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An American National Standard

Standard Test Method for Simulative Recirculating System Testing of Aerospace Hydraulic Fluids[1]

This standard is issued under the fixed designation D 2428; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers a procedure for system evaluation of aerospace hydraulic fluids. The test method recommends control of test variables, a typical test system geometry, data to be obtained, and procedures which will assure a uniform approach to fluid screening and evaluation. Recommendations concerning specific hardware and rigid techniques have been avoided where possible to allow the test method to be used as the state-of-the-art advances.

1.2 Each agency using the test method can simulate a specific system, thus fluids can be qualified for use in applications having unique hardware and design concepts. This approach provides the test flexibility needed to meet the rapid changes in fluid requirements and also provide valuable comparative data for both users and developers of hydraulic fluids.

1.3 Since the test system was purposely generalized, it is important that the specified data be obtained in order that fluid flow dynamics can be defined. Such factors as shear rate, mass flow rate, temperature gradients, etc., must be defined for valid comparisons.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 The values stated in metric units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

D 88 Test Method for Saybolt Viscosity[2]
D 92 Test Method for Flash and Fire Points by Cleveland Open Cup[3]
D 97 Test Method for Pour Point of Petroleum Oils[3]
D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[3]
D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration[3]
D 941 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Lipkin Bicapillary Pycnometer[3]
D 974 Test Method for Acid and Base Number by Color-Indicator Titration[3]
D 1298 Practice for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[3]
D 1480 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Bingham Pycnometer[3]
D 1481 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Lipkin Bicapillary Pycnometer[3]
D 1533 Test Method for Water in Insulating Liquids (Karl Fischer Method)[4]
D 2155 Test Method for Autoignition Temperature of Liquid Petroleum Products[5]
F 303 Practices for Sampling Aerospace Fluids from Components[6]
F 313 Test Method for Insoluble Contamination of Hydraulic Fluids by Gravimetric Analysis[7]

3. Summary of Test Method

3.1 Hydraulic fluids are evaluated in a system which simulates as closely as practical that in which the fluid is to operate. System variables and test procedures have been purposely generalized while system description and data to be obtained have been rigidly defined.

4. Significance and Use

4.1 The usefulness of this test method is related directly to the ability to correlate valid test results from different laboratories. Results validity and correlativity are related directly to the care with which data is obtained and reported as well as instrumentation accuracy and test concept.

4.2 Instrumentation accuracy is a function not only of resolution but also placement in the system.

4.2.1 Pressure piezometer rings are fabricated and placed in accordance with "Fluid Meters, Their Theory and Applications," ASME, 1959, p. 18.[8] Thermocouple probes are placed in the line to read the maximum fluid temperature. For inside-out heat flow this is generally at the tube

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[2] *Annual Book of ASTM Standards*, Vol 04.04.
[3] *Annual Book of ASTM Standards*, Vol 05.01.
[4] *Annual Book of ASTM Standards*, Vol 10.03.
[5] *Discontinued 1980*—Replaced by E 659.
[6] *Annual Book of ASTM Standards*, Vol 10.05.
[7] *Annual Book of ASTM Standards*, Vol 15.03.
[8] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

centerline while for outside-in heat flow the maximum temperature generally occurs at the wall.

5. Apparatus

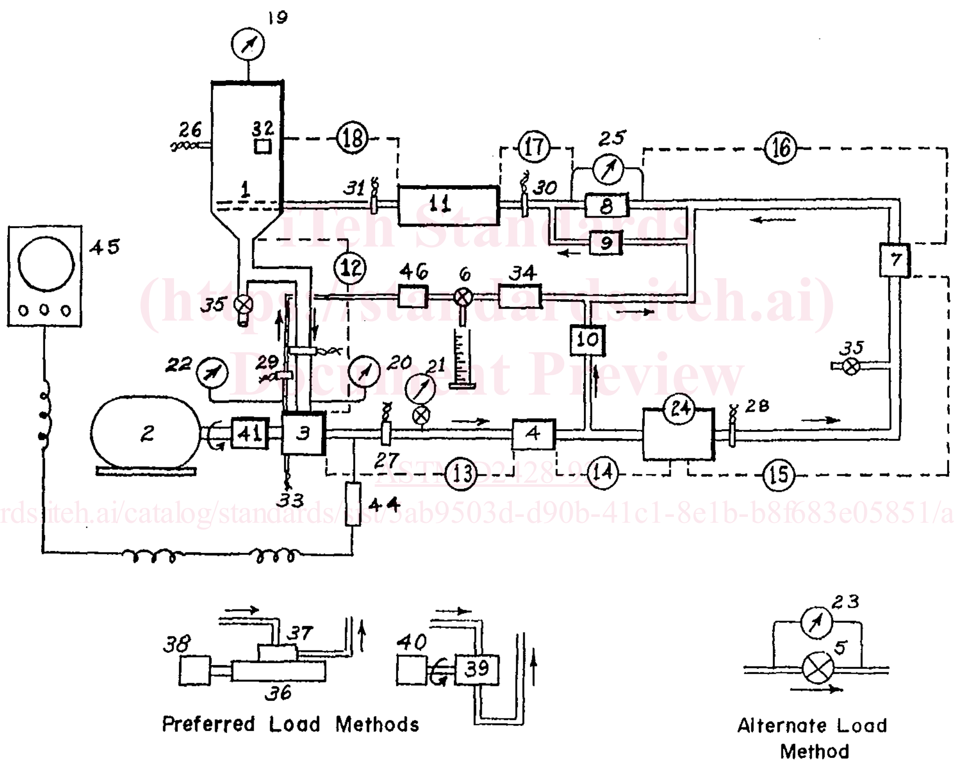
5.1 *Test System,* consisting essentially of a hydraulic power source, drive dynamometer (see Note), fluid lines, load device, reservoir, heat exchanger, a means of limiting the degree of particulate contamination, and associated pressure, flow, and temperature-sensing instrumentation. Heaters can be included where necessary or desirable to maintain narrowly or widely varied temperatures at various locations in the system, depending on the system being simulated. Considerable care must be exercised in the selection and use of heaters to preclude overheating of the fluid at heater surfaces. A power density of 15.5 kW/m^2 (10 W/$in.^2$) shall not be exceeded. A suggested test system is shown in Fig. 1.

NOTE—It may be necessary to include a torque sensor if the driver is not capable of registering this parameter.

5.2 System hardware design and materials are tailored for acceptable compatibility with the fluid temperature, physical, and chemical classifications. Selection is based upon minimizing fluid and hardware breakdown and shall reflect, where possible, the latest advances in the state-of-the-art.

5.3 Typical chemical properties which are considered are fluid oxidation, thermal, and hydrolytic stability as well as compatibility with elastomers and system materials. In examining fluid properties, samples include fluid extracted from the system, and any collected external leakage, as from the pump shaft seal, etc. Samples taken as described above are not mixed with each other as they can differ considerably in properties, especially if the system under consideration is operating at a relatively high temperature.

5.4 Consideration is given to viscosity, density, bulk modulus, gas solubility and solution, and evolution rates when designing or selecting hardware to ensure that the fluid is not penalized in a way which would not occur in the



1. Reservoir
2. Drive dynamometer
3. Pump
4. Surge damper
5. Load valve
6. Valve, case drain
7. Flow sensor
8. Filter
9. Relief valve
10. Relief valve
11. Heat exchanger
12. Suction loop
13. High-pressure loop
14. High-pressure loop
15. Return loop
16. Return loop
17. Return loop
18. Return loop
19. Gage
20. Gage
21. Gage
22. Gage
23. Gage
24. Pressure-load loop
25. Gage
26. Thermocouple
27. Thermocouple
28. Thermocouple
29. Thermocouple
30. Thermocouple
31. Thermocouple
32. Corrosion test cell
33. RPM sensor
34. Filter
35. Sample port
36. Hydraulic actuator
37. Valve
38. Inertial load[A]
39. Hydraulic motor
40. Absorption dynamometer
41. Torque sensor
42. Heater
43. Heater controller
44. Pressure transducer
45. Oscilloscope
46. Flow sensor

[A] Inertial loading may also incorporate a displacement function (for example, spring, hydraulic accumulator, etc.)

FIG. 1 Schematic Diagram of the Suggested Test System

TABLE 1 Standard Test Limitations

	Actual System Anticipated Fluid-Temperature Range, °K (°F)	Stimulated Test System Fluid Temperature max, °K (°F)
Type I	291 (65) to 344 (160)	344 (160)
Type II	291 (65) to 408 (275)	408 (275)
Type III	291 (65) to 477 (400)	477 (400)
Type IV	above 477 (400)	[A]

[A] Same as actual system anticipated upper-range fluid temperature.

TABLE 2 Limits of Variables

Temperature, K (°F)	±2.2 (±4)
Pressure kPa (psi)	±172 (±25)
Fluid volume, %	±5 of rated pump output
Flow, %	±5
Particulate contamination	optional—but sufficient to meet the requirements given in 6.6

system being simulated, for example, excessive cavitation, springiness, turbulence, etc.

5.4.1 It may be desirable in some instances, such as ascertaining the envelope of fluid usability, to operate the fluid beyond the manufacturer's intended performance range. In such instances, make a statement to that effect.

6. Variables and Limits

6.1 *Pressure*—System pressure of 21 MPa (3000 psi) is considered as standard. Tests conducted at other pressures are considered as nonstandard but can be adaptable to the method.

6.1.1 Care shall be taken to place pressure instrumentation such that reflected waves do not give erroneous data if line and load impedance are not matched. Wherever possible system line and load impendance shall be matched to eliminate standing waves. The degree of pressure pulsation damping at the pump outlet shall be optional but in all cases consistent with the requirements of the system being simulated. Piezometers shall have a straight unrestricted path 10 diameter upstream and 5 diameter downstream. Thermocouple probes should be placed in accordance with 4.2.1.

6.2 *Pressure Loading*—The principal means of providing hydraulic load is by the use of hydraulic motors, actuators, or other similar devices, depending on the system being simulated. An alternative means of imposing hydraulic load is by resisting flow with a restrictor valve. This test method is generally not simulative of most actual applications and therefore is to be referenced when used. The percentage of total flow routed through the restrictor load is recorded.

6.3 *Flow*—The test system may be designed for any desired range of flow (see also 6.5). Lines are sized to provide a Reynold's number corresponding to that of the system being simulated or the expected end use condition. The Reynold's number is recorded. Tests conducted with cycling flow are considered nonstandard but can be adapted to the method providing the profiles of pressure, flow, revolutions per minute, temperature, and other pertinent parameters are known.

6.4 *Temperature*—The bulk fluid temperature for a standard test is consistent with the temperature of the system being simulated within the limitations given in Table 1. For nonstandard tests in which the temperature does not fall under the noted classification system, maximum fluid temperature is equivalent to the maximum fluid temperature anticipated in the system being simulated.

6.5 *Fluid Volume*—It is desirable that the fluid volume in the test system be such that the time required for a complete fluid cycle through the pump, equal to total volume ((litre pump delivery (L/min)) (gallon/pump delivery (gal/min)) be not less than 1½ nor more than 2 min under the operating conditions defined in 6.1, 6.2, 6.3, and 6.4). Other volumes are considered nonstandard but can be adapted as necessary to meet that of the system being simulated or to provide for extensive sampling.

6.6 *Cleanliness*—Fluid filtration is sufficient to maintain the contamination level below that recommended by the pump and component manufacturer, or both, for operation at the selected test conditions. (Later test methods include subsystems with different cleanliness requirements.) Careful attention is paid to materials as well as filter size and configuration to meet the requirements of the simulated system. Filter location is optional, but must not be installed in the suction line. Filtration may be provided in any part of the system, except in the pump suction line, as required for proper simulation.

6.6.1 It may be desirable under certain circumstances to use a screen in the pump suction line. In such an event the mesh size can be small enough to afford the required protection to the pump but the surface area shall be sufficient to preclude cavitating the pump by starvation.

6.7 *Instrumentation and Controls Measuring*—Recording and controlling devices capable of monitoring and controlling test variables as defined in this section are provided. Instrumentation accuracy is sufficient to assure the compliance of variables within the limits given in Table 2.

6.7.1 Stated accuracies refer to the accuracies of the measuring and controlling devices when operated at the selected test conditions of temperature, pressure, and flow. The method of stating accuracy is optional but shall be referenced.

7. Procedure

7.1 *Cleaning*—Clean the internal portions of the system prior to each test. Procedures and cleaning equipment shall provide for removal of fluid, surface coatings, and particulate contamination consistent with the system requirements being simulated.

7.2 *Run-In*—Conduct pump run-in procedures in accordance with manufacturers recommendations. Where comparative pump life is to be used as an index of performance all pumps are run-in using identical procedures and the same type of fluid. In general, the fluid used for run-in is drained and not used for the test. If a weight loss analysis is desired, the pump components are weighed prior to run-in.

7.3 *Operation*—Operation of the test system is continuous for standard tests. Nonstandard tests in which the operation of the test system is not continuous may be adapted to the general test method, but must bear the notation *noncontinuous* and make reference in the test results or data the number of equipment shutdowns, the reason for and duration of the shutdown, as well as the total time in days and hours required to complete the test.

7.4 *Fluid Sampling*—Fluid samples are taken at intervals sufficient to define changes in physical and chemical properties of the fluid with operation of the test device, and to ensure that particle contamination requirements are maintained in accordance with 6.6. In general, sampling intervals must be more frequent during the initial phases of an evaluation. This is particularly true if polymeric thickeners (viscosity index improvers) are compounded with the fluid which tend to decrease their effect on viscosity with continued use. Whenever possible, portions of samples which have not been destructively tested (for example, those from viscosity, cloud and pour points, or density) are returned to the system. Take care when returning samples to high-temperature systems. Samples removed at high temperatures, when suddenly exposed to the atmosphere, can oxidize, or otherwise react in a manner not representative of the reactions taking place within the relatively air-free hydraulic system. If sampling or other loss leads to deviation from the ratios given in 6.5, fresh fluid may be added. The volume and time of such additions must be recorded.

7.5 *Fluid Analysis*—The fluid analysis is made in accordance with the following methods:

7.5.1 *Particulate Contamination:*

7.5.1.1 *Identification*—Practices F 303. Test Method F 313.

7.5.1.2 *Gravimetric*—Test Method F 313.

7.5.2 *Physical Properties:*

	ASTM Test Methods[A]
Autogenous Ignition Temperature	D 2155
Cloud and Pour Points	D 97
Density (Pycnometer)	D 941
Flash and Fire Point (COC)	D 92
Neutralization Number	D 974 or D 664
Viscosity (Kinematic)	D 445
Viscosity (Saybolt)	D 88
Water Content (Karl Fischer)	D 1533

[A] These designations refer to the following ASTM methods:

8. Report

8.1 Report all the applicable data on the following forms (examples are illustrated in the Appendix):

8.1.1 Results,

8.1.2 Test procedure log,

8.1.3 System configuration log,

8.1.4 Test parameter log, and

8.1.5 Component identification log.

9. Precision and Bias

9.1 Because of the complex nature of Test Method D 2428 for simulative recirculating system testing and because of the expensive equipment involved in the initial set-up of the test method, there is not a sufficient number of volunteers to permit a cooperative laboratory program for determining the precision and bias of this test method. If the necessary volunteers can be otained, a program will be undertaken at a later date.

10. Keywords

10.1 aerospace hydraulic fluids; hydraulic fluids; recirculating system

APPENDIX

(Nonmandatory Information)

X1. DATA COMPILATION

X1.1 Results

X1.1.1 Place the tabulated results on Table X1.1 and the plotted data on Figs. X1.1 to X1.5 as applicable.

X1.2 Test Procedure Log

X1.2.1 *Cleanliness*—Describe the test method in the same sequence as used. List solvents or flushing fluids, number of flushings, mechanical scrubbing, etc. State method used to determine the cleanliness level obtained.

X1.2.2 *Run-In*—Describe the pump run-in method, defining temperature, pressure flow, fluid used, and time. In the event pump components are weighed prior to run-in, tabulate the weights, providing space for entrance of successive weighing data.

X1.2.3 *Operation*—Describe any pertinent information not specified on the configuration log, Table X1.2.

X1.3 System Configuration Log

X1.3.1 Tabulate the system information noted in Table X1.2.

X1.4 Test Parameter Log

X1.4.1 Tabulate the data on Table X1.3.

X1.5 Component Identification Log

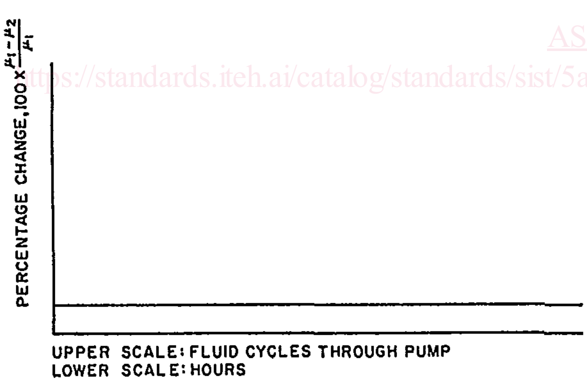
X1.5.1 Compile the information noted in Table X1.4. It is important that all the information, as applicable, be obtained.

TABLE X1.1 System Operating Data

Data							
Time reference		—	—	—	—	—	—
Case drain flow	(5B)	—	—	—	—	—	—
Flow, L/min (gal/min)	(6)	—	—	—	—	—	—
Reservoir pressure, kPa (psia)	(12)	—	—	—	—	—	—
Pump inlet pressure, kPa (psia)	(13)	—	—	—	—	—	—
Pump outlet pressure, kPa (psi)	(14)	—	—	—	—	—	—
Loading valve differential pressure, kPa (psi)	(16)	—	—	—	—	—	—
Filter differential pressure, kPa (psi)	(17)	—	—	—	—	—	—
Reservoir temperature, K (°F)	(18)	—	—	—	—	—	—
Pump outlet temperature, K (°F)	(19)	—	—	—	—	—	—
Return fluid temperature, K (°F)	(20)	—	—	—	—	—	—
Case drain temperature, K (°F)	(21)	—	—	—	—	—	—
Heat exchanger inlet temperature, K (°F)	(22)	—	—	—	—	—	—
Heat exchanger outlet temperature, K (°F)	(23)	—	—	—	—	—	—
Corrosion cell	(24)	—	—	—	—	—	—
Pump, rpm	(25)	—	—	—	—	—	—
Input torque, n·m (in.·lb)	(2)	—	—	—	—	—	—
Other Data							
		—	—	—	—	—	—
		—	—	—	—	—	—
		—	—	—	—	—	—
		—	—	—	—	—	—
		—	—	—	—	—	—
		—	—	—	—	—	—
		—	—	—	—	—	—

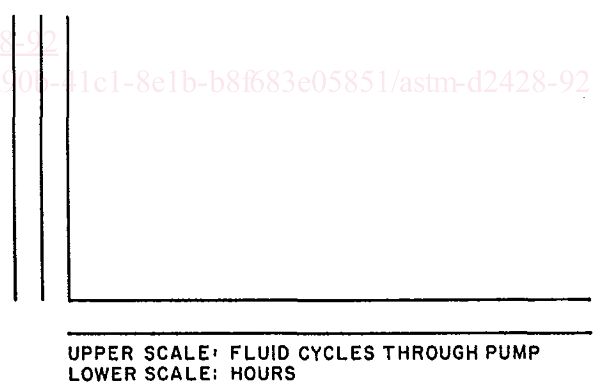
Operating Continuity

	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop	Start	Stop
Date												
Time												
Total hours												



NOTE—Kinematic viscosity, cSt (mm²/s), measured at 38°C (100°F) atmospheric pressure, using Test Method D 445, unless otherwise specified.

FIG. X1.1 Viscosity Change



NOTE—Any significant fluid variable, such as specific gravity (Test Methods D 1298, D 941, D 1480, and D 1481), neutralization number (Test Methods D 664 and D 974), water content (Test Method D 1533), flash point (Test Method D 92), etc., can be plotted as the ordinate.

FIG. X1.2 Fluid Performance

TABLE X1.2 System Configuration Log

Item	Description	Value
1	Total system volume, L (gal), ± 10 %	—
2	Pump flow at test pressure L/min (gal/min)	—
3	Period for one theoretical fluid cycle-through pump;	
	$\frac{\text{Total system volume, initial}}{\text{Pump output flow plus case leakage at test pressure, initial}}$ = minutes, initial	—
	$\frac{\text{Total system volume, one fourth completed}}{\text{Pump flow at test pressure, one fourth completed}}$ = minutes, one fourth completed	—
	$\frac{\text{Total system volume, one half completed}}{\text{Pump flow at test pressure, one half completed}}$ = minutes, one half completed	—
	$\frac{\text{Total system volume, three fourths completed}}{\text{Pump flow at test pressure, three fourths completed}}$ = minutes, three fourths completed	—
	$\frac{\text{Total system volume, test completed}}{\text{Pump flow at test pressure, test completed}}$ = minutes, test completed	—
4	Schematic diagram of actual test stand	—
5	Chronological listing of component or configuration changes:	

Date	Item Number	Total Test Time When Part Changed	Total Hours on Part	Reason
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______
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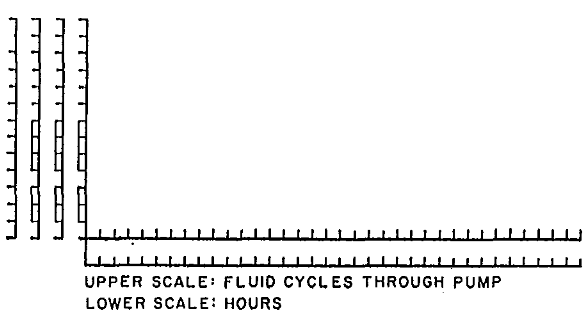
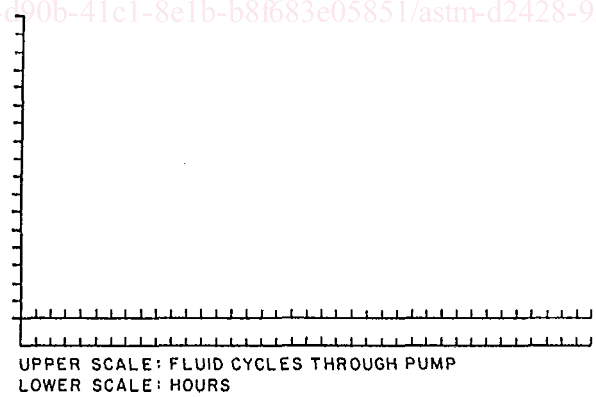


NOTE—Test Method D 2387, and Test Method D 2430.

FIG. X1.3 Contamination



NOTE 1—Any significant pump variable, such as case leakage flow, efficiency, or component weight loss, can be plotted as the ordinate.

NOTE 2—Flow measured with pump operating at: ______ kPa (psig) outlet; ______ (°C °F); ______ rpm.

FIG. X1.4 Pump Performance