



Brake Systems for Passenger Cars, Harmonized Certification 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. To evaluate the braking system performance of category passenger vehicles consistent with the requirements of United Nations Economic Commission Europe (ECE) Regulation Number R13-H, and Australia Motor Vehicle Standards Act Australian Design Rule (ADR) 31/01, including new regulations with regard to requirements on “electric regenerative braking” systems (from ECE R13-H to new revision UN R13H).

Note: This procedure requires review whenever a new revision of ECE R13-H is enacted. The document describes all type approval relevant behaviors and parts of the entire car. For further information on ECE R13-H document see the GM Legal Database.

Note: Suppliers will work with the responsible GM Engineer to comprehend this requirement.

Vehicle Technical Specification (VTS) requirements are always higher or equivalent as normally agreed.

1.2 Applicability. This standard is applicable to passenger vehicles with hydraulic brake systems.

1.3 Remarks. This standard covers the road based brake performance only. It does not evaluate compliance to the non-road-based brake system design requirements specified in the regulation (such as master cylinder reservoir capacity, warning indicators, etc.)

2 References

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

2.1 External Standards/Specifications.

ADR 31/01	ECE R13-H	UN R13H
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2.2 GM Standards/Specifications.

GMW14927	GMW14974	GMW15102
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2.3 Additional References.

- Evaluation Report Template
- Global Document Management System
- GM Legal Database:
<https://usabhem0db10.mail.gm.com/apps/abh01055.nsf/MainWebPageNavigator?OpenNavigator>

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 A test surface having a coefficient of adhesion ≥ 0.8 for straight line stops and skid pad.

3.1.4 Test hills of 12% and 20% uphill and downhill grades.

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3.1.5 For antilock brake system (ABS) tests: A test area having a level surface with a peak coefficient of adhesion of ≤ 0.3 (low- μ , see 7.1), large enough for the testing to be performed in safety. It should be preceded and followed by a level surface with a coefficient of adhesion of ≈ 0.8 (high- μ , see 7.1), which is of sufficient length on the approach side to enable the test speeds to be attained. For testing category one (1) and two (2) antilock devices it is also necessary for the low- μ surface to have a high- μ surface on at least one side to enable the split- μ tests to be performed. Optional: If a suitable surface with a peak coefficient of adhesion of ≤ 0.3 is not available, worn tires and a surface with a higher coefficient of adhesion up to 0.4 may be used at the discretion of the test officer. In this case the details shall be recorded on the test report.

3.1.6 Weighing scales, including ballast materials.

3.1.7 Wheel alignment machine.

3.2 Equipment.

3.2.1 Stopwatch.

3.2.2 Torque wrench.

3.2.3 Tire pressure gauge.

3.2.4 Weather station capable of recording ambient temperature and pressure, humidity and wind velocity.

3.2.5 Appropriate data acquisition equipment. Minimum sampling frequency per channel: 100 Hz.

3.2.6 One accelerometer 0 m/s² to 10 m/s².

3.2.7 One pedal force transducer 0 N to 500 N.

3.2.8 One pedal travel transducer 0 mm to 200 mm.

3.2.9 One vehicle speed and distance transducer 0 km/h to 250 km/h. Speed and distance measurement shall be accurate to within 1%.

3.2.10 Minimum 8 thermocouples 0 °C to +800 °C to measure pad temperatures.

3.2.11 Optional: Four (4) fluid temperature thermocouples 0 °C to +250 °C, eight (8) thermocouples for brake hoses, master cylinder and ambient temperature as required, four (4) disc thermocouples 0 °C to +800 °C.

3.2.12 Four (4) brake line pressure transducers 0 MPa to 15 MPa (0 bar to 150 bar). Optional for all tests except Torque Wheel Test and ABS Tests.

3.2.13 Additional Equipment for Torque Wheel Test and ABS Tests.

3.2.13.1 Four (4) brake line pressure transducers 0 MPa to 15 MPa (0 bar to 150 bar), installed downstream of any proportioning or limiting valve so that the pressure for at least one front and one rear wheel is recorded.

3.2.13.2 Four (4) Angular wheel speed sensors, 0 km/h to 120 km/h.

3.2.13.3 Four (4) wheel torque transducers.

3.2.14 Additional Equipment for ABS Tests:

3.2.14.1 Adjustable pressure regulating valves (allowing fine adjustment of output pressure) fitted in the line to each wheel.

3.2.14.2 A means of isolating axles so that each axle equipped with antilock can be braked independently of the other when the brake pedal is applied. The pressure regulating valves (reference 3.2.13.1) may be used for this purpose if the output from the valves can be reduced to zero.

3.2.14.3 Suitable equipment to produce event markers showing the point of transition from the low to high- μ surfaces and vice versa.

3.2.15 All equipment should be approved for regulatory testing.

3.2.16 Additional Instrumentation Requirements for Electric Vehicles.

a. Propulsion battery power consumption (for state of charge (SOC)).

3.2.17 Additional Instrumentation Requirements for Electrically Actuated Brakes.

a. Current at each applicable corner.

b. Voltage at each applicable corner.

3.3 Test Vehicle/Test Piece. In selection of the test vehicle, consideration shall be given to the following, which shall be representative of the worst-case characteristics of the vehicle family under evaluation.

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3.3.1 Laden Mass. Greatest gross vehicle mass (GVM) in model range.

3.3.2 Unladen Mass. Highest front/rear ratio of mass in the model range.

3.3.3 Suspension. Worst case variant with regard to adhesion, mass distribution or control of load sensing devices.

3.3.4 Wheelbase. Use the shortest in range for dynamic tests but with piping to simulate longest wheelbase for reaction time and depletion tests (if applicable).

3.3.5 Maximum Speed. Powertrain capable of achieving the initial speed of the 80% maximum speed (v_{max}) Type-0 test with engine connected and achieving acceleration for the Type-I fade test of fastest variant in range.

3.3.6 Engine. That which contributes the least engine braking effect. If this is not compatible with the speed and acceleration requirements, an additional vehicle may be required.

3.3.7 Gearbox. Select manual or automatic, whichever contributes the least engine braking effect.

3.3.8 Overall Transmission Ratio. That which contributes the least engine braking effect at the critical speeds for the Type-0 and Type-I Fade tests (see Table 2). If this is not compatible with the speed and acceleration requirements, an additional vehicle may be required.

3.3.9 Foundation Brakes and Brake Transmission Components. All variants shall be tested. Where alternative makes of valves are used, it may only be necessary to carry out static tests on all variants.

3.3.10 Tires. Largest rolling radius and worst adhesion performance.

3.3.11 Wheels. Steel wheels where alloy wheels of the same size are available.

3.3.12 Body Style. Options giving worst case brake cooling package for model range.

3.4 Test Time.

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

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. One operator experienced and trained in regulatory brake testing.

4 Procedure

4.1 Preparation.

4.1.1 Test Vehicle Preparation.

4.1.1.1 Fit tow bar to vehicle, if requested.

4.1.1.2 Install worst case front spoiler for brake cooling. Blank-off the bumper fascia cooling ducts, if requested.

4.1.1.3 Install side skirts, if requested.

4.1.1.4 Blank off cooling holes in wheel trims/alloy wheels, if requested.

4.1.1.5 Close off functional louvers or cooling ducts, if requested.

4.1.1.6 Perform powertrain break-in procedure, if required.

4.1.1.7 Ensure vehicle is equipped with fire extinguisher, if required.

4.1.2 Brakes Preparation.

4.1.2.1 The vehicle shall be fitted with a new brake system as specified by the brake engineer.

4.1.2.2 Install thermocouples in requested location in brake pads/linings where required. Recommended installation procedure is as per GMW15102.

4.1.2.3 Install new discs/drums, thermocoupled pads/linings and calipers/cylinders as per GMW14974.

4.1.2.4 Install thermocouples for brake discs or drums, if requested.

4.1.2.5 Install brake fluid temperature thermocouples in the bleeder screws in contact with the brake fluid where required.

4.1.2.6 Using new brake fluid, fully flush and fill the brake system, then bleed hydraulic circuit. Check bleeders for leaks after stationary brake applies.

4.1.2.7 Fit master cylinder reservoir and ambient temperature thermocouples where required.

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4.1.3 Instrumentation.

4.1.3.1 Install data acquisition system securely in the test vehicle.

4.1.3.2 Connect all thermocouples to data acquisition system.

4.1.3.3 Check calibration of transducers. Calibration information should be documented in the test record.

4.1.3.4 Ensure all instrumentation is working correctly by performing an instrumentation check.

4.1.4 Test Preparation.

4.1.4.1 Check and record vehicle details in test record.

4.1.4.2 Check and adjust vehicle service items as requested. Adjust tire pressures according to prescribed test mass and speed condition.

4.1.4.3 Measure maximum speed of vehicle if required.

4.1.4.4 Ballast the vehicle's front and rear axles to requested test mass as specified by test originator prior to burnish sequence (seq.). Document the distribution and position of ballast in the test record.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 Ambient Temperature: 0 °C to +40 °C.

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

Fade test sections should be run with a wind speed of ≤ 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 < 5 m/s and gusting is only an occasional occurrence.

4.2.1.3 Road surfaces shall be dry, except for ABS test surfaces.

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 Fill the fuel tank to the level appropriate to the required vehicle test mass prior to all test sequences, and every 100 km during burnish sequence.

4.2.2.2 All vehicle openings (except flow through ventilation system) shall be closed during all decelerations.

4.2.2.3 Although there is no specific order in which tests shall be conducted, the Type-I Fade test should be left until all other dynamic testing has been completed.

4.2.2.4 The minimum specified performance limits for each of the dynamic tests shall be met for both stopping distance and mean fully developed deceleration.

4.2.2.5 If the maximum design speed of the test vehicle is lower than the prescribed test speed, the test shall be performed at the vehicle's maximum speed.

4.2.2.6 Maximum allowable pedal force of 500 N applies, unless otherwise specified. Consideration should be given to instrument uncertainty.

4.2.2.7 Test road surface to have a good coefficient of adhesion (dry road).

4.2.2.8 At the start of the tests, the tires shall be cold and at the appropriate pressure to suit the prescribed test mass condition.

4.2.2.9 The prescribed performance shall be obtained without wheel locking at speeds > 15 km/h, without deviation of the vehicle from a 3.5 m wide lane, without exceeding a yaw angle of 15% and without abnormal vibrations. If any instability occurs during braking, this should be reported. The vehicle shall be aligned in the center of the lane at the start of each brake application. Steering correction is permitted provided it does not involve significant effort or any sudden steering reaction.

4.2.2.10 When conducting a Type-0 test with engine disconnected, accelerate the vehicle to at least 5 km/h above the prescribed test speed. Shift the transmission into neutral, coast down to the prescribed initial speed and apply the brakes. The actual speed at the point of brake application shall not be less than 98% of the prescribed test speed.

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4.2.2.11 When conducting a Type-0 test with engine connected, accelerate the vehicle to at least 5 km/h above the prescribed test speed using the highest appropriate gear for the speed. Release the accelerator and, with the gear still engaged, coast down to the prescribed initial speed and apply the brakes. The clutch may be disengaged at the end of the stop to prevent stalling. The actual speed at the point of brake application shall not be less than 98% of the prescribed test speed.

4.2.2.12 When conducting wheel lock sequence engine disconnected tests, accelerate the vehicle to ≥ 5 km/h above the prescribed test speed. Shift the transmission into neutral, coast down to the prescribed initial speed and apply the brakes. The actual speed at the point of brake application shall not be less than 98% of the prescribed test speed.

4.2.2.13 The temperature of the service brakes shall be at the required initial brake temperature (IBT) prior to any brake application, unless specified otherwise (see 7.1 for details). If required to heat the brakes up to initial brake temperature, make up to ten snubs from 60 km/h to 15 km/h at a maximum deceleration of 3 m/s^2 .

4.2.2.14 Unless otherwise specified, each test may comprise up to six stops including any needed for familiarization. Perform only as many effectiveness tests as necessary, within the allowable number, until the maximum braking performance that the vehicle can achieve without wheel lock is obtained.

4.2.3 Characteristics of Braking Systems. In the case of vehicles equipped with electric regenerative braking systems of Category B, the braking input from other sources of braking, may be suitably phased to allow the electric regenerative braking system alone to be applied, provided that both the following conditions are met:

Intrinsic variations in the torque output of the electrical regenerative braking system (e.g., as a result of changes in the electric SOC in the traction batteries) are automatically compensated by appropriate variation in the phasing relationship as long as the requirements of one of the following annexes to UN R13H are satisfied.

Note: The Type Approval Authority, which is to grant approval, shall have the right to check the service braking system by additional vehicle test procedures.

4.2.3.1 The service, secondary and parking braking systems must act on braking surfaces connected to the wheels through components of adequate strength.

Where braking torque for a particular axle or axles is provided by both a friction braking system and an electrical regenerative braking system of Category B, disconnection of the latter source is permitted, providing that the friction braking source remains permanently connected and able to provide the compensation.

- a. In the case of short disconnection transients, incomplete compensation is accepted, but within 1 s, this compensation shall have attained at least 75% of its final value.
- b. In all cases, the permanently connected friction braking source shall ensure that both the service and secondary braking systems continue to operate with the prescribed degree of effectiveness. Disconnection of the braking surfaces of the parking braking system shall be permitted only on condition that the disconnection is controlled exclusively by the driver from his driving seat, by a system incapable of being brought into action by a leak.

4.2.3.2 Additional requirements for vehicles equipped with electric regenerative braking systems. Vehicles fitted with an electric regenerative braking system of Category A. The electric regenerative braking shall only be activated by the accelerator control and/or the gear neutral position.

4.2.3.3 Vehicles fitted with an electric regenerative braking system of Category B. It shall not be possible to disconnect, partially or totally, one part of the service braking system other than by automatic means. This should not be construed as a departure from the requirements: "The service, secondary and parking braking systems must act on braking surfaces connected to the wheels through components of adequate strength".

4.2.3.4 The service braking system must have only one control device. The service braking system shall not be adversely affected by the disengagement of the motor(s) or by the gear ratio used.

4.2.3.5 If the operation of the electric component of braking is ensured by a relation established between information coming from the control of the service brake and the braking force to the wheels which of it results, a failure of this relation leading to the non-respect of the prescriptions of distribution of braking among the axles (with and without ABS) shall be warned to the driver by an optical warning signal at the latest when the control is actuated and having to remain lit as long as this defect exists and that the switch of "contact" is in the position "Go". For vehicles fitted with an electric regenerative braking system of either category, all the relevant prescriptions shall apply except "The electric regenerative braking shall only be activated by the accelerator control and/or the gear neutral position". In this case, the electric regenerative braking may be actuated by the

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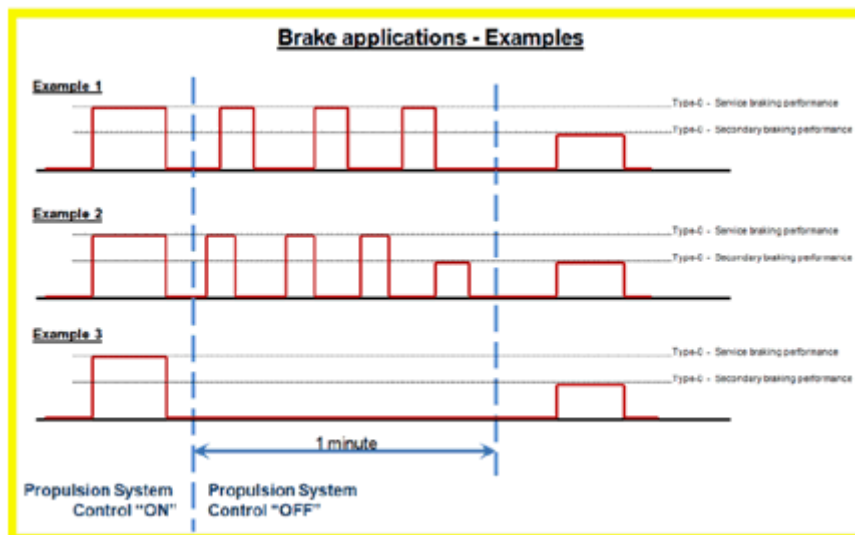
accelerator control and/or the gear neutral position. Additionally, the action on the service braking control shall not reduce the braking effect generated by the release of the accelerator control in vehicles fitted with an electric regenerative braking system of Category A or B.

4.2.3.6 The operation of the electric braking shall not be adversely affected by magnetic or electric fields. For vehicles equipped with an antilock device, the antilock device must control the electric braking system. The SOC of the traction batteries is determined by the method defined in UN R13H.

4.2.3.7 Special additional requirements for service braking systems with electric control transmission. With the parking brake released, the service braking system shall be able to fulfil the following requirements:

- With the propulsion system on/off control in the "On" (Run) position, generate a static total braking force at least equivalent to that required by the Type-0 test for service braking performance as prescribed in UN R13H.
- During the first 60 s after the propulsion system on/off control has been deactivated to the "Off" or "Lock" position and/or the ignition key has been removed, three brake applications shall generate a static total braking force at least equivalent to that required by the Type-0 test for service braking performance as prescribed in UN R13H. Reference Figure 1.

Figure 1: Brake Applications Example



- After the period shown in Figure 1, or as from the fourth brake application within the 60 s period, whichever occurs first (e.g., in a time frame of 60 s after Control "OFF" 3 brake applies should be possible with full service braking performance the 4th application should have the performance of the secondary braking system), generate a static total braking force at least equivalent to that required by the Type-0 test for secondary braking performance as prescribed in UN R13H.
- Example one (1) means three (3) applications with fully brake performance, 4th application emergence function only.
- Example two (2) means three (3) applications with fully brake performance and 4th application (within a time frame of 60 s) with emergency function only. 5th application emergence function only.
- Example three (3) means 0 applications within a time frame of 60 s, after the 60 s requirement emergence function only.

With the parking brake released, the service braking system shall be able to generate a static total braking force at least equivalent to that required by the prescribed Type-0 test, even when the ignition/start switch has been switched off and/or the key has been removed.

It should be understood that sufficient energy is available in the energy transmission of the service braking system.

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4.2.3.8 Procedure for monitoring the SOC of the batteries is in one of the following conditions. This condition is deemed to be satisfied if the SOC of the batteries is in one of the following conditions:

- a At the maximum charge level recommended by the manufacturer.
- b At a level not less than 95% of the full charge level (where the manufacturer has made no specific recommendation).
- c At a maximum level resulting from automatic charge control on the vehicle.
- d When the tests are conducted without a regenerative braking component regardless of the SOC of the batteries.
- e Generation of a braking signal to illuminate stop lamps according to Table 1.

Table 1: Electric Regenerative Braking System - Signal to Illuminate the Stop Lamps ^{Note 1}

Vehicle Decelerations	Signal Generation
$\leq 0.7 \text{ m/s}^2$	signal shall not be generated
$> 0.7 \text{ m/s}^2$ and $\leq 1.3 \text{ m/s}^2$	signal may be generated
$> 1.3 \text{ m/s}^2$	signal shall be generated

Note 1: In all cases the signal shall be de-activated at the latest when the deceleration has fallen $< 0.7 \text{ m/s}^2$.

4.3 Instructions.

4.3.1 Static Brake System Tests.

Note: Conduct all static tests with cold brakes.

4.3.1.1 Warning Signal Pressure Differential Check. This test is applicable to vehicles without a low master cylinder fluid level warning light.

4.3.1.1.1 Connect a pressure gauge/transducer to both of the master cylinder outlet ports.

4.3.1.1.2 Start the engine and apply a sustained pedal effort to the brake system of 100 N.

4.3.1.1.3 Slowly open one bleed nipple to provide a slow drop in line pressure in the circuit being failed.

4.3.1.1.4 Monitor the Brake Failure Indication Lamp and the line pressures.

4.3.1.1.5 On activation of the Brake Failure Indication Lamp, record line pressures for both the active and failed circuit. Stop engine and restore braking system to normal function.

4.3.1.1.6 Repeat this procedure on the other circuit.

4.3.1.1.7 Regulatory limit is no more than 1550 kPa (15.5 bar).

4.3.1.2 Check and Record Brake Line Pressure versus Pedal Force (Optional). Conduct this test if requested by engineer.

4.3.1.2.1 Connect a pressure gauge/transducer to both of the master cylinder outlet ports and after any load proportioning valve with the vehicle in unladen condition.

Note: Perform a floor check before and after installation of pressure transducers to ensure that pedal travel is restored to pre-instrumentation levels, refer to GMW14927 for floor check procedure.

4.3.1.2.2 Fit a force transducer to the brake pedal, centrally located on the pedal pad with the line of action coincident with the line of travel of the pedal.

4.3.1.2.3 Conduct this test both with and without power assistance.

4.3.1.2.4 Apply a progressively increasing effort to the brake pedal, up to 600 N.

4.3.1.2.5 For non-power-assisted test, evacuate booster completely by cycling brake pedal. Conduct power assisted tests with engine idling at operating temperature. Allow approximately two (2) minutes from start up to stabilize booster vacuum. Consult engineer for hydraulic boost vehicle or hybrid powertrain vehicle test instructions.

4.3.1.3 Check and Record Brake Pedal Travel Versus Pedal Force (Optional). Conduct this test if requested by engineer.

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4.3.1.3.1 Fit a force transducer and a distance transducer to the brake pedal. Measurements made shall be in relation to the center of the brake pad with the line of action coincident with the line of travel of the pedal.

4.3.1.3.2 Conduct this test both with and without power assistance.

4.3.1.3.3 Apply a progressively increasing effort to the brake pedal, up to 600 N.

4.3.1.3.4 For non-power-assisted test, evacuate booster completely by cycling the brake pedal. Conduct power assisted tests with engine idling at operating temperature. Allow approximately two minutes from start up to stabilize booster vacuum. Consult engineer for hydraulic boost or hybrid powertrain vehicle test instructions.

4.3.2 Dynamic Brake System Tests.

4.3.2.1 Pre-Conditioning Procedure. Perform the pre-test instrumentation check (Seq. 1) and the brake burnish procedures (Seq. 2, Seq. 3 if requested) described in Table A1 in Appendix A.

4.3.2.1.1 For an electric vehicle, fully charge the propulsion batteries. If vehicle labeling and the owner's manual lack instructions, charge the batteries to 95% or greater SOC to meet this requirement. Throughout the burnish, fully recharge after every 40 stops or when 80 km/h cannot be attained, whichever occurs first.

4.3.2.1.2 For an electric vehicle having a manual control for setting of regenerative braking, the manual control at the beginning of the burnish procedure is set to provide maximum regenerative braking throughout the burnish.

4.3.2.2 Suggested Dynamic Test Sequence. The suggested test sequence for the dynamic testing is shown in the Table 2. The unladen tests should be run before the laden tests whenever possible. The instructions for the testing are in the listed Appendices. Perform the tests following those instructions.

4.3.2.2.1 For the remainder of tests of an electric vehicle with regenerative braking that is not part of the brake system, and which does not have a neutral transmission selection or clutch to automatically disable the regenerative braking manually, disable the regenerative braking now.

4.3.2.2.2 For vehicles not equipped with ABS, perform the wheel lock tests described in Appendix B instead of the ABS performance tests. Also perform the torque wheel test described in Appendix C, C2, if needed based on the performance during the wheel lock tests.

4.3.2.2.3 If the brake system has vacuum assist from the vehicle engine and a separate vacuum pump, and if each vacuum assist source circuit is fitted with a discrete vacuum check valve between the source and the booster, this test section should be run by disconnecting one (1) of the vacuum assist sources, whichever would result in a worst-case power assist condition.

4.3.3 Braking Tests (Electrical Regenerative Braking System).

4.3.3.1 For vehicles as fitted with an electric regenerative braking system of Category A, behavior tests shall be carried out on a track with a low adhesion coefficient at a speed equal to 80% of the maximum speed but not exceeding 120 km/h, to check that stability is retained. See Category A description in 4.3.4.

4.3.3.2 Moreover, for vehicles fitted with an electric regenerative braking system of Category A, transient conditions such as gear changes or accelerator control release shall not affect the behavior of the vehicle in condition described in paragraph 4.3.3.1.

4.3.4 Type-0 Test (Ordinary Performance Test with Cold Brakes). In the case of a vehicle equipped with an electric regenerative braking system, the requirements depend on the category of this system:

Category A Any separate electric regenerative braking control which is provided shall not be used during the Type-0 tests.

Category B The contribution of the electric regenerative braking system to the braking force generated shall not exceed that minimum level guaranteed by the system design.

This condition is deemed to be satisfied if the SOC of the batteries is in one of the following conditions:

- a At the maximum charge level recommended by the manufacturer, as listed in the vehicle owner's manual.
- b At a level not less than 95% of the full charge level, where the manufacturer has made no specific recommendation.
- c At a maximum level resulting from automatic charge control on the vehicle.

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4.3.5 Type-I Test (Fade and Recovery Test). For vehicles equipped with an electric regenerative braking system of Category B, the condition of the vehicle batteries at the start of the test, shall be such that the braking force contribution provided by the electric regenerative braking system does not exceed the minimum guaranteed by the system design. This requirement is deemed to be satisfied if the batteries are at one of the SOC conditions as listed in a, b, or c in 4.3.4.

4.3.6 Hot Performance. According to ECE R13-H.

4.3.7 Recovery Procedure. According to ECE R13-H.

4.3.8. Recovery Performance. According to ECE R13-H.

4.3.9 Secondary Braking System. For vehicles employing electric regenerative braking systems, the braking performance shall additionally be checked under the two following failure conditions:

- a For a total failure of the electric component of the service braking output.
- b In the case where the failure condition causes the electric component to deliver its maximum braking force.

4.3.10 Procedure for Monitoring the State of Battery Charge According to ECE R13-H, Annex 3. This procedure is applicable to vehicle batteries used for traction and regenerative braking. The procedure requires the use of a bi-directional direct current (DC) Watt-hour meter.

Table 2: Dynamic Brake Systems Tests

Testing Order		Appendix/Sequence
Vehicle Loaded to UNLADEN Mass:		
1	ABS performance tests (Approved facility required)	D
2	Type-0 test, engine connected Service brake system $v = 80\% v_{\max} \leq 160 \text{ km/h}$	A seq. 5
3	Type-0 test, engine disconnected Service brake system $v = 100 \text{ km/h}$	A seq. 4
4	Type-0 test, engine disconnected Failed ABS	A seq. 7d
5	Type-0 test, engine disconnected Circuit failures	A seq. 7a,b
6	Type-0 test, engine disconnected Failed Brake Proportioning System	A seq. 8
7	Type-0 test, disconnected, engine off Non-Return Valve	A seq. 8a
8	Type-0 test, connected High Speed, $v = 80\% v_{\max}$	A seq. 6
Vehicle Loaded to LADEN Mass		
9	Park brake – Vehicle only, 20% grade	A seq. 9
10	Park brake – Vehicle and Trailer, 12% grade	A seq.10
11	Dynamic Park Brake, Type 0, engine disconnected, Vehicle only	A seq. 11
12	ABS performance tests (Approved facility required)	D
13	Type-0 test, engine connected Service brake system $v = 80\% v_{\max} \leq 160 \text{ km/h}$	A seq. 5

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Testing Order		Appendix/Sequence
14	Type-0 test, engine disconnected Service brake system $v = 100 \text{ km/h}$	A seq. 4
15	Type-0 test, engine disconnected Failed ABS	A seq. 7d
16	Type-0 test, engine disconnected Circuit failures Note: For electric vehicles, consult test engineer	A seq. 7a,b
17	Type-0 test, engine disconnected Boost failure Note: For vacuum pump applications, consult test engineer	A seq. 7c
18	Type-0 test, engine disconnected Failed Brake Proportioning System	A seq. 8
19	Type-0 test, disconnected, engine off Non-Return Valve	A seq. 8a
20	Type-0 test, connected High Speed, $v = 80\% v_{\max}$	A seq. 6
21	Type-I heating procedure	A seq. 12
22	Type-0 hot performance	A seq. 13
23	Fade recovery procedure	A seq. 14
24	Type-0 recovery performance	A seq. 15

4.3.11 Final Inspection.

- 4.3.11.1** The vehicle passes the test if all the performance requirements are met without a component failure.
- 4.3.11.2** Allow the brakes to cool and ensure there is no binding or rubbing of the brakes.
- 4.3.11.3** Inspect appearance of brake lining surfaces for detachment or tear-out of friction material.
- 4.3.11.4** Check that there is no detachment or malfunction of any mechanical component of the braking system.
- 4.3.11.5** Check that there is no visible evidence of brake fluid on brake friction surfaces, at wheel cylinders, or at fluid line junction.
- 4.3.11.6** Document appearance of friction surfaces and degree of burnish of park brake linings.
- 4.3.11.7** Photograph brake linings.
- 4.3.11.8** Photograph test vehicle; frontal and side view.
- 4.3.11.9** Replace calipers and visually worn parts after test if requested.
- 4.3.11.10** Remove all friction material, label with test information, and store per test request or facility procedures.

5 Data

5.1 Calculations. See test instruction sections in the Appendices for any calculations required.

5.2 Interpretation of Results. Results from this testing should be compared to the requirements in the applicable regulatory standards.

5.2.1 Results from this testing should be compared to the requirements in the applicable regulatory standards.

5.2.2 For vehicles fitted with an electric regenerative braking system of Category B, where the electric regenerative braking capacity is influenced by the electric SOC, the curves shall be plotted by taking account of the electric braking component under the minimal and maximum conditions of delivered braking force. This

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requirement is not applicable if the vehicle is equipped with an antilock device which controls the wheels connected to the electric braking. For further information see Annex 6 of ECE R13-H.

5.3 Test Documentation. Publish the test results and all test information in an engineering report following General Motors corporate protocol using the Evaluation Report Template and Global Document Management system or its successor.

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.

Δd : Distance between the initiation of one brake application and the initiation of the next, in km.

Δt : Duration of braking cycle, time elapsed between the initiation of one brake application and the initiation of the next, in s.

Directly Controlled Wheel: A wheel whose braking force is modulated according to data provided at least by its own sensor.

Electric Vehicle: A motor vehicle that is powered by an electric motor drawing current from rechargeable storage batteries, fuel cells, or other portable sources of electrical current, and which may include a non-electrical source of power designed to charge batteries and components thereof.

Electric Regenerative Braking: A braking system which, during deceleration, provides for the conversion of vehicle kinetic energy into electrical energy.

Electric Regenerative Braking Control: A device which modulates the action of the electric regenerative braking system.

Electric Regenerative Braking System of Category A: An electric regenerative braking system which is not part of the service braking system.

Electric Regenerative Braking System of Category B: An electric regenerative braking system which is part of the service braking system.

Electric State of Charge: The instantaneous ratio of electric quantity of energy stored in the traction battery relative to the maximum quantity of electric energy which could be stored in this battery.

Electrically-Actuated Service Brakes: Service brakes that utilize electrical energy to actuate the foundation brakes.

Gross Combination Mass: The value specified by the manufacturer as being the maximum loaded mass allowable of a vehicle and trailer combination.

High- μ : Defines a friction level about 0.8 (dry asphalt concrete).

Initial Brake Temperature: The average temperature of the service brakes on the hottest axle of the vehicle, measured inside the brake linings or on the braking path of the disc or drum shall be between +65 °C and +100 °C prior to brake application, unless otherwise specified.

Initial Vehicle Speed: The speed at the moment when the driver begins to actuate the control of the braking system. The method of triggering the moment of brake actuation is defined under stopping distance. The initial speed shall be no less than 98% of the prescribed speed for the test in question.

Laden Test Mass: The maximum mass stated by the manufacturer to be technically permissible (i.e., maximum permissible at GVM). Where provision is made for several arrangements of the load on the axles, the distribution shall be such that the load on each axle is proportioned according to the maximum permissible load for each axle, e.g., the maximum front test mass equals the quotient of the maximum front axle rating divided by the sum of the maximum front axle rating and the maximum rear axle rating times the GVM.

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