



Brake Actuation 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 test is to objectively quantify brake actuation system performance.

1.2 Applicability. This test applies to light or medium duty vehicles equipped with a hydraulic brake system and a brake power assist unit.

1.3 Remarks. This procedure outlines a brake actuation subsystem bench test. The brake booster and master cylinder are evaluated as an assembly without measurement fixtures between the components. Test conditions are established to approximate the conditions the components experience in a vehicle. This test procedure shall be used for development and/or validation testing.

The performance metrics validated with this procedure are:

- Apply and release response time.
- Average pressure hysteresis.
- Cut-in.
- Effective area.
- Initial rise.
- Initial travel loss and efficiency.
- No power force loss and efficiency.
- Power slope.
- Primary, secondary, and total travel and displacement.
- Return cut-out.
- Total boost force.
- Total output efficiency.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

None

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3 Resources

3.1 Facilities. Milford Proving Ground Chassis Component Development apply bench facility or equivalent test facility. Test Improvement Process (TIP) approved test equipment shall be used.

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.

3.2.1 Test Bench and Capability. An actuation system test bench shall be capable of measuring these required performance parameters:

- Input force (Newton).
- Input travel (millimeter.)
- Output line pressure (kilopascal).
- Output fluid displacement (cubic centimeter).
- Booster and source vacuum (kilopascal).

3.2.2 Test Bench Features. The test bench shall incorporate the following features/functions:

- Vacuum pump and vacuum reservoir tank with automatic vacuum level control.
- Displacement simulation devices and/or plumbing for calipers/drums.

3.3 Test Vehicle/Test Piece. Test parts and brake corner compliance information shall be attained from the requesting engineer. A minimum of three (3) parts shall be tested to attain confidence in the results.

3.4 Test Time.

Calendar time:	1 day to 2 days
Test hours:	2 hours to 8 hours
Coordination hours:	1 hour to 2 hours

Note: The times listed are for each individual part.

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. One (1) technician trained in the operation of the actuation system test machine.

4 Procedure

4.1 Preparation.

4.1.1 Fabricate the appropriate fixture such that the actuation system can be mounted to the test bench.

4.2 Conditions.

4.2.1 Environmental Conditions. Ambient conditions during the test shall be between 10 °C and 30 °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.

4.3 Instructions. The test is divided into five (5) separate sections: Stroke Limits, No Power Performance, Full Power Performance, Pressure Response Time and Pressure Hysteresis. Prior to conducting any measurements, conduct one (1) brake apply to 3000 N of input force at 2 mm/s with 67.0 kPa vacuum.

4.3.1 Stroke Limit Test.

4.3.1.1 Initially, adjust the source vacuum to 74.5 kPa and maintain for 5 s. Lower the source vacuum to 67.7 kPa and maintain the level for the remainder of the test.

4.3.1.2 Open the bypass valves of the fluid circuits downstream from the master cylinder to allow fluid to bypass the compliance simulators.

4.3.1.3 Close the secondary circuit valve.

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4.3.1.4 Record the following channels at 100 Hz or greater:

- Input Force.
- Input Travel.
- Output Pressures.
- Output Displacements.

4.3.1.5 Advance the input rod at 2 mm/s until an input force of 500 N is reached. Release the input rod at 2 mm/s until the rod has returned to the home position.

4.3.1.6 Open the secondary circuit valve and close the primary circuit valve.

4.3.1.7 Repeat 4.3.1.4 and 4.3.1.5.

4.3.1.8 Calculate the following metrics:

- Primary Circuit Travel and Displacement.
- Secondary Circuit Travel and Displacement.

4.3.2 No Power Performance Test.

4.3.2.1 Release the source vacuum and remove the vacuum source hose from the booster.

4.3.2.2 Select the combination of compliance cylinders that simulates the corner compliance expected on the vehicle.

4.3.2.3 Record the following channels at 100 Hz or greater:

- Input force.
- Input travel.
- Output pressures.
- Output displacements.

4.3.2.4 Advance the input rod at 2 mm/s until an input force of 3000 N is reached. Release the input rod at 2 mm/s until the rod has returned to the home position.

4.3.2.5 Calculate the following metrics:

- No power assist force loss.
- No power assist force efficiency.

Repeat the test a total of three (3) times for each assembly.

4.3.3 Full Power Performance Test.

4.3.3.1 Select the combination of compliance cylinders that simulates the corner compliance expected on the vehicle.

4.3.3.2 Initially adjust the source vacuum to 74.5 kPa and maintain for 5 s. Lower the source vacuum to 67.7 kPa and maintain the level for the remainder of the test.

4.3.3.3 Record the following channels at 100 Hz or greater:

- Input Force.
- Input Travel.
- Output Pressures.
- Output Displacements.
- Source Vacuum.
- Booster Vacuum.

4.3.3.4 Advance the input rod at 2 mm/s until an input force of 3000 N is reached. Release the input rod at 2 mm/s until the rod has returned to the home position.

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4.3.3.5 Calculate the following metrics:

- Initial travel loss.
- Travel efficiency.
- Cut-in.
- Initial rise (Jump In).
- Power-slope.
- Return cut-out.
- Total boost force.
- Total output efficiency.
- Effective area.

Repeat the test a total of three (3) times for each assembly.

4.3.4 Pressure Response Time Test.**4.3.4.1** Bypass the fluid displacement meters.**4.3.4.2** Select the combination of compliance cylinders that simulates the corner compliance expected on the vehicle.**4.3.4.3** Determine the target force level as 80% of the input force at the booster run out point.**4.3.4.4** Initially adjust the source vacuum to 74.5 kPa and maintain for 5 s. Lower the source vacuum to 67.7 kPa and maintain the level for the remainder of the test.**4.3.4.5** Record the following channels at 500 Hz or greater:

- Input Force.
- Input Travel.
- Output Pressures.
- Source Vacuum.
- Booster Vacuum.

4.3.4.6 Apply a step input to the booster input rod with amplitude of 80% of the run out force (as calculated in 4.3.4.3) and hold the force level for 2.5 s. Rapidly release the input force to 0 N. The step input shall rise to 50% of the steady-state force within 20 ms with a peak overshoot < 20% of the steady-state force. It shall then settle to < 5% of the steady-state force within 100 ms.**4.3.4.7** Calculate the following metrics:

- Apply response time.
- Release response time.

Repeat the test a total of three (3) times for each assembly.

4.3.5 Pressure Hysteresis.**4.3.5.1** Select the combination of compliance cylinders that simulates the corner compliance expected on the vehicle.**4.3.5.2** Determine the target force, input rate and release rate as 80% of the input force at the booster run-out point during a performance test.**4.3.5.3** Initially adjust the source vacuum to 74.5 kPa and maintain for 5 s. Lower the source vacuum to 67.7 kPa and maintain the level for the remainder of the test.**4.3.5.4** Record the following channels at 250 Hz or greater:

- Input Force.
- Input Travel.
- Output Pressures.
- Output Displacements.
- Source Vacuum.

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- Booster Vacuum.

4.3.5.5 Apply a 0.5 Hz triangle wave to the input rod by advancing the input rod until the target force is reached. Release the input rod until it has returned to the home position.

4.3.5.6 Calculate the average pressure hysteresis.

4.3.5.7 Repeat the test a total of three (3) times for each assembly.

5 Data

5.1 Calculations. Not applicable.

5.2 Interpretation of Results.

5.2.1 Graphical Summaries.

Note: Plot each of the three (3) test runs on the same plot and plot the results from each assembly on a separate plot. Use the same axis scales for each family of plots.

5.2.1.1 No Power Assist. Plot master cylinder output force vs. booster input force up to the maximum input force (Appendix A, Figure A1).

5.2.1.2 Full Power Assist.

5.2.1.2.1 Travel Loss and Efficiency. Plot master cylinder output travel vs. booster input travel up to the booster run-out point (Appendix A, Figure A6).

5.2.1.2.2 Full Power Performance Test. Plot master cylinder output force vs. booster input force up to the maximum input force (Appendix A, Figure A1).

5.2.1.2.3 Return Cut-out. Plot the release cycle master cylinder output travel vs. booster input travel. Scale the axes appropriately to expand the area of low input and output force (Appendix A, Figure A8).

5.2.1.3 Pressure Response Time.

5.2.1.3.1 Apply Response Time. Plot booster input force on the primary axis and primary output pressure on the secondary axis vs. time (Appendix A, Figure A11).

5.2.1.3.2 Release Response Time. Plot booster input force on the primary axis and primary output pressure on the secondary axis vs. time (Appendix A, Figure A12).

5.2.1.4 Pressure Hysteresis. Plot the primary output pressure vs. booster input force. (Appendix A, Figure A10).

5.2.2 Tabular Summaries.

5.2.2.1 Test Results Summary. Assemble a table of results as in Appendix B, Table B1.

5.3 Test Documentation. Publish and distribute an engineering report. Publish the engineering report according to company protocol using the Evaluation Report template and Global Document Management (GDM) system.

6 Safety

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

7 Notes

7.1 Glossary.

7.1.1 General Terms.

Hydraulic Brake System: A system that uses hydraulic fluid as a medium for transmitting force from a service brake control to the service brake, and incorporates a brake power assist unit.

Input Force: Input force is the measured booster pushrod force.

Input Travel: Input travel is the measured booster pushrod travel.

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