



Transfer Case/Power Transfer Unit Efficiency and Spin Loss Test Procedure

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose.

- To provide a method to measure the Efficiency and Spin Loss of various driveline torque transfer components at the component level.
- To provide a means to consistently measure and quantify the speed-dependent parasitic loss ("Spin Loss") characteristics of transfer cases (Tcases) and Power Transfer Units (PTU) in support of modeling and analysis of vehicle-level emissions and fuel economy.
- To result in data which are comparable from one test to another and between laboratories.

1.2 Applicability. This standard is applicable to:

- Transfer cases and PTUs used in passenger car and light truck applications.
- All drivelines that incorporate a torque transfer device.
- Tcases/PTUs mounted in a bench level test fixture.
- It is not applicable to Tcases/PTUs installed in the vehicle.

1.3 Remarks.

1.3.1 General.

- The primary intent of this test is to provide a measurable effect the Tcase/PTU will have on the overall Efficiency of a vehicle powertrain.
- For Efficiency testing, the test cell is configured with a dynamometer driving the Tcase/PTU input shaft and braking dynamometers on the front and rear output.
- For Spin Loss testing, this procedure applies to the 2WD/RWD operation mode only. The test cell is configured with a motor driving the Tcase/PTU input, a precision torque measurement device mounted between the motor and Tcase/PTU, and the front/rear outputs unloaded and unconstrained (not connected, except during break-in, if required).

1.3.2 Procedures. The following SAE procedures were used in developing this procedure.

- SAE J1952 All Wheel Drive Systems Classification.
- SAE J2059 All-Wheel-Drive Drivetrain Schematic Symbol Standards.
- SAE J2263 Road Load Measurement Using Onboard Anemometry and Coastdown Techniques.
- SAE J2985 Definition and Measurement of Transfer Case Speed Dependent Parasitic Loss.
- SAE J3039 Definition and Measurement of FWD based Power Transfer Unit Dependent Parasitic Loss.

1.3.3 Break-in Dynamometer Schedule.

1.3.3.1 Transfer Case.

- a. One of the two procedures presented in 4.3.4 must be utilized for break-in.
 1. 4.3.4.1 presents a traditional break-in schedule where a load applied at the input is reacted at the rear output (the front output is unconstrained).

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2. 4.3.4.2 presents a significantly abbreviated break-in schedule that is achieved by spinning cold (-7 °C) test units unloaded (both front and rear outputs are unconstrained).

Note: Both methods will yield directly comparable results for speed dependent parasitic loss measurements.

Note: It is surmised that, at the low temperature of -7 °C, the internal running clearances of the transfer case are minimized, hence spinning the input for 10 minutes at 2930 rpm results in comparable data to that achieved by running the longer (loaded) break-in schedule outlined in 4.3.4.1.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

SAE J1952	SAE J2263	SAE J3039
SAE J2059	SAE J2985	

2.2 GM Standards/Specifications.

None

2.3 Additional References.

- CG4206.
- Component drawing.
- Component Technical Specification (CTS).
- Driveline Math Data.
- Electrical Mechanization Information.
- Master Process Document (MPD).
- Subsystem Technical Specification (SSTS).

3 Resources

3.1 Facilities. Test laboratories.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.1.1 Torque Meter. Prior to each test, the torque meter zero must be checked or adjusted to zero at zero applied torque. Zero applied torque means that the torque meter couplings are completely disconnected from the drive shafts to remove any locked-in torque. Pre-test and post-test readings are to be recorded with each set of Efficiency test data in the Tcase Data Sheet in CG4206. No other torque meter calibrations or adjustments are to be made. Factory calibrations are to be verified by the torque meter manufacturer at regular intervals (typically six months). The required precision cannot be duplicated outside of the torque meter manufacturer laboratory so on-site calibrations are not needed.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Dynamometers and related torque measurement equipment (torque measuring devices capable of ± 0.05 Nm accuracy).

3.2.2 Standard horizontal axis test stand.

Note: If a linkshaft or gearbox are utilized, they should be located between the drive motor and input torque meter.

3.2.2.1 The test bench should have tilt capability in order to conduct the testing with the unit mounted in the as-installed vehicle position/angle (typically 5° to 7° off horizontal with the rear output of the transfer case lower than the input; this will more accurately replicate the in-vehicle oil level and flow behavior). The installation angle must be documented in the test report.

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3.2.2.2 For Efficiency measurements, test stand with dynamometer driving the transfer case input shaft and braking dynamometers on the front and rear output. Torque and speed measurements will need to be recorded at all three positions.

3.2.2.3 For Spin Loss measurements, test stand with a motor driving the Tcase/PTU input and a precision torque measurement device mounted between the motor and Unit under Test (UUT) as shown schematically in Appendix A, Figure A1.

3.2.3 Temperature control must be via external (environmental) conditioning.

3.2.3.1 Temperature-Controlled Chamber.

- Chamber must be capable of controlling the Tcase/PTU temperature without directly conditioning the oil inside the case (i.e., via convection).
- The method used should minimize the creation of localized hot or cold spots on the case (a heat gun blowing directly on the UUT, for example).
- The chamber must be capable of achieving an average skin temperature (AST) in the range of -7 °C (20 °F) to +65 °C (150 °F) with a tolerance of ± 1 °C (± 1.8 °F).
- It is recommended that Liquid Nitrogen (LN₂) be utilized to achieve the lower temperature range of -7 °C.
- A schematic of the a typical chamber is shown in Appendix B, Figure B1 and a photograph of the chamber is shown in Appendix B, Figure B2.

3.2.4 Torque and speed capabilities of the test stand are to be appropriately sized for the UUT.

3.2.5 A sampling rate ≥ 10 Hz is recommended for data acquisition.

3.2.6 The torque meter should be appropriately sized in consideration of the low drag torques (< 10 Nm) expected and transducer with a smaller range (0 Nm to 100 Nm) is recommended.

- Torque meter accuracy is to be ± 0.05 Nm over the full scale range.
- Input speed measurement is to be accurate to within ± 2 rpm of actual speed. **Note:** No specification for the input shaft stiffness is provided since data used in the analysis is collected during steady state conditions.

3.2.7 Sump Temperature.

- A thermocouple installed in the drain plug (as shown in Appendix B, Figure B3) of the UUT to record the temperature of the oil **within** the test unit. This temperature is used in conjunction with the AST to establish the temperature state of the UUT. **Note:** Sump temperature is not included in the AST calculation/definition defined in 3.3.1.

3.3 Test Vehicle/Test Piece.

3.3.1 Transfer case (each UUT to be prepared with the following thermocouple array) as shown in Appendix C, Figure C1 Average Skin Temperature (AST) sample locations.

Note: Thermocouples should be "soldered tip" type (i.e., exposed wires, tip) and adhered to the unit using thermally conductive adhesive to be most representative of the metal temperature. The AST measurement to be composed of the arithmetic average readings of seven (7) thermocouples located as follows:

- Number 1 through Number 4: As close to the outer race of the input and output shaft support bearings as possible (four (4) total thermocouples).
- Number 5: As close to the vent as possible, but not inside the vent.
- Number 6: Top of transfer case housing (center/middle of main input shaft).
- Number 7: Top of transfer case above torque multiplying gear set (for multi-speed units; for single speed, as close as possible to the "transfer gear"– belt/chain/gear - which drives the front output shaft).

3.3.2 Power Transfer Unit (PTU) (each UUT to be prepared with the following thermocouple array):

- Number 1: Input bearing (transmission side).
- Number 2: Input bearing (halfshaft output side, opposite mounting flange).
- Number 3: Propshaft output bearing (12 o'clock position).
- Number 4: Housing top (input section).
- Number 5: Housing top (output section).

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- Number 6: Housing bottom (input section).
- Number 7: Housing bottom (output section).

3.4 Test Time.

Transfer Case Break-in:

Calendar time:	3 days (break-in)
Test hours:	72 h (break-in)
Coordination hours:	4 h (component builds)

PTU Break-in:

Calendar time:	3 days (break-in)
Test hours:	72 h (break-in)
Coordination hours:	4 h (component builds)

Tcase Spin Loss Test:

Calendar time:	1 day (per component)
Test hours:	4 h total (per component)
Coordination hours:	4 h (per component)

PTU Spin Loss Test:

Calendar time:	1 day (per component)
Test hours:	4 h total (per component)
Coordination hours:	4 h (component builds)

3.5 Test Required Information.

3.5.1 Vehicle identification.

3.5.1.1 Transfer case/PTU, Regular Production Option (RPO) and description, if applicable.

3.5.2 Special Identification (if applicable).

3.5.2.1 Remote mounted transfer case.

3.5.2.2 Transverse powertrain with PTU.

3.5.3 Test Reference Documents.

3.5.3.1 Driveline Math Data. Driveline Math Data is used in verifying relative position and angle of the driveline components.

3.5.3.2 Electrical Mechanization Information. Electrical Mechanization Information is needed to enable the Tcase/PTU to run in the dynamometer (non-vehicle) environment.

3.5.3.3 Master Process Document (MPD). These aid in proper assembly. Nominal dynamic or minimum static fastener torques must be used.

3.5.3.4 Data Sheets. Use Data Sheets in CG4206.

3.6 Personnel/Skills.

3.6.1 Test Engineer. Understand the role that the Spin Loss testing and analysis plays in the vehicle development process.

3.6.2 Test Technician. Should be proficient in proper selection and operation of the equipment listed in 3.2.

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4 Procedure

4.1 Preparation.

4.1.1 Test Stand Connections.

4.1.1.1 For Efficiency measurements, assemble test cell with dynamometer driving the transfer case input shaft and braking dynamometers on the front and rear output. Torque and speed measurements will need to be recorded at all three positions.

4.1.1.2 For Spin Loss measurements, assemble standard horizontal axis test stand with a motor driving the Tcase/PTU input and a precision torque measurement device mounted between the motor and UUT as shown schematically in Appendix A, Figure A1.

4.1.2 Insure that all safety shields are in place.

4.1.3 Install proper fluids to the design intent levels.

The standard test lubricant for these tests is per GM production specification. Prior to each test, all component fluid levels are to be checked and topped-off if necessary.

4.1.4 Pre-test Decisions.

4.1.4.1 Deviations from the requirements of this procedure must be approved by the GM Driveline Engineering Group and noted in the test report. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.1.4.2 Sample Inspection. All driveline components should be visually checked for correct part number(s), suffix levels, proper assembly, weld quality, defects, and overall appearance. Note and correct any deficiencies before continuing.

4.1.5 Test Specifications.

4.1.5.1 Obtain minimum torque specification for all driveline components from the MPD or the GM Fastener Engineer. Install the driveline components with minimum static or nominal dynamic specification torques.

4.2 Conditions.

4.2.1 Environmental Conditions. This test is performed in an indoor dynamometer-equipped test cell.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.2.1 Test temperatures (confirmed using AST within ± 1 °C):

- a. -7 °C
- b. 21 °C
- c. 65 °C

4.2.2.2 Test speeds for PTU (input speed within ± 2 rpm):

- a. 117
- b. 233
- c. 467
- d. 933

4.2.2.3 Test speeds for transfer cases (input speed within ± 2 rpm):

- a. 250
- b. 300
- c. 500
- d. 600
- e. 900
- f. 1000
- g. 1500
- h. 1600
- i. 2000

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- j. 2500
- k. 2900
- l. 3000
- m. 3500

4.2.3 Soak Time. The soak time is defined as the minimum amount of time the UUT must be maintained at target average skin temperature in order to achieve repeatable results. An example of the temperature profile for the temperatures included in the AST (defined in 3.3) is shown in Appendix D, Figure D1 (note that the offset in temperatures T1 and T5 represents standard measurement variation - measurement error, temperature distribution within the cold box, etc.) Soak 4 h followed by a 45 minute soak. The soak requirements are further outlined in 4.3.4.2.

Note: If the available cooling system is not be capable of reaching an AST of $-7\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ within 4 h, additional "pre-soak" time will be required prior to the 45 minute additional soak (at target temperature).

Appendix D, Figure D2 shows a soak following a completed test run; the AST must be brought back within $\pm 1\text{ }^{\circ}\text{C}$ of the target test temperature and all components of the AST within $\pm 2.5\text{ }^{\circ}\text{C}$, then an additional 45 minute soak needs to be performed prior to acquiring the next test run.

4.2.4 Stabilization Time (Inertia Influence). The stabilization time is defined as the minimum amount of time required to hold the input speed constant in order to achieve a representative input torque measurement and remove any dynamometer or UUT inertial influence. Note: The control capability of the dynamometer will likely impact the severity of this influence. It is important that enough stabilization time passes to remove the inertial influence, but it is equally important not to remain at any given input speed long enough to cause the AST and/or oil sump temperature to rise significantly as this will distort the measured input torque.

Appendix D, Figure D3 shows an example of the influence motor controls and inertia may have on the input torque measurement. As noted in 4.2.5, a suitable "window" should be chosen to be a certain torque is measured/averaged only while the input speed is constant (i.e., not while transitioning). In addition to eliminating the inertial influence, it is important to have the test stand controls configured to minimize the overall time required to complete the full "stepped sweep" (defined in 4.2.6) data run to minimize the warming of the lubricant and test unit.

4.2.5 Run-to-Run Repeatability. In order to verify representative results are being achieved, it is important to establish reasonable run-to-run repeatability. For a given UUT the run-to-run repeatability under the same temperature/input speed conditions shall be within 0.5 Nm.

4.2.6 Stepped Sweep Test Series. In order to maximize run-to-run repeatability, data is acquired as shown in Appendix D, Figure D4. The stepped sweep test series is defined as a procedure whereby the dynamometer input motor is ramped to the target input speed over a maximum of 2.5 s, data is recorded/averaged over 5 s (excluding trimming of inertial influence), and the input motor is ramped to the next target input speed (again, over a maximum of 2.5 s).

Note: It is recommended this process be automated in the test cell control system in order to minimize the total time for the sweep test (which can cause the unit to heat up beyond the target temperature if the sweep takes too long).

4.2.6.1 The total time for each sweep test (including 8 set speeds to 10 set speeds, 5 s of data collection per set speed, 2.5 s ramp times, and 0.2 s of data trimming before and after the ramp) should be a maximum of 63 s to 80 s.

Note: Utilizing a single stepped sweep test series with automated programming will significantly improve repeatability vs. methods that required stopping data acquisition to re-soak the UUT to a target temperature.

4.2.7 Data Acquisition.

- Torque accuracy: $\pm 0.05\%$.
- 1 Hz filters.
- 0.2 Hz sampling rate (every 5 s).
- Automated data taking.
- Speeds to be recorded with 0.5 rpm resolution.

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