# Standard Test Method for Indicating Wear Characteristics of Petroleum Hydraulic Fluids in a High Pressure Constant Volume Vane Pump[1]

This standard is issued under the fixed designation D6973; 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.

ε[1] NOTE—Changes were made to Fig. 1 and Note 4, and Note 7 was added editorially in May 2008.

## 1. Scope

1.1 This test method covers a constant volume high-pressure vane pump test procedure for indicating the wear characteristics of petroleum hydraulic fluids. See Annex A1 for recommended testing conditions for water-based synthetic fluids.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *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 limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standards:*[3]

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

ISO 4406 Hydraulic Fluid Power—Fluids—Method for Coding the Level of Contamination by Solids Particles

ISO 7745 Hydraulic Fluid Power—Fire-Resistant (FR) Fluids—Guidelines for Use

ISO 11171 Hydraulic Fluid Power—Calibration of Automatic Particle Counters for Liquids

ISO 11500 Hydraulic Fluid Power—Determination of Particulate Contamination by Automatic Counting Using the Light Extinction Principle

2.3 *Other Documents:*

SAE 100R13–20 Hydraulic Hose Specification[4]

ANSI/(NFPA) T2.13.1 R3-1998 Recommended Practice—Hydraulic Fluid Power—Use of Fire-Resistant Fluids in Industrial Systems[5]

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *flushing*, *v*—the process of cleaning the test system before testing to prevent cross-contamination.

## 4. Summary of Test Method

4.1 Hydraulic fluid in the amount of 190 ± 4 L (50 ± 1 gal) is circulated through a rotary vane pump system for 50 h at a pump speed of 2400 ± 20 r/min and a pump outlet pressure of 20.7 ± 0.2 MPa (3000 ± 20 psig). Fluid temperature at the pump inlet is 95 ± 3°C (203 ± 5°F). An ISO Grade 32 or 10W viscosity is required.

4.2 The cam ring and all ten vanes should be individually weighed before and after the test. The weight loss of the cam ring should be reported with the combined weight loss of all ten vanes. The intra-vanes (inserts) are not part of the required weight loss measurements and should be separately measured if desired. Other reported values are fluid cleanliness before and after the test, initial flow rate, and final flow rate.

4.3 Prior to installing the hydraulic test fluid into the rig, a stand flush is required to remove any contaminants. A minimum quantity of 190 ± 4 L (50 ± 1 gal) of fluid (see Note 1) made of the same chemical formulation as the test fluid, is required for the stand flush. Therefore the total quantity of oil required for the test is 380 L (100 gal).

[1] This test method 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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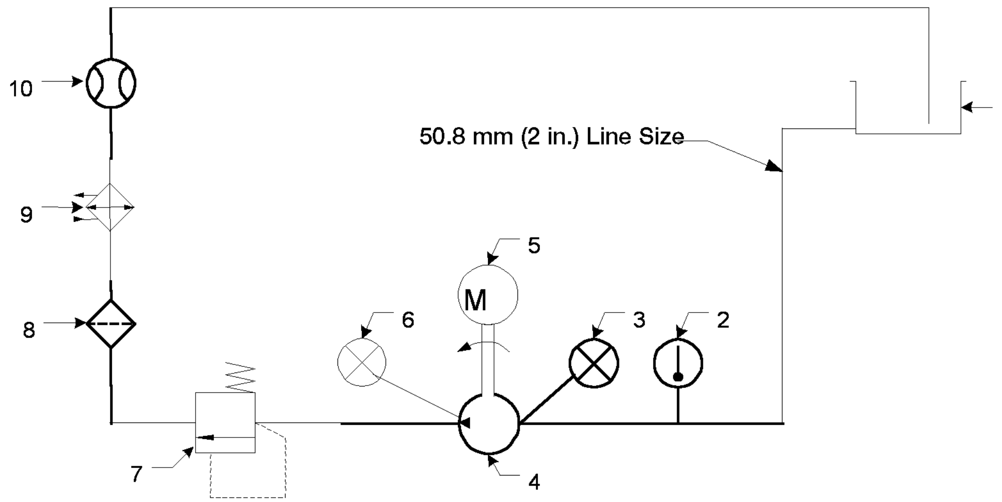
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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

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




Description of Components:

1 Reservoir, 190 L (50 gal) of oil; elevated above pump centerline to provide gravity feed
2 Temperature gage or thermocouple
3 Inlet pressure gage
4 Pump: 35VQ25A-11*20 (Cartridge kit P/N 4998040–002)
5 Electric motor, 93 kW (125 hp)
6 Outlet pressure gage
7 Pressure relief valve
8 Filter
9 Cooler
10 Flowmeter

NOTE—See Eaton Overhaul Manual I-3144–S (Appendix B) (available from any Eaton distributor).

**FIG. 1 System Schematic**

## 5. Significance and Use

5.1 This test method is an indicator of the wear characteristics of petroleum hydraulic fluids operating in a constant volume vane pump. Excessive wear in vane pumps could lead to malfunction of hydraulic systems in critical industrial or mobile hydraulic applications.

## 6. Apparatus

6.1 The basic system consists of the following (see Fig. 1):

6.1.1 *Electric Motor*, or other suitable drive, capable of a rotational speed of 2400 rpm with 93 kW (125 hp) as suggested minimum power requirement (see Fig. 1, Item 5).

6.1.2 *Test Stand Base*, with appropriate, rigid mounting for the motor, pump, reservoir, and other components.

6.1.3 *Rotary Intra-Vane Pump*, replaceable cartridge type,[6,7] Vickers 35VQ25A-11*20 (Cartridge Kit P/N 4998040-002)[8] rated at 81 $cm^3$/rev (4.98 $in.^3$/rev) flow at 1200 rev/min. A protective shield around the pump is recommended.

6.1.3.1 There are to be no modifications to the pump housing.

6.1.4 *Reservoir*, equipped with a baffle and lid, all of stainless steel construction.

6.1.4.1 Additional fluid ports may be added to the reservoir as required by the user to assist in measuring fluid level, reservoir temperature, and so forth.

6.1.4.2 If the reservoir is positioned so that the contents cannot be visually checked for air entrainment by removing the lid, a fluid-sight glass viewing port may be located in the side of the reservoir.

6.1.5 *Pump Outlet Pressure Control Valve*, with either manual or remote control (see Fig. 1, Item 7).

6.1.6 *Temperature-control Device*, suitable for controlling coolant flow to the heat exchanger to maintain test fluid at the specified temperature (see Fig. 1, Item 9).

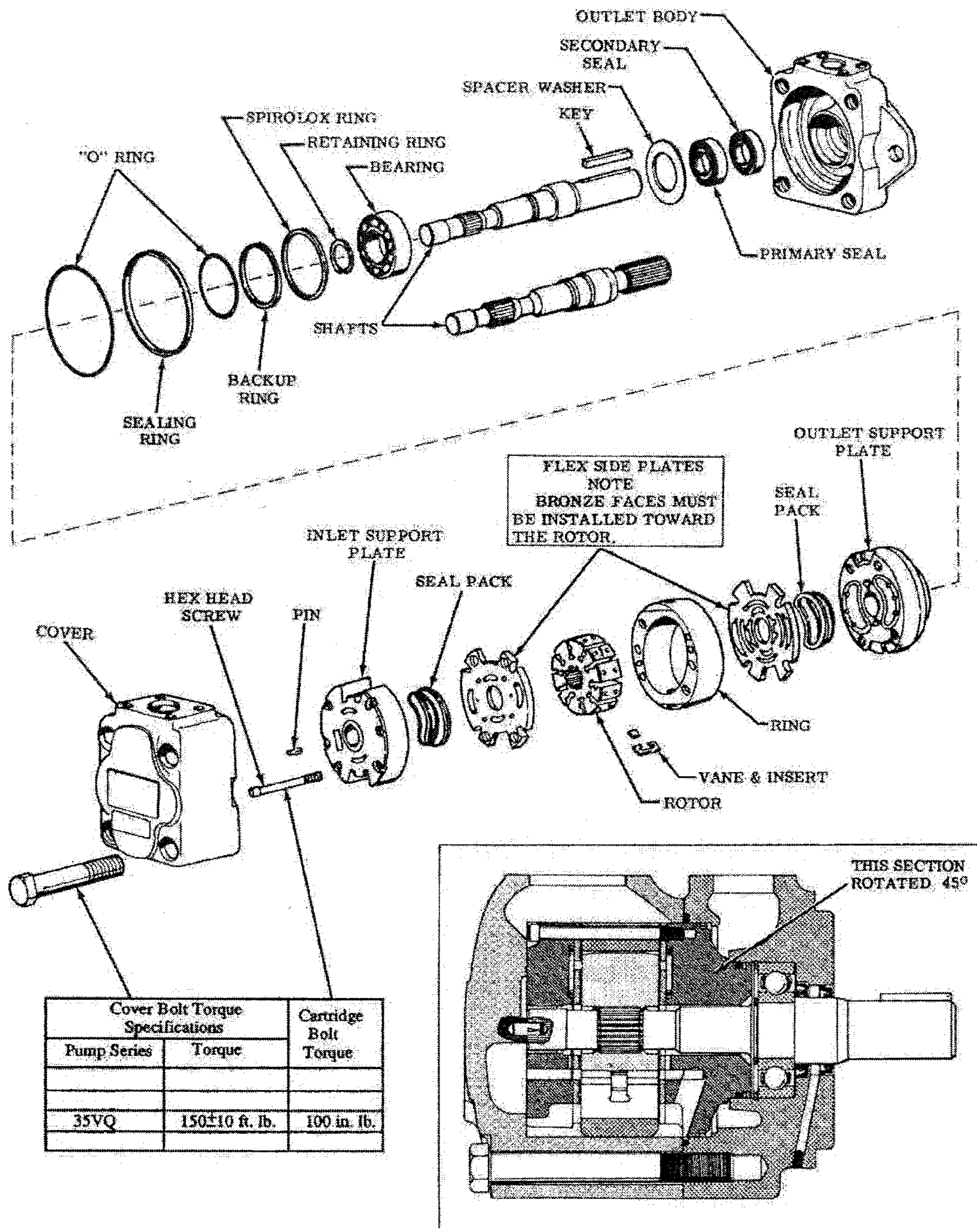
6.1.7 *Temperature Indicator*, (see Fig. 1, Item 2) shall have a minimum accuracy of ±1°C and shall have an appropriate sensor to monitor pump inlet temperature.

6.1.7.1 To prevent a flow disturbance near the pump inlet port, the temperature probe shall have a diameter of not more

[6] The replaceable cartridge consists of the inlet support plate, outlet support plate, flex side plates, seal pack, rotor, cam ring, intra-vane, and vanes.

[7] The individual cartridge parts can be purchased separately, if desired. The Eaton part numbers for these items are cartridge screws: P/N 410609, alignment pins: P/N 418108, inlet support plate: P/N 430806, outlet support plate: P/N 412003, flex side plate kit: P/N 923953, seal pack: P/N 433766, rotor: P/N 262154, cam ring: P/N 4999594-001, vane kit (includes ten intra-vanes and ten vanes): 922700.

[8] Available from any Eaton distributor.




NOTE—See Eaton Overhaul Manual I-3144–S (Appendix C) (available from any Eaton distributor).

**FIG. 2 Pump Components**

than 6 mm (0.25 in.) and positioned not less than 30 cm (12 in.) from the pump inlet port.

6.1.7.2 The test fluid temperature probe shall be positioned greater than 30 cm (12 in.) from the pump inlet cover (see Fig. 2). The fluid temperature probe shall be inserted into the midpoint of flow.

6.1.8 *Heat-Exchanger*, (see Fig. 1, Item 9). The heat exchanger should be of adequate size and design to remove the excess heat from the test system when utilizing the available coolant supply.

6.1.9 *Outlet Pressure Indicator*, (see Fig. 1, Item 6), to measure pump discharge pressure, and shall have an accuracy of at least ±1 bar (±15 psi).

6.1.10 *Inlet Pressure Indicator*, (see Fig. 1, Item 3), to measure pump inlet pressure, and shall have an accuracy of at least ±7 kPa (±1 psi).

6.1.11 *Filter Unit*, (see Fig. 1, Item 8), to limit system debris from causing wear to the test pump. The filter performance should be $\beta_3 \geq 100$.

6.1.11.1 The filter housing shall be installed with dual pressure gages (see Fig. 1, Item 13) or a differential pressure transducer to monitor pressure across the filter to warn of impending collapse of the element.

6.1.11.2 If dual pressure gages are used to monitor filter pressure, the rated collapse pressure of the filter element should be known.

6.1.12 *Flow-Measuring Device*, (see Fig. 1, Item 12), with an accuracy of at least ±1 L/min (±0.25 gpm).

6.1.12.1 It is suggested that the test circuit be equipped with some automated shutdown capabilities for safety reasons. Safety relays could be any of the following: low-level, high pressure, high temperature, and low flow safety switches incorporated into the system.

6.1.12.2 A check should be made to ensure that the flush and test fluid are compatible with seals or any other materials in the system.

6.1.13 *Flexible Motor Coupling*, to connect the motor drive and the pump.

6.1.14 *Fluid Sampling Port*, in accordance with ISO 4021.

6.2 The various components of the test system shall be placed in the system as indicated in Fig. 1.

6.2.1 The test system shall be arranged and provided with necessary drain valves so that complete draining is possible with no fluid trap areas.

6.2.2 Good hydraulics piping practices should be used when constructing the test system to avoid air entrainment points and flow restrictions.

6.2.3 The pump should be mounted so that its internal surfaces can easily be inspected and cleaned, alignment can be checked, and the operator has comfortable access when torquing the head.

6.2.4 A pressure transducer, to measure inlet pressure, shall be placed within 30.5 cm (12 in.) of the opening of the pump cover.

6.2.5 The inlet pressure of the pump shall be 13.8 ± 7 kPa (2 ± 1 psig) once the break-in procedure is complete and test conditions have been met (see 12.2).

NOTE 1—See Annex A1 for recommended testing conditions for water-based synthetic fluids.

6.2.6 The reservoir should be mounted so that it can be cleaned and filled with ease and the contents may be readily inspected by removal of the reservoir lid or inspection cover.

6.2.7 The inlet line (from the reservoir to the pump intake) shall have an internal diameter of at least 5.08 cm (2 in.) and shall have a straight run of at least 61 cm (24 in.) to the pump inlet port.

NOTE 2—Some users prefer to use a radius bend at the reservoir outlet instead of an elbow. If used, the straight run described in 6.2.7, shall still be measured between the end of the bend and the pump inlet port.

6.2.8 The high pressure discharge line (from the pump to the pressure control valve) shall have a minimum inside diameter of 1¼ in. with a maximum allowable working pressure rating greater than 207 Bar (3000 psi). A seamless steel pipe size and schedule (2 in. double extra strong pipe–XXS) or equivalent high-pressure hose (SAE 100R13–20) are recommended for the discharge line.

6.2.9 The fluid return line and fittings (from the pressure control valve to the filter, flowmeter, heat exchanger, and reservoir) should have a minimum inside diameter of 2.54 cm (1 in.). A seamless steel pipe size of (1 in. Schedule 40) is recommended.

6.2.10 A shut-off valve may be located in the plumbing between the reservoir and the inlet to the pump. The full flow valve shall have a minimum orifice diameter of 5.08 cm (2 in.) and shall be positioned no closer than 30 cm (12 in.) from the pump inlet port.

NOTE 3—Some users find the addition of a shut-off valve on the return line to be a useful addition to the piping since it allows filter changes and other system maintenance to be performed without draining the reservoir. (**Warning**—If a shut-off valve is installed in the fluid return line, the user shall take procedural steps to ensure that this valve has been opened before the pump is started. If the valve is not opened, low pressure system components may rupture.)

## 7. Reagents and Materials

7.1 (**Warning—**Use adequate safety provisions with all solvents.)

7.2 *Aliphatic Naphtha*, Stoddard solvent or equivalent is satisfactory. (**Warning—**Combustible. Vapor harmful.)

7.3 *Precipitation Naphtha*. (**Warning—**Extremely flammable. Harmful if inhaled. Vapors can cause flash fire.)

7.4 *Isopropanol*. (**Warning—**Flammable, vapor harmful in large amounts, eye irritant, extremely combustible when hot.) (**Warning—**In instances when the solvents listed in Section 7 are not effective, alternative solvents may be used. It is the responsibility of the user to determine the suitability of alternative solvents and any hazards associated with their use.)

## 8. Test Stand Maintenance

8.1 Temperature, pressure, flow sensors and shut-off switches shall be checked periodically for proper calibration and operation in accordance with good engineering practice, as determined by the user.

NOTE 4—If an axial turbine flowmeter is used, calibrate with 0.876 specific gravity, ISO Grade 32 hydraulic oil. Perform a 10–point calibration over a ranges of 0–227 L/m (0–50 gpm). This calibration shall be performed by the flowmeter manufacturer or other qualified personnel.

8.2 It is recommended that the pump shaft (P\N 242287), shaft seal (P\N 394973), and shaft bearings (P\N 38441 or equivalent)[8] (see Fig. 2) be replaced after every ten test runs (or sooner if high weight loss, vibration, cavitation, or visual deterioration is encountered).

8.3 Inspect the pump cover and body for evidence of galling marks or excessive wear and replace if distress is observed. Visually examine the interior of the pump cover and outlet body. Replace if evidence of deterioration is observed.

8.4 Check the surface inside the pump outlet body, where the shaft seal is positioned, for conditions that may cause the seal to leak.

8.5 Check alignment of the pump and motor shafts. Maximum values of 0.08 mm (0.003 in.) parallel misalignment and 0.3° angular misalignment are suggested limits.

8.6 Alignment checks shall be made with a torqued cartridge in place.

8.7 Using a dial indicator to check run out, inspect the shaft for a bent condition by rotating it by hand with the motor coupling removed.

8.8 Periodically clean the four tapped holes, which receive the pump head bolts and the threads of the head bolts themselves. The threads may be coated with a light oil to prevent corrosion. To ensure even torquing of the cartridge, housings, or head bolts with damaged threads shall be discarded.

8.9 Periodic disassembly of the relief valve for cleaning and inspection is recommended.

## 9. Sampling

9.1 The sample of fluid shall be thoroughly representative of the material in question, and the portion used for the test shall be thoroughly representative of the sample itself.

## 10. Flushing

10.1 Proper cleaning and flushing of the entire system is extremely important in order to prevent cross-contamination of test fluids.

10.2 *Flushing Procedure for Petroleum and Synthetic Fluids*:

NOTE 5—This flushing sequence is not adequate when changing fluid types, such as from glycol to phosphate ester, oil to glycol, and so forth. It is the responsibility of the user to determine the suitability of alternative solvents and any hazards associated with their use. Please reference ANSI/(NFPA) document No. T2.13.1 or ISO 7745, or both, for additional instructions.

10.2.1 Drain all old fluid from the system, remove used test cartridge (if not already done), and remove and discard old filter.

10.2.2 Before setting up and installing the test pump, the system must be clean from debris and leftover fluid. Install a new filter, flush pump with 190 ± 4 L (50 ± 1 gal) of the test fluid (ISO VG 32).

10.2.3 Allow the system to flush for a minimum of 30 min at the following conditions: motor speed = 2400 ± 50 rpm, outlet pressure = 3.5 ± 0.2 MPa (500 ± 20 psi).

10.2.4 After the stand flush is complete, drain the entire system, remove the filter, and remove the slave pump.

10.2.5 If in the opinion of the lab personnel the stand needs additional flushing, repeat 10.2.1-10.2.4.

10.2.6 Install a new filter and charge the system with 190 ± 4 L (50 ± 1 gal) of new test fluid. Before starting a test, the fluid cleanliness level shall be less than or equal to ISO cleanliness code 18/16/13 (see ISO 4406). Particle counting shall be in accordance with ISO 11500, or use an automatic particle counter calibrated in accordance with ISO 11171. Fluid cleaning consists of using a filter cart to clean the fluid before installing it into the stand. A flush pump can also be used to circulate the fluid in the stand until the required ISO cleanliness code is met. If a circulating cart is used, be sure to flush with next test fluid and change out filter to ensure no cross contamination.

## 11. Preparation and Installation of Test Cartridge

11.1 Disassemble the 35VQ25A-11*20, Fig. 1, and identify the vanes, cam ring, and side plates, Fig. 2, for reassembly into the same location.

11.2 Using a solvent, thoroughly clean the cam ring and set of ten vanes. Allow the cam ring and vanes to dry. Weigh (separately) the cam ring and the complete set of ten vanes (without intra-vanes or inserts). Determine these weights to the nearest milligram and record the values. The vanes shall be demagnetized before being weighed. Demagnetize with a degausser as needed.

11.3 Assemble the test cartridge according to Eaton Overhaul Manual I-3144-S. Make certain of proper vane insertion into the rotor and correct rotor and inner and outer bushing direction and alignment. The vanes shall be checked for free movement in rotor slots when assembling.

## 12. Procedure

12.1 *Break-in*:

12.1.1 Install the 35VQ25A-11*20 pump.

12.1.2 Jog the pump to release any entrained air that is in the system.

12.1.3 Set the pump speed to 2400 ± 20 rpm, pump outlet pressure = 6.9 ± 0.2 MPa (1000 ± 20 psig), and run for 30 min. Allow the pump inlet temperature to rise and not exceed 52 ± 3°C (125 ± 5°F).

12.1.4 Set the pump speed to 2400 ± 20 rpm, pump outlet pressure = 13.8 ± 0.2 MPa (2000 ± 20 psig), and run for 30 min. Allow the pump inlet temperature to rise and not exceed 79 ± 3°C (175 ± 5°F).

NOTE 6—See A1.4.1 for recommended break-in procedure for water-based synthetic fluids.

NOTE 7—It is recommended that the temperature in each stage of break-in meet conditions in 15 min or less.

12.2 *Performance Testing*:

12.2.1 Set the pump speed to 2400 ± 20 rpm, pump outlet pressure = 20.7 ± 0.2 MPa (3000 ± 20 psig), and run for 49 h. Allow the pump inlet temperature to rise and not exceed 95 ± 3°C (203 ± 5°F).

12.2.2 The minimum pump flow is 132.5 L/m (35 gpm). The test should be stopped if the pump flow falls below the minimum specification.

NOTE 8—See A1.4.2 for recommended performance testing procedure for water-based synthetic fluids.

12.3 *Restarting A Test*:

12.3.1 If for any reason a 50-h test must be stopped, the test can be resumed after the test conditions are established once again. Set the pump speed to 2400 ± 20 rpm, pump outlet pressure = 6.9 ± 0.2 MPa (1000 ± 20 psig), and run for 30 min. Raise the pump inlet temperature to 52 ± 3°C (125 ± 5°F).

12.3.2 Set the pump speed to 2400 ± 20 rpm, pump outlet pressure = 13.8 ± 0.2 MPa (2000 ± 20 psig), and run for 30 min. Raise the pump inlet temperature to 79 ± 3°C (175 ± 5°F).

12.3.3 Set the pump speed to 2400 ± 20 rpm, pump outlet pressure = 20.7 ± 0.2 MPa (3000 ± 20 psig). Raise the pump

TABLE 1 Mass Loss, mg

| Material | Average, $\bar{x}$ | Standard Deviation | Repeatability, Standard Deviation, sr | Reproducibility, Standard Deviation, sR | Repeatability Limit, r | Reproducibility Limit, R |
|---|---|---|---|---|---|---|
| A | 39.073 | 5.552 | 14.835 | 14.835 | 41.539 | 41.539 |
| B | 28.837 | 5.888 | 9.887 | 9.992 | 27.685 | 27.978 |
| C | 56.987 | 9.859 | 20.871 | 20.871 | 58.440 | 58.440 |

inlet temperature to 95 ± 3°C (203 ± 5°F). The test timer can resume from the point that it left off only when test conditions have been reestablished. Then run for the balance of the 49 h remaining at the point the test was interrupted.

12.3.4 Once test conditions have been met, the flow rate at restart cannot be lower than 5 % of the last recorded flow for the test results to be valid.

12.4 *Test Shutdown*:

12.4.1 After completion of the test, draw off a fluid sample, in accordance with ISO 4021, to determine the fluid cleanliness in accordance with ISO 4406.

12.4.2 Reduce the pressure control valve setting and stop pump operation.

12.4.3 Stop the flow of the cooling water.

12.4.4 Observe and record the condition of the test fluid, noting any unusual appearance or odor.

12.4.5 Open all drain valves and drain the test system.

12.4.6 After the pump has cooled sufficiently, remove the pump cover and carefully remove the test cartridge.

## 13. Disassembly and Inspection

13.1 *Disassembly*:

13.1.1 When 50-h test has been completed, disassemble the 35VQ25A-11*20, Fig. 2.

13.2 *Weight Loss Measurements and Inspection*:

13.2.1 Using a solvent, thoroughly clean the cam ring and set of ten vanes. Allow the cam ring and vanes to dry. Determine the mass of the pump cam ring and the mass of the ten vanes (separately) to the nearest milligram.

13.2.2 Calculate the weight loss of the pump cam ring and ten vanes, sustained during pump operation, by subtracting the post-test weights from the pre-test weights.

13.2.3 Inspect the pump components for any unusual wear.

## 14. Report

14.1 Report the following information:

14.1.1 Mass loss of the ring and vanes in milligrams (mg).

14.1.2 Flow rate at the start and end of the test.

14.1.3 Any unusual observations on wear, scuffing, deposits, cavitation damage, deterioration of seals, and bushing replacement.

14.1.4 Fluid cleanliness at the start and end of the test.

14.1.5 List any modifications to the test method procedure, conditions, or apparatus, and report as "A Modification to Test Method D6973."

## 15. Precision and Bias [9]

15.1 The precision of this test method is based on an interlaboratory study conducted in 2006. Each of five laboratories tested three different materials in triplicate. Every test result represents an individual determination. For Materials A and B, one laboratory reported only duplicate results. See Table 1.

15.1.1 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

15.1.2 *Reproducibility*—Two test results shall be judged not equivalent if the differ by more than the "*R*" value for that material; "*R*" is the interval representing the difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

15.1.3 Any judgment in accordance with these two statements would have an approximate 95 % probability of being correct.

15.2 *Bias*—At the time of the study, there was no accepted reference material for determining the bias for this test method, therefore no statement on bias is being made.

15.3 The precision statement was determined through statistical examination of 43 results, from five laboratories, on three materials. The requirement of six participating laboratories, as found in Practice E691, was not met for this study.

15.3.1 The three materials tested were at various levels of performance and were identified as follows:

Material 1: mineral zinc-based hydraulic fluid
Material 2: mineral zinc-based hydraulic fluid
Material 3: mineral zinc-based hydraulic fluid

15.3.2 To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to a test material.

## 16. Keywords

16.1 hydraulic fluid; vane pump; wear

[9] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1634.

# ANNEX

**(Mandatory Information)**

## A1. TESTING CONDITIONS FOR WATER-BASED SYNTHETIC FLUIDS

### A1.1 Introduction

A1.1.1 For water-based synthetic fluids, the inlet conditions and fluid operating temperatures cited in this test method would impose an inadequate inlet condition at the pump. The following guidelines are recommended testing conditions for water-based synthetic fluids.

### A1.2 Fluid Cleanliness (see 10.2.6)

A1.2.1 Follow the same cleanliness levels and procedures. (There may be varying results on cleanliness levels due to the make-up of the fluid.)

### A1.3 Apparatus (see 6.2.5)

A1.3.1 The inlet pressure of the pump shall be 21 ± 13.8 kPa (3 ± 2 psig) once the break-in procedure is complete and test conditions have been met (see 12.2).

### A1.4 Procedure (see Section 12)

A1.4.1 *Break-in*:

A1.4.1.1 Install the 35VQ25A-11*20 pump.

A1.4.1.2 Jog the pump to release any entrained air that is in the system.

A1.4.1.3 Set the pump speed to 2400 ± 20 rpm, pump outlet pressure = 6.9 ± 0.2 MPa (1000 ± 20 psig), and run for 30 min. Allow the pump inlet temperature to rise and not exceed 43 ± 3°C (110 ± 5°F).

A1.4.1.4 Set the pump speed to 2400 ± 20 rpm, pump outlet pressure = 13.8 ± 0.2 MPa (2000 ± 20 psig), and run for 30 min. Allow the pump inlet temperature to rise and not exceed 54 ± 3°C (130 ± 5°F).

A1.4.2 *Performance Testing*:

A1.4.2.1 Set the pump speed to 2400 ± 20 rpm, pump outlet pressure = 20.7 ± 0.2 MPa (3000 ± 20 psig), and run for 49 h. Allow the pump inlet temperature to rise and not exceed 65 ± 3°C (150 ± 5°F).

A1.4.2.2 The minimum pump flow is 132.5 L/m (35 gpm). The test should be stopped if the pump flow falls below the minimum specification.