



Brake Assist System Performance

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 standard is to determine the performance of a vehicle fitted with a brake assist system. This standard may be used for development or validation of requirements within the GM VTS and for regional regulations. This standard is consistent with characteristics identified by Chapter VIII Brake Assist Systems (BAS) of the European Parliament and of the Council; Pedestrian Protection - Regulation (e.g., Phase of Directive 2003-102-EC).

Two (2) different technical versions of brake assist systems are considered:

- Brake Pedal Application Speed
- Pedal Force Application.

1.2 Applicability. This standard is applicable for vehicles with antilock brake system/electronic stability control (ABS/ESC) hydraulic based brake assist systems.

1.3 Remarks. This procedure is designed to quantify the performance of a brake assist system that is based on:

- Brake pedal application speed (see Appendices A and B).
- Pedal application force. See Appendix C, Figure C1.

2 References

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

2.1 External Standards/Specifications.

2003-102-EC FMVSS 135

2.2 GM Standards/Specifications.

None

2.3 Additional References.

Vehicle Technical Specification (VTS)

3 Resources

3.1 Facilities.

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.

3.1.3 Garage equipped for test vehicle build and instrumentation installation.

3.1.2 Dry asphalt test surfaces are located at North/South (N/S) Straightaway or on Vehicle Dynamics Test Area (VDTA) or equivalent.

3.1.4 A vehicle weight station capable of measuring vehicle weight at each corner.

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3.2 Equipment.

3.2.1 Brake Pedal Force Transducer (0.0 N to 2000 N $\pm$ 1 N). See Appendix D, Figure D1.

3.2.2 Longitudinal Velocity Sensor.

3.2.3 Longitudinal Accelerometer. Longitudinal accelerometer at vehicle's center of gravity ($\pm$ 1.25G).

3.2.4 Brake Pad Temperature Thermocouples. Brake pad temperature thermocouples at each corner or external thermocouples (0 °C to 1000 °C). See Appendix D, Figure D1.

3.2.5 Brake Pressure Sensors. Brake pressure sensors located at each corner and at master cylinder. Note that this equipment is required to determine whether panic brake assist was active during testing for brake pedal application speed based brake assist systems. Not required for pedal force application based system.

3.2.6 Brake Pedal Displacement (Optional).

3.2.7 Wheel Speed Sensors. Wheel speed sensors at each corner (optional).

3.2.8 Data Acquisition System (DAS). Data acquisition system capable of collecting data channels at 1 kHz sample rate. DAS analog/digital (A/D) converter shall have a resolution of 12 bits or more and an accuracy of 2 (two) least significant bits. Four (4) low pass anti-aliasing filters with cutoff frequency of 72 Hz shall be used on pedal force and longitudinal accelerometer signals.

Note: All instrumentation is to be calibrated as required. Record instrumentation details (serial number) and date of calibration in Appendix B of the test report. Contact the responsible Vehicle Dynamics engineer for details and/or access.

3.3 Test Vehicle/Test Piece. See Section 4.

3.4 Test Time.

Instrumental time:	2 days
Test time:	Variable
Calendar time:	2 days
Coordination time:	3 days

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills.

3.6.1 Experienced chassis test technician for vehicle instrumentation.

3.6.2 Chassis test driver certified for braking tests.

4 Procedure

4.1 Preparation.

4.1.1 Build or verify the test vehicle brake apply system. Record vehicle and brake system information in the test record. The vehicle to be tested must be in safe operating condition for maneuvering levels approaching the limit of vehicle performance. Condition of tire, brake and suspension components should be inspected carefully. All vehicle safety equipment must be in proper operating condition.

4.1.2 Information about the vehicle and the brake system should be recorded in Appendix A of the test report. Contact the responsible Vehicle Dynamics engineer for details and/or access.

4.1.3 Perform burnish snubs in accordance with FMVSS 135 test specifications or equivalent. Install new tires before burnishing.

4.1.4 Install instrumentation. All instrumentation must be securely fastened to the vehicle due to the nature of test maneuver. Instrumentation should be located on the passenger seat. See 3.2 for sensor and DAS requirements.

4.1.5 Ballast the vehicle to curb weight, meaning the mass of the vehicle in running order including fuel, fluids, driver plus 75 kg for measuring equipment.

4.1.6 Inflate tires to manufacturer's recommended pressure or per test engineer's instructions.

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4.2 Conditions.

4.2.1 Environmental Conditions. Wind speed should be less than 16 km/h.

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 Dry asphalt test surfaces are required.

4.2.2.2 Test speed is 100 km/h $\pm$ 2 km/h.

4.2.2.3 Loading condition is curb weight, meaning the mass of the vehicle in running order including fuel, fluids, driver plus 75 kg for measuring equipment.

4.3 Instructions.

4.3.1 Ramp Stops.

4.3.1.1 Verify that all instrumentation is functioning properly. Calibrate instrumentation as necessary.

4.3.1.2 Brake pad temperatures shall be less than 100 °C.

4.3.1.3 All tests shall be performed on same portion of test surface as a method to reduce test variation caused by changes in road surface friction.

4.3.1.4 Accelerate vehicle on dry asphalt to the test speed of 100 km/h $\pm$ 2 km/h and hold test speed for at least 10 s with vehicle traveling in a straight line.

4.3.1.5 Trigger DAS for data collection.

4.3.1.6 Apply brake pedal slowly to create a constant increase of deceleration until ABS is fully active. The full deceleration must be reached within the time frame of 2.0 s $\pm$ 0.5 s. Full deceleration is defined as the first cycle of ABS activating for the remainder of the stop. Once full deceleration has been achieved, brake pedal force and travel shall not be decreased for at least 1 s. Typical brake pedal force ramp rates are in the range of 100 N/s.

4.3.1.7 Stop DAS.

4.3.1.8 Repeat 4.3.1.3 thru 4.3.1.6 at least four (4) more times for a total of at least five (5) test runs.

Note: Multiple brake ramp apply rates are done in groups of at least five (5) to expedite the data processing required for the following paragraphs.

4.3.2 Based on Brake Pedal Application Speed. Provide engineer with test data to determine the minimum force on brake pedal ($F(ABS)$), sufficient to achieve deceleration $a(ABS)$, reference value required for remainder of test. Engineer will also determine $F(ABS)_{Upper}$ and $F(ABS)_{Lower}$. See 5.1 for calculations.

4.3.2.1 Verify that all instrumentation is functioning properly. Calibrate instrumentation as necessary.

4.3.2.2 Brake pad temperatures shall be < 150 °C.

4.3.2.3 Accelerate vehicle on dry asphalt to the test speed of 100 km/h $\pm$ 2 km/h and hold test speed for at least 10 s with vehicle traveling in a straight line.

4.3.2.4 Trigger DAS for data collection.

4.3.2.5 Apply brake pedal quickly, as shown in Appendix B, Figure B1, simulating emergency braking so that the BAS and ABS are fully active. In order to activate the BAS, the brake pedal shall be applied as specified by the Performance Engineer. Eight hundred (800) ms after the brake pedal force has exceeded 20 N, the brake pedal force shall be kept between $F(ABS)_{Upper}$ and $F(ABS)_{Lower}$ as shown in Appendix B, Figure B1. Note that the test operator should bias pedal force hold level towards $F(ABS)_{Lower}$ to bias test to be more severe.

4.3.2.6 Stop DAS.

4.3.2.7 Repeat 4.3.2.1 thru 4.3.2.5 at least nine (9) more times for a total of at least ten (10) test runs.

4.3.3 Based on Brake Pedal Force. Provide engineer with test data to determine $F(ABS)_{extrapolated}$ reference value required for remainder of test. Engineer will also determine the threshold brake force for brake pedal force based brake assist ($F(T)$), the threshold deceleration for brake pedal force based brake assist ($a(T)$), and the reference deceleration ($a(ABS)$). See 5.1.2 for calculations. Systems sensitive to pedal force show a significant increase in the ratio of pedal force to vehicle deceleration at brake pedal force $F(T)$, which should occur within the deceleration range of 3.5 m/s² to 5 m/s², see Appendix C, Figure C1.

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5 Data

Note: Data is to be reviewed by engineer to resolve any issues surfacing during vehicle testing.

5.1 Calculations.

5.1.1 Analysis Based on Brake Pedal Application Speed.

5.1.1.1 Filter the brake pedal force and deceleration signals using a zero phase lag low pass Finite Impulse Response (FIR) digital filter with a corner frequency of 2 Hz and a Blackman window of 0.5 s.

5.1.1.2 Plot the deceleration and brake force signals in the time domain for each brake ramp apply test run. Determine the maximum value for the vehicle deceleration ($a(\text{maximum})$) from each of the five (5) brake ramp apply test runs. A method for determining $a(\text{maximum})$ for a brake ramp apply is to look for the maximum deceleration value from the time where brake pedal force is applied to the time where the vehicle speed is less than 15 km/h. The average of the maximum values for the five (5) brake ramp apply tests is the $a(\text{maximum})$.

5.1.1.3 Plot the deceleration versus brake pedal force curve for each brake ramp apply test run. Brake pedal force will be on the x-axis. For each test run, plot the data from the point where the brake ramp apply begins to the point where the vehicle speed is less than 15 km/h. For each test run, curve fit the brake pedal force versus deceleration plot. This can be done in Microsoft Excel by right clicking on the curve and selecting the trend line function. Use an n^{th} order polynomial for the curve fit and determine the n^{th} order that yields a best fit (use R^2 value in Microsoft Excel) while also yielding a curve that has the magnitude of deceleration increasing as a function of the brake pedal force throughout the brake pedal force range. A 4th thru 6th order polynomial fit has been typically used on previous applications. Make sure that truncation and rounding has not occurred with the curve fit equation. This can be done in Microsoft Excel by defining the curve fit equation coefficients as numbers with 17 digits to the right of the decimal point when using a 4th thru 6th order polynomial fit.

5.1.1.4 Create a column vector for brake pedal force from 0 N to 1200 N in increments of 1 N. Apply each of the curve fit equations to this column vector. Limit the maximum value of each curve fit equation to the corresponding $a(\text{maximum})$ value. Create a column vector that averages the results of each of the curve fit equations per N. Plotting the brake pedal force column vector versus the column vector containing the average of the curve fit equations will create the mean acceleration force (maF) curve.

5.1.1.5 Determine 90% of $a(\text{maximum})$. Plot $a(\text{maximum})$ on the maF curve as constant accelerations versus brake pedal force. See Appendix A, Figure A1 for example of maF curve.

5.1.1.6 Determine $a(\text{ABS})$ by averaging all deceleration values that are higher than 90% of $a(\text{maximum})$ at vehicle speeds greater than 15 km/h. To determine on maF curve the location of where the vehicle speed is less than 15 km/h, find the pedal force for each of the individual tests runs where vehicle speeds decreases below 15 km/h. Average the five (5) pedal forces and then use the average as the point on maF curve where vehicle speed decreases below 15 km/h. Plot $a(\text{ABS})$ and 90% of $a(\text{maximum})$ on the maF curve. See Appendix A, Figure A1 for example of maF curve.

5.1.1.7 Determine $F(\text{ABS})$. $F(\text{ABS})$ is defined as the force at the acceleration value $a(\text{ABS})$. Also determine:

$$F(\text{ABS})_{\text{Upper}} = 0.7 \times F(\text{ABS})$$

and

$$F(\text{ABS})_{\text{Lower}} = 0.5 \times F(\text{ABS})$$

These values will be needed to perform panic brake assist portion of test.

5.1.1.8 For each of the five (5) brake ramp apply test runs, determine the full deceleration time. The full deceleration time is defined as the amount of time between the time the brake pedal force exceeds 2 N and the first peak of the deceleration curve where ABS becomes active. The full deceleration time is required to be $2.0 \text{ s} \pm 0.5 \text{ s}$ for the brake ramp apply test to be valid (see Appendix A, Figure A2). Brake ramp apply rates of approximately 100 N/s are typically required to yield the full deceleration time.

5.1.1.9 Process panic brake apply data. Filter the brake pedal force and deceleration signals using a low pass FIR digital filter with a corner frequency of 10 Hz and a Blackman window of 0.5 s.

5.1.1.10 Plot the brake pedal force in the time domain. Plot $F(\text{ABS})_{\text{Upper}}$ and $F(\text{ABS})_{\text{Lower}}$ as constants in the time domain. See Appendix E, Figure E1 for an example. Observe brake pedal force to ensure that the brake pedal

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