

Development of a Standard Spin Loss Test Procedure for FWD-Based Power Transfer Units

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ABSTRACT

As vehicle fuel economy continues to grow in importance, the ability to accurately measure the level of efficiency on all driveline components is required. A standardized test procedure enables manufacturers and suppliers to measure component losses consistently and provides data to make comparisons. In addition, the procedure offers a reliable process to assess enablers for efficiency improvements. Previous published studies have outlined the development of a comprehensive test procedure to measure transfer case speed-dependent parasitic losses at key speed, load, and environmental conditions. This paper will take the same basic approach for the Power Transfer Units (PTUs) used on Front Wheel Drive (FWD) based All Wheel Drive (AWD) vehicles. Factors included in the assessment include single and multi-stage PTUs, fluid levels, break-in process, and temperature effects. The resultant procedure is proposed as a new SAE J-standard (Surface Vehicle Recommended Practice) for release by the AWD Standards Committee.

The overview presented in this paper includes definitions for the PTUs used in the study along with an overview of the test setup and instrumentation. This paper will outline some of the key investigations undertaken including the step size and duration, assessment of repeatability, as well as the influences of break-in and oil level.

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INTRODUCTION

The purpose of the study was to develop a test procedure which could form the basis of an SAE J-standard for measurement of parasitic losses (spin losses) of PTUs used in front-wheel-drive-based passenger car and light duty truck applications. The standard is intended to cover PTUs of various designs and configurations including single and multiple stage and disconnectable.

The basic test procedure outlined in this paper on PTUs is based on a test methodology developed during a previous study focused on measurement of spin losses in transfer cases

[1, 2, 3]. In this previous transfer case spin loss measurement study, a detailed section is dedicated to the analysis of the use of traditional methods for measurement of test unit temperature during data acquisition. The traditional method of temperature control was measurement of the transfer case temperature via a thermocouple installed in the sump of the test unit. Upon review of the initial parasitic losses data acquired using the traditional temperature monitoring/control methods at low temperature (i.e., -7°C), it was clear that the repeatability was not acceptable and another procedure would need to be developed. The previous transfer case paper outlines in detail the steps taken to develop a new test

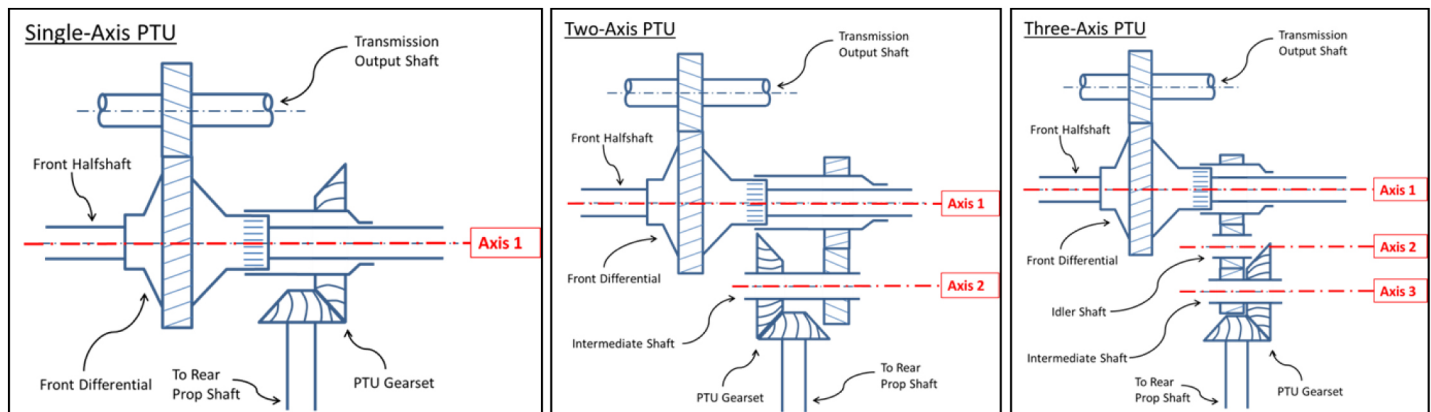


Figure 1. Schematics of PTU Designs

procedure and compares the results of traditional methods to the newly developed Average Skin Temperature (AST) method. Use of this new unit temperature measurement methodology for the development of a test of spin loss for PTUs greatly expedited the completion of this study.

POWER TRANSFER UNIT PARASITIC LOSS TESTING

The traditional method for assessing the losses of transmission and driveline components is to use a single dynamometer to measure the torque needed to spin the unit under test at a typical (warm) operating temperature (as measured at the sump). It is important to utilize a process that can consistently and accurately measure such losses across a range of operating temperatures (cold to hot) as well as input speeds. As mentioned previously, the traditional method (for spin loss testing on transfer cases) was noted to fall short of meeting this objective, necessitating the development of a refined test process [3].

This paper discusses the development of such a process (focused on PTUs), the details of which are advanced in the following sections.

Objectives of the Study

This study had several objectives, the most important of which was to develop a standardized procedure (SAE J-standard) to facilitate comparison of parasitic loss measurements. The primary objective of the study (and the proposed J-standard) was to provide a procedure that met the following criteria:

- Works for multiple test temperatures (-7°C , 21°C , & 65°C)
- Covers a range of PTU input test speeds (100 - 1000 rpm)
- Can be used to obtain reliable results in a time-efficient manner
- Uses non-invasive instrumentation which can be installed without disassembly of the unit (which may influence preloads, etc.)

- Considers / captures the influence of break-in on component efficiency

- Demonstrates consistent and reliable results on multiple test samples (of various architectures) while also considering influence of soak time, measurement positions, and test operation / sequence during data acquisition

Definitions/Schematics

Several types of PTUs are currently in production vehicles. They may be generally categorized by the degree of separation between the input and output axes, as illustrated in Figure 1 below.

Spin Loss Test Setup and Boundary Conditions

In this section, the setup used for the spin loss testing is described and the primary test parameters / boundary conditions are outlined.

Spin Loss Testing Setup

The PTU was tested in an enclosed, insulated temperature control box. Liquid nitrogen (LN_2), a heater, and blowers were used to maintain PTU set temperature. Adapter plates and spline adapters were used to adapt different mounting flanges and input spline configurations of the units to the dynamometer. In addition, each PTU was mounted on the test fixture at a standardized in-vehicle installation angle by changing the bed plate angle to match the in-vehicle condition. During the -7°C test liquid nitrogen (LN_2) was used in conjunction with the heater (activated intermittently) to maintain set temperature. During the 21°C test the heater and minimal amounts of LN_2 were used to maintain temperature. During the 65°C test the heater was used to maintain temperature (LN_2 was not used).

Diagrams and photos of the test set-up are in Figures 2, 3, 4 below, and define both the typical test configuration as well as the requirement to measure/generate data for both 'drive' and 'coast' conditions on the PTUs.

Drive & Coast Side Definitions

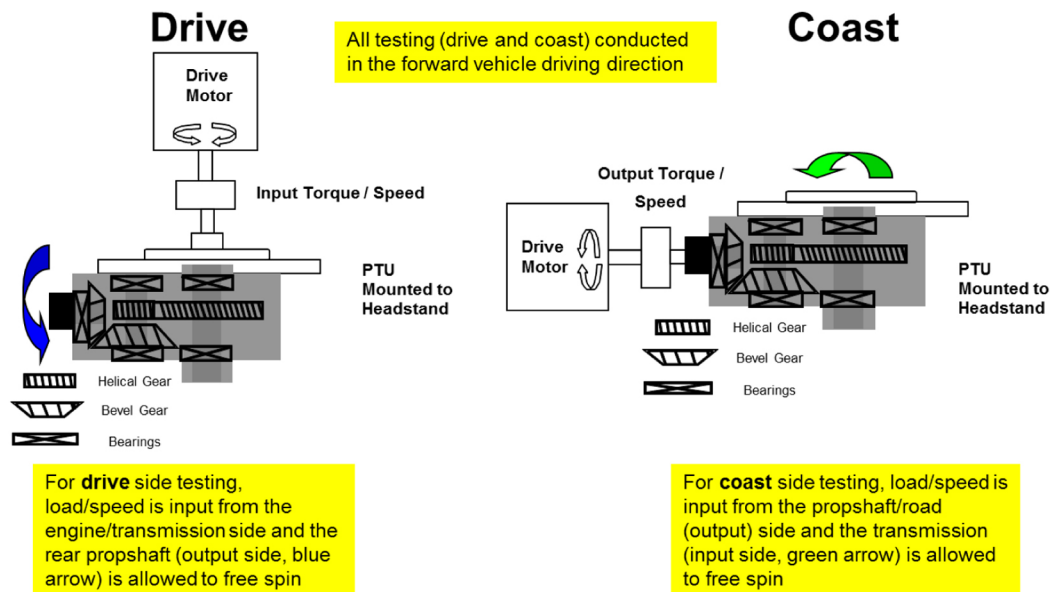


Figure 2. Schematic of Test Setup



Figure 3. Setting In-Vehicle Installation Angle

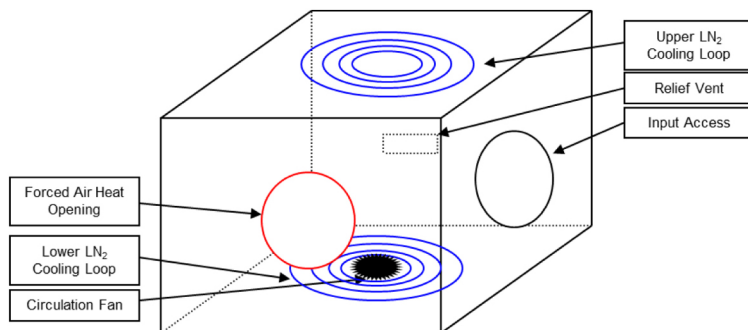


Figure 4. Schematic of Temperature Controlled Chamber

Boundary Conditions

The following boundary conditions were employed during the PTU testing:

- Speeds
 - Four input (transmission output / wheel) speeds of 117, 233, 467, and 933 rpm
 - Equivalent output speeds used for coast testing (based on given ratio) to achieve target input speeds
- Sump temperatures
 - -7°C (20°F)
 - 21°C (70°F)
 - 65°C (150°F)
- Operating Modes
 - All PTUs were tested for spin loss in both drive and coast modes as described above
 - Side and Rear output shafts allowed to spin freely (the side halfshaft outputs and the interface to the rear driveshaft)
 - All speed combinations run three times at desired temperature to assess repeatability

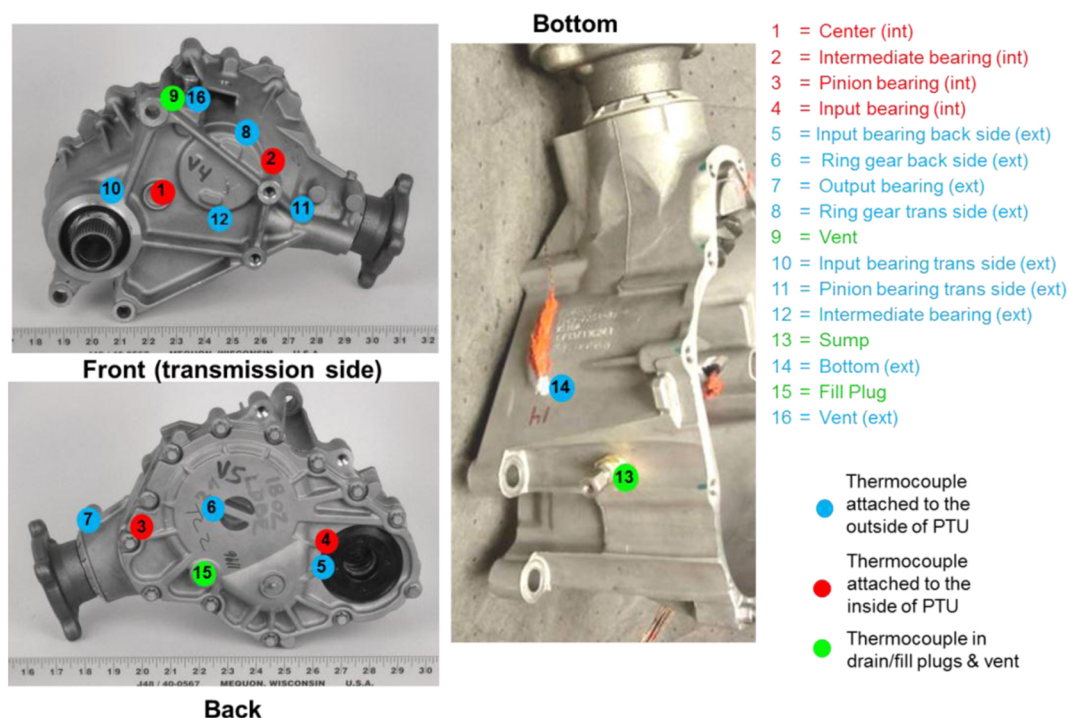


Figure 5. Enhanced Instrumentation

TEMPERATURE STUDIES

As outlined in prior transfer case spin loss studies [3], the traditional method of sump temperature measurement as the primary control parameter for characterizing the test unit's temperature and for comparing run-to-run was found to be flawed, particularly for cold temperatures. In order to improve test repeatability, a better understanding of the temperature distribution within / around the PTU was required. To that end, various temperature studies were undertaken and enhanced instrumentation was employed as outlined in the following sections.

Enhanced Instrumentation

A specific type of PTU was chosen to undergo extensive instrumentation in which a total of 16 thermocouples were installed at internal and external locations in/on the unit. The detailed monitoring of the temperature at selected locations was intended to support understanding of the temperature distribution inside the PTU as well as the heat generation at various operation points. Further, this detailed instrumentation was used to define the AST.

Based on the findings on the fully instrumented PTU, a test procedure and an instrumentation specification was developed, applied, and verified on the remaining PTUs. Figure 5 summarizes the locations instrumented for the temperature distribution study.

Temperature Distribution Studies

Using the enhanced instrumentation, temperature distribution studies were undertaken with the goal of analyzing temperature distribution in/around the PTU to determine locations on the outside of the case that thermally represent the 'core' temperature of the test unit. Development of this representative thermocouple set avoids the cost/time (and potential data quality degradation) associated with disassembling the PTUs for internal instrumentation.

A. Cool-Down

A cool-down from 65°C to -7°C was performed to monitor the behavior of each thermocouple relative to the unit average temperature when the unit is being cooled down after a high speed/high load operation. Figure 6 shows how the various thermocouples behave during the cool-down. The red line indicates the unit average temperature (i.e., average of all measured temperatures). As outlined above, the cool-down was achieved using a temperature control chamber (Figure 4) with liquid nitrogen as the cooling medium. The PTU sump temperature is also shown (bold black line) as a reference to what is typically measured.

Figure 7 shows the difference between each measured temperature and the average unit temperature (during the same cool-down run as outlined in Figure 6). Using the results outlined on the figures above/below and knowledge gained from previous published studies [3], the AST was defined and is indicated by the bold blue line.

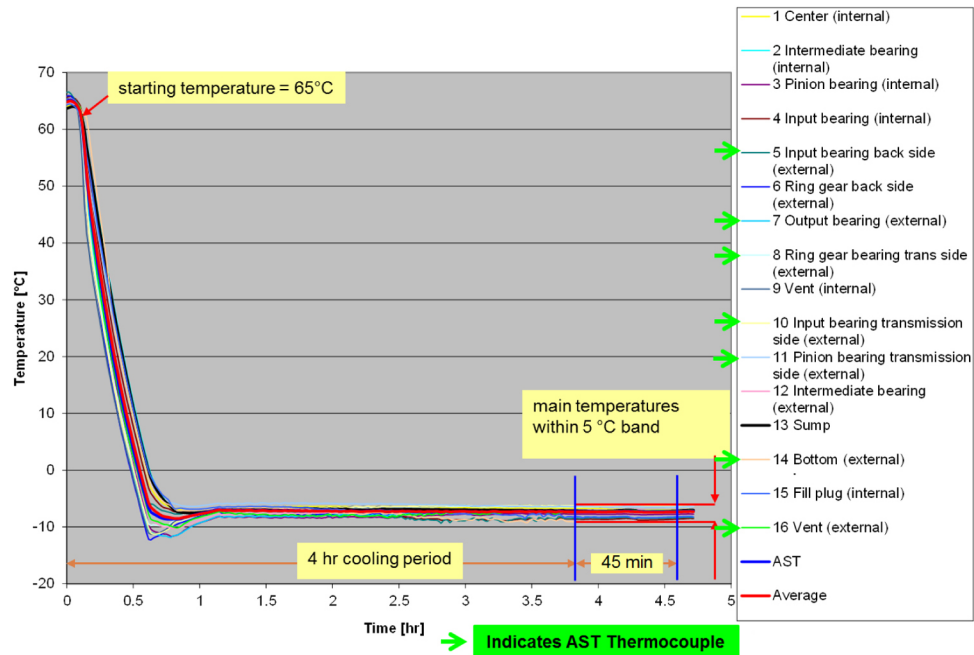


Figure 6. 65°C → -7°C Cool-down

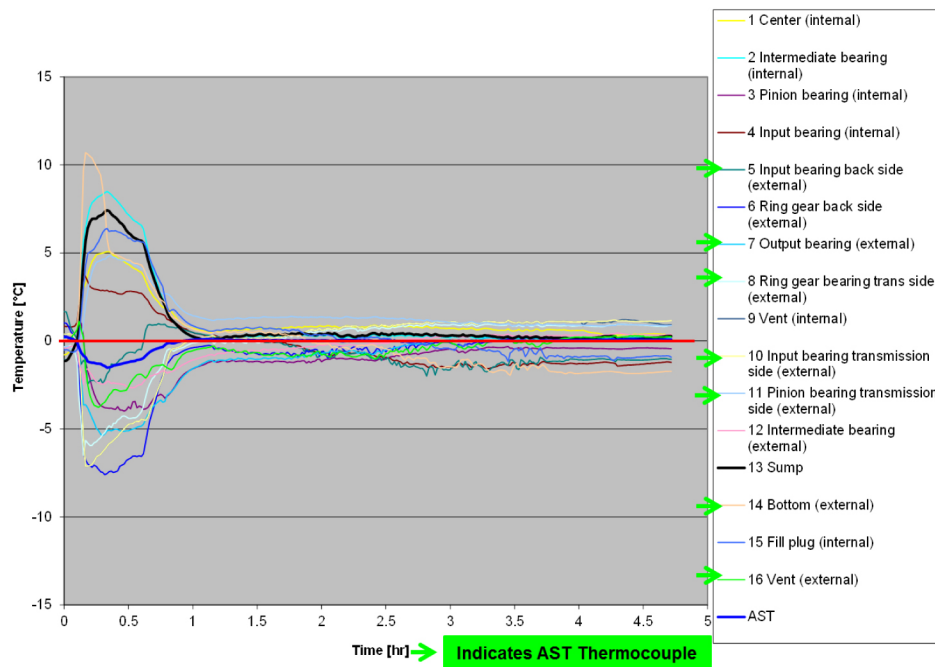


Figure 7. 65°C → -7°C Cool-down, Temperature Difference to Overall Avg.

The AST represents the average of the following externally measured temperatures spread over the housing near the input / output bearings of each shaft, the top/center of the housing, the transfer gear, and the case vent:

1. Input bearing (transmission side)
2. Input bearing (halfshaft output side, opposite mounting flange)

3. Propshaft output bearing (12 O'clock)
4. Housing top (input section)
5. Housing top (output section)
6. Housing bottom (output section)
7. Housing bottom (input section)