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# HANDBOOK OF FLUIDS AND LUBRICANTS FOR DEEP OCEAN APPLICATIONS



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December 1969

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# HANDBOOK OF FLUIDS AND LUBRICANTS
# FOR
# DEEP OCEAN APPLICATIONS


Compiled and Edited by

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## ABSTRACT

The critical factors involved in the selection of fluids and lubricants for deep ocean equipment are defined, and methods of determining critical properties are described. The values of critical properties are given for fluids and lubricants as they have been determined or are known from previous literature. Suggestions also are given on the applicability and possible limitations of the fluids and lubricants for deep submergence vehicle use. It is planned to revise and update the contents of this handbook periodically.

# PREFACE

The Deep Ocean Technology (DOT) "Handbook of Fluids and Lubricants for Deep Ocean Applications" was prepared to provide critical properties, evaluation methods, and other pertinent fluid and lubricant information to designers, engineers, and operating personnel concerned with deep ocean applications.

This handbook is a "guide," not a specification. It cannot be cited as authority for action. It supplements published information and aids the user in selection of a fluid or lubricant applicable to a particular deep ocean application.

## Content and Organization of the Handbook

Chapter I defines and discusses the factors involved in the selection and performance of fluids and lubricants in deep ocean applications. This chapter is written as an integrated account to be read in sequence as in a book.

Chapter II describes in detail the methods employed for establishing the fluid properties presented in Chapter III. This last chapter provides suggested applications and possible limitations in addition to the properties.

In compiling these data we have consulted many sources and utilized applicable experience wherever found. Thus, the Bibliography represents, in effect, contributors as well as source material.

## Revisions, Growth, and "User Comment Return Form"

The DOT "Handbook of Fluids and Lubricants for Deep Ocean Applications" is designed to be periodically revised to include new data and considerations for fluid encapsulated system design and additional deep ocean applications. Responsibility for the maintenance and expansion of the handbook has been assigned, under the supervision of the Naval Ship Systems Command (SHIPS 03424), to the Naval Ship Research and Development Laboratory, Annapolis, Maryland.

Revisions to the handbook will be effected by the use of page changes and additions. As the handbook is published in loose-leaf form, revisions may easily be made.

PREFACE (Cont)

Using commands and individuals within the Navy and the non-military marine community are encouraged to submit additional data, paragraphs, or chapters. Less extensive feedback - even mere indications that specified sections are judged to be too general - is useful and solicited. Feedback may be forwarded directly to

Deep Ocean Technology Program
Naval Ship Research and Development Laboratory
Annapolis, Maryland 21402

Material received will be carefully reviewed and coordinated prior to publication. A handy preaddressed user comment return form is included for your convenience.

## ADMINISTRATIVE INFORMATION

This first edition of the handbook was begun by the Naval Ship Research and Development Laboratory, Annapolis, Maryland, as part of the Deep Ocean Technology Program, S4636, Task 12315, Work Unit 1-821-118-A "Fluids and Lubricants for Deep Submergence Applications." The Program Manager was the Naval Ship Systems Command (SHIPS 03424), and Naval Ship Engineering Center (SEC 6101F) was the Technical Agent. It was completed under S4636, Task 14745, Laboratory Work Unit 1-723-113-A, "DOT Compensating Systems." The Program Manager was Naval Ship Systems Command (SHIPS 03424), and Naval Ship Engineering Center (SEC 6141) was the Technical Agent.

IDENTIFICATION OF FLUID CODES

| Fluid Code | Commercial Name | Supplier |
|---|---|---|
| A | PR-1192 | E. F. Houghton Co., 303 W. Lehigh Ave., Philadelphia, Pa. 19133 |
| B | Micronic 713 | Bray Oil Co., 3344 Medford St., Los Angeles, Calif. 90063 |
| C | Micronic 762 | Bray Oil Co., 3344 Medford St., Los Angeles, Calif. 90063 |
| D | NDH-TD4-1 | New Departure - Hyatt Bearings, Hayes Ave., Sandusky, Ohio 44871 |
| E | Hoover Submersible Fluid No. 2 | Hoover Electric Co., 2100 South Stoner St., Los Angeles, Calif. 90025 |
| F | Tellus 11 | Shell Oil Co., 50 W. 50th St., New York, N. Y. 10020 |
| G | Tellus 15 | Shell Oil Co., 50 W. 50th St., New York, N. Y. 10020 |
| H | Tellus 27 | Shell Oil Co., 50 W. 50th St., New York, N. Y. 10020 |
| J | Primol 207 | Humble Oil and Refining Co., P.O. Box 1288, Baltimore, Md. 21203 |
| K | Marcol 52 | Humble Oil and Refining Co., P.O. Box 1288, Baltimore, Md. 21203 |
| L | SF-1143 | General Electric Co., Silicone Products Dept., Waterford, N.Y. 12188 |
| M | C-141 | Royal Lubricants Co., River Rd., Hanover, N. J. 07936 |
| N | PR-85-29-129 | E. F. Houghton Co., 303 W. Lehigh Ave., Philadelphia, Pa. 19133 |

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# INTRODUCTION

In the typical U. S. Navy submarine, most of the operating machinery for propulsion, maneuvering, and other required functions is located within the pressure hull. In contrast, only the control equipment of deep submergence vehicles is housed within the pressure capsule. It is connected by wires through glass-to-metal seals through the capsule to external machinery. Thus, only electrical control signals are provided to pumps, motors, winches, hydraulic systems, and the other required machinery operating in the ambient pressure, temperature, and contaminants of the deep ocean.

To shield system components from the corrosive action of seawater and other effects of the ocean environment requires that equipment be operated within some sort of protective medium. Three approaches are being pursued: (1) encapsulation, (2) the "hard shell," and (3) fluid compensation. Encapsulation of components in a material such as epoxy resin is under investigation. As an alternative, the sealed case, or "hard shell," is not always applicable. Its disadvantages are the size and weight required to withstand the pressure of the deep ocean environment, means to achieve adequate heat transfer, and the problem of penetrations that can withstand high-pressure differentials. A fluid-filled, pressure-compensated case for these components external to the pressure hull has been the preferred protective approach. This is the alternative that requires consideration of suitable protective fluids.

# CHAPTER I
## FLUID AND LUBRICANT PROPERTIES AND USE CLASSIFICATION

The exploration of the ocean depths has created requirements for fluids and lubricants for which no precedent exists. The hostile environment of the ocean, and not necessarily the sophistication of the equipment, has placed new demands on fluids and lubricants. Fluids will have to withstand exposure to ambient temperatures ranging from 28° to 130° F, pressures up to 20,000 psi, and a chemically corrosive environment.* Undersea exploration is being performed by means of manned and unmanned submersibles, with externally placed pressure-compensated machinery, manned submerged habitats, and submerged instrument packages, each of which may have fluid or lubricant needs.

Generally speaking, there are three main uses for fluids and lubricants in deep ocean applications:

- Power transmission; i.e., the fluid for a hydraulic system.
- Lubrication; i.e., friction and wear reduction for system bearings and gears.
- Shielding from environment; i.e., a fluid to fill externally placed electric motors, switches, and relay boxes, to protect the components from seawater.

Ideally one fluid could serve all three purposes, but most fluids will not be suitable for all three.

Furthermore, it must be remembered that when products purchased under a military or federal specification are used, properties not specifically required by the specification may vary widely from one manufacturer to another and from one manufacturer's batch to another.

### Viscosity

Viscosity is one of the most important single properties of any fluid that is to be used for power transmission or for lubrication. In surface vessels, submarines, and aircraft, viscosity

*Abbreviations used in this text are from the GPO Style Manual, 1967, unless otherwise noted.

is no longer a serious problem, since representatives of the various types of hydraulic fluids and lubricants are available in suitable viscosities, and with improved additives to yield very favorable viscosity/temperature relationships. While the effect of temperature is still the major consideration, a new variable, introduced with deep submergence, the viscosity/pressure relationship, is superimposed on the temperature effect.

In nearly all planned uses, as many components as possible are placed external to the pressure hull where the fluid serves as a protective medium for the mechanical and electrical system components and, of course, is subjected to the ambient pressure at the dive depth. Moreover, the fluid in a hydraulic system is usually pressurized to 3000 psi above the ambient pressure to operate the system components. Such systems could subject the fluid to a total of 20,000 psi at the maximum known depth of the ocean.

It is well known that viscosity increases with pressure. The viscosity of pure petroleum oils may increase as much as 30 times at a pressure of 20,000 psi. The viscosity of petroleum oils with polymeric additives that improve the viscosity index exhibits an increase of only 10-15 times the atmospheric pressure value. Silicone oil of low viscosity increases 8-10 times in the same range. Several mathematical relationships for predicting the increase of viscosity with pressure have been studied. The best representation has been obtained from a third-order polynomial expansion of the logarithm of viscosity at pressure which agrees with measured values to within 1%; i.e.,

$$\ln \upsilon = \ln \upsilon_o + bp + cp^2 + dp^3$$

where

$\upsilon$ = viscosity at the measured pressure

$\upsilon_o$ = viscosity at atmospheric pressure

p = pressure

b = coefficient characteristic of the fluid measured

c = coefficient characteristic of the fluid measured

d = coefficient characteristic of the fluid measured.

(A straight-line fit logarithm of viscosity versus pressure data, $\ln \nu = \ln \nu_0 + bp$, will predict values to within 10% of the measured values. The coefficients of the equations are characteristic of the fluid measured.)

The pressure/viscosity relationship imposes a new restriction on the choice of fluids. The information available at the present time offers some guidelines upon which to base a selection:

- Lower viscosity fluids are less affected by pressure than higher viscosity fluids.

- Low viscosity permits higher speeds in electric motors.

- The viscosities of gas-saturated fluids are less affected by pressure than are those of the gas-free fluids.

- Additives which improve the viscosity/temperature relationship appear to significantly reduce the viscosity change due to pressure increase.

- Low viscosity has also been shown to be a desirable characteristic of fluids used in the satisfactory operation of switching electrical devices in fluids under high pressure. The failure of electrical devices due to the buildup of solid products or "clinkers" between contact surfaces in pressure compensating fluids takes place less readily, the lower the viscosity of the fluid.

The addition of polymeric viscosity index improvers offer an attractive possibility for alleviation of both temperature and pressure effects on viscosity. These materials render a fluid non-Newtonian; that is, its viscosity becomes dependent upon the shear-rate condition to which the fluid is subjected. The system designer must take into account that the apparent viscosity of a non-Newtonian fluid in a system with a high shear rate will be significantly lower than the viscosity measured by conventional laboratory viscometers. The same shear which lowers the viscosity of the fluid, due to its non-Newtonian behavior, has the undesirable property of eventually degrading the viscosity-improving additive (a polymer of high molecular weight) by reducing its molecular weight, thus permanently reducing the viscosity of the fluid.

Viscosity may be an important consideration for fluids which are intended to provide environmental protection for nonmoving electrical and electronic components. There are indications that in the event of sea-water contamination, all other things being equal, fluids of higher viscosity have a greater tendency to keep water in suspension, a characteristic which lowers the dielectric breakdown voltage and insulation resistance of the fluid to unacceptable levels.

Low viscosity may also be desirable in relation to electrical equipment, from the standpoint of heat transfer. The lower the viscosity of the fluid, the more rapid will be the desired dissipation of heat generated by motors, switches, solid-state devices, and other electrical components.

## Lubricating Ability

The lubricating ability of a fluid or lubricant is a critical consideration in the selection of an immersion medium for moving parts. While viscosity has been separately discussed as a critical property, it also affects lubricating ability. The present requirement for lubrication of moving parts under deep submergence pressure, when considered in the light of the properties of known lubricants, dictates the use of low viscosity fluids. On the other hand, such fluids present serious lubrication problems at atmospheric pressure. A fluid for deep ocean use will have its highest viscosity at the maximum operating depth and thus at the lowest ambient temperature. It will also have its lowest viscosity while operating on the surface or at its shallowest operating depth, where the ambient pressure is at a minimum and ambient temperature is at the maximum. Thus, a fluid may have adequate viscosity for lubrication over most of a machine's operating depth; yet when the machine is operated on the surface, its viscosity may be below acceptable levels for good lubrication. Conversely, a machine may have good efficiency due to low viscosity when operating near the surface and have poor efficiency due to high viscosity when operating at maximum depth. In applications where viscosity is an important factor (motors, gears, and hydraulic systems) it is necessary to consider these operating extremes. A fluid whose viscosity shows a small variation with pressure and temperature and has good lubricating properties would be desirable for that machine. However, in most instances, today, a tradeoff must be made since fluids with these ideal properties do not exist for all required applications.

A similar set of requirements was encountered in "Aerospace" applications where low viscosity lubricants had to be employed due to the extremely low temperature of the operating environment. The solution to the problem was to develop additives to improve the load-carrying ability (i.e., the ability of a lubricant to maintain a film between two moving metal components preventing metal-to-metal contact, despite extremely high pressures), to develop additives to improve the viscosity/temperature relation, and to develop additives to keep the lubricants from oxidizing from the heat generated by less-than-satisfactory lubrication. In addition to the development of lubricants, changes were made in design of the equipment to make it tolerate the low viscosity lubricants. Furthermore, the nature of the application made the relatively short running time and short equipment life acceptable.

"Aerospace"-type lubricants are currently in use in both Navy and commercial deep submergence vehicles. While they have proved satisfactory for present short-term operations, improvements are required for reliable long-term operation in the pressure range expected in the deep ocean environment.

## Effects of Contamination

It is well known that water in a lubricant reduces the life of loaded rolling angular-contact bearings by accelerating rolling-contact fatigue failure. Water in a lubricant also alters its rheological properties which ultimately affect its lubricating ability for gears and sliding contacts.

Solid contaminants in the lubricant act as abrasives to increase the wear on moving parts, and if solid particles are present in sufficient quantities, the filters and valves in moving systems may become clogged and fail to operate as designed.

The acceptable limits of both sea-water and solid contamination have not been established.

## Corrosion Protection

Fluids and lubricants for deep ocean uses must provide protection from the corrosive character of the environment, seawater. The fluid or lubricant must be capable of protecting the system from corrosion, for seawater has a high probability of entering the system.

Rust-inhibiting fluids and lubricants of many types have been available for years and are available in the low viscosity types required for deep ocean applications. However, the ability of many fluids to inhibit corrosion has, in the past, been evaluated chiefly in terms of the rust prevention of ferrous metals. To depend on such fluids may be hazardous since there are also nonferrous metals in all deep submergence systems. It is not always possible to use the fluid which has given maximum protection to a mild steel specimen in a laboratory test, since there are numerous examples of rust-inhibited fluids which severely attack nonferrous metals. The specifications of fluids for corrosion inhibition should be prepared, or revised, so that uniform protection is provided for all the metals encountered in the various systems.

A fluid which is to be used for any of the three main functions - power transmission, lubrication, environmental protection - must display the ability to protect all system metals from corrosion. This is a property which must be continually improved so that system components are protected from all forms of corrosion, that is, stress, galvanic, crevice, and pitting, as well as general chemical attack by the action of seawater.

Dielectric Properties

A pressure-compensating fluid for electric motors, relays, switching devices, and electronic equipment must have good dielectric properties and ideally should be otherwise inert to the effects of electrical equipment operation.

The dielectric quality of a fluid is measured in terms of electrical resistivity, dissipation factor, and dielectric breakdown voltage. Dielectric properties of a fluid as received result from its chemical nature and from the presence of additives in certain cases. In practice, several factors affect dielectric properties during usage.

Contamination of the fluid by sea-water leakage is an important cause of failure. As little as 0.1% contamination by seawater reduces the resistivity of some fluids below suggested limits. Fluid chemical changes and carbon produced by arc discharge through the fluid or from brush wear also lower its resistivity and breakdown voltage below suggested limits. Equipment failures due to lowered resistivity and dielectric breakdown voltage also have been caused by contamination with metallic particles resulting from the wear processes of moving parts. A commonly observed failure at high pressures and high current densities of fluid-compensated electrical switching devices is the deposition of carbon or silica on electrical contacts, where arcing occurs. At present no fluid has been found that can provice long life under these conditions.

## Dissipation Factor

The need for fluids and lubricants with corrosion protection properties and improved lubricating ability has led to the formulation of products which contain polar additives and those in which water is soluble or with which water is miscible. In addition to lowering the resistivity and dielectric breakdown voltage, the polar materials also decrease the efficiency of an electric motor by transformation of electrical energy into heat energy in a nonsinusoidal alternating-current system. A useful measure of this property is the dissipation factor of the fluid. A high dissipation factor predicts dielectric heating losses. Dissipation factor is defined as the tangent of the loss angle expressed as percent for a dielectric material. (A perfect insulator would have a loss angle of 0 degree and thus a dissipation factor of 0%.) Dielectric heating losses are proportional to the square of the voltage gradient, frequency of applied voltage, dielectric constant, and dissipation factor. The trend in submersible equipment is to use inverters and choppers, without filters to save weight; thus, high frequencies are encountered. It then becomes obvious that dielectric losses through the fluid will increase if the dissipation factor of the immersion fluid is high or if it increases due to contamination. The losses would not be immediately obvious in laboratory bench studies where commercial electric power is the energy source. In actual naval service unfiltered inverters and choppers with a large percentage of high-frequency component are used. Evaluation methods which consider this operating condition have not been devised.

## Ability to Form Stable Emulsions

When the fluid encapsulating any electrical equipment becomes sea-water contaminated, it is clear from the statements in the preceding paragraphs on dielectric properties that efficiency may be lost or failure may occur. The quantity of the seawater in the fluid and its state of subdivision may determine whether failure or efficiency losses will occur. This factor is especially important in the operation of electric motors where motor shaft seals may allow leakage of the external seawater. If the oil permits the water to separate in large drops, a short circuit and catastrophic failure can occur when one of the drops of seawater bridges the electrical gap. If, on the other hand, the water is emulsified in extremely small droplets, the motor may still operate, even though dielectric heating and loss of efficiency may occur. In this case, even though emulsified water in the immersion fluid may ultimately lead to motor failure, the failure is not of the catastrophic type. Present methods of evaluation of emulsifying ability have not yet been correlated with performance capability. The limits of emulsified water in oil and the limits of polar-type emulsifiers have not been established, nor has the use of nonpolar emulsifiers been investigated. These considerations are not so important in electrical components other than motors where little agitation occurs.

## Material Compatibility

The use of compatible materials in a system which is to be fluid-filled is of prime importance regardless of the fluid used. No system should be designed without considering the compatibility of the fluid and material. When a fluid is selected, a list of compatible materials should be compiled or consulted to determine whether the metals, coatings, insulations, seals, and elastomers in the system are compatible. If a specific material is required for a particular application, then the fluid selection must be governed by its compatibility with that material. Incompatible coatings or elastomers may cause the formation of sludge in the fluids. System leaks can develop when incompatible elastomers are used for sealing. Electrical failures can result from the use of incompatible fluids and insulating materials. Accelerated corrosion usually results when a fluid is in contact with an incompatible metal.

## Volatility and Toxicity

These two related properties require consideration for any fluid or lubricant application. Nearly all volatile materials pose a certain degree of toxicity, but not all toxic liquid materials are volatile. The toxicity may be exhibited in various ways. Volatile materials may affect lungs, bronchi, and nasal passages either by irritant action, by chemical or solvent action on tissue, or by forming an inert coating to interfere with the respiratory process. Toxic liquids in contact with the skin or eyes cause irritation, destruction of tissue by chemical action, or dermatitis, in sensitive individuals. Inert liquids such as silicone oils, which are not considered toxic in the usual sense of the word, present special problems when they get in the eyes or are inhaled. Their insolubility and immiscibility with water make it impossible for body fluids to carry them away, and in the case of the eye, a condition similar to cataract can result. In most cases, fluids and lubricants used in deep submergence will be volatile and toxic. Such use, however, will be in capsules external to the pressure hull of manned vehicles. The breathing atmospheres of manned habitats will have to be reviewed, particularly from the standpoint of sources of fluid vapors or solid lubricant dust. The volatility of all solid and liquid lubricants should be specified properly for all deep ocean applications. The effect of pressure should be included since in most cases volatility increases with pressure.

## Compressibility and Density

Ideally a liquid is incompressible, but existing fluids and lubricants show 5%-7% decrease in volume in the case of petroleum fluids, and 8%-13% in the case of silicone-base fluids when they are in the pressure range from atmospheric to 20,000 psi. Fluid-encapsulated systems must be designed to allow sufficient fluid to ensure that the system components will be lubricated and protected from the environment in spite of any volume reduction in the fluid. Compressible liquids can cause some operational sluggishness if they are employed in a hydraulic system.

It is desirable to have liquids with a density less than 1.0 gram per cc at atmospheric pressure since this will save weight in the system. All of the petroleum oils and most of the applicable silicone oils have a density of less than 1.0 at atmospheric pressure. The more inert classes of liquids all have high densities and are not being generally utilized for that reason. Since there is an increase in density with an increase in pressure and the weight of the fluid head will change, the circulation rate may decrease for fluids or lubricants which are pump-circulated. The density as well as the compressibility of fluids as a function of both temperature and pressure should be considered by vehicle and machinery designers.

## Chemical Stability

The term "chemical stability" is used here to indicate the ability of a fluid or lubricant to resist oxidative, hydrolytic, or thermal degradation. Failure of a fluid or lubricant to resist oxidation or hydrolysis creates a hostile environment for the system components even in the absence of contamination. Such breakdown results in the formation of sludge and fluid viscosity changes which can promote wear and impair system operation. In the case of oxidation or hydrolysis, organic acids are formed which can be corrosive to system metals. Such breakdown of fluids and lubricants is considered normal and likely to occur in any type of service to various degrees. The problem of arcs caused by the make and break of electrical contacts has already been discussed under dielectric properties. Under high pressure and high current densities an electric arc will cause the formation of large particles of carbon and silica. In some cases these particles bridge the gap between electrical contacts preventing complete interruption of the circuit.

All fluids (hydrocarbons and silicones) tested thus far under electrical arcing also produce gaseous decomposition products. The accumulation of gaseous products in a pressure compensator, under submerged conditions, presents the problem of possible rupture of compensating chamber walls, or flexible membranes, on surfacing. Since sizable quantities of gas have been observed under experimental conditions, a means of safely bleeding off gases while surfacing will be required.

Accurate figures on the rate of gas production under various arcing conditions are not available.

Oxidation resistance, arc-breakdown resistance, and thermal-breakdown resistance tests and standards have not been developed to provide selection criteria for fluids and lubricants.

Fire Resistance

Fire hazards exist in hydraulic systems, air compressor systems, and fluid-lubricated systems which are located inside the pressure hull of a submersible; in such cases care must be taken to eliminate air from the system and prevent overheating to reduce the fire hazard. Care must always be taken to prevent fire while draining or filling any system using a combustible fluid. The low viscosity fluids for deep submersibles are more readily ignited than the fluids used on surface ships and conventional submarines; greater precautions must be taken to prevent ignition. Petroleum oils and silicone oils are both relatively easily ignited. Fluids with flash points below 300° F should be treated with extreme care. Suitable published precautions should be observed. The more fire-resistant fluids and lubricants are among the inert fluids having densities which are too high for consideration.

## Cost and Availability

The small volume and specialized nature of the deep ocean systems have caused the designers to consider the cost factor of fluids as secondary. Fluid availability has been the principal consideration. The petroleum-based fluids are usually readily available and procurable in drum quantities at a reasonable cost. The specially purified aerospace oils are moderately expensive. If and when fluid cost becomes a problem, the use of the relatively expensive silicone fluids will have to be limited to critical application. Specially developed new fluids will be expensive due to high development and testing costs and because the limited market for deep ocean applications at the present time will not encourage large volume production and competition which tend to reduce costs.

\- - - -

This chapter has attempted to define and discuss the factors involved in the use of fluids and lubricants in deep ocean applications. At the time of writing, the above selection and definitions of the critical properties are those which appear to be the main factors to consider in the selection of a fluid or lubricant for use in a deep ocean application. It is the intent to revise this handbook on an annual basis. When it is established that a new consideration is needed, it will be added. As items prove to be noncritical they will be deleted.

# CHAPTER II
## METHODS FOR ESTABLISHING FLUID PROPERTIES

The methods described in this chapter have all been developed especially for the conditions of deep ocean applications, and sea-water and solid contamination anticipated for fluids and lubricants in deep ocean equipment. These methods are in various states of development, and as yet limits have not been established for all methods. Ratings in some cases are still on a comparative basis. Standard methods, such as those described by the American Society for Testing and Materials (ASTM), Federal Test Method Standard No. 791a, and the Society of Automotive Engineers (SAE) Aerospace Recommended Practices (ARP), are not described in this chapter. Procedures described in detail by other reports will be referenced when data are presented in Chapter III. The methods described in this chapter are tentative and may have published counterparts which would be preferable. The results of these methods will be compared with the published methods in the future if any are found to exist. All methods and data will be reviewed periodically and replaced or updated in subsequent revisions.

## C1. Ambient Pressure Stirred Corrosion Procedure

Scope - This method conducted at atmospheric pressure is intended to measure the relative protection provided by fluids and lubricants to metals and alloys used in deep submergence components when exposed to contamination by seawater.

Outline of Method - A sample of oil in a glass beaker is brought to a predetermined temperature in an oil bath. Corrosion specimens isolated from each other are mounted on a metal rod which is then stirred in test oil. Seawater is added to the test oil. After the desired exposure period, the specimens are cleaned, dried, weighed, and photographed to measure degree of corrosion.

### Apparatus

a. The heating bath, stirring motor and assembly, beaker and beaker cover are the same as those used in ASTM (Method) D-665.

b. A 304 stainless steel rod, 9 1/2 inches long and 1/4 inch in diameter, with 4 1/2 inches of 1/4-inch 20 threads in one end is substituted for the ASTM D-665 stirrer. Stainless steel nuts (304) (1/4-inch 20) are used to hold specimens on the rod.

c. Spacers for specimens shall be made of polytetrafluoroethylene (PTFE). They shall be cut from 1/4-inch inside diameter (ID), 3/8-inch outside diameter (OD) tubing and shall be 1/8 inch thick.

d. Corrosion specimens shall be 1 x 1 x 0.032 inch with a 1/4-inch hole in the center. The specimens shall have a finish (before polishing) conforming to Federal Test Method Standard No. 791a, Method 5308.4. The specimen shall be of any alloy or metal used in the deep submergence components. Those used by NAVSHIPRANDLAB, Annapolis are shown in Figure 1. A typical specimen rod assembly is shown in Figure 2.

| |
|---|
| STEEL, Stainless, Type 316 |
| ALUMINUM 6061, Specification QQ-A-250-11 |
| COPPER-NICKEL, 70-30, Specifications MIL-C-15726 or MIL-T-00/6420 |
| STEEL, QQ-S-698, Grade 1009 |
| ALUMINUM, QQ-A-250-4b |
| COPPER, QQ-C-576a |
| NICKEL-COPPER, QQ-N-281, Class A, Monel 400 |
| BRONZE, MIL-B-16541A(WEP) (1/16 inch thick) |
| PHOSPHOR-BRONZE, QQ-B-750, Composition A |
| SILVER BASE BRAZING ALLOY, MIL-B-15395A, Grade IV |
| STEEL, Galvanized, Electrodeposited, QQ-Z-325A, Type II, Class I |
| **Specification for Items Above** |
| Metal Specimens, 1 x 1 x 0.032 inch with a 1/4-inch hole in center, finish to conform to that given in Federal Test Method Standard No. 791a, Method 5308.4 |

Figure 1 (C1)
Specimens Used

1 - Copper
2 - 316 Stainless Steel
3 - Copper-Nickel, 70-30
4 - Aluminum, QQ-A-250-4b
5 - Phosphor, Bronze
6 - Galvanized Steel
7 - Steel, 1009
8 - Aluminum, QQ-A-250-11
9 - Bronze
10 - Monel
11 - Silver Base Brazing Alloy

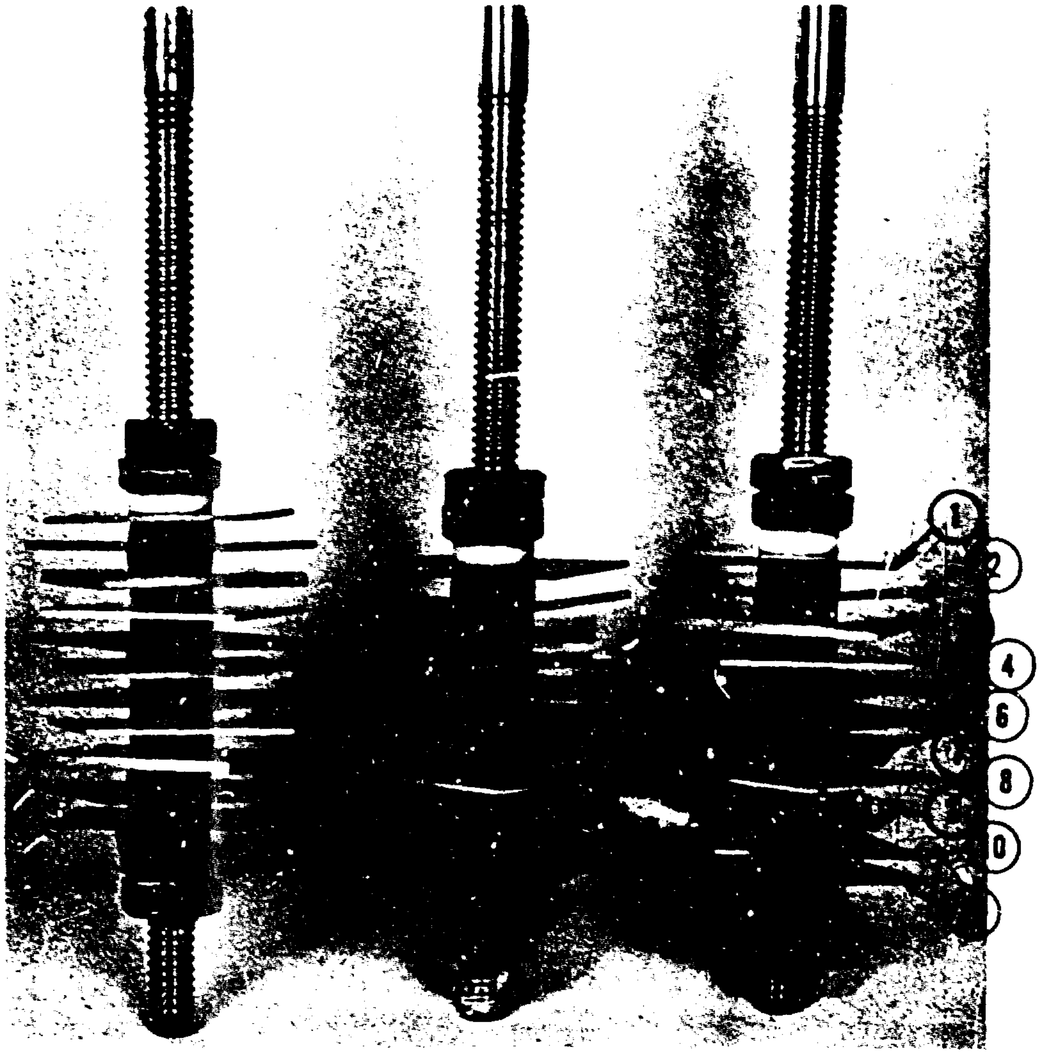


Figure 2 (Cl)
Typical Specimen Rod Assembly

## Materials

a. Naphtha solvent conforming to ASTM-D-91 method.

b. Freon TF solvent-trichlorotrifluoroethane obtained from E. I. du Pont de Nemours and Company.

c. Aluminum oxide polishing compound, 150 grit.

d. Seawater, ASTM D-665.

e. PTFE tape, 1/2-inch wide, Scotch Brand No. 48 obtained from Minnesota Mining and Manufacturing Company.

f. Typewriter brush, Federal Specification H-B-00681C.

## Preparation of Corrosion Specimens

a. Handle specimens with disposable polyethylene gloves.

b. Flush with naphtha to remove preservatives.

c. Polish with 150 grit aluminum oxide powder on medicinal cotton wads (do not polish plated specimens).

d. Make polish strokes in one direction.

e. Turn specimen 90° and polish until previous polish marks are removed.

f. Brush with camel hair brush.

g. Use wash bottle to flush specimens with jet of naphtha then with Freon TF.

h. Air dry and place in desiccator.

i. Weigh on semimicrobalance; record weight to 0.00001 gram.

## Procedure

a. Place 270-ml test oil in a clean beaker. Heat in an oil bath to 140° F.

b. Clean the specimen rod with soap and water, then with distilled water and oven dry at 220° F.

c. Wrap the rod with PTFE tape to insulate from specimens.

d. Assemble specimens as shown in Figures 1 and 2. Use clean polyethylene gloves to handle specimens and rod. Separate specimens from each other and end nuts using the PTFE spacers. Secure with nuts on both ends.

e. Insert the rod assembly in stirring device with specimens in oil and beaker cover in place.

f. Stir for 1 hour.

g. Add 30-ml ASTM D-665 seawater while stirring. Plug excess holes in the cover with inert material, such as glass plugs.

h. Inspect the fluid level daily and add distilled water to make up for losses by evaporation.

i. At the end of the test period remove specimens and store in naphtha prior to cleaning.

j. Clean the specimens by successive flushes with naphtha and brushing with a naphtha-wet typewriter brush.

k. Make a final flush with Freon TF; then place the specimens in a desiccator to condition prior to weighing.

l. Record weight changes and changes in appearance of specimens by written descriptions and photographs.

## C2. 20,000 PSIG Pressure-Cycled Compatibility Procedure

Scope - This method is intended to measure the effects of cycled-pressure on deep submergence fluid compatibility with materials of construction.

Outline of Method - A high-pressure reaction vessel, filled with a temperature- and pressure-transfer oil, is brought to a test temperature of 140° F. A test cell consisting of metallic or nonmetallic compatibility specimens immersed in the oil being studied contained in a PTFE bag is immersed in the transfer oil. The reaction vessel is closed. The maximum selected test pressure is applied to test assembly via the transfer oil and then returned to ambient pressure over a 30-minute cycle. The test temperature and pressure cycling are maintained throughout the test period (usually 30 days). At the end of the test, specimens and fluid are examined for evidence of physical and chemical changes and performance properties.

Apparatus

a. Reaction vessel - The reaction vessel shall have 4-inch ID and 16-inch useful height. It shall have a 3300-ml capacity. The top shall have fluid inlet and outlet ports and a thermocouple well.

b. Test cell - The fluid specimens are contained in a PTFE cylindrical bag (3-inch ID, 8-inch-long) with 304 stainless steel end closures. (See Figure 1.)

c. Specimen holder - The specimen holder shall be of any design suitable to hold specimens in fluid with ample space between specimens and between test cell wall and specimens. It shall be of 304 stainless steel. A typical holder for metal specimens is shown in Figure 2.

d. Spacers - The spacers shall be made of either 304 stainless steel or PTFE. They shall be cut from 1/4-inch ID, 3/8-inch OD tubing and shall be 1/8 inch thick.

e. Constant-temperature bath - The constant-temperature bath shall contain MS 2190-TEP petroleum oil as the heating medium. It shall be designed to permit immersion of the reaction vessel up to the lower rim of the locking nut. The bath shall be capable of maintaining the vessel and transfer oil at any temperature between 100° and 250°±2° F. During pressure cycles, the test oil temperature varies, for example, at the selected pressure, transfer oil temperature will vary from the set temperature of 140° F, as the pressure is released and applied, from 125° to 155° F.

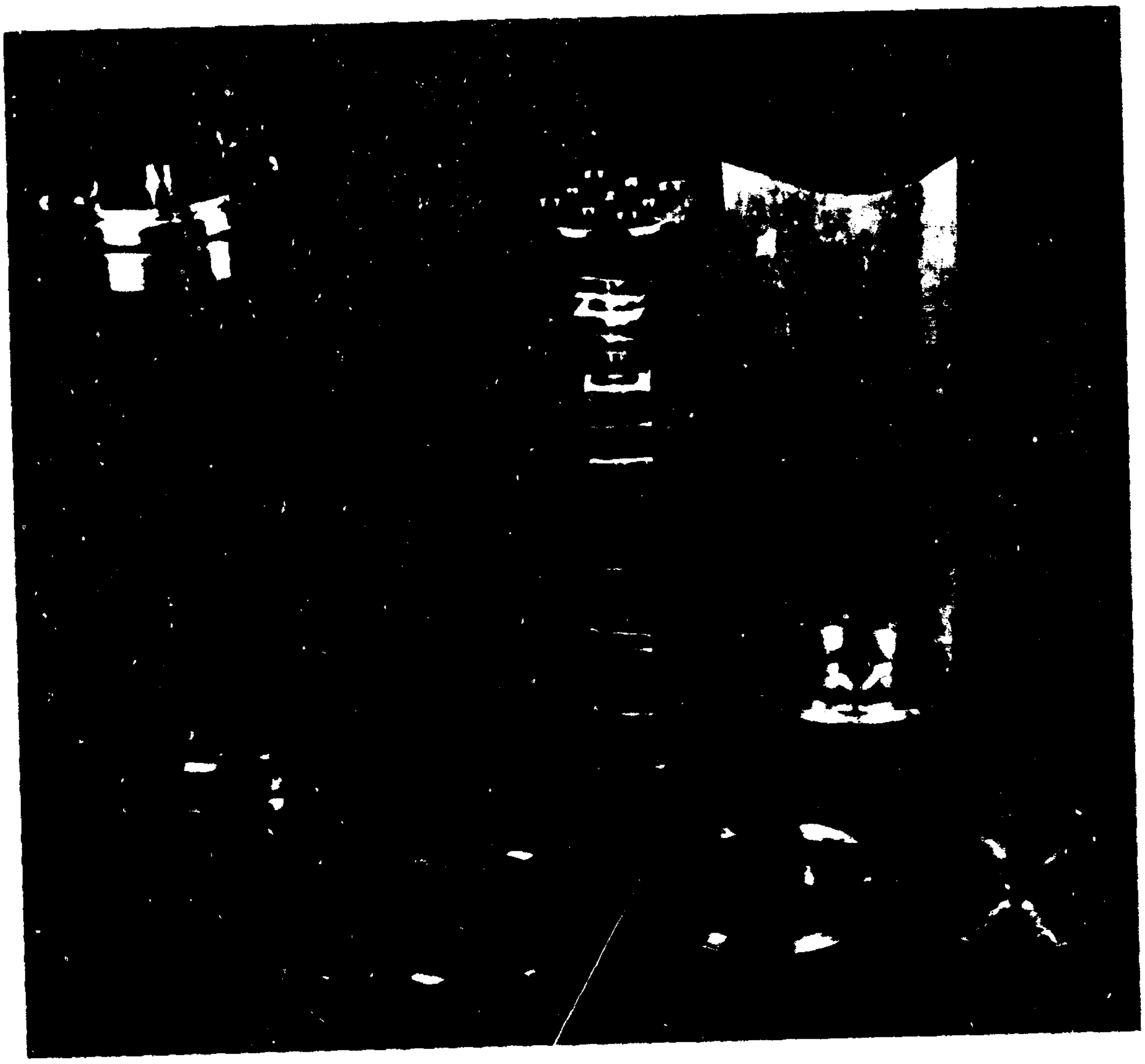

Figure 1 (C2)
Test Cell

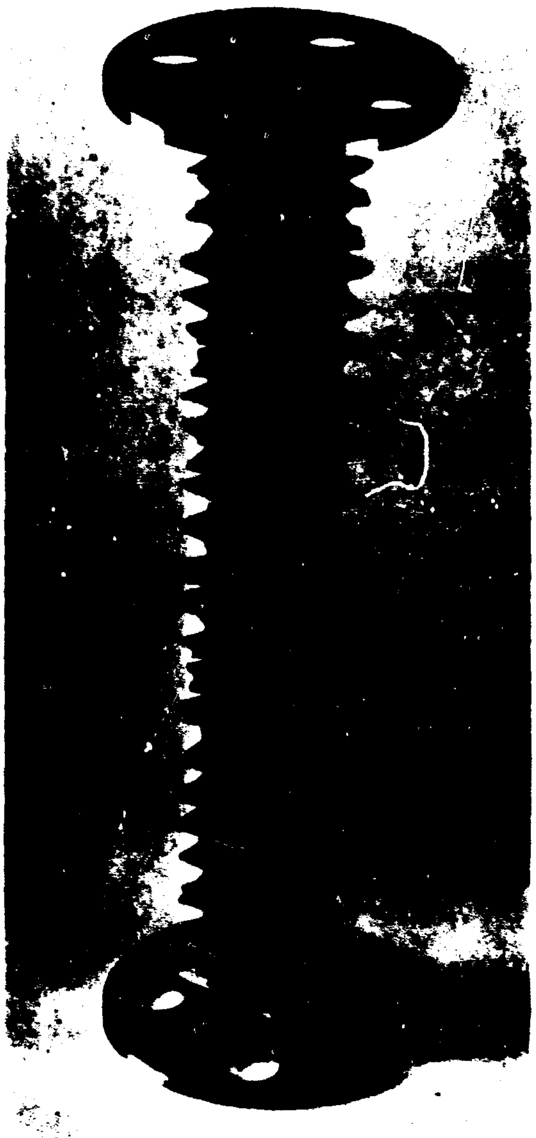

Figure 2 (C2)
Typical Metal Specimen Holder

f. Pressure supply - The pressure shall be supplied by a high-pressure pump, such as a 30,000 psig Sprague diaphragm pump, Model S-216-CPR-300. All tubing and fittings shall be high-pressure 304 or 316 stainless steel. The pump controls shall be capable of linearly cycling the pressure in the reaction vessel from 0-20,000 psig and back to 0 psi over a 30-minute period, with a variation of ±200 psig. A schematic diagram of the pressure supply is shown in Figure 3.

g. Recording potentiometer - A recording potentiometer capable of recording oil temperatures from 100° to 250°±2° F shall be used.

h. Specimens

(1) Metal specimens shall be of any deep submergence alloy or metal to be studied. The size shall be 1 x 1 x 0.032 inch with a 1/4-inch hole in the center. The specimens shall have a finish (before polishing) conforming to Federal Test Method Standard No. 791a, Method 5308.4. The metals used by NAVSHIPRANDLAB Annapolis are given in Figure 4.

(2) Nonmetallic specimens shall be of any deep submergence elastomer, plastic, or insulating material contacting fluids of interest. Where possible, specimens shall be prepared in a Type C dumbbell shape as in ASTM D-412-66.

Materials

a. Naphtha solvent, conforming to ASTM D-91 method.

b. Freon TF solvent, trichlorotrifluoroethane, E. I. du Pont de Nemours and Company.

c. Aluminum oxide polishing compound, 150 grit.

d. Seawater, ASTM D-665.

e. PTFE tape, 1/2-inch-wide, Scotch Brand No. 48, Minnesota Mining and Manufacturing Company.

f. Typewriter brush, Federal Specification H-B-00681C.

g. Temperature and pressure transfer oil - MIL-L-17331, MS 2190-TEP.

A - Air Driven Pump (rated 30,000 psig)
B - Pump reservoir (capacity 3 gallons)
C - Rupture Assembly (set 22,500 psig
D - Pressure gage (25,000 psig)
E - Air Operated, Flow Control Valve (50,000 psig)
F - Pneumatic Indicating Controller (100 psig)
G - Microset Hand Valve
H - Check-Valve (40 psig working pressure)
H' - Check-Valve (10 psig working pressure)
I - Solenoid Valve (110 vac)
J - Bleed-Down Sump (1 quart)
K - Support Stand (30 x 36 x 40 inches)
L - Heated Oil Bath (20 gallons, 140° F, 2190-TEP)
M - Reaction Vessel (3300-ml, rated 30,000 psig at 125° F)
N - Thermocouple

All high-pressure tubing - 1/4-inch OD, 1/16- or 3/32-inch ID, rated 60,000 psig.
All valves, tees, elbows - rated 30,000 psig (superpressure).

Auxiliary Equipment (Not Shown)

High-Speed Bath Stirrer
Immersion heaters (1500 watts)
Bath Temperature Control
Recording Potentiometer
Air Operated Cycling Device
Electric Timer
Air Filters, Regulators, etc

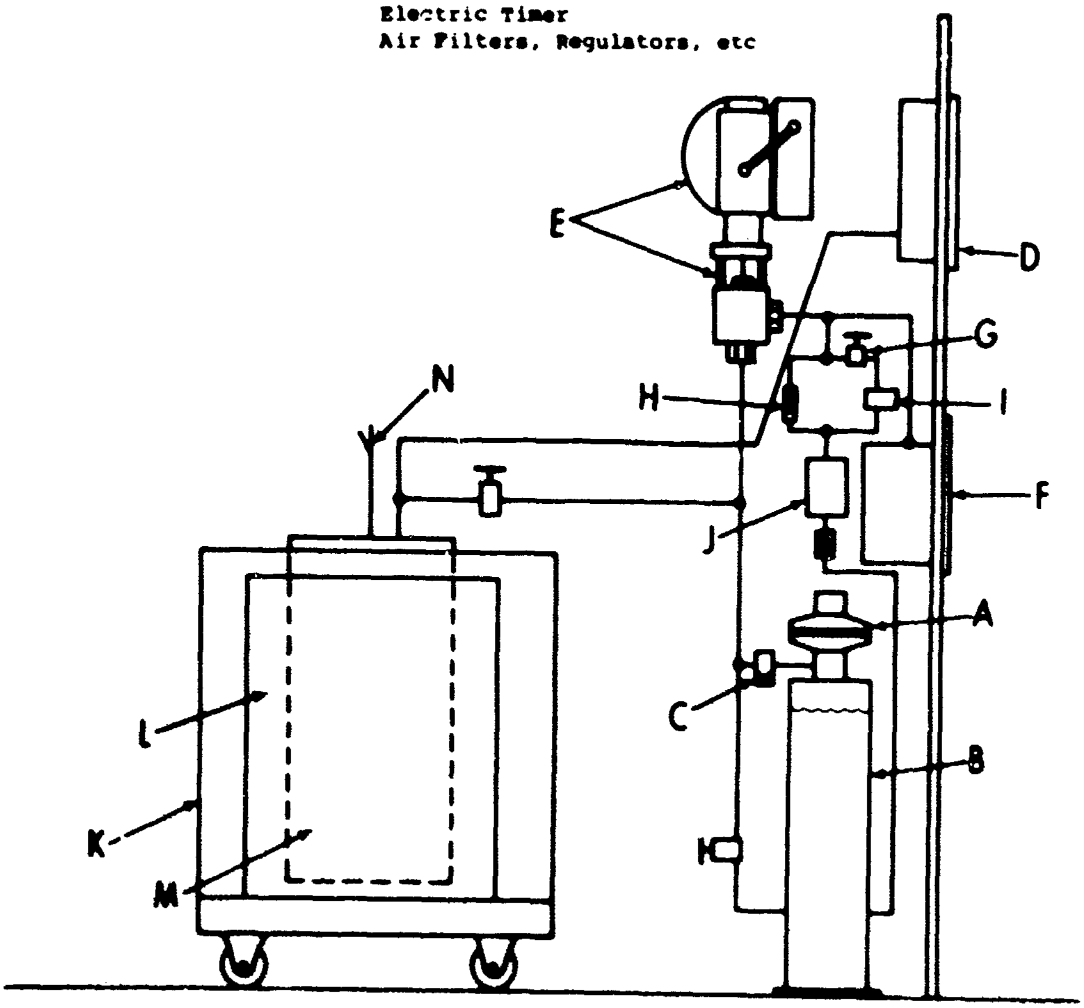


Figure 3 (C2) - Cycling Unit

STEEL, Stainless, Type 316

ALUMINUM 6061, Specification QQ-A-250-11

COPPER-NICKEL, 70-30, Specifications MIL-C-15726 or MIL-T-00/6420

STEEL, QQ-S-698, Grade 1009

ALUMINUM, QQ-A-250-4b

COPPER, QQ-C-576a

NICKEL-COPPER, QQ-N-281, Class A, Monel 400

BRONZE, MIL-B-16541A(WEP) (1/16 inch thick)

PHOSPHOR-BRONZE, QQ-B-750, Composition A

SILVER BASE BRAZING ALLOY, MIL-B-15395A, Grade IV

STEEL, Galvanized, Electrodeposited, QQ-Z-325A, Type II, Class I

<u>Specifications for Items Above</u>

Metal Specimens, 1 x 1 x 0.032 inch with a 1/4-inch hole in center, finish to conform to that given in Federal Test Method Standard No. 791a, Method 5308.4

Figure 4 (C2)
Metal Specimens Used

## Preparation of Sample Container and Specimen Holder

a. The PTFE bag, end pieces, and specimen holder shall be successively washed with ASTM D-91 naphtha, soap and water, and distilled water; then oven dried at 140° F.

## Preparation of Specimens

a. Metallic specimens shall be cleaned, polished, and weighed as in the "Ambient Pressure Stirred Corrosion Procedure," Method C1.

b. Nonmetallic specimens shall be prepared, cleaned, and volume measured as in ASTM D-471-66.

c. The specimens shall be attached to the specimen holder so as to provide space between the individual specimens and also between the specimens and the wall of test cell so that all parts of specimen are flooded by test fluid. Where insulated metallic specimens are used, the order of assembly shall be as given in Method C1. When metallic couples also are to be studied, the order of assembly shall be as shown in Method C4 ("20,000 PSIG Stirred Corrosion Procedure"), except that the insulated specimens shall be placed on the specimen holder above the coupled specimens.

## Procedure

a. Bring reaction vessel and transfer of oil to test temperature.

b. Assembly of test cell.

(1) The PTFE bag is fitted into the bottom and top closures.

(2) The specimen assembly is inserted into the bag through a removable part of top closure placed on the bag.

(3) The cell is filled with 825 ml of test fluid through the top port, taking care to purge out the air. The top port is closed.

(4) Get the total weight of the test cell. The test cell is again weighed after the test period. The weights are obtained to determine whether the test cell leaked during the test.

c. Place the test assembly in the reaction vessel in transfer oil.

d. If sea-water contaminant is to be used, allow the test cell to remain in the reaction vessel for 1 hour. Then remove the test cell from the reaction vessel and add seawater through the top port. Close the top port and return the test cell to the reaction vessel.

e. Close the reaction vessel, placing the thermocouple end at the top of the test cell.

f. Add sufficient additional transfer oil to finish filling the reaction vessel and purging out the air. Close the reaction vessel.

g. Begin pressure cycling and maintain pressure cycling and test temperature for the test period.

h. At the end of the test period remove the test cell.

i. Separate the specimens and the test oil.

j. Measure the properties of the test oil to detect changes (viscosity, acid content, density, metal content, etc).

k. Measure changes in the specimens.

(1) Clean and weigh the metal specimens as in Method Cl.

(2) Determine volume, hardness, tensile strength, and elongation changes in the nonmetallic specimens as in ASTM D-471-66.

## C3. 20,000 PSIG Static Compatibility Procedure

Scope - This method is intended to measure the effects of pressure on deep submergence fluid-material compatibility.

Outline of Method - A high-pressure reaction vessel, filled with a temperature-pressure transfer oil, is brought to a test temperature of 140° F. A test cell, consisting of metallic or non-metallic compatibility specimens immersed in the oil being studied contained in a PTFE bag, is immersed in the transfer oil. The reaction vessel is closed, and the test pressure, 20,000 psig maximum, is applied to the contents of the reaction vessel. Temperature and pressure are maintained constant throughout the test period. At the end of the test the specimens and the fluid are examined for evidence of physical and chemical changes and performance properties.

Apparatus

a. Reaction vessel - The reaction vessel shall have a 3 1/2-inch ID and a 12-inch useful height. It shall have approximately a 2000-ml capacity. The top shall have fluid inlet and outlet ports and a thermocouple well.

b. Test cell - The fluid and specimens are contained in a PTFE cylindrical bag with 304 stainless steel end closures as shown in Figure 1.

c. Specimen holder - The specimen holder shall be of any design suitable to hold specimens in the fluid with ample space between specimens and between the test cell wall and specimens. It shall be of 304 stainless steel. A typical holder for metal specimens is shown in Figure 2.

d. Spacers - Spacers shall be made of either 304 stainless steel or PTFE. They shall be cut from 1/4-inch ID, 3/8-inch OD tubing and shall be 1/8-inch-thick.

e. Constant-temperature bath - The constant-temperature bath shall contain MS 2190-TEP petroleum oil as heating medium. It shall be designed to permit immersion of the reaction vessel up to the lower rim of the locking nut. The bath shall be capable of maintaining the vessel and tranfer oil at any temperature between 100° and 250°±2° F.

Figure 1 (C3)
Test Cell

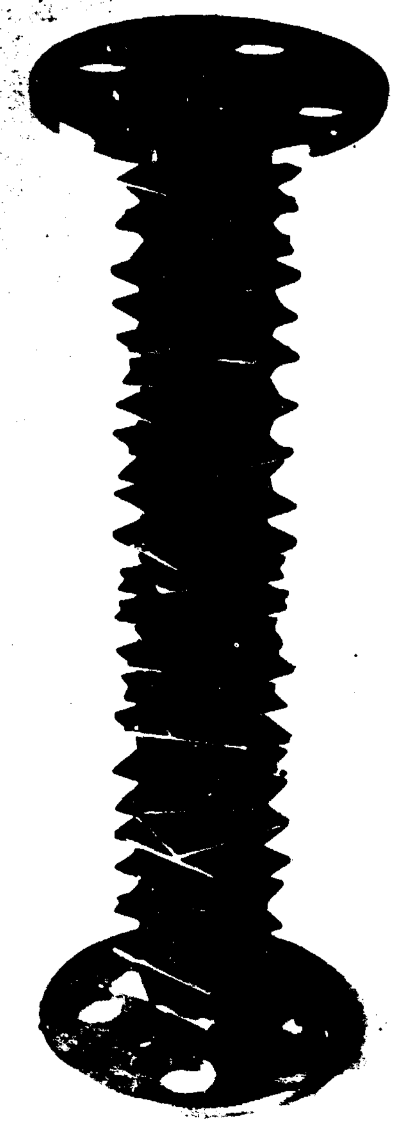

Figure 2 (C3)
Specimen Holder

f. <u>Pressure supply</u> - The pressure shall be supplied by a high-pressure pump, such as a 30,000 psig Sprague diaphragm pump, Model S-216-CPR-300. All tubing and fittings shall be high-pressure 304 or 316 stainless steel. The pump shall be capable of maintaining the test oil at 0-20,000±25 psig. A schematic of the system is shown in Figure 3.

g. <u>Recording potentiometer</u> - A recording potentiometer capable of recording oil temperatures from 100°-250°±2° F shall be used.

h. <u>Specimens</u>

(1) Metallic specimens shall be of any deep submergence alloy or metal to be studied. The size shall be 1 x 1 x 0.032 inch with a 1/4-inch hole in the center. The specimens shall have a finish (before polishing) conforming to Federal Test Method Standard No. 791a, Method 5308.4. The metals used by NAVSHIPRANDLAB, Annapolis are given in Figure 4.

(2) The nonmetallic specimens shall be of any deep submergence elastomer, plastic, or insulating material contacting fluids. Where possible, specimens shall be prepared in a Type C dumbbell shape as in ASTM D-412-66.

<u>Materials</u>

a. Naphtha solvent, conforming to ASTM D-91.

b. Freon TF solvent, trichlorotrifluoroethane, E. I. du Pont de Nemours and Company.

c. Aluminum oxide polishing compound, 150 grit.

d. Seawater, ASTM D-665.

e. PTFE tape, 1/2-inch-wide, Scotch Brand No. 48, Minnesota Mining and Manufacturing Company.

f. Typewriter brush, Federal Specification H-B-00681C.

g. Temperature and pressure transfer oil MIL-L-17331, MS 2190-TEP.

A - Air Driven Pump (rated 30,000 psig)
B - Pump Reservoir (capacity 3 gallons)
C - Pressure Generator (30,000 psig) 11 cc)
D - Pressure Gage (25,000 psig)
E - Rupture Assembly Set (22,000 psig)
F - Fluid Separator (325 cc, 30,000 psig at 72° F)
G - Support Stand (30 x 36 x 40 inches)
H - Heated Oil Bath (20 gallons, 140° F, 2190-TEP)
I - Reaction Vessel (2000-ml, rated 30,000 psig at 125° F)
J - Thermocouple

All tubing - 1/4-inch OD, 1/16- or 3/32-inch ID, rated 60,000 psig.
All valves, tees, elbows - rated 30,000 psig.
All connections use superpressure fittings.

Auxiliary Equipment (Not Shown)

High-Speed Bath Stirrer
Immersion Heaters (1500 watts maximum)
Bath Temperature Control
Recording Potentiometer
Air Lines, Filters, Pressure Regulators, etc

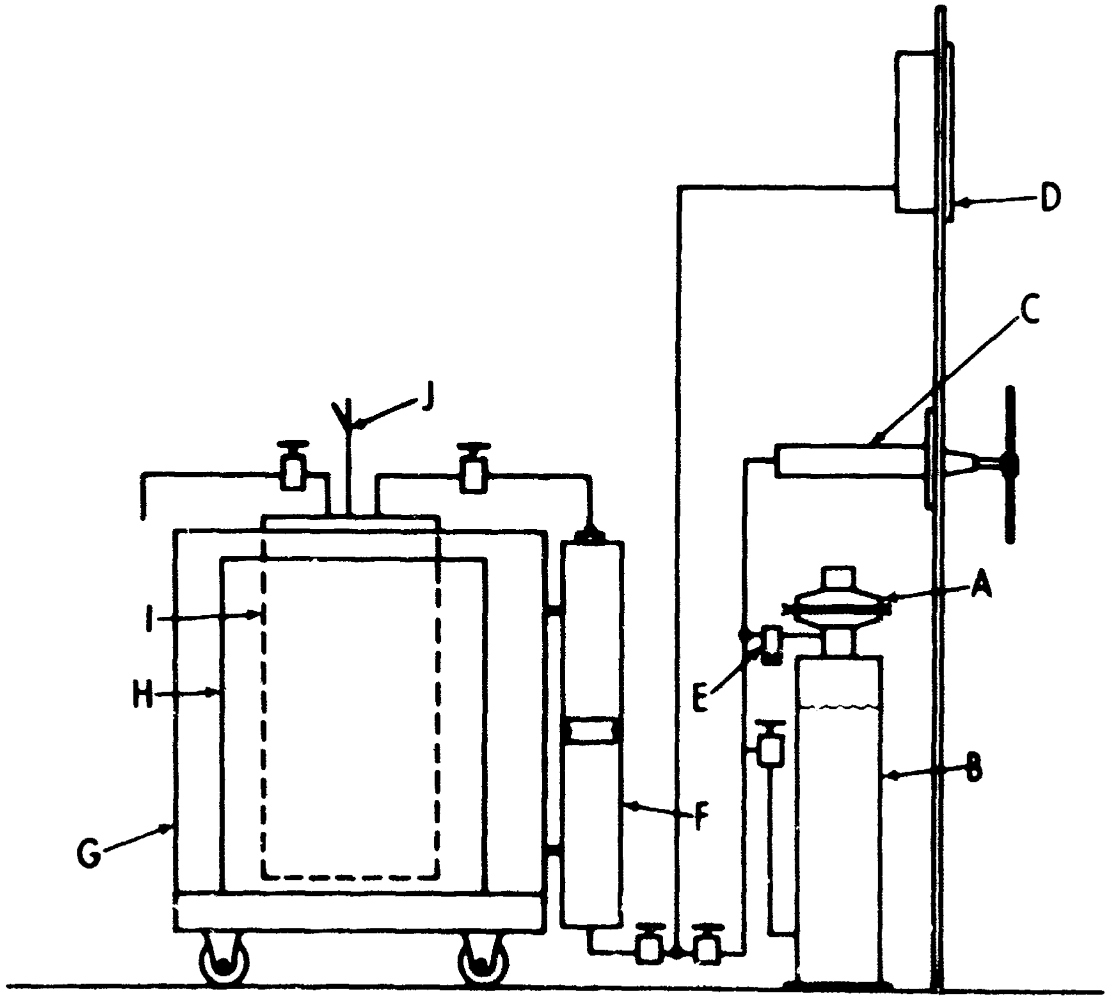


Figure 3 (C3) - 20,000 PSIG Static Test Unit

STEEL, Stainless, Type 316

ALUMINUM 6061, Specification QQ-A-250-11

COPPER-NICKEL, 70-30, Specifications
MIL-C-15726 or MIL-T-00/6420

STEEL, QQ-S-698, Grade 1009

ALUMINUM, QQ-A-250-4b

COPPER, QQ-C-576a

NICKEL-COPPER, QQ-N-281, Class A, Monel 400

BRONZE, MIL-B-16541A(WEP) (1/16 inch thick)

PHOSPHOR-BRONZE, QQ-B-750, Composition A

SILVER BASE BRAZING ALLOY, MIL-B-15395A,
Grade IV

STEEL, Galvanized, Electrodeposited,
QQ-Z-325A, Type II, Class I

Specifications for Items Above

Metal Specimens, 1 x 1 x 0.032 inch with a 1/4-inch hole in center, finish to conform to that given in Federal Test Method Standard No. 791a, Method 5308.4

Figure 4 (C3)
Metal Specimens Used

## Preparation of Sample Container and Specimen Holder

a. The PTFE bag, end pieces, and specimen holder shall be washed with ASTM D-91 naphtha, soap and water, distilled water, and oven-dried at 140° F.

## Preparation of Specimens

a. Metallic specimens shall be cleaned, polished, and weighed as in "Ambient Pressure Stirred Corrosion Procedure," Method C1.

b. Nonmetallic specimens shall be prepared, cleaned, and volume measured as in ASTM Method D-471-66.

c. The specimens shall be attached to the specimen holder so as to provide space between specimens, and between the specimens and the wall of the test cell so that all parts of the specimen are flooded with the fluid. Where insulated metallic specimens are used, the order of assembly shall be as given in Method C1. When metallic couples also are to be studied the order of assembly shall be as shown in the "20,000 Stirred Corrosion Procedure," Method C4, except that the insulated specimens shall be placed on the specimen holder above the coupled specimens.

## Procedure

a. Bring reaction vessel and transfer oil to test temperature.

b. Assembly of test cell.

(1) Fit PTFE bag into the bottom and top closures.

(2) Insert the specimen assembly into the bag through removable part of the top closure placed on the bag.

(3) Fill the cell with 825 ml of test fluid through the top port, taking care to purge out the air. Close the top port.

(4) Determine the total weight of the test cell. This is done to determine if the cell leaks during test. The test cell weight is again measured after the test period.

c. Place the test assembly in the reaction vessel in transfer oil.

d. If sea-water contaminant is to be used, allow the test cell to remain in the reaction vessel for 1 hour. Then remove the test cell from the reaction vessel and add seawater through the top port. Close the top port and return the test cell to the reaction vessel.

e. Close the reaction vessel, placing the thermocouple end at the top of the test cell.

f. Add sufficient additional transfer oil to fill the reaction vessel and purge out the air and close the vessel.

g. Bring the system to test pressure, Maintain constant pressure and temperature throughout the test.

h. At the end of the test period remove the test cell from the reaction vessel and separate the specimens and the test fluid.

i. Measure the properties of the test fluid to detect changes (viscosity, acid content, density, metal content, etc).

j. Measure changes in the specimens.

(1) Clean, weigh, and photograph the specimens as in Method C2 ("20,000 PSIG Pressure-Cycled Compatibility Procedure").

(2) Determine the volume, hardness, tensile strength, and elongation changes in the nonmetallic specimens as in ASTM D-471-66.

## c4. 20,000 PSIG, Stirred Corrosion Procedure

Scope - This method is intended to measure the relative protection provided to metals and alloys used in deep submergence equipment upon contamination with seawater at high ambient pressures.

Outline of Method - A sample of test oil is brought to a predetermined temperature in a high-pressure reaction vessel. A weighed metal specimen assembly is immersed in the oil, and the stirrer blade and vessel cover are fitted onto the vessel. After stirring for a 1-hour conditioning period, the desired amount of sea-water contaminant is added to the oil. The desired test pressure is applied to the vessel contents. The test temperature, pressure, and stirring are maintained for a predetermined reaction period (usually 30 days). The specimen assembly is removed from the vessel. The specimens are cleaned, weighed, and photographed.

Apparatus

a. Reaction vessel - The reaction vessel shall have a 3 5/8-inch ID and a 13-inch useful height. It shall have a 2100-ml capacity and be made of, or completely lined with, a corrosion resistant alloy, such as Hastelloy C. The stirrer shall have a speed of 1000±50 rpm. The vessel cover shall have fluid inlet and outlet ports, thermocouple well, and blowout disk assembly.

b. Specimen holder - The specimen holder shall be of 304 stainless steel and of a configuration so that up to 50 specimens are held between stirrer and wall. Figure 1 shows a typical holder and specimen array.

c. Constant-temperature bath - The constant-temperature bath shall contain MS 2190-TEP petroleum oil as a heating medium. It shall be designed to permit the immersion of the reaction vessel up to the lower rim of the locking nut. The bath shall be capable of maintaining the test oil at any temperature between 100°-250°±2° F.

d. Pressure supply - The pressure shall be supplied by a high-pressure pump, such as a 30,000 psig Sprague diaphragm pump, Model S-216-CPR-300. All tubing and fittings shall be high-pressure 304 or 316 stainless steel. The pump shall be capable of maintaining test oil at 0-20,000±25 psig. A diagram of the system is shown in Figure 2.

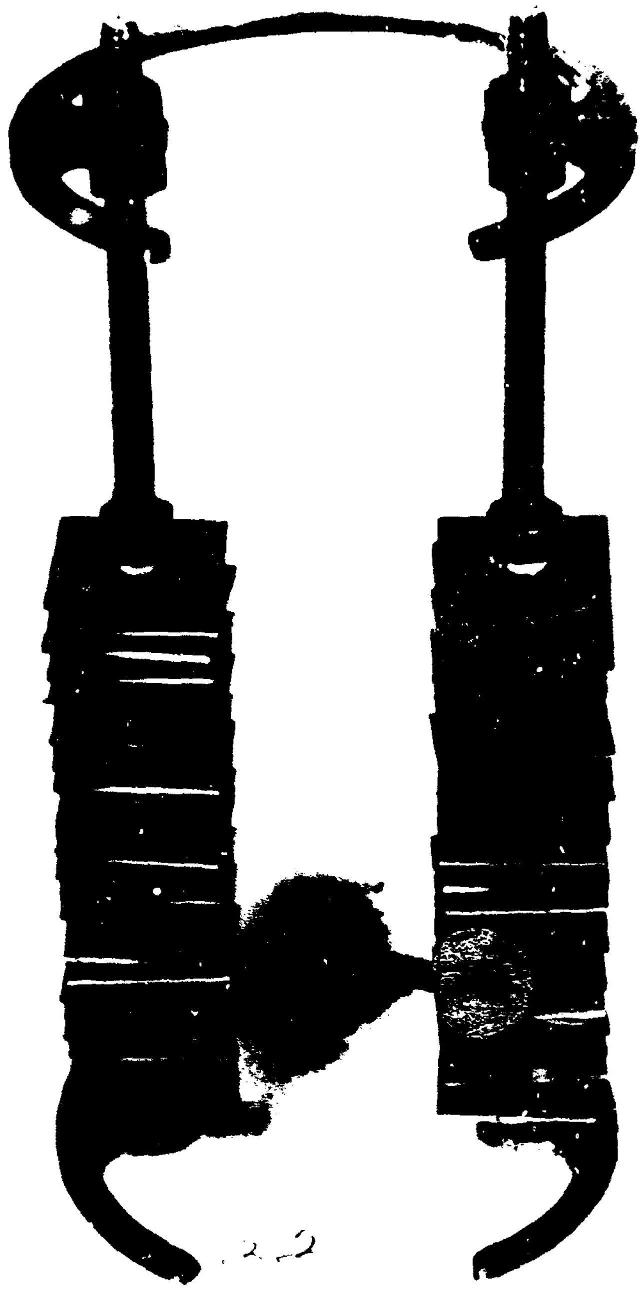

Figure 1 (C4)
Specimen Holder and Specimens

A - Air Driven Pump (rated 30,000 psig)
B - Pump Reservoir (capacity 3 gallons)
C - Pressure Generator (30,000 psig, .11 cc)
D - Pressure Gage (25,000 psig)
E - Rupture Assembly Set (22,000 psig)
F - Fluid Separator (325 cc, 30,000 psig at 72° F)
G - Support Stand (30 x 36 x 40 inches)
H - Heated Oil Bath (20 gallons, 140° F, 2190-TEP)
I - Reaction Vessel (2100-ml, rated 30,000 psig at 1[illegible]5° F)
J - Thermocouple
K - Marine Propeller
L - Permanent Magnetic Drive

All tubing - 1/4-inch OD, 1/16- or 3/32-inch ID, rated 60,000 psig.
All valves, tees, elbows - rated 30,000 psig.
All connections use superpressure fittings.

Auxiliary Equipment (Not Shown)

High-Speed Bath Stirrer
Immersion Heaters (1500 watts maximum)
Bath Temperature Control
Recording Potentiometer
Air Lines, Filters, Pressure Regulators, etc

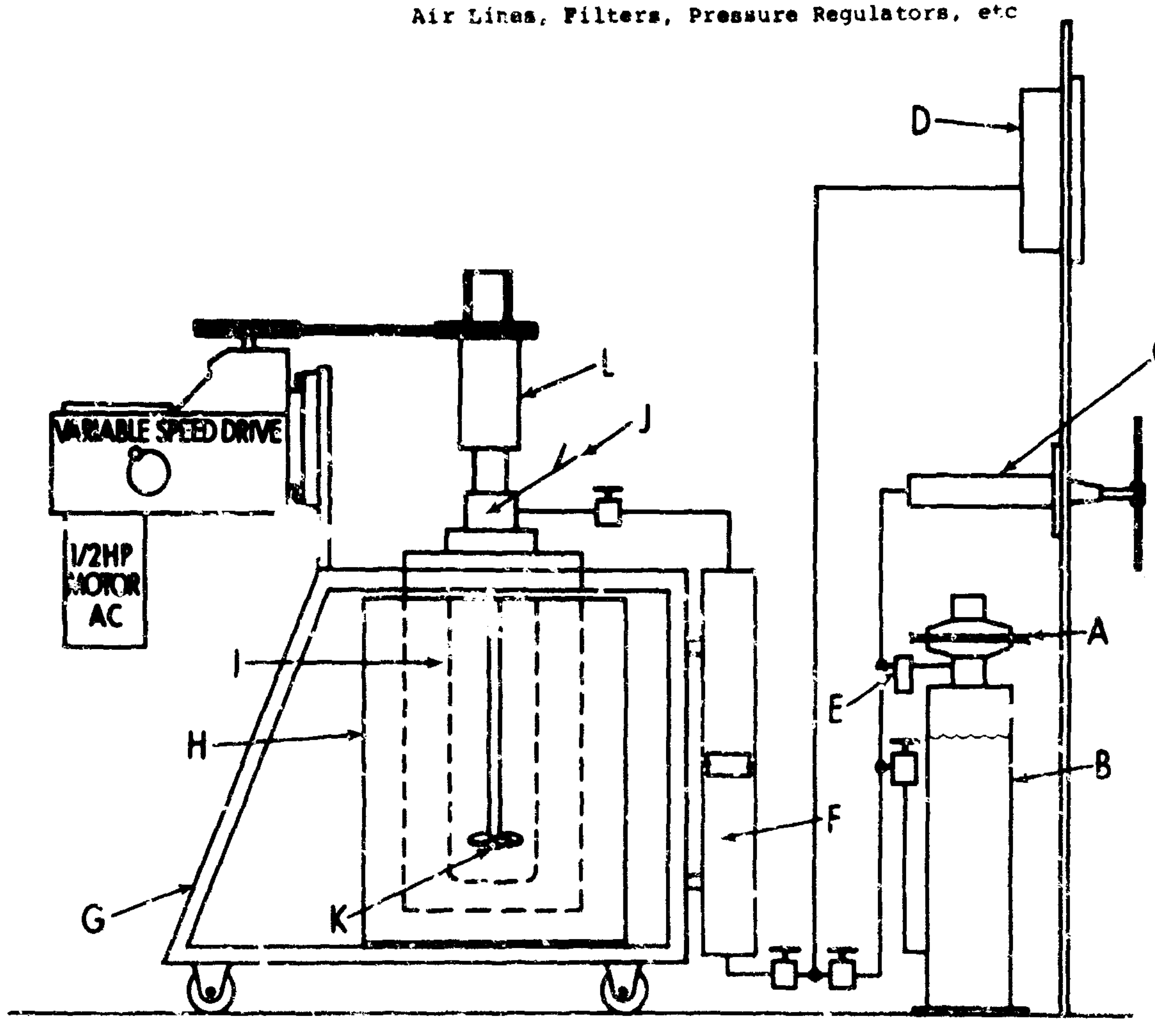


Figure 2 (C4) - Stirred Reaction Vessel for 20,000 PSIG

e. Recording potentiometer - A recording potentiometer capable of recording oil temperatures of 100°-250°±2° F shall be used.

f. Corrosion specimens - The corrosion specimens shall be 1 x 1 x 0.032 inch with a 1/4-inch hole in the center. The specimen shall have a finish (before polishing) conforming to Federal Test Method Standard No. 791a, Method 5308.4. The specimens shall be of any deep submergence alloy or metal to be studied. Those used by NAVSHIPRANDLAB Annapolis are shown below.

(1) STEEL, Stainless, Type 316.

(2) ALUMINUM 6061, Specification QQ-A-250-11

(3) COPPER-NICKEL, 70-30, MIL-C-15726 or MIL-T-00/6420.

(4) STEEL, QQ-S-698, Grade 1009.

(5) ALUMINUM, QQ-A-250-4b.

(6) COPPER, QQ-C-576a.

(7) NICKEL-COPPER, QQ-N-281, Class A, Monel 400.

(8) BRONZE, MIL-B-16541A(WEP) (1/16-inch-thick).

(9) PHOSPHOR-BRONZE, QQ-B-750, Composition.

(10) SILVER BASE BRAZING ALLOY, MIL-B-15395A, Grade IV.

(11) STEEL, Galvanized, Electrodeposited, QQ-Z-325A, Type II, Class I.

A typical order of assembly of electrically coupled and insulated specimens is shown in Figure 3.

g. Spacers - Spacers for specimens shall be made of 304 stainless steel and of PTFE. They shall be cut from 1/4-inch ID, 3/8-inch OD tubing and shall be 1/8-inch-thick.

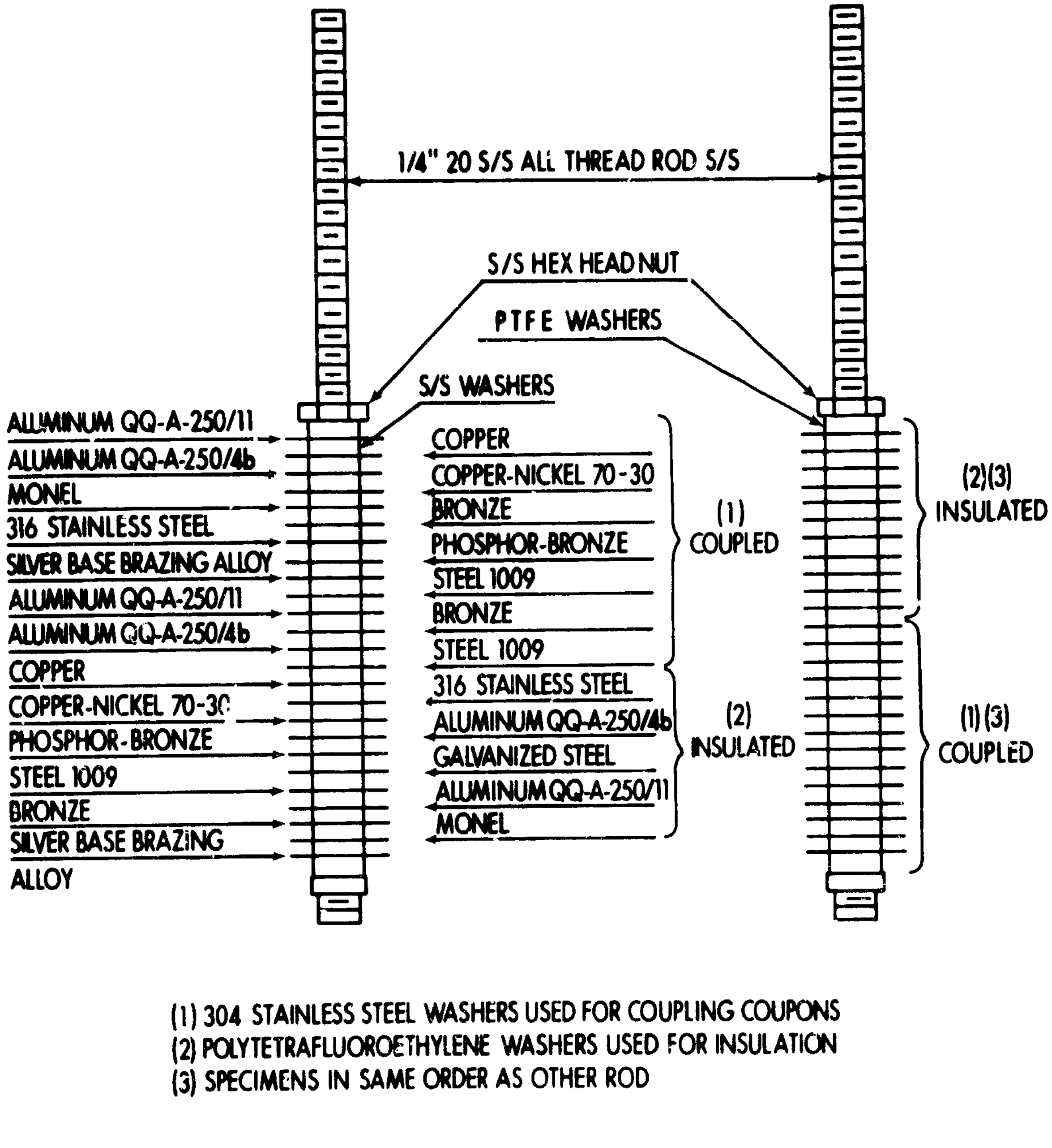


Figure 3 (C4) - Specimen Assembly for Stirred Corrosion Test

## Materials

a. Naphtha solvent - conforming to ASTM D-91.

b. Freon TF solvent - trichlorotrifluoroethane, E. I. du Pont de Nemours and Company.

c. Aluminum oxide polishing compound, 150 grit.

d. Seawater ASTM D-665.

e. PTFE tape, 1/2-inch-wide, Scotch Brand No. 48, Minnesota Mining and Manufacturing Company.

f. Typewriter brush, Federal Specification H-B-00681C.

## Preparation of Apparatus

a. Piping and connections shall be drained free of oil.

b. The internal surfaces of the reaction vessel shall be wiped clean with lint free rags.

c. The vessel shall be filled with test oil and stirred for 1 hour, then drained free of oil.

d. Repeat a., b., and c. two additional times.

e. Drain and fill with test oil.

## Preparation of Corrosion Specimens

a. Handle specimens with disposable polyethylene gloves.

b. Flush with naphtha to remove preservatives.

c. Polish with 150 grit aluminum oxide powder on medicinal cotton wads (do not polish plated specimens).

d. Make polishing strokes in one direction.

e. Turn specimen 90° and polish until previous polishing marks are removed.

f. Brush with camel hair brush.

g. Use wash bottle to flush specimen with jet of naphtha, then a jet of Freon TF.

h. Air dry and place in desiccator.

i. Weigh on semimicrobalance, record weight to 0.00001 gram.

Preparation of Specimen Holder and Spacers - Specimen holder and spacers shall be cleaned with naphtha, soap and water, distilled water and then oven-dried at 140° F.

Procedure

a. Assembly of specimens - Handle the specimens and specimen rack with polyethylene gloves. Wrap the 1/4-inch specimen rack and rods with PTFE tape to insulate from the specimens. Place the specimens on rods in desired order, Use two PTFE spacers to prevent electrolytic contact between the specimens, or use two stainless steel spacers to form electrolytic couples between the specimens. Order of assembly is shown in Figure 3.

b. Add the test oil to the reaction vessel. (The reaction vessel remains in constant temperature bath at all times.) After the test oil is at desired temperature, soak the specimen assembly in the reaction vessel for 1 hour and securely close the reaction vessel.

c. Attach the specimen assembly to the cover. Add the desired amount of seawater. Lower the cover into the vessel.

d. Bleed off the air from the reaction vessel by pumping in excess oil.

e. Close the valves, pressurize the system, and start the stirrer.

f. The stirrer may be operated continuously or intermittently, as desired.

g. At the end of the test period the pressure is released and the specimen assembly is removed. The specimens are stored in naphtha prior to cleaning.

h. The specimens are cleaned by successive flushes with naphtha and brushing with a naphtha-wet typewriter brush.

i. A final flush with Freon TF is made, then the specimens are placed in a desiccator and weighed to obtain the gain or loss due to corrosion.

j. Record of changes in the weight and the appearance of specimen is made by written notes and photographs.

## C5. On-Off Rust Test Procedure

Scope - This method is intended to establish the ability of a fluid to prevent corrosion when contaminated with seawater under conditions of intermittent agitation.

Outline of Method and Apparatus - The ASTM D-665 method and apparatus is used except as described below. An ASTM D-665, double-blade stirrer, paragraph 9b, is used. The specimen is polished and attached to the holder using a 1/16-inch-thick, 1/2-inch-diameter PTFE gasket between specimen shoulder and holder. After the 30-minute soaking period, 150 ml of the 300-ml fluid sample is removed and 150 ml of seawater is added. The seawater is added dropwise from a burette while stirring. The burette top is just above the surface of the fluid. The seawater shall be added within 30 minutes. The oil and water sample is stirred for 15 minutes, once every 24 hours. After the first 24 hours the specimen is observed for rusting and the fluid-water emulsion examined for stability; it is then examined twice weekly during the test period. Distilled water is added at these times to make up for water lost by evaporation. The test period is 30 days. Quadruplicate determinations will be made. A fluid is considered to have satisfactory rust protection if three out of four specimens show no rust and no more than light rust is observed on the fourth specimen after 30 days.

## ELECTRICAL PROPERTY MEASUREMENT PROCEDURES

Methods of determining dielectric properties of fluids at temperatures as low as 28° F and pressures up to 20,000 psig, particularly as they are affected by seawater and carbon contamination, have not been fully developed. The following test methods, E1 through E7, are performed at room temperature and atmospheric pressure and are expected to give a good first approximation of the properties being measured. As these methods are improved and high pressure methods are developed they will be added.

## E1. Resistivity

Scope - This method is intended to measure the insulating characteristics of a fluid. It determines the value of resistivity of a fluid.

Outline of Method and Apparatus - ASTM Method D1169 is used except as noted below. The fluid sample is placed in a test cell and resistivity measured with a General Radio Type 1644A megohm bridge or equivalent. The test cell may be any one of three cells described in Figure 2, 3, or 4 of the appendix to ASTM D1169 (Specific Resistance of Electrical Insulating Liquids). The temperature of the fluid is held between 65°-85° F and preferably 77±2° F. Resistivity is recorded as ohm-cm at °F. A tentative standard of acceptable resistivity for dielectric fluids has been set at $3.0 \times 10^{11}$ ohm-cm. minimum.

## E2. Dissipation Factor

Scope - This method is intended as a measure which will be useful in predicting decreases in the efficiency of fluid immersed electrical equipment due to electrical energy losses through a fluid in an electric field in a nonsinusoidal a-c system. Specifically, the method measures the loss angle of a fluid filled cell on a capacitance bridge.

Outline of Method and Apparatus - The fluid sample is placed in a test cell of the type referred to under Test Method E1, "Resistivity". Dissipation factor is measured with a General Radio Type 1615 or 1617 capacitance bridge or the equivalent of either or these. The temperature of the fluid is held between 65°-85° F and preferably 77±2° F. Dissipation factor is recorded as percent at °F. A tentative standard of acceptable dissipation factor for dielectric fluids has been set at 5.0%, maximum.

## E3. Dielectric Breakdown Voltage

Scope - This method is intended to measure the ability of a fluid to withstand electrical stress. It determines the voltage at which breakdown occurs between two electrodes under prescribed conditions.

Outline of Method and Apparatus - ASTM D877 is used, with the following exceptions:

a. The electrode spacing is 0.050±0.001 inch.

b. Voltage rise rate is 600 volts per second ±20%.

c. Five separate readings are taken on the same sample, with a 3-minute wait between readings. The result is reported as the average of the five readings, in kilovolts.

d. The temperature of the fluid sample should be between 65°-85° F and preferably 77±2° F. The temperature of the fluid is recorded. A convenient single package instrument for this test is a Model 4507 "Oil Testing Hypot" manufactured by Associated Research, Incorporated, Chicago, Illinois. A tentative standard of acceptable dielectric breakdown voltage for dielectric fluids has been set at 15.0 kv, minimum, at a 0.05-inch electrode gap.

## E4. Stability of Seawater - Fluid Emulsions

Scope - This method describes a procedure for determining the stability of water dispersed in a pressure-compensating fluid in order to estimate fluid utility for electrical equipment service.

Outline of Method - Oil (100 ml) and synthetic seawater (10 ml) are stirred for 15 minutes and transferred to a 100-ml graduated cylinder. The time required for separation of synthetic seawater from the compensating fluid is recorded.

### Apparatus

a. Beaker, 250 ml.

b. Mechanical stirrer as described in ASTM D1479 or equivalent.

c. Buret, 25 ml.

d. Cylinder, graduated, 100 ml in 1-ml increments.

e. Volt-ohmmeter capable of measuring 1 megohm and less.

### Procedure

a. Measure 100 ml of the test fluid into a 250-ml beaker.

b. Add 10 ml of synthetic seawater (SSW), prepared according to ASTM D665 (IP 135), dropwise, with stirring.

c. Stir the mixture vigorously with a mechanical stirrer, for 15 minutes.

d. Stop the mixing and transfer the mixture immediately to a 100-ml graduated (glass) cylinder. This latter step should require about 10-20 seconds. (At this point the mixture may have completely separated into two layers, or it may be a milky emulsion.)

e. The time require for separation of a small quantity (1/2 ml or less) of SSW is now measured as follows: Two bare 1/16-inch-diameter copper wires, connected to a volt-ohmmeter, are inserted into the graduated cylinder, touching the bottom of the cylinder. The wires are kept 1/4 to 1/2 inch apart. Separation of SSW is indicated when resistance across the wires drop to less than 0.1 megohm.

f. Stability of the emulsion is recorded as the time required for the separation of synthetic seawater, as described in e. The fluid is classified according to time required for separation. A tentative standard is as follows:

| Classification | Time Required for Water Separation |
|---|---|
| A. Suitable for use with motors | 5 minutes or more |
| B. Questionable for use with motors | 1-5 minutes |
| C. Unsuitable for use with motors | <1 minute |
| D. Suitable for contactors, switches, etc | No emulsion stability requirement |

E5. Changes in Dielectric Properties Resulting from Sea-Water Contamination

Scope - This method describes the preparation of samples to determine the effect of sea-water contamination on the electrical properties of fluids as determined by Methods E1, E2, and E3.

Outline of Method - The methods described in E1, E2, and E3 are used to measure the changes in dielectric properties brought about by contamination with SSW. The effects of three concentrations, 0.1%, 0.5%, and 2.0%, are measured.

Procedure

a. 0.1% SSW - To 400 ml of the test fluid, 0.4 ml of SSW is added dropwise, with stirring. The mixture is stirred vigorously with a mechanical stirrer (ASTM D1479) for 15 minutes, then it is allowed to stand for 5 minutes. The required sample is carefully poured (to avoid pouring out any settled water) into the appropriate test cell. Resistivity and dissipation factor are measured per Test Methods E1 and E2. The sample is then recombined with the remaining portion and the mixture is stirred vigorously for 5 minutes more. A 100-ml sample is removed, and dielectric breakdown voltage is measured per Test Procedure E3. The 100-ml sample is then discarded.

b. 0.5% SSW - The procedure of a. is repeated, except add 1.2 ml of SSW to the 300 ml of liquid remaining from a.

c. 2.0% SSW - The procedure of a. is repeated, except add 3.0 ml of SSW to the 200 ml of liquid remaining from a.

Results are reported as resistivity, dissipation factor, and dielectric breakdown voltage at the three levels of SSW contamination.

E6. Changes in Dielectric Properties Resulting from Carbon Contamination

Scope - This method describes the preparation of samples to determine the effect of fluid contamination by finely divided carbon on the electrical properties as determined by Methods E1, E2, and E3.

Outline of Method - The methods described in E1, E2, and E3 are used to measure the changes in dielectric properties brought about by contamination by finely divided carbon which simulates brush wear or fluid degradation. The effects of three concentrations, 0.1%, 0.25%, and 0.50%, are measured.

Procedure

a. 0.1% carbon - To 250 ml of test fluid is added 0.025 gram of "Eagle" brand lamp black, manufactured by Columbian Carbon Company, New York, New York, while stirring (ASTM D1479 stir er). After all the lampblack has been wetted by the fluid, stirring is continued vigorously for 15 minutes. Resistivity, dissipation factor, and dielectric breakdown voltage are measured on the test mixture. The sample used for the dielectric measurements (approximately 100 ml) is recombined with the remaining material prior to Step b.

b. 0.25% carbon - To the 250-ml mixture of Step a., 0.0375-gram additional lampblack is added, with stirring, and stirring is continued for 15 minutes. The procedure of Step a. is then repeated.

c. 0.50% carbon - Additional lampblack (0.0625-gram) is added and Step b. repeated.

Results are reported as resistivity, dissipation factor, and dielectric breakdown voltage at the three levels of carbon contamination.

## E7. Effects of Electrical Arcing on Fluids

Scope - This method determines the ability of a fluid to withstand the effects of electric arc discharge.

Outline of Method - The fluid is subjected to a series of arcs at a specified rate, and the electrical properties are measured by Methods E1, E2, and E3 to determine fluid property changes.

Apparatus - In addition to the apparatus required for Methods E1-E3, the following are required:

a. Guardian Manufacturing Company Type 2110V double-pole/single-throw, normally open (D.P.S.T., N.O.) relay with silver cadmium contacts.

b. Millipore membrane filter, diameter 47-mm pore size 0.8-micrometer or equivalent , as described in SAE Aerospace Recommended Practice, ARP 785.

c. Power supply, 90-volt open circuit, 10-ampere closed circuit.

d. Counter capable of recording 50,000 operations.

Procedure

a. The testing is carried out with a Guardian Manufacturing Company Type 2110V D.P.S.T., N.O. relay having silver-cadmium contacts. The outer covering of the coil and the adhesive material are first removed and the coil recoated with RTV silicone rubber, to minimize interaction with the test fluid.

b. The cleaned relay is immersed in 400 ml of the test fluid at the desired test temperature. The fluid is subjected to 50,000 arcs (1 arc = 1 make + 1 break of the contacts) under a primarily resistive load with an open-circuit voltage of 90 volts and a closed-circuit current of 10 amperes. The rate of arcing is 5 to 10 arcs per minute. If the contacts fail, as indicated by arcing when closed, before 50,000 operations, they must be replaced.

c. The following are measured and reported as indicated:

(1) Resistivity, dissipation factor, and dielectric breakdown voltage (see Test Methods E1-E3) initially and after 50,000 arcs.

(2) The amount of solid products generated is measured gravimetrically by the method described in SAE Aerospace Recommended Practice, ARP 785. The weight is reported in milligrams in total sample.

(3) The measurements of (1) are repeated on the filtered fluid.

**NOTE:** This test is to be revised when more experience is gained at higher current values.

## E8. Life of Contacts in the Fluid under Pressure

Scope - This method determines the effect of fluid immersion on relay contacts subjected to high pressure.

Outline of Method - A relay is operated immersed in fluid under 6000 psi pressure to the point of failure of the electrical contacts.

Apparatus - In addition to the apparatus required for Method E7, the following will be required:

a. Cylindrical PTFE or polyethylene container capable of containing relay immersed in fluid.

b. Pressure vessel to pressurize fluid and relay to 6000 psi with electrical connections for relay operation under pressure.

c. Counter to record number of cycles to failure.

d. Power supply capable of 50 volts open circuit, 10 amperes closed circuit.

Procedure

a. The test device used is the same as that described under Method E7, a. The relay is mounted inside a test cell having a cylindrical thin PTFE or polyethylene wall. The volume of fluid used is not critical.

b. The test cell is pressurized to 6000 psi. Arcing is then carried out a rate of five to ten operations (makes and breaks) per minute, to the failure point. A primarily resistive load is used, with an open-circuit voltage of 50 volts and a closed-circuit current of 10 amperes. Failure normally occurs by a buildup of solid products between contact surfaces, preventing circuit interruption when contacts are in the open position.

c. Since contact life varies randomly over a wide range a minimum of ten tests is desirable and the spread as well as the average value are to be reported.

NOTE: This test is to be revised when more experience is gained at higher currents and higher pressures.

## CHAPTER III

## FLUID AND LUBRICANT PROPERTY VALUES, APPLICATIONS AND LIMITATIONS

This chapter provides available physical and chemical properties of fluids, suggested applications, and possible limitations of fluids for deep submergence vehicles. Where known, the estimated fluid cost is given. The tables have been prepared to provide for the addition of properties, when available, and of other fluids as they become known and applications warrant.

The possible limitations are given as a warning so that particular attention will be focused on any fluid property weakness. These limitations are based on general use of the fluid for all types of applications in a deep ocean environment.

Careful design and selection of system components may permit the use of a fluid or lubricant which would be unacceptable by the usual standards. This handbook does not consider the exceptions, but rather states the limitations as a warning. If a designer is compelled by circumstances to create an exception, these warnings should show where the design effort must be directed.

Tentative guidelines for suggested fluid uses and possible fluid limitations have been developed. They are based on the combination of application requirements, equipment developments, laboratory measurements of fluid properties, and field experience.

In systems with moving parts, the fluid depth capability is that at which pressure or temperature effects cause the viscosity to exceed 100 centistokes.

Fluid lubricating-ability criteria are based on: (1) wear-test and rolling-contact/fatigue-test performance, (2) known viscometric characteristics, and (3) known performance in operating equipment.

Corrosion protection is based on laboratory and field evidence of inertness of system ferrous and nonferrous metals, with and without sea-water contamination.

The limiting density for fluids in deep submergence vehicle applications where weight is critical is considered to be 1.0 gram per cubic centimeter.

The criteria for the fire resistance of fluids are based on the autoignition temperature of their vapors and combustion characteristics at high pressures. Fluids having ambient pressure flash points under 300° F are considered flammable.

Electrical application guidance for fluids is based on their tentative laboratory dielectric test limits given in Chapter II, on their ability to cope with intrinsic (carbon) and extrinsic (sea-water) contamination, and on their sea-water fluid emulsion stability. Critical fluid properties for each of the following uses are:

- Electric motors: initial dielectric properties, reaction to arcing (for d-c motors), heat transfer properties, emulsion stability, and compatibility with other materials.

- Switches, contactors, and circuit breakers: initial dielectric properties, heat transfer properties, reaction to arcing, and compatibility with other material.

- Stationary electrical components: initial dielectric properties, heat transfer properties, and compatibility with other materials.

Fluids for power transmission, such as hydraulic systems, must have satisfactory performance in all fluid and lubricant property categories, including dielectric properties. Fluids for mechanical elements, such as gear trains and hydraulic motors, must exhibit good lubricating properties and good corrosion inhibition while dielectric properties are less critical. Fluids for environmental protection of moving electrical components must have favcrable dielectric properties, afford good corrosion inhibition, and have favorable lubricating properties with and in the absence of sea-water contamination. Fluids for environmental protection of nonmoving electrical components in sealed cases must have favorable dielectric and corrosion inhibiting properties, but here the lubricating properties are less critical.

Representative federal specification products and representative military specification products are tabulated in numerical order. Proprietary products are coded and are listed in the order in which they were received for evaluation.

The fluids are listed in Table 1 (see page III-4) for ready reference in the order as noted above, along with common designation, base fluid composition, and a listing of possible uses with a general assessment of applicability to possible uses. The assessment of the fluid utility is based on its use for deep ocean applications. Even though a fluid may have been used successfully for aircraft, missile, or surface ship requirements, its satisfactory performance under deep ocean conditions is not assured. The symbols on the summary table are defined as follows:

- P - indicates that the fluid may be used in the listed application with normal design precautions and considerations.

- Q - indicates that the fluid has properties which make its use in the listed application questionable. It does not mean that the fluid cannot be used in the listed application. It does mean that if the fluid is used in such an application, special precautions and special design considerations must be observed. A fluid in this category may possibly be suited for short-term use only.

- K - indicates that the fluid has either been used or has been tried in the listed application.

- Blank (-) - indicates that there is insufficient available information to make any assessment of the utility of the fluid in the listed application.

In the case of a combined symbol, such as KP or KQ, the K indicates that the fluid has been tried for the use indicated, and the P or Q indicates that it is either possible or questionable, as defined above.

The listing of P after a product does not constitute endorsement for use, and the listing of Q does not constitute condemnation.

# Table 1
## Summary List of Fluids and Lubricants Tabulated

| Specification or Trade Name | Other Designation | Base Fluid Composition | Application: Power Transmission | Lubrication | Motor Immersion | Switching Component Immersion | Nonmoving Electrical Equipment Immersion |
|---|---|---|---|---|---|---|---|
| **Federal Specification Products** | | | | | | | |
| VV-I-530a | Transformer Oil | Petroleum | - | - | Q | KP | KP |
| VV-D-001078(10 cs) | Damping Fluid | Silicone | Q | Q | KQ | KQ | KP |
| VV-D-001078(50 cs) | Damping Fluid | Silicone | KQ | Q | Q | Q | Q |
| **Military Specification Products** | | | | | | | |
| MIL-H-5606B | Aircraft Hydraulic Fluid | Petroleum | KP | KP | KP | P | P |
| MIL-J-5624F | JP-5 | Petroleum | - | KQ | KQ | Q | Q |
| MIL-L-6081C, Grade 1010 | Jet Engine Lubricating Oil | Petroleum | KQ | KQ | KQ | KQ | Q |
| MIL-H-6083C | Aircraft Hydraulic System Preservative | Petroleum | K | KQ | KQ | KQ | KQ |
| MIL-L-6085A | Aircraft Instrument Oil | Synthetic | KQ | KQ | KQ | Q | Q |
| MIL-L-7808G | Gas Turbine Lubricating Oil | Synthetic | - | KQ | Q | Q | Q |
| MIL-L-7870A | - | Petroleum | - | K | Q | Q | Q |
| MIL-C-8188C | Gas Turbine Engine Preservative | Synthetic | KQ | KQ | Q | Q | Q |
| MIL-F-17111 | Ordnance Hydraulic Fluid | Petroleum | Q | P | - | - | P |
| MIL-L-17672, MS 2110-TH | Turbine Oil and Hydraulic Fluid | Petroleum | KQ | KQ | Q | Q | P |
| MIL-S-21568A | Damping Fluid | Silicone | Q | Q | KQ | KP | KP |
| MIL-L-23699A | Aircraft Turboprop and Turboshaft Lubricant | Synthetic | - | KQ | - | - | - |
| MIL-H-27601A | Aircraft High Temperature Hydraulic Fluid | Petroleum | - | - | - | - | - |
| MIL-H-46004 | Missile Hydraulic Fluid | Petroleum | KQ | - | - | - | - |
| MIL-H-81019B | Aircraft and Missile Hydraulic Fluid | Petroleum | P | Q | - | - | P |
| **Proprietary Fluids** | | | | | | | |
| Fluid Code A | Sea-water Emulsifying Fluid, Type I | Petroleum | KQ | KQ | Q | Q | Q |
| Fluid Code B | - | Petroleum | KP | KQ | Q | Q | Q |
| Fluid Code C | Proposed Specification MIL-H-25598 Missile Hydraulic Fluid | Petroleum | KP | KQ | Q | Q | Q |
| Fluid Code D | Traction Drive Fluid | Petroleum | - | - | - | - | - |
| Fluid Code E | - | Petroleum | - | KQ | KQ | - | P |
| Fluid Code F | - | Petroleum | P | P | - | - | P |
| Fluid Code G | - | Petroleum | P | P | - | - | P |
| Fluid Code H | - | Petroleum | P | P | - | - | - |
| Fluid Code J | USP Mineral Oil | Petroleum | - | Q | KQ | KQ | KP |
| Fluid Code K | NF Mineral Oil | Petroleum | - | Q | - | - | - |
| Fluid Code L | Lubricity Improved Silicone | Silicone | Q | Q | KQ | KP | KP |
| Fluid Code M | - | Petroleum | - | P | Q | Q | Q |
| Fluid Code N | Sea-water Compatible Water Glycol | Water | - | Q | Q | Q | Q |

P - Possible use
K - Known or attempted use
Q - Questionable for use in this application
- (blank) - Insufficient information available for assessment of use

## FEDERAL SPECIFICATION PRODUCTS

## Suggested Uses and Possible Limitations

The oil covered by Federal Specification VV-I-530a is a petroleum-based fluid intended to serve as an insulating and cooling medium for transformers, oil switches, and circuit breakers at atmospheric pressure. The VV-I-530a fluid also can be used as an immersion medium for equipment to a depth capability of 8000 feet. The fluid lacks adequate inhibition to prevent sea-water corrosion of ferrous and nonferrous system components. Its relative lubricating ability has not yet been established. Its poor sea-water emulsion stability makes it unacceptable for use in electric motors. Good dielectric properties and intermediate viscosity make it a moderately good choice for all other electrical applications.

Properties of VV-I-530a(1)
(Petroleum Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 50° F | 100° F | 150° F | | |
| 0 psig | 57.00 | 9.65 | 4.86 | | |
| 3,000 psig | 99.96 | 16.78 | 6.44 | | See NSRDL |
| 5,000 psig | 154.9 | 20.47 | 8.05 | | Annapolis Report |
| 8,000 psig | 259.9 | 30.57 | 11.54 | | MATLAB 5[illegible] |
| 10,000 psig | 370.1 | 39.21 | 15.35 | | - |
| 15,000 psig | 912.0 | 76.67 | 21.62 | | |
| 20,000 psig | 1016 | 141.5 | 36.21 | | - |
| Viscosity, centistokes, at 210° F, 0 psig | | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.822 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method [illegible] (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| Rolling Contact Fatigue Test | | | | | MIL-H-19457 |
| Life to 10% Failure | | | | | |
| Life to 50% Failure | | | | | |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter [illegible] Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter [illegible] Test C-1 |
| Copper | -54.5 | | | | - |
| Stainless Steel, 316 | +3.2 | | | | - |
| Copper-Nickel (70-30) | +2.1 | | | | - |
| Aluminum, QQ-A-250-4b | -124.2 | | | | - |
| Phosphor-Bronze | -61.3 | | | | - |
| Steel, galvanized | -46.9 | | | | - |
| Steel, 1009 | -547.5 | | | | - |
| Aluminum, QQ-A-250-11 | +4.3(2) | | | | - |
| Bronze | -11.8 | | | | - |
| Monel | +3.1 | | | | - |
| Silver Base Brazing Alloy | -14.3 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter [illegible] Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2, Test E-1 |
| Resistivity, 78° F, ohm-cm: | | | | | |
| As-Received | $5.2 \times 10^{13}$ | | | | |
| With Sea-Water Contamination:(3) | $15.0 \times 10^{13}$ | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | |
|---|---|---|---|---|---|
| [illegible] (Cont) | | | | | [illegible] |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | $3.4 \times 10^{15}$ | | | | - |
| Filtered | $14.0 \times 10^{14}$ | | | | - |
| Solids generated, gram | [illegible] | | | | - |
| Dissipation Factor, 73° F, [illegible] | | | | | See Chapter 2 Test E-2 |
| As-Received | 2.0 | | | | |
| With Sea-Water Contamination:(3) | | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | 2.5 | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 1.0 | | | | - |
| Filtered | 0.6 | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 73° F, kv | | | | | ASTM D-877 (modified). See Chapter 2, Test E-3 |
| As-Received | 25.0 | | | | |
| With Sea-Water Contamination:(3) | 8.9 | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 10.1 | | | | - |
| Filtered | 22.4 | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | 4 | | | | - |
| Operations to failure (range) | 4-300 | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | 0.2 | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Fair | | | | - |

* Based on atmospheric pressure data.

| Property | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 0.7947 | 0.8700 | 0.8511 | | See NSRDL Annapolis Report MATLAB [illegible] |
| 3,000 psig | 0.9037 | 0.8804 | 0.8636 | | |
| 5,000 psig | 0.9093 | 0.8868 | 0.8711 | | |
| 8,000 psig | 0.9169 | 0.8952 | 0.8812 | | |
| 10,000 psig | 0.9216 | 0.9006 | 0.8871 | | |
| 15,000 psig | 0.9325 | 0.9122 | 0.8996 | | |
| 20,000 psig | 0.9421 | 0.9174 | 0.9105 | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 90° F | 150° F | | See NSRDL Annapolis Report MATLAB [illegible] |
| 0 psig | | | | | |
| 3,000 psig | 1.00 | 1.12 | 1.45 | | |
| 5,000 psig | 1.61 | 1.84 | 2.30 | | |
| 8,000 psig | 2.42 | 2.73 | 3.41 | | |
| 10,000 psig | 2.92 | 3.29 | 4.06 | | |
| 15,000 psig | 4.03 | 4.50 | 5.38 | | |
| 20,000 psig | 5.03 | 5.23 | 6.50 | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 325 | | | | ASTM D-92 |
| Fire Point, °F | 345 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 51/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-40 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | <10 | | | | - |
| Time out, minutes | 0 | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | 0.01 | | | | ASTM D-974 |
| Water Content, % by weight | 0.007 | | | | ASTM D-1744 |
| Neutrality, qualitative | Neutral | | | | Fed. Method [illegible] |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Color | | | | | ASTM D-1500 |
| Cost, $/gal | $.70 | | | | - |
| Availability | Govt spec | | | | - |

[1]Determinations made at atmospheric pressure, unless noted. [2]Heavy deposits indicate corrosion not shown by weight change. [3]Saturated with seawater.

Supplementary Properties of VV-I-530a

| | | Method |
|---|---|---|
| **Material Compatibility with:*** | | See Chapter 2 Test C-3 |
| Buna S | Poor | |
| Natural Rubber | Poor | |
| Polyurethane | Good | |
| **Miscellaneous Properties** | | |
| Specific Gravity at 60/60° F | 0.88 | ASTM D-1298 |

* Based on atmospheric pressure data.

## VV-D-001078 (10 CS)

### Suggested Uses and Possible Limitations

The fluid covered by Federal Specification VV-D-001078 is a dimethyl polysiloxane developed for use as a damping fluid and is available in viscosities from 0.65 to 200,000 centistokes. The VV-D-001078, 10-cs fluid can be used as an immersion medium for nonmoving equipment and has a depth capability of 16,000 feet. It has poor sea-water corrosion inhibition capability. Its high compressibility must be considered in system design. The poor lubricating ability (particularly with steel-on-steel components) of silicone fluids limits its application to nonmoving components. Although this fluid has been used in deep submergence electrical applications, it is considered a questionable choice for electrical usage because of borderline dielectric breakdown voltage.

Properties of VV-D-001078 (10 cS)[1]
(Silicone Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 35° F | 100° F | 140° F | | |
| 0 psig | 17.86 | 8.66 | 4.75 | | |
| [illegible],000 psig | 25.67 | 12.37 | 8.30 | | See NSRDL |
| 5,000 psig | 31.98 | 14.99 | 10.11 | | Annapolis Report |
| 8,000 psig | 44.45 | 20.16 | 12.63 | | MATLAB 550 |
| 10,000 psig | 49.44 | 23.82 | 15.00 | | - |
| 15,000 psig | 78.64 | 35.52 | 21.90 | | - |
| 20,000 psig | 123.5 | 51.12 | 30.55 | | - |
| Viscosity, centistokes, at 210° F, 0 psig | 3.76 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.430 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6504 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -1.7 | | | | - |
| Stainless Steel, 316 | +7.7 | | | | - |
| Copper-Nickel (70-30) | +14.2 | | | | - |
| Aluminum, QQ-A-250-4b | -198.9 | | | | - |
| Phosphor-Bronze | -63.4 | | | | - |
| Steel, galvanized | -97.6 | | | | - |
| Steel, 1009 | -1009.8 | | | | - |
| Aluminum, QQ-A-250-11 | +210.9 | | | | - |
| Bronze | -1.4 | | | | - |
| Monel | +11.3 | | | | - |
| Silver Base Brazing Alloy | +19.2 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm² | | | — | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 80° F, ohm-cm: | | | | | |
| As-Received | $3.6 \times 10^{14}$ | | | | |
| With Sea-Water Contamination:(2) | $8.6 \times 10^{13}$ | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 80° F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 0.0 | | | | |
| With Sea-Water Contamination:(2) | 0.7 | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 80° F, kv | | | | | ASTM D-877 (modified). See Chapter 2, Test E-3 |
| As received | 14.8 | | | | |
| With sea-water contamination:(2) | 5.8 | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | - Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 90 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | 0 | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor-Fair | | | | |
| Buna N | Fair | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | - | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | Good | | | | - |
| Silicone | Poor | | | | - |
| Fluorosilicone | Poor | | | | - |

* Based on atmospheric pressure data.

| Volatility / Toxicity | Silicone | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 0.9572 | 0.9238 | 0.8973 | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | 0.9788 | 0.9514 | 0.9315 | | |
| 5,000 psig | 0.9924 | 0.9663 | 0.9484 | | |
| 8,000 psig | 1.0095 | 0.9859 | 0.9708 | | |
| 10,000 psig | 1.0062 | 0.9976 | 0.9831 | | |
| 15,000 psig | 1.0892 | 1.0206 | 1.0092 | | |
| 20,000 psig | 1.1093 | 1.0404 | 1.0314 | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 90° F | 150° F | | See NSRDL Annapolis Report MATLAB 350 |
| 0 psig | | | | | |
| 3,000 psig | 1.88 | 2.11 | 2.62 | | |
| 5,000 psig | 2.97 | 3.38 | 4.02 | | |
| 8,000 psig | 4.40 | 4.95 | 5.72 | | |
| 10,000 psig | 5.21 | 5.82 | 6.75 | | |
| 15,000 psig | 5.98 | 7.66 | 8.74 | | |
| 20,000 psig | 8.49 | 9.22 | 10.51 | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 355 | | | | ASTM D-92 |
| Fire Point, °F | 415 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-65 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | 0 | | | | - |
| Time out, minutes | - | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | 0.010 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Color | | | | | ASTM D-1500 |
| Cost, $/gal | $20.00 | | | | - |
| Availability | Govt spec | | | | - |

[1]Determinations made at atmospheric pressure, unless noted. [2]Saturated with seawater.

Supplementary Properties of VV-D-001078 (10 cs)

| | | Method |
|---|---|---|
| **Material Compatibility with:*** | | See Chapter 2 Test C-3 |
| Buna S | Poor | |
| Polyurethane | Fair | |
| **Miscellaneous Properties** | | |
| Specific Gravity at 60/60° F | 0.941 | |

* Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by Federal Specification VV-D-001078 in the 50-cs viscosity has been used in the missile hold-down system in submarines. The VV-D-001078, 50-cs silicone fluid can be used as an immersion medium for equipment to a depth capability of 1000 feet. The fluid lacks adequate sea-water corrosion inhibition. Its high compressibility must be considered in system design. The poor lubricating ability (particularly with steel-on-steel components) limits its use. Due to a low dielectric breakdown voltage and poor sea-water emulsion stability and relatively high viscosity, this fluid is not recommended for any electrical applications.

Properties of VV-D-001078 (50 CS)
(Silicone Fluid)

| | 77° F | 100° F | [illegible] F | | Method |
|---|---|---|---|---|---|
| Viscometric Properties | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| [illegible],000 psig | | | | | See NSRDC |
| [illegible],000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 550 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 77° F, 0 psig | 50 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | | | | | - |
| Lubricating Ability | | | | | |
| 4-Ball Wear Test, 30 min, 40° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| Corrosion Protection | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel. 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| **Corrosion Protection (Cont)** | | | | | |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, $mg/cm^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| **Dielectric Properties** | | | | | ASTM D-1169 (modified). See Chapter 2, Test E-1 |
| Resistivity, 77° F, ohm-cm: | | | | | |
| As-Received | $7.8 \times 10^{13}$ | | | | |
| With Sea-Water Contamination:(2) | $14.4 \times 10^{13}$ | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| **Dielectric Properties (Cont)** | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 77° F, % | | | | | See Chapter 2 |
| As-Received | 0.0 | | | | Test E-2 |
| With Sea-Water Contamination:(2) | 0.9 | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 77° F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 6.3 | | | | |
| With sea-water contamination:(2) | 6.1 | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 90 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| **Emulsion Stability** | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | 3 | | | | See Chapter 2 Test E-4 |
| **Material Compatibility** Static 20KPSI* | | | | | See Chapter 2 |
| Butyl | Poor-Fair | | | | Test C-3 |
| Buna N | Fair | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | - | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | Good | | | | - |
| Silicone | Poor | | | | - |
| Fluorosilicone | Poor | | | | - |

* Based on atmospheric pressure data.

| | Silicone | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL |
| 3,000 psig | | | | | Annapolis Report |
| 5,000 psig | | | | | MATLAB 450 |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume | 35° F | 100° F | 150° F | | |
| decrease, %, at: | | | | | See NSRDL |
| 0 psig | | | | | Annapolis Report |
| 3,000 psig | | | | | MATLAB 550 |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specifi- |
| Specimen change, mg | | | | | cation MIL-H- |
| Specimen appearance | | | | | 19457B |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | >535 | | | | ASTM D-92 |
| Fire Point, °F | | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report |
| Minimum spontaneous ignition temperature, °F | | | | | 31/66 of March 1967 |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-65 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Color | | | | | ASTM D-1500 |
| Cost, $/gal | $15.00 | | | | - |
| Availability | Govt spec | | | | - |

[1]Determinations made at atmospheric pressure, unless noted. [2]Saturated with seawater.

Supplementary Properties of VV-D-001078 (50 cs)

| | | Method |
|---|---|---|
| Material Compatibility with:* | | See Chapter II Test C-5 |
| Buna S | Poor | |
| Polyurethane | Fair | |
| Miscellaneous Properties | | |
| Specific Gravity, 60/60° F | 0.961 | ASTM D-1298 |

* Based on atmospheric pressure data.

MILITARY SPECIFICATION PRODUCTS

## Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-H-5606B is a petroleum-base, low-viscosity fluid which has been used extensively in aircraft and missile hydraulic systems. The properties of MIL-H-5606B indicate that it is suitable for use as hydraulic fluid, as a motor immersion fluid, as a general lubricant, and for environmental protection of electrical equipment at depth capability of 20,000 feet. Its limitations are lack of corrosion protection, poor sea-water compatibility, and its high flammability. There are reported field application failures due to formation of large carbon deposits under pressure in electric arcing conditions; however, this problem is common to all hydrocarbon fluids. (See Chapter I.) Its combination of good sea-water emulsion stability, good dielectric properties, and intermediate viscosity makes this fluid the best choice known to date for electric motor usage and a moderately good choice for all other electrical applications.

Properties of MIL-H-5606B(1)
(Petroleum Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| Viscometric Properties | | | | | |
| Viscosity, high shear, cs, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 29.85 | 12.26 | 7.21 | | |
| 3,000 psig | 43.44 | 16.31 | 9.74 | | See NSRDL |
| 5,000 psig | 52.89 | 19.21 | 11.39 | | Annapolis Report |
| 8,000 psig | 76.16 | 24.90 | 14.24 | | MATLAB 550 |
| 10,000 psig | 92.62 | 29.32 | 16.07 | | - |
| 15,000 psig | 152.8 | 42.90 | 22.88 | | - |
| 20,000 psig | 264.4 | 62.55 | 31.65 | | - |
| Viscosity, low shear, cs, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 40.50 | 13.80 | 8.60 | | |
| 3,000 psig | 60.55 | 18.39 | 11.53 | | |
| 5,000 psig | 86.66 | 21.87 | 14.01 | | |
| 8,000 psig | 113.4 | 32.33 | 18.82 | | |
| 10,000 psig | 147.1 | 39.78 | 23.53 | | |
| 15,000 psig | 270.5 | 58.41 | 35.07 | | |
| 20,000 psig | 504.8 | 92.59 | 52.38 | | |
| Viscosity, centistokes, at 210° F, 0 psig | 5.16 | - | - | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.457 | - | - | | - |
| Lubricating Ability | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: 1 kg | | | | | Fed. Method 6503 (modified) |
| 3 kg | | | | | - |
| 5 kg | 0.19 | - | - | | - |
| Rolling Contact Fatigue Test, hr: | | | | | - |
| B10 life: Dry | 34.9 | | | | |
| With 1% synthetic seawater | 12.7 | | | | |
| B50 life: Dry | 94.3 | | | | |
| With 1% synthetic seawater | 35.8(4) | | | | |
| Corrosion Protection | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | - | | | | See Chapter 2 Test C-1 |
| Copper | -4.1 | | | | - |
| Stainless Steel, 316 | +0.1 | | | | - |
| Copper-Nickel (70-30) | +0.1 | | | | - |
| Aluminum, QQ-A-250-4b | +0.7 | | | | - |
| Phosphor-Bronze | +0.2(2) | | | | - |
| Steel, galvanized | -116.5 | | | | - |
| Steel, 1009 | -110.8 | | | | - |
| Aluminum, QQ-A-250-11 | +0.6 | | | | - |
| Bronze | +2.1 | | | | - |
| Monel | +0.2 | | | | - |
| Silver Base Brazing Alloy | -0.7 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | - | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | -0.2 | | | | - |
| Stainless Steel, 316 | +0.1 | | | | - |
| Copper-Nickel (70-30) | +0.1 | | | | - |
| Aluminum, QQ-A-250-4b | 0 | | | | - |
| Phosphor-Bronze | -0.2 | | | | - |
| Steel, galvanized | +0.3 | | | | - |
| Steel, 1009 | +0.1 | | | | - |
| Aluminum, QQ-A-250-11 | +0.1 | | | | - |
| Bronze | 0 | | | | - |
| Monel | 0 | | | | - |
| Silver Base Brazing Alloy | 0 | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | +0.2 | -0.1 | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | +0.2 | 0 | | | - |
| Monel-Bronze | +0.1 | +0.2 | | | - |
| Stainless Steel (316) - Phosphor-Bronze | +0.2 | 0 | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | 0 | +0.2 | | | - |
| Aluminum QQ-A-250-11 - Bronze | +0.1 | +0.2 | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | +0.2 | +0.1 | | | - |
| 10,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | -2.6 | | | | - |
| Stainless Steel, 316 | 0 | | | | - |
| Copper-Nickel (70-30) | 0 | | | | - |
| Aluminum, QQ-A-250-4b | -1.9 | | | | - |
| Phosphor-Bronze | -2.1 | | | | - |
| Steel, galvanized | -0.1 | | | | - |
| Steel, 1009 | -18.8 | | | | - |
| Aluminum, QQ-A-250-11 | -0.1 | | | | - |
| Bronze | -2.5 | | | | - |
| Monel | 0 | | | | |
| Silver Base Brazing Alloy | -0.4 | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | -2.0 | +0.1 | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | +0.2 | 0 | | | - |
| Monel-Bronze | +0.2 | -2.6 | | | - |
| Stainless Steel (316) - Phosphor-Bronze | +0.1 | -3.1 | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | -0.3 | -11.1 | | | - |
| Aluminum, QQ-A-250-11 - Bronze | +0.2 | -2.7 | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | -0.6 | -15.4 | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | 15 | | | | |
| Bronze Bushings | 9 | | | | |
| Corrosion Coupons, weight loss, each, mg/cm² | | | | | |
| Copper | 0.01 | | | | - |
| Aluminum | 0.04 | | | | - |
| Steel, galvanized | 0.01 | | | | - |
| Steel, 1009 | 0.03 | | | | - |
| Silver Base Brazing Alloy | 0.02 | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2, Test E-1 |
| Resistivity, 77° F, ohm-cm: | | | | | |
| As-Received | 3.0x10¹² | | | | |
| With Sea-Water Contamination:(3) | 4.6x10¹² | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.1% wt vol. | | | | | |
| 0.25% wt vol. | | | | | - |
| 0.5% wt vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | $8.0x10^{11}$ | | | | - |
| Filtered | $8.6x10^{11}$ | | | | - |
| Solids generated, gram | 0.81 | | | | - |
| Dissipation Factor, 77° F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 2.0 | | | | |
| With Sea-Water Contamination:(3) | 2.1 | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | - |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 0.8 | | | | - |
| Filtered | 0.5 | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 77° F, kv | | | | | ASTM D-877 (modified). See Chapter 2 . Test E-3 |
| As received | 23.8 | | | | |
| With sea-water contamination:(3) | 7.2 | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 10.8 | | | | - |
| Filtered | 15.8 | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 33 | | | | - |
| Emulsion, ml | 30 | | | | - |
| Water, ml | 14 | | | | - |
| Electric Probe Test, time for water separation, min | 10 | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Fair-Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | - | | | | - |
| Silicone | Poor | | | | - |
| Fluorosilicone | Poor | | | | - |

* Based on atmospheric pressure data.

| | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 0.8659 | 0.8401 | 0.8202 | | See NSRDL |
| 3,000 psig | 0.8756 | 0.8516 | 0.8335 | | Annapolis Report |
| 5,000 psig | 0.8818 | 0.8585 | 0.8414 | | MATLAB 350 |
| 8,000 psig | 0.8905 | 0.8679 | 0.8515 | | |
| 10,000 psig | 0.8957 | 0.8739 | 0.8580 | | |
| 15,000 psig | 0.9076 | 0.8867 | 0.8720 | | |
| 20,000 psig | 0.9189 | 0.8981 | 0.8839 | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 90° F | 150° F | | See NSRDL |
| 0 psig | | | | | Annapolis Report |
| 3,000 psig | 1.12 | 1.29 | 1.60 | | MATLAB 350 |
| 5,000 psig | 1.81 | 2.07 | 2.52 | | |
| 8,000 psig | 2.76 | 3.12 | 3.66 | | |
| 10,000 psig | 3.33 | 3.75 | 4.40 | | |
| 15,000 psig | 4.60 | 5.12 | 5.94 | | |
| 20,000 psig | 5.77 | 6.32 | 7.21 | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 215 | | | | ASTM D-92 |
| Fire Point, °F | 250 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-75 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | 55 | | | | - |
| Time out, minutes | 1 | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | 0.18 | | | | ASTM D-974 |
| Water Content, % by weight | 0.011 | | | | ASTM D-1744 |
| Neutrality, qualitative | - | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Color | | | | | ASTM D-1500 |
| Cost, $/gal | $2.60 | | | | - |
| Availability | Govt spec | | | | - |

[1]Determinations made at atmospheric pressure, unless noted. [2]Heavy deposits indicate corrosion not shown by weight change. [3]Saturated with seawater. [4]Some rust observed in system.

Supplementary Properties of MIL-H-5606B

| | | Method |
|---|---|---|
| **Material Compatibility with:*** | | See Chapter II Test C-3 |
| Natural Rubber | Poor | |
| Buna S | Poor | |
| **Miscellaneous Properties** | | |
| Specific Gravity | 0.86 | ASTM D-1298 |

* Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-J-5624F is petroleum-base jet engine fuel. The JP-5 grade of the fluid has been suggested for deep ocean applications because of its low viscosity. The few relevant values known for MIL-J-5624F (JP-5) indicate it to be of questionable value for any electrical applications because of low dielectric breakdown voltage. Studies of diesel fuel as a lubricant lead to the prediction that JP-5 would have poor lubricating ability. It lacks corrosion inhibiting properties and is also highly flammable.

Properties of MIL-J-5624F, JP-5[1]
(Petroleum Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 350 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at -30° F, 0 psig | 16.5 max | | | | ASTM D-445 |
| Viscosity Slope, ASTM | | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| **Corrosion Protection (Cont)** | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, $mg/cm^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | |
| Resistivity, 72° F, ohm-cm: | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| As-Received | $4.0 \times 10^{1}$ | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | - |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | - |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 72° F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 1.3 | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 72° F, kv | | | | | ASTM D-877 (modified). See Chapter 2, Test E-3 |
| As received | 13.1 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 90 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | | | | | - |
| Emulsion, ml | | | | | - |
| Water, ml | | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 Test C-3 |
| Butyl | | | | | |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 140 min | | | | ASTM D-92 |
| Fire Point, °F | | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NEL Report 51/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific Gravity, 60/60° F | 0.79-0.85 | | | | |
| Color | | | | | ASTM D-1500 |
| Cost, $/gal | available from supplier | | | | - |
| Availability | Govt spec | | | | - |

## MIL-L-6081C, Grade 1010

### Suggested Uses and Possible Limitations

The fluid covered by MIL-L-6081C is a low-viscosity, petroleum-base fluid originally developed as a jet engine lubricating oil. The data given here were collected on the 1010 grade. The lubricating, electrical, and chemical properties of MIL-L-6081C indicate that it may be used as a general purpose fluid for depths down to 8000 feet. All of its properties deteriorate rapidly when it becomes contaminated with seawater. Its corrosion inhibiting properties are so poor that ball bearings in moving machinery rusted in MIL-L-6081C contaminated with seawater. Its flammability properties are marginal. While its initial dielectric properties are good, it shows a rapid drop in dielectric breakdown voltage with sea-water contamination. This makes it a questionable choice for any electrical application.

Properties of MIL-L-6081C(1)
(Petroleum Base Fluid)

| | 35° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | 53.73 | 10.08 | 5.85 | | |
| 3,000 psig | 93.56 | 15.43 | 6.50 | | See NSRDI |
| 5,000 psig | 139.7 | 19.77 | 7.81 | | Annapolis Report |
| 8,000 psig | 228.5 | 28.98 | 11.15 | | MATLAB 55[illegible] |
| 10,000 psig | 323.6 | 37.37 | 13.35 | | - |
| 15,000 psig | 778.6 | 69.84 | 21.98 | | - |
| 20,000 psig | 1834 | 129.9 | 36.23 | | - |
| Viscosity, centistokes, at 210° F, 0 psig | 2.51 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.833 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | |
| 3 kg | | | | | - |
| 5 kg | 0.43 | | | | - |
| 15 kg | 0.70 | | | | - |
| Rolling Contact Fatigue Test, hr: | | | | | |
| B10 life: Dry | 33.5 | | | | |
| With 1% synthetic seawater | 15.3 | | | | |
| B50 life: Dry | 135.4 | | | | |
| With 1% synthetic seawater(4) | 28.7 | | | | |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -42.6 | | | | - |
| Stainless Steel, 316 | + 1.0 | | | | - |
| Copper-Nickel (70-30) | - 0.1 | | | | - |
| Aluminum, QQ-A-250-4b | +185.2(2) | | | | - |
| Phosphor-Bronze | -54.2 | | | | - |
| Steel, galvanized | -661.4 | | | | - |
| Steel, 1009 | -74.7 | | | | - |
| Aluminum, QQ-A-250-11 | -60.5 | | | | - |
| Bronze | -34.2 | | | | - |
| Monel | + 0.4 | | | | - |
| Silver Base Brazing Alloy | -5.4(2) | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1009 | | | | | |
| Aluminum QQ-A-250-11 - | | | | | - |
| Bronze | | | | | |
| Aluminum QQ-A-250-4b - | | | | | - |
| Steel, 1009 | | | | | |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1009 | | | | | |
| Aluminum, QQ-A-250-11 - | | | | | |
| Bronze | | | | | |
| Aluminum, QQ-A-250-4b - | | | | | - |
| Steel, 1009 | | | | | |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | 298 | | | | |
| Bronze Bushing | 31 | | | | |
| Corrosion Coupons, weight loss, each, $mg/cm^2$ | | | | | |
| Copper | 0 | | | | - |
| Aluminum | 0 | | | | - |
| Steel, galvanized | 3.2 | | | | - |
| Steel, 1009 | 1.4 | | | | - |
| Silver Base Brazing Alloy | 0.02 | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter [illegible], Test E-1 |
| Resistivity, 78° F, ohm-cm: | | | | | |
| As-Received (3) | $6.4\times10^{12}$ | | | | |
| With Sea-Water Contamination: | [illegible].7x$10^{12}$ | | | | See Chapter 2 Test E-5 |
| [illegible]% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| **Dielectric Properties (Cont)** | | | | | |
| After 50,000 Electric Arcs | | | | | See Chapter 2 |
| (makes and breaks) at 90 | | | | | Test E-7 |
| volts, 10 amperes, resis- | | | | | |
| tive load | | | | | |
| Not filtered | $2.0\times10^{12}$ | | | | - |
| Filtered | $1.9\times10^{12}$ | | | | - |
| Solids generated, gram | 0.70 | | | | - |
| Dissipation Factor, 78° F, % | | | | | See Chapter 2 |
| As-Received | 1.0 | | | | Test E-2 |
| With Sea-Water Contamination:(3) | 3.7 | | | | See Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs | | | | | |
| (makes and breaks) at 90 | | | | | |
| volts, 10 amperes, resis- | | | | | |
| tive load | | | | | |
| Not filtered | 0.3 | | | | - |
| Filtered | 1.0 | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, | | | | | ASTM D-877 (mod- |
| 0.05-inch gap, 78° F, kv | | | | | ified). See Chap- |
| As received | 20.5 | | | | ter 2, Test E-5 |
| With sea-water contamination:(3) | <5.0 | | | | See Chapter 2 |
| | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs | | | | | |
| (makes and breaks) at 90 | | | | | |
| volts, 10 amperes, resis- | | | | | |
| tive load | | | | | |
| Not filtered | 17.6 | | | | - |
| Filtered | 22.8 | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 | | | | | See Chapter 2 |
| volts, 10 amperes, resistive | | | | | Test E-8 |
| load, 6000 psi, 65°-85° F | | | | | |
| Number of tests | | | | | - |
| Operations to failure ([illegible]) | | | | | |
| **Emulsion Stability** | | | | | |
| Paddle Test, after 1-hour set- | | | | | ASTM D-1401 |
| tling: | | | | | |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for | 1.5 | | | | See Chapter 2 |
| water separation, min | | | | | Test E-4 |
| **Material Compatibility** Static 20KPSI* | | | | | See Chapter 2 |
| Butyl | Poor | | | | Test C-3 |
| Buna N | Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Fair | | | | - |

*Based on atmospheric pressure data.

| Property | Petroleum | | | | Method |
| --- | --- | --- | --- | --- | --- |
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 0.8812 | 0.8567 | 0.8380 | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | 0.8905 | 0.8671 | 0.8501 | | |
| 5,000 psig | 0.8959 | 0.8740 | 0.8576 | | |
| 8,000 psig | 0.9041 | 0.8831 | 0.8677 | | |
| 10,000 psig | 0.9092 | 0.8884 | 0.8738 | | |
| 15,000 psig | 0.9200 | 0.9003 | 0.8871 | | |
| 20,000 psig | 0.9304 | 0.9112 | 0.8992 | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 90° F | 150° F | | See NSRDL Annapolis Report MATLAB 350 |
| 0 psig | | | | | |
| 3,000 psig | 1.04 | 1.18 | 1.42 | | |
| 5,000 psig | 1.64 | 1.91 | 2.29 | | |
| 8,000 psig | 2.54 | 2.91 | 3.42 | | |
| 10,000 psig | 3.08 | 3.48 | 4.10 | | |
| 15,000 psig | 4.22 | 4.73 | 5.53 | | |
| 20,000 psig | 5.29 | 5.86 | 6.80 | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | - |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 305 | | | | ASTM D-92 |
| Fire Point, °F | 335 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | - |
| Minimum reaction temperature, °F | | | | | |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-70 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | 45 | | | | - |
| Time out, minutes | 1 | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | 0.05 | | | | ASTM D-974 |
| Water Content, % by weight | 0.004 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60° F | 0.89 | | | | ASTM-D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | $0.75 | | | | - |
| Availability | Gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted. [3]Saturated with seawater.
[2]Heavy deposits: indicates corrosion not sho[illegible] by weight change. [4]Races and balls severely rusted. Entire oil circulating system clogged with [illegible]st.

Supplementary Properties of MIL-L-6081C(1)
(Petroleum Base Fluid)

| | | Method |
|---|---|---|
| Material Compatibility with* | | See Chapter II Test C-3 |
| Buna S | Poor | |
| Natural Rubber | Poor | |
| Polyurethane | Good | |

*Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-H-6083C is a low-viscosity, petroleum-base fluid which was developed as an aircraft and missile hydraulic system preservative. It has the same viscometric properties as MIL-H-5606B fluids, but was not intended as a working system fluid and lubricant. The properties of MIL-H-6083C indicate that it can be used for all mechanical purposes at depths to 20,000 feet with good corrosion protection and sea-water emulsifying abilities. Its lubricating ability is marginal and it is highly flammable. Low electrical resistivity and high dissipation factor make it a questionable choice for any electrical application.

Properties of MIL-H-6083C[1]
(Petroleum Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, high shear, cs, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 30.25 | 11.78 | 7.27 | | |
| 3,000 psig | 43.35 | 15.66 | 9.24 | | See NSRDL |
| 5,000 psig | 55.28 | 18.64 | 10.75 | | Annapolis Report |
| 8,000 psig | 77.65 | 24.30 | 13.45 | | MATLAB 350 |
| 10,000 psig | 101.6 | 28.59 | 14.02 | | - |
| 15,000 psig | 173.9 | 42.57 | 21.99 | | - |
| 20,000 psig | 311.7 | 63.64 | 30.30 | | - |
| Viscosity, low shear, cs, at: | 35° F | 100° F | 210° F | | |
| 0 psig | 49.00 | 15.80 | 9.40 | | |
| 3,000 psig | 74.17 | 21.42 | 11.92 | | |
| 5,000 psig | 92.71 | 26.05 | 14.62 | | |
| 8,000 psig | 136.8 | 33.94 | 18.92 | | |
| 10,000 psig | 175.3 | 39.51 | 22.13 | | |
| 15,000 psig | 325.6 | 61.13 | 33.53 | | |
| 20,000 psig | 591.2 | 93.77 | 48.27 | | |
| Viscosity, centistokes, at 210° F, 0 psig | 4.39 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.484 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: 1 kg | 0.12 | | | | Fed. Method 6503 (modified) |
| 3 kg | 0.15 | | | | - |
| 5 kg | 0.16 | | | | - |
| Rolling Contact Fatigue Test, hr: | | | | | - |
| B10 life: Dry | 20.0 | | | | |
| With 1% synthetic seawater | 14.5 | | | | |
| B50 life: Dry | 50.6 | | | | |
| With 1% synthetic seawater[3] | 22.0 | | | | |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Pass | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -20.5 | | | | - |
| Stainless Steel, 316 | - 0.1 | | | | - |
| Copper-Nickel (70-30) | - 4.6 | | | | - |
| Aluminum, QQ-A-250-4b | - 1.1 | | | | - |
| Phosphor-Bronze | -15.4 | | | | - |
| Steel, galvanized | -11.4 | | | | - |
| Steel, 1009 | + 0.3 | | | | - |
| Aluminum, QQ-A-250-11 | + 0.3 | | | | - |
| Bronze | - 8.4 | | | | - |
| Monel | 0 | | | | - |
| Silver Base Brazing Alloy | - 7.1 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | - 6.8 | | | | - |
| Stainless Steel, 316 | 0 | | | | - |
| Copper-Nickel (70-30) | - 0.4 | | | | - |
| Aluminum, QQ-A-250-4b | - 0.1 | | | | - |
| Phosphor-Bronze | - 0.8 | | | | - |
| Steel, galvanized | - 0.1 | | | | - |
| Steel, 1009 | - 0.2 | | | | - |
| Aluminum, QQ-A-250-11 | - 0.1 | | | | - |
| Bronze | - 1.0 | | | | - |
| Monel | - 0.2 | | | | - |
| Silver Base Brazing Alloy | - 0.3 | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | - 0.8 | -0.1 | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | - 0.2 | -0.5 | | | - |
| Monel-Bronze | - 0.2 | -0.5 | | | - |
| Stainless Steel (316) - Phosphor-Bronze | 0 | -0.6 | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | - 0.3 | -0.1 | | | - |
| Aluminum QQ-A-250-11 - Bronze | - 0.1 | -0.8 | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | - 0.1 | 0 | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | (10% seawater) | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | - 0.1 | | | | - |
| Stainless Steel, 316 | - 0.2 | | | | - |
| Copper-Nickel (70-30) | - 0.3 | | | | - |
| Aluminum, QQ-A-250-4b | + 0.1 | | | | - |
| Phosphor-Bronze | - 0.6 | | | | - |
| Steel, galvanized | - 0.7 | | | | - |
| Steel, 1009 | - 0.6 | | | | - |
| Aluminum, QQ-A-250-11 | - 0.7 | | | | - |
| Bronze | - 0.4 | | | | - |
| Monel | - 0.6 | | | | - |
| Silver Base Brazing Alloy | - 0.6 | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | -0.4 -0.1 | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | -0.2 -0.3 | | | | - |
| Monel-Bronze | +0.2 0 | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | -0.2 -0.3 | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | +0.1 -0.1 | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | +0.2 +0.9 | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | +0.2 +0.8 | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | 3 | | | | |
| Bronze Bushings | 3 | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2, Test E-1 |
| Resistivity, 74° F, ohm-cm: | | | | | |
| As-Received | $4.0\times10^{10}$ | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | - |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | - |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | |

| | | | | | Method |
|---|---|---|---|---|---|
| **Dielectric Properties (Cont)** | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | $2.0 \times 10^{10}$ | | | | - |
| Filtered | $2.0 \times 10^{10}$ | | | | - |
| Solids generated, gram | 1.00 | | | | - |
| Dissipation Factor, 74° F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 6.1 | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.5% by volume(2) | | | | | - |
| 2.0% by volume(2) | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 10.2 | | | | - |
| Filtered | 10.7 | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 74° F, kv | | | | | ASTM D-877 (modified). See Chapter 2, Test E-3 |
| As received | 25.5 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 14.0 | | | | - |
| Filtered | 26.5 | | | | - |
| | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | 2 | | | | - |
| Operations to failure (range) | 72-404 | | | | |
| **Emulsion Stability** | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 1 | | | | - |
| Water, ml | 39 | | | | - |
| Electric Probe Test, time for water separation, min | 20 | | | | See Chapter 2 Test E-4 |
| **Material Compatibility** Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Fair-Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | - | | | | - |
| Silicone | Poor | | | | - |
| Fluorosilicone | Poor | | | | - |

*Based on atmospheric pressure data.

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | Petroleum | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 0.8698 | 0.8445 | 0.8253 | | See NSRDL Annapolis Report MATLAB 550 |
| 3,000 psig | 0.8795 | 0.8560 | 0.8388 | | |
| 5,000 psig | 0.8859 | 0.8630 | 0.8472 | | |
| 8,000 psig | 0.8948 | 0.8729 | 0.8573 | | |
| 10,000 psig | 0.9003 | 0.8786 | 0.8680 | | |
| 15,000 psig | 0.9122 | 0.8915 | 0.8773 | | |
| 20,000 psig | 0.9234 | 0.9029 | 0.8898 | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 90° F | 150° F | | See NSRDL Annapolis Report MATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | 1.10 | 1.29 | 1.62 | | |
| 5,000 psig | 1.82 | 2.08 | 2.58 | | |
| 8,000 psig | 2.79 | 3.17 | 3.74 | | |
| 10,000 psig | 3.39 | 3.79 | 4.93 | | |
| 15,000 psig | 4.65 | 5.15 | 5.93 | | |
| 20,000 psig | 5.81 | 6.33 | 7.24 | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 230 | | | | ASTM D-92 |
| Fire Point, °F | 235 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-75 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | 45 | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | 1 | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | 0.043 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60° F | 0.87 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | 2.00 | | | | - |
| Availability | Gov. spec | | | | - |

[1]Determinations made at atmospheric pressure, unless noted. [2]Saturated with seawater.
[3]No rust observed.

Supplementary Properties of MIL-H-6083C[1]

| | | Method |
|---|---|---|
| Material Compatibility with: | | See Chapter 2 Test C-3 |
| Natural Rubber | Poor | |
| Buna S | Poor | |

MIL-H-6083C fluid at 1000 psi, 230 ml of gas (measured at atmospheric pressure and 77° F) was produced by 115,000 arcs, with no arc suppression, at 50-volt open-circuit voltage and 5-ampere closed-circuit current on the contacts.

*Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by MIL-L-6085A is a synthetic-base material usually consisting mainly of esters of dibasic organic acids. It has a low volatility and was developed for use as an aircraft instrument lubricating oil. The atmospheric pressure viscosity of MIL-L-6085A would lead to the prediction that it might be a satisfactory general-purpose fluid down to depths of 8000 feet. However, this fluid provides some limited corrosion protection. It is hydrolytically unstable. The low electrical resistivity and very high dissipation factor make its use questionable around electrical equipment. Before this oil is used in any application, the designer should consult a list of compatible materials available from the manufacturer.

Properties of MIL-L-6085A[1]
(Synthetic Base Fluid)

| | 35° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 550 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 12.7 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 3.31 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.709 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -225.3 | | | | - |
| Stainless Steel, 316 | 0 | | | | - |
| Copper-Nickel (70-30) | - 2.6 | | | | - |
| Aluminum, QQ-A-250-4b | - 0.2 | | | | - |
| Phosphor-Bronze | - 47.4 | | | | - |
| Steel, galvanized | - 43.1 | | | | - |
| Steel, 1009 | - 2.4 | | | | - |
| Aluminum, QQ-A-250-11 | 0 | | | | - |
| Bronze | - 38.0 | | | | - |
| Monel | - 0.2 | | | | - |
| Silver Base Brazing Alloy | - 48.9 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm² | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2, Test E-1 |
| Resistivity, 78° F, ohm-cm: | | | | | |
| As-Received | $8.0 \times 10^8$ | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 76° F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | >60 | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 78° F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 26.8 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 8 | | | | - |
| Emulsion, ml | 72 | | | | - |
| Water, ml | 0 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Fair | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Poor | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Good | | | | - |

*Based on atmospheric pressure data.

| | Synthetic | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 550 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 385 | | | | ASTM D-92 |
| Fire Point, °F | 440 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-70 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60° F | | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | $10.00 | | | | - |
| Availability | gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-L-6085A(1)

| | | Method |
|---|---|---|
| Material Compatibility with: | | See Chapter 2 Test C-3 |
| Natural Rubber | Poor | |
| Polyurethane | Poor | |
| Buna S | Poor | |

*Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by MIL-L-7808G is a synthetic-base material. It was developed originally as a lubricating oil for aircraft gas turbine engines. The atmospheric viscosity indicates that MIL-L-7808G would be a general-purpose fluid with a depth capability of 5000 feet. This fluid provides some limited corrosion protection. It has poor hydrolytic stability. Caution should be used in applying this fluid to electrical equipment since its resistivity and its dissipation factor are borderline, and no data are presently available under arcing conditions. Before using this fluid the system designer should consult a list of compatible materials available from the manufacturer.

## Properties of MIL-L-7808F[1]
## (Synthetic Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 350 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 17.30 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 4.50 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.629 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| Corrosion Protection | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -3.3 | | | | - |
| Stainless Steel, 316 | -0.1 | | | | - |
| Copper-Nickel (70-30) | -0.1 | | | | - |
| Aluminum, QQ-A-250-4b | -0.1 | | | | - |
| Phosphor-Bronze | -0.8 | | | | - |
| Steel, galvanized | -1.0 | | | | - |
| Steel, 1009 | +0.1 | | | | - |
| Aluminum, QQ-A-250-11 | -0.1 | | | | - |
| Bronze | -0.8 | | | | - |
| Monel | -2.6 | | | | - |
| Silver Base Brazing Alloy | -0.4 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 10[illegible] | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Allo[illegible] - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-2[illegible]0-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, $mg/cm^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2, Test E-1 |
| Resistivity, 76° F, ohm-cm: | $2.2x10^{10}$ | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 76° F, % | | | | | See Chapter 2 |
| As-Received | 5.5 | | | | - Test E-2 |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | - Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 76° F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 25.6 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | - Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 2 | | | | - |
| Emulsion, ml | 78 | | | | - |
| Water, ml | 0 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Fair | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Poor | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Good | | | | - |

*Based on atmospheric pressure data.

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1004 | | | | | |
| Aluminum QQ-A-250-11 - | | | | | - |
| Bronze | | | | | |
| Aluminum QQ-A-250-4b - | | | | | - |
| Steel, 1009 | | | | | |
| 20,000 PSIG Stirred Corrosion | | | | | See Chapter 2 |
| Test, weight change, mg | | | | | Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1009 | | | | | |
| Aluminum, QQ-A-250-11 - | | | | | - |
| Bronze | | | | | |
| Aluminum, QQ-A-250-4b - | | | | | - |
| Steel, 1009 | | | | | |
| Pump Test | | | | | Proposed military |
| Average Weight Loss, mg | | | | | specification for |
| Steel Gears | | | | | sea-water emulsi- |
| Bronze Bushings | | | | | fying oils |
| Corrosion Coupons, weight loss, | | | | | |
| each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (mod- |
| Resistivity, 76° F, ohm-cm: | $2.2x10^{10}$ | | | | ified). See Chap- |
| As-Received | | | | | ter 2. Test E-1 |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.1% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 76° F, % | | | | | See Chapter 2 |
| As-Received | 5.5 | | | | - Test E-2 |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | - Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 76° F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 25.6 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | - Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 2 | | | | - |
| Emulsion, ml | 78 | | | | - |
| Water, ml | 0 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 |
| Butyl | Poor | | | | - Test C-3 |
| Buna N | Fair | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Poor | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Good | | | | - |

*Based on atmospheric pressure data.

| | Synthetic | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 4[illegible] |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 5[illegible] |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | 0.11 | | | |
| Specimen appearance | | satisfac | | | |
| Fluid acid number increase, mg KOH/gram fluid | | 0.20 | | | - |
| Water acidity, mg KOH | | - | | | - |
| Insolubles, % | | nil | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 415 | | | | ASTM D-92 |
| Fire Point, °F | 445 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-40 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-598 |
| Specific gravity at 60/60°F | 0.9[illegible]8 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | $5.[illegible]0 | | | | - |
| Availability | gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted

Supplementary Properties of MIL-L-7808F[1]

| Material Compatibility with* | | Method |
|---|---|---|
| | | See Chapter 2 Test C-3 |
| Natural Rubber | Poor | |
| Polyurethane | Poor | |
| Buna S | Poor | |

*Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by the Military Specification MIL-L-7870A is a petroleum-base fluid developed for a low-temperature, general-purpose lubricant. The atmospheric pressure viscosity of MIL-L-7870A would lead to the prediction that it would be suitable for a general-purpose fluid for depth capability of 8000 feet. Its resistivity is low and its dissipation factor is high, making its use around electrical equipment questionable. It offers some limited corrosion protection. The low flash and fire points indicate that this fluid is readily flammable.

Properties of MIL-L-7870A(1)
(Petroleum Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, c[illegible]tistokes, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 350 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 10.3 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 2.52 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.927 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred P[illegible] Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -39.7 | | | | - |
| Stainless Steel, 316 | + 0.1 | | | | - |
| Copper-Nickel (70-30) | - 2.0 | | | | - |
| Aluminum, QQ-A-250-4b | + 0.2 | | | | - |
| Phosphor-Bronze | -12.8 | | | | - |
| Steel, galvanized | - 0.6 | | | | - |
| Steel, 1009 | - 0.4 | | | | - |
| Aluminum, QQ-A-250-11 | + 0.4 | | | | - |
| Bronze | - 6.6 | | | | - |
| Monel | - 2.2 | | | | - |
| Silver Base Brazing Alloy | -10.3 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 78°F, ohm-cm: | | | | | |
| As-Received | $7.6\times10^9$ | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.1% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 78° F, % | 14.4 | | | | See Chapter 2 |
| As-Received | | | | | Test E-2 |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 78° F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 30.4 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 2 | | | | - |
| Emulsion, ml | 78 | | | | - |
| Water, ml | 0 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Fair | | | | - |

*Based on atmospheric pressure data.

| | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 32° F | 100° F | 210° F | | |
| 0 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 6,000 psig | | | | | MATLAB [illegible] |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 32° F | 100° F | 210° F | | See NSRDL |
| 0 psig | | | | | Annapolis Report |
| 5,000 psig | | | | | MATLAB [illegible] |
| 6,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 285 | | | | ASTM D-92 |
| Fire Point, °F | 310 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-70 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 70/60° F | 0.876 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | $1.30 | | | | - |
| Availability | gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-L-7870A(1)

| | | Method |
|---|---|---|
| Material Compatibility with* | | See Chapter 2 Test C-3 |
| Buna S | Poor | |
| Natural Rubber | Poor | |
| Polyurethane | Good | |

*Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-C-8188C is a corrosion-inhibited, synthetic-based oil which was developed as a corrosion-preventive oil for the preservation of engines which operated on MIL-L-7808 oil. It has poor hydrolytic stability. The viscosity of MIL-C-8188C leads to the prediction that it could be used at depth capability of 6000 feet. Its poor dielectric properties make it unsatisfactory for use in electrical equipment. Before using this fluid, the system designer should consult a list of compatible materials available from the manufacturer.

Properties of MIL C 8188C(1)

(Synthetic Base Fluid)

| | 55° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 550 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 14.14 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 3.90 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.645 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, [illegible]0% seawater, 140° F, 2 days | | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -27.6 | | | | - |
| Stainless Steel, 316 | 0 | | | | - |
| Copper-Nickel (70-30) | - 9.4 | | | | - |
| Aluminum, QQ-A-250-4b | + 0.3 | | | | - |
| Phosphor-Bronze | -12.7 | | | | - |
| Steel, galvanized | - 1.7 | | | | - |
| Steel, 1009 | 0 | | | | - |
| Aluminum, QQ-A-250-11 | + 0.2 | | | | - |
| Bronze | - 8.0 | | | | - |
| Monel | - 1.8 | | | | - |
| Silver Base Brazing Alloy | - 7.7 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 10,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| **Dielectric Properties** | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 78° F, ohm-cm: | | | | | |
| As-Received | $7.8\times10^{8}$ | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 78° F, % | >60 | | | | See Chapter 2 Test E-2 |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 78° F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 25.2 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Fair | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Poor | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Good | | | | - |

*Based on atmospheric pressure data.

| | Synthetic | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 55° F | 100° F | 150° F | | See NSRDL Annapolis Report NATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 55° F | 100° F | 150° F | | See NSRDL Annapolis Report NATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 455 | | | | ASTM D-92 |
| Fire Point, °F | 500 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NRL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-15 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60°F | 0.938 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | $5.30 | | | | - |
| Availability | gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-C-8188C[1]

| | | Method |
|---|---|---|
| Material Compatibility with:* | | See Chapter 2 Test C-3 |
| Natural Rubber | Poor | |
| Polyurethane | Poor | |
| Buna S | Poor | |

*Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-F-17111 is a petroleum-base fluid which was developed as a hydraulic fluid for ordnance hydraulic systems. The viscosity at atmospheric pressure of MIL-F-17111 leads to the prediction that this fluid would be a satisfactory general-purpose fluid to depth capability of 5000 feet only. It provides some degree of corrosion protection and it is highly flammable. Initial dielectric properties are good, but additional information relating to its electrical application is lacking.

## Properties of MIL-F-17111 (1)
## (Petroleum Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| Viscometric Properties | | | | | |
| Viscosity, centistokes, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 550 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F | 28.8 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 10.14 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.391 | | | | - |
| Lubricating Ability | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| Corrosion Protection | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | pass | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | +0.1 | | | | - |
| Stainless Steel, 316 | 0 | | | | - |
| Copper-Nickel (70-30) | 0 | | | | - |
| Aluminum, QQ-A-250-4b | 0 | | | | - |
| Phosphor-Bronze | +0.2 | | | | - |
| Steel, galvanized | -0.9 | | | | - |
| Steel, 1009 | -0.4 | | | | - |
| Aluminum, QQ-A-250-11 | +1.5 | | | | - |
| Bronze | 0 | | | | - |
| Monel | -0.2 | | | | - |
| Silver Base Brazing Alloy | -0.4 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 30,000 PSIG Stirred Corrosion Test, weight change, % | (10% seawater) | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | 0 | | | | - |
| Stainless Steel, 316 | +0.1 | | | | - |
| Copper-Nickel (70-30) | +0.3 | | | | - |
| Aluminum, QQ-A-250-4b | +0.1 | | | | - |
| Phosphor-Bronze | 0 | | | | - |
| Steel, galvanized | +0.3 | | | | - |
| Steel, 1009 | +0.2 | | | | - |
| Aluminum, QQ-A-250-11 | +0.1 | | | | - |
| Bronze | +0.4 | | | | - |
| Monel | +0.1 | | | | - |
| Silver Base Brazing Alloy | -0.3 | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | +0.1-0.1 | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | -0.1-0.1 | | | | - |
| Monel-Bronze | -0.1+0.2 | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | +0.1 0 | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | +0.1+0.2 | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | 0 +0.3 | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | -0.1 0 | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | 6 | | | | |
| Bronze Bushings | 25 | | | | |
| Corrosion Coupons, weight loss, each, mg/cm² | - | | | | |
| Copper | 0.01 | | | | - |
| Aluminum | 0.03 | | | | - |
| Steel, galvanized | 0.25 | | | | - |
| Steel, 1009 | 0.05 | | | | - |
| Silver Base Brazing Alloy | 0.03 | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 77° F, ohm-cm: As-Received | $8.2 \times 10^{11}$ | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 77° F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 1.9 | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | - |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 77° F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 23.2 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 1 | | | | - |
| Emulsion, ml | 79 | | | | - |
| Water, ml | 0 | | | | - |
| Electric Probe Test, time for water separation, min. | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Fair-good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | - | | | | - |
| Silicone | Poor | | | | - |
| Fluorosilicone | Poor | | | | - |

*Based on atmospheric pressure data.

| | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | >220 | | | | ASTM D-92 |
| Fire Point, °F | >235 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-40 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | 0.010 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity, 60/60°F | 0.856 | | | | - |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | $3.00 | | | | - |
| Availability | gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-F-17111(1)

| | | Method |
|---|---|---|
| Material Compatibility with:* | | See Chapter 2 Test C-3 |
| Buna S | Poor | |
| Natural Rubber | Poor | |

*Based on atmospheric pressure data.

MIL-L-17672, MS 2110-TH

Suggested Uses and Possible Limitations

The fluids covered by MIL-L-17672 are petroleum-base fluids which are intended for use as hydraulic fluids and light steam turbine lubricants. The fluid described here is Military Symbol (MS) 2110-TH. Although MIL-L-17672, MS 2110-TH, is used in present-day submarines, its high viscosity eliminates its use in most deep ocean applications.

## Properties of MIL-L-17672B, MS2110TH[1]

### (Petroleum Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 338.1 | 35.68 | 12.69 | | |
| 3,000 psig | 628.4 | 59.23 | 18.71 | | See NSRDL |
| 5,000 psig | 984.4 | 79.88 | 24.42 | | Annapolis Report |
| 8,000 psig | 1776 | 125.4 | 35.15 | | MATLAB 350 |
| 10,000 psig | 2626 | 167.0 | 44.76 | | - |
| 15,000 psig | 6800[2] | 334.1 | 80.04 | | - |
| 20,000 psig | 17,400[2] | 660.8 | 140.9 | | - |
| Viscosity, centistokes, at 210° F, 0 psig | 5.35 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.771 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | Dry<br>Dry argon | Dry<br>Dry Oxygen | 1% Seawater<br>Wet Argon | 1% Seawater<br>Wet Oxygen | Fed. Method 6503 (modified) |
| 5 kg | 0.17 | - | 0.31 | - | - |
| 10 kg | 0.24 | - | 0.38 | 0.60 | - |
| 20 kg | 0.27 | 0.57 | 0.41 | 0.64 | - |
| 30 kg | 0.72 | 0.62 | 0.65 | 0.70 | |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -2.7 | | | | - |
| Stainless Steel, 316 | -0.7 | | | | - |
| Copper-Nickel (70-30) | -1.7 | | | | - |
| Aluminum, QQ-A-250-4b | +0.1 | | | | - |
| Phosphor-Bronze | -2.1 | | | | - |
| Steel, galvanized | -6.5 | | | | - |
| Steel, 1009 | 0 | | | | - |
| Aluminum, QQ-A-250-11 | -0.1 | | | | - |
| Bronze | -2.0 | | | | - |
| Monel | -0.3 | | | | - |
| Silver Base Brazing Alloy | -2.1 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | 138 | | | | |
| Bronze Bushings | 480 | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | 0.01 | | | | - |
| Aluminum | 0.05 | | | | - |
| Steel, galvanized | 0.01 | | | | - |
| Steel, 1009 | 0.04 | | | | - |
| Silver Base Brazing Alloy | 0.02 | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2, Test E-1 |
| Resistivity, 72° F, ohm-cm: | | | | | |
| As-Received | $4.4\times10^{12}$ | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | $5.4\times10^{11}$ | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination:(3) | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | $8.6x10^{11}$ | | | | - |
| Filtered | $4.2x10^{11}$ | | | | - |
| Solids generated, gram | 1.33 | | | | - |
| Dissipation Factor, 72° F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 1.0 | | | | |
| With Sea-Water Contamination: | 0.9 | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | - |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 1.6 | | | | - |
| Filtered | 1.2 | | | | - |
| | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 72° F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-2 |
| As received | 15.3 | | | | |
| With sea-water contamination:(3) | 5.5 | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 10.7 | | | | - |
| Filtered | 22.1 | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-3 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | 18 | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokel | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Fair | | | | - |

*Based on atmospheric pressure data.

| | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 0.8866 | 0.8632 | 0.8468 | | See NSRDL |
| 3,000 psig | 0.8958 | 0.8735 | 0.8580 | | Annapolis Report |
| 5,000 psig | 0.9014 | 0.8796 | 0.8656 | | MATLAB 550 |
| 8,000 psig | 0.9092 | 0.8879 | 0.8747 | | |
| 10,000 psig | 0.9140 | 0.8935 | 0.8805 | | |
| 15,000 psig | 0.9213 | 0.9050 | 0.8928 | | |
| 20,000 psig | 0.9347 | 0.9157 | 0.9041 | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL |
| 0 psig | | | | | Annapolis Report |
| 3,000 psig | 1.03 | 1.14 | 1.40 | | MATLAB 550 |
| 5,000 psig | 1.64 | 1.80 | 2.17 | | |
| 8,000 psig | 2.48 | 2.73 | 3.19 | | |
| 10,000 psig | 3.00 | 3.29 | 3.83 | | |
| 15,000 psig | 4.11 | 4.53 | 5.15 | | |
| 20,000 psig | 5.15 | 5.62 | 6.34 | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | 1000+ | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specifi- |
| Specimen change, mg | | | | | cation MIL-H- |
| Specimen appearance | | | | | 19457B |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 360 | | | | ASTM D-92 |
| Fire Point, °F | 385 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | 690 | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NEL Report |
| Minimum spontaneous ignition temperature, °F | 453 | | | | 31/66 of March 1967 |
| Minimum reaction temperature, °F | 425 | | | | - |
| No indication of fire, °F | 425 | | | | - |
| Maximum pressure change, psi | 325 | | | | - |
| Lowest temperature of maximum pressure change, °F | 453 | | | | - |
| Temperature range explored, °F | 425-479 | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | -15 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | 40 | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | 1 | | | | - |
| Foam after 10-minute settling, ml | 0 | | | | - |
| Neutralization Number, mg KOH/gram | 0.02 | | | | ASTM D-974 |
| Water Content, % by weight | 0.015 | | | | ASTM D-1744 |
| Neutrality, qualitative | Neutral | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60° F | 0.88 | | | | - |
| Color | 1.5 | | | | ASTM D-1500 |
| Cost $/gal | $0.60 | | | | - |
| Availability | gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted. [2]Extrapolated value. [3]Saturated with seawater.

Supplementary of Properties of MIL-L-17672B, MS 2110TH[1]
(Petroleum Base Fluid)

| | | Method |
|---|---|---|
| Material Compatibility with:* | | See Chapter 2 Test C-5 |
| Buna S | Poor | |
| Natural Rubber | Poor | |
| Polyurethane | Good | |

*Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by MIL-S-21568A is a 1-cs viscosity dimethyl polysiloxane fluid. MIL-S-21568A has been superseded by Federal Specification VV-D-001078. Since there is no 1-cs viscosity fluid covered by VV-D-001078, the older specification which contains such a fluid had to be used. MIL-S-21568A (1 cs) is considered unsatisfactory for use with motors because of its very low viscosity and poor sea-water emulsion stability. Because of its good dielectric properties, as well as low viscosity, it is the best choice known to date for switching devices and other nonmoving electrical applications.

Properties of MIL-S-21568A(1 CS )[1]

(Silicone Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| Viscometric Properties | | | | | |
| Viscosity, centistokes, at: | 35° F | 100° F | 150° F | | |
| 0 psig | 1.19 | 0.76 | 0.44 | | |
| 3,000 psig | 2.19 | 0.96 | 0.68 | | See NSRDL |
| 5,000 psig | 2.95 | 1.25 | 0.83 | | Annapolis Report |
| 8,000 psig | 4.29 | 1.73 | 1.19 | | MATLAB 350 |
| 10,000 psig | 5.11 | 1.97 | 1.31 | | - |
| 15,000 psig | 8.12 | 2.91 | 1.77 | | - |
| 20,000 psig | 11.56 | 3.92 | 2.46 | | - |
| Viscosity, centistokes, at 210° F, 0 psig | - | - | - | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.854 | - | - | | - |
| Lubricating Ability | Dry | + 1% Synthetic Seawater | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | 0.65 | - | | | |
| 15 kg | 1.02 | - | | | |
| 30 min, 50° C, 52100 steel | 0.63 | 0.39 | | | |
| 60 min, 10° C, 52100 steel | 0.70 | 0.50 | | | |
| Corrosion Protection | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | - | | | | - |
| Stainless Steel, 316 | - | | | | - |
| Copper-Nickel (70-30) | - | | | | - |
| Aluminum, QQ-A-250-4b | - | | | | - |
| Phosphor-Bronze | - | | | | - |
| Steel, galvanized | - | | | | - |
| Steel, 1009 | - | | | | - |
| Aluminum, QQ-A-250-11 | - | | | | - |
| Bronze | - | | | | - |
| Monel | - | | | | - |
| Silver Base Brazing Alloy | - | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-2?0-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 10,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter ? Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-116? (modified). See Chapter 2. Test E-1 |
| Resistivity, 78° F, ohm-cm: | | | | | |
| As-Received | $2.2\times10^{13}$ | | | | |
| With Sea-Water Contamination(2) | $2.4\times10^{13}$ | | | | Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| **Dielectric Properties (Cont)** | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 78° F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 2.0 | | | | |
| With Sea-Water Contamination:(2) | 1.5 | | | | See Chapter 2 - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 78° F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 26.2 | | | | |
| With sea-water contamination:(2) | 16.4 | | | | See Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | 3 | | | | - |
| Operations to failure (range) | >10,000 | | | | |
| **Emulsion Stability** | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | 0 | | | | See Chapter 2 Test E-4 |
| **Material Compatibility, Static 20K PSI** | | | | | See Chapter 2 Test C-3 |
| Butyl | | | | | |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| Property[1] | Silicone | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | See NSRDL Annual Report MATLAB |
| 0 psig | 0.8393 | 0.8009 | 0.7709 | | |
| 4,000 psig | 0.8543 | 0.8189 | 0.7916 | | |
| [illegible],000 psig | 0.8659 | 0.8[illegible] | 0.[illegible] | | |
| [illegible],000 psig | 0.8769 | 0.8455 | 0.8177 | | |
| 10,000 psig | 0.8844 | 0.8516 | 0.8267 | | |
| 1[illegible],000 psig | 0.9012 | 0.8687 | 0.8447 | | |
| [illegible]0,000 psig | 0.9161 | 0.8840 | 0.8614 | | |
| Isothermal Compressibility, volume decrease, %, at: | 3[illegible]° F | 90° F | 1[illegible]° F | | See NSRDL Annual Report MATLAB |
| 0 psig | | | | | |
| 4,000 psig | 2.21 | 2.75 | 3.65 | | |
| [illegible],000 psig | 3.55 | 4.21 | 5.38 | | |
| 8,000 psig | 5.19 | 6.11 | 7.56 | | |
| 10,000 psig | 5.61 | 7.17 | 8.7[illegible] | | |
| 1[illegible],000 psig | 8.20 | 9.21 | 11.[illegible] | | |
| [illegible] psig | 3.85 | 10.93 | 13.00 | | - |
| **Chemical Stability** | | | | | |
| Oxidation Stability Test, 20[illegible]° F, hours to failure | | | | | ASTM D-[illegible] |
| Oxidation Stability Test, [illegible]0° F | | | | | Fed. Method [illegible] |
| Hydrolytic Stability Test | | | | | Military Specification MIL-H-[illegible] |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| **Fire Resistance** | | | | | |
| Flash Point, °F | 115 | | | | ASTM D-92 |
| Fire Point, °F | 115 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | - |
| Minimum reaction temperature, °F | | | | | |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| **Miscellaneous Properties** | | | | | |
| Pour Point, °F | <-70 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | 0 | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | 0.026 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method [illegible] |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60°F | 0.8[illegible] | | | | ASTM D-1[illegible] |
| Color | | | | | - |
| Cost $/gal | $35.00 | | | | - |
| Availability | gov. spec. | | | | |

[1]Determinations made at atmospheric pressure unless noted. [2]Saturated with seawater.

## Suggested Uses and Possible Limitations

The fluid described in Military Specification MIL-L-23699A is a synthetic-base lubricant which was developed for aircraft turboprop and turboshaft engines. The atmospheric pressure viscosity of MIL-L-23699A leads to the prediction that it would be too viscous for most deep ocean applications. It has poor hydrolytic stability. It does provide some limited corrosion protection. Dielectric properties have not been determined. Before using this fluid, a system designer should consult a list of compatible materials available from the manufacturer.

Properties of MIL-L-23699A[1]
(Synthetic Base Fluid)

| | 35° F | 100° F | 1[illegible]0° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 5[illegible] |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 25.67 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 5.00 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.702 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method [illegible] (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -0.2 | | | | - |
| Stainless Steel, 316 | +0.1 | | | | - |
| Copper-Nickel (70-30) | -0.2 | | | | - |
| Aluminum, QQ-A-250-4b | +0.5 | | | | - |
| Phosphor-Bronze | -0.3 | | | | - |
| Steel, galvanized | -1.5 | | | | - |
| Steel, 1009 | -186.2 | | | | - |
| Aluminum, QQ-A-250-11 | +0.2 | | | | - |
| Bronze | -0.2 | | | | - |
| Monel | -0.1 | | | | - |
| Silver Base Brazing Alloy | -0.2 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1004 | | | | | |
| Aluminum QQ-A-250-11 - | | | | | - |
| Bronze | | | | | |
| Aluminum QQ-A-250-4b - | | | | | - |
| Steel, 1009 | | | | | |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1009 | | | | | |
| Aluminum, QQ-A-250-11 - | | | | | - |
| Bronze | | | | | |
| Aluminum, QQ-A-250-4b - | | | | | - |
| Steel, 1009 | | | | | |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, °F, ohm-cm: | | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, °F, % | | | | | See Chapter 2 |
| As-Received | | | | | - Test E-2 |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05 inch gap, °F, kv | | | | | ASTM D-877 (modified), See Chapter 2, Test E-3 |
| As received | | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20%PSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Fair | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Poor | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Good | | | | - |

*Based on atmospheric pressure data.

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | Synthetic | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL |
| 3,000 psig | | | | | Annapolis Report |
| 5,000 psig | | | | | MATLAB 350 |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL |
| 0 psig | | | | | Annapolis Report |
| 3,000 psig | | | | | MATLAB 350 |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 490 | | | | ASTM D-92 |
| Fire Point, °F | 550 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-65 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | <25 | | | | - |
| Time out, minutes | 1/2 | | | | - |
| Foam after 10-minute settling, ml | 0 | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60°F | 0.978 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | $4.70 | | | | - |
| Availability | gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-L-23699A(1)

| | | Method |
|---|---|---|
| Material Compatibility with:* | | See Chapter ?<br>Test C-3 |
| Natural Rubber | Poor | |
| Polyurethane | Poor | |
| Buna S | Poor | |

*Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by MIL-H-27601A is a petroleum-base hydraulic fluid developed for use on high-velocity flight vehicles whose hydraulic components may be subjected to high temperatures. MIL-H-27601A is not suggested for any deep ocean applications until more information is available. Its viscosity is somewhat high, and atmospheric pressure corrosion tests indicate that the fluid provides little if any corrosion protection. Its dielectric properties have not been determined.

Properties of MIL-H-27601A[1]
(Petroleum Base Fluid)

| | 55° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 250 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 15.11 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 3.31 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.793 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | - 8.5 | | | | - |
| Stainless Steel, 316 | + 2.3 | | | | - |
| Copper-Nickel (70-30) | + 6.9 | | | | - |
| Aluminum, QQ-A-250-4b | - 251.5 | | | | - |
| Phosphor-Bronze | - 96.6 | | | | - |
| Steel, galvanized | + 101.7 | | | | - |
| Steel, 1009 | -1046.6 | | | | - |
| Aluminum, QQ-A-250-11 | + 117.1 | | | | - |
| Bronze | - 4.4 | | | | - |
| Monel | + 1.5 | | | | - |
| Silver Base Brazing Alloy | + 10.2 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2 Test E-1 |
| Resistivity, °F, ohm-cm: | | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, °F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility, Static 20K PSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Fair | | | | - |

* Based on atmospheric pressure data.

| Volatility<br>Toxicity | Petroleum | | | | Method<br>-<br>- |
|---|---|---|---|---|---|
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 350 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | 0.01 | | | |
| Specimen appearance | | Satisfactory | | | |
| Fluid acid number increase, mg KOH/gram fluid | | 0.02 | | | - |
| Water acidity, mg KOH | | 0.41 | | | - |
| Insolubles, % | | Nil | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 390 | | | | ASTM D-92 |
| Fire Point, °F | 420 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-65 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | 0.007 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 70/60°F | 0.844 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | $65.00 | | | | - |
| Availability | gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

Supplementary of Properties of MIL-H-27601A(1)

| Material Compatibility with:* | | Method |
|---|---|---|
| | | See Chapter 2 Test C-5 |
| Buna S | Poor | |
| Natural Rubber | Poor | |
| Polyurethane | Good | |

* Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid described by MIL-H-46004 is a petroleum-base hydraulic fluid developed for use in missiles where low temperatures are anticipated. The atmospheric pressure viscosity of MIL-H-46004 indicates that it might be satisfactory at a depth capability of 20,000 feet. This fluid provides no corrosion protection, and it is highly flammable. Its lubrication and electrical properties have not been measured.

Properties of MIL-H-46004[1]
(Petrole[illegible] Base Fluid)

| | 5[illegible]° C | 100° [illegible] | 1[illegible]0° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| [illegible],000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB [illegible] |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 2.88 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 1.21 | | | | ASTM D-44[illegible] |
| Viscosity Slope, ASTM | 0.741 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method [illegible] (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-6[illegible] |
| On-Off Rust Test, [illegible]0% seawater, 140° F, 30 days | | | | | See Chapter [illegible] Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter [illegible] Test C-1 |
| Copper | - 29.2 | | | | - |
| Stainless Steel, 316 | + 0.6 | | | | - |
| Copper-Nickel (70-30) | - 0.4 | | | | - |
| Aluminum, QQ-A-250-4b | - 132.7 | | | | - |
| Phosphor-Bronze | - 6.8(2) | | | | - |
| Steel, galvanized | -1194.1 | | | | - |
| Steel, 1009 | -1369.5 | | | | - |
| Aluminum, QQ-A-250-11 | - 147.8 | | | | - |
| Bronze | - [illegible]5.7 | | | | - |
| Monel | - 1.5 | | | | - |
| Silver Base Brazing Alloy | - [illegible]9.1 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter [illegible] Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-[illegible]-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-[illegible]-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum. QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, $mg/cm^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2, Test E-1 |
| Resistivity, °F, ohm-cm: | | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, °F, % | | | | | See Chapter 2 |
| As-Received | | | | | - Test E-2 |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | - Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Fair | | | | - |

* Based on atmospheric pressure data.

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | Petroleum | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 350 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 210 | | | | ASTM D-92 |
| Fire Point, °F | 220 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-75 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 70/60 °F | 0.850 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | $2.00 | | | | - |
| Availability | gov. spec. | | | | - |

[1]Determinations made at atmospheric pressure, unless noted. [2]Heavy deposits indicates corrosion not shown by weight change.

Supplementary Properties of MIL-H-46004

| Material Compatibility with:* | | Method |
|---|---|---|
| | | See Chapter 2 Test C-5 |
| Buna S | Poor | |
| Natural Rubber | Poor | |
| Polyurethane | Good | |

* Based on atmospheric pressure data.

## Suggested Uses and Possible Limitations

The fluid covered by MIL-H-81019B is a petroleum-base hydraulic fluid for use in aircraft, missiles, and ordnance hydraulic systems in the -90° to +210° F temperature range. MIL-H-81019B appears to have properties for use at great depth. Its viscosity appears to be too low at atmospheric pressure for use as a general-purpose lubricant. It provides some degree of corrosion inhibition, and it is highly flammable. Initial dielectric properties are good, but additional information relating to electrical applications is lacking.

Properties of MIL-H-81019B[1]

(Petroleum Base Fluid)

| | 55° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 550 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 7.20 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 2.82 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.565 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -1.0 | | | | - |
| Stainless Steel, 316 | -0.1 | | | | - |
| Copper-Nickel (70-30) | -0.5 | | | | - |
| Aluminum, QQ-A-250-4b | 0 | | | | - |
| Phosphor-Bronze | -0.4 | | | | - |
| Steel, galvanized | -0.3 | | | | - |
| Steel, 1009 | 0 | | | | - |
| Aluminum, QQ-A-250-11 | 0 | | | | - |
| Bronze | -0.5 | | | | - |
| Monel | -0.2 | | | | - |
| Silver Base Brazing Alloy | -0.4 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1004 | | | | | |
| Aluminum QQ-A-250-11 - | | | | | - |
| Bronze | | | | | |
| Aluminum QQ-A-250-4b - | | | | | - |
| Steel, 1009 | | | | | |
| 20,000 PSIG Stirred Corrosion | | | | | See Chapter 2 |
| Test, weight change, mg | | | | | Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1009 | | | | | |
| Aluminum, QQ-A-250-11 - | | | | | - |
| Bronze | | | | | |
| Aluminum, QQ-A-250-4b | | | | | - |
| Steel, 1009 | | | | | |
| Pump Test | | | | | Proposed military |
| Average Weight Loss, mg | | | | | specification for |
| Steel Gears | | | | | sea-water emulsi- |
| Bronze Bushings | | | | | fying oils |
| Corrosion Coupons, weight loss, | | | | | |
| each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (mod- |
| Resistivity, 75° F, ohm-cm: | $2.6 \times 10^{11}$ | | | | ified). See Chap- |
| As-Received | | | | | ter 2. Test E-1 |
| With Sea-Water Contamination: | | | | | Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 |
| 0.1% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 76 °F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 1.3 | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 76 °F kv | | | | | ASTM D-877 (modified). See Chapter 2, Test E-3 |
| As received | 22.4 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 28 | | | | - |
| Emulsion, ml | 48 | | | | - |
| Water, ml | 4 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Fair | | | | - |

* Based on atmospheric pressure data.

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | Petroleum | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 212 | | | | ASTM D-92 |
| Fire Point, °F | 225 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-90 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific Gravity at 70/60 °F | 0.858 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | Available | from supplier | | | - |
| Availability | gov. spec | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

Supplementary of Properties of MIL-H-81019B[1]

| Material Compatibility with:* | | Method |
|---|---|---|
| Buna S | Poor | See Chapter 2 Test C.3 |
| Natural Rubber | Poor | |
| Polyurethane | Good | |

* Based on atmospheric pressure data.

PROPRIETARY FLUIDS

## Fluid Code A

### Suggested Uses and Possible Limitations

Fluid Code A, a sea-water emulsifying hydraulic fluid, Grade 1, petroleum-base oil, has the same viscosity as MIL-L-17672, MS 2110-TH, which is too high for most deep ocean applications. It has good lubricating properties and good corrosion-inhibiting properties. Its dielectric properties are questionable for deep ocean applications in that it has a low resistivity and a high dissipation factor.

## Fluid Code A[1]

(Petroleum Base Fluid)

| Property | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 550 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100°F, | 41.9 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 5.93 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.768 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | Dry<br>Dry Argon | Dry<br>Dry Oxygen | 1% Seawater<br>Wet Argon | 1% Seawater<br>Wet Oxygen | Fed. Method 6503 (modified) |
| 5 kg | 0.16 | - | 0.36 | - | - |
| 10 kg | 0.26 | 0.24 | 0.38 | 0.48 | - |
| 20 kg | 0.29 | - | 0.41 | 0.50 | - |
| 30 kg | 0.34 | 0.32 | 0.43 | 0.66 | |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Pass | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -69.5 | | | | - |
| Stainless Steel, 316 | - 0.2 | | | | - |
| Copper-Nickel (70-30) | - 0.1 | | | | - |
| Aluminum, QQ-A-250-4b | + 0.1 | | | | - |
| Phosphor-Bronze | - 1.0 | | | | - |
| Steel, galvanized | - 2.6 | | | | - |
| Steel, 1009 | + 0.1 | | | | - |
| Aluminum, QQ-A-250-11 | + 0.1 | | | | - |
| Bronze | - 1.2 | | | | - |
| Monel | - 0.3 | | | | - |
| Silver Base Brazing Alloy | -72.4 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | 3 | | | | |
| Bronze Bushings | 1 | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | - | | | | |
| Copper | 0.40 | | | | - |
| Aluminum | 0.01 | | | | - |
| Steel, galvanized | 0.02 | | | | - |
| Steel, 1009 | 0.01 | | | | - |
| Silver Base Brazing Alloy | 0.51 | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 77 °F, ohm-cm: | | | | | |
| As-Received | $7.4 \times 10^9$ | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-[illegible] |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 77 °F, % | | | | | See Chapter 2 |
| As-Received | 20.0 | | | | Test E-2 |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 77 °F, kv | | | | | ASTM D-877 (modified). See Chapter 2, Test E-3 |
| As received | 21.6 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 0 | | | | - |
| Emulsion, ml | 80 | | | | - |
| Water, ml | 0 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI* | | | | | See Chapter 2 Test C-3 |
| Butyl | Poor | | | | |
| Buna N | Good | | | | - |
| Viton B | Good | | | | - |
| Ethylene-Propylene | Poor | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | - |
| Neoprene | Fair | | | | - |
| Thiokol | - | | | | - |
| Silicone | Fair | | | | - |
| Fluorosilicone | Fair | | | | - |

* Based on atmospheric pressure data.

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | Petroleum | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL |
| 3,000 psig | | | | | Annapolis [illegible] |
| 5,000 psig | | | | | MATLAB [illegible] |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume | 35° F | 100° F | 150° F | | |
| decrease, %, at: | | | | | See NSRDL |
| 0 psig | | | | | Annapolis [illegible] |
| 3,000 psig | | | | | MATLAB [illegible] |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | 525 | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method [illegible] |
| Hydrolytic Stability Test | | | | | Military specifi- |
| Specimen change, mg | | | | | cation MIL-H- |
| Specimen appearance | | | | | 19457B |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 375 | | | | ASTM D-92 |
| Fire Point, °F | 430 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report |
| Minimum spontaneous ignition temperature, °F | | | | | 31/66 of March 1967 |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | -10 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | <10 | | | | - |
| Time out, minutes | 0 | | | | - |
| Foam after 10-minute settling, ml | 0 | | | | - |
| Neutralization Number, mg KOH/gram | 0.9 | | | | ASTM D-974 |
| Water Content, % by weight | 0.076 | | | | ASTM D-1744 |
| Neutrality, qualitative | Neutral | | | | Fed. Method [illegible]101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | 582 | | | | - |
| 100-500 micrometers | 6 | | | | - |
| over 500 micrometers | 6 fibers | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | 0 | | | | - |
| Gravimetric Value, mg/100 ml | 8.9 | | | | SAE Method ARP-785 |
| Specific gravity, 60/60 °F | 0.889 | | | | ASTM D-1298 |
| Color | 3.5 | | | | ASTM D-1500 |
| Cost $/gal | Available from supplier | | | | - |
| Availability | proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

Fluid Code A

| Material Compatibility with:* | | Method |
|---|---|---|
| | | See Chapter Test C.3 |
| Buna S | Poor | |
| Natural Rubber | Poor | |
| Polyurethane | Good | |

* Based on atmospheric pressure data.

## Fluid Code B

### Suggested Uses and Possible Limitations

Fluid Code B, a petroleum oil product, was originally developed for missile use. Its viscosity at atmospheric pressure is too low for a general lubrication or hydraulic fluid over sustained time periods; however, it would be in the right viscosity range at great depths. It provides excellent corrosion inhibition for ferrous metals but provides no protection for nonferrous metals. Its electrical resistivity is low and its dissipation factor is very high, making it questionable for known deep ocean electrical application. It is extremely flammable.

Fluid Code B[1]

(Petroleum Base Fluid)

| | 55° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 2,500 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 350 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100 °F, | 3.42 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 1.36 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.803 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -39.2 | | | | - |
| Stainless Steel, 316 | + 0.2 | | | | - |
| Copper-Nickel (70-30) | - 3.8 | | | | - |
| Aluminum, QQ-A-250-4b | + 0.4 | | | | - |
| Phosphor-Bronze | -17.8 | | | | - |
| Steel, galvanized | -16.6 | | | | - |
| Steel, 1009 | - 0.2 | | | | - |
| Aluminum, QQ-A-250-11 | + 0.3 | | | | - |
| Bronze | -20.9 | | | | - |
| Monel | - 0.2 | | | | - |
| Silver Base Brazing Alloy | -10.2 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 76 °F, ohm-cm: | $1.0 \times 10^9$ | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 76 °F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | >60 | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | - |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 76 °F, kv | 25.4 | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter [illegible] Test E-[illegible] |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 23 | | | | - |
| Emulsion, ml | 57 | | | | - |
| Water, ml | 0 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 Test C-3 |
| Butyl | | | | | |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 350 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| **Chemical Stability** | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | 0.12 | | | |
| Specimen appearance | | Satisfactory | | | |
| Fluid acid number increase, mg KOH/gram fluid | | 0.21 | | | - |
| Water acidity, mg KOH | | 10 | | | - |
| Insolubles, % | | nil | | | - |
| Thermal Stability Test | | | | | - |
| **Fire Resistance** | | | | | |
| Flash Point, °F | 205 | | | | ASTM D-92 |
| Fire Point, °F | 215 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| **Miscellaneous Properties** | | | | | |
| Pour Point, °F | | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | 0.09 | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method [illegible] |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-[illegible] |
| Specific gravity at 70/70 °F | 0.852 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-[illegible] |
| Cost $/gal | Available from supplier | | | | - |
| Availability | proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

## Fluid Code C

### Suggested Uses and Possible Limitations

As a petroleum oil product, Fluid Code C has viscosity properties similar to those of MIL-H-46004 and has been used as an immersion medium for electric motors at pressures corresponding to a depth capability of 20,000 feet. Its viscosity is too low at atmospheric pressure to consider it as a general lubricant over sustained periods of time. It shows good corrosion inhibition for both ferrous and nonferrous metals. It has a low electrical resistivity and a high dissipation factor, making it questionable for any known deep ocean electrical application. It is extremely flammable.

Fluid Code C[1]
(Petroleum Base Fluid)

| | 50° F[2] | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | 12 | | | | |
| 3,000 psig | 17 | | | | See NSRDL |
| 5,000 psig | 22 | | | | Annapolis Report |
| 8,000 psig | 32 | | | | MATLAB 550 |
| 10,000 psig | 42 | | | | - |
| 15,000 psig | 82 | | | | - |
| 20,000 psig | 180 | | | | - |
| Viscosity, centistokes, at 100 °F, | 3.73 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 1.41 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.825 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 65[illegible] (modified) |
| 1 kg | 0.18 | | | | - |
| 3 kg | 0.25 (scuffing, oil film lost) | | | | - |
| 5 kg | 0.30 (scuffing, oil film lost) | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter [illegible] Test C-[illegible] |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter [illegible] Test C-1 |
| Copper | -17.8 | | | | - |
| Stainless Steel, 316 | + 0.3 | | | | - |
| Copper-Nickel (70-30) | - 0.4 | | | | - |
| Aluminum, QQ-A-250-4b | +0.6 | | | | - |
| Phosphor-Bronze | - 5.5 | | | | - |
| Steel, galvanized | - 0.2 | | | | - |
| Steel, 1009 | + 0.2 | | | | - |
| Aluminum, QQ-A-250-11 | + 0.4 | | | | - |
| Bronze | - 5.6 | | | | - |
| Monel | + 0.2 | | | | - |
| Silver Base Brazing Alloy | - 5.2 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter [illegible] Test C-[illegible] |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | (10% seawater) | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | -1.4 | | | | - |
| Stainless Steel, 316 | -1.3 | | | | - |
| Copper-Nickel (70-30) | -0.3 | | | | - |
| Aluminum, QQ-A-250-4b | +0.1 | | | | - |
| Phosphor-Bronze | +0.1 | | | | - |
| Steel, galvanized | -0.2 | | | | - |
| Steel, 1009 | -0.3 | | | | - |
| Aluminum, QQ-A-250-11 | +0.2 | | | | - |
| Bronze | -1.3 | | | | - |
| Monel | -2.1 | | | | - |
| Silver Base Brazing Alloy | -4.7 | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | -2.2 +[illegible] | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | -0.3 -0.5 | | | | - |
| Monel-Bronze | +0.2 +0.6 | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | +0.8 +0.7 | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | +0.2 +0.1 | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | +1.2 +0.5 | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | +0.1 -0.1 | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 77 °F, ohm-cm: | $4.0\times10^8$ | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs | | | | | See Chapter 2 |
| (makes and breaks) at 90 | | | | | Test E-7 |
| volts, 10 amperes, resis- | | | | | |
| tive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 77 °F, % | | | | | See Chapter 2 |
| As-Received | >60 | | | | Test E-2 |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs | | | | | |
| (makes and breaks) at 90 | | | | | |
| volts, 10 amperes, resis- | | | | | |
| tive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, | | | | | ASTM D-877 (mod- |
| 0.05-inch gap, 77 °F, kv | | | | | ified). See Chap- |
| As received | 28.4 | | | | ter 2. Test E-3 |
| With sea-water contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | - Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs | | | | | |
| (makes and breaks) at 90 | | | | | |
| volts, 10 amperes, resis- | | | | | |
| tive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 | | | | | See Chapter 2 |
| volts, 10 amperes, resistive | | | | | Test E-8 |
| load, 6000 psi, 65°-85° F | | | | | |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour set- | | | | | ASTM D-1401 |
| tling: | | | | | |
| Oil, ml | 25 | | | | - |
| Emulsion, ml | 55 | | | | - |
| Water, ml | 0 | | | | - |
| Electric Probe Test, time for | | | | | See Chapter 2 |
| water separation, min | | | | | Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 |
| Butyl | | | | | Test C-5 |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | Petroleum | | | | - |
| Density, grams/cubic centimeter, at: | 52° F | 73° F | 150° F | | |
| 0 psig | 0.860 | 0.852 | | | See NSRDL |
| 3,000 psig | 0.871 | 0.864 | | | Annapolis Report |
| 5,000 psig | 0.879 | 0.872 | | | MATLAB 350 |
| 8,000 psig | 0.888 | 0.882 | | | |
| 10,000 psig | 0.896 | 0.889 | | | |
| 15,000 psig | 0.909 | 0.903 | | | |
| 20,000 psig | 0.923 | 0.917 | | | |
| Compressibility, volume decrease, %, at: | 52° F | 73° F | 100° F | | See NSRDL |
| 0 psig | | | | | Annapolis Report |
| 3,000 psig | 1.4 | 1.5 | 1.7 | | MATLAB 350 |
| 5,000 psig | 2.2 | 2.3 | 2.6 | | |
| 8,000 psig | 3.3 | 3.5 | 3.8 | | |
| 10,000 psig | 3.9 | 4.2 | 4.6 | | |
| 15,000 psig | 5.5 | 5.7 | 6.3 | | |
| 20,000 psig | 6.8 | 7.1 | 7.8 | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 200 | | | | ASTM D-92 |
| Fire Point, °F | 220 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-90 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | 0.09 | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 70/60 °F | 0.858 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | Available from supplier | | | | - |
| Availability | proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

## Fluid Code D

### Suggested Uses and Possible Limitations

Fluid Code D has been suggested for use in a friction drive system. Its relatively high viscosity and lack of corrosion inhibition make it questionable for use as a general petroleum lubricant or hydraulic fluid. Its dielectric properties have not been determined. It is flammable.

Fluid Code D(1)
(Petroleum Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | 19.7 | | | |
| 3,000 psig | | - | | | See New Departure Letter to NSRDC, 26 Feb 1968 |
| 5,000 psig | | 53.2 | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100 °F. | 19.7 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 3.86 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.776 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | - 50.1 | | | | - |
| Stainless Steel, 316 | + 0.6 | | | | - |
| Copper-Nickel (70-30) | - 0.7 | | | | - |
| Aluminum, QQ-A-250-4b | -133.5 | | | | - |
| Phosphor-Bronze | - 70.7 | | | | - |
| Steel, galvanized | -290.5 | | | | - |
| Steel, 1009 | -828.6 | | | | - |
| Aluminum, QQ-A-250-11 | - 25.8 | | | | - |
| Bronze | - 33.1 | | | | - |
| Monel | + 0.5 | | | | - |
| Silver Base Brazing Alloy | - 2.5 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1004 | | | | | |
| Aluminum QQ-A-250-11 - | | | | | - |
| Bronze | | | | | |
| Aluminum QQ-A-250-4b - | | | | | - |
| Steel, 1009 | | | | | |
| 20,000 PSIG Stirred Corrosion | | | | | See Chapter 2 |
| Test, weight change, mg | | | | | Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4 b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - | | | | | - |
| Copper-Nickel (70-30) | | | | | |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - | | | | | - |
| Phosphor-Bronze | | | | | |
| Silver Base Brazing Alloy - | | | | | - |
| Steel, 1009 | | | | | |
| Aluminum, QQ-A-250-11 - | | | | | - |
| Bronze | | | | | |
| Aluminum, QQ-A-250-4b - | | | | | - |
| Steel, 1009 | | | | | |
| Pump Test | | | | | Proposed military |
| Average Weight Loss, mg | | | | | specification for |
| Steel Gears | | | | | sea-water emulsi- |
| Bronze Bushings | | | | | fying oils |
| Corrosion Coupons, weight loss, | | | | | |
| each, $mg/cm^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (mod- |
| Resistivity, °F, ohm-cm: | | | | | ified). See Chap- |
| As-Received | | | | | ter 2 Test E-1 |
| With Sea-Water Contamination: | | | | | Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 |
| 0.1% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, °F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | | | | | |
| With sea-water contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | - Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 Test C-3 |
| Butyl | | | | | |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 32° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 32° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | - |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 270 | | | | ASTM D-92 |
| Fire Point, °F | 295 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NEL Report 51/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | - |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | -60 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | - | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | <1 | | | | - |
| Foam after 10-minute settling, ml | 0 | | | | - |
| Neutralization Number, mg KOH/gram | 0.01 | | | | ASTM D-974 |
| Water Content, % by weight | 0.010 | | | | ASTM D-1744 |
| Neutrality, qualitative | neutral | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60 °F | 0.837 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | Available from supplier | | | | - |
| Availability | proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

## Fluid Code E

### Suggested Uses and Possible Limitations

Fluid Code E is used in submersible motors. There is considerable field experience to show that this fluid may be used as a motor immersion fluid. Its viscosity is low, it provides no corrosion protection, and it is extremely flammable. Initial dielectric properties are good, but additional information relating to electrical applications is lacking.

Fluid Code E(1)

(Petroleum Base Fluid)

| | 55° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 350 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100 °F, | 4.26 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 1.50 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.839 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | - 74.2 | | | | - |
| Stainless Steel, 316 | + 1.2 | | | | - |
| Copper-Nickel (70-30) | + 0.7 | | | | - |
| Aluminum, QQ-A-250-4b | -456.5 | | | | - |
| Phosphor-Bronze | - 25.9 | | | | - |
| Steel, galvanized | -1227.4 | | | | - |
| Steel, 1009 | -1598.2 | | | | - |
| Aluminum, QQ-A-250-11 | + 159.7 | | | | - |
| Bronze | - 46.7 | | | | - |
| Monel | + 0.1 | | | | - |
| Silver Base Brazing Alloy | - 17.3 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4 b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| <u>Dielectric Properties</u> | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 73 °F, ohm-cm: | $2.6 \times 10^{13}$ | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 73 °F, % | 0.8 | | | | See Chapter 2 |
| As-Received | | | | | Test E-2 |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 73 °F, kv | | | | | ASTM D-877 (modified). See Chap- |
| As received | 27.2 | | | | ter 2. Test E-3 |
| With sea-water contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-3 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 |
| Butyl | | | | | Test C-3 |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | Petroleum | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 185 | | | | ASTM D-92 |
| Fire Point, °F | 190 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60 °F | 0.830 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | Available from supplier | | | | - |
| Availability | Proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

## Fluid Code F

### Suggested Uses and Possible Limitations

Fluid Code F has a low atmospheric pressure viscosity for a general-purpose petroleum lubricant over a sustained time period. Its corrosion-inhibiting properties are moderately good for both ferrous and nonferrous metals. It is flammable. Initial dielectric properties are good, but additional information relating to electrical applications is lacking.

Fluid Code F[1]

(Petroleum Base Fluid)

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 55° F | 100° F | 1[illegible]0° F | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB [illegible] |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 4.68 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 1.59 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.836 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter [illegible] Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter [illegible] Test C-1 |
| Copper | - 0.5 | | | | - |
| Stainless Steel, 316 | - 0.2 | | | | - |
| Copper-Nickel (70-30) | - 0.4 | | | | - |
| Aluminum, QQ-A-250-4b | - 0.2 | | | | - |
| Phosphor-Bronze | - 0.4 | | | | - |
| Steel, galvanized | - 8.0 | | | | - |
| Steel, 1009 | - 0.2 | | | | - |
| Aluminum, QQ-A-250-11 | - 0.2 | | | | - |
| Bronze | - 0.7 | | | | - |
| Monel | - 0.3 | | | | - |
| Silver Base Brazing Alloy | - 0.2 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter [illegible] Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| **Corrosion Protection (Con't)** | | | | | |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, $mg/cm^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| **Dielectric Properties** | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 75 °F, ohm-cm: | | | | | |
| As-Received | $1.2 \times 10^{14}$ | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 75 °F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 0.7 | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 75 °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 24.6 | | | | |
| With sea-water contamination: | | | | | Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 8 | | | | - |
| Water, ml | 32 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 Test C-3 |
| Butyl | | | | | |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | |
| Toxicity | | | | | |
| Density, grams/cubic centimeter, at: | [illegible]° F | 100° F | 1[illegible]0° F | | |
| 0 psig | | | | | See NSRDL |
| 4,000 psig | | | | | Annapolis [illegible] |
| 6,000 psig | | | | | MATLAB [illegible] |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, % Volume decrease, %, at: | [illegible]° F | 100° F | 1[illegible]° F | | See NSRDL |
| 0 psig | | | | | Annapolis Report |
| 4,000 psig | | | | | MATLAB [illegible] |
| 6,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| **Chemical Stability** | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | 1000+ | | | | ASTM D-[illegible] |
| Oxidation Stability Test, 250° F | | | | | Fed. Method [illegible] |
| Hydrolytic Stability Test | | | | | Military specifi- |
| Specimen change, mg | | | | | cation MIL-H- |
| Specimen appearance | | | | | 19457B |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| **Fire Resistance** | | | | | |
| Flash Point, °F | [illegible]80 | | | | ASTM D-[illegible] |
| Fire Point, °F | 300 | | | | ASTM D-[illegible] |
| Autogenous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report |
| Minimum spontaneous ignition temperature, °F | | | | | 31/66 of March 1967 |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| **Miscellaneous Properties** | | | | | |
| Pour Point, °F | | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | 0.08 | | | | ASTM D-974 |
| Water Content, % by weight | 0.016 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 71/60 °F | 0.832 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost, $/gal | Available from supplier | | | | - |
| Availability | Proprietary | | | | - |

1. Determinations made at atmospheric pressure, unless noted.

## Fluid Code G

### Suggested Uses and Possible Limitations

The atmospheric pressure viscosity of Fluid Code G suggests that it could be a general-purpose petroleum fluid. Its corrosion-inhibiting properties are moderately good for both ferrous and nonferrous metals. Initial dielectric properties are good, but additional information relating to electrical applications is lacking.

Fluid Code G(1)

(Petroleum Base Fluid)

| | 55° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 550 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 10.80 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 2.50 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.823 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 20 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -0.1 | | | | - |
| Stainless Steel, 316 | +0.2 | | | | - |
| Copper-Nickel (70-30) | -0.1 | | | | - |
| Aluminum, QQ-A-250-4b | +0.2 | | | | - |
| Phosphor-Bronze | 0 | | | | - |
| Steel, galvanized | -6.6 | | | | - |
| Steel, 1009 | +0.5 | | | | - |
| Aluminum, QQ-A-250-11 | +0.2 | | | | - |
| Bronze | -0.3 | | | | - |
| Monel | +0.1 | | | | - |
| Silver Base Brazing Alloy | -0.7 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | (10% seawater) | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | -0.5 | | | | - |
| Stainless Steel, 316 | 0 | | | | - |
| Copper-Nickel (70-30) | 0 | | | | - |
| Aluminum, QQ-A-250-4b | -0.1 | | | | - |
| Phosphor-Bronze | -0.1 | | | | - |
| Steel, galvanized | -0.3 | | | | - |
| Steel, 1009 | 0 | | | | - |
| Aluminum, QQ-A-250-11 | 0 | | | | - |
| Bronze | +0.1 | | | | - |
| Monel | 0 | | | | - |
| Silver Base Brazing Alloy | -0.6 | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | -1.3 -0.3 | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30, | -0.3 -0.1 | | | | - |
| Monel-Bronze | 0 +0.3 | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | 0 -0.1 | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | -0.6 -0.3 | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | -0.1 +0.3 | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | -0.1 0 | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | 1 | | | | |
| Bronze Bushings | 8 | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | - | | | | |
| Copper | 0.01 | | | | - |
| Aluminum | 0.03 | | | | - |
| Steel, galvanized | 0.01 | | | | - |
| Steel, 1009 | 0.01 | | | | - |
| Silver Base Brazing Alloy | 0.02 | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 75 °F ohm-cm: | $8.0 \times 10^{13}$ | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 75 °F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | 0.8 | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 75 °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. |
| As received | 29.9 | | | | Test E-3 |
| With sea-water contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-3 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 38 | | | | - |
| Emulsion, ml | 30 | | | | - |
| Water, ml | 12 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 |
| Butyl | | | | | Test C-3 |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| Property | Petroleum 35° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 5[illegible] |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 5[illegible] |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | 1000+ | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5[illegible] |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 300 | | | | ASTM D-92 |
| Fire Point, °F | 325 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | <-45 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | 0.10 | | | | ASTM D-974 |
| Water Content, % by weight | 0.005 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method [illegible]101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific Gravity at 70/60 °F | 0.872 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | available from supplier | | | | - |
| Availability | proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

## Fluid Code H

### Suggested Uses and Possible Limitations

The atmospheric pressure viscosity of Fluid Code H would lead to the prediction that it would not be suitable for hydraulic systems or lubrication uses at more than 4000-foot depth. properties are moderately good for both ferrous and nonferrous metals.

Fluid Code H(1)

(Petroleum Base Fluid)

| | 35° F | 100° F | 1[illegible]0° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 55[illegible] |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100 °F, | 34.0 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 5.31 | | | | ASTM D-44[illegible] |
| Viscosity Slope, ASTM | 0.764 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 65[illegible] (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | +2.0 | | | | - |
| Stainless Steel, 316 | +0.1 | | | | - |
| Copper-Nickel (70-30) | +0.1 | | | | - |
| Aluminum, QQ-A-250-4b | +0.3 | | | | - |
| Phosphor-Bronze | +0.2 | | | | - |
| Steel, galvanized | -0.9 | | | | - |
| Steel, 1009 | +0.5 | | | | - |
| Aluminum, QQ-A-250-11 | +0.3 | | | | - |
| Bronze | +0.2 | | | | - |
| Monel | +0.1 | | | | - |
| Silver Base Brazing Alloy | -0.3 | | | | - |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, $mg/cm^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, °F, ohm-cm: | | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, °F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 Test C-3 |
| Butyl | | | | | - |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | Petroleum | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL |
| 3,000 psig | | | | | Annapolis Report |
| 5,000 psig | | | | | MATLAB 350 |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume | 35° F | 100° F | 150° F | | |
| decrease, %, at: | | | | | See NSRDL |
| 0 psig | | | | | Annapolis Report |
| 3,000 psig | | | | | MATLAB 350 |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 395 | | | | ASTM D-92 |
| Fire Point, °F | 445 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report |
| Minimum spontaneous ignition temperature, °F | | | | | 31/66 of March 1967 |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | 0.002 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 70/60 °F | 0.866 | | | | ASTM-D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | available from supplier | | | | - |
| Availability | proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

## Fluid Code J

### Suggested Uses and Possible Limitations

Fluid Code J, a petroleum oil product, meets the requirements of the United States Pharmacopeia (USP) for medicinal mineral oils. It has been used in a deep submergence vehicle as an immersion fluid for nonmoving electrical parts. Field experience has shown that it has failed as a lubricant for electric motors and gears at 1000 psig. It provides no corrosion protection. It has satisfactory dielectric properties. Its poor sea-water emulsion stability makes it questionable for use with motors at deep submergence pressures. Although its dielectric properties are good, its relatively high viscosity makes it a questionable choice for other electrical applications at deep submergence pressures.

Fluid Code J(1)

(Petroleum Base Fluid)

| | 55° F | 100° F | [illegible]0° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | - |
| 5,000 psig | | | | | - |
| 8,000 psig | | | | | - |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Viscosity, centistokes, at 100° F, | 44.1 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 6.08 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.771 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C. 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | - 8.5 | | | | - |
| Stainless Steel, 316 | + 2.7 | | | | - |
| Copper-Nickel (70-30) | + 1.3 | | | | - |
| Aluminum, QQ-A-250-4b | +552.1 | | | | - |
| Phosphor-Bronze | - 12.7 | | | | - |
| Steel, galvanized | + 62.9 | | | | - |
| Steel, 1009 | -909.7 | | | | - |
| Aluminum, QQ-A-250-11 | +134.9 | | | | - |
| Bronze | - 10.0 | | | | - |
| Monel | - 2.4 | | | | - |
| Silver Base Brazing Alloy | + 2.5 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Inhibition (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 80 °F, ohm-cm: | | | | | |
| As-Received (2) | $12.6 \times 10^{14}$ | | | | |
| With Sea-Water Contamination: | $4.4 \times 10^{14}$ | | | | Chapter 2 Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | $5.4x10^{14}$ | | | | - |
| Filtered | $2.2x10^{14}$ | | | | - |
| Solids generated, gram | 1.16 | | | | - |
| Dissipation Factor, 80 °F, % | | | | | See Chapter 2 |
| As-Received | 0.0 | | | | Test E-2 |
| With Sea-Water Contamination: | 0.0 | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 0.9 | | | | - |
| Filtered | 0.6 | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 80 °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 27.6 | | | | |
| With sea-water contamination: | 9.0 | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | 7.2 | | | | - |
| Filtered | 28.6 | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | 0.2 | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 |
| Butyl | | | | | Test C-3 |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | Petroleum | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10 000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, % at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB 350 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | 0.12 | | | |
| Specimen appearance | | Satisfactory | | | |
| Fluid acid number increase, mg KOH/gram fluid | | 0 | | | - |
| Water acidity, mg KOH | | 0.31 | | | - |
| Insolubles, % | | nil | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 400 | | | | ASTM D-92 |
| Fire Point, °F | 435 | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | -5 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | 0.03 | | | | ASTM D-974 |
| Water Content, % by weight | 0.005 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 60/60 °F | 0.868 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | available from supplier | | | | - |
| Availability | proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted. [2]Saturated with seawater.

## Fluid Code K

### Suggested Uses and Possible Limitations

Fluid Code K meets the requirements of the National Formulary (NF) for medicinal mineral oils. As a petroleum oil product its dielectric properties have not been determined. It has been used as an immersion fluid for nonmoving electric components at depths not exceeding 2000 feet. In one particular instance in the field, it failed as a lubricant for moving parts. It provides no corrosion protection.

**Fluid Code K(1)**
**(Petroleum Base Fluid)**

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 350 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 7.68 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 2.23 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.782 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 5 kg | | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, °F, ohm-cm: | | | | | |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.3% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 Test E-6 |
| 0.1% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, °F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | | | | | See Chapter 2 Test E-5 |
| With Sea-Water Contamination: | | | | | |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | | | | | - |
| Emulsion, ml | | | | | - |
| Water, ml | | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 Test C-3 |
| Butyl | | | | | |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | Petroleum | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | 35° F | 100° F | [illegible]° F | | See NSRDL Annapolis Report MATLAB [illegible] |
| 0 psig | | | | | |
| 4,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | [illegible]° F | | See NSRDL Annapolis Report MATLAB 550 |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-[illegible] |
| Oxidation Stability Test, 250° F | | | | | Fed. Method [illegible] |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 330 | | | | ASTM D-[illegible] |
| Fire Point, °F | | | | | ASTM D-[illegible] |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-[illegible] |
| High-Pressure Spray Combustor | | | | | See MEL Report 51/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | +15 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method [illegible] |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-[illegible] |
| Color | | | | | ASTM D-[illegible] |
| Cost $/gal | available from supplier | | | | - |
| Availability | proprietary | | | | - |

[1]Determinations made to atmospheric pressure, unless noted.

## Fluid Code L

### Suggested Uses and Possible Limitations

Fluid Code L is a silicone oil containing an additive for improving lubrication. Laboratory wear measurements show that the additive has improved the lubricity when compared to a silicone of the same viscosity. However, the wear tests indicate that the lubricity of Code L is still not suitable for a motor or gear lubricant under deep submergence conditions. It affords no corrosion protection, and it is extremely flammable. Its initial dielectric properties are good. Because this product is a slight modification of MIL-S-21568A, 1-cs fluid, it should be a good second choice to the latter product for all electrical applications other than motors.

**Fluid Code L(1)**

**(Silicone Base Fluid)**

| | | | | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | 55° F | 100° F | [illegible] F | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB [illegible] |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 0.76 | | | | |
| Viscosity, centistokes, at 150° F, 0 psig | 0.44 | | | | ASTM D-44[illegible] |
| Viscosity Slope, ASTM | - | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, [illegible]0 min, 80° C, 52100 steel, average scar dia., mm: | Dry | 1% Synthetic Seawater | | | Fed. Meth. [illegible] (modified) |
| 1 kg | - | - | | | - |
| 3 kg | - | - | | | - |
| 5 kg | 0.55 | - | | | - |
| 15 kg | 0.78 | - | | | |
| 30 min, 50° C, 52100 steel 1 kg | 0.26 | 0.40 | | | |
| 60 min, 50° C, 52100 steel, 1 kg | 0.30 | 0.45 | | | |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Fail | | | | ASTM D-66[illegible] |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | | | | | See Chapter [illegible] Test C-[illegible] |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter [illegible] Test C-1 |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-2[illegible] | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| Resistivity, 76 °F, ohm-cm: | | | | | |
| As-Received | $5.0 \times 10^{11}$ | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter 2 |
| 0.1% wt/vol. | | | | | - Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 76 °F, % | | | | | See Chapter 2 |
| As-Received | 0.9 | | | | Test E-2 |
| With Sea-Water Contamination: | | | | | See Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 |
| 0.10% wt/vol. | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 76 °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 26.2 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | - |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | - |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-8 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 40 | | | | - |
| Emulsion, ml | 0 | | | | - |
| Water, ml | 40 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 Test C-3 |
| Butyl | | | | | - |
| Buna N | | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

| | Silicone | | | | Method |
|---|---|---|---|---|---|
| **Volatility** | | | | | - |
| **Toxicity** | | | | | - |
| **Density, grams/cubic centimeter, at:** | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| **Isothermal Compressibility**, volume decrease, %, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB 350 |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| **Chemical Stability** | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-19457B |
| Specimen change, mg | | | | | |
| Specimen appearance | | | | | |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| **Fire Resistance** | | | | | |
| Flash Point, °F | | | | | ASTM D-92 |
| Fire Point, °F | | | | | ASTM D-92 |
| Autogeneous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | | | | | |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| **Miscellaneous Properties** | | | | | |
| Pour Point, °F | | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | 0.030 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 5101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Color | | | | | ASTM D-1500 |
| **Cost** $/gal | available from supplier | | | | - |
| **Availability** | proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

## Fluid Code M

### Suggested Uses and Possible Limitations

Fluid Code M has a low viscosity which would indicate that it may be suitable for special requirements at great depths. Its wear test is rather good, indicating the possibility of favorable lubrication properties. It provides some corrosion inhibition. It has a low resistivity and a high dissipation factor, making it questionable for any electrical application at deep ocean pressure. It is highly flammable.

## Fluid Code M(1)
## (Petroleum Base Fluid)

| | 35° F | 100° F | 150° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | |
| 3,000 psig | | | | | See NSRDL |
| 5,000 psig | | | | | Annapolis Report |
| 8,000 psig | | | | | MATLAB 550 |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | - |
| Viscosity, centistokes, at 100° F, | 3.08 | | | | |
| Viscosity, centistokes, at 210° F, 0 psig | 1.20 | | | | ASTM D-445 |
| Viscosity Slope, ASTM | 0.865 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 60 min, 80° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6503 (modified) |
| 40 kg | 0.75 | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-665 |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter 2 Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter 2 Test C-1 |
| Copper | -14.8 | | | | - |
| Stainless Steel, 316 | + 0.3 | | | | - |
| Copper-Nickel (70-30) | - 1.1 | | | | - |
| Aluminum, QQ-A-250-4b | + 0.5 | | | | - |
| Phosphor-Bronze | - 9.8 | | | | - |
| Steel, galvanized | - 6.8 | | | | - |
| Steel, 1009 | + 0.2 | | | | - |
| Aluminum, QQ-A-250-11 | - 0.6 | | | | - |
| Bronze | - 7.8 | | | | - |
| Monel | - 1.[illegible] | | | | - |
| Silver Base Brazing Alloy | - 6.7 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter 2 Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Corrosion Protection (Cont) | | | | | |
| Electrically Coupled Specimens: | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1004 | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Electrically Coupled Specimens: | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | - |
| Monel-Bronze | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | - |
| Pump Test | | | | | Proposed military specification for sea-water emulsifying oils |
| Average Weight Loss, mg | | | | | |
| Steel Gears | | | | | |
| Bronze Bushings | | | | | |
| Corrosion Coupons, weight loss, each, mg/cm$^2$ | | | | | |
| Copper | | | | | - |
| Aluminum | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Silver Base Brazing Alloy | | | | | - |
| Dielectric Properties | | | | | |
| Resistivity, 77 °F. ohm-cm: | $2.8 \times 10^3$ | | | | ASTM D-1169 (modified). See Chapter 2. Test E-1 |
| As-Received | | | | | |
| With Sea-Water Contamination: | | | | | Chapter 2 |
| 0.1% by volume | | | | | - Test E-5 |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | Chapter ? |
| 0.1% wt/vol. | | | | | - Test E- |
| 0.25% wt/vol. | | | | | - |
| 0.5% wt/vol. | | | | | - |

| | | | | | Method |
|---|---|---|---|---|---|
| Dielectric Properties (Cont) | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | See Chapter 2 Test E-7 |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Dissipation Factor, 77 °F, % | | | | | See Chapter 2 Test E-2 |
| As-Received | >60 | | | | |
| With Sea-Water Contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | - |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | - |
| With Carbon Contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | - |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solidx generated, gram | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, 77 °F, kv | | | | | ASTM D-877 (modified). See Chapter 2. Test E-3 |
| As received | 20.6 | | | | |
| With sea-water contamination: | | | | | See Chapter 2 Test E-5 |
| 0.1% by volume | | | | | - |
| 0.5% by volume | | | | | - |
| 2.0% by volume | | | | | |
| With carbon contamination: | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | - |
| 0.25% wt/vol. | | | | | - |
| 0.50% wt/vol. | | | | | |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | |
| Not filtered | | | | | - |
| Filtered | | | | | - |
| Solids generated, gram | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | See Chapter 2 Test E-3 |
| Number of tests | | | | | - |
| Operations to failure (range) | | | | | |
| Emulsion Stability | | | | | |
| Paddle Test, after 1-hour settling: | | | | | ASTM D-1401 |
| Oil, ml | 32 | | | | - |
| Emulsion, ml | 23 | | | | - |
| Water, ml | 25 | | | | - |
| Electric Probe Test, time for water separation, min | | | | | See Chapter 2 Test E-4 |
| Material Compatibility Static 20KPSI | | | | | See Chapter 2 Test C-3 |
| Rubber swell, %, 158° F, 168 hr. | | | | | |
| Butyl | | | | | - |
| Buna N - L stock | 21.1 | | | | - |
| Buna N - H stock | 8.1 | | | | - |
| Viton B | | | | | - |
| Ethylene-Propylene | | | | | - |
| Tetrafluoroethylene (Teflon) | | | | | - |
| Neoprene | | | | | - |
| Thiokol | | | | | - |
| Silicone | | | | | - |
| Fluorosilicone | | | | | - |

* Based on atmospheric pressure data.

| | | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| Density, grams/cubic centimeter, at: | Petroleum 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL |
| 3,000 psig | | | | | Annapolis Report |
| 5,000 psig | | | | | MATLAB 350 |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Isothermal Compressibility, volume decrease, %, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL |
| 3,000 psig | | | | | Annapolis Report |
| 5,000 psig | | | | | MATLAB 350 |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| Chemical Stability | | | | | |
| Oxidation Stability Test, 205° F, hours to failure | Satisfactory | | | | ASTM D-943 |
| Oxidation Stability Test, 250° F | | | | | Fed. Method 5308 |
| Hydrolytic Stability Test | | | | | Military specifi- |
| Specimen change, mg | | | | | cation MIL-H- |
| Specimen appearance | | | | | 19457B |
| Fluid acid number increase, mg KOH/gram fluid | | | | | - |
| Water acidity, mg KOH | | | | | - |
| Insolubles, % | | | | | - |
| Thermal Stability Test | | | | | - |
| Fire Resistance | | | | | |
| Flash Point, °F | 215 | | | | ASTM D-92 |
| Fire Point, °F | 220 | | | | ASTM D-92 |
| Autogenous Ignition Temperature, °F | | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | | | | | See NEL Report |
| Minimum spontaneous ignition temperature, °F | | | | | 31/66 of March 1967 |
| Minimum reaction temperature, °F | | | | | - |
| No indication of fire, °F | | | | | - |
| Maximum pressure change, psi | | | | | - |
| Lowest temperature of maximum pressure change, °F | | | | | - |
| Temperature range explored, °F | | | | | - |
| Miscellaneous Properties | | | | | |
| Pour Point, °F | < -90 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, [illegible] | | | | | - |
| Time out, minutes | | | | | - |
| Foam after 10-minute settling, ml | | | | | - |
| Neutralization Number, mg KOH/gram | 0.03 | | | | ASTM D-974 |
| Water Content, % by weight | 0.035 | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method 3101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Specific gravity at 70/60 °F | 0.856 | | | | ASTM D-1298 |
| Color | | | | | ASTM D-1500 |
| Cost $/gal | available from supplier | | | | - |
| Availability | proprietary | | | | - |

[1]Determinations made at atmospheric pressure, unless noted.

## Fluid Code N

### Suggested Uses and Possible Limitations

Fluid Code N is a sea-water-compatible/water-glycol-type hydraulic fluid and lubricant. Its viscosity is high, but since it has a water base it is possible that pressure would increase the viscosity by only a small amount. It provides fair lubrication for all conditions except rolling contact. It provides some corrosion protection. It will be unsuitable for any electric application at deep ocean pressure since its water base gives it unsuitable dielectric properties. It is fire resistant in spite of its low flash point since it will cease to burn when the source of ignition is removed.

Fluid Code M(1)

(Water-Glycol Type Fluid)

| | 35° F | 100° F | 1[illegible]° F | | Method |
|---|---|---|---|---|---|
| **Viscometric Properties** | | | | | |
| Viscosity, centistokes, at: | | | | | |
| 0 psig | | | | | See NSRDL |
| 3,000 psig | | | | | Annapolis Report |
| 5,000 psig | | | | | NATLAB 3[illegible]0 |
| 8,000 psig | | | | | - |
| 10,000 psig | | | | | - |
| 15,000 psig | | | | | - |
| 20,000 psig | | | | | |
| Viscosity, centistokes, at 100° F, | 67.3 | | | | |
| Viscosity, centistokes, at 150° F, | 28 | | | | ASTM D-44[illegible] |
| 0 psig | | | | | |
| Viscosity Slope, ASTM | 0.533 | | | | - |
| **Lubricating Ability** | | | | | |
| 4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm: | | | | | Fed. Method 6[illegible] (modified) |
| 1 kg | | | | | - |
| 3 kg | | | | | - |
| 15 kg | 0.81 | | | | - |
| **Corrosion Protection** | | | | | |
| Stirred Rust Test, 10% seawater, 140° F, 2 days | Pass | | | | ASTM D-66[illegible] |
| On-Off Rust Test, 50% seawater, 140° F, 30 days | Fail | | | | See Chapter [illegible] Test C-5 |
| Ambient Pressure, coupon stirred, corrosion test, weight change, mg | | | | | See Chapter [illegible] Test C-1 |
| Copper | + 3.9 | | | | - |
| Stainless Steel, 316 | + 0.5 | | | | - |
| Copper-Nickel (70-30) | + 1.3 | | | | - |
| Aluminum, QQ-A-250-4b | + 1.4 | | | | - |
| Phosphor-Bronze | - 3.3 | | | | - |
| Steel, galvanized | - 6.0 | | | | - |
| Steel, 1009 | -452.4 | | | | - |
| Aluminum, QQ-A-250-11 | - 0.7 | | | | - |
| Bronze | + 3.2 | | | | - |
| Monel | + 1.1 | | | | - |
| Silver Base Brazing Alloy | - 9.2 | | | | |
| 20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg | | | | | See Chapter [illegible] Test C-2 |
| Insulated Specimens: | | | | | |
| Copper | | | | | - |
| Stainless Steel, 316 | | | | | - |
| Copper-Nickel (70-30) | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | - |
| Phosphor-Bronze | | | | | - |
| Steel, galvanized | | | | | - |
| Steel, 1009 | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | - |
| Bronze | | | | | - |
| Monel | | | | | - |
| Silver Base Brazing Alloy | | | | | - |

| | | | | | | [illegible] |
|---|---|---|---|---|---|---|
| **Corrosion Protection (Cont)** | | | | | | |
| Electrically Coupled Specimens: | | | | | | - |
| Copper-Aluminum, QQ-A-250-11 | | | | | | - |
| Aluminum QQ-A-250-4b - Copper-Nickel (70-30) | | | | | | - |
| Monel-Bronze | | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | | - |
| Aluminum QQ-A-250-11 - Bronze | | | | | | - |
| Aluminum QQ-A-250-4b - Steel, 1009 | | | | | | - |
| 20,000 PSIG Stirred Corrosion Test, weight change, mg | | | | | | See Chapter 2 Test C-4 |
| Insulated Specimens: | | | | | | |
| Copper | | | | | | - |
| Stainless Steel, 316 | | | | | | - |
| Copper-Nickel (70-30) | | | | | | - |
| Aluminum, QQ-A-250-4b | | | | | | - |
| Phosphor-Bronze | | | | | | - |
| Steel, galvanized | | | | | | - |
| Steel, 1009 | | | | | | - |
| Aluminum, QQ-A-250-11 | | | | | | - |
| Bronze | | | | | | - |
| Monel | | | | | | - |
| Silver Base Brazing Alloy | | | | | | - |
| Electrically Coupled Specimens: | | | | | | |
| Copper-Aluminum, QQ-A-250-11 | | | | | | - |
| Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) | | | | | | - |
| Monel-Bronze | | | | | | - |
| Stainless Steel (316) - Phosphor-Bronze | | | | | | - |
| Silver Base Brazing Alloy - Steel, 1009 | | | | | | - |
| Aluminum, QQ-A-250-11 - Bronze | | | | | | - |
| Aluminum, QQ-A-250-4b - Steel, 1009 | | | | | | - |
| Pump Test | | | | | | Proposed military |
| Average Weight Loss, mg | | | | | | specification for |
| Steel Gears | 8.1 | | | | | sea-water emulsi- |
| Bronze Bushings | 35.1 | | | | | fying oils |
| Corrosion Coupons, weight loss, each, $mg/cm^2$ | | | | | | |
| Copper | | | | | | - |
| Aluminum | | | | | | - |
| Steel, galvanized | | | | | | - |
| Steel, 1009 | | | | | | - |
| Silver Base Brazing Alloy | | | | | | - |
| **Dielectric Properties** | | | | | | ASTM D-1169 (modi- |
| Resistivity, °F, ohm-cm: | | | | | | fied), see Chap- |
| As-Received | | | | | | ter 2, Test E-1 |
| With Sea-Water Contamination: | | | | | | Chapter 2 |
| 0.1% by volume | | | | | | Test E- |
| 0.5% by volume | | | | | | - |
| 2.0% by volume | | | | | | - |
| With Carbon Contamination: | | | | | | Chapter 2 |
| 0.1% wt/vol. | | | | | | Test E-6 |
| 0.25% wt/vol. | | | | | | - |
| 0.5% wt/vol. | | | | | | - |

| | | | | | | Method |
|---|---|---|---|---|---|---|
| Dielectric Properties (Con.) | | | | | | |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | | See Chapter [illegible] Test E-7 |
| Not filtered | | | | | | - |
| Filtered | | | | | | - |
| Solids generated, gram | | | | | | - |
| Dissipation Factor, °F, [illegible] | | | | | | See Chapter [illegible] Test E-[illegible] |
| As-Received | | | | | | |
| With Sea-Water Contamination: | | | | | | See Chapter [illegible] Test E-[illegible] |
| 0.1% by volume | | | | | | - |
| 0.5% by volume | | | | | | - |
| 2.0% by volume | | | | | | - |
| With Carbon Contamination: | | | | | | See Chapter 2 Test E-[illegible] |
| 0.10% wt/vol. | | | | | | |
| 0.25% wt/vol. | | | | | | - |
| 0.50% wt/vol. | | | | | | - |
| After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | | |
| Not filtered | | | | | | - |
| Filtered | | | | | | - |
| Solids generated, gram | | | | | | - |
| Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv | | | | | | ASTM D-877 (modified). See Chapter 2. Test E-5 |
| As received | | | | | | |
| With sea-water contamination: | | | | | | See Chapter 2 Test E-[illegible] |
| 0.1% by volume | | | | | | |
| 0.5% by volume | | | | | | - |
| 2.0% by volume | | | | | | - |
| With carbon contamination: | | | | | | See Chapter 2 Test E-6 |
| 0.10% wt/vol. | | | | | | |
| 0.25% wt/vol. | | | | | | - |
| 0.50% wt/vol. | | | | | | - |
| After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load | | | | | | |
| Not filtered | | | | | | - |
| Filtered | | | | | | - |
| Solids generated, gram | | | | | | - |
| Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F | | | | | | See Chapter [illegible] Test E-3 |
| Number of tests | | | | | | - |
| Operations to failure (range) | | | | | | |
| Emulsion Stability | | | | | | |
| Paddle Test, after 1-hour settling: | | | | | | ASTM D-1401 |
| Oil, ml | | | | | | - |
| Emulsion, ml | | | | | | - |
| Water, ml | | | | | | - |
| Electric Probe Test, time for water separation, min | | | | | | See Chapter [illegible] Test E-[illegible] |
| Material Compatibility Static 200RPSI* | | | | | | See Chapter [illegible] Test C-3 |
| Butyl | Good | | | | | |
| Buna N | Good | | | | | - |
| Viton B | Good | | | | | - |
| Ethylene-Propylene | Good | | | | | - |
| Tetrafluoroethylene (Teflon) | Good | | | | | - |
| Neoprene | Fair-Good | | | | | - |
| Thiokol | - | | | | | - |
| Silicone | Poor | | | | | - |
| Fluorosilicone | Poor | | | | | - |

* Based on atmospheric pressure data

| Property | Pass Water Glycol | | | | Method |
|---|---|---|---|---|---|
| Volatility | | | | | - |
| Toxicity | | | | | - |
| **Density**, grams/cubic centimeter, at: | 35° F | 100° F | 150° F | | |
| 0 psig | | | | | See NSRDL Annapolis Report MATLAB [illegible] |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| **Isothermal Compressibility**, volume decrease, %, at: | 35° F | 100° F | 150° F | | See NSRDL Annapolis Report MATLAB [illegible] |
| 0 psig | | | | | |
| 3,000 psig | | | | | |
| 5,000 psig | | | | | |
| 8,000 psig | | | | | |
| 10,000 psig | | | | | |
| 15,000 psig | | | | | |
| 20,000 psig | | | | | |
| **Chemical Stability** | | | | | |
| Oxidation Stability Test, 203° F, hours to failure | | | | | ASTM D-94[illegible] |
| Oxidation Stability Test, 250° F | | | | | Fed. Method [illegible] |
| Hydrolytic Stability Test | | | | | Military specification MIL-H-194[illegible]78 |
| Specimen change, mg | | 0.02 | | | |
| Specimen appearance | | Satisfactory | | | |
| Fluid acidity pH | | 9.8 | | | - |
| Insolubles, % | | nil | | | - |
| | | | | | - |
| Thermal Stability Test | | | | | - |
| **Fire Resistance** | | | | | |
| Flash Point, °F | 265 | | | | ASTM D-92 |
| Fire Point, °F | 270 | | | | ASTM D-9[illegible] |
| Autogeneous Ignition Temperature, °F | 825 | | | | ASTM D-2155 |
| High-Pressure Spray Combustor | - | | | | See MEL Report 31/66 of March 1967 |
| Minimum spontaneous ignition temperature, °F | 500 | | | | |
| Minimum reaction temperature, °F | 460 | | | | - |
| No indication of fire, °F | 450 | | | | - |
| Maximum pressure change, psi | 200 | | | | - |
| Lowest temperature of maximum pressure change, °F | 560 | | | | - |
| Temperature range explored, °F | 450-560 | | | | - |
| **Miscellaneous Properties** | - | | | | |
| Pour Point, °F | -[illegible]0 | | | | ASTM D-97 |
| Foaming Tendency, 75° F | | | | | ASTM D-892 |
| Foam after 5-minute aeration, ml | 280 | | | | - |
| Time out, minutes | 4 | | | | - |
| Foam after 10-minute settling, ml | 0 | | | | - |
| Neutralization Number, mg KOH/gram | | | | | ASTM D-974 |
| Water Content, % by weight | | | | | ASTM D-1744 |
| Neutrality, qualitative | | | | | Fed. Method [illegible]101 |
| Contamination | | | | | - |
| Number and size of particles and fibers in 100-ml fluid | | | | | SAE Method ARP-598 |
| 25-100 micrometers | | | | | - |
| 100-500 micrometers | | | | | - |
| over 500 micrometers | | | | | - |
| particles over 250 micrometers except fibers (length ten times diameter) | | | | | - |
| Gravimetric Value, mg/100 ml | | | | | SAE Method ARP-785 |
| Color | | | | | ASTM D-1500 |
| **Cost** $/gal | Available from supplier | | | | - |
| **Availability** | Proprietary | | | | - |

[1] Determinations made at atmospheric pressure, unless noted.

Fluid Code N

| Material Compatibility with:* | | Method |
|---|---|---|
| Natural Rubber | Fair | See Chapter 2 Test C-3 |
| Polyurethane | Poor | |

* Based on atmospheric pressure data.

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13. ABSTRACT


The critical factors involved in the selection of fluids and lubricants for deep ocean equipment are defined, and methods of determining critical properties are described. The values of critical properties are given for fluids and lubricants as they have been determined or are known from previous literature. Suggestions also are given on the applicability and possible limitations of the fluids and lubricants for deep submergence vehicle use. It is planned to revise and update the contents of this handbook periodically.

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| Pressures | | | | | | |
| Fluids | | | | | | |
| Properties | | | | | | |
| Power | | | | | | |
| Lubrication | | | | | | |
| Shielding | | | | | | |