



SURFACE VEHICLE RECOMMENDED PRACTICE

J2311™

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Automatic Transmission Hydraulic Pump Test Procedure

RATIONALE

This document has been revised for clarification of test methods and to support advances in automatic transmission pump technology.

SAE J2311 has been reaffirmed to comply with the SAE Five-Year Review policy.

A reaffirmed status is given to technical reports that have been reviewed by the technical committee and deemed to be current with no need for immediate revision. No changes have been made to this document as a result of this review.

1. SCOPE

This SAE Recommended Practice provides a method to determine the performance characteristics of the hydraulic oil pumps used in automatic transmissions and automatic transaxles. This document outlines the specific tests that describe the performance characteristics of these pumps over a range of operating conditions and the means to present the test data. This document is not intended to assess pump durability.

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 J311 Fluid for Passenger Car Type Automatic Transmissions

SAE J1165 Reporting Cleanliness Levels of Hydraulic Fluids

SAE J1276 Standardized Fluid for Hydraulic Component Tests

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2.1.2 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 1219-1	Fluid Power Systems and Components - Graphical Symbols and Circuit Diagrams - Part 1: Graphical Symbols for Conventional Use and Data-Processing Applications
ISO 1219-2	Fluid Power Systems and Components - Graphical Symbols and Circuit Diagrams - Part 2: Circuit Diagrams
ISO 4406	Hydraulic Fluid Power - Fluids - Method for Coding the Level of Contamination by Solid Particles
ISO 4409	Hydraulic Fluid Power - Positive-Displacement Pumps, Motors and Integral Transmissions - Methods of Testing and Presenting Basic Steady State Performance
ISO 4412-1	Hydraulic Fluid Power - Test Code for Determination of Airborne Noise Levels - Part 1: Pumps
ISO 4412-3	Hydraulic Fluid Power - Test Code for Determination of Airborne Noise Levels - Part 3: Pumps - Method Using a Parallelepiped Microphone Array
NFPA T2.6.1.R2	Method for Verifying the Fatigue and Static Pressure Ratings of the Pressure Containing Envelope of a Metal Fluid Power Component

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 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 J745	Hydraulic Power Pump Test Procedure
SAE J1116	Categories of Off-Road Self-Propelled Work Machines

3. DEFINITIONS

3.1 ACTUAL CAPACITY

Measured output flow at prescribed conditions of pressure, speed, and temperature. It is actual flow rate delivered from the pump discharge port while operating at the prescribed conditions.

3.2 ACTUAL DISPLACEMENT

See 3.24.

3.3 ACTUAL TORQUE

The measured input torque required to operate the pump at prescribed conditions of pressure, temperature, and speed. It includes frictional losses.

3.4 AERATION

The mixing beyond the solution point of gas and fluid so as to provide a fluid medium having two distinct phases, namely one liquid, and one gaseous.

3.5 AIRBORNE NOISE

Pressure fluctuation of the ambient air surrounding a vibrating element, the magnitude of the pressure fluctuations being sufficient for the human ear to sense sound.

3.6 AXIAL THRUST CAPACITY

The maximum externally applied force applied to the pump assembly allowable without negatively affecting performance. It may be applied to the housing which carries the force to ground or applied to the input shaft which transmits the force to the pumping elements.

3.7 BULK MODULUS

The reciprocal of compressibility. A measure of fluid "stiffness," expressed in pressure units, defined as Differential Pressure/(Initial Volume - Final Volume).

3.8 CAVITATION

The formation of bubbles or vapor "cavities" in liquid when the local static pressure is reduced to below the fluid vapor pressure.

3.9 CAVITATION NOISE

The audible noise caused by the collapse of fluid vapor or entrained air upon pressurization.

3.10 CRITICAL INLET

That operating condition of constant speed, inlet temperature and decreasing suction pressure that result in less than complete filling of the pumping chamber.

3.11 DIRECTION OF ROTATION

When viewed from the pump drive shaft end, the clockwise (right hand) or counterclockwise (left hand) rotation of the shaft that produces discharge from the discharge port.

3.12 DISCHARGE PRESSURE

The static pressure at the pump discharge port, downstream of the confluence of all pumping chambers.

3.13 ENTRAINED AIR (AIR ENTRAINMENT)

The result of aeration. The mixture of undissolved gas, usually air, beyond the solution point, usually expressed in percent air by volume.

3.14 EROSION

The damage, loss of material, or permanent deformation of pressure containing surfaces as the result of collapsing bubbles, either from aeration or cavitation.

3.15 FLUID BORNE NOISE

The oscillations of fluid static pressure resulting from fluid disturbances due to discharging pump chambers, standing waves, oscillating valves, or other disturbances.

3.16 HEAD LOSS

A loss in total energy of a fluid in motion, usually the result of frictional losses in conduits, but often includes component losses (orifices, valves, etc.) and energy loss from work exerted on the system. Also known as "pressure drop."

3.17 HIGH-SPEED FILL LIMIT

The rotational speed at which the pump delivery/speed curve diverges from theoretical. It is differentiated from “critical inlet” in that the inlet port is unrestricted. The divergence results from the inability of the available inlet energy to accelerate the inlet fluid to a velocity equal to the moving pump inlet chambers. “Theoretical HSFL” is calculated assuming no inlet losses.

3.18 HYDRAULIC OUTPUT POWER

The fluid power, expressed in watts, available to do useful work. See Equation 1.

$$P_{out} = \frac{Q_d \times (p_d - p_i)}{60} \quad (\text{Eq. 1})$$

3.19 INLET PRESSURE

The static pressure at the pump inlet port upstream of the pumping chambers.

3.20 LEAKDOWN RATE

The rate, expressed in time units, that characterizes the ability of a pump assembly with all ports closed and sealed to maintain a vacuum above a specified level. A measure of air infiltration.

3.21 MAXIMUM RATED PRESSURE

The maximum functional discharge pressure, excluding tolerances and pulsation, the pump is designed to operate at continuously for a specified period.

3.22 MAXIMUM RATED SPEED

The maximum input speed the pump is designed to operate at continuously for a specified period.

3.23 MAXIMUM RATED TEMPERATURE

The maximum fluid temperature at the pump inlet that the pump is designed to operate continuously for a specified period.

3.24 MEASURED DISPLACEMENT

The measured amount of volume displaced through one revolution by a positive displacement pump. The measured displacement does not include any losses for internal pump leakage. May also be known as “actual displacement.”

3.25 MECHANICAL EFFICIENCY

The ratio, expressed in percent, of potential torque to actual torque. See Equation 2.

$$E_m = \frac{T_p}{T_a} = \frac{D_m \times (p_d - p_i)}{(2 \times \pi \times T_a)} \times 100\% \quad (\text{Eq. 2})$$

3.26 MECHANICAL INPUT POWER

The mechanical (shaft) power, expressed in watts, consumed by the pump. See Equation 3.

$$P_{in} = \frac{T_a \times N \times 2 \times \pi}{60} \quad (\text{Eq. 3})$$

3.27 OVERALL EFFICIENCY

The ratio, expressed in percent, of output power to input power. See Equations 1, 4, and 5.

$$E_o = \frac{P_{out}}{P_{in}} \times 100\% \quad (\text{Eq. 4})$$

Where fluid or hydraulic output power is expressed, in watts, as shown in Equation 1, and mechanical input power is expressed, in watts, as shown in Equation 3.

3.28 OVER PRESSURE RATING

The maximum discharge pressure the pump is expected to endure without permanent damage. After exposure to this condition, and upon return to operation within designed maximum ratings (see 3.21 through 3.23), all performance requirements must be met.

3.29 OVER SPEED RATING

The maximum input speed the pump is expected to endure without permanent damage. After exposure to this condition, and upon return to operation within designed maximum ratings (see 3.21 through 3.23), all performance requirements must be met.

3.30 OVER TEMPERATURE RATING

The maximum inlet temperature the pump is expected to endure without permanent damage. After exposure to this condition, and upon return to operation within designed maximum ratings (see 3.21 through 3.23), all performance requirements must be met. See Figure 1.

3.31 POTENTIAL CAPACITY

The potential output flow at a given speed, expressed in L/min. It is a function of the measured displacement, D_m , and input speed, N . It assumes 100% volumetric efficiency and differs from theoretical capacity only in the use of measured displacement versus theoretical displacement. See Equation 5.

$$Q_m = \frac{D_m \times N}{1000} \quad (\text{Eq. 5})$$

3.32 POTENTIAL TORQUE

The torque required to rotate the pump input shaft due to a specified pressure rise between pump inlet and discharge ports. It is a function of measured displacement, D_m , and differential pressure, and does not include frictional losses. See Equation 6, expressed in Nm.

$$T_p = (p_d - p_i) \frac{D_m}{2 \times \pi \times 1000} \quad (\text{Eq. 6})$$

3.33 POWER LOSS

The power lost by the pump, usually in the form of heat, expressed in watts. It is the difference between input and output power. See Equation 7.

$$P_l = P_{in} - P_{out} \quad (\text{Eq. 7})$$

3.34 PRESSURE RIPPLE

The peak-to-peak amplitude of fluid pressure oscillations.

3.35 PUMP DELIVERY

The measured flow rate from the discharge port at a specified gauge pressure, inlet temperature, and input speed. See 3.1.

3.36 RADIAL BEARING CAPACITY

The maximum permitted force applied to the pump support bearing, defined as a radial force at a specified speed and duration.

3.37 RATED FATIGUE PRESSURE

That pressure which the pressure containing envelope can sustain for 10×10^6 cycles without failure, defined as any fracture, crack, excessive seal leakage caused by deformation, or any permanent deformation which interferes with related component function.

3.38 SLIP FLOW

The difference between pump delivery (actual flow) and potential capacity, usually referred to as "internal leakage." In the absence of a measured displacement, the difference between pump delivery (actual flow) and theoretical capacity.

3.39 SOUND POWER

The measure of total sound energy radiated from a theoretical point source, expressed in decibels.

3.40 TARE TORQUE

The torque required to overcome bearing and seal drag, and is not a component of the lost work due to pumping mechanism inefficiency. Typically included in pump assembly measurements to ascertain total power draw.

3.41 THEORETICAL CAPACITY

The theoretical output flow at a given speed, expressed in L/min. It assumes 100% volumetric efficiency, is independent of discharge pressure, and is a function of theoretical displacement and input speed, N , similar to Equation 5.

3.42 THEORETICAL DISPLACEMENT

The calculated volume displaced by the pump mechanism in one rotation. It is derived from the geometry of the pumping mechanism and assumes 100% volumetric efficiency.

3.43 THEORETICAL TORQUE

The torque required to rotate the pump input shaft due to a specified pressure rise between pump inlet and discharge ports. It is a function of theoretical displacement rather than measured displacement, D_m . See Equation 6.

3.44 TORQUE RIPPLE

The peak-to-peak amplitude of torsional oscillations measured at the pump input shaft.

3.45 VOLUMETRIC EFFICIENCY

The ratio, expressed in percent, of pump delivery to potential capacity. In the absence of a measured displacement, potential capacity may be replaced with theoretical capacity. See Equation 8.

$$E_v = \frac{Q_a}{Q_p} \times 100\% \quad (\text{Eq. 8})$$

4. SYMBOLS

E_m	= Mechanical efficiency (%)
E_o	= Overall efficiency (%)
E_v	= Volumetric efficiency (%)
Q_t	= Theoretical capacity (L/min)
Q_a	= Actual capacity (L/min)
Q_p	= Potential capacity (L/min)
D_m	= Measured displacement - (actual displacement) (cc/rev)
N	= Pump rotational speed (rpm)
P_{out}	= Hydraulic power output (W)
P_{in}	= Mechanical power Input (W)
P_l	= Power loss (W)
T_t	= Theoretical (input) torque (Nm)
T_a	= Actual (input) torque (Nm)
T_p	= Potential (input) torque (Nm)
p_i	= Pump inlet pressure (kPa)
p_d	= Pump discharge pressure (kPa)
W	= Power units (W)
L/min	= Flow rate units (L/min)
Nm	= Torque units (Nm)

4.1 Symbols in Figures 2A to 2C

M	= Motor
P 1	= Discharge pressure
P 2	= Inlet pressure
T 1	= Sump temperature
T 2	= Inlet temperature
RV1	= Relief valve 1
SORV1,2	= Solenoid-operated directional valve 1 and 2, respectively
TV1,2,3,6	= Throttle valve or variable orifices 1, 2, 3, and 6, respectively
SOVA, B	= Shut-off valve A and B, respectively
FM1	= Flow meter 1
S1	= Input speed sensor
TQ	= Torque meter
TR	= Temperature regulator

5. TEST PREPARATION

During installation of the pump into a mounting fixture, special attention should be focused on properly aligning the pump, torque transducer, and drive motor. These component centerlines should be aligned to within 0.025 mm (0.001 inch) or within “pump design sheet” (see Figure 1) requirements, whichever is more restrictive. Final alignment must be verified, and documented in accordance with laboratory practice approved by customer.

5.1 Material and Apparatus

5.1.1 Test Fluid

Test fluid and properties shall be as specified by the customer or per SAE J1276. The fluid must be identified on the pump build sheet, test data sheets, or laboratory log. Fluid properties must be included in any report.

5.1.2 Reservoir

The inlet circuit should include a sight glass to verify no visible air is in the inlet stream. To minimize aeration, returning fluid from all circuits other than atmospheric drain lines shall enter the reservoir at a point below the surface of the fluid and shall be diffused in such a manner as to minimize turbulence in the reservoir. Include a “re-circulation circuit” to minimize inlet losses if the application provides such a feature. See Figures 2A through 2C.

Filtration shall be provided to maintain fluid cleanliness level, as defined by SAE J1165, within the pump manufacturer's recommendations. The test circuit and reservoir shall be configured to replicate as closely as practical the characteristics of the given application, e.g., inlet pressure drop, velocity, etc. See Figure 1. The pump design sheet must accompany each test specimen model.

A temperature probe shall be placed as close as practical to the inlet strainer and within the stream lines of the inlet flow to record inlet fluid temp.

Appropriate fluid conditioning and auxiliary circuits must be installed to control temperature and cleanliness. The system may be designed to also provide hydraulic signals for integral pump controls. See Figures 2A through 2C.

Pump Design Sheet		
Parameter	Units	Design Requirement
Ratings		
Pump Theoretical Displacement	CC/rev	
Theoretical High Speed Fill Limit	RPM	
Rated Fatigue Pressure	kPa	
Rated Sound Power (@ tbd RPM, tbd kPa)		
Rated External Radial Load	N	
Rated Axial Thrust Load	N	
Max Rated Speed	RPM	
Min Rated Speed (idle)	RPM	
Max Overspeed	RPM	
Max Rated Pressure	kPa	
Max Overpressure	kPa	
Min Inlet Pressure	kPa	
Max Rated Inlet Temperature	°C	
Max Inlet Over Temperature	°C	
Min Flowrate (@ tbd RPM, tbd kPa)	lpm	
Operating Environment		
Fluid Cleanliness Level (ISO code)		
Drive alignment		
Max Angular Error	Degrees	
Min Offset Error	mm	

Figure 1 - Pump design sheet

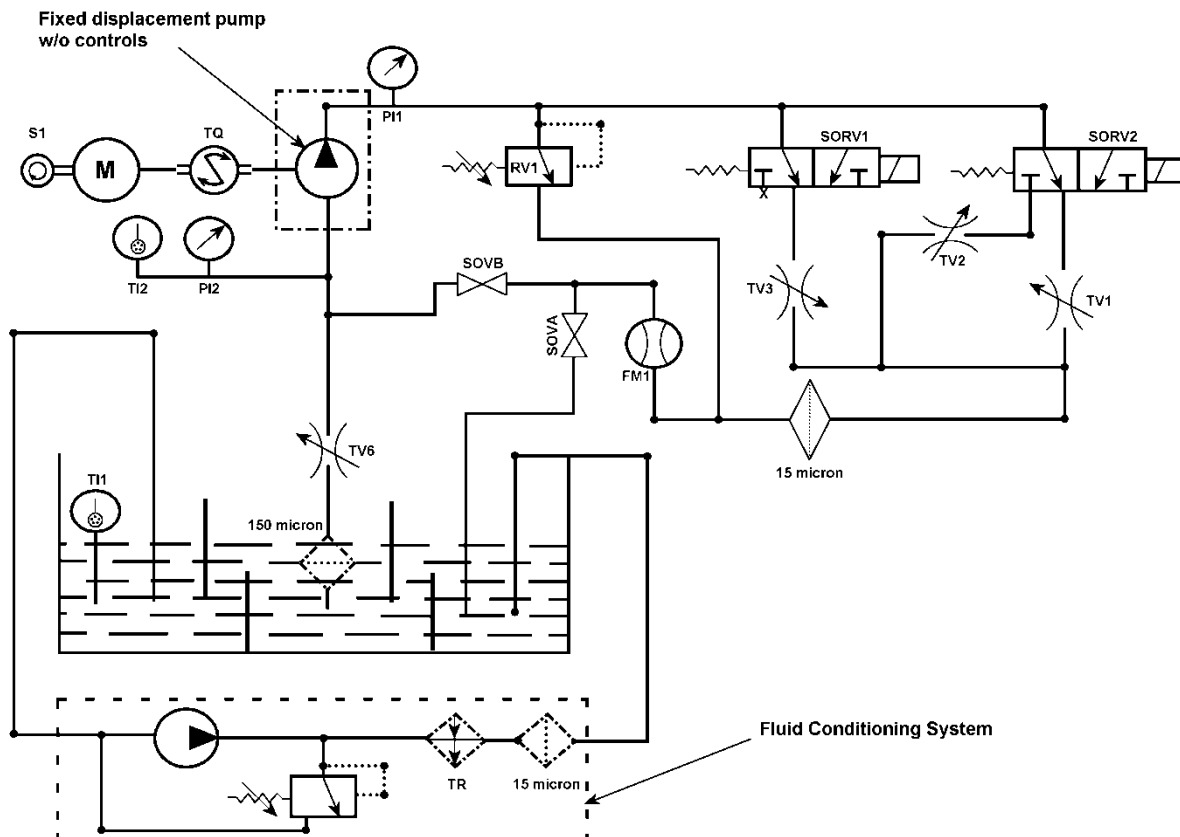


Figure 2A - Test circuit - fixed displacement pump

