



Exhaust System Structural Durability Test

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. This procedure evaluates the structural durability of passenger car, sport utility vehicle, and truck (light and medium duty) exhaust systems when subjected to real-time load and displacement profiles simulating proving ground road test modules. This procedure describes the test development and durability test execution.

1.2 Applicability.

1.2.1 This procedure is applicable to all passenger cars, sport utility vehicles, and trucks (light and medium duty) equipped with an exhaust system.

1.2.2 This procedure is used to develop or validate the structural durability of a vehicle exhaust system. Exhaust system components that are not sensitive to fatigue damage from road inputs may not experience the same level of correlation.

1.2.3 This procedure does not provide a total exhaust system structural durability test. Degradation or failure modes related to environmental factors such as corrosion, humidity and dust are not simulated. Powertrain inputs such as engine firing pulses, engine vibration, exhaust gas backpressure, and exhaust gas thermal duty cycles associated with a running engine are not simulated on tests using a natural gas furnace/burner.

1.2.4 Exhaust hanger insulators are known to wear prematurely during durability test execution due to excess internal heat generation, which is not dissipated as in normal vehicle operation. Therefore, such components are usually monitored and replaced as necessary during the durability test. If external cooling is determined to be necessary by the test requester and test engineer, a compressed air cooling system or electric fans can be used to provide airflow over the exhaust hanger insulator during durability test execution.

1.3 Remarks.

1.3.1 Two (2) styles of test rig can be employed for executing this procedure: Multi-Axial Simulation Test Rig and Vertical Simulation Test Rig. The test rig used in executing this procedure must fulfill the validation requirements specified by the test requester.

1.3.2 A heat source, typically a natural gas furnace/burner or an operational engine assembly, is used to simulate an engine exhaust gas thermal input into the exhaust system during the durability test execution. Durability test execution with a natural gas furnace/burner will not simulate inputs produced by a running engine such as engine firing pulses, engine vibration, exhaust gas backpressure, and exhaust gas thermal duty cycles.

1.3.3 This procedure simulates road induced loading or acceleration, using repeatable profiles, designed to represent road durability modules that make up the proving ground road major durability tests. These loads or accelerations cause fatigue damage and wear phenomena on the exhaust system.

1.3.4 This procedure typically requires a Road Load Data Acquisition (RLDA) data or computer generated load data, sometimes referred to as virtual loads, a drive file development exercise, and correlation evaluation. Less time is required if carryover or modified carryover drive files are used. However, this approach may result in reduced correlation to the proving ground road durability test. The RLDA and the computer load generation processes are not defined in this procedure; only the test requirements related to each process are discussed here.

1.3.5 This procedure is written as a supplemental guide for engineers and technicians. It does not cover every possible aspect of an exhaust system structural durability test. Additionally, it is not intended to be used alone, since the road simulation process inherently requires engineering judgment and/or technical experience.

1.3.6 This procedure is intended to produce an exhaust system structural durability test for a specific exhaust system. That is, a set of test rig drive files developed from road data or computer generated loads for a specific exhaust system will closely reproduce measured responses from remote parameter control and correlation transducers for that particular exhaust system's configuration. If any of the exhaust system's characteristics (i.e., mass, pipe routing, number and location of exhaust hangers, pipe diameter) are changed post RLDA or post computer load generation, the degree of laboratory-to-road correlation may be reduced.

1.3.7 This document refers to many procedures, see 2.2. These procedures contain detailed information that is closely tied to specific equipment and practices. Some of the GMWs were specifically written for full vehicle structural durability testing, but are also applicable to this procedure. Reference Appendix B, Table B3 for a list of GM Procedures.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14555	GMW15232	GMW15243	GMW15245
GMW14566	GMW15242	GMW15244	GMW15269
GMW15219			

2.3 Additional References.

- MTS RPC Pro Software and Reference Manuals.
- Release Documentation: This includes any documents which show product assembly, orientation, fit, assembly specifications, etc. for the exhaust system being evaluated.
- Technical Specifications: This includes the Subsystem Technical Specification (SSTS), which defines the subsystem level testing and reliability requirements.

3 Resources

This procedure refers to typical facilities and equipment used to perform this procedure. Other equipment may be substituted at the discretion of the testing facility as long as it provides the same data and/or data record, with equivalent accuracy as specified herein or by the requester.

3.1 Facilities.

Note: This procedure assumes adequate physical testing facilities and infrastructure for an exhaust system structural durability test are available. The following sections provide a partial list of the major facilities required.

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: This procedure assumes adequate physical equipment for an exhaust structural durability test is available and installed. The following sections provide a partial list of the equipment required. Other equipment may be substituted at the discretion of the 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 A surface plate/bed plate large enough for securing the test rig and capable of withstanding the dynamic loading of the test.

3.2.2 A high-pressure hydraulic system and associated servo hydraulic controls capable of supplying oil at a rate consumed by the test rig.

3.2.3 A natural gas furnace/burner and temperature controller (required for durability tests without an operational engine) capable of 1500 °C gas temperature at 6 m³/minute to simulate engine exhaust gases.

3.2.4 Test Rig. Two (2) styles of test rig can be employed for executing an exhaust system structural durability test. They are a Multi-Axial Simulation Test Rig and a Vertical Simulation Test Rig. These test rigs differ primarily in the number and location of control channels required for the test development and the test development methodology.

3.2.4.1 Multi-Axial Simulation Test Rig. The multi-axial simulation test rig is capable of controlling six (6) degrees of freedom (vertical, lateral, longitudinal, roll, pitch, and yaw) to both the powertrain and exhaust system. The inputs to the powertrain and exhaust system are provided by a single simulation table or dual simulation tables (a separate simulation table for the powertrain and exhaust system). A ballasted powertrain assembly (functional or nonfunctional) with correct powertrain mounts is required for this style test rig. The powertrain assembly should include all the components whose mass is supported by the powertrain mount system. It must also include accessory components such as: alternator, starter, air conditioning compressor, etc. Any missing components which contribute significantly to the ballast condition of the powertrain should be replaced with appropriate ballast in the same location. If powertrain torque inputs are to be simulated, the test rig must also incorporate a torque input device. Powertrain torque inputs are typically through the transmission half shafts or prop shaft, requiring the transmission to be locked-out to prevent rotation. Test fixtures are typically required to mount the powertrain and exhaust assembly to the simulation table. This is an inertial reacted test system that can reproduce real-time data to a typical bandwidth of 1 Hz to 50 Hz (0 Hz to 20 Hz for torque inputs).

3.2.4.2 Vertical Simulation Test Rig (Appendix C, Figure C9). The vertical simulation test rig is capable of controlling three (3) degrees of freedom (vertical, roll, and pitch) to the powertrain and one (1) degree of freedom (vertical) to the exhaust system. Powertrain inputs are controlled by a single simulation table or by individually controlled inputs at each of the powertrain mount locations.

3.2.4.3 Vertical Simulation Test Rig with a Simulation Table. A simulation table is used to provide three (3) degrees of freedom (vertical, pitch, and roll) to the powertrain assembly. A ballasted powertrain assembly with correct powertrain mounts is required for this style test rig. The powertrain should include all the components whose mass is supported by the powertrain mount system. It must also include accessory components such as: alternator, starter, air conditioning compressor, etc. Any missing components which contribute significantly to the ballast condition of the powertrain should be replaced with appropriate ballast in the same location. If powertrain torque inputs are to be simulated, the test rig must also incorporate a torque input device. Powertrain torque inputs are typically through the transmission half shafts or prop shaft, requiring the transmission to be locked-out to prevent rotation. Individually controlled vertical input fixtures are used to simulate exhaust system motion at each of the frame or body-side hanger locations. Test fixtures are typically required to mount the powertrain and exhaust system to the test rig. This is an inertial reacted test system that can reproduce real-time data to a typical bandwidth of 1 Hz to 50 Hz (0 Hz to 20 Hz for torque inputs). Lateral and longitudinal powertrain and exhaust system inputs are not simulated.

3.2.4.3.1 Vertical Simulation Test Rig with Individually Controlled Powertrain Vertical Inputs (Appendix C, Figures C1 thru C8). Individually controlled vertical input fixtures are used to provide three (3) degrees of freedom (vertical, pitch, and roll) to the powertrain assembly at each powertrain mount locations. A partial engine assembly (engine block and cylinder heads) and a partial transmission assembly (transmission case) are required for this style test rig. A ballasted powertrain assembly is not required. A simulated powertrain assembly can be used instead of a partial engine and transmission assembly (Appendix C, Figures C6 and C7). The simulated powertrain assembly must be fabricated with the exhaust manifolds mounting surfaces (turbocharger adapter for diesel engines) and powertrain load inputs locations in vehicle design position. Individual controlled vertical inputs are used to simulate exhaust system motion at each of the frame or body-side hanger locations. Test fixtures are typically required to mount the powertrain and exhaust system to the test rig. This is an inertial reacted test system that can reproduce real-time data to a typical bandwidth of 2.4 Hz to 40 Hz (0 Hz to 20 Hz for torque inputs). Actual bandwidths achieved may vary due to test rig performance and sample responses. During the drive development process, the test engineer should employ the maximum control bandwidth possible while simultaneously balancing the best possible correlation across all channels of interest. Lateral and longitudinal powertrain and exhaust system inputs may not be simulated.

3.2.5 Exhaust Hanger Insulator Cooling. Depending on system configuration and thermal environments, exhaust hanger insulators may wear prematurely. Such components should be monitored and replaced as necessary during the durability test. If external cooling is determined to be necessary by the test requester and test engineer, a compressed air cooling system or electric fans can be used to provide airflow over the exhaust hanger insulator during durability test execution.

3.2.6 Transducers. Remote parameter control transducers are used to measure powertrain and exhaust system responses during the test development process. Loads and transducers required for laboratory test development are defined in Appendix B, Table B1.

3.2.6.1 Accelerometers. Accelerometers (typical input range: $\pm 25G$, 0 Hz to 500 Hz) are typically used to collect acceleration data at strategic locations on the powertrain and exhaust system during the test development process.

3.2.6.2 Strain Gages. Strain gages (typically full bridge bending, moment or shear configurations) are applied at various locations on the exhaust system to measure exhaust system responses during the test development process. Strain gages (full bridge torque configuration) are used to measure prop-shaft or half-shaft torque for use with torque input devices on test rigs with a simulation table. See Appendix C, Figures C10 thru C12 for examples of a strain gauged exhaust system. Strain gages are not required if you are using body side or frame side acceleration to develop the test.

3.2.6.3 String Potentiometers. String Potentiometers (range ± 50 mm) are used to measure powertrain (vertical and roll) and flex coupler displacements during the test development process.

3.2.7 Instrumentation.

3.2.7.1 Transducer Signal Conditioner. Transducer signal conditioners are used to condition signal inputs from the remote parameter control transducers during the test development process.

3.2.8 Test Controllers. The test controller may be equipped with a filter or have a filter that can be turned on or off. When conditioning and/or collecting data with one (1) of the controllers that follows, the user needs to be aware of any filters that may be applied and the affect they may have on the data collected. Seek assistance of an instrumentation technician if help or clarification is needed.

3.2.8.1 Automated Site Controller (ASC). The ASC is used for test development. The ASC outputs send drive signals to the test rig and collects responses back from the remote parameter and test rig system transducers. The ASC can also be used as a Test Site Controller (TSC) during the durability portion of the test.

3.2.8.2 Test Site Controller (TSC). The TSC is used to send the drive signals out to the test rig during the durability portion of the test. It can also be used to collect responses from the site transducers.

3.2.8.3 Hydraulic Controller. The hydraulic controller provides closed loop control to the servo-hydraulic loops on the test rig. Drive signals (commands) are sent into the hydraulic controllers from either the ASC or the TSC. The hydraulic controller also provides shut down limits that can be tailored by the user for a specific test. These limits prevent unsafe operation of the test rig when control is interrupted.

3.2.8.4 Heat Source Temperature Controller. A temperature controller is used to control the heat source (typically a natural gas furnace/burner) for laboratory tests without an operational powertrain. The temperature controller maintains the desired exhaust gas or skin temperature during the durability portion of the test.

3.2.8.5 Engine Operation Controller. An engine operation controller is used to control engine operation during thermal heat and cool cycles on laboratory test with an operational powertrain assembly.

3.3 Test Material.

3.3.1 Test Samples. A test sample is one (1) complete exhaust system with representative components. One (1) complete exhaust system is required for test setup in addition to each sample to be tested. Typical parts include: converter assembly, muffler assembly, exhaust manifolds (turbocharger adapter if diesel engine), insulators, hanger brackets and related hardware, gaskets, seal and fasteners.

3.4 Test Time. The following is an estimate of the amount of time needed to perform this procedure. These time estimates are approximate and may vary based on the type of test rig, test development methodology used, durability road schedule simulated and the equivalent customer usage mileage for one (1) life. These times include preparation, planned downtime, actual test and analysis of data in capturing a total calendar time. Report writing is not included as part of these times.

Test Fixture Design/Build:	4 to 8 weeks
Data Processing/Test Development:	2 to 4 weeks
Durability Test per Life (Car):	6 to 15 days
Durability Test per Life (Mid-Size Truck):	8 to 10 days
Durability Test per Life (Full-Size Truck):	16 to 18 days

3.5 Test Required Information. The following specifications or information are required to run this test:

3.5.1 Test Specifications. The requesting engineer is responsible for identifying the durability test to be simulated and providing test specifications, Subsystem Technical Specifications (STS) paragraph numbers, appropriate to the particular exhaust system being tested.

3.5.2 Time History Source Data. It is recommended data should be provided to the test lab in RPCPro format having 2048 points per frame, and 512 samples per second. However, the points per frame and sample rate can deviate from this recommendation with the approval of the test engineer and data provider. File name must adhere to the local standard naming convention. Refer to Appendix B, Table B3 for the Procedure regarding file naming.

3.5.3 Remote Parameter Control Transducer Locations. The test engineer should obtain exact locations to place the remote parameter control transducers on the test development specimen. For RLDA source data, the locations should be obtained from the RLDA engineer or supporting report. If source data is computer generated, the responsible Computer Aided Engineering (CAE) engineer should provide remote parameter control transducer locations.

3.5.4 Design Position Data. If necessary, math data must be provided to the fixture design group to design fixtures to support the exhaust system in design position on the test rig.

3.5.5 Durability Part Information. Exhaust system part numbers, design level, Uniform Parts Classification (UPC) codes, and Functional Name Address (FNA) codes for the production intent material to be evaluated. Additionally, fastener torque specifications must be provided along with assembly sequences that may apply to properly assemble the exhaust system.

3.5.6 Test Temperature. The desired test temperature profile the exhaust system is subjected to during the durability test. The temperature profile is based on the heat source used (operational engine or natural gas burner). Test development is performed with the exhaust system at room temperature (reference 4.2.1.1).

3.5.7 Test Inspections. The standard lab practice is to inspect the test specimen three (3) times per 8 h work shift during the 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 and training in setting up and running similar tests and experience and training in the use of the referenced test equipment are required for a successful test. This experience is critical to achieving the estimated times shown in 3.4. If assistance is needed, contact the local test expert.

4 Procedure

There are two (2) parts to the following procedure. Both are included in 4.3 Instructions; 4.3.2 describes the procedure for developing the test, 4.3.3 describes the procedure for executing the durability test.

4.1 Preparation.

4.1.1 Test Planning. Create a test plan that details the timeline of events that are to take place in executing this procedure. This may include the RLDA or computer loads generation, test fixture design/build, data editing, test site/rig preparation, the drive file development process and durability test execution. The test requester and test laboratory must agree on the scope of work and required delivery dates. Process diagrams for a typical exhaust durability test can be seen in Appendix A, Figures A1 and A2.

4.1.2 Loads Data Planning. Ensures the loads data channels and the road durability modules required to develop the test are collected via an RLDA or generated via a computer loads model. Loads and transducers required for laboratory test development are defined in Appendix B, Table B1. Loads data may not be required if existing test rig drive files can be used. Use existing drive files only if they will produce adequate correlation for the test specimen(s). Comparing the current vehicle configuration information to the vehicle information for

which the drive files were developed can help make this decision. The following vehicle parameters should be compared.

- Suspension configuration
- Exhaust configuration.
- Tire size.
- Wheelbase.
- Track width.
- Vehicle mass.
- Powertrain mount location and rates.
- Engines used, including torque curves.
- Transmissions used, including gear ratio, final drive ratio, and torque management algorithms.

4.1.3 Fixture Design Planning. If the test setup will require the use of non-standard test fixtures, the local fixture design group should be notified early in the planning stages. Design and build of the necessary fixtures can commence as soon as the required math data is made available, see 3.5.4.

4.1.4 Sample Inspection. The test and requesting engineers should inspect the test samples to ensure all material listed in 3.3.1 is the correct design level.

4.1.5 Facilities and/or Equipment Preparation. Confirm that the test rig is in proper operating condition. The test technician or qualified person should inspect all hydraulic components and cable connections for safe operation and make sure everything is in good working order. Verify calibration dates for all test site instrumentation per the current laboratory standard. All calibration information and documentation should be included in the test site logbook.

4.1.6 Gate Review - Project Plan. Obtain test requester sign-off on the project plan, road events to record or computer generated, channel list, and vehicle content/design level.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 Test Development Environmental Conditions. Unless otherwise specified in this procedure's text or by the requesting engineer, the typical environmental conditions for test development are the temperature, humidity and pressure at the test facility. Unless otherwise noted, these conditions are typically $22\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$, relative humidity of $40\% \pm 20\%$, and atmospheric pressure equivalent to the local barometric pressure (which is variable during any given day and from day to day).

4.2.1.2 Durability Test Environmental Conditions. Unless otherwise specified in this procedure's text or by the requesting engineer, the typical environmental conditions for test execution are the temperature profiles listed as follows. The test requester will provide the desired test temperature profile based on the heat source used (operational engine or natural gas burner) and the road exhaust thermal data collected.

4.2.1.3 Temperature Profile.

4.2.1.3.1 Steady State Temperature Profile with Natural Gas Burner Heat Source. A steady state temperature profile is generated from data collected during the Powertrain Cooling and Thermal Performance Test (GMW14555). The durability test steady state temperature will be 80% of the maximum temperature (exhaust down pipe surface temperature) noted during the execution of GMW14555. As a default inlet gas temperature, if no data is available, use $600\text{ }^{\circ}\text{C}$ for gasoline and $500\text{ }^{\circ}\text{C}$ for diesel engine applications. Final direction should be agreed to by the responsible design and validation engineers. The natural gas burner/furnace is turned off for 1 h per day during the test execution to induce a cool down cycle and to facilitate a leak check inspection. Note that the specified temperature is a target; however, due to limitations of the executing facility, the actual steady state temperature during test execution may be less.

4.2.1.3.2 Steady State Temperature Profile with Diesel Particulate Filter Regeneration. To simulate the diesel particulate filter regeneration cycle, the sample is subjected to an elevated temperature for 1 h per day prior to the cool down cycle. The elevated temperature is based on vehicle data and is provided by the responsible design engineer. As a default inlet gas temperature, if no data is available, use $600\text{ }^{\circ}\text{C}$ for the diesel regeneration cycle.

4.2.1.3.3 Variable Temperature Profile with Natural Gas Burner Heat Source. A variable temperature profile is generated from data collected during a “hot” exhaust system RLDA. A “hot” exhaust system RLDA is a separate road data collection for recording exhaust system surface and gas temperatures at various locations using a vehicle that allows the engine hot exhaust gases to flow through the exhaust system. The variable temperature profile is generated from these temperature data and shall incorporate 110% of the maximum temperature noted during the “hot” RLDA.

4.2.1.3.4 Heating and Cooling Cycles with Operational Engine. Equal length heating and cooling cycles (typically 8 minutes to 13 minutes) are applied to the exhaust system during the test execution for test with an operational engine. Heating cycles are generated when an engine load is produced at a prescribed engine speed. The engine speed is based on the engine type (gas or diesel). Cooling cycles are produced with no engine load and at idle speed. Typical engine load and thermal cycle settings are listed in Appendix B, Table B2.

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 Insulator Cooling. If determined to be necessary, the exhaust insulator cooling system needs to be operational whenever the test rig is used for continuous testing. If possible, the test should be configured with an interlock to prevent commencement of testing if the cooling system is not operational.

4.3 Instructions. 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 results where applicable.

4.3.1 Obtaining Loads Source Data. Loads source data required to develop the test inputs will be RLDA based or computer generated. The RLDA process and the computer load generation process are not defined in this procedure. Only the test requirements related to these processes are discussed here.

4.3.1.1 Road Load Data Acquisition Vehicle. A vehicle containing components of a level consistent with the project plan (i.e., exhaust system, powertrain, suspension and wheelbase) is required for the RLDA. The test engineer and the test requester should inspect the vehicle to ensure all material is the correct design level and assembled properly. Verify that the exhaust system is positioned in the vehicle as per design specifications. Any variation from design position must be corrected before the RLDA begins. Document the exhaust system's position in the RLDA vehicle with appropriate dimensions and provided to the test lab for duplication on the test rig. The RLDA vehicle's engine exhaust gases must be diverted from entering the exhaust systems if normal temperature rated transducers (strain gages and accelerometers) are to be used. The exhaust gas does not need to be diverted if you are collecting only body side or frame side acceleration data. Diverting the exhaust must not restrict powertrain motion during normal engine operation. If the exhaust cannot be diverted, transducers designed to operate at high temperatures will be needed. Reference GMW14566 for further information regarding the exhaust system road load measurements procedure.

4.3.1.2 Remote Parameter Control (RPC) Transducers. Locate the transducers in locations where hydraulic actuators will be used on the test rig in order to maximize the test rig transfer function. Avoid placing accelerometers in areas that may be sensitive to local vibration behavior. Locate strain gages on the exhaust system in full bridge bending, moment, or shear configuration. A list of typical RPC transducers for each type of test rig is shown in Appendix B, Table B1.

4.3.1.3 Correlation Transducers. Correlation transducers are added to provide additional information regarding the accuracy of the road simulation at locations other than the remote parameter transducer locations. They can also be used as alternative RPC transducers if the chosen RPC transducers do not provide the expected performance or are damaged. A list of typical correlation transducers are shown in Appendix B, Table B1.

4.3.1.4 Road Events. Select the road events (also referred to as durability modules, schedules or maneuvers) to record. Reference GMW15219 for road events to provide for a typical exhaust system RLDA or computer generated load source file. A road event may be omitted only if the areas of interest are not affected. Upon completion of the RLDA, if applicable, remove the instrumented exhaust system from the vehicle and ship to the test laboratory. Transfer the road data time histories and supporting documentation to the laboratory test engineer.

4.3.2 Test Development. The goal in test development is to reproduce the exhaust system load source data. Two (2) methods of test development are described in 4.3.2.1 and 4.3.2.2. The most common method (4.3.2.1) is developed from load source data. Development from rig responses (4.3.2.2) is primarily used when moving from one (1) test rig to another. Follow the appropriate method based upon the test to be developed.

4.3.2.1 Test Development from Load Source Data.

4.3.2.1.1 Prepare Time History Data. The loads source data should be checked for integrity and proper format. Reference GMW15243 for information on initial data review. Data that does not meet the minimum requirements must be repaired or re-collected. Also, if necessary, extract the channels of data pertinent to this test from the road time histories. The resulting files will be the road baseline time histories.

4.3.2.1.2 Calculate Time History Statistics. Time history statistics (e.g., maximum, minimum, etc.) must be determined for the data representing the road baseline. Comparisons 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.

Note: All time history statistics calculations are made on unfiltered data. Also, static offsets are removed from time history data prior to statistic calculations.

4.3.2.1.3 Calculate Pseudo-Fatigue Damage or Pseudo-Energy Baseline. A pseudo-fatigue damage road baseline is determined when correlating to load, stress, or strain data. Reference GMW15269 for guidance on Pseudo Fatigue Damage calculations. A pseudo energy road baseline is determined when correlating acceleration data. Reference GMW15244 for guidance on Pseudo-Energy calculations. The Pseudo-Fatigue Damage or Pseudo-Energy for a given data channel represents the sum of the calculated fatigue damage or energy from each road module multiplied by the repetitions specified in the road durability test. Likewise, comparisons back to the fatigue damage or energy 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-fatigue damage or baseline pseudo energy calculation.

Note: All pseudo fatigue damage baseline and pseudo energy baseline calculations are made on unfiltered data. Also, static load offsets are removed from time history data prior to baseline calculations.

4.3.2.1.4 Edit Time History Data. The primary purpose of data editing is to reduce test time while still retaining sufficient test severity. This is accomplished by eliminating the road modules that contain insignificant fatigue damage or energy content and editing the remaining road modules to remove the less severe sections of the road modules. The significance is determined using the techniques described in 4.3.2.1.2 and 4.3.2.1.3. At least 90% of the calculated road pseudo-fatigue damage or pseudo-energy should be retained on each load channel after data editing is completed. Also, overall maximum and minimum peak loads should be retained for each data channel. Edited time history statistics and pseudo-fatigue damage or pseudo-energy should be compared to the road baseline to determine if these criteria have been met. These edited data are the desired remote parameter control responses for the test development.

4.3.2.1.4.1 Pre-edit Filtering. The typical inertial 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 test rigs with a simulation table is 1 Hz to 50 Hz. Powertrain torque input channels are the exception and capable of reproducing low frequency data. Therefore, filtering prior to editing is not recommended for these channels.

4.3.2.1.5 Gate Review - Editing Results. During this gate review, the edited data is compared to the road response data. The criteria specified in the project objectives are the basis for determining adequate results. Reports usually required for this review include retained fatigue damage or retained energy by channel comparison tables and peak/range ratios by channel comparison tables. Other reports are sometimes useful, such as selected Auto Spectral Density (ASD) plots, XY plots and time history comparisons for transient events. Once these results are approved, the edited road responses become the unfiltered desired response files in the iteration process.

4.3.2.1.6 Install Test Rig Fixtures. Install or adjust the test fixtures to mount the exhaust system in design position on the test rig. The test fixtures were designed and built, if needed, early in the test planning phase by the fixture design group (see 3.5.4). A test layout drawing should be provided with test setup dimensions to show test fixture position and location on the test rig.

4.3.2.1.7 Verify Test Rig Performance. Set up the servo-hydraulic control hardware according to standard laboratory procedure for the equipment in use. Confirm that there is proper control of the servo-hydraulic actuators before installing a test specimen on the test rig.