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SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

SAE J651

**REV.
JAN91**

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Superseding J651 JAN89

(R) PASSENGER CAR AND TRUCK AUTOMATIC TRANSMISSION TEST CODE

1. SCOPE:

To provide a means of comparing the performance characteristics of automatic transmissions. It outlines dynamometer tests that cover the range of operation of transmissions and provides a method of presenting the test data. This procedure must be followed with similar test facilities so that results obtained from different laboratories are comparable.

For this SAE Recommended Practice, the transmission is defined as the complete assembly driven by the engine and used to effect a ratio change in transmitting power to the final drive system.

2. REFERENCES:

There are no referenced publications specified herein.

3. SCOPE OF TESTS:

The range of test conditions on the dynamometer must be sufficient to determine the characteristics corresponding to the full range of vehicle operations.

The transmission characteristics to be determined for all driving ranges or gears are:

- a. Efficiency vs output speed;
- b. Torque ratio vs output speed;
- c. Input speed vs output speed;
- d. Output torque vs output speed;
- e. Parasitic losses vs input speed.

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4. EQUIPMENT AND TEST PROCEDURE:

- 4.1 Driving and absorbing dynamometers capable of speed measurement within ± 5 rpm and torque measurement within ± 0.7 N·m or $\pm 0.5\%$ of full load are to be used for all tests except Test 7 (6.3.1). Test 7 (parasitic losses) is to be performed using a driving dynamometer capable of speed measurement within ± 5 rpm and torque measurement within ± 0.3 N·m or $\pm 1\%$ of maximum value, whichever is greater.
- 4.2 The transmission must be fitted with suitable pressure and temperature indicators in order to assure proper control of transmission test conditions.
- 4.3 Before starting tests for the transmission characteristics, calibration curves should be obtained on the dynamometers and instruments to be used for the measurement of torque, speed, pressure, and temperature.
- 4.4 A fluid of known physical and chemical characteristics and approved by the manufacturer of the unit should be used, and the fluid level maintained according to the manufacturer's specifications.
- 4.5 Fluid temperatures for all standard tests should be 90 to 100°C at the sump and 130°C maximum at the outlet of the hydrodynamic drive. Temperature for the hydraulic retarder coast test must not exceed 175°C. Higher or lower temperatures may be used if recommended by the manufacturer. At or near stall, the sump temperature may be reduced to maintain outlet temperature.
- 4.6 Suitable heat exchangers must be used to control sump temperature and avoid altering transmission performance.
- 4.7 Equipment may be required to control or position the transmission torque sensing device for line pressure control.
- 4.8 All readings must be taken simultaneously with loads, speeds, temperatures, and pressures stabilized when possible. When such stabilization is not possible, the time interval between readings and the rate of change must be noted.
- 4.9 The automatic action of shift valves may require blocking to prevent the transmission from shifting during the test, since the characteristics of the test dynamometer during a shift may not be comparable to those of the vehicle for which the transmission is designed.
- 4.10 To assure proper functioning before the recording of test data, it may be advisable to establish a pre-run at the approximate test conditions.
- 4.11 Added run-in time on the transmission may be required to achieve the desired degree of break-in. A 1 h run in with a minimum of 50 medium torque runs through the shift pattern is recommended.
- 4.12 It may be necessary to orient the transmission in its normal vehicle position to obtain similar operating conditions.
- 4.13 It may be necessary to add supplementary lubrication at certain points, such as the extension bearing and seal.

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- 4.14 For coast tests, it may be necessary to provide initial system oil pressure from an external source.

5. OPERATING MODES:

There are three operational modes for which data must be obtained:

5.1 Drive:

Normal rotation with normal power flow (transmission input driving).

5.2 Coast:

Normal rotation with reverse power flow (transmission output shaft driving) as in vehicle closed-throttle coasting operation, with and without hydraulic retarder functioning (if included with transmission).

5.3 Parasitic Losses:

Normal rotation with no power output (transmission output shaft free).

6. STANDARD TESTS:

All tests are to be run in all forward driving ranges or ratios, including converter clutch applied, if applicable. Reverse tests are optional.

6.1 Drive Mode:

- 6.1.1 Test 1 - Full-Throttle Performance: This test is run by setting the input dynamometer speed and torque to corresponding values on the full-throttle-installed net torque curve of an engine used in a typical application of the automatic transmission. The output speed for the lowest gear range is set at or near stall and increased in selected increments to span the full range of vehicle speeds. Data for the other gear ranges shall be taken from speeds above which the full-throttle down-shift occurs. The transmission torque sensing device (throttle valve and/or vacuum modulator) must be locked in full throttle position.

- 6.1.2 Test 2 - Constant Input Torque (Optional for Trucks): This test is run by controlling the speed of the driving dynamometer to obtain the torque selected while controlling the output dynamometer speed. The output speed is varied in selected increments, keeping the input torque constant. The procedure is repeated for several input torque values. Torque values are commonly chosen as approximate percentages of the maximum full-throttle, vehicle-installed engine torque for a typical application of the automatic transmission being tested - for example, 100, 50, and 25%. For passenger cars, the lowest torque value is approximately that required for level road operation at constant speed in the middle of the vehicle speed range.

Output speed values are chosen to span the full range of vehicle operating conditions. The transmission torque sensing device must be set to provide proper pressures for the torque input used.

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- 6.1.3 Test 3 - Cross-Sectional Road Load Performance (Passenger Car): This test is to be run when the transmission is used in many vehicle applications. With the information obtained, it is possible to evaluate transmission performance for any specific vehicle road load requirement. The test is run by setting the output dynamometer to a constant torque and varying its speed in increments. The test is repeated for several output torques. Output torque values are chosen to span the full range of vehicle road load requirements. A minimum value of (25 N·m) and a maximum of (200 N·m) is a suitable range for most transmission installations. The speed range tested for each output torque should be consistent with vehicle road-load requirements. For example, at 25 N·m the output speed range could be 600 to 1800 rpm, whereas for 100 N·m the range could be 3000 to 4200 rpm. For each torque, the transmission torque sensing device is adjusted to the position setting it would have in a typical vehicle installation when driven at a constant speed equivalent to the mean of the speed for that torque.
- 6.1.4 Test 4 - Specific Road Load Performance (Passenger Car): This test is to be used for a specific or very limited number of transmission-vehicle applications. It is run by adjusting the input dynamometer speed and torque to obtain the required output speed and torque values corresponding to zero acceleration requirements of the vehicle on level ground for the full range of vehicle speeds. For each speed, the transmission torque sensing device is adjusted to the position setting it would have in the vehicle when driven at that constant speed.
- 6.2 Coast Mode:
- NOTE: For coast tests, it may be necessary to provide initial system oil pressure from an external source.
- 6.2.1 Test 5 - Cross-Section Coast Performance: This test is run when the transmission is used in vehicles that have a variety of engine sizes. With the information obtained, it is possible to evaluate the coasting performance of any specific transmission-engine combination. For this test, the driving dynamometer powers the transmission output shaft. The test is run by controlling the absorbing dynamometer to hold constant torque at the transmission input member (usually the torque converter impeller) while varying its speed incrementally. It is repeated for several torque values. The torque values are selected to cover the full range of engine friction torques. For example (for passenger cars), at 20 N·m engine torque the engine speed might range from 1000 to 2000 rpm, and at 60 N·m the engine speed might range from 3000 to 4000 rpm. The transmission torque sensing device is set to engine idle condition during the entire test.
- 6.2.2 Test 6 - Specific Coast Performance: This test is to be used for a specific vehicle application and the test set-up is the same as for Test 5 (6.2.1). It is run by driving the output shaft while absorption dynamometer speed and torque are adjusted to a closed-throttle engine torque curve with ignition on. The transmission torque sensing device must be locked in closed-throttle position throughout the test. A standard vehicle engine may be used instead of the absorption dynamometer.

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6.3 Parasitic Losses:

- 6.3.1 Test 7: The parasitic loss test is run in all driving ranges or gears with the transmission output shaft permitted to turn freely.

The torque and speed of the driving dynamometer indicate the losses attributable to pumping, windage, and friction within the transmission. The transmission torque sensing device is locked in the no-load position during the test. If transmission line pressure is affected by the torque signal, the test must be repeated with the torque sensing device locked at maximum and any desired intermediate torque positions.

It is frequently desirable to distinguish between losses which are a function of engine speed and those which are related kinematically to vehicle speed. This is of most significance when the test results will be used for any sort of mathematical analysis which addresses the speed differential across the hydrodynamic unit.

When the losses are to be separated, the test is run in two parts. Engine related losses are determined by modifying the transmission such that there is no connection between the hydrodynamic unit output member and the transmission gearbox. Vehicle speed related losses are determined by driving the hydrodynamic unit output shaft directly with dynamometer. This may be done with the hydrodynamic unit removed or with the unit locked and all engine speed losses disconnected. If the transmission pump is inoperable during the test, the transmission is pressurized by an external source.

7. REQUIRED DATA: (See Table 1)

TABLE 1

Performance	Test Condition
Input torque	Specification number or trade name of the fluid
Input speed	Transmission line pressure
Output torque	Pressure and flow to cooler
Output speed	Position of torque sensing device
	Temperature in and out of cooler
	Sump temperature
	Hydrodynamic unit outlet temperature
	Test fixture friction and windage losses

8. PRESENTATION OF RESULTS:

- 8.1 Completely identify the transmission unit and record test conditions on all data and curve sheets.

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- 8.2 Develop the desired performance curves. Examples of typical plots are shown in Figures 1 to 7 for a three-speed torque converter transmission (for passenger cars) without lock-up. Other transmissions may have 4 to 6 speeds and lock-up. In preparing curves using engine and vehicle data, it is essential that the data precisely describe the net power to and from the transmission; that is, all corrections for accessories, air temperature, barometer reading, air cleaners, mufflers, and fan losses must be considered. The words "vehicle-installed" engine torque and horsepower express this condition.
- 8.3 Include copies of the data or identify the data sheets with the reported results.

9. COMPUTATIONS:

$$\text{Speed ratio} = \frac{\text{output speed}}{\text{input speed}} \quad (\text{Eq.1})$$

$$\text{Torque ratio} = \frac{\text{output torque}}{\text{input torque}} \quad (\text{Eq.2})$$

$$\text{Transmission efficiency, \%} = (\text{Speed ratio})(\text{Torque ratio})(100) \quad (\text{Eq.3})$$

Power Input =

SI Units

U.S. Customary Units

$$P_i = \frac{T_I N_I \pi}{30\,000} \quad P_i = \frac{T_I N_I}{5252} \quad (\text{Eq.4})$$

where:

P_i = input power, kW
 T_I = input torque, N·m
 N_I = input speed, rpm

P_i = input power, hp
 T_I = input torque, lbf·ft
 N_I = input speed, rpm

$$\text{Power loss} = (\text{input power})(1.00 - \text{transmission efficiency}/100) \quad (\text{Eq.5})$$

$$\text{Tractive effort attributable to drivetrain:} \quad (\text{Eq.6})$$

$$\text{Tractive effort (driving)} = \frac{\text{engine torque} \cdot \text{TTR} \cdot R_d \cdot E_d / 100}{RR}$$

$$\text{Tractive effort (retarding)} = \frac{\text{engine motoring friction torque} \cdot \text{TTR} \cdot R_d \cdot 100 / E_d}{RR}$$

where:

TE = tractive effort, N (lbf)
 TTR = Trans. torque ratio
 R_d = final drive axle ratio
 $E_d/100$ = rear axle efficiency
 RR = rolling radius, m (ft)

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9. (Continued):

Tractive effort is defined as the tangential force transmitted between the tire and the road. The component attributable to the drivetrain usually cannot exceed the product of the normal force times the coefficient of friction.

Road load tractive force and power required for passenger cars on level road at constant speed: (For trucks refer to SAE J688)

S.I. Units:

(Eq.7)

$$\begin{aligned} TF_{RL} &= K_1 F_g + K_2 AV^2 \\ P_{RL} &= (K_1 F_g + K_2 AV^2) V / 3600 \end{aligned}$$

where:

TF_{RL} = road load tractive force, N
 P_{RL} = road load power, kW
 F_g = test gravitational force of vehicle, N
 V = velocity, km/h
 A = frontal area, m^2
 K_1 = rolling resistance coefficient
 K_2 = wind resistance coefficient

U.S. Customary Units:

$$\begin{aligned} TF_{RL} &= K_1 W + K_2 AV^2 \\ P_{RL} &= (K_1 W + K_2 AV^2) / 375 \end{aligned}$$

where:

TF_{RL} = road load tractive force, lbf
 P_{RL} = road load power, hp
 W = test gravitational force of vehicle, lbf
 V = velocity, mph
 A = frontal area, ft^2
 K_1 = rolling resistance coefficient
 K_2 = wind resistance coefficient

Sample calculation (for checking values of constants):

SI Units		U.S. Customary Units
20 000 N	F_g, W	4496.18 lbf
2.5 m^2	A	26.9098 ft^2
80 km/h	V	49.710
0.016	K_1 (typical)	0.016
0.0231	K_2 (typical)	0.0012496
300.0 N	$K_1 F_g$	67.443 lbf
350.0 N	$K_2 AV^2$	78.683 lbf
650.0 N	TF_{RL}	146.126 lbf
$\frac{FV}{3600} = 15.00$ kW	P_{RL}	$\frac{FV}{375} = 20.1153$ hp

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9. (Continued):

$$\text{Rolling radius (m)} = \frac{1000}{2\pi(\text{rev/km})} \quad (\text{Eq.8})$$

$$\text{Rolling radius (ft)} = \frac{5280}{2\pi(\text{rev/mile})}$$

SI Units:

$$N/V = \frac{(\text{rev/km})(\text{final drive axle ratio})}{60} \quad (\text{Eq.9})$$

U.S. Customary Units:

$$N/V = \frac{(\text{rev/mile})(\text{final drive axle ratio})}{60}$$

This ratio is used as the ratio of driveshaft speed to vehicle velocity.

where:

N = rpm

V = kph or mph

The force which accelerates the vehicle down any grade is given by:

SI Units:

$$F = F_g \sin [\arctan (\% \text{ of grade}/100)] \quad (\text{Eq.10})$$

where:

F = force component downhill, N

F_g = test gravitational force of vehicle, N

U.S. Customary Units:

$$F = W \sin [\arctan (\% \text{ of grade}/100)]$$

where:

F = force component downhill, lbf

W = test gravitational force of vehicle, lbf

The (R) is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

PREPARED BY THE SAE AUTOMATIC TRANSMISSION/TRANSAXLE STANDARDS COMMITTEE

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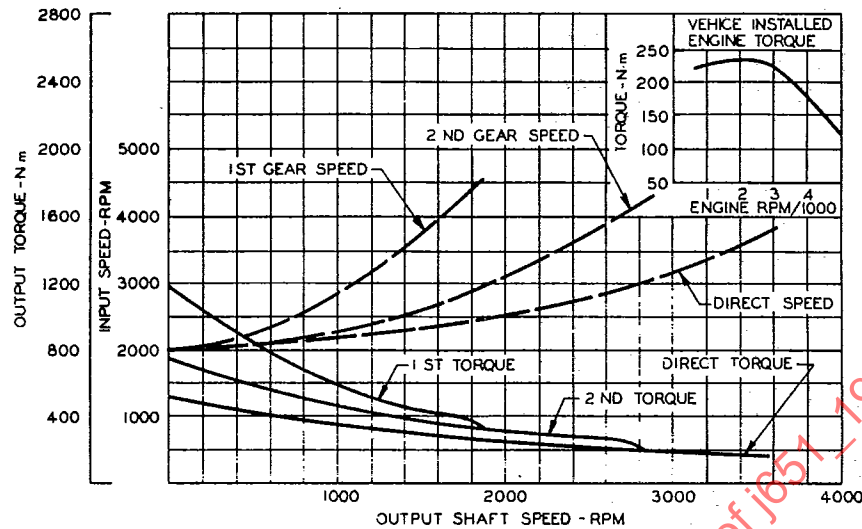


FIGURE 1 - Test 1 - Typical Output Speed Plot of Transmission, Full Throttle Performance

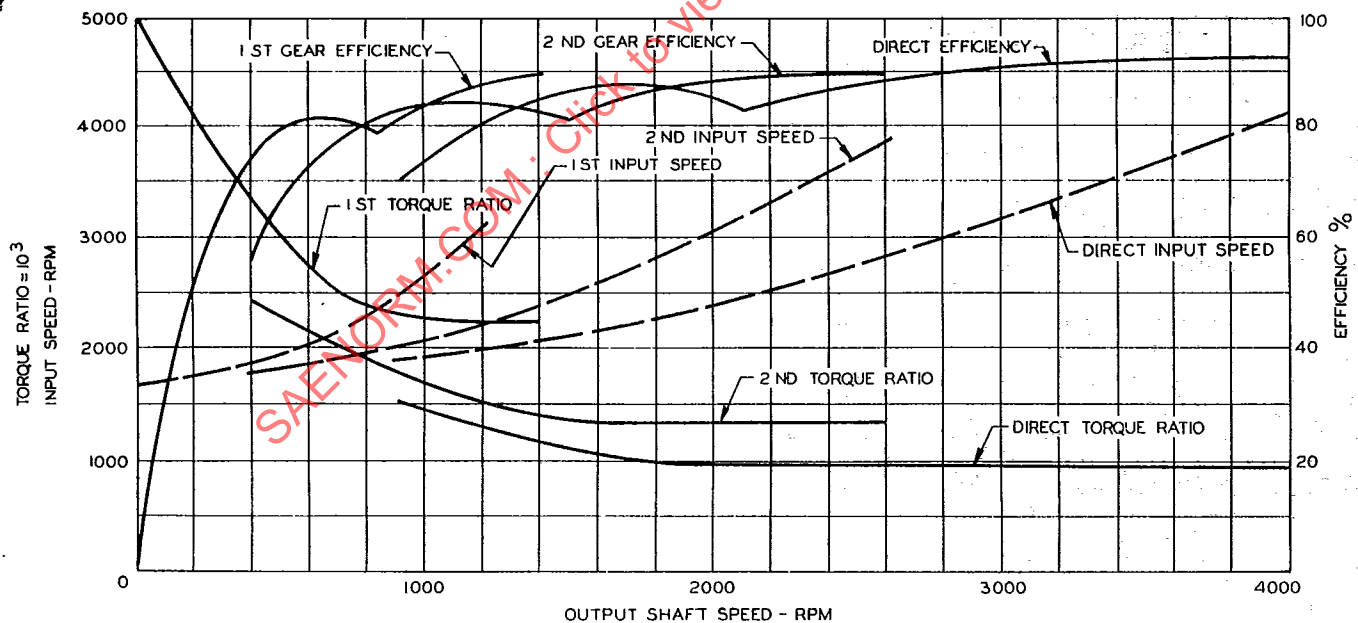


FIGURE 2 - Test 2 - Typical Output Speed Plot of Transmission Characteristics Constant Input Torque (150 N·m)

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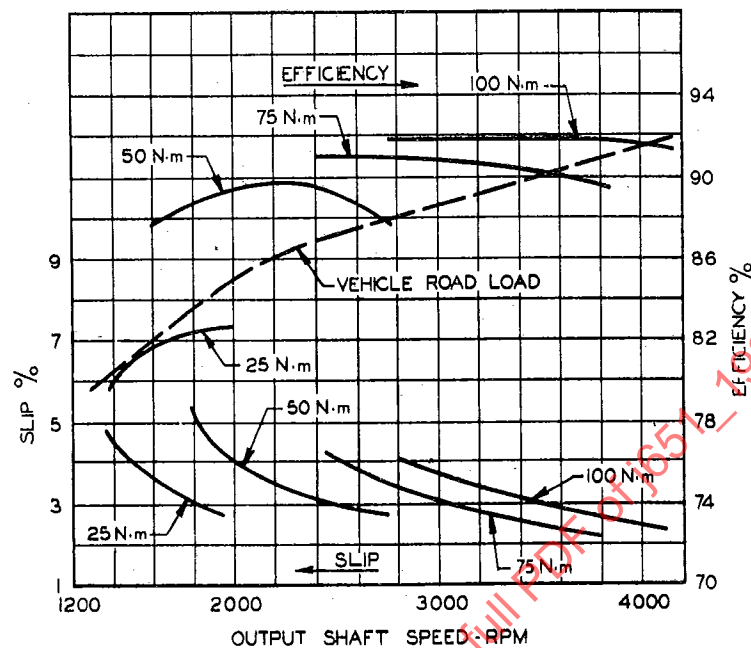


FIGURE 3 - Test 3 - Typical Output Speed Plot of Transmission Cross Sectional Road Load Performance

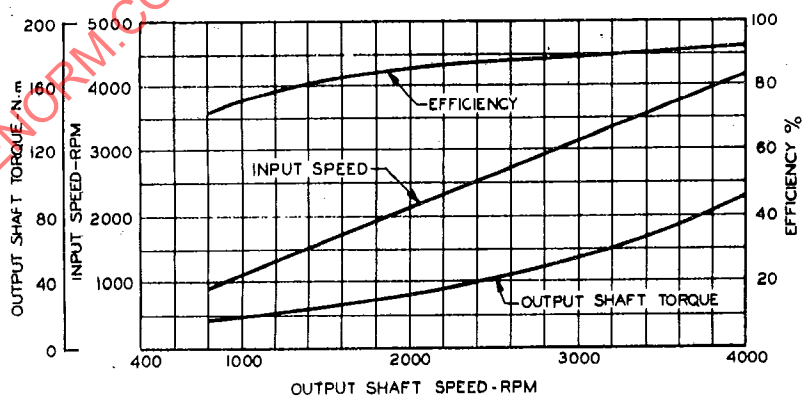


FIGURE 4 - Test 4 - Typical Output Speed Plot of Transmission, Specific Road Load Performance-Direct Gear

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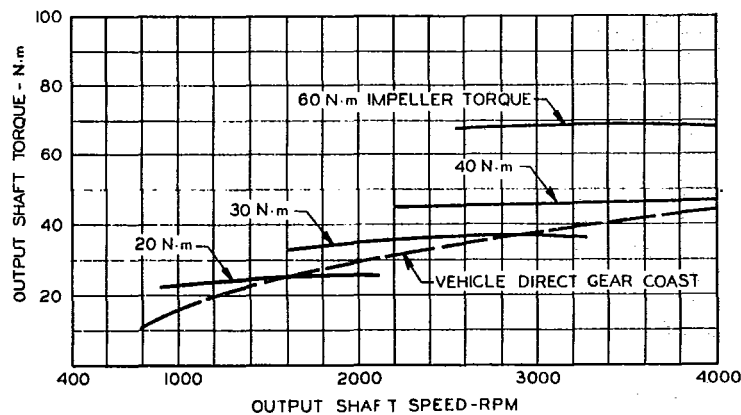


FIGURE 5 - Test 5 - Typical Output Speed Plot of Transmission Cross Sectional Coast Performance

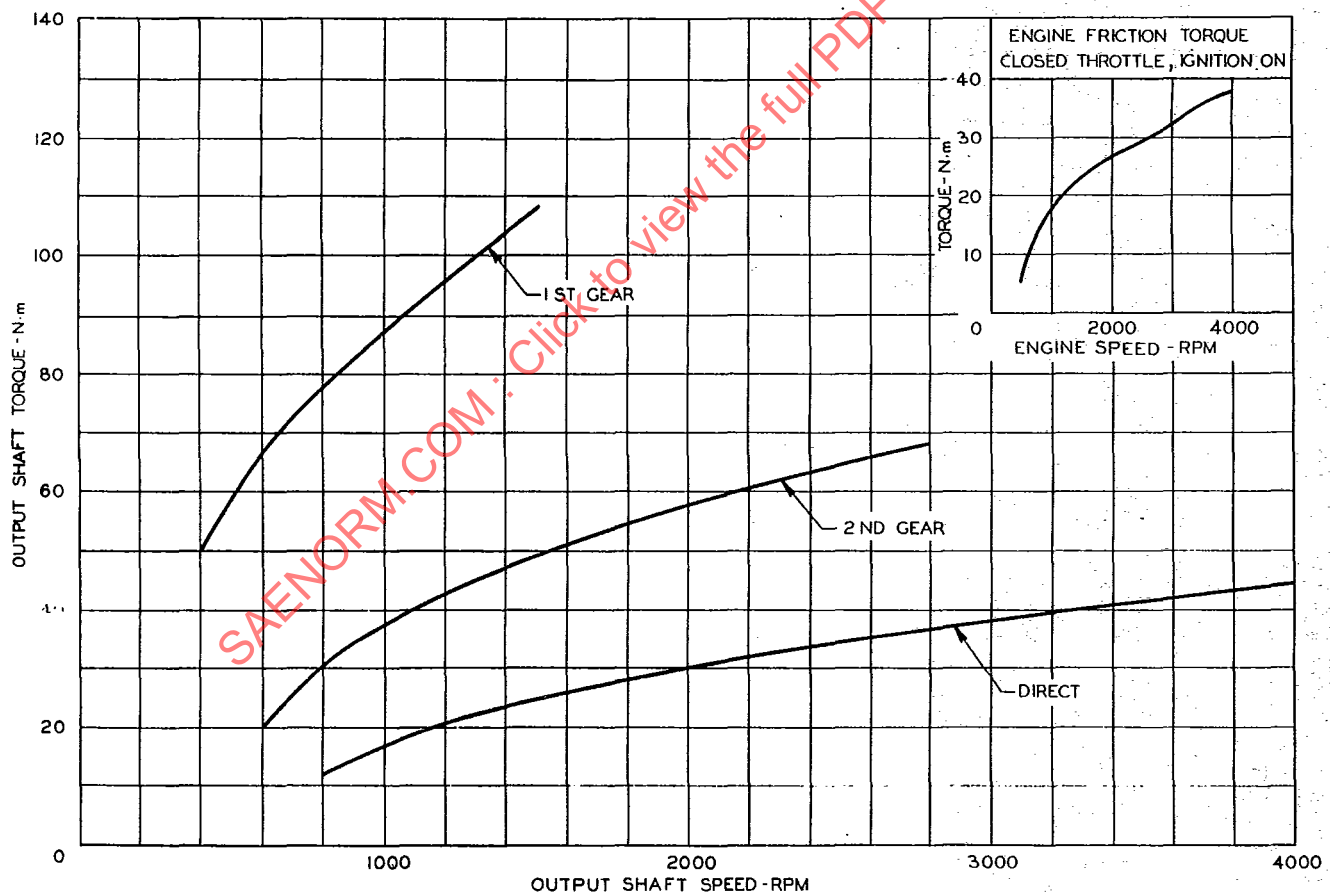


FIGURE 6 - Test 6 - Typical Output Speed Plot of Specific Transmission Coast Performance