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SURFACE VEHICLE RECOMMENDED PRACTICE

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Superceding J1227

Submitted for recognition as an American National Standard

ASSESSING CLEANLINESS OF HYDRAULIC FLUID POWER COMPONENTS AND SYSTEMS

Foreword—This Reaffirmed Document has not changed other than to put it into the new SAE Technical Standards Board Format.

There is an increasing awareness that the reliability, productivity, and economy of use of hydraulic systems is directly related to the cleanliness level achieved. In addition, there is strong evidence that start up failures of both new and overhauled systems are often contaminant-caused catastrophic failures. Contaminant built in to each component making up a hydraulic system, and contaminant generated in assembling the components and systems, are significant contributors to these failures. Working Group 6 of Subcommittee IV of the SAE Off-Road Machinery Technical Committee agreed to establish a project and to do a survey which showed a significant interest in this subject. This resulted in a Task Group being formed to draft this recommended practice.

This SAE Recommended Practice is intended as a guide toward standard practice but may be subject to frequent change to keep pace with experience and technical advances, and this should be kept in mind when considering its use.

1. ***Scope***—To describe laboratory methods for determining and reporting the contaminant level of the wetted portion of hydraulic fluid power components, parts, subsystems and systems, and of fill fluids. For each type of item it provides a method of obtaining the liquid sample and the contamination level thereof. It also includes procedures for establishing a sampling plan and guidelines for establishing levels of acceptace, but does not set those levels.

1.1 **Purpose**—To provide a basis for measuring and reporting cleanliness levels so that built-in contamination and premature failures of hydraulic systems can be minimized.

2. ***References***

2.1 **Applicable Publications**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the lastest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE ARP 588A—The Determination of Particulate Contamination in Liquids by the Particle Count Method
SAE ARP 785—Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure
SAE J1277—Method for Assessing the Cleanliness Level of New Hydraulic Fluid
SAE J1165—Reporting Cleanliness Levels of Hydraulic Fluids

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SAE WEB ADDRESS http://www.sae.org

ISO 3722—1976
ISO 4021—1977

2.1.2 ANSI DOCUMENTS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI B93.2—1971
ANSI Z1.4—1971

2.1.3 ASTM DOCUMENTS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D95
ASTM D96
ASTM D1744

2.1.4 MILITARY PUBLICATION—Available from DODSSP, Subscripton Services Desk, Building 4D, 700 Robins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-105

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 ANSI DOCUMENTS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI B93.2—1972
ANSI B93.20—1972
ANSI B93.28—1973
ANSI B93.30—1973
ANSI B93.44—1978

2.2.2 NFPA PUBLICATIONS—Available from the National Fluid Power Associatio, 3333 North Mayfair Road, Milwaukee, WI 53222-3219.

NFPA T2.1.1-1972
NFPA T2.1.2-1974
NFPA T2.9.1
NFPA T2.9.2
NFPA T2.9.3
NFPA T2.9.6
NFPA T2.9.8-19xx
NFPA T2.9.9
NFPA T3.10.3-1967

2.2.3 DIS PUBLICATIONS

DIS 3938
DIS 4402
DIS 4406

3. Outline Of Method

a. Select the item to be evaluated using a sampling plan per Section 4.
b. Obtain representative liquid sample per Section 5.
c. The fluid sample should be evaluated per Section 6.
d. Report resulting data in accordance with Section 7.
e. Compare the results with the requirements of Sections 8, 9, and 10.
f. Resolve any disputes using the guidelines of Section 9.
g. Before tests are started verify that all needed information is available in accordance with Section 11.
h. Define new terms (see italics) per Section 12.
i. Index per Section 13.

4. Guidelines For Establishing Sampling Plans—In some type systems, adequate reliability requires 100% cleanliness testing of systems and components. However, for most industrial and mobile hydraulic systems, a sampling plan is justified. Such a sampling plan can vary from the simplicity of testing the first and last item from each lot, to a full statistical sampling plan. Ref. c-1 of Table 1 is a useful guide for establishing such a statistical plan.

5. Methods Of Obtaining Representative Liquid Samples

5.1 Collection methods for obtaining representative liquid samples are considered for the following categories:

a. Complete systems and integral subsystems—see 5.2 and Section 5.
b. Static components—see 5.2 and 5.4.
c. Dynamic components—see 5.2 and 5.5.
d. Parts—see 5.2 and 5.6.
e. Fill-hydraulic fluid—see 5.7.

5.1.1 Following collection in a verified clean container (see 12.6) the liquid sample is to be evaluated in accordance with the appropriate methods of Section 6.

5.1.2 Items a, b, and c in 5.1 provide for collecting a sample from complete components or systems without disassembly. Some may prefer to disassemble the components and to obtain the contaminated sample from the parts. It is unlikely that the contamination removed from the parts will equal that removed from the assembled component or system for the following reasons:

a. The process of disassembly and assembly generates contaminants.
b. Areas of parts may be exposed which are not accessible in the assembled components.
c. Moving a dynamic component will generate contaminant which would not be observed when evaluating the parts.

5.2 General Cautions Applicable to Obtaining Representative Liquid Samples

5.2.1 REYNOLDS NUMBER—It is possible for a unit to test clean when using oil at room temperature, but test dirty when tested with the same oil at high temperature. Likewise, it is possible for a unit to test clean during an evaluation and test dirty if evaluated using a higher flow rate or using an oil with lower viscosity.

These results are to be expected because the removal of particles from surfaces is proportional to the turbulence in the system which, in turn, is dependent upon the Reynolds number attained. Ideally, flushing and cleanliness testing should be performed at a Reynolds number which is at least as high as the maximum Reynolds number that the unit will see in normal service. To achieve this, it is sometimes necessary to flush with a low viscosity liquid.

Reynolds number can be calculated with the following equations:

English Units	Metric Units
$R = \frac{35\,873Vd}{\upsilon}$	$R = \frac{1000Vd}{\upsilon}$
$R = \frac{14\,646Q}{\upsilon d}$	$R = \frac{21\,220Q}{\upsilon d}$

(Eq. 1)

where:

R = Reynolds number	dimensionless	dimensionless
V = Fluid velocity	feet per second	meters per second
d = Pipe inside diameter	inches	millimeters
υ = Viscosity	Saybolt seconds	centistokes
Q = Flow rate	U.S. gallons per minute	liters per minute

5.2.2 VIBRATION AND SHOCK—With some components and systems, a cleanliness level measured at one laboratory will be significantly changed when measured at another laboratory, if the unit is subjected to vibration and shock during transit. Likewise, the cleanliness level of a unit can be significantly changed when installed on a vehicle in field operations. To determine if vibration and shock are significant in altering contaminant levels in a particular case, it is recommended that the unit or system be tested for contamination both before and after being subjected to the worst vibration and shock expected in shipping and use.

5.2.3 SELECTING A CLEAN TEST LIQUID (SEE 12.2)—Select a clean test liquid that is compatible with the component or system being evaluated. If different from the system hydraulic fluid assure that either:

a. The clean test liquid is totally removed so that it does not contaminate the system fluid, OR
b. The two liquids are compatible—including additive packages—so that the mixture will still meet system requirements.

CAUTION: Halogenated hydrocarbons (such as trichloroethane and other chlorinated solvents) have been reported to be a source of accelerated corrosive/erosive wear in hydraulic systems, special precautions should therefore be taken to remove them so as to assure that none can be carried over into the hydraulic fluid.

5.2.4 DRAINING COMPONENTS—When draining components, care must be exercised to assure that the fluid sample is not contaminated by contact with normally non-wetted surfaces, such as external surfaces and threaded portion of ports. This can be minimized by installing a precleaned fitting into the port (hand tighten without thread sealant) so that the fluid can be poured in a controlled stream into the verified clean container.

5.2.5 LOCATION OF SAMPLING VALVES—Locate sampling taps and valves in a turbulent portion of the line, and above the centerline of any horizontal line so as to avoid trapping contaminants. For maximum assurance that the samples taken and the counts reported are indeed representative, please also refer to Refs. b-1, -2, -3.

5.2.6 DIFFUSERS—Where diffusers are called out Figure 1, Figure 2, and Figure 3, select to avoid breaking of fluid surface by returning fluid.

5.2.7 DILUTION FACTORS WHEN USING CIRCULATING SYSTEMS—If the volume of the liquid in the circulating system is large as compared to the volume of the component or subsystem being tested there will be a distortion in the number of large particles reported. This volume ratio should be kept as small as is practical.

5.3 Complete Systems and Integral Subsystems—(those which can be pressurized and have normal flow such as some hydrostatic and steering systems):

5.3.1 Evaluate complete systems in accordance with Ref. b-7 of Table 1.

5.3.2 Evaluate integral subsystems by withdrawing a sample from the turbulent portion of the pressurized subsystem using the method shown in Ref. b-1, or sample from the reservoir using the Ref. b-5 method. Such sampling should occur after the subsystem has reached an agreed upon temperature, and has been fully exercised and pressurized. The temperature selected should consider both safety and 5.2.1. Exercise subsystem by operating a portion of the time at maximum rated flow so as to obtain maximum Reynolds number per 5.2.1, and for a time sufficient to pass ten times the total test system hydraulic fluid volume through the subsystem. While still operating, withdraw the fluid samples into a verified clean container. If it is necessary to connect the subsystem to a precleaned (≤10% rule) flow test stand the comments of 6.4 and definition of 12.4 should be considered.

5.4 Static components (such as reservoirs, fittings, tubing, filter housings, manifolds, etc.)—Static components can be evaluated by two basic methods. The first (which is historically probably the most commonly used) is a slosh test, which uses movement of a partially filled component to transfer the contaminant from the wetted surfaces of the static component to the clean test liquid. The second method is a flow test and recognizes the importance of achieving a Reynolds number equal to or greater than that achieved in service (see 5.2.1), and which measures the contaminant increase contributed by the static component to a circulating system. The slosh test is normally simpler and more economical and should suffice, except where it can be shown that the flow test removed significantly more contaminant.

5.4.1 SLOSH TEST—Fill the component 1/3 to 1/2 full with clean test liquid and seal the component so that it can be mechanically agitated, vibrated, and shocked so as to loosen contaminants without spilling the test liquid. A specified plan for agitation, vibration, and shock consistent with the geometry of the component should be followed (see 5.2.2). The sealing method should be validated to assure that it does not add significant contamination. The fluid sample should be removed from large components, using the method of Ref. b-5. Smaller components should be completely drained into a verified clean container (see 5.2.4).

5.4.2 FLOW TEST—Where appropriate, connect the static component to a precleaned (≤10% rule) flow test stand capable of achieving a Reynolds number at the wetted surfaces of the component at least equal to the maximum it will see in service (see 5.2.1). The test stand can be similar to that shown in Figure 3 with the static component connected at points A and B and the directional control valve (7) positioned such that flow through the static component is in the normal direction of flow. Flow through the component for a time sufficient to assure that a hydraulic fluid volume at least equal to ten times the test system liquid volume has passed through the component. After the minimum flow time withdraw a sample per Ref. b-1 or b-5 (see 6.4).

5.5 Dynamic Components—Dynamic components are considered in the following subcategories:

a. Rotating components—pumps and motors—see 5.5.1.
b. Reciprocating components—cylinders and accumulators—see 5.5.2.
c. Hoses—see 5.5.3.
d. Valves—see 5.5.4.

Obtain the liquid sample for each subcategory of dynamic components, as follows:

5.5.1 ROTATING COMPONENTS—Connect the component's inlet directly to its outlet through a precleaned (≤10% rule) system (see Figure 1) so as to allow the component to be rotated at its maximum speed. Rotate the component at its maximum speed under no load for a length of time sufficient to achieve tenfold minimum circulation of the system oil volume. During rotation, keep the hydraulic fluid at the minimum recommended operating viscosity. After tenfold circulation and with the component rotating, withdraw a sample per the

method described in Ref. b-1 or b-5 (see 6.4). During the test, no hydraulic fluid shall be taken from the system other than for contaminant sampling, for instance, any case drain line should be connected back to reservoir. For pumps/motors with an external case drain, the test duration should be sufficient to pass a hydraulic fluid oil volume through the case drain line at least equal to ten times the wetted volume of the pump case plus case drain line. As an alternate for components with low case drain flow, collect all of the case drain flow during the test for separate analysis.

5.5.1.1 Hydraulic motors may be operated as a pump where operating parameters permit. When not possible, a pump is to be added to the system to drive the motor.

5.5.1.2 Use a hydraulic fluid as agreed to between the component manufacturer and the test laboratory.

5.5.1.3 Test variable volume components at full displacement; however, they shall be cycled ten times from zero to maximum to zero displacement at the start of the evaluation.

5.5.1.4 Test over-center variable volume components in each flow direction.

5.5.1.5 It is important to note that this method of taking a liquid sample is not intended to measure nor in any way account for the contaminant generated during break-in under load.

5.5.2 RECIPROCATING COMPONENTS—Cause the component to be cycled with the same clean test liquid 10 times at 120% of the maximum rate expected in service, using test liquid of viscosity equivalent to that expected at maximum operating temperature. Remove a fluid sample using the method of Ref. b-1 or b-5, as is most appropriate (see 6.4)—or, in the case of small components, by completely draining (see 5.2.4).

5.5.2.1 Circuit for cylinders is to provide for varied configurations, such as:

a. Double acting—balanced and unbalanced area—small rod and large rod displacement.
b. Single acting.
c. Telescopic.

Figure 2 shows the typical test configuration for external cycling of cylinders.

Where space is not sufficient the test circuit should be set up per Figure 3 where the cylinder is driven hydraulically.

5.5.2.1.1 The major components of Figure 3 are:

a. Reservoir (1) with conical bottom with built-in perforated diffuser (2) located below minimum operating fluid surface level. (See 5.2.6.)
b. Variable displacement pump (3)—of sufficient max flow rate to stroke cylinders at maximum specified rate.
c. Relief valve (4)—to control maximum circuit pressure for safety and temperature elevation.
d. Directional valve (5)—manually positioned for free circulation to reservoir or flow through clean-up filter for initial cleanliness qualification of fluid (≤10% rule).
e. Filter (6)—for clean-up of fluid to specified level prior to test.
f. Directional valve (7)—manually positioned for manipulation of test cylinders.
g. Variable orifice (8)—for pressure control during circuit clean-up and for use with a check valve (10) for accumulator testing.
h. Hoses or tubing (9)—as short as is practicable and precleaned.

5.5.2.1.2 Procedure for Circuit Clean-up to Required Pre-Test Contaminant Level: Figure 3.

a. Fill the system (without cylinder or accumulator under test connected) with a volume of clean test liquid equal to a minimum of 1.2 times the fully extended internal volume of the cylinder or accumulator.
b. With the open adjustable orifice (8) connected at points A and B to the hoses (9) to be used to connect the test cylinder, valve (7) in center position and valve (5) positioned to direct fluid flow to filter (6) and pump (3) set to deliver near minimum flow rate, start the motor.
c. Adjust the pump displacement to deliver flow rate required to stroke the cylinder to be tested at the required maximum velocity, or for testing accumulators to fill the accumulator at the required rate.
d. Position valve (7) to deliver pump flow to orifice (8) and reduce the orifice size to raise the pressure to the desired maximum test level. Delete this step for testing accumulators.
e. Adjust relief valve (4) to limit the pressure to the level of (d) above except in the case of accumulators, adjust the relief valve (4) to four times the precharge gas pressure.
f. Manipulate valves (7) and (5) to thoroughly flush all portions of the circuit--using orifice (8) settings both smaller and larger than that of step (d) to flush the relief valve and its related conduits. It is important that at least part of the flushing be done at a higher flow rate (120%) than will be used for the evaluation (see 5.2.1).
g. Continue above until determinations of particulate content at the indicated sampling point (see 5.2.5) with valve (5) positioned to bypass the filter show the content to be no more than 10% of the allowable contaminant level for the test cylinder.
h. For accumulator testing, adjust the orifice (8) by setting the flow of pump (3) to the maximum discharge flow rate of the accumulator. The orifice should be gradually restricted until relief valve (4) opens. Orifice (8) so adjusted is then connected in parallel with a check valve (10) to the accumulator port and hose end (A). Cap hose end (B). Return pump (3) flow setting to that of step (C).

5.5.2.1.3 Procedure for Cylinder Contaminant Assessment

a. With valve (7) in center position and pump off, remove orifice (8) and connect cylinder to be evaluated at A and B if double acting or at A and B plugged if single acting. The orientation of the cylinder should be with ports down. If ports are on opposite sides of cylinder, place ports in horizontal plane.
b. With pump running, valve (5) positioned to by-pass filter (6), operate valve (7) to fully extend and retract the test cylinder a minimum of 10 times.
c. Extract a sample of test liquid per Reference b-1 from sampling point of circuit (se 6.4).

5.5.2.2 Circuit for accumulators is to provide for both bladder and piston types as shown in Figure 3.

5.5.2.2.1 The major components of Figure 3 are described in 5.5.2.1.1 noting particularly item (g). The circuit clean-up and adjustment for accumulator testing is described in 5.5.2.1.2, noting particularly items (c), (d), (e), and (h).

5.5.2.2.2 Precharge the accumulator to take minimum pressure required to achieve the maximum flow rate in the test set-up of Figure 3 consistent with the application and with the maximum system test pressure being equal to four times the precharge pressure.

CAUTION: Do not exceed the maximum working pressure of the accumulator.

5.5.2.2.3 Procedure for Accumulator Contaminant Assessment

a. With valve (7) in center position and pump off, connect orifice (8), check valve (10) and accumulator to be evaluated at A with B plugged. The orientation of the accumulator should be with port down.
b. With pump running, valve (5) positioned to by-pass filter (6), operate valve (7) to fill and exhaust accumulator a minimum of 10 times. The opening of relief valve (4) is a positive indication that the accumulator is full.
c. Extract a sample of test liquid per Ref. b-1 from sampling point of circuit (see 6.4).

5.5.3 HOSE—Hose can be evaluated by one or more of four methods. The first (which is, historically, probably the most commonly used) is a slosh test. The second method is similar, but the sloshing is followed by bending the hose ten times to the minimum recommended bend radius and then sloshing is repeated. The third method involves pressurization of the hose followed by a maximum Reynolds number flush, and the fourth method adds bending to the third method. The slosh test is obviously the simplest and most economical test, and should suffice except where it can be shown that the other methods remove significantly more contaminant.

5.5.3.1 *Slosh Test*—The hose assembly shall be filled 1/3 to 1/2 full with clean test liquid, and the ends shall be sealed with non-contaminating plugs. The test liquid viscosity shall not be greater than that of the system hydraulic fluid at maximum operating temperature. The liquid in the assembly shall then be agitated by turning the assembly vertically end for end for ten complete cycles. Following agitation the test liquid shall be drained into a verified clean container (see 5.2.4).

5.5.3.2 *Bend and Slosh Test*—Conduct test as per 5.5.3.1 except that, after filling with clean test liquid and sealing ends, agitate per 5.5.3.1, bend hose ten times to the minimum recommended bend radius, returning to straight after each bend. A bend radius mandrel is recommended to avoid subjecting the hose to too small a bend radius. Following the ten bend cycles, agitate the drain per 5.5.3.1.

5.5.3.3 *Pressurize and Flush Test*—Connect the hose to points A and B of Figure 3, assuring that the test stand is capable of pressurizing the hose to maximum recommended working pressure and of flowing at a sufficient rate so that the Reynolds number at the wetted surfaces is at least equal to the maximum it will see in service (see 5.2.1).

CAUTION: Excessive velocity can damage hose lines. Pressurize the hose once to maximum recommended working pressure, then flow test liquid through it for a time sufficient to assure that a liquid volume at least equal to ten times the test system liquid volume has passed through the hose. After the minimum flow time withdraw a sample per Reference b-1 or b-5 (see 5.2.7 and 6.4).

5.5.3.4 *Pressurize, Bend, and Flush Test*—Conduct this test per 5.5.3.3 except that, after pressurization and prior to start of flushing, bend the hose ten times from straight to the minimum recommended bend radius and return to straight. A bend radius mandrel is recommended to avoid subjecting the hose to too small a bend radius.

5.5.4 VALVES—Connect the valve to a suitable test fixture and flush every flow passage at its maximum rated flow with a clean test liquid (hydraulic fluid) of a viscosity equivalent to that of the system fluid at maximum operating temperature. Flush each flow passage for a time sufficient to assure that a hydraulic fluid volume at least equal to ten times the test system liquid volume has passed through the valve. After all flow passages have been flushed for the minimum time, withdraw a sample per Reference b-1 or b-5 (see 5.2.7 and 6.4).

5.5.4.1 Where contaminants may be released by high pressure, such as in cored passages, pressurize the valve to system maximum operating pressure prior to the flushing cycle.

5.5.4.2 The test stand can be similar to that shown in Figure 3 with the valve connected to points A and B and work ports connected to each other as appropriate.

5.6 Parts, Rinse Test

5.6.1 Checking will be made just prior to normal usage or packaging.

5.6.2 Measure and record magnetism. Demagnetize to 12 gauss maximum if required.

5.6.3 Thoroughly rinse the wetted portion of the part with a stream of designated clean test liquid.

5.6.3.1 Test liquid and contaminant are to be collected in a verified clean container.

5.6.3.2 Core sand, machining chips, etc., loosened by rinsing will be removed from the unit part and added to the verified clean container. If the quantity of chips is significant then the evaluation methods of 6.2 and 6.2.1 are recommended.

5.7 **Fill Hydraulic Fluid—**Used to fill components, subsystems, and systems for either testing, shipment or use, should be checked by sampling from the filling line per Ref. b-1 or by sampling from the stored container per Reference b-5 and b-13. If the container is normally shippable, it should be agitated prior to sampling to duplicate shipping shock and vibration per 5.2.2.

6. ***Evaluation Of Liquid Samples—***Use one or more of the following methods:

6.1 Provide gravimetric analysis in accordance with Reference b-9.

6.2 Provide particle count analysis in accordance with:

6.2.1 Microscopic--Reference b-8.

6.2.2 Automatic Particle Counter Calibration--Reference b-3.

6.2.3 As an alternative, when only particulate contaminant is of interest, an in-line automatic particle counter may be attached to the system. Care must be exercised because free water and entrained air can be counted as particulate contaminants.

CAUTION: When using an automatic particle counter, be aware of the largest contaminant size that needs to be measured and compare with the largest size that will pass through the counter. If incompatible, the counter can be protected with a chip filter which can be inspected before and after each test, however, this assumes that only a few chips will be present in each test.

6.3 Sampling bottles and laboratory beakers should be verified as having a Required Cleanliness Level (RCL) of no more than one percent of the Allowable Cleanliness Level (ACL) in accordance with Reference b-2.

6.4 When components or subsystems have been evaluated in a circulating system (see 5.3.2, 5.4.2, 5.5.1, 5.5.2, 5.5.2.1.3, 5.5.2.2.3, 5.5.3.3, and 5.5.4), the contaminant results for the sample withdrawn are to be multiplied by the ratio of the total test system oil volume to the component (or subsystem) wetted volume to obtain the contaminant value for the component or subsystem. It is recommended that the test system liquid volume be as small as is practical to minimize the dilution factor. (See 5.2.7.)

6.5 Analyze for water in oil samples per Reference b-10, b-11, and b-12.

6.6 Analyze for liquid hydrocarbon contaminants such as kerosene, solvents, etc. using differential infra-red spectrographic analysis.

7. ***Reporting Cleanliness Level Data—***Report data using one or more of the following:

7.1 Milligram per meter squared of wetted surfaces.

7.2 Milligram per liter of internal wetted volume (see 6.4).

7.3 Particle count greater than 5 and 15 micrometers per milliliter of wetted volume and report as ISO Solid Contaminant Code per Reference b-6 (see 6.4).

7.4 Measure and report the RCL of both the verified clean container and clean test liquid (see 6.3).

8. Guidelines For Establishing Allowable Cleanliness Levels (Acl)

8.1 The Allowable Cleanliness Level (ACL) values to be used for a given item need to be established for a particular application and included in the detailed specification for that component. Ideally, the ACL of a particular component or subsystem should be such that it does not add to the contamination level of the system in which it is to be used. For systems, the ACL should be consistent with the contaminant tolerance of the most sensitive components and desired life. Such specification of ACL should also consider Sections 9, 10, and 11 of this recommended practice.

9. Resolution Of Disputes—Attempt to resolve disputes by carefully reviewing the following:

9.1 Method of obtaining fluid sample.

9.2 Degree of turbulence of fluid sampling point (maximum Reynolds number, location of sampling point, etc.).

9.3 Degree of component or system agitation prior to sampling.

9.4 Type of liquid being used to obtain fluid sample.

9.5 Comparative shock and vibration applied to item prior to evaluation.

9.6 Method of fluid sample evaluation in accordance with Appendix Z of Reference b-4.

10. Criteria For Acceptance—The specific methods of collecting and evaluation of test liquid samples should be evolved in accordance with this recommended practice. It is recommended that each specific method be evaluated by multiple tests on each of several components in more than one laboratory, so that reasonable confidence in test repeatability and reproducibility can be established. Once the method has been established, the Allowable Cleanliness Level (ACL) should be established per Section 8.

11. Summary Of Designated Information—The following designated information is needed when applying this recommended practice to a particular application or use:

11.1 Type item to be evaluated and maximum conditions (flow, pressure, velocity, etc.) of test.

11.2 System hydraulic fluids (both brand and type).

11.3 Maximum system temperature.

11.4 Minimum viscosity of system hydraulic fluid at maximum temperature.

11.5 Acceptable test liquids for contaminant assessment (see 5.2.3).

11.6 Maximum expected shipping and operating shock and vibration.

11.7 Method desired for evaluating test liquid samples and reporting results.

11.8 Desired Allowable Cleanliness Level (ACL) .

12. Terminology—The following terms are used herein and are not covered in References a-1 - a-4:

12.1 Allowable Cleanliness Level (ACL)—A value for comparison with a measurement of the amount of particulate and liquid contaminant in hydraulic fluids, parts, components, subsystems, and systems. The value describes an acceptable contaminant level which is consistent with the contaminant tolerance of the most sensitive system components and desired life.

12.2 Clean Test Liquid—A fluid that has been precleaned so that its Required Cleanliness Level (RCL) is not more than 10% of the Allowable Cleanliness Level (ACL) of the component under test (see 5.2.3).

12.3 Cleanliness Level—A property of a component, fluid, or system that is a measurement of its relative freedom from particulate and liquid contaminants.

12.4 Pre-Cleaned (≤10% rule)—A test stand is considered pre-cleaned when its contaminant level is less than 10% of the Allowable Cleanliness Level (ACL) of the component or system under test.

12.5 Required Cleanliness Level (RCL)—The contaminant level associated with the apparatus, solvents, and liquids used to collect, transfer, and analyze the contaminants in a liquid sample. No matter how clean a sample is in reality, the lower limit of measurement of the ACL is the RCL. (RCL is usually 1-10% of ACL.)

12.6 Verified Clean Container—A suitable collection vessel that has been satisfactorily cleaned and whose cleaniness has been checked per Ref. b-2 and exhibits an acceptable RCL.

12.7 Wetted Volume—The liquid volume of a component or system normally in contact with hydraulic fluid from the system.

TABLE 1—REFERENCED DOCUMENTS

(a) Terminology:

1. ANSI/B93.2-1971
2. NFPA/T3.10.3-1967
3. NFPA/T2.1.1-1972
4. NFPA/T2.1.2-1974

(b) Contamination:

Standard No.	ANSI Standard No.	ISO No.	Brief Title
1. NFPA/T2.9.1	B93.19-1972	ISO 4021 1977	Sampling Fluid from Pressurized Lines
2. NFPA/T2.9.2	B93.20-1972	ISO 3722 1976	Verification of Sample Bottle Cleanliness
3. NFPA/T2.9.6	B93.28-1973	DIS 4402	Calibration of Automatic Particle Counters
4. NFPA/T2.9.3	B93.30-1973	DIS 3938	Reporting Contamination Analysis Data
5. NFPA/T2.9.9	B93.44-1978	—	Sampling Fluid from a Reservoir
6. SAE/RP-J1165 1977	—	DIS 4406	ISO Solid Contaminant Code (Ref. Fitch paper OSU/P76-26)
7. NFPA/T2.9.8 19xx	—	—	End Item (Roll-off) Cleanliness (in process) (Ref. Karhnak 1973 and 1974 NCFP papers)
8. SAE/ARP 598A	—	—(1)	Microscopic Particle Counting Method
9. SAE/ARP 785	—	—1	Gravimetric Method for Measuring Contamination
10. ASTM/D 95	—	—	Total Water in Oil
11. ASTM/D 1744	—	—	Total Water in Oil
12. ASTM/D 96	—	—	Free Water in Oil
13. SAE/RPXJ1277	—	—	Assessing Cleanliness of New Hydraulic Fluid (2)

(c) Sampling Plan:

1. ANSI/Z1.4-1971 (MIL-STD-105)

1. ISO is currently finalizing an international version.
2. Proposed draft currently under review.

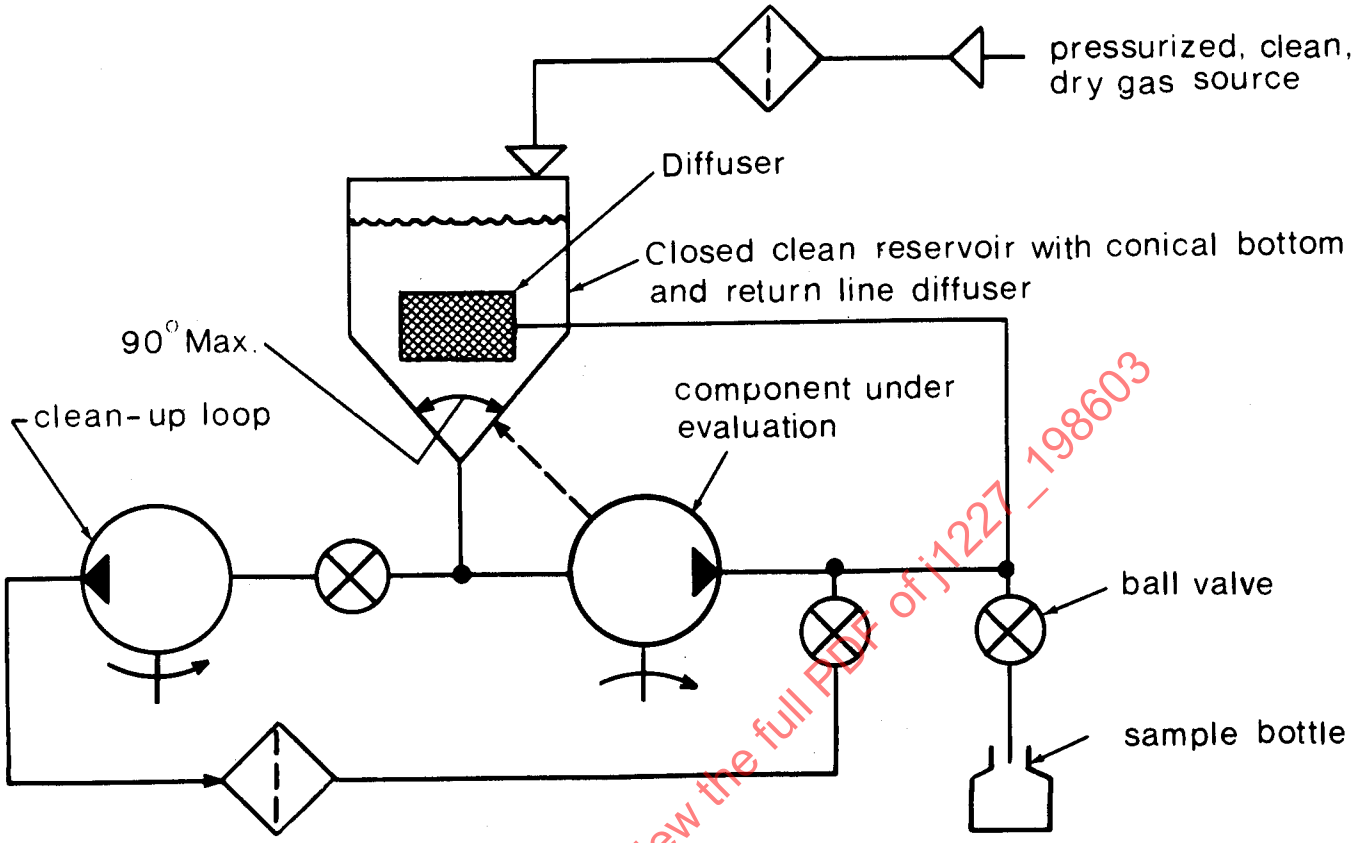

FIGURE 1—TYPICAL ROTATING COMPONENT (PUMPS AND MOTORS) CIRCUIT FOR ASSESSING CLEANLINESS