SPACECRAFT MATERIALS GUIDEBOOK

JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, California

JPL TECHNICAL MEMORANDUM NO. 33-124

Prepared Under Contract No. NAS 7-100
National Aeronautics & Space Administration

SPACECRAFT MATERIALS GUIDEBOOK

A guide to the engineering designer in the selection of spacecraft materials of construction

Compiled by

Materials Section
Jet Propulsion Laboratory
Pasadena, California

FOREWORD

This *Guidebook* has been prepared by the Materials Section of the Jet Propulsion Laboratory's Engineering Mechanics Division. Its purpose is to assist Laboratory engineers and designers in the selection of suitable materials for use in the construction of spacecraft. The intention is to provide, as a continuing process, up-to-date information on these materials, together with recommendations based on the most recent reliable data.

The *Guidebook* is divided into seven basic sections, which are listed with their main subsections in the Table of Contents. Section 1.0 contains general introductory remarks regarding the scope of the book and the criteria used in determining the materials to be recommended. In Section 2.0, classes of applications for materials in spacecraft are tabulated, together with general recommendations for materials in each class. Section 3.0 presents descriptions of all the recommended classes of materials, and also explanatory comments on those of potential interest to the design engineer which are not presently recommended. More generalized materials information is outlined alphabetically in the Glossary of names and terms, Section 4.0; it is recommended that the Glossary be consulted whenever unfamiliar products or terms appear in the *Guidebook*. In Section 5.0, the organization of the JPL Materials Section is briefly described, and cognizant personnel are listed for various areas of materials applications. The Appendix, Section 6.0, presents detailed information on the properties of certain materials, and

serves also as a source of miscellaneous reference data. A complete Index is provided in Section 7.0.

To facilitate revisions, additions, and deletions, the *Guidebook* is designed in a loose-leaf-binder format. The decimal-number system is used for the headings of the seven main Sections and their subsidiary divisions, and the noncontinuous pagination of the volume is keyed to these headings. For example, subheading 2.3.4 in Section 2.0 carries the number 2.3.4 in the lower right-hand corner of the page; if the discussion under this heading continues throughout multiple pages, the pagination is 2.3.4–1, 2.3.4–2, 2.3.4–3, etc. Tables and Figures (if employed) are identified by consecutive numbers preceded by the applicable Section number: for example, Tables 6-1, 6-2, 6-3, in Section 6.0.

Each page of the original issue carries in the upper left-hand corner the initial publication date, August 1, 1963. A revised page, subsequently replacing an original page, presents the following typical notation: Revised November 1, 1963. An entirely new page for insertion displays only the date of its release: for example, March 1, 1964. As the *Guidebook* is updated by these revisions and additions, concurrent changes are made in the List of Effective Pages which follows the Table of Contents. The deletion of a page is indicated only by omission from this tabulation of effective material.

As noted in the Table of Contents and throughout the text, some Sections of the *Guidebook* are incomplete. Data for various categories of recommended materials and for portions of the Glossary and Appendix are still being compiled and will be added as completed. It is, however, considered desirable to publish all currently available information at the earliest possible date.

As an additional aid to the spacecraft designer, members of the Materials Section are available for consultation on materials problems. Questions regarding the contents of the *Guidebook* should also be directed to this section.°

° It should be noted that the *Guidebook* is published for the use of JPL personnel and, when appropriate, to JPL subcontractors. It is an internal publication of the Laboratory and is not designed for circulation to other persons or organizations.

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†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

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†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

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*iv	Revised	July 1, 1964
*v	Revised	July 1, 1964
*vi	Revised	December 1, 1965
*vii	Revised	December 1, 1965
*viii	Revised	December 1, 1965
*ix	Revised	December 1, 1965
*x	Revised	December 1, 1965
*xi	Revised	December 1, 1965
*xii	Revised	December 1, 1965
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*1.0–3	Revised	July 1, 1964
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*2.2.1	Revised	December 1, 1965
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*2.3	Revised	November 1, 1963
*2.3.1	Revised	March 1, 1964
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1.0 SCOPE

The successful launching and subsequent flight of instrumented spacecraft depend, in large measure, upon the proper selection of materials of construction. Such materials must be capable of performing in a satisfactory manner, not only in the familiar environment of the Earth's atmosphere, but, of more importance, in the less familiar and less understood environment of space.

The user of this *Guidebook* should recognize that the recommendations stated here are intended only as a guide to the design engineer in his selection of materials. There is no easy way of selecting materials. Before a final selection can be made, many factors and "trade-offs" must be considered. The most certain way of assuring a satisfactory selection is a thorough analysis of the application, performed jointly by the design engineer and materials specialist.

The space environment is unique. There are many single environmental factors which can combine to produce deleterious effects on some materials. In other instances, the space environment appears to be less severe than the Earth environment. A case in point is that of the materials whose degradation involves oxidation processes. The lack of oxygen in the space environment can raise the upper temperature limit of usefulness of some polymers, can cause an improvement in radiation resistance (e.g., Teflon plastics), or can eliminate the catastrophic oxidation behavior of some metals at high temperatures (e.g., molybdenum). Whether some of the advantages of space environment can be realized in practice is somewhat problematical, since checkout procedures usually dictate that a hardware item be capable of performing in air. Thus, in practice, the real problem of materials selection usually resolves to the choice of a material that will perform satisfactorily in *both* Earth and space environments.

It is the purpose of this *Guidebook* to recommend materials which appear to be suitable for use in spacecraft, rather than to define the space environment. Suitability will be determined (1) from information gathered in space flights, especially those designed to give useful materials data, (2) from data obtained in simulated-space-environment research and development, (3) from the judgment of qualified materials experts, and (4) from information supplied by materials producers.

1.0 (Cont'd)

It is obviously impossible to supply complete materials information in the *Guidebook*. In order to maintain a manageable situation, it is necessary to establish restraints. The following restraints have been established to serve as general criteria for inclusion of material:

1. Coverage is generally limited to information which is considered particularly applicable to the field of instrumented spacecraft.
2. In addition, long-established information is included where it is apparent that such information may be useful to Laboratory personnel.

The selections indicated in the *Guidebook* are, of necessity, conservative. If a material of interest does not appear, one or more of the following reasons govern its omission:

1. It is not considered suitable in spacecraft applications.
2. Too little is presently known about it to permit its inclusion.
3. A recommendation is scheduled for future release as an addition to the *Guidebook*.
4. Another material described in the *Guidebook* will do the job as well or better.
5. Standard technology will suffice; that is, its application presents no problems unique to spacecraft.
6. Its usage is restricted to a small area of application.

In connection with point 4, above, it is of utmost importance that the total list of materials used in a spacecraft be kept as small as possible. The cooperation of the design engineer is requested in this regard.

In general, there appear to be more questions regarding the use of organic polymers than is the case with the inorganic materials. For this reason, initial emphasis is placed on the former substances. In this connection, only polymers capable of operating, at least intermittently, at a minimum temperature of 125°C (255°F) are included. Such an approach should tend to ease both sterilization problems and difficult temperature-control problems. Very little information of direct use to engineering selection is available on

1.0 (Cont'd)

polymers. For this reason, the information presented must be considered tentative at this time.

In some instances, it will be necessary to conduct special tests before a final materials selection can be made. The Materials Section is available to assist in planning such tests, and can further serve as a "clearing house" for such information.

The Table of Contents lists those subjects which appear to be of general interest to designers of instrumented spacecraft. It is recognized that there are groups of individuals at JPL who are more qualified in some special areas than is the Materials Section. However, since it is desirable to have a single source for the type of information contained in this volume, it is requested that qualified individuals or groups submit information to the Materials Section for possible inclusion in the *Guidebook*.

2.0 RECOMMENDED MATERIALS

In this Section, the materials described represent *only* those which are currently recommended for spacecraft construction. They are categorized by function, rather than by individual material type, and the information is presented throughout in tabular form. It should be noted that the property data listed are based upon optimum conditions and, therefore, are intended to be used only for purposes of comparison and general information; these are not design or specification values.

The condensed tabular data outlined in this Section are amplified in Section 3.0 by discussions of the general classes of materials recommended, and are further supplemented in the Appendix (Section 6.0) by detailed information on certain products of especial interest.

It is recommended, particularly with respect to polymeric materials, that appropriate screening tests be performed prior to final material selection. These tests should include evaporation or outgassing rates from thermal-vacuum evaluations. Other tests directed toward specific environmental conditions, such as ultraviolet stability, should be included. Volatile formulations should be excluded whenever possible. Materials having questionable temperature stability should not be used. Before proceeding with screening tests, the designer should consult the Materials Section.

The materials cited should be processed in accordance with the manufacturer's recommended procedure. Care must be taken to ensure that they have been properly processed and fabricated. Particular attention must be directed to proper cure and post-cure (heat and/or vacuum) cycles. When applicable, attention should be directed toward problems of creep, cold flow, thermal stability, ultraviolet stability, etc.

The suppliers noted in this Section are, in general, manufacturers of the basic materials and are listed to provide a source of further information. They do not necessarily supply the finished product. For example, du Pont produces Teflon, but does not supply Teflon-insulated wire and cable.

2.1 Seals and Gaskets

The materials covered in this subsection comprise flexible to semirigid substances for use as seals, including various O-rings and gaskets. These materials are to be obtained in finished form before application, as opposed, for example, to foaming materials in place.

The information is presented in the following categories:

2.1.1 Seals and Gaskets: Organic Materials

2.1.2† Seals and Gaskets: Inorganic Materials

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†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

2.1.1 Seals and Gaskets: Organic Materials

Pertinent information	Recommended material					
	Hypalon	Viton B	Hycar	Enjay Butyl	G. E. Silicones	Teflon*
Chemical type	CSPE	VFHE	PA	IIR	SE	FEP/TFE
Strength	Medium to high	Medium to high	Low to medium	Low to medium	Low to medium	Medium to high
Hardness range (Durometer A)	40 to 95	60 to 95	40 to 90	40 to 90	30 to 90	Does not apply
Compression set	Excellent	Good	Good	Good	Good to excellent	Does not apply
Gas permeability	Low to very low	Low to very low	Low to medium	Very low	Medium to high	Low to very low
Long-time at 150°C (300°F)	Poor	Excellent	Good	Poor	Excellent	Excellent
Long-time at 125°C (255°F)	Fair	Excellent	Excellent	Good	Excellent	Excellent
Low-temperature limit	−40°C (−40°F)	−40°C (−40°F)	−40°C (−40°F)	−100°C (−150°F)	−100°C (−150°F)	−260°C (−435°F)
General oil resistance	Good	Excellent	Excellent	Poor	Fair	Excellent
Resistance to specific environments	Consult Materials Section					
General notes	With the exception of the Teflons, these materials must be compounded to meet the requirements of the specific environments involved. Hycar polyacrylic is recommended, not Hycar nitrile.					
Supplier	Elastomer Chemicals Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464	B. F. Goodrich Chemical Co. 3135 Euclid Ave. Cleveland, Ohio 44115 Phone, (216) TO 1-3500	Enjay Chemical Co. 615 S. Flower St. Los Angeles, Calif. Phone, MA 6-5664	General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	Plastics Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464	

*Amplified data for this material appear in the Appendix, subsection 6.1.

2.2 Sealant, Potting, and Encapsulating Materials

This subsection covers (1) nonvolatile liquid materials which can be vulcanized or cured to solid form with minimum shrinkage for potting, casting, or encapsulating applications; and (2) the same materials, as well as those containing volatile components, such as solvents, for use as sealants for voids, gaps, seams, etc. Metallic sealants, such as solders and brazing and welding materials, are discussed in subsection 2.4.

The information is presented in the following categories:

2.2.1 Sealants: General Purpose, Flexible

2.2.2 Potting and Encapsulating Materials: General Purpose, Flexible

2.2.1 Sealants: General Purpose, Flexible

Pertinent information	Recommended material		
	RTV Adhesive/Sealants[a]	Stycast 2741/15	Epocast 202/9615
Chemical type	Silicone	Epoxy	Epoxy
Form and color	Depends on type of RTV	Two liquids, black when mixed	Two liquids, light amber-clear when cured
Viscosity, poises at 25°C (75°F)	Does not apply	Mixture: 400 range	Mixture: 9 to 11
Method of application	Squeeze tube	Caulking, brush, spray, pour	Pour, brush, spray
Shelf life at 25°C (75°F)	6 mo to 1 yr	1 yr	6 mo
Pot life at 25°C (75°F)	Does not apply	2 hr	3 hr
Minimum cure cycle	1 week at 25°C (75°F)	8 hr at 25°C (75°F)	8 hr at 65°C (150°F)
Tensile shear at 25°C (75°F), psi	300	3200	2200 range
Service temperature limits	−60 to 260°C (−75 to 500°F)	−70 to 190°C (−95 to 375°F)	−70 to 205°C (−95 to 400°F)
General notes	Low strength, cures by contact with moisture in air. Good electrical properties. Before using, consult Materials Section.	Flexibility can be controlled from flexible to semirigid. Good electrical properties.	Flexible, low viscosity. Good electrical properties.
	In many instances, materials may be used as adhesives and also as potting and encapsulating materials.		
Supplier	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	Emerson and Cuming, Inc. 604 W. 182nd St. Gardena, Calif. Phone, FA 1-6650	Furane Plastics, Inc. 4516 Brazil St. Los Angeles, Calif. Phone, CH 5-1151

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.2.2 Potting and Encapsulating Materials: General Purpose, Flexible

Pertinent information	Recommended material				
	Stycast 1264 A/B	Eccogel 1265 A/B	Stycast 2741/15	Epocast 202/9615	RTV types*
Chemical type	Epoxy	Epoxy	Epoxy	Epoxy	Silicone
Form and color	Two liquids, almost water-clear when mixed	Two liquids, almost water-clear when mixed	Two liquids, black when mixed	Two liquids, light amber-clear when cured	Liquid to stiff pastes. Color varies with type
Viscosity, poises at 25°C (75°F)	Mixture, 9.5	Mixture, 9	Mixture, 400 range	Mixture, 90 to 110	Mixture, 80 to 15,000
Method of application	Pour	Pour	Pour, caulk	Pour	Pour, caulk
Shelf life at 25°C (75°F)	1 yr	6 mo	1 yr	6 mo	3 to 6 mo
Pot life at 25°C (75°F)	3 hr	24 hr	2 hr	2 to 3 hr	2 to 8 hr
Minimum cure cycle	8 hr at 25°C (75°F)	48 hr at 45°C (110°F)	8 hr at 25°C (75°F)	8 hr at 65°C (150°F)	20 hr at 25°C (75°F)
Tensile shear strength, psi, at 25°C (75°F)	80	250	3200	2200 range	Variable up to 400
Shore durometer hardness	80D	25A	30D to 80D	60D to 75D	25A to 70A
Service temperature limits	−60 to 150°C (−75 to 300°F)	−60 to 175°C (−75 to 345°F)	−70 to 190°C (−95 to 375°F)	−70 to 205°C (−95 to 400°F)	−100 to 350°C (−150 to 660°F)
General notes	Semirigid.	Very flexible and soft.	Flexibility can be varied from flexible to rigid. Other colors available.	Flexibility can be varied from flexible to semirigid.	Primers needed for best adhesion. Varied flexibility.
	All materials have good electrical properties and in many instances can also be used as coatings and adhesives.				
Supplier	Emerson and Cuming, Inc. 604 W. 182nd St. Gardena, Calif. Phone, FA 1-6650			Furane Plastics, Inc. 4516 Brazil St. Los Angeles, Calif. Phone, CH 5-1151	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144

*Amplified data for this material appear in the Appendix, subsection 6.1.

2.3 Adhesives

This subsection covers adhesives for both structural and nonstructural use. As defined here, a structural adhesive supports a load and, therefore, is under stress. In a sense, the material would replace, or would be used in conjunction with, a rivet, bolt, weld, etc. A nonstructural adhesive is intended to adhere to or hold materials, but would be subjected to a minimum of stress.

The information is presented in the following categories:

2.3.1 Adhesives: General Purpose, Structural

Pertinent information	Recommended material				
	Epon VIII A/B	Epon 901 B-1	Epon 901 B-3	Epon 917	Epon 934 A/B
Application	Metal, plastics, elastomers	Metal, plastics, elastomers, wood, glass	Metal, plastics, elastomers, wood, glass	Metal, plastics, elastomers	Metal, plastics, elastomers, wood, glass
Form and color	Thixotropic paste and liquid curing agent, reddish-grey when mixed	Thixotropic paste and liquid curing agent, red when mixed	Thixotropic paste and liquid curing agent, grey when mixed	Low-temperature-melting powder, grey	Thixotropic paste and liquid curing agent, red-grey when mixed
Viscosity, poises, at 25°C (75°F)	Paste: 7000 to 20,000 Liquid: 0.11	Paste: 3000 to 6500 Liquid: 18 to 32	Paste: 3000 to 6500 Liquid: 4 to 7	Does not apply	Paste: 5000 Liquid: 20
Shelf life	1 yr at 25°C (75°F)	1 yr at 25°C (75°F)	1 yr at 25°C (75°F)	6 mo at 0°C (30°F)	3 mo at 25°C (75°F)
Pot life	2.5 hr at 25°C (75°F)	¾ hr at 25°C (75°F)	4 hr at 25°C (75°F)	1 wk at 25°C (75°F)	40 min at 25°C (75°F)
Minimum cure cycle	90 min at 95°C (305°F)	24 hr at 25°C (75°F)	1 hr at 120°C (250°F)	4 hr at 75°C (165°F)	24 hr at 25°C (75°F)
Tensile shear strength, psi, at					
−55°C (−65°F)	2650	3400	3100	2100	2600
25°C (75°F)	3550	3500	3100	2400	3200
120°C (250°F)	1200	700	3800	3100	1800
150°C (300°F)	400	Does not apply	3000	3500	1400
Service temperature limits	−75°C to 125°C (−105°F to 260°F)	−75°C to 120°C (−105°F to 250°F)	−75°C to 165°C (−105°F to 300°F)	−75°C to 205°C (−105°F to 400°F)	−75°C to 205°C (−105°F to 400°F)
General notes	All materials are epoxies. Use contact or clamp pressure as required during cure.				
Supplier	Adhesives Department, Shell Chemical Co., P. O. Box 831, Pittsburg, Calif. Phone, GL 8-3332.				

2.3.2 Adhesives: Special Purpose, Structural

Pertinent information	Recommended material				
	Epon 422	Epon 903	Epon 912 A/B	Epon 914	Epon 919 A/B
Application	Metal, reinforced plastics, honeycomb, for high strength and wide temperature range	Metal, elastomers, glass, elevated-temperature cure	Low-density honeycomb for filling and edge sealing compounds	Metal, glass, elevated-temperature cure	Metal, plastics, elastomers, wood, oily metal, sprayable
Form and color	Grey adhesive impregnated on glass cloth	Grey thixotropic paste	Thixotropic paste and liquid curing agent, reddish-brown when mixed	Dark-grey thixotropic paste	Thixotropic paste and liquid curing agent, red-brown when mixed
Viscosity, poises, at 25°C (75°F)	Does not apply	14,000	Paste: Does not apply Liquid: 0.11	12,000	Paste: 200 Liquid: 4 to 7
Shelf life	6 mo at −20°C (−50°F)	1 yr at 25°C (75°F)	1 yr at 25°C (75°F)	1 yr at 25°C (75°F)	1 yr at 25°C (75°F)
Pot life	5 days at 25°C (75°F)	1 yr at 25°C (75°F)	40 min at 25°C (75°F)	1 yr at 25°C (75°F)	8 to 9 hr at 25°C (75°F)
Minimum cure cycle	30 min at 175°C (350°F)	4 hr at 150°C (300°F)	24 hr at 25°C (75°F)	1 hr at 175°C (350°F)	3 hr at 80°C (180°F)
Tensile shear strength, psi, at					
−55°C (−65°F)	2700	3400	Does not apply	2600	4200
25°C (75°F)	2500	3700		2900	5000
120°C (250°F)	2300	3500		3900	450
150°C (300°F)	2200	2000		3800	400
Service temperature limits	−250°C to 370°C (−420°F to 700°F)	−75°C to 160°C (−105°F to 320°F)	−75°C to 120°C (−105°F to 250°F)	−75°C to 190°C (−105°F to 375°F)	−75°C to 120°C (−105°F to 250°F)
General notes	With the exception of Epon 422 (epoxy-phenolic), all materials are epoxies. Use contact or clamp pressure as required during cure. Epon 422 requires a minimum of 10 psi during cure.				
Supplier	Adhesives Department, Shell Chemical Co., P. O. Box 831, Pittsburg, Calif. Phone, GL 8-3332.				

2.3.2 (Cont'd)

Pertinent information	Recommended material			
	Epon 921 A/B	Epon 924 A/B	Epon 929	Epon 931 A/B
Application	Low modulus for metal, plastics, elastomers, wood, glass	Thread-locking and -sealing compound	Metals, plastics, glass, elevated-temperature cure	Metals, plastics, glass, elastomers, variable cure
Form and color	Thixotropic paste and liquid curing agent, red-grey when mixed	Thixotropic paste and liquid curing agent, dark red when mixed	Thixotropic paste yellow-green	Greyish-black paste and red liquid
Viscosity, poises, at 25°C (75°F)	Paste: 3000 to 6500 Liquid: 18 to 25	Mixture: 50 to 100	4000	Paste: 12,500 Liquid: 2.5
Shelf life	1 yr at 25°C (75°F)	1 yr at 25°C (75°F)	3 mo at 25°C (75°F)	2 mo at 25°C (75°F) 1 yr at −20°C (−5°F)
Pot life	45 min at 25°C (75°F)	40 min at 25°C (75°F)	3 mo at 25°C (75°F)	40 min at 25°C (75°F)
Minimum cure cycle	48 hr at 25°C (75°F)	6 hr at 25°C (75°F)	3 hr at 120°C (250°F)	Variable, 25°C (75°F) to 175°C (350°F)
Tensile shear strength, psi, at				
−55°C (−65°F)	3200	3600	2600	Variable, up to 1000 psi at 205°C (400°F)
25°C (75°F)	3900	3200	2700	
120°C (250°F)	500	1600	3100	
150°C (300°F)	350	700	3400	
Service temperature limits	−75°C to 120°C (−105°F to 250°F)	−75°C to 150°C (−105°F to 300°F)	−75°C to 250°C (−105°C to 480°F)	−75°C to 205°C (−105°F to 400°F)
General notes	All materials are epoxies. Use contact or clamp pressure as required during cure.			
Supplier	Adhesives Department, Shell Chemical Co., P.O. Box 831, Pittsburg, Calif. Phone, (415) 458-3332.			

2.3.2 (Cont'd)

Pertinent information	Recommended material		
	FM-1044	Eccobond 55/9	Eccobond 56C/9
Application	Copper to other metals and plastics laminates	Metals, plastics, glass	Low resistance for making electrical connections
Chemical type	Epoxy-polyamide	Epoxy	Epoxy
Form and color	Brown unsupported film	Milky paste and pink to amber liquid	Silver thixotropic paste and pink to amber liquid; silver when mixed
Viscosity, poises, at 25°C (75°F)	Does not apply	Paste: 14,000 to 22,000 Liquid: 0.8 to 1.1	Paste: does not apply Liquid: 0.8 to 1.1
Shelf life	9 mo at 25°C (75°F)	6 mo at 25°C (75°F)	6 mo at 25°C (75°F)
Pot life	9 mo at 25°C (75°F)	30 min at 25°C (75°F)	30 min at 25°C (75°F)
Minimum cure cycle	30 min at 165°C (330°F)	24 hr at 25°C (75°F)	1 hr at 65°C (150°F)
Tensile shear strength, psi at 25°C (75°F)		1500	450
Service temperature limits	−250°C to 260°C (−420°F to 500°F)	−60°C to 150°C −75°F to 300°F	−60°C to 175°C (−75°F to 345°F)
General notes	Minimum of 200 psi clamp pressure needed		
Supplier	Bloomingdale Dept. American Cyanamid Co. 24217 Hawthorne Blvd. Torrance, California Phone, FR 8-4251	Emerson and Cuming, Inc., 605 West 182nd Street Gardena, California, Phone, FA 1-6650	

2.3.3 Adhesives: General Purpose, Nonstructural

Pertinent information	Recommended material				
	Stycast 1264 A/B	Eccogel 1265 A/B	Stycast 2741/15	Eccocoat IC2 A/B	Epocast 202/9615
Chemical type	Epoxy	Epoxy	Epoxy	Polyurethane	Epoxy
Form and color	Two water-clear liquids, almost water-white when cured	Two water-white liquids	Two liquids, black when mixed	Two water-clear liquids, almost water-clear when cured	Two liquids, amber-clear when cured
Viscosity, poises at 25°C (75°F)	Mixture, 9.5	Mixture, 9	500 range	Mixture, 4	Mixture, 90 to 110
Shelf life at 25°C (75°F)	1 yr	6 mo	1 yr	1 yr	6 mo
Pot life at 25°C (75°F)	3 hr	24 hr	2 hr	8 hr	2 to 3 hr
Minimum cure cycle	8 hr at 25°C (75°F)	48 hr at 45°C (110°F)	8 hr at 25°C (75°F)	8 hr at 65°C (150°F)	8 hr at 65°C (150°F)
Tensile shear strength, psi, 25°C (75°F)	1180	250	3200	1280	2200 range
Service temperature limits	−60 to 150°C (−75 to 300°F)	−60 to 175°C (−75 to 345°F)	−70 to 190°C (−95 to 375°F)	−70 to 205°C (−95 to 400°F)	−70 to 205°C (−95 to 400°F)
General notes	Semirigid	Very flexible and soft	Flexibility can be controlled	Flexible, very tough and abrasion resistant	Controlled flexibility, semirigid to flexible
	All materials require contact or clamp pressure, have good electrical properties, and in some instances, can be used as coating, potting, or encapsulating materials. All materials are, in general, suitable for bonding, metals, rubber, plastics, glass, and ceramics. Eccocoat IC2 contains a solvent.				
Supplier	Emerson and Cuming, Inc. 604 W. 182nd St. Gardena, Calif. Phone, FA 1-6650				Furane Plastics, Inc. 4516 Brazil St. Los Angeles, Calif. Phone, CH 5-1151

2.3.4 Adhesives: Special Purpose, Nonstructural

Pertinent information	Recommended material
	RTV types[a]
Form and color	Liquids to stiff pastes, color varying with type
Viscosity at 25°C (75°F), poises	5 to 15,000
Shelf life at 25°C (75°F), mo	3 to 6
Pot life at 25°C (75°F), hr	1 to 12
Minimum cure cycle at 25°C (75°F), hr	12 to 30
Tensile shear strength, psi	50 to 700
Service temperature limits	−70 to 315°C (−95 to 600°F)
General notes	A post-cure is necessary for best environmental performance.
	Primers are needed for best adhesive strength. All materials are silicones, have good electrical properties, and can also be used as coating, potting, and encapsulating materials. Some can be used as adhesive/sealants (e.g., RTV-102, RTV-103, etc.). Materials are, in general, suitable for bonding metal, rubber, plastics, glass, and ceramics.
Supplier	Silicone Products Department, General Electric Co., 8555 E. Florence Ave., Downey, Calif. Phone, SP 3-3144

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.6 Coatings and Finishes

This subsection covers various types of coatings and finishes, both organic and inorganic, for use as protective and insulating materials, and also in temperature-control applications. Decorative finishes and marking materials are discussed in subsection 2.24.†

The information is presented in the following categories:

†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

2.6.1 Coatings: Temperature Control, White (Solar Reflectors)

Pertinent information	Recommended material			
	Cat-A-Lac 443-1(500)	PV-100	Z-93	S-13
Chemical type	Epoxy	Alkyd-silicone	Potassium silicate	Silicone
Pigment	Variable	Rutile-clay	Zinc oxide	Zinc oxide
Typical use	General purpose maneuver white	General purpose stable white	General purpose maneuver white	General purpose stable white
Type of surface	Gloss	Gloss	Flat	Gloss
General notes	All materials are air dry-curing. The Materials Section should be consulted for specific material selection for each application.			
Supplier	Finch Paint and Chemical Co. 1536 W. 228th St. Torrance, Calif. Phone, SP 5-3313	Vita Var Paint Co. 117 Oakwood Ave. Orange, N. J.	Materials Section, JPL	

2.6.2 Coatings: Temperature Control, Black (Flat Absorbers)

Pertinent information	Recommended material			
	Cat-A-Lac 463-1-8	3M 101-C-10	Laminar X-500	du Pont No. 585
Chemical type	Epoxy	Modified alkyd	Polyurethane	Epoxy
Typical use	General purpose for outside surfaces of spacecraft	Special purpose for extreme flat-black applications	Special purpose for solar panels	Special purpose for applications inside spacecraft
Type of surface	Flat	Extremely flat	Flat or gloss	Gloss
General notes	All materials contain carbon black (and flatteners as necessary) and are air dry-curing except 101-C-10, which requires moderate heat. The Materials Section should be consulted for specific material selection and method of application.			
Supplier	Finch Paint and Chemical Co. 1536 W. 228th St. Torrance, Calif. Phone, SP 5-3313	Reflective Products Div. Minnesota Mining and Mfg. Co. 6023 S. Garfield Los Angeles, Calif. Phone, RA 3-6641	Magna Coatings and Chemical Corp. 1785 N. Eastern Ave. Los Angeles, Calif. Phone, 261-7111	Fabrics and Finishes Div. E. I. du Pont de Nemours and Co. 2000 S. Garfield Los Angeles, Calif. Phone, RA 3-8401

2.6.3 Coatings: Temperature Control (Special Purpose)

Pertinent information	Recommended materials	
	Laminar X-500 clear	UC-11659
Chemical type	Polyurethane	Silicone
Typical use	For applications to increase emittance of metallic surfaces	For applications requiring the use of a flat reflector
General notes	The materials are generally applied in the air dry-cured state for spacecraft applications. The Materials Section should be consulted for specific material selection and method of application.	
Supplier	Magna Coatings and Chemical Corp. 1785 N. Eastern Ave. Los Angeles, Calif. Phone, 261-7111	Paint Division Pittsburg Plate Glass Co. 465 Crenshaw Blvd. Torrance, Calif. Phone, 775-2551

2.6.4 Coatings: Protective and Electrical Insulating, General Purpose

Pertinent information	Recommended material				
	Eccocoat VE A/B	Eccocoat IC2 A/B	Eccocoat EC 200 A/B	Eccocoat EP3 A/B	Epocast 202/9615
Chemical type	Epoxy	Polyurethane	Epoxy	Epoxy	Epoxy
Form and color	Two liquids, almost water-clear when cured	Two liquids, almost water-clear when cured	Two liquids, containing solvents, almost water-clear when cured	Two liquids, almost water-clear when cured	Two liquids, light-amber-clear when cured
Viscosity, poises, at 25°C (75°F)	Low, variable	Mixture, 4	Mixture, 5	Mixture, 9	Mixture, 90 to 110
Shelf life at 25°C (75°F)	1 yr	1 yr	1 yr	1 yr	6 mo
Pot life at 25°C (75°F)	4 hr	8 hr	24 hr	6 hr	2 to 3 hr
Minimum cure cycle	8 hr at 25°C (75°F)	8 hr at 65°C (150°F)	30 min at 65°C (150°F)	48 hr at 25°C (75°F)	1 to 3 hr at 65°C (150°F)
Tensile shear strength, psi, 25°C (75°F)	715	1280	150	1180	2200 range
Service temperature limits	−60 to 150°C (−75 to 300°F)	−70 to 205°C (−95 to 400°F)	−70 to 150°C (−95 to 300°F)	−60 to 150°C (−75 to 300°F)	−70 to 205°C (−95 to 400°F)
Shore durometer hardness	80A	80A	(5H pencil)	80D	60 to 75D
General notes	Flexibility and viscosity can be varied	Flexible, tough and abrasion resistant	Flexible. Pigmented versions are termed Eccocoat EC 210	Can be diluted to lower viscosity	Flexibility and viscosity can be varied
	All materials possess good adhesion qualities and can be diluted with solvents. All materials can be applied by pour, brush, spray, or dip techniques, and also can be used as adhesives, potting (except Eccocoat EC 200 and Eccocoat IC2), and encapsulating materials.				
Supplier	Emerson and Cuming, Inc. 604 W. 182nd St. Gardena, Calif. Phone, FA 1-6650				Furane Plastics, Inc. 4516 Brazil St. Los Angeles, Calif. Phone, CH 5-1151

2.6.5 Coatings: Conformal

The recommended materials are JPL No. 1001 and JPL No. 1002 polyurethane conformal coatings formulated to JPL Material Specifications ZME-1061-0001-A and ZME-1061-0002, respectively. JPL No. 1001 contains a fluorescent dye for inspection purposes.

2.7 Films, Sheets, Tapes, and Textiles

This subsection covers general materials and specific products for (1) plastics films, (2) plastics and elastomeric sheets, (3) plastics and elastomeric tapes, and (4) textiles. Laminated plastics sheets, metallic sheets, ceramic sheets, metallic films and foils, and composite materials are discussed in subsection 2.25.† It should be noted that, in some instances, the terms *films*, *tapes*, and *textiles* can be used interchangeably.

The information is presented in the following categories:

2.7.1 Films: Plastics (Thickness 0.010 in. or Less)

2.7.2 Sheets: Plastics (Thickness Greater Than 0.010 in.)

2.7.3 Sheets: Elastomers (Thickness Greater Than 0.010 in.)

2.7.4 Tapes: Plastics Films

2.7.5 Tapes: Elastomeric

2.7.6 Tapes: Specific Products

2.7.7 Textiles

2.7.8 Textiles: Coated Fabrics

2.7.9 Textiles: Tie Cord (Lacing Tape)

2.7.10 Textiles: Sleeving

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†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

2.7.1 Films: Plastics (0.010 in. or Less in Thickness)

Pertinent information	Recommended material					
	Kapton[a]	Tedlar[a]	Mylar[a]	FEP Teflon[a]	TFE Teflon[a]	Lexan[a]
Chemical type	Polyimide	Polyvinyl fluoride	Polyester	Fluorocarbon	Fluorocarbon	Polycarbonate
Color (natural)	Amber-clear	Water-clear	Water-clear to translucent	Water-clear to translucent	Translucent to white-opaque	Water-clear
Refractive index		1.46	1.64	1.34	1.35	1.58
Tensile strength, 1,000 psi	20	9 to 19	23 to 40	2.5 to 3.0	1.5 to 4.0	10
Elongation, %	70	110 to 260	100	300	100 to 350	80
Tear strength, gm to propagate	8	12 to 48	10 to 27	125	10 to 100	10 to 16
Gas permeability	High	Very low	Low	Low	Very low	High
Service temperature limits	−250 to 400° C (−420 to 750°F)	−75 to 205°C (−105 to 400°F)	−70 to 165°C (−95 to 330°F)	−260 to 230°C (−435 to 445°F)	−260 to 320°C (−435 to 610°F)	−160 to 150°C (−255 to 300°F)
General notes	All materials have good electrical properties and can be used as electrical insulation. All materials except H-Film can be colored. Other film materials are listed in subsection 2.25.					
Supplier	Film Dept. E. I. du Pont de Nemours and Co. 4435 Fruitland Ave. Vernon, Calif. Phone, LU 2-7361					Chemical Materials Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.7.2 Sheets: Plastics (Greater Than 0.010 in. in Thickness)

Pertinent information	Recommended material				
	Polymer SP	FEP Teflon[a]	TFE Teflon[a]	Delrin	Lexan[a]
Chemical type	Polyimide	Fluorocarbon	Fluorocarbon	Acetal	Polycarbonate
Hardness	M-112 (Rockwell)	R-25 (Rockwell)	50 to 65 (Shore D)	M94, R120 (Rockwell)	M-70 to R-118 (Rockwell)
Tensile strength, 1,000 psi	13.5	2.5 to 3.0	1.5 to 4.0	9	8 to 10
Elongation, %	5	200 to 350	100 to 400	10 to 70	60 to 100
Impact strength, ft-lb/in	0.55	No break	3.0	1.2 to 2.2	12 to 16
Flexural strength, 1,000 psi	14.7	Does not apply	Does not apply	14	11 to 13
Compressive strength, 1,000 psi	27.5	Does not apply	1.7	—	11
Service temperature limits	−250 to 400°C (−420 to 750°F)	−260 to 230°C (−435 to 445°F)	−260 to 320°C (−435 to 610°F)	−75 to 120°C (−105 to 250°F)	−160 to 150°C (−255 to 300°F)
General notes	All materials have good electrical properties and can be used as electrical insulation. Other sheet materials are listed in subsection 2.25.				
Supplier	Plastics Dept., and/or Film Dept. E. I. du Pont de Nemours and Co. 1800 N. Highland Ave. Hollywood, Calif. 90028 Phone, 466-6361				Chemical Materials Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.7.3 Sheets: Elastomers (Greater Than 0.010 in. in Thickness)

Pertinent information	Recommended material				
	Hypalon	Viton B	Hycar	Enjay Butyl	G. E. Silicones
Chemical type	Chlorosulfonated polyethylene	Fluoroelastomer	Polyacrylic	Isobutylene-isoprene	Silicone
Hardness range, Shore Durometer A	40 to 95	60 to 95	40 to 90	40 to 90	30 to 90
Strength	Medium to high	Medium to high	Low to medium	Low to medium	Low to medium
Compression set	Excellent	Good	Good	Good	Good to excellent
Temperature range Long-time at 150°C (300°F) Long-time at 120°C (250°F)	 Poor Fair	 Excellent Excellent	 Good Excellent	 Fair Good	 Excellent Excellent
Low-temperature limit	−40°C (−40°F)	−40°C (−40°F)	−40°C (−40°F)	−100°C (−150°F)	−100°C (−150°F)
General oil resistance	Good	Excellent	Excellent	Poor	Fair
Gas permeability	Low to very low	Low to very low	Low to medium	Very low	Medium to high
Resistance to specific environments	Consult Materials Section				
General notes	All materials must be compounded to meet the specific environmental conditions involved. All materials may be used as electrical insulation. Other sheet materials are listed in subsection 2.25. Elastomers reinforced with, or coated on, fabrics can also be used as sheet materials. See p. 2.7.7 for types of fabrics to be used.				
Supplier	Elastomer Chemicals Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif Phone, LU 2-6464	B. F. Goodrich Chemical Co. 3135 Euclid Ave. Cleveland, Ohio 44115 Phone, (216) TO 1-3500	Enjay Chemical Co. 615 S. Flower St. Los Angeles, Calif. Phone, MA 6-5664	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	

2.7.4 Tapes: Plastics Films

Pertinent information	Recommended material					
	Kapton[a]	Tedlar[a]	Mylar[a]	FEP Teflon[a]	TFE Teflon[a]	Lexan[a]
Chemical type	Polyimide	Polyvinyl fluoride	Polyethylene terephthalate	Fluorocarbon	Fluorocarbon	Polycarbonate
Natural color	Amber-clear	Water-clear	Water-clear to translucent	Water-clear to translucent	Translucent to white-opaque	Water-clear
Recommended form	Plain or supported	Plain or supported	Plain	Plain or supported	Plain	Plain or supported
Supporting or reinforcing agent	Consult Materials and Methods Group	Glass or asbestos	None	Glass or asbestos	None	Glass
Method of bonding	Adhesive	Heat seal or adhesive	Adhesive	Heat seal or adhesive	Heat fuse	Heat seal or adhesive
Service temperature range	−250 to 400° C (−420 to 750°F)	−75 to 205°C (−105 to 400°F)	−70 to 165°C (−95 to 330°F)	−260 to 230°C (−435 to 445°F)	−260 to 320°C (−435 to 610°F)	−160 to 150°C (−255 to 300°F)
General notes	All materials have good electrical properties. See subsection 2.7.6 for more information on glass, Dacron, and asbestos.					
Supplier	Film Dept. E. I. du Pont de Nemours and Co. 4435 Fruitland Ave. Vernon, Calif. Phone, LU 2-7361					Chemical Materials Dept., and Insulating Materials Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.7.5 Tapes: Elastomeric

Pertinent information	Recommended material				
	Hypalon	Viton B	Hycar	G. E. Silicones	Enjay Butyl
Chemical type	Chlorosulfonated polyethylene	Fluoroelastomer	Polyacrylic	Silicone	Isobutylene-isoprene
Supporting or reinforcing agent	Glass, Dacron, asbestos, or Nomex	Glass, asbestos, or Nomex	Glass, Dacron, or Nomex	Glass, asbestos, or Nomex	Glass, Dacron, asbestos, or Nomex
Service temperature range	−40 to 150°C (−40 to 300°F)	−40 to 300°C (−40 to 570°F)	−40 to 205°C (−40 to 400°F)	−100 to 350°C (−150 to 660°F)	−100 to 200°C (−150 to 390°F)
General notes	All materials may be bonded by vulcanization or with adhesives. All materials can be used plain, supported, or reinforced.				
Supplier	Elastomer Chemicals Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464	B. F. Goodrich Chemical Co. 3135 Euclid Ave. Cleveland, Ohio 44115 Phone, (216) TO 1-3500	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	Enjay Chemical Co. 615 S. Flower St. Los Angeles, Calif. Phone, MA 6-5664	

2.7.6 Tapes: Specific Products

Pertinent information	Recommended material		
	Mystik 7351, 7352, 7355	Mystik 7452, 7453	Mystik 7455
Description	Transparent pressure-sensitive polyester	Pressure-sensitive aluminum foil	Aluminum foil/glass cloth, pressure-sensitive
Adhesion, oz/in. width, minimum	30	45	30
Unwind force, oz/in. width, minimum	10	23	20
Tensile strength, lb/in. minimum	15	20	80
Thickness, in., nominal	0.0025 (7351) 0.0038 (7352) 0.0075 (7353)	0.0045 (7452) 0.0055 (7453)	0.0055
Service temperature limits	−60 to 160°C (−75 to 320°F)	−60 to 160°C (−75 to 320°F)	−110 to 285°C (−165 to 540°F)
General notes	All materials have good electrical properties and can be used as electrical insulation.		
Supplier	Mystik Tape, Inc., Division of the Borden Chemical Co. 1260 S. Central Ave., Glendale, Calif. 91204 Phone, 245-7477		

2.7.7 Textiles

The following textile materials are recommended for use as fabrics, staple fibers, roving, mat, felt, etc. Generally speaking, they would be suitable for such applications as reinforcing agents, tie cords, seals, and filters.

Pertinent information	Recommended material (organic)		
	TFE Teflon	Nomex	Dacron
Chemical type	Fluorocarbon	Polyamide	Polyester
Service temperature range			
Intermittent	−260 to 320°C (−435 to 610°F)	−90 to 250°C (−130 to 480°F)	−90 to 175°C (−130 to 345°F)
Long-time	−150 to 260°C (−240 to 500°F)	−90 to 170°C (−130 to 340°F)	−75 to 125°C (−105 to 255°F)
General notes	Service temperature range of composite materials will depend upon type of organic resin used in system.		
Supplier	Textile Fibers Dept. E. I. du Pont de Nemours and Co. 4435 Fruitland Ave. Vernon, Calif. Phone, LU 2-7361		

Pertinent information	Recommended material (inorganic)			
	Asbestos	Fiberglas	Graphite	Potassium titanate (Tipersul)
Service temperature range				
Intermittent	−260 to 760°C (−435 to 1400°F)	−260 to 350°C (−435 to 660°F)	−260 to 1500°C (−435 to 2730°F)	−260 to 1200°C (−435 to 2190°F)
Long-time	−260 to 370°C (−435 to 700°F)	−260 to 285°C (−435 to 545°F)	−260 to 1500°C (−435 to 2730°F)	−260 to 980°C (−435 to 1795°F)
Supplier	Johns-Manville 611 S. Catalina Los Angeles, Calif. Phone, DU 5-0595	Owens-Corning Fiberglas Corp. 5933 Telegraph Rd. Los Angeles, Calif. Phone, RA 3-9761	National Carbon Co. 2770 Leonis Blvd. Los Angeles, Calif. Phone, LU 3-3061	Pigments Dept. E. I. du Pont de Nemours and Co., Inc. 3750 E. Foothill Blvd. Pasadena, Calif. Phone, 684-0925

2.7.8 Textiles: Coated Fabrics

Pertinent information	Recommended material					
	Fairprene 84-001	Fairprene 98-101	SRD-5905	SRG-1810	SRGA-0214	TB5 PTFE
Description	Fluoroelastomer coated on polyester fabric	Fluorocarbon plastic coated on polyamide fabric (Nomex)	Silicone-rubber coated polyester fabric	Silicone-rubber-coated glass fabric	Silicone-rubber-coated aluminized glass fabric	Fluorocarbon-coated glass fabric
Color	Black	Tan	Black	Red	Red/alum.	Light tan
Coated thickness, in.	0.008	0.010	0.005	0.011	0.013	0.005
Coated weight, oz/yd^2	9.0	12.0	5.0	10.5	13.0	8.0
Tensile strength lb/in.						
Warp	65	—	50	175	200	80
Fill	55	—	29	140	160	80
Breaking strength, psi	—	100	—	—	—	—
Tear strength, lb						
Warp	1.5	3.1	2.3	7.0	5.0	20
Fill	2.5	4.2	2.0	7.0	6.0	20
Service temperature limits	−40 to 150°C (−40 to 300°F)	−90 to 250°C (−130 to 480°F)	−75 to 150°C (−105 to 300°F)	−90 to 260°C (−130 to 500°F)	−90 to 260°C (−130 to 500°F)	
Supplier	Fabrics Division, E. I. du Pont de Nemours and Co., Inc. 2000 South Garfield Ave. Los Angeles, Calif. 90022 Phone, RA 3-8401			Irvington Division, Minnesota Mining and Manufacturing Co. 1601 South Shamrock Ave. Monrovia, Calif. Phone, 358-0136		

2.7.9 Textiles: Tie Cord (Lacing Tape)

Pertinent information	Recommended material			
	Gude-Space 18D96	Pre-Shrunk Temp-Lace 256	Stur-D-Lace H 18DH	Temp-Lace H 256H
Description	Rubber-impregnated Dacron	Fluorocarbon	Wax-impregnated Dacron	Rubber-impregnated fluorocarbon
Color	White	Olive drab	White	Olive drab
Strength, lb, minimum	50	33	50	33
Width, in., nominal	0.090	0.125	0.090	0.110
Thickness, in., nominal	0.0125	0.015	0.0125	0.011
Service temperature limits	−75 to 175°C (−105 to 345°F)	−75 to 230°C (−105 to 445°F)	−75 to 175°C (−105 to 345°F)	−75 to 230°C (−105 to 445°F)
Supplier	Electronics Div., Gudebrod Brothers Silk Co., Inc. 2636 Ontario Street, Burbank, Calif. 91504 Phone, 849-4876			

2.7.10 Textiles: Sleeving

Pertinent information	Recommended material			
	Ben-Har Acryl A Grade BA-1	Ben-Har 263 Grade BC-2	Ben-Har 1062 Grade HA-1	Ben-Har 1151 Grade HA-1
Description	Acrylic resin-coated fiberglass	Thermosetting acrylic Polymer on fiberglass	Silicone varnish-coated fiberglass	Silicone rubber-coated fiberglass
Color	Tan	Yellow	Tan	White
Dielectric breakdown, short-time minimum volts, individual	5000	800	5000	5000
Dielectric constant, 60 cps, max.	2.8	3.0	3.2	2.6
Dissipation factor, 60 cps, max.	0.020	0.030	0.015	0.009
Service temperature limits	−50 to 150°C (−60 to 300°F)	−50 to 150°C (−60 to 300°F)	−85 to 220°C (−20 to 430°F)	−85 to 220°C (−120 to 430°F)
Supplier	Bentley-Harris Manufacturing Co. 1050 Colwell Lane, Conshohocken, Pa.			

2.9 Insulation

This subsection contains descriptions of materials which are recommended for use as electrical and/or thermal insulation. Since many of these materials are listed elsewhere in the *Guidebook*, a minimum amount of information is included here. For more details on these substances, references are provided.

The information is presented in the following categories:

2.9.1 Insulation: Electrical, Plastics

Pertinent information	Recommended material						
	Lexan[a]	Mylar[a]	Tedlar[a]	FEP Teflon[a]	TFE Teflon[a]	Kapton[a]	Polymer SP
Chemical type	Polycarbonate	Polyester	Polyvinyl fluoride	Fluorocarbon	Fluorocarbon	Polyimide	Polymer
Forms available	Molding powder, sheet, film, rod, tube	Film, sheet	Film	Molding powder, sheet, film, rod, tube	Molding powder, sheet, film, rod, tube	Film	Molded blanks
Service temperature range	−160 to 165°C (−255 to 330°F)	−70 to 150°C (−95 to 300°F)	−75 to 205°C (−105 to 400°F)	−260 to 230°C (−435 to 445°F)	−260 to 320°C (−435 to 610°F)	−250 to 400°C (−420 to 750°F)	−250 to 400°C (−420 to 750°F)
Reference (*Guidebook* subsection)	2.7.1, 2.7.2, 2.7.4, 3.1.12	2.7.1, 2.7.4	2.7.1, 2.7.4, 3.1.10	2.7.1, 2.7.2, 2.7.4, 3.1.10	2.7.1, 2.7.2, 2.7.4, 3.1.10	2.7.1, 2.7.4, 3.1.14	2.7.2, 3.1.14
Supplier	Chemical Materials Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	Plastics Dept. and/or Film Dept. E. I. du Pont de Nemours and Co. 2930 W. 44th St. or 4455 Fruitland Ave. Vernon, Calif. Phone, LU 2-6464 or LU 2-7361					

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.9.2 Insulation: Electrical, Elastomers

Pertinent information	Recommended material				
	Hypalon	Viton B	Hycar	Enjay Butyl	G. E. Silicones
Chemical type	Chlorosulfonated polyethylene	Fluoroelastomer	Polyacrylic	Isobutylene-isoprene	Silicone
Hardness range, Shore A	40 to 95	60 to 95	40 to 90	40 to 90	30 to 90
Service temperature range	−40 to 150°C (−40 to 300°F)	−40 to 300°C (−40 to 570°F)	−40 to 205°C (−40 to 400°F)	−100 to 200°C (−150 to 390°F)	−100 to 350°C (−150 to 660°F)
Reference (*Guidebook* subsection)	2.1.1, 2.7.3, 3.1.1	2.1.1, 2.7.3, 3.1.3	2.1.1, 2.7.3, 3.1.22	2.1.1, 2.7.3, 3.1.4	2.1.1, 2.7.3, 3.1.5
General notes	All materials must be compounded to meet requirements of the specific environments involved.				
Supplier	Elastomer Chemicals Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464	B. F. Goodrich Chemical Company 3135 Euclid Ave. Cleveland, Ohio 44115 Phone, (216) TO 1-3500	Enjay Chemical Co. 615 S. Flower St. Los Angeles, Calif. Phone, MA 6-5664	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	

2.9.3 Insulation: Electrical, Varnishes

Pertinent information	Recommended material									
	SR-17	SR-155	SR-220	SR-224	SR-290	B-109-4	B-185	B-161	B-224-2	B-276
Chemical type	Silicone	Silicone	Silicone	Silicone	Silicone	Phenyl ether	Modified polyester	Phenolic	Alkyd	Modified epoxy
Minimum cure time	30 min at 250°C (480°F)	6 hr at 200°C (390°F)	8 hr at 100°C (210°F)	10 min at 150°C (300°F)	2 hr at 100°C (210°F)	2 hr at 250°C (480°F)	6 hr at 135°C (275°F)	4 hr at 135°C (275°F)	8 hr at 25°C (75°F)	1 hr at 25°C (75°F)
Maximum continuous-service temperature	180°C (355°F)	180°C (355°F)	180°C (355°F)	180°C (355°F)	180°C (355°F)	180°C (355°F)	155°C (310°F)	130°C (265°F)	130°C (265°F)	130°C (265°F)
Typical uses	Flexible, for coating fabrics and general-purpose applications	General-purpose dipping and impregnating	Low-temperature curing, for dipping and impregnating	Low-temperature curing, for textile coating and general-purpose applications	Low-temperature curing, for textile treating, sealing, and protective coating materials	General-purpose applications	General-purpose impregnating and dipping	General-purpose impregnating and dipping	General-purpose air-dry varnishes	General-purpose, air-dry, for sealing and coating
General notes	Data given for cure times are approximate, since component size and desired service temperature will dictate actual cure schedule. Step cures may be required in some cases. Service-temperature ranges will depend on type of component and cure schedule used.									
Supplier	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144					Micarta Division Westinghouse Electric Corp. 600 St. Paul Ave. Los Angeles, Calif. Phone, HU 2-9660				

2.9.4 Insulation: Electrical; Coating, Encapsulating, and Potting Materials

Pertinent information	Recommended material								
	Stycast 2741	Eccogel 1265	Stycast 1264	Eccocoat IC2	Eccocoat VE	Eccocoat EP3	Eccocoat EC200	Epocast 202/9615	RTV types[a]
Chemical type	Epoxy	Epoxy	Epoxy	Polyurethane	Epoxy	Epoxy	Epoxy	Epoxy	Silicone
Typical uses	Sealant, potting, encapsulating, coating, adhesive	Potting, encapsulating, coating, adhesive	Potting, encapsulating, coating, adhesive	Encapsulating, coating, adhesive	Encapsulating, coating, adhesive	Potting, encapsulating, coating, adhesive	Encapsulating, coating, adhesive	Sealant, potting, encapsulating, coating, adhesive	Sealant, potting, encapsulating, coating, adhesive
Form	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid to stiff pastes
Minimum cure time	8 hr at 75°F	48 hr at 75°F	8 hr at 75°F	8 hr at 150°F	8 hr at 75°F	48 hr at 75°F	30 min at 150°F	8 hr at 150°F	20 hr at 75°F
Service temperature range	−70 to 190°C (−95 to 375°F)	−60 to 175°C (−75 to 345°F)	−60 to 150°C (−75 to 300°F)	−70 to 205°C (−95 to 400°F)	−60 to 150°C (−75 to 300°F)	−60 to 150°C (−75 to 300°F)	−70 to 150°C (−95 to 300°F)	−70 to 205°C (−95 to 400°F)	−100 to 350°C (−150 to 660°F)
Reference (*Guidebook* subsection)	2.2.2, 3.1.13	2.2.2, 3.1.13	2.2.2, 3.1.13	2.3.3, 3.1.13	2.6.3, 3.1.13	2.6.3, 3.1.13	2.6.3, 3.1.13	2.2.2, 3.1.13	2.2.2, 3.1.7
Supplier	Emerson and Cuming, Inc., 604 W. 182nd St., Gardena, Calif. Phone, FA 1-6650							Furane Plastics, Inc. 4516 Brazil St. Los Angeles, Calif. Phone, CH 5-1151	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.9.5 Insulation: Electrical, Shrinkable Materials

Pertinent information	Recommended material				
	Thermofit CRN	Thermofit Kynar	Thermofit RNF-100	Thermofit TFE	Thermofit TFE-R
Chemical type	Inadiated polyolefin	Inadiated fluorocarbon	Inadiated polyolefin	TFE Fluorocarbon	TFE Fluorocarbon
Color	Black	Transparent to translucent	Clear	Transparent to light tan	Transparent to light tan
Shrinkage temperature, in excess of	130°C (275°F)	175°C (345°F)	120°C (250°F)	330°C (625°F)	330°C (625°F)
Longitudinal shrinkage, approx. %	2	3	2	3	3
Tensile strength, psi	3000	7300	2400	4500	4500
Elongation, %	250	200	300	200	200
Service temperature limits	−60 to 150°C (−75 to 300°F)	−75 to 275°C (−105 to 525°F)	−60 to 150°C (−75 to 300°F)	−75 to 275°C (−105 to 525°F)	−75 to 275°C (−105 to 525°F)
General notes	All materials, which are supplied as tubing, if not restricted, will shrink to approximately 50% of the original diameter. Above values are typical; they will vary with sample thickness.				
Supplier	Rayclad Tubes, Inc., Oakside and Northside, Redwood City, Calif. Phone, (415) 369-7171				

2.9.5 (Cont'd)

Pertinent information	Recommended material		
	Penntube II-SMT	Hi-Shrink Tape	Shrinkable Mylar
Chemical type	FEP Fluorocarbon	Polyester	Polyester
Color	Clear (blue tint)	Clear	Clear
Shrinkage temperature, in excess of	95°C (205°F)	80°C (175°F)	105°C (220°F)
Diameter shrinkage, % (unrestrained)	40	—	30
Longitudinal shrinkage, % (unrestrained)	3	20	15
Tensile strength, psi	3000	35,000	—
Elongation, %	200	25	—
Service temperature limits	−75 to 205°C (−105 to 400°F)	−60 to 150°C (−75 to 300°F)	−60 to 150°C (−75 to 300°F)
General notes	Penntube and Shrinkable Mylar are supplied as tubing. Above values are typical; they will vary with thickness.		
Supplier	Western Fibrous Glass Products Co. 4423 Fruitland Ave. Los Angeles, Calif. 90058 Phone, LU 8-3211	Ram Chemicals, Inc. 210 East Alondra Blvd. Gardena, Calif. Phone, 321-5421	Mossman-Pacific, Inc. 776 West Front St. Covina, Calif. Phone, 331-2223

2.9.6 Insulation: Electrical, Foams

Pertinent information	Recommended material								
	Stycast 1090	Stycast 1090 SI	Stycast 1095	Eccosil 4640	Eccosil 5000	Eccosil FD 34	Eccofoam SIL	Eccofoam FPH	Eccofoam S
Chemical type	Epoxy	Epoxy	Epoxy	Silicone	Silicone	Silicone	Silicone	Polyurethane	Polyurethane
Density, lb/ft^3	50	45	50	50	30	20	20	2 to 14	2 to 26
Form	Cellular-filled liquid	Cellular-filled liquid	Cellular-filled liquid	Cellular-filled liquid	Cellular-filled liquid	Foam-in-place liquid	Foam-in-place liquid	Foam-in-place liquid	Foamed solid
Type	Closed cell (rigid)	Closed cell (rigid)	Closed cell (rigid)	Closed cell (flexible)	Closed cell (flexible)	Closed cell (flexible)	Closed cell (flexible)	Closed cell (rigid)	Closed cell (rigid)
Service temperature range	−70 to 205°C (−95 to 400°F)	−70 to 150°C (−95 to 300°F)	−70 to 260°C (−95 to 500°F)	−90 to 315°C (−130 to 600°F)	−90 to 315°C (−130 to 600°F)	−90 to 315°C (−130 to 600°F)	−90 to 315°C (−130 to 600°F)	−70 to 235°C (−95 to 455°F)	−70 to 150°C (−95 to 300°F)
Application or special features	Encapsulating, potting, bonding, structural uses	Better flow characteristics than Stycast 1090	High-temperature version of Stycast 1090	Encapsulating, potting, sealing	Encapsulating, potting, sealing	Dip coating	Encapsulating, potting, sealing	Encapsulating, sealing, structural uses	Structural uses
General notes	For most foam materials, heat resistance depends on density. In most instances, these materials can also be used for thermal insulation.								
Supplier	Emerson and Cuming, Inc., 604 W. 182nd St., Gardena, Calif. Phone, FA 1-6650								

2.9.6 (Cont'd)

Pertinent information	Recommended material								
	Eccofoam FS	Eccofoam SH	Eccofoam SR	Eccofoam FP	Eccofoam GL	Eccofoam EFF	Eccofoam PT	Eccofoam DPT	Eccofoam FPF
Chemical type	Polyurethane	Polyurethane	Silicone	Polyurethane	Phenolic	Epoxy	Epoxy	Epoxy	Polyurethane
Density, lb/ft^3	2.5	2 to 14	10	2 to 26	15 to 22	4 to 15	20	18 to 23	3
Form	Foamed solid	Foamed solid	Foamed solid	Foam-in-place liquid	Foam-in-place powder	Foam-in-place powder	Pack-in-place slurry	Pack-in-place slurry	Foam-in-place liquid
Type	Open cell (flexible)	Closed cell (rigid)	Open cell (flexible)	Closed cell (rigid)	Closed cell (rigid)	Closed cell (rigid)	Closed cell (rigid)	Closed cell (rigid)	Closed cell (flexible)
Service temperature range	−55 to 150°C (−65 to 300°F)	−70 to 235°C (−95 to 455°F)	−90 to 315°C (−130 to 600°F)	−70 to 150°C (−95 to 300°F)	−70 to 175°C (−95 to 345°F)	−55 to 175°C (−65 to 345°F)	−55 to 175°C (−65 to 345°F)	−55 to 205°C (−65 to 400°F)	−60 to 150°C (−75 to 400°F)
Application or special features	Vibration control, packaging	Structural uses	Vibration control, packaging	Encapsulating, potting, bonding, structural uses	Potting, structural uses	Potting, structural uses	Potting, structural uses	Potting, structural uses	Light weight to fill voids
General notes	For most foam materials, heat resistance depends on density. In most instances, these materials can be used for thermal insulation.								
Supplier	Emerson and Cuming, Inc., 604 West 182nd St., Gardena, Calif., Phone, FA 1-6650								

2.9.7 Insulation: Electrical, Miscellaneous Materials

Supporting or reinforcing textiles. Refer to subsection 2.7.6.

Laminated or reinforced plastics. Refer to subsection 2.25.3.

Mica composition. Refer to subsection 2.25†.

Tapes. Refer to subsections 2.7.4 and 2.7.5.

Fluids. Refer to subsection 2.17†.

Wire enamels. Refer to subsection 2.10.5.

Circuit boards. Refer to subsection 2.25.5.

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†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook.*

2.9.8 Insulation: Thermal, Plastics Films

The following plastics films are recommended for thermal insulation applications. The Materials Section should be consulted for specific properties and methods of fabrication.

Mylar Type A aluminized

Tedlar 200BG30WH

Tedlar Modification B Aluminized

Teflon FEP Type A Aluminized

2.10 Insulated Wire and Cable, and Associated Hardware

This subsection covers materials which are recommended for insulated-wire and -cable constructions.

The information is presented in the following categories:

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†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

2.10.1 Wire and Cable Materials: Jacket and Insulation, Elastomers

Pertinent information	Recommended material				
	Hypalon	Viton B	Hycar	Enjay Butyl	G. E. Silicones
Chemical type	Chlorosulfonated polyethylene	Fluoroelastomer	Polyacrylic	Isobutylene-isoprene	Silicone
Hardness range, Shore A Durometer	40 to 95	60 to 95	40 to 90	40 to 90	30 to 90
Strength	Medium to high	Medium to high	Low to medium	Low to medium	Low to medium
Compression set	Excellent	Good	Good	Good	Good to excellent
Service temperature range					
Long-time at 150°C (300°F)	Poor	Excellent	Good	Fair	Excellent
Long-time at 120°C (250°F)	Fair	Excellent	Excellent	Good	Excellent
Low-temperature limit	−40°C (−40°F)	−40°C (−40°F)	−40°C (−40°F)	−100°C (−150°F)	−100°C (−150°F)
General oil resistance	Good	Excellent	Excellent	Poor	Fair
Resistance to specific environments	Consult Materials Section				
General notes	All materials must be compounded to meet the specific environmental conditions involved.				
Supplier	Elastomer Chemicals Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464	B. F. Goodrich Chemical Co. 3135 Euclid Ave. Cleveland, Ohio 44115 Phone, (216) TO 1-3500	Enjay Chemical Co. 615 S. Flower St. Los Angeles, Calif. Phone, MA 6-5664	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	

2.10.2 Wire and Cable Materials: Jacket and Insulation, Extrudable Plastics

Pertinent information	Recommended material		
	Lexan[a]	FEP Teflon[a]	TFE Teflon[a]
Chemical type	Polycarbonate	Fluorocarbon	Fluorocarbon
Hardness	M-70 to R-118 (Rockwell)	R-25 (Rockwell)	50 to 60 (Shore D)
Tensile strength, 1,000 psi	8 to 10	2.5 to 3.0	1.5 to 4.0
Elongation, %	60 to 100	200 to 350	100 to 400
Impact strength, ft-lb. in.	12 to 16	No break	3.0
Flexural strength, 1,000 psi	11 to 13	Does not apply	Does not apply
Compressive strength, 1,000 psi	11	Does not apply	1.7
Service temperature limits	−165 to 150°C (−265 to 300°F)	−260 to 230°C (−435 to 445°F)	−260 to 320°C (−435 to 610°F)
Supplier	Chemical Materials Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	Plastics Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464	

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.10.3 Wire and Cable Materials: Insulation, Wrapped Films

Pertinent information	Recommended material					
	Lexan[a]	Mylar[a]	Kapton[a]	TFE Teflon[a]	FEP Teflon[a]	Tedlar[a]
Chemical type	Polycarbonate	Polyester	Polyimide	Fluorocarbon	Fluorocarbon	Fluorocarbon
Tensile strength, 1,000 psi	8 to 10	23	20	1.5 to 4.0	3.0	9 to 19
Elongation, %	60 to 100	100	70	100 to 400	300	110 to 260
Method of bonding	Heat seal or adhesive	Adhesive	Adhesive	Heat fuse or adhesive	Heat seal or adhesive	Heat seal or adhesive
Service temperature range	−160 to 150°C (−255 to 300°F)	−70 to 165°C (−95 to 330°F)	−250 to 400°C (−420 to 750°F)	−260 to 320°C (−435 to 610°F)	−260 to 230°C (−435 to 445°F)	−75 to 205°C (−105 to 400°F)
Supplier	Chemical Materials Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	Film Dept. E. I. du Pont de Nemours and Co. 4435 Fruitland Ave. Vernon, Calif. Phone, LU 2-7361				

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.10.5 Wire and Cable Materials: Wire Enamels

Pertinent information	Recommended material			
	Formex	Alkenex	PYRE-ML	Teflon (TFE)[a]
Chemical type	Vinyl acetal	Modified polyester	Polyimide	Fluorocarbon
Service temperature range				
Intermittent	−90°C (−130°F) to 120°C (250°F)	−100°C (−150°F) to 225°C (435°F)	−250°C (−420°F) to 400°C (750°F)	−260°C (−435°F) to 320°C (610°F)
Long-time	−60°C (−75°F) to 105°C (220°F)	−90°C (−130°F) to 190°C (375°F)	−190°C (−310°F) to 275°C (525°F)	−150°C (−240°F) to 260°C (500°F)
General notes	These materials are recommended for all metallic conductors requiring a wire enamel. Care must be taken to ensure that polyimide has received the manufacturer's recommended cure cycle.			
Supplier	Wire and Cable Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144		Finishes Division E. I. du Pont de Nemours and Co. 2000 S. Garfield Los Angeles, Calif. Phone, RA 3-8401	

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.24 Marking Materials

The materials covered in this subsection are general purpose medium-fast, non-etching, pigment-type opaque inks, and a photosensitive material for general purpose use.

The information is presented in the following categories:

2.24.1 Marking Materials: General Purpose

2.24.1 Marking Materials: General Purpose

Pertinent information	Recommended material		
	73X Black and 73X White	Kodak Photo Resist (KPR)	Eccocoat EC 200 A/B
Chemical type	—	—	Epoxy
Form	Inks in solvent	Solvent solution of an ultraviolet sensitive plastic	Two liquids containing solvents
Viscosity, poises at 25°C (75°F)	—	1500	Mixture, 5
Shelf life at 25°C (75°F)	6 mo	6 mo	1 yr
Pot life at 25°C (75°F)	6 mo	6 mo	24 hr
Minimum cure cycle	[illegible] at 25°C (75°F)	Dry to touch at 25°C (75°F) plus 1 hr at 110°C (230°F)	6 hr at 25°C (75°F) plus 2 hr at 120°C (250°F)
Service temperature limits	−60 to 150°C (−75 to 300°F)	−60 to 120°C (−75 to 300°F)	−70 to 205°C (−95 to 400°F)
General notes	The materials are generally suited for marking on absorbent, semi-absorbent, and non-absorbent surfaces. The Eccocoat is used only as a protective coating for the inks.		
Supplier	Independent Ink Co. 14705 S. Avalon Gardena, Calif. Phone, 321-0181	Eastman Kodak Co. Pacific Southern Sales Division 808 Rivera Road Whittier, Calif. Phone, 685-5610	Emerson and Cuming, Inc. 604 West 182nd St. Gardena, Calif. Phone, FA 1-6650

2.25 General Structural Materials

This subsection covers both organic and inorganic materials which are suitable for use for general-purpose structural applications. Composites which contain both organic and inorganic components (e.g., epoxy-fiberglass laminates) are treated here as organic materials. The materials listed may also be used, as appropriate, for nonstructural applications.

The information is presented in the following categories:

†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

2.25.1 Organic Materials: Thermosetting Plastics

Pertinent information	Recommended material					
	Diall FS-4	Diall FS-80	Diall FS-10	Diall FS-40	Epiall 1914	Epicap 360
Chemical type	Diallyl phthalate	Diallyl phthalate	Diallyl phthalate	Diallyl phthalate	Epo	Epoxy
Reinforcing agent	Long glass fiber	Long glass fiber	Short glass fiber	Medium glass fiber	Glass	Glass
Specific gravity	1.61	1.86	1.74	1.75	1.92	1.74
Tensile strength, psi, at 25°C (75°F)	8,700	12,000	11,000	15,000	9,500	9,000
Compressive strength, psi, at 25°C (75°F)	32,000	34,000	32,000	30,000	34,000	31,200
Flexural strength, psi, at 25°C (75°F)	11,000	28,000	20,000	20,000	20,000	16,000
Hardness, Barcol and (Rockwell)	52	63	60	60	(M104)	(M104)
Impact strength, Izod, ft-lb/in of notch	10	16+	1.0	2.0	0.50	0.45
Thermal conductivity, 10^{-4} cal/sec/cm^2/°C/cm, near room temperature	5 to 12	5 to 12	5 to 12	5 to 12	7 to 10	7 to 10
Linear coefficient of expansion in./in./°C, near room temperature	33×10^{-6}	33×10^{-6}	33×10^{-6}	33×10^{-6}	20×10^{-6}	20×10^{-6}
Service temperature limits	−150 to 315°C (−240 to 600°F)	−150 to 315°C (−240 to 600°F)	−150 to 315°C (−240 to 600°F)	−150 to 315°C (−240 to 600°F)	−150 to 290°C (−240 to 555°F)	−150 to 220°C (−240 to 430°F)
Heat-distortion temperature	285°C+ (545°F+)	285°C+ (545°F+)	285°C+ (545°F+)	285°C+ (545°F+)	>260°C (>500°F)	190°C (375°F)
General notes	These materials are also suitable for electrical applications.					
Supplier	Mesa Products, Plastics Div., Allied Chemical Corp., 12270 Nebraska Ave., Los Angeles, Calif. 90025 Phone, 272-4471, 477-8531.					

2.25.1 (Cont'd)

Pertinent information	Recommended material		
	Phenall 8010	Phenall 8060	M-9-1012
Chemical type	Phenolic	Phenolic	Silicone
Reinforcing agent	Short glass fiber	Long glass fiber	Glass
Specific gravity	1.85	1.69	1.88
Tensile strength, psi, at 25°C (75°F)	9,100	16,500	6,000
Compressive strength, psi, at 25°C (75°F)	22,500	39,000	12,500
Flexural strength, psi, at 25°C (75°F)	17,500	24,800	20,000
Hardness, Barcol and (Rockwell)			
Impact strength, Izod, ft-lb/in of notch	0.52	13.0	M84
Thermal conductivity, 10^{-4} cal/sec/cm^2/°C/cm, near room temperature	15	32	10
Linear coefficient of expansion in./in./°C, near room temperature			0.8×10^{-5}
Service temperature limits	−150 to 220°C (−240 to 430°F)	−150 to 220°C (−240 to 430°F)	−200 to 500°C (−300 to 930°F)
Heat-distortion temperature	190°C (375°F)	285°C (545°F+)	
Supplier	Mesa Products, Plastics Div. Allied Chemical Corp. 12270 Nebraska Ave. Los Angeles, Calif 90025 Phone, 272-4471, 477-8531		Dow Corning Corp. 3033 W. Mission Rd. Alhambra, Calif. Phone, AT 9-5186

2.25.2 Organic Materials: Thermoplastic Plastics

Pertinent information	Recommended material					
	Penton	Polymer SP	Delrin	Lexan[a]	PPO	Polysulfone
Chemical type	Polyether	Polyimide	Acetal	Polycarbonate	Polyphenylene Oxide	Polysulfone
Reinforcing agent	None or minerals	None	None	None, or glass	None	None
Specific gravity	1.4	1.43	1.452	1.2	1.06	1.25
Tensile strength, psi, at 25°C (75°F)	6,000	13,500	9,000	12,000	10,000	10,000
Compressive strength, psi, at 25°C (75°F)	9,000	27,500	--	11,000	—	—
Flexural strength, psi, at 25°C (75°F)	5,000	14,700	14,000	12,000	14,000	15,400
Hardness, Rockwell	R100	M112	M94, R120	M70 to R118	R119	M69, R120
Impact strength, Izod ft-lb/in. of notch	0.4	0.55	1.2 to 2.2	14	1.8	1.3
Thermal conductivity, cal/sec/in.^{2}/°C/in., near room temperature	3.13×10^{-4}	7.2×10^{-4}	—	4.6×10^{-4}	—	—
Linear coefficient of expansion, in./in./°C, near room temperature	12.6×10^{-5}	4.1×10^{-5}	8.1×10^{-5}	7×10^{-5}	5.4×10^{-5}	3.2×10^{-5}
Service temperature limits	−55 to 150°C (−70 to 300°F)	−250 to 400°C (−420 to 750°F)	−75 to 120°C (−105 to 250°F)	−160 to 150°C (−255 to 300°F)	−170 to 205°C (−257 to 400°F)	−100 to 175°C (−150 to 345°F)
General notes	Many materials classified as adhesives, potting compounds, etc., may often be used for structural applications. Lexan can be reinforced with glass; Penton and Polymer SP can be reinforced with various minerals.					
Supplier	Hercules Powder Co. 3450 Wilshire Blvd. Los Angeles, Calif. Phone, DU 7-8151	Plastics Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464	Chemical Materials Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	Plastics Division Union Carbide Corp. 2770 Leonis Blvd. Los Angeles, Calif. 90058 Phone, LU 3-3061		

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.25.3 Organic Materials: Laminated Plastics

Pertinent information	Recommended material				
	Micarta H-5834	Micarta H-8457	Micarta H-17480	Micarta 259-2	Micarta 20201-2
Chemical type	Phenolic	Epoxy	Epoxy	Melamine	Silicone
Tubing grade	HY-322	HY-180	HY-902	5A4	20000-2
Maximum continuous-service temperature	155°C (310°F)	130°C (265°F)	130°C (265°F)	130°C (265°F)	180°C (355°F)
Specific gravity	1.94	1.86	1.93	1.91	1.80
Tensile strength, psi, at 25°C (75°F)	50,000	65,000	75,000	40,000	25,000
Flexural strength, psi, at 25°C (75°F)	74,000	77,000	121,000	50,000	27,000
Flexural modulus of elasticity, psi, at 25°C (75°F)	3.7×10^6	3.8×10^6	3.4×10^6	2.2×10^6	2.2×10^6
Linear coefficient of expansion, in./in./°C	2.66×10^{-5}	1.7×10^{-5}	1.7×10^{-5}	1.0×10^{-5}	0.8×10^{-5}
Thermal conductivity, cal/sec/cm²/°C/cm	6.79×10^{-4}	6.27×10^{-4}	6.27×10^{-4}	12×10^{-4}	7×10^{-4}
Dielectric strength, short-time, v/mil	500	550	470	300	350
Volume resistivity, ohm-cm	5×10^{12}	3.5×10^{13}	13×10^{12}	6×10^{13}	5×10^{13}
Surface resistivity, ohms	1×10^{12}	5×10^{11}	4×10^{11}	6×10^{12}	1×10^{13}
General notes	Tubing grade number is shown separately, because it differs from the general grade number assigned to sheets, angles, channels, zees, and cured rods. All materials are reinforced with fiber glass.				
Supplier	Micarta Division Westinghouse Electric Corp. 600 St. Paul Ave. Los Angeles, Calif. Phone, HU 2-9660				

2.25.4 Organic Materials: Honeycomb Core

Pertinent information	Recommended material		
	HRP	HRS	HMH
Description	Reinforced honeycomb impregnated with a heat-resistant phenolic resin	Glass reinforced honeycomb impregnated with a silicone resin	Mylar polyester honeycomb
Color	Brown	Tan	Light bluish tint
Service temperature limits	−75 to 175°C (−105 to 345°F)	−75 to 260°C (−105 to 500°F)	−75 to 150°C (−105 to 300°F)
General notes	If the materials are to be used for such end products as honeycomb sandwiches, adequate venting must be provided for, or care taken to insure that pressure will not build up causing rupture in service. HRP and HRS materials should be post cured 8 hours at the maximum temperature expected in service prior to fabrication.		
Supplier	Hexcel Products, Inc., 2332 Fourth St., Berkeley, Calif. 94710. Phone, (415) 843-4664.		

2.25.5 Organic Materials: Circuit Boards

Pertinent information	Recommended material
	Micarta 65M25
Description	Copper clad Epoxy-glass laminate
Bond strength, lb	
1-oz copper	10
2-oz copper	12
Heat resistance, hot solder sec at 260°C (500°F)	20
Flexural strength, flatwise, LW, psi ultimate	76,000
Impact strength, Izod, edgewise, LW, ft-lb/in notch	10
Tensile strength, LW, psi ultimate	65,000
Hardness, Rockwell	M115
Supplier	Micarta Division Westinghouse Electric Corporation 600 St. Paul Avenue Los Angeles, Calif. Phone, HU 2-9660

2.26 General Nonstructural Materials

This subsection covers both organic and inorganic materials which are suitable for use for general-purpose nonstructural applications. Composites which contain both organic and inorganic components (e.g., epoxy–fiber-glass laminates) are treated here as organic materials.

The information is presented in the following categories:

†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook.*

2.26.1 Organic Materials: Plastics

Pertinent information	Recommended material				
	FEP Teflon[a]	TFE Teflon[a]	n-Film	Mylar[a]	Tedlar[a]
Chemical type	Fluorocarbon	Fluorocarbon	Polyimide	Polyester	Fluorocarbon
Specific gravity	2.0	3 to 4	1.38	1.38	1.38
Forms available	Molding powder, film	Molding powder, film	Film	Film	Film
Tensile strength, 1,000 psi	2.5 to 3.0	1.5 to 4.0	20	23 to 40	9 to 19
Elongation, %	300	100 to 350	70	100	110 to 260
Tear strength, grams to propagate	125	10 to 100	8	10 to 27	12 to 48
Gas permeability	Low	Very low		Low	Very low
Refractive index	1.34	1.35		1.64	1.46
Color, natural	Water clear to white opaque	Translucent to white opaque	Amber clear	Water clear to translucent	Water clear
Service temperature limits	−260 to 230°C (−435 to 445°F)	−260 to 320°C (−435 to 610°F)	−250 to 400°C (−420 to 750°F)	−70 to 165°C (−95 to 330°F)	−75 to 205°C (−105 to 400°F)
General notes	Structural plastics may also be used for nonstructural applications. Many of the materials classified as adhesives, potting compounds, etc., may often be used for nonstructural applications.				
Supplier	E. I. du Pont de Nemours and Co. Plastics Department 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464		Film Department 4455 Fruitland Ave. Vernon, Calif. Phone, LU 2-7361		
	Note: Both Teflons (depending on form) may be obtained from either the Plastics Department or the Film Department.				

[a]Amplified data for this material appear in the Appendix, subsection 6.1.

2.26.2 Organic Materials: Elastomers

Pertinent information	Recommended material				
	Enjay Butyl	G. E. Silicones	Viton B	Hypalon	Hycar
Chemical type	Isobutylene-isoprene	Silicone	Fluoroelastomer	Chlorosulfonated polyethylene	Polyacrylic
Hardness range, Shore A	40 to 90	30 to 90	60 to 95	40 to 95	40 to 90
Strength	Low to medium	Low to medium	Medium to high	Medium to high	Low to medium
Compression set	Good	Good to excellent	Good	Excellent	Good
Gas permeability	Very low	Medium to high	Low to very low	Low to very low	Low to medium
Service temperature limits	−100 to 200°C (−150 to 390°F)	−100 to 350°C (−150 to 660°F)	−40 to 300°C (−40 to 570°F)	−40 to 150°C (−40 to 300°F)	−40 to 205°C (−40 to 400°F)
General oil resistance	Poor	Fair	Excellent	Good	Excellent
Resistance to specific environments	Consult Materials Section				
General notes	All materials must be compounded to meet specific end-use applications and environmental requirements.				
Supplier	Enjay Chemical Co. 615 S. Flower St. Los Angeles, Calif. Phone, MA 6-5664	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	Elastomer Chemicals Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464		B. F. Goodrich Chemical Co. 3135 Euclid Ave. Cleveland, Ohio 44115 Phone, (216) TO 1-3500

2.26.3 Organic Materials: Coated Fabrics

Pertinent information	Recommended coating material				
	Enjay Butyl	G. E. Silicones	Viton B	Hypalon	Hycar
Chemical type	Isobutylene-isoprene	Silicone	Fluoroelastomer	Chlorosulfonated polyethylene	Polyacrylic
Gas permeability	Very low	Medium to high	Low to very low	Medium to high	Low to medium
Preferred fabric(s)	Glass, Nomex, Dacron	Glass	Glass	Glass, Nomex, Dacron	Glass, Nomex, Dacron
Serivce temperature limits	−100 to 200°C (−150 to 390°F)	−100 to 350°C (−150 to 660°F)	−40 to 300°C (−40 to 570°F)	−40 to 150°C (−40 to 300°F)	−40 to 205°C (−40 to 400°F)
Resistance to specific environments	Consult Materials Section				
General notes	Coating materials must be compounded to meet specific end-use applications and environmental conditions. Other materials classified as adhesives, coatings, etc., may also be used for coating fabrics. In many instances, the fabrics must be pretreated for optimum performance. For information on fabrics, refer to subsection 2.7.1–7. For coated fabric products, see subsection 2.7.8.				
Supplier	Enjay Chemical Co. 615 S. Flower St. Los Angeles, Calif. Phone, MA 6-5664	Silicone Products Dept. General Electric Co. 8555 E. Florence Ave. Downey, Calif. Phone, SP 3-3144	Elastomer Chemicals Dept. E. I. du Pont de Nemours and Co. 2930 E. 44th St. Vernon, Calif. Phone, LU 2-6464	B. F. Goodrich Chemical Co. 3135 Euclid Ave. Cleveland, Ohio 44115 Phone, (216) TO 1-3500	

3.0 GENERAL MATERIALS INFORMATION

Since the term *materials* covers a broad spectrum of types and forms, as well as chemical and physical make-up, it is extremely difficult (if not impossible) for one person to be well versed in all aspects of materials applications. Therefore, this Section is intended to amplify the information given in Section 2.0 by presenting brief descriptions of the various types. (Detailed supplementary data for some of the materials discussed in this Section are presented in the Appendix, Section 6.0.) In addition, some new or familiar materials which are *not* recommended are discussed to clarify the reasons for their omission. It should be noted that the property data listed are based upon optimum conditions and, therefore, are intended to be used only for comparative purposes and general information; they are not design or specification values.

The suppliers listed in each category are, in general, manufacturers of the basic materials, and are noted to provide sources of more detailed information. They do not necessarily supply the finished product. For example, General Electric produces Lexan, but does not furnish molded products of Lexan.

The information is presented in the following categories:

3.1 Organic Materials

3.2† Inorganic Materials

Generally speaking, the organic materials are listed by chemical class, whereas the inorganic materials are listed by their common names.

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† Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

3.1 Organic Materials

The organic materials described in this Section are listed below. In referring to the more detailed information presented in the Appendix, Section 6.0, note that the numbering system parallels that employed here: for example, polycarbonate plastics are discussed in subsections 3.1.9 and 6.1.9.

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†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

3.1.1 Chlorosulfonated Polyethylene Elastomers

Hypalon 20, 30, and 40 are related elastomeric copolymers of chlorosulfonated polyethylene which can be compounded to satisfy a great variety of end uses. Hypalon 40 is generally recommended because of its easy processing. Hypalon 20 is slightly better for electrical applications. Hypalon 30 is used for solution coatings, alone or in combination with Hypalon 20. In some instances, Hypalon 20 can be used alone for solution coatings.

Advantages. Good resistance to chemicals, ozone, heat, radiation, oil, oxidation, and abrasion. Good mechanical and electrical properties.

Disadvantages. Poor low-temperature properties. Not resistant to prolonged exposure to high temperatures.

Temperature ranges.

Intermittent: −40 to 150°C (−40 to 300°F)

Long-time: −25 to 110°C (−15 to 230°F)

Precautions. Since Hypalon is compounded to meet specific end uses, the resulting materials may not necessarily be equivalent in their resistance to deleterious environments. Heat-sterilization cycles may produce incipient-to-moderate damage.

Typical uses. Wire and cable insulation and jacket, mechanical goods, seals, hose, linings, coatings.

Manufacturer of base polymers. Elastomer Chemicals Department, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware. West Coast Office: 2930 East 44th Street, Vernon, California; phone, LUdlow 2-6464.

Tradenames. Hypalon 20, Hypalon 30, Hypalon 40.

Generic names. Chlorosulfonated polyethylene, CSPE.

3.1.2 Polyacrylic Elastomers

The commercially important polyacrylic elastomers comprise copolymers of acrylic acid esters and halogen-containing derivatives. Compounding ingredients are added to raw gum stocks which are then processed and fabricated to the desired end-use item.

Advantages: Good resistance to oxidation, oils, and permeability by many gases. Excellent ozone resistance.

Disadvantages: Poor resistance to low temperatures, water, and many water-soluble materials, and alkalis and acids.

Temperature ranges.

Intermittent: −40 to 205°C (−40 to 400°F)

Long-time: −20 to 350° (−5 to 300°F)

Precaution. Since polyacrylic gums are compounded to meet specific end uses, the resulting compounds may not necessarily be equivalent in their resistance to deleterious environments.

Typical uses. Mechanical goods, wire and cable jacket, hose, coatings, seals and gaskets.

Manufacturer of base polymer. B. F. Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland, Ohio 44115. West Coast office: 714 West Olympic Boulevard, Los Angeles, California 90015. Phone, 749-9157.

Tradename. Hycar 4021.

Generic Name. Polyacrylic.

3.1.3 Fluoroelastomers

Fluoroelastomer is a generic name relating elastomers which have fluorine in the polymer molecule. At present, only the elastomeric copolymers of vinylidene fluoride and hexafluoropropylene are recommended.

Advantages. Excellent resistance to heat, chemicals, ozone, oils, oxidation.

Disadvantages. Poor-low temperature properties. Relatively poor radiation resistance in air.

Temperature ranges.

Intermittent: −40 to 300°C (−40 to 570°F)

Long-time: −20 to 200°C (−5 to 390°F)

Precautions. Since the fluoroelastomer base gum is compounded to meet specific end uses, the resulting compounds may not necessarily be equivalent in their resistance to deleterious environments. A post-cure is necessary for best environmental performance.

Typical uses. Mechanical goods, seals, coatings, linings, wire and cable insulation and jacket.

Manufacturer of base polymer. Elastomer Chemicals Department, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware. West Coast Office: 2930 East 44th Street, Vernon, California; phone, LUdlow 2-6464.

Tradename. Viton E.

Generic names. Fluoroelastomer, fluorocarbon rubber, VFHE.

3.1.4 Isobutylene-Isoprene Elastomers

The copolymerization of isobutylene with small amounts of isoprene results in an elastomeric raw gum rubber which is generally known as butyl rubber. The copolymers may be modified by such chemicals as bromine or chlorine to produce special properties.

Advantages. Good resistance to gas permeability, ozone, heat, oxidation, hydrazine. Good electrical properties.

Disadvantages. Poor resistance to many organic solvents. Poor radiation resistance in air.

Temperature ranges.

Intermittent: −100 to 200°C (−150 to 390°F)

Long-time: −60 to 140°C (−75 to 285°F)

Precautions. Since butyl rubber is compounded to meet specific end uses, the resulting compounds may not necessarily be equivalent in their resistance to deleterious environments.

Typical uses. Mechanical goods, seals, wire and cable insulation and jacket, coatings.

Manufacturer of base polymer. Enjay Chemical Company, 15 West 51st Street, New York 19, New York. West Coast Office: 615 Flower Street, Los Angeles 17, California; phone, MAin 6-5664.

Tradename. Enjay Butyl HT-1066.

Generic names. Butyl, IIR.

3.1.5 Silicone Elastomers (Millable)

Silicone elastomers are generally divided chemically into five types: (1) dimethyl, (2) methyl vinyl, (3) methyl phenyl, (4) methyl phenyl vinyl, and (5) fluorocarbon. Physically, they can be divided into two groups: (1) millable types, and (2) liquid and paste types (see page 3.1.8). Only the millable types are considered on this page.

Advantages. Excellent resistance to high and low temperatures. Excellent resistance to oxidation, ozone, and weathering. Good electrical properties.

Disadvantages. Relatively poor mechanical properties for most types except the methyl phenyl vinyl materials.

Temperature ranges.

Intermittent: −100 to 350°C (−150 to 660°F)

Long-time: −70 to 230°C (−95 to 445°F)

Precautions. Since the silicone elastomers comprise a variety of different types, and since they are often compounded to meet specific end uses, the resulting materials may not necessarily be equivalent in their resistance to deleterious environments. For best environmental performance, a post-cure is necessary.

Typical uses. Wire and cable insulation and jacket. Seals, mechanical goods.

Manufacturer of base polymers. Silicone Products Department, General Electric Company, Waterford, New York. West Coast Office: 8555 East Florence Avenue, Downey, California: phone SPruce 3-3144.

Tradename. G.E. silicone elastomers.

Generic names. Silicone, SE.

3.1.6 Silicone Elastomers (Liquid and Paste)

Fluid silicone elastomers are commercially available in forms ranging from free-flowing liquids to stiff pastes. They can be cured over a wide range, from room temperature up to a temperature of the order of 100°C. Cure is accomplished with a catalyst or by hydrolysis from moisture in the air.

Advantages. Versatile processing characteristics. Excellent resistance to high and low temperatures. Excellent resistance to oxidation, ozone, and weathering. Good electrical properties.

Disadvantages. Relatively poor mechanical properties.

Temperature ranges.

Intermittent: −100 to 350°C (−150 to 660°F)

Long-time: −70 to 230°C (−95 to 445°F)

Precautions. Since the fluid silicone elastomers comprise a variety of different types, and since they are often compounded to meet specific end uses, the resulting materials may not necessarily be equivalent in their resistance to deleterious environments. For best environmental performance, a post-cure is necessary.

Typical uses. Adhesives, coatings, sealants, electrical insulation, coatings, potting and encapsulating substances.

Manufacturer of base polymers. Silicone Products Department, General Electric Company, Waterford, New York. West Coast Office: 8555 East Florence Avenue, Downey, California; phone, SPruce 3-3144.

Tradename. G.E. silicone elastomers.

Generic name. Silicone, RTV.*

*Amplified data for these materials appear in the Appendix, subsection 6.1.

3.1.7 Fluorocarbon Plastics

Plastics which contain fluorine in their polymer molecules are generically called fluorocarbons. The recommended materials are thermoplastic polymers based on tetrafluoroethylene (TFE), thermoplastic copolymers based on tetrafluoroethylene and hexafluoropropylene (FEP), and thermoplastic polymers based on polyvinyl fluoride (PVF, discussed on p. 3.1.10–2). The TFE resins generally have better environmental resistance, while the FEP materials are more easily processed.

Advantages. Maximum resistance to chemicals. Outstanding resistance to high and low temperatures. Excellent electrical properties and flex life.

Disadvantages. Poor radiation resistance in air. Not easily bonded by conventional methods. Fabrication difficulties sometimes encountered with TFE.

Temperature ranges.	TFE	FEP
Intermittent:	−260 to 320°C (−435 to 610°F)	−260 to 230°C (−435 to 445°F)
Long-time:	−150 to 260°C (−240 to 500°F)	−150 to 200°C (−240 to 390°F)

Precautions. Degradation products, formed at extremely high temperatures, may present a corrosion hazard.

Typical uses. Wire and cable insulation and jacket, wire enamel, coatings, seals, insulation, molded items, textile fibers.

Manufacturer of base resins. Plastics Department, Fabrics and Finishes Division, and Textile Fibers Department, all of E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware. West Coast Offices:

Plastics: 2930 West 44th Street, Vernon, California; phone, LUdlow 2-6464.

Fabrics: 2000 South Garfield Avenue, Los Angeles 22, California; phone, RAymond 3-8401.

Textile, film: 4455 Fruitland Avenue, Vernon, California; phone, LUdlow 2-7361.

Tradename. Teflon.

Generic names. Fluorocarbon, TFE, FEP.*

*Amplified data for these materials appear in the Appendix, subsection 6.1.

3.1.7 (Cont'd)

Unplasticized thermoplastic polymers of vinyl fluoride are currently being extruded to produce film in the thickness range of 0.0005 to 0.002 in. The films are produced in several tensile-strength ranges and are available in both clear and pigmented forms. The materials may be fabricated by heat sealing, laminating, or adhesive bonding.

Advantages. Good resistance to ultraviolet radiation. Good electrical properties. Good abrasion and chemical resistance. Low gas permeability.

Disadvantages. Availability limited to thin films.

Temperature ranges.

Intermittent: −75 to 205°C (−105 to 400°F)

Long-time: −60 to 110°C (−75 to 230°F)

Typical uses. Temperature-control surfaces, wire and cable insulation and jacket, electrical insulation.

Manufacturer of film. Film Department, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware. West Coast Office: 4455 Fruitland Avenue, Vernon, California; phone, LUdlow 2-7361.

Tradename. Tedlar.

Generic name. Polyvinyl fluoride, PVF.*

*Amplified data for this material appear in the Appendix, subsection 6.1.

3.1.8 Polyesters

The term *polyester* is chemically descriptive of a class of polymers formed by the reaction of organic polyhydric alcohols and polybasic acids (and many modifications thereof). Because of the broad spectrum of materials involved, it is impractical to generalize on overall properties. Each polyester, with the exception of polycarbonates and some polyurethanes, must be treated as a separate entity, rather than as a member of a specific polymer class.* Commercially available polyesters are produced in many physical forms for all varieties of end uses. These types can be classified as follows:

Unsaturated polyesters. Polyester resins can be crosslinked by means of a vinyl (unsaturated) group to form a thermosetting material. They are usually in liquid form before curing.

Alkyd resins. These substances are polyester resins which are used as coating and molding materials. They are usually polyesters modified with fatty acids and oils.

Film and fiber polyesters. Usually thermoplastic in nature, these materials are based upon specific organic acids and alcohols. During manufacture they are sometimes highly oriented to give specific properties.

Plasticizers. Polyester resins, usually of the lower-molecular-weight species, are used extensively for plasticizing certain resins. They are often referred to as polymeric plasticizers.

Elastomeric polyesters. The copolymerization of certain materials can yield polyester copolymers which are elastomeric in nature.

Miscellaneous polyesters. Polyesters can be used as high-molecular-weight monomers or prepolymers in a polymerization; for example, they are used with isocyanates to produce elastomers, molding compounds, plastics, foams, and coatings. The final products are more commonly referred to as polyurethanes, q.v. Polyesters derived from carbonic acid comprise a special class of plastics called polycarbonates, q.v.

Generic name. Polyester.

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*Such treatment will be added to the *Guidebook* as the need arises.

3.1.8 (Cont'd)

Film polyester

The reaction of ethylene glycol and terephthalic acid yields a thermoplastic polymer (polyethylene terephthalate) which can be formed into a clear-transparent film or fiber for textiles. Orientation of the film during manufacture gives it unique properties. The materials may be fabricated by laminating or adhesive bonding. The film is available in thicknesses of 0.00015 to 0.010 in. and, in sheet form, up to 0.014 in.

Advantages. Good mechanical strength and electrical properties. Tough and abrasion resistant.

Disadvantages. Relatively poor resistance to ultraviolet radiation. Availability limited to sheets in 0.00015- to 0.014-in. thickness range.

Temperature ranges.

Intermittent: −70 to 165°C (−95 to 330°F)

Long-time: −60 to 150°C (−75 to 300°F)

Typical uses. Wire and cable insulation and jacket, temperature-control surfaces (usually metallized film), electrical insulation, magnetic tape.

Manufacturer of film. Film Department, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware. West Coast Office: 4455 Fruitland Avenue, Vernon, California; phone LUdlow 2-7361.

Tradename. Mylar.*

Generic name. Polyester.

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*Amplified data for this material appear in the Appendix, subsection 6.1.

3.1.8 (Cont'd)

Fiber polyester

As indicated on p. 3.1.11–2, the reaction of ethylene glycol and terephthalic acid produces a thermoplastic polymer which can be processed to yield staple fibers for textile products.

Advantages. Good strength, flex life, and electrical properties. Good resistance to abrasion, heat, and many chemicals.

Temperature ranges.

Intermittent: −70 to 165°C (−95 to 330°F)

Long-time: −60 to 150°C (−75 to 300°F)

Typical uses. Reinforcing agent for plastics, coated fabrics, tie cord, miscellaneous textile products.

Manufacturer of polymer. Textile Fibers Department, E. I. du Pont de Nemours and Company, Inc., 4455 Fruitland Avenue, Vernon, California, LUdlow 2-7361.

Tradename. Dacron.

Generic name. Polyester.

3.1.9 Polycarbonate Plastics

Polycarbonates are a special class of thermoplastic polyester resins derived from dihydroxy compounds and carbonic acid or derivatives of carbonic acid, such as phosgene. They may be filled with glass reinforcing agents to produce special properties.

Advantages. Excellent impact strength and dimension stability. Good electrical and mechanical properties. Easy fabrication techniques.

Disadvantages. Not resistant to some cleaning or degreasing solvents.

Temperature ranges.

Intermittent: −160 to 150°C (−255 to 300°F)

Long-time: −135 to 125°C (−210 to 255°F)

Typical uses. Wire and cable insulation and jacket, gaskets, gears, electrical insulation, structural items, films.

Manufacturer of base resins. Chemical Materials Department, General Electric Company, One Plastics Avenue, Pittsfield, Massachusetts. West Coast Office: 8555 East Florence Avenue, Downey, California; phone, SPruce 3-3144.

Tradename. Lexan.*

Generic name. Polycarbonate.

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*Amplified data for this material appear in the Appendix, subsection 6.1.

3.1.10 Epoxy Resins

Epoxy resins comprise a broad class of polymeric materials based upon ethylene oxide or its derivatives. For example, resins formed from the reaction of epichlorohydrin with bisphenol-A. Commercially, they are manufactured in many physical forms for a wide variety of end uses. Often, they are modified, blended, or copolymerized with other materials for special properties.

Because of the broad spectrum of materials involved, it is impractical to generalize on overall properties. Each material must be treated as a separate entity, rather than as a member of a specific polymer class.*

Generic name. Epoxy.

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*Such treatment will be added to the *Guidebook* as the need arises.

3.1.11 Polyimide Resins

The polyimide resins comprise a relatively new class of polymers which are chemically related to the polyamides (nylons), but differ in physical properties. Forms available include film, solid shapes (see p. 3.1.14–2), and wire enamels and varnishes (see p. 3.1.14–3).

Film

Advantages. Outstanding resistance to high and low temperatures and chemicals. Excellent radiation resistance in air. Good electrical properties.

Disadvantages. Availability limited to thin films.

Temperature ranges.

Intermittent: −250 to 400°C (−420 to 750°F)

Long-time: −190 to 275°C (−310 to 525°F)

Typical uses. Electrical insulation, film.

Manufacturer of film. Film Department, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware. West Coast Office: 4455 Fruitland Avenue, Vernon, California; phone, LUdlow 2-7361.

Tradename. Kapton.

Generic names. Polyimide, H-Film.

3.1.11 (Cont'd)

Solid shapes

Polyimide resins are available in solid cylindrical form (up to 5 in. in diameter by 5 in. in length) for machining into the desired shape.

Advantages. Outstanding resistance to high and low temperatures and chemicals. Excellent radiation resistance in air. Good electrical properties.

Disadvantages. Availability limited to relatively simple shapes.

Temperature ranges.

Intermittent: −250 to 400°C (−420 to 750°F)

Long-time: −190 to 275°C (−310 to 525°F)

Typical uses. Mechanical and electrical parts. Structural items.

Manufacturer of polymer. Plastics Department, E. I. du Pont de Nemours and Company, Inc., 2930 East 44th Street, Vernon, California; phone LUdlow 2-6464.

Tradename. Vespel.

Generic name. Polymer SP.

3.1.11 (Cont'd)

Wire enamels and varnishes

Liquid polyimide resins are available for use as wire enamels and varnishes for electrical insulation and coated fabrics.

Advantages. Outstanding resistance to high and low temperatures and chemicals. Excellent radiation resistance in air. Good electrical properties.

Disadvantages. Relatively long cure cycles at elevated temperatures.

Temperature ranges.

Intermittent: −250 to 400°C (−420 to 750°F)

Long-time: −190 to 275°C (−310 to 525°F)

Typical uses. Wire enamel, coated fabrics, varnish, electrical insulation.

Manufacturer of polymer. Fabrics and Finishes Department, E. I. du Pont de Nemours and Company, Inc., 2000 South Garfield Avenue, Los Angeles 22, California; phone, RA 3-8401.

Trade names. PYRE-M.L. RK-692 insulating varnish; PYRE-M.L. coated glass fabrics; PYRE-M.L. wire enamel.

Generic name. Polyimide.

3.1.12 Alkyd Resins

Alkyd resins are a special class of polyesters (q.v.) and comprise a broad class of materials suitable for use as molding compounds, coatings, paints, and wire enamels.

Because of the broad spectrum of materials involved, it is impractical to generalize on overall properties. Each material must be treated as a separate entity rather than as a member of a specific polymer class.*

Generic name. Alkyd.

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*Such treatment will be added to the *Guidebook* as the need arises.

3.1.13 Phenolic Resins

Phenolic resins are based upon condensation reactions between aromatic alcohols and aldehydes. The most important commercial class comprises resins derived from phenol and formaldehyde. They are suitable for use for many applications, including molding compounds, adhesives, coatings, electrical insulation, laminates, and specialty items.

Because of the broad spectrum of materials involved, it is impractical to generalize on overall properties. Each material must be treated as a separate entity, rather than as a member of a specific polymer class.*

Generic name. Phenolic.

---

*Such treatment will be added to the *Guidebook* as the need arises.

3.1.14 Silicone Resins

Silicone resins are three-dimensional cross-linked polymeric materials which require heat for curing. The resins are derived from different chlorosilanes than are the silicone elastomers, fluids, and greases. In many instances, the base silicone resins can be copolymerized with other polymeric materials, such as alkyd resins, to obtain special properties. The resins are supplied as molding compounds, solvent-solution coatings, and casting materials.

Because of the broad spectrum of materials involved, it is impractical to generalize on overall properties. Each material must be treated as a separate entity, rather than as a member of a specific polymer class.*

Generic name. Silicone.

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*Such treatment will be added to the *Guidebook* as the need arises.

3.1.15 Polyamide Resins

The polyamide resins generally comprise two types: (1) those formed from a condensation reaction between a polybasic acid and a diamine (e.g., 6-6 nylon), and (2) those formed from a condensation reaction of an amine-containing acid (e.g., polycaprolactam). They are chemically related to the polyimide resins, but differ in physical properties. Forms available include molding powders, film, and fibers for textiles. Only the fibers or textiles are recommended at this time.

Advantages. Good resistance to heat and good retention of properties at high temperatures. Good radiation resistance in air.

Temperature ranges.

Intermittent: −90 to 250°C (−130 to 480°F)

Long-time: −90 to 170°C (−130 to 340°F)

Typical uses. Reinforcing or supporting organic resins, tapes, tie cord, coated fabrics.

Manufacturer of base resin. Textile Fibers Department, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware. West Coast Office: 612 South Flower, Los Angeles, California; phone, MAin 4-9841.

Tradename. Nomex.

Generic names. Polyamide, nylon.

3.1.16 Chlorinated Polyether Plastic

The polymerization of a chlorinated oxetane produces a thermoplastic chlorinated polyether polymer which has a good balance of overall properties. The material may be reinforced with appropriate fillers to enhance mechanical and physical properties.

Advantages. Good resistance to oxidation, heat, and chemicals. Dimensionally stable. Good electrical properties.

Disadvantages. Poor radiation resistance in air.

Temperature ranges.

Intermittent: −55 to 150°C (−70 to 300°F)

Long-time: −40 to 115°C (−40 to 240°F)

Typical uses. Pipe, coatings, linings, structural parts.

Manufacturer of base polymer. Hercules Powder Company, 910 Market Street, Wilmington 99, Delaware. West Coast Office: 3460 Wilshire Boulevard, Los Angeles 5, California; phone DUnkirk 7-8151.

Tradename. Penton 9215.

Generic names. Chlorinated polyether, polyether.

3.1.17 Melamine Resins

Melamine resins are based upon condensation reactions between melamine and aldehydes, or their polymers. The most important commercial classes comprise resins derived from melamine and formaldehyde. They are suitable for use for a wide variety of applications, including molding compounds, electrical insulation, laminates, and specialty items.

Because of the broad spectrum of materials involved, it is impractical to generalize on overall properties. Each material must be treated as a separate entity, rather than as a member of a specific polymer class.*

Generic names. Melamine, amino.

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*Such treatment will be added to the *Guidebook* as the need arises.

3.1.18 Allyl Resins

Allyl resins comprise those materials containing allyl esters of dibasic acids, which act as cross-linking agents. These resins, usually produced as liquid-casting resins or thermosetting molding compounds, exhibit minimum shrinkage on bulk polymerization.

Because of the broad spectrum of materials involved, it is impractical to generalize on overall properties. Each material must be treated as a separate entity, rather than as a member of a specific polymer class.*

Generic name. Allyl

*Such treatment will be added to the *Guidebook* as the need arises.

4.0 GLOSSARY

The purpose of this Section is to identify those materials which are most commonly known by trade or generic name, and also to define selected terms which are peculiar to certain materials or classes of materials. The definitions given coincide with *Guidebook* content and do not necessarily reflect definitions set forth in other publications.

To avoid ambiguity, only the tradenames which apply to materials mentioned in the *Guidebook* are defined. For example, *Hycar* is a tradename which is associated with several chemically different elastomers.

Broadly speaking, the organic materials are listed alphabetically by chemical class, whereas the inorganic materials are listed in the alphabetical order of their common names.

The Glossary is divided into four categories, as follows:

4.1 Trade and Generic Names: Organic Materials

4.2† Trade and Generic Names: Inorganic Materials

4.3 Definition of Terms: Organic Materials

4.4† Definition of Terms: Inorganic Materials

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†Information for this subsection is being compiled and, when completed, will be added to the *Guidebook*.

4.1 Trade and Generic Names: Organic Materials

acetal. Generic name for highly crystalline polymers of formaldehyde. See Delrin.

Alkenex. Tradename for modified polyetser wire enamels.

alkyd. A special class of polyester resins.

allyl. Chemically descriptive of, and a generic name for, allyl esters of dibasic acids.

B. Designation for various types of insulating varnishes.

Ben-Har. Tradename for various types of flexible sleeving for electrical insulation.

butyl. Generic name for elastomeric copolymers of isobutylene and isoprene. See *IIR*.

Cat-A-Lac. Tradename for several types of temperature-control coatings.

chlorinated polyether. Chemically descriptive of a polyether which contains chlorine. See *Penton*.

chlorosulfonated polyethylene. Chemically descriptive of, and a generic name for, elastomeric polymers of chlorosulfonated polyethylene. See *Hypalon, CSPE*.

CSPE. Chlorosulfonated polyethylene elastomer. Generic name for elastomeric polymers of chlorosulfonated polyethylene. See *Hypalon*.

4.1 (Cont'd)

Dacron. Tradename for polyester fibers.

Delrin. Tradename for certain acetal polymers.

Diall. Tradename for diallyl phthalate molding compounds.

du Pont No. 585. Tradename for an epoxy black-flat-absorber temperature-control coating.

Eccobond. Tradename for epoxy adhesives.

Eccocoat. Tradename for polyurethane and epoxy resins.

Eccofoam. Tradename for certain foams.

Eccogel. Tradename for epoxy resins.

Eccosil. Tradename for certain silicone elastomers.

Enjay Butyl. Tradename for isobutylene-isoprene elastomers.

Epiall. Tradename for certain epoxy molding compounds.

Epicap. Tradename for certain epoxy molding compounds.

Epocast. Tradename for epoxy resins.

Epon. Tradename for epoxy and modified epoxy adhesives.

epoxy. Chemically descriptive of, and a generic name for, polymers derived from ethylene oxide or its derivatives: for example, materials based upon the reaction of bisphenol-A with epichlorohydrin.

Fairprene. Tradename for coated fabrics.

FEP. See *Teflon.*

4.1 (Cont'd)

fluorocarbon. Chemically descriptive of, and a generic name for, both plastics and elastomers which contain fluorine. See *fluoroelastomer, Teflon, Viton, Tedlar.*

fluoroelastomer. Generic name relating elastomers which contain fluorine in their polymer chains. See *Viton.*

FM-1044. Designation for an adhesive film.

Formex. Tradename for vinyl acetal wire enamels.

Gude-Space. Tradename for certain tie cords or lacing tapes.

Hexcel. Tradename for various types of honeycomb.

H-Film. Obsolete generic name for polyimide films. See *Kapton.*

HMH. Designation for Mylar polyester honeycomb.

HRP. Tradename for heat resistant phenolic honeycomb.

HRS. Tradename for heat resistant silicone honeycomb.

Hycar. Tradename for polyacrylic elastomers. See *PA.*

Hypalon. Tradename for elastomeric polymers of chlorosulfonated polyethylene. See *CSPE.*

IIR. Isobutylene isoprene rubber. Generic name for elastomeric copolymers of isobutylene and isoprene. See *butyl.*

isobutylene-isoprene. Chemically descriptive of elastomeric copolymers of isobutylene and isoprene. See *butyl, IIR.*

4.1 (Cont'd)

JPL. Designation assigned by the Jet Propulsion Laboratory to various polymeric products (e.g., JPL No. 1001).

Kapton. Tradename for a polyimide film (formerly called H-Film).

Kodak Photo Resist. A marking material.

Laminar. Tradename for temperature-control coatings.

Lexan. Tradename for polycarbonate plastics.

M-9-1012. A glass-reinforced silicone molding compound.

3M 101-C-10. Tradename for a modified-alkyd black-flat-absorber temperature-control coating.

melamine. Generic name for resins based upon condensation reactions between melamine and aldehydes, or their polymers.

Micarta. Tradename for various laminated plastics.

Mylar. Tradename for a polyester film and sheet.

Mystik. Tradename for various pressure sensitive tapes.

Nomex. Tradename for a high-temperature-resistant aromatic polyamide (nylon) fiber.

nylon. Generic name for polyamide polymers.

PA. Polyacrylic. Generic name for polyacrylic elastomers. See *Hycar.*

Penntube II-SMT. Tradename for shrinkable fluorocarbon tubing.

4.1 (Cont'd)

Penton. Tradename for a chlorinated polyether thermoplastic.

Phenall. Tradename for phenolic molding compounds.

phenolic. Generic name for resins derived from aromatic alcohols and aldehydes.

polyacrylic. Chemically descriptive of, and a generic name for, elastomeric copolymers derived from acrylic acid esters and other materials.

polyamide. Chemically descriptive of, and a generic name for, resins containing amide linkages. See *nylon.*

polycarbonate. Chemically descriptive of, and a generic name for, plastics derived from carbonic acid. See *Lexan.*

polyester. Generic name for a class of polymers formed by the reaction of organic polyhydric alcohols and polybasic acids (and many modifications thereof).

polyether. Chemically descriptive of, and a generic name for, polymers containing ether linkages in their chains.

polyimide. Chemically descriptive of, and a generic name for, polymers with imide linkages.

polymer SP. Generic name for polyimide plastics.

Polyphenylene oxide. Chemically descriptive of plastics derived from phenylene oxide.

Polysulfone. Chemically descriptive of, and a generic name for, thermoplastics containing isopropylidene, ether, and sulfone groups in the backbone chain.

PPO. Tradename for polyphenylene oxide plastics.

Preshrunk Temp-Lace. Tradename for certain tie cords or lacing tapes.

4.1 (Cont'd)

PVF. Polyvinyl fluoride. Generic name for plastics polymeres derived from vinyl fluoride. See *Tedlar.*

PV-100. Generic name for a silicone white-solar-reflector temperature-control coating (replaces JW-40).

PYRE-ML. Tradename for polyimide varnishes, wire enamels, and coated glass fabrics.

RTV. See subsection 4.3.

SE. Silicone elatsomer. See subsection 4.3, *silicone terms.*

Shrinkable Mylar. A heat-shrinkable polyester tubing.

silicone. Chemically descriptive of, and a generic name for, oils, greases, plastics, and elastomers derived from organosilicon compounds. See subsection 4.3, *silicone terms.*

Silicone resin. See subsection 4.3, *silicone terms.*

SP. Generic name for polyimide platsics. See *polymer SP.*

SR. Silicone resin. See subsection 4.3, *silicone terms.*

SRD. Silicone rubber Dacron. Designation for coated fabrics.

SRG. Silicone rubber glass. Designation for coated fabrics.

SRGA. Silicone rubber glass aluminum. Designation for coated fabrics.

Stur-D-Lace. Tradename for certain tie cords or lacing tapes.

Stycast. Tradename for epoxy resins.

S-13. Generic name for potassium silicate white-solar-reflector temperature-control coating (replaces ARF-ZnO).

4.1 (Cont'd)

TB5-PTFE. Designated for fluorocarbon coated glass fabrics.

Tedlar. Tradename for polyvinyl fluoride plastics films.

Teflon. Tradename for thermoplastic fluorocarbon plastics. FEP (fluorinated ethylene-propylene) is a copolymer of tetrafluoroethylene and hexafluoropropylene). TFE is a polymer of tetrafluoroethylene. See *fluorocarbon.*

Temp-Lace. Tradename for certain tie cords or lacing tapes.

TFE. See Teflon.

Thermofit. Tradename for shrinkable irradiated polyolefin, silicone, and fluorocarbon materials.

Thiokol. Tradename for polysulfide elastomers.

Tipersul. Tradename for potassium titanate fibers.

UC 11659. Designation for a silicone flat reflector temperature control coating.

Vespel. Tradename for items fabricated from polymer SP, which see.

VFHE. Vinylfluoride hexafluoropropylene elastomer. Generic name for elastomeric copolymers of vinylidene fluoride and hexafluoropropylene. See *fluoroelastomer, Viton.*

vinyl. Generic name for such plastics as polyvinyl chloride; also, a generic name for all vinyl-type plastics. See subsection 4.3, *vinyl.*

vinylidene fluoride-hexafluoropropylene. Chemically descriptive of elastomeric copolymers of vinylidene fluoride and hexafluoropropylene. See *fluoroelastomer, VFHE, Viton.*

Viton. Tradename for elastomeric copolymers of vinylidene fluoride and hexafluoropropylene. See *fluoroelastomer, VFHE.*

4.1 (Cont'd)

Z-93. Designation for a potassium silicate white-solar-reflector temperature control coating.

73X. Designation for certain marking inks.

4.3 Definition of Terms: Organic Materials

accelerator. A catalyst.

additives. Chemicals added to a polymeric material. These may be stabilizers, plasticizers, catalysts, etc.

cast. (1) To form a polymer by pouring it into a mold, where it polymerizes or hardens to a solid form. (2) To form a polymeric film or sheet by pouring the material onto a flat surface, where it air-dries or polymerizes into a solid form.

catalyst. A chemical additive which is necessary to initiate or accelerate the cure of a polymeric material.

cold flow. See *creep.*

compression set. The residual decrease in thickness of a material at a specified time after removal from a device in which the material has been subjected to a compressive deformation under specific conditions of load and temperature. Generally applicable to cured or vulcanized elastomers.

conformal coating. A term most generally used in the electronics field to designate those coating materials which serve as dielectric insulation, moisture and soil barriers, mechanical reinforcers, and often vibration dampers. The materials usually give visual access to the components they cover. They serve essentially as encapsulating materials.

copolymer. See *polymer.*

creep. The dimensional change with time of a material under load, following the initial instantaneous plastic deformation. *Creep* at room temperature is sometimes called *cold flow*

crosslinking. The producing of chemical links between polymer chains to give a three-dimensional network (see *cure*). The process results in modification of the physical and mechanical properties of the polymeric materia'.

cure. The process of causing crosslinking of the polymeric material to occur. The term is often used interchangeably with *air-drying processes.*

4.3 (Cont'd)

elastomer. A substance generally accepted as comprising relatively flexible polymeric materials which, when force is applied, will be elongated in the order of 50% or more, and will rapidly return to essentially the initial state upon removal of the stress. Natural rubber is considered a natural elastomer. The terms *rubber* and *elastomer* have been used interchangeably.

encapsulate. To enclose an object with a polymer by immersing it in the liquid casting polymer and allowing it to polymerize or harden to a solid form.

ester. The reaction product of an alcohol and carboxylic acid.

ether. One of a class of organic compounds in which two organic groups are attached directly to a single oxygen atom.

film. A term for polymers in sheet form, having a nominal thickness no greater than 0.010 in.

firm time. As used here, the time required to obtain a durometer hardness of approximately 40 Shore A on a ½-in.-thick sample of a silicone RTV elastomer.

foam terms.

cellular-filled materials contain lightweight fillers. There is essentially no expansion during cure. Density ranges from approximately 30 to 55 lb/ft.^{3}

foam-in-place materials contain blowing agents which expand the material during cure. Density ranges from approximately 2 to 50 lb/ft.^{3}

foamed materials are expanded prior to application and are available in various forms, such as sheets, blocks, etc. Density ranges from approximately 2 to 50 lb/ft.^{3}

pack-in-place materials contain lightweight fillers and resemble damp sand. It is necessary for the material to be pushed, tamped, or packed in place. There is essentially no expansion during cure. Density ranges from approximately 18 to 30 lb/ft.^{3}

open-cell materials have connected cells and will pick up moisture.

closed-cell materials have unconnected cells and are usually quite resistant to moisture pickup.

4.3 (Cont'd)

hardener. A substance added to a polymeric material to control or promote the curing reaction by taking part in the process. Also used to designate a substance added to control the final hardness of the polymer.

heat treatment for glass cloth. *Carmelized* cloth has been heat-treated to reduce its sizing content to about 0.5%, and is called *Finish 111.* It is best for mechanical applications. *Desized* cloth has been heat-treated to remove all its sizing, and is called *Finish 112.* It is best for heat and electrical applications.

homopolymer. See *polymer.*

honeycomb. A product consisting of a thin film or sheet (metal, plastics, impregnated fiberglass, etc.) which has been formed into a series of hexagonal cells similar in appearance to a cross-sectional slice of a beehive. Honeycomb is not an end-product; it is a material form. In its expanded form, it is 90 to 99% open space.

inhibitor. A substance that slows down or retards a chemical reaction

inorganic. As used with respect to polymers, a term descriptive of inorganic polymeric materials containing no carbon atoms. The function of the inorganic polymer would be identical with that of the organic polymer.

laminate. As used herein (as a noun), two or more layers of a base material (e.g., fiberglass cloth) impregnated or coated with a synthetic resin and bonded together by means of heat and/or pressure.

mill. To mix compounding ingredients into polymeric materials by using roll equipment, such as rubber mill. The term is generally applicable to elastomers; however, liquid elastomers may or may not require the use of such equipment.

4.3 (Cont'd)

millable. The ability of a polymer to be milled. Generally applicable to those elastomeric polymers which are "dry" (e.g., crepe rubber) in base-gum form. These materials require the mechanical action of a mill for incorporation of the necessary compounding ingredients to produce the desired elastomeric compound for molding, extruding, etc.

modified. A term denoting that a base polymeric material has been physically or chemically changed by other substances. For example, a modified alkyd could be a copolymer of an alkyd and a silicone.

modulus. As used with respect to elastomers, the stress in pounds per square inch (of original cross section) required to produce a certain elongation. Thus, if a tensile stress of 1,000 psi produces an elongation of 300%, the material is said to have a 300% modulus of 1,000 psi.

monomer. A substance which is capable of being reacted to form a polymer.

plastic. (1) As a noun*: a high-molecular-weight substance including either natural or synthetic materials, but excluding the elastomers. The term has been used interchangeably with *resin*, q.v. (2) As an adjective: capable of flow or deformation under pressure or stress; made of a plastic.

plasticizer. A chemical material added to polymers to make them more flexible or softer for processing and/or end-use performance.

polymer. Descriptive of high-molecular-weight materials which are made up of relatively simple units derived from one or more monomers. A *homopolymer* is derived from one monomer; a *copolymer*, from two monomers; a *terpolymer*, from three monomers. The term *copolymer* is often used in a generic sense to cover polymers from two or more monomers (*poly* = many; *mer* = unit).

polymerization. A term descriptive of the chemical reaction process taking place when a monomer is converted to a polymer.

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*In the noun sense, the terms *plastic* and *plastics* may be used interchangeably.

4.3 (Cont'd)

post-cure. The normal cure or vulcanization of polymers is never 100% complete. In addition, many of the curing agents are not completely reacted. To complete the cure, to drive off unreacted additives and other volatile substances (e.g., low-molecular-weight fragments), and to enhance properties, a post-cure is necessary. The post-cure consists of oven aging (if size permits aging *in vacuo* makes the process more efficient) for a specified time. For example, some silicone elastomers require a post-cure of 24 hr at 250°C for optimum resistance to service environments. In some instances, materials must be post-cured up to at least the maximum temperature they will see in service. The post-cure generally is applicable to thermosetting materials and, more specifically, to elastomeric compounds.

pot life. The period of time during which a liquid resin remains useful after having been mixed with a catalyst or other compounding ingredients. Also known as *working life.*

potting. Enclosing an object with a polymer by immersing it in the liquid polymer, with care that all voids have been penetrated prior to polymerization or to hardening in a solid form .

promotor. A weak catalyst that accelerates the activity of a specific catalyst.

radiation resistance. As used here, a material with poor radiation resistance might be suitable for use in the space environment, but would not be recommended for exposure to nuclear radiation environments from propulsion or power sources. Good radiation resistance materials would generally be suited for both environments. The difference between high vacuum and air effects on the radiation resistance of materials is not being taken into account at this time.

resin. Descriptive of the pure, virgin, or base polymer. In many instances, additives must be added to the polymer to make it more processable, to stabilize it against environmental effects, or to modify its performance properties. For example, polyvinyl chloride is considered a resin. This material containing additives would now be a polyvinyl chloride plastic. The same considerations are applicable to elastomers. However, the terms gum rubber, base gum, raw gum, etc., are generally used for elastomers. The term *resin* has been used interchangeably with *plastic* and *varnish.*

4.3 (Cont'd)

rubber. A generic name for natural and synthetic elastomers. Has also been used interchangeably with *elastomer.*

RTV. Room temperature vulcanizing.

sheet. A term for polymers in sheet form having a nominal thickness greater than 0.010 in.

shelf life. The period of time during which a liquid or solid resin system can be stored under specific temperature conditions and remain suitable for use. Also known as *storage life.*

silicone terms.

SE	silicone elastomer
SF	silicone fluid
SM	silicone emulsion
SR	silicone resin
SS	silicone specialty
SRC	silicone rubber catalyst

stabilizer. A chemical additive used to stabilize a particular property of polymers.

siloxane. A term descriptive of the silicone polymer chain and the silicone-oxygen bond.

storage life. See *shelf life.*

tack-free time. As used here, the time after which all surface tack is eliminated on a fluid polymer which is in the process of curing.

temperature-control terms.

white. A surface which absorbs only a small portion of the incident solar energy and is an effective radiator of thermal energy.

stable white. A white surface which is relatively unaffected by ultraviolet light in space. In general, this type of surface will have less desirable physical properties and should be used only where required.

maneuver white. A white surface which is exposed to solar radiation only for short periods of time, such as during a midcourse trajectory cor-

4.3 (Cont'd)

rection, and where moderate changes in solar absorptance are not critical to spacecraft thermal control.

solar reflector. A surface which reflects the incident solar energy while emitting infrared energy.

solar absorber. A surface which absorbs solar energy while emitting only a small percentage of the infrared energy.

flat reflector. A surface which reflects the energy incident upon it throughout the spectral range from ultraviolet to far infrared.

flat absorber. A surface which absorbs the energy incident upon it throughout the spectral range from ultraviolet to far infrared.

terpolymer. See *polymer.*

thermoplastic. A term descriptive of plastics which are capable of being shaped by the application of heat and/or pressure (e.g., paraffin wax).

thermosetting. A term descriptive of plastics which, during the process of being shaped, (usually under pressure and/or heat), have been cross-linked (chemically cured) to an infusible mass. They cannot be reprocessed. They generally compose a heat-resistant group, and will char under high-heat exposure, rather than soften or melt. For example, most epoxy resins are thermosetting. Elastomers which are cured or vulcanized may also be considered thermosetting.

thixotropic. Pertaining to thixotropy.

thixotropy. A property of certain pastes or gels which permits them to become fluid when shaken or agitated.

vinyl. A chemical group through which polymerization takes place. Often used to describe such plastics as polyvinyl chloride. However, polyethylene, polystyrene, etc., are vinyl-type plastics.

vulcanize. A term relating to the chemical action of curing elastomers by crosslinking.

working life. See *pot life.*

5.0 JPL MATERIALS SECTION

Personnel in the Materials Section of the Engineering Mechanics Division are available to assist engineers and designers. Such assistance may consist of materials selection and handling of materials and processing problems encountered in development of spacecraft. Engineers in all divisions are encouraged to contact the Materials Section for such assistance.

5.0 (Cont'd)

Names of professional personnel in the Materials Section, along with some of the technical specialties of each, are noted below.

BERNETT, EUCENE C. — Metallurgical testing. Failure analysis. Environmental testing. Heat treatment and design consulting.

BOUNDY, ROBERT A. — Supervisor, Materials Engineering Group. Brazing, fusion welding. Solid-rocket materials. Polymer applications in spacecraft.

CARROLL, WILLIAM F. — Temperature-control coatings. Ceramic applications. Ultraviolet radiation and vacuum evaluations.

CROSBY, JAMES R. — Temperature control surfaces. Radiation effects on materials.

FISCHBACH, DAVID B. — Carbon and graphite research (structural transformation, mechanical, magnetic, and electronic properties). Mechanical damping in metals and alloys. Magnetic and electronic properties of materials.

FREEMAN, ROBERT F. — Aluminum and magnesium fusion and resistance welding. Brazing. Bonded sandwich construction. General fabrication of metals. Ceramic spraying.

HALL, WILLIAM M. — Optics and thermal radiation measurements. Optical properties.

HAPPE, RALPH A.—Copper alloys, titanium alloys, stainless steels, high temperature metals. Welding, brazing, pressure vessels. Design, materials applications, and fabrication consulting. Space environment effects on materials.

HARRINGTON, ROBERT — Polymer evaluation, nuclear shielding. Radiation sterilization. Radiation effects on materials.

HARVEY, HERMAN—Heat-sterilization effects on polymers. Polymer applications.

KOHORST, DONALD P. — Supervisor, Materials Support Group. Propulsion materials. Pressure vessels. Refractory metals. Design consulting. Component development.

LARDENOIT, VERNON F. — Resistance welding related to electronic components. Metals applications.

LEIPOLD, MARTIN H. — Mechanical, thermal, and chemical behavior of ceramic oxides and carbides. Fabrication of ceramics.

MAXWELL, HUGH G.—Polymeric materials specifications. Polymer applications.

NAGLER, ROBERT G.—Ablation and heat-protection materials. Combined effects of vacuum and high temperature on materials. Thermal-property measurement techniques.

WEINBERG, IRVING — Low temperature electrical and thermal properties of metals and alloys. Superconducting devices.

6.0 APPENDIX

It is the purpose of this Appendix to provide (1) detailed materials information supplemental to that presented in Sections 2.0 and 3.0, and (2) a source of miscellaneous reference information which will be added as its usefulness becomes apparent.

It should be noted that the property data listed are based on optimum conditions and, therefore, are intended to be used only for purposes of comparison and general information; they are not design or specification values.

The information is presented in the following categories:

6.1 *Organic Materials*

6.2† *Inorganic Materials*

6.3 *Silicone Adhesives and Primers*

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†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

6.1 Organic Materials

This subsection presents supplemental data on the organic materials listed below. It will be noted that the various categories are keyed to the numbering system of Section 3.0: for example, information on fluorocarbon plastics is contained in the parallel subsections 3.1.7 and 6.1.7.

6.1.1† *Chlorosulfonated Polyethylene Elastomers*

6.1.2† *Polyacrylic Elastomers*

6.1.3† *Fluoroelastomers*

6.1.4† *Isobutylene-Isoprene Elastomers*

6.1.5† *Silicone Elastomers (Millable)*

6.1.6 *Silicone Elastomers (Liquid and Paste)*

6.1.7 *Fluorocarbon Plastics*

6.1.8 *Polyesters*

6.1.9 *Polycarbonate Plastics*

6.1.10† *Epoxy Resins*

6.1.11 *Polyimide Resins*

6.1.12† *Alkyd Resins*

6.1.13† *Phenolic Resins*

6.1.14† *Silicone Resins*

6.1.15† *Polyamide Resins*

6.1.16† *Chlorinated Polyether Plastic*

6.1.17† *Melamine Resins*

6.1.18† *Allyl Resins*

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†Data for this subsection are being compiled and, when completed, will be added to the *Guidebook*.

6.1.6 Silicone Elastomers (Liquid and Paste)

The fluid silicone elastomers (RTV types) are commercially available in many grades, exhibiting a wide variety of physical properties. Detailed information on the properties and cure rates of these elastomers is listed in Tables 6–1, 6–2, and 6–3.

6.1.6 (Cont'd) Table 6–1. Properties of uncured and cured RTV silicone elastomers

Material	Color	Nominal viscosity, poises	Minimum shelf life at 25°C (75°F), mo	Specific gravity	Hardness, Shore A	Tensile strength, psi	Elongation, %	Tear strength lb/in, Die B	Remarks
RTV-11	White	120	6	1.18	45	350	180	15	Easily pourable, M[a]
RTV-20	Pink	300	3	1.35	50	450	140	25	Pourable, M
RTV-21	Pink	300	6	1.32	35	590	130	20	Pourable, M
RTV-30	Red	300	4	1.47	60	850	130	40	Pourable, M
RTV-40	White	450	3	1.37	55	550	120	25	Pourable, M
RTV-41	White	450	6	1.30	50	450	200	30	Pourable, M
RTV-60	Red	550	6	1.47	60	650	110	50	Pourable, M
RTV-60 spray	Red	DNA	6	1.47	60	650	110	50	Spray, supplied in aerosol package, M
RTV-77	White	8,000	4	1.33	50	500	220	25	Thixotropic paste, M
RTV-88	Red	10,000	4	1.47	65	750	110	40	Thixotropic paste, M
RTV-90	Red	12,000	6	1.47	60	750	160	35	Stiff paste, M
RTV-102	White	DNA	12	1.07	30	350	400	45	Thixotropic paste, an adhesive/sealant supplied in a tube, M
RTV-103	Black	DNA	12	1.07	30	350	400	45	
RTV-106	Red	DNA	12	1.07	35	350	400	50	
RTV-108	Clear	DNA	12	1.07	30	350	400	45	
RTV-109	Alum.	DNA	12	1.07	30	350	400	45	
RTV-112	White	300	12	1.05	30	350	350	25	Flowable adhesive/sealant supplied in a tube, M

General notes

[a]M = dimethyl silicone type; MP = methyl phenyl silicone type.

The typical values shown above were obtained after a 1-wk cure at room temperature. For best environmental performance, a post-cure is necessary.

6.1.6 (Cont'd)

Material	Color	Nominal viscosity, poises	Minimum shelf life at 25°C (75°F), mo	Specific gravity	Hardness, Shore A	Tensile strength, psi	Elongation, %	Tear strength lb/in, Die B	Remarks
RTV-340	White	800	4	1.15	25	250	450	25[b]	Pourable, M[a]
RTV-431	Red	2,500	8	1.78	88	980	60	65	Spreadable paste, M
RTV-511	White	200	6	1.18	45	350	180	25	Easily pourable, MP
RTV-560	Red	400	4	1.42	60	800	160	45	Pourable, MP
RTV-577	White	6,000	4	1.35	50	480	180	25	Thixotropic paste, MP
RTV-580	Red	8,000	4	1.49	65	800	110	40	Thixotropic paste, MP
RTV-602	Clear	10	6	0.99	15	Low	Low	Low	Easily pourable, primarily an encapsulant, M
RTV-603	Clear	10	6	0.99	15	Low	Low	Low	Easily pourable, primarily an encapsulant, MP
RTV-615	Clear	35	6	1.02	35	900	150	40	Easily pourable, primarily an encapsulant, M
RTV-616	Black	40	6	1.23	45	900	150	20	Easily pourable, primarily an encapsulant, M
RTV-655	Clear	50	6	1.07	35	900	150	20	Easily pourable, primarily an encapsulant, MP

General notes

[a]M = dimethyl silicone type; MP = methyl phenyl silicone type.

[b] = Die C used.

6.1.6 (Cont'd)

Table 6–2. Typical room-temperature cure rates for RTV liquids and pastes

Material	0.1% Thermolite-12			0.5% Thermolite-12		
	Pot life, hr	Tack-free time, hr	Firm time, hr	Pot life, hr	Tack-free time, hr	Firm time, hr
RTV-11	4 to 6	8 to 12	48	1 to 2	3 to 5	24
RTV-20	3 to 5	8 to 12	36	1 to 2	4 to 6	24 +
RTV-30	4 to 5	7 to 10	18 to 24	1 to 2	2 to 3	8 to 12
RTV-40	5 to 8	12 to 16	36 to 48	2 to 3	5 to 8	24 +
RTV-60	3 to 5	8 to 12	24 +	1 to 2	4 to 6	24
RTV-77	2 to 3	6 to 10	36 to 48	1 to 2	2 to 3	24
RTV-88	4 to 6	8 to 12	24	1 to 2	4 to 6	16 to 24
RTV-90	0.5 to 1	2 to 3	18 to 24	0.5	2 to 3	8 to 12
Supplier	Thermolite-12 catalyst is obtainable from Metal and Thermit Corp., Rakway, N. J.; or, in small quantities, from Silicone Products Dept., General Electric Co., 8555 E. Florence Ave., Downey, Calif. Phone, SPruce 3-3144.					

6.1.6 (Cont'd)

Table 6–3. Typical cure data for RTV-602, -615, -102, and -108

RTV-602			
Catalyst level, %	Catalyst SRC-05		
	Pot life	Cure time at 65°C (150°F), hr	Cure time at room temperature, hr
0.25	2 to 3 hr	5	24 to 36
0.50	20 to 30 min	2	Less than 24
	Catalyst SRC-04		
	Pot life, hr	Cure time at 80°C (175°F), hr	Cure time at room temperature
0.50	8	8 to 16	SRC-05 recommended
1.00	8	5 to 6	
RTV-615			
Catalyst level, %	Catalyst RTV-615B		
	Pot life, hr	Cure time at 65°C (150°F), hr	Cure time at room temperature, hr
10	3 to 5	4	168
RTV-102 and -108			
Under typical ambient conditions (approximately 50% relative humidity at 25°C (75°F), RTV-102 and -108 develop a tack-free surface in 15 to 30 min, and cure through a ⅛-in. thickness in less than 24 hr. Lower temperatures and humidities will slow the rate of cure; higher temperatures and humidities will accelerate the cure. The bond strength of RTV-102 and -108 improves with time. After 3 wk, the bond strength exceeds that of the elastomers themselves.			

6.1.7 Fluorocarbon Plastics

Types of Polyvinyl Fluoride Film. Tedlar polyvinyl fluoride film is available in five basic types:

Type 15. A film possessing high shrinkage properties compatible with those of curing polyester resins. It is designed primarily as a surfacing film in applications where it is desirable to screen out UV.

Type 20. A film possessing high tensile strength and having high folding endurance.

Type 25. A film combining medium elongation, medium gloss, and good clarity. It is especially suitable as a surfacing film in applications where it is unnecessary to screen out UV.

Type 30. A film having medium tensile strength (also available in colors).

Type 40. A film having low shrinkage and good formability.

Tedlar is supplied with three different surface characteristics and with low-, medium-, or high-gloss surface appearance. The three surface modifications are known by the letter designations A, B, and S, are defined as follows:

Modification A. One side is adherable, for use with inks, adhesives, and coatings. The other side is non-adherable, but is heat-sealable.

Modification B. Both sides are adherable, but neither side is heat-sealable.

Modification S. Both surfaces have excellent anti-stick properties for use as a mold-release agent in reinforced plastics processing. These surfaces are also heat-sealable.

More detailed information on the types, gauges, colors, and surface characteristics of Tedlar is presented in Table 6–4.

6.1.7 (Cont'd)

Table 6–4. Available types, colors, gauges, and surface characteristics of Tedlar film

Gauge	Thickness, mils	Surface	Gloss[a]	Type	Color[b]	Approx. Area Factors		Approx. roll length,[c] ft
						(ft^2/lb)	($in.^2$/lb)	
50	0.5	A, S	G	20	TR	278	40,000	10,000
100	1.0	B, S	G	30	TR	139	20,000	5,000
200	2.0	S	G	40	TR	69	10,000	2,500
100	1.0	B, S	G	30	WH	119	17,100	5,000
200	2.0	B, S	G	30	WH	60	8,500	2,500
200	2.0	A	M	30	WH, BE, AQ, LR, GY, BG, TQ, GO, SN, GR	63	9,100	2,500
200	2.0	A	M	30	YE	58	8,350	2,500
150	1.5	A	L	30	WH	76	10,950	2,700
150	1.5	A	L	30	LG, GY, BG	87	12,500	3,100
50	0.5	A	M	25	TR	278	40,000	10,000
100	1.0	A	G	15	WH	119	17,100	5,000
100	1.0	A	G	15	UT	139	20,000	5,000
100	1.0	A	G	15	UG	139	20,000	5,000

[a]G = highly glossy surface; M = medium glossy surface; L = low gloss or matte surface.

[b]AQ = Aquamarine
BE = Blue
BG = Beige
GO = Gold
GR = Fern Green
GY = Gray
WH = White
SG = Spruce Green
SN = Sand Tone
TR = Transparent
YE = Yellow
TQ = Turquoise
UG = UV Absorbing Green
UT = UV Absorbing TR

[c]Roll lengths shown are 9.5 in. OD

6.1.7 (Cont'd)

Types and gauges of FEP Teflon fluorocarbon film and sheet. FEP Teflon film (transparent) and sheet (translucent) can be heat-sealed, thermoformed, metalized, or processed by other standard techniques. It is available in two types:

Type A. This is the general-purpose grade. It is also used for heat-sealing to itself or heat-bonding to other materials.

Type C. In this type, one surface is modified to permit its use in laminations, in conjunction with many commercially available adhesives.

FEP Teflon is available in widths up to 36 in. for thicknesses of ½, 1, 2, 5, 10, and 20 mils. Development quantities of 30-, 60-, and 90-mil material are also obtainable.

Types of FEP Teflon fluorocarbon resins. FEP Teflon fluorocarbon resins are melt-processible copolymers made from tetrafluoroethylene and hexafluoropropylene. The resins are supplied in three grades:

Teflon 100. A general purpose resin used primarily for melt extrusion.

Teflon 110. An injection-molding-grade resin.

Teflon 120. An aqueous dispersion, used primarily in coating applications.

6.1.7 (Cont'd)

Types of TFE Teflon fluorocarbon resins. TFE Teflon fluorocarbon resins are supplied in nine grades, designed for various types of applications:

Teflon 1. A general-purpose powder for molding and extrusion.

Teflon 1B. A powder similar to Teflon 1, but having better flow properties.

Teflon 5. A specially granulated material for molding cylinders for skived tape.

Teflon 6. A product specially manufactured for processing by a modified extrusion technique involving the use of organic extrusion aids.

Teflon 6C. A newer product designed to provide improved performance as an extrusion material, particularly for wire coating.

Teflon 7. A molding and extrusion material for use where void-free moldings and skived tape of the highest quality are required.

Teflon 30. An aqueous dispersion for general coating and impregnation purposes and for use where superior finish and heat-aging characteristics are needed.

Teflon 30B. An aqueous dispersion for glass- and asbestos-reinforced impregnation where superior dispersion wetting characteristics are needed.

Teflon 41BX. A developmental material used for preparing reinforced gasketing and molding powders, and also for special-purpose blending where a choice in wetting agent is desired.

6.1.8 Polyesters

Types of Mylar polyester film. Nine types of Mylar polyester film are available for a wide variety of applications:

Type A. The general-purpose material, commonly used for laminating and electrical insulation. It is more heat-resistant than the other types and is available in thicknesses up to 0.014 in.

Type C. A material having better insulation resistance than Type A and, hence, recommended for use in capacitors. It is clearer than Type A and is also recommended for metallizing.

Type CS-77. A colored, heat-sealable material.

Type D. A product used in the graphic arts and drafting. It has high transparency in the thicker gauges.

Type HS. A substance used for applications requiring a shrinkable material. When heated to 100°C (212°F), it shrinks about 30% in both directions.

Type M. A material having a heat-sealable coating. It is recommended for applications requiring heat sealing.

Type S. A material used for book covers, sheet protectors, and other miscellaneous stationery supplies.

Type T. A product recommended for magentic tapes and pressure-sensitive tapes because of its high tensile strength in the longitudinal direction.

Type W. A substance more resistant to weathering than the other types. It is recommended for exterior-glazing applications.

Detailed information on the available types and gauges of Mylar polyester film is listed in Table 6–6. Type A information applies to Type C.

6.1.8 (Cont'd)

Table 6–5. Types and gauges of Mylar polyester film

Type	Gauge	Approx. thickness, in.	Approx. length of roll, ft			Approx. yield, $in.^2/lb$	Approx. yield, ft^2/lb
			3 in. ID 9½ in. OD	6 in. ID 11 in. OD	6 in. ID 14 in. OD		
A	50	.00050	10,000	10,000	20,000	40,000	278
A	100	.00097	5,400	5,400	10,800	21,500	149
A	150	.00142	3,500	3,500	7,000	14,000	98
A	200	.00200	2,500	2,500	5,000	10,000	69
A	300	.00300	1,700	1,700	3,400	6,700	46
A	500	.00500	1,000	1,000	2,000	4,000	28
A	750	.00750	650	650	1,325	2,650	18
A	1000	.01000	500	500	1,000	2,000	14
A	1400	.01400	350	350	700	1,430	10
S	25	.00025	20,000	20,000	40,000	80,000	556
S	35	.00035	14,300	14,300	28,600	57,150	397
S	50	.00050	10,000	10,000	20,000	40,000	278
S	75	.00075	6,650	6,650	13,300	26,650	185
S	100	.00100	5,000	5,000	10,000	20,000	139
S	150	.00145	3,500	3,500	7,000	14,000	98
S	200	.00200	2,500	2,500	5,000	10,000	69
D	300	.00300	1,700	1,700	3,400	6,700	46
D	500	.00500	1,000	1,000	2,000	4,000	28
D	750	.00750	650	650	1,350	2,650	18
D	1000	.01000	500	500	1,000	2,000	14

6.1.9 Polycarbonate Plastics

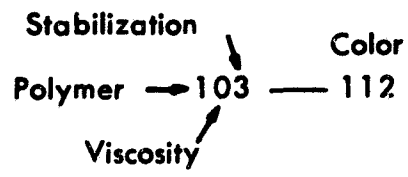
The recommended grades of Lexan polycarbonate plastics are listed in Table 6–7, together with detailed information on the available colors, viscosities, and stabilization of these materials.

6.1.9 (Cont'd)

Table 6–6. Available grades and colors of polycarbonate plastics[a]

Pertinent information	Lexan polycarbonate plastics		
	Medium-viscosity grades	Low-viscosity grades	High-viscosity grades
Application	General use	Intricate, hard-to-fill parts	Thick sections, involving problems of sink and vacuum bubbles
Recommended grades	100 unstabilized 101 heat-stabilized 103 heat- and UV-stabilized	140 unstabilized 141 heat-stabilized	130 unstabilized 131 heat-stabilized 133 heat- and UV-stabilized
Natural colors (all transparent)	100-111 light straw 101-111 light straw 101-112 tinted 103-112 tinted	140-111 light straw 141-111 light straw 141-112 tinted	130-111 light straw 131-111 light straw 131-112 tinted 133-112 tinted
Standard colors[b]	101-201 blue 101-301 green 101-303 green 101-311 green (transparent) 101-313 green (transparent) 101-401 yellow 101-502 brown 101-5001 brown 101-601 red 101-611 red (transparent) 101-701 black 101-702 grey 101-703 grey 101-801 white 101-803 white 101-808 white 101-821 white (translucent)	141-201 blue 141-301 green 141-303 green 141-311 green (transparent) 141-313 green (transparent) 141-401 yellow 141-502 brown 141-5001 brown 141-601 red 141-611 red (transparent) 141-701 black 141-702 grey 141-703 grey 141-801 white 141-803 white 141-808 white 141-821 white (translucent)	131-223 blue (translucent) 131-313 green (transparent) 131-326 green (translucent) 131-424 yellow (translucent) 131-522 beige (translucent) 131-626 orange (translucent) 131-627 red (translucent) 131-701 black 131-721 grey (translucent) 131-803 white 131-8031 white

[a]The following example illustrates the code for grade, color, and stabilization:



[b]In the UV-stabilized grades (103-, 133-), only the 12 transparent and translucent colors listed are standard. Special colors are available on request.

6.1.11 Polyimide Resins

Types of polyimide film. Kapton polyimide film is available in two basic types:

Type H. A general purpose film.

Type HF. A film coated on one or both sides with various thicknesses of Teflon FEP fluorocarbon resin.

Available types and constructions are presented in Table 6–8.

Table 6–8. Available types and constructions of Kapton polyimide film

Designation	Thickness, mils	Construction			Area factor, ft^2/lb
100XH667	1	DNA			135
200XH667	2				67.5
300XH667	3				45
500XH667	5				27
150XHF019A	1.5	0-mil FEP	1-mil H	½-mil FEP	77
200XHF919A	2.0	½-mil FEP	1-mil H	½-mil FEP	54
200XHF011A	2.0	0-mil FEP	1-mil H	1-mil FEP	54
300XHF111A	3.0	1-mil FEP	2-mil H	½-mil FEP	34
300XHF929A	3.0	½-mil FEP	2-mil H	½-mil FEP	39
300XHF021A	3.0	0-mil FEP	2-mil H	1-mil FEP	39
400XHF022A	4.0	0-mil FEP	2-mil H	2-mil FEP	27
400XHF031A	4.0	0-mil FEP	3-mil H	1-mil FEP	30
500XHF131A	5.0	1-mil FEP	3-mil H	1-mil FEP	22.5
600XHF051A	6.0	0-mil FEP	5-mil H	1-mil FEP	21

6.3 Silicone Adhesives and Primers

Because of the wide variety in available silicone elastomers (millable, liquid, and paste types), there are several systems for bonding these materials to themselves and to other materials. The adhesives and primers currently recommended for use with silicone elastomers are listed in Table 6–9.

Table 6–9. Silicone Adhesives and Primers

Material	Prepares surfaces for	Application	Minimum cure time	Remarks
Primers				
SS-4004 Fluorescent pink with solvent	RTV silicone elastomers	Bonding RTV silicone elastomers to other surfaces	½ to 1 hr at 25°C (75°F)	Brush or dip. Use with SS-4056 sealer for porous surfaces.
SS-4044 Clear with solvent	RTV silicone elastomers	Bonding RTV silicone elastomers to other surfaces	½ to 1 hr at 25°C (75°F)	Brush or dip. Use with SS-4056 sealer for porous surfaces.
SS-4101 Blue with solvent	RTV silicone elastomers	Bonding RTV silicone elastomers to other surfaces	½ to 1 hr at 25°C (75°F)	Brush, dip, or spray. Use with SS-4056 sealer for porous surfaces.
SS-4120 Clear with solvent	RTV-615 silicone elastomer	Bonding RTV-615 silicone elastomer to other surfaces	1 hr at 25°C (75°F)	Brush, dip, or spray.
Chemlock 607 Clear with solvent	Uncured silicone elastomers, except the RTV's	Bonding uncured silicone elastomers to metals and to cured silicone elastomers	10 to 30 min at 25°C (75°F)	Brush, dip, or spray.
Adhesives				
RTV-102, white, and RTV-108, clear	RTV silicone elastomers	Bonding cured silicone elastomers and most other materials	Variable, up to 24 hr at 25°C (75°F)	Use as both an adhesive and a primer.
SE-5504 self-bonding silicone elastomer	Not applicable	Producing an elastomeric bond to metals	30 min at 165°C (330°F)	No primer is needed for clean surfaces.
RTV silicone elastomers	Not applicable	Bonding cured silicone elastomers and most other materials	Variable, up to 24 hr at 25°C (75°F)	Primers are needed in most cases.
SE silicone elastomers	Not applicable	Bonding cured silicone elastomers and metals	Variable, up to 1 hr at 150°C (300°F)	Primer is generally not needed, except with metals.
General notes	In most cases, a post-cure is needed to provide optimum properties. Also available are silicone pressure-sensitive adhesives. For additional information consult Materials Section.			
Supplier	Chemlock 607 is distributed by R. D. Abbot Co., Inc., 5268 Alhambra Ave., Los Angeles 32, Calif. Phone. CA 3-1348. All other materials are supplied by Silicone Products Dept., General Electric Co., 8555 E. Florence Ave., Downey, Calif. Phone, SP 3-3144.			

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