

Submitted for recognition as an American National Standard

**(R) PASSENGER CAR AND LIGHT TRUCK AUTOMATIC TRANSMISSION
AND AUTOMATIC TRANSAXLE TEST CODE**

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. **Scope**—To provide a means of obtaining the performance characteristics of automatic transmissions and automatic transaxles. It outlines dynamometer tests that map the steady-state characteristics over a range of operations of an automatic transmission/automatic transaxle and provides a method of presenting 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 automatic transmission or transaxle assembly between the engine and the driveshaft(s) used to effect a ratio change in transmitting power.

This test procedure deals with the aspect of conducting complete transmission and transaxle assembly testing. However, by its very nature a transmission should be viewed as a compilation of three major component systems: pump, torque converter, and gearbox (all ratio change elements).

From a design perspective, it is important that the losses associated with each of these components be determined by conducting separate tests of each component under controlled test conditions that simulate the in-transmission operating conditions. Torque converter testing is described in SAE J643. If done with strict attention to detail it is possible to subtract off the pump and torque converter losses from the transmission assembly losses in order to obtain gearbox losses only, eliminating the need to conduct a separate gearbox test.

2. **References**

- 2.1 **Applicable Publication**—The following publication forms a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J643—Hydrodynamic Drive Test Code

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3. Scope of Tests—The extent of test conditions on the dynamometer must be sufficient to determine the characteristics corresponding to the following range of vehicle operations in all gear ratios with open and locked torque converters where appropriate.

- a. Efficiency versus output speed versus input torque
- b. Torque ratio versus output speed
- c. Input speed versus output speed
- d. Output torque versus output speed
- e. Parasitic loss versus input speed (spin losses)
- f. Cooler flow
- g. Output torque bias (front wheel drive transaxles)

4. Equipment and Test Procedure

4.1 Driving and absorbing dynamometers capable of speed measurement within ± 5 rpm and torque measurement within ± 1.0 N·m or $\pm 0.5\%$ of full load are to be used for all tests except Test 6 (6.3.1). Test 6 (parasitic losses) is to be performed using a driving dynamometer capable of speed measurements within ± 5 rpm and torque measurement within ± 0.5 N·m or $\pm 1\%$ of maximum value, whichever is greater.

4.1.1 TORQUE BIAS FOR FRONT-WHEEL DRIVE TRANSAXLES—The optimum test setup is dual output torque measurement with identical right- and left-hand output speeds and to record the right- and left-hand output torque. If this is not possible, mechanical lock of the differential is required.

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 for the dynamometer(s) and instruments for the measurement of torque, speed, and temperature, pressure, and flows.

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 $80\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ at the sump and $130\text{ }^{\circ}\text{C}$ maximum at the outlet of the hydrodynamic drive. At or near stall, the sump temperature may be reduced to maintain outlet temperature.

4.6 Suitable heaters and heat exchangers must be used to obtain specified operating conditions. Special attention should be taken of the watt density of the heater to prevent transmission fluid overheating.

4.6.1 The lube flow schedule should be incorporated into the test, since it affects the transmission efficiency.

4.7 Mechanical or electrical equipment may be required to control the desired transmission line pressure.

4.8 Shift valves and solenoids may require mechanical blocking and/or electrical actuation to prevent the transmission from shifting during the test, thus allowing steady-state operation for data acquisition.

4.9 All readings must be sampled simultaneously, with loads, speeds, temperatures, pressures, and flows stabilized where possible. When such stabilization is not possible, the time interval between readings and the rate of change must be noted.

4.10 To assure proper function before data acquisition, it is advisable to conduct a pre-run at the approximate test conditions.

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- 4.11 Break-in time is required on the transmission. A 1 h break-in with a minimum of 50 medium torque runs through the shift pattern is recommended.
- 4.12 The transmission should be oriented in its normal installed position to simulate in-vehicle operating conditions.
- 4.13 It may be necessary to add supplementary lubrication at certain points, such as the extension bearing and its seal.
5. **Operating Modes**—There are three operating 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 driving) as in vehicle closed-throttle coasting operation.
- 5.3 **Parasitic Losses**—Normal rotation in drive direction with no power output (transmission output free).
6. **Standard Tests**—All tests are to be run in all forward driving ranges or ratios, with and without converter clutch applied, if appropriate. 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 torque to corresponding values on the full-throttle installed net torque curve (accessories included) 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 (powertrain control module or equivalent throttle valve and/or vacuum modulator) must be adjusted or commanded to full throttle position.
- 6.1.2 **TEST 2—CONSTANT INPUT TORQUE**—This test is run by controlling the torque of the input 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 transmission being tested—for example, 75%, 50%, and 25%. The lowest torque value approximates road load operation (0% grade) 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 or commanded to provide proper pressures for the torque input used.
- 6.1.3 **TEST 3—CROSS-SECTIONAL ROAD LOAD PERFORMANCE**—This test is run by setting the output dynamometer to a constant torque and varying the input dynamometer 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 300 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 each speed sweep for a given torque, the transmission torque-sensing device is adjusted or commanded to a position simulating vehicle conditions at the mean speed of the sweep. See Table 1.

TABLE 1—SAMPLE VALUES

Torque	Speed Sweep	Torque Sensing Equivalent Setting
25 N·m	600 to 1800 rpm	120 rpm
300 N·m	3000 to 4200 rpm	3600 rpm

6.1.4 TEST 4—SPECIFIC ROAD LOAD PERFORMANCE—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 vehicle acceleration on level ground for the full range of vehicle speeds. For each speed, the transmission torque-sensing device is adjusted or commanded to the position setting it would have in the vehicle at that constant speed.

6.2 Coast Mode

NOTE—To simulate a coast test, the input dynamometer must be running at the appropriate speed for the transmission operating condition.

6.2.1 TEST 5—CROSS SECTION COAST PERFORMANCE—This test is run to cover the coast performance over the full operating range. The torque values are selected to cover the full range of engine friction torques. For example at 40 N·m engine torque, the engine speed ranges from 1000 to 7000 rpm. The transmission torque-sensing device is adjusted or commanded to engine idle condition during the entire test.

6.3 Parasitic Losses

6.3.1 TEST 6—The parasitic loss test is run in all driving ranges or gears with the transmission output permitted to turn freely except in those ranges or gears that require a minimal load to engage an overrunning clutch. The torque and speed of the input dynamometer indicate the pumping, windage, and friction losses within the transmission. The transmission torque-sensing device is adjusted or commanded to the no-load position during the test.

7. Required Data-Measured Test Parameters

- a. Input Torque
- b. Input Speed
- c. Output Torque(s)
- d. Output Speed(s)
- e. Transmission Line Pressure(s)
- f. Pressure and Flow to Cooler
- g. Temperature In and Out of Cooler
- h. Sump Temperature(s)
- i. Hydrodynamic Unit Outlet Temperature
- j. Test Fixture Friction and Windage Losses

8. Presentation of Results

8.1 Completely identify the transmission unit and record test conditions and specifications or trade name of the fluid on all tabular and graphical data and curve sheets.

8.1.1 Examples of typical component data presentation are shown in Figures 1 and 2.

Typical Torque Converter Performance

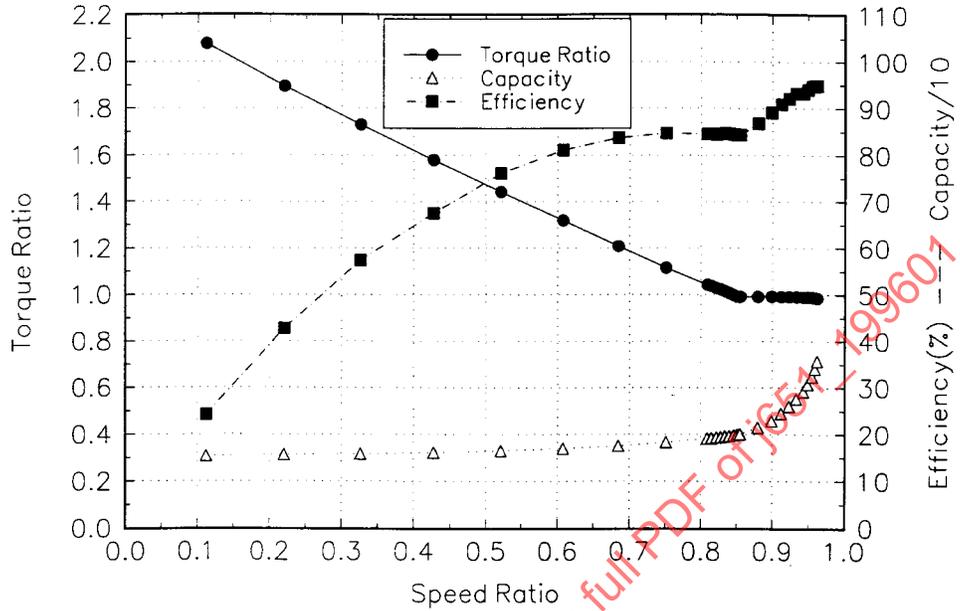


FIGURE 1—TORQUE CONVERTER PERFORMANCE

Pump Performance as a Function of Speed
(Constant 71 Deg. C Temperature and 1.03 MPa Pressure)

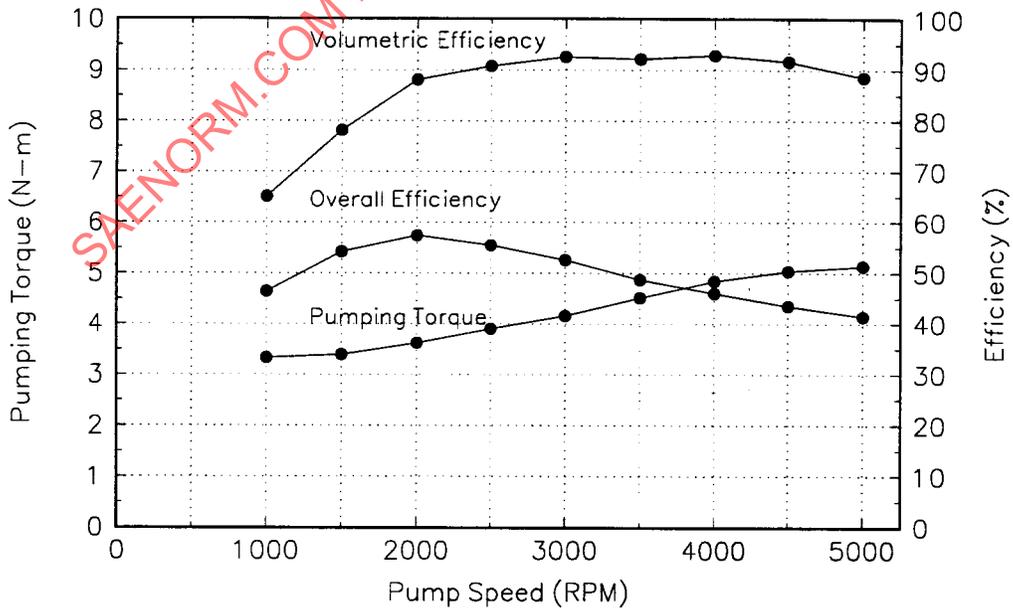


FIGURE 2—PUMP PERFORMANCE

8.1.2 Examples of typical torque loss data presentation are shown in Figures 3 through 7.

Torque Losses for Fourth Gear Locked Converter
(High and Low Line Pressures with Constant 125 N-m Torque)

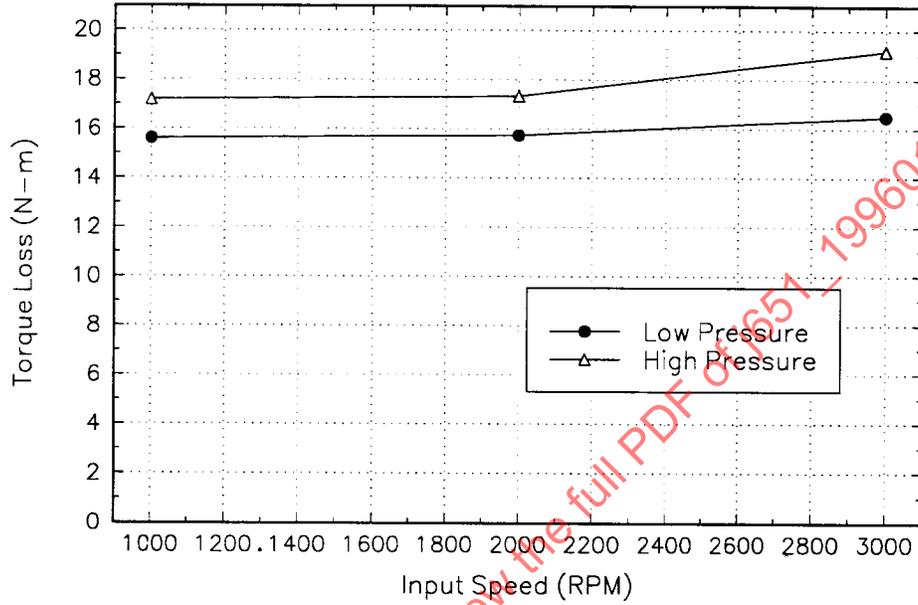


FIGURE 3—LINE PRESSURE EFFECT ON TORQUE LOSS

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Transmission Torque Losses as a Function of Input Speed and Torque
(Third Gear Locked Converter)

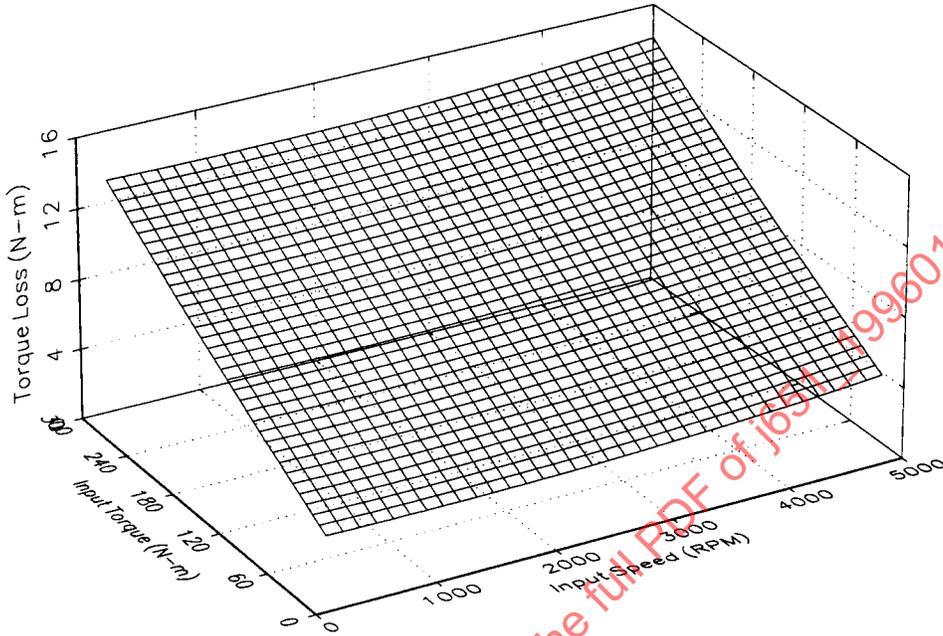


FIGURE 4—TRANSMISSION TORQUE LOSS THIRD GEAR CONVERTER LOCKED

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Gearbox Torque Losses as a Function of Input Speed and Torque

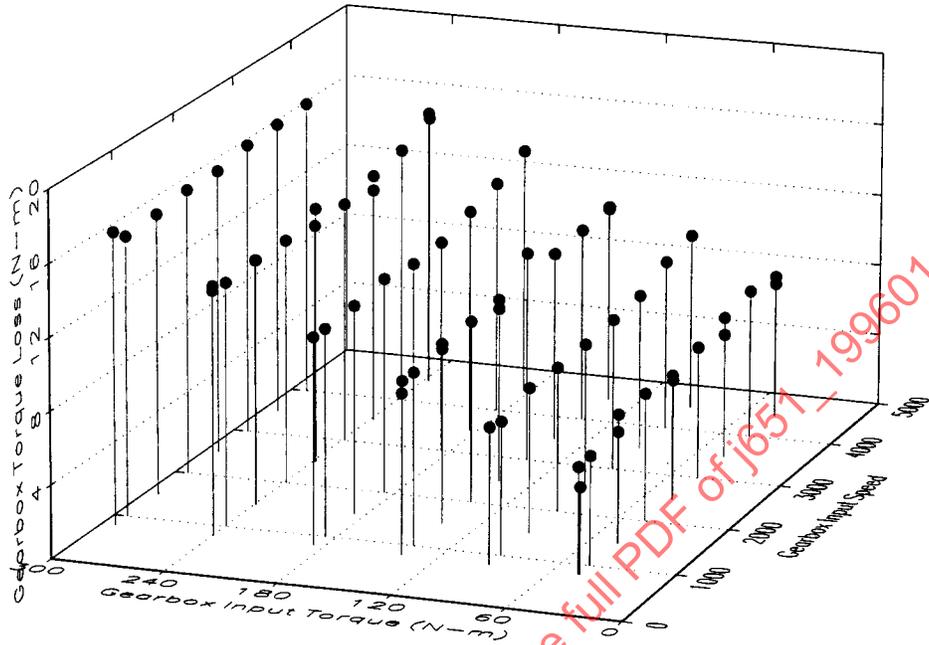


FIGURE 5—OBSERVED TORQUE LOSS VERSUS INPUT TORQUE AND SPEED

Predicted Versus Observed Torque Loss

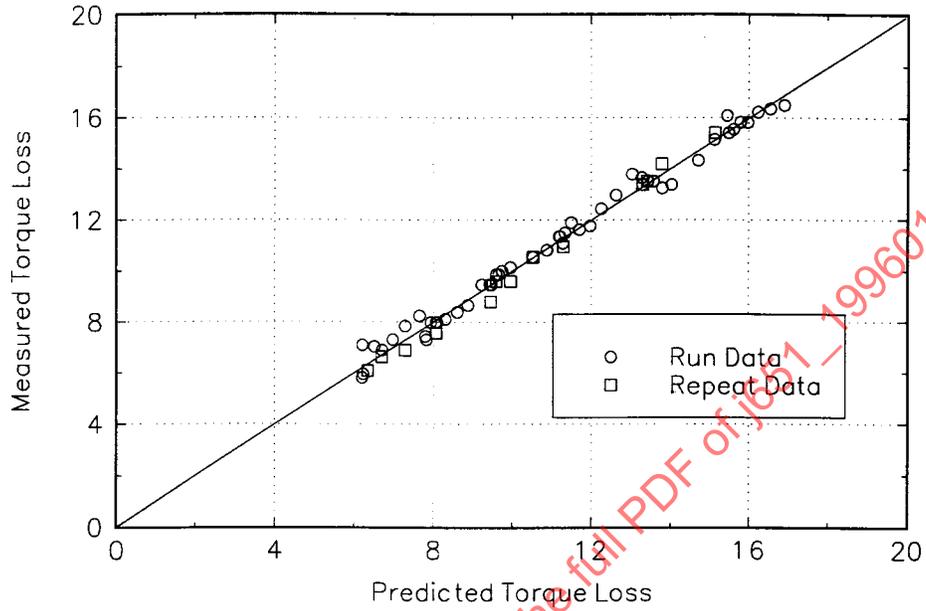


FIGURE 6—PREDICTED VERSUS OBSERVED TORQUE

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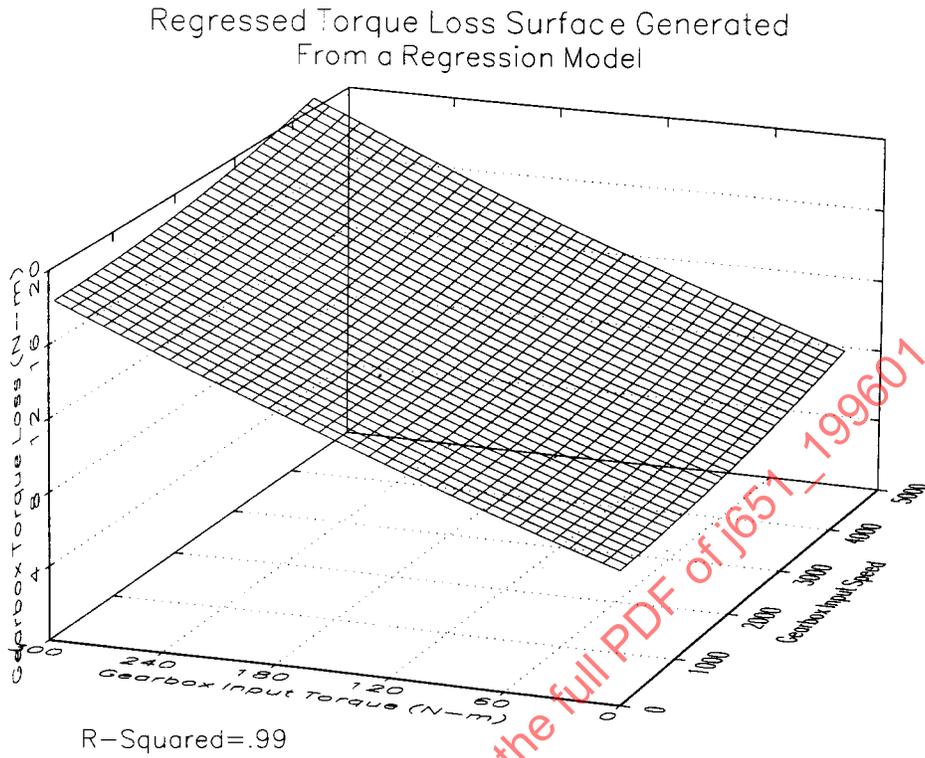


FIGURE 7—TORQUE LOSS RESPONSE SURFACE GENERATED FROM REGRESSION MODEL

8.1.3 Examples of typical transmission assembly efficiency data presentation are shown in Figures 8 through 10.

Transmission Efficiency as a Function of Input Speed
(Fourth Gear Locked Converter at Five Torque Levels)

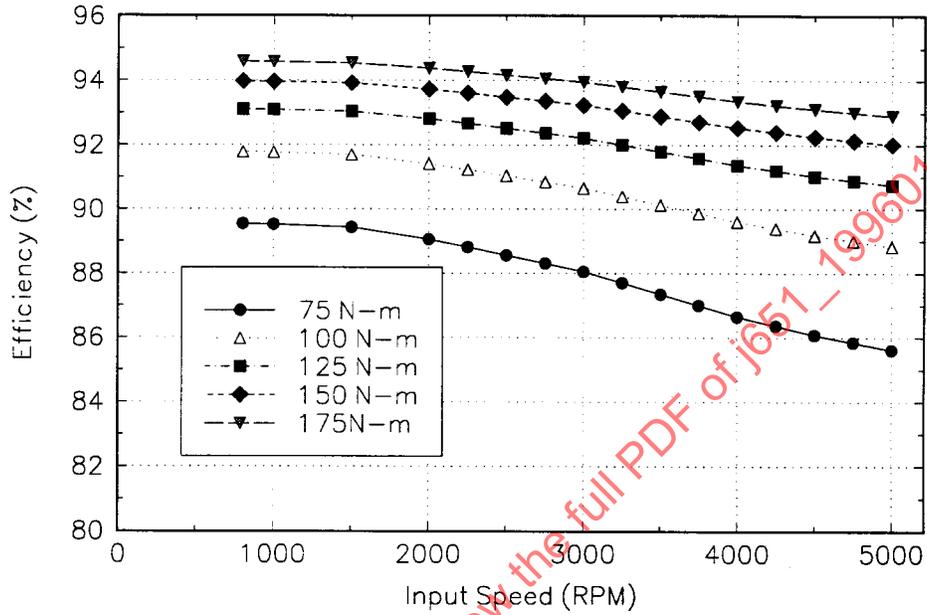


FIGURE 8—TRANSMISSION EFFICIENCY FIRST GEAR UNLOCKED CONVERTER

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Transmission Efficiency as a Function of Input Speed
(Fourth Gear Locked Converter at Five Torque Levels)

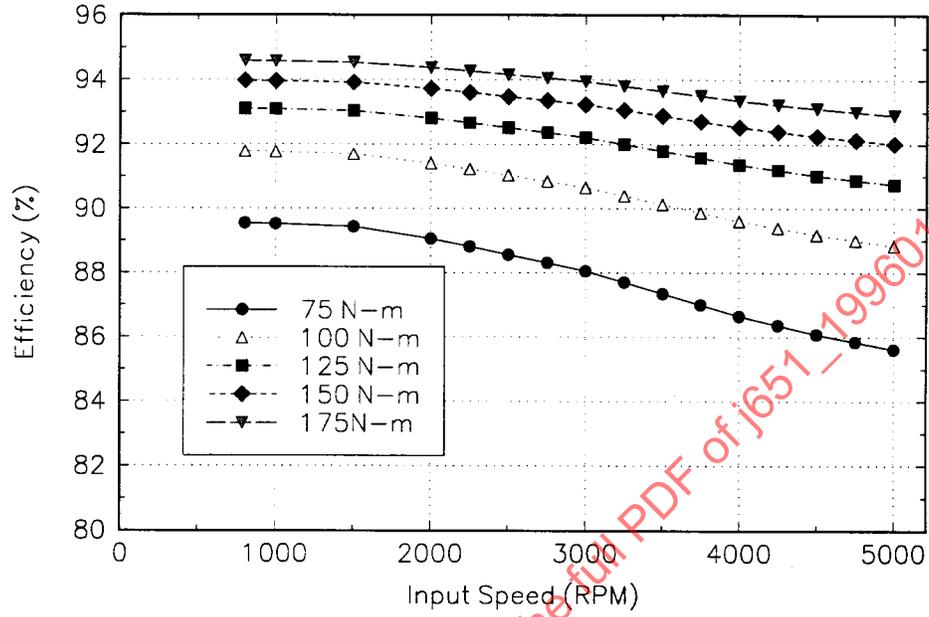


FIGURE 9—TRANSMISSION EFFICIENCY FOURTH GEAR CONVERTER LOCKED

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Transmission Efficiency as a Function of Input Speed
(Engine Driving Model for Different Gears)

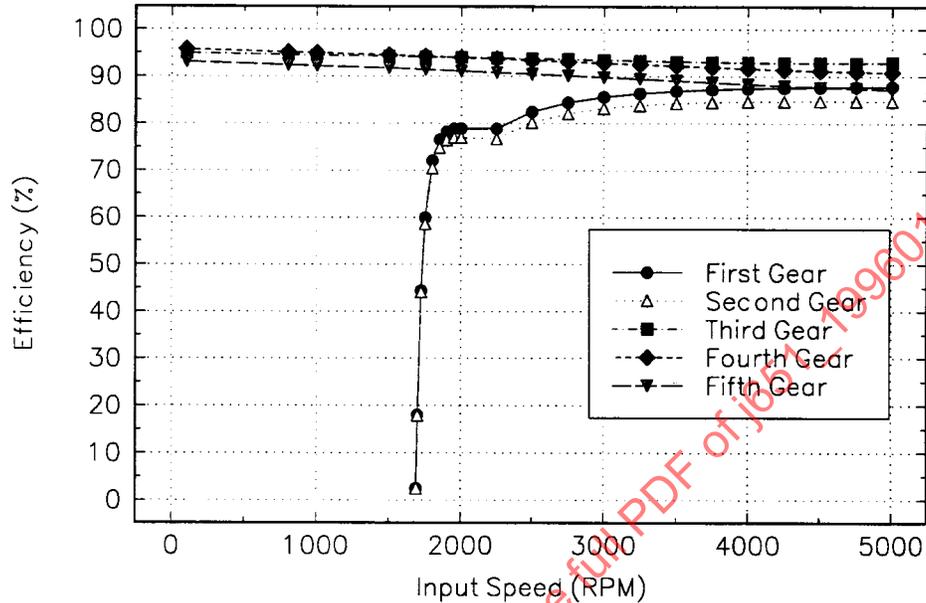


FIGURE 10—TRANSMISSION EFFICIENCY DIFFERENT GEARS

8.2 Include copies of the data or identify the data sheets with the reported results.

8.3 **Statistical Repeats**—In order to confirm the degree of repeatability of the test data obtained, repeat testing should be performed after the main series of test has been completed. The repeat testing should consist of approximately 15% of the test conditions of the main test procedure. The repeat of torque and speed conditions should be uniformly distributed over the torque and speed regime. (Note some scatter in the data is normal.)

8.4 **Torque Loss Data Reduction Using Statistical Response Surface Regression Techniques**—Statistical regressions are performed in order to determine the relationship of torque loss, input speed, and input torque to the measured torque points.

8.4.1 **DATA PLOTTING**—A three-dimensional polynomial response surface is fit to the input speed and input torque using a quadratic relationship to speed, speed², torque, and torque².

8.4.2 **ADEQUACY OF THE REGRESSION MODEL**—Adequacy is confirmed using R², RMSE, and residual plots.

- a. R² is the adequacy of the fit.
- b. RMSE is standard error of torque loss.
- c. A two-dimensional scatter plot of observed torque losses versus predicted torque losses as determined from the regression model is constructed to establish residuals. (Residuals are the difference between the predicted and actual torque losses.)
- d. An ideal model will generate predicted points that would be on the 45 degree line passing through 0.
- e. Speed and input torque data outliers are identified and removed.