Standard Test Method for Indicating Wear Characteristics of Petroleum and Non-Petroleum Hydraulic Fluids in Constant Volume Vane Pump[1]

This standard is issued under the fixed designation D 2882; 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 test method covers a constant volume high-pressure vane pump test procedure for indicating the wear characteristics of petroleum and non-petroleum hydraulic fluids.

1.2 The values stated in SI units are to be regarded as standard. The values 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.* For specific hazard statements, see 6.1.3, 7.1, 7.2, 7.3, 7.4, and Note 7.

2. Referenced Documents

2.1 *ISO Standards:*[2]

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 Level of Contamination by Solids Particles

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.

3.1.2 *torquing*, *v*—the process of tightening the pump head bolts to achieve a uniform clamping force.

4. Summary of Test Method

4.1 An amount of 18.9 ± 0.5 L (see Note 1) (5 ± 0.13 gal) of a hydraulic fluid are circulated through a rotary vane pump system for 100 h at a pump speed of 1200 ± 60 r/min and a pump outlet pressure of 13.8 ± 0.3 MPa (2000 ± 40 psi). Fluid temperature at the pump inlet is 66 ± 3°C (150 ± 5°F) for all water glycols, emulsions, and other water-containing fluids and for petroleum and synthetic fluids of ISO Grade 46 or lighter. A temperature of 80 ± 3°C (175 ± 5°F) is used for all other synthetic and petroleum fluids.

NOTE 1—To improve reproducibility, fluid volume has been standardized in this revision of Test Method D 2882.

4.2 The result obtained is the total mass loss from the cam ring and the twelve vanes during the test. Other reported values are fluid cleanliness before and after the test, initial flow rate, and final flow rate.

4.3 The total quantity of test oil required for a run is 26.5 L (7 gal).

5. Significance and Use

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

6. Apparatus

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

6.1.1 *Twelve Hundred rpm AC Motor*, or other suitable drive, with 11 kW (15 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 Vane Pump*, replaceable cartridge type,[3,4] Vickers 104C or 105C rated at 28.4 L/min (7.5 gal/min) flow at 1200 r/min with ISO Grade 32 fluid at 49°C (120°F), and 6.9 MPa (1000 psi) (see Fig. 1, Item 4; Fig. 2; and Fig. 3). (**Warning**—The test pump is rated at 6.9 MPa (1000 psi) but is being operated at 13.8 MPa (2000 psi). A protective shield around the pump is therefore recommended.)

6.1.3.1 There are to be no modifications to the pump housing, such as plugging the drain hole in the pump body or drilling and tapping a hole in the head for an external drain.

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[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.N on Hydraulic Fluids.

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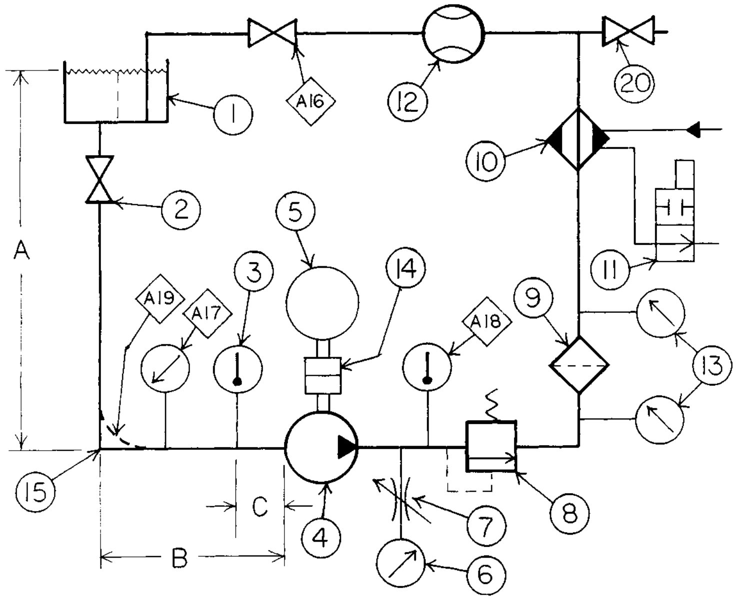
[2] Available from American National Standards Institute, 11 W 42nd St., 13th Floor, New York, NY 10017.

[3] The replaceable cartridge consists of the cam ring, the rotor, two bushings, a set of twelve vanes, and an alignment pin. Two different cartridges are available for this pump. Cartridge No. 429126 is intended to give better performance at 13.8 Mpa and uses Rotor No. 429446 and Cam Ring No. 574814. Cartridge No. 912014 uses Rotor No. 2008 and Cam Ring No. 2013. Some users report fewer pump failures when using Rotor No. 2008.

[4] The individual cartridge parts can be purchased separately, if desired. The Vickers part numbers for these items are Cam Ring No. 2013 or 574814, Pin No. 2020, Rotor No. 429446 or 2008, Bronze Bushings Nos. 2015 and 2016, and Vane Kit (twelve vanes) No. 912021.



ITEM DESCRIPTION
1. Reservoir
2. Pump inlet shut off valve
3. Pump inlet temperature sensor
4. Pump
5. Motor
6. Pressure gage for high pressure line
7. Snubber valve
8. Relief valve for pressure control
9. Return line filter
10. Heat exchanger
11. Temperature control valve
12. Flow meter
13. Pressure gages for return line filter
14. Flexible coupling
15. Inlet elbow
20. Fluid sampling port

Required Dimensions:
A. 61 - 66 cm (24 - 26 in)
B. 15.2 cm (6 in)
C. 10.2 cm (4 in)

Additional Non-required Items
A16. Return line shut off valve
A17. Pump inlet vacuum gage
A18. Pump outlet temperature sensor
A19. Radius bend at pump inlet

FIG. 1 System Schematic

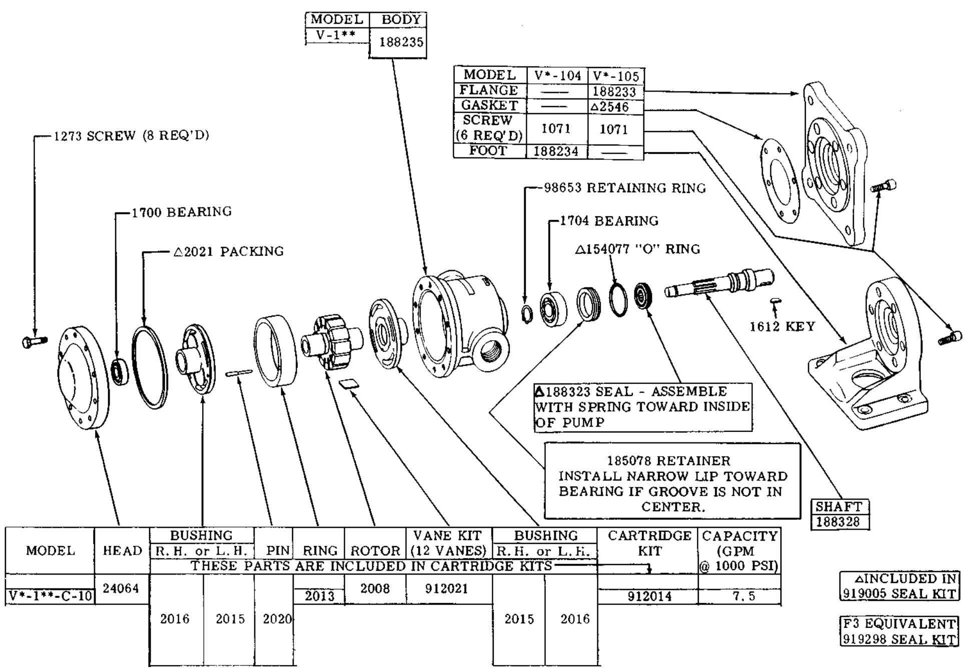


FIG. 2 Pump Components

6.1.4 *Reservoir*, (see Fig. 1, Item 1), equipped with a removable baffle and lid, all of stainless steel construction. The reservoir design is shown in Figs. 4-6.

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

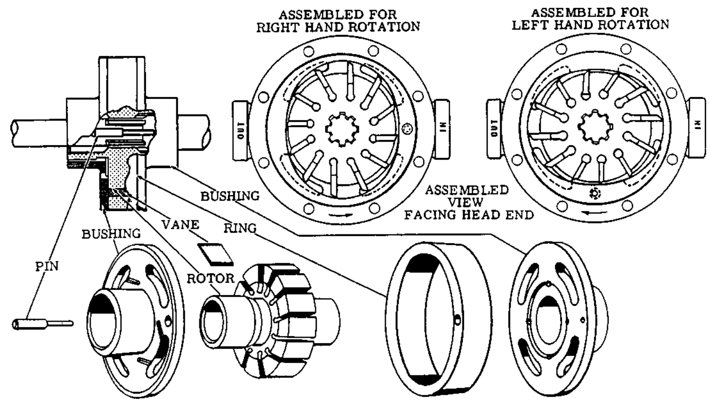


FIG. 3 Cartridge Kit

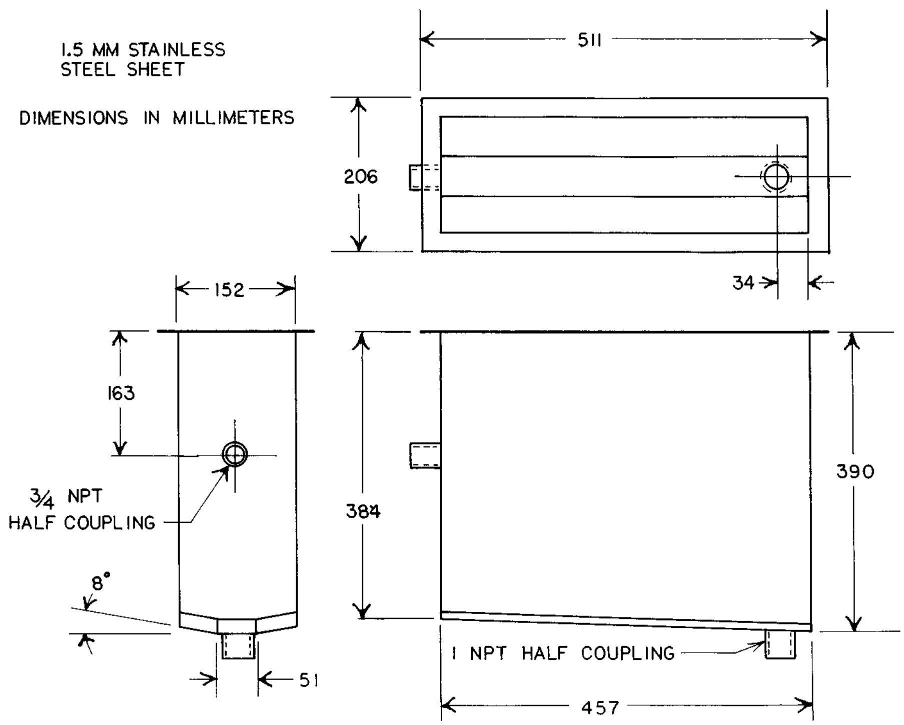


FIG. 4 Reservoir

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

6.1.5 *Outlet Pressure Control Valve*, Vickers pressure relief valve (CT-06-C/500-2000 psi) with either manual or remote control (see Fig. 1, Item 8, and Fig. 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 11).

6.1.7 *Temperature Indicator* (see Fig. 1, Item 3) shall have an accuracy of ± 1°C and shall have an appropriate sensor to monitor pump inlet temperature.

6.1.7.1 To prevent a flow restriction near the pump inlet port, the temperature probe shall have a diameter of not more than 6 mm (0.25 in.).

6.1.7.2 The test fluid temperature shall be measured within 10.2 cm (4 in.) of the pump inlet (see Fig. 1, Dimension C). The sensing probe shall be inserted into the midpoint of flow.

NOTE 2—Some users have found the addition of a pump outlet temperature sensor to be a useful diagnostic tool. If used, it shall be suitable for 13.8 MPa duty and should be placed in the high pressure line between the pump and the relief valve (see Fig. 1, Item A18).

6.1.8 *Heat-Exchanger* (see Fig. 1, Item 10)—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.

NOTE 3—It is suggested that a shell-and-tube type heat exchanger, if used, should be connected in reverse (the hydraulic fluid is passed through the tubes and not around them) so that the interior of the heat exchanger can be effectively cleaned between tests.

6.1.9 *Pressure Indicator* (see Fig. 1, Item 6), to measure pump discharge pressure shall have an accuracy of at least ± 0.3 MPa (± 40 psi). The pressure indicator should be snubbed (see Fig. 1, Item 7) to prevent damage from pulsations or

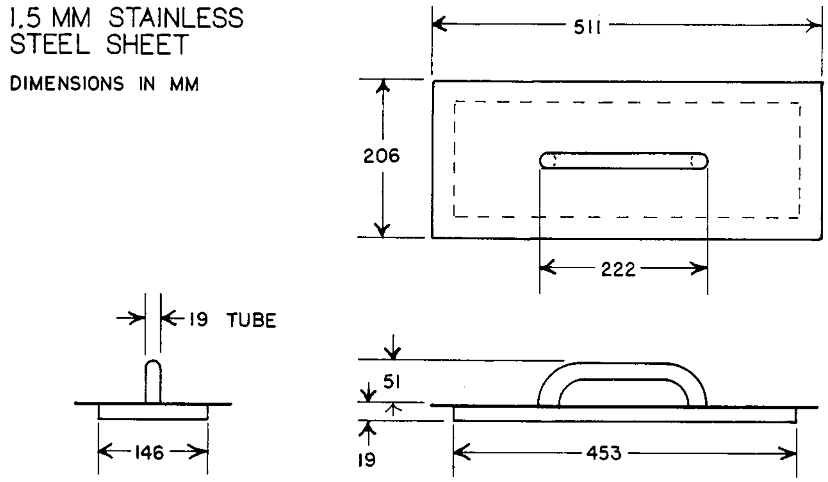


FIG. 5 Reservoir Lid

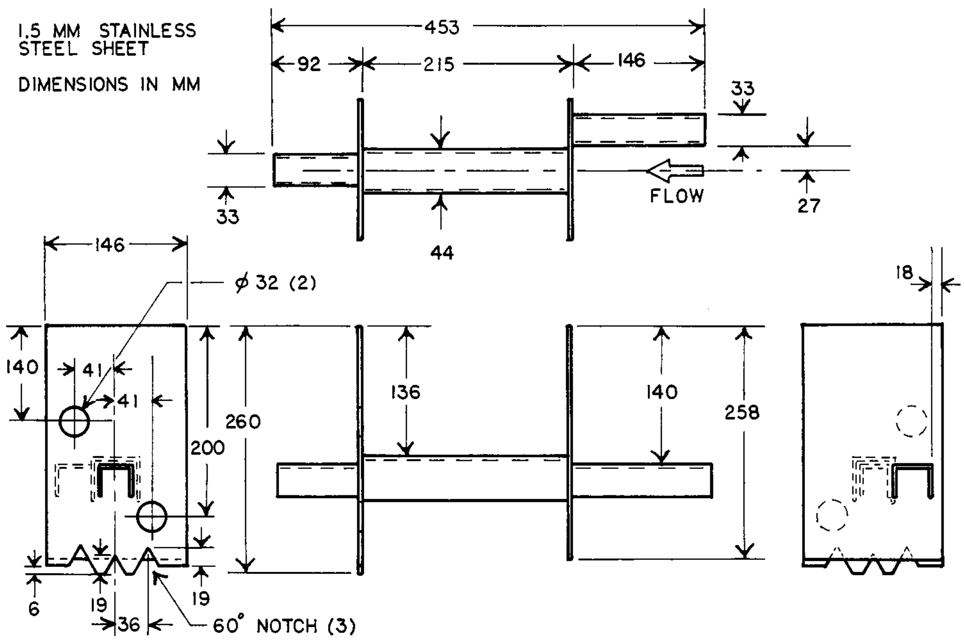


FIG. 6 Reservoir Baffle

sudden fluctuations of system pressure.

6.1.10 *Filter Unit* (see Fig. 1, Item 9), 3 µm (minimum Beta 3 ratio of 100) replaceable fiberglass element with housing. Two new filter elements are required for each test.

6.1.10.1 The filter housing shall be nonbypassing and shall be provided with dual pressure gages (see Fig. 1, Item 13) or another suitable indicator to monitor pressure across the filter to warn of impending collapse of the element.

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

6.1.11 *Flow-Measuring Device* (see Fig. 1, Item 12), with an accuracy of at least ± 0.4 L/min (0.1 gpm).

6.1.12 While not required, it is suggested that low-level, high pressure, high temperature and low flow safety switches be incorporated into the system.

6.1.13 A check should be made to ensure that the flush and test fluid are not incompatible with seals or any other materials in the system.

NOTE 4—The use of galvanized iron, aluminum, zinc, and cadmium should be avoided due to their high potential for corrosion in the presence of many non-petroleum hydraulic fluids.

6.1.14 *Flexible Motor Coupling* (see Fig. 1, Item 14).

6.1.15 *Fluid Sampling Port*, in accordance with ISO 4021 (see Fig. 1, Item 16).

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 ingestment points and flow restrictions.

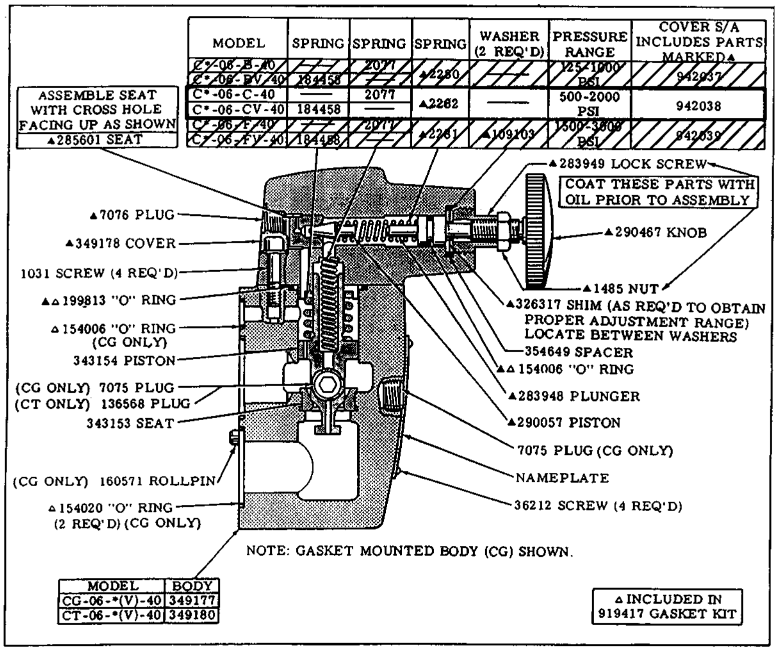


FIG. 7 Relief Valve

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 The reservoir shall be located above the pump so that the fluid level in the reservoir will be between 61 and 66 cm (24 to 26 in.) above the center line of the pump when the test system is fully charged with test fluid (see Fig. 1, Dimension A).

6.2.4.1 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.

6.2.5 The inlet line (from the reservoir to the pump intake) shall have an internal diameter of at least 25 mm (1 in.) and shall have a straight horizontal run of at least 15 cm (6 in.) between the inlet elbow (see Fig. 1, Item 15) and the pump inlet port (see Fig. 1, Dimension B).

NOTE 5—Some users have found the addition of a compound pressure gage near the pump inlet port to be a useful diagnostic tool (see Fig. 1, Item A17). However, care should be taken to ensure that any ports added to the inlet line do not become air ingestment points.

NOTE 6—Some users prefer to use a radius bend instead of an elbow at the pump inlet (see Fig. 1, Item A19 instead of Item 15). If used, the straight run described in 6.2.5, shall still be measured between the end of the bend and the pump inlet port.

6.2.6 The high pressure discharge line (from the pump to the pressure control valve) shall have an outer diameter of 26.7 mm and a wall thickness of 5.56 mm (¾in. Schedule 160) and be made from steel or stainless steel.

6.2.7 The fluid return line and fittings (from the pressure control valve to the filter, flow counter, heat exchanger, and reservoir) should have an inside diameter of at least 20.9 mm and a wall thickness of 2.87 mm (¾ in. Schedule 40).

NOTE 7—Some users find the addition of a shut-off valve on the return line (see Fig. 1, Item A16) 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.)

6.2.8 A shut-off valve shall be provided in the reservoir outlet line (see Fig. 1, Item 2). A "full flow" type of valve with an orifice of at least 25 mm (1 in.) is recommended.

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.) (**Warning—**In instances when the solvents listed in Section 7 are not effective, alternative solvents may be used (see Notes 9 and 10 and 12.4.10). 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 Sensors and shut-off switches should be checked periodically for proper calibration and operation in accordance with good engineering practice, as determined by the user.

8.2 It is recommended that the pump shaft (see Fig. 2, Item 188328), seals (see Fig. 2, Items 188323, 154077, and 2021), and bearings (see Fig. 2, Items 1704 and 1700) be replaced after every five runs (or sooner if high weight loss, vibration, cavitation, or visual deterioration is encountered).

8.2.1 Special seals are required for testing with synthetic fluids. The different Vickers gasket kits that are available for the V-104C/105C pump are as follows: 919005 for water-glycols, water-in-oil emulsions, and petroleum; 919298 for water-in-oil emulsions, water-glycols, aryl phosphate esters, and phosphate ester-hydrocarbon blends; and 919038 for alkyl and aryl phosphate esters.

8.3 *Inspect the Pump Body and Head*:

8.3.1 Visually examine the pump head and the interior of the pump body (see Fig. 2, Items 24064 and 188235). Replace if evidence of deterioration is observed.

8.3.2 When the pump has been disassembled for seal and bearing replacement, carefully inspect the faces of the pump body and head, which seal against the bushing faces (see Fig. 8, Surfaces A and B) for high spots, warped condition, or other damage, which may interfere with a good fluid seal. Discard any unsuitable components.

8.3.3 Check that the head bearing (see Fig. 2, Item 1700) is a press fit into the head. If it is loose, discard the head.

8.3.4 Check that the shaft bearing (see Fig. 2, Item 1704) makes a close slip fit into the body. If loose, discard the body.

8.3.5 Check that the bore for the cartridge (76.2 mm) (see Fig. 8, Diameter E) is not oversized for the cam ring. If the bore is more than 0.05-mm (0.002-in.) larger than the ring diameter, the ring may crack. See Note 20 for remedial measures.

8.3.6 Check that the pump body ports align properly with the bushing ports, with no overlapping, which might restrict fluid flow.

NOTE 8—In some cases in which operational problems continue without apparent cause, a change of pump body or head, or both, have been known to alleviate the problem.

8.4 Inspect the shaft (see Fig. 8) (see Fig. 2, Item 188328).

8.4.1 Check that the splines of a new shaft are smoothly cut, have consistent width from the outer diameter to the root, and are parallel with the axis of the shaft. Avoid reusing shafts if the rotor has worn deep marks in the splines (see Fig. 9, Items 1, 2, 3, and 4).

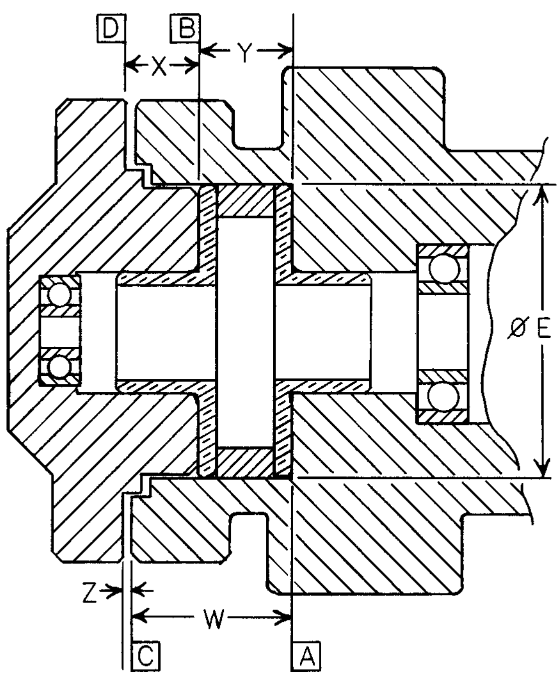


FIG. 8 Pump Housing

8.4.2 Check new shafts and used shafts that have been subjected to pump failure or overheating for bending, twist, or damage to the key seat or splines (see Fig. 9, Items 5, 7, and 8).

8.4.3 Check the surface where the shaft seal rides for conditions that may cause the seal to leak (see Fig. 9, Item 6).

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.

8.5.1 Alignment checks should be made with a torqued cartridge in place.

8.5.2 Using a test indicator, inspect the shaft for a bent condition by rotating it by hand with the motor coupling removed (see Fig. 9, Item 7).

8.6 Periodically clean the eight tapped holes, which receive the pump head bolts (see Fig. 10) and the threads of the head bolts themselves (see Fig. 2, Item 1273). 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 should be discarded.

8.7 Periodic disassembly of the relief valve (see Fig. 1, Item 8, and Fig. 7) 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 9—This flushing sequence is not adequate when changing fluid types, such as from glycol to phosphate ester, oil to glycol, and so forth (**Warning**—In instances when the solvents listed in Section 7 are not effective, alternative solvents may be used (see Notes 9 and 10 and 12.4.10). It is the responsibility of the user to determine the suitability of alternative solvents and any hazards associated with their use.)

10.2.1 Drain all old fluid from the system, remove used test cartridge (if not already done), and remove and discard old filter. Wipe out pump and filter housings and the reservoir and baffle.

10.2.2 Install a flush cartridge (any good, previously used cartridge) and a new filter.

10.2.3 Close all drain valves, torque the pump head, and make sure that the pump inlet valve and any return line valves are open.

10.2.4 Charge the system with 7.6 L (2 gal) of flushing fluid. For petroleum and synthetic fluids, use either Stoddard solvent (**Warning**—see 7.2) or base stock, depending on the similarity of the old and new test fluids.

NOTE 10—One flush of this petroleum solvent is usually sufficient to clean a system in which an oil was run. Other solvents can be used when oxidized oil has coated the reservoir and lines (**Warning**—see 10.2.1). Repeat the flush if the first flush is cloudy or opaque.

10.2.5 If not already done, reduce the setting of the pressure control valve so that pressure will not be generated when flow starts.

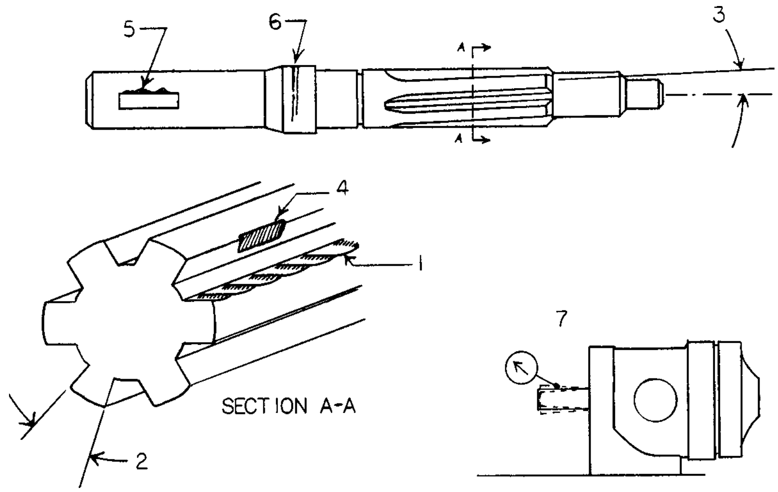


FIG. 9 Shaft Inspection

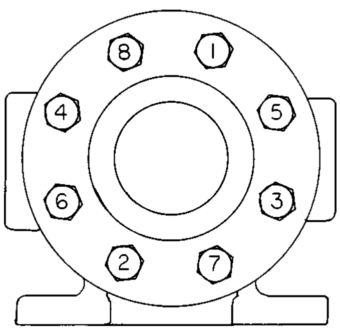


FIG. 10 Pump Head Bolts Torquing Sequence

10.2.6 Jog the pump drive motor ON and OFF switches to remove the air from the test system. Continue until the fluid returning to the reservoir is visually free of air.

10.2.7 Flush for 30 min at 0.7 MPa (100 psi) and 38 to 49°C (100 to 120°F).

10.2.8 Drain system, remove filter element, and flush cartridge. Wipe out pump and filter housings and the reservoir and baffle.

10.2.9 Reinstall used filter element and flush cartridge, torque pump head, reduce setting of pressure control valve, close all drain valves, and open pump inlet and return-line valves.

10.2.10 Recharge system with 7.6 L (2 gal) of test fluid.

10.2.11 Jog the pump drive motor ON and OFF switches to remove the air from the test system. Continue until the fluid returning to the reservoir is visually free of air.

10.2.12 Flush for 30 min at 0.7 MPa (100 psi) and 38 to 49°C (100 to 120°F).

10.2.13 Completely drain the system of all fluid.

10.2.14 Remove the flush cartridge, and wipe out the pump housing.

10.2.15 Remove and discard the used filter element, clean the filter housing, and install a new filter element.

10.3 *Flushing Procedures for Water Glycol and Other Water Based Fluids*:

10.3.1 To clean the system for water glycol testing, disassemble the system, including the pump body, heat exchanger (see Note 3), and relief valve.

10.3.2 Water rinse and clean rubber hoses by passing a bristle brush through the length of the hose several times. Then rinse hoses with water and dry with compressed air. Check hoses for cracking, hardening, and tackiness. Replace as needed.

10.3.3 Water rinse and dry other rubber parts and gaskets with compressed air. Check for wear, cracks, and tackiness. Replace as needed.

10.3.4 Clean metal parts by first rinsing with water, then scrubbing with a soft bristle brush and rinsing with water again, and then blowing dry with air. Clean the heat exchanger tubes with a 0.25-caliber (6.4-mm) brass rifle cleaning brush, or other suitable brush. Clean the metal tubing and holes in the castings with a test tube brush.

10.3.5 After water cleaning, place all metal parts in a solvent bath composed of a mixture of 50 % naphtha and 50 % isopropanol (**Warning**—see 7.2 and 7.4) and agitate for at least 30 min. Then drain the parts and dry with compressed air.

NOTE 11—It is critically important not to wash pumps run with other fluids, for example, polyol esters and mineral oils, in the same bath used to clean pumps run with water glycol.

NOTE 12—Hoses that have been previously used with mineral oils, phosphate esters, polyol esters, or PAO fluids should not be used with water glycols.

11. Preparation of Test Cartridge

11.1 Figs. 2 and 3 show the various components of the test cartridge.

11.2 Inspect all cartridge components for manufacturing or material irregularities. Use a new ring and set of vanes for each test. Reuse of the rotor and bushings is permissible if they are in satisfactory condition.

11.3 It is essential that the user is familiar with precision inspection practices, has quality instruments, and is adept in their use.

11.4 *Rotor Selection and Preparation* (see Fig. 9):

11.4.1 Visually inspect new rotors for deep longitudinal tool marks in the slot terminal hole and for slots that are not fully overlapped by the terminal hole (see Fig. 11, Items 1 and 3). Discard rotors with these defects, which may weaken the rotor segment.

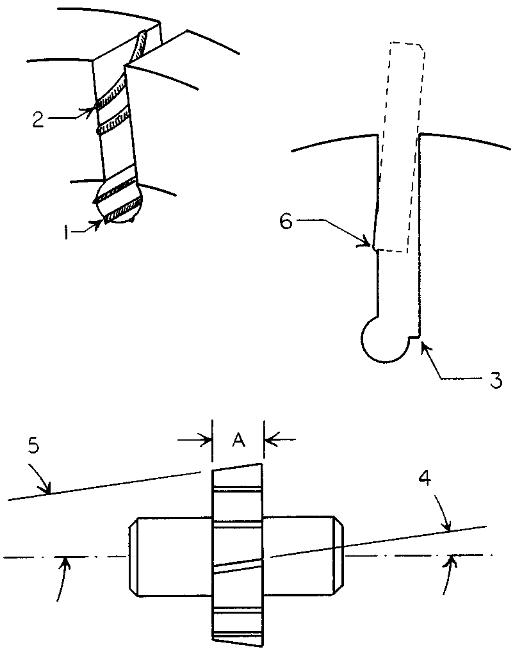


FIG. 11 Rotor Inspection

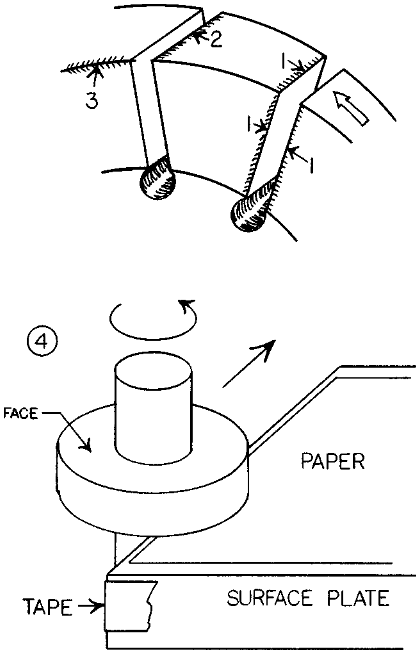


FIG. 12 Rotor Preparation

NOTE 13—While not required to, some laboratories lap the terminal holes at the base of the vane slots in the rotor in an attempt to minimize the possibility of rotor segment breakage. To do this, each hole is lapped for several minutes, using a 2.4-mm (3⁄32-in.) diameter drill rod with lapping compound or with a slurry of carborundum powder and oil.

NOTE 14—Vigorous lapping might have a detrimental effect on the rotor strength. Depending on how the lapping is done, this could cause an imbalance in the compressive residual stresses on the surface of the metal. These stresses are induced by the carbonizing and hardening process and are a major factor in developing the rotor fatigue strength.

11.4.2 Inspect new rotors for deep machining marks in the vane slots, for taper of the outer diameter, and for slots not cut parallel to the axis (see Fig. 11, Items 2, 4, and 5). Discard rotors with these defects since they may cause the vanes to wear into the bushings.

11.4.3 Deburr new rotors with a fine oil stone or other suitable tool. Remove any sharp edges where the vane slots meet the faces and the outer diameter of the rotor (see Fig. 12, Item 1) and where the faces meet the outer diameter (see Fig. 12, Item 3).

11.4.3.1 Exercise care to produce an even chamfer at the outer diameter (see Fig. 12, Item 2) since it acts to guide the following face of the vane. If this chamfer is uneven, the vane may wear into the bushings.

11.4.4 Polish both faces of the rotor by holding it flat against a piece of 600-grit paper that is supported by a glass plate or other suitable flat surface (see Fig. 12, Item 4). Protect the rotor journal by placing a piece of masking tape on the vertical edge of the glass or by wrapping the journal with masking tape. Push the rotor along the paper while giving the rotor a one-quarter turn. Repeat until all portions of both rotor faces have been polished.

11.4.5 In some cases it may be necessary to polish the inside surfaces of the vane slots to remove surface corrosion or burrs. A piece of 600-grit paper wrapped around a strip of steel or brass has proven satisfactory.

11.4.6 Wash the rotor with Stoddard solvent (**Warning**—see 7.2), and brush out the vane slots to remove any grit and oil. Air dry.

11.4.7 Check that clean, deburred vanes will fall freely through the vane slots.

11.4.8 Inspect used rotors for a pronounced step (see Fig. 11, Item 6) worn in the leading face of the rotor slot by the vanes. Also check for excessive vane play in the slots.

11.4.9 Measure the thickness (see Fig. 11, Dimension A) of the twelve rotor segments and record the measurements. Discard rotors when the thickness of the segments varies more than 0.005 mm (0.0002 in.).

11.5 *Vane Selection and Preparation* (see Fig. 13):

11.5.1 Visually inspect vanes for surface irregularities and proper amount of chamfer. Discard vanes with deep marks on the faces or with unevenly cut chamfers, which may cause the vane to wear into the bushings. Discard vanes that have no apparent chamfer (see Fig. 13, Items 1, 2, and 3).

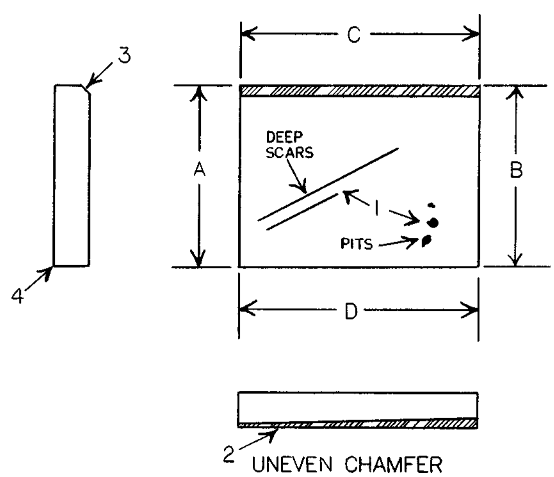


FIG. 13 Pump Vane

11.5.2 Measure each vane top to bottom (see Fig. 13, Measurements A and B) at each end to determine if the bottom edge is parallel to the chamfered edge. Discard vanes that are more than 0.050-mm (0.002-in.) out of parallel.

11.5.3 Use a sheet of 400-grit paper, wetted with water or light oil and supported on a glass plate to deburr all vane edges (except the wear chamfer), to produce a 0.05 to 0.10-mm (0.002-0.004-in.) × 45° chamfer. Take care that the chamfered edge diagonally opposed to the wear chamfer (see Fig. 13, Item 4) is even since it guides the vane motion inside the rotor slot.

11.5.4 Measure the length of each vane at top and bottom (see Fig. 13, Measurement C and D). Discard vanes that are more than 0.005-mm (0.0002-in.) out of parallel. Segregate vanes into groups by length of 0.002-mm (0.0001-in.) increments.

NOTE 15—It may be necessary to prepare a quantity of vanes in advance to have twelve suitable vanes of similar length available for any given test.

11.5.5 Use a degausser to demagnetize the vanes before use.

11.6 *Ring Selection and Preparation*:

11.6.1 Visually inspect the ring for surface irregularities or poor finish on the cam wear surface. Discard rings with unusually coarse wear surfaces, surface pits, and grinding chatter (see Fig. 14, Items 1 and 2).

NOTE 16—Some users discard rings that have a mass of less than 180 g. Light rings have been associated with ring cracking and rotor failure.

11.6.2 Lightly deburr the edges where the cam surface and faces meet (see Fig. 14, Item 3). Use a fine, round oil stone held at a 45° angle to the axis of the ring. Push the stone from the inside toward the outer diameter while following the periphery of the cam. The object is to remove any burr by pushing it away from the cam surface where it may interfere with the vanes.

11.6.3 Using a flat oil stone, deburr the edges where the outer diameter and the faces meet (see Fig. 14, Item 4).

11.6.4 Polish the flat faces of the ring (see Fig. 14, Item 5), using a Figure *8* motion on 600-grit paper, supported on a surface plate to remove any burrs, which may have been raised by the previous deburring procedures.

11.6.5 Use a degausser to demagnetize the ring before use.

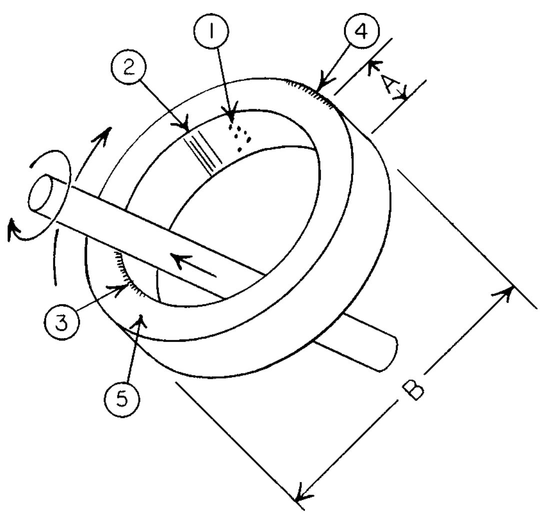


FIG. 14 Pump Ring

11.6.6 Wash the ring with Stoddard solvent (**Warning**—see 7.2) to remove any grit and oil. Air dry.

11.6.7 Measure the thickness of the ring (see Fig. 14, Dimension A) at twelve places equally spaced around the ring. If the thickness varies more than 0.005 mm (0.0002 in.), the ring should be discarded or lapped, as described in 11.6.4, until the condition has been corrected. Record the final thickness of the ring.

NOTE 17—To lap the ring when an out-of-parallel condition exists, it is advisable to remove all necessary material from one face only. The procedure is performed by identifying the thickest region and dragging only that region across the paper, increasing the extent of the region as the two faces become parallel. It is suggested that 400 or 280-grit paper be used for the initial material removal, proceeding to a finer grit as the finished dimension is approached. The paper should be kept wet, and the ring should be allowed to cool before taking intermediate measurements. When the ring faces have been made parallel, a final polishing with 600-grit paper is performed. This procedure can also be used to reduce the overall thickness of rings if it is desired to reduce the clearance within the cartridge.

11.7 *Bushing Selection and Preparation*:

11.7.1 Visually inspect the bushings for surface defects, and check that the gashes on the pressure ports are oriented properly (point against direction of pump rotation) and that the oil grooves on the rear face of the bushings connect with pressure ports. Discard bushings that fail this inspection.

11.7.2 Discard bushings that do not have a concave face. For this inspection it is assumed that the front and rear faces of the bushing are parallel. With the bushing resting on a precision surface plate, use a dial-test indicator to measure the slope between the outer diameter and the shank (see Fig. 15, Measurements A and B). There should be a rise of 0.025 to 0.050 mm (0.0010 to 0.0020 in.) from the outer diameter to the shank.

NOTE 18—In cases in which instruments are not available to make the inspection described in 11.7.2, the working face of the bushing is lapped by barely touching it on 600-grit paper, supported by a surface plate. AFigure *8* motion is used, and only enough material is removed to verify the shape of the bushing.

11.7.3 Discard bushings that are warped or have nonparallel front and rear faces. With the bushing resting on a precision surface plate, use a dial-test indicator to measure the thickness of the bushing at several points around its outer diameter (see Fig. 15, Measurement C). The thickness should not vary more than 0.010 mm (0.0004 in.).

NOTE 19—While not required to, some laboratories polish the bushings in an attempt to minimize internal pump leakage at elevated pressures and temperatures. This polishing is done on a piece of crocus cloth or 400 wet paper with plate glass or a surface plate under it. The polishing (Figure *8* motion) is continued until the outer 6 mm (¼ in.) of the bushing is flat, with all tool marks removed. The bushings are then finish polished in the

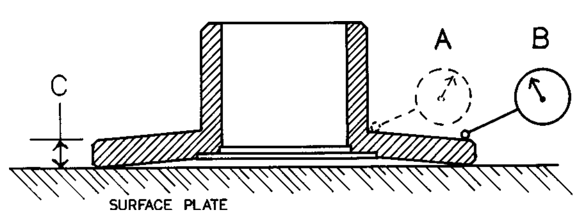


FIG. 15 Bushing Inspection

same manner, using 600 wet paper or polishing paper. Coating the outer 6 mm (¼ in.) of the inner surface of the bushing with Prussian blue dye before polishing will aid in determining whether that portion of the bushing is flat.

11.8 Roll the alignment pin on a flat surface to determine if it is straight. Discard bent pins.

11.9 *Cartridge Assembly* (see Fig. 3):

11.9.1 Choose a set of components so that the average rotor thickness (see Fig. 11, Dimension A) will be 0.017 to 0.035 mm (0.0007 to 0.0014 in.) less than the average ring thickness (see Fig. 14, Dimension A). Choose a set of vanes of equal length (see Fig. 13, Dimension D) so that they will be 0.002 to 0.015 mm (0.0001 to 0.0006 in.) less than the average rotor thickness.

11.9.2 Measure the ring outside diameter (see Fig. 14, Dimension B) to determine if it is suitable for the pump housing (see 8.3.5).

NOTE 20—If the ring is undersized, a piece of 0.025-mm (0.001-in.) shim stock trimmed to 20 by 235 mm (0.8 by 9.25 in.) can be wrapped around the ring to pack out the excess clearance. Installation of the shim requires that the cartridge assembly be made in the pump housing and that the housing and ring are clean and dry.

11.9.3 Clean the cartridge parts in Stoddard Solvent (**Warning**—see 7.2), rinse with precipitation naphtha (**Warning**—see 7.3), and air dry.

11.9.4 Determine the mass (separately) of the cam ring and the complete set of twelve vanes. Determine these two masses to the nearest milligram, and record these values.

NOTE 21—Magnetized parts can affect the performance of electronic balances.

12. Procedure

12.1 *Pump Cartridge Assembly*:

12.1.1 Assemble the test cartridge, wetting all parts with a film of test fluid and making certain of proper vane insertion into the rotor and correct rotor and inner and outer bushing direction and alignment (see Fig. 3). The vanes should be checked for free movement in rotor slots when assembling.

12.1.2 Insert and bottom the assembly alignment pin. Only about 3 mm (0.125 in.) of the large end should be visible above the outer bushing surface.

12.2 *Installation of Test Cartridge*:

12.2.1 Insert a properly prepared pump test cartridge into the pump housing, being careful to completely seat it using the alignment pin hole (small hole near inlet of pump housing) for right hand rotation (counterclockwise as viewed from the pump head).

NOTE 22—If the pump has left hand rotation (clockwise as viewed from the pump head), the large end of the alignment pin is meant to engage the larger hole, which is at 90° to the inlet of the pump housing (see Fig. 3, "Assembled for Left Hand Rotation").

12.2.2 Install the packing and pump head, and bring the head bolts to finger tight.

12.2.3 Close all drain valves, and open pump inlet and return line valves.

12.2.4 Pour enough test fluid into the reservoir to ensure that the pump case is full.

12.2.5 Use a torque wrench to tighten the eight head bolts (see Fig. 10) a maximum of 1130 N-mm (10 in.-lb) at a time, using the following sequence: top right (1), bottom left (2), right low (3), left high (4), and then bolts (5), (6), (7), and (8). Slowly rotate the pump shaft by hand while tightening the bolts or at the end of each sequence. Record the final level of torque (usually about 4520 to 7910 N-mm (40 to 70 in.-lb). The pump should rotate with a slight drag on the shaft, but there should be no binding.

NOTE 23—While not required to, some laboratories disconnect the pump to motor shaft coupling during torquing to eliminate the drag of the motor while rotating the pump shaft.

NOTE 24—Bind is characterized by a catch or tight spot in an otherwise smooth shaft rotation or complete seizure or stoppage requiring abnormal hand effort to turn the shaft, or both.

NOTE 25—If binding occurs at less than 3390 N-mm (30 in.lb), there probably is a misalignment within the pump and it should be disassembled and all components checked.

NOTE 26—Some users have found that reversing the torquing sequence (that is, 2-1-4-3-6-5-8-7) every other sequence helps avoid binding and cocking of the pump head.

NOTE 27—To get more even torquing, some users utilize brass washers under the head bolts to reduce tightening friction.

NOTE 28—To ensure that the cartridge seats properly against the pump housing and head sealing faces (see Fig. 8, Planes A and B), some users place feeler strips between the head and housing while torquing the head. This technique requires that the head and housing have parallel faces and shoulders (see Fig. 8, Planes A and C, B and D) and accurate measurements have been made (see Fig. 8, Measurements W and X). The gap (Z), which should be present when the cartridge has been properly seated, will be equal to Y (cartridge thickness) + X – Y. Checking that the gap is consistent around the pump head during the torquing procedure will also guard against cocking the head, which may cause it to jam in the housing bore.

12.3 *Test Start-up and Operation*:

12.3.1 If not already done, close all drain valves and open the reservoir outlet valve and return line valve to allow the test fluid to fill the pump housing, and test the system's lower lines.

12.3.2 Pour approximately 12 L (3 gal) of the test fluid into the reservoir.

12.3.3 Reduce the setting of the pressure control valve so that pressure will not be generated when flow starts, and turn off cooling water if not already done.

12.3.4 Jog the pump drive motor ON and OFF switches until fluid is returned to the reservoir.

12.3.5 Pour the remainder of the test fluid into the reservoir.

12.3.6 Start the pump, and adjust the speed to 1200 r/min.

12.3.7 Observe the fluid in the reservoir to make sure that it is clear and does not contain noticeable amounts of entrained air before increasing pressure.

12.3.8 After the fluid has circulated for 15 min, draw off a representative fluid sample from the test system to determine fluid cleanliness at the start of the test.

12.3.8.1 The fluid sampling port and sampling procedure shall be in compliance with ISO 4021.

12.3.8.2 In accordance with ISO 4406, verify that fluid is ISO Class 18/16/14, or cleaner.

12.3.9 Adjust the pump outlet pressure to 2.1 MPa (300 psi).

12.3.10 Warm up for 1 h in six 10-min steps, at increased pressure levels. The pressure levels are 2.1, 4.1, 6.2, 6.9, 10.3, and 12.4 MPa (300, 600, 900, 1000, 1500, and 1800 psi). During this warm-up period, the pump inlet temperature will be rising. When this temperature is within 3°C (5°F) of the control level, start to apply cooling through the heat exchanger system to minimize temperature override on the test fluid.

NOTE 29—If pump vane noise (chatter) is heard during the warm up, the pump can be shut down and the pump head bolts tightened in 560 N·mm (5 in.-lb) increments, using the same tightening sequence as described in 12.2.5, in an effort to eliminate the noise.

12.3.11 Make certain that pump speed, pump inlet temperature, and flow are at test conditions, and adjust the pump outlet pressure to exactly 13.8 MPa (2000 psi).

NOTE 30—Do not start the test if the pressure gage shows evidence of unusual relief valve fluctuation or pulsations or if unusual noise or vibration are present.

12.3.12 Measure and record the fluid flow rate.

12.3.13 Record clock time or adjust the test system timer to zero and consider this the start of the test.

NOTE 31—It is advisable to monitor test conditions for at least the initial few hours of the test to ensure that conditions are stable. A continual drop in the flow rate indicates increasing internal leakage caused by bushing wear or improper seating of the cartridge.

12.3.14 Operate the system at the following conditions, uninterrupted for 100 h or until operating difficulties dictate test termination:

12.3.14.1 Pump outlet pressure: 13.8 ± 3 MPa (2000 ± 40 psi).

12.3.14.2 Pump speed: 1200 ± 60 r/min.

12.3.14.3 Pump output: >15.0 L/min (>4.0 gpm).

12.3.14.4 Fluid temperature at pump inlet (see Fig. 1, Item 3):

(*a*) Water-glycols, emulsions, and other water containing fluids: 66 ± 3°C (150 ± 5°F).

(*b*) Petroleums and synthetic fluids of ISO Grade 46 or lighter: 66 ±3°C (150 ±5°F).

(*c*) All other petroleum and synthetic fluids: 80 ± 3°C (175 ± 5°F).

12.3.15 It is not acceptable to replace the ring or vanes during the test. The test should be terminated if flow drops to 15.0 L/min (4.0 gpm) or less, if system pressure cannot be maintained, or if there is excessive noise or leaking.

12.3.16 It is permissible to replace the bushings during the test if loss of flow has caused an early termination. Vanes should be replaced in their original slots after such a rebuild. Report the bushing failure.

12.4 *Test Shutdown and Final Parts Inspection*:

12.4.1 After completion of the 100-h test, draw off a fluid sample, in accordance with ISO 4021, to determine end of test 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 head and carefully remove the test cartridge.

NOTE 32—The use of a bent piano wire inserted through an inlet or outlet port to catch and hold the inner bushing or the use of needle nose pliers to grasp the outer bushing and the rotor hub, or both, facilitates removal of the cartridge.

12.4.7 Observe and record the condition of the reservoir surfaces, noting any deposits. System preparation for additional testing can now proceed.

12.4.8 Carefully disassemble the test cartridge, and inspect the individual pump cartridge parts for signs of wear, deposit formation, or discoloration. Record any observations.

12.4.9 Demagnetize the cam ring and vanes.

12.4.10 Remove all deposits from the test cartridge cam ring and vanes by thorough nonabrasive cleaning. Rinse in precipitation naphtha (**Warning**—see 7.3), or other appropriate solvent (**Warning**—see 10.2.1), and air dry.

13. Calculation

13.1 Determine the mass (separately) of the used cam ring and the set of twelve used vanes to the nearest milligram. Record these two masses and their total.

13.2 Subtract the after-test total mass (cam ring plus twelve vanes) from the unused mass total to determine the mass loss sustained during the run.

14. Report

14.1 Report the following information:

14.1.1 Mass loss of the ring and vanes in milligrams.

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 "Modified Test Method D 2882."

15. Precision and Bias

15.1 In light of the many changes made to this test method, a new precision statement is needed. Members of Subcommittee D02.NO.07 are currently working to generate a valid precision statement.

16. Keywords

16.1 hydraulic fluid; vane pump; wear