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Hydraulic Power Pump Test Procedure

SAE Standard
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Submitted for Recognition as an American National Standard

SAE The Engineering Society For Advancing Mobility Land Sea Air and Space

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OFF-HIGHWAY MACHINERY STANDARD

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∅ HYDRAULIC POWER PUMP TEST PROCEDURE

CONSTANT AND VARIABLE POSITIVE DISPLACEMENT HYDRAULIC PUMPS

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. 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 herein. Two sets of data sheets are to be submitted: one at 49°C (120°F) and one at 82°C (180°F).

3. 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 measured at the compensator sensing port, while the flow compensator is 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 Fig. 3).

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 Fig. 3).

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 Fig. 3).

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 Fig. 4).

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 Fig. 4).

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 Fig. 3).

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 the work sheets.

4.2 Pump Torque and Speed Measuring Apparatus: Torque measurement must be accurate within ±1% and speed measurement must be accurate within ±0.5%. The test setup shall not impose radial or axial loads upon the drive shaft 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 ±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 +3°C (5°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.

5. WORKING FORMULAS: The following formulas may be utilized to calculate performance parameters:

5.1 SAE Theoretical Hydraulic Power:

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

$$= \frac{\text{Derived Cap. (in3/rev.)} \times \text{Speed (rpm)} \times \text{Pressure (psig)}}{396000} \quad \text{(HP)}$$

5.2 Hydraulic Power:

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

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

5.3 Power Input:

$$= \frac{\text{Torque (N·m)} \times \text{Speed (rpm)}}{9.549} \quad \text{(W)}$$

$$= \frac{\text{Torque (lbf·in)} \times \text{Speed (rpm)}}{63025} \quad \text{(HP)}$$

5.4 Torque Efficiency, (%):

$$= \frac{\text{Theoretical hydraulic power}}{\text{Power Input}} \times 100$$

5.5 Overall Efficiency, (%):

$$= \frac{\text{Hydraulic Power}}{\text{Power Input}} \times 100$$

5.6 Power Loss:

= Power Input - Hydraulic Power

6. CONSTANT DISPLACEMENT OPEN CIRCUIT HYDRAULIC PUMP TESTS:

6.1 Test 1 - SAE Derived Capacity:

6.1.1 Set up pump as recommended in Fig. 1.

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 paragraph 6.1.3 (delivery/rpm).

6.2 Test 2 - Performance Characteristics:

6.2.1 Set up pump as recommended in Fig. 1.

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 paragraph 6.2.2 at rated and at least one intermediate discharge pressure.

6.2.4 Repeat paragraphs 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 paragraphs 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.

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 paragraphs 6.1 and 6.2 in an open circuit mode with externally supplied charge pressure. Omit paragraph 6.2.4. Alternatively, use the modified circuit of Fig. 1a. 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 paragraphs 6.1 and 6.2. Maximum pressure can be 5 - 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 paragraph 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 paragraph 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 into the pump outlet line so that instantaneous pressure can be recorded against time on an oscilloscope (or oscillograph). (See circuit drawing in Fig. 2.)

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/sec) when shutoff valve is closed. Use 1 380 000 kPa/s (200 000 psi/sec) 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.

a) Close shutoff valve while recording instantaneous pressure against time. From this recording, determine the rate of pressure rise in kPa/s or psi/sec, overshoot in kPa or psi, and pressure compensator response and settling times in milliseconds (See Fig. 3).

b) Open shutoff valve while recording instantaneous pressure against time. From this recording, determine the rate of pressure drop in kPa/s or psi/sec and pressure compensator recovery time in milliseconds (See Fig. 3).

8.2.4 Repeat paragraph 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.

9. VARIABLE DISPLACEMENT PRESSURE AND FLOW COMPENSATED (LOAD SENSING) PUMP TESTS: Set up the test circuit shown in Fig. 5. The flow compensator shall be rendered inoperative during test by opening the flow control orifice fully. Maximum pressure can be 5 - 20% below deadhead pressure. Perform Tests 1 and 2, and present data in a format similar to that shown in Work Sheet 1. Where required by the pump's control system, increase the specified pressure differential in Test 1 so that full flow is achieved.

9.1 Test 5 - Compensator Performance:

9.1.1 Using the circuit shown in Fig. 5, adjust the flow control orifice such that the pump is at full flow.

9.1.2 At the minimum, rated, and one intermediate speed used in paragraph 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. Present data in a format similar to that shown on Work Sheet 2. Record standby power data for reporting on Work Sheet 3.

9.1.3 Repeat step 2 at recommended minimum and one intermediate deadhead setting.

9.1.4 With manual restrictor valve fully open and flow control valve set at full flow, record delivery versus speed as shaft speed is varied from minimum to maximum rated RPM and back to minimum. Repeat procedure with flow control valve set at 75%, 50% and 25% of maximum flow. Present data in a format similar to that shown in the plot on Work Sheet 3.

9.1.5 Adjust manual restrictor valve fully open and operate pump at rated speed. With a differential pressure transducer installed between the pump outlet and pump sensing ports, record margin pressure as the flow is varied from zero to maximum via the flow control valve in at least four steps. Alternatively, install two individual pressure transducers and calculate the margin pressure at each condition. Present the data in the form of a table listing margin pressure for each flow or as a continuous plot of margin pressure vs flow.

9.2 Test 6 - Response and Recovery:

9.2.1 Condition the circuit of Fig. 5 such that it conforms to the requirements of paragraph 8.2.2. If the pump does not contain an integral signal bleed orifice, install one as shown in Fig. 5, sized per the pump manufacturer's recommendations.

9.2.2 With flow control orifice fully open, perform paragraphs 8.2.3, 8.2.4, and 8.2.5.

9.2.3 With pump running at rated speed, deadhead pressure set at rated pressure, shutoff valve open, and flow control orifice set for full pump flow, adjust manual restrictor valve to produce 75% of deadhead pressure.

a) Energize signal valve to disconnect pump signal line while recording instantaneous pressure against time. From this recording, determine the rate of pressure drop in kPa/s or psi/sec and the flow compensator response time in milliseconds (See Fig. 4).

b) De-energize signal valve while recording instantaneous pressure against time. From this recording, determine the rate of pressure rise in kPa/s or psi/sec and the flow compensator recovery time in milliseconds (See Fig. 4).

9.2.4 Repeat paragraph 9.2.3 at minimum speed and at one intermediate speed.

9.2.5 Present flow compensator dynamic test data in a format similar to that shown in the table on Work Sheet 3.

10. REFERENCES:

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

SAE J1276, Standardized Fluid for Hydraulic Component Tests

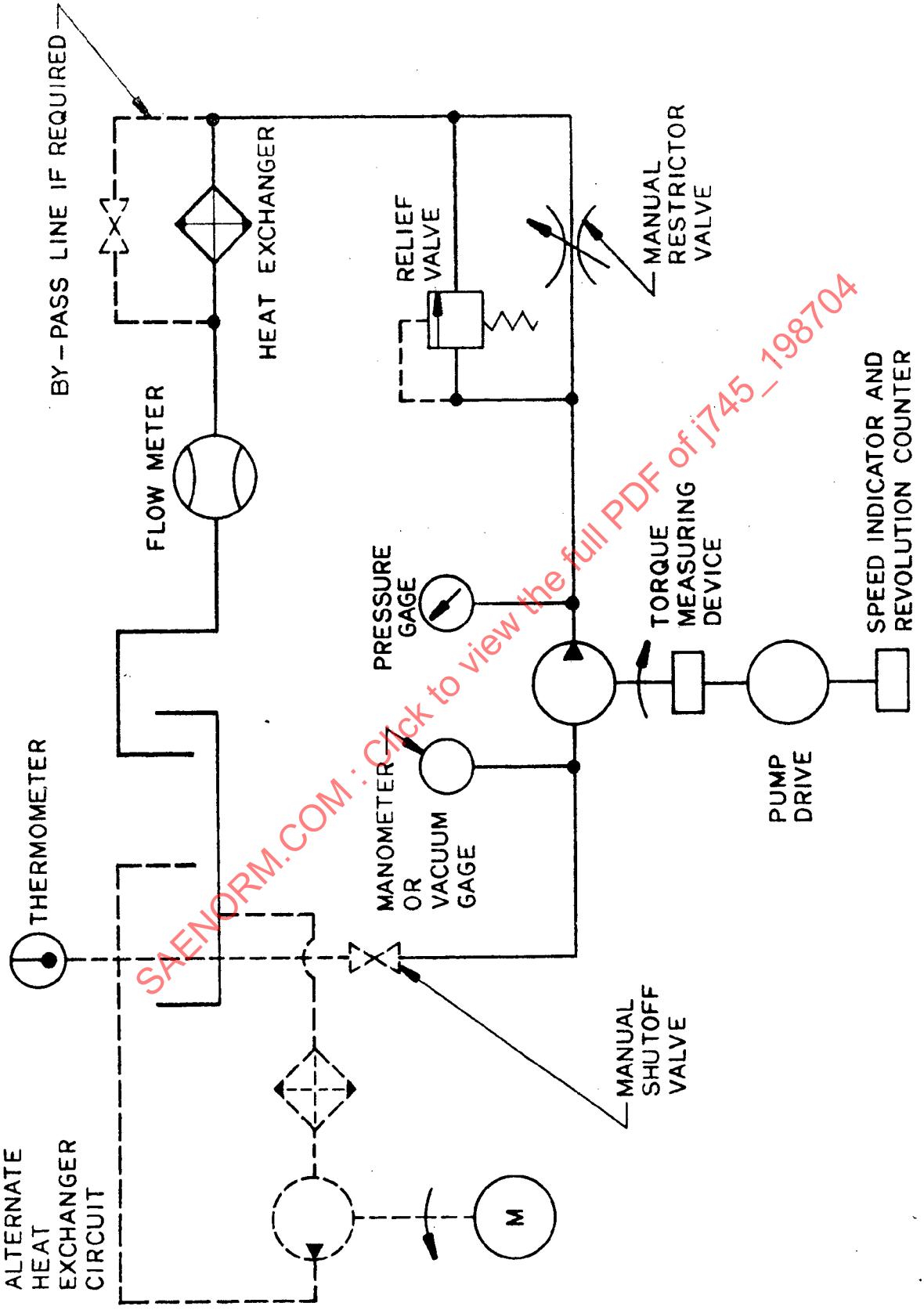


FIG. 1 - TYPICAL TEST SETUP FOR DELIVERY AND POWER DETERMINATION

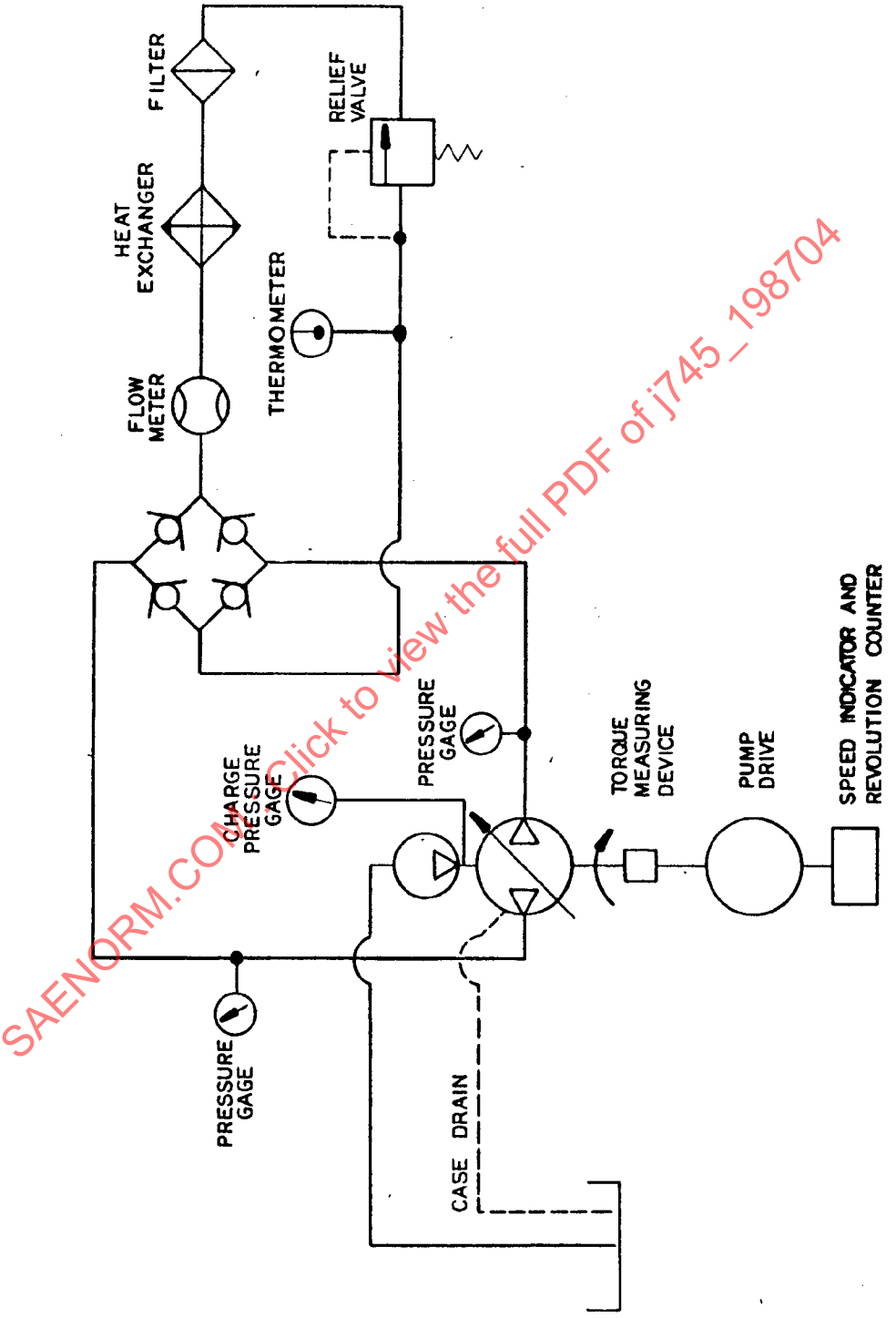


FIG. 1A - TYPICAL TEST SETUP FOR DELIVERY AND POWER DETERMINATION FOR CLOSED CIRCUIT PUMPS

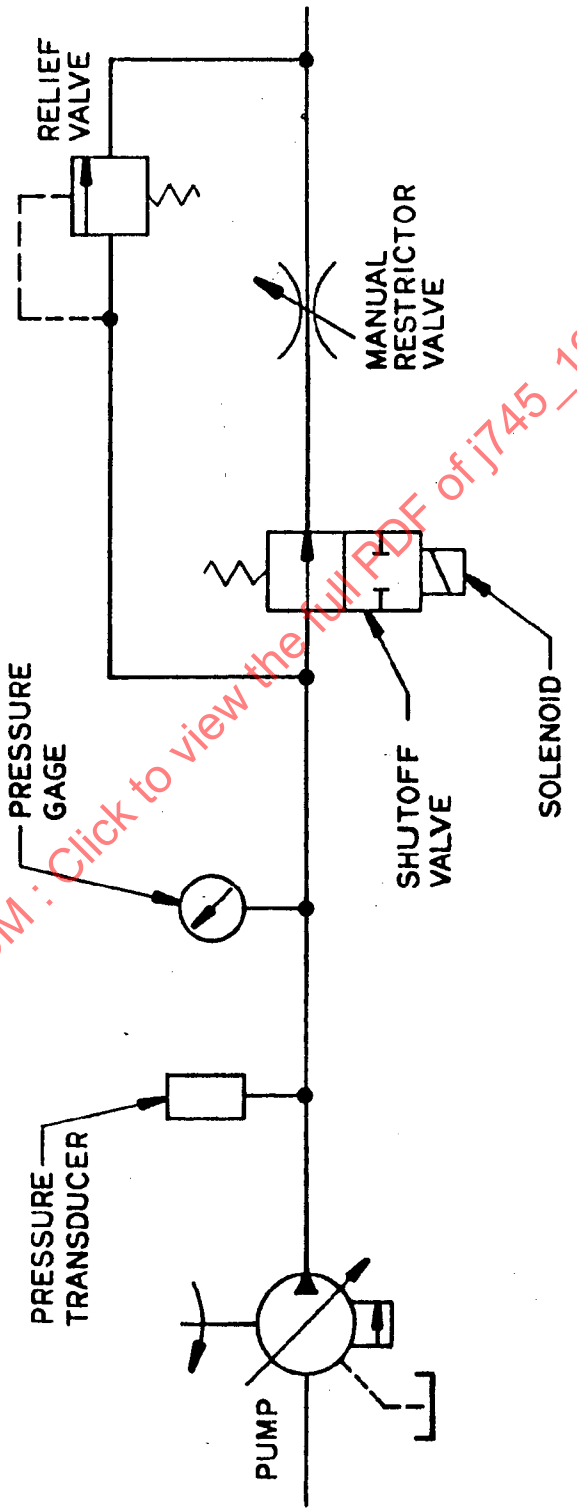


FIG. 2 - TYPICAL TEST SETUP FOR RESPONSE TIME OF PRESSURE COMPENSATOR

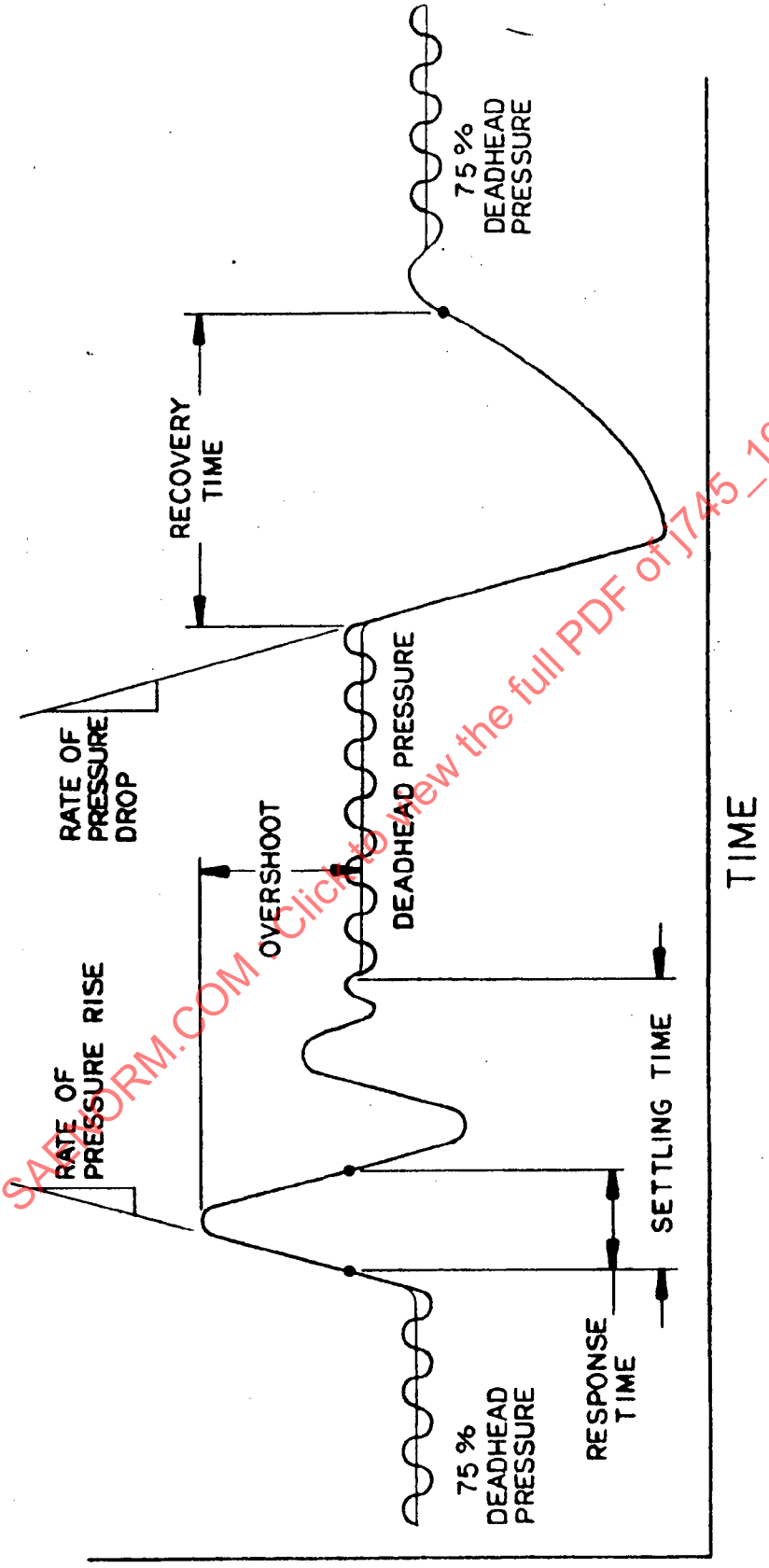


FIG. 3 - PRESSURE COMPENSATOR RESPONSE AND RECOVERY

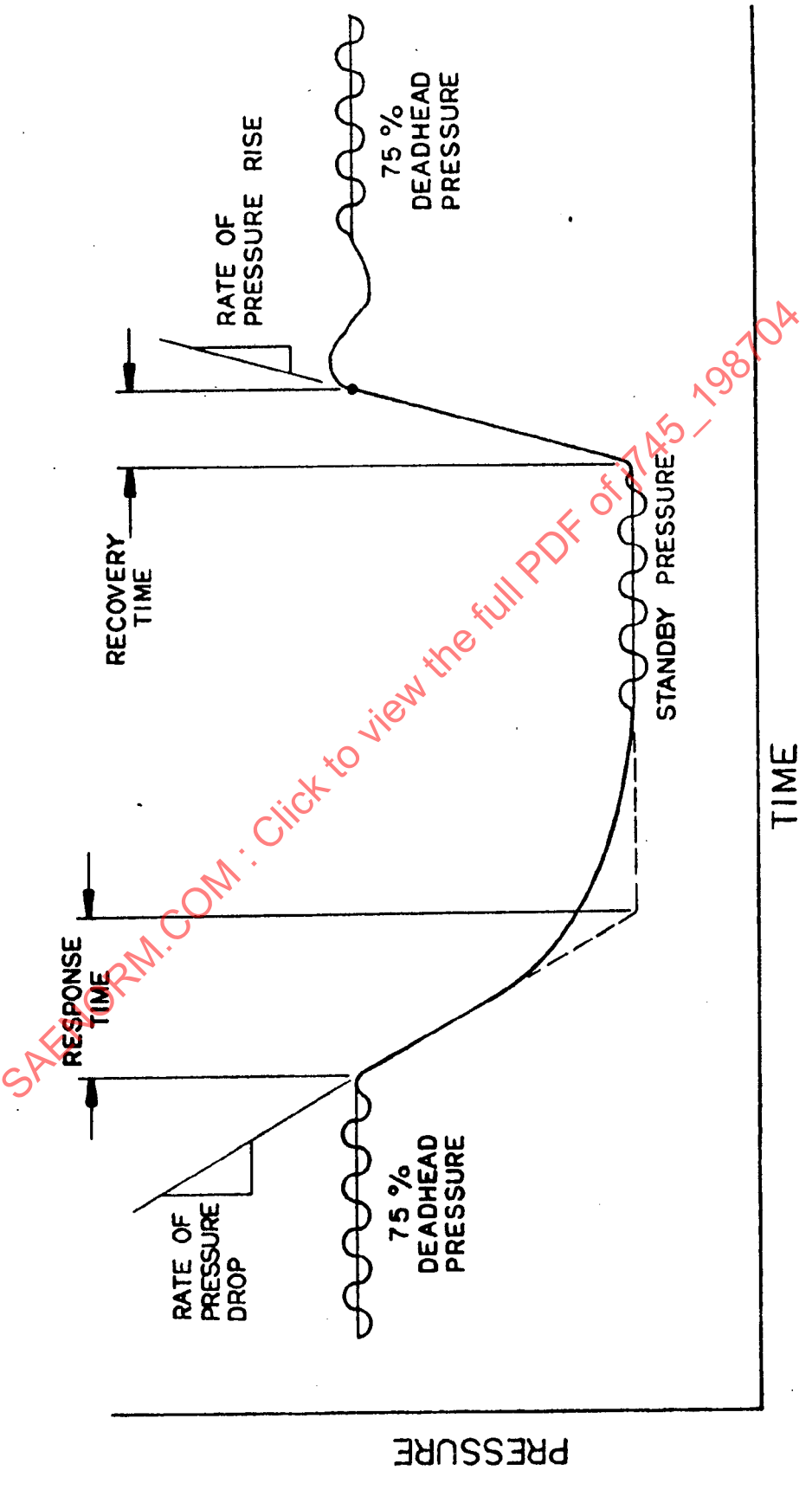


FIG. 4 - FLOW COMPENSATOR RESPONSE AND RECOVERY

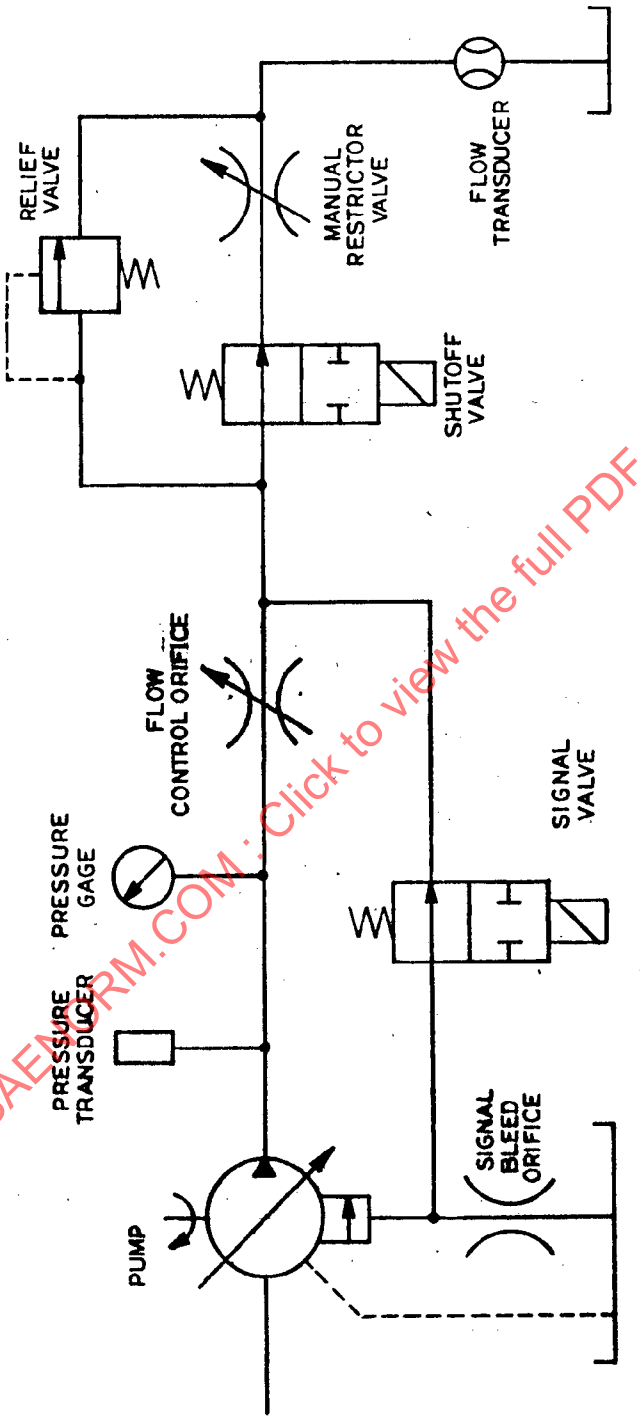
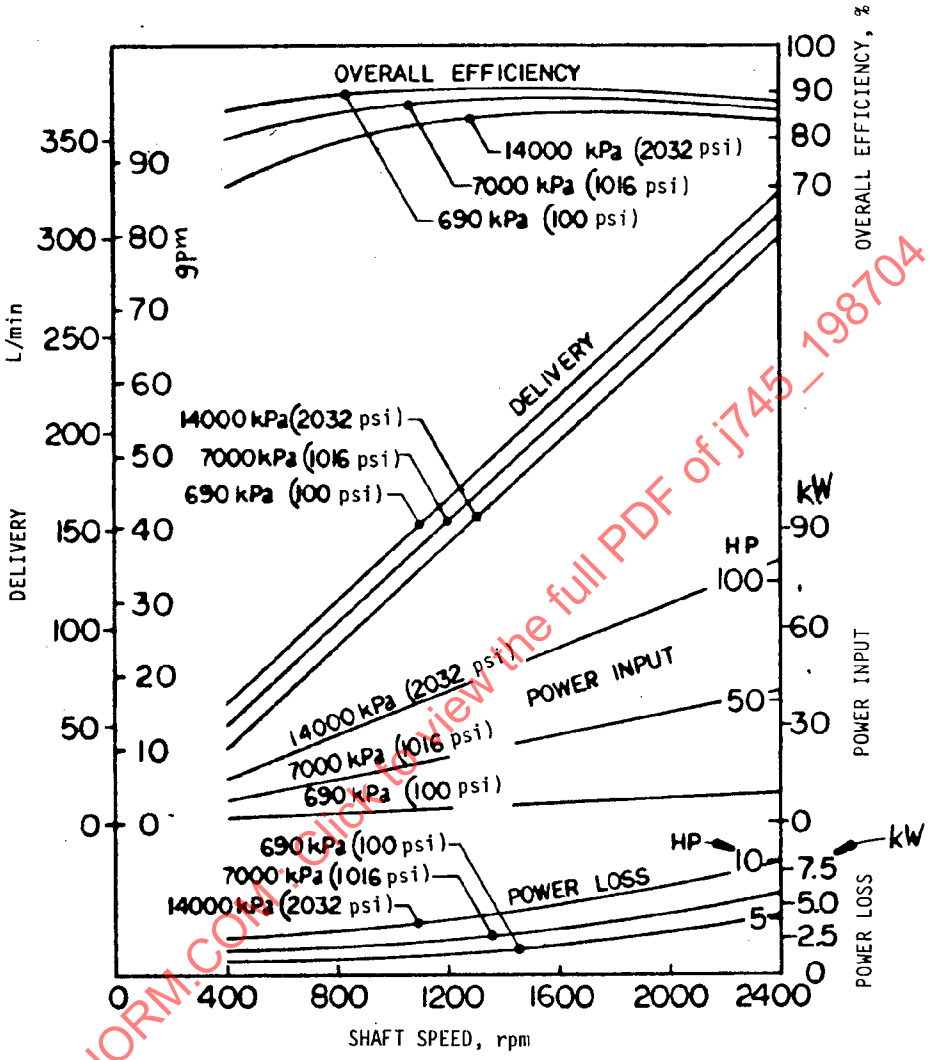


FIG. 5 - TYPICAL TEST SETUP FOR PRESSURE-FLOW COMPENSATOR PERFORMANCE



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

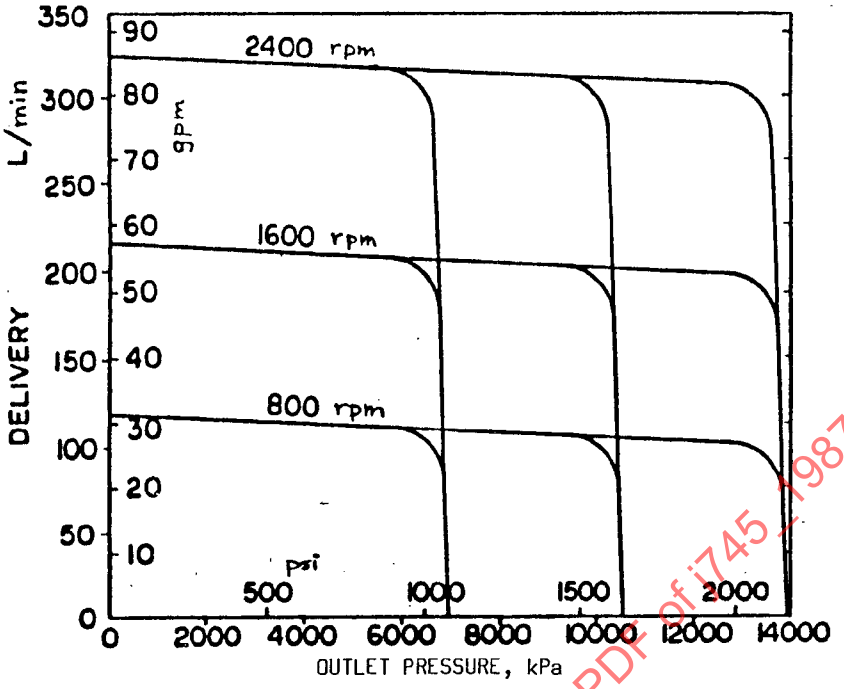
FLUID TEMPERATURE: 49°C (120°F)

FLUID VISCOSITY: 24.5 mm^2/s (114 SUS)

PUMP INLET PRESSURE: 772 mm HG abs (14.9 psi a)

SAE DERIVED CAPACITY: 134.4 mL/rev (8.2 in^3/rev)

WORK SHEET 1



SPEED	DEADHEAD PRESSURE		DEADHEAD INPUT POWER		RESPONSE/ SETTLING TIME	RECOVERY TIME	RATE OF PRESSURE RISE		RATE OF PRESSURE DROP		OVER-SHOOT	
rpm	kPa	psi	kW	HP	ms	ms	kPa/s	psi/sec	kPa/s	psi/sec	kPa	psi
2400	14000	2032	7.5	10.1	55/150	75	1,380,000	200,000	1,380,000	200,000	3440	500
2400	10500	1524	5.0	6.7	60/155	80	1,380,000	200,000	1,380,000	200,000	2750	400
2400	7000	1016	2.3	3.1	65/160	85	1,380,000	200,000	1,380,000	200,000	2400	350
1600	14000	2032	5.0	6.7	70/170	100	1,380,000	200,000	1,380,000	200,000	2750	400
1600	10500	1524	3.2	4.3	70/175	105	1,380,000	200,000	1,380,000	200,000	2400	350
1600	7000	1016	1.6	2.1	75/180	110	1,380,000	200,000	1,380,000	200,000	2400	350
800	14000	2032	2.5	3.4	105/205	130	1,380,000	200,000	1,380,000	200,000	2060	300
800	10500	1524	1.6	2.1	105/225	135	1,380,000	200,000	1,380,000	200,000	2060	300
800	7000	1016	0.8	1.1	110/230	135	1,380,000	200,000	1,380,000	200,000	1890	275

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 mm^2/s (114 SUS)

PUMP INLET PRESSURE: 772 mm HG abs (14.9 psi a)

SAE DERIVED CAPACITY: 134.4 mL/rev (8.2 in^3/rev)

WORK SHEET 2