SURFACE VEHICLE STANDARD

J745™ NOV2024

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Superseding J745 NOV2019

Hydraulic Power Pump Test Procedure

RATIONALE

Removed imperial unit equivalents from all sections. Updated ISO 4406 cleanliness code in 4.8 to 19/17/14.

1. SCOPE

This test code describes tests for determining characteristics of hydraulic positive displacement pumps used on off-road self-propelled work machines as referenced in SAE J1116.

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

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2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

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

SAE J1276 Standardized Fluid for Hydraulic Component Tests

2.1.2 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 4406 Hydraulic Fluid Power - Fluids - Method for Coding the Level of Contamination by Solid Particles

3. DEFINITIONS

3.1 DELIVERY

The flow output per unit time expressed in liters per minute (L/min).

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 A4).

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 A4).

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 A4).

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 A5).

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 A5).

3.10 DERIVED CAPACITY

The actual pump displacement as measured in Test 1, expressed in mL/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 A4).

4. MATERIAL AND APPARATUS

4.1 Test Fluid

Test fluid shall comply with SAE J1276. The actual fluid type and viscosity shall be recorded on worksheets (see Figures A1 to A3).

4.2 Pump Torque and Speed Measuring Apparatus

Torque measurement shall be accurate within ±1% and speed measurement shall be accurate within ±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).

4.3 Flow Measurement

Flow measurement shall be expressed in liters per minute (L/min) and accurate within ±2.0%.

4.4 Pressure Measurement

Outlet pressure shall be expressed in kilopascals gauge (kPag). Inlet pressure shall be expressed in millimeters of Mercury absolute (mm Hg abs). Pressure measurement shall be accurate to within ±2.0%

4.5 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. Temperature shall be expressed in degrees Celsius (°C).

4.6 Pump Inlet Line

Total pressure drop from the reservoir to the pump inlet shall not exceed 127 mm Hg. Unless otherwise required, the pump inlet pressure at the inlet fitting shall be maintained within 25.4 mm 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 shall 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.

4.7 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.

4.8 System Cleanliness

Test system shall have a contamination level not to exceed ISO 4406 Code 19/17/14.

5. WORKING FORMULAS

The following formulas may be utilized to calculate performance parameters:

5.1 SAE Theoretical Hydraulic Power (Watts)

See Equation 1.

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

5.2 Hydraulic Power (Watts)

See Equation 2.

$$= \frac{Delivery\ (L/min) \times\ Pressure\ (kPag)}{60} \quad \text{(Eq. 2)}$$

5.3 Power Input (Watts)

See Equation 3.

$$= \frac{Torque\ (N{\cdot}m) \times\ Speed\ (rpm)}{9.549} \quad \text{(Eq. 3)}$$

5.4 Torque Efficiency, (%)

See Equation 4.

$$= \frac{Theoretical\ Hydraulic\ Power}{Power\ Input} \times 100 \quad \text{(Eq. 4)}$$

5.5 Overall Efficiency, (%)

See Equation 5.

$$= \frac{Hydraulic\ Power}{Power\ Input} \times 100 \quad \text{(Eq. 5)}$$

5.6 Power Loss (Watts)

See Equation 6.

$$= Power\ Input\ - Hydraulic\ Power \quad \text{(Eq. 6)}$$

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 A6A.

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.

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 A6A.

6.2.2 With discharge pressure adjusted to 690 kPa maximum at rated speed, operate pump from minimum to rated speed in a suitable number of steps using fluid at 49 °C. 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 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.

6.2.6 Present performance data in a format similar to that shown on Worksheet 1 (see Figure A1).

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 A6B. 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 A7.)

8.2.2 Condition circuit such that pressure rise rate is between 690000 kPa/s and 2060000 kPa/s when shutoff valve is closed. Use 1380000 kPa/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.

a. Close shutoff valve while recording instantaneous pressure against time. From this recording, determine the rate of pressure rise in kPa/s, overshoot in kPa, and pressure compensator response and setting times in milliseconds (see Figure A4).

b. Open shutoff valve while recording instantaneous pressure against time. From this recording, determine the rate of pressure drop in kPa/s and pressure compensator recovery time in milliseconds (see Figure A4).

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 Worksheet 2 (see Figure A2).

9. VARIABLE DISPLACEMENT PRESSURE AND FLOW-COMPENSATED (LOAD SENSING) PUMP TESTS

Set up the test circuit shown in Figure A8. 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 Worksheet 1 (see Figure A1). 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 Figure A8, 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 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 Worksheet 2 (see Figure A2). Record standby power data for reporting on Worksheet 3 (see Figure A3).

9.1.3 Repeat 9.1.2 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 Worksheet 3 (see Figure A3).

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 versus flow.

9.2 Test 6 - Response and Recovery

9.2.1 Condition the circuit of Figure A7 such that it conforms to the requirements of 8.2.2. If the pump does not contain an integral signal bleed orifice, install one as shown in Figure A8, sized per the pump manufacturer's recommendations.

9.2.2 With flow control orifice fully open, perform 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 and the flow compensator response time in milliseconds (see Figure A5).

b. De-energize signal valve while recording instantaneous pressure against time. From this recording, determine the rate of pressure rise in kPa/s and the flow compensator recovery time in milliseconds (see Figure A5).

9.2.4 Repeat 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 Worksheet 3 (see Figure A3).

10. PRESENTATION OF RESULTS

10.1 Charts and Graph of Results

a. The characteristics are to be recorded on data sheets similar to the ones shown in Figures A1 to A3.

b. Two sets of data sheets are to be submitted: one at 49 °C and one at 82 °C.

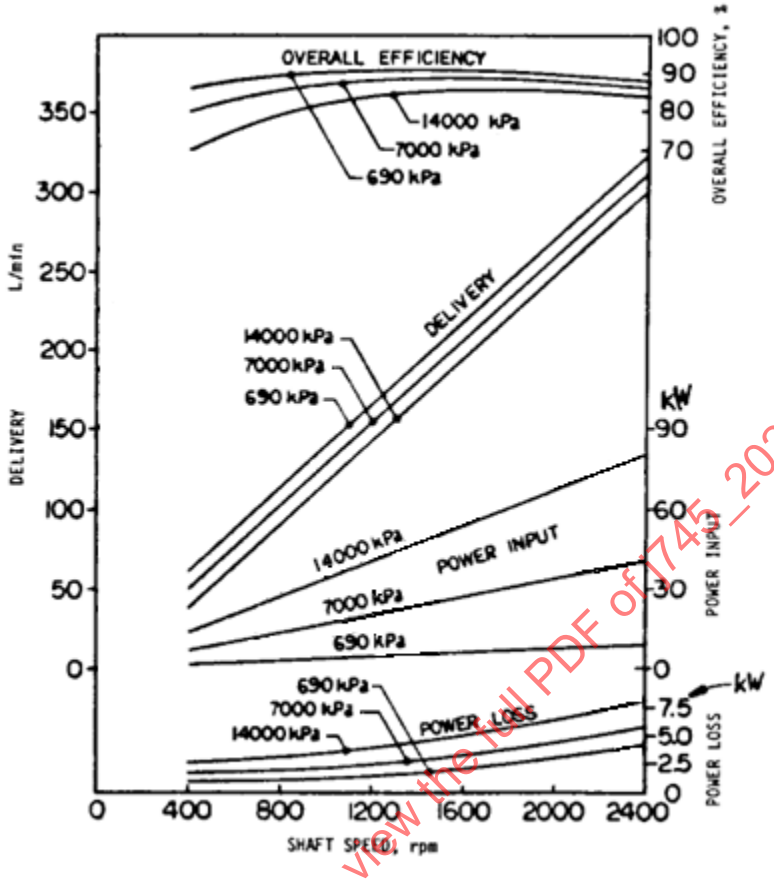
11. NOTES

11.1 Revision Indicator

A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE CTTC C1, HYDRAULIC SYSTEMS

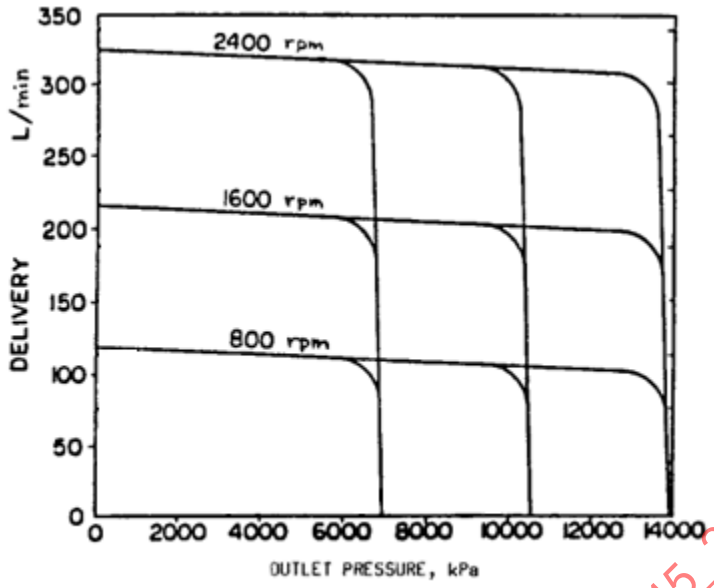
APPENDIX A



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
Fluid Viscosity:	24.5 mm^2/s
Pump Inlet Pressure:	772 mm Hg abs
SAE Derived Capacity:	134.4 mL/rev

Figure A1 - Worksheet 1

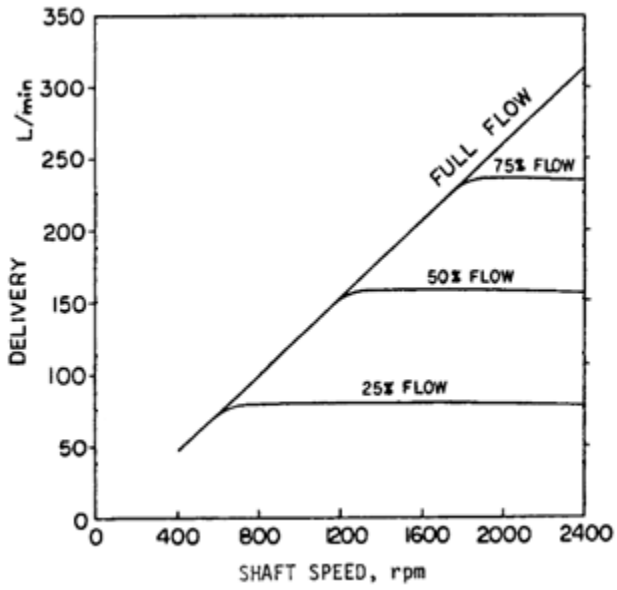


PERFORMANCE DATA FOR A PRESSURE COMPENSATED HYDRAULIC PUMP

Manufacturer:	ACME Mfg. Co.
Series or Type:	ZYX
Model:	9Y13
Rotation:	Clockwise
Test Fluid:	Dexron II ATF
Fluid Temperature:	49 °C
Fluid Viscosity:	24.5 mm^2/s
Pump Inlet Pressure:	772 mm Hg abs
SAE Derived Capacity:	134.4 mL/rev

Speed	Deadhead pressure	Deadhead Input Power	Response/ Settling Time	Recovery Time	Rate of Pressure Rise	Rate of Pressure Drop	Overshoot
rpm	kPa	kW	ms	ms	kPa/s	kPa/s	kPa
2400	14000	7.5	55/150	75	1380000	1380000	3440
2400	10500	5	60/155	80	1380000	1380000	2750
2400	7000	2.3	65/160	85	1380000	1380000	2400
1600	14000	5	70/170	100	1380000	1380000	2750
1600	10500	3.2	70/175	105	1380000	1380000	2400
1600	7000	1.6	75/180	110	1380000	1380000	2400
800	14000	2.5	105/205	130	1380000	1380000	2060
800	10500	1.6	105/225	135	1380000	1380000	2060
800	7000	0.8	110/230	135	1380000	1380000	1890

Figure A2 - Worksheet 2



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
Fluid Viscosity:	24.5 mm^2/s
Pump Inlet Pressure:	772 mm Hg abs
SAE Derived Capacity:	134.4 mL/rev

Speed	Standby Pressure	Standby Input Power	Flow Response Time	Flow Recovery Time	Rate of Pressure Rise	Rate of Pressure Drop
rpm	kPa	kW	ms	ms	kPa/s	kPa/s
1400	1400	1	60	80	750000	700000
1600	1400	0.7	85	140	750000	700000
800	1400	0.3	125	200	750000	700000

Figure A3 - Worksheet 3