



Brake Component Articulation

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 define a method for checking the routing of articulated brake components, such as brake hoses, wheelspeed sensors, electronic pad wear sensors, electric parking brake wire harnesses, and parking brake cables for passenger cars and light duty trucks for all conditions of steering linkage position, suspension travel, wheel alignment, brake hose mounting positions, and component tolerances. Brake component clearances, and where applicable, the bend radii and tension are measured as a quantitative evaluation of the routing.

1.2 Applicability. For passenger cars, multipurpose vehicles, and light duty trucks.

1.3 Remarks. There are no regulatory requirements pertaining to brake corner articulation. For GM requirements for brake corner articulation see the GM Best Practices database (BRAKES-55 for brake hoses and BRAKES-236 for wheelspeed and electronic pad wear sensors). The supplier shall work with the GM responsible engineer to comprehend these requirements.

The Design Engineer is responsible for review of the test results (distances, bend radii, and tension) that are not compliant with these (BRAKES-55 and BRAKES-236). The supplier shall work with the GM responsible engineer to comprehend these requirements.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW3056 GMW15387

2.3 Additional References.

- Excel Spreadsheet: Test Documentation (Milford Proving Ground developed; available from Global Document Management (GDM)
<https://documents.gm.com/gdm3/drl/objectId/090163bc81878ad3/chronicleId/090163bc81268642>) (ID)
- Global Document Management (GDM) System (<https://documents.gm.com/gdm3/component/main>) (ID)
- GM Best Practice Numbers (BRAKES-55 and BRAKES-236) (ID)
- Inland Industrial Supply LTD, Edmonton, Alberta, Canada (www.inlandindustrial.ca)
- Service Manual Procedure
- Starrett Products, Athol, Massachusetts (www.starrett.com)

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3 Resources

3.1 Facilities. A facility having the test equipment described in 3.2 appropriate for the test measurements.

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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 Vehicle Hoist.

3.2.2 Jack Stands.

3.2.3 Jacking Device. Jacking device for cycling suspension through extremes of travel.

3.2.4 Shims. Simulated shim packs or alignment cam kits. Required for setting extreme alignment conditions and nominal conditions (if requested).

3.2.5 Scale and Dividers. For measuring clearances.

3.2.6 Gauges. Radius gauges from 5 mm to 25 mm in 2 mm or 2.5 mm increments. Figure A1 (Appendix A) shows an example gauge. (Possible sources: Inland Industrial Supply, Part Number LF-3950 or Starrett Number S167MD Radius Gauge Set Stainless Steel).

3.2.7 Force Gauge. Handheld force gauge that can record force applied to hose segment by pushing on it in a range of 0 N to at least 150 N.

3.2.8 Paddle. Profile **paddle** to be specified by requesting engineer, and should represent the maximum composite of all possible design intent tire/wheel profiles. It does not include tire **flops** or dynamic deflection. See Figure A3 (Appendix A).

3.2.8.1 Tire paddle to be built from three (3) sections: the lug nut ring, extension arm, and tire/rim paddle. The method of assembly is optional, but the assembled paddle must be torsionally rigid. The paddle must also incorporate proper clearances for drive axles, spindles, and rotor flanges, etc. The specifications for the minimum stock materials are:

- Lug nut ring: Aluminum plate at least 6.35 mm (0.25 in) thick.
- Tire/wheel paddle: Aluminum plate at least 4.76 mm (0.1875 in) thick for tires up to 215 mm wide and at least 6.35 mm (0.25 in) for larger tires.
- Extension arm: Aluminum angle 25.4 mm (1 in) wide by at least 4.76 mm (0.1875 in) thick for rims up to 381 mm (15 in) in diameter and at least 6.35 mm (0.25 in) for larger rims.

3.2.9 Camera. Camera and appropriate recording media to document test.

3.2.10 All instrumentation is to be calibrated as required. Record instrumentation details and date of calibration in the test record.

3.2.11 Caliper to Rotor Spacing Shim. A shim simulating the pad backing plate thickness that can be inserted between the caliper fingers and outboard rotor friction plate (simulates full pad and rotor wear condition).

3.2.12 Suspension Spring Mockup. In vehicles for which the articulated components will pass close to a suspension spring (that has been removed to enable articulation), a mockup of the spring (cardstock or other easy-to-use modeling material) that can be inserted in and removed from the spring seat, and that takes up the same physical space as the spring should be created.

3.3 Test Vehicle/Test Piece.

3.3.1 Test Vehicle. A vehicle equipped to the extent necessary (and as prescribed by the requesting engineer) to perform the test. See 4.1.1.

3.3.2 Test Materials and Components. See Appendix A (Figure A8) for a tabular summary of typical component test configurations.

3.3.2.1 Hoses at maximum length, maximum clockwise coupling orientation.

3.3.2.2 Hoses at maximum length, maximum counter-clockwise coupling orientation.

3.3.2.3 Hoses at minimum length, maximum clockwise coupling orientation.

3.3.2.4 Hoses at minimum length, maximum counter-clockwise coupling orientation.

3.3.2.5 Hoses at nominal length, zero orientation.

3.3.2.6 Left and right hand samples of above, if applicable.

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3.3.2.7 Wheelspeed sensors at maximum attachment spacing, at either side of articulation loop(s).

3.3.2.8 Wheelspeed sensors at minimum attachment spacing, at either side of articulation loop(s).

3.3.2.9 Electronic pad wear sensors (if applicable) at maximum attachment spacing, at either side of articulation loop(s).

3.3.2.10 Electronic pad wear sensors (if applicable) at minimum attachment spacing, at either side of articulation loop(s).

3.3.2.11 If testing components other than those specified in 3.3.2.1 to 3.3.2.10, such as minimum/maximum length park brake cables, electric parking brake wiring harnesses, crossover pipes, or other articulated brake component, required test materials should be prescribed by the requesting engineer.

3.4 Test Time.

Calendar time: 18 days

Test hours: 120 hours

Coordination hours: 24 hours

3.5 Test Required Information. Specialized equipment and a standard data sheet pack are required to conduct this procedure. Consult the Milford Proving Ground Brake Development Group as needed.

3.6 Personnel/Skills. Brake technician or engineer trained for vehicle set up and for performing the instructions in Section 4.

4 Procedure

4.1 Preparation.

4.1.1 Vehicle.

4.1.1.1 Establish ride height condition for front and rear suspension. Ensure the alignment is correct. Determine the required number of turns for each steering tie rod to achieve the oversteer condition detailed in Appendix B, Section B1, while at design ride height.

4.1.1.2 Place vehicle on hoist and support it so that the front and rear suspensions hang free. Remove tire and wheel assemblies.

4.1.1.3 Remove currently installed brake hoses, and cap exposed hydraulic lines.

4.1.2 Front Suspension.

4.1.2.1 Disconnect and remove stabilizer bar. Disconnect the outboard tire rod ends. Loosen control arm pivot bolts to free bushings. Remove suspension travel bumpers. Ensure that shocks/struts can extend to travel limits.

4.1.2.2 Remove suspension coil springs. On torsion bar equipped vehicles, remove the adjustment stop blocks. On leaf spring equipped vehicles, remove all but the main leaf, and provide a spacer for height control. On vehicles for which articulated brake components route near the removed suspension spring, place a mockup of the spring suitable for each suspension travel position in place of the spring.

4.1.2.3 Where applicable, remove control arm mounting nuts and alignment shim packs. Replace self-locking nuts with common nuts to facilitate installation and removal of simulated shim packs.

4.1.2.4 Per test vehicle type, complete 4.1.2.4.1 through 4.1.2.4.3.

4.1.2.4.1 For design development vehicles, qualify all brake hose clips, suspension members, brackets, and chassis members for specifications, proper location, and attachment. Obtain a pretest signoff to record the part level/part number used on the test vehicle and to obtain engineering concurrence that the design represents the latest release (or note exceptions).

4.1.2.4.2 For design check vehicles, qualify all brake hose clips, suspension members, brackets, and chassis members to ensure that the minimum and/or maximum specifications are achieved, and are properly located and attached. Obtain a pretest signoff, to record the part level/part number used on the test vehicle and to obtain engineering concurrence that the design represents the latest release (or note exceptions).

4.1.2.4.3 For monitoring production vehicles, assume all parts and part locations are correct.

4.1.2.5 On vehicles equipped with sliding caliper disc brakes, remove the outboard brake shoe and replace with a shim of equivalent thickness to the pad backing plate (a backing plate without linings or rivets may also be

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used). This simulates a worn lining condition and/or a minimum rotor thickness condition, resulting from service grinding.

4.1.2.6 Reconnect the tie rods.

4.1.3 Rear Suspension.

4.1.3.1 Remove rear suspension springs and loosen control arm pivot bolts to free bushings. On vehicles equipped with leaf springs, remove all leaves except main leaf (**Note:** Main leaf should be the lowest rate released for vehicle under test.) Replace leaves with a shim of equal thickness. On vehicles equipped with coil springs, remove springs. Remove shock absorbers if they are not at the limit of travel. On vehicles for which articulated brake components route near the removed suspension spring, place a mockup of the spring suitable for each suspension travel position in place of the spring.

4.1.3.2 Remove jounce travel bumpers and axle nose pinion bumper. In the case of integral jounce bumpers and/or active suspension components, substitute surrogate component(s) that allow the suspension to articulate through the full dynamic range.

4.1.3.3 Remove or loosen any other component which prevents full suspension travel.

4.1.3.4 On vehicles equipped with sliding caliper disc brakes, remove the outboard brake shoe and replace with a shim of equivalent thickness to the pad backing plate (a backing plate without linings or rivets may also be used). This simulates a worn lining condition and/or a minimum rotor thickness condition, resulting from service grinding.

4.2 Conditions.

4.2.1 Environmental Conditions. Not applicable.

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. All references to Requirements throughout 4.3 refer to the Requirements contained in the Best Practices cited in 1.3 and 2.3. All results documentation invoked in 4.3 shall be recorded in the in the test workbook (Excel spreadsheet; see 2.3).

4.3.1 Photographs. Take photographs of the steering and suspension system at any height and steer position suitable to give full view of all steering and suspension parts. At least one (1) photo set for one (1) front and one (1) rear brake corner should be documented.

4.3.2 Measurements. With the suspensions positioned as listed in 4.3.3 and 4.3.4, record measurements in 4.3.2.1 through 4.3.2.4.

4.3.2.1 Brake Hose Measurements.

4.3.2.1.1 Hose Clearance or Touch. Measure brake hose clearance to stationary components when closer than 10 mm. Measure brake hose clearance to simulated tire wheel paddle, when closer than the limits specified in Requirements. Measure brake hose clearance to rotating components (half shaft, Constant Velocity (CV) joint, boot) when closer than the **green** limit specified in Requirements. Measure brake hose clearance to moving components (control arm, strut, etc.) when closer than the **green** limit specified in Requirements. Measure brake hose clearance to a shielded heat source when less than the **green** limit specified in Requirements, taking note of whether the heat source is shielded or unshielded. If the hose touches any suspension and chassis member, document with photographs as necessary. Denote as **T** for Touch.

4.3.2.1.2 Hose Manipulated Touch. Manually attempt to put brake hose in contact with the tire or wheel or any other part. Denote as **M** for Manipulated touch, all conditions in which the hose can be pushed against another object, but will return to its original position when the pressure is released. If the hose remains against the object and will not return, denote the condition as **R** for Retained touch. Record whether the **R** will release with suspension or steering movement. Hose manipulation should adhere to the following guidelines:

- The hose should be moved with one (1) finger, in one (1) direction at a time.
- The manipulation should stop as soon as a noticeable increase in hose resistance to movement occurs (or when it contacts another object).

4.3.2.1.3 Hose Hooking. Manually attempt to hook brake hose on any projecting fastener or fitting, such as bleeder fitting, control arm shaft end or bolt, casting fin, etc. The opportunity for manually hooking the hose may occur at some intermediate position between jounce and rebound and left to right steer. If it is possible to hook an object, denote the condition as **H** for Hooked.

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4.3.2.1.4 Hose Tension. Hose tension should be assessed subjectively in each articulation position, called for in 4.3.3 and 4.3.4 (and summarized in Appendix A, Figure A6) by gripping the hose near the center of the articulated span and moving it in a circular motion, with a radius defined by the deflection at which the hose tension increases noticeably. If this diameter exceeds 25.4 mm and the requirements for hose bend radii in hose section are met, then no further checks are needed. If the diameter is less than 25.4 mm, or one or more bend radius in the hose section does not meet requirements, then perform the hose tension measurement described in Appendix A, Figure A2.

4.3.2.1.5 Hose Radius. Check and record hose bend radius using gauges.

4.3.2.1.6 Hose Error-Proofing. Check that the rotational error-proofing features on both ends of the brake hose will effectively prevent an incorrect build condition. Check if left hand and/or right hand hose can be installed on opposite side of the vehicle. If the brake hose can be oriented out of design position and still be assembled, record details in the test record. Check if the hose can be installed with 360 degrees of twist beyond the design intent installation between attachment points (for hoses with two (2) attachments, this twist is between the female, body-side fitting and the banjo, caliper side fitting; and for hoses with three attachments, this twist is checked separately between the center fitting and the caliper, and again between the center fitting and the female fitting).

4.3.2.2 Brake System Electrical Conduits; Wheel Speed, Brake Pad Electronic Wear Sensor Harness, and Electric Parking Brake Wire Harness Measurements. Check and record the conditions for electric conduit routing, as shown in 4.3.2.2.1 through 4.3.2.2.4. The text of 4.3.2.2 will refer to wheelspeed sensors, but is applicable to electronic pad wear sensors and electric parking brake harnesses as well.

4.3.2.2.1 Wire Clearance or Touch. Measure wire clearance to suspension, body sheet metal, close-out panels, wiring harness(es), and chassis members when closer than the **green** specification limit. Measure wire clearance to a shielded heat source when less than the specification **green** limits for clearance to heat sources, taking note of whether the heat source is shielded or unshielded. Measure wire clearance to the simulated paddle of tire and wheel, when closer than the **green** limit specified for clearance to wheels/tires. If the wire touches any suspension and chassis member, document with photographs as necessary, and denote as **T** for Touch.

4.3.2.2.2 Wire Manipulated Touch. Manually attempt to put wire in contact with the tire or wheel or any other part. Denote as **M** for Manipulated touch, all conditions in which the wire can be pushed against another object, but will return to its original position when the pressure is released. If the wire remains against the object and will not return, denote the condition as **R** for Retained touch. Record whether the **R** will release with suspension or steering movement.

4.3.2.2.3 Wire Hooking. Manually attempt to hook wire on any projecting fastener or fitting, such as bleeder fitting, control arm shaft end or bolt, casting fin, etc. The opportunity for manually hooking the wire may occur at some intermediate position between jounce and rebound and left to right steer. If it is possible to hook an object, denote the condition as **H** for Hooked.

4.3.2.2.4 Wire Tension. Wire tension should be assessed subjectively in each articulation position called for in 4.3.3 and 4.3.4 (and summarized in Appendix A, Figure A6) by gripping the wire near the center of the articulated span and moving it in a circular motion with a radius defined by the deflection, at which the wire tension increases noticeably. If this diameter exceeds 25.4 mm and the requirements for wire bend radii in wire section are met, then no further checks are needed. If the diameter is less than 25.4 mm or one (1) or more bend radius in the wire section does not meet requirements, then perform the tension measurement described in Appendix A, Figure A2.

4.3.2.3 Manual Park Brake Cable. Check and record for the following conditions for the park brake cable(s).

4.3.2.3.1 Cable Clearance or Touch. Measure park brake cable clearance to moving components when closer than 25 mm. Measure park brake cable clearance to stationary or adjoining components when closer than 5 mm (excluding cable brackets). If the park brake cable touches any other component, document with photographs as necessary, and denote as **T** for Touch.

4.3.2.3.2 Cable Manipulated Touch. Manually attempt to put wire in contact with the tire or wheel or any other part. Denote as **M** for Manipulated touch, all conditions in which the park brake cable can be pushed against another object or the sheet metal underbody, but will return to its original position when the pressure is released. If the park brake cable remains against the object and will not return, denote the condition as **R** for Retained touch. Record whether the **R** will release with suspension or steering movement.

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4.3.2.3.3 Cable Hooking. Manually attempt to hook park brake cable on any projecting fastener or fitting, such as bleeder fitting, control arm shaft end or bolt, casting fin, etc. The opportunity for manually hooking the park brake cable may occur at some intermediate position between jounce and rebound and left to right steer. If it is possible to hook an object, denote the condition as **H** for Hooked.

4.3.2.4 Suspension/Axle Mounted Components. This section applies to components that are mounted on and articulate with the front or rear vehicle suspension. Common examples include crossover pipes and mounting brackets on a solid rear axle, or a pipe/hose section and brackets on a rear suspension arm. For these components, check and record the conditions in 4.3.2.4.1 and 4.3.2.4.2.

4.3.2.4.1 Suspension/Axle Mounted Component Clearance or Touch to Articulated Components with Two (2) Degrees of Freedom. Measure clearance to any moving components with two (2) degrees of freedom (such as translation and rotation) when closer than the limits specified for brake pipe clearance to Two-Dimensional (2-D) moving components in Requirements. If the mounted component touches any other component, document with photographs as necessary, and denote as **T** for Touch.

4.3.2.4.2 Suspension/Axle Mounted Component Clearance or Touch to Articulated Components with One (1) Degree of Freedom. Measure clearance to any moving components with one (1) degree of freedom (such as pure translation or pure rotation) when closer than limits specified for brake pipe clearance to 2-D moving components in Requirements. If the mounted component touches any other component, document with photographs as necessary, and denote as **T** for Touch.

4.3.3 Front (Steered) Suspension Test. For each of the test hose assemblies specified in 3.3.2.1 through 3.3.2.5 and installed in accordance with Service Manual Procedure, set the suspension and alignment at each of the following in sequence, and check the brake component routing with caliper inboard and with caliper outboard. Allow brackets and fittings to rotate in their natural position, as bolts are tightened. However, monitor clearance condition when bracket and hose fitting are rotated in opposite direction of their natural rotation, and record any abnormal or unusual conditions. Specific clearance measurements in the rotated position are not required unless needed to show significant differences. A visual map of articulation positions appears in Appendix A, Figure A6. For vehicles equipped with sliding disc brake calipers, check each articulation position with the caliper at the maximum inboard (full pad wear) and outboard (new pad condition) positions.

4.3.3.1 Suspension at full rebound, at center steer position. Suspension alignment set to maximum obtainable positive caster with positive camber where possible.

4.3.3.2 Same as 4.3.3.1 except at extreme **left** steering position. As the suspension is articulated from center, the operator should observe for any minimum clearance conditions. If a minimum clearance condition exists at an interim steer angle, details should be documented.

4.3.3.3 Same as 4.3.3.1 except at extreme **right** steer position. As the suspension is articulated from center, the operator should observe for any minimum clearance conditions. If a minimum clearance condition exists at an interim steer angle, details should be documented.

4.3.3.4 Repeat 4.3.3.1 through 4.3.3.3 except at ride height condition as designated in 4.1.1.1.

4.3.3.5 Repeat 4.3.3.1 through 4.3.3.3 except at full jounce position.

4.3.3.6 Vehicles with adjustable caster and camber only. Repeat 4.3.3.1 through 4.3.3.5 three (3) more times except with the alignment set at:

4.3.3.6.1 Maximum negative caster, with negative camber where possible.

4.3.3.6.2 Maximum positive camber, with negative caster where possible.

4.3.3.6.3 Maximum negative camber, with positive caster where possible.

4.3.3.6.4 Repeat 4.3.3.1 through 4.3.3.5 for nominal camber and caster, using the nominal hose (3.3.2.5).

4.3.3.7 Repeat 4.3.3.1 through 4.3.3.6 Front Suspension Test, both minimum and maximum lengths of any applicable electrical harnesses (wheelspeed sensors, electronic pad wear sensors, and electric parking brake harnesses).

4.3.3.8 Repeat 4.3.3.1 through 4.3.3.6 Front Suspension Test for additional components or component configurations called for by the test requestor.

4.3.3.9 When all components on test have completed 4.3.3 Front Suspension Test, review the results with the test requestor to determine if there are any interactions between component configurations that need to be evaluated. Interactions between component configurations are situations where the combination of one (1)

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