SURFACE VEHICLE RECOMMENDED PRACTICE

J2985 FEB2014

Issued 2014-02

Definition and Measurement of Transfer Case Speed-Dependent Parasitic Loss

RATIONALE

New government regulations that raise automotive fuel economy requirements and change the methods by which vehicle level fuel economy is measured drive the need for improved methods to measure component level parasitic loss. The intent of this standard is to provide the means to generate consistent component level parasitic loss data in support of modeling and analysis of vehicle-level emissions and fuel economy.

1. SCOPE

This SAE Recommended Practice covers transfer cases used in passenger car and light truck applications. Transfer cases are of the chain, geared, manually and electronically shifted types although other configurations are possible. The operating points (speeds, temperatures, etc.) were chosen to mirror those of the United States Environmental Protection Agency Vehicle Chassis Dynamometer Driving Schedules (DDS).

1.1 Purpose

To provide a common means to consistently measure and quantify the speed-dependent parasitic loss ("spin loss") characteristics of transfer cases.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

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 724-776-4970 (outside USA), www.sae.org.

SAE J1952 All Wheel Drive Systems Classification

SAE J2059 All-Wheel-Drive Drivetrain Schematic Symbol Standards

SAE J2263 Road Load Measurement Using Onboard Anamometry and Coastdown Techniques

2.1.2 Other Publications

United States Code of Federal Regulations, Title 40 - Protection of Environment [40 CFR], Part 86 - Control of Emissions from New and In-Use Highway Vehicles and Engines [40 CFR 86]

United States Environmental Protection Agency, Emission Standards Reference Guide

3. DEFINITIONS

3.1 Transfer Case

In a longitudinal mounted drivetrain based vehicle, this term refers to the drive mechanism that distributes power to the front and rear axles. The transfer case may also contain torque management devices. Externally the transfer case is mechanically connected to the transmission, which provides its input power, and to the front and rear axles via drive shafts, which distribute its output power (as shown schematically in Figure 1). Internally, the transfer case mechanically connects the front and rear outputs via chain or gears. Depending on the design, the transfer case may be electronically or manually shifted between two wheel drive (2WD) and all-wheel drive (AWD) modes or it may only have an AWD mode. Transfer cases may be single or multi-speed depending on the design and application.

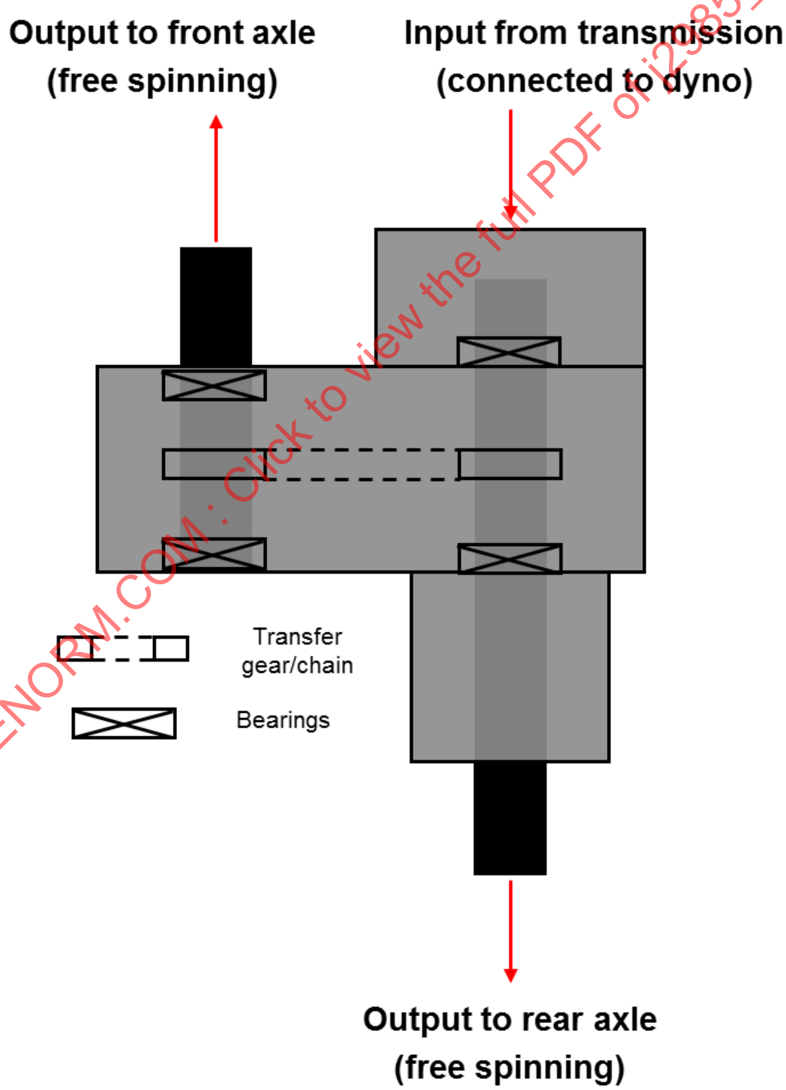

FIGURE 1 - TRANSFER CASE SCHEMATIC (SHOWN WITH REFERENCES TO VEHICLE POSITION)

3.2 Unit Under Test (UUT)

This term and its associated acronym is used to describe the test article (transfer case) undergoing the tests outlined herein.

3.3 Average Skin Temperature (AST)

To accurately represent the temperature of the unit under test (UUT), a metric has been developed using the average of multiple thermocouples. This method has been demonstrated to accurately represent the internal / overall ('core') temperature of the UUT and is based on a detailed study using an array of internal and external thermocouples. The thermocouples should be 'soldered tip' type (i.e., exposed wires/tip) and adhered to the unit using a thermally conductive adhesive to be most representative of the metal temperature. The AST measurement is composed of the arithmetic average readings of seven (7) thermocouples located as follows:

1-4) As close to the outer race of the input and output shaft support bearings as possible (4 total thermocouples)
5) As close to the vent as possible, but not inside the vent
6) Top of transfer case housing (center/middle of main input shaft)
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)

A pictorial example of sample locations is shown in Figure 2.

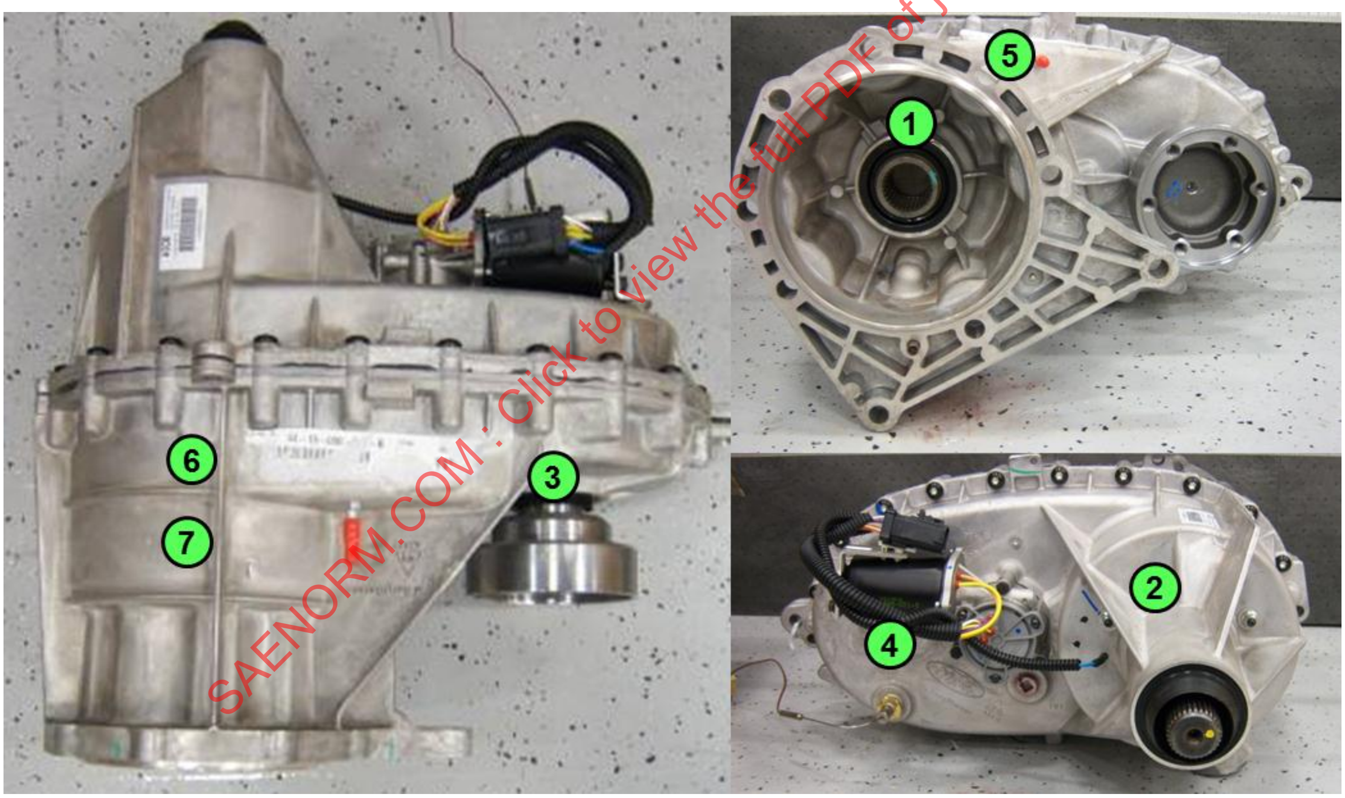

FIGURE 2 - AVERAGE SKIN TEMPERATURE SAMPLE LOCATIONS

1= Input Shaft; 2 = Prim. Shaft Rear; 3 = Sec. Shaft Front; 4 = Sec. Shaft Rear; 5 = Vent; 6 = Top/Mid, 7 = Ring Gear/Top

3.4 Sump Temperature

A thermocouple is installed in the drain plug (as shown in Figure 3) 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 above in Section 3.3.)

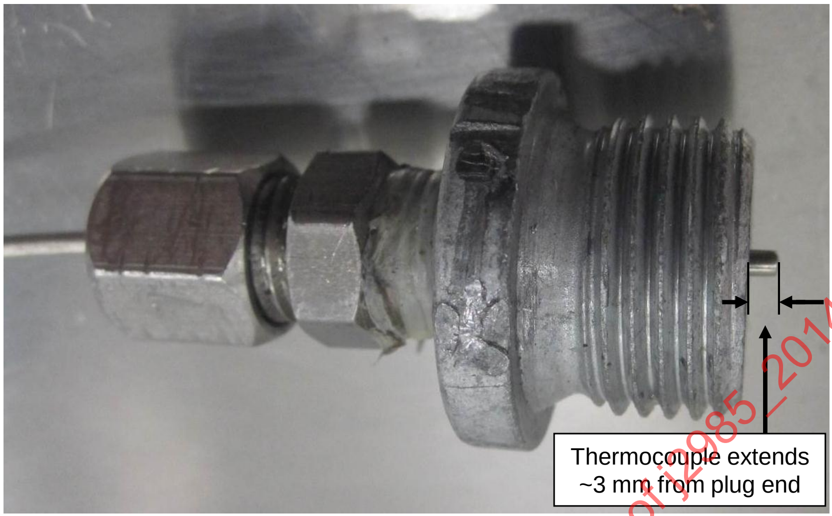

FIGURE 3 - SUMP TEMPERATURE VIA DRAIN PLUG

3.5 Temperature-Controlled Chamber

In order to conduct the testing outlined in Section 4, a suitable temperature-controlled chamber must be used. The chamber should be capable of controlling the transfer case temperature without directly conditioning the oil inside the transfer case (i.e., via convection). The method used should minimize the creation of localized hot or cold spots on the transfer case (a heat gun blowing directly on the UUT, for example). The chamber should be capable of achieving an average skin temperature (AST) in the range of -7 °C (20 °F) to +65 °C (150 °F), ± 1 °C. Note, to achieve this range it is likely the chamber will need to be capable of achieving temperatures slightly above and below these target temperatures. Specific design of the chamber is beyond the scope of this specification; however, during the development of this specification, liquid nitrogen (LN_2) was utilized to achieve the lower range (-7 °C) of the specification. If liquid nitrogen is used, care should be taken to ensure no liquid nitrogen is spilled or splashed directly on the UUT as it could damage the unit. A schematic of the chamber used is shown below in Figure 4 and a photograph of the chamber used is shown in Figure 5.

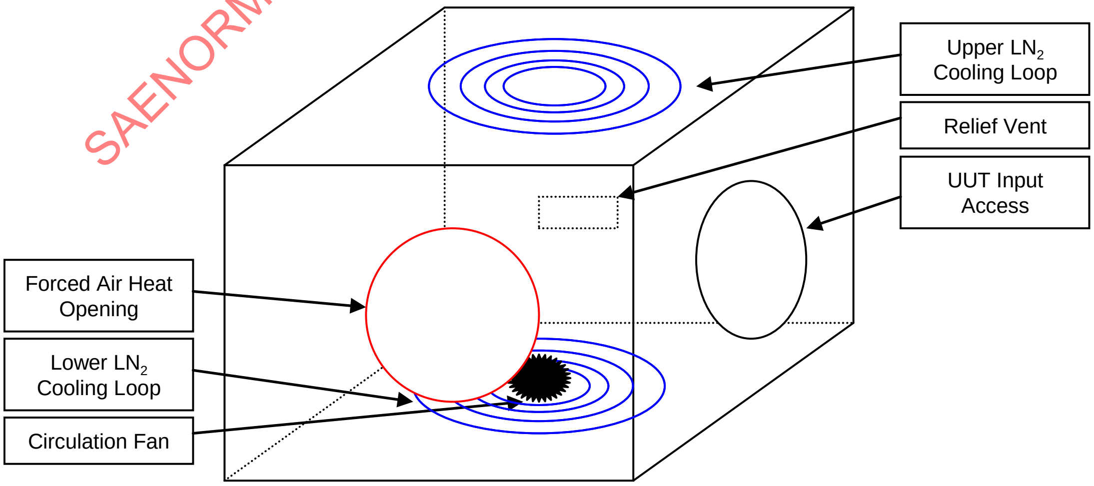

FIGURE 4 - SCHEMATIC OF TEMPERATURE-CONTROLLED CHAMBER

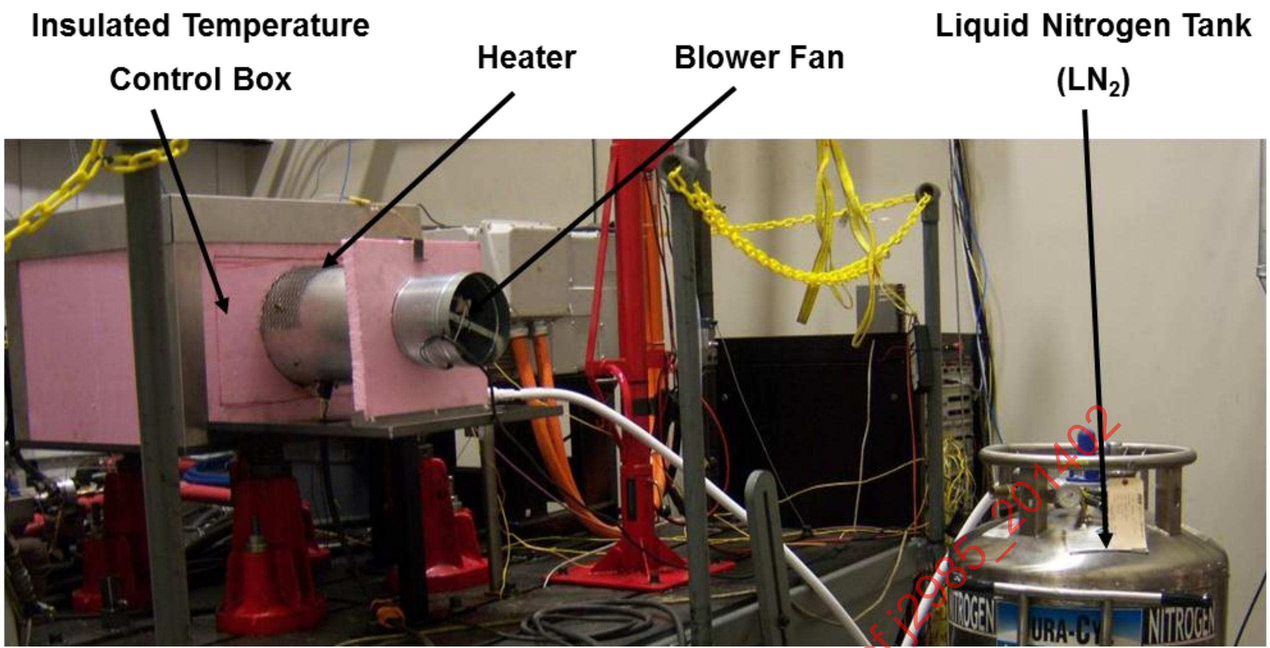

FIGURE 5 - PHOTOGRAPH OF TEMPERATURE-CONTROLLED CHAMBER

3.6 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 above in Section 3.3) is shown below in Figure 6 (note that the offset in temperatures T1 and T5 represents standard measurement variation – measurement error, temperature distribution within the cold box, etc. – and is further justification for using an AST instead of individual temperatures). As noted in the figure, an initial (pre) soak of four (4) hours was used followed by a 45 minute soak; the soak requirements are further outlined in Section 4.3.1.2. Should the available cooling system not be capable of reaching an AST of -7 °C ± 1 °C within 4 hours, additional 'pre-soak' time will be required prior to the 45 min additional soak (at target temperature).

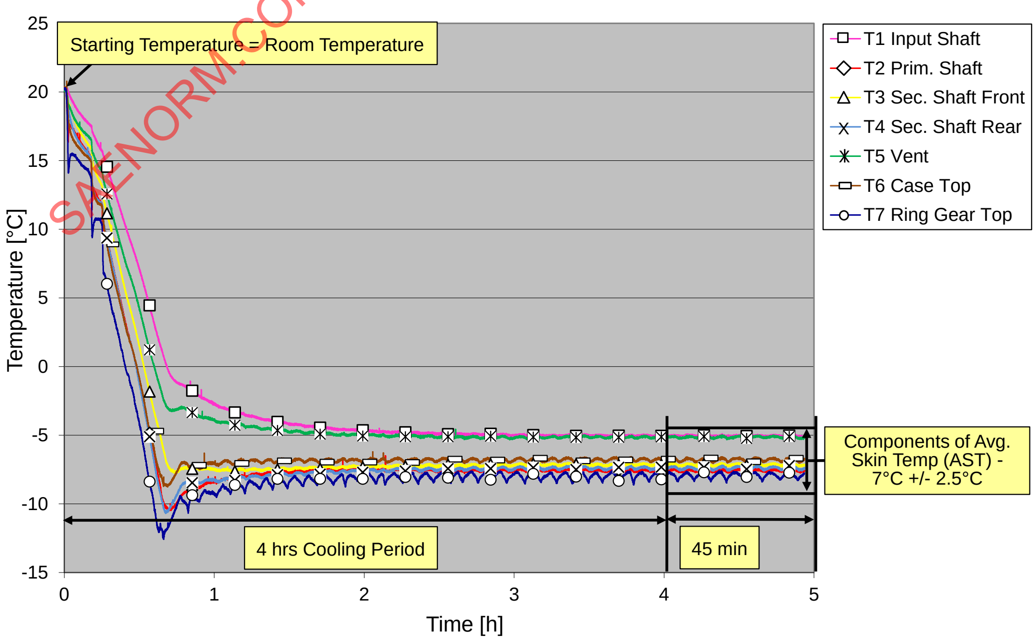

FIGURE 6 - 7 °C INITIAL SOAK

Figure 7 shows a soak following a completed test run; the AST must be brought back within ± 1 °C of the target test temperature and all components of the AST within ± 2.5 °C, then an additional 45 minute soak needs to be performed prior to acquiring the next test run.

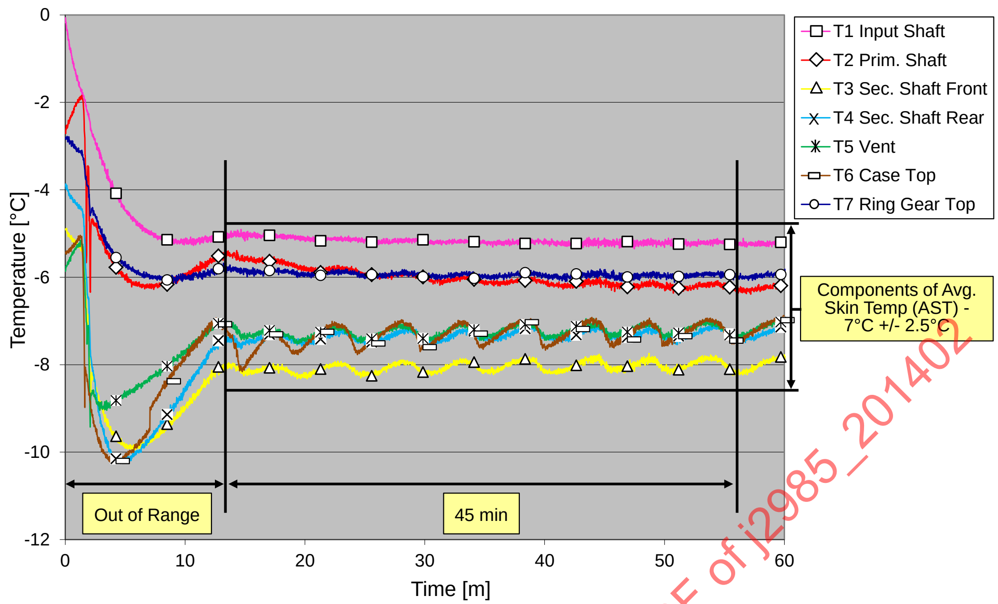

FIGURE 7 - RUN TO RUN SOAK

3.7 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. Figure 8 shows an example of the influence motor controls and inertia may have on the input torque measurement. As noted below, a suitable 'window' should be chosen to be 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 below in Section 3.9) data run to minimize the warming of the lubricant and test unit.

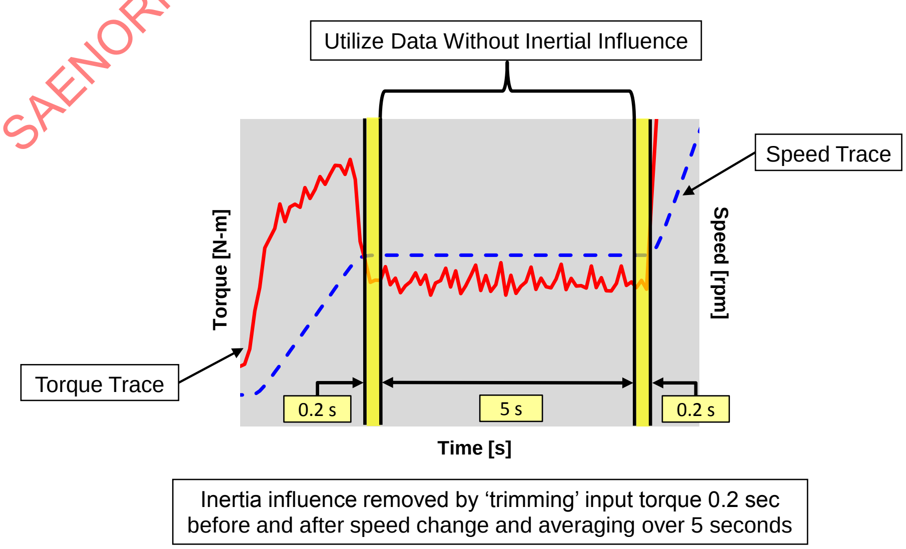

FIGURE 8 - INERTIA INFLUENCE

3.8 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 should be within 0.5 N-m.

3.9 Stepped Sweep Test Series

In order to maximize run-to-run repeatability, data is acquired as a ‘stepped sweep’ test series as shown in Figure 9. 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 seconds, data is recorded/averaged over 5 seconds (excluding trimming of inertial influence), and the input motor is ramped to the next target input speed (again, over a maximum of 2.5 seconds). 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): The total time for each sweep test (including 8 set speeds, 5 seconds of data collection per set speed, 2.5 second ramp times, and 0.2 seconds of data trimming before and after the ramp) should be a maximum of 63 seconds. During development of this procedure, utilizing a single stepped sweep test series with automated programming was shown to significantly improve repeatability verses methods that required stopping data acquisition to re-soak the UUT to a target temperature. This was particularly true for the -7 °C condition, but soak interruptions were also shown to affect the 21 °C and 65 °C conditions.

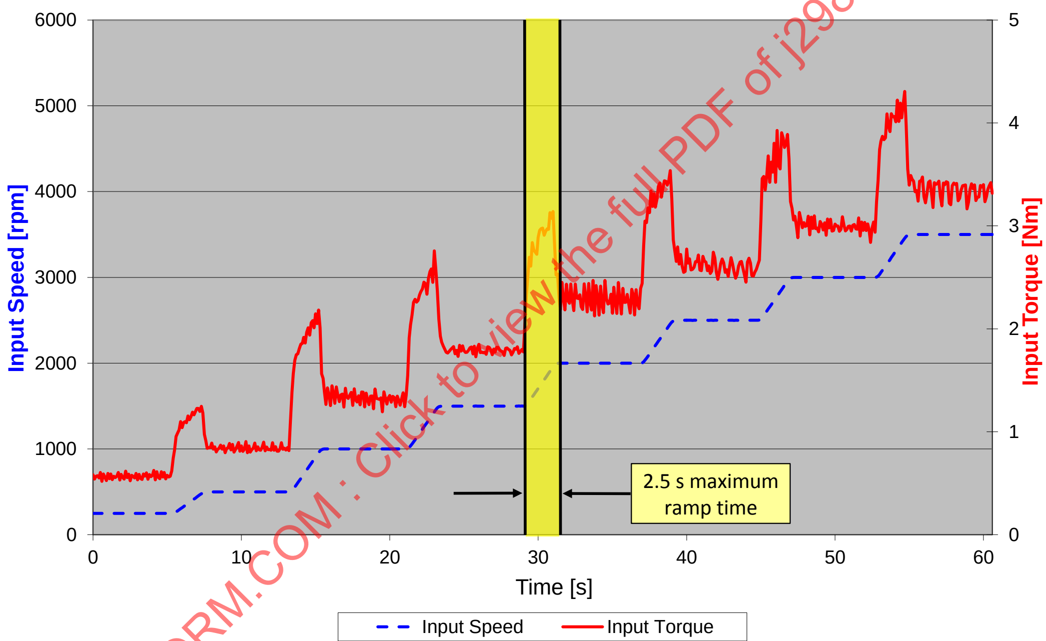

FIGURE 9 - STEPPED SWEEP TEST SERIES

4. PROCEDURES

4.1 Equipment Requirements

Measurements are to be performed on a standard horizontal axis test stand with a motor driving the transfer case input and a precision torque measurement device mounted between the motor and UUT as shown schematically in Figure 10. (NOTE: If a linkshaft or gear box are utilized, they should be located between the drive motor and input torque meter). The tests outlined in this procedure focus on the 2WD/RWD operation mode only and the front/rear outputs should be unloaded and unconstrained (not connected, except during break-in, if required). Ideally, 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 5-7 degrees 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). Regardless of which method used, the installation angle should be documented in the test report. Temperature control must be via external (environmental) conditioning rather than direct conditioning of the oil within the test unit (as described earlier in Section 3.5). Torque and speed capabilities of the test stand are to be appropriately sized for the UUT. A sampling rate greater than or equal to 10 Hz is recommended for data acquisition. The torque meter should be appropriately sized in consideration of the low drag torques (<10 N-m) expected and a transducer with a smaller range (0 - 100 N-m) is recommended. Torque meter accuracy is to be ± 0.05 N-m 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.)

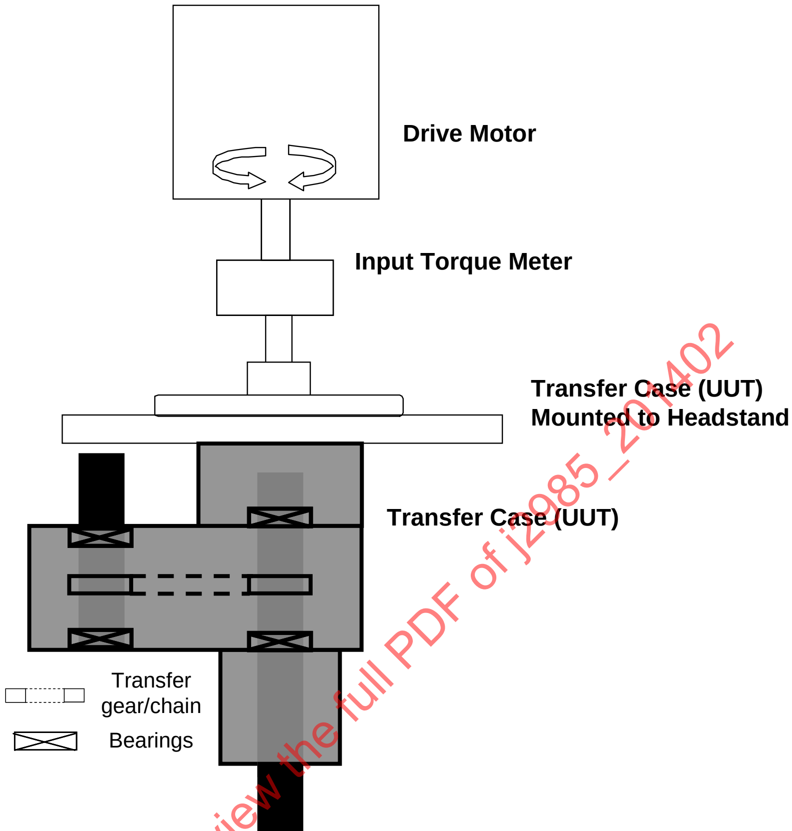

FIGURE 10 - TEST RIG SCHEMATIC FOR DATA ACQUISITION AND 'COLD' BREAK-IN

4.2 Break-in

In order to achieve repeatable and comparable results, it is required that the test unit(s) undergo a uniform break-in procedure. It is recommended that one of the two procedures presented in Sections 4.2.1 or 4.2.2 be utilized for this purpose. Section 4.2.1 presents a traditional break-in schedule where a load applied at the input is reacted at the rear output (the front output is unconstrained). Section 4.2.2 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). During the course of developing this specification, it was demonstrated that both methods will yield directly comparable results for speed-dependent parasitic loss measurements. (NOTE: Neither break-in schedule was evaluated with respect to torque-dependent loss measurements; therefore comparable results may not be achievable for these conditions.)

4.2.1 ‘Warm’ Break-in (21 °C & 65 °C)

A warm temperature break-in schedule is shown in Figure 11 where the clockwise direction is noted as typical engine rotation that propels the vehicle in a forward direction. The UUT (and its oil temperature) does not need to be conditioned during the break-in to any specified temperature value; however, specifications for the maximum allowable unit/oil temperatures should not be exceeded. Note that the input torque for this break-in schedule must be reacted at the rear output (labeled “output to rear axle” in Figure 1); thus an absorber motor must be added to the rig schematic shown in Figure 10.