Passenger Car and Light Truck Automatic Transmission
and Automatic Transaxle Test Code

RATIONALE

This Recommended Practice had defined a test procedure and process which gave a reasonably complete description of the efficiency and performance of a 20th century automatic transmission. With the introduction of electronic controls, the number of parameters which control the transmission's operation have expanded extensively and these need to be defined for each test. The interaction between the transmission, the environment, the engine, the cooling and other systems have also made test definition very difficult and complex. Finally, the diversity, the rapid changes, and the component complexity introduced by electric and hybrid drive system combine with the above difficulties to make it impractical to define a Recommended Practice which could provide a meaningful description of performance and efficiency of 21st century automotive transmissions.

The existing Recommended Practice J651 is being stabilized to preserve the test procedures for future reference.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE Automatic Transmission Transaxle Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1.   REFERENCES

1.1   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.

1.1.1   SAE Publication

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

SAE J643   Hydrodynamic Drive Test Code

SAE J2311   Hydraulic Pump Test Code

2.   SCOPE OF TESTS

The extent of test conditions on the dynamometer must be sufficient to determine the efficiency characteristics corresponding to the following range of vehicle operations in all gear ratios with locked torque converters (open converter can also be done where appropriate and noted).

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)

3.   EQUIPMENT AND TEST PROCEDURE

3.1   Driving and absorbing dynamometers capable of speed measurement within ±5 r/min and torque measurement within ±1.0 N·m or ±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 r/min and torque measurement within ±0.5 N·m or ±1% of maximum value, whichever is greater.

3.1.1   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.

3.2   The transmission must be fitted with suitable pressure and temperature indicators in order to assure proper control of transmission test conditions.

3.3   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.

3.4   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.

3.5   Fluid temperatures for all standard tests should be 80 °C ± 3 °C at the sump.

3.6   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.

3.7   The lubrication circuit(s) flow and pressure schedule should be incorporated into the test, since it affects the transmission efficiency.

3.8   Mechanical or electronic equipment may be required to replicate the transmission line pressure with typical actual operating pressures. These adjustments should be recorded.

3.9   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.

3.10   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. Data acquisition should be time history based with a suggested sampling rate of 10 Hz.

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

3.12   Break-in time is required on the transmission. Examples could include a 1 hour break-in with a minimum of 50 medium torque runs through the shift pattern, or 30 minutes in each gear at 70 N·m. Break-in should include some number of shifts to exercise the clutches as well.

3.13   The transmission should be oriented in its normal installed position to simulate in-vehicle operating conditions. An example for a typical RWD is 4 to 5 degree installed angle. If it is necessary to run at non-representative installed angle, insure that the oil level relationships are not compromised.

3.14   It may be necessary to add supplementary lubrication at certain points, such as the extension bearing or bushing and its seal.

4.   OPERATING MODES

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

4.1   Drive

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

4.2   Coast

Normal rotation with reverse power flow (transmission output driving) as in vehicle closed-throttle coasting operation.

4.3   Parasitic Losses

Normal rotation in drive direction with no power output (transmission output free).

5.   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.

5.1   Drive Mode

NOTE: The following is a menu of Drive Mode test options; not all are required.

5.1.1   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.

5.1.2   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%.

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.

5.1.3   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 1800 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 r/min	120 r/min
1800 N·m	3000 to 4200 r/min	3600 r/min

5.1.4   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.

5.2   Coast Mode

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

5.2.1   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 r/min. The transmission torque-sensing device is adjusted or commanded to engine idle condition during the entire test.

5.3   Parasitic Losses

5.3.1   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 provide proper one-way clutch operation. 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.

6.   RECOMMENDED DATA-MEASURED TEST PARAMETERS

6.1   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.   Case Out Temperature

6.2   To confirm test system repeatability, it is suggested to run pre-test and post-test data quality assurance tests to insure equipment has functioned reliably and accurately.

7. PRESENTATION OF RESULTS

7.1   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.

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

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

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

FIGURE 1 - TORQUE CONVERTER PERFORMANCE

Pump Performance as a Function of Speed
(Constant 71 Deg. C Temperature and 1.03 MPa Pressure)
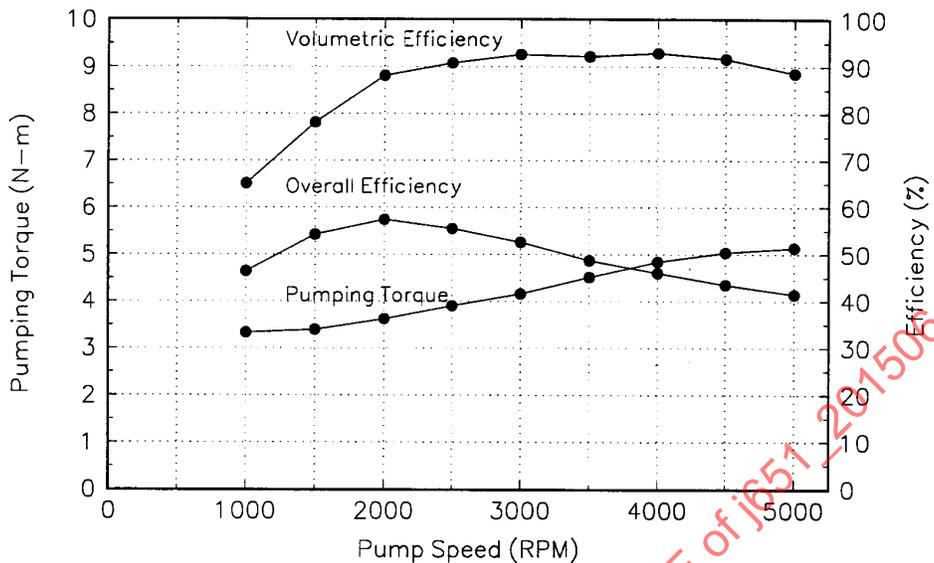
FIGURE 2 - PUMP PERFORMANCE

Torque Losses for Fourth Gear Locked Converter
(High and Low Line Pressures with Constant 125 N-m Torque)
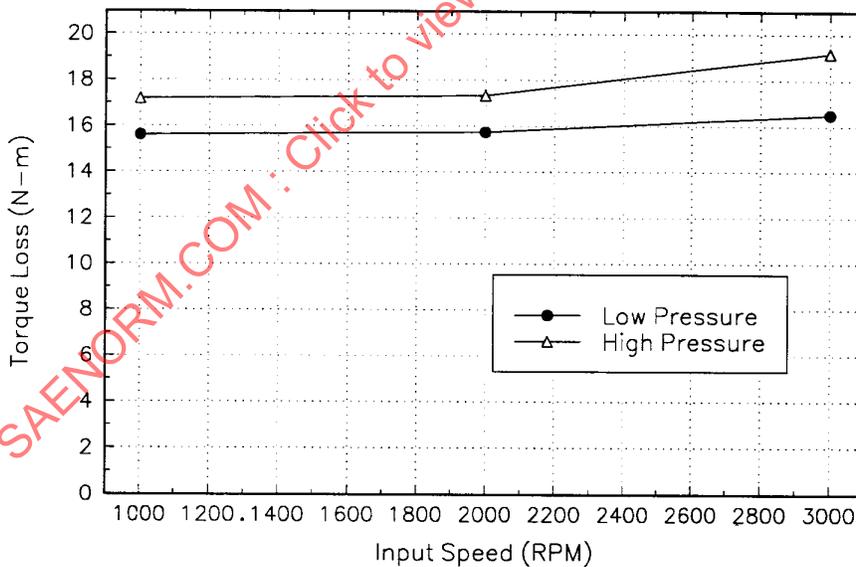
FIGURE 3 - LINE PRESSURE EFFECT ON TORQUE LOSS

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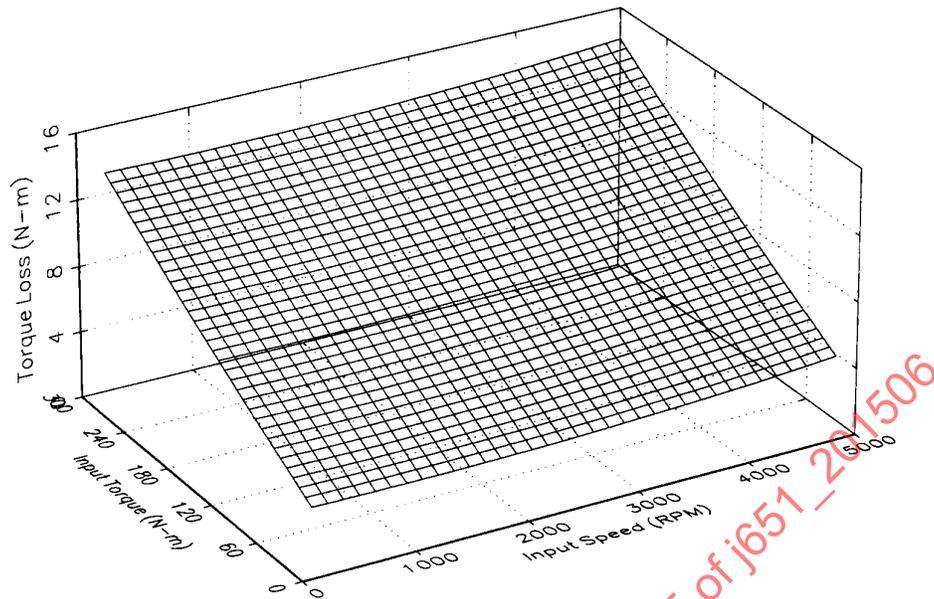(Third Gear Locked Converter)

FIGURE 4 - TRANSMISSION TORQUE LOSS THIRD GEAR CONVERTER LOCKED

Gearbox Torque Losses as a Function of Input Speed and Torque
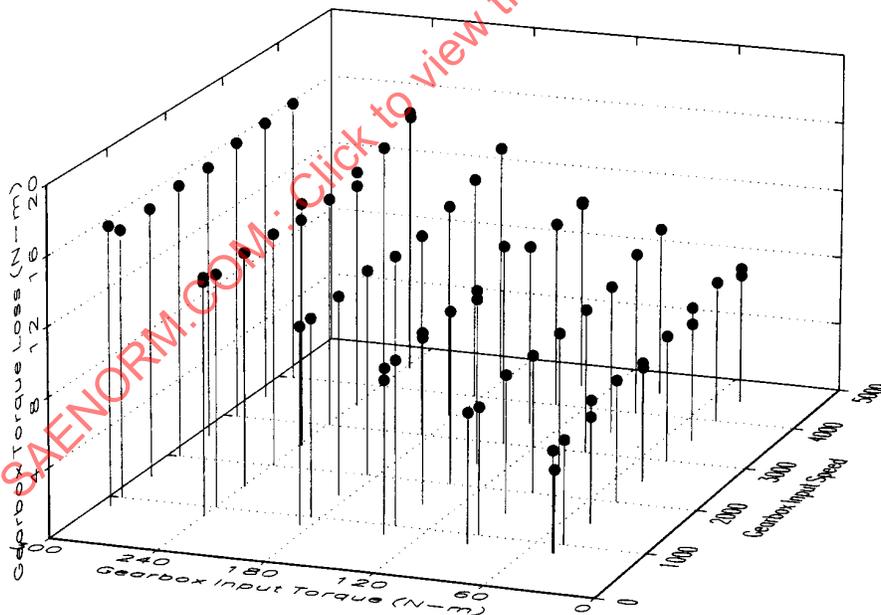
FIGURE 5 - OBSERVED TORQUE LOSS VERSUS INPUT TORQUE AND SPEED
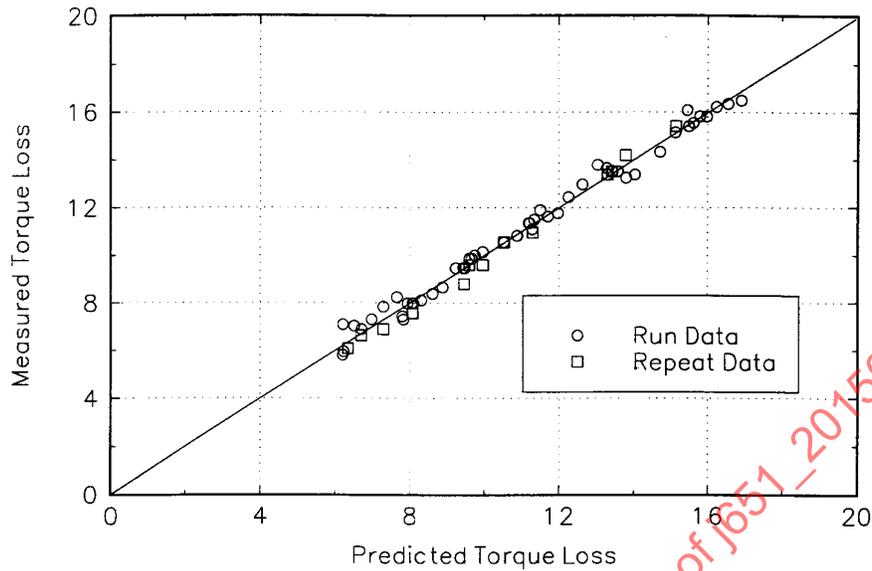
Predicted Versus Observed Torque Loss

FIGURE 6 - PREDICTED VERSUS OBSERVED TORQUE

Regressed Torque Loss Surface Generated
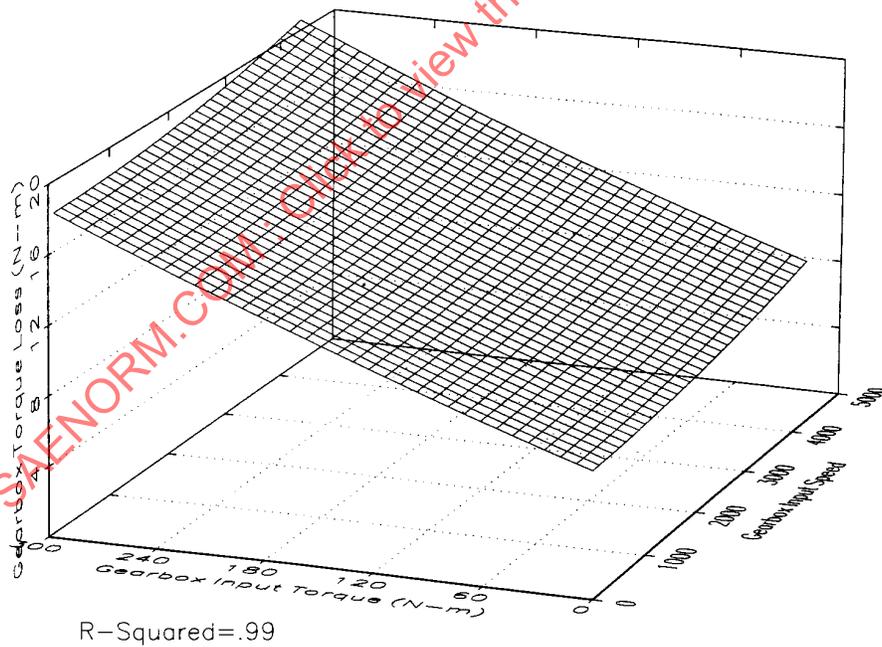From a Regression Model

R-Squared=.99

FIGURE 7 - TORQUE LOSS RESPONSE SURFACE GENERATED FROM REGRESSION MODEL

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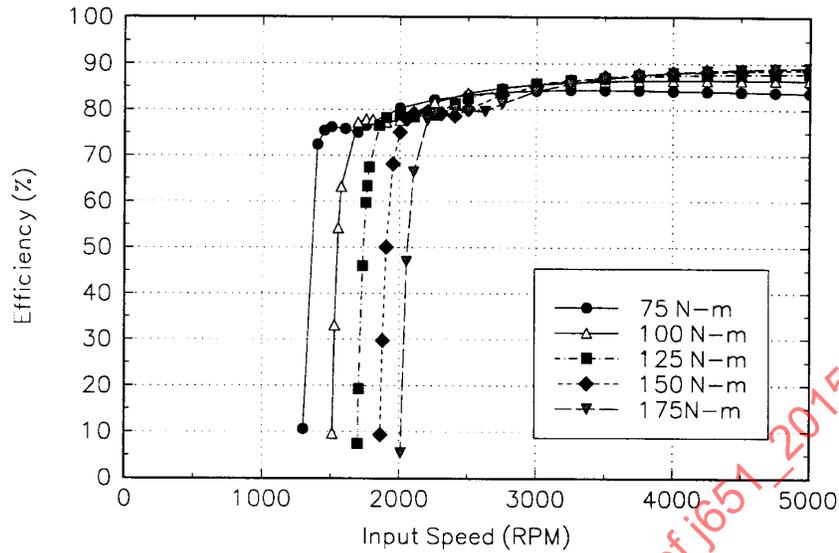

FIGURE 8 - TRANSMISSION EFFICIENCY FIRST GEAR UNLOCKED CONVERTER

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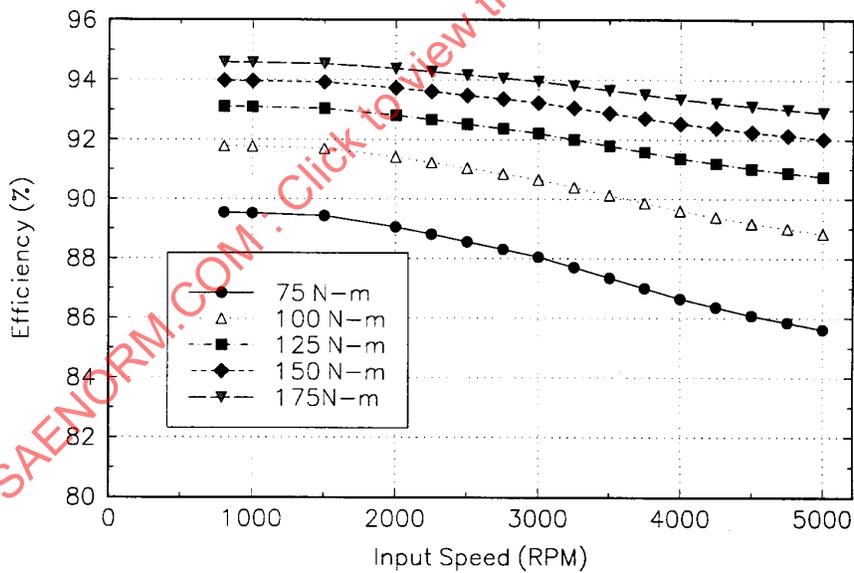(Fourth Gear Locked Converter at Five Torque Levels)

FIGURE 9 - TRANSMISSION EFFICIENCY FOURTH GEAR CONVERTER LOCKED

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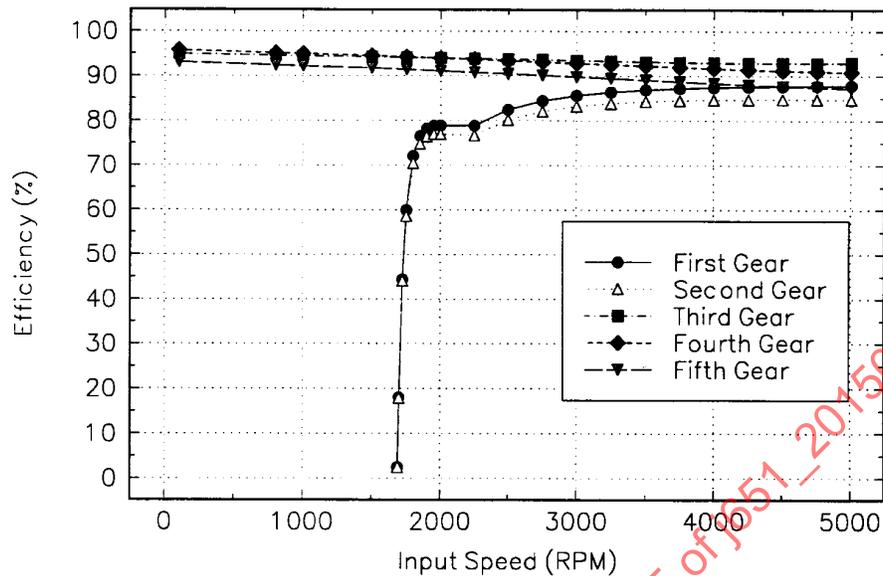

FIGURE 10 - TRANSMISSION EFFICIENCY DIFFERENT GEARS

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

7.3   Statistical Repeats

In order to confirm the degree of repeatability of the test data, repeat testing should be considered. Below are some recommended strategies for repeat testing:

7.3.1   Reduced Run Plans

This strategy calls for running a reduced set of the entire test array. A recommended target is 20% of the original run plan. For example, if the original run plan consisted of an array of five gears, five input load levels, and two transmission sump temperatures (i.e., a 5X5X2 array, or 50 elements) across the full operating speed range of the transmission, then the reduced run plan could consist of five gears, two input loads and one operating temperature (a 5X2X1 array, or 10 elements). Note that the test target levels are unchanged. Only the number of targets change. This reduced test plan could be run on the same sample multiple times or on new test samples, up to the discretion of the designer's test plan.

7.3.2   Full Run Plans

The entire test plan could be repeated on the same sample or on multiple samples.