SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J1778

REV. NOV1998

Issued 1972-04
Revised 1998-11

Superseding J1778 FEB89

Submitted for recognition as an American National Standard

(R) Ship Systems and Equipment—Recommended Practice for Hydraulic Fluid Selection

1. *Scope*—This SAE Recommended Practice identifies general requirements for hydraulic fluids to be used for ship systems and equipment with respect to power transmission, lubrication, and passive applications. It also indicates the environmental limits within which the fluids shall perform their intended purpose satisfactorily and reliably. Characteristics of particular importance to ship systems and equipment are discussed.

1.1 Purpose—This document provides the general environment and equipment imposed requirements that dictate fluid and lubricant characteristics. The purpose of this document is to provide system and equipment designers with guidance necessary for the selection of a satisfactory hydraulic fluid for a particular application. This document does not recommend a particular fluid for any application. Rather, this document identifies the parameters that must be considered in the selection of fluids. Examples of specification and typical values for properties of fluids often used in ships systems and equipment are listed in Appendix A. While most of the data applies to Military Specification fluids, many commercial fluids are available with similar properties.

2. *References*

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

The following documents are listed to be utilized only as a guide. The specifications are to serve as a guide to the types of fluids and lubricants available. The other references are to serve as guide to the available methods to define fluid characteristics.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE AIR81—Hydrocarbon Based Hydraulic Fluid Properties
SAE AS1241—Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft
SAE AIR1362—Physical Properties of Aerospace Hydraulic Fluids
SAE J1779—Hydraulic System Design Criteria for High Performance Surface Vehicles and Small Submersible Vehicles

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 92—Flash and Fire Points by Cleveland Open Cup
ASTM D 93—Flash Point by Pensky-Martens Closed Tester
ASTM D 97—Pour Point of Petroleum Products
ASTM D 287—API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
ASTM D 445—Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)
ASTM D 665—Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water, Test for
ASTM D 943—Oxidation Characteristics of Inhibited Mineral Oils, Test for
ASTM D 972—Evaporation Loss of Lubricating Greases and Oils, Test for
ASTM D 892—Foaming Characteristics of Lubricating Oils
ASTM D 1298—Density, Specific Gravity, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method, Test for
ASTM D 1401—Water Solubility of Petroleum Oils and Synthetic Fluids, Test for
ASTM D 1947—Load-Carrying Capacity of Petroleum Oil and Synthetic Fluid Gear Lubricants, Test for
ASTM D 2270—Calculating Viscosity Index from Kinematic Viscosity at 40 and 100 °C
ASTM D 2619—Hydrolytic Stability of Hydraulic Fluids (Beverage Bottle Method) Test for
ASTM D 4898—Insoluble Contamination of Hydraulic Fluids by Gravimetric Analysis
ASTM D 5864—Determining Aerobic Biodegradation of Lubricants or Their Components

2.1.3 NFPA PUBLICATIONS—Available from National Fluid Power Association, 3333 N. Mayfair Road, Milwaukee, WI 53222-3219.

NFPA T2.13.3—Bibliography of non-proprietary hydraulic fluid specifications and selected recommended practices

2.1.4 U. S. GOVERNMENT PUBLICATIONS—Available from DODSSP, Subscripton Services Desk, Building 4D, 700 Robins Avenue, Philadelphia, PA 19111-5094.

2.1.4.1 Military Handbooks

MIL-HDBK-267(SH)—Guide for Selection of Lubricants & Hydraulic Fluids for Use in Shipboard Equipment

2.1.4.2 Federal Specifications

Federal Specification—VV-D-1078—Damping Fluid, Silicone Base (Dimethyl Polysiloxane)

2.1.4.3 Federal Standards

Federal Test Method Standard 791—Methods of Testing Lubricants, Liquid Fuels, and Related Products

2.1.4.4 Military Specifications

MIL-H-5606—Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance (Inactive for new design)
MIL-H-6083—Hydraulic Fluid, Petroleum Base, for Preservation and Testing
MIL-F-17111—Power Transmission Fluid
MIL-L-17331—Lubricating Oil, Steam Turbine, Non-Corrosive
MIL-PRF-17672—Hydraulic Fluid Petroleum Inhibited
MIL-H-19457—Hydraulic Fluid, Fire-Resistant
MIL-H-22072—Hydraulic Fluid, Catapult
MIL-PRF-23699—Lubricating Oil, Aircraft Turbine Engines, Synthetic Base
MIL-PRF-83282—Hydraulic Fluid, Fire-Resistant Synthetic Hydrocarbon, Aircraft

2.1.5 DEFENCE STANDARDS—Available from Ministry of Defence, Directorate of Standardization, Kentigern House, 65 Brown Street, Glasgow G2 8AR.

DEF STAN 91-35—Hydraulic Fluid Petroleum, Emulsifying, Joint Service Designation: OX-30

2.2 Other Publications—(Order by AD Number from Defense Technical Information Center, 8725 John J Kingman Road, Suite 0944, Fort Belvoir, VA 22060-6218.)

2.2.1 "Handbook of Fluids and Lubricants for Deep Ocean Applications," compiled and edited by R.W. McQuaid and C.L. Brown, Naval Ship R&D Laboratory, Annapolis, MD, Report MATLAB 360 - REV. AD-893-990L

2.2.2 "Viscosity of Seven Fluids at Ambient Deep Submergence Temperatures and Pressures," D.R. Ventrigilo, C.L. Brown, and R.W. McQuaid, Naval Ship R&D Laboratory, Annapolis, MD, Report 8-350 (also contains measurements of fluid compressibility), AD-686-244L

3. Definitions

3.1 Viscosity Index—An arbitrary number used to characterize the variation of the kinematic viscosity with temperature. For fluids of similar kinematic viscosity, the higher the viscosity index the smaller the effect of temperature on its kinematic viscosity. (See ASTM D 2270).

4. Fluid Properties

4.1 Fluid Properties and their Influence—Hydraulic fluids have many physical and chemical properties which must be considered in the design of a hydraulic system. These properties and their primary influence are listed in Table 1. The importance of any particular factor will often depend upon the design of the hydraulic system. For guidance on hydraulic system design for ship systems see SAE J1779.

TABLE 1—FLUID PROPERTIES AND THEIR INFLUENCE

Fluid Property	Primary Influence	Section
1. Bulk Modulus	System Stiffness	5.1.8
2. Viscosity	Power Losses	5.1.1
3. Density and Compressibility	System Weight and Power Losses	5.1.8
4. Specific Heat	Thermal Characteristics	
5. Thermal Conductivity	Heat Exchange	
6. Thermal Expansion	Reservoir Sizing	
7. Chemical Stability (Oxidation)	Formation of Breakdown Products	5.1.9
8. Thermal Stability	Deterioration of Fluid Properties	
9. Shear Stability	Viscosity and Loss of Lubricity	5.1.12
10. Hydrolytic Stabiility and Effects of Sea Water	Corrosion	5.1.3 to 5.1.4
11. Lubricity	Component Wear	5.1.2
12. Compatibility	System Materials	5.1.6
13. Volatility	Cavitation and Evaporation	5.1.7
14. Toxicity	Safety	5.1.7
15. Foaming	Cavitation and System Stiffness	5.1.11
16. Fire Resistance	Safety	5.1.10
17. Cleanliness	System Wear and Filtration Requirements	5.1.5
18.Dielectric Breakdown	Loss of Resistivity	5.1.13
19. Dampening	Viscosity	5.1.14
20. Biodegradability	Aerobic Aquatic Biodegradation	5.1.15

NOTE—Table 1 listing sequence has no bearing on relative importance.

The first six fluid properties listed are addressed in SAE AIR1362 and SAE AIR81 in greater detail than covered herein. This document provides invaluable insight to the ship system and equipment designer by relating many of the previous properties to the three major types of application for ship system hydraulic fluids as well as providing typical industry values for applicable fluids.

The three applications are:

Use 1—Power Transmission
Use 2—Lubrication
Use 3—Passive Applications

5. General Fluid and Lubricant Requirements—This section presents characteristics of fluids and lubricants as they are affected by system design and environment. The fluid characteristics will be presented in the framework of the three use applications of 4.1 and as they apply to all pertinent ship systems and equipment. There is also the possibility of using sea water from the environment to serve as the fluid. This possibility presents certain special requirements which are discussed only briefly in this document.

5.1 Fluid Characteristics—SAE AIR1362 identifies the physical properties of many fluids. Tests for measurement of several fluid characteristics are listed in 2.1.2. NFPA T2.13.3 is a bibliography containing references to many fluids specifications and tests used to evaluate fluids. FED-STD-791 contains many tests that can be used to evaluate hydraulic fluids.

5.1.1 VISCOSITY

*5.1.1.1 Use 1—(Power Transmission)—*The designer of the system or components usually establishes the viscosity requirements. The requirement for viscosity in a power transmission system is dependent on system design and independent of vehicle type. Low fluid viscosity is desirable for efficient power transmission, while suitable viscosity must be maintained for pump efficiency and lubrication. Fluid viscosity is affected by heat development in a system and by ambient temperatures. It also is affected by vehicle operating depth in the case of hydraulic systems placed outside the pressure hull and filled with fluid exposed to the ambient temperature and pressure. Minimum sea water temperature is –2 °C. While operating temperature is the principal factor in viscosity control, fluids in external systems on deep submersibles will show a significant 3 to 5 fold increase in viscosity due to the effect of pressure at 3000 m. Publications listed in 2.2.1 and 2.2.2 provide discussions on the effects of pressure on fluid viscosity and pressure-viscosity data on deep submergence fluids. Figures A1 through A4 of Appendix A provide pressure-viscosity data on some petroleum base fluids commonly used in ship hydraulic systems. Figure A5 shows temperature-viscosity data on the same fluids. Fluids that have the greatest viscosity changes with temperature change, also have the greatest change in viscosity due to pressure change.

*5.1.1.2 Use 2—(Lubrication)—*The immersion of moving equipment such as motors and pumps in a lubricant presents a new problem introduced by deep submersible vehicles. The viscosity increase due to hydrostatic pressure causes a viscous medium drag on the moving parts and diminishes efficiency and can cause brushes to lose contact. Low viscosity oils, less than 10 centistokes at 40 °C, can be used to overcome this problem. Bearing lubricity can be improved synthetically when the viscosity is too low for formation of a good hydrodynamic film. Gear lubrication presents a serious problem and may require designing for light loads when operating in a fluid with inferior lubricity.

*5.1.1.3 Use 3—(Passive Applications)—*Viscosity is of minor importance in all vehicles and systems where a fluid is present for environment control (that is, corrosion prevention, pressure compensation, insulation, dielectric characteristics).

The one exception occurs when the fluid acts as a heat sink medium in electrical systems in which the most severe problem is usually contamination. If the fluid is very viscous, the contaminant will not settle out rapidly and may cause serious operational problems such as short circuits. Since circulation is not part of the system, it is not possible to filter the fluid.

5.1.2 LUBRICITY

5.1.2.1 *Use 1*—The lubrication of pump bearings, motor bearings, and valve internals is required of the fluid in almost all ship hydraulic systems. The component wear considerations for a lubricant are as follows:

Prepressurized Systems
Type of Pump Used
Frequency of Operation
Operating Pressure
Actuator Load
Load Impact Anticipation
System Materials
Operating Temperature
Pump Speed
Accumulator Design
Valve Design
Fluid Cleanliness

When these conditions are specified, the system fluid lubricity can be defined. In cases where sea water is used as a fluid, the low lubricity of sea water must be considered in the equipment design.

5.1.2.2 *Use 2*—The same considerations are required as in 5.1.2.1. Also see 2.2.1, Sec. III, pp 74, 80.

5.1.2.3 *Use 3*—Lubricity need only be considered in systems with moving parts. In nearly all cases of Use 3, lubricity is not a consideration.

5.1.3 CORROSION PROTECTION

5.1.3.1 *Use 1*—The fluid in any power transmission system should provide corrosion protection for system components. This property becomes increasingly important in undersea systems and in surface vehicles where sea water contamination becomes likely. Fluids must be capable of protecting ferrous and nonferrous metals from the corrosive effects of sea water. Corrosion products add to fluid system particulate contamination and can cause clogging of orifices, improper seating of valves and seals, and wear on moving surfaces. If sea water is used as a fluid, special materials that will resist corrosion must be selected.

NOTE—Barium additives in fluids, such as preservative fluid MIL-H-6083, have caused valve sticking when the preservative fluid has not been removed upon component installation. Some activities are now using system fluid for component preservation to prevent this problem.

5.1.3.2 *Use 2*—Lubrication properties are often radically altered when corrosion takes place in the lubricant. Chemical changes taking place in the lubricant caused by reactions with metal ions and salts from corrosion can alter load-carrying ability and surface-active properties. The physical changes that result are degraded component operating surfaces and sub-surfaces with the formation and release of hard particles which can severely alter lubricity and promote wear on system component operating surfaces. If sea water is used as a fluid, components must be specially designed due to the poor lubricity of sea water. Also see 2.2.1, Sec. III, pp 74, 80.

5.1.3.3 *Use 3*—The same considerations as apply to Uses 1 and 2 apply. Although there are no moving parts, there is still the need for the corrosion protection of metal components.

5.1.4 EFFECT OF SEA WATER CONTAMINATION

5.1.4.1 *Use 1*—The effect of sea water corrosion is discussed in 5.1.3. Oils with superior corrosion-inhibiting properties often contain additives which will emulsify sea water. The change in viscosity may impair the operation of a hydraulic system. In small submersible vehicles of 100 m or greater depth capability, it has been common practice, in order to conserve space, to place the hydraulic system external to the pressure hull with motor, pump, and control valves in the fluid sump to utilize the hydraulic fluid for environmental control and pressure compensation as well as power transmission. In such cases, the hydraulic fluid must have good electrical insulating properties even when there is some sea water contamination. When sea water is used as a fluid, electrical components must be isolated from the fluid.

It should be noted that inhibited fluids such as MIL-H-6083 which may provide excellent sea water corrosion protection may form insoluble reaction products with sea water which could adversely affect hydraulic system operation. However, emulsifying petroleum-base fluids are available which provide good corrosion protection against water and sea water up to 10% by volume. OX-30 per Defence Standard 91-35 is one such fluid with a viscosity of 32 centistokes at 40 °C.

5.1.4.2 *Use 2*—The considerations discussed in 5.1.4.1 also apply here.

5.1.4.3 *Use 3*—The primary consideration here is the electrical insulating ability of the fluid which is discussed in 5.1.4.1.

5.1.5 CLEANLINESS

5.1.5.1 *Use 1*—Cleanliness in hydraulic fluids has received considerable attention in recent years. There are some undersea vehicle hydraulic systems which seem to be able to function efficiently with only moderate attention to fluid cleanliness. Some marine vehicles have systems that more closely resemble aerospace hydraulic systems and are extremely sensitive to contamination. Fluid cleanliness is of primary importance as contaminants can cause malfunction of components, prevent proper seating of valves, cause wear in components (which increases systems contamination), reduce fluid resistance to oxidation and alter dielectric properties of the fluid. Silt may significantly increase the response time of servo valves. Initial fluid cleanliness can be achieved by procuring fluid packaged to stringent cleanliness requirements or by filtering all fluid added to the system. Installation of properly sized filters in the system to maintain cleanliness is recommended in preference to periodic flushing using portable filter units.

The cleanliness requirements to be specified for a fluid must be based on system and component cleanliness requirements. From a cost standpoint, the fluid cleanliness requirement should not be significantly more stringent than that which can be maintained by the system filters. Many fluids are produced to established cleanliness requirements. If more stringent fluid cleanliness is required for a particular application, it may be less expensive to clean the standard fluid before or during installation than to buy the fluid to special cleanliness requirements. Another alternative is to install a filter which cleans fluid being added to the system.

5.1.5.2 *Use 2*—The presence of dirt in a lubricant obviously reduces its effectiveness and causes increased wear in the system. In some types of bearings, a small amount of dirt may initiate a catastrophic failure. The other considerations are similar to those in 5.1.5.1 and use limits are often needed to ensure that fluid qualities are maintained.

5.1.5.3 *Use 3*—Since dirt may have an influence on fluid dielectric properties, cleanliness becomes one of the important factors to consider in Use 3 where electric switching equipment is involved.

5.1.6 MATERIAL COMPATIBILITY—The use of compatible materials in a system that will contain a hydraulic fluid or lubricant is of equal importance for all three use classes. No system should be designed without considering the most appropriate fluid for the application, and no material should be selected that will react with the fluid. When a fluid is selected, a list of compatible materials should be consulted to determine if all metals, coatings, seals, and elastomers both in the system and the area, in case of spills, will be compatible with the fluid. Incompatible coatings or elastomers may cause the formation of sludge in the fluid or cause the system to develop leaks where incompatible elastomers are used for sealing. It should be noted that zinc and cadmium plate are not compatible with many fluids, and copper components, such as piping, may react with sulfur-containing petroleum fluids. Table 2 is useful as a general guide for fluid-seal compatibility and for comparison of physical properties of elastomers. Many seal manufacturer's catalogs provide more extensive lists for the compatibility of various fluids and seal materials.

TABLE 2—SEAL PROPERTIES AND FLUID COMPATIBILITY

HYDRAULIC FLUIDS / **SEAL MATERIALS**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
AIRCRAFT PHOSPHATE ESTER (Typical: SAE AS1241)	U	U	F	U	E	U	U	D	G
TRI ARYL PHOSPHATE ESTER (Typical: MIL-H-19457)	U	U	E	U	E	G	U	D	E
MEDIUM ANALINE POINT PETROLEUM OIL (Typical: MIL-PRF-17672)	E	U	U	FG	U	E	U	U	E
LOW ANALINE POINT PETROLEUM OIL (Typical: MIL-F-17111)	E	U	U	F	U	E	U	U	E
SYNTHETIC HYDROCARBON (Typical: MIL-PRF-83282)	E	U	U	F	U	E	U	D	E
GENERAL SEAL PROPERTIES WITH COMPATIBLE FLUIDS									
IMPERMEABILITY	G	F	E	G	G	G	F	P	G
COLD RESISTANCE	G	F	G	G	GE	F	G	E	E
TEAR RESISTANCE	FG	PF	FG	FG	GE	F	GE	PF	E
ABRASION RESISTANCE	G	G	FG	GE	GE	G	E	PF	E
SET RESISTANCE	GE	F	FG	F	GE	GE	G	GE	P
DYNAMIC PROPERTIES	GE	G	F	F	GE	GE	G	P	P
TENSILE STRENGTH	GE	GE	G	G	GE	GE	E	P	E
WATER/STEAM RESISTANCE	FG	FG	G	F	E	FG	FG	F	E
HEAT RESISTANCE	G	F	GE	F	E	E	F	E	E

E = EXCELLENT P = POOR
G = GOOD D = DOUBTFUL
F = FAIR U = UNSATISFACTORY

1. NITRILE (BUNA-N)
2. STYRENE BUTADIENE (SBR, BUNA-S)
3. BUTYL RUBBER
4. CHLOROPRENE (NEOPRENE)
5. ETHYLENE PROPYLENE RUBBER
6. FLUOROCARBON RUBBER
7. NATURAL RUBBER
8. SILICONE
9. PTFE (PLASTIC) - Polytetrafluorethylene

5.1.7 VOLATILITY AND TOXICITY—These properties are applicable to all use classes. Nearly all volatile materials possess a certain degree of toxicity, but not all toxic fluids are volatile. Fluids with any significant toxicity should be avoided because of the danger to human health and the environment in handling the fluids even if a system failure is unlikely to endanger personnel (as in the case of an unmanned submersible vehicle). Volatile and toxic fluids require careful management during storage, handling, and system maintenance to ensure adequate ventilation, protection of personnel, and protection from sources of ignition.

5.1.8 DENSITY AND COMPRESSIBILITY

5.1.8.1 *Use 1*—A fluid specific gravity of less than 1.0 is desirable in weight critical applications although with proper design, most systems can tolerate a specific gravity over 1.0. Most petroleum base hydraulic fluids have a volume decrease between 5 and 7% in the range from atmospheric pressure to 13.8 x 10^7 pascal (20 000 psi) (see 2.2.2). Some sluggishness in operation will be observed if a highly compressible fluid is selected; in small, low-speed vehicles this does not present a serious problem, but must be considered in the operating instructions. (Compressibility is usually calculated from measurement of the fluid's bulk modulus.) Consideration also should be given to the effect of operating over a wide temperature range on the fluid's density and compressibility (bulk modulus). In military applications, where avoidance of detection is desirable, a fluid specific gravity greater than one may be desirable, as leaking fluid will sink rather than rise to the surface.

5.1.8.2 *Use 2*—The density requirements for lubricants are the same as for Use 1 (see 5.1.8.1). Compressibility of lubricants does not ordinarily play an important role in their usefulness. There is a possibility that the lubricant circulation rate could be affected by a volume change. This latter problem can be planned for in the initial system design.

5.1.8.3 *Use 3*—Density requirements are the same here as for Uses 1 and 2. Oil flooded systems must be designed to allow sufficient fluid so that the system components will still be protected from the environment in spite of a 5% or greater volume reduction.

5.1.9 OXIDATION STABILITY

5.1.9.1 *Use 1*—Failure of the fluid in a power transmission system to resist oxidation creates a hostile environment for the system components even in absence of contamination. Oxidation of the fluid, results in the formation of sludge and viscosity changes which promote wear and impair the operation of the system. The remaining liquid is usually acidic and shows corrosive tendencies to metal parts which impair system operation and reduce the life of system components.

5.1.9.2 *Use 2*—All of the effects of low oxidation stability mentioned in 5.1.9.1 apply to lubrication. In addition, a lubricant is often selected with a viscosity to provide optimum lubrication for bearing type, clearance, and speed. If oxidation changes the viscosity in either direction, the design criteria may not be met and lubrication may be inadequate, perhaps resulting in premature system failure.

5.1.9.3 *Use 3*—The corrosive nature of the oxidation products of fluids and lubricants has been mentioned in 5.1.9.1 and is of significance here as well. An electric arc in a fluid under pressure has been observed to cause the formation of large particles of carbon or silica depending on the chemical composition of the fluid. In some cases, carbon particles formed across the gap between the electrodes that produced the arc causing failure due to a conductive path between terminals. It has not been established whether a relationship exists between oxidation stability and arc breakdown.

5.1.10 FIRE RESISTANCE AND AUTOIGNITION

5.1.10.1 Use 1—Fire hazards exist in hydraulic systems which are located inside the marine vehicle and, in such cases, care must be taken to eliminate air from the system and avoid overheating of the system to prevent fire and autoignition. Such hazards generally do not exist in systems which are placed external of the vehicle's hull. Care must always be taken to prevent fire during draining or filling of any system with a combustible fluid. The low viscosity fluids in deep diving vehicles and in some surface vehicles are more readily ignited than the fluids used on conventional submarines and surface vessels, and greater precautions should be taken to prevent ignition. The operating fluid temperature range should be out of the fire hazardous zone with ignition source as far as possible from the fluid. As a guide, the fire hazard zone is bordered by the flash and fire points and the autogenous ignition temperature. Fire resistance is also measured by spray ignition and hot manifold tests.

See NFPA T2.13.3 .for identification of tests which may be used to evaluate fire resistance.

5.1.10.2 Use 2—Same considerations as in 5.1.10.1.

5.1.10.3 Use 3—As long as air is excluded from the system, no problem exists in Use 3 other than at drain and refill of the system. Thermal and pressure expansion and contractions must be considered in the design so that air is not admitted to the system during fluid contraction as has occurred in certain reported mishaps.

5.1.11 FOAMING

5.1.11.1 Use 1—Foam, an emulsion of gas bubbles in the fluid, can cause hydraulic component malfunction and reduced system response. The presence of foam in hydraulic fluid is due to the compressibility properties of gas. At high pressure, a fluid can contain a greater volume of gas or air bubbles. When this fluid is depressurized, as in a reservoir, the gas bubbles in the fluid expand and foaming occurs. Foaming can cause pump cavitation. It also reduces the bulk modulus of the fluid producing poor system response and spongy control. To prevent foaming, defoaming agents are often added to the fluid. The Use 2 temperature concerns can also be present in Use 1 applications.

5.1.11.2 Use 2—Foaming is equally detrimental to lubrication applications. In addition to the previous considerations, compression of an aerated fluid increases its temperature which can cause thermal breakdown and oxidation leading to decreased viscosity, component wear, and corrosion.

5.1.11.3 Use 3—Same conditions apply as for other uses as there is a need for protection of metal components. Also, fluid aerated at high pressures and expelled through vents or filler tubes can lead to fires in hot spots.

5.1.12 SHEAR STABILITY—Heavy mechanical shear forces can break down molecular bonds in some fluids such as MIL-F-17111. If the fluid used cannot handle the shear forces without breakdown, system components must be able to handle any changes. Mechanical shear forces are highest when high fluid velocities meet small clearances. Bond breakdown affects viscosity and lubrication. Use 1 and Use 2 are most affected.

5.1.13 DIELECTRIC PROPERTIES—A pressure-compensating fluid for electric motors, relays, switching devices, and electronic equipment must have good dielectric properties and should be inert to the effects of electrical equipment operation. The dielectric quality of a fluid is measured by electrical resistivity, dissipation factor, and dielectric breakdown voltage. See 2.2.1 for a discussion of these properties and resistivity data on various fluids.

5.1.14 DAMPENING—When a hydraulic fluid is used as a dampening fluid, the viscosity of the fluid is of prime consideration. VV-D-1078, a silicone base damping fluid, is available in viscosities of 0.65 through 2 500 000 centistokes. This material is also used as transducer fluids, lubricants, heat transfer fluids, dielectric fluids, and hydraulic fluids.

5.1.15 BIODEGRADABLE PROPERTIES—As environmental concerns become more important, biodegradability of hydraulic fluids is often a factor in their selection. ASTM D 5864 is a test for determining the aerobic aquatic biodegradation of lubricants. Test substances that achieve a high degree of biodegradation in this test may be assumed to easily biodegrade in many aerobic aquatic environments. Some vegetable-based biodegradable hydraulic fluids offer the following advantages over petroleum-base fluids:

a. Pollution Prevention—No “rainbow” or sheen on water from spills
b. Non-Hazardous Disposal
c. Higher Viscosity Index and Higher Flash Point

5.2 Fluids Recommended for Use in Ship Systems and Equipment

5.2.1 GENERAL RECOMMENDATIONS—Where suitable, it is recommended that the guidance of MIL-HDBK-267 be followed in selection of hydraulic fluids for military ship systems and equipment. The fluids and lubricants listed in MIL-HDBK-267 have definitive specifications and are usually available from multiple sources.

5.2.2 CONSIDERATION OF FIRE RESISTANCE—While proper system design can minimize the fire hazard, consideration must always be given to selection of fluids with adequate fire resistance. Fluids are listed as follows in increasing order of fire resistance:

a. Petroleum Base Fluids
b. Synthetic Hydrocarbons, Fire-Resistant
c. Biodegradeable Vegetable-Base Fluids
d. Invert Emulsions (60% water, 40% oil)
e. Water Glycols
f. Phosphate Esters
g. High Water Base Fluids (95% water)

5.2.3 FLUIDS FOR POWER TRANSMISSION (USE 1)—Typical values and specification requirements for the characteristics of fluids most often recommended for use in power transmission systems of marine vehicles are listed in Appendix A. Comparing these characteristics with the requirements of a specific application is necessary in selecting a suitable fluid for a specific application.

6. Summary—All aspects of the chemistry and characteristics of fluids for power transmission, lubrication, and passive applications are important and will affect the operation of systems on submersible vehicles and surface ships of all classes and types. Due to the general nature of this document, only the most significant factors have been presented.

7. Notes

7.1 Marginal Indicia—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE SHIP SYSTEMS AND EQUIPMENT COMMITTEE

APPENDIX A

TYPICAL PROPERTY VALUES FOR HYDRAULIC FLUIDS

TABLE A1—TYPICAL PROPERTY VALUES FOR HYDRAULIC FLUIDS

Property Fluid Type	Spec Requirement	Typical Values	Standard Test
1. Flash Point (Minimum):			ASTM D 92
MIL-H-5606	82 °C		ASTM D 93(1)
MIL-L-17331-2190TEP	204 °C (400 °F)	240 °C	
MIL-PRF-17672-2075TH	157 °C (315 °F)	200 °C	
2110TH	163 °C (325 °F)	205 °C	
2135TH	171 °C (340 °F)	215 °C	
MIL-L-17111 NATO-H-575	104 °C (220 °F)		
MIL-H-22072 WATERBASE	NR(2)	N.A.	
MIL-H-19457	NR(1)		
MIL-PRF-83282	204 °C (400 °F)	204 °C (400 °F)	
MIL-PRF-23699	246 °C (475 °F)		
2. Pour Point:			ASTM D 97
MIL-H-5606	–60 °C		
MIL-L-17331-2190TEP	–7 °C (20 °F)		
MIL-PRF-17672-2075TH	–29 °C (–20 °F)		
2110TH	–23 °C (–10 °F)		
2135TH	–18 °C (0 °F)		
MIL-L-17111 NATO-H-575	–40 °C (–40 °F)		
MIL-H-22072 WATERBASE	NR(1)	–29 °C (–20 °F)	
MIL-H-19457	–18 °C (0 °F)		
MIL-PRF-83282	–55 °C (–67 °F)		
MIL-PRF-23699	–54 °C (–65 °F)		
3. Density			ASTM D 1298(1)
MIL-H-5606	NR(1)		ASTM D 287
MIL-L-17331-2190TEP	NR(1)	0.883 kg/L	
MIL-PRF-17672-2075TH	NR(1)	0.871 kg/L	
2110TH	NR(1)	0.872 kg/L	
2135TH	NR(1)	0.880 kg/L	
MIL-L-17111 NATO-H-575	NR(1)		
MIL-H-22072 WATERBASE	1.04 to 1.09 mg/L		
MIL-H-19457	NR(1)		
MIL-PRF-83282	0.85 mg/L		
MIL-PRF-23699	NR(1)		
4. Particle Contamination (of new fluid)			ASTM D 4898
MIL-H-5606	0.3 mg/100 mL (also particle counts)		
MIL-L-17331-2190-TEP	4 mg/100 mL		
MIL-PRF-17672-2075-TH	4 mg/100 mL	1.2 mg/100 mL	
2110-TH	4 mg/100 mL	1.2 mg/100 mL	
2135-TH	4 mg/100 mL	1.2 mg/100 mL	
MIL-L-17111 NATO-H-575	NR(1)		
MIL-H-322072 WATERBASE	NR(1)		
MIL-H-19457	NR(1)		
MIL-PRF-83282	0.3 mg/100 mL		
MIL-PRF23699	1 mg/100 mL		

TABLE A1—TYPICAL PROPERTY VALUES FOR HYDRAULIC FLUIDS

Property Fluid Type	Spec Requirement	Typical Values	Standard Test
5. Foaming Tendencies(3)			ASTM D 892
MIL-H-5606	65 mL/0 mL		
MIL-L-17331-2190TEP	65 mL/0 mL		
MIL-PRF-17672-2075TH	65 mL/0 mL		
2110TH	65 mL/0 mL		
2135TH	65 mL/0 mL		
MIL-L-17111 NATO-H-575	NR(1)		
MIL-H-22072 WATERBASE	—/10 mL		
MIL-H-19457	65 mL/0 mL	45 mL/0 mL	
MIL-PRF-83282	65 mL/0 mL		
MIL-PRF-23699	25 mL/0 mL		
6. Viscosity	Centistokes		ASTM D 445
At 40 °C (104 °F)			
MIL-H-5606	13.2 (min)		
MIL-L-17331-2190TEP	74 to 97	(4)	
MIL-PRF-17672-2075TH	28.8 to 35.2	(3)	
2110TH	41.4 to 50.6	(3)	
2135TH	61.2–74.8	(3)	
MIL-L-17111 NATO-H-575	25 (min)		
MIL-H-22072 WATERBASE	20.45 (38 °C)		
MIL-H-19457	38.5-45.5		
MIL-PRF-83282	14 (min)		
MIL-PRF-23699	25.0 (38 °C)		
7. Viscosity Index			ASTM D 2270
MIL-H-5606			
MIL-L-17331-2190TEP	NR(1)	94	
MIL-PRF-17672-2075TH	94 (min)	105 to 110	
2110TH	94 (min)	105 to 110	
2135TH	94 (min)	105 to 110	
MIL-L-17111 NATO-H-575	NR(1)	200+	
MIL-H-22072 WATERBASE	NR(1)		
MIL-H-19457	NR(1)	50	
MIL-PRF-83282	NR(1)	150	
MIL-PRF-23699	NR(1)		

1. Applies to MIL-H-5606 only.
2. No Requirement.
3. Values given are after 5 min aeration/after 10 min settling periods except MIL-PRF-23699: 5 min aeration/1 min setting.
4. See Figures 1 through 5 for typical viscosity values.

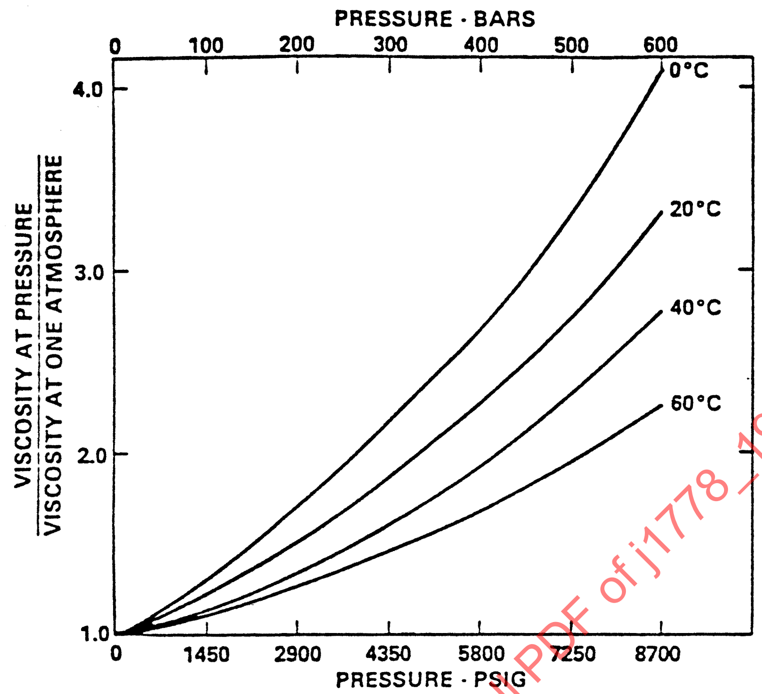

FIGURE A1—VARIATION OF VISCOSITY WITH PRESSURE FOR MIL-PRF-17672 2075TH FLUID

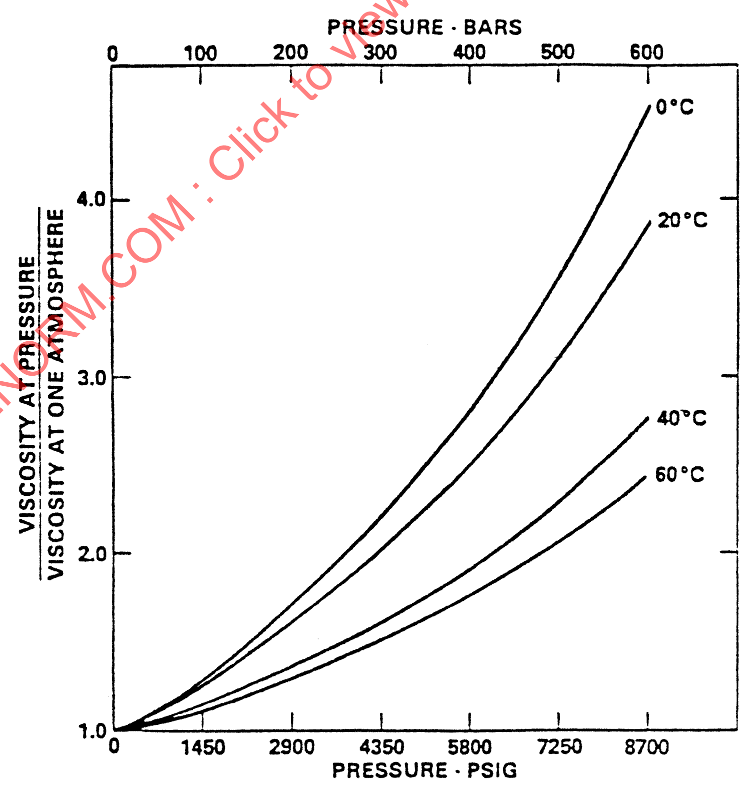

FIGURE A2—VARIATION OF VISCOSITY WITH PRESSURE FOR MIL-PRF-17672 2110TH FLUID-NATO SYMBOL H-573