



Powertrain Mounting System: Inertia-Reacted, Real-Time Structural Durability

1 Scope

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. This standard evaluates the structural durability of the powertrain mounting system when subjected to real-time load profiles simulating proving ground road test modules. It describes test development and durability test execution.

1.2 Foreword.

1.2.1 The powertrain mounting system under evaluation includes the rubber/hydraulic mounts, dampers and associated brackets/fasteners. The mount, damper, and/or bracket interface with the powertrain, body, and/or frame may also be evaluated.

1.2.2 The Multi-Axial Simulation Table (MAST), Figure A1, provides controlled, multi-axial input (six (6) degrees of freedom: vertical, lateral, fore/aft, roll, pitch, and yaw).

1.3 Applicability. This procedure applies to all passenger cars and light duty trucks having powertrains mounted on frames, cradles, and/or body structure. Additionally, it applies to transverse and longitudinal mounted powertrains, as well as front, rear, and all-wheel drive powertrain configurations.

Note: Test rig capacity limitations may prevent the evaluation of large/massive powertrains and their associated mount systems by this procedure. If the specimen and fixture mass estimates exceed capacity limits of the chosen test rig, consider executing GMW15946.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW3425 (I)	GMW15219	GMW15242	GMW15269
GMW14883	GMW15232	GMW15245	GMW15946
GMW15019 (I)	GMW15235	GMW15268	GMW16217

(I) = This is a standard that is distributed only internally within General Motors. This standard cannot be distributed outside of General Motors. Contact the GM lead engineer for any instructions.

2.3 Additional References.

Component Technical Specification (CTS)

Subsystem Technical Specification (SSTS)

3 Resources

3.1 Facilities. A bedplate large enough for securing the test rig and capable of withstanding dynamic loading of the test rig/specimen is required. Also required is a hydraulic system capable of supplying oil at a rate consumed by a MAST (approximately 750 L/minute to 1500 L/minute). The test facilities and equipment shall be in good working order and shall have a valid calibration.

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

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.

Note: The following includes test rig, fixtures, transducers, instrumentation, and controllers typically used by GM Structural Development Laboratories to perform this test. Other equipment may be substituted at the discretion of the local testing facility as long as it provides the same data and/or data record, with equivalent accuracy as specified herein or by the requester.

3.2.1 Test Rig. A simulation table capable of controlling six (6) degrees of freedom (MTS System Corporation, Model 323 – typical MAST), Figure A1 through Figure A4.

3.2.1.1 The simulation table surface area should be adequate to fixture in position the powertrain and its supporting body and/or frame structure. The hydraulic actuators should be sized appropriately to reproduce the acceleration experienced on the road (reference 3.2.3.2.1).

3.2.1.2 The test rig must also incorporate a torque input device. The MAST uses a torque input device to apply a force-couple to the engine/transmission case requiring an adapter fixture to make the attachment, Figure A5. A linear, hydraulic actuator (typically mounted off the table) or a rotary, hydraulic actuator (typically mounted on the table) can provide the necessary torque/force input. Either method requires an actuator/fixture capable of generating enough torque to replicate the reaction force measured at the powertrain mounts.

3.2.1.3 A heat source must be located near the simulation table. The durability portion of the test must subject the rubber powertrain mounts to a specified temperature (reference 3.5.5) simulating the under hood thermal environment experienced in the vehicle. A typical method is to attach electric heat gun blowers on a stand adjacent to the test rig, Figure A6. Heat duct is then used to convey heat to the mount location where an oven roasting bag (turkey bag) surrounds the mount and contains the desired thermal environment, Figure A7.

3.2.2 Fixtures.

3.2.2.1 Option One (1). Structural supports (i.e., angle/tube stands, angle brackets, etc.) can be used to secure the body buck and/or frame in design position on the table surface. This option uses a portion of the vehicle structure to support the powertrain in design position (reference Figures A1, Figure A2, and Figure A4).

Note: Option 1 is the preferred method because it allows thorough evaluation of fastener joint integrity when the mounts/brackets are attached to the associated body/frame component.

3.2.2.2 Option Two (2). Structural supports (i.e., angle/tube stands, angle brackets, beams, etc.) can provide the design mounting location for the powertrain mount and/or the associated powertrain mount brackets. This option replaces the supporting vehicle structure with fixtures (reference 3.5.3).

3.2.2.3 Option Three (3). Any combination of Options 1 and 2.

3.2.3 Transducers.

3.2.3.1 Test Rig Transducers.

3.2.3.1.1 Linear/Rotational Variable Differential Transformer (LVDT/RVDT). Linear/rotary, hydraulic actuators must be outfitted with an LVDT/RVDT to allow displacement measurement and control of the actuator. This will also allow displacement limits to be enabled for the safety of personnel and equipment.

3.2.3.1.2 Load/Torque Cell. Linear or rotary hydraulic actuators, attached to torque input fixtures, must be equipped with a load/torque cell to allow load measurement and control of the actuator. This will also allow load limits to be enabled for the safety of personnel and equipment.

3.2.3.2 Specimen Transducers. GMW15268 defines the minimum transducer set required for road load data acquisition (RLDA) and the test development portion of the test procedure. GMW15019 defines the RLDA process in which the transducers are used.

3.2.3.2.1 Accelerometer. Accelerometers are typically used to collect acceleration data at strategic locations during the RLDA and test development. The accelerometers will serve as the remote parameter control (RPC) transducers in developing the simulation table drive signals. An acceleration response is required for each of the hydraulic actuators controlling the motion of the table. Acceleration responses collected on the body and/or frame side are required.

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Note: The optimum location for the acceleration measurement depends on the powertrain configuration. For transverse powertrains, acceleration responses should be collected at the four corners of the engine compartment, preferably on the body rails or cradle, Figure A8. For longitudinal powertrains, acceleration responses should be collected at the left and right engine mounts and the transmission mount. In all cases, tri-axial acceleration responses should be collected at each location, preferably on the body and/or frame side of the powertrain mounting system. The performance of the test rig will be optimized if the accelerometer location on the specimen corresponds to the direction and line of action of the actuator it will control as an RPC transducer.

3.2.3.2.2 Load Cells. Load cells are used to measure reaction forces at the individual powertrain mounts. Sometimes, mounts/brackets are strain gauged for load measurement as well. This information is used to correlate the powertrain mounting system response on the test rig to that of the RLDA. It also serves as an RPC channel in developing the torque input to the specimen during test development.

3.2.3.2.3 LVDT/String Potentiometers. LVDTs or string potentiometers may be used to measure displacement at individual mounts. This information may be used to correlate the powertrain mounting system response on the test rig to that of the RLDA.

3.2.3.2.4 Torque Wrench. A torque wrench is used to tighten all threaded fasteners to the specified torque.

3.2.3.2.5 Weight Scale. A scale is used to record the weight of the powertrain.

3.2.4 Instrumentation.

3.2.4.1 Transducer Conditioner. The transducer conditioner is used to condition the inputs from the specimen transducers. A setup file is created at the start of the RLDA, which defines the gain, full scale, excitation, and sensitivity for each transducer. This information is saved and transferred to the test lab along with the RLDA transducers. This allows use of the same transducers/parameters during test development.

3.2.4.2 Miscellaneous Cabling. Cabling with appropriate end connectors will be required to connect the transducers to the instrumentation, and controllers to the test rig and instrumentation.

3.2.5 Controllers.

3.2.5.1 Test Site Controller (TSC). A test site controller system is required that provides servo-hydraulic control and test site supervision (real-time file management and playback). The two functions may be in two separate but integrated units or a single unit that performs both functions. The system must provide closed loop control of the servo-hydraulic actuators including safety limits, management of the real-time digital file playback commands to the servo-hydraulic loop, data acquisition of high level signals during the test development iteration process, and test monitoring.

3.2.5.2 Heat Source Temperature Controller. A heat source (typically electric gun blowers, Figure A6) must be controlled to provide the elevated thermal environment required for powertrain mount durability testing. The controller, Figure A9, should be capable of controlling the heat source from the output of a thermocouple.

3.3 Test Vehicle/Test Piece.

Note: The following includes items other than powertrain mounts/brackets and should be provided by the requester. Verify that all parts properly assemble to one another or required modifications are made.

3.3.1 Body/Frame Integral Vehicle. The following components are necessary unless fixtures are substituted in their place. The fixture designer should be contacted in the planning phase for assistance in developing fixtures (reference 4.1.2).

3.3.1.1 Body Buck. The portion of the body forward of and including the front body hinge pillar and below the base of the windshield is required. When using the body buck, typical practice has been to cut the buck down to the minimum structure necessary to adequately support the powertrain for testing. This can provide for better viewing and easier sample changes. Use engineering judgment or discuss with the requester when cutting the buck so as not to degrade the structural integrity of the supporting structure. Be aware that the same buck is generally used for multiple durability lives and samples.

3.3.1.2 Cradle. The powertrain/suspension cradle will be required if it provides structure/support to the powertrain mounting system. Cradle mounting hardware such as isolators (if applicable) and fasteners will also be required. The cradle may also be used for multiple durability lives unless directed otherwise by the requester.

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3.3.2 Body-on-Frame Vehicle. The section of frame and its associated cross members that support the powertrain are required.

3.3.3 Powertrain. A ballasted powertrain is required. The powertrain includes all components whose mass is supported by the powertrain mount system and may include the following: engine, transmission, transfer case, all-wheel drive power take-off unit, axle/differential housing, front wheel drive intermediate shaft, etc. It must also include accessory components such as: alternator, starter, air conditioning compressor, etc. Any missing component, which contributes significantly to the ballast distribution of the powertrain, should be replaced with appropriate ballast in the same location to maintain the center of gravity of the powertrain. Center of gravity determination can be accomplished as outlined in GMW14883.

Note: Some components, such as the exhaust system, radiator hoses, etc., connect the powertrain and other parts of the vehicle. Past evaluations have proven that these components do little to affect the motion of the powertrain and can therefore, be eliminated from the test setup.

3.3.4 Mounts/Brackets/Fasteners. All mounts, struts, dampers, etc., associated with supporting and/or restraining the powertrain are required. Brackets that adapt these components to the powertrain, body and/or frame, as well as the fasteners used to assemble them, are also required. These components are generally replaced at each sample change. The number of samples required is prescribed by the requester's validation plan or reliability requirement specified in the Subsystem Technical Specification (SSTS).

3.3.5 RLDA Hardware. A duplicate set of hardware must be provided by the RLDA requester **if**: the hardware used in performing the RLDA will not be made available for developing the test in the lab; or any RLDA hardware removed and provided to the lab will have to be replaced on the RLDA vehicle. This may include: body/buck, cradles, or frames pocketed for load cell installation; powertrain mounts and/or brackets modified for load measurement; powertrain mounts with specific rates or special construction; special transducers; etc. A request to the RLDA group to duplicate the hardware with the specific modifications should be made at the time of the RLDA request.

3.4 Test Time. The following is an estimate of the amount of time (work hours) needed to perform this standard.

Note: These time estimates are approximate averages. Actual times vary considerably depending on early component failures (and subsequent availability of replacement parts), testing to varying multiples of cycle lives, varying requirements for frequency of environmental test conditions, scheduling problems for test facilities, test equipment malfunctions, scheduling of overtime and/or multiple shifts, actual readiness of test samples upon receipt, unique or additional requests for detailed test information, running multiple samples (times shown are for one system), etc.

The reported times consider preparation and other downtime, actual test, and analysis of data in capturing a total calendar time. They are estimated ranges for a typical durability test and will vary based upon the chosen durability schedule. Report writing, approval, processing, etc., are not part of the reported times.

Coordination/Planning:	40 to 56 hours
Data Editing /Development:	280 to 400 hours
Durability Test (per life):	8 to 18 days

3.5 Test Required Information. The requesting engineer is responsible for identifying the durability schedule to be simulated and provide test specifications, SSTS or Component Technical Specification (CTS) paragraph numbers, appropriate to the powertrain mounting subsystem being tested. Reference GMW3425 for test modules that may be collected in the RLDA and simulated in this test.

Testing worst case scenarios may uncover some potential problems. Discuss with the requesting engineer if testing should include some worst case scenarios. The test plan may not include testing all powertrain options or variants such as front wheel drive and all-wheel drive. Certain components may be considered worst case for a particular variant. Components not evaluated by the test may be validated by analysis. Also, consider if any of the following may apply: tolerance stack ups, build variations, misalignment, minimum/maximum fastener torque(s), environmental extremes, symmetry (**left hand vs. right hand**), mold or die source, etc.

The following specifications or information are required to run this test:

3.5.1 RLDA Report. This should include the following: vehicle/powertrain/mount information (i.e., identifying numbers, design level, Regular Production Option (RPO) codes, etc.), powertrain mount rates, static offset

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loads measured at powertrain mounts, photos of transducer locations, and transducer setup information (electronic file preferred). Additionally, if mounts and/or brackets are reworked to accommodate load cells, any resulting "out-of-position" mounts must be documented with appropriate dimensions and provided to the test lab for duplication on the test development setup.

3.5.2 Time History Data. RLDA data should be provided to the test lab in RPC format. File names should adhere to standard naming conventions (for example GMW15219). Modifications to the provided data should be documented in the RLDA report.

3.5.3 Design Position Data. If necessary, provide math data to the fixture designer who will design fixtures to support the powertrain in design position. This data should be provided by the requester directly to the fixture designer.

3.5.4 Durability Part Information. Powertrain mount/bracket/fastener part numbers, design level, Uniform Parts Classification (UPC) codes, Functional Name Address codes, etc., must be provided for the production intent material to be evaluated during the test. Additionally, fastener torque specifications must be provided along with assembly sequences that may apply to properly assemble the powertrain mount system.

3.5.5 Test Temperature. Refer to GMW16217 for instructions on how to establish the desired steady state test temperature that each powertrain mount is to be subjected to during the durability test.

3.5.6 Test Inspections. The standard lab practice is to inspect the test specimen three (3) times per 8 h shift during durability testing. Any increase in inspection frequency should be specified by the requester at the start of durability testing.

3.6 Personnel/Skills. Prior experience/training in setting up and running similar tests and experience/training in the use of the referenced test equipment are required for a successful evaluation. This experience is also critical to achieving the estimated times shown in 3.4, Test Time. If assistance is needed, contact the local test expert.

4 Procedure

Note: There are two parts to the following procedure. Both are included in 4.3, Instructions. Section 4.3.1 describes the procedure for developing the test. Section 4.3.2 describes the procedure for executing the durability test.

4.1 Preparation.

4.1.1 Test Plan. Create a test plan that details the timeline of events that are to take place in executing this procedure. This may include fixture design/build, data editing, test site/rig preparation, test rig drive file development, durability test execution, etc. Reference checklist in Appendix B for a general "check list" of steps to perform in this test.

4.1.2 Fixture Design. If the setup will require the use of non-standard fixtures, the fixture designer should be notified as soon as possible. Design and build of the necessary fixtures can commence as soon as the required math data is made available (reference 3.5.3).

4.1.3 Facilities and/or Equipment Preparation. Confirm that the test rig is in proper operating condition. Request that the items in Table 1 be inspected by the responsible person or a qualified substitute:

Table 1: Responsible Equipment Inspectors

Item	Responsible Person
Actuator Seals	Hydraulic Service Technician
Hydraulic Hose	Hydraulic Service Technician
Bearings	Test Technician
Accumulators	Hydraulic Service Technician
Instrument Cables	Instrumentation Technician
Test Rig Tuning	Instrumentation Technician

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Record all site and instrumentation calibration information per the current lab standard. Request the following equipment in Table 2 be set up at the test site by the responsible person or a qualified substitute as required:

Table 2: Responsible Set Up Technicians

Equipment	Responsible Person
Signal Conditioning Equipment	Instrumentation Technician
Test Development Controller	RPC Technician
Durability Test Controller	RPC Technician
Servo-Hydraulic Controller	Instrumentation Technician

The instrumentation or RPC technician should verify continuity of cable connections used in controlling the test site. An improperly connected controller could damage the test equipment and/or specimen.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 Test Development Environmental Conditions. Development of drive signals will be performed at the durability test conditions as specified in 3.5.5.

4.2.1.2 Durability Test Environmental Conditions. The following environmental conditions apply during the durability sequence play back described in 4.3.2.5.1. (Exception: the shipping test modules (shipping matrix) should be executed with the mounts at ambient temperature.) Additionally, when the environmental conditions (reference 4.2.1.2.1) are imposed, a 2 h heat soak at the specified temperature should be enacted prior to the start of the durability test matrix.

4.2.1.2.1 Powertrain Mount Test Temperature. Rubber powertrain mounts must be tested at the steady state temperature as specified in 3.5.5. The elevated temperature simulates the under hood environment most likely to degrade the durability life of the rubber. The typical method of heating is to use an oven roasting bag (turkey bag) to surround the mount and associated hardware. A flexible heat duct is used to connect the bag to a heat source that can provide forced convection. Holes are cut in the opposite end of the bag to allow continuous movement of air through the bag. A thermocouple placed within 25 mm of the mount (inside the bag) is used to control the heat source and maintain the desired temperature. Airflow into the bag should not be directed at the mount. Direct the flow away from the mount or use a deflector to direct the airflow around the mount.

Note: When employing this technique, care must be exercised so as not to pinch or clamp the bag between the powertrain mounts/brackets and their mating surfaces. Degradation of clamp load may result if the bag is included in the joint. Seek the assistance of an experienced test technician for proper thermocouple placement and bag installation.

Alternatives using similar equipment and materials are possible. The requester should approve any method used.

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.

Note: The equipment, methods, and software references that follow serve as an example in creating/running a real-time durability test. Local laboratory customs should be substituted to achieve the same result where applicable.

4.3.1 Test Development. The goal in test development is to reproduce the powertrain mounting system response measured on the road during the RLDA. The two methods of test development are described in 4.3.1.1 and 4.3.1.2. The most common method (4.3.1.1) is development from RLDA responses. Development from test rig responses (4.3.1.2) is primarily used when moving from one test rig to another. Follow the appropriate method based upon the test to be developed.

4.3.1.1 Test Development from RLDA Responses.

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4.3.1.1.1 Prepare Time History Data. The time history data received from the RLDA should be checked for integrity and proper format. Reference GMW15232 Generic Data Processing Flow, for reviewing RLDA data and an outline of data processing required in this standard. Also, if necessary, extract the channels of data pertinent to this test from the time histories. GMW15268 lists the channels required for this test. The resulting files will be the road baseline time histories.

4.3.1.1.2 Calculate Time History Statistics. Time history statistics (e.g., maximum, minimum, etc.) must be determined for the data representing the "road baseline" (baseline statistics). Comparison, back to the road baseline, will be made at several points during the test development process. Statistics should be determined for each data channel across all files as well as for each file individually.

4.3.1.1.3 Calculate Pseudo Damage. A pseudo road damage baseline is also determined when correlating to load, stress, or strain data. Reference GMW15269, Structural Labs Pseudo-Fatigue Analysis, for an example on how to perform damage calculations. Likewise, comparisons back to the pseudo road damage baseline will be made at critical points during the test development to determine the quality of the evaluation. The standard test module repeats defined in the specified durability test should be used in the road baseline pseudo damage calculation.

Note: All baseline calculations must be made on unfiltered data. Also, static load offsets should be removed from time history data prior to baseline calculations. Powertrain mount static load offsets are due to the weight of the powertrain. A properly ballasted powertrain (reference 3.3.3) will provide the correct static load offsets, thereby negating the need to include them in data calculations. Powertrain mounting system time history responses generally do not include static loads when using an inertia-reacted test rig.

4.3.1.1.4 Edit Time History Data. Time history data editing tools are available in the RPC software (MTS Systems Corporation product).

The primary purpose of editing data is to reduce test time. This is accomplished by the elimination of non-damaging data. This is determined using the techniques described in 4.3.1.1.2 and 4.3.1.1.3. Ninety percent or more of the calculated road pseudo damage should be retained on each load channel after editing is complete. Also, overall maximum and minimum peak loads should be retained for each channel. Edited time history statistics and pseudo damage should be compared to the road baseline to determine if these criteria have been met.

4.3.1.1.4.1 Pre-edit Filtering. The typical inertia-reacted test rig is not capable of reproducing low frequency events requiring large displacements. Filtering the data to the control bandwidth of each channel is recommended prior to editing. This will identify data that cannot be reproduced on the test rig, thereby allowing its deletion. The typical control bandwidth for the simulation table is 0.4 Hz to 50 Hz. Channels having mount loads produced primarily as a reaction to the torque input are an exception. The fixed-reacted torque input is capable of reproducing low frequency data. Therefore, filtering prior to editing is not recommended for these channels.

4.3.1.1.4.2 Compress Time History. Some test modules may require time compression if simulating low frequency data content is necessary. Inclusion of such events is sometimes necessary to meet pseudo damage retention targets for lateral and fore/aft loads. If this is required, do not filter or edit the time histories as described in 4.3.1.1.4 and 4.3.1.1.4.1 (reference GMW15235 for compression of time history data).

Note: The process of deleting data during editing should be applied to the unfiltered road time history described in 4.3.1.1.1. Historically, when editing is complete, an average test time of 200 h is achieved. Test time will vary with the schedule being simulated.

4.3.1.1.5 Inspect RLDA Hardware. The RLDA hardware should be inspected upon receipt. Ensure that all hardware needed to develop the test has been provided or is available at the test site. This may include but is not limited to transducers, mounts, brackets, cradle, body buck/frame section, powertrain, etc.

4.3.1.1.5.1 Perform Instrumentation Checks. Prior to assembly, perform a function check of the transducers. Connect the transducers to the instrumentation and perform standard balance, calibration, and polarity checks using the information provided in the RLDA report. Exception: In the event the entire RLDA vehicle/buck is provided as an assembly, do not disassemble to perform these checks. Perform whatever checks are possible leaving all transducers assembled as provided. Disassemble only if a faulty component must be replaced.

Note: Monitoring powertrain vertical acceleration response is recommended. Request that the instrumentation technician install and condition the necessary transducers if they are not already included in the RLDA

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