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| GM | WORLDWIDE ENGINEERING STANDARDS | Test Procedure | GMW17305 |

# Evaluation of Acceleration on a Grade

## 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.** Provide a common global development and validation performance evaluation of a driveline system that utilizes traction enhancing driveline hardware, e.g., Active On Demand (AOD) All Wheel Drive (AWD) and Limited Slip Differential (LSD) with electronic controls. This procedure is also performed to evaluate the performance of driveline components after being subjected to severe loads resulting from multiple vehicle launches on grade with "split mu" surfaces, i.e., left (or right) side of the vehicle on a small frictional coefficient (μ) surface, i.e., "low mu" surface, and the other side on a large frictional coefficient surface, i.e., "hi mu" surface.

**1.2 Applicability.** Passenger cars and light trucks equipped with driveline traction enhancing hardware beyond normal brake system traction control systems.

**1.3 Remarks.** This test is typically run by the GM Vehicle Dynamics group or the GM Driveline group and is used for development/validation of the drivetrain or traction performance. These systems may include but, are not limited to, AOD AWD and regular AWD systems, LSD, drive shafts, half shafts, axles, torque couplings, and driveline disconnects.

## 2 References

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

**2.1 External Standards/Specifications.**

None

**2.2 GM Standards/Specifications.**

GMW14264

## 3 Resources

**3.1 Facilities.** The test is typically run at Milford Proving Ground (MPG), 12% and 20% grade hills with "low mu" (ceramic tiles) test surfaces within the Vehicle Dynamics Test Area (VDTA) or on ice at the Winter Test Facility with adjacent dry pavement ("hi mu") creating right to left "split mu" across the vehicle. See 4.2 for "low mu" and "hi mu" surface definitions.

The MPG 12% and 20% grade hills with "low mu" (approximately 0.1 μ) ceramic tiles test lane shall consist of the entire length of the longest ceramic tile area of the grade. The tiles shall be kept wet during the test run.

The Winter Test Facility traction hills (approximately 0.1 μ) test lane shall consist of the longest ice surface on the grade.

The "low mu" test surface (approximately 0.1 μ), 19 m for the 12% grade and 10 m for the 20% grade, shall be adjacent to a "hi mu" (approximately 0.9 μ) asphalt or concrete surface. There should be an adequate run off area at the end of the grade to bring the vehicle to a complete stop.

**Note:** The test track shall have at least a 3.5 m wide test lane straddling the "low mu" and "low mu" surfaces at the vehicle centerline. The test track shall also have an adjacent 3.5 m wide test lane for testing "hi mu" launches.

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

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**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 Data Acquisition System (DAS).** The DAS is used for recording vehicle communication bus, e.g., Controller Area Network (CAN), Local Interconnect Network (LIN), etc. channels and instrumented driveline or chassis controller channels (if requested/necessary). The vehicle communication bus shall be recorded at full bus speed, e.g., Global A CAN is 500 kbit/s, but individual modules on the bus may have slower update rates as compared to overall vehicle bus. The DAS shall have at a minimum a recording speed matching the fastest communication bus rate for all data channels.

**Note:** When recording digital data or external analog data it should be broadcast and recorded at a sample rate of no less than 100 Hz. Examples of external data include throttle pedal position and axle torque.

**3.2.2 Longitudinal Speed Measurement Device and Readout.** The speed transducer must be capable of reading velocity in excess of the vehicle test speed. A minimum of 150 km/h is recommended. The transducer accuracy must be within 0.5 km/h over the speed range of 5 km/h to 150 km/h.

**3.2.3 Lateral Speed Measurement Device and Readout.** The speed transducer must be capable of reading velocity in excess of the vehicle test speed. A minimum of 50 km/h is recommended. The transducer accuracy must be within 0.5 km/h over the speed range of ±50 km/h.

**3.2.4 Accelerometer Oriented to Measure Longitudinal Acceleration.** The accelerometer must be capable of measuring a minimum of 11.75 $m/s^2$ (1.2G), with an accuracy of 0.1 $m/s^2$ (0.01G).

**3.2.5 Accelerometer Oriented to Measure Lateral Acceleration.** The accelerometer must be capable of measuring a minimum of 11.75 $m/s^2$ (1.2G), with an accuracy of 0.1 $m/s^2$ (0.01G).

**3.2.6 Angular Rate Sensor Oriented to Measure Yaw Velocity.** The angular rate transducer must be capable of measuring at ±50 degrees/s with an accuracy of 0.01 degrees/s.

**3.2.7 Throttle Pedal Percentage/Travel.** Record signal direct from pedal position sensor.

**3.2.8 Time Marker (T-Marker).** A reflector on the vehicle at the primary drive axle and a sensor at the end of the 120 m "split mu" test lane to indicate the end of the test run.

**3.2.9 Driveline Torque Data for Each Wheel.** Instrumented half shafts and/or axle shafts and associated slip rings and signal conditioning devices.

**Note:** Do not use wheel force transducers as wheel inertia maybe different than the Original Equipment Manufacturer (OEM) recommended wheel inertia.

**3.2.10 Wheel Velocity Data for Each Wheel.** The transducers must be capable of reading velocity in excess of the vehicle test speed, a minimum of 50 km/h over test velocity is recommended. The transducer accuracy must be within 0.5 km/h over the speed range of 5 km/h to 150 km/h.

**3.2.11 Hydraulic Brake Pressure at Each Wheel.** The transducers must be capable of reading brake pressure in excess of the rated system pressure**.**

**Note:** 3.2.9 through 3.2.11 are typically required only for driveline development testing unless requested.

**Note:** All instrumentation shall be calibrated as required. Record instrumentation details and date of calibration on Data Sheet A1 in Appendix A, unless information is maintained in the testing laboratory records.

**3.3 Test Vehicle/Test Piece.** The vehicle shall be equipped with specific driveline configuration requested. It may be possible to interchange driveline, chassis controls, tires and wheels, and powertrain hardware and software to accomplish multiple test configurations on the same vehicle.

**Note:** All available combinations of engine, transmission, AWD, LSD, final drive ratios, i.e., all possible propulsion systems, and tire and wheel combinations may need to be tested separately due to differences in driveline reactions and other hardware or electronic influences. Consult the Requesting Engineer for the test objectives and required combinations required to meet the test objectives.

**Note**: Tire and wheel combinations should be the OEM recommended type, i.e., brand, size, construction, etc. Although required in many regions, “snow” tires often do not react similarly on artificial surfaces (ceramic tiles) as compared to actual (ice) "low mu" test surfaces. Snow tires must be tested on actual "low mu" (ice) surfaces.

**Note**: All drivetrain hardware that is being tested for validation purposes should be "new" or have ≤ 500 km (310 mi) of accumulated general usage (without abuse testing). If the hardware has ≥ 250 km (155 mi) no

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additional break in is required. See 4.1.6 for break in procedure. Evaluations using this test procedure can be performed using hardware with higher usage for informational, special evaluations or development.

**Note:** Vehicle ballast should be production intent vehicle curb weight plus driver and equipment. Other ballast/trailer conditions can be tested if requested. Document vehicle mass condition on Data Sheet A3 in Appendix A.

**3.4 Test Time.**

| | |
|---|---|
| Calendar time: | 5 days |
| Test hours: | 24 hours |
| Coordination hours: | 16 hours |

**3.5 Test Required Information.** Possible sources are:

- Statement of Requirements (SOR)
- Vehicle Technical Specification (VTS)
- Subsystem Technical Specification (SSTS)
- Analysis/Development/Validation (ADV) Plan
- Validation Cross Reference Index (VCRI)
- Application Engineer
- Development Groups
- Drawings

**3.6 Personnel/Skills.** Trained driver. Ability to conduct end of test inspection of test parts if required.

## 4 Procedure

**4.1 Preparation.**

**4.1.1** Determine and record the velocity ratio targets and number of consecutive "split mu" accelerations, throttle pedal positions, and chassis/driveline mode combinations to be tested based on requirements in 3.5 or as required by Requesting Engineer. Document the test configuration on Data Sheets A2 and A3 in Appendix A. Multiple copies of Data Sheet A3 will be required to document the various grades, ballast conditions and test modes. Provide the following:

- Fleet Number or Vehicle identification Number (VIN)
- Vehicle configuration
- Test surface (simulated or actual "low mu" surface) and any special temperature requirements.
- Number of consecutive "split mu" tests in each mode.
- Elapsed time between the start of consecutive runs, i.e. total cycle time of each run, which allows for returning the vehicle to start of the test surface and incidental cool down of drivetrain components. This is typically approximately (≈) 30 s if not specified in the requirements in 3.5.
- Throttle pedal positions, typically 30% + ½ the grade angle measured in percent and Wide Open Throttle (WOT). Positions shall be achieved within ±5% with no overshoot and ramped in with throttle pedal application within 2 s. A throttle application defined as Drivers Best Effort (DBE) can also be performed if requested. DBE is typically defined as maximum acceleration obtainable without significant traction control or stability control actuation.

**4.1.2** Install instrumentation for recording test data as required by Requesting Engineer. The following channels being critical to most tests:

- Wheel speeds (all wheels)
- Transmission gear state (or ratio)
- Throttle pedal position
- Estimated torque signals (if available, i.e., anything pertaining to driveline engine/hybrid systems)

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- Traction/stability control status
- User selected modes effecting driveline/vehicle performance
- Vehicle Velocity

**Note:** Optional channels are defined in 3.2.8 and 3.2.10.

**4.1.3** Set tire pressure to specifications.

**4.1.4** Check all fluid levels. Fill as required.

**4.1.5** Inspect all driveline torque carrying components with vehicle on hoist. Record any leaks or unusual conditions on Data Sheet A2 in Appendix A using the subjective scales of GMW14264.

**4.1.6 Break In.** A break in is recommended for new engines and transmissions. It is mandatory if a new axle is installed in the test vehicle or the test vehicle/axle has accumulated ≤ 200 km (125 mi) of usage. Complete the break in as follows:

- Accelerate lightly to 100 km/h (65 mph) using normal shifts, and then vary vehicle speed between 100 km/h and 125 km/h (65 mph to 75 mph). Upshift every 5 km (3 mi), for manual transmission vehicles, and lightly accelerate through top gear.
- Decelerate lightly, while downshifting normally at 3000 rpm, for manual transmission vehicles, to a stop.
- Repeat cycles previously stated until a distance of 200 km (125 mi) is attained. A minimum of 200 km (125 mi) is mandatory if rear axle is included in a validation test (in such case, measure and record axle sump temperature during the break-in).

**4.2 Conditions.** Road surface coefficients are defined in Table 1.

**Table 1: Road Surface Coefficients**

| Road Surface | Peak Friction Coefficient (μ) | Example Road Surface |
|---|---|---|
| High coefficient | $\mu > 0.8$ | Dry Asphalt/Dry Concrete |
| Medium coefficient | $0.4 < \mu < 0.7$ | Wet Jennite or Wet Basalt/Packed Snow |
| Low coefficient | $\mu < 0.3$ | Wet ice, Wet Ceramic Tile, or Wet Polished Concrete/Ice |
| Split coefficient | Road surface with different peak friction coefficients under left and right driven wheels, e.g., low and high or medium and high peak friction coefficient combinations only. | |

**4.2.1 Environmental Conditions.** Dry "hi mu" surface and simulated/actual "low mu" surface, e.g., wet ceramic tiles/ice, per Table 1.

**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.

**4.3 Instructions.** This test procedure shall be run in all "driver selected option" modes, i.e., Traction Control (TC) "on" or "off", snow and launch control, winter, sport, off-road, etc. Consult the Requesting Engineer to determine applicable modes.

**4.3.1** Perform the test as defined in 4.1.1 or complete (4) four runs per mode at 30%, 60%, 100% (WOT), and DBE throttle pedal positions. Document modes and cycle counts on Data Sheet A3 in Appendix A.

**Note:** Allow the drivetrain to cool after completing each mode of this test procedure. Extended duration cool down is mandatory if automatic thermal shut down or thermal temperature limits per requirements in 3.5 are reached during any event. Thermal shut down limits indicate system thermal capacity and completion of that test mode.

**4.3.2 Launch Conditions.**

**4.3.2.1 Manual Transmission:** Launch the vehicle at the engine speed, revolutions per minute (RPM), based on requirements in 3.5 or as required by Requesting Engineer, with a rapid release of the clutch pedal (foot does

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