



Damper Basic Performance 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. The purpose of this test procedure is to outline a method for determining the performance characteristics of a suspension damper.

1.2 Applicability. This procedure applies to all passive suspension dampers. It may also be applied to electronically controlled suspension dampers provided that appropriate control equipment, power source, logic, etc., is supplied or available. However, details specific to electronically controlled damper testing are not within the scope of this procedure.

This procedure applies to servo-hydraulic or electro-mechanical test stations capable of performing multiple test steps incorporating multiple frequency and displacement combinations (hence, multiple velocities).

1.3 Remarks. Metrics obtained from this test include gas force, friction force, peak force, peak velocity, dynamic stiffness, effective damping, phase, lag and harmonic distortion.

2 References

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

2.1 External Standards/Specifications.

ISO 17025 SAE J670

2.2 GM Standards/Specifications.

GMW14540 GMW14804 GMW15462

2.3 Additional References.

- GM Engineering Report PG075180 (**Note:** The supplier will work with the responsible GM Engineer to comprehend this requirement.)

3 Resources

3.1 Facilities. The test facilities and equipment shall be in good working order and shall have valid calibration records.

Damper tests are normally performed using GM damper test stations. These stations can be either waveform-controlled such as servo-hydraulic units (e.g., MTS Brand) or fixed-waveform (sine) such as electro-mechanical units (e.g., Verband der Automobilindustrie (VDA) Association of German Automobile Manufacturers standard test machine). Alternative test facilities and equipment may also be used provided they have the capability to complete the test and processing per this test procedure.

Test stations shall be capable of producing a sine wave input within the test ranges as specified in Table A1 in Appendix A.

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.

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3.2 Equipment.

3.2.1 Test system must be capable of running at required speeds without any appreciable variation in test velocity or wave form for the duration of the test.

3.2.2 Data acquisition and storage system capable of cyclic sampling (250 points/cycle minimum).

3.2.3 Attachment fixtures specific to damper being tested.

3.2.4 Damper test software and controller, if applicable.

3.2.5 Hydraulic power supply, if applicable.

3.3 Test Vehicle/Test Piece. This procedure applies to all types of dampers that are used in vehicle suspension systems.

3.4 Test Time.

3.4.1 Typical test duration, including preparation, execution and teardown is 30 minutes.

3.4.2 If necessary, multiple days may be required to fabricate fixtures to attach dampers to the load frame actuator.

Calendar time: 0.1 to 2 days

Test hours: 0.5 hour

Coordination hours: 0.1 hour

3.5 Test Required Information.

3.5.1 Test Conditions. Standard tests consist of pre-determined test steps, as specified by the local test site. If a non-standard test is required, the requestor will specify the test step conditions (frequencies and amplitudes). If no prescribed set of conditions is desired/provided, the default set provided in Table A2 can be used. As a safety precaution, always verify that the test procedure does not exceed the maximum stroke of the damper.

3.5.2 Design center of damper stroke = Center test stroke = L_M .

3.5.3 Test State (as delivered, broken in).

3.6 Personnel/Skills. Operators shall be qualified and documented as capable to perform this test as required by ISO 17025.

4 Procedure

4.1 Preparation.

4.1.1 Install Fixtures. Fixtures may include passive bolted or clamped units as well as hydraulically-controlled side-load equipment, if required/applicable.

4.1.2 Start Up Test Station. This includes personal computer, controller, and hydraulic power supply, if applicable.

Note: For hydraulic test stations, the machine should undergo a warm-up period lasting at least ten (10) minutes. This can be achieved by using a low frequency, high amplitude sine wave input (e.g., 0.2 Hz, 100 mm peak-to-peak amplitude).

4.1.3 If the damper to be tested is "new," it shall be subjected to an appropriate "break-in" period prior to performance evaluation. The recommendation is a sine wave input of 1 Hz with amplitude of ± 30 mm for a duration of ten (10) minutes.

Note: A fan may be needed to keep the damper temperature below 80 °C.

Let the damper cool back down to the desired test condition prior to start of test.

4.1.4 For dampers with additional air spring/leveling system:

Test A: Inflate air sleeve to an internal pressure of 100 kPa $\pm$ 10 kPa.

4.1.5 Acquisition.

4.1.5.1 Four (4) channels of data acquisition are required. Table 1 identifies these channels and the required units.

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Table 1: Data Channels

Channel	Units
Time ^{Note 1}	s
Displacement	mm
Velocity ^{Note 2}	mm/s
Force	N

Note 1: Time data can be from a recorded time signal or a temporal sampling rate.

Note 2: Velocity data can be measured directly or calculated from time-based displacement data.

4.1.5.2 Data shall be acquired for at least one (1) complete stable cycle. "Stable" refers to a cycle that is free of acceleration and deceleration effects.

4.2 Conditions.

4.2.1 Environmental Conditions. All tests shall be performed at room temperature (approximately 23 °C).

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 Waveform-Controlled Test Stations, e.g., servo-hydraulic.

At a minimum, the following test steps are required:

4.2.2.1.1 One (1) Stroke-Check Step. One (1) cycle, sine waveform, 0.2 Hz, amplitude 2 mm larger (peak-peak) than maximum stroke condition.

4.2.2.1.2 One (1) Warm-Up/Gas Purge Step. Five (5) to ten (10) consecutive cycles, sine waveform, 0.5 Hz $\pm$ 40 mm.

4.2.2.1.3 One (1) Gas Force/Friction Step. One (1) cycle, MTS Gas Test Waveform, 0 mm test position, 2 mm test profile displacement, 1.3 mm/s test velocity, 12 mm seal reset profile, 50 mm/s seal reset velocity.

4.2.2.1.4 Five (5) to Eight (8) Performance Steps. Three (3) cycles for each step, vehicle ride natural frequency, various amplitudes. See **Note**.

4.2.2.1.5 Five (5) to Eight (8) Performance Steps. Three (3) cycles for each step, vehicle wheel-hop natural frequency, various amplitudes. See **Note**.

Note: In lieu of known ride and wheel-hop natural frequencies, use 1.2 Hz and 12 Hz, respectively.

See Table A2 for default performance step conditions.

4.2.2.2 Fixed-Waveform (sine) Test Stations (e.g., electro-mechanical with fixed test amplitude).

At a minimum, the following test steps are required:

4.2.2.2.1 One (1) Warm-up Step. Five (5) cycles, 50 cpm, at test amplitude.

4.2.2.2.2 One (1) Gas Force/Friction Step. One (1) cycle, test speed of 10 cpm, with a slowdown to 0.5 cpm as the rod guide passes through the center of the test stroke in both rebound and compression.

4.2.2.2.3 Minimum 7 Performance Steps. Four (4) cycles for each step. Three (3) pre-stroke cycles and one (1) measurement cycle or as equipment capability dictates, fixed amplitude, various speeds.

See Table A2 for default performance step conditions.

4.3 Instructions.

4.3.1 Verify that the actuator is at rest at its mid-stroke position (0.00 mm).

4.3.2 Perform a load cell auto-zero or reference-zero reset. This step must be completed after fixture installation and prior to damper installation.

4.3.3 Install the damper in the load frame at its center of test stroke (L_m). If L_m is not provided, set damper to mid-stroke position. For dampers with internal rebound springs or self-leveling capability, the test position shall be defined by the part drawing.

4.3.4 Verify secure attachment at both ends of the damper.

4.3.5 Perform the damper test per the prescribed test conditions.

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5 Data

5.1 Calculations.

5.1.1 Gas force/friction Steps shall produce gas force and friction force results. Performance Steps shall produce peak force, peak velocity at a minimum. It is desirable to also produce force at peak velocity, velocity at peak force, harmonic amplitude, dynamic stiffness, effective damping, phase, and harmonic distortion results. See GM Engineering Report PG075180 for more specific information with respect to these results.

5.1.2 Determination of Frictional Force F_F and Gas Force F'_G . See 7.1.

$$F_F = F'_b - F'_a \text{ (Peak to Peak – GME method) or}$$

$$F_F = \frac{F'_b - F'_a}{2} \text{ (Zero to Peak – MTS method)}$$

$$F'_G = \frac{F'_a + F'_b}{2}$$

5.1.3 Determination of Damping Force in direction of rebound (F_R) and direction of compression (F_C). See 7.2.

$$F_R = F'_R - F'_G$$

$$F_C = F'_C - F'_G$$

See Figures B1 and B2 in Appendix B for a graphical description of the aforementioned variables.

Note: Values for rebound force are positive while values for compression force are negative.

5.2 Interpretation of Results.

5.2.1 Review all test results for outlier data. Verify that no appreciable lag or springiness is apparent in the data that would invalidate peak force vs. peak velocity results.

Harmonic distortion results for the displacement and velocity signals may be reviewed to verify appropriate test station performance (large distortion indicates a poor performance).

Compare measured damper performance to target performance, if available.

5.2.2 Refer to the Figures in Appendix C for sample test data outputs. Figure C1 contains sample Force-Displacement Curves and Peak Force-Peak Velocity Curves. Figure C2 contains a Sample Peak Force vs. Peak Velocity Plot. Figure C3 contains a Sample Effective Damping Coefficient Plot. Figure C4 contains a Sample Lag Angle Plot. Figure C5 contains a Sample Displacement and Velocity Harmonic Distortion Plot. Figure C6 contains a Sample Force Harmonic Distortion Plot. Refer to the Figures Appendix D sample results summaries. Figure D1 contains a sample Force-Displacement Curve with Damping Lag. Figure D2 contains sample Force-Velocity Curves with Temperature Fade. Figure D3 contains sample Plots for a Single Test Step (15 Hz at 0.1 mm). Figure D4 contains a sample Summary Plot of Force vs. Velocity for First Harmonic Content. Figure D5 contains a Sample Summary Plot of Dynamic Impedance vs. Force for First Harmonic Content. Figure D6 contains a Sample Summary Plot of Dynamic Phase Lag vs. Force for First Harmonic Content.

5.3 Test Documentation. General damper description as required per local test site. At a minimum, required information includes part number, damper type (mono-tube/twin-tube), damper setting for variable dampers, actual test stroke, working fluid and gas charge, and manufacturer.

Exception GMNA. Test documentation, including a test summary (*.pdf file) and all appropriate database entries, is automatically completed by the GM Damper Test System as a part of data processing. See the GM Damper Test System Web Site for more information.

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems associated with its use. It is the responsibility of the user of the standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

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6.1 Servo-Hydraulic Test Stations. High-pressure (20 MPa (3000 psi)) servo-hydraulic test systems, such as those used within GM, demand the highest level of operator attention. They are unforgiving to any lapse in operator attention.

Note: Remember the following items.

6.1.1 Install and uninstall fixtures and dampers with the load frame actuator de-energized (no hydraulic power).

6.1.2 Always enable applicable safety limits (load, displacement, etc.,) when the actuator is energized.

6.1.3 Only operate the test station with the load frame guard in the closed position.

6.1.4 Verify that the test procedure does not exceed the maximum stroke of the damper.

6.1.5 In the event of unexpected test station behavior (particularly unexpected actuator movement), quickly press one (1) of the red emergency-stop buttons located at the station.

7 Notes

7.1 Glossary. See GM Engineering Report PG075180 for more detailed metric definitions from Basic Performance test. Details for metric definitions derived from other test procedures may be found in the procedures themselves.

Dynamic Stiffness (N/mm): The magnitude of the ratio of the fundamental components of the force and displacement signals.

Effective Damping Coefficient (N-s/mm): The magnitude of the damping coefficient due to the fundamental frequency component (calculated using the Loss Stiffness/(2 π f)). This can also be thought of as the average slope of the F vs. v curve up to a given velocity.

Electronically-controlled Damper: Meant to encompass dampers in which damping characteristics can be modified via an external power source. Conversely, the term “passive” suspension damper is meant to encompass dampers that operate without the assistance of an external power source.

F_a: For the sine wave test, the measured compression force at mid-stroke or peak velocity. For the ramp wave test, the average force during the compression step ramp.

F_b: For the sine wave test, the measured rebound force at mid-stroke or peak velocity. For the ramp wave test, the average force during the rebound step ramp.

F_c: Damping force in the direction of compression with gas force included.

F_G: Gas force (static force exerted on the damper piston in the direction of rebound as a result of the gas charge).

F_R: Damping force in the direction of rebound with gas force included.

F_C: Damping force in the direction of compression with gas force removed.

F_F: Sliding friction force at the interface between the damper rod and rod guide.

F_R: Damping force in the direction of rebound with gas force removed.

Harmonic Distortion Nth (%): The power of the Nth harmonic of a signal expressed as a percent of the power of the fundamental frequency of the signal.

Lag (degrees): The phase difference between the fundamental components of the velocity and force signals (velocity-force).

Lag (mm): The delay over stroke of force build-up as measured from a force-displacement plot.

Loss Stiffness (N/mm): The magnitude of the imaginary component of the Dynamic Stiffness.

Phase (degrees): The phase difference between the fundamental components of the displacement and force signals (displacement-force).

Storage Stiffness (N/mm): The magnitude of the real component of the Dynamic Stiffness.

Suspension Damper or simply Damper: A general term meant to encompass all devices used to attain damping in suspension systems (includes both shock absorbers and struts). See SAE J670 for similar definitions with respect to damping devices.

Total Harmonic Distortion (%): The sum of the powers of all of the higher order harmonics of a signal expressed as a percent of the power of the fundamental frequency of the signal.

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