AEROSPACE RECOMMENDED PRACTICE

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(R) Acceptance Test Procedures and Standards to Ensure Clean Fuel System Components

RATIONALE

This document has been modified to: (1) Update outdated references and delete references that are no longer valid, (2) Add references to ISO 4402 and AIR5455, (3) Reference ISO 11171 for the calibration of automatic particle counters and provide the corresponding size ranges with this calibration in Table 1, (4) Add a paragraph 4.2.2.1 discussing the ISO 11171 automatic particle counter calibration, and (5) Editorial changes.

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1. SCOPE

To describe general guidelines for achieving selected levels of cleanliness in gas turbine engine fuel system components and to describe laboratory methods for measuring and reporting the contamination level of the wetted portion of fuel system components. As in SAE J1227 (covering hydraulic components) this practice includes guidelines for levels of acceptance but does not attempt to set those levels.

1.1 Purpose

To provide standards and procedures for processing and verification to insure an acceptable level of product cleanliness in gas turbine engine fuel system components.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

ARP598	Aerospace Microscopic Sizing and Counting of Particulate Contamination for Fluid Power Systems
AIR5455	Impact of Changes in Test Dust Contaminants and Particle Counter Calibration on Laboratory Filter Element Performance and Fluid Cleanliness Classes
J1227	Assessing Cleanliness of Hydraulic Fluid Power Components and Systems

2.2 U.S. Government Publications

Available from DLA Document Services, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6396, http://quicksearch.dla.mil/.

MIL-C-15074	Military Specification: Corrosion Preventive, Fingerprint Remover
MIL-STD-2073-1	Department of Defense Standard Practice for Military Packaging
MIL-PRF-7024	Performance Specification, Calibrating Fluids, Aircraft Fuel System Components
MIL-PRF-16173	Performance Specification: Corrosion Preventive Compound, Solvent Cutback, Cold Application

2.3 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 4021	Hydraulic Fluid Power - Particulate contamination analysis - Extraction of fluid samples from lines of an operating system
ISO 4402[1]	Hydraulic fluid power - Calibration of automatic-count Instruments for particles suspended in liquids - Method using classified AC Fine Test Dust contaminant

[1] ISO 4402 has been withdrawn as of 12/9/1999.

ISO 11171 Hydraulic Fluid Power - Calibration of automatic particle counters for liquids

ISO 14644 Clean Rooms and Associated Controlled Environments Package

2.4 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ANSI B93.44 (1978) Extracting Fluid Samples from a Reservoir of an Operating Hydraulic Fluid Power System

3. GUIDELINES FOR ACHIEVING PROPER LEVELS OF CLEANLINESS

Most manufacturers of gas turbine engine fuel system components rely on process control to maintain the necessary degree of cleanliness in the products they produce. However, a quantitative cleanliness requirement, issued by the airframe or engine manufacturer, consistent with the contamination tolerance of the most sensitive components in the fuel system, will establish a logic for each component manufacturer to follow. Subtier vendors would then have a clearly established allowable cleanliness level for their particular application which would be included as a detailed specification for that component. The vendor specification should define two terms in order to be consistent with existing hydraulic system cleanliness guidelines.

a. Allowable Cleanliness Level: The allowable cleanliness level must be consistent with the contamination tolerance of the most sensitive component in the fuel system. It will be abbreviated throughout the remainder of this document for simplicity and called "ACL". The ACL is organized as a series of particle sizes per 100 ml of test fluid arranged into classes. The classes are defined in this document in Table 1.

b. Recommended Cleanliness Level: The recommended cleanliness level is the initial cleanliness of the entire test apparatus used for measuring ACL and should be specified as not more than 10% of the count permitted for ACL. This will insure that test apparatus will have a minor impact on the ACL measurement. This level will be abbreviated throughout this document as "RCL".

The subtier vendor will then select appropriate processes consistent with the specification and could, if required, verify on a statistical basis, compliance with that requirement. The phases of production which must be controlled and monitored to achieve satisfactory levels of cleanliness will be described in this section. No order of preference for methods is implied. No attempt will be made to establish what level of control is required to lead to a level of cleanliness. This must be established and verified separately by suppliers in their own facilities. The proof of conformance will be with periodic verification tests of the end product against the specified system allowable cleanliness level.

Table 1

Table 1A - Allowable cleanliness level (ACL)
Particle size and count per 100 ml sample volume

Particle Size Range		ACL 6	ACL 5	ACL 4	ACL 3	ACL 2	ACL 1
Optical Microscope Count (µm)	Automatic Particle Counter; ISO 11171 calibration [µm(c)] [1]						
> 100	> 71	1	1	1	1	4	10
50 – 100	38 - 71	2	5	15	40	100	270
25 - 50	21 - 38	30	85	250	600	1700	4200
15 - 25	14 - 21	170	480	1300	3500	9000	24 000
10 - 15	10 - 14	550	1500	4000	11 000	29 000	75 000
5 - 10	6 - 10	2700	17 000	19 500	50 000	130 000	350 000
1 - 5	4 - 6	11 000	30 000	85 000	210 000	600 000	1 500 000
Total Particle Count		14 453	39 071	110 066	275 141	769 804	1 953 480

Note 1: ISO 11171 particle size ranges equivalent to the size ranges for optical microscope count. See 4.2.2.1 for more information regarding ISO 11171 automatic particle counter calibration.

Table 1B - Typical areas in which these classifications can be used

ACL 1	Gear Boxes
ACL 2	Pumps
ACL 3	Servo Valves
ACL 4	Sensor and Miniature Servo Valves
ACL 5	Very Small Clearances
ACL 6	Very Low Force Margins

3.1 Cleaning of Detail Parts

The cleaning of mechanical and electromechanical parts must be performed on a 100% basis with procedures compatible with the materials of the part. Special precautions are advised on parts which have cavities not visually inspectable. The basic methods which follow are for use as guidelines and do not prohibit the user from using other procedures which can be proven effective.

3.1.1 Vapor Degreasing

Operator must visually check parts to see that they are free of all chips, burrs, and surface stains.

3.1.2 Sonic Cleaning

Part must be oriented to maximize the effect of sound vibrations in assisting to remove contamination.

3.1.3 Probing

Ports, cavities, intersecting holes, etc., may require probing using a suitable wire to help dislodge chips or foreign material.

3.1.4 Vacuum Cleaning

In the same manner as probing, ports, cavities, intersecting holes, etc., may require vacuuming.

3.1.5 Flushing

Flushing with a liquid or air at a constant pressure level in all ports, cavities, intersecting holes, etc., may be required. Since removal of particles from surfaces is proportional to the turbulence in the system, the flushing should be performed at Reynolds numbers at least equal to, and preferably higher than, those seen by the article in normal service. Vibration and shock of the article during flushing may assist in obtaining the necessary degree of cleanliness. If a liquid is used it must be drained following flushing. Cleaned parts should be placed in sealed clean plastic bags following this operation to prevent recontamination.

3.1.6 Rinsing

Simple parts with no complex passages or cavities may be simply rinsed with a standard degreasing medium and placed in clean containers or clean plastic bags.

3.2 Inspection of Detail Parts

Detail parts shall be inspected under the conditions of magnification and lighting specified in Table 2 for an allowable cleanliness level. The part shall be free of all chips, burrs, and films perceptible under the conditions specified.

3.2.1 Particle Contamination

The inspection of detail parts per Table 2 is intended to allow inspection personnel to make a judgment relative to the ACL level specified and to be described in this document in Table 1. If parts examined per Table 2 are obviously in compliance, no further inspection effort is required. If the visual check indicates parts are marginal, a verification test per Section 4 must be performed.

Table 2

Allowable Cleanliness Level Code	Magnification	Lighting Intensity Min Foot Candles
ACL 1	1X	100
ACL 2	3X	100
ACL 3	5X	150
ACL 4	10X	300
ACL 5	15X	300
ACL 6	30X	300

3.3 Preservation and Handling of Detail Parts Following Inspection

Cleaned parts shall be protected to the extent selected in Table 3 to assure a proper level of cleanliness at final assembly. Additional information is available in MIL-STD-2073-1.

3.3.1 Throughout manufacture and specifically following final inspection, all parts should be handled, stored, and transported in such manner and by such means to preclude contamination of, or damage to, final surfaces until used on the assembly floor. All corrosion inhibiting compounds and fingerprint neutralizers must be under strict control so that cleanliness is measured and controlled so as to be as good as the ACL of the actual component. Acceptable corrosion inhibiting compounds and fingerprint neutralizers suggested are MIL-C-15074 and MIL-PRF-16173.

3.3.2 Detail parts requiring a protection level of P6, P7, and P8 require a vapor barrier bag and a seal bag. The barrier bag suggested is made of a transparent, thermoplastic, nylon film. The barrier bag must be cleaned immediately before sealing by purging with prefiltered dry nitrogen. The second or sealing bag shall be made of a transparent, thermoplastic, polyethylene film.

3.4 Assembly

Detail parts shall be assembled in a controlled environment to insure the required cleanliness of the final assembly. Specific installations may, of necessity, vary in design. The selection of an area may be made from the levels specified in ISO 14644.

Particular attention must be paid to containers for holding parts and assembly tools in the controlled environment. They must never be contaminated in excess of the level specified for the cleanest detail part requirement and must be periodically inspected for conformance.

It must be recognized that the actual assembly processes can generate contamination. Even with relatively clean parts and tools and normal aerospace assembly practices, contamination can be generated during assembly. A final assembly cleaning operation such as flushing is therefore required.

Table 3

Preservation Level Code	Preservation
P1	No preservation required.
P2	Apply corrosion inhibiting compound to exposed surfaces as required. All exposed surfaces shall have been previously treated with a suitable fingerprint neutralizer prior to application of corrosion inhibiting compound. Application of the corrosion inhibiting compound shall be in such a manner as to displace the fingerprint neutralizer. This level is intended for parts to be immediately assembled where long term storage is not a consideration.
P3	Apply corrosion inhibiting compound to exposed surfaces as required. All exposed surfaces shall have been previously treated with a suitable fingerprint neutralizer prior to application of a corrosion inhibiting compound. Application of the corrosion inhibiting compound shall be in such a manner as to displace the fingerprint neutralizer. Enclose part in polyethylene or equivalent vapor barrier bag and seal bag.
P4	Cap and plug all openings to retain residual test fluids, apply corrosion inhibiting compound to exposed surfaces. All exposed shall have been previously treated with a suitable fingerprint neutralizer prior to application of the corrosion inhibiting compound. Application of corrosion inhibiting compound shall be in such a manner as to displace the fingerprint neutralizer. Enclose part in polyethylene or equivalent type bag and seal bag.
P5	Apply corrosion inhibiting compound and encapsulate in a sealed, dehumidified container. All exposed surface shall have been previously treated with a suitable fingerprint neutralizer prior to application of the corrosion inhibiting compound. Application of corrosion inhibiting compound shall be in such a manner as to displace the fingerprint neutralizer.
P6	Enclose part in vapor barrier bag and seal bag.
P7	Apply preservative specified on the drawing to exposed surfaces and enclose in a vapor barrier bag and seal.
P8	Enclose part in a vapor barrier bag, seal bag, and place in an enclosed, rigid, individual container.

3.5 Flushing after Final Assembly

An additional degree of cleanliness will be gained by flushing partially assembled fuel system components prior to final closure. In general, it is recommended that the partially assembled unit be positioned with the open face or feature down in a compartment of a flushing rig. Be sure that electrical components, which operate dry, are protected from exposure to the flushing fluid. The unit is then flushed with an upward stream of pressurized MIL-PRF-7024 Type II calibrating fluid[2]. External areas of the component should be flushed with a horizontal stream of the same calibrating fluid. Following flushing, drain the flushing fluid. This procedure must be repeated if components are later opened for repair or adjustment in the controlled environment. Proper quality precautions must be taken to periodically check the fluid in the flushing rig to assure cleanliness. The RCL of the flushing fluid is expected to have not more than 10% of the particle count specified for the level of the ACL of the actual component.

[2] This is the typical hydrocarbon fuel system calibrating fluid. In some applications, other fluids may be used at the discretion of the customer such as P-D-680 Type II.

3.6 Calibration and Acceptance Tests

All fuel system components requiring calibration and acceptance testing must have a proper level of fluid filtration and quality control provisions for periodically checking the contamination level of the rig test fluid. As in the case of flushing procedures, the RCL of test fluid must be not more than 10% of the level of the ACL of the component undergoing test.

3.7 Preparation for Shipment

Fuel system components must be protected from contamination following any final test operation. Proper enclosures should be utilized. All shipping closures, caps, etc., should be under the same quality control provisions as specified for the detail parts and controlled assembly environment. A moisture proof, sealed container, or bag, is recommended to enclose the component prior to placement in the final shipping container.

4. TEST PROCEDURES FOR VERIFICATION OF LEVEL OF CLEANLINESS

Recognizing that there are many different types of fuel system components, it is necessary to define procedures which have the broadest possible application and produce repeatable results. The first differentiation to be considered is static versus dynamic components. Any component with rotating or reciprocating parts such as valves, servos, motors and transducers should be considered a dynamic component. As in hydraulics, hoses are considered dynamic parts. Any component which does not fit any of the requirements to make it dynamic shall be considered static. Generally speaking, it should be required to run a simple "slosh" test of a static component, while a dynamic component should be flowed while being functionally exercised. Recognizing that electrical interface devices may have a wet section and a dry section, it is recommended that for purposes of this procedure the wet and dry sections be isolated from one another and only the wet section be evaluated. For purposes of consistency, the fluid recommended for use in the procedure should be MIL-PRF-7024, Type II. It should follow the RCL rule for cleanliness which is that the RCL permits not more than 10% of the level specified for the ACL for the component.

4.1 Methods to Obtain Fluid Samples

Two methods of obtaining fluid samples will be described. For static systems, the simple slosh test of 4.1.1 should suffice. For dynamic systems, which require exercising of moving parts, 4.1.2 applies.

4.1.1 Static Components

Fill the component from 1/3 to 1/2 full with clean fluid and seal the component. Seal all ports with clean closures and agitate the component mechanically. The plan for agitation, vibration, or shock shall be specified by the user. Fluid samples from very large static components should be removed using the method of ANSI B93.44 (1978).

Samples from small components may be completely drained into a verified clean container. When draining, care must be exercised to assure that the fluid sample is not contaminated by contact with normally nonwetted surfaces.

4.1.2 Dynamic Components

Using the established guidelines for hydraulic components, dynamic fuel system components should be exercised prior to or during the obtaining of the fluid sample. In case of rotating devices, such as driven pilot valves, the device should be at 100% speed and minimum load while 10 times the component volume is circulated. In case of reciprocating components, the moving device should be cycled full stroke 10 times at 100% of expected maximum velocity to achieve maximum fluid velocities and maximum flow rates. The system requirements will specify the procedures for obtaining a proper sample from dynamic components. The basic concept will be to exercise at maximum velocity for a time period long enough to obtain a sample fluid volume at least equal to ten (10) times the component volume. In the case of fuel controls, this may mean separate tests for metering and computing sections with separate ACL. The actual fluid sample should be obtained by one of the methods called out in ISO 4021 or ANSI B93.44.

The sample must be drawn from the effluent flow at the component's applicable port. The applicable port will be either flow discharge or cavity drain.