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An American National Standard

# Standard Guide for Performance Evaluation of Hydraulic Fluids for Piston Pumps[1]

This standard is issued under the fixed designation D 6813; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

## 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 Cup[2]

D 93 Test Methods for Flash-Point by Pensky-Martens Closed Cup Tester[2]

D 95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation[2]

D 97 Test Method for Pour Point of Petroleum Products[2]

D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test[2]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids[2]

D 482 Test Method for Ash from Petroleum Products[2]

D 611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents[2]

D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration[2]

D 665 Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water[2]

D 874 Test Method for Sulfated Ash from Lubricating Oils and Additives[2]

D 877 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes[3]

D 892 Test Method for Foaming Characteristics of Lubricating Oils[2]

D 943 Test Method for Oxidation Characteristics of Inhibited Mineral Oils[2]

D 974 Test Method for Acid and Base Number by Color-Indicator Titration[2]

D 1121 Test Method for Reserve Alkalinity of Engine Coolants and Antirusts[4]

D 1123 Test Methods for Water in Engine Coolant Concentrate by the Karl Fischer Reagent Method[4]

D 1169 Test Method for Specific Resistance (Resistivity) of Electrical Insulating Liquids[3]

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]

D 1401 Test Method for Water Separability of Petroleum Oils and Synthetic Fluids[2]

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 Titration[3]

[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.

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D 2070 Test Method for Thermal Stability of Hydraulic Oils[2]

D 2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100°C[2]

D 2272 Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel[2]

D 2273 Test Method for Trace Sediment in Lubricating Oils[2]

D 2422 Classification of Industrial Fluid Lubricants by Viscosity System[2]

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 Fuels[2]

D 2717 Test Method for Thermal Conductivity of Liquids[2]

D 2766 Test Method for Specific Heat of Liquids and Solids[2]

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 Isoteniscope[2]

D 2882 Test Method for Indicating Wear Characteristics of Petroleum and Non-Petroleum Hydraulic Fluids in Constant Volume Vane Pump[2]

D 2983 Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer[2]

D 3427 Test Method for Air Release Properties of Petroleum Oils[5]

D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter[5]

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 Lubrication[5]

D 4308 Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter[5]

D 4310 Test Method for Determination of the Sludging and Corrosion Tendencies of Inhibited Mineral Oils[5]

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 Fluids[6]

D 5621 Test Method for Sonic Shear Stability of Hydraulic Fluid[6]

D 6006 Guide for Assessing Biodegradability of Hydraulic Fluids[6]

D 6046 Classification of Hydraulic Fluids for Environmental Impact[6]

D 6080 Practice for Defining the Viscosity Characteristics of Hydraulic Fluids[6]

D 6158 Specification for Mineral Hydraulic Oils[6]

D 6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration[6]

D 6376 Test Method for Determination of Trace Metals in Petroleum Coke by Wavelength Dispersive X-Ray Fluorescence Spectroscopy[7]

D 6546 Test Methods for and Suggested Limits for Determining Compatibility of Elastomer Seals for Industrial Hydraulic Fluid Applications[7]

D 6547 Test Method for Corrosiveness of a Lubricating Fluid to a Bimetallic Couple[7]

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 Spectrometry[7]

E 70 Test Method for pH of Aqueous Solutions With the Glass Electrode[4]

E 203 Test Method for Water Using Volumetric Karl Fischer Titration[4]

E 659 Test Method for Autoignition Temperature of Liquid Chemicals[8]

F 312 Test Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters[8]

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 Pressensi, 93571 Saint-Denis La Plaine Cedex.

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

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CETOP RP 67H Antiwear Vane Pump Test for Hydraulic Fluids[11]

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 Automatic Particle Counters for Liquids

ISO 12922 Lubricants, Industrial Oils and Related Products (Class L)—Family H (Hydraulic Systems)—Specifications for Categories HFAE, 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 fur 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 Varembé, 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.



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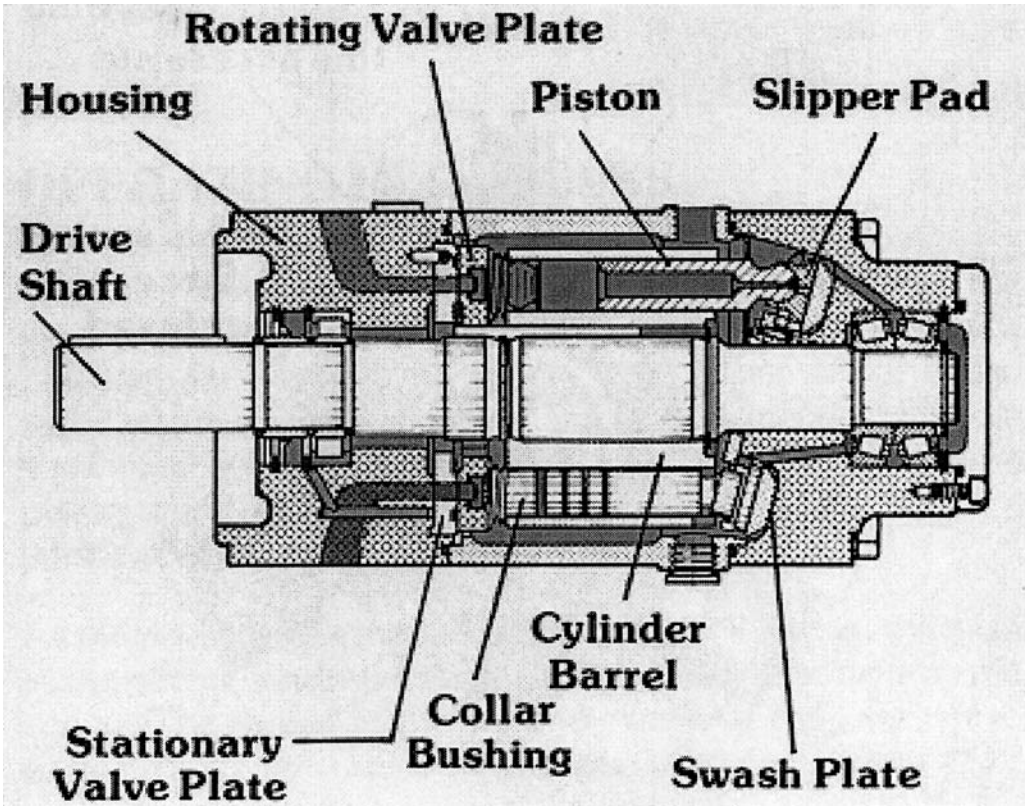


FIG. 1 Illustration of an Axial Piston Pump

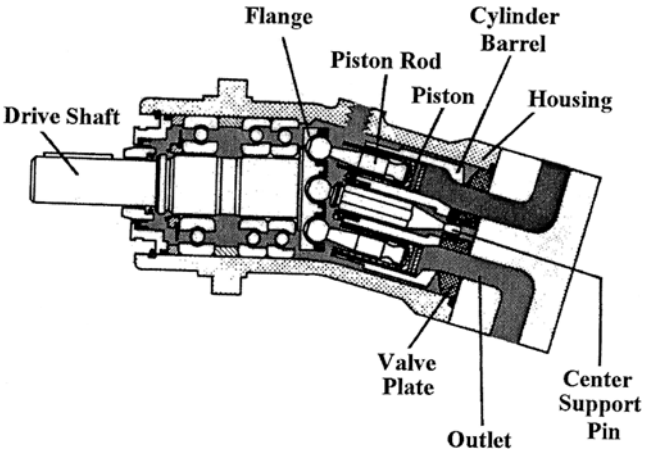


FIG. 2 Illustration of a Bent Axis Piston Pump

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 $in.^3$/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.

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

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

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



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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:

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

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

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 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.

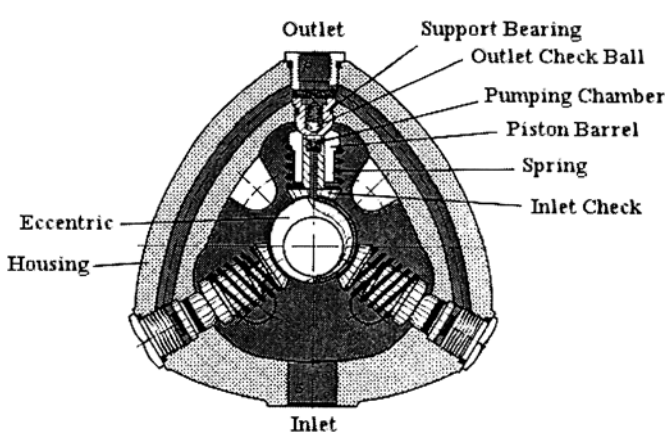


FIG. 3 Schematic Illustration of a Radial Piston Pump

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

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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 | 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 | | | X | | ASTM D 943 |
| Oxidation Stability—Cincinnati Milacron | X | 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 | | | X | | DIN 51554, Part 3 |
| Oxidation Stability | X | X | X | X | X | X | X | X | X | X | X | X | DIN 51373 |
| Sludging Tendency | X | 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 | X | ASTM D 665 |
| Copper Corrosion | X | X | X | X | X | X | X | X | | | X | | ASTM D 130 |
| Galvanic Corrosion | X | 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 | X | ASTM D 5534 |
| Corrosion | X | 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 | X | ASTM D 4172 |
| Four-Ball Extreme Pressure | X | X | X | X | X | X | X | X | X | X | X | X | ASTM D 2783 |



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