



Designation: D 6813 – 02

An American National Standard

Standard Guide for Performance Evaluation of Hydraulic Fluids for Piston Pumps¹

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1. Scope

1.1 This guide establishes test protocols and methodologies for determining the suitability of fluids for use in fluid power systems that incorporate axial or radial piston pumps. The suitability of all fluid types to meet specific levels of performance in piston pumps is addressed. These fluids include, but are not limited to formulations based on mineral, synthetic or vegetable oil base stocks. The finished fluids may be in the form of straight oils, soluble oils or invert emulsions.

1.2 The test protocols and methodologies described in this guide have been selected for their ability to distinguish between highly acceptable, acceptable and unacceptable fluid performance in piston pumps. They take into account the broad range of operating conditions piston pumps are subjected to, as well as the common variations in design and materials of construction among pump manufacturers.

1.3 This guide is intended to complement proprietary test protocols and methodologies employed by some piston pump manufacturers. The test protocols and methodologies within this guide may help pump manufacturers, fluid formulators and end users accurately screen potential fluids for specific performance characteristics. The results of this screening may be sufficient in certain instances for pump manufacturers to forego requirements for additional fluid performance tests.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- D 92 Test Method for Flash and Fire Points by Cleveland Open Cup²
- D 93 Test Methods for Flash-Point by Pensky-Martens Closed Cup Tester²
- D 95 Test Method for Water in Petroleum Products and

Bituminous Materials by Distillation²

- D 97 Test Method for Pour Point of Petroleum Products²
- D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test²
- D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids²
- D 482 Test Method for Ash from Petroleum Products²
- D 611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents²
- D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration²
- D 665 Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water²
- D 874 Test Method for Sulfated Ash from Lubricating Oils and Additives²
- D 877 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes³
- D 892 Test Method for Foaming Characteristics of Lubricating Oils²
- D 943 Test Method for Oxidation Characteristics of Inhibited Mineral Oils²
- D 974 Test Method for Acid and Base Number by Color-Indicator Titration²
- D 1121 Test Method for Reserve Alkalinity of Engine Coolants and Antirusts⁴
- D 1123 Test Methods for Water in Engine Coolant Concentrate by the Karl Fischer Reagent Method⁴
- D 1169 Test Method for Specific Resistance (Resistivity) of Electrical Insulating Liquids³
- D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method²
- D 1401 Test Method for Water Separability of Petroleum Oils and Synthetic Fluids²
- D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)²
- D 1533 Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration³
- D 2070 Test Method for Thermal Stability of Hydraulic Oils²

¹ This guide is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.N0.07 on Lubricating Properties.

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² Annual Book of ASTM Standards, Vol 05.01.

³ Annual Book of ASTM Standards, Vol 10.03.

⁴ Annual Book of ASTM Standards, Vol 15.05.

- D 2270** Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100°C²
- D 2272** Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel²
- D 2273** Test Method for Trace Sediment in Lubricating Oils²
- D 2422** Classification of Industrial Fluid Lubricants by Viscosity System²
- D 2619** Test Method for Hydrolytic Stability of Hydraulic Fluids (Beverage Bottle Method)²
- D 2624** Test Methods for Electrical Conductivity of Aviation and Distillate Fuels²
- D 2717** Test Method for Thermal Conductivity of Liquids²
- D 2766** Test Method for Specific Heat of Liquids and Solids²
- D 2783** Test Method for Extreme-Pressure Properties of Lubricating Fluids (Four-Ball Method)²
- D 2879** Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope²
- D 2882** Test Method for Indicating Wear Characteristics of Petroleum and Non-Petroleum Hydraulic Fluids in Constant Volume Vane Pump²
- D 2983** Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer²
- D 3427** Test Method for Air Release Properties of Petroleum Oils⁵
- D 4052** Test Method for Density and Relative Density of Liquids by Digital Density Meter⁵
- D 4172** Test Method for Wear Preventive Characteristics of Lubricating Fluid (Four-Ball Method)⁵
- D 4293** Specification for Phosphate Ester Based Fluids for Turbine Lubrication⁵
- D 4308** Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter⁵
- D 4310** Test Method for Determination of the Sludging and Corrosion Tendencies of Inhibited Mineral Oils⁵
- D 5182** Test Method for Evaluating the Scuffing Load Capacity of Oils (FZG Visual Method)⁵
- D 5185** Test Method for Determination of Additive Elements, Wear Metals, and Contaminants in Used Lubricating Oils and Determination of Selected Elements in Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)⁵
- D 5534** Test Method for Vapor-Phase Rust-Preventing Characteristics of Hydraulic Fluids⁶
- D 5621** Test Method for Sonic Shear Stability of Hydraulic Fluid⁶
- D 6006** Guide for Assessing Biodegradability of Hydraulic Fluids⁶
- D 6046** Classification of Hydraulic Fluids for Environmental Impact⁶
- D 6080** Practice for Defining the Viscosity Characteristics of Hydraulic Fluids⁶
- D 6158** Specification for Mineral Hydraulic Oils⁶
- D 6304** Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration⁶
- D 6376** Test Method for Determination of Trace Metals in Petroleum Coke by Wavelength Dispersive X-Ray Fluorescence Spectroscopy⁷
- D 6546** Test Methods for and Suggested Limits for Determining Compatibility of Elastomer Seals for Industrial Hydraulic Fluid Applications⁷
- D 6547** Test Method for Corrosiveness of a Lubricating Fluid to a Bimetallic Couple⁷
- D 6595** Test Method for Determination of Wear Metals and Contaminants in Used Lubricating Oils or Used Hydraulic Fluids by Rotating Disc Electrode Atomic Emission Spectrometry⁷
- E 70** Test Method for pH of Aqueous Solutions With the Glass Electrode⁴
- E 203** Test Method for Water Using Volumetric Karl Fischer Titration⁴
- E 659** Test Method for Autoignition Temperature of Liquid Chemicals⁸
- F 312** Test Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters⁸
- 2.2 *AFNOR Standards:*⁹
- AFNOR NF E48-690** Hydraulic Fluid Power. Fluids. Measurement of Filterability of Mineral Oils
- AFNOR NF E48-691** Hydraulic Fluid Power. Fluids. Measurement of Filterability of Minerals Oils in the Presence of Water
- AFNOR NF E48-692** Hydraulic Fluid Power. Fluids. Measurement of Filterability of HFC and HFD Class Fire Resistant Fluids
- 2.3 *ANSI (NFPA) Standards:*¹⁰
- ANSI/(NFPA) Standard T2.13.7R1-1996** Hydraulic Fluid Power—Petroleum Fluids—Prediction of Bulk Moduli
- ANSI/Standard NFPA/JIC T2.24.1-1990** Hydraulic Fluid Power—Systems Standard for Stationary Industrial Machinery
- ANSI/(NFPA) Standard T3.9.20-1992** Hydraulic Fluid Power—Pumps—Method of Testing and Presenting Basic Performance Data for Pressure Compensated Pumps
- ANSI/(NFPA) Standard T3.9.33-1997** Hydraulic Fluid Power—Pumps—Method of Testing and Presenting Basic Performance Data for Load Sensing Pumps
- ANSI/(NFPA) Standard T3.16.2-R1-1997** Hydraulic Fluid Power—Design for Nonintegral Industrial Reservoirs
- 2.4 *CETOP Standard:*

⁵ Annual Book of ASTM Standards, Vol 05.02.

⁶ Annual Book of ASTM Standards, Vol 05.03.

⁷ Annual Book of ASTM Standards, Vol 05.04.

⁸ Annual Book of ASTM Standards, Vol 14.02.

⁹ Available from AFNOR, Administration des Ventes, 11, avenue Francis de Pressensy, 93571 Saint-Denis La Plaine Cedex.

¹⁰ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

CETOP RP 67H Antiwear Vane Pump Test for Hydraulic Fluids¹¹

2.5 DIN Standards:¹²

DIN 51348 Testing of Fire Resistant Governor Fluids; Determination of Hydrolytic Stability

DIN 51373 Testing of Fire Resistant Governor Fluids; Determination of Oxidative Stability Including Evaluation of Catalyst Plates

DIN 51389/2 Determination of Lubricants; Mechanical Testing of Hydraulic Fluids in the Vane-Cell-Pump; Method A for Anhydrous Hydraulic Fluids

DIN 51389/3 Determination of Lubricants; Mechanical Testing of Hydraulic Fluids in the Vane-Cell-Pump—Part 3: Method B for Aqueous Not Easily Inflammable Hydraulic Fluids

DIN 51515, Part 1 Lubricants and Governor Fluids for Steam Turbines; L-TD Lubricating Oils and Governor Oils; Minimum Requirements

DIN 51554, Part 3 Testing of Mineral Oils; Test of Susceptibility to Aging According to Baader; Testing at 95°C

2.6 British Standard:¹³

IP 281 Determination of Anti-Wear Properties of Hydraulic Fluids—Vane Pump Method

2.7 ISO Standards:¹⁴

ISO 4021 Hydraulic Fluid Power—Particulate Contamination Analysis—Extraction of Fluid Samples From Lines of an Operating System

ISO 4402 Hydraulic Fluid Power—Calibration of Automatic-Count Instruments for Particles Suspended in Liquids—Method Using Classified AC Fine Test Dust Contaminant

ISO 4404 Petroleum and Related Products—Determination of the Corrosion Resistance of Water-Containing Fire-Resistant Fluids for Hydraulic Systems

ISO 4406 Hydraulic Fluid Power—Fluids—Method for Coding The Level of Contamination by Solid Particles

ISO 4407 Hydraulic Fluid Power—Fluid Contamination—Determination of Particulate Contamination by the Counting Method Using a Microscope

ISO 5884 Aerospace—Fluid Systems and Components—Methods for System Sampling and Measuring the Solid Particle Contamination of Hydraulic Fluids

ISO 6073 Petroleum Products—Prediction of the Bulk Moduli of Petroleum Fluids Used in Hydraulic Power Systems

ISO 6743/4 Part 4: Family H (Hydraulic Systems), Lubricants, Industrial Oils and Related Products (Class L) : Classification Part 4: Family H (Hydraulic Systems)

ISO 11171 Hydraulic Fluid Power—Calibration of Auto-

matic Particle Counters for Liquids

ISO 12922 Lubricants, Industrial Oils and Related Products (Class L)—Family H (Hydraulic Systems)—Specifications for Categories HFAS, HFAS, HFB, HFC, HFDR and HFDU

ISO 13357-2 Part 2: Petroleum Products—Determination of the Filterability of Lubricating Oils—Part 2: Procedure for Dry Oils

ISO 14935 Petroleum and Related Products—Determination of Wick Flame Persistence of Fire-Resistant Fluids

ISO 15029 Petroleum and Related Products—Determination of Spray Ignition Characteristics of Fire-Resistant Fluids—Part I: Spray Flame Persistence—Hollow Cone Nozzle Method

2.8 LUX Standard:¹⁵

LUX 5.9 Determination of the Corrosion Inhibiting Properties of Fluids, Requirements for Tests Applicable to Fire-Resistant Fluids Used for Power Transmission and Control (Hydrostatic and Hydrokinetic), April, 1994

2.9 SAE Standards:¹⁶

SAE J745 Surface Vehicle Recommended Practice, Hydraulic Power Pump Test Procedure

SAE J1276 MAR86 Standardized Fluid for Hydraulic Component Tests

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *abrasive wear*—wear due to hard particles, including wear debris or fluid contaminants, or hard protuberances forced against and moving along a hard surface.

3.1.2 *axial piston pump*—in the axial piston pump, the pistons are positioned axially, parallel to the driveshaft, and their reciprocating motion is caused by an inclined swash plate as illustrated in Fig. 1.

3.1.3 *bent axis piston pump*—in the bent axis piston pump, the axis of the cylinder barrel is held at a fixed angle relative to the centerline of the driveshaft as illustrated in Fig. 2.

3.1.4 *biodegradable*—capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, or biomass in which the predominant mechanism is the enzymatic action of microorganisms that can be measured by standardized tests, in a specific period of time, reflecting available disposal conditions.

3.1.5 *biomass*—any material, excluding fossil fuels, which is or was a living organism that can be used as a fuel. Peanut hulls, agricultural waste, corn and other grains, and sugar are all examples of biomass.

3.1.6 *case drainage*—leakage from around piston clearances and control valves to the case drain port in the pump housing which returns fluid to the reservoir.

¹¹ Per the CETOP website, this standard is no longer available for purchase and is officially withdrawn. Most CETOP technical documents have been replaced by ISO standards over the years (a cross-reference list is available from CETOP). This standard will be retained pending completion of work in CEN/TC19/WG28.

¹² Available from Beuth Verlag GmbH (DIN-- DIN Deutsches Institut für Normung e.V.), Burggrafenstrasse 6, 10787, Berlin, Germany.

¹³ Available from Institute of Petroleum (IP), 61 New Cavendish St., London, WIG 7AR, U.K.

¹⁴ Available from International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland.

¹⁵ Available from European Safety and Health Commission for the Mining and Other Extractive Industries, Doc. No. 4746/10/91, EN, Luxembourg.

¹⁶ Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

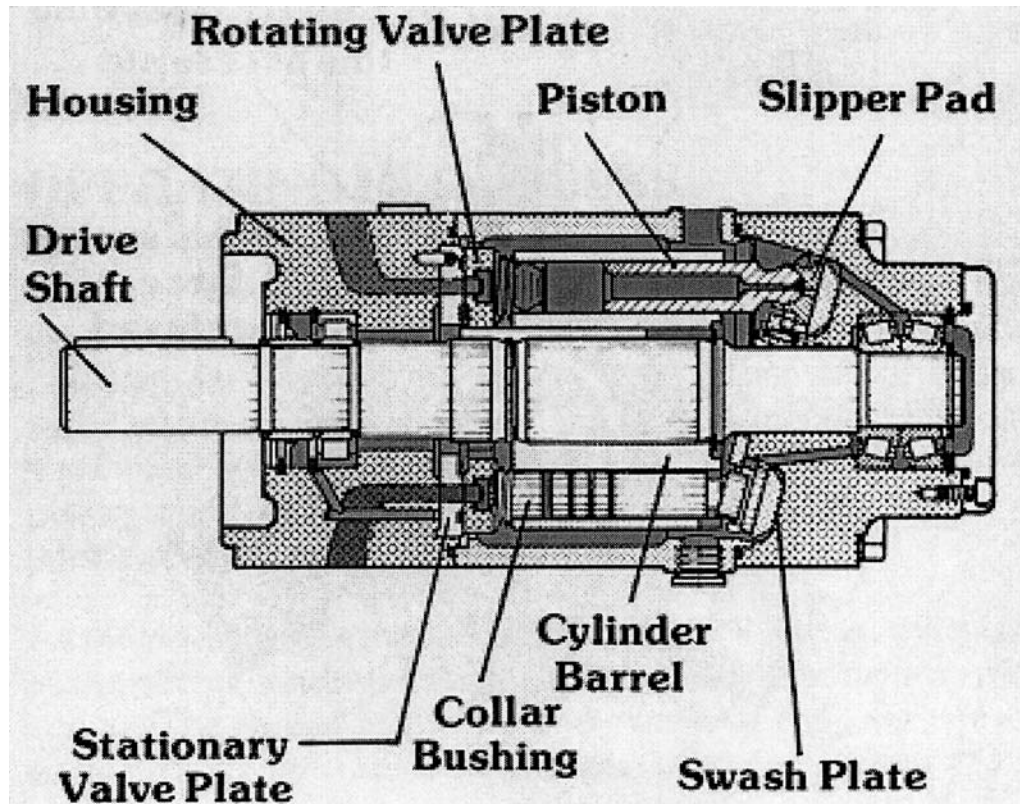


FIG. 1 Illustration of an Axial Piston Pump

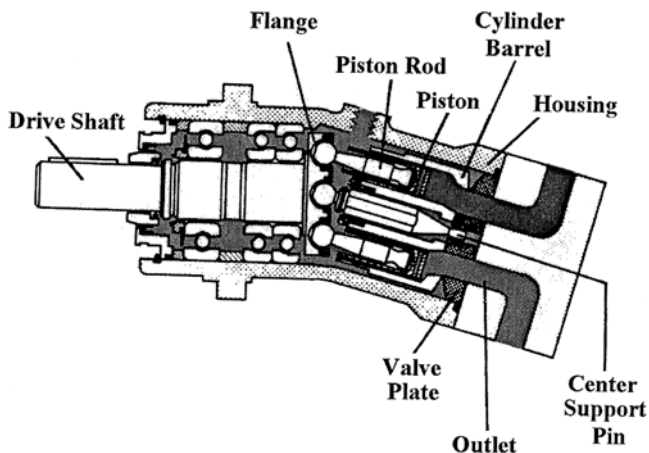


FIG. 2 Illustration of a Bent Axis Piston Pump

3.1.7 *cycled volume*—cycled volume testing subjects a hydraulic pump or component to repeated pulses of volume flow from a predetermined minimum to a maximum flow at a constant pressure.

3.1.8 *delivery*—the flow output per unit time expressed in litres per minute (L/min) or in gallons per minute (gal/min).

3.1.9 *displacement (geometrical)*—the volume of hydraulic fluid that is transported through the hydraulic pump during a single rotation of the pump shaft and is expressed in volume output per revolution (cm^3/rev or $\text{in.}^3/\text{rev}$).

3.1.10 *face plate (valve plate, port plate, lens plate)*—the face plate, which is held at a fixed position, controls the timing of the inlet and outlet of the fluid flow, depending on the position of the cylinder barrel, during rotation of the pump.

3.1.11 *filterability*—a measure of the fluid's ability to pass through filter media.

3.1.12 *fixed displacement*—the amount of flow cannot be varied per each shaft rotation although it can be varied by varying the rotational speed of the shaft.

3.1.13 *flow degradation*—flow degradation refers to the loss of flow through the hydraulic pump caused by lubrication wear, cavitation erosion, or contamination wear and is expressed as the ratio of flow rate delivered after the test to the flow rate delivered before the test.

3.1.14 *fluid residence time (turnover time)*—the average time that a given volume of fluid remains in the reservoir from the time of entry into the reservoir from the system until it enters the pump inlet is determined by the reservoir volume/flow rate.

$$W (\text{Watt}) = \frac{\text{Delivery (L/min)} \times \text{Pressure (kPag)}}{60} \quad (1)$$

3.1.15 *hydraulic power*—the output power of a hydraulic pump which is defined by:

$$\text{hp (Horsepower)} = \frac{\text{Delivery (gal/min)} \times \text{Pressure (psig)}}{1714} \quad (2)$$

3.1.16 *inlet pressure (minimum)*—the minimum inlet pressure, specified by the pump supplier, for each set of operating parameters.

3.1.17 *leakage flow*—this is related to the annular clearance between the piston and the cylinder; increased clearances due to erosion and wear results in a loss of volumetric efficiency (see 3.1.26).

3.1.18 *leakage pressure (case drain pressure)*—back-pressure that the case experiences during leakage which is determined by the size of the case drain port, hose, fluid viscosity, and the rate of leakage flow to the reservoir via the case drain.

3.1.19 *operating pressure*—the pressure at the discharge port of the hydraulic pump.

3.1.20 *pulsed (cycled) pressure*—pulsed pressure testing subjects a hydraulic pump or component to repeated pressure pulses (at a constant volume), often from close to zero (minimum load) to a predetermined maximum pressure, in order to evaluate fatigue life or moving part interaction problems and leakage.

3.1.21 *pump capacity (pump displacement)*—the actual pump displacement expressed in volume per revolution (cm^3/rev).

3.1.22 *radial piston pump*—in the radial piston pump, the pistons are positioned radially, perpendicular to the driveshaft, and piston motion is caused by the use of a fixed cylinder and rotating cam plate as illustrated in Fig. 3, or a rotating block around a stationary cam can also be used.

3.1.23 *reservoir; hydraulic*—a container for the storage of a fluid used in a hydraulic system.

3.1.24 *shaft power*—the input power driving the hydraulic pump (often from an electric motor) which is defined by:

$$W \text{ (Watt)} = \frac{\text{Torque (N-m)} \times \text{Speed (rpm)}}{9.549} \quad (3)$$

$$\text{hp (Horsepower)} = \frac{\text{Torque (lbf-in.)} \times \text{Speed (rpm)}}{63\,025} \quad (4)$$

3.1.25 *swash plate (creep plate, wear plate, wobble plate)*—in a swash-plate (axial) piston pump, the shaft rotates the piston block, thus rotating the pistons, which are held against the surface of a swash plate by springs and a retainer plate. For the piston pump to produce a flow, the swash plate must be held at some angle relative to the centerline of the shaft

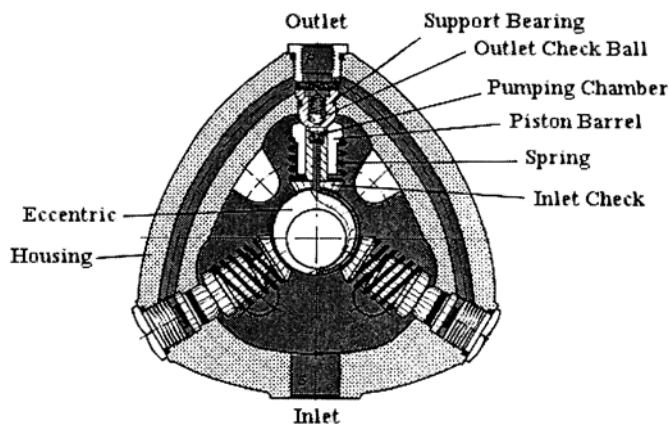


FIG. 3 Schematic Illustration of a Radial Piston Pump

and the angle will force the pistons to move in and out of the piston or cylinder barrel of the pump as shown in Fig. 1.

3.1.26 *total efficiency*—hydraulic pumping efficiency, or total efficiency (E_T), is a combination of two efficiencies, volumetric efficiency (E_v) and mechanical efficiency (E_m) and is determined from variable displacement.

$$E_v = \frac{\text{Actual Flow Output}}{\text{Theoretical Flow Output}} \quad (5)$$

$$E_m = \frac{\text{Theoretical Torque Input}}{\text{Actual Torque Output}} \quad (6)$$

$$E_T = E_v \times E_m \quad (7)$$

3.1.27 *variable displacement*—the amount of flow per each shaft revolution may be varied to limit the outlet flow to a preselected value.

4. Significance and Use

4.1 Users of hydraulic equipment which includes piston pumps would like assurance that the fluids they use will allow their systems to operate safely with reasonable equipment life. This assurance is commonly provided by the fluid supplier in the form of results of standardized tests on the fluid, or demonstrated success in field use in similar systems, or both. This guide will help fluid developers and users develop testing protocols which demonstrate the suitability of a fluid for its intended use, including any required limitations on hydraulic system operating conditions.

4.2 The significance and use of each test method cited in this guide will depend upon the system in use and the purpose of the test method. Use the most recent editions of ASTM test methods.

5. Fluid Classification

5.1 Mineral oil hydraulic fluids are classified in Specification D 6158. Fire-resistant hydraulic fluids are classified in ISO 6743/4 and the specifications for these fluid classes are provided in ISO 12922.

5.2 Mineral Oil Hydraulic Fluids:

5.2.1 *Type HH Hydraulic Oils*—Non-inhibited refined mineral oils for hydraulic systems that do not have specific requirements of oxidation stability, rust protection, or anti-wear properties. Type HH oils are usually intended for total loss systems or very light duty equipment.

5.2.2 *Type HL Hydraulic Oils*—Refined mineral oils with improved rust protection and oxidation stability for hydraulic systems where relatively high temperatures and long periods of operation time are expected, and where there is the possibility of water or humidity that could rust metal parts of the machinery. These oils are intended for use in systems where only full film lubrication is expected between the moving parts. Usually systems working at low pressures specify HL oils. Some high-pressure piston pumps can operate satisfactorily on these oils.

5.2.3 *Type HM Hydraulic Oils*—Oils of HL type with improved anti-wear properties, for general hydraulic systems, especially for those working at high pressure and where the possibility of metal to metal contact exists. Type HM oils are usually specified for hydraulic systems with some pumps.

when the system is intended to work at maximum pump capacity for long periods of time.

5.2.4 Type HV Hydraulic Oils—Oils of the HM type with improved viscosity/temperature properties, for general hydraulic systems where equipment is intended to operate over a wide range of ambient temperatures.

5.3 Fire-Resistant Hydraulic Fluids:

5.3.1 Type HFA Hydraulic Fluids—Fire-resistant hydraulic fluids that may be further classified as:

5.3.1.1 Type HFAE Hydraulic Fluids—Mineral oil-in-water emulsions containing less than 20 % by volume mineral oil.

5.3.1.2 Type HFAS Hydraulic Fluids—Mineral oil-free aqueous synthetic polymer-thickened solutions, often micro-emulsions, containing >80 % water. These fluids are suitable for use at low working pressures and temperatures varying from 5 to <55°C.

5.3.2 Type HFB Hydraulic Fluids—Water-in-mineral oil emulsions containing <60 % mineral oil, which are used as fire-resistant hydraulic fluids at operating temperatures of 5 to <55°C.

5.3.3 Type HFC Hydraulic Fluids—Thickened water-glycol fluids containing >35 % water which are suitable for use at operating temperatures of -20 to <60°C.

5.3.4 Type HFD Hydraulic Fluids—Anhydrous synthetic fire-resistant fluids used at operating temperatures of <120°C. Type HFD fluids are further subdivided into Types HFD-R and HFD-U. Type HFD-R fluids are based on phosphate esters and Type HFD-U fluids are based on polyol esters.

5.4 Biodegradable Hydraulic Fluids:

5.4.1 Type HETG Hydraulic Fluids—Typically, biodegradable, water-insoluble hydraulic fluids derived from vegetable oils. These fluids may be used at operating temperatures of -20 to <80°C.

5.4.2 Type HEES Hydraulic Fluids—Typically biodegradable fluids derived from synthetic esters, such as polyol ester and diesters, which may be used at operating temperatures of -35 to <90°C.

5.4.3 Type HEPG Hydraulic Fluids—Polyalkylene glycol derived fluids that may be water-soluble or insoluble with varying degrees of biodegradability and fire resistance. These fluids are suitable for use at operating temperatures of -30 to <90°C.

5.4.4 Type HEPR Hydraulic Fluids—Biodegradable fluids whose basestocks are derived from polyalphaolefin and related hydrocarbons.

5.4.5 Other Biodegradable Fluids—Paragraphs 5.4.1-5.4.4 describe HETG, HEES, HEPG, and HEPR fluids as biodegradable fluids. However, there are other types of biodegradable fluids not included in a listing. Fluid biodegradability is established by specific testing protocol. For example, some fire-resistant fluids of the HFC and HFD type are readily biodegradable as established by Guide D 6006, but this is not reflected in the current ISO specifications. In this guide, reference to biodegradable fluids indicates that they pass appropriate biodegradability standards, not necessarily their placement on a listing of biodegradable fluid classes.

6. Fluid Properties and Performance Testing Procedures

6.1 The hydraulic fluid is a component of the total hydraulic system and to be used properly, various properties of the fluid must be considered relative to system design. These properties are determined by various tests procedures which include: physical properties, chemical properties, oxidative stability, corrosion, fire-resistance, biological and ecological compatibility, other bench tests, and pump tests. A summary of important fluid properties and associated test procedures is provided in **Table 1**.

NOTE 1—Every test is not appropriate for every fluid class shown in **Table 1**. The test procedures that are appropriate for a given fluid class are identified by an “X.”

NOTE 2—Every fluid test shown in the table need not be performed before for every pump test; however, it is recommended that after selecting those tests that are deemed most critical for the hydraulic fluid to be tested, that the test selection and properties of interest be reviewed with the component manufacturer to ensure that the fluid properties will meet the design and operational requirements for both the pump/motor/components and the application of interest before the hydraulic piston pump test is conducted.

6.2 Typical Physical Properties:

6.2.1 ISO Viscosity Grade (Classification D 2422)—The International Standards Organization has established a viscosity classification system for industrial fluid lubricants. Such lubricants are classified by grades designated as ISO-VG based on their viscosities in centistokes at 40°C. The choice of viscosity grade for use in a particular hydraulic system should meet the manufacturer's recommendations.

TABLE 1 Hydraulic Fluid Physical Property Characterization Tests

Characteristics	Hydraulic Fluid Classification												Test According to:
	HH	HL	HM	HV	HETG	HEES	HEPG	HEPR	HFA	HFB	HFD	HFC	
Kinematic viscosity at 40°C	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 445
Low Temperature Viscosity	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 2983, ASTM D 6080
ISO Viscosity Grade	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 2422
Viscosity Index	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 2270
Pour point	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 97
Density at 15°C	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 1298, ASTM D 4052
Air release at 50°C	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 3427

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TABLE 1 *Continued*

Characteristics	Hydraulic Fluid Classification												Test According to:
	HH	HL	HM	HV	HETG	HEES	HEPG	HEPR	HFA	HFB	HFD	HFC	
Foam volumes (5 min. blowing, 10 min settling)	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 892
Sequence I													
Initial Volume													
Final Volume, Time													
Sequence II													
Initial Volume													
Final Volume, Time													
Sequence III													
Initial Volume													
Final Volume, Time													
Emulsion stability at 54°C	X	X	X	X	X	X	X	X			X		ASTM D 1401
Viscosity Stability (Ultrasonic Test)	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 5621
Dielectric Breakdown Voltage (45-65 Hz)	X	X	X	X									ASTM D 877
Electrical Conductivity at 20°C	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 4308
Thermal conductivity	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 2717
Specific heat capacity at 20°C	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 2766
Vapor pressure	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 2879
Bulk Modulus	X	X	X	X	X	X	X	X	X	X	X	X	ISO 6073
Fluid Cleanliness													
Instrumental Test Method	X	X	X	X	X	X	X	X	X	X	X	X	ISO 11171
Microscopic Test Method	X	X	X	X	X	X	X	X	X	X	X	X	ASTM F 312, ISO 4407
Cleanliness Code	X	X	X	X	X	X	X	X	X	X	X	X	ISO 4406
In-Line Sampling Method	X	X	X	X	X	X	X	X	X	X	X	X	ISO 4021
Drum Sampling	X	X	X	X	X	X	X	X	X	X	X	X	ISO 5884
Sediment Content	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 2273
Seal Compatibility	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 6546

Hydraulic Fluid Chemical Property Characterization Tests (Including Seal Compatibility)

Characteristics	Hydraulic Fluid Classification												Test According to:
	HH	HL	HM	HV	HETG	HEES	HEPG	HEPR	HFA	HFB	HFD	HFC	
Ash (sulfated ash) proportion by mass	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 874, ASTM D 482
Water content—Hydraulic Oils	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 95, ASTM D 1533, ASTM D 6304, ASTM E 203
pH value at 20°C									X	X		X	ASTM E 70
Neutralization number		X	X	X	X	X	X	X	X	X	X	X	ASTM D 664, ASTM D 974
Alkaline Reserve to pH 5.5 (0.1N HCl)									X	X		X	ASTM D 1121
Hydrolytic Stability (mg KOH, mg Cu/cm ²)	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 2619
Aniline Point	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 611

Hydraulic Fluid Thermal and Oxidative Stability, Corrosion and Bench Test Characterization Tests

Characteristics	Hydraulic Fluid Classification												Test According to:
	HH	HL	HM	HV	HETG	HEES	HEPG	HEPR	HFA	HFB	HFD	HFC	
Oxidation Stability—TOST		X	X	X	X	X	X	X				X	ASTM D 943
Oxidation Stability—Cincinnati Milacron		X	X	X	X	X	X	X				X	ASTM D 2070
Oxidation Stability—RBOT		X	X	X	X	X						X	ASTM D 2272
Oxidation Stability—Baader Test		X	X	X	X	X	X	X				X	DIN 51554, Part 3
Oxidation Stability		X	X	X	X	X	X	X	X	X	X	X	DIN 51373
Sludging Tendency		X	X	X	X	X	X	X				X	ASTM D 4310
Thermal Stability (Copper and Steel Rods, sludge)		X	X	X	X	X	X	X				X	ASTM D 2070
Turbine Oil Rust Test		X	X	X	X	X	X	X	X	X	X	X	ASTM D 665
Copper Corrosion		X	X	X	X	X	X	X				X	ASTM D 130
Galvanic Corrosion		X	X	X	X	X	X	X	X	X	X	X	ASTM D 6547
Vapor Phase Corrosion		X	X	X	X	X	X	X	X	X	X	X	ASTM D 5534
Corrosion		X	X	X	X	X	X	X	X	X	X	X	LUX 5.9, ISO 4404
Aluminum													
Brass													
Cadmium													
Copper													
Magnesium													
Steel													
Zinc													
Steel and Zinc													
Copper and Zinc													
Aluminum and Zinc													
Steel and Aluminum													
Four-Ball Anti-wear		X	X	X	X	X	X	X	X	X	X	X	ASTM D 4172
Four-Ball Extreme Pressure		X	X	X	X	X	X	X	X	X	X	X	ASTM D 2783

Hydraulic Fluid Thermal and Oxidative Stability, Corrosion and Bench Test Characterization Tests

Characteristics	Hydraulic Fluid Classification												Test According to:
	HH	HL	HM	HV	HETG	HEES	HEPG	HEPR	HFA	HFB	HFD	HFC	
FZG-gear rig test method	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 5182
Vane pump anti-wear test	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 2882
AFNOR Filterability (dry)	X	X	X	X	X	X	X	X			X		AFNOR NF E48-690
AFNOR Filterability (wet)	X	X	X	X	X	X	X	X					AFNOR NF E48-691
AFNOR Filterability (HDC and HFD)											X	X	AFNOR NF E48-692
ISO Filterability (Dry)	X	X	X	X	X	X	X	X			X		ISO 13357-2

Hydraulic Fluid Fire-Resistance Characterization Tests

Characteristics	Hydraulic Fluid Classification												Test According to:
	HH	HL	HM	HV	HETG	HEES	HEPG	HEPR	HFA	HFB	HFD	HFC	
Fire Point	X	X	X	X	X	X	X	X			X		ASTM D 92
Flash Point (Open Cup)	X	X	X	X	X	X	X	X			X		ASTM D 92
Determination of auto ignition temperature	X	X	X	X	X	X	X	X			X		ASTM E 659
Factory Mutual Tests:									X	X	X	X	Factory Mutual Standard 6930
Hot Channel Ignition Test													
Spray Ignition Test													
Linear Flame Propagation Test											X		ASTM D 5306
Hot Manifold Test									X	X	X	X	
Wick Flame Persistence									X	X	X	X	ISO 14935
Spray Flame Test									X	X	X	X	ISO 15029
Biodegradability	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 6006
Classification for Environmental Impact	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 6046

Hydraulic Fluid Fire-Resistance Characterization Tests

Characteristics	Hydraulic Fluid Classification												Test According to:
	HH	HL	HM	HV	HETG	HEES	HEPG	HEPR	HFA	HFB	HFD	HFC	
Biodegradability	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 6006
Classification for Environmental Impact	X	X	X	X	X	X	X	X	X	X	X	X	ASTM D 6046

6.2.2 Viscosity (Test Methods D 445 and D 2983, and Practice D 6080)—Viscosity is the measurement of a fluid's resistance to flow; it is considered to be the most important characteristic of a hydraulic fluid. The optimum value is always a compromise; it has to be high enough, at the working temperature, to ensure that the fluid will not leak through the seals or junctions and to maintain proper lubrication. Also, the viscosity has to be low enough to ensure fluid flow at start-up and to maintain system efficiency and lubrication and avoid cavitation.

6.2.2.1 High VI hydraulic fluids often contain high molecular weight thickeners, called viscosity index (VI) improvers, which may impart non-Newtonian characteristics to the fluid. These polymers may shear degrade with use, and reduce the in-service viscosity of the fluids. Practice D 6080 provides uniform guidelines for characterizing oils in terms of both their high and low temperature viscosities before and after exposure to high shear stress. Since the performance of fluids at temperatures higher than 40°C is determined in the worst case, that is, most severe situation, by the sheared oil viscosity, the viscosity and viscosity index used to characterize fluids in this practice are those of the sheared fluid.

6.2.2.2 Practice D 6080 classifies oils at low temperature by their new oil properties. Low temperature viscosities do not decrease greatly, if at all, with polymer shear degradation. Furthermore, this approach ensures that the fluid will be properly classified under worst-case conditions, that is, when the fluid is new. Practice D 6080 may be used with new or

used, Newtonian or non-Newtonian, hydraulic fluids. This practice is used for the determination of viscosities at low temperatures applicable to all hydraulic fluids based either on petroleum, synthetic, or naturally occurring base stocks. It is not intended for water-containing hydraulic fluids.

6.2.3 Viscosity Index (VI) (Practice D 2270)—The VI number signifies the decrease of a fluid's viscosity as the temperature increases. The greater the VI, the less viscosity changes with temperature. In general, the VI is not very critical when the system works at a stable operating temperature. When the variation of temperature among different points in the system is high (over 30°C), or the operational temperatures vary considerably, then a high VI (over 90) is usually recommended.

6.2.4 Density—Relative Density (Test Methods D 1298 and D 4052)—This property is of value to hydraulic system designers and operators for calculating system weight, internal pressure, wall thickness, and pump requirements. Density (or relative density) is measured at, or converted to, a standard reference temperature, normally either 15°C or 60°F, and these need to be quoted alongside the result. Test Method D 1298 uses a hydrometer plus thermometer for measurement while Test Method D 4052 uses a digital density meter.

6.2.5 Pour Point (Test Method D 97, Low Temperature Viscosity (Test Method D 2983)—The pour point is an indication of the lowest temperature at which an oil will flow by gravity. The fluid viscosity must allow the system to start up and operate at low temperatures. As a practical rule, the fluid should have a pour point 10°C below the minimum temperature