



SURFACE VEHICLE RECOMMENDED PRACTICE

J2490™

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SAE No. 2 Friction Test Machine μ PVT Test

RATIONALE

SAE J2490 has been revised to include test revisions and an update of the scope.

1. SCOPE

This SAE Recommended Practice is intended as the definition of a standard test, which may be subject to frequent change to keep pace with experience and technical advances. This should be kept in mind when considering its use.

The SAE No. 2 Friction Test Machine is used to evaluate the friction characteristics of automatic transmission plate clutches with automotive transmission fluids. It can also be used to conduct durability tests on wet friction systems.

The specific purpose of this document is to define a μ PVT Test for the evaluation of the variation of wet friction system performance as a function of speed, temperature, and pressure. This procedure is intended as a standard for both suppliers and end users.

The only variables selected by the supplier or user of the friction system are:

- a. Friction material
- b. Fluid
- c. Reaction plates

These three variables must be clearly identified when reporting the results of this test. If any of the test parameters or system hardware as described in this document are changed, other than the friction material, test fluid, or reaction plates, the data may not be reported as having been obtained using this document.

This procedure is intended to evaluate the midpoint, endpoint, and breakaway coefficients and endpoint/midpoint ratios. The procedure can be used to demonstrate changes that occur between the different levels of engagement speed, sump temperature, and apply pressure. Refer to SAE J2487, SAE J2488, or SAE J2489 for coefficient variations due to changes in power level.

The procedure, as described in detail in Table 1, consists of four 50 cycle break-in levels at 3500 rpm with increasing steps of apply pressure, followed by 16 levels consisting of 25 dynamic engagements, and one breakaway following completion of the 25th dynamic cycle. The 16 levels are achieved by varying initial engagement speed, apply pressure, and oil sump temperature while the inertia is kept constant at 0.701 kg/m².

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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 J286	SAE No. 2 Clutch Friction Test Machine Guidelines
SAE J1646	Glossary of Terms - Lubricated Friction Systems
SAE J2487	SAE No. 2 Friction Test Machine 3600 rpm Stepped Power Test
SAE J2488	SAE No. 2 Friction Test Machine 6000 rpm Stepped Power Test
SAE J2489	SAE No. 2 Friction Test Machine Durability Test
SAE J2964	Low-Speed Continuous Slip SAE No. 2 μ PVT Procedure

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 J1499	SAE Band Friction Test Machine Guidelines
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Smith, G., Ross, W., Silbert, P., and Herndon, W., "Putting Automatic Transmission Clutch Friction Researchers on Speaking Terms," SAE Technical Paper 670051, 1967, <https://doi.org/10.4271/670051>.

3. TEST EQUIPMENT

- 3.1 SAE No. 2 Friction Test Machine with breakaway accessory or SAE No. 2 equivalent machine with inertia simulation.
- 3.2 Flywheel to deliver desired kinetic energy or inertia simulation that creates similar kinetic energy from the torque reaction of the motor. The flywheel or inertia simulation is required to provide the specified total system inertia of 0.701 kg/m² as shown in Tables 1A and 1B.

3.3 Data Acquisition

At not less than 1000 samples per second and storage system with at least four channels with response as follows:

- a. Torque Channel, Bandwidth, 500 Hz
- b. Apply Pressure Channel, Bandwidth, 500 Hz
- c. Speed Channel, Bandwidth, 500 Hz
- d. Test Fluid Temperature Channel, Bandwidth, 3 Hz

(All channels are to be calibrated to maintain $\pm 2\%$ accuracy throughout the range of 10% of full scale to full scale.)

Table 1A - Required parameters μ PVT test

Test Level	Cycles	Inertia (kg/m ²)	Speed (rpm)	Kinetic Energy (kJ)	Apply Pressure (kPa)	Oil Inlet Temperature (°C)	
BI 1	50	0.701	3500	47.09	165	50	Break-in Levels 1-4
BI 2	50	0.701	3500	47.09	235	50	
BI 3	50	0.701	3500	47.09	305	50	
BI 4	50	0.701	3500	47.09	370	50	
A	25	0.701	750	2.16	83	50	Low Pressure and Speed Levels A-H
B	25	0.701	1500	8.65	83	50	
C	25	0.701	750	2.16	166	50	
D	25	0.701	1500	8.65	166	50	
E	25	0.701	750	2.16	83	110	
F	25	0.701	1500	8.65	83	110	
G	25	0.701	750	2.16	166	110	
H	25	0.701	1500	8.65	166	110	
I	25	0.701	2700	28.02	248	110	High Pressure and Speed Levels I-P
J	25	0.701	3500	47.09	248	110	
K	25	0.701	2700	28.02	373	110	
L	25	0.701	3500	47.09	373	110	
M	25	0.701	2700	28.02	248	50	
N	25	0.701	3500	47.09	248	50	
O	25	0.701	2700	28.02	373	50	
P	25	0.701	3500	47.09	373	50	

Table 1B - Flywheels required for the test

Code	Quantity	Inertia (kg/m ²)
A	1	As required to achieve an effective inertia of 0.701 kg/m ²

3.4 Instrumentation

- Torque Transducer: Full bridge, strain gage type, combined nonlinearity, and hysteresis effects not to exceed 0.5% of full scale, such as Lebow Load Cell, Model 3397.
- Apply Pressure Transducer: Full bridge, strain gage type, combined nonlinearity, and hysteresis effects not to exceed 0.5% of full scale, such as SensoTech, Model TJU708-12.
- Speed Transducer: Optical encoder, such as BEI Model 924-01002-4839. For drive motor.
- Thermocouple(s): Type J with high-impedance amplifier and cold junction compensator, or equivalent.

3.5 Test Fluid System

Refer to Figure 1C in SAE J286. Heated sump including immersion or jacket heater with sufficient watt density for test fluid temperature control and the associated hardware for external fluid flow control. Care should be taken that the fluid is not altered or modified by contact with the immersion heater by ensuring that the heater does not exceed a power density of 2 W/cm².

3.6 Lubrication System Flow Configuration

3.6.1 External Flow

Refer to Figure 7C in SAE J1646. This represents the configuration wherein an external pump supplies fluid at a specific flow rate through a line to the centerline of the shaft. A flow meter must be installed in the line to the cover to measure the flow supplied to the head. The drain from the test head back to the sump is from the 5 o'clock, 6 o'clock, and 7 o'clock positions.

3.7 Adapters and Reaction Plates

The required friction and reaction plates, hub, retainer, pressure plate, and spacers are all described in Appendix A.

3.8 Apply Piston Seal

- a. VITON®
- b. Teflon® (recommended for use in high-temperature fluid tests)

4. TYPICAL OPERATING CONDITIONS AND TEST PARAMETERS

4.1 Piston Area

15110 mm²

4.2 Piston Available Travel

4.57 mm

4.3 Piston Apply Pressure

As required in Tables 1A and 1B for each test level. Allowable variation in apply pressure is $\pm 0.5\%$. Refer to SAE J1646 for definitions.

- a. Start Threshold - Torque
- b. Stop Threshold - Torque

4.4 Piston Apply Pressure Rise

The apply pressure must be stable at the required level within 200 ms $\pm$ 5 ms for stability (for the highest pressure level). The maximum overshoot must not exceed 2% of the required pressure level. Pressure rise time to be included in the final report.

4.5 Piston Release Pressure

Thirty to 100 kPa and must be 0 kPa during the apply period.

4.6 Effective Inertia

The μ PVT test inertia remains constant for the entire test. A flywheel specific to an individual dynamometer or inertia simulation is required to attain the inertia of 0.701 kg/m² within $\pm 1\%$. See Tables 1A and 1B. Effective inertia, as defined by SAE J1646, is the total rotating inertia that the friction elements work against.

4.7 Engagement Speed Range

- a. Break-in: Four pressure levels at 3500 rpm
- b. Low Speed Sequence: Four levels at 750 rpm and four levels at 1500 rpm
- c. High Speed Sequence: Four levels at 2700 rpm and four levels at 3500 rpm
- d. All dynamic speeds are $\pm 1\%$

4.8 Kinetic Energy

As shown in Tables 1A and 1B. These kinetic energy values must be as required for the specific level. The allowable variation in kinetic energy is $\pm 5\%$.

4.9 Breakaway Speed

4.37 rpm

4.10 Test Fluid

- a. Quantity: 18 L, minimum, and must be replaced with new fluid at the beginning of the procedure.
- b. Temperature: $50\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ for break-in levels 1 through 4, levels A through D, and M through P; $110\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ for levels E through L measured in the inlet line as shown in Appendix A.
- c. Test Fluid Flow: The test fluid flow rate is $1.0\text{ L/min} \pm 0.05\text{ L/min}$.
- d. Fluid Flow Configuration: The flow configuration is external flow as described in SAE J1646 and 3.6.

4.11 Pack Clearance

$1.143\text{ mm} \pm 0.127\text{ mm}$

4.12 Test Periods

Refer to SAE J1646 for the definitions of the test periods. The total period for one dynamic engagement cycle is 30 seconds ± 1 second.

- a. T_1 , Stabilization Period: 24 seconds ± 0.5 second
- b. T_2 , Coast Period: 0 seconds
- c. T_3 , Apply Period: 2 seconds ± 0.1 second
- d. T_4 , Dwell Period: 4 seconds ± 0.5 second
- e. T_5 , Soak Period: 2.5 seconds ± 2.5 seconds
- f. T_6 , Breakaway Period: 2 seconds ± 0.5 second
- g. T_7 , Cooling Period: 0 seconds

5. GENERAL TEST INFORMATION

5.1 Clean

Prior to each test, the fixture and sump must be cleaned thoroughly and fixture and sump washed with solvent. The sump is then filled with the new test fluid.

5.2 Inspect

Inspect rotating shaft seal for deterioration and replace, if necessary. If this seal is replaced, also replace the non-rotating lip seals.

5.3 Soak

Soak friction elements in the test fluid for at least 10 minutes at room temperature.

5.4 Install Clutch Pack

The clutch pack is comprised of five steel reaction plates and four friction plates. Install a reaction plate to contact the pressure plate. Follow with a friction assembly, reaction plate, and so on until all the required components have been installed. The last plate to be installed must be a reaction plate. Spacer thickness must be selected to ensure that the pack clearance is as defined in 4.11. The pack configuration is PRFRFRFRSC, where P is the piston, R is a reaction plate, F is a friction plate, S is the spacer plate (as required), and C is the cover. Reaction plates may be used as the spacer. To verify axial alignment of hub oil holes and friction plates, see Appendix A.

5.5 Install Housing Cover

Start the circulation pump and the temperature controller to heat the fluid and internal elements to the required control temperature, as given in 4.10.

5.6 Install Flywheels

Install the flywheel required to achieve the correct effective inertia or set up correction inertia reaction amount.

5.7 Check Fluid Flow and Temperature

Check, with the motor off, that the fluid control temperature and the flow rate are as given in 4.10.

5.8 Start Test

Initiate the testing for the first break-in level, as defined in Tables 1A and 1B.

- a. Set the apply pressure per Tables 1A and 1B. The stop time is allowed to float for each test level.
- b. Initiate the testing for the required level as defined in Tables 1A and 1B.

6. DATA ACQUISITION

6.1 Data Acquisition Rate

For digital data acquisition systems, the data is to be recorded at 1000 samples per second per channel using a 15-ms time constant RC filter. (Filtering will slew data. Preferred method is to record all raw data and manipulate later.)

6.2 Data Averaging and Filtering

Data is to be averaged at the specified location in either the time or speed domain as specified in 6.1 with midpoint coefficient average values calculated using data points ± 80 ms on both sides of the required calculation point. The midpoint coefficient averages are based on 161 data points for the 1000-Hz sampling rate. Endpoint coefficient average values are calculated from non-filtered peak torque data measured in the last 100 ms of the engagement.

6.3 Coefficient Calculations

Coefficients are calculated for the following dynamic coefficient at every 25th engagement. (Refer to SAE J1646.)

Midpoint dynamic: $50\mu_d$

The breakaway coefficients, obtained following every 25th dynamic engagement at each level, is defined as:

Breakaway coefficient: $1.0\mu_{s4.37}$

The static peak coefficient obtained from the maximum torque measurement during the first 100 ms after the start threshold, as defined in 4.3, $\tau > 5 \text{ N}\cdot\text{m}$, may also be reported for levels A through P. Refer to Figure 5 in SAE J2964, 6.5, for illustration of a static breakaway measurement.

7. DATA REPORTING

7.1 Data Tables

A data table showing the friction material, separator plate, and fluid along with the system performance at each level in terms of the coefficients and ratios, as given in 6.3. An example table is given in Appendix B.

7.2 Figures

There are two figures required in reporting the results of this test. Examples of the two figures are given in Appendix B, Figure B2.

- Figure of the midpoint dynamic coefficient versus the level letters A through P.
- Figure of the E/M ratio and breakaway coefficient versus level letters A through P.

If the system does not successfully complete both the 25 dynamic engagements and the breakaway test, there is no data reported for that level. Alternatively, only data for the successful completion of a level are to be reported. Failure is defined as complete destruction of the friction material/system, such as defacing of the friction material from the steel core(s) or extreme warping of the steel plate(s). (Report number of cycles into level at which failure occurred.)

7.3 Optional Data

Instantaneous plots of the 25th dynamic engagement at each level may be provided. Examples of such optional data are shown in Appendix B, Figure B1.