AN AMERICAN NATIONAL STANDARD

SAE The Engineering Resource For Advancing Mobility

400 Commonwealth Drive, Warrendale, Pa 15096

AEROSPACE STANDARD

AS 1241A

Issued MARCH 1974
Revised MARCH 1983

AEROSPACE STANDARD AS 1241

FIRE RESISTANT PHOSPHATE ESTER HYDRAULIC FLUID FOR AIRCRAFT

TABLE OF CONTENTS

PREPARED BY

SAE COMMITTEE A-6, AEROSPACE FLUID POWER & CONTROL TECHNOLOGIES

Printed in U.S.A.

1. SCOPE

This specification establishes the requirements for phosphate ester hydraulic fluids for use in aircraft systems where fire resistance is required.

2. COMPOSITION

The composition of these fluids is not limited except that they must serve satisfactorily in systems designed to be compatible with phosphate ester fluids. New candidate fluids must be compatible with all fluids previously approved to this specification.

3. TYPES

Materials furnished to this specification shall be of the following types:

TYPE I -65°F to 225°F Fluid (-54°C to 107°C) - Obsolete

TYPE II -65°F to 225°F Fluid (-54°C to 107°C)

TYPE III Low Density, High Thermal Stability, -65°F to 250°F (-54°C to 121°C)

TYPE IV Erosion Resistance, High Thermal Stability, -65°F to 275°F Fluid (-54°C to 135°C)

Class 1: low density
Class 2: high density

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.

Note: The trend in fluid production is toward restricting availability of Types II and III fluids and increasing availability of the more advanced Type IV products.

4. PHYSICAL AND CHEMICAL PROPERTIES

4.1 New Fluid:

		TYPE I Obsolete	TYPE II	TYPE III	TYPE IV Class 1	TYPE IV Class 2
Viscosity, cs (ASTM D455)	-65°F (-54°C)	4200 max	4200 max	2000 max	2000 max	4200 max
	100°F (38°C)	9.0-12.5	9.0-12.5	9.0-12.5	9.0-12.5	9.0-12.5
	210°F (99°C)	3.0-4.0	3.0-4.0	3.0-4.0	3.0-4.0	3.0-4.0
Moisture Content, % H_2O by Weight (ASTM D1744)		0.29 max	0.40-0.60	0.40-0.60	0.10-0.30	0.10-0.30
Density, gm/ml at 77°F (25°C) (ASTM D941, ASTM D1217)		0.990 -1.066	0.990 1.066	0.990 -1.020	0.990 -1.020	1.020 -1.066

Total Acid Number mg KOH/gm (ASTM D974) or (ASTM D664)	0.20 maximum
Pour Point (ASTM D97)	less than -80°F (-62°C)
Flash Point (ASTM D92)	320°F (160°C) minimum
Fire Point (ASTM D92)	350°F (177°C) minimum
Auto Ignition Temp. (ASTM D2155)	700°F (371°C) minimum
Hot Manifold Test	Paragraph 5.1.1
High Pressure Spray Ignition Test	Paragraph 5.1.2
Wick Ignition Test	Paragraph 5.1.3
Color	Clear, blue to purple when viewed with white light passing through a fluid column of approximately one inch diameter.
State	Clear liquid, without layering or separation.
Bulk Modulus (Isothermal Secant)	210,000 psi (1448 MPa) min at 100°F (38°C) and 0-3000 psi (0-20685 KPa) (using the method of paragraph 5.2 on fluid saturated with air at room temperature and pressure).
Coefficient of Thermal Expansion (ASTM D941 or ASTM D1217)	1.0×10^{-3} $in^3/in^3°F$ ($.6 \times 10^{-3}$ cc/cc°C) max between 77°F and 210°F (25° and 99°C)
Dielectric Strength (ASTM D877)	KV/mil - No limit but determine value
Electrical Resistivity (ASTM D877)	No limit but determine value at 212°F (100°C) and 1000 Hz in an ac conductivity bridge

Foaming (ASTM D892)

Sequence	Temp.	Foam after 5 minutes blowing	Foam after 10 minutes settling	Time for complete foam collapse
1	75°F (24°C)	250 ml max	0	100 sec max
2	200°F (93°C)	150	0	50
3	75°F (24°C)	450	0	250

Specific Heat (ASTM D2766)	No limit but determine value
Toxicity	Paragraph 5.10 No hazard on normal skin or from occasional breathing vapors
Hydrolytic Stability	Paragraph 5.3
Thermal Stability	Paragraph 5.4

Effect on Metals at 425°F (218°C)	Paragraph 5.6.2
Compatibility with other Materials	Paragraph 5.5
Flow Control Valve Life	Paragraph 5.8
Particulate Contamination, max.	NAS 1638, Class 7

Chemical Contamination, max ppm 1	Type I	Type II	Type III	Type IV Class 1	Type IV Class 2
Chlorine	--	80	50	50	80
Calcium	--	--	--	10	10
Sodium	--	--	--	10	10
Potassium	--	--	--	10	10
Sulfur	--	--	--	150	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.

Anti-erosion Additive	Concentration and tolerance are to be specified by supplier/purchaser agreement.

4.2 Fluid Mixtures, with other approved products:

Miscibility	Complete in all mixture proportions, without precipitation or cloudiness.

Foaming 25/75, 50/50, 75/25 mixes (ASTM D892)	Sequence	Temp.	Foam after 5 minutes blowing	Foam after 10 minutes settling	Time for complete foam collapse
	1	75°F (24°C)	400 ml max	0	250 sec max
	2	200°F (93°C)	425	0	200
	3	75°F (24°C)	425	0	220

5. DETAIL REQUIREMENTS

The following tests are required for fluid evaluation. In most cases, limits are given in paragraph 4. covering Physical and Chemical Properties.

5.1 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 conditions, SAE AS 1241 Test Fluid 1 is used as a reference material in the following tests. Overall performance of the qualifying fluid shall be essentially equivalent to that of SAE AS 1241 Test Fluid 1. Refer to paragraph 9.20 for SAE AS 1241 Test Fluid 1 source.

In the following tests, miniaturized testing methods (similar to those in reference 9.18) may be used, provided correlation with full scale test results has been established.

5.1.1 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. (74 x 31 x 3 cm), 0.633 ohms, made by Carborundum Co.,

Niagara Falls, N.Y., or equivalent) into the tube and make the necessary electrical connections. Adjust 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.

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

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.

5.1.2 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 inches (38.1 to 304.8 mm) from the orifice with an oxy-acetylene torch (Purox Type W-400 with a 4 tip, or equivalent), while maintaining the pressure at 1000 psi ± 50 (6895 KPa ± 345). Ambient air shall be 75°F to 95°F (24°C to 35°C). Record 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 AS 1241 Test Fluid 1, the tests on both fluids should be performed under identical atmospheric conditions, preferably one immediately following the other.

5.1.3 Wick Ignition Test: Arrange a means for cycling an oridinary pipe cleaner in a horizontal plane through the flame from a laboratory burner at a fixed rate, preferably 0.5 to 0.67 hertz. Soak the pipe cleaner with the test fluid and allow the excess to drain off. Adjust the burner with sufficient air to provide a non-luminous flame, but not enough to form a sharp inner cone. For best results, a flame height of approximately 4 inches (101.6 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.

5.2 Bulk Modulus: The isothermal secant bulk modulus for each air saturated fluid shall be at least 210,000 psi (1448 MPa) at 100°F (38°C), as determined between atmospheric pressure and 3000 psi (20685 KPa). Air saturate the fluid per ASTM D892 except at room temperature, and allow complete foam collapse prior to proceeding with tests.

5.2.1 Test Set-Up (See Figure 3): A receiver capable of withstanding the 3000 psi (20685 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 9.19.

5.2.2 Determine the receiver expansion between ambient and test pressures at 100°F (38°C).

5.2.3 Test Procedure: Fill and bleed all free air from the receiver. Close the outlet valve and pressurize to 3000 psi ± 25 (20685 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.

5.2.4 Method of Computation:

5.2.4.1 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:

$$B = \frac{(P - P_o)\, V_o}{(V_o - V)}$$

B = secant bulk modulus, psi (Pa)
P = test pressure, psig (Pa)
P_o = initial pressure, psig (normally 0 psig)
V_o = quantity at P_o (receiver volume)
V = quantity at P (V_o plus effluent volume)

5.2.4.2 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.

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

5.3 Hydrolytic Stability

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

5.3.2 Materials to be Tested: (Material specification numbers shown are for information - approximate equivalents may be substituted.)

5.3.2.1 Material	Composition	Ref. Spec. Numbers
Steel	0.95Cr, 0.20 Mo, 0.30 C or 0.55 Ni, 0.50 Cr, 0.20 Mo, 0.30 C or 0.1Q C	4130, MIL-S-18729, AMS 6350 8630,MIL-S-6050, AMS 6280 1010, QQ-S-698, AMS 5044
Cadmium Plate		QQ-P-416, Type I, Class 2
Aluminum	1.5 Mg, 4.4 Cu, 0.6 Mn or 2.5 Mg, 1.6 Cu, 5.6 Zn, 0.26 Cr	2024, QQ-A-250/4, AMS 4035 7075, QQ-A-250/12, AMS 4045
Magnesium	3.0 Al, 1.0 Zn	AZ31B, QQ-M-44, AMS 4375

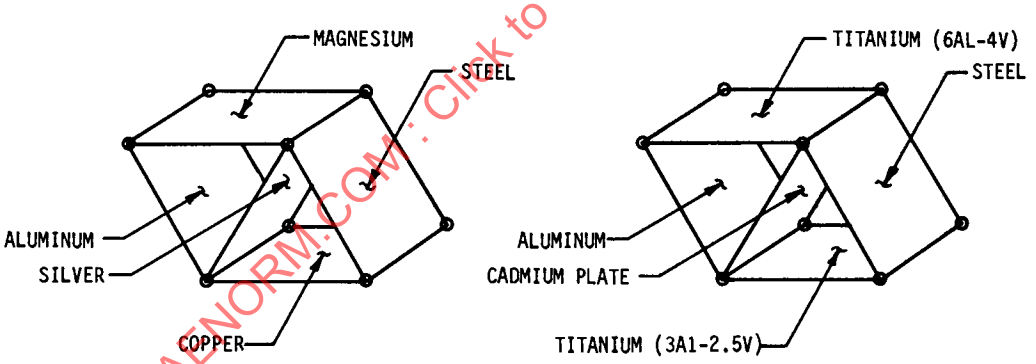
5.3.2.1 (Cont.)	Material	Composition	Ref. Spec. Numbers
	Silver		QQ-S-365
	Copper		101, 110, QQ-C-476, AMS 4500
	Titanium	6 Al - 4 V	C120AV, MIL-T-9046 TYP III, AMS 4911
		3 Al - 2.5 V	AMS 4944

5.3.2.2 Metal specimens are to be approximately 1 x 1 x 0.062 inch (25 x 25 x 1.58 mm). Drill 4 holes approximately 0.062 in. (1.58 mm) diameter, one at each corner of the specimen.

5.3.2.3 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.

5.3.2.4 Weigh each specimen and determine its surface area in cm^2.

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



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

(1) Kinematic viscosity at 100° and 210°F (38° and 99°C).
(2) Neutralization Number.
(3) Water Content.

5.3.2.7 Mount each metal parallelogram, from 5.3.2.5, on a suitable polytetrafluoroethylene (PTFE) stand so that the set-up is rigidly centered inside a 250 ml wide-mouth bottle. The PTFE stand shall not impede fluid circulation.

5.3.3 Test

5.3.3.1 Place 125 ml of the fluid in a 250 ml wide mouth bottle and in each of the two bottles from 5.3.2.7. Seal each bottle with an ethylene propylene rubber lined cover. Weigh each of the bottles to the nearest 0.01 gm.

5.3.3.2 Mount the 3 bottles (1 with fluid, 2 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 ± 10 (82°C ± 6) and tumble under these conditions for 168 hours.

5.3.3.3 Remove the bottles. Weigh each of the bottles to the nearest 0.01 gm and determine that no weight loss greater than 0.1 gm has occurred due to leakage. Filter the test fluids through compatible one micron membrane filters. Any precipitation retained on the filters is to be weighed and recorded. (No limit is yet established for precipitate but when determined will be included in a future revision of this specification.)

5.3.3.4 Determine the following for each of the 3 fluid samples:

(1) Viscosity at 100°F (38°C).
(2) Viscosity at 210°F (99°C).
(3) Neutralization Number.
(4) Water Content, %.

5.3.3.5 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 cheese cloth wetted with acetone. Dry again. Weight each metal specimen and calculate its weight change in mg and mg/cm^2.

5.3.4 Limits

5.3.4.1 Weight change of metal test specimens.

Material	Specification Limits
Steel	± 0.1 mg/cm^2 maximum
Cadmium Plate	± 0.4 mg/cm^2 maximum
Aluminum	± 0.1 mg/cm^2 maximum
Magnesium	± 0.2 mg/cm^2 maximum
Titanium	± 0.1 mg/cm^2 maximum
Copper	± 0.4 mg/cm^2 maximum
Silver	± 0.2 mg/cm^2 maximum

5.3.4.2 Fluid characteristic changes (with and without metal samples in bottle) relative to values determined in 5.3.2.6.

Property	Specification Limits
Neutralization Number	± 0.3 mg KOH/gm maximum
Viscosity at 100°F (38°C)	± 3.0 cs maximum
at 210°F (99°C)	± 1.0 cs maximum
Water Content, %	Record before and after test

Difference in fluid changes due to metal samples in the test can also be calculated but are not limited except as noted above.

5.4 Thermal Stability

5.4.1 Closed bottle corrosion tests under high temperature conditions are required. Use the same test method as the Hydrolytic Stability Test, paragraph 5.3, except:

5.4.1.1 Water content must be within limits stated in paragraph 4.1.

5.4.1.2 Test temperature shall be 250°F ± 10 (121°C ± 6) for 168 hours, instead of 180°F (82°C).

5.4.2 Limits

5.4.2.1 Weight change of metal test specimens.

Specification Limits

Metal	Fluid Type I & II	Fluid Type III & IV	Units
Steel	± 1.5	± 0.3	mg/cm^2 maximum
Cadmium Plate	± 1.5	± 0.3	mg/cm^2 maximum
Aluminum	± 0.3	± 0.2	mg/cm^2 maximum
Magnesium	± 20.0	± 5.0	mg/cm^2 maximum
Titanium	± 1.0	± 0.6	mg/cm^2 maximum
Copper	± 2.0	± 0.5	mg/cm^2 maximum
Silver	± 1.0	± 0.3	mg/cm^2 maximum

5.4.2.2 Fluid characteristics changes (with and without metal samples in bottles).

Specification Limits

Property	Fluid Type I & II	Fluid Type III	Fluid Type IV	Units
Neutralization Number	± 15	± 0.5	± 0.1	mg KOH/gm, max
Viscosity at 100°F (38°C)	± 2.0	± 1.0	± 0.1	cs, maximum
at 210°F (99°C)	± 1.0	± 0.3	± 0.3	cs, maximum
Water Content, %	Record before and after test.			

5.5 Fluid Compatibility

5.5.1 Other Type I, II, III and IV Fluids: When thoroughly mixed for 30 minutes at ratios of 25/75, 50/50 and 75/25 by volume with each of the fluids qualified to this specification, there shall be no separation, precipitation, cloudiness or visible change after standing 48 hours. The color of each mixture must lie within the spectrum from blue to purple.

5.5.1.1 For Type IV fluids only, prepare mixtures as in 5.5.1 and heat to 250 ± 10°F (121 ± 6°C) for 168 hours. Allow to cool and visually examine for evidence that there is no separation, cloudiness or precipitation. Color change is acceptable.

5.5.2 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 minutes 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 hours. 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 AS 1241 hydraulic fluids.

5.5.2.1 Stoddard Petroleum Solvent (Fed. Spec. P-D-680 or equivalent).

5.5.2.2 1,1,1 Tri-Chloro-Ethane.

5.5.2.3 1,1,2 Trichloro-Trifluoro-Ethane

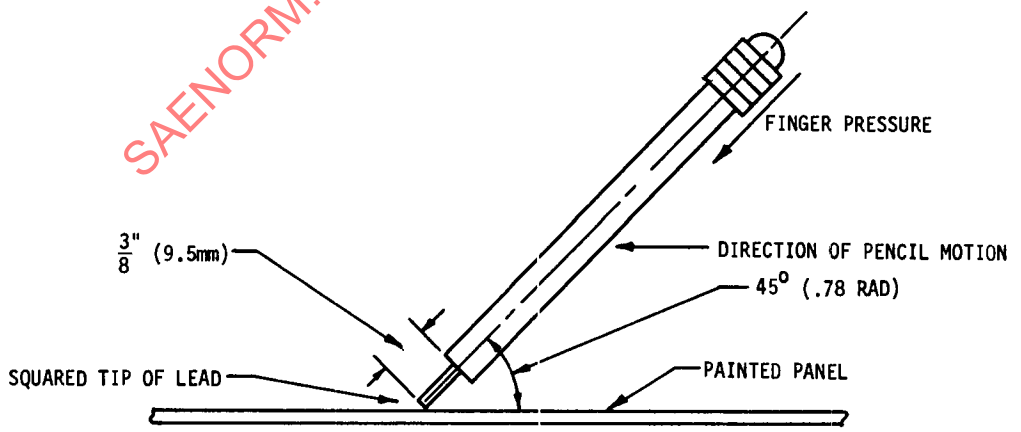
5.5.3 Paints: To qualify, fluids must be compatible with aircraft paints, such as urethane or epoxy paints (including primers, enamels and lacquers) proven to be resistant to phosphate ester fluids.

Aluminum panels (2024, 7075 or equivalent) primed to a dry film 0.5 to 0.7 mils thickness and finish coated to a dry film 1.4 to 2.4 mils thick are required for compatibility test. After painting, air dry the panels at least 168 hours before immersion. Panels are to be tested in the candidate fluid and in SAE AS 1241 Test Fluid 1.

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 AS 1241 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:

5.5.3.1 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 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 deg (0.78 rad) 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.



5.5.4 Elastomers: Fluids must pass compatibility tests with ethylene propylene rubber (NAS 1613 or equivalent) sheet stock soaked in the candidate fluid according to the following schedule. Tests should be run with SAE AS 1241 Test Fluid 1 as reference. Effects of the soak periods on the physical characteristics of the rubber compounds shall be no more severe than SAE AS 1241 Test Fluid 1 effects on the same compounds and must be within the limits shown. Average the results on three specimens for each determination.

Soak Schedules					
Temperature, °F ± 4 (°C ± 2)		160 (71)	250 (121)	225 (107)	225 (107)
Time, Hours ± 2		70	70	334	670
Physical Characteristics					**Samples Required (Test Spec.)**
Durometer Hardness Change - Shore A Scale Maximum		-12	-25	-20	-25	2 x 1 x 0.250 inch (51 x 25 x 6.35 mm) (ASTM D2240)
Volume Swell - %						
Minimum	EPR	4	5	5	5	2 x 1 x 0.125 inch (51 x 25 x 3.18 mm) (ASTM D471)
Maximum	EPR	15	25	20	25	
Tensile Strength - psi (KPa)						
Minimum	EPR	--	1500 (10343)	1300 (8964)	--	2 x 1 x 0.125 inch (51 x 25 x 3.18 mm) (ASTM D412)
Elongation - %						
Minimum	EPR	--	125	125	--	2 x 1 x 0.125 inch (51 x 25 x 3.18 mm) (ASTM D412)

5.5.5 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 AS 1241 fluids, samples of these materials shall be immersed in SAE AS 1241 Test Fluid 1 for 30 days at room temperature. Compatibility will be approved if the tested materials meet performance requirements following the immersion test.

5.6 Effect on Metals Exposed at 425°F (218°C)

5.6.1 Metal Specimen Change Limits: The following applies to all fluid types:

Metal weight change and hydrogen input shall not exceed the following values when tested according to 5.6.3.

Metal	Weight Change (mg/cm^2)	Hydrogen Input (PPM)
Titanium	150 Max.	850
Stainless Steel	15 Max.	---

5.6.2 Tests on Metals at 425°F (218°C)

5.6.2.1 Test Materials: 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).

5.6.2.2 Test Equipment: Use a heat transfer apparatus consisting of 1.12 in. (28.5 mm) I.D., Type 301 stainless steel cups, suitable temperature probes, hot plate, and heater control.

5.6.3 Test Procedure:

5.6.3.1 Measure ppm of hydrogen present (by vacuum gas analysis) in a control panel obtained from the metal sheet from which the test specimens were cut.

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

5.6.3.3 Drip the test fluid onto test panels at a rate approximately 3/4 cc per hour. 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 hours) at 425°F ± 20 (218°C ± 11). Every 24 hours inspect test specimens and if a surface film or coating occurs, remove such film with acetone. (Allow specimens to cool before cleaning.)

5.6.3.4 Following the 4 day test, clean each test specimen, weigh to nearest 0.1 mg, and measure ppm hydrogen by vacuum gas analysis.

5.6.3.5 Determine weight change (average of 2 readings) in grams and increase in hydrogen content in ppm (average of 2 readings).

5.7 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 - reservoir loop is required.

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:

- Total Test Time - 500 hours
- Total Fluid Cycles = 30,000 cycles
- Ratio of hot section fluid capacity to total fluid capacity - about 1:5.

5.7.1 Fluid Test Circuit (See Schematic, Figure 4):

- Test Loop - Capacity - "X" gallons.
- Load Valve - 2850 psid (19800 KPa) at "Y" GPM.
- Insulated reservoir between load valve and heat exchanger with about 25% of the capacity of the remaining system including the supply reservoir. (This keeps the fluid hot for about 1/5 of the test time.)
- Heat exchanger - Heat transfer capacility at least that of energy input to pump, approximately 73 BTU/min per GPM (291 J/s per M^3/s).
- Reservoir - Sufficient size to provide remainder of fluid required so system capacity and pump flow yields the desired number of fluid cycles in the desired time period.

$$\text{i.e. } \frac{500 \text{ Hrs} \times 60 \text{ Min/Hr}}{30{,}000 \text{ Cycles}} \times (\text{flow rate-GPM}) = \text{Total System Capacity - Gallons}$$

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

5.7.2 Test:

5.7.2.1 Circulate fluid through the load valve and insulated section for 30,000 fluid cycles. Maintain fluid temperature in the downstream insulated area at 225°F (107°C) for Types I and II fluids, and at 250°F (121°C) for Types III and IV fluids, by regulating cooling water flow to the heat exchanger. Maintain supply pressure at 2850 ± 50 psi (19800 ± 345 KPa) using a commercially available aircraft hydraulic pump.

For Type IV fluid only: After completing the above test elevate the control temperature to 275°F (135°C). Continue testing for 5 hours at the raised temperature to demonstrate acceptability for short duration.

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

5.7.2.3 Test result limits - Fluid characteristics after 30,000 cycles. (Note: shear stability can be determined by plotting viscosity data obtained from samples taken during the test.)

Property		Specification Limits			
		Type I	Type II	Type III	Type IV
Neutralization No. Chg.		1.00 Max	2.40 Max	0.30 Max	0.10 Max
Viscosity, Cs.	100°F (38°C)	6.00 Min	6.00 Min	6.00 Min	6.00 Min
	210°F (99°C)	2.00 Min	2.00 Min	2.00 Min	2.00 Min

5.7.2.4 System Condition: 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 over 10,000 hour normal life of aircraft hydraulic components. Pump shaft seals and valve metering edges should receive specific attention.

5.8 Flow Control Valve Life: Flow control valves used with these types of fire resistant hydraulic fluids have tended to develop increased internal leakage after several hundred hours of use. The mechanism by which the valve parts wear, corrode, or erode is uncertain and is probably related to the design of the valves as well as to the conditions under which they are used. However, it has been found possible to produce fluids which minimize this increase in internal leakage under most operating conditions. Vendors of fluids to be qualified per this specification must demonstrate acceptable valve life characteristics using either typical aircraft valves or simulated valves. For examples of acceptable test methods and test devices see Appendix 10.1.

5.9 Seal Functional Tests:

5.9.1 Install NAS1611 Seals (ethylene propylene rubber per NAS1613) for functional testing in a cylinder. Seal grooves are to be in accordance with MIL-P-5514, Rev. E or later; all seals with one MS28774 back-up ring (PTFE) downstream of the O-ring pressure side (a back-up ring on each side of the O-ring is optional). A test cylinder schematic is shown in Figure 5. A typical test circuit is shown in Figure 6.

5.9.2 Fill the cylinder with the candidate fluid at atmospheric pressure. Heat the cylinder and maintain at 160°F ± 4 (71°C ± 2) for six days.

5.9.3 Raise the cylinder pressure to 3000 psi (20685 KPa) and maintain temperature at 160°F (71°C). After 24 hours under these conditions:

5.9.3.1 Operate the piston through 4 in. (101.6 mm) stroke, 10 cycles with a pressure pulse of 0 to 3000 psi (0 - 20685 KPa) on each cycle, pressure rise 200,000 ± 20,000 psi per second (1380 ± 138 MPa/s).

5.9.3.2 Repeat, 10 cycles - 0 to 10 psi (0 - 69 KPa) on each cycle.

5.9.3.3 Maintain 10 psi (69 KPa) for one hour with the piston rod stationary.

5.9.3.4 Leakage for the above tests must not exceed 1.2 cc (20 drops) total for each dynamic seal.

5.9.4 Continue the test at room temperature. Pressure to 3000 psi (20685 KPa) then allow to fall to 10 psi (69 KPa). Refrigerate, using liquid nitrogen to chill the cylinder. Maintain at -65°F ± 2 (-54°C ± 1). After soaking at this temperature for 24 hours:

5.9.4.1 Pressurize to 50 psig (345 KPa). Remove ice from the rod and operate the piston through a 4 in. (101.6 mm) stroke, 10 cycles with a pressure pulse of 0 to 50 psi (0 - 345 kPa) on each cycle.

5.9.4.2 Repeat, 10 cycles - 0 to 3000 psi (0 - 20685 kPa) on each cycle.

5.9.4.3 Maintain 3000 psi (20685 kPa) for one hour with the piston rod stationary.

5.9.4.4 Leakage for above tests must not exceed 1.2 cc (20 drops) total for each dynamic seal.

5.9.5 Allow the cylinder to warm to room tempearture and the cylinder pressure to drop to atmospheric during a period of at least 18 hours.

5.9.5.1 Operate the piston through a 4 in. (101.6 mm) stroke, at 30 cycles per minute, for a total of 70,000 cycles at 3000 psi (20685 KPa) with a momentary drop to 0 psi once during each cycle. (1 cycle - 1 stroke of 4" (10.2 cm) in each direction). Maintain cylinder temperature at 160°F ± 4 (71°C ± 2.2).

This test is to be operated in batches of 10,000 cycles (approximately 5.6 hours) followed by 1.4 hours at 3000 psi (20685 kPa) and no piston rod motion.

5.9.5.2 Leakage for the above test must not exceed 2 cc for each dynamic seal for any group of 10,000 cycles.

5.9.5.3 Operate the piston through a 1/4 in. (6.35 mm) stroke at 60 hertz for a total of 100,000 cycles. Maintain cylinder temperature at 200°F (93°C) and pressure at a constant 3000 psi (20685 KPa). (The gearbox and eccentric shown in Figure 6 will have to be changed for this test and the microswitch used for cycling the pressure need not be used.)

5.9.5.4 Total leakage in this test must not exceed 20 cc and leakage in the last 30 minutes must not exceed 2 cc.

5.10 Toxicity

The supplier of any fluid to this standard will furnish to the user toxicological data pertinent to the product offered. The data shall include instructions on handling of the product offered as it relates to the intended application in the user's system.

6. QUALIFICATION

New fluids or changes in formulation.

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 specification.

7. QUALITY CONTROL

The vendor shall perform the necessary tests to certify that each batch of fluid matches the qualification values within limits specified for the following characteristics: These allowable deviations are not to be construed as a relaxation of any previously stated limits.

7.1 Viscosity: ± 0.5 cs at 100°F (38°C); ± 0.20 cs at 210°F (99°C).

7.2 Chlorine Content: within maximums stated in paragraph 4.1.

7.3 Density: ± 0.005 gm/ml.

7.4 Total Acid Number: 0.20 maximum.

7.5 Water Content: within range stated in paragraph 4.1.

7.6 Autoignition Temperature: 700°F (371°C) Min.

7.7 Flash Point: 320°F (160°C) Min.

7.8 Cleanliness:

7.8.1 Particle count per ARP 598, or alternate method per Society of British Aircraft Companies Specification T.S. 64, using compatible filters rated 1 micron. Particles per 100 ml of fluid:

Particle Size	Max. Count (Class 7 per NAS1638)
5 - 15 Microns	32,000
15 - 25	5,700
25 - 50	1,012
50 - 100	180
> - 100	32

8. PACKAGING AND MARKING

8.1 The hydraulic fluid supplied in 55-gallon (208-dm^3) drums shall be clean and not lined with material that is soluble in or might contaminate the hydraulic fluid. The hydraulic fluid supplied in quart (0.95 dm^3) or gallon (3.79 dm^3) containers shall use sealant compatible with the fluid.

8.2 Each container shall be legibly and durably marked with the following information:

Hydraulic Fluid, Fire Resistant
SAE AS 1241 Type ---, Class ---.
Supplier's Name and supplier's product name
Batch Number
Date of Manufacture
Supplier's Designation or Number
Quantity
Purchase Order Number
Labeling will conform with identified toxicological characteristics of the fluid.

8.3 In addition to the above data, the container may be marked to show all other specification numbers for which the product qualifies (i.e. Boeing BMS 3-11 Type IV, Class 1; Douglas DMS 2014 Type IV, Class 2; Lockheed LAC C-34-1224 Type IV, Class 2; etc.)

9. REFERENCES

9.1	ARP 598	Procedure for the Oetermination of Particulate Contamination of Hydraulic Fluids by the Particle Count Method
9.2	ASTM D664	Standard Test Method for Neutralization Number by Potentiometric Titration
9.3	ASTM D92	Test for Flash and Fire Points by Cleveland Open Cup
9.4	ASTM D97	Test for Pour Point
9.5	ASTM D412	Tension Testing of Vulcanized Rubber
9.6	ASTM D445	Test for Viscosity of Transparent and Opague Liquids (Kinematic and Dynamic Viscosities)
9.7	ASTM 0471	Test for Change in Properites of Elastomeric Vulcanizates Resulting from Immersion in Liquids
9.8	ASTM D877	Test for Oielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
9.9	ASTM D892	Test for Foaming Characteristics of Lubricating Oils
9.10	ASTM 0941	Test for Density and Specific Gravity of Liquids by Lipkin Bicapillary Pyconometer
9.11	ASTM D974	Test for Neutralization Number by Color-Indicator Titration
9.12	ASTM D1217	Test for Density and Specific Gravity of Liquids by Bingham Pyconometer
9.13	ASTM D1744	Test for Water in Liquid Petroleum Products by Karl Fischer Reagen.
9.14	ASTM D2155	Test for Autoignition Temperature of Liquid Petroleum Products
9.15	ASTM D2240	Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer
9.16	ASTM D2766	Specific Heat of Liquids and Solids

9.17 Society of British Aerospace Companies. Technical Specification No. 64, Standard Method for (Projection) Microscopic Evaluation of Hydraulic Fluid Samples for Particle Contamination.

9.18 Miniaturized Tests for Fire Resistance of Hydraulic Fluids by D. E. Johnson and N. W. Furby, Chevron Research Company, presented at the ASTM meeting, New Orleans, Louisiana, January 24, 1966.

9.19 Iso-thermal bulk modulus of distilled water, 0-3000 psi at 100°F is 329,000 psi. From specific volumes given in page 74, Table 4, Compressed Liquids, Thermodynamic Properties of Steam, J. H. Keanan and F. G. Keyes 1936, First Edition, 29th Printing, 1956, John Wiley and Son, Publishers.

9.20 SAE AS 1241 Test Fluid 1 is available from:

Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166

9.21 NAS1611 Packing, Preformed O-ring, Phosphate Ester Resistant (-65°F to +160°F)

9.22 NAS1613 Packing, O-ring, Phosphate Ester Resistant

9.23 NAS1638 Cleanliness Requirements of Parts Used in Hydraulic Systems

10. APPENDIX

10.1 Flow Control Valve Life Test Methods: The following two test methods have been found to give reasonably repeatable results which can be correlated to valve life in some aircraft systems. These methods are recognized as exhaustive tests that fully evaluate the anti-erosion characteristics of a candidate fluid under simulated aircraft operational conditions.

10.2 Valve Life Test using Boeing Test Method (for Type IV fluids only).

10.2.1 Test A

a. The test system to be used is schematically shown in Figure 7. The test system requires a minimum capacity of 2.5 gallons (9.5 dm^3) of fluid under test. A maximum of 5.0 gallons (19 dm^3) may be used. Fluid temperature is to be maintained at 100 ± 10°F (38 ± 4°C), pressure at 3000 psig (20685 kPa).

b. 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 - 3 gallons (7.6 - 11.4 dm^3) of new fluid circulated through a combination of both the erode and desilt loops for a total of 0.5 hours. 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.

c. 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 two hours 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 four hours.

d. Add 1,1,1 - trichloroethane to yield 1000 ppm $\pm \frac{200}{0}$ 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 15 minutes with System Bypass partially open to insure uniform distribution of the trichloroethane.

e. Operate the system through automatic sequencing for 300 hours, beginning with the addition of the 1,1,1 - trichloroethane. The continuously repeated test sequence is to be five minutes erode followed by six seconds desilt. The six seconds will include two seconds at full open stroke, in each direction of the valve slide. An automatic record of system pressure, temperature and leakage flow will be obtained each 10 hours.

f. Test fluid samples will be taken at the hypodermic valve within 0.5 hours of the beginning of test and at the conclusion of 300 hours. The samples will be checked for total chlorine against the amount added in step d. above. The increase in leakage flow through the valve must be less than 125 cc/min.

10.2.2 Test B

a. The test setup used is the same as in 10.2.1 for Test A.

b. Prior to beginning the test, the system is to be drained of any previously tested fluid, and flushed with SAE AS 1241 Test Fluid 1. Flushing is to be accomplished using 2 to 3 gallons (7.6 to 11.4 dm^3) of new fluid, circulated through a combination of both the erode and desilt loops for a total of 0.5 hours. Repeat with a second flush using new fluid. Flushing fluid is to be drained and not to be reused.

c. A measured volume of 2.5 gallons (9.5 dm^3) of clean SAE AS 1241 Test Fluid 1 is to be installed, and air bleeding procedures conducted. The system is to be operated a minimum of two hours through a combination of both the erode and desilt loops. The test valve, Figure 8, is then to be calibrated for flow gain, as in 10.2.1.c above. Valves with leakage at the calibrated test position of greater than 750 cc/min shall not be used. The total accumulated time of operation during run-in and calibration is to be a minimum of four hours.

d. Add 1,1,1 - trichloroethane to yield 1000 ppm $\pm \frac{200}{0}$ by weight of chlorine, in the fluid to be qualified, by injection through the hypodermic valve put in the system for this purpose. Circulate fluid through the automatic valve cycle operation (5 minutes erode + 6 seconds desilt) and establish leakage rate change on one hour intervals. The leakage change shall result in an average straight line slope of greater than 100 cc/min/hr over a five hour period with such slope demonstrated within 20 hours of test initiation with 1,1,1 - trichloroethane. Valve leakage will not be allowed to exceed 2000 cc/min in obtaining this result.

e. Upon obtaining the above slope, the test will be stopped and the total fluid volume in the system will be determined based on the reservoir volume level indication. This volume may be slightly lower than the 2.5 gallons (9.5 dm^3) at the initiation of the test due to system bleed and minor fluid leaks. Add a quantity of the candidate fluid equal to the total volume that is determined to presently be in the system established above. The mixture will be circulated for 15 minutes with the System Bypass partially open to assure uniform mixing.

f. Automatic cycling will be conducted (5 minutes erode + 6 seconds desilt) for 300 hours beginning with the addition of the candidate fluid. An automatic record of system pressure, temperature, and valve leakage will be obtained each 10 hours, beginning 1 hour after addition of the candidate fluid.

g. Test fluid samples will be taken as in 10.2.1.f above. Total chlorine will be greater than 500 ppm. The increase in leakage flow must meet the following requirements:

- less than 450 cc/min in the first 100 hours
- less than 125 cc/min in the final 200 hours.

10.3 Valve Life Test Using Lockheed Test Method (for Type IV fluids only)

10.3.1 Erosion Test Procedure. Testing shall be performed in a closed loop pumping system capable of subjecting an aircraft valve specimen to pressure, flow and temperature conditions typical of aircraft service conditions. The system shall be equipped with a reservoir capable of retaining volatile contaminants, filtration typical of aircraft systems, heat exchanger and flow restrictor as required to maintain temperatures and flow rates typical of aircraft service conditions. Instrumentation shall include pressure indicators, thermocouples, timers and flow measurement devices capable of establishing system conditions and initial leakage rate and a fluid sampling system for control of fluid condition. Provisions for cycling of the test valve during operation shall be provided. Before qualification of a candidate fluid the system shall have demonstrated ability to erode the test valve at an accelerated rate with SAE AS 1241 Test Fluid 1. The configuration and materials of the test valve shall be typical of aircraft design for current production models at the time of qualification. Use of a simulated valve is permitted when equivalency of test data in a parallel test has been demonstrated. The initial leakage rate of the valve shall be determined at the start of each test.

10.3.2 Basic Erosion Test. The test fluid shall be subjected to a minimum of 100 hours test at 170 ± 5°F (77 ± 3°C). The maximum change in leakage rate shall not exceed 1 cc/min/hr during testing. The test fluid shall then be subjected to a minimum of 100 hours test at 225 ± 5°F (107 ± 3°C) (temperature measured immediately after flowing through the test valve). During testing at this temperature the maximum change in leakage rate shall not exceed 1.5 cc/min/hr. Chlorine in the form of 1,1,1 trichloroethane shall then be added as 1000 (+200, -0) ppm by weight and testing continued for a minimum of 100 hours. The maximum change in leakage rate with the 1,1,1 - trichloroethane added shall not exceed 2.0 cc/min/hr.

10.3.3 Dilution Test. Fill the system with qualified Type III fluid contaminated with chlorine in the same proportion as in 10.3.2 above and test at 170°F (77°C) until a basic erosion rate of 1 cc/min/hr is established. Remove 50 ± 5% of the Type III contaminated fluid and replace with fresh candidate fluid and measure and record leakage rate. The fluid shall be tested for a minimum of 100 hours. The maximum change in leakage rate during this testing shall not exceed 1.5 cc/min/hr.

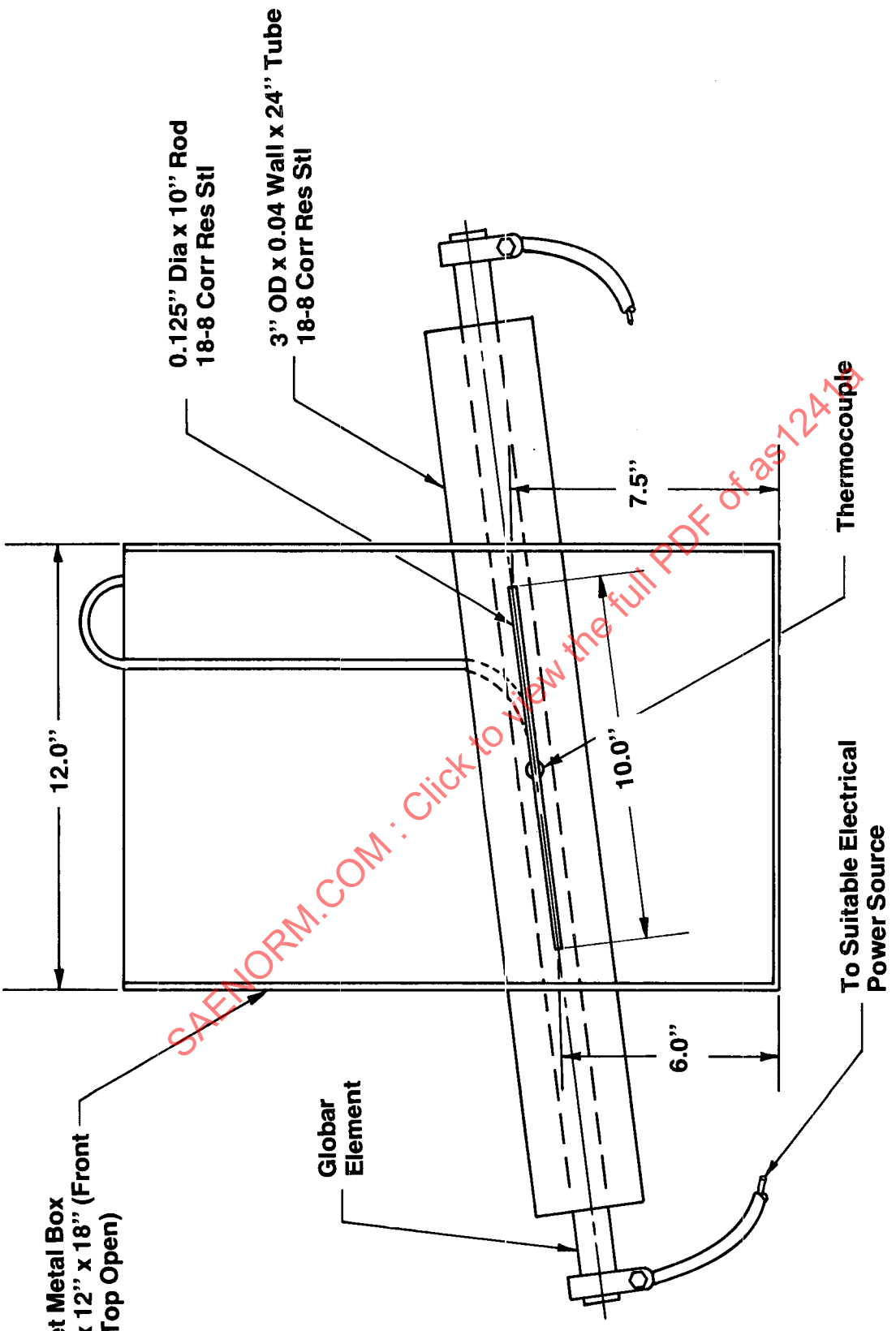


Figure 1. Exhaust Manifold Test

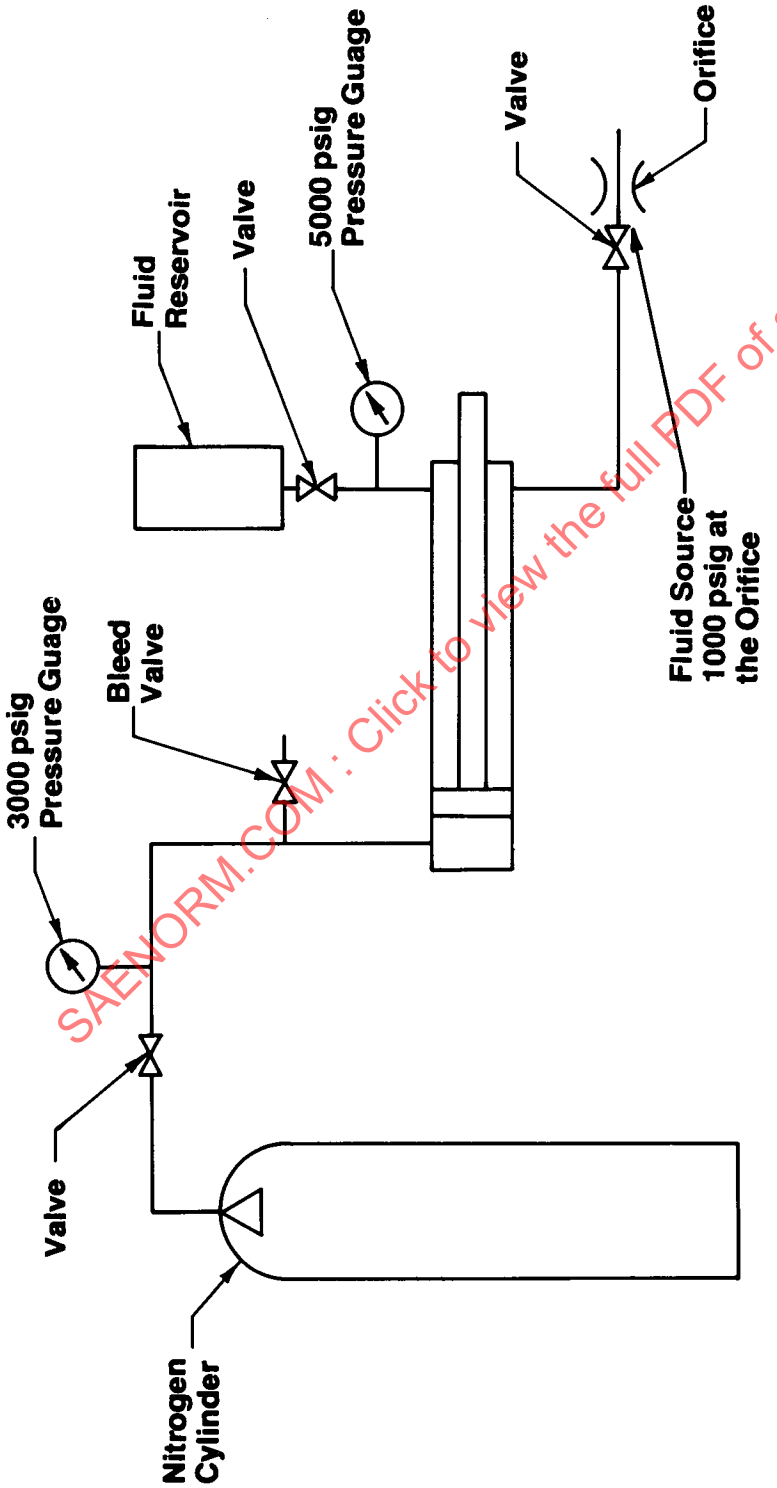


Figure 2. High Temperature Ignition Test

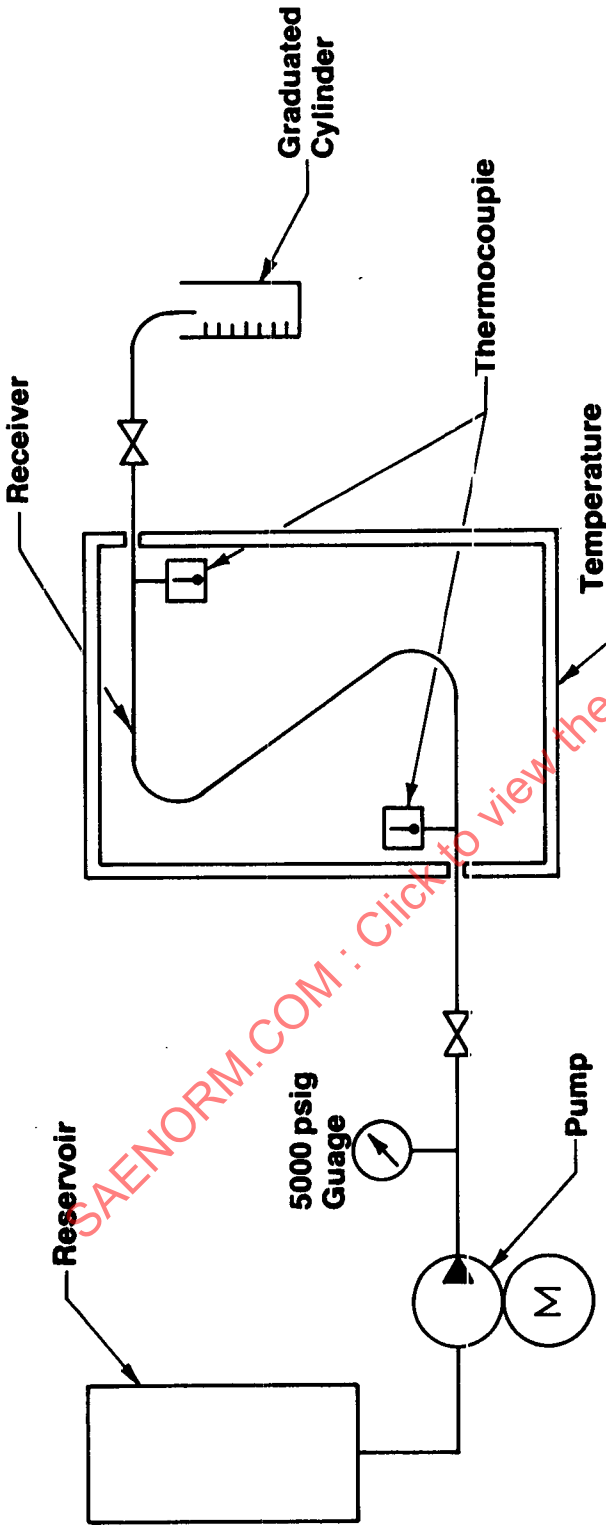


Figure 3. Isothermal Secant Bulk Modulus Determination Schematic