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LUBRICATION HANDBOOK FOR THE SPACE INDUSTRY
Part A: Solid Lubricants
Part B: Liquid Lubricants

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Materials and Processes Laboratory
Science and Engineering Directorate

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16. ABSTRACT

This handbook is intended to provide a ready reference for many of the solid and liquid lubricants used in the space industry. Lubricants and lubricant properties are arranged systematically so that designers, engineers, and maintenance personnel in the space industry can conveniently locate data needed for their work.

This handbook is divided into two major parts (A and B). Part A is a compilation of solid lubricant suppliers information on chemical and physical property data of more than 250 solid lubricants, bonded solid lubricants, dispersions and composites. Part B is a compilation of chemical and physical property data of more than 250 liquid lubricants, greases, oils, compounds and fluids. The listed materials cover a broad spectrum from manufacturing and ground support to hardware applications of spacecraft.

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FOREWORD

This handbook was prepared by Ernest L. McMurtrey, Lubrication and Surface Physics Branch, Engineering Physics Division, Materials and Processes Laboratory, National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Marshall Space Flight Center, Alabama 35812.

The previous handbook was prepared by Midwest Research Institute, 425 Volker Boulevard, Kansas City, Missouri 64110, Report No. NASA CR-161109, Report Date September 1978, Contract No. NAS8-31715, Sponsoring Agency: National Aeronautics and Space Administration, Washington, D.C. 20546, under the technical supervision of Ernest L. McMurtrey.

Part A of the handbook is divided into six major sections and Part B into four sections. Section I, introduction, defines solid lubricants, outlines their advantages and disadvantages, states the purpose of Part A and gives a general description of the various types of solid lubricants; Section II contains alphabetical lists of manufacturers and products, compatibility, and usage tables for selected bonded solid lubricants and composite materials; Section III contains data sheets which give general composition and physical properties of selected lubricants; Section IV includes data sheets listing manufacturer supplied test and application data; Section V covers laboratory test data obtained at MRI on selected solid film lubricants, gear test data and composite materials; Section VI containing three appendices, one a glossary of terms, the second containing excerpts of solid lubricant specifications, and the third, description of test apparatus and procedures used in laboratory evaluation of solid lubricants.

The four sections of Part B are Section I, introduction, which states the purpose of Part B, gives instructions for use of Part B, presents indices of all materials included, and a series of charts illustrating various kinds of potential application; Section II includes brief written description of military specifications; Section III contains data sheets, listing physical and chemical properties of selected lubricants; Section IV contains results of long-term evaluation of selected grease lubricants; and Section V containing three appendices, one a glossary of lubrication terms, the second a series of summaries of standard testing methods used to evaluate lubricating oils, gears, and fluids and the third information system international (SI) units and conversion factors.

Units are given in the SI System with the traditional units in parentheses.

ACKNOWLEDGMENTS

The author wishes to thank R. L. Merrell, C. A. Torstenson, and H. G. Gibson for their work and support on this project.

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NOTICE

The inclusion or exclusion of any manufacturer's product in or from this handbook shall not be construed as either approval or disapproval of any product or manufacturer by the United States Government.

The information contained in this handbook was obtained primarily from government reports, military specifications, qualified products lists and suppliers of commercial lubricants.

The handbook will answer many questions that confront designers and other lubricant users; however, questions will arise which are outside the scope of the handbook. In addition, only a small percentage of the available lubricants are included in the handbook. Obviously, lubricants not given in the handbook can be found that will satisfy some of the same applications as those included herein. The chief advantage of the handbook is that it aids in matching a specific lubricant to a particular application.

PART A – SOLID LUBRICANTS

A-I. INTRODUCTION

Solid film lubricants can generally be defined as materials that provide lubrication to two relatively moving surfaces under essentially dry conditions. The most common, and still the most widely used, of the solid film lubricants, powdered graphite and molybdenum disulfide, have been known and used limitedly for more than 100 years. The development of these and other solid lubricants, as has also been the case of fluid lubricants and greases, has not been an exact science but an "art" or technology that has developed through many years of service experience. And, it has been only in the last 25 years that they have been recognized and accepted to any significant extent by industry due to need for lubricants that would meet temperature and other environmental conditions beyond the range of conventional fluid and synthetic lubricants.

Bonded solid film lubricants in which the lubricating solid film is attached to the substrate by a binder material is even more recent in development than the powdered solid films. In the early development of bonded films, a large variety of binder materials were evaluated including such materials as corn syrup, asphalt base varnish, silicon base varnish, and glycerol. Binder materials now include thermoplastic and thermosetting resins, metals, ceramics and metal salts. Lubricating solids now being investigated and developed include soft metals, metallic oxides, metallic sulfides and many others.

The study of solid lubricants, as they are now known, is a relatively new field of lubrication. No systematic study of these materials began until a considerable time after they were introduced in the aircraft industry (1940 to 1950). In their early applications, they were erroneously sold as "cure-all" lubricants, resulting in misapplications. Unfortunately, these misapplications frequently outweighed the proper applications, thereby slowing down the general acceptance of these lubricants by industry. There are many areas of lubrication in which specific types of solid films can be used to advantage and there are also areas when they should not be used, as there is also no single solid film lubricant that will meet all requirements.

Many authors have discussed the applications and listed the various advantages and disadvantages of solid film lubricants, some of these are:

A. Advantages of Solid Lubricants

1. Do not collect grit.
2. Can be used under extremely high load conditions.
3. Excellent storage stability.
4. LOX and oxygen compatible (inorganically bonded films).
5. Suitable for use over wide temperature range.
6. Resistant to the effects of nuclear and gamma radiation.
7. No disposal problem.

8. Friction decreases with increased load.

9. In some applications solid films will provide lubrication for the life of the parts.

B. Disadvantages of Solid Lubricants

1. Limited amount of lubricant available.

2. Friction coefficient higher than with hydrodynamic lubrication.

3. Provisions for the effective removal of wear debris must be provided.

4. Considerations must be given to removing heat from contact zone of bearings and gears when using solid film lubricants.

5. More expensive (costly relubrication).

6. Avoidance of contamination during coating processes and assembly of parts lubricated with solid film lubricants.

7. Elevated temperature cure cycle of some solid films will damage the mechanical properties of some materials.

The selection of the proper solid film lubricant for a particular application is a complex problem for the lubricant engineer, involving a consideration of specific lubricant properties and operating parameters and environment of the equipment. A lengthy discussion of the theory of lubrication by solid materials, such as graphite and molybdenum disulfide, and others, is beyond the scope of this handbook. The material in this handbook is intended as a general aid or guide to the designers of spacecraft and ground support equipment in selection of solid film lubricants for specific applications. This book is not intended to supplant other publications or expert opinions on specific problems, such as corrosion protection, LOX, fuel, solvent and other material compatibility.

Many bonded solid lubricant films will provide a degree of corrosion protection; however, some are much better than others. The degree of corrosion protection provided depends primarily on film constituents and film thickness. Several bonded solid lubricant films have been specifically formulated with special corrosion inhibitors to improve their corrosion protection qualities. One military specification has been written to cover corrosion protecting solid lubricant films. These films have been successfully used by the Army for numerous applications. They are valuable in applications where the system using the film operates infrequently and spends long periods in storage such as missiles which remain in a ready condition between brief periods of test. These films, however, do not provide the protection afforded by cadmium or nickel plating. Under conditions where severe corrosion conditions exist, solid lubricant films should be applied over a suitable corrosion protective metal plating.

Users of this handbook are urged to contact the Engineering Physics Division of the Materials and Processes Laboratory, Marshall Space Flight Center, for aid in selecting solid lubricants for special applications.

The inclusion or exclusion of any manufacturer's product in or from this handbook shall not be construed as either approval or disapproval of any product or manufacturer by the United States Government.

The information contained in this handbook was obtained primarily from government reports, military and federal specifications, and from data sheets and product literature from suppliers and manufacturers of solid film lubricants. Some of the data are also based on tests conducted in the Institute laboratory.

This handbook will answer many of the problems confronting designers and users of solid film lubricants; however, questions will undoubtedly arise which are outside the scope of this handbook. In addition, only a representative portion of the numerous solid film lubricants are included in this handbook and there are, no doubt, other solid films not listed which will satisfy the same applications of some of these listed herein.

C. Description of Solid Film Lubricants

Solid film lubricants encompass many separate and distinct types of classes of lubricating materials, each having somewhat different properties, operating ranges, method of attachment to the substrate material, etc. These film lubricants could be grouped in many ways; one of the most logical, and the one used herein, is to classify them according to the manner by which they are attached to the substrate, since in many cases similar lubricating compounds are used in more than a single class of solid films.

Unbonded Solid Lubricants

The unbonded solid films, in granular or powdered form, are the simplest types of the solid film lubricants, and, although not physically or chemically attached to the substrate material, they do adhere to many substrate materials by mechanical or molecular action, and provide a low friction lubricated surface. In general, these film lubricants will have lower adhesion, wear-life, load carrying capacity, fluid resistance, and other properties than the bonded solid film lubricants. The most common of the unbonded lubricants are graphite and molybdenum disulfide, although other materials, such as: Teflon and other plastics, talc, and metallic salts are used in this form. The temperatures at which these lubricants may be used is determined by their reaction in air; molybdenum disulfide oxidizes at about 399°C (750°F) (molybdenum trioxide) and tends to reduce its lubricating properties. Graphite loses its absorbed water at elevated temperatures and is generally not recommended for temperatures above 538°C (1000°F). Some metallic salts also exhibit reasonably good lubricating properties at temperatures up to 538°C (1000°F); however, most unbonded film lubricants are limited to temperatures of 260°C (500°F) or lower.

Unbonded solid film may be applied by several methods depending on the type or form in which it is applied. In the dry powder condition, it may be applied by brushing, spraying or burnishing. In a fluid suspension or colloidal form (water or solvent), it may be applied by the brush, dip, or spray method, allowing the non-adhesive carrier to evaporate. In aerosol containers (gas carrier, i.e., Freon), the powdered dry film may be sprayed directly on the lubricated surface. In both the latter forms the fluid or gas carrier does not improve the adhesion or lubricating properties of the film, but only provides a convenient form of application.

Resin-Bonded Solid Lubricants

Resin-bonded films are currently the most widely used solid lubricant. This group includes both air-cured and heat-cured materials (air-cured and heat-cured refer to the methods used in polymerizing the resin binder). The solid lubricant pigments used most frequently in resin-bonded films are: molybdenum disulfide (MoS_2), tungsten disulfide (WS_2), polytetrafluoroethylene (PTFE), and graphite.

The pigment may be one lubricating solid or a mixture of several. The function of the pigment is to provide the wear reduction and low friction required for the system being lubricated. The binder serves to hold the lubricating pigment to the metal surface so that the motion of parts does not result in the complete loss of the pigment from the system. In the formulation of resin-bonded solid lubricants, the proper pigment-to-binder ratio is very important. However, the pigment-to-binder ratio can vary widely with the particular resin used.

There are certain factors that can affect the overall performance of bonded films in any given situation. One is the condition of the metal surfaces being lubricated. In most cases the surface is changed or modified by some pretreatment to obtain optimum film performance. Other factors involve the variables directly related to the application of the film, such as spraying techniques. In addition to application factors, environmental conditions and the operating characteristics of the system being lubricated can drastically affect the film. These factors should be considered in any final selection of a bonded solid lubricant.

The resin-bonded solid lubricants are generally applied in thin films to the surfaces of the components being lubricated. In most cases the surfaces have been pretreated in a manner that will depend on the substrate being used and the service for which the parts are intended. The resin-bonded solid lubricant films can be applied by spray, dip, or brush methods. Spray application is usually the most satisfactory. Spray coating thickness should range from 5×10^{-6} to 2×10^{-5} m. (0.0002 to 0.0008 in.), the optimum being about 1.27×10^{-5} m. (0.0005 in.). If the film is too thick, it will be structurally weak and peel or flake off with sliding motion under load; on the other hand, a film that is too thin may result in premature failure due to the rupture. Although some test results are contradictory, it appears that for high load a thinner film (7.6×10^{-6} m. (0.0003 in.) per surface will give the longest wear-life. For lighter load conditions the thickness can be substantially increased. However, economics of the coating process (spray time, curing time, etc.) should enter into any decision involving the use of thicker films. A second area that must be considered if thick films are used is wear debris generation. Large amounts of wear debris are generated from thick films and some provision must be made for the removal of this debris from the bearing area.

The wear behavior and wear-life characteristics of a resin-bonded solid lubricant are different from those of most other solid film lubricants. In its intial wear-in, it will exhibit relatively high wear which will become less with time. The initial high wear rate can be attributed to the loss of loose material from the surface of the film and the compaction of the film by the applied load. As running continues, the film will appear glossy or burnished. The best performance, lowest wear and steadiest friction, are obtained during this time.

Bonded dry film lubricants can provide long wear-life, good abrasion resistance, good adhesion, and good resistance to a variety of solvents. Performance o^c the film depends to a large extent on the cured properties of the binders used.

Air-Cured Resin-Bonded Solid Lubricants

An air-cured resin-bonded solid lubricant consists of a lubricating powder, or powders, in an air-curing resin binder material. The lubricating pigments most frequently used are molybdenum disulfide, graphite, or a lubricating plastic such as polytetrafluoroethylene. This type of solid film lubricant usually contains a lower total solid content than heat-cured film to provide a more satisfactory solution for aerosol application.

Binder materials used in the air-drying solid lubricants are thermoplastic resins such as cellulosics and acrylics. These resins require no heat cure and therefore can be used on substrates that cannot be baked. They produce a fairly hard film, but do not have good resistance to solvents.

Heat-Cured Resin-Bonded Solid Lubricants

Heat-cured, resin-bonded solid lubricants are the most widely used in the dry film lubricant industry. The materials consist of the lubricating pigment and a specially formulated resin binder. The lubricating pigment is usually a mixture of approximately 90% molybdenum disulfide and 10% graphite, which seems to give the best results when friction and wear are considered. The relatively small concentration of graphite appears to improve the low load performance (lower friction) of the MoS_2. Replacing graphite with antimony trioxide (Sb_2O_3) produces the same effect. Films are available that contain small percentages of silver, indium, lead, and so forth, as well as a mixture of MoS_2 and graphite, but the lubricant coatings containing only graphite and molybdenum disulfide are more readily available.

Curing of the binders in these films will usually require a bake of approximately 1 hr at 149°C to 204°C (300°F to 400°F). Special films such as those containing polyimide binders require baking temperatures of 302°C (575°F) for 2 hr. Because of the baking temperature, care in the selection of the metal substrate is required. Temperatures of about 135°C (275°F) for 1 hr can weaken certain aluminum alloys.

Binders that are normally used in the heat-cured solid lubricants are thermosetting and include alkyds, phenolics, epoxides, silicones, polyimides, and polyphenylene sulfide (PPS). Alkyds are relatively inexpensive, cure at low temperatures and are generally easy to handle. Phenolics have good surface adhesion and are harder than the alkyds, but require a high-temperature curing cycle, usually 149°C to 204°C (300°F to 400°F) for 1 hr. Epoxy resins have excellent solvent resistance and very good adhesion, but are softer than phenolics. Modified epoxyphenolics combine the good properties of both materials. Silicones offer a higher operating temperature, but are softer and have only fair adhesion. Normally, they are used only for high-temperature service and then only when the brittleness of the silicate type of binder presents a problem.

The polyimides are relatively new in the adhesive field. They were originally intended as laminating resins for use with fiber glass cloth. The have also been used as a wire insulation in electric motors where high temperature is a problem. The polyimide binder materials have extended the useful range of the resin-bonded lubricant films up to approximately 371°C (700°F). Films containing these materials have been evaluated at temperatures up to 538°C (1000°F) in vacuum. Such tests have demonstrated that the polyimide resins do have a limited life at extreme temperatures. The polyimide bonded solid-lubricant films have also demonstrated their superiority in extremely high load application.

There are several other new binder materials being considered for use with solid lubricants. These materials are similar in structure to the polyimides and include the pyrones, PBI (polybenzimidazole), PBT (polybenzothiazole), and polyphenylene sulfide. Of these four materials, the pyrones are very resistant to oxygen and strong acids.

These heat-cured materials are superior to the air-drying materials and should be used where high load-carrying ability or long life is required. They are usable over the temperature range of -73°C to 371°C (-100°F to +700°F).

The importance of the resin-bonded solid lubricants has grown rapidly over the past 20 years. Because of this rapid growth, means of controlling the quality of the bonded films was needed. To insure that quality be maintained, government agencies have prepared specifications covering the materials and their uses. Typical of these specifications are MIL-L-8937, MIL-L-23398, and MIL-L-46010. There are also several custom variations available in these heat-cured solid film lubricants.

<u>Inorganic-Bonded Solid Film Lubricants</u>

Inorganic-bonded lubricating pigments are usually referred to as high-temperature solid lubricants. These materials are intended for use at temperatures from approximately 260°C (500°F) to in excess of 649°C (1200°F). There is considerable overlap in applicable temperature ranges for the various binder materials; however, certain ones operate very satisfactorily at temperatures down to 149°C (300°F). The high-temperature inorganic-bonded solid lubricants are a logical extension to the resin-bonded types. They employ ceramic or salt-based binders to give greater temperature resistance than resins and usually employ lubricating solids which are more thermally and oxidatively stable than graphite or MoS_2. Solid lubricants of this type usually contain lubricating solids (pigments) such as lead oxide, lead sulfide, calcium fluoride, gold, silver, and so forth. There are exceptions, however, and a number of the ceramic and salt-based binders are used with MoS_2 and graphite.

<u>Nonceramic (Silicate, Phosphate)</u>

The bonding technique for these materials commonly employs water-soluble silicates, phoshates, etc., which produce a hard coating that tends to be brittle when cured (curing is accomplished by slowly driving out the excess water by heating). In general, they can be used at temperatures from -73°C to 538°C (-100°F to +1000°F). Solid lubricants containing the salt-based binders usually contain graphite, MoS_2, lead sulfide, powdered metals, etc. They can be used in extremely high load areas, with loads in excess of 6.895×10^8 N/m^2 (100,000 psi). However, for applications where movement is a prime design consideration, they are not as good as resin-bonded films as far as wear-life and strength are concerned. Two advantages of these films over others are that (1) they will not outgas significantly in a vacuum of 10^{-9} torr, and (2) they are compatible with liquid oxygen. However, there are disadvantages such as (1) lack of corrosion protection, and (2) softening of the film in the presence of water or moisture for extended periods of time.

Ceramic-Bonded

The ceramic bonding agents are glasses rather than resins, and soften when heated. On cooling they solidify and serve as a bonding agent for the dispersed lubricant. Their principal advantage is their good strength at elevated temperatures. The lubricating solids commonly employed with ceramic binders are graphite, calcium fluoride (CaF_2), lead oxide, and mixture of barium fluoride (BaF_2) and CaF_2. Useful temperature ranges are from approximately 260°C (500°F) to more than 816°C (1500°F).

Although the ceramic-bonded materials, as a class, do not perform as well (i.e., have low friction and wear) as the resin-bonded materials at lower (room) temperatures, they generally exceed the resin-bonded films' capabilities by a considerable amount (over 10 times) at higher temperature 371°C (700°F). There are exceptions, however, one being when the lubricants are run at high speeds which result in high temperatures over 371°C (700°F) being generated in the contact zone. In such cases, the ceramic-bonded films will generally outperform the resinous films.

One problem in the use of ceramic-bonded materials is the thermal expansion of the cured coating. This must be matched closely with the expansion of the base material. If the thermal expansion characteristics are not the same or very similar, the coating will be fractured and be easily removed from the substrate.

D. Pretreatment for Solid Films

Pretreatment of the substrate material prior to the application of any bonded solid film lubricant can greatly affect its performance; in most cases, it improves the wear-life and other properties of solid films and, in many cases, it is a prerequisite for satisfactory adhesion and optimum lubricant properties. The type of substrate pretreatment recommended is dependent on several factors; including the specific substrate material, the bonding resin employed, and the operating environment of the film application. However, in general, pretreatments of the substrate are grouped into one of two classes: cleaning to remove dirt, grease, oil, surface scale, etc.; and surface treatment by chemical or mechanical means to improve the surface for better mechanical bond of the resin. The chemical treatment can provide corrosion resistance and a surface to which the bonding resin will adhere better than to the substrate.

Cleaning of the substrate is usually by means of sanding, scraping, grit or sand blasting to remove dirt, scale and foreign material, and a solvent, acid or other chemical rinse to remove any surface oils. A clean surface free of any oil film is essential for good bonding and adhesion of any adhesive or resin bond. Substrate-treated films to improve corrosion resistance and improve resin bond include phosphating, sulfiding, anodizing, chemical, etc.

The chemical pretreatments mentioned above are used primarily in conjunction with the resin-bonded solid lubricants that have curing temperatures below 204°C (400°F). These same pretreatments can be used with the inorganic-nonceramic-bonded lubricants if the curing temperatures can be held below 204°C (400°F). The most accepted surface pretreatments for the inorganic-bonded films are the vapor or grit blast. Pretreatment of surfaces for ceramic-bonded solid lubricants is, in nearly all cases, grit blasting.

E. Application Processes

The processes by which the bonded solid lubricants are applied to bearing surfaces can have considerable effect on the film behavior and performance. All of the various types of bonded films (resin, inorganic nonceramic, and ceramic) can be applied by spraying, dipping, or brushing.

Of the three common methods, spraying and dipping are most often used. However, there certainly are cases where brushing can be used to advantage. The commonly held opinion that "spraying a dry lubricant is just like spraying paint," is not correct. A dry lubricant is a very special material and should be treated as such. Applying a solid lubricant in the sloppy manner often used in spray painting will result in a very degraded film. In a dipping process, the entire part is usually completely immersed in a lubricant bath. Sometimes the dip process will produce a film of nonuniform thickness.

Sputtering

Films applied by the conventional methods mentioned above have film thicknesses greater than 2.54×10^{-6} m (0.0001 in.) per surface. In many specialized applications, such as close tolerance ball bearings, the aforementioned film thickness is too great and can cause interference and jamming of the bearing with wear debris. For the application where thin films are required because of close tolerances, the application of lubricants by the sputtering technique appears to have the most promise.

Sputtering of materials is not new; the process used has been in use for over 100 years. However, the application of solid lubricant materials to surfaces by the sputtering process is relatively new.

Sputtering is generally performed in an inert gas atmosphere (argon, xenon, etc.) of several microns pressure. A potential is applied across the electrodes to ionize the inert gas. The material to be sputtered is the cathode (target). The sputtered material from the target is ejected through the plasma and deposits on the part being coated. The basic mechanism of sputtering is thus a process where the positive ions of the inert gas, which forms a gaseous plasma, are accelerated through an electron free region with enough energy to knock off or sputter the negatively charged target material. The sputtered material is deposited on the work piece substrate, which is placed close to the target source. Lubricant film thicknesses of from 2×10^{-7} m to 1×10^{-6} m (2,000 to 10,000 A) can be applied by the sputtering process.

The most frequently used sputtering systems are powered by either DC or RF power supplies. Sputtered film of MoS_2 lubricant has been successfully applied to journal bearings, spur gears, ball bearings, and many other parts requiring lubrication.

Personnel at the NASA-Lewis Research Center have conducted extensive studies in the area of sputtered lubricants. Their outstanding work in this field has resulted in the widespread interest now being shown in the sputtering process.

There is only one sputtered lubricant film identified by number in this document. It is identified as MEL-1 and is available from Midwest Research Institute. The MEL-1 film contains only molybdenum disulfide. However, other materials such as CaF_2, BaF_2, and mixtures of these high temperature solid lubricants have been successfully applied by the sputtering process.

A-II. INDICES OF MANUFACTURERS AND PRODUCTS, USAGE TABLES – SELECTED SOLID LUBRICANTS AND COMPOSITES

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Tiodize Company, Inc. Huntington Beach, California	9, 10, 13, 14, 16, 23	40-42	33-34	-

Notes:
* Material data reported on several pages of referenced section.
-- Not included in referenced section.

SOLID LUBRICANT PRODUCT LIST

Manufacturer and Lubricants	Page Nos. Sections AIII	AIV
Acheson Colloids Company		
DAG 154	1	1
DAG 217	1	-
DAG 243	1	-
DAG 250	1	1
Molydag GT-261	1	1
Molydag 254	1	1
Emralon 310	1	2
Emralon 311	1	2
Emralon 312	1	2
Emralon 314	1	4
Emralon 317	2	2
Emralon 320	2	2
Emralon 321	2	2
Emralon 328	2	3
Emralon 329	2	3
Emralon 330	2	3
Emralon 333	2	3
Emralon 336	2	4
Emralon 343	2	4
American Durafilm Company		
"Teflon"	3	-
Durafilm CTF, TCGF	3	-
Oil-ES-Oil	3	-
Ball Aerospace Systems Division		
VAC KOTE BPS 18.06	4	-
VAC KOTE BPS 18.07	4	5
VAC KOTE 21207	4	5
VAC KOTE BPS 32599	4	-
VAC KOTE BPS 23561	4	-
VAC KOTE BPS 23974	4	-
VAC KOTE 44153	4	-
Bel-Ray Company, Inc.		
Molylube AR	5	6
Molylube SR	5	6
Molylube N	5	6
Molylube Spraycote	5	-
Molylube 1200	5	-

Manufacturer and Lubricants	Page Nos. Sections AIII	AIV
Electrofilm Corporation		
Lubri-bond A	14	12
Lubri-bond B	14	12
Lubri-bond 220	14	12
Lubri-bond N	14	12
Lubri-bond Ht	14	12
Electrolube	14	13
Lube-Lok 66-C	14	13
Lube-Lok 1000	15	13
Lube-Lok 1000X	15	13
Lube-Lok 2006	15	13
Lube-Lok 2109	15	-
Lube-Lok 2306	15	14
Lube-Lok 2396	15	14
Lube-Lok 2406	15	14
Lube-Lok 4306	15	14
Lube-Lok 4396	16	14
Lube-Lok 5306	16	14
Lube-Lok 5396	16	14
E/M Lubricants, Inc.		
Everlube 620, 620A, 620C	17	15
Everlube 626	17	15
Perma-Slik G	17	19
Everlube 629	17	15
Everlube 690	17	15
Everlube 810	18	16
Everlube 811	18	16
Everlube 812, 812-3	18	16
Everlube 823	18	16
Everlube 860	19	19
Everlube 967	19	17
Everlube 1120-8	19	19
Everlox 16 and 16B	19	17
Everlox 17	19	17
Everlox 18	19	17
Ecoalube 642	20	17
Inlox 44 and 88	20	17
Esnalube 382	20	19
Microseal 100-1	20	17
Microseal 100-2	20	-
Microseal 200-1	21	17
Microseal 200-23	-	17
Microseal 300-1	21	17

Manufacturer and Lubricants	Page Nos. Sections AIII	AIV
Sandstrom Products Company		
Sandstrom 9A	39	32
Sandstrom 26A	39	32
Sandstrom LC-300	39	32
Sandstrom Hi-T-650	39	32
Tiodize Company, Inc.		
Tiolon A20	41	-
Tiolon E20	41	-
Tiolon X20	41	-
Tiolube 70	42	-
Tiolon 1000	42	-
Tiolube 29	40	33
Tiolube 31	40	33
Tiolube 39	40	33
Tiolube 460	40	34
Tiolube 1175	41	34
Tiolube 21	41	34

SOLID LUBRICANT CLASSIFICATION

	Lubricant Name or Code	Page Nos. Sections AIII	AIV
I. Unbonded			
	Release Coating No. 7	-	-
	DAG 154	1	1
	DAG 243	1	1
	Colloidal Graphite	8	-
	Dri-Slide	13	-
	Graphite	8	
II. Organic-Bonded Films			
A. Air-Dry Films			
	Drilube 107	11	10
	Drilube 108	12	-
	Drilube 272	12	-
	Drilube 831	12	10
	Emralon 314	1	4
	Emralon 320	2	2
	Emralon 321	2	2
	Emralon 327	2	-
	Emralon 328	2	3
	Emralon 329	2	3
	Emralon 336	2	4
	Durafilm CTF	3	-
	Molylube AR	5	6
	Molykote 3402	9	-
	Everlox 17	19	17
	Graphokote 143, 220, 95	8	-
	Molykote 321R	9	7
	Lubri-Bond A	14	12
	Lubri-Bond B	14	12
	Lubri-Bond N	14	12
	Lubri-Bond HT	14	12
	Lubri-Bond 220	14	12
	Perma-Slik G	17	19
	Fel-Pro C-300	22	20
	Surf-kote A-2178A	28	25
	Surf-kote A-1625	27	24
	Poxylube 330	35	31
	Poxylube 420	35	31
	Sandstrom 26A	39	32
	Sandstrom Hi-T-650	39	32
	Tiolube 31	40	33
	Tiolube 21	41	34

B. Heat-Cured Film

Lubricant Name or Code	Page Nos. Sections AIII	AIV
Molydag 261	1	1
DAG 250	1	1
DAG 154	1	1
Emralon 312	1	2
Molydag 254	1	1
Emralon 310, 311	1	2
Emralon 312	1	2
Emralon 314	1	4
Emralon 317	2	2
Emralon 330	2	3
Emralon 333	2	3
Emralon 336	2	4
Emralon 343	2	4
VAC KOTE 18.07	4	5
VAC KOTE 44153	4	-
Molylube SR	5	6
Molylube N	5	6
Graphokote-120	8	-
Molykote 106	9	7
Molykote 3400A	9	7
Drilube No. 1A	11	9
Drilube 2	11	9
Drilube 6A	11	9
Drilube 90	11	9
Drilube 101	11	-
Drilube 273	11	-
Drilube 701	11	10
Drilube 805N	11	-
Lube-Lok 66C	14	13
Electrolube	14	13
Lube-Lok 1000	15	13
Lube-Lok 2006	15	13
Lube-Lok 2109	15	-
Lube-Lok 2306	15	14
Lube-Lok 2396	15	14
Lube-Lok 2406	15	14
Lube-Lok 2606	15	-
Lube-Lok 2696	15	-
Lube-Lok 4306	15	14
Lube-Lok 4396	16	14
Lube-Lok 5306	16	14
Lube-Lok 5396	16	14
Electrolube	14	13
Everlube 620, 620A, and 620C	17	15
Everlube 626	17	15
Everlube 629	17	15
Everlube 690	17	15
Everlube 810	18	16

Lubricant Name or Code	Page Nos Sections AIII	AIV
B. Heat-Cured Film (Continued)		
Everlube 811	18	16
Everlube 812, 812-3	18	16
Everlube 823	18	16
Everlube 860	19	19
Everlube 967	19	17
Everlube 1120-8	19	19
Everlox 16	19	17
Inlox 44 and 88	20	17
Esnalube 382	20	19
Microseal 100-1	20	17
Microseal 100-2	20	-
Microseal 200-1, and 200-23	21	17
Microseal 300-1	21	17
Ecoalube 642	20	17
Fel-Pro C-200	22	20
Henderlube 402A	26	23
Henderlube 413	26	23
Henderlube 426	26	23
Henderlube 462A	26	23
Surf-kote M-2036	28	25
Surf-kote M-2049	28	25
Surf-kote A-1625	27	24
Surf-kote A-2178A	28	25
Surf-kote H-108	27	24
Surf-kote 359	27	24
Surf-kote 360	27	24
Surf-kote M-1284	27	24
LOB-1800-G	28	25
Lubeco M-390	-	26
Lubeco 905	31	26
Lubeco 2123	31	26
Lubeco 2023	31	-
Lubeco 2023B	31	26
AFSL-28	32	28
AFSL-29	32	28
MLF-5	32	27
MLF-9	32	27
MLR-2	32	27
MLR-66	32	27
NPI-14	33	29
NPI-16	33	29
NPI-5	-	-
NPI-1220	33	30
NPI-132	33	29
NPI-2500	34	30
NPI-425	34	30
Poxylube 500	35	31
Poxylube 750	35	31

V. Composites

Lubricant Name or Code	Page Nos. Sections AIII	AIV	AV
Bartemp	-	-	19
RT/Duroid 4000	37	-	-
RT/Duroid 5813 and 5813M	37	-	19
RT/Duroid 4300	37	-	19
Purebon	36	-	-
Molalloy PM 101	36	-	20
Molalloy PM 103	36	-	20
Molalloy PM 104	36	-	20
Molalloy PM 105	36	-	20
Molalloy 107	36	-	-
Molalloy PM 108	36	-	20
Salox M	-	-	19
Rulon A	6	-	19
Rulon II	6	-	-
Rulon J	7	-	-
Delrin 100	-	-	20
Delrin-AF	-	-	20
Zytel	-	-	20
Ryton (PPS)	-	-	20
SP-1 (Vespel)	-	-	18
SP-21	-	-	18
SP-22	-	-	18
SP-211	-	-	18
SP-31	-	-	18
SP-5	-	-	-
Feurlon-CT	-	-	18
Feurlon-AW	-	-	18
Feurlon-C	-	-	18
Meldin-PI	6	-	18
Meldin-PI-30X	6	-	18
Meldin-PI-15Y	6	-	18
Pennlon	6	-	-
Thermid 600	-	-	-
Fluoroloy C	23	-	-
Kel-F	23	-	-
Kynar	23	-	-

SPECIFICATION SOLID LUBRICANTS

Specification	Lubricant Name or Code	Manufacturer or Suppliers
MIL-M-7866C(1)	Powdered Molybdenum Disulfide (MoS_2)	Climax Molybdenym Company Dow Corning Corporation Electrofilm, Inc. Tiodize Co., Inc.
SS-G-659A	Graphite	Electrofilm, Inc. The Dixon Ticonderoga Company
MIL-L-8937D	Molydag 254 RFU Drilube 2 Kal-Gard FA Everlube 620C Lube-Lok 5306 LF 711 Henderlube M-390 Sandstrom LC-300 Poxylube 500 Tiolube 460	Acheson Colloids Company Drilube Company Kal-Gard Coating & Mfg. Co. E/M Lubricants, Inc. Electrofilm, Inc. Lubri-Film Inc. H. A. Henderson Company Lubeco, Inc. Sandstrom Products Company Poxylube, Inc. Tiodize Company, Inc.
MIL-L-23398C	Molykote 3402 Kal-Gard AD Lubri-Bond 220 Perma-Slik G Surf-Kote A5021	Dow Corning Corporation Kal-Gard Coating & Mfg. Co. Electrofilm, Inc. E/M Lubricants, Inc. Hohman Plating & Mfg. Co., Inc.
MIL-L-46010A(2)	Drilube 6A Ecoalube 642 Fel-Pro C 651A Henderlube 413 Molykote 3400A Sandstrom 9A Lube-Lok 2109	Drilube Company E/M Lubricants, Inc. Fel-Pro, Inc. H. A. Henderson Company Dow Corning Corporation Sandstrom Products Company Electrofilm, Inc.
MIL-L-81329C	Drilube 805N Molylube N Everlube 811 and 812-3 Lube-Lok 2306 Tiolube 29	Drilube Company Bel-Ray Company, Inc. E/M Lubricants, Inc. Electrofilm, Inc. Tiodize Company, Inc.
NASA-1367	Lube-Lok 2306	Electrofilm, Inc.
NASA-A-D-66A	Lube-Lok 4306	Electrofilm, Inc.
05-10626-A (USN/BW)	Microseal 100-1	E/M Lubricants, Inc.

SPECIFICATION SOLID LUBRICANTS (Concluded)

Specification	Lubricant Name or Code	Manufacturer or Suppliers
MSFC 502	MLF-5 NPI-5	Midwest Research Institute National Process Industries
MSFC 253	MLF-9	Midwest Research Institute
NASA 50M60434	MLR-2 NPI-425	Midwest Research Institute National Process Industries
MIL-L-46147A	Lubri-Bond 220 Perma-Slik G Molykote 3400A	Electrofilm, Inc. E/M Lubricants, Inc. Dow Corning Corporation
MIL-M-45202C	Magnadize	General Magnaplate Corporation
MIS-19350D	Emralon 330	Acheson Colloids Company
NAVORD WS 9004	Lubribond N	Electrofilm, Inc.
MPD-9706	Lube-Lok 1000 and 1000X	Electrofilm, Inc.

SOLID FILM LUBRICANT "LOX" AND ROCKET FUEL COMPATIBILITY

Product Name or Code	Compatibility Rating "LOX" *	Compatibility Rating Rocket Fuels **	Manufacturer	Reference
DAG 154	Batch Test	-	Acheson Colloids Company	*, a/
Molykote Spray	Batch Test	-	Dow Corning Corporation c/	*, a/
Molykote 321R	Satisfactory	Satisfactory	Dow Corning Corporation	*, b/, **, b/
Molylube AR	No Reaction	-	Bel-Ray Company, Inc.	*, b/
Molylube N	No Reaction	-	Bel-Ray Company, Inc.	*, b/
Molylube Spray	Batch Test	No Reaction	Bel-Ray Company, Inc.	*, a/, **, b/
CL-5940	Batch Test	-	CBS Laboratories	*, a/
CLD-5940	Satisfactory	-	CBS Laboratories	*, a/
Drilube 701	Batch Test	-	Drilube Company, Inc.	*, a/, **, b/
Drilube 702	Satisfactory	-	Drilube Company, Inc.	*, a/, **, b/
Drilube 805	No Reaction	-	Drilube Company, Inc.	*, b/, **, b/
Drilube 831	No Reaction	No Reaction	Drilube Company, Inc.	*, b/, **, b/
Drilube 842	No Reaction	No Reaction	Drilube Company, Inc.	*, b/, **, b/
Drilube 861	No Reaction	-	Drilube Company, Inc.	*, b/, **, b/
Drilube 867	No Reaction	-	Drilube Company, Inc.	*, b/, **, b/
Drilube 868	No Reaction	-	Drilube Company, Inc.	*, b/, **, b/
Drilube 869	No Reaction	-	Drilube Company, Inc.	*, b/, **, b/
Drilube 870	No Reaction	-	Drilube Company, Inc.	*, b/, **, b/
Drilube 898	No Reaction	-	Drilube Company, Inc.	*, b/, **, b/
Electrofilm 66-C	Batch Test	-	Electrofilm Corporation	*, a/
Electrofilm 2306	No Reaction	-	Electrofilm Corporation	*, b/
Electrofilm 2396	Batch Test	-	Electrofilm Corporation	*, a/
Electrofilm 2406	No Reaction	No Reaction	Electrofilm Corporation	*, b/, **, b/
Electrofilm 2606	No Reaction	-	Electrofilm Corporation	*, b/
Electrofilm "M"	No Reaction	-	Electrofilm Corporation	*, b/
Inlox 44	No Reaction	No Reaction	E/M Lubricants, Inc.	*, b/, **, b/
Everlube 811	Batch Test	No Reaction	E/M Lubricants, Inc.	*, a/
Everlube 811	Batch Test	No Reaction	E/M Lubricants, Inc.	*, a/
Everlube 812	No Reaction	No Reaction	E/M Lubricants, Inc.	*, b/
Surf-kote LO-1800	No Reaction	-	Hohman Plating and Manufacturing, Inc.	*, b/
Lubeco 905	No Reaction	-	Lubeco, Inc.	b/
Sodium Silicate and Graphite	Batch Test	-	Materials and Processes Laboratory Marshall Space Flight Center	*, a/
Sodium Silicate and Talc	Batch Test	-	Materials and Processes Laboratory Marshall Space Flight Center	*, a/

Product Name or Code	Compatibility Rating: "LOX" *	Compatibility Rating: Rocket Fuels *	Manufacturer	Reference
Microseal 100-1	No Reaction	-	E/M Lubricants, Inc.	*, b/
Microseal 200-1	No Reaction	-	E/M Lubricants, Inc.	*, b/
Microseal 300-1	No Reaction	-	E/M Lubricants, Inc.	*, b/
MLF-5	Satisfactory	-	Midwest Research Institute	
MLF-9	Satisfactory	-	Midwest Research Institute	*, a/
9A	No Reaction	No Reaction	Sandstrom Products Company	*, b/, **, b/

a/ NASA TM X-985, "Compatibility of Materials with Liquid Oxygen," August 1964.
b/ Manufacturer's literature or test reports.
c/ Manufactured and distributed by Alpha-Molykote Division of the Dow Corning Corporation

NOTES: No Reaction - This notation identifies that the material does not react in the presence of "LOX" or rocket fuels, but has not been submitted to or will not pass the "ABMA" Impact Tester Requirements.

- \- Not recommended for usage, or no information available.
- * "LOX" compatibility
- ** Rocket fuels compatibility

USAGE TABLE - SELECTED SOLID LUBRICANTS AND COMPOSITES

Film Material Designation	Types of Applications: Bearings: Ball	Bearings: Roller	Bearings: Journal	Gears	Sliding Surfaces	Threaded Fasteners	Metal-working	Use Conditions: Load	Speed	Vacuum Out-gassing	Temperature	Corrosion Resistance: Fretting	Corrosion Resistance: Environmental	Ref. Pages Sections: AIII	AIV
AFSL-28 (MRIONITE)	X		X		X	X		Medium to High	Low to High		21°C (70°F) to 816°C (1500°F)	X			
AFSL-29			X		X	X		Medium to High	Low to High		21°C (70°F) to (1200°F)	X			
AFSL-41	X	X	X		X	X	X	Low to High	Low to Medium		-54°C (-65°F) to 399°C (750°F)	X			
DOW CORNING Molykote 3402	X	X	X		X	X	X	Low to High	Low to Medium		-198°C (-325°F) to 315°C (600°F)	X	X		
DRILUBE No. 1A	X	X	X		X	X	X	Low to High	Low to Medium		-184°C (-300°F) to 343°C (650°F)	X			
DRILUBE 702					X	X		Low	Low		-184°C (-300°F) to 454°C (850°F)	X			
EVERLUBE 620	X	X	X		X	X	X	Low to High	Low to Medium		-211°C (-365°F) to 260°C (500°F)	X	X		
EVERLUBE 811	X	X	X		X	X	X	Low to High	Low to Medium		-212°C (-365°F) to 649°C (1200°F)	X			
FEL-PRO C-200	X	X	X	A	X	X		Low to High	Low to High	OK	-54°C (-65°F) to 816°C (1500°F)	X			
FEL-PRO C-300	X	X	X	A	X	X		Low to Medium	Low to Medium	OK	-54°C (-65°F) to 649°C (1200°F)	X			
INLOX 44					X	X		Low	Low		-240°C (-400°F) to 371°C (700°F)	X	X		

Film Material Designation	Types of Applications: Bearings: Ball	Bearings: Roller	Bearings: Journal	Gears	Sliding Surfaces	Threaded Fasteners	Metal-working	Use Conditions: Load	Speed	Vacuum Out-gassing	Temperature	Corrosion Resistance: Fretting	Corrosion Resistance: Environmental	Ref. Pages Sections: AIII	Ref. Pages Sections: AIV
LUBECO 905	X	X	X	A	X	X		High	Low to Medium	OK	-269°C (-452°F) to 260°C (500°F)	X			
LUBE-LOK 5396	X	X	X		X	X	X	Low to High	Low to Medium		-184°C (-300°F) to 316°C (600°F)	X			
LUBE-LOK 5306	X	X	X		X	X	X	Low to High	Low to Medium		-273°C (-459°F) to 232°C (450°F)	X	X		
LUBE-LOK 4396	X	X	X		X	X		Low to High	Low to High		273°C (459°F) to 232°C (450°F)	X	X		
LUBE-LIK 66C					X	X		Low to Medium	Low to Medium		-184°C (-300°F) to 371°C (700°F)	X			
LUBE-LOK 2006		X	X		X	X		Low	Low		-273°C (-459°F) to 454°C (850°F)	X			
LUBRI-BOND A	X	X	X		X	X		Low to High	Low to Medium		-212°C (-350°F) to 204°C (400°F)	X			
LUBRI-BOND N	Solid Film Lubricant of Niobium Diselenide for Use Where Electrical Conductivity is Required														
MICROSEAL 100-1 a/	X	X	X	A	X	X		Low	Low	OK	-253°C (-425°F) to 1093°C (2000°F)	X			
MICROSEAL 200-1 a/	X	X	X		X	X		Low	Low	OK	-198°C (-325°F) to 371°C (700°F)	X			
MEL-1	X	Sputtered MoS_2 Film						Low	Low to Medium		-73°C (-100°F) to 399°C (750°F)				

Film Material Designation	Types of Applications: Bearings: Ball	Bearings: Roller	Bearings: Journal	Gears	Sliding Surfaces	Threaded Fasteners	Metal-working	Use Conditions: Load	Speed	Vacuum Out-gassing	Temperature	Corrosion Resistance: Fretting	Environmental	Ref. Pages Sections: AIII	AIV
MLF-5	X	X	X	A	X	X	X	Low to High	Low to Medium	OK	-100° to 538°C	X			
MLF-9	X	X	X	A	X	X	X	Low to High	Low to Medium	OK	-100° to 538°C	X			
MLR-2 NPI 425 VAC KOTE 18.07			X	A	X	X	X	Low to High	Low to Medium	OK	-184°C (-300°F) to 288°C (550°F)	X	X		
MOLYKOTE 106	X	X	X		X	X		High	Low to High		-54°C (-65°F) to 316°C (600°F)	X	X		
MOLYKOTE 3402	X	X	X	X	X	X		High	Low to Medium		-198°C (-325°F) to 315°C (600°F)	X	X		
MOLYKOTE 321R	X	X	X		X	X		Medium	Low	OK	-180°C (-292°F) to 450°C (892°F)	X			
NPI 14	X	X	X		X	X	X	Low to High	Low to Medium		-54°C (-65°F) to 204°C (400°F)	X	X		
NPI 1220 (VITROLUBE)			X		X	X		Low to High	Low to High		-134°C (-210°F) to 371°C (750°F)	X			
SANDSTROM 9A			X		X	X		Medium	Medium		-196°C (-320°F) to 260°C (500°F)	X	X		
SURF-KOTE M 1284 b/	X	X	X		X	X	X	High	Medium		-100°C (212°F) to 300°C (572°F)	X			
SURF-KOTE A-1625 c/	X	X	X		X	X		Medium	Medium		-54°C (-65°F) to 260°C (500°F)	X			

Film Material Designation	Types of Applications: Bearings: Ball	Roller	Journal	Gears	Sliding Surfaces	Threaded Fasteners	Metal-working	Use Conditions: Load	Speed	Vacuum Out-gassing	Temperature	Corrosion Resistance: Fretting	Environmental	Ref. Pages Sections: AII	AIV
SURF-KOTE M-2049			X		X	X		Medium	Medium		-54°C (-65°F) to -260°C (500°F)	X	X		
Tiolube 460			X	X	X	X		High	Medium	X	-240°C (-400°F) to 343°C (650°F)	X	X		
VACKOTE 21207	X			A	X	X		Low to High	Low to Medium	OK	-260°C (-436°F) to 150°C (-302°F)	X			

Composite Material Designation	Ball	Roller	Journal		Section AV
BARTEMP	x	Primarily Used as Crowned Bearing Retainer Material			
DUROID 5813	X		X	Primarily Used as Retainer Material in Ball Bearings	
DUROID 4300	X		X	Primarily Used as Retainer Material in Ball Bearings	
MALALLOY PM 101	X			Primarily Used as Retainer Material in Ball Bearings	
MOLALLOY PM 103	X		X	High Load Bearings	
MOLALLOY PM 105	Electrical Brush Material				
SALOX M	X			Primarily Used as Retainer Material in Ball Bearings	

a/ Extremely thin films of doubtful value in high load applications.
b/ MIL-L-8937 like material.
c/ MIL-L-23398 like material.
NOTES: A = Has been evaluated on gears for certain space applications.
X = Satisfactory.

A-III. GENERAL DESCRIPTION OF COMMERCIAL SOLID LUBRICANTS AND SELF-LUBRICATING COMPOSITE MATERIALS

ACHESON COLLOIDS COMPANY

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
DAG 154	Colloidal graphite, isopropyl alcohol	Electrically conductive-printed circuits, static bleeds, etc. Lube for business machines, gaskets, mechanisms, rubber components, etc.	Not LOX or rocket fuels. Limited fluids and solvents.	Liquid, 20%, solids, density; 888 kg/m^3 (7.5 lb/gal), diluent, alcohol, esters, and ketones.
MOLYDAG 261	MoS_2, high temperature thermosetting resin	Low friction, high wear and temperature resistance for variety of industrial and consumer applications.	Not LOX or fuels. Most ferrous and non-ferrous metals.	Static friction = 0.105. Service temperature 260°C (500°F), intermittent 316°C (600°F). Density 1,138 kg/m^3 (9.5 lb/gal). Shelf life 6.0 months.
DAG 217	Graphite and nonflammable organic carrier. 24% solid content	Thread compound, antiseize and sealing, for gaseous oxygen systems.	Oxygen pressure to 13.8 x 10^6 N/m^2 (2,000 psi)	Meets MIL-T-5542B (ASG). Temperature range -51°C to 71°C (-65°F to 160°F).
DAG 243	Graphite/MoS_2 Petroleum oil 37% solids	Anti-seize thread lube. Prevents corrosion, eliminate galling and seizing of ferrous metals.	Not with LOX or fuels.	Temperature range to 566°C (1050°F). Meets MIL Specification No. 907B (NAVY). Density = 1,198 kg/m^3 (10.0 lb/gal).
DAG 250	MoS_2 graphite, phenolic resin 42% solids.	Corrosion resistance and moderate to high loan capacity.	Not LOX or rocket fuels.	Liquid: 42% solid, density = 1,092 kg/m^3 (9.1 lb/gal), cure temperature 149°C (300°F), 1 hr.
MOLYDAG 254	MoS_2/lube pigments, thermosetting resin	Bearing surfaces, sliding, rubbing or turning. Meets load and endurance requirements of MIL-L-8937A.	Not LOX or rocket fuels, but many hydrocarbon fluids and solvents.	Good wear-life and corrosion properties. Service temperature 135°C (275°F), maximum 149°C (300°F), 55% solid. Density; 1,296 kg/m^3 (10.8 lb/gal); friction coefficients 0.123.
EMRALON® 310	PTFE coating phenolic resin	Dry film lubricant for material requiring low temperature cure. Has good adhesion, corrosion resistance, and release properties.	Not LOX or rocket fuels. Moderate resistance to chemicals and solvents.	Liquid density; 984 kg/m^3 (8.2 lb/gal). Cure at 149°C (300°F), 1.0 hr, service temperature 177°C (350°F), maximum 204°C (400°F).
EMRALON® 311	PTFE coating phenolic resin	Dry film for food handling and processing equipment. Properties similar to EMRALON® 310.	See EMRALON® 310	Same as EMRALON® 310.
EMRALON® 312	PTFE coating acrylic resin (thermosetting)	Dry film has low friction, good adhesion and release. May be used on most materials including flexible substrates, "O"-rings, seals, etc.	Moderate resistance to chemicals, solvents, and gasoline. Also some organic acids.	Liquid density; 1,068 kg/m^3 (8.9 lb/gal). Cure at 149°C (300°F), 30 min. Service temperature 149°C (300°F), max. 177°C (350°F) intermittent. Shelf life 6.0 months.
EMRALON® 314	Fluoropolymer coating epoxy-bonded	Dry film lubricant for substrates where thermally cured coatings are either undesirable or impractical. Has good adhesion, chemical resistance, and release properties.	Not LOX or rocket fuels. Good resistance to chemicals and solvents.	Applied density; 1,130 kg/m^3 (9.4 lb/gal). Air cure 72 hr at 20°C (68°F) or 52°C (125°F). Service temperature 163°C (325°F). Friction coefficient 0.08 to 0.09.

ACHESON COLLOIDS COMPANY (Concluded)

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
EMRALON® 317	PTFE coating polyurethane resin	Dry film has low friction, good adhesion and corrosion resistance. Easily applied to most materials, wood, glass, plastic, rubber, etc. Air dry 5-6 hr room temperature.		Liquid density; 864 kg/m^3 (7.2 lb/gal). May be cured at 93°C (200°F) in 30 min. Service temperature 121°C (250°F), maximum 149°C (300°F). Coefficient of friction 0.8-0.9. Shelf life 3 months.
EMRALON® 320	PTFE coating, thermoplastic resin	Air-dry film for heat sensitive materials, light load mechanisms. May be used on wood, rubber, metal glass and plastics	Moderate resistance to some inorganic corrosive. Not to organic solvents.	Static friction 0.05 to 0.07 density, 948 kg/m^3 (7.9 lb/gal). Air-dry 2 hr. Service temperature 82°C (180°F); maximum 116°C (240°F). Shelf life 6.0 months.
EMRALON® 321	PTFE coating, thermoplastic resin	Air-dry film, properties similar to EMRALON® 320 but developed for food processing and handling equipment.	Same as EMRALON® 320	Same as EMRALON® 320.
EMRALON® 328	PTFE coating, thermoplastic resin	Properties®and use similar to EMRALON 327.	See EMRALON® 327	Same as EMRALON® 327, but in bulk liquid, shelf life 6 months. Friction coefficient 0.6-0.9, film thickness 0.2-0.7 mils. Density 946 kg/m^3 (7.9 lb/gal). Shelf life 6.0 months.
EMRALON® 329	PTFE coating, thermoplastic resin	Properties and use similar to EMRALON® 328.	See EMRALON® 320 and 327	Similar to EMRALON® 328. Same except density 1,174 kg/m^3 (9.8 lb/gal).
EMRALON® 330	PTFE coating, thermoplastic resin	Excellent adhesion, low friction, resistant to corrosion, abrasion, flex and impact. Applied to metals, wood, rubber and some plastics; on sliding, rubbing or turning surfaces.		Friction, 0.07 to 0.05, cure at 177°C (300°F), 1.0 hr. Service temperature 135°C (275°F), maximum 177°C (300°F). Film thickness 0.0003 in.
EMRALON® 333	Fluorocarbon lubricant and organic resin	Low friction, good hardness, adhesion, resiliency. Many uses; automotive, office machinery, tools, aerospace parts, valves, etc.	Resists many solvents, acids, chemicals (salt and acids).	Friction coefficient 0.08-0.09, film thickness 0.001-0.015 in. Air curee 2-5 min, 10 min at 150°C (300°F). Density; 1,042 kg/m^3 (8.7 lb/gal).
EMRALON® 336	Fluorocarbon lubricant and water miscible resin emulsion	Dry film lubricant and release agent for use where organic solvents are prohibited.		Static friction coefficient 0.07. Air dry cure 24 hr. or heat 1 hr at 71°C (160°F). Continuous service to 121°C (250°F). Density 1,080 kg/m^3 (9 lb/gal).
EMRALON® 343	Fluoropolymer coating, water base, heat cure, resin binded	Dry film lubricant and release agent.		Static friction coefficient 0.06. Cure at various temperatures for various times Continuous service temperature 135°C (275°F). Density 1,090 kg/m^3 (9.1 lb/gal).

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
"Teflon" Coatings Types: TFE, FEP, PFA & TEFLON "S"	As formulated by Dupont	Mold release, low load-bearing surfaces, aircraft tooling, wood drill bits, hand saws, circular saws, etc.	Some types are and some types are not compatible.	Properties: Excellent release non-wetting, heat resistance, low coefficient of friction, cryogenic stability, chemical resistance, unique electrical properties, etc.
Durafilm CTF	Teflon compounded with binder resins.	Low friction coating for any surface.	Not LOX, fuels and most solvents.	Air dries in 3 hrs. Low friction properties. Maximum operating temperature 149°C (300°F).
OIL-ES-OIL	Teflon-like material with air-drying carrier and propellants in aerosol.	Non-staining, low friction can be used on wood, metal, paper, canvas, rubber, leather, etc.	Not LOX, fuels or some solvents. Chemically stable with many materials	Non-gumming, non-hardening, high and low temperature tolerant. For use where oil or grease are objectionable.
"Teflon" Coated Glass & Kevlar Fabrics	"Teflon" on a glass or Kevlar fabric.	Belting, release liners, bearings, antenna covers, etc.	Yes	Good mechanical stability, chemical and solvent resistant, temperature range to 500°F, low friction, excellent release, dry lubrication.
"Teflon" Films Types: FEP, PFA and Tefzel	As formulated by Dupont	Molding, lighting, chemical processing, medical, aircraft, food, packaging, etc.	Not LOX, but excellent with chemicals and solvents.	Films can be heat sealed, die cut and thermoformed into various shapes.
Durafilm TCGF Cylinders	"Teflon" Coated Glass Fabric	Bearing retainers in space applications	Yes	Cylinders are machined into bearing retainers and used in the liquid oxygen pumps of our space shuttles.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
VAC KOTE PROCESS BPS 18.07	MoS_2 lube solids, organic binder, xylene/alcohol; film thickness 2.54-12.7 x 10^{-6} M (1.0-5.0 x 10^{-4} in.)	Journal bearings, gears, bearing retainers may be applied to most metals. Sliding surfaces, low and high loads, low to high temperature, air to hard vacuum, space environment. Good corrosion resistance with precoating of 48804.	Not LOX or rocket fuels. Compatible with jet fuel, hydrocarbons, and solvents.	Cure, 300°C (590°F), 1 hr or 149°C (300°F) 16 hr. Friction coefficient, 0.04 to 0.20. Usable temperature range, low -271°C (-456°F) to high, 288°C (550°F). Rated satisfactory for vacuum outgassing per MSFC 50M02442.
18.06	MoS_2 mechanically bonded-no binder film thickness 1.02-2.54 x 10^{-6} M (40-100 microinches)	Balljoints, cams, larger bearings and other rolling or sliding interface. Can be applied to most materials. Can be used with BPS 18.07	Similar to 18.07	Very low outgassing use near optics in vacuum. Temperature range -260°C to 500°C (-436°F to 932°F). Avoid high humidity.
32599	Same as 18.06	Instrument size ball bearings with metal ribbon retainers. Can be applied to most materials.	Similar to 18.06.	Same as 18.06
21207	Same as 18.06, film thickness 1.53-5.08 x 10^{-5} M (6-20 microinches)	Instrument ball bearings with MoS_2 impregnated retainers. Miniature ball bushing with shaft.	Similar to 18.06	Very low outgassing use near optics in vacuum. Temperature range 260°C to 150°C (-436°F to 302°F). Low load due to Teflon retainer. Avoid high humidity.
23561	Same as 21207	Precision instrument spur gears. Preferred metals 300 and 400 series stainless steel and 17-4 pH steel.	Same as 21207	Same as 18.06.
23974	Same as 23561	For shafting, general purpose gears, cams, threaded and flat parts.	Same as 23561.	Same as 23561.
44153	MoS_2 and graphite lube solids, organic binder, xylene/alcohol; film thickness 2.54-12.7 x 10^{-6}M (1.0 - 5.0 x 10^{-4} in.)	Gears, bearing retainers, journal bearings and other sliding surfaces, may be applied to most metals. Usable in low to high loads low to high temperatures. Primarily for air application. Good corrosion resistance with precoating of 48804.	Same as BPS 18.07	Same as BPS 18.07.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
MOLYLUBE® AR	MoS_2 microfine, resin bond	General purpose dry film for high loads or speed, machine tools, sleeve bearing, threaded connections. Will reduce fretting, galling and seizing. May be used on most materials. Steels, copper, aluminum, titanium, and plastics and wood in some applications.	Resists most solvents, hydrogen fluids, and fuels.	Air-dry film, cure temperature, 6.0 hr; usable temperature range -73°C to 399°C (-100°F to +750°F). Coefficient of friction 0.035 to 0.04 at 572 x 10^6 n/m^2 (83,000 psi) at 0.132 m/sec (26 fpm). Shelf life 1.0 yr.
MOLYLUBE® SR	MoS_2 microfine, and resin bond	Long-life dry film for excellent antigalling and seizing properties when exposed to high bearing loads and temperature. For sliding and rolling surfaces. Provides corrosion resistance. May be applied to most metal survaces (pretreatment improves results).	Not LOX or rocket fuels. Has chemical resistance to oils, greases, some solvents, acids and alkalis.	Heat cured film; cure 177°C (350°F), 30 min; brush, spray or dip. May be applied without surface pretreatment. Usable temperature range -73°C to 399°C (-100°F to +750°F). Coefficient of friction 0.025 at 6.875 x 10 n/m^2 (100,000 psi).
MOLYLUBE® N	MoS_2 inorganic-organic resin bond, 30% solids	Dry film for extreme temperature and LOX applications. Has good adhesion and may be used on ball joints, rod end actuators, etc. For vacuum use also.	LOX insensitive may be used with most chemicals, and solvents.	Heat cure; 83°C (180°F). 2.0 hr. Higher heat cycle improves film hardness; usable temperature ranges, -184°C to 760°C (-300°F to +1400°F). Meets MIL-L-81329 requirements.
MOLYLUBE®	MoS_2 blended solvents and bonding agent	For excellent lubricity, extreme pressure and rust protection. To prevent galling and seizing on rolling and sliding surfaces. Machine tools, machinery, mechanisms, etc.	Not for LOX or oxygen.	May be applied by aerosol can, brush, dip, or spray; rapid air-dry.
MOLYLUBE® 1200	MoS_2 and graphite in inorganic resin	Machine cutting tools, pins, threads, sliding, surfaces, plain bearings, splines, etc., metal working and injection molding.	LOX compatible, resistant to hydrocarbon solvents, chemically stable.	Wide temperature range, -149°C to 538°C (-300°F to 1000°F). Specific gravity 60°/60°F = 1.475. Density 1,438 kg/m^3 (12 lb/gal). Meets MIL-L-23398B but not yet qualified.

DIXON INDUSTRIES CORPORATION

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
MELDIN® PI	Polyimide Plastic	Thrust washers, compressor vanes, seals, ball bearing retainers.	Resistant to most chemicals except strong alkalies and oxidizing agents.	Good physical properties. Tensile strength at room temperature is 75.84 x 10^6 N/m^2 (11,000 psi) at 260° (500°F), 41.37 x 10^6 N/m^2 (6,000 psi). Compressive strength at room temperature 427. x 10^6 N/m^2 (61,900 psi) at 260°C (500°F) 214 x 10^6 N/m^2 (31,000 psi). Temperature range up to 371°C (700°F), higher for short time periods. Dynamic coefficient of friction 0.5. Machinability-good. Specific gravity = 1.40.
MELDIN® PI-30X	Polyimide Plastics and lubricating additives	Non-lubricated bearings, ball bearing retainers, piston rings, thrust washers, etc.	Same as PI	Good physical properties. Tensile strength 25-30% of PI. Compressive strength 20-25% PI. Machinability-very good. Dynamic coefficient of friction 0.2-0.25. Temperature range to 371°C (700°F). Specific gravity =1.58.
MELDIN® PI-15Y	Polyimide Plastics and lubricating additives	Non-lubricated bearings, ball bearing retainers, thrust washers, compressor vanes, seals, piston rings, high temperature electrical insulation.	Same as PI and PI-30X	Physical properties are midway between PI and PI30X polyimide compounds. Dynamic coefficient of friction 0.30 to 0.35. Good machinability. Specific gravity = 1.48. Temperature range is same as PI-30X.
PENNLON®	Special Polyolefin	For conditions that require a tough, low friction, chemically stable material; acid pumps, impellers, bearings, gears, etc.	Inert to most chemicals except oxidizing acids. Good electrical properties.	Easily machined like wood, sawed, milled, planned, welded, and adhesive bonded. Specific gravity = 0.94. Coefficient of friction down to 0.11. Temperature to 121°C (250°F).
RULON® A	Specially compounded fluorocarbon, and other inert ingredients.	For low cost, high performance bearings in continuous service. For bearings, bushings, and gears in corrosive conditions, non-lubricating liquids, and high or low humidity.	Inert to virtually all process chemicals. Approved for use with liquid oxygen, high strength hydrogen peroxide, N_2O_4, hydrazine, UDMH, hydrocarbon fuels, etc.	Tensile strength at 23°C (73°F) is 8.27 x 10^6 N/m^2 (1,200 psi). Compressive stress at 23°C (73°F) is 8.27 x 10^6 N/m^2 (1,200 psi). Coefficient of friction dry; static is 0.04-0.16, dynamic is 0.12 to 0.19. Dielectric strength 35.33-43.31 x 10^{-8} v/m (900-1,100 v/mil). Usable at 20,000 PV. For temperatures from -240°C to 288°C (-400°F to 550°F).
RULON® II	Specially compounded thermoplastic self-lubricating bearing material offering the economies of injection molding.	For low cost, high strength bearings, gears, cams, slides, etc., to be used in corrosive conditions non-lubricating liquids and areas where lubrication is desirable.	Resistance to most chemicals except strong oxidizing agents.	Tensile strength at 23°C (73°F) is 55.2-62.0 x 10^6 N/m^2 (8,000-9,000 psi). Compressive stress at 23°C (73°F) is 51.2-58.6 x 10^6 N/m^2 (8,000 psi). Dynamic coefficient of friction 0.05-0.15. Continuous use temperature 177°C (350°F). Specific gravity 1.6.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
RULON® J	Specially compounded fluorocarbon, containing all polymeric, non-abrasive fillers.	For low cost, high performance bearings where soft mating materials such as stainless steel and brass are used. For non-lubricated bearings, bushings, seals, and gaskets in corrosive conditions and high or low humidity.	Inert to most inorganic and organic acids, attacked by concentrated alkalis.	Tensile strength at 73°F is 1900 psi. Compressive stress at 1% strain is 1000 psi. Coefficient of friction-static and dynamic are between 0.12-0.20. Dielectric strength (0.080 thick) is 200 volts/mil. Usable at 7500 PV at room temperature. Usable temperature range is -400°F to +550°F.

Note: In addition to Rulon A, there are more than a dozen other formulations of Rulon developed for specific operation or application conditions. Rulon is also available in a dispersion form in aerosol cans.

DIXON TICONDEROGA COMPANY
Graphite and Lubricants Division

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
GW-430	Graphite and silicate binder. Total dried solids 34% ± 3%.	Bearing and sliding surfaces. Electrical conductive coating. High temperature conditions to 538°C (1000°F).	Not LOX or fuels. Chemically inert to many materials.	Density 1,222 kg/m^3 (10.2 lb/gal). Air dry or heat cure to 400°C (752°F). Particle size 2-1/2 x 10^{-6} m (2-1/2 micron).
GRAPHOKOTE-200 PLUS AEROSOL	Narural flake graphite in lacquer-aerosol solution. Particle size 2-1/2-1 x 10^{-6} m (2-1/2-1 micron).	Dry film lubricant for sliding and related parts, and as mild rust preventive. Press fit parts, printed circuits, threaded parts. Applications for which MIL-G-26548 was issued as on electrical conductive nonmagnetic film.	Not LOX or fuels. Chemically inert to many materials.	Instant drying; non-flammable, noncombustible, greaseless and oilless. Can be applied to metal, wood and many other surfaces. Temperature range up to 204°C (400°F) to 260°C (500°F).
GL-420	Natural graphite in a lacquer binder. Particle size 2-1/2 x 10^{-6} m (2-1/2 micron). Total dried solids 20% ± 1%.	May be applied to metal, wood and many other materials. For sliding surfaces, printed circuits, mild rust preventive, press fits, threaded parts, electrical switching gear, etc.	Not LOX or fuels. Chemically inert to many materials.	Very fast drying, greaseless, static electricity reducer. Density 1,090 kg/m^3 (9.1 lb/gal). Temperature range -54°C (-65°F) to 204°C (400°F). Long shelf life.
GRAPHOKOTE-50	Graphite and alkyd resin. Solids content 40% including 25% graphite. Particle size 40 x 10^{-6} m (40 microns).	Quick drying general purpose dry film lubricant. Corrosion resistant on metals, sliding surfaces. Medium heavy, wear resistant, dry film lubricant.	Not LOX or rocket fuels. Resistant to oils and is chemically inert, withstand weathering, water, acids and alkalis.	Fast drying. Drying time in air, for 0.00381 x 10^{-8} m (0.0015 in.), thick film, 6.0 min, for 0.00762 x 10^{-8} (0.0030 in.) film, 10 min. Temperature range above 204°C (400°F). Density 1,090 kg/m^3 (9.1 lb/gal).
GRAPHOKOTE-95	Graphite and alkyd resin. Solids content 60%, including 36% graphite. Particle size 40 x 10^{-6} m (40 microns).	Quick drying very heavy duty dry film lubricant. For sliding surfaces, very heavy, wear resistant dry film lubricant.	Graphokote-50.	Drying time in air, for 0.0038 x 10^{-8} M (0.0015 in.) film, 7.0 min, for 0.00762 x 10^{-8} m (0.0030 in.) film, 11.0 min. Density 1,246 kg/m^3 (10.4 lb/gal). Temperature range above 260°C (400°F).

NOTE: In addition to dry film lubricants, Dixon Ticonderoga Company is a major supplier of Graphite powder used in dry film lubricants, colloidal lubricants, additives to oils and greases and other industrial application. Graphite powder of several types are available: Natural crystalline (vein), Flake, Amorphous, and artificial (synthetic) graphite. The chemical purity of these graphite powders are as high as 99% for crystalline graphite down to 60% for some amorphous graphite. The particle size of the graphite in dispersions is as low as 1/2 x 10^{-6} m (1/2 microns). Dixon Ticonderoga also supplies several sizes and combinations of thickness, width and length of graphite lubricating plates for industrial use.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
MOLYKOTE® 106 (NATO Code No. S 1738 (MIL-L-8937B)	Boundary lubricating solids and thermo-setting resin dispersed in a solvent systems.	Reduces fretting, galling and seizing under high loads, low speed and temperature extremes. Use in dirty or abrasive environments, where mating surfaces are inaccessible to relubricate. For wear-in of new or rebuilt equipment. Good weaar-life.	Not LOX or focket fuels. Resists most hydrocarbon fluids, hydraulic fluid, engine oils, jet fuels, and materials in referenced MIL specifications.	Heat cured at 149°C (300°F) for 60 min. Temperature range -54°C (-65°F) to 316°C (600°F). Density 1,078 kg/m^3 (9.0 lb/gal). Shelf life 12 months.
MOLYKOTE® 321R	MoS_2 and blended solid lubricants, and inorganic binder; non-flammable solvent system	Reduces galling, seizing and fretting for, cutting tools, machinery pin, levers, splines and threaded parts. Instrument operating in a vacuum, near radiation and low or high temperatures.	Compatibility with VDMH, LOX (Batch Test Required), most fuels and solvents, chemically stable.	Air dries in 5 min. at 20°C (68°F). Temperature range in air -198°C (-325°F) to 450°C (842°F) and in vacuum up to 650°C (1202°F). Available in bulk or aerosol cans. Density 12.5 lb/gal.
MOLYKOTE® 557	Waxlike compound, color-free, non-staining lubricant.	To lubricate most materials in sliding contact; especially aluminum and stainless steel in sliding or rolling contact. Also used on wood, glass, leather, rubber and plastic parts.	No data on material compatibility.	Air dries to a dry waxlike slippery film that adheres well to metal surfaces. Usable temperature range -18°C (0°F) to 46°C (115°F). Short time use to 350°F as a liquid lube. Available in aerosol can.
MOLYKOTE® 3400A (MIL-L-46010A) (RIA-PD42)	Dispersion of solid lubricants, corrosion inhibitors in a thermo-setting resin	Aerospace: Hinge pins, sleeve bearings, cams, linkage controls, self-aligning bearings. Servo-mechanisms and instrument bearings. Disconnect and threaded fasteners, spline and geared couplings and control bellows. Also for automotive, farm and construction equipment. Provides corrosion protection.	Not LOX or rocket fuels. No film deterioration or adhesion from all fluid test in MIL-L-46010A.	Air dried for at least 30 min, heat cured at 204°C (400°F) for 1.0 hr. Exceeds corrosion, temperature and wear. Life requirements of MIL-L-46010A. Load carrying capacity, Falex Test, 17,347 N (3,900 lb). Usable temperature range -198°C (-325°F) to 315°C (600°F) and in vacuum up to 482°C (900°F).
MOLYKOTE® 3402 (MIL-L-23398) (RIA-PD42) (RIA-PD703)	Selected blend of solid lubricants, corrosion inhibitors and organic binder dispersed in a solvent; contains no graphite or powdered metals.	Long lasting corrosion protectant lubricant, under condition of heavy loads, high and low speeds, dirty or abrasive environments. For metal to metal mating surfaces (both alike and unalike). Wear-in lubricant on new or rebuilt equipment. For touch-up of factory-applied bonded lubricant coatings.	Similar to MOLYKOTE® 3400A, except MIL specifications are changed. As well as most plastics and rubbers.	Air-cured at room temperature 25°C (77°F) in 4 hr. May be cured at 38°C (100°F) in 1.0 hr. Exceeds corrosion, temperature and wear life requirements of MIL-L-23398 and RIA-PD-703. Load carrying capacity, Falex Test, 12,788 N (2,875 lb). Temperature range -198°C (-325°F) to 315°C (600°F). Storage life 1.0 yr.
MOLYKOTE®7400	Dispersion of solid lubricants in water-dilutable organic resin binder.	Particularly suitable for running-in of gears, lubrication of ball-joints, ball bearing cages and the cold-forging of steel.	No data on material compatability.	Air cured at room temperature 23°C(73°F) and 70% relative humidity-dry in 40 minutes. Operating temperature range - -70°C (-94°F) to +250°C (+482°F). Storage life 1 yr. Load carrying capacity, Falex test, 10,208N (2,250 lb.), non-flammable.

DOW CORNING CORPORATION (Concluded)

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
MOLYKOTE® 7409	Dispersion of solid lubricants in an organic resin-solvent binder.	Recommended for coating of brake mechanism components and treatment of pistons to prevent damage during cold-starting. A suitable replacement for cadmium and zinc plating on hydraulic and other equipment parts.	No data on material compatibility.	Air cured at room temperature - dry in 6 hrs., at 150°C (302°F) in 2 hrs., and at 220°C (428°F) in 1 hr. Operating temperature range -70°C (-94°F) to 380°C (+716°F). Caution: Flammable.

DRILUBE COMPANY

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
DRILUBE 1A (MIL-L-8937A)	MoS_2, graphite and thermosetting resin (epoxy). Catalyst available; for low temperature bake (cure)	For high pressures and moderately elevated temperatures. For sliding mechanisms, threaded connectors, sprockets and fasteners. Spray application recommended.	Not LOX or N_2O_4 or N_2H_4. Resists water, solvents and hydrocarbons.	Heat cure 1.0 hr at 149°C (300°F). Falex wear life 4,448 N (1,000 lb) load 150 minutes. Density 1,114 kg/m^3 (9.3 lb/gal.). Temperature range -184°C (-300°F) to 343°C (650°F). Shelf life 12 months.
DRILUBE 2 (MIL-L-8937B&C)	MoS_2, and antimony oxide in a thermosetting resin (modified epoxy). No graphite or powdered metals	For sliding mechanisms, threaded connectors, fasteners, gears, etc. Where corrosion protection is needed.	Not LOX or rocket fuels.	May be applied by spray or dipping. Heat cure 1.0 hr at 149°C (300°F). Falex wear life 4,448 N (1,000 lb), load 500 minutes. Temperature range -184 °C (-300°F) to 343°C (650°F). Shelf life 12 months.
DRILUBE 6A (MIL-L-46010)	MoS_2 and antimony oxide in a phenolic epoxy resin. No graphite or powdered metals. Catalyst available for low temperature bake (cure)	For long wear life, and moderate corrosion protection where graphite is prohibited (vacuum). For sliding surfaces and mechanisms.	Not LOX or rocket fuels. Resist to moisture and not soluble in water.	May be applied by spray or dipping. Heat cure 1.0 hr at 204°C (400°F). Falex wear life 4,448 N (1,000 lb) load 400 minutes. Temperature range -184°C (-300°F) to 343°C (650°F). Shelf life 12 months.
DRILUBE 90	MoS^2, in a alkyd-epoxy resin	Low cost, corrosion resistant film for mechanisms of all types. Can be applied to nearly all metals and metal plated surfaces. For bulk processing of small parts.	not LOX or N_2O_4 or N_2H_4. Resists water, solvents and hydrocarbons.	Heat cure 1.0 hr at 191°C (375°F). Shelf life 12 months, min. Spray or dip application. Temperature range -184°C (-300°F) to 343°C (650°F).
DRILUBE 101	PTFE telomar (Teflon) in a thermosetting resin (epoxy)	Lightly loaded sliding mechanism requiring moderate corrosion protection; instrument, camera, and electronic parts.	Not LOX or rocket fuels Resistant to water and some chemical.	Spray application. Heat cure 1 hr at 191°C (375°F). Temperature range -73°C (-100°F) to 204°C (400°F). Shelf life 12 months.
DRILUBE 273	PTFE telomer (Teflon) in a thermosetting resin (acrylic/epoxy)	For flexible substrates, under lightly loaded conditions. Such a natural or synthetic rubber, O-rings, etc.	Not LOX or rocket fuels.	Spray or dip application. Heat cure 1/2 hr at 121°C (250°F). Temperature range -73°C (-100°F) to 204°C (400°F). Shelf life 12 months.
DRILUBE 701	MoS_2 in an inorganic phosphate binder (complex phosphate)	For extremely good adhesion, smoothness and anti-galling properties over a wide temperature range. For sliding surfaces, threaded connectors, fasteners, etc.	LOX compatible. Not N_2O_4 or N_2H_4. Resists water and most solvents.	Spray application. Heat cure 2-1/2 hr at 204°C (400°F). Temperature range -184°C (-300°F) to 454°C (850°F). Density 961 kg/m^3 (8.02 lb/gal). Shelf life 12 months.
DRILUBE 805N (MIL-L-81329)	MoS_2 and graphite in a sodium silicate binder (ceramic)	High load capacity film lubricant for sliding or rolling contact. Threaded connectors, sliding mechanisms.	LOX, but not N_2O_4 and N_2H_4. Resistant to water and most solvents.	Spray application. Heat cure 2 hr at 82°C (180°F) followed by 2 hr at 204°C (400°F). Temperature range -212°C (-350°F) to 538°C (1000°F). Shelf life 12 months.
AIR DRY LUB. DRILUBE 107 (MIL-L-46147) (MIL-L-23398)	MoS_2 and air cure resin binder	Sliding mechanisms, threaded connectors, single-installation fasteners, metal furniture, touch-up of heat cured dry film lubricants.	Not LOX or rocket fuels.	Spray application. Falex wear life 4,448 N (1,000 lb) load, 150 min (MIL-L-46147), 90 min (MIL-L-23398). Room temperature cure time; 18 hr (MIL-L-46147), 6 hr)MIL-L-23398). Shelf life 12 months.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
DRILUBE 108 and DRILUBE 111 (same except 111 supplied in aerosol cans)	MoS_2 and acrylic binder	For touch-up or pre-assembly lubrication of critical parts. Provides long wear life.	Not LOX or rocket fuels.	Spray application. Air-dry in 1.0 hr at room temperature. Falex wear life 4,448 N (1,000 lb) load 60 min. Shelf life 12 months.
DRILUBE 272	PTFE (Teflon) resin in a thermoplastic binder (acrylic)	On flexible substrates; some metals and plastics, natural or synthetic rubber, etc. May be used on rubber O-rings, lightly loaded sliding mechanisms, wood furniture, etc.	Not LOX or rocket fuels.	Cure 1.0 hr at room temperature. Temperature range -73°C (-100°F) to 204°C (400°F). Shelf life 18 months.
DRILUBE 702	MoS_2 in an inorganic phosphate binder (complex phosphate)	Threaded connectors fasteners, and sliding surfaces. For extreme conditions and/or LOX exposure occurs.	Same as 701	Brush application. Air dry cure time not speci- at same procedure as 701 Temperature range - 184°C (-300°F) to 454°C (850°F). Shelf life 12 months.
DRILUBE 703	MoS_2 in an inorganic phosphate binder (Complex phosphate)	Threaded connectors, sliding surfaces, sealant for liquid oxygen exposure.	LOX compatible, but not N_2O_4 or N_2H_4. Moderate resistance to water and some solvents.	Brush or swab application. Air dry cure time not specified. Temperature -184°C (-300°F) to 454°C (850°F). Shelf life 12 months.
DRILUBE 831 (MIL-L-60326) (TYPE II) DRILUBE 842 (in aerosol can)	PTFE telomer (Teflon) dispersion with fluorinated hydrocarbon, binder not specified	Excellent lubricity and wear life for lightly loaded mechanisms, thread sealant in oxygen systems.	Compatible with LOX, NTO, UDMH, and hydrazine. Resist water and most solvents.	Spray application. Air dry in 1/2 hr at room temperature. Temperature range -34°C (-30°F) to 260°C (500°F).

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
DRI-SLIDE®	MoS_2 powder, 0.50 x 10^6 M (0.50 Micron), light hydrocarbon petroleum liquid. Anticorrosive additives.	Lubricant under adverse conditions; dust, water, dirt and alkalis. General purpose; electric equipment, small mechanisms, office machinery, vending machine, machine tools, automotive, etc. May be used to impregnate laminated bushings and slide pads, rub strips.	Resist most acids, alkalis, water. Compatible with greases and oils.	DRI-SLIDE® provides considerable rust or corrosion protection. Temperature range, -64°C to 399°C (-50°F to +750°F). Should not be applied at more than 52°C (125°F) (flash point of carrier 71°C (160°F). Nontoxic and dust free.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
AIR-DRY LUBRICANT LUBRI-BOND A	MoS_2 - graphite phenolic resin; solids content >10%	General purpose solid film may be used for production, touch-up, and field repair. Apply by spray, dip, oe spray/tumble.	Compatible with hydrocarbon fluids. Not LOX or rocket fuels.	Air dry 18 hr. Coefficient of friction (dynamic) 0.03-0.13 depending on load and velocity. Density 875 kg/m^3 (7.3 lb/gal). Temperature range -212°C (-350°F) to 204°C (400°F). Shelf life 12 months.
LUBRI-BOND B (SANDIA 828286-00) (THIOKOL 55-1043-12)	Same as LUBRI-BOND A, except in a consistency for brush or dip application. Solids content > 20%	Same as LUBRI-BOND A.	Same as LUBRI-BOND A.	Same as LUBRI-BOND A except density 922 kg/m^3 (7.7 lb/gal).
LUBRI-BOND 220 (LOCKHEED LCM 34-1213) (MIL-L-23398C) and (MIL-L-46147A)	Corrosion resistant air dry solid film lubricant. Contains no graphite, halides or powdered metals. Solids content > 10%.	For high loads and high speeds, exceptional wear life. For field touch-up of bake-on films or on parts that cannot withstand baking.	Not LOX or rocket fuels, but resists moisture, most solvents.	Air dry 6 hr. Meets or exceeds requirements of MIL-L-8937, but not qualified, also meets some requirements of MIL-L-46010. Coefficient of friction 0.03-0.20 depending on load and velocity. Density 1,234 kg/m^3 (10.3 lb/gal). Temperature range and shelf life same as LUBRI-BOND A.
LUBRI-BOND N (NAVORD WS 9004)	$NbSe_2$ and phenolic resin. Solids content > 44%	General purpose: Solid film where extremely high electrical conductivity is required. Medium load carrying capacity. May be used on ferrous and non-ferrous metals, plastics, rubber and most materials.	Not LOX or rocket fuels. Compatible with jet fuel, hydrocarbons and solvents.	Application by brush, dip or spray. Air dry 18 hr. Coefficient of friction 0.04-0.14 depending on load and velocity. Density 1,210 kg/m^3 (10.1 lb/gal). Temperature range -212°C (-350°F) to 204°C (400°F). Shelf life 12 months.
LUBRI-BOND HT (AFSL-41)	MoS_2-Sb_2O_3 silicone binder. No chlorides or graphite. Solids content > 22%	High temperature film developed for rubbing surfaces; antifretting, antigalling and antiseize. Primarily for use on titanium. Based on Air Force Laboratory development of AFSL-41. Suited for field application or for parts too big to bake.	Not LOX or rocket fuels. Compatible with most hydrocarbon fluids and solvents.	Spray application. Air dry 72 hr or heat cure 10 min at 249°C (480°F). Coefficient of friction 0.02-0.14 depending on load and velocity. Density 1,054 kg/m^3 (8.8 lb/gal). Temperature range -273°C (-459°F) to 399°C (750°F). Shelf life 12 months.
HEAT CURED LUBRICANTS ELECTROLUBE E40	MoS_2, graphite and modified phenolic resin. Solids content > 40% (E50 has no graphite).	Lubrication conditions of sliding friction; screws, fasteners, washers, gears, bearings, shafts, etc. For moderate load, wear life, and corrosion protection spray or dip application.	Not LOX or rocket fuels. Satisfactory with hydrocarbons, solvents, chemicals and other materials.	Spray or dip application. Cure 1.0 hr at 149°C (300°F). Coefficient of friction 0.02-0.16 depending on load and velocity. Density 1,054 kg/m^3 (8.8 lb/gal). Temperature range -273°C (-459°F to 450°F), intermittent to 316°C (600°F). Shelf life 12 months.
LUBE-LOK® 66-C	MoS_2 - graphite, corrosion inhibitors in thermosetting phenolic resin. MoS_2, graphite and phenolic binder	General purpose light to heavy duty lube for fretting and sliding surfaces. Dry film for corrosive environments where low friction is needed.	Not rocket fuels. Satisfactory with most hydrocarbon fuels, oils, and solvents.	Spray, dip or brush application. Cure at 191°C (375°F) 1.0 hr. Usable temperature range, -184°C to 371°C (-300°F to 600°F).

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
LUBE-LOK® 1000 (MPD-9076)	Synthetic graphite and lead oxide with a ceramic binder. Solids content > 35%	Heavy duty film for fretting and sliding metal surfaces operating at high temperatures. Spray application.	LOX and hydrocarbon fuels, oils and solvents. Limited use with jet fuels.	Cure at 538°C (1000°F) for 15 min. Usable temperature, -73°C to 1093°C (-100°F to 2000°F). Density 1,186 kg/m^3 (9.9 lb/gal). Coefficient of friction 0.12 depending on load and velocity. Shelf life 12 months.
LUBE-LOK® 1000X	Base coat of LUBE 1000 with top-coat of LUBE-LOK 2006	See LUBE-LOK 1000. For operating condition at lower temperatures and to >538°C (1000°F).	Same as LUBE-LOK 1000.	Cure 2 hr at 260°C (500°F). Durable surface resists handling and installation conditions better than LUBE-LOK 1000. Spray application.
LUBE-LOK® 2006	MoS_2 - graphite in silicone-formaldehyde resin. Solid content > 38.5%	Wide temperature range solid film for sliding and fretting surfaces; cams, threaded connections, plain or spherical bearings. Application by spray, dip or spray/tumble.	Not LOX or rocket fuels. OK with most hydrocarbon fuels, oils, and solvents.	Cure at 260°C (500°F) 2.0 hr. Usable temperature range -273°C to 454°C (-459°F to 850°F). Density 1,078 kg/m^3 (9.0 lb/gal). Coefficient of friction 0.05-0.16 depending on load and velocity. Shelf life 12 months.
LUBE-LOK® 2109 (MIL-46010)	MoS_2 - thermosetting epoxy resin	Solid film for sliding motion, plain and spherical bearings, hinges, cams and threaded applications. High load carrying capacity.	Nor LOX or rockets. OK with most hydrocarbon fuels, oils and solvents.	Cure at 149°C (300°F) for 2.0 hr or at 204°C (400°F) for 1.0 hr. Usable temperature range, -251°C to 316°C (-420°F to 450°F). Spray, dip, or brush application.
LUBE-LOK® 2306 (NAS 1367)	MoS_2, and inorganic binder	Solid film for high vacuum ball and roller bearings, spherical bearings and sliding applications.	LOX and hydrocarbon fuels and oils. Limited solvent use.	Cure 82°C (180°F), 2.0 hr plus 204°C (400°F), 2.0 hr. Usable temperature range, -251°C to 427°C (-420°F to 800°F). Spray application.
LUBE-LOK® 2396 (MIL-L-81329)	MoS_2 - graphite in sodium silicate binder. Solids content > 53%	Solid film lubricant for use where LOX compatibility is primary requirement.	OK with LOX, rocket fuels, hydrocarbon fuels, and oils. Limited use with solvents.	Cure at 82°C (180°F), 2.0 hr plus 204°C (400°F), 2.0 hr. Usable temperature range, -251°C to 459°C (-420°F to 850°F). Spray application. Density 1,474 kg/m^3 (12.3 lb/gal). Coefficient of friction 0.05-0.06 depending on load and velocity. Shelf life 6.0 months.
LUBE-LOK® 2406	Graphite in a sodium silicate binder	Resistant to fretting threaded connections, sleeve bearing, rolling surfaces, etc. Where compatibility with N_2O_4, N_2H_2 and aerozem are required.	OK with LOX, rocket fuels, hydrocarbon fuels, and oils. Limited solvent use.	Same cure cycle and usable temperature range as LUBE-LOK 2396. Spray application.
LUBE-LOK® 4306 (NASA-A-D-66A)	MoS_2 and phenolic binder. No graphite Solid content > 30%	General purpose heavy duty lubricant. Prevent fretting, sliding surfaces, threads, sleeve bearing, rolling surfaces, etc. Widely tested and approved for deep space and high vacuum applications.	Not LOX or rocket fuels. Satisfactory for jet fuel, hydrocarbon and solvents.	Spray, dip or brush application. Cure 1.5 hr at 191°C (375°F). Coefficient of friction 0.03-0.12 depending on load and velocity. Density 109 kg/m^3 (9.1 lb/gal). Temperature range -273°C (-459°F) to 232°C (450°F), intermittent to 316°C (600°F). Shelf life 12 months.

ELECTROFILM CORPORATION (Concluded)

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
LUBE-LOK® 4396 (NAVOR-12-31100-13)	MoS_2 and graphite and phenolic resin binder. Solid content > 32%	High load and speed application. General purpose lubricant that resists corrosion and fretting. Use for sliding and rolling conditons. May be applied to most material including dissimilar metals	Not LOX or rocket fuels, but satisfactory for hydrocarbons and solvents.	Spray, dip or spray/tumble applicaiton. Cure 1.5 hr at 191°C (375°F). Coefficient of friction 0.03-0.15 depending on load and velocity. Density 1,138 kg/m^3 (9.5 lb/gal). Temperature range -273°C (-459°F) to 232°C (450°F), intermittent to 316°C (600°F). Shelf life 12 months.
LUBE-LOK® 5306 (MIL-L-8937B)	MoS_2 and a thermoset phenolic resin. Solid content > 32%. Contians no graphite or powdered metals.	Good all purpose solid film fubricant. Has long wear life, exceptional corrosion protection, and high load capacity. For fretting, sliding and rolling contact and low temperature cure.	Not LOX or rocket fuels. Satisfactory with other materials, some fuels, hydrocarbons, solvents, metals, etc.	Spray, dip or spray/tumble application. Cure 1.0 hr at 149°C (300°F) or at lower temperature for longer time. Coefficient of friction 0.02-0.11 depending on load and velocity. Density 1,054 kg/m^3 (8.8 lb/gal). Temperature range -273°C (-459°F) to 232°C (450°F), intermittent to 316°C (600°F). Shelf life 12 months.
LUBE-LOK® 5396	MoS_2 and graphite in a thermoset phenolic resin	Excellent load and wear-life capacity. For use in conditons similar to LUBE-LOK 5306, except contains graphite.	Same as LUBE-LOK 5306.	Same as LUBE-LOK 5306.

E/M LUBRICANTS, INC.
(Everlube Corporation Merged with Microseal Corporation)

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
EVERLUBE® 620 MIL-L-8937D	MoS_2, graphite and modified phenolic resin. Solids content 37 ± 0.5%. Density 1,103 Kg/m^3 (9.2 lb/gal), flash point (tag) 2.8°C (37°F).	Dry film to reduce wear, prevent galling and provide antiseize properties Good for extreme loads and high temperatures.	Not LOX, hard vacuum, or extreme radiation. Resistant to most chemicals, gases, etc., but not strong oxidizers.	Available-Ready to Apply (RTA) and concentrate. Dilute conc. with 50% ethyl alcohol, 50% toluene, two parts solvent to one part conc. by volume. Spray application recommended. Cure 1 hr at 191°C (375°F). Temp range -220°C (-365°F) to 343°C (650°F) static.
EVERLUBE 620A MIL-L-8937A (ASG)	MoS_2 and modified phenolic resin. Solids content 30 ± 0.5%. Density 994 kg/m^3 (8.3 lb/gal.), flash point (tag) 2.8°C (37°F).	Low temperature heat dry film lubricant for aluminum and magnesium alloys and other materials that cannot stand 149°C (300°F) or above, cure temp. Excellent adhesion to most any substrate.	(Same as Everlube 620).	Available RTA and conc. Dilute conc. as per Everlube 620. Spray application recommended. Cure 2 hr at 121°C (250°F). Temp. range -54°C (-65°F) to 260°C (500°F).
EVERLUBE 620C MIL-L-8937D	MoS_2 and modified phenolic resin. Solids content 30 ± 0.5%. Density 1,030 Kg/m^3 (8.6 lb/gal.), flash point (tag) 4.4°C (40°F).	Dry film to reduce wear and provide excellent corrosion resistance. For applications where oils and greases are not satisfactory.	(Same as Everlube 620).	Available RTA and conc. Dilute conc. as per Everlube 620. Spray application recommended. Cure 1 hr at 191°C (375°F), temp. range -220°C (-365°F) to 260°C (500°F).
EVERLUBE 626	MoS_2 and modified phenolic resin. Solids content 29 ± 0.5%. Density 970 Kg/m^3 (8.1 lb/gal.), flash point (tag) 0°C (32°F).	(Same as Everlube 620).	(Same as Everlube 620).	Available RTA and conc. Dilute conc. with 50% ethyl alcohol, 50% tolene, four parts solvent to one part conc. Cure 1 hr at 149°C (300°F), temp. range -220°C (-365°F) to 343°C (650°F).
Permaslik-G MIL-L-23398C MIL-L-46147A	MoS_2 in an air-dry resin. Solids -25%. Density 8.15 lb/gal. Flash point (COC), 15°C (59°F).	Recommended where typical solid film lubrication is required, but where oven curing is impractical. Also useful as a touch-up.	(Same as Everlube 620).	Available RTA, concentrate and aerosol. Dilute with methyl ethyl ketone. Spray application recommended Cure 6 hrs. at room temp.
EVERLUBE® 629	Graphite and modified phenolic resin. Solids content 29.5 ± 0.5%. Density 1,006 Kg/m^3 (8.4 lb/gal.), flash point (tag) 2.2°C (36°F)	A thin, dry film to reduce wear, prevent galling and provide anti-seize properties. For use in applica- where normal oil and greases fail.	(Same as Everlube 620).	Available RTA and conc. Dilute conc. as per Everlube 626. Apply by spray, brush or dip. Cure: air dry 15 min, bake 1 hr at 149°C (300°F). Temp range -220°C (-365°F) to 343°C (650°F).
EVERLUBE 690 MIL-L-8937D	MoS_2, corrosion inhibitors, and modified phenolic resin. Solids content 42.5 ± 0.5%. Density 1,090 Kg/m^3 (9.1 lb/gal.), flash point (tag) 22°F.	A thin dry film to reduce wear, prevent galling and provide anti-seize properties. Recommended for self-locking nuts per MIL-N-25027, and all types of fasteners, nuts, bolts, screws, etc.	Not LOX, rocket fuels, hard vacuum or extreme radiation. Resistant to all solvents, most chemicals, will not smudge or rub off.	Available RTA and conc. Dilute conc. with 50% ethyl alcohol-50% toluene, 2 to 3 parts solvent to 1 part conc. Cure 1 hr at 191°C (375°F), temp. range -220°C (-365°F) to 260°C (500°F) and higher in nonoxidizing atmosphere.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
EVERLUBE 810	MoS_2, graphite, soft metal and silicone resin. Solids content 37 ± 0.5%, density 982 Kg/m^3 (8.2 lb/gal.).	Dry film lubricant to provide anti-friction or anti-sieze, and reduced wear at high temp. Parts should be coated before assembly.	Not for LOX, hard vacuum, high radiation or strong oxidizers. OK for most hydrocarbon chemical, gases, etc.	Available RTA and conc. Dilute with toluene, 2 to 4 parts solvent to 1 part conc. Apply by brush, spray, or dip after proper pretreatment. Cure: air dry 15 min, bake 1 hr at 288°C (550°F). Temp range 316°C (600°F) to 538°C (1000°F), also stable to -54°C (-65°F).
EVERLUBE 811 MIL-L-81329 (WP)	MoS_2, graphite and sodium silicate binder. Solids content 26 ± 0.5%. Density 1,247 Kg/m^3 (10.4 lb/gal.), flash point (tag) 80°C (47°F).	Dry film to reduce wear, prevent galling of metals and lubricants under extreme conditions of vacuum radiation, high and cryogenic temp. Used and specified for vacuum of 1.33 x 10^{-7} N/m^2 (10^9 mm Hg), and gamma radiation 10^2 MJ/kg carbon (10^{12} ERG/gram carbon) without loss to wear life. Use only in dry conditions.	Insoluble in solvents and conventional fuels, solvents, grease, and is LOX compatible. Should not be exposed to strong oxidizers such as N_2O_4, IRFNA, etc.	Available RTA, apply by spray, brush or dip after surface treatment per specification. Cure: air dry for 15 min, bake 2 hr at 66°C (150°F) and 2 hr at 204°C (400°F); may be reduced to 149°C (300°F) to 149°C (300°F) for aluminum. Temp. range -220°C (-365°F) to 649°C (1200°F) loads exceeding 1,034 MPa (150,000 psi).
EVERLUBE® 812	MoS_2 and sodium silicate binder. Solids content 31.5 ± 0.5%. Density 1,307 Kg/m^3 (10.9 lb/gal.).	Same as Everlube 811	Same as Everlube 811.	Available RTA, apply by spray, brush, and dip, after surface treatment per specification. Cure: air dry 15 min, bake 2 hr at 66°C (150°F) and 2 hr at 204°C (400°F). May be reduced to 149°C (300°F) for aluminum, temp. range -251°C (-420°F) to 399°C (750°F). To 704°C (1300°F) in hard vacuum or nonoxygen atmoshere. Loads exceeding 1,379 MPa (20,000 psi). Under high loads coefficient of friction is 0.03 to 0.04. Exceeds MIL-L-81329 spec. requirements (except graphite free).
EVERLUBE 812-3	Same as Everlube 812.	Same as Everlube 812.	Same as Everlube 812.	Same as Everlube 812.
EVERLUBE 823	Graphite, only, and so-sodium silicate binder. Solids content 24.5 ± 0.5%. Density 1,175 Kg/m^3 (9.8 lb/gal.).	A thin, dry flim containing no MoS_2, only moderate wear life. Recommended for possible exposure to UDMH, N_2O_4 IRFNA, N_2H_2 (hydrazine and aerozene fuels), not for extended endurance life. To lubricate under extreme conditions; high temp., strong oxidizers used in rocket engines, missiles and space craft industries. Satisfactory for threads, shafts, etc.	Not for LOX, but satisfactory with most fluids.	See 811 process spec. for application instructions. Cure and temp. range also similar to 811.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
EVERLUBE® 860	MoS_2 and modified silicone resin binder. Solids content 32.5 ± 0.5%. Density 1,043 Kg/m^3 (8.7 lb/gal.), flash point (COC) 33°C (91°F).	Dry film lubricant for friction and wear reduction over wide temperature range. Anti-seize to 816°C (1500°F).	Not LOX. Resistant to hydrocarbons, hydraulic fluids, oils, and greases.	Available RTA and conc. Dilute conc. with xylene or toluene, 3 parts solvent to 1 part conc. Apply by spray, dip or brush as per Everlube 860 processing spec. Cure: air dry for 15 min, bake 1 hr at 260°C (500°F). Temp. range -157°C (-250°F) to 371°C (700°F), static to 816°C (1500°F).
EVERLUBE 967	MoS_2 corrosion inhibitors, and organic resin binder. Contains no graphite, powdered metals, or halogens. Solids content 25 ± 0.5%, density 1,271 Kg/m^3 (10.6 lb/gal.), flash point (tag) 31°C (88°F).	Dry film lubricant for extreme temperature and pressure conditions.	Not LOX, or rocket fuels. Resistant to hydrocarbon, hydraulic fluids, oils, or greases.	Available RTA and conc. Dilute with 967 solvent Surface to be coated must be pretreated and the conc. thinned as per process spec. for 967. May be applied to most ferrous metals, as well as titanium, silver, nickel, and chrome plating. Application by spray, brush or dip. Cure: air dry 15 min, then 1 hr. at 66°C (150°F) to 121°C (250°F), followed by 1 hr at 191°C (375°F). Temp range -149°C (-300°F) to 399°C (750°F).
EVERLUBE 1120-8	MoS_2 and phenolic resin. Solids content 34 ± 0.5% Density 1,127 Kg/m^3 (9.4 lb/gal.).	Dry film to prevent galling and reduce wear in hot forging, heading, and wire drawing operations. Extend life of dies and fixtures.	Not LOX.	Available as conc. only. Dilute with 50% ethyl alcohol - 50% toluene, 2 to 3 parts solvent to 1 part conc. Apply by spray, dip or brush. Cure 1 hr at 191°C (375°F). Temp. range -220°C (-365°F) to 984°C (1800°F).
EVERLOX® 16, 16B, 17, 18	MoS_2 and proprietary inorganic binder system.	Provide a thin, dry film to reduce wear and galling. Anti-seize compound for threaded part. Designed for fittings, valves, fasteners, etc., in pure gaseous oxygen, and is nonimpact sensitive to liquid oxygen or hydrogen and other systems on aircraft, missiles, rocket engines, space vehicles, industrial applications, etc.	LOX, gaseous oxygen and liquid hydrogen approved under MSFG-106A. Vacuum and radiation stable.	Everlox 16 and 16B are a custom spray applied after coating. Everlox 17 is a brush-on coating for parts that cannot be baked. Everlox 18 is a paste used as an anti-seize and sealant compound. All parts to be coated should be vapor degreased or solvent wiped, and pretreated using standard procedures, per spec. Everlox 16, spray application, cured 1 hr. minimum at 149°C (300°F). Everlox 17, air dry, Everlox 18, paste in and squeeze bottle for field application--air dry. These products approved by NASA Atomic Energy Commission, National Aerospace Standards, and proprietary spec.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
ECOALUBE® 642 (MIL-L-46010A)	MoS_2-metallic oxides, corrosion inhibitors, resin binder.	Dry film has low friction, reduces wear and good corrosion resistance.	Not LOX, but OK for jet fuel, hydrocarbons, hydraulic fluids, silicones, etc.	Available RTA and conc. Dilute conc. with dioxane or 50% methyl ketone 50% toluene, 3 parts solvent to 1 part conc. Apply by spray, dip or brush. Cure at 204°C (400°F) for 1 hr. Temp. range -220°C (-365°F) to 260°C (500°F).
INLOX® 44 and 88	MoS_2 inorganic graphite, phosphoric acid binder (also available graphite free).	Dry film for cryogenic applications. Should be specified where organic resin binder coatings are objectionable in solid film lubricants. Film to reduce wear and prevent galling. Inlox 44 has good wear-life, while Inlox 88 is an anti-seize coating for threads, fittings, couplings, etc.	LOX and liquid hydrogen compatible, as well as most; hydrocarbon fluids and solvents, but not strong oxidizers or IRFNA.	Available RTA, apply by spray as per process spec. Air dry 15 min, bake 1-1/2 hr at 191°C (375°F). Aluminum 2 hr at 135°C (275°F). Temp. range -240°C (-400°F) to 371°C (700°F).
ESNALUBE 382	MoS_2 and silicate binder.	Dry film primarily intended for threaded surfaces of corrosion and heat resistant steel fasteners, couplings, and nuts. Excellent anti-wear and anti-friction. Capable of performance to 1097°C (2000°F).	Not LOX	Available RTA. Apply by spray. Air dry for 15 min, bake 2 hr at 66°C (150°F) and 2 hr at 204°C (400°F).
MICROSEAL 100-1 (NBW OS-10626A)	High purity electric furnace graphite (98% pure) and inorganic binder.	Sliding surfaces, rotating and oscillatory mechanical hardware, lubricant, coating applied to materials, such as metals, plastics, glass, rubber, etc. As a lubricant for plastic mold release, hydraulic pumps and cylinders, dies computer printer, welding nozzles, and boundary lubricant in fluids, etc.	Inert, stable insoluable in most environments and compatible with; distilled water, MIL-H-hydraulic fluid, silicone fluid-DC 200, Rockwell Nordstrom 147 grease, UDMH greases IR-FNA greases, solid propellents, Skydrol 500 and N_2D_4.	Nontoxic, noncorrosive, impinged solid lubricant. Special spray applicator (proprietary process). (Cure cycle variable depending on application: room temperature, and 7 days; heat cure, 15 min at room temperature, and 232°C (450°F) for 1.0 hr. Temperature range in air; -253°C (-423°F) to 1093°C (2000°F) in vacuum 133.3 x 10^{-9} Pa (10^{-9} torr) 1482°C (2700°F). Load capacity sliding dry; 27,579 kPa (4,000 psi) sliding with fluid, 344.738 kPa (50,000 psi) Maximum strength depend upon substrate; load 1,723,689 kPa (250,000 psi) have been achieved.
MICROSEAL 100-2	Mixture of proprietary constituents in a high heat inorganic binder.	A high friction impinged plating used on pulleys, clutches, capstans in the computer and recorder manufacturing industries. Can be applied to most materials, such as (same 100-1).	(Same as 100-1)	Nontoxic impinged coating that provides an increase of friction up to 100%. (Application and cure temperature range--same as 100-1) omit load capacity.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
MICROSEAL 200-1	MoS_2 as the lubricating solid and inorganic binder impinged on coated material.	Sliding and rolling surfaces on items such as; specialty bearings, springs, gears, cutting tools, cams, office equipment, etc. Sliding coefficients of friction from 0106 down to 0.02 through break-in depending on load and substrate surface.	Inert, stable, insoluble in most environments and compatible with; distilled water, MIL-H-hydraulic fluid, silicone fluid-DC 200, Rockwell Nordstrom 147 grease, UDMH greases, IRFNA greases.	Nontoxic, noncorrosive, impinged solid lubricant. Special spray applicator (proprietary process). (Cure cycle variable depending on application: room temperature 7 days; heat cure, 15 min at room temperature, and 232°C (450°F) for 1.0 hr. Temperature stability in air up to 399°C (750°F) and in vacuum to 760°C (1400°F) at vacuum pressure of 133.3 x 10^{-9} Pa (10^{-9} torr). Load capacity are determined by substrate strength, on certain materials loads of 2,757,902 KPa (400,000 psi) have been obtained.
MICROSEAL 300-1	Tungsten disulfide high heat inorganic binder (proprietary)	Similar to MICROSEAL 100-1 except for thermal range: Air 482°C (900°F) (max.); vacuum 1.33 x 10^{-7} N/m^2 10^{-9} torr 760°C (1400°F).	Similar to MICROSEAL 100-1	Similar to MICROSEAL 100-1

FEL-PRO, INC.
(Division, Felt Products Manufacturing Company)

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
FEL-PRO C-200	Forty-six percent solids consisting of MoS^2, graphite, and PbO, 8% thermosetting resin, 4% organic carrier. Film concentrate. Density 1,474 kg/m^3 (12.3 lb/gal)	Baked-on dry film for high temperature medium speed and heavy loads. Prevents corrosion, galling, seizing and wear. Uses include missile and aircraft components, actuators, gears journals, bearings, hinge pins, thrust reversers, etc.	Resist most hydrocarbon fluids and compounds.	Dry film lubricant may be applied by brush, dip or spray. Lubricant conc. should be thinned and the material to be coated, cleaned and pretreated as per manufacturing spec. Cure for steel; air dry, then 1 hr. at 260°C (500°F). For aluminum and other temperature limiting materials; air-dry 3-1/2 hr at 191°C (375°F). Coefficient of friction, 0.07 to 0.11. Usable temperature, range, -54°C to 816°C (-65°F to 1500°F) (limited to 1316°C (2400°F). Vacuum stable and shelf life, 6 months.
FEL-PRO C-300	Forty-nine percent solids consisting of MoS_2, graphite, and semiorganic binder 50% solvent. Film concentrate density 1,438 kg/m^3 (11 lb/gal). Solids content 50%.	Air-dry, solid film lubricant for high temperature. Usage industries include aerospace, automotive, machinery, household, petrochemical, etc. Recommended for sliding, rolling and rotating surfaces, where galling, seizure fretting exist; and where wear and friction are high	After 500°F bake, resists JP-4, hydraulic fluid (non-petro), brake fluid synthetic lub. oil, silicone fluids, and trichloroethylene; not LOX.	Dry film lubricant may be applied by brush, dip or spray. Lubricant concentrate should be thinned and the material to be coated cleaned and pretreated as per manufacturing spec. Air-dry in 1.0 hr, or for best proper entries heat cure; 1/2 hr. 260°C (500°F) for 3-1/2 hr. at 375°F. Friction coefficeient, 0.07 to 0.11. Usable temperature range, -54°C to 649°C (-65°F to 1200°F). Vacuum stable and good shelf life 6 months.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
FLUOROLOY® C	Proprietary homogeneous composite with inorganic reinforcing aggregate bound by Teflon® resin (TFE). Sp. Gr. = 3.76	High-speed bearing service in dry environments. In many mechanical applications that require low frictional coefficient high thermal conductivity, dimensional stability, hardness, wear resistance and rubbing contact strength.	Not LOX. Satisfactory with moisture, hydrocarbons and mild chemicals such as, oxidizing acids, and salts, and strong alkalis.	Compressive strength 8,963.2 kPa (1,300 psi) minimum. Coefficient of friction at 230 kPa (33.3 psi); 0.12 (static), 0.20 (dynamic). Usable temperature range -268°C (-450°F) to 260°C (500°F).
KEL-F® (C.T.F.E.)	Dense fluorocarbon plastic polymer. Amorphous grade. Sp. Gr. = 2.10	For bushings, seals and bearings in sliding and rotational contact. For compression molding, extruding or hot forming of part. High mechanical strength and toughness, and for cryogenic applications.	Chemically inert to most chemicals except strong acids and alkalis. Amorphous grade is LOX grade.	Tensile strength 34,956 kPa (5,070 psi). Shear strength 41,437 kPa (6,010 Psi). LOX impact 2,102 mPa (162 ft/lb/in.^{2}). Usable temperature range -269°C (-435°F) to 204°C (400°F).
KYNAR® (PVF_2)	Polyvinylidene fluoride plastic. Sp. Gr. 1.75 to 1.78.	For sliding and rotational contact surfaces. Good for process piping and components.	Not LOX or rocket fuels. Withstands alpha and neutron radiation.	Tensile strength; 35.85 MPa (5,200 psi) to 51.71 MPa (7,500 psi). Melting point 171°C (340°F). Compressive strength; 55.16 MPa (8,000 psi) to 68.95 MPa (10,000 psi).

Fluoroloy registered Trademark of the Fluorocarbon Company.
Teflon registered Trademark of DuPont.
Kel-F registered Trademark of 3M Company.
Kynar registered Trademark of Pennwalt Corporation.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
TUFRAM®	Anodize aluminum surface converted to aluminum oxide) impregnated with TFE particles by a proprietary electrochemical process.	Sliding surfaces dies, molds, electrical equipment, bearings, valves, pumps, power transmission equipment, almost any machine part, etc. Aluminum and its alloy that contain ⩾ 5% copper and > 7% silicon; wrought, cast, forged or extruded (not 1,000 series aluminum). Vacuum conditions to 133.3 x 10^{-6} N/m^2 (10^{-8} Torr). Spacecraft components, etc.	Most hydrocarbon fluids, solvents, oils, chemicals, etc.	For aluminum only; hard wear-resistant surfaces greater abrasion resistance than case-hardened steel or hard chrome. TFE polymer surface has low friction, effective corrosion, resistance improved electrical resistance and rapid heat transfer. Temperature range of cryogenic -79°C (-110°F) to 177°C (350°F) and 316°C (600°F).
HI-T-LUBE®	Proprietary process for the electroplating of any metal surface with layers of low-shear metallic films, nickel-silver and other lubricant compounds.	Aircraft and missile parts requiring wide temperature range, high loads and severe environmental conditions. Bearings, screws, gears, sliding surfaces. Not intended for corrosion resistance in warm acids. For high moisture condition base coat pretreatment is necessary to prevent moisture break through.	Impact sensitive in LOX. Not compatible with most missile and aerospace propellants. Compatible with space, gaseous and liquid oxygen, nitrogen, hydrogen, helium and most solvents and chemicals.	Dry film lubricant has good adhesion, rapid transfer of surface temperature, and long wear life. Usable temperature range dependent on base metal properties, but film has operated satisfactory from -218°C to 538°C (-360°F to 1000°F).
NEDOX®	Proprietary process for electrodepositing a porous hard cobalt-nickel alloy (electroless nickel) on any ferrous or coper alloy. The process also includes the infusion of PTFE lubricant material.	Sliding surfaces; connectors, screws and fasteners. Wear plates, pump in pellers, mold release. Chemical process equipment, nuclear application.	Most hydrocarbon fluids, solvents, oils, chemicals, etc.	Prevent galling, seizing and provides and abrasion resistant surface with a hardness of 750 Vickers scale. Seals against water and resis corrosion. Good adhesion to base metal and permanent lubrication with a coefficient of friction of 0.05 to 0.20. Temperature range -212°C (-350°F) to 260°C (500°F).
CANADIZING®	Electro-chemical process give titanium a hard surface impregnated with a fluorocarbon (TFE), MoS_2 or graphite, also colors.	Proprietary film for titanium, provides a hard, corrosion-resistant, low friction surface. Usage includes: aircraft, naval craft and ordinance including undersea craft, torpedos, and other weaponry. Used on fasteners, fittings, and space probe component to prevent galling, seizure and welding.	Most hydrocarbon fluids, solvents, oils, chemicals, etc.	Properties similar to TURFRAM® and NEDOX® . Canadized titanium has high fatigue-strength bearing surfaces, fracture toughness superior to steel, and excellent crack propagation characteristics. Usable temperature range, from -268°C (-450°F) to 371°C (700°F).
LECTROFLUOR®	Ferrous or nonferrous metals coated up to 0.75 mm (30 mils) thickness of fluoropolymer coatings in one coat. Requires pretreatment of metal before coating and a two-stage fusing of the Halar powder resin coating.	Proprietary process for applying fluoropolymer coating to most metals. Provides a hard tough permanently lubricated surface that resist abrasion and has good wear-life properties. Uses include; valve and valve parts, pipes and pipe fittings, rotating and sliding parts, reactor vessels and many solvent containers.	Coating is compatible or resistant to many substances; strong mineral acid oxidizing acids, alkalies, liquid oxygen and almost all solvents. Is not compatible with hot amines.	Coating may be applied by either fluidized bed or electrostatically, depending of specific application. Good dielectric properties, oxidation stable, and resistant to cobalt 60 irradiation to 200 megrads. Coefficient of friction 0.12 to 0.30. Usable temperature range -196°C (-320°F) to 177°C (350°F).

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
MAGNADIZE® (MIL-M-45202) (AMC -2476)	Anodizing process applicable to all types of magnesium alloys. Porous surface impregnated with TFE resins, epoxies, urethanes, graphite and MoS_2.	For dimensional build-up and hard surface. To improve wear and corrosion resistance, including joint galvanic corrosion. Applications, such as housing, rotor vanes, engine cases, handles, casting, fittings, fasteners, etc.	Chemically resistant to salt spray steam, oils, acids and alcohols.	Coating include 4 types and 5 classes, usage and properties depend on coating applied. Dissimilar metals should be stopped-off, with tape or lacquers, or installed after coating. Friction coefficient 0.08 to 0.05. Temperature range, ambient to 399°C. (750°F).
MAGNAGOLD	Titanium reacted with N_2 gas in vacuum chamber to form titanium nitride.	For cutting tools such as hobs, drills and taps. Dies and molds have been coated. Useful in heavy wear applications.	Most hydrocarbon fluids, solvents, oils, chemicals, etc.	Coating is nonsolderable. Primarily used on hard metals.
MAGNAPLATE HMF	Proprietary process for reduction of a hard cobalt-nickel alloy on ferrous and nonferrous alloys.	Excellent as wear surface for paper packaging, chutes, hoppers, etc. Where high wear encountered and product micro-finsih is important.	Same as Magnagold.	Propertiers similar to NEDOX. Microfinish (4 RMS) can be used to 427°C (800°F). Salt spray resistance. > 360 hrs. Low coefficient of friction.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
HENDERLUBE® 402A (MIL-L-8937D) Fed. Govt. QPL	MoS_2 and corrosion inhibitive additives in modified phenolic resin binder. Contains no graphite or powdered metals.	Suitable for coating aluminum and copper alloys, and ferrous alloys. Uses include aircraft and missiles assemblies, sprockets and drive chains precision instruments, valves and controls, nuts, bolts and threaded parts to prevent seizure. For sliding or rolling surfaces and gear trains under high loads.	LOX resistannt marginal - not recommended. Resistant to hydrocarbons, solvents, hydraulic fluid, oils, greases, chemicals, etc.	Good wear-life and corrosion resistance. Eliminates possibility of galvanic action. Cure 30 min. at 149°C (300°F) or 1.0 hr at 135°C (275°F). Recommended, 30 min at 163°C (325°F). Dry-film will not support growth of fungus or mold (MIL-E-5272A).
HENDERLUBE® 413 (MIL-L-46010A) Fed Govt. QPL	Same as 402A, except uses a modified epoxy resin binder in place of phenolic. Contains no graphite or powdered metals.	Suitable for coating any metal that will withstand 1.0 hr. at 177°C (350°F) bake cycle. Compounded to meet needs of the aerospace and missile fields. For bearing and sliding surfaces. Properties are similar to 402A, but has slightly better wear-life and corrosion resistance. Very good coating for steel, carbon and stainless, and is replacing 402A on these surfaces.	Same as HENDERLUBE® 402A.	Excellent wear-life and high resistance to corrosion, eliminates possibility of galvanic action. Cure for 1.0 hr. at 177°C (350°F). Usable temperature range -73°C (-100°F) to 260°C (500°F). Dry film will not support growth of fungus or mold (MIL-E-5272A).
HENDERLUBE® 426 (MIL-L-23398B)	Micro size MoS_2 and fortifying additives in blended organic resin. Contains no graphite or conductive additives that might induce a corrosion.	Air dry solid film lubricant for use where oven cure is not practical. Outstanding wear life and good corrosion protection. For use on rolling or sliding contact surfaces; gears, bolts, screws, nut, fasteners, splines, valves, mechanical mechanisms, and etc. Good for field application and repair of heat cured coatings.	Compatible with: standard aviation gasolines, and jet fuels, lubricating oils, hydraulic fluids, silicone fluids, standard test fluids, and some types of solvents and chemicals in general use by industry. Not for prolonged exposure to strong solvents such as toluene, methyl ethyl ketone, or ethylene dichloride.	Available in bulk concentrate from requireing dilution before application. Parts to be coated should be cleaned and pretreated per manufacturing Spec. May be applied by brush, dip or spray, which is recommended. Allow parts to air dry, or if baking facilities are available, heat cure 30 min at 149°C (300°F) for maximum wear life, resistance to corrosion, chemicals and solvents.
HENDERLUBE® 462A	MoS_2; thermosetting silicone resin binder. Contains no graphite, nor powdered metals, nor any conductive additives, which might induce corrosion	Medium high heat, dry film for ferrous alloys and materials where temperatures exceed 260°C (500°F). Applications similar to HENDERLUBE® 413.	Not LOX. Not recommended for hydrocarbons or solvents, and is affected by the ester, ketone and chlorides.	Good mechanical properties at high temperatures, similar to HENDERLUBE® 413. Cure 2.0 hr. at 232°C (450°F). Temperature range -73°C (-100°F) to 454°C (850°F) and to 482°C (900°F) for short intervals.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
SURF-KOTE® H-108	Modified MoS_2 in a resin binder concentrate density; 958 kg/m^3 (8.0 lb/gal).	Economical film, excellent where large quantities of small parts are coated by dipping or tumbling. May also be sprayed or brushed Prevents seizing, cold welding, fretting, corrosion and has very good wear-life.	Resistant to humidity, oils, greases, solvents, acids and alkalis.	Dry film concentrate should be diluted, and the surfaces to be coated, cleaned, and pretreated as per manufacturing spec. Cure for 45 min to 1.0 hr. at 191°C (375°F) to 204°C (400°F). Kinetic coefficient of friction 0.01 to 0.03.
SURF-KOTE® 359	TFE pigment in a phenolic resin binder density; 982 kg/m^3 (8.2 lb/gal).	Low temperature cure film has excellent adhesion and corrosion resistance, and in addition has low friction and release properties. May be applied to metal, rubber, plastic, fiber, etc.	Resists hydraulic fluids, oils, most solvents (not esters and ketones)	Spray application, not by dip or brush. Surface to be coated should be cleaned and pretreated as per manufacturing spec. Cure 1.0 hr. at 149°C (300°F). Shelf life 2 months.
SURF-KOTE® 360	TFE pigment in a modified alkyl binder density; 1,066 kg/m^3 9.89 lb/gal).	Water dispersible dry film for use on elastomeric parts and where flexibility is required (i.e., "O" rings, seals, etc.).	Resistant to oils hydraulic fluids, etc.	Dry film may be brushed or dipped, but spray application is most suitable. Parts to be coated should be cleaned and conditioned as per manufacturing spec. Cure 30 min at 149°C (300°F). Shelf life 4 months.
SURF-KOTE® M1284	MoS_2 and other material that form a matrix type bond. Density 1,018 kg/m^3 (8.5 lb/gal).	Eliminates galling, seizing, cold welding, prevents fretting, corrosion and lubricates under extreme pressure and temperatures.	Compatible with hydrocarbon fluids, and functions well at high humidity. Because of matrix bond heat resistance M-1284 functions well as high surface speeds and ambient temperatures. May be applied to most metals.	Endurance life is good and has low friction. Parts to be coated should be cleaned and pretreated per manufacturing spec. Dry film may be applied by dip or brush, but spray is recommended. Cure 1.0 hr. at 149°C (300°F) or 2 hr. at 121°C (250°F) to 135°C (275°F). Kinetic coefficient of friction 0.025 to 0.30. Shelf life 1.0 year.
SURF-KOTE® A-1625	Dry film lubricant suspended in suitable air drying resin. Density 1,018 kg/m^3 (8.5 lb/gal).	Film for bearing or rubbing surfaces; has bood adhesion and low friction. Prevents wear, seizing and galling. Uses include: assembly line, machine shop, automotive, baking, house and office equipment. May be applied to ferrous and nonferrous metals.	Resistant to: hydrocarbons - aviation gas, petroleum hydraulic fluid, lubricating oils, jet fuel.	May be applied by brush or dip, but spray is preferred. Parts to be coated should be cleaned and pretreated per manufacturing spec. Air-dry in 30 min or cured at 149°c (300°F) 15 min. Kinetic coefficient of friction 0.008 to 0.036. Usable temperature range -54°C (-65°F) to 260°C (500°F). Available in bulk or aerosol container. Shelf life 1 year.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
SURF-KOTE® LOB-1800-G	Graphite and other high temperature lubricating additives in a modified silicate binder. Solids content by weight; 30 to 32% (Class A), 40 to 42% (Class B). Density 1,018 kg/m³ (8.5 lb/gal) (Class A), 1,378 kg/m³ (11.5 lb/gal) (Class B).	Nonflammable solid film lubricant available in two forms: Class A, low density for spray application; Class B, high density for brush or dip application. For high temperature usage: kiln furnace cartwheels, conveyor and furnace door hinge pints. For sliding and rolling surfaces to prevent contact between metals, eliminating galling, seizing, fretting, etc.	Not LOX, most fuels or solvents. Corrosion resistance properties at film are low and is recommended primarily on corrosion resistant alloys.	May be applied by brush or dip, but spraying is preferred. Parts to be coated should be cleaned and pretreated per manufacturing spec. Air-dry 15 min then heat. Cure 1.0 hr. at 149°C (300°F). For maximum moisture resistance; air dry 15 min, then bake 2 hr. at 82°C (180°F) plus 3 hr. at 149°C (300°F). High temperature range 371°C (700°F) to 760°C (1400°F). Shelf life 6 months.
SURF-KOTRE® M-2036	MoS_2 and other lubricating pigments with a heat curing resin. Density 1,318 kg/m³ (11.0 lb/gal) No graphite.	For maximum endurance life and wide temperature range. Used on metal that can withstand high temperature cure. Usage include: hinge pins, links, adjustment nuts, bushings, drive assemblies pistons, steel wheels and roller bearings worm gears.	Not LOX, not recommended for severe corrosion applications.	May be applied by brush or spray, but the latter is preferred. Parts to be coated should be cleaned and pretreated per manufacturing spec. Cure: air dry 30 min, heat 1.0 hr. at 93°C (200°F) and then 1.0 hr. at 288°C (550°F). Temperature range -54°C (-65°F) to 399°C (750°F) Shelf life 12 months.
SURF-KOTE® M-2049	MoS_2 and other lubricating pigments blended with a heat curing resin, corrosion inhibited. Suspended in a volatile carrier. Density 1,198 kg/m³ (10.0 lb/gal).	Material has excellent adhesion and corrosion properties over a variety of materials, and excellent wear-life over a wide range of conditions, and environments including speed ranges and loads.	Resistant to: hydrocarbons, hydraulic fluids, jet fuel, silicone fluids and similar material.	May be applied by spray brush, or dip, but spray is preferred. May be applied to any metal that can withstand the cure temperature. Parts to be coated should be cleaned and pretreated per manufacturing spec. Cure: air dry 30 min, heat cure 1.0 hr. at 204°C (400°F). Usable temperature range -54°C (-65°F) to 260°C (500°F). Shelf life 12 months.
SURF-KOTE® A-2178A	MoS_2 and other lubricating pigments suspended in a solution of organic resins. Density 1,018 kg/m³ (8.5 lb/gal). (Similar to AFSL-41).	Good lubricant for titanium. Good for field application where baking is not possible and performance at high temperature is required. Excellent adhesion and fluid resistance. Usage include: hinge pins, gears for actuator, shafts, screws, gears, adjustment rods, nut tube joint coupling, control assemblies and etc	Resistant to: hydrocarbons, hydraulic fluids, jet fuel, silicone fluids and simialr material.	May be applied by brushing dipping or spraying with the latter preferred. Parts to be coated should be cleaned and pretreated per manufacturing spec. Cure by air drying for 72 hr., or heat cure at 249°C (480°F) for 30 min. Usable temperature range -54°C (-65°F) to 399°C (750°F). Shelf life 12 months.

NOTES: Hohman Plating and Manufacturing, Inc., are liscensed applicators of Teflon coating for many industrial applications.

New Processes: In addition to the air-drying and heat-cured solid film lubricants, some of which are listed in these tables, "Homan Plating and Manufacturing, Inc.," have conducted extensive research and development of new processes for applying various material coatings, these include; plasma flame spray coatings, materials ion plating coatings, and materials sputtering deposition coating process.

Plasma flame spray coatings have physical and metallurgical properties superior to conventional flame spray coatings. These include reduced porosity, improved bond and tensile strength, less oxide in the case of metal and higher density. Coating densities up to 98% of theoretical can be obtained and easily controlled. For example, pure W and W_2C can be applied to almost any base material with densities of 95%. Most inorganic material that can be melted without decomposition can be applied and when inert gases are used oxidization is minimized.

Ion plating is a process whereby a coating material is evaporated in the positive glow region of a gas discharge. The evaporant is ionized and accelerated under influence of electrical fields and deposits are made on atomically clean working piece surfaces with high energy. The deposits are very uniform in thickness and have excellent adhesion and density. The process is conducted in a vacuum chamber capable of pressures of 6.65×10^{-5} N/m^2 (5×10^{-7} Torr).

Ion plating offers coating combinations not obtainable by other methods. Metals such as aluminum, beryllium, cadnium, chromium, cobalt, copper, gallium, gold, hafnium, indium, iron, lanthanum lead, manganese, molybdenum, neodymium, nickel, niobium, palladium, platinum, rhodium, ruthenium, silicon, silver, tungsten, tin, titanium, vanadium and zirconium may be deposited on selected substrates. In addition several hard to coat metals, borides, nitrides, carbides, etc., can be coated by the ion process. At present ion plating is considerably more expensive than normal plating processes but does provide a means of applying many coatings and combinations that can be achieved in no other process.

Sputtering deposition is a process where in material from a target source is transported in a vapor phase through an ionized gas plasma to the substrate material to be coated where it is deposited as a coating with the same chemical characteristic as the original target material. The sputtering process requires equipment similar to that for ion plating, vacuum chamber capable of very low pressures, chamber charged with inert gas or gases, and an electrical power source. The sputtering process permit the use of several targets of different materials to be used simultaneously to give coating combinations. When different target materials are used sequentially, grade coating can be obtained, which is very useful when a certain coating is desired on a substrate that is not compatible with the coating material.

Sputtering is usually considered for thin film coating in the range of a few 10^{-10} m (1.0 angstroms) to 10^{-5} m (10^5 angstroms); however, each material application differs from the others.

MoS_2 is widely used dry lubricant and is usually applied by spraying as a resin bond, by brushing or by mechanical working. None of these methods offers the adhesion or film control of sputtering MoS_2. Film thicknesses of 10^{-7} m (10^3 angstroms) to 2×10^{-6} m (2×10^4 angstroms) can be obtained and is desirable for precision bearings, gears, splines and sliding parts. Sputtered film of MoS_2 generally provide endurance in excess of 10 times that of other methods based on per unit thickness.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
FIBRILOID® FABROID® FIBERGLIDE® Lined Bearings	A family of proprietary self-lubricating woven liner systems containing Teflon (PTFE) applied to rigid metal or molded phenolic backing	Low speed, high load, low friction applications. Used on aircraft airframes and controls, turbine engines, automotive, truck, construction, farm equipment and valves.	Resistant to most fluids; such as fuels, hydraulic fluids, greases, oils, chemicals, sea water, etc.	Fabricated as journal, spherical, rod end and thrust bearings. Static compressive strengths up to 8.27×10^8 N/m^2 (120,000 psi), dynamic loading up to 2.76×10^8 N/m^2 (40,000 psi). Coefficient of friction 0.02 to 0.06. Temperature range -240°C to 316°C (-400 to 600°F).

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
LUBECO 905	MoS_2, graphite and other friction and wear reducing materials in a complex binder system of electrodecomposition based on self-induced type of electrophoresis.	Primarily as an antifriction coating to reduce wear, prevent galling, scoring, seizing or abrasion on ferrous and nonferrous material subject to sliding or rolling contact. Used on spherical ball and sleeve bearings. Screws, cams, bolts, fasteners, coupling, shafts, etc.	ABMA-LOX impact sensitivity test, vacuum hydrocarbon, fluid, etc. Not compatible with most propellants for mmissiles and aerospace, hydrazine N_2O_4, etc.	Slow chemical bond is accelerated by heat stabilizing 204°C (400°F) on steel and 163°C (325°F) on aluminum. Temperature range -269°C (-452°F) to 260°C (500°F), continuous and 316°C (600°F) limited. Nontoxic, good wear life, corrosion resistant, except poor in salt spray. Kinetic coefficient of friction 0.008 to 0.060.
LUBECO 2123	Inorganic dry film lubricant, electrophoretic binder system (similar to 905).	Long wear-life under high loads and low speeds at elevated temperature (higher than 905). Particularly successful on titanium, because it does not induce stress-corrosion.	Resist chemical attack better than most inorganic lubricants. Used in LOX, liquid hydrogen and hard vacuum.	Cure at 399°C (750°F) for 2 hr. Usable temperature range -269°C to 427°C (452°F to 800°F). Very low friction film, other properties similar to 905.
LUBECO 2023	Similar to 905.	Extremely high temperature resistance. Wear-life is slightly lower and friction is a little higher than 2123. Low friction properties maintained up to 649°C (1200°F), lowest friction ever measured above 538°C (1000°F).	Similar to LUBECO 2123.	Cure at 399°C (750°F) for 2 hr. Usable temperature range -269°C to 649°C (-452°F to (1200°F) for prolonged exposure and to 816°C (1500°F) for short periods. Most other properties similar to 2123.
LUBECO 2023B	Similar to 905.	Dry film inert to most any chemical attack: fuels, oxidizers and agressive chemicals. Good wear-life and lubricity. Primary use is on threaded fittings, valve seats, poppets or other liquid propellant components.	May be used with hydrazine, UDMH, monomethyl hydrazine, LOX, IRFNA, nitrogen tetroxide, hydrogen peroxide, 75% nitric acid, and diethyltramine.	Cure at 399°C (750°F) for 2 hr. Other properties similar to 2023.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
MEL-1	MoS_2 (DC-sputtering)	Experimental sputtered film primarily for use on ball bearing or other application requiring extremely thin film. May be used in vacuum.	Good outgassing properties.	Usable temperature range (air or vacuum): -73°C (-100°F) to 399°C (750°F).
AFSL-28	Calcium fluoride, barium fluoride, aluminum phosphate.	High temperature film developed for use at 538°C (1000°F) in an air environment where best friction and wear properties are obtained. Best on Ni-based alloys. Developed on an Air Force Laboratory Contract.	No fluids, use dry.	Cure at 925°C (1697°F) for 1.0 min. Usable temperature range in air; 21°C (70°F) to 816°C (1500°F) and in vacuum; -21°C (70°F) to 538°C (1000°F). Relatively high friction.
AFSL-29	Calcium fluoride, barium fluoride, magnesium fluoride, aluminum phosphate.	High temperature film that is similar to AFSL-28, but cures at lower temperature and has lower friction. Has very good load capacity and wear-life. Also developed on an Air Force Laboratory Contract.	No fluids, use dry.	Cure at 750°C (1382°F) for 1.0 min. Usable temperature range in air: 21°C (70°F) to 649°C (1200°F).
MLR-2 (50M60434)	MoS_2 and Sb_2O_3, polyimide resin.	For severe wear-life and elevated temperature use. Has acceptable outgassing and excellent radiation properties moderately high friction.	Hydrocarbon fluids and gaseous oxygen.	Air-dry 30 min, then cure: 149°C (300°F), 1.0 hr. plus 302°C (575°F), 1.0 hr. Usable from low temperature to 260°C (500°F).
MLF-5 (MSFC 502)	MoS_2, graphite, gold sodium silicate, water.	Good for high temperature and loads. Developed for LOX compatible film. May be used on ball and roller bearings. Excellent radiation and satisfactory outgassing properties.	LOX and gaseous oxygen. Not with fluids.	Air-dry 30 min, then cure 82°C (180°F), 2.0 hr and 149°C (300°F) 8.0 hr. Usable temperature range (air and vacuum): -73°C (-100°F) to 538°C (1000°F).
MLF-9 (MSFC 253)	MoS_2, graphite, bismuth, sodium silicate, water.	LOX compatible film, less expensive than MLF-5. Has high load capacity, but other properties are lower than MLF-5.	Same as MLF-5.	Air-dry 30 min, then cure 82°C (180°F), 2.0 hr. and 149°C (300°F) 2.0 hr. Usable temperature range (air or vacuum) -73°C (-100°F) to 371°C (700°F).
MLR-66	MoS_2, Sb_2O_3 polyphenylene sulfide-ethyl alcohol.	New experimental film has very good load capacity, wear-life and high temperature properties.	Use dry.	Cure at 93°C (200°F) for 1.0 hr. and then 371°C (700°F) 30 min. Usable from room temperature to 427°C (800°F).

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
*VITRO-LUBE (NPI-1220)	MoS_2, graphite, silver and a proprietary ceramic in a solvent carrier.	Heavy duty, long wearing dry lubricant; antifretting, anti-seizing for sliding surfaces. Recommended for dry surfaces. Can be applied to most metals and plating that will withstand cure temperature. Used for low velocity conditions on; bushings, ball, journal and gimbal bearings, splines, screws, shafts, gears, cams, etc.	Insoluble in air-crafts fluids, but should be used dry as fluids damage properties and shorten wear life.	Dry film lubricant for high temperature and loads, developed for B-70 airplane use. Surface to be coated should be cleaned and pretreated per manufacturing spec. Critical application technique required. Cure at 524°C (975°F) for 1.0 min. Usable temperature range -134°C (-210°F) to 371°C (700°F) continuous and 399°C (750°F) limited. Kinetic coefficient of friction 0.10.
NPI-14	MoS_2, lubricative pigments in an organic resin binder and commercial grade denatured alcohol.	For metals subject to wear, reduce friction, prevent galling, seizure and remain stable in presence of fluids at extreme temperature. For surfaces in sliding, reciprocal or oscillatory motion.	Resistant to: hydrocarbons, gas, hydraulic fluid, turbine fuel, oil, silicones, and some solvents.	Solid film lubricant has good corrosion resistance and wear life at high and low loads. Meets requirements of: MIL-L-8937, MIL-L-22273 and MIL-L-25504. Parts to be coated should be cleaned and pretreated per manufacturing spec. Spray application preferred. Air dry 30 min and heat cure 1.0 hr. at 149°C (300°F).
NPI-16	MoS_2, Sb_2O_3 disbursed in a thermal setting resin. Contains no graphite or powdered metals.	To reduce friction, inhibit fretting and eliminate galling or seizure. Not corrosion resistant but will not cause corrosion.	Resistant to aviation gasoline and turbine fuel, hydrocarbon, hydraulic fluids, oils, silicones and some solvents.	Apply by brush, or dip, but spraying is preferred. Parts to be coated should be cleaned and pretreated per manufacturing spec. Heat cure 1.0 hr. at 140°C (300°F). Temperature range -54°C (-65°F) to 149°C (300°F) and to 260°C (500°F) limited.
NPI-132 (DYNA-LUBE)	Metallic alloy of silver and refractory metals applied by electroplating.	To reduce wear, prevent galling and seizure. Withstand elevated temperatures for long soak periods. Electrically conductive. As base for conventional lubricants, and act as secondary lubricant. Kinetic coefficient of friction (dry) 0.20 to 0.40, with grease 0.02.	Compatible with hydrocarbon oils and greases.	Dry film placed on metal surfaces by electrolysis. Parts to be coated should be cleaned and pretreated per manufacturing spec. After plating parts must be baked at same bake cycle as other platings for hydrogen embrittlement relief. Corrosion resistance fair (same as silver). Dynamic compressive strength 344.7 MPa (50,000 Psi). Temperature range -62°C (80°F) to 760°C (1400°F).

NATIONAL PROCESS INDUSTRIES (Concluded)

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
NPI-425	MoS_2, Sb_2O_3, solvent and polyimide resin.	For bearing and sliding surfaces; severe wear-life requirements. Has very good corrosion resistance. Not for cryogenic use and should not be used with other lubricants or in contaminated environments. On metals that can withstand heat cure temperatures.	Compatible with fluids common to aircraft.	Parts to be coated must be cleaned and pretreated per manufacturing spec. Spray application preferred. Air dry 30 min and cured at 149°C (300°F), 1.0 hr. plus 302°C (575°F) for 1.0 hr. Usable to 260°C (500°F). Identical to NASA formula MLR-2, licensed and marketed by NPI.
NPI-2500 (MIRONITE) (AFSL-28)	Calcium fluoride, barium fluoride, aluminium phosphate.	High temperature film developed for use at 538°C (1000°F) in air. Works best on nickel-based alloys. Best friction and wear properties are in air.	No fluids.	Cure at 925°C (1697°F) for 1.0 min. Usable temperature range: air, 21°C (70°F) to 816°C (1500°F), in vacuum. 21°C (70°F) to ~ 538°C (> 1000°F).

*Coating applied only by NPI.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
POXYLUBE 330	Blended dry film (contains MoS_2, graphite, others) and small amount of air-dry resin. Solids content 15%. Density 1,054 kg/m^3 (8.80 lb/gal).	Sliding and rolling contacts, machinery break-in, screws, gear trains, T-slots, bolts, universal joints, latches, mechanical mechanisms, general purpose lube, may be applied to most metals, glass, plastics and woods. May be applied to some mechanisms without disassembly.	Moisture resistant, but not good in strong chemicals, solvents, acids, etc.	Paint-like dry-film that air dries in 30 min. Good shelf storage life. Spray, dip or brush application, some agitation required. Usable temperature -212°C (-350°F) to about 93°C (200°F).
POXYLUBE 420	Similar to POXYLUBE 330, but contains more resin. Solids content 14%. Density 1,045 kg/m^3 (8.72 lb/gal).	Similar to POXYLUBE 330.	Resist moisture and most petroleum fuels. Not corrosion resistant. Not good in strong chemicals, acids or solvents.	Similar to Poxylube 330 air-dries in 24 hr. Temperature range -212°C (-350°F) to 79°C to 93°C (175°F to 200°F).
POXYLUBE 500	Blended dry film (contains MoS_2, graphite, others) and heat cured resin. Solids content 22%. Density 1,105 kg/m^3 (9.22 lb/gal).	Similar to POXYLUBE 330 and 420 but has more wear strength, adhesion and chemical resistance, heat cure limits in some cases materials that can be coated.	Not LOX or rocket fuel but most hydrocarbon fluids and solvents, not as good as POXYLUBE 750.	Improved properties over POXYLUBE 330 and 420. Heat cure cycle 149°C (300°F), 1.0 hr. Usable temperature range -212°C to 316°C (-350°F to +600°F).
POXYLUBE 750	Similar lube blend to POXYLUBE 500 but has more resin. Solids content 26%. Density 1,037 kg/m^3 (8.66 lb/gal).	Similar to POXYLUBE 500 but slightly improved properties.	Resistant to solvents, gasoline, hydraulic fluids, oils, etc.	Similar to POXYLUBE 500. Cure cycle, 191°C (375°F) 1.0 hr. Usable temperature range -212°C to 260°C (-350°F to 500°F).

NOTE: <u>Surface Preparation:</u> To insure excellent adhesion and lubricity for POXYLUBE films it is necessary to remove all grease, dirt, and loose scale. Vapor degreasing is the most thorough method of cleaning. However, simple washing with solvents or strong detergents is usually sufficient.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
PUREBON® (Typical) PBA-3 PBA-5 PBH-3 P-3W P-03HT P-5J P-9 PBX-50 P-55 P-55HT P-56HT P-303C P-2003 P-4229	Graphite and metal impregnant. Graphite, inorganic additive. Carbon-graphite. Carbon-graphite and inorganic additive. Carbon-graphite and metal impregnant. Carbon-graphite and resin impregnant.	Nongalling and self-lubricating carbon graphite material that can be used for extreme temperatures and environments where conventional oils and greases cannot be used. Such as bearings of all types; flanged, sleeve, thrust, unball. Jet engine rotor bearing seals, exhaust actuator rollers, turbine rings, and compressor variable stator bearings. Jet aircraft flap spindle roller bearings, hydraulic pumps, fuel pump and booster fuel pump bearings. Also helicopter rotor drive shaft ball socket. Nuclear reactor control mechanisms.	Excellent chemical corrosion resistance, may be used in air liquified gasses, hydrocarbon fuels, liquids, and greases, solvents, etc. Only strong oxidizing acids, such as fuming nitric or oleum will attack Purebon.	Will carry high loads; static to more than 173 MN/m^2 (25,000 psi) and dynamic loads to 35 MN/m^2 (5,000 psi). Densities from 1,600 kg/m^3 (9.99 lb/ft^3) to 2,400 kg/m^3 (14.98 lb/ft^3). Coefficient of friction from 0.05 to 0.30 static and dynamic both in air and vacuum. Temperature range from -240°C (-400°F) to 1371°C (2500°F) and in vacuum or inert atmosphere to 3,038°C (5,500°F).
MOLALLOY® (Typical) PM-101 PM-103 PM-104 PM-105 PM-107 PM-108	MoS_2 bound in refractory metal matrices (molybdenum, tungsten, niobium, tantalum,etc).	Many application similar to the PUREBON® carbon-graphite materials listed above. Also for bearings, seals, gears, clutch facings, electric motor brushes--wherever high loads high temperature or vacuum make conventional lubrication impossible. PBM-5 was employed in the motors for the clamshell trench digger mechanisms for Survey or III and IV space programs. PBM-8 is used for jet aircraft clutch-brake mechanism for the engine throttle control. MOLALLY® parts should be used in compression where possible. Fillets and chamfers should be employed on corners and edges when subjected to loads. Widely used for heavy loaded sliders and bearings.	Compatible with conventional lubricants, hydraulic fluids and degreasing solvents.	Will carry static and dynamic loads five times higher than those of Purebon® carbon-graphite materials. Densities from 5,600 kg/m^3 (34.96 lb/ft^3). Coefficient of friction 0.03 to 0.50. Temperature limit in ambient oxidizing air to 399°C to 420°C (750°F to 800°F) because the MoS_2 ingredient oxidizes. In inert gas or vacuum to 1149°C (2100°F). May be bonded to metals using epoxy, phenolic or polyimide adhesives. Vapor honing of the MOLALLOY® surface improves adhesion.

NOTES: The Pure Industries materials of Purebon® and Molalloy® are only a few of many materials and grades that are made of carbon, graphite, MoS_2 and other additives, some of which are used in the aircraft and space program. Purebon Purebide® materials and grade are not listed because their usage is not generally in the aircraft or space applications. They have properties that combine the wear resistance of carbides and the lubricity of graphite. They are effective in handling abrasive slurries, such as, sand slurry pump seals and mating rings.

Some of the Molalloy® solid-lubricant compacts and typical usage are:

(a) PM-101 Ball-bearing separators.
(b) PM-103 High load bearings.
(c) PM-104 High load bearings.
(d) PM-105 Bearings and electrical brushes
(e) PM-107 High load bearings.
(f) PM-108 Clutch facings.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
RT/DUROID® 4300	Moldable reinforced PTFE, Density 3,400 kg/m^3 (212 lb/ft^3).	For heavily loaded applications; bearings, sleeve liners, bushings, etc. Also, nonlubricated machinery, aircraft engine accessory equipment, fans and blowers, compressor piston rings, etc.	Good chemical and corrosion resistance. Compatible with most fluids.	Tensile strength is 17.24 MPa (2,500 psi) compressive strength 114.45 MPa (16,600 psi) Limiting PV = 70,000. Low friction and heat distortion temperature of 122°C (252°F) at 1,820 kPa (264 psi). Temperature range -240°C (-400°F) to 274°C (525°F).
RT/DUROID® 4000	Reinforced PTFE, using a proprietary combination of glass fibers and PTFE resin. Density of 2,160 kg/m^2 (134.8 lb/ft^3).	Seals and packings at elevated temperatures, bushings and spacers, ball bearing retainers, and nonlubricated sliding surfaces. Excellent machine ability and dimensionally stable.	Compatible with most fluids, solvents and chemicals.	Material available in molded shapes and billets. Superior creep resistance, frictional and chemical properties. Tensile strength 7.6 MPa (1,100 psi). Compressive strength 82.7 MPa (12,000 psi).
RT/DUROID® 5813	Random oriented glass reinforced PTFE sheet containing MoS_2. Density of 2,420 kg/m^3 (151 lb/ft^3).	Self-lubricating applications such as liners for sleeve bearings and retainers for ball bearings. For sliding or rubbing surfaces such as aerospace wear strips.	Compatible with most fluids, solvents and chemicals	Available in sheet form. Tensile strength 32.1 MPa (4,640 psi). Compressive strength 25 MPa (3,630 psi). Heat distortion temperature 243°C (469°F). Coefficient of friction at 6.894 MPa (1,000 psi) is 0.061 static and 0.046 dynamic.
RT/DUROID® 5813M	Similar to 5813 except is available in molded form. Density 2,290 kg/m^3 (143 lb/ft^3).	Similar to 5813 for self-lubricating applications.	(Same as 5813)	Similar to 5813 except material may be molded.
RT/DUROID® 5801	Random oriented glass reinforced PTFE sheet.	Self-lubricating applications such as aerospace wear strips.	Compatible with most fluids, solvents, and chemicals.	Available in sheet form. Tensile strength 7500 psi. Compressive strength 10,000 psi. Heat distortion temperature 500°F. Coefficient of friction .028.
ENVEX® 1000	High strength thermoplastic polyimide available in assorted stock shapes and molded or machined parts.	Structural parts, insulators, seals, gaskets, valve seats.	Compatible with most fluids, solvents, and chemicals excluding basic solutions.	Can be used at temperatures up to 288°C (550°F). Tensile strength is 12,800 lbs per square inch. Compressive strength is 29,600 psi.
ENVEX® 1115	Thermoplastic polyimide reinforced with MoS_2.	Structural and/or self-lubricating applications such as vacuum bearings, seals, and nuclear components.	Compatible with most fluids, solvents and chemicals excluding basic solutions.	Can be used at 288°C (550°F). Compressive strength 28,000 psi.
EMVEX 1228	Thermoplastic polyimide lubricated with PTFE.	Carriage bearings, bushings, bearings, piston rings, sealing rings, electrical insulators.	Compatible with most fluids, solvents and chemicals excluding basic solutions.	Can be used at 288°C (550°F). Low coefficient of friction (.28) and low wear.

ROGERS CORPORATION (Concluded)

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
ENVEX® 1228	Thermoplastic polyimide lubricated with PTFE.	Carriage bearings, bushings, bearings, piston rings, sealing rings, electrical insulators.	Compatible with most fluids, solvents and chemicals excluding basic solutions.	Excels in unlubricated bearing applications. Can be used to 288°C (550°F). Low coefficient of friction (.12) and low wear.
ENVEX® 1315	Thermoplastic polyimide lubricated with graphite.	Bushings, bearings, seals, structural parts.	Compatible with most fluids, solvents and chemicals excluding basic solutions.	Can be used at 288°C (550°F). Low coefficient of friction (.28) and low wear. Compressive strength of 30,000 psi.
ENVEX® 1330	Thermoplastic polyimide lubricated with graphite.	Bearings, seals	Compatible with most fluids, solvents and chemicals excluding basic solutions.	Can be used at 288°C (550°F). Low coefficient of thermal expansion. Low coefficient of friction (.26) and low wear.

SANDSTROM PRODUCTS COMPANY

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
SANDSTROM 9A (MIL-L-46010-A)	MoS_2 in epoxy-phenolic binder. Contains no graphite. Density 1,154 kg/m^3 99.63 lb/gal). Solid content weight 41%.	Heat cured dry film lube for sliding surfaces, high temperatures and loads. Prevent galling, fretting and seizing. Good wear-life and corrosion protection contains no graphite and will not promote cathodic or galvanic corrosion. Used for parts seldom lubricated where operating pressures exceed load capacity of oils and greases. Splines, bolts, nuts, universal joints, bearings, ordinance and missile equipment, threads, pipe fittings, high pressure seals helicopter shafts, etc. May be used in vacuum as film does (not outgassing at 133 > Pa (1.0 > Torr).	LOX compatible and shock resistant. Unaffected by hydraulic fluids, rocket and hydrocarbon fuels, solvents, acids, oils and greases, alkalis and degreasers.	Available in bulk ready to apply by brush, dip or spray, which is preferred. Parts to be coated should be cleaned and pretreated per manufacturing spec. Air 30 min. to 1.0 hr. before baking. Cure for 1.0 hr. at 204°C (400°F). If substrate requires, cure at 163°C (325°F) for at least 6.0 hr. Usable temperature -196°C (-320°F) to 260°C (500°F). Shelf life 1 to 2 years.
SANDSTROM 26A (RIAPD-703)	MoS_2 and corrosion-inhibiting pigments, lacquer-like air-dry binder (epoxy). Contains no graphite. Density 1,222 kg/m^3 (10.2 lb/gal) solid content weight 24%.	Air-dry film lube. Properties are similar to 9A. This material is good as a field or touchup coating where heat cure film cannot be applied. Will stand loads exceeding 689.5 MPa (100,000 psi).	(Same as 9A)	Air-dry film. Operating range, -196°C to 149°C (-320°F to 300°F).
SANDSTROM LC-300 (MIL-L-8937D)	MoS_2 and corrosion-inhibiting pigments in an epoxy phenolic resin binder with modifiers. Contains no graphite.	Should be applied in place of 9A where maximum wear-life and corrosion protection are required on metals that are affected by 9A heat cure. Properties are similar to 9A. Will stand loads in excess of 689.5 kg/m^3 (100,000 psi). Corrosion protection, chemical resistance and long wear-life are outstanding properties.	Similar to 9A.	Heat cured film available in bulk or aerosol cans. Parts should be cleaned and pretreated per manufacturing spec. Apply by dip or spray, which is preferred. Air dry 15 to 20 min and then heat cure for 1.0 hr. at 140°C (300°F). Shelf life 1 to 2 years.
SANDSTROM Hi-T-650	MoS_2 and corrosion-inhibiting pigment, modified silicone binder (contains no graphite). Density 1,066 kg/m^3 (8.9 lb/gal) solids content, weight 21%.	Developed for high temperature use 260°C to 399°C (500°F to 750°F). May be used at temperatures exceeding 538°C (1000°F) for short intervals.	Not for fluids or fuels.	Air-dry or heat cure. Parts should be cleaned and pretreated per manufacturing spec. Coating applied by brush, dip or spray which is preferred. Air dry 72 hr. or heat cured 1.0 hr at 249°C (480°F). Shelf life 1.0 year. This film is based on Air Force Material Laboratory Development of AFSL-41.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
TIODIZE Tiolube 29 (MIL-L-81329C)	Inorganic solid film lubricant. Density 1,198 kg/m^3 (10.0 lb/gal).	Fasteners, nuts and bolts, sleeve bearings, rocket engine hot gas valves, jet engine shafts, bushings, etc. May be used in vacuum to 133.3 x 10^{-12} Pa (10^{-12} mm Hg), liquid hydrogen, and for radiation exposure. May be applied to ferrous and nonferrous metals and materials that can withstand heat cure.	LOX compatible, and impact insensitive at 99 N-m (73 ft/lb).	May be applied by brush, dip or spray, which is recommended. Parts should be cleaned and pretreated per manufacturing spec. Heat cure 1.0 hr. at 66°C (150°F) plus 1.0 hr. at 204°C (400°F). Loads to 827 MPa (120,000 psi). Usable temperature range -240°C (-400°F) 1093°C (2000°F). Good wear-life. Shelf life 1.0 year.
TIODIZE Tiolube 31	Organic, nonmetallic solid film lubricant and a thermoplastic binder. Density 958 kg/m^3 (8.0 lb/gal).	For self-locking nuts, electronic hardware, and for antistatic properties to bleed off static electricity from aircraft or electronic equipment.	Not LOX or rocket fuels, but is resistant to most fluids.	Apply by brush, dip, tumble or spray. Parts should be cleaned and pretreated per manufacturing spec. Cure: air dry 1.0 hr. or bake 15 min at 52°C (125°F). Allowable load to 827 MPa (120,000 psi). Usable temperature range -204°C (-400°F) to 93°C (200°F). Applied to self locking nuts, film passes 15 cycle reusable test per MIL-N-25027. Shelf life 1.0 year.
TIODIZE Tiolube 39	MoS_2 and inorganic binder solid lubricant. Contains no metallics. Density: 1,198 kg/m^3 (10.0 lb/gal).	For extreme environments and high temperatures. To prevent galling and seizing of threaded fasteners. Due to high temperatures in jet engines, superalloys are frequently used for fasteners in this application. Most superalloys, like titanium, have a severe tendency to galling. Also may be used in vacuum to 133.3 x 10^{-12} Pa (10^{-12} mm Hg).	Not LOX or rocket fuels.	Apply by brush, dip or spray. Parts should be cleaned and pretreated per manufacturing spec. Heat cure 1.0 hr. at 66°C (150°F) plus 1.0 hr. at 204°C (400°F). Allowable load to 827 MPa (120,000 psi). Operating temperature 204°C (400°F) to 760°C (1400°F). Applied to self-locking nut film passes 15 cycle usable per MIL-N-25027. Shelf life 1.0 year.
TIODIZE Tiolube 460 (MIL-L-8937D) (MIL-L-46010) (PD-42)	MoS_2 compound and a thermosetting resin binder. No graphite. Solids content, weight 43%.	For aerospace and aviation use to prevent or reduce the effects of metal-to-metal contact such as friction, galling, fretting wear and as a lubricant having superior antifriction and wear, anticorrosion properties for parts such as fasteners, threads, bearings, hydraulic fittings, etc. Where pressures exceed limits of oils and greases, or together with oils and greases where required. Has exceptional wear life and corrosion protection highly corrosive environments.	Not LOX or rocket fuels, or strong oxidizing acids. Resistant to most solvent, acids, oils, fluids, etc.	May be applied to most metals; ferrous and nonferrous, including aluminum, by brush, dip, tumble or spraying. Parts should be cleaned and pretreated per manufacturing spec. Cure: air dry 30 min plus 1.0 hr at 191°C (350°F) or 2 hr. at 149°C (300°F) or 2.5 hr. at 121°C (250°F). Allowable load to 827 MPa (120,000 psi). May be used in vacuum to 133.3 x 10^{-12} Pa (10^{-12} mm Hg). Operating temperature -240°C (400°F) to 343°C (650°F). Shelf life 1.0 year. Only known solid film lubricant which meets all three referenced spec.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
TIODIZE Tiolube 1175	MoS_2 and graphite in a patented inorganic binder, (no glass compounds)	Primary function is to prevent galling or seizing and to increase wear life of metal-to-metal surfaces. Low static coefficient of friction of 0.1 to 0.2. Used in many jet aircraft, missile, and space vehicle applications. Developed for use on nuts, bolts, fasteners, hydraulic fittings, bearings, valves, controls, etc.	Meets impact sensitivity requirements of NHB 8060.1A at 68.9 MPa (10,000 psi) in liquid oxygen. Resistant to most fluids; liquid oxygen, hydrazine, UDMH, N_2O_4, liquid helium, air, and fluorine gas.	May be applied to ferrous and nonferrous metals; steels, titanium and aluminum, by brush, dip or spray. Parts should be cleaned or pretreated per manufacturing spec. Cure: 1.0 hr. at 149°C (300°F) for aluminum and magnesium alloys or 204°C (400°F) for steel and titanium. Load capacity 827 MPa (120,000 psi). May be used in vacuum environment. Operating temperature -251°C (420°F) to 649°C (1200°F). Has good adhesion and will not crack or flake.
TIODIZE Tiolube 21 (MIL-L-23398C) (MIL-L-46147A) Designated as Tiolube 70 in aerosol cans	MoS_2 compound and a thermoplastic resin binder. No graphite.	For usage where a heat cured lubricant is not feasible, or in field-touch-up applications. This lacquer-like material, when properly applied, will provide exceptionally long wear life and good corrosion protection.	Meets all compatibility requirements of MIL-L-23398 and MIL-L46147A,	May be applied to metals; ferrous and nonferrous, including aluminum, by brush, dip, tumble, or spraying. Parts should be cleaned and pretreated per Mfg. spec. Cure: 24 hr air dry or accelerated drying 15 min at 66°C (150°F). Operating temp. -54°C (-65°F) to 121°C (250°F), intermittent to 260°C (500°F).
TIODIZE Tiolon A20	PTFE lubricative pigment suspended in fast-drying thermoplastic resin.	After appropriate pretreatment can be used with following materials: wood, steel, stainless steel, aluminum, titanium, rubber, plastics, and glass.	No data available	Specially designed for low friction and light loads. Static coefficient of friction 0.06 to 0.09. Coating thickness 0.0002 to 0.0007 provides optimum low friction properties. Air cure. Dries to touch in 3 to 5 min. Heat cure at
TIODIZE Tiolon E20	PTFE dispersed in thermosetting resin.	After appropriate pretreatment can be used with following materials: steel, stainless steel, aluminum, titanium, and also chrome molds.	No data available.	This dispersion can be used at speeds from 2 to 50 fpm and loads from 5 to 300 pounds. Coefficient of friction 0.05 to 0.08. Cure at 163°C (325°F) for 2 hrs. Optimum cure at 204°C (400°F) for 1 hour.
TIODIZE Tiolube X20	PTFE dispersed in solvent	After appropriate pretreatment, can be used with the following materials: Chrome molds, wood, steel, stainless steel, aluminum, titanium, rubber, glass and plastics.	No data available.	Can be air cured in 3 min. Designed for low friction, light load repetitive stresses and for areas requiring release properties. Coefficient of friction same as A20.

MANUFACTURER'S DESIGNATION	COMPOSITION	SUGGESTED USE	COMPATIBILITY LOX, FUEL, ETC.	NOTES
TIODIZE Tiolube 70	MoS_2 in a thermosetting resin binder.	Recommended and tested uses in such areas as: automotive, marine, aircraft, farm equipment, etc	No data available.	Can be air cured in 12 hrs. cured in 12 hrs. Recommended thickness 0.0002 to 0.0005. Average wear life 4 hrs. (Falex Tester). Corrosion resistance, 4130 steel, 240 hrs.
TIODIZE Tiolon 1000 Series Coatings	PTFE available in several formulas.	Expecially for industrial and mechanical applications.	No data available.	Tensile strength 2,000 to 4,000 psi. Continuous service temperature up to 260°C (500°F). Dielectric strength 1,200 to 2,000 volts per mil. Excellent corrosion resistance in chemicals such as water, acids, bases, solvents, etc.

A-IV. MANUFACTURER SUPPLIED APPLICATION DATA FOR SOLID LUBRICANTS

ACHESON COLLOIDS COMPANY

PROPERTIES \ PRODUCT NAME OR CODE	DAG 154	MOLYDAG 261	DAG 250	MOLYDAG 254
SPECIFICATION	-	-	-	MIL-L-8937A
COMPOSITION: Lubricant	Graphite	MoS_2 and thermo-setting Resin	MoS_2/Graphite	MoS_2/Lub. Pigments
Binder/Carrier	Isopropyl Alcohol 20% Solid		Phenolic Resin 42% Solid	Thermoset Resin (55% solid)
APPLICATION: Brush	X	-	-	X
Dip or Tumble	X	X	-	X
Spray	Best	X	X	X
CURE CYCLE: Air Dry	Yes	To Remove Solvents plus 10 Min. at 149°C (300°F)	-	
Heat	No		149°C (300°F)	10 Min. and 232°C (450°F) (1)
Temp/Time	-		1.0 Hr.	30 Min.
COMPATIBILITY: LOX	Batch Test	-	-	-
Oxygen (gas)	Batch Test	-	-	-
Rocket Fuel	-		-	-
Jet Fuel	-	M	X	X
Hydrocarbon	L	M	X	X
Solvents	L	M	X	X
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	-	-	-	-
USABLE TEMP. Air: (high)	204°C (400°F) 1/	260°C (500°F)	204°C (400°F)	135°C (275°F)
(low)	-	-	-	-
Vacuum: (high)	-	-	-	-
(low)	-	-	-	-
LOAD CAPACITY: Force	M-G	G	M	15,568 N (3,500 lb.)
Test Method		-	-	Falex
WEAR-LIFE: Load	2,802 N (630 lb)	G	2,802 N (630 lb)	4,448 N (1,000 lb)
Test Method	Alpha Tester	-	Alpha Tester	Falex
Time	1.0 Hr	-	150 Hr	350 Min
Test Cond.	7.9 m (26 ft/min)	-	7.9 m (26 ft/min)	7.9 m (26 ft/min)
FRICTION COEF.; STATIC, Air	L	0.105 (Steel)	L	L
Vacuum	-	-	-	-
DYNAMIC, Air	0.15	-	0.01	0.123
Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	Good	-	-	-
CORROSION RESISTANCE	L		G	G
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	X	-	-	L
Wood, Leather, Fibers	-	-		-
Glass and Ceramics	X	-	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	-	-	-
NOTES: V.G. - Very Good G - Good M - Medium P - Poor L - Limited or Low - - No Data or Not Applicable X - Satisfactory	Conductive lubricants have excellent film forming properties. Have many uses including assembly and "run-in" of O.E.M. items 1/ May be used to 454°C (850°F) for limited periods.	Tough film with high wear resistance. Corrosion protection. Limited service to 316°C (600°F)	Good adhesion, hard film. Good corrosion properties. Moderate load and speed applications.	May be cured at 149°C (300°F) but properties are reduced. Limited use to 149°C (300°F). Available in 20% solids as Molydag 254 RFU.

PROPERTIES / PRODUCT NAME OR CODE	EMRALON 310 (EMRALON 311)*	EMRALON 312	EMRALON 317	EMRALON 320 (EMRALON 321)*
SPECIFICATION	-	-	-	-
COMPOSITION: Lubricant / Binder/Carrier	PTFE Coating / Phenolic Resin	PTFE Coating / Acrylic Resin	PTFE Coating / Polyurethane Resin	PTFE Coating / Thermoplastic Resin
APPLICATION: Brush	-	-	X	-
Dip or Tumble	-	-	X	L
Spray	X	X	Best	Best
CURE CYCLE: Air Dry	-	-	5-6 Hr, or 66°-93°C (150°-200°F) 30 Min. (high humidity)	2 Hr
Heat Temp/Time	149°C (300°F) 60 Min	149°C (300°F) 30 Min.		-
COMPATIBILITY: LOX	-	-	-	-
Oxygen (gas)	-	-	-	-
Rocket Fuel	-	-	-	-
Jet Fuel	L	M	L	X
Hydrocarbon	X	X	X	X
Solvents	L	M	L	L
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	-	-	-	-
USABLE TEMP. Air: (high)	177°C (350°F)**	-149°C (300°F)	121°C (250°F)	82°C (180°F)
(low)	-34°C (-30°F)	-34°C (-30°F)	-	-
Vacuum: (high)	-	-	-	-
(low)	-	-	-	-
LOAD CAPACITY: Force	G	M	M	G
Test Method	Low load	Low load	Low load	Low load
WEAR-LIFE: Load / Test Method	150 lb Alpha tester	150 lb Alpha tester	150 lb Alpha tester	150 lb Alpha tester
Time	E	V.G.	E	V.G.
Test Cond.	7.9 m (26 ft/min)	7.9 m (26 ft/min)	7.9 m (26 ft/min)	7.9 m (26 ft/min)
FRICTION COEF.; STATIC, Air	0.05-0.07	0.08-0.10	0.08-0.10	0.05-0.07
Vacuum	-	-	-	-
DYNAMIC, Air	-	-	-	-
Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	V.G.	G	M	M
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	L	X	X	L
Wood, Leather, Fibers	L	X	X	X
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	L	-	X	X
Release Agent or Metal Work	L	L	X	X
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Good adhesion friction, corrosion and release properties. * 311 is equivalent to 310. ** Limited use at 204°C (400°F) 311 may be used in food processing equipment.	Excellent adhesion, low friction and good release properties. for flexible substrate. Limited use to 177°C (350°F)	Excellent adhesion, low friction, corrosion resistance and good release properties. Abrasion resistance better than pure PTFE. Limited use at 149°C (300°F)	Excellent adhesion, low friction, good corrosion and release properties. Limited use to 116°C (240°F). * 321 and 323 are equivalent to 320. 321 may be used on food equipment.

ACHESON COLLOIDS COMPANY

PROPERTIES \ PRODUCT NAME OR CODE		EMRALON 328	EMRALON 329	EMRALON 330	EMRALON 333
SPECIFICATION		-	-	MIS-19350D	-
COMPOSITION:	Lubricant	PTFE Coating	PTFE Coating	PTFE Coating	PTFE Coating Organic Resin, and Solvent
	Binder/Carrier	Thermoplastic	Thermoplastic Resin	Resin	
APPLICATION:	Brush	X	X	-	-
	Dip or Tumble	X	X	X	X
	Spray	X	X	Best	Best
CURE CYCLE:	Air Dry	2 Hr	2 Hr	2-5 min, and	2-5 min, 10 min
	Heat	-	-	149°C (300°F)	149°C (300°F)
	Temp/Time	-	-	1.0 Hr	5 min. 316°C (600°F)
COMPATIBILITY:	LOX	-	-	-	-
	Oxygen (gas)	-	-	-	-
	Rocket Fuel	L	L	L	
	Jet Fuel	L	L	X	
	Hydrocarbon	L	L	X	X
	Solvents	-	-	L	V.G.
RADIATION PROPERTIES		-	-	-	-
OUTGASSING PROPERTIES		-	-	-	-
USABLE TEMP.	Air: (high)	82°C (180°F)	82°C (180°F)	135°C (275°F)	232°C (450°F)
	(low)	-	-	-	-
	Vacuum: (high)	-	-	-	-
	(low)	-	-	-	-
LOAD CAPACITY:	Force	G Low load	G Low load	V.G. Low load	V.G. Low load
	Test Method				
WEAR-LIFE:	Load	150 lb	150 lb	150 lb	150 lb
	Test Method	Alpha tester	Alpha tester	Alpha tester	Alpha tester
	Time	V.G.	V.G.	E	42,000 cycles
	Test Cond.	7.9 m (26 ft/min)	7.9 m (26 ft/min)		
FRICTION COEF.; STATIC,	Air	0.06-0.09	0.06-0.09	0.05-0.07	0.08-0.09
	Vacuum	-	-	-	-
DYNAMIC,	Air	-	-	-	0.059
	Vacuum	-	-	-	-
ELECT. CONDUCTIVITY		-	-	-	-
CORROSION RESISTANCE		M	M	V.G.	V.G.
VACUUM WT. LOSS,	N/m^2	-	-	-	-
	mg/cm^2	-	-	-	-
	Vacuum	-	-	-	-
	Time	-	-	-	-
USES ON:	Rubber and Plastics	X	X	L	L
	Wood, Leather, Fibers	X	X	L	L
	Glass and Ceramics	X	X	X	X
	Metals	X	X	X	X
TYPICAL USES:	Gen. Purp. Lub.	X	X	X	X
	Fretting, Galling, Seizing	X	X	X	X
	Cams, Gears, Slide Surf.	X	X	X	X
	Rolling Surf.	X	X	X	X
	Release Agent or Metal Work	X	X	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory		Low friction and release properties. Moderate chemical resistance (i.e., H_2SO_4 and NaOH). Limited use to 116°C (240°F)	Low friction and release properties. Moderate chemical resistance. May be applied by electrostatic spray. Limited use to 116°C (240°F)	Excellent adhesion, and low friction. Resist corrosion abrasion, flex and impact. Limited use to 149°C (300°F). Used on gears, shafts, slides bearings, etc.	Chemical and abrasion resistant. Good film friction. Used on aerospace parts, valves, valve plugs, slides, etc.

PROPERTIES / PRODUCT NAME OR CODE	EMRALON 314	EMRALON 336	EMRALON 343
SPECIFICATION	-	-	-
COMPOSITION: Lubricant Binder/Carrier	Fluoropolymer epoxy, high build	Fluoropolymer water based thermoplastic resin	Fluoropolymer water based thermosetting resin
APPLICATION: Brush	X	X	X
Dip or Tumble	-	X	X
Spray	X	X	X
CURE CYCLE: Air Dry	72 hr or 66°C	24 hr or 71°C	-
Heat Temp/Time	(150°F) 2 hr	(160°F) 1 hr	160°C (320°F) 15 min Alternative cures
COMPATIBILITY: LOX	-	-	-
Oxygen (gas)	-	-	-
Rocket Fuel	L	-	L
Jet Fuel	X	L	X
Hydrocarbon	X	L	X
Solvents	L	-	L
RADIATION PROPERTIES	-	-	-
OUTGASSING PROPERTIES	-	-	-
USABLE TEMP. Air: (high)	163°C (325°F)	121°C (250°F)	135°C (275°F)
(low)	-	-	-
Vacuum: (high)	-	-	-
(low)	-	-	-
LOAD CAPACITY: Force	G	G	V.G.
Test Method	Low load	Low load	Low load
WEAR-LIFE: Load	150 lb	150 lb	150 lb
Test Method	Alpha tester	Alpha tester	Alpha tester
Time	-	V.G.	E
Test Cond. m/sec (ft/min)	0.13 (26)	0.13 (26)	0.13 (26)
FRICTION COEF.; STATIC, Air	0.08	0.07	0.06
Vacuum	-	-	-
DYNAMIC, Air	-	-	-
Vacuum	-	-	-
ELECT. CONDUCTIVITY	-	-	-
CORROSION RESISTANCE	V.G.	P	G
VACUUM WT. LOSS, N/m^2	-	-	-
mg/cm^2	-	-	-
Vacuum	-	-	-
Time	-	-	-
USES ON: Rubber and Plastics	X	X	L
Wood, Leather, Fibers	X	X	-
Glass and Ceramics	X	X	X
Metals	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X
Fretting, Galling, Seizing	X	L	X
Cams, Gears, Slide Surf.	X	X	X
Rolling Surf.	X	X	X
Release Agent or Metal Work	X	L	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Two component high-built lubricant coating for use where thermal curing is either undesirable or impractical.	Air dry, water based lubricant coating for use where OSHA or EPA regulations restrict organic solvents.	Thermosetting, water based lubricant coating for use where OSHA or EPA regulations restrict organic solvents. Good corrosion resistance.

PROPERTIES \ PRODUCT NAME OR CODE	VAC KOTE 21207	VAC KOTE BPS 18.07
SPECIFICATION	-	-
COMPOSITION: Lubricant	MoS_2	MoS_2 and Solids, Organic Binder,
Binder/Carrier	None	Xylene/Alcohol
APPLICATION: Brush	Proprietary Process	X
Dip or Tumble		X
Spray		X
CURE CYCLE: Air Dry	None	
Heat	-	300°C (590°F) 1 hr or 149°C (300°F) 16 hr
Temp/Time	-	
COMPATIBILITY: LOX	-	-
Oxygen (gas)	-	-
Rocket Fuel	-	-
Jet Fuel	X	X
Hydrocarbon	X	X
Solvents	X	X
RADIATION PROPERTIES	-	-
OUTGASSING PROPERTIES	E	E
USABLE TEMP. Air: (high)	149°C (300°F)	288°C (550°F)
(low)	-268°C (-450°F)	-184°C (-300°F)
Vacuum: (high)	371°C (700°F)	288°C (550°F)
(low)	-268°C (-450°F)	-184°C (-300°F)
LOAD CAPACITY: Force	>1.379 N/m^2 (>200,000 psi)	>0.689 N/m^2 (>100,000 psi)
Test Method	Shell 4 ball	FALEX, LFW-1
WEAR-LIFE: Load	7.12 N (1.6 lb)	4,448 N (1,000 lb)
Test Method	0.013 m (0.5 in.) Ball on flat;	Falex
Time	300 min	340 min
Test Cond.	Inert Gas	Room Temperature
FRICTION COEF.; STATIC, Air	0.10 to 0.20	0.10 to 0.20
Vacuum	-	-
DYNAMIC, Air	0.03 to 0.10	0.04 to 0.10
Vacuum	-	-
ELECT. CONDUCTIVITY	-	-
CORROSION RESISTANCE	-	L
VACUUM WT. LOSS, N/m^2	-	-
mg/cm^2	10^{-12}	10^{-11} at
Vacuum	<1.33×10^{-4} N/m^2	<1.33×10^{-4} N/m^2
Time	(<10^{-6} torr)/sec	(<10^{-6} torr)/sec
USES ON: Rubber and Plastics	-	-
Wood, Leather, Fibers	-	-
Glass and Ceramics	L	L
Metals	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X
Fretting, Galling, Seizing	L	E
Cams, Gears, Slide Surf.	X	E
Rolling Surf.	E	E
Release Agent or Metal Work	L	L
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	For rolling contact bearings operating in vacuum. Ball bearings, ball bushing, Inst. gears, hard vacuum and space.	High loading surface in air and vacuum. Sliding surfaces, low-high loads and low-high temperature.

PROPERTIES \ PRODUCT NAME OR CODE	MOLYLUBE AR	MOLYLUBE SR	MOLYLUBE N
SPECIFICATION	-	MIL-L-8937 (ASG) (1)	MIL-L-81329 (WEP)
COMPOSITION: Lubricant	MoS_2	MoS_2	MoS_2
Binder/Carrier	Resin	Resin	Inorganic-Organic Resin (30% Solid)
APPLICATION: Brush	X	X	X
Dip or Tumble	X	X	-
Spray	X	X	X
CURE CYCLE: Air Dry	6 Hr	-	1.0 Hr
Heat	-	177°C (350°F)*	79°C (175°F)
Temp/Time	-	30 Min	30 Min
COMPATIBILITY: LOX	-	-	Batch Test
Oxygen (gas)	No Reaction	-	X
Rocket Fuel	No Reaction	X	-
Jet Fuel	X	X	X
Hydrocarbon	X	X	X
Solvents	X	X	L
RADIATION PROPERTIES	-	-	-
OUTGASSING PROPERTIES	-	-	-
USABLE TEMP. Air: (high)	399°C (750°F)	399°C (750°F)	760°C (1400°F)
(low)	-73°C (-100°F)	-73°C (-100°F)	-184°C (-300°F)
Vacuum: (high)	-	-	-
(low)	-	-	-
LOAD CAPACITY: Force	E	16,680 N (3,750 lb)	V.G.
Test Method	-	Falex	-
WEAR-LIFE: Load	M	4,448 N (1,000 lb)	V.G.
Test Method	-	Falex	-
Time	M	535 Min	-
Test Cond.	-	Ambient	-
FRICTION COEF.; STATIC, Air	-	-	L
Vacuum	-	-	L
DYNAMIC, Air	0.035 to 0.04	0.025	L
Vacuum	-	-	L
ELECT. CONDUCTIVITY	-	-	-
CORROSION RESISTANCE	G	G	G
VACUUM WT. LOSS, N/m^2	-	-	-
mg/cm^2	-	-	-
Vacuum	-	-	1.33×10^{-7} N/m^2 (10^{-9} mm. Hg)
Time	-	-	G
USES ON: Rubber and Plastics	-	-	-
Wood, Leather, Fibers	L	-	-
Glass and Ceramics	X	X	X
Metals	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X
Fretting, Galling, Seizing	X	X	X
Cams, Gears, Slide Surf.	X	X	X
Rolling Surf.	X	X	X
Release Agent or Metal Work	-	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Odorless and non-flammable. Excellent for extreme temp. and pressure and for high speeds. Resistant to chemicals. Will not pick up dust, dirt or lint.	Hard chemical resistant film. Excellent antigalling and seizing properties. Long wear-life. *Maximum properties are obtained by cure at 204°C (400°F) for 60 min.	Very tough film, good adhesion for extreme temperature ranges and vacuum. Maximum properties obtained by cure at 82°C (180°F) for 2 hr. then 260°C (500°F) for 2 hr.

DOW CORNING CORPORATION

PROPERTIES \ PRODUCT NAME OR CODE	MOLYKOTE 106	MOLYKOTE G-RAPID SPRAY	MOLYKOTE 321R	MOLYKOTE 3400A
SPECIFICATION	-	-	-	MIL-L-46010A
COMPOSITION: Lubricant Binder/Carrier	Solid lube blend (in. MoS_2) thermoset resin	MoS_2 + other solid lube in special oil	Solid Lube Blend (incl. MoS_2) Inorganic binder	Solid Lube Blend Plus Additives Thermoset Resin
APPLICATION: Brush	X	Aerosol only	X	X
Dip or Tumble	X		X	X
Spray	X		X, Aerosol	X
CURE CYCLE: Air Dry	-	Air dry - fast	Air Dry, 5 min.	-
Heat Temp/Time	149°C (300°F) 1 hr		-	204°C (400°F) 1.0 Hr.
			-	
COMPATIBILITY: LOX	-	-	X	-
Oxygen (gas)	-	-	X	-
Rocket Fuel	-	-	X	L
Jet Fuel	X	L	X	X
Hydrocarbon	X	L	X	X
Solvents	X	-	X	X
RADIATION PROPERTIES	-	-	G	-
OUTGASSING PROPERTIES	Unacceptable	-	-	-
USABLE TEMP. Air: (high)	316°C (600°F)	399°C (750°F)	450°C (892°F)	482°C (900°F)
(low)	-54°C (-65°F)	-35°C (-31°F)	-180°C (-292°F)	-198°C (-325°F)
Vacuum: (high)	-	-	-650°C (-1202°F)	-
(low)	-	-	-	-
LOAD CAPACITY: Force	15,569 N (3,500 lb)	-	1,120 N (2,500 lb)	17,347 N (3,900 lb)
Test Method	Falex		Falex	Falex
WEAR-LIFE: Load	2.802 N (630 lb)	-	2,802 N (630 lb)	2,802 N (630 lb)
Test Method	LFW-1		LFW-1	LFW-1
Time	6,250 min		4,861 min	1,389 min
Test Cond.	7.9 m (26 ft/min)		7.9 m (26 ft/min)	7.9 m (26 ft/min)
FRICTION COEF.; STATIC, Air	L	0.05	-	-
Vacuum	L	0.05	-	-
DYNAMIC, Air	0.03-0.07	0.03-0.05	0.03-0.07	<0.10
Vacuum	L	0.03-0.05	-	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	G	L	G	Best
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	G	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	L	X	-
Wood, Leather, Fibers	-	X	L	-
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	L	L	L	X
Release Agent or Metal Work	-	X	L	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Good adhesion, and chemical resistance. Most widely used. Dow heat cured bonded film.	Replaces Molykote® Spraykote. Very good running-in lube., immediate low coeff. of fric. and lowest of all products. Good for precision equipment and lead screws.	Extreme environment film. Excel. on alum. Soft film best on nonphosphated surfaces.	Best corrosion resistance of all films. Extreme pressure also. Intend to protect bearing surfaces. Has high friction during wear-in. Also meets RIA-PD-42.

DOW CORNING CORPORATION

PROPERTIES \ PRODUCT NAME OR CODE	MOLYKOTE 7400	MOLYKOTE 557	MOLYKOTE 7409
SPECIFICATION	-	-	-
COMPOSITION: Lubricant Binder/Carrier	Solid lube blend, air-cured, water-dilutable, organic resin	Clear Wax-Like Lube, in fast evaporating Solvent	Solid lube blend, organic resin
APPLICATION: Brush	X	X	L
Dip or Tumble	X	X	X
Spray	X	X, Aerosol	X
CURE CYCLE: Air Dry	Air dry, 40 min	Very fast, room temperature	-
Heat			150°C (302°F)
Temp/Time		-	2.0 Hr
COMPATIBILITY: LOX	-	-	-
Oxygen (gas)	-	-	-
Rocket Fuel	-	-	E
Jet Fuel	-	-	E
Hydrocarbon	-	-	E
Solvents	-	-	E
RADIATION PROPERTIES	-	-	E
OUTGASSING PROPERTIES	-	-	-
USABLE TEMP. Air: (high)	250°C (482°F)	60°C (140°F)	-
(low)	-70°C (-94°F)	-18°C (0°F)	-
Vacuum: (high)	-	-	-
(low)	-	-	-
LOAD CAPACITY: Force	100,000 N (2,250 lb)	4,448 N (1,000 lb)	13,344 N (3,000 lb)
Test Method	Falex	Falex	Falex
WEAR-LIFE: Load	2,860 N (643 lb)	2,802 N (630 lb)	2,802 N (630 lb)
Test Method	LFW-1	LFW-1	LFW-1
Time	4,766 min	70 min	6,000 min
Test Cond.	7.9 m (26 ft/min)	7.9 m (26 ft/min)	7.9 m (26 ft/min)
FRICTION COEF.; STATIC, Air	-	L	L
Vacuum	-	-	-
DYNAMIC, Air	0.03-0.07	L	L
Vacuum	-	-	-
ELECT. CONDUCTIVITY	-	-	P
CORROSION RESISTANCE	P	P	V.G.
VACUUM WT. LOSS, N/m^2	-	-	-
mg/cm^2	-	-	-
Vacuum	-	-	-
Time	-	-	-
USES ON: Rubber and Plastics	X	L	G
Wood, Leather, Fibers	X	L	X
Glass and Ceramics	P	L	X
Metals	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	-	X
Fretting, Galling, Seizing	X	X	G
Cams, Gears, Slide Surf.	X	L	G
Rolling Surf.	L	L	L
Release Agent or Metal Work	X	X	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Water based dry film lubricant. Environmentally safe.	Clear, colorless, nontoxic lube. Excellent for alum. and other cold metal working.	Extreme pressure lubricant. Excellent solvent and radiation resistance.

DRILUBE COMPANY

PROPERTIES \ PRODUCT NAME OR CODE	DRILUBE 1A	DRILUBE 2	DRILUBE 6A	DRILUBE 90
SPECIFICATION	MIL-L-8739A	MIL-L-8937B	MIL-L-46010	-
COMPOSITION: Lubricant Binder/Carrier	MoS_2, Graphite Epoxy Blend	MoS_2, Antimony*, Oxide Modified Epoxy Resin	MoS_2, Antimony* Oxide, Phenolic Epoxy Resin	MoS_2* Alkyd-Epoxy Resin
APPLICATION: Brush	X	-	-	-
Dip or Tumble	X	X	X	X
Spray	Best	Best	Best	Best
CURE CYCLE: Air Dry	-	-	-	-
Heat Temp/Time	149°C (300°F) 1.0 Hr	149°C (300°F) 1.0 Hr	204°C (400°F) 1.0 hr	191°C (375°F) 1.0 hr
COMPATIBILITY: LOX	-	No	No	No
Oxygen (gas)	-	-	-	-
Rocket Fuel	-	-	X	X
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	-	-	-	-
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	Acceptable	-	-	-
USABLE TEMP. Air: (high)	343°C (650°F)	343°C (650°F)	343°C (650°F)	343°C (650°F)
(low)	-184°C (-300°F)	-184°C (-300°F)	-184°C (-300°F)	-184°C (-300°F)
Vacuum: (high)	427°C (800°F)		-	-
(low)	-184°C (-300°F)	-	-	-
LOAD CAPACITY: Force	G	V.G.	V.G.	G
Test Method	Falex	Falex	Falex	Falex
WEAR-LIFE: Load	4,448 N (1,000 lb)	4,448 N (1,000 lb)	4,448 N (1,000 lb)	G
Test Method	Falex	Falex	Falex	-
Time	150 min	500 min	400 min	-
Test Cond.	Ambient	Ambient	Ambient	-
FRICTION COEF.; STATIC, Air	L	L	L	L
Vacuum	L	-	-	-
DYNAMIC, Air	L	L	L	L
Vacuum	L	-	-	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	M	V.G.	V.G.	M
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	-	-	-
Wood, Leather, Fibers	-	-	-	-
Glass and Ceramics	X	M	M	X
Metals	X	G	G	G
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	-	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Excellent wear-life. Resist heat or pressure. Used on aircraft, electronic and industrial items.	*No graphite or powdered metals. For high temp. and pressures, low speeds and resists moisture Resists corrosion shelf life 12 months.	*No graphite or powdered metals. Catalyst available for low temperature cure. For sliding mechanisms where no graphite is allowed and where moderate corrosion protection is required.	*Also contains corrosion inhibitors. For lightly loaded mechanisms of all types, cadinum plated parts, etc. Cured at lower temperature and longer time if needed.

DRILUBE COMPANY

PROPERTIES \ PRODUCT NAME OR CODE	DRILUBE 107	DRILUBE 701, 702 & 703	DRILUBE 805N	DRILUBE 831 & 842*
SPECIFICATION	MIL-L-46147*	-	MIL-L-81329	MIL-L-60326**
COMPOSITION: Lubricant	MoS_2	$MoS_2/SrCrO_4$	MoS_2 and graphite	PTFE Tolomer
Binder/Carrier	Modified Alkyd Binder	Phosphoric Binder	Silicate Binder	None
APPLICATION: Brush	-	X (703)	-	L
Dip or Tumble	-	X (702)	-	X
Spray	Best	X (701)	X	X
CURE CYCLE: Air Dry	18 Hr or 6 HR*	-	Air Dry, 1.0 Hr	1/2 Hr at R.T.
Heat	-	204°C (400°F)	82°C (180°F) 2 Hr	-
Temp/Time	R.T.	1.0 Hr	204°C (400°F) for 2 Hr	-
COMPATIBILITY: LOX	No	X	X*	X
Oxygen (gas)	-	X	X*	X
Rocket Fuel	L	L	-	L
Jet Fuel	X	X	X	X
Hydrocarbon	-	X	X	X
Solvents	-	X	L	G
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	-	-	-	-
USABLE TEMP. Air: (high)	343°C (650°F)	454°C (850°F)	538°C (1000°F)	260°C (500°F)
(low)	-73°C (-100°F)	-184°C (-300°F)	-212°C (-350°F)	-34°C (-30°F)
Vacuum: (high)	-	-	649°C (1200°F)	-
(low)	-	-	-240°C (-400°F)	-
LOAD CAPACITY: Force	G	G	V.G.	M
Test Method	-	-	-	-
WEAR-LIFE: Load	4,448 N (1,000 lb)	-	-	M
Test Method	Falex	-	-	-
Time	150 min, 90 min*	P (G)	P (G)	-
Test Cond.	Ambient	R.T. (Hi-T)	R.T. (Hi-T)	-
FRICTION COEF.; STATIC, Air	L	L	L	V.G.
Vacuum	-	L	L	-
DYNAMIC, Air	L	L	L	V.G.
Vacuum	-	L	L	-
ELECT. CONDUCTIVITY		-	-	-
CORROSION RESISTANCE	-	Fair	Fair	M
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	-	-	-
Wood, Leather, Fibers	X	-	-	X
Glass and Ceramics	M	X	X	X
Metals	G	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	L	X
Release Agent or Metal Work	-	-	-	L
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	*Also MIL-L-23398 at shorter cure time. For sliding mechanisms, threaded connectors, fasteners, metal furniture, touch-up over heat cured dry film. Shelf life 1.0 year.	Good high temp. wear-life and other properties. Binder is acidic and contact with skin should be avoided. 701 is heat cured 702 and 703 air dry.	High load film, for high temp. LOX compt.	*Aerosol cans. **Type II, excellent lubricity and insoluble in water. For lightly loaded mechanisms, thread sealant and oxygen systems, lock nuts, etc.

PROPERTIES \ PRODUCT NAME OR CODE	DRI-SLIDE	DRI-SLIDE SYNTHETIC
SPECIFICATION	-	-
COMPOSITION: Lubricant Binder/Carrier	MoS_2, Volatile carrier and anti-corrosion additive	Organic Molybdenum, soluble sulfur
APPLICATION: Brush	X	-
Dip or Tumble	L	-
Spray	L	Aerosol
CURE CYCLE: Air Dry	X	X
Heat	-	-
Temp/Time	-	-
COMPATIBILITY: LOX	-	-
Oxygen (gas)	-	-
Rocket Fuel	-	-
Jet Fuel	X	X
Hydrocarbon	X	X
Solvents	L	L
RADIATION PROPERTIES	-	-
OUTGASSING PROPERTIES	-	-
USABLE TEMP. Air: (high)	399°C (750°F)	G
(low)	-73°C (-100°F)	M
Vacuum: (high)	538°C (1000°F)	G
(low)	-73°C (-100°F)	M
LOAD CAPACITY: Force	689 MPa (100,000 psi)	G
Test Method	Falex or Timkin	-
WEAR-LIFE: Load	High	G
Test Method	-	-
Time	G	G
Test Cond.	-	-
FRICTION COEF.; STATIC, Air	L	L
Vacuum	L	L
DYNAMIC, Air	L	L
Vacuum	L	L
ELECT. CONDUCTIVITY	-	-
CORROSION RESISTANCE	G	G
VACUUM WT. LOSS, N/m^2	-	-
mg/cm^2	-	-
Vacuum	-	-
Time	-	-
USES ON: Rubber and Plastics	X	X
Wood, Leather, Fibers	X	X
Glass and Ceramics	X	X
Metals	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X
Fretting, Galling, Seizing	X	X
Cams, Gears, Slide Surf.	X	X
Rolling Surf.	X	X
Release Agent or Metal Work	X	X
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Good for general lubrication of machinery, tools, office machinery, gears, sliding surfaces, etc. Contains a rust inhibitor.	*Contains no solids. Nonoxidizing, resist elements, good penetration, corrosion resistance.

PROPERTIES / PRODUCT NAME OR CODE	LUBRI-BOND A&B	LUBRI-BOND 220	LUBRI-BOND N	LUBRI-BOND HT
SPECIFICATION		MIL-L-23398	NAVORD WS 9004	AFSL-41
COMPOSITION: Lubricant	MoS_2-Graphite	Solid Lubes, No Graphite, Halides or Powdered Metal	$NbSe_2$	MoS_2-Sb_2O_3 Graph.
Binder/Carrier	Alkyd resin 10% Solids		Phenolic 44% Solids	Silicone Resin, >22% Solids
APPLICATION: Brush	-	L	L	X
Dip or Tumble	X	L	L	-
Spray	Best	Bulk or Aerosol	Best	-
CURE CYCLE: Air Dry	Air Dry, 18 Hr	Air Dry, 6.0 Hr	Air Dry, 18 Hr	Air Dry
Heat	-	-	-	R.T.
Temp/Time	-	-	-	72 Hr (*)
COMPATIBILITY: LOX	-	-	-	-
Oxygen (gas)	-	-	-	-
Rocket Fuel	-	-	-	-
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	L	G	X	X
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	-	V.G.	V.G.	-
USABLE TEMP. Air: (high)	204°C (400°F)	204°C (400°F)	204°C (400°F)	399°C (750°F)
(low)	-212°C (-350°F)	-212°C (-350°F)	-212°C (-350°F)	-273°C (-459°F)
Vacuum: (high)	-	-	X	-
(low)	-	-	-	-
LOAD CAPACITY: Force	M	V.G.	M	>11,120 N (>2,500 lb)
Test Method	Falex	Falex	-	Falex
WEAR-LIFE: Load	G	V.G.	L	2,802 N (630 lb)
Test Method	-	-	-	Macmillan
Time	-	-	-	>380 Hr
Test Cond.	-	-	-	7.9 m (26 ft/min)
FRICTION COEF.; STATIC, Air	0.13	0.20	0.14	0.14
Vacuum	-	-	-	-
DYNAMIC, Air	0.03	0.03	0.04	0.02
Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	L	L	G	-
CORROSION RESISTANCE	X	V.G.	L	G
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	X	-	X	X
Wood, Leather, Fibers	X	X	X	X
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	L	X
Cams, Gears, Slide Surf.	X	X	L	X
Rolling Surf.	X	X	L	X
Release Agent or Metal Work	-	-	-	X
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Most widely used air dry Electrofilm solid film lube. General use for light-medium load and wear-life. *Lubri-Bond B same as Lubri-Bond A, except 18% solids.	Wear life, corrosion and solvent resistant properties approach those of heat cured films. Second in vol. of air dry lube usage.	High temp., air dry solid film lube.	Air dry solid film lube developed by Air Force Laboratory. Good for use on titanium.* May also be heat cured 10 min at 249°C (480°F)

PROPERTIES \ PRODUCT NAME OR CODE	ELECTROLUBE E40	LUBE-LOK 66-C	LUBE-LOK 1000 & 1000X*	LUBE-LOK 2006
SPECIFICATION	-	-	MPD-9706	O.D. 16199
COMPOSITION: Lubricant Binder/Carrier	MoS_2, Graphite, Modified Phenolic 40% Solids	MoS_2/Graphite Phenolic Resin	Synthetic Graphite and Lead Oxide, Ceramic Bin.	MoS_2-Graph. in Silicone-Formaldehyde Resin >38.5% Solids
APPLICATION: Brush	L	X	-	L
Dip or Tumble	X	X	X	X
Spray	Best	X	Best	Best
CURE CYCLE: Air Dry	-	-	-	-
Heat	X	191°C (375°F)	X	
Temp/Time	149°C (300°F)	1.0 Hr	260°C (500°F)** 2 Hr	260°C (500°F) 2 Hr
COMPATIBILITY: LOX	No	Batch Test	X	No
Oxygen (gas)	-	Batch Test	X	-
Rocket Fuel	-	Batch Test	L	-
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	X	X	X	L
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	V.G.	V.G.	V.G.	V.G.
USABLE TEMP. Air: (high)	232°C (450°F)	371°C (700°F)	1093°C (2000°F)	454°C (850°F)
(low)	-273°C (-459°F)	-184°C (-300°F)	-184°C (-300°F)	-273°C (-459°F)
Vacuum: (high)	-	-	-	-
(low)	-	-	-	-
LOAD CAPACITY: Force	G	High	V.G.	Good
Test Method	-	-	-	-
WEAR-LIFE: Load	V.G.	5.52×10^8 N/m^2		2,802 N (630 lb)
Test Method	-	(80,000 psi)		Maxmillan
Time	-	Macmillan, 70 Hr		160 Hr
Test Cond.	-	7.9 m (26 ft/min)		7.9 m (26 ft/min)
FRICTION COEF.; STATIC, Air	0.16	-	-	0.10-0.13
Vacuum	-	-	-	-
DYNAMIC, Air	0.02	0.04	0.12	0.025-0.05
Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	G	G	L	L
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	-	-	-
Wood, Leather, Fibers	L	-	-	-
Glass and Ceramics	M	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	-	L
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	-	-	-
NOTES: E - Excellent V.G. - Very Good G - Good M - Medium P - Poor L - Limited or Low - - No Data or Not Applicable X - Satisfactory	*Intermittant use to 316°C (600°F). For jack screws, adjustment screws, fasteners, threads, gears, bearings, shafts, etc.	General purpose solid film lube for heavy duty and good wear-life. Third in volume usage among electrofilm heat cured solid lubes.	*1000X is a 1000 coating with a top-coat of Lube-Lok 2006. May be used to 1092°C (2000°F) *Cure is 15 min. 538°C (1000°F) for 1000 cure for 2006 topcoat.	For high loads and excellent wear-life and high temp. Jet and missile applications. Fourth in volume usage among Electrofilm heat cured solid lubes.

PROPERTIES / PRODUCT NAME OR CODE	LUBE-LOK 2306 (2396)*	LUBE-LOK 2406	LUBE-LOK 4306 (4396*)	LUBE-LOK 5396 (5306)*
SPECIFICATION	NAS-1367	-	NASA-A-D-66A	MIL-L-8937*
COMPOSITION: Lubricant	MoS_2	Graphite	MoS_2	MoS_2 + Graphite
Binder/Carrier	Sodium Silicate	Sodium Silicate	Phenolic	Phenolic
APPLICATION: Brush	L	L	X	X
Dip or Tumble	L	L	X	X
Spray	X	X	X	X
CURE CYCLE: Air Dry	-	-	-	-
Heat Temp/Time	82°C (180°F) 2 Hr + 204°C (400°F) 2 Hr	82°C (180°F) 2 Hr + 204°C (400°F) 2 Hr	191°C (375°F) 1-1/2 Hr	-149°C (300°F) 1.0 Hr
COMPATIBILITY: LOX	X	X	-	-
Oxygen (gas)	X	X	-	-
Rocket Fuel	X	X	-	-
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	L	L	X	X
RADIATION PROPERTIES	-	X	P	-
OUTGASSING PROPERTIES	V.G.	G	G	L
USABLE TEMP. Air: (high)	454°C (850°F)	454°C (850°F)	316°C (600°F)	316°C (600°F)
(low)	-273°C (-459°F)	-251°C (-420°F)	-184°C (-300°F)	-184°C (-300°F)
Vacuum: (high)	-	-	-	-
(low)	-	-	-	-
LOAD CAPACITY: Force	L	L	G	E
Test Method	-	-	-	-
WEAR-LIFE: Load	M	M	2,802 N (630 lb)	E
Test Method	-	-	Macmillan	-
Time	-	-	60 Hr	G
Test Cond.	-	-	7.9 m (26 ft/min)	-
FRICTION COEF.; STATIC, Air	L	L	L	0.02
Vacuum	-	-	-	-
DYNAMIC, Air	L	L	L	0.02-0.04
Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	-	-	X	X
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	-	L	-
Wood, Leather, Fibers	-	-	L	-
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	L	L	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	L	L	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	-	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Rolling element bearings and high vacuum. *2396 contains MoS_2/graphite and has properties similar to 2306, and meets MIL-L-81329 and temp. to 454°C (850°F)	General use at high temp. Lube properties not as good as MoS_2 films. May be used with N_2O_4, N_2H_2, and aerozene. Preferred for radiation environment.	Heavy-duty film for use where graphite is not allowed. *4396 is similar but has small quantity of graphite. Second in volume usage among electrofilm heat cured solid lubes.	Low temp. cure. Good chem. resist. *5306 is similar and meets MIL-L-8937 Spec. 5306 is most used electrofilm heat cured solid film. 5396 is a close second.

E/M LUBRICANTS, INC.
(Successor to Everlube Corporation and Microseal Corporation)

PRODUCT NAME OR CODE / PROPERTIES	EVERLUBE 620 (620A, 620C)	EVERLUBE 626	EVERLUBE 629	EVERLUBE 690
SPECIFICATION	MIL-L-8937B&C	-	-	MIL-L-8937
COMPOSITION: Lubricant / Binder/Carrier	MoS_2 Phenolic Resin (Modified)	MoS_2 Phenolic Resin (Modified)	Colloidal Graphite Modified Organic Resin Binder	MoS_2, Corrosion Inhibitor, Modified Phenolic Binder
APPLICATION: Brush	X	X	X	X
Dip or Tumble	X	X	X	X
Spray	Best	Best	X	X
CURE CYCLE: Air Dry / Heat Temp/Time	- / 191°C (375°F) 1.0 Hr	Air Dry, 15 Min Plus 149°C (300°F)/1.0 Hr	Air Dry, 15 Min Plus 149°C (300°F)/1.0 Hr	- / 191°C (375°F)/ 1.0 Hr
COMPATIBILITY: LOX	-	-	-	-
Oxygen (gas)	-	-	-	-
Rocket Fuel	L	L	L	M
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	X	X	L	X
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	-	-	-	-
USABLE TEMP. Air: (high)	260°C (500°F)	260°C (500°F)	260°C (500°F)	260°C (500°F)
(low)	-221°C (-365°F)	-221°C (-365°F)	-221°C (-365°F)	-221°C (-365°F)
Vacuum: (high)	-	-	X	X
(low)	-	-	X	X
LOAD CAPACITY: Force	689 MPa (100,000 psi)	Less Than EVERLUBE 620	G	G
Test Method	Falex	-	-	-
WEAR-LIFE: Load	2,224 N (500 lb)	Less than EVERLUBE 620	-	-
Test Method	Falex		-	-
Time	70 Hr		G	G
Test Cond.	7.9 m (26 ft/min)		-	-
FRICTION COEF.; STATIC, Air	<0.10	L	G	G
Vacuum	-	-	-	-
DYNAMIC, Air	<0.10	L	G	G
Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	-	-	G	-
CORROSION RESISTANCE	G	V.G.	M	G
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	X	L	L	-
Wood, Leather, Fibers	X	L	L	-
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	-	L	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	*Also MIL-L-25504 MIL-L-22273 (WEP) Good adhesion, fluid resistance. 620A, low temp. cure. 620 C contains corrosion inhibitors.	For general use, excellent fluid resistance. Good antifriction film but not as good as 620.	Good adhesion and wear properties. Will not chip, crack or peel.	*Solvent carrier and no graphites or carbons. Meets MIL-N-25027 spec. for self-locking nuts. Also for fasteners, nuts, bolts, screws, etc.

E/M LUBRICANTS, INC.
(Successor to Everlube Corporation and Microseal Corporation)

PROPERTIES / PRODUCT NAME OR CODE	EVERLUBE 810	EVERLUBE 811	EVERLUBE 812-3	EVERLUBE 823
SPECIFICATION		MIL-L-81329(WEP)*	MIL-L-81329*	
COMPOSITION: Lubricant Binder/Carrier	MoS_2, Graphite, Soft Metals and Silicone Resin Binder	MoS_2/Graphite Sodium Silicate	MoS_2 in Sodium Silicone Binder. (Graphite & Carbon Free)	Graphite Inorganic Binders
APPLICATION: Brush	X	X	X	
Dip or Tumble	X	X	X	
Spray	X	Best	X	
CURE CYCLE: Air Dry Heat Temp/Time	Air Dry, 15 Min Plus 288°C (550°F)/1.0 Hr	Air Dry, 15 min + 66°C (150°F)/2 Hr and 204°C (400°F) /2 Hr	Same as 811	Same as 811
COMPATIBILITY: LOX	-	X	X	-
Oxygen (gas)	-	X	X	X
Rocket Fuel	L	L	L	X
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	-
Solvents	X	X	X	-
RADIATION PROPERTIES	V.G.	V.G.	V.G.	-
OUTGASSING PROPERTIES	-	-	-	-
USABLE TEMP. Air: (high)	649°C (1200°F)	649°C (1200°F)	399°C (750°F)	399°C (750°F)
(low)	Static 538°C	-240°C (-400°F)	-251°C (-420°F)	-240°C (-400°F)
Vacuum: (high)	(1000°F) Dyn.	X	-	-
(low)	-54°C (-65°F)	X	-	-
LOAD CAPACITY: Force	G	10.4×10^8 N/m² (>150,000 psi)	>1,379 MPa (>200,000 psi)	M
Test Method	-	-	-	-
WEAR-LIFE: Load	G	G	G	L
Test Method	-	-	-	Falex
Time	-	-	-	L
Test Cond.	-	-	-	-
FRICTION COEF.; STATIC, Air	-	L	0.03 - 0.04	L
Vacuum	-	L	-	L
DYNAMIC, Air	-	L	-	L
Vacuum	-	L	-	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	G	G	G	M
VACUUM WT. LOSS, N/m²	-	Negl.	-	-
mg/cm²	-	-	-	-
Vacuum	-	1.33×10^{-7} N/m²	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	-	-	-
Wood, Leather, Fibers	L	-	-	-
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	-
Release Agent or Metal Work	-	✓	-	
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Used to reduce wear, prevent galling, seizing, etc., at high temperatures. Not for use in hard vacuum, extreme radiation or strong oxidizers.	E.P. and high temp., radiation and vacuum. *Also to NASA Spec. MSFC-106, -143, -238. KSC-F-124 and NASA 1008939 and many indust. spec.	*Except graphite free. Good adhesion, tough film, to reduce wear and prevent galling. Not in strong oxidizers, N_2O_4, IRFNA, etc.	Reduces wear, prevents galling. Extreme conditions of high temperature.

C-2

E/M LUBRICANTS, INC.
(Successor to Everlube Corporation and Microseal Corporation)

PROPERTIES \ PRODUCT NAME OR CODE	EVERLUBE 967	EVERLOX 16, 16B 17, 18*	INLOX 44 & 88	MICROSEAL 100-1
SPECIFICATION	-	-		05-10626A*
COMPOSITION: Lubricant Binder/Carrier	MoS_2 and Additives. Matrix Binder	MoS_2 and Chemical Bonded	MoS_2/Graphite Phosphoric Acid Binder	High Purity Electric Furnace Graphite. Prop. Binder**
APPLICATION: Brush	X	X	-	-
Dip or Tumble	X	X	-	-
Spray	X	X	X	Impinged
CURE CYCLE: Air Dry / Heat / Temp/Time	Air-Dry, 15 Min. and 66°C (150°F) 1.0 Hr and 302°C (575°F), 1.0 Hr	- 149°C (300°F) 1.0 Hr	Air-Dry, 30 Min. then 191°C (375°F) 1-1/2 Hr	7 Days 149°C (300°F) 2.0 Hr
COMPATIBILITY: LOX	-	X	X	No Reaction
Oxygen (gas)	-	X	X	No Reaction
Rocket Fuel	L	X	X	X
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	X	L	X	X
RADIATION PROPERTIES	-	G	-	G
OUTGASSING PROPERTIES	-	-	-	G
USABLE TEMP. Air: (high)	399°C (750°F)	X	371°C (700°F)	1093°C (2000°F)
(low)	-184°C (-300°F)	Cryogenic	-240°C (-400°F)	-253°C (-423°F)
Vacuum: (high)	-	X	X	1482°C (2700°F)
(low)	-	X	X	-253°C (-423°F)
LOAD CAPACITY: Force	689 MPa (100,000 psi)	G	-	Limited By Base Material
Test Method	-	-	-	-
WEAR-LIFE: Load	G	G	-	34.5 MPa (5,000 psi)
Test Method	-	-	-	-
Time	-	-	-	-
Test Cond.	-	-	-	
FRICTION COEF.; STATIC, Air	L	-	L	L
Vacuum	-	-	L	L
DYNAMIC, Air	L	-	L	0.06-0.07
Vacuum	-	-	L	L
ELECT. CONDUCTIVITY	-	-	-	X
CORROSION RESISTANCE	G	G	G	X
VACUUM WT. LOSS, N/m^2	-	X	Negl.	133 nN/m^2
mg/cm^2	-	X	-	Negl.
Vacuum	-	X	-	(10^{-9} Torr)
Time	-	X	-	-
USES ON: Rubber and Plastics	-	L*	-	X
Wood, Leather, Fibers	-	L*	-	X
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	-	-	L
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Contains no graphites, powdered metals or halogens Special high temp. film. For use by aircraft, missile and general industry.	*Everlox 16B is for spray application, -17 brush-on air dry, -18 is an air dry paste. Antiseizing, antigalling, used on aircraft, missiles, rocket engines, aerospace and space vehicles.	Antiseize coating threads, fittings couplings, etc. Primarily for cryogenic use. *Also NASA 1367.	*USN/BW Spec. Nonflammable and nonexplosive. General purpose lube. For vacuum use. Chemically stable and insoluble in most environments.

E/M LUBRICANTS, INC.
(Successor to Everlube Corporation and Microseal Corporation)

PROPERTIES \ PRODUCT NAME OR CODE	MICROSEAL 200-1	MICROSEAL 200-23	MICROSEAL 300-1	ECOALUBE® 642
SPECIFICATION		-	-	MIL-L-46010
COMPOSITION: Lubricant Binder/Carrier	MoS_2, Inorganic Binder System (Proprietary)	MoS_2 and High Temp. Binder	Tungsten Disulfide Inorganic Binder (Proprietary)	MoS_2-Metallic Oxide, Corrosion Inhibitor Resin Binder
APPLICATION: Brush	-	-	-	X
Dip or Tumble	-	-	-	X
Spray	Impinged	Impinged	Impinged	Best
CURE CYCLE: Air Dry	7 Days or	7 Days or	7 Days or	-
Heat	149°C (300°F)	149°C (300°F)	149°C (300°F)	204°C (400°F)
Temp/Time	2.0 Hr	2.0 Hr	2.0 Hr	1.0 Hr
COMPATIBILITY: LOX	-	-	-	-
Oxygen (gas)	No Reaction	No Reaction	No Reaction	-
Rocket Fuel	X	X	X	-
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	X	X	X	L
RADIATION PROPERTIES	G	G	G	-
OUTGASSING PROPERTIES	G	G	G	-
USABLE TEMP. Air: (high)	371°C (700°F)	593°C (1100°F)	482°C (900°F)	260°C (500°F)
(low)	-198°C (-325°F)	-109°C (-165°F)	-198°C (-325°F)	-221°C (-365°F)
Vacuum: (high)	760°C (1400°F)	760°C (1400°F)	760°C (1400°F)	-
(low)	-198°C (-325°F)	-109°C (-165°F)	-298°C (-325°F)	-
LOAD CAPACITY: Force	Limited By Base Material	Limited By Base Material	Limited By Base Material	8,896 N (2,000 lb)
Test Method	-	-	-	Falex
WEAR-LIFE: Load	V.G.		V.G.	4,448 N (1,000 lb)
Test Method	-	-	-	Falex
Time	-	-	-	>450 mm
Test Cond.	-	-	-	Ambient
FRICTION COEF.; STATIC, Air	L	L	L	L
Vacuum	L	L	L	-
DYNAMIC, Air	0.02-0.06	0.02	0.04	L
Vacuum	L	L	L	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	X	-	G	V.G.
VACUUM WT. LOSS, N/m^2	34.5 nN/m^2	34.5 nN/m^2	34.5 nN/m^2	-
mg/cm^2	Negl.	Negl.	Negl.	-
Vacuum	(10^{-9} Torr)	(10^{-9} Torr)	(10^{-9} Torr)	-
Time		-		-
USES ON: Rubber and Plastics	L	-	-	-
Wood, Leather, Fibers	L	-	-	-
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	L	L	L	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Similar to 100-1 but has much lower friction due to MoS in place of graphite. Higher loads than 100-1.	Thicker film build-up than 200-1, good for extreme pressure. Used on tools shear-spinning and extrusion.	Tungsten disulfide for specialized applications. Good chemical resistance.	Good corrosion resist., reduce wear, prevent galling. Good adhesion and fluid resist., for parts in storage or adverse environment.

E/M LUBRICANTS, INC.
(Successor to Everlube Corporaiton and Microseal Corporation)

PRODUCT NAME OR CODE / PROPERTIES	EVERLUBE 860	EVERLUBE 1120-8	ESNALUBE 382	PERMA-SLIK G
SPECIFICATION				MIL-L-23398C MIL-46147A
COMPOSITION: Lubricant	MoS_2, graphic	MoS_2, graphic	MoS_2	MoS_2, air-dry
Binder/Carrier	Silicone resin	Phenolic	Inorganic	Resin binder
APPLICATION: Brush	X	X	X	X
Dip or Tumble	X	X	X	X
Spray	Best	Best	Best	X
CURE CYCLE: Air Dry	15 min	-	15 min	Air dry
Heat	260°C (500°F)	191°C (375°F)	66°C (151°F)/2 hr	
Temp/Time	1 hr	1 hr	204°C (399°F)/2 hr	6 hr
COMPATIBILITY: LOX	-	-	-	-
Oxygen (gas)	-	-	-	-
Rocket Fuel	L	L	-	-
Jet Fuel	X	X	-	X
Hydrocarbon	X	X	-	X
Solvents	X	X	-	X
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	-	-	-	-
USABLE TEMP. Air: (high)	371°C (700°F)	260°C (500°F)	1093°C (2000°F)	-
(low)	-157°C (-250°F)	-221°C (-365°F)	-	-221°C (-365°F)
Vacuum: (high)	-	-	-	-
(low)	-	-	-	-
LOAD CAPACITY: Force	G	689 MPa (100,000 psi)	G	2,000 lbf
Test Method	MacMillan	Falex	-	Falex
WEAR-LIFE: Load	V.G.	Similar		4448 N
Test Method	MacMillan	Similar to Everlube 620		Falex
Time				60 Hr
Test Cond.	Ambient			7.9 m (26 ft/min)
FRICTION COEF.; STATIC, Air	-	<0.10		<0.10
Vacuum	-	-		-
DYNAMIC, Air	-	<0.10		<0.10
Vacuum	-	-		-
ELECT. CONDUCTIVITY	-	-		-
CORROSION RESISTANCE	-	G		M
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	L	X	L	X
Wood, Leather, Fibers	L	X	L	X
Glass and Ceramics	L	X	L	X
Metals	X	X	E	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	-	E	X
NOTES: E - Excellent V.G. - Very Good G - Good M - Medium P - Poor L - Limited or Low - - No Data or Not Applicable X - Satisfactory				Also available in aerosol.

FEL-PRO, INC.

PROPERTIES / PRODUCT NAME OR CODE	FEL-PRO C-200	FEL-PRO C-300
SPECIFICATION	-	-
COMPOSITION: Lubricant	MoS_2 blended lube	MoS_2 blended lube
Binder/Carrier	Organic Binder	Semi-inorganic Binder
APPLICATION: Brush	X	X
Dip or Tumble	X	X
Spray	X	X
CURE CYCLE: Air Dry	-	Air-dry - 24 Hr
Heat	260°C (500°F)	260°C (500°F)
Temp/Time	1 hr	1/2 hr
COMPATIBILITY: LOX	-	-
Oxygen (gas)	-	-
Rocket Fuel	-	-
Jet Fuel	X	X
Hydrocarbon	X	X
Solvents	L	L
RADIATION PROPERTIES	-	-
OUTGASSING PROPERTIES	-	Acceptable
USABLE TEMP. Air: (high)	816°C (1500°F)	649°C (1200°F)
(low)	-54°C (-65°F)	-54°C (-65°F)
Vacuum: (high)	1316°C (2400°F)	X
(low)	-54°C (-65°F)	X
LOAD CAPACITY: Force	15,569 N (3,500 lb)	16,680 N (3,750 lb)
Test Method	Falex	Falex
WEAR-LIFE: Load	4,448 N (1,000 lb)	4,448 N (1,000 lb)
Test Method	Falex	Falex
Time	>150 Min	164 Min
Test Cond.	Ambient	Ambient
FRICTION COEF.; STATIC, Air	L	L
Vacuum	-	-
DYNAMIC, Air	0.07 - 0.11	0.07 - 0.11
Vacuum	-	-
ELECT. CONDUCTIVITY	-	-
CORROSION RESISTANCE	G	M
VACUUM WT. LOSS, N/m^2	-	-
mg/cm^2	-	-
Vacuum	G	G
Time	-	-
USES ON: Rubber and Plastics	-	L
Wood, Leather, Fibers	-	L
Glass and Ceramics	X	X
Metals	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X
Fretting, Galling, Seizing	X	X
Cams, Gears, Slide Surf.	X	X
Rolling Surf.	X	X
Release Agent or Metal Work	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Extreme loads, temp. and med. speed. Widely used on aircraft and missiles--on steels, Mag., Titanium, Alum., etc.	Used on aero., automotive and general machinery. Improved properties are obtained by heat cure at 260°C (500°F) 1/2 hr.

PROPERTIES \ PRODUCT NAME OR CODE	TUFRAM®	NEDOX®	CANADIZING®	HI-T-LUBE®
SPECIFICATION	-	-	-	-
COMPOSITION: Lubricant Binder/Carrier	TFE impregnated on Al_2O_3 surface (proprietary)	PTFE 7 nickel alloy film, proprietary process	Proprietary film for Titanium (see note)	Proprietary film and process
APPLICATION: Brush		-	-	-
Dip or Tumble	-	-	-	-
Spray	See Note	See Note	See Note	See Note
CURE CYCLE: Air Dry	See Note	See Note	See Note	See Note
Heat	-	-	-	-
Temp/Time	-	-	-	-
COMPATIBILITY: LOX	-	-	-	Impact Sensitive
Oxygen (gas)	-	-	-	L
Rocket Fuel	-	-	-	No
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	X	X	L	X
RADIATION PROPERTIES	X	X	X	X
OUTGASSING PROPERTIES	X	X	X	X
USABLE TEMP. Air: (high)	316°C (600°F)	260°C (500°F)	371°C (700°F)	538°C (1000°F)
(low)	-268°C (-450°F)	-210°C (-350°F)	-75°C (-100°F)	-54°C (-65°F)
Vacuum: (high)	-	-	-	-
(low)	-	-	-	-
LOAD CAPACITY: Force	V.G.	-	-	High
Test Method	-	-	-	-
WEAR-LIFE: Load	V.G.	G	G	High
Test Method	-	-	-	-
Time	-	-	G	G
Test Cond.	-	-	-	-
FRICTION COEF.; STATIC, Air	<0.05	0.05	0.05	<0.10
Vacuum	L	-	-	-
DYNAMIC, Air	-0.05	0.05	-	<0.10
Vacuum	L	-	0.05	-
ELECT. CONDUCTIVITY	Non-Cond.	-	X	-
CORROSION RESISTANCE	V.G.	V.G.	V.G.	-
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	Nil	-	-	-
Vacuum	10^{-8} Torr	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	-	-	-
Wood, Leather, Fibers	-	-	-	-
Glass and Ceramics	-	-	-	-
Metals	Aluminum	Ferrous & Copper	Titanium	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	X	X	X	-
NOTES: E - Excellent V.G. - Very Good G - Good M - Medium P - Poor L - Limited or Low - - No Data or Not Applicable X - Satisfactory	Electrochemical bonded film for alum. Hard film good wear and abrasion prop. corrosion resist., low friction and good heat transfer. For close tolerances.	Electrochemical bonded film of hard-nickel & PTFE. Resist abrasion and corrosion. Proprietary process and heat treat. film for steel and copper alloys for close tolerances.	Electrochemical bonded hard film impregnated with TFE, MoS_2 or Graphite. Resist corrosion and has high fatigue-strength bearing prop.	Good adhesion, and heat cond. Proprietary film and cure cycle. Primarily for high strength high temp. and chemical resistance.

PROPERTIES / PRODUCT NAME OR CODE	LECTROFLUOR®	MAGNADIZE®	MAGNAGOLD	MAGNAPLATE HMF
SPECIFICATION	-	MIL-M-45202*		
COMPOSITION: Lubricant	Fluoropolymer	Teflon or MoS_2	Titanium	Ni Phosphate with
Binder/Carrier	Halar Powder	Epoxies, or ure-	Nitride	Trace of Co/CR
	Resin*	thane resins etc.		
APPLICATION: Brush	-	-	Physical Vapor	
Dip or Tumble	X or	-	Deposition	Proprietary
Spray	Electrostatic	Propri. Anodize		
CURE CYCLE: Air Dry	-	*	N/A	N/A
Heat	240°C-288°C	Proprietary		
Temp/Time	(464°F-550°F)	Process		
COMPATIBILITY: LOX	-	-	-	-
Oxygen (gas)	L	-	-	-
Rocket Fuel	L	-	E	X
Jet Fuel	X	X	-	-
Hydrocarbon	X	X	-	-
Solvents	-	L	-	-
RADIATION PROPERTIES	G	-	E	E
OUTGASSING PROPERTIES	-	-	E	E
USABLE TEMP. Air: (high)	177°C (350°F)	399°C (750°F)	1093°C (2000°F)	426°C (800°F)
(low)	-196°C (-320°F)	-	-212°C (-350°F)	-212°C (-350°F)
Vacuum: (high)	-	-	-	-
(low)	-	-	-	-
LOAD CAPACITY: Force		M		V.G.
Test Method		-		
WEAR-LIFE: Load	-	G		
Test Method	-	-	E	V.G.
Time	-	G		
Test Cond.	-	-		
FRICTION COEF.; STATIC, Air	0.12-0.30	0.08-0.25	<0.10	<0.10
Vacuum	-	-	-	-
DYNAMIC, Air	-	0.08-0.25	<0.10	<0.10
Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	-	-	V.G.	G
CORROSION RESISTANCE	V.G.*	V.G.	E	V.G.
VACUUM WT. LOSS, N/m^2	-	-		
mg/cm^2	-	-	None	None
Vacuum	-	-		
Time	-	-		
USES ON: Rubber and Plastics	-	-	Tools steels, high	Ferrous and
Wood, Leather, Fibers	-	-	hardened steel	nonferrous
Glass and Ceramics	-	-	alloys, titanium, &	metals
Metals	Ferrous & Nonferrous	Magnesium	nonferrous metals	
TYPICAL USES: Gen. Purp. Lub.	X		Cutting tools such	Packaging equip-
Fretting, Galling, Seizing	X		as drills, hobs,	ment in contact
Cams, Gears, Slide Surf.	X		and taps for heavy	with paper
Rolling Surf.	X		wear applications	
Release Agent or Metal Work	-	X		
NOTES: E - Excellent V.G. - Very Good G - Good M - Medium P - Poor L - Limited or Low - - No Data or Not Applicable X - Satisfactory	*Two stage fusing of powder resin coating. Inert to acids, bases, strong oxidizers, and most organic chemicals.	*Meets requirements for coating Class A thru C. Some coating classes are air-dry and other heat cure. Outstanding corrosion resistance and hardness for magnesium.	Physical vapor deposition of titanium nitride by reactive plasma ion bombardment in vacuum chamber. Thickness - 2 microns; hardness - Rc 85.	

PROPERTIES \ PRODUCT NAME OR CODE	HENDERLUBE 402A	HENDERLUBE 413	HENDERLUBE 426	HENDERLUBE 462A
SPECIFICATION	MIL-L-8937D	MIL-L-46010A	MIL-L-23398C	-
COMPOSITION: Lubricant Binder/Carrier	MoS_2, Corrosion Inhibitor and Modified Phenolic	MoS_2, Corrosion Inhibitor and Modified Epoxy	MoS_2 (Microfine), Select Additives,* Organic Resin	MoS_2, Corrosion Inhibitor and Modified Silicon
APPLICATION: Brush	X	X	X	X
Dip or Tumble	X	X	X	X
Spray	X	Best	Preferred	Best
CURE CYCLE: Air Dry	-	-	X	-
Heat Temp/Time	163°C (325°F) 30 Min	177°C (350°F) 1.0 Hr	If available 149°C (300°F)/ 30 Min	232°C (450°F) 2 Hr
COMPATIBILITY: LOX	No	No*	No	-
Oxygen (gas)	L	L	L	-
Rocket Fuel	L	L	L	-
Jet Fuel	X	X	X	-
Hydrocarbon	X	X	X	-
Solvents	L	L	L	-
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	-	-	-	-
USABLE TEMP. Air: (high)	260°C (500°F)	260°C (500°F)	260°C (500°F)	454°C (850°F)
(low)	-73°C (-100°F)	-73°C (-100°F)	-73°C (-100°F)	-73°C (-100°F)
Vacuum: (high)	-	-	-	593°C (1100°F)
(low)	-	-	-	-73°C (-100°F)
LOAD CAPACITY: Force	13,789 N (3,100 lb)	10,008 N (2,250 lb)	13,789 N (3,100 lb)	-
Test Method	Falex	Falex	Falex	-
WEAR-LIFE: Load	4,448 N (1,000 lb)	4,448 N (1,000 lb)	4,448 N (1,100 lb)	-
Test Method	Falex	Falex	Falex	-
Time	>330 Min	>600 Min	270 to 300 Min	-
Test Cond.	Ambient	Ambient	Ambient	-
FRICTION COEF.; STATIC, Air	L	L	L	L
Vacuum	-	-	-	-
DYNAMIC, Air	0.035 to 0.040	L	0.035 to 0.040	L
Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	E	E	E	G
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	-	-	-
Wood, Leather, Fibers	-	-	-	-
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	-	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Sliding and rolling surfaces at high loads and speeds. Reduces galling, wear, and fretting. Fungus resist. per MIL-E-5272A. Most widely used Henderson dry film.	*6 hr at 204°C (400°F) cure reported compt. to LOX. Properties similar to 402A. Second most used Henderson dry film film.	*No graphite nor conductive pigments. Heat cure for increased wear life, resistance to chemicals, corrosion, solvents. etc. Similar to 402A. Available in aerosol cans, used for field.	For medium high temperature above 260°C (500°F). Not in presence of solvents, hydrocarbons, etc. Short periods of time above 454°C (850°F)

PRODUCT NAME OR CODE / PROPERTIES	SURF-KOTE® H-108	SURF-KOTE® 359 (360*)	SURF-KOTE® M-1284	SURF-KOTE® A-1625
SPECIFICATION	-	-		
COMPOSITION: Lubricant	MoS_2	TFE	MoS_2	Pigment Lube
Binder/Carrier	Modified Resin Binder	Phenolic Resin	Metal Matrix Resin	Resin Bond
APPLICATION: Brush	X	-	X	X
Dip or Tumble	X	-	X	X
Spray	Best	X	X	Aerosol
CURE CYCLE: Air Dry	Air-Dry, 45 Sec	-	-	Air-Dry, 30 Min
Heat	191°C (375°F)	149°C (300°F)	177°C (350°F)	-
Temp/Time	1.0 Hr	1.0 Hr	1.0 Hr	-
COMPATIBILITY: LOX	-	-	-	-
Oxygen (gas)	-	-	-	-
Rocket Fuel	L	X	-	-
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	X	L	L	L
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	-	-	-	-
USABLE TEMP. Air: (high)	260°C (500°F)	177°C (350°F)	>427°C (>800°F)	260°C (500°F)
(low)	L	L	X	-54°C (-65°F)
Vacuum: (high)	-	-	-	-
(low)	-	-	-	-
LOAD CAPACITY: Force	M	M	V.G.	M
Test Method	-	-	-	-
WEAR-LIFE: Load	2,802 N (630 lb)	-	2,802 N (630 lb)	-
Test Method	MacMillan	-	MacMillan	-
Time	V.G. - P	-	>80 Hr	-
Test Cond.	Ambient - Hi-T	-	7.9 m (26 ft/min)	-
FRICTION COEF.; STATIC, Air	-	L	L	L
Vacuum	-	-	-	-
DYNAMIC, Air	0.012 to 0.03	L	0.03	L
Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	L	V.G.	V.G.	L
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	X	-	L
Wood, Leather, Fibers	-	X	-	L
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	X	-	L
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Durable solid film, used for break-in lube on assembled parts, intermittent operated mechanisms. Eliminates galling, seizing, fretting corrosion, etc.	Excellent adhesion and corrosion protection, low cure. Toxic fumes released above 204°C (400°F). Flammable film as sprayed. *SURF-KOTE 360 similar, has alkyd resin.	For part assembly break-in lube, prevents fretting corrosion. Anti-seize film for extreme pressure and temperature.	Excellent adhesion, low friction, reduces wear, seizing and galling. Part assembly, machine shop, truck automotive, office and home use.

PROPERTIES / PRODUCT NAME OR CODE	SURF-KOTE® LOB-1800-C	SURF-KOTE® M-2036	SURF-KOTE® M-2049	SURF-KOTE® A-2178A
SPECIFICATION	-	-	MIL-L-46010	-
COMPOSITION: Lubricant Binder/Carrier	Graphite, Lube Additives, Modified Silicate Binder	MoS_2 and Other Solid Lube, Polyimide Binder	MoS_2 and Other Solid Lube, Resin Binder	MoS_2 and Other Solid Lubes, Organic Resin
APPLICATION: Brush	X Class B	X	X	X
Dip or Tumble	X Class B	-	X	-
Spray	X Class A	X	Best	X and Aerosol
CURE CYCLE: Air Dry Heat Temp/Time	Air dry, 15 Min, 82°C (180°F) 2 Hr and 149°C (300°F) 2.0 Hr	Air-Dry, 30 Min, 93°C (200°F) 1.0 Hr and 288°C (550°F) 1.0 Hr	Air-Dry, 30 Min and 204°C (400°F) 1.0 Hr	Air-Dry, 72 Hr or 249°C (480°F) 30 Min
COMPATIBILITY: LOX	-	-	-	-
Oxygen (gas)	-	-	-	-
Rocket Fuel	L	-	L	L
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	L	L	L	L
RADIATION PROPERTIES	-	-	-	-
OUTGASSING PROPERTIES	-	-	-	-
USABLE TEMP. Air: (high)	371°C-760°C	399°C (750°F)	260°C (500°F)	399°C (750°F)
(low)	(700°F-1400°F)	-54°C (-65°F)	-54°C (-65°F)	-54°C (-65°F)
Vacuum: (high)	X	-	-	-
(low)	X	-	-	-
LOAD CAPACITY: Force	G	G	G	-
Test Method	-	-	-	-
WEAR-LIFE: Load	G	G	4,448 N (1,000 lb)	-
Test Method	-	-	Falex	-
Time	G	G	500 Min	-
Test Cond.	-	-	Ambient	-
FRICTION COEF.; STATIC, Air	L	L	L	L
Vacuum	L	L	-	-
DYNAMIC, Air	L	L	L	L
Vacuum	L	L	-	-
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	L	L	E	-
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	-	-	-	-
Time	-	-	-	-
USES ON: Rubber and Plastics	-	-	-	L
Wood, Leather, Fibers	-	-	-	X
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	-	-	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Nonflammable. For use in a vacuum or liquid oxygen systems.	Contains MoS_2 and other pigment lubes, but no graphite. Has maximum endurance life to 399°C (750°F)	Contains no graphite or powdered metals. Excellent corrosion and adhesion properties. Contains compounds and solvents that may be toxic, do not breath fumes or use on food equipment.	Similar to AFSL-41 but has better adhesion and fluid resistance.

PRODUCT NAME OR CODE / PROPERTIES	Lubeco 905	Lubeco 2123	Lubeco 2023B	Lubeco M-390
SPECIFICATION	-	-	-	-
COMPOSITION: Lubricant Binder/Carrier	MoS_2, Graphite and Other Solid Lubes, Complex Chemical Binder	Blended Inorganic Solid Lubes	Blended Inorganic Solid Lubes	Blended Solid Lubes, Organic Binder
APPLICATION: Brush Dip or Tumble Spray	Electrodeposition (Applied by Lubeco Only)	Electrophoretic Binder System	Electrophoretic Binder System	X X X
CURE CYCLE: Air Dry Heat Temp/Time	- 204°C (400°F), Accelerates Plating	Nonrequired See Above - -	Nonrequired See Above - -	- - - -
COMPATIBILITY: LOX Oxygen (gas) Rocket Fuel Jet Fuel Hydrocarbon Solvents	- - - - - -	No Reaction No Reaction No Reaction X X L	X X X X X L	- - - X X L
RADIATION PROPERTIES	X	-	-	-
OUTGASSING PROPERTIES	G	-	G	-
USABLE TEMP. Air: (high) (low) Vacuum: (high) (low)	260°C (500°F) -269°C (-452°F) X X	427°C (800°F) -269°C (-452°F) - -	649°C (1200°F) 269°C (-452°F) - -	260°C (500°F) -213°C (-352°F) - -
LOAD CAPACITY: Force	G	G	G	-
Test Method	-	-	-	-
WEAR-LIFE: Load Test Method Time Test Cond.	2802 N (630 lb) McMillan 164 Hr Ambient	V.C. - - -	G - - -	E - - -
FRICTION COEF.; STATIC, Air Vacuum DYNAMIC, Air Vacuum	0.060 - 0.010 - 0.050 0.040	L L L L	L L L L	- - - -
ELECT. CONDUCTIVITY	-	-	-	-
CORROSION RESISTANCE	M	M	M	-
VACUUM WT. LOSS, N/m^2 mg/cm^2 Vacuum Time	<0.01% (1 x 10^{-6} Torr) -	- - Hard Vacuum X	- - Hard Vacuum -	- - - -
USES ON: Rubber and Plastics Wood, Leather, Fibers Glass and Ceramics Metals	- - - X	- - - X	- - - X	X X X X
TYPICAL USES: Gen. Purp. Lub. Fretting, Galling, Seizing Cams, Gears, Slide Surf. Rolling Surf. Release Agent or Metal Work	X X X X -	X X X X -	X X X X -	X X X X -
NOTES: E - Excellent V.G. - Very Good G - Good M - Medium P - Poor L - Limited or Low - - No Data or Not Applicable X - Satisfactory	Used on metal substrates. Parts that rub, side or roll at temp. up to 260°C (500°F) Ball, roller, and sleeve bearings, screws, nuts, gears, etc.	Nontoxic low friction lube; long wear-life, high loads, and low speeds at elevated temp. Adheres to all nonferrous metals without heat cure cycle.	Low friction at high temp., 816°C (1500°F) for short periods. Vacuum compatible nontoxic and good chemical resistance. Lubeco 2023B is similar, very inert to chem. attack.	All purpose dry film for general use. Gears, Fasteners, slide surfaces, machinery, etc.

PROPERTIES / PRODUCT NAME OR CODE	MLF-5	MLF-9	MLR-2	MLR-66
SPECIFICATION	MSFC 502	MSFC 253	50M60434	-
COMPOSITION: Lubricant / Binder/Carrier	MoS_2, Graphite Gold, Sodium Silicate, Water	MoS_2, Graphite Bismuth, Aluminum Phosphate Water	MoS_2 + Sb_2O_3 Polymide	MoS_2 + Sb_2O_3 Polyphenylene Sulfide - Alcohol
APPLICATION: Brush	X	X	X	-
Dip or Tumble	X	X	X	-
Spray	X	X	X	X
CURE CYCLE: Air Dry / Heat / Temp/Time	Air Dry 30 Min 82°C (180°F) 2 Hr and 149°C (300°F) 8 Hr	Air Dry 30 Min 82°C (180°F) 2 Hr and 149°C (300°F) 8 Hr	Air Dry 30 Min 149°C (300°F) 1.0 Hr and 302°C (575°F) 1 Hr	- 94°C (200°F) 1 Hr 371°C (700°F) 1/2 Hr
COMPATIBILITY: LOX	E	E	-	-
Oxygen (gas)	X	X	G	-
Rocket Fuel	-	-	-	-
Jet Fuel	-	-	X	-
Hydrocarbon	-	-	X	-
Solvents	-	-	-	-
RADIATION PROPERTIES	Excellent	Excellent	Excellent	-
OUTGASSING PROPERTIES	Acceptable	-	Acceptable	-
USABLE TEMP. Air: (high)	538°C (1000°F)	371°C (700°F)	260°C (500°F)	427°C (800°F)
Air: (low)	-73°C (-100°F)	-73°C (-100°F)	X	R.T.
Vacuum: (high)	538°C (1000°F)	371°C (700°F)	-	-
Vacuum: (low)	-73°C (-100°F)	-73°C (-100°F)	-	-
LOAD CAPACITY: Force	16,680 N (3,750 lb)	20,016 N (4,500 lb)	20,016 N (4,500 lb)	20,016 N (4,500 lb)
Test Method	Falex	Falex	Falex	Falex
WEAR-LIFE: Load	4448 N (1,000 lb)	4448 N (1,000 lb)	4448 N (1,000 lb)	4448 N (1,000 lb)
Test Method	Falex	Falex	Falex	Falex
Time	86 Min	57 Min	502 Min	>600 Min
Test Cond.	5.78 m* (19 ft/min)	5.78 m* (19 ft/min)	5.78 m* (19 ft/min)	4.78 m* (19 ft/min)
FRICTION COEF.; STATIC, Air	0.29	0.30	0.23	-
STATIC, Vacuum	-	-	-	-
DYNAMIC, Air	0.15	0.20	0.18	0.1
DYNAMIC, Vacuum	-	-	-	-
ELECT. CONDUCTIVITY	M	-	-	-
CORROSION RESISTANCE	No	-	-	-
VACUUM WT. LOSS, N/m^2 / mg/cm^2 / Vacuum / Time	0.465 1.33×10^{-4} N/m^2 (10^{-6} torr) 528 Hr	0.340 1.33×10^{-4} N/m^2 (10^{-6} torr) 528 Hr	0.0775 1.33×10^{-4} N/m^2 (10^{-6} torr) 528 Hr	- - - -
USES ON: Rubber and Plastics	-	-	-	-
Wood, Leather, Fibers	-	-	-	-
Glass and Ceramics	-	-	-	-
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	-
Release Agent or Metal Work	-	-	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Developed on a NASA contract for LOX compt. and high temp.	LOX compt. film good for high loads. Less expensive than MLF-5.	Do not use with other lubes. For severe wear-life cond. and elevated temp.	New film that has not yet been completely evaluated.

* Meters per minute velocity.

PROPERTIES \ PRODUCT NAME OR CODE	AFSL-28	AFSL-29	MEL-1*
SPECIFICATION	-	-	-
COMPOSITION: Lubricant Binder/Carrier	Calcium Fluoride Barrium Fluoride Aluminum Phosphate	Calcium Fluoride Barium Fluoride Magnesium Fluoride Aluminum Phosphate	MoS_2
APPLICATION: Brush	-	-	
Dip or Tumble	-	-	DC Sputtering
Spray	X	X	
CURE CYCLE: Air Dry	-	-	
Heat Temp/Time	925°C (1,697°F) 1.0 Min	750°C (1,382°F) 2.0 Min	None
COMPATIBILITY: LOX	-	-	-
Oxygen (gas)	-	-	-
Rocket Fuel	-	-	-
Jet Fuel	-	-	-
Hydrocarbon	-	-	-
Solvents	-	-	-
RADIATION PROPERTIES	-	-	-
OUTGASSING PROPERTIES	G	G	G
USABLE TEMP. Air: (high)	816°C (1500°F)	649°C (1200°F)	399°C (750°F)
(low)	21°C (70°F)	21°C (70°F)	-73°C (-100°F)
Vacuum: (high)	>538°C (>1000°F)	-	399°C (750°F)
(low)	21°C (70°F)	-	-73°C (-100°F)
LOAD CAPACITY: Force	V.G.	V.G.	-
Test Method	-	-	-
WEAR-LIFE: Load	V.G.	V.G.	4,448 N (1,000 lb)
Test Method	-	-	Falex
Time	V.G.	V.G.	>40 Min
Test Cond.	-	-	Ambient
FRICTION COEF.; STATIC, Air	-	-	0.04 to 0.08
Vacuum	-	-	-
DYNAMIC, Air	<0.20	<0.20	0.04 to 0.08
Vacuum	<0.20	-	-
ELECT. CONDUCTIVITY	-	-	-
CORROSION RESISTANCE	-	-	L
VACUUM WT. LOSS, N/m^2	-	-	-
mg/cm^2	-	-	-
Vacuum	-	-	-
Time	-	-	-
USES ON: Rubber and Plastics	-	-	-
Wood, Leather, Fibers	-	-	-
Glass and Ceramics	X	X	X
Metals	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	L
Fretting, Galling, Seizing	X	X	X
Cams, Gears, Slide Surf.	X	X	X
Rolling Surf.	-	-	-
Release Agent or Metal Work	-	-	-
NOTES: E - Excellent V.G. - Very Good G - Good M - Medium P - Poor L - Limited or Low - - No Data or Not Applicable X - Satisfactory	High temperature film. Developed for use at 1000°F in an air environment where it has its best friction and wear properties. Works best on Ni-based alloys Developed on Air Force contract.	High temperature film. Cures at lower temperature than AFSL-28. Has lower friction than AFSL-28 at temperatures below 1000°F. Developed on Air Force contract.	*Experimental sputtered film. Primarily used on ball bearing races and other applications requiring extremely thin films.

PROPERTIES \ PRODUCT NAME OR CODE	NPI-14	NPI-16	NPI-132 Dyna-Lube
SPECIFICATION	MIL-L-8937		-
COMPOSITION: Lubricant Binder/Carrier	Lubricative Pigments (MoS_2), Organic Resin	MoS_2, Sb_2O_3* Thermal Setting Resin Binder	Silver and Refractory Metals, Electro-Plated
APPLICATION: Brush	X	X	-
Dip or Tumble	X	X	Electro-Deposited
Spray	Best	Best	-
CURE CYCLE: Air Dry	Air Dry - 15 Min	-	-
Heat	149°C (300°F)	X	-
Temp/Time	1.0 Hr	149°C (300°F)/ 1.0 Hr	-
COMPATIBILITY: LOX	-	-	-
Oxygen (gas)	-	-	-
Rocket Fuel	-	-	-
Jet Fuel	X	X	-
Hydrocarbon	X	X	X
Solvents	L	X	X
RADIATION PROPERTIES	-		-
OUTGASSING PROPERTIES	-		-
USABLE TEMP. Air: (high)	G	149°C (300°F)	760°C (1400°F)
(low)	G	-54°C (-65°F)	-62°C (-80°F)
Vacuum: (high)	-	-	-
(low)	-	-	-
LOAD CAPACITY: Force	>11,120 N (>2,500 lb)	G	G
Test Method	Falex	-	-
WEAR-LIFE: Load	4,448 N (1,000 lb)	-	M
Test Method	Falex	Falex	-
Time	>3.0 Hr	G	-
Test Cond.	Ambient	-	-
FRICTION COEF.; STATIC, Air	L	L	0.40
Vacuum	-	-	-
DYNAMIC, Air	L	L	0.20-0.40
Vacuum	-	-	-
ELECT. CONDUCTIVITY	-	-	X
CORROSION RESISTANCE	-	M	F
VACUUM WT. LOSS, N/m^2	-	-	-
mg/cm^2	-	-	-
Vacuum	-	-	-
Time	-	-	-
USES ON: Rubber and Plastics	-	-	-
Wood, Leather, Fibers	-	L	-
Glass and Ceramics	-	X	-
Metals	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X
Fretting, Galling, Seizing	X	X	X
Cams, Gears, Slide Surf.	X	X	X
Rolling Surf.	X	X	X
Release Agent or Metal Work	-	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	For metal surfaces subject to mechanical wear, in fluids, extreme temperature and high loads.	*Contains no graphite, carbon or powdered metals. Limited use to 260°C (500°F)	May be used with conventional lubes as a backup with grease, friction coefficient is 0.02. Conduct elect. Good storage and heat properties.

PROPERTIES \ PRODUCT NAME OR CODE	NPI-425 (MLR-2)	NPI-1220 Vitro-Lube	NPI-2500* MRIONITE
SPECIFICATION	NASA 50M60434	-	-
COMPOSITION: Lubricant	MoS_2 and Sb_2O_3	MoS_2, Graphite	Calcium Fluoride, Barium Fluoride,
Binder/Carrier	Polymide Resin	Ceramic Binder (Proprietary)	Aluminum Phosphate
APPLICATION: Brush	X	-	-
Dip or Tumble	X	Dip, Preferred	-
Spray	Best	X	X
CURE CYCLE: Air Dry	Air Dry, 30 Min	-	-
Heat Temp/Time	149°C (300°F), 1.0 Hr, 302°C (575°F), 1.0 Hr	524°C (975°F) 1.0 Min	925°C (1697°F) 1.0 Min
COMPATIBILITY: LOX	-	-	-
Oxygen (gas)	G	-	-
Rocket Fuel	-	-	-
Jet Fuel	X	-	-
Hydrocarbon	X	-	-
Solvents	-	-	-
RADIATION PROPERTIES	E	-	-
OUTGASSING PROPERTIES	Acceptable	-	G
USABLE TEMP. Air: (high)	260°C (500°F)	399°C (750°F)	816°C (1500°F)
(low)	Cryogenic	-134°C (-210°F)	21°C (70°F)
Vacuum: (high)	-	-	538°C (>100°F)
(low)	-	-	21°C (70°F)
LOAD CAPACITY: Force	20,016 N (4,500 lb)	V.G.	V.G.
Test Method	Falex	-	-
WEAR-LIFE: Load	4,448 N (1,000 lb)	G	V.G.
Test Method	Falex	-	-
Time	>8.0 Hr	V.G.	V.G.
Test Cond.	Ambient	-	-
FRICTION COEF.; STATIC, Air	0.23	X	-
Vacuum	-	-	-
DYNAMIC, Air	0.18	<0.10	<0.20
Vacuum	-	-	<0.20
ELECT. CONDUCTIVITY	-	-	-
CORROSION RESISTANCE	-	-	-
VACUUM WT. LOSS, N/m^2	-	-	-
mg/cm^2	0.0775	-	-
Vacuum	1.33×10^{-4} N/m^2 (10^{-6} Torr)	-	-
Time	528 Hr	-	-
USES ON: Rubber and Plastics	-	-	-
Wood, Leather, Fibers	-	-	-
Glass and Ceramics	-	-	X
Metals	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X
Fretting, Galling, Seizing	X	X	X
Cams, Gears, Slide Surf.	X	X	X
Rolling Surf.	X	L	-
Release Agent or Metal Work	-	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Do not use with other lubes. For severe wear-life condition and elevated temperature.	Developed for XB-70. Highest friction at R.T., lowest at 288°C (550°F). Should be used dry, no fluid. May be applied to steel and titanium some aluminum alloys.	*AFSL-28 Developed for use at 1000°F in air environment. Where it has its best friction and wear properties. Works best on Ni-based alloys.

PROPERTIES \ PRODUCT NAME OR CODE		Poxylube 420 (330)*	Poxylube 500	Poxylube 750
SPECIFICATION		-	MIL-L-8937D	-
COMPOSITION:	Lubricant Binder/Carrier	MoS_2, Graphite, Solid Blend Thermoplastic	Blend MoS_2 Graphite and Solids, Epoxy Resin	Blend MoS_2 Graphite and Solids, Epoxy Resin
APPLICATION:	Brush	X	X	X
	Dip or Tumble	X	X	X
	Spray	Best	Best	Best
CURE CYCLE:	Air Dry	Air Dry, 24 Hr	-	-
	Heat	-	149°C (300°F)	191°C (375°F)
	Temp/Time	-	1.0 Hr	1.0 Hr
COMPATIBILITY:	LOX	-	-	-
	Oxygen (gas)	-	-	-
	Rocket Fuel	-	-	-
	Jet Fuel	L	X	X
	Hydrocarbon	L	X	X
	Solvents	L	L	X
RADIATION PROPERTIES		-	-	-
OUTGASSING PROPERTIES		-	-	-
USABLE TEMP.	Air: (high)	79°C (175°F)	260°C (500°F)	288°C (550°F)
	(low)	-221°C (-350°F)	-212°C (-350°F)	212°C (-350°F)
	Vacuum: (high)	-	-	-
	(low)	-	-	-
LOAD CAPACITY:	Force	G	V.G.	V.G.
	Test Method	-	-	-
WEAR-LIFE:	Load	M	G	G
	Test Method	-	-	-
	Time	M	G	G
	Test Cond.	-	-	-
FRICTION COEF.;	STATIC, Air	L	L	L
	Vacuum	-	-	-
	DYNAMIC, Air	L	L	L
	Vacuum	-	-	-
ELECT. CONDUCTIVITY		-	-	-
CORROSION RESISTANCE		L	L	Fair
VACUUM WT. LOSS,	N/m^2	-	-	-
	mg/cm^2	-	-	-
	Vacuum	-	-	-
	Time	-	-	-
USES ON:	Rubber and Plastics	L	L	L
	Wood, Leather, Fibers	L	L	L
	Glass and Ceramics	X	X	X
	Metals	X	X	X
TYPICAL USES:	Gen. Purp. Lub.	X	X	X
	Fretting, Galling, Seizing	X	X	X
	Cams, Gears, Slide Surf.	X	X	X
	Rolling Surf.	X	X	X
	Release Agent or Metal Work	-	-	-
NOTES:	E - Excellent V.G. - Very Good G - Good M - Medium P - Poor L - Limited or Low - - No Data or Not Applicable X - Satisfactory	General use for antiseize and antigalling. For moderate temp., loads and wear. *330 is similar, has less resin and will air-dry in 30 min.	General use, good wear-life heat stability. Better adhesion and chemical resistance than air dry film. This film is most widely used polylube film. (Military)	Hard durable film for general use. Very good adhesion and wear-life and good chemical resistance.

PRODUCT NAME OR CODE / PROPERTIES	SANDSTROM 9A	SANDSTROM 26A	SANDSTROM LC-300	SANDSTROM Hi-T-650*
SPECIFICATION	MIL-L-46010A	MIL-L-46147A	MIL-L-8937D	
COMPOSITION: Lubricant Binder/Carrier	MoS_2 corrosion inhibited in Epoxy-Phenolic Binder	MoS_2-corrosion Inhibited Epoxy Resin	MoS_2 corosion inhibited in Mod. Epoxy Phenolic Resins	MoS_2, corrosion Inhibited Modified Silicone Resin
APPLICATION: Brush	X	X	X	X
Dip or Tumble	X	X	X	X
Spray	X	X, Aerosol	X	X
CURE CYCLE: Air Dry	Air Dry, 30 Min	Air Dry, 16 Hr	-	Air Dry, 72 Hr
Heat	204°C (400°F)	-	X	249°C (480°F)
Temp/Time	1.0 Hr	-	149°C (300°F)/ 1.0 Hr	1.0 Hr
COMPATIBILITY: LOX	X	X	-	-
Oxygen (gas)	X	X	-	-
Rocket Fuel	X	L	L	L
Jet Fuel	X	X	X	X
Hydrocarbon	X	X	X	X
Solvents	X	X	X	X
RADIATION PROPERTIES	-	-		-
OUTGASSING PROPERTIES	None at 10^{-6} Torr	None at 10^{-6} Torr		-
USABLE TEMP. Air: (high)	260°C (500°F)	149°C (300°F)	204°C (400°F)	399°C (750°F)
(low)	-196°C (-320°F)	-196°C (-320°F)	-196°C (-320°F)	-196°C (-320°F)
Vacuum: (high)	-	-	-	-
(low)	-	-	-	-
LOAD CAPACITY: Force	12,232 N (2,750 lb)	11,120 N (2,500 lb)	12,232 N (2,750 lb)	>13,340 N (>3,000 lb)
Test Method	Falex	Falex	Falex	Falex
WEAR-LIFE: Load	4,448 N (1,000 lb)	4,448 N (1,000 lb)	4,448 N (1,000 lb)	4,448 N (1,000 lb)
Test Method	Falex	Falex	Falex	Falex
Time	>500 Min	>170 Min	400 Min	>200 Min
Test Cond.	5.79 m (19 ft/sec)	5.79 m (19 ft/sec)	Ambient	5.79 m (19 ft/sec)
FRICTION COEF.; STATIC, Air	L	L	Low	Very Low
Vacuum	L	-	-	-
DYNAMIC, Air	L	L	<0.08	Very Low
Vacuum	L	-		-
ELECT. CONDUCTIVITY	1.4 x 10^6 ohms CM	1.4 x 10^5 ohms CM	-	-
CORROSION RESISTANCE	E	E	E	P
VACUUM WT. LOSS, N/m^2	-	-	-	-
mg/cm^2	-	-	-	-
Vacuum	1.33 x 10^{-4} N/m^2	-	-	-
Time	(10^{-6} Torr)	-	-	-
USES ON: Rubber and Plastics	-	X	-	-
Wood, Leather, Fibers	-	X	X	-
Glass and Ceramics	X	X	X	X
Metals	X	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X	X
Fretting, Galling, Seizing	X	X	X	X
Cams, Gears, Slide Surf.	X	X	X	X
Rolling Surf.	X	X	X	X
Release Agent or Metal Work	X	X	X	X
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Prevents corrosion, galling, seizing and fretting. Chemical resistant and long wear-life. Contains no graphite.	*Formerly RIAPD-703. Easy to apply air dry film. Properties are similar to 9A, but lower limits. For use where heat cure cycle for 9A is not allowable. No graphite.	Excellent corrosion protection, chemical resistance and long wear-life are major properties. Properties are similar to 9A. Contains no graphite. For use where heat cure cycle for 9A is not allowable.	*Based on AFSL-41 properties similar to 9A and 26A but for higher temperature to 538°C (1000°C) for short periods. Contains no graphite.

PROPERTIES / PRODUCT NAME OR CODE	Tiolube 29	Tiolube 31	Tiolube 39
SPECIFICATION	MIL-L-81329	-	-
COMPOSITION: Lubricant	MoS_2, Additives	Graphite, Additives.	MoS_2, Additives
Binder/Carrier	Ceramic Binder	Thermoplastic Resin	Ceramic Binder
APPLICATION: Brush	X	X	X
Dip or Tumble	X	X	X
Spray	Best	Best	Best
CURE CYCLE: Air Dry	-	1.0 Hr, or	-
Heat	X	X	X
Temp/Time	66°C (150°F)/1.0 Hr + 204°C (400°F)/ 1.0 Hr	52°C (125°F)/Min 15 Min	66°C (150°F)/1.0 Hr + 204°C (400°F)/ 1.0 Hr
COMPATIBILITY: LOX	X	-	-
Oxygen (gas)	X	-	-
Rocket Fuel	X	L	L
Jet Fuel	X	X	X
Hydrocarbon	X	X	X
Solvents	-	-	-
RADIATION PROPERTIES	-	-	-
OUTGASSING PROPERTIES	G	-	-
USABLE TEMP. Air: (high)	1093°C (2000°F)	93°C (200°F)	638°C (1000°F)
(low)	-240°C (-400°F)	-240°C (-400°F)	-240°C (-400°F)
Vacuum: (high)	-	-	-
(low)	-	-	-
LOAD CAPACITY: Force	827 MPa (120,000 psi)	827 MPa (120,000 psi)	827 MPa (120,000 psi)
Test Method	-	-	-
WEAR-LIFE: Load	4,448 N (1,000 lb)	G	4,448 N (1,000 lb)
Test Method	Falex	-	Falex
Time	60 Min	G	60 M
Test Cond.	Ambient	-	Ambient
FRICTION COEF.; STATIC, Air	L	L	L
Vacuum	-	-	-
DYNAMIC, Air	V.L.	X	X
Vacuum	-	-	-
ELECT. CONDUCTIVITY	-	-	-
CORROSION RESISTANCE	M	M	-
VACUUM WT. LOSS, N/m^2	-	-	-
mg/cm^2	Negl.	-	Negl.
Vacuum	133.3 pPa (10^{-12} mm Hg)	-	133.3 pPa (10^{-12} mm Hg)
Time		-	
USES ON: Rubber and Plastics	-	X	-
Wood, Leather, Fibers	-	X	-
Glass and Ceramics	L	X	X
Metals	X	X	X
TYPICAL USES: Gen. Purp. Lub.	X	X	X
Fretting, Galling, Seizing	X	X	X
Cams, Gears, Slide Surf.	X	X	X
Rolling Surf.	X	X	X
Release Agent or Metal Work	-	-	-
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	Limited use at 1093°C (2000°F). Used on fasteners, sleeve bearings, rocket and jet engine parts, bushings, locknuts, hydraulic fittings, etc.	Non-metallic antistatic film. Used for static electricity bleed-off of aircraft parts and connections. Self-locking nuts, electronic parts, fluid resistant.	Contains no metallic powders. Limited use at 760°C (1400°F) Used on super alloy, titanium etc. Passes MIL-N-25027 reuseability test.

PRODUCT NAME OR CODE / PROPERTIES	TIODIZE Tiolube 460	TIODIZE Tiolube 1175	TIODIZE Tiolube 21
SPECIFICATION	MIL-L-8937*	-	MIL-L-23398*
COMPOSITION: Lubricant	MoS_2, No Graphite	MoS_2, Graphite	MoS_2, No Graphite
Binder/Carrier	Thermosetting Resin	Patented Inorganic Binder*	Thermoplastic Resin
APPLICATION: Brush	V.G.	V.G.	V.G.
Dip or Tumble	E	V.G.	V.G.
Spray	Best	Best	Best
CURE CYCLE: Air Dry Heat Temp/Time	30 Min + 177°C (375°F)/ 1.0 Hr + 149°C (300°F)/ 2.0 Hr + 121°C (250°F)/ 2.5 Hr	149°C (300°F)/1 Hr** 204°C (400°F)/1.0 Hr***	12-24 Hr 15 min/150°F
COMPATIBILITY: LOX	-	X	-
Oxygen (gas)	-	X	-
Rocket Fuel	L	X	
Jet Fuel	V.G.	X	
Hydrocarbon	V.G.	X	
Solvents	V.G.	X	
RADIATION PROPERTIES	-	G	-
OUTGASSING PROPERTIES	V.G.	V.G.	-
USABLE TEMP. Air: (high)	343°C (650°F)	649°C (1200°F)	500°F
(low)	-240°C (-400°F)	-251°C (-420°F)	-65°F
Vacuum: (high)	-	-	-
(low)	-	-	-
LOAD CAPACITY: Force	11,120 N (2,500 lb)	E	11,120 N (2,500 lb)
Test Method	Falex	LFW-1	Falex
WEAR-LIFE: Load	4,448 N (1,000 lb)	630 lb	4,448 N (1,000 lb)
Test Method	Falex	LFW-1	Falex
Time	450-800 Min.	E	4 hr minimum
Test Cond.	Ambient	Ambient	Ambient
FRICTION COEF.; STATIC, Air	L	L	L
Vacuum	V.L.	V.L.	-
DYNAMIC, Air	V.L.	V.L.	V.L.
Vacuum	V.L.	V.L.	-
ELECT. CONDUCTIVITY	-	-	-
CORROSION RESISTANCE	V.G.	-	V.G.
VACUUM WT. LOSS, N/m^2	-	-	-
mg/cm^2	None	<0.10%	-
Vacuum	133.3 pPa (10^{-12} mm Hg)	133.3 nPa (10^{-8} mm Hg)	-
Time	-	-	-
USES ON: Rubber and Plastics	-	-	V.G.
Wood, Leather, Fibers	-	-	V.G.
Glass and Ceramics	V.G.	X	V.G.
Metals	E	E	E
TYPICAL USES: Gen. Purp. Lub.	E	E	E
Fretting, Galling, Seizing	E	E	E
Cams, Gears, Slide Surf.	E	E	E
Rolling Surf.	E	E	E
Release Agent or Metal Work	E	E	E
NOTES: E - Excellent; V.G. - Very Good; G - Good; M - Medium; P - Poor; L - Limited or Low; - - No Data or Not Applicable; X - Satisfactory	*Also MIL-L-46010 properties and uses similar to 450.	*Contains no glass compounds. **Cure for aluminum or magnesium alloys ***Cure for steel and titanium.	*Also meets MIL-L-46147A. Designated as Tiolube 70 in aerosol cans.

A-V. LABORATORY EVALUATIONS, SOLID LUBRICATED GEARS, COMPOSITE MATERIALS

The data presented in this section were collected from tests conducted on 21 solid lubricant films. All tests were conducted at Midwest Research Institute. All materials were applied in accordance with the manufacturer's direction, except that pre-treatment of all metal substrates was by dry honing with 220 mesh Al_2O_3. There has been no attempt to rate the lubricants. Data presented provides a basis for computing solid lubricant films.

Falex load carrying and wear-life test data are presented in Tables 1 and 2. Lightly loaded three-pellet wear-life test data are presented in Table 3. Electrical conductivity and vacuum weight loss data are included as Table 4. Table 5 presents data on the static and dynamic friction values for the films at -73°C (-100°F), 27°C (80°F), and 204°C (400°F). All the films were also evaluated on journal bearing test equipment. Data for the journal bearing tests are presented in Table 6.

Tables 7, 8, 9, 10, and 11 and Figures 1, 2, and 3 contain test data obtained on solid film lubricated gears. Data presented in Tables 7, 8, and 9 and Figures 1, 2, and 3 are from laboratory tests whereas data shown in Tables 10 and 11 are from actual hardware tests conducted at the NASA Marshall Space Flight Center.

A large number of plastics, reinforced plastics and metal composites are available and used frequently in space applications. Many of the aforementioned materials are used as bearing or bearing components (separators, etc.). Tables 12, 13, and 14 contain a minimal amount of manufacturer supplied data on some of the most frequently used plastics, reinforced plastics and composite materials. More information can be obtained on the materials by contacting the manufacturers.

Laboratory test equipment used in evaluating the solid lubricants are described in Appendix A.

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TABLE 1

FALEX TESTS LOAD-CARRYING ABILITY

Test Method: Test Method Standard No. 791a, Method 3812
Test Condition: Ambient Temperature, AISI 4130 V-Block and Pin, R_C 40-45
Test Load: Load Increased in 1,112 N (250 lb) Increments at 1.0 Min Intervals Until Failure*

Solid Film	Average** Maximum Load - kN (lb)	Average** Maximum Torque - N · m, (in-lb)	Average** Time to Failure (min)
Drilube No. 1	20.0 (4,500)	1.16 (10.3)	23
Drilube 805	6.7 (1,500)	3.39 (30.0)	8
Electrofilm 2306	10.0 (2,250)	1.16 (10.3)	11
Electrofilm 5396	18.9 (4,250)	2.77 (24.5)	21
Lubribond "A"	10.0 (2,250)	2.26 (20.0)	12
Everlube 620	18.9 (5,250)	2.26 (20.0)	20
Everlube 811	18.9 (4,250)	2.88 (25.5)	18
Fel-Pro C-200	20.0 (5,400)	1.85 (16.4)	23
Fel-Pro C-300	20.0 (4,500)	2.15 (19.0)	22
MLR-2 (NPI 425) (VAC KOTE 18.07)	20.0 (4,500)	1.05 (9.3)	92
MLF-5	16.7 (3,750)	3.05 (27.0)	18
MLF-9	20.0 (4,500)	2.63 (23.3)	23
Molykote X-15	12.2 (2,750)	2.63 (23.7)	13
Molykote X-106	20.0 (1,500)	1.42 (12.6)	25
Molykote 321	11.1 (2,500)	2.00 (17.7)	12
NPI-14	17.8 (4,000)	2.91 (25.8)	19
Vitrolube	20.0 (4,500)	3.39 (30.0)	372
Poxylube No. 500	20.0 (4,500)	1.86 (16.5)	22
RIA No. 9	11.1 (2,500)	2.75 (24.3)	13
Surfkote M-1284	16.7 (3,750)	2.11 (18.7)	18
Surfkote A-1625	8.9 (2,000)	2.63 (23.3)	11

Notes: * Failure is indicated by inability of film to maintain load for 1.0 min, breaking of shear pin or sharp rise in torque of more than 0.791 N · m, (7.0 in-lb).

** Average of 3 test runs.

TABLE 2

FALEX TESTS-WEAR-LIFE

Test Method: Federal Test Method Standard No. 791a, Method 3807
Test Condition: Ambient Temperature, AISI 4130 V-Block and Pin R_c 40-45
Test Load: Load Increased in 1,112 N (250 lb) Increments at 1.0 Min Up to 4,448 N (1,000 lb) Load Maintained Until Failure*

Solid Film	Average** Torque - N · m (in-lb)	Average** Wear-Life (min)
Drilube No. 1	0.599 (5.3)	335
Drilube 805	1.74 (15.4)	12
Electrofilm 2306	1.57 (13.9)	10
Electrofilm 5396	0.926 (8.2)	169
Lubribond "A"	0.542 (4.8)	66
Everlube 620	0.881 (7.8)	93
Everlube 811	0.825 (7.3)	67
Fel-Pro C-200	0.395 (3.5)	564
Fel-Pro C-300	0.610 (5.4)	424
MLR-2 (NPI 425) (VAC KOTE 18.07)	0.316 (2.8)	502
MLF-5	0.972 (8.6)	86
MLF-9	0.542 (4.8)	57
Molykote X-15	1.15 (10.2)	27
Molykote X-106	0.802 (7.1)	242
Molykote 321	0.452 (4.0)	115
NPI-14	0.904 (8.0)	71
Vitrolube	0.599 (5.3)	727
Poxylube No. 500	0.723 (6.4)	247
RIA No. 9	0.599 (5.3)	305
Surfkote M-1284	0.566 (5.0)	246
Surfkote A-1625	0.757 (6.7)	23

Notes: * Failure is indicated by a torque rise of 0.566 N m (5.0 in-lb) above the steady state value, or breakage of shear pin.

** Average of 6 test runs.

TABLE 3

PELLET WEAR-LIFE TESTS

Test Method: Pellet Wear-Plate Equipment, Pellet, 440-C Stainless, R_c 15-20; Wear-Plate, 440-C Stainless, R_c 55-59

Test Condition: Load, 93,079 Pa (13.5 psi); Speed, 3.88 m/sec (765 fpm); Ambient Temperature; Nitrogen Atmosphere

Wear-Life: High-Friction Shut-off Switch Set for Maximum Friction Coefficient - 0.30.

Solid Film	Mean Average Wear-Life (hr)	Log Mean Average Wear-Life (hr)
Drilube No. 1	5.5	3.24
Drilube 805	4.2	1.92
Electrofilm 2306	26.1	20.64
Electrofilm 5396	2.7	1.8
Lubribond "A"	3.4	2.82
Everlube 620	4.7	4.32
Everlube 811	9.5	8.54
Fel-Pro C-200	1.7	1.26
Fel-Pro C-300	3.1	2.39
MLR-2 (NPI 425) (VAC KOTE 18.07)	83.8	66.4
MLF-5	31.2	28.3
MLF-9	34.2	32.34
Molykote X-15	11.3	7.40
Molykote X-106	5.1	3.65
Molykote 321	6.9	4.70
NPI-14	7.1	3.64
Vitrolube	8.0	3.8
Poxylube No. 500	6.7	4.64
RIA No. 9	1.8	1.77
Surfkote M-1284	6.3	4.68
Surfkote A-1625	2.5	2.91

Notes: *Average of 20 test runs.

TABLE 4

ELECTRICAL CONDUCTIVITY AND VACUUM WEIGHT LOSS

Solid Film	Electrical Resistance Ohms 0.0254 Meter Gap (1.0 in.)	Vacuum Weight Loss** 0.1 Kg/m^2 (mg/cm^2)
Drilube No. 1	500,000	0.186
Drilube 805	200,000	0.062
Electrofilm 2306	10,000	0.171
Electrofilm 5396	25,000	0.000
Lubribond "A"	3,000,000	0.155
Everlube 620	44,000	0.1395
Everlube 811	7,000	0.062
Fel-Pro C-200	12,200	0.031
Fel-Pro C-300	1,835	0.0155
MLR-1 (NPI 425) (VAC KOTE 18.07)	10,000,000	0.0775
MLF-5	2,500	0.0465
MLF-9	6,000	0.340
Molykote X-15	875	0.1085
Molykote X-106	640	0.124
Molykote 321	560	0.186
NPI-14	16,300	0.233
Vitrolube	*	*
Poxylube No. 500	745	0.0775
RIA No. 9	10,000,000	0.155
Surfkote M-1284	400,000	0.233
Surfkote A-1625	85,000	0.0775

Notes: * No samples obtained.
** Vacuum environment, 0.1333 x MPa (10^{-6} torr) at room temperature for 528 hr.

TABLE 5

VACUUM FRICTION AND WEAR LIFE

Test Method: Pellet-Wear Plate Equipment; Pellet, 440-C Stainless R_c 15-20; Wear-Plate, 440-C Stainless R_c 55-59

Test Condition: Load, 15.170 Pa (2.2 psi); Speed, 3.88 m/sec (765 fpm)

Environment: (1) Vacuum, 1.33332 mPa (10^{-5} torr), Nitrogen
(2) Ambient, Air
(3) 204°C (+400°F), Nitrogen

Solid Film		Friction Coefficient Static (average)*	Friction Coefficient Dynamic (average)*	Wear-Life Minutes (average)*
Drilube No. 1	-73°C (-100°F) (1)	0.18	0.15	435
	Ambient (2)	0.25	0.23	48
	204°C (+400°F) (3)	0.30	0.20	2,065
Drilube 805	-73°C (-100°F) (1)	0.32	0.28	60
	Ambient (2)	0.20	0.19	78
	204°C (+400°F) (3)	0.20	0.07	618
Electrofilm 2306	-73°C (-100°F) (1)	0.35	0.20	45
	Ambient (2)	0.39	0.14	83
	204°C (+400°F) (3)	0.12	0.07	65
Electrofilm 5396	-73°C (-100°F) (1)	0.29	0.18	54
	Ambient (2)	0.33	0.23	58
	204°C (+400°F) (3)	0.14	0.17	70
Lubribond "A"	-73°C (-100°F) (1)	0.32	0.15	33
	Ambient (2)	0.33	0.18	60
	204°C (+400°F) (3)	0.33	0.10	113
Everlube 620	-73°C (-100°F) (1)	0.30	0.19	16
	Ambient (2)	0.30	0.20	123
	204°C (+400°F) (3)	0.13	0.15	130
Everlube 811	-73°C (+100°F) (1)	0.18	0.28	1
	Ambient (2)	0.27	0.15	60
	204°C (+400°F) (3)	0.25	0.12	58
Fel-Pro C-200	-73°C (-100°F) (1)	0.25	0.23	95
	Ambient (2)	0.29	0.19	69
	204°C (+400°F) (3)	0.24	0.15	72
Fel-Pro C-300	-73°C (-100°F) (1)	0.24	0.18	217
	Ambient (2)	0.59	0.20	80
	204°C (+400°F) (3)	0.27	0.22	25
MLR-2 (NPI 425) (VAC KOTE 18.07)	-73°C (-100°F) (1)	0.35	0.30	90
	Ambient (2)	0.23	0.18	75
	204°C (+400°F)	0.23	0.05	5,178

TABLE 5. (Concluded)

Solid Film		Friction Coefficient Static (average)*	Friction Coefficient Dynamic (average)*	Wear-Life Minutes (average)*
MLF-5	-73°C (-100°F) (1)	0.25	0.28	137
	Ambient (2)	0.29	0.15	69
	204°C (+400°F)	0.14	0.10	480
MLF-9	-73°C (-100°F) (1)	0.23	0.18	744
	Ambient (2)	0.30	0.20	768
	204°C (+400°F) (3)	0.21	0.15	1,056
Molykote X-15	-73°C (-100°F) (1)	0.30	0.21	109
	Ambient (2)	0.30	0.12	91
	204°C (+400°F) (3)	0.17	0.09	729
Molykote X-106	-73°C (-100°F) (1)	0.25	0.23	50
	Ambient (2)	0.29	0.18	59
	204°C (+400°F) (3)	0.23	0.16	57
Molykote 321	-73°C (-100°F) (1)	0.24	0.20	3
	Ambient (2)	0.33	0.18	80
	204°C (+400°F) (3)	0.22	0.13	60
NPI-14	-74°C (-100°F) (1)	0.28	0.30	44
	Ambient (2)	0.27	0.23	92
	204°C (+400°F) (3)	0.23	0.09	75
Vitrolube	-73°C (-100°F) (1)	0.30	0.28	38
	Ambient (2)	0.20	0.20	60
	204°C (+400°F) (3)	0.09	0.15	42
Polylube No. 500	-73°C (-100°F) (1)	0.33	0.18	36
	Ambient (2)	0.30	0.22	64
	204°C (+400°F) (3)	0.20	0.05	51
RIA No. 9	-73°C (-100°F) (1)	0.35	Would not Start	No time
	Ambient (2)	0.35	0.13	78
	204°C (+400°F) (3)	0.15	0.08	48
Surfkote M-1284	-73°C (-100°F) (1)	0.25	0.25	90
	Ambient (2)	0.20	0.14	60
	204°C (+400°F) (3)	0.15	0.18	120
Surfkote A-1625	-73°C (-100°F) (1)	0.29	0.23	26
	Ambient (2)	0.35	0.18	75
	204°C (+400°F) (3)	0.30	0.10	65

Notes: * Average of 3 tests.

TABLE 6

JOURNAL BEARING WEAR-LIFE TESTS*

(Average of Three Tests at Each Load)

Solid Film	Film Thickness (in.) a/		Bearing Wear-Life: Condition A, Load = 21 MPa (3,000 psi), Speed = 0.084 x m/sec (16.5 fpm)		Bearing Wear-Life: Condition B, Load = 68.9 MPa (10,000 psi), Speed = 0.017 x m/sec (3.3 fpm)	
	Pin	Bushing	Minutes	Cycles	Minutes	Cycles
Drilube No. 1	0.0005	0.0003	1,669	166,900	3,030	60,600
Drilube 805	0.0011	0.0007	856	85,600	3,453	69,060
Electrofilm 2306	0.0006	0.0005	399	39,900	1,600	32,000
Electrofilm 5396	0.0003	0.0004	1,476	147,600	1,873	37,460
Lubribond "A"	0.0004	0.0004	1,770	177,000	3,235	65,700
Everlube 620	0.0003	0.0002	965	96,500	3,405	68,100
Everlube 811	0.0003	0.0005	2,054	205,400	4,665	93,293
Fel-Pro C-200	0.0006	0.0002	236	23,600	1.236	24,720
Fel-Pro C-300	0.0008	0.0002	900	90,000	4,620	92,400
MLR-2 (NPI 425) (VAC KOTE 18.07)	0.0002	0.0003	487	48,700	1,535	28,700
MLF-5	0.0004	0.0001	1,148	114,800	3,166	63,333
MLF-9	0.0005	0.0004	586	52,000	1,835	36,700
Molykote X-15	0.0014	0.0006	887	88,700	3,435	68,700
Molykote X-106	0.0010	0.0004	4,842	484,200	8,680	173,600
Molykote 321	0.0006	0.0006	1,215	121,500	4,672	94.446
NPI-14	0.0005	0.0004	1,774	177,400	4,762	95,240
Vitrolube	0.0008	**	773	77,300	2,037	40,740
Poxylube No. 500	0.0012	0.0004	960	96,000	2,174	43,480
RIA No. 9	0.0010	0.0005	525	52,500	4,506	90,140
Surfkote M-1284	0.0013	0.0008	2,916	291,600	7,275	145,500
Surfkote A-1625	0.0002	0.0004	425	42,500	3,990	79,800

Notes: * All tests conducted in ambient environment conditions
** Thickness not determined.

a/ Film thickness can be converted to SI units by multiplying thickness times 0.0254 m.

TABLE 7

DRY LUBRICANT WEAR-LIFE - INSTRUMENT-TYPE SPUR GEARS

Conditions:
- Load: 0.14 N · m (20 in-oz)
- Speed: 1800 rpm
- Temperature: ambient (no heat added)
- Atmosphere: dry nitrogen

Gears:
- 48 pitch, 55 and 56 teeth
- 20 degrees pressure angle, 3.17 mm (1/8 in.) face
- 303 stainless steel
- AGMA class 12

Lubricant	Binder	Lubricant-to-Binder Ratio	Log Mean Average Life (hr)
20 w mineral oil	--	--	679.4
MLF-5	soldium silicate		36.1
MLF-9	Al. phosphate		42.7
MLR-1	PI-1101		112.7
MLR-1-A*	PI-1101	1.0/0.27	118.0
MLR-1-1*	PI-1101	1.0/0.18	64.0
MLR-1-2*	PI-1101	1.0/0.36	71.0
MLR-1-L*	PI-1101	1.0/0.27	70.0
MLR-1-A[a/]	PI-1101	1.0/0.27	4.4
MLR-1-A[b/]	PI-1101	1.0/0.27	67.3
MLR-2 (NPI 425) (VAC KOTE 18.07)	PI-4701		36.1
MLR-2-5	PI-4701		39.4
MLR-2[a/]	PI-4701		23.0
MLR-15-7*	skybond 704	1.0/0.41	72.0
MLR-15-8*	skybond 704	1.0/0.26	109.0
MLR-15-9*	skybond 704	1.0/0.63	72.0
MLR-20			17.6
MLR-21			31.4
MLR-30			17.95
FEL-PRO	C-200 (commercial, proprietary)		22.8
FEL-PRO	C-200/MLR-1-A		15.0
VAC-KOTE			1.6
Gold plating (over electrolytic nickel)			0.2
Sputtered MoS_2			6.1

* MoS_2 particle size for standard MLR- and MLF- films is 45 μm (44 μm) or less (microsize). Particle size for all tests marked with * is (44 to 77 μm), Type Z (MoS_2).

a/ These tests used 1.6 mm (1/16 in.) face gears.

b/ These tests used 1.6 mm (1/16 in.) face gears and were run at 0.049 x m N · m (7 in.-oz) loading. The stress level is equivalent to a 3.17 mm (1/8 in.) face gear of 0.14 x N · m, (20 in.-oz) loading.

TABLE 8

DRY LUBRICANT WEAR-LIFE - LOW SPEED GEAR TESTS

Load: 5.29 N · m (3.9 ft-lb)
Speed: 150 rpm
Temperature: Ambient (no heat added)
Atmosphere: Dry nitrogen

Gear Data: 16 pitch, 64 tooth, 20 degree pressure angle, steel, 6.35 mm (1/4 in) face, and 12.7 mm (1/2 in.) face

Lubricant	Wear-Life (hr)	Log Mean Avearge Life (hr)
MLR-1-A[a/]	24.74	
MLR-1-A[a/]	29.50	27.6
MLR-1-A	66.42	
MLR-1-A	34.62	48.0
MLR-20	37.68	
MLR-20	24.17	30.2
MLR-21	26.08	
MLR-21	40.07	32.33
MLR-30	34.45	
MLR-30	63.48	46.76

a/ These gears were case iron with 14-1/2 degree pressure angle. They were available from stock and used for check-out purposes only while 20 degree pressure angle gears were on order.

TABLE 9

WEAR-LIFE OF SOLID LUBRICANT COATED WORM GEARS

Temperature: Room ambient
Speed: 1,750 rpm (worm)
Worm: Case hardened alloy steel
25 degrees pressure angle
17 degrees, 28 sec lead angle
4 threads
1.6 cm (0.643 in.) pitch diameter

Atmosphere: Air
Worm Gear: Nickel bronze alloy
25 degrees pressure angle
27 degrees, 28 sec lead angle
40 tooth 5.16 cm (2.032 in.) pitch diameter
Input: 0.280 horsepower

Test	Lubricant	Average Efficiency (%)	Wear-Life (10^6 Revolutions)	Average Wear-Life (10^6 Revolutions)
-	20 W Oil	63-66	-	
-	140 W Oil	59-62	-	
-	600 W Oil	63-66	-	-
1-A a/	MLF-5	50-55	0.24	
1-B a/	MLF-5	56-66	0.35	0.30
2-A	MLF-9	69-72	1.36	
2-B	MLF-9	69-72	0.92	
3-A b/	MLR-1	-	-	1.14
3-B	MLR-1	29-72	1.81	
4-A-0 c/	MLR-1	60-65	1.34	
4-B-0	MLR-1	60-65	0.62	
5-A-0	MLR-1	69-71	1.98	
5-B-0 b/	MLR-1	-	-	
6-A-0	MLR-2	54-57	3.56	1.44
6-B-0	MLR-2 (NPI 425)	51-54	1.67	
7-A-0	MLR-2 (VAC KOTE	75-85	2.94	
7-B-0 b/	MLR-2 18.07)	-	--	2.72

a/ A-ftont side of teeth/ B-back side of teeth.
b/ Test stopped early, uneven tooth contact.
c/ o indicates oil run-in used.

TABLE 10

ATM ROLL RING SIMULATOR (RACK & PINION)*

Pinion Lubricant (A-286 steel)	Rack Lubricant (410 SS)	Torque N m (ft-lb)	Total Operating Distance m (ft)
MLR-2 (NPI 425) (VAC KOTE 18.07)	None	1.9 (1.4)	7,462 (24,480)
Glass bonded MoS_2	None	1.9 (1.4)	18,824 (61,760)
Glass bonded MoS_2	None	5.29 (3.9)	18,824 (61,760)
MLR-1	None	1.9 (1.4)	19,586 (64,259)
MLR-1	None	5.29 (3.9)	357 (1,170)
MLR-1	None	5.29 (3.9)	686 (2,250)
MLR-1	None	5.29 (3.9)	4,402 (13,260)
MLR-1	Air drying bonded MoS_2 lube	1.9 (1.4)	18,824 (61,760)
MLR-1	Air drying bonded MoS_2 lube	5.29 (3.9)	20.820 (68,340)
MLR-1	Air drying bonded MoS_2 lube	9.49 (7.0)	1,899 (6,230)

* Tests made at 13.3 μPa (10^{-7} torr).

TABLE 11

ATM CMG ACTUATOR GEAR TRAIN EVALUATION*

Gear Material	Gear Hardness	Lubricant	Total Operating Time	Total Pinion Revolutions
420 Series steel	RC 32-38	MLR-2**	Intermittent 29 days	600,000
420 Series steel	RC 32-38	MLR-2**	7 Days	148,000
420 Series steel	RC 32-38	MLR-2**	28 Days	590,000
420 Series	RC 32-38	MLR-2**	56 Days and 5 hr	1,180,000
Nitralloy	Case RC 58	MLR-1	12 Days and 10 hr	260,000
Nitralloy	Case RC 58	MLR-1	6 Days and 5 hr	130,000

* Tests made at 13.3 μPa (10^{-7} torr).
** Available as NPI 425 and VAC KOTE 18.07.

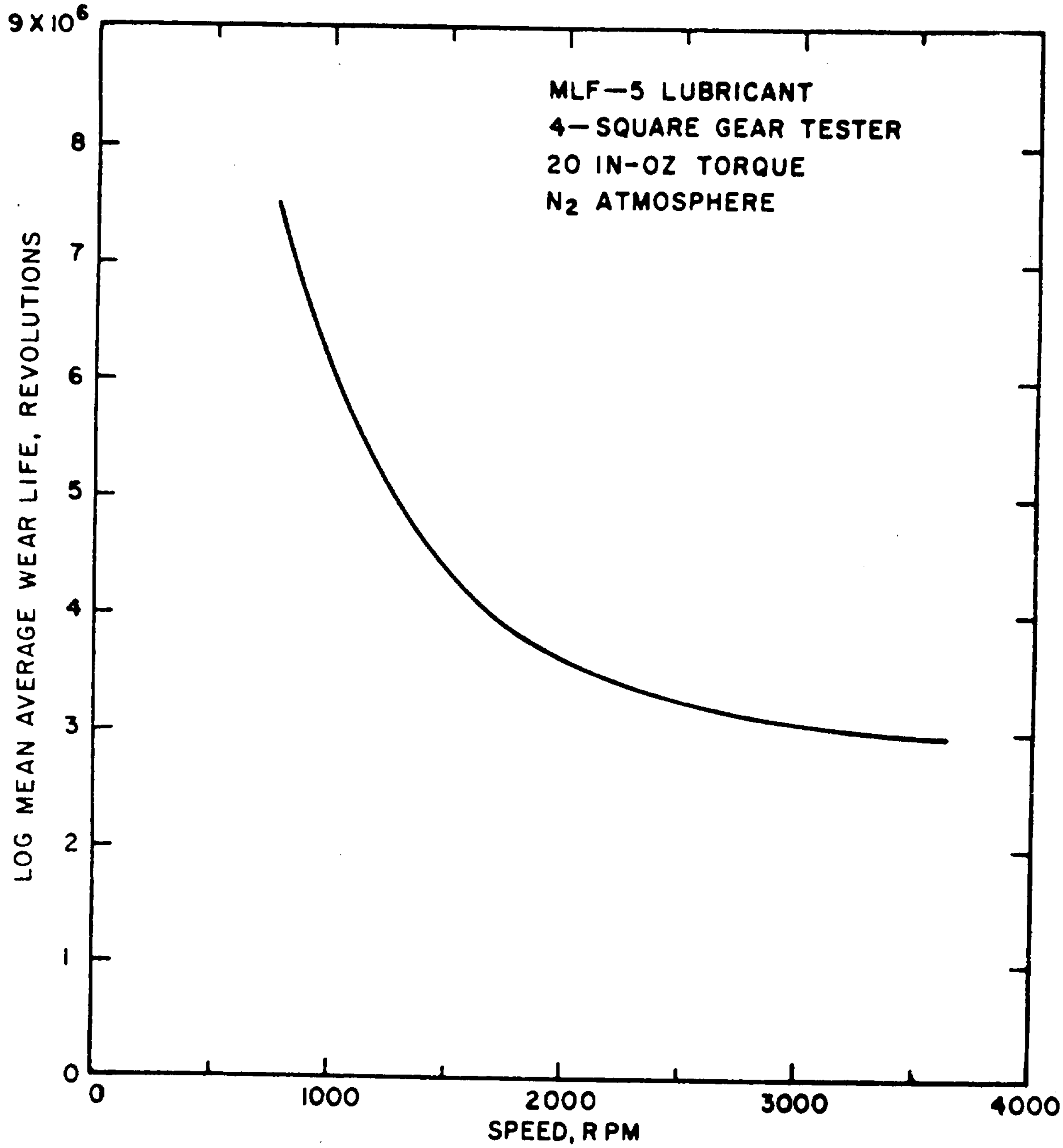

Figure 1. Lubricant Film Wear-Life Versus Speed

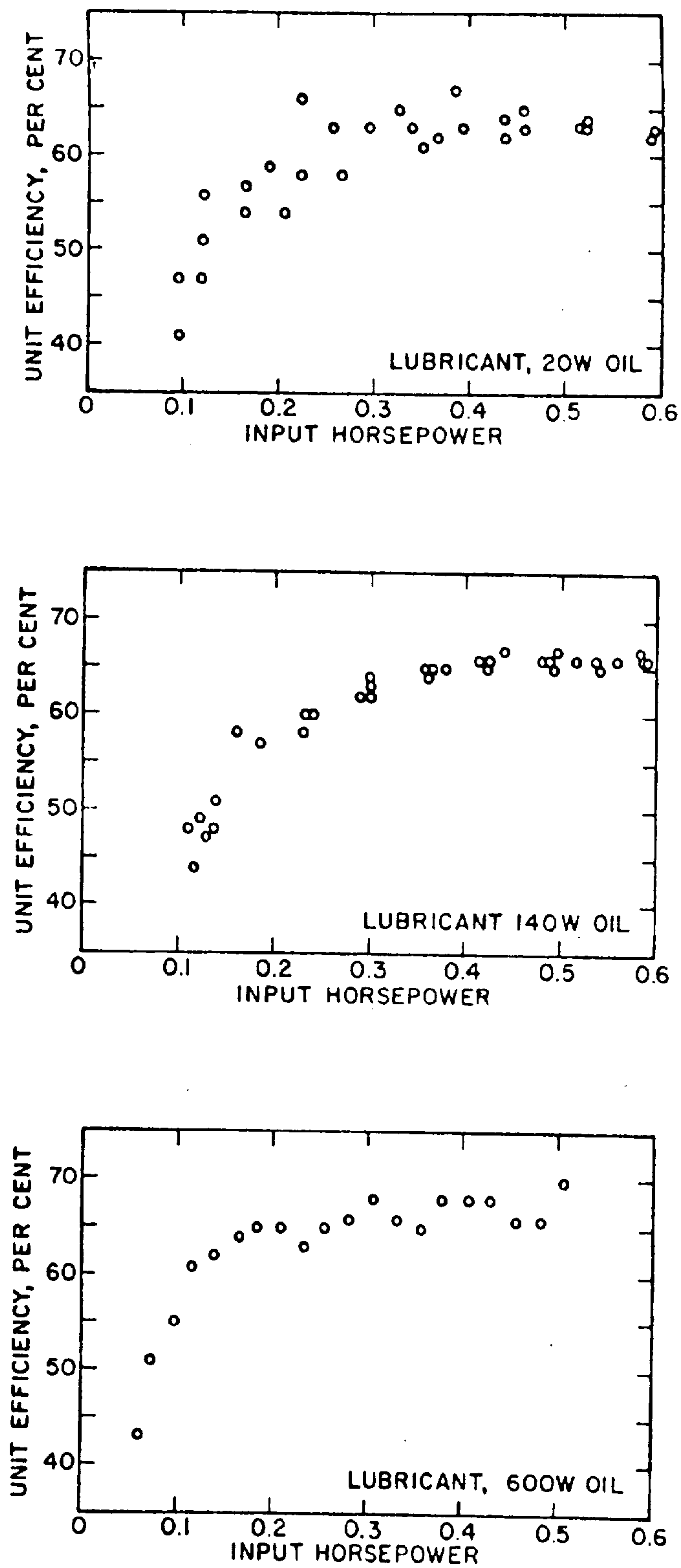

Figure 2. Oil Lubrication Efficiency Versus Input Horsepower

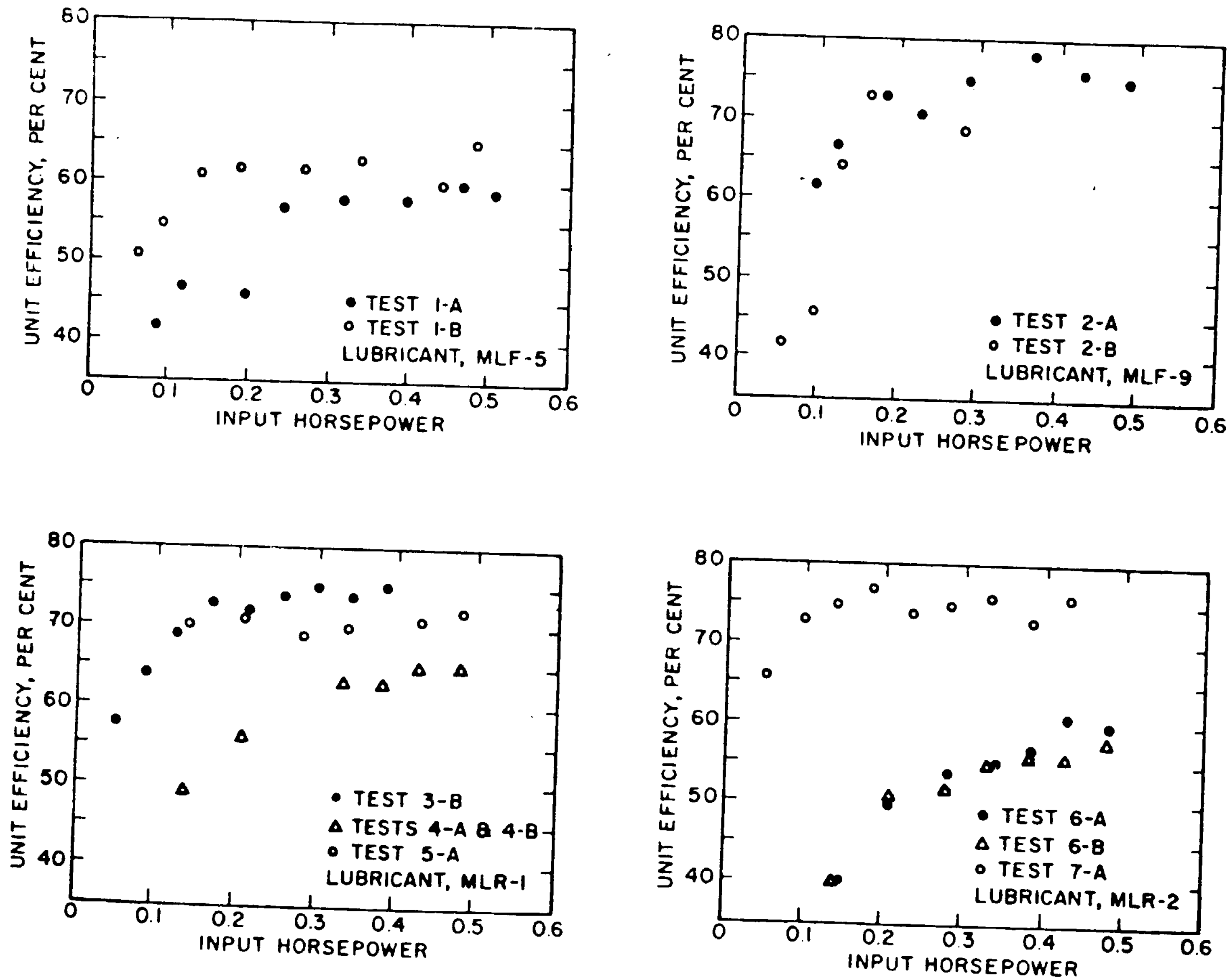

Figure 3. Solid Film Lubrication Efficiency Versus Input Horsepower

TABLE 12

SELF-LUBRICATING MATERIALS — POLYIMIDES

Designation	Filler Material	Friction Coefficient	Tensile Strength MPa (PSI) at R.T.		Uses
SP-1 (Vespel Parts and Shapes)	None	0.29 in Air	86.2	(12,500)	Used for high temp. mechanical and electrical parts where maximum physical strength, elongation, toughness is desired. SP-1 also provides the best thermal and electrical insulation properties of all the SP resins. Typical applications include spacers, soldering fixtures, valve seats, balls, gaskets, poppets and static seals. Vespel parts can operate continuously from cryogenic temps to 500°F (288°C) and can withstand excursions to 900°F (480°C).
SP-21 (Vespel Parts and Shapes)	15% by W. Graphite	0.12-0.24 in Air	65.5	(9,500)	Used in low wear and friction applications such as bearings, thrust washers, bushings, seal rings, slide blocks and other wear surfaces. SP-21 has the best physical strength, elongation and toughness of our graphite filled resins.
SP-22 (Vespel Parts and Shapes)	40% by Wt. Graphite	0.09-0.30 in Air	51.7	(7,500)	SP-22 provides the best oxidative stability and the lowest coefficient of thermal expansion. Applications are similar to those listed for SP-21.
SP-211 (Vespel Parts and Shapes)	15% by Wt. Graphite 15% by Wt. P.T.F.E.	0.08-0.12 in Air	44.8	(6,500)	SP-211 provides the lowest coefficient of friction over a wide range of operating conditions up to 300°F (140°C). Typical applications include sliding or linear bearings as well as many of the wear and friction applications listed above.
SP-3 (Vespel Parts and Shapes)	15% by Wt. MoS_2	0.17-0.25 in Air 0.03 in Vacuum	58.5	(8,200)	SP-3 provides maximum wear and friction resistance in vacuum and other moisture free environments where graphite can become abrasive. Typical applications include seals, bearings, bushings and other wear surfaces in outerspace, ultra-high vacuum and/or dry gas application.
FEURLON-CT	Graphite-P.T.F.E.	-	42.8 min.	(6,200)	For areas where temperatures are less than 140°C (300°F)
FUERLON-AW	Silver-Ws_2	-	38.6 min.	(5,600)	Vacuum and inert environments
FEURLON-C	Graphite	-	44 x min.	(6,400)	Air operation over the temp. range of 159-399°C (300-750°F)
MELDIN-PI	None	0.5	79.9	(11,600)	Seals, thrust washers, bearing retainers, piston rings
MILDIN-PI-30X	Lubricative Additive	0.2-0.25	22.9	(3,320)	Same as Above
MELDIN-PI-15Y	Lubricative Additive	0.3-0.35	49.6	(7,200)	Same as Above

* This information is for reference purposes only. Since service conditions may differ from laboratory test conditions, users of Vespel parts and shapes should independently evaluate the suitability of Vespel parts for each application using their own test procedures.

NOTE: All information obtained from manufacturer's literature. (Vespek) SP- Trade name of E. I. DuPont de Nemours & Company. FEURLON - Trade name of Bemol Corporation. MELDIN - Trade name of Dixon Corporation.

TABLE 13

SELF-LUBRICATING MATERIALS - FLUOROCARBONS

Designation	Filler Material	Friction Coefficient	Tensile Strength MPa (PSI) at R. T.	Uses[c]
TEFLON	None	0.05-0.20	10.3 (1500) Min	Lightly Loaded Bearings
DUROID 5813	Micro-Fiber Glass MoS_2	0.018	48.3 (7000) Min.	Bearings Retainers, Journal Bearings
DUROID 4300	Bronze MoS_2	-	9.8 (1430)	Same as Above - Higher Load Capacity
RULON A[a]	-	0.12-0.19	9.65 (1400) Min.	Bushings-Retainers Seals Etc.
SALOX-M2[b]	Metal Powder		12.1 (1735) Min.	
BARTEMP	Same as DUROID 5813		-	Crowned Bearing Retainers

TEFLON - Trade Name of DuPont
DUROID - Trade Name of Rogers Corporation
RULON - Trade Nameo f Dixon Corporation
SALOX - Trade Name of Allegheny Plastics
BARTEMP- Trade Name of The Barden Corporation

a/ Several other Rulon Materials are available.
b/ Several other Salox materials are available.
c/ All fluorocarbons have temperature limitations; generally (300°F to 500°F), See Manufacturing Recommendations.

TABLE 14

SELF-LUBRICATING MATERIALS MISCELLANEOUS COMPOSITES

Designation	Filler Material	Friction Coefficient	Tensile Strength MPa (PSI) at R. T.	Uses
DELRIN 100 (Acetal Resin)	None	0.1-0.3	-	Bearings - Lightly loaded gears
DELRIN-AF (Acetal Resin)	Fluorocarbon Fibers	0.05-0.15	-	Bearing and Sliding Applications
ZYTEL (Nylon)	None	0.04-0.14	-	Lightly Load Bearing and Sliding Applications
POLYPHENYLENE SULFIDE (PPS) (Ryton)	Asbestors, Graphite, Teflon and Others	0.2-0.4	45.4 x (10,800)	Seals, Bearing, Sliding Surfaces in Reactive Environments, High Temperatures
WDC-140*	MoS_2, Sb_2O_3 and PPS Resin	0.092-0.15 79°C (175°F)	-	Temperatures to 204°C (400°F). Limited to 316°C (600°F). For bearings, sliding surfaces, seals, ball bearing retainers. Wear Factor (10^{-8} in/in) 1.93 to 45.0. Temperature; 132°C (270°F) to 260°C (500°F)
MOLALLOY			Compressive Strength MPa (PSI) at R. T.	
Pm 101	MoS_2 and Metal Powders	0.03	76 (11,000)	Ball Bearing Separators
Pm 103	MoS_2 and Metal Powders	-	750 (109,000)	High Load Bearings
Pm 104	MoS_2 and Metal Powders	-	607 (88,000)	High Load Bearings
Pm 105	MoS_2 and Metal Powders	-	190 (28,000)	Electrical Brushes
Pm 108		0.5	448 (65,000)	Clutch Facing

DELRIN - Trade Name of DuPont
ZYTEL - Trade Name of Dupont
RYTON - Trade Name of Phillips Petroleum Company
MOLALLOY - Trade Name of Pure Industries, Inc.

A-VI. APPENDICES

A - GLOSSARY FOR SOLID FILM LUBRICANTS
B - SOLID FILM LUBRICANT SPECIFICATIONS
C - TEST EQUIPMENT AND PROCEDURES

APPENDIX A

GLOSSARY FOR SOLID LUBRICANTS

Binder: Material used to hold the pigment of a solid lubricant system to the substrate.

Carrier: Liquid, solvent or gas in which the lubricant solid is suspended to facilitate handling or application, but does not form part of the solid film lubricant or affect the adhesion properties.

Cure: Process followed to convert a binder material from the application state to the final state. This process usually follows a schedule of set temperatures for specified times.

Degrease: Process followed to remove oil, dirt and grease from a substrate surface. This process could involve washing in solvent, washing in detergent and rinsing in solvent.

Free sintering: Heating a free standing green preform until matrix particles bond to each other but at a temperature less than the melting point of the matrix material.

Hard vacuum: Term used to denote a high vacuum 1.3332×10^{-4} N/m^2 (low pressure, $<10^{-6}$ torr).

Impact sensitivity: Tendency of some materials to react with liquid oxygen when subject to mechanical impact or vibration. This reaction is frequently explosive in nature.

"LOX" Compatible: Denotes solid film lubricants that have passed the "ABMA" test (97.6 joule) (72 ft-lb) impact in liquid oxygen with no reaction in accordance with MSFC-SPEC-106.

"LOX" resistant or "LOX" insensitive: Denotes solid film lubricants which do not react with and have some resistance to liquid oxygen, but have not passed or will not pass the ABMA "LOX" Impact Test.

Matrix material: The structural material that holds lubricant powder(s) in self-lubricating materials.

Pigment: Solid lubricant material (MoS_2, graphite, etc.) used in a solid lubricant system.

Pressure sintering: Heating a mixture under pressure until adjacent matrix particles bond to each other but at a temperature less than the melting temperature of the matrix material.

Pretreatment: Usually refers to the treatment of a substrate or the base material to improve solid film adhesion or the corrosion protection.

PTFE: Polytetrafluoroethylene.

Self-lubricating composite: A lubricative solid material which contains fibers or powders to improve the strength of the material.

Solid lubricant: A solid material that provides lubrication between two relatively moving surfaces.

Solid lubricant compact: A metal matrix lubricative solid formed by a pressure sintering process.

Solid lubricant concentrate: A slurry of binder and/or dispersant which contain a high percentage of suspended solid lubricant powder(s).

Solvent: Liquid used to thin solid lubricant solutions or to remove solid film lubricant from substrate.

Torr: Unit of pressure adopted by the American Vacuum Society. It is defined in terms of standard atmosphere (1,013,250 dynes/cm^2). Torr is 1/760 atmosphere, or 1,340 dynes/cm^2. One torr is approximately 1.0 mm mercury, and in SI units 133.322 N/m^2.

TFE: Tetrafluoroethylene.

APPENDIX B

SOLID FILM LUBRICANT SPECIFICATIONS

MIL-M-7866B(1); Molybdenum Disulfide, Technical, Lubrication Grade

This specification covers the requirements for procurement of one grade of powdered molybdenum disulfide, to be used for the lubrication of surfaces when boundary conditions exist. The powder shall have a purity (95.5% pure MoS_2, minimum) and a particle size (average, >5 μm and <10 μm) suitable for general lubricating use.

Uses: Intended for use as a dry lubricant or as a component with suitable specification oils or greases for special applications where other lubricants are not satisfactory. Reduces friction and wear under low and high sliding velocities; used as thread anti-seize for lightly loaded applications where fluid lubricant is objectionable; and is an effective lubricant over a wide range of temperatures.

Limitations: The unbonded lubricant does not give corrosion protection. The material must be bonded and cured to develop maximum lubrication potential and corrosion protection. Mixtures of this powder with oils or greases should not be done in field applications where performance data have not been established.

SS-G-659a: Graphite, Dry (Lubricating, NATO Code: S-732)

General characteristics: This specification covers a powdered lubricating graphite free from any indications of caking or lumping which may be made from natural or manufactured graphite, unless otherwise specified. The graphite-carbon content must not be less than 95%. No particle size shall be larger than 149 μm (100 mesh); 88% must be smaller than μm (200 mesh); and at least 60% must be smaller than 44 μm (325 mesh).

Uses: Intended for use as a dry lubricant or to be compounded with oils and greases. As a dry lubricant, it may be applied by burnishing, spray, or dipping. It may also be compounded with resinous binders, alone or with other materials to form solid lubricants and composite lubricants.

Limitations: The powdered lubricant does not provide corrosion protection. It may be used over a wide temperature range. The powder must be free from abrasives or other undesirable impurities, and must not contain more than 2.5% ash or volatile matter.

MIL-L-8937D: Lubricant, Solid Film, Heat-Cured

This specification established the requirements for a solid film lubricant intended to reduce wear, prevent galling and seizure of metals, and provide corrosion protection to metals.

Condensed specification requirements:

Material: Finely powdered lubricating solids dispersed in suitable binders are capable of being cured within 60 min at 149°C (300°F).

Film appearance and thickness: The bonded film lubricant shall appear smooth and free from cracks, scratches, pinholes, blisters, bubbles, runs, sags, foreign matter, grit, rough particles, separation of ingredients, or other imperfections.

Film adhesion: The bonded solid film lubricant shall not be lifted from the test panel by the pressure-sensitive masking tape method. A uniform deposit of powdery material may cling to the tape, but lifting of any flakes or particles which expose any bare metal shall indicate unsatisfactory adhesion.

Thermal stability: The bonded solid film lubricant shall not flake, crack nor soften, and shall have satisfactory adhesion when tested for 3 hr at -54°C (-65°F) and 260°C (+500°F).

Fluid resistance: The bonded solid film lubricant shall not soften, lift, blister, crack or peel, and shall have satisfactory adhesion when half immersed for 24 hr at room temperature in each of the following fluids: standard hydrocarbon test fluid, aviation gasoline, jet fuel, hydraulic fluids (petroleum and nonpetroleum base), aircraft lubricating oils (petroleum and synthetic base), silicone fluid, and trichloroethylene.

Endurance life: The bonded solid film lubricant when tested in the Falex Lubricant Tester shall have an average life of not less than 120 min at 4,448 N (1,000 lb) gage load. The minimum life of any single run shall not be less than 100 min.

Load carrying capacity: The bonded solid film lubricant when tested in the Falex Lubricant Tester shall have a minimum load carrying capacity of 11,120 N (2,500 lb) gage load.

Corrosion resistance: The bonded solid film lubricant on anodized aluminum panels shall show or cause no discoloration, pitting, formation of white deposits or other evidence of corrosion after 500 hr at 49°C (120°F) and 95% humidity. The bonded solid film lubricant on steel specimens shall show no pitting, visible corrosion or staining after four cycles of exposure in the sulfurous acid-salt spray test.

Uses: This solid film lubricant is intended for use on steel, titanium, aluminum, aluminum alloys and other metals. Useful where other lubricants are difficult to apply or where they may be contaminated by dirt and dust. Suitable for sliding motion surfaces, such as plain spherical bearings, flap tracks, hinges, and cams.

Limitations: This solid film lubricant should not be used with oil or grease unless experience indicates otherwise. Because of the 149°C (300°F) cure temperature, it should not be used on materials which are adversely affected by exposure to this temperature. It should not be used where there is potential contact with liquid oxygen. Storage or shelf-life is limited and should not be used beyond 6 months from date of manufacture.

MIL-L-23398C; Lubricant, Solid Film, Air Drying

This specification establishes the requirements for an air-drying solid film lubricant intended to reduce wear, prevent seizing and galling and provide corrosion protection to metals (NATO Code S-749).

Condensed specification requirements:

Material: Finely powdered lubricating solids in suitable binder, which are in a spraying consistency. The applied film shall cure at room temperature, 25°C (77°F) in not more than 6.0 hr. Additives if necessary to meet specification requirements. Specification covers bulk solution (Type I) and aerosol propelled (Type II) formulations.

Film condition: The bonded solid film lubricant shall appear uniform in color, smooth, free from cracks, scratches, blisters, foreign matter, grit, rough particles, bubbles, pinholes, runs, sags, or other surface imperfections, and shall show no evidence of separation of ingredient.

Film adhesion: The bonded solid film lubricant shall not be lifted from the test panel by the pressure-sensitive masking tape method. A uniform deposit of powdery material may cling to the tape, but lifting of any flakes or particles which expose any bare metal shall indicate unsatisfactory adhesion.

Thermal stability: The bonded solid film lubricant shall not flake, crack or soften, and shall have satisfactory adhesion when tested for 3 hr at -54°C (-65°F) and 260°C (+500°F).

Fluid resistance: The bonded solid film shall not flake, crack or peel, and shall have satisfactory adhesion after immersion for 24 hr at room temperature in each of the following fluids: standard hydrocarbon test fluid, aviation gasoline, jet fuel, hydraulic fluid (petroleum base), lubricating oils (petroleum and synthetic base) and anti-icing/deicing/defrosting fluid, hydraulic fluids (nonpetroleum base), silicone fluid (Dow-Corning - 550 or equivalent), tricholoroethylene, and lubricating oil internal combustion (heavy duty).

Endurance life: The bonded solid film lubricant when tested in the Falex lubricant tester shall have an endurance life of not less than 60 min at 4,448 N (1,000 lb) gage load. Using zinc phosphate specimens the average life shall not be less than 120 min and none less than 90 min.

Load capacity: The bonded solid film lubricant, tested in the Falex Lubricant Tester, shall have a minimum load capacity of 11,120 N (2,500 lb) gage.

Corrosion protection: The bonded solid film lubricant on anodized aluminum panels shall show or cause no discoloration, pitting, formation of white deposits, or other evidence of corrosion when subjected to heat and high humidity conditions for at least 500 hr.

Storage stability: This solid film solution shall remain in a homogeneous blend showing no evidence of gelation after storage in a closed container for 12 months at room temperature, 25°C (77°F). After storage, the bonded solid film lubricant must conform to the other requirements of this specification.

Uses: This air-drying solid film lubricant is intended for use on steel, titanium, aluminum and aluminum alloys. It is useful where conventional fluid lubricants are difficult to apply or may be contaminated with dirt and dust. Generally suitable for sliding motion surfaces, such as plain spherical bearings, tracks, hinges, cams, etc. Recommended for applications where solid film lubricants that require elevated temperature cures cannot be applied because of material or other reasons, but may be heat cured at temperatures up to 121°C (250°F).

Limitations: This solid film lubricant should not be used with oil and grease unless experience indicates otherwise. Application should be conducted in a well ventilated area where no flame or ignition sources are present. This material is not a substitute for MIL-L-8937 lubricants, as it has lower wear-life and load carrying ability. Not for use on roller bearings. Should not be stored at temperatures above 49°C (120°F).

MIL-L-46010 (2); Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting

This specification covers a resin-bonded, heat-cured, solid film lubricant intended to reduce wear, prevent galling and seizure, and provide corrosion protection to metals. This lubricant does not contain graphite or powdered metals.

Condensed specification requirements:

Materials: The lubricant shall consist of a dispersion of finely powdered lubricative pigment or pigments in a thermosetting resin with or without additives.

Film thickness: The lubricant shall be capable of being applied by brush, dip or spray methods and cured to a film thickness of 0.508×10^{-5} and 1.27×10^{-5} m (0.0002 and 0.0005 in.). All film measurements must be within these limits.

Wear-life: The cured lubricant film shall provide an average minimum Falex wear-life of 450 min at 4,448 N (1,000 lb) gage load. No single test shall have less than a 390-min wear-life. A minimum of four tests is required.

Load carrying capacity: The cured lubricant film shall provide an average minimum Falex load carrying capacity of 8,896 N (2,000 lb) gage. No single test shall have a load capacity of less than 7,784 N (1,750 lb) gage. A minimum of two tests is required.

Corrosion protection: The cured lubricant film when applied to 0.0762 x 0.1524 m (3 x 6 in.) steel sheet (SAE 1009) test panels shall show a maximum of three rust dots per panel after a salt spray exposure of 100 hr.

Film adhesion: The cured lubricant film shall not be lifted from the test panel by the pressure-sensitive masking tape method. A uniform deposit of powdery material may cling to the tape, but lifting of any flake or particles which expose any bare metal shall indicate unsatisfactory adhesion.

Fluid resistance: The cured lubricant film shall pass the film adhesion test after half immersion for 24 hr at 23°C (74°F) in each of the following fluids: standard hydrocarbon test fluid, aviation gasoline, jet fuel, hydraulic fluids (petroleum and nonpetroleum base), aircraft lubricating oils (petroleum and synthetic base), silicone fluid, trichloroethylene and anti-icing fluid.

High and low temperature stability: The cured lubricant film shall pass the film adhesion test after high temperature of 260°C (500°F) for 3 hr, and low temperature cycle of 24 hr placed on a cake of dry ice (carbon dioxide).

Storage stability: The lubricant dispersion stored in a closed container for 6 months at room temperature shall meet the wear-life and corrosion protection requirements of this specification.

Uses: This resin-bonded solid film is intended for use on aluminum, copper, copper alloys, steel, stainless steel, titanium, and chromium and nickel-bearing surfaces. Generally suitable for sliding motion applications, such as plain and spherical bearings, tracks, hinges, threads, and cam surfaces. Useful under the following conditions: where conventional lubricants are difficult to apply or retain; where other lubricants may be contaminated by dirt or dust; temperature ranges between -68°C (-90°F) to 204°C (400°F) in mechanisms operated at infrequent intervals; and in mechanisms to be lubricated for life.

Limitations: This film lubricant should not be used on materials adversely affected by the heat-cure cycles of 204°C (400°F) for 1.0 hr, or 149°C (300°F) for 2 hr. Application should be conducted in well ventilated areas where no flame or ignition source is present. This lubricant shall contain no graphite or powdered metals.

MIL-L-46147A; Lubricant, Solid Film, Air Cured (Corrosion Inhibiting)

This specification covers two types of an air-curing solid film lubricant identified by Military Symbol SFD. This lubricant provides both lubrication and corrosion protection and can be applied by brushing, dipping or spraying from gas-pressurized (aerosol) cans.

Condensed specification requirements:

Materials: Shall be of the following composition: (a) Fast-drying vehicle such that the applied film shall dry to the touch in 30 min and shall fully cure in 18 hr at 25°C (77°F). (b) Lubricative pigment or mixture of lubricative pigments. (c) Additives, if necessary.

Film adhesion: The lubricant, applied to anodized aluminum, cured to 0.0002 to 0.0005 film thickness and tested with tape (ASTM D2510) when lifted shall not expose any bare surface.

Endurance life: The lubricant, applied to phosphated steel, cured to 0.0002 to 0.0005 film thickness, shall have a Falex endurance life test of not less than 2 hr under a gage load of 1,000 lbf (4,448 N).

Load-carrying capacity: The lubricant, applied to phosphated steel, cured to 0.0002 to 0.0005 film thickness shall have a Falex load-carrying capacity of not less than 2,500 lbf (11,120 N) with no single test less than 2,000 lbf (8,900 N).

Corrosion protection (salt spray): The lubricant, applied to phosphated steel, cured to 0.0002 to 0.0005 film thickness shall have no more than three rust spots, none exceeding 1 mm in any direction after 100 hr exposure to 5% salt spray.

Thermal shock sensitivity: The lubricant, applied to anodized aluminum, cured to 0.0002 to 0.0005 film thickness, shall not flake, crack, or soften.

Removability: The lubricant, applied to anodized aluminum, cured to 0.0002 to 0.0005 film thickness shall withstand minimum of 500 strokes before bare metal exposed.

Uses: The lubricant is intended for use on aluminum, aluminum alloys, copper and copper alloys, steel, stainless steel, titanium, chromium, and nickel surfaces.

Limitations: Caution: Flammable. Use only in a well-ventilated area or in a hood where no flames or other ignition soruces are present. Harmful if inhaled.

MIL-L-81329C; Lubricant, Solid Film, Extreme Environment

This specification establishes the requirements for a solid film lubricant to be used in extreme environments, including temperatures from -184°C (-300°F) to 399°C (+750°F) liquid oxygen, and vacuum, to reduce wear and prevent galling and seizing of metal surfaces.

Condensed specification requirements:

Material: High quality lubricating solids in a suitable binder at spraying consistency. Organic materials are not suitable for this lubricant. The lubricant material shall be nonflammable when heated by a Bunsen Burner flame. The applied lubricant film shall be capable of being cured by the following heating schedule: 1/2 hr at 25°C (77°F), 2 hr at 82°C (180°F), and 2 hr at 240°C (300°F).

Appearance and film thickness: The solid film lubricant shall be free of surface imperfections and show no evidence of separation of material ingredients; the finished film thickness shall be between 2.54 and 3.56 x 10^{-5} m (0.0010 and 0.0014 in.).

Film adhesion: The bonded film lubricant shall not be lifted from the test panel by the pressure-sensitive masking tape method. A uniform deposit of powdery material may cling to the tape, but lifting of any flakes or particles which expose any bare metal shall indicate unsatisfactory adhesion.

Thermal stability: The bonded solid film lubricant applied to 18-8 stainless steel panels and exposed to 399°C (750°F) for 3 hr followed by 1 hr at -184°C (-300°F) shall show no flaking, cracking or softening.

Endurance life: The solid film lubricant shall have a minimum average life of 80 min on the Falex Lubricant Tester at 4,448 N (1,000 lb) gage load. A minimum of four tests is required. No single test shall have a life of less than 70 min.

High temperature performance: The solid film lubricant tested by the method and equipment described in Federal Standard No. 791, Method 333, shall demonstrate a useful life of 500 hr at 399°C (750°F) and 10,000 rpm continuous running on M-10 steel, SAE 204 bearing with ABEC-3 tolerance.

Vacuum performance: The solid film lubricant shall be applied to an anti-friction bearing and subjected to a vacuum environment of (1.0 x 10^{-6}) 1.333 x 10^{-4} N/m^2 torr at 538°C (1000°F) and 1,250 rpm. A 22.24 N (5.0 lb) axial and a 13.34 N (3.0 lb) radial load shall be applied to the bearing. The solid film lubricant shall demonstrate a minimum life of 100 hr. Failure is indicated by 7°C (20°F) rise in temperature of the bearing case or a 50% increase in power required.

Shock sensitivity with "LOX": The solid film lubricant tested in accordance with U.S. Air Force Specification Bulletin 527 shall give no reaction in 20 test drops at 94.91 joule (70 ft/lb) energy level. The solid film lubricant shall be spray deposited and cured in test cups prior to testing.

Storage stability: A closed quart container of the solid film solution shall be stored at 25°C (77°F) for 6 months. It shall then be mechanically agitated for 5 min, the container opened, and the lubricant examined for homogeneity. Cured solid film specimens shall then pass the film adhesion, thermal stability and endurance life tests.

Uses: This solid film lubricant is intended for use in liquid oxygen systems, space vehicles, bearing and other equipment where the environments of temperature, nuclear radiation and vacuum will not permit the use of conventional lubricants or organic-bonded solid film lubricants.

Limitations: This solid film lubricant should not be used on materials which may be adversely affected by the required cure temperature of 149°C (300°F). It should not be used with oils or greases unless experience indicates otherwise.

MSFC-SPEC-253A; Lubricant, Dry Film, Ceramic, MLF-5 and MLF-9 (Preparation and Application)

This specification covers the requirements for the preparation of parts and application of two types of dry film lubricating materials, designated MLF-5 and MLF-9, that have low friction and will support high loads.

Condensed specification requirements: Surface finish and preparation for these solid film lubricants required a chemically and mechanically cleaned surface with a smooth dry-honed finish not exceeding 0.20 to 0.33 x 10^{-6} m (8. to 13 μin) (rms).

MLF-5 solid film: Preparation requires careful mixing of specified amounts and particle sizes of several solid film powders, including: molybdenum disulfide, graphite, gold and sodium silicate in specified proportions of distilled water. Powdered ingredients for this solid film lube shall pass through a 325-mesh sieve (44 μm).

MLF-9 solid film: Preparation requires careful mixing of specified amounts and particle sizes of several granular powders, including: molybdenum disulfide, graphite, bismuth and aluminum phosphate in specified proportions of distilled water. The powdered ingredients for this solid film shall pass through a 325 mesh sieve (44 μm).

Mixing, application and cure: Both MLF-5 and MLF-9 must be continuously stirred during mixing, and the mixed lubricant solution must also be stirred in the container during spray application. The solid film must be applied as a fine mist spray, using a dry-nitrogen pressure source. The rate of application should be such that the film appears to dry on contact and no wet spot should appear. Individual coats or layers of film lubricant should be between 2.54 and 10.16 μm (0.0001 and 0.0004 in). Both MLF-5 and MLF-9 require sequential heat cure cycles, the maximum for MLF-5 is 149°C (300°F); for MLF-9 the maximum is 227°C (440°F).

Workmanship: When applied to parts and cured as specified, both MLF-5 and MLF-9 lubricants shall show no evidence of cracking, flaking, or other defects that adversely affect their intended use.

MSFC SPEC-502: Lubricant, Dry Film, Ceramic, MLF-5, Preparation and Application of

This specification covers the requirements for the preparation and application of a LOX compatible dry film lubricant designed MLF-5. Included are: qualification of the facility and process, spray operator, and new raw materials used. MLF-5 dry film is available in two grades: Type I - heavy duty, long life; Type II - light duty, short life.

Facility and process approved: To obtain facility and process approval, the supplier must prepare a complete description of the method of compounding and applying the lubricant. Preparation of endurance test samples meeting specification requirements are also required. Reapproval is also required for significant changes in procedure, facility or changes in operating personnel or if procedure is not used within 3 months.

Raw material approval: Each new batch combination of raw materials (except distilled water) requires preparation of three endurance test samples meeting specification requirements.

Spray operator approval: Each new spray operator must demonstrate his skill in spraying parts with MLF-5 lubricant by preparing three endurance test samples that meet specification requirements. Reapproval of operator is required if more than 1 month occurs between spraying operations.

Preparation of parts: Specification requirements cover method of surface preparation prior to application of lubricants. These include machine finish, grit blast finish, and surface cleaning. Unless detailed drawing specify otherwise, the surface finish should be in the range of 4.06 to 7.62 x 10^{-7} m (16 to 30 μin.) rms.

Preparation of MLF-5 lubricant: Specification included completely the quantity and quality of each ingredient in MLF-5 lubricant. This includes molybdenum disulfide powder, graphite powder, sodium silicate, gold powder, NPC turgitol nonionic, and distilled or deionized water.

Film thickness: Optimum thickness of MLF-5 lubricant depends on anticipated use and available clearance. Unless specified on detailed drawings, recommended film thickness should be between 1.02 to 3.05 x 10^{-5} m (0.0004 to 0.0012 in.).

Film cure cycle: The applied lubricant shall be heat cured in a three-step cure cycle.

1. Heat at 80°C ± 5°C for 2 hr.

2. Heat at 149°C ± 5°C for 8 hr.

3. Reduce slowly from 149°C to ambient temperature.

Shelf life: MLF-5 lubricant not used within 5 days after mixing shall be discarded.

Intended use: This specification is intended for use in the preparation and application of MLF-5 lubricant to specified parts or components of space vehicles and associated equipment.

MSFC (Drawing); 50M60434: Lubricant, Dry Film, MLR-2 Preparation and Application of (NATO Code: None)

This specification covers the requirements for the preparation of parts and applications of dry film lubricating materials, designated MLR-2, that has low friction coefficients and the capacity of supporting high loads without penetration. This dry film lubricant is not compatible with LOX.

Preparation of parts: Specification requirements cover method of surface preparation prior to application of lubricant. These include machine finish, grit blast finish, and surface cleaning. The prepared surface should have a random finish of 4.06 to 6.10 x 10^{-7} m (16 to 24 μin.) rms.

Preparation of MLR-2 lubricant: Specifications list the ingredients and quantities of each as well as the method of mixing MLR-2 lubricants. Materials used are: molybdenum disulfide powder, antimony trioxide powder, polyimide high temperature binder solution, xylene-xylol, and pyrrolidinone. Ingredients must be thoroughly mixed for 5 min in a sealed high-speed blender.

Application and film thickness: MLR-2 lubricant must be continuously stirred in a special side outlet flask during application to prevent particle settling. The mixture shall be applied by an air brush spray using nitrogen on air (MSFL-PROC-404) and the parts to be sprayed shall be heated to 49°C to 60°C (120°F to 140°F) prior to spraying. Heat lamps are required to assure a dry surface and to accelerate evaporation of the film mixture. After spraying, part should be dried at ambient temperature for 10 to 20 min. Film thickness shall be as specified on the applicable detail drawing. Optimum film performance is usually obtained with a film thickness of 7.62 x 10^{-6} m (0.003 in.).

Film cure cycle: After the applied film has dried at ambient temperature, it shall be cured by the following three-step cycle: (1) 93°C (200°F) for 1.0 hr, (2) 302°C (575°F) for 1.0 hr, and (3) remove and allow to cool to ambient temperature.

Intended use: This specification is intended for use in the preparation and application of MLR-2 lubricant to specified parts and compoents of space vehicles and associated eqiupment.

APPENDIX C

TEST EQUIPMENT AND PROCEDURES

Falex Lubricant Tester

A. Apparatus

The Falex tester utilizes a rotating pin and V-block test configuration as shown in Figure 1. The Falex Lubricant Tester consists of a drive motor, loading mechanism, reaction-torque sensing system, and elapsed running time control unit with an automatic cutoff switch (see Figure 2). The control unit and cutoff device were designed and fabricated at Midwest Research Institute. This tester, which has been used throughout the solid lubricant industry, provides a means for evaluating the load carrying capability and the wear-life of a film at high loads.

B. Test Procedures

1. Life tests:*

a. Insert the solid film coated V-blocks in the recesses of the loading device.

b. Mount the solid film coated test pin in the test shaft and insert the brass shear pin.

c. Position the loading mechanism and turn the ratchet wheel by hand until the loading mechanism engages (indicated on the load gauge). Position the load applying arm and energize the drive motor until a gauge load of 1,334 N (300 lb) is reached; remove the load applying arm and continue running for 3 min; then increase the load to 2,224 N (500 lb) using the load applying arm, and run for 1 min.

d. Apply loads in increments of 1,112 N (250 lb); run for 1 min at each load until a 4,448 N (1,000 lb) gauge load is reached on the 20,016 N (4,500 lb) gauge. Maintain a 4,448 N (1,000 lb) load and measure the time-to-failure.

e. Failure is indicated by a torque rise of 0.566 joule (5 in-lb) above the steady state value or breakage of the test or shear pin.

2. Load carrying capacity:**

a. Insert the solid film coated V-blocks in the recesses of the loading device.

b. Mount the solid film coated test pin in the test shaft and insert the brass shear pin.

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* Test procedure requirements of Federal Test Method Standard No. 791a, Method 3807.

** Test procedure requirements of Federal Test Method Standard No. 791a, Method 3812.

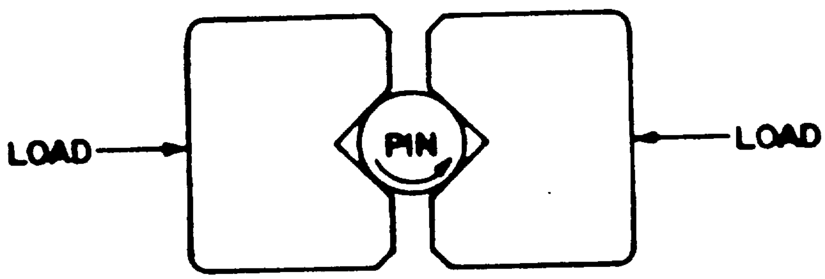

Figure 1. Falex Test Configuration.

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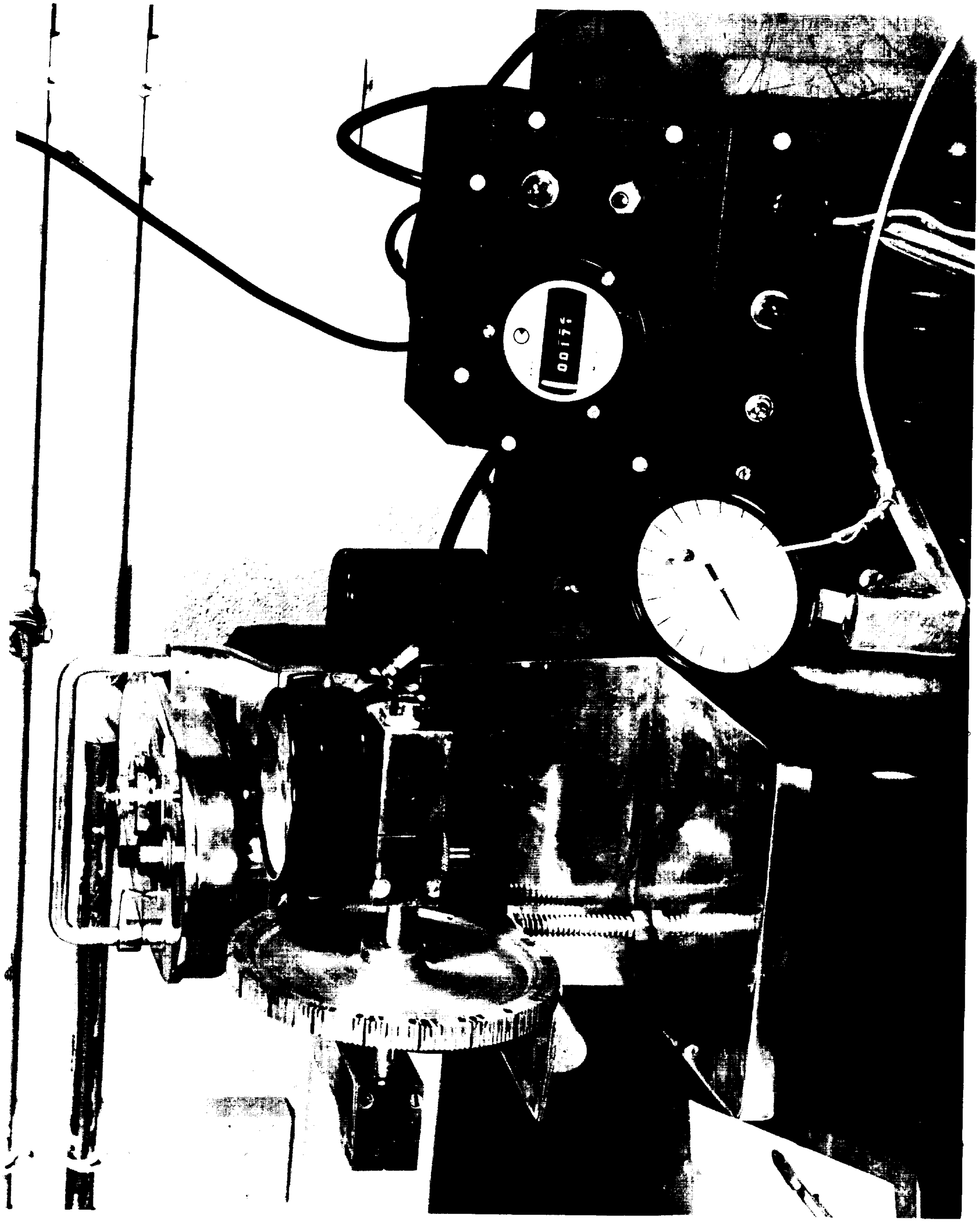

Figure 2. Falex Tester with Torque Cutoff

c. Position the loading mechanism and turn the ratchet wheel by hand until the loading mechanism engages (indicated on the load gauge). Position the load applying arm and energize the drive motor until a gauge load of 1,334 N (300 lb) is reached; remove the load applying arm and continue running for 3 min; then increase the load to 2,224 N (500 lb) using the load applying arm and run for 1 min.

d. Apply load in increments of 1,112 N (250 lb) (gauge load) with 1 min runs at each load until a gauge of 20,016 N (4,500 lb)* is reached or until failure occurs.

e. Failure is indicated by inability of the lubricating film to maintain the load for 1 min, breakage of the shear or test pin, or a sharp increase in torque, 0.791 joule (7 in-lb or more) over the gradual increase accompanying the increase in load.

Vacuum Weight Loss of Bonded Solid Film Lubricants

Metal specimens, 1 in. x 1 in., were cleaned and coated with the test solid lubricant materials. All lubricant samples were cured in accordance with the manufacturer's requirements. Samples were then weighed on an analytical balance to the nearest 0.1 mg. Test samples were placed in holders and subjected to a vacuum of 1.3332×10^{-4} N/m^2 (10^{-6} torr) for a period of 528 hr. Samples were then reweighed and weight loss calculated on the basis of weight loss per square centimeter.

Electrical Conductivity

A. Apparatus

1. Glass slides, 0.0762 x 0.0254 m (3 in. x 1 in.).

2. Silver paint.

3. Wheatstone bridge.

B. Test Procedure

1. Apply silver paint to the areas of the glass slide shown in Figure 3.

2. Apply and cure test lubricants in accordance with the manufacturer's requirements to areas shown in Figure 3.

3. Connect leads to silvered areas of slide and to Wheatstone Bridge.

4. Determine resistance of films and report results in ohms resistance for a 1-in. gap.

* Not required by Federal Test Method Standard No. 791a, Method 3812.

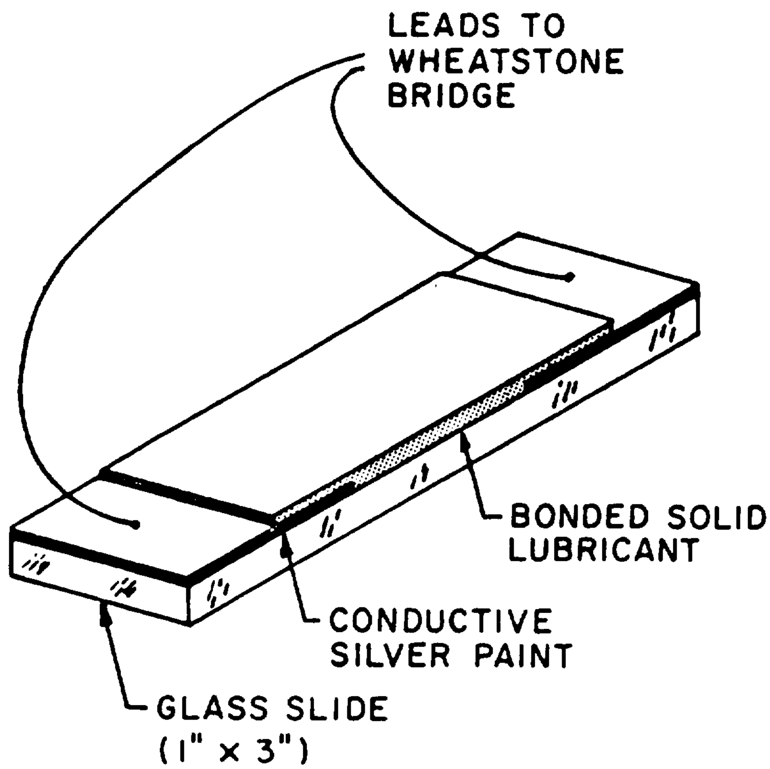

Figure 3. Electrical Conductivity Apparatus

Pellet Wear-Life

A. Apparatus

The wear-life runs were performed on a 12-station bench setup (Fig. 4). Each station consists of a wear-life tester and a control unit. The lubrication film was applied to the flat ends of the three pellets which are rigidly mounted in the pellet holder. The pellet holder was driven at 900 rpm (765 fpm) and loaded to 2.94 N (300 g/contact), 93,079 N/m^2 (13.5 psi projected area). Film thickness was controlled between 1.01 and 1.52 x 10^{-5} m (0.0004 and 0.0006 in.) for the resin-bonded films and 2.29 and 2.79 x 10^{-5} m (0.0009 to 0.0011 in.) for the silicate-bonded films. A controlled flow of dry nitrogen was supplied to each station for the duration of each run.

The atmosphere was selected because it was inert, easily reproduced, and offered the possibility of correlation with vacuum environment data. The high friction shutoff switch was set so that the tester would shut down when the frictional torque reached a value corresponding to a frictional coefficient of 0.3 (Fig. 5).

The pellets were annealed, 440-C stainless steel, 0.00635 m (0.25 in.) diameter by 0.00635 m (0.25 in.) length, and the wear plates were hardened 440-C stainless steel (Fig. 6). The hardness of the 440-C stainless steel was 15 to 20 Rockwell C in the annealed condition and 55 to 59 Rockwell C in the hardened condition.

B. Test Procedure

1. All commercial solid lubricants were applied and cured in accordance with the manufacturer's requirements.

2. Film thicknesses were measured to the nearest 2.54 x 10^{-6} m (0.0001 in.).

3. Samples were then run for 10 min at no load. This was done to smooth the film and transfer a thin film to the wear track.

4. Film thickness measured.

5. Item (3) was repeated under half load (150 g) for 10 min.

6. Film thickness measured.

7. Full load of 300 g applied to tester.

8. Tests terminated when friction reached 0.3.

Pellet Friction and Wear-Life (Environment)

A. Apparatus

The vacuum friction apparatus consists primarily of a dynamometer mounted, variable speed motor, fed into a vacuum chamber by means of a magnetic coupling.

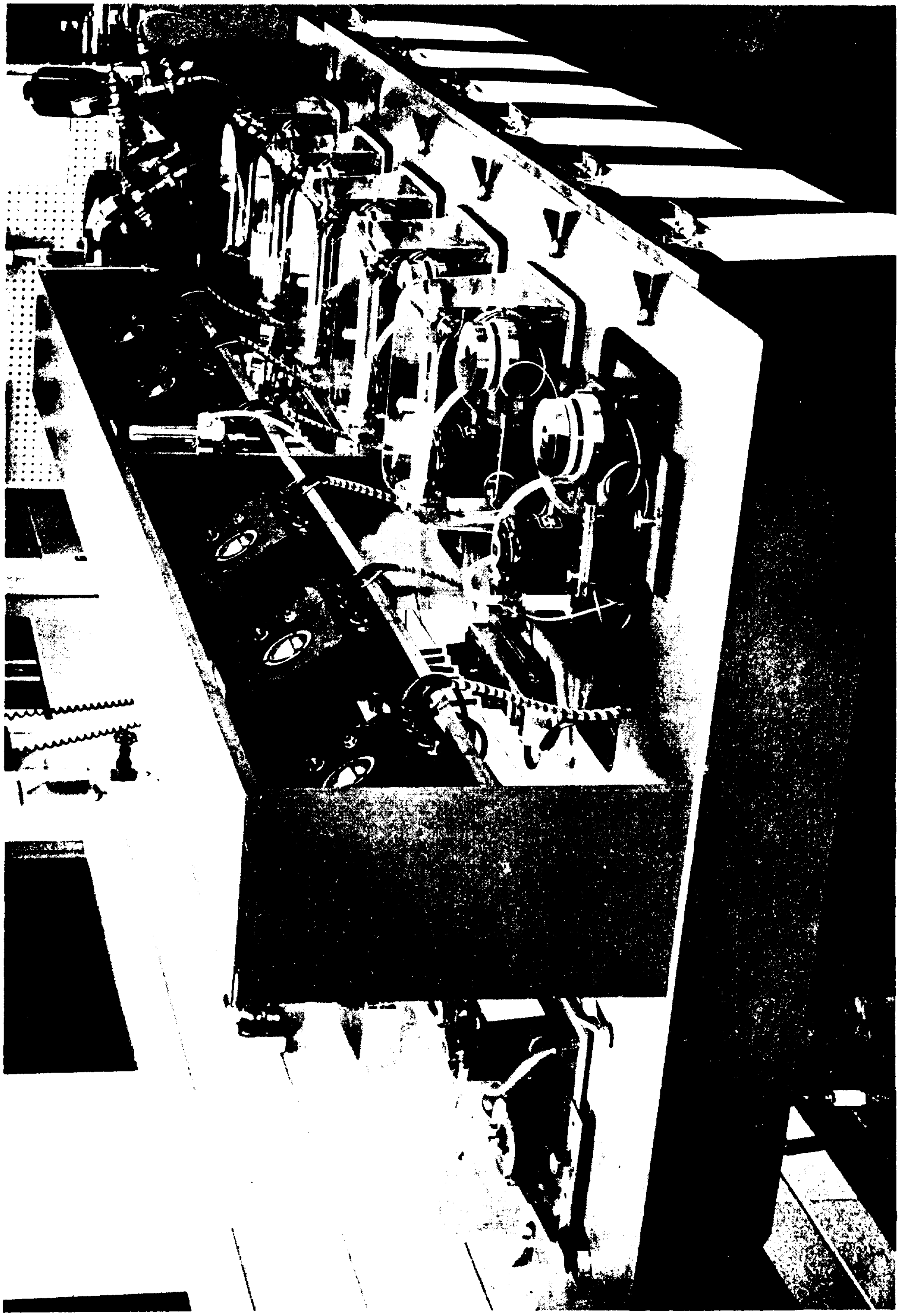

Figure 4. Wear-Life Testers - 12 Stations

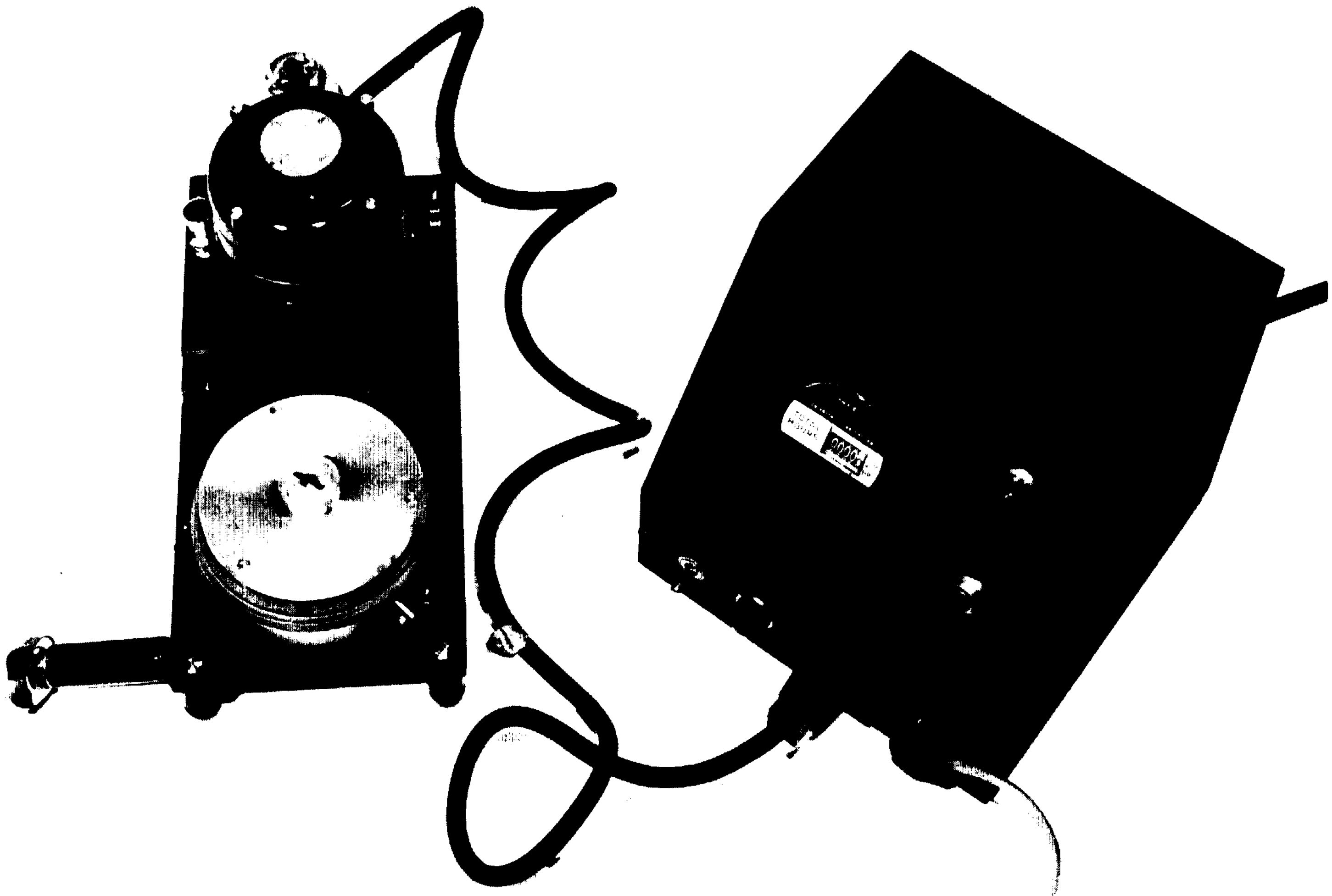

Figure 5. Wear-Life Tester and Control Unit

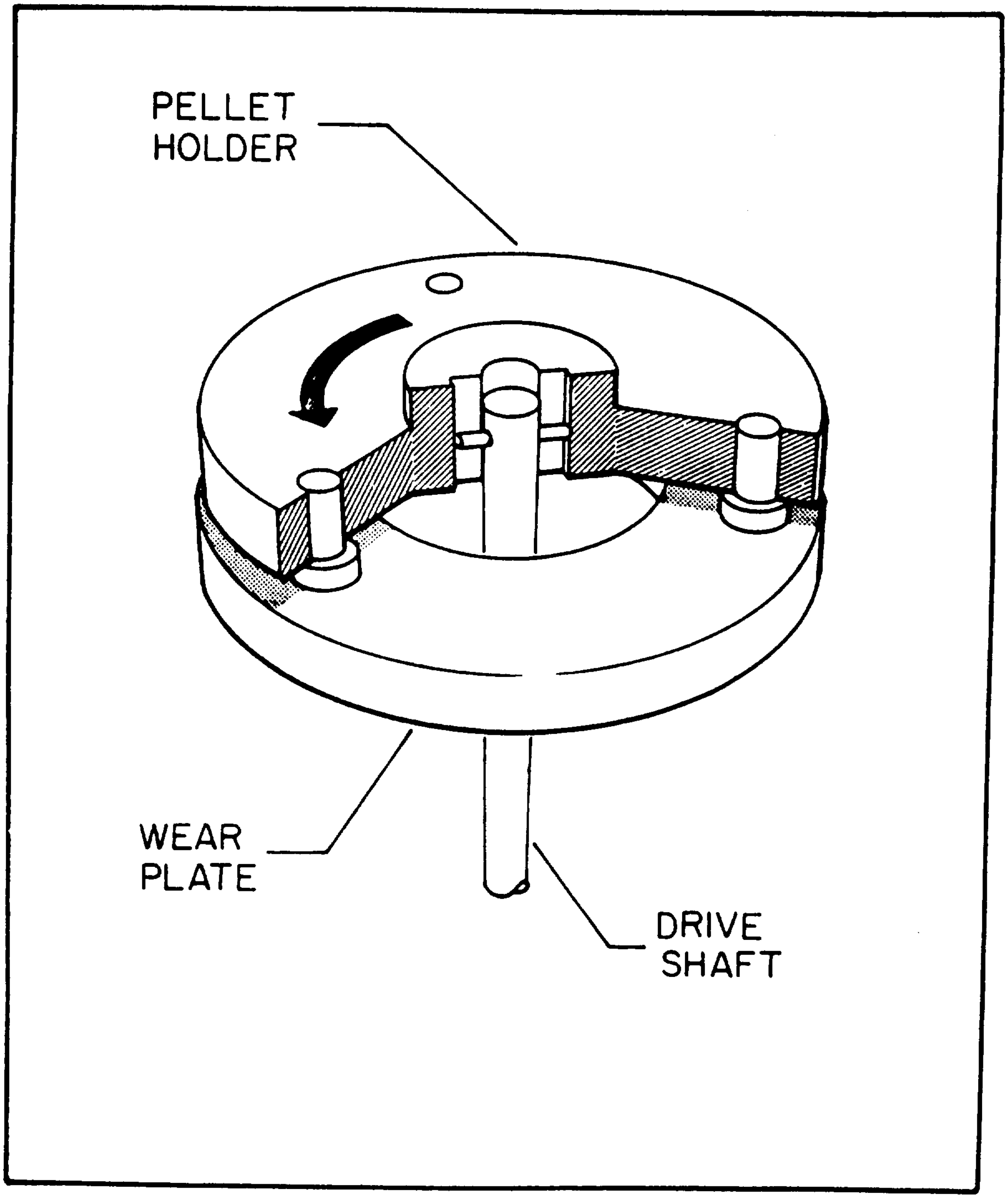

Figure 6. Wear-Life Test Configuration

A wear track and pellet holder are placed on a pedestal inside the chamber and the pellet holder is driven by means of a drive pin inserted in the drive shaft (Fig. 7).

Frictional torque is sensed by means of a transducer which sends a signal into a Bausch & Lomb strip recorder. The recorder is equipped with a variable over-torque shutoff switch and a clock timer measures the elapsed running time. The system is equipped with a mechanical vacuum pump and an oil diffusion pump. The test configuration is shown in Figure 6.

All tests were conducted at 0.49033 N (50.0 g) contact 15,168 N/m^2 (2.2 psi projected area), 900 rpm (765 fpm). The environment for these tests was ambient to 6.667×10^{-5} N/m^2 (5×10^{-7} torr).

The pellets were annealed, 440-C stainless steel, 0.00635 m (0.25 in.) diameter by 0.00635 m (0.25 in.) length, and the wear plates were hardened, 440-C stainless steel. The hardness of the 440-C stainless steel was 15 to 20 Rockwell C in the annealed condition and 55 to 59 Rockwell C in the hardened condition.

Test lubricants were applied and cured in accordance with the manufacturer's requirements. Films ranged in thickness from 1.01 and 1.52×10^{-5} m (0.0004 to 0.0006 in.) for the resin-bonded materials to 2.29 and 2.79×10^{-5} m (0.0009 to 0.0011 in.) for the silicate type materials.

B. Test Procedures

1. -100°F tests: The -100°F friction tests were accomplished by passing liquid nitrogen through the coils in contact with the wear track. Tests were conducted in vacuum to prevent the formation of ice on the wear track. Tests were started under full load 0.49033 N (50.0 g). Static friction was measured at test start-up. Dynamic friction was monitored during the entire test. Tests were terminated when the coefficient of friction reached a value of 0.3.

2. Room temperature tests (ambient): Tests were conducted as described above except no cooling was required. Tests were conducted in dry-nitrogen atmosphere.

3. High temperature tests, 204°C (400°F): Tests were conducted as described in (1) and (2) above except heat was applied to maintain the 204°C (400°F) temperature. Tests were conducted in dry-nitrogen atmosphere.

Journal Bearing Tests

A. Apparatus

The journal bearing tester, shown in Figure 8, is used to measure coefficients of friction and wear-life of bonded solid lubricants applied to plain journal bearings operating on cylindrical shafts. The test shafts, Figure 9, are hardened dowel pins chucked in two precision collets mounted in pillow blocks. The journal is the base of a standard, 1.58×10^{-2} (5/8 in.) diameter spherical bearing. The spherical surface is used only for initial alignment and is not lubricated. A loader slot,

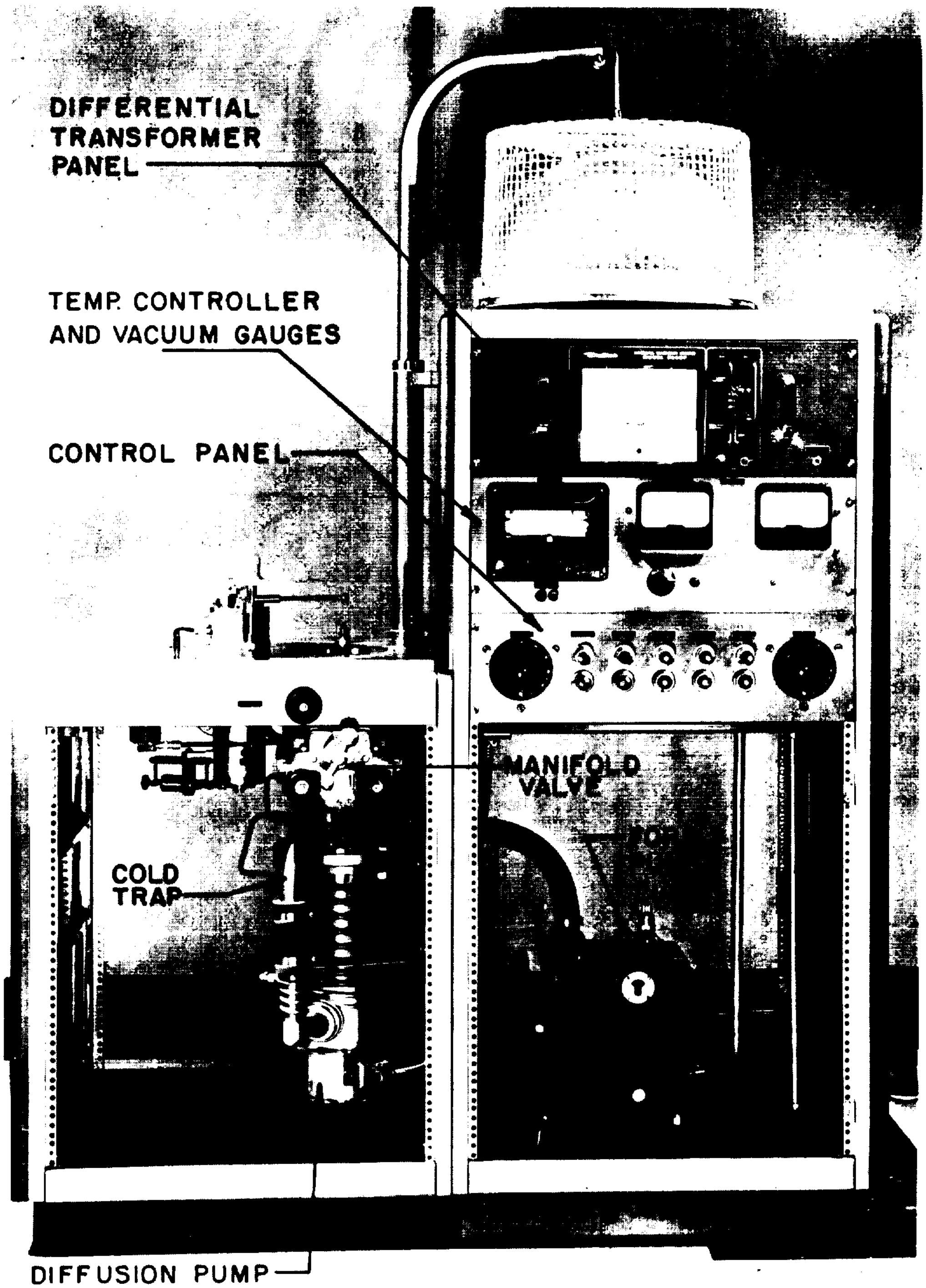

Figure 7. Vacuum Friction Apparatus

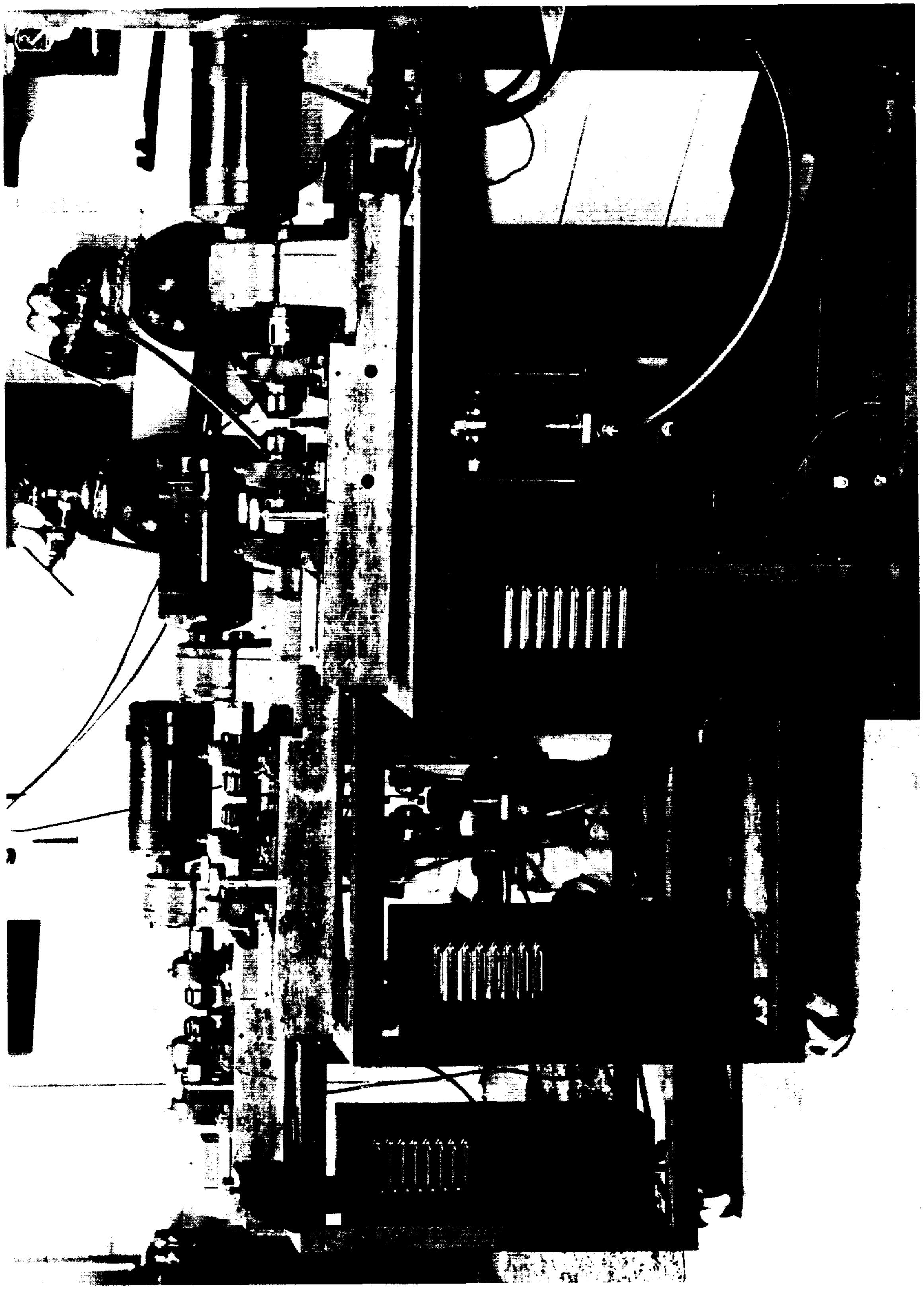

Figure 8. Journal Bearing Test Machines

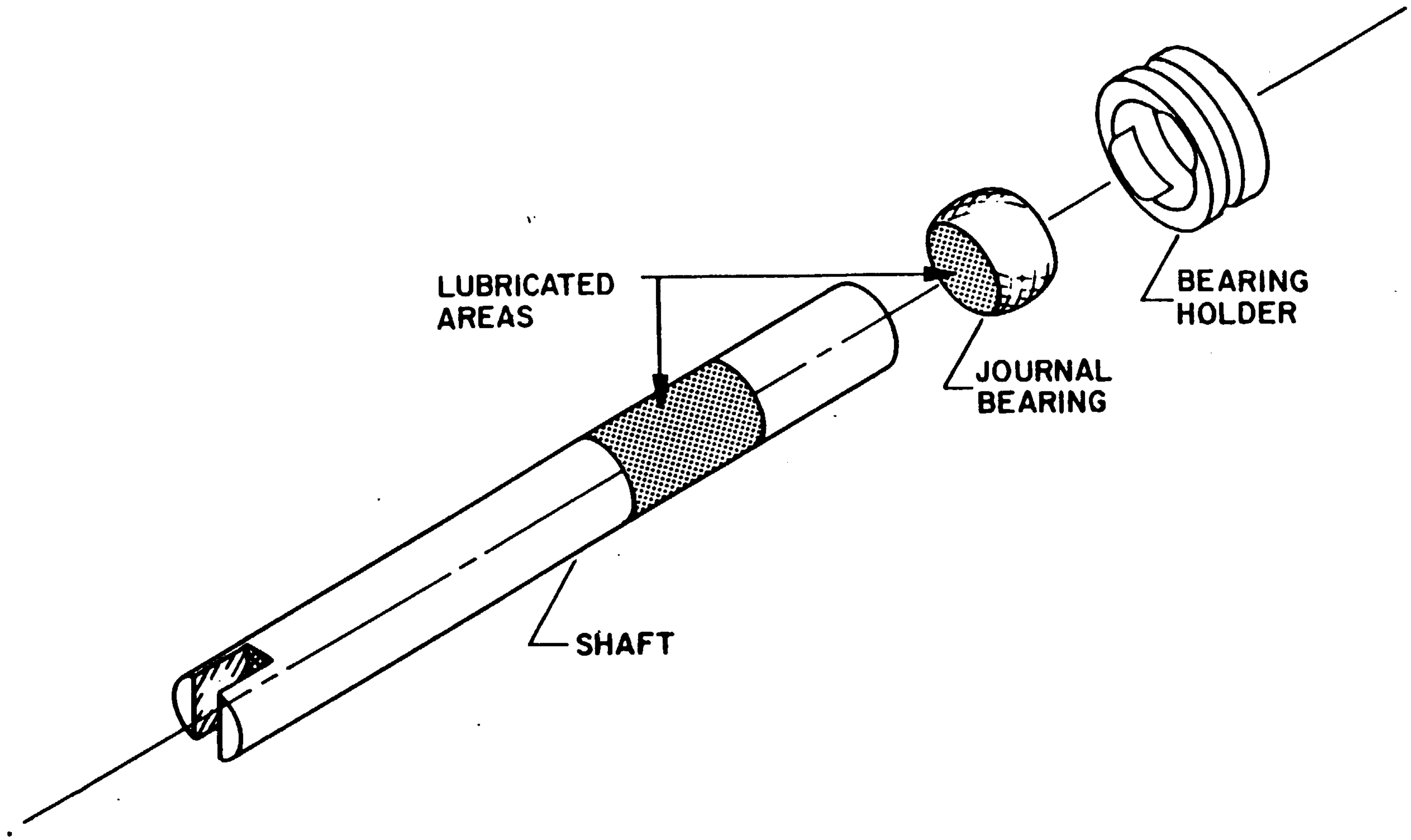

Figure 9. Journal Bearing Test Specimen Configuration

spherical bearing seat is used to facilitate replacement of the journal. Load is applied to the journal by a 0.127 m (5 in.) bore pneumatic cylinder through a hanger in which the spherical bearing seat is mounted. Regulated air or nitrogen is used to control the load on the journal bearing. The load hanger is instrumented with semi-conductor strain gauges for measurement of both load and torque.

One of the collets holding the shaft is driven by an SCR controlled DC motor with integral gear reducer. Shaft speed is adjustable from 5 to 100 rpm. A running time meter on the motor controller provides a measure of the wear-life of the journal bearing.

Torque sensed by the strain gauges is indicated on a meter relay and recorded on an external recorder. The meter relay is used to turn off the drive motor when a preset torque limit is exceeded.

B. Test Procedure

1. Assemble coated test specimens in the machine.
2. Tighten holding collets.
3. Set gas regulators for desired load.
4. Set the machine for desired test speed.
5. Connect gas hoses to pneumatic load cylinders.
6. Reset timer to zero minutes.
7. Set automatic shutoff at desired maximum friction.
8. Start test machine.
9. Run test until failure.

The purpose of this appratus (Fig. 10) is to evaluate solid film lubricant applied to instrument size spur gears. The test head is shown below. In this unit, torque loads to 20 oz-in. are locked into the four square arrangement and the gears are driven at selected speeds between 50 and 5,000 rpm. Two of the 48-pitch 20-deg pressure angle test gears have 55 teeth and the other two have 56 teeth. The 55-tooth gears have a pitch diameter of 1.1458 and 1/8-in. face width. The 56-tooth gears have pitch diameters of 1.667 and a face width of 3/16 in. This test head is one of six in a test setup which permits operation in air or inert gas. In addition, the test head is driven through a magnetic coupling to facilitate installation on a 4- or 6-in. vacuum flange for gear lubricant testing in a vacuum.

The purpose of this apparatus (Fig. 11) is to: (a) measure tooth-to-tooth errors (variation in circular pitch, tooth thickness, and profile); (b) measure total composite error (total tooth and run-out variations); and (c) measure solid lubricant film thickness applied to teeth. The composite gear measuring fixture consists of a calibrated master gear mounted on a movable arm, a linear displacement transducer, a transducer indicator amplifier, a strip chart recorder, and a drive motor for the

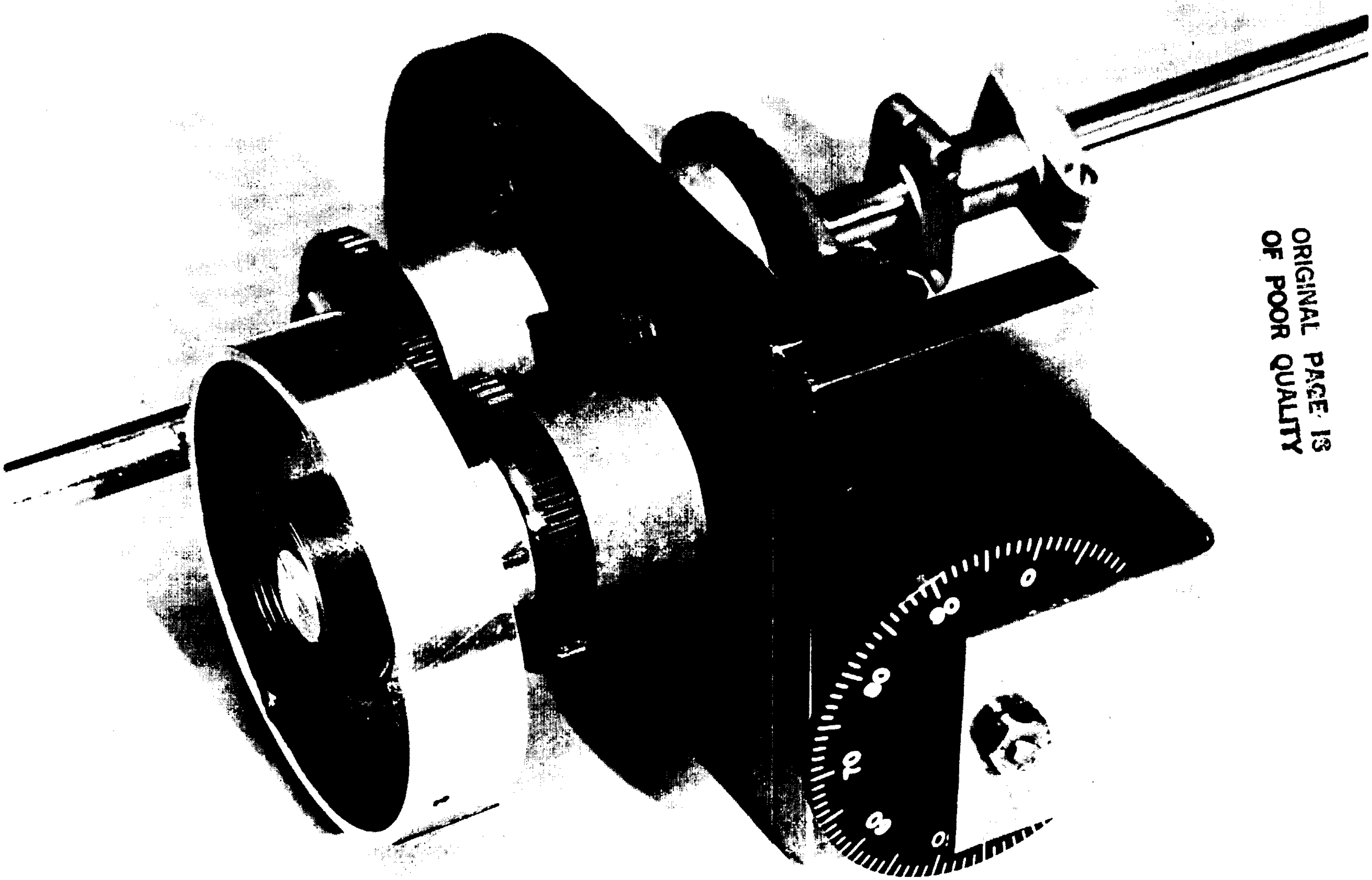

Figure 10. Four-Square Instrument-Gear Test Apparatus

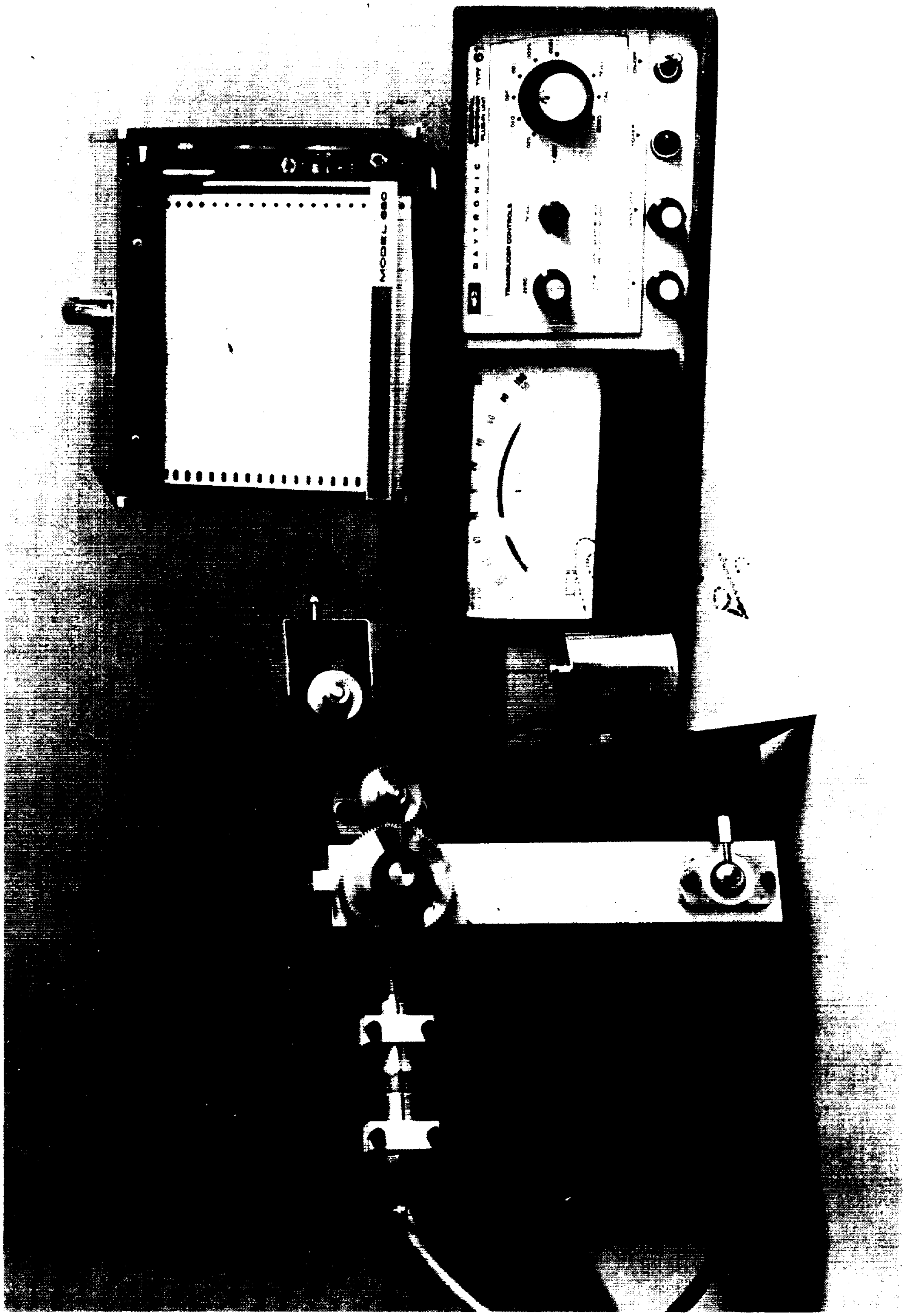

Figure 11. Composite Gear Measuring Apparatus

test gear. The gear being tested is mounted on the driven shaft and loaded against the master gear with a 20-oz weight. The changes in center distance as the two gears revolve are detected by the transducer which bears against the movable arm carrying the master gear. While the test gear is rotated through one complete revolution, the variation in center distance is recorded on the chart recorder.

Test Procedure: Four-Square Gear Tester (Instrument Gears)

1. Clean one set of test gears (four gears): (a) wash in detergent; (b) rinse with water; (c) rinse with acetone; and (d) dry with nitrogen.

2. Determine profile of each test gear using a variable center distance composite gear measuring apparatus tester. (Applies to Step 5.)

3. Prepare test gears for lubricant application by grit blasting with air carrier to obtain 15-25 rms surface finish. Clean test gears by: (a) detergent scrub; (b) ultrasonic cleaning with detergent; (c) water rinse; (d) acetone rinse; and (e) dry with nitrogen.

4. Apply dry film lubricant and cure.

5. Obtain profile of lubricated gears with gear tester. Determine lubricant film thickness by comparing before- and after-lubrication profiles.

6. Install gears in test fixture and adjust center distance for 0.0012 in. clearance (manufacturer's recommendation).

7. Run gears for 10 min without load. Reset center distance to 0.0012 in.

8. Apply desired test load and evacuate and back-fill test chamber with nitrogen. Start drive motor and set speed at desired value.

9. Measure drive motor torque and set over-torque leaf spring to shut off at 25% increase in torque.

10. Allow test to run until failure occurs.

The purpose of this spur gear test apparatus (Fig. 12) is used to evaluate films and and composite materials on gears large enough to be considered as power-transmitting rather than instrument gears. Two DC torque motors, which provide constant torque at a given speed, are mounted so that the center distance between their shafts can be varied from 4 in. to 12 in. One motor serves as the driver and the other loads the gears. These functions are reversible and interchangeable. Test gears are mounted directly on the rotor shafts and may be of 10-20 diametral pitch. Performance data of the motors are:

	Motor 1	Motor 2
Maximum torque (ft-lb)	22	7
No load speed (rpm)	153	258
Maximum voltage (volts DC)	67.0	45.7
Maximum current (amp)	7.8	5.4

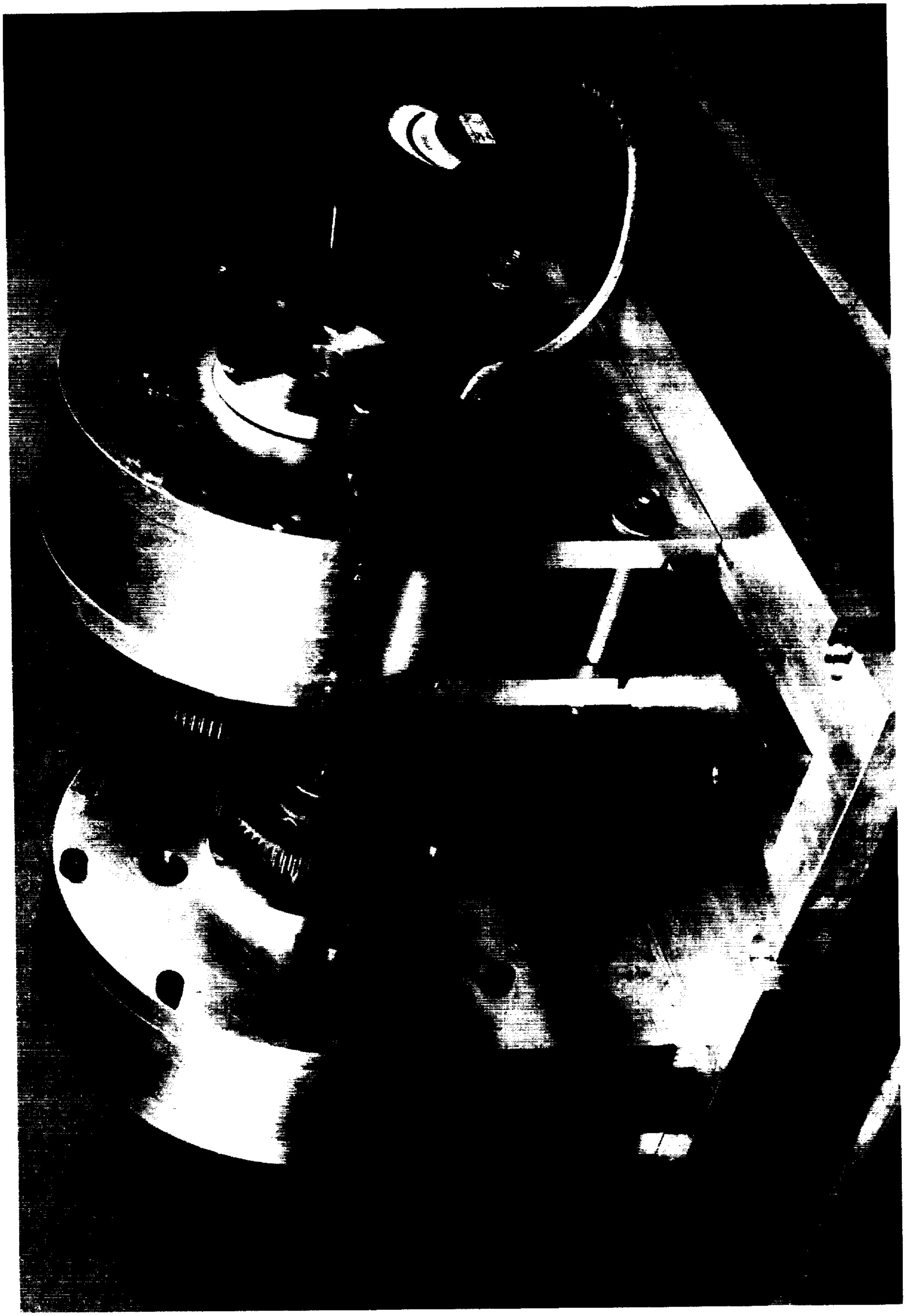

Figure 12. Power-Transmitting Gear Test Apparatus

The motors are cooled by a forced draft and, when desired, the atmosphere surrounding the test gears may be controlled.

Test Procedure: Power-Transmitting Spur Gear Tester

1. Grit blast one set of test gears (two gears) with air carrier to obtain 15-25 rms surface finish. Clean gears by: (a) detergent scrub; (b) ultrasonic cleaning with detergent; (c) water rinse; (d) acetone rinse; and (e) dry with nitrogen.

2. Apply dry film lube and cure.

3. Install test gears on tester.

4. Adjust center distance to desired value.

5. Turn on cooling air to drive and load motors.

6. Start drive motor and adjust speed to 150 rpm.

7. Increase current on loading motor until desired load is obtained.
NOTE: Do not exceed 3.9 ft-lb (3.0 amp) on load motor.

8. Allow test to run until lubricant failure is determined by visual observations of gear teeth. (Stop tester and examine gears every 1/2 hr).

WORM GEAR TESTER

The purpose of the worm gear tester (Fig. 13) is to evaluate solid film lubricants applied to fractional horsepower worm gears. The tester consists of a 1/2 h.p. drive motor, the worm gear unit, and a 1/2 h.p. DC generator used as a loading device. The worm gear unit is a commercial 1/2 h.p., 10 to 1 reduction unit. The worm is case-hardened steel, with four threads and a 20-deg pressure angle. The worm wheel is brass with 40 teeth. Lubricant film is applied to both the worm and worm wheel. Both the drive motor and loading generator are dynamometer mounted to measure input and output horsepower. Worm temperature is monitored by a thermocouple in the shaft and tooth contact temperature is measured with an optical pyrometer.

Test Procedure: Worm Gear Tester

1. Clean one set of test gears (one worm gear and one worm wheel): (a) wash in detergent; (b) rinse with acetone; and (c) dry with nitrogen.

2. Install test gears in tester and connect drive motor and loading generator.

3. Lubricate the gears with 600 w. heavy-duty gear-box lube, start the drive motor, increase load until input is 0.28 h.p., and allow gears to run in for 30 min.

4. Drain oil from gear box and mark gears for proper indexing. Remove gears from tester.

Figure 13. Worm Gear Tester

5. Girt blast gears with air carrier to obtain 15-25 rms surface finish. Clean gears by: (a) detergent scrub; (b) ultrasonic cleaning with detergent; (c) water rinse; (d) acetone rinse; (e) vapor degreasing with Freon solvent; and (f) dry with nitrogen.

6. Apply dry film lubricant and cure.

7. Install gears in tester with index marks aligned and connect drive motor and loading generator.

8. Start drive motor and run-in gears for 10 min at no load while brushing loose MoS_2 over worm gear.

9. Increase load to require 0.1 h.p. input. Record input and output torques. Repeat in 0.1 h.p. steps up to 0.6 h.p. and back to no load. Allow unit to operate 1 min at each load level.

10. Adjust load to require 0.28 h.p. input and record output torque. Allow test to run until output torque increases 25% or until severe fluctuations (± 50% of average) occur in output torque.

PART B — LIQUID LUBRICANTS

B-I. INTRODUCTION

In the design and maintenance of mechanical systems, lubrication is as important as bearing loads, speeds of rotation, torque and serviceability. Lubrication is not an exact science, but rather a technology that has been developed through service experience. Consequently, little effort has been made to systematically arrange the physical, chemical and use properties of liquid lubricants such that designers, maintenance workers and others can conveniently obtain the information needed for their work. The intent of Part B of this handbook is to provide information on liquid lubricants that will be helpful in selecting a suitable lubricant for various applications.

The material in this handbook is intended as a general aid to the designers of spacecraft and ground support equipment. This book is not intended to supplant other publications or expert opinion on such special problems as corrosion protection, LOX and fuel compatibility, or compatibility of lubricants with various elastomers and plastics.

Users of the information presented are urged to contact the Engineering Physics Division of the Materials and Processes Laboratory, Marshall Space Flight Center, for aid in selecting liquid lubricants for special applications.

A. Description of Handbook - Part B

This part of the handbook is divided into five separate sections: (I) Introduction; (II) Lubricant Descriptions; (III) Lubricant Data Sheets; (IV) Long Term Evaluation of Selected Grease; and (V) Appendix.

Section I, the introduction includes the cross index, lubricant applications guide and a description of how to use the handbook. The above mentioned cross index has been devised to aid the reader in matching trade names to military specifications. This index is comprised of two separate parts. The first part is arranged alphabetically by manufacturer's designations in the areas of oils, greases, hydraulic fluids and compounds. The second is a numerical listing by military specifications.

Section II, lubricant descriptions, contains written descriptions of specifications materials listed in the document in ascending numerical order in the categories of oils, greases, hydraulic fluids and compounds.

Section III, lubricant data sheets, is comprised of data sheets covering physical and chemical properties for all of the materials listed. In addition, there are several pages giving special uses of fluids and typical viscosity versus temperature curves for a variety of fluid materials.

Section IV, long term tests, contains information on selected greases tested in small ball bearings. This information includes volatility and cold start data as well as operating time at high temperature and in a corrosive atmosphere.

Section V, the Appendix, contains a glossary of terms used in lubrication, brief descriptions of test methods used to determine physical and chemical properties of both grease and oil lubricants, viscosity conversion charts and the international system of units and conversion factors.

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
Aeroshell Fluid 3	MIL-L-7870A	36
Aeroshell Fluid 5L-A, M-A	MIL-L-6086C	30, 32
Aeroshell Oil 65	MIL-L-6082D	24, 26
Aeroshell W80, W120	MIL-L-22851C	48
Aeroshell Oil 65,100	MIL-L-6082D	24, 26
Aeroshell Turbine Oil 500	MIL-L-23699C(1)	50
Airborne Concentrate	MIL-L-22851C	48
Aircraft Engine Oil	MIL-L-6082D	24, 26
All Fleet Plus Motor Oil	MIL-L-2104D	9, 13
AMOCO MP Gear Lubricant No. 80W-90	MIL-L-2105C(2)	17
AMOCO MP Gear Lubricant No. 85W-140	MIL-L-2105C(2)	18
AMOCO 200, MV, 300 SAE 15W-40	MIL-L-46152B(1)	53
AMOCO 300 Motor Oil	MIL-L-2104D	9
Anderol L-401D	MIL-L-6085B(1)	28
Anderol L-402	BMS-3-7A	80
Apiezon	None	59
Arco XHD SAE 10W-30	MIL-L-46152B(1)	53
Arcofleet S-3 Plus SAE 30	MIL-L-2104D	9
Batco SAE 10W Motor Oil	MIL-L-2104D	7
Batco 9000G	MIL-L-9000G(4)	38
Batco MIL-L-21260C SAE 10W, SAE 30, SAE 50	MIL-L-21260C	42, 44. 46
Brayco 300	VV-L-800C	1
Brayco 363	MIL-L-7870A	36
Brayco 423 J, 426A, 426N	MIL-L-2104D	9, 13
Brayco 441, 443, 445	MIL-L-21260C	42, 44, 46
Brayco 460	MIL-L-6081C(2)	22
Braycote 461 A, 462A, 463A	MIL-L-46152B(1)	53
Brayco 490, 490B	MIL-L-9000G(4)	38
Brayco 689F	MIl-L-2105C(2)	18
Brayco 808H	MIL-L-7808J	34
Brayco 810-13	None	70
Brayco 880H	MIL-L-7808J	34
Brayco 885	MIL-L-6085B(1)	28
Brayco 899M	MIL-L-23699C(1)	51
Brayco NPT3A, 4, 9	None	72
Calvis 300	VV-L-825A(2)	3
Castrol 399	MIL-L-7808J	34
Castrolaero 113,117	MIL-L-6082D	24, 26
Comproil II	VV-L-825A(2)	3
Chevron Aero Oil Grade 120	MIL-L-22851C	46
Chevron Aviation Oil 100	MIL-L-6082D	26
Chevron Oil Fluids	None	166
Chevron Turbine Oil 100TEP	MIL-L-1733H	40
Citgo Aviation Oil 1065, 1100	MIL-L-6082D	26
Citgo No. 93418, SAE 15W-40	MIL-L-2104D	13
Citgo No. 93416, SAE 30	MIL-L-2104D	9
Citgo 93418, 93149, 93416	MIL-L-46152B(1)	53
Citgo No. 93011, 80W-90, 85W-140	MIL-L-2105C(2)	18, 20
Code 18831	MIL-L-3150B(2)	21
Conoco Fleet Oil	MIL-L-2104D	9, 13
Cosmoline 1116	VV-L-800C	1

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
Delta Arctic Flow	MIL-L-46167A	55
Delta Aviation Oil 80, 120	MIL-L-22851C	48
Delta 1065	MIL-L-6082D	24
Delta 1280 Jet Engine Oil	MIL-L-6081C(2)	22
DP concentrate 160	MIL-L-22851C	48
Dow Corning Silicone Fluids	None	168
DSL Preservative Oil Grade 10W, 30, 50	MIL-L-21260C	42, 44, 46
Du Pont Freon Fluids	None	67
EL-1160	MIL-L-2104D	9
Exxon 1209 Turbine Lubricant	MIL-L-17331H	40
Exxon Aviation Oil 100	MIL-L-6082D	24
Exxon Aviation Oil EE-80, EE-120	MIL-L-22851C	48
Exxon Turbine Oil 500	MIL-L-23699C(1)	51
Exxon Turbo Oil 2389	MIL-L-7808J	34
Five Star C GR10W	MIL-L-2104D	7
Five Star D, Grade 40, Grade 15W40	MIL-L-2104D	13
Fomblin Y Fluorinated Fluids	None	62, 64, 164
Formula No. LP-883	MIL-L-46167A	55
Formula No. MTN542C	MIL-L-2104D	9
Formula No. MTN545, 606; RN2587	MIL-L-46152B(1)	53
Formula No. MTN568A#	MIL-L-2104D	7
Formula No. RP649BC	MIL-L-2105C(2)	17
Formula No. RP649BBD	MIL-L-2105C(2)	20
Formula No. RN2380C	MIL-L-2104D	11

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
Formula No. RN2533BBD	MIL-L-2104D	13
Formula No. TL-11031A	MIL-L-2105C(2)	20
Formula No. TL-11172	MIL-L-2105C(2)	19
Formula No. Tl-11547C	MIL-L-2104D	13
Formula No. TL-11572B	MIL-L-2104D	9
Formula No. TL-11829	MIL-L-2104D	13
GB 2190 Turbine	MIL-L-17331H	40
GB 3896 L, M	MIL-L-6086C	30, 32
Gearborne L, M	MIL-L-6086C	30, 32
Gulf A-1100	MIL-L-6082D	24
Gulf Harmony 78EP	MIL-L-17331H	40
Gulf Gear Lube 80W90, 85W140	MIL-L-2105C(2)	18, 20
Gulf SD Motor Oil 15W-40	MIL-L-2104D	13
Gulflube Motor Oil XHD30, 10W-30, 15W-40	MIL-L-46152B(1)	53
Halocarbon Fluids	None	74, 167
Hatcol 1278	MIL-L-7808J	34
Hatcol 3211	MIL-L-23699C(1)	51
Hatcol 3885	MIL-L-6085B(1)	28
IL-9000-G3	MIL-L-9000G(4)	38
Imperial Oil 2190-TEP-3	MIL-L-17331H	40
Kendall KG-80	MIL-L-83176A	68
Kendall Super-D III	MIL-L-2104D	13
Kendall SRG-60, SRG-160	None	68
Kendall Super-D III	MIL-L-46152B(1)	53

LUBRICATING OILS AND FLUIDS (continued)

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
MacMillan Jet Engine Oil 1010	MIL-L-6081C(2)	22
Motrex 651	MIL-L-9000G(4)	38
MTN 581A-1, C-1	MIL-L-21260C	42, 44
Multi-Gear Lubricant EP, 80W-90	MIL-L-2105C(2)	18
Nox-Rust X-275	MIL-L-6081C(2)	22
Nox-Rust 518	VV-L-800C	1
Octoil 70	MIL-L-7870A	36
Octoil 90	VV-L-800C	1
Paranox 160	MIL-L-22851C	48
PED 5598, 5599	MIL-L-2104D	9, 13
PED 5598, 5599	MIL-L-46152B(1)	53
Petrolube 1065, 1100	MIL-L-6082D	24, 26
Petrolube 4142	MIL-L-6081C(2)	22
Petrotect 90B	MIL-L-3150B(2)	21
Petrotect 800	VV-L-800C	1
Petrotect 7870A	MIL-L-7870A	36
Phillips 66 Aviation Oil Grade 1100	MIL-L-6082D	26
Phillips Super HD II SAE 10W, 30W, 15W-40	MIL-L-2104D	7
Posolube 9250	MIL-L-9000G(4)	38
Precision 1100	MIL-L-6082D	26
Precision LX 9250	MIL-L-9000G(4)	38
Precision PE-1, -2, -3	MIL-L-21260C	42, 44, 46
PQ 823 SAE 30, SAE 50	MIL-L-21260C	44, 46
PQ 3872, 3882	MIL-L-22851C	48
PQ 9600	MIL-L-46167A	55
PQ Rust Preventive No. 107	MIL-L-7870A	36
PQ Rust Preventive No. 160	MIL-L-6085B(1)	28
PQ Rust Preventive No. 172	VV-L-800C	1
PQ SAE 10W/30	MIL-L-46152B(1)	53
PQ Super Fleet IV	MIL-L-2104D	13
PQ Super Fleet IV	MIL-L-46152B(1)	53
PQ Turbine Lubricant 9598	MIL-L-23699C(1)	51
PQ Turbine Oil 8365	MIL-L-7808J	34
PQ Turbo Oil	MIL-L-6081C(2)	22
Product 80	MIL-L-6085B(1)	28
Protexol Compressor Oil Type II	VV-L-825A(2)	3
Quaker State Gear Lube, SAE 75W	MIL-L-2105C(2)	15
RM 173E	MIL-L-22851C	48
RM-223E	MIL-L-6082D	26
RM-248A	MIL-L-7808J	34
RM-270A	MIL-L-23699C(1)	51
Royco No. 2 Instrument Oil	None	80
Royco 308A	VV-L-800C	1
Royco 315	MIL-L-3150B(2)	21
Royco 363	MIL-L-7870A	36
Royco 460	MIL-L-6081C(2)	22
Royco 586, Grade L, M	MIL-L-6086C(1)	30, 32
Royco 767, 767A	MIL-L-46167A	55
Royco 808H	MIL-L-7808J	34
Royco 885	MIL-L-6085B(1)	28

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
RT 451	MIL-L-22851C	48
Rust Foil No. 2675	VV-L-800C	1
SC 8440085	MIL-L-21260C	46
Shell Concentrate A	MIL-L-22851C	48
Shell 9195 Motor Oil 30	MIL-L-2104D	44
Shell 9250	MIL-L-9000G(4)	38
Shell S9516	MIL-L-2104D	13
Shell XSL-9127	MIL-L-17331H	40
Shell Turbo 78	MIL-L-17331H	40
SR GL5 85W-140	MIL-L-2105C(2)	20
SR 2600, Grades 10W, 30, 50	MIL-L-21260C	42, 44, 46
SR MIL-L-9000G	MIL-L-9000G(4)	38
Standard 9250	MIL-L-9000G(4)	38
Sunoco Marine Turbine Oil 17331	MIL-L-17331H	40
Sunoco Multi-Purpose Gear Lube GL-5	MIL-L-2105C(2)	18
TC 9670A	MIL-L-22851C	48
Tectyl 802-A	MIL-L-3150B(2)	21
Tectyl 900	VV-L-800C	1
Tectyl 910A, 930A	MIL-L-21260C	42, 44
TL 9297, 9790	MIL-L-22851C	48
TL-9932A	MIL-L-17331H	40
TL 11829, 118324	MIL-L-46152B(1)	53
Tracon 30, Supreme 10W-30, Supreme 15W-40	MIL-L-46152B(1)	53
Union M6174	MIL-L-2104D	9
Union Guardol Motor Oil	MIL-L-2104D	13
Union MP Gear Lube - LS 75W	MIL-L-2105C(2)	15
Union Symbol Oil 9250	MIL-L-9000G(4)	38
Univis P-12	MIL-L-6085B(1)	28
Vac Kote 36233, 36234, 27995, 48784	None	60
Vanellus MCS-3-30	MIL-L-2104D	9
Valvoline All-Fleet Plus Motor Oil	MIL-L-2104D	13
Withrow 829, 828, 827	MIL-L-21260C	42, 44, 46
WS Motor Oil 1577, 1578, 1579	MIL-L-21260C	42, 44, 46
WS 1475 S-3 Motor Oil 30	MIL-L-2104D	9
WS 1588 S-3 Motor Oil	MIL-L-2104D	8
WS 1630 Motor Oil 15W-40	MIL-L-2104D	13
WS 1663, 1821, 1828 Motor Oil	MIL-L-46152B(1)	53
WS 1765 Motor Oil 40	MIL-L-2104D	11
XI-OE/HDO-40	MIL-L-2104D	11

LUBRICATING GREASES

Trade Name or Commercial Designation	Specificaiton No. If Qualified	Data Sheet Page No. Section BIII
Aeroshell Grease 6	MIL-G-24139A	96
Aeroshell Grease 7	MIL-G-23827B	94
Aeroshell Grease 14	MIL-G-25537C	100
Aeroshell Grease 17	MIL-G-21164D	90
Aeroshell 22C	MIL-G-81322D	104
Aeroshell 23C	MIL-G-81827A	106
Apiezon Grease	None	110
Batam S-830-RR	MIL-G-10924D(1)	86
Batam 10924D	MIL-G-10924D(1)	86
Braycote 631A	None	108
Braycote 632B	MIL-G-6032D	84
Braycote 664	MIL-G-21164D	90
Braycote 804, 805,806	MIL-G-27617D	102
Braycote 6275	MIL-G-23827B	94
Castrolease Al	MIL-G-23827B	94
Castrolease PS	MIL-G-4343C	82
Chevron Launch Pad Grease	MIL-G-23549C	92
Code 5542-C	MIL-G-10924D(1)	86
Code SA 824 3332	MIL-G-10924D(1)	86
Code 82002	MIL-G-25537C	100
Cosmolube 615	MIL-G-4343C	82
Dow Corning FS-3452	MIL-G-6032D	84
Dow Corning 44 Grease	MIL-G-15719A(3)	88
Du Pont KRYTOX 240AC, AZ, AB	MIL-G-27617D	102

Trade Name or Commercial Disignation	Specification No. If Qualified	Data Sheet Page No. Section BIII
Du Pont KRYTOX 250AC, 260AC, 280AC	None	120
Molykote 55M Grease	MIL-G-4343C	82
Everlube 211-G	MIL-G-21164D	90
E-Z Turn Lubricant	MIL-G-6032D	84
Fomblin Y-VAC-3	MIL-G-27617D	102
GN 22	MIL-G-81322D	104
Halocarbon Greases	None	112
KL-89 Grease	MIL-L-15719A(3)	88
Low Temp. Grease EP	MIL-G-23827B	94
Micronic 803	None	116
MIL-G-10924D-SW	MIL-G-10924D(1)	86
Mobilgrease 27	MIL-G-23827B	94
Mobilgrease 28	DOD-G-24508A(1)	97
Mobilgrease 28	MIL-G-81322D	104
Mobilgrease 29	MIL-G-81827A	106
Rockwell 950	MIL-G-6032D	84
Royco 13E	MIL-G-25013E	98
Royco 22C	MIL-G-81322D	104
Royco 22MS	MIL-G-81827A	106
Royco 24R	MIL-G-10924D(1)	86
Royco 27A	MIL-G-23827B	94
Royco 32	MIL-G-6032D	84
Royco 37A	MIL-G-25537C	100
Royco 43	MIL-G-4343C	82

LUBRICATING GREASES (continued)

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
Royco 48	DOD-G-24508A(1)	97
Royco 49B	MIL-G-23549C	92
Royco 64D	MIL-G-21164D	90
SA-823922	MIL-G-23549C	92
Southwest Grease No. 16215	MIL-G-23827B	94
Supermil Grease A 72832	MIL-G-23827B	94
Supermil Grease No. 1371	MIL-G-25013E	98
Tectyl 858C	MIL-G-10924D(1)	86
Tribolube 10A, 10C, 16	MIL-G-27617D	102
Ultra-Seal 125,822	MIL-G-6032D	84
Vac Kote 37963C, 37987, 44147, 44177	None	118
Versilube G-351	MIL-G-15719A(3)	88

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII

HYDRAULIC AND DAMPING FLUID SPECIFICATIONS

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
Aeroshell Fluid 41	MIL-H-5606E(1)	137
Aeroshell Fluid 61	MIL-H-46170B	147
Aeroshell Fluid 71	MIL-H-6083D(3)	139
Avrex 904	MIL-H-6083D(3)	139
Brayco 717	MIL-F-17111B	143
Brayco 756E	MIL-H-5606E(1)	137
Brayco 759C	MIL-H-81019D	150
Brayco 771	MIL-H-27601A(1)	141
Brayco 783 C/E	MIL-H-6083D(3)	139
Brayco 882	MIL-H-83282B	153
Brayco 883	MIL-H-46170B	147
Chevron 2110TH, 2135TH	MIL-H-17672D	144
Chevron Fluid M2-V	None	157
Delco 69-0-5-4	VV-B-680B(1)	136
Du Pont KRYTOX 143	None	76, 165
DX Oil 2135-T-H	MIL-H-17672D	144
Emery 2857	MIL-H-83282B	153
F-885-1	MIL-H-46170B	147
Formula No. LP-803	MIL-H-46170B	147
GE 475-195	MIL-B-46176(2)	149
Grade 2135TH, Code B9257	MIL-H-17672D	144
Gulf TS-864-32, -46, -68	MIL-H-17672D	144
H-70	VV-B-680B(1)	136
Hatcol 4285	MIL-H-83282B	153
Houghto-Safe 1055, 1120	MIL-H-19457C(1)	146
Hyspin P	MIL-H-6083D(3)	139
Imperial 2075 T-H, 2110 T-H, 2135TH	MIL-H-17672D	144
Kronitex 280, 600	MIL-H-19457C(1)	146
LWS-5	VV-B-680B(1)	136
NC-2021.1	VV-B-680B(1)	136
P 1615-129	MIL-B-46176(2)	149
PED 5225	MIL-H-5606E(1)	137
Petrofluid 171	MIL-F-17111B	143
Petrofluid 822	MIL-H-83282B	153
Petrofluid 4146	MIL-H-5606E(1)	137
Petrotect 4066C	MIL-H-6083D(3)	139
PQ 1307	MIL-H-6083D(3)	139
PQ 4100	MIL-H-46170B	147
PQ 4923	MIL-H-83282B	153
PQ C-4417, -4465, -4466	MIL-H-17672D	144
PQ Hydraulic Fluid 4328	MIL-H-5606E(1)	137
Royco 601 AH	MIL-H-27601A(1)	139
Royco 717	MIL-F-17111B	143
Royco 719C	MIL-H-81019D	150
Royco 756E	MIL-H-5606E(1)	137
Royco 770	MIL-H-46170B	147
Royco 782-2	MIL-H-83282B	153
Royco 783 B	MIL-H-6083D(3)	139
Royco 820X	None	156
SE 8610632, 8610646	MIL-H-17672D	144
Sunvis 2110TH, 2135TH	MIL-H-17672D	144
Technolube	MIL-H-83282B	153
TL-10711A	MIL-H-5606E(1)	137
TL-11014, -11015, -11016	MIL-H-17672D	144
UCON 4961	VV-B-680B(1)	136
Univis PJ-42	MIL-H-6083D(3)	139
X2-1143	MIL-B-46176(2)	149
Y-7694	MIL-B-46176(2)	149

ANTISEIZE AND CORROSION COMPOUND SPECIFICATIONS

Trade Name or Commercial Designation	Specificaiton No. If Qualified	Data Sheet Page No. Section BIII
Aeroshell Fluid 2F, 2XN	MIL-C-6529C(2)	125
Amalie Film Spray	MIL-C-0083933A	135
Braycote 103, 137, 153E, 194, 198E	MIL-C-16173D(2)	130
Braycote 202, 265, 248	MIL-C-11796B	129
Braycote 236	VV-P-236A(2)	122
Braycote 581H, 482H, 483H	MIL-C-6529C(2)	125
Chesterton	MIL-A-907D	123
Code SF 891, 1009	MIL-C-11796B	129
Code 62069	MIL-C-0083933A	135
Compound 77	MIL-A-907D	123
Cosmoline 1058, 1102, 1112	MIL-C-16173D(2)	130
Cosmoline 1060, 1062	MIL-C-11796B	129
DAG 243	MIL-A-907D	123
DC 4 Compound	MIL-S-8660C	133
Fel-Pro C-661	MIL-A-907D	123
GC-76	MIL-A-907D	123
Insul-Grease G-624	MIL-S-8660C	133
Kopr-Kote	MIL-A-907D	123
Kopr-Shield	MIL-A-907D	123
Led-Plate 250	MIL-A-907D	123

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
Liqui Moly N.V. Thread Compound	MIL-A-907D	123
Low-Viscosity Anti-Seize	MIL-A-907D	123
L-2196A	MIL-C-5545C	124
Never-Seez	MIL-A-907D	123
NII HBC-20, -21, -22	MIL-C-6529C(2)	125
Nox-Rust 201B, 207, 208, X-110	MIL-C-16173D(2)	130
Nox-rust 507, 509	MIL-C-11796B	129
Nox-Rust X-118	MIL-C-0083933A	135
Petrotect ARP	MIL-C-0083933A	135
Petrotect 3, 5	MIL-C-16173D(2)	130
Petrotect 6529C, 65292, 65293	MIL-C-6529C(2)	125
PQ Corrosion Preventive Oil	MIL-C-8188C	127
Royco 1R	VV-P-236A(2)	122
Royco 195	MIL-C-16173D(2)	130
Royco 581, 482, 483	MIL-C-6529C(2)	125
Shell Storage Oil	MIL-C-6529C(2)	125
Tectyl 165-G	MIL-C-0083933A	135
Tectyl 435, 437	MIL-C-11796B	129
Tectyl 890, 502C, 894, 846, 511M	MIL-C-16173D(2)	130
Thred-Gard	MIL-A-907D	123

COMPOUNDS

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
Braycote 202	MIL-C-11796B	129
Braycote 236	VV-P-236A(2)	122
Braycote 248	MIL-C-11796B	129
Braycote 265	MIL-C-11796B	129
Cosmoline 1060	MIL-C-11796B	129
Cosmoline 1062	MIL-C-11796B	129
Dow Corning 4 Compound	MIL-S-8660C	133
Insul-Grease G-624	MIL-S-8660C	133
Nox-Rust 507	MIL-C-11796B	129
Nox-Rust 509	MIL-C-11796B	129
Royco IR	VV-P-236A(2)	122
Tectyl 435	MIL-C-11796B	129
Tectyl 437	MIL-C-11796B	129

NONSPECIFICATION FLUIDS

Trade Name or Commercial Designation	Specification No. If Qualified	Data Sheet Page No. Section BIII
Anderol L-402	None	80
Apiezon Fluids	None	59
Ball Aerospace Systems Division 48784, 36233, 36234, 37995	None	60
Brayco 810, 811, 812, 813A	None	70
Brayco NPT 3A, 4, 9	None	72
Chevron Oil Fluids	None	166
Dow Corning Silicones	None	168
DuPont Krytox 143 Fluids	None	76, 165
Fomblin Y Fluids	None	62, 64, 164
Freon E1, E2, E3, E4, E5	None	66
G. E. Silicone Fluids (Viscasil)	None	159, 160, 162
Halocarbons 4-11S, 11-14S, 11-21S, 13-21S, 10-25S, 14-25S	None	74, 167
Kendall Gyro Lubricants SRG-60	None	68
Royco No. 2	None	80

NONSPECIFICATION GREASES

Trade Name or Commercial Designation	Specification No. If qualified	Data Sheet Page No. Section BIII
Apiezon Greases	None	59
Braycote 631A	None	108
Vac Kote 37963C, 37987, 44147, 44177	None	118
Micronic 803	None	116
Halocarbon Synthetic Greases	None	112
Krytox Greases	None	120

LUBRICATING OIL SPECIFICATIONS

		Page Numbers Section BII	Page Numbers Section BIII
VV-L-800C	Lubricating Oil, General Purpose, Preservative/Water Displacing (Low Temperature)	1	1, 2
VV-L-820C	Lubricating Oil, General Purpose (light)	6	
VV-1-825A(2)	Lubricating Oil, Refrigerant Compressor	1	3, 4
VV-L-001071A	Lubricating Oil, Steam Cylinder, Mineral	2	5, 6
MIL-L-2104D	Lubricating Oil, Internal Combustion Engine (heavy duty)	2	7-14
MIL-L-2105C(2)	Lubricating Oil, Gear, Multipurpose	3	15-20
MIL-L-3150B(2)	Lubricating Oil, Preservative, Medium	3	21
MIL-L-3572A	Lubricant, Colloidal Graphite in Oil	3	
MIL-L-3918A	Lubricating Oil, Instrument, Jewel Bearing, Nonspreading, Low Temperature	4	
MIL-L-6081C(2)	Lubricating Oil, Jet Engine	4	22, 23
MIL-1-6082D	Lubricating Oil, Aircraft Reciprocating Engine (piston)	4	24-27
MIL-L-6085B(1)	Lubricating Oil, Instrument, Aircraft, Low Volatility	5	28, 29
MIL-L-6086C	Lubricating Oil, Gear Petroleum Base	5	30-33

		Page Numbers Section BII	Page Numbers Section BIII
MIL-L-7808J	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base	5	34, 35
MIL-L-7870A	Lubricating Oil, General Purpose, Low Temperature	6	36, 37
MIL-L-9000G(4)	Lubricating Oil, International Combustion Engine, Diesel	6	38, 39
MIL-L-17331H	Lubricating Oil, Steam Turbine (noncorrosive)	7	40-41
MIL-L-21260C	Lubricating Oil, Internal Combustion Engine, Preservative	7	42-47
MIL-L-22851C(2)	Lubricating Oil, Aircraft Piston Engine (ashless dispersant)	8	48-49
MIL-L-23699C(1)	Lubricating Oil, Aircraft Turboprop and Turboshaft Engine, Synthetic Base	8	50-52
MIL-L-27502(1)	Lubricating Oil, Aircraft Turbine Engine, Ester Base	8	-
MIL-L-46152B(1)	Lubricating Oil, Internal Combustion Engine, Administrative Service	8	53-54
MIL-L-46167A	Lubricating Oil, Internal Combustion Engine, Arctic	9	55-58
MIL-L-0083176A	Lubricant, Instrument Bearing, Petroleum Base	9	68-69
MIL-L-83767B(1)	Lubricating Oil, Vacuum Pump Mechanical Ejector, Diffusion Ejector	9	-

LUBRICATING GREASES SPECIFICATIONS

		Page Numbers	
		Section BII	Section BIII
VV-G-632A(1)	Grease, Industrial, General Purpose	10	-
MIL-G-4343C	Grease, Pneumatic System	10	82-83
MIL-G-6032D	Grease, Plug Valve, Gasoline and Oil Resistant	10	84-85
MIL-G-10924D(1)	Grease, Automotive and Artillery	11	86-87
MIL-L-15719A(3)	Lubricating Grease (high-temperature) Electric Motor, Ball and Roller Bearings	11	88-89
MIL-G-21164D	Grease, Molybdenum Disulfied (for low and high temperatures)	11	90-91
MIL-G-23549C	Grease, General Purpose	12	92-93
MIL-G-23827B	Grease, Aircraft and Instrument, Gear and Actuator Screw	12	94-95
MIL-G-24139(1)	Grease, Multipurpose, Quiet Service	13	96
DOD-G-24508A(1)	Grease, High Performance, Multipurpose (Metric)	13	97
MIL-G-25013E	Grease, Aircraft, Ball and Roller Bearing	13	98-99
MIL-G-25537C	Grease, Aircraft, Helicopter Oscillating Bearing	13	100-101
MIL-G-27617D	Grease, Aircraft, Fuel and Oil Resistant	14	102-103
MIL-G-81322D	Grease, Aircraft, General Purpose Wide Temperature Range	14	104-105
MIL-G-81827A	Grease, Aircraft, High Load Capacity, Wide Temperature Range	14	106-107
MIL-G-83261(4)	Grease, Aircraft, Extreme Pressure, Antiwear	15	-

ANTISEIZE AND CORROSION COMPOUNDS SPECIFICATIONS

		Page Numbers Section BII	Page Numbers Section BIII
VV-P-236A(2)	Petrolatum, Technical	15	122
TT-S-1732	Antiseize Compound, White Lead Base, General Purpose	15	
MIL-A-907D	Antiseize Compound, High Temperature	16	123
MIL-C-5545C	Corrosion Preventive, Aircraft Engine, Heavy Oil Type	16	124
MIL-C-6529C(2)	Corrosion Preventive, Aircraft Engine	16	125-126
MIL-C-8188C	Corrosion Preventive Oil, Gas Turbine Engine, Aircraft Synthetic Base	16	127-128
MIL-S-8660C	Silicone Compound	17	133-134
MIL-C-11796B	Corrosion Preventive, Petrolatum, Hot Application	17	129
MIL-C-16173D(2)	Corrosion Preventive Compound, Solvent Cutback, Cold Application	17	130-132
MIL-T-83483A	Thread Compound, Antiseize, Molybdenum Disulfide-Petrolatum	18	
MIL-C-0083933A(3)	Corrosion Preventive Compound, Cold Application	18	135

HYDRAULIC AND DAMPING FLUID SPECIFICATIONS

		Page Numbers	
		Section BII	Section BIII
VV-B-680B(1)	Brake Fluid, Automotive	19	136
VV-D-1078B	Damping Fluid, Silicone Base, Dimethyl Polysiloxane	19	
MIL-H-5606E(1)	Hydraulic Fluid, Petroleum, Base, Aircraft, Missile and Ordnance	20	137-138
MIL-H-6083D(3)	Hydraulic Fluid, Petroleum Base for Preservation and Testing	20	139-140
MIL-F-17111B	Fluid, Power Transmission	20	143
MIL-H-17672D	Hydraulic Fluid, Petroleum, Inhibited	21	144-145
MIL-H-19457C(1)	Hydraulic Fluid, Fire Resistant	21	146
MIL-H-27601A(1)	Hydraulic Fluid, Petroleum Base, High Temperature, Flight Vehicle	22	141-142
MIL-H-46170B	Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base	22	147-148
MIL-B-46176(2)	Brake Fluid, Silicone Automotive, All Weather, Operational and Preservative	22	149
MIL-H-81019D	Hydraulic Fluid, Petroleum Base, Ultralow Temperature	23	150-151
MIL-S-81087C(1)	Silicone Fluid, Chlorinated Phenyl Methyl Polysiloxane	23	152
MIL-H-83282B	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft	23	153-154

NONSPECIFICATION HYDRAULIC FLUIDS

		Page Numbers Section III
Royco 820X	None	155
Chevron M2-V	None	157

LUBRICATING OILS

Properties and Uses \ Spec. or Name	VV-L-800C	VV-L-825A(2)	MIL-L-2104D	MIL-L-2105C(2)	MIL-L-3918A	MIL-L-6081C(2)	MIL-L-6082D
Fluid Type	Petroleum	Petroleum	Petroleum	Petroleum	Synthetic	Petroleum	Petroleum
Fluid Properties							
Foam-Resistant		X	X	X			
Wear-Resistant (E.P.)			X	X			
Corrosion Inhibiting	X		X	X	X	X	X
Oxidation-Resistant		X	X	X	X	X	
Water-Resistant	X						
Detergent Containing			X				
Good Storage Stability	X	X	X	X			X
Usable Temperature Range							
Low, °C (°F)	-40 (-40)	-37 (-35)	-23 (-10)	-34 (-30)	-40 (-40)	-54 (-65)	-18 (0)
High, °C (°F)	93 (200)	218 (425)	82 (180)	82 (180)	121 (250)	107 (225)	177 (350)
Flash Point, °C (°F)	135 (275)	232 (450)	204 (400)	191 (375)	149 (300)	107 (225)	216 (420)
Compatibility with:							
Rubber	X	X	X	X		X	X
Jet Fluel							
Rocket Fuel, Liquid							
Rocket Fuel, Solid							
"LOX"							
Other Fluids							
Uses							
General Purpose	X		X	X			
Bearings:							
Low Speed	X					X	
High Speed						X	X
Journal	X		X	X	X	X	X
Sliding Surfaces	X		X	X		X	X
Ball			X	X		X	X
Roller			X	X		X	X
Instrument					X		
Sintered							
Gears:							
Planetary							
Spur				X			
Worm				X			
Heavy Duty				X			
Light Duty				X			
Compressors:							
Reciprocating		X					
Rotary		X					
Engines:							
Inter. Comb.			X				
Aircraft, Reciprocating							X
Aircraft, Jet						X	
Electrical Equipment							
High Speed Equipment			X	X		X	X
Low Speed Equipment	X		X	X		X	X
Fluid Couplings							
Torque Converters							
Heat Transfer							
NOTES:		Four Oil types.	Three Oil grades.	Three Oil grades	For Use with jewel bearings.	Can be used as hyd. oil.	Nonadditive oil two grades.

LUBRICATING OILS

Spec. or Name / Properties and Uses	MIL-L-6085A(2)	MIL-L-6086B(1)	MIL-L-7808J	MIL-L-7870A	MIL-L-9000G(4)
Fluid Type	Synthetic1/	Petroleum	Synthetic1/	Petroleum	Petroleum
Fluid Properties					
Foam-Resistant		X	X		X
Wear-Resistant (E.P.)		X	X		X
Corrosion Inhibiting	X	X	X	X	X
Oxidation-Resistant	X	X	X	X	X
Water-Resistant		X		X	
Detergent Containing					X
Good Storage Stability	X	X			X
Usable Temperature Range					
Low, °C (°F)	-57 (-70)	-40 (-40)	-54 (-65)	-54 (-65)	-29 (-20)
High, °C (°F)	121 (250)	121 (250)	149 (300)	71 (160)	204 (400)
Flash Point, °C (°F)	185 (365)	154 (310)	204 (400)	129 (265)	
Compatibility with:					
Rubber	X-Syn.	X	X-Syn.	X	X
Jet Fluel					
Rocket Fuel, Liquid					
Rocket Fuel, Solid					
"LOX"					
Other Fluids					
Uses					
General Purpose	X			X	
Bearings:					
Low Speed	X	X	X	X	X
High Speed	X	X	X		X
Journal		X	X	X	X
Sliding Surfaces		X	X	X	X
Ball	X	X	X	X	X
Roller	X	X	X	X	X
Instrument	X			X	
Sintered				X	
Gears:					
Planetary			X		
Spur		X			
Worm		X			
Heavy Duty					
Light Duty		X	X		
Compressors:					
Reciprocating					
Rotary					
Engines:					
Inter. Comb.					Diesel
Aircraft, reciprocating					
Aircraft, Jet			X		
Electrical Equipment			X		
High Speed Equipment	X		X		
Low Speed Equipment	X		X	X	
Fluid Couplings					
Torque Converters					
Heat Transfer					
NOTES: 1/ Diester Oil.	Squirt can type applications.	Reduction gear boxes two grades.		Squirt can type applications see VV-L-800.	

LUBRICATING OILS

Spec. or Name / Properties and Uses	MIL-L-15019E	MIL-L-21260C	MIL-L-23699C(1)	MIL-L-25681D	Wide Temperature Oils: Brayco NPT3A	Du Pont Krytox-143
Fluid Type	Petroleum	Petroleum	Syn-thetic2/	Silicone	Synthetic	Synthetic
Fluid Properties						
Foam-Resistant		X	X		X	X
Wear-Resistant (E.P.)			X	X		
Corrosion Inhibiting	X	X	X			X
Oxidation-Resistant		X	X		X	X
Water-Resistant	X					
Detergent Containing						
Good Storage Stability	X		X	X		X
Usable Temperature Range						
Low, °C (°F)	-23 (-10)	-29 (-20)	-40 (-40)	-43 (-45)	-34 (-30)	-46 (-50)
High, °C (°F)	177 (350)	182 (360)	204 (400)	260 (500)	260 (500)	371 (700)
Flash Point, °C (°F)		182 (360)	232 (45)	274 (525)	260 (500)	732 (1350)
Compatibility with:						
Rubber	X	X	X-Syn.	X	X	X
Jet Fuel						X
Rocket Fuel, Liquid						X
Rocket Fuel, Solid						X
"LOX"						X
Other Fluids						X
Uses						
General Purpose	X					
Bearings:						
Low Speed	X	X	X	X	X	X
High Speed		X	X		X	X
Journal		X	X	X	X	X
Sliding Surfaces	X	X	X	X	X	X
Ball	X	X	X		X	X
Roller	X	X	X		X	X
Instrument						
Sintered						
Gears:						
Planetary			X		X	X
Spur					X	X
Worm	X					
Heavy Duty			X		X	
Light Duty	X	X	X		X	
Compressors						
Reciprocating						
Rotary						
Engines:						
Inter. Comb.		X				
Aircraft, Reciprocating						
Aircraft, Jet			X	Sliding surfaces		
Electrical Equipment						X
High Speed Equipment	X	X	X			X
Low Speed Equipment		X	X	X	X	X
Fluid Couplings						
Torque Converters						
Heat Transfer						
NOTES: 1/ Used in wick feed lubrication. 2/ Diester oil.	Contains a fatty acid ad-ditive.	Preserva-tive type oil.	Improved diester syn.	Contains MoS_2 addi-tive.	Ester base gear, box oil.	Hyd. fluid or turbine engine oil.

LUBRICATING OILS

Spec. or Name / Properties and Uses	Vac. Pump Oil Apiezon 1/	Use in Vacuum: Vac Kote 36234	Use in Vacuum: Apiezon 1/	Liquid Oxygen Compatible: Krytox 143	Liquid Oxygen Compatible: Vac Kote 48784	Liquid Oxygen Compatible: Halocarbon
Fluid Type	Hydrocarbon	Synthetic	Hydrocarbon	Synthetic	Synthetic	Fluorocarbon
Fluid Properties						
Foam-Resistant	X	X	X	X	X	X
Wear-Resistant (E.P.)		X			X	X
Corrosion Inhibiting	X	X				X
Oxidation-Resistant	X	X			X	X
Water-Resistant		X			X	
Detergent Containing						
Good Storage Stability	X	X	X	X	X	X
Usable Temperature Range						
Low, °C (°F)	-15 (5)	-48 (-55)	-1 (30)	-57 (-70)	-40 (-40)	-96 (-140)
High, °C (°F)	210 (410)	150 (502)	X	260 (500)	232 (450)	204 (400)
Flash Point, °C (°F)	246 (475)	288 (550)	310 (590)	None	None	None
Compatibility with:						
Rubber	X		X		X	X
Jet Fuel		X		X	X	
Rocket Fuel, Liquid				X	X	X
Rocket Fuel, Solid						
"LOX"				X	X	
Other Fluids		X	X	X		X
Uses:						
General Purpose						
Bearings:						
Low Speed		X	X	X	X	X
High Speed		X		X	X	
Journal		X	X	X	X	X
Sliding Surfaces	X	X	X	X	X	X
Ball		X		X	X	X
Roller	X	X	X	X	X	X
Instrument	X	X		X	X	X
Sintered		X		X		
Gears:						
Planetary		X			X	
Spur		X		X	X	X
Worm		X		X	X	X
Heavy Duty		X	X		X	X
Light Duty		X	X	X	X	X
Compressors:						
Reciprocating		X				X
Rotary						X
Engines:						
Inter. Comb.						
Aircraft, Reciprocating						
Aircraft, Jet						
Electrical Equipment					X	X
High Speed Equipment	X	X		X	X	
Low Speed Equipment	X	X		X	X	X
Fluid Couplings						X
Torque Converters						X
Heat Transfer						X
NOTES: 1/ Apiezon oils in different grades; see Section BIII for specific ranges.	For sealed systems.	For vacuum and space.	Oil for gland seals, etc.	Not for Al or Mg parts.	For vacuum and space.	

LUBRICATING OILS

Spec. or Name / Properties and Uses	Low Temperature		Low Volatility	Instrument Oils		
	Halocarbon Fluids	Fomblin Y	Du Pont Freon	Kendall SRG & KG-80	Royco No. 2	Anderol L-402
Fluid Type	Fluoro-carbon	Fluoro-carbon	Fluoro-carbon	Mineral	Synthetic	
Fluid Properties						
Foam-Resistant	X	X				
Wear-Resistant (E.P.)	X	X		X		
Corrosion Inhibiting	X	X	X			
Oxidation-Resistant	X	X	X	X	X	
Water-Resistant						
Detergent Containing						
Good Storage Stability	X	X		X	X	
Usable Temperature Range						
Low, °C (°F)	-79 (-110)	-73 (-100)	-71 (-95)	-26 (-15)	-62 (-80)	-59 (-75)
High, °C (°F)	260 (500)	260 (500)	204 (400)	260 (500)	210 (410)	149 (300)
Flash Point, °C (°F)	None	None	200(392)min.	288 (550)	191 (375)	227 (440)
Compatibility with:						
Rubber	X	X	X			
Jet Fuel						
Rocket Fuel, Liquid	X					
Rocket Fuel, Solid						
"LOX"	X	X				
Other Fluids		X				
Uses:						
General Purpose						
Bearings:						
Low Speed	X	X	X			
High Speed						
Journal	X	X	X			
Sliding Surfaces	X	X	X			
Ball	X	X	X	X	X	X
Roller	X	X	X	X	X	X
Instrument	X	X	X	X	X	X
Sintered						
Gears:						
Planetary						
Spur	X	X				
Worm	X	X				
Heavy Duty	X	X				
Light Duty	X	X	X	X	X	X
Compressors:						
Reciprocating	X	X				
Rotary	X	X				
Engines:						
Inter. Comb.						
Aircraft, Reciprocating						
Aircraft, Jet						
Electrical Equipment	X	X				
High Speed Equipment				X	X	X
Low Speed Equipment	X	X	X	X	X	X
Fluid Couplings	X	X				
Torque Converters	X	X				
Heat Transfer	X	X				
NOTES:	Good lub. not for Al or Mg parts.	not for Al or Mg parts.	Includes many fluids.	Three grades of gryo oil.		

LUBRICATING GREASES

Spec. or Name / Properties and Uses	MIL-G-4343C	MIL-G-6032D	MIL-G-10924D(1)	MIL-L-15719A(3)
Lubricant Properties:				
Base Oil	Silicone	No Limit	Pet/Syn.	Silicone
Thickener	X	X	X	Lith.-Soap
Dropping Point, °C (°F)	163 (325)	127 (260)		191 (375)
Usable Temp. Range				
Low, °C (°F)	-54 (-65)	-29 (-20)	-54 (-65)	-18 (0)
High, °C (°F)	93 (200)	149 (300)	79 (175)	149 (300)
Wear-Resistant (E.P.)				
Corrosion-Inhibiting	X	X	X	X
Oxidation-Resistant	X	X	X	X
Water-Resistant	X	X	X	X
Good Storage Stability	X	X	X	X
Compatibility with:				
Rubber & Neoprene	X	X		
Paint & Lacquers	X	X		
Plastics	X	X		
Jet Fuel & Gasoline		X		
Solvents		X		
Acids				
Rocket Fuels, Liquid				
Rocket Fuels, Solids				
"LOX"				
Nitrogen Tetroxide				
Impact Compatibility				
"LOX" (AMBA)				
Nitrogen Tetroxide				
Uses:				
General Purpose		X	X	
Electrical Equipment	X			X
Aircraft	X	X		X
Instrument				
Ball or Roller Bearings				X
Low Speed				X
Medium Speed				X
High Speed				X
Plain Bearings	X	X	X	No
Sliding Surfaces	X	X	X	No
Gears:				
Spur			X	No
Worm			X	No
Planetary				No
NOTES:	Pneumatic system lubricant, rubber to metal.	Plug valve grease, resist fuels, water and some solvents, low evaporation. Two types.	Corrosion resistant lubricant for sliding surfaces; automotive and artillery equipment.	High temperature grease for ball and roller bearings.

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LUBRICATING GREASES

Properties and Uses \ Spec. or Name	MIL-G-21164D	MIL-G-23549C	MIL-G-23827B	MIL-G-25013E	MIL-G-25537C	MIL-G-27617D	MIL-G-81322D
Lubricant Properties:							
Base Oil	Pet/Syn.	Petroleum	Synthetic		Petroleum	Synthetic	Pet/Syn.
Thickener	X	Nonsoap	X		X	Vydax	X
Dropping Point, °C (°F)	163 (325)	232 (450)	163 (325)	232 (450)	138 (280)	-	260 (500)
Usable Temp. Range							
Low, °C (°F)	0 (32)	-18 (0)	-54 (-65)	-73 (-100)	-54 (-65)	-34 (-30)	-54 (-65)
High, °C (°F)	121 (250)	177 (350)	121 (250)	232 (450)	71 (160)	288 (550)	177 (350)
Wear-Resistant (E.P.)		X	X		X	X	X
Corrosion Inhibiting	X	X	X	X	X		X
Oxidation-Resistant	X	X	X	X	X	X	X
Wear-Resistant	X	X	X	X	X	X	X
Good Storage Stability	X	X	X	X	X	X	X
Compatibility with:							
Rubber & Neoprene		X			X		
Paint & Lacquers		X			X		
Plastics		X			X		
Jet Fuel & Gasoline						X	
Solvents						X	
Acids							
Rocket Fuels, Liquid						X	
Rocket Fuels, Solids							
"LOX"						X	
Nitrogen Tetroxide							
Impact Compatibility (AMBA)						X	
"LOX"						X	
Nitrogen Tetroxide							
Uses:							
General Purpose	X	X	X		X	X	X
Electrical Equipment						X	
Aircraft	X	X	X	X	X		X
Instrument			X			X	
Ball or Roller Bearings	X	X		X	X	X	X
Low Speed	X	X		X	X	X	X
Medium Speed	X	X		X	X	X	X
High Speed				X			X
Plain Bearings	X	X		X	X	X	X
Sliding Surfaces	X	X		X	X	X	X
Gears:							
Spur	X	X	X	X	X	X	X
Worm	X	X	X	X	X	X	X
Planetary				X	X	X	X
NOTES:	Shear-resistant wide temperature grease. Metal-to-metal anti-friction bearings. Contains micro-MoS_2.	Contains MoS_2 high pressure, medium speed grease, for sliding surfaces and rust protection.	Antifriction bearing grease for low temperature and torque.	Aircraft ball and roller bearings. Extreme high and low temperature.	Bearing lubricant for oscillating motion. Helicopter gear, etc.		Wide temperature general purpose grease. Antifriction bearings, gear boxes and plain bearings.

LUBRICATING GREASES

Spec. or Name / Properties and Uses	Braycote 617	Apiezon Greases	Micronic 803	Krytox Greases	Halocarbon Greases
Lubricant Properties:					
Base Oil	Perfluoro-carbon	Hydrocarbon	Synthetic	Synthetic	Synthetic
Thickener	TFE	Some grades		Vydax	Sil. Gal/Wax
Dropping Point, °C (°F)			253 (488)	>232 (>450)	149 (300)
Usable Temperature Range					
Low, °C (°F)		-40 (-40)	-23 (-10)	-54 (-65)	-40 (-40)
High, °C (°F)		240 (464)	260 (500)	288 (550)	260 (500)
Wear-Resistant (E.P.)	X		X	X	
Corrosion Inhibiting	X				
Oxidation-Resistant	X	X	X	X	X
Water-Resistant	X	X		X	X
Good Storage Stability	X	X		X	X
Compatibility with:					
Rubber & Neoprene	X	X			X
Paint & Lacquers	X	X			
Plastics	X				X
Jet Fuel & Gasoline		X	X	X	
Solvents	X	X	X	X	X
Acids	X	X			
Rocket Fuels, Liquid	X		X	X	
Rocket Fuels, Solids	X				
"LOX"	X		X	X	
Nitrogen Tetroxide	X				
Impact Compatibility					
(AMBA)			X	X	
"LOX"	X		X	X	
Nitrogen Tetroxide	X		X		
Uses:					
General Purpose		X	X	X	X
Electrical Equipment		X		X	X
Aircraft				X	
Instrument	X			X	X
Ball or Roller Bearings		X	X	X	X
Low Speed	X		X	X	X
Medium Speed		X	X	X	X
High Speed					
Plain Bearings	X	X	X	X	X
Sliding Surfaces	X	X	X	X	X
Gears:					
Spur			X	X	X
Worm			X	X	X
Planetary				X	X
NOTES:	Manufactured in accordance with Formula PD-817, Frankford Arsenal.	Vaccuum and laboratory grease. High purity. Seven greases, wide range of properties.	High vacuum grease with oxidizer. Fuel resistant.	Seven high temperature multi-purpose greases, missile and space usage.	Eleven synthetic greases, wide property range. Not for use in aluminum or magnesium parts.

LUBRICATING GREASES

Properties and Uses / Spec. or Name	Vac Kote 37963C	Vac Kote 37987	Vac Kote 44147	Vac Kote 44177
Lubricant Properties:				
Base Oil	Synthetic	Synthetic	Synthetic	Hydrocarbon
Thickener	Organic/Inorganic	Nonmelt Organic	Organic/Inorganic	Inorganic
Dropping Point, °C (°F)	204 (399)	> 204 (> 399)	> 250 (> 482)	> 175 (> 347)
Usable Temperature Range				
Low, °C (°F)	-73 (-100)	-62 (-80)	-62 (-80)	-20 (-4)
High, °C (°F)	200 (400)	121 (250)	150 (300)	100 (212)
Wear-Resistant (E.P.)	X	X	X	X
Corrosion Inhibiting	X	X	X	X
Oxidation-Resistant	X	X	X	
Water-Resistant	X	X	X	
Good Storage Stability	X	X	X	X
Compatibility with:				
Rubber & Neoprene	X			X
Paint & Lacquers	X	X	X	X
Plastics	X			X
Jet Fuel & Gasoline		X	X	X
Solvents	X	X	X	X
Acids	X			
Rocket Fuels, Liquid				
Rocket Fuels, Solids				
"LOX"				
Nitrogen Tetroxide	X			
Impact Compatibility (AMBA)				
"LOX"				
Nitrogen Tetroxide				
Uses:				
General Purpose	X	X	X	X
Electrical Equipment	X			X
Aircraft	X	X	X	X
Instrument	X	X	X	X
Ball or Roller Bearings				
Low Speed		X		
Medium Speed	X	X	X	X
High Speed	X		X	
Plain Bearings		X		X
Sliding Surfaces	X	X	X	X
Gears:				
Spur	X	X	X	X
Worm	X			X
Planetary	X		X	X
NOTES:	High temperature, corrosion resistant, water resistant, for space and vacuum.	For space and vacuum applications. Smooth operating. Suitable near optics.	For space and vacuum. Good for ultra-high speed.	For space and vacuum. Very good E.P. properties and wear resistance.

ANTISEIZE AND CORROSION PREVENTIVE COMPOUNDS

Spec. or Name / Properties and Uses	TT S-1732	Antiseize Compounds MIL-T-5544C	VV-P-236A(2)	MIL-S-8660C	Corrosion Preventive Materials MIL-C-8188C	MIL-C-11796B
Lubricant Properties:						
Base Oil	Petroleum	Petroleum	Petroleum	Silicone	Diester	Petroleum
Thickener	White Lead	Graphite				
Dropping Point °C (°F)			38 (100)			135 (57)
Usable Temperature Range						
Low, °C (°F)	-40 (-40)	0 (32)	-18 (0)	-54 (-65)	-54 (-65)	
High, °C (°F)	177 (350)	538 (1000)	38 (100)	204 (400)	149 (300)	57 (135)
Wear-Resistant (E.P.)					X	
Corrosion Inhibiting	X	X	X	X	X	X
Oxidation-Resistant	X	X	X	X	X	X
Water-Resistant	X	X	X	X	X	X
Good Storage Stability	X		X	X	X	X
Compatibility with:						
Rubber & Neoprene	X		X	X	X-Syn.	X
Paint & Lacquers	X		X	X	X	X
Plastics	X		X	X	X	X
Jet Fuel & Gasoline						
Solvents			X			
Acids						
Rocket Fuels, Liquid						
Rocket Fuels, Solids						
"LOX"	No	No				
Nitrogen Tetroxide						
Impact Compatibility						
"LOX" (AMBA)						
Nitrogen Tetroxide						
Uses:						
General Purpose Lubricant			X	X	X	
Electrical Equipment		No	X	X		
Aircraft			X	X	X	
Instrument			X	X	X	
Ball or Roller Bearings			X	X	X	
Low Speed			X	X	X	
Medium Speed					X	
High Speed					X	
Plain Bearings			X	X	X	
Sliding Surfaces			X	X	X	
Gears:						
Spur			X	X	X	
Worm			X	X	X	
Planetary			X		X	
NOTES:	Antiseize compound for threaded fitting, steam, water and oil system to 150 psi. See BII-29 Section 3.1.2.	Graphite antiseize high-temperature compound for spark plugs, etc.	Light duty, homogeneous material not for heavy loads or high temperature. Intended as preservative from moisture and corrosion.	For seals and electrical equipment, resist corrosion and moisture.	Oil-type corrosion preventive. Short life lubricant (25 hr.). Costly.	Hot application corrosion preventive for ferrous or nonferrous metals. Dip or brush application.

HYDRAULIC AND SILICONE FLUIDS

Spec. or Name / Properties and Uses		Hydraulic Fluids			Silicone Fluids	
	MIL-H-5606E(1)	MIL-H-6083D(3)	MIL-H-27601A(1)	BRAYCO Micronic 762	VV-D-001078B (GSA-FSS)	MIL-S-81087C(1)
Fluid Type	Petroleum	Petroleum	Pet/Syn. Hyd.	Petroleum	Silicone	Silicone
Fluid Properties						
Foam-Resistant	X	X	X	X		
Wear-Resistant	X	X	X	X		
Corrosion Inhibiting	X	X	X	X		
Oxidation-Resistant			X	X		
Water-Resistant					X	
Detergent Containing						
Good Storage Stability	X	X	X	X		
Usable Temerature Range						
Low, °C (°F)	-54 (-65)	-54 (-65)	-40 (-40)	-68 (-90)		-73 (-100)
High, °C (°F)	135 (275*)	93 (200)	316 (600*)	99 (210)		260 (500)
Flash Point, °C (°F)	93 (200)	93 (200)	182 (360)	93 (200)		
Compatibility with:						
Rubber	X	X	X	X		
Jet Fuel						
Rocket Fuel, Liquid						
Rocket Fuel, Solid						
"LOX"						
Other Fluids						
Uses:						
General Purpose						
Bearings:						
Low Speed	X	X	X	X		X
High Speed						
Journal	X	X	X	X		X
Sliding Surfaces	X	X	X	X		
Ball	X	X	X	X		X
Roller						
Instrument						X
Sintered						X
Gears:						
Planetary						X
Spur						X
Worm						X
Heavy Duty						
Light Duty						X
Compressors:						
Reciprocating						
Rotary						
Engines:						
Inter. Comb.						
Aircraft, Reciprocating						
Aircraft, Jet						
Electrical Equipment					X	X
High Speed Equipment						
Low Speed Equipment	X	X	X	X		X
Fluid Couplings	X	X	X	X		X
Torque Converters	X	X	X	X		X
Heat Transfer				X	X	X
NOTES:	* Closed system.	Preservative type hyd. fluid.	* Closed system.	Ultra-low temp. hyd. fluid.	See Sec. II, Item 4.1.2.	See Sec. II, Item 4.1.18.

HYDRAULIC AND SILICONE FLUIDS

Spec. or Name / Properties and Uses	Silicone Fluids: General Electric	Silicone Fluids: Dow Corning	Hydraulic Fluids: Chevron M2-V	Hydraulic Fluids: Royco 820X
Fluid Type	Many fluids having wide range of prop- erties.	Many fluids having wide range of prop- erties.	Silicate Ester	Synthetic
Fluid Properties				
Foam-Resistant			X	X
Wear-Resistant (E.P.)			X	X
Corrosion Inhibiting				X
Oxidation-Resistant			X	X
Water-Resistant				
Detergent Containing				
Good Storage Stability			X	X
Usable Temperature Range				
Low, °C (°F)			-54 (-65)	-73 (-100)
High, °C (°F)			260 (500)	177 (350)
Flash Point, °C (°F)			216 (420)	216 (420)
Compatibility with:				
Rubber			WRT-Elas- tomers	Limited
Jet Fuel				
Rocket Fuel, Liquid				
Rocket Fuel, Solid				
"LOX"				
Other Fluids				X
Uses:				
General Purpose				
Bearings:				
Low Speed			X	X
High Speed			X	X
Journal			X	
Sliding Surfaces			X	X
Ball				
Roller				
Instrument				
Sintered				
Gears:				
Planetary				
Spur				
Worm				
Heavy Duty				
Light Duty				
Compressors:				
Reciprocating			X	X
Rotary			X	X
Engines:				
Inter. Comb.				
Aircraft, Reciprocating				X
Aircraft, Jet				X
Electrical Equipment				
High Speed Equipment				X
Low Speed Equipment				X
Fluid Couplings			X	X
Torque Converters			X	
Heat Transfer			X	X
NOTES:	See Section III.	See Section III.	Nontoxic, shear and thermal sta- ble. Aircraft systems.	For missile systems.

B-II. LUBRICATING MATERIALS - GENERAL DESCRIPTION

This section contains a listing of all lubricant materials that have been selected for inclusion in the handbook. In addition, there are several other material listings that do not appear on data sheets in Section III. It is felt that certain of these may be of interest, but specific data could not be obtained on them.

The lubricants included have been subdivided into two main classes; those conforming to military specifications and nonspecification materials. Again, the two main classes have been subdivided into the general classes of oils, greases, hydraulic fluids and compounds.

The remainder of this section contains an ascending numerical listing of lubricants by classes, along with general descriptions of their chemical nature, limitations and use areas.

1.0 DESCRIPTION OF SPECIFICATION LUBRICANT MATERIALS

1.1 Lubricating Oils

1.1.1 VV-L-800C: Lubricating Oil, General Purpose, Preservative (Water-Displacing, Low Temperature) (Military Symbol PL-S, NATO Code: 0-190)

General characteristics: General purpose lubricating oil for protection of parts from corrosion and low temperature applications. Composition of oil is a petroleum fraction and additives, as required to meet specifications. This oil is used in many applications in place of MIL-L-7870.

Uses: General purpose preservative oil, intended for lubrication and protection against corrosion of small arms, automatic weapons, freeze mechanisms, squirt-can aircraft applications and whenever a general purpose, water-displacing, low temperature lubricating oil is required. Recommended usable temperature range, -40°C to 129°C (-40°F to 200°F). Usage below -40°C (-40°F) requires test application before adoption.

Limitations: Should not be used on aircraft equipment such as guns where operations at -54°C (-65°F) is necessary. Do not use this oil in food-processing or food-handling equipment which may contact food. Do not store gas-pressurized can of this oil at temperatures above 84°C (120°F).

1.1.2 VV-L-825A(2): Lubricating Oil, Refrigerant Compressor (NATO Code: None)

General characteristics: Refrigerant compressor lubricating oils consisting of well-refined petroleum oil base with additives to provide antifoam, pour point depressant, antioxidant, and viscosity improvers permitted. Available in four types.

Uses: For lubricating of compressor units in refrigeration equipment:

Type I (NATO Code 0-282) - reciprocating-type compressor (sulfur dioxide).
Type II (NATO Code 0-283) - reciprocating-type compressor (using Freon 12, methyl chloride, or ammonia).

Type III (NATO Code 0-284) - two-stage rotary type compressors.
Type IV (no NATO Code) - for use with Freon 22 type refrigerants.

Limitations: Usable temperature range:

Type I: -37°C to +149°C (-35°F to 300°F).
Type II: -36°C to +163°C (-32°F to +325°F).
Type III: -18°C to +218°C (0°F to +425°F).
Type IV: -37°C to +149°C (-35°F to +300°F).

1.1.3 VV-L-001071A: Lubricating Oil, Steam Cylinder, Mineral (NATO Code: None)

General characteristics: This specification covers one type and two grades of mineral oil suitable for lubricating steam cylinders. Material shall contain no additives other than pour point depressants.

Uses: Military symbol 5190 (NATO Code 0-258) lubricating oil intended for use in saturated and superheated steam systems.

Military symbol 5230 (no NATO symbol) lubricating oil is essential to the lubrication of uniflow steam engine cylinders.

Limitations: Minimum pour point of both oils is 16°C (60°F). This specification encompasses the scope and incorporates the requirements of VV-0-611 and MIL-L-15018B. Military symbol 5190 oil replaces military symbol 5150 oil included in MIL-L-15018B.

1.1.4 MIL-L-2104D: Lubricating Oil, Internal Combustion Engine Tactical Service

General characteristics: This specification covers four viscosity grades (10W, 30, 40, 15W-40) of engine lubricating oils derived from petroleum fractions, synthetically prepared compounds or a combination of these two types of products. These may be virgin or re-refined stocks or a combination thereof. The stocks shall be compounded with such functional additives (detergents, dispersants, oxidation inhibitors, corrosion inhibitors, etc.) as are necessary to meet the specified requirements.

Uses: The engine lubricating oils are suitable for lubrication of reciprocating internal combustion engines of both spark-ignition and compression-ignition types and for power transmission fluid applications in equipment used in tactical service.

Limitations: Recommended ambient temperature ranges:

Grade 10W	-25°C (-13°F) to 5°C (41°F)
Grade 30	-10°C (14°F) to 30°C (86°F)
Grade 40	0°C (32°F) to above 30°C (86°F)
Grade 15W-40	-15°C (5°F) to above 30°C (86°F)

NOTE: For power transmission, hydraulic system and nonhypoid gear box applications, these lubricants may be used at all temperatures above the low temperature recommendations.

1.1.5 MIL-L-2105C(2): Lubricating Oil, Gear, Multipurpose (NATO Code: None)

General characteristics: This specification covers one type and three viscosity grades (80, 90 and 140) of a multipurpose lubricating oil consisting of a petroleum or synthetically prepared base fluid and additives necessary to meet specification requirements. It has good moisture corrosion, load-carrying and extreme pressure characteristics as well as satisfactory thermal-oxidation stability. Operating temperature range is not specified, but is not recommended for extremely low temperatures below -34°C (-30°F).

Uses: Gear lubricant intended for automatic gear units, heavy-duty industrial type inclosed gear units, steering gears and fluid lubricated universal joints of automotive equipment (conditions of high speed and shock loading).

Limitations: These oils must not contain any re-refined components.

1.1.6 MIL-L-3150B(2): Lubricating Oil, Preservative, Medium (Military Symbol PL-M (NATO Code: 0-192)

General characteristics: Preservative lubricating oil consisting of a petroleum fraction containing additives necessary to meet specification requirements.

Uses: Intended for lubrication and protection against corrosion of ferrous and nonferrous metals, interior of gear assemblies, transmissions, differentials, etc. Not intended for the protection of internal combustion engines.

Limitations: This lubricating oil should not be used in food-processing or food-handling machinery on surfaces that may contact food. Storage temperature range -40°C to +54°C (-40°F to +130°F).

1.1.7 MIL-L-3572A: Lubricant, Colloidal Graphite in Oil (NATO Code: None)

General characteristics: This specification covers three grades (A - light, B - medium, and C - heavy) of lubricant consisting of stabilized colloidal electric furnace graphite dispersed in refined mineral lubricating oils. Operating temperature ranges are not specified.

Uses: Grade A oil is suitable for machine gun housing guides, windshield wipers, and other lightly loaded, sliding members exposed to weather. Grade B oil is suitable for gear trains of hot running torpedoes. Grade C oil is suitable for the lubrication of medium or heavy-duty gun slides without causing excessive resistance to counter-recoil at ambient temperatures down to -23°C (-10°F). It should retain sufficient lubricating properties to permit free recoil and counter-recoil when the gun is heated as a result of sustained fire.

Limitations: It is not recommended for use in electrical equipment or for extremes of temperature.

1.1.8 MIL-L-3918A: Lubricating Oil, Instrument, Jewel Bearing, Nonspreading, Low Temperature (NATO Code: None)

General characteristics: A nonpetroleum, special purpose lubricant consisting of a mixture of approximately 60% benzyl phenylundicarbonate, 40% diethylene glycol di-n-caproate with small amounts of dodecylpiperidine sterate (for oiliness) and p-test-butyl catechol (antioxidant). Although usable temperature range is not specified, this oil has good lubricating qualities at low to moderate temperatures.

Uses: This oil is intended for lubrication of steel pivot and jewel bearing combinations in timepieces and other fine instruments. It will allow operation of most instrument mechanisms at temperatures as low as -40°C (-40°F).

Limitations: This oil should not be used on instrument-type ball bearings because of the nonspreading properties of the material. Also not recommended for use at high temperatures above 121°C (250°F); nor on rough metal surfaces or in an environment containing dust or other foreign material that would reduce its nonspreading qualities.

1.1.9 MIL-L-6081C(2): Lubricating Oil, Jet Engine

Oil Grade	NATO Code
1005	0-132
1010	0-133

General characteristics: This specification covers two grades of jet engine lubricating oil consisting of a refined petroleum base and may contain oxidation inhibitors and pour point depressant to meet specification requirements. Operating temperature range is not specified but is usable as low as -40°C (-40°F) and -54°C (-65°F) depending on the grade of oil.

Uses: This oil is intended for lubrication of specific models of aircraft turbine engines.

Limitations: This oil shall not be used in aircraft turbine engines for which other lubricants are specified. Oil shall not contain any viscosity index improver.

1.1.10 MIL-L-6082D: Lubricating Oil, Aircraft Reciprocating Engine (Piston) (Grade 1068, NATO Code 0-113, and Grade 1100, NATO Code 0-117)

General characteristics: Specification covers two grades of refined petroleum product that may contain a pour point, but no other additive.

Uses: Intended for use in an aircraft reciprocating engine and for blending type IIa and type IIIa oils under MIL-L-22851.

Limitations: Temperature range: Grade 1065, -18°C to +149°C (0°F to 300°F); Grade 1100, -12°C to +177°C (10°F to 350°F).

1.1.11 MIL-L-6085B(1): Lubricating Oil, Instrument, Aircraft, Low Volatility (NATO Code: 0-147)

General characteristics: This oil is a low volatility, non-petroleum base lubricating oil with wide temperature, corrosion and oxidation properties. Composition consists of a synthetic base oil (carboxylic acid ester) with additives to impart oxidation stability and corrosion protection properties. It contains no pour point depressants or VI improvers. The operating temperature range is not specified but has a pour point of -57°C (-70°F) and a flash point of 185°C (365°F).

Uses: Intended for use in aircraft instruments, electronic equipment, or where a low evaporation oil is required for both high and low temperatures, and where oxidation and corrosion resistances are desired.

Limitations: The finished fluid must contain no resins, gums, rubber, fatty oils, oxidized hydrocarbons or other additives not approved by the qualifying agency. Containers for the fluid must have a warning note that this fluid may soften paint, natural rubber or neoprene and electrical insulating materials.

1.1.12 MIL-L-6086C: Lubricating Oil, Gear, Petroleum Base

Oil Grade	NATO Code
L (light)	0-153
M (medium)	0-155

General characteristics: This specification covers two grades of gear oil consisting of a well-refined mineral oil containing a suitable load-carrying additive. Operating temperature ranges are not specified but these oils have a pour point of -40°C to -29°C (-40°F to -20°F) and a flash point of +138°C to +154°C (+280°F to +310°F) depending upon the grades of oil.

Uses: Intended for the lubrication of aircraft gears at low temperature. Grade L oil is for extreme low temperatures. Grade M is for general use in aircraft gear mechanisms.

Limitations: This oil contains extreme pressure additives and is not suitable for lubrication of internal combustion engines. The EP additives in this oil shall not be corrosive, or cause excessive foaming and must not precipitate upon diluting the oil with additional mineral oil base stock.

1.1.13 MIL-L-7808J: Lubricating Oil, Aircraft Turbine Engine, Synthetic Base (NATO Code: 0-148)

General characteristics: This oil is a nonpetroleum base lubricating oil for aircraft turbine engines and similar equipment. It has good storage, wide temperature and environment limits. This oil shall be a synthetic base fluid (carboxylic acid ester), but additives to impart oxidation stability, corrosion-preventive properties, and antiwear properties are permitted.

The operating temperature range is not specified, but the nominal operating temperature range is -54°C to 149°C (-65°F to 300°F).

Uses: This oil is intended as a lubricating oil in spedific models of aircraft turbine engines, helicopter transmissions and similar equipment.

Limitations: This oil should not be mixed with any oils other than MIL-L-7808 oils and revisions thereto. If the oil contains tricresyl phosphate additive, the supplier must certify that it contains less than 1.0% of the ortho isomer. It should not be used in systems designed solely for petroleum lubricants, as serious deterioration of rubber parts coatings and other organic materials may result.

1.1.14 MIL-L-7870A: Lubricating Oil, General Purpose, Low Temperature

General characteristics: This specification covers one grade of general purpose, low-temperature lubricating oil. The oil shall be a fraction of petroleum refined to meet the requirements of this specification, and containing additive materials to impart corrosion-protective and oxidation-resistant properties.

Uses: The oil covered by this specification is intended for use wherever a general purpose, low temperature, lubricating oil is required. It is especially designed for use where an oil of low evaporation, possessing rust protective properties is desired.

Limitations: Failure of any sample of oil to conform to any one of the requirements of this specification shall be cause for rejection of the lot represented. Oil which has been rejected may be reworked or replaced to correct the defects, and resubmitted for acceptance. Before resubmitting, full particulars concerning previous rejection and the action taken to correct the defects found in the original shall be furnished to the Inspector. Oils rejected after retest shall not be resubmitted without the specific approval of the procuring activity.

1.1.15 VV-L-820C: Lubricating Oil, General Purpose (light) (NATO Code: NONE)

General characteristics: This specification covers a refined, low-viscosity petroleum product free from any extraneous material and objectionable odor. Usable temperature range is not specified but should be restricted to moderate temperatures.

Uses: Intended for lubrication of miscellaneous equipment requiring a light lubricating oil, such as typewriters, sewing machines, etc.

Limitations: Not recommended for extreme temperature ranges, low or high, nor for high loads.

1.1.16 MIL-L-9000G(4) (Ships): Lubricating Oil, Shipboard Internal Combustion Engine, High Output Diesel (Military Symbol 9250, NATO Code: 0-274)

General characteristics: Homogeneous blend of petroleum base lubricating oil stock and additives, as necessary, to meet the specification requirements as a lubricant for high-output marine diesel engine and parts. When contaminated with sea water, this oil must still provide lubrication within specified limits.

Uses: Intended for use in advanced design high-output shipboard main propulsion and auxiliary diesel engines using fuel conforming to MIL-F-16884.

Limitations: Recommended temperature range, -12°C to +190°C (+10°F to 390°F). This oil is not suitable for crankcase use of gasoline engines. Future procurement of oils formerly covered by military symbol oils 9110 and 9500 of MIL-L-9000F should use applicable grades of MIL-L-2104. Requirement for military symbol 9170 of MIL-L-9000F is not included because of limited usage.

1.1.17 MIL-L-17331H: Lubricating Oil, Steam Turbine (Noncorrosive) (NATO Code: 0-250, Military Symbol: 2190-TEP)

General characteristics: This liquid is a petroleum base steam turbine lubricating oil which may or may not contain additives. The liquid is noncorrosive and has a work factor of 0.9 min and is a homogeneous blend of virgin petroleum lubricating oil plus required additives to meet requirements of the specification. The operating temperature range is not specified, but general usage is between -7°C and 88°C (+20°F and 190°F) with short duration elevated temperature use to 121°C (250°F).

Uses: This liquid is a steam turbine lubricating oil for main turbines and gears, auxiliary turbine installations, certain hydraulic equipment, general mechanical lubrication, and air compressors.

Limitations: The liquid has limited use as hydraulic fluid and is not for low temperatures (minimum recommended temperature is -7°C (+20°F)). It is compatible with reference oils furnished by the government and other oils to this specification. Additives if used shall contain no chlorine or chlorinated materials.

1.1.18 MIL-L-21260C: Lubricating Oil, Internal Combustion Engine, Preservative

Product Symbol	NATO Code
PE-1 (light)	C-640
PE-2 (medium)	C-642
PE-3 (heavy)	C-644

General characteristics: This specification covers three viscosity grade preservative lubricating oils used as lubricants in spark-ignition and compression-ignition types of reciprocating internal combustion engines. The finished oil may be a petroleum base of a synthetically prepared product, or a combination thereof, with or without additives. However, no re-refined components are permitted. The operating temperature ranges are not specified.

Uses: The oil is a crankcase oil for diesel or spark-ignition type internal combustion engines. Although intended principally as a static preservative, this oil may be used as an operating lubricant for short periods, and for some hydraulic equipment. It is compatible with other fluids to this specification and MIL-L-2104.

Limitations: This oil is not for low temperature usage and not generally for gear box applications.

1.1.19 MIL-L-22851C(2): Lubricating Oil, Aircraft Piston Engine (Ashless Dispersant) (NATO Code: None)

General characteristics: This specification covers one type of additive concentrate and two types of lubricating oil blended of lubricating oil and additives to impart oxidation stability and dispersant properties to aircraft engine oils qualified under MIL-L-6082, Grade 1100 and Grade 1065. Type I (no NATO code), additive concentrate; Type II (NATO Code 0-128), lubricating oil blend; Type III (NATO Code 0-123), lubricating oil blend.

Uses: These lubricating oils are intended for use in aircraft piston engines and must give a minimum of 1,000 hr satisfactory service.

Limitations: Type II is for engines having a normal rating of 1,000 hp or greater. Type III is for engines having a normal rating of 1,000 or lower.

1.1.20 MIL-L-23699C(1): Lubricating Oil, Aircraft Turbine Engine, Synthetic Base (NATO Code 0-156)

General characteristics: One grade of aircraft gas turbine engine lubricating oil is not limited in composition, except that it must not contain any organic compounds of titanium. Similar to MIL-L-7808 but has a higher viscosity and pour point.

Uses: Intended for use in specific models of aircraft gas turbine engines, helicopter transmissions and other aircraft machine gear boxes in the temperature range -40°C to +200°C (-40°F to +400°F). May be used where MIL-L-7808 has previously been used.

Limitations: Not suitable below -40°C (-40°F). Tricresyl phosphate additives, if present, shall not be more than 1% of the ortho isomer.

1.1.21 MIL-L-27502(1): Lubricating Oil, Aircraft Turbine Engine, Ester Base

General characteristics: Composition is not limited except organometallic compounds of titanium are prohibited and the basestock must be an ester. If this lubricating oil contains a tricresyl phosphate additive, the manufacturer must certify that not more than one percent of the tricresyl phosphate additive is orthoisomer.

Uses: This oil is intended for use in special aircraft turbine engine applications requiring a synthetic ester base oil with an approximate temperature range capability from -40°C (-40°F) to +220°C (+428°F).

Limitations: Before any change is made in quality, composition, source of ingredients, or site of manufacturing, blending, or rebranding, the supplier must request the qualifying activity to determine if requalification is required.

1.1.22 MIL-L-46152B(1): Lubricating Oil, Internal Combustion Engine, Administrative Service

General characteristics: This specification covers engine oils suitable for lubrication of commercial-type reciprocating internal combustion engines of both spark-ignition and compression-ignition types used in administrative service. These engine lubricants shall be of the following viscosity grades: 10W, 30, 5W-20, 10W-30, and 15W-40.

Uses: The lubricating oils covered by this specification are intended for crankcase lubrication of: (1) gasoline engines in passenger cars and light to medium duty trucks operating under manufacturers' warranties, and (2) lightly supercharged diesel engines operated in moderate duty.

Limitations: These lubricating oils are for use, as defined by vehicle manufacturers, when ambient temperatures are above -35°C (-31°F).

1.1.23 MIL-L-46167A: Lubricating Oil, Internal Combustion Engine, Arctic

General characteristics: This specification covers one grade of engine oil suitable for ground equipment. Arctic is the viscosity grade for this lubricant.

Uses: This lubricating oil is intended for crankcase lubrication of reciprocating spark-ignition and compression-ignition engines when ambient temperatures are between -55°C (-67°F) and 5°C (41°F). In addition, this lubricating oil is intended for use in arctic regions as an all-weather transmission fluid for ground equipment.

Limitations: The aforementioned 5°C (41°F) temperature limit only applies when the expected low temperature will be below -25°C (-13°F).

1.1.24 MIL-L-83176A: Lubricant, Instrument Bearing, Petroleum Base (NATO Code: None)

General characteristics: Specially refined lubricant, composition limited to a natural paraffinic base stock derived from Pennsylvania Crude Oil and only specified oxidation inhibitor (hindered bis-phenol) and antiwear (tricresyl phosphate) additives. No re-refined products are permitted.

Uses: Intended for use in the spin axis bearings of inertial guidance gyros, accelerometers and other suitable instrument applications.

Limitations: Do not mix with any fluid except those to this specification. Contains tricresyl phosphate and must not be used as medical or food product or in food machinery on surfaces that may contact food.

1.1.25 MIL-L-83767B(1): Lubricating Oil, Vacuum Pump, Mechanical Ejector, Diffusion-Ejector (NATO Code: None)

General characteristics: This specification covers four types (viscosity ranges) of special purpose vacuum pump lubricating oil consisting of a homogeneous blend of highly refined petroleum base stock necessary to meet specification requirements. The four types are: Type I - light viscosity; Type II - medium viscosity; Type III - heavy viscosity, and Type IV - extra heavy viscosity.

Uses: The vacuum pump oils are intended to provide an oil seal, to act as a coolant, and to serve as a lubricant or working fluid for mechanical, ejector, and diffusion-ejector vacuum pumps. The choice of types (viscosity-range) should be in accordance with pump manufacturer's recommendations.

2.1 Lubricating Greases

2.1.1 VV-G-632A(1): Grease, Industrial, General Purpose (NATO Code: None)

General characteristics: This specification covers one type and three grades of lubricating greases intended primarily for lubricating machinery equipped with compression type grease cups. Composition of these greases shall consist of mineral oil base, calcium soap thickener of one or more of the higher fatty acids, with or without additives to meet specification requirements. All grades of this grease are water-resistant and are suitable where moisture is present.

Uses: Grade 1, soft, lubricating grease intended for use where a soft grade (NLGI No. 1) cup grease is specified. Operating temperature range should be -23°C to +49°C (-10°F to +120°F).

Grade 2, medium, lubricating grease intended for use where a medium grade (NLGI No. 2) cup grease is specified. Operating temperature range should be -18°C to +54°C (0°F to 130°F).

Grade 3, hard, lubricating grease intended for use where a hard grade (NLGI No. 3) cup grease is specified. Operating temperature range should be -12°C to +60°C (+10°F to +140°F).

Limitations: None of these specification greases should be used on automatic or artillery equipment. They may not be inhibited against oxidation and may not prevent corrosion under adverse conditions. Automatic and artillery equipment should use MIL-G-10924, Grease, Automatic and Artillery; intended for application formerly covered by Type A (for automatic use), Grades 1, 2, and 3 of VV-G-632 (1948) and can be substituted for these discontinued automatic grades.

2.1.2 MIL-G-4343C: Grease, Pneumatic System (NATO Code: G-392)

General characteristics: Good low temperature properties under both static and dynamic conditions. Lithium soap thickener and a blend of diester and silicone fluid as the base oil. Operational temperature range -54°C to +93°C (-65°F to +200°F).

Uses: This grease is intended for use in pneumatic systems as a lubricant between rubber seals and metal parts (under dynamic conditions). Specification performance tests show that it may be used at pressures up to 11.03 x 10^{-6} N/m^2 (1,600 psi) however, MIL-G-4343 greases have proven satisfactory in service at pressures to 13.79 x 10^{-6} N/m^2 (2,000 psi).

Limitations: This material is suitable for use on Buna N type or Specification MIL-P-5516 rubber. It should not be used with other types of rubber without determining the compatibility between the rubber and grease.

1.2.3 MIL-G-6032D: Grease, Plug Valve, Gasoline and Oil Resistant

General characteristics: This specification covers two types of grease resistant to petroleum oils and fuels, made from animal, vegetable, or synthetic oils (i.e., polyester), or a combination thereof, and suitable gelling agent (soap or nonsoap). Contains no fillers such as graphite, mica, clay, etc.

Type I (NATO Code G363) - bulk grease

Type II (No NATO Code) - stick grease

Uses: Intended for use as lubricant on tapered plug valves, gaskets, or seals and other plug value service in systems where resistance to gasoline, oil, alcohol or water is required.

Limitations: Not suitable for use with strong acids, alkalis or hydrogen peroxide.

2.1.4 MIL-G-10924D(1): Grease; Automotove and Artillery (NATO Code: None)

General characteristics: Good corrosion resistance including salt spray. Composition not specified but can be a mixture of mineral or synthetic oil or a combination thereof with a suitable thickeneer. Operational temperature range -54°C to +79°C (-65°F to +175°F).

Uses: Ground handling equipment under all conditions of service for temperatures of -54°C to +52°C (-65°F to 125°F).

Limitations: Not for high temperature use.

2.1.5 MIL-L-15719A(3): Lubricating Grease (High Temperature Electric Motor, Ball and Roller Bearings) (NATO Code: None)

General characteristics: High temperature silicone grease (Type HTG). Composition consists of polymethylphenyl silicone fluid in a lithium soap thickener. Normal temperature range -18°C to +149°C (0°F to +300°F).

Uses: Intended for lubrication of ball and roller bearings, primarily for lubricating Class H electric motors with heat stabilized ball bearings.

Limitations: It should never be used in areas of sliding metal such as journal bearings, spiral gears or gear trains, etc. Direct contact may irritate eyes.

2.1.6 MIL-G-21164D: Grease, Molybdenum Disulfide, for Low and High Temperatures (Military Symbol CMD, NATO Code 9-358)

General characteristics: This grease consists essentially of a suitable liquid lubricant, a gelling agent, and molybednum disulfide. The molybdenum disulfide shall conform to MIL-M-7866, and its content by weight shall be not less than 4.5% and not more than 5.5%. This grease has good corrosion protection and water resistance; combined with extreme pressure and under temperature range properties.

Uses: This grease is intended for use as a lubricant for accessory splines, heavily loaded sliding steel surfaces or for antifriction bearing carrying high loads and operating through wide temperature ranges when molybdenum disulfide will prevent or delay seizure in the event of inadequate lubrication. Recommended temperature range 0°C (32°F) to 121°C (+250°F).

Limitations: This grease should not be used for other than steel surfaces without prior performance evaluations.

2.1.7 MIL-G-23549C: Grease, General Purpose

General characteristics: This specification covers the requirements for one type and grade of a general purpose (molybdenum disulfide) grease for extended use at temperatures up to 177°C (350°F) and for brief periods of use at temperatures up to 204°C (400°F).

Uses: This molybdenum disulfide grease is intended for general purpose use for environments requiring normal high temperatures and brief exposure to temperatures as stated previously. It is also intended for use with systems requiring low speed, high load, salt water and contact with high pressure steam.

Limitations: The composition of this grease is not limited, except that it shall contain a high-viscosity mineral oil with a non-soap thickener, 5 percent molybdenum disulfide conforming to MIL-M-7866 and a suitable corrosion inhibitor.

2.1.8 MIL-G-23827B: Grease, Aircraft and Instrument, Gear and Actuator Screw (NATO Code: G-354)

General characteristics: Extreme pressure grease with good corrosion protection. Water resistant with low oil separation. It has a composition of a synthetic base oil with extreme pressure additive in a lithium or calcium stearate or hydroxystearates.

Uses: The grease is intended for use in ball, roller, and needle bearings, gears, and on sliding and rolling surfaces of such equipment as instruments, cameras, electronic gear, and aircraft control systems. It is particularly suitable for equipment which must operate at both low and high temperatures. Its extremely low volatility is of advantage in preventing oil fogging in optical instruments. This grease is also intended for general use on aircraft gears, actuator screws, and other equipment requiring a lubricant with high load-carrying capacity over a temperature range of -54°C (-65°F) to 121°C (+250°F) and for short periods up to 149°C (+300°F). This material replaces MIL-G-3278A, MIL-G-7118A, MIL-G-007118B, and MIL-G-15793.

Limitations: Specification MIL-G-23827 grease contains a relatively low viscosity oil in order to obtain adequate low temperature properties. The low oil viscosity results in a generally higher rate of storage separation or service "bleeding" of the oil components than is generally experienced with high temperature greases such as Specification MIL-G-3545 greases. The special synthetic oils used in this grease may soften paint, natural rubber, neoprene, and electrical insulating materials. Generally, this grease will allow equipment to operate at -54°C (-65°F); however, the increase in torque at -54°C (-65°F), due to the increase in viscosity may amount to as much as tenfold over the torque at normal temperatures. This factor must be taken into consideration in the design of equipment.

2.1.9 MIL-G-24139(1): Grease, Multipurpose, Quiet Service (NATO Code: None)

General characteristics: Smooth homogeneous mixture free from lumps, abrasives and undesirable fillers or impurities; consists essentially of a petroleum oil and suitable gelling agent.

Uses: This grease is for multipurpose usage in quiet service. In ball and roller bearings, it may be used for continuous service from 0°C to +106°C (+32°F to +228°F) and for moderate periods up to +121°C (+250°F).

Limitations: Shall have no odor of rancidity or perfume.

2.1.10 DOD-G-24508A(1): Grease, High Performance, Multi-purpose (Metric)

General characteristics: The grease shall consist essentially of a wide temperature range liquid lubricant and suitable gelling agent. It shall not be comprised of silicones or contain any silicone additives.

Uses: The grease covered by this specification is intended for multipurpose use and can be used in grease-lubricated ball and roller bearings operating at a continuous temperature up to 149°C (300°F) and up to 177°C (350°F) for periods up to 4 hours in any 24 hour period.

Limitations: The grease shall not have an objectionable odor, or odor of rancidity, perfume, or free alcohol.

2.1.11 MIL-G-25013E: Grease, Aircraft, Ball and Roller Bearing (NATO Code: G-372)

General characteristics: Excellent high temperature properties. This grease shall be a mixture of a suitable liquid lubricant, a gelling agent and additive needed to meet specification requirements. Frequent composition is a nonsoap thickened silicone oil grease.

Uses: This grease is intended for use in ball and roller bearings over the temperature range of -73°C to +232°C (-100°F to +450°F). It is particularly designed for those high temperature ball and roller bearing applications where soap-type thickeners may not be applicable. It will permit operation of equipment at -73°C (-100°F) and will lubricate antifriction bearings continuously at temperatures as high as +232°C (450°F) when the speed factor or DN value of the bearing does not exceed 200,000. This grease replaces that conforming to MIL-G-27343.

Limitations: This grease should not be specified for applications in which the main action involves the sliding of metal-on-metal as in journal bearings, spiral gears, gear trains, and similar applications unless performance evaluation tests have proven it satisfactory.

2.1.12 MIL-G-25537C: Grease, Aircraft, Helicopter Oscillating Bearing (NATO Code G-366)

General characteristics: Good corrosion protection and water resistance. Soft consistency designed to minimize fretting corrosion, composition is not specified.

Normal temperature range -54°C to +71°C (-65°F to +160°F) for extended operation and to +93°C (+200°F) for short periods.

Uses: This grease is intended for use in bearings having oscillating motion of small amplitude, such as helicopter rotor head bearings. It is suitable for use in equipment which must operate at ambient temperatures of -54°C to +71°C (-65°F to +160°F).

Limitations: This grease should not be used for ball or roller bearings operating at high speeds or high temperatures.

2.1.13 MIL-G-27617D: Grease, Aircraft, Fuel and Oil Resistant (NATO Code: None)

General characteristics: Wide temperature homogeneous compound consisting of a gelling agent and a suitable liquid lubricant. Resistant to fuel, oil and liquid oxygen. Usable at temperatures from -34°C to +204°C (-30°F to +400°F).

Uses: Intended for use in the lubrication of taper plug valves, gaskets, and bearings in fuel systems of aircraft and ground support equipment. Also for use in the presence of liquid oxygen as a lubricant of valves, threads and bearings in aerospace vehicles and supporting equipment.

Limitations: May not be suitable for aluminum or magnesium dynamic bearing lubrication because of possible ignition hazards. Not recommended for general antifriction bearing lubrication.

2.1.14 MIL-G-81322D: Grease, Aircraft, General Purpose - Wide Temperature Range (Military Symbol WTR, NATO Code: G-395)

General characteristics: A wide temperature range general purpose grease that consists principally of a wide temperature range liquid lubricant and a high melting point gelling agent. This specification consolidates the requirements of, and in many applications has superseded the following greases: MIL-G-7711A, MIL-G-25760A, and MIL-G-3545.

Use: A general purpose grease applicable where operating temperatures are as low as -54°C (-65°F) and as high at +177°C (+350°F). Specifically designed for wheel bearings in internal brake wheel assemblies, antifriction bearings, gear boxes and plain bearings, also applications such as aircraft accessories operating at high speeds over a wide temperature range.

Limitations: Grease must not have any objectionable odor, or odor of rancidity, perfume, or free alcohol.

2.1.15 MIL-G-81827A: Grease, Aircraft, High Load Capacity, Wide Temperature Range

General characteristics: This grease shall consist essentially of a suitable liquid lubricant, a gelling agent and molybdenum disulfide powder in the 4-10 micron particle size and of purity and grade suitable for general lubricating use.

Uses: This grease is intended for use as a lubricant for heavily loaded accessory splines, sliding steel surfaces and anti-friction bearings where molydenum disulfide will delay or prevent seizure in the event of inadequate lubrication. It is also compatible with elastomeric seals.

Limitations: Allowable wide temperature range is from -54°C to +177°C (-65°F to +350°F).

2.1.16 MIL-G-83261(4): Grease, Aircraft, Extreme Pressure, Antiwear (NATO Code: None)

General characteristics: This specification covers one type of heavy load bearing grease consisting essentially of a suitable liquid lubricant, a nonsoap gelling agent, and necessary additives. Has wide range temperature properties.

Uses: Intended for use in aircraft actuators, gear boxes, gimbal rings, oscillation bearings, and other applications involving heavy loads and elevated temperatures.

Limitations: Allowable temperature range from -73°C to +232°C (-100°F to +450°F).

3.1 Compounds

3.1.1 VV-P-236A(2): Petrolatum, Technical (NATO Code: S-743)

General characteristics: This specification covers the requirement for petrolatum that is uniform in quality, clean, homogeneous and refined, and free from adulteration.

Uses: Intended for use as a light grade of lubricating grease, may also be used as a constituent in certain types of rust preventive compounds.

Limitations: Not recommended for use as a lubricant in heavy loaded or hot running bearings.

3.1.2 TT-S-1732: Antiseize Compound, General Purpose (for Threaded Fittings) (NATO Code: S-725)

General characteristics: High quality antiseize compound used as sealing compound for steam, water and threaded fittings. Composition is not specified but lead content shall not exceed 1.0% of total solids. Material shall be applicable by paddle at temperatures from -23°C (-10°F) to +60°C (+140°F), shall form a flexible non-shrinking bond that inhibits rust and corrosion and will not gall, seize or block threads.

Uses: General purpose antiseize compound for threaded fittings for steam and water at pressures up to 1.034×10^6 N/m^2 (150 psi) and temperatures up to 177°C (350°F). May also be used on flared or cone type fittings in gaseous systems at higher pressures when compatibility exists between the system media and the antiseize compound.

Limitations: Not suitable for use on spark plugs, oxygen systems or hydraulic systems.

3.1.3 MIL-A-907D: Antiseize Compound, High Temperature (NATO Code: None)

General characteristics: This specification covers an antiseize compound of homogeneous mixture, free from ingredients which are corrosive to ferrous metals. Six-month storage life minimum.

Uses: Antiseize compound for use on threads of steel nuts and bolts of super-heated steam installations at temperatures up to 566°C (1050°F).

Limitations: Not intended for use with austenitic steels.

3.1.4 MIL-C-5545C: Corrosion Preventive, Aircraft Engine, Heavy Oil Type (NATO Code: None)

General characteristics: Nontoxic heavy oil type corrosion preventive. Easily poured at 710°C (50°F) and flash point more than +177°C (+350°F).

Uses: Compound intended for use on internal parts and surfaces of engines and equipment to prevent damage by corrosion. For static preservation only, and should be removed from engine prior to flight.

Limitations: Material is not for operational use, and should not be confused with MIL-C-6529 lubricant.

3.1.5 MIL-C-6529C(2): Corrosion Preventive, Aircraft Engine

General characteristics: This specification covers an oil-type corrosion preventive which shall be a satisfactory lubricant for aircraft engines when used as specified herein.

Uses: Types I and II materials are used in preservation of reciprocating engines and equipment for prevention of damage by corrosion. Types I and II materials are used in preservation of turbojet engines and equipment.

Limitations: Type I material must be diluted with three parts of lubricating oil qualified under MIL-L-6081 or MIL-L-6082.

3.1.6 MIL-C-8188C: Corrosion Preventive Oil, Gas Turbine Engine, Aircraft Synthetic Base (NATO Code: C-638)

General characteristics: Corrosion-preventive oil which is not limited in composition. Additives necessary to meet specification requirements are permitted.

Uses: Intended for preservation of turboprop and turbojet engines using specifications MIL-L-7808 lubricating oil.

Limitations: Capable of limited use, not exceeding 25 hr., as an aircraft engine lubricant, and can be used for both preservation and final acceptance rur s of aircraft engines. Recommended temperature range -54°C to +149°C (-65°F to +300°F).

3.1.7 MIL-S-8660C: Silicone Compound (NATO Code: S-736)

General characteristics: This specification covers one type of nonmelting heat stable silicone compound. It is effective in the temperature range 54°C (-65°F) to 204°C (400°F) for extended periods and up to 260°C (500°F) for short periods.

Uses: This material is used as a sealant to prevent galvanic corrosion due to moisture penetration in areas of dissimilar metal contact; for sealing high tension electrical connections of aircraft and automotive engines; sealing and insulating electronic equipment where material must remain in soft state to allow easy diassembly, as a lubricant and sealant for rubber "O" rings and gaskets; when mixed with molybdenum disulfide, for threaded connections on piping and valves that come in contact with corrosive liquids and gases.

Limitations: Not to be used on electrical connectors having natural rubber inserts, as noted in applicable technical orders or specifications for connectors. Not intended for use as a heat sink. Materials having properties more suitable for this application are currently commercially available.

3.1.8 MIL-C-11796B: Corrosion Preventive, Petrolatum, Hot Application

General characteristics: This specification covers a suitably formulated petroleum-base corrosion preventive compound, available in three classes. The flash point of this compound is 177°C (350°F) and the melting point is from 57°C (135°F) to 68°C (155°F).

Uses: This material is intended for protection of ferrous and nonferrous metals. Use of this corrosion preventive should be restricted to Class 1 and Class 3 materials. Class 1 is a hard film compound applied in the molten state by dipping, bushing, swabbing, etc. and may be used for the protection of small metal parts either packaged or unpackaged and for long-term indoor storage protection of highly finished metal parts. Class 3 is a soft film compound applied either by brushing or swabbing at room temperature or by dipping in the molten state and may be used for the preservation of antifriction bearings and on machine surfaces for which a protective material which is easily removable at room temperature is required.

Limitations: Material must not foam or separate after storage at 107°C (225°F) and -40°C (-40°F). Maximum temperatures of application are: Class 1 or 1A, 93°C (200°F); Class 2, 88°C (190°F); and Class 3, 82°C (180°F).

3.1.9 MIL-C-16173D(2): Corrosion Preventive Compound, Solvent Cutback, Cold Application (NATO Code: See below)

General characteristics: This specification covers one type and five grades of a corrosion preventive compound composed of a nonvolatile base material in a petroleum solvent (no benzol or chlorinated hydrocarbon). Compounds must be free of abrasives, water, chlorides and other impurities, and not injurious to personnel using reasonable care.

Uses: These materials are intended as corrosion preventive compounds which deposit thin, easily removed films after evaporation of solvent. Grade 1 (NATO Code C-632) - provides a hard film for general purpose preservation indoor or outdoor, with or without cover, where a dry-to-touch film is required. Grade 2 (NATO Code C-620) - provides a soft film for extended undercover protection of interior or exterior surfaces of machinery, instruments or bearings with or without barrier materials. Also for outdoor protection of material for limited periods where metal surface temperatures do not cause prohibitive flow of preventive film. Grade 3 - provides a water displacing soft film for use where water or saline solutions must be displaced from corrodible surfaces. For protection of interior surfaces of machinery, instruments and other material under cover for limited periods, and for protection of critical bare steel or phosphated surfaces for extended periods using a barrier material. Grade 4 - provides a transparent nontacky film for general purpose indoor and outdoor use, where a tack-free coating is required, and where miscibility with lubricating oil is not required and the film must be easily removable with Stoddard's solvent. Grade 5 - low pressure steam removable film for use in place of Grade 3 where chemical "boil-out" cannot be used for removal.

Limitations: Contains combustible petroleum thinner of 38°C (100°F) minimum flash point. Avoid use near open flame, sparks, or welding equipment. Also avoid prolonged or repeated contact with skin or breathing of vapors.

3.1.10 MIL-T-83483A: Thread Compound, Antiseize, Molybdenum Disulfide - Petrolatum

General characteristics: Specification covers one type of thread compound composed of molybdenum disulfide and petrolatum.

Uses: This compound is particularly suitable for use on aircraft engine spark plugs and threaded fasteners and fittings at temperatures below 427°C (800°F).

Limitations: This material is an electrical conductor. Apply light coating to lower spark plug threads only. Material must not come in contact with spark plug terminal or electrode. Do not use in oxygen systems - explosion may result.

3.1.11 MIL-C-0083933A(3): Corrosion Preventive Compound, Cold Application

General characteristics: This specification covers a solvent dispersed corrosion preventive compound for spray, brush, or dip application to vehicle underbodies and enclosed or concealed surfaces.

Uses: This corrosion preventive compound is used for preserving the underside and internal areas of vehicles.

Limitations: Lead content shall not exceed 0.015 percent. When applied to test panels and air-dried for seven days, this compound shall not flow below 225°F (107°C).

4.1 Hydraulic and Damping Fluids

4.1.1 VV-B-680B(1): Brake Fluid, Automotive (Military Symbol HB) (NATO Code: H-542)

General characteristics: Specification covers one type and one grade of brake fluid of unrestricted composition, but generally a glycol base.

Uses: Intended for use as an operating fluid in automotive hydraulic systems at ambient temperatures ranging from -35°C (-31°F) to +55°C (131°F), and fluid temperatures from -40°C (-40°F) to 190°C (374°F).

Limitations: Not to be used in preserving brake parts and components in warehouse storage nor in brake systems of vehicles subjected to prolonged periods of standby storage.

4.1.2 VV-D-1078B: Damping Fluid, Silicone Base Dimethyl Polysiloxane)

NATO Code	Viscosity Grades 10^{-6} m^2/sec (Centistokes)
S-1714	10
S-1718	50
S-1720	100
S-1724	7,500
S-1726	20,000
S-1728	100,000
S-1732	200,000

General characteristics: This specification includes multigrade silicone damping fluids, based on dimethyl polysiloxane, having a wide range of viscosities – 0.65 to 200,000 x 10^{-6} m^2/sec (0.65 to 200,000 centistokes) at 25°C (77°F). These fluids are of high quality, free of suspended matter and water or sediment, and contain no unapproved admixtures or other fluids. This specification supersedes MIL-S-21568A which covered a similar class of damping fluids. Temperature range from -54°C to +316°C (-65°F to +600°F) depending on pour and flash point and viscosity grade.

Uses: These multigrade fluids are intended for many uses such as damping fluids, transducer fluids, lubricants, heat transfer fluids, dielectric fluids, mole release agents, water repellants, hydraulic fluids, protective dressings, and impregnants.

Limitations: These fluids should not be mixed with any other type of lubricating oil or hydraulic fluid. When replacing another oil with this fluid, parts must be disassembled and thoroughly cleaned with fresh solvent. Consideration must be given to the type of elastomer used in contact with the fluids because they tend to cause certain elastomers to shrink and harden. This is particularly true of the lower viscosity fluids.

4.1.3 MIL-H-5606E(1): Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance (NATO Code: H-515)

General characteristics: Good low temperature hydraulic fluid that is clear and transparent consisting of petroleum products with additive materials to improve the viscosity-temperature characteristics, resistance to oxidation and antiwear properties. Fluid is dyed red for identification purposes. May be used at temperatures ranging from -54°C to +71°C (-65°F to +160°F) in open systems and up to +135°C (+275°F) in closed airless systems.

Uses: Primarily as an operating oil in aircraft hydraulic systems, automatic pilots, loading gears, shock struts, brakes, flap-control mechanisms, missile hydraulic servo-controlled systems and other hydraulic systems using synthetic sealing materials.

Limitations: Since this fluid has a rather high rate of evaporation, it should not be used as a general-purpose high-temperature lubricant. It is not interchangeable with any other type of hydraulic fluid. Must not contain any pour point depressants.

4.1.4 MIL-H-6083D(3): Hydraulic Fluid, Petroleum Base, for Preservation and Testing (NATO Code: C-635)

General characteristics: This liquid is a petroleum base corrosion preventive oil for hydraulic equipment. It contains additives to provide corrosion protection and to improve viscosity-temperature characteristics and resistance to oxidation, but no pour point depressent additive is allowed. The fluid shall have no deleterious effect on pressure-seal packing used in aircraft hydraulic systems and shock struts. Operating temperature range is -54°C to +71°C (-65°F to +160°F).

Uses: This fluid is intended as a preservative oil in aircraft and ordnance hydraulic systems during shipment and storage, and also as a testing and flushing liquid for hydraulic system components. It is not intended as an operational hydraulic fluid, but may be used for limited operational use.

Limitations: Not recommended for high temperature use or for heavy duty requirements. This liquid is not interchangeable with hydraulic fluid, castor oil base, Specification MIL-H-7644 (USAF) or hydraulic fluid, nonpetroleum base, automotive, Specification VV-B-680a.

4.1.5 MIL-F-17111B: Fluid, Power Transmission (NATO Code: H-575)

General characteristics: A petroleum base fluid plus an anti-wear agent, tricresyl phosphate, and other approved additives to improve the fluid with respect to viscosity-temperature and lubricating properties, resistance to oxidation, and corrosion protection. Fluid must be suitable for hydraulic systems employing mechanical or fibrous type filters or centrifugal purification, and shall be noncorrosive to bearings and hydraulic systems and not cause clogging of oil screens or valves. ASTM Color Code No. 2. Usable temperature range is not specified but generally between -32°C and +93°C (-35°F and +200°F).

Uses: This fluid is intended for use in connection with the hydraulic transmission of power, particularly in Naval ordnance hydraulic equipment.

Limitations: Not for high temperature applications since fluid is inflammable.

4.1.6 MIL-H-17672D: Hydraulic Fluid, Petroleum, Inhibited

Military Symbol	NATO Code	Viscosity Grades, 99°C (210°F) 10^{-6} m^2/sec (centistokes)
2075 T-H	None	4.3 - 5.3
2110 T-H	None	5.3 - 6.7
2135 T-H	None	6.7 - 7.7

General characteristics: This specification covers one type and three grades of virgin petroleum base oil plus anticorrosion and antioxidation additive agents to meet specification requirements. Operating temperature range is not specified but generally from -18°C to +121°C (0°F to +250°F).

Uses: This fluid is intended for use in steam turbines, hydraulic systems, water turbines, water-wheel type generators, hydraulic-turbine governors, and in other applications where a high-grade lubricating oil having anticorrosion and antioxidation properties is required.

Limitations: There are no storage life requirements, but the liquid has good storage properties if stored in closed containers at normal temperatures. It shall be compatible with other reference oils furnished by the government. Compatibility is determined by mixing equal portions of specification oil and reference oil and passing requirements of this specification.

4.1.7 MIL-H-19457C(1): Hydraulic Fluid, Fire Resistant (Type I -- Low Viscosity, NATO Code H-550; Type II -- High Viscosity, NATO Code, None)

General characteristics: These two viscosity grades of non-petroleum base, fire resistant, hydraulic fluids are compositions of phosphoric acid base and such other ingredients as are required to meet specification requirements. These fluids are dyed green for identification. The operating temperature range is not specified, but the fluids are intended for low ambient temperatures; above -18°C (0°F) for Type I and above -4°C (+25°F) for Type II, and for moderate high temperatures to roughly 93°C (+200°F). The minimum compression combustion ratio is 42.0.

Uses: These fire resistant hydraulic fluids are intended for use in high-pressure hydraulic systems at moderate temperature ranges, and also for use in air compressors. Also as a lubricant for angular contact ball bearings and should provide at least 50% as good a bearing life as lubricating oil, Military Symbol 2110 H (MIL-L-15017). These fluids are compatible with butyl rubber seals and packing.

Limitations: Material qualified under MIL-H-19457B (Ships) has a low ortho isomer content (TOCP equivalent $\leq$25%) in order to pass the specification toxicity requirements. The Bureau of Medicine and Surgery has approved the shipboard use of these qualified products as a result of careful consideration by a committee of competent toxicologists. Containers must be properly marked with warning labels as required by the specification.

> WARNING: TOXIC CONTAINS TRIARYL PHOSPHATE. AVOID INHALING, SWALLOWING OR CONTACT WITH SKIN. IN CASE OF CONTACT, REMOVE SOILED CLOTHING AND THOROUGHLY WASH EXPOSED SKIN.

4.1.8 MIL-H-27601A(1): Hydraulic Fluid, Petroleum Base, High Temperature, Flight Vehicle (NATO Code: None)

General characteristics: This liquid is a petroleum or synthetic hydrocarbon base fluid with specified amounts of hindered bisphenol oxidation inhibitor and tricresyl phosphate antiwear additives. No other additives are to be used unless specifically approved. The finished fluid has good thermal and electrical properties and a viscosity index of 89 (min). Usable temperature range of -40°C to +285°C (-40°F to +550°F).

Uses: This hydraulic fluid is intended for use in high-temperature hydraulic systems, principally for flight vehicles.

Limitations: Not suitable or recommended for very low temperature operation. Also, this fluid is not compatible with any other hydraulic fluids except those meeting this specification.

4.1.9 MIL-H-46170B: Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base

General characteristics: This specification covers the requirements for two types of synthetic hydrocarbon base hydraulic fluids. Type I is undyed Military Symbol FRH and NATO Code No. H-544. Type II is dyed red for aerospace use.

Uses: Type I is used in tank recoil mechanisms and hydraulic systems. Type II is used in aerospace test stands.

Limitations: Mark Types I and II as follows: This fluid is not interchangeable with any other type or grade of hydraulic fluid. It is compatible with MIL-H-5606, MIL-H-6083, and MIL-H-83282. "Warning: this fluid may contain tricresyl phosphate which may be absorbed through the skin and produces paralysis if taken internally. Appropriate protective measures should be taken to avoid such exposures. Decontaminate containers before reuse." Type II shall also be marked "Not for ground equipment use."

4.1.10 MIL-B-46176(2): Brake Fluid, Silicone, Automotive All Weather, Operational and Preservative

General characteristics: This specification covers one type and one grade of silicone-based hydraulic brake fluid which is identified by Military Symbol BFS and NATO Code No. H-547.

Uses: This brake fluid is intended for use as an operational fluid and preservative fluid in automotive hydraulic brake systems at ambient temperatures ranging from -55°C (-67°F) to +55°C (+131°F) and fluid temperatures ranging from -55°C (-67°F) to +205°C (+401°F).

Limitations: Adequate flushing of the brake system must be accomplished to remove all traces of any previous types of brake fluid. If previously used fluids are not completely removed, the corrosion-protective and preservative properties of this silicone fluid will be negated.

4.1.11 MIL-H-81019D: Hydraulic Fluid, Petroleum Base, Ultra-Low Temperature NATO Code: None)

General characteristics: This liquid is a very low temeprature, petroleum base, hydraulic fluid containing specified additives to improve viscosity temperature characteristics, oxidation resistance and antiwear properties. The fluid has a pour point of -68°C (-90°F) and a storage life of 12 months. Operating temperature range -68°C to +99°C (-90°F to +210°F).

Uses: Intended for use in automatic pilots, shock absorbers, brakes, flap-control mechanisms, missile hydraulic servo-controlled systems, and other hydraulic systems using synthetic sealing materials.

Limitations: This fluid is not interchangeable with any other type or grade of hydraulic fluid than Specification MIL-H-5606B which is to be substituted only in emergencies.

4.1.12 MIL-S-81087C(1): Silicone Fluid, Chlorinated Phenyl Methyl Polysiloxane (NATO Code: H-536)

General characteristics: This specification covers two types of methyl chlorophenyl-polysiloxane fluid for lubrication and other applications over a wide temperature range. It has good thermal stability. Type I fluid is a copolymer containing only dimethyl siloxy and methyl chlorophenyl siloxy units, with trimethyl siloxy terminal groups. Type II fluid is a Type I fluid with the addition of an oxidation inhibitor.

Uses: This fluid is for lubricating, hydraulic damping, and related applications over the temperature range of -73°C to +260°C (-100°F to +500°F), including hydraulic systems and servomechanisms; crankcase and gear boxes for mechanical drives and compressors, engines and pumps; ball, sleeve, and pivot bearings in instruments, electronic equipment, electric motors, etc.; clocks and timing devices; fluid transmissions. Type I is not oxidation inhibited, and in applications where it is exposed to air, the temperature range is -73°C to +218°C (-100°F to +425°F). Type II fluid is inhibited and is suitable for use in oxidative environments over the -97°C to +260°C (-100°F to +500°F) range.

Limitations: Type II fluid, when exposed to temperatures above +260°C (500°F) in an inert atmosphere, has a tendency for the oxidation inhibitor to separate forming a soft gelatinous sludge or precipitate which will not decrease lubricity, but may cause a pressure drop in systems having filters or small orifices. Type II should be reserved for severe and relatively continuous oxidizing environments. Neither type should be mixed with any other lubricating oil or hydraulic fluid. When replacing another oil with this fluid, parts must be disassembled and cleaned with solvents.

4.1.13 MIL-H-83282B: Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft

General characteristics: Synthetic hydrocarbon base stock hydraulic fluid containing only specified oxidation inhibitor (phenolic type) and antiwear agent (tricresyl phosphate) additives.

Uses: Fire resistant hydraulic fluid for use in a temperature range from -45°C to +204°C (-50°F to 400°F) in automatic pilots, shock absorbers, brakes, flap-control mechanisms, missile hydraulic fluid servo-controlled systems, and other hydraulic systems using synthetic sealing materials.

Limitations: Not interchangeable with any other type or grade of hydraulic fluid, but shall be miscible with MIL-H-46004 hydraulic fluids. No pour point depressant or viscosity index improver permitted. Do not use in any application where it could, in any way, contaminate foodstuff.

B-III. LIQUID LUBRICANT DATA SHEETS

FEDERAL SPECIFICATION: VV-L-800C LUBRICATING OIL
GENERAL PURPOSE, PRESERVATIVE (WATER DISPLACING, LOW TEMPERATURES)

PROPERTIES	SPEC. REQ.	BRAYCO[a/] 300	PETROTECT[b/] 800 or 4072C
COMPOSITION Base Oil	Petroleum	Petroleum	Petroleum
Additives	As Necessary		
Viscosity Index Improver			
Oxidation Inhibitor		Yes	Yes
Detergent			
EP (extreme pressure)			
Pour Point Depressant			
Antifoam Additive			
Corrosion Protection		Yes	Yes
Other			
VISCOSITY: 10^{-6} m^2/Sec (Cs) at			
-54°C (-65°F)	60,000	52,313	38,660
-40°C (-40°F)	7,000	4,868	3,605
40°C (104°F), Minimum	11	12.87	12.31
VISCOSITY INDEX, Minimum			
SPECIFIC GRAVITY, 16°C (60°F)	-	0.8762	0.8927 (approx.)
FLASH POINT, COC, Minimum	135°C (275°F)	146°C (295°F)	143°C (290°F)
FIRE POINT, COC	-	-	-
POUR POINT, Maximum	-57°C (-70°F)	-59°C (-75°F)	< -59°C (< -75°F)
CORROSION AND OXIDATION STABILITY			
Weight Change, 10^{-2} kg/m^2 (mg/cm^2)			
Copper	±0.2	0.0	-0.04
Steel	0.2	0.0	-0.02
Aluminum	0.2	0.0	-0.02
Magnesium	0.2	0.0	-0.01
Cadmium	0.2	-0.01	-0.04
Pitting or Etching, Under 20X	None	None	None
Change in Viscosity, %, at 38°C (100°F)	-5 to +20	4.8	+3.3
Increase in Neutralization Number 10^{-3} kg KOH/kg (mg, KOH/g), Maximum	0.20	0.05	0.11
Insolubles or Gumming	None	None	None
COPPER CORROSION, ASTM Scale, Maximum	3.0	16.0	Pass
CORROSION PROTECTION			
Humidity Cabinet, Sandblasted Steel at 38°C (100°F), 100% Relative Humidity, Days (minimum)	8.0	8+	Pass
Water Displacement and Stability Oil as Received, Rust or Stains	None	None	None
After Storage With Water, Rust, or Stain	None	None	None
Corrosivity, Brass-Steel, 10 Days, 27°C (80°F) and 50% Relative Humidity	None	None	None
EVAPORATION LOSS, at 100°C (212°F), Maximum	25	-	Pass
PRECIPITATION NUMBER, Maximum, 10^{-6} m^3 (ml)	0.05	0.00	OK--Trace
CLOUD INTENSITY, -54°C (-65°F) for 72 hr			
Gel, Crystals, Solids or Separation	None	None	None
Compared to Turbidity Standard	< Standard	Pass	Pass

FEDERAL SPECIFICATION: VV-L-800C LUBRICATING OIL
GENERAL PURPOSE, PRESERVATIVE (WATER DISPLACING, LOW TEMPERATURES)

PROPERTIES	SPEC. REQ.	BRAYCO[a/] 300	PETROTECT[b/] 800 or 4072C
FILM CHARACTERISTICS No Gum, Tack, or Hardness After 24 Hr at 99°C (210°F)	None	None	None
REMOVABILITY Naphtha Rinse After Humidity Test	Pass	Pass	Pass
COLOR, ASTM D 1500	7.0	4.0	3.5
MACHINE GUN PERFORMANCE, 0.50 cal., M-2 at -57°C (-70°F)	No Stoppage	Pass	-

Note: For description of this lubricating oil and recommended usage, see Section II.

In addition to the products listed, the following oils supplied by the listed manufacturers meet the general requirements of this specification.

Product Name	Manufacturer
1. PQ Rust Preventive No. 172	American Oil & Supply Company
2. Nox-Rust 518	Daubert Chemical Company
3. Rust Foil No. 2675	Franklin Oil Corporation
4. Cosmoline 1116	E. F. Houghton and Company
5. Octoil 90	Octagon Process, Inc.
6. Royco 308A	Royal Lubricants Company, Inc.
7. Tectyl 900	Valvoline Oil Company

a/ Bray Products Division, Burmah Castrol, Inc.
b/ Penreco

FEDERAL SPECIFICATION: VV-L-825A (2)
LUBRICATING OIL, REFRIGERANT COMPRESSOR, TYPE II

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	
Additives	
Viscosity Index Improver	
Oxidation Inhibitor	
Detergent	
EP (extreme pressure)	
Pour Point Depressant	
Antifoam Additive	
Corrosion Protection	
Other	
VISCOSITY: 10^{-6} m^2/Sec (Cs) at	
38°C (100°F)	61.5 to 69.0
54°C (130°F)	-
99°C (210°F)	-
VISCOSITY INDEX, Minimum	-
SPECIFIC GRAVITY, 16°C (60°F)	-
FLASH POINT. COC, Minimum	177°C (350°F)
FIRE POINT, COC	-
POUR POINT, Maximum	-32°C (-25°F)
OXIDATION STABILITY at 54°C (130°F)	
Viscosity Increase, %, Maximum	
Neutralization Number Increase	
CORROSION, COPPER STRIP, ASTM Scale 3 Hr at 100°C (212°F)	Pass
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity	
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.05
EVAPORATION, %, Maximum (22 hr at 99°C (210°F)	
CARBON RESIDUE, %, Maximum	0.3
ASH, % Maximum	0.005
FLOCK POINT, Maximum	-32°C (-25°F)
JOURNAL BEARING TEST 200 Hr at 135°C (275°F), 3,500 rpm	Pass
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels	
LOX	
COLOR, ASTM D 1500	Report

FEDERAL SPECIFICATION: VV-L-825A (2)
LUBRICATING OIL, REFRIGERANT COMPRESSOR, TYPE II

PROPERTIES	SPEC. REQ.

NOTE:

1. Type II oil is intended for use with reciprocating-type refrigerant compressor refrigerants (i.e., Freon 12, methylchloride, or ammonia).

2. In addition to Type II, whose specification properties are shown in this table, this specification also covers three other types of oil which have a viscosity range approximately one-half that of Type II, but otherwise have similar properties.

   a. Type I, intended for use with refrigerant compressor systems using sulfur dioxide.
   b. Type III, intended for special applications such as two-stage rotary compressors.
   c. Type IV, intended for use in compressor systems using Freon 22 or similar refrigerants.

3. For description of lubricating oil composition and recommended usage see Section II.

4. In addition to the products listed, the following oils supplied by the listed manfacturers meet the general requirements of this specification; however, no specific data on their properties are available.

Product Name	Manufacturer
Calvis 300	Davis, Howland Oil Corporation
Protexol Refrigerant Compressor Oil, Type II	Golden Bear Division (Witco Chemical Corp.)
COMPROIL II	Octagon Process, Inc.

FEDERAL SPECIFICATION: VV-L-001071A
LUBRICATING OIL, STEAM CYLINDER, MINERAL

PROPERTIES	SPECIFICATION MILITARY SYMBOL 5190	REQUIREMENTS MILITARY SYMBOL 5230
COMPOSITION Base Oil	Mineral	Mineral
Additives		
Viscosity Index Improver		
Oxidation Inhibitor		
Detergent		
EP (extreme pressure)		
Pourpoint Depressant	Yes	Yes
Corrosion Protection		
Other		
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
38°C (100°F)		
54°C (130°F)		
99°C (210°F)	38.45 to 47.20	47.20 to 51.50
VISCOSITY INDEX, Minimum	-	90
SPECIFIC GRAVITY, 16°C (60°F)	-	-
FLASH POINT, COC, Minimum	274°C (525°F)	304°C (580°F)
FIRE POINT, COC		
POURPOINT, Maximum	16°C (60°F)	16°C (60°F)
OXIDATION STABILITY at 54°C (130°F)		
Viscosity Increase, %, Maximum		
Neutralization Number Increase		
CORROSION, COPPER STRIP, ASTM Scale 3 Hr at 100°C (212°F)	1 Maximum	1 Maximum
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity		
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.15	0.10
EVAPORATION, %, Maximum (22 Hr at 99°C) (210°F)		
CARBON RESIDUE, %, Maximum	3.25	3.25
NATURE OF CARBON	Loose and Flaky	Loose and Flaky
ASH, %, Maximum	0.05	0.05
TOTAL SULFUR, %, Maximum	0.50	0.50
PRECIPITATION NUMBER, Maximum, 10^{-6} m^3 (ml)	0.05	0.05
SAPONIFICATION NUMBER, Maximum	0.5	0.5
WATER, %	None	None
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels		
LOX		
COLOR, ASTM D 1500	-	-

FEDERAL SPECIFICATION: VV-L-001071A
LUBRICATING OIL, STEAM CYLINDER, MINERAL

PROPERTIES	SPECIFICATION MILITARY SYMBOL 5190	REQUIREMENTS MILITARY SYMBOL 5230

NOTE: For a description of these lubricating oils and recommended usage see Section II.

MILITARY SPECIFICATION: MIL-L-2104D
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, TACTICAL SERVICE GRADE 10W

PROPERTIES	SPEC. REQ.	PHILLIPS 66[a/] SUPER HD II SAE 10W
COMPOSITION Base Oil	Petroleum, synthetic or combination	Petroleum
Additives (see note)	-	-
Viscosity Index Improver	- -	No
Oxidation Inhibitor	X	Yes
Detergent	X	Yes
Phosphorus, %	X	0.10
Chlorine (bomb), %	X	Nil
Sulfur (bomb), %	X	0.50
Sulfated residue, %	X	0.95
Zinc, %	X	0.12
Nitrogen, %	X	0.23
EP (extreme pressure)	-	-
Pour Point Depressant	X	Present
Antifoam Additive	-	Present
Corrosion Inhibitor	X	Present
Others	X	-
VISCOSITY: 10^{-6} m^2/Sec (Cs) Min. & Max. at		
40°C (104°F)	X	40
99°C (210°F)	5.6 to 7.39	6.5
BORDERLINE PUMPING TEMP. (Max)	-25°C (-13°F)	
VISCOSITY INDEX, Minimum	X	110
API GRAVITY, 16°C (60°F)	X	29.5
FLASH POINT, COC, Minimum	205°C (401°F)	204°C (400°F)
FIRE POINT, COC		
POUR POINT, Maximum	-32°C (-26°F)	-32°C (-25°F)
OXIDATION CHARACTERISTICS CLR ENGINE (Method 3405)	Pass	Pass
RING-STICK, WEAR, AND DEPOSIT FORMATION UNDER HIGH TEMPERATURE (STP509A & M355T)	Pass	Pass
MOISTURE CORROSION CHARACTERISTICS (STP315H, sequence IID)	Pass	Pass
LOW TEMPERATURE DEPOSIT PROPERTIES (STP315H, sequence V-D)	Pass	Pass
Wear protection characteristics (STP315H, sequence IIID)	Pass	
TOTAL ACID & BASE NOS.		8.0 (TBN)
EVAPORATION, %, Maximum (22 hr at 99°C) (210°F)		
CARBON RESIDUE, %, Maximum	X	X
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, 5 Min Blowing/ 10 Min. Settling		
(a) Sequence 1, 24°C (75°F)	25/0	Pass
(b) Sequence 2, 93°C (200°F)	25/0	Pass
(c) Sequence 3, 24°C (75°F) (retest)	25/0	Pass
BEARING CORROSION (STP509A, Labeco L-38A) Bearing weight loss, mg (max.)	50	
FRICTION RETENTION CHARACTERISTICS AND WEAR		
Slip time and torque (Allison C-3)	Pass	
Stop time and wear (caterpillar TO-2)	Pass	

PROPERTIES	SPEC. REQ.	PHILLIPS 66[a/] SUPER HDII SAE 10W
STABILITY AND COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX (Method 3470)	Pass	Pass
SEAL COMPABILITY Effect on rubber seals (Allison C-3)	Pass	Pass
COLOR, ASTM D 1500	X	X

NOTE: For description of this lubricating oil and recommended usage, see Section II. "X" indicates reports.

In addition to the products listed, most of the commercial petroleum and lubrication companies manufacture general purpose lubricating oils which meet the requirements of this specification. Some of these are:

Product Name	Manufacturer
BATCO SAE 10W Motor Oil	Battenfeld Grease & Oil Corp. of NY
Five Star C GR 10W	Delta Petroleum Company, Inc.
WS 1588 S-3 Motor Oil 10	Exxon Company, U.S.A.
Formula No. MTN 568 A#	Mobil Oil Corporation
All-Fleet Plus Motor Oil SAE 10W	Valvoline Oil Company

a/ Phillips Petroleum Company

MILITARY SPECIFICATION: MIL-L-2104D
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, TACTICAL SERVICE, GRADE 30

PROPERTIES	SPEC. REQ.	BRAYCO 423J[a]/
COMPOSITION Base Oil		
Additives (see note)	Petroleum, synthetic or combination	-
Viscosity Index Improver	-	No
Oxidation Inhibitor	X	Yes
Detergent	X	Yes
Phosphorus, %	X	0.098
Chlorine (bomb), %	X	Present
Sulfur (bmonb), %	X	0.337
Sulfated Residue, %	X	0.962
Zinc, %	X	0.098
Nitrogen, %	X	0.244
EP (extreme pressure)	-	
Pour Point Depressant	X	
Antifoam Additive	-	
Corrosion Inhibitor	X	
Others	X	
VISCOSITY: 10^{-6} m^2/Sec (Cs) Min. & Max. at		
40°C (104°F)	X	X
100°C (212°F)	9.3	X
VISCOSITY INDEX, Minimum	75	91
API GRAVITY, 16°C (60°F)	X	25.5
FLASH POINT, COC, Minimum	220°C (428°F)	241°C (465°F)
FIRE POINT, COC	-	-
POUR POINT, Maximum	-18°C (0°F)	-18°C (0°F)
OXIDATION CHARACTERISTICS CLR ENGINE (Method 3405)	Pass	Pass
RING-STICK, WEAR, AND DEPOSIT FORMATION UNDER HIGH TEMPERATURE (STP509A & M355T)	Pass	Pass
LOW TEMPERATURE DEPOSIT PROPERTIES (STP315H, sequence V-D)	Pass	Pass
MOISTURE CORROSION CHARACTERISTICS (STP315H, sequence II D)	Pass	Pass
TOTAL ACID & BASE NOS.	X	
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F)		
CARBON RESIDUE, %, Maximum	X	1.03
WEAR PROTECTION CHARACTERISTICS (STP 315H, sequence III D)	Pass	
BEARING CORROSION (STP 509A, Labeco L-38A)		
Bearing weight loss, mg (max.)	50	
FRICTION RETENTION CHARACTERISTICS AND WEAR		
Slip time and torque (Allison C-3)	Pass	
Stop time and wear (Caterpillar TO-2)	Pass	

MILITARY SPECIFICATION: MIL-L-2104D
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE TACTICAL SERVICE, GRADE 30

PROPERTIES	SPEC. REQ.	BRAYCO 423J[a/]
FOAM CHARACTERISTICS (method D 892) 10^{-6} m^3 (ml) Foam, 5 min. Blowing/10 min. Settling		
(a) Sequence 1, 24°C (75°F)	25/0	0/0
(b) Sequence 2, 93°C (200°F)	150/0	5/0
(c) Sequence 3, 24°C (75°F) (retest)	25/0	0/0
STABILITY AND COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX (method 3470)	Pass	
SEAL COMPATIBILITY Effect on rubber seals (Allison C-3)	Pass	
COLOR, ASTM D 1500	X	4

NOTE: For description of this lubricating oil and recommended usage, see Section II. "X" indicates reports.

In addition to the products listed, most of the commercial petroleum and lubrication companies manufacture general purpose lubricatring oils which meet the requirements of this specification. Some of these are:

Product Name	Manugacturer
Amoco 300 Motor Oil	Amoco Oil Company
Arcofleet S-3 Plus SAE30	Atlantic Richfield Company
PED 5598	Chevron U.S.A. Inc.
Citgo No. 93416, SAE30	Citgo Petroleum Corporation
Conoco Fleet Oil	Conoco, Inc.
WS 1475 S-3 Motor Oil 30	Exxon Company, U.S.A.
EL-1160	Gulf Oil Corporation
Kendall Super-DIII	Kendall Amalie Div., Witco Chemical Corp.
Formula No. MTN542C	Mobile Oil Corporation
Super H.D. II SAE30	Phillips Petroleum Company
Shell 9195 Motor Oil 30	Shell Oil Company
Formula No. TL-11572B	Texaco, Inc.
Vanellus MCS-3-30	The Standard Oil Company (Ohio)
Union M6174	Union Oil Company of California
All-Fleet Plus Motor Oil SAE30	Valvoline Oil Company

a/ Bray Products Division, Burmah-Castrol Inc.

MILITARY SPECIFICATION: MIL-L-2104D
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE TACTICAL SERVICE, GRADE 40

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	Petroleum, synthetic or combination
Additives (see note)	-
Viscosity Index Improver	-
Oxidation Inhibitor	X
Detergent	X
Phosphorus, %	X
Chlorine (bomb), %	X
Sulfur (bomb), %	X
Sulfated Residue, %	X
Zinc, %	X
Nitrogen, %	X
EP(extreme pressure)	-
Pour Point Depressant	X
Antifoam Additive	-
Corrosion Inhibitor	X
Others	X
VISCOSITY: 10^{-6} m^2/Sec (Cs) Min. & Max. at	
40°C (104°F)	X
100°C (212°F)	12.5 to 16.29
VISCOSITY INDEX, Minimum	80
API GRAVITY, 16°C (60°F)	X
FLASH POINT, COC, Minimum	225°C (437°C)
FIRE POINT, COC	-
POUR POINT, Maximum	-15°C (5°F)
OXIDATION CHARACTERISTICS, CLR ENGINE (Method 3405)	Pass
RING-STICK, WEAR, AND DEPOSIT FORMATION UNDER HIGH TEMPERATURE (STP 509A & M355T)	Pass
LOW TEMPERATURE DEPOSIT PROPERTIES (STP 315H, sequence V-D)	Pass
MOISTURE CORROSION CHARACTERISTICS (STP 315H, sequence IID)	Pass
TOTAL ACID & BASE NOS.	
EVAPORATION, %, Maximum (22 hr at 99°C (210°F)	
CARBON RESIDUE, %, Maximum	X
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, 5 min. Blowing/ 10 min. Settling	
(a) Sequence 1, 24°C (75°F)	25/0
(b) Sequence 2, 93°C (200°F)	150/0
(c) Sequence 3, 24°C (75°F) (retest)	25/0
WEAR PROTECTION CHARACTERISTICS (STP 315H, sequence III D)	Pass
BEARING CORROSION (STP 509A, Labeco L-38A)	
Bearing weight loss, mg (max.)	50

MILITARY SPECIFICATION: MIL-L-2104D
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE TACTICAL SERVICE, GRADE 40

PROPERTIES	SPEC. REQ.
FRICTION RETENTION CHARACTERISTICS AND WEAR	
Slip time and torque (Allison C-3)	Pass
Stop time and wear (Caterpillar TO-2)	Pass
STABILITY AND COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels	
LOX (method 3470)	Pass
SEAL COMPATIBILITY	
Effect on rubber seals (Allison C-3)	Pass
COLOR, ASTM D 1500	X

NOTE: For description of this lubricating oil and recommended usage see Section II. "X" indicates reports.

In addition to the products listed, most of the commercial petroleum and lubrication companies manufacture general purpose lubricating oils which meet the requrements of ths specification. Some of these are:

Product Name	Manufacturer
Five Star D Grade 40	Delta Petroleum Company, Inc.
WS 1765 Motor Oil 40	Exxon Company, U.S.A.
XI-OE/HDO-40	Imperial Oil Company, Inc.
Formula No. RN 2380C	Mobil Oil Corporation

MILITARY SPECIFICATION: MIL-L-2104D
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, TACTICAL SERVICE GRADE 15W-40

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	Petroleum, synthetic or combination
Additives (see note)	
Oxidation Inhibitor	X
Corrosion Inhibitor	X
Pour Point Depressant	X
Disperants	X
Detergents	X
Phosphorus, %	X
Chlorine (bomb), %	X
Sulfur (bomb), %	X
Sulfated residue, %	X
Zinc, %	X
Nitrogen, %	X
Other	X
VISCOSITY, 10^{-6} m^2/Sec (Cs) Min. & Max. at	
40°C (104°F)	X
100°C (212°F)	12.50 to 16.29
VISCOSITY INDEX, Minimum	X
BORDERLINE PUMPING TEMP. (Maximum)	-20°C (-4°F)
SPECIFIC GRAVITY, 16°C (60°F)	X
FLASH POINT, COC, Minimum	215°C (419°F)
POUR POINT, Maximum	-23°C (-10°F)
RING-STICK, WEAR, AND ACCUMULATION OF DEPOSITS (STP509A and Method 355T)	Pass
MOISTURE-CORROSION CHARACTERISTICS (STP 315H, sequence II D)	Pass
LOW TEMPERATURE DEPOSITS AND WEAR (STP 315H, sequence V-D)	Pass
TOTAL ACID & BASE NUMBERS	X
CARBON RESIDUE, % Maximum	X
FOAM CHARACTERISTICS (D892)	
10^{-6} m^3 (ml) Foam, 5 min. Blowing/ 10 min. Settling	
(a) Sequence 1, 24°C (75°F)	25/0
(b) Sequence 2, 93°C (200°F)	150/0
(c) Sequence 3, 24°C (75°F)	25/0
WEAR PROTECTION CHARACTERISTICS (STP 315H, sequence III D)	Pass
BEARING CORROSION (STP 509A, Labeco L-38A)	
Bearing Weight Loss, mg (max.)	50
SHEAR STABILITY	
Remain in viscosity range at 100°C (212°F)	X

MILITARY SPECIFICATION: MIL-L-2104D
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, TACTICAL SERVICE GRADE 15W-40

PROPERTIES	SPEC. REQ.
FRICTION RETENTION CHARACTERISTICS AND WEAR	
Slip time and torque (allison C-3)	X
Stop time and wear (Caterpillar TO-2)	X
SEAL COMPATIBILITY	
Effect on rubber seals (Allison C-3)	Pass
STABILITY AND COMPATIBILITY	
(Method 3407)	Pass
COLOR (D1500)	X

NOTE: For description of this lubricating oil and recommended usage see Section II. "X" indicates reports.

In addition to the products listed, most of the commercial petroleum and lubrication companies manufacture general purpose lubricating oils which meet the requirements of this specification. Some of these are:

Product Name	Manufacturer
PQ Super Fleet IV	American Oil & Supply Company
Amoco 300 SAE 15W 40	Amoco Oil Company
Formula No. TL-11829	Atlantic Richfield Company
Brayco 426A, 426N	Bray Products Division, Burmah-Castrol Inc.
PED 5599	Chevron U.S.A. Inc.
Citgo No. 93418, SAE 15W-40	Citgo Petroleum Corporation
Conoco Fleet Supreme Motor Oil	Conoco, Inc.
Five Star D Grade 15W-40	Delta Petroleum Company, Inc.
WS 1630 Motor Oil 15W-40	Exxon Company, U.S.A.
Gulf Super Duty Motor Oil 15W-40	Gulf Oil Corporation
Kendall Super-D III	Kendall/Amalie Division, Witco Chemical Corp.
Formula No. RN2533 BBD	Mobil Oil Corporation
Super HD II 15W-40	Phillips Petroleum Company
Shell S9516	Shell Oil Company
Formula No. TL-11547C	Texaco, Inc.
Union Guardol Motor Oil	Union Oil Company of California
Valvoline All-fleet Plus Motor Oil	Valvoline Oil Company

MILITARY SPECIFICATION: MIL-L-2105C (2)
LUBRICATING OIL, GEAR, MULTIPURPOSE, GRADE 75W

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	Petroleum or Synthetic
Additives (see note)	As necessary
Viscosity Index Improver	-
Oxidation Inhibitor	-
Detergent	-
Sulfur, %	X
Phosphorus, %	X
Chlorine, %	X
Nitrogen, %	X
Organo-Metallics, %	X
EP (extreme pressure)	-
Pour Point Depressant	-
Antifoam Additive	-
Corrosion Protection	-
Other	No re-refined component
VISCOSITY: 10^{-6} m^2/Sec (Cs) at 100°C (212°F)	4.1 min.
VISCOSITY INDEX, Minimum	X
CHANNEL CHARACTERISTICS °C (°F) Maximum	-45°C (-49°F)
SPECIFIC GRAVITY OK, 16°C (60°F)	X
FLASH POINT, COC, Minimum	150°C (302°F)
FIRE POINT, COC	-
Storage Stability FTMS No. 791, Method 3440	Pass
POUR POINT, Maximum	X
THERMAL OXIDATION STABILITY at 54°C (130°F)	
Viscosity Increase, %, Maximum	100% in 50 hr
N-pentane Insolubles; Weight %, Maximum	X
Benzene Insolubles, Weight %, Maximum	2.0
CORROSION, COPPER STRIP 3 hr at 121°C (250°F)	Discoloration not greater than ASTM No. 3.0
HUMIDITY TEST: 100 hr 49°C (120°F) 100% RH	-
MOISTURE CORROSION FTMS No. 791, Method 5326	Pass
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/g (mg KOH/g)	-
EVAPORATION, %, Maximum (22 hr at 99°C) (210°F)	-
CARBON RESIDUE, % Maximum	-

PROPERTIES	SPEC. REQ.
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml); Foam after 5 Minutes Blowing	
(a) Sequence 1, 24°C (75°F)	20
(b) Sequence 2, 93°C (200°F)	50
(c) Sequence 3, 24°C (75°F) retest)	20
COMPATIBILITY WITH: Rubber Jet and Rocket Fuel	Other lubricants qualified to this spec.
COLOR, ASTM D 1500	-
Load-Carrying and Extreme Pressure Characteristics of Gear Lubricants in Axles Under Conditions of High Speed and Shock Loading, FTMS No. 791, Method 6507	Pass
Load-Carrying and Extreme Pressure Characteristics of Gear Lubricants in Axles Under Condtions of High Speed, Low-Torque Operation Followed by Low-Speed, High Torque Operation, FTMS No. 791, Method 6506	Pass

NOTE: When a series of gear lubricants in the 80,90 and 140 grades are submitted for qualification, the Load-Carrying Tests are required only for the 90 grade, provided the additive type and concentrations, and the base stock source and types of treatment are identical for all three grades. "X" indicates reports.

Intended use of this specification gear lubricant is for automotive gear units, heavy duty industrial type enclosed gear units, steering gear and fluid lubricated universal joints of automotive units.

For description of this lubricating oil and recommended usage, see Section II.

In addition to the products listed, many of the commercial petroleum and lubrication companies manufacture multi-purpose gear lubricants which meet the requirements of this specification; some of these are:

Product Name	Manufacturer
Quaker State High Performance Gear Lubricant, SAE 75W	Quaker State Oil Refining Corp.
Union MP Gear Lube-LS75W	Union Oil Company of California

MILITARY SPECIFICATION: MIL-L-2105C (2)
LUBRICATING OIL, GEAR, MULTIPURPOSE, GRADE 80W-90

PROPERTIES	SPEC. REQ.	CITGO No. 93011	GULF[b/] GEAR LUB. 80W-90	MULTIGEAR LUBRICANT EP 80W-90
COMPOSITION Base Oil	Petroleum or Synthetic	Petroleum	Petroleum	Petroleum
Additives	As necessary	Yes	Yes	
Viscosity Index Improver	-	Yes	Yes	-
Oxidation Inhibitor	-	-	-	-
Detergent	-	-	-	-
Sulfur, %	X	X	-	2.3
Phosphorus, %	X	X	-	0.12
Chlorine, %	X	-	-	-
Nitrogen, %	X	-	-	-
Organo-Metallics, %	X	-	-	-
EP (extreme pressure)	-	Yes	Yes	Yes
Pour Point Depressant	-	-	Yes	Yes
Antifoam Additive	-	-	Yes	Yes
Corrosion Protection	-	-	-	-
Other	No re-refined components	-	-	-
VISCOSITY: 10^{-6} m^2/Sec (Cs) at 100°C (212°F)	13.5 to 23.9	14.5	16.3 to 18.7	14.5
VISCOSITY INDEX, Minimum	X	95	90	100
CHANNEL CHARACTERISTICS, °C (°F), Max.	-35°C (-31°F)	X	X	X
SPECIFIC GRAVITY OK, 16°C (60°F)	X	0.895	0.897	0.901
FLASH POINT, COC, Minimum	165°C (329°F)	193°C (380°F)	191°C (375°F)	218°C (425°F)
FIRE POINT, COC	-	100°C (390°F)	227°C (440°F)	235°C (455°F)
STORAGE STABILITY FTMS No. 791, Method 3440	Pass	-29°C (20°F)	-29°C (-20°F)	-20°C (-4°F)
POUR POINT, Maximum	X			
THERMAL OXIDATION STABILITY at 54°C (130°F)				
Vixcosity Increase, %, Maximum	100% in 50 hr	-	-	
N-pentaine Insolubles, Weight %, Maxi.	X	-	-	
Benzene Insolubles, Weight %, Max.	2.0	-	-	
CORROSION, COPPER STRIP 3 hr at 121°C (250°F)	Discoloration not greater than ASTM No. 3.0	2.0 (3 hr at 121°C (250°F)	Passes No. 2	No blackening; 121°C (250°F)
HUMIDITY TEST: 100 hr 49°C (120°F) 100% RH	-	-	-	
MOISTURE CORROSION FTMS No. 791, Method 5326	Pass	Passes	Passes	Passes
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g),	-	-	-	
CARBON RESIDUE, %, Maximum	-	-	0.64	-

PROPERTIES	SPEC. REQ.	CITGO[a] No. 93011	GULF[b] GEAR LUB 85W-140	MULTIGEAR[c] LUBRICANT EP SAE 85W-140
COMPOSITION Base Oil	Petroleum or synthetic	Petroleum	Petroleum	Petroleum
Additives	As necessary	Yes	Yes	-
Viscosity Index Improver	-	Yes	Yes	-
Oxidation Inhibitor	-	-	-	-
Detergent	-		-	-
Sulfur, %	X	X	X	2.3
Phosphorus, %	X	X	X	0.12
Chlorine, %	X	X	X	X
Nitrogen, %	X	X	X	X
Organo-Metallics, %	X	X	X	X
EP (extreme pressure)	-	Yes	Yes	Yes
Pour Point Depressant			Yes	-
Antifoam Additive			Yes	-
Corrosion Protection			-	-
Other	No re-refined components	-	-	-
VISCOSITY: 10^{-6} m^2/Sec (Cs) at 100°C (212°F)	24.0 to 40.9	25.5	27.2 to 28.8	27.5
VISCOSITY INDEX, Minimum	X	95	90	91
CHANNEL CHARACTERISTICS, °C (°F)	-20°C (-4°F)	X	X	X
SPECIFIC GRAVITY 16°C (60°F)		0.904	0.891	0.911
FLASH POINT, COC, Minimum	180°C (356°F)	180°C (356°F)	204°C (400°F)	191°C (375°F)
FIRE POINT, COC	-		238°C (460°F)	-
STORAGE STABILITY, FTMS No. 791, Method 3440	Pass			
POUR POINT, Maximum	-	-12°C (10°F)	-15°C (5°F)	-12°C (10°F)
THERMAL OXIDATION STABILITY at 54°C (130°F)				
Viscosity Increase, %, Maximum	100% in 50 hr	-	-	
N-pentane Insolubles, Weight %, Maximum	X	-	-	
Benzene Insolubles, Weight %, Maximum	2.0	-	-	
CORROSION, COPPER STRIP 3 hr at 121°C (250°F),	Discoloration not greater than ASTM No. 3.0	2.0 (3.0 hr at 121°C (250°F)	Passes No. 2	1b (3.0 hr at 121°C (250°F)
HUMIDITY TEST: 100 hr 49°C (120°F) 100% RH	-	-	-	-
MOISTURE CORROSION FTMS No. 791, Method 5326	Pass	Passes	Passes	Passes
NEUTRALIZATION NUMBER, Max. 10^{-3} kg KOH/kg (mg KOH/g)	-	-	-	-
EVAPORATION, %, Maximum (22 hr at 99°C (210°F)	-	-	-	-
CARBON RESIDUE, %, Maximum	-	-	0.73	-
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, after 5 Minutes Blowing Period				
(a) Sequence 1, 24°C (75°F)	20	Passes	20 max.	20
(b) Sequence 2, 93°C (200°F)	50	Passes	50 max.	0
(c) Sequence 3, 24°C (75°F)	20	Passes	20 max.	10

PROPERTIES	SPEC. REQ.	CITGO[a] No. 93011	GULF[b] GEAR LUB 80W-90	MULTIGEAR LUBRICANT EP 80W-90
Foam CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, after 5 min blowing Period				
(a) Sequence 1, 24°C (75°F)	20	Passes	5	Passes
(b) Sequence 2, 93°C (200°F)	50	Passes	10	Passes
(c) Sequence 3, 24°C (75°F) (retest)	20	Passes	5	Passes
COMPATIBILITY WITH: Rubber Jet and Rocket Fuel LOX	Other lubricants qualified to this Specification			
COLOR, ASTM D 1500	-	-	L-55	5
Load-Carrying and Extreme Pressure Characteristics of Gear Lubricants in axles Under Conditions of high Speed and Shock Loading, FTMS No. 791, Method 6507	Pass	Passes	Passes	Passes
Load-Carrying and Extreme Pressure Characteristics of Gear Lubricants in Axles Under Conditions of High Speed, Low-Torque Operation Followed by Low-Speed, High Torque Operation, FTMS No. 791, Method 6506	Pass	Passes	Passes	Passes

NOTE: When a series of gear lubricants in the 80, 90 and 140 grades are submitted for qualification, the Load-Carry Tests are required only for the 90 grade, provided the additive type and concentrations, and the base stock source and types of treatment are identical for all three grades. "X" incidates reports.

Intended use of this specification gear lubricant is for automotive gear units, heavy duty industrial type enclosed gear units, steering gear and fluid lubricated universal joints of automotive units.

For description of this lubricating oil and recommended usage see Section II. In addition to the products listed, many of the commercial petroleum and lubrication companies manufacture multipurpose gear lubricants which meet this specification. Some of these are:

Product Name	Manufacturer
Amoco Multipurpose Gear Lub. No. 80W-90	Amoco Oil Company
Brayco 689F	Bray Products Division, Burmah-Castrol, Inc.
Formula No. RP649BC	Mobil Oil Corporation
Sunoco Multi-Purpose Gear Lub. GL-5	Sun Refining & Marketing Company
Formula No. TL-11172	Texaco Inc.

a/ Citgo Petroleum Corporation
b/ Gulf Oil Corporation
c/ Getty Refining and Marketing Company (now part of Texaco Inc.)

MILITARY SPECIFICATION: MIL-L-2105C (2)
LUBRICATING OIL, GEAR, MULTIPURPOSE, GRADE 85W/140

PROPERTIES	SPEC. REQ.	CITGO No. 93011	GULF[b/] GEAR LUB. 85W/140	MULTIGEAR[c/] LUBRICANT EP SAE 85W-140
COMPATIBILITY WITH: Rubber Jet and Rocket Fuel LOX	Other Lubricants qualified to this specification	-	Pass	-
COLOR, ASTM D 1500	-	-	L6.0	-
Load-Carrying and Extreme Pressure Characteristics of Gear Lubricants in Axles Under Conditions of High Speed and Shock Loading, FTMS No. 791, Method 6507 '.	Pass	Passes	Passes	Passes
Load-Carrying and Extreme Pressure Characteristics of Gear Lubricants in Axles Under Under Conditions of High Speed, Low-Torque Operation Followed by Low-Speed, High Torque Operation FTMS No. 791, Method 6506	Pass	Passes	Passes	Passes

NOTE: For description of this lubricating oil and recommended usage see Section II.

When a series of gear lubricants in the 80, 90 and 140 grades are submitted for qualification, the Load-Carrying Tests are required only for the 90 grade, provided the additive type and concentrations, and the base stock source and types of treatment are identical for all three grades. "X" indicates reports.

Intended use of this specification gear lubricant is for automotive gear units, heavy duty industrial type enclosed gear units, steering gear and fluid lubricated universal joints of automotive units.

In addition to the products listed, many of the commercial petroleum and lubrication companies manufacture multipurpose gear lubricants which meet the requirements of this specification, some of these are:

Product Name	Manufacturer
Amoco Multipurpose Gear Lubricant 85W-140	Amoco Oil Company
Formula No. RP649BBD	Mobil Oil Corporation
SR GL5 85W-140	Sun Refining & Marketing Company
Formula No. TL-11031A	Texaco Inc.

a/ Citgo Petroleum Corporation
b/ Gul Oil Corporation
c/ Texaco Inc.

MILITARY SPECIFICATION: MIL-L-3150B (2)
LUBRICATING OIL, PRESERVATIVE, MEDIUM

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	Petroleum fraction
Additives	if needed
VISCOSITY, 10^{-6} m^2/Sec (Cs) at 37.8°C (100°F)	100 to 130
POUR POINT, Maximum	-6°C (20°F)
EVAPORATION, %, Maximum at 99°C (210°F)	5.0
CORROSION, COPPER STRIP at 100°C (212°F)	ASTM 2e max.

NOTE: For a description and recommended usage of this lubricating oil, see Section II.

Products listed below meet the requirements of this specification.

Product	Manufacturer
Tectyl 802-A	Ashland Oil, Inc.
Petrotect 90B	Pennsylvania Refining Company
Royco 315	Royal Lubricants Co., Inc.
Code 18831	Southwest Petro-Chem. Div. (Witco Chemical Corp.)

MILITARY SPECIFICATION: MIL-L-6081C (2)
LUBRICATING OIL, JET ENGINE: GRADE 1010

PROPERTIES	SPEC. REQ.	ROYCO[a/] 460	BRAYCO[b/] 460
COMPOSITION Base Oil	Petroleum		
Additives			
Viscosity Index Improver	None	-	-
Oxidation Inhibitor	None	-	-
Detergent	Allowed	Yes	Yes
EP (extreme pressure)			
Pour Point Depressant			
Antifoam Additive	Allowed	-	Yes
Corrosion Protection			
Other			
VISCOSITY: 10^{-6} m^2/Sec (Cs) at			
-40°C (-40°F)	3,000	3,000	2,850
38°C (100°F)	10.0	10.0	10.2
99°C (210°F)	-	-	-
VISCOSITY STABILITY, % Change (3 hr at 4°C (40°F)	2	1.0	0.23
SPECIFIC GRAVITY, 16°C (60°F)	-	-	0.8762
FLASH POINT, COC, Minimum	132°C (270°F)	132°C (270°F)	141°C (285°F)
FIRE POINT, COC			
POUR POINT, Maximum	-57°C (-70°F)	-57°C (-70°F)	-59°C (-75°F)
CORROSION AND OXIDATION STABILITY			
168 Hr at 121°C (250°F)			
Weight Change 10^{-2} kg/m^2 (mg/cm^2)			
Copper, Steel, Aluminum Alloys, Magnesium Alloys, and Cadmium-Plated Steel	±0.2	0.2	0.03
Visible Corrosion (20X)	None	None	None
Viscosity Change at 38°C (100°F), %	-5 to +20	Pass	Pass
Neutralization Number Increase, Maximum	0.20	0.20	Pass
Insoluble Materials or Gumming	None	Pass	Pass
CORROSION, COPPER STRIP, ASTM Scale, Maximum	1.0	Pass	Pass
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity			
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.10	0.10	0.00
PRECIPITATION NUMBER	-	0	
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels			
LOX			
COLOR, ASTM D 1500	5.5	5.0	L1.5

MILITARY SPECIFICATION: MIL-L-6081C (2)
LUBRICATING OIL, JET ENGINE: GRADE 1010

PROPERTIES	SPEC. REQ.	ROYCO[a/] 460	BRAYCO[b/] 460

NOTE: For description of the refined petroleum base lubricating oil and recommended usage, see Section II.

In addition to the products listed, many of the commercial petroleum and lubrication companies manufacture jet engine oils which meet the requirements of this specification. Some of these are:

Product Name	Manufacturer
P.Q. Turbo Oil	American Oil & Supply Company
NOX-Rust X-275	Daubert Chemical Company
Delta 1280 Jet Engine Oil 1010	Delta Petroleum Company, Inc.
MacMillan Jet Engine Oil 1010	MacMillan Petroleum Corporation
Petrolube 4142	Penreco

a/ Royal Lubricants Company, Inc.
b/ Bray Products Division, Burmah-Castrol Inc.

MILITARY SPECIFICATION: MIL-L-6082-D
LUBRICATING OIL, AIRCRAFT RECIPROCATING ENGINE (PISTON) GRADE 1065

PROPERTIES	SPEC. REQ.	CITGO[a/] AVIATION OIL 1065	AIRCRAFT[b/] ENGINE OIL 65
COMPOSITION Base Oil	Petroleum		
Additives			
Viscosity Index Improver	None	-	None
Oxidation Inhibitor	None	-	None
Detergent	None	-	None
EP (extreme pressure)	None	-	None
Pour Point Depressant	1.0% Maximum	-	Pass
Antifoam Additive	None	-	None
Corrosion Protection	None	-	None
Other			
VISCOSITY: 10^{-6} m^2/Sec (Cs) at			
38°C (100°F)	-	110	116.0
54°C (130°F)	-	50.6	-
99°C (210°F)	10.76 to 12.4	11.3 to 12.25	11.9
VISCOSITY INDEX, Minimum	100	100	103
SPECIFIC GRAVITY, 16°C (60°F)	-	-	0.8756
FLASH POINT, COC, Minimum	205°C (400°F)	216°C (420°F)	232°C (450°F)
FIRE POINT, COC			
POUR POINT, Maximum			
Undiluted	-18°C (0°F)	-18°C (0°F)	-26°C (-15°F)
Diluted	-54°C (-65°F)	-54°C (-65°F)	-59°C (-75°F)
OXIDATION STABILITY at 54°C (130°F)			
Viscosity Increase, %, Maximum			
Neutralization Number Increase			
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)	1.0	1.0	1B
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity			
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.10	0.10	0.02
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F)			
CARBON RESIDUE, %, Maximum	0.60	0.30	0.14
WORK FACTOR	0.85	0.85	-
ASH, Weight, % Maximum	0.0025	0.0025	0.002
SEDIMENTATION, Volume, %, Maximum	0.005	0.005	
CONTAMINATION, 10^{-4} kg/m^3 (mg/gal), Maximum	39.7 (15.0)	39.7 (15.0)	-
COLOR, ASTM D 1500	-	6.0	4.5

MILITARY SPECIFICATION: MIL-L-6082-D
LUBRICATING OIL, AIRCRAFT RECIPROCATING ENGINE (PISTON) GRADE 1065

PROPERTIES	SPEC. REQ.	CITGO[a/] AVIATION OIL 1065	AIRCRAFT[b/] ENGINE OIL 65

NOTE: For a description of this petroleum base lubricating oil for reciprocating aircraft engines and recommended usage see Section II.

In addition to the products listed, most of the commercial petroleum and lubrication companies manufacture lubricating oils which meet the requirements of specification. Some of these are:

Product Name	Manufacturer
Castrolaero 113	Burmah-Castrol, Inc.
Delta 1065	Delta Petroleum Co., Inc.
Petrolube 1065	Penreco-A Pennzoil Division
Aeroshell Oil 65	Shell Oil Company

a/ Citgo Petroleum Corporation
b/ Texaco Inc.

MILITARY SPECIFICATION: MIL-L-6082D
LUBRICATING OIL, AIRCRAFT RECIPROCATING ENGINE (PISTON): GRADE 1100

PROPERTIES	SPEC. REQ.	CITGO[a/] AVIATION OIL 1100	AIRCRAFT[b/] ENGINE OIL 100
COMPOSITION Base Oil	Petroleum	-	-
Additives			
Viscosity Index Improver	None	-	-
Oxidation Inhibitor	None	-	-
Detergent	None	-	-
EP (extreme pressure)	None	-	-
Pour Point Depressant	1.0%, Maximum	-	-
Antifoam Additive	None	-	-
Corrosion Protection	None	-	-
Other	None	-	-
VISCOSITY: 10^{-6} m^2/Sec (Cs) at			
38°C (100°F)	-	259	225.0
40°C (104°F)			
100°C (212°F)	18.7 to 21.0	19.42 to 20.4	19.7
VISCOSITY INDEX, Minimum	95	95	102
SPECIFIC GRAVITY, 16°C (60°F)	-	-	0.8854
FLASH POINT, COC, Minimum	243°C (470°F)	277°C (530°F)	263°C (505°F)
FIRE POINT, COC			
POUR POINT, Maximum			
Undiluted	-12°C (10°F)	-15°C (5°F)	-23°C (-10°F)
Diluted	-54°C (-65°F)	-54°C (-65°F)	-62°C (-80°F)
OXIDATION STABILITY at 54°C (130°F)			
Viscosity Increase, %, Maximum			
Neutralization Number Increase			
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)	1.0	1.0	Pass
HUMIDITY TEST: 100 hr 49°C (120°F) 100% Relative Humidity			
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.10	0.10	Pass
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F)			
CARBON RESIDUE, % Maximum	1.2	0.25	0.22
WORK FACTOR	0.85	0.85	-
ASH, Weight %, Maximum	0.0025	0.0025	Pass
SULFUR, %, Maximum	0.5	0.05 to 0.25	Pass
SEDIMENTATION, Volume %, Maximum	0.005	0.005	-
CONTAMINATION 10^{-4} kg/m^3 (mg/gal), Maximum	39.7 (15.0)	39.7 (15.0)	Pass
COLOR, ASTM D 1500	-	5.0	-

MILITARY SPECIFICATION: MIL-L-6082D
LUBRICATING OIL, AIRCRAFT RECIPROCATING ENGINE (PISTON): GRADE 1100

PROPERTIES	SPEC. REQ.	CITGO[a] AVIATION OIL 1100	AIRCRAFT[b] ENGINE OIL 100

NOTE: For a description of this petroleum base lubricating oil for reciprocating aircraft engines and recommended usage, see Section II.

In addition to the products listed, most of the commercial petroleum and lubrication companies manufacture lubricating oils which meet the requirements of specificaiton. Some of these are:

Product Name	Manufacturer
Castrolaero 117	Burmah-Castrol Inc.
Chevron Aviation Oil 100	Chevron U.S.A., Inc.
Precision 1100	Delta Petroleum Co., Inc.
Exxon Aviation Oil 100	Exxon Company, U.S.A.
Gulf A-1100	Gulf Oil Corporation
RM-223E	Mobil Oil Corp.
Petrolube 1100	Penreco-A Pennzoil Division
Phillips 66 Aviation Oil, Grade 1100	Phillips Petroleum Company
Aeroshell Oil 100	Shell Oil Company

a/ Citgo Petroleum Corporation
b/ Texaco Inc.

MILITARY SPECIFICATION: MIL-L-6085B (1)
LUBRICATING OIL, INSTRUMENT, AIRCRAFT, LOW VOLATILITY

PROPERTIES	SPEC. REQ.	BRAYCO[a]/ 885	ANDEROL[b]/ L-401-D
COMPOSITION Base Oil	Synthetic	Synthetic	Synthetic
Additives			
Viscosity Index Improver	None	-	-
Oxidation Inhibitor	None	-	-
Detergent	Allowed	Yes	-
EP (extreme pressure)	Allowed	-	-
Pour Point Depressant	Allowed	-	-
Antifoam Additive	None	-	-
Corrosion Protection	Allowed	Yes	-
Other	Allowed	Yes	-
VISCOSITY: 10^{-6} m^2/Sec (Cs) at			
-54°C (-65°F), Maximum	12,000	10,800	11,200
38°C (100°F)	-	-	12.65
54°C (130°F)	8.0	9.0	8.10
99°C (210°F)	-	-	3.40
VISCOSITY INDEX, Minimum	-	-	168
SPECIFIC GRAVITY, 16°C (60°F)			
FLASH POINT, COC, Minimum	185°C (365°F)	210°C (410°F)	227°C (440°F)
FIRE POINT, COC	-	-	-
POUR POINT, Maximum	-57°C (-70°F)	-65°C (-85°F)	-65°C (-85°F)
CORROSION AND OXIDATION STABILITY			
168 Hr at 121°C (250°F)			
Weight Change 10^{-10} kg/m^2 (mg/cm^2)			
Aluminum	0.2	0.0	-
Copper	0.2	0.1	-
Magnesium	0.2	0.0	-
Steel	0.2	0.0	-
Cadmium-Plated Steel	0.2	0.0	-
Pitting on Etching (visible, 20X)	None	None	-
Viscosity Increase at 54°C (130°F), Maximum	±5	-0.8	-
Neutralization Number Increase	0.5	0.2	-
GALVANIC CORROSION: Steel-Brass 10 Days at 27°C (80°F)	Pass	Pass	Pass
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)			
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity	Pass	-	Pass
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	-	Neutral	-
EVAPORATION, %, Maximum (22 Hr at 120°C (248°F)	1.8	0.5	0.84
CARBON RESIDUE, %, Maximum	-	-	-
COLOR, ASTM D 1500	5.0	2.5	-

PROPERTIES	SPEC. REQ.	BRAYCO[a/] 885	ANDEROL[b/] L-401 D
PRECIPITATION NUMBER	0	Pass	-
SULFATED RESIDUE, Weight %	-	-	-
LOW TEMPERATURE STABILITY 72 Hr at -54°C (-65°F)	Pass	Pass	-

NOTE: For a description of this synthetic base lubricating oil composition and recommended usage, see Section II.

In addition to the products listed, the following low volatility oils supplied by the listed manufacturers meet the general requirements of this specification:

Product Name	Manufacturer
"PQ" Rust Preventive No. 160	American Oil & Supply Company
Hatcol-3885	Hatco Chemical Corporation
Univis P-12	Exxon Company, U.S.A.
Product 80	Octagon Process, Inc.
Royco 885	Royal Lubricants Company, Inc.

a/ Bray Products Division, Burmah-Castrol, Inc.
b/ Tenneco Chemicals, (Nuodex, Inc.)

MILITARY SPECIFICATION: MIL-L-6086C
LUBRICATING OIL, GEAR, PETROLEUM BASE, GRADE L

PROPERTIES	SPEC. REQ.	ROYCO[a] 586 GRADE L MINERAL OIL
COMPOSITION Base Oil		
Additives		
Viscosity Index Improver	-	
Oxidation Inhibitor		
Detergent		
EP (extreme pressure)	-	Yes
Pour Point Depressant		
Antifoam Additive		
Corrosion Protection	-	
Other		
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
38°C (100°F)	23 to 34	31.6
54°C (130°F)		5.3
99°C (210°F)	-	
VISCOSITY INDEX, Minimum	80	110
SPECIFIC GRAVITY, 16°C (60°F)	-	
FLASH POINT, COC, Minimum	138°C (280°F)	182°C (360°F)
FIRE POINT, COC	-	
POUR POINT, Maximum	-40°C (-40°F)	43°C (-45°F)
OXIDATION STABILITY at 54°C (130°F)		
Viscosity Increase, %, Maximum		
Neutralization Number Increase		
CORROSION, COPPER STRIP		
3 Hr at 100°C (212°F)	2 Maximum	1A
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity		
NEUTRALIZATION NUMBER, Maximum		
10^{-3} kg KOH/kg (mg KOH/g)	1.0	0.05
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F)		
CARBON RESIDUE, %, Maximum		
FOAM CHARACTERISTICS (ASTM D 892)		
10^{-6} m^3 (ml) Foam, 5 min. Blowing/ 10 Min. Settling		
(a) Sequence 1, 24°C (75°F)	5/0	
(b) Sequence 2, 93°C (200°F)	20/0	
(c) Sequence 3, 24°C (75°F) (retest)	5/0	
COMPATIBILITY WITH: Mineral Oil Base	Pass	-
COLOR, ASTM D 1500	8.0	-

MILITARY SPECIFICATION: MIL-L-6086C
LUBRICATING OIL, GEAR, PETROLEUM BASE, GRADE L

PROPERTIES	SPEC. REQ.	ROYCO[a] 586 GRADE L MINERAL OIL
MEAN HERTZ LOAD, Minimum (Shell 4-ball tester)	392.3 N (40 kg)	421.7 N (43 kg)
PRECIPITATION NUMBER, ASTM, Maximum	0.10	Trace
CHLORINE, Weight %	-	-

NOTE: For a description of this low temperature mineral oil lubricant and recommended usage see Section II.

In addition to the products listed, the following lubricating oils supplied by the listed manufacturers also meet the general requirements of this specification.

Product Name	Manufacturer
Gearborne L	Borne Chemical Co., Inc.
GB 3896 L	Golden Bear Division (Witco Chemical Corp.)
Aeroshell Fluid 5 L-A	Shell Oil Company

a/ Royal Lubricants Company, Inc.

MILITARY SPECIFICATION: MIL-L-6086C
LUBRICATING OIL, GEAR, PETROLEUM BASE, GRADE M

PROPERTIES	SPEC. REQ.	ROYCO[a] 586M GRADE M MINERAL OIL
COMPOSITION Base Oil		
Additives	-	
Viscosity Index Improver		
Oxidation Inhibitor		
Detergent		
EP (extreme pressure)	-	Yes
Pour Point Depressant		
Antifoam Additive		
Corrosion Protection	-	
Other		
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
38°C (100°F)	60 to 82	70.4
54°C (130°F)		
99°C (210°F)	-	7.9
VISCOSITY INDEX, Minimum	80	
SPECIFIC GRAVITY, 16°C (60°F)		
FLASH POINT, COC, Minimum	154°C (310°F)	188°C (370°F)
FIRE POINT, COC	-	
POUR POINT, Maximum	-29°C (-20°F)	-31.7°C (-25°F)
OXIDATION STABILITY at 54°C (130°F)		
Viscosity Increase, %, Maximum		
Neutralization Number Increase		
CORROSION, COPPER STRIP		
3 Hr at 100°C (212°F)	2.0	1A
HUMIDITY TEST: 100 hr 49°C (120°F)		
100% Relative Humidity		
NEUTRALIZATION NUMBER, Maximum		
10^{-3} kg KOH/kg (mg KOH/g)	1.0	
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F)		
CARBON RESIDUE, %, Maximum		
FOAM CHARACTERISTICS (ASTM D 892)		
10^{-6} m^3 (ml) Foam, 5 Min. Blowing/ 10 Min. Settling		
(a) Sequence 1, 24°C (75°F)	5/0	
(b) Sequence 2, 93°C (200°F)	20/0	
(c) Sequence 3, 24°C (75°F) (retest)	5/0	
COMPATIBILITY WITH: Mineral Oil Base	Pass	
COLOR, ASTM D 1500	8.0	

MILITARY SPECIFICATION: MIL-L-6086C
LUBRICATING OIL, GEAR, PETROLEUM BASE, GRADE M

PROPERTIES	SPEC. REQ.	ROYCO[a/] 586M GRADE M MINERAL OIL
MEAN HERTZ LOAD, Minimum (Shell 4-ball tester)	392.3 N (40 kg)	441.3 (45 kg)
PRECIPITATION NUMBER, ASTM, Maximum	0.10	Trace
CHLORINE, Weight %		

NOTE: For a description of this mineral oil general purpose gear lubricant and recommended usage, see Section II.

In addition to the products listed, the following lubricating oils supplied by the listed manufacturer also meet the general requirements of this specification:

Product Name	Manufacturer
Gearborne M	Borne Chemical Co., Inc.
GB 3896 M	Golden Bear Division (Witco Chemical Corp.)
Aeroshell Fluid 5 M-A	Shell Oil Company

a/ Royal Lubricants Company, Inc.

MILITARY SPECIFICATION: MIL-L-7808J
LUBRICATING OIL, AIRCRAFT TURBINE ENGINE, SYNTHETIC BASE

PROPERTIES	SPEC. REQ.	ROYCO[a]/ 808 H
COMPOSITION Base Oil	Not limited	Synthetic Ester
Additives	Not limited	
Viscosity Index Improver	-	
Oxidation Inhibitor	-	Yes
Detergent	-	
EP (extreme pressure)	TCP 1.0% orthoisomer	Yes
Pour Point Depressant		
Antifoam Additive		Yes
Corrosion Protection		Yes
Other	No metalorganic titanium	
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
40°C (104°F)	Report	12.9
-54°C (-65°F)	17,000 max.	-
100°C (212°F)	3.0 min.	3.2
VISCOSITY STABILITY, 3 Hr at -54°C (-65°F)		
Viscosity at -54°C (-65°F) 10^{-6} m^2/Sec (cs), Minimum	17,000	11,900
Viscosity Variation, %	±6.0	
VISCOSITY INDEX, Minimum	-	
SPECIFIC GRAVITY, 16°C (60°F)	-	
FLASH POINT, COC, Minimum	210°C (410°F)	(405°F)
FIRE POINT, COC	-	-
AUTOIGNITION POINT	-	-
POUR POINT, Maximum	-59°C (-75°F)	(< -80°F)
OXIDATION STABILITY		
Viscosity Increase at 40°C (104°F)	-5 to +15	3.9
Neutralization Number Increase	2.0	
CORROSION, 72 Hr at 175°C (347°F)		
Weight Change, 10^{-2} kg/m^2 (mg/cm^2)		
Steel	±0.2	0.000
Silver	±0.2	-0.007
Aluminum Alloy	±0.2	0.000
Magnesium Alloy	±0.4	-0.007
Copper	±0.4	-0.007
Bronze	±0.4	
Titanium	±0.2	
PITTING, ETCHING, AND VISIBLE CORROSION (20X)	None	
LEAD CORROSION, 1.0 Hr at 164°C (325°F) Weight Loss, 15.5 kg/m^2 (mg/in^2)	< 9.3	0.1
SILVER AND COPPER CORROSION, 50 Hr at 232°C (450°F) Weight Loss, 15.5 kg/m^2 (mg/in^2)	< 4.5	0.02 Copper 0.04 Gain-Silver
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.30	-

MILITARY SPECIFICATION: MIL-L-7808J
LUBRICATING OIL, AIRCRAFT TURBINE ENGINE, SYNTHETIC BASE

PROPERTIES	SPEC. REQ.	ROYCO[a/] 808H
EVAPORATION (6.5 Hr at 205°C (401°F)) Weight Loss, %	30	17
CARBON RESIDUE, %, Maximum		
FOAM CHARACTERISTICS		
10^{-6} m^3 (ml) Foam, After Blowing (and time to collapse), Sec		
(a) Sequence 1, 80°C (176°F)	150/60	0
(b) Sequence 2, 110°C (230°F)	150/60	0
COMPATIBILITY WITH ELASTOMERS		
168 Hr at 70°C (158°F)		
Rubber "H", Swelling, %	12 to 35	30.6
Rubber "F", Swelling, %	2 to 25	18
Tensile Strength Change, %	50	-42
Elongation Change, %	50	-21.5
Hardness Shore Durometer Number Change	20	-12
COMPATIBILITY WITH MIL-L-7808 and 6081 OILS	Pass	MIL_L-7808 Oils
COLOR, ASTM D 1500	-	
DEPOSITION NUMBER	1.5	0.26
LOAD CARRYING ABILITY (Ryder) % Reference Oil, Minimum	Report	Passess
STORAGE STABILITY, 110°C (230°F)		
Lead Corrosion, g/m^2		
2 Days	40	Passes
7 Days	230	Passes
EXTENDED STORAGE STABILITY 12 Months at 24°C (75°F)	No Separation	-
100 HR ENGINE TEST (J-57-19 or 29 Engine)	Pass	Pass

NOTE: For a description of this synthetic ester base stock lubricant, possessing good thermal and oxidative stability, and recommended usage, see Section II.

In addition to the products listed, the lubricant listed below also meets the general requirements of this specificaiton; however, specific properties are not available:

Product Name	Manufacturer
PQ Turbine Oil 8365	American Oil & Supply Company
Brayco 880H	Bray Products Division, Burmah-Castrol Inc.
Castrol 399	Burmah-Castrol Inc.
Exxon Turbo Oil 2389	Exxon Company U.S.A.
Hatcol 1278	Hatco Chemical Corporation
RM-248A	Mobil Oil Corporation

a/ Royal Lubricants Company, Inc.

MILITARY SPECIFICATION: MIL-L-7870A
LUBRICATING OIL, GENERAL PURPOSE, LOW TEMPERATURE

PROPERTIES	SPEC. REQ.	ROYCO[a/] 363	BRAYCO[b/] 363
COMPOSITION Base Oil	Petroleum		
Additives			
Viscosity Index Improver			
Oxidation Inhibitor	Allowed		
Detergent			
EP (extreme pressure)			
Pour Point Depressant			
Antifoam Additive			
Corrosion Protection	Allowed		
Other			
VISCOSITY: 10^{-6} m^{-2}/SEC (Cs) at			
-40°C (-40°F), Maximum	4,000	3,400	3,227
38°C (100°F), Minimum	10	10.5	10.7
99°C (210°F)			
VISCOSITY INDEX, Minimum			
SPECIFIC GRAVITY, 16°C (60°F)			
FLASH POINT, COC, Minimum	130°C (265°F)	135°C (275°F)	138°C (280°F)
POUR POINT, Maximum	-57°C (-70°F)	-59°C (-75°F)	-59°C (-75°F)
CORROSIVITY, GALVANIC 10 Days at 27°C (80°F) No Corrosion or Attack	Pass	Pass	Pass
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)	None	None	None
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity	Pass	Pass	Pass
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)			
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F))	22	20	18.6
CORROSION AND OXIDATION STABILITY 168 Hr at 121°C (250°F)			
Weight Change 10^{-2} kg/m^2 (mg/cm^2)			
Copper	±0.2	±0.2	-0.01
Steel	±0.2	±0.2	-0.01
Aluminum	±0.2	±0.2	-0.03
Magnesium	±0.2	±0.2	0.00
Cadmium-Plated Steel	±0.2	±0.2	0.00
Viscosity Change at 38°C (100°F), %	-5 to +20	Pass	5.04
Neutralization Number Increase 10^{-3} kg KOH/kg (mg KOH/g), Maximum	0.20	0.20	0.06
COLOR, ASTM D 1500	5	5	4
PRECIPITATION NUMBER	0	0	0

MILITARY SPECIFICATION: MIL-L-7870A
LUBRICATING OIL, GENERAL PURPOSE, LOW TEMPERATURE

PROPERTIES	SPEC. REQ.	ROYCO[a/] 363	BRAYCO[b/] 363
LOW TEMPERATURE STABILITY 72 Hr at -54°C (-65°F) No Gel on Separation	Pass	Pass	Pass

NOTE: In addition to the products listed, the following also meet the general requirements of this specificaiton. For a description and recommended usage of this general purpose low temperature oil, see Section II.

Product Name	Manufacturer
"PQ" Rust Preventive No. 107	American Oil & Supply Company
Octoil 70	Octagon Process, Inc.
Petrotect 7870A	Penreco, Inc.
Aeroshell Fluid 3	Shell Oil Company

a/ Royal Lubricants Company, Inc.
b/ Bray Products Division, Burmah-Castrol Inc.

PROPERTIES	SPEC. REQ.	BRAYCO 490[a/] 490B
COMPOSITION Base Oil	Petroleum	Petroleum
Additives (see Note)	-	
Viscosity Index Improver	-	
Oxidation Inhibitor	-	
Detergent	-	
Sulfur, Weight %	X	X
Sulfated Ash, %	X	X
Chlorine, %	X	X
Phosphorus, %	X	X
Calcium, %	X	X
Zinc, %	X	X
Barium, %	X	NIL
Magnesium, %	X	Present
Nitrogen, %	X	NIL
EP (extreme pressure)	-	
Pour Point Depressant	-	
Antifoam Additive	-	
Corrosion Protection		
Other	X	X
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
38°C (100°F)		
100°C (212°F)	11.4 to 14.1	12.47
VISCOSITY INDEX, Minimum	X	93
SPECIFIC GRAVITY, 16°C (60°F)	-	
FLASH POINT, COC, Minimum	199°C (390°F)	246°C (475°F)
FIRE POINT, COC	-	
POUR POINT, Maximum	-12°C (10°F)	-12°C (10°F)
OXIDATION STABILITY at 54°C (130°F)		
Viscosity Increase, %, Maximum		
Neutralization Number Increase		
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)		
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity		
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	-	
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F))		
CARBON RESIDUE, %, Maximum		
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, 10 Min Settling		
(a) Sequence 1, 24°C (75°F)	300	0/0
(b) Sequence 2, 93°C (200°F)	25	15/0
(c) Sequence 3, 24°C (75°F) (retest)	300	0/0

MILITARY SPECIFICATION: MIL-L-9000G (4)
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, DIESEL: SYMBOL 9250

PROPERTIES	SPEC. REQ.	BRAYCO 490[a/] 490B
COMPATIBILITY WITH: (oils of same spec.)	Pass	Pass
COLOR, ASTM D 1500	-	
HOMOGENEITY 24 Hr at -32°C (-25°F) No Separation	Pass	Pass
CONTAMINATION: Solid Particles		
10^{-4} kg/m^3 (mg/gal) Maximum	10	0.5
Fibrous Material (fibre/gal) Maximum	1.0	0

NOTE: For a description of this diesel internal combustion engine lubricating oil and recommended usage see Section II. "X" indicates reports.

In addition to the products listed, many commercial petroleum and lubrication companies manufacture diesel engine lubricating oils which meet the general requirements of this specification. Some of these are:

Product Name	Manufacturer
Batco 9000G	Battenfeld Grêase & Oil Corp. of NY
Standard 9250	Chevron U.S.A., Inc.
Precision LX9250	Delta Petroleum Co., Inc.
IL-9000-G3	Imperial Oil Co., Inc.
Motrex 651	Mobil Oil Corporation
Shell 9250	Shell Oil Company
SR MIL-L-9000G	Sun Refining and Marketing Co.
Union Symbol Oil 9250	Union Oil Co. of California
Posolube 9250	Golden Bear Division (Witco Chemical Corp.)

a/ Bray Products Division, Burmah-Castrol Inc.

MILITARY SPECIFICATION: MIL-L-17331 H
LUBRICATING OIL, STEAM TURBINE, AND GEAR, MODERATE SERVICE

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	
Additives	
Sulfated Residue, %	record
Sulfur, %	record
VISCOSITY: 10^{-6} m^2/Sec (Cs) at	
38°C (100°F)	82-110
99°C (210°F), Minimum	8.2
API GRAVITY, 16°C (60°F)	record
FLASH POINT, COC, Minimum	204°C (400°F)
POUR POINT, Maximum	-7°C (20°F)
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.30
OXIDATION TEST, ASTM D943 Minimum hrs to reach neutralization valve 2.0 mg	Pass
CORROSION, SALT WATER	None
FOAM CHARACTERISTICS (Method D892) 10^{-6} m^3 (ml) Foam, 5 min. blowing/ 10 min. Settling	
(a) Sequence 1, 24°C (75°F)	No limit/300
(b) Sequence 2, 93°C (200°F)	No limit/25
(c) Sequence 3, 24°C (75°F)	No limit/300
CORROSION COPPER STRIP ASTM D130	Pass
EMULSION TEST, Minutes ASTM D1401, Settle out/ Stirred	3/30
COLOR, ASTM D1500	record
BEARING COMPATIBILITY	Pass

MILITARY SPECIFICATION: MIL-L-17331-H
LUBRICATING OIL, STEAM TURBINE AND GEAR, MODERATE SERVICE

PROPERTIES	SPEC. REQ.
WATER, ASTM D95	None
CARBON RESIDUE, %, Maximum	Record
LOAD CARRYING ABILITY, ASTM D1947 p.p.i., minimum	2,200
WEAR TEST, ASTM D6503 Scar diameter, mm, Maximum	0.33
CONTAMINATION mg. Maximum/gal	10
CONTAMINATION Fibers/gal, Maximum	1

NOTE: For a description and recommended usage of this lubricating oil, see Section II.

Products listed below meet the requirements of this specification.

Product Name	Manufacturer
Chevron Turbine Oil 100 TEP	Chevron U.S.A., Inc.
1209 Turbine Lubricant	Exxon Company, U.S.A.
Gulf Harmony 078 EP	Gulf Oil Corporation
Imperial Oil 2190-TEP-3	Imperial Oil Co., Inc.
Shell XSL-9127	Shell Oil Company
Shell Turbo 78	Shell Oil Company
Sunoco Marine Turbine Oil 17331	Sun Refining and Marketing Company
TL-9932A	Texaco U.S.A. (Division of Texaco, Inc.)
GB 2190 Turbine	Golden Bear Division (Witco Chemical Corporation)

MILITARY SPECIFICATION: MIL-L-21260C
LUBRICATING OIL, INTERNAL-COMBUSTION ENGINE, PRESERVATIVE
GRADE 10W

PROPERTIES	SPEC. REQ.	BRAYCO[b]/ 441 SAE-10
COMPOSITION Base Oil	-	Petroleum
Re-Refined Components	None	None
Additives (see note)		
Viscosity Index Improver		Yes
Oxidation Inhibitor		Yes
Detergent		
EP (extreme pressure)		
Pour Point Depressant		
Antifoam Additive		Yes
Corrosion Protection		Rust Preventive
Other		Acid Neutralizer
Metallic Components	X	
Sulfur	X	
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
-18°C (0°F), Maximum		
40°C (104°F)	-	38.2
100°C (212°F)	5.6 to < 7.4	5.76
VISCOSITY INDEX, Minimum	X	100
SPECIFIC GRAVITY, 16°C (60°F)	X	-
FLASH POINT, COC, Minimum	205°C (401°F)	204°C (400°F)
FIRE POINT, COC,	-25°C (-13°F)	
BORDERLINE PUMPING TEMP. Maximum	-25°C (-13°F)	
POUR POINT, Maximum	-32°C (-26°F)	-29°C (-20°F)
STABLE POUR POINT, Maximum	-32°C (-26°F)	-29°C (-20°F)
CORROSION PROTECTION (mild steel spec. oil coated)		
(a) Humidity; 720 Hr at 38°C (100°F) Relative Humidity, Maximum Corrosion "Trace" (3 dots, 1.0 mm dia.)	Trace	None
(b) Salt Water; 20 Hr at 25°C (77°F), Maximum Corrosion, "Trace" (3 dots, 1.0 mm dia.)	Trace	None
TOTAL ACID & BASE NUMBERS	X	X
VOLATILE MATTER, 4 Hr Steam Bath, % Weight Loss, Maximum	2.0	Passes
CARBON RESIDUE, %, Maximum	X	X
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, 5 Min. Blowing/ 10 Min. Settling, Maximum		
(a) Sequence 1, 24°C (75°F)	25/0	5/0
(b) Sequence 2, 93°C (200°F)	150/0	45/0
(c) Sequence 3, 24°C (75°F) (retest)	25/0	5/0

MILITARY SPECIFICATION: MIL-L-21260C
LUBRICATING OIL, INTERNAL-COMBUSTION ENGINE, PRESERVATION
GRADE 10W

PROPERTIES	SPEC. REQ.	BRAYCO[a/] 441 SAE-10
COMPATIBILITY WITH: MIL-L-2104 Oils	Required	Passes
COLOR, ASTM D 1500		4.0
SULFATED RESIDUE, %	X	X

NOTE: For a description and recommended usage of this preservative lubricating oil, see Section II. "X" indicates reports.

In addition to the products listed, several other petroleum and lubricant companies manufacture products which meet the requirements of this specification. Some of these are:

Product Name	Manufacturer
Withrow 829 SAE 10W	Arthur C. Withrow Company
Batco MIL-L-21260C SAE10W Motor Oil	Battenfeld Grease & Oil Corp. of New York
DSL Preservative 21260	Davis-Howland Oil Corp.
Precision PE-1	Delta Petroleum Company, Inc.
WS1577 Motor Oil 10W	Exxon Company, U.S.A.
MTN-581A-1	Mobil Oil Corp.
SR 2600	Sun Refining & Marketing Co.
Tectyl 910A	Valvoline Oil Company

a/ Bray Products Division, Burmah-Castrol Inc.

MILITARY SPECIFICATION: MIL-L-21260C
LUBRICATING OIL, INTERNAL-COMBUSTION ENGINE, PRESERVATIVE
GRADE 30

PROPERTIES	SPEC. REQ.	BRAYCO[a] 443 SAE 30
COMPOSITION Base Oil	-	Petroleum
Re-Refined Components		
Additives (see note)	None	None
Viscosity Index Improver	-	
Oxidation Inhibitor	-	Yes
Detergent	-	Yes
EP (extreme pressure)	-	
Pour Point Depressant	-	
Antifoam Additive	-	
Corrosion Protection	-	Rust Preventive
Other		Acid Neutralizer
Metallic Components	X	
Sulfur	X	
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
-18°C (0°F), Maximum	X	
40°C (104°F)	X	122
100°C (212°F)	0.3 to 12.5	10.1
VISCOSITY INDEX, Minimum	75	59
SPECIFIC GRAVITY, 16°C (60°F)	X	
FLASH POINT, OCO, Minimum	220°C (428°F)	221°C (430°F)
FIRE POINT, COC		
POUR POINT, Maximum	-32°C (-26°F)	-23°C (-10°F)
CORROSION PROTECTION (mild steel spec. oil coated)		
(a) Humidity; 200 Hr at 38°C (100°F), 100% Relative Humidity; Maximum Corrosion "Trace" (3 dots, 1.0 mm dia.)	Trace	None
(b) Salt Water; 20 Hr at 25°C (77°F) Maximum Corrosion "Trace" (3 dots, 1.0 mm dia.)	Trace	None
TOTAL ACID & BASE NUMBERS	X	X
VOLATILE MATTER, 4 Hr Steam Bath, 5% Weight Loss, Maximum	2.0	Passes
CARBON RESIDUE, %, Maximum	X	X
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, 5 Min. Blowing/ 10 Min. Settling, Maximum		
(a) Sequence 1, 24°C (75°F)	25/0	35/9
(b) Sequence 2. 93°C (200°F)	150/0	300/0
(c) Sequence 3, 24°C (75°F) (retest)	25/0	40/10
COMPATIBILITY WITH:		
MIL-L-2104 Oils	Required	Passes

MILITARY SPECIFICAITON: MIL-L-21260C
LUBRICATING OIL, INTERNAL-COMBUSTION ENGINE, PRESERVATIVE
GRADE 30

PROPERTIES	SPEC. REQ.	BRAYCO[a/] 443 SAE 30
COLOR, ASTM D 1500		4.5
SULFATED RESIDUE	X	X

NOTE: For a description and recommended usage of this preservative lubricating oil, see Section II. "X" indicates reports.

In addition to the products listed, several other petroleum and lubricant companies manufacture products which meet the requirements of this specification. Some of these are:

Product Name	Manufacturer
PQ823 SAE30	American Oil & Supply Co.
Withrow 828 SAE30	Arthur C. Withrow Co.
Batco MIL-L-21260C SAE30	Battenfeld Grease & Oil Corp. of New York
DSL Engine Preservative Oil	Davis-Howland Oil Corp.
Precision PE-2	Delta Petroleum Company, Inc.
WS 1578 Motor Oil 30	Exxon Company, U.S.A.
MTN 581 C-1	Mobil Oil Corp.
SR 2600	Sun Refining & Marketing Co.
Tectyl 930A	Valvoline Oil Company

a/ Bray Products Division, Burmah-Castrol Inc.

MILITARY SPECIFICATION: MIL-L-21260C
LUBRICATING OIL, INTERNAL-COMBUSTION ENGINE, PRESERVATIVE
GRADE 50

PROPERTIES	SPEC. REQ.	BRAYCO[a/] 445 SAE-50
COMPOSITION Base Oil		
Re-Refined Components	-	Petroleum
Additives (see note)	None	None
Viscosity Index Improver		
Oxidation Inhibitor	-	Yes
Detergent	-	Yes
EP (extreme pressure)		Yes
Pour Point Depressant		
Antifoam Additive		
Corrosion Protection	-	Rust Preventive
Other		Acid Neutralizer
Metallic Components	X	
Sulfur	X	
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
-18°C (0°F), Maximum	X	-
40°C (104°F)	X	
100°C (212°F)	16.83 to 22.75	20.6
VISCOSITY INDEX, Minimum	85	95
SPECIFIC GRAVITY, 16°C (60°F)	X	
FLASH POINT, COC, Minimum	204°C (400°F)	241°C (465°F)
FIRE POINT, COC		
POUR POINT, Maximum	-9°C (+15°F)	-12°C (+10°F)
CORROSION PROTECTION (mild steel spec. oil coated)		
(a) Humidity: 200 Hr at 38°C (100°F), 100% Relative Humidity; Maximum Corrosion "Trace" (3 dots, 1.0 mm dia.)	Trace	None
(b) Salt Water; 20 Hr at 25°C (77°F), Maximum Corrosion "Trace" (3 dots, 1.0 mm dia.)	Trace	None
TOTAL ACID & BASE NUMBERS	X	
VOLATILE MATTER, 4 Hr Steam Bath, % Weight Loss	2.0	Passes
CARBON RESIDUE, %, Maximum	X	X
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, 5 Min. Blowing/ 10 Min Settling, Maximum		
(a) Sequence 1. 24°C (75°F)	25/0	30/10
(b) Sequence 2, 93°C (200°F)	150/0	20/0
(c) Sequence 3, 24°C (75°F)	25/0	40/0
COMPATIBILITY WITH:		
MIL-L-2104 Oils	Required	Passes
COLOR, ASTM D 1500		5.5
SULFATED RESIDUE, %	X	X

MILITARY SPECIFICATION: MIL-L-21260C
LUBRICATING OIL, INTERNAL-COMBUSTION ENGINE, PRESERVATIVE
GRADE 50

PROPERTIES	SPEC. REQ.	BRAYCO[a/] 445 SAE-50

NOTE: For a description and recommended usage of this preservative lubricating oil, see Section II. "X" indicates reports.

In addition to the products listed, several other petroleum and lubricant companies manufacture products which meet the requirements of this specification. Some of these are:

Product	Manufacturer
PQ 823 SAE50	American Oil & Supply Company
Withrow 827 SAE50	Arthur C. Withrow Company
Batco MIL-L-21260C SAE50 Motor Oil	Battenfeld Grease & Oil Corp. of New York
DSL Super Preservative Oil SAE50	Davis-Howland Oil Corp.
Precision PE-3	Delta Petroleum Company, Inc.
WS 1579 Motor Oil 50	Exxon Company, U.S.A.
SC 8440085	Southwest Petro-Chem Division (Witco Chemical Corporation)
SR 2600	Sun Refining & Marketing Company

a/ Bray Products Division, Burmah-Castrol, Inc.

MILITARY SPECIFICATION: MIL-L-22851C
LUBRICATING OIL, AIRCRAFT PISTON ENGINE, (ASHLESS DISPERSANT)

PROPERTIES	SPEC. REQ.
COMPOSITION	TYPE II
VISCOSITY, 10^{-6} m^2/Sec (Cs) at 99°C (210°F)	18.7 - 26.1
VISCOSTIY INDEX, Minimum	95
GRAVITY, °API	Report
FLASH POINT, COC, Minimum	244°C (470°F)
POUR POINT, Maximum	-18°C (0°F)
CORROSION, COPPER STRIP, ASTM SCALE	
3 hr. at 100°C (212°F)	1
3 hr. at 204°C (400°F)	3
TRACE SEDIMENT, ml/100 ml oil, max.	0.005
TRACE METAL CONTENT, ppm, maximum	
Iron	5
Silver	2
Aluminum	7
Chromium	5
Copper	3
Magnesium	3
Nickel	3
Lead	5
Silicon	10
Tin	10
Titanium	2
Molybdenum	4
ASH, %, Maximum	0.0025
CARBON RESIDUE, %, Maximum	1.2
SULFUR, %, Maximum	1.2
FOAM CHARACTERISTICS (D892)	
10^{-6} m^3 (ml) Foam, 10 min. settling, max.	
(a) Sequence 1, 24°C (75°F)	300
(b) Sequence 2, 93°C (200°F)	25
(c) Sequence 3, 24°C (75°F)	300
CONTAMINATION	
Foreign solid particles, milligram/gallon	15 Maximum
Fibrous material, milligram/gallon	5 Maximum

MILITARY SPECIFICATION: MIL-L-22851C
LUBRICATING OIL, AIRCRAFT PISTON ENGINE, (ASHLESS DISPERSANT)

PROPERTIES	SPEC. REQ. TYPE II
OXIDATION AND THERMAL STABILITY CLR oil test engine (method 3407)	Pass
LOW TEMPERATURE DISPERSANCY AND DETERGENCY, CLR oil test engine (method 347)	Pass
STORAGE STABILITY	
(1) 14 day storage test, separation	None
(2) 12 month storage test, separation	None
COMPATIBILITY	
No turbidity or trace sediment 0.005 ml/100 ml of oil	Pass

NOTE: For a description and recommended usage of this lubricating oil, see Section II.

The products listed below meet the requirements of this specification.

Product	Manufacturer
Type I	
Air Borne Concentrate 1	Borne Chemical Co., Inc.
DP Concentrate 160	Delta Petroleum Co., Inc.
Paranox 160	Exxon, U.S.A
RT - 451	Mobil Oil Corp.
Shell Concentrate A	Shell Oil Company
TC - 9670A	Texaco, Inc.
Type II	
PQ 3872	American Oil and Supply Co.
Airborne AD 120	Borne
Chevron Aero Oil Grade 120	Chevron U.S.A., INC.
Delta Aviation Oil 120	Delta Petroleum Co., Inc.
Exxon Aviation Oil EE-120	Exxon
RM - 173E	Mobil
Aeroshell W120	Shell
Aircraft Engine Oil Premium AD 120 (TL - 9297)	Texaco
Type III	
PQ 3882	American
Airborne AD 80	Borne
Delta Aviation Oil 80	Delta
Exxon Aviation Oil EE-80	Exxon
Aeroshell W80	Shell
Aircraft Engine Oil Premium AD 80 (TL-9790)	Texaco

MILITARY SPECIFICATION: MIL-L-23699C(1); (NATO CODE NUMBER 0-156)
LUBRICATING OIL, AIRCRAFT TURBINE ENGINE, SYNTHETIC BASE

PROPERTIES	SPEC. REQ.	HATCOL[a]/ 3211	BRAYCO[b]/ 899 M
COMPOSITION Base Oil	Synthetic	Synthetic	Synthetic Ester
Additives	NoLimit		
Viscosity Index Improver			
Oxidation Inhibitor		Yes	
Detergent			
EP (extreme pressure)			
Pour Point Depressnat			
Antifoam Additive			
Corrosion Protection		Yes	
Other			
VISCOSITY: 10^{-6} m^2/Sec (Cs) at			
-40°C (-40°F), Maximum	13,000	10,630	10,216
38°C (100°F)	25.0	27.7	27.6
99°C (210°F)	5.0 to 5.5	5.08	5.1
VISCOSITY STABILITY (72 Hr at -40°C (-40°F), % Change, Maximum	±6.0		
SPECIFIC GRAVITY, 16°C (60°F)	-	-	0.9937
FLASH POINT, COC, Minimum	246°C (475°F)	246°C (475°F)	257°C (495°F)
FIRE POINT, COC			
POUR POINT, Maximum	-54°C (-65°F)	-62°C (-80°F)	-59°C (-74°F)
CORROSION AND OXIDATION STABILITY			
(a) 72 Hr at 175°C (347°F)			
Viscosity Change, %	-5 to 15	+7.0	-
Neutralization Number Change, Maximum	2.0	0.07	-
Weight Change, 10^{-2} kg/m^2 (mg/cm^2)			
Steel	±0.2	0.00	-
Silver	±0.2	0.00	-
Aluminum	±0.2	0.00	-
Magnesium	±0.2	0.00	-
Copper	±0.4	-0.03	-
(b) 72 Hr at 204°C (400°F)			
Viscosity Change, %	-5 to 25	15.8	27.55
Neutralization Number Change, Maximum	3.0	1.92	1.24
Weight Change, 10^{-2} kg/m^2 (mg/cm^2)			
Steel	±0.2	0.00	0.008
Silver	±0.2	0.00	0.048
Aluminum	±0.2	-0.09	0.007
Magnesium	±0.2	-0.09	0.023
Copper	±0.4	-0.23	0.078
Sludge, mg/100 ml (maximum)	1.0	0	-
(c) 72 Hr at 218°C (425°F)			
Viscosity Change, %	Report	Report	-
Neutralization Number Change	Report	Report	-
Weight Change, 10^{-2} kg/m^2 (mg/cm^2)			
Steel	±0.2	0.00	-
Silver	±0.2	-0.02	-
Aluminum	±0.2	-0.01	-
Magnesium	-		-
Copper	-		-
Titanium	±0.2	0.50 max.	-

MILITARY SPECIFICATION: MIL-L-23699C(1); (NATO CODE NUMBER 0-156)
LUBRICATING OIL, AIRCRAFT TURBINE ENGINE, SYNTHETIC BASE

PROPERTIES	SPEC. REQ.	HATCOL[a/] 3211	BRAYCO[b/] 899M
THERMAL STABILITY, 24 Hr at 274°C (525°F)			
Viscosity Change at 38°C (100°F), %	5.0	0.40	-
Neutralization Number Change, Maximum	6.0	0.35	4.10
Weight of Metal Change, mg/cm^2	4.0 max.	-	0.6
NERTRALIZATION NUMBER, Maximum 10^{-3}kg KOH/kg (mg KOH/g)	0.5	0.04	-
EVAPORATION, %, Maximum (6-1/2 Hr at 204°C (400°F), % Weight Loss (Maximum)	10.0	3.07	2.97
CARBON RESIDUE, %, Maximum			
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam After 5 Min Aeration/ After 10 Min Settling			
(a) Sequence 1, 24°C (75°F)	25/0	0/0	20/0
(b) Sequence 2, 93°C (200°F)	25/0	5/0	10/0
(c) Sequency 3, 24°C (75°F) (retest)	25/0	0/0	20/0
COMPATIBILITY WITH: Oils Per Spec., MIL-L-7808	Pass	Pass	-
RUBBER SWELL			
"H" Synthetic, 72 Hr at 70°C (158°F), %	5 to 25	21.7	14.4
"F" Synthetic, 72 Hr at 204°C (400°F), %	5 to 25	-	-
COLOR	-	Light Tan	3.5
SEDIMENT, 7 Days at 24°C (75°F), mg/200 ml, Maximum	0.005	0.001	-
STORAGE STABILITY			
Lead Corrosion Weight Loss			
48 Hr at 110°C (230°F), Weight Loss mg/in^2	25	+0.3	-
168 Hr at 110°C (230°F), Weight Loss, mg/in^2, Maximum	150	-1.1	-
LOW TEMPERATURE STORAGE 6 Weeks at -18°C (0°F) No Crystallization, Separation, or Gelling	Pass	Pass	-
EXTENDED STORAGE 12 Months at 24°C (75°F)	Pass	-	-
GEAR TEST (RYDER) % Ref. Oil "Hercolube A," Minimum	102	101.8	104
BEARING TEST 100 Hr at 138°C (280°F)			
Deposit Demerit Rating	80 Maximum	55.1	-
Filter Deposit, g	3.0 Maximum	1.37	-
Viscosity Change at 38°C (100°F), %	-5 to 30	20.8	-
Neutralization Number Change	2.0 Maximum	1.43	-
Total Oil Consumption, ml	2,000	1,745	

MILITARY SPECIFICATION: MIL-L-23699C(1); (NATO CODE NUMBER O-156)
LUBRICATING OIL, AIRCRAFT TURBOPROP AND TURBOSHAFT ENGINES, SYNTHETIC BASE

PROPERTIES	SPEC. REQ.	HATCOL[a/] 3211	BRAYCO[b/] 899M
SHEAR STABILITY (sonic test), 30 Min at 38°C (100°F) Viscosity Change, % Maximum	4.0	-0.1	0.14
TURBO ENGINE TEST	Pass	Pass	Passes
TRACE METAL CONTENT, ppm, Maximum			
Aluminum	2	-	0.8
Iron	2	-	1.2
Chromium	2	-	0.16
Silver	1	-	0.16
Copper	1	-	0.16
Tin	4	-	2.4
Magnesium	2	-	0.08
Nickel	2	-	0.10
Titanium	2	-	1.6
Silicon	Report	-	
Lead	Report	-	
Molybdenum	Report	-	

NOTE: For a description and recommended usage of this high temperature, long-service life, synthetic turbojet engine lubricating oil, see Section II.

In addition to the products listed, other lubricating oils which meet the requirements of this specification are:

Product Name	Manufacturer
PQ Turbine Lubricant 9598	American Oil and Supply Co.
Exxon Turbo Oil 2380	Exxon Company, U.S.A.
RM -270A	Mobil Oil Corp.
Aeroshell Turbine Oil 500	Shell Oil Company, Inc.

a/ Hatco Chemical Corporation
b/ Bray Products Division, Burmah-Castrol Inc.

MILITARY SPECIFICATION: MIL-L-46152 B(1)
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, ADMINISTRATIVE SERVICE

PROPERTIES	SPEC. REQ. Grade 10W	Grade 30	Grade 5W-20	Grade 10W-30	Grade 15W-40
COMPOSITION, Base oil, synthetic compounds, or combination	x	x	x	x	x
Additives (all grades)					
Oxidation Inhibitor	x	x	x	x	x
Detergent	x	x	x	x	x
Dispersant	x	x	x	x	x
Corrosion Inhibitor	x	x	x	x	x
Pour Point Depressant	x	x	x	x	x
Other	x	x	x	x	x
VISCOSITY, Kinematic, cs					
40° C (104°F)	x	x	x	x	x
100°C (212°F)	5.6 to < 7.4	9.3 to < 12.5	5.6 to < 9.3	9.3 to < 12.5	12.5 to < 16.3
VISCOSITY, @ Temperature apparent, centipoise @°C					
Min.	3500 @ -25	-	3250 @ -30	3500 @ -25	3500 @ -20
Max.	3500 @ -20	-	3500 @ -25	3500 @ -20	3500 @ -15
BORDERLINE PUMPING TEMPERATURE (Max.) °C	-25	-	-30	-25	-20
VISCOSITY INDEX, Min.	x	75	x	x	x
POUR POINT, C° (Max.)	-32	-18	-40	-32	-23
STABLE POUR-POINT, °C (Max.)	-32	-	-40	-32	-23
FLASH POINT, °C (Min.)	205	220	200	205	215
PHOSPHORUS, Mass % (Max.)					
OTHER PROPERTIES					
Gravity, API	x	x	x	x	x
Carbon Residue	x	x	x	x	x
Sulfur	x	x	x	x	x
Sulfated Residue	x	x	x	x	x
Metallic Components	x	x	x	x	x
SAPONIFICATION NUMBER (Method D94)					
FOAM CHARACTERISTICS (Method D892) 10^{-6} m^3 (ml), Foam after 5 Min. Blow/10 Min. Settling (all grades)					
(a) Sequence 1, 24°C (75°F)		25/0			
(b) Sequence 2, 93°C (200°F)		150/0			
(c) Sequence 3, 24°C (75°F)		25/0			

"x" Indicates Retest Report

MILITARY SPECIFICATION: MIL-L-46152 B(1)
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, ADMINISTRATIVE SERVICE

NOTE: For a description and recommended usage of this lubricating oil, see Section II.

Products listed below meet the requirements of this specification.

Product Grade		Manufacturer
30	PQ Super Fleet IV	American Oil and Supply Company
10W-30	PQ SAE 10W-30	
15W-40	PQ Super Fleet IV	
30	Amoco 200 Motor Oil	Amoco Oil Company
10W/30	Amoco MV Motor Oil	
15W/40	Amoco 300 SAE 15W-40	
30	Formula No. TL-11832A	Atlantic Richfield Company
10W-30	Arco XHD SAE 10W-30	
15W-40	Formula No. TL-11829	
30	Brayco 463A	Bray Products Division, Burmah-Castrol, Inc.
10W/30	Brayco 462A	
15W/40	Brayco 461A	
30	PED 5598	Chevron U.S.A., Inc.
15W/40	PED 5599	
30	Citgo No. 93418, SAE 30	Citgo Petroleum Corporation
10W/30	Citgo No. 93149	
15W/40	Citgo No. 93416, SAE 15W-40	
30	Tracon 30	Conoco, Inc.
10W-30	Conoco Tracon Supreme 10W-30 Motor Oil	
15W-40	Conoco Tracon Supreme Motor Oil	
30	WS 1828 Motor Oil 30	Exxon Company, U.S.A.
10W/30	WS 1663 Motor Oil 10W-30	
15W/40	WS 1821	
30	Gulflube Motor Oil XHD 30	Gulf Oil Corporation
10W/30	Gulflube Motor Oil XHD 10W-30	
15W/40	Gulflube Motor Oil XHD 15W-40	
30	Kendall Super-D III	Kendall/Amalie Division,
10W/30	Kendall Super-D III and Super DSL	Witco Chemical Corporation
15W/40	Kendall Super-D III	
30	Formula No. MTN 606 C	Mobil Oil Corporation
10W/30	Formula No. RN 2587 AC	
15W/40	Formula No. MTN 545 BBD (BMT)	

MILITARY SPECIFICATION: MIL-L-46167A
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, ARCTIC

PROPERTIES	SPEC. REQ.
COMPOSITION	Base oil, synthetic compounds, or combination
Additives, as necessary	
Oxidation Inhibitor	x
Detergent	x
Dispersant	x
Corrosion Inhibitor	x
Pour Point Depressant	x
Other	x
VISCOSITY, 10^{-6} m^2/sec (cs) at	
100°C (212°F) Minimum	5.6
40°C (104°F)	x
-40°C (-40°F) Maximum	8,800
-55°C (-67°F) Maximum	75,000
VISCOSITY INDEX	x
POUR POINT, Maximum	-55°C (-67°F)
STABLE POUR POINT, Maximum	-55°C (-67°F)
FLASH POINT, Minimum	220°C (428°F)
OTHER PROPERTIES	
Gravity	x
Carbon Residue	x
Sulfur	x
Nitrogen	x
Sulfated Residue	x
Total Acid Number	x
Total Base Number	x
Metallic Components	x
FOAM CHARACTERISTICS (Method D892)	
10^{-6} m^3 (ml), Foam after 5 Min. Blow/10 Min. Settling	
(a) Sequence 1, 24°C (75°F)	25/0
(b) Sequence 2, 93°C (200°F)	150/0
(c) Sequence 3, 24°C (75°F)	25/0
STABILITY AND COMPATIBILITY (Method 3470)	
Evidence of Separation	None
MOISTURE-CORROSION CHARACTERISTICS (ASTM STP 315H, Engine Test Sequence II D)	
Average Rust, Minimum	8.5
Lifter Sticking	None

MILITARY SPECIFICATION: MIL-L-47167A
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, ARCTIC

PROPERTIES	SPEC. REQ.
WEAR PROTECTION CHARACTERISTICS	
(ASTM STP 315H, Engine Test Sequence III D)	
Scuffing and Wear, 64 Hr.	
Cam or Lifter Scuffing	None
Cam plus Lifter Wear, Microns (Max.)	
Average	102
Maximum	254
LOW TEMPERATURE DEPOSITS AND WEAR	
(ASTM STP 315H, Engine Test Sequence V-D)	
Average Engine Sludge (Min.)	8.7
Average Engine Varnish (Min.	5.9
Average Piston Skirt Varnish (Min.)	6.0
Oil Screen Clogging, % (Max.)	10.0
Oil Ring Clogging, % (Max.)	10.0
Ring Sticking	None
Cam Wear, Microns (Max.)	
Average	51
Maximum	102
RING-STICKING, WEAR, AND ACCUMULATION OF DEPOSITS, STICKING, CLOGGING, MINIMAL WEAR	Pass
Four-stroke Cycle Diesel Engine	
(ASTM STP 509A, Part I, Caterpillar 1 H2)	
Top Groove Filling, % (Max.)	45
Total weighted Deposit, (Max.)	140
Two-stroke Cycle Diesel Engine	
(Fed-Std-791, Method 354.1T)	
Piston Area	
Average Total Deposits (Max.)	400
Hot Stuck Rings	None
Average Ring Face Distres (Max.)	
Fire Ring	Report
Nos. 2 and 3 Compression	35
Liner and Head Area	
Average Liner Scuffing, % Area (Max.)	45
Valve Distress	None
Port Plugging, %	Report
BEARING CORROSION	
(ASTM STP 509A, Part IV, Labeco L-38A)	
Bearing Weightloss, Milligrams (Max.)	50

PROPERTIES	SPEC. REQ.
FRICTION RETENTION CHARACTERISTICS AND WEAR	
Maintain Stable Coefficient of Friction	Pass
Minimal Distress and Wear	Pass
Slip Time and Torque	
(Detroit Diesel Allison C-3 Fluid Specification, Test Procedure Item 9)	
Slip Time at 5500 Cycles, Sec. (Max.)	0.85
Torque, Nm	
At 0.2 Sec Slip Time (Min.)	101.7
Difference Between 1550 & 5500 Cycles (Max.)	40.7
Stopping Time and Wear	
(Caterpillar Oil Test No. TO-2) and two of three tests exhibit results meeting following criteria (Report all results, when two passing tests obtained, third test not required):	
Stopping Time Increase % (Max.)	15
Average Total Wear, Microns (Max.)	350
SEAL COMPATIBILITY	
Minimize Deterioration of Seal and Friction Materials	Pass
Effect on Rubber Seals	
(Detroit Diesel Allison C-3 Fluid Specification, Test Procedure Item 6)	
(a) Total Immersion (Buna N)	
Volume Changes, %	0 to +5
Hardness Changes, Points	0 to ±5
(b) Dip Cycle (Polyacrylate)	
Volume Changes, %	0 to +10
Hardness Changes, Points	0 to +5
(c) Tip Cycle (Silicone)	
Volume Changes, %	0 to +5
Hardness Changes, Points	0 to -10
ANTI-WEAR CHARACTERISTICS	
Minimize Wear of Loaded Hydraulic-Transmission Components	
(Detroit Diesel Allison C-3 Fluid Specification, Test Procedure Item 4)	
Degrees of Remaining Grinding Pattern	360
Scuffing, Scoring or Chatter Wear Marks	None

MILITARY SPECIFICATION: MIL-L-46167A
LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, ARCTIC

NOTE: For a description and recommended usage of this lubricating oil, see Section II.

Products listed below meet the requirements of this specification.

Product	Manufacturer
PQ 9600	American Oil and Supply Co.
Delta Arctic Flow	Delta Petroleum Co., Inc.
Formula No. LP-883	Gulf Oil Corp.
Royco 767,767A	Royal Lubricants Co., Inc.

LOW VAPOR PRESSURE SYNTHETIC FLUIDS
"APIEZON" HIGH VACUUM AND LUBRICATING OILS (JAMES G. BIDDLE COMPANY)

PROPERTIES	DIFFUSION PUMP OILS			LUBRICATE AND SEALING OILS	
	OIL A	OIL B	OIL C	OIL J	OIL K
ULTIMATE PRESSURE OBTAINABLE					
N/m^2	6.65×10^{-3}	1.33×10^{-4}	1.33×10^{-5}	-	-
Torr	5×10^{-5}	10^{-6}	10^{-7}	-	-
AVERAGE BOILING POINT at 133.3 N/m^2 (1.0 torr), °C (°F)	190 (374)	220 (428)	255 (491)	-	-
SPECIFIC GRAVITY at 20°C/15.5°C (68°F/60°F)	0.865	0.873	0.876	0.918	0.919
30°C/15.5°C (86°F/60°F)	0.859	0.869	0.869	0.911	0.914
DENSITY, g/ml at:					
10°C (50°F)	0.871	0.878	0.881	0.923	0.921
20°C (68°F)	0.865	0.872	0.875	0.918	0.916
30°C (86°F)	0.859	0.866	0.869	0.909	0.912
40°C (104°F)	0.852	0.859	0.863	0.903	0.904
FLASH POINT, °C (F) Closed	210 (410)	243 (470)	246 (475)	310 (590)	341 (645)
Open	210 (410)	243 (470)	266 (510)	352 (665)	349 (660)
Fire	232 (450)	263 (505)	293 (560)	371 (> 700)	371 (> 700)
VISCOSITY, KINEMATIC, 10^{-6} m^2/Sec (Cs) at					
20°C (68°F)	59	142	283		
40°C (104°F)	23.4	49.3	90	3,330	5,710
100°C (212°F)	4.5	7.0	10.6	107	177
VISCOSITY, DYNAMIC, 10^{-3} N Sec/m^2 (cP) at 40°C (104°F)	19.9	42.4	77.2	3,005	5,160
FOUR POINT, ASTM, °C (°F)	-7 (20)	-9 (15)	-15 (5)	-1 (30)	-1 (30)
COEFFICIENT OF EXPANSION OVER 10°C to 40 °C (50°F to 104°F)					
Per °C	0.00083	0.00080	0.00080	0.00083	0.00070
Per °F	0.00046	0.00044	0.00044	0.00046	0.00039
THERMAL CONDUCTIVITY Btu in					
ft^2/h, °F	0.91	0.91	0.96	1.16	1.17
w/m, °C	0.132	0.132	0.139	0.167	0.169
SPECIFIC HEAT at 25°C (77°F)					
cal/g	0.46	0.49	0.46	0.48	0.46
Joule/g	1.9	2.0	1.9	2.0	1.9
AVERAGE MOLECULAR WEIGHT	354	420	479	1,130	1,355
REFRACTIVE INDEX at 20°C (68°F) (ASTM D 1807 62T Sodium D line)	1.4780	1.4815	1.4830		

NOTE: The fluids combine good lubricating properties with low vapor pressure, and are intended for lubrication of all movable parts in a vacuum system. They also have good chemical stability.

"Apiezon" Oils A, B, and C are primarily vacuum diffusion pump oils, while Oils J and K are lubricating and sealing oils for rotating gland seals and similar equipment. Oil J is moderately viscous with a low vapor pressure, and K is exceedingly viscous and has even lower vapor pressure than J.

LIQUID LUBRICANTS FOR SPACE APPLICATIONS
BALL AEROSPACE SYSTEMS DIVISION

PROPERTIES	VACKOTE OIL 48784	VACKOTE OIL 36233	VACKOTE OIL 36234	VACKOTE OIL 37995
COMPOSITION Base Oil	Synthetic	Hydrocarbon	Synthetic	Synthetic
Additives				
Viscosity Index Improver				
Oxidation Inhibitor	-	Yes	Yes	Yes
Friction Reducer				Yes
EP (extreme pressure)	Yes (Add EP to Code)	Yes	Yes	No
Pour Point Depressant				
Antifoam Additive				
Corrosion Protection	-	Yes	Yes	Yes
Other				
VISCOSITY: 10^{-6} m^2/Sec (Cs) at				
38°C (100°F)	92	100	56	120
54°C (130°F)	-	-	-	-
99°C (210°F)	10	10	9	18
VISCOSITY INDEX, Minimum	110	93	129	138
SPECIFIC GRAVITY, 16°C (60°F)	1.9	0.85	1.0	0.95
FLASH POINT, COC, Maximum	None	> 200°C (392°F)	288°C (550°F)	> 230°C (446°F)
FIRE POINT	> 260°C (> 500°F)	> 260°C (> 500°F)	> 288°C (> 550°F)	> 260°C (500°F)
POUR POINT, Maximum	-40°C (-40°F)	-9.4°C (15°F)	-51°C (-60°F)	-40°C (-40°F)
OXIDATION STABILITY: (Bomb) at 99°C (210°F)				
Pressure Drop at 100 Hr N/m^2 (psi)	0 (0)	28,960 (4.2)	4,137 (0.6)	-
Viscosity Increase, %, at 38°C (100°F), 10^{-6} m^2/Sec (Cs)	0	3.8	0.2	-
Neutralization Number Increase, 10^{-3} kg KOH/kg (mg KOH/g)	0	0.65	0.72	-
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)				
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity				
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)				
EVAPORATION, %, Weight Loss, 28 Hr at 154°C (310°F)	1.8	0.90	0.40	1.2
CARBON RESIDUE, %, Maximum				

LIQUID LUBRICANTS FOR SPACE APPLICATIONS
BALL AEROSPACE SYSTEMS DIVISION

PROPERTIES	VACKOTE OIL 48784	VACKOTE OIL 36233	VACKOTE OIL 36234	VACKOTE OIL 37995
FOAM CHARACTERISTICS	Foam Resistant	-	-	Foam Resistant
COMPATIBILITY WITH:				
Rubber	Synthetic	Satisfactory	Synthetic	Satisfactory
Jet and Rocket Fuels	-	-	-	-
LOX	Satisfactory	-	-	No
COLOR, ASTM D 1500				
COMPATIBILITY WITH METALS				
48 Hr in 0.1 at 64°C (148°F), 440C and 52100 Steel, Brass, and Copper	No Change	No Change	No Change	No Change
Silver, Aluminum (2024T3) and Titanium (6Al-4V)	No Change	No Change	No Change	No Change
SHELL FOUR-BALL WEAR TEST at 100°C (212°F) 90 Min, 600 rpm, 9807 N (10 kg); Average Scar Dia,. mm	0.207	0.483	0.266	0.270
USABLE TEMPERATURE RANGE				
Low	-40°C (-40°F)	-12°C (10°F)	-48°C (-55°F)	-40°C (-40°F)
High	232°C (450°F)	121°C (250°F)	150°C (300°F)	121°C (250°F)
SURFACE TENSION:				
Dynes/cm, 23°C (73°F)	23	34	28.5	-
OTHER PROPERTIES				
Water Resistant	Yes	Yes	Yes	Yes
Storage Stability	Good	Good	Good	Good

NOTE: Vackote Oil 48784 is a chemically and thermally stable oil for air vacuum and space lubrication. Typical uses are for low and high speed bearing, journal, ball or roller, sliding surfaces, gears and electrical equipment.

Vackote Oils 36233 and 36234 are extreme pressure oils for air, vacuum, and space lubrications. Typical applications are similar to Vackote Oil 48784.

Vackote Oil 37995 is an excellent lubricant for sintered bronze bushings operating on steel shafting. Typical uses are in electric motors and disc drive mechanisms.

LOW TEMPERATURE SYNTHETIC FLUIDS
"FOMBLIN" PERFLUORINATED POLYETHER FLUIDS (Montefluos, S.p.a.)

PROPERTIES	Y04	Y06	Y16
COMPOSITION Base Oil			
Additives			
Viscosity Index Improver			
Oxidation Inhibitor			
Detergent			
Phosphorus, %			
Chlorine (bomb), %			
Pour Point Depressant			
Antifoam Additive			
Other			
VISCOSITY: 10^{-6} m^2/Sec,(Cs) at			
-18°C (0°F)	600	2,000	6,000
38°C (100°F)	16	28	54
99°C (210°F)	3.2	4.0	6.5
VISCOSITY INDEX	52	58	-
DENSITY, kg/m^3 (lb/gal)	1,872 (15.6)	1,884 (15.7)	1,884 (15.7)
FLASH POINT, COC	None	None	None
FIRE POINT, COC	None	None	None
POUR POINT	< -68°C (-90°F)	< -46°C (-50°F)	< -43°C (-45°F)
STABLE TEMPERATURE			
24 Hr Micro-Oxidation Test (FTM 791 Method 5308.4)			
Maximum Temperature for Little Change in Fluid or Metal			
Hastelloy B, Monel, Nickel, Magnesium, Silver, Lead, Aluminum Alloy (4 Cu, 1.5 Mg, 0.5 Mn)	343°C (650°F)	343°C (650°F)	343°C (650°F)
Brass, Copper Alloy (7 Al, 2 Fe), Stainless Steel (18 Cr, 2 Mo, 12 Ni, 0.5 Ti), Copper, Cadmium	316°C(600°F)	316°C (600°F)	316°C (600°F)
Stainless Steel (18 Cr, 8 Ni), Tool Steel (8 Mo, 4 Cr, 3 W, 1 V), Aluminum	288°C (550°F)	288°C (550°F)	288°C (550°F)
Titanium, Titanium Alloy (6 Al, 4 V), Titanium Alloy (4 Al, 2 Mn)	260°C (500°F)	260°C (500°F)	260°C (500°F)
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.00	0.00	0.00
EVAPORATION, % (22 Hr at 300°F)	60	40	10
FOAM CHARACTERISTICS (Method D 892)			
10^{-6} m^3 (ml) Foam, After 5 Min Blowing/ After 10 Min Settling	20/0	-	-
(a) Sequence 1, 24°C (75°F)			
(b) Sequence 2, 93°C (200°F)			
(c) Sequence 3, 24°C (75°F) (retest)			
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels			
LOX	See Note No. 4		

LOW TEMPERATURE SYNTHETIC FLUIDS
"FOMBLIN" PERFLUORINATED POLYETHER FLUIDS (Montefluos, S.p.a.)

PROPERTIES	Y04	Y06	Y16
APPEARANCE	Clear and Colorless		
DISTILLATION RANGE, 10-90% at 0.3-04 mm Hg			
°C	176-410	284-392	356-464
(°F)	(349-770)	(543-738)	(673-867)
VAPOR PRESSURE, Torr at 149°C (300°F)	5.5	1.0	0.05
AVERAGE COEFFICIENT OF THERMAL EXPANSION			
-1°C to 121°C x 10^4/°C	10.8	10.4	9.8
(30°F to 250°F) x 10^4/°F	6	5.8	5.4
THERMAL CONDUCTIVITY (16 to 93°C) (60 to 200°F) Watt/m °C (Btu ft/hr ft^2 °F)	0.000492 (0.041) for all grades		
SPECIFIC HEAT, Joule/kg (Btu/lb) at 38°C (100°F)	558 (0.24) for all grades		
REFACTORY INDEX $n_D^{20°C}$	1.296	1.296	1.298

NOTE: 1. General properties: The Fomblin fluids are linear perfluoropolyethers and are available in several grades with different average molecular weights. These fluids possess outstanding resistance to oxidation and chemical attack, have excellent thermal stability, a wide liquid-temperature range, and good lubricating capability. They are suggested as lubricants, sealing compounds, and heat transfer fluid for applications requiring exceptional thermal resistance, or resistance to oxidation and chemical attack.

2. Lubricity: The Fomblin fluids are good lubricants, particularly under boundary and EP conditions. For example, with Fomblin Y25 in the 4-ball wear test with steel on steel for 2 hr at 40 kg and 1,200 rpm, the average wear scar diameter was only 0.86 mm. In the 4-ball E. P. test for 1 min at 1,500 rpm the maximum load before seizure was 50 kg.

3. Chemical stability: The Fomblin fluids are stable in contact with fuels, strong acids and bases, chlorine, fluorine, bromine, oxygen, oxidizing agents, water, and steam. The Fomblin Y04 and Y25 fluids will not react with pure oxygen at 249°C (480°F) at pressures up to 11.7 x 10^6 N/m^2 (1,700 psi). The Fomblin YR fluids will not react with pure oxygen at 249°C (480°F) at pressures up to 8.6 x 10^6 N/m^2 (1,250 psi). The Fomblin fluids are decomposed by halogenated Lewis acids such as $AlCl_3$, SbF_5, and CoF_3 at temperatures above 100°C (212°F). The Fomblin fluids (in common with other highly fluorinated fluids) may react violently with aluminum and magnesium and their alloys under conditions where fresh, active metal surfaces may be created; such as under high rates of shear or high bearing loads. These conditions could occur during machining and drilling of parts; or during the operation of a loaded bearing; or movement of a threaded connector.

4. Compatibility with plastics and elastomers: The Fomblin fluids do not affect most commercially available plastic and elastomeric materials. For example, elastomers such as nitrile, butyl, fluorosilicone, Viton are unchanged after soaking 1 month in Fomblin Y04 fluid at 70°C (158°F). Most plastics (polyamides, polyacetals, PTFE, etc.) may be used in contact with the fluids up to the top temperature limitation of the plastic material itself.

5. These oils are used in special greases, see Micronic® 803, Bray Oil Company.

LOW TEMPERATURE SYNTHETIC FLUIDS
"FOMBLIN" PERFLUORINATED POLYETHER FLUIDS (Montefluos, S.p.a.)

PROPERTIES	Y25	YR
COMPOSITION Base Oil		
Additives		
Viscosity Index Improver		
Oxidation Inhibitor		
Detergent		
Phosphorus,%		
Chlorine (bomb), %		
Pour Point Depressant		
Antifoam Additive		
Other		
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
-18°C (0°F)	11,000	70,000
38°C (100°F)	90	516
99°C (210°F)	9.4	41
VISCOSITY INDEX	106	134
DENSITY, kg/m^3 (lb/gal)	1,896 (15.8)	1,908 (15.9)
FLASH POINT, COC	None	None
FIRE POINT, COC	None	None
POUR POINT	< -34°C (-30°F)	< -23°C (-10°F)
STABLE TEMPERATURE		
24 Hr Micro-Oxidation Test (FTM 791 Method 5308.4)		
Maximum Temperature for Little Change in Fluid or Metal		
Hastelloy B, Monel, Nickel, Magnesium, Silver, Lead, Aluminum Alloy (4 Cu, 1.5 Mg, 0.5 Mn)	343°C (650°F)	343°C (650°F)
Brass, Copper Alloy (7 Al, 2 Fe), Stainless Steel (28 Cr, 2 Mo, 12 Ni, 0.5 Ti), Copper, Cadmium	316°C (600°F)	316°C (600°F)
Stainless Steel (18 Cr, 8 Ni), Tool Steel (8 Mo, 4 Cr, 3 W, 1 V), Aluminum	288°C (550°F)	288°C (550°F)
Titanium, Titanium Alloy (6 Al, 4 V), Titanium Alloy (4 Al, 2 Mn)	260°C (500°F)	260°C (500°F)
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.00	0.00
EVAPORATION, % (22 hr at 300°F)	7	< 1
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, After 5 Min Blowing/ After 10 Min Settling	410/0	90/0
(a) Sequence 1, 24°C (75°F)		
(b) Sequence 2, 93°C (200°F)		
(c) Sequence 3, 24°C (75°F) (retest)		
COMPATIBLITY WITH: Rubber and Jet and Rocket Fuels		
LOX	See Note No. 4	

LOW TEMPERATURE SYNTHET'C FLUIDS
"FOMBLIN" PERFLUORINATED POLYETHER FLUIDS (Montefluos, S.p.a.)

PROPERTIES	Y25	YR
APPEARANCE		
DISTILLATION RANGE, 10-90% at 0.3-0.4 mm Hg °C (°F)	374-554 (705-1029)	> 518 > 964
VAPOR PRESSURE, Torr at 149°C (3000°F)	0.3	0.0003
AVERAGE COEFFICIENT OF THERMAL EXPANSION -1°C to 121°C x 10^4/°C (30°F to 250°F) x 10^4/°F	9.4 5.2	9.4 5.2
THERMAL CONDUCTIVITY (16 to 93°C) (60 to 200°F) watt/m °C (Btu ft/hr ft^2 °F)	0.000492 (0.041) for all grades	
SPECIFIC HEAT, Joule/kg (Btu/lb) at 38°C (100°F)	558 (0.24) for all grades	
REFRACTORY INDEX $n_D^{20°C}$	1.300	1.304

NOTE: 1. General properties; The Fomblin fluids are linear perfluoropolyethers and are available in several grades with different average molecular weights. These fluids possess outstanding resistance to oxidation and chemical attack, have excellent thermal stability, a wide liquid-temperature range, and good lubrication capability. They are suggested as lubricants, sealing compounds, and heat transfer fluid for applications requiring exceptional thermal resistance, or resistance to oxidation and chemical attack.

2. Lubricity: The Fomblin fluids are good lubricants, particularly under boundary and EP conditions. For example, with Fomblin Y25 in the 4-ball wear test with steel on steel for 2 hr at 40 kg and 1,200 rpm, the average wear scar diameter was only 0.86 mm. In the 4-ball E. P. test for 1 min at 1,500 rpm the maximum load before seizure was 50 kg.

3. Chemical stability; The Fomblin fluids are stable in contact with fuels, strong acids and bases, chlorine, fluorine, bromine, oxygen, oxidizing agents, water, and steam. The Fomblin Y04 and Y25 fluids will not react with pure oxygen at 249°C (480°F) at pressures up to 11.7 x 10^6 N/m^2 (1,7000 psi). The Fomblin YR fluids will not react with pure oxygen at 249°C (480°F) at pressures up to 8.6 x 10^6 N/m^2 (1,250 psi). The Fomblin fluids are decomposed by halogenated Lewis acids such as $AlCl_3$, SbF_5, and CoF_3 at temperatures above 100°C (212°F). The Fomblin fluids (in common with other highly fluorinated fluids) may react violently with aluminum and magnesium and their alloys under conditions where fresh, active metal surfaces may be created; such as under high rates of shear or high bearing loads. These conditions could occur during machining and drilling of parts; or during the operation of a loaded bearing; or movement of a threaded connector.

4. Compatibility with plastics and elastomers: The Fomblin fluids do not affect most commercially available plastic and elastomeric materials. For example, elastomers such as nitrile, butyl, fluorosilicone, Viton are unchanged after soaking 1 month in Fomblin Y04 fluid at 70°C (158°F). Most plastics (polyamides, polyacetals, PTFE, etc.) may be used in contact with the fluids up to the top temperature limitation of the plastic material itself.

5. These oils are used in special greases, see Micronic® 803, Bray Oil Company.

FLUOROCARBON LIQUIDS: FLUORINATED ETHER FLUIDS
(i.e., Hydraulic and Instrument Fluids; E. I. du Pont de Nemours and Company)

PROPERTIES	FREON E1*	FREON E2*	FREON E3*	FREON E4*	FREON E5*
COMPOSITION Base Oil					
Additives					
Viscosity Index Improver					
Oxidation Inhibitor					
Detergent					
EP (extreme pressure)					
Pour Point Depressant					
Antifoam Additive					
Corrosion Protection					
Other					
VISCOSITY: 10^{-6} m^2/Sec (Cs) at					
-54°C (-65°F)	-	5.0	21.6	140[a]/	-
25°C (77°F)	0.33	0.61	1.2	2.3	3.9
VISCOSITY INDEX, Minimum					
DENSITY 10^{-3}kg/m^3 (g/cm^3) at					
-54°C (-65°F)	1.752	1.841	1.882	1.909	1.924
25°C (77°F)	1.538	1.659	1.732	1.765	1.796
FLASH POINT, COC, Minimum	None	None	None	None	None
FIRE POINT, COC	None	None	None	None	None
POUR POINT, Maximum	-154°C (-246°F)	-122°C (-188°F)	-115°C (-175°F)	-95°C (-139°F)	-72°C (-98°F)
BOILING POINT	39°C (102°F)	101°C (214°F)	152°C (306°F)	193°C (380°F)	218°C (424°F)
VAPOR PRESSURE at 25°C (77°F)					
N/m^2	57,300	3,870	320	-	-
mm Hg	430	29	2.4	-	-
COMPRESSIBILITY, % at 25°C (77°F), 101 x 10^{-5} N/m^2 (100 atms)	2.38	1.81	1.55	1.42	1.34
505 x 10^{-5} N/m^2 (500 atms)	8.20	6.48	5.46	5.18	4.85
1,010 x 10^{-5} N/m^2 (1,000 atms)	12.13	9.93	8.81	8.14	7.76
SPECIFIC HEAT OF LIQUID at 25°C (77°F)					
Joule/kg °C	-	1,021	1,017	-	-
(cal/g/°C)	-	0.244	0.243	-	-
THERMAL CONDUCTIVITY OF LIQUID at 25°C (77°F)					
Watts/m °C	-	0.0778	0.0713	-	-
Btu·ft/hr ft^2°F		0.045	0.0412	-	-
DIELECTRIC STRENGTH					
KV_{rms}/0.00254 m					
KV_{rms}/0.10 in.	-	34.6	39.5	44.5	49.5
DIELECTRIC CONSTANT (100 cps)	-	2.76	2.58	-	-
COMPATIBILITY WITH: Plastics	Yes	Yes	Yes	Yes	Yes
Elastomers	Yes	Yes	Yes	Yes	Yes
COLOR, ASTM D 1500					

FLUOROCARBON LIQUIDS: FLUORINATED ETHER FLUIDS
(i.e., Hydraulic and Instrument Fluids; E. I. du Pont de Nemours and Company)

PROPERTIES	FREON E1*	FREON E2*	FREON E3*	FREON E4*	FREON E5*

NOTE: These fluids are part of a series of Freon E, homologous flourinated ethers, low volatility fluids which cover a wide range of properties. All are usable at very high and low temperatures, non-flammable, have a low order of acute toxicity, excellent electrical properties, and have good heat transfer properties.

Some of the recommended usages are: liquids for extreme environment conditions, as hydraulic and instrument fluids, heat transfer media, and as dielectric-coolants.

* DuPont has stopped manufacture of "Freon" E series fluorinated ether fluids and only sales from remaining inventory are available.

GYRO LUBRICANTS
KENDALL/AMALIE DIVISION, WITCO CHEMICAL CORP.

PROPERTIES	SRG-60	KG-80(2)	SRG-160(3)
COMPOSITION Base Oil	Super refined mineral oil		
Additives			
Viscosity Index Improver	-	-	-
Oxidation Inhibitor, wt %	0.5%	0.5%	0.5%
Detergent	-	-	-
EP (extreme pressure) wt %			
Tri-cresyl-phosphate	1	1	1
Pour Point Depressant	-	-	-
Antifoam Additive	-	-	-
Corrosion Protection	-	-	-
Other	-	-	-
VISCOSITY: 10^{-6} m^2/Sec (Cs) at			
38°C (100°F)	77.6	164	517
54°C (130°F)			
99°C (210°F)	9.44	15.3	34.15
VISCOSITY INDEX	106	101	107
SPECIFIC GRAVITY, 16°C (60°F)	0.871	0.878	0.883
FLASH POINT, COC	232°C (450°F)	274°C (525°F)	302°C (575°F)
FIRE POINT	277°C (530°F)	324°C (615°F)	343°C (650°F)
POUR POINT	-12°C (10°F)	-9°C (15°F)	-7°C (20°F)
OXIDATION STABILITY at 54°C (130°F) Viscosity Increase, %, Maximum Neutralization Number Increase	-	-	-
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)	-	-	-
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity	-	-	-
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	-	-	-
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F)	-	-	-
CARBON RESIDUE, %, Maximum	-	-	-
VAPOR PRESSURE TEMPERATURE (1)			
133.3 N/m^2(1.0 torr)	263°C (505°F)	298°C (568°F)	
13.3 N/m^2 (0.1 torr)	226°C (439°F)	260°C (500°F)	
1.33 N/m^2 (0.01 torr)	198°C (338°F)	232°C (450°F)	
0.133 N/m^2 (0.001 torr)	178°C (352°F)	212°C (414°F)	
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX	-	-	-
COLOR, ASTM D 1500	-	1/2 Max.	-
Sulphur, wt % Max.	-	0.10	-

GYRO LUBRICANTS
KENDALL/AMALIE DIVISION, WITCO CHEMICAL CORP.

PROPERTIES	SRG-60	KG-80(2)	SRG-160(3)

NOTE: 1. These vapor pressure-temperature relations are based on the ASTM distillation 50% boiling point. The Meyers vapor pressure-temperature correlation was used to convert to other pressures.

2. Conforms to MIL-L-83176A and MIL-L-0083176A. (USAF) Grade 80

3. Conforms to MIL-L-0083176A. (USAF) Grade 160

4. These gyro lubricants are limited in availability and production.

PERFLUORINATED LUBRICANTS OR HYDRAULIC FLUIDS
NONFLAMMABLE AND CHEMICALLY INERT (Bray Products Division, Burmah-Castrol, Inc.)

PROPERTIES	BRAYCO 810	BRAYCO 811	BRAYCO 812	BRAYCO 813A
COMPOSITION Base Oil	Linear Perfluoroalkyl Polyethers			
Additives				
Viscosity Index Improver				
Oxidation Inhibitor				
Detergent				
Phosphorus, %				
Chlorine (bomb), %				
Pour Point Depressant				
Antifoam Additive				
Other				
VISCOSITY: 10^{-6} m^2/Sec (Cs) at				
-40°C (-40°F)	-	9,400	-	-
-18°C (0°F)	16,800	625	8,800	75,000
38°C (100°F)	153	18.7	96.3	424
99°C (210°F)	16.1	3.29	10.9	35.5
204°C (400°F), Extrapolated	2.98	0.96	2.20	5.00
VISCOSITY INDEX, Minimum	119	25	106	133
DENSITY, 16°C (60°F) kg/10^{-3} m^3 (g/ml)	1.913	1.888	1.910	1.924
FLASH POINT, COC, Minimum	Nonflammable			
FIRE POINT, COC	Nonflammable			
POUR POINT, Maximum	-32°C (-25°F)	-48°C (-55°F)	-29°C (-20°F)	-18°C (0°F)
CORROSION AND OXIDATION STABILITY 204°C (400°F) for 72 Hr				
Weight Change (mg/cm^2)				
Copper	0.00	+0.01	+0.02	+0.04
Aluminum Alloy	+0.03	+0.05	+0.02	+0.01
Magnesium Alloy	+0.03	+0.05	-0.02	+0.02
Steel	+0.03	+0.06	+0.00	+0.02
Silver	+0.03	+0.06	-0.02	0.00
Appearance-Pitting, Etching, Corrosion	None	None	None	None
Viscosity Change at 38°C (100°F), %	+2.62	+2.25	+0.06	+0.24
Neutralization Number Increase	0.00	0.0	0.0	0.0
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.0	0.0	0.0	0.0
EVAPORATION, %				
22 Hr at 149°C (300°F)	6	52	2	Nil
6-1/2 Hr at 204°C (400°F)	11.40	81.0	7.12	0.12
CARBON RESIDUE, %, Maximum				
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, 10 Min Settling				
(a) Sequence 1, 24°C (75°F)				
(b) Sequence 2, 93°C (200°F)				
(c) Sequence 3, 24°C (75°F) (retest)				

PERFLUORINATED LUBRICANTS OR HYDRAULIC FLUIDS
NONFLAMMABLE AND CHEMICALLY INERT (Bray Products Division, Burmah-Castrol, Inc.)

PROPERTIES	BRAYCO 810	BRAYCO 811	BRAYCO 812	BRAYCO 813A
COMPATIBILITY WITH; Rubber, Jet, and Rocket Fuels				
LOX				
COLOR, Saybolt	+30	+30	+30	+30
DISTILLATION RANGE, °C at 0.4 x 10^{-3} m	-	80 to 210	190 to 290	> 270
(°F at 0.4 mm)	-	176 to 410	374 to 554	> 518
REFRACTIVE INDEX, n_D^{20}	1.300	1.296	1.300	1.304
SURFACE TENSION, Dyne/cm at 20°C (68°F)	20	19	20	21
THERMAL CONDUCTIVITY, Watt/m °C at 38°C	-	-	0.0709	-
Btu/hr (ft^2) (°F/ft) at 100°F)	-	-	0.041	-
SPECIFIC HEAT, Joule/kg/°C	557.9	557.9	557.9	557.9
(Btu/lb/°F)	(0.24)	(0.24)	(0.24)	(0.24)
DIELECTRIC STRENGTH (kv)	35+	35+	35+	35+
DIELECTRIC CONSTANT, at 50 Hz,	2.15	2.15	2.15	2.15
at 1,000 Hz	2.17	2.17	2.17	2.17
VOLUME RESISTIVITY (ohm-cm) at 25°C (77°F)	$> 10^{15}$	$> 10^{15}$	$> 10^{15}$	$> 10^{15}$
DISSIPATION FACTOR at 25°C (77°F), %	$< 10^{-4}$	$< 10^{-4}$	$< 10^{-4}$	$< 10^{-4}$
PARTICLE CONTAMINATION, Number of Particles/10^{-4} m^3 (particles/100 ml) Particle Size Range (microns)				
5-15	750	750	750	750
15-25	200	200	200	200
25-50	35	35	35	35
50-100	18	18	18	18
100+	2	2	2	2

NOTE: 1. Description: BRAYCO 810-13 oils are linear perfluoroalkyl polyethers. BRAYCO 810 is the total polymer and 811-13 are distillate fractions of increasing molecular weight. They are colorless and odorless, are nonflammable, and are generally chemically inert. They are thermally stable, either alone or in the presence of oxygen, have low volatility and have no tendency to form deposits. Excellent lubricating properties, good dielectric properties, excellent shear stability, and a very low order of acute toxicity characterize these unusual fluids.

2. Compatibility: BRAYCO 810-13 oils are insoluble or at most sparingly soluble in most organic solvents and materials other than fluorinated solvents. They are compatible at normal operating temperatures with conventional metals, plastics, and elastomers.

3. Limitations: BRAYCO 810-3 oils are adversely affected by Friedel-Crafts catalysts such as $AlCl_3$ at elevated temperatures. Rubbing surfaces of aluminum or magnesium under certain conditions may react. Such systems should be thoroughly evaluated. The fluids should be evaluated for corrosivity with materials of construction design temperatures are above 204°C (400°F).

4. Uses: BRAYCO 810-813 oils are designed for use as a lubricant or hydraulic fluids where they may be exposed to fuels and oxidizers or to systems operating up to temperatures of 316°C (600°F). They have been used as damping fluids, flotation fluids, lubricants for electrical contacts, lubricants in corrosive service, heat treansfer media, and dielectric fluids. Their wide range of viscosities enable their use for most applications either as provided or by blending.

5. Specifications: BRAYCO 810-3 oils are proprietary products manufactured by Montecatini Edison S.p.a. under the trademark Fomblin Fluorinated Fluids.

SYNTHETIC HIGH TEMPERATURE OILS
(LOW VOLATILITY, ESTER BASE LUBRICATING OIL)

PROPERTIES	BRAYCO[a/] NPT3A	BRAYCO NPT4	BRAYCO NPT9
COMPOSITION Base Oil	Synthetic Ester	Synthetic Ester	Synthetic Ester
Additives			
Viscosity Index Improver			
Oxidation Inhibitor			
Detergent			
Phosphorus, %			
Chlorine (bomb), %			
Pour Point Depressant			
Antifoam Additive			
Other			
VISCOSITY: $10^{-6}m^2$/Sec (Cs) at			
-18°C (0°F)	230		
-40°C (-40°F)	2,200		
-54°C (-65°F)	10,900	26,900	38,800
38°C (100°F)	12.7	19.83	55.0
99°C (210°F)	3.12	4.24	8.73
VISCOSITY INDEX	119	139	147
DENSITY, gm/ml, 16°C (60°F)	0.965	0.951	1.009
FLASH POINT, COC	218°C (425°F)	235°C (455°F)	257°C (495°F)
FIRE POINT, COC	-		
AUTO. IGNITION TEMPERATURE	399°C (750°F)	399°C (750°F)	399°C (750°F)
POUR POINT	-68°C (-90°F)	-62°C (-80°F)	-46°C (-50°F)
OXIDATION CORROSION, 72 Hr at 175°C (347°F)			
Weight Loss 10^{-2} kg/m^2 (mg/cm^2)			
Steel	-0.02	-0.024	0.00
Silver	+0.01	-0.024	+0.01
Aluminum	-0.01	-0.016	0.00
Magnesium	0.00	-0.016	0.00
Copper	-0.03	-0.056	-0.04
Viscosity Change at 38°C (100°F), %	+3.44	+4.69	+8.2
Neutralization Number Change	+0.24	+0.24	+0.38
Evaporation Loss, %	-	-	
Corrosion, Pitting or Etching	None	None	None
Separation of Insolubles	None	None	None
Gumming of Fluid	None	None	None
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.0	0.05	0.02
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F) 6-1/2 Hr at 204 °C (400°F), % Weight Loss	20	6.5	3.4
LEAD CORROSION, SOD, mg/in^2	+1.3	-0.20	-1.35
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, 10 Min Settling	Passes	Passes	
(a) Sequence 1, 24°C (75°F)			
(b) Sequence 2, 93°C (200°F)			
(c) Sequence 3, 24°C (75°F) (retest)			

SYNTHETIC HIGH TEMPERATURE OILS
(LOW VOLATILITY, ESTER BASE LUBRICATING OIL)

PROPERTIES	BRAYCO[a/] NPT3A	BRAYCO NPT4	BRAYCO NPT9
COMPATIBILILTY WITH: Other Turbine Fluids	Passes	Passes	
SYNTHETIC ELASTOMER SWELLING			
1 Week at 70 °C (158°F), % Volume Change			
"H" Stock	-	-	
Viton A	-	-	
COLOR, ASTM D 1500	2b	3b	2b
PARTICLE CONTAMINATION			
Particles/100 ml			
Particle Size Range, Microns			
5-15	360	-	320
16-25	42	-	40
26-50	21	-	12
51-100	7	-	9
100+	1	-	1
SHELL FOUR BALL WEAR TEST			
Scar Diameter, 10^{-3} m			
1 Hr at 600 rpm and 70°C (158°F)			
9.81 N (1 kg) load	-	-	
372.4 N (40 kg) load	-	-	
2 Hr at 600 rpm and 75°C (167°F)			
9.81 N (1 kg) load	0.324	-	
37.2 N (4 kg) load	0.518	-	
98.1 N (10 kg) load	0.686	-	
491 n (50 kg) load	0.805	-	
USABLE TEMPERATURE RANGE	-40C to 260°C (-40°F to 500°F)	-34°C to 260°C (-29°F to 500°F)	

a/ Bray Products Division, Burmah-Castrol, Inc.: A light, intermediate viscosity, ester base lubricating oil of low volatility. It is shear stable, oxidation resistant, has high load-carrying ability, and a wide temperature range, -40°C to 260°C (-40°F to 500°F). Recommended for fine clearance uses, gear boxes, hydraulic systems, etc. It may adversely affect paints and elastomers.

LOW TEMPERATURE FLUIDS
CHLOROFLUOROCARBON LUBRICANTS (Halocarbon Products Corporation)

PROPERTIES	4-11S*	11-14S	11-21S	13-21S	10-25S	14-25S
COMPOSITION Base Oil						
Additives						
Viscosity Index Improver						
Oxidation Inhibitor						
Detergent						
Phosphorus, %						
Chlorine (bomb), %						
Pour Point Depressant						
Antifoam Additive						
Other						
VISCOSITY: 10^{-6} m^2/Sec (Cs) at						
-54°C (-65°F)	-	-	-	-	-	-
38°C (100°F)	4.2	6.2	33	56	400	1,000
71°C (160°F)	1.9	2.6	8.0	11	42	83
99°C (210°F)	1.2	1.6	3.8	4.9	13	22
VISCOSITY INDEX						
DENSITY, kg/m^3 (0.001 gm/cc)						
38°C (100°F)	1.85	1.87	1.90	1.92	1.94	1.95
71°C (160°F)	1.80	1.82	1.85	1.87	1.89	1.90
99°C (210°F)	1.75	1.77	1.80	1.82	1.84	1.85
FLASH POINT, COC, Minimum						
BOILING POINT, ATMOSPHERIC	221°C (430°F)	238°C (460°F)	260°C (500°F)	260°C (500°F)	260°C (500°F)	260°C (500°F)
POUR POINT	-73°C (-100°F)	-71°C (-95°F)	-37°C (-35°F)	-34°C (-30°F)	2°C (35°F)	7°C (45°F)
CLOUD POINT	< -87°C (< -125°F)	< -87°C (< -125°F)	-71°C (-95°F)	-34°C (-30°F)	4°C (40°F)	4°C (40°F)

COMPATIBLIITY DATA:

Temp. °C	Temp. (°F)	Oxidizer	Time Hours	Ratio, Oxidizer to Oil 99:1	8:1	4:1	2:1	1:4	1:99	Color Initial	Color Final	Pressure
21	(70)	H_2O_2	24	No reaction at any ratio						Clear	Clear	Ambient
71	(160)	H_2O_2	24	No reaction at any ratio						Clear	Clear	Ambient
184	(-300)	LOX	24	No reaction at (1:1) ratio (only ratio tested for LOX)						Clear	Clear	Ambient

SHOCK SENSITIVITY DATA[a]/

Oxidizer	Ratio, Oxidizer to Oil 8:1	4:1	2:1	1:1	Treatment Temperature °C	(°F)	Test Temperature[b]/ °C	(°F)
H_2O_2	None	None	None	-	71	(160)	21	(70)
H_2O_2	None	None	None	-	21	(70)	21	(70)
LOX	_	_	_	None	-184	(-300)	-184	(-300)

LOW TEMPERATURE FLUIDS
CHLOROFLUOROCARBON LUBRICANTS (Halocarbon Products Corporation)

PROPERTIES	4-11S*	11-14S	11-21S	13-21S	10-25S	14-25S
WEAR TEST, SHELL FOUR-BALL 600 rpm, 2 hr. at 75°C (167°F))steel-on-steel) Average Wear Spot Dia., mm.:						
Load, 10 kg.	0.224	0.196	0.210	0.189	0.175	0.182
40 Kg.	0.707	0.630	0.693	0.658	0.693	0.623
MEAN HERTZ LOAD, kg.	102.0	102.6	100.8	101.3	107.4	103.7
Material Compatibility:						
Elastomens and Plastics	satisfactory for most applications					
Metals	Noncorrosive to 177°C (350°F), except copper and aluminum.					

* The suffix S designates an oxygen-compatible rust-inhibited oil. However, the rust inhibitor system while it passes the ASTM turbine oil specification D-665 is not as effective as petroleum lubricant inhibitor systems. These oils are also available without the inhibitor in which case the suffix S is dropped.

a/ Tests run on a Picatinny Arsenal type impact tester.

b/ Mixture of halocarbon oil and 90% H_2O_2 held at constant temperature for 24 hr. prior to test.

NOTES:

1. Maximum safe operating temperature is 204°C (400°F), short-term temperature up to 260°C (500°F).

2. These halocarbon oils may be used with most elastomers and solvent-resistant plastics at room temperatures. For elevated temperatures it is recommended that tests be conducted at anticipated temperatures and pressure.

3. These oils are noncorrosive toward metals up to 177°C (350°F), except for copper and some of its alloys which discolor at 49°C (120°F). These oils should not be used for aluminum thread applications or where high shear stresses are present or detonation may result.

4. The lubricity properties of these oils are at least equivalent to petroleum oils.

HIGH TEMPERATURE SYNTHETIC FLUIDS
PERFLUOROALKYLPOLYETHER FLUIDS (E. I. du Pont de Nemours and Company)

PROPERTIES	KRYTOX® 143AZ	KRYTOX® 143AA	KRYTOX® 143AY	KRYTOX® 143AB
COMPOSITION Base Oil	Perfluoroalklypolyether			
Additives				
Viscosity Index Improver				
Oxidation Inhibitor				
Detergent				
Phosphorus, %				
Chlorine (bomb), %				
Pour Point Depressant				
Antifoam Additive				
Other				
VISCOSITY: 10^{-6} m^2/Sec (Cs) at				
-40°C (-40°F)	8,000	35,000	-	-
-32°C (-25°F)	2,500	9,500	21,000	46,000
-18°C (0°F)	500	1,800	3,500	6,900
38°C (100°F)	18	36	55	85
54°C (130°F)				
99°C (210°F)	3.3	5.3	7.5	10.3
204°C (400°F)	0.8	1.1	1.4	1.8
VISCOSITY INDEX	29	89	107	113
ASTM SLOPE	0.844	0.770	0.720	0.686
DENSITY, kg/m^3 (lb/gal) at 24°C (75°F)	1,860 (15.5)	1,884 (15.7)	1,884 (15.7)	1,896 (15.8)
FLASH POINT, COC, Minimum	Products are nonflammable			
FIRE POINT, COC	Products are nonflammable			
POUR POINT, Maximum	-57°C (-70°F)	-46°C (-50°F)	-46°C (-50°F)	-43°C (-45°F)
EVAPORATION, Weight Loss, % after 6.5 Hr at				
149°C (300°F)	19	2	-	-
204°C (400°F)	83	26	6	5
260°C (500°F)	-	93	64	27
VAPOR PRESSURE, mm of Hg at				
149°C (300°F)	2.2	0.4	-	0.3
204°C (400°F)	23.5	4.8	-	2.5
260°C (500°F)	145.0	32.0	-	10.3
316°C (600°F)	600.0	157.0	-	52.5
371°C (700°F)	-	625.0	-	295.0
THERMAL DECOMPOSITION POINT				
Differential Thermal Analysis	471°C (880°F)	471°C (880°F)	471°C (880°F)	471°C (880°F)
Isoteniscope	354°C (670°F)	354°C (670°F)	354°C (670°F)	354°C (670°F)
APPROXIMATE BOILING RANGE at 0.8 mm Hg				
°C	143 to 185	185 to 210	210 to 227	227 to 251
°F	289 to 365	365 to 410	410 to 441	441 to 484

HIGH TEMPERATURE SYNTHETIC FLUIDS
PERFLUOROALKYLPOLYETHER FLUIDS (E. I. du Pont de Nemours and Company)

PROPERTIES	KRYTOX 143AZ	KRYTOX 143AA	KRYTOX 143AY	KRYTOX 143AB
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, after 5 min Blowing/ after 10 min Settling				
(a) Sequence 1, 24°C (75°F)	10/0	10/0	5/0	5/0
(b) Sequence 2, 93°C (200°F)	0/0	0/0	0/0	0/0
(c) Sequence 3, 24°C (75°F) (retest)	5/0	0/0	0/0	0/0
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels	See notes	See notes	See notes	See notes
LOX	Yes	Yes	Yes	Yes
COLOR, ASTM D 1500				
THERMAL EXPANSION COEFFICIENT				
Vol/Vol-°C, Average from 25° to 99°C (x 10^{-4})	11.0	10.4	-	10.1
Vol/Vol-°F, Average from 77° to 210°F (x 10^{-4})	6.1	5.8	-	5.6

NOTE: 1. Chemical inertness: KRYTOX® 143 oils have remarkable inertness and show no reactions with the following materials at room temperature: ethyl alcohol, JP-4 turbine fuel, hydrazine, unsymmetrical dimethyl hydrazine, aniline, 90% hydrogen peroxide, inhibited red fuming nitric acid and nitrogen tetroxide. They also show no reaction with many acids at elevated temperatures.

These oils do not react with gaseous oxygen under shock loads at pressures of 51.7 x 10^6 N/m^2 (7,500 psi) and temperatures to 93°C (200°F). Passes "LOX" test per MSFC-Spec-106.

2. Lubrication and load carrying: KRYTOX® 143 oils compare favorably with diester base stock containing no additives, synthetic hydraulic oils and petroleum-base E.P. type gear oils.

3. Compatibility: KRYTOX® oils are inert to most metals to 288°C (550°F), at higher temperatures oxidation-corrosion may develop. Also these fluorinated oils may detonate in the presence of aluminum or magnesium when metals are subject to shear such as in bearing surface, and tests are recommended. KRYTOX® oils are compatible with most elastomers below 93°C (200°F) except natural rubber, cis-1, 4-polybutadiene, and SBR. At higher temperatures they casue deterioration of elastomers.

4. These oils have a usable temperature range from a low of their pour point to a high of 260°C (500°F) to 371°C (700°F).

5. Oil properties which change with molecular weight are: pour point, viscosity, viscosity index, and volatility, all increase with molecular weight except volatility which decreases. These oils are resistant to heat, alone or in the presence of oxygen, decomposing to gaseous products above 371°C (700°F) without altering appreciably.

6. Some laboratory tests indicate that KRYTOX® 143 fluorinated oils are capable of detonating in the presence of aluminum or magnesium when the metals are subject to shear. It is recommended that tests be conducted before using these oils on aluminum or magnesium bearing surfaces where metal seizure or shear might occur.

HIGH TEMPERATURE SYNTHETIC FLUIDS
PERFLUOROALKYLPOLYETHER FLUIDS (E. I. du Pont de Nemours and Company)

PROPERTIES	KRYTOX® 143AX	KRYTOX® 143AC	KRYTOX® 143AD
COMPOSITION Base Oil		Perfluoroalkylpolyether	
Additives			
Viscosity Index Improver			
Oxidation Inhibitor			
Detergent			
Phosphorus, %			
Chlorine (bomb), %			
Pour Point Depressant			
Antifoam Additive			
Other			
VISCOSITY: 10^{-6} m^2/Sec (Cs) at			
-18°C (0°F)	13,800	33,000	-
38°C (100°F)	150	270	500
99°C (210°F)	2.7	3.9	6.0
204°C (400°F)	-	2.1	3.0
260°C (500°F)	125	134	145
VISCOSITY INDEX	125	134	144
ASTM SLOPE	0.625	0.589	0.549
DENSITY, kg/m^3 (lb/gal) at 24°C (75°F)	1,908 (15.9)	1,908 (15.9)	1,920 (16.0)
FLASH POINT, COC		Products are Nonflammable	
FIRE POINT, COC		Products are Nonflammable	
POUR POINT	-37°C (-35°F)	-34°C (-30°F)	-29°C (-20°F)
EVAPORATION, Weight Loss, % After 6.5 Hr			
at 149°C (300°F)	-	-	-
at 204°C (400°F)	-	1.0	-
at 260°C (500°F)	-	4.0	1.4
VAPOR PRESSURE, mm of Hg			
at 149°C (300°F)	-	-	-
at 204°C (400°F)	-	0.3	0.1
at 260°c (500°F)	-	2.9	1.4
at 316°C (600°F)	-	19.3	9.0
at 371°C (700°F)	-	165.0	80.0
THERMAL DECOMPOSITION POINT			
Differential Thermal Analysis	471°C (880°F)	471°C (880°F)	471°C (880°F)
Isoteniscope	354°C (670°F)	354°C (670°F)	354°C (670°F)
APPROXIMATE BOILING RANGE at 0.8 mm Hg			
°C	251 to 270	-	-
°F	484 to 518		
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, After 5 Min Blowing/ After 10 Min Settling			
(a) Sequence 1, 24°C (75°F)	390/20	400/0	400/100
(b) Sequence 2, 93°C (200°F)	90/0	265/0	375/20
(c) Sequence 3, 24°C (75°F) (retest)	310/50	360/0	350/200

HIGH TEMPERATURE SYNTHETIC FLUIDS
PERFLUOROALKYLPOLYETHER FLUIDS (E. I. du Pont de Nemours and Company)

PROPERTIES	KRYTOX® 143AX	KRYTOX® 143AC	KRYTOX® 143AD
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels	See notes	See notes	See notes
LOX	Yes	Yes	Yes
COLOR, ASTM D 1500			
THERMAL EXPANSION COEFFICEINT			
Vol/Vol-°C, Average From 25 to 99°C (x 10^{-4})	-	10.3	9.5
Vol/Vol-°F, Average Form 77 to 210°F (x 10^{-4})	-	5.7	5.3

NOTE: 1. Chemical inertness: KRYTOX® 143 oils have remarkable inertness and show no reactions with the following materials at room temperature: ethyl alcohol, JP-4 turbine fuel, hydrazine, unsymmetrical dimethyl hydrazine, aniline, 90% hydrogen peroxide, inhibited red fuming nitric acid and nitrogen tetroxide. They also show no reaction with many acids at elevated temperatures.

These oils do not react with gaseous oxygen under shock loads at pressures of 51.7 x 10^6 N/m^2 (7,500 psi) and temperatures to 93°C (200°F). Passes "LOX" test per MSFC-Spec-106.

2. Lubrication and load carrying: KRYTOX® 143 oils compare favorably with diester base stock containing no additives, synthetic hydraulic oils and petroleum-base E.P. type gear oils.

3. Compatibility: KRYTOX® oils inert to most metals to 288°C (550°F), at higher temperatures oxidation-corrosion may develop. Also these fluorinated oils may detonate in the presence of aluminum or magnesium when metals are subject to shear such as in bearing surface, and tests are recommended. KRYTOX® oils are compatible with most elastomers below 93°C (200°F) except natural rubber, cis-1, 4-polybutadiene, and SBR. At higher temperatures they cause deterioration of elastomers.

4. These oils have a usable temperature range from a low of their pour point to a high of 260°C (500°F) to 371°C (700°F).

5. Oil properties which change with molecular weight are: pour point, viscosity, viscosity index and volatility, all increase with molecular weight except volatility which decreases. These oils are resistant to heat, alone or in the presence of oxygen, decomposing to gaseous products above 371°C (700°F) without altering appreciably the characteristics of the remaining fluid.

6. Some laboratory tests indicate that KRYTOX® 143 fluorinated oils are capable of detonating in the presence of aluminum or magnesium when the metals are subject to shear. It is recommended that tests be conducted before using these oils on aluminum or magnesium bearing surfaces where metal seizure or shear might occur.

LOW VISCOSITY, SYNTHETIC INSTRUMENT OIL

PROPERTIES	ROYCO No. 2 INSTRUMENT OIL	Anderol[b/] L-402
COMPOSITION Base Oil		
Additives		
Viscosity Index Improver		
Oxidation Inhibitor	Yes	
Detergent		
Phosphorus, %		
Chlorine (bomb), %		
Pour Point Depressant		
Antifoam Additive		
Other		
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
38°C (100°F)	13.31	12.66
99°C (210°F)	2.91	3.4
VISCOSITY INDEX	168	
SPECIFIC GRAVITY, 16°C (60°F)		0.031
FLASH POINT, COC	191°C (375°F)	227°C (44°F)
FIRE POINT	210°C (410°F)	
POUR POINT	-62°C (-80°F)	-68°C (-90°F)
OXIDATION STABILITY at 54°C (130°F)		
Viscosity Increase, %, Maximum		
Neutralization Number Increase		
CORROSION, 72 Hr at 100°C (212°F)	No Corrosion or Stain or Copper, Cadmium Plated Steel, Magnesium, Aluminum, or Steel	None
HUMIDITY TEST: 100 Hr 49°C (120°F) 100% Relative Humidity		
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)		
EVAPORATION, Weight Loss, %		
60 Hr at 66°C (150°F)	0.5	0.7
CARBON RESIDUE, Weight Loss, %	0.03	-
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam, 10 min Settling		
(a) Sequence 1, 24°C (75°F)		
(b) Sequence 2, 93°C (200°F)		
(c) Sequence 3, 24°C (75°F) (retest)		
COMPATIBILITY WITH: Rubber and Jet, and Rocket Fuels		
LOX		
COLOR, ASTM D 1500		

LOW VISCOSITY, SYNTHETIC INSTRUMENT OIL
(ROYAL LUBRICANTS COMPANY)

PROPERTIES	ROYCO[a/] NO. 2 INSTRUMENT OIL	Anderol[b/] L-402

NOTE: ROYCO No. 2 and L-402 Instrument Oil is intended for use as an instrument lubricant where spreading of the oil into a thin film is required. Extreme low temperature properties for low temperature operation of "flea powered" equipment.

a. Royal Lubricants Company, Inc.
b. Tenneco Chemicals (Nuodex Inc.)

MILITARY SPECIFICATION: MIL-G-4343C
GREASE, PNEUMATIC SYSTEM

PROPERTIES	SPEC. REQ.	COSMOLUB[a]/ 615	ROYCO[b]/ 43	Molykote 55M[c]/
COMPOSITION Base Oil	-	Silicone	Synthetic	Silicone
Additives				
Rust Inhibitor	-			
EP (extreme pressure)	-			
Thickener	-	Metallic Soap	Lithium	-
Solids	-			
Antioxidant	-	Yes	Yes	-
Other	-			
VISCOSITY, Base Oil, at 38°C (100°F), 10^{-6} m^2/Sec (Cs)				
APPARENT VISCOSITY: 10^{-1} N Sec/m^2 at -54°C (-65°F) and Shear Rate of 20 sec^{-1}	5,000 Maximum	2,950	2,750	4,300
VISCOSITY INDEX, Base Oil				
DROPPING POINT	163°C (325°F) Minimum	193°C (380°F)	175°C (347°F)	> 177°C (> 350°F)
PENETRATION				
Unworked at 25°C (77°F)	-	-	-	-
Worked at 25°C (77°F)	260 to 300	260	269	275
SPECIFIC GRAVITY, 16°C (60°F)	-	-	-	-
USABLE TEMPERATURE RANGE	-	-54°C (-65°F) to 93°C (200°F)	Low to High	-65°C (-85°F) to 177°C (350°F)
LOW TEMPERATURE TORQUE				
WATER RESISTANCE				
OIL SEPARATION, % Weight Loss 30 Hr at 100°C (212°F)	5.0 Maximum	3.51	0.3	3.2
BOMB OXIDATION STABILITY, Pressure Drop, N/m^2 (psi)				
100 Hr at 99°C (210°F)	34,470 (5.0) Maximum	2,070 (0.5)	19,310 (2.8)	< 34,470 (< 5.0)
500 Hr at 99°C (210°F)	-			
STORAGE STABILITY, 6 Months at 38°C (100°F)				
Unworked Penetration				
Worked Penetration Change	30 Points Maximum	Passes	Passes	Passes
CORROSION ON COPPER 24 Hr at 100°C (212°F) (No etching on pitting--stain removed by benzene)	Pass	Passes	Passes	Passes
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity				
RUST PREVENTIVE PROPERTIES (Number of small dots)	3.0 Maximum	Passes	None	Passes
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)				

MILITARY SPECIFICATION: MIL-G-4343C
GREASE, PNEUMATIC SYSTEM

PROPERTIES	SPEC. REQ.	COSMOLUB[a] 615	ROYCO[b] 43	Molykote 55M[c]
EVAPORATION, % Weight Loss (22 Hr at 99°C (210°F))	2.5 Maximum	0.76	1.9	0.8
COMPATIBILITY WITH: Rubber (Buna N and MIL-P-5516) Jet and Rocket Fuels LOX	-	Passes	Passes	Passes
COLOR, ASTM D 1500	-	Flesh-Tan	-	Light Beige
RUBBER SWELL, Vol % (L-type Synthetic in grease 1 Week)	19-30	27.52	24.3	Passes
CYCLE TEST: Rubber-Metal 50,000 cycles	Pass	Passes	Passes	Passes
ODOR (No rancidity or perfume)	Pass	Passes	Passes	Passes
NLGI Number	-	-	2	-
LUBRICITY (Falex)	-	-	-	1,690 N (380 lb)

NOTE: For a description and recommended usage of this high-low temperature range grease, compatible with rubber and possessing good metal-to-metal lubricating properties, see Section II.

In addition to the products listed, the following greases manufactured by the companies shown also meet the requirements of this speicfication.

Product Name	Manufacturer
Castrolease PS	Castrol Oil Company

a/ E. F. Houghton and Company.
b/ Royal Lubricants Company, Inc.
c/ Dow Corning Corporation.

MILITARY SPECIFICATION: MIL-G-6032D
GREASE, PLUG VALVE, GASOLINE AND OIL RESISTANT

PROPERTIES	SPEC. REQ.	ROYCO[a/] 32
COMPOSITION Base Oil (Animal, vegetable or synthetic)	Note	Synthetic
Additives		
Rust Inhibitor		
EP (extreme pressure		
Thickener (gelling agent)	Note	Lithium
Solids		Passes
Antioxidant		
Other		
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C (100°F)		
VISCOSITY INDEX, Base Oil		
DROPPING POINT	127°C (260°F) Minimum	177°C (350°F)
PENETRATION		
Unworked Type I at 25°C (77°F)	100 Minimum	-
Worked Type I at 25°C (77°F)	310 Maximum	225
Unworked (1/4 Scale) Type II at 25°C (77°F)	23 Maximum	-
Worked Type II at 25°C (77°F)	20 to 42	-
SPECIFIC GRAVITY, 16°C (60°F)	-	-
USABLE TEMPERATURE RANGE	-	-
LOW TEMPERATURE TORQUE		
WATER RESISTANCE		
OIL SEPARATION, % Weight Loss 30 Hr at 100°C (212°F)	-	Nil
BOMB OXIDATION STABILITY		
Pressure Drop, Maximum		
100 Hr at 99°C (210°F)		
500 Hr at 99°C (210°F)		
STORAGE STABILITY, 120 Days at 54°C (130°F)		
No Stock Softening or Deterioration	Pass	Passes
Type II (1/4 scale) Unworked Penetration	23 Maximum	Passes
No Stick Crumbling or Distortion	Req.	Passes
CORROSION ON COPPER 24 Hr at 100°C (212°F) (no etching or pitting)	Pass	Passes
CORROSION ON STEEL 1 Week at 100°C (212°F)	None	Passes
FILM STABILITY 1 Week at 100°C (212°F)	Stable	Stable
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity		

MILITARY SPECIFICATION: MIL-G-6032D
GREASE, PLUG VALVE, GASOLINE AND OIL RESISTANT

PROPERTIES	SPEC. REQ.	ROYCO[a/] 32
RUST PREVENTIVE PROPERTIES		
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	-	-
EVAPORATION, % (22 Hr at 99°C (210°F))	-	Nil
COMPATIBILITY WITH: Rubber and		
Jet and Rocket Fuel	-	No
LOX	-	No
COLOR	-	-
NLGI NUMBER	-	3.0
DIRT COUNT	-	-
RESISTANCE TO FUEL: 8 Hr		
Weight %, Soluble	20 Maximum	15.0
Adhesion to Aluminum (no blisters or swelling)	Pass	None
RESISTANCE TO AQUEOUS SOLUTION		
Water	None	Nil
50% Alcohol and Water	None	Nil
SOLUBILITY, %		
Mil-H-3136	-	-
Mixed Alcohols	-	-
Mixed Keotane	-	-
Toluene	-	-
Benzene	-	-
Carbon Tetrachloride	-	-

NOTE: For a description and recommended usage of this gasoline and oil resistant grease see Section II.

In addition to the products listed, the following grease manufactured by the companies shown also meet the requirements of this specification.

Product Name	Manufacturer
Dow Corning FS-3452	Dow Corning Corporation
Braycote 632B	Bray Products Division, Burmah-Castrol, Inc.
Rockwell 950	Rockwell International
E-Z Turn Lubricant	United Erie, Inc.
Ultra-Seal 125	Southwest Petro-Chem., Inc.
Ultra-Seal 822	Southwest Petro-Chem., Inc.

a/ Royal Lubricants Company, Inc.

MILITARY SPECIFICATION: MIL-G-10924D(1)
GREASE, AUTOMOTIVE AND ARTILLERY

PROPERTIES	SPEC. REQ.	ROYCO [a/] 24R
COMPOSITION Base Oil	-	Mineral
Additives		
Rust Inhibitor		
EP (extreme pressure)		
Thickener	10 Weight %, Minimum	Lithium Soap
Solids		
Antioxidant	-	Yes
Other		
VISCOSITY, Base Oil at 38°C (100°F), 10^{-6} m^2/Sec (Cs)		
VISCOSITY INDEX, Base Oil		
DROPPING POINT		
PENETRATION		
Unworked at 25°C (77°F)	265 to 295	-
Worked at 25°C (77°F)	265 to 295	265 to 295
SPECIFIC GRAVITY, 16°C (60°F)		
USABLE TEMPERATURE RANGE	-54°C (-65°F) to 74°C (175°F)	-
LOW TEMPERATURE TORQUE		
WATER RESISTANCE		
Worked in Water 10^5 Cycles at 25°C (77°F) (allowable change in worked penetration)	-10 to +60	Passes
OIL SEPARATION, % Weight Loss, Maximum 30 Hr at 100°C (212°F)	5.0	Passes
BOMB OXIDATION STABILITY		
Pressure Drop/100 Hr, N/m^2 (psi)		
100 Hr at 99°C (210°F)	34,470 (5.0), Maximum	Passes
400 Hr at 99°C (210°F)	137,880 (20) Maximum	
STORAGE STABILITY, 6 Months at 38°C (100°F)		
Unworked Penetration		
Worked Penetration	255, Minimum	Passes
WORK STABILITY		
100 Hr, 66°C (150°F), 10 rpm (allowable change in worked penetration)	-25 to +60	Passes
CORROSION, COPPER STRIP 20 Hr at 99°C (210°F)	None	Passes
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity		
RUST PREVENTIVE PROPERTIES, Roller Bearing 2 Weeks at 25°C (77°F), 100% Relative Humidity	None	Passes
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg/KOH/kg (mg KOH/g)		

MILITARY SPECIFICATION: MIL-G-10924D(1)
GREASE, AUTOMOTIVE AND ARTILLERY

PROPERTIES	SPEC. REQ.	ROYCO[a/] 24R
EVAPORATION, % Weight Loss (22 Hr at 99°C (210°F)	6.0, Maximum	< 10.0
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX		
COLOR	-	-
NLGI NUMBER	-	-
APPARENT VISCOSITY 10^{-1} N sec/m^2 (poises)		
at -54°C (-65°F) and Shear Rate of 25 Sec^{-1}	9,500/20,000	-
at -54°C (-65°F) and Shear Rate of 100 Sec^{-1}	--/10,000, Maximum	< 8,500

NOTE: For a description of this general purpose grease, see Section II.

In addition to the product listed, several other general purpose greases also meet the requirements of this specification. Some of these are:

Product Name	Distributor
BATAM 10924 D and	Battenfeld Grease & Oil Corporation of New York
BATAM S-830-RR	Battenfeld Grease & Oil Corporation of New York
MIL-G-10924D-SW	Bottish Industrial Products Company
CODE 5542-C	Southwest Petro-Chem, Inc. (Div. of Witco Chem. Corp.)
CODE SA 824 3332	Southwest Petro-Chem, Inc. (Div. of Witco Chem. Corp.)
Tectyl 858C	Valvoline Oil Company (Div. of Ashland Oil, Inc.)

a/ Royal Lubricants Company, Inc.

MILITARY SPECIFICAITON: MIL-L-15719A(3)
LUBRICATING GREASE (High-Temperature Electric Motor, Ball and Roller Bearings)

PROPERTIES	SPEC. REQ.	DOW CORNING[a/] 44 GREASE	VERSILUBE[b/] G-351
COMPOSITION Base Oil	Phenylmethylphenyl Silicone	Passes	Passes
Additives			
Rust Inhibitor			
EP (extreme pressure)			
Thickener	Lithium Soap	Passes	Passes
Solids			
Antioxidant			
Other			
VISCOSITY, Base Oil, 10^{-6} m^2/sec (Cs) at 38°C (100°F) (Apparent viscosity 10^{-1} N sec/m^2 (poises) at -18°C (0°F) and Shear Rates of 20 sec^{-1})	10,000 Maximum	Passes	-
VISCOSITY INDEX, Base Oil			
DROPPING POINT	191°C (375°F) Minimum	Passes	Passes
PENETRATION Worked at 25°C (77°F)	260 to 330	290 to 330	260 to 330
WORK STABILITY, 10^{-5} Cycles Penetration	375.0 Maximum	Passes	-
SPECIFIC GRAVITY, 16°C (60°F)	-	1.05	1.05
USABLE TEMPERATURE RANGE	-18°C (0°F) to 149°C (300°F)	-40°C (-40°F) to 204°C (400°F)	-40°C (-40°F) to 204°C (400°F)
LOW TEMPERATURE TORQUE, 2 Hr at -18°C (0°F) with Torque of 0.1962 Nm (2,000 g cm) Time for One Rev.	15.0 sec Maximum	Passes	-
WATER RESISTANCE (8 ball bearing) 1.0 Hr at 49°C (120°F), % Weight Loss	20.0 Maximum	Passes	-
BLEEDING, % Weight Loss 100 Hr at 149°C (300°F)	12.0 Maximum	5.0	5.0
BOMB OXIDATION STABILITY Pressure Drop, N/m^2 (psi) 50 Hr at 149°C (300°F)	34,470 (5.0) Maximum	Passes	-
STORAGE STABILITY, 6 Months at 38°C (100°F) Unworked Penetration Worked Penetration			
CORROSION, COPPER (bomb) 24 Hr at 100°C (212°F) (no etching or pitting)	Pass	Passes	Passes
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity			

MILITARY SPECIFICATION: MIL-L-15719A(3)
LUBRICATING GREASE (High-Temperature Electric Motor, Ball and Roller Bearings)

PROPERTIES	SPEC. REQ.	DOW CORNING[a/] 44 GREASE	VERSILUBE[b/] G-351
RUST PREVENTIVE PROPERTIES			
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)			
EVAPORATION, % Weight Loss 50 Hr at 149°C (300°F)	2.0 Maximum	< 2.0	< 2.0
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX			
COLOR	_	Amber	Light Brown
ODOR (no rancidity or perfume)	Pass	Passes	Passes
DIRT CONTENT: Particle Count Per 10^{-6} m^3 (cm^3)			
25 x 10^{-6} m^3 (micron) Dia. or Larger	7,500 Maximum	Passes	Passes
75 x 10^{-6} m^3 (micron) Dia. or Larger	1,600 Maximum	Passes	Passes
125 x 10^{-6} m^3 (micron) Dia. or Larger	None	Passes	Passes
LUBRICITY (Falex)	-	1,068 N (240 lb)	-
MOTOR TEST PERFORMANCE Bearing, Useful Life Hours	2,000	Passes	Passes
MAXIMUM SPEED FACTOR DN Value	-	200,000	200,000

NOTE: For a description and recommended usage of this high temperature silicone base grease, see Section II.

In addition to the products listed, the following grease meets the requirements of this specification:

Product	Manufacturer
KSL-89 Grease	Keystone Division of Pennwalt Corporation

a/ Dow Corning Corporation.
b/ General Electric, Silicone Products Department.

MILITARY SPECIFICAITON: MIL-G-21164D
GREASE, MOLYBDENUM DISULFIDE (for low and high temperatures)

PROPERTIES	SPEC. REQ.	AEROSHELL[a/] GREASE 17	ROYCO[b/] 64D
COMPOSITION Base Oil	-	Diester	Synthetic
Additives			
Rust Inhibitor	-	-	Yes
EP (extreme pressure)	-	-	Yes
Thickener (gelling agent)		Microgel	Lithium
Solids (molybdenum disulfide), %	4.5 to 5.5	Passes	Passes
Antioxidant	-	-	Yes
Other			
VISCOSITY, Base Oil, 10^{-6} m^2/sec (Cs) at 38°C (100°F)			
APPARENT VISCOSITY 10^{-1} N sec/m^2 (poises) at			
-54°C (-65°F) and Shear Rate of 20 sec^{-1}	-	-	5,000
-54°C (-65°F) and Shear Rate of 50 sec^{-1}	-	-	3,000
VISCOSITY INDEX, Base Oil			
DROPPING POINT	165°C (329°F) Minimum	< 260°C (< 500°F)	185°C (365°F)
PENETRATION			
Unworked at 25°C (77°F)	200 Minimum	278	-
Worked at 25°C (77°F)	260 to 310	288	285
WORK STABILITY, 10^5 Cycles Penetration	375 Maximum	-	340
SPECIFIC GRAVITY, 16°C (60°F)			
USABLE TEMPERATURE RANGE	-	-62°C (-80°F) to 149°C (300°F)	Wide
LOW TEMPERATURE TORQUE, Nm (g cm) at -73°C (-100°F)			
Starting	0.981 (10,000) Maximum	-	Passes
Running	0.0981 (1,000) Maximum	-	Passes
WATER RESISTANCE, 1 Hr at 38°C (100°F) % Weight Loss	20.0 Maximum	2.8	6.0
OIL SEPARATION, % Weight Loss 30 Hr at 100°C (212°F)	5.0 Maximum	2.0	3.0
BOMB OXIDATION STABILITY			
Pressure Drop, N/m^2 (psi)			
100 Hr at 99°C (210°F)	68,950 (10)	44,818(6.5)	-
500 Hr at 99°C (210°F)	103,420 (15)	75,845 (11)	44,820 (6.5)
STORAGE STABILITY, 6 Months at 40°C (104°F)			
Unworked Penetration	200 Minimum	Passes	Passes
Worked Penetration, Change	30 Maximum	Passes	Passes
CORROSION ON COPPER 24 Hr at 100°C (212°F) (no etching or pitting)	Pass	Passes	None
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity			
BEARING RUST PROTECTION, 14 Days (3 Dots Maximum)	Pass	Passes	None

MILITARY SPECIFICATION: MIL-G-21164D
GREASE, MOLYBDENUM DISULFIDE (for low and high temperatures)

PROPERTIES	SPEC. REQ.	AEROSHELL[a/] GREASE 17	ROYCO[b/] 64D
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)			
EVAPORATION, % Weight Loss (22 Hr at 99°C (210°F))	2.0 Maximum	0.9	2.0
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuel			
LOX			
COLOR	-	Dark Grey	Grey-Black
NLGI NUMBER	-	-	2.0
DIRT CONTENT			
Particle Count Per 10^{-6} m^3 (cm^3)			
25 x 10^{-6}(micron) Dia. or Larger	-	-	750
75 x 10^{-6} (micron) Dia. or Larger	-	-	150
125 x 10^{-6} (micron) Dia. or Larger	-	-	None
HIGH TEMPERATURE TEST			
Bearing Life, Hr at 121°C (250°F)	1,000 Minimum	1,000	> 2,000
LOAD-WEAR INDEX			
Mean Hertz Load N (kg)	491 (50)	834 (85)	491 (50)

NOTE: For a description and recommended usage of this wide temperature range, molybdenum disulfide grease, see Section II.

In addition to the products listed, there are other greases manufactured and other lubricant companies which meet the requirements of this specificaiton. Some of these are:

Product	Manufacturer
Everlube 211-G	E/M Lubricants, Inc.
Braycote 664	Bray Products Division, Burmah-Castrol, Inc.

a/ Shell Oil Company.
b/ Royal Lubricants Company, Inc.

MILITARY SPECIFICATION: MIL-G-23549C
GREASE, GENERAL PURPOSE

PROPERTIES	SPEC. REQ.	ROYCO[a/] 49B	CHEVRON LAUNCH PAD[b/] GREASE
COMPOSITION BAse Oil	Mineral	Mineral	Paraffinic
Additives			
Rust Inhibitor		Yes	Yes
EP (extreme pressure)	-	-	Yes
Thickener	Nonsoap	Nonsoap	Complex
Solids	5% MoS_2	MoS_2	Yes
Antioxidant	-	Yes	-
Other			
VISCOSITY, Base Oil, 10^{-6} m^2/sec (Cs) at 38°C (100°F)			
VISCOSITY INDEX, Base Oil			
DROPPING POINT	232°C (450°F) Minimum	282°C (540°F)	270°C (518°F)
PENETRATION			
Worked at 25°C (77°F)	270 to 315	300	300
SPECIFIC GRAVITY, 16°C (60°F)			
MAXIMUM USABLE TEMPERATURE	177°C (350°F) to 204°C (400°F)	204°C (400°F)	-
LOW TEMPERATURE TORQUE			
WATER RESISTANCE			
Boiling 10.0 Min (no disintegration)	Pass	Passes	Passes
OIL SEPARATION, % Weight Loss			
30 Hr at 177°C (350°F)	6.0 Maximum	5.0	2.2
BOMB OXIDATION STABILITY			
Pressure Drop, Maximum			
100 Hr at 99°C (210°F)			
500 Hr at 99°C (210°F)			
STORAGE STABILITY, 6 Months at 38°C (100°F)			
Unworked Penetration			
Worked Penetration Change	±30 Maximum	Stable	Passes
CORROSION ON COPPER			
24 Hr at 177°C (350°F) (no pitting or etching)	Pass	Passes	Passes
SALT SPRAY			
48 Hr at 35°C (95°F) (no corrosion)	Pass	Passes	Passes
RUST PREVENTIVE PROPERTIES			
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)			
EVAPORATION, % Weight Loss (22 hr at 177°C (350°F))	7.0 Maximum	6.0	2.0
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels			
LOX			

MILITARY SPECIFICATION: MIL-G-23549C
GREASE, GENERAL PURPOSE

PROPERTIES	SPEC. REQ.	ROYCO[a] 49B	CHEVRON LAUNCH PAD[b] GREASE
COLOR	-	Grey-Black	-
LOAD CARRYING CAPACITY Mean Hertz, N (kg)	491 (50)	491 (50)	736 (75)

In addition to the greases listed, another grease which meets the requirements of this specification is:

Product	Manufacturer
SA-823922	Southwest Petro-Chem, Inc., Division of Witco Chem. Corp.

a/ Royal Lubricants Company, Inc.
b/ Chevron U.S.A., Inc.

MILITARY SPECIFICATION: MIL-G-23827B
GREASE, AIRCRAFT AND INSTRUMENT, GEAR AND ACTUATOR SCREW

PROPERTIES	SPEC. REQ.	ROYCO[a]/ 27A	AEROSHELL[b]/ GREASE 7	LOW TEMP[c]/ GREASE EP
COMPOSITION Base Oil	-	Synthetic	Synthetic	Synthetic
Additives				
Rust Inhibitor		Yes	Yes	Yes
EP (extreme pressure)	-	Yes	Yes	Yes
Thickener	-	Lithium	Microgel	Lithium
Solids				
Antioxidant				
Other	-	Yes	Yes	Yes
VISCOSITY, Base Oil, 10^{-6} m^2/sec (Cs) at 38°C (100°F)				14.02
VISCOSITY INDEX, Base Oil				
DROPPING POINT	165°C (329°F) Minimum	193°C (380°F)	260°C (500°F)	183°C (361°F)
PENETRATION				
Unworked at 25°C (77°F)	200 Min	260	283	275
Worked at 25°C (77°F)	270 to 310	275	296	284
WORK STABILITY 10^{-5} Cycles at 25°C (77°F) Worked Penetration	375 Maximum	340	Passes	298
SPECIFIC GRAVITY, 16°C (60°F)				
USABLE TEMPERATURE RANGE	-73°C (-100°F) to 121°C (250°F)	-	-73°C (-100°F) to 149°C (300°F)	-78°C (-100°F) to 121°C (250°F)
LOW TEMPERATURE TORQUE, Nm (g cm) at -73°C (-100°F)				
Starting	0.981 (10,000) Maximum	0.241 (2,450)	-	0.508 (5,190)
Running	0.098Γ (1,000) Maximum	0.0216 (220)	-	0.043 (440)
WATER RESISTANCE, % Weight Loss 1 Hr at 38°C (100°F)	20 Maximum	2	1.3	-
OIL SEPARATION, % Weight Loss 30 Hr at 100°C (212°F)	5.0 Maximum	1.7	2.1	2.4
BOMB OXIDATION STABILITY Pressure Drop N/m^2 (psi)				
100 Hr at 99°C (210°F)	68,950 (10)	13,790 (2.0)	34,475 (5)	14,000 (2)
500 Hr at 99°C (210°F)	103,420 (15)	31,028 (4.5)	68,950 (10)	-
STORAGE STABILITY, 6 Months at 38°C (100°F)				
Unworked Penetration at 25°C (77°F)	200 Min	290	Passes	Passes
Worked Penetration Change at 25°C (77°F)	±30	290	Passes	Passes
CORROSION ON COPPER (bomb test) 20 Hr at 99°C (210°F)				
Pressure Drop N/m2 (psi)	6,895 (1.0) Maximum	0.0	-	-
Copper Strip (no corrosion)	Pass	Pass	Pass	Pass
Grease (no discoloration)	Pass	Pass	Pass	Pass

MILITARY SPECIFICATION: MIL-G-23827B
GREASE, AIRCRAFT AND INSTRUMENT, GEAR AND ACTUATOR SCREW

PROPERTIES	SPEC. REQ.	ROYCO[a/] 27A	AEROSHELL[b/] GREASE 7	LOW TEMP[c/] GREASE EP
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity				
RUST PREVENTIVE PROPERTIES 14 Day Bearing TEst at 25°C (77°F), 100% Relative Humidity (no discoloration or corrosion in excess of 3 small dots)	Pass	Passes	Passes	Passes
NEUTRALIZATION NUMBER, maximum 10^{-3} kg KOH/kg (mg KOH/g)				
EVAPORATION, % Weight Loss (22 hr at 100°C (212°F))	2.0 Maximum	1.7	0.70	0.9
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX				
COLOR	-	-	Buff	Purplish Brown
ODOR (no objectionable odors)	Pass	-	-	-
DIRT CONTENT, Particle Count Per 10^{-6} m^3 (cm^3)				
25×10^{-6} (microns) or Larger	1,000	450	-	-
75×10^{-6} (microns) or Larger	None	0	-	-
HIGH TEMPERATURE BEARING TEST Life (hr) at 121°C (250°F)	1,000 Min.	Passes	1,150+	1,183
LOAD CARRYING CAPACITY Mean Hertz Load, N (kg)	294 (30) Min	339 (34.6)	549 (56)	452 (46)
GEAR WEAR, 10^{-6} kg/1,000 Cycles (mg/1,000 cycles) at				
22.24 N (5 lb) Load	2.5 Maximum	1.5	-	-
44.48 N (10 lb) Load	3.5 Maximum	2.0	-	-

NOTE: This specification supersedes the following grease MIL specifications: MIL-G-7118A, MIL-G-007118B, MIL-G-7421B, MIL-G-3278A, and MIL-G-15793.

For a description of this aircraft and instrument grease, and recommended usage, see Section II.

In addition to the products listed, other greases which meet the requirements of this specification are:

Product	Manufacturer
Supermill Grease No. A72832	Amoco Oil Company
Braycote 6275	Bray Oil Company
Castrolease A 1	Burmah-Castrol, Inc.
Mobilgrease 27	Mobil Oil Corporation
Southwest Grease No. 16215	Southwest Petro-Chem, Inc. (Division of Witco Chemical Corp.)

a/ Royal Lubricants Company, Inc.
b/ Shell Oil Company.
c/ Texaco Inc.

MILITARY SPECIFICATION: MIL-G-24139A
GREASE, MULTIPURPOSE, WATER RESISTANT

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	Petroleum oil, gelling agent
DROPPING POINT	149°C (300°F), Minimum
PENETRATION	
Worked at 25°C (77°F)	250 to 310
WORK STABILITY, 10^5 Cycles	
Worked Penetration	355 Maximum
LOW TEMPERATRUE TORQUE, Nm (g cm) at -29°C (-20°F)	
Starting	0.441 (4,500) Maximum
Running	0.147 (1,500) Maximum
WATER RESISTANCE, % Weight Loss	
1 Hr at 38°C (100°F)	15 Maximum
BOMB OXIDATION STABILITY	
Pressure Drop, N/m^2 (psi)	
100 Hr at 99°C (210°F)	68,950 (10)
500 Hr at 99°C (210°F)	172,400 (25)
CORROSION ON COPPER	
24 Hr at 100°C (212°F)	
Copper Strip (no corrosion)	Pass
Grease (no discoloration)	Pass
HIGH TEMPERATURE BEARING TEST	
Life (hr) at 121°C (250°F)	2,000 min.
DIRT CONTENT, Particle Count Per 10^{-6} m^3 (cm^3)	
25×10^{-6} (micron) or Larger	7,500
75×10^{-6} (micron) or Larger	1,600
125×10^{-6} (micron)	None

NOTE: For a description and recommended usage of this multipurpose grease, see Section II.

Product listed below meets the requirements of this specificaiton.

Product	Manufacturer
Aeroshell Grease 6	Shell Oil Company

MILITARY SPECIFICATION: DOD-G-24508A(1)
GREASE, HIGH PERFORMANCE, MULTI-PURPOSE (Metric)

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	Petroleum Oil, Gelling Agent
DROPPING POINT	232°C (450°F) Minimum
PENETRATION	
Worked at 25°C (77°F)	265 to 320
Worked 10^5 Cycles at 25°C (77°F)	350 min.
LOW TEMPERATURE TORQUE, Nm (g cm) at -29°C (-20°F)	
Starting	0.441 (4,500) Maximum
Running	0.147 (1,500) Maximum
WATER RESISTANCE, % Weight Loss	
1 Hr at 38°C (100°F)	10 Maximum
OIL SEPARATION, % Weight Loss	
30 Hr at 177°C (350°F)	10 Maximum
BOMB OXIDATION STABILITY	
Pressure Drop, N/m^2 (psi)	
100 Hr at 99°C (210°F)	103,425 (15)
500 Hr at 99°C (210°F)	172,400 (25)
STORAGE STABILITY, 6 Months at 38°C (100°F)	
Unworked Penetration at 25°C (77°F)	200
Worked Penetration Change at 25°C (77°F)	±30 of original
CORROSION, Copper Strip at 49°C (120°F)	
100% Relative Humidity	None
RUST PREVENTIVE PROPERTIES	
Maximum Bearing Ratio	2
EVAPORATION, % Maximum	
22 Hr at 177°C (350°F)	12
LOAD WEAR INDEX, kg	30
STEEL ON STEEL WEAR	
Wear Scar Diameter, mm	1.30 Max.
DIRT, Particle Count per 10^{-6} m^3 (cm^3)	
25 x 10^{-6} (micron) Dia. or Larger	1,000 Max.
75 x 10^{-6} (micron) Dia. or Larger	None
GEAR WEAR, 10^{-6} kg/1,000 cycles (mg/1,000 cycles)	
22.24 N (5 lb) Load	2.5 Max.
44.48 N (10 lb) Load	3.5 Max.
OSCILLATION	
Friction and Wear	35,000 Cycles
Oxidation	200 Hr
HIGH TEMPERATURE PERFORMANCE	
Hrs at 177°C (350°F)	400 Min.

NOTE: For a description and recommended usage of this general purpose grease, see Section II.

Products listed below meet the requirements of this specification.

Product	Manufacturer
Mobilgrease 28	Mobil Oil Corporation
Royco 48	Royal Lubricants Company

MILITARY SPECIFICATION: MIL-G-25013E
GREASE, AIRCRAFT, BALL AND ROLLER BEARING

PROPERTIES	SPEC. REQ.	SUPERMIL[a] ASU GREASE No. 1371
COMPOSITION Base Oil	-	Silicone
Additives		
Rust Inhibitor	-	Yes
EP (extreme pressure)		
Thickener	-	Arylurea
Solids		
Antioxidant		Yes
Other		
VISCOSITY, Base Oil, 10^{-6} m^2/sec (Cs) at 38°C (100°F)		75
VISCOSITY INDEX, Base Oil		
DROPPING POINT	232°C (450°F)	Passes
PENETRATION		
Unworked at 25°C (77°F)	-	-
Worked at 25°C (77°F)	260-330	300
WORK STABILITY		
10^5 Cycles at 25°C (77°F) Worked Penetration	375 Maximum	-
SPECIFIC GRAVITY, 16°C (60°F)		
USABLE TEMPERATURE RANGE	-73°C (-100°F) to 232°C (450°F)	-73°C (-100°F) to 232°C (450°F)
LOW TEMPERATURE TORQUE, Nm (g cm) at -54°C (-65°F)		
Starting	0.1962 (2,000) Maximum	Passes
Running (after 1 hr)	0.0490 (500) Maximum	Passes
WATER RESISTANCE, 1 Hr at 38°C (100°F) % Weight Loss	20.0 Maximum	1.4
OIL SEPARATION, % Weight Loss 30 Hr at 204°C (400°F)	7.5 Maximum	6.8
BOMB OXIDATION STABILITY Pressure Drop, N/m^2 (psi) 100 Hr at 121°C (250°F)	34,480 (5.0) Maximum	0
STORAGE STABILITY, 6 Months at 38°C (100°F)		
Unworked Penetration at 25°C (77°F)	200 Minimum	Passes
Worked Penetration Change at 25°C (77°F)	± 30	Passes
CORROSION, COPPER 24 Hr at 100°C (212°F) (no pitting or etching	Pass	Passes
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity		
DIRT CONTENT Particle Count Per 10^{-6} m^3 (cm^3)		
25×10^{-6} (micron) Dia. or Larger	1,000 Maximum	Passes
75×10^{-6} (micron) Dia. or Larger	None	Passes

MILITARY SPECIFICATION: MIL-G-25013E
GREASE, AIRCRAFT, BALL AND ROLLER BEARING

PROPERTIES	SPEC. REQ.	SUPERMIL[a/] ASU GREASE No. 1371
RUST PREVENTIVE PROPERTIES: 14 Days No Discoloration or Corrosion in Excess of 3 Small Spots Per Bearing; No Pitting or Etching	Pass	Passes
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)		
EVAPORATION at (22 hr at 204°C (400°F)) % Weight Loss	4.0 Maximum	2.2
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX		
COLOR		
HIGH TEMPERATURE PERFORMANCE Bearing Life, Hr at 232°C (450°F)	500 Minimum	> 500

NOTE: For a description and recommended usage of this wide temperature range bearing grease, see Section II.

In addition to the products listed, other greases which meet the requirements of this specification are:

Product	Manufacturer
Royco 13E	Royal Lubricants Company, Inc.
Aeroshell Grease 15A	Shell Oil Company

This specification supersedes MIL-G-27343A (ASG), "Grease, Ball and Roller Bearing, for Temperature Ranging from -73°C to +204°C (-100°F to +400°F)."

a/ Amoco Oil Company.

MILITARY SPECIFICATION: MIL-G-25537C
GREASE, AIRCRAFT: HELICOPTER OSCILLATORY BEARING

PROPERTIES	SPEC. REQ.	AEROSHELL[a/] GREASE 14	ROYCO[b/] 37A
COMPOSITION Base Oil	-	Mineral	-
Additives			
Rust Inhibitor			
EP (extreme pressure)			
Thickener (gelling agent)	-	Calcium Soap	-
Solids			
Antioxidant			Yes
Other			Wear
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 99°C (210°F)	-	3.1	
APPARENT VISCOSITY, 10^{-1} N Sec/m^2 (poises) at			
-54°C (-65°F) and Shear Rate of 25 sec^{-1}	15,000 Maximum	-	10,000
-54°C (-65°F) and Shear Rate of 100 sec^{-1}	7,000 Maximum	-	5,000
VISCOSITY INDEX, Base Oil			
DROPPING POINT	140°C (284°F) Minimum	149°C (300°F)	143°C (290°F)
PENETRATION			
Unworked at 25°C (77°F)	200 to 305	272	290
Worked at 25°C (77°F)	265 to 305	278	295
Worked 10^5 Cycles at 25°C (77°F)	265 to 375	-	300
SPECIFIC GRAVITY, 16°C (60°F)			
USABLE TEMPERATURE RANGE	-	-54°C (-65°F) to 121°C (250°F)	-54°C (-65°F) to 93°C (200°F)
LOW TEMPERATURE TORQUE, -55°C (-67°F)			
Starting, NM max. (g cm)	1.47 (15,000)	-	-
Running (1 hr), NM max. (g cm)	0.196 (2,000)	-	-
WATER STABILITY			
Worked in Water 10^5 Cycles			
Work Penetration Change	70 Maximum	-	Passes
OIL SEPARATION, % Weight Loss 30 Hr at 100°C (212°F)	5.0 Maximum	2.0	< 5.0
BOMB OXIDATION STABILITY			
Pressure Drop, N/m^2 (psi)			
400 Hr at 99°C (210°F)	34,480 (5.0) Maximum	62,055 (9)	6,895 (1.0)
STORAGE STABILITY, 6 Months at 38°C (100°F)			
Unworked Penetration	200 to 305	Passes	Stable
Worked Penetration	265 to 305	Passes	Stable
CORROSION ON COPPER 24 Hr at 100°C (212°F) (no pitting or etching)	Pass	Passes	None
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity			
RUST PREVENTIVE PROPERTIES, Spots on Bearing After 2 Weeks at 25°C (77°F) and 100% Relative Humidity	3 Maximum	Passes	None

MILITARY SPECIFICATION: MIL-G-25537C
GREASE, AIRCRAFT: HELICOPTER OSCILLATORY BEARING

PROPERTIES	SPEC. REQ.	AEROSHELL[a/] GREASE 14	ROYCO[b/] 37A
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)			
EVAPORATION at 22 Hr at 100°C (212°F) % Weight Loss	7.0 Maximum	6.8	5.0
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX			
COLOR	-	Tan	Light Brown
ODOR, Nonobjectionable, No Rancidity, Perfume or Alcohol	Pass	Passes	Passes
DIRT CONTENT: Particle Count Per 10^{-6} m^3 (cm^3)			
25×10^{-6} m (microns) or Larger	5,000 Maximum	-	950
75×10^{-6} m (microns) or Larger	1,000 Maximum	-	10
125×10^{-6} m (microns) or Larger	None, Maximum	-	0
OSCILLATING BEARING TEST Life, Hr	250 Min	Passes	> 250
USEFUL SPEED RANGE	-	Slow to Medium	Slow to Medium

NOTE: For a description and recommended usage of this bearing grease, having good low temperature and shear resistance properties, see Section II.

a/ Shell Oil Company
b/ Royal Lubricants Comapny, Inc.

In addition to greases listed, another grease which meets the requirements of this specification is:

Product	Manufacturer
Code 82002	Southwest Petro-Chem., Inc. (Div. of Witco Chemical Corp.)

MILITARY SPECIFICATION: MIL-G-27617D
GREASE, AIRCRAFT AND INSTRUMENT, FUEL AND OXIDIZER RESISTANT

PROPERTIES	SPEC. REQ.	Braycote 804, Type I[a]/	KRYTOX[b]/ GREASE 240 AC, Type III
COMPOSITION Base Oil	-	Perfluoroalkyl Polyether	Perfluoroalkyl Polyether
Additives			
Rust Inhibitor			-
EP (extreme pressure)			-
Thickener	-		Vydax 1000
Solids			-
Antioxidant			-
Other			-
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at			
38°C (100°F)	-		270
99°C (210°F)	-		30
APPARENT VISCOSITY, 10^{-1} N sec/m^2 (poises) at			
-18°C (0°F) Shear Rate of 20 Sec^{-1}	-		4,410
Shear Rate of 100 Sec^{-1}	-		3,400
25°C (77°F) Shear Rate of 20 Sec^{-1}	-		432
Shear Rate of 100 Sec^{-1}	-		167
VISCOSITY INDEX, Base Oil			134
DROPPING POINT	-		> 232°C (450°F)
PENETRATION			
Unworked at 25°C (77°F)	300 Min	328 Min	274
Worked 10^5 Cycles at 25°C (77°F)	310 to 340	330	282 (after 60 strokes)
SPECIFIC GRAVITY, 16°C (60°F)	-		
DENSITY at 25°C (77°F) g/ml (lb/gal)			1.93 (16.1)
USABLE TEMPERATURE RANGE	-	-54°C (-65°F) to 149°C (300°F)	-34°C (-30°F) to 288°C (550°F)
LOW TEMPERATURE TORQUE, Nm (g cm)			
Ball Bearing at -62°C (-80°F) and	800 start		
-73°C (-100°F), Min.	300 run		
Starting	2800 start		Passes
Running	800 run		Passes
WATER RESISTANCE, % Weight Loss at 80°C (175°F)	-		1
RESISTANCE TO AQUEOUS SOLUTIONS Must Not Disintegrate or Dissolve After 1 Week at 21°C (70°F) in:			
(a) Distilled Water	Pass	Pass	Passes
(b) 50% Alcohol and Water	Pass	Pass	Passes
OIL SEPARATION, % Weight Loss			
30 Hr at 204°C (400°F), Type II	15.0 Maximum		11
Type III, IV	20.0 Maximum		
BOMB OXIDATION STABILITY, Type II Pressure Drop, Maximum (psi)			
100 Hr at 99°C (210°F)	5.0	-	0
EXTREME PRESSURE WELD, kg (Type IV)	700		
STORAGE STABILITY, 8 Months at 38°C (100°F), Type I			
Unworked Penetration	300 Minimum	Pass	-
Worked Penetration Change	± 30 Maximum		-
CORROSION, COPPER, all Types			
24 Hr at 100°C (212°F) (no pitting or etching)	2 b Max.	Pass	Passes
LIQUID OXYGEN IMPACT SENSITIVITY			
20 Impacts at 1100 mm, Type II	No Reaction	Pass	
EVAPORATION, % Weight Loss			
22 Hr at 149°C (300°F)	-	19.8	

MILITARY SPECIFICATION: MIL-G-2761D
GREASE, AIRCRAFT AND INSTRUMENT, FUEL AND OXIDIZER RESISTANT

PROPERTIES	SPEC. REQ.	Braycote 804, Type I[a/]	KRYTOX[b/] GREASE 240 AC, Type III
HUMIDITY TEST: 100 hr at 49°C (120°F) 100% Relative Humidity			
RUST PREVENTIVE PROPERTIES			
No Deposit or Corrosion on Steel After 1.0 Week at 100°C (212°F)	Pass		Passes
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)			
EVAPORATION, % Weight Loss			
22 Hr at 149°C (300°F), Type I	25.0 Max	19.8	-
22 Hr at 204°C (400°F), Type II	15.0 Max		2
22 Hr at 204°C (400°F), Type III	12.0 Max	-	8
22 Hr at 204°C (400°F), Type IV	5.0 Max	-	
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels	-	-	No Reaction
LOX	No Reaction	Pass	Passes
COLOR	-		White
NLGI NUMBER	-	1	2
HIGH TEMPERATURE PERFORMANCE			
Ball Bearing Life, Hr at 204°C (400°F) 5 lb load, Types II, III & IV	500 Min		> 500
EFFECT OF FUELS			
Solubility % Weight Loss After 1/2 Hr in Shaker	20 Maximum		Passes
Resistance, 8 Hr at 21°C (70°F) (No visible effect (swelling, blistering or cracking)), Types II, III & IV	Pass		Passes
WEAR AND LOAD CARRYING CAPACITY, Type IV			
Four-Ball Wear Tests			
Wear Scar, 10^{-3} m (mm) After 2 Hr at 75°C (167°F),	1.0	0.280	-
and at 204°C (400°F), 1,200 rpm and 98 N (10kg) Load	1.3	-	
Falex EP Test, Jaw Load, N (lb)	-		-
Mean Hertz Load, N (kg)	-		> 589 (60)
DIELECTRIC BREAKDOWN VOLTAGE (kv)	-	-	> 40

NOTE: For a description and recommended usage of this series of chemically inert fluorosilicone base greases, see Section II.

a/ Bray Products Division, Burmah-Castrol, Inc.
b/ E. I. du Pont de Nemours and Company.

In addition to the products listed others which meet the requirements of this specification are:

Product	Manufacturer
Type I Krytox 240 AZ II Krytox 240AB	Du Pont Company
Type I Tribolube 10A III Tribolube 10C II & III Tribolube 16	Aerospace Lubricants, Inc.
Type II Braycote 805 III Braycote 806	Bray Products Division, Burmah-Castrol, Inc.
Type III Fomblin Y-VAC-3	Montedison USA, Inc.

MILITARY SPECIFICATION: MIL-G-81322D
GREASE, AIRCRAFT, GENERAL PURPOSE, WIDE-TEMPERATURE RANGE

PROPERTIES	SPEC. REQ.	MOBILGREASE 28[a]/
COMPOSITION Base Oil		Synthetic
Additives		X
Rust Inhibitor		X
EP (extreme pressure)		X
Thickener		
Solids		X
Antioxidant		
Other		
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C (100°F)		
VISCOSITY INDEX, Base Oil		
DROPPING POINT	232°C (450°F) Minimum	> 260°C (> 500°F)
PENETRATION		
Worked at 25°C (77°F)	265 to 320	315
Worked 10^5 Cycles	350 Maximum	337
SPECIFIC GRAVITY, 16°C (60°F)		
USABLE TEMPERATURE RANGE	-54°C (-65°F) to 177°C (350°F)	
LOW TEMPERATURE TORQUE, Nm (g cm) at -54°C (-65°F)		
Starting	0.981 (10,000) Maximum	0.422 (4,305)
Running	0.0981 (1,000) Maximum	0.0564 (575)
WATER RESISTANCE, Bearing Washout 1.0 Hr at 41°C (105°F), % Weight Loss	20.0 Maximum	3.1
OIL SEPARATION, % Weight Loss 30 Hr at 100°C (212°F)	10.0 Maximum	4.2
BOMB OXIDATION STABILITY		
Pressure Drop, N/m^2 (psi)		
100 Hr at 99°C (210°F)	83,000 (12.0) Maximum	
500 Hr at 99°C (210°F)	172,000 (25.0) Maximum	124,100 (18.0)
STORAGE STABILITY, 6 Months at 38°C (100°F)		
Unworked Penetration	200 Minimum	300
Worked Penetration Change	± 30 Maximum	325
Separation of Crystalline Material	None	
CORROSION, COPPER 24 Hr at 100°C (212°F) No Green Color Pitting or Etching	Pass	Passes
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity		
RUST PREVENTIVE PROPERTIES, Bearing Test for 14 Days at 25°C (77°F) and 100% Relative Humidity; 3 Small Spots Maximum ASTM Rating, Maximum	2	Passes
NEUTRALIZATION Number , Maximum 10^{-3} kg KOH/kg (mg KOH/g)		
EVAPORATION, % Weight Loss 22 Hr at 177°C (350°F)	12.0 Maximum	7
DIRT CONTENT. Particle Count per 10^{-6} m^3 (cm^3)		
25 x 10^{-6} (micron) or Larger	1,000	
75 x 10^{-6} (micron) or Larger	None	

MILITARY SPECIFICATION: MIL-G-81322D
GREASE, AIRCRAFT, GENERAL PURPOSE, WIDE-TEMPERATURE RANGE

PROPERTIES	SPEC. REQ.	MOBILGREASE 28[a/]
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuel		
LOX		
COLOR		
ODOR, No Objectionable Odors	Pass	Passes
HIGH TEMPERATURE BEARING TEST		
Hr Life at 177°C (350°F)	400 Minimum	> 500
GEAR WEAR, mg/10^3 Cycles, Max.		
2.27 kg (5 lb) Load	2.5	
4.54 kg (10 lb) Load	3.5	
OSCILLATION		
Friction & Wear, 35 K Cycles		
Wear Scar Width, mm (in) Maximum	6.35 (0.25)	
Friction Oxidation, 200 Hr, Maximum Drag, lbs	60	
STEEL ON STEEL WEAR		
Four-Ball Wear Test 2 Hr at 75°C (167°F), 1,200 rpm and 392 N (40 kg) Load Avg Scar Dia. 10^{-3} m (mm)	1.3 Maximum	0.63
LOAD CAPACITY		
Mean Hertz Load, N (kg)	294 (30.0) Minimum	304 (31.0)
RUBBER SWELL, % Vol		
1.0 Week at 70°C (158°F)		
"L" Synthetic Rubber	10 Maximum	8

NOTE: For a description and recommended usage of this general purpose, aircraft grease, see Section II.

a/ Mobil Oil Corporation.

Products listed below meet the requirements of this specification.

Product	Manufacturer
Royco 22C	Royal Lubricants Company, Inc.
GN 22	NYCO International, Inc.
Aeroshell 22C	Shell Oil Company

MILITARY SPECIFICATION: MIL-G-81827A
GREASE, AIRCRAFT, HIGH LOAD CAPACITY, WIDE TEMPERATURE RANGE

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	
Additives	
Rust Inhibitor	
EP (extreme pressure)	
Thickener	
Solids	
Antioxidant	
Other	
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C (100°F)	
VISCOSITY INDEX, Base Oil	
DROPPING POINT	232°C (450°F) Minimum
PENETRATION	
Worked at 25°C (77°F)	265 to 320
Worked 10^5 Cycles	350 Maximum
SPECIFIC GRAVITY, 16°C (60°F)	
USABLE TEMPERATURE RANGE	-54°C (-65°F) to 177°C (350°F)
LOW TEMPERATURE TORQUE, Nm (g cm) at -54°C (-65°F)	
Starting	0.981 (10,000) Maximum
Running	0.0981 (1,000) Maximum
WATER RESISTANCE, Bearing Washout 1.0 Hr at 41°C (105°F), % Weight Loss	20.0 Maximum
OIL SEPARATION, % Weight Loss 30 Hr at 177°C (350°F)	10.0 Maximum
BOMB OXIDATION STABILITY	
Pressure Drop, N/m^2 (psi)	
100 Hr at 99°C (210°F)	
500 Hr at 99°C (210°F)	172,400 (25.0) Maximum
STORAGE STABILITY, 6 Months at 38°C (100°F)	
Unworked Penetration	200 Minimum
Worked Penetration Change	± 30 Maximum
Separation of Crystalline Material	None
CORROSION, COPPER	
24 Hr at 177°C (350°F)	1b
No Green Color Pitting or Etching	
HUMIDITY TEST: 100 hr at 49°C (120°F) 100% Relative Humidity	
RUST PREVENTIVE PROPERTIES, Bearing Test for 14 Days at 25°C (77°F) and 100% Relative Humidity; 3 Small Spots Maximum	ASTM 2
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	
EVAPORATION, % Weight Loss 22 Hr at 177°C (350°F)	12.0 Maximum

MILITARY SPECIFICATION: MIL G-81827A
GREASE, AIRCRAFT, HIGH LOAD CAPACITY, WIDE TEMPERATURE RANGE

PROPERTIES	SPEC. REQ.
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuel LOX	
COLOR	
ODOR, No Objectionable Odors	Pass
HIGH TEMPERATURE BEARING TEST Hr Life at 177°C (350°F)	400 Minimum
STEEL ON STEEL WEAR Four-Ball Wear Test 2 Hr at 75°C (167°F),1 1,200 rpm and 392 N (40 kg) Load Avg Scar Dia. 10^{-3} m (mm)	
EXTREME PRESSURE PROPERTIES (load-wear index)	50
RUBBER SWELL, % Vol 1.0 Week at 70°C (158°F) "L" Synthetic rubber	10
GEAR WEAR, 10^{-6} kg/10^3 Cycles (mg/10^3 cycles) at	
22.24 N (5 lb) Load	2.5 Maximum
44.48 N (10 lb) Load	3.5 Maximum
MOLYBDENUM DISULFIDE CONTENT, %	4.5 to 5.5
SALT SPRAY (galvanic corrosion), 48 Hr	Pass
BOILING WATER IMMERSION, 10 Minutes	Pass
OSCILLATION Friction & Wear, 35 K Cycles, Wear Scar Width, mm (in)	6.35 (0.25) Maximum
Friction Oxidation, 200 Hr, Drag, lbs	60 Maximum

NOTE: For a description and recommended usage of this general purpose, aircraft grease, see Section II.

Products listed below meet the requirements of this specification.

Product	Manufacturer
Royco 22 MS	Royal Lubricants Company, Inc.
Mobilgrease 29	Mobil Oil Corporation
Aeroshell 23C	Shell Oil Company

SYNTHETIC GREASE, ROCKET PROPELLANT COMPATIBLE
PERFLUOROALKYLPOLYETHER BASE FLUID, TETRAFLUOROETHYLENE TELOMER THICKENER

PROPERTIES	BRAYCOTE[a/] 631A
COMPOSITION Base Oil	Perfluoroalkylpolyether
Additives	
Rust Inhibitor	
EP (extreme pressure)	
Thickener (gelling agent)	Tetrafluoroethylene Telomer
Solids	
Antioxidant	
Other	
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C (100°F)	
VISCOSITY INDEX, Base Oil	
DROPPING POINT	260°C (500°F)
PENETRATION	
Worked at 25°C (77°F)	295
Worked at 10^5 Cycles	310
DENSITY, 16°C (60°F), kg/10^{-3} m^3 (g/ml)	1.9
USABLE TEMPERATURE RANGE	-34°C (-30°F) to 204°C (400°F)
LOW TEMPERATURE TORQUE	
WATER RESISTANCE, % Weight Loss, 1 Hr at 79°C (175°F)	1.0
OIL SEPARATION, % Weight Loss 30 Hr at 100°C (212°F)	0.03
BOMB OXIDATION STABILITY, Pressure Drop, Maximum	
100 Hr at 99°C (210°F)	0
500 Hr at 99°C (210°F)	0
STORAGE STABILITY, 6 Months at 38°C (100°F)	
Unworked Penetration	
Worked Penetration	
CORROSION, COPPER (bomb), 24 Hr at 99°C (210°F)	
Discoloration of Grease	None
Discoloration of Copper	None
Pressure Drop	0
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity	
RUST PREVENTIVE PROPERTIES	
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	
EVAPORATION, % Weight Loss (216 hr at 204°C (400°F))	1.45
CONTACT COMPATIBILITY	
Most Elastomers	Passes
Aluminum (fresh cut)	Passes
DIRT CONTENT, Particle Count Per 10^{-6} m^3 (cm^3)	
25 x 10^{-6} (microns) or Larger	1,000 Maximum
75 x 10^{-6} (microns) or Larger	None

SYNTHETIC GREASE, ROCKET PROPELLANT COMPATIBLE
PERFLUOROALKYLPOLYETHER BASE FLUID, TETRAFLUOROETHYLENE TELOMER THICKENER

PROPERTIES	BRAYCOTE[a/] 631A
IMPACT COMPATIBILITY (ABMA Tester)	
LOX	Passes
Nitrogen Tetroxide, N_2O_4	Passes
COLOR	Translucent White
STATIC SERVICE TEST	
Liquid Oxygen	Passes
Nitrogen Tetroxide	Passes
50:50 Blend, Hydrazine and Monomethyl Hydrozine	Passes
IMMERSION IN FUELS AND OXIDIZERS	
72 Hr at 25°C (77°F) (change in appearance)	
Ethanol (etoh); Jet Fuel (JP-4); Aniline	None
Diethylenetriamine (deta); 60:40 UDMH: Deta	None
50:50 VDMH; N_2H_4; Hydrogen Peroxide, 90 degrees, H_2O_2	None
Inhibited Red Fuming Nitric Acid (IRENA)	None
Nitrogen Tetroxide (N_2O_4)	None
WEAR TESTS: Shell Four-Ball	
Scar Diameter, 10^{-3} m (mm)	
1 Hr at 600 rpm, 75°C (167°F)	
98.1 N (10 kg)	0.24
372.4 N (40 kg)	0.55
EXTREME PRESSURE	
Shell Four-Ball, Weld Load N (kg)	3,385 (345)

a/ Bray Products Division, Burmah-Castrol, Inc.

LOW VAPOR PRESSURE SYNTHETIC GREASES
"APIEZON" HIGH VACUUM GREASE (James G. Biddle Company)

PROPERTIES	GREASE AP 100	GREASE AP 101	GREASE H	GREASE L	GREASE M	GREASE N	GREASE T
COMPOSITION Base Oil			Pure Hydrocarbon				
Additives							
Rust Inhibitor							
EP (extreme pressure)							
Thickener			X			X	X
Solids			X				X
Antioxidant	Anti-seize	Anti-Seize					
Other							
VISCOSITY, Molten Grease 10^{-3} N Sec/m^2 (cP) at							
50°C (122°F)	-	-	-	0.766 (766)	0.413 (413)	-	-
100°C (212°F)	-	-	-	0.0623 (62.3)	0.0298 (29.8)	-	-
VISCOSITY INDEX, Base Oil							
APPROXIMATE MELTING POINT	47°C (117°F)	a	a	47°C (117°F)	44°C (111°F)	43°C (109°F)	125°C (257°F)
PENETRATION							
Unworked							
Worked							
SPECIFIC GRAVITY at							
20°C/15.5°C (68°F/60°F)	1.042	0.981	-	0.896	0.884	0.911	0.912
30°C/15.5°C (86°F/60°F)	1.036	0.974	-	0.889	0.887	0.904	0.905
AVERAGE MOLECULAR WEIGHT	-	-	-	1,300	950	-	-
USABLE TEMPERATURE RANGE							
°C	10 to 30	-40 to 80	-10 to 240	10 to 30	10 to 30	10 to 30	0 to 120
(°F)	(50 to 86)	(-40 to 292)	(14 to 464)	(50 to 86)	(50 to 86)	(50 to 86)	(32 to 248)
LOW TEMPERATURE TORQUE							
WATER RESISTANCE							
OIL SEPARATION, % Weight Loss Maximum							
30 Hr at 100°C (212°F)							
BOMB OXIDATION STABILITY							
Pressure Drop, Maximum							
100 Hr at 99°C (210°F)							
500 Hr at 99°C (210°F)							
STORAGE STABILITY, 6 Months at 38°C (100°F)							
Unworked Penetration							
Worked Penetration							
CORROSION, COPPER STRIP							
24 Hr at 100°C (212°F)							
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity							
RUST PREVENTIVE PROPERTIES							
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)							

LOW VAPOR PRESSURE SYNTHETIC GREASES
"APIEZON" HIGH VACUUM GREASE (James G. Biddle Company)

PROPERTIES	GREASE AP 100	GREASE AP 101	GREASE H	GREASE L	GREASE M	GREASE N	GREASE T
VAPOR PRESSURE, N/m^2 (torr) at 20°C (68°F)	1.07×10^{-8} (8×10^{-11})	6.67×10^{-4} (5×10^{-6})	1.33×10^{-7} (1×10^{-9})	1.07×10^{-8} to 8×10^{-11}	2.67×10^{-7} to 2×10^{-9}	1.07×10^{-7} to 8×10^{-10}	6.67×10^{-7} 5×10^{-9}
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX							
COLOR							
COEFFICIENT OF EXPANSION Over 20°C to 30°C (68°F to 86°F) Per °C	0.00062	0.00066		0.00076	0.00075	0.00072	0.00073
°F	0.00034	0.00037		0.00042	0.00042	0.00040	0.00041
THERMAL CONDUCTIVITY Btu in/ft² Hr, °F			1.50	1.40	1.33	1.31	1.22
w/m, °C			0.216	0.202	0.192	0.189	0.176
SPECIFIC HEAT at 25°C (77°F), cal/g			0.42	b/	b/	b/	b/
Joule/g			1.7	b/	b/	b/	b/
LATENT HEAT OF FUSION cal/g				15.1	18.7	15.0	
Fusion Peak, °C (°F)				32 (90)	34 (93)	31 (88)	
VOLUME RESISTIVITY, ohm cm				1.2×10^{16}	2.6×10^{16}	2.0×10^{16}	3.3×10^{12}
PERMITIVITY				2.3	2.1	2.3	2.3
LOSS TANGENT					< 0.0001		
SURFACE BREAKDOWN, kv at Flashover				24	28	27	24
ELECTRIC STRENGTH, v/mil				730	850	820	730

NOTE: 1. These low vapor pressure greases are used largely as vacuum greases, but because of their high purity they are also excellent laboratory greases. Most "Apiezon" greases are expensive but Grease M is competitive with the best general purpose laboratory lubricants and is a general purpose grease with excellent lubricating properties as well as a high vacuum grease.
2. These greases are also used with the liquid medium in gas-liquid chromatography.

a/ Greases AP 101 and H do not melt at high temperatures and consequently many of the above physical properties cannot readily be measured.

b/ Specific heats of Greases L, M, N, and T cannot be measured as their fusion peaks are too close to room temperature.

HYDROCARBON SYNTHETIC GREASES
HALOCARBON PRODUCTS CORPORATION

PROPERTIES	STANDARD STOPCOCK GREASE	HIGH-TEMP. STOPCOCK GREASE	25-10	25-10M	25-10MS	25-20M
COMPOSITION Base Oil	Halocarbon Oil					
Additives						
Rust Inhibitor	-	-	-	-	Yes	-
EP(extreme pressure)						
Thickener						
Solids						
Antioxidant						
Other	Polychlorotrifluoroethylene Wax					
GREASE MILLED	-	-	-	Yes	Yes	Yes
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C (100°F)						
VISCOSITY INDEX, Base Oil						
DROPPING POINT, Minimum	149°C (300°F)	149°C (300°F)	149°C (300°F)	149°C (300°F)	149°C (300°F)	160°C (320°F)
PENETRATION (ASTM-D217)						
Unworked	210	235	170	300	230	145
Worked	350	340	290	310	280	200
SPECIFIC GRAVITY, 16°C (60°F)						
USABLE TEMPERATURE RANGE	16°C (60°F) to 60°C (140°F)	29°C (85°F) to 104°C (220°F)	1°C (30°F) to 135°C (275°F)	1°C (30°F) to 135°C (275°F)	1°C (30°F) to 121°C (250°F)	1°C (30°F) to 149°C (300°F)
LOW TEMPERATURE TORQUE						
WATER RESISTANCE						
OIL SEPARATION, % Weight Loss, Maximum 30 Hr at 100°C (212°F)						
BOMB OXIDATION STABILITY, Pressure Drop, Maximum						
100 hr at 99°C (210°F)						
500 Hr at 99°C (210°F)						
STORAGE STABILITY, 6 Months at 38°C (100°F)						
Unworked Penetration						
Worked Penetration						
CORROSION, COPPER STRIP 24 Hr at 100°C (212°F)						
HUMIDITY TEST: 100 hr at 49°C (120°F), 100% Relative Humidity						
RUST PREVENTIVE PROPERTIES						

HYDROCARBON SYNTHETIC GREASES
HALOCARBON PRODUCTS CORPORATION

PROPERTIES	STANDARD STOPCOCK GREASE	HIGH-TEMP. STOPCOCK GREASE	25-10	25-10M	25-10MS	25-20M
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)						
EVAPORATION, % Maximum 22 Hr at 99°C (210°F)						
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX						
COLOR	White	White	White	White	Brown	White
FLUID RANGE °C (°F)	149-260 (300-500)	149-260 (300-500)	149-260 (300-500)	149-260 (300-500)	149-260 (300-500)	160-260 (320-500)
MEAN HERTZ LOAD, N (kg)	-	-	1,024 (104.4)	1,024 (104.4)	-	1,045 (106.6)

NOTE: 1. Halocarbon greases are noncorrosive toward metals at temperatures up to 177°C (350°F), except for copper and some of its alloys which discolor at 49°C (120°F). These greases are not recommended for aluminum applications where localized temperatures and stresses of minute seizure may result in detonation.

2. Halocarbon greases may be used with most elastomers and solvent-resistant plastics at room temperatures. For elevated temperatures, it is recommended that tests be conducted at anticipated temperatures and pressures.

3. These greases are chemically inert, have light thermal stability, good lubricity, high dielectric strength and density.

POLYCHLOROTRIFLUOROETHYLENE AND SILICA GEL GREASES
HALOCARBON PRODUCTS CORPORATION

PROPERTIES	25-20M-SA	X90-10M	X90-15M	25-5S	11B3
COMPOSITION Base Oil	Halocarbon Oil				
Additives					
Rust Inhibitor	Yes	-	-	-	-
EP (extreme pressure)					
Thickener	Polychlorotrifluoroethylene Wax			Silica Gel	Silica Gel
Solids					
Antioxidant					
Other					
GREASE MILLED	Yes	Yes	Yes	-	-
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C					
VISCOSITY INDEX, Base Oil					
DROPPING POINT	149°C (300°F)	149°C (300°F)	146°C (295°F)	None	None
PENETRATION					
Unworked	170	280	265	230	230
Worked	235	330	310	230	230
SPECIFIC GRAVITY, 16°C (60°F)					
USABLE TEMPERATURE RANGE	1°C (30°F) to 121°C (250°F)	-40°C (-40°F) to 73°C (200°F)	-40°C (-40°F) to 93°C (200°F)	-18°C (0°F) to 177°C (350°F)	-40°C (-40°F) to 93°C (200°F)
LOW TEMPERATURE TORQUE					
WATER RESISTANCE					
OIL SEPARATION, % Weight Loss Maximum 30 Hr at 100°C (212°F)					
BOMB OXIDATION STABILITY					
Pressure Drop, Maximum					
100 Hr at 99°C (210°F)					
500 Hr at 99°C (210°F)					
STORAGE STABILITY, 6 Months at 38°C (100°F)					
Unworked Penetration					
Worked Penetration					
CORROSION, COPPER STRIP 24 Hr at 100°C (212°F)					
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity					
RUST PREVENTIVE PROPERTIES					
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)					
EVAPORATION, % Maximum (22 Hr at 99°C (210°F))					

POLYCHLOROTRIFLUOROETHYLENE AND SILICA GEL GREASES
HALOCARBON PRODUCTS CORPORATION

PROPERTIES	25-20M-SA	X90-10M	X90-15M	25-5S	11B3
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels LOX					
COLOR	Brown	White	White	White	White
FLUID RANGE					
°C	160-260	149 to 260	149 to 260	None	None
(°F)	(320-500)	(300 to 500)	(300 to 500)	None	None
MEAN HERTZ LOAD, N (kg)	-	-	926 (94.4)	981 (100.0)	953 (97.2)

NOTE: 1. Halocarbon greases are noncorrosive toward metals at temperatures up to 177°C (350°F), except for copper and some of its alloys which discolor at 49°C (120°F). These greases are not recommended for aluminum applications where localized temperatures and stresses of minute seizure may result in detonation.

2. Halocarbon greases may be used with most elastomers and solvent-resistant plastics at room temperatures. For elevated temperatures it is recommended that tests be conducted at anticipated temperatures and pressures.

3. These greases are chemically inert, have light thermal stability, good lubricity, high dielectric strength and density.

HIGH TEMPERATURE, HIGH VACUUM GREASES
OXIDIZER AND FUEL RESISTANT (Bray Products Division, Burmah-Castrol, Inc.)

PROPERTIES	MICRONIC® 803
COMPOSITION Base Oil	Perfluoroalkyl Polyether (high molecular weight)
Additives	
Rust Inhibitor	
EP (extreme pressure)	
Thickener	Tetrafluoroethylene Telomen
Solids	
Antioxidant	
Other	
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C (100°F)	-
VISCOSITY INDEX, Base Oil	
DROPPING POINT	192°C (377°F)
FLASH POINT	None
FIRE POINT	None
AUTOIGNITION TEMPERATURE	None
PENETRATION at 25°C (77°F)	
Unworked	290
Worked	290
SPECIFIC GRAVITY, 16°C (60°F)	1.92
USABLE TEMPERATURE RANGE	
Air	-23°C (-10°F) to 260°C (500°F)
Inert Atmospheres	-23°C (-10°F) to 300°C (680°F)
LOW TEMPERATURE TORQUE	
SOLUBILITY AND WASH-OUT RESISTANCE	Insoluble in Most Fluids; Soluble Only in Highly Fluorinated Liquids
OIL SEPARATION, % Weight Loss 30 Hr at 204°C (400°F)	9.3
BOMB OXIDATION STABILITY	
Pressure Drop, Maximum	
100 Hr at 99°C (210°F)	
500 Hr at 99°C (210°F)	
STORAGE STABILITY, 6 Months at 38°C (100°F)	
Unworked Penetration	
Worked Penetration	
CORROSION, COPPER STRIP 24 Hr at 100°C (212°F)	
HUMIDITY TEST: 100 Hr at 49°C (120°F), 100% Relative Humidity	
RUST PREVENTIVE PROPERTIES	
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	
EVAPORATION, % Weight Loss 22 Hr at 240°C (400°F)	0.2 to 1.8

HIGH TEMPERATURE, HIGH VACUUM GREASES
OXIDIZER AND FUEL RESISTANT (Bray Products Division, Burmah-Castrol, Inc.)

PROPERTIES	MICRONIC® 803
OXIDIZER RESISTANCE	
Impact Test: MSFC-Spec.-101	Resistance to All Oxidizers
MSFC Spec.-106B	Passes
FUEL AND REDUCER RESISTANCE	No Reactions
COLOR	White Transparent
FLASH POINT, COC	Nonflammable
FIRE POINT, COC	Nonflammable
VACUUM PROPERTIES	Excellent
VACUUM, % Weight Loss	
46 Hr at 121°C (250°F) and 1.33×10^{-5} N/m^2 (10^{-7} torr)	Nil
LUBRICATING ABILITY	Excellent EP Properties
WEAR PREVENTION	
Four-Ball Test, 8 Hr at 60°C (140°F) and 600 rpm, Scar Diameter, mm; Load - Maximum Hertz Stress	
1.214×10^9 N/m^2 (176,000 psi)	0.398
3.654×10^9 N/m^2 (530,000 psi)	1.199
VAPOR PRESSURE at	
71°C (160°F)	2.6×10^{-9}
91°C (195°F)	1.6×10^{-8}
108°C (227°F)	5.2×10^{-8}
127°C (260°F)	1.3×10^{-7}

LOW VOLATILITY SYNTHETIC GREASE
FOR AIR, VACUUM AND SPACE APPLICATIONS (Ball Aerospace Systems Division)

PROPERTIES	VAC KOTE 37987	VAC KOTE 37963C	VAC KOTE 44147	VAC KOTE 44177
COMPOSITION Base Oil	Synthetic	Synthetic	Synthetic	Hydrocarbon
Additives				
Rust Inhibitor	yes	Yes	Yes	Yes
EP (extreme pressure)	Yes	No	Yes	Yes
Thickener	Nonmelting	Nonmelting	Nonmelting	Nonmelting
Solids				
Antioxidant	Yes	No	Yes	Yes
Other				
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C (100°F)				
VISCOSITY INDEX, Base Oil				
DROPPING POINT	204°C (> 400°F)	204°C (> 400°F)	250°C (> 482°F)	175°C (> 350°F)
PENETRATION Worked at 24°C (77°F)	320	260	260	280
SPECIFIC GRAVITY, 16°C (60°F)				
USABLE TEMPERATURE RANGE	-62°C (-80°F) to 121°C (250°F)	-73°C (-100°F) to 200°C (400°F)	-62°C (-80°F) to 150°C (300°F)	-206°C (-4°F) to 100°C (212°F)
LOW TEMPERATURE TORQUE				
WATER RESISTANCE	Good	Excellent	Good	
OIL SEPARATION, % Weight Loss Maximum 670 Hr at 70°C (158°F)	1.0	1.6	0.1	2.6
OXIDATION RESISTANCE	Good	Excellent	Good	Good
STORAGE STABILITY	Good	Good	Good	Good
CORROSION, COPPER STRIP 24 Hr at 100°C (212°F)	Not Run			
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity	No Change	No Change	No Change	
RUST PREVENTIVE PROPERTIES	Good	Excellent	Excellent	Good
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g) Total Acid No. ASTM D-974	2.8	0.2	1.7	2.0
EVAPORATION, % Maximum (22 Hr at 99°C (210°F) test equivalent to high vacuum at 150°C for 4 hr)	0.35	0.5	0.15	2.0
COMPATIBILITY WITH:				
Rubber, Neoprene, Plastics	Some	Yes	Some	Yes
Paints, Lacquer, Solvents	Yes	Yes	Yes	Yes
Jet Fuel and Gasoline	Yes	No	Yes	Yes
Rocket Fuel	No	No	No	No
LOX	No	Yes	No	No
COLOR	White	Off-White	Off-White	Brown/Black

LOW VOLATILITY SYNTHETIC GREASE
FOR AIR, VACUUM AND SPACE APPLICATIONS (Ball Aerospace Systems Division)

PROPERTIES	VAC KOTE 37987	VAC KOTE 37963C	VAC KOTE 44147	VAC KOTE 44177
VACUUM PROPERTIES	Excellent	Excellent	Excellent	Good
WEAR RESISTANCE (EP)	Excellent	Good	Excellent	Good
SHELL FOUR-BALL WEAR TEST at 70°C (150°F), 600 rpm and 98.07 N (10 kg); Average Scar Dia., mm	0.244	0.344	0.288	0.440
CHANNELING	No	Yes	Yes	No

NOTE: 37987 is a smooth grease for use near optics. 37963C provides high temperature lubrication with corrosion protection. 44147 is excellent for ultra-high speed applications with good wear prevention. 44177 is designed primarily for high sliding contacts such as gears. Has good adhesion to metal surfaces.

HIGH TEMPERATURE SYNTHETIC GREASES
KRYTOX FLUORINATED GREASES (E. I. du Pont de Nemours and Company)

PROPERTIES	KRYTOX® 250AC	KRYTOX® 260AC	KRYTOX® 280AC
COMPOSITION Base Oil	KRYTOX 143AC (perfluoroalkyl-polyethers)	KRYTOX 143AC (perfluoroalkyl-polyethers)	KRYTOX 143AC (perfluoroalkyl-polyethers)
Additives			
Rust Inhibitor		Yes	Yes
EP (extreme pressure)			
Thickener	VYDAX 1000 (tetrafluoro-ethylene telomer)	VYDAX 1000 (tetrafluoro-ethylene telomer)	VYDAX 1000 (tetrafluoro-ethylene)
Solids	MoS_2 (5 wt %)	MoS_2 (5 wt %)	
Antioxidant			
Other			
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C (100°F)	270	270	270
APPARENT VISCOSITY, 10^{-1} N Sec/m^2 (poises) at -18°C (0°F)			
Shear Rate of 20 Sec^{-1}	-	-	-
Shear Rate of 100 Sec^{-1}	-	-	-
at 25°C (77°F)			
Shear Rate of 20 Sec^{-1}	-	-	-
Shear Rate of 100 Sec^{-1}	-	-	-
VISCOSITY INDEX, Base Oil	134	134	134
DROPPING POINT	> 232°C (> 450°F)	> 232°C (> 450°F)	> 232°C (> 450°F)
PENETRATION			
Unworked at 25°C (77°F)	242	243	244
Worked at 25°C (77°F), 60 Strokes	249	250	253
SPECIFIC DENSITY, 16°C (60°F)			
DENSITY at 25°C (77°F), g/ml (lb/gal)	2.02 (16.85)	2.03 (16.9)	1.95 (16.3)
USABLE TEMPERATURE RANGE	-34°C (-30°F) to 288°C (550°F)	-34°C (-30°F) to 288°C (550°F)	-34°C (-30°F) to 288°C (550°F)
LOW TEMPERATURE TORQUE			
WATER RESISTANCE, % Weight Loss at 80°C (175°F)	1	1	1
OIL SEPARATION, % Weight Loss			
30 Hr at 99°C (210°F)	5	4	5
30 Hr at 204°C (400°F)	13	6	14
BOMB OXIDATION STABILITY Pressure Drop			
600 Hr at 99°C (210°F)	0.0	-	0.0
STORAGE STABILITY	Excellent	Excellent	Excellent
CORROSION, COPPER STRIP 24 Hr at 100°C (212°F)			
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity			
RUST PREVENTIVE PROPERTIES			

HIGH TEMPERATURE SYNTHETIC GREASES
KRYTOX FLUORINATED GREASES (E. I. du Pont de Nemours and Company)

PROPERTIES	KRYTOX® 250AC	KRYTOX® 260AC	KRYTOX® 280AC
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/mg)			
EVAPORATION, % Weight Loss			
22 Hr at 204°C (400°F)	-	-	-
22 Hr at 260°C (500°F)	-	-	-
COMPATIBILITY WITH: Rubber and			
Jet and Rocket Fuels	Yes	Yes	Yes
LOX, Impact Tests			
NASA MSFC Spec 106B	-	-	-
USAF Spec Bulletin 527	Passes	Passes	Passes
SwRI Reaction Intensity	-	-	-
COLOR	Black	Black	White
NLGI NUMBER	2	2	2
TEXTURE	Buttery	Buttery	Buttery
HIGH TEMPERATURE PERFORMANCE Ball Bearing Life, Hr at 204°C (400°F) and 20,000 rpm	-	-	-
LOAD CARRYING CAPACITY Mean Hertz Load, N (kg)	-	-	-
WEAR PREVENTION Shell 4-Ball Wear Tester 1 Hr, 392N (40 Kg) load Avg Wear Scar Dia., mm at			
75°C (167°F)	1.69	-	-
204°C (400°F)	1.13	-	-

NOTE: 1. KRYTOX® fluorinated greases are multipurpose lubricants with superior high temperature stability, chemical inertness and solvent resistance and usually good lubricity properties. They are ideal in many industrial applications where long service life is not possible with other available lubricants. KRYTOX® greases are extensively used to lubricate aircraft components, missiles, space vehicles, and attendant support equipment.

2. KRYTOX® greases are prepared by thickening KRYTOX® fluorinated oils with VYDAX® fluorotelomer solids. These greases have similar chemical and compatibility characteristics as the base oils from which they are made, see III-59, 71, and 72.

3. A 283 Series KRYTOX® grease is also available. They are the same as the 240 Series grease except the 283 Series has a higher concentration of rust inhibitor than the 280 Series.

4. The KRYTOX® 250 grease meets MIL-M-7866.

FEDERAL SPECIFICATION VV-P-236A (2)
PETROLATUM, TECHNICAL

PROPERTIES	SPEC. REQ.	BRAYCOTE[a/] 236	ROYCO[b/] 1R
COMPOSITION Base Oil			
Additives			
Rust Inhibitor			
EP (extreme pressure)			
Thickener			
Solids			
Antioxidant			
Other			
VISCOSITY 100°C (212°F), cs	11.6-18.0	13.1	70-95
VISCOSITY INDEX, Base Oil			
MELTING POINT	46°C to 60°C (115°F to 140°F)	54°C (130°F)	46°C to 60°C (115°F to 140°F)
FLASH POINT, COC	199°C (390°F) Min	216°C (421°F)	199°C (390°F)
PENETRATION Unworked, 10^{-4} m (0.1 mm)	150 to 275	183	150 to 275
SPECIFIC GRAVITY, 16°C (60°F)			
USABLE TEMPERATURE RANGE	-	Cool	Cool
CONSISTENCY	-	Soft	Soft
ABRASIVE MATERIAL	None	None	None
PRECIPITATION NUMBER	0.1 Max	0.0	< 0.1
ASH CONTENT, %	0.1 Max	0.03	< 0.1
STORAGE STABILITY			
CORROSION, COPPER STRIP 24 Hr at 100°C (212°F)	None	None	None
HUMIDITY TEST: 100 Hr at 49°C (120°F) 100% Relative Humidity			
RUST PREVENTIVE PROPERTIES			
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	0.1 Max	0.0	-
EVAPORATION, % Maximum (1 Hr at 107°C (225°F)	2.0	0.08	< 2.0
USABLE LOAD RANGE	-	Low	Low
COMPATIBILITY WITH:			
Rubber, Neoprene, Plastics			
Paints, Lacquer, Solvents			
Jet Fuel and Gasoline			
Rocket Fuel			
LOX			
COLOR, ASTM	2 to 8	2.0	Amber
TRANSLUCENT	-	Yes	Yes

a/ Bray Products Division, Burmah-Castrol, Inc.
b/ Royal Lubricants Company, Inc.
Notes: See Section II for description and recommended usage.

MILITARY SPECIFICATION: MIL-A-907D
ANTISEIZE COMPOUND, HIGH TEMPERATURE

PROPERTIES	SPEC. REQ.
MATERIAL	
Homogeneous Mixture, Free from Ingredients Corrosive to Ferrous Metals	Pass
STORAGE STABILITY	
Six Months, Remain Homogeneous with No Deterioration	Pass
GALLING AND ANTISEIZE PROPERTIES	
No Galling, with Average Torque for Removal of Nuts from Bolts Not to Exceed 210 lb-ft	Pass

NOTE: For a description and recommended usage of this antiseize compound, see Section II.

Products which meet the requirements of this specification are listed below.

Product	Manufacturer
DAG-243	Acheson Colloids Company
Led-Plate 250	Armite Laboratories
Never-Seez	Bostik, Div. of Emhart Corp.
Chesterton	A. W. Chesterton Co.
Thred-Gard	John Crane-Houdaille, Inc.
Fel-Pro C-661	Fel-Pro, Inc.
GC-76	General Compounds Co. (Div. of Kai R. Kuhl Co., Inc.)
Kopr-Kote	Jet-Lube, Inc.
Liqui Moly N.V. Thread Compound	The Lockrey Company, Inc.
Low-Viscosity Anti-Seize	Loctite Corp.
Compound #77	Micro-Metals Compounds Ltd.
Kopr-Shield	Thomas & Betts Co.

MILITARY SPECIFICATION: MIL-C-5545C
CORROSION PREVENTIVE, AIRCRAFT ENGINE, HEAVY OIL TYPE

PROPERTIES	SPEC. REQ.
TEMPERATURE STABILITY High 24 Hr @ 96°C (205°F) Low 4 Hr @ -18°C (0°F) Allowed to Stand 240 Hr, Separation of Insoluble Material	None
CARBON RESIDUE, % Loose and Flaky	3.0 maximum
VISCOSITY, 10^{-6} m^2/Sec (Cs) 99°C (210°F)	24-32
FLASH POINT, COC, Minimum	177°C (350°F)
CORROSION, COPPER STRIP 20 Hr at 100°C (212°F)	Pass
SULFATED RESIDUE, %	1.0 Maximum
VOLATILITY, % by Weight 24 Hr at 104°C (220°F)	3.0 Maximum
FOAM CHARACTERISTICS 10^{-6} m^3 (ml), Foam 5 Min Aerating 10 Min Settling	 25 None

NOTE: For a description and recommended usage of this corrosion preventive, see Section II.

Product listed below meets the requirements of this specification.

Product	Manufacturer
L-2196A	Franklin Oil Corporation

MILITARY SPECIFICATION: MIL-C-6529C(2)
CORROSION PREVENTIVE, AIRCRAFT ENGINE

PROPERTIES	SPEC. REQ.*	BRAYCOTE 581H TYPE I[a]/	BRAYCOTE 482H TYPE II[a]/	BRAYCOTE 483H TYPE III[a]/
STORAGE STABILITY, 12 Months at 25°C (77°F), Separation	None	-	-	-
HIGH AND LOW TEMPERATURE Stability, Separation	None	-	None	-
PROTECTION, Humidity Cabinet, 14 Days at 49°C (120°F), Polished Steel, Failures in 5 Panels	1 Max.	-	None	-
CARBON RESIDUE, % Loose and Flaky	2.0 Max.	-	0.47	-
POUR POINT, Maximum	-12°C (10°F)	-	-12°C (10°F)	-
VOLATILE CONTENT, % by Weight	3.0 Max.	-	0.1	-
VISCOSITY, SUS				
38°C (100°F)	-	1408	1207	95.6
99°C (210°F)	90 to 110	114	98	39.3
VISCOSITY INDEX	95 Min.	106	96	107
FLASH POINT, Minimum	204°C (400°F)	266°C (510°F)	266°C (510°F)	152°C (305°F)
PRECIPITATION NUMBER	0.1 Max.	-	0.0	0.0
CORROSION, COPPER STRIP 99°C (210°F) Pitting or Discoloration	2a	-	None	None
ASH, % Maximum	0.015	-	0.003	0.002
HYDROBROMIC ACID NEUTRALIZATION, Corrosion, Pitting, or Other Attack	< Control	-	None	None
EFFECT ON INDICATING SILICA JEL	Pass	-	Pass	Pass
LEAD CORROSION (SOD)				
121°C (250°F), mg/in^2 (mg/cm^2), Loss	40 (6.20) Max.	-	26 (4.03)	-
149°C (300°F), mg/in^2 (mg/cm^2), Loss	70 (10.85) Max.	-	55 (8.53)	-
DENSITY, 16°C (60°F) lbs/gal (gm/cm^3)	-	7.54 (0.904)	7.43 (0.890)	7.32 (0.877)
GRAVITY °API 16°C (60°F)	-	24.7	27.1	29.4

* Requirements established for Type II material only.

a/ Bray Products Division, Burmah-Castrol, Inc.

NOTE: For a description and recommended usage of this corrosion preventive, see Section II.

Products listed below meet the requirements of this specification.

Product		Manufacturer
Type I	NII HBC-20	Nyco International, Inc.
	Petrotect 6529C	Penreco, A Pennzoil Div.
	Royco 581	Royal Lubricants Co.
	Aeroshell Fluid 2XN	Shell Oil Co.
Type II	NII HBC-21	Nyco International, Inc.
	Petrotect 65292	Penreco, A Pennzoil Div.
	Royco 482	Royal Lubricants Co.
	Aeroshell Fluid 2F	Shell Oil Co.
Type III	NII HBC-22	Nyco International, Inc.
	Petrotect 65293	Penreco, A Pennzoil Div.
	Royco 483	Royal Lubricants Co.
	Shell Storage Oil 3	Shell Oil Co.

MILITARY SPECIFICATION: MIL-C-8188C
CORROSION-PREVENTIVE OIL, GAS TURBINE ENGINE, AIRCRAFT SYNTHETIC BASE

PROPERTIES	SPEC. REQ.
COMPOSITION Synthetic Base Oil	
Additives	
Oxidation Stability	Not Limited
Corrosion Inhibitor	Not Limited
Antiwear	Not Limited
Other, if Necessary	Not Limited
VISCOSITY: 10^{-6} m^2/Sec (Cs) at	
-54°C (-65°F)	18,000 Max.
38°C (100°F)	11.0 Min.
99°C (210°F)	3.0 Min.
VISCOSITY STABILITY, % at	
-54°C (-65°F)	± 10.0
FLASH POINT, COC, Minimum	204°C (400°F)
POUR POINT, Maximum	-59°C (-75°F)
OXIDATION STABILITY	
Viscosity Increase at 38°C (100°F), %	-5 to +25
Neutralization Number Increase	3.0
CORROSION, 72 Hr at 175°C (347°F)	
Weight Change, 10^{-2} kg/m^2 (mg/cm^2)	
Steel	± 0.2
Silver	± 0.2
Aluminum Alloy	± 0.2
Magnesium Alloy	± 0.2
Copper	± 0.4
PITTING, ETCHING, VISIBLE CORROSION (20X)	None
LEAD CORROSION, 1 Hr at 163°C (325°F)	
Weight Loss, 15.5 kg/m^2 (mg/in^2)	< 6.0
SILVER AND COPPER CORROSION, 50 Hr at 232°C (450°F)	
Weight Loss, 15.5 kg/m^2 (mg/in^2)	< 3.0
FOAM CHARACTERISTICS	
10^{-6} m^3 (ml) Foam, after Bubbling (and time to collapse)	
(a) Sequence 1, 24°C (75°F)	100 (5 min)
(b) Sequence 2, 93°C (200°F)	25 (3 min)
(c) Sequence 3, 24°C (75°F)	100 (5 min)

MILITARY SPECIFICATION: MIL-C-8188C
CORROSION-PREVENTIVE OIL, GAS TURBINE ENGINE, AIRCRAFT SYNTHETIC BASE

PROPERTIES	SPEC. REQ.
EVAPORATION (6.5 hr at 204°C (400°F)) Weight Loss, % Maximum	50
PROTECTION, Humidity Cabinet, 6 Days at 49°C (120°F), Polished Steel, Failures in 5 Panels	1 Max.
COKING, Splasher, 8 Hr at 1,000 rpm, 315°C (600°F), Max. Deposit	100 mg
COMPATIBILITY WITH ELASTOMERS Rubber H, Swelling, %	12 to 35
COMPATIBILITY WITH MIL-L-7808 and MIL-C-8188 Oils	Pass
LOAD CARRYING ABILITY (Ryder) % Reference Oil, Minimum	70
EXTENDED STROAGE STABILITY 12 Months at 24°C (75°F)	No Separation
25 HR ENGINE TEST	Pass

NOTE: For a description and recommended usage of this corrosion-preventive oil, see Section II.

The product listed below meets the requirements of this specification.

Product	Manufacturer
PQ Corrosion Preventive Oil No. 3475	American Oil and Supply Co.

MILITARY SPECIFICATION: MIL-C-11796B CLASS (1 and 1A HARD FILM)
CORROSION PREVENTIVE COMPOUND, PETROLATUM, HOT APPLICATIONS

PROPERTIES	SPEC. REQ.	BRAYCOTE[a/] 202	COSMOLINE[b/] 1060
COMPOSITION Base Oil			
Additives			
Rust Inhibitor			
EP (extreme pressure)			
Thickener			
Solids			
Antioxidant			
Abrasives	None	Passes	Passes
MELTING POINT	68°C (155°F) Minimum	78°C (172°F)	68°C (155°F)
FLOW POINT	66°C (150°F) Minimum	Passes	No Flow at 66°C (150°F)
PENETRATION, 10^{-4} m (tenths of mm)	30-80	38	30-80
FLASH POINT, COC	177°C (350°F) Minimum	279°C (535°F)	177°C (350°F)
LOW TEMPERATURE ADHESION			
After 1 Hr at -40°C (-40°F)	No Flaking	Passes	Passes
STABILITY (cycled between 107°C (225°F) and -40°C (-40°F))	No Foaming or Separation	Passes	Passes
CORROSION PROTECTION			
Weatherometer, Has to Rust	300 Minimum	Passes	Passes
Outdoor Exposure, Years to Rust	1 Minimum	Passes	passes
CORROSIVENESS, 14 Days at 82°C (180°F)			
Pitting or Etching	None	Passes	Passes
WEIGHT CHANGE, 10^{-10} kg/m^2 (mg/cm^2)			
Aluminum	± 0.2	+ 0.04	None
Brass	± 0.2	- 0.01	None
Cadmium	± 0.2	+ 0.02	None
Magnesium	± 0.5	+ 0.07	None
Steel	± 0.2	- 0.01	None
Zinc	± 0.2	+ 0.03	None
REMOVABILITY			
(after weatherometer, cycles)	15 Maximum	6	-
(after outdoor exposure, cycles)	150 Maximum	120	-
EVAPORATION, % Weight Change (3 Hr at 107°C (225°F))	1.0 Maximum	0.12	Passes

a/ Bray Products Division, Burmah-Castrol, Inc.
b/ E. F. Houghton and Company

NOTE: For description of this material and recommended usage, see Section II. Other companies supplying material to these specifications include:

Product		Manufacturer
Class 1,1A	NOX Rust 507	Daubert Chemical Co.
	Tectyl 435	Valvoline Oil Company
Class 2	Braycote 265	Bray Products Division, Burmah-Castrol, Inc.
Class 3	Braycote 248	Bray Products Division, Burmah-Castrol, Inc.
	Tectyl 437	Valvoline Oil Company
	NOX-Rust 509	Daubert Chemical Co.
	Cosmoline 1062	E. F. Houghton and Company
	Code SF871 1009	Southwest Petro-Chem, Inc.

Materials are also available conforming to classes 2 and 3 of this specification. Class 2 is a hot application medium film and Class 3 is either a hot or cold application soft film. These materials are generally available from suppliers of Class 1 and 1A materials.

MILITARY SPECIFICATION: MIL-C-16173D(2)
CORROSION PREVENTIVE COMPOUND, SOLVENT CUTBACK, COLD-APPLICATION

PROPERTIES		SPEC. REQ.
MATERIAL		Nonvolatile Base, Pertroleum Solvent
FILM CHARACTERISTICS		
Grades 1, 2, 3, 4, and 5. Compounds readily wet surfaces of panels and upon evaporation of solvent coating to be continuous.		Pass
Grade 4. Compound to be transparent during protective life of coating.		Pass
NONVOLATILE CONTENT		
Percent by weight established when qualified. On any succeeding lot of product nonvolatile content to be not more than 5 percent lower or 10 percent higher than established value, based on nonvolatile as received as being 100 percent.		Pass
DISCERNIBILITY		
Grades 1 and 2 permanently discernible, and grades 3 and 5 discernible for two weeks after application. Color of finished compound black or brown.		Pass
STABILITY		
Compound shall be stable and homogeneous.		Pass
SPRAYABILITY		
Compound shall be sprayable at 4.4°C (40°F) minimum and above.		Pass
CORROSION		
No pitting, etching, dark discoloration, or weight change in excess as follows:		
Brass	1.0 mg/cm^2	Pass
Cadmium	5.0 mg/cm^2	Pass
Zinc	7.5 mg/cm^2	Pass
Magnesium	0.5 mg/cm^2	Pass
Aluminum	0.2 mg/cm^2	Pass
Steel	0.2 mg/cm^2	Pass
Lead-Calcium Alloy (grade 2 only)	5.0 mg/cm^2	Pass
LOW TEMPERATURE ADHESION (grades 1, 2, and 4)		
Grade 1 compound adheres to metal at -18°C (0°F).		Pass
Grades 2 and 4 compounds adhere to metal at -40°C (-40°F).		Pass

MILITARY SPECIFICATION: MIL-C-16173D(2)
CORROSION PREVENTIVE COMPOUND, SOLVENT CUTBACK, COLD-APPLICATION

PROPERTIES	SPEC. REQ.
DRYING (grades 1, 2, 3, and 5)	
Grade 1 compound sufficiently dry in 4 hours to permit handling without injury to coating.	Pass
Grades 2, 3, and 5 films to remain soft on drying and exposure.	Pass
Grade 4 coating to sufficiently dry in 4 hours to permit handling of film without injury, and after 24 hours to be tack free.	Pass
WATER DISPLACEMENT (grades 3 and 5) (1) After storage in contact with water and (2) Upon 1:1 dilution with paraffin oil, shall satisfactorily displace water.	Pass

REQUIREMENTS FOR INDIVIDUAL GRADES

	GRADE 1	GRADE 2	GRADE 3	GRADE 4	GRADE 5
FLASH POINT, °C (°F) Minimum	38°C (100°F)	38°C (100°F)	38°C (100°F)	38°C (100°F)	38°C (100°F)
PENETRATION OF NONVOLATILE FRACTION		200 Min			
MISCIBILITY WITH LUBRICATING OIL		Complete			
REMOVABILITY AFTER EXPOSURE, Cycles (max.)	30	15	6	15	
HOT WATER REMOVABILITY, Residue, g/sq. ft. (max.)					0.15
LOW PRESSURE STEAM REMOVABILITY, Residue, g/sq. ft. (max.)					0.15
PROTECTION TESTS:					
FILM THICKNESS, mils (max.)	4.0	2.0	1.0	2.0	1.0
HUMIDITY, Days (min.)		30	30	30	30
SALT SPRAY, Days (min.)	14	7		14	
WEATHERING, Accelerated, Operating Hours (min.)					
SHED STORAGE, Years (min.)		1	1/2	1	1/2
FLOW POINT, °C (°F) Minimum	79°C (175°F)			75°C (175°F)	

MILITARY SPECIFICATION: MIL-C-16173D(2)
CORROSION PREVENTIVE COMPOUND, SOLVENT CUTBACK, COLD-APPLICATION

NOTE: For a description and recommended usage of this corrosion preventive compound, see Section II.

Products listed below meet the requirements of this specification.

Product		Manufacturer
Grade 1	Tectyl 890	Ashland Oil, Inc.
	Braycote 103	Bray Products Division, Burmah-Castrol, Inc.
	Nox-Rust 201B	Daubert Chemical Company
	Cosmoline 1058	E. F. Houghton and Company
Grade 2	Tectyl 502C	Ashland Oil, Inc.
	Braycote 137	Bray Products Division, Burmah-Castrol, Inc.
	Nox-Rust 207	Daubert Chemical Company
	Cosmoline 1102	E. F. Houghton and Company
Grade 3	Tecty 894	Ashland Oil, Inc.
	Braycote 153E	Bray Products Division, Burmah-Castrol, Inc.
	Nox-Rust 208	Daubert Chemical Company
	Petrotect 3	Penreco, A Pennzoil Division
Grade 4	Tectyl 846	Ashland Oil, Inc.
	Braycote 194	Bray Products Division, Burmah-Castrol, Inc.
	Nox-Rust X-110	Daubert Chemical Company
	Cosmoline 1112	E. F. Houghton and Company
Grade 5	Tectyl 511M	Ashland Oil, Inc.
	Braycote 198E	Bray Products Division, Burmah-Castrol, Inc.
	Petrotect 5	Penreco, A Pennzoil Division
	Royco 195	Royal Lubricants Company

MILITARY SPECIFICATION: MIL-S-8660C
SILICONE COMPOUND

PROPERTIES	SPEC REQ.	DOW CORNING[a/] 4 COMPOUND	INSUL[b/] GREASE G-624
COMPOSITION Base Oil			Dimethyl Polysiloxane
Additives			
Rust Inhibitor			
EP (extreme pressure)			
Thickener			SiO_2
Solids			
Antioxidant			
Other			
VISCOSITY, Base Oil, 10^{-6} m^2/Sec (Cs) at 38°C (100°F)			-
FLAMMABILITY TEST (nonflammable)	Pass	-	Pass
HIGH TEMPERATURE BLEED, 30 Hr at 204°C (400°F), % Weight Loss	8.0	4.0	4.0
PENETRATION, Unworked at 24°C (77°F)	200 to 260	200	200 to 260
Worked at 24°C (77°F) plus	310 Maximum	240	< 310
Worked at 24°C (77°F) plus 24 Hr at 204°C (400°F)	310	Passes	Passes
SPECIFIC GRAVITY, 16°C (60°F)	-	-	1.03
USABLE TEMPERATURE RANGE	-	-57°C to 204°C (-70°F to 400°F)	-54°C to 204°C (-65°F to 400°F)
LOW TEMPERATURE TORQUE, ASTM D-1478, -54°C (-65°F), Nm (g-cm)			
Starting Torque	0.491 Nm (5,000)	Passes	Passes
Running Torque	0.0981 Nm (1,000)	Passes	Passes
WATER PROOF SEAL TEST, 24 Hr at 24°C (77°F)	Pass	Passes	Passes
STORAGE STABILITY, 6 Months at 38°C (100°F) Penetration Changes	None	-	-
CORROSIVE PROPERTIES (70 hr at 100°C (212°F))			
Metals: Aluminum Alloy, Copper, Lead, Magnesium Alloy, Solder, Zinc and Cadium Plated Steel: singly or coupled	No Pit or Etch	Passes	Passes
Nonmetals: Natural on Synthetic Rubber, Phenol Formaldehyde Resin, Urea Formaldehyde Resin, Copolymer of Vinyl Chloride and Vinyl Acetate Resin	No Change	Passes	Passes
EVAPORATION, 30 Hr at 204°C (400°F) % Weight Loss	2.0 Maximum	1.5	< 2.0
RUBBER SWELL, 16 Hr at 70°C (150°F) % Volume	± 7.0	-	-
COLOR (grey or cream, color dye permitted)	Note	Light Grey	Light Grey
TOXICITY	None	None	-

MILITARY SPECIFICATION: MIL-S-8660C
SILICONE COMPOUND

PROPERTIES	SPEC. REQ.	DOE CORNING[a] 4 COMPOUND	INSUL[b] GREASE G-624
INSOLUBILITY, 7 Days at 25°C (77°F), % Weight Loss			
Distilled Water	0.4	Passes	Passes
Isopropyl Alcohol (91%)	10.0	Passes	Passes
Ethyl Alcohol	7.0	Passes	Passes
Ethylene Glycol	0.5	Passes	Passes
Glycerine	0.5	Passes	Passes
ARC RESISTANCE, (Method 4011, Fed. Std. 406)			
Time, Sec.	60	100	> 100
DIELECTRIC STRENGTH (Method 4031, Fed. Std. 406)			
1.27×10^{-6} m (0.050 in.) Electrode Gap	11.8×10^6 volts/m (300 volts/mil)	11.8×10^6 volts/m (300 volts/mil)	11.8×10^6 volts/m (300 volts/mil)
0.254×10^{-6} m (0.010 in.) Electrode Gap	19.7×10^6 volts/m (500 volts/mil)	-	19.7×10^6 volts/m (500 volts/mil)
DIELECTRIC CONSTANT AND DISSIPATION FACTOR (Method 4021, Fed. Std. 406), 23°C (73.4°F), 50% RH, 24 Hr			
Dielectric Constant at 1.0 kc., 1 and 10 Megacycles	2.9 (maximum)	2.85	< 2.9
Dissipation Factor at 1.0 kc., 1 and 10 Megacycles	0.0025 (maximum)	0.0006	< 0.0025
ELECTRICAL RESISTANCE (volume, 24 Hr at 23°C (73.4°F), ohms, 10^{-2} m (cm) (minimum)	1.0×10^{13}	1.0×10^{14}	1.0×10^{14}
4 Hr at 177°C (350°F), ohms 10^{-2} m (cm) Minimum	1.0×10^{12}	1.0×10^{12}	1.0×10^{12}

a/ Dow Corning Corp.
b/ General Electric, Silicone Products Department
NOTE: For description and recommended usage of this grease-like silicone compound, see Section II.

MILITARY SPECIFICATION: MIL-C-0083933A
CORROSION PREVENTIVE COMPOUND, COLD APPLICATION (For Motor Vehicles)

PROPERTIES	SPEC. REQ.
FLASH POINT, Minimum	38°C (100°F)
FIRE POINT, Minimum	41°C (105°F)
WATER CONTENT, % Maximum	1.0
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)	2e
SULFATED RESIDUE, %	Report
HALOGEN CONTENT, High Toxicity	None
FIRE RESISTANCE, 7 Days Support Combustion, Sec	< 15
LOW TEMPERATURE STABILITY 16 Hr at -29°C (-20°F), Separation	None
CORROSION PROTECTION Salt Spray Resistance, 500 Hr Exposure Salt Spray Immersion, 14 Days	3 Dots

NOTE: For a description and recommended usage of this corrosion preventive compound, see Section II.

Products listed below meet the requirements of this specification.

Product	Manufacturer
Amalie Film Spray	Amalie Refining Co. (Division of Witco Chemical Corp.)
Tectyl 165-G	Valvoline Oil Co. (Division of Ashland Petroleum Co.)
Nox-Rust X-118	Daubert Chemical Co.
Petrotect ARP	Penreco, A Pennzoil Division
Code 62069	Southwest Petro-Chem, Inc. (Div. of Witco Chemical Corp.)

MILITARY SPECIFICATION: VV-B-680B(1)
BRAKE FLUID, AUTOMOTIVE

PROPERTIES	SPEC. REQ.
VISCOSITY 10^{-6} m^2/Sec (Cs) at	
-35°C (-31°F) Max.	900
50°C (122°F) Min.	3.5
100°C (212°F) Min.	1.5
FLASH POINT, Min.	82°C (180°F)
BOILING POINT, Min.	205°C (401°F)
EVAPORATION, % by Weight 48 Hr at 100°C (212°F)	< 80
POUR POINT (Method D97) 20 ml Residue	Pass
pH VALUE	7.0 to 11.0
APPEARANCE AND FLUIDITY at Sub-Zero Temperatures -50°C (-58°F) -40°C (-40°F)	Pass
WATER TOLERANCE	Pass
RUBBER SWELL, Limits, Min. to Max., in. (mm)	0.001 (0.03) to 0.050 (1.30)
CORROSIVENESS, 120 hr at 100°C (212°F) Change in Weight, mg/cm^2 Max.	
Tinned Steel	0.2
Carbon Steel	0.2
Aluminum Alloy	0.1
Cast Iron	0.2
Brass	0.4
Copper	0.4
STROKING, Procedure A, Method 361 FTMS No. 791	Pass
COMPATIBILITY, Appendix A of SAE Standard J1703	Pass
STABILITY, Permissible Average Loss in Weight, mg/cm^2	
Aluminum	0.05 Max.
Cast Iron	0.30 Max.

NOTE: For a description and recommended usage of this brake fluid, see Section II.

Products listed below meet the requirements of this specification.

Product	Manufacturer
69-0-5-4	Delco Moraine Division, GMC
NC-2021.1	Dow Chemical Company
LWS-5	Olin Corporation
UCON 4961	Chemicals Division, Union Carbide Corp.
H-70	Wagner Electric Corp.

MILITARY SPECIFICATION: MIL-H-5606E(1)
HYDRAULIC FLUID, PETROLEUM BASE, AIRCRAFT AND ORDNANCE

PROPERTIES	SPEC. REQ.	ROYCO[a/] MICRONIC 756 E	BRAYCO[b/] MICRONIC 756 E	AIRCRAFT[c/] TL-10711A
COMPOSITION Base Oil	-	-		
Additives				
Viscosity-Temperature Coefficient Improvers	< 20 Weight %	Yes	Yes	Yes
Oxidation Inhibitor	< 2.0 Weight %	Yes	Yes	Yes
Antiwear (tricresyl phosphate)	0.5 ± 0.1 Weight %	Yes	Yes	Yes
Corrosion Inhibitors	-	-		
EP (extreme pressure)	-	-		
Other	-	-		
VISCOSITY: 10^{-6} m^2/Sec (Cs) at				
-54°C (-65°F)	2,500, Maximum	2,127	2,327	2,070
-40°C (-40°F)	600, Maximum	473	454	450
40°C (104°F)	13.2, Minimum	10.16	13.43	10.2
100°C (212°F)	4.90, Minimum	-	5.03	
VISCOSITY INDEX, Minimum	-	-		
SPECIFIC GRAVITY, 16°C (60°F)	-	0.867	0.873	0.861
FLASH POINT, PMCT	82°C (180°F) Minimum	102°C (215°F)	90°C (194°F)	93°C (200°F)
FIRE POINT,	-	-		
POUR POINT, Maximum	-59°C (-75°F)	< -65°C (< -85°F)	< -62°C (-80°F)	< -59°C (< -75°F)
USABLE TEMPERATURE RANGE	-54°C (-65°F) to 71°C (160°F)	-	-	-
EVAPORATION 6 Hr at 71°c (160°F) Oily, Not Hard or Tacky	20, Maximum	Passes	Passes	Passes
CORROSION AND OXIDATION STABILITY 135°C (275°F) for 168 Hr				
Weight Change, 10^{-2} kg/m^2 (mg/cm^2)				
Steel	±0.2	-0.02	0.00	0.01
Aluminum Alloy	±0.2	0.00	-0.023	0.03
Magnesium	±0.2	-0.01	-0.015	0.01
Cadium-Plated Steel	±0.2	-0.04	+0.007	0.02
Copper	±0.6	-0.03	0.053	0.07
No Pitting or Etching at 20X	Passes	Passes	Passes	Passes
Corrosion (ASTM Copper Corr. Std.), Maximum	3	Passes	Passes	Passes
Viscosity Change, 54°C (130°F), %	-5 to +20	+4	+9.6	+6
Neutralization Number Increase, 10^{-3} kg KOH/kg (mg KOH/g)	±0.20	0.04	0.02	None
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)	2e, Maximum	1	1b	1a
NEUTRALIZATION NUMBER 10^{-3} kg KOH/kg (mg KOH/g)	0.20, Maximum	0.07	0.07	0.06
STEEL-ON-STEEL WEAR, mm	1 Maximum		0.8	

MILITARY SPECIFICATIONS: MIL-H-5606E(1)
HYDRAULIC FLUID, PETROLEUM BASE, AIRCRAFT AND ORDNANCE

PROPERTIES	SPEC. REQ.	ROYCO[a] MICRONIC 756 E	BRAYCO[b] MICRONIC 756E	AIRCRAFT[c] TL-10711A
FOAM CHARACTERISTICS (Method D 892) Foam Volume, 10^{-6} m^3 (ml) After 5 Min Blowing/After 10 Min Settling	65/0	55/0	55/0	-
COMPATIBILITY WITH:				
Jet and Rocket fuels	-	-		
LOX	-	-		
RUBBER SWELL, % Volume Change Type "L"	19.0 to 30.0	26.2	26.2	23.5
SHEAR STABILITY, Viscosity Decrease, %, at				
40°C (104°F)	Less than Reference Fluid	Passes	Passes	Passes
-40°C (-40°F)	Less than Reference Fluid	Passes	Passes	Passes
Neutralization Number Change	+0.20, Maximum	Passes	Passes	Passes
LOW TEMPERATURE STABILITY 72 Hr at -54°C (-65°F) (no separation or gelling)	Pass	Passes	Passes	Passes
SOLID PARTICLE CONTAMINATION, No. Parts, 10^{-4} m^3 (No. particles/ 100 ml), Maximum (automatic count)				
5 to 15 x 10^{-6} m (microns)	10,000	460	466	-
16 to 25 x 10^{-6} m (microns)	1,000	87	87	-
26 to 50 x 10^{-6} m (microns)	150	29	29	-
51 to 100 x 10^{-6} m (microns)	20	9	9	-
Over 100 x 10^{-6} m (microns)	5	0.65	0.65	-
WATER CONTENT, %	0.01	0.004	0.004	0.01 Max
COLOR, ASTM STD (max.) No.1	Red Dye	Yes	Yes	Yes
STORAGE STABILITY	Passes	-	-	Passes

NOTE: For a description of this hydraulic fluid and recommended usage, see Section II. Fluids may be used to 135°C (275°F) in closed systems.

In addition to the products listed, the hydraulic fluids supplied by the following manufacturers also meet the general requirements of this specification.

Product	Manufacturer
PQ Hydraulic Fluid 4328	American Oil and Supply Company
Aeroshell Fluid 41	Shell Oil Company
PED 5225	Chevron U.S.A. Inc.
Petrofluid 4146	Penreco-A Pennzoil Division

a/ Royal Lubricants Company, Inc.
b/ Bray Products Division, Burmah-Castrol, Inc.
c/ Texaco Inc.

MILITARY SPECIFICATION: MIL-H-6083D(3)
HYDRAULIC FLUID, PETROLEUM BASE, FOR PRESERVATION AND OPERATION

PROPERTIES	SPEC. REQ.	ROYCO[a/] 783 B
COMPOSITION Base Oil		
Additives		
Viscosity-Temperature Coefficient Improvers	< 20 Weight %	Yes
Oxidation Inhibitor	< 2 Weight %	Yes
Antiwear (tricresyl phosphate)	0.5 ± 0.1 Weight %	Yes
Corrosion Inhibitors	Yes	Yes
EP (extreme pressure)		
Other		
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
-40°C (-40°F)	800, Maximum	795
38°C (100°F)	14, Minimum	10.05
-54°C (-65°F)	3,500, Maximum	-
VISCOSITY INDEX	-	-
SPECIFIC GRAVITY, 16°C (60°F)	Report	-
FLASH POINT, COC	93°C (200°F)	99°C (210°F)
FIRE POINT, COC		
POUR POINT	-59°C (-75°F)	< -59°C (< -75°F)
USABLE TEMPERATURE RANGE		
EVAPORATION LOSS, % Max.		
22 Hr at 99°C (210°F)		
Oily, Not Hard or Tacky	70	Passes
CORROSION AND OXIDATION STABILITY		
168 Hr at 121°C (250°F) Weight Change, 10^{-2} kg/m^2 (mg/cm^2)		
Steel	± 0.2	Passes
Aluminum Alloy	± 0.2	Passes
Magnesium Alloy	± 0.2	Passes
Cadmium-Plated Steel	± 0.2	Passes
Copper	± 0.6	Passes
No Pitting, Etching, or Corrosion at 20X	Passes	-
Viscosity Change, at 54°C (130°F), %	-5 to +20	-
Neutralization Number Increase, Maximum	0.20	-
CORROSION PROTECTION, 100 Hr at 49°C (120°F) and 100% Relative Humidity	Passes	-
CORROSION, COPPER STRIP 72 Hr at 100°C (212°F)	< 3	Passes
NEUTRALIZATION NUMBER, Maximum 10^{-3} kg KOH/kg (mg KOH/g)	Report	-
FOAM CHARACTERISTICS (Method D 892)		
10^{-6} m^3 (ml) Foam 5 Min Blowing/10 Min Settling		
(a) Sequence 1, 24°C (75°F)	65/0	
(b) Sequence 2, 93°C (200°F)	65/0	
(c) Sequence 3, 24°C (75°F) (retest)	65/0	

MILITARY SPECIFICATION: MIL-H-6083D(3)
HYDRAULIC FLUID, PETROLEUM BASE, FOR PRESERVATION AND OPERATION

PROPERTIES	SPEC. REQ.	ROYCO[a] 783 B
COMPATIBILITY WITH:		
Jet and Rocket Fuels		
LOX		
RUBBER SWELL, % Volume Increase		
Type "L"	19.0 to 28.0	Passes
LOW TEMPERATURE STABILITY		
72 Hr at -54°C (-65°F) (no gelling, crystallization or separation)	Passes	Passes
SOLID PARTICLE CONTAMINATION		
No. Particles/100 ml, Maximum		
5-15 microns	2,500	
16-25 microns	1,000	
26-50 microns	250	
51-100 microns	25	
Over 100 microns	5	
SHEAR STABILITY,		
Viscosity Change at 38°C (100°F), %	Less than Reference Fluid	Passes
Neutralization Number Increase	0.20	Passes
PRECIPITATION NUMBER	0	0
COLOR	Clear, Transparent with Red Dye	Passes

NOTE: For a description of this hydraulic preservative oil and recommended usage, see Section II.

In addition to the hydraulic fluids listed, several other manufacturers produce hydraulic fluids which meet the requirements of this specification.

a/ Royal Lubricants Company, Inc.

Product	Manufacturer
Brayco 783 C/E	Bray Products Division, Burmah-Castrol, Inc.
PQ 1307	American Oil and Supply Company
Petrotect 4066C	Penreco-A Pennzoil Division
AVREX 904	Mobil Oil Corporation
Univis PJ-42	Exxon Company, U.S.A.
Hyspin P	Castrol Oils, Inc.
Aeroshell Fluid 71	Shell Oil Company

MILITARY SPECIFICATION: MIL-H-27601(A)(1)
HYDRAULIC FLUID, PETROLEUM BASE, HIGH TEMPERATURE, FLIGHT VEHICLE

PROPERTIES	SPEC. REQ.	BRAYCO[a/] 771
COMPOSITION Base Oil	Natural Hydrocarbon	Natural Hydrocarbon
Additives		
Viscosity-Temperature Coefficient Improvers		
Oxidation Inhibitor	Bis-phenol 0.45 to 1.0 Weight %	Report
Antiwear	Tricresyl Phosphate 1.0 Weight %	Report
Corrosion Inhibitors		
EP (extreme pressure)		
Other		
VISCOSITY: 10^{-6} m^2/Sec (Cs) at		
-54°C (-65°F)	Report	39,306
-40°C (-40°F)	4,000	3,672
-18°C (0°F)	385	335.6
38°C (100°F)	Report	14.62
99°C (210°F)	3.20	3.21
288°C (550°F)	Report	0.57
VISCOSITY INDEX, Minimum	89, Minimum	92
SPECIFIC GRAVITY, 16°C (60°F)	QUAL ± 0.008	0.8519
FLASH POINT, COC, Minimum	182°C (360°F), Minimum	201°C (395°F)
FIRE POINT, COC		
POUR POINT, Maximum	-54°C (-65°F), Maximum	-59°C (-75°F)
USABLE TEMPERATURE RANGE		
EVAPORATION, %, Maximum (22 Hr at 99°C (210°F))		
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)		
NEUTRALIZATION NUMBER 10^{-3} kg KOH/kg (mg KOH/g), Maximum	0.20	0.00
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam; After 5 Min Blow/3 Min Settling		
(a) Sequence 1, 24°C (75°F)	75/0	60/0
(b) Sequence 2, 93°C (200°F)	75/0	20/0
(c) Sequence 3, 24°C (75°F) (retest)	75/0	40/0
COMPATIBILITY WITH: Rubber and		
Jet and Rocket Fuels		
LOX		
SYNTHETIC RUBBER SWELL, % Volume Change Viton, 72 Hr at 204°C (400°F), Maximum	10	1.34
SHEAR STABILITY		
CORROSION AND OXIDATION STABILITY 48 Hr at 175°C (347°F)		
Weight Loss, mg/cm^2, Maximum		
Silver	0.2	+0.028
Steel 350ST	0.2	+0.024
Steel 440ST	0.2	+0.028
Titanium	0.2	+0.028
Copper	0.6	+0.00
Viscosity Change at 38°C (100°F)	-5 to +20	+7.11
Change in Total Acid or Base No.	2.0 Max.	0.81
Insolubles, gm/100 ml	0.1 Max.	0.0009

MILITARY SPECIFICATION: MIL-H-27601(A)(1)
HYDRAULIC FLUID, PETROLEUM BASE, HIGH TEMPERATURE, FLIGHT VEHICLE

PROPERTIES	SPEC. REQ.	BRAYCO[a/] 771
SOLID PARTICLE CONTAMINATION		
LUBRICITY, Shell Four-Ball Wear Test		
1 Hr, 600 rpm		
65°C (167°F) 52100 Steel, Maximum Scar Diameter		
9.81 N (1 kg) Load, 10-3 m (mm)	0.21	0.161
98.1 N (10 kg) Load, 10^{-3} m (mm)	0.30	0.273
372.4 N (40 kg) Load, 10^{-3} m (mm)	0.65	0.393
THERMAL STABILITY, 371°C (700°F), 6 Hr		
a. Viscosity Change at 38°C (100°F), %	±25	-15.25
b. Neutralization Number Increase	0.40	0.00
c. Appearance of Fluid	-	Passes
d. Metal Weight Change, 10^{-2} kg/m^2 (mg/cm^2)		
1. Naval Bronze	0.1	+0.002
2. M10 Tool Steel	0.1	+0.006
3. 52100 Steel	0.1	+0.004
TRACE SEDIMENT, Volume %, Maximum	0.025	0.001
DIELECTRIC STRENGTH, 20°C (68°F), Minimum	11.8 x 10^6 Volts/m (300 volts/mil)	13.8 x 10^6 Volts/m (350+ volts/mil)
SPECIFIC HEAT, Joule/kg °C at 93°C (Btu/lb °F) at 200°F, Minimum	2,031 (0.484)	2,312 (0.551)
THERMAL CONDUCTIVITY: Watt/m °C at 204°C (Btu/(sq ft) Hr (°F)/ft) at 400°F, Minimum	0.000756 (0.063)	0.000852 (0.071)
THERMAL EXPANSION: Per °C at 204°C Per °F at 400°F, Maximum	0.00108 (0.00060)	0.00108 (0.00060)
BULK MODULUS: Isothermal Secant		
0 to 68.9 x 10^6 N/m^2 at 38°C (100°F) (0 to 10,000 psi), Minimum	1.38 x 10^9 N/m^2 (200,000 psi)	1.86 x 10^9 N/m^2 (269,000 psi)
No. Particles/100 ml, Maximum		
5-15 microns	2,500	645
16-25 microns	1,000	171
26-50 microns	250	74.7
51-100 microns	25	9.8
Over 100 micons	5	0.83

NOTE: For a description and recommended usage of this hydraulic fluid, see Section II.

Product below meets the requirements of this specification.

Product	Manufacturer
Royco 601AH	Royal Lubricants Company, Inc.

a/ Bray Products Division, Burmah-Castrol, Inc.

MILITARY SPECIFICATION: MIL-F-17111B
FLUID, POWER TRANSMISSION

PROPERTIES	SPEC. REQ.	BRAYCO 717[a/]
COMPOSITION Petroleum Base Stock Plus 1% TCP		
Additives, Permissible		
Polymeric Material	x	
Oxidation Inhibitor	x	
Rust Preventive	x	
Anti-Wear Agent	x	
I. PROPERTIES OF PETROLEUM BASE STOCK		
Neutralization No., mg KOH/gm	0.05 Max.	0.00
Aniline Point, 77°C (170°F)	170°F Min.	173.5
Aniline Point Change, -15°C (5°F)	5°F Max.	+1.5
Precipitation No., ml	0.05 Max.	< 0.001
II. PROPERTIES OF FINISHED FLUID		
Gravity, °API @ 16°C (60°F)	(30.6 typical)	31.6
Viscosity, Cs, -32°C (-25°F)	600 Max.	486.92
Viscosity, Cs, -18°C (0°F)	215 Max	190.32
Viscosity, Cs, 38°C (100°F)	27 Min.	27.57
Viscosity, Cs, 99°C (210°F)	10 Min.	10.19
Pour Point, COC, Maximum	-40°C (-40°F)	(-80°F)
Flash Point, COC, Min.	104°C (220°F)	(235)
Fire Point, COC, Min.	113°C (235°F)	(255)
Neutralization No. (mg KOH/gm)	0.3 Max.	0.0561
Precipitation No., ml	0.05 Max.	< 0.01
Water, %	0.0	0.0045
Color, ASTM Max.	2	0.5
Low Temperature Turbidity, 72 Hr @ -37°C (-35°F)	Pass	Pass
Rust Prevention, Proc. A (D665)	Pass	Pass
Corrosion and Oxidation Stability 72 Hr @ 93°C (200°F)	Pass	
Viscosity Change @ 99°C (210°F)	(0 to +15)	+3.82
Viscosity Change @ -18°C (0°F)	(0 to +15)	+7.46
Neut. No., Oil Layer, mg KOH/gm	0.5 Max.	0.0561
Neut. No., Water Layer, mg KOH/gm	0.5 Max.	0.0840
Loss of Liquid, gm	10 Max.	4.0
Evaporation, 6 Hr @ 65°C (150°F), %	20 Max.	8.12
Water Sludging, 24 Hr @ 38°C (100°F), Viscosity Change, %	-2 to +10	+2.5

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a/ Bray Products Division, Burmah-Castrol, Inc.

NOTE: For a description and recommended usage of this power transmission fluid, see Section II.

Other products that meet the requirements of this specification are:

Product	Manufacturer
Petrofluid 171	Penreco, A Pennzoil Div.
Royco 717	Royal Lubricants Company

MILITARY SPECIFICATION: MIL-H-17672D
HYDRAULIC FLUID, PETROLEUM, INHIBITED

PROPERTIES	SPEC. REQ. 2110 T-H
COMPOSITION Base Oil	Petroleum Base
Additives	
Rust Inhibitor	Yes
Antioxidant	Yes
VISCOSITY 10^{-6} m^2/Sec (Cs) at	
40°C (104°F)	41.4-50.6
100°C (212°F)	Report
VISCOSITY INDEX, Minimum	94
POUR POINT, °C (°F) Maximum	-23°C (-10°F)
FLASH POINT, °C (°F) Minimum	163°C (325°F)
NEUTRALIZATION NUMBER, Maximum	0.20
NEUTRALITY, Qualitative	Neutral
CORROSION, COPPER STRIP at 100°C (212°F)	1 Max.
RUST PREVENTIVE CHARACTERISTIC In Presence of Water	Pass
WATER, Percent	None
ASH, Sulfated Residue, Percent Maximum	Report
VALVE STICKING CHARACTERISTICS	Pass
FOAM CHARACTERISTICS	
Tendency/Stability	
Sequence 1, ml Maximum	65/0
Sequence 2, ml Maximum	65/0
Sequence 3, ml Maximum	65/0
EMULSION TEST after 30 Min Settling Time	
Oil Layer, Maximum	40 ml
WATER LAYER AND LACY CUFF, Maximum	40 ml
Lacy cuff, Maximum	3 ml

PROPERTIES	SPEC. REQ. 2110T-H
OXIDATION TEST, Time Required in Hours to Reach Neutralization Value of 2.0 mg KOH	
After 1000 Hr	
Total Sludge, mg, Maximum	100
Total Iron, mg Maximum	100
Total Copper, mg Maximum	100
OXIDATION By Rotating Bomb	Report
CONTAMINATION mg/100 ml, Maximum	4.0
COLOR	Report
SULFUR	Report
CARBON RESIDUE	Report

NOTE: For a description and recommended usage of this hydraulic fluid, see Section II.

Other products that meet the requirements of this specification are:

Symbol	Product	Manufacturer
2075T-H	PQ C-4417	American Oil & Supply Co.
	Gulf TS-864-32	Gulf Oil Corporation
	Imperial 2075T-H	Imperial Oil Co., Inc.
	SE 8610632	Southwest Petro-Chem (Div. of Witco Chemical)
	TL-11014	Texaco U.S.A. (Div. of Texaco Inc.)
2110T-H	PQ C-4465	American Oil & Supply Co.
	Chevron 2110TH	Chevron U.S.A., Inc.
	Gulf TS-864-46	Gulf Oil Corporation
	Imperial 2110T-H	Imperial Oil Co., Inc.
	SE 8610646	Southwest Petro-Chem (Div. of Witco Chemical)
	Sunvis 2110TH	Sun Refining and Marketing Compnay
	TL-11015	Texaco U.S.A. (Div. of Texaco Inc.)
2135T-H	PQ C-4466	American Oil & Supply Co.
	Chevron 2135TH	Chevron U.S.A., Inc.
	Gulf TS-864-68	Gulf Oil Corporation
	Imperial 2135TH	Imperial Oil Co., Inc.
	Grade 2135T-H Code B 9257	Southwest Petro-Chem (Div. of Witco Chemical)
	DX Turbine & Hydraulic Oil 2135-T-H	Sun Refining and Marketing Company
	Sunvis 2135-TH (68)	Sun Refining and Marketing Company
	TL-11016	Texaco U.S.A.(Div. of Texaco Inc.)

MILITARY SPECIFICATION: MIL-H-19457C(1)
HYDRAULIC FLUID, FIRE-RESISTANT, NON-NEUROTOXIC

PROPERTIES	SPEC. REQ.
COMPOSITION Tertiary Butylated Triphenyl Phosphate	
VISCOSITY, 10^{-6} m^2/Sec (Cs) at 40°C (104°F) 100°C (212°F)	 38.5-45.5 4.8
POUR POINT, °C (°F), Max.	-18°C (0°F)
EVAPORATION, % Weight Loss, Max. at 100°C (212°F)	0.3
ACID NUMBER, Max.	0.1
NEUTRALITY (qualitative)	Neutral
FOAM CHARACTERISTICS, Volume, ml, at 24°C (75°F), 5 Min. Blowing/ 10 Min Settling, Max.	65/0
EMULSION TEST (time to settle out), Minutes, Max., When Stirred at 54°C (130°F) with Distilled Water	30
SPECIFIC GRAVITY, 16°C (60°F)	Report
REFRACTIVE INDEX, Nd at 20°C (68°F)	Report
PRECIPITATION NUMBER, Max.	0.01
FIRE RESISTANCE, CFR Compression Ratio, Min.	42:1
WEAR TEST, Scar Dia., mm Max.	0.6
WATER, Allowable, %	None
CORROSION, Copper Strip 48 Hr at 93°C (200°F), mg/cm^2, Max.	0.3
APPEARANCE, No Pitting, Etching or Visible Corrosion	Pass
ACID NUMBER INCREASE, mg KOH/gm Fluid, Max.	0.2
ACIDITY, Water Layer, mg KOH, Max.	5.0
INSOLUBLES, % Max.	0.5

NOTE: For a description and recommended usage of this hydraulic fluid, see Section II.

Other products that meet the requirements of this specification are:

Product		Manufacturer
Type I,	Kronitex 280	FMC Corporation
	Houghto-Safe 1120	E. F. Houghton & Company
Type II,	Kronitex 600	FMC Corporation
	Houghto-Safe 1055	E. F. Houghton & company

MILITARY SPECIFICATION: MIL-H-46170B
HYDRAULIC FLUID, RUST INHIBITED, FIRE RESISTANT, SYNTHETIC HYDROCARBON BASE

PROPERTIES	SPEC. REQ.	BRAYCO 883[a]/
COMPOSITION Synthetic Hydrocarbon	-	
Additives		
Corrosion Inhibitors	Report	x
Rubber Swell Agent	Report	x
Anti-Wear Agent	Report	x
Other	Report	x
VISCOSITY, Cs		
40°C (104°F)	19.5	16.73
100°C (212°F)	3.4	3.78
-40°C (-40°F)	2600	2429
-54°C (-65°F)	Report	-
SPECIFIC GRAVITY, 16°C (60°F)	Report	0.8576
and API Gravity	Report	33.5
FLASH POINT, COC, Minimum	204°C (400°F)	218°C (425°F)
FIRE POINT, COC, Minimum	246°C (475°F)	249°c (480°F)
POUR POINT, Minimum	-54°C (-65°F)	-62°C (-80°F)
WATER, % Wt. (KFR) Maximum	0.05	0.03
ACID or Base Number, mg KOH/gm, Maximum	0.20	0.08
AUTOIGNITION TEMPERATURE, °C (°F), Minimum	343°C (649°F)	382°C (720°F)
TRACE SEDIMENT, ml, Maximum	0.005	0.002
CORROSION AND OXIDATION STABILITY		
168 Hr at 121°C (250°F),		
mg/cm^2, Maximum		
Cadmium Plated Steel	±0.2	0.00
Steel	±0.2	0.00
Aluminum Alloy	±0.2	0.00
Magnesium Alloy	±0.2	0.00
Copper	±0.6	-0.01
Pitting, Etching, Corrosion	None	Pass
Viscosity Change at 40°C (104°F), Percent, Maximum	10	2.5
Separation or Gumming	None	Pass
LOW TEMPERATURE STABILITY		
72 Hr, -40°C (-40°F)		
(no gelling, crystallizing or separation)	Pass	Pass
RUST PREVENTION, 100 Hr at 49°C (120°F) and 95 to 100% Humidity	Pass	Pass

MILITARY SPECIFICATION: MIL-H-46170B
HYDRAULIC FLUID, RUST INHIBITED, FIRE RESISTANT, SYNTHETIC HYDROCARBON BASE

PROPERTIES	SPEC. REQ.	BRAYCO 883[a/]
SWELLING OF SYNTHETIC RUBBER, Type NBR-L, Percent	15 to 25	21.3
SOLID PARTICLE CONTAMINATION, Number Per 100 ml, Particle Size (microns)		
5-25	10,000	530
26-50	250	14
51-100	50	3
Over 100	10	1
FOAM CHARACTERISTICS 10^{-6} m^3 (ml) 5 Min Blowing/ 10 Min Settling		
24°C (75°F)	65/0	10/0
94°C (200°F)	65/0	10/0
24°C (75°F)	65/0	10/0
SHELL FOUR-BALL WEAR TEST (D2266), Load (kg) and Scar Dia., mm, Max		
10	0.30	0.23
40	0.65	0.45
BULK MODULUS, Isothermal Secant, 0 to 10,000 psi at 38°C (100°F), psi (min.)		
2,000	200,000	206,000
4,000	200,000	219,000
6,000	200,000	234,000
8,000	200,000	240,000
10,000	200,000	262,000

a/ Bray Products Division, Burmah-Castrol, Inc.

NOTE: For a description and recommended usage of this hydraulic fluid, see Section II.

Other products which meet the requirements of this specification are:

Product	Manufacturer
PQ 4100	American Oil & Supply Co.
Formula No. LP-803	Gulf Oil Corporation
F-885-1	Hanover Processing Corp., Inc.
Royco 770	Royal Lubricants Co.
Aeroshell Fluid 61	Shell Oil Company

MILITARY SPECIFICATION: MIL-B-46176(2)
BRAKE FLUID, SILICONE, AUTOMOTIVE, ALL WEATHER, OPERATIONAL AND PRESERVATIVE

PROPERTIES	SPEC. REQ.
COMPOSITION	Diorgano Polysiloxane 70% Min. by Weight
VAPOR LOCK TEMPERATURE (VLT) and Wet VLT, Minimum	230°C (446°F) 177°C (350°F)
VISCOSITY, Cs, Maximum	
-55°C (-67°F)	900
100°C (212°F)	1.3
CORROSIVENESS, Change in Weight, mg/cm^2, Maximum	
Tinned Steel	0.1
Carbon Steel	0.1
Aluminum Alloy	0.1
Cast Iron	0.1
Brass	0.2
Copper	0.2
APPEARANCE at Sub-Zero Temperatures, -55°C (-67°F), Stratification, Separation, Precipitation, Crystallization	None
FLUIDITY at Sub-Zero Temperatures, -55°C (-67°F), Air Bubble Travel, Seconds, Max.	10
COMPATIBILITY, Percent Sediment by Volume, Maximum	0.05
FLASH POINT, COC, Minimum	204°C (400°F)
RUBBER SWELLING, Types SBR, Polychloroprene, EPR, Natural	Pass
TOLERANCE TO HIGH HUMIDITY, -40°C (-40°F), Stratification, Sediment, or Crystals	None
STROKING TEST, -55°C (-67°F) to +120°C (248°F), Pressure (500-1,000) psi, (3,000 to 44,000) Strokes	Pass
HYDROVAC PERFORMANCE, Bendix Corp. Life Test (2511170) with Silicone Brake Fluid, KXA-112342, at 82°C (180°F)	Pass

NOTE: For a description and recommended usage of this brake fluid, see Section II.

Products which meet the requirements of this specification are:

Product	Manufacturer
X2-1143	Dow Corning Corporation
P1615-129	Delco Moraine Division, General Motors Corporation
475-195	General Electric Corporation
Y-7694	Union Carbide Corporation

MILITARY SPECIFICATION: MIL-H-81019D
HYDRAULIC FLUID, PETROLEUM BASE, ULTRA-LOW TEMPERATURE, METRIC

PROPERTIES	SPEC. REQ.
COMPOSITION Base Oil	
Additives	
Viscosity-Temperature Coefficient Improvers, Weight %	10 Max.
Oxidation Inhibitor, Weight %	2 Max.
Corrosion Inhibitor	Yes
Anti-Wear Agent (tricresyl phosphate)	Yes
VISCOSITY, 10^{-6} m^2/Sec (Cs) at	
100°C (212°F), Minimum	2.5
40°C (104°F), Minimum	7.0
-54°C (-65°F), Maximum	800
-70°C (-94°F), Maximum	0.008
POUR POINT, Maximum	-75°C (-103°F)
FLASH POINT, Minimum	95°C (203°F)
FIRE POINT, Minimum	110°C (230°F)
NEUTRALIZATION NUMBER 10^{-3} kg KOH/kg (mg KOH/g)	0.20
EVAPORATION, %, Weight Loss, 4 Hr at 70°C (158°F), Maximum	12
RUBBER SWELL, % Volume Change, NBR-L Type	19.0-28.0
WATER CONTENT, ppm, Maximum	200
CORROSION AND OXIDATION STABILITY	
168 Hr at 121°C (250°F), Weight Loss, 10^{-2} kg/m^2 (mg/cm^2), Maximum	
Steel	±0.2
Aluminum Alloy	±0.2
Magnesium Alloy	±0.2
Cadmium Plated Steel	±0.2
Copper	±0.6
Pitting, Etching, Corrosion	None
Viscosity Change at 40°C (104°F)	-5 to +20
Neutralization Number Increase, Maximum	0.20
Separation or Gumming	None
LOW TEMPERATURE STABILITY	
72 Hr at -54°C (-65°F)	
Gelling, Crystallization, Solidification, Separation	None

MILITARY SPECIFICATION: MIL-H-81019D
HYDRAULIC FLUID, PETROLEUM BASE, ULTRA-LOW TEMPERATURE, METRIC

PROPERTIES	SPEC. REQ.
SHEAR STABILITY, Viscosity Decrease, %	
at 40°C (104°F)	< Reference Fluid
at -40°C (-40°F)	< Reference Fluid
Neutralization Number Change	0.20
CORROSION, Copper Strip	
72 Hr at 100°C (212°F)	< 2
SOLID PARTICLE CONTAMINATION	
No. Parts, 10^{-4} m^3 (No. particles/ 100 ml), Maximum (microscopic count)	
5 to 15	2,500
16 to 25	1,000
26 to 50	250
51 to 100	25
Over 100	10
Weight of Residue, mg/l, Maximum	0.3
FOAMING CHARACTERISTICS, 10^{-6} m^3 (ml)	
Foam 5 Min Blowing	
10 Min Settling	
(a) Sequence 1, 25°C (77°F)	65/0
(b) Sequence 2, 93°C (200°F)	65/0
(c) Sequence 3, 25°C (77°F)	65/0
LUBRICITY (4-Ball Wear Test), Wear Scar, mm, Maximum	1.0
STORAGE STABILITY	
12 Months	
COLOR (D1500), Red Dye	Passes

NOTE: For a description and recommended usage of this hydraulic fluid, see Section II.

Products which meet the requirements of this specification are:

Product	Manufacturer
Brayco 759C	Bray Products Division, Burmah-Castrol, Inc.
Royco 719C	Royal Lubricants Company, Inc.

MILITARY SPECIFICATION: MIL-S-81087C(1)
SILICONE FLUID, CHLORINATED PHENYL METHYL POLYSILOXANE

PROPERTIES	SPEC. REQ.
VISCOSITY, 10^{-6} m^2/Sec (Cs) at	
-55°C (-67°F), Max.	3,500
40°C (104°F)	48-58
100°C (212°F)	15-19
POUR POINT, Max.	-75°C (-103°F)
FLASH POINT, COC, Min.	288°C (550°F)
FIRE POINT, COC, Min.	340°C (644°F)
SPECIFIC GRAVITY, 25°C (77°F)	1.03-1.06
NEUTRALIZATION NUMBER 10^{-3} kg KOH/kg (mg KOH/g)	0.05
LUBRICITY (Four-Ball Wear Test) Wear Scar Diameter, mm, Max.	0.60
VOLATILITY, Weight Loss, % Max.	1.0
GEL TIME, 72 Hr at 250°c (482°F)	No Gelling
Viscosity after Gel Test, 40°C (104°F), Cs, Max.	700
OXIDATION AND CORROSION STABILITY	
168 hr at 121°C (250°F), Weight Loss, mg/cm^2, Maximum	
Stainless Steel	±0.10
Aluminum Alloy	±0.10
Titanium	±0.10
Silver	±0.10
Mild Steel	±0.10
Pitting, Etching, corrosion	None
Viscosity Change at 40°C (104°F), Percent, Maximum	±10
Neutralization Number Increase, Maximum	0.20
SOLID PARTICLE CONTAMINATION	
Particles, No./100 x 10^{-6} m^3, (ml)	
Particle Size 10^{-6} m (microns)	
10-25	5,000
26-50	500
51-100	75
Over 100	15
STOARGE STABILITY	
Viscosity, after 6 Weeks at 40°C (104°F), Cs	50-60

NOTE: For a description and recommended usage of this silicone fluid, see Section II.

A product which meets the requirements of this specification is:

Product	Manufacturer
Versilube F-50	General Electric Company

MILITARY SPECIFICATION: MIL-H-83282B
HYDRAULIC FLUID, FIRE RESISTANT, SYNTHETIC HYDROCARBON BASE, AIRCRAFT

PROPERTIES	SPEC. REQ.	BRAYCO 882[a]/
COMPOSITION Base Oil	Synthetic Hydrocarbon	Synthetic Hydrocarbon
Additives		
Oxidation Inhibitor	< 2.0%	Report
Anti-Wear Agent (TCP)	Yes	Report
VISCOSITY, 10^{-6} m^2/Sec (Cs) at		
205°C (401°F), Minimum	1.0	1.16
100°C (212°F), Minimum	3.5	3.54
40°C (104°F), Minimum	14.0	15.39
-40°C (-40°F), Maximum	2,200	2,062
VISCOSITY INDEX		129
SPECIFIC GRAVITY, 16°C (60°F)	Report	0.8499
FLASH POINT, COC, Minimum	205°C (401°F)	229°C (444°F)
FIRE POINT, COC, Minimum	245°C (473°F)	254°C (489°F)
AUTOIGNITION TEMPERATURE, Minimum	343°C (650°F)	416°C (781°F)
POUR POINT, Maximum	-55°C (-67°F)	-68°C (-90°F)
USABLE TEMPERATURE RANGE	-40°C (-40°F) to 205°C (401°F)	-45°C (-49°F) to 204°C (399°F)
EVAPORATION, Weight Percent, Max. 6.5 Hr at 205°C (401°F)	20.0	
CORROSION AND OXIDATION STABILITY		
168 Hr at 135°C (275°F)		
Weight Change, 10^{-2} kg/m^2 (mg/cm^2)		
Steel	±0.20	0.00
Aluminum	±0.20	0.00
Magnesium	±0.20	0.00
Cadmium	±0.20	0.00
Copper	±0.60	-0.01
No Pitting, Etching, or Corrosion at 20X	Pass	Pass
Viscosity Change at 40°C (104°F), % Max.	10	2.5
Neutralization Number Increase, Max.	0.20	0.05
No Separation of Insolubles or Gumming	Pass	Pass
LOW TEMPERATURE STABILITY		
72 Hr at -40°C (-40°F)		
No Gelling, Clouding, Crystallization, Solidification or Separation	Pass	Pass
HIGH TEMPERATURE STABILITY		
100 Hr at 204°C (400°F)		
Viscosity Change, Percent, Maximum	5	+0.3
Neutralization Number Increase, Maximum	0.1	0.03
No formation of Precipitates or Insolubles	Pass	Pass
HIGH TEMP-HIGH PRESSURE SPRAY IGNITION	Pass	Pass
SWELLING OF SYNTHETIC RUBBER, Type NBR-L, % Volume Increase	18 to 30	21.3
WATER (KFR), ppm, Maximum	100	60

MILITARY SPECIFICATION: MIL-H-83282B
HYDRAULIC FLUID, FIRE RESISTANT, SYNTHETIC HYDROCARBON BASE, AIRCRAFT

PROPERTIES	SPEC. REQ.	BRAYCO 882[a/]
LUBRICITY (Four-Ball Wear Test)		
1 Hr each Load in kg, Wear Scar Diameter, mm, Maximum		
1 kg	0.21	0.15
10 kg	0.30	0.25
40 kg	0.65	0.48
FOAMING CHARACTERISTICS, 10^{-6} m^3 (ml)		
Foam, 5 Min Blowing/10 Min Settling		
(a) Sequence 1, 25°C (77°F)	65/0	30/0
(b) Sequence 2, 93°C (200°F)	65/0	30/0
(c) Sequence 3, 25°C (77°F)	65/0	30/0
SOLID PARTICLE CONTAMINATION		
No. of Particles Per 100 ml, microns		
5-15	2,500	800
16-25	1,000	200
26-50	250	50
51-100	25	5
Over 100	10	0
BULK MODULUS, Isothermal Secant,		
(0 to 10,000 psi) at 40°C (104°F), psi Minimum		
2,000	200,000	206,000
4,000	200,000	219,000
6,000	200,000	234,000
8,000	200,000	240,000
10,000	200,000	262,000

a/ Bray Products Division, Burmah-Castrol, Inc.

NOTE: For a description and recommended usage of this hydraulic fluid, see Section II.

Other products that meet the requirements of this specification are:

Product	Manufacturer
Royco 782-2	Royal Lubricants Company, Inc.
PQ 4923	American Oil & Supply Co.
Emery 2857	Emery Industries, Inc.
Hatcol 4285	Hatco Chemical Corp.
Petrofluid 822	Penreco, A Pennzoil Div.
Technolube	Technolube Products Company

LOW VOLATILITY, SYNTHETIC HYDRAULIC FLUID
AIRCRAFT DISILOXANE BASE (ROYAL LUBRICANTS COMPANY)

PROPERTIES	ROYCO 820X
COMPOSITION Base Oil	Disiloxane
Additives	
Viscosity-Temperature Coefficient Improvers	
Oxidation Inhibitor	Yes
Antiwear	
Corrosion Inhibitors	Yes
EP (extreme pressure)	
Other (hydrolysis)	Yes
VISCOSITY: 10^{-6} m^2/Sec (Cs) at	
-54°C (-65°F)	2,400
38°C (100°F)	32.0
99°C (210°F)	11.1
204°C (400°F)	3.7
VISCOSITY INDEX	
SPECIFIC GRAVITY, 16°C (60°F)	
FLASH POINT, COC	216°C (420°F)
FIRE POINT, COC	243°C (470°F)
AUTO IGNITION	399°C (750°F)
POUR POINT	< -73°C (< -100°F)
USABLE TEMPERATURE RANGE	-54°C (-65°F) to 177°C (350°F)
EVAPORATION, % (22 Hr at 99°C (210°F))	
VAPOR PRESSURE, N/m^2 (mm Hg) at 204°C (400°F)	133.32 (1.0)
CORROSION, COPPER STRIP 3 Hr at 100°C (212°F)	
NEUTRALIZATION NUMBER 10^{-3} kg KOH/kg (mg KOH/g)	0.01
FOAM CHARACTERISTICS (Method D 892) 10^{-6} m^3 (ml) Foam 10 Min Settling	
(a) Sequence 1, 24°C (75°F)	
(b) Sequence 2, 93°C (200°F)	
(c) Sequence 3, 24°C (75°F) (retest)	
COMPATIBILITY WITH: Rubber and Jet and Rocket Fuels	
LOX	
RUBBER SWELL, % Volume Change	
70 Hr at 121°C (25C°F), S Rubber	+7.0
148 Hr at 204°C (400°F), 26C rubber	+10.0
SHEAR STABILITY	Stable

LOW VOLATILITY, SYNTHETIC HYDRAULIC FLUID
ARICRAFT DISILOXANE BASE (ROYAL LUBRICANTS COMPANY)

PROPERTIES	ROYCO 820X
LOW TEMPERATURE STABILITY	
72 Hr at -54°C (-65°F)	Clear Liquid; No Haze or Crystals
SOLID PARTICLE CONTAMINATION	
HYDROLYTIC STABILITY, 48 Hr at 121°C (250°F)	
Weight Change, Copper, 10^{-2} kg/m^2 (mg/cm^2)	-0.02
Copper Appearance	Slight, Dulling
Acid No. Change	
Oil Layer	0.08
H_2O	0.02
Viscosity Change at 99°C (210°F), % Change	+1.8
Insolubles, % Weight	0.05

NOTE: Royco 820X is a disiloxane base synthetic hydraulic fluid with good viscosity temperature properties and low volatility. It also has good oxidation and corrosion properties and is shear stable.

USE: Newly designed aircraft and missile hydraulic systems operating at temperatures between -54°C and 177°C (-65°F and 350°F) and as a heat transfer media.

HIGH TEMPERATURE HYDRAULIC FLUID
SILICATE ESTER (CHEVRON INTERNATIONAL OIL COMPANY, INC.)

PROPERTIES	CHEVRON HYDRAULIC FLUID M2-V
COMPOSITION Base Oil	Silicate Ester
Additives	
Viscosity-Temperature Coefficient Improvers	
Oxidation Inhibitors	
Antiwear	
Corrosion Inhibitors	
EP (extreme pressure)	
Other	
VISCOSITY: 10^{-6} m^2/Sec (Cs) at	
-54°C (-65°F)	2,650
38°C (100°F)	17.6
99°C (210°F)	5.45
177°C (350°F)	2.14
232°C (450°F)	1.32
VISCOSITY INDEX	
SPECIFIC GRAVITY, 16°C (60°F)	
DENSITY, 16°C (60°F) kg/10^{-3} m^3 (g/cc)	0.9464
FLASH POINT, COC	216°C (420°F)
FIRE POINT, COC	260°C (500°F)
AUTO IGNITION TEMPERATURE	404°C (760°F)
POUR POINT	< -79°C (< -110°F)
USABLE TEMPERATURE RANGE	-54°C (-65°F) to 260°C (500°F)
EVAPORATION, % (22 Hr at 99°C (210°F))	
VAPOR PRESSURE, N/m^2 (mm Hg) at 204°C (400°F)	77.33 (0.58)
OXIDATION AND CORROSION STABILITY	
204°C (400°F) 72 Hr	
Silver	Nil
Aluminum	Nil
Weight Change, 10^{-2} kg/m^2 (mg/cm^2)	
Steel	+0.01
Copper	-0.55
CORROSION, COPPER STRIP	
3 Hr at 100°C (212°F)	0.04
NEUTRALIZATION NUMBER	
10^{-3} kg KOH/kg (mg KOH/g)	
FOAM CHARACTERISTICS (Method D 892)	
10^{-6} m^3 (ml) Foam 5 Min Blow/Time to Break	
(a) Sequence 1, 24°C (75°F)	130/4.75
(b) Sequence 2, 93°C (200°F)	40/1.33

HIGH TEMPERATURE HYDRAULIC FLUID
SILICATE ESTER (CHEVRON INTERNATIONAL OIL COMPANY, INC.)

PROPERTIES	CHEVRON HYDRAULIC FLUID M2-V
COMPATIBILITY WITH: Rubber and	
Jet and Rocket Fuels	
LOX	
SHEAR STABILITY	
LOW TEMPERATURE STABILITY	
SOLID PARTICLE CONTAMINATION	
SHEAR STABILITY, 2 Hr Sonic Osc. Test % Original Viscosity at 99°C (210°F)	98.8
THERMAL STABILITY, % 99°C (210°F) Viscosity after 2 Hr at 316°C (600°F)	-
LUBRICITY, 4-Ball Wear Test (2 Hr, 1,200 rpm, 135°C (275°F) 52100 Steel))	
98.1 N (10kg) Load, Scar Diameter, 10^{-3} m	0.78
372.4 N (40 kg) Load, Scar Diameter, 10^{-3} m	0.88

NOTE: M2-V has an operating range of -54°C to 260°C (-65°F to +500°F) and is recommended for Type III and higher aircraft hydraulic systems. It is a stable nontoxic fluid requiring no special handling. Contains no VI improvers, thus has good viscosity stability. Also has good thermal and shear stability and extended service life.

TYPICAL PROPERTIES OF GENREAL ELECTRIC SILICONE FLUIDS

Silicone Fluid	Flash Point, °C	Pour Point, °C	Specific Gravity, 25°C	Viscosity 10^{-6} m^2/Sec (Cs) at 25°C	Viscosity Temperature Coefficient	Refractive Index, 25°C	Surface Tension, 25°C, Dynes/Cm	Thermal Expansion (vol/vol/°C) 25°C to 150°C	Thermal Conductivity Watt/m°C, 66°C	Maximum Volatility, % Wt. Loss, 24 Hr at 150°C (760 mm. Hg.)	Specific Heat Joule/kg-°C	Electrical Properties			
													25°C, 10^2 - 10^6 Cycles		
												Dielectric Strength (kv/mil)	Dissipation Factor	Dielectric Constant	Volume Resistivity (ohm-cm)
SF-97	>300	-55	0.960	50	0.59	1.402	20.8	0.00106	0.1496	0.5	1.507	35.0	0.0001	2.70	1×10^{14}
Viscasil	316 316	-49 -40	0.975 0.978	5,000.0 100,000.0	0.60 0.60	1.4035 1.4035	21.3 21.3	0.000925 0.000925	0.1556 0.1336	2.0 2.0	1,507 1,507	35.0 35.0	0.0001 0.0001	2.75 2.75	1×10^{14} 1×10^{14}
SF-81	>232	-84	0.972	50	0.57	1.403	21.0	0.000950	0.1496	0.5	1,507	35.0	0.0001	2.74	1×10^{14}
SF-99	63	-	0.970	10	0.59	-	20.5	-	-	0.36	-	-	-	-	-
SF-1154	302	-46	1.07	125	0.79	1.498	24.7	0.00075	0.1411	0.30	1,633	32.5	0.0005	2.88	1×10^{14}
F-50	>288	-73	1.05	70	0.68	1.4280	21.0	0.000975	0.1556	0.5	1,424	29.0	0.0013	2.90	8×10^{12}
SF-1147	>315	-51	0.89	50	0.76	1.4433	26.0	0.00085	0.1228	2.5	1,303	-	0.0001	2.43	3.6×10^{12}

NOTES:
1. These are typical values for General Electric silicone fluids, several additional viscosity ranges are available in most grades within the limits shown.
2. SF-97 and VISCASIL (this page) and SF-96 (next page) meet requirements of VV-D-1078A.
3. F-50 meets requirements of MIL-S-81087C.

APPLICATION GUIDE - GENERAL ELECTRIC SILICONE FLUIDS

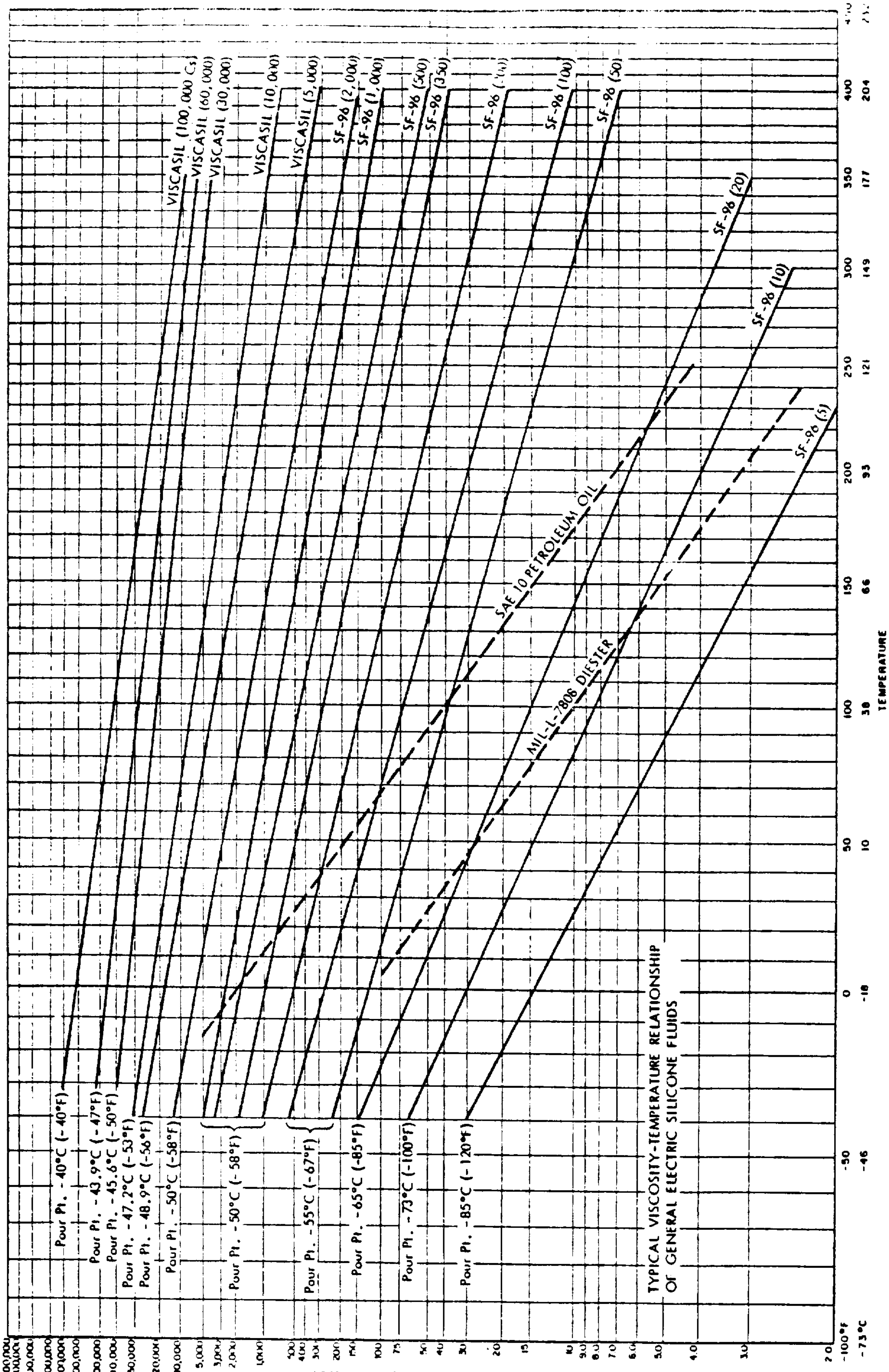
		Damping Fluids								Heat Transfer				Power Transmission		Other Mechanical Uses				Lubrication				Electrical**			
Product	Nominal Viscosity	Dashpots	Aircraft Instruments	Time Delay Relays	Gyros	Shock Absorbers	Meters	Torsional Vibration Dampers	Timing Devices	Heating Baths	Low Temperature Baths	Heat Exchangers	Thermostats	Fluid Clutches*	Controlled Speed Devices*	Hydraulic Fluids	Fluid Springs	Electrical Discharge Machining Coolants	Rust Preventive Oil	Transducers	Lubricate O-rings	Lubricate Rubber or Plastic Parts	Base Fluids for Grease	Sliding Metal on Metal Lubrication	Coolant for Transformer Capacitors & Amplifiers	Coolant for Tubes, Rectifiers, Electronic Modules	Extreme Temperature Range Coolant	Curable Treatment for Electrodes
SF-96	5																x	x		x								
	20				x							x	x												x	x		
	50		x		x		x			x		x	x			x				x					x	x		
	100	x	x	x	x		x			x		x	x				x			x		x	x					
	200	x	x	x	x		x															x						
	350	x	x	x	x		x	x														x						
	500	x	x	x	x		x	x						x	x							x	x					
	1,000	x	x	x	x	x		x						x	x		x					x	x					
Viscasil	5,000	x	x	x	x	x		x	x					x	x						x							
	10,000	x	x	x		x		x	x					x	x		x				x		x					
	30,000	x	x	x		x		x	x					x							x							
	60,000	x	x	x		x		x	x					x							x							
	100,000	x	x	x		x		x	x					x							x							
SF-18	350																					x						
SF-81	50		x	x			x				x		x										x		x	x		
SF-99	10																											x
SF-1154	175									x		x								x					x	x		
F-50	70															x							x	x				
SF-1147	50					x	x		x							x				x		x		x				

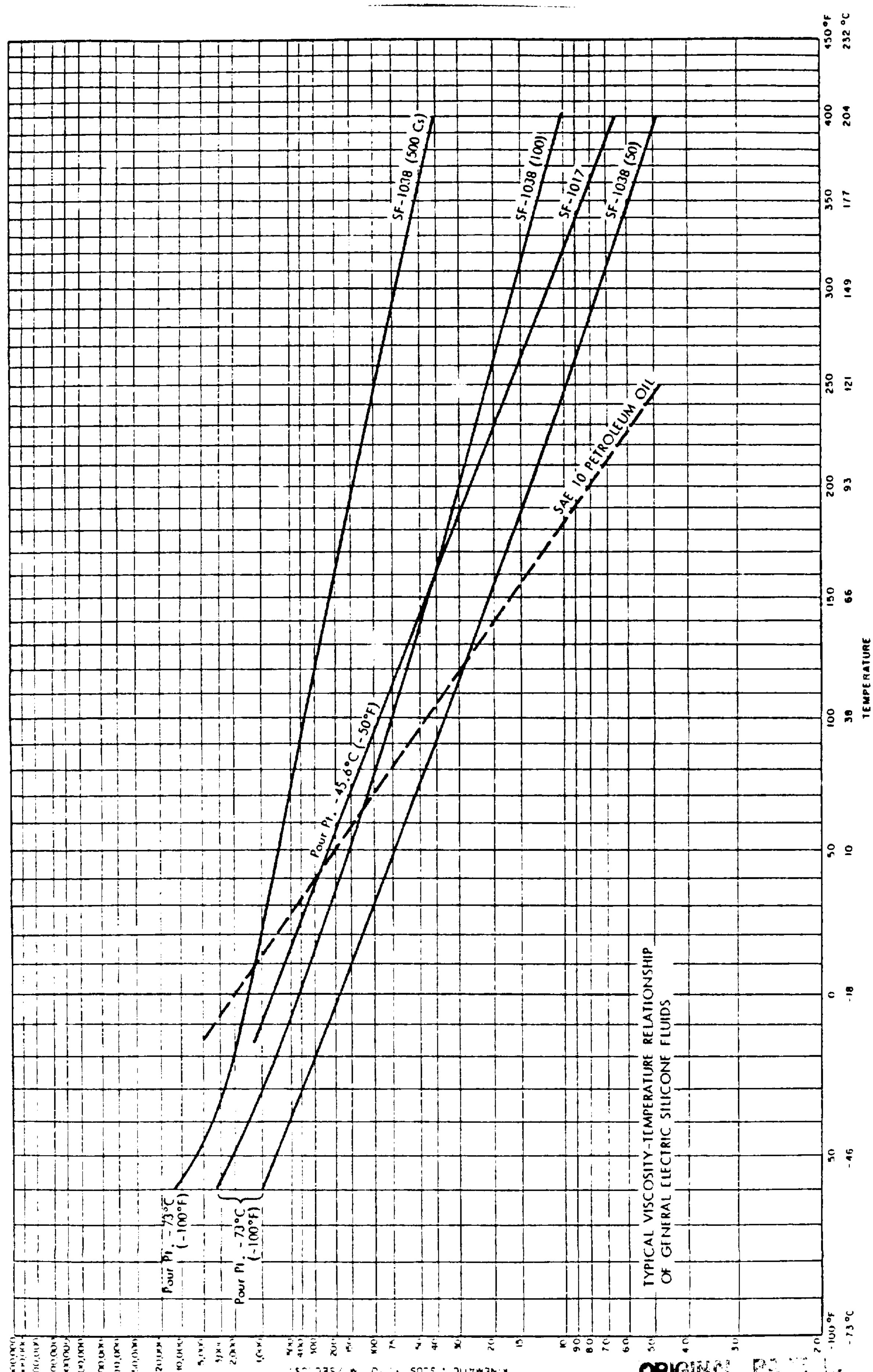
* Special blending of fluids may be required for obtaining specific shear viscosity characteristics.
** SF-97 electrical grade versions of SF-96 series are recommended for these applications.

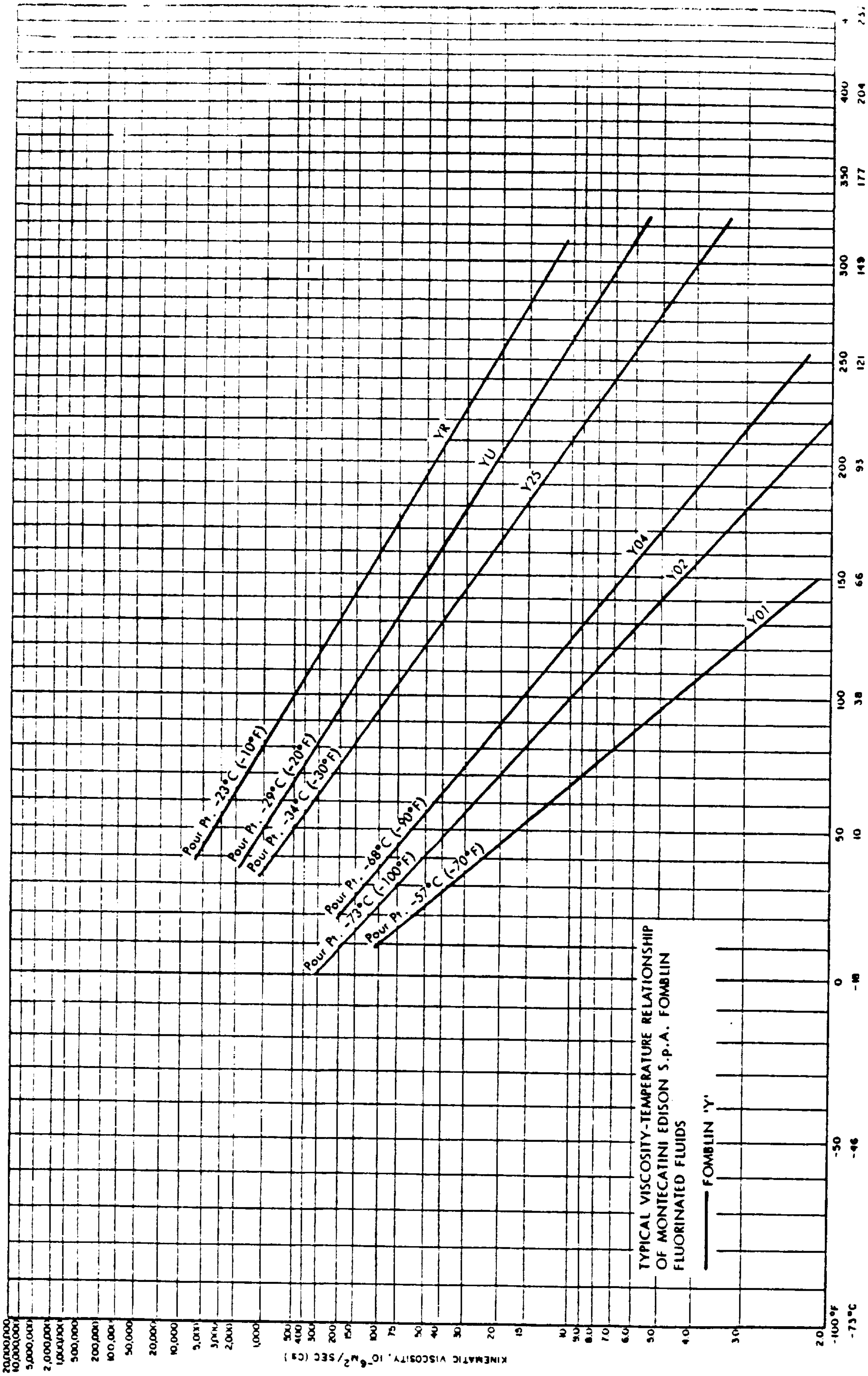
TYPICAL PROPERTIES OF DOW CORNING SILICONE FLUIDS

Dow Corning Fluids	Viscosity, 10^{-6} m²/sec (Cs.) 25°C (77°F)	Flash Point	Pour Point (freezing point)*	Specific Gravity 25°C	Coefficient of Expansion (cc/cc, °C)	Refractive Index 25°C	Surface Tension, 25°C, Dynes/Cm	Thermal Conductivity Watt/m°C at 25°C	Boiling Point	Specific Heat Joule/kg 40°C	Specific Heat Joule/kg 100°C	Specific Heat Joule/kg 200°C	Electric Strength (volts/ml)	Dielectric Constant 10^2 Cycles	Dielectric Constant 10^6 Cycles	Volume Resistivity (ohm-cm.)
200	0.65 to 20.0	-1°C to 232°C	-84°C* to -60°C	0.761 to 0.955	0.00096 to 0.00134	1.375 to 1.400	15.9 to 20.6	0.10042 to 0.14226	99.5°C-230°C at 760 mm. Hg. and 70°C-200°C 0.5 mm. Hg.	1444	1464	1502	250 to 350	2.18 to 2.68	2.18 to 2.68	1 x 10^{16} to 1 x 10^{14}
									Volatility (48 hr. wt. loss at temp.)							
	50 to 60,000	279°C to 316°C	-55°C to -41°C	0.960 to 0.973	0.00104 to 0.00096	1.402 to 1.4035	20.8 to 21.5	0.15062 to 0.15899	2.5% at 200°C to 2.0% at 200°C	1402	1443	1477	350 to 375	2.71 to 2.76	2.71 to 2.76	1 x 10^{14} to 2 x 10^{5}
210	1,000 to 30,000	316°C to 316°C	-58°C to -44°C	0.972 to 0.973	0.00096 to 0.00096	1.4035 to 1.4035	21.2 to 21.5	0.15899 to 0.15899	2.0% at 200°C to 2.0% at 200°C	-	-	-	350 to 375	2.74 to 2.76	2.74 to 2.76	5 x 10^{14} to 2 x 10^{15}
330	50	291°C	-100°C*	0.968	0.00107	1.4023	20.5	0.14226	3.2% at 200°C	1464	1506	1573	375	2.73	2.73	5 x 10^{14}
510	50 to 1,000	274°C to 274°C	-73°C* to -73°C*	1.00 to 1.00	0.00096 to 0.00096	1.425 to 1.425	25.0 to 24.7	0.14644 to 0.15481	14% at 250°C to 3% at 250°C	1556 / 1556	1657 / 1657	1824 / 1824	350 to 350	2.77 to 2.81	2.77 to 2.81	1 x 10^{14} to 1 x 10^{14}
550	125	302°C	-51°C*	1.07	0.00075	1.50	24.5	0.14644	9% at 250°C	1498	1615	1812	350	2.89	2.89	1 x 10^{14}
555	20	121°C	-43°C*	1.06	0.00093	1.49	25.0	0.12552	8% at 150°C	-	-	-	350	2.71	2.71	2 x 10^{14}
560	75	288°C	-70°C*	1.04	0.00095	1.436	23.0	0.15062	14% at 250°C	1464	1565	1728	350	2.92	2.92	2 x 10^{14}
710	500	302°C	-22°C	1.11	0.00077	1.533	28.5	0.14644	13% at 250°C	1519	1900	2113	350	2.95	2.95	1 x 10^{14}
FS 1265	300 to 10,000	260°C to 316°C	-48°C* to -32°C*	1.25 to 1.30	0.00095 to 0.00095	1.381 to 1.383	25.7 to 28.7	-	10% at 200°C to 1.5% at 200°C	-	-	-	200 to 175	6.95 to 7.35	6.90 to 7.30	3 x 10^{10} to 1.5 x 10^{11}

These are typical values for Dow Corning Silicon Fluids; several viscosity ranges are available in each grade within the limits shown.

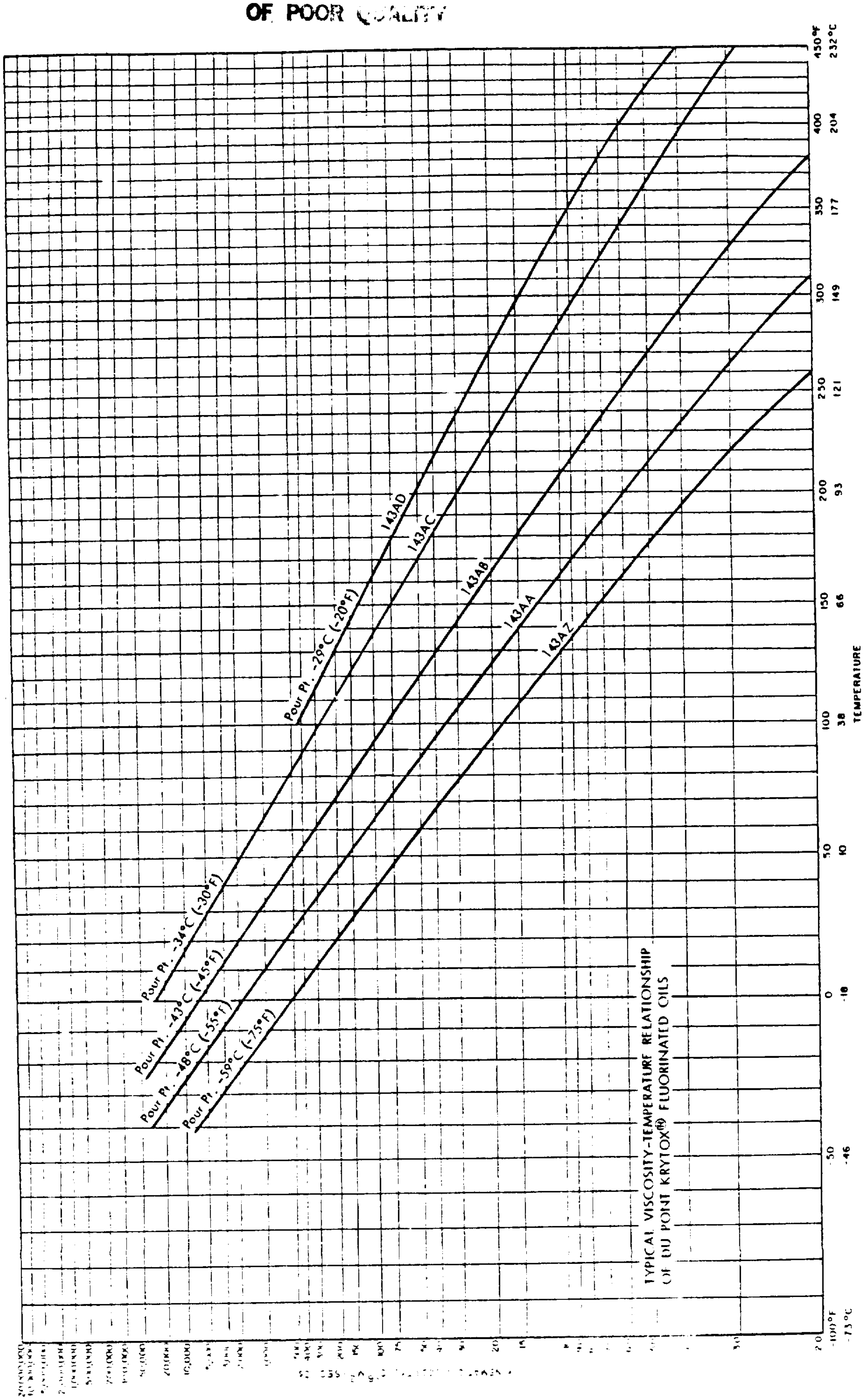

TYPICAL VISCOSITY-TEMPERATURE RELATIONSHIP OF GENERAL ELECTRIC SILICONE FLUIDS
VISCASIL (100,000 Cs)
VISCASIL (60,000)
VISCASIL (30,000)
VISCASIL (10,000)
VISCASIL (5,000)
SF-96 (2,000)
SF-96 (1,000)
SF-96 (500)
SF-96 (350)
SF-96 (100)
SF-96 (50)
SF-96 (20)
SF-96 (10)
SF-96 (5)
SAE 10 PETROLEUM OIL
MIL-L-7808 DIESTER
Pour Pt. -40°C (-40°F)
Pour Pt. -43.9°C (-47°F)
Pour Pt. -45.6°C (-50°F)
Pour Pt. -47.2°C (-53°F)
Pour Pt. -48.9°C (-56°F)
Pour Pt. -50°C (-58°F)
Pour Pt. -50°C (-58°F)
Pour Pt. -55°C (-67°F)
Pour Pt. -65°C (-85°F)
Pour Pt. -73°C (-100°F)
Pour Pt. -85°C (-120°F)
TEMPERATURE
-100°F -73°C
-50 -46
0 -18
50 10
100 38
150 66
200 93
250 121
300 149
350 177
400 204
KINEMATIC VISCOSITY, 10⁻⁶ M²/SEC (CS)
20,000,000
10,000,000
5,000,000
2,000,000
1,000,000
500,000
200,000
100,000
50,000
20,000
10,000
5,000
3,000
2,000
1,000
500
400
300
200
150
100
75
50
40
30
20
15
10
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0

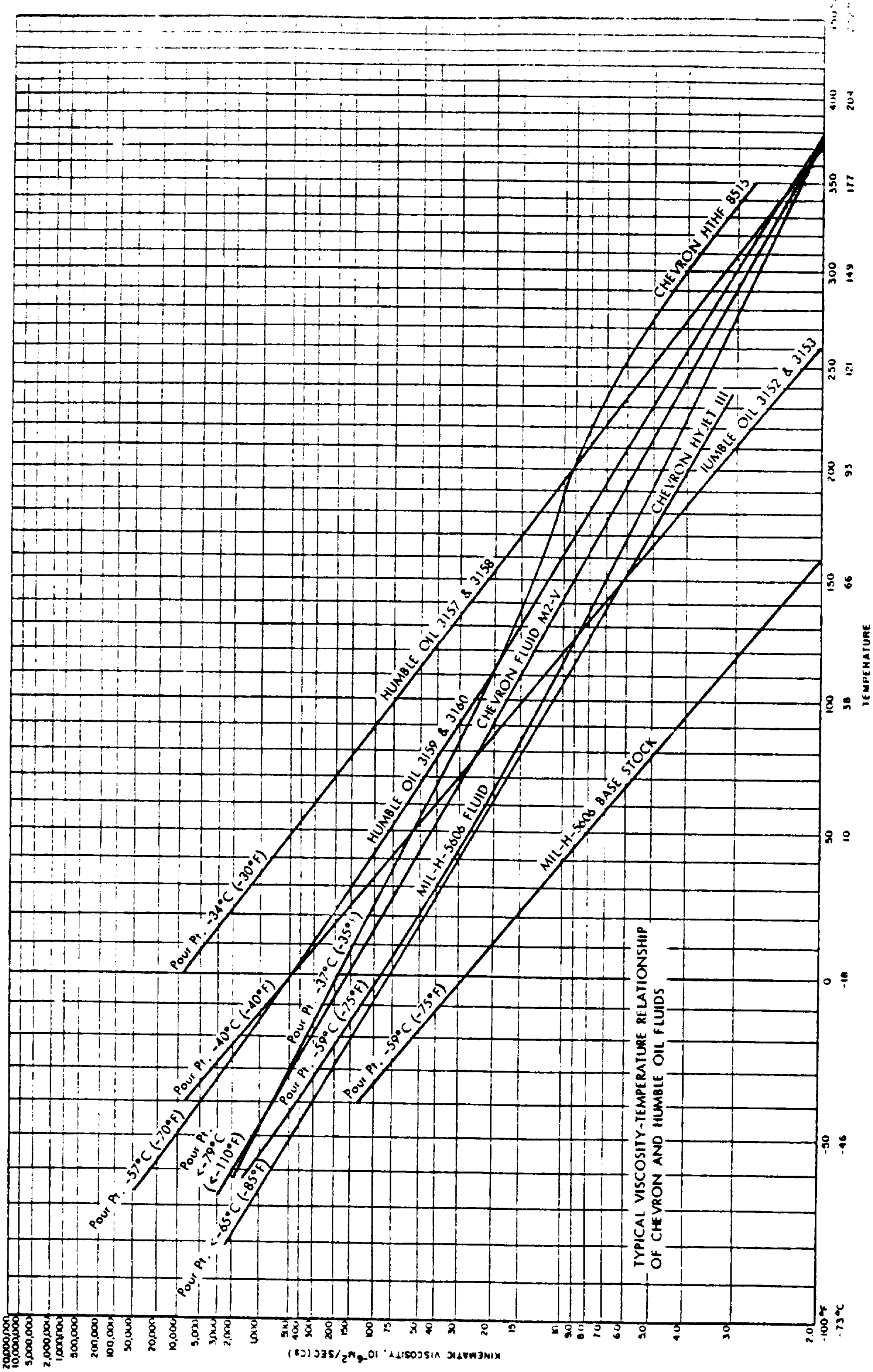

TYPICAL VISCOSITY-TEMPERATURE RELATIONSHIP
OF GENERAL ELECTRIC SILICONE FLUIDS
SF-1038 (500 Cs)
SF-1038 (100)
SF-1017
SF-1038 (50)
SAE 10 PETROLEUM OIL
Pour Pt. -45.6°C (-50°F)
Pour Pt. -73°C (-100°F)
Pour Pt. -73°C (-100°F)
TEMPERATURE
-100 °F
-73 °C
-50
-46
0
-18
50
10
100
38
150
66
200
93
250
121
300
149
350
177
400
204
450 °F
232 °C

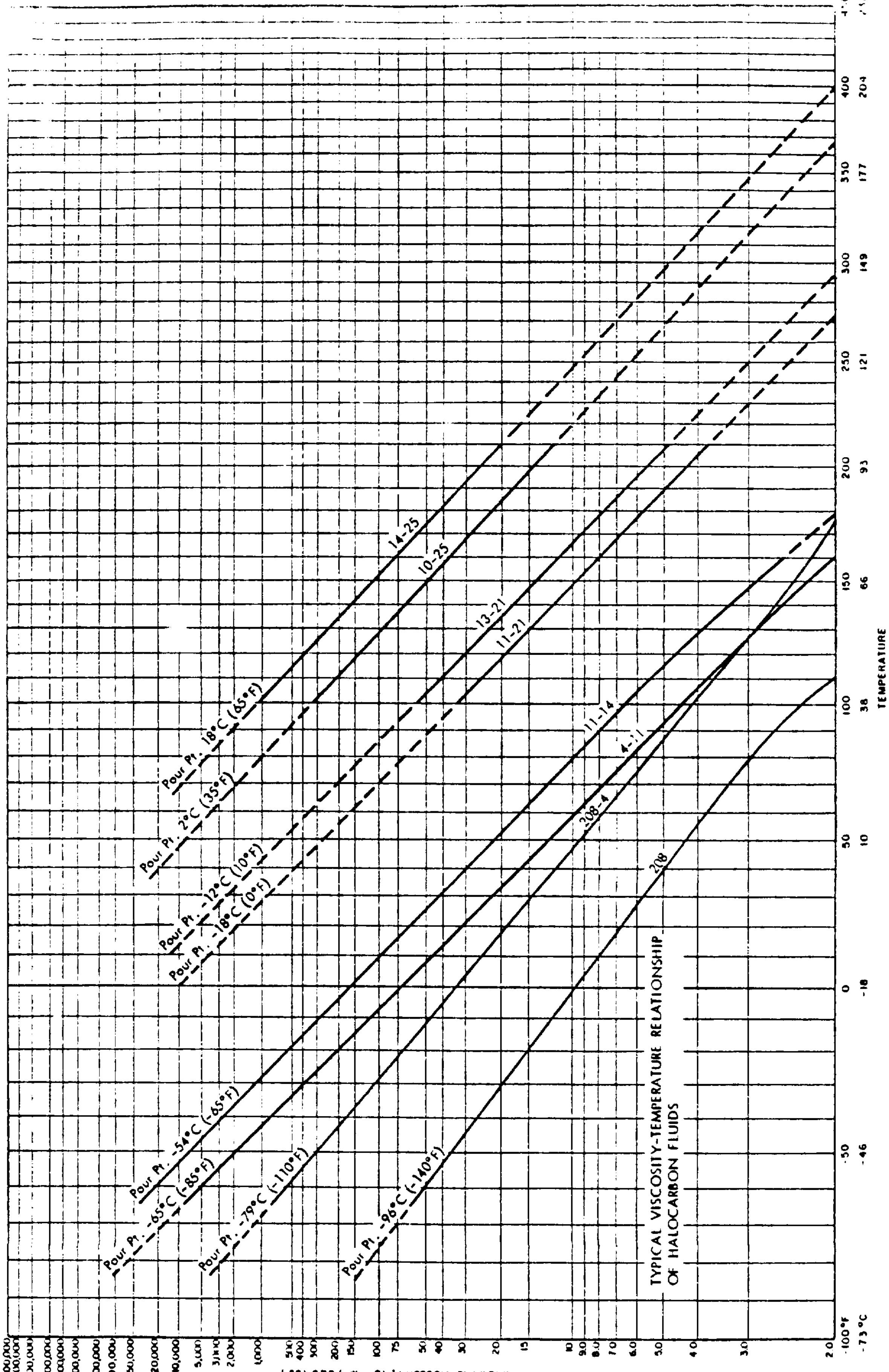


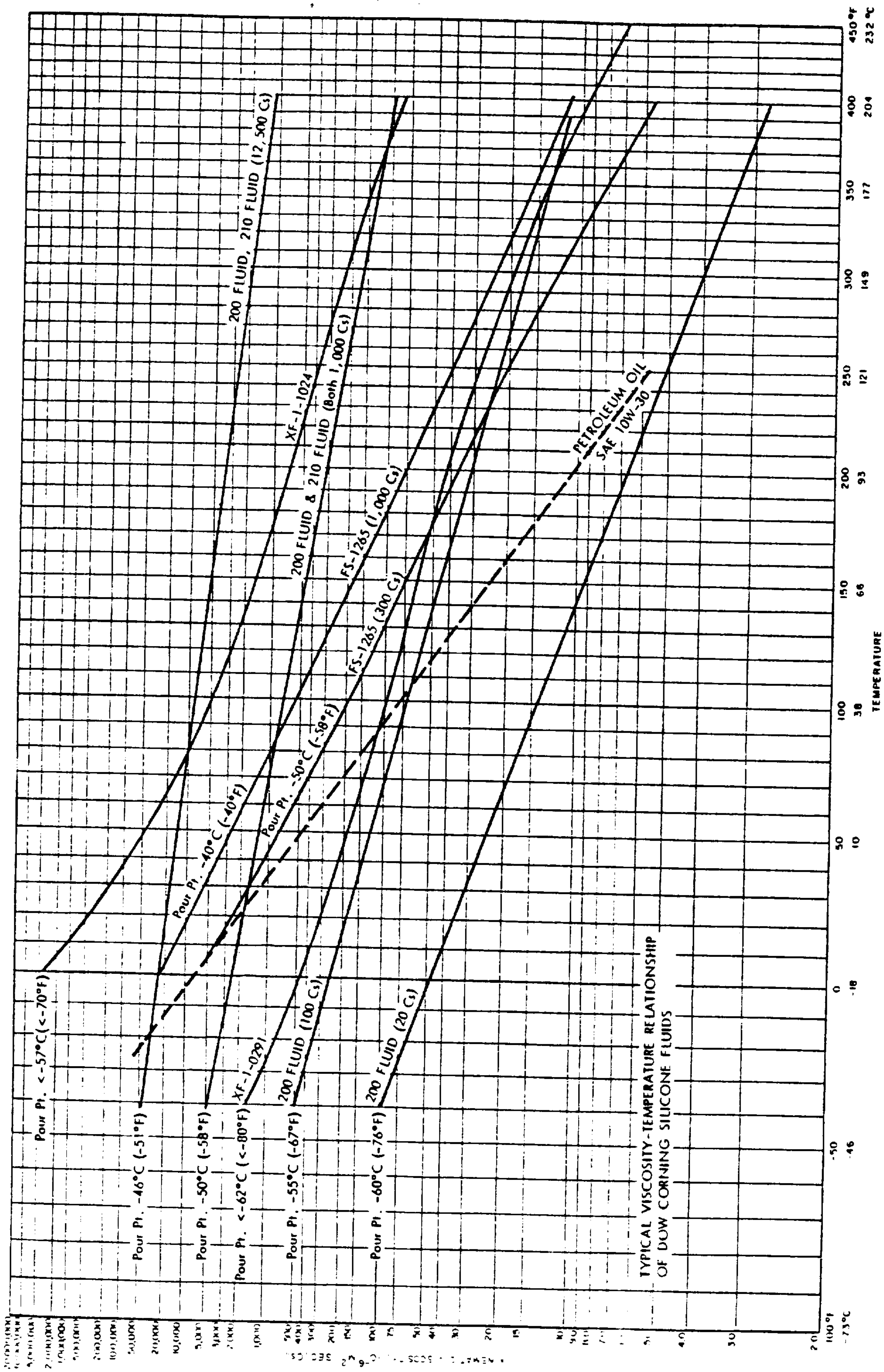
TYPICAL VISCOSITY-TEMPERATURE RELATIONSHIP
OF MONTECATINI EDISON S.p.A. FOMBLIN
FLUORINATED FLUIDS
FOMBLIN 'Y'
YR
YU
Y25
Y04
Y02
Y01
Pour Pt. -23°C (-10°F)
Pour Pt. -29°C (-20°F)
Pour Pt. -34°C (-30°F)
Pour Pt. -68°C (-90°F)
Pour Pt. -73°C (-100°F)
Pour Pt. -57°C (-70°F)
KINEMATIC VISCOSITY, $10^{-6}M^2$/SEC (CS)
TEMPERATURE
-100°F -73°C
-50 -46
0 -18
50 10
100 38
150 66
200 93
250 121
300 149
350 177
400 204
20,000,000
10,000,000
5,000,000
2,000,000
1,000,000
500,000
200,000
100,000
50,000
20,000
10,000
5,000
3,000
2,000
1,000
500
400
300
200
150
100
75
50
40
30
20
15
10
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0

C-5


TYPICAL VISCOSITY-TEMPERATURE RELATIONSHIP
OF DU PONT KRYTOX® FLUORINATED OILS
143AD
143AC
143AB
143AA
143AZ
Pour Pt. -29°C (-20°F)
Pour Pt. -34°C (-30°F)
Pour Pt. -43°C (-45°F)
Pour Pt. -48°C (-55°F)
Pour Pt. -59°C (-75°F)
TEMPERATURE
-100°F -73°C
-50 -46
0 -18
50 10
100 38
150 66
200 93
250 121
300 149
350 177
400 204
450°F 232°C


TYPICAL VISCOSITY-TEMPERATURE RELATIONSHIP
OF CHEVRON AND HUMBLE OIL FLUIDS
CHEVRON HTHF 8515
HUMBLE OIL 3157 & 3158
CHEVRON FLUID M2-V
HUMBLE OIL 3159 & 3160
MIL-H-5606 FLUID
MIL-H-5606 BASE STOCK
CHEVRON HYJET III
HUMBLE OIL 3152 & 3153
Pour Pt. -34°C (-30°F)
Pour Pt. -40°C (-40°F)
Pour Pt. -37°C (-35°F)
Pour Pt. -59°C (-75°F)
Pour Pt. -59°C (-75°F)
Pour Pt. -57°C (-70°F)
Pour Pt. <-79°C (<-110°F)
Pour Pt. <-65°C (-85°F)
TEMPERATURE
KINEMATIC VISCOSITY, 10^{-6} M^2/SEC (CS)


TYPICAL VISCOSITY-TEMPERATURE RELATIONSHIP
OF HALOCARBON FLUIDS
14-25
10-25
13-21
11-21
11-14
4-21
208-4
208
Pour Pt. 18°C (65°F)
Pour Pt. 2°C (35°F)
Pour Pt. -12°C (10°F)
Pour Pt. -18°C (0°F)
Pour Pt. -54°C (-65°F)
Pour Pt. -65°C (-85°F)
Pour Pt. -79°C (-110°F)
Pour Pt. -96°C (-140°F)
TEMPERATURE
400 204
350 177
300 149
250 121
200 93
150 66
100 38
50 10
0 -18
-50 -46
-100°F -73°C
KINEMATIC VISCOSITY, 10⁻⁶M²/SEC (CS)
20,000,000
10,000,000
5,000,000
2,000,000
1,000,000
500,000
200,000
100,000
50,000
20,000
10,000
5,000
3,000
2,000
1,000
500
400
300
200
150
100
75
50
40
30
20
15
10
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0


TYPICAL VISCOSITY-TEMPERATURE RELATIONSHIP
OF DOW CORNING SILICONE FLUIDS
TEMPERATURE
200 FLUID, 210 FLUID (12,500 Cs)
XF-1-1024
200 FLUID & 210 FLUID (Both 1,000 Cs)
FS-1265 (1,000 Cs)
FS-1265 (300 Cs)
PETROLEUM OIL
SAE 10W-30
Pour Pt. -40°C (-40°F)
Pour Pt. -50°C (-58°F)
XF-1-0291
200 FLUID (100 Cs)
200 FLUID (20 Cs)
Pour Pt. <-57°C (<-70°F)
Pour Pt. -46°C (-51°F)
Pour Pt. -50°C (-58°F)
Pour Pt. <-62°C (<-80°F)
Pour Pt. -55°C (-67°F)
Pour Pt. -60°C (-76°F)
450°F 232°C
400 204
350 177
300 149
250 121
200 93
150 66
100 38
50 10
0 -18
-50 -46
-100°F -73°C

B-IV. LONG TERM LABORATORY EVALUATIONS

I. INTRODUCTION

A group of 38 grease lubricants have been subjected to long-term tests under various conditions at the Marshall Space Flight Center by E. L. McMurtrey. The conditions used in these evaluations were selected to provide information needed for prior lubricant-bearing applications on actual spacecraft. The test conditions included: low temperature, vacuum and oxidation environments and start-stop operation in vacuum.

The lubricants, which include seven general chemical classes, are described in Table 1. These lubricants were selected to represent most of the military grease specifications, as well as specific nonspecification materials which had shown promise in space applications. The lubricants were evaluated in R-4 ball bearings for a period up to 1 year. Each test ran four times to permit statistical appraisal of the data. This series of tests was used to select four grease lubricants for tests of 5-year duration.

The following parts of this section will: (a) describe the test equipment; (b) outline the test procedures; and (c) present the tests results.

II. TEST EQUIPMENT

To provide a statistical sample of a number of lubricants operating under various environmental conditions, it was necessary to conduct a large number of tests simultaneously. Therefore, 20 test motors, each containing two test bearings, were set up in each chamber. Each test set consists of four samples (eight bearings) of five different lubricants. The bearings chosen for testing are size R-4, 0.635 cm ID by 1.59 cm OD (0.25 in. ID x 0.625 in. OD), 440 C steel (RC 60-65) with ribbon type stainless steel cages. An approximate 25 to 30% fill of the candidate greases was applied to each bearing, unless otherwise specified.

The motors used in these tests have the following characteristics:

1. Type — ac hysteresis, single phase, 60 cycle.

2. Speed — 3,600 rpm, synchronous.

3. Current — 0.22 amps.

Since these motors do not use brushes, no problems are encountered with brush dust contamination of the bearings. In addition, these motors use approximately the same current when stalled as when operating at 3,600 rpm, so a bearing failure does not cause motor damage from overheating.

To control temperature, the motors are mounted in an aluminum plate which is furnished with passages so that thermal control fluids (water or liquid nitrogen) may be used to control the motor temperature. Temperature is measured by thermocouples attached to the mounting plate and to selected motor cases.

TABLE 1. DESCRIPTION OF TEST LUBRICANTS

Manufacturer Designation	Lubricant Code	MIL Spec	Gen. Chem. Class of Base Oil	Thickener	38C Oil Viscosity (cs)	Oil Viscosity Index	Description of Greases
KG80	M-1	83176 A	Highly Refined Mineral	Inorganic	158	101	Instrument Brg.
SRG 200	M-2		Highly Refined Mineral	Inorganic	400	110	Brg.
Aeroshell 5	M-3	3545B	Mineral	Microgel	300		Hi Temp Acft
Royco 24R	M-4	10924 D(1)	Mineral	Li Soap			General Purpose
Royco 49	M-5	23549 C	Mineral	MoS_2-Nonsoap			General Purpose
Royco 49B		23549 C	Mineral	MoS_2-Nonsoap			General Purpose
Aeroshell 14	M-6	25537 C	Mineral	Ca Soap	14		Oscillating Brg.
Aeroshell 16	M-7	25760A	Synthetic Mineral	Microgel	38		Brg., Wide Temp. Range
Apiezon L	M-8		Straight Chain Hydrocarbon	None			Vacuum
Unitemp 500	M-9		Mineral-Diester	Na Soap	55		Brg., Wide Temp. Range
Mobilgrease 28	M-10	81322 D	Synthetic Hydrocarbon	Nonsoap			Hi Temp. Acft.
Conoco HD #2	M-11		Mineral	Synthetic	108		Hi Temp. Corr. Resistant
BP 2110	M-12		Mineral	Graphite-Lead	119.7	107	Brg., Vacuum
Exxon Andok C	M-13		Mineral	Na Soap	110		Long Life Anti-Friction
Supermil 06752	ES-1	25760A	Diester	Arylurea			Brg., Wide Temp.
Aeroshell 17	ES-2	21164D	Diester	Microgel	14		Wide Temp. with MoS_2
Aeroshell 7	ES-3	23827B	Diester	Microgel	14		Acft. Instrument
L-11G	ES-4		Diester	Li Soap + MoS_2	14		Acft. Instrument
Exxon 5182	ES-5		Synthetic Ester	Li Soap	162	160	Hi Temp. Acft.
Beacon 325	ES-6	23827B	Synthetic Ester	Li Soap	11.8		Low Temp.
BP 8135	ES-7		Ester	Graphite-Lead	27.5	137	Brg., Vacuum
DC No. 33	Si-1		Silicone	Li Soap	750		Vacuum
G-351	Si-2		Silicone	Li Soap			Hi Temp. Ball Brg.
Supermil 31052	Si-3	25013E	Silicone	Organic Dye			Ball and Roller Brg.
G-330M	Si-4		Silicone				General Purpose
G-341L	Si-5		Silicone				Acft. and Instrument
3L27-2	Si-X		Silicone	Silica			Rad. Res't. Brg. Experimental
FS-1281	FS-1		Fluoro-Silicone	Silica			Vac. Low Speed Brg.
FS-1290	FS-2		Fluoro-Silicone				Chem. Inert Brg.
Kel-F No. 90	FCC-1		Fluoro-Carbon	Silica			Chem. Inert Hi Temp.
803	PFPE-1		PFPE	Fluorotelomer	424	129	Hi Vac. Brg.
3L-38RP	PFPE-2		PFPE	Fluorotelomer	129	350	Chem. Inert Hi and Low Temp.
3L-38RP Baked*			PFPE	Fluorotelomer			
631A	PFPE-3		PFPE	Fluorotelomer	153	110	Chem. Inert Brg.
240AZ	PFPE-4		PFPE	Fluorotelomer	18	23	Chem. Inert Low Temp.
240AB	PFPE-5		PFPE	Fluorotelomer	85	113	Chem. Inert Vacuum, Hi Temp.
240AC	PFPE-6		PFPE	Fluorotelomer	270	134	Chem. Inert Vacuum, Hi Temp.
3L-38-MS	PFPE-7		PFPE	Fluorotelomer			Chem. Inert Wide Temp. with MoS_2

* Vacuum baked at 100°C (212°F) for 20 hr.

Note: M-3 MIL-SPEC-3545B superseded by MIL-G-81322D
M-7 MIL-SPEC-25760A superseded by MIL-G-81322D
ES-1 MIL-SPEC-25760A superseded by MIL-G-81322D

Each mounting plate with its motor set is placed in a glass bell jar vacuum system. These bell jars are part of a 12 position vacuum system which is capable of maintaining pressures in the 1.3×10^{-4} N/m^2 (1×10^{-6} torr) range during test operation. The same bell jars are used for the oxidation and low temperature tests.

III. TEST PROCEDURE

Since most bearings operating in space are not subject to a radial load, the major load to the test bearings is a thrust load applied by a wave washer. The motors, specially ordered from the manufacturer, are shimmed to maintain a 2.27 kg (5 lb) thrust load on both bearings. This load is equivalent to a 1.28×10^9 N/m^2 (185,000 psi) Hz stress on the balls and inner races. The speed of 3,600 rpm allows 216,000 revolutions on each bearing per hour until failure. Each bearing which survives the 1-year test will have completed approximately 1,892,000,000 revolutions.

The environments for the test program are as follows:

1. 10.134×10^4 N/m^2 (14.7 psi) air at 90% relative humidity (oxidation tests).
2. 6.894×10^4 N/m^2 (10 psi) O_2 at 90% relative humidity (oxidation tests).
3. Vacuum, ambient temperature (38°C).
4. Vacuum, high temperature (93.3°C).
5. Vacuum, ambient temperature, with start-stop operation.
6. Low temperature start.

The evaluations for all tests, except the low temperature tests, are primarily on a go/no-go system. The motor torque is low and the inertia of the system is low; therefore, when the bearing tends to seize, the motor stops without further damage to the bearings. The following data are taken during the test:

1. Total test time.
2. Vacuum or atmospheric conditions.
3. Temperature.

The bearings are weighed before and after testing and the weight loss of lubricant is calculated.

In the low temperature tests, the motors are installed in the cooling plate and the system is evacuated to prevent frost formation. Liquid nitrogen is circulated through the cooling plate. The temperature is measured with thermocouples in contact with the outer race of the front bearing. Before cooling is initiated, the motors are operated for 30 min to channel the grease. The temperature is dropped to -100°C and held approximately 30 min. The temperature is then allowed to rise slowly using a thermocopule of the mounting plate for control. After each 3°C, the motors are switched on for approximately 5 sec and the temperature of the front bearings is recorded. When each motor starts and comes up to full speed, the front bearing temperature is used as the low temperature starting capability of the lubricant. Starting torque of the motors used in this test is 1.05 x 10^{-2} N/m (1-1/2 in. oz). Each low temperature test is repeated at least twice, and an average temperature is taken of the four motors and two tests.

IV. TEST RESULTS

A. Low Temperature Tests

Twenty-six lubricants have been evaluated for low temperature capability. The temperature at which the bearings will stall is a function of the volume of grease in the bearing as well as the viscosity of the grease; therefore, some variation in stall temperature will occur. To help overcome this difficulty, four motors are tested with each lubricant and at least two tests are made on each motor. The resulting stall temperatures are then averaged. Results of these tests are given in Table 2. The grease lubricants are arranged in the order of lowest to highest stall (start) temperature. Ordinarily the vacuum stability requirements are mutually exclusive because low viscosity fluid provides better low temperature capabilities and a high viscosity fluid tends to be more vacuum stable. The results of these tests are, therefore, rather surprising since the PFPE-2 grease which has 38°C viscosity of 130 cs has superior low temperature capabilities, and is also one of the most vacuum stable greases evaluated. These capabilities are somewhat more understandable when it is noted that the base oil for this grease has a viscosity index of 350 and a molecular weight of over 9,000.

TABLE 2. LOW TEMPERATURE START, °C

Lubricant	1	2	3	4	Average
Si-3	-62.8	-78.9	-76.1	-70.0	-71.9
PFPE-7	-68.6	-68.6	-68.6	-68.6	-68.6
PFPE-2	-61.4	-57.5	-72.5	-82.2	-68.4
PFPE-2 Baked*	-68.1	-66.7	-64.7	-64.7	-66.0
M-4	-58.9	-70.8	-60.0	-58.9	-62.1
M-6	-56.7	-55.0	-60.3	-60.3	-58.1
ES-4	-53.9	-57.8	-55.8	-55.0	-55.6
ES-1	-51.1	-53.8	-51.1	-51.1	-51.8
Si-5	-49.2	-49.2	-49.2	-49.2	-49.2
ES-3	-53.9	-41.1	-56.1	-42.1	-48.3
PFPE-1	-44.3	-44.3	-49.4	-48.0	-46.5
ES-5	-42.5	-42.5	-46.4	-46.4	-44.5
ES-7	-43.6	-42.8	-43.6	-43.6	-43.4
M-12	-42.8	-42.8	-42.8	-44.2	-43.2
ES-6	-41.4	-41.4	-41.4	-41.4	-41.4
PFPE-4	-36.1	-36.1	-36.1	-36.7	-36.3
Si-4	-34.4	-34.4	-34.4	-34.4	-34.4
M-13	-30.3	-31.7	-30.3	-30.3	-30.7
M-5	-23.1	-20.3	-26.4	-21.1	-22.7
M-11	-21.9	-21.9	-21.9	-21.9	-21.9
Si-2	-16.7	-16.7	-16.1	-16.1	-16.4
M-3	-16.1	-10.3	-16.1	-18.1	-15.2
M-1	- 6.7	- 4.4	- 4.4	- 4.4	- 4.98
PFPE-6	- 4.4	- 4.4	+ 1.1	- 4.4	- 3.02
PFPE-3	- 0.56	0.0	0.0	0.0	- 0.14
M-2	+ 3.30	+ 3.30	- 8.30	+ 3.30	+ 0.40

*Baked in vacuum at 100°C for 20 hr.

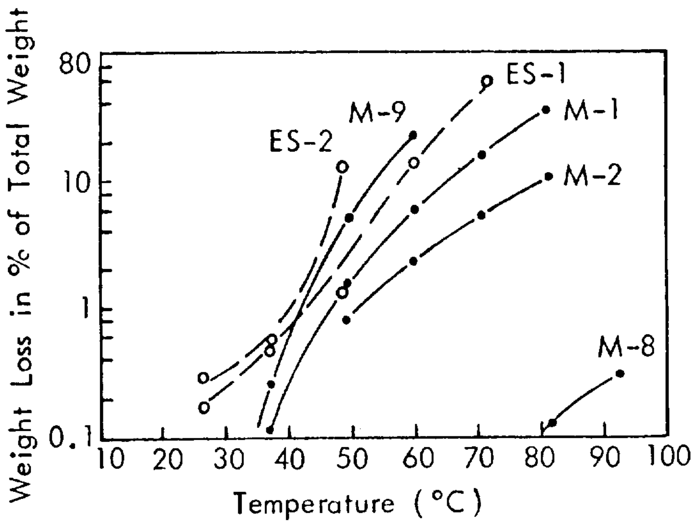


Figure 1. Vacuum weight loss versus temperature.

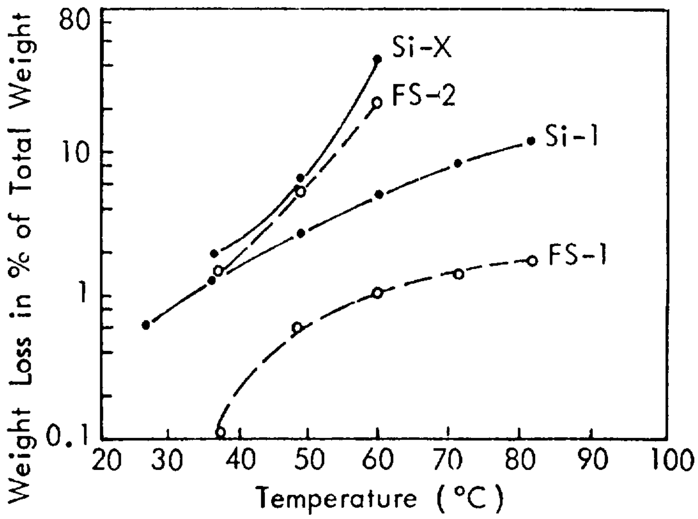


Figure 2. Vacuum weight loss versus temperature.

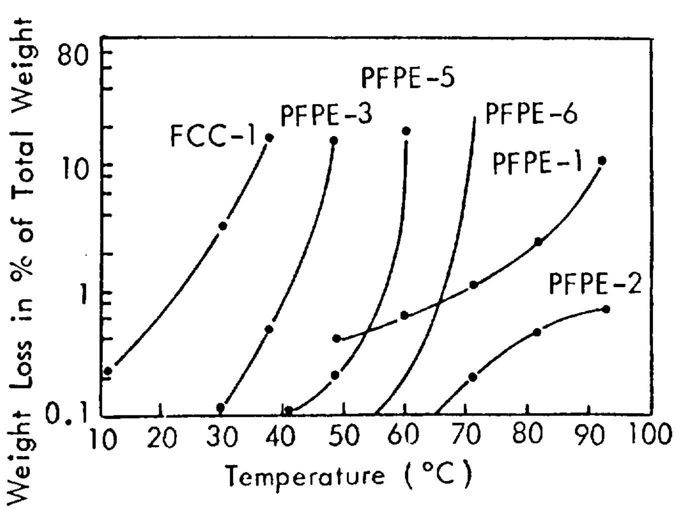


Figure 3. Vacuum weight loss versus temperature.

B. Standard Vacuum Weight Loss Tests

Since the capabilities of a grease type lubricant operating in vacuum are a function of the outgassing rate, some of the lubricants have been evaluated in a standard outgassing test. The outgassing rate is determined using a Knudsen cell with a 0.508 cm diameter hole. Approximately 50 to 60 mg of the grease is placed in the Knudsen cell and the cell is attached to an electronic balance having an accuracy of 5 x 10^{-5} gm. The system is pumped down to 1.333 x 10^{-4} N/m^2 (10^{-6} torr) using a LN_2 trapped diffusion pump. The temperature is then raised in 11.1°C increments and held for 1 hr at each increment. The test is carried to 93.3°C (200°F) or until the grease exhibits 30% total weight loss, whichever comes first. Results of the vacuum weight loss tests are shown in Figures 1, 2, and 3. The weight loss shown in these figures is a function of temperature and time since the vacuum system is maintained at approximately 1.33 x 10^{-4} N/m^2 during the test. The information on the perfluoropolyether greases shown in Figure 3 is of particular interest. The PFPE-1 grease is essentially the PFPE-3 material which has been vacuum distilled or outgassed to improve the vacuum stability of the material. It is obvious that this procedure is effective; however, it also increases the 38°C viscosity of the base oil from approximately 150 cs to 420 cs, which is an undesirable side effect. The PFPE-2 material, which is by far the most vacuum stable grease in this group, has a 38°C base oil viscosity of 130 cs.

C. Continuous Vacuum Ambient Temperature Tests

The results of the continuous vacuum ambient temperature tests are shown in Table 3. The greases are listed in order of average running time, longest to shortest. Each of the first sixteen greases ran for the entire year without failure. These sixteen greases are arranged in the order of least to most grease loss. Weight loss of the grease in the bearings was measured at the completion of each test. The results of these measurements for 35 greases are shown in Table 3. This table gives individual and average weight loss values of lubricant from the eight bearings tested with each grease. The best results were obtained with a perfluoropolyether grease PFPE-2. The poorest results were obtained with grease M-6 and FS-1 where all four tests for each failed within the 1-year period.

D. Continuous Vacuum High Temperature Tests

Thirty-two lubricants have also completed the vacuum high temperature life tests. In these tests all of the perfluoroalkylpolyether base lubricants completed the 1-year period without any failures while all of the experimental silicone grease tests and all of the fluorocarbon grease tests failed. On each of a highly refined mineral oil grease and a fluorosilicone grease failed with the remaining three samples completing 1 year. Table 4 shows the results of these tests.

Temperature in the vacuum high temperature tests is controlled by regulating the cooling water supply to the mounting plate, so that the mounting plate temperature is maintained at 65°C (150°F). The thermocouples on the bearings then show a temperature of approximately 93°C on the front bearing and 107°C on the rear bearing.

TABLE 3. RESULTS OF VACUUM TESTS AT 38°C

Lubricant	Hours to Failure[a] 1	2	3	4	Average	Weight Loss (%)[b] 1	2	3	4	Average
PFPE-2	8760	8760	8760	8760	8760	5.1	6.9	8.1	5	6.3
Si-2	8760	8760	8760	8760	8760	3.5	12	6	4.5	6.5
M-5	8760	8760	8760	8760	8760	7.5	5	8	6.5	6.8
PFPE-2[d]	8760	8760	8760	8760	8760	7.7	5.4	8.8	5.7	6.9
Si-4	8760	8760	8760	8760	8760	9.4	8.6	5.7	5.7	7.4
ES-5	8760	8760	8760	8760	8760	7.6	8.6	6.4	7.5	7.5
M-12	8760	8760	8760	8760	8760	6.5	12.4	12.6	6.1	9.4
PFPE-6	8760	8760	8760	8760	8760	6	13.5	12.5	7	9.8
M-3	8760	8760	c	8760	8760	5.9	13.1	11.9	8.2	9.8
PFPE-3	8760	8760	8760	8760	8760	10	15.5	8.5	8	10.5
FS-2	8760	8760	8760	8760	8760	7	21	17.5	10.5	14
ES-7	8760	8760	8760	8760	8760	14.3	13.7	12	16.6	14.2
PFPE-1	8760	8760	8760	8760	8760	10.5	33	15	17	18.9
M-10	8760	8760	8760	8760	8760	26	20.5	19	23	22.1
M-13	8760	8760	8760	8760	8760	28	41.8	31.9	28.2	32.5
M-2	8760	8760	8760	8760	8760	66	49	40	50	51.3
M-11	8513	8760	8760	8760	8698	20.1	19.6	15.4	22	19.3
Si-5	4739	8760	8760	8760	7755	9.5	5.4	11.4	3.1	7.4
PFPE-7	4397	8760	8760	8760	7669	27.2	6	2.5	2.3	9.5
M-1	8760	8760	3700	8760	7495	21.5	27.5	23	25	24.3
Si-1	8760	8760	1709	8760	6997	35	25	41	22.5	30.9
PFPE-4	684	8760	8760	8760	6741	26	11.5	13	9	14.9
ES-1	3524	8760	8437	4397	6280	24.5	39.5	23.5	18.5	26.5
M-7	2530	8760	8760	3367	5854	53.8	46.8	54.3	41.9	49.2
PFPE-5	2096	3517	8760	8760	5783	33.5	40.5	3.5	3.5	20.3
Si-X	1041	6015	8760	5710	5382	27.5	28	40	47.5	35.8
M-8	392	8760	8524	1976	4913	3.3	0.8	0.8	22.5	6.9
ES-6	3563	5199	8760	1894	4854	61	67.8	59.6	68.3	64.2
M-9	2543	1487	1199	8760	3497	34.2	27.6	49.3	24.4	33.9
Si-3	5613	2164	1659	456	2473	52.5	27	43.5	24.5	36.9
M-4	2671	859	311	160	1000	74.5	73.5	82	78	77
ES-2	427	696	743	911	694	61.4	56.1	72.3	61.8	62.9
ES-4	559	593	559	823	634	30.5	32.5	39	41	35.8
FS-1	174	245	831	511	440	7.5	14.5	22.5	15.5	15
M-6	473	219	336	286	329	67	76	68.5	70.5	70.5

Lubricant	Hours to Failure[a] 1	2	3	4	5	Average	Weight Loss (%)[b] 1	2	3	4	5	Average
PFPE-1	31918	22676	43800	21140	32173	30341	52.1	32.7	7.51	43.2	46.7	36.4
PFPE-2	43800	43800	43800	43800	43800	43800	7.2	16.1	8.5	12	9.9	10.7
M-3	43800	43800	43800	43800	43800	43800	15.9	18.2	11.4	9.6	13.7	13.8
Si-2	19323	21424	32086	43800	1411	23609	35.7	33.5	47.7	10.4	37.6	33

a. Or to end of test (1 year = 8760 hr and 5 years = 43800 hr).
b. Percent of weight loss of total weight of grease added to the two bearings of each motor (motor Nos. 1 through 4 or motor Nos. 1 through 5).
c. Drive motor failed.
d. Baked in vacuum at 100°C for 20 hr.

At the conclusion of all vacuum tests, the bearings are reweighed and the loss of lubricant is calculated. Since the motors which fail are turned off and the temperature at the front and rear bearing is approximately 65°C, these bearings should show less weight loss than the bearing with the same lubricant which operate for a longer period of time. Results of the lubricant weight loss in vacuum at high temperature are shown in Table 4. The lubricants are arranged in this table on the basis of running time, longest to shortest. Those greases which completed the 1-year test are arranged in order of lubricant loss, least to most.

Eleven of the 32 lubricants completed the 1 year vacuum high temperature test. The best results have been obtained with the perfluoropolyether materials. All tests on PFPE-1, PFPE-2, PFPE-3, PFPE-5, and PFPE-6 completed 1 year of operation without failure. All of these bearings appear to be in relatively good condition with the exception of the bearings lubricated with PFPE-5. This set of bearings appeared to be on the verge of failure.

The poorest results were obtained with the diester ES-3. All of the bearings lubricated with this material failed in 82 or less hr during the high temperature tests.

E. Oxidation Tests

During the development of the Skylab thermal control fan, problems were encountered with bearings operating in a highly oxidizing atmosphere; therefore, it was believed that a highly oxidative environment should form a part of the present evaluation.

The first set of tests was made in air at 90% relative humidity. However, it appeared that a pure oxygen environment might be more severe; therefore, some additional tests were made in 10 psi pure oxygen at 90% relative humidity. Results of all grease lubricants tested in an oxidizing atmosphere are shown in Table 5. Eleven of the air and 15 of the 10 psi Oxygen lubricants ran for the entire 1-year test period. The lubricants are listed in this table on the basis of running time, longest to shortest. Those lubricants which completed the 1-year test without a failure are arranged in order of lubricant weight loss, least to most.

F. Start-Stop Test

Since many mechanisms do not operate continuously, it was decided to simulate the boundary conditions which exist between the balls and races of a bearing during deceleration and acceleration. This test is set up in vacuum and held at ambient temperature. A timer is used to shut off the motors for 10 sec every 150 sec or for 20 sec every 80 sec. Forty-five lubricants have been evaluated in this system. Results of these tests are shown in Table 6. Twenty-six of the lubricants completed the 1-year test without a single failure. As with the other tables the lubricants are listed in order of average test time, longest to shortest. Those lubricants which completed the entire year without failure are arranged in order of lubricant weight loss, least to most.

TABLE 4. RESULTS OF VACUUM TESTS AT 93.3°C

Lubricant	Hours to Failure[a] 1	2	3	4	Average	Weight Loss (%)[b] 1	2	3	4	Average
PFPE-2	8760	8760	8760	8760	8760	13	13.5	14	17	14.5
PFPE-2[d]	8760	8760	8760	8760	8760	14.2	14.2	17.3	14.4	15
PFPE-6	8760	8760	8760	8760	8760	19.5	9	19.5	13.5	15.5
PFPE-5	8760	8760	8760	8760	8760	14	21.5	12	15.5	16
PFPE-1	8760	8760	8760	8760	8760	18	12.5	24.5	12	17
M-5	8760	8760	8760	8760	8760	15	24.5	14.5	15.5	17.4
PFPE-3	8760	8760	8760	8760	8760	18	16.5	24	19	19.5
M-3[e]	8760	8760	8760	8760	8760	27.4	25	24.6	23	25
M-3	8760	8760	8760	8760	8760	29.5	35	27	34.5	31.5
M-1	8760	8760	8760	8760	8760	29	37	32	43	35.5
M-2	8760	c	8760	8760	8760	55	31	50	47.5	46
FS-2	6813	8760	8760	8760	8273	59	35.5	30.5	35	40.5
M-5[e]	4979	8760	8760	8760	7815	31.6	28.3	15.4	11.4	21.7
M-12	8760	4745	8760	8760	7756	18	42.6	29.3	34.5	31.1
PFPE-2[e]	4979	8760	6659	8760	7290	79.3	12.9	40	4.9	34.3
Si-2	8760	2870	8760	8760	7288	23	51	23.5	36	33.4
PFPE-1[e]	6980	8760	8760	4187	7172	27.6	10.7	11.4	28.5	19.6
M-11	8760	5658	2432	8760	6403	34.9	41.7	23.7	43.6	36
Si-4	1218	8760	7940	6609	6132	50.5	9	27	25	27.9
Si-2[e]	4691	8760	8760	2156	6092	30.5	20.4	17.9	19.9	22.2
PFPE-7	2073	2057	8760	8760	5413	50	49.5	26.3	16.3	35.5
Si-5	8760	755	515	8760	4698	6.7	11.8	12.2	10.7	10.4
M-13	1905	1673	1362	5995	2734	70.7	67	60.2	75.1	68.3
ES-5	2432	1445	4442	1327	2412	23.8	32.7	40.8	34.9	33.1
Si-3	686	2290	1702	2327	1751	47.5	41	48.5	35.5	43.5
PFPE-4	3193	350	2523	282	1587	54	39	63	44	50
M-10	1091	1338	2222	1274	1481	68.7	73.8	48.3	63.3	63.5
ES-6	1031	1761	729	594	1029	83.9	73.6	79.1	61.9	74.6
FCC-1	353	1280	521	166	580	47	53	47.5	54	50.5
Si-X	174	101	1047	68.5	348	70.5	59.5	56	62.5	62.5
ES-7	161	57	125	177	130	54.7	56	56.9	85.5	63.3
ES-3	82	73	70	71	74	85.5	91.5	83.5	88	87.1

Lubricant	Hours to Failure[a] 1	2	3	4	5	Average	Weight Loss (%)[b] 1	2	3	4	5	Average
PFPE-1	27063	3971	5754	9012	26278	14416	26.3	28.7	22.8	23.7	35.8	27.5
PFPE-2	c	38749	26647	43800	42452	37912	14.4	71.2	53.6	15.7	42.6	41.5
M-3	38764	37886	26285	19557	43800	33258	40.2	49.6	33.2	51.8	24.5	39.9
Si-2	17877	25881	1759	21393	20277	17437	35	53.3	38.8	44.2	42.3	42.7

a. Or to end of test (1 year = 8760 hr and 5 years = 43800 hr).

b. Percent of weight loss of total weight of grease added to the two bearings of each motor (motor Nos. 1 through 4 or motor Nos. 1 through 5).

c. Drive motor failed.

d. Baked in vacuum at 100°C for 20 hr.

e. 10-15 percent fill, all others 25-30 percent fill.

TABLE 5. RESULTS OF OXIDIZING TESTS

14.7 psi Air at 90% Relative Humidity										
	Hours to Failure[a]					Weight Loss (%)[b]				
Lubricant	1	2	3	4	Average	1	2	3	4	Average
PFPE-1	8760	8760	8760	8760	8760	5	5.5	5	5.5	5.3
PFPE-3	8760	8760	8760	8760	8760	5.9	5.4	7.2	6.3	6.2
M-3	8760	8760	8760	8760	8760	6.8	5.7	6.3	9.6	7.1
FS-2	8760	8760	8760	8760	8760	4.8	8.5	9	8.5	7.7
Si-5	8760	8760	8760	8760	8760	8	7.1	12.2	6.6	8.5
ES-1	8760	8760	8760	8760	8760	12.5	12	11.5	12	12
M-10	8760	8760	8760	8760	8760	11.9	12.1	9.5	16.7	12.6
M-13	8760	8760	8760	8760	8760	31.9	15.5	15.2	12.3	18.7
M-11	8760	8760	8760	8760	8760	29.9	35	26.7	38.5	32.5
Si-X	8760	8760	8760	8760	8760	35.5	40.5	43	42	40
Si-1	8760	8760	c	8760	8760	48.5	47	40	46	45.4
M-12	8688	8760	8760	8760	8742	24.3	8.9	5.8	3.9	10.7
PFPE-4	8760	8760	8760	8357	8659	25	33.5	33.6	41.4	33.3
PFPE-5	8760	7147	8760	8598	8316	8.3	35.6	5.9	30.2	20
ES-6	8760	8760	8760	6456	8184	20.8	28	32.7	47.4	32.2
M-5[e]	4884	8760	8760	8760	7791	32	5.7	5.2	5.9	12.2
Si-2	8760	8760	6065	5287	7218	7.6	8.5	44.1	34.7	23.7
ES-7	8760	8760	2445	8760	7181	6.9	6.6	15.2	9	9.4
M-1	8760	8760	2116	8760	7099	16.8	19.5	24.5	12.1	18.2
ES-5	1714	8760	8760	8760	6999	19.5	12.7	14.8	19.5	16.6
FS-1	8760	405	8760	8760	6671	3	3.5	3	4.5	3.5
PFPE-2	8760	7709	5699	2480	6162	19.2	36.4	34	32.3	30.5
PFPE-7	4117	8760	5699	5467	6011	47.2	10.8	30.7	49.8	34.6
PFPE-7	7938	4473	8262	3077	5938	26.1	44.5	17.3	39.7	31.9
PFPE-2[d]	1955	851	995	8760	3140	30.4	29.6	30.9	3	23.5

10 psi Oxygen at 90% Relative Humidity										
	Hours to Failure[a]					Weight Loss (%)[b]				
Lubricant	1	2	3	4	Average	1	2	3	4	Average
ES-7	8760	8760	8760	8760	8760	2.6	1.5	1.6	1.8	1.9
Si-2	8760	8760	8760	8760	8760	9.6	1.7	4	3.7	4.8
M-3	8760	8760	8760	8760	8760	6.3	4	6.3	6	5.7
M-5[e]	8760	8760	8760	8760	8760	10.3	4	3.5	7.4	6.3
M-12	8760	8760	8760	8760	8760	12.9	7.2	7	3.8	7.7
ES-5	8760	8760	8760	8760	8760	7	10.5	10.6	5.6	8.4
PFPE-1	8760	8760	8760	8760	8760	6.7	3.8	20.8	8.8	10
PFPE-6	8760	8760	8760	8760	8760	15.7	10.2	9.3	14.3	12.4
Si-5	8760	8760	8760	8760	8760	14.7	11.8	13	17.3	14.2
FS-2	8760	8760	8760	8760	8760	14.4	13.7	13.2	20	15.3
PFPE-3	8760	8760	c	8760	8760	11.3	11.6	32.4	12.1	16.9
M-1	8760	8760	8760	8760	8760	20	19	17.8	22.6	19.9
ES-6	8760	8760	8760	8760	8760	24.7	27.8	13.7	17.4	20.9
M-10	8760	8760	8760	8760	8760	19.4	22.8	21.8	20.4	21.1
PFPE-4	8760	8760	8760	8760	8760	50.9	30	70.7	39	47.7
M-13	8760	8760	8760	8369	8662	52	44.5	51	64.5	53
PFPE-7	8760	8760	8760	7946	8557	3.4	2.3	2.4	1.8	2.5
PFPE-2	8760	4795	8760	8760	7769	6.7	47.1	11.8	11.3	19.2
M-11	8369	8689	3806	8477	7335	54.1	47.8	59.6	51.8	53.3
PFPE-5	3119	6399	8760	8760	6760	38.1	31.9	24.8	27.7	30.6

a. Or to end of test (1 year = 8760 hr).
b. Percent of weight loss of total weight of grease added to the two bearings of each motor (motor Nos. 1 through 4).
c. Drive motor failed.
d. Baked in vacuum at 100°C for 20 hr.

TABLE 6. RESULTS OF START-STOP TESTS

Lubricant	Hours to Failure[a] 1	2	3	4	Average	Weight Loss (%)[b] 1	2	3	4	Average	Cycle Time (s)
PFPE-6	8760	8760	8760	8760	8760	8	3	6.5	4	5.4	180
PFPE-1	8760	8760	8760	8760	8760	4.5	5	3.5	10	5.8	150
PFPE-2[c]	8760	8760	8760	8760	8760	5.7	6.1	6.7	6.1	6.2	180
PFPE-2	8760	8760	8760	8760	8760	7	8.5	4.5	7.5	7	150
ES-5	8760	8760	8760	8760	8760	7.1	7.4	8.8	5.2	7.1	180
M-3	8760	8760	8760	8760	8760	12	6	8.5	10.5	9.3	180
PFPE-7	8760	8760	8760	8760	8760	17.2	15.6	18.8	10.5	15.5	150
PFPE-3	8760	8760	8760	8760	8760	9.5	20.5	12	28	18	180
ES-7	8760	8760	8760	8760	8760	24.7	11	15	25.9	19.2	150
M-5[d]	8760	8760	8760	8760	8760	21.5	22.8	17.3	20	20.4	150
M-11	8760	8760	8760	8760	8760	24.3	21.1	20.6	17.3	20.8	180
M-5	8760	8760	8760	8760	8760	23	31	12	25	22.8	180
M-13	8760	8760	8760	8760	8760	37.8	34.6	26	19.1	29.4	150
M-1	8760	8760	6790	8760	8268	6.5	14	36.5	11	17	180
Si-3	5409	8760	8760	8760	7922	32	12.5	12	14	17.5	180
M-12	8760	8760	4232	8760	7628	14.7	14.6	46.4	15.8	22.9	150
M-10	6261	6313	8760	8760	7524	47.4	46.6	22.8	37.1	38.5	180
PFPE-5	8760	8760	8760	2817	7274	5	3.5	1.5	23	8	150
ES-1	5783	8760	5497	8760	7200	44.5	16	57	15	33.5	180
M-2	8760	8760	1848	8760	7032	27	26	46	20	30	180
Si-2	8760	1557	8760	8760	6957	3	9.5	5	5	5.5	150
FS-2	685	8760	8760	5684	5972	15	19	21.5	25.5	20.5	150
Si-5	5577	8760	629	8760	5932	40.3	5.1	31.8	8.5	21.4	180
PFPE-4	4977	4737	5926	6586	5557	84	76.5	66.5	70	74.3	180
ES-3	3345	3501	2117	4340	3326	76	69.5	68.5	68	70.5	180

Lubricant	Hours to Failure[a] 1	2	3	4	5	Average	Weight Loss (%)[b] 1	2	3	4	5	Average	Cycle Time (s)
PFPE-1	43800	43800[e]	43800	11116	43800	37263	18.7	18.9	39.5	39.4	15.7	26.4	150
PFPE-2	43800	43800	43800	43800[e]	43800	43800	19.6	8.5	12	15.9	13.5	13.9	150
M-3	43800	39210	24431[e]	19544[e]	20276[e]	29452	27.6	29.7	20.4	24.7	22.8	25	150
Si-2	38661	40174	15905[e]	29133	39040[e]	32583	18	20.6	23.2	13	24.5	19.9	150

a. Or to end of test (1 year = 8760 hr and 5 years = 43800 hr.
b. Percent of weight loss of total weight of grease added to the two bearings of each motor (motor Nos. 1 through 4 or motor Nos. 1 through 5).
c. Baked in vacuum at 100°C for 20 hr.
d. Royco 49B (Table 1).
e. Drive motor failed. Bearings not removed from armatures. Since the last status report, armatures with bearings assembled in new motors were further tested in Start-Stop tests.

G. Future Plans

Due to the present and future emphasis on the Space Station program, this is the last report on the lubricants specified in Table 1. A new series of reports is forthcoming on an updated group of lubricants which will be replacing those for the most part in the aforementioned table.

H. Conclusions

Since testing has been completed in this program, the following conclusions, from the 1-year and 5-year vacuum tests data, have been made:

1. As a whole, the chemical class listed as PFPE in Table 1 has given the best results in all the vacuum tests completed.

2. In the 1-year vacuum ambient temperature tests, PFPE-2 (as manufactured and vacuum baked) and PFPE-6, Si-2 and Si-4, M-5 and M-12, and ES-5 have given the best results with less than a 10 percent average weight loss. In the 5-year vacuum ambient temperature tests, PFPE-2 and M-3 have given the best results with less than a 14 percent average weight loss.

3. In the 1-year vacuum high temperature tests, M-5 and all the PFPE greases, except PFPE-4 and PFPE-7, have given the best results with less than a 20 percent average weight loss. In the 5-year vacuum high temperature test, one PFPE-2 motor and one M-3 motor completed the test with weight losses of 15.7 and 24.5 percent, respectively.

4. In the 1-year start-stop tests, ES-5, M-3, and PFPE greases (except PFPE-3, PFPE-4, and PFPE-5) have given the best results with less than a 10 percent average weight loss. In the 5-year start-stop test, PFPE-2 has given the best results with a 13.9 percent average weight loss. Since there were seven motor failures in the test, further testing has been completed on the armatures with bearings (see note e of Table 6).

5. A 25 to 30 percent fill of a grease gives better results, on the whole, than a 10 to 15 percent fill.

6. The use of PFPE-2 as received gives better results, on the whole, than using PGPE-2 after a vacuum bake at 100°C for 20 hours.

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B-V. APPENDICES

A - LUBRICANT GLOSSARY
B - SUMMARIES OF STANDARD TEST METHODS
C - VISCOSITY CONVERSION DATA
D - THE INTERNATIONAL SYSTEM OF UNITS AND
CONVERSION FACTORS

APPENDIX A

LUBRICANT GLOSSARY

Absolute viscosity: The absolute or dynamic viscosity of a Newtonian liquid is the tangential force on unit area of either of two parallel planes at unit distance apart when the space is filled with the liquid and one plane moves relative to the other with unit velocity in its own plane. The cgs. unit of absolute viscosity is the poise, which has the dimension grams per cubic centimeters per second.

Additive: Any material added to a lubricating grease or a lubricating oil to improve its suitability for service. It may improve a property already possessed by the lubricant or give it properties not naturally possessed. Typical examples are antioxidants and "EP" or antiweld additive.

Antioxidants: Any additive for the purpose of reducing the rate of oxidation and subsequent deterioration of oils or greases. (See oxidation stability.)

Apparent viscosity: The ratio of shear stress to rate of shear of a non-Newton fluid, as calculated from Poiseuille's equation and measured in poises. Apparent viscosity is dependent on temperature and rate of shear and therefore must be reported as the value at a given shear rate and temperature.

ASTM: An abbreviation for the American Society for Testing and Materials, which publishes a widely used set of standards for materials and test methods commonly known as the "ASTM Standards."

Autogenous ignition point: The temperature at which a liquid or semiliquid petroleum product ignites and burns without an outside flame or spark source. It is usually determined at atmospheric pressure in air of a controlled volume.

Bleeding: The separation of liquid lubricant from a lubricating grease for any cause. The showing of free oil on the surface of a grease or in the cracks of a cracked grease. Usually reported in percent weight loss.

Bomb Oxidation: The oxidation of a substance by combustion in a closed, sealed container, called a "bomb," containing oxygen under pressure. Results reported in pressure drop of the "bomb" psi, at a specified temperature, pressure and time.

Centistoke: 1/100th of a stoke. A stoke is the unit of kinematic viscosity with dimensions of square centimeters per second.

Centane number: A measure of the ignition quality of a fuel or petroleum product with reference to normal cetane high ignition quality fuel with an arbitrary number of 100.

Channeling:

1. A term used in connection with lubricating greases to describe the usually desirable tendency to form a channel by working down of lubricating grease in a bearing, leaving shoulders of unworked grease which serve as seal and reservoir.

2. A term in connection with liquid lubricants and flow type lubricating grease to describe the tendendy, at low temperatures, for these materials to form a plastic structure sufficiently strong to resist flow under gravitational forces only.

Cloud point: The temperature at which paraffin wax or other solid substances begin to crystalline out or separate from solution when an oil is chilled under definite prescribed conditions.

Compatibility: A measure of the ability of a lubricant to be mixed with other lubricants or petroleum products and form a uniform mixture without causing any resultant reaction or precipitation of material.

Contamination: The presence of foreign materials in a lubricant usually refers to solid material. Results are reported as the weight of foreign solid material per given weight of sample.

Corrosion: The gradual destruction and/or pitting of a metal surface due to chemical attack. This chemical attack may be, but is not necessarily, due to the formation of acidic materials in the lubricant.

Dielectric strength - kilovolts: Dielectric strength is a measure of the ability of a product to resist a flow of electric current through it and is measured as the minimum voltage in kilovolts that will produce arcing through the material under standard conditions.

Dirt content: A measure of the size and concentration of foreign particles present in a lubricant. Dirt content is usually reported as the number of particles per cubic centimeter, for specified particle sizes.

Distillation: A process for determining the range of temperature for which boiling occurs for a product and the temperature at which a certain percentage will be completely boiled off.

DN value: Product of bearing bore diameter in millimeters and speed in revolutions per minute.

Dropping point: The temperature at which a lubricating grease passes from the semisolid to the liquid state under standard conditions of test. Dropping point is manifested by the falling of one drop of material from an orifice in the test apparatus. It is not the melting point of grease, but a temperature characteristic of the grease.

Emulsifiability: A measure of the ability of an oil to form and maintain an emulsion with water. Demulsibility, the exact opposite, is a measure of the ability of an oil to break from an emulsion.

Fire point: The temperature at which the material will continue to burn for at least 5 sec without the benefit of an outside flame.

Flash point: The lowest temperature of a lubricating oil at which vapors above the liquid surface will ignite, or flash, upon application of a small test flame. (Or) that temperature of a petroleum product where sufficient evaporation occurs so that the vapor to air ratio at the product surface is high enough to support momentary combustion (flash) when a source of ignition is present.

Flock point: A measure of the tendency of a lubricant to precipitate wax or other solids from solution. Depending on test used, the flock point is the temperature required for precipitation or the time required at a given temperature for precipitation.

Fluidity: The reciprocal of viscosity. In the cgs. system the unit of fluidity is the "rhe" which has the units of grams per centimeter second.

Fretting Corrosion: The oxidation of finely divided wear particles, which have been worn from bearing surfaces to a corrosion product. Corrosion, however, is not a part of the basic mechanism.

Gravity (API): Gravity is an expression of the weight-to-volume relationship of a product and is expressed as specific gravity, or weight per unit volume at a given temperature. API gravity is an arbitrary scale, in degrees, and is found from the specific gravity by:

$$\text{API gravity (degrees)} = \frac{141.5}{\text{specific gravity at } 60/60°\text{F.}} - 131.5$$

Insoluble matter: Components of a lubricant which are insoluble in the prescribed reagents used in an analytical procedure. The analytical procedure used should be indicated when insolubles are specified.

Kinematic viscosity: The quotient of the dynamic or absolute viscosity divided by the density, both determined at the same temperature. The cgs. unit of kinematic viscosity is the stoke (or centistokes where 1 stoke equals 100 cs.) which has dimensions of square centimeters per second.

Neutralization number: A measure of the acidity or alkalinity of an oil. Actually is not one number but several numbers (strong acid number, total acid number, strong base number, and total base number). The acid numbers are the number of milligrams of potassium hydroxide required to raise the pH of 1 g. of the sample to a certain value and the base numbers are the number of milligrams of hydrochloric acid required to lower the pH to a certain value. For uniform results, base numbers are converted to the number of milligrams of potassium hydroxide that the milligrams of hydrochloric acid required would neutralize to a pH value of 7. When only a neutralization is requested, it usually means the total acid number.

Oil separation: In greases, the separation of the oil present in the grease into free oil, usually evidenced as free surface oil. (See bleeding.) Reported in percent weight loss at specified conditions of temperature and time.

Oxidation stability: A measure of the resistance of lubricants to oxidation when stored under static conditions for long periods of time. (Or) a measure of the resistance of lubricants to oxidation, a chemical reaction between portions of the lubricant and any oxygen present.

Penetration: An arbitrary measure of the consistency (hardness) of lubricating grease. The depth, in tenths of a millimeter, that a standard cone penetrates the sample in a standard cup under prescribed conditions of weight, time, and temperature.

Unworked penetration: The penetration of a sample of lubricating grease which has received a minimum of handling and has not been subjected to the action of a grease worker.

Worked penetration: The penetration of a sample of lubricating grease after it has been brought to standard temperature and subjected to a prescribed amount of strokes in a standard grease worker.

pH value: An arbitrary scale for measuring the acidity or alkalinity of a product. Zero is maximum acidity, 14 is maximum alkalinity, and 7 is neutral.

Poise: The cgs. unit of dynamic or absolute viscosity which has the dimensions of grams per centimeter per second.

Pour point: The pour point of a petroleum oil is the lowest temperature at which the oil will pour or flow when it is chilled without disturbance under definite prescribed conditions.

Saponification number: A measure of the amount of constituents of petroleum that will easily saponify under test conditions. The number of milligrams of potassium hydroxide which is consumed by 1 g. of oil under test conditions. Saponification number is a measure of fatty materials compounded in an oil.

Saponify: To convert into soap; to subject to, or to undergo, saponification.

Storage stability: A measure fo the ability of a lubricant to undergo prolonged periods of storage without showing any adverse conditions due to oxidation, oil separation, contamination or any type of deterioration.

Viscosity: A measure of the flow characteristics of a fluid. The higher a fluid viscosity, the greater the resistance to flow. A viscosity usually varies with temperature; and is usually reported at a standard temperature.

Work factor: A measure of the stability of lubricants when subjected to an endurance test. The work factor is expressed as the average value of the ratio to three characteristics (viscosity, carbon residue, neutralization number) as measured before and after the test.

APPENDIX B

SUMMARIES OF STANDARD TEST METHODS

B-I. Test Methods for Lubricating Fluids

1. Autogenous Ignition Temperatures of Petroleum Products

Specification: Federal Test Method Standard No. 791b, Method 9101.3, ASTM D-2155-66

This method of test is intended for use in the determination of the autogenous ignition temperature of liquid and semiliquid petroleum products.

A flask is heated in a bath of molten alloy and small amounts of the sample are injected into the heated flask. The minimum temperature at which ignition of the sample will occur is recorded.

Precision: Results should be duplicable to within ±2°C of the indicated temperature.

2. Color of Lubricating Oil and Petroleum

Specification: Federal Test Method Standard No. 791b, Method 102.7, ASTM D-1500-64

This method describes a procedure for the visual determination of the color of a wide variety of petroleum products such as lubricating oils, heating oils, diesel fuel oils, and petroleum waxes.

A measured sample of test fluid is diluted with kerosene and placed in a standard glass sample jar in a colorimeter and its color is compared to the color of standard glasses. The color of the sample is reported as the color of the next darkest glass standard that matches it.

Precision: The following data should be used for judging the acceptability of results. Results should not be considered suspect unless they differ by more than the following amounts:

Repeatability - 0.5 color units
Reproducibility - 0.5 color units

3. Cloud and Pour Points

Specification: Federal Test Standard No. 791b, Method 201.9, ASTM D-97-66

This method describes procedures for determining the cloud point for oils which are transparent in layers 3.8×10^{-2} m (1-1/2 in.) in thickness and for determining pour point for any petroleum oil. Cloud point is that temperature at which paraffin wax or other solid substances begin to crystallize out or separate from solution when the oil is chilled under prescribed conditions.

Cloud point: A sample of the oil is placed in a test jar and is chilled slowly. At intervals of 1°C (2°F), other samples are inspected for clouding. When a distinct cloudiness or haze appears at the bottom of the test jar, the temperature reading is recorded as the cloud point.

Pour point: A sample of the oil is placed in a test jar and heated to a predetermined temperature. The sample is then chilled slowly and at intervals of 2.8°C (5°F), the jar is tilted and the oil is inspected for movement. When the oil reaches a temperature where the jar can be tilted horizontally for 5 sec with no movement, the pour point is taken as the temperature 2.8°C (5°F) above the solid point temperature.

Precision: Individual results of the pour point in one lab may vary by 2.8°C (5°F) and in different labs by 5.6°C (10°F), although the average of three or more results in different labs should show a difference between averages no greater than 2.8°C (5°F).

4. Pour Stability Characteristics

Specification: Federal Test Method Standard No. 791b, Method 203

This method is used for determining the pour stability of blends of winter grade (regular, heavy duty, and diluted heavy duty) motor oil, and of certain types of hydraulic fluids.

A sample of the oil is placed in a glass jar in a cooling bath and subjected to a predetermined schedule of temperature variations, and then determining the lowest temperature at which no surface movement will occur when the sample is turned horizontally for 3 sec.

Precision:

Repeatability: Results may vary by 2.8°C (5°F) for oils with poor pour stability characteristics. For blends with solid points below -18°C (0°F), the results may vary 5.6°C (10°F).

Reproducibility: Results may vary by 5.6°C (10°F). The average of three or more results in different laboratores show (should) not differ between averages no more than 2.8°C (5°F).

5. Pour Point

Specification: Federal Test Method Standard No. 791a, Method 204

This method is used for indicating the flow characteristics of engine oils that have been diluted with aviation gasoline.

A sample of the oil is diluted with a mixture of naphtha and xylene and then the pour point is determined as outlined in ASTM Method D-97 (Federal Test Method 201) cloud and pour point.

Precision: The same limits as set forth in ASTM D-97 (Federal Test Method 201) apply to this method.

6. Kinematic Viscosity

Specification: Federal Test Method Standard No. 791b, Method 305.6, ASTM D-445-65

This method describes the procedure for determining the kinematic viscosity of transparent or opaque fluids in the range of 0.2 cs. and higher. Determinations may be made at any temperature when the flow in the glass capillary-type viscometers is Newtonian.

The time is measured for a fixed volume of the liquid to flow through the capillary of a calibrated glass capillary-type viscometer under an accurately reproducible head and at a closely controlled temperature. The kinematic viscosity is then calculated from the efflux time and the viscometer calibration factor.

Precision: For clean transparent oils tested at 38.0°C (100°F) and 100°C (212°F), results should not be considered suspect unless they differ by more than the following amounts.

Repeatability - 0.35% of mean
Reproducibility - 0.7% of mean

7. Viscosity and Viscosity Stability at -54°C (-65°F)

Specification: Federal Test Method Standard No. 791b, Method 307.2, ASTM D-2532-68

This method is used for determining the kinematic viscosity of transparent lubricants at -54°C (-65°F), and the stability with respect to time of this viscosity at -54°C (-65°F).

A sample of the lubricant is placed in a calibrated glass-type viscometer in a bath at -54°C (-65°F). The kinematic viscosity is then calculated. The viscometer and the sample are kept in the both at -54°C (-65°F) for 72 hr and calculation of the kinematic viscosity is made at different intervals during the 72 hr to determine the viscosity stability at -54°C (-65°F).

8. API Gravity of Petroleum Products

Specification: Federal Test Method Standard No. 791b, Method 401.7, ASTM D-287-67

This method describes a procedure for the determination by means of a glass hydrometer of the API gravity of petroleum products normally handled as liquids and having a Reid Vapor pressure of 11.8 kg (26 lb) or less.

A sample of fluid is heated to the proper test temperature and placed in a glass cylinder. The hydrometer is inserted, and the API gravity in degrees is read from the hydrometer and the temperature of the sample is noted. All readings are then corrected to API gravity at 15.8°C (60°F).

Precision: The following criteria should be used for judging results obtained at temperatures of 15.8°C ± 10°C (60°F ± 18°F). Results should not be considered suspect unless they differ by more than the following amounts.

Repeatability - 0.2 degrees API
Reproducibility - 0.5 degrees API

9. Flash and Fire Point (Cleveland Open Cup)

Specification: Federal Test Method Standard No. 791b, Method 1103.7, ASTM D-92-66

This method describes a procedure for determining the flash and fire points of petroleum products except fuel oils and those having an open cup flash below 79°C (175°F).

The test cup is filled with the sample. The temperature of the sample is increased rapidly and then at a slow constant rate as the flash point is approached. At specified intervals, a test flame is passed over the cup. The lowest temperature at which application of the test flame causes the vapors above the surface of the sample to ignite is taken as the flash point. The test is continued until the application of the test flame causes the oil to ignite and burn for at least 5 sec. That temperature is the fire point.

Precision: The following data should be used for judging the acceptability of results. Results should not be considered suspect unless they differ by more than the following amount:

Repeatability - flash point, 8.3°C (15°F)
- fire point, 5.5°C (10°F)
Reproducibility - flash point, 16.7°C (30°F)
- fire point, 11.1°C (20°F)

10. Thermal Oxidation Stability of Gear Lubricants

Specification: Federal Test Method Standard No. 791b, Method 2504

This method is used for determining the deterioration of lubricants under severe oxidation conditions.

A sample of the oil is placed in a gear case in which two spur gears and a test bearing are operated under a load. The gear case is heated to 163°C (325°F ± 1°) and air is bubbled through the lubricant at the rate of 0.0011 m^3 (1.11 liters) per hour as 6,894 N/m^2 (1.0 psi). A copper strip is placed in the gear box with the lubricant.

The test apparatus is operated for 30 min and then stopped and the viscosity of the lubricant is determined. The test apparatus is then operated continuously, and viscosity measurements taken very 10 hr until the desired viscosity is obtained.

At completion of test, the apparatus is then examined and all deposits are recorded as well as the conditions of the gears, bearings, and the copper strip and any wear of the bearing is noted.

11. Thermal Stability of Lubricating and Hydraulic Fluids

Specification: Federal Test Method Standard No. 791b, Method 2508

This method describes a procedure for determining the thermal stability of fluid. In this method, the volatile decomposition products are held in continuous contact with the fluid during the test. This method does not measure the temperature of which oil fragments begin to form, but will indicate bulk fragmentation occurring at a specified temperature and testing period.

A sample is placed in a glass test cell, and all air and moisture are removed to reduce the variables of oxidation and hydrolysis. The cell is then sealed airtight under a vacuum and heated to 260°C ± 1°C (500°F ± 2°F) for a period of 24 hr. The sample is then observed for evidence of insolubles, phase separation, or other change. The specimen is removed from the cell and the kinematic viscosity (Federal Method 306, ASTM D-1092) and the acid and base numbers (Federal Method 5106, ASTM D-664) are determined for the heated sample and an unheated specimen and the valves compared.

12. Trace Sediment in Lubricating Oils

Specification: Federal Test Method Standard No. 791b, Method 3004.6, ASTM D-2273-67

This method is used for determining trace amounts (less than 0.05 volume%) of sediment in lubricating oils.

A 50 ml. sample of the test oil, mixed with 50 ml. of naphtha, is centrifuged at a relative centrifugal force of 600-700 for 10 min. The mixture is decanted and the sediment is left in the tube. Another mixture of 50 ml. naphtha and 50 ml. of oil is mixed in the tube and centrifuged for 10 min. The final volume of sediment is noted and the results are reported as the volume of sediment per 100 ml. of sample.

13. Contamination

Specification: Federal Test Method Standard No. 791b, Method 3006

This method is used for determining the degree of contamination caused by foreign solid material in engine oil.

A 0.015 m^3 (4 gal) sample of the oil is mixed with 0.015 m^3 (4 gal) of naphtha and the mixture is filtered through a 200-mesh sieve. The remaining solid material is weighed and reported as the weight of solid material in the specimen.

14. Precipitation Number of Lubricating Oils

Specification: Federal Test Method Standard No. 791b, Method 3103.5, ASTM D-91-61

This method gives the procedures for determining the precipitation number of steam cylinder stock and block oils, and may be used for other lubricating oils. The precipitation number is the number of milliliters of precipitate found when a sample of the lubricating oil is treated and centrifuged under prescribed conditions.

A 10-ml. sample of the lubricating oil is mixed with 90 ml. of precipitation naphtha and centrifuged at a relative centrifugal force of 600-700 for 10-min periods. The amount of preciptate formed in milliliters is read as the precipitation number.

Precision: Results should not be considered suspect unless they differ by more than the following amounts:

Precipitation No., 0.00 - 1.20;
Repeatability, 10% of mean;
Reproducibility, 30% of mean.

15. Insolubles in Used Lubricating Oils

Specification: Federal Test Method Standard No. 791b, Method 3121.5, ASTM D-893-69

This method describes the procedures for the determination of pentane and benzene insolubles in used lubricating oils. One procedure covers the determination of insolubles without the use of coagulant in the pentane. The second procedure covers the determination of insolubles in oils containing detergents and employs a coagulant for both the pentane and benzene isolubles.

In the first procedure, a sample of the used oils is mixed with pentane and centrifuged. The precipitate is washed with pentane twice, dried and weighed to give the pentane insolubles. For benzene insolubles, a separate sample is mixed with pentane and centrifuged. The precipitate is washed twice with benzene, and with benzene-alcohol, and once with benzene, dried and weighed to give the benzene insolubles.

In the second procedure a sample of used oil is mixed with pentane coagulant solution and centrifuged. The precipitate is washed twice with pentane, dried and weighed to give the coagulated pentane insolubles. For coagulated benzene insolubles, a separate sample is mixed with pentane-coagulant solution and centrifuged, the precipitate is washed twice with pentane, once with benzene-alcohol solution, and once with benzene, dried, and weighed to give the coagulated benzene insolubles.

Precision: The following data should be used for judging the acceptability of results. Results should not be considered suspect unless they differ by more than the following amounts:

Insolubles,%	Repeatability	Reproducibility
0.0 - 1.0	0.07%	0.10%
over 1.0	10% of mean	15% of mean

16. Foaming Characteristics of Lubricating Oils

Specification: Federal Test Method Standard No. 791b, Method 3211.3, ASTM D-892-63

This method test is intended for the determination of the foaming characteristics of lubricating oils at specified temperatures. Means of empirically rating the foaming tendency and the stability of the foam are described.

The sample is maintained at a temperature of 24°C (75°F), is blown with air at a constant rate for 5 min. and then allowed to settle for 10 min. The volume of foam is measured at the end of both periods. The test is repeated on a second sample at 93°C (200°F), and then after collapsing the foam, at 24°C (75°F).

Precision: The following data should be used for judging the acceptability of results. Results should not be considered suspect unless they differ by more than the following amounts at the end of the 5-min blowing period.

Repeatability - 10 ml. or 15% of average, whichever is greater
Reproducibility - 10 ml. or 38% of average, whichever is greater

17. Compatibility of Turbine Lubricating Oils

Specification: Federal Test Method Standard No. 791b, Method 3403.1

This method is used to determine the compatibility of aircraft turbine lubricants with specific referee lubricants.

The sample lubricant is mixed with the referee lubricant in three different ratios of 10%, 50%, and 90%, by volume. The mixtures are then heated at 105°C ± 2°C (221°F ± 5°F) for 168 hr. The mixtures are thoroughly agitated and centrifuged for 10-min intervals until the volume of sediment becomes constant. The results are reported as the average volume of sediment per mixture.

18. Stability of Lubricating Oils (Work Factor)

Specification: Federal Test Method Standard No. 791b, Method 3451.3

This method is used for determining the stability of lubricating oils when subjected to an endurance test. The specimen to be tested is examined before the test for the following: (a) Carbon Residue (Federal Test Method 5002); (b) Neutralization Number (Federal Test Method 5105); (c) Precipitation Number (Federal Test Method 3101); (Astra Method D-91); (d) Viscosity (Federal Test Methods 304 or 305, ASTM Method D-88 or D-445).

The specimen is then tested in a journal bearing with a babbitt-metal bearing. The journal is operated at 3000-5100 rpm/2000 ± 100 rpm for certain samples, with an oil pressure of 10 psig (15 psig for certain samples) and a bearing load of 1,034,100 N/m^2 (150 psi) for a period of 100 ± 1/2 hr. After the test, the oil is again tested for the above properties and a work factor number for the sample is calculated from the changes observed.

19. Separation Characteristics of Universal Gear Lubricants

Specification: Federal Test Method Standard No. 791b, Method 3455.1

This method is used for determining the separation characteristics of universal gear lubricants during storage.

A 100-ml. sample of the lubricant is stored in a dark room at room temperature 29°C ± 8°C (85°F ± 15°F) for 30 days and centrifuged and examined for solid separation. If none occurs, then the sample is stored for 30 more days. The sample is then centrifuged and examined for solid and/or liquid separation. If a solid separates, it is weighed and results are reported as the percent by weight of the nonpetroleum solid material in the sample. If a liquid separates, it is measured and the results are reported as the percent, by volume, of nonpetroleum liquid in the sample.

20. Hydrolytic Stability

Specification: Federal Test Method Standard No. 791b, Method 3457.1

This method is used for determining the resistance of an oil to reaction in contact with water. The test consists of tumbling; under specified conditions of time, temperature and tumbling rate, a mixture of test oil and water in a bottle containing a copper strip, and then testing for changes in the oil, water, and copper.

21. Swelling of Synthetic Rubbers

Specification: Federal Test Method Standard No. 791b, Method 3603.4

This method is used for determining the swelling effects of petroleum products upon synthetic rubber.

The volumes of three standard test sheets of rubber are determined by water displacement. The sheets are then immersed in the sample for 168 hr at 70°C (158°F), and the average change in the volume of the sheets is computed. The results are reported as percentage change in the volume.

Precision: Test results by one operator, at one laboratory, shall not vary from the average by more than the following: if average volume change is 0-5% units, then variation must not exceed 0.5% unit; if average volume change is about 5% units, then variation must not exceed 1% units.

22. Swelling of Synthetic Rubber (Aircraft Turbine Lubricants)

Specification: Federal Test Method Standard No. 791b, Method 3604.1

This method is used for determining the swelling effects of aircraft turbine lubricants on synthetic rubber.

Three sheets of a standard test rubber are immersed with lubricant which is heated to 70°C ± 1°C (150°F ± 2°F). After their volume has been determined by water displacement, the rubber sheets remain in the heated lubricant for 168 hr. The sheets are then removed, cleaned, and any change in volume is determined by water displacement. The results are reported as the average percent volume change of the three rubber sheets.

Precision: Results should not differ by more than the following:

Repeatability - 1%
Reproducibility - 2%

23. Carbon Residue (Conradson)

Specification: Federal Test Method Standard No. 791b, Method 5001.11, ASTM D-189-65

This method describes a procedure for the determination of the carbon residue left after evaporation and pyrolysis of an oil, and is intended to provide some indication of relative coke-forming properties. It is generally applicable to relatively nonvolatile petroleum products which partially decompose on distillation at atmospheric pressure. Petroleum products containing ash-forming constituents will have an erroneously high carbon residue, depending on the amount of ash formed.

The weight quantity of the sample is placed in a crucible and subjected to destructive distillation. The residue undergoes cracking and coking reactions during a fixed period of severe heating. At the end of the heating period, the crucible with the residue is cooled in a dessicator and weighed. The residue remaining is calculated as a percentage of the original sample and reported as the Conradson carbon residue.

24. Deposit-Forming Tendencies of Aircraft Turbine Lubricants

Specification: Federal Test Method Standard No. 791b, Method 5003.1

This test method describes a procedure for determining the deposit and sludge-forming tendencies of aircraft turbine lubricants.

A sample of the lubricant is circulated, in a special decomposition tester, under prescribed conditions, for a prescribed period of time through an aerated test chamber containing an aluminum tube held at a constant temperature of 310°C ± 1°C (590°F ± 5°F). From the chamber the oil passes through a cooler, a line filter, a circulating pump and back into the chamber. At the end of 12 hr, the test run is stopped. The weight of solid decomposition products on the heated tube is recorded as coke. The weight of the products found in the line filter is recorded as sludge. The deposit rating is calculated from: deposit rating = sludge + 10 (coke).

Precision: The results should not differ by more than the following amounts:

Repeatability - 0.75 deposit rating
Reproducibility - 0.75 deposit rating

25. Neutralization Number by Color Indicator Titration

Specification: Federal Test Method Standard No. 791b, Method 5105.5, ASTM D-974-64, Institute of Petroleum: IP-139/64T

This method is intended for the determination of acidic or basic constituents in petroleum products and lubricants soluble or nearly soluble in mixtures of toluene and isopropyl alcohol. It is applicable for the determination of acids or bases whose dissociation constants in water are larger than 10^{-9}; extremely weak acids or bases whose disassociation constants are smaller than 10^{-9} do not interfere.

To determine the total acid or strong base number, the sample is dissolved in a mixture of toluene and isopropyl alcohol containing a small amount of water, and the resulting single-phase solution is titrated at room temperature with standard alcoholic base or alcoholic acid solution, respectively, to the end point indicated by the color change of the added p-naphtholbenzoin solution (orange in acid and green-brown in base). To determine the strong acid number, a separate portion of the sample is extracted with hot water and the aqueous extract is titrated with potassium hydroxide solution, using methyl orange as an indicator. Calculate and report acid or base number as the number of milligrans of potassium hydroxide to neutralize 1.0 g of the sample.

26. Neutralization Number by Potentiometric Titration

Specification: Federal Test Method Standard No. 791b, Method 5106.4, ASTM D-664-58

This method describes procedures for the determination of acidic or basic constituents in petroleum products and lubricants. The method resolves these constituents into groups, having weak acid, strong acid, weak base, and strong base ionization properties, provided the dissociation constants of the more strongly acidic or basic compounds are at least 1,000 times that of the next weaker groups.

A sample is dissolved in a mixture of toluene and isopropyl alcohol containing a small amount of water and titrated potentiometrically with alcoholic potassium hydroxide and hydrochloric acid solution, using a glass indicating electrode and a calomel reference electrode. The meter readings are plotted against the respective volumes of titrating solutions and the end points are taken at the inflection point in the resulting curve.

27. Sulfur (Bomb Method)

Specification: Federal Test Method Standard No. 791b, Method 5202.12, ASTM D-129-64

This method describes the procedure for the determination of sulfur in petroleum products that cannot be burned completely in a wick lamp. The method is applicable to any petroleum product sufficiently low in volatility that it can be weighed accurately in an open sample boat and containing at least 0.1% surfur.

The sample is oxidized by complete combustion in a bomb containing oxygen under pressure. The sulfur, as a sulfate in the bomb washings, is determined gravimetrically as barium sulfate. The results are reported as sulfur percent by weight.

Precision: Duplicate results should not be considered suspect unless they differ by more than the following amounts:

Sulfur (% by weight)	Repeatability	Reproducibility
0.1-0.5	0.04	0.05
0.5-1.0	0.06	0.09
1.0-1.5	0.08	0.15
1.5-2.0	0.12	0.25
2.0-5.0	0.18	0.27

28. Corrosion Test at 232°C (450°F)

Specification: Federal Test Method Standard No. 791b, Method 5305

This method is used for determining the corrosive tendencies of lubricants at high temperatures.

A prepared silver strip and a prepared copper strip are immersed in two samples of the lubricant and heated to 232°C (450°F) for 50 hr. The strips are then removed, washed, and weighed and any change of weight is recorded. The results are then reported as the average change in weight per square inch of the two strips.

Precision: Results should not differ by more than the following amounts:

Average Change (mg/sq. in.)	Repeatability	Reproducibility
0-3	0.3 mg/sq. in.	0.6 mg/sq. in.
above 3	10%	20%

29. Corrosiveness and Oxidation Stability of Light Oils (Metal Strip)

Specification: Federal Test Method Standard No. 791b, Method 5308.6

This method is used for testing hydraulic oils (and similar, highly refined, light oils) to determine their ability to resist oxidation and their tendency to corrode various metals.

Five different metal strips (one each of copper, steel, aluminum alloy, magnesium alloy, and cadmium-plated steel) are immersed in a sample of the oil and heated at 121°C (250°F) for 168 hr while air is bubbled through. The strips are then removed and weighed and the results recorded as change in weight per square inch. Each strip is examined for any evidence of pitting or etching or stains. The oil sample is examined before and after the test for neutralization number (Federal Test Method 5105 or 5106) and for viscosity (Federal Test Method 305, ASTM D-445) and the percent of change of each is determined.

30. Copper Corrosion by Petroleum Products (Copper Strip Test)

Specification: Federal Test Method Standard No. 791b, Method 5325.4, ASTM D-130-68

This method describes procedures for the detection of the corrosiveness to copper of fuels, gasolines, cleaners, fuel oils, and other petroleum products.

A polished copper strip is immersed in a given quantity of the sample and heated at a temperature and for a time characteristic of the material being tested. At the end of the period, the copper strip is removed and compared with the ASTM copper strip corrosion standards. The results are reported as the class of corrosion the strip falls into.

31. Lead Corrosion Test

Specification: Federal Test Method Standard No. 791b, Method 5321.1

This method is used for measuring the corrosiveness of lubricating oils on lead in the presence of a copper catalyst.

A lead panel is attached to a stirrer after polishing and weighing. The stirrer is immersed in a sample of the lubricating oil which is heated to 163°C ± 1°C (325°F ± 2°F). The stirrer is rotated at 600 ± 50 rpm for 60 min while air is bubbled through the oil. The lead panel is then weighed and any change in weight is recorded in milligrams per square inch of surface area.

Precision:

Weight Change (mg/sq. in.)	Repeatability	Reproducibility
0-10	1 mg/sq. in.	2 mg/sq. in.
above 10	10% of average	20% of average

32. Moisture Corrosion Characteristics of Gear Lubricants

Specification: Federal Test Method Standard No. 791b, Method 5326.1

This method is used to determine the corrosion preventive properties of gear lubricants. It duplicates normal service conditions wherein moisture condenses on the metal parts during cyclic ambient temperatures. The procedure can be used on new or used oil samples.

The sample and a small amount of water are placed in a differential assembly test unit with a prepared cover plate. The unit is maintained at 82°C (180°F) and operated at 2500 rpm for 4 hr. The unit is then stopped and placed in a storage box at 52°C ± 1°C (125°F ± 2°F) for a stipulated time (either 1 day or 7 days). The unit is disassembled and examined for evidence of corrosion.

33. Saponification Number (Color Indicator Titration)

Specification: Federal Test Method Standard No. 791b, Method 5401.8, ASTM D-94-62

This method of test intended for determining the amount of constituents in petroleum products that will easily saponify under the conditions of the test. The saponification number of an oil is the number of milligrams of potassium hydroxide which is consumed by 1 g. of oil under the conditions of the test.

A weighed sample of the oil, dissolved in methylethylketone, with a measured quantity of a standard alcoholic solution of KOH, is heated. The amount of unconsumed KOH is determined after heating by titration with a standard solution of HCl. The KOH consumed is calculated and divided by the weight of the sample.

Precision: With care, determination by different operators should agree within ±0.5 saponification numbers for values less than 5.0, and within ±0.7 saponification numbers for values above 5.0.

34. Ash Content

Specification: Federal Test Method Standard No. 791b, Method 5421.4, ASTM D-482-63

This method describes a procedure for determining the ash from distillate and residual oils, crude oils, lubricating oils, waxes, and other petroleum products, in which any ash-forming materials present are normally considered to be undesirable impurities or contaminants. The method is limited to products which are free from added ash-forming additives.

A measured sample of the product is placed in a suitable dish and ignited and allowed to burn until only ash and carbon remain. The carbonaceous residue is reduced to ash by heating in a muffle furnace at 775°C (1427°F), cooled in a dessicator, and weighed.

Precision: The following data should be used for judging the acceptability of results. Results should not be considered suspect unless they differ by the following amounts:

Ash (%)	Repeatability	Reproducibility
0.0-0.15	0.003	0.005

35. Sulfated Residue (New Lubricating Oils)

Specification: Federal Test Method Standard No. 791b, Method 5422.3, ASTM D-874-63

This method describes a procedure for determining the sulfated ash from unused lubricating oils containing additives and from additive concentrates used in compounding. These additives usually contain one or more of the following metals: barium, calcium, magnesium, zinc, potassium, sodium, and tin. They may be in combination with one or more of the elements sulfur, phosphorus, and chlorine. The sulfated ash may be used to indicate the concentration of additives in new oils.

A sample is ignited and burned until only ash and carbon remain. After cooling, the charred ash is treated with sulfuric acid and heated at 550°C (1022°F) until the oxidation of the carbon is nearly complete. The ash is then cooled, retreated with sulfuric acid, heated at 775°C (1427°F) and weighed.

Precision: The following data should be used for judging the acceptability of results. Results should be considered suspect unless they differ by more than the following amounts:

Sulfated Ash (%)	Repeatability	Reproducibility
0-1	0.04	4% of the mean
over 1	0.06	6% of the mean

36. Metals in Lubricating Oils

Specification: Federal Test Method Standard No. 791b, Method 5601.1, ASTM D-811-48

This method describes the procedures intended for the determination of barium, tin, silica, zinc, aluminum, calcium, magnesium, sodium, and potassium in new and used lubricating oils. Other metallic elements--sulfur, phosphorus, and chlorine in amounts commonly found in lubricating oils--do not interfere in this method.

The analytical procedures follow the well known scheme of separating the metals into groups for more convenient determination. This scheme provides a rapid and accurate method for the determination of all, several, or any one of the metals as may be seen necessary from an initial qualitative inspection of the oil sample.

37. Chlorine in Lubricating Oils (Bomb Method)

Specification: Federal Test Method Standard No. 791b, Method 5651.4, ASTM D-808-63

This method covers the determination of chlorine in lubricating oils and greases, including new and used lubricating oils and greases containing additives, and in additive concentrates. Its range of applicability is 0.1-50% chlorine.

A small sample is oxidized by combustion in a bomb containing oxygen under pressure. The chlorine compounds thus liberated are absorbed in a sodium carbonate solution and the amount of chlorine present is determined gravimetrically by precipitation as silver chloride.

Precision: The following criteria should be used for judging the acceptability of results. Results should not be considered suspect unless they differ by more than the following amounts:

Range of Chlorine Content (%)	Repeatability	Reproducibility
oil - 2 exclusive	0.07	0.10
2-5 inclusive	0.15	0.30
above 5	3% of amount present	5% of amount present

38. Phosphorus in Lubricating Oils

Specification: Federal Test Method Standard No. 791b, Method 5661.5, ASTM D-1091-64

These methods are applicable to the determination of phosphorus in unused lubricating oils, lubricating oil additives, and their concentrates. The methods are not restricted with respect to the type of phosphorus compounds that may be present since all are quantitatively converted to an aqueous solution of orthophosphate ion by oxidation of the sample during the course of analysis.

The organic material in the sample is removed and the phosphorus is converted to phosphate ion by oxidation with sulfuric acid, nitric acid, and hydrogen peroxide. One of two procedures is then followed: the photometric method or the gravimetric method. The photometric method is used where the phosphorus content is estimated to be under 2%, and the gravimetric method for phosphorus contents of 2% or over.

39. Load Carrying Capacity (Mean Hertz Load)

Specification: Federal Test Method Standard No. 791b, Method 6503.2

This method describes a procedure for determining the load carrying ability of a lubricant under extremely high pressure.

A sample of the lubricant (500 ml.), either grease or oil, is placed in the ball pot of a Shell Four Ball Extreme Pressure Tester. Three 1/2 in. steel bearing balls are held stationary in the ball pot and immersed in the lubricant. A fourth ball is mounted in a rotating chuck to which a thrust load is applied and rotated at 1800 rpm against the three stationary balls. The bearing thrust load of 40 kg. is increased in 5 kg. increments until welding occurs. Welding is indicated by a sharp traverse movement of the indicator pen signifying momentary locking of the four balls. The mean loads are calculated from the sizes of the scars produced.

40. Load Carrying, Wear, and Extreme Pressure Characteristics of Gear Lubricants in Axles Under High Speed, Low-Torque Operation, Followed by Low-Speed, High-Torque Operation

Specification: Federal Test Method Standard No. 791b, Method 6506.1

This method is used for determining the load carrying, wear and extreme pressure characteristics of gear lubricant in axles under conditions of high-speed, low-torque, and low-speed, high-torque operation, using a single set of gears.

A sample of the oil is placed in a test assembly of a hypoid rear axle carrier. The assembly is then driven at 445 rpm with a torque of 1,069 N/m (9,460 lb-in.) and, with the lubricant at 149°C (300°F) for 100 min, for the high-speed, low-torque test. The apparatus is then examined (still intact) for corrosion. The assembly is then driven at 80 rpm with a torque of 4,723 N/m (41,800 lb-in.) and with the lubricant at 135°C (275°F) for 24 hr. The apparatus is then disassembled and examined for wear, corrosion, deposits, discoloration, rust, fatigue, scratches, burnishing, etc.

41. Load Carrying and Extreme Pressure Characteristics of Gear Lubricants in Axles Under Conditions of High Speed and Shock Loading

Specification: Federal Test Method Standard No. 791b, Method 6507.1

This method is used for determining the antiscoring properties of gear lubricants under high speed and shock conditions.

A sample of the lubricant is placed in a test assembly of a Spicer Model 44-1 rear axle, 47 to 12 ratio. An examination of the gear teeth is made before testing. The apparatus is then operated beginning at 99°C (200°F). Lubricant temperature while the axle speed is accelerated from 550-1,100 rpm and then decelerated to 550 rpm for 5 cycles with inertia torque only. Without disassembling, the nature, extent and location of the drive and coast contact areas are observed and recorded. Then, beginning at 138°C (280°F) lubricant temperature, the apparatus is operated with a 178 N/m (131 ft/lb) torque on each axle while the speed is accelerated rapidly from 550-650 rpm and decelerated rapidly to 550 rpm for 10 cycles. The apparatus is disassembled and the nature, extent and location of drive and coast contact areas are noted and any disturbances to the ring gear tooth forces.

42. Load Carrying Ability of Lubricating Oils (Ryder Gear Machine)

Specification: Federal Test Method Standard No. 791b, Method 6508.1

This method describes a procedure for determining the load carrying ability of lubricating oils with respect to gears.

The two special test gears are mounted in a Ryder Gear-Erdco Universal Tester. The test oil is heated to 74°C (165°F) and the gears rotated at 10,000 rpm in cycles of 10 min each with uniform increases in gear load for each cycle. The gears are examined for scuffing at the end of each cycle. The cycles are continued until a preset percent of gear tooth scuffing is observed. The load carrying ability is that gear tooth load which produces an average gear tooth scuffing of 22.5% of force areas. Results are reported as the percent of load carrying ability of the test oil to a reference oil.

Precision:

Repeatability: Relative readings should not differ from their mean by more than 10%.

Reproducibility: Relative readings should not differ from their mean by more than 5%.

43. Gear Fatigue Characteristics of Aircraft Gas Turbine Lubricants at 204°C (400°F)

Specification: Federal Test Method Standard No. 791b, Method 6509.1

This method describes a procedure for determining the fatigue characteristics of aircraft gas turbine engine lubricants at 204°C (400°F) with respect to gears.

Two special test gears are mounted in a WADD High-Temperature Gear Machine adapted to a modified Ryder Gear-Erdco Universal drive system. The test oil is heated to 204°C (400°F) and the gears rotated at 10,000 rpm in 10 min cycles with uniform increases in load at each cycle. At the end of each cycle the gears are examined for scuffing. When a predetermined maximum load is reached, the cycle duration is increased to 2 hr at constant load. At the end of each cycle, the gears are then observed for development of fatigue pits which are large enough to be readily discernible to the eye.

Results are reported as the percent of load carrying ability with respect to a reference oil of the test oil and the rating of each fatigue cycle in terms of the number of fatigue pits.

44. Load Carrying Ability of Lubricating Oils at 204°C (400°F)

Specification: Federal Test Method Standard No. 791b, Method 6511.1

This method describes a procedure for determining the load carrying ability of lubricating oils at 204°C (400°F) with respect to gears.

Two special test gears are mounted in a WADD High-Temperature Gear Machine adapted to a modified Ryder Gear-Erdco Universal drive system. The test oil is heated to 240°C (400°F) and the gears rotated at 10,000 rpm in cycles of 10 min with uniform increases in gear load for each cycle. The cycles are continued until a set percentage of gear tooth force scuffing is observed. The load carrying ability is that gear tooth load which produces an average gear tooth scuffing of 22.5%. Results are reported as the percent of load carrying capacity of the test oil to a reference oil.

45. Viscosity Index (Calculation)

Specification: Federal Test Method Standard No. 791b, Method 9111.3, ASTM D-2270-64

This method gives the necessary equations and tables for the calculation of the viscosity index of a petroleum product or lubricant from its viscosity at 38°C (100°F) and 99°C (210°F). This method provides tables for oils with viscosities at 99°C (210°F) between the values of 2.0 and 75.0 x 10^{-6} m^2/sec (centistokes). Equations are provided for calculating basic values for oils having viscosities at 99°C (210°F) below 2.0 x 10^{-6} m^2/sec (centistokes) or above 0.00163 m^2/sec (350 sec), Saybolt Universal at 99°C (210°F).

The viscosity index is an empirical number indicating the effect of change of temperatures on the viscosity of an oil. A low viscosity index signifies relatively large change of viscosity with temperature.

B-II. Test Methods for Lubricating Greases

1. Apparent Viscosity of Lubricating Greases

Specification: Federal Test Method Standard No. 791b, Method 306.4, ASTM D-1092-62

This method describes a procedure for measuring, in poises, the apparent viscosity of lubricating greases in the temperature range of -54°C to 38°C (-65°F to 100°F). Measurements are limited to the range of 2.5 to 10,000 N-sec/m^2 (25 to 100,000 poises) at 10 reciprocal seconds, and 0.1 to 10 N-sec/m^2 (1 to 100 poises) at 15,000 reciprocal seconds.

A grease sample is forced through a capillary by means of a floating piston actuated by a hydraulic system. From a predetermined rate of flow and the force in the system, the apparent viscosity is calculated by means of Poiseuille's equation. The apparent viscosity is determined at 16 different shear rates by use of two pump speeds and eight sizes of capillaries. The results are expressed by a log plot of apparent viscosity versus shear rate.

Precision: The following data should be used for judging the acceptability of results. Results should be considered suspect if they differ by more than the following:

		Percent of Mean	
Sample	Temperature	Repeatability	Reproducibility
Smooth, NLGI 2 Diester oil	-54°C (-65°F)	7	12
Smooth, NLGI 2 SAE 20 oil	25°C (77°F)	6	19
Fibrous, NLGI 1 SAE 20 oil	25°C (77°F)	6	23
Viscous, NLGI 1 SAE 90 oil	25°C (77°F)	7	30

2. Penetration of Lubricating Grease

Specification: Federal Test Method Standard No. 791b, Method 311.8, ASTM D-217-68

This method describes three test procedures for measuring the consistency of lubricating grease by penetration of a standard cone. This method includes procedures for the measurement of worked, unworked, and block penetrations.

Penetrations, measured in tenths of a millimeter, are determined at 25°C (77°F) by releasing a standard cone assembly and allowing the cone to drop into the grease for 5 sec. Worked penetrations are determined immediately after working the sample for 60 strokes in a standard grease worker. Unworked penetrations are determined on the sample as received. Block penetrations are determined on a freshly prepared face of a cube cut from a block of grease with a standard cutter.

Precision: Two results should not be considered suspect unless they differ more than the following amounts:

	Worked	Unworked	Block
Penetration range (0.1 mm)			
Original penetrometer cone	130-400	85-400	Under 85
Alternate penetrometer cone	130-475	85-475	Under 85
Repeatability	7 Units	9 Units	3 Units
Reproducibility	15 Units	18 Units	7 Units

3. Penetration of Lubricating Greases After Mechanical Working

Specification: Federal Test Method Standard No. 791b, Method 313.2

This method is used for determining the consistency of lubricating greases that have been subjected to severe mechanical working. The sample is placed in a grease working machine and worked for 100,000 double strokes at 60 double strokes per minute. A standard cone penetration test, as described in ASTM D-217-60T and Federal Standard Test 311.6, is made on the worked sample.

Penetration, measured in tenths of a millimeter, is determined at 25°C (77°F) by releasing a standard cone assembly and allowing the cone to drop into the grease for 5 sec.

4. Oil Separation from Lubricating Grease (Static Technique)

Specification: Federal Test Method Standard No. 791b, Method 321.2

This method is used for determining the tendency of the oil in lubricating grease to separate at elevated temperature.

A measured sample (10 g.) of the grease is placed in a nickel wire gauze cone (60 mesh) under static conditions for the time and temperature specified (usually 30 hr at 100°C (212°F)) and then determining the percentage by weight of the oil drained through the cone.

5. Oil Separation from Lubricating Grease During Storage (Air Pressure Technique)

Specification: Federal Test Method Standard No. 791a, Method 322.3, ASTM D-1742-64

This method describes a procedure for determining the tendency of lubricating grease to separate oil during storage in both conventional and cratered containers. This method is not suitable for use with greases softer than NLGI No. 1 consistency, because of a tendency for the grease to seep through the screen. It does not predict the stability of grease under dynamic conditions.

A sample of grease is placed on a No. 200 sieve and subjected to 1,723 N/m^2 (0.25 psi) air pressure for 24 hr at 25°C (77°F). Any oil seepage which occurs drains into a beaker and is weighed. The results are reported as the percentage weight of the oil separated.

6. Performance Characteristics of Lubricating Greases in Antifriction Bearings at Elevated Temperatures

Specification: Federal Test Method Standard No. 791b, Method 331.2

This method is used for determining the lubricating ability of greases in antifriction bearings under axial and radial loads to withstand elevated temperatures.

A sample of test grease (3.0 g.) is packed in a No. 204K ball bearing; the bearing then mounted on the test spindle and installed in the test fixture with the specified radial 13.44 N (3 lb) and thrust 22.40 N (5 lb) bearing loads. The test fixture is installed in an oven at a specified temperature, and the spindle and bearing inner race are rotated at 10,000 rpm. The bearing is inspected for wear and grease leakage at 20 hr intervals for a specified time or until failure. Failure is indicated by: increase in frictional torque sufficient to trip motor overload switch, locking of bearing and belt slippage at startup, and by excessive grease leakage indicated by grease on face of bearing housing.

7. Functional Life of Ball Bearing Grease

Specification: ASTM D-1741-60T

This method provides two procedures for evaluating the functional life of ball bearing greases when tested under prescribed laboratory conditions. It is not the equivalent of long time service tests and is limited to greases for operating temperatures up to 125°C (257°F).

Procedure A – Performance life, including leakage evaluation. Two No. 30BC03406 ball bearings are cleaned and packed with the sample grease and placed in the shaft of a special belt-driven grease tester equipped with a thermostat controlled heater. The grease tester end caps are filled with grease and the unit assembled. The tester is operated at 3,500 rpm and 125°C (257°F) for 20 hr and then stopped for 4 hr and the cycle repeated until lubricant failure occurs. This procedure simulated "in-the-field" grease-gun bearing lubrication.

Procedure B – Performance life alone. This is the same as Procedure A above except only one-third of the bearing ball space is packed with grease and no grease is packed in the housing. This procedure simulated "factory-packed" bearings applications.

Grease failure may be considered to occur by one of the following conditions; stalling of motor during operation, stalling of motor during restart after shutdown, temperature rise of 10°C (18°F) and by an increase in noise level lasting more than 10 min.

The results are reported as test conditions, type of failure, bearing inspection after test, and grease leaking.

8. Low Temperature Torque of Ball Bearing Greases

Specification: Federal Test Method Standard No. 791, Method 401.7
ASTM D-287-67

This method determines the extent to which a low temperature grease retards the rotation of a slow speed ball bearing when subjected to subzero temperature. The method employs grease of extremely low torque characteristics at -54°C (-65°F) and may not be applicable to other greases, speeds, or temperatures.

A No. 204 ball bearing is packed completely full of the test grease and cleaned flush with the sides. The bearing remains stationary while its temperature is lowered to -54°C (-65°F) and held for 2 hr. At the end of this time, the inner ring of the bearing is rotated at 1 rpm and the retaining force on the outer ring is determined. The starting and running torques in grams-centimeters are computed and recorded.

Precision: Results should be considered suspect if they differ by more than the following amounts.

	Percent of Mean	
	Repeatability	Reproducibility
Starting torque	15.0	50
Running torque	35.0	73

9. Gear Wear

Specification: Federal Test Method Standard No. 791a, Method 335.2

This method describes a procedure for determining the relative lubricity of grease.

A set of special test gears of known wear properties, brass and steel, are lubricated with the test grease and mounted in the tester. The brass gear is driven by an oscillating drive mechanism and drives the steel gear which is torque loaded by suspended weight. After the test, the loss of weight of the brass gear is determined. The results are reported as the average loss of weight per 1,000 cycles.

10. Evaporation Loss of Lubricating Greases and Oils

Specification: Federal Test Method Standard No. 791b, Method 351.2, ASTM D-972-56

This method describes the test procedure for determining the evaporation loss of lubricating greases and oils for applications where evaporation loss is a factor. Evaporation loss data can be obtained at any temperature in the range of 99°C to 149°C (210°F to 300°F).

A measured sample is placed in a standard evaporation cell and the cell then placed in a bath maintained at the desired temperature. Heated air is passed through the cell at a standard rate for 22 hr. The evaporation loss is calculated from the weight loss of the sample.

Precision: Results should not differ from the mean by more than the following amounts:

Repeatability - 2.5% of mean
Reproducibility - 10% of mean.

11. Dropping Point of Lubricating Grease

Specification: Federal Test Method Standard No. 791b, Method 1421.2, ASTM D-566-64

This method covers the procedure for the determination of the ASTM-IP dropping point of lubricating grease. The dropping point is that temperature at which the grease passes from a semisolid state to a liquid state under the conditions of test.

A reproducible sample of grease is placed in a specified standard cup which has a small calibrated orifice in the bottom. The cup is placed in a special test tube with a thermometer held in the grease by a rubber stopper in the test tube. The test tube assembly is placed in an oil bath and the bath is heated slowly in a prescribed manner. The temperature of the grease and the temperature of the oil bath are recorded when a drop of grease protrudes through the hole in the bottom of the standard cup and drops into the test tube. The average of the two temperatures is the dropping point.

Precision: A sufficient number of determinators shall be made so that an average deviation from the mean is 1.5°C (3°F), or less. The average results so obtained by different operators with different appratus shall agree within 3°C (6°F).

12. Thermal Stability of Greases

Specification: Federal Test Method Standard No. 791b, Method 2503.2

This method is used for providing an indication of the thermal stability of a grease in the presence of steel. It consists of heating a "sandwich" of test grease and two steel plates in an oven at 100°C (212°F) for 7 days, then checking visually the grease for hardening, separation or any other changes except color.

13. Dirt Content of Grease

Specification: Federal Test Method Standard No. 791a, Method 3005.3

This method is used for determining the size and concentration of foreign particles in lubricating greases.

A known quantity of grease is applied to a microscope slide and the slide is examined under a microscope, with an eyepiece micrometer, to determine the size and number of particles present. Results are reported as the number of particles per cubic centimeter of grease, for three groups of particle size; 25-75 microns, 75-125 microns, and those over 125 microns.

14. Estimation of Deleterious Particles in Lubricating Grease

Specification: ASTM D-1404-56T

This method describes a procedure for the detection and estimation of deleterious particles in lubricating grease. A deleterious particle by this method is one which will scratch a polished plastic surface.

A small sample of the grease is placed between two clean, highly polished acrylate plastic plates held rigidly and parallel to each other in metal holders. The assembly is pressed together, squeezing the grease between the plates in a thin layer. Any particles larger than the distance of separation of the plates and harder than plastic will become imbedded in the plastic surfaces. One plate is rotated at 30 degrees with respect to the other, while the assembly is under pressure. The imbedded particles will then form characteristic arc-shaped scratches on one or both plates. The scratches are counted and the number reported.

15. Water Resistance of Lubricating Greases

Specification: Federal Test Method Standard No. 791b, Method 3252.3, ASTM D-1264-63

This method is intended to evaluate the resistance of a lubricating grease to washout by water from a bearing when tested at 38°C (100°F) and 79°C (175°F) under prescribed laboratory conditions, but is not considered the equivalent of service evaluation tests.

A measured sample of the grease is packed in a standard ball bearing, and the bearing accurately weighed and inserted in a housing with specified clearances and rotated at 600 ± 30 rpm. At the specified test temperature, water impinges on the bearing housing at a rate of 5 ± 0.5 ml/sec. The amount of grease washed out in 1 hr, as determined by weight change, is a measure of the resistance of the grease to water washout.

Precision:

Reproducibility: Results should not differ by more than ±10% grease washout.

16. Oxidation Stability of Lubricating Greases (Oxygen Bomb)

Specification: Federal Test Method Standard No. 791b, Method 3453.2, ASTM D-942-70, Institute of Petroleum, IP 142/64

This method describes the test for determining the resistance of lubricating greases to oxidation when stored under static conditions for long periods of time, as, for instance, thin coatings on antifriction bearings and on motor parts, etc.

Samples of the grease are placed in a standard oxygen bomb and the bomb is heated to 99°C (210°F) and filled with oxygen at 7.58×10^5 N/m^2 (110 psi). The degree of oxidation after a given period of time is determined by the corresponding decrease in oxygen pressure. Specifications are usually given in terms of pressure drop in psi or N/m^2 at one or more time intervals, for instance after 100 hr, 200 hr, etc.

Precision: Results should not differ from the mean by more than the following amounts.

Pressure Drop		Repeatability		Reproducibility	
SI N/m^2	(English) (psi)	SI N/m^2	(English) (psi)	SI N/m^2	(English) (psi)
$0 - 3.48 \times 10^4$	(0 - 5)	6,895	(1)	20.685	(3)
$3.48 \times 10^4 - 6.89 \times 10^4$	(5 - 10)	13,790	(2)	27,580	(4)
$6.89 \times 10^4 - 13.79 \times 10^4$	(10 - 20)	20,685	(3)	41,370	(6)
$13.79 \times 10^4 - 37.9 \times 10^4$	(20 - 55)	34,475	(5)	68,950	(10)

17. Channeling Characteristics

Specification: Federal Test Method Standard No. 791b, Method 3456

This method is used for determining the channeling characteristics of lubricants at low temperature.

A 650 ml. sample is placed in a round container and cooled to the specified temperature for ±18 hr. A channel is then cut through the sample and observations made to determine if the sample flows back to completely cover the bottom of the container in 10 sec. If it has, it is reported as nonchanneling; if not, it is reported as channeling.

18. Rust Preventive Properties of Lubricating Greases

Specifications: Federal Test Method Standard No. 791b, Method 4012.1, ASTM D-1743-64

This method describes a test for determining the corrosion preventive properties of greases, using grease lubricated tapered roller bearings stored under wet conditions.

Clean new bearings are lubricated, then run under a light thrust load for 60 sec so as to distribute the lubricant in a pattern that might be found in service. The bearings are then stored for 2 weeks at 25°C (77°F) and 100% relative humidity.

After cleaning, the bearings are inspected for evidence of corrosion. Results are reported as ratings of 1, 2, or 3, with 1 being no observable corrosion.

Precision: Repeatability may be judged by the fact that 99% of results obtained by 20 labs, with 10 samples, were in agreement. Reproducibility may be judged by the fact that the 20 labs matched the concensus at least 84% of the time on the seven samples with good or bad protection, but only 44% of the time on the three samples with marginal protections.

19. Corrosiveness of Greases (Copper Strip 100°C (212°F))

Specification: Federal Test Method Standard No. 791b, Method 5309.4

This method is used to determine the corrosive properties of grease at elevated temperatures.

A prepared copper strip is partially immersed in a sample of the grease at 100°C (212°F) for 24 hr and then the strip and the sample of grease are visually inspected for any change in color of specimen or other evidence of corrosion. The strip is further examined under a microscope of approximately 60 diameter magnification and any corrosion described. Any green color in the grease is also reported.

20. Rust Protection by Metal Preservatives in the Humidity Cabinet

Specification: Federal Test Method Standard No. 791b, Method 5310.2, ASTM D-1748-70

This method is used for evaluating the rust preventative properties of method preservatives under conditions of high humidity.

Cold rolled steel test panels (SAE 1010, 2 x 4 x 1/8 in.) are prepared to a prescribed surface finish, dipped in the test preventative, allowed to drain, and then suspended in a humidity cabinet at 49°C (120°F) for a specified number of hours. The preventative oil fails or passes the test according to the size and number of rust dots on the test surface of the panels as follows:

Pass - not more than three dots of rust, none larger than 1.0 mm in diameter.

Fail - four or more rust dots, or one larger than 1.0 mm in diameter.

21. Corrosiveness of Greases (Oxygen Bomb Copper Strip)

Specification: Federal Test Method Standard No. 791b, Method 5314.1, ASTM D-1261-55

This method describes the test for determining the effect of grease on copper parts of bearing assemblies with which the grease comes in contact. Although test procedure is not intended as a stability test of grease, some indication of the stability of greases in storage in contact with copper may be found by visual inspection of the grease at the end of the test.

A prepared copper strip is partially immersed in a sample of grease and heated to 99°C (210°F) in a bomb filled with oxygen at 7.58×10^5 N/m^2 (110 psi) for 20 hr. The copper strip is removed, washed, and examined for evidence of discoloration, etching and corrosion. The examination is made by comparison with reference strips mutually approved by purchaser and seller.

22. Cycling Performance Test of Grease

Specification: Federal Test Method Standard No. 791b, Method 5413

This method is used for providing an indication of the suitability of a grease for use in pneumatic systems between rubber and metal parts.

Three O-rings are placed in a standard piston and cylinder cycling system and lubricated with a sample of the grease. The assembled piston is then stored at 14°C (58°F) for 14 days to "age" the grease. The aged piston and cylinder are then connected to a cycling ring under pneumatic pressure of $9.65 - 11.01 \times 10^6$ N/m^2 (1,400-1,600 psi) and cycled at 36 cpm for 50,000 cycles with a 1.397×10^{-1} m (5-1/2 in.) stroke, cylinder temperature controlled at 52°C (125°F). The setup is then disassembled and bearing surfaces, O-rings and lubricant are examined.

23. Resistance of Grease to Fuel

Specification: Federal Test Method Standard No. 791b, Method 5414.3

This method is used for determining the resistance of grease to the solvent action of fuel. It consists of determining the solubility of the grease in a standard test fluid (1/2 hr shaker cycle with MIL-S-3136, Type II fluid), and observing the physical changes caused by an 8-hr immersion in the test fluid 25°C (77°F). The solubility is reported as percent weight loss of the grease specimen.

APPENDIX C

VISCOSITY CONVERSION DATA

Viscosity index (VI) is an arbitrary method of stating the rate of change of viscosity of an oil with change of temperature. Pennsylvania crude oils, refined by conventional methods, suffer comparatively little change in viscosity with temperature; Gulf Coastal crudes change considerably. These two crudes and their fractions have been assigned viscosity index numbers of 100 and 0, respectively. The average viscosity characteristics of these two standardized oils have been obtained by Dean and Davis (Chem. Met. Eng., 36, 1929, p. 618). The procedure in finding the VI of an oil is to determine its viscosity (Saybolt Universal) at 210 and at 100F. The viscosities at 100F of oils that have the same viscosity at 210F, but are of VI 100 and 0, are then found from A.S.T.M. D567-40T. The VI of the oil under consideration is then found, by simple ratio, by comparison of its increase in viscosity from 210 to 100F with the corresponding increases in the two standardized oils. Since the viscosity at 210F is taken at the same value for all three oils, the VI of the oil under investigation can be written

$$VI = \frac{L - U}{L - H} \times 100$$

where U, H, and L are the viscosities at 100F of the oil under test, of the VI = 100 oil, and of the VI = 0 oil, respectively. It should be noted that values of VI may be negative or may exceed 100.

Average values of VI for other crudes and their derivatives are about as follows: Mid-Continent, 70; East Texan, 60; Colombian, 40; Peruvian, 20.

By the use of addition compounds, such as paratone and acrylic ester, lubricating oils are raised to a higher viscosity index than normally obtained. Solvent refining also raises the viscosity index but has disadvantages that the oils are corrosive and are lower in lubricating value.

When lubricating oils are subjected to high pressure, there is a marked increase in viscosity. Paraffinic oils of high viscosity index vary less with pressure than do naphthenic oils, and fixed oils vary least.

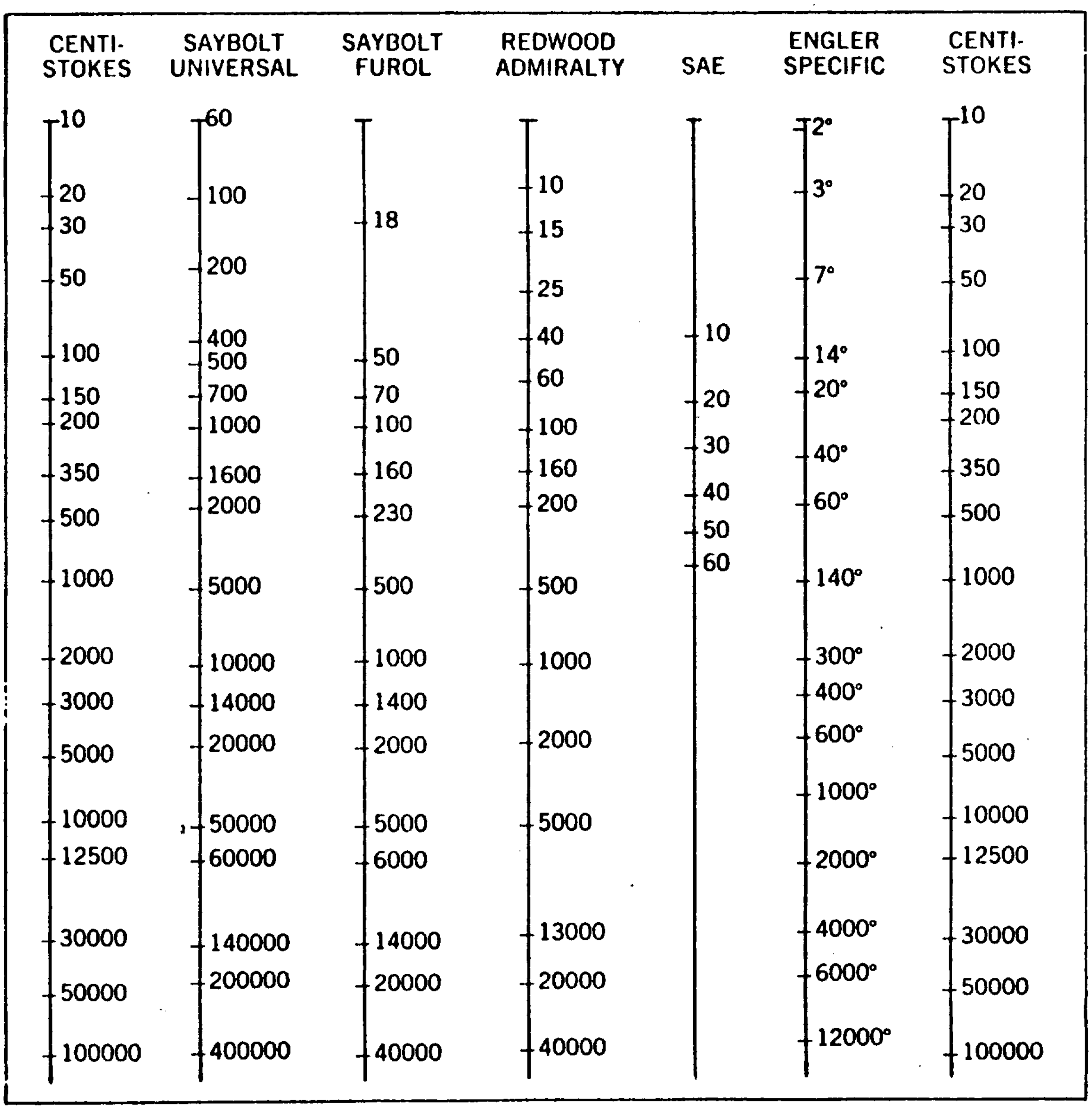
Lubricants with good temperature-viscosity curves (high viscosity index) are desirable. In cold starting, the flatter the temperature-viscosity curve, the less the energy required and better the fluidity. In normal operation and at high temperatures and at high pressures, the flatter temperature-viscosity curve oils have less friction and higher load-carrying capacity.

VISCOSITY CONVERSION TABLE

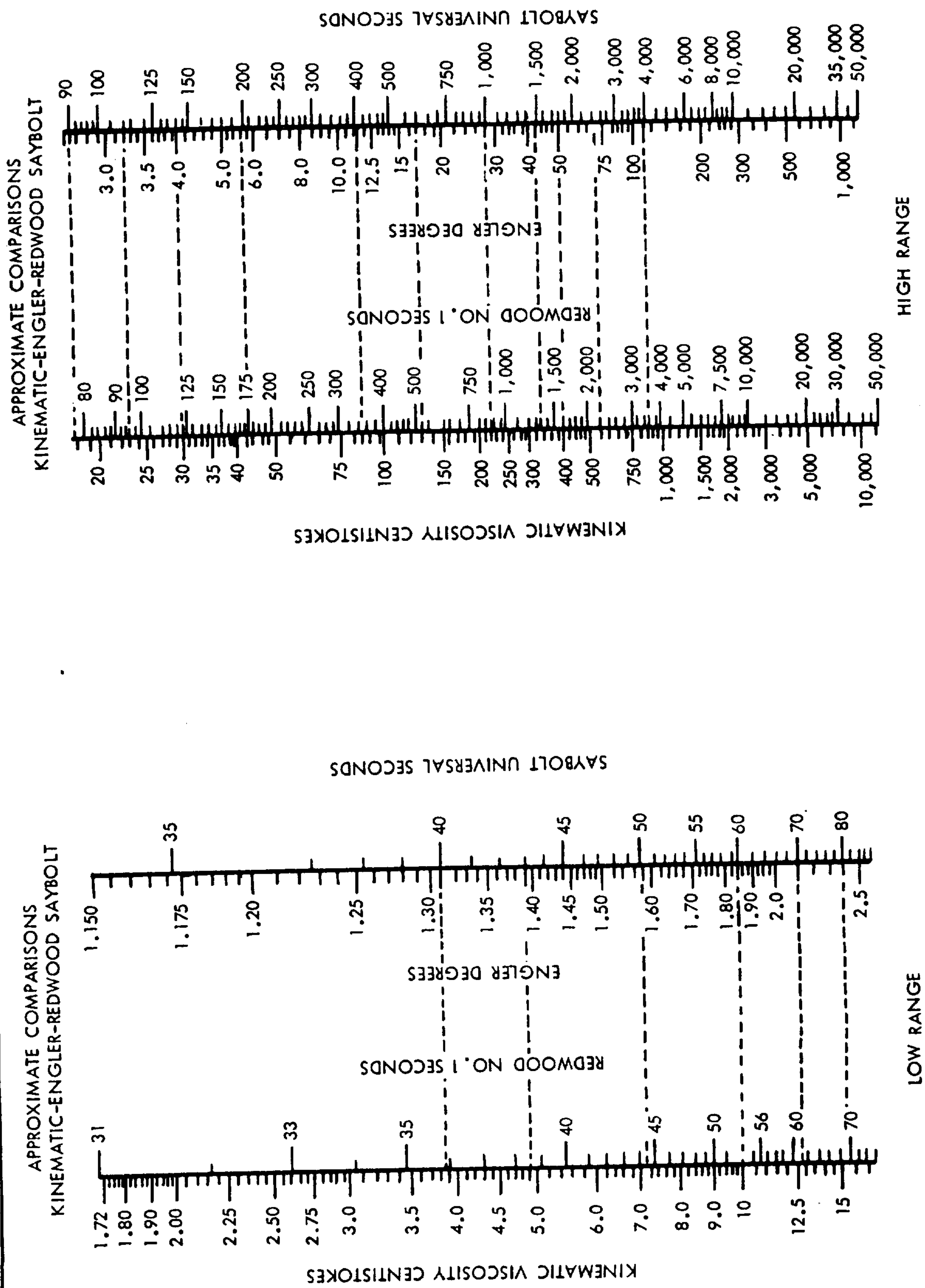
To convert viscosity from centistokes to centipoises - multiply by the specific gravity of the fluid.

Example: A fluid has a 0.65 centistokes viscosity and a specific gravity of 0.761, viscosity in centipoises is 0.65 x 0.761 = 0.49 centipoise.

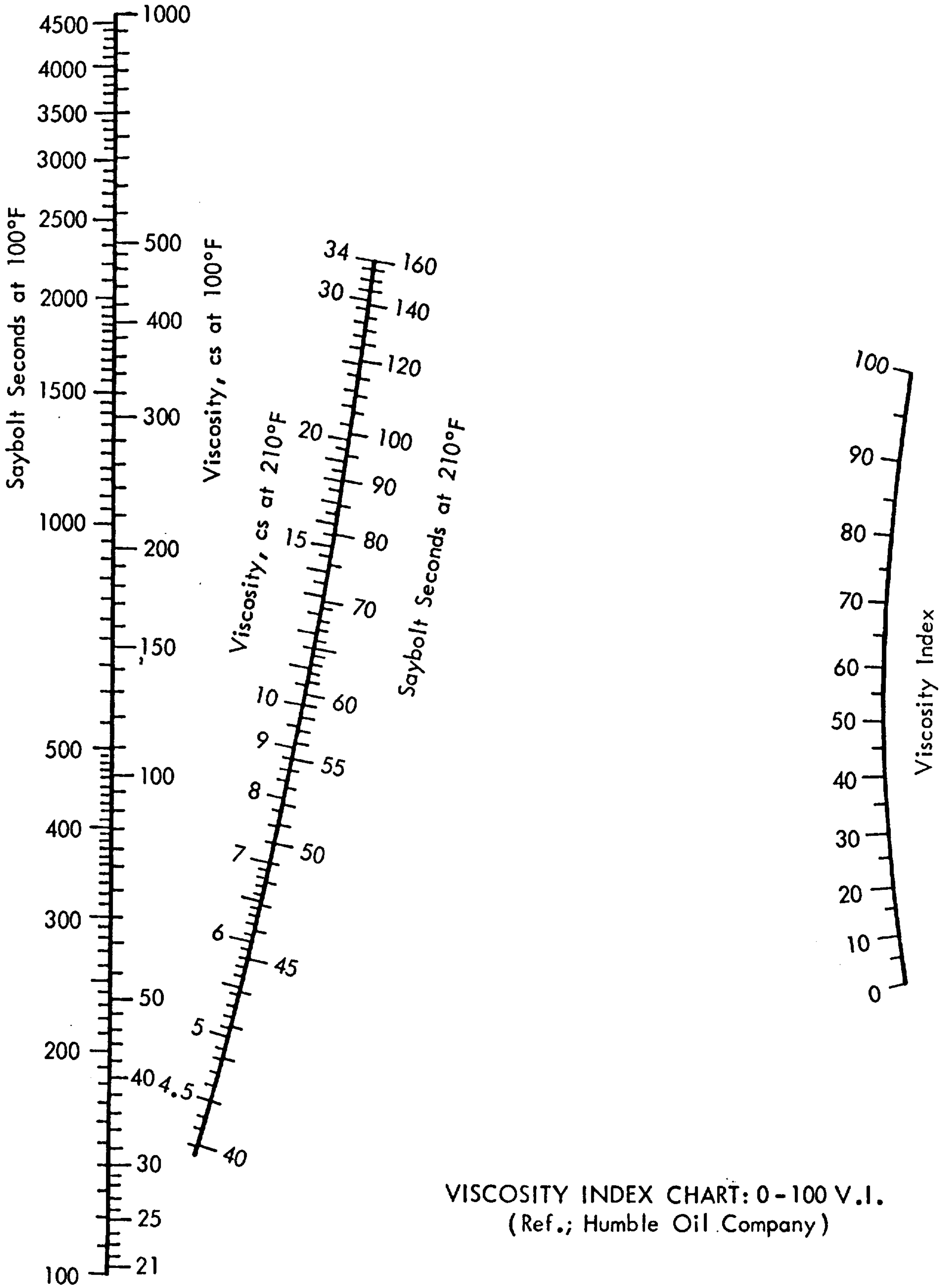
The chart below may be used to convert from Centistokes to other standard units. The SAE figures are valid only at 75°F. The other Scales are not limited to specfic temperature.



(Ref. Dow Corning Corp.)



VISCOSITY CHART
(Ref.; Imperial Oil and Grease Co.)



VISCOSITY INDEX CHART: 0 - 100 V.I.
(Ref.; Humble Oil Company)

APPENDIX D

THE INTERNATIONAL SYSTEM OF UNITS AND CONVERSION FACTORS

NAMES AND SYMBOLS OF SI UNITS

Quantity	Unit Name	Unit Symbol	Expression in SI Base Units
SI BASE UNITS			
length	meter	m	
mass	kilogram	kg	
time	second	s	
electric current	ampere	A	
thermodynamic temperature	kelvin	K	
luminous intensity	candela	cd	
amount of substance	mole	mol	
SI DERIVED UNITS			
area	square meter	m^2	
volume	cubic meter	m^3	
frequency	hertz	Hz	s^{-1}
mass density (density)	kilogram per cubic meter	kg/m^3	
speed, velocity	meter per second	m/s	
angular velocity	radian per second	rad/s	
acceleration	meter per second squared	m/s^2	
angular acceleration	radian per second squared	rad/s^2	
force	newton	N	$kg \cdot m/s^2$
pressure (mechanical stress)	pascal	Pa	N/m^2
kinematic viscosity	square meter per second	m^2/s	
dynamic viscosity	newton-second per square meter	$N \cdot s/m^2$	
work, energy, quantity of heat	joule	J	$N \cdot m$
power	watt	W	J/s
quantity of electricity	coulomb	C	$A \cdot s$
potential difference, electromotive force	volt	V	W/A
electric field strength	volt per meter	V/m	
electric resistance	ohm	Ω	V/A
capacitance	farad	F	$A \cdot s/V$
magnetic flux	weber	Wb	$V \cdot s$
inductance	henry	H	$V \cdot s/A$
magnetic flux density	tesla	T	Wb/m^2
magnetic field strength	ampere per meter	A/m	
magnetomotive force	ampere	A	
luminous flux	lumen	lm	$cd \cdot sr$
luminance	candela per square meter	cd/m^2	
illuminance	lux	lx	lm/m^2
wave number	1 per meter	m^{-1}	
entropy	joule per kelvin	J/K	
specific heat capacity	joule per kilogram kelvin	$J/(kg \cdot K)$	
thermal conductivity	watt per meter kelvin	$W/(m \cdot K)$	
radiant intensity	watt per steradian	W/sr	
activity (of a radioactive source)	1 per second	s^{-1}	
SI SUPPLEMENTARY UNITS			
plane angle	radian	rad	
solid angle	steradian	sr	

UNITS IN USE WITH THE INTERNATIONAL SYSTEM

Name	Symbol	Value in SI unit
minute	min	1 min = 60 s
hour	h	1 h = 60 min = 3,600 s
day	d	1 d = 24 h = 86,400 s
degree	°	$1^\circ = (\pi/180)$ rad
minute	'	$1' = (1/60)^\circ = (\pi/10{,}800)$ rad
second	"	$1'' = (1/60)' = (\pi/648{,}000)$ rad
liter	l	1 l = 1 $dm^3 = 10^{-3}$ m^3
tonne	t	1 t = 10^3 kg

SI PREFIXES

The names of multiples and submultiples of SI units may be formed by application of the prefexes:

Factor by which unit is multiplied	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

CONVERSION FACTORS

The first two digits of each numerical conversion factor represent a power of 10. An asterisk follows each number which expresses an exact definition. Numbers not followed by an asterisk are only approximate representations of definitions, or are the result of physical measurements.

LISTING BY PHYSICAL QUANTITY

To convert from	to	multiply by
ACCELERATION		
foot/second^2	meter/second^2	-01 3.048*
free fall, standard	meter/second^2	+00 9.806 65*
gal (galileo)	meter/second^2	-02 1.00*
inch/second^2	meter/second^2	-02 2.54*
AREA		
acre	meter^2	+03 4.046 856 422 4*
are	meter^2	+02 1.00*
barn	meter^2	-28 1.00*
circular mil	meter^2	-10 5.067 074 8
foot^2	meter^2	-02 9.290 304*
hectare	meter^2	+04 1.00*
inch^2	meter^2	-04 6.4516*
mile^2 (U.S. statute)	meter^2	+06 2.589 988 110 336*
section	meter^2	+06 2.589 988 110 336*
township	meter^2	+07 9.323 957 2
yard^2	meter^2	-01 8.361 273 6*
DENSITY		
gram/centimeter^3	kilogram/meter^3	+03 1.00*
lbm/inch^3	kilogram/meter^3	+04 2.767 990 5
lbm/foot^3	kilogram/meter^3	+01 1.601 846 3
slug/foot^3	kilogram/meter^3	+02 5.153 79
ENERGY		
British thermal unit:		
(IST before 1956)	joule	+03 1.055 04
(IST after 1956)	joule	+03 1.055 056
British thermal unit (mean)	joule	+03 1.055 87
British thermal unit (thermochemical)	joule	+03 1.054 350
British thermal unit (39°F)	joule	+03 1.059 67
British thermal unit (60°F)	joule	+03 1.054 68
calorie (International Steam Table)	joule	+00 4.1868
calorie (mean)	joule	+00 4.190 02
calorie (thermochemical	joule	+00 4.184*
calorie (15°C)	joule	+00 4.185 80
calorie (20°C)	joule	+00 4.181 90
calorie (kilogram, International Steam Table)	joule	+03 4.1868

to convert from	to	multiply by
calore (kilogram, mean)	joule	+03 4.190 02
calorie (kilogram, thermochemical	joule	+03 4.184*
electron volt	joule	-19 1.602 191 7
erg	joule	-07 1.00*
foot lbf	joule	+00 1.355 817 9
foot poundal	joule	-02 4.214 011 0
joule (international of 1948)	joule	+00 1.000 165
kilocalorie (International Steam Table)	joule	+03 4.1868
kilocalorie (mean)	joule	+03 4.190 02
kilocalorie (thermochemical)	joule	+03 4.184*
kilowatt hour	joule	+06 3.60*
kilowatt hour (international of 1948)	joule	+06 3.600 59
ton (nuclear equivalent of TNT)	joule	+09 4.20
watt hour	joule	+03 3.60*

ENERGY/AREA TIME

Btu (thermochemical)/foot^2 second	watt/meter^2	+04 1.134 893 1
Btu (thermochemical)/foot^2 minute	watt/meter^2	+02 1.891 488 5
Btu (thermochemical)/foot^2 hour	watt/meter^2	+00 3.152 480 8
Btu (thermochemical)/inch^2 second	watt/meter^2	+06 1.634 246 2
calorie (thermochemical)/cm^2 minute	watt/meter^2	+02 6.973 333 3
erg/centimeter^2 second	watt/meter^2	-03 1.00*
watt/centimeter^2	watt/meter^2	+04 1.00*

FORCE

dyne	newton	-05 1.00*
kilogram force (kgf)	newton	+00 9.806 65*
kilopond force	newton	+00 9.806 65*
kip	newton	+03 4.448 221 615 260 5*
lbf (pound force, avoirdupois)	newton	+00 4.448 221 615 260 5*
ounce force (avoirdupois)	newton	-01 2.780 138 5
pound force, lbf (avoirdupois)	newton	+00 4.448 221 615 260 5*
poundal	newton	-01 1.382 549 543 76*

LENGTH

angstrom	meter	-10 1.00*
astronomical unit (IAU)	meter	+11 1.496 00
astronomical unit (radio)	meter	+11 1.495 978 9
cable	meter	+02 2.194 56*
caliber	meter	-04 2.54*
chain (surveyor or gunter)	meter	+01 2.011 68*
chain (engineer or ramden)	meter	+01 3.048*
cubit	meter	-01 4.572*
fathom	meter	+00 1.8288*
fermi (femtometer	meter	-15 1.00*
foot	meter	-01 3.048*
foot (U.S. survey)	meter	+00 1200/3937*
foot (U.S. survey)	meter	-01 3.048 006 096
furlong	meter	+02 2.011 68*
hand	meter	-01 1.016*
inch	meter	-02 2.54*
league (U.K. nautical)	meter	+03 5.559 552*
league (international nautical)	meter	+03 5.556*
league (statute)	meter	+03 4.828 032*
light year	meter	+15 9.460 55
link (engineer or ramden)	meter	-01 3.048*
link (surveyor or gunter)	meter	-01 2.011 68*
meter	wavelengths Kr 86	+06 1.650 763 73*
micron	meter	-06 1.00*
mil	meter	-05 2.54*
mile (U.S. statute)	meter	+03 1.609 344*
mile (U.K. nautical)	meter	+03 1.853 184*

To convert from	to	multiply by
mile (international nautical)	meter	+03 1.852*
mile (U.S. nautical)	meter	+03 1.852*
nautical mile (U.K.)	meter	+03 1.853 184*
nautical mile (international)	meter	+03 1.852*
nautical mile (U.S.)	meter	+03 1.852*
pace	meter	-07 7.62*
parsec (IAU)	meter	+16 3.085 7
perch	meter	+00 5.0292*
pica (printers)	meter	-03 4.217 517 6*
point (printers)	meter	-04 3.514 598*
pole	meter	+00 5.0292*
rod	meter	+00 5.0292*
skein	meter	+02 1.097 28*
span	meter	-01 2.286*
statute mile (U.S.)	meter	+03 1.609 344*
yard	meter	-01 9.144*

MASS

carat (metric)	kilogram	-04 2.00*
gram (avoirdupois)	kilogram	-03 1.771 845 195 312 5*
gram (troy or apothecary)	kilogram	-03 3.887 934 6*
grain	kilogram	-05 6.479 891*
gram	kilogram	-03 1.00*
hundredweight (long)	kilogram	+01 5.080 234 544*
hundredweight (short)	kilogram	+01 4.535 923 7
kgf second^2 meter (mass)	kilogram	+00 9.806 65*
kilogram mass	kilogram	+00 1.00*
lbm (pound mass, avoirdupois)	kilogram	-01 4.535 923 7*
ounce mass (avoirdupois)	kilogram	-02 2.834 952 312 5*
ounce mass (troy or apothecary)	kilogram	-02 3.110 347 68*
pennyweight	kilogram	-03 1.555 173 84*
pound mass, lbm (avoirdupois)	kilogram	-01 4.535 923 7*
pound mass (troy or apothecary)	kilogram	-01 3.732 417 216*
scruple (apothecary)	kilogram	-03 1.295 978 2*
slug	kilogram	+01 1.459 390 29
ton (assay)	kilogram	-02 2.916 666 6
ton (long)	kilogram	+03 1.016 046 908 8*
ton (metric)	kilogram	+03 1.00*
ton (short, 2000 pound)	kilogram	+02 9.071 847 4*
tonne	kilogram	+03 1.00*

POWER

Btu (thermochemical)/second	watt	+03 1.054 350 264 488
Btu (thermochemical)/minute	watt	+01 1.757 250 4
calorie (thermochemical)/second	watt	+00 4.184*
calorie (thermochemical)/minute	watt	-02 6.973 333 3
foot lbf/hour	watt	-04 3.766 161 0
foot lbf/minute	watt	-02 2.259 696 6
foot lbf/second	watt	+00 1.355 817 9
horsepower (550 foot lbf/second)	watt	+02 7.456 998 7
horsepower (boiler)	watt	+03 9.809 50
horsepower (electric)	watt	+02 7.46*
horsepower (metric)	watt	+02 7.354 99
horsepower (U.K.)	watt	+02 7.457
horsepower (water)	watt	+02 7.460 43
kilocalorie (thermochemical)/minute	watt	+01 6.973 333 3
kilocalorie (thermochemical)/second	watt	+03 4.184*
watt (international of 1948)	watt	+00 1.000 165

To convert from	to	multiply by

PRESSURE

atmosphere	newton/meter^2	+05 1.013 25
bar	newton/meter^2	+05 1.00*
barye	newton/meter^2	-01 1.00*
centimeter of mercury (0°C)	newton/meter^2	+03 1.333 22
centimeter of water (4°C)	newton/meter^2	+01 9.806 38
dyne/centimeter^2	newton/meter^2	-01 1.00*
foot of water (39.2°F)	newton/meter^2	+03 2.988 98
inch of mercury (32°F)	newton/meter^2	+03 3.386 389
inch of mercury (60°F)	newton/meter^2	+03 3.376 85
inch of water (39.2°F)	newton/meter^2	+02 2.490 82
inch of water (60°F)	newton/meter^2	+02 2.4884
kgf/centimeter^2	newton/meter^2	+04 9.806 65*
kgf/meter^2	newton/meter^2	+00 9.806 65*
lbf/foot^2	newton/meter^2	+01 4.788 025 8
lbf/inch^2 (psi)	newton/meter^2	+03 6.894 757 2
millibar	newton/meter^2	+02 1.00*
millimeter of mercury (0°F)	newton/meter^2	+02 1.333 224
pascal	newton/meter^2	+00 1.00*
psi (lbf/inch^2)	newton/meter^2	+03 6.894 757 2
torr (0°F)	newton/meter^2	+02 1.333 22

SPEED

foot/hour	meter/second	-05 8.466 666 6
foot/minute	meter/second	-03 5.08*
foot/second	meter/second	-01 3.048*
inch/second	meter/second	-02 2.54*
kilometer/hour	meter/second	-01 2.777 777 8
knot (international)	meter/second	-01 5.144 444 444
mile/hour (U.S. statute)	meter/second	-01 4.4704*
mile/minute (U.S. statute)	meter/second	+01 2.682 24*
mile/second (U.S. statute)	meter/second	+03 1.609 344*

TEMPERATURE

Celsius	kelvin	$t_k = t_c + 273.15$
Farhenheit	kelvin	$t_k = (5/9)(t_F + 459.67)$
Fahrenheit	celsius	$t_c = (5/9)(t_F - 32)$
Rankine	kelvin	$t_k = (5/9)t_R$

TIME

day (mean solar)	second (mean solar)	+04 8.64*
day (sidereal)	second (mean solar)	+04 8.616 409 0
hour (mean solar)	second (mean solar)	+03 3.60*
hour (sidereal)	second (mean solar)	+03 3.590 170 4
minute (mean solar)	second (mean solar)	+01 6.00*
minute (sidereal)	second (mean solar)	+01 5.983 617 4
month (mean calendar)	second (mean solar)	+06 2.628*
second (ephemeris)	second	+00 1.000 000 000
second (mean solar)	second (ephemeris)	Consult American Ephemeris and Nautical Almanac

To convert from	to	multiply by
second (sidereal)	second (mean solar)	-01 9.972 695 7
year (calendar)	second (mean solar)	+07 3.1536*
year (sidereal)	second (mean solar)	+07 3.155 815 0
year (tropical)	second (mean solar)	+07 3.155 692 6
year 1900, tropical, Jan., day 0, hour 12	second (ephemeris)	+07 3.155 692 597 47*
year 1900, tropical, Jan., day 0, hour 12	second	+07 3.155 692 597 47

VISCOSITY

centistoke	meter^2/second	-06 1.00*
stoke	meter^2/second	-04 1.00*
foot^2/second	meter^2/second	-02 9.290 304*
centipoise	newton second/meter^2	-03 1.00*
lbm/foot second	newton second/meter^2	+00 1.488 163 9
lbf second/foot^2	newton second/meter^2	+01 4.788 025 8
poise	newton second/meter^2	-01 1.00*
poundal second/foot^2	newton second/meter^2	+00 1.488 163 9
slug/foot second	newton second/meter^2	+01 4.788 025 8
rhe	meter^2/newton second	+01 1.00*

VOLUME

acre foot	meter^3	+03 1.233 481 837 547 52*
barrel (petroleum, 42 gallons)	meter^3	-01 1.589 837
board foot	meter^3	-03 2.359 737 216*
bushel (U.S.)	meter^3	-02 3.523 907 016 688*
cord	meter^3	+00 3.624 556 3
cup	meter^3	-04 2.365 882 365*
dram (U.S. fluid)	meter^3	-06 3.696 691 195 312 5*
fluid ounce (U.S.)	meter^3	-05 2.957 352 956 25*
foot^3	meter^3	-02 2.831 684 659 2*
gallon (U.K. liquid)	meter^3	-03 4.546 087
gallon (U.S. dry)	meter^3	-03 4.404 883 770 86*
gallon (U.S. liquid)	meter^3	-03 3.785 411 784*
gill (U.K.)	meter^3	-04 1.420 652
gill (U.S.)	meter^3	-04 1.182 941 2
hogshead (U.S.)	meter^3	-01 2.384 809 423 92*
inch^3	meter^3	-05 1.638 706 4*
liter	meter^3	-03 1.00*
ounce (U.S. fluid)	meter^3	-05 2.957 352 956 25*
peck (U.S.)	meter^3	-03 8.809 767 541 72*
pint (U.S. dry)	meter^3	-04 5.506 104 713 575*
pint (U.S. liquid)	meter^3	-04 4.731 764 73*
quart (U.S. dry)	meter^3	-03 1.101 220 942 715*
quart (U.S. liquid)	meter^3	-04 9.463 529 5
stere	meter^3	+00 1.00*
tablespoon	meter^3	-05 1.478 676 478 125*
teaspoon	meter^3	-06 4.928 921 593 75*
ton (register)	meter^3	+00 2.831 684 659 2*
yard^3	meter^3	-01 7.645 548 579 84*

APPROVAL

LUBRICATION HANDBOOK FOR THE SPACE INDUSTRY
PART A: SOLID LUBRICANTS
PART B: LIQUID LUBRICANTS

By Ernest L. McMurtrey

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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