.0 maximum
Dissipation factor	0.09 maximum
Dielectric strength (50 mils)	500 volts/mil thickness minimum
Volume resistivity (ambient)	1×10^{12} ohms-cm minimum
Surface resistivity	1×10^{12} ohms minimum
Arc resistance	45 seconds minimum
Insulation resistance (ambient)	100,000 megohms minimum
Insulation resistance (125 degrees C)	750 megohms minimum
High potential resistance 60 cps/1 minute	No breakdown
Temperature resistance (125 degrees C)	1×10^{9} ohms/cm minimum
Tear strength	125 psi minimum
Tensile strength	1400 psi minimum
Elongation	500 percent minimum
Shrinkage	3 percent maximum
Hardness (after full cure)	80-90 (Shore A)
Compression set	30 percent maximum
Viscosity (24 degrees C) (freshly mixed from two-part kits)	250 poises maximum
Viscosity at 45 degrees C	100 poises maximum
Viscosity (24 degrees C) (freshly thawed when premixed and frozen)	Not less than 100 poises nor more than 450 poises
Adhesion bond strength (metal) (epoxy fiberglass)	15 lbs/inch minimum (without primer)
Specific gravity	1.2 maximum
Nonvolatile content	99 percent by weight

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4.2.1.1 Qualification rejection. - If any specimen of the qualification sample fails to meet the requirements of any inspection specified herein, the qualification sample and the entire lot shall be rejected and a detailed report covering the cause(s) for rejection shall be forwarded to the manufacturer. A reworked qualification sample shall not be submitted.

4.2.2 Preproduction. - Unless otherwise specified by the procuring activity, the preproduction sample shall consist of at least five kits, twenty fluid ounces each, and twelve, 6-ounce frozen cartridges representative of the identical material and manufacturing processes to be used in production.

4.2.2.1 Preproduction rejection. - If any specimen of the preproduction sample fails to meet the requirements of any inspection specified herein, the preproduction sample shall be rejected. Before a new sample is submitted, a detailed report shall be forwarded to the procuring activity covering the rejection and the action taken to prevent recurrence of the defect causing failure. A reworked preproduction sample shall not be submitted. Production lots will not be considered for acceptance until the preproduction sample has been approved.

4.2.3 Quality assurance. - The quality assurance sample shall be selected at random from the production lots submitted for acceptance. The quality assurance sample shall be subjected to all examinations and tests specified herein (see 6.2).

4.2.3.1 Quality assurance rejection. - If any specimen of the quality assurance sample fails any inspection specified herein, the entire lot represented by the sample shall be rejected. Before the rejected lot can be resubmitted for acceptance, a detailed report shall be forwarded to the procuring activity covering the rejection and the action taken to prevent recurrence of the defect causing failure. The defect causing failure and the corrective action taken will be the basis for permitting resubmittal. Any reworked lot must be accompanied by a detailed report concerning previous rejection and corrective action taken.

4.2.4 Acceptance inspection. - The acceptance sample shall be selected at random from each lot submitted for acceptance and shall consist of one kit or frozen cartridge from each of the lots submitted for acceptance at any one time as specified in the contract or order.

4.2.4.1 Acceptance inspection rejection. - Any item that fails any acceptance inspection shall be rejected. Rejected items may be resubmitted at the discretion of the procuring activity, after corrective action has been taken. The number and type of defects shall be the basis for permitting resubmittal. Any reworked items shall be accompanied by a detailed report concerning the previous rejection and corrective action taken.

4.3 Examination. - The compound shall be examined to determine conformance to the requirements of 3.4.1, 3.4.2, and 3.6. Upon completion of testing, examine preservation, packaging, packing, and marking for conformance to the requirements of section 5.

4.4 Qualification tests. - The qualification tests shall consist of all the tests specified herein.

4.5 Test procedures.

4.5.1 Test conditions.

4.5.1.1 Standard conditions. - Standard conditions are defined as 24 ± 5 degrees C and 50 percent maximum relative humidity. Unless otherwise specified, tests shall be conducted at standard conditions.

4.5.1.2 Thawing conditions. - The premixed frozen cartridges of coating compound shall be thawed for 30 minutes in a 49 ± 3 degrees C thermostatically controlled oven or heating block when taken from a storage temperature of minus 29 degrees C prior to testing.

4.5.1.3 Mixing and degassing. - When the material is supplied in two parts, the curing agent may partially crystallize. It is permissible to warm the curing agent in accordance with the manufacturer's recommendation, except the temperature shall not exceed 60 degrees C. When heating, the curing agent shall not require more than 60 minutes to completely liquify and become smooth and uniform without any crystallization or graininess. When returned to 24 degrees C after heating, the curing agent shall remain smooth and uniform. Place the curing agent and the base compound in a clean, nonporous container having approximately four times the volume of the material. Mix the curing agent and the base compound throughly and degas at a maximum pressure of 5 millimeters of mercury. The material shall be agitated or vibrated during degassing to break foam. Degas until foaming subsides. The time required to degas a one quart quantity shall not exceed twenty minutes.

4.5.2 Preproduction tests. - The preproduction tests, when required, shall consist of all the acceptance tests specified herein. The items subjected to the tests of 4.5.2.1 through 4.5.2.15 shall be considered unserviceable but may be retained for examination by the procuring activity.

4.5.2.1 Dielectric constant and dissipation factor. - Disc specimens, 2 inches in diameter and 1/8 inch thick, shall be cured at standard conditions. Tests shall be conducted in accordance with Method ASTM D150-59T. The specimen shall be tested at 1-megacycle per second and standard test conditions to determine conformance to 3.5 (see 4.5.1).

4.5.2.2 Dielectric strength. - Disc specimens, 4 inches in diameter and 50 mils thick, shall be prepared as specified in 4.5.1. The tests shall be conducted in accordance with Standard FED-STD-406. The tests shall be made under oil and at a frequency of 100 cycles per second, maximum. The voltage shall be increased uniformly at the rate of 500 volts per second to determine conformance to 3.5

4.5.2.3 Volume and surface resistivity. - Three disc specimens, 4 inches in diameter and 1/8 inch thick, shall be prepared as specified in 4.5.1. Tests shall be conducted in accordance with Method ASTM D257-61. using a general radio-type 544B bridge, or equivalent, with a test voltage of 500. Readings shall be made after application of current. Lead or tinfoil electrodes shall be used and applied to the specimen with silicon grease that conforms to Specification MIL-I-8660. The guarded electrode shall be a disc 2 inches in diameter, centrally located on one face of the specimen. The guard electrode shall be a concentric ring with a 2 9/32-inch inside diameter and an outside diameter equal to that of the specimen. The unguarded electrode shall be a foil disc 4 inches in diameter applied to the opposite side of the specimen. The test current shall be introduced to the guarded electrode, the guard electrode, and the unguarded electrode by means of a brass disc, 2 inches in diameter by 1 inch thick; a brass ring, 2 5/16 inches inside diameter by 4 inches outside diameter by 1/8 inch thick; and a brass ring, 4 inches in diameter, respectively. Calculations necessary for volume and surface resisitivity shall be made, using the ASTM formulas for effective areas and effective perimeter. All specimens shall conform to the requirements of 3.5.

4.5.2.4 Arc resistance. - Three disc specimens, 4 inches in diameter and 1/8 inch thick, shall be prepared as specified in 4.5.1. Tests shall be conducted in accordance with Specification MIL-C-5015, at a temperature of 24 $\pm$ 1 degrees C and 50 $\pm$ 5 percent relative humidity maximum, to determine conformance to 3.5. The surface of the test specimen shall be smooth and free from dust and other contamination.

4.5.2.5 Insulation resistance. - Three specimens shall have dimensions as specified in figure 1 or 2. The mold in which the specimens are cast shall provide for the accurate spacing of brass rod electrodes. They shall be inserted at the opposite end of the specimen in such a manner that 1 1/2 inches of the length of each pair shall be spaced 0.050 $\pm$ 0.010 inch apart. Measurements shall be made using a potential of 500 volts. Electrification time shall not exceed 2 minutes. Tests to determine conformance to 3.5 shall be conducted at 24 and 121 $\pm$ 1 degrees C after a conditioning period of 30 minutes at test temperature.

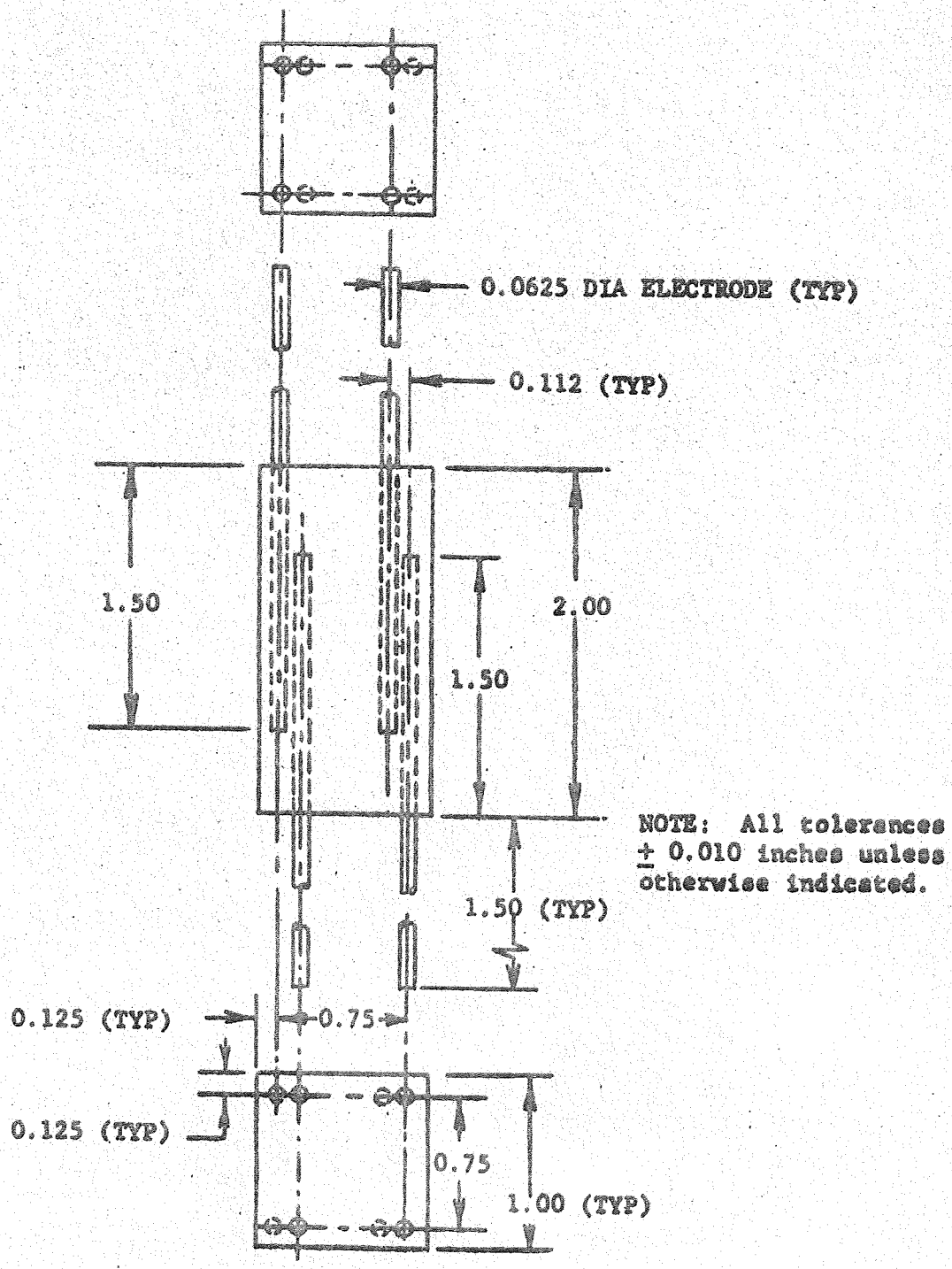


Figure 1. Insulation resistance test specimen.

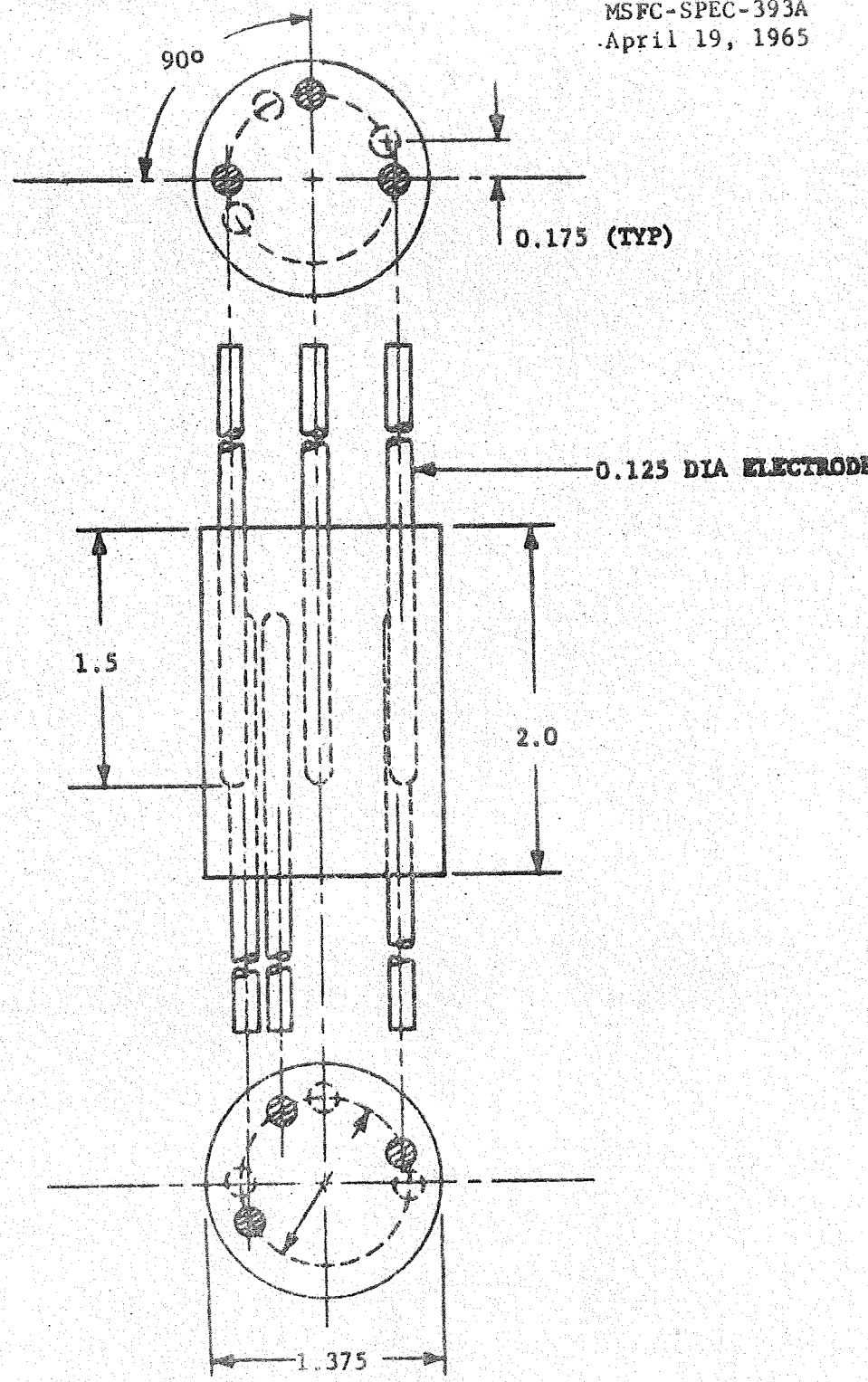


Figure 2. Insulation resistance test specimen.

4.5.2.6 High potential. - Test specimens as specified in 4.5.2.5 shall be utilized for this test. A potential of 1,000 volts root mean square, 60 cycles per second shall be applied between all contacts for a period of 1 minute. The test voltage to determine conformance to 3.5 shall be applied gradually at the rate of 500 volts each second.

4.5.2.7 Temperature resistance. - The volume resistivity shall be determined in accordance with paragraph 4.5.2.3, except the testing to determine conformance to 3.5 shall be conducted at 121 ± 1 degrees C after a conditioning period of 30 minutes at the test temperature.

4.5.2.8 Fungus resistance. - The test specimen shall be tested in accordance with procedure I of Specification MIL-E-5272 to determine conformance to 3.4.5.

4.5.2.9 Tear strength. - Test specimens cured in accordance with the manufacturer's instructions shall be subjected to the tear resistance tests specified in method 4211 of Standard FED-STD-601 to determine conformance to 3.5. The test specimens shall be cut with a model C die.

4.5.2.10 Moisture resistance. - Three test specimen cast for insulation resistance shall have dimensions as specified in figure 1 or 2. The mold in which the specimens are cast shall provide for the accurate spacing of brass rod electrodes. They shall be inserted at the opposite end of the specimen in such a manner that 1 1/2 inches of the length of each pair shall be spaced 0.050 ± 0.010 inch apart. The specimens shall be placed in a humidity chamber at 24 ± 1 degrees C. The chamber temperature shall be raised uniformly to 71 degrees C during a two-hour period, maintaining 95 percent relative humidity. These conditions shall be maintained for six hours. During the next 16-hour period, the temperature of the chamber shall drop, at a uniform rate, to 26 degrees C. This shall constitute one cycle. A test to determine conformance to 3.4.6 shall consist of five complete cycles after which the test specimen shall be tested as specified in 4.5.2.5.

4.5.2.11 Tensile strength or elongation. - The tensile strength or elongation testing shall be in accordance with method 4111 of Standard FED-STD-601. The dumbbell specimens shall be cut from the cast sheets of the molding compound that has been cured for 16 hours at 82 ± 3 degrees C. The procedure for determining elongation shall be in accordance with method 4121 of Standard FED-STD-601 and shall determine conformance to 3.5.

4.5.2.12 Shrinkage. - A cubical mold, approximately 1 inch on each side and having an open top shall be constructed. The volume at 24 ± 1 degrees C shall be determined. The volume shall be utilized for the preparation of the compound as described by the manufacturer's recommended procedure. After subjecting the specimens to 24 ± 1 degrees C, the compound

shall be placed in an air circulating oven at 82 ± 3 degrees C for 96 hours. The compound shall then be removed, cooled, examined, and its volume at 24 ± 1 degrees C determined by the water displacement method. The percent shrinkage shall be calculated as follows and shall be as specified in 3.5:

$$\text{Percent shrinkage} = \frac{V_1 - V_2 \times 100}{V_1}$$

V_1 = volume of mold

V_2 = final volume of compound

4.5.2.13 Compression set. - To determine conformance to 3.5, the compound shall be tested in accordance with method 3311 of Standard FED-STD-601, except the test sample shall be cured for 16 hours maximum at 82 degrees C and cast in a suitable mold instead of cutting with a circular metal die.

4.5.2.14 Storage life.

4.5.2.14.1 Two-part kits. - The two-part compound shall be capable of passing all examinations and tests specified herein and of conforming to 3.4.4 after being stored for 6 months at 27 degrees C maximum.

4.5.2.14.2 Frozen compound. - The frozen premixed compound shall be capable of passing all examinations and tests specified herein and of conforming to 3.4.4 after being stored for 7 days at 29 degrees C maximum.

4.5.3 Acceptance tests.

4.5.3.1 Nonvolatile content. - Fresh coating compound shall be transferred immediately to tared containers 1 3/4 inches in diameter and 1/2 inch deep. The compound shall be leveled even with the top of the dish. The dish shall be weighed and then exposed to 82 ± 1 degrees C for 24 ± 1 hours. The samples shall then be removed from the oven, placed in a desiccator, and allowed to cool to room temperature. The dish shall be weighed again to determine conformance to 3.3.3. Percent nonvolatile content equals weight of compound after heating, times 100, divided by the weight of compound before heating.

4.5.3.2 Specific gravity. - The test specimen shall be tested in accordance with method 14011 of Standard FED-STD-601 to determine conformance to 3.5.

4.5.3.3 Application life.

4.5.3.3.1 Two-part material. - A 250-gram sample of mixed compound shall be used to determine application life, which shall commence at the end of the mixing period. A standard one-half pint can with its retaining flange removed shall be utilized, in conjunction with a Brookfield Viscosimeter Model RVF equipped with a number 7 spindle, for testing and shall be operated at 10 revolutions per minute. Consistency shall be determined at the end of a 50-minute period. Supplemental readings shall be made at 10-minute intervals until a reading of 1,000 poises is attained, which shall be considered as the end of the application life test. The spindle shall not be drawn from the material during the test. Readings shall be taken to determine conformance to 3.4.2.1, when the pointer on the viscosimeter dial first assumes a steady position after a minimum of three revolutions.

4.5.3.3.2 Premixed, frozen material. - A 6 fluid ounce compound cartridge thawed in accordance with paragraph 4.5.1.2 shall be equipped with a 4 inch nozzle having a 0.125 ± 0.005 inch orifice. The gun and material shall be maintained at a standard condition throughout the test. The gun shall be attached to a constant air supply of 75 ± 5 pounds per square inch gage. From 2 to 3 inches of material shall be extruded initially to fill the nozzle and clear any trapped air. Material will be extruded into a suitable container and application life determined as specified in 4.5.3.3.1.

4.5.3.4 Hardness. - The hardness tests shall be performed in conformance with method 3021 of Standard FED-STD-601 to determine conformance to 3.5.

4.5.3.5 Adhesion.

4.5.3.5.1 Metal test specimens. - A 3 by 6 by approximately 1/16 inch aluminum alloy panel conforming to Specification QQ-A-287 shall be cleaned with a suitable solvent, conforming to Specification TT-M-261. Clean cotton gauze shall be used to wipe the wet solvent from the surfaces and avoid redeposit of contaminants. The cleaned surfaces shall be primed with a thin coat of primer recommended by the coating compound manufacturer and shall be allowed to dry in accordance with the manufacturer's recommendations, but not to exceed 60 minutes. A 1/8 inch coating of the compound shall be applied to the primed metal panel. A 3 by 6 inch area of a 3 by 12 inch strip of cotton duck sheeting shall be intimately coated on one side with coating compound and placed on the panel leaving a loose end approximately 6 inches in length. The panel shall be cured for 16 hours at 82 ± 3 degrees C.

Two 1 inch wide strips shall be cut through the compound and fabric to the panel surface and extended the full length of the loose end of the fabric. The edge of the panel shall not be used as one edge of the test strip.

4.5.3.5.2 Fiberglass test specimens. - A 3 by 6 by approximately 1/16 inch epoxy fiberglass panel conforming to Specification MSFC-SPEC-377 shall be cleaned with a suitable solvent--alcohol, conforming to Specifications MIL-E-463, MIL-A-6091, or MIL-I-10428; or xylene, conforming to Specification TT-X-916. Clean cotton gauze shall be used to wipe the wet solvent from the surfaces and avoid redeposit of contaminants. The cleaned surface shall be primed with a thin coat of primer recommended by the coating compound manufacturer, but not to exceed 60 minutes. A 1/8 inch coating of the compound shall be applied to the primed metal panel. A 3 by 6 inch area of a 3 by 12 inch strip of cotton duck sheeting shall be intimately coated on one side with coating compound and placed on the panel, leaving a loose end approximately 6 inches in length. The panel shall be cured for 16 hours at 82 $\pm$ 3 degrees C. Two 1 inch wide strips shall be cut through the compound and fabric to the panel surface and extended the full length of the loose end of the fabric. The edge of the panel shall not be used as one edge of the test strip.

4.5.3.5.3 Test method. - The test specimens prepared in accordance with 4.5.3.5.1 and 4.5.3.5.2 shall be tested in accordance with method 8031 of Standard FED-STD-601, except that a 180 degree pull and a jaw separation rate of 2 $\pm$ 1/8 inch per minute shall be used to determine conformance to 3.5.

5. PREPARATION FOR DELIVERY

5.1 Unit packaging.

5.1.1 Two-part kits. The base compound and curing agent shall be packaged in individual containers. The ratio of the quantity contained in the base compound container to the quantity contained in the curing agent container shall be the same as the recommended mixing ratio of the base compound and curing agent.

5.1.2 Frozen compound. - The frozen compound shall be premixed, degassed, and packaged in 5, 6, or 12 ounce polyethylene cartridges complete with a plunger and cartridge cap.

5.2 Packing. - All exterior shipping containers in the shipment shall contain the same number of the type of unit packages. Shipping containers shall be of uniform size and shall be so designed as to ensure that damage is prevented during handling and shipping. Frozen shipments shall be packed in a manner that will prevent thawing or other damage during transit.

5.3 Marking.

5.3.1 Base compound containers. - Each base compound container shall be durably and legibly marked with the following information:

(a) Title and number of this specification.

(b) Manufacturer's name and address.

(c) Manufacturer's product designation.

(d) Manufacturer's batch designation.

(e) Manufacturer's batch designation for the curing agent that the base compound is to be used with.

(f) Stock number.

(g) Date of manufacture.

(h) Contract number.

(i) Quantity contained.

5.3.2 Curing agent container. - Each curing agent container shall be durably and legibly marked with the following information:

(a) Manufacturer's name and address.

(b) Manufacturer's product designation.

(c) Manufacturer's batch designation.

(d) Manufacturer's batch designation for the base compound that the curing agent is to be used with.

(e) Date of manufacture.

5.3.3 Frozen cartridges. - Each frozen cartridge shall be durable and legibly marked with the following information:

(a) Title and number of this specification.

(b) Manufacturer's name and address.

(c) Manufacturer's product designation.

(d) Manufacturer's batch designation.

(e) Stock number.

(f) Date of manufacture.

(g) Contract number.

(h) Quantity contained.

(i) Date mixed, degassed, and frozen.

5.3.4 Exterior shipping containers. - Each exterior shipping container shall be durably and legibly marked with adequate instructions to ensure that damage during handling and shipping is prevented. Instructions for handling to prevent thawing during transit from the manufacturer to the procuring activity and storage after receiving shall be marked on all exterior shipping containers for frozen cartridges.

6. NOTES

6.1 Intended use. - This specification is intended for use in qualifying elastomeric compound (for conformal coating) to be used on printed circuit boards and associated equipment.

6.2 Ordering data. - Procurement documents should specify the following:

(a) Title, number, and date of this specification.

(b) Whether preproduction sample is required (see 3.2.2).

(c) Whether quality assurance sample is required (see 3.2.3).

(d) Applicable quality control publication (see 4.1).

(e) Amount of compound required for preproduction sample (see 4.2.2).

(f) Where the preproduction test will be accomplished (see 4.2.2).

(g) Amount of compound required for quality assurance sample (see 4.2.3).

(h) Where quality assurance test will be accomplished (see 4.2.3).

(i) Whether special preservation, packaging, packing, and marking is required.

6.3 Provisions for qualification. - With respect to products requiring qualification, awards will be made only for such products as have, prior to the bid opening date, been tested and approved for inclusion into the applicable qualified products list whether or not such products have actually been listed by that date. The supplier's attention is called to this requirement, and manufacturers are urged to make arrangements for qualification testing of the products covered by this specification. Request for information pertaining to qualification of products covered by this specification should be addressed to:

Chief, Pilot Manufacturing Branch
Astrionics Laboratory
George C. Marshall Space Flight Center
Huntsville, Alabama

Notice. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodian:

NASA - George C. Marshall Space Flight Center

Preparing activity:

George C. Marshall Space Flight Center

APPENDIX 2

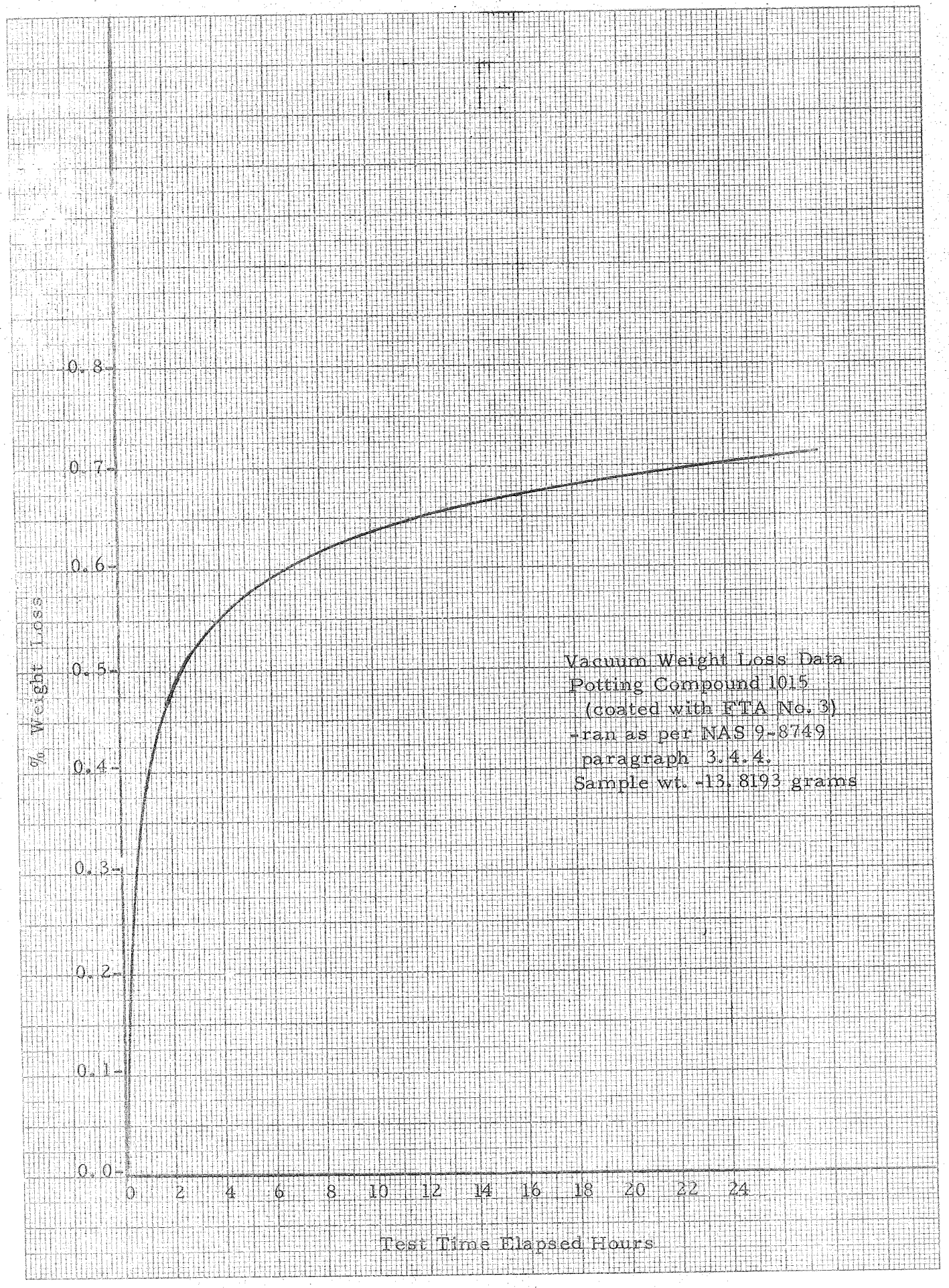
Vacuum Weight Loss Test Data on Potting Compounds 1015 and QC-15 and on Conformal Coating MRTA-5 from NASA White Sands Test Facility.

VACUUM WEIGHT LOSS DATA

Sample: Potting compound 1015 coated with FTA# 3

Original Weight: 13.8193

Elapsed Time	Gms. Wt. Loss	% Wt. Loss	Elapsed Time	Gms. Wt. Loss	% Wt. Loss
½ hr.	0.03565	0.258	11 hrs.	0.08880	0.643
1 hr.	0.05120	0.370	12 hrs.	0.08980	0.650
1½ hrs.	0.05983	0.433	13 hrs.	0.09070	0.656
2 hrs.	0.06540	0.473	14 hrs.	0.09150	0.662
2½ hrs.	0.06945	0.503	15 hrs.	0.09225	0.668
3 hrs.	0.07265	0.526	16 hrs.	0.09300	0.673
3½ hrs.	0.		17 hrs.	0.09362	0.677
4 hrs.	0.0.07609	0.551	18 hrs.	0.09425	0.682
4½ hrs.			19 hrs.	0.09479	0.686
5 hrs.	0.07913	0.573	20 hrs.	0.09535	0.690
5½ hrs.			21 hrs.	0.09585	0.694
6 hrs.	0.08160	0.590	22 hrs.	0.09635	0.697
7 hrs.	0.08365	0.605	23 hrs.	0.09685	0.701
8 hrs.	0.08525	0.617	24 hrs.	0.09735	0.704
9 hrs.	0.08671	0.627	25 hrs.	0.09765	0.707
10 hrs.	0.08770	0.635			

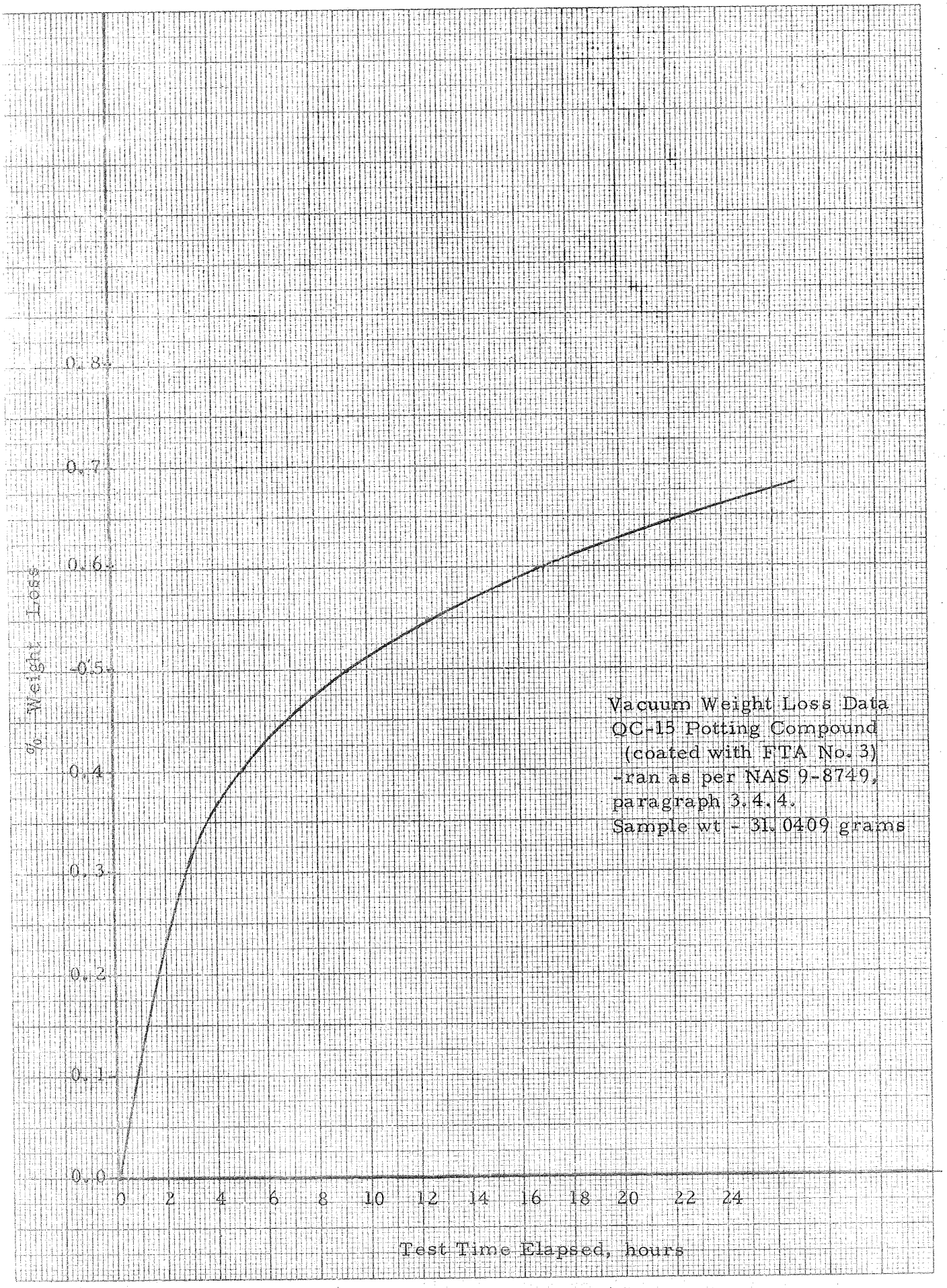

% Weight Loss
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
Test Time Elapsed Hours
Vacuum Weight Loss Data
Potting Compound 1015
(coated with FTA No. 3)
-ran as per NAS 9-8749
paragraph 3.4.4.
Sample wt. -13.8193 grams

VACUUM WEIGHT LOSS DATA

Sample: QC 15 potting compound coated with FTA #5

Original Weight: 21.0409 gms.

Elapsed Time	Gms. Wt. Loss	% Wt. Loss	Elapsed Time	Gms. Wt. Loss	% Wt. Loss
½ hr.	0.02590	0.083	11 hrs.	0.16455	0.530
1 hr.	0.04720	0.152	12 hrs.	0.16917	0.545
1½ hrs.	0.06415	0.207	13 hrs.	0.17340	0.557
2 hrs.	0.07686	0.248	14 hrs.	0.17730	0.571
2½ hrs.	0.08730	0.281	15 hrs.	0.18080	0.582
3 hrs.	0.09610	0.310	16 hrs.	0.18414	0.593
3½ hrs.	0.10466	0.337	17 hrs.	0.18730	0.603
4 hrs.	0.11148	0.359	18 hrs.	0.19013	0.613
4½ hrs.	0.11745	0.378	19 hrs.	0.19295	0.622
5 hrs.	0.12290	0.396	20 hrs.	0.19560	0.630
5½ hrs.			21 hrs.	0.19815	0.638
6 hrs.	0.13230	0.426	22 hrs.	0.20050	0.646
7 hrs.	0.14060	0.453	23 hrs.	0.20280	0.653
8 hrs.	0.14760	0.476	24 hrs.	0.20510	0.661
9 hrs.	0.15385	0.496	25 hrs.	0.20720	0.668
10 hrs.	0.15945	0.514			

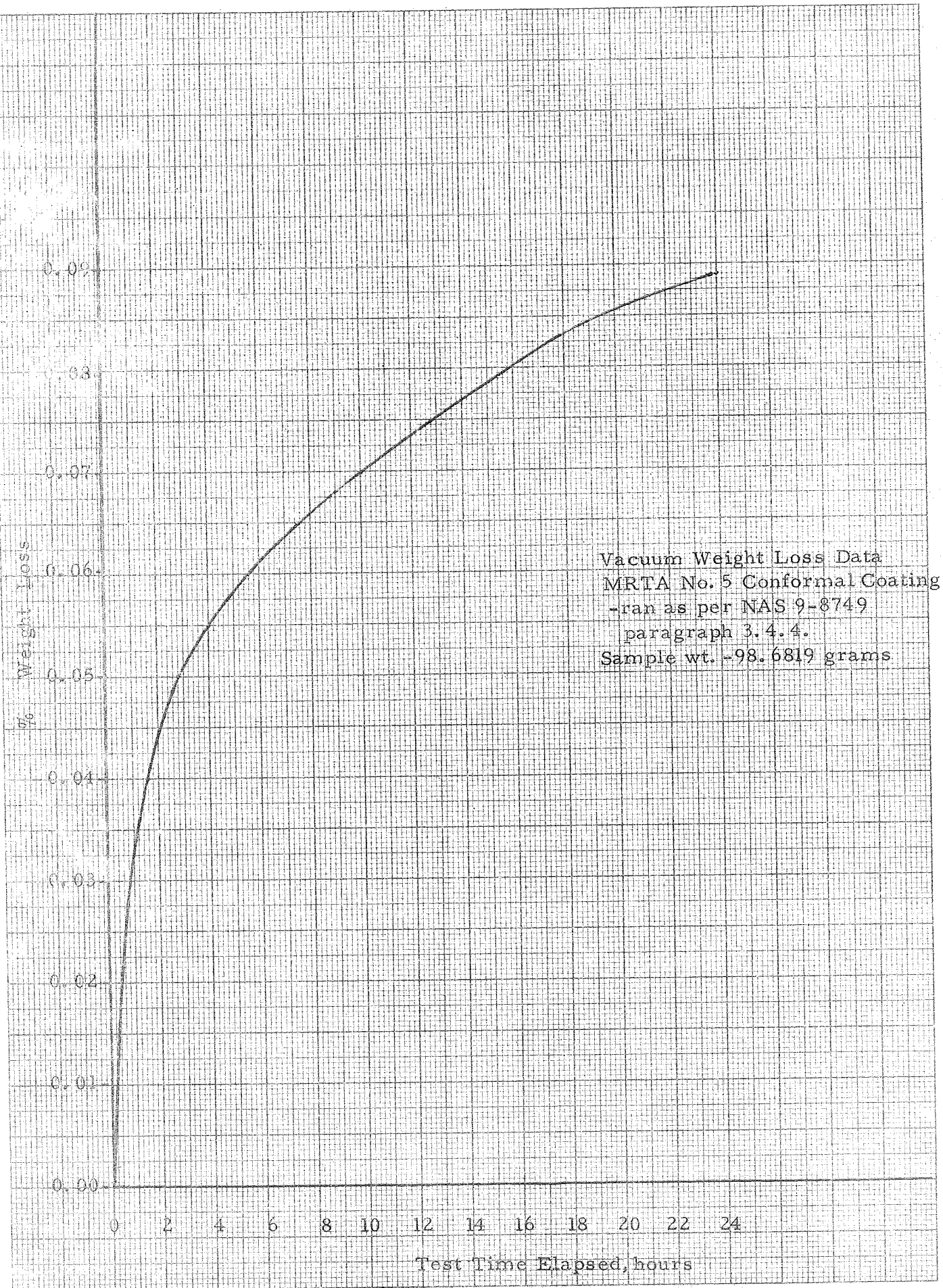


VACUUM WEIGHT LOSS DATA

Sample: Conformal coating MRTA # 5

Original Weight: 98.6818 gms.

Elapsed Time	Gms. Wt. Loss	% Wt. Loss	Elapsed Time	Gms. Wt. Loss	% Wt. Loss
½ hr.	0.01491	0.015	11 hrs.	0.07051	0.072
1 hr.	0.03077	0.031	12 hrs.	0.07313	0.074
1½ hrs.	0.03790	0.038	13 hrs.	0.07476	0.076
2 hrs.	0.04378	0.044	14 hrs.	0.07636	0.077
2½ hrs.	0.04656	0.047	15 hrs.	0.07776	0.079
3 hrs.	0.04931	0.050	16 hrs.	0.07921	0.080
3½ hrs.	0.05176	0.052	17 hrs.	0.08053	0.082
4 hrs.	0.05393	0.055	18 hrs.	0.08176	0.083
4½ hrs.	0.05591	0.057	19 hrs.	0.08293	0.084
5 hrs.	0.05752	0.058	20 hrs.	0.08403	0.085
5½ hrs.	0.05906	0.060	21 hrs.	0.08511	0.086
6 hrs.	0.06050	0.061	22 hrs.	0.08617	0.087
7 hrs.	0.06306	0.064	23 hrs.	0.08714	0.088
8 hrs.	0.06541	0.066	24 hrs.	0.08811	0.089
9 hrs.	0.06758	0.068	25 hrs.	0.08896	0.090
10 hrs.	0.06956	0.070			


0.09
.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
% Weight Loss
0
2
4
6
8
10
12
14
16
18
20
22
24
Test Time Elapsed, hours
Vacuum Weight Loss Data
MRTA No. 5 Conformal Coating
-ran as per NAS 9-8749
paragraph 3.4.4.
Sample wt. -98.6819 grams