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SURFACE VEHICLE RECOMMENDED PRACTICE

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Hydraulic Fluid Power—Valves—Method for Assessing the Lock Sensitivity to Contaminants

Foreword

NOTE—Some Test Procedures are potentially dangerous. SAE Technical Reports do not purport to address all of the safety problems, if any, associated with their use. It is the responsibility of the user of an SAE Technical Report to establish and employ appropriate safety practices. Tests should only be conducted by individuals who have been properly trained in the test procedure and who are aware of any hazards which may be present. Appropriate safety and health precautions must be employed when conducting any test.

1. Scope

1.1 This SAE Recommended Practice defines a procedure, which will aid in assessing the contaminant sensitivity of hydraulic valves. The approach taken defines a test procedure with flexibility for testing valves in a wide range of contamination levels. The user of this procedure must establish the contamination levels for testing. Three levels are suggested which should cover the range for most valve applications. This procedure does not establish the contaminant sensitivity requirements for any valve. The user of this procedure needs to be aware of the system contamination level that the valve will operate in and select test contamination levels significantly higher than the operating level to assess the suitability of the valve. The test procedure permits a valve to be tested without disassembly and therefore permits protection of proprietary design information.

1.2 This procedure assesses the contamination sensitivity of valves by contaminant lock. The procedure indicates the sensitivity of valves by contaminant lock due to various sizes of contaminants. The test is designed to assess the contaminant sensitivity of valves in tests of relatively short duration. See Appendix A for guidance as to how the tests and their results may be used.

1.3 The tests are purposely designed to be severe in order to be applicable to a wide range of contaminated environments. The use of valves in many applications and for various purposes results in differing levels of acceptable performance. That is, the same valve may be unacceptable — in relation to operation in a contaminated environment — in one application and be acceptable in another. The user must make that decision based on a review of the expected level of the specific application and the test results obtained.

NOTE—See 7.2 if document is to be contractually invoked.

2. *References*

2.1 Applicable Publications—The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of the documents shall be used except in those cases where an invitation for bid or procurement contract specifically identifies the issues in effect on a particular date.

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

SAE ARP 490—Electrohydraulic Flow Control Servovalves
SAE ARP 785—Aerospace—Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure

2.1.2 NFPA PUBLICATIONS—Available from the National Fluid Power Association, 3333 North Mayfair Road, Milwaukee, WI 53222-2319.

ANSI/(NFPA) T2.9.11—Hydraulic Fluid Power—Methods for determining the particle count of an oil sample (using liquid automatic counters)
ANSI/(NFPA) T2.9.14—Hydraulic fluid power—Fluid contamination—Determination of solid contaminate level by the gravimetric method

2.1.3 ISO PUBLICATIONS—Available from International Organization for Standardization, 1 rue de Varembe, 1211 Geneva, 20 Switzerland or from the National Fluid Power Association (NFPA).

ISO 1219-1—Fluid power systems and components—Graphic symbols and circuit diagrams—Part 1: Graphic symbols
ISO 4021—Hydraulic fluid power—Particulate contamination analysis—Extraction of fluid samples from lines of an operating system
ISO 4405—Hydraulic fluid power—Fluid contamination—Determination of particulate contamination by the gravimetric method
ISO 4406—Hydraulic fluid power—Fluids—Code for defining the level of contamination of solid particles
ISO 5598—Fluid power systems and components—Vocabulary
ISO 6403—Hydraulic fluid power—Valves controlling flow and pressure—Test methods
ISO 10770-1—Hydraulic fluid power—Electrically modulated hydraulic control valves—Part 1: Test methods for four-way directional flow control valves
ISO 10770-2—Hydraulic fluid power—Electrically modulated hydraulic control valves—Part 1: Test methods for three-way directional flow control valves
ISO 12103-1—Road vehicles—Test dust for filter evaluation—Part 1: Arizona test dust

3. ***Definitions*—**For definitions of other terms, see ISO 5598.

3.1 Contaminant Lock—The process of restricting movement by contaminant buildup between two surfaces which move in relation to each other, such as spool/bore or spool/sleeve assemblies.

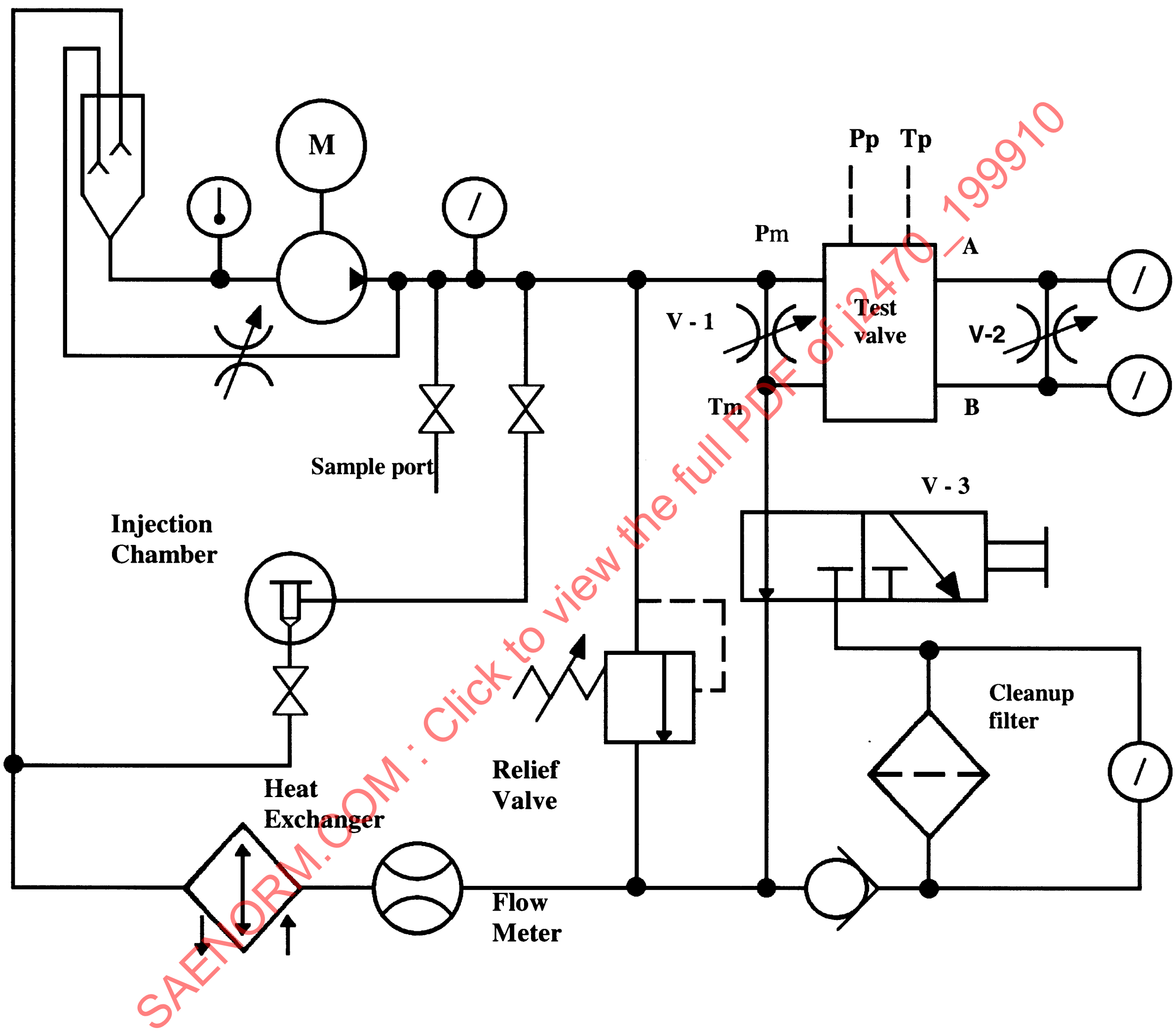
3.2 Contaminant Sensitivity—The change in valve performance caused by particulate contaminants in the fluid.

4. *Test Requirements*

4.1 Test Equipment

4.1.1 The test system shall consist of a hydraulic test circuit, as illustrated in Figure 1, comprising of a reservoir, a pumping unit, an injection system, a heat exchanger, a flowmeter, pressure gauges, a temperature indicator, a relief valve, a control valve, and cleanup control filters. Select components for the test circuit which are of a design known to function satisfactorily with contaminated fluid.

V - 1 Throttling bypass valve to maintain flow in test circuit if test valve is closed.
V - 2 Throttling bypass valve to maintain pressure in test circuit when there is flow through the test valve.
V-3 Clean-up filter selector valve -shown in contaminant test position.



Note: Symbols are in accordance with ISO 1219-1 except for the injection chamber.

FIGURE 1—TYPICAL VALVE CONTAMINANT SENSITIVITY TEST CIRCUIT

4.1.2 Construct the reservoir with a conical bottom having an included angle of less than 90 degrees to ensure sufficient fluid agitation. Diffuse the hydraulic fluid entering the reservoir below the surface of the fluid.

4.1.3 Construct an injection chamber, which will ensure that no contaminant is trapped in the injection chamber. A chamber with a volume of approximately 500 mL, with a length to diameter ratio of approximately 10 and having a conical bottom with an included angle of less than 90 degrees, is recommended.

4.1.4 Use a heat exchanger that does not constitute a contaminant trap.

NOTE— It is recommended that either a one or two-pass unit be used and mounted vertically with the hydraulic fluid entering the heat exchanger from the bottom. It is also recommended that the hydraulic fluid be circulated through the tube side and the water through the shell side.

4.1.5 Use a flowmeter that is insensitive to contaminant and is accurate to within 2% of full value.

4.1.6 Use control filters which are capable of providing a contaminant background of less than or equal to 40 particles/mL greater than 5 µm size and less than or equal to 10 particles/mL greater than 15 µm size.

4.1.7 Provide a facility for gravimetric measurement of the contamination level of the fluid in accordance with SAE ARP 785, ANSI(NFPA) T2.9.14 or ISO 4405.

4.1.8 The test circuit requires one or more bypass throttling valves to maintain flow and pressure as shown in 7.2. When the test valve is in a position that permits flow through the test valve, the throttling bypass valve V-1 shall be closed and V-2 adjusted to maintain the required pressure. The test circuit may require slight modifications to suit the particular valve being tested. For valves with one or more external pilots, a pilot line will be required. Unless otherwise specified, pilot lines shall be subjected to the same contaminant source as the rest of the test valve. A relief valve or rupture disc may be incorporated into the system to protect the pump, however, no fluid should pass through it during the testing of the valve at selected positions. (Flow through the relief at time of shifting is permissible for blocked center valves and valves with blocked crossover.)

4.2 Test fluid and volume

4.2.1 Use a mineral oil ISO viscosity grade 32 fluid, unless the customer identifies a specific fluid. Report the fluid specification, brand name, supplier, and batch identification.

4.2.2 A test system (exclusive of the system cleanup filter circuit) with a fluid volume that is numerically equal to one-fourth to one-half the designated test volume flow per minute is recommended. In some valve positions, there will only be leakage flow through the valve. However, flow must be kept relatively high to keep the contaminant in suspension in order to qualify the system. In other valve positions, the force to shift the valve may be a function of the flow rate and operating pressures and the maximum shift forces may occur at specific flow and pressure conditions. The fluid volume shall be recorded.

4.3 Materials

4.3.1 Have available a supply of clean fluid sample bottles with a required cleanliness level of less than 10 particles greater than 10 µm per mL of bottle volume in accordance with ISO 4021.

4.3.2 Have available a supply of clean slurry injection bottles.

4.4 Precautions

4.4.1 Ensure that the connecting lines and the hydraulic components are of such size that turbulent mixing will exist throughout the test circuit, including the test valve.

4.4.2 Take precautions to prevent contaminant traps, silting areas, and combinations of cyclonic separation zones and quiescent chambers. Also ensure that the test system does not exhibit the presence of entrained air.

4.5 Selection of Test Contaminants and Concentrations

4.5.1 TEST CONTAMINANT—Table 1 lists two options for the silt lock contaminant. For Option A, the contaminant to be used is the size of ISO 12103-1 A1 Ultrafine or A3 Medium Arizona test dust or a classified cut of one of these test dusts. The contaminant for Option B is a mixture of the test dust and carbonyl iron. Table 2 lists the carbonyl iron grades.

a. Option A—In Option A, classified Arizona Test Dust is the only contaminant. Option A is recommended for testing when the magnetic properties of the contaminant are not a concern. This is generally the case except for electrically operated valves.

a. Option B—In Option B, the contaminant, in each size range through 40 µm, is a mixture of Arizona Test Dust and Carbonyl Iron (C.I.) In the 0 to 80 µm size range, the contaminant is the same as Option A. Option B is recommended for electrically operated valves. For Option B, the mixture by weight is 50% Arizona Test Dust and 50% C.I. The C.I. particles have a density of approximately three times that of the test dust particles. Therefore, for Option B, the majority of the particles will be Arizona test dust, as in Option A, with the total number of particles in Option B about two-thirds the number in Option A.

TABLE 1—TEST CONTAMINANTS

Run	Contaminants Test Dust ISO 12103-1 (size)	Contaminants Carbonyl Iron (grade)	Options A	Options B
1	0 – 5 µm (See 4.5.4)	SF	100% Test Dust of Specified Size	50% Test Dust of specified size and 50% C. I. of the specified size (by weight)
2	0 – 10 µm ISO 12103-1 A-1 ultrafine dust	F		
3	0 – 20 µm (See 4.5.4)	C		
4	0 – 40 µm (See 4.5.4)	L		
5	0 – 80 µm ISO 12103-1 A3 medium dust	None		100% ISO 12103-1 A3 Medium Test Dust

TABLE 2—CARBONYL IRON GRADES

Grade	Maximum Size Micrometers	Reported Size (µm) (by convention, this is the 50% weight point)
SF	6	3
F	12	6
C	24	12
L	42	21

4.5.2 CONTAMINANT CONCENTRATION LEVELS—Table 3 identifies three concentrations of contaminants recommended for testing. These levels are 10, 50, and 100 mg of contaminant per liter of fluid. These three levels should be adequate to cover all hydraulic systems applications. As indicated in Table 3, the ingression rate and system filtration characteristics can be considered in the selection process. However, since silt-lock can result in valve and system failure, it is prudent to select a contaminant level of not less than the maximum contaminant level which may occur rather than the normal operating level. In general, a level at least 7 to 10 times that of the normal operating level is recommended. In comparing different valves and in determining required filtration levels, it will generally be more efficient to first conduct tests at the highest concentration level of interest.

TABLE 3—RECOMMENDED VALVE TEST CONTAMINANT CONCENTRATIONS

Concentration X(mg/L)	Tolerance ± (mg/L)	Valve Application
10	1	Limited contaminant ingression, system possesses high degree of filtration
50	5	Some contaminant ingression, system possesses some degree of filtration
100	10	Heavy contaminant ingression, system possesses little or no degree of filtration

4.5.3 SELECTION OF TEST CONTAMINANT SIZE RANGES—A complete test would consist of 5 runs each with a different size range of contaminant as identified in Table 1. However, in many cases testing with a reduced number of contaminant ranges will be satisfactory and will reduce test time and costs. For non-electrical valves, the test contaminants for runs 2 (0 to 10 µm) and 5 (0 to 80 µm) are recommended for reduced testing. If a valve should perform unsatisfactorily in one of these size ranges, additional testing can be conducted to more accurately determine the size contaminant to which the valve is sensitive. Similarly, for electrically operated valves, contaminants for runs 2 (0 to 10 µm) and 4 (0 to 40 µm) are recommended for reduced testing. For electrically operated valves in systems with limited filtration, the contaminant for run 5 (0 to 80 µm) in Table 1 should also be considered when conducting reduced testing.

4.5.4 ARIZONA TEST DUSTS—Have a supply of ISO 12103-1 A1 Ultrafine test dust and ISO 12103-1 A3 Medium test dust. For complete testing, the specified fractions of Arizona Test Dust as identified in Table 1 which have been provided by a recognized commercial source are also required. See Appendix B for requirements and sources for the specified fractions of Arizona Test Dust. For each test dust used, make a 3 mg/L sample and measure the particle count in accordance with NFPA T2.9.11 and identify counter and calibration method used.

4.5.5 CARBONYL IRON—Have available a supply of classified carbonyl iron which meets the requirements of Table 1 when testing per Option B. The grades of carbonyl iron are identified in Table 2. See Appendix B for suggested sources of carbonyl iron.

4.6 Qualification of the system

4.6.1 For flushing the system, a flushing block may be installed in place of the valve to be tested. A flushing block is simply a ported manifold which replaces the test valve and will pass fluid through the test system and allow all lines to be flushed.

4.6.2 Circulate fluid through the clean-up filter until the contaminant background is ISO 4406 Code 12/10 or cleaner. (See ANSI/(NFPA) T2.9.11 for guidance.

4.6.3 Adjust the flow rate through the test circuit to approximately the lowest flow rate for which the stand is to be used for testing. Adjust the pressure to be the maximum for which the stand is to be used.

4.6.4 Position valve V-3 to bypass the clean-up filter.

4.6.5 Add a quantity G of test contaminant to bring the contamination level of the system to the required test level using the following expression: $G = X \times V$ where: X = concentration (milligrams per liter) as defined in Table 3, and V = volume of the system (in liters).

The test contaminant to be used during test equipment qualification is the largest classified size of the contaminant to be used during the silt lock test. See Table 1 for the two options for the silt lock test contaminants. (If option B is being used, the test contaminant for qualification of the test system shall be the contaminant specified for the mixture of test dust and carbonyl iron containing the largest size particles.) Table 3 provides three contaminant concentration levels for X and some guidance on selection of the test concentration level.

4.6.6 Drain the injection chamber and fill it with the prepared contaminant (see 4.6.5) in the form of a well-mixed slurry to prevent agglomeration of particles. Ultrasonic vibration of the slurry must be performed for 1 min.

4.6.7 Inject slowly, over a 3 to 5 min period, the contents of the injection chamber while fluid is flowing at flow rate per 4.6.3.

4.6.8 The period of operation for qualifying the test circuit shall not be less than the expected time for which one injection of the contaminant for the contaminant lock test will be circulated during the test. Approximately 90 min of circulation is required for each operating position in which the valve is to be tested.

4.6.9 During the system operation required in 4.6.8, extract fluid samples at equally spaced intervals not to exceed 15 min from the system in the manner specified in ISO 4021. This is a minimum of six extractions for a test period of 90 min.

4.6.10 Measure the contamination level of each sample in accordance with SAE ARP 785, ANSI/(NFPA) T2.9.14 or ISO 4405. The first sample shall be within the tolerance specified in Table 3.

4.6.11 Consider the system qualified for testing if the contamination levels obtained from all the subsequent samples (see 4.6.10) are within ±10% of the value determined for the first sample.

4.6.12 After the system qualification test, circulate the test system fluid through the control filter until the contaminant background is code number 12/10 or cleaner in accordance with ISO 4406.

4.6.13 Repeat the qualification procedure when any modification to the flow path or reservoir is made, or if the concentration level is increased.

4.7 Contaminant Lock Sensitivity Test Procedure

4.7.1 Ensure test system is qualified to 4.6 requirements and install the test valve in place of the flushing block if a flushing block has been installed.

4.7.2 Install appropriate valve control means and data recording devices.

4.7.3 Prepare sample slurries each containing G grams of test contaminant in clean sample bottles in the ranges defined for test assessment, per Tables 1 and 3.

NOTE—See 4.6.5 for quantity of contaminant required.

4.7.4 Increase the system pressure to the specified test pressure. Unless otherwise specified, the test pressure shall not be less than 90% of the rated pressure of the valve. Shift the test valve 12 times, recording the clean valve operating parameter to be measured for at least the last six shifts. Depending upon the type of valve, the parameter measured may be shift time, actuation force to shift, electrical voltage to shift, etc. In some cases, it may be useful to calculate the standard deviation of the measured parameter for use in comparing measurements between clean and contaminated fluid.

4.7.5 Position Valve V-3 in Figure 1, to bypass flow around the clean-up filter.

4.7.6 Inject slowly, over a 3 to 5 min period, the first test contaminant range slurry while fluid is circulating. Obtain fluid sample and analyze for gravimetric weight in accordance with SAE ARP 785, ANSI/(NFPA) T2.9.14 or ISO 4405. Weight shall be within the tolerance in Table 3 for the applicable concentration level.

4.7.7 Cycle the test valve at a rate not to exceed one cycle per minute for an adequate time to ensure the contaminated fluid is distributed within the valve (minimum of five cycles)

4.7.8 Set the test valve to the position or condition most critical for silt lock sensitivity (see 5.1.1) for a stationary time of 30 s. Shift valve and record operating parameters period as indicated in 4.7.4. Return valve to its initial position/condition and repeat for stationary times of 1, 2, 4, 8, 16, and 32 min using the same injection of test contaminant. Time periods should not be cumulatively measured but reinitiated after each measure of valve response.

4.7.9 Fluid cleanup shall be performed before continuing testing with injection of a new contaminant size range (see 4.6.2 for cleanliness requirements). Shift Valve V-3 in Figure 1 so that flow is routed through the clean-up filter. During cleanup, the test valve must be cycled to remove contaminant. (A minimum of five cycles is recommended.)

4.7.10 Repeat 4.7.4 through 4.7.9 until all required test contaminant ranges are injected and tested.

NOTE—Before testing with a new contaminant size range, it is desirable to measure the parameter being evaluated with clean fluid. This is particularly important if the performance deteriorated in the previous test with contaminated fluid. The results of the test with clean fluid will tend to validate whether deterioration was the result of contamination. Measurement of the test parameters in clean fluid is not required if the performance did not degrade during the previous test. Similarly, testing with clean fluid after testing the last contaminant size range is optional, but is recommended if degraded performance was noted.

4.7.11 Unless otherwise specified or agreed to by the customer, the test should proceed progressively from the smallest contamination ranges to the largest contamination ranges. (See 7.2e.)

5. Recommendations for Types of Tests to Measure Valve Contaminant Lock Sensitivity

5.1 Contaminant Lock Sensitivity Measurement for Directional Control Valves

5.1.1 The evaluation of contaminant lock involves the measurement of force changes as particles in the oil become lodged between the spool and sleeve as fluid flow migrates from a high-pressure area to a lower pressure area while the spool is stationary. After a silting period, the force required to move the spool has increased, it is desirable to measure the increased force and initial movement of the spool. Many valves have indirect means of creating the force (i.e., solenoids, springs, pilot pressure, etc.) and the initial spool movement is inaccessible to measure. Since the net result to valve function is of highest interest, measurement of pertinent input and output parameters is important, such as pressure differential, current for DC coils, voltage for AC coils, etc,. (or spring return) versus pressure differential, flow, etc. In some cases, the input is ramp increased (or decreased) until output change is recorded, in others the input is stepped to operating level (or reduced) and output response time is recorded. Also, due to the various types (two-way, three-way, four-way, etc.) and positions of valves, it may be necessary to run several tests at different positions to determine the most sensitive position. Note that the most sensitive position may depend on the application. Normally, the test pressure should be the normal system operating pressure to which the valve is subjected to in service. With flow through the valve, a throttling valve may be required to maintain this pressure. The user of this procedure must determine the parameters to be measured. (See 6.1 for listing of documents that may be used for guidance in determining the parameters to be measured.)

5.2 Contaminant Lock Sensitivity Measurement for Servo-Control Valves—The valve is set so that the cylinder port pressures at null flow are within the allowable specification limits. After being subjected to the specified stationary time, the amount of signal required to cause a detectable change (typically 1.5% of rated flow) in output flow shall be measured. Use the manufacturer's recommended dither if applicable. The user of this procedure must determine the parameters to be measured. (See 6.1 for listing of documents that may be used for guidance in determining the parameters to be measured.)

6. Test results

6.1 Data Presentation—Valve identifications, test conditions, test configurations, and operating conditions (test fluid, temperature, and pressure) should be noted. The particle count distribution of the test dust identified in 4.5.1 shall be recorded. All initial (clean fluid) and contaminated fluid measurements for assessing contaminant lock should be presented. This shall include a particle count of each test contaminant. Valve leakage data should be listed in tabular form listing pressure, leakage path, leakage level, and fluid temperature for each contaminant range tested. Data for directional and pressure control valves should be presented in a manner consistent with ISO 6403. Servo-valve and modulating valves static and dynamic performance characteristics should be presented in a manner consistent with ISO 10770-1, ISO 10770-2, and SAE ARP 490. Appendix C is included as an example of the minimum recommended information to be recorded in addition to the particle count for each test contaminant.

7. Notes

7.1 Section 7 contains information of a general or explanatory nature that may be helpful, but is not mandatory.

7.2 Tailoring the Requirements—If this document is to be contractually invoked, it is necessary to tailor the document to the particular valve or application or to identify specific pass/fail requirements. As a minimum, the following items need to be addressed:

a. Test fluid if other than that identified in 4.2.1.
b. Operating pressure at which test is to be conducted. (If not specified, the test is to be conducted at not less than 90% of the rated pressure of the valve as required in 4.7.4.)
c. Whether or not Test Contaminants per Option B of Table 1 are to be used for electrically operated valves.
d. Test contaminant concentration (mg/L) required. (See Table 3.)
e. Contaminant size ranges to be tested. (See Table 1 and 4.5.3.) Example: Test 0 to 10 µm and 0 to 80 µm ranges only.
f. Pass/Fail Criteria—Examples: Valve shall shift in not more than 500 ms. Force to shift valve shall not exceed 5 Kg force.
g. Valve Shifts to be Tested—Examples: (1) Test all spring return solenoid valves starting in the solenoid energized mode and then de-energize the solenoid; (2) test in most sensitive position (as determined by the lowest force available to shift).
h. Flow Rate at Which Test is to be Conducted When There is Flow Through the Valve—Examples: (1) At rated flow, except for positions in which flow through the valve is blocked. For blocked positions, flow as low as 10% of rated flow is permissible when the test circuit is qualified at this low flow rate. (2) At not less than 80% of rated flow.

7.3 Keywords—Servo-valve, hydraulic control valves, contaminant lock, particulate contamination.

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APPENDIX A

USE AND EVALUATION OF TEST RESULT (INFORMATIVE)

A.1 Use of test results

A.1.1 The tests for the determination of contaminant lock sensitivity may be conducted for a number of purposes as determined by the user of the tests. The purpose of this appendix is not to define the manner in which the tests are to be used or how to interpret the results. The purpose is merely to provide some guidance as to how the tests and their results may be used.

A.1.2 It is not practical to test for all the operating conditions that occur in the field. Pressures, flows, fluid temperatures, and the time between valve actuations can all influence performance degradation due to contamination sensitivity.

A.1.3 Data is not currently available to correlate the test results from the procedure herein with field service experience. While the tests are useful for comparative purposes, one should not attempt to precisely quantify service performance because of differences with in-service contaminants and the operating environment.

A.2 Contaminant Lock Test

A.2.1 This test indicates the size of particles and the concentration levels that can cause lock up of the valve. While in-service contaminants and levels will differ, the test provides a basis on which to evaluate the contaminant sensitivity. The valve user needs to determine whether the contamination lock sensitivity of the valve is satisfactory for a particular application. A valve satisfactory in one application may not be satisfactory in another application. Take for example, a valve that is not sensitive to contaminant lock at 10 mg/L but is sensitive at 50 mg/L. This valve may perform satisfactorily in a relatively clean system with a high degree of filtration but may be unsatisfactory in a heavily contaminated system. One must not assume that the valve is suitable for service in a system contaminated to the 10 mg/L level. This is an accelerated test method that uses very high levels of contaminants for a very short duration, while in service one expects prolonged exposure to much lower levels of contamination. Accordingly, it is not recommended that the test be used to predict in-service performance at a system contamination level greater than 10 to 15% of the test contaminant level

A.2.2 If a valve is subject to contaminant lock at a particular contamination level, the user has several alternatives. One is to look for a valve less sensitive to contamination. Another is to ensure that filtration is provided which will maintain system cleanliness at a level below that at which contaminant lock occurs. Another alternative is for the valve manufacturer to make proprietary design changes such as modifying moving part clearances slightly. An increase or decrease in clearance may have a significant impact on the sensitivity to contaminant lock.

NOTE— Tests should normally be conducted at flow rates and differential pressures similar to those existing in the application where the valve will be used. If tests are conducted under less severe conditions, the fact that no degradation occurs can not be extended to other more severe operating conditions. Valves can often be tested at considerably less than their application flow rates without a significant influence on the silt lock characteristics. Flow rates other than application flow rates should be as agreed to by interested parties; i.e., customer, system designer, valve supplier, and test laboratory.