

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.

1.2 Rationale—This document has been reaffirmed to comply with the SAE 5-Year Review policy.

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, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

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

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2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

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 the National Fluid Power Association, 3333 North Mayfair Road, Suite 211, Milwaukee, WI 53222-3219, Tel: 414-778-3344, www.nfpa.com.

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, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-2179, <http://assist.daps.mil> or <http://stinet.dtic.mil>.

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, Room 1138, Kentigern House, 65 Brown Street, Glasgow G2 8EX, UK, Tel: +44-0-141-224-2531, www.dstan.mod.uk.

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 Stability 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.