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Investigation of Conformal Coatings for Electronic Circuits

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13. ABSTRACT *(Maximum 200 words)*

Dielectric coating of semiconductor device packages is important not only for insulation and humidity protection but also to protect the metal leads of a package from being exposed to nuclear weapon x-rays. If exposed, these leads emit electrons, creating unwanted currents which could disrupt electronic circuits or damage sensitive electronic devices. As electronic devices have become more complex, so have their packages. A consequence of this complexity is the difficulty of thoroughly coating all the leads (pins) of the device with at least 3 mils of dielectric and assuring that there are no voids around any of the pins.

Seven products were evaluated for their ability to uniformly coat (void-free) the pins of a 244-pin grid array. Four products, Conap EN-11, Dow Corning 93-500, McGhan Nusil CU-2500, and Solithane 113, were found to be acceptable. Of the four, Solithane 113 and Conap EN-11 are the most cost effective.

The report provides the experimental procedure, pricing information, and technical data sheets which list specific information on those products that were found to be acceptable.

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1. Introduction

Dielectric coating of semiconductor device packages is important not only for insulation and humidity protection but also to guard the metal leads of a package from being exposed to nuclear weapon x-rays. On exposure, these leads emit electrons, creating unwanted currents which could disrupt electronic circuits or damage sensitive electronic devices. Thorough coating of devices has become more difficult as electronic devices have become more complex and thus require more complex packaging (fig. 1). Such packaging makes it difficult to thoroughly coat all the leads (pins) of the device with at least 3 mils of dielectric and assure that there are no voids (bubbles) around any of the pins.

In a program for the U.S. Army Strategic Defense Command (SDC), a prototype computer board was developed especially to demonstrate the ability of state-of-the-art devices to survive severe nuclear weapon environments. Effective dielectric (conformal) coating of the semiconductor devices was an important requirement. Unfortunately, we were to learn that coating of complex electronic device packages was not as easy as initially believed.

Close examination of the conformal coating applied to computer boards revealed an insufficient, nonuniform coating of the pins around the edges of the central processing unit (CPU) and the configurable gate array (CGA) pin grid array (PGA) packages (fig. 2). This observation led us to believe that such pin coating problems were also likely under the packages. In this investigation we wanted to determine whether the observed bubbles were the

Figure 1. Pin grid array (PGA).

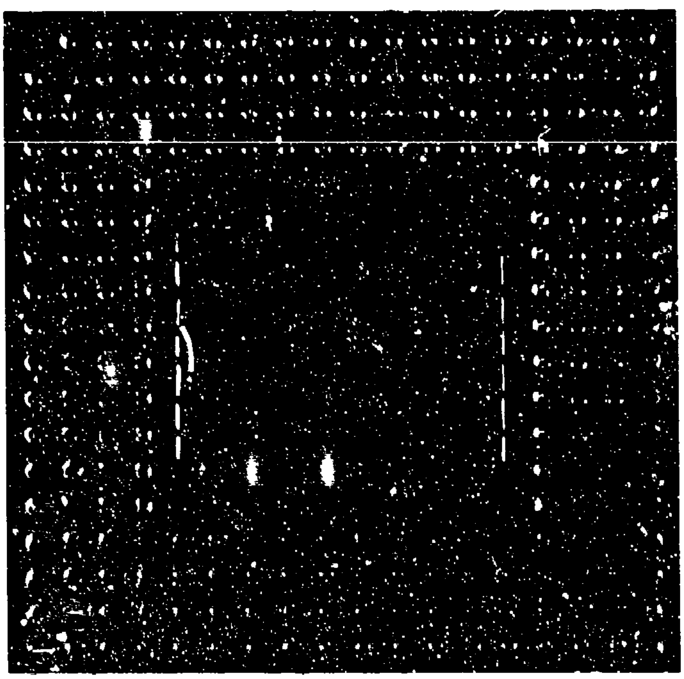
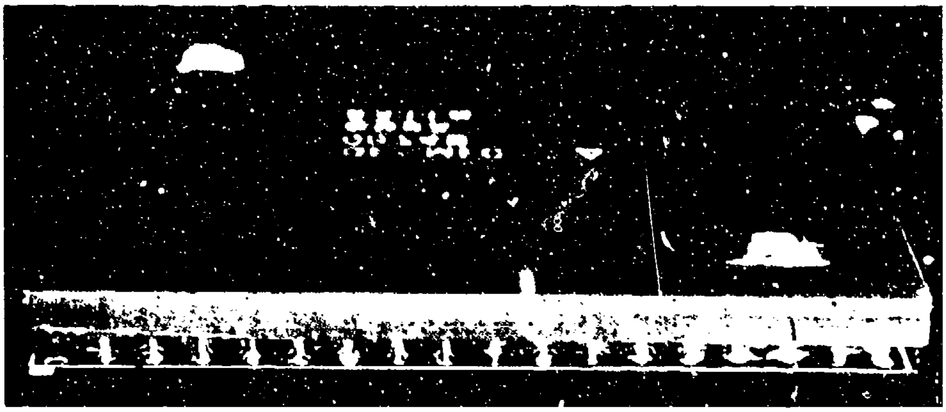


Figure 2. Edge of mounted central processing unit (CPU).



product solely of inadequate quality control or whether the coating being used, Hysol PC-18, was a poor choice for a conformal coating material. In either case, we wanted to identify the appropriate materials and procedures for applying void-free conformal coatings to PGA semiconductor packages. Additionally, the coating of choice must also be readily available at a reasonable cost, be easily applied, and meet temperature and outgassing specifications for space applications. The materials chosen for this study were Hysol PC-18, Dow Corning Q1-2620, Dow Corning 93-500, Conap EN-11, McGhan Nusil CV-2500, Solithane 113, and Uralane 5750.

2. Experiment Description

2.1 Hysol PC-18

Hysol PC-18 is a one-part polyurethane coating which cures in about 24 hr at room temperature when exposed to the atmosphere. To determine the mixture providing the best coating of the pins on the PGA, we thinned the polyurethane with the manufacturer's recommended thinner, methyl ethyl ketone (MEK). Thinning ratios of 4:1, 4:2, 4:3, 4:4, 4:5, and 4:6 parts by volume polyurethane to MEK were mixed and outgassed in a forepump vacuum for 10 min.* Six 1/16-in.-thick samples were poured, 1 in.^{2} for each mix ratio (fig. 3); after curing, all the samples had voids, but the 4:2 mixture had the least.

In order to observe the pin side of the PGA, and thus ensure that no voids formed and the coating was complete, a transparent test fixture was made

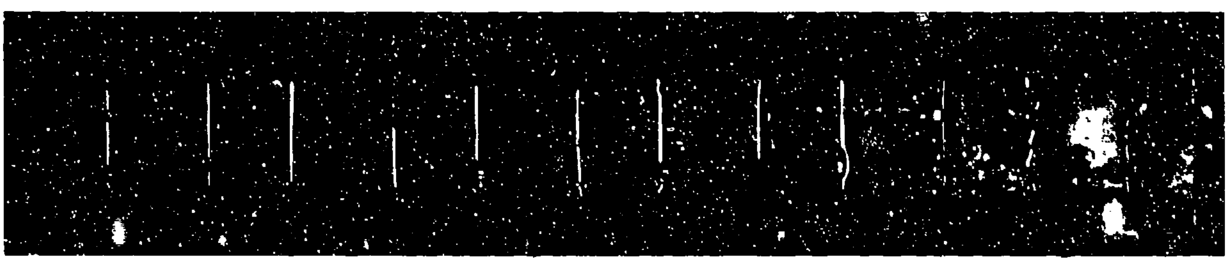


Figure 3. Test samples, Hysol PC-18. (Thinning ratios, left to right, 4:1 to 4:6.)

**Material outgassing referred to in this report was performed at forepump vacuum for 10 min.*

from a 6- × 3- × 0.25-in. Plexiglas plate with holes drilled in it to accept the CPU PGA package, composed of 224 closely spaced pins. Four 4- × 0.5- × 0.0625-in. pieces of Plexiglas were epoxied to the Plexiglas plate so as to surround the PGA on four sides (fig. 4), confining the coating and allowing for complete filling under and around the PGA.

A PC-18 4:2 mixture was outgassed and poured in a vacuum around the PGA to a depth of about 1/16 in. This procedure caused the coating material to flow around the pins beneath the package. After curing, from the underside of the test fixture, we could see voids on almost every pin of the PGA package (fig. 5). In a second attempt, the test fixture was heated to 125°F while in a forepump vacuum during curing; the results were the same.

What appears to happen is that the exposed surface layer of the polyurethane cures first. entrapping the solvent and restricting lateral movement of the gases from under the PGA package, thus creating voids. Consultation with the manufacturer produced no suggestions to obtain a better result. We conclude that PC-18 is a poor choice for a void-free conformal coating.

2.2 Dow Corning Q1-2620

We evaluated Dow Corning Q1-2620, a silicone coating, for void formation first by pouring a small amount, about 0.250 in., in an aluminum container, outgassing this sample, and curing it at room temperature; no voids were observed. In a second test, Q1-2620 was outgassed, then poured in a forepump

Figure 4. Test fixture.

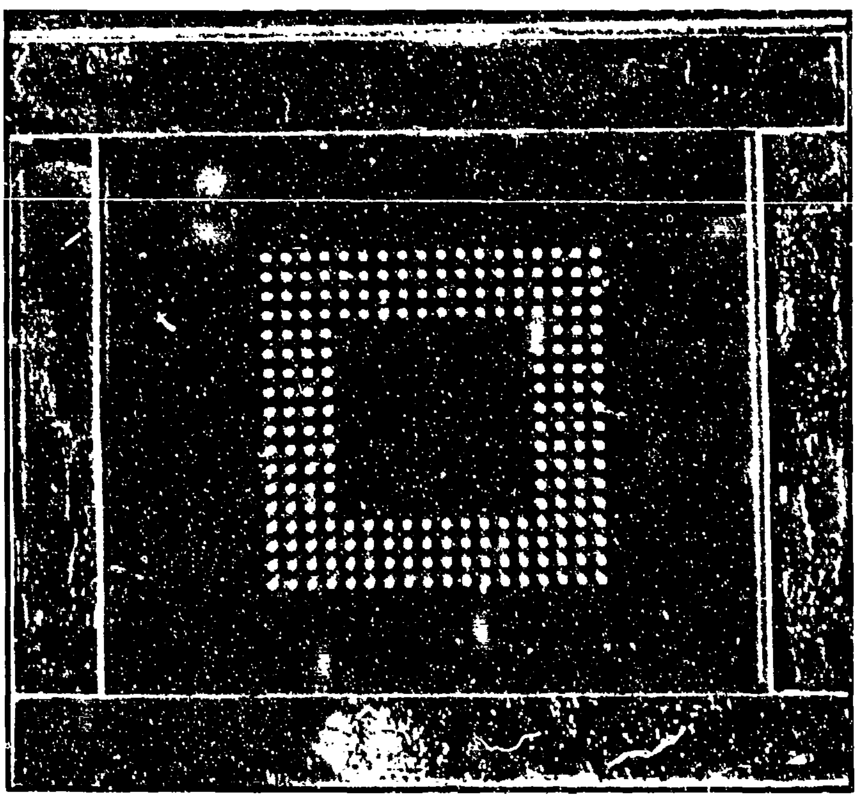
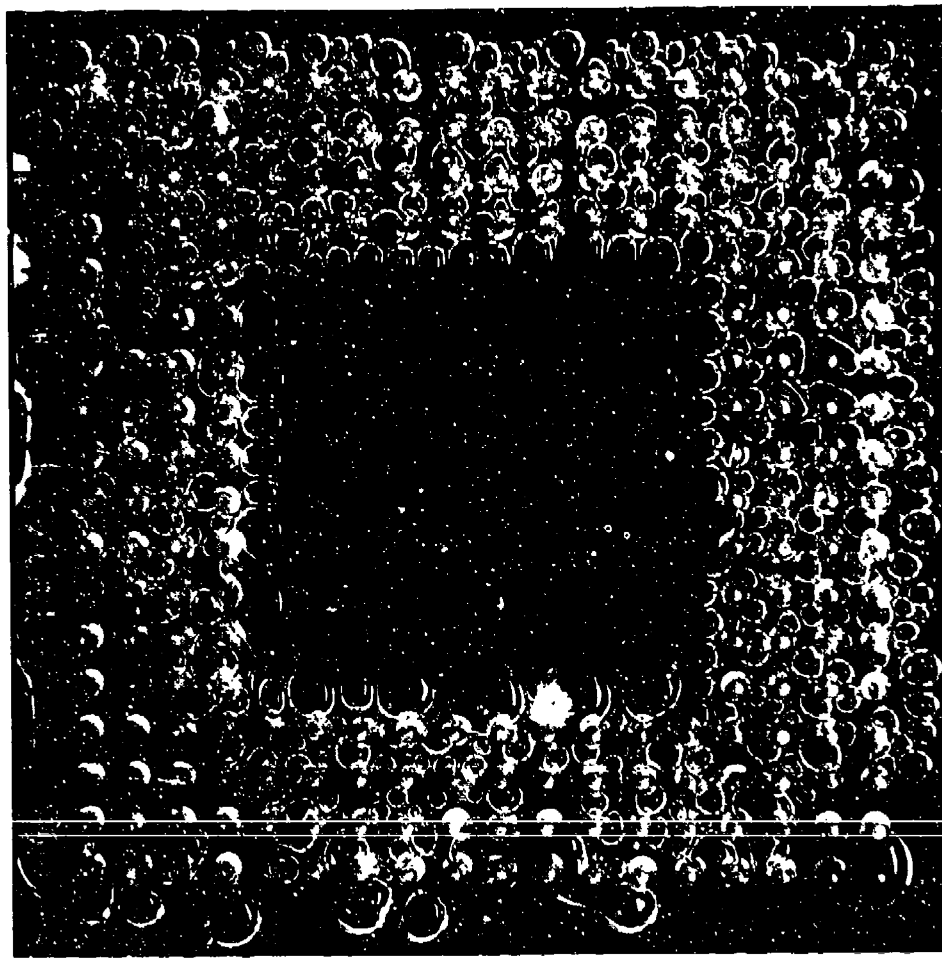


Figure 5. Hysol PC-18.



vacuum around the CPU PGA package on the Plexiglas test fixture. No voids were observed initially. About 72 hr later, after room temperature and atmospheric pressure curing, voids had formed around some of the pins. We conclude from this test that, although better than PC-18, the Q1-2620 is not desirable for producing a void free coating.

2.3 Dow Corning 93-500

The third product evaluated was Dow Corning 93-500, a clear rubber two-part mixture. Product 93-500 is a space-qualified material, certified by the National Aeronautics and Space Administration (NASA). This certification means the material meets all temperature and out-gassing specifications for space applications. The material exhibits low-volatility properties and cures at room temperature. The material was mixed in the recommended ratio of 10:1 (base encapsulant to curing agent parts by weight—PBW), outgassed, and applied to the PGA test fixture in a forepump vacuum. No voids formed around the pins of the PGA in the first seven days; however, the material had not cured completely. Heating of the material to speed the curing process was attempted; however, this experiment was abandoned when voids began forming around the PGA pins. According to the manufacturer's data sheet, the material may have to be applied in a controlled environment to prevent contamination of the curing agent.

A second attempt at coating produced excellent results (fig. 6). The material was mixed in the recommended ratio as described above, outgassed in a contaminant-free vacuum chamber, and applied to the test fixture at room temperature and atmospheric pressure. We took care to eliminate the possibility of contamination by pouring the coating material on the high side of the test fixture, which was tilted about 5°, instead of applying it through a piece of tubing in a vacuum chamber since, according to the manufacturer's data sheet, the tubing may contain compounds that contaminate the curing agent. This procedure allowed the material to flow under the PGA, forcing any entrapped air out the opposite side. The material cured to a tacky state in about 48 hr, and tack-free in about 72 hr. No voids have formed around the pins of the PGA.

2.4 Conap EN-11

The fourth coating material, manufactured by Conap Corporation, is a two-part polyurethane coating (EN-11). EN-11 is certified by NASA and meets all temperature and outgassing specifications for space applications. A test

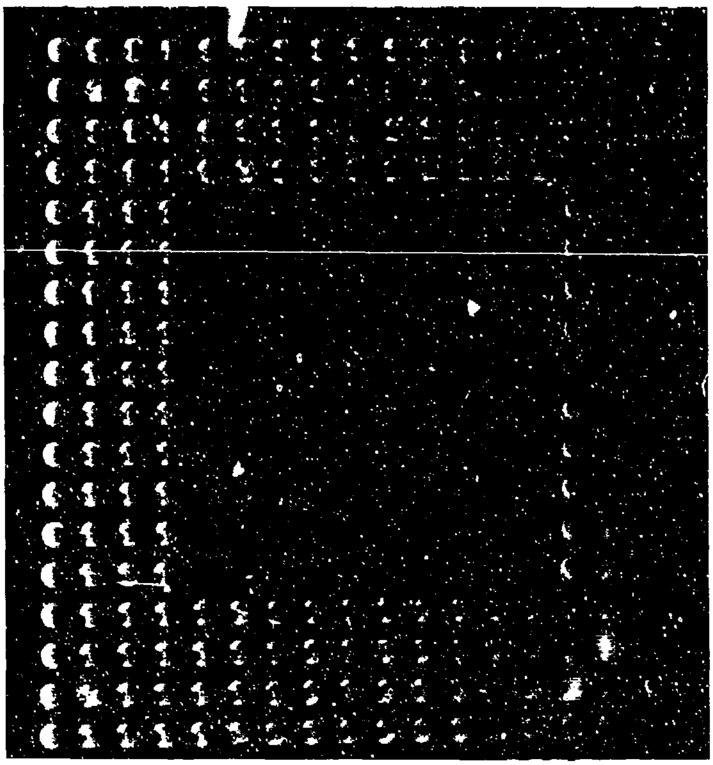


Figure 6. Dow Corning 93-500.

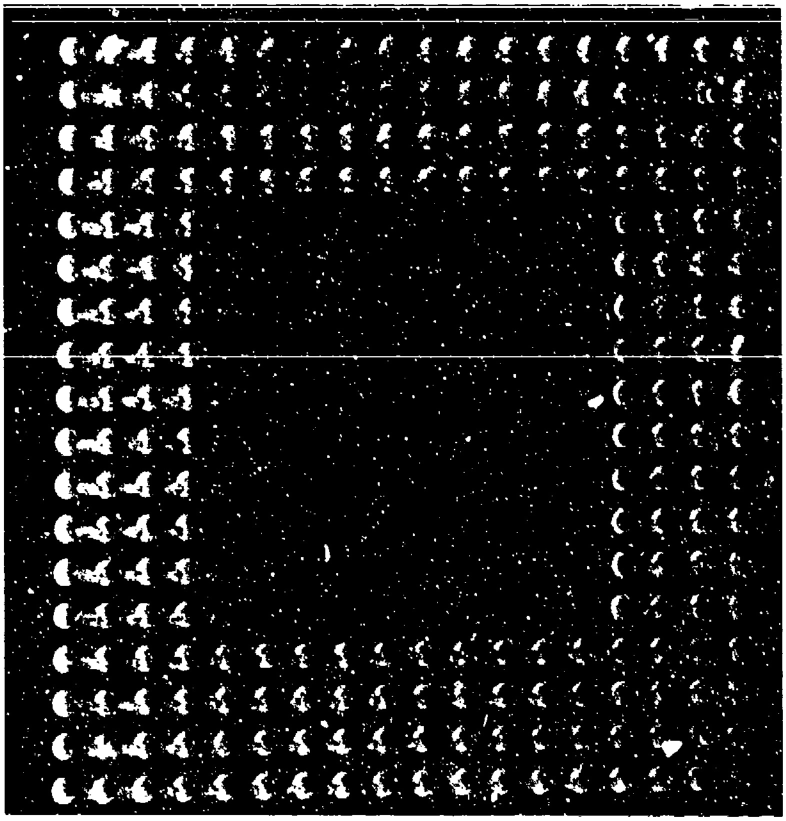
sample was mixed in the recommended ratio of 1:0.55 PBW, part A to B, outgassed, applied in a forepump vacuum to the PGA test fixture, and allowed to cure at room temperature and atmosphere. A void was observed around the underside central section of the PGA package about 3 hr after pouring. The test fixture was placed in a forepump vacuum for about 20 min and the void disappeared. For reasons which are unclear, the material had not cured completely after 72 hr; however, no voids were observed. We attempted to accelerate the curing by placing the test fixture in an oven at 90°F. Some voids formed after about 15 min.

This material looked promising, so a second test was done without oven heating. This second attempt with Conap EN-11 produced excellent results (fig. 7). The material was mixed as described above and outgassed. The polyurethane was applied to the high side of the test fixture, which was tilted at about 5°, at atmospheric pressure and room temperature. The material flowed under the PGA, forcing air out the far side. Complete void-free curing took about 24 hr.

2.5 McGhan Nusil CV-2500

The fifth material, McGhan Nusil CV-2500, is a two-part silicone which has been certified by NASA* to meet all temperature and outgassing specifica-

Figure 7. Conap EN-11.



NASA certification verified by telephone conversation with Carroll Clatterbuck (Materials Engineering Technician, NASA).

tions for space applications. The material was mixed in the recommended ratio of 10:1 base to curing agent PBW, outgassed, and applied to the test fixture at atmospheric pressure and room temperature. The test fixture was tilted about 5°, thus allowing the silicone to flow under the PGA. The material cured to a tacky state in about 72 hr and completely cured in about four days. The results are excellent (fig. 8); no voids formed around the pins of the PGA.

2.6 Solithane 113

The sixth material, Solithane 113 from Morton Thiokol, is a two-part polyurethane that has been certified by NASA to meet all temperature and outgassing requirements for space applications. The material was mixed in the recommended ratio of 100:73.5 PBW resin to curing agent, and outgassed. The material was applied at atmospheric pressure and room temperature to the high side of a test fixture tilted about 5°. The polyurethane flowed under the PGA, forcing air out the opposite side. The material was allowed to cure at room temperature. No voids formed under the PGA during the curing process (fig. 9). In a separate experiment, JAYCOR reported separation of the material from some of the pins on a PGA (private communication with William Seidler, October 1989). We believe this problem is due to elevated temperature curing. In our experiment, no separation of the material from the pins was observed.

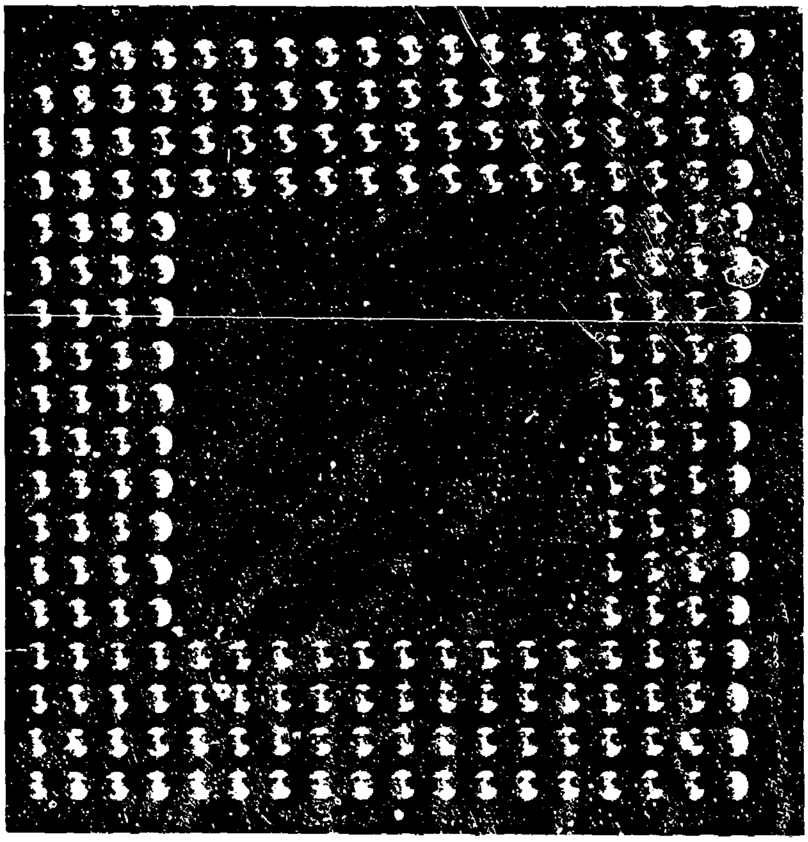
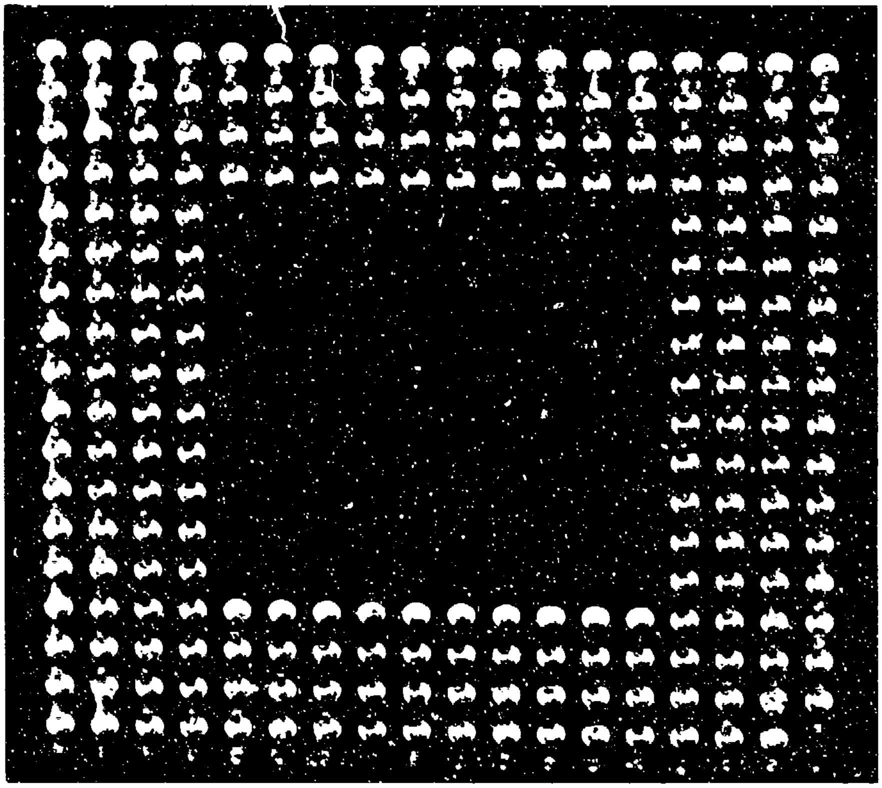


Figure 8. McGhan Nusil CV-2500.

Figure 9. Solithane 113.



2.7 Uralane 5750

The seventh material, Uralane 5750, is a two-part polyurethane from Furane. The material was mixed in the recommended ratio, 18:100 PBW, resin to hardener. It was outgassed and applied in the same manner as Solithane 113. Initially, no voids were observed. However, 24 hr after application, a few very small voids had formed under the PGA (fig. 10) The material cured to a tacky state in about 48 hr. Uralane 5750 is not a good candidate for coating PGAs.

3. Discussion of Experiments

Table 1 summarizes the results of the experiments, with a list of the seven products evaluated along with our evaluation as to whether they could produce void-free coatings under PGAs. We have listed the cost (as of July 1990) of those products which produced void-free coatings. The product data sheets for the four acceptable coatings are provided in appendix A.

In this evaluation, all the coating materials were poured, even though these materials could be sprayed or the circuit board dipped into them. Our goal was to evaluate a material and procedure with the greatest likelihood of void-free coating of the underside of a PGA package. Therefore, it is possible that the conformal coatings that failed our test are suitable for circuit board applications which do not include PGA packages.

Figure 10. Uralane 5750.

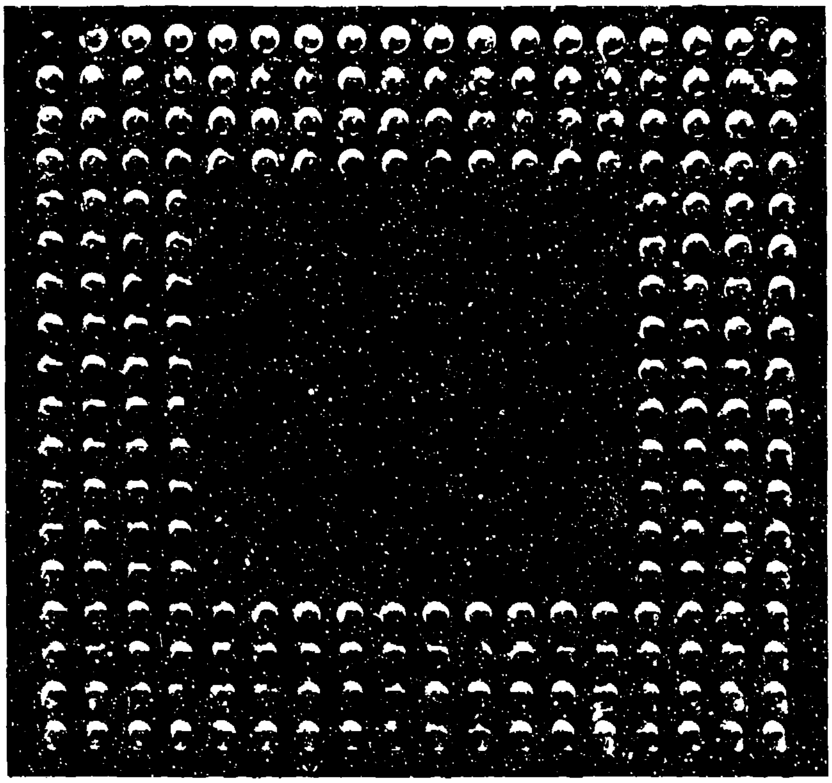


Table 1. Conformal Coatings: Product Data

Product	Void free coating		Cost
	Pass	Fail	
Hysol PC-18	–	X	N/A
Dow Corning Q1-2620 (silicone)	–	X	N/A
Dow Corning 93-500 (silicone)	X	--	$1000/lb
Conap EN-11 (polyurethane)	X	–	$105.25/gal.
McGhan Nusil CV-2500 (polyurethane)	X	–	$1000/lb
Solithane 113 (polyurethane)	X	–	$287.13/gal.
Uralane 5750 (polyurethane)	–	X	

Table 2 lists the advantages and disadvantages of the acceptable products. All of these products were outgassed before application; we did not evaluate the product's capabilities without outgassing.

A quick look at the table reveals that the desirable features are common to all of these coatings: they are all two-part materials, flow easily, cure at room ambient temperature and pressure, and are certified by NASA as qualified for space application. Where they differ is in material composition, price (table 1), viscosity, and time to cure (table 2).

Table 2. Product Comparison of Acceptable Conformal Coatings

Product	Desirable attributes	Undesirable attributes
Conap EN-11	Two-part system Easy application* Atmospheric cure at room temperature Complete void-free coating of pin grid array (PGA) Certified by NASA†	Takes about 24 hr for complete cure. High viscosity; pours and runs slowly. Requires outgassing.
Morton Thiokol Solithane 113	Two-part system Easy application. Amospheric cure at room temperature Complete void-free coating of PGA Certified by NASA	Takes about 24 hr for complete cure. High viscosity; pours and runs slowly. Requires outgassing.
McGhan Nusil CV-2500	Two-part system Easy application Atmospneric cure at room temperature Complete void-free coating of PGA Certified by NASA	Takes about 96 hr for complete cure. Requires outgassing.
Dow Corning 93-500	Two-part system Easy application Atmospheric cure at room temperature Complete void-free coating of PGA Certified by NASA	Easily contaminated; affects curing time. Complete cure in about 72 hr. Requires outgassing.

**Room ambient temperature and pressure application by pouring.*
†National Aeronautics and Space Administration.

In table 2 we also note that the viscosity of two of the acceptable products creates a slight disadvantage for them. Their product data sheets recommend solvents to thin these products, but solvents are not recommended since we believe that entrapped solvent vapor creates the unwanted voids.

4. Summary of Experiments

Of the seven products tested, four produced conformal coatings that were found to fit the requirements and specifications for application to the PGA. Two polyurethanes, Solithane 113 and Conap EN-11, may require more time to apply due to their high viscosity. They do, however, exhibit excellent results. The manufacturer's data sheet recommends some solvents that may be added to reduce the viscosity; however, the addition of solvents is not recommended for coating PGA because of the possible entrapment of solvent gases, which could cause voids and also lead to ionization when exposed to radiation. Two silicones, Dow Corning 93-500 and McGhan Nusil CV-2500, also exhibit excellent results; however, their cost, at about $1000/lb, may be prohibitive. Hysol PC-18 is clearly the wrong choice for a conformal coating although it is often used for that purpose (and is represented by the manufacturer as suitable).

5. Conclusions

Seven products were evaluated for their ability to produce void-free coatings of a 224 PGA package. Four products were determined to be suitable, varying most significantly in time to cure and price. Both the Conap EN-11 and the Solithane 113 cure in the shortest time and have the lowest prices of the acceptable products; therefore, we would most highly recommend the use of these two products.

Appendix A.—Manufacturers' Product Data Sheets for Acceptable Conformal Coating

Information about Materials for High Technology Applications

DOW CORNING

DESCRIPTION

Dow Corning 93-500 space-grade encapsulant is a transparent, room-temperature-curing, solventless silicone material designed for potting, filling, embedding and encapsulating electronic and other equipment for use in the space environment. It is supplied as a nearly colorless, free flowing, low viscosity fluid.

Features of the uncured encapsulant

Dow Corning 93-500 space-grade encapsulant and its curing agent blend readily, and the low viscosity of the catalyzed material (under 80 poises) aids in the potting and filling of deep, intricately shaped components. After addition of the curing agent, Dow Corning 93-500 space-grade encapsulant remains workable for about 1 hour at 24 C (75.2 F). The encapsulant cures in unlimited thickness in 24 hours at 25 C (77 F) ...even in confined areas... without exotherm. This material is not recommended for use in thin coatings of less than 0.010 inch unless confined or covered.

Features of the cured encapsulant

Dow Corning 93-500 space-grade encapsulant has been specially prepared for use in systems that will operate in hard vacuum, but where a high temperature post cure is not feasible. When used as supplied, the encapsulant exhibits extremely low weight loss. It has a total mass loss of less than 0.35% and less than 0.1% collected volatile condensable materials (condensed on a 25 C [77 F] collector plate) when exposed for 24 hours at 125 C (275 F) and less than 10^{-6} torr vacuum. Thus, chances of contamination of critical surfaces, such as optical systems and exposed electrical contacts, are greatly reduced. Dow Corning 93-500 space-grade encapsulant can be placed in service immediately following the completion of its room temperature curing schedule. Other features of the cured encapsulant include:

- Transparency—embedded parts can be visually inspected.
- Wide operating temperature— -65 to 200 C (-85 to 392 F).
- Easy repairability—sections of the encapsulant can be cut out for replacement of components; new encapsulant can be poured in place and cured to re-form a tight seal.
- Good physical and electrical stability—retains properties from -65 to 200 C (-85 to 392 F), over a wide range of frequency and humidity.
- Good firmness and flexibility—Shore A scale hardness of approximately 45; elongation of about 100 percent.
- Good damping qualities—low transmission of vibration and shock.
- Good environmental protection—low water absorption (less than 0.10% after 7 days immersion at 25 C [77 F]); high resistance to radiation (useable after exposure to 200 megarads).
- Low shrinkage during cure—does not exert pressure on encapsulated or embedded components.

DOW CORNING® 93-500 SPACE-GRADE ENCAPSULANT

Type	Silicone rubber
Physical Form	
as supplied	Clear, pourable fluid
as cured	Firm, flexible rubber
Cure	Room-temperature curing in approximately 24 hours
Primary Uses	Potting, filling, embedding, and encapsulating electronic equipment used in space environment

USES

Dow Corning 93-500 space-grade encapsulant is used as an embedding and potting compound to provide resilient environmental protection for modules, relays, power supplies, delay lines, cable connectors or complete electronic assemblies. It can also be used as an encapsulant for electronic components, circuit boards, and as a solar cell adhesive.

In use, the encapsulant assures the protection of electronic circuits and components from temperature extremes, high humidity, radiation, thermal shock and mechanical vibration. In addition, its inherent physical and electrical properties make it ideally suited for the harsh *environment of space*.

ENGINEERING DATA

Operating Temperature Range

Cured sections of Dow Corning 93-500 space-grade encapsulant are useable over a wide temperature

TYPICAL PROPERTIES

These values are not intended for use in preparing specifications.

As Supplied	
Color	Light straw
Specific Gravity at 25 C (77 F)	1.08
Viscosity at 25 C (77 F), poises	80
Pot Life at 25 C (77 F), with curing agent added, hours	1
Silicone Resin Content, percent	100
As Cured — 7 days at 25 C (77 F)*	
Color	Transparent; colorless to light straw
Refractive Index	1.4124
Durometer Hardness, Shore A, points	46
Total Mass Loss, % after 24 hrs at 125 C (275 F) and ≤10^{-6} torr	0.25
Collected Volatile Condensable Materials at 25 C (77 F), percent	0.05
Tack-Free Time at 25 C (77 F), hours	24
Specific Gravity at 25 C (77 F)	1.08
Thermal Conductivity, cal per [(cm) (degree C) (sec)]	3.5 x 10^{-4}
Linear Coefficient of Expansion, in/in°C-min	300 x 10^{-6}
Thermal Shock Resistance, from -55 to 155 C (-67 to 312 F), MIL-I-16923C	Pass 10 cycles
Water Absorption, after 7 days immersion at 25 C (77 F), percent	Less than 0.10
Brittle Point, degrees	-65 C (84 F)
Radiation Resistance, Cobalt 60 source	Still usable after exposure to 200 megarads, hard and brittle after 500 megarads
ASTM D 149 Dielectric Strength,† volts/mil	570
ASTM D 150 Dielectric Constant, at 100 Hz	2.75
at 100 KHz	2.73
ASTM D 150 Dissipation Factor, at 100 Hz	0.0011
at 100 KHz	0.0013
ASTM D 257 Volume Resistivity, ohm-cm	6.9 x 10^{13}
ASTM D 412 Tensile Strength, die C, psi	790
ASTM D 412 Elongation, die C, percent	110

* 1 part by weight of curing agent to 10 parts by weight of base encapsulant.
†Tested on specimen 0.062-inch thick using ¼-inch standard ASTM electrodes; 500 volts per second rate of rise.

Specification Writers: Please contact Dow Corning Corporation, Midland, Michigan, before writing specifications on this product.

range of -65 to 200 C (-85 to 392 F). Short time exposure (less than two hours) at temperatures as high as 300 C (572 F) will not degrade the encapsulant. However, generation of volatile species increases as the temperature is elevated.

When parts are embedded in Dow Corning 93-500 space-grade encapsulant, differences in thermal expansion values between the encapsulant and the embedded parts—and the shape of these parts—may influence temperature limits at which such systems may be used. For this reason, thermal operating limits for embedded components should be accurately determined by laboratory tests before large scale use.

Compatibility

Materials which have been found to inhibit the cure of Dow Corning 93-500 space-grade encapsulant include:

- Polyvinylchloride, plasticized
- Epoxy — amine cured
- Dow Corning® 630 protective coating
- Dow Corning® 3110, 3112, and 3120 RTV silicone rubber cured with Dow Corning RTV catalysts S or F; cured 7 days at room temperature (Dow Corning 3110, 3112, and 3120 RTV silicone rubbers cured with Dow Corning RTV catalyst S and F at room temperature plus 4 hours at 150 C do not inhibit cure.)
- Polysulfide MIL-S-8516
- Humiseal® 1B-27 coating
- Mystik® 5207 tape
- Mystik® 6215 tape
- Scotch® cellophane tape

Scotch® 360 tape
Permacel® masking tape
Vinyl electric tape
Pliobond® adhesive
Latex vacuum tubing
Neoprene rubber
Buna N rubber
GRS rubber
Natural rubber
Viton® A rubber
Acid core solder flux
Rosin core solder flux
Sulphur Compounds,
  Thiols
  Sulphides
  Sulphates
  Silphites
  Thioureas
Nitrogen Compounds,
  Amines
  Amides
  Imides
  Azides

Each application should be pretested with the product in question.

Corrosion
No corrosion has been observed on common metals—notably copper—when used with Dow Corning 93-500 space-grade encapsulant.

Mixing
Dow Corning® 93-500 curing agent is supplied with the encapsulant. Just prior to use, the two are blended in the ratio of 10 parts of encapsulant to 1 part of the curing agent, by weight. Thorough mixing is easy, since both encapsulant and curing agent are supplied as low viscosity fluids. During mixing, care should be taken to minimize entrapment of air. Any entrapped air should be removed before the encapsulant is poured.

If the encapsulant is cured in sections less than 1 inch deep, all entrapped air should escape before the cure is complete. For thick sections and quick de-airing, the use of a vacuum is required. The vacuum should be applied slowly; otherwise, the material may foam and overflow the container. As a rule, containers should be no more than half full. Vacuum should be held for 3 to 5 minutes after all bubbles have collapsed.

The encapsulant and the curing agent present no handling problems in normal industrial practice, either from the standpoint of skin irritation or accidental ingestion. Eye contact produces a slight temporary discomfort and essentially no irritation.

Varying Curing Agent Concentration
Variations of up to 10 percent in the concentration of curing agent in Dow Corning 93-500 space-grade encapsulant have little effect upon set-up time or on the properties of the final cured part. Lowering the curing agent concentration by more than 10 percent will result in a softer, weaker material which could have higher vacuum weight loss characteristics; increasing the percent will result in an overhardening of cured encapsulant and will tend to degrade physical and thermal-vacuum properties.

Preparing Containers and Components
Containers, molds or components which come into contact with Dow Corning 93-500 space-grade encapsulant should be clean and dry. Containers or molds which have been used to handle room temperature vulcanizing silicone rubber, organic rubber, or plastics should not be used, since traces of these materials may inhibit the cure or contaminate the encapsulant. Inhibition of cure which results from an incompatible component or substrate can usually be prevented by one of the following methods.

1. Wash the contaminants off with solvent; ultrasonic cleaning has also been found to be effective.

2. Volatilize the contaminants by heating prior to applying the encapsulant.

Applying and Curing
When pouring Dow Corning 93-500 space-grade encapsulant into the unit in which it is to be cured, care should be taken to minimize air entrapment within the system. Where practical, it is suggested that pouring be done under vacuum, particularly if the component being cast has many fine voids. When this technique cannot be used the unit should be evacuated after the encapsulant has been poured.

Dow Corning 93-500 space-grade encapsulant can be satisfactorily cured either exposed to air or completely sealed, and at temperatures ranging from 25 to 150 C (77 to 302 F).

After 24 hours at 25 C (77 F), Dow Corning 93-500 space-grade encapsulant will have cured sufficiently to allow handling. Full mechanical and electrical strength, and optimum weight loss properties, however, will not be achieved for 7 days. Curing time can be appreciably decreased by heating the compound. Suggested quick curing cycles are as follows: 65 C (149 F) for 4 hours or 100 C (212 F) for 1 hour or 150 C (302 F) for 15 minutes. Relatively massive parts will require additional time in the oven to bring them up to the required temperature

SHIPPING LIMITATIONS

None.

STORAGE AND SHELF LIFE

When stored in original unopened containers at or below 32 C (77 F), Dow Corning 93-500 space-grade encapsulant has a shelf life of 6 months from date of shipment.

PACKAGING

Dow Corning 93-500 space-grade encapsulant is supplied in packages that contain the encapsulant and its curing agent in separate containers. Net weights for complete packages —encapsulant and curing agent—are:

3.9-oz (110-gm) kit
1.1-lb (.5-kg) kit

USERS PLEASE READ

The information and data contained herein are believed to be accurate and reliable; however, it is the user's responsibility to determine suitability of use. Since Dow Corning cannot know all of the uses to which its products may be put or the conditions of use, it makes no warranties concerning the fitness or suitability of its products for a particular use or purpose.

You should thoroughly test any proposed use of our products and independently conclude satisfactory performance in your application. Likewise, if the manner in which our products are used requires governmental approval or clearance, you must obtain it.

Dow Corning warrants only that its products will meet its specifications. There is no warranty of merchantability or fitness for use, nor any other express or implied warranty. The user's exclusive remedy and Dow Corning's sole liability is limited to refund of the purchase price or replacement of any product shown to be otherwise than as warranted. Dow Corning will not be liable for incidental or consequential damages of any kind.

Suggestions of uses should not be taken as inducements to infringe any patents.

DOW CORNING CORPORATION
MIDLAND, MICHIGAN 48640

Printed in U.S.A. Form No. 10-102-82

DOW CORNING

Technical Data

conap®

LOW DUROMETER
REVERSION RESISTANT
POLYURETHANE MOLDING
AND POTTING SYSTEM

High Technology Polyurethane and Epoxy Resin Systems

CONAP, INC. • 1405 BUFFALO STREET • OLEAN, NEW YORK 14760-1139 • (716) 372-9650 • TWX 510-245-2769

CONATHANE®

EN-10 **EN-11** **EN-12**

This series of CONATHANE® two component, highly flexible liquid polyurethane molding and encapsulating systems assure the performance of electrical/electronics assemblies exposed to severe environmental extremes. Elastomers prepared from these systems exhibit the following outstanding properties:

- ° Superior Hydrolytic Stability ° Non-MOCA* Curing Systems ° Excellent Flexibility
- ° Low Dielectric Constant ° Low Viscosity ° Thermal Shock Resistance (-70°C to 135°C)
- ° Exceptionally High Dielectric Strength (600 vpm) ° Fungus resistance

The systems are recommended for cable and connector potting and molding - both military and commercial - electronic module potting, wire wound device encapsulation and strain sensitive component potting. Their excellent moisture resistance also suggest their use as 100% solids, thick film coatings for printed circuitry or, because of their soluability in most commercially available solvents as flexible thin film coatings. These systems have also shown exceptional adhesion to a wide variety of substrates.

Electrical properties of these systems are excellent; the dieletric constant and dissipation factor are exceptionally low and main relatively unchanged over the recommended operating temperature range of -65°C to 130°C.

EN-10 cures to a Shore A Hardness of 75 ± 5; EN-11 cures to a Shore A Hardness of 65 ± 5; EN-12 cures to a Shore A Hardness of 55 ± 5. Each of the three systems offer an application life of 60 minutes at 25°C and are available in translucent amber or black in preweighed two component units.

PRODUCT SPECIFICATIONS (TENTATIVE)

	EN-10	EN-11	EN-12
Color, Part A	<------ Translucent Amber ------>		
Part B	<------ Amber or Black ------>		
Viscosity @ 25°C, cps, Part A	7500 ± 2500	7500 ± 2500	7500 ± 2500
Part B	4000 ± 1000	3500 ± 1000	3000 ± 1000
Specific Gravity @ 25°C, Part A	0.97 ± .02	0.97 ± .02	0.97 ± .02
Part B	0.91 ± .02	0.91 ± .02	0.91 ± .02
NCO Content, %, Part A	9.0 ± .2	9.0 ± .2	9.0 ± .2
Unopened Shelf Stability, minimum @ 25°C (Parts A & B), Months	12	12	12

TYPICAL CURED PROPERTIES

The properties presented below are typical, based on several determinations, and are not intended for specification purposes. All test specimens were cured 16 hours at 80°C and conditioned at 25°C for 2-3 days prior to testing.

PHYSICAL PROPERTIES	EN-10	EN-11	EN-12	TEST METHOD
Color	<------ Translucent Amber or Black ------>			Visual
Specific Gravity @ 25°C	0.99	0.98	0.97	ASTM D-792
Hardness, Shore A	75 ± 5	65 ± 5	55 ± 5	ASTM D-2240
Tensile Strength, psi	1000 - 1250	600 - 900	200 - 400	ASTM D-412
100% Modulus, psi	300 - 500	200 - 350	100 - 200	
300% Modulus, psi	800 - 1000	400 - 450	---	

* DuPont Trademark

PHYSICAL PROPERTIES (con't)

	EN-10	EN-11	EN-12	TEST METHOD
Ultimate Elongation, %	400 - 500	350 - 400	215 - 250	ASTM D-412
Tear Strength, Graves, pli	140 - 180	100 - 140	65 - 90	ASTM D-624
Shrinkage, Linear, %	1.19	1.15	1.25	CONAP
Water Absorption, %, 24 hours	0.24	0.23	0.20	ASTM D-570
30 days	0.43	0.42	0.31	
Heat Stability, % wt. - Gain				MIL-I-16923E
After 7 days @ 135°C	0.95	0.13	0.05	
Fungus Resistence	NON Nutrient	NON Nutrient	NON Nutrient	MIL-STD-810B MIL-E-5272C
Thermal Shock, 10 cycles				MIL-I-16923E
Olyphant washer 130°C to -70°C	Passes	Passes	Passes	
Peel Strength, piw				MIL-M-24041
Aluminum primed with AD-1146-C	>20	>20	>20	
Stain.St.primed with AD-1146-C	>20	>20	>20	
Neoprene primed with PR-1167	>20	>20	>20	
PVC primed with AD-1161	>20	>20	>20	
Compression Set, %, 22 hours @ 70°C	32	24	10	ASTM D-395 Method B

ELECTRICAL PROPERTIES

	EN-10 25°C	EN-10 130°C	EN-11 25°C	EN-11 130°C	EN-12 25°C	EN-12 130°C	TEST METHOD
Dielectric Constant							ASTM D-150
100Hz	3.1	3.5	3.3	3.4	3.4	3.1	
1KHz	3.0	3.4	3.1	3.4	3.2	3.2	
1MHz	2.7	3.2	2.9	3.2	2.9	3.1	
Dissipation Factor							ASTM D-150
100Hz	.027	.028	.027	.030	.026	.029	
1KHz	.028	.033	.028	.036	.025	.036	
1MHz	.014	.043	.009	.023	.010	.017	

	EN-10	EN-11	EN-12	TEST METHOD
Volume Resistivity, ohm-cm				ASTM D-257
@ 25°C	$>4.3 \times 10^{15}$	$>4.3 \times 10^{15}$	$>4.3 \times 10^{15}$	
@130°C	9.9×10^{11}	4.8×10^{11}	4.5×10^{11}	
Surface Resistivity, ohms				ASTM D-257
@ 25°C	$>1.0 \times 10^{15}$	$>1.0 \times 10^{15}$	$>1.0 \times 10^{15}$	
@ 130°C	1.3×10^{12}	5.3×10^{12}	2.5×10^{12}	
Insulation Resistance, ohms				MIL-M-24041
@25°C	$>2.5 \times 10^{13}$	$>2.5 \times 10^{13}$	$>2.5 \times 10^{13}$	
@ 130°C	1.6×10^{10}	6.3×10^{10}	6.6×10^{10}	
Dielectric Strength, vpm (1/16")	710	610	600	ASTM D-149
Arc Resistance, sec.	>120	>120	>120	ASTM D-495
Flame Resistance, 55 amps D.C.	NO Ignition	NO Ignition	NO Ignition	MIL-M-24041

HYDROLYTIC STABILITY

Elastomers prepared from these systems offer unsurpassed reversion resistance. Physical property test data is available for each of these systems exposed to 97°C - 95% Relative Humidity, at 28-day periods up to 112 days of continuous exposure. electrical properties are also reported after completion of the 112 day exposure period. Please request CONAP Lab Report Number 459.

RECOMMENDED PROCESSING PROCEDURES

	EN-10	EN-11	EN-12
Mixing Ratio, pbw, Part A	100.0	100.0	100.0
Part B	37.0	55.0	95.0
Mixed Viscosity @ 25°C, cps. Initial	5500	5750	6500
30 Mins	9,000	12,000	18,500
60 Mins.	57,000	75,000	100,000
Exotherm (1/2 Lb. Mass), Mixed @ 25°C	55°C	55°C	55°C
Cure Time @ 60°C	24 hours	24 hours	24 hours
@ 80°C	16 hours	16 hours	16 hours
Demold time @ 60°C	8-10 hours	8-10 hours	8-10 hours
@ 80°C	2-3 hours	2-3 hours	2-3 hours

NOTE: Part A component of these systems may crystallize upon storage or during shipment. If this has occurred, heat to 60°C, mix thoroughly and cool to room temperature before processing.

THE PART B COMPONENT SHOULD BE THOROUGHLY MIXED PRIOR TO USE.

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Mix the two components together thoroughly at 25°C-40°C using metal, plastic or glass stirrers and containers. Degas the mixed material at 1-5 mm of mercury and pour into molds at 25°C-80°C. Containers should be large enough to allow for volume expansion during the degassing cycle. Any material or container that could introduce moisture in the system should be avoided.

SPECIAL NOTICE: Due to the excellent solubility of these liquid systems in solvents, such as methyl ehtyl ketone, xylene, toluene and various blends of them, these systems show promise also as flexible conformal coatings for printed circuitry and electronic assemblies. Initial laboratory evaluation has shown excellent dipping and spraying qualities when diluted 40-60% with a 50/50 blend of MEK/Toluene.

HANDLING AND STORAGE

The component parts of these systems are storage stable for a minimum of 12 months in the original, unopened containers when stored at temperatures of 70°F-85°F. If containers are opened and the contents only partially used, containers should be flushed with dry nitrogen or dry air before resealing to prevent waste of material.

CAUTION: Avoid contact with the resins and hardeners. The use of protective clothing is recommended. Should contact occur, wash with mild soap and water. Use only in well ventilated areas and avoid prolonged or repeated breathing of fumes. Curing ovens should be vented to the atmosphere.

COLORING

These systems can be supplied to cure to either a translucent amber or black solid. Please specify color when ordering. CONAP color concentrates can be added to make color variations. Please request technical Bulletin AC-112.

AVAILABILITY

CONATHANES® EN-10, EN-11 and EN-12 are available in two component, preweighed units in quart, gallon, 5-gallon and 55-gallon sizes.

One-quart EVALUATION KITS of any one of these systems are available at a nominal fee.

F.O.B. Olean, New York 14760

TERMS: Net 30 Days

021108

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SILICONE TECHNOLOGY

CV-2500
Controlled Volatility RTV Silicone

Description:

McGhan Nusil CV-2500 is a two -part, clear RTV Silicone specifically designed for applications requiring low outgassing and minimal volatile condensibles under extreme operating conditions.

Applications:

McGhan Nusil CV-2500 may be used as an embedding or potting compound for environmental protection of electronic asssemblies and components in industrial and space applications where minimal outgassing is essential to avoid condensation in sensitive devices. In addition to providing protection from extremes in temperature, humidity, radiation, thermal and mechanical stresses, CV-2500 is suitable as an adhesive in low-strength applications such as solar cell arrays where clarity and low volatility are of particular importance.

Mixing:

McGhan Nusil CV-2500 is mixed just prior to use in a ratio of 10 parts base to 1 part curing agent. Base and curing agent should be thoroughly mixed and vacuum deaired prior to use. Apply vacuum slowly to a container several times the volume of material mixed to avoid overflow of the bubbles.

Typical Properties as Supplied:

Chemical Classification	VMQ
Color	Clear
Viscosity, cps	8000
Working Time, hours	1
Mix Ratio	100 : 10
Cure Time, @ 25 C	
Set Up, hours	24
Full Cure, days	7
Cure System	Pt Addition

Typical Properties:
Cured 30 minutes @ 150 C

Appearance	Clear, elastomer
Specific Gravity @ 25°C (77°F)	1.04
Durometer, Type A	50
Tensile Strength, psi	900
Elongation, %	100
Dielectric Strength, volts/mil	550
Volume Resistivity, ohm-cm	1×10^{15}
Collected Volatile Condensable Material, % (CVCM)	0.01
Total Mass Loss, % (TML)	0.50

TOTAL MASS LOSS AND COLLECTED VOLATILE CONDENSABLE MATERIAL ARE TESTED IN ACCORDANCE WITH ASTM E-595-77 AND NASA SP-R-0022A. CURED PER McGHAN NuSIL TEST METHOD #TM-012A.

Typical Cure Schedule:

McGhan Nusil CV-2500 is designed to cure at room temperature as well as at elevated temperatures. The following table illustrates the effects of temperature on cure time:

Temperature C (F)	Cure Time
25C (77F)	24 Hours
65C (149F)	2 Hours
100C (212F)	30 Minutes
150C (302F)	10 Minutes

Substrate Considerations:

CV-2500 will cure in contact with most materials. Exceptions include butyl and chlorinated rubbers, some RTV silicones and unreacted residues of some curing agents.

NOTE: A PRIMER MAY BE REQUIRED IN SOME BONDING APPLICATIONS. McGHAN NuSIL CF1-135 SILICONE PRIMER IS RECOMMENDED.

Storage and Shelf Life:

Shelf life of CV-2500 is 6 months from date of shipment when stored in original unopened containers at 25C. Refrigeration may extend the shelf life, but care should be taken to warm the CV-2500 to ambient temperature before opening the container.

Packaging:

50 gram kit
100 gram kit
500 gram kit

Specifications:

The typical properties shown in this technical profile should not be used as a basis for preparing specifications. Please contact McGhan NuSil Corporation for assistance and recommendations on specification limits.

CAUTION:

IT IS RECOMMENDED THAT THE PURCHASER THOROUGHLY TEST PERFORMANCE AND SAFETY OF ANY APPLICATION PRIOR TO FULL SCALE PRODUCTION OR COMMERCIALIZATION. TYPICAL APPLICATIONS LISTED IN THIS TECHNICAL PROFILE SHOULD NOT BE TAKEN AS INDUCEMENT TO INFRINGE ANY PATENT. McGHAN NuSIL WARRANTS ONLY THAT ITS PRODUCTS MEET ITS SPECIFICATIONS. THERE IS NO WARRANTY OF MERCHANTIBILITY OF FITNESS FOR USE OR ANY OTHER EXPRESS OR IMPLIED WARRANTIES. McGHAN NuSIL CORPORATION MAKES NO GUARANTEE OF SATISFACTORY RESULTS FROM RELIANCE UPON INFORMATION, STATEMENTS OR RECOMMENDATIONS CONTAINED HEREIN AND DISCLAIMS ALL LIABILITY FROM ANY RESULTING LOSS OR DAMAGE.

Appendix A

SOLITHANE® 113 PREPOLYMER

Morton Thiokol, Inc.

DESCRIPTION

Solithane 113 resin is an extremely versatile liquid urethane prepolymer which can be cured with a variety of polyol and/or amine curing agents. Processing temperatures can range from 80°F to 300°F (27°C to 149°C) permitting low temperature, non-exothermic cure systems for temperature-sensitive parts. Depending upon the selection and amount of curative employed, the cured compounds can display hardness ranging from 15 Shore A to 80 Shore D.

APPLICATIONS

The processing versatility of Solithane 113 resin permits it to be cast into intricate, void-free shapes for a variety of applications. Although cure temperatures as high as 300°F (149°C) are generally recommended for rapid mold turnover, longer cure cycles at lower temperatures can be utilized for potting temperature-sensitive parts or sophisticated electric hardware. The outstanding electrical properties inherent in every product derived from Solithane 113 resin designate it as an ideal prepolymer for electrical potting, encapsulation and conformal coating applications. Protective coatings formulated from Solithane 113 resin can be applied by spraying, dipping or brushing techniques to metallic and non-metallic surfaces.

In addition, Solithane 113 resin can be used for photo-elastic stress analysis. Cured compounds, when placed under stress, rotate the plane of polarized light along the principal stress axis. By bonding films of Solithane 113 resin to complex objects, or by molding prototype parts from this urethane rubber, the strain areas can be observed visually (using polarized light as an analyzer) when the object is placed under stress. Several publications* described characterization of Solithane 113 resin compounds for photo-elastic stress analysis.

1. "The Mechanical and Optical Characteristics of Solithane 113 Resin and Investigation of Optical Lag in Photoviscoelastic Analysis," California Institute of Technology, Technical Report No. WLTR-64-15;

2. "Make Strain Visible," Product Engineering, November 8, 1965, pp. 98-101;

3. "New Method to Determine Restrained-Shrinkage Stresses in Propellant-Grain Models," A.J. Durelli and V.J. Parks, Prof. and Asst. Prof., respectively, Catholic University of America, Washington, DC;

4. "Some Low-Modulus Birefringent Resins," A. San Miguel and E.N. Duran, Senior Research Engineer and Assistant Engineer, respectively, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California.

**These have been summarized in Morton Thiokol's Materially Speaking No. 3, May, 1966.*

POLYMER PROPERTIES

Appearance	Pale yellow liquid
Isocyanate (NCO) %	10.6 ± 0.2
Average Viscosity, poise	
at 80°F (27°C)	200-300
at 140°F (60°C)	10- 20
at 212°F (100°C)	2- 3
Average Specific Gravity	1.073
Flash Point (ASTM D97-66)	430°F (221°C)
Storage Stability	(See Figure I)

® Registered trademark

PHYSICAL PROPERTIES

The physical properties of cured Solithane 113 resin compounds are controlled by the type and amount of curative or combination of curing agents used. Two typical curing agents are C113-300 and TIPA (triisopropanolamine)*, supplied by Morton Chemical Division. By varying the quantity of C113-300, materials within a hardness range of 15 Shore A to 60 Shore A can be formed. Blending C113-300 curing agent with TIPA in varying proportions, makes it possible to produce cured compounds within the 40 Shore A to 75 Shore D hardness range. (Refer to Table I for properties obtained with Solithane compounds cured with C113-300 curing agent or TIPA.)

Cured compounds of Solithane 113 resin exhibit excellent electrical properties throughout the broad range of hardness values. (Typical electrical properties of cured compounds listed in Table I are shown in Table V.)

The chemical resistance of two compounds taken from Table I, which represent opposite extremes in the range of hardness, indicates an excellent resistance to water, oils, dilute acids and bases. (Refer to Table VI.)

Cured Solithane 113 resin compounds also show exceptional hydrolytic stability (as indicated in Table VII.)

For special applications such as potting, coating and encapsulation of electronic circuits in rocket guidance systems, Solithane 113 resin compounds provide superior resistance to ultra-high vacuum environments. (Table VIII shows typical outgassing data for cured Solithae 113 resin compounds.)

PROCESSING

Processing Temperatures

Although Solithane 113 resin is pourable at 80°F (27°C), heating the prepolymer will make it easier to handle. (The effect of temperature on the viscosity of Solithane 113 resin is shown in Figure II.)

Curing Agent C113-300, a clear liquid polyol, will cure Solithane 113 resin at room temperature (80°F (27°C) without any noticeable exotherm. This system is most practical when potting temperature-sensitive parts.

Curing agent TIPA, a low melting solid, will cure Solithane 113 resin either alone or in varying proportions with C113-300 curing agent. Melting TIPA (m.p. 137°F (58°C) prior to its addition to Solithane 113 resin alleviates "lumping" in the cure. When blends of TIPA and C113-300 curing agent are heated together in the proportions recommended in Table I, a very stable, clear, homogenous mixture is obtained. Separation of these mixtures will not cure, even when stored at low temperatures.

Solithane 113 resin can be cured at temperatures as high as 300°F (149°C), when rapid mold turnover is desired. (The effect of different cure temperatures on two formulations from Table I is shown in Table II).

Mixing and Degassing

Solithane 113 resin can be processed by the "hand batch" technique or with automatic mixing and metering machines.

The prepolymer can be adequately mixed at 80°F (27°C) with C113-300 curing agent and/or TIPA. As the amount of C113-300 curing agent is increased, the initial mix viscosity is decreased (as shown in Figure III). Effective degassing of these compositions is dependent upon the percentage of C113-300 curing agent used, the total amount of material being degassed, and the efficiency of the vacuum system.

McKesson Chemical Co.

When processing at higher temperatures, degassing of the mix is faster and easier, and can be further improved by taking the following steps:

1. Preheat Solithane 113 urethane prepolymer to processing temperature.
2. Degas the prepolymer at a vacuum less than 10 mm Hg.
3. Return prepolymer to processing temperature.
4. Heat the curing agent and maintain in the molten state.
5. Combine prepolymer and curing agent, blend thoroughly.
6. Degas the blended material and release vacuum slowly when bubble formation is minimal.
7. Pour the blend into a properly released mold which has been preheated to curing temperature.
8. Cure the cast in a circulating hot air oven.

Additives

Plasticizers

The low temperature properties of Solithane 113 resin compounds are improved by the addition of plasticizers. A variety of plasticizers, (listed in Table III), can be used effectively up to 20 parts per 100 parts of prepolymer. Heat aging plasticized compounds 70 hours at 212°F (100°C) produces insignificant changes in physical properties.

Morton Thiokol's TP®-90B plasticizer effectively extends low temperature properties, and additionally incorporates fungus resistance into cured Solithane 113 resin compounds.

Accelerators

The effect of a typical organo-metallic compound on Formulation No. 1 from Table I is shown below:

Catalyst T-12*, pph	Pot Life, 80°F (27°C)
None	180 minutes
0.120	90 - 120 minutes
0.135	50 minutes
0.500	15 minutes

**M & T Chemicals, Inc.*

Colorants

Solithane 113 resin compounds can be formulated with pigment dispersions designed for polyester resins. The translucence, opacity and intensity of color is based on the amount of color paste used. Colorants supplied by Ferro Corporation, Claremont Pigment Dispersion Corporation, and Harwick Standard Chemical Corporation can effectively be added to Solithane 113 resin prior to degassing. The effect of increasing concentrations (using one of Claremont's 4000 series) on the physical properties of Formulation No. 1 from Table I is shown in Table IX.

Curing

Cure Systems

As indicated in Table I, the physical properties of the cured compound depend upon the type and amount of curing agent used, either alone or in combination with other curatives. An increase in the amount of C113-300 curing agent:

- Lowers initial mix viscosity of system
- Increases pot life
- Lowers durometer hardness
- Lowers stress-strain properties
- Increases low-temperature properties

An increase in the amount of TIPA:

- Decreases pot life, cure time
- Increases durometer hardness
- Increases stress-strain properties*

Alternate cure systems by polyfunctional curing agents containing active hydrogens are also possible, (but not discussed in this bulletin). However, the use of the above cure system minimizes the number of curatives necessary to formulate different applications.

The rate of cure for three formulations from Table I, expressed as the change in viscosity at 15 minute intervals at 140°F (60°C) is illustrated in Figure IV.

**when used in blends with C113-300 curing agent*

Post Cure

Optimum properties are generally obtained after 7 days at 80°F (27°C) (R.T.). Solithane 113 resin compounds are relatively unaffected by additional heating at temperatures up to 250°F (121°C). However, signs of instability become evident in some formulations after three weeks exposure to 300°F (149°C). The effect on the physical properties of cured Solithane 113 compounds exposed to various temperatures is shown in Table IV.

Bonding

Solithane 113 resin compounds adhere to most substrates without the use of a primer. Some substrates can be simply treated with a solvent wipe or light abrading with sandpaper. However, bonding surfaces should be clean and free of oily films.

If a primer is used, the manufacturer's recommendations should be followed. Some bonding agents used effectively with Solithane 113 resin compounds are Chemlok 218, Thixon XAB-936, Thixon XAB-1153, and Conap's 1146C.

Release Agents

Molds used for casting Solithane 113 resin compounds should be clean and lubricated properly for easy removal of the finished product. A variety of release agents are commercially available and the manufacturer's recommendations should be followed. Some release agents used effectively with Solithane resins are Exxit II, Korac 1711 (both aerosols) from Contour Chemical Company and DC-7 or DC-20 mold release (wipe-on or brush-off release agents) from Dow Corning Corporation.

STORAGE AND HANDLING

Solithane 113 resin can be handled conveniently at 140°F (60°C). This temperature is sufficient to reduce its viscosity for easy pouring without fear of thermal molecular degradation or undue chain extension of the prepolymers.

Solithane 113 resin is available in 1 gallon or 5 gallon containers. Generally, compounders will "break down" these quantities into smaller units to minimize undue exposure of the entire batch to heat or atmospheric humidity. Flushing the container with nitrogen, prior to resealing, will inhibit "skinning" of the prepolymer.

To eliminate unnecessary thickening of the resin at elevated temperatures, refer to Figure I.

SAFETY (TOXICITY)

Toluene diisocyanate (TDI) and, to a lesser degree, urethane prepolymers are irritating substances in liquid or vapor forms. They produce irritation if contact is made with skin or eyes and they may cause burns if not immediately removed.

Inhalation of the vapors may be injurious to the lungs, and the vapor may make breathing difficult. In some cases, the vapor can cause respiratory distress, even at extremely low concentrations. Therefore, care in handling and good housekeeping practices are recommended.

Safety Precautions

Ventilation

Good ventilation is essential in rooms or areas where diisocyanate containing materials are handled. Hood-type ventilation units installed over processing equipment or (where this is not possible) effective mechanical ventilation of the entire area should be provided.

Air Analyzers

Calibrated equipment for detecting diisocyanate containing vapors is commercially available.

Safety Equipment

Personal Protection

Properly designed emergency showers and eye baths should always be available in convenient locations and employees should be advised of their location and instructed in their use.

TDI urethane prepolymers are not serious industrial hazards if workers are adequately informed and supervised in the proper means of handling these materials.

Personal Hygiene

Clean work clothing and clean working areas help prevent contamination.

Eye Protection

Safety glasses or chemical safety goggles should be worn.

Respiratory Protection

A suitable air mask, gas mask or some breathing apparatus should be worn by employees exposed to higher levels of vapor concentration.

Body, Hand Protection

Appropriate clothing (e.g. long sleeved shirts) and rubber gloves should be worn where there is danger of skin contamination. Protective hand creams are also available. Contaminated clothing should be removed and laundered before reuse.

Skin Contact

The polymer should be removed from the skin by wiping (clean cloth or disposable paper towels), followed by washing with soap and water, or with rubbing alcohol. Solithane 113 resin is not a primary irritant, but a physician should be consulted if a rash or irritation develops.

Eye Contact

Wash eyes immediately with large amounts of water for at least 15 minutes.
TREATMENT BY A PHYSICIAN SHOULD FOLLOW IMMEDIATELY.

Inhalation of Vapor

A person showing symptoms of isocyanate fume irritation, (such as respiratory distress, severe coughing) should be removed promptly from the contaminated area and administered oxygen by a trained person. Artificial respiration should be applied immediately if breathing stops. A PHYSICIAN SHOULD BE CALLED IMMEDIATELY.

Additional Information

For more detailed information about safe handling and use of TDI and isocyanate containing materials, refer to the "Chemical Safety Data Sheet SD-73" from the Manufacturing Chemists Association, Inc.

TEST METHODS

All test methods are ASTM methods, unless otherwise specified.

Hardness, Shore A/D	D-2240-75
Stress-Strain (Tensile testing of vulcanized rubber)	D-412-68
Stress-Strain (Tensile properties of plastics)	D-638-72
Impact Resistance	MIL-C-16923G (October, 1972)
Volume & Surface Resistivity	D-257-75a
Dielectric Constant & Dissipation Factor	D-150-74
Dielectric Strength	D-149-75

TABLE I
TYPICAL ALTERNATE CURE CYCLES

Formulation	**1**	**17**
Solithane 113 resin, pbw	100	100
C113-300	73	---
TIPA	---	15
Cured At 75°F (23°C)		
Set Time	Overnight*	60 minutes
Tack-Free Time	48 hours	130 minutes
Cure Time (1)	48 hours	Overnight
Shore Hardness (2)	35A	40D
Cured at 150°F (66°C)		
Set Time	90 minutes	20 minutes
Tack-Free Time	150 minutes	40 minutes
Cure Time	180 minutes	15 hours
Shore Hardness	36A	54D
Cured at 200°F (93°C)		
Set Time	50 minutes	12 minutes
Tack-Free Time	80 minutes	20 minutes
Cure Time	120 minutes	120 minutes
Shore Hardness	40A	60D
Cured at 250°F (121°C)		
Set Time	12 minutes	7 minutes
Tack-Free Time	15 minutes	10 minutes
Cure Time	90 minutes	60 minutes
Shore Hardness	53A	65D

* 12 - 16 hours
(1) Time required to demold
(2) After cure time

TABLE II
PLASTICIZERS FOR SOLITHANE 113 RESINS

Control Formula: Compound No. 1 (See Table No. 1)

Original Physical Properties

Plasticizer	Parts	Tensile psi, (kg/cm²)	Elongation %	Shore A Hardnes	Die C Tear pli (kg/cm)	L.T. Torsional ($G_{10,000}$) Modulus °F (°C)
Control	none	400 (28)	100	60	15 (2.7)	+3 (-16)
TP-90B Plasticizer	5	330 (23)	95	60	19 (3.4)	-6 (-21)
	10	290 (20)	80	58	19 (3.4)	-15 (-26)
	20	235 (17)	60	56	17 (3.0)	-33 (-36)
Di-Octyl Sebacate	5	450 (32)	130	58	25 (4.5)	0 (-18)
	10	325 (23)	95	56	22 (3.9)	-20 ([illegible])
	20	225 (16)	60	54	16 (2.8)	-30 (-34)
Tri-Octyl Phosphate	5	340 (24)	95	57	24 (4.3)	-2 (-19)
	10	260 (13)	80	55	19 (3.4)	-12 (-24)
	20	195 (14)	55	52	16 (2.8)	---

TABLE III
HEAT RESISTANCE OF SOLITHANE 113 RESIN COMPOUNDS

Physical Properties (After 28 Days at Temperature Indicated)

Temperature	100% Modulus psi (kg/cm²)		Elongation, %		Shore Hardness		Tensile psi (kg/cm²)	
Formulation No.	1	17	1	17	1	17	1	17
80°F (27°C)	---	---	80	5	66A	79D	375 (26)	3060 (215)
158°F (70°C)	430 (30)	---	105	5	68A	77D	470 (33)	3450 (242)
212°F (100°C)	450 (31)	---	105	5	67A	75D	460 (32)	3760 (264)
250°F (121°C)	460 (32)	---	105	20	65A	72D	525 (37)	4010 (282)
300°F (149°C)	525 (37)	---	160	100	65A	25D	675 (47)	2165 (152)

TABLE IV
COMPOUNDS OF SOLITHANE 113 RESIN CURED WITH C113-300 CURING AGENT & TIPA

Formulation, pbw	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Solithane 113 Resin	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C113-300	73.0	80.0	90.0	100.0	110.0	120.0	150.0	65.5	58.0
TIPA	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1.5	3.0
Working Properties at 80°F (27°C)									
Pot Life, Hours	3	6	6	6.5	6.5	6.5	8	3.5	3.6
Set Time, Hours	Overnight*	Overnight	Overnight	Overnight	Overnight	48	Overnight	Overnight	8
Tack Free Time, Days	4	3	3	4	4	4	4	4	3
Properties After 1 Hr. at 300°F (149°C)									
Shore Hardness									
After: 1 day at 80°F (27°C)	55A	53A	52A	49A	44A	35A	16A	40A	55A
3 days at 80°F (27°C)	57A	54A	51A	48A	43A	35A	- - -	55A	58A
5 days at 80°F (27°C)	58A	- - -	- - -	- - -	43A	35A	15A	62A	62A
7 days at 80°F (27°C)	60A	54A	51A	47A	43A	36A	15A	62A	64A
Properties After 1 Hr. at 300°F (149°C) and 7 Days at 80°F (27°C)									
Stress-Strain Properties:									
Tensile Strength, psi (kg/cm²)	400 (28)	340 (24)	280 (20)	245 (17)	140 (10)	160 (11)	70 (5)	460 (32)	495 (35)
Elongation, %	100	95	85	95	75	110	145	115	125
100% Modulus, psi (kg/cm²)	350 (25)	- - -	- - -	- - -	- - -	155 (11)	50 (4)	395 (23)	425 (30)
Tear Properties:									
Tear Strength, Die C, pli (kg/cm)	10 (1.8)	18 (3.2)	15 (2.7)	15 (2.7)	10 (1.8)	0	0	20 (3.6)	20 (3.6)
Bashore Resilience:									
Rebound, %	4	7	6	10	10	15	10	3	6
Falling Ball Impact:									
Impact Strength, ft.-lbs. (kg/cm)	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9
Taber Abrasion:									
Abrasion Index	70	65	45	45	40	70	150	85	105

TABLE IV (Continued)
COMPOUNDS OF SOLITHANE 113 RESIN CURED WITH C113-300 CURING AGENT & TIPA

Formulation, pbw	10	11	12	13	14	15	16	17
Solithane 113 Resin	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C113-300	51.0	44.0	36.5	29.0	21.5	14.7	7.3	- - -
TIPA	4.5	6.0	7.5	9.0	10.5	11.8	13.2	15.0
Working Properties at 80°F (27°C)								
Pot Life, Hours	1.8	1.7	1	0.5	0.5	0.4	0.5	0.3
Set Time, Hours	7	4.5	6	6.5	3.2	1	1.8	1
Tack Free Time, Days	2	3	3	3	2	2	Overnight	Overnight
Properties After 1 Hr. at 300°F (149°C)								
Shore Hardness								
After: 1 day at 80°F (27°C)	55A	68A	70A	72A	40D	49D	65D	75D
3 days at 80°F (27°C)	60A	68A	72A	78A	52D	41D	68D	75D
5 days at 80°F (27°C)	61A	70A	78A	85A	56D	47D	69D	80D
7 days at 80°F (27°C)	66A	70A	80A	87A	58D	60D	70D	80D
Properties After 1 Hr. at 300°F (149°C) and 7 Days at 80°F (27°C)								
Stress-Strain Properties:								
Tensile Strength, psi (kg/cm²)	770 (54)	1310 (92)	2100 (148)	2750 (193)	2890 (203)	3200 (225)	3480 (295)	2530 (178)
Elongation, %	130	150	120	120	95	60	50	20
100% Modulus, psi (kg/cm²)	475 (33)	670 (147)	1140 (80)	2335 (164)	- - -	- - -	- - -	- - -
Tear Properties:								
Tear Strength, Die C, pli (kg/cm)	45 (8.0)	65 (11.6)	110 (19.6)	175 (31.3)	310 (55.4)	450 (80.4)	445 (79.5)	425 (75.9)
Bashore Resilience:								
Rebound, %	25	20	25	35	40	40	40	30
Falling Ball Impact:								
Impact Strength, ft.-lbs. (kg/cm)	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	>107.4 >14.9	87.2 12.1	95 13.1
Taber Abrasion:								
Abrasion Index	120	130	120	175	165	165	195	150

Note: ASTM Test Methods used in all Tables are indicated on page 7
* - 12 - 16 hours

TABLE V
ELECTRICAL PROPERTIES OF TYPICAL SOLITHANE 113 RESIN COMPOUNDS

Formulation No. (Refers to Table 1)	1	6	12	15
Hardness				
Shore A or D	60A	35A	80A	60D
Vol. Resistivity, ohm-cm				
80°F (27°C)	$2.5x10^{14}$	$7.0x10^{12}$	$2.7x10^{14}$	$3.6x10^{14}$
185°F (85°C)	$7.2x10^{12}$	$5.0x10^{10}$	$2.7x10^{12}$	$2.4x10^{13}$
Surface Resistivity, ohm				
80°F (27°C)	$1.5x10^{15}$	$1.5x10^{15}$	$1.5x10^{15}$	$1.5x10^{15}$
185°F (85°C)	$1.5x10^{15}$	$1.5x10^{15}$	$1.5x10^{15}$	$1.5x10^{15}$
Dielectric Constant, 1 Kc				
80°F (27°C)	4.2	5.0	3.6	2.8
185°F (85°C)	4.8	4.8	5.1	4.5
Dissipation Factor, 1 Kc				
80°F (27°C)	0.162	0.091	0.056	0.014
185°F (85°C)	0.006	0.079	0.028	0.120
Dielectric Constant, 80°F (27°C)				
50 Kc	3.6	3.8	3.5	2.8
100 Kc	3.5	3.8	3.5	2.8
500 Kc	3.4	3.4	3.5	2.8
2 Mc	3.2	3.3	3.4	2.8
10 Mc	3.0	3.2	3.4	2.8
Dissipation Factor, 80°F (27°C)				
50 Kc	0.040	0.074	0.018	0.007
100 Kc	0.039	0.069	0.016	0.007
500 Kc	0.038	0.047	0.014	0.006
2 Mc	0.015	0.014	0.005	0.004
10 Mc	0.010	0.012	0.005	0.004
Dielectric Strength, Volts/Mil, 80°F (27°C), 75 Mil Sheet				
Short Time	378	512	440	340
Step/Step	324	473	347	334

(Samples cured 2 Hours at 300°F (149°C) + 7 Days at 75°F (23°C)

TABLE VI
RESISTANCE OF SOLITHANE 113 RESIN COMPOUNDS TO COMMON CHEMICALS AND SOLVENTS*

Formulation No. (Refer to Table 1)	1 % Vol. Swell	1 % Wt. Gain	17 % Vol. Swell	17 % Wt. Gain
Fluid Tested				
Acetone				
1 Day				
30 Days	Specimens Cracked			
Toluene				
1 Day				
30 Days	Specimens Cracked			
Ethyl Acetate				
1 Day				
30 Days	Specimens Cracked			
Ethyl Alcohol				
1 Day	6.6	18.3	1.0	10.8
30 Days	6.3	16.0	6.7	18.2
Water				
1 Day	0	0.23	0	0.25
30 Days	0	0.18	-0.7	0.33
Sodium Hydroxide, 10%				
1 Day	0	0.24	0	0.30
30 Days	---	0.04	---	0.16
Hydrochloric Acid, 10%				
1 Day	0	0.30	-0.7	0.23
30 Days	30	0.16	0	0.27
Sulfuric Acid, 10%				
1 Day	0	0.31	0	0.31
30 Days	0	0.15	-0.7	0.28
SR-6 Ref. Fuel				
1 Day	23.6	66.9	9.3	26.0
30 Days	---	---	13.7	38.6
ASTM Fuel No. 1				
1 Day	5.6	11.0	0	0.50
30 Days	6.7	14.9	0	3.2

*At room temperature by immersion

TABLE VII
EFFECT OF BOILING WATER ON PHYSICAL PROPERTIES OF SOLITHANE 113 RESIN COMPOUNDS

Formulation No. (Refers to Table 1)	**1**		**17**	
Conditions:	7 days/75°F (23°C) (Control)	7 days/H_2O (at 212°F) (100°C)	7 days/75°F (23°C) (Control)	7 days/H_2O (at 212°F) (100°C)
Physical Properties:				
Modulus, psi at 100% (kg/cm²)	270 (19)	270 (19)	610 (45)	530 (37)
Tensile, psi (kg/cm²)	320 (22)	420 (30)	1840 (129)	1700 (120)
Elongation, %	120	130	170	175
Shore A	55	55	80	78

TABLE VIII
TYPICAL OUTGASSING DATA

	pbw
Solithane 113 Resin	100
C113-300 cure agent	74
Temperature	Weight loss (at 10 x 10^7mm Hg)
R.T.	0 136%)
140°F (60°C)	0.199%) Entirely Water
180°F (82°C)	0.260%)
248°F (120°C)	1.39%)

TABLE IX

Formulation:	Solithane 113 Resin	100 pbw
	C113-300 cure agent	73.5
	Claremont Leaf Green Paste 4060-Cro-1	(As indicated)

Paste Concentration, pbw	Hardness, Shore A	Tensile Strength, psi (kg/cm²)	Elongation, %
	(Samples cured 2 hrs. at 300°F (149°C) + 7 days at 73°F (23°C)		
0.0	59	370 (26.0)	96
0.5	59	395 (27.8)	98
1.0	60	385 (27.1)	96
2.0	60	375 (26.4)	97
5.0	60	406 (28.5)	103
10.0	61	429 (30.2)	99
15.0	61	412 (29.0)	98

FIGURE I

Effects of Storage Temperature on Viscosity of Solithane 113 Resin

Brookfield Viscosimeter, Model RVF
Spindles No. 3

Solithane 113 resin may be stored under the usual warehouse conditions. Repeated freezing and thawing does not affect the performance of the polymer. No noticeable changes in it stability under ambient conditions have been experienced to date.

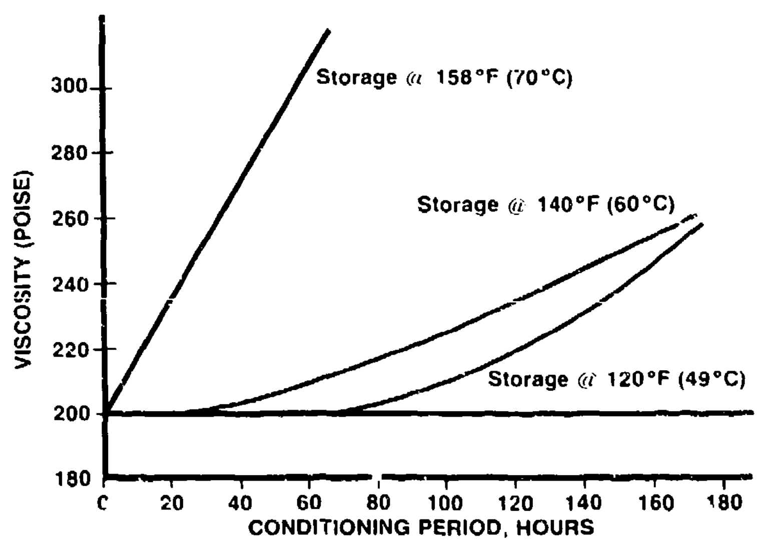


FIGURE II
Effect of Temperature on Viscosity of Solithane 113

Brookfield Viscosimeter
Model RVF

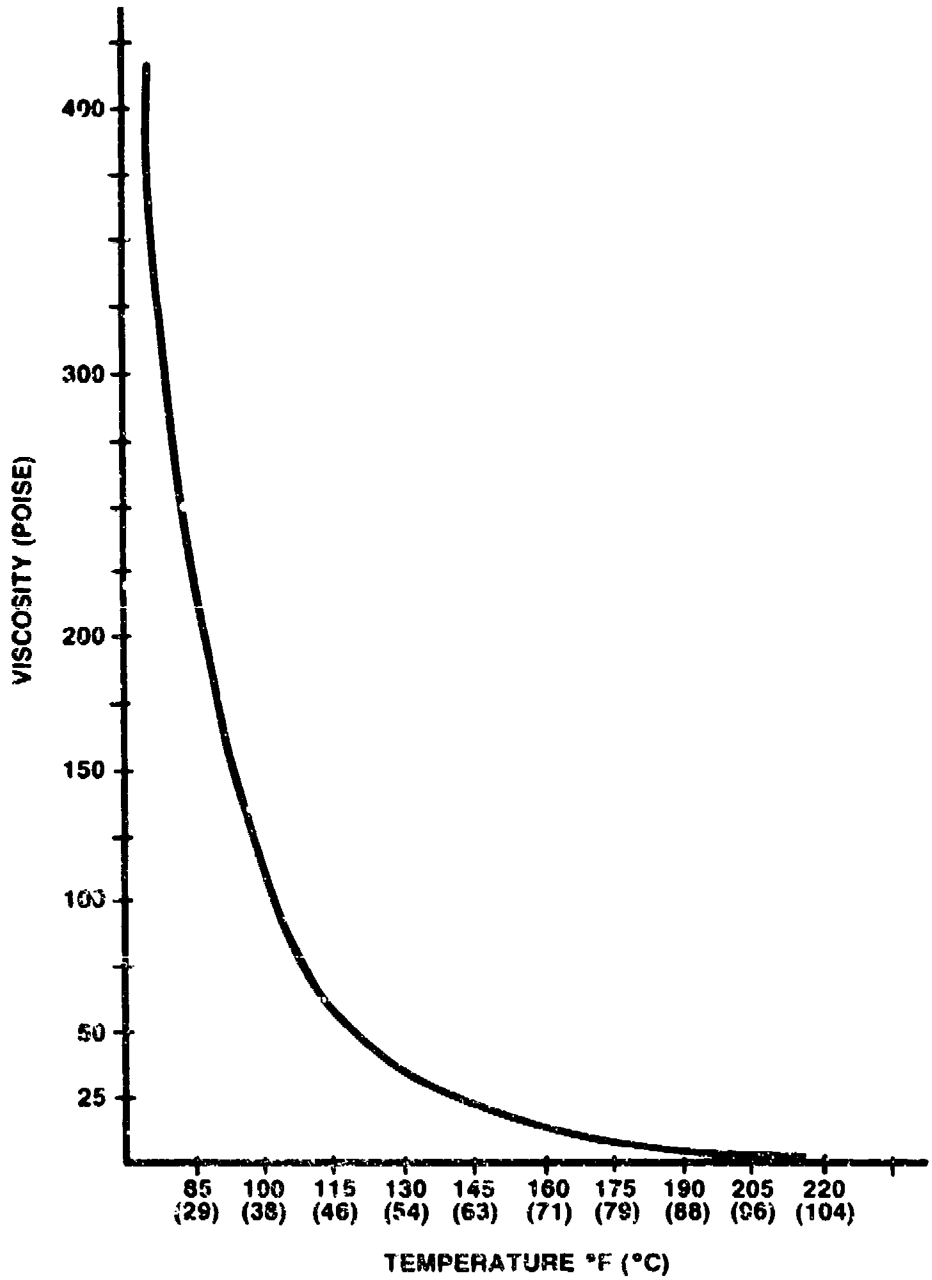
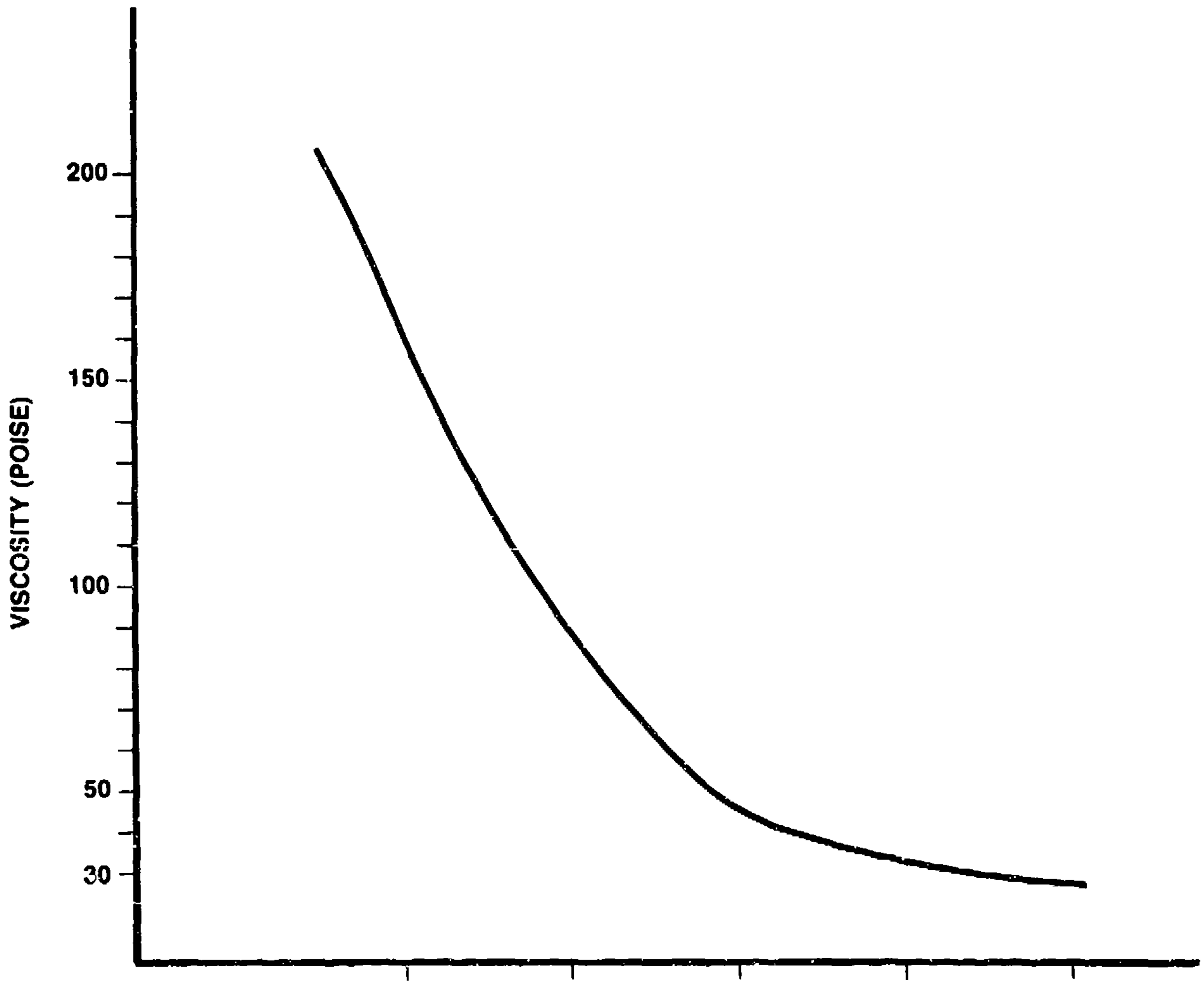


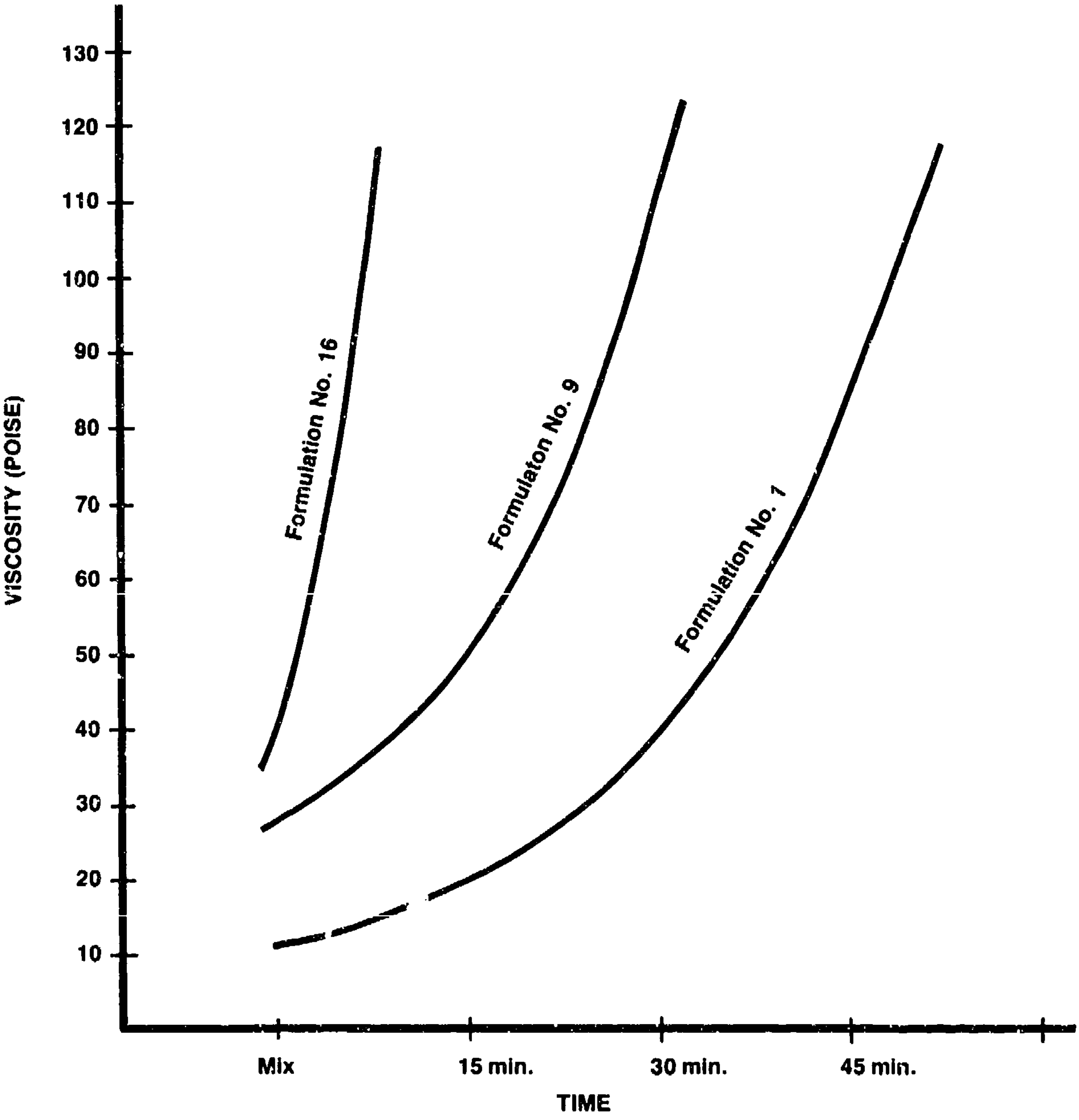
FIGURE III
Effects of C113-300 on Viscosity of Solithane 113 Resin

Brookfield Viscometer
Model RVF
Spindle No. 3
80°F (27°C)



Formulation No.	12	9	1	3	6
C113-300, pph.	36.5	58	73	90	120
TC-700, pph.	7.5	3	--	--	--

FIGURE IV
Rate of Cure Expressed by Viscosity Change
At 15 Minute Increments at 140°F (60°C)



Listed below are data on SOLITHANE 113 resin (100 parts) when cured with C-113-300 curing agent (73 parts). Such data may be helpful in aerospace applications.

1. Coefficient of Lineal Expansion
   7×10^{-5} inches/inch/degree F (from -65°F to + 160°F)

2. Specific Heat
   0.44 calories/°C/gram

3. Thermal Conductivity
   5.0×10^{-4} calories/second/sq. cm/°C/cm

4. Ionising Radiation Resistance
   10 million RAD

5. Brittle Point
   +6.2°F (-14°C)

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