

Submitted for recognition as an American National Standard

Hydraulic Power Pump Test Procedure

Foreword—This Reaffirmed document has been changed only to reflect the new SAE Technical Standards Board format.

1. Scope—This test code describes tests for determining characteristics of hydraulic positive displacement pumps used on construction and industrial machinery as referenced in SAE J1116. These characteristics are to be recorded on data sheets similar to the ones shown in Figures 1 to 3. Two sets of data sheets are to be submitted: one at 49 °C (120 °F) and one at 82 °C (180 °F).

1.1 Purpose—This test code establishes conditions for pump tests, outlines a procedure for tests, and establishes a method of presenting pump test data. The procedure covers the following determinations:

- a. Derived capacity
- b. Delivery characteristics
- c. Power input
- d. Power loss
- e. Overall efficiency
- f. Pressure compensator response and recovery
- g. Flow compensator response and recovery

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

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

SAE J1116—Categories of Off-Road Self-Propelled Work Machines

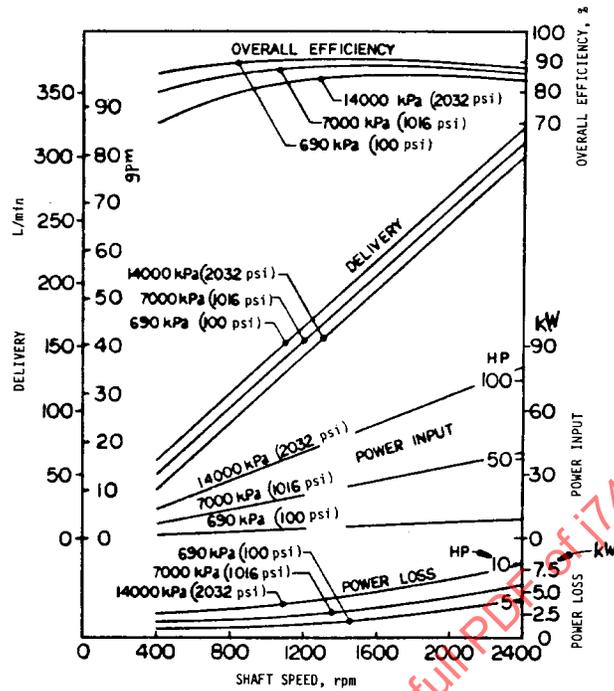
SAE J1276—Standardized Fluid for Hydraulic Component Tests

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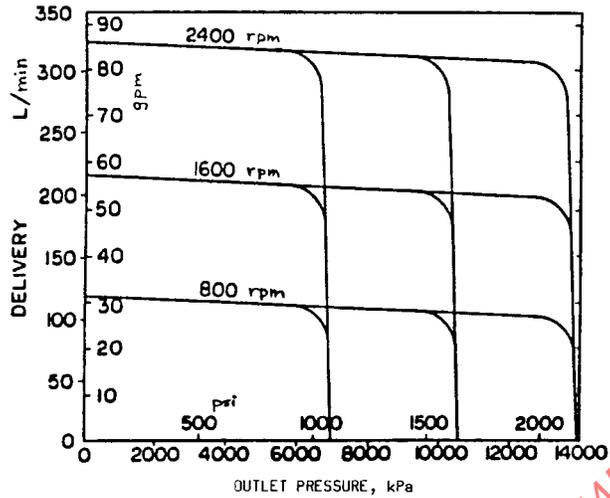
PERFORMANCE DATA FOR A CONSTANT DISPLACEMENT HYDRAULIC PUMP

Manufacturer: ACME Mfg. Co.
 Series or Type: ZYX
 Model: 9Y13
 Rotation: Clockwise

Test Fluid: Dexron II ATF
 Fluid Temperature: 49 °C (120 °F)
 Fluid Viscosity: 24.5 mm²/s (114 SUS)
 Pump Inlet Pressure: 772 mm Hg abs (14.9 psia)
 SAE Derived Capacity: 134.4 mL/rev (8.2 in³/rev)

FIGURE 1—WORK SHEET 1

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PERFORMANCE DATA FOR A PRESSURE COMPENSATED HYDRAULIC PUMP

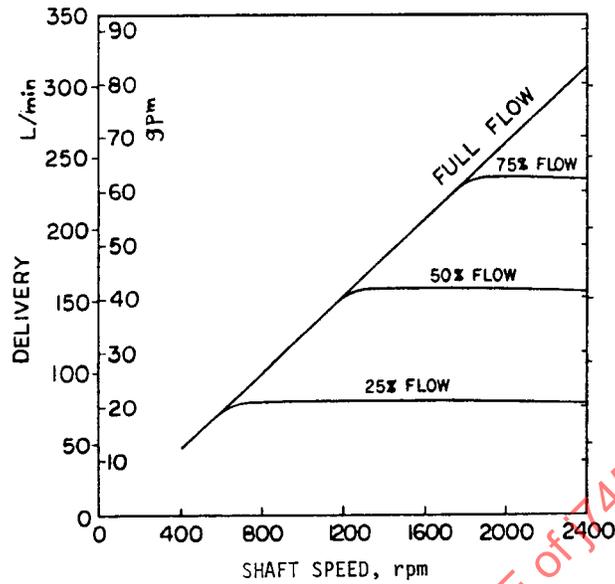
Manufacturer: ACME Mfg. Co.
 Series or Type: ZYX
 Model: 9Y13
 Rotation: Clockwise

Test Fluid: Dexron II ATF
 Fluid Temperature: 49 °C (120 °F)
 Fluid Viscosity: 24.5 mm²/s (114 SUS)
 Pump Inlet Pressure: 772 mm Hg abs (14.9 psia)
 SAE Derived Capacity: 134.4 mL/rev (8.2 in³/rev)

Speed	Deadhead pressure		Deadhead Input Power		Response Settling Time	Recovery Time	Rate of Pressure Rise		Rate of Pressure Drop		Overshoot	
	rpm	kPa	psi	kW	HP	ms	ms	kPa/s	psi/s	kPa/s	psi/s	kPa
2400	14 000	2032	7.5	10.1	55/150	75	1 380 000	200 000	1 380 000	200 000	3440	500
2400	10 500	1524	5.0	6.7	60/155	80	1 380 000	200 000	1 380 000	200 000	2750	400
2400	7 000	1016	2.3	3.1	65/160	85	1 380 000	200 000	1 380 000	200 000	2400	350
1600	14 000	2032	5.0	6.7	70/170	100	1 380 000	200 000	1 380 000	200 000	2750	400
1600	10 500	1524	3.2	4.3	70/175	105	1 380 000	200 000	1 380 000	200 000	2400	350
1600	7 000	1016	1.6	2.1	75/180	110	1 380 000	200 000	1 380 000	200 000	2400	350
800	14 000	2032	2.5	3.4	105/205	130	1 380 000	200 000	1 380 000	200 000	2060	300
800	10 500	1524	1.6	2.1	105/225	135	1 380 000	200 000	1 380 000	200 000	2060	300
800	7 000	1016	0.8	1.1	110/230	135	1 380 000	200 000	1 380 000	200 000	1890	275

FIGURE 2—WORK SHEET 2

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PERFORMANCE DATA FOR A PRESSURE COMPENSATED HYDRAULIC PUMP

Manufacturer: ACME Mfg. Co.
 Series or Type: ZYX
 Model: 9Y13
 Rotation: Clockwise

Test Fluid: Dexron II ATF
 Fluid Temperature: 49 °C (120 °F)
 Fluid Viscosity: 24.5 mm²/s (114 SUS)
 Pump Inlet Pressure: 772 mm Hg abs (14.9 psia)
 SAE Derived Capacity: 134.4 mL/rev (8.2 in³/rev)

Speed	Standby Pressure		Standby Input Power		Flow Response Time	Flow Recovery Time	Rate of Pressure Rise		Rate of Pressure Drop	
	kPa	psi	kW	HP			kPa/s	psi/s	kPa/s	psi/s
2400	1400	203	1.0	1.3	60	80	750 000	109 000	700 000	102 000
1600	1400	203	0.7	0.9	85	140	750 000	109 000	700 000	102 000
800	1400	203	0.3	0.4	125	200	750 000	109 000	700 000	102 000

FIGURE 3—WORK SHEET 3

3. Constant and Hydraulic Positive Displacement Hydraulic Pumps—General Definitions

- 3.1 Delivery**—The flow output per unit time expressed in liters per minute (L/min) or gallons per minute (gpm).
- 3.2 Deadhead Pressure**—The pressure developed by a pressure compensated pump when the outlet is blocked (delivery is zero).
- 3.3 Standby Pressure**—The pressure developed by a flow compensated pump when no load signal pressure is present and the pump outlet is blocked.
- 3.4 Margin Pressure**—In a flow compensated pump, the differential between the pressure measured at the pump outlet port and the pressure controlling pump displacement at some condition other than standby.
- 3.5 Response Time, Pressure Compensator**—The time in milliseconds between the instantaneous pressure's crossing of deadhead pressure on the pressure rise and its subsequent reaching of deadhead pressure on the pressure drop when tested according to Test 4 of this procedure. (See Figure 4.)

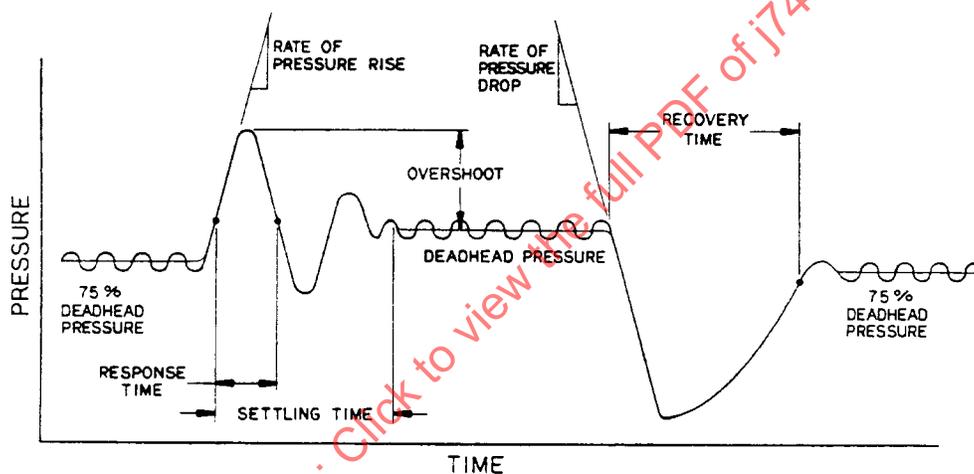


FIGURE 4—PRESSURE COMPENSATOR RESPONSE AND RECOVERY

- 3.6 Recovery Time, Pressure Compensator**—The time in milliseconds between the start of the pressure drop and the subsequent reaching of 75% of the deadhead pressure on the first rise of the instantaneous pressure curve when tested according to Test 4 of this procedure. (See Figure 4.)
- 3.7 Settling Time**—The time in milliseconds between the instantaneous pressure's crossing of deadhead pressure on the pressure rise and its subsequent decay into the repeatable pressure ripple when the pressure compensator is tested according to Test 4 of this procedure. (See Figure 4.)
- 3.8 Response Time, Flow Compensator**—The time in milliseconds between the start of the pressure drop and the subsequent reaching of the standby pressure when tested according to Test 6 of this procedure. (See Figure 5.)
- 3.9 Recovery Time, Flow Compensator**—The time in milliseconds between the start of the pressure rise and the initial development of 75% of deadhead pressure when tested according to Test 6 of this procedure. (See Figure 5.)
- 3.10 Derived Capacity**—The actual pump displacement as measured in Test 1, expressed in mL/rev or in 3 rev.

3.11 Overshoot—The difference between the peak pressure spike and the mean steady-state deadhead pressure observed during the response time test. (See Figure 4.)

4. Material and Apparatus

4.1 Test Fluid—Test fluid shall preferably be per SAE J1276. The actual fluid type and viscosity shall be recorded on work sheets (Figures 1 to 3).

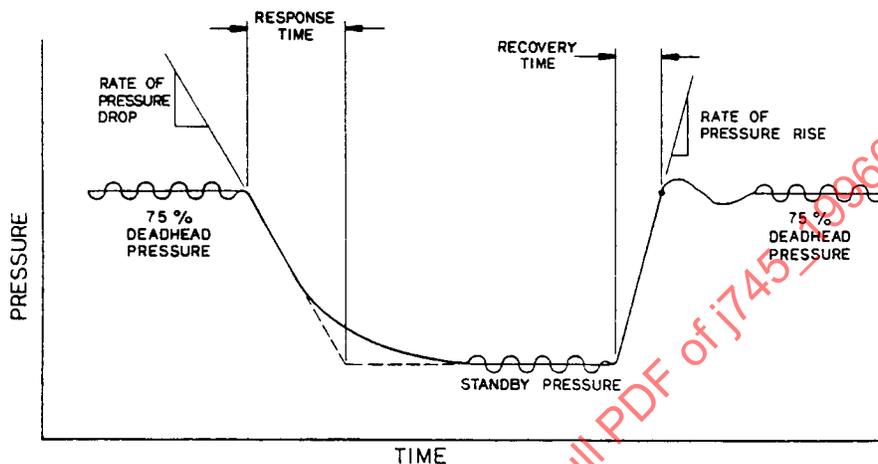


FIGURE 5—FLOW COMPENSATOR RESPONSE AND RECOVERY

4.2 Pump Torque and Speed Measuring Apparatus—Torque measurement must be accurate within $\pm 1\%$ and speed measurement must be accurate within $\pm 0.5\%$. The test setup shall not impose radial or axial loads upon the driveshaft of the hydraulic pump under test. Torque shall be expressed in Newton meters (N·m) or inch pound-force (lbf·in).

4.3 Flow Measurement—Flow measurement shall be accurate within $\pm 1.0\%$. Outlet pressure shall be expressed in kilo-pascals gage (kPag) or pounds per square inch gage (psig). Inlet pressure shall be expressed in millimeters of Mercury absolute (mm Hg abs) or inches of Mercury absolute (in Hg abs).

4.4 Temperature Measurement and Control—Fluid Temperature shall be measured in the reservoir at the entrance to the pump supply line by means of a thermometer or thermocouple. Fluid temperature shall be maintained at the prescribed level throughout the test within $\pm 3\text{ }^{\circ}\text{C}$ ($5\text{ }^{\circ}\text{F}$). Temperature shall be expressed in degrees Celsius (C) or degrees Fahrenheit (F).

4.5 Pump Inlet Line—Total pressure drop from the reservoir to the pump inlet shall not exceed 127 mm (5 in) Hg. Unless otherwise required, the pump inlet pressure at the inlet fitting shall be maintained within 25.4 mm (1 in) Hg of atmospheric pressure at pump maximum displacement and rated speed. This can be controlled by reservoir fluid level and/or reservoir pressure. The inlet pressure will be permitted to rise as variable pump displacement is reduced. A shutoff valve may be installed at least 20 diameters upstream from the pump in the inlet line.

4.6 Reservoir—To minimize aeration, the return fluid shall enter the reservoir at a point below the surface of the fluid. Return fluid shall be diffused in such a manner as to minimize turbulence in the reservoir and to prevent the return fluid short circuiting to the pump inlet. Provision shall be made to prevent settlings entering the inlet line. Filtration shall be provided such that the fluid cleanliness level is maintained within the pump manufacturer's recommendations.

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5. Working Formulas—The following formulas may be utilized to calculate performance parameters:

5.1 SAE Theoretical Hydraulic Power—See Equations 1 and 2.

$$= \frac{\text{Derived Cap. (mL/rev.)} \times \text{Speed (rpm)} \times \text{Pressure (kPag)}}{60000} \text{ (W)} \quad \text{(Eq. 1)}$$

$$= \frac{\text{Derived Cap. (in}^3\text{/rev)} \times \text{Speed (rpm)} \times \text{Pressure (psig)}}{396000} \text{ (HP)} \quad \text{(Eq. 2)}$$

5.2 Hydraulic Power—See Equations 3 and 4.

$$= \frac{\text{Delivery (L/min)} \times \text{Pressure (kPag)}}{60} \text{ (W)} \quad \text{(Eq. 3)}$$

$$= \frac{\text{Delivery (gpm)} \times \text{Pressure (psig)}}{1714} \text{ (HP)} \quad \text{(Eq. 4)}$$

5.3 Power Input—See Equations 5 and 6.

$$= \frac{\text{Torque (N} \cdot \text{m)} \times \text{Speed (rpm)}}{9.549} \text{ (W)} \quad \text{(Eq. 5)}$$

$$= \frac{\text{Torque (lbf} \cdot \text{in)} \times \text{Speed (rpm)}}{63025} \text{ (HP)} \quad \text{(Eq. 6)}$$

5.4 Torque Efficiency, (%)—See Equation 7.

$$= \frac{\text{Theoretical Hydraulic Power}}{\text{Power Input}} \times 100 \quad \text{(Eq. 7)}$$

5.5 Overall Efficiency, (%)—See Equation 8.

$$= \frac{\text{Hydraulic Power}}{\text{Power Input}} \times 100 \quad \text{(Eq. 8)}$$

5.6 Power Loss—See Equation 9.

$$= \text{Power Input} - \text{Hydraulic Power} \quad \text{(Eq. 9)}$$

6. Constant Displacement Open Circuit Hydraulic Pump Tests

6.1 Test 1—SAE Derived Capacity

6.1.1 Set up pump as recommended in Figure 6.

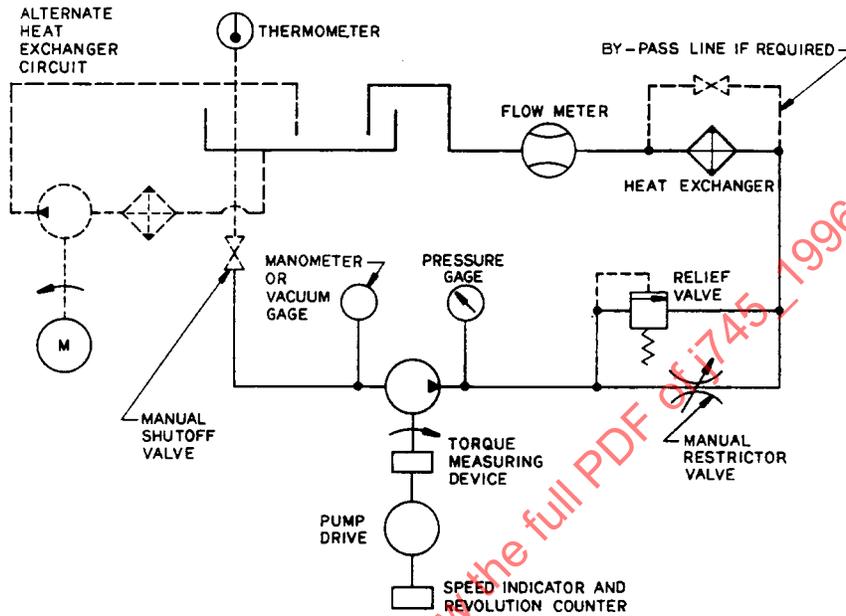


FIGURE 6—TYPICAL TEST SETUP FOR DELIVERY AND POWER DETERMINATION

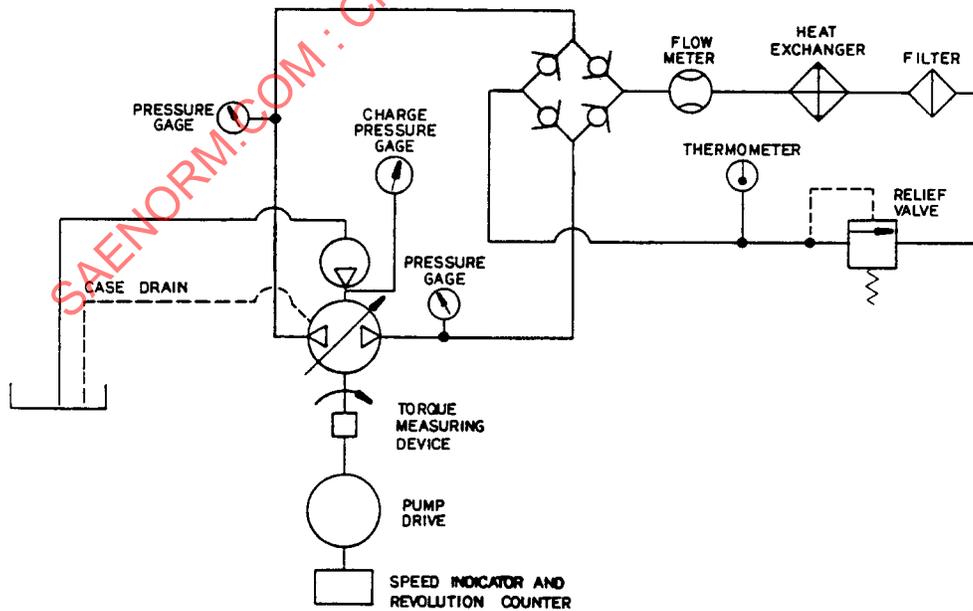


FIGURE 6A—TYPICAL TEST SETUP FOR DELIVERY AND POWER DETERMINATION FOR CLOSED CIRCUIT PUMPS

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- 6.1.2 Operate pump with an inlet to outlet differential pressure equal to 5% of the pump's continuous pressure rating using fluid at 49 °C (120 °F).
- 6.1.3 Record delivery at selected speeds over the full rated speed range.
- 6.1.4 Ignoring nonlinear ends of the speed-delivery curve, determine the SAE derived capacity as the slope of the curve obtained in 6.1.3 (delivery/rpm).

6.2 Test 2—Performance Characteristics

- 6.2.1 Set up pump as recommended in Figure 6.
- 6.2.2 With discharge pressure adjusted to 690 kPa (100 psi) maximum at rated speed, operate pump from minimum to rated speed in a suitable number of steps using fluid at 49 °C (120 °F). Record input torque, delivery, inlet pressure, outlet pressure, and speed.
- 6.2.3 Repeat 6.2.2 at rated and at least one intermediate discharge pressure.
- 6.2.4 Repeat 6.2.2 and 6.2.3 with the inlet at 127 mm (5 in) Hg below atmospheric by adjusting the shutoff valve in the inlet line. Use precautions to avoid the excessive release of entrained air or the ingestion of air into the inlet line.
- 6.2.5 Repeat 6.2.2, 6.2.3, and 6.2.4 with fluid temperature at 82 °C (180 °F).
- 6.2.6 Present performance data in a format similar to that shown on Work Sheet 1 (Figure 1).

- 7. **Closed Circuit Hydraulic Pump Tests at Constant Displacement**—This section applies only to pumps without full flow charge pumps.

Perform Tests 1 and 2 per 6.1 and 6.2 in an open circuit mode with externally supplied charge pressure. Omit 6.2.4. Alternatively, use the modified circuit of Figure 6A. Maintain pump inlet pressure consistent with the pump manufacturer's recommendations. Recognize that inlet to outlet differential pressure should be used in working formulas rather than outlet pressure.

- 8. **Variable Displacement Pressure Compensated Pump Tests**—Perform Tests 1 and 2 per 6.1 and 6.2. Maximum pressure can be 5 to 20% below deadhead pressure, so that pump remains at full displacement. Where required by the pump's control system, increase the specified pressure differential in Test 1 so that full flow is achieved.

8.1 Test 3—Pressure Compensator Performance

- 8.1.1 At the minimum, rated, and one intermediate speed used in 6.2 and at rated deadhead pressure, reduce pump delivery from maximum to zero with manual restrictor valve in adequate steps to define performance curves. Record input torque, pressure, delivery, and speed.
- 8.1.2 Repeat 8.1.1 at recommended minimum and one intermediate deadhead setting.

8.2 Test 4—Response Time and Recovery Time

- 8.2.1 Add a rapid shutoff valve (such as a direct solenoid operated valve) in series with the manual restrictor valve and connect a pressure transducer in the pump outlet line so that instantaneous pressure can be recorded against time on an oscilloscope (or oscillograph). (See circuit drawing in Figure 7.)

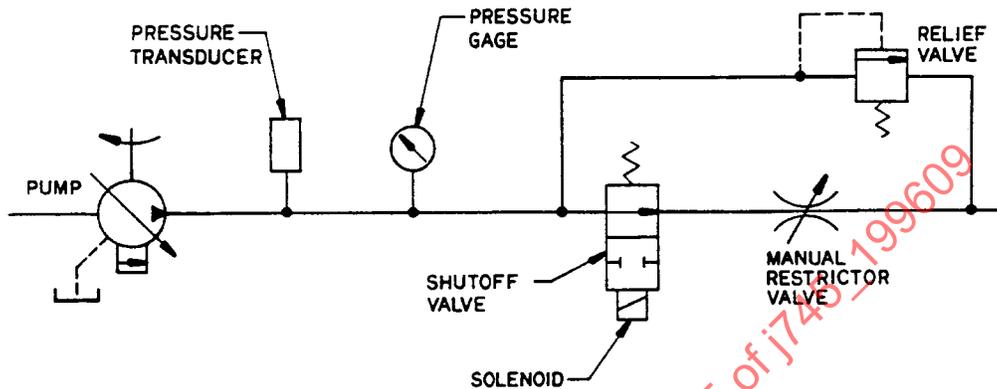


FIGURE 7—TYPICAL TEST SETUP FOR RESPONSE TIME OF PRESSURE COMPENSATOR

- 8.2.2 Condition circuit such that pressure rise rate is between 690 000 and 2 060 000 kPa/s (100 000 and 300 000 psi/s) when shutoff valve is closed. Use 1 380 000 kPa/s (200 000 psi/s) as the target pressure rise rate.
- 8.2.3 With pump running at rated speed, deadhead pressure set at rated pressure, relief valve set to limit maximum steady-state pressure to no less than 125% of deadhead pressure setting, and shutoff valve open, adjust manual restrictor valve to maintain 75% of deadhead pressure.
- Close shutoff valve while recording instantaneous pressure against time. From this recording, determine the rate of pressure rise in kPa/s or psi/s, overshoot in kPa or psi, and pressure compensator response and settling times in milliseconds. (See Figure 4.)
 - Open shutoff valve while recording instantaneous pressure against time. From this recording, determine the rate of pressure drop in kPa/s or psi/s and pressure compensator recovery time in milliseconds. (See Figure 4.)
- 8.2.4 Repeat 8.2.3 at minimum speed and at one intermediate speed.
- 8.2.5 Present pressure compensator test data in a format similar to that shown on Work Sheet 2 (Figure 2).
- 9. Variable Displacement Pressure and Flow Compensated (Load Sensing) Pump Tests**—Set up the test circuit shown in Figure 8. The flow compensator shall be rendered inoperative during test by opening the flow control orifice fully. Maximum pressure can be 5 to 20% below deadhead pressure. Perform Tests 1 and 2, and present data in a format similar to that shown in Work Sheet 1 (Figure 1). Where required by the pump's control system, increase the specified pressure differential in Test 1 so that full flow is achieved.