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TECHNOLOGY UTILIZATION

MATERIALS

A COMPILATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Foreword

The National Aeronautics and Space Administration has established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of its research and development, NASA earns for the public an increased return on the investment in aerospace research and development programs.

This document is one of a series intended to furnish such information. The Compilation is divided into two sections, each describing properties, compositions, or uses of materials. These innovations were developed to meet problems arising in the space research and development program, both in house and by NASA.

The first section covers properties and fabrication of metals and alloys. Section Two is concerned with polymeric materials, such as lubricants, coatings, and insulation.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader Service Card included in this Compilation.

The latest patent information available at the final preparation of this Compilation is presented on the page following the last article in the text. For those innovations on which NASA has decided not to apply for a patent, a Patent Statement is not included. Potential users of items described herein should consult the cognizant organization for updated patent information at that time.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this Compilation.

Jeffrey T. Hamilton, *Director*
Technology Utilization Office
National Aeronautics and Space Administration

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Contents

Section 1. Metallurgy

TD NiCr TECHNOLOGY: A REPORT

A literature study presents the most recent processing and fabricating technology for thoria-dispersed nickel chrome (TD NiCr). The report discusses the advantages and disadvantages of the alloy and those areas in which it might be used.

Chemical and physical properties of TD NiCr are presented and compared to those of other alloys. Mechanical properties such as tensile strength, yield, ductility and hardness are presented for several temperatures. In addition, alpha particle radiation and required safety precautions are presented.

A section on forming indicates that several forming methods may be used with TD NiCr. These are discussed and compared. Standard machining techniques can be used if they are slightly modified to deal with the high strength of the alloy. Turning, milling, reaming, and other machining methods are reviewed.

A section on processing includes the results of experiences with stress relief, cleaning, descaling, and metallographic polishing.

The final areas discussed are joining and bonding. Thoria-dispersed NiCr has been successfully joined by brazing, spot welding, diffusion bonding, and mechanical fastening. Each of these is discussed and compared.

The data in the report, and the conclusions and recommendations for the use of TD NiCr, should be of interest to current users of this alloy and to those searching for a strong high-temperature material.

Source: W. L. Harps
Marshall Space Flight Center
(MFS-21489)

Circle 1 on Reader Service Card.

MECHANICAL PROPERTIES AND STRESS CORROSION OF MP35N MULTIPHASE ALLOY

The alloy MP35N is a member of the relatively new family of multiphase alloys. It is composed of 35% Ni, 35% Co, 20% Cr, and 10% Mo. The strength of the alloy is achieved through phase transformation and aging reactions. The low-temperature mechanical and corrosion properties of this alloy have been evaluated and published in a report.

Solution-treated, work-strengthened, age-hardened bar stock samples are examined over the temperature range 75° F (23.9° C) to -423° F (-252.8° C). The ultimate tensile and yield strengths increase with decreasing temperature, as do elongation values. The percent reduction in area changes very little down to -200° F (-129° C) and then begins to decrease gradually.

Alternate-immersion corrosion tests are made on stressed and unstressed longitudinal tensile specimens [0.125 in. (0.3175 cm) diameter] and transverse O-ring specimens machined from 1.0 in. (2.54 cm) diameter bars. The tests show that MP35N is not susceptible to stress-corrosion cracking when immersed in a 3.5 percent NaCl solution for 180 days. The general conclusion is that this corrosion resistant alloy is suitable for cryogenic environments.

Source: J. R. Montano
Marshall Space Flight Center
(MFS-21521)

Circle 2 on Reader Service Card.

METAL STRUCTURES WITH PARALLEL PORES

The fabrication of porous metal parts by powder metallurgy procedures is a well-established technology. Plates for electrochemical cells and electrodes for certain types of fuel cells, for instance, are presently made by such procedures. The resulting random pore structure, however, is not the optimum pore geometry for all applications. In many cases, parallel pores of a uniform size maybe more suitable. Therefore, an evaluation has been made of a number of possible methods of fabricating metal plates with uniformly-sized parallel pores that could improve cell performance. Four of these methods are discussed in detail.

(1) The elongate-bundle approach,
(2) The wind-and-sinter approach,
(3) The extrude-and-sinter approach, and
(4) The corrugate-stack approach.

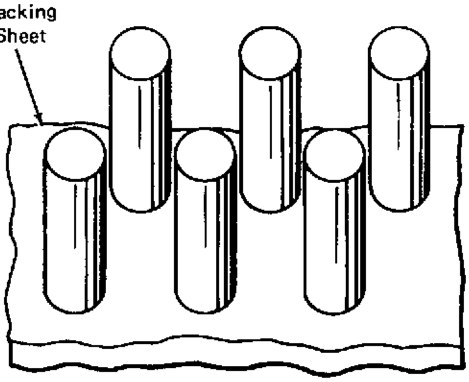


Figure 1. One Possible Structure Produced By the Elongate-Bundle Approach.

In the elongate-bundle approach, a copper rod is clad with a thick-walled nickel tube. This is then machined to obtain a billet having a square cross-section. The billet is elongated by a factor of 81 and cut into 81 sections. These sections are reassembled into a 9-by-9 array that is about the same size as the original billet but contains 81 copper rods, each one-ninth the starting diameter. This new billet can again be elongated, cut into 81 sections and reassembled as before. The process may be repeated several times to yield copper rod filaments as small as 4 micrometers in diameter. After the copper rods are reduced to the desired size, the billet is sliced and the copper is leached out, leaving a porous nickel plate. Modifications of this process are possible; for example, if the roles of the copper and nickel are reversed, a plate with the structure shown in Figure 1 will be formed.

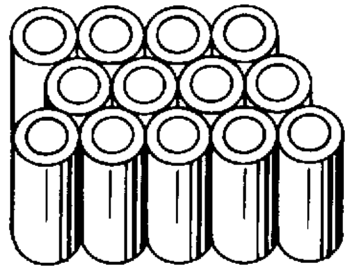


Figure 2. The Structure Produced by the Electrode-Position Method of the Wind-and-Sinter Approach.

The wind-and-sinter approach consists of coating fine copper wire with nickel by electrodeposition and winding it onto a spool. The wound wire is then sintered to form a coherent mass and removed from the spool. The sintered wire coil is cut perpendicular to the wires to yield slices of the desired thickness. The copper is leached out, leaving a structure which has the appearance shown in Figure 2.

The essential aspects of the extrude-and-sinter method are illustrated in the following example: A heavy slurry of water, chopped fused quartz fibers, nickel powder, a wetting agent, and a thickener is forced through a small orifice. This process aligns the quartz fibers parallel to the extrusion axis. The extruded material is cut into convenient lengths, stacked, and compacted. The compact is fired at a low temperature to remove water and organic matter and is then fired at a higher temperature to sinter the nickel powder. The fused quartz fibers are removed by dissolving them in hydrofluoric acid.

In the fourth approach, corrugated-stack plates are fabricated by stacking electroformed, corrugated metal sheets, with the grooves of all the sheets running parallel. The stack is sintered to form a coherent mass and is sliced perpendicular to the grooves. In this system, adjacent sheets tend to nest and obliterate the pores. Figure 3 illustrates how the use of alternate uncorrugated sheets combined with nonparallel stacking can be used to avoid nesting.

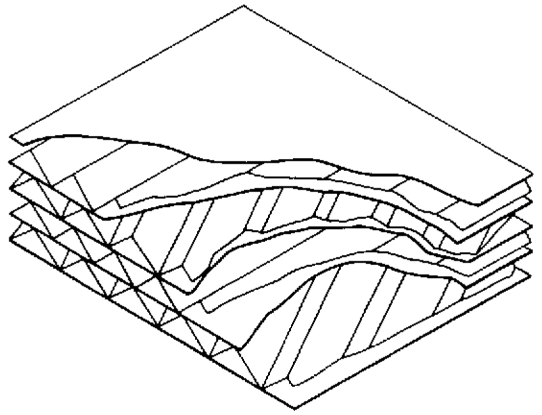


Figure 3. The Deployment of Nonparallel Corrugated Layers To Prevent Nesting in the Corrugate-Stack Approach.

The following documentation may be obtained from:
National Technical Information Service
Springfield, Virginia 22151
Single document price $3.00
(or microfiche $1.45)
Reference: NASA TN D-6259 (N71-23184) Metal Structures With Parallel Pores of Uniform Size

Source: Joseph M. Sherfey
Goddard Space Flight Center
(GSC-10984)

ZM-21 MAGNESIUM ALLOY CORROSION AND MECHANICAL PROPERTIES

Mechanical, corrosion, and stress corrosion properties of bare ZM-21 magnesium alloy flat tensile specimens were determined using both longitudinal and transverse cut sections. The mechanical properties were evaluated at temperatures from 77 K (-320° F) to 477 K (+400° F) for 0.229 cm (0.090-inch) thick material. The tensile test data indicate increasing ultimate tensile and 0.2% offset yield strengths, with decreasing temperature. Elongation, measured in a 2.54-cm (1.0-inch) gauge length, decreases with decreasing temperatures. At all testing temperatures used in this evaluation, the transverse test specimens had better mechanical properties than the longitudinal specimens.

Corrosion and stress corrosion tests were conducted for eight weeks using 0.127-cm (0.050-inch) thick material specimens stressed to 50 and 75 percent of the 0.2% offset yield strength and subjected to the following environments: (a) Marshall Space Flight Center outside atmosphere during the unseasonably wet and mild temperature months of November, December, 1971, and January, 1972; (b) humidity cabinet at 100° F (310 K) with 95% humidity; and (c) 100-ppm chloride solution completely immersed.

The atmospheric environment produced no adverse effects on the mechanical properties of the test specimens. Tests performed in the 95% relative humidity environment indicated crevice corrosion in the test specimen at the contact points of the specimen with the stress jigs. Test specimens immersed in the 100 ppm chloride solution indicated a rather severe chemical attack which preferentially etched tiny pinholes in the material. This alloy was not susceptible to stress corrosion cracking under the conditions of these tests. As in the mechanical properties evaluation at cryogenic and elevated temperatures, the transverse test specimens exposed to the stress corrosion conditions indicated more consistent mechanical properties than the longitudinal test specimens.

Source: J. W. Montana and E. E. Nelson
Marshall Space Flight Center
(MFS-22049)

Circle 3 on Reader Service Card.

STRESS CORROSION CRACKING OF ALUMINUM AND STEEL IN DIMETHYLDICHLOROVINYL PHOSPHATE

A proposed method of insect removal for commercial aircraft making international flights involves use of a relatively new organic phosphorus compound known as dimethyldichlorovinyl phosphate (DDVP). In considering the proposed, automatic, in-flight disinsection system or aerosol disinsection on the ground upon arrival of aircraft, one of several factors evaluated concerning the system was the effect of the disinsectant on the service life of the aircraft. Since aluminum alloys (2024-T351 and 7075-T651) and steel are the two most prevalent structural metals used in commercial aircraft, specimens of these materials were prepared for testing by cleaning thoroughly and placing them in a stressing fixture to obtain the desired measured strain. The specimens were then submerged in test solutions.

Three specimens (Al 2024-T351, Al 7075-T651 and 18 Ni maraging steel) loaded to 50 percent of their yield strengths, three specimens loaded to 75 percent, and three unstressed control specimens were placed in each of five beakers. Three of the beakers contained solutions of 0.001, 0.01, and 0.1 percent DDVP, one beaker a solution of 3.5 percent NaCl, and another beaker held distilled water containing less than 0.5 ppm ionizable chlorides.

Test duration was 42 days (approximately 1000 hours); visual inspection was made daily. Metallographic examination of selected specimens was made with a scanning electron microscope to verify and record failure modes. The results of the investigation show that stress corrosion cracking susceptibility of 2024-T351 and 7075-T651 aluminum and 18 nickel maraging steel was not accelerated by exposure to low concentrations (up to 0.1 percent) of DDVP. Stress corrosion cracking susceptibility was found to be no worse in DDVP than in pure distilled water and better than in a 3.5-percent salt solution.

Source: T. S. Humphries
Marshall Sapce Flight Center
(MFS-21690)

Circle 4 on Reader Service Card.

AN EVALUATION OF MECHANICAL AND CORROSION PROPERTIES OF A-286 ALLOY

Many problems are associated with the thermal treatment, procurement, and processing of AM-355 stainless steel used in the space program. An evaluation of an alternative alloy, A-286, has been conducted and the results published in a report. Alloy A-286 has the following approximate composition: Fe-54%, Ni-25%, Er-15%, Ti-2%, Mo-1%, Mn-1½%, and other elements less than 1½%.

The report presents the mechanical properties of 40-percent-minimum cold worked, precipitation hardened, A-286. Corrosion-resistant bar stock of this alloy is examined over the temperature range: 75° F (23.9° C) to -423° F (-253° C). Several sources of the alloy are evaluated for stress corrosion susceptibility, chemical composition, microstructure, microhardness, tensile and yield strengths, elongation, and reduction in area.

The results show that the ultimate tensile and yield strengths increase with decreasing temperature, as do the elongation valves. The percent reduction in area changes very little with decreasing temperature down to -200° F (-129° C). Below this temperature the area begins to gradually decrease.

Alternate-immersion, stress corrosion tests are performed on stressed and unstressed tensile specimens [0.125 in. (0.3175 cm) in diameter] and transverse C-ring specimens machined from 1.0-in. (2.54-cm) diameter bars. Results indicate that the material is not susceptible to stress corrosion cracking when immersed in 3.5 percent NaCl solution for 180 days.

Source: J. W. Montano
Marshall Space Flight Center
(MFS-21359)

Circle 5 on Reader Service Card.

STRESS CORROSION CRACKING OF FERROUS AND NICKEL ALLOYS

Several high-strength alloys were tested to determine their stress corrosion susceptibility. The alloys evaluated were AISI 410 and 431 stainless steel, multiphase MP35N, Carpenter 20 Cb and 20 Cb-3, Inconel 718, Unitemp L-605, 18 Ni maraging steel (250 grade), and type 4130 steel. The alloys that are hardenable only by cold work (Carpenter 20 Cb and 20 Cb-3, and Unitemp L-605) were evaluated in the annealed condition, and the remaining alloys were evaluated in their commonly used heat treatments. Three types of specimens were used to test the stress corrosion resistance of these alloys in at least two directions of grain orientation. Flat tensile specimens were used to test sheet material and were loaded by constant deflection. Round tensile specimens stressed in uniaxial tension were used, to test the longitudinal and long transverse direction of 0.635-cm (0.250-inch) thick plate, the longitudinal direction of all bar stock, and the transverse direction of 5.08 cm (2 inches) of greater diameter bar stock. C-rings, utilizing the constant deflection method, were used for the transverse direction of stock less than 5.08 cm in diameter.

All heat-treated round and flat tensile specimens were wet-grit blasted with (quartz) abrasive to remove surface oxides, and all specimens were washed in cold running water and rinsed in alcohol to facilitate drying. Specimens fabricated from type 4130 steel were cadmium plated (per QQ-P-416, Class 2, Type II), baked 24 hours at 450 K to prevent hydrogen embrittlement and then given a chromate treatment. The tests were conducted in a ferris wheel like, alternate-immersion tester containing a 3.5-percent solution (in deionized water) of sodium chloride at a pH of from 6.8 to 7.2. The exposure cycle was: 10 minutes in solution and 50 minutes drying. Type 431 stainless steel was also tested in a 5-percent salt spray cabinet.

Results indicate that 20 Cb and 20 Cb-3 stainless steel, Inconel 718, Unitemp L-605, and Multiphase MP35N are all highly resistant to stress corrosion cracking, and to general surface corrosion in a 3.5 percent sodium chloride solution, in all conditions tested. Test results also indicate that type 410 stainless steel, 18 Ni maraging steel (250 grade) and type 4130 steel are susceptible to stress corrosion cracking in a 3.5-percent salt water solution. Type 431 stainless steel cracked in the salt spray environment, but not in the alternate immersion tester. In most of the alloys tested the unstressed and stressed specimens showed a negligible loss in tensile strength after 180 days of exposure in the alternate immersion tester, with the exception of alloy 410 stainless steel, 18 Ni maraging steel (250 grade), and alloy 4130 steel specimens.

Source: E. E. Nelson
Marshall Space Flight Center
(MFS-21764)

Circle 6 on Reader Service Card.

COLUMBIUM ALLOY MATERIALS STUDY

A study of columbium alloys presents a background of the development of the alloys and a comparison of mechanical properties such as ultimate yield, modulus, and creep. Also presented is a discussion of fabricability, coating, and the total structural cost.

Up to the time of this presentation, an authoritative comparison of columbium alloys did not exist. Previous studies were restricted, in that they did not address themselves to material stability as a manufacturing limitation. This study covers columbium alloys from their manufacture to the final product stage and recommends the optimum choice for selection to be used in the Space Shuttle Program.

Source: J. W. Davis of
McDonnell Douglas Corp.
under contract to
Marshall Space Flight Center
(MFS-21898)

Circle 7 on Reader Service Card.

TENSILE DATA DETERMINED FOR TD NiCr AND HS188 ALLOYS

Tensile strength tests on TD NiCr and HS188 alloys were performed in conventional creep machines, using procedures appropriate for high test temperatures and thin-sheet specimens. Six-element (Kanthal A-1) zone-controlled furnaces capable of operating at 1478 K (2200° F) in air, where used to heat the samples, and they were loaded by directly suspended weights. Strains for tests at 1033, 1143, 1254, and 1366 K (1400°, 1600°, 1800°, and 2000° F) were sensed at 2.54-cm (1-in.) gauge points by double-dial gauge-averaging extensometers that can be read to 2 μm (0.00001 in.). At 1478 K (2200° F), mechanical extensometers were used for two tests; but because of excessive oxidation of the rods and tubes and because there was an indication of negative creep after an initial period of positive creep, their use was discontinued. In the remaining four tests at 1478 K, creep was measured with telescoping Pt-strip extensometers, spotwelded to the specimen by means of a small welder. A filar microscope was sighted on the Pt-strip extensometer through a quartz window in the furnace wall. Temperature was monitored by two 20-gauge Chromel-Alumel thermocouples at each gauge point for tests at 1033, 1143, 1254, and 1366 K. At 1478 K a single 14-gauge Chromel-Alumel thermocouple was used to monitor the specimen temperature. Temperature was controlled by a saturable-reactor magnetic-amplifier system.

A summary of creep data for all HS188 alloy specimens, 0.038-cm (0.015-in.) sheets, shows the following results:

HS188, Stress for 0.5% Creep, 100-Hr.

Temperature °F (K)	kg/mm^2	ksi	(N/m^2)
1400 (1033)	12.2	17.4	(120 x 10^6)
1600 (1143)	5.8	8.2	(56.5 x 10^6)
1800 (1254)	1.0	1.5	(10.4 x 10^6)
1900 (1311)	0.49	0.70	(4.84 x 10^6)
2000 (1366)	0.16	0.23	(1.59 x 10^6)

The results of the tests on the TD NiCr specimens, 0.038-cm (0.015-in.) sheets, provide the following summary on creep data:

TD NiCr, Stress for 0.5% Creep, 100-Hr.

Temperature °F (K)	kg/mm^2	ksi	(N/m^2)
1400 (1033)	10.7	15.2	(105 x 10^6)
1800 (1254)	4.8	6.8	(46.9 x 10^6)
2000 (1366)	2.3	3.3	(22.8 x 10^6)
2200 (1478)	2.5	3.5	(24.2 x 10^6)

Source: C. L. Dotson of
Vulcan Testing Laboratory
under contract to
Marshall Space Flight Center
(MFS-21803)

Circle 8 on Reader Service Card.

COATED PROPERTIES OF COLUMBIUM ALLOY FS-85

Baseline properties were required to characterize FS-85 metal during the Phase B study of the Space Shuttle. Since the columbium alloy FS-85 was to be coated, coated properties were required, and no data on these properties existed. To meet this need, a report has been prepared on the mechanical properties of coated columbium FS-85.

The report describes changes in alloy strength (ultimate and yield) as a function of temperature. These data were previously unavailable to the engineer. The coated properties of FS-85 are represented by means of plots of ultimate tensile strength, yield strength, and modulus of elasticity as a function of temperature. These properties are applicable for up to 100 hours of continuous exposure at temperatures up to 1644 K (2500° F).

Source: J. W. Davis of
McDonnell Douglas Corp.
under contract to
Marshall Space Flight Center
(MFS-21902)

Circle 9 on Reader Service Card.

Section 2. Polymers, Insulation, and Coatings

EXTRUDED FLUOROCARBON ELASTOMER

In order to make a safe bumper for air-lock hatches, it was necessary to find a suitable nonflammable shock-absorbent material. A fluorocarbon elastomer was chosen; but, because of its shape and large size, the bumper could not be made by the conventional process of molding. The bumper was to be a circular [48 inches (122 cm) in diameter] strip, 0.06 in. (0.15 cm) thick.

It was found that this part could be made economically by special extrusion techniques and that the ends could be spliced by vulcanizing. The completed bumper was solvent vulcanized and bonded to the air lock. It absorbed shock without rebounding, resisted cutting and abrasion, and markedly reduced fire hazards.

The potential applications of this fabrication-material combination are many. They include use in aircraft, cars, operating rooms, explosive plants, and other instances where shock absorption and nonflammability are important.

Source: J. E. Gaughan and
R. F. Henke of
McDonnell Douglas Corp.
under contract to
Marshall Space Flight Center
(MFS-21715)

Circle 10 on Reader Service Card.

THERMAL INSULATION TECHNIQUES: A STUDY

A thorough test and evaluation program was devised to select the best thermal insulation for the Lunar Module. Significant design parameters were developed for the fabrication and analysis of multilayer insulation. These testing procedures, the hardware, and the fabrication techniques may be of interest to many designers and users of multilayer insulation systems.

It was determined that the best measure of thermal performance was the effective emittance. Conductance was found to be an appropriate measure only when the insulation was sandwiched between two fixed layers.

Test procedures and apparatus were developed for heat-flow measurements, crinkling, storage life, gas pressures, seam effectiveness, and other parameters. Fabrication techniques evaluated included blanket splices, folded seams, overlap seams, and Velcro.

Reference: Tawil, M. N., and Caloger, P.: "The Use of Multilayer Insulation on the LM Vehicle". AIAA 4th Thermophysics Conference Paper No. 60.609.

Source: E. W. Lee, A. Bartilucci, and
M. Tawil of
Grumman Aircraft Corp.
under contract to
Johnson Space Center
(MSC-12369)

STAINLESS-STEEL INSULATING MATERIAL

High-temperature processes require special insulating materials. Though current materials perform adequately in most instances, for some purposes they are too dense, expensive, and weak.

A new insulation developed for high-temperature processes consists of several alternating layers of perforated stainless-steel foil and mesh. The layers are diffusion bonded to each other and the container wall.

The wire layers separate the foil and provide open spaces. Convection currents, which could conduct heat, are broken up by the foil. Perforations are included to relieve internal pressure differentials. Bond points between different layers are small and not aligned. This increases the insulation by avoiding direct paths for heat flow.

This system has a low density (less area for heat conduction), has excellent strength, and is temperature resistant and stiff. Potential uses include metal ducts and pressure vessels used in high-temperature processes.

Source: N. C. Wood of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-19177)

Circle 11 on Reader Service Card.

AN IMPROVED CONFORMAL COATING PROCESS

Problems are frequently encountered when printed-circuit boards and cordwood assemblies are conformal coated. Component leads and cordwood conductors, especially those with sharp edges, do not always receive uniform coats. The coating tends to accumulate between the components and the printed-circuit boards (bridging). In addition, the coated boards frequently do not provide good heat conduction from the component to the heat sink.

A new process for the application of conformal coatings overcomes all of these difficulties. The process is as follows:

1. The components are cleaned in trichloroethane, and a coat of thixotropic urethane is applied to lead ends and sharp edges. A hypodermic needle with a funneled end is used to apply the urethane.
2. The cordwood is immersed in polyurethane, removed, and allowed to drain from 1 to 2 minutes, while the heat sink is held in the vertical plane. The module is then placed in a vacuum chamber and evacuated to 5.0 mm of mercury, to remove any trapped air. This insures that all cracks or crevices are filled.
3. Draining does not remove all excess coating, so the remainder is removed by spinning while the coating is still in a fluid state. Rotation rates, temperature, and time can be adjusted to achieve the desired coating thickness. After drying, vacuum or wire probes, nitrogen blowing, or solvent sprays may be used to correct defects such as webs or thick spots.
4. The correctly applied coating is cured for approximately 6 hours while rotating the cordwood. The heat sinks are kept vertical to keep the polyurethane where it is needed, while the coating is smoothed out over the entire assembly.

Source: H. G. Franklund, A. S. Garcia,
N. J. Sawyer, A. P. Coha, and
C. Crownhart of
Ryan Aeronautical Co.
under contract to
Johnson Space Center
(MSC-12340)

Circle 12 on Reader Service Card.

BONDED SOLID-FILM DRY LUBRICANT: GLASS RESIN

A new method has been developed for preparing lubricating powders. Powders such as molybdenum disulphide, graphite, gold, bismuth or Teflon, are mixed with a glass-resin polymer or a polyphenylene sulphide, which serve as binders, in a suitable solvent (e.g., xylene or toluene, for the glass resin; alcohol or water, for the polyphenylene sulphide). A film of the mixture is then applied by spraying, brushing, or dipping. It is bonded to one or more of the mating surfaces and is expected to reduce friction (coefficients of friction less than 0.15) and extend the life of lubricated parts.

These binders are superior to other adhesives, as they can be cured at room temperature in air and require no pretreatment of the substrate.

The proportions of lubricant and binder used to make up a film will influence the final properties. Two formulations tested are:

MoS_2	- 10 parts	MoS_2	- 10 parts
Graphite	- 1 part	Graphite	- 1 part
Gold	- 5 parts	Resin	- 5.1 parts
Resin binder	- 7.4 parts		

The lubricant-to-binder ratio can vary from 1:0.2 to 1:1.2.

These lubricants were originally developed for use with bearings in spacecraft. However, they are suitable for most industrial or commercial products having bearings or other moving parts subject to frictional wear, especially where liquid lubricants may be too messy.

Source: M. E. Campbell, W. L. Cunningham, and W. D. Walker of Midwest Research Institute under contract to Marshall Space Flight Center (MFS-21633, 21872)

No further documentation is available.

SPRAYED FLUOROCARBON COATINGS

Fluorocarbon coatings may be applied by a series of sprayings. This technique is useful when thick coatings are needed. A smooth continuous fluorocarbon coating cannot be obtained with the conventional fill-and-drain or slurry-coat methods. During successive coatings, the solvent carrier penetrates or dissolves the previous coats, causing blistering and wrinkling.

Additional solvents allow the application of the coating to be controlled. Volatile solvents, such as methyl ethyl ketone and methyl isobutyl ketone, are added to the fluorocarbon solution, causing the fluorocarbon coatings to dry faster and allowing rapid repetition of the process. To prepare a suitable solution of a 20%-solids fluorocarbon, an elastomer coating in methyl ethyl ketone is further diluted with one part of methyl isobutyl ketone. The major advantage of this process is that it permits the repeated coating of complex surfaces without the formation of blisters or wrinkles.

Source: J. P. Mills and J. E. Gaughan of McDonnell Douglas Corp. under contract to Marshall Space Flight Center (MFS-21776)

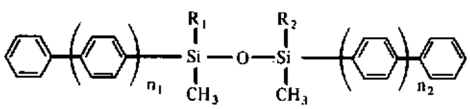
Circle 13 on Reader Service Card.

LUBRICANTS RESISTANT TO NUCLEAR RADIATION

A series of lubricants resistant to nuclear radiation have been developed for use with nuclear power and spacecraft or under exposure to long-term natural radiation. These same lubricants may be useful in commercial nuclear power plants or in machinery used with radionucleides.

The lubricants are polymers that take advantage of the radiation resistance of polyphenylenes and the fludity and nonvolatility of silicones.

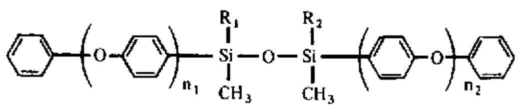
The basic structures first synthesized were of the type



(I)

where n_1 and n_2 may be from 1 to 4 and R_1 and R_2 are CH_3 or C_6H_5.

A second class of compounds was synthesized incorporating the increased lubricity of polyphenyl ethers. They were of the type

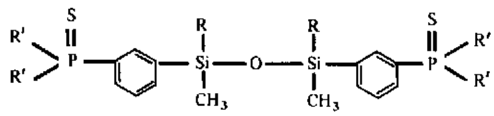


(II)

where n_1 and n_2 may be from 1 to 5 and R_1 and R_2 are CH_3 or C_6H_5.

The synthesis of these two classes is similar. The starting polyphenyl hydrocarbon or polyphenyl ether is brommated and undergoes a Grignard's reaction series with $(CH_3)_2SiCl_2$, to form essentially one-half of the desired product as a silicon chloride. Hydrolysis then removes the Cl, and the silicon atoms are joined through an oxygen linkage to give the compound I or II, depending on the starting material. Similar compounds in which the terminal phenyl groups are monohologenated can also be prepared.

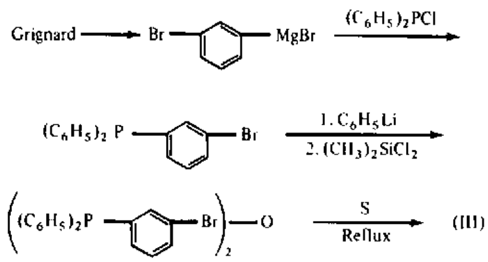
Another class of lubricants incorporates phosphorus within the structure, to improve the miscibility of the lubricant. These compounds are of the type



(III)

where R is CH_3 or C_6H_5 and R′ may be the same or different alkyl, aryl, alkyaryl, or holoaryl groups.

A sample synthesis is as follows:



These or similar materials, prepared as part of the same study, have low pour characteristics and good antiwear properties. The compounds are radiation resistant, and synthetic techniques have been advanced to the point where relatively large quantities can be produced in a short time.

Source: R. I. Akawie, N. Bilow, D. Brittian, M. N. Gardos, and J. R. Jones of Hughes Aircraft Co. under contract to Marshall Space Flight Center (MFS-21452)

Circle 14 on Reader Service Card.

MOLDING PLASTICS AND POLYMERS: SELF-LUBRICATING FLUOROCARBON ELASTOMERS

The substitution of Teflon for the small quantities of polyethylene customarily used as a process aid and for smooth-surface finishing in the manufacture of elastomers and thermoplastics, has shown promising results. When cryogenically-pulverized Teflon powder was compounded with Fluorel gum stock for the fabrication of space suit material, the Teflon proved to be a highly satisfactory slip agent. In this instance, white FEP Teflon was selected because of its color, particle size, and nonagglomerative characteristics. (The complex molding of some items of the astronaut's equipment demands a good mold flow.) At two parts per hundred of rubber, the FEP Teflon coats the mold surface during the molding or extrusion process and forms a thin film on the surface of the material. This reduces the sticking of the gum stock to the mold and extruder barrels.

Another advantage derives from the fact that the incorporation of FEP Teflon improves the abrasion resistance of the molded material by lowering the coefficient of surface friction. The low-temperature characteristics also appear likely to show improvement. Results are exemplified by the following:

a. A 12.5-mm (50-mil) thick sheet, compounded by pulverized FEP Teflon powder of 0.7-micrometer size and with Fluorel 2140 gum stock, passed cold flexing 355 K (180° F), over a 0.3-cm (1/8-inch) mandrel and 233 K (-40° F) and flexed to approximately 321 and 200 K (120° and -100° F).
b. A 0.1-mm (4-mil) coating of a Beta fiberglass fabric with Teflon yarn binder passed -100° F flexing over 1/8-inch mandrel without cracking.
c. The coated fabric also passed at 365 K (200° F).

Source: T. R. Parker of
ILC Industries, Inc.
under contract to
Johnson Space Center
(MSC-13720)

Circle 15 on Reader Service Card.

CRYOGENIC MULTILAYER INSULATION TECHNOLOGY

A summary has been compiled of the development of multilayer insulation systems. The summary consists of the results of work performed over a period of nine years at Marshall Space Flight Center and in industry; the work performance at MSFC covers three categories:

(1) The generation and compilation of multilayer insulation composite test data;
(2) The analysis, design, and testing of heat flow through multilayer insulation applied to ducting, seams, electrical feedthroughs, structural supports, and tank sidewall; and
(3) The development, modification, and utilization of new testing procedures, tanks, and test facilities.

Data have been generated, analyzed, and documented for different multilayer insulation composites. The data include the effects of: temperature, layer density, bearing pressure, interstitial gas pressure, panel-joint application techniques, multilayer insulation material, and thermal penetration. Also, studies have been made on heat flow through penetrations, with and without mass flow through or around the penetration.

Source: E. H. Hyde, J. M. Walters, and
I. C. Yates, Jr.
Marshall Space Flight Center
(MFS-22008)

Circle 16 on Reader Service Card.

LOW-TEMPERATURE LUBRICANTS

A new group of fluorine-substituted esters have a wide liquid range, are thermally stable, and maintain their lubricity at cryogenic temperatures.

The properties of a sample lubricant are as follows:

Pour Point	–50° F (228 K)
Viscosity	47.95 cst at 100° F (311 K)
Evaporation Rate	1.36%/hr at 300° F (422 K)

The compounds are of the type

$$CH_3CH[CH_2\underset{\underset{O}{\|}}{C}\text{-}O\text{-}CH_2\text{-}\underset{\underset{CF_3}{|}}{CF}\text{-}O\text{-}CH_2(CF_2)_nH]_2$$

where n may be 2, 4, 6, or 8.

The ester with n=6 is prepared by condensing hexafluoropropylene oxide with heptyl alcohol, in the presence of NaOH, to form 2-heptyloxytetrafluoroprolonic acid. The acid is reduced with sodium borohydride in tetrahydrofuran to 2-heptyloxy-2,3,3,3-tetrafluoropropanol-l. The alcohol is reacted with 3-methylglutaric acid to give the ester product.

Source: L. W. Breed and R. Elliott of
Midwest Research Institute
under contract to
Marshall Space Flight Center
(MFS-21040)

Circle 17 on Reader Service Card.

LUBRICANT FOR MILL CUTTING

In some instances, such as in clean-assembly rooms, a part may need to be mill-cut without scattering chips around the area.

A lubricant* developed as a vacuum grease for space flight has been discovered to be an excellent machining lubricant, with the added advantage that the lubricant holds even heavy chips on the tool. Machining refuse that normally would scatter around the work area sticks to the grease. In this way, the surrounding area may be kept chip-free without elaborate cleaning procedures. Furthermore, the lubricant reduces chatter and improves the machined finish.

*The lubricant used is "Krytox #25AC", "Space Grease", manufactured by Dupont Corporation.

Source: J. M. Dimino of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-15700)

No further documentation is available.

FOAM/MULTILAYER INSULATION SYSTEM

High-performance insulation (HPI) used on cryogenic tanks provides a very effective insulation system. But HPI must be protected from degradation caused by compressive loads. Normally this requires a full-scale structural bulkhead.

A new method of installing HPI uses a spray-on foam as a supporting matrix for the insulation. The HPI is placed in grooves in the foam that protects and holds the insulation in place. The bulkhead is replaced by a thin, sealing membrane. The result is a considerable saving in weight and material.

The thermal conductivity of this system may be varied by controlling the vacuum in the insulation. Maximum insulation is achieved at pressures of 10^{-5} torr.

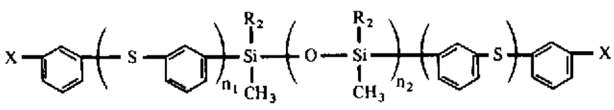
Source: H. S. Ishikawa and
J. J. Florey of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-24080)

Circle 18 on Reader Service Card.

VERSATILE THERMALLY-STABLE LUBRICANT

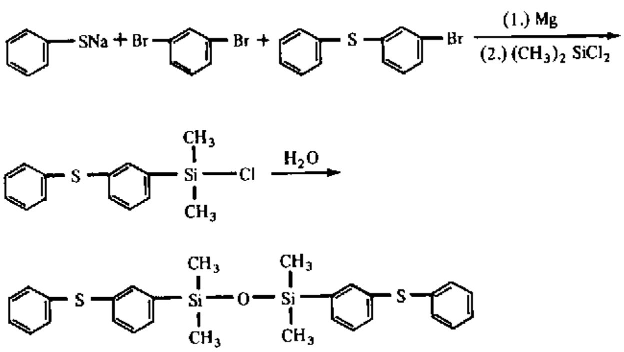
A new class of lubricants has several useful properties that make them of interest to a wide variety of users. The compounds are di- and tri-siloxane thiophenyl ethers. They have very broad liquid ranges (down to -49° C), excellent lubricities, and very low vapor pressures. In addition, they are radiation resistant, nonvolatile under high vacuums, and can be mixed with many other lubricants to achieve special properties.

The general structure of the compounds is shown below.



The values of n_1, n_2, and n_3 may be the same or different and may be from 1 to 3; X may be chlorine, methyl, alkyl, aryl, aralkyl, alkaryl groups, or hydrogen; and R_1 and R_2, which can be the same or different, may be methyl or phenyl groups.

As an example, the synthesis of the compound with X = hydrogen, R_1 and R_2 = CH_3, and n_1, n_2, and n_3 = 1 is described. Sodium thiophenoxide is refluxed with M-dibromobenzene to yield 1-bromo-3-(phenylthio)benzene. This product is converted by a Grignard's reaction in tetrahydrofuran to the final compound



Source: R. I. Akawei and N. Bilow of
Hughes Aircraft Company
under contract to
Marshall Space Flight Center
(MFS-22411)

Circle 19 on Reader Service Card.

FOAM INSULATION WITH DIRECTIONAL PROPERTIES

Polyphenylene oxide (PPO) foam is made by adding a gas-generating agent to the PPO resin. The gas causes the plastic to foam during cure. The foam normally consists of minute spherical bubbles, and it responds to stresses such as stretching without regard to the direction of the stress.

A new anisotropic foam, made by a special curing process, has a useful directional response to stress. This foam is made by placing the resin between two parallel platens during curing. While the resin is curing and the foam is forming, the platens are pulled apart. Instead of spherical bubbles, the foam will consist of bubbles elongated in the direction perpendicular to the plane of the platens.

This process produces a more elastic foam that can be stretched without splitting in all directions parallel to the platens, but the foam maintains its rigidity in the direction perpendicular to the platens.

Foam of this structure is especially suited as insulation for vessels which may expand or contract because of temperature changes or for other reasons. As a vessel changes size, the foam will stretch or compress without cracking. With the bubbles perpendicular to the vessel wall, the thickness of the insulation will not change appreciably.

Source: J. H. Heathman and
G. B. Yeats of
General Dynamics
under contract to
Johnson Space Center
(MSC-14303)

Circle 20 on Reader Service Card.

NEW HEAT-SHIELD FLEXIBLE CURTAINS FOR OPERATION AT HIGH TEMPERATURES

A new heat-shield flexible curtain is made by sandwiching a high silica batting material between two new outer fabrics and sewing them together to form a blanket. The blanket is designed to reduce the temperature from the hot side of the curtain to the cold side, to meet the thermal requirements for protection of the structure, components, wiring, etc., on the S-II Skylab stage. The thickness of the curtain can be altered to provide additional thermal insulation.

The heat-shield flexible curtain [designed for a 1255 K (1800° F) environment] is installed by mounting one end to the heat-shield rigid panels and the other end to the engine hatband. The combination of the heat-shield rigid panels and the flexible curtains provides an insulation barrier when the engine hot gas exhaust thrusts forward. The flexible curtain accommodates the excursion of the engines, while still retaining its insulation capabilities.

Source: W. T. Barthe of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-24113)

Circle 21 on Reader Service Card.

IMPROVED CONFORMAL COATING

A new conformal coating protects electronic circuitry from moisture, mechanical shock, and vibration. The coating material has a low dielectric constant, a low dissipation factor, and high resistivity. It will not absorb moisture and does not release gas (out-gassing) after cure.

The formulation can be applied by dipping or spraying, then it is cured by heating at 60° to 100° C. The film maintains its elastomeric properties from -60° to 150° C.

The formulation consists of two parts: 1) a commercially available tolylene diisocyanate capped diol prepolymer, and 2) a diol-triol mixture of 2-ethyl-1,3-hexane diol and trimethyolhexane as a curing agent. The triol is specially synthesized for this coating and provides more transparent polymer than previously available triols.

Source: J. A. Webster of
Monsanto Corp.
under contract to
Marshall Space Flight Center
(MFS-21091)

Circle 22 on Reader Service Card.

Patent Information

The following innovations, described in this Compilation, have been patented or are being considered for patent action as indicated below:

Extruded Fluorocarbon Elastomer (Page 7) MFS-21715

Inquiries concerning rights for the commercial use of this invention should be addressed to:

Patent Counsel
Marshall Space Flight Center
Code A&PS-PAT
Marshall Space Flight Center, Alabama 35812

Bonded Solid-Film Dry Lubricant: Glass Resin (Page 9) MFS-21633, 21872

Inquiries concerning rights for the commercial use of this invention should be addressed to:

Patent Counsel
Marshall Space Flight Center
Code A&PS-PAT
Marshall Space Flight Center, Alabama 35812

Sprayed Fluorocarbon Coatings (Page 9) MFS-21776

Inquiries concerning rights for the commercial use of this invention should be addressed to:

Patent Counsel
Marshall Space Flight Center
Code A&PS-PAT
Marshall Space Flight Center, Alabama 35812