



Braking in a Turn

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 objectively quantify the yaw response of a vehicle to brake application while negotiating a steady state turn.

1.2 Applicability. This standard is applicable to passenger cars and light trucks up to 3500 kg (7716 lb) Gross Vehicle Mass (GVM) loaded within permissible limits. Trucks with GVM greater than 3500 kg (7716 lb) may use this procedure, but reduced test speeds may be necessary.

1.3 Remarks. This standard is intended to quantify the yaw response of a vehicle to braking in a turn. The entire deceleration range is considered to address that influence of chassis, tire, brake, and control system.

2 References

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

2.1 External Standards/Specifications.

FMVSS 135

2.2 GM Standards/Specifications.

None

2.3 Additional References. None.

3 Resources

3.1 Facilities. Test is to be conducted on flat, level surfaces (less than 1% grade in any direction) with adequate length, width and runoff to allow fixed, control steering and braking. Surface friction characteristics should be known to allow comparisons between vehicles and test sites.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Speed Measurement Device and Readout. The speed transducer must be capable of reading velocity in excess of the vehicle test speed, a minimum of 150 km/h (93.2 mph) is recommended. The transducer accuracy must be within 0.5 km/h (0.3 mph) over the speed range of 5 km/h to 150 km/h (3.1 mph to 93.2 mph).

3.2.2 Accelerometer. Oriented to measure longitudinal acceleration at vehicle's center of gravity (CG). The accelerometer must be capable of measuring a minimum of 1.2G, with an accuracy of 0.01G.

3.2.3 Accelerometer. Oriented to measure lateral acceleration at vehicle's center of gravity. The accelerometer must be capable of measuring a minimum of 1.2G, with an accuracy of 0.01G.

3.2.4 Angular Rate Sensor. Oriented to measure yaw velocity. The angular rate transducer must be capable of measuring at ± 50 degrees with an accuracy of 0.5 degrees.

3.2.5 Steering wheel angle transducer and constraint.

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3.2.6 Driver-readable deceleration indicator.

3.2.7 Brake application indicator or pedal force transducer.

3.2.8 Digital data acquisition system.

3.2.9 Appropriate signal conditioning equipment and cabling.

3.2.10 Roll angle transducer (optional).

3.2.11 Sideslip angle transducer (required on vehicles with Electronic Stability Control (ESC), optional on all other vehicles).

3.3 Test Vehicle/Test Piece. The specific vehicle chosen for testing should be representative of the vehicle population with respect to brake system, tire, suspension and mass distribution properties. Extreme cases of the preceding parameters should also be addressed.

3.4 Test Time.

Calendar time: 2 days

Test time: 4 hours

Coordination time: 8 hours

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. An experienced brake/vehicle dynamics test technician is required to perform vehicle and instrumentation setup and conduct the test.

4 Procedure

4.1 Preparation.

4.1.1 The vehicle to be tested must be in safe operating condition for maneuvering levels approaching the limit of vehicle performance. Condition of tire, brake and suspension components should be inspected carefully. All vehicle safety equipment must be in proper operating condition.

4.1.2 Vehicles with obviously high CG must be reviewed for roll stability and maneuvers limited or safety equipment added as appropriate.

4.1.3 Brake components are to be prepared per test engineer's instructions. Burnish per FMVSS 135 Light Vehicle Brake Systems, in the absence of other instructions.

4.1.4 Install transducers, data acquisition, driver readouts and steering control equipment.

4.1.5 Calibrate instrumentation as necessary.

4.1.6 Ballast vehicle to achieve loading desired. All ballast must be properly secured.

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

4.1.8 Weigh vehicle in test configuration with full fuel load and driver.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 Wind speed should be less than 24 km/h (14.9 mph).

4.2.1.2 Test surface should be clean and appropriately wetted for the test condition being sought.

4.2.1.3 Recommended test speeds are compiled as shown in Table 1.

Table 1: Recommended Test Speeds

Surface	Recommended Test Speed
Dry Asphalt or Concrete	100 km/h (62.1 mph)
Wet Surfaces, Coefficient < 0.6	50 km/h (31.1 mph)

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4.2.1.4 Other speeds may be specified to suit the vehicle/surface combination depending on facility, vehicle or safety constraints.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions.

4.3.1 Braking in a Turn Test.

4.3.1.1 Accelerate vehicle to test speed and stabilize.

4.3.1.2 Stabilize vehicle in a straight running condition approaching test area.

4.3.1.3 Lock steering in straight ahead position.

4.3.1.4 Start data acquisition.

4.3.1.5 Maintain test speed for a minimum of 1.0 s.

4.3.1.6 Input desired steer angle and hold steer against steering wheel lock device. Maintain steer input and vehicle velocity constant for at least 2.0 s, allow vehicle to stabilize.

4.3.1.6.1 Steer amplitude to be specified by test engineer. It is typical that it corresponds to 80% of maximum lateral acceleration, though other levels may be used to accommodate specific vehicle configurations. The steer angle to be used can be determined using a step steer, control response or ramp steer test.

4.3.1.7 Apply brakes with a step-like input of brake force to attain the desired deceleration. For high coefficient surfaces, the recommended deceleration levels are 0.2G to the vehicle limit in 0.2G increments. For lower coefficients (< 0.6), 0.1G to vehicle limit in 0.1G increments is recommended.

4.3.1.7.1 The vehicle limit for non-Anti-Lock Brake System (ABS) equipped vehicles is defined as first axle lock. For ABS equipped vehicles, spike applies are defined to be the limit.

4.3.1.8 For vehicles not equipped with ESC, or vehicles with ESC disabled or malfunctioning, hold brake force constant and steer fixed for 4 s after brake application. For vehicles equipped with ESC, enabled and functioning properly, hold brake force constant and steer fixed until vehicle comes to a complete stop.

4.3.1.9 Stop data acquisition.

4.3.1.10 Repeat 4.3.1.1 thru 4.3.1.9 until two (2) runs have been completed for each sub-limit brake application level and five (5) runs have been completed with spike applies (for ABS equipped vehicles only).

4.3.1.11 Repeat 4.3.1.1 thru 4.3.1.9 for right and left turns.

5 Data

5.1 Calculations.

5.1.1 Yaw Velocity Response Metrics.

5.1.1.1 Calculate initial yaw velocity before brake application. This value becomes the “zero” for the run.

5.1.1.2 Reference Calculations. After correcting for the run zero, calculate the average yaw velocity and vehicle velocity occurring between 1.0 s and 0.25 s before yaw initiation. These are defined as the reference yaw velocity and vehicle velocity.

5.1.1.2.1 The braking event is defined to begin with the signal from the brake application indicator, or 10 N (2.25 lbf) of brake force. The end of the data to be processed shall occur when the vehicle speed falls below 10 km/h (6.21 mph).

5.1.1.3 One Second Yaw Velocity (Rate) Ratio. After correcting for the run zero, calculate the average yaw velocity occurring between 0.9 s and 1.1 s after brake initiation. This is the one second yaw velocity. The one second yaw velocity ratio is defined as the one second yaw velocity divided by the reference yaw velocity from 5.1.1.2.

5.1.1.4 Peak Yaw Velocity (Rate) Ratio. Determine the maximum (absolute) value of the yaw velocity of the vehicle after brake initiation. The ratio of the value to the reference is defined as the peak yaw velocity ratio.

5.1.1.5 Normalized Yaw Velocity (Rate) Ratio. The normalized yaw velocity is defined as the instantaneous yaw velocity divided by the instantaneous vehicle velocity. The proper units for these quantities are radians/s and m/s, however there is no need to convert the units if the normalized yaw velocity ratio is all that is to be calculated.

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5.1.1.5.1 The normalized yaw velocity ratio is defined as the instantaneous normalized yaw velocity divided by the reference yaw velocity over the reference velocity.

5.1.1.6 One Second Sideslip Angle. After correcting for the run zero, calculate the average sideslip angle occurring between 0.9 s and 1.1 s after brake initiation. This value is defined as the one second sideslip angle.

5.1.1.7 Peak Sideslip Angle. Determine the maximum (absolute) value of the vehicle sideslip angle after brake initiation. This value is defined as the peak sideslip angle.

5.1.1.8 Deceleration Calculation. Calculate the average deceleration for the run using a linear regression on vehicle speed vs. time for the interval 0.5 s to 1.5 s after brake initiation.

5.1.1.9 Plots. The yaw rate ratios and sideslip angle responses are plotted as a function of the deceleration calculated in 5.1.1.8.

5.1.2 Deceleration Ratio Metric.

5.1.2.1 Run five (5) corrective steer stops with spike applied from the test speed on the surface used for the braking in a turn test.

5.1.2.2 Calculate the average deceleration of the stop (test speed to 10 km/h (6.2 mph)) using a linear regression on velocity as a function of time. Calculate the average of the average decelerations.

5.1.2.3 Calculate the deceleration ratio by dividing the deceleration calculated in 5.1.1.8 by the average deceleration calculated in 5.1.2.2.

5.2 Interpretation of Results.

5.3 Test Documentation. Publish test information and results according to departmental protocol. Example data sheets are in Appendix A, Data Sheets A1 thru A7.

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

7 Notes

7.1 Glossary.

Sideslip Angle: The angle between the vehicle centerline and the vehicle instantaneous velocity vector.

Spike Brake Apply: Application of the brake pedal to a minimum pedal force of 667 N (150 lbf) with a minimum average application rate of 6667 N/s (1500 lbf/s). The maximum pedal force should not exceed 1334 N (300 lbf). After the initial application, the pedal force is held at a level greater than 667 N (150 lbf).

Yaw Velocity (Yaw Rate): Rotational velocity of the test vehicle about a vertical axis.

7.2 Acronyms, Abbreviations, and Symbols.

ABS	Anti-Lock Brake System
CG	Center of Gravity
ESC	Electronic Stability Control
GVM	Gross Vehicle Mass
GVW	Gross Vehicle Weight
LVM	Light Vehicle Mass

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Test to GMW15052

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