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AEROSPACE STANDARD

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SAE AS1241 REV. B

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FIRE RESISTANT PHOSPHATE ESTER HYDRAULIC FLUID FOR AIRCRAFT

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1. SCOPE:

This document establishes the requirements for physical and chemical properties and the minimum tests to evaluate suitability of phosphate ester hydraulic fluids for use in aircraft systems where fire resistance is required. Additional tests may be specified by procuring agencies to demonstrate compliance with specific requirements.

2. REFERENCES:

2.1 SAE Publications:

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

2.1.1 ARP598 Procedure for the Determination of Particulate Contamination of Hydraulic Fluids by the Particle Count Method

2.1.2 SAE 1241 Test Fluid 1 may be procured from: Monsanto Company, 800 N. Lindbergh Boulevard, St. Louis, MO 63167

2.1.3 AS4059 Aerospace-Cleanliness Classification for Hydraulic Fluids

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

2.2.1 ASTM D 92 Test for Flash and Fire Points by Cleveland Open Cup

2.2.2 ASTM D 97 Test for Pour Point

2.2.3 ASTM D 445 Test for Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities)

2.2.4 ASTM D 941 Test for Density and Specific Gravity of Liquids by Lipkin Bicapillary Pyconometer

2.2.5 ASTM D 974 Test for Neutralization Number by Color-Indicator Titration

2.2.6 ASTM D 1744 Test for Water in Liquid Petroleum Products by Karl Fischer Reagen

2.2.7 ASTM D 664 Standard Test Method for Neutralization Number by Potentiometric Titration

2.2.8 ASTM D 412 Tension Testing of Vulcanized Rubber

2.2.9 ASTM D 471 Test for Change in Properties of Elastomeric Vulcanizates Resulting from Immersion in Liquids

2.2.10 ASTM D 877 Test for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes

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2.2.11 ASTM D 892 Test for Foaming Characteristics of Lubricating Oils

2.2.12 ASTM D 1217 Test for Density and Specific Gravity of Liquids by Bingham Pyconometer

2.2.13 ASTM D 2155 Test for Autoignition Temperature of Liquid Petroleum Products

2.2.14 ASTM D 2240 Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer

2.2.15 ASTM D 2766 Specific Heat of Liquids and Solids

2.3 IP Publications:

Available from The Institute of Petroleum, 61 New Cavendish Street, London, WIM8AR, U.K.

2.3.1 IP 36 Flash and Fire Point (Cleveland Open Cup)

2.3.2 IP 15 Pour Point of Petroleum

2.3.3 IP 71 Kinematic Viscosity and Calculation of Dynamic Viscosity

2.3.4 IP 160 Density/Specific Gravity/API Gravity of Liquid Petroleum Products

2.3.5 IP 139 Neutralization Number by Titration (Acid No. or Base No.)

2.3.6 IP 74 Water Content (by Distillation) (Dean and Starke)

2.4 National Aerospace Standards Publications:

Available from Aerospace Industries Association of America, Inc., 1250 Eye Street NW, Washington, DC 20005.

2.4.1 NAS 1611 Packing, Preformed O-ring, Phosphate Ester Resistant (-65°F to +160°F)

2.4.2 NAS 1613 Packing, O-ring, Phosphate Ester Resistant

2.5 Other References:

2.5.1 Technical Specification 64, Society of British Aerospace Companies Standard Method for (Projection) Microscopic Evaluation of Hydraulic Fluid Samples for Particle Contamination

2.5.2 D. E. Johnson and N. W. Furby, Chevron Research Co. presentation at ASTM Meeting, New Orleans, LA, January 24, 1966 Miniaturized Tests for Fire Resistance of Hydraulic Fluids

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2.5.3 J. H. Keanan and F. G. Keyes, Thermodynamic Properties of Steam, John Wiley & Son, 29th Printing 1956
Iso-thermal bulk modulus of distilled water, 0-3000 psi at 100°F is 329 000 psi from Pg. 74 Table 4 of compressed liquids

2.5.4 Mechanical/Electrical Systems - Compliance and Requirements, Boeing Commercial Airplane Co., P.O. Box 3707, Seattle, WA 98124-2207
Erosion Test Valve Drawings

3. TECHNICAL REQUIREMENTS:

Fluid approvals are granted by certifying authorities, i.e., FAA, CAA, etc., for use on airframe types requested in the approval, based on data provided by airframe manufacturers to demonstrate qualification to this document.

3.1 Composition:

The fluid shall consist of a phosphate ester base to which an additive package is blended. The composition must serve satisfactorily in systems designed to be compatible with phosphate ester fluid. New candidate fluids must be compatible with all fluids previously approved to this document and in current usage. Information on approved fluids may be obtained from such airframe manufacturers as Airbus Industries, Boeing Commercial Airplane Group, British Aerospace, Douglas Division of McDonnell Douglas, etc.

3.2 Types, Classes, Grades:

3.2.1 Types:

a. Type I: Obsolete

b. Type II: Obsolete

c. Type III: Obsolete

d. Type IV: Erosion Arresting, Fire Resistant, -65 to 275 °F Fluid (-54 to 135 °C)

NOTE: The upper and lower limits of the temperature ranges stated indicate capability for only limited operational life and the upper limit relates to local temperature at the hottest part of the system.

3.2.2 Classes:

a. Class 1: Low density - specific gravity 0.990 to 1.020

b. Class 2: High density - specific gravity 1.021 to 1.066

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3.2.3 Grades:

a. Grade A: Erosion resistant tested at 225 °F ± 10 (107 °C ± 6)

b. Grade B: Erosion resistant tested at 100 °F ± 10 (38 °C ± 6)

3.3 Physical and Chemical Properties:

3.3.1 New Fluid Properties: Properties of new fluids are stated in Table 1.

TABLE 1 - New Fluid Properties

Property		Type IV Class 1	Type IV Class 2
Viscosity, cSt (ASTM D 455, Ref. 2.2.3) (IP-71, Ref. 2.3.3)	-65 °F (-54 °C) 100 °F (38 °C) 210 °F (99 °C)	2000 max 9.0 to 12.5 3.0 to 4.0	4200 max 9.0 to 12.5 3.0 to 4.0
Chemical contamination, max ppm /1/	Chlorine Calcium Sodium Potassium Sulfur	50 10 10 10 150	80 10 10 10 150
	/1/ Elements introduced as part of the base stock or the additive package shall not be considered as contamination, and shall be assigned a nominal value by the supplier.		
Moisture content, % H_2O by weight (ASTM D 1744, Ref. 2.2.4) (IP-74, Ref. 2.3.6)		0.30 max	0.30 max
Density, gm/ml at 77 °F (25 °C) (ASTM D 941, Ref. 2.2.4) (ASTM D 1217, Ref. 2.2.12) (IP-160, Ref. 2.3.4)		0.990 to 1.020	1.021 to 1.066
Total acid number, mg KOH/gm (ASTM D 974, Ref. 2.2.5) (ASTM D 664, Ref. 2.2.7) (IP-139, Ref. 2.3.5)		0.20 max	
Pour point (ASTM D 97, Ref. 2.2.2) (IP-15, Ref. 2.3.2)		less than -80 °F (-62 °C)	
Flash point (ASTM D 92, Ref. 2.2.1) (IP-36, Ref. 2.3.1)		320 °F (160 °C) min	
Fire point (ASTM D 92, Ref. 2.2.1) (IP-36, Ref. 2.3.1)		350 °F (177 °C) min	
Auto ignition temp. (ASTM D 2155, Ref. 2.2.13)		700 °F (371 °C) min	
Exhaust manifold test		3.4.1.1	

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TABLE 1 (Continued)

Property	Type IV Class 1	Type IV Class 2
High pressure spray ignition test	3.4.1.2	
Wick ignition test	3.4.1.3	
Color	Clear, blue to purple when viewed with white light passing through a fluid column of approximately 1 in diameter.	
State	Clear liquid, without layering or separation.	
Bulk modulus (isothermal secant)	210 000 psi (1 450 000 kPa) min at 100 °F (38 °C) and 0 to 3000 psi (0 to 20 700 kPa) using the method of 4.2 on fluid saturated with air at room temperature and pressure.	
Coefficient of thermal expansion (ASTM D 941, Ref. 2.2.4 or ASTM D 1217, Ref. 2.2.12)	1.0×10^{-3} in^3/in^3 °F (0.6×10^{-3} ml/ml °C) max between 77 and 210 °F (25 and 99 °C)	
Dielectric strength, KV/mil (ASTM D 877, Ref. 2.2.10)	No limit - but determine value	
Electrical resistivity (ASTM D 877, Ref. 2.2.10)	No limit - but determine value at 212 °F (100 °C) and 1000 Hz in an AC conductivity bridge	
Specific heat (ASTM D 2766, Ref. 2.2.15)	No limit - but determine value	
Toxicity	Minimal irritant properties, low sensitization potential, see 4.10	
Hydrolytic stability	4.3	
Thermal stability	4.4	
Effect on metals at 425 °F (218 °C)	4.6	
Compatibility with other materials	4.5	
Flow control valve life	4.8	
Particulate contamination, max	AS 4059, Class 7 (Ref. 2.1.3)	
Antierosion additive	Concentration and tolerance are to be specified by supplier/purchaser agreement.	

Foaming (ASTM D 892 Ref. 2.2.11)	Sequence	Temp.	Foam after 5 min blowing	Foam after 10 min settling	Time for complete foam collapse
	1	75 °F (24 °C)	250 ml max	0	100 s max
	2	200 °F (93 °C)	150	0	50
	3	75 °F (24 °C)	450	0	250

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3.3.2 Fluid Mixtures: When mixed with any other approved product, the mixture shall meet the requirements as stated in Table 2.

TABLE 2 - Mixture Properties

Property	Requirement
Miscibility	Complete in all mixture proportions, without precipitation or cloudiness.
Foaming, for 25/75, 50/50, 75/25 mixes (ASTM D 892, Ref. 2.2.11)	

Sequence	Temp.	Foam after 5 min blowing	Foam after 10 min settling	Time for complete foam collapse
1	75 °F (24 °C)	400 ml max	0	250 s max
2	200 °F (93 °C)	425	0	200
3	75 °F (24 °C)	425	0	220

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4. QUALIFICATION:

Qualification of a new fluid, or after a change in formulation, shall be by a laboratory acceptable to the vendor and the potential users. The laboratory may be the vendors, the users, any approved commercial laboratory, or any combination of these as required to perform the required qualification testing. The supplier must furnish the fluid required for qualification testing. Vendor certification must be based on tests showing that the fluid meets all the requirements of this document.

The following tests are required for fluid qualification. In most cases, the limits are given in 3.3 covering physical and chemical properties.

4.1 Flammability:

Flammability depends on obtaining a combustible fuel/oxidizer mixture under ambient conditions. In some cases, minor changes in environment could cause drastic changes in flame characteristics. Rather than attempt to control atmospheric variables to standard condition, SAE AS1241 Test Fluid 1 (Reference 2.1.2) is used as a reference material in the following tests. Overall performance of the qualifying fluid shall be essentially equivalent to that of SAE AS1241 Test Fluid 1. In the following tests, miniaturized testing methods (similar to those in Reference 2.5.2) may be used, provided correlation with full-scale test results have been established.

4.1.1 Exhaust Manifold Test: Fabricate a simulated exhaust stack section and mount in a shield as shown in Figure 1. Opposite the steel rod, spotweld a thermocouple, and insulate the leads to insure proper temperature readings. Insert a heating element [Globar Type At, 31 x 12 x 1 in (790 x 305 x 25 mm), 0.633 Ω, made by Carborundum Co., Niagara Falls, NY, or equivalent] into the tube and make the necessary electrical connections. Adjust the voltage so that the temperature of the tube is 1300 °F ± 25 (704 °C ± 14). Clean the tube before each series of tests with steel wool.

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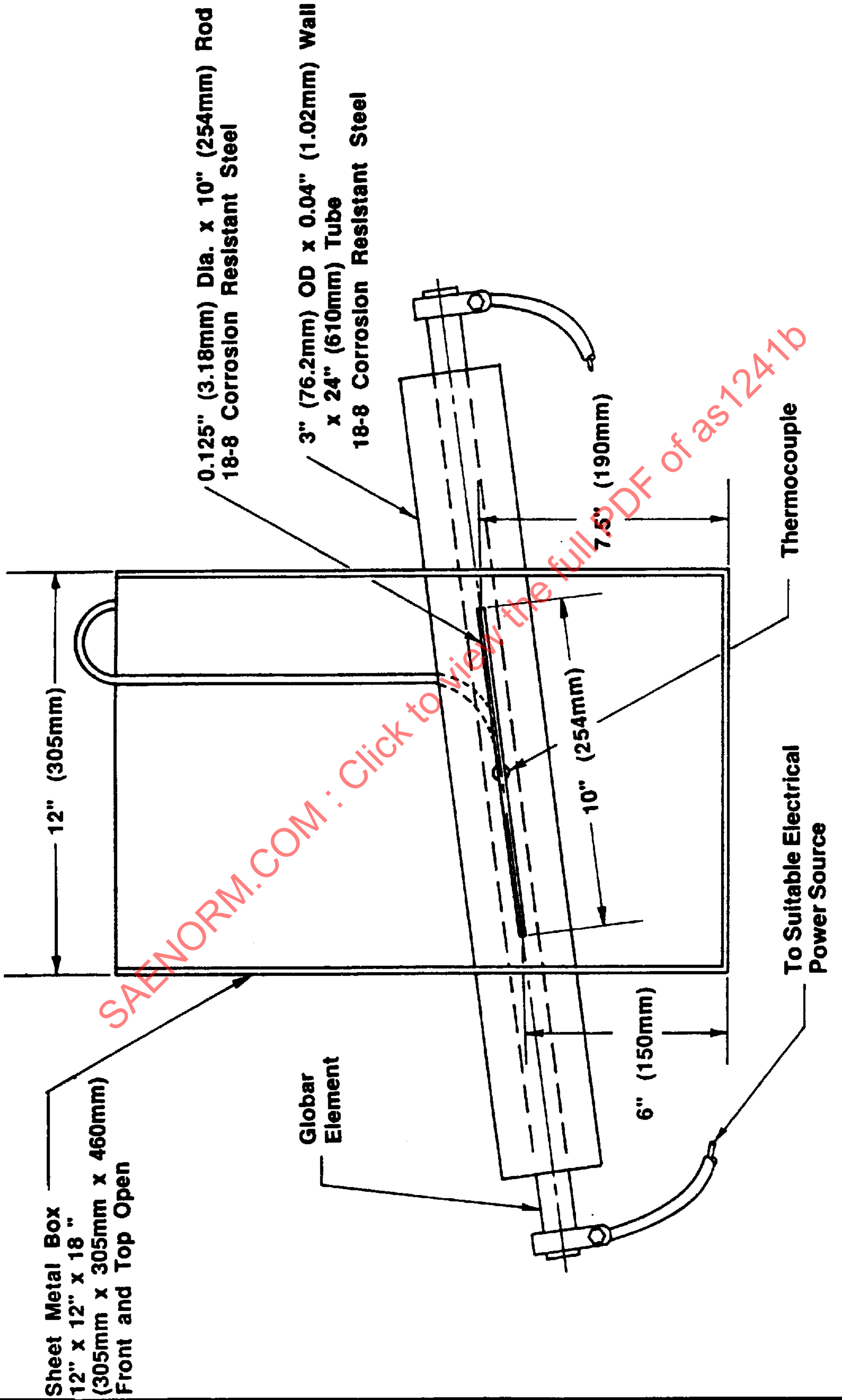

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FIGURE 1 - Exhaust Manifold Test

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4.1.1 (Continued):

Slowly pour 10 ml of test fluid on the simulated exhaust stack in not less than 40 s.

Record the results as follows: "fluid burns on the tube", "fluid does not burn on the tube", and "burns", "flashes", or "does not burn" in the bottom of the shield.

4.1.2 High Pressure Spray Ignition Test: Assemble equipment for applying 1000 psi ± 50 (6895 kPa ± 345) to the test fluid. A suggested arrangement, shown in Figure 2, consists of a large hydraulic cylinder, a nitrogen bottle, and necessary lines, valves, and gages. Use a steel disc 0.063 in (1.60 mm) thick with a sharp edged orifice 0.0145 in (0.368 mm) in diameter to spray the fluid.

Charge the cylinder with the test fluid. Apply nitrogen pressure so that the gage on the fluid side reads 1000 psi ± 50 (6895 kPa ± 345). Open the valve at the orifice and attempt to ignite the spray at a point 1.5 to 12 in (38 to 305 mm) from the orifice with an oxy-acetylene torch (Purox Type W-400 with a No. 4 tip, or equivalent), while maintaining the pressure at 1000 psi ± 50 (6895 kPa ± 345). Ambient air shall be 75 to 95 °F (24 to 35 °C). Record the air temperature at the time of test.

Record test results as follows: "Will not ignite", "flashes with difficulty", or "flashes readily". Also, indicate whether any flashing is self-extinguishing or results in a sustained fire.

If the fluid cannot be ignited, repeat the test by applying the flame at increasing distances from the orifice up to the limit of the spray. If ignition or flashing can be produced, record the minimum distance from the orifice at which ignition or flashing is produced. Also, indicate whether any flashing is self-extinguishing or results in a sustained fire.

For proper comparison with SAE AS1241 Test Fluid 1 (Reference 2.1.2), the tests on both fluids should be performed under identical atmospheric conditions, preferably one immediately following the other.

4.1.3 Wick Ignition Test: Arrange a means for cycling an ordinary pipe cleaner in a horizontal plane through the flame from a laboratory burner at a fixed rate, preferably 0.5 to 0.67 Hz. Soak the pipe cleaner with the test fluid and allow the excess to drain off. Adjust the burner with sufficient air to provide a nonluminous flame, but not enough to form a sharp inner cone. For best results, a flame height of approximately 4 in (102 mm) is recommended. Cycle the pipe cleaner through the hottest part of the flame and count the number of cycles until a self-sustaining flame is achieved.

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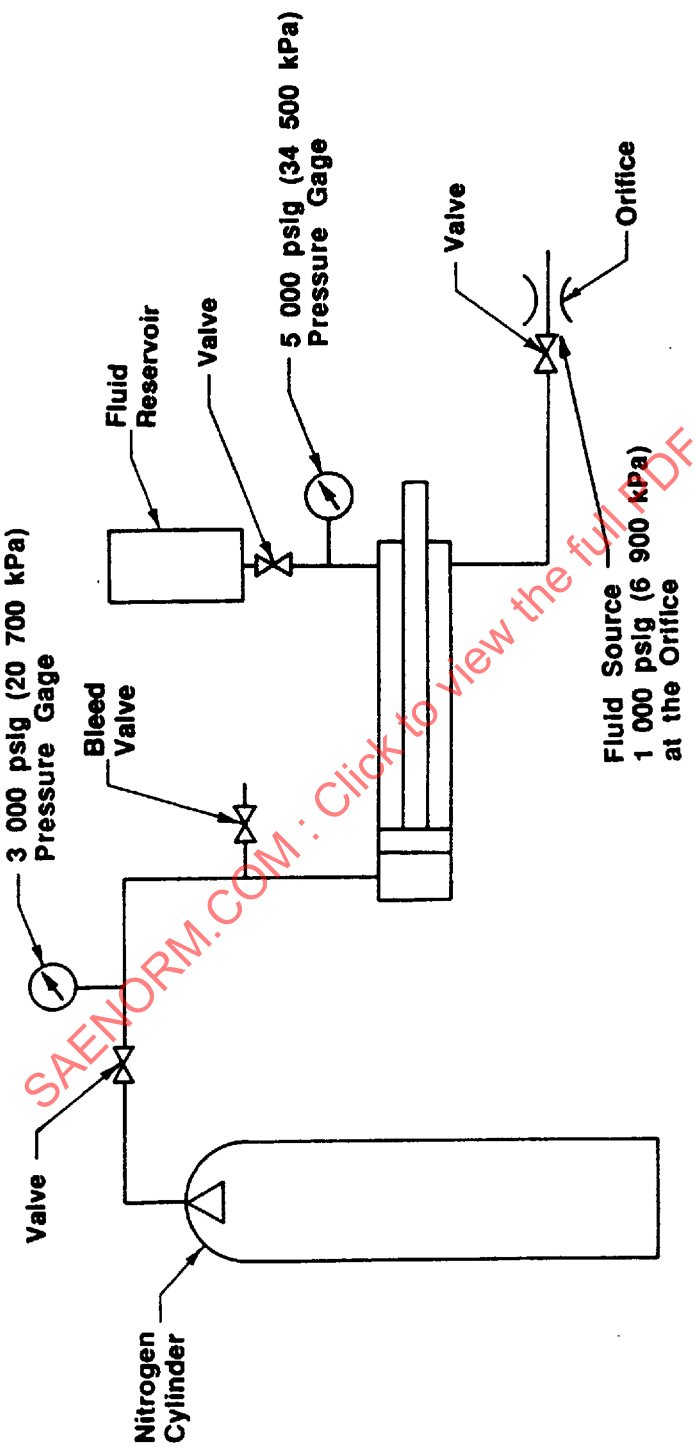

FIGURE 2 - High Temperature Ignition Test

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4.2 Bulk Modulus:

The isothermal secant bulk modulus for each air saturated fluid shall be at least 210 000 psi (1 450 000 kPa) at 100 °F (38 °C) as determined between atmospheric pressure and 3000 psi (20 700 kPa). Air saturate the fluid per ASTM D 892 (Reference 2.2.11) except at room temperature, and allow complete foam collapse prior to proceeding with tests.

4.2.1 Test Setup (see Figure 3): A receiver capable of withstanding the 3000 psi (20 700 kPa) test pressure is required, along with suitable pumps, pressure gages, and temperature indicating equipment. Sufficient time must be allowed for fluid/apparatus temperatures to stabilize to 100 °F (38 °C) both pressurized and unpressurized to eliminate effects of thermal expansion. Calibrate the test equipment with water using values in Reference 2.5.3.

4.2.2 Receiver Expansion: Determine the receiver expansion between ambient and test pressures at 100 °F (38 °C).

4.2.3 Test Procedure: Fill and bleed all free air from the receiver. Close the outlet valve and pressurize to 3000 psi ± 25 (20 700 kPa ± 173) and 100 °F ± 5 (38 °C ± 3). Close the inlet valve. Open the outlet valve and catch the fluid released on expansion to atmospheric pressure. Measure at 100 °F (38 °C) and record the volume. Subtract receiver expansion from this quantity.

4.2.4 Method of Computation: The secant bulk modulus is the total change in fluid pressure divided by the total change in fluid volume per unit volume under pressure. Calculate bulk modulus as follows:

$$B = (P-P_o)\, V_o/(V_o-V) \qquad \text{(Eq.1)}$$

where:

- B = Secant bulk modulus, psi (kPa)
- P = Test pressure, psig (kPa)
- P_o = Initial pressure, psig (normally 0 psig)
- V_o = Quantity at P_o (receiver volume) in^3 (m^3)
- V = Quantity at P (V_o plus effluent volume) in^3 (m^3)

Correct the volume of the receiver for changes due to pressure and temperature. Correct the effluent volume for the difference between its temperature at the time of reading and its temperature when it is in the receiver.

Note that in the Equation 1 calculation, bulk modulus is a negative value. This indicates that the fluid contracts under pressure. These values are customarily quoted as positive numbers.

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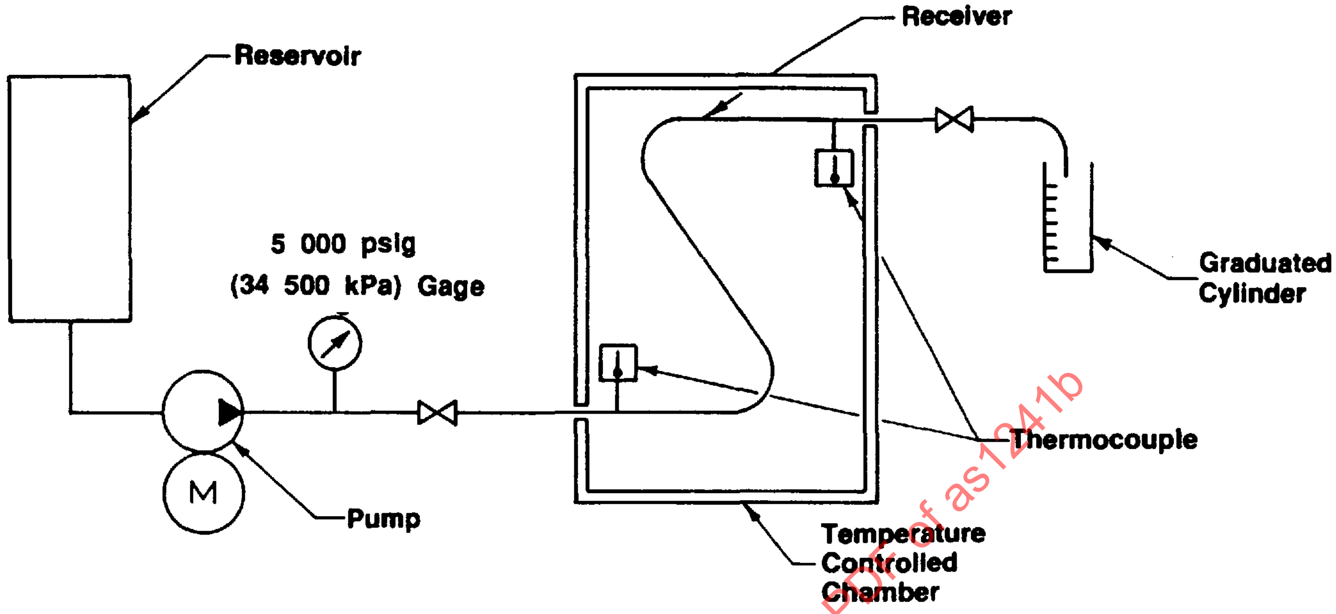

FIGURE 3 - Isothermal Secant Bulk Modulus Test

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4.3 Hydrolytic Stability:

Closed bottle corrosion tests under high moisture content conditions are required to evaluate fluid compatibility with materials normally found in aircraft hydraulic systems.

4.3.1 Materials to be Tested: The qualification requestor must specify the required materials to be tested for corrosion resistance. The list in Table 3 are potential candidates. Materials specification numbers shown are for information - approximate equivalents may be substituted.

TABLE 3 - Materials for Hydrolytic Stability Test

Material	Composition	Specification
Steel	9.95Cr, 0.20Mo, 0.30C or 0.55Ni	4130, MIL-S-18729, AMS 6350
	0.50Cr, 0.20Mo, 0.30C or 0.10C	8630, MIL-S-6050, AMS 6280 1010, QQ-S-698, AMS 5044
Cadmium Plate		QQ-P-416, Type I, Class 2
Aluminum	1.5Mg, 4.4Cu, 0.6Mn or 2.5Mg, 1.6Cu, 5.6Zn, 0.26Cr	2024, QQ-A-250/4, AMS 4035 7075, QQ-A-250/12, AMS 4045
Magnesium	3.0Al, 1.0Zn	AZ31B, QQ-M-44, AMS 4375
Silver		QQ-S-365
Copper		101, 110 QQ-C-476, AMS 4500
Titanium	6Al - 4V 3Al - 2.5V	C120AV, MIL-T-9046 Type III, AMS 4911 AMS 4944

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4.3.2 Metal Specimens: Metal specimens are to be approximately 1 x 1 x 0.062 in (25 x 25 x 1.57 mm). Drill 4 holes approximately 0.062 in (1.57 mm) diameter, one at each corner of the specimen.

Polish each specimen, except cadmium plate, with 600 grit paper to remove all surface oxidation. Rinse in acetone to remove contamination. Do not polish cadmium plated steel specimens, but rinse in acetone to remove contamination.

Weigh each specimen and determine its surface area in cm².

Arrange the specimens as shown in Figure 4. Tie the strips together with a fluid resistant cord (i.e., nylon) previously washed with acetone and dried.

Mount each metal parallelogram, from Figure 4, on a suitable polytetrafluoroethylene (PTFE) stand so that the setup is rigidly centered inside a 250 ml widemouthed bottle. The PTFE stand shall not impede fluid circulation.

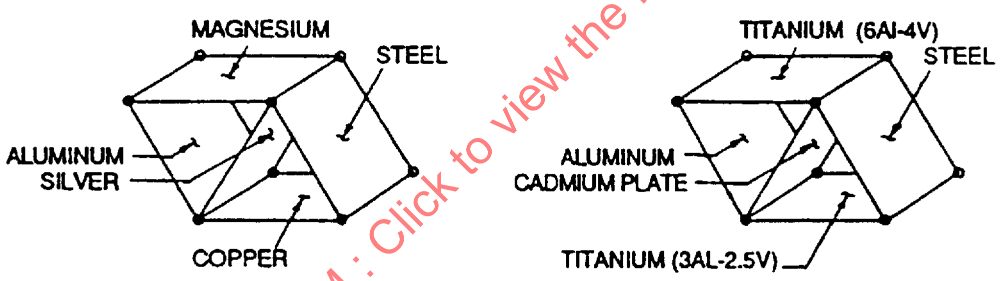

FIGURE 4 - Material Arrangement, Hydrolytic Stability Test

4.3.3 Fluid Preparation: Prepare the test fluid by adjusting the water content of the fluid to 0.80% by weight. Use distilled water for water adjustment. Determine the following:

a. Kinematic viscosity at 100 and 210 °F (38 and 99 °C)
b. Neutralization number
c. Water content

4.3.4 Test: Place 125 ml of the fluid in a 250 ml widemouthed bottle and in each of the two bottles from 4.3.3. Seal each bottle with an ethylene propylene rubber lined cover. Weigh each of the bottles to the nearest 0.01 g.

Mount the 3 bottles (one with fluid, two with fluid and metal samples) in a tumbling mechanism such that the bottles will be rotated end-over-end at approximately 5 rpm. Mount in an air convection oven at 180 °F ± 2 (82 °C ± 1) and tumble under these conditions for 168 h.

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4.3.4 (Continued):

Remove the bottles. Weigh each of the bottles to the nearest 0.01 g and determine that no weight loss greater than 0.1 g has occurred due to leakage. Filter the test fluids through compatible 1 μm membrane filters. Any precipitation retained on the filters is to be weighed and recorded.

Determine the following for each of the three fluid samples:

a. Viscosity at 100 °F (38 °C)
b. Viscosity at 210 °F (99 °C)
c. Neutralization number
d. Water content, %

Disassemble the two metal parallelograms, wash each metal specimen in acetone, and dry. Remove any corrosion products adhering to the metals by rubbing firmly with a piece of cheesecloth wetted with acetone. Dry again. Weigh each metal specimen and calculate its weight change in milligrams and milligrams per squared centimeters.

4.3.5 Limits of Results: The weight change of the metal test specimens shall be as follows:

a. ±0.1 mg/cm^2 maximum for steel
b. ±0.4 mg/cm^2 maximum for cadmium plate
c. ±0.1 mg/cm^2 maximum for aluminum
d. ±0.2 mg/cm^2 maximum for magnesium
e. ±0.1 mg/cm^2 maximum for titanium
f. ±0.4 mg/cm^2 maximum for copper
g. ±0.2 mg/cm^2 maximum for silver

Fluid characteristic changes relative to values determined in 4.3.3 shall be as follows:

a. ±0.3 mg KOH/g maximum change in neutralization number
b. ±3.0 cSt maximum change in viscosity at 100 °F (38 °C)
c. ±1.0 cSt maximum change in viscosity at 210 °F (99 °C)
d. Record the percent water content before and after test

4.4 Thermal Stability:

4.4.1 Test Setup: Closed bottle corrosion tests under high temperature conditions are required. Use the same test method as the hydrolytic stability test (see 4.3) except:

a. Water content must be within the limits stated in Table 1
b. Test temperature shall be 250 °F ± 2 (121 °C ± 1) for 168 h, instead of 180 °F (82 °C)

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4.4.2 Limits of Results: The weight change of the metal test specimens shall be within the following limits:

a. ±0.3 mg/cm^2 maximum for steel
b. ±0.3 mg/cm^2 maximum for cadmium plate
c. ±0.2 mg/cm^2 maximum for aluminum
d. ±0.5 mg/cm^2 maximum for magnesium
e. ±0.6 mg/cm^2 maximum for titanium
f. ±0.5 mg/cm^2 maximum for copper
g. ±0.3 mg/cm^2 maximum for silver

Fluid characteristics changes (with and without metal samples in bottles) relative to values determined in 4.3.3 shall be as follows:

a. ±0.1 mg KOH/g maximum change in neutralization number
b. ±0.1 cSt maximum change in viscosity at 100 °F (38 °C)
c. ±0.3 cSt maximum change in viscosity at 210 °F (99 °C)
d. Record water content percent before and after test

4.5 Fluid Compatibility:

4.5.1 Other Type IV Fluids: When thoroughly mixed for 30 min at ratios of 25/75, 50/50, and 75/25 by volume, and heated to 250 °F ± 2 (121 °C ± 1) for 168 h with each of the fluids qualified to this document and in current use, there shall be no separation, precipitation, cloudiness, or visible change after cooling 48 h. The color of each mixture must lie within the spectrum from blue to purple. Color change is acceptable.

4.5.2 Solvents: Cleaning solvent compatibility is required to assure that parts can be cleaned or flushed without forming residues detrimental to the fluids and hydraulic components. When the subject fluid is mixed for 30 min at ratios of 25/75, 50/50, and 75/25 with the following solvents, there shall be no immediate separation, precipitation, cloudiness, or visual fluid change. There also shall be no precipitation, cloudiness, or reaction after the mixtures have been standing for 24 h. The color of each mixture may be only a dilution of the original hydraulic fluid color.

NOTE: This requirement is not intended to imply that these solvents are compatible as flushing fluids for systems using AS1241 hydraulic fluids.

Stoddard Petroleum Solvent (Federal Specification P-D-680, or equivalent)
1,1,1 Trichloroethane
1,1,2 Trichlorotrifluoroethane

4.5.3 Paints: To qualify, fluids must be compatible with aircraft paints, such as urethane or epoxy paints (including primers, enamels, and lacquers) proven to be resistant to phosphate ester fluids and which may be exposed to contact by these hydraulic fluids. Paints selected for this test will be identified by the airframe manufacturer requesting qualification.

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4.5.3 (Continued):

Aluminum panels (2024, 7075, or equivalent) primed to a dry film 0.0005 to 0.0007 in (0.013 to 0.018 mm) thickness and finish coated to a dry film 0.0014 to 0.0024 in (0.036 to 0.061 mm) thick are required for compatibility test. After painting, air dry the panels at least 168 h before immersion. Panels are to be tested in the candidate fluid and in SAE AS1241 Test Fluid 1 (Reference 2.1.2).

Immerse the painted test panels in fluid at room temperature for 30 days. Observe daily for evidence of softening or paint deterioration.

After 30 days, remove the test panels from the fluid, wash with one of the compatible solvents listed above, and dry with gauze. The painted panels in the candidate fluid shall not soften more than those in SAE AS1241 Test Fluid 1. No panels shall soften more than two grades in "pencil hardness" during the 30 day immersion. Final "pencil hardness" shall be at least grade "B". Determine "pencil hardness" as follows:

A set of drawing pencils (KOH-I-NOOR 1500, Venus Drawing Pencils, A. W. Faber-Castell, Eagle Turquoise, or equivalent) ranging in hardness from 6B to 5H shall be prepared by stripping the wood away from the end approximately 3/8 in (9.5 mm) without damaging the lead. The tip of the lead shall be squared as shown in Figure 5 by holding the pencil in a vertical position and moving the lead back and forth over 400 grit or finer abrasive paper. The tip of the lead shall be squared after each trial. Alternatively, drafting leads held in a clutch type holder such as Locktite 9400 may be used. Place the test panels in a horizontal position. Push pencils of increasing hardness across the coated surface of the panel at a 45° angle until one is found which will cut or scratch the coating. The number of this pencil shall be used to express the pencil hardness.

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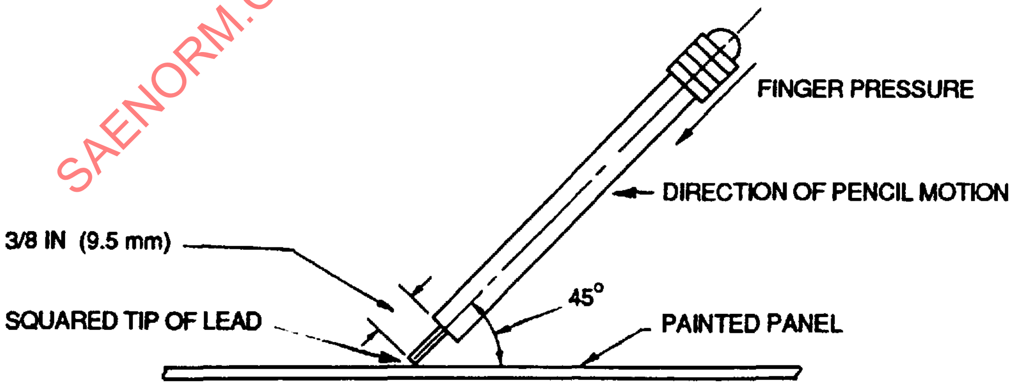

FIGURE 5 - Pencil Test of Paints

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4.5.4 Elastomers: Fluids must pass compatibility tests with ethylene propylene rubber [NAS 1613 (Reference 2.4.2) or equivalent] sheet stock soaked in the candidate fluid according to the following schedule. Tests should be run with SAE AS1241 Test Fluid 1 (Reference 2.1.2) as reference. Effects of the sock periods on the physical characteristics of the rubber compounds shall be no more severe than SAE AS1241 Test Fluid 1 effects on the same compounds and must be within the limits shown in Table 4. Average the results on three specimens for each determination.

TABLE 4 - Elastomer Test Properties

SOAK SCHEDULES				
Temperature, °F ± 4 (°C ± 2)	160 (71)	250 (121)	225 (107)	225 (107)
Time, h ± 2	70	70	334	670
PHYSICAL CHARACTERISTICS				
Durometer Hardness				
Maximum change in Shore A scale 2 x 1 x 0.25 in test specimen (51 x 25 x 6.35 mm) ASTM D 2240 (Ref. 2.2.14)	-12	-25	-20	-25
Volume Swell %				
Minimum EPR	4	5	5	5
Maximum EPR 2 x 1 x 0.125 in test specimen (51 x 25 x 3.18 mm) ASTM D 471 (Ref. 2.2.9)	15	25	20	25
Tensile Strength psi (kPa)				
Minimum psi EPR	--	1500	1300	--
Minimum (kPa) EPR 2 x 1 x 0.125 in test specimen (51 x 25 x 3.18 mm) ASTM D 412 (Ref. 2.2.8)	--	(10 340)	(8960)	--
Elongation %				
Minimum EPR 2 x 1 x 0.125 in test specimen (51 x 25 x 3.18 mm) ASTM D 412 (Ref. 2.2.8)	--	125	125	--

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4.5.5 Other Materials: Most materials that are compatible with phosphate esters are not compatible with petroleum or synthetic hydrocarbon fluids. When compatibility has not been previously defined for materials that are to be used in contact with SAE AS1241 fluids, samples of these materials shall be immersed in SAE AS1241 Test Fluid 1 (Reference 2.1.2) for 30 days at room temperature. Compatibility will be approved if the tested materials meet performance requirements following the immersion test.

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4.6 Effects on Metals Exposed at 425 °F (218 °C):

4.6.1 Metal Specimen Change Limits: Metal weight change and hydrogen input shall not exceed the values in Table 5 when tested according to 4.6.3.

TABLE 5 - Metal Specimen Change Limits

Metal	Weight Change (mg/cm^2)	Hydrogen Input (ppm)
Titanium	150 max	850
Stainless steel	15 max	--

4.6.2 Setup: Use specimens 0.75 x 0.75 in (19 x 19 mm) by any available thickness up to 0.10 in (2.5 mm). Titanium (6Al-4V) and stainless steel (Type 321) samples are required (or approximate equivalents).

Use a heat transfer apparatus consisting of 1.12 in (28.4 mm) inside diameter, Type 301 stainless steel cups, suitable temperature probes, hot plate, and heater control.

4.6.3 Test Procedure: Measure the parts per million of hydrogen present (by vacuum gas analysis) in a control panel obtained from the metal sheet from which the test specimens were cut.

Prior to running the test, clean and dry each test specimen with acetone and weigh to the nearest 0.1 mg.

Drip the test fluid onto test panels at a rate approximately 3/4 cm^3/h. Test fluid shall be at room temperature. Heat specimens of titanium and stainless steel in the heat transfer cups on a temperature controlled hot plate. Conduct tests for a period of 4 days (96 h) at 425 °F ± 20 (218 °C ± 11). Every 24 h inspect test specimens and if a surface film or coating occurs, remove such film with acetone (allow specimens to cool before cleaning).

Following the 4 day test, clean each test specimen, weigh to the nearest 0.1 mg, and measure parts per million of hydrogen by vacuum gas analysis.

Determine the weight change (average of 2 readings) in grams and increase in hydrogen content in parts per million (average of 2 readings).

4.7 Fluid Performance Test:

Fluid cycling is a method of determining changes in fluid characteristics, and the effects on system components under controlled conditions. A pump, load valve, heat exchanger, and reservoir loop is required.

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4.7 (Continued):

The fluid is worked and thermally stressed while passing through the load valve until it is cooled in the heat exchanger. The number of fluid cycles through the load valve and the time that the fluid is hot, between the load valve and heat exchanger, is the total exposure to thermal degradation; provided the remainder of the loop is relatively cool, i.e., less than 180 °F (82 °C).

In order to obtain similar results for any conforming test rig, the following parameters must be controlled:

a. Total test time: 500 h
b. Total fluid cycles: 30 000
c. Ratio of hot section fluid capacity to total fluid capacity: 1 to 5

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4.7.1 Fluid Test Circuit: See schematic on Figure 6. Characteristics shall be as follows:

a. Test loop capacity "X" gallons

b. Load valve 2850 psid (19 650 kPa) at "Y" gpm

c. Insulated reservoir between the load valve and the heat exchanger to hold about 25% of the capacity of the total system (including the supply reservoir capacity)

d. Heat exchanger capacity at least that of the energy input to the pump, approximately 73 Btu/min/gpm (20.3 kW/L/s)

e. Reservoir size to provide the fluid required so that system capacity and pump flow yields the desired number of fluid cycles in the desired time period per Equation 2

$$\frac{(500\text{ h})(60\text{ min/h})(\text{flow rate in gpm})}{30\,000\text{ cycles}} = \text{system capacity in gallons} \qquad \text{(Eq.2)}$$

A fluid cycle is defined as all of the fluid in the test loop completing one pass through the test loop.

4.7.2 Test: Circulate fluid through the load valve and insulated section for 30 000 fluid cycles. Maintain fluid temperature in the downstream insulated area at 250 °F ± 5 (121 °C ± 3) by regulating cooling water flow to the heat exchanger. Maintain supply pressure at 2850 psi ± 50 (19 650 kPa ± 345) using a commercially available aircraft hydraulic pump.

After completing the above test, elevate the control temperature to 275 °F (135 °C). Continue testing for 5 h at the raised temperature to demonstrate acceptability for short duration.

Take fluid samples at 6000 to 10 000 fluid cycle intervals.

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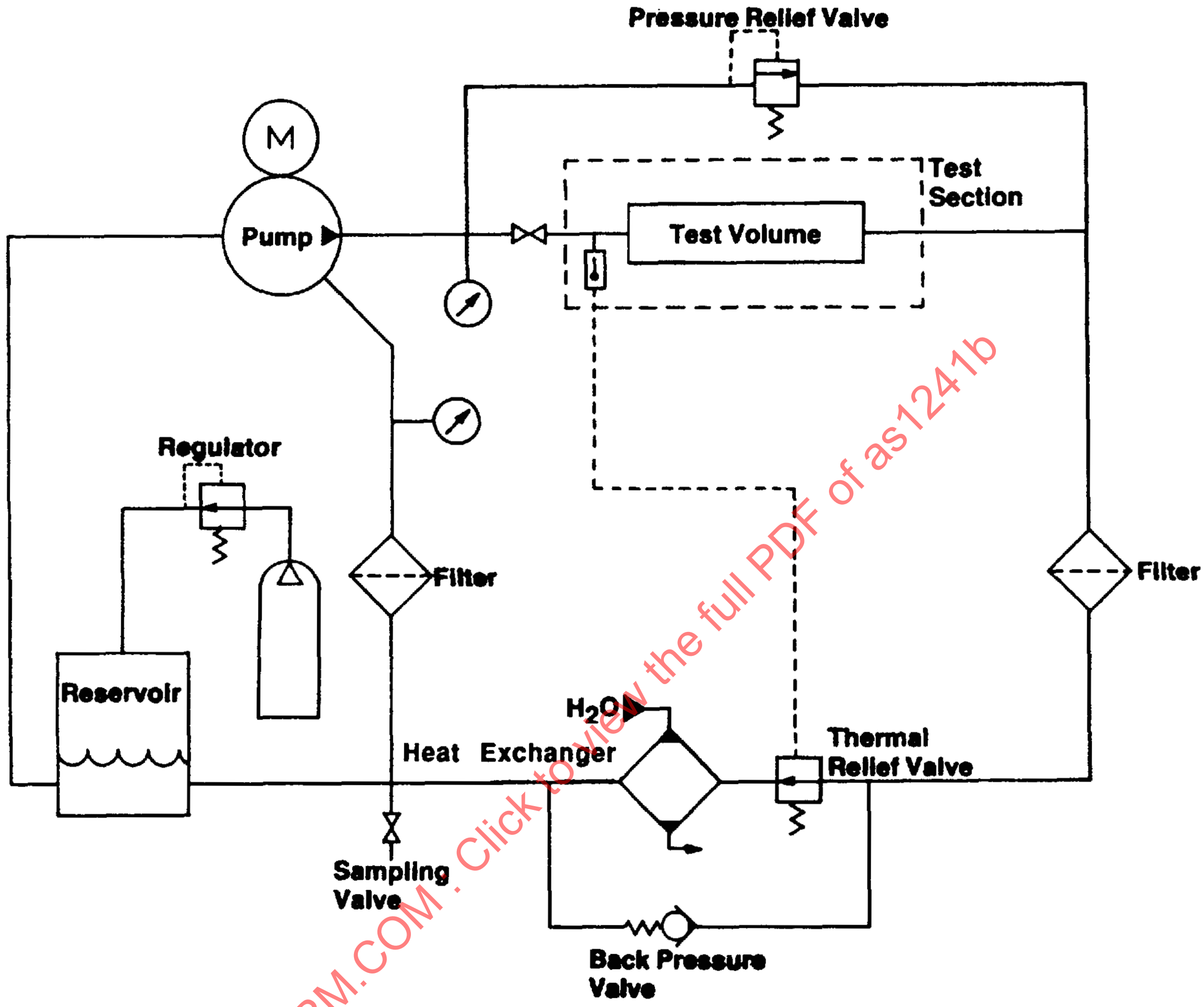

FIGURE 6 - Pumping Test Circuit Schematic

4.7.2 (Continued):

Limits of fluid characteristics after 30 000 cycles shall be as follows:

a. 0.10 max change in neutralization number
b. 6.00 cSt minimum viscosity at 100 °F (38 °C)
c. 2.00 cSt minimum viscosity at 210 °F (99 °C)

NOTE: Shear stability can be determined by plotting viscosity data obtained from samples taken during the test.

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4.7.3 Posttest Inspection: Following the fluid performance test, disassemble the system components (pump, filters, and valves) and inspect for evidence of any erosion, unusual deposits, or unacceptable wear condition that developed during the test. Evaluation of this evidence should be done keeping in mind the >10 000 h normal life of aircraft hydraulic components. Pump shaft seals and valve metering edges should receive specific attention.

4.8 Flow Control Valve Life:

The following are the minimum requirements to demonstrate the antierosion characteristics of a product under simulated aircraft operational conditions. Other test valves may additionally be included at the discretion of the qualifying agency.

4.8.1 Grade A Fluid Test:

4.8.1.1 Test System: The test system to be used is schematically shown in Figure 7. The test system requires a minimum capacity of 2.5 gal (9.5 L) of fluid under test. A maximum of 5.0 gal (19 L) may be used. Fluid temperature is to be maintained at 225 °F ± 10 (107 °C ± 6). Normal system pressure shall be 3000 psig (20 700 kPa) with a minimum of 2850 psig (19 700 kPa) allowable if the bypass valve is used in an open position as a means of regulating system temperature.

4.8.1.2 Preparation: Prior to beginning the test, the system is to be drained of any previously tested fluid and flushed with the fluid to be tested. Flushing is to be accomplished using 2 to 3 gal (7.6 to 11.4 L) new fluid circulated through a combination of both the erode and desilt loops for a total of 0.5 h. A second flush will be accomplished in the same manner, if considered necessary, to thoroughly clean the system. Flushing fluid is to be drained and not to be reused.

4.8.1.3 Calibration: A measured volume of new test fluid of near maximum capacity for the system is to be installed, and air bleeding procedures conducted. The system is to be operated a minimum of 2 h through a combination of both the erode and desilt loops. The test valve, Figure 8, is then to be calibrated for flow gain and set to operate within the knee of the flow gain curve, as illustrated on Figure 9. The calibration is to be accomplished by repeating testing for flow gain until five consecutive curves are obtained. Total accumulated time of operation during run-in and calibration is to be a minimum of 4 h.

4.8.1.4 Testing: Operate the system through automatic sequencing for 500 h beginning with the accomplishment of the test valve calibration. The automatic sequence is a 5 min cycle, the last 6 s of this cycle being the desilt cycle. For 2 of the 6 s the valve slide shall be shuttled to a fully open position. Throughout the 500 h of testing the two sleeve lock screws (see Figure 7) shall be retorqued to 45 in-lb ± 5 (5.1 J ± 0.6) on a periodic cycle (no less frequent than 96 h intervals). A record of system pressure, temperature, and leakage flow will be obtained at least each 10 h.

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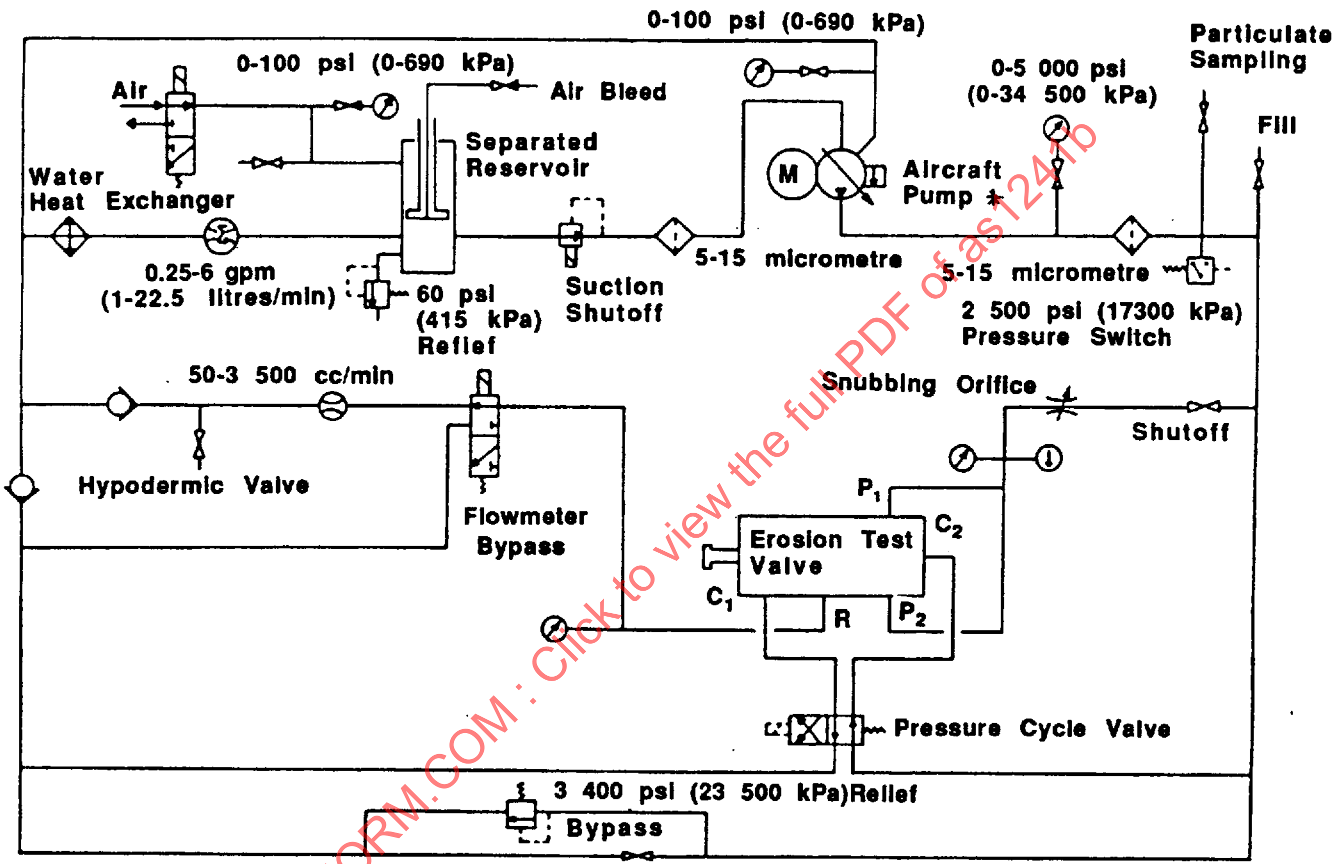

✱ 0-6 gpm (0-22.5 litres/min)
3 000 psi (20 700 kPa)

FIGURE 7 - Erosion Test System

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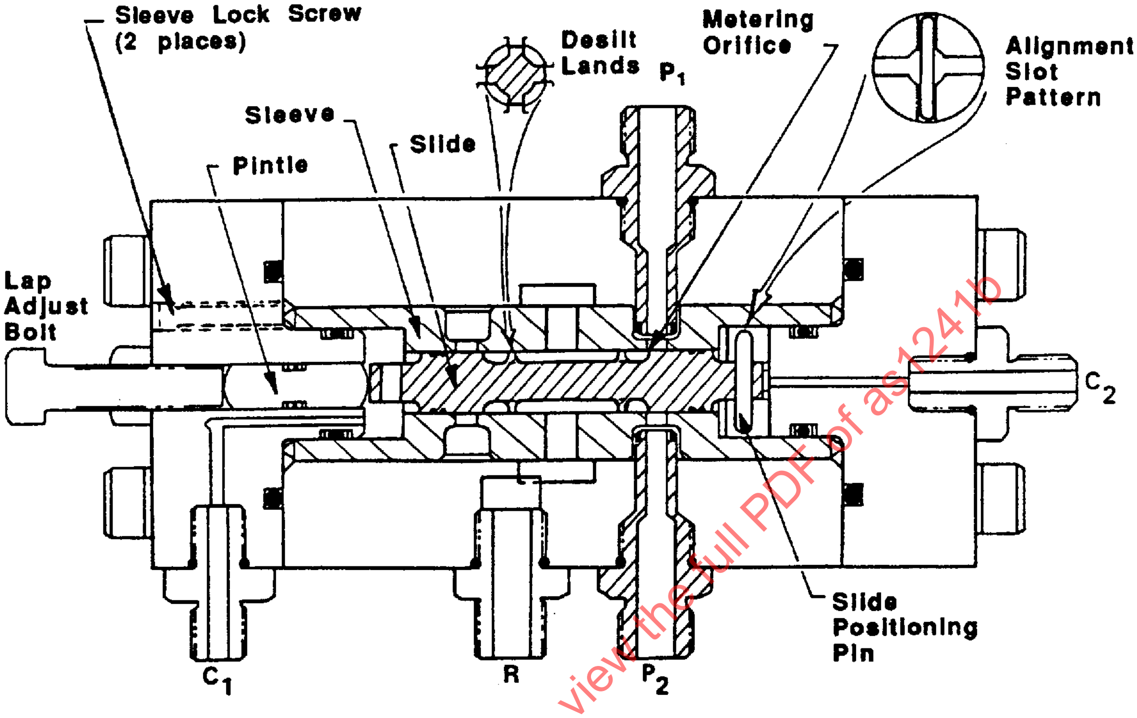

FIGURE 8 - Erosion Test Valve Schematic
(see Reference 2.5.4)

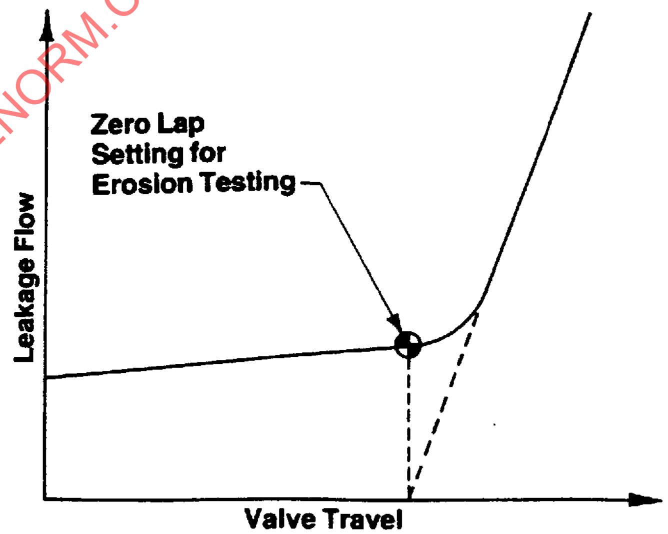

FIGURE 9 - Erosion Test Flow Gain Calibration

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4.8.1.5 Chlorine Addition: After the first 200 h of testing add methyl chloroform (1,1,1 thichloroethane) to yield 1000 ppm +200/-000 by weight of chlorine, in the fluid to be qualified, by injection through the hypodermic valve installed in the system for this purpose. Circulate fluid for at least 15 min with the system bypass partially open to insure uniform distribution of the methyl chloroform and to restore the system bulk fluid temperature to 225 °F ± 10 (107 °C ± 6).

4.8.1.6 Sampling: Test fluid samples will be taken at the hypodermic valve within 0.5 h of the beginning of test, after the addition of chlorine at 200 h, and at the completion of 500 h. The samples will be checked for total chlorine against the amount added in step 4.8.1.5 and retained for chemical analysis. The increase in leakage flow through the valve shall not exceed 200 cm^2/min maximum after 300 h of testing with methyl chloroform added and with no greater than a 0.5 cm^2/min/h rate of change in leakage in the final 50 h.

4.8.2 Grade B Fluid Test:

4.8.2.1 Test System: The test system to be used is schematically shown in Figure 7. The test system requires a minimum quantity of 2.5 gal (9.5 L) of fluid under test. A maximum of 5.0 gal (19.1 L) may be used. Fluid bulk temperature is to be maintained at 100 °F ± 10 (38 °C ± 6). Nominal system pressure shall be 3000 psig (20 700 kPa) with a minimum of 2850 psig (19 700 kPa) allowable if the bypass valve is used in an open position as a means of regulating system temperature.

4.8.2.2 Preparation: Prior to beginning the test, the system is to be drained of any previously tested fluid and flushed with the fluid to be tested. Flushing is to be accomplished using 2 to 3 gal (7.6 to 11.4 L) of the fluid circulated through a combination of both the erode and desilt loops for a total of 0.5 h. A second flush will be accomplished in the same manner, if considered necessary, to thoroughly clean the system. Flushing fluid is to be drained and not to be reused.

4.8.2.3 Calibration: A measured volume of new fluid of near maximum capacity for the system is to be installed, and air bleeding procedures conducted. The system is to be operated a minimum of 2 h at 100 °F ± 10 (38 °C ± 6) through a combination of both the erode and desilt loops. The test valve, Figure 8, is then to be calibrated for flow gain at 100 °F ± 10 (38 °C ± 6) and set to operate within the knee of the flow gain curve, as illustrated on Figure 9. The calibration is to be accomplished by repeating testing for flow gain until five consecutive curves are obtained. Total accumulated time of operation during run-in and calibration is to be a minimum of 4 h.

4.8.2.4 Chlorine Addition: Add methyl chloroform (1,1,1-trichloroethane) to yield 1000 ppm +200/-000 by weight of chlorine, in the fluid to be qualified, by injection through the hypodermic valve installed in the system for this purpose. Circulate the fluid for 15 min with the system bypass partially open to insure uniform distribution of the methyl chloroform.

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