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Data for selection of space materials

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ABSTRACT

This document is intended to assist the designers and members of project groups in the selection of space materials. Also enclosed are data sheets on space-proven materials for general space applications, i.e. materials that have been successfully used for some applications in ESA space systems and associated equipment.

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SECTION 1: SCOPE

This document is intended to assist the designers and members of project groups in the selection of space materials. Also enclosed are data sheets on space-proven materials for general space applications, i.e. materials that have been successfully used for some applications in ESA space systems and associated equipment.

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SECTION 2: GENERAL

2.1 INTRODUCTION

This document is intended to:

- assist spacecraft and payload designers in their preliminary selection and application of materials;
- orient the designers and members of project groups towards well-known products that are currently available and that have been successfully used in past spacecraft programmes;
- control and minimise the variety of materials used in ESA programmes.

2.2 CRITERIA FOR THE LISTING OF MATERIALS

2.2.1 Selection of materials

The materials for which data sheets are included are either:

- capable of satisfying a wide range of design applications;
- mature in their technology and suitable for a range of flight hardware;
- predicted to have a significant utilisation in present and future programmes;
- characterised by a sufficient test or use history; or
- available from suppliers or manufacturers whose previous performance indicates that they are capable of providing products of the desired quality.

Nevertheless, it is not an exhaustive list, and industrial users and manufacturers are invited to comment on the existing sheets and to submit new or updated sheets for materials they would like to propose for inclusion in later issues.

2.2.2 Removal of materials

A material may be removed from this list for any of the following reasons:

- material has become obsolete;
- adequate sources no longer available;
- material has been replaced by a functionally similar but improved material;
- inherent reliability/quality problems have been experienced;
- more accessible sources have been found (e.g. in Europe) for the same (or similar) material.

2.2.3 Selection of manufacturers

The selection of manufacturers has been based on their proven ability in the past to supply the corresponding product to the quality and reproducibility required for ESA space applications. Whenever a manufacturer's product receives ESA's recognition, the materials will be listed herein and the manufacturer shall also be considered as preferred.

2.3 REFERENCE DOCUMENTS

Some or all of the content of the documents listed below is directly related to this specification and referenced in the text. The applicability of these documents will be defined in the contract.

ESA PSS-01-20	Quality assurance of ESA spacecraft and associated equipment.
ESA PSS-01-70	Material and process selection and quality control for ESA space systems and associated equipment.
ESA PSS-01-702	A thermal vacuum test for the screening of space materials.
ESA PSS-01-704	A thermal cycling test for the screening of space materials and processes.
ESA PSS-01-706	The particle and ultraviolet (UV) radiation testing of space materials.
ESA PSS-01-709	Measurement of thermo-optical properties of thermal control materials.
ESA PSS-01-713	Measurement of the peel and pull-off strength of coatings and finishes with pressure-sensitive tapes.
ESA PSS-01-700	The technical reporting and approval procedure for materials, mechanical parts and processes.
ESA PSS-01-721	Flammability testing for the screening of space materials.
ESA PSS-01-729	The determination of offgassing products from materials and assembled articles to be used in a manned space vehicle crew compartment.

ESA PSS-01-737	Determination of the susceptibility of metals to stress corrosion cracking.
NASA NHB 8060.1	Flammability, odor and offgassing requirements and test procedures for materials in environments that support combustion.

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SECTION 3: CONTRACTORS' RESPONSIBILITIES

3.1 SELECTION OF MATERIALS

Space-proven materials shall be selected at the earliest design stage, the maximum use being made of the types listed herein. However, the contractor remains responsible for the selection of materials that must be capable of meeting the requirements of his contract. Moreover, for all materials, the requirements of ESA PSS-01-70 must be observed and the chosen material must receive ESA approval according to ESA PSS-01-700 before being employed in the fabrication of ESA space systems and associated equipment.

3.2 SPECIFICATION

The requirements for material specifications/standards are given in ESA PSS-01-70.

3.3 PROCUREMENT

The contractor is responsible for controlling and ensuring that all materials procured for the project meet the specified requirements. The requirements of procurement and quality assurance/control are defined in specifications ESA PSS-01-70 and ESA PSS-01-20.

3.4 SELECTION OF NON-LISTED/NON-PROVEN MATERIALS

Whenever the contractor intends to select materials for which no or insufficient data exist, he shall justify the proposed use and obtain ESA approval as detailed in ESA PSS-01-700.

3.5 APPLICATION

To achieve high reliability and good performance, the use of the material shall be restricted well within its maximum qualified range of physical and mechanical properties.

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SECTION 4: DATA SHEETS

4.1 IDENTIFICATION OF DATA SHEETS

In order to facilitate the identification and location of the appropriate data sheet, an index (see Section 6) which cross-references material name/identification to data sheet numbers is included as a foreword to the actual data sheets. The alphabetical-numerical code used for the data-sheet page sequence is as follows:

Code: A — 5

FIRST DIGIT	First letter of material/name identification (i.e. ALUMINIUM ZINC ALLOY)
SECOND DIGIT	Sheet number in alphabetical subsection

Note: Preceding sheet code = A – 4
Following sheet code = A – 6 or B – 1 etc.

4.2 MATERIAL DESCRIPTION AND PROCUREMENT DETAILS

The referenced name/type designations are selected from industrial standards or established trade names, and identify only the similarity to the actual style whose precise characteristics are defined in the applicable specification which is also referenced. The procurement details indicate the manufacturer(s) address and give some information about the status of that product.

4.3 MATERIAL PROPERTIES

The properties given are typical values at normal ambient temperature (unless otherwise stated); they shall not be used for design or specification purposes, but only as screening parameters. Properties defined by the manufacturer shall be studied in conjunction with the manufacturer's catalogue/data.

4.4 PROPERTIES RELEVANT TO SPACE USE

Properties relevant to space use are those tested by ESA or other recognized test agencies and in most cases are covered by the ESA PSS-01-7XX series of documents.

Information (test data) available in industry may be sent to ESA for inclusion in updated data sheets in order to expand the information on material properties revelant to space use.

4.5 SPECIAL PRECAUTIONS/CONDITIONS/CONSTRAINTS

Within this area special information is given about material concerning treatments, precautions, application, limited behaviour of material for certain environmental conditions etc.

SECTION 5: UPDATING AND REVISION PROCEDURE

This document will be revised regularly and updated as required.

Revisions to this document will be communicated by the issue of modified or additional pages with the appropriate revision number and date. They will be accompanied by an updated cover sheet (page i) and document change record (page v).

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SECTION 6: INDEX OF MATERIAL DATA SHEETS

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SECTION 7: DATA FOR SPACE APPLICATIONS OF MATERIALS

7.1 MATERIAL APPLICATION INFORMATION

This is a short guide to a vast subject. Its purpose is therefore limited to the presentation of basic considerations and examples in order to orient spacecraft and payload designers in their preliminary selection. It is intended to stress points (features) which should be dealt with at the beginning of the design phase in order to avoid basic errors which may be very difficult to correct later.

The final choice of materials must be made only after careful evaluation by specialists in the field of space materials in accordance with the provisions of ESA PSS-01-70.

The document is concerned mainly with the constraints which are specific to space use, i.e. vacuum, radiation etc. **It is therefore assumed that the designer does his part of the task to ensure that the materials he proposes to use are at least able to satisfy the more classical constraints of the design, i.e. loads, vibration, high voltage etc.**

There are thousands of materials on the market which have never been tested for space use. Guidance is given only to a restricted number of materials on which enough tests have been conducted to allow some statement to be made. Owing to the present demand for 'clean' satellites, the first screen applied is a mass-loss and contamination test, such as the 'Micro VCM'. To complete the evaluation, suitable UV- and particulate-radiation-resistance tests have been designed and are applicable to all the materials that have to be exposed to space radiation. Moveover, materials for manned projects will have to be tested for flammability, odour and toxicity.*

The citation of names of products and manufacturers does not by itself constitute an ESA recommendation or approval. Unless otherwise stated, it merely indicates materials which have been submitted to such preliminary tests and are suitable for further testing in support of an approval process. Even when data on a material are sufficient, quality-control tests should be run on each new batch before use, except where a continuous good record leads to confidence in the material's consistency.

Both European and American materials are identified. Inevitably, many are of US origin. Wherever possible, the examples given are European-made materials or those from the USA which are readily available on the European market. It is ESA policy to redress the balance and increase the proportion of suitable European materials, and the evaluation and approval programme is directed towards this objective.

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* NOTE: A collection of existing data appears in ESA RD-01 and RD-02.

The discussion of each class of material is presented according to the following plan:

Use in spacecraft
Brief non-exhaustive account of some typical uses.

Main categories
Chemical nature and aspects of the various products which may be useful in spacecraft manufacture.

Processing (or assembly)
Mention of the main fabrication methods involved.

Precautions
Some points to be considered when designing with this class of materials.

Hazardous/precluded
Meaning obvious.

Effects of space environment
Summary of the possible damage mechanisms under vacuum, radiation, thermal stresses and atomic oxygen.

Some representative products
this is a short list of products that have been subjected to sufficient testing and/or have accumulated sufficient flight experience to enable designers to recommend them as first choice. The list refers either to a generic class of product or to individual materials described more extensively in Appendix A.

7.2 CLASSES OF MATERIALS

7.2.1 Adhesives

(a) Use in Spacecraft
'Structural' adhesives appear where high load-bearing capability is needed, for example in the face-to-core bond of honeycombs*. Nonstructural adhesives (glues, bonding agents) are found particularly in solar-cell assembly, optical-component bonding, screw locking etc. Adhesives are most useful in the bonding of dissimilar materials which are difficult (or impossible) to assemble by other means: glass, ceramics, etc. They ensure good thermal contact and low stress concentration at the joint, but such assemblies are difficult to take apart after fabrication. Electrically conductive adhesives find a use as grounding points for conductive surfaces.

(b) Main categories
In current use are epoxies, phenolics, 'modified epoxies', polyurethanes, silicones, polyimides and cyano-acrylates. Their consistency is quite variable: liquid, paste, powder, supported or unsupported films. Some have to be kept

*NOTE: Consult ESA PSS-03-210 for design information on structural adhesives.

cold until used; others are prepared by mixing two or more components just before application. They can contain fillers or be clear and transparent. Adhesives are in general quite complex (and proprietary) formulations, and appear on the market under many trade names; it is frequently difficult to determine their basic chemical nature from the manufacturer's data.
Anything can be bonded with adhesives, but no adhesive exists that can effectively bond everything.

(c) Processing
Processing varies from simple room temperature curing under contact pressure to intricate pressure/temperature exposures depending upon the category and type of the adhesive. Typical examples in the case of structural adhesives are:
— low temperature (50°C) and pressure (2 kg/cm^2) for epoxy/amines;
— high temperature (150°C) and low pressure for epoxy/anhydrides;
— high temperature and high pressure (5 to 20 kg/cm^2) for phenolics;
— very high temperature (250°C) and high pressure for polyimides.
Many nonstructural adhesives cure under contact pressure at moderate temperatures, e.g. RTV silicone rubbers (some of which cure with atmospheric moisture), cyano-acrylates (which cure by air exclusion) and polyurethanes. Some of these adhesives are quite sensitive to contaminants, the presence of which sometimes prevents correct curing.

(d) Precautions
It is very easy to misuse adhesives, particularly in critical applications. They have normally a limited shelf life (mentioned on the package), which should be respected and the conditions under which they are stored should be adequately controlled. They frequently have a short useful life after their component parts are mixed or brought to activation temperature. The adhesive must be physically and chemically compatible with the component parts to be bonded:
— physically, the adhesive must attach itself to the two surfaces to be bonded and in general this requires special pretreatment (cleaning, etching, priming). The adhesive must also be capable of accommodating dimensional changes in the bonded surfaces (expansion-coefficient matching);
— chemically, the adhesive should not be corrosive to the adherents used (corrosion action is frequently due to hardeners).
Many adhesives or curing agents are harmful to human beings and should be handled with the necessary care. Adhesive bonding is in general quite sensitive to small changes in the process. This leads to considerable variations of performance if strict control is not exercised. Moisture, either contained in the constituents or in the atmosphere, can impair the cure of some adhesives (epoxies for example): **humidity must therefore be controlled.**

Atmospheric carbon dioxide may react with some curing agents and affect the properties of the cured product.

(e) Hazardous/precluded

Many adhesives on the market are solutions or emulsions. Although these products may be excellent for their intended terrestrial use, they shall not be applied to space vehicles since they are potential outgassers. **Ensure that your adhesives are quoted '100% solid'.**

Structural adhesives for which the maximum temperature of use is low (60 to 70°C) are likely to evolve contaminants at quite low temperature under vacuum (epoxy/amine). Adhesives which need atmospheric moisture to cure shall not be used in confined areas (large bonds between nonporous surfaces). Never use the famous 'glue which glues everything...' bought in the drugstore: **your problem is specific; use a specific adhesive.**

(f) Effects of space environment

Vacuum exposure provokes outgassing of the adhesive by extracting from it unreacted compounds, low-molecular-weight constituents and the remaining light reaction products. The exposed surface being small (only the bond line), outgassing rates can be quite low. Effects of vacuum alone on the bond integrity are normally not observed, but some of the evolved constituents can be condensible and may create a contamination danger in a spacecraft ('coating' of electrical or optical components). Many epoxies are acceptable from an outgassing point of view, but are rather sensitive to humidity conditions at the time of curing. 'Modified' epoxies, particularly the flexible ones, can be dangerous. Nearly all RTV silicones are known to be contaminant, but some manufacturers have developed special compounds for space use.

Particle radiation at the level encountered in space is not harmful for adhesives which are anyway protected by the items they are bonding.

UV radiation can darken the optical adhesives. In this context silicones are superior to epoxies. UV and particle radiation both increase the outgassing rate of adhesives.

High temperature degrades adhesives. For long-term exposure polyimide can be used up to more than 300°C; the best epoxies are normally limited to 170°C. Phenolics and silicones come in between. High temperature accelerates outgassing.

Low temperature hardens adhesives and causes brittle bonds. Some polyurethane adhesives are still useful at very low temperatures (cryogenic).

Thermal cycling leads to failure of the bond when expansion coefficients of the adherents and adhesives are not matched and when the adhesive is not flexible enough to cope with the substrate. Thick layers of rigid adhesives are liable to high stresses.

(g) Some representative products

The following materials, which are listed in Appendix A, can be considered:

- Araldite AV 100
- Araldite AV 138
- DC 6-1104
- DC 93500
- Eccobond Solder 56C
- Redux 312
- RTV 566
- RTV S 691
- RTV S 695
- Scotch Weld EC 2216
- Solithane 113

7.2.2 Adhesive tapes

(a) Use in spacecraft

In existing satellites, adhesive tapes are used mainly in the thermal-control subsystems. They function either as thermal-control surfaces themselves or are used in assembling thermal blankets. They can also be used as electrical insulators. Such tapes may be used extensively during qualification tests as a means of attaching sensors and temporary wiring to the spacecraft. Adhesive tapes are rather easy to handle, can be cut to size and used to make patterns. They can be removed easily after temporary use.

(b) Main categories

The backing of adhesive tapes can be made from polyester, polyimide, polyolefin, fluorinated polymers, fibreglass cloth, metal sheet, metallised (aluminised, gold-plated) polymers and pigmented polymers.

Most common tapes have a 'pressure-sensitive' adhesive based on rubber-like polymers containing a number of additives (tackifier, plasticiser etc.), and the composition is normally proprietary. Basic rubber-like polymers used are natural rubber, acrylates, acrylic rubbers, silicones, butyl etc. Adhesive tapes are sold in rolls of different widths with or without intermediate liner. Some can be heat or solvent activated. Thermosetting adhesive tapes also exist. Transfer tapes (2 adhesive sides), supported or unsupported, find extensive use in the bonding of metallised films.

(c) Processing

The processing and use of adhesive tapes appear to be extremely simple; cut to size and apply. One must, however, ensure that the adherent surface is clean enough, that the application pressure is even and that the tape surface is not damaged during the application. Sometimes tapes must be perforated all over their surfaces; this allows evacuation of trapped and/or generated gas bubbles under vacuum (particularly with metal-backed tapes).

(d) Precautions

Because of the complex and frequently unknown nature of their adhesives, **tapes should rarely be used and then only with enormous care in their choice and application.** When an adhesive tape is applied temporarily, it generally contaminates the underlying surface which should be carefully cleaned after tape removal. When tape is applied permanently it can be displaced by creep and leaves a dirty spot. Cleaning solvents can accidentally damage the adhesive and/or the tape, or be absorbed into them and diffuse out when vacuum exposure takes place. The top face of some adhesive tapes is coated with a release agent which can discolour during subsequent vacuum/UV exposure – this should be removed.

(e) Hazardous/precluded

Polyvinylchloride backing tapes which are frequently used for electrical insulation must not be applied to space vehicles. Also cellulose (cellophane), cellulose acetate, paper and fabric should be avoided. **Do not use the tape which you find in your drawer without knowing exactly what it is or where it comes from.**

(f) Effects of space environment

Vacuum exposure can draw products out of the backing when it is a polymer and also out of the adhesive. When the tape is applied, outgassing takes place through the backing by diffusion when it is permeable and also through the bond line. Outgassing products and entrapped air can lift the tape or bubble it unless the tape is perforated. Adhesives mainly generate condensible products which are dangerous contaminants for optics and electronics. The release of such products, which are frequently plasticisers or tackifiers, can harden the adhesive layer and render it inoperative. Practically each new type of tape must be tested for outgassing: present results do not allow a generalised statement to be made regarding safe tapes for space application, but acrylic adhesive seems to be a better choice.
Radiation (UV and particle) is to be considered mainly when tapes are used for thermal-control purposes. Most polymer backings are sensitive and their solar absorptivity increases rapidly under irradiation. The best choice for UV resistance is polyimide or fluorinated resins. When the backing is metallised on the side of the incident light, optical properties are quite stable. Metals are not affected, although discoloration can occur when they are coated with a protective varnish. Radiation has a tendency to harden polymers and render them brittle. Dimensional stability of polymer tapes is frequently poor under space conditions.
Hiqh temperature up to 200°C can be sustained by polyimide, silicone and PTFE tapes with suitable adhesives (silicone). Metal and glass tapes are limited by the properties of the adhesive to similar high temperatures.
Low temperature hardens the adhesive and backing. Polyimide and teflon-based tapes can still be used as well as metal.

Thermal cycling is in general not a problem since the pressure-sensitive adhesives are quite flexible except at rather low temperatures.
Atomic oxygen in low orbit may attack polymer tapes.

(g) Some representative products
The following materials, which are listed in Appendix A, can be considered:
— Eccoshield PST-CA
— Scotchtape No. 5
— Scotchtape No. 60
— Scotchtape No. 425
— Scotchtape No. 850 silver
— Scotchtape Y966

7.2.3 Coatings and varnishes

(a) Use in spacecraft
Coatings and varnishes appear as electrical insulating layers, corrosion protection and mechanical protection mainly in electronic circuitry. Coatings for thermal-control purposes will be treated separately under 'Paints'.

(b) Main categories
Current polymer bases are alkyd, epoxy, polyester, polyimide, polyurethane, silicone, polyesterimide and polybenzimide. Coatings appear as one- or two-component systems, frequently containing solvents (thinner) to give the necessary low viscosity. Some are crystal clear, while some contain organic dye (mainly for quality control in the application). There are also products containing fillers. Finished layers can be thin (e.g. varnishes) or rather thick (e.g. conformal coatings). From the mechanical point of view, all grades are found from quite rigid to elastic products. As in the case of adhesives, coatings are frequently proprietary mixtures, the composition of which is difficult to trace.

(c) Processing
Application is by brush, dipping, flow or spray processes. Curing is very similar to that of adhesives but no pressure is applied. Since coatings and varnishes frequently contain solvents, these have to be dried out before curing commences (air drying or forced air drying). Solvent retention frequently occurs and tends to increase as the square of the thickness. It is reduced by a high-temperature bake. Low viscosity sometimes creates flow problems which can be corrected by the use of thixotropic agents.

(d) Precautions
Storage, shelf life and pot life should be controlled in the same way as those of adhesives. When the purpose of varnishes and coatings is to protect and/or insulate the underlying item, care must be taken to produce a

continuous and adherent layer. Adhesion can be promoted by the use of suitable surface treatments (e.g. when a conformal coating has to adhere to Teflon insulation) and priming. Debubbling under low pressure with careful control of the process aids the formation of an intact protective surface.
The proportion of catalyst, the temperature of the applied product and of the substrate, and the topography and orientation of the substrate must all be controlled. Thick coatings may generate mechanical stresses and fairly high temperature during their cure, and any damaging effect of these on the item to be protected must be assessed by tests. Coatings cured at high temperature contain residual stresses at lower temperatures. Some catalysts also give rise to corrosion problems with certain metals (copper, silver). Corrosion appears also where impurities (solder flux, moisture) are trapped in voids or cracks in the coating. Finally, thinners as well as base compounds can be toxic and/or flammable.

(e) Hazardous/precluded
Most varnishes and coatings which rely only on solvent evaporation to harden (solvent types like cellulose varnishes or dispersions like acrylics) are not suitable for space applications. These products are most likely to be profuse outgassers even after long drying periods. Solvent elimination is an exponential function of absolute temperature (Arrhenius equation) and is inversely proportional to the square of the coating's thickness. Other coatings, containing solvent as a thinner but relying on a subsequent curing reaction to harden, should be avoided as far as possible. (It is sometimes difficult to attain the required viscosity, however, without using a solvent). Solvents sometimes attack insulation in the device to be coated. Alkyd and polyester are in general not good enough for space use. Polysulphides, which are unstable in a thermal-vacuum environment, must also be avoided. **Coatings and varnishes usually present very large surfaces to the space environment; this makes them particularly dangerous when not well chosen.**

(f) Effect of space environment
Vacuum exposure makes all coatings outgas. This is particularly noticeable for types containing solvent. This phenomenon can sometimes be reduced by extended curing at high temperature and under vacuum, but such a method is not very practical and is not always successful. Atmospheric gases trapped within cracks and voids in the coating can leak out under vacuum and produce pressures in the 'corona range'. Cracks formed under vacuum can fill with outgassing products up to the same pressures. These two phenomena lead to troubles when high field strengths are present during spacecraft equipment operation.
Radiation is only a potential hazard for coatings exposed on the satellite surface. UV radiation and proton fluxes are the main factors in this case and mainly cause darkening and hardening of coatings and increase the out-

gassing rate. Insulating varnishes used on items inside 'black boxes' are well protected against particle fluxes and are not subjected to UV at all.
Thermal environment, and particularly thermal-cycling due to shadow-sunlight passage or to variable internal heat sources caused by switching equipment on and off, has to be considered. Mismatch of expansion coefficients between coating and coated items gives rise to high stresses and eventually to cracks. Thermal insulation by the coating can lead to overheating of high-power components, particularly in vacuum. For high temperatures, silicones are recommended (class 180). For very high temperatures, 'ladder-polymers', such as polyimide or polybenzimide, are the only possible candidates (class 200).
When flammability is a property to be considered, silicone materials should be chosen in preference to polyurethane coatings.
Atomic oxygen in low orbit may attack coatings – silicones and fluorinated products are probably resistant.

(g) Some representative products
The following materials, descriptions of which are included in the Material Data Sheets, can be considered:
— DC 93500
— MAPSIL 213
— Solithane 113
— RTV S 695

7.2.4 Glasses

(a) Use in spacecraft
Glasses, inorganic as well as organic, appear as optical elements: windows, lenses, prisms, solar-cell covers, filters etc.
Glasses and oxide ceramics are also used as electrical insulators.

(b) Main categories
The classical meaning of the word 'glass' is extended in this chapter to cover 'organic glass' and some crystalline optical materials. Optical glasses such as silicates, alumino-silicates and boro-silicates can be used as well as pure silica, sapphire and transparent fluorides. In the case of polymers, polystyrene, acrylic and polycarbonate can be cited.

(c) Assembly
Inorganic glass parts are mainly assembled by means of flanges and gaskets or adhesives. Glass-to-metal welds are possible. Assembly must be rigid enough to provide accurate alignment but must also be designed to cope with thermal expansion and provide suitable damping. Organic glasses are easily machined: this operation can also be performed on inorganic glasses by using special techniques (ultrasonic machining for example).

(d) Precautions

Glasses are transparent only to a certain wavelength range and should be chosen in accordance with the mission requirements. Inorganic glasses are sensitive to mechanical and thermal shocks. Organic glasses are easily scratched and lose their polish. **Assembly methods are the most important points in the design of parts containing glass** and particular attention has to be given to matching the refractive index and expansion coefficient.

(e) Hazardous/precluded

Canada Balsam and other similar products must not be used in the assembly, since they are liable to give contaminants. **Organic glasses should not appear in high-precision equipment** except as plain windows or light-pipes.

(f) Effects of space environment

Vacuum exposure does not affect inorganic glasses or most organic glasses. The only danger comes from bonding agents, optical coupling agents and all other assembly materials which can contaminate the optics by yielding condensible products. A contaminated optic is in general very difficult to clean.

Radiation is the most harmful factor to be considered for glasses. Some inorganic glasses are already damaged by doses of the order of 10^3 rad (1 rad = 100 erg g^{-1} of absorbed energy) of ionising radiation: the damage is a loss of transparency in certain wavelength ranges due to colour-centre formation. UV is less harmful, at least for inorganic glasses. Particle radiation may also distort the shape of optical elements. Plastics can be damaged by particle and UV radiation. The result is in general a 'yellowing', and the damage under sunlight can be autoaccelerated by the increase in temperature due to higher absorption.

Thermal shock can lead to fracture in inorganic glasses.

Also, distortion can be noted in precision optics when the assembly is not designed to compensate correctly for the low expansion of these glasses and the high expansion of the metal mountings.

Organic glasses soften at quite low temperature (80 – 100°C frequently) and have rather high expansion coefficients.

Atomic oxygen may attack organic glasses.

(g) Some representative products

In the case of inorganic glasses pure silica is the safest to use. This is sold by many European firms under many different trade names, for example:

— ULTRASIL, SUPRASIL, HERASIL from HERAEUS, FRG
— PURSIL, TETRASIL from QUARTZ & SILICE, France
— SPECTROSIL, VITREOSIL from THERMAL SYNDICATE, UK

Optical glasses are mainly designated by reference numbers from manufacturers like SCHOTT (D), CORNING (U.S.) and PILKINGTON (U.K.). For solar-cell covers, the main sources are still OCLI (U.S.A.) and PILKINGTON (U.K.). Some are manufactured with an electrically conductive surface (indium oxide) by the same manufacturers.
Optical solar reflectors (OSR) based on silica/silver/inconel or silica/aluminium are manufactured by OCLI. PILKINGTON produces OSR's based on cerium glass/silver nickel-chrome. Filters are made by BALZERS (Switzerland), SCHOTT (Germany), MATRA (France), M.T.O. (France), BARR & STROUD (U.K.) and PILKINGTON (U.K.).
Organic glasses based on acrylic and methacrylic polymers are well known:
PLEXIGLAS from ROHM & HAAS, FRG
PERSPEX frmn ICI, U.K.
Polycarbonates like MAKROLON (BAYER, FRG) can also be considered as well as several polystyrene grades.

7.2.5 Lubricants

(a) Use in spacecraft
All moving parts under vacuum, either 'one shot' or constantly operating items, have to be lubricated. These include mechanisms and slip rings of deployable and orientable solar panels, bearings of rotating antennae, mechanisms of orientable experiments, deployment systems, active thermal control louvres etc. Moving parts appear also in pressurised systems where the situation is more or less similar to that of conventional ground use. An additional use for greases and compounds is the thermal coupling of boxes and structural elements.

(b) Main categories
Basic oils are hydrocarbons, silicones, diesters, polyglycols and fluorinated compounds. Commercial products normally contain several additives to improve their lubricating properties. Greases are based on the same oils thickened with organic or inorganic gelling agents (metal soaps, silica, arylurea, indanthrene blue). 'Compounds' are high-molecular-weight organics which do not need any gelling agent to make them semisolid. Besides these 'wet lubricants', many 'dry' types find a use in spacecraft. These are:

— laminar inorganic substances, such as MoS_2 and WSe_2, which are applied by burnishing, molecular sputtering or as an inorganic or resin-bound curing compound;
— self-lubricating polymers, such as polyamide, Teflon or polyimide, sometimes reinforced or modified by a filler (copper powder, MoS_2 or carbon fibres).

(c) Processing

Application of oil or grease is straightforward, except on bearings where a porous retainer (phenolic, polyamide) is used; in this case the retainer is first solvent extracted, then vacuum impregnated (in 1 torr range vacuum) by dipping in the oil used to make the grease. Dry lubricants are more difficult to apply and some processes are proprietary. In the case of metals, chemical and electrochemical plating can be used, as well as vacuum deposition. Molecular compounds such as MoS_2, which are rather sensitive to heat, can be sputtered (ion-sputtering, RF-sputtering). Simple burnishing is also used. When binders are used in combination with MoS_2, the application process resembles that of curing a paint, and the items to be lubricated should have increased clearance to compensate for the lubricant thickness. In any case, it is recommended that new lubricants should be 'run-in' before operational use is commenced. Particles given off during running in must be removed by a stream of clean dry air.

(d) Precautions

The main problem is to ensure that the lubricant stays where it is useful and does not migrate to places where it is not wanted. Wet lubricants can disappear by evaporation and/or creep. Dry lubricants are destroyed by wear and/or by lack of adhesion to the substrate. Replenishment is possible with wet lubricants (e.g. from a sintered reservoir). Oil lubrication is basically hydrodynamic and does not operate in low-speed devices or under high loads. When the lubricant has disappeared, mating parts weld readily in vacuum. Moreover, the evolved residues create a danger of contamination in the vicinity.

Lubricants should be applied only on clean surfaces, and lubricated items should be protected from dust and dirt. Some lubricants intended for use under vacuum are degraded by running in normal atmosphere (lead for example) or by humidity (some silicate combinations). When lubricants are used in devices which should be electrically conducting, problems of electrical noise appear and wear can be increased at high current density. Thermally conductive compounds used at interfaces are prone to creep: they must be kept in place by a suitable seal placed around the area concerned.

(e) Hazardous/precluded

Oils and greases, except certain special grades, must never be exposed directly to space conditions: use of labyrinth seals is recommended and the 'exhaust pipe' should always be far away from sensitive satellite parts. **Graphite is not a lubricant in vacuum, but an abrasive** (it can be used in combination with other lubricating materials such as silver or MoS_2). Ester-type oils can develop corrosivity under high radiation: this is infrequent in space. Nylon absorbs considerable amounts of water, which are released

subsequently in vacuum; because of this, its dimensional stability is not good. Sintered nylon, however, can be vacuum impregnated with oil to serve as a reservoir.

(f) Effects of space environment

Vacuum effects are mainly evaporation of oils and 'dry-off' of greases. Surface 'cleaning' due to vacuum encourages oils to creep out of their location; this is particularly so with silicones. Wet lubricants are liable to contaminate optical and electrical parts under vacuum. Some dry lubricants also evolve contaminating substances (particularly the resin-bound types). Thin metal films must be paired with the rubbing part in order to avoid as far as possible the tendency to cold weld: a good criterion is to avoid pairing materials which alloy readily.

Under radiation, oils have a tendency to evolve gases or corrosive products, to foam or to gel, but this requires rather high doses (over 10 Mrad in general) which are not normally encountered in space except for very special applications. Greases show the same damage, but at a lower rate since they are partly protected by their gelling agent. Dry lubricants are quite resistant to all types of radiation. In any case, lubricants are normally screened from high radiation doses by the mechanical parts to which they are applied.

The main temperature effect is to encourage evaporation of wet lubricants. Temperatures high enough to degrade lubricants should not be encountered in correctly designed parts and, in any case, lubricants are more stable in space, owing to the absence of oxidation. Normally, friction generates higher temperatures in space than on the ground for the same part: this is due to the difficulty of eliminating heat under vacuum (no convective cooling, no conductance through atmosphere). Wet lubricants allow better cooling than dry lubricants, but the gain is minimal in comparison with the other dangers already mentioned.

Atomic oxygen can degrade MoS_2 and similar solid lubricants which are exposed to it.

(g) Some representative products

In sealed instruments (or semisealed when contamination is not a problem), many oils can be considered:

- Silicones [Dow Corning (U.S.), General Electric (U.S.), Wacker (D), Rhone-Poulenc (France), ICI (U.K.) etc.];
- Diesters [Lehigh (U.S.), Kluber (D) etc.];
- Fluorocarbon [Du Pont (U.S.)];
- Greases based on the above-mentioned oils also exist.

For direct space exposure, very few noncontaminating silicone oils, greases or compounds exist; solid lubricants are also useful materials for direct exposure to space.

The following materials, for which data sheets are included, can be considered:

— Apiezon L
— DC 340
— Fomblin Z25
— Kinel 5518
— MAPSIL 210
— PTFE

7.2.6 Metals

(a) Use in spacecraft

Metals are the basic building materials of existing spacecraft; they appear in all subsystems and an extensive study of such applications is outside the scope of this document. Only a few specific points of special interest for the spacecraft designer will be considered, since the basic aspects of metal assemblies are already well known in the similar field of aeronautical design.

(b) Main categories

In primary and secondary structures, light alloys based on aluminium and magnesium are used, together with some titanium and beryllium. Plumbing utilises aluminium alloys, stainless steels and titanium alloys. Wiring is based on copper and solder alloys. Plating appears in many applications (electronics, thermal control, corrosion protection etc.) and calls mainly for copper, silver, gold. aluminium and nickel. Reinforced metals now exist (whiskers, metal wires or boron fibres in aluminium, silver or copper matrix; carbon fibres in aluminium or magnesium). Magnetic alloys find a limited but important role. 'Memory alloys' based on titanium and nickel may find interesting use as actuators.

(c) Processing/assembly

All classical methods find a use: welding, brazing, soldering, riveting, bolting, adhesive bonding etc. Space use does not raise special problems in this respect, except that processes must be extremely reliable. Aircraft industry standards are normally followed.

(d) Precautions

The properties of metals are strongly dependent on the latter's previous thermal and/or mechanical history. This point should be taken into account in specifications and checked after processing. Brittle intermetallic compounds may form by diffusion during welding and soldering operations. They can be avoided by a correct choice of metals used and by applying a suitable temperature profile during the joining operation. Corrosion has to be considered during the whole manufacture and prelaunch phase (see Table 7.2.1); electrolytic couples should be avoided and all metals suitably protected against external damage by plating, conversion coatings, paints

and strippable coatings. This should be particularly considered in special working environments (fuel tanks for example).
Processing of metals gives rise to residual stresses that may cumulatively reach design-stress levels, particularly as regards fatigue phenomena. Such stresses must be checked.
Stress corrosion cracking (SCC), defined as the combined action of sustained tensile stress and corrosion, can cause the premature failure of metals. The metallic components proposed for use in most spacecraft must be screened to prevent failures resulting from SCC. Such metal-alloy selection must in particular be applied during the design phases of all spacecraft making use of the Space Shuttle, items intended for long-term storage prior to launch, highly stressed structures, all parts used or associated with the fabrication of launch vehicles, etc. SCC ratings have been attributed to the major aircraft alloys*; these are based on service experience and testing programmes.
Three ratings of alloys have been chosen: high-resistance, moderate-resistance and low-resistance to SCC (these are listed in Tables I, II and III respectively of ESA PSS-01-736. The alloys listed in Table I are to be preferred for space use. Alloys listed in Table II or III will require a detailed justification for use, demonstrating that SCC testing according to the standard method detailed in ESA PSS-01-737 (method incorporates constant load and alternate immersion in 3.5% NaCl solution) has taken place. Note that all the Al-Li alloys known at present are very sensitive to SCC (Table III).
Machining and assembly methods can leave residues of chemicals (particularly cutting oils and dye penetrants). Methods of cleaning should be applied and the design shall not permit inaccessible 'contamination traps'.
Beryllium dust and vapours are toxic; work on this metal requires special precautions. It is strongly recommended that parts fabricated from machined beryllium be chemically etched in order to remove subsurface microcracks.
Dusts of magnesium and its alloys are flammable; this also leads to special safety measures. Some magnesium alloys (with thorium) may have a slight residual radioactivity. Iron and nickel alloys can interfere with magnetic cleanliness demands. Solder and other joining alloys have properties which depend heavily on the exact composition and impurity levels. These must be carefully controlled (see ESA PSS-01-708). Only rosin-based soldering fluxes are permitted for assembly work; they must be either nonactivated or mildly organically halogen-free activated. (Halogen-free is defined as containing less than 0.005% halides.)

(e) Hazardous/precluded

Some metals, such as cadmium and zinc, are rather volatile and should not appear in space hardware. Platings of these metals, as well as tin, are known to grow whiskers both in air and under vacuum. They must be excluded from

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* ESA PSS-01-736 and NASA MSFC Spec-522B

all spacecraft and ground-support equipment. Electrolytic couples must be avoided or corrected by a suitable insulation between the metals concerned. Porous platings are potential sources of danger and these occur frequently with gold plate over silver. Bare metal-to-metal contact is to be avoided in any movable part.

(f) Effects of space environment

In general, metals do not suffer from space-environment conditions.

Vacuum gives no special problem except for the most volatile metals, such as cadmium and zinc. These metals sublime readily at temperatures over 100°C and 150°C respectively, and may form conductive deposits on insulators or opaque deposits on optical components. Oxide layers slow down the process of evaporation when they are thick enough and not cracked. All metals in contact under vacuum conditions or in inert gas have a tendency to cold weld. This phenomenon is enhanced by mechanical rubbing or any other process which can remove oxide layers. It is particularly intense for pairs of cubic-lattice metals which alloy readily (see 'Lubricants').

Radiation at the level existing in space does not modify the properties of metals.

Temperature problems are analogous to those encountered in technologies other than space, except for a complication arising from the difficulty of achieving good thermal contact in vacuum and due to the absence of any convective cooling.

Atomic oxygen in low earth orbit attacks some metals, such as silver (solar-cell interconnectors) and osmium (extreme-UV mirrors).

(g) Some representative products

There are many European manufacturers of classical metals and alloys, generally procurement to internationally recognized specifications is preferred such as ISO, Mil Specs, B.S., SAE, DIN or AFNOR specifications.

Beryllium is used in its pure form, but it is both brittle and difficult to fabricate as well as being fairly toxic. This metal is produced by the powder metallurgy route by hot isostatic processing and it is recommended that component parts are initially rough machined, heat treated to remove major residual stresses and then fine machined. A final etching treatment with a removal of 0.1 mm from the surface will generally remove mechanical damage such as microcracks and deformation twins.

The principal titanium alloy is Ti6Al4V for which extensive mechanical and corrosion property data are available.

Solder alloys consist of the tin-lead and indium-lead alloys defined in ESA PSS-01-708 and PSS-01-738. They are procured according to these specifications, which define purity levels and, where necessary, fluxes of suitable

formulation for the assembly of spacecraft electronics. Solder alloys are not permitted for structural applications.

— Beryllium: SAGEM (F), Royal Ordnance Factory (UK), Heraeus (D)
— Titanium: Imperial Metal Industries (UK), Tital (D), Ugine Kuhlmann (F)
— Solder alloys: Bleiwerk Goslar (D)
— Super alloys: Aubert and Duval (F)

Fasteners, such as high-reliability, high-strength bolts are made from the following recommended alloys: 15-5 PH, Ti6Al4V, A286, Waspaloy, Inconel 718, Multiphase MP35N and MP159. Suitable fabricators include Blanc Aero (F), Kamax (D) and Linread (UK).

7.2.7 Paints

(a) Use in spacecraft
The most critical use of paints is in the thermal-control subsystem, but paints can also be employed for corrosion protection and for identification (if marking inks are included in paints).

(b) Main categories
Common binders are epoxies, acrylics, silicones, polyurethanes and silicates. Pigments are chosen to produce the required optical properties:
white pigments for low solar absorptance and high emittance [zinc oxide (ZnO), titanium dioxide (TiO_2), zinc orthotitanate (Zn_2TiO_4) and zirconium dioxide (ZrO_2) are the most common];
aluminium flakes for medium absorptance and emittance;
carbon black for high absorptance and emittance.

Electrically conductive thermal-control paints have been developed to avoid charging-up and discharges in geostationary orbit. Some, which are based on metal or carbon pigments, may be used when a α/ϵ ratio close to one is acceptable. Electrically conductive white paints are based on semi-conductive pigments; their stability in the space environment has now been assessed in some cases. Paints normally contain several proprietary components intended to give them good application properties. They come in the form of one-part or two-part, rather viscous liquids. They are brought to the right viscosity by some mixture of solvents. Solvent-free paints also exist.

(c) Processing
Hardening of the paint layer is due first to the evaporation of the solvents followed by some chemical reaction producing an insoluble film; the reaction may be controlled by the atmosphere (oxygen or moisture) in one-part paints or by an added catalyst in two-part systems.

Processing generally requires mixing: application of one or more coats by brush or by spray with intermediate partial drying; final drying and curing takes place at room temperature or in an oven. Inorganic paints are more difficult to apply and good adhesion is difficult to obtain.

(d) Precautions

Paints have to be stored under controlled conditions. Shelf and pot life must be observed. Good adhesion of the paint coating requires special pretreatment of the item to be painted: cleaning, abrading, priming etc., as for adhesives or varnishes (see Sections 7.2.1 and 7.2.3). Paints stay sticky for rather a long time and should not be applied in dusty atmospheres. Paint layers are fragile and can be damaged by abrasion and shocks.

Contamination by oils and chemicals should be avoided since the cleaning of a painted item is a difficult operation: this is particularly acute for inorganic-base paints . Most of the solvents used in paints are toxic and/or flammable.

(e) Hazardous/precluded

It is very difficult to find a good 'space' paint, particularly a white one, in view of the different requirements of mechanical resistance, space environment stability and outgassing. **As far as possible the use of any paint should be kept to a minimum and other methods of coating such as chemical conversion, plating, second-surface mirrors, plasma spray etc. envisaged.** When paints cannot be avoided, some 'less bad compromise' can be found, but this normally results in the recommendation of rather lengthy and difficult cure schedules and extreme cleanliness precautions during and after application.

(f) Effects of the space environment

Vacuum exposure of paints produces high outgassing due mainly to solvent residues (see also Para. 7.2.3e) and also quite an amount of condensible products. The only way to reduce this inconvenience is to prescribe extremely long and difficult cure processes, sometimes under vacuum. Even in this case, only very few of the commercial paints can qualify. The method is in any case frequently impracticable since the painted items cannot resist the cure temperature if they contain electronic or other sensitive devices. During the outgassing period paint layers harden and become more brittle, but the main risk is contamination of the optics and electronics in the vicinity (see 'Coatings').

Inorganic paints are generally less contaminating, since they evolve mainly water.

Radiation is the most damaging environment factor for paints used on the exterior of spacecraft. Particles and UV tend to embrittle paint layers. Their main effect, however, is the degradation of optical properties: emittance of

paints is in general stable under radiation. Some black paints bleach slightly under the combined effects of vacuum, particles and UV. **These factors are very dangerous for white paints,** which undergo a drastic increase in absorptance. This effect can be studied only by measurements under vacuum, since atmospheric gases may bleach the defects created in the paint. The increase in absorptance is due to changes in both pigment and binder. In the former, colour centres are created which absorb at specific wavelengths; in the latter the absorption edge of the UV side is moved towards longer wavelengths and sometimes new bands appear.
Inorganic-base white paints (silicate binder) are more stable than those with an organic base, and some of them are quite good from an optical-properties point of view. The stability of white paint under radiation depends to a large extent on the physico-chemical purity of the pigment used.
High temperature degrades paints ('smoking' under ascent conditions). In this respect, silicones and silicates are best. Heat can be beneficial in accelerating the bleaching of certain colour centres in pigments, but normally increases the yellowing of binders. Thermal cycling may cause deterioration in paints that are not flexible enough to cope with the substrate's dimensional changes: flaking, blistering, cracking can occur. Paints with inorganic binders are rather sensitive in this respect.
Atomic oxygen in low earth orbit attacks paints. Those with silicone and perfluorinated base seem better. Silicate should not be damaged.

(g) Some representative products
No commercial white paint is perfectly satisfactory for space use, since most of them outgas too much and/or are unstable under radiation. The situation is a bit less critical for black paints. Many commercial paints have been flown with but average success. Many space paints, and particularly white, are not commercial items and are prepared in-house or under contract by spacecraft builders. The following materials, which are listed in Appendix A, can be considered:

- Chemglaze H322 (Aeroglaze)
- Chemglaze L300 (Aeroglaze)
- Chemglaze Z306 (Aeroglaze)
- Electrodag 501 and 503
- PCBZ
- Pyrolac PSGI2O FD
- Pyrolac PSZ184
- S13GLO
- MAP-PCBZ
- MAP-PSB
- MAP-PU1
- MAP-PUC
- MAP-SG 11 FD
- MAP-SG 120 FD

7.2.8 Plastic films

(a) Use in spacecraft

Plastic films appear in electronic circuitry as insulant, dielectrics and bases for printed wiring. They are basic components in multilayer insulations used for thermal-control purposes. They find a 'structural' use in inflatable and erectile devices. Flexible second-surface mirrors (solar reflectors) based on plastic films are commercially available.

(b) Main categories

The main film-forming polymers used are polyolefins, polyester, fluorinated plastics, polyimides, polycarbonates and acetals. Composite laminated films are commercially available. Films are originally transparent to translucent white to yellow, but dyed and pigmented grades exist in any shade. Classical plastic additives are used in films: plasticisers, antioxidants, antistatic agents. Film surfaces can be modified by chemical treatment and by metallisation. The latter call mainly for vacuum-deposited aluminium, silver, gold or copper. Films are sold in rolls or sheets. Thickness varies from a few micrometres upwards. Thicknesses of less than 5 to 7 micrometres are generally difficult to procure in large quantities.

(c) Assembly

Films can be cut to size and tailored to intricate shapes. Attachment is made by gluing, sewing or welding (heat sealing, ultrasonic welding), though not all methods are applicable to any one type of film; for example, plain polyester or polyimide cannot be heat-sealed, but some laminated composites exist which can.

(d) Precautions

Films are more or less fragile with respect to tearing, cutting, puncturing or folding, particularly in thin gauges. Anisotropy is frequent, the properties in one direction (extrusion) being quite different from those in the perpendicular direction. The dimensional stability of plastic films in severe environments is not very good. They may be stabilised by a suitable thermal treatment. **Static charges can develop on most plastic films** (unless they are specially treated or metallised). Sensitivity to chemicals and solvents is similar to that of the base plastics (see Subsection 7.2.12), but attack is rather rapid, owing to high surface/volume ratio. Metallised films are sensitive to abrasion, since the metal layer is extremely thin. Cleaning is not recommended and contamination must therefore be avoided. Electrical grounding of metallised films is difficult; contacts are very sensitive to corrosion in the terrestrial environment. Most plastic films are flammable.

Absorption of water by some plastic films can drastically change their electrical and thermo-optical properties.

(e) Hazardous/precluded

Polyvinylchloride, cellulose and acetate are not stable enough for the space environment. Polyamide films absorb water in normal atmospheres and desorb it in vacuum with dimensional changes and are therefore unsuitable. Many commercial films contain volatile additives (the most dangerous are plasticisers and antistatic agents) and must not be used in space.

(f) Effect of space environment

Physico-chemical degradation of plastic films is similar to that of bulk plastics described in Subsection 7.2.12. The overall effects can be different, owing to the particular aspects of films: thinness, need for flexibility, frequent need for stable optical properties.

Vacuum exposure tends to stiffen plastic films, particularly those containing plasticisers. Since the exposed surface areas are often large, contamination dangers are high. Polyimides, TFE, FEP and polyterephthalates are generally safe in this respect. Multilayer systems should be properly vented to eliminate internal overpressure; they tend to accumulate large amounts of contaminants during handling and should be baked under vacuum before integration into a spacecraft.

Radiation is quite damaging for thin polymer films exposed to the total space environment. The primary effects are generally deformation, embrittlement and discoloration, which in turn affect the mechanical integrity and the thermal equilibrium of the devices concerned.

TFE is very sensitive to particle radiation; polyterephthalates are damaged by solar UV. The best choice is FEP or polyimides (the latter being normally yellow). Radiation effects are frequently enhanced by impurities and oxidation consecutive to processing.

High temperature degrades polymer films and low temperature embrittles them. Fluorinated polymers and polyimides can be used over a wide range of temperatures from cryogenic to more than 200°C.

Thermal cycling may be damaging to some metallised films where tiny metal flakes can loosen and contaminate the vicinity.

Atomic oxygen in low orbit attacks hydrocarbon-based polymer films with a carbon/hydrogen skeleton and particularly polyimide. An ITO layer seems to be protective. FEP is sensitive to the combination of ATOX and UV light.

(g) Some representative products

The following materials, for which data sheets are provided, can be considered:

- Kapton H
- FEP
- Makrofol N
- PET
- Sheldahl G401500
- Sheldahl G400900
- Sheldahl G410620

7.2.9 Potting compounds

(a) Use in spacecraft

Under the generic name 'Potting Compounds' are understood here all types of products which can be applied in bulk fluid form and become relatively rigid subsequently. This also covers sealants. Their use in spacecraft is multiple: electrical and mechanical insulation, damping, sealing and thermal coupling. They appear in practically all subsystems.

(b) Main categories

Chemically speaking, three types of polymers predominate: epoxies, silicones and polyurethanes. Physically the hardened potting compounds and sealants come in the form of bulk components, 'true' foams or 'syntactic' foams (containing micro-balloons); pigments, fillers and dyes are used. All these products vary from soft and elastic to hard and rigid. Density is from 0.1 for some foams to more than 2 for bulk-filled resins. Syntactic foams are between 0.5 and 0.8. Before the hardening (curing) process, potting compounds are liquids, pastes or even powders. Some cure by atmospheric exposure (one-part systems), others by the addition of a catalyst (two-part systems).

(C) Processing

The assembly to be sealed or potted is first cleaned. Sometimes a surface treatment (for example etching of PTFE parts) or a primer application is necessary. Two-part potting compounds require mixing in the required proportions. Application is by pouring into open or closed moulds, caulking or smearing.

To avoid the formation of bubbles, it is frequently necessary to pour small quantities, degas under low vacuum (few torrs), pour again, and so on.

True foam products foam and rise in place (the 'debubbling' operation is not applicable). When closed moulds are used, the quantity of initial product must be carefully calculated to produce the required density. Moulds equipped with overflow vents are also used. The hardening of potting compounds requires a certain cure schedule, which can be as simple as a few hours exposure at room temperature.

Sometimes a simple heat treatment is necessary, however. In other cases, post-curing under vacuum is required. When curing is by atmospheric moisture, the curing time depends on the accessibility of air; thick samples require a longer time. The curing of foams occurs simultaneously with the rising process and the rate of both should be matched to produce the required density which implies **a good control of the curing-temperature profile.** When fillers are used, they must be carefully dried and must be kept dry until and during mixing.

(d) Precautions

Many potting compounds create rather high temperature and pressure during curing, and damage to potted compounds can occur unless some countermeasure is taken: use of low-temperature, long-duration cure profile, use of either a flexibiliser as a component of the potting or of a precoat on the device or special design aimed at limiting the stresses induced by curing etc. have to be employed. Precoating the device can be essential to obtain good adhesion to all components. When different potting material or coatings are used successively, it is necessary to ensure that they are 'compatible': some components of one mixture may have a deleterious effect on the curing of the other (the same effect can be noted with atmospheric components: water vapour, for example).

Some catalysts used in potting compounds and sealants have corrosive effects on metals (for example dibutyl-tin-dilaurate on copper). Most of them are in one way or another harmful to man and safety precautions are necessary. The need for correct debubbling procedures has been stressed above. The viscosity of the mixture to be poured should be low enough to permit a good flow in intricate devices. Most potting compounds and sealants have a limited shelf life and pot life depending on the conditions of storage and use.

Except when special fillers are used, potting compounds and sealants have a rather low thermal conductivity and **overheating of enclosed parts can occur** in powered devices.

(e) Hazardous/precluded

The present trend in space systems is **to avoid potting** as far as possible and to use conformal coatings in preference. This leads to weight savings and ease of repair, but diminishes the protection against mechanical stresses.

Most of the flexible potting compounds and sealants outgas too much to be useful in space. Polysulphide potting materials are not stable enough under space environment. Products that shrink severely and/or are highly exothermal during curing should be avoided. 'Open cell' foams are not recommended, since they do not protect the potted items against corrosion in the atmosphere.

(f) Effect of space environment

Vacuum exposure of potting and sealant materials leads to problems analogous to those of conformal coatings (see Subsection 7.2.3), i.e. contamination of the vicinity and possibility of corona effect due to release of gases in cracks and voids when these products are used in the presence of strong electrical fields.

Closed-cell foams contain gas (CO_2 or freon), which normally takes a very long time to evolve even under space vacuum: some foams can be considered for space insulation up to 5 kV.

Contamination of the vicinity by potting materials is sometimes diminished by

a postcure under vacuum or by an 'egg-shell' varnish applied as a thin layer over the potted module.
Radiation exposure of potting and sealant materials is normally minimal, since they are mostly used inside modules.
Temperature effects have to be considered. On the low side, potting and sealants shrink and become more rigid, their damping ability gets worse and internal stresses rise, particularly in potting cured at high temperatures. On the high side, chemical degradation can occur, particularly around a power-dissipation component. Silicones have the best high-temperature properties (class 180). Thermal cycling due to the switching on and off of equipment can lead to cracking and debonding.

(g) Some representative products
Some epoxies, polyurethanes and silicones can be considered for potting as well as for conformal coating or adhesion (Subsections 7.2.1. and 7.2.3.). The following materials, for which data sheets are included, can be considered:
— Araldite CY205
— Eccofoam FPH
— Epikote 828
— RTV 566
— RTV S691
— Solithane 113
— Stycast 1090
— Stycast 2850FT

7.2.10 Reinforced and thermosetting resins

(a) Use in spacecraft
Reinforced plastics find structural and semistructural uses: honeycomb facings, antennae, trays, structural members, fairings, spacecraft skin, solar cell substrate etc.*. They are also basic materials in printed-circuit boards. Thermosetting resins can also be used without any reinforcement as bulk plastics or as foams. Other uses are dealt with in sections on adhesives, coatings potting compounds etc.

(b) Main categories
Plastics used are mainly epoxies, cyanates, phenolics, melamine, polyesters, bismaleimides, polyimides**, silicones, diallylphthalate and diphenyloxide. Reinforcement is usually by short or long glass fibres or glass cloth. The use of asbestos has been discontinued owing to its carcinogenic nature. In ad-

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* See the 'Structural Materials Handbook', ESA PSS-03-203.
** Polyimides are really thermoplastic ladder polymers, but are included here by analogy.

vanced technologies new reinforcements have been introduced, such as carbon fibres, boron fibres, aromatic polyamide fibres, whiskers and metal wires, for high-strength, high-modulus structural laminates. Reinforced plastics can be found in the trade as semifinished items ready for machining to shape. They can also be made from individual resin, hardener and reinforcing agent by many different methods: hand-laying, press-moulding, filament winding. A very useful commercial shape is 'prepreg', i.e. reinforcement sheet or tape already impregnated with partially cured resin (B-stage).

(c) Processing

Except where semi-finished products are bought and machined to shape, the user has to apply a curing process. Some resins, such as certain grades of epoxies, polyesters and silicones, cure at low temperature and pressure. Phenolics — and even more polyimides — require elevated temperature and pressures for curing (see 'Adhesives'). The main problems in processing are to ensure as far as possible the absence of voids, to maintain the reinforcement in good mechanical condition (high-strength fibres are quite sensitive to surface defects created by handling), and to achieve a good bonding at the fibre interface (a coupling agent or a pretreatment of the fibres can be used). Thermal-expansion matching with the mould material must be ensured (use of ceramics, cast iron, graphite etc.).
The curing schedule should be carefully studied by means of a preliminary test programme. (Thermal-analysis equipment is required for these tests.) This must ensure that there is sufficient flow, that the cure is complete and that no thermal degradation of the resin takes place, in order to obtain a final product with optimum properties.

(d) Precautions

Most reinforced plastics are anisotropic in all their properties. Design criteria used must take this fact into account. It is frequently possible to reduce anisotropy by using multidirectional reinforcement, but this is done at the cost of a reduction in overall strength or of an increase in weight. Reinforced plastics generally retain internal stresses after moulding. These can be relieved by thermal treatment at subzero temperatures.
Assembly methods are of prime importance. Reinforced plastics are quite sensitive to stress-raisers created by classical fasteners, and hence adhesive bonding is preferred. Failure of reinforced plastics occurs frequently at the fibre/matrix interface. This type of failure can be accelerated by some terrestrial environments (high humidity, for example). Carbon-reinforced resins generally show water absorption/desorption associated with dimensional changes.

(e) Hazardous/precluded

Polyester laminates are not generally suitable for space uses. Some reinforcements appearing in ground electronics, such as cotton and paper, have also to be rejected.

Polyimide or polybenzimide resins are applied to prepregs with the use of a low-volatility solvent, traces of which may stay in the cured item: this sometimes renders them unsuitable. All designs directly translated from the classical metal design concepts must be avoided: **designers working with new products have to revise their usual way of thinking.**

(f) Effects of space environment

Thermosetting plastics are in general quite stable under space conditions if the comments already made are borne in mind when they are selected.

Vacuum can lead to outgassing. This does not generally degrade the properties of the plastic, but can raise corona and/or contamination problems in its vicinity.

Radiation at levels existing in space is unimportant. In fact reinforced organic materials could find some structural uses to replace metals where Bremsstrahlung is a problem, i.e. around sensitive electronics.

Thermal effects are more noticeable, especially problems raised by the thermal anisotropy of most reinforced plastics (expansion varies with the direction). Microcracks are formed in thermal cycling which could jeopardise long-term properties. The temperature range within which reinforced plastics can be used is similar to that for adhesives of the same chemical nature (see Subsection 7.2.1).

Atomic oxygen etches classical reinforced plastics and may cause damage to thin structures. Since resin is generally etched more quickly than fibres, fragments of these can be released and contaminate the environment.

(g) Some representative products

There are many large manufacturers on the European market, some of them having a link with the U.S.A. There are also small firms making reinforced products from commercial resins. Some names can be cited, but the following list is far from being complete:

— **Epoxy resins**
  Araldite, CIBA, Switzerland
  Epikote (or Epon), Shell, The Netherlands (Shell, U.S.)
— **Phenolics, melamine and silicones**
  Dynamit-Nobel, Germany
  Kuhlmann, France (Wyandotte, U.S.)
  Chemical and Insulating Ltd., U.K. (Hitco, U.S.)
  M.A.S., Italy (Synthane, U.S.)
— **Polyimide**
  Rhone-Poulenc, France (trade name Kerimid)

— **Carbon-fibre prepregs**
For information on this subject, see the Structural Materials Handbook, ESA PSS-03-203.

PCB's used in space hardware must be qualified in accordance with ESA PSS-01-710. A list of qualified manufacturers is maintained by QM Division, ESTEC. For other uses, the following materials, for which data sheets are provided, can be considered:
— Araldite CY205
— Cycon C 69/HM-S
— Epikote 828
— Rexolite 1422

7.2.11 Rubbers

(a) Use in spacecraft
There are many applications throughout a vehicle for rubber compounds: mechanical damping systems, seals and gaskets, electrical insulants, membranes, bladders for fluids etc. In this section, we consider only vulcanised-rubber items extruded or moulded in their final shape. Some other rubber-compound applications have been referred to under adhesive tapes and potting compounds, where there is either no cure or a cure-in-place application (like RTV rubbers).

(b) Main categories
Commercial 'rubbers' contain not only one or more rubber polymers, but many additives, fillers, pigments etc. The most useful for space applications are based on polybutadiene, polychloroprene, polyurethanes, acrylics, nitrile, ethylene-propylenes, silicones and fluorinated polymers. They appear as moulded parts, films, coated textiles, extruded insulation, sleeves, shrinkable items etc. It is practically impossible to obtain details from the manufacturers of the formulations they sell. For critical applications it is sometimes better to use a special formulation tailored to the use with the help of a local compounder.

(c) Processing
Except in the case mentioned above, the user is not concerned with rubber processing. This operation is rather complicated and calls for specialised equipment. It consists in hot-mixing rubber polymers with pigments, fillers, reinforcing agents, antioxidants, vulcanising agent etc., followed by shaping (extrusion, moulding) and curing. All the steps are quite sensitive to processing variables and have to be carefully controlled. On the other hand,

the use of finished or semifinished items is normally straightforward and only bonding of rubber to other materials or to itself is a possible problem which is solved by adhesive techniques.

(d) Precautions

Under the same generic name, for example 'butyl', an immense number of different formulations can exist. **The identification of a rubber product is difficult, but should nevertheless be made carefully.**

Rubbers, depending on their nature and composition and on the type of environmental exposure, have a tendency to 'set' under stress, i.e. to suffer a nonreversible deformation, which should be taken into account. Cyclic stresses produce heat in rubber structures; this can lead to thermal degradation. Some rubber mixtures contain products that are corrosive to certain metals. **Most rubbers are quite sensitive to chemical attack** by gas, liquids and solvents. Tables of chemical resistance should be consulted.

(e) Hazardous/precluded

Polysulphide rubbers are not stable enough in the space environment. Chlorinated rubbers are marginal in outgassing. In many types of use, the choice is dictated not by the space environment, but by the compatibility with some fluid and/or gas (membranes, bladders etc.). Silicones are not to be used where low gas permeability is required (pressurised systems). Rubbers containing plasticisers, extending oils etc. are unstable in vacuum and must be excluded. Fillers may be leached out by a fluid and clog small apertures (such as the pores of a catalyst, for example).

(f) Effects of space environment

Vacuum exposure provokes outgassing, which is particularly due to volatile additives, but also to depolymerisation of the base polymer. Both these phenomena lead to a change in mechanical and physical properties of rubber items. The risk of contamination of the vicinity is also high. **Outgassing and contamination should be measured for each formulation:** results cannot be generalised safely to a full series, except perhaps in the case of the perfluorinated rubbers, which are safe and for the silicone rubbers, which become generally acceptable **only after a long post-cure at 250°C.**

Radiation attacks rubber either by hardening it (cross-link) or by softening it to form a viscous medium. Most common rubbers cannot be used if the ionising radiation is more than a few Mrad. Polyurethanes and fluorinated rubber can go up to 10 Mrad. Uses inside a spacecraft are not limited by these features, but external applications require care in the selection, particularly because of the added action of solar UV.

The temperature range for useful rubber properties is rather narrow, from −100°C for the best low-temperature silicones to 300°C for short exposure of fluorinated rubbers. At low temperature, one observes hardening,

stiffening and eventually crazing and crushing. High temperatures provoke decomposition. Some boron-based experimental rubbers exist now for temperatures up to 400°C. The temperature resistance is lessened in the presence of incompatible fluids.

(g) Some representative products
As for plastics, raw products and some semifinished items are produced by the large firms, but there are many relatively small compounders manufacturing catalogue and/or 'on-demand' items. The following materials, for which data sheets are provided, can be considered:
— Eccoshield SV-R
— Vibrachoc VHDS
— Viton B910

7.2.12 Thermoplastics

(a) Use in spacecraft
Thermoplastics, either plain or reinforced, find multiple uses in spacecraft as electrical insulants, gaskets, small mechanical parts, lacing and tie devices, sleeves and tubing etc. Optical plastics are treated separately under 'Glasses'; other plastics have appeared already under 'Plastic Films'. Some self-lubricating products appear under 'Lubricants'.

(b) Main categories
Commercial plastics are extremely numerous. Most of them can find some space use: polyamides, acetal, polyolefins, polycarbonate, acrylics, polystyrene, fluorinated resins, polyphenylene oxide etc. Some are hard and brittle, others are tough; some are rather flexible and soft. Pure products vary from transparently clear to translucent white or light yellow, but most of them can be dyed or pigmented. Fillers are sometimes used as well as different additives such as antioxidants, plasticisers, UV stabilisers and processing aids. There also exist reinforced thermoplastics based on glass fibres or chopped carbon fibres, and continuous carbon fibre-reinforced high-performance thermoplastics are commercially available. Many types of thermoplastics appear as textile items. Shrinkable plastics exist on the market, as well as foamed plastics.

(c) Processing
Moulding, extrusion, textile processing etc. are generally done by specialised firms, and aerospace users are mainly concerned with semifinished or finished items. Most plastics can be machined and assembled by classical techniques; adhesive bonding is one of the most versatile; welding is sometimes possible. The processing of reinforced thermoplastics is very similar to that of light metals.

(d) Precautions

Thermoplastics soften at rather low temperatures (from ± 80°C for polystyrene to more than 300°C for polytetrafluoroethylene (PTFE). This should be kept in mind during processing. Thermoplastics are sometimes quite sensitive to chemicals and/or solvents: tables of chemical resistance should be consulted, particularly when one is devising cleaning methods. **The dimensional stability of many plastics is inferior to that of conventional metals:** many fluorinated resins have a tendency to creep under load; polyamide plastics absorb water in normal atmosphere and shrink under dry conditions. Tough plastics may retain internal stresses after machining or forming operations, and this renders some stress-relieving thermal treatment necessary (polycarbonate, acetal). Thermal conductivity of plastics is low; this must be allowed for in the design and during processing. Most current plastics are flammable, but some exceptions exist (fluorinated), and self-extinguishing grades of conventional types can be found. Filled thermoplastics are generally more stable thermally and mechanically than plain grades. Further improvement is given by reinforcement, which permits the design of rather precise small mechanical parts.

(e) Hazardous/precluded

Many additives commonly used in plastics can be detrimental in space applications. **This is particularly so with plasticisers, which have a tendency to evaporate in space vacuum.** Polyvinyl chloride (PVC) is not stable enough under vacuum and must not be used (particularly in electrical insulation). The same is true of polyvinyl acetate and butyrate. Many polyamides are dangerous because they absorb water and shrink under vacuum; they should be excluded.

(f) Effects of space environment

Space vacuum tends to extract several additives from plastics, the consequence of which is a degradation of the properties that were stabilised by the additives (increase in rigidity and fragility when a plasticiser is lost, for example). There is also a great risk of contamination by the evolved products, which are generally rather high-boiling-point chemicals. 'Pure' plastics, with the exception of PVC, polyamides, polyvinyl acetates and butyrates, are in general safe to use, but it is very difficult to assess this 'purity', since manufacturers tend to 'improve' their products by adding chemicals. In addition, it frequently happens that processing aids or miscellaneous impurities stay absorbed in commercial plastics. The electrical properties of these plastics, which tend to absorb water, are improved by the drying action of a vacuum. ***Radiation,*** both UV and particle, may modify plastic materials. The result is frequently discoloration accompanied by evolution of gas and hardening. Some fluorinated plastics are rather sensitive to particle radiation (PTFE is limited to 1 Mrad) and must not be used in such a way that it is fully exposed

to space. However, a minimal amount of shielding reduces doses to acceptable levels. Other plastics are far more resistant and are not significantly modified by particle fluxes encountered in space, particularly the filled or reinforced grades. UV damage is generally limited to a very thin surface layer and can be disregarded when optical properties are not of concern.

High temperature softens thermoplastics, and their low thermal conductivity makes it difficult to eliminate heat except when a suitable filler is present (metal powder for example). Most plastics harden significantly and become brittle at temperatures lower than their 'glass-transition temperature'. Fluorinated plastics can be used down to cryogenic temperatures.

Atomic oxygen attacks thermoplastic and is dangerous for thin items (see also plastic films).

(g) Some representative products

It is impossible to cite all the trade names in this enormous domain. Big European chemical firms are engaged in producing most of the plastics that can be used in aerospace vehicles. Among them we can mention:

— BASF, BAYER, HUELS, DYNAMIT-NOBEL and HOECHST in Germany;
— ICI in U.K;
— AQUITAINE-ORGANICO, KUHLMANN, RHONE-POULENC in France;
— MONTECATINI-EDISON in Italy.

The following materials, for which data sheets are provided, can be considered:

— Hostaform C9020
— Makrolon GV3O
— PTFE
— Super:Gude Space PT
— Thermofit RT850
— Thermofit RT876
— Wire Type 44

Advanced thermoplastic polymers for fibre reinforcement:

— VICTREX-PEEK from ICI-UK (Polyether-ether ketone)
— VICTREX-PES from ICI-UK (Polyether sulphone)
— UDEL from Union-Carbide-US (Polysulfone)
— ULTEM from General Electric-US (Polyetherimide)

TABLE 7.2.1. COMPATIBLE COUPLES FOR BIMETALLIC CONTACTS

Group No.	Metallurgical Category The metals having the greater negative E.M.F. will tend to corrode and form oxides	E.M.F. between calomel electrode and sea water	Compatible Couples Maximum potential difference for A) 0.25 V Non-clean-room environment	 B) 0.5 V Clean-room or hermetically sealed environment
1.	Graphite, epoxy components Gold, solid or plated, gold/platinum alloys, wrought platinum	0.15		
2.	Rhodium or rhenium	0.05		
3.	Silver, solid or plated on copper, high-silver alloys	0		
4.	Nickel, solid or plated, monel metal and high-nickel/copper alloys, titanium	−0.15		
5.	Copper, solid or plated; low brasses or bronzes, silver solder; German silver, high copper/nickel alloys; nickel/chromium alloys; austenitic highly corrosion-resistant steels	−0.20		
6.	Commercial yellow brasses and bronzes; Ti6Al4V	−0.25		
7.	High brasses and bronzes; naval brass; Muntz metal	−0.30		
8.	18% chromium-type corrosion-resistant steels	−0.35		
9.	Chromium- or tin-plated (nonporous) metals, 12% chromium-type corrosion-resistant steels	−0.45		
10.	Tin/lead solder, solid or plated; Terne plate; indium/lead solder	−0.50		
11.	Lead, solid or plated; high-lead alloys	−0.55		
12.	Duralumin-type aluminium wrought alloys	−0.60		
13.	Iron, wrought, grey or malleable; Armco iron; plain carbon and low-alloy steels	−0.70		
14.	Aluminium, wrought alloys other than Duralmin type. Aluminium, cast alloys of the silicon type (7075, 5052)	−0.75		
15.	Aluminium, cast alloys other than silicon type; cadmium platings (generally not approved for space use)	−0.80		
16.	Hot-dipped zinc plate (generally not approved for space use)	−1.05		
17.	Zinc, wrought; zinc-base die casting alloys; zinc plate (generally not approved for space use)	−1.10		
18.	Magnesium and magnesium-base alloys, cast or wrought	−1.60		

For individual alloys and their heat treatments, refer to ESA Journal 1989, Vol. 13, pp. 199-209

APPENDIX A

MATERIAL DATA SHEETS

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SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-1 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: ALUMINIUM (I.S.O. Al 99.5)
CHEMICAL COMPOSITION	: 99.5% Al
TYPE OF PRODUCT	: METAL ALLOY

MANUFACTURER	: ALCAN KITTS GREEN BIRMINGHAM UK	L'ALUMINIUM FRANÇAISE 23, RUE BALZAC PARIS 8e F	OTTO FUCHS 5882 MEINERZHAGEN 1 D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: AA 1050, B.S. 1B, AFNOR A5, DIN Al 99.5
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.71 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	0.75 to 1.46 × 10^4 N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	0.55 to 1.33 × 10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	25%	At room temperature
THERMAL CONDUCTIVITY	2.30 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	24 × 10^{-6} $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	0.028 × 10^{-4} Ω cm	At room temperature

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-1 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION	Excellent resistance to atmospheric corrosion. For more severe environments, part can be either: (i) chromated, (ii) chromated and painted, (iii) suphuric anodised, or (iv) chromic anodised	
STRESS CORROSION	High resistance.	

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-2 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: ALUMINIUM/COPPER ALLOY (I.S.O. AlCu4Mg1)
CHEMICAL COMPOSITION	: 4.5% Cu, 1.5% Mg, 0.6% Mn, rem Al99.5% Al
TYPE OF PRODUCT	: METAL ALLOY

MANUFACTURER	: B.A.C.O. NORFOLK HOUSE ST. JAMES'S SQ. LONDON UK	L'ALUMINIUM FRANÇAISE 23, RUE BALZAC PARIS 8e F	OTTO FUCHS 5882 MEINERZHAGEN 1 D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: AA 2024; B.S. L97, L98; AFNOR A-U4G1; DIN 1725
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.77 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	3.85 to 4.95 × 10^4 N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	2.60 to 4.70 × 10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	3 to 16%	At room temperature
THERMAL CONDUCTIVITY	1.5 to 1.8 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	22 to 24 × 10^{-6} $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	0.089 × 10^{-4} Ω cm	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION	Relative poor resistance to atmospheric corrosion and should always be anodised or chromated and painted.	
STRESS CORROSION	Only limited forms and temper conditions have high resistance to stress corrosion cracking. (Refer to ESA PSS-01-736 for approval of this alloy.) Furthermore, only rod and bar forms in the T8 condition have a high resistance. Plate, extrusions and forgings have moderate to low resistance.	

4. SPECIAL RECOMMENDATION

For precipitation-hardened parts, heating above the precipitation temperature may result in a susceptibility to intergranular and stress corrosion.
The room-temperature-aged conditions may become susceptible to intergranular corrosion if the alloy is heated above 65°C.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-3 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: ALUMINIUM/MAGNESIUM ALLOY (I.S.O. Al Mg2)
CHEMICAL COMPOSITION	: 1.7 to 2.4% Mg, rem Al
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: ALCAN KITTS GREEN BIRMINGHAM UK L'ALUMINIUM FRANÇAISE 23, RUE BALZAC PARIS 8e F OTTO FUCHS 5882 MEINERZHAGEN 1 D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: AA 5052, B.S. N4, AFNOR A-G2, DIN 1725
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.69 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	1.80 to 2.50 × 10^4 N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	0.87 to 1.90 × 10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	16%	At room temperature
THERMAL CONDUCTIVITY	1.55 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	24 × 10^{-6} $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	0.047 × 10^{-4} Ω cm	At room temperature

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-3 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION	Very good resistance to atmospheric corrosion. For more severe environments, part can be either: (i) chromated, (ii) chromated and painted, (iii) suphuric anodised, or (iv) chromic anodised	
STRESS CORROSION	High resistance.	

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-4 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: ALUMINIUM/MAGNESIUM/SILICON ALLOY (I.S.O. AlMgSi)
CHEMICAL COMPOSITION	: 0.4 to 0.9% Mg, 0.3 to 0.7% Si, rem Al
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: ALCAN KITTS GREEN BIRMINGHAM UK L'ALUMINIUM FRANÇAISE 23, RUE BALZAC PARIS 8e F OTTO FUCHS 5882 MEINERZHAGEN 1 D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: AA 6063, B.S. H9, AFNOR A-GS, DIN 1746
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.70 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	1.55 to 2.10 × 10^4 N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	0.90 to 1.80 × 10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	8 to 14%	At room temperature
THERMAL CONDUCTIVITY	1.97 to 2.01 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	23 × 10^{-6} $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	0.034 × 10^{-4} Ω cm	At room temperature

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-4 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION	Moderate resistance to atmospheric corrosion. Generally, one of the following treatments will be required: (i) chromating, (ii) chromating and painting, (iii) suphuric anodising, or (iv) chromic anodising	
STRESS CORROSION	High resistance.	

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-5 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: ALUMINIUM/ZINC ALLOY
CHEMICAL COMPOSITION	: 5.6% Zn, 2.5% Mg, 1.6% Cu, 0.3% Cr, rem Al
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: ALCAN KITTS GREEN BIRMINGHAM UK L'ALUMINIUM FRANÇAISE 23, RUE BALZAC PARIS 8e F OTTO FUCHS 5882 MEINERZHAGEN 1 D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: AA 7075, D.T.D.5074A, AFNOR A-Z5GU, WERK no. 3.4364
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.80 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	4.00 to 6.50 $\times 10^4$ N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	3.40 to 5.95 $\times 10^4$ N cm^{-2}	At room temperature
ELONGATION AT BREAK	3 to 8%	At room temperature
THERMAL CONDUCTIVITY	1.34 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	22 $\times 10^{-6}$ $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	0.089 $\times 10^{-4}$ Ω cm	At room temperature

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-5 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION	Poor resistance to atmospheric corrosion and should always be protected. Although anodising is possible, the degree of protection it affords is not as great as with other Al alloys, so painting is the recommended treatment.	
STRESS CORROSION	In some tempers, it has moderate to low resistance. (Refer to ESA PSS-01-736 for approval of this alloy.) Furthermore, in the T6 condition, it is susceptible to stress corrosion. However, this can be overcome by application of the T73 treatment (overaging), which provides a high resistance to SCC.	

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-6 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: APIEZON L
CHEMICAL COMPOSITION	: HYDROCARBON
TYPE OF PRODUCT	: GREASE LUBRICANT
MANUFACTURER	: SHELL CHEMIE DEN HAAG THE NETHERLANDS

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	0.896 g cm^{-3}	at 20°C
MELTING POINT	47°C	Manuf. data
VISCOSITY	766 cp	at 50°C
THERMAL EXPANSION COEFFICIENT	7.6×10^{-4} $°C^{-1}$	Manuf. data
THERMAL CONDUCTIVITY	2×10^{-3} W cm^{-1} $°C^{-1}$	Manuf. data
HEAT OF FUSION	63 J g^{-1}	Manuf. data
VOLUME RESISTIVITY	1.2×10^{16} Ω cm	Manuf. data
DIELECTRIC STRENGTH	730 V/mil	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-6 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Around room temperature	
OUTGASSING	TML = 0.13% RML = 0.12% CVCM = 0.04%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— A drived product, Apiezon AP100, contains PTFE additive for superior anti-seize properties.
— Does not pass odour test.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-7 REVISION : 3 DATE : January 1994

TRADE NAME	: ARALDITE AV100/HV100 (1 pbw/1 pbw)
CHEMICAL COMPOSITION	: EPOXY
TYPE OF PRODUCT	: 2-PART ADHESIVE LIQUID
MANUFACTURER	: CIBA-GEIGY DUXFORD U.K.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
POT LIFE	2 hours	at R.T.
TENSILE SHEAR STRENGTH	1500 N cm^{-2}	at 20°C
TENSILE MODULUS	2.7×10^5 N cm^{-2}	ISO 178
THERMAL EXPANSION COEFF.	6×10^{-5} $°C^{-1}$	ASTM D696-70
SHELF LIFE	3 years	Manuf. data
GLASS TRANS. TEMP.	50-60°C	T.M.A.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-7 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TOXICITY/OFFGASSING	Pass	NHB 8060-1A
OUTGASSING	TML = 1.1% RML = 0.5% CVCM = 0.07%	ESA PSS-01-702 (only with fully controlled process)
FLAMMABILITY	Pass 23.8% O_2	NHB 8060-1B

4. SPECIAL RECOMMENDATION

- Sensitive to water absorption by the catalyst before use. This degrades outgassing and mechanical properties. Therefore quality control test by micro-VCM method (ESA PSS-01-702) is compulsory.
- Does not pass odour test.
- Recommended cure is 24 hours at room temperature followed by 24 hours at 60°C.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-8 REVISION : 3 DATE : January 1994

TRADE NAME	: ARALDITE AV138M/HV998 (100/40 pbw)
CHEMICAL COMPOSITION	: EPOXY
TYPE OF PRODUCT	: 2-PART ADHESIVE PASTE
MANUFACTURER	: CIBA-GEIGY BASLE SWITZERLAND

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: UNKNOWN
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
POT LIFE	30 min.	at 23°C
TENSILE SHEAR STRENGTH	1836 N cm^{-2}	at 20°C
FATIGUE STRENGTH	$>10^7$ cycles	at 25% max strength
ELASTICITY MODULUS	9.5×10^5 $°C^{-1}$	
THERMAL EXPANSION COEFF.	5.4×10^{-5} $°C^{-1}$	between 23 and 70°C
THERMAL CONDUCTIVITY	3.5×10^{-3} $W.cm^{-1}$ $°C^{-1}$	at 30°C
VOLUME RESISTIVITY	1.9×10^{15} Ω cm	at 22°C
GLASS TRANS. TEMP.	66°C	T.M.A.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-8 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 120°C	Long term
TOXICITY/OFFGASSING	Pass	NHB 8060-1A
OUTGASSING	TML = 0.84% RML = 0.57% CVCM = 0.02%	ESA PSS-01-702
FLAMMABILITY	Pass 24.5% O_2	NHB 8060-1B

4. SPECIAL RECOMMENDATION

- The material is available in thicknesses of 12, 25, 50, 75, and 125 μm.
- Sensitivity to water absorption by the catalyst before use. This may degrade outgassing and mechanical properties.
- Does not pass odour test with cure at RT; passes with cure at 65°C.
- Recommended cure time: 48 hours at room temperature
- AV 138 M is a newer version of AV 138

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-9 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: ARALDITE CY205/HY905 (100/100pbw)
CHEMICAL COMPOSITION	: EPOXY
TYPE OF PRODUCT	: MOLDING AND POTTING RESIN
MANUFACTURER	: CIBA-GEIGY BASLE SWITZERLAND

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
VISCOSITY (BEFORE REACTION)	60 cps	at 60°C
POT LIFE	6 days	at 60°C
SPECIFIC GRAVITY	1.2 g cm^{-3}	
TENSILE STRENGTH	4000 N cm^{-2}	at room temperature
ELASTICITY MODULUS	4.3×10^5 N cm^{-2}	at room temperature
THERMAL EXPANSION COEFF.	6×10^{-5} $°C^{-1}$	at room temperature
THERMAL CONDUCTIVITY	1.7×10^{-3} W cm^{-1} $°C^{-1}$	at room temperature
ELECTRICAL RESISTIVITY	4×10^{16} Ω cm	at 25°C
DIELECTRIC CONSTANT	3.4	at 25°C
LOSS FACTOR	0.4	at 25°C, 50 Hz
DIELECTRIC STRENGTH	200 kV cm^{-1}	at 25°C, 50 Hz

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-9 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 120°C	Long term
OUTGASSING	TML = 0.4% RML = 0.2% CVCM = 0.0%	ESA PSS-01-702
TOXICITY/OFFGASSING	Pass	NHB 8060-1A
IONISING RADIATION	10^7 rad	Threshold
WATER ABSORPTION	0.3%	10 days at 20°C
FLAMMABILITY	Fail	NHB 8060-1B

4. SPECIAL RECOMMENDATION

- This molding compound must be hot cured - at least 2 hours @ 90°C + 2 hours @ 120°C + 6 hours @ 160°C.
- Cure may be accelerated by using accelerator DY061.
- Different fillers may be used and particularly dry silica powder.
- Other hardeners are available for CY205 - some of them are not suitable for space use (e.g. HY956)
- The material is also designated 'Araldite F'.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-11 REVISION : 0 DATE : January 1988

TRADE NAME	: ANDUS FILM
CHEMICAL COMPOSITION	: FLUOROCARBON (FEP), SILVER & ICONEL COATED
TYPE OF PRODUCT	: THERMAL-CONTROL POLYMER FILM
MANUFACTURER	: ANDUS CORPORATION 21019 OSBORNE ST. CANOGA PARK, CA 91304 U.S.A.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
DENSITY	2.15 $g.cm^{-3}$	DuPont's data
THICKNESS	50 μm	Manufacturer's data
STANDARD WIDTH	1220 mm	Manufacturer's data
ULTIMATE TENSILE STRENGTH	2.1×10^{3} $N.cm^{-2}$	DuPont's data 298 K
COEFF. OF LINEAR EXPANSION	8.3×10^{-5} $°C^{-1}$	DuPont's data 223-343 K
COEFF. OF THERMAL CONDUCTIVITY	1.94×10^{-3} $W.cm^{-1}$ $°C^{-1}$	DuPont's Data 223-343 K
SPECIFIC HEAT	1.17 $J.g^{-1}$ $°C^{-1}$	Dupont's data 223-343 K
DIELECTRIC STRENGTH (OF FEP FILM)	160 kV/mm	DuPont's data 296 K
SURFACE RESISTANCE	$> 10^{15}$ Ω	Dupont's data 296 K - 38% RH
VOLUME RESISTIVITY	$>10^{17}$ $\Omega.cm$	DuPont's data 296 K -38% RH
SOLAR ABSORPTANCE	0.10	Typical values only
THERMAL EMITTANCE	0.61	Typical values only

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-11 REVISION : 0 DATE : January 1988

3. PROPERTIES RELEVANT TO SPACE USE - EFFECTS OF AND/OR ON ENVIRONMENT

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	88 K to 423 K	DuPont's data
MOISTURE ABSORPTION	0.01%	Dupont's data
OXYGEN INDEX		
TOXICITY/OFFGASSING		
OUTGASSING		
UV/PARTICLE RADIATION		

4. SPECIAL RECOMMENDATION

— The material is available in thicknesses of 12, 25, 50, 75, and 125 μm.

— The material is available in widths up to 1220 mm.

— The material is available with # 966 acrylic adhesive on the metallised side.

— The material is available with perforations.

— An ITO transparent conductively coated film is available. Consult the manufacturer for further details.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-12 REVISION : 0 DATE : January 1988

TRADE NAME	:	ANDUS FILM
CHEMICAL COMPOSITION	:	FLUOROCARBON (FEP), ALUMINISED
TYPE OF PRODUCT	:	THERMAL-CONTROL POLYMER FILM
MANUFACTURER	:	ANDUS CORPORATION 21019 OSBORNE ST. CANOGA PARK, CA 91304 U.S.A.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	:	SPECIAL COMMERCIAL PRODUCT
COST RANGE	:	HIGH
LOT REPRODUCIBILITY	:	GOOD
SPACE EXPERIENCE	:	LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
DENSITY	2.15 $g.cm^{-3}$	DuPont's data
THICKNESS	50 μm	Manufacturer's data
STANDARD WIDTH	1220 mm	Manufacturer's data
ULTIMATE TENSILE STRENGTH	2.1×10^{3} $N.cm^{-2}$	DuPont's data 298 K
COEFF. OF LINEAR EXPANSION	8.3×10^{-5} $°C^{-1}$	DuPont's data 223-343 K
COEFF. OF THERMAL CONDUCTIVITY	1.94×10^{-3} $W.cm^{-1}$ $°C^{-1}$	DuPont's Data 223-343 K
SPECIFIC HEAT	1.17 $J.g^{-1}$ $°C^{-1}$	Dupont's data 223-343 K
DIELECTRIC STRENGTH (OF FEP FILM)	160 kV/mm	DuPont's data 296 K
SURFACE RESISTANCE	$> 10^{15}$ Ω	Dupont's data 296 K - 38% RH
VOLUME RESISTIVITY	$> 10^{17}$ $\Omega.cm$	DuPont's data 296 K -38% RH
SOLAR ABSORPTANCE	0.16	Typical values only
THERMAL EMITTANCE	0.47	Typical values only

3. PROPERTIES RELEVANT TO SPACE USE - EFFECTS OF AND/OR ON ENVIRONMENT

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	88 K to 423 K	DuPont's data
MOISTURE ABSORPTION	0.01%	Dupont's data
OXYGEN INDEX		
TOXICITY/OFFGASSING		
OUTGASSING		
UV/PARTICLE RADIATION		

4. SPECIAL RECOMMENDATION

— The material is available in thicknesses of 12, 25, 50, 75, and 125 μm.

— The material is available in widths up to 1220 mm.

— The material is available with # 966 acrylic adhesive on the metallised side.

— The material is available with perforations.

— An ITO transparent conductively coated film is available. Consult the manufacturer for further details.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-13 REVISION : 0 DATE : January 1988

TRADE NAME	:	ANDUS FILM
CHEMICAL COMPOSITION	:	POLYIMIDE KAPTON HN ALUMINIUM AND ITO COATED
TYPE OF PRODUCT	:	ELECTRICALLY CONDUCTIVE, THERMAL-CONTROL POLYMER FILM
MANUFACTURER	:	ANDUS CORPORATION 21019 OSBORNE ST. CANOGA PARK, CA 91304 U.S.A.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	:	SPECIAL COMMERCIAL PRODUCT
COST RANGE	:	HIGH
LOT REPRODUCIBILITY	:	GOOD
SPACE EXPERIENCE	:	LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
DENSITY	1.42 $g.cm^{-3}$	DuPont's data
THICKNESS	50 μm	Manufacturer's data
STANDARD WIDTH	1220 mm	Manufacturer's data
ULTIMATE TENSILE STRENGTH	1.7×10^{4} $N.cm^{-2}$	DuPont's data 298 K
COEFF. OF LINEAR EXPANSION	2×10^{-5} $°C^{-1}$	DuPont's data 259-311 K
COEFF. OF THERMAL CONDUCTIVITY	1.55×10^{-3} $W.cm^{-1}$ $°C^{-1}$	DuPont's Data 296 K
SPECIFIC HEAT	1.09 $J.g^{-1}$ $°C^{-1}$	Dupont's data 296 K
SURFACE RESISTANCE	$< 1000\ \Omega$	Manufacturer's data 296 K - 2 VDC
SOLAR ABSORPTANCE	0.50	Typical values only
THERMAL EMITTANCE	0.72	Typical values only

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-13 REVISION : 0 DATE : January 1988

3. PROPERTIES RELEVANT TO SPACE USE - EFFECTS OF AND/OR ON ENVIRONMENT

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	78 K to 473 K	DuPont's data
MOISTURE ABSORPTION	1.3% @ 50% RH, 296 K	Dupont's data
OXYGEN INDEX		
TOXICITY/OFFGASSING		
OUTGASSING		
UV/PARTICLE RADIATION		

4. SPECIAL RECOMMENDATION

— Normal use is for the external sheet of multilayer insulation. Suitable venting must be provided.

— The material is available in thicknesses of 8, 12, 25, 50, 75 and 125 μm.

— The material is available in widths of up to 1220 mm.

— The front surface ITO coating will withstand light handling and light abrasion, but it should be protected against excessive handling. Consult the manufacturer for further details.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-14 REVISION : 0 DATE : January 1988

TRADE NAME	:	ANDUS FILM
CHEMICAL COMPOSITION	:	FLUOROCARBON (FEP), ALUMINISED & ITO COATED
TYPE OF PRODUCT	:	THERMAL-CONTROL, ELECTRICALLY CONDUCTIVE POLYMER FILM
MANUFACTURER	:	ANDUS CORPORATION 21019 OSBORNE ST. CANOGA PARK, CA 91304 U.S.A.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	:	SPECIAL COMMERCIAL PRODUCT
COST RANGE	:	HIGH
LOT REPRODUCIBILITY	:	GOOD
SPACE EXPERIENCE	:	LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
DENSITY	2.15 $g.cm^{-3}$	DuPont's data
THICKNESS	50 μm	Manufacturer's data
STANDARD WIDTH	1220 mm	Manufacturer's data
ULTIMATE TENSILE STRENGTH	2.1×10^{3} $N.cm^{-2}$	DuPont's data 298 K
COEFF. OF LINEAR EXPANSION	8.3×10^{-5} $°C^{-1}$	DuPont's data 223-343 K
COEFF. OF THERMAL CONDUCTIVITY	1.94×10^{-3} $W.cm^{-1}$ $°C^{-1}$	DuPont's Data
SPECIFIC HEAT	1.17 $J.g^{-1}$ $°C^{-1}$	Dupont's data
DIELECTRIC STRENGTH OF FEP FILM	160 kV/mm	DuPont's data 296 K
SURFACE RESISTANCE	$< 1000\ \Omega$	Manufacturer's data - 2 VDC
VOLUME RESISTIVITY	$> 10^{17}\ \Omega.cm$	DuPont's data 296 K -38% RH
SOLAR ABSORPTANCE	0.16	Typical values only
THERMAL EMITTANCE	0.47	Typical values only

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-14 REVISION : 0 DATE : January 1988

3. PROPERTIES RELEVANT TO SPACE USE - EFFECTS OF AND/OR ON ENVIRONMENT

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	88 K to 423 K	DuPont's data
MOISTURE ABSORPTION	0.01%	Dupont's data
OXYGEN INDEX		
TOXICITY/OFFGASSING		
OUTGASSING		
UV/PARTICLE RADIATION		

4. SPECIAL RECOMMENDATION

— The material is available in thicknesses of 12, 25, 50, 75 and 125 μm.

— The material is available in widths up to 1220 mm.

— The material is available with # 966 acrylic adhesive on the metallised side.

— The material is available with perforations.

— The front surface ITO coating will withstand light handling and light abrasion, but it should be protected against excessive handling. Consult the manufacturer for further details.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-15 REVISION : 2 DATE : June 1990

TRADE NAME	: APC 2
CHEMICAL COMPOSITION	: POLYETHERETHERKETONE
TYPE OF PRODUCT	: CARBON FIBRE REINFORCED THERMOPLASTIC
MANUFACTURER	: ICI Advanced Materials Fiberite Europe GmbH Erkelenzer Strasse 20 D-4050 Mönchengladbach FRG

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	:
LOT REPRODUCIBILITY	:
SPACE EXPERIENCE	: NONE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
TENSILE STRENGTH	2130 MPa (0°) 80 MPa (90°)	ASTM D-3039
THERMAL EXPANSION	0.5×10^{-6} (0°) 30×10^{-6} (90°)	Manuf. data (23 - 143°C) Manuf. data (23 - 143°C)
SPECIFIC GRAVITY	1.6 g cm^{-3}	
CARBON FIBRE WEIGHT FRACTION	68%	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : A-15 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
FLAMMABILITY	67% oxygen index	ASTM D-2863
FLAMMABILITY	Pass 24.5% O_2	NHB 8060-1B, Test 1
OFFGASSING (of PEEK matrix only)	Total organic 0.30 μg/g Carbon dioxide 0.40 μg/g	ESA PSS-01-729

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : B-1 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: BERYLLIUM - COPPER (CDA 170)
CHEMICAL COMPOSITION	: 1.8% Be, 0.3% Co + Ni, rem Cu
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: IMI P.O. BOX 216 WITTON BIRMINGHAM U.K.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: ASTM B194; B.S. 2870; B.S. 2873; CB101
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	8.25 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	4.60 to 15 × 10^4 N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	1.25 to 11 × 10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	2 to 50%	At room temperature
THERMAL CONDUCTIVITY	0.84 to 1.5 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	17 × 10^{-6} $°C^{-1}$	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION	Generally good	
STRESS CORROSION	High resistance only when solution-treated/work-hardened, then precipitation-hardened.	

4. SPECIAL RECOMMENDATION

— The alloy is age-hardenable and the typical heat treatment is as follows:
solution treat 760 - 820°C - water quench
age 315 - 350°C - air cool.

— Solution treatment may be from 10 to 30 minutes for light materials (i.e. wire and strip), extending up to several hours for bulky castings. Precipitation-hardening normally requires 2 hours at 310°C or 30 minutes at 350°C.

— Fabrication methods involving either welding, brazing or high-temperature soldering should be performed whilst the alloy is in the soft condition and then followed by the solution and ageing treatments.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : B-2 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: BRASS (α-β) LEADED
CHEMICAL COMPOSITION	: 40% Zn, 2% Pb, rem Cu
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: IMI P.O. BOX 216 WITTON BIRMINGHAM U.K.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: ASTM B1224/2; B.S. 2870 CZ120; Cu Zn40 Pb2
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	8.4 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	3.50 to 4.60 $\times$ 10^4 N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	1.00 to 3.90 $\times$ 10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	20 to 45%	At room temperature
THERMAL CONDUCTIVITY	1.17 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	20.9 $\times$ 10^{-6} $°C^{-1}$	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
ATMOSPHERIC CORROSION	The resistance to atmospheric corrosion is fair. The material is generally plated for protection.	
STRESS CORROSION	The resistance ot stress corrosion is low (see notes).	

4. SPECIAL RECOMMENDATION

- When this material is used for PCB terminals (machined), there must be a Cu or Ni diffusion barrier layer (3 μm) between the solder coating and the brass (see ESA PSS-01-708). For swaged terminals, the lead-free variety should be used.
- Resistance to stress corrosion is low when the material is 50% cold rolled. Furthermore, it should not be used in stressed conditions. See ESA PSS-01-736 for alternative copper alloys withg high resistance to stress corrosion.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-1 REVISION : 3 DATE : January 1994

TRADE NAME	: CARBOFORM 69/HM-S (40/60 pbv) (now Cycon C 69)
CHEMICAL COMPOSITION	: MODIFIED EPOXY/HIGH MODULUS CARBON FIBRES
TYPE OF PRODUCT	: PREPREG FOR LAMINATES
MANUFACTURER	: Fothergill & Harvey LTD., LITTLEBOROUGH UK (now Cyanamid UK)

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: VERY GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.63 g.cm $^{-3}$	
0° TENSILE STRENGTH	9.3×10^4 N cm $^{-2}$	Manuf. data, 21°C
0° TENSILE MODULUS	1.95×10^7 N cm $^{-2}$	Manuf. data
90° TENSILE STRENGTH	3.3×10^3 N cm $^{-2}$	Manuf. data
90° TENSILE MODULUS	8.2×10^5 N cm $^{-2}$	Manuf. data
0° INTERLAMINAR	7×10^3 N cm $^{-2}$	(span/depth = 5/1) 21°C
THERMAL EXPANSION COEFF.	LONG. -0.7×10^{-6} °C $^{-1}$ TRANS. 3×10^{-5}°C $^{-1}$	Manuf. data Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-1 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−130°C to 180°C	Manuf. data
OUTGASSING	TML = 0.6% RML = 0.3% CVCM = 0.01%	ESA PSS-01-702
HUMID HEAT	750 h: no sizeable effect	70°C - 95%

4. SPECIAL RECOMMENDATION

— Recommended cure is one step at 140°C, pressure application (70 N cm^{-2}), then 1 hour at 170°C. Post cure 3 h/180°C.
— The same resin can accommodate High Strength (HT-S) or type A.S. carbon fibres.
— When continuous use temperature does not exceed 120°C, another prepreg with similar properties, Carboform 87, can be used.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-2 REVISION : 3 DATE : January 1994

TRADE NAME	: CHEMGLAZE H322 (now AEROGLAZE)
CHEMICAL COMPOSITION	: POLYURETHANE
TYPE OF PRODUCT	: HEAT ACTIVATED ELECTRICALLY CONDUCTIVE MAT BLACK COATING
MANUFACTURER	: LORD-HUGHSON CHEMICALS (LORD CORP. ERIE STRETFORD PENN MANCHESTER USA UK)

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLID CONTENT	25%	Manuf. data
VISCOSITY	500 cps	Manuf. data
ELECTRICAL SURFACE RESISTIVITY	5 kΩ	At 1 V, nonconductive substrate
SOLAR ABSORPTANCE	0.95	ESA PSS-01-709
HEMISPHERICAL EMITTANCE	0.85	ESA PSS-01-709
SHELF LIFE	6 months	20°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-2 REVISION : 3 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
FLAMMABILITY	Pass 21% O_2 (on 1 mm thick Al foil)	NHB 8060-1B
OUTGASSING	TML = 1.6% RML = 0.9% CVCM = 0.04%	ESA PSS-01-702
UV/PARTICLE EFFECTS	$\Delta\alpha_s$ = −0.025	3 years/OTS spec.
THERMAL CYCLING	Pass	ESA PSS-01-704

4. SPECIAL RECOMMENDATION

- Recommended cure 15 min. at 125°C after last layer + post cure 50 hours at 100°C (specification ESA PSS-01-734)
- Primer Lesonol 01-66050 may be used for increased adhesion.
- This paint (like most others) is not recommended for use in badly vented places where high electrical fields are present in the vicinity (corona risk).
- Quality control tests according to ESA PSS-01-702 are recommended.
- Difficult to procure in Europe.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-3 REVISION : 3 DATE : January 1994

TRADE NAME	: CHEMGLAZE L300 (now AEROGLAZE)
CHEMICAL COMPOSITION	: POLYURETHANE
TYPE OF PRODUCT	: LOW TEMPERATURE CURING ELECTRICALLY CONDUCTIVE MAT BLACK COATING
MANUFACTURER	: LORD-HUGHSON CHEMICALS (LORD CORP. ERIE STRETFORD PENN MANCHESTER USA UK)

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLID CONTENT	22%	Manuf. data
VISCOSITY	400 cps	Manuf. data
ELECTRICAL SURFACE RESISTIVITY	3 kΩ	At 1 V, nonconductive substrate
SOLAR ABSORPTANCE	0.955	ESA PSS-01-709
NORMAL EMITTANCE	0.85	ESA PSS-01-709
SHELF LIFE	6 months	20°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-3 REVISION : 3 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
FLAMMABILITY	Pass 21% O_2	NASA NHB 8060-1B
OUTGASSING	TML = 1.7% RML = 0.9% CVCM = 0.04%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704

4. SPECIAL RECOMMENDATION

- Recommended curing time: 16 hours at 65°C after last layer of paint has been applied in accordance with ESA PSS-01-735.
- This paint (like most others) is not recommended for use in badly ventilated places where high electrical fields are present in the vicinity (corona risk).
- Quality control tests by micro-VCM (ESA PSS-01-702) are recommended.
- Flammability test on 1 mm aluminium substrate in 21% O_2.
  Material burns when applid to 0.3 Mil Kapton.
  Configuration test mandatory.
- Use with Pyrolac P123 primer for better adhesion.
- Difficult to procure in Europe.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-4 REVISION : 3 DATE : January 1994

TRADE NAME	: CHEMGLAZE Z306 (now AEROGLAZE)
CHEMICAL COMPOSITION	: POLYURETHANE
TYPE OF PRODUCT	: FLAT BACK, FLEXIBLE, ONE-PART PAINT
MANUFACTURER	: LORD-HUGHSON CHEMICALS (LORD CORP. ERIE STRETFORD PENN MANCHESTER USA UK)

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLID CONTENT	26-29% (pbw)	Manuf. data
VISCOSITY	150 cps	Manuf. data
SOLAR ABSORPTANCE	0.95	ESA PSS-01-709
HEMISPHERICAL EMITTANCE	0.90	ESA PSS-01-709
SHELF LIFE	6 months	20°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-4 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
FLAMMABILITY	Pass 24.5% O_2 (on 1 mm thick Al foil)	NASA NHB 8060-1B
OUTGASSING	TML = 1.5% RML = 0.6% CVCM = 0.03%	ESA PSS-01-702
UV/PARTICLE EFFECTS	$\Delta\alpha = 0$	7 years/OTS specif.
THERMAL CYCLING	Pass	ESA PSS-01-704
OFFGASSING/TOXICITY	pass	NASA NHB 8060-1A

4. SPECIAL RECOMMENDATION

- Cuvertin 306 made by Henkel (Germany) generally shows a higher TML/CVCM.
- This paint (like most others) is not recommended for use in badly ventilated places where high electrical fields are present in the vicinity (corona risk).
- Coating to be applied according to ESA PSS-01-725 with use of Pyrolac P123 primer.
- Quality control test by micro-VCM method (ESA PSS-01-702) recommended.
- Flammability test performed on 1 mm aluminium substrate in 24.5% O_2.
  Material burns when applied to other substrates (e.g. Kapton) Configuration test mandatory.
- This paint has been shown to contaminate space hardware returned from space. This is probably due to processing aids based on silicones.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-5 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: COPPER (OXYGEN-FREE/HIGH-CONDUCTIVITY)
CHEMICAL COMPOSITION	: 99.95% Cu
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: THOMAS BOLTON FROGHALL STOKE ON TRENT U.K.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: ASTM B152 OF; B.S. 2870 C103; AFNOR 53-100; DIN 1708.
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	8.9 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	2.20 to 4.50 $\times 10^4$ N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	0.45 to 3.20 $\times 10^4$ N cm^{-2}	At room temperature
ELONGATION AT BREAK	5 to 50%	At room temperature
THERMAL CONDUCTIVITY	3.94 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	17.7 $\times 10^{-6}$ $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	0.017 $\times 10^{-4}$ Ω cm	At room temperature

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-5 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION	Copper corrodes if sulphur is present and forms the familiar green surface patina which inhibits further corrosion.	

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-6 REVISION : 2 DATE : June 1990

TRADE NAME	: COHRLASTIC F 12
CHEMICAL COMPOSITION	: SILICONE
TYPE OF PRODUCT	: FOAM
MANUFACTURER	: CHR Europe BV Industrieweg 9 Postbus 124 NL-7640 AC Wierden The Netherlands

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: HFL 679 per metre 914 mm × 12.7 mm (1989 price)
LOT REPRODUCIBILITY	:
SPACE EXPERIENCE	: NONE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.44 to 2.24 g cm^{-3}	Manuf. data
TENSILE STRENGTH	0.17 MPa	Manuf. data
ELONGATION AT BREAK	60%	Manuf. data
TEMPERATURE RANGE	−52 to 200°C	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-6 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
FLAMMABILITY	Pass 24.5% O_2	NHB 8060-1B
OUTGASSING	TML = 0.85% CVCM = 0.17%	ESA PSS-01-702
OFFGASSING	Carbon monoxide 0.1 μg/g Total organic 0.1 μg/g	ESA PSS-01-729

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-7 REVISION : 2 DATE : June 1990

TRADE NAME	: CV-1142
CHEMICAL COMPOSITION	: PHENYL SILICONE
TYPE OF PRODUCT	: NONCORROSIVE CONTROLLED VOLATILITY RTV SILICONE ADHESIVE SEALANT
MANUFACTURER	: McGhan-Nusil Corp. 1150 Mark Avenue Carpinteria, CA 93013 USA European Agent: Dunlop Adhesives Chester Road Birmingham B35 7AL UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
APPEARANCE	Translucent, elastomer	
CONSISTENCY	Non-slump	
SPECIFIC GRAVITY	1.10 $\pm$0.02 g cm^{-3}	25°C
HARDNESS	25 minimum	Durometer, Type A
TENSILE STRENGTH	2.9 MPa minimum	Manuf. data
ELONGATION	150% minimum	Manuf. data
TEAR STRENGTH	30 ppi minimum	Die B
REFRACTIVE INDEX	1.434 $\pm$ 0.005	Manuf. data
DIELECTRIC STRENGTH	500 V/mil	Manuf. data
VOLUME RESISTIVITY	1 $\times$ 10^{15} Ω cm	Manuf. data
SHELF LIFE	6 months	25°C Refrigeration may extend shelf life

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-7 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−115 to 260°C	Manuf. data
OUTGASSING	TML = 0.41% RML = 0.31% CVCM = 0.01%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— A primer may be required on some bonding applications. McGhan-Nusil SP-120 silicone primer is recommended.
— Cure time at 25°C and 50% RH:
Tack-free time - 30 minutes
Full cure - 7 days

Thick sections may require extended cure times.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-8 REVISION : 2 DATE : June 1990

TRADE NAME	: CV-1143
CHEMICAL COMPOSITION	: DIMETHYL SILICONE POLYMER
TYPE OF PRODUCT	: NONCORROSIVE CONTROLLED VOLATILITY RTV SILICONE ADHESIVE SEALANT
MANUFACTURER	: McGhan-Nusil Corp. 1150 Mark Avenue Carpinteria, CA 93013 USA European Agent: Dunlop Adhesives Chester Road Birmingham B35 7AL UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
APPEARANCE	Translucent, elastomer	
CONSISTENCY	Non-slump	
SPECIFIC GRAVITY	1.10 $\pm$0.02 g cm^{-3}	25°C
HARDNESS	30 minimum	Durometer, Type A
TENSILE STRENGTH	3.4 MPa minimum	Manuf. data
ELONGATION	250% minimum	Manuf. data
TEAR STRENGTH	50 ppi minimum	Die B
REFRACTIVE INDEX	Not tested	Manuf. data
DIELECTRIC STRENGTH	500 V/mil	Manuf. data
VOLUME RESISTIVITY	1 $\times$ 10^{15} Ω cm	Manuf. data
SHELF LIFE	6 months	25°C Refrigeration may extend shelf life

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−65 to 260°C	Manuf. data
OUTGASSING	TML = 0.34% RML = 0.28% CVCM = 0.050%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— A primer may be required on some bonding applications. McGhan-Nusil SP-120 silicone primer is recommended.
— Cure time at 25°C and 50% RH:
Tack-free time - 30 minutes
Full cure - 7 days

Thick sections may require extended cure times.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-9 REVISION : 2 DATE : June 1990

TRADE NAME	: CV-1144-0
CHEMICAL COMPOSITION	: DIMETHYL DIPHENYL SILICONE POLYMER
TYPE OF PRODUCT	: CONTROLLED VOLATILITY RTV SILICONE ATOMIC OXYGEN PROTECTIVE OVERCOAT
MANUFACTURER	: McGhan-Nusil Corp. 1150 Mark Avenue Carpinteria, CA 93013 USA European Agent: Dunlop Adhesives Chester Road Birmingham B35 7AL UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
APPEARANCE	Clear, elastomer	
VISCOSITY	265 ± 50 cps	Manuf. data
REFRACTIVE INDEX	1.43 ± 0.05	Manuf. data
NONVOLATILE CONTENT	60 ± 2%	Manuf. data
SHELF LIFE	6 months	25°C Refrigeration may extend shelf life

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−115 to 232°C	Manuf. data
OUTGASSING	TML = 0.30% RML = 0.25% CVCM = 0.01%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— CV-1144-0 is normally self bonding. If a primer is required, McGhan-Nusil SP-120 silicone primer is recommended.
— Cure time at 25°C and 50% RH:
Tack-free time - 1 hour
To handle - 24 hours

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-10 REVISION : 2 DATE : June 1990

TRADE NAME	: CV-1152
CHEMICAL COMPOSITION	: DIMETHYL DIPHENYL SILICONE POLYMER
TYPE OF PRODUCT	: CONTROLLED VOLATILITY RTV SILICONE CONFORMAL COATING
MANUFACTURER	: McGhan-Nusil Corp. 1150 Mark Avenue Carpinteria, CA 93013 USA European Agent: Dunlop Adhesives Chester Road Birmingham B35 7AL UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
APPEARANCE	Clear, elastomer	
VISCOSITY	7000 ± 1000 cps	Manuf. data
SPECIFIC GRAVITY	1.00 ± 0.02 g cm^{-3}	25°C
REFRACTIVE INDEX	1.43 ± 0.005	Manuf. data
DIELECTRIC STRENGTH	500 V/mil	Manuf. data
VOLUME RESISTIVITY	1×10^{15} Ω cm	Manuf. data
SHELF LIFE	6 months	25°C Refrigeration may extend shelf life

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−115 to 232°C	Manuf. data
OUTGASSING	TML = 0.18% RML = 0.15% CVCM = 0.00%	ESA PSS-01-702
OFFGASSING/TOXICITY	Pass	NHB 8060.1B
FLAMMABILITY	Pass (24.5% O_2	NHB 8060.1B

4. SPECIAL RECOMMENDATION

— CV-1152 is normally self bonding. If a primer is required, McGhan-Nusil SP-120 silicone primer is recommended.
— Cure time at 25°C and 50% RH:
Tack-free time - 1 hour
Full cure - 7 days

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-11 REVISION : 2 DATE : June 1990

TRADE NAME	: CV-1500
CHEMICAL COMPOSITION	: PHENYL SILICONE POLYMER-CARBON
TYPE OF PRODUCT	: CONTROLLED VOLATILITY ELECTRICALLY CONDUCTIVE RTV SILICONE, ADHESIVE, SEALANT
MANUFACTURER	: McGhan-Nusil Corp. 1150 Mark Avenue Carpinteria, CA 93013 USA European Agent: Dunlop Adhesives Chester Road Birmingham B35 7AL UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
APPEARANCE	Black, elastomer	
CONSISTENCY	Non-slump	
SPECIFIC GRAVITY	1.24 ± 0.02 g cm^{-3}	25°C
HARDNESS	60 minimum	Durometer, Type A
TENSILE STRENGTH	3.1 MPa minimum	Manuf. data
ELONGATION	20% minimum	Manuf. data
VOLUME RESISTIVITY	1.5 Ω cm	Manuf. data
SHELF LIFE	6 months	25°C Refrigeration may extend shelf life

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−115 to 260°C	Manuf. data
OUTGASSING	TML = 0.29% RML = 0.25% CVCM = 0.02%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704

4. SPECIAL RECOMMENDATION

— A primer may be required in some applications. McGhan-Nusil SP-120 silicone primer is recommended.

— Cure time at 25°C and 50% RH:
Tack-free time - 30 minutes
Full cure - 7 days

Thick sections may require extended cure times.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-12 REVISION : 2 DATE : June 1990

TRADE NAME	: CV-2500
CHEMICAL COMPOSITION	: SILICONE
TYPE OF PRODUCT	: CONTROLLED VOLATILITY RTV SILICONE, ADHESIVE, POTTING
MANUFACTURER	: McGhan-Nusil Corp. 1150 Mark Avenue Carpinteria, CA 93013 USA European Agent: Dunlop Adhesives Chester Road Birmingham B35 7AL UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
APPEARANCE	Clear, elastomer	
POT LIFE	2 hours minimum	
VISCOSITY	8000 ± 2000 cps	Manuf. data
SPECIFIC GRAVITY	1.04 ± 0.02 g cm^{-3}	25°C
HARDNESS	50 minimum	Durometer, Type A
TENSILE STRENGTH	4.1 MPa minimum	Manuf. data
ELONGATION	80% minimum	Manuf. data
DIELECTRIC STRENGTH	550 V/mil	Manuf. data
VOLUME RESISTIVITY	1 × 10^{15} Ω cm	Manuf. data
SHELF LIFE	6 months	25°C Refrigeration may extend shelf life

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.16% RML = 0.16% CVCM = 0.01%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704

4. SPECIAL RECOMMENDATION

— A primer may be required in some bonding applications. McGhan-Nusil CF1-135 silicone primer is recommended.
— Cure time at 25°C: 24 hours to handle carefully; 7 days to cure fully

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-13 REVISION : 2 DATE : June 1990

TRADE NAME	: CV-2566
CHEMICAL COMPOSITION	: DIPHENYL/DIMETHYL SILICONE POLYMER
TYPE OF PRODUCT	: CONTROLLED VOLATILITY RTV SILICONE ADHESIVE, COATING, SEALING, POTTING
MANUFACTURER	: McGhan-Nusil Corp. 1150 Mark Avenue Carpinteria, CA 93013 USA European Agent: Dunlop Adhesives Chester Road Birmingham B35 7AL UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
APPEARANCE	Red, elastomer	
POT LIFE	60 minutes minimum	
VISCOSITY	30 000 to 70 000 cps	25°C
SPECIFIC GRAVITY	1.46 to 1.52 g cm^{-3}	
HARDNESS	50 minimum	Durometer, Type A
TENSILE STRENGTH	3.4 MPa minimum	Manuf. data
ELONGATION	100% minimum	Manuf. data
TEAR STRENGTH	23 ppi minimum	Die B
DIELECTRIC STRENGTH	500 V/mil	Manuf. data
VOLUME RESISTIVITY	1×10^{15} Ω cm	25°C
SHELF LIFE	6 months	Refrigeration may extend shelf life

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−115 to 300°C	Manuf. data
OUTGASSING	TML = 0.40% RML = 0.28% CVCM = 0.01%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704

4. SPECIAL RECOMMENDATION

— A primer may be required in some bonding applications. McGhan-Nusil SP-120 silicone primer is recommended.
— Cure time at 25°C: 24 hours to handle carefully; 7 days to cure fully

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : C-14 REVISION : 2 DATE : June 1990

TRADE NAME	: CV-2640
CHEMICAL COMPOSITION	: PHENYL SILICONE - CARBON
TYPE OF PRODUCT	: CONTROLLED VOLATILITY ELECTRICALLY CONDUCTIVE RTV SILICONE FOR EMI AND RF SHIELDING
MANUFACTURER	: McGhan-Nusil Corp. 1150 Mark Avenue Carpinteria, CA 93013 USA European Agent: Dunlop Adhesives Chester Road Birmingham B35 7AL UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
APPEARANCE	Black, elastomer	
POT LIFE	1 hour minimum	
VISCOSITY	100 000 ± 20 000 cps	Manuf. data
SPECIFIC GRAVITY	1.25 ± 0.05 g cm^{-3}	25°C
HARDNESS	50 minimum	Durometer, Type A
TENSILE STRENGTH	0.5 MPa minimum	Manuf. data
ELONGATION	25% minimum	Manuf. data
VOLUME RESISTIVITY	10.0 Ω cm maximum	Manuf. data
SHELF LIFE	6 months	25°C Refrigeration may extend shelf life

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−115 to 260°C	Manuf. data
OUTGASSING	TML = 0.19% RML = 0.17% CVCM = 0.00%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704

4. SPECIAL RECOMMENDATION

— A primer may be required in some bonding applications. McGhan-Nusil CF1-135 silicone primer is recommended.
— Base should be mixed thoroughly before use to dissipate filler.
— Cure time at 25°C: 24 hours to handle carefully; 7 days to cure fully

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-1 REVISION : 2 DATE : June 1990

TRADE NAME	: D.C. 6-1104
CHEMICAL COMPOSITION	: SILICONE
TYPE OF PRODUCT	: ONE PART ADHESIVE, SEALANT
MANUFACTURER	: Dow Corning Corp. Midland Michigan USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: VERY HIGH
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.12 g cm^{-3}	at 25°C
HARDNESS	27	Shore A
TENSILE STRENGTH	340 N cm^{-2}	
SHELF LIFE	3 months	
THERMAL EXPANSION	38.7 × 10^{-5} $°C^{-1}$	10 to 90°C - TMA
GLASS TRANS. TEMP.	−117°C	TMA
SPECIFIC HEAT	1.56 J g^{-1} $°C^{-1}$	0°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-1 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−65 to 150°C	Long term
OUTGASSING	TML = 0.18% RML = 0.14% CVCM = 0.03%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
FLAMMABILITY	Pass (23.8% O_2	NASA NHB 8060.1B
TOXICITY/OFFGASSING	Pass	NASA NHB 8060.1A

4. SPECIAL RECOMMENDATION

— Recommended cure: 7 days at room temperature.
— This product cures with air moisture and should not be used to bond large nonporous items.
— This product does not evolve corrosive products during cure.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-2 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: DC 340
CHEMICAL COMPOSITION	: SILICONE COMPOUND, FILLED
TYPE OF PRODUCT	: HEAT-TRANSFER COMPOUND
MANUFACTURER	: Dow Corning Corp. Midland Michigan USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.3 g cm^{-3}	Manuf. data
PENETRATION (WORKED)	250	ASTM D217
THERMAL CONDUCTIVITY	4×10^{-3} W cm^{-1} $°C^{-1}$	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-2 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.33% RML = 0.31% CVCM = 0.11%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— This product is only tolerated in small quantity and must be fully sealed around with an approved sealant to prevent creep.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-3 REVISION : 2 DATE : June 1990

TRADE NAME	: D.C. 93500
CHEMICAL COMPOSITION	: SILICONE
TYPE OF PRODUCT	: TWO-PART ADHESIVE, POTTING, COATING
MANUFACTURER	: Dow Corning Corp. Midland Michigan USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: VERY HIGH
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE*	REMARKS
SPECIFIC GRAVITY	1.08 g cm^{-3}	at 25°C
VISCOSITY	80 poises	at 25°C
POT LIFE	1 hour	at 25°C
TENSILE STRENGTH	580 N cm^{-2}	ASTM D412 die C
HARDNESS	46	Shore A
THERMAL EXPANSION COEFFICIENT	3×10^{-4} °C^{-1}	Manuf. data
THERMAL CONDUCTIVITY	1.46×10^{-3} W cm^{-1} °C^{-1}	Manuf. data
ELECTRICAL RESISTIVITY	6.9×10^{13} Ω cm	ASTM D257
DIELECTRIC CONSTANT	2.75	100 Hz ASTM D150
LOSS FACTOR	0.0011	100 Hz ASTM D150
DIELECTRIC STRENGTH	570 V/mil	ASTM D149
OPTICAL TRANSMISSION	97.5%	Solar cell measurement
SHELF LIFE	6 months	Manuf. data
GLASS TRANSITION TEMPERATURE	−84°C	TMA
SPECIFIC HEAT	0.867 J g^{-1} °C^{-1}	0°C
	*standard version	

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−65 to 200°C	Long term
OUTGASSING	TML = 0.30% RML = 0.28% CVCM = 0.03%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
OXYGEN INDEX	49.5	ESA PSS-01-721
IONISING RADIATION	200 Mrad	Manuf. data
FLAMMABILITY	Pass (24.5% O_2 (tested as coating on FR4 PCB)	NASA NHB 8060.1B

4. SPECIAL RECOMMENDATION

- Recommended cure: 7 days at room temperature.
- Where high adhesion is required, use a primer: DC 1200 (red) or DC 92023 (clear).
- DC 93500 can be filled with silica for thixotropy and with silver powder for electrical conductance. In these cases, a high-temperature cure is necessary (24 h at 80°C).
- Sensitive to contamination, particularly when cured in thin layers.
- Three commercial versions are available:
  DC 93500 thixotropic
  DC 93500 high viscosity
  DC 93500 low viscosity.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-4 REVISION : 2 DATE : June 1990

TRADE NAME	: DUNMORE AE 05090
CHEMICAL COMPOSITION	: POLYIMIDE (KAPTON-HN) ALUMINISED WITH PROTECTIVE COATING
TYPE OF PRODUCT	: THERMAL CONTROL POLYMER FILM
MANUFACTURER	: Dunmore Corporation 207 Penns Trail Newtown, PA 18940 USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.42 g cm^{-3}	Dupont's data
THICKNESS	7.6 μm	Manufacturer's data
TENSILE STRENGTH	1.7×10^{4} N cm^{-2}	Dupont's data
THERMAL EXPANSION COEFFICIENT	2×10^{-5} °C^{-1}	Dupont's data
THERMAL CONDUCTIVITY	2.8×10^{-4} W cm^{-1} °C^{-1}	Dupont's data (@ 23°C)
SPECIFIC HEAT	1.09 J g^{-1} °C^{-1}	Dupont's data (@ 23°C)
VOLUME RESISTIVITY	1×10^{12} Ω cm	Dupont's data (@ 23°C)
SOLAR ABSORPTANCE	0.14	Manuf. data
NORMAL EMITTANCE	0.030	Manuf. data
STANDARD WIDTH	122 cm	Manuf. data

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−190 to 204°C	Manuf. data
OUTGASSING	TML = 0.64% CVCM = 0.03%	ASTM E-595
MOISTURE ABSORPTION	1.8% @ 50% RH	Dupont's data

4. SPECIAL RECOMMENDATION

— Complies with MIL-STD-810 Method 509 after 24 hours exposure to 5% salt fog, and ASTM B-117.

— Intended primarily for use as inner layers on MLI thermal-control blankets for space vehicles where condensation may be a problem.

— Also available in 12.5, 25, 51 and 76 μm thicknesses.

— The seven-digit Dunmore part number (2 letters and 5 figures) must be designated for precise material description.

— Perforation or embossed versions of the above-mentioned films are available, although film thickness may control selection. Patterns are to be clarified at the time of ordering.

— These films can be aluminised and corrosion-resistant coated on one or both sides.

— Protective coating is a proprietary, fully cured clear overcoat which protects the aluminised surface from moisture that causes corrosion.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-5 REVISION : 2 DATE : June 1990

TRADE NAME	: DUNMORE AM 05326
CHEMICAL COMPOSITION	: POLYIMIDE (KAPTON-HN) ALUMINISED/ACRYLIC ADHESIVE
TYPE OF PRODUCT	: ALUMINISED KAPTON HN, ACRYLIC (Y966) PRESSURE-SENSITIVE RELEASE LINER
MANUFACTURER	: Dunmore Corporation 207 Penns Trail Newtown, PA 18940 USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.42 g cm^{-3}	Dupont's data
THICKNESS	25 μm	Dupont's data
TENSILE STRENGTH	1.7×10^{4} N cm^{-2}	Dupont's data
THERMAL EXPANSION COEFFICIENT	2×10^{-5} $°C^{-1}$	Dupont's data (−14°C to 38°C)
THERMAL CONDUCTIVITY	1.55×10^{-4} W cm^{-1} $°C^{-1}$	Dupont's data (@ 23°C)
SPECIFIC HEAT	1.09 J g^{-1} $°C^{-1}$	Dupont's data (@ 23°C)
VOLUME RESISTIVITY	1.5×10^{17} Ω cm	Dupont's data (@ 38% RH)
SOLAR ABSORPTANCE	0.15	Manuf. data
NORMAL EMITTANCE	0.60	Typical value only
STANDARD WIDTH	2.54 cm	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-5 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−40 to 160°C	Manuf. data
OUTGASSING	TML = 0.70% CVCM = 0.04%	3M data/NASA 1061 and ASTM E-595
MOISTURE ABSORPTION	1.8% @ 50% RH	Dupont's data (@ 23°C)
ADHESION	1417 g.inch-width	Manuf. data/ASTM D3330
TOXICITY/OFFGASSING	Pass	NHB 8060.1A

4. SPECIAL RECOMMENDATION

— All tapes are a standard length of 105 ft ± 5%. (Maximum length available is ca. 160 ft.).

— All tapes are wound on a 3 ± 0.5 in dia. core.

— Recommended shelf life is a period of one year after date of manufacture, when tape has been stored properly at normal room temperature.

— Kapton-HN/Y966 acrylic pressure-sensitive tapes can be perforated.

— This product is also available with Dunmore's 'corrosion-resistant coating'.

— 'Y966' acrylic P/S release liner can also be applied to the metallised surface to provide second-surface mirror capabilities, if desired.

— 'Y966' acrylic P/S release liner can also be applied to 51, 76 and 125 μm thick films.

— The Dunmore item number (two letters and five figures) must be designated for precise material description.

— 'Y966' high-temperature acrylic tapes are primarily used when high-temperature performance and excellent bond strength are required.

— Solar absorptance value is measured on the aluminised side only.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-6 REVISION : 2 DATE : June 1990

TRADE NAME	: DUNMORE DE 028
CHEMICAL COMPOSITION	: POLYETHYLENE TEREPHTHALATE/PETP ALUMINISED
TYPE OF PRODUCT	: THERMOPLASTIC FILM
MANUFACTURER	: Dunmore Corporation 207 Penns Trail Newtown, PA 18940 USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW TO MEDIUM
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.4 g cm^{-3}	Dupont's data
THICKNESS	6.3 μm	Manuf. data
TENSILE STRENGTH	2.1 $\times$ 10^{4} N cm^{-2}	Dupont's data (@ 25°C)
THERMAL EXPANSION COEFFICIENT	3 $\times$ 10^{-5} °C^{-1}	Dupont's data
THERMAL CONDUCTIVITY	6.1 $\times$ 10^{-3} W cm^{-1} °C^{-1}	Dupont's data
SPECIFIC HEAT	1.3 J g^{-1} °C^{-1}	Dupont's data
SURFACE RESISTANCE	1 $\times$ 10^{16} Ω	Dupont's data (@ 25°C, 30% RH)
VOLUME RESISTIVITY	1 $\times$ 10^{18} Ω cm	Dupont's data (@ 25°C)
SOLAR ABSORPTANCE	0.07	ASTM E 424 Method A
NORMAL EMITTANCE	0.020	Manuf. data
STANDARD WIDTH	142 cm	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-6 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−180 to 150°C	Dupont's data
OUTGASSING	TML = 0.29% CVCM = 0.00%	ASTM E-595
MOISTURE ABSORPTION	Less than 0.8% @ 23°C	ASTM D 570-63
TOXICITY/OFFGASSING	Pass	NHB 8060.1A

4. SPECIAL RECOMMENDATION

— Normal use is for internal sheets of multilayer insulation. Use depends on blanket type and requirement. Suitable venting should be considered for blanket use. Can also be used in crinkled form for cryogenic insulation.

— This product is available with vacuum-deposited aluminium on one or both sides.

— Available in widths up to 1574 mm on special request.

— The five-digit Dunmore item number (2 letters and 3 figures) must be designated for precise material description.

— This product can be perforated, embossed or crinkled if desired. Patterns are to be specified at the time of ordering.

— Also available in 12.5, 25, 51 and 76 μm thicknesses.

— Normal emittance value is measured on the aluminised surface.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-7 REVISION : 2 DATE : June 1990

TRADE NAME	: DUNMORE DE 320
CHEMICAL COMPOSITION	: POLYIMIDE (KAPTON HN) ALUMINISED
TYPE OF PRODUCT	: THERMAL-CONTROL POLYMER FILM
MANUFACTURER	: Dunmore Corporation 207 Penns Trail Newtown, PA 18940 USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.42 g cm^{-3}	Dupont's data
THICKNESS	25 μm	Dupont/Manuf. data
TENSILE STRENGTH	1.7×10^{4} N cm^{-2}	Dupont's data (@ 25°C)
THERMAL EXPANSION COEFFICIENT	2×10^{-5} $°C^{-1}$	Dupont's data (@ −14°C to 38°C)
THERMAL CONDUCTIVITY	1.55×10^{-3} W cm^{-1} $°C^{-1}$	Dupont's data (@ 23°C)
SPECIFIC HEAT	1.09 J g^{-1} $°C^{-1}$	Dupont's data (@ 23°C)
VOLUME RESISTIVITY	1.5×10^{17} Ω cm	Dupont's data
SOLAR ABSORPTANCE	0.14	Manuf. data
NORMAL EMITTANCE	0.02	Manuf. data
STANDARD WIDTH	112 cm	Manuf. data

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−190 to 204°C	Average exposure range
OUTGASSING	TML = 0.21% CVCM = 0.00%	ASTM E-595
MOISTURE ABSORPTION	1.8% @ 23°C and 50% RH	Dupont's data

4. SPECIAL RECOMMENDATION

— Normal use is for external sheet on multilayer insulation. Suitable venting must be provided, where applicable.

— This product is also available in 7.6, 12.6, 51.76 and 125 μm thicknesses.

— 7.6 and 12.6 μm grades are available in widths up to 1270 mm; 25 to 125 μm grades in widths up to 1524 mm.

— The five-digit Dunmore part number (2 letters and 3 figures) must be designated for precise material description.

— Perforated or embossed versions of the above-mentioned films are available. Patterns are to be specified at the time of ordering (film thickness may determine selection).

— These products can also be aluminised on both sides, if desired.

— Normal emittance value of the aluminised surface is 0.02; the film side has an emittance value of 0.70.

— Solar absorptance value is measured on the aluminised surface.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : D-8 REVISION : 2 DATE : June 1990

TRADE NAME	: DUNMORE DE 430
CHEMICAL COMPOSITION	: FLUOROCARBON (FEP-TYPE C) ALUMINISED
TYPE OF PRODUCT	: THERMAL-CONTROL PLASTIC FILM
MANUFACTURER	: Dunmore Corporation 207 Penns Trail Newtown, PA 18940 USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.15 g cm^{-3}	Dupont's data
THICKNESS	50 μm	Manuf. data
TENSILE STRENGTH	2.1 × 10^{3} N cm^{-2}	Manuf. data
THERMAL EXPANSION COEFFICIENT	8.93 × 10^{-5} $°C^{-1}$	Dupont's data (−50°C to 70°C)
THERMAL CONDUCTIVITY	1.94 × 10^{-3} W cm^{-1} $°C^{-1}$	Dupont's data
SPECIFIC HEAT	1.17 J g^{-1} $°C^{-1}$	Dupont's data (−50°C to 70°C)
DIELECTRIC STRENGTH (of the FEP film)	160 kV/mm	Dupont's data (@ 23°C)
SURFACE RESISTANCE	> 10^{15} Ω	Dupont's data/ASTM D257-61
VOLUME RESISTIVITY	> 10^{17} Ω cm	Dupont's data (@ 23°C) and 38% RH)
SOLAR ABSORPTANCE	0.07	ASTM E424 Method A
NORMAL EMITTANCE	0.02	ASTM E-408 Method A
STANDARD WIDTH	122 cm	Manuf. data

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−175 to 150°C Max operating temp.: 205°C	Dupont's data
OUTGASSING	TML = 0.21% CVCM = 0.00%	ASTM E-595
MOISTURE ABSORPTION	1.3% @ 50% RH	Dupont's data (@ 23°C)

4. SPECIAL RECOMMENDATION

— Normal use is for external sheet on multilayer insulation. Suitable venting is recommended.

— This product is also available in 8, 12, 75 and 125 μm thicknesses.

— Available in a range of widths, depending on film thickness.

— Also available in two(2)-side-treated form for VDAL bonding, designated as Type C-20; to be specified at time of purchase.

— The five-digit Dunmore part number (2 letters and 3 figures) must be designated for precise material description.

— Perforated versions of the above-mentioned films are available. Patterns are to be specified at the time of ordering.

— Solar absorptance value measured on the aluminised surface is 0.07 and on the film side 0.10.

— Normal emittance value measured on the aluminised surface is 0.02; the film side has an emittance value of 0.67.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-1 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: ECCOBOND SOLDER 56C
CHEMICAL COMPOSITION	: EPOXY - SILVER LOADED
TYPE OF PRODUCT	: ELECTRICALLY CONDUCTIVE ADHESIVE PASTE
MANUFACTURER	: EMERSON & CUMING (EMERSON & CUMING EUROPE CANTON OEVEL MASS BELGIUM) USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SHEAR STRENGTH	565 N cm^{-2}	Manuf. data
THERMAL EXPANSION COEFF.	3.6×10^{-5} $°C^{-1}$	Manuf. data
THERMAL CONDUCTIVITY	5.8×10^{-2} W cm^{-1} $°C^{-1}$	Manuf. data
ELECTRICAL RESISTIVITY	2×10^{-4} Ω cm	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-1 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 175°C	Manuf. data
OUTGASSING	TML = 0.30% RML = 0.20% CVCM = 0.02%	ESA PSS-01-702
TOXICITY/OFFGASSING	Pass	NHB 8060-1A
FLAMMABILITY	Pass 23.8% O_2	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— Recommended proportions are 100 pbw resin + 2.5 pbw catalyst 9.
— Recommended cure is 16 hours at 50°C.
— Peel strength of this adhesive is low. Cycling to subzero temperature can be detrimental.
— Electrical bonds made with this adhesive to metals having a different EMF are likely to degrade in a humid environment, particularly if the metal layers are thin (e.g. vacuum deposits).

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-2 REVISION : 3 DATE : January 1994

TRADE NAME	: ECCOFOAM FPH
CHEMICAL COMPOSITION	: POLYURETHANE
TYPE OF PRODUCT	: CLOSED CELL POTTING FOAM
MANUFACTURER	: EMERSON & CUMING (EMERSON & CUMING EUROPE CANTON OEVEL MASS BELGIUM) USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	0.03 to 0.22 g cm^{-3}	Manuf. data
COMPRESSIVE STRENGTH	22 to 430 N cm^{-2}	Manuf. data
THERMAL EXPANSION COEFF.	2.5×10^{-5} to 5×10^{-5} $°C^{-1}$	Manuf. data
THERMAL CONDUCTIVITY	2.1×10^{-4} to 6.3×10^{-4} W cm^{-1} $°C^{-1}$	Manuf. data
DIELECTRIC CONSTANT	1.04 to 1.25	10^4 to 10^{10} Hz
LOSS FACTOR	10^{-3} to 5×10^{-3}	10^{10} Hz
DIELECTRIC STRENGTH	1.6 kV mm^{-1}	Manuf. data
SHELF LIFE	6 months	

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-2 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 135°C	Long term
OUTGASSING	TML = 2.1% RML = 0.6% CVCM = 0.01%	ESA PSS-01-702
OXYGEN INDEX	20	ESA PSS-01-721
TOXICITY/OFFGASSING	Pass	NHB 8060-1A
WATER ABSORPTION	3 to 0.1% (depending on specific gravity)	
FLAMMABILITY	Fail 21% O_2	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— In general, lower densities are used for space hardware and the recommended proportions are 100 pbw resin + 65 pbw catalyst 12-2H.
— Recommended process is: foaming four hours at 40°C + postcure 48 hours at 100°C.
— Low-density foam may distort near 100°C.
— Not acceptable in manned spacecraft (even when the 'fire-resistant' FPH-FR is concerned) unless fully enclosed with no ignition source present.
— Quality-control test according to ESA PSS-01-702 recommended.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-3 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: ECCOSHIELD PST-CA
CHEMICAL COMPOSITION	: ALUMINIUM
TYPE OF PRODUCT	: ELECTRICALLY CONDUCTIVE ADHESIVE TAPE
MANUFACTURER	: EMERSON & CUMING (EMERSON & CUMING EUROPE CANTON OEVEL MASS BELGIUM) USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
THICKNESS	75 μm	Backing only
PEEL STRENGTH	0.8 N cm^{-1}	Manuf. data
ELECTRICAL RESISTIVITY	$< 10^{-3}$ Ω cm	Manuf. data
SOLAR ABSORPTANCE	0.205	ESA PSS-01-709
HEMISPHERICAL EMITTANCE	0.04	ESA PSS-01-709
SHELF LIFE	1 year	at 25°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-3 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 120°C	Long term
OUTGASSING & CONTAMINATION	TML = 0.21% CVCM = 0.0%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— Perforate the tape evenly to avoid lifting under vacuum.
— Press down firmly with roller for maximum adhesion.
— Maximum width available: 10.2 cm.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-4 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: ECCOSHIELD SV-R
CHEMICAL COMPOSITION	: METAL-FILLED SILICONE
TYPE OF PRODUCT	: ELECTRICALLY CONDUCTIVE RUBBER, GASKET
MANUFACTURER	: EMERSON & CUMING (EMERSON & CUMING EUROPE CANTON OEVEL MASS BELGIUM) USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	3.5 g cm^{-3}	Manuf. data
TENSILE STRENGTH	106 N cm^{-2}	Manuf. data
HARDNESS	40	Shore A
THERMAL CONDUCTIVITY	4.3×10^{-2} W $cm^{-1}{}^{\circ}C^{-1}$	Manuf. data
ELECTRICAL RESISTIVITY	10^{-3} Ω cm	Manuf. data

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 200°C	Long term
OUTGASSING	TML = 0.3% RML = 0.3% CVCM = 0.08%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— Standard dimension of sheets is 30.5 cm × 15.25 cm × (0.5, 1 or 1.5) mm.
— The adhesive proposed by the manufacturer is 'ECCOSHIELD RVS', which is not qualified for space use and is thus forbidden.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-5 REVISION : 2 DATE : June 1990

TRADE NAME	: ECCOSORB AN
CHEMICAL COMPOSITION	: LOADED POLYURETHANE
TYPE OF PRODUCT	: FLEXIBLE FOAM MICROWAVE ABSORBER
MANUFACTURER	: Emerson & Cuming Europe Oevel Belgium

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: VARIABLE
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
FREQUENCY RANGE	455 MHz	Manuf. data
MASS PER UNIT AREA	0.05 to 1 g cm^{-2}	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-5 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Max. 150°C	Long term
OUTGASSING	TML = 1.30% RML = 0.4% CVCM = 0.04%	ESA PSS-01-702 (after cleaning*)
FLAMMABILITY	No ignition	NHB 8060.1B

4. SPECIAL RECOMMENDATION

* Cleaning process according to ESA PSS-01-727 compulsory.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-6 REVISION : 3 DATE : January 1994

TRADE NAME	: ELECTRODAG 501
CHEMICAL COMPOSITION	: FLUORINATED BINDER
TYPE OF PRODUCT	: ELECTRICALLY CONDUCTIVE BLACK PAINT
MANUFACTURER	: ACHESON COLLOIDEN POSTBUS 1 NL-9697 ZG SCHEEMDA THE NETHERLANDS

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	:
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLID CONTENT WEIGHT	14.7% 30 g/m^2 for layer 20μm thick	Manuf. data
VISCOSITY	800 $\pm$ 200 cps, no. 2 spindle at 20 rpm Brookfield	Manuf. data
ELECTRICAL SURFACE RESISTIVITY	1000 Ω for 1 mil thickness	Manuf. data
VOLUME RESISTIVITY	2.54 Ω cm	Manuf. data
TEMP. RANGE * SERVICE TEMP. *	-40°C to over 260°C 275°C	Manuf. data
SHELF LIFE	6 months	
SOLAR ABSORPTANCE	0.965	ESA PSS-01-709
NORMAL EMITTANCE	0.829	ESA PSS-01-709
* Can withstand 400°C for short period		

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-6 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.86% RML = 0.44% CVCM = 0.00%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
RADIATION	$\Delta\alpha_s$ = 0.01	5 years GEO
FLAMMABILITY	Pass (21% O_2) Kapton substrate	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— Each lot of this paint must be checked for its normal emittance value, since large variations have been observed in this parameter, which is not systematically controlled by the manufacturer.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-7 REVISION : 2 DATE : June 1990

TRADE NAME	: ELECTRODAG 503
CHEMICAL COMPOSITION	: FLUOROCARBON BINDER/SILVER PIGMENT
TYPE OF PRODUCT	: ELECTRICALLY CONDUCTIVE SILVER PAINT
MANUFACTURER	: Acheson Colloiden BV Postbus 1 NL-9697 ZG Scheemda The Netherlands

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	:
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT	62%	Manuf. data
VISCOSITY	1200 $\pm$300 cps, No. 2 spindle at 20 rpm BROOKFIELD	Manuf. data
ELECTRICAL SURFACE RESISTIVITY	0.05 Ω for 1 Mil thickness	Manuf. data
VOLUME RESISTIVITY	127 $\times$ 10^{-6} Ω cm	Manuf. data
TEMPERATURE RANGE	-40°C to over 260°C	Manuf. data
SERVICE TEMPERATURE	275°C	Manuf. data
SHELF LIFE	6 months	Manuf. data
SOLAR ABSORPTANCE	0.370	ESA PSS-01-709
NORMAL EMITTANCE	0.440	ESA PSS-01-709
SPECIFIC HEAT	0.295 J g^{-1} $°C^{-1}$	0°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-7 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.22% RML = 0.21% CVCM = 0.06%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : E-8 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: EPIKOTE 828/EPIKURE Z (100 pbw/20 pbw)
CHEMICAL COMPOSITION	: EPOXY, AROMATIC AMINE CURED
TYPE OF PRODUCT	: TWO-PART POTTING RESIN
MANUFACTURER	: SHELL DEN HAAG NL

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
POT LIFE	8 hours	at 25°C
VISCOSITY	9000 cps	at 25°C
SPECIFIC GRAVITY	1.2 g cm^{-3}	
HARDNESS	105	Rockwell M
TENSILE STRENGTH	9200 N cm^{-2}	at 25°C
TENSILE MODULUS	2.55×10^5 N cm^{-2}	at 25°C
IMPACT STRENGTH	0.5 ft-lb/inch of notch	Izod
THERMAL EXPANSION COEFF.	5.1×10^{-5} $°C^{-1}$	−50°C to +50°C
VOLUME RESISTIVITY	2×10^5 Ω cm	ASTM D257-61 at 23°C
DIELECTRIC CONSTANT	3.9	at 23°C 1 kHz
LOSS FACTOR	0.02	at 23°C 1 kHz

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 130°C	Manuf. data
OUTGASSING	TML = 0.6% RML = 0.3% CVCM = 0.02%	ESA PSS-01-702
WATER ABSORPTION	0.67%	24 h - boiling water

4. SPECIAL RECOMMENDATION

— Recommended cure is 2 hours at 75°C + 2 hours at 135°C.
— Different fillers may be used (alumina, silica, glass microballoons) to adjust the properties to the application. These fillers must be carefully dried before mixing.
— Epikote 828 may be used with a number of other hardeners, some of which are not suitable for space use.
— Quality-control test according to ESA PSS-01-702 recommended.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : F-1 REVISION : 3 DATE : January 1994

TRADE NAME	: FOMBLIN Z25
CHEMICAL COMPOSITION	: PERFLUORALKYLETHER
TYPE OF PRODUCT	: OIL
MANUFACTURER	: MONTEDISON MILAN ITALY

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: AVAILABLE AS RAW STOCK Z; LIMITED LABORATORY PRODUCTION OF Z25 AVAILABLE FROM ESTEC.
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED IN EUROPE; WIDER IN USA AS BRAY MICRONIC 815Z.

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
KINEMATIC VISCOSITY	(20°C, 68°F) 250 ± 50 cs (38°C, 100°F) 140 ± 30 cs (99°C, 210°F) 45 ± 10 cs	
ASTM SLOPE	0.30 ± 0.3	
VISCOSITY INDEX	360 ± 10	
EXTRAPOLATED VAPOUR PRESSURE	(20°C.68°F) $< 5 \times 10^{-12}$ torr (93.3°C, 200°F) $5 \pm 4 \times 10^{-9}$ torr (204.4°C, 400°F) $5 \pm 4 \times 10^{-6}$ torr	
POUR POINT	−60 ± 10°C	
SPECIFIC GRAVITY	1.85 ± 0.05 g cm^{-3}	
VOLATILITY LOSS	<0.1%	149°C - 22 h
INTERFACIAL TENSION	40 ± 5 dyn cm^{-1}	L/W
AVERAGE MOLECULAR WEIGHT	15000	

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : F-1 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.06% RML = 0.05% CVCM = 0.01%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— May show some undesirable reaction to metal surfaces after long-term operation. Any long-term use should be discussed with the European Space Tribology Laboratory (ESTL) before the design is finalised.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : G-1 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: GUDE SPACE D96
CHEMICAL COMPOSITION	: DACRON FIBRES (IMPREGNATED)
TYPE OF PRODUCT	: LACING TAPE, FLAT BRAID
MANUFACTURER	: GUDEBROD BROS. SILK NEW YORK, N.Y. USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
STRENGTH	18 to 600 N	Manuf. data
WIDTH	0.09 to 0.5 cm	Manuf. data
THICKNESS	0.012 to 0.04 cm	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : G-1 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−73°C to 177°C	Manuf. dat
OUTGASSING	TML = 0.5% RML = 0.4% CVCM = 0.04%	ESA PSS-01-702 (after cleaning: see section 4, below)
FLAMMABILITY	Burns (21% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— Cleaning according to ESA PSS-01-732 is compulsory.
— Nonimpregnated version exists under the name Super Gude Space PT and this does not require cleaning.
— If used as individual ties on nonflammable insulation, this material may be acceptable from the point of view of flammability. Configuration must be discussed beforehand.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : H-1 REVISION : 2 DATE : June 1990

TRADE NAME	: HOSTAFORM C9021
CHEMICAL COMPOSITION	: ACETAL COPOLYMER
TYPE OF PRODUCT	: THERMOPLASTIC
MANUFACTURER	: Ticona Polymerwerke Kelsterbach FRG

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.41 g cm^{-3}	Manuf. data
TENSILE STRENGTH	7.3×10^3 N cm^{-2}	Manuf. data
TENSILE MODULUS	3.5×10^5 N cm^{-2}	Manuf. data
HARDNESS	85	Shorre D
IMPACT STRENGTH	9 Kp cm cm^{-2}	Notched. Manuf. data DIN spec.
THERMAL CONDUCTIVITY	3.1×10^{-3} W cm^{-1} °C^{-1}	Manuf. data
SPECIFIC HEAT	1.46 J g^{-1} °C^{-1}	Manuf. data
THERMAL EXPANSION COEFFICIENT	1.1×10^{-4} °C^{-1}	Manuf. data
VOLUME RESISTIVITY	10^{15} Ω cm	Manuf. data
DIELECTRIC CONSTANT	4	50 Hz, 20°C
DISSIPATION FACTOR	1.1×10^{-3}	Manuf. data
DIELECTRIC STRENGTH	> 700 kV cm^{-1}	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : H-1 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−40°C to 100°C	Long term
OUTGASSING	TML = 0.4% RML = 0.2% CVCM = 0.02%	ESA PSS-01-702
IONISING RADIATION	5 Mrad	Mechanical properties
WATER ABSORPTION	0.6%	Immersion
OXYGEN INDEX	> 15	Manuf. data
FLAMMABILITY	Burnt	NHB 8060.1B

4. SPECIAL RECOMMENDATION

— This material may be reinforced by glass fibres (e.g. Hostaform C9021 GV1/30) or carbon fibres.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : K-1 REVISION : 2 DATE : June 1990

TRADE NAME	: KAPTON H
CHEMICAL COMPOSITION	: POLYIMIDE
TYPE OF PRODUCT	: PLASTIC FILM
MANUFACTURER	: Du Pont (Du Pont International Wilmington Geneva Delaware Switzerland) USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE*	REMARKS
SPECIFIC GRAVITY	1.42 g cm^{-3}	ASTM D1505-63T
TENSILE STRENGTH	1.7×10^4 N cm^{-2}	ASTM D882-64T
TENSILE MODULUS	3×10^5 N cm^{-2}	ASTM D882-64T
INITIAL TEAR STRENGTH	510 g/Mil	ASTM D1004-61
THERMAL EXPANSION COEFFICIENT	2×10^{-5} $°C^{-1}$	ASTM D696-44
THERMAL CONDUCTIVITY	1.55×10^{-3} W cm^{-1} $°C^{-1}$	Manuf. data
SPECIFIC HEAT	1.09 J g^{-1} $°C^{-1}$	Manuf. data
DIELECTRIC CONSTANT	3.5	ASTM D150-64T (1 kHz)
LOSS FACTOR	0.003	ASTM D150-64T
VOLUME RESISTIVITY	10^{18} Ω cm	ASTM D257-61
DIELECTRIC STRENGTH	7000 V/Mil	ASTM D149-64
SOLAR ABSORPTANCE	0.35	ESA PSS-01-709 (alum. back)
HEMISPHERICAL EMITTANCE	0.61	ESA PSS-01-709

* 25μm film at 25°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : K-1 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−269°C to 300°C	Long term
OUTGASSING	TML = 1.3% RML = 0.2% CVCM = 0.02%	ESA PSS-01-702
IONISING RADIATION	5000 Mrad	Manuf. data
UV/PARTICLE EFFECTS	$\Delta\alpha_s$ = 0.12	7 years/OTS spec. 75 μm film
MOISTURE ABSORPTION	1.3%	50% RH, 23.5°C
OXYGEN INDEX	32.7	ESA pSS-01-721
TOXICITY/OFFGASSING	Pass	NHB 8060-1A
FLAMMABILITY	Self-extinguishing	NHB 8060.1B 23.8% O_2

4. SPECIAL RECOMMENDATION

— Desorption of water corresponds to a geometrical shrinkage and to a change in hemispherical emittance.

— Available thickness ranges from 7.6 μm to 127 μm; maximum width is 1.5 m. Thinner film may become available soon.

— Flammability depends on film thickness.

— Etched by oxygen atoms in low earth orbit at a rate of $\pm 3 \times 10^{-24}$ cm^3/atom.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : K-2 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: KINEL 5518
CHEMICAL COMPOSITION	: POLYIMIDE/PTFE
TYPE OF PRODUCT	: THERMOSETTING, SELF-LUBRICATING RESIN
MANUFACTURER	: RHONE - POULENC PARIS FRANCE

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: UNKNOWN
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.42 g cm^{-3}	Manuf. data
HARDNESS	115	Rockwell M
TENSILE STRENGTH	3.5×10^{3} N cm^{-2}	Manuf. data
COMPRESSIVE STRENGTH	1.4×10^{4} N cm^{-2}	Manuf. data
IMPACT STRENGTH	0.25 ft lb/in	Izod-Notched.
THERMAL CONDUCTIVITY	2.2×10^{-3} W cm^{-1} $°C^{-1}$	Manuf. data
THERMAL EXPANSION COEFFICIENT	6.6×10^{-5} $°C^{-1}$	Manuf. data
DYNAMIC FRICTION COEFFICIENT	0.1 to 0.2	Under 40 N speed: 0.6 m s^{-1}

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : K-2 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	up to 250°C	Manuf. dat
OUTGASSING	TML = 1.6% RML = 0.6% CVCM = 0.01%	ESA PSS-01-702
IONISING RADIATION	10^{10} rad	Manuf. data
WATER ABSORPTION	0.3%	in 24 hours

4. SPECIAL RECOMMENDATION

— Because of its high water-absorption characteristic, this material is not to be used in badly vented places where strong electrical fields may be present.
— Other grades of Kinel exist with different fillers. Grade 5517 filled with graphite + MoS_2 may be suitable in space applications.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-1 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: MAGNESIUM - ALUMINIUM - ZINC ALLOY
CHEMICAL COMPOSITION	: 8.5% Al, 0.5% Zn, rem Mg
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: M.E.L. P.O. BOX 6 LUMMS LANE CLIFTON JUNCTION MANCHESTER U.K.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: ASTM AZ80; AZ855; DIN 1729, MgAl8Zn
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.80 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	2.35 to 3.30 $\times 10^4$ N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	1.50 to 2.27 $\times 10^4$ N cm^{-2}	At room temperature
ELONGATION AT BREAK	2 to 9%	At room temperature
THERMAL CONDUCTIVITY	0.9 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	26 to 27 $\times 10^{-6}$ $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	0.14 $\times 10^{-4}$ Ω cm	At room temperature

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-1 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION	1. Has very poor resistance to atmospheric corrosion and should always be protected. 2. Is prone to SCC in air, fresh water, sea water and salt solutions. Not suitable for structural applications. For high stress applications, see ESA PSS-01-736.	
TEMPERATURE RANGE	Maximum temperature of application is 150°C.	

4. SPECIAL RECOMMENDATION

— The part should be lanolin covered or oiled at all times during maching and prior to the protective treatments so as to avoid corrosion.
Protective treatments can be either:
(i) anodising and painting;
(ii) chromating and painting.

— The part should never make direct contact with other metals. Magnesium is more electrochemically negative than all other commonly used metals and will therefore be sacrificially corroded in any electrochemical cell that is created.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-2 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: MAGNESIUM - ALUMINIUM - ZINC - MANGANESE ALLOY
CHEMICAL COMPOSITION	: 3% Al, 1% Zn, rem Mg
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: M.E.L. P.O. BOX 6 LUMMS LANE CLIFTON JUNCTION MANCHESTER U.K.

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: ASTM AZ31B; B.S. 111; DIN 1729, Mg Al3 Zn
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.78 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	2.20 to 2.75 $\times 10^4$ N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	1.05 to 2.00 $\times 10^4$ N cm^{-2}	At room temperature
ELONGATION AT BREAK	4 to 12%	At room temperature
THERMAL CONDUCTIVITY	0.84 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	26 to 27 $\times 10^{-6}$ $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	0.092 $\times 10^{-4}$ Ω cm	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION	1. Has very poor resistance to atmospheric corrosion and should always be protected. Protective treatment can be either anodising or chromating and painting 2. Is prone to SCC in air, fresh water, sea water and salt solutions. Not suitable for structural applications. For high stress applications, see ESA PSS-01-736.	
TEMPERATURE RANGE	Maximum temperature of application is 150°C.	

4. SPECIAL RECOMMENDATION

— The part should be lanolin covered or oiled at all times during machining and prior to the protective treatments so as to avoid corrosion.
Protective treatments can be either:
(i) anodising and painting;
(ii) chromating and painting.

— The part should never make direct contact with other metals. Magnesium is more electrochemically negative than all other commonly used metals and will therefore be sacrificially corroded in any electrochemical cell that is created.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-3 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: MAKROFOL N
CHEMICAL COMPOSITION	: POLYCARBONATE
TYPE OF PRODUCT	: PLASTIC FILM
MANUFACTURER	: BAYER LEVERKUSEN D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.2 g cm^{-3}	Manuf. data
TENSILE STRENGTH	8.5×10^3 N cm^{-2}	Manuf. data
SURFACE RESISTIVITY	10^{13} Ω	(4 days at 80% RH)
DIELECTRIC CONSTANT	3.1	50 Hz
DISSIPATION FACTOR	2.5×10^{-3}	50 Hz
DIELECTRIC STRENGTH	170 kV/mm	(4 days at 80% RH)

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-3 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	up to 140°C	Manuf. data
OUTGASSING	TML = 1.4% RML = 0.35% CVCM = 0.01%	ESA PSS-01-702
IONISING RADIATION	10 Mrad	Mechanical properties
WATER ABSORPTION	0.5%	24 h immersion
FLAMMABILITY	Fail (21% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— Post cure 24 h at 80°C recommended.
— Other grades of Makrofol exist, of which the space qualification is incomplete.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-4 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: MAKROLON GV 30
CHEMICAL COMPOSITION	: POLYCARBONATE / GLASS
TYPE OF PRODUCT	: THERMOPLASTIC, REINFORCED
MANUFACTURER	: BAYER LEVERKUSEN D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: UNKNOWN
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.42 g cm^{-3}	Manuf. data
TENSILE STRENGTH	9×10^3 N cm^{-2}	Manuf. data
TENSILE MODULUS	6×10^5 N cm^{-2}	Manuf. data
IMPACT STRENGTH	40 Kp cm/cm^2	DIN 53453
THERMAL CONDUCTIVITY	1.6×10^{-3} W cm^{-1} $°C^{-1}$	Manuf. data
SPECIFIC HEAT	1.1 J g^{-1} $°C^{-1}$	Manuf. data
THERMAL EXPANSION COEFFICIENT	3×10^{-5} $°C^{-1}$	Manuf. data
VOLUME RESISTIVITY	$>10^{17}$ Ω cm	Manuf. data
DIELECTRIC CONSTANT	3.3	50 Hz
DISSIPATION FACTOR	9×10^{-4}	50 Hz

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	up to 145°C	Long term
OUTGASSING	TML = 0.15% CVCM = 0.0%	ESA PSS-01-702
IONISING RADIATION	10^7 rad	Mechanical properties
WATER ABSORPTION	0.1%	Manuf. data
FLAMMABILITY	Result depends on thickness and whether or not edges are protected	NHB 8060-1B

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-5 REVISION : 3 DATE : January 1994

TRADE NAME	: MAP-PCBZ
CHEMICAL COMPOSITION	: SILICONE/METALLIC BASE - SILICONE/ZINC STANNATE TOPCOAT
TYPE OF PRODUCT	: MATT WHITE CONDUCTIVE THERMAL-CONTROL PAINT
MANUFACTURER	: MAP Z.I. Chemin de la Rijole F-09100 Pamiers France Tel: 61 60 27 00 Fax: 61 60 28 77

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT		
— BASE	65 ± 2%	Manuf. data
— TOPCOAT	71 ± 2%	Manuf. data
APPLICATION VISCOSITY		
— BASE	16″ to 20″ AFNOR No. 4	Manuf. data
— TOPCOAT	33″ to 35″ AFNOR No. 2.5	Manuf. data
TYPICAL THICKNESS		
— BASE	40 to 50 μm	Manuf. data
— TOPCOAT	30 to 40 μm	Manuf. data
TYPICAL ELECTRICAL SURFACE RESISTANCE	$\leq$ 10 kΩ	Manuf. data
TYPICAL SOLAR ABSORPTANCE (depends on topcoat thickness)	0.26 ± 0.02	ESA PSS-01-709 (aluminium substrate)
TYPICAL HEMISPHERICAL EMITTANCE	0.83	ESA PSS-01-709
SHELF LIFE	4 months	At 5 ± 2°C in original closed package

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.55% RML = 0.52% CVCM = 0.08%	ESA PSS-01-702
THERMAL CYCLING	Pass	200 cycles (−150°C; +100°C)
UV RADIATION	$\Delta\alpha_s$ = 0.03	1045 ESH at 25°C
FLAMMABILITY	Pass (21% O_2)	NBH 8060.1B

4. SPECIAL RECOMMENDATION

— Room temperature curing.
— On certain substrates (composites), it is necessary to use PS primer to prove the adhesion before PCBZ.

SUBSTRATES	PRIMERS	
	NONE	PS
NATURAL ALUMINIUM	possible	recommended
ALUMINIUM WITH ALODINE TREATMENT	recommended	possible
COMPOSITE	not possible	recommended

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-6 REVISION : 3 DATE : January 1994

TRADE NAME	: MAP-PSB
CHEMICAL COMPOSITION	: POTASSIUM SILICATE - ZINC ORTHOTITANATE
TYPE OF PRODUCT	: MATT WHITE THERMAL-CONTROL PAINT
MANUFACTURER	: MAP Z.I. Chemin de la Rijole F-09100 Pamiers France Tel: 61 60 27 00 Fax: 61 60 28 77

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT	44 ± 2%	Manuf. data
APPLICATION VISCOSITY	35″ to 39″ AFNOR No. 2.5	Manuf. data
TYPICAL THICKNESS	130 to 150 μm	Manuf. data
TYPICAL SOLAR ABSORPTANCE (depends on topcoat thickness)	0.12 ± 0.02	ESA PSS-01-709 (aluminium substrate with coating 150 μm thick)
TYPICAL HEMISPHERICAL EMITTANCE	0.88	ESA PSS-01-709
TYPICAL NORMAL EMITTANCE	0.90 ± 0.04	ESA PSS-01-709
SHELF LIFE	3 months	At 20 ± 2°C in original closed package

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-6 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 3.04% RML = 0.04% CVCM = 0.00%	ESA PSS-01-702
THERMAL CYCLING	Pass	200 cycles (−150°C; +100°C)
UV RADIATION	$\Delta\alpha_s$ = 0.02	1080 ESH at 25°C

4. SPECIAL RECOMMENDATION

— Room temperature curing.
— This paint is usable directly on aluminium substrate exclusively without any chemical treatment.
— The high value of TML is due to water.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-7 REVISION : 3 DATE : January 1994

TRADE NAME	: MAP-PU1
CHEMICAL COMPOSITION	: POLYURETHANE / CARBON BLACK
TYPE OF PRODUCT	: MATT BLACK THERMAL-CONTROL PAINT
MANUFACTURER	: MAP Z.I. Chemin de la Rijole F-09100 Pamiers France Tel: 61 60 27 00 Fax: 61 60 28 77

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT — BASE — HARDNER	 50 ± 3% 100% approx.	 Manuf. data Manuf. data
APPLICATION VISCOSITY	40″ to 55″ AFNOR No. 2.5	Manuf. data
TYPICAL THICKNESS	50 to 60 μm	Manuf. data
TYPICAL SOLAR ABSORPTANCE (depends on coating thickness)	0.96 ± 0.02	ESA PSS-01-709 (aluminium substrate with coating 50 μm thick)
TYPICAL HEMISPHERICAL EMITTANCE	0.89	ESA PSS-01-709
TYPICAL NORMAL EMITTANCE	0.88 ± 0.04	ESA PSS-01-709
SHELF LIFE	6 months	At 5 to 25°C in original closed package

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.91% RML = 0.52% CVCM = 0.00%	ESA PSS-01-702 without primer
	TML = 0.99% RML = 0.49% CVCM = 0.00	ESA PSS-01-702 with PS primer
	TML = 1.10% RML = 0.60% CVCM = 0.00	ESA PSS-01-702 with WP primer
THERMAL CYCLING	Pass	200 cycles (−150°C; +100°C)

4. SPECIAL RECOMMENDATION

— Room temperature curing.
— On certain substrates, it is necessary to use PS or WP primer to improve the adhesion.
— Usable on flexible substrates (Kapton).

SUBSTRATES	PRIMERS		
	NONE	PS	WP
NATURAL ALUMINIUM	not possible	recommended	recommended
ALUMINIUM WITH ALODINE TREATMENT	recommended	possible	possible
COMPOSITE	not possible	recommended	not possible
KAPTON	recommended	not possible	not possible

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-8 REVISION : 3 DATE : January 1994

TRADE NAME	: MAP-PUC
CHEMICAL COMPOSITION	: POLYURETHANE / CARBON BLACK GRAPHITE
TYPE OF PRODUCT	: BLACK CONDUCTIVE THERMAL-CONTROL PAINT
MANUFACTURER	: MAP Z.I. Chemin de la Rijole F-09100 Pamiers France Tel: 61 60 27 00 Fax: 61 60 28 77

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT — BASE — HARDNER	 53 ± 3% 100% approx.	 Manuf. data Manuf. data
APPLICATION VISCOSITY	40″ to 55″ AFNOR No. 2.5	Manuf. data
TYPICAL THICKNESS	50 to 60 μm	Manuf. data
TYPICAL ELECTRICAL SURFACE RESISTANCE (depends on coating thickness)	5 to 25 kΩ	Manuf. data
TYPICAL SOLAR ABSORPTANCE (depends on coating thickness)	0.94 ± 0.02	ESA PSS-01-709 (aluminium substrate)
TYPICAL HEMISPHERICAL EMITTANCE	0.80	ESA PSS-01-709
SHELF LIFE	4 months	At 5 to 25°C in original closed package

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.83% RML = 0.55% CVCM = 0.02%	ESA PSS-01-702
THERMAL CYCLING	Pass	100 cycles (−150°C; +100°C)

4. SPECIAL RECOMMENDATION

— Room temperature curing.
— On certain substrates, it is necessary to use PS or WP primer to improve the adhesion.
— Usable on flexible substrates (Kapton).

SUBSTRATES	PRIMERS		
	NONE	PS	WP
NATURAL ALUMINIUM	not possible	recommended	recommended
ALUMINIUM WITH ALODINE TREATMENT	recommended	possible	possible
COMPOSITE	not possible	recommended	not possible
KAPTON	recommended	not possible	not possible

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-9 REVISION : 3 DATE : January 1994

TRADE NAME	: MAP-SG 11 FD
CHEMICAL COMPOSITION	: SILICONE-ZINC ORTHOTITANATE
TYPE OF PRODUCT	: MATT WHITE THERMAL-CONTROL PAINT
MANUFACTURER	: MAP Z.I. Chemin de la Rijole F-09100 Pamiers France Tel: 61 60 27 00 Fax: 61 60 28 77

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT — BASE — CATALYST	 87 ± 2% 4.8% approx.	 Manuf. data Manuf. data
APPLICATION VISCOSITY	18″ to 22″ AFNOR No. 4	Manuf. data
TYPICAL THICKNESS	130 to 150 μm	Manuf. data
TYPICAL SOLAR ABSORPTANCE (depends on coating thickness)	0.15 ± 0.02	ESA PSS-01-709 (aluminium substrate with coating 150 μm thick)
TYPICAL HEMISPHERICAL EMITTANCE	0.80	ESA PSS-01-709
TYPICAL NORMAL EMITTANCE	0.84 ± 0.04	ESA PSS-01-709
SHELF LIFE	3 months	At 20 ± 2°C in original closed package

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.29% RML = 0.26% CVCM = 0.06%	ESA PSS-01-702 (with PSI primer)
THERMAL CYCLING	Pass	100 cycles (−150°C; +100°C)
UV RADIATION	$\Delta\alpha_s$ = 0.02	1000 ESH at 40°C

4. SPECIAL RECOMMENDATION

— Room temperature curing.
— It is mandatory to use PSI or PSW primer before SG 11 FD to ensure its adhesion to any substrate. Moreover, on certain substrates (composites), it is necessary to use PS or EPOX FD surfacer before applying PSI or PSW primers.
— Usable on flexible substrates (Kapton).

SUBSTRATES	PRIMERS							
	PSI	PSW	PS		WP		EPOX FD	
			+PSI	+PSW	+PSI	+PSW	+PSI	+PSW
NATURAL ALUMINIUM	maybe	maybe	yes	yes	yes	yes	no	no
ALUMINIUM WITH ALODINE TREATMENT	yes	yes	maybe	maybe	maybe	maybe	no	no
COMPOSITE	no	no	yes	yes	no	no	yes	yes
KAPTON	yes	yes	no	no	no	no	no	no

Legend: yes = recommended practice
no = must not be used
maybe = may in some cases be used

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-10 REVISION : 3 DATE : January 1994

TRADE NAME	: MAP-SG 120 FD
CHEMICAL COMPOSITION	: SILICONE-ZINC OXIDE
TYPE OF PRODUCT	: MATT WHITE THERMAL-CONTROL PAINT
MANUFACTURER	: MAP Z.I. Chemin de la Rijole F-09100 Pamiers France Tel: 61 60 27 00 Fax: 61 60 28 77

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT — BASE — CATALYST	 77 ± 2% 7% approx.	 Manuf. data Manuf. data
APPLICATION VISCOSITY	16″ to 20″ AFNOR No. 4	Manuf. data
TYPICAL THICKNESS	100 to 120 μm	Manuf. data
TYPICAL SOLAR ABSORPTANCE (depends on coating thickness)	0.18 ± 0.02	ESA PSS-01-709 (aluminium substrate with coating 100 μm thick)
TYPICAL HEMISPHERICAL EMITTANCE	0.83	ESA PSS-01-709
TYPICAL NORMAL EMITTANCE (depends on coating thickness)	0.87 ± 0.02	ESA PSS-01-709 (aluminium substrate)
SHELF LIFE	6 months	At 20 ± 2°C in original closed package

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.55% RML = 0.54% CVCM = 0.04% TML = 0.98% RML = 0.87% CVCM = 0.03%	ESA PSS-01-702 (with PSW primer) ESA PSS-01-702 (with PS + PSW primers)
THERMAL CYCLING	Pass	200 cycles (−170°C; +120°C)
UV RADIATION	$\Delta\alpha_s$ = 0.05	1000 ESH at 40°C

4. SPECIAL RECOMMENDATION

— Room temperature curing.
— It is mandatory to use PSI or PSW primer before SG 120 FD to ensure its adhesion to any substrate. Moreover, on certain substrates (composites), it is necessary to use PS primer before applying PSI or PSW primers.

SUBSTRATES	PRIMERS					
	PSI	PSW	PS		WP	
			+ PSI	+ PSW	+ PSI	+ PSW
NATURAL ALUMINIUM	maybe	maybe	yes	yes	yes	yes
ALUMINIUM WITH ALODINE TREATMENT	yes	yes	maybe	maybe	maybe	maybe
COMPOSITE	no	no	yes	yes	no	no

Legend: yes = recommended practice
no = must not be used
maybe = may in some cases be used

— Analogous to PSG 120 FD

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-11 REVISION : 3 DATE : January 1994

TRADE NAME	: MAPSIL 210
CHEMICAL COMPOSITION	: SILICONE / METALLIC OXIDES
TYPE OF PRODUCT	: THERMALLY CONDUCTIVE GREASE
MANUFACTURER	: MAP Z.I. Chemin de la Rijole F-09100 Pamiers France Tel: 61 60 27 00 Fax: 61 60 28 77

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT	100% approx.	Manuf. data
THERMAL CONDUCTIVITY	0.41 W m^{-1} K^{-1} approx.	Manuf. data
SHELF LIFE	6 months	At 5 to 25°C in original closed package

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-11 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.06% RML = 0.03% CVCM = 0.01%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— Can be used for thermally conductive interfaces.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-12 REVISION : 3 DATE : January 1994

TRADE NAME	: MAPSIL 213
CHEMICAL COMPOSITION	: ELASTOMERIC SILICONE
TYPE OF PRODUCT	: ENCAPSULATING RESIN OR TRANSPARENT CONFORMAL COATING (TWO PARTS)
MANUFACTURER	: MAP Z.I. Chemin de la Rijole F-09100 Pamiers France Tel: 61 60 27 00 Fax: 61 60 28 77

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT		
— PRIMER BASE	100% approx.	Manuf. data
— FINISH HARDENER	100% approx.	Manuf. data
ELECTRICAL SURFACE RESISTANCE (depends on coating thickness)	$> 10^{12}\ \Omega$	Manuf. data
ELECTRICAL VOLUME RESISTANCE (depends on coating thickness)	$> 10^{14}\ \Omega\ cm^{-3}$	Manuf. data
SHELF LIFE	6 months	At 5 to 25°C in original closed package

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : M-12 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.30% RML = 0.27% CVCM = 0.04%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— Room temperature (with activator). Cured by heating.
— Fully evaluated for application in ESTEC - QM.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : P-1 REVISION : 2 DATE : June 1990

TRADE NAME	: PCB Z
CHEMICAL COMPOSITION	: SILICONE/METALLIC PRIMER - SILICONE ZINC ORTHOTITANATE FINISH
TYPE OF PRODUCT	: ELECTRICALLY CONDUCTIVE MATT WHITE PAINT
MANUFACTURER	: MAP Z.I. Chemin de la Rijole F-09100 Pamiers France

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLID CONTENT		
— PRIMER	65% ± 2%	Manuf. data
— FINISH	71 ± 2%	Manuf. data
VISCOSITY		
— PRIMER	15 to 18″ Afnor No. 6	Manuf. data (20°C)
— FINISH	18 to 25″ Afnor No. 4	Manuf. data (20°C)
ELECTRICAL SURFACE RESISTIVITY*	2 Ω to 10 kΩ	Manuf. data
SHELF LIFE	4 months	At 5 ± 2°C
SOLAR ABSORPTANCE*	0.26 ± 0.02	ESA PSS-01-709
HEMISPHERICAL EMITTANCE*	0.80 ± 0.04	ESA PSS-01-709
* depend on coating thickness		

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : P-1 REVISION : 2 DATE : June 1990

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.6% RML = 0.6% CVCM = 0.1%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
RADIATION	$\Delta\alpha_s$ = 0.03	1045 Es h
FLAMMABILITY	Pass (21% O_2	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— On certain substrates, it is necessary to use either PSI primer or Pyrolac P123 primer.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : P-2 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: P.E.T.P. (MYLAR, MELINEX, TERPHANE...)
CHEMICAL COMPOSITION	: POLYETHYLENE TEREPHTHALATE
TYPE OF PRODUCT	: THERMOPLASTIC FILM
MANUFACTURER	: SEVERAL (DU PONT US, ICI UK, LA CELLOPHANE F...)

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.4 g cm^{-3}	
TENSILE STRENGTH	2.1×10^4 N cm^{-2}	
TEAR STRENGTH	20 g/mil	
FOLDING ENDURANCE	> 100 000	ASTM D2176
THERMAL EXPANSION COEFFICIENT	3×10^{-5} °C^{-1}	
THERMAL CONDUCTIVITY	6.1×10^{-3} W cm^{-1} °C^{-1}	
SPECIFIC HEAT	1.3 J g^{-1} °C^{-1}	
VOLUME RESISTIVITY	10^{18} Ω cm	
DIELECTRIC CONSTANT	3.2	50 Hz - 25°C
DISSIPATION FACTOR	2×10^{-3}	50 Hz - 25°C
DIELECTRIC STRENGTH	280 kV/mm	
REFRACTIVE INDEX	1.64	

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−180°C to +150°C	Long term
OUTGASSING	TML = 0.3% RML = 0.1% CVCM = 0.03%	ESA PSS-01-702
OXYGEN INDEX	31	ESA PSS-01-721
IONISING RADIATION	10 Mrad	Mechanical properties
UV RADIATION	Unstable	
WATER ABSORPTION	0.6%	Immersion
TOXICITY/OFFGASSING	Pass	NHB 8060.1A
FLAMMABILITY	Fail (21% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

- Aluminised films (1 or 2 faces) exist in the trade and are extensively used in space programmes since Al protects the plastic against destruction by unfiltered UV light.
- Sizes available are down to 3 μm thick and up to 300 cm wide, depending on vendor.
- Flammability depends on thickness and configuration.
- PETP is etched by atomic oxygen in low earth orbit at a rate of ca. 3.4×10^{-24} cm^3/atom.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : P-3 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: PHOSPHOR BRONZE (CDA 510)
CHEMICAL COMPOSITION	: 5% Sn, 0.2% P, rem Cu
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: THOMAS BOLTON FROGHALL STOKE ON TRENT UK IMI P.O. BOX 216 WITTON BIRMINGHAM UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: VERY LOW
LOT REPRODUCIBILITY	: ASTM B103A; B.S. 2870 PB102; AFNOR UE5P; DIN 1733.
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	8.85 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	3.20 to 7.70 $\times$ 10^4 N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	1.10 to 6.90 $\times$ 10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	3 to 60%	At room temperature
THERMAL CONDUCTIVITY	0.75 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	17.9 $\times$ 10^{-6} $°C^{-1}$	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
ATMOSPHERIC CORROSION	Good up to 700°C.	
STRESS CORROSION	High resistance	

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : P-4 REVISION : 3 DATE : January 1994

TRADE NAME	: PSG 120 FD
CHEMICAL COMPOSITION	: SILICONE, ZINC OXIDE
TYPE OF PRODUCT	: MATT WHITE PAINT, 2 PARTS
MANUFACTURER	: ASTRAL - AIRCRAFT DEPT. ST. DENIS FRANCE

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT	38%	Manuf. data
VISCOSITY	37″ (C.F. 2.5 at 20°C	Manuf. data
SOLAR ABSORPTANCE	0.19	ESA PSS-01-709
HEMISPHERICAL EMITTANCE	0.88	ESA PSS-01-709
SHELF LIFE	6 months	at 20°C

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.56% RML = 0.54% CVCM = 0.03%	ESA PSS-01-702
UV/PARTICLE EFFECTS	$\Delta\alpha_s$ = 0.2	3 years/OTS spec. (tested value refers to PSG120)
THERMAL CYCLING	Pass	ESA PSS-01-704
FLAMMABILITY	Pass (21% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— This paint is a low-outgassing version of PSG120 from the same manufacturer, which was used on several space projects.
Whereas the PSG120 version requires a high-temperature cure, PSG 120 FD can be cured at room temperature.

— On high-absorptance substrates, the paint layer must be at least 200 μm thick if low final absorptance is required.

— Must be used with primer P128 from Astral.

— See ESA PSS-01-733 for application process.

— Equivalent MAP product: SG 120 FD.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : P-5 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: PSZ 184
CHEMICAL COMPOSITION	: POTASSIUM SILICATE, ZnO
TYPE OF PRODUCT	: INORGANIC, WHITE, THERMAL-CONTROL PAINT
MANUFACTURER	: ASTRAL, AIRCRAFT DEPT. ST. DENIS F

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
POT LIFE	24 h	Manuf. data
SOLAR ABSORPTANCE	0.14	Manuf. data
HEMISPHERICAL EMITTANCE	0.94	Manuf. data

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 2.3% (nearly 100% water) CVCM = 0.01%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
OFFGASSING / TOXICITY	Pass	NHB 8060-1A
OXYGEN INDEX	100	ESA PSS-01-721
UV / PARTICLE EFFECTS	$\Delta\alpha_s$ = 0.13	OTS Spec./3 years

4. SPECIAL RECOMMENDATION

- This paint must be prepared at the time of use by mixing 5 constituents in accordance with manufacturer's instructions.
- Paint must be applied at a temperature between 18°C and 25°C and with RH > 65%.
- Primer Pyrolac P131 recommended for good adhesion.
- Extensive training of the painter is required.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : P-6 REVISION : 2 DATE : June 1990

TRADE NAME	: P.T.F.E. (TEFLON, HALON, FLUON, HOSTFLON)
CHEMICAL COMPOSITION	: POLYTETRAFLUOROETHYLENE
TYPE OF PRODUCT	: THERMOPLASTIC
MANUFACTURER	: SEVERAL (DU PONT US, HOECHST D, MONTECATINI I ETC.)

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXCELLENT

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.15 g cm^{-3}	
HARDNESS	55	Shore D
TENSILE STRENGTH	2500 N cm^{-2}	
TENSILE MODULUS	4.2×10^{4} N cm^{-2}	
THERMAL CONDUCTIVITY	2.5×10^{-3} W cm^{-1} °C^{-1}	
SPECIFIC HEAT	1 J g^{-1} °C^{-1}	±40°C
THERMAL EXPANSION COEFFICIENT	10^{-4} °C^{-1}	
VOLUME RESISTIVITY	$> 10^{18}$ Ω cm	
DIELECTRIC CONSTANT	2.1	60 Hz
DISSIPATION FACTOR	0.0002	60 Hz
DIELECTRIC STRENGTH	480 V/Mil	ASTM D149

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Cryogenic to 260°C	Long term
OUTGASSING	TML = 0.05% RML = 0.02% CVCM = 0.0%	ESA PSS-01-702
OXYGEN INDEX	95	ESA PSS-01-721
IONISING RADIATION	10^5 rad	Threshold damage under vacuum
OFFGASSING/TOXICITY	Pass	NHB 8060-1A
FLAMMABILITY	Pass (30% O_2	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— PTFE has a strong tendency to creep and is unable to sustain constant high load. Creep way occur during thermal cycling.

— All PTFE-insulated wires and cables tested up to now have been found acceptable for space use.

— PTFE is rather sensitive to radiation and its use outside a spacecraft, particularly in high-radiation zones (Van Allen belts, geostationary orbit) requires special testing.

— Volume change associated with a change of cristallinity occurs between ca. 22°C and ca. 27°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : R-1 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: REDUX 312
CHEMICAL COMPOSITION	: EPOXY, MODIFIED
TYPE OF PRODUCT	: ADHESIVE FILM, STRUCTURAL, UNSUPPORTED
MANUFACTURER	: CIBA-GEIGY DUXFORD UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
MASS PER UNIT AREA	300 g m^{-2}	Manuf. data
TENSILE SHEAR STRENGTH	4500 N cm^{-2}	Manuf. data, at 24°C
TENSILE PEEL STRENGTH	48.6 N cm^{-1}	Manuf. data, at 24°C
FLATWISE TENSILE STRENGTH	750 N cm^{-2}	Manuf. data, at 24°C
FLEXURAL STRENGTH	13.3 kN	Manuf. data, at 24°C
SHELF LIFE	3 months 12 months	Manuf. data, at 24°C Manuf. data, at −18°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : R-1 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−55°C to +120°C	Long term
OUTGASSING	TML = 1.1% RML = 0.4% CVCM = 0.05%	ESA PSS-01-702
FLAMMABILITY	Fail (21% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

- Recommended cure is 90 minutes at 120°C or 60 minutes at 130°C.
- A lighter version of the film exists under the name 312 L (150 g m^{-2}) and 312 UL (100 g m^{-2}).
- The same adhesive exists as supported film under the name 312/5 (knitted Nylon carrier).
- Primer Redux 112 may be used with this adhesive.
- Where high temperatures (175°C, short term) are expected, Redux 319 is recommended.
- Quality control test according to ESA PSS-01-702 is recommended.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : R-2 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: REXOLITE 1422
CHEMICAL COMPOSITION	: POLYSTYRENE CROSS-LINKED
TYPE OF PRODUCT	: THERMOSETTING RESIN LAMINATE
MANUFACTURER	: ATLANTIC LAMINATES FRANKLIN NH USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	:
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.05 g cm^{-3}	ASTM D 792
TENSILE STRENGTH	5×10^3 N cm^{-2}	Manuf. data
FLEXURAL STRENGTH	8×10^3 N cm^{-2}	Manuf. data
THERMAL EXPANSION COEFFICIENT	7×10^{-5} $°C^{-1}$	Manuf. data
THERMAL CONDUCTIVITY	1.46×10^{-3} W cm^{-1} $°C^{-1}$	Manuf. data
VOLUME RESISTIVITY	$>10^{16}$ Ω cm	Manuf. data
DIELECTRIC CONSTANT	2.53	Manuf. data
DISSIPATION FACTOR	1.2×10^{-4}	At 1 MHz
DIELECTRIC STRENGTH	500 V/mil	(1/8 inch sample)

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : R-2 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−60°C to 100°C	Manuf. dat
OUTGASSING	TML = 0.2% RML = 0.2% CVCM = 0.01%	ESA PSS-01-702
WATER ABSORPTION	< 0.05%	Manuf. data
IONISING RADIATION	10^3 Mrad	Manuf. data

4. SPECIAL RECOMMENDATION

— Material is sold as rods, sheets and copper-clad laminates.
— A glass mat reinforced version of the same product is Rexolite 2200, which is recommended for cases where high mechanical stresses are present.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : R-3 REVISION : 3 DATE : January 1994

TRADE NAME	: RTV 566
CHEMICAL COMPOSITION	: SILICONE (METHYL. PHENYL)
TYPE OF PRODUCT	: 2-PART ADHESIVE, SEALANT, POTTING
MANUFACTURER	: GENERAL ELECTRIC, WATERFORD NY USA (GENERAL ELECTRIC SILICONES EUROPE, BERGEN OP ZOOM NL)

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: VERY HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
POT LIFE	30 minutes	
VISCOSITY	450 poise	Manuf. data
SPECIFIC GRAVITY	1.51	Manuf. data
HARDNESS	64	Shore A
TENSILE STRENGTH	660 N cm^{-2}	Manuf. data
TEAR STRENGTH	45 lb/inch	ASTM die B
THERMAL EXPANSION COEFFICIENT	2×10^{-4} $°C^{-1}$	
THERMAL CONDUCTIVITY	3×10^{-3} W cm^{-1} $°C^{-1}$	
ELECTRICAL RESISTIVITY	10^{15} Ω cm	
DIELECTRIC CONSTANT	4.2	at 60 Hz
LOSS FACTOR	0.006	at 60 Hz
DIELECTRIC STRENGTH	500 V/mil	
SOLAR ABSORPTANCE	0.65	ESA PSS-01-709
SHELF LIFE	4 months	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : R-3 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−115 to 315°C	Manuf. data
OUTGASSING	TML = 0.27% RML = 0.23% CVCM = 0.03%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
OXYGEN INDEX	23.6	ESA PSS-01-721 (0.5 mm thick
OFFGASSING/TOXICITY	Pass	NHB 8060-1A

4. SPECIAL RECOMMENDATION

- Recommended proportions: 100 pbw part A, 0.2 pbw part B. Thorough mixing is necessary. Cure: seven days at room temperature.
- For superior adhesion, use primer DC1200 (Dow Corning) or SS4155 (General Electric).
- Can be made electrically conductive with Cho-bond 1029B: 250 pbw for 100 pbw RTV566.
- RTV 567, a nonfilled version of 566, is very difficult to procure in Europe.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : R-4 REVISION : 3 DATE : January 1994

TRADE NAME	: RTV S 691
CHEMICAL COMPOSITION	: SILICONE, FILLED
TYPE OF PRODUCT	: TWO-PART ROOM-TEMPERATURE VULCANISING ADHESIVE
MANUFACTURER	: WACKER-CHEMIE BURGHAUSEN FRG

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: VERY HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
POT LIFE	90 to 110 minutes	Up to 200 Pa.s viscosity
INITIAL VISCOSITY	18 to 26 Pa s	$D = 16\ s^{-1}$
SPECIFIC GRAVITY	1.41 to 1.43 g cm^{-3}	
HARDNESS	50 to 60 Shore A	DIN 53505
TENSILE STRENGTH	400 to 600 N cm^{-2}	DIN 53504
TEAR STRENGTH	4 to 6 N mm^{-1}	ASTM D624B
THERMAL EXPANSION COEFFICIENT	2×10^{-4} °C^{-1} 4×10^{-5} °C^{-1}	$T > -105$°C $T < -105$°C
THERMAL CONDUCTIVITY	0.53 W m^{-1} °C^{-1}	
VOLUME RESISTIVITY	$10^{14}\ \Omega$ cm	DIN 53482 [100 V, 1 min]
BRITTLENESS TEMPERATURE	−105°C	
SHELF LIFE	1 year (room temperature)	Manuf. data
GLASS TRANSITION TEMPERATURE	−111°C	TMA

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : R-4 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−180°C to 200°C	
OUTGASSING	TML = 0.45% RML = 0.41% CVCM = 0.07%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
TOXICITY/OFFGASSING	Fails	NASA NHB 8060-1A
FLAMMABILITY	Burnt	NASA NHB 8060.1B

4. SPECIAL RECOMMENDATION

— Recommended proportions are 90 pbw A, 10 pbw B. Thorough mixing is necessary. Cure 7 days at room temperature.

— This adhesive produces three times more contaminant than RTV 566 in the ESA PSS-01-702 test.

— Quality control test according to ESA PSS-01-702 is recommended.

— Use with primer Wacker G 790 for superior adhesion.

— Offgassing can be reduced to an acceptable level by curing at 65°C.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : R-5 REVISION : 3 DATE : January 1994

TRADE NAME	: RTV S 695
CHEMICAL COMPOSITION	: SILICONE
TYPE OF PRODUCT	: TWO-PART ROOM-TEMPERATURE VULCANISING ADHESIVE
MANUFACTURER	: WACKER-CHEMIE BURGHAUSEN FRG

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: VERY HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
POT LIFE	8 hours (23°C)	Manuf. data
INITIAL VISCOSITY	6.6 Pa s	Manuf. data
HARDNESS	12 (23°C)	Manuf. data
SHEAR STRENGTH	70 $N\,cm^{-2}$ (23°C)	Manuf. data
SHEAR MODULUS	20 $N\,cm^{-2}$ (23°C)	Manuf. data
THERMAL EXPANSION COEFFICIENT	$3.2 \times 10^{-4}\ °C^{-1}$ $7.6 \times 10^{-5}\ °C^{-1}$	23°C to 100°C −180°C to −140°C
THERMAL CONDUCTIVITY	$2.1 \times 10^{-3}\ W\,cm^{-1}\ °C^{-1}$	at 93.5°C
BRITTLENESS TEMPERATURE	−110°C	Manuf. data
SHELF LIFE	1 year (room temperature)	Manuf. data
GLASS TRANSITION TEMPERATURE	−110°C	TMA
REFRACTIVE INDEX (n_D)	1.424 to 1.428	Manuf. data (at 25°C)

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−180°C to 200°C	
OUTGASSING	TML = 0.05% RML = 0.04% CVCM = 0.01%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
UV RESISTANCE	Similar to that of D.C. 93500	
FLAMMABILITY	Self extinguishing Burnt	NASA NHB 8060.1B 21% O_2 NASA NHB 8060-1B 24.5% O_2

4. SPECIAL RECOMMENDATION

— Recommended proportions are 90 pbw A, 10 pbw B. Thorough mixing is necessary. Cure 7 days at room temperature.

— Mechanical resistance of this adhesive is low. Its use is mainly for optical purposes; a typical application is as solar-cell/cover-glass adhesive.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-1 REVISION : 3 DATE : January 1994

TRADE NAME	: S 13 GLO
CHEMICAL COMPOSITION	: SILICONE, ZINC OXIDE, POTASSIUM SILICATE
TYPE OF PRODUCT	: MATT WHITE PAINT, 2 PARTS
MANUFACTURER	: IITRI CHICAGO IL USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: PILOT SCALE
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SOLIDS CONTENT	20%	Manuf. data
SOLAR ABSORPTANCE	0.18	ESA PSS-01-709
HEMISPHERICAL EMITTANCE	0.90	ESA PSS-01-709

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-1 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.5% RML = 0.15% CVCM = 0.03%	ESA PSS-01-702
UV/PARTICLE EFFECTS	$\Delta\alpha_s$ = 0.30	3 years/OTS spec.
THERMAL CYCLING	Pass	ESA PSS-01-704

4. SPECIAL RECOMMENDATION

- Recommended proportions: 100 pbw paint + 1 pbw catalyst + diluent as needed. Cure at room temperature.
- Must be used with primers Dow Corning DC 1200, General Electric SS 4044 or SS 4155 for better adhesion. Avoid primers with dyes.
- When the paint is applied to a high α_s substrate, a layer thickness of at least 200 μm is recommended when low final α_s is required.
- This product is now out of trade and has been replaced by a similar paint with a silicone base other than RTV 602 under the name S 13 GLO-1.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-2 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SCOTCH TAPE No. 5
CHEMICAL COMPOSITION	: POLYESTER / ACRYLIC
TYPE OF PRODUCT	: ADHESIVE TAPE, THERMOSETTING, TRANSPARENT
MANUFACTURER	: MINNESOTA MINING & MANUFACTURING ST. PAUL, MN USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
THICKNESS	63 μm	Manuf. data
TENSILE STRENGTH	45 N cm^{-1}	Manuf. data
PEEL STRENGTH	3.9 N cm^{-1}	Manuf. data
INSULATING RESISTANCE	$>10^6$ MΩ	Manuf. data
DIELECTRIC STRENGTH	6000 V	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-2 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 130°C	Long term
OUTGASSING	TML = 0.9% RML = 0.7% CVCM = 0.08%	ESA PSS-01-702
FLAMMABILITY	Pass (23.8% O_2)	NHB 8060.1B
OFFGASSING / TOXICITY	Pass	NHB 8060.1A

4. SPECIAL RECOMMENDATION

— Adhesion and solvent resistance are enhanced by a thermal treatment of 3 hours at 120°C or 1 hour at 150°C.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-3 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SCOTCH TAPE No. 60
CHEMICAL COMPOSITION	: PTFE / SILICONE
TYPE OF PRODUCT	: ADHESIVE TAPE, THERMOSETTING
MANUFACTURER	: MINNESOTA MINING & MANUFACTURING ST. PAUL, MN USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	:
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
THICKNESS	88 μm	Manuf. data
TENSILE STRENGTH	35 N cm^{-1}	Manuf. data
PEEL STRENGTH	3.3 N cm^{-1}	Manuf. data
INSULATING RESISTANCE	$>10^6$ MΩ	Manuf. data
DIELECTRIC STRENGTH	9000 V	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-3 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 180°C	Long term
OUTGASSING	TML = 0.45% RML = 0.4% CVCM = 0.1%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— This tape must be cured 3 hours at 260°C in order to develop its full adhesion. This treatment also reduces the contaminant (CVCM), which is marginal.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-4 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SCOTCH TAPE No. 425
CHEMICAL COMPOSITION	: ALUMINIUM / ACRYLIC
TYPE OF PRODUCT	: ADHESIVE TAPE
MANUFACTURER	: MINNESOTA MINING & MANUFACTURING ST. PAUL, MN USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: VERY GOOD
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
THICKNESS	130 μm	Manuf. data
PEEL STRENGTH	7 N cm^{-1}	Manuf. data
TENSILE STRENGTH	53 N cm^{-1}	Manuf. data
SOLAR ABSORPTANCE	0.25	ESA PSS-01-709
HEMISPHERICAL EMITTANCE	0.035	ESA PSS-01-709

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-4 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−54°C to 149°C	Manuf. data (long term)
OUTGASSING	TML = 0.20% RML = 0.12% CVCM = 0.02%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704

4. SPECIAL RECOMMENDATION

— This tape must be carefully and firmly applied with a roller to avoid crinkled surface.
— Tape must be regularly perforated to facilitate outgassing and avoid air bubbles.
— A lighter version of the same tape exists under the name Scotchtape 431 (90 μm).

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-5 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SCOTCH TAPE No. 850 SILVER
CHEMICAL COMPOSITION	: POLYESTER / ALUMINISED / ACRYLIC
TYPE OF PRODUCT	: ADHESIVE TAPE
MANUFACTURER	: MINNESOTA MINING & MANUFACTURING ST. PAUL, MN USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
THICKNESS	50 μm	Manuf. data
PEEL STRENGTH	3.8 N cm^{-1}	Manuf. data
TENSILE STRENGTH	35 N cm^{-1}	Manuf. data
SOLAR ABSORPTANCE	0.135	ESA PSS-01-709
HEMISPHERICAL EMITTANCE	0.63	ESA PSS-01-709

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-5 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−50°C to 150°C	Manuf. data (long term)
OUTGASSING	TML = 0.6% RML = 0.3% CVCM = 0.03%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704

4. SPECIAL RECOMMENDATION

— A 'lined' version of the same tape is available under the name Scotchtape No. 852.
— Tape 850 is also available in a transparent version and in different colours. Only silver has been proven for space use.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-6 REVISION : 3 DATE : January 1994

TRADE NAME	: SCOTCH TAPE Y 966
CHEMICAL COMPOSITION	: ACRYLIC
TYPE OF PRODUCT	: ADHESIVE TRANSFER TAPE
MANUFACTURER	: MINNESOTA MINING & MANUFACTURING ST. PAUL MN USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT (HIGH-PERFORMANCE VERSION OF SCOTCH TAPE 467)
COST RANGE	: LOW
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
THICKNESS	50 μm	Manuf. data
HOLDING STRENGTH	3 N cm^{-2}	Manuf. data. At 160°C. Test piece: 1.27 × 7.65 cm^2.
PEEL STRENGTH	1.80 N cm^{-1}	Manuf. data (90° peel)
CREEP	3000 min	Under 3 N cm^{-2} (test piece: 1.27 × 7.65 cm^2)

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−40°C to +150°C	Manuf. data
OUTGASSING & CONTAMINATION	TML = 0.93% RML = 0.37% CVCM = 0.01%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
OFFGASSING/TOXICITY	Pass	NHB 8060-1A

4. SPECIAL RECOMMENDATION

- Recommended as a replacement for Scotch tape 467 (same basic properties, but better temperature and solvent resistance).
- When used to bond fragile materials such as SSM, the tape must be applied first on the structure side. The liner is then removed and a suitable shape SSM bonded. If tape is already applied to the back of the SSM (as in some Sheldahl products), the liner must be removed with the utmost care so as to avoid stresses on the SSM.
- Availability in Europe is limited when purchased quantity is very small. Maximum width is 122 cm.
- Not to be used when peel forces are applied.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-7 REVISION : 3 DATE : January 1994

TRADE NAME	: SCOTCHWELD EC 2216 (5 pbw base/7 pbw accel.)
CHEMICAL COMPOSITION	: MODIFIED EPOXY
TYPE OF PRODUCT	: 2-PART STRUCTURAL ADHESIVE
MANUFACTURER	: MINNESOTA MINING & MANUFACTURING ST. PAUL MN USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
POT LIFE	90 minutes	Manuf. data
TENSILE SHEAR STRENGTH	2130 N cm^{-2}	at 24°C
TENSILE PEEL STRENGTH	36 N cm^{-1}	at 24°C
SPECIFIC HEAT	1.340 J g^{-1} $°C^{-1}$	0°C
GLASS TRANS. TEMP.	11.8°C	T.M.A.
THERMAL EXPANSION COEFFICIENT	4.5×10^{-5} $°C^{-1}$ 18.2×10^{-5} $°C^{-1}$	−100°C to 0°C 40°C to 100°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-7 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−50 to 80°C	
TOXICITY/OFFGASSING	Pass	NHB 8060-1A
OUTGASSING	TML = 1.42% RML = 0.75% CVCM = 0.01%	ESA PSS-01-702
FLAMMABILITY	Pass	NHB 8060-1B

4. SPECIAL RECOMMENDATION

- The accelerator (catalyst) is sensitive to atmospheric humidity and CO_2. Minimal exposure to atmosphere is recommended during storage and mixing.
- Recommended cure is 2 hours at 70°C.
- Quality control test by micro-VCM method (ESA PSS-01-702) is recommended.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-8 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SHELDAHL G 401500
CHEMICAL COMPOSITION	: FLUOROCARBON (FEP), SILVER & ICONEL COATED
TYPE OF PRODUCT	: THERMAL-CONTROL PLASTIC FILM
MANUFACTURER	: SHELDAHL NORTHFIELD MN USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.15 $g.cm^{-3}$	DuPont's data
THICKNESS	127 μm	Manuf. data
TENSILE STRENGTH	2.1×10^{3} $N.cm^{-2}$	DuPont's data
COEFFICIENT OF THERMAL EXPANSION	8.3×10^{-5} $°C^{-1}$	DuPont's data (−70°C to +70°C)
COEFFICIENT OF THERMAL CONDUCTIVITY	1.94×10^{-3} $W.cm^{-1}$ $°C^{-1}$	DuPont's data (−70°C to +70°C)
SPECIFIC HEAT	1.17 $J.g^{-1}$ $°C^{-1}$	Dupont's data (−70°C to +70°C)
DIELECTRIC STRENGTH (OF FEP FILM)	3500 V/mil	DuPont's data (−70°C to +70°C) 25°C - 60 Hz
SURFACE RESISTIVITY	10^{16} Ω cm	ASTM D257-61
VOLUME RESISTIVITY	10^{18} Ω.cm	ASTM D257-61
SOLAR ABSORPTANCE	0.08	ESA PSS-01-709
HEMISPHERICAL EMITTANCE	0.78	ESA PSS-01-709
STANDARD WIDTH	122 cm	Manuf. data

3. PROPERTIES RELEVANT TO SPACE USE - EFFECTS OF AND/OR ON ENVIRONMENT

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−185°C to +150°C	Manuf. data
OUTGASSING	TML = 0.05% CVCM = 0.01%	ESA PSS-01-702
UV / PARTICLE RADIATION	$\Delta\alpha_s$ = 0.18	OTS Spec 7 years
MOISTURE ABSORPTION	<0.01%	Dupont's data
OXYGEN INDEX	95	ESA PSS-01-721
TOXICITY/OFFGASSING	Pass	NHB 8060.1A

4. SPECIAL RECOMMENDATION

- There exist thinner films of the same material: 50μm (GA00300), 25μm(G401400) and also thicker. Other widths than standard can be obtained.
- There exist similar films with incorporated adhesive, either acrylic pressure sensitive, suitable for space, or silicones of which the suitability is doubtful. It is anyway preferable to fasten the film on a separately applied double-sided adhesive tape in order to avoid crazing in the metal layer due to the peeling off of the liner.
- The nomenclature of the Sheldahl company is not logical, and identification of films must be known very precisely for each type used (letter + 6 digits).
- Depending on the adhesive used, Sheldahl silvered FeP may be damaged by thermal cycling according to ESA PSS-01-704.
- Perforated versions of the film are available.
- Electrically conductive versions are also made by Sheldahl (front layer ITO deposit). However, conductivity is not maintained during wide temperature band of thermal cycling and ITO layer is degraded by long-term exposure to RH > 60%.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-9 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SHELDAHL G 400900
CHEMICAL COMPOSITION	: FLUOROCARBON (FEP) - ALUMINISED
TYPE OF PRODUCT	: THERMAL-CONTROL PLASTIC FILM
MANUFACTURER	: SHELDAHL NORTHFIELD MN USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	2.15 $g.cm^{-3}$	DuPont's data
THICKNESS	127 μm	Manuf. data
TENSILE STRENGTH	2.1×10^{3} $N.cm^{-2}$	DuPont's data
COEFFICIENT OF THERMAL EXPANSION	8.3×10^{-5} $°C^{-1}$	−70°C to +70°C
COEFFICIENT OF THERMAL CONDUCTIVITY	1.94×10^{-3} $W.cm^{-1}$ $°C^{-1}$	DuPont's data
SPECIFIC HEAT	1.17 $J.g^{-1}$ $°C^{-1}$	Dupont's data
DIELECTRIC STRENGTH (OF FEP FILM)	3500 V/mil	25°C - 60 Hz
SURFACE RESISTIVITY	10^{16} Ω cm	ASTM D257-61
VOLUME RESISTIVITY	10^{18} Ω.cm	ASTM D257-61
SOLAR ABSORPTANCE	0.13	ESA PSS-01-709
HEMISPHERICAL EMITTANCE	0.77	ESA PSS-01-709
STANDARD WIDTH	122 cm	Manuf. data

3. PROPERTIES RELEVANT TO SPACE USE - EFFECTS OF AND/OR ON ENVIRONMENT

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−185°C to +150°C	Manuf. data
OUTGASSING	RML = 0.05% CVCM = 0.01%	ESA PSS-01-702
UV / PARTICLE RADIATION	$\Delta\alpha_s$ = 0.18	OTS Spec 7 years
MOISTURE ABSORPTION	<0.01%	Dupont's data
OXYGEN INDEX	95	ESA PSS-01-721
TOXICITY/OFFGASSING	Pass	NHB 8060.1A

4. SPECIAL RECOMMENDATION

- There exist thinner films of the same material: 50μm (G.400500), 25μm(G402000) and also thicker. Other widths than standard can be obtained.
- There exist similar films with incorporated adhesive, either acrylic pressure sensitive, suitable for space, or silicones of which the suitability is doubtful. It is anyway preferable to fasten the film on a separately applied double-sided adhesive tape in order to avoid crazing in the metal layer due to the peeling off of the liner.
- The nomenclature of the Sheldahl company is not logical, and identification of films must be known very precisely for each type used (letter + 6 digits).
- Depending on the adhesive used, Sheldahl aluminised FeP may be damaged by thermal cycling according to ESA PSS-01-704.
- Perforated versions of the film are available. Perforation is recommended for space use.
- Electrically conductive versions are also made by Sheldahl (front layer ITO deposit). However, conductivity is not maintained during wide temperature band of thermal cycling and ITO layer is degraded by long-term exposure to RH > 60%.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-10 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SHELDAHL G 410620
CHEMICAL COMPOSITION	: POLYIMIDE (KAPTON H) ALUMINISED
TYPE OF PRODUCT	: THERMAL-CONTROL, ELECTRICALLY CONDUCTIVE PLASTIC FILM
MANUFACTURER	: SHELDAHL NORTHFIELD MN USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: HIGH
LOT REPRODUCIBILITY	: UNKNOWN
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.42 $g.cm^{-3}$	DuPont's data
THICKNESS	25 μm	Manuf. data
TENSILE STRENGTH	1.7×10^{4} $N.cm^{-2}$	DuPont's data
COEFFICIENT OF THERMAL EXPANSION	2×10^{-5} $°C^{-1}$	DuPont's data
COEFFICIENT OF THERMAL CONDUCTIVITY	1.55×10^{-3} $W.cm^{-1}$ $°C^{-1}$	DuPont's data
SPECIFIC HEAT	1.09 $J.g^{-1}$ $°C^{-1}$	Dupont's data
SURFACE RESISTIVITY	200 kΩ cm	At 1 V
SOLAR ABSORPTANCE	0.35	ESA PSS-01-709
NORMAL EMITTANCE	0.61	ESA PSS-01-709
STANDARD WIDTH	122 cm	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-10 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE - EFFECTS OF AND/OR ON ENVIRONMENT

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−250°C to +285°C	Manuf. data (continuous exposure)

4. SPECIAL RECOMMENDATION

- Normal use is as external sheet of multilayer insulation. Suitable venting must be provided.
- There exist other thicknesses of the same material from 12.5μm (G410660) to 127μm (G410650).
- The nomenclature of the Sheldahl company is not logical, and identification of films must be known very precisely for each type used (letter + 6 digits).
- Front face ITO layer is degraded by long-term exposure to RH > 60%.
- The ITO layer protects the film from atomic oxygen etching if not damaged.
- The ITO layer is stabilised against handling damage by a thermal treatment in air of 250°C.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-11 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SIGRAFLEX F
CHEMICAL COMPOSITION	: GRAPHITE
TYPE OF PRODUCT	: HEAT-TRANSFER FOIL
MANUFACTURER	: SIGRI ELEKTROGRAPHIT GmbH MEITINGEN BEI AUGSBURG D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: UNKNOWN
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	0.7 to 1.9 $g.cm^{-3}$	Manuf. data 20°C
COEFFICIENT OF THERMAL EXPANSION (for 1.7 to 1.9 $g\ cm^{-3}$)	$6 \times 10^{-6}\ °C^{-1}$	Manuf. data 20°C
COEFFICIENT OF THERMAL CONDUCTIVITY		
IN PLANE	$2.2\ W\ cm^{-1}\ °C^{-1}$	Manuf. data
PERPENDICULAR	$7 \times 10^{-2}\ W\ cm^{-1}\ °C^{-1}$	Manuf. data
EMISSIVITY	0.5	Manuf. data extrapolated to 20°C
ELECTRICAL RESISTIVITY		
IN PLANE	$10^{-4}\ \Omega\ cm$	Manuf. data 20°C
PERPENDICULAR	$6.5 \times 10^{-2}\ \Omega\ cm$	Manuf. data 20°C

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-11 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE - EFFECTS OF AND/OR ON ENVIRONMENT

NATURE	TYPICAL RESULT	TYPE OF TEST
OUTGASSING	TML = 0.92% RML = 0.88% CVCM = 0.01%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— This material may be a source of stains and particle contamination.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-12 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SOLDER SOFT, Sn60 (SPACE QUALITY)
CHEMICAL COMPOSITION	: 60% Sn, 40% Pb
TYPE OF PRODUCT	: METAL ALLOY, WIRE
MANUFACTURER	: BLEIWERK GOSLAR KG D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: ESA PSS-01-708 Issue 1: Type Sn60; DIN 1707: Type L Sn 60 Pb; BS 219: Type KP; ASTM-B32-66T: Type 60A.
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	8.5 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	0.39×10^4 N cm^{-2}	At room temperature
PROFF STRESS	0.28×10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	52%	At room temperature
THERMAL EXPANSION	16.0×10^{-6} $°C^{-1}$	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Suitable for extensive periods at +80°C or short periods to a maximum of +120°C.	

4. SPECIAL RECOMMENDATION

— Recommended for pre-tinning of component leads (see ESA PSS-01-708) and can be used for soldering stranded wire. For assembly of components on printed circuit boards, use alloy type 63 Sn.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-13 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SOLDER SOFT, Sn63 (SPACE QUALITY)
CHEMICAL COMPOSITION	: 63% Sn, 37% Pb
TYPE OF PRODUCT	: METAL ALLOY, WIRE OR BAR
MANUFACTURER	: BLEIWERK GOSLAR KG, D ALPHA METALS VACULOY, UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: ESA PSS-01-708 Issue 1: Type Sn63; DIN 1707: Type L Sn 63 Pb; BS 219: Type AP.
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	8.5 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	0.47 × 10^4 N cm^{-2}	At room temperature
PROOF STRESS	0.35 × 10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	46%	At room temperature
THERMAL EXPANSION	16.0 × 10^{-6} $°C^{-1}$	At room temperature

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-13 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Suitable for extensive periods at +80°C or short periods to a maximum of +120°C.	
THERMAL CYCLING	Test programme showed no electrical failures after 1000 cycles.	Joints made to ESA PSS-01-708 requirements; −60°C to +80°C under vacuum with ΔT of 10°C/min.

4. SPECIAL RECOMMENDATION

— Mandatory for the assembly of components on printed circuit boards (ESA PSS-01-708).

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-14 REVISION : 2 DATE : June 1990

TRADE NAME	: SOLDER SOFT, SILVER LOADED (SPACE QUALITY)
CHEMICAL COMPOSITION	: 62% Sn, 2% Ag, rem. Pb
TYPE OF PRODUCT	: METAL ALLOY, WIRE
MANUFACTURER	: Bleiwerk Goslar KG FRG

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: ESA PSS-01-708 Type 62 Sn; DIN 1707 Type L Sn60PbAg; BS 219 Type 62S
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	8.5 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	0.63×10^4 N cm^{-2}	At room temperature
PROOF STRESS	0.52×10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	46%	At room temperature
THERMAL EXPANSION COEFFICIENT	16.0×10^{-6} $°C^{-1}$	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Suitable for extensive periods at 80°C or short periods to a maximum of 120°C	

4. SPECIAL RECOMMENDATION

— Not generally recommended for spacecraft use. Only used to prevent scavenging (dissolution) effect when soldering to silver-plated surface (e.g. silver-painted or plated components, silver wire etc.).

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-15 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: SOLDER, TIN SILVER EUTECTIC (SPACE QUALITY)
CHEMICAL COMPOSITION	: 96% Sn, 4% Ag
TYPE OF PRODUCT	: METAL ALLOY, WIRE AND BAR
MANUFACTURER	: BLEIWERK GOSLAR KG D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: ESA PSS-01-708 Issue 1: Type 96 Sn
SPACE EXPERIENCE	: LIMITED

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	10.4 g cm^{-3}	
ULTIMATE TENSILE STRENGTH	0.36×10^{4} N cm^{-2}	At room temperature
ELONGATION AT BREAK	31%	At room temperature
THERMAL EXPANSION	20×10^{-6} °C^{-1}	At room temperature
ELECTRICAL RESISTIVITY	12.3×10^{-5} Ω cm	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Suitable for extensive periods at +120°C or short periods to a maximum of +150°C.	

4. SPECIAL RECOMMENDATION

— Is suitable for special applications, such as solder attachment of terminal posts to one side of a printed circuit board (ESA PSS-01-708) and for assembly of connectors to semirigid cables (ESA PSS-01-718).

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-16 REVISION : 3 DATE : January 1994

TRADE NAME	: SOLITHANE 113/C 113-300 (100/73 pbw)
CHEMICAL COMPOSITION	: POLYURETHANE
TYPE OF PRODUCT	: TWO-PART SOFT, TRANSPARENT POTTING, CONFORMAL COATING, BONDING AGENT
MANUFACTURER	: Thiokol Chemical Corp. Trenton NJ USA now: Uniroyal Chemical Company Inc. 214 West Ruby Ave. Gastonia NC USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.073 g cm^{-3}	
VISCOSITY	200 poise	@ 27°C
POT LIFE	3 hours	@ 27°C
HARDNESS	55m to 60	
TENSILE STRENGTH	285 N cm^{-2}	
GLASS TRANSITION TEMPERATURE	−10°C	Thermal expansion measurement
DIELECTRIC CONSTANT	4.2	@ 27°C, 1 kHz
DISSIPATION FACTOR	0.162	@ 27°C, 1 kHz
DIELECTRIC STRENGTH	378 V/mil	@ 27°C
VOLUME RESISTIVITY	2.5×10^{14} Ω cm	@ 27°C
THERMAL EXPANSION	1.26×10^{-4} $°C^{-1}$ 2.38×10^{-4} $°C^{-1}$	−55°C to −15°C 0°C to 70°C

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−60°C to 120°C	Long term
OUTGASSING	TML = 0.37% RML = 0.21% CVCM = 0.01%	ESA PSS-01-702
THERMAL CYCLING	Pass	ESA PSS-01-704
IONISING RADIATION	10 Mrad	Manuf. value
OXYGEN INDEX	24.7	ESA PSS-01-721
FLAMMABILITY	Fail (21% O_2)	NHB 8060.1B

4. SPECIAL RECOMMENDATION

- Recommended cures are 7 days at RT or 24 hours at 70°C.
- Compositions other than the one referenced here are possible. Large amount of experimental data on them exists and is available on demand.
- Not resistant to solar U;v radiation.
- Owing to flammability risk, not to be used as a conformal coating in manned spacecraft unless a fire-resistant overcoating is used. Its acceptability as an adhesive will depend on the configuration
- Possible use as a screw-locking compound.
- Possible use an ink with suitable addition of pigments and solvents.
- Possible use as a conductive coating when filled with silver powder.
- Flammability highly dependent on coating thickness. Configuration flammability tests required.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-17 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: STAINLESS STEEL (A286)
CHEMICAL COMPOSITION	: 25% Ni, 15% Cr, 2%Ti, 1.5%Mn, 1.3%Mo, 0.3%V, rem Fe
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: ROCHLING IRON AND STEEL WORKS D-6620 VOLKINGEN (SAAR) D

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: WERKST.NR.1.4980; Z6 NCT 25/15
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	7.92 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	10.07×10^4 N cm^{-2}	At room temperature
PROOF STRESS	6.9×10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	25%	At room temperature
THERMAL CONDUCTIVITY	0.237 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION	18.5×10^{-6} $°C^{-1}$	At room temperature

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-17 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
ATMOSPHERIC CORROSION	High resistance up to 700°C.	
STRESS CORROSION	High resistance.	

4. SPECIAL RECOMMENDATION

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-18 REVISION : 3 DATE : January 1994

TRADE NAME	: STYCAST 1090/9 (100 pbw/9 pbw)
CHEMICAL COMPOSITION	: EPOXY
TYPE OF PRODUCT	: SYNTACTIC CASTING, POTTING, FOAM, 2 PARTS
MANUFACTURER	: EMERSON & CUMING (EMERSON & CUMING EUROPE CANTON OEVEL MA BELGIUM) USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
VISCOSITY (BEFORE REACTION)	30 000 cps	Manuf. data
POT LIFE	30 min.	Manuf. data
SPECIFIC GRAVITY	0.88 g cm^{-3}	Manuf. data
HARDNESS	82	Shore D
COMPRESSIVE MODULUS	2.5×10^{5} N cm^{-2}	Manuf. data
THERMAL EXPANSION COEFF.	4×10^{-5} °C^{-1}	Manuf. data
THERMAL CONDUCTIVITY	1.67×10^{-3} W cm^{-1} °C^{-1}	Manuf. data
DIELECTRIC CONSTANT	3.9	at 60 Hz
LOSS FACTOR	0.02	at 60 Hz
DIELECTRIC STRENGTH	375 V/mil	Manuf. data
ELECTRICAL SENSITIVITY	10^{12} Ω cm	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-18 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−75°C to +200°C	Manuf. data
OUTGASSING	TML = 0.75% RML = 0.35% CVCM = 0.06%	ESA PSS-01-702
TOXICITY/OFFGASSING	Pass	NHB 8060-1A
WATER ABSORPTION	0.4%	at 25°C in 24 h
FLAMMABILITY	Pass (23.8% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

- This product is filled with micro-balloons which must be thoroughly dispersed at the time of use.
- The resin must be deaerated (by vacuum exposure) before casting and also briefly after casting.
- Recommended cure is 24 hours at room temperature. Post cure at 60°C may be applied to reduce outgassing.
- Post cure at 60°C for 24 hours is compulsory when material is used as insert potting.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-19 REVISION : 3 DATE : January 1994

TRADE NAME	: STYCAST 2850 FT/9 (100 pbw/3.5 pbw)
CHEMICAL COMPOSITION	: EPOXY
TYPE OF PRODUCT	: TWO-PART POTTING RESIN
MANUFACTURER	: EMERSON & CUMING (EMERSON & CUMING EUROPE CANTON OEVEL MA BELGIUM) USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
VISCOSITY (BEFORE REACTION)	70 000 cps	Manuf. data
POT LIFE	45 min.	Manuf. data
SPECIFIC GRAVITY	2.3 g cm^{-3}	Manuf. data
HARDNESS	94	Shore D
TENSILE STRENGTH	6000 N cm^{-2}	Manuf. data
ELASTIC MODULUS (COMPRESSIVE)	8×10^5 N cm^{-2}	Manuf. data
THERMAL EXPANSION COEFF.	2.9×10^{-5} $°C^{-1}$	Manuf. data
THERMAL CONDUCTIVITY	1.44×10^{-2} W cm^{-1} $°C^{-1}$	Manuf. data
ELECTRICAL RESISTIVITY	5×10^{14} Ω cm	at 25°C
DIELECTRIC CONSTANT	6.5	at 60 Hz
LOSS FACTOR	0.02	at 60 Hz
DIELECTRIC STRENGTH	380 V/mil	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-19 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 150°C	Manuf. data
OUTGASSING	TML = 0.38% RML = 0.24% CVCM = 0.01%	ESA PSS-01-702
OXYGEN INDEX	29.8	ESA PSS-01-721
TOXICITY/OFFGASSING	Pass	NHB 8060-1A
WATER ABSORPTION	< 0.15%	Over 7 days
FLAMMABILITY	Pass (23.8% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

- Recommended cure is 24 hours at room temperature plus 4 hours at 60°C.
- Other catalysts are available for the same resin: catalyst 11 for high-temperature cure; catalyst 24 LV for low viscosity. Some experience in space use is available for both.
- A derived resin called 2850 KT can be used when extremely high thermal conductance is required (4.2×10^{-2} W cm^{-1} °C^{-1}).

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-20 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: 'SUPER' GUDE SPACE PT
CHEMICAL COMPOSITION	: DACRON (POLYETHYLENE TEREPHTHALLATE)
TYPE OF PRODUCT	: LACING TAPE, FLAT BRAID
MANUFACTURER	: GUDEBROD BROS. SILK NEW YORK, NY USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: SPECIAL COMMERCIAL PRODUCT
COST RANGE	: LOW
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: FAIR

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
STRENGTH	54 to 360 N	Manuf. data
WIDTH	0.12 to 0.27 cm	Manuf. data
THICKNESS	0.017 to 0.037 cm	Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : S-20 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−75°C to 180°C	Manuf. dat
OUTGASSING	TML = 0.35% RML = 0.19% CVCM = 0.02%	ESA PSS-01-702
IONISING RADIATION	$>10^7$ rad	
FLAMMABILITY	Fail (23.8% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— Same product, but uncoated, known as Gude Space D96, for which extensive space experience exists, must be washed in methanol and dried to get a correct outgassing value.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : T-1 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: THERMOFIT RT 850
CHEMICAL COMPOSITION	: FLUOROCARBON (KYNAR)
TYPE OF PRODUCT	: HEAT-SHRINKABLE INSULATING SLEEVE
MANUFACTURER	: RAYCHEM MENLO PARK, CA USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: VERY GOOD
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.8 g cm^{-3}	Manuf. data
DIAMETER (BEFORE SHRINKAGE)	1.2 to 25.4 mm	Manuf. data
SHRINKAGE	50%	
TENSILE STRENGTH	5600 N cm^{-2}	Manuf. data
TENSILE MODULUS	7×10^5 N cm^{-1}	Manuf. data
ELECTRICAL RESISTIVITY	2×10^{15} Ω cm	Manuf. data
DIELECTRIC STRENGTH	30 kV/mm	Transverse

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : T-1 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−55°C to 175°C	Long term
OUTGASSING	TML = 0.36% RML = 0.33% CVCM = 0.07%	ESA PSS-01-702
WATER ABSORPTION	< 0.1%	Manuf. data
OFFGASSING / TOXICITY	Pass	NHB 8060-1A
FLAMMABILITY	Fail (23.8% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— Shrinks when heated over 175°C. Not to be used in the vicinity of solder joints.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : T-2 REVISION : 3 DATE : January 1994

TRADE NAME	: THERMOFIT RT 876
CHEMICAL COMPOSITION	: POLYOLEFIN
TYPE OF PRODUCT	: HEAT-SHRINKABLE INSULANT SLEEVE
MANUFACTURER	: RAYCHEM MENLO PARK CALIFORNIA USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	:
LOT REPRODUCIBILITY	: GOOD
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.3 g cm^{-3}	Manuf. data
DIAMETER (BEFORE SHRINKAGE)	1.2 20 101.6 mm	Manuf. data
SHRINKAGE	50%	Manuf. data
TENSILE STRENGTH	1400 N cm^{-2}	Manuf. data
TENSILE MODULUS	6.7×10^4 N cm^{-2}	Manuf. data
ELECTRICAL RESISTIVITY	10^{14} Ω cm	Manuf. data
DIELECTRIC STRENGTH	19.7 kV/mm	Transverse

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : T-2 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−55°C to +135°C	Long term
OUTGASSING	TML = 0.8% RML = 0.72% CVCM = 0.08%	ESA PSS-01-702
WATER ABSORPTION	<0.2%	Manuf. data
OFFGASSING/TOXICITY	Pass	NHB 8060-1A
FLAMMABILITY NHB 8060.1B	Pass (24.5% O_2) on nonflammable wire insulation	NHB 8060-1B

4. SPECIAL RECOMMENDATION

- Shrinks when heated over 100°C; do not exceed 140°C in the vicinity of solder joints.
- In manned spacecraft applications, use should be limited to discrete pieces (max. 10 cm) separated by at least 5 cm.
- **Each batch and each colour must be tested according to ESA PSS-01-702 for quality control, since this product has been proven extremely variable as regards outgassing.**

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : T-3 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: TITANIUM (PURE) IMI 115
CHEMICAL COMPOSITION	: COMMERCIALLY PURE
TYPE OF PRODUCT	: METAL
MANUFACTURER	: IMI P.O. BOX 216 WITTON BIRMINGHAM UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW TO MEDIUM
LOT REPRODUCIBILITY	: ASTM B265; B.S. TA1; AFNOR T35; WERK NO. 3.7024
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	4.51 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	3.69×10^4 N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	2.46×10^4 N cm^{-2}	At room temperature
ELONGATION AT BREAK	35%	At room temperature
THERMAL CONDUCTIVITY	0.16 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	7.6×10^{-6} $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	0.48×10^{-4} Ω cm	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
ATMOSPHERIC CORROSION	Exceptional resistance to corrosion by oxidising media up to 700°C.	

4. SPECIAL RECOMMENDATION

— Methyl alcohol should not be used in the pressure testing of tanks, since failure can occur due to stress-corrosion cracking.

— Should have very low interstitial content (i.e. oxygen, hydrogen, nitrogen) to avoid hydrogen embrittlement etc. This is particularly important when there is a need for welding or heat testing.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : T-4 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: TITANIUM ALLOY IMI 318
CHEMICAL COMPOSITION	: 6% Al, 4% V, rem Ti
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: IMI P.O. BOX 216 WITTON BIRMINGHAM UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW TO MEDIUM
LOT REPRODUCIBILITY	: AMS 4911, 4928; B.S. TA10, 11; AFNOR TA6V; WERK NO. 3.7164
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	4.42 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	9.24 to 11.55 $\times 10^4$ N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	8.47 to 10.78 $\times 10^4$ N cm^{-2}	At room temperature
ELONGATION AT BREAK	10 to 12%	At room temperature
THERMAL CONDUCTIVITY	0.060 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	7.9 $\times 10^{-6}$ $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	1.68 $\times 10^{-4}$ Ω cm	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION / THERMAL	(i) Oxidation resistant with retention of useful strength and creep resistance up to 500°C. (ii) Strong affinity for H_2 (above 130°C), N_2 (above 800°C) and O_2 (above 700°C), which cause embrittlement.	
STRESS CORROSION	High resistance (see note).	

4. SPECIAL RECOMMENDATION

— Alloy possesses poor notch sensitivity characteristics, so considerable care should be taken to avoid the presence of stress raisers.

— Methyl alcohol should not be used in the pressure testing of tanks, since failure can occur due to stress-corrosion cracking.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : T-5 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: TITANIUM ALLOY (IMI 550)
CHEMICAL COMPOSITION	: 4% Al, 4% Mo, 2% Sn, 0.5% Si, rem Ti
TYPE OF PRODUCT	: METAL ALLOY
MANUFACTURER	: IMI P.O. BOX 216 WITTON BIRMINGHAM UK

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: LOW TO MEDIUM
LOT REPRODUCIBILITY	: B.S. TA45-51; AFNOR A4DE
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	4.60 g cm^{-3}	At room temperature
ULTIMATE TENSILE STRENGTH	10.62 to 12.1 $\times 10^4$ N cm^{-2}	At room temperature
PROOF STRESS (0.2%)	9.70 to 11.09 $\times 10^4$ N cm^{-2}	At room temperature
ELONGATION AT BREAK	12%	At room temperature
THERMAL CONDUCTIVITY	0.08 W cm^{-1} $°C^{-1}$	At room temperature
THERMAL EXPANSION COEFFICIENT	8.8 $\times 10^{-6}$ $°C^{-1}$	At room temperature
ELECTRICAL RESISTIVITY	1.59 $\times 10^{-4}$ Ω cm	At room temperature

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
CORROSION / THERMAL	(i) Oxidation resistant with retention of useful strength and creep resistance up to 500°C. (ii) Strong affinity for H_2 (above 130°C), N_2 (above 800°C) and O_2 (above 700°C), which cause embrittlement.	

4. SPECIAL RECOMMENDATION

— Alloy possesses poor notch sensitivity characteristics, so considerable care should be taken to avoid the presence of stress raisers.

— Methyl alcohol should not be used in the pressure testing of tanks, since failure can occur due to stress-corrosion cracking.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : V-1 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: VHDS
CHEMICAL COMPOSITION	: SILICONE
TYPE OF PRODUCT	: ELASTOMER, RUBBER, ANTIVIBRATION
MANUFACTURER	: VIBRASHOC ST. CLOUD FRANCE

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	:
LOT REPRODUCIBILITY	: FAIR
SPACE EXPERIENCE	: GOOD

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.1 to 1.4 g cm^{-3}	Manuf. data
HARDNESS	3 to 77	DIDC
TENSILE STRENGTH	650 to 1050 N cm^{-2}	Manuf. data
STRAIN AT FAILURE	400 to 800%	Manuf. data
TEAR STRENGTH	250 to 300 N cm^{-1}	Manuf. data
REBOUND	26 to 30%	Zwick at R.T.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : V-1 REVISION : 0 DATE : Nov. 1985

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	−80°C to 200°C	Long term
OUTGASSING	TML = 0.2% RML = 0.2% CVCM = 0.02%	ESA PSS-01-702

4. SPECIAL RECOMMENDATION

— Elastromer pieces to be used in space receive a special thermal treatment by the manufacturer to reduce their outgassing to the above-mentioned value. This must be specified at the time of procurement.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : V-2 REVISION : 0 DATE : Nov. 1985

TRADE NAME	: VITON B910
CHEMICAL COMPOSITION	: VINYLIDENE FLUORIDE, HEXAFLUOROPROPYLENE COPOLYMER
TYPE OF PRODUCT	: ELASTOMER, RUBBER
MANUFACTURER	: DUPONT WILMINGTON, DE USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	: MEDIUM
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
SPECIFIC GRAVITY	1.85 g cm^{-3}	Manuf. data
TENSILE STRENGTH	1500 N cm^{-2}	Manuf. data
HARDNESS	78	Manuf. data
MODULUS (100%)	650 N cm^{-2}	Manuf. data
ELECTRICAL RESISTIVITY	2×10^{13} Ω cm	Manuf. data

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Cryogenic to 230°C −25°C to 230°C	Long term Long term dynamic
OUTGASSING	TML = 0.5% RML = 0.3% CVCM = 0.02%	ESA PSS-01-702
IONISING RADIATION	10 Mrad	Dynamic application
OXYGEN INDEX	50	ESA PSS-01-721
OFFGASSING / TOXICITY	Pass	NHB 8060-1A
FLAMMABILITY	Pass (24.5% O_2)	NHB 8060-1B

4. SPECIAL RECOMMENDATION

— There are many other grades of Viton with modified properties; e.g. GLT for extra low temperature (−40°C), VTR-4590 for high fluid resistance. Moreover, gasket manufacturers have their own designations.

— All Viton formulations tested so far pass ESA PSS-01-702 and have an oxygen index in the range cited above.

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : W-1 REVISION : 3 DATE : January 1994

TRADE NAME	: WIRE & CABLES TYPE 44 (SPACE SERIES)
CHEMICAL COMPOSITION	: INSULANT: IRRADIATED POLYOLEFIN AND POLYVINYLIDENE FLUORIDE CONDUCTOR: SILVER-, NICKEL- OR TIN-PLATED COPPER
TYPE OF PRODUCT	: INSULATED WIRE
MANUFACTURER	: RAYCHEM MENLO PARK CALIFORNIA USA

1. EXPERIENCE & AVAILABILITY

DEVELOPMENT STATUS	: COMMERCIAL PRODUCT
COST RANGE	:
LOT REPRODUCIBILITY	: EXCELLENT
SPACE EXPERIENCE	: EXTENSIVE

2. GENERAL PROPERTIES (Physical, Mechanical, Thermal, Electrical, Optical)

NATURE	TYPICAL VALUE	REMARKS
TENSILE STRENGTH OF INSULANTS	1720 N cm^{-2}	Manuf. data (2 insulant layers)
ELECTRICAL BREAKDOWN	1500 V	Manuf. data (minimum at 50 Hz)
INSULATING RESISTANCE RATING	 1500 MΩ/km 600 V	 Manuf. data Manuf. data

SPECIFICATION ESA PSS-01-701 ISSUE 1	MATERIAL DATA SHEET	SHEET NO. : W-1 REVISION : 3 DATE : January 1994

3. PROPERTIES RELEVANT TO SPACE USE (Effects of and/or on environment)

NATURE	TYPICAL RESULT	TYPE OF TEST
TEMPERATURE RANGE	Up to 135°C	Long term
OUTGASSING	TML = 0.48% RML = 0.45% CVCM = 0.02%	ESA PSS-01-702
IONISING RADIATION	500 Mrad	Manuf. data
FLAMMABILITY / ELECTRICAL OVERLOAD	Variable	NHB 8060-1B
TOXICITY / OFFGASSING	Pass	NHB 8060-1A

4. SPECIAL RECOMMENDATION

- Tin-plated conductor is the recommended version for soldering.
- Silver-plated conductor is recommended version for crimping or where soldering and crimping are requested.
- Flammability depends on colour pigment.
- Many sizes (AWG 12 to 30) and constructions available.
- Space series are characterised by a digit 4, 5 or 6 as fifth character. Other series are not approved. In general, these digits exist only in 44/ and not in 44A.