SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE

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FMVSS Inertia Dynamometer Test Procedure for Vehicles Below 4540 kg GVWR

RATIONALE

The current version of this recommended practice corrects the calculations for brake effectiveness, provides a definition of average by distance, and clarifies the scope related to tow vehicles and trailering applications. This revision also includes several edits to improve readability. The technical content, the test conditions, and the test sequences from previous versions remain unchanged.

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1. SCOPE

This document derives from the Federal Motor Vehicle Safety Standards (FMVSS) 105 and 135 vehicle test protocols as single-ended inertia-dynamometer test procedures. The test sequences enable brake output measurement, friction material effectiveness, and corner performance in a controlled and repeatable environment. This SAE Document also includes optional sections for parking brake output performance for rear brakes with hydraulic or Electric Park Brakes (EPB). It applies to brake corners from vehicles covered by the FMVSS 105 and 135 when using the appropriate brake hardware and test parameters. The FMVSS 135 applies to all passenger cars and light trucks up to 3500 kg of gross vehicle weight (GVWR). The FMVSS 105 applies to all passenger cars, multi-purpose vehicles, buses, and trucks above 3500 kg of GVWR. This document does not include testing for school bus applications or vehicles equipped with hydraulic brakes with a GVWR above 4540 kg.

This document does not evaluate or quantify other brake system characteristics such as wear, noise, judder, ABS performance, or braking under extreme temperatures or speeds. This document does not include minimum performance requirements. Consistency and margin of pass/fail of the minimum requirements related to stopping distance or equivalent deceleration levels of the FMVSS 105 or FMVSS 135 vehicle test can be assessed as part of the project in coordination with the test requestor when using the appropriate vehicle information and vehicle dynamics modeling. Nevertheless, this procedure and its results do not replace the vehicle-level test to demonstrate compliance with FMVSS for hydraulic brake systems or other mandatory regulations (e.g., ECE R13H or ECE R13).

Towing and trailering applications are not part of this document and require a separate assessment per SAE J2807.

1.1 Purpose

This procedure aims to assess the performance of a brake corner assembly during conditions that correspond to the FMVSS 105 and 135 vehicle test procedures.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2789 Inertia Calculation for Single-Ended Inertia-Dynamometer Testing

SAE J2807 Performance Requirements for Determining Tow-Vehicle Gross Combination Weight Rating and Trailer Weight Rating

SAE J2986 Brake Pads, Lining, Disc, and Drum Wear Measurements

2.1.2 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO/PAS 12158:2002 Road Vehicle - Braking Systems - Temperature Measuring Methods

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

Yuan, Y. and Halloran, P., "Calculation of Average Coefficient of Friction During Braking," SAE Technical Paper 1999-01-3410, 1999, https://doi.org/10.4271/1999-01-3410.

2.2.2 NHTSA Publications

Available from National Highway Traffic Safety Administration, 1200 New Jersey Avenue, SE, Washington, DC 20590, Tel: 1-888-327-4236, https://www.nhtsa.gov/.

571.105	Standard No. 105 - Hydraulic and Electric Brake Systems
571.135	Standard No. 135 - Light Vehicle Brake Systems
TP-105-03	OVSC Laboratory Test Procedure for FMVSS 105 Hydraulic and Electric Brake Systems
TP-135-01	OVSC Laboratory Test Procedure for FMVSS 135 Light Vehicle Brake Systems

2.2.3 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 611:2003	Road Vehicles - Braking of Automotive Vehicles and Their Trailers - Vocabulary
ISO/TR 13487:1997	Braking of Road Vehicles - Considerations on the Definition of Mean Fully Developed Deceleration

3. DEFINITIONS

3.1 Applicable to Both FMVSS 135 and FMVSS 105

3.1.1 APPARENT COEFFICIENT OF FRICTION FOR DISC BRAKES

Per Equation 1:

$$\mu = \frac{10^6 \cdot T}{2 \cdot (p - p_{Threshold}) \cdot A_p \cdot r_{eff} \cdot \eta} \quad \text{(Eq. 1)}$$

where:

μ = apparent friction for disc brakes (unitless)

3.1.2 DRUM BRAKE EFFECTIVENESS (C*)

Per Equation 2:

$$C^* = \frac{10^6 \cdot T}{(p - p_{threshold}) \cdot A_p \cdot r_{eff} \cdot \eta} \quad \text{(Eq. 2)}$$

where:

C^* = effectiveness for drum brakes (unitless)

T = output torque (N·m)

p = brake pressure (kPa)

$p_{threshold}$ = minimum pressure required to start developing braking torque; unless otherwise directed, use threshold pressure derived from Table 3, Section 20 or Table 4, Section 30 (kPa)

A_p = total piston area acting on one side of the caliper for disc brakes; total wheel cylinder area for drum brakes (mm^2)

r_{eff} = radial distance from the centerline of the piston to the axis of rotation for disc brakes; internal drum diameter divided by two for drum brakes, unless the requestor provides other dimensions (mm)

η = efficiency (%)

3.1.3 AVERAGE BY DISTANCE

Averaging method where the sampling frequency is a unit of vehicle distance (between data points) traveled during a braking event. The average by distance correlates to the vehicle stopping distance and the mean fully developed deceleration (refer to references in 2.2.1 and 2.2.3). As the literature indicates, this value yields the same result as the integration between two distance points per Equation 3A. The first term in Equation 3A provides the total distance traveled during the averaging period. The integral provides the area under the curve for the measurand in the distance domain for the same averaging period.

Equation 3B provides a working version of Equation 3A relating to the actual calculation as part of the dynamometer data collection or spreadsheet calculations. The first term on the numerator provides the average value of the measurement between two consecutive averaging points. The numerator's second and third terms provide the distance between two measurement points (distance = speed x time). The denominator provides the total distance traveled for the entire period used to compute the average by distance:

$$m_{dist} = \frac{1}{s_e - s_b} \times \int_{s_b}^{s_e} m(d) \cdot d_s \quad \text{(Eq. 3A)}$$

$$m_{dist} = \frac{\sum_b^e [(m_i + m_{i+1})/2] \cdot (v_{i+1} - v_i) \cdot \Delta t_i}{\sum_b^e (v_{i+1} - v_i) \cdot \Delta t_i} \quad \text{(Eq. 3B)}$$

where:

m_{dist} = average by distance for the measurand (torque, pressure, apparent friction, or brake effectiveness)

s_e = distance traveled from the initiation of the brake application to the time the average ends

s_b = distance traveled from the initiation of the brake application to the time the average begins

$m(d)$ = average value of the measurand during the increment of distance d_s

d_s = distance increment between two sampling points

m_i = measurand value at time i

v_i = speed at time i

Δt_i = increment of time between two consecutive measuring points and equal to 1 divided by the sampling rate in Hz

3.1.4 BREAKAWAY TORQUE

Minimum torque required to initiate brake rotation after applying cable tension or clamping force to the parking brake. (N·m)

3.1.5 DECELERATION-CONTROLLED BRAKE APPLICATION

Control algorithm to adjust the real-time brake pressure to maintain a constant torque output calculated from the instantaneous deceleration specified in the test procedure.

3.1.6 GROSS VEHICLE WEIGHT (GVWR)

Maximum vehicle weight indicated by the manufacturer. (kgf)

3.1.7 INITIAL BRAKE TEMPERATURE (IBT)

Rotor or drum temperature at the start of the brake application. (°C)

3.1.8 LIGHTLY LOADED VEHICLE WEIGHT (LLVW)

Unloaded vehicle weight plus 180 kg for the driver and test instrumentation. (kgf)

3.1.9 MAXIMUM VEHICLE SPEED (V_{MAX})

Highest speed attainable by accelerating at a maximum rate from a standstill to a distance of 3.2 km on a level surface, with the vehicle at LLVW for vehicles per FMVSS 135 or GVWR for vehicles per FMVSS 105. For electric vehicles, ensure the propulsion batteries are at a state of charge of not less than 95% at the beginning of the run. See Sections 50 and 70 in Table 3 and Sections 70 and 250 in Table 4. (km/h)

3.1.10 PRESSURE-CONTROLLED BRAKE APPLICATION

Control algorithm to maintain a constant input pressure to the brake irrespective of the torque output.

3.1.11 TIRE DYNAMIC ROLLING RADIUS

Equivalent tire radius generating the revolutions per mile (RPM) for the specific tire size using Equation 4. Use the tire dynamic rolling radius to calculate the dynamometer rotational speed for a given linear vehicle speed. (mm)

$$RR = \frac{1609344}{2 \cdot \pi \cdot RPM} \quad \text{(Eq. 4)}$$

where:

RR = tire dynamic rolling radius (mm)

RPM = tire manufacturer specification for RPM; typically available on the manufacturer's website

3.2 Applicable to FMVSS 135 Only

3.2.1 PRESSURE LEVEL AT 500 N PEDAL FORCE WITH BRAKE POWER ASSIST SYSTEM OPERATIONAL ($p_{500N\ OPERATIONAL}$)

Brake system pressure at the front or rear corner with 500 N of pedal force applied with the brake system and power assist unit fully operational, including rear brake proportioning. (kPa)

NOTE: Determine this value using vehicle measurements or the default value per 8.1.7.

3.2.2 PRESSURE LEVEL AT 500 N PEDAL FORCE WITH BRAKE POWER ASSIST SYSTEM FULLY DEPLETED ($p_{500N\ DEPLETED}$)

Brake system pressure at the front or rear corner with 500 N of pedal force applied and the power assist unit fully depleted, including rear brake proportioning. (kPa)

NOTE: Determine this value using vehicle measurements or the value provided by the test requestor.

3.2.3 PRESSURE LEVEL DURING BEST COLD EFFECTIVENESS STOP ($p_{BEST\ COLD\ EFFECT}$)

The lowest distance-weighted average brake pressure from all the brake applications is in Section 40, Table 3, Cold Effectiveness. (kPa)

3.3 Applicable to FMVSS 105 Only

3.3.1 BRAKE POWER ASSIST UNIT

A device installed in a hydraulic brake system to reduce the driver effort required to actuate the system. If the device is inoperative, it does not prevent the driver from braking the vehicle by a continued application of pedal force on the service brake control.

3.3.2 BRAKE POWER UNIT

A device part of the braking system that provides the energy required to actuate the brakes, directly or indirectly, through an auxiliary device, with the driver action consisting only of modulating the energy application level.

3.3.3 PRESSURE LEVEL AT 667 N PEDAL FORCE WITH BRAKE POWER ASSIST OR BRAKE POWER UNIT SYSTEM OPERATIONAL ($p_{667N\ OPERATIONAL}$)

Brake system pressure at the front or rear corner with 667 N of pedal force applied with the brake system and power assist unit fully operational, including rear brake proportioning. (kPa)

NOTE: Determine this value using vehicle measurements or the default value per 8.2.8.

3.3.4 PRESSURE LEVEL AT 667 N PEDAL FORCE WITH BRAKE POWER ASSIST SYSTEM FULLY DEPLETED ($p_{667N\ DEPLETED}$)

Brake system pressure at the front or rear corner with 667 N of pedal force applied and the power assist unit fully depleted, including rear brake proportioning. (kPa)

NOTE: Determine this value using vehicle measurements or the value provided by the test requestor.

3.3.5 PRESSURE LEVEL AT 890 N PEDAL FORCE WITH BRAKE POWER ASSIST OR BRAKE POWER UNIT SYSTEM OPERATIONAL ($p_{890N\ OPERATIONAL}$)

Brake system pressure at the front or rear corner with 890 N of pedal force applied with the brake system and power assist unit fully operational, including rear brake proportioning. The spike stops section uses this pressure level. (kPa)

NOTE: Determine this value using vehicle measurements or the value provided by the test requestor.

3.3.6 SPIKE STOP

Stop resulting from applying a service brake pressure of $p_{890N\ operational}$ in 0.08 seconds.

4. TEST CYCLES

4.1 Dynamic Brake Application

Figure 1 illustrates the main time stamps used to characterize the brake application.

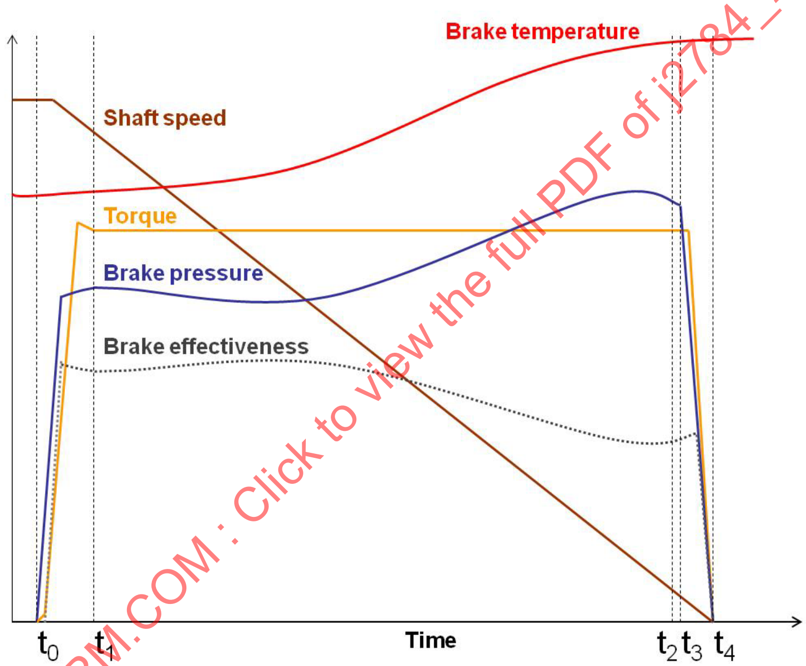

Figure 1 - Typical brake application time stamps

4.1.1 Time t_0

Brake application initiation. At this time, the pressure starts to rise.

4.1.2 Time t_1

Time at the level reached for the setpoint. At this time stamp, the brake reaches its target torque or pressure control level. At time t_1, calculating the average by time and the average by distance begins.

4.1.3 Time t_2

Time at the end of averages. At time t_2, the inertia-dynamometer data acquisition system terminates the calculation of average by time and average by distance. Time t_2 is the end of the stable portion of the brake application when the speed is 0.5 km/h above the release speed (t_3).

4.1.4 Time t_3

Time at release speed. At time t_3, the inertia-dynamometer servo controller releases the brake (specified in 8.1.3).

4.1.5 Time t_4

Time at brake pressure and torque lost. At time t_4, pressure and torque are below the minimum thresholds. The inertia-dynamometer considers the braking event complete.

4.2 Parking Brake Application

See Appendix A.

5. TEST EQUIPMENT

5.1 Applicable to Both FMVSS 135 and FMVSS 105

5.1.1 Single-ended brake inertia dynamometer capable of performing deceleration and pressure-controlled brake applications.

5.1.1.1 Automatic data collection system capable of recording the following channels digitally at 50 Hz minimum:

5.1.1.1.1 Brake equivalent linear speed. (km/h)

5.1.1.1.2 Brake input pressure. (kPa)

5.1.1.1.3 Brake output torque. (N·m)

5.1.1.1.4 Brake fluid displacement. (mm^3)

5.1.1.1.5 Shaft angular position. (degrees)

5.1.1.1.6 Parking brake cable tension for mechanical park brake. (N)

5.1.1.1.7 Parking brake input voltage or current for EPB. (V, A)

5.1.1.1.8 Parking brake cable travel. (mm)

5.1.1.2 Automatic data collection system capable of recording the following channels digitally at 10 Hz minimum:

5.1.1.2.1 Brake rotor or drum temperature. (°C)

5.1.1.2.2 Brake pad or brake shoe temperature. (°C)

5.1.2 Cooling Air Temperature, Relative Humidity, and Speed

5.1.2.1 Control brake cooling air temperature 25 °C ± 5 °C and humidity to 9.92 g/kg (11.57 g/m^3) at sea level. Use a psychrometric chart to find acceptable air temperature and relative humidity conditions to meet absolute humidity requirements.

5.1.3 Park Brake Testing Capabilities

5.1.3.1 Ability to apply torque from zero shaft rotational speed enough to cause breakaway (Method A) or ability to maintain a static torque for five continuous minutes (Method B).

5.1.3.2 A mechanism to apply and control input cable tension.

5.1.3.3 A mechanism to lock the parking brake cable travel in position during parking brake output evaluation.

5.1.3.4 Have the appropriate electrical input for EPB systems.

5.2 Applicable to FMVSS 135

There are no specific requirements for the test cycle related to this regulation.

5.3 Applicable to FMVSS 105

5.3.1 Water spray testing capabilities (for FMVSS 105 testing only).

5.3.2 System to deliver a steady stream of water on both sides of the rotor or directed into the drum assembly at a rate of 5 L/min ± 2 L/min.

5.3.3 System to adjust the position, orientation, and distance from the stream of water to the brake assembly. For disc brakes, align the water stream in the radial direction with the center of the rotor and within 50 to 100 mm from the brake on the leading edge of the caliper. See Figure 2.

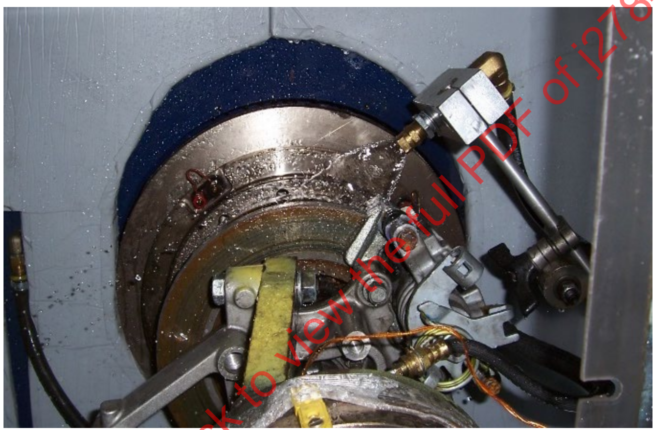

Figure 2 - Water spray setup for disc brakes

6. TEST CONDITIONS AND SAMPLE PREPARATION

6.1 Use new rotor and brake pads or new drum and brake shoe linings for each test.

6.2 For brake rotors, install a thermocouple at a depth of 1.0 mm below the surface. Locate the thermocouple on the outboard face near the centerline of the braking surface.

6.3 For brake pads, install one thermocouple at a depth of 2.0 mm near the center of the friction surface. For disc brake pads with grooves, install the thermocouple at least 4.0 mm from the groove edge on the leading side of the pad.

6.4 For disc brakes, the assembled lateral run-out shall not exceed 50 µm when measured on the outboard surface and 10 mm from the outside diameter.

6.5 For brake drums, install a thermocouple at a depth of 1.0 mm on the centerline of the braking surface.

6.6 For brake shoes, install a thermocouple at a depth of 1.0 mm near the center of the friction surface of the most heavily loaded shoe.

6.7 Drum roundness (ovality) of 75 µm for drums under 280 mm diameter and 100 µm for those over 280 mm diameter.

6.8 For drum brakes, set the diametric cage clearance to the value indicated by the test requestor, the vehicle service manual, or the brake assembly print. If no other information is available, set the diametric cage clearance to 0.6 to 0.8 mm, measured at the center of the shoes. Rotate to check for excessive drag and adjust if necessary.

6.9 Calculate the dynamometer rotational speed based on the tire's dynamic rolling radius.

6.10 Set the cooling air temperature and humidity per 5.1.3.

6.11 Measure and record the initial and final thickness and mass of friction materials, discs, or drums per SAE J2986 - pre- and post-lining - and rotor/drum photographs per Appendix B.17.

7. DYNAMOMETER TEST INERTIA

Table 1 indicates the equations to calculate inertia levels for the different sections of the test. The correct values are a function of the dynamic vehicle braking torque distribution.

NOTE 1: X1, X2, Y1, and Y2 values are not equivalent to the static vehicle weight distribution.

NOTE 2: The test requestor provides X1, X2, Y1, and Y2 values.

NOTE 3: For vehicles with regenerative braking, review in detail with the test requestor the strategy to reflect the brake inertia at the foundation brake for specific sections.

NOTE 4: Verify with the test requestor whether a loss factor is required to adjust the calculated inertia from Equations 5 through 14.

NOTE 5: For test sections with a deceleration of 0.65 g or higher, use the dynamic weight transfer method from SAE J2789 using a deceleration of 0.9 g. This deceleration reflects similar decelerations observed during vehicle testing.

Table 1 - Equations to calculate corner test inertia per section and axle in combination with SAE J2789

Vehicle Test Weight and Brake System Condition	Front Brake Test	Rear Brake Test
GVWR Brake system is fully operational	$I_{front\ GVWR} = \frac{1}{2} \cdot X_1 \cdot GVWR \cdot RR^2$ (Eq. 5)	$I_{rear\ GVWR} = \frac{1}{2} \cdot Y_1 \cdot GVWR \cdot RR^2$ (Eq. 6)
LLVW Brake system is fully operational	$I_{front\ LLVW} = \frac{1}{2} \cdot X_2 \cdot LLVW \cdot RR^2$ (Eq. 7)	$I_{rear\ LLVW} = \frac{1}{2} \cdot Y_2 \cdot LLVW \cdot RR^2$ (Eq. 8)
GVWR Brake system with front-to-rear split Partial circuit failure	$I_{front\ GVWR\ FR\ Split} = \frac{1}{2} \cdot GVWR \cdot RR^2$ (Eq. 9)	Use Equation 9
LLVW Brake system with front-to-rear split Partial circuit failure	$I_{front\ LLVW\ FR\ Split} = \frac{1}{2} \cdot LLVW \cdot RR^2$ (Eq. 10)	Use Equation 10
GVWR Brake system with a diagonal split Partial circuit failure	$I_{front\ GVWR\ Diag\ Split} = 2 \cdot I_{front\ GVWR}$ (Eq. 11)	$I_{rear\ GVWR\ Diag\ Split} = 2 \cdot I_{rear\ GVWR}$ (Eq. 12)
LLVW Brake system with a diagonal split Partial circuit failure	$I_{front\ LLVW\ Diag\ Split} = 2 \cdot I_{front\ LLVW}$ (Eq. 13)	$I_{rear\ LLVW\ Diag\ Split} = 2 \cdot I_{rear\ LLVW}$ (Eq. 14)

where:

I = test inertia calculated using Equations 5 through 14 ($kg \cdot m^2$)

X1 = percentage of brake torque provided by the front axle at GVWR with the brake system fully operational

X2 = percentage of brake torque provided by the front axle at LLVW with the brake system fully operational

Y1 = percentage of brake torque provided by the rear axle at GVWR with the brake system fully operational

Y2 = percentage of brake torque provided by the rear axle at LLVW with the brake system fully operational

RR = tire dynamic rolling radius calculated per Equation 4

8. TEST PROCEDURES

8.1 Service Brake Test Procedure Applicable to FMVSS 135

8.1.1 Use cooling airspeed equal to 30 km/h at the brake for all sections except 50 km/h for Section 10, Burnish.

8.1.2 The dynamometer shaft rotational speed during cooling between brake events equals 50% of the braking speed for the next brake application, except for Sections 160, 170, 180, and 190, respectively, the braking speed for the next brake application.

8.1.3 The dynamometer release speed is 3 km/h, except for Section 160, which uses 60 km/h, and Section 140 is a full stop to 0 km/h.

8.1.4 During Section 10, Burnish, use the first five stops as the Instrument Check Stops.

8.1.5 During Sections 20 and 30, Adhesion Utilization Ramps, release the brake when the brake pressure reaches the pressure limit.

8.1.6 During Section 140, Failed Power-Brake Unit, if the brake pressure at a pedal force of 500 N with the power assist fully depleted ($p_{500N\ depleted}$) is not available, perform stops as torque control equivalent to the deceleration values per Table 2. The test inertia is a function of the deceleration setpoint and item 7.

Table 2 - Default deceleration levels

Boost Assist Options	Description	Deceleration Level (g)
Without Assist	These default values apply when the requestor knows the vehicle does not have a boost assist and the specific pressure value is unavailable.	0.26, 0.28, 0.30, 0.32, 0.34, 0.36
Unknown	These default values apply when the requestor is unaware that the vehicle has a boost assist system.	0.26, 0.30, 0.34, 0.66, 0.70, 0.76
With Assist	These default values apply when the requestor knows the vehicle has a boost assist system and the specific pressure values are unavailable.	0.66, 0.68, 0.70, 0.72, 0.74, 0.76

NOTE: Certain vehicles manufactured starting around 2010 may have failed boost assist.

8.1.7 If the value of $p_{500N\ operational}$ is not available for front brakes, use a pressure limit of 12000 kPa. For rear brakes with electronic brake distribution, use 12000 kPa.

8.1.8 During Sections 150 and 155 for rear brakes, follow the test sequence described in Appendix A.

8.1.9 During Sections 170 and 200, First Hot Stop and Recovery Performance, perform stops as pressure-controlled using the lowest distance-weighted average pressure ($p_{best\ cold\ effect}$) from Section 40, Cold Effectiveness.

8.1.10 Time t_4 determines the end of the stop or snub for all brake applications per Figure 1.

Table 3 - Service brakes test procedure - FMVSS 135

Section Number	FMVSS 135 Reference	Inertia Level (Equation from Table 1)	Braking Speed (km/h)	Brake Application Control (IBT, Cycle Time, or Distance)	Pressure Apply Rate (kPa/s)	Pressure Limit (kPa)	Decel Level (g)	No. of Stops/ Snubs
10	7.1 Burnish at GVWR	Eq. 5 or 6	80	IBT = 100 °C	20000	$p_{500N\ operational}$	0.31	200
20	7.4 (1) 3500 kPa Adhesion Utilization Ramps at GVWR	Eq. 5 or 6	50	IBT = 65 °C first, then 100 °C	700-2000	3500 kPa	-	3
30	7.4 (2) 12000 kPa Adhesion Utilization Ramps at GVWR	Eq. 5 or 6	100	IBT = 65 °C first, then 100 °C	5000	12000 kPa	-	3
40	7.5 Cold Effectiveness at GVWR	Eq. 5 or 6	100	IBT = 100 °C	20000	$p_{500N\ operational}$	0.90	6
50	7.6 High-Speed Effectiveness at GVWR	Eq. 5 or 6	160 (80% V_{max} for V_{max} < 200 km/h)	IBT = 100 °C	20000	$p_{500N\ operational}$	0.80	6
55	7.7 Stops with Engine Off at GVWR	Eq. 5 or 6	100	IBT = 100 °C	20000	$p_{500N\ operational}$	0.90	6
60	7.5 Cold Effectiveness at LLVW	Eq. 7or 8	100	IBT = 100 °C	20000	$p_{500N\ operational}$	0.90	6
70	7.6 High-Speed Effectiveness at LLVW	Eq. 7or 8	160 (80% V_{max} for V_{max} < 200 km/h)	IBT = 100 °C	20000	$p_{500N\ operational}$	0.80	6
80	7.8 Failed Antilock System at LLVW	Eq. 7or 8	100	IBT = 100 °C	20000	$p_{500N\ operational}$	0.60	6
90.a	7.10 Hydraulic Circuit Failure at LLVW for Front Brakes	Eq. 10 for front-to-rear split Eq. 13 or 14 for diagonal split	100	IBT = 100 °C	20000	$p_{500N\ operational}$	0.70 front-to-rear split 0.45 diagonal split	4
90.b	7.10 Hydraulic Circuit Failure at LLVW for Rear Brakes	Eq. 10 for front-to-rear split Eq. 13 or 14 for diagonal split	100	IBT = 100 °C	20000	$p_{500N\ operational}$	0.35 front-to-rear split 0.45 diagonal split	4
100.a	7.10 Hydraulic Circuit Failure at GVWR for Front Brakes	Eq. 9 for front-to-rear split Eq. 11 or 12 for diagonal split	100	IBT = 100 °C	20000	$p_{500N\ operational}$	0.60 front-to-rear split 0.40 diagonal split	4
100.b	7.10 Hydraulic Circuit Failure at GVWR for Rear Brakes	Eq. 9 for front-to-rear split Eq. 11 or 12 for diagonal split	100	IBT = 100 °C	20000	$p_{500N\ operational}$	0.40 front-to-rear split 0.40 diagonal split	4
110	7.8 Failed Antilock System at GVWR	Eq. 5 or 6	100	IBT = 100 °C	20000	$p_{500N\ operational}$	0.60	6
120	Cool Down at GVWR	Eq. 5 or 6	5	Until 5 °C above cooling air temp	-	-	-	-
130	Warm Up at GVWR	Eq. 5 or 6	50	Until 65 °C at 60 seconds cycle time	20000	$p_{500N\ operational}$	0.31	As needed
140	7.11 Failed Power-Brake Unit at GVWR	Eq. 5 or 6	100	IBT = 65 °C first, then 100 °C	20000	$p_{500N\ depleted}$ or item 8.1.6	-	6
150	7.12 Parking Brake Forward	See 8.3						

Section Number	FMVSS 135 Reference	Inertia Level (Equation from Table 1)	Braking Speed (km/h)	Brake Application Control (IBT, Cycle Time, or Distance)	Pressure Apply Rate (kPa/s)	Pressure Limit (kPa)	Decel Level (g)	No. of Stops/ Snubs
155	7.12 Parking Brake Reverse	-	See 8.3					
160	7.13 Heating Snubs at GVWR	Eq. 5 or 6	120-60	IBT = 55 °C first, then cycle time of 45 seconds	20000	$p_{500N\ operational}$	0.31	15
170	7.14-1 First Hot Stop at GVWR	Eq. 5 or 6	100	20 seconds after the end of the last snub from Section 160	20000	$p_{best\ cold\ effect}$	-	1
180	7.14-2 Second Hot Stop at GVWR	Eq. 5 or 6	100	20 seconds after the end of Section 170	20000	$p_{500N\ operational}$	0.90	1
190	7.15 Brake Cooling Stops at GVWR	Eq. 5 or 6	50	Cycle distance = 1.5 km after the end of Section 180	20000	$p_{500N\ operational}$	0.31	4
200	7.16 Recovery Performance at GVWR	Eq. 5 or 6	100	Cycle distance = 1.5 km after the start last stop of Section 190	20000	$p_{best\ cold\ effect}$	-	1
				20 seconds after the end of stop 1 of this section				1
210	7.17 Final Inspection	Perform final inspection and measurements						

8.2 Service Brake Test Procedure Applicable to FMVSS 105 (Except School Buses)

8.2.1 Use cooling airspeed equal to 30 km/h at the brake for all sections, except 50 km/h for Section 40, Burnish.

8.2.2 The dynamometer shaft rotational speed during cooling between brake events equals 50% of the braking speed for the next brake application, except for Sections 150, 160, 170, 190, 200, 210, 280, and 290, where it shall be equal to the braking speed for the next brake application.

8.2.3 The dynamometer release speed is 3 km/h, except for full stops to 0 km/h for Sections 280 and 290.

8.2.4 Section 10, Instrument Check Stops: If instrument repair, replacement, or adjustment is necessary, make at most 10 additional stops.

8.2.5 Sections 70 and 250 apply only to vehicles with a maximum speed of 135 km/h or higher.

8.2.6 Section 100 applies only to vehicles with a GVWR of less than 3630 kg.

8.2.7 Section 140, Failed Power-Brake Unit: If the brake pressure at a pedal force of 667 N with the power assist fully depleted ($p_{667N\ depleted}$) is not available, perform stops as torque control with a deceleration level of 0.34 g. This section does not include other optional test sequences allowed by the FMVSS 105. If the vehicle has vacuum assist, review with the requestor to determine the applicable deceleration and inertia levels.

8.2.8 If the value of $p_{667N\ operational}$ is unavailable, use a pressure limit of 12000 kPa for front or rear brakes on vehicles with electronic brake distribution.

8.2.9 During Sections 90 and 95 for rear brakes, follow the test sequence described in Appendix A.

8.2.10 Time t_4 determines the end of the stop or snub for all brake applications per Figure 1.

8.2.11 When the initial brake temperature for the first stop in a test section (other than 7.7, Parking Brake, and 7.16, Water Recovery Test) is below the setpoint, perform a series of brake snubs. Conduct up to 10 snubs from not more than 65 to 20 km/h at a deceleration not greater than 0.31 g.

Table 4 - Service brakes test procedure - FMVSS 105 (except school buses)

Section Number	FMVSS 105 Reference	Inertia Level (Equation from Table 1)	Braking Speed (km/h)	Brake Application Control (IBT, Cycle Time, or Distance)	Pressure Apply Rate (kPa/s)	Pressure Limit (kPa)	Deceleration Level (g)	No. of Stops/ Snubs
10	7.2 Instrumentation Check at GVWR	Eq. 5 or 6	48	IBT = Ambient or less than 100 °C	20000	$p_{667N\ operational}$	0.31	10
20	7.3 First Effectiveness Test (Preburnish) at GVWR 48 km/h	Eq. 5 or 6	48	IBT = 100 °C	20000	$p_{667N\ operational}$	0.90	6
30	7.3 First Effectiveness Test (Preburnish) at GVWR 97 km/h	Eq. 5 or 6	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.90	6
40	7.4 Burnish at GVWR	Eq. 5 or 6	64	IBT = 100 °C or 1.6 km cycle distance	20000	$p_{667N\ operational}$	0.37	200
50	7.5 Second Effectiveness at GVWR 48 km/h	Eq. 5 or 6	48	IBT = 100 °C	20000	$p_{667N\ operational}$	0.95	6
60	7.5 Second Effectiveness at GVWR 97 km/h	Eq. 5 or 6	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.95	6
70	7.5 Second Effectiveness at GVWR 130 km/h	Eq. 5 or 6	130	IBT = 100 °C	20000	$p_{667N\ operational}$	0.90	6
80	7.6 First Reburnish at GVWR	Eq. 5 or 6	64	IBT = 100 °C or 1.6 km cycle distance	20000	$p_{667N\ operational}$	0.37	35
90	7.7 Parking Brake Forward	See 8.3						
95	7.7 Parking Brake Reverse	See 8.3						
100	7.8 Third Effectiveness at LLVW 97 km/h	Eq. 7 or 8	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.95	6
110.a	7.9 Hydraulic Partial Failure at LLVW for Front Brakes	Eq. 10 for front-to-rear split	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.70 front-to-rear split	4
		Eq. 13 or 14 for diagonal split					0.45 diagonal split	
110.b	7.9 Hydraulic Partial Failure at LLVW for Rear Brakes	Eq. 10 for front-to-rear split	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.40 front-to-rear split	4
		Eq. 13 or 14 for diagonal split					0.45 diagonal split	
120.a	7.9 Hydraulic Partial Failure at GVWR for Front Brakes	Eq. 9 for front-to-rear split	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.60 front-to-rear split	4
		Eq. 11 or 12 for diagonal split					0.40 diagonal split	
120.b	7.9 Hydraulic Partial Failure at GVWR for Rear Brakes	Eq. 9 for front-to-rear split	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.40 front-to-rear split	4
		Eq. 11 or 12 for diagonal split					0.40 diagonal split	

Section Number	FMVSS 105 Reference	Inertia Level (Equation from Table 1)	Braking Speed (km/h)	Brake Application Control (IBT, Cycle Time, or Distance)	Pressure Apply Rate (kPa/s)	Pressure Limit (kPa)	Deceleration Level (g)	No. of Stops/ Snubs
130	7.9 Failed Antilock System at GVWR	Eq. 5 or 6	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.75	4
140	7.10 Inoperative Brake Power or Power Assist Unit at GVWR	Eq. 5 or 6	97	IBT = 100 °C	20000	$p_{667N\ depleted}$ or 8.2.7	-	4
150	7.11 First Fade and Recovery at GVWR - Baseline Stops	Eq. 5 or 6	48	IBT = 100 °C	20000	$p_{667N\ operational}$	0.31	6
160	7.11 First Fade and Recovery at GVWR - Fade Stops	Eq. 5 or 6	97	IBT = 55 °C first, then a cycle distance of 0.64 km	20000	$p_{667N\ operational}$	0.47	10
170	7.11 First Fade and Recovery at GVWR - Recovery Stops	Eq. 5 or 6	48	First 1.6 km after the end of Section 160, then 60 seconds cycle time	20000	$p_{667N\ operational}$	0.31	5
180	7.12 Second Reburnish at GVWR	Eq. 5 or 6	64	IBT = 100 °C or 1.6 km cycle distance	20000	$p_{667N\ operational}$	0.37	35
190	7.13 Second Fade and Recovery at GVWR - Baseline Stops	Eq. 5 or 6	48	IBT = 100 °C	20000	$p_{667N\ operational}$	0.31	6
200	7.13 Second Fade and Recovery at GVWR - Fade Stops	Eq. 5 or 6	97	IBT = 55 °C first, then a cycle distance of 0.64 km	20000	$p_{667N\ operational}$	0.47	15
210	7.13 Second Fade and Recovery at GVWR - Recovery Stops	Eq. 5 or 6	48	First 1.6 km after the end of Section 160, then 60 seconds cycle time	20000	$p_{667N\ operational}$	0.31	5
220	7.14 Third Reburnish at GVWR	Eq. 5 or 6	64	IBT = 100 °C or 1.6 km cycle distance	20000	$p_{667N\ operational}$	0.37	35
230	7.15 Fourth Effectiveness at GVWR 48 km/h	Eq. 5 or 6	48	IBT = 100 °C	20000	$p_{667N\ operational}$	0.95	6
240	7. 15 Fourth Effectiveness at GVWR 97 km/h	Eq. 5 or 6	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.95	6
250	7. 15 Fourth Effectiveness at GVWR 130 km/h	Eq. 5 or 6	130	IBT = 100 °C	20000	$p_{667N\ operational}$	0.95	6
260	7.16 Water Recovery at GVWR - Baseline Check Stops	Eq. 5 or 6	48	IBT = 100 °C	20000	$p_{667N\ operational}$	0.31	3
270	7.16 Water Recovery at GVWR - Water Spray	Eq. 5 or 6	8 for 2 minutes	IBT < 100 °C with no warm-up	20000	-	-	1
280	7.16 Water Recovery at GVWR - Recovery Stops	Eq. 5 or 6	48	First, immediately after the end of Section 270, then 20 seconds of cycle time	20000	$p_{667N\ operational}$	0.31	5
290	7.17 Spike Stops at GVWR	Eq. 5 or 6	48	IBT = 100 °C	P_{890N}/0.08 seconds	$p_{890N\ operational}$	0.95	10
300	7.17 Post Spike Stops Effectiveness at GVWR 97 km/h	Eq. 5 or 6	97	IBT = 100 °C	20000	$p_{667N\ operational}$	0.95	6
310	7.18 Final Inspection	Perform final inspection and measurements						

8.3 Parking Brake

8.3.1 Cable Tension

8.3.1.1 Apply cable tension between 900 and 1000 N, hold for 10 seconds, and then release. Repeat for a total of three tensioning cycles.

8.3.1.2 Set the park brake cable's initial tension to 50 N unless specified by the test requestor.

8.3.1.3 Zero the cable travel measurement device.

8.3.2 Parking Brake Burnish

8.3.2.1 For vehicles with parking brake systems not utilizing the service friction elements, burnish the friction elements of such a system before the parking brake test according to the manufacturer's published recommendations furnished to the purchaser. If there are no specific recommendations or instructions, conduct the test in an unburnished condition.

8.3.2.2 Parking brake systems utilizing service brake friction materials shall be tested with the IBT ≤100 °C (212 °F). They shall have no additional burnishing or artificial heating before the start of the parking brake test.

8.3.2.3 Parking brake systems utilizing non-service brake friction materials shall be tested with the friction materials at ambient temperature at the start of the test. The friction materials shall have no additional burnishing or artificial heating before or during the parking brake test.

8.3.3 Test Procedure for the Torque Output Method

8.3.3.1 Start the continuous data collection for torque, pressure, tension, and cable travel.

8.3.3.2 Apply service brake pressure to P_{HH}.

8.3.3.3 Apply static torque to T_{HH}. Verify that the brake assembly remains stationary, and that no rotor/drum rotation occurs. If rotor/drum rotation occurs, increase service brake pressure by 20% and apply static torque T_{HH} again. Continue increasing the service brake pressure until the brake assembly remains stationary.

8.3.3.4 If applicable, apply cable tension to 250 N for the mechanical parking brake or requestor-provided voltage or current for EPB at a lower level (defined by the test requestor).

8.3.3.5 Lock the cable input travel for the mechanical parking brake.

8.3.3.6 Release the service brake pressure.

8.3.3.7 If the breakaway has not yet occurred, increase the torque to the brake at a rate not to exceed 1000 N·m/s until achieving the breakaway. Limit the amount of brake rotation to 20 degrees to limit the bedding effect.

8.3.3.8 Repeat A.5.3 through A.5.10 at 750 N cable tension for mechanical parking brake or requestor-provided voltage or current for EPB at a higher level, if applicable.

NOTE: Cable loads other than 250 N and 750 N are allowed if the requestor indicates.

8.3.3.9 Repeat 8.3.1.2, 8.3.1.3, and 8.3.3.1 through 8.3.3.8 in the reverse vehicle direction.

8.3.3.10 Method A (Torque Output Method)

Figure 3 illustrates the main steps followed during the execution of a static parking brake test sequence described in 8.3.3:

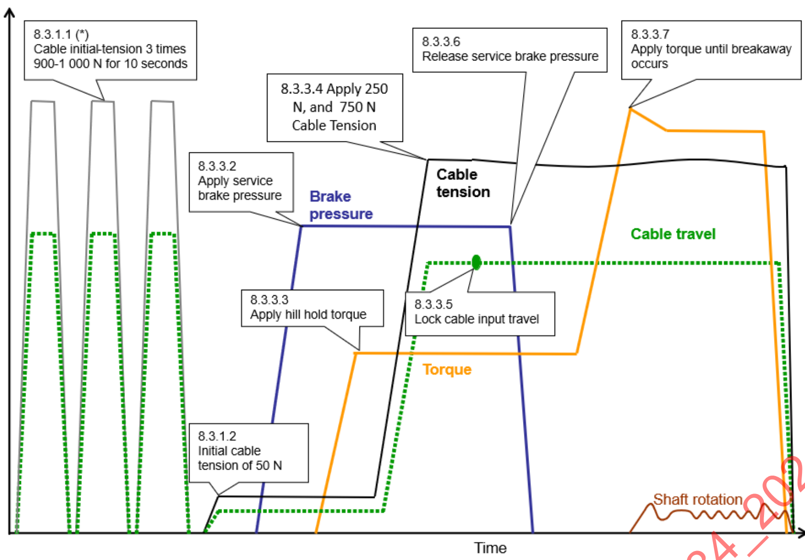

Figure 3 - Typical torque output static parking brake application sequence

8.3.4 Test Procedure for Hill-Hold Method

8.3.4.1 Apply service brake pressure to P_{HH}. If it is not sufficient to hold, then increase the pressure without exceeding the pressure limit of the brake corner.

8.3.4.2 Apply static torque to T_{HH}.

8.3.4.3 For vehicles with mechanical parking brakes, apply once the parking brake control with force allowed for the specific vehicle. Apply a cable force to the parking brake resulting from the parking brake input force at the cabin.

8.3.4.3.1 For vehicles under FMVSS 135, apply a parking brake input force that does not exceed 400 N for hand brake control and does not exceed 500 N for foot brake control.

8.3.4.3.2 For vehicles under FMVSS 105, apply a parking brake input force that does not exceed 400 N for hand brake control and does not exceed 556 N for foot brake control.

8.3.4.4 For vehicles with EPB, apply the parking brake by activating the control following the manufacturer's specified operational current and voltage. If the manufacturer cannot provide this, obtain this value measuring on a vehicle following the setup per TP-135. If the dynamometer cannot energize the caliper, then use the equivalent service brake pressure.

8.3.4.5 Lock the cable input travel; not applicable for EPB.

8.3.4.6 Following the application of the parking brakes, release all force on the service brake control and apply static torque drive to generate a torque level of T_{HH}. If the vehicle remains stationary, start the measurement of 315 seconds.

8.3.4.7 The parking brake system shall hold the vehicle stationary for 5 minutes in both a forward and reverse direction on the grade.

8.3.4.8 Repeat the sequence two additional times for a total of three applies.

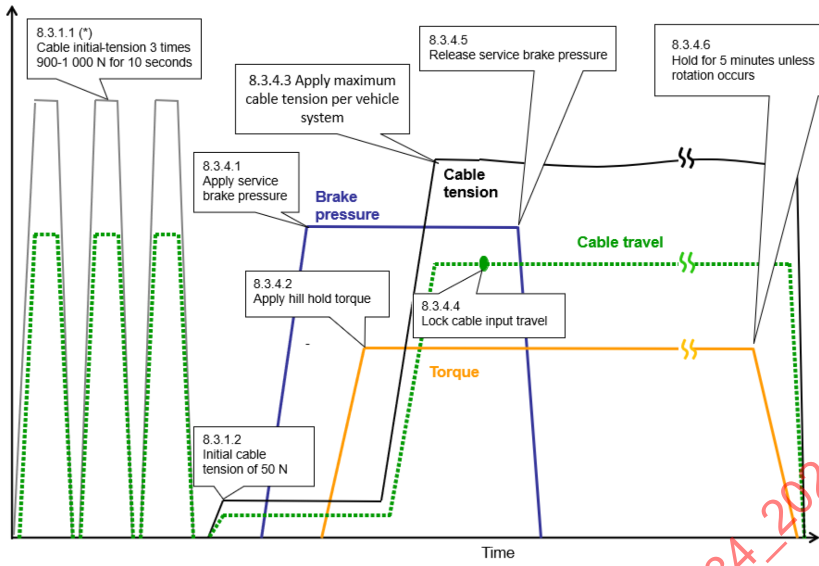

Figure 4 - Typical hill-hold static parking brake application sequence

9. TEST REPORT

9.1 Applicable to FMVSS 135

9.1.1 Graphs

For the entire test, present the following:

In-stop pressure, brake temperature, and apparent coefficient of friction (or brake effectiveness) for all brake applications. For the Burnish Section, graph every 10th stop. See Appendix C.

9.1.2 Tabular Data

For each brake application, indicate the appropriate units of measurement. See Appendix C.

a. Braking and release speed.

b. Cycle time.

c. Average by distance apparent coefficient of friction (or drum brake effectiveness), torque, and pressure.

d. Initial and final apparent coefficient of friction (or drum brake effectiveness) at times t_1 and t_2, respectively.

e. Minimum and maximum torque and pressure between time t_1 and time t_2.

f. Brake temperature of the rotor or drum, and optionally the lining at time t_0 and time t_4.

g. Maximum fluid displacement.

9.1.3 Cooling Air Temperature and Humidity for Each Section of the Test

9.1.4 Wear Measurements and Final Integrity Inspection

Measure and report initial and final thickness and mass loss for rotor or drum and all friction materials under testing per SAE J2986. Record and report cracks, detachment, delamination, brake fluid leaks, or any unusual condition on the rotor or drum.

9.1.5 Test Conditions

Record and report brake parameters, brake hand, rotor or drum, lining identification, test conditions, and total test run-time.

9.1.6 Cooling Air Conditions

Report cooling air direction and orientation.

9.2 Applicable to FMVSS 105

9.2.1 Same as 9.1.

9.3 Parking Brake Behavior and Output

a. Breakaway torque and equivalent percent grade.

b. Cable travel versus the input cable tension (or equivalent).

c. Each level for both forward and reverse directions.

d. Input cable tension for mechanical systems or current and voltage for EPB. Input clamping force for EPB is optional.

e. Input cable travel.

f. Hold time (for hill-hold method).

10. NOTES

10.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE BRAKE DYNAMOMETER STANDARDS COMMITTEE

APPENDIX A - PARKING BRAKE CALCULATIONS

A.1 SCOPE

The following paragraphs describe the formulas used for the parking brake section.

A.1.1 Torque and Pressure Calculations for Service Brake Hill-Hold

Calculate the total braking torque required to hold the vehicle on a hill using Figure A1 and Equation A1.

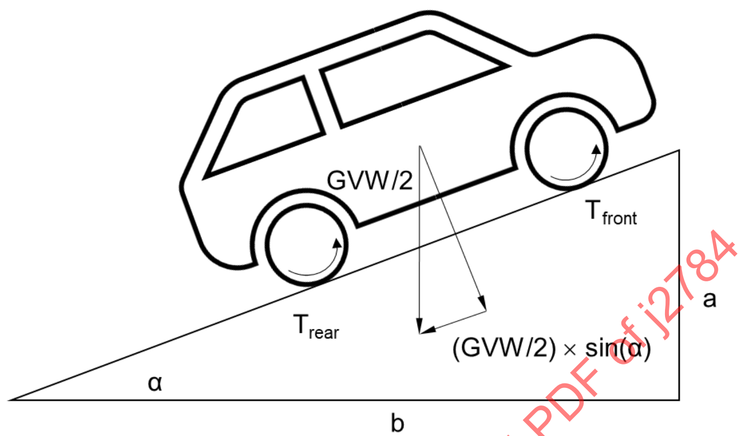

Figure A1 - Hill-hold acting forces and torques

$$T_{HH} = (9.81 \cdot GVWR/2) \cdot \sin[\tan^{-1}(Grade/100)] \cdot SLR \qquad \text{(Eq. A1)}$$

where:

T_{HH} = total brake torque required to hold half the vehicle on a hill of a given grade

Grade = a/b (unitless)

SLR = tire static loaded radius is the vertical distance from the tire center of rotation to the ground calculated from Equation A2 when the tire is at its maximum load capacity at the specified inflation pressure (m)

$$SLR = \frac{dr}{2} + 0.78 \cdot (w \cdot ar) \qquad \text{(Eq. A2)}$$

where:

dr = nominal rim diameter (m)

w = nominal section width of the tire (m)

ar = aspect ratio of the tire (unitless)

Table A1 shows example calculations for two vehicle weights and three grade levels.

Table A1 - Example calculations for hill-hold torque values

Grade	Vehicle GVWR (kg)	Rear Tire SLR (m)	Torque Required to Hold Half Vehicle Stationary T_{HH} (N·m)
10%	2000	0.325	317
20%	2000	0.325	625
30%	2000	0.325	915
10%	3000	0.325	476
20%	3000	0.325	937
30%	3000	0.325	1373

Calculate the specific torque for the rear brake using Equation A3.

$$RT_{SP} = T / p \tag{Eq. A3}$$

where:

RT_{SP} = rear brake specific torque (Nm/kPa)

T = average by distance torque from the last 10 brake applications from Table 3, Section 10 or Table 4, Section 40 (N·m)

p = average by distance pressure from the last 10 brake applications from Table 3, Section 10 or Table 4, Section 40 (kPa)

Calculate total vehicle-specific torque assuming a torque split equal to the inertia split at GVWR with the brake system fully operational using Equation A4.

$$TT_{SP} = RT_{SP} / Y_1 \tag{Eq. A4}$$

where:

TT_{SP} = total vehicle-specific torque (N·m/kPa)

Y_1 = rear axle torque split per Equation A5

Calculate rear brake pressure to hold the half vehicle on a hill using Equation A5.

$$P_{HH} = T_{HH} / TT_{SP} \tag{Eq. A5}$$

where:

P_{HH} = brake pressure (kPa)

Alternatively, when the torque values for the front and rear brake are available, calculate brake pressure for the rear corner to hold half a vehicle on a hill using Equation A6.

$$P_{HH} = \frac{T_{HH}}{FT_{SP} + RT_{SP}} \quad \text{(Eq. A6)}$$

where:

FT_{SP} = front brake specific torque (Nm/kPa)

APPENDIX B - EXPLANATORY NOTES

B.1 APPLICABLE TO FMVSS 135 AND FMVSS 105

B.1.1 Start Time for Brake Application

During an FMVSS 135 vehicle sequence, the brake application starts at time t_0 when the pedal force reaches or exceeds 22 N. During inertia-dynamometer testing, convert this pedal force to the equivalent brake pressure. This pressure setpoint becomes the brake threshold pressure for the different calculations and time marks.

B.2 ROTOR/DRUM VERSUS LINING/SHOE TEMPERATURE

Even though the vehicle test uses thermocouples on the stationary components (brake lining or brake shoe), the Task Force recommends using thermocouples on the rotors or drums and using those temperatures to control the test. The thermal properties of cast iron rotors and drums are more stable and predictable than the linings. Since the cooling air systems of most brake dynamometers do not duplicate the actual cooling environment of the vehicle, it was determined that having accurate and repeatable temperature profiles outweighed the concerns of controlling the initial temperature of the rotors/drums rather than the linings/shoes. The Task Force recommends measuring lining/shoe temperatures for reference.

B.3 DECELERATION CONTROL

The FMVSS vehicle tests limit the maximum pedal force applied during the different brake events, which becomes the input brake pressure to the foundation brakes. The evaluation of the stopping distance for the vehicle has an equivalent deceleration level. Based on the experience gathered during the development of this document, controlling brake deceleration level for most of the sections during the test and limiting the brake pressure provides a more accurate representation of the lining conditioning observed during the actual vehicle test compared to pressure control alone.

B.4 20-SECOND CYCLE TIME DURING THE HOT PERFORMANCE SECTION FOR FMVSS 135

The FMVSS 135 specifies that the vehicle shall accelerate as rapidly as possible after the 15th heating snub and the first hot performance stop. To eliminate the vehicle-to-dyno and the vehicle-to-vehicle variation in acceleration times, this recommended practice introduces a constant cycle time that most modern inertia dynamometers can meet.

B.5 INERTIA-DYNAMOMETER COOLING SPEED

One of the critical elements during inertia-dynamometer testing is the efficiency and the time required to execute the test. This efficiency improves by minimizing the time the brake takes to cool down to the required temperature for the next brake event. It is common practice to use 50% of the braking speed for the next brake event as an efficient speed for sections controlled by the initial brake temperature at the start of the brake application. This cooling speed also allows the inertia dynamometer to accelerate to the braking speed using standard drive capabilities and does not compromise the initial temperature for the next brake event.

During vehicle testing, factors such as brake drag, brake cooling capacity, the thermal conductivity of the friction material, rotor thermal mass distribution and fin design, drum design and thermal characteristics, air circulation around the brake components, and brake position (front or rear) affect the actual temperature at the beginning of the brake application. Another source of standardization is the definition of initial brake temperature as the temperature at the start of the brake application instead of the average temperature of the service brake 0.32 km before any brake application during an actual FMVSS 135 vehicle test. Rotating the brake assembly for extended periods can alter the transfer layer or extend the test duration.