



Brake System Performance, FMVSS 105

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. To evaluate hydraulic brake system performance consistent with the requirements of United States of America (USA), Federal Safety Standards, Motor Vehicle Safety Standard No. 105 (FMVSS 105), Hydraulic Brake Systems, 70 FR 37706-13.

The purpose of Federal Safety Standards, Motor Vehicle Safety Standard No. 105 (FMVSS 105) is to ensure safe braking performance under normal and emergency conditions.

1.2 Foreword. This standard determines the vehicle performance requirements of FMVSS 105, section S5 under the conditions prescribed in section S6, according to the procedures and in the sequence set forth in section S7. Where a range of conditions is specified, the vehicle shall be capable of meeting the requirements at all points within the range.

Some of the requirements of FMVSS 105 must be substantiated by engineering documentation other than this road performance test, such as drawings, layouts, or laboratory tests. Validation requires evidence of compliance with all requirements of the regulation, including those validated with this standard.

The data sheets pack is part of this standard and shall be used to perform the tests. If any discrepancies between this standard and the data sheets pack exist, the data sheets pack shall be considered correct and takes precedence. The content owner of this standard should be notified of the discrepancies. In no event does this standard take precedence over the FMVSS 105 regulation.

Note: This standard requires review whenever a new issue of the FMVSS 105 is enacted. Also, 4.2.2.21.1 requires review whenever a new issue of SAE International (SAE) Recommended Practice SAE J227a, Electric Vehicle (EV) Test Procedure; is enacted.

1.3 Applicability. This standard applies to multi-purpose passenger vehicles, trucks, and buses with a gross vehicle weight rating (GVWR) greater than 3500 kg (7716 lb) that are equipped with hydraulic or electric brake systems.

2 References

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

2.1 External Standards/Specifications.

ASTM E274-70	ASTM E1337-90	SAE J227a
ASTM E1136	FMVSS 105	SAE J972

2.2 GM Standards/Specifications.

None

2.3 Additional References.

- Hydraulic Brake Systems, 70 FR 37706-13
- Sec. 568.4(a) (7) (ii) and Sec. 568.5 of title 49 of the Code of Federal Regulations, USA

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 1 of 32

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 Vehicle weighing station capable of measuring, at least, the weight at each axle and ballast materials.

3.1.4 Road Test Surfaces. Except for the parking brake test surface, each roadway should be flat within $\pm 1\%$ grade in all directions including crown.

3.1.4.1 For vehicles with a GVWR of 4536 kg (10 000 lb) or less, road tests are conducted on a 3.7 m (12 ft) wide, level roadway, having a skid number of 81. Burnish stops are conducted on any surface.

3.1.4.2 For vehicles with a GVWR greater than 4536 kg (10 000 lb), the road tests, excluding stability and control during braking tests, are conducted on a 3.7 m (12 ft) wide, level roadway, having a peak friction coefficient of 0.9 when measured using an ASTM International (ASTM) E1136 standard reference test tire, in accordance with method ASTM E1337-90, at a speed of 64 km/h (40 mph), without water delivery. The test road used shall have the peak friction coefficient (PFC) measured on a monthly basis and a correction algorithm for PFC shall be used when appropriate. Burnish stops are conducted on any surface.

3.1.4.3 For vehicles with a GVWR greater than 4536 kg (10 000 lb), the stability and control during braking tests are conducted on a 152 m (500 ft) radius curved roadway with a wet level surface having a peak friction coefficient of 0.5 when measured on a straight or curved section of the curved roadway using an ASTM E1136 standard reference tire, in accordance with method ASTM E1337-90, at a speed of 64 km/h (40 mph), with water delivery.

3.1.5 Vehicle center of gravity height measurement facility that accommodates both lightly loaded and gross loading conditions.

3.1.6 Variable Grade Ramp (VGR) facility or parking brake test grades. The parking brake test surface is clean, dry, smooth, Portland cement concrete or equivalent.

3.1.7 Front wheel alignment measurement and adjustment facility, if required.

3.2 Equipment.

3.2.1 Instrumentation. Equipment to measure the following data is required. Follow instructions in the data sheets pack for details on which instrumentation is required in each test section.

3.2.1.1 Vehicle speed.

3.2.1.2 Vehicle stopping distance.

3.2.1.3 Vehicle deceleration.

3.2.1.4 Vehicle distance interval.

3.2.1.5 Service brake pedal force.

3.2.1.6 Service brake pedal travel.

3.2.1.7 Parking brake apply force; (optional) travel.

3.2.1.8 Brake pad temperatures.

3.2.1.9 Ambient air temperature.

3.2.1.10 Wind speeds.

3.2.1.11 Wheel speeds.

3.2.1.12 Wheel torques.

3.2.1.13 Tire pressure.

3.2.1.14 Brake line pressure.

3.2.1.15 Master cylinder pressure.

3.2.1.16 Assist vacuum or hydraulic pressure.

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 2 of 32

3.2.2 Data Acquisition. A continuous recorder or a computer utilizing a digital data acquisition system to make a permanent record of the test data with the same accuracies as the above direct reading instrumentation or as otherwise indicated.

3.2.3 Brake Apply Machine. An application device may be used for the spike stops, which meets the application rate requirement of the applicable test. The use of the brake machine is optional if the driver is capable of applications that meet the rate requirements.

3.2.4 Calibration. All instrumentation is to be calibrated as required. Document the instrumentation identification, date of last calibration, and due date for next calibration in the test record, unless the information is otherwise preserved in the testing facility records.

3.3 Test Vehicle/Test Piece.

3.3.1 Service Brake System. Each vehicle shall be equipped with a service brake system acting on all wheels. Wear of the service brake shall be compensated for by means of automatic adjustment.

3.3.2 Parking Brake System. Each vehicle shall be manufactured with a parking brake system of a friction type with a solely mechanical means to retain engagement. At the option of the manufacturer, the parking brake system and a parking mechanism within the transmission or transmission control, which must be engaged before the ignition key can be removed, may be used to meet the requirements for the parking brake system.

3.3.3 Indicator Lamp(s). Each vehicle shall have a brake system indicator lamp or lamps, mounted in front of and in clear view of the driver, which may include one indicator which is common for gross loss of pressure, drop in the level of brake fluid, and/or application of the parking brake, but shall have a separate indicator lamp for antilock brake system malfunction.

3.3.4 Antilock Brake System (ABS). Each vehicle with a GVWR greater than 4536 kg (10 000 lb), except for any vehicle with a speed attainable in 3.2 kg (2 mi) of not more than 53 km/h (33 mph), shall be equipped with an antilock brake system that directly controls the wheels of at least one front axle and the wheels of at least one rear axle of the vehicle.

3.3.5 Representative Vehicle. In selection of the test vehicle, consideration is to be given to the combination of axle ratio, type and size of tires, type of wheels and wheel covers, engine, body type, front-to-rear mass (weight) distribution which is representative of the extreme characteristics of the vehicle family. A pretest analysis of the vehicle family to select the appropriate test vehicle is recommended.

3.3.6 Vehicle Weight.

3.3.6.1 For First Effectiveness, Burnish, and Adhesion Utilization, the vehicle GVWR is in proportion to its gross axle weight rating (GAWR). For the remainder of the test, the vehicle GVWR should be loaded to represent worst case minimum or maximum percent front-biased from Adhesion Utilization results.

3.3.6.2 For applicable tests specified at lightly loaded vehicle weight, the added weight, except for the roll bar structure allowed for trucks and buses with a GVWR greater than 4536 kg (10 000 lb), should be distributed in the front passenger seat area in multipurpose passenger vehicles and trucks and in the area adjacent to the driver's seat in buses.

3.4 Test Time.

Calendar time: 7 to 10 days (10 to 15 days for EVs without Fast Charge)

Test hours: Not applicable

Coordination hours: Not applicable

3.5 Test Required Information.

3.5.1 Compliance of vehicles manufactured in two or more stages may, at the option of the final-stage manufacturer, be demonstrated to comply with this standard by adherence to the instructions of the incomplete vehicle manufacturer provided with the vehicle in accordance with Sec. 568.4(a) (7) (ii) and Sec. 568.5 of title 49 of the Code of Federal Regulations, USA.

3.5.2 A data sheets pack used to conduct the test and document results is available and is required to run the test. Data processing software and instructions for use of the software are available and are required for data reduction.

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 3 of 32

Documents
Document Sharing Hub

3.6 Personnel/Skills. Brake technician(s) or engineer(s) with training and experience appropriate to build, instrument, and test applicable vehicles per instructions in Section 4.

4 Procedure

4.1 Preparation.

4.1.1 Test Data. Document vehicle and brake system data in the test record. Vehicle preparation data, in addition to that listed in this section, may be requested per divisional practice.

4.1.2 Thermocouples. Install plug-type thermocouples in linings and/or pads. Install in the approximate center of the facing length and width of the most heavily loaded shoe or disc pad, one per brake. See Figure A1 for an example of a typical thermocouple installation. A second thermocouple may be installed at the beginning of the test sequence if the lining wear is expected to reach a point causing the first thermocouple to contact the metal rubbing surface of a drum or rotor. For center-grooved shoes or pads, thermocouples are installed within 3 to 6 mm ($\frac{1}{8}$ in to $\frac{1}{4}$ in) of the groove and as close to the center as possible.

4.1.3 Brake Hardware. Install new brake drums and/or rotors, return and hold-down springs, and thermocoupled friction material. New park brake cables are recommended. Replacement of park brake cables is mandatory if cables are worn, rusty, or kinked. Adjust the brakes and park brake to manufacturer's specifications. Any brake or park brake hardware that is not new at start of test must be approved by the test engineer and condition must be documented in the test record.

4.1.4 Fluid Levels. Check all vehicle fluid levels (oil, coolant, etc.) and fill to maximum recommended capacity, except fuel which should be between 75% and 100% of capacity.

4.1.5 Brake System. Check the brake system for proper operation. An option during vehicle build is to perform a static check and record the pedal force versus line pressure characteristics.

4.1.6 Engine. Check and reset, if necessary, the engine idle speed and timing settings according to manufacturer's recommendation.

4.1.7 Transmission. Check and adjust, if necessary, the transmission control devices as required for proper operation.

4.1.8 Operating Software. Verify that vehicle control module, engine, fuel system, antilock brake system, maximum speed control, and transmission calibrations are current versions of the software.

4.1.9 Alignment. Check and reset, if necessary, the front suspension, caster, camber, and toe-in. Unless otherwise specified, make measurements at unloaded vehicle weight.

4.1.10 Center of Gravity (CG). Perform vehicle CG test procedure, if requested. Determine CG height to wheelbase ratio from the measured data or from supplied data at both lightly loaded vehicle weight (LLVW) and GVWR.

4.1.11 Tires. Inflate tires to manufacturer's recommended maximum pressure for GVWR. Document tire size, type, brand, and wheel code in the test record.

4.2 Conditions. The performance requirements of FMVSS 105 shall be met under the following conditions.

4.2.1 Environmental Conditions. Vehicle shall be capable of meeting performance requirements given the following conditions or range of conditions. Where a range of conditions is specified, the vehicle shall be capable of meeting the requirements at all points within the range.

4.2.1.1 Ambient Temperature. The ambient temperature range is to be between 0 °C and 38 °C (32 °F and 100 °F). The stated temperature range refers to the range of ambient temperatures over which vehicle must comply with the FMVSS 105 requirements and is not intended to limit manufacturer testing to within this range. For this test standard, the ambient temperature shall be any temperature between -20 °C (-4 °F) and 40 °C (104 °F) for all test sections, except the thermal fade sections, which will be restricted to ambient temperatures between 0 °C (32 °F) to 40 °C (104 °F).

4.2.1.2 Wind Velocity. All test sections, except fade sections, should be run while adhering to the following: For wind speeds not greater than 5 m/s (11 mph) run stops in either direction. For wind speeds of 5 m/s to 9 m/s (11 mph to 20 mph) parallel to the road, run stops with the wind direction. For crosswinds at speeds of 5 m/s to 9 m/s (11 mph to 20 mph), run stops in either direction. Do not run if wind speed exceeds 9 m/s (20 mph).

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 4 of 32

Documents
Document Sharing Hub

Fade test sections should be run with a wind speed of not greater than 5 m/s. Occasional gusting above this limit is permitted. If wind is frequently gusting above this speed, do not run fade testing until wind speed decreases to less than 5 m/s and gusting is only an occasional occurrence.

4.2.1.3 Road Surface. Road surfaces must be dry at time of test.

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 Adjustable Brake Pedal Assembly. If vehicle is equipped with an adjustable brake pedal assembly, the pedals should be adjusted to the position with the lowest pedal ratio. This pedal position shall be used for all test sections. The lowest pedal ratio shall be determined by comparing pressures generated during floor checks with no apply system power assist (no-power).

4.2.2.2 Brake Applications. During the tests, the brakes may be applied by the driver directly or by the use of a Brake Test Machine. However, a vehicle must be able to meet the requirements of this specification with the brakes applied manually by an expert driver. Therefore, when the Brake Test Machine is used, its servo response times are to be set such that they are slower than that demonstrated by an expert driver.

4.2.2.3 Control Forces. Unless otherwise specified, the force applied to a brake control is to be not less than 67 N (15 lb) and not more than 667 N (150 lb).

4.2.2.4 Initial Brake Temperature. Unless otherwise specified, the initial brake temperature (IBT) is to be 66 °C to 93 °C (150 °F to 200 °F). If the IBT for the first stop in a test sequence, other than the parking brake test and the water recovery test, has not been reached, heat the brakes to the IBT by making not more than 10 snubs from not more than 64 km/h to 16 km/h (40 mph to 10 mph), at a deceleration not greater than 3 m/s² (10 ft/s²).

4.2.2.5 Repeated Stops. Complete stops are to be made during each attempt for a stopping distance and each stop is to represent a realistic attempt to meet the specified stopping distance, even though the requirement might have been satisfied in a previous stop.

4.2.2.6 Stopping Distance. For the test vehicle to comply with the stopping distance requirements, at least one of the stops at each speed and load specified in each of the effectiveness tests, the partial system tests, and the inoperative brake power unit or brake power assist unit test, must be made within a stopping distance that does not exceed the applicable distance specified in Table A2 and Table A3.

4.2.2.7 Test Speed. If the vehicle speed attainable in 3.2 km (2 mi) is less than 97 km/h (60 mph), the test speed is to be specified as the metric equivalent of test speeds under 60 in multiples of 5, as close to the vehicle top speed as possible. For example, a vehicle with a top speed of 92 km/h (57 mph) would be tested at 89 km/h (55 mph).

4.2.2.8 Tests with Transmission Selector Control in Neutral. For effectiveness tests, fade and recovery tests, and park brake tests, the transmission selector control is to be in Neutral for all decelerations and park brake applies.

4.2.2.9 Tests with Transmission Selector Control in Gear. For all other tests during all decelerations, the transmission selector is to be in the control position, other than overdrive, recommended by the manufacturer for driving on a level surface at the applicable test speed.

4.2.2.10 Deceleration with Transmission Selector Control in Gear. To avoid engine stall during tests required to be run in gear, a manual transmission may be shifted to Neutral (or the clutch disengaged) when the vehicle speed decreases to 33 km/h (20 mph).

4.2.2.11 Deceleration with Transmission Selector Control in Neutral. When the transmission selector control is required to be in Neutral for a deceleration, a stop or snub shall be obtained by the following procedure. Exceed the test speed by 6 km/h to 13 km/h (4 mph to 8 mph). Close the throttle and coast in gear to approximately 3 km/h (2 mph) above the test speed. Shift to Neutral and, when the test speed is reached, apply the service brakes.

4.2.2.12 Vehicle Loading. Refer to 7.1 Glossary for definitions of GVWR and LLVW. The test vehicle weights and weight distributions for GVWR and LLVW shall be specified in the test request. Each test section of this standard shall specify the required loading condition.

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 5 of 32

Documents
Document Sharing Hub

4.2.2.13 Vehicle Position. The vehicle is to be aligned in the center of the roadway at the start of each brake application. Stops are to be made without any part of the vehicle leaving the roadway. The lanes shall be clearly marked.

4.2.2.14 Vehicle Openings. All vehicle openings (doors, windows, hood, trunk, convertible top, cargo doors, etc.) shall be closed, except as required for instrumentation purposes.

4.2.2.15 Automatic Brake Adjusters. Automatic brake adjusters must remain activated at all times.

4.2.2.16 Brake Warming. If the initial brake temperature for the first stop in a test procedure has not been reached, heat the brakes to the initial brake temperature by making 64 km/h to 16 km/h (40 mph to 10 mph) snubs at a deceleration not greater than 3 m/s² (10 ft/s²).

4.2.2.17 Wheel Lockup.

4.2.2.17.1 For each vehicle with a GVWR of 4536 kg (10 000 lb) or less, the stops shall be made with wheel lockup permitted only as follows:

4.2.2.17.1.1 At vehicle speeds above 16 km/h (10 mph), there may be controlled wheel lockup on an antilock-equipped axle, and lockup of not more than one wheel per vehicle uncontrolled by an antilock system. Dual wheels on one side of an axle are considered a single wheel.

4.2.2.17.1.2 At the vehicle speeds of 16 km/h (10 mph) or less, any wheel may lock up for any duration.

4.2.2.17.1.3 Unlimited wheel lockup is allowed during spike stops (but not spike check stops), partial failure stops, and inoperative brake power or power assist unit stops.

4.2.2.17.2 For each vehicle with a GVWR greater than 4536 kg (10 000 lb), stops are made with wheel lockup permitted only as follows:

4.2.2.17.2.1 At vehicle speeds above 32 km/h (20 mph), any wheel on a non-steerable axle, other than the two rear-most non-liftable, non-steerable axles, may lock up for any duration. The wheels on the two rear-most non-liftable, non-steerable axles may lock up according to 4.2.2.17.2.2

4.2.2.17.2.2 At vehicle speeds above 32 km/h (20 mph), one wheel on any axle or two wheels on any tandem axle may lock up for any duration.

4.2.2.17.2.3 At vehicle speeds above 32 km/h (20 mph), any wheel not permitted to lock in 4.2.2.17.2.1 or 4.2.2.17.2.2 may lock up repeatedly, with each lockup occurring for duration of 1 s or less.

4.2.2.17.2.4 At vehicle speeds of 32 km/h (20 mph) or less, any wheel may lock up for any duration.

4.2.2.17.2.5 Unlimited wheel lockup is allowed during partial failure stops, and inoperative brake power or power assist stops.

4.2.2.18 Special Drive Train Conditions. A vehicle with a GVWR greater than 4536 kg (10 000 lb), equipped with an interlocking axle system or a front wheel drive system that is engaged and disengaged by the driver, shall be tested with the system disengaged.

4.2.2.19 Selection of Compliance Options. Where manufacturer options are specified, the manufacturer shall select the option by the time it certifies the vehicle and may not thereafter select a different option for the vehicle. Each manufacturer shall, upon request from the National Highway Traffic Safety Administration, provide information regarding which of the compliance options it has selected for a particular vehicle or make/model.

4.2.2.20 In the event of any failure (structural or functional) in an antilock or variable proportioning brake system, the vehicle shall be capable of meeting the stopping distance requirements specified for service brake system partial failure.

4.2.2.21 Conditions for Electric Vehicles and Electric Brakes.

4.2.2.21.1 The state of charge of the propulsion batteries is determined in accordance with SAE Recommended Practice SAE J227a, EVz Test Procedure.

4.2.2.21.2 At the beginning of the first effectiveness test and at the beginning of each burnishing procedure, each propulsion battery of an EV is at the maximum state of charge recommended by the manufacturer, as stated in the vehicle operator's manual or on a label that is permanently attached to the vehicle, or, if the manufacturer has made no recommendation, at a state of charge of not less than 95%. If a battery is replaced rather than recharged, the replacement battery is to be charged and measured for state of charge in accordance with these procedures. During each burnish procedure, each propulsion battery is restored to the

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 6 of 32

Documents
Document Sharing Hub

recommended state of charge or a state of charge of not less than 95% after each increment of 40 burnish stops until each burnish procedure is complete. The batteries may be charged at a more frequent interval if, during a particular 40 stop increment, the EV is incapable of achieving the initial burnish test speed. During each burnish procedure, the propulsion batteries may be charged by an external means or replaced by batteries that are charged to the state of charge recommended by the manufacturer or a state of charge of not less than 95%. For an EV having a manual control for setting the level of regenerative braking, the manual control, at the beginning of each burnish procedure, is set to provide maximum regenerative braking throughout the burnish.

4.2.2.21.3 At the beginning of each performance test in the test sequence, unless otherwise specified, each propulsion battery of an EV is at the maximum state of charge recommended by the manufacturer, as stated in the vehicle operator's manual or on a label that is permanently attached to the vehicle, or, if the manufacturer has made no recommendation, at a state of charge of not less than 95%. If batteries are replaced rather than recharged, each replacement battery shall be charged and measured for state of charge in accordance with these procedures. No further charging of any propulsion battery occurs during any of the performance tests in the test sequence of this standard. If the propulsion batteries are depleted during a test sequence such that the vehicle reaches automatic shut-down, will not accelerate or the low state of charge warning lamp is illuminated, the vehicle is to be accelerated to the brake test speed by auxiliary means.

4.2.2.21.4 For an EV equipped with a regenerative brake system (RBS), the RBS is considered to be part of the service brake system if RBS is automatically controlled by an application of the service brake control, if there is no means provided for the driver to disconnect or otherwise deactivate RBS, and if RBS is activated in all transmission positions, including Neutral. The RBS is operational during all burnishes and all tests, except for the test of a failed RBS.

4.2.2.21.5 For an EV equipped with an RBS that is not part of the service brake system, the RBS is operational and set to produce the maximum regenerative braking effect during the burnishes, and is disabled during the test procedures. If the vehicle is equipped with a Neutral gear that automatically disables the RBS, the test procedures which are designated to be conducted in gear may be conducted in Neutral.

4.2.2.21.6 For tests conducted in Neutral, the operator of an EV with no Neutral position, or other means such as a clutch for disconnecting the drive train from the propulsion motors(s), does not apply any electromotive force to the propulsion motor(s). Any electromotive force that is automatically applied to the propulsion motor(s) remains in effect unless otherwise specified by the test procedure.

4.2.2.21.7 A vehicle equipped with electrically-actuated service brakes also performs the following test series. Conduct 10 stopping tests from a speed of 100 km/h or the maximum vehicle speed, whichever is less. At least two of the 10 stopping distances must be less than or equal to 70 m. The vehicle is loaded to GVWR for these tests, and the transmission is in the Neutral position when the service brake control is actuated and throughout the remainder of the stop. The battery or batteries providing power to those electrically-actuated brakes, at the beginning of each stop, shall be in a depleted state of charge for conditions 4.2.2.21.7.1, 4.2.2.21.7.2, or 4.2.2.21.7.3 of this paragraph as appropriate. An auxiliary means may be used to accelerate an EV to test speed.

4.2.2.21.7.1 For an EV equipped with electrically-actuated service brakes deriving power from the propulsion batteries, and with automatic shut-down capability of the propulsion motor(s), the propulsion batteries are at not more than 5% above the EV actual automatic shut-down critical value. The critical value is determined by measuring the state-of-charge of each propulsion battery at the instant that automatic shut-down occurs and averaging the states-of-charge measured.

4.2.2.21.7.2 For an EV equipped with electrically-actuated service brakes deriving power from the propulsion batteries, and with no automatic shut-down capability of the propulsion motor(s), the propulsion batteries are at an average of not more than 5% above the actual state of charge at which the brake failure warning signal is illuminated.

4.2.2.21.7.3 For a vehicle which has an auxiliary battery (or batteries) that provides electrical energy to operate the electrically-actuated service brakes, the auxiliary battery (batteries) is (are) at (at an average of) not more than 5% above the actual state of charge at which the brake failure warning signal is illuminated.

4.3 Instructions. Each test vehicle must proceed through the following test procedures in the sequence set forth in Table A1, with specific sequences detailed in Table A2, Table A3, and Table A4. A vehicle will run only the tests specified for its type and weight classification. Use the tables in Table A1, Table A5; Table A6 and

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 7 of 32

Table A7 to determine the required tests, test speeds, and requirements for the test vehicle. Use the data sheets pack when running the tests.

4.3.1 Start-Of-Test Static Line Pressure Check. Check and record the pedal force versus line pressure characteristics. Perform checks with and without power assist. For with power assist condition, start engine and idle for 2 minutes. Apply engine throttle to obtain vacuum. If the brake system has vacuum boost, maintain a vacuum of 67.7 kPa in the booster during the pedal force versus line pressure check. For vehicles with hydraulic booster, engine rotational speed shall be as specified by design engineer or test requestor. For runs with power assist, apply the brake control to 890 N at 133 N/s apply rate. For runs without power assist conditions, turn off engine, for vacuum assist system deplete booster, and perform checks to 890 N apply force at 133 N/s (30 lb/s) apply rate. For systems with a supplementary vacuum supply, use the vacuum level at engine idle.

4.3.2 Pretest Instrumentation Check. Vehicle at GVWR. Conduct a general check of instrumentation by making not more than ten stops from 48 km/h (30 mph) or ten snubs from 64 km/h (40 mph) to 16 km/h (10 mph). Make stops or snubs in normal driving gear at 1.6 km (1 mi) intervals with a deceleration rate of not more than 3 m/s^2 (10 ft/s^2). Moderately accelerate to cooling speed 64 km/h (40 mph) for the interval. Record maximum pedal force, minimum deceleration, and brake temperatures at end of each stop or snub. If instrument repair, replacement, or adjustment is necessary, make not more than 10 additional stops or snubs after such repair, replacement, or adjustment. The total number of stops or snubs shall not exceed twenty.

4.3.3 First Effectiveness Test (or Pre-Burnish). Vehicle at GVWR. Make stops with the transmission in Neutral, attempting to achieve a minimum stopping distance without wheel lockup above 32 km/h (20 mph) other than as permitted in 4.2.2.18. Document the occurrence of wheel lockup and whether lockup occurred above 32 km/h (20 mph) for each stop. Make six stops from 48 km/h (30 mph). Then make six stops from 97 km/h (60 mph).

4.3.4 Burnish. Vehicle at GVWR.

4.3.4.1 For Vehicles with GVWR of 4536 kg (10 000 lb) or Less. Burnish the brakes by making 200 stops from 64 km/h (40 mph) at 3.7 m/s^2 (12 ft/s^2). The 667 N (150 lb) control force limit does not apply here. The interval from the start of one service brake application to the start of the next shall be either the time necessary to reduce the initial brake temperature to between 110 °C (230 °F) and 132 °C (270 °F), or the distance of 1.6 km (1 mi), whichever occurs first. Accelerate to 64 km/h (40 mph) after each stop and maintain that speed until making the next stop.

4.3.4.2 For Vehicles with GVWR Greater than 4536 kg (10 000 lb). Burnish the brakes by making 500 snubs between 64 km/h to 32 km/h (40 mph to 20 mph) at a deceleration rate of 3 m/s^2 (10 ft/s^2). Except where an adjustment is specified, after each brake application accelerate to 64 km/h (40 mph) and maintain that speed until making the next brake application at a point 1.6 km (1 mi) from the initial point of the previous brake application. If the vehicle cannot attain a speed of 64 km/h (40 mph) in 1.6 km (1 mi), continue to accelerate until the specified speed is reached or until the vehicle has traveled 2.4 km (1.5 mi) from the initial point of the previous brake application, whichever occurs first. The brakes shall be adjusted three times during the burnish procedure, in accordance with the manufacturer's recommendations, after 125, 250, and 375 snubs.

4.3.4.3 Post Burnish Brake Adjustment. At the completion of burnish, adjust the brakes in accordance with the manufacturer's published recommendations. Document adjustment method used.

4.3.5 Adhesion Utilization Test (Torque Wheel Method).

4.3.5.1 Adhesion Utilization Test Instructions.

4.3.5.1.1 Install torque wheels and ballast vehicle to the maximum percent front LLVW mass distribution and LLVW mass. A separate set of tires identical to those used for all other sections of this procedure may be used on the torque wheels. This test is run for both ABS and non-ABS vehicles.

4.3.5.1.2 If the test vehicle is equipped with ABS or with ABS and electronic brake distribution (EBD) or dynamic rear proportioning (DRP), the ABS and the EBD or DRP must be completely disabled during this test. Consult the design release engineer or the test requestor for the method needed to disable the system(s).

4.3.5.1.3 Establish the IBT for the first stop. With transmission in Neutral, make five stops from a speed of 100 km/h and five stops from a speed of 50 km/h, while alternating between the two test speeds. Increase pedal force at a linear rate between 100 N/s and 150 N/s for the 100 km/h test speed and between 100 N/s and 200 N/s for the 50 km/h test speed until the first axle locks or until a pedal force of 1000 N is

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 8 of 32

reached, whichever occurs first. Between brake applications, drive vehicle at speeds up to 100 km/h until IBT is reached.

4.3.5.1.4 Ballast vehicle to total GVWR in proportion to the GAWR and repeat 4.3.5.1.3.

4.3.5.1.5 Remove torque wheels and install vehicle test wheels, unless otherwise instructed. Return the ABS, EBD or DRP systems to operational condition.

4.3.5.2 Adhesion Utilization Data Reduction. A data reduction program has been designed specifically to analyze data from this portion of the brake test. The software directly reads the raw data files generated by the brake data acquisition instrument, analyzes the data, and generates plots and reports.

4.3.5.2.1 The data from each brake application under 4.3.5.1.3 and 4.3.5.1.4 are filtered using a five-point, on-center moving average for each data channel.

4.3.5.2.2 For each brake application under 4.3.5.1.3 and 4.3.5.1.4, determine the slope (brake factor) and the pressure axis intercept (brake hold-off pressure) of the linear least squares equation best describing the measured torque output at each braked wheel as a function of measured line pressure applied at the same wheel. Only torque output values obtained from data collected when the vehicle deceleration is within the range of 0.15G to 0.80G are used in the regression analysis.

4.3.5.2.3 Average the results of 4.3.5.2.2 to calculate the average brake factor and brake hold-off pressure for all brake applications for the **front** axle.

4.3.5.2.4 Average the results of 4.3.5.2.2 to calculate the average brake factor and brake hold-off pressure for all brake applications for the **rear** axle.

4.3.5.2.5 Using the relationship between front and rear brake line pressure determined in 4.3.1 and the tire rolling radius, calculate the braking force at each axle as a function of front brake line pressure.

4.3.5.2.6 Calculate the braking ratio of the vehicle as a function of the front brake line pressure using the following equation:

$$z = \frac{T_1 + T_2}{P}$$

Where:

z = Braking ratio at a given front line pressure

P = total vehicle weight

T₁, T₂ = Braking forces at the front axle and at the rear axle, respectively, corresponding to the same front brake line pressure

4.3.5.2.7 Calculate the adhesion utilized at each axle as a function of braking ratio using the following equations:

$$f_1 = \frac{T_1}{P_1 + zhP / E}$$

$$f_2 = \frac{T_2}{P_2 - zhP / E}$$

Where:

f_i = Adhesion utilized by axle i

T_i = Braking force at axle i (from (e))

P_i = Static weight on axle i

i = 1 for the front axle, or 2 for the rear axle

z = Braking ratio (from (f))

h = Height of center of gravity of the vehicle

P = Total vehicle weight

E = Wheelbase

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 9 of 32

4.3.5.2.8 Plot f_1 and f_2 obtained in 4.3.5.2.7 as a function of z , for both GVWR and LLVW load conditions. These are the adhesion utilization curves for the vehicle, shown graphically in Figure A2.

4.3.6 Worst Case Mass Distribution Analysis. The worst case mass distribution must be calculated based on the adhesion utilization torque wheel test results. The calculation requires the CG heights, front and rear static tire loaded radii, wheelbase, proportioning valve information, and vehicle mass information. The worst case mass distributions to use for partial system tests and full system tests at both GVWR and LLVW are to be calculated. Each of the subsequent tests should specify the required worst case loading conditions in the test data sheets. Check the test weights before running the tests.

4.3.7 Second Effectiveness Test. Vehicle at GVWR. Make stops with the transmission in Neutral, attempting to achieve a minimum stopping distance without wheel lockup above 32 km/h (20 mph) other than as permitted in 4.2.2.18. Document the occurrence of wheel lockup and whether lockup occurred above 32 km/h (20 mph) for each stop.

4.3.7.1 For Vehicles with GVWR of 4536 kg (10 000 lb) or less or any school bus: Make six stops from 48 km/h (30 mph).

4.3.7.2 Then for any vehicle: Make six stops from 97 km/h (60 mph).

4.3.7.3 Then for Vehicles with GVWR of 4536 kg (10 000 lb) or less: Make four stops from 129 km/h (80 mph) if the speed attainable in 3.2 km (2 mi) is not less than 135 km/h (84 mph).

4.3.8 First Reburnish. Vehicles at GVWR. Repeat the appropriate burnish in 4.3.4.1 or 4.3.4.2, except make 35 burnish stops or snubs. Repeat the brake adjustment 4.3.4.3.

4.3.9 Parking Brake Test. If using a VGR, follow instructions in 4.3.9.1 thru 4.3.9.6. If VGR is not available, follow instructions in 4.3.9.1 thru 4.3.9.5, and 4.3.9.7. Use of the VGR is recommended.

4.3.9.1 Ballast test vehicle to specified GVWR and mass distribution.

4.3.9.2 For vehicles with parking brake systems not utilizing the service friction elements, the friction elements of such a system are burnished prior to the parking brake test according to the published recommendations furnished to the purchaser by the manufacturer. If no recommendations are furnished, the vehicle's parking brake system is tested in an unburnished condition. For the vehicles with the parking brake system not utilizing the service brake friction elements, the service brake IBT shall be $<66^{\circ}\text{C}$ (150°F), and the park brake friction material will be at ambient temperature, defined as the natural temperature when the service brakes are $<66^{\circ}\text{C}$ (150°F). No artificial heating of the park brake is allowed.

4.3.9.3 Vehicles with parking brake systems utilizing service brake friction materials shall be tested with the IBT $<66^{\circ}\text{C}$ (150°F) and shall have no additional burnishing or artificial heating prior to the start of the parking brake test.

4.3.9.4 When setting the apply force be careful not to overshoot the travel or bottom out the pedal at end of travel. Force continues to increase after a ratchet click and before the next click. Minimize the distance applied after the click to avoid additional overshoot force. Avoid bottoming out the pedal at the end of travel. This provides false readings due to a spike in the application force.

4.3.9.5 The vehicle is allowed to settle a maximum of 150 mm during the transfer of vehicle loads from the service brake system to the static park brake system.

4.3.9.6 Variable Grade Ramp. This section is used to determine maximum grade a vehicle will hold at a specified force using a VGR.

4.3.9.6.1 Drive the vehicle onto VGR and operate the ramp to set a 20% grade with the longitudinal axis of the vehicle in the direction of the grade. Apply the service brakes just enough to hold the vehicle stationary. Place the transmission control in Neutral, increasing the service brake force just enough to hold the vehicle stationary. Document service brake pedal force.

4.3.9.6.2 Apply the parking brake by a single application up to either the specified pedal force limit or the travel limit of the apply system, whichever occurs first. The force limit is 667 N (150 lb) for foot operated system or 555 N (125 lb) for hand operated system for vehicles greater than 4536 kg (10 000 lb). The force limit is 555 N (125 lb) for foot operated system or 400 N (90 lb) for hand operated system for vehicles between 3629 kg (8000 lb) and equal to or less than 4536 kg (10 000 lb). Hand operated parking brake control force should be measured as specified in Figure A3. The force required for actuation of a hand-operated brake system shall be measured at the center of the hand grip area or at a distance of 38 mm (1.5 in) from the end of

GM Confidential

© Copyright 2013 General Motors Company All Rights Reserved

September 2013

Page 10 of 32

Documents
Document Sharing Hub