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OUTGASSING STUDIES ON SOME POLYMER SYSTEMS  
FOR GSFC COGNIZANT SPACECRAFT

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ABSTRACT

The data presented in this document indicate that many glass-filled thermoplastic polymers (potential structural materials for space applications) have very low outgassing profiles and that two room-temperature curing silicone potting compounds are also in this category. Many elastomeric-type silicones are entirely suitable after high-temperature post-cure. Methacrylates have been shown acceptable as optical elements. This document also presents results on some miscellaneous functional systems.

Materials were heated at 125°C for 24 hours at from  $1 \times 10^{-6}$  to  $1 \times 10^{-7}$  torr. Outgassed products were condensed on a 25°C surface. Criteria for acceptable materials are 1 percent total vacuum outgassing and 0.1 percent condensables.

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OUTGASSING STUDIES ON SOME POLYMER SYSTEMS  
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INTRODUCTION

GSFC project engineers and contractors have become increasingly aware of the need for "clean," low-outgassing polymer materials for use in and next to critical spacecraft optical systems. First-hand experience with optical-system or experiment failure, resulting from inadequate preliminary review of polymer materials at elevated test temperatures has sharpened this critical awareness. Many project engineers have provided some suspect items for this study. In addition, the Polymer Section has investigated potentially suitable formulations for future spacecraft-engineering use. The following is an initial list of the items examined.\*

The following tables can assist the engineer in selecting materials and design. However, it is desirable that the engineer continue to seek specific guidance on hardware compatibility from a total material system viewpoint.

The following tables will be increased as additional data become available.

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\*For test details see "GSFC Micro-Volatile Condensable Materials System for Polymer Outgassing Studies," X-735-69-471, A. Fisher and B. Mermelstein, available on request to Code 735.

Table 1

## Glass-Reinforced Polymers

Description of Materials	Percent of Resin/Glass (pbw)	Code	Percent Weight Loss	Percent Condensables*
<u>Acrylonitrile-butadiene-glass</u>	70/30	AF 1006	0.20	0.01
<u>Nylon 6/6-glass</u>	70/30	RF 1006	0.81	0.04
<u>Nylon 6-glass</u>	70/30	PF 1006	1.50	0.01
<u>Nylon 6/10-glass</u>	70/30	QF 1006	0.65	0.04
<u>Polycarbonate-glass</u>	70/30	DF 1006	0.14	0.01
<u>Polyester-glass</u>	70/30	WF 1006	0.19	0.01
<u>Polyphenylene-oxide-glass</u>	70/30	NF 1006	0.11	0.01
<u>Polyphenylene-oxide Noryl-glass</u>	70/30	ZF 1006	0.04	0.01
<u>Polysulphone-glass</u>	70/30	GF 1006	0.24	0.01
<u>Polyurethane-glass</u>	80/20	TF-1004	0.56	0.17
<u>Polyurethane-glass</u>	60/40	TF-1008	0.37	0.08
<u>Polyurethane-glass</u>	65/35	VF-1007	0.36	0.05
<u>Polyvinyl Chloride-glass</u>	70/30	CF 1006	0.10	0.01
<u>Polystyrene-glass</u>	70/30	BF 1006	0.24	0.01
<u>Polystyrene-acrylonitrile-glass</u>	80/20	Formafil G80/20**	0.44	0.01
<u>Polyacetal-glass</u>	80/20	Carbafil G50/20/nat.	0.12	0.01
<u>Polycarbonate-glass</u>	75/20-5	Styrafil G37/20/Cr	0.53	0.01
<u>Polystyrene-glass Cr oxide</u>	80/20	Acrylafil G47/20	0.23	0.01
<u>Polystyrene-acrylonitrile-glass</u>	65/35	Acrylaglas S40/35***	0.22	0.03
<u>Polysulfone-glass</u>	80/20	Sulfil G1500/20	0.20	0.01

As-received, molded specimens were tested. Acceptable materials are underlined. All items are as received molded specimens.

\* All positive VCM values under 0.01 are noted at 0.01.

\*\*The G series indicates glass fiber lengths of 3/8 to 1/2 inch.

\*\*\*The S series indicates glass fiber lengths of up to 1/8 inch.

Table 2  
Copper Corrosion-Resistant Silicone Potting Polymers  
(RTV Material)

RTV Material	Resin-Catalyst Concentration (pbw)	Pretest Cure	Percent Weight Loss	Percent Condensables
8111/9891*	97/3	18 h at room temp	1.36	0.41
8111/9891*	97/3	18 h at 65°C	1.02	0.28
8112/9858	94/6	18 h at room temp	1.33	0.36
8112/9858	94/6	18 h at 65°C	1.09	0.36
8223/9859	96/4	18 h at room temp	1.23	0.24
8243/9858	96/4	18 h at room temp	1.38	0.15
8262/9858	94/6	18 h at room temp	0.79	0.25
8262/9858	94/6	18 h at 65°C	0.73	0.24
8263/9858	96/4	18 h at room temp	0.90	0.21
8263/9858	94/4	18 h at 65°C	0.87	0.17
8372/9858	95/5	18 h at room temp	1.41	0.28
8372/9858	95/5	18 h at 65°C	1.32	0.21
8373/9858	97/3	18 h at room temp	1.31	0.22
8373/9858	97/3	18 h at 65°C	1.19	0.20
8382/9858	95/5	18 h at room temp	1.10	0.36

These systems meet MIL S-23586 WP and induce minimal copper corrosion.

All catalyst concentrations and types are as the vendor recommended.

\*RTV 8111 with catalyst 9891 will not tend to depolymerize in a sealed container at elevated temperatures. It is reversion resistant.

Table 2 (continued)  
Copper Corrosion-Resistant Silicone Potting Polymers  
(RTV Material)

RTV Material*	Resin-Catalyst Concentration (pbw)	Pretest Cure	Percent Weight Loss	Percent Condensables
NR 68-110	100/4	24 h at room temp	1.23	0.26
NR 68-120	100/4	24 h at room temp	0.84	0.25
NR 68-210	100/4	24 h at room temp	1.22	0.24
NR 68-220	100/4	24 h at room temp	0.91	0.16
NR 68-310	100/4	24 h at room temp	1.56	0.25
NR 68-320	100/4	24 h at room temp	1.64	0.32
NR 68-330	100/4	24 h at room temp	1.29	0.28
RR 69-210**	100/10	24 h at room temp	1.02	0.24
RR 69-220**	100/4	24 h at room temp	1.16	0.28

All catalyst concentrations and types are as the vendor recommended.

\*The 68 and 69 prefixed systems meet MIL S-23586 (AS) and induce minimal copper corrosion.

\*\* RTV's 69-210 and 69-220 will not tend to depolymerize in a sealed container at elevated temperatures. These RTV's are reversion resistant.

Table 3  
Conventional Silicone Potting Polymers

Manufacturing Number	Resin-Catalyst Concentration (pbw)	Pretest Cure	Percent Weight Loss	Percent Condensables
Sylgard 51	100/10	72 h at 66°C	2.40	0.80
Sylgard 182	100/10	7 days at room temp	1.09	0.33
Sylgard 182	100/10	22 h at 60°C	1.03	0.23
Sylgard 182	100/10	4 h at 65°C	2.00	0.59
Sylgard 183	100/10	1 h at 100°C	2.00	0.61
Sylgard 184	100/10	4 h at 65°C	1.32	0.41
Sylgard 184	100/10	4 h at 65°C + 24 h at 150°C	0.92	0.40
Sylgard 185	100/10	1 h at 100°C	1.80	0.59
Sylgard 187	100/10	24 h at room temp	2.54	1.20
Silastic 881	100/4	1.5 h at 37.8°C	1.63	0.43
Castable 325	100/8	3 min. at 149°C	1.46	0.36
63-488	100/10	4 h at 60°C	1.42	0.74
63-489	100/10	4 h at 60°C	1.42	0.57
<u>93-500</u>	100/10	24 h at room temp	0.29	0.01
<u>93-500</u>	100/10	7 days at room temp	0.16	0.01
RTV 118		24 h at room temp	2.21	1.07
RTV 615	100/10	24 h at room temp	1.82	0.83
<u>RTV 566 A/B</u>	100/0.1	24 h at room temp	0.14	0.02
<u>RTV 566 A/B</u>	100/0.2	24 h at room temp	0.25	0.03
Eccosil 4850	100/0.5	"Red Devil" shake* + 18 h at room temp	1.00	0.31
Eccosil 4850	100/0.5	"Red Devil" shake* + 2 h at 66° + 1 h at 121°C	0.97	0.28

Acceptable materials are underlined.

All catalyst concentrations and types are as the vendor recommended.

\*The "Red Devil" is a shaker paint mixer.

Table 4  
Silicone Coatings and Sealants

Manufacturing Number	Pretest Cure	Percent Weight Loss	Percent Condensables
RTV 140	24 h at room temp, 50% relative humidity	1.38	0.22
RTV 577*	48 h at room temp	2.99	0.57
RTV 731	24 h at room temp, 50% relative humidity	1.39	0.38
RTV 732	1 wk at room temp, 50% relative humidity	3.40	1.43
RTV 3140	24 h at room temp, 50% relative humidity	3.09	0.48
RTV 3140	24 h at room temp, 50% relative humidity + 24 h at 65°C	1.34	0.61
RTV 3145	3 days at room temp, 50% relative humidity	2.18	1.08
RTV 3145	24 h at room temp, 50% relative humidity + 24 h at 65°C	1.70	0.60
EC 1663	100/10, 4.5 mo at room temperature	1.00	0.23
EC 1663	100/10, 3 h at 52°C, 4.5 mo at room temp	1.07	0.26
Vac Seal	1 week at room temp, 50% relative humidity	3.52	0.70
Vac Seal	24 h at 65°C	2.02	0.40
Vac Seal	24 h at 100°C	1.48	0.45
90-006**	100/10, 24 h, + 71°C at $10^{-3}$ torr	1.23	0.32
90-031	As received	1.09	0.27
90-031	As received, 24 h, 70°C at $10^{-3}$ torr	0.98	0.18
90-031	As received, 4 h, 150°C at $10^{-3}$ torr	0.54	0.15
92-024	DC-1200, primer was air-dried for 30 min, then 92-024 was applied, 5 days at room temp, 50% relative humidity	2.07	0.84

\*Used 0.1 percent T-12 catalyst.

\*\*Used 90-006 catalyst.

Table 5  
Silicone Elastomer Materials

Manufacturing Number	Cure	Percent Weight Loss	Percent Condensables
<u>Silastic 35</u>	5 min, 116°C + 24 h at 249°C post cure	0.14	0.06
Silastic 75	10 min at 171°C	1.29	0.33
<u>Silastic 75</u>	10 min at 171°C + 3 h at 204°C post cure	0.31	0.10
<u>Silastic 916</u>	5 min at 116°C + 24 h at 249°C post cure	0.40	0.01
<u>SE 4401</u>	10 min at 110°C + 24 h at 249°C post cure	0.06	0.01
<u>SE 4404</u>	10 min at 110°C + 24 h at 249°C post cure	0.10	0.01
<u>SE 5211</u>	10 min at 110°C + 4 h at 249°C post cure	0.08	0.02
<u>SE 5403U</u>	3 h at 204°C no post cure	0.10	0.02
<u>MS 20L08</u>	2 min at 163°C + 2 h at 249°C post cure	0.04	0.01
<u>MS 30C02</u>	2 min at 163°C + 2 h at 249°C post cure	0.07	0.05
Fairprene SR 5520	Unknown	0.53	0.17

Acceptable materials are underlined.

All items are as received molded specimens.

Table 6  
Miscellaneous Silicone Applications

Material	Manufacturing Number	Pretest Cure	Percent Weight Loss	Percent Condensables
Grease	Hi-Vac	—	1.52	0.34
Grease	G-340	—	0.35	0.11
Grease	G-640	—	0.71	0.12
Tape	7100*	—	3.60	0.79
Tape	7100**	—	3.22	0.67
Tape	Y9040*	—	1.12	0.64
<u>Tape</u>	70**	121°C, 24 h and $1 \times 10^{-3}$ torr	0.40	0.07
Tape	TGL	—	1.26	0.36
<u>Paint</u>	Pyromark white***	On aluminum substrate On epoxy substrate	0.06 0.40	0.02 0.03
Paint	Sicon black	24 h at room temp	6.04	0.36
<u>Paint</u>	Sicon black	30 min at 177°C	0.98	0.04
Tubing	Silastic 1410	Preshrunk at 121°C	0.56	0.15
<u>Thermoset</u>	Silicone asbestos 2106****	Long, gradually rising bake cycle, including 12 h at 249°C	0.06	0.02
High-voltage cable	B1WP/N F5639-L-G22	As received	0.51	0.16
<u>High-voltage cable</u>	F5639-L-G22	Post-cured 24 h at 232°C	0.03	0.01

Acceptable materials are underlined.

\* Applied on stainless screen

\*\* Applied on glass rod

\*\*\* Baked in accordance with Kollsman Instrument Corporation (KPS-4B.216 of 6/30/67, (Silicone-base paint))

\*\*\*\* Rigid silicone composite

Table 7  
Miscellaneous Polymers

Material Description	Percent Weight Loss	Percent Condensables
Polyvinyl acetate butyrate*	4.73	0.01
<u>Methyl methacrylate (mod) Bavick II*</u>	0.59	0.01
<u>Plexiglas II ultra violet resistant*</u>	0.57	0.01
<u>Plexiglas VS-100 Optical*</u>	1.00	0.01
<u>Polystyrene-cross-linked Q200.5</u>	0.09	0.01
<u>Polycarbonate-Lexan 9034-112</u>	0.19	0.01
<u>Dexsil-201</u>	0.07	0.01
<u>Surlyn A</u>	0.55	0.06
<u>Diallyl Phthalate/glass/fire retardant FS-80</u>	0.44	0.01
<u>Diallyl Phthalate/Glass, C 2580-118</u>	0.30	0.01
<u>Acrylite, Lucerne 011-V</u>	0.51	0.05

Acceptable materials are underlined.  
All items were as received molded specimens.

\*Fresnel lenses examined for potential optical-element application

## CONCLUSIONS

The low-outgassing glass-reinforced polymers noted in this document may become more applicable to space structures and components because they also have excellent strength and dimensional-stability characteristics.

Most silicone potting compounds, sealants, and coatings do not meet the established 1 percent total and 0.1 percent volatile-condensable criteria. However, two room-temperature vulcanizing types are excellent: Dow Corning's 93-500 and General Electric's 566A/B. Although these silicones are costly, the judicious incorporation of various types of inert fillers may lower the cost. The 93-500 with excellent optical characteristics will soon be studied for radiation resistance for a solar-cell coverslip adhesive application.

Molded silicone elastomer products, adequately postcured at 400°-480°F, should be successful in space applications. Suitable compounds with desirable properties are available in many company formulations.

To avoid the gross satellite contamination seen in thermal vacuum testing, already fabricated individual satellite component systems should be prebaked. These systems should be prebaked for 24 to 48 hours in a vacuum of  $10^{-6}$  torr at the highest allowable temperature, possibly 10°-25°C above the maximum thermal-vacuum test-level exposure. Heat sensitivity of the electronic components and coefficients of thermal expansion should be primary considerations in determining all bakeout temperatures. Temperatures should not exceed prescribed electronic-component limits.

## SOURCES

Fiberfil Corporation, resin glass  
composites:

Formafil G80-20  
Carbafil G-50-20 Nat.  
Styrafil G37-20 Cr  
Acrylafil G47-20  
Sulfil G1500-20

Liquid Nitrogen Process Corporation,  
resin glass composites:

AF 1006 - ZF 1006  
RF 1006 - GF 1006  
PF 1006 - TF 1004  
QF 1006 - TF 1008  
DF 1006 - VF 1007  
WF 1006 - CF 1006  
NF 1006 - BF 1006

Cryton Company, Fresnel lens elements:	Polyvinyl acetate butyrate Bavick II Plexiglass II, UV resist Plexiglass, VS-100
General Electric, silicones:	8111-8383, RTV 118, 615 RTV 566/A/B, RTV 577 SE 4401, 4404, 5211, 5403U
Dow Corning, silicones:	(68-110 through 69-220) all Sylgards, silastic 881 63-488, 63-489, 93-500, 325, 732, 3140, 3145, 90-006, 90-031, 92-024, 731, 140, Silastic 35, 75, 916, 1410 2106, Hi-Vac, G340, G-640
Allied Chemical:	Diallyl Phthalate/glass - C2580-118
Food Machinery Corp.:	Diallyl Phthalate/glass/fire retardant FS-80
DuPont:	Surlyn A, Fairprene SR-5520
General Electric:	Lexan 9034 - 112
Polypenco:	Polystyrene X-linked Q 200.5
Olin-Mathesin:	Dexsil 201
American Cyanamid:	Acrylite Lucerne 011-4
Emerson and Cumings:	EC 1663
Moxness Co.:	MS 20L08, MS30C02
Mystic Tape Co.:	7100, double-sided silicone adhesive on glass base
Minnesota Mining and Manufacturing:	Y9040, silicone adhesive on aluminum foil, 70 silicone adhesive on silicone base

Markel Co.:	TGL undercured silicone wrapping tape
Tempil Co.:	Pyromark white
Midland (Division of Dexter Corp.):	Sicon black 7X9055
Boston Wire and Cable:	BIWP/N F 5636-L-G22
Space Environment Laboratories:	Vac-Seal

Dr. Benjamin Seidenberg and Dr. John Park served as liaison specialists with spacecraft project engineers and assisted in obtaining materials for this document.