



Hydraulic Brake Hose Assembly

1 Scope

This specification defines the requirements for hydraulic brake (jounce) hose assemblies. This hose assembly is suitable for use at temperatures of -40 °C to 120 °C, and operating pressures up to 20.7 MPa.

1.1 Material Description.

1.1.1 Hose Construction.

1.1.1.1 Inner Tube. The inner tube of the hose shall consist of a smooth inner rubber tube of Ethylene Propylene Diene Monomer (EPDM), or a blend of Ethylene Propylene Diene Monomer and Isobutene-Isoprene Rubber (EPDM-IIR). There shall be no materials in the tube compound extractable through exposure to either DOT 3 or DOT 4 brake fluids, as evidenced by 0 or positive values for volume change when the hose is tested to the requirements of 3.1.3.4 for each of the two (2) fluids, DOT 3 and DOT 4. No halogenated butyl polymer may be added to the rubber of the inner tube.

1.1.1.2 Reinforcement. The reinforcement for the hose shall consist of two (2) layers of Polyvinyl Alcohol (PVA) or rayon. A rubber cushion liner may be placed between the two (2) layers of reinforcement. Alternative reinforcement materials may be considered after review and approval by the GM Materials Engineer issuing the specification approval.

1.1.1.3 Cover. The outer cover of the hose shall consist of a layer of EPDM.

1.1.2 Coupling Construction.

1.1.2.1 Coupling Design. The coupling shall be designed, inserted, swaged or crimped so that no internal tube abrasions, cuts or flaws shall result under any condition or combination of assembly component dimensioning or tolerancing allowed by supplier production specifications or under any condition of rubber hose compression allowed by supplier production specifications.

1.1.2.2 Corners. Sharp corners shall be avoided where the coupling contacts the tube to prevent cutting of the hose when subjected to internal pressure.

1.1.2.3 Tube Insert. The tube insert must not extend past the end of the crimp shell after crimping, and the end of the tube insert must be radiused to eliminate burrs or sharp edges which might cause hose damage under conditions of assembly vibration or pressure impulse.

1.1.2.4 Damage. Damage to hose rubber or reinforcement generated by the crimping of the hose is not permissible under any possible production manufacturing conditions or supplier production tolerance stack-up, including variations in hose compression concentricity.

1.1.2.5 Tube Collapse. Metal tube insert collapse during crimping is not permissible, except when this collapse is limited, predictable, controllable and does not increase the potential for assembly leakage or other malfunction.

1.1.2.6 Design Restrictions. Grooves, upsets, or serrations are not permitted on the tube stem Outside Diameter (OD), or on the crimp shell Inside Diameter (ID), except that these grooves, upsets, or serrations do not cause hose cutting or other damage under any condition or combination of assembly component dimensioning or tolerancing allowed by supplier production specifications, or under any condition of rubber hose compression allowed by supplier production specifications.

1.1.2.7 Skiving, Adhesives. Skiving of the hose is not permissible. Use of adhesives in the crimped joint is not permissible.

1.1.2.8 Flow Requirements. The coupling shall be designed for low flow restriction.

1.1.2.9 Fluid Compatibility. All hose assemblies supplied to this specification must be compatible with the following brake fluids. Use of these hose assemblies with other grades or types of brake fluid requires complete retest to this specification with those brake fluid(s), for those test procedures requiring the use of brake fluid.

- DOT 3.
- DOT 4.

1.1.2.10 Dimensions and Tolerances. Bulk hose shall conform to the dimensions shown in Table 1.

Table 1: Bulk Hose Dimensions

Inside Diameter (ID)	millimeters	inches
	3.0	1/8 (0.125)
	3.2	1/8 (0.125)
	4.0	3/16 (0.1875)
	4.5	3/16 (0.1875)
	4.8	3/16 (0.1875)
	5.0	3/16 (0.1875)

1.1.3 Material Identification and Marking. To properly define the hose, the material specification number (GMW3056) is to be referenced. The hose marking must conform to labeling requirements specifying government regulations, such as United States of America Federal Motor Vehicle Safety Standard (FMVSS) 106.

1.2 Symbols. Not applicable.

1.3 Applicability. Hydraulic brake (jounce) hose assemblies.

1.4 Remarks. None.

2 References

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

2.1 External Standards/Specifications.

ASTM D380	ASTM D865	ISO 37	ISO 7619-1
ASTM D395	ASTM D2240	ISO 188	SAE J1401
ASTM D412	ASTM E4	ISO 815	SAE J1927
ASTM D413	FMVSS 106	ISO 1817	SAE J2995
ASTM D471	ISO 36	ISO 7500-1	

2.2 GM Standards/Specifications.

GMW3059	GMW14361	GMW15272	GMW17436
GMW3221	GMW14362	GMW15387	GMW17836
GMW3286	GMW14731	GMW16837	
GMW14270	GMW14872	GMW16955	

2.3 Additional References.

- GM Drawing 9442997

3 Requirements

3.1 Requirements on Test Specimens. Reference GMW3221.

3.1.1 General Test Requirements. Ambient temperature test conditions shall be held to 23 °C ± 5 °C. All other temperatures except 23 °C ± 5 °C shall be held to ± 3 °C, and all pressures to -0 kPa/+690 kPa unless otherwise noted. Where DOT 3 fluid is referenced for test purposes, brake fluid meeting specification GMW16955, Fluid A2

shall be used. Where DOT 4 fluid is referenced for test purposes, brake fluid meeting specification GMW16955, Fluid A1 shall be used.

Note: Additional general test requirements are referenced in 3.1.4. It is suggested that this section be read first, before reading 3.1.1.1 thru 3.4.

3.1.1.1 Oil Resistance Test. See Table 2.

Table 2: Oil Resistance Test

Test	Requirement	Pass Criteria
Oil Resistance of Rubber Cover	48 h at 70 °C	Maximum swell shall be no more than 15%

3.1.1.1.1 Test Procedure. Six (6) hose assembly samples at nominal hose compression are to be tested using DOT 4 brake fluid meeting GMW16955, Fluid A1.

3.1.1.1.2 Fluid Fill and Oil Immersion. The hose assembly shall be filled with brake fluid, sealed, immersed in oil according to GMW16955, Fluid F and stored for 48 h at 70 °C $\pm$ 3 °C.

3.1.1.1.3 Acceptance Determination. The outer diameter of the hose shall not increase more than 15% after storage.

3.1.1.2 Stress-Corrosion Cracking. See Table 3.

Table 3: Stress-Corrosion Cracking

Test	Requirement	Pass Criteria
Stress Corrosion Cracking	4 h at 23 °C	No evidence of cracks

3.1.1.2.1 Test Procedure. Twelve (12) hose assembly samples at nominal hose compression are to be exposed to an atmosphere of ammonia as the corrosive medium for 4 h. The test shall be performed at a temperature of 23 °C $\pm$ 3 °C.

3.1.1.2.2 Test Method. Equipment and test procedure shall be prepared in accordance with test method GMW14731.

3.1.1.2.3 Acceptance Determination. Following examination under 7 $\times$ magnification, the test piece shall be free of cracks.

3.1.1.3 Static Ozone Test. See Table 4.

Table 4: Static Ozone Test

Test	Requirement	Pass Criteria
Static Ozone	336 h	No cracks shall be visible after 336 h of testing

3.1.1.3.1 Test Procedure. Six (6) hose samples shall be tested. After removing any armor on the sample, bend a brake hose 360 degrees around a mandrel and bind the ends. Mandrel diameter is to be 76.2 mm for 3.0 mm ID hose, and 88.9 mm for 4.5 mm ID hose. In the case of a hose sample shorter than the circumference of the cylinder, bend the hose so that as much of its length as possible is in contact. The cylinder and binding shall be made of metal or materials that consume the minimum of ozone. If the hose collapses when bent around the cylinder, provide for internal support of the hose by use of a metal liner.

3.1.1.3.2 Hose Conditioning. Condition the hose on the cylinder for 24 h $\pm$ 0.5 h in ozone-free air at room temperature, and then place it in an exposure chamber containing ozone in the proportion of 100 pphm $\pm$ 10 pphm for 336 h $\pm$ 2 h. Ambient air temperature in the chamber during the test shall be 40 °C $\pm$ 2 °C.

3.1.1.3.3 Examination Procedure. Examine the cover of the hose for cracks under 7× magnification, ignoring the areas immediately adjacent to or within the area covered by the binding. Record whether or not cracks in the hose are present.

3.1.1.3.4 Acceptance Determination. No cracks shall be visible under 7× magnification.

3.1.1.4 Dynamic Ozone Test. See Table 5.

Table 5: Dynamic Ozone Test

Test	Requirement	Pass Criteria
Dynamic Ozone	840 h	No cracks shall be visible after 840 h of testing

3.1.1.4.1 Test Procedure. Six (6) hose samples shall be tested. Conduct the test per SAE J1401, 3.2.13. Test duration is to be 840 h.

3.1.1.4.2 Acceptance Determination. No cracks will be visible on the hose under 7× magnification after 840 h of testing.

3.1.2 Mechanical Requirements.

3.1.2.1 Leak Test. See Table 6.

Table 6: Leak Test

Test	Requirement	Pass Criteria
Leak	10.3 MPa to 14.5 MPa (1495 psig to 2103 psig)	No evidence of leakage

3.1.2.1.1 Test Procedure. The test assembly shall be pressurized with air or an inert gas to a minimum pressure of 10.3 MPa (1494 psig), maximum pressure of 14.5 MPa (2103 psig). Pressure shall be held for a minimum of 10 s, a maximum of 25 s.

3.1.2.1.2 Acceptance Determination. There shall be no evidence of leakage at the coupling or in the hose member.

3.1.2.1.3 Production Process Requirement. This test, or equivalent safeguard, must be employed for 100% of production parts. The method of testing shall be determined by the manufacturer and approved by the GM Materials Engineer issuing the Engineering Source Approval for the brake hose assembly.

3.1.2.2 Burst Test. See Table 7.

Table 7: Burst Test

Test	Requirement	Pass Criteria
Burst	78.0 MPa (11 300 psig)	Minimum burst pressure
Burst (3.1.2.5, 3.1.2.9, 3.3.2.9)	70.0 MPa (10 145 psig)	Minimum burst pressure
Burst (3.1.2.11, 3.3.2.6)	65.5 MPa (9493 psig)	Minimum burst pressure
Burst (3.3.1.1)	50.0 MPa (7250 psig)	Minimum burst pressure

3.1.2.2.1 Test Apparatus. The test apparatus shall consist of a pressure source capable of generating fluid pressure of 172 MPa/minute $\pm$ 69 MPa/minute (25 000 psig/minute $\pm$ 10 000 psig/minute), at an increasing rate and a system in which the internal fluid pressure of the hose assembly can be controlled and measured, provision for filling the hose with water and hardware as required that is adapted to high-pressure work. The pressure shall be obtained by a suitable means and measured with a calibrated gage. All piping and connections shall be smooth bore with a minimum of recesses or offsets, so that air may be freely removed from the system before

running each test. The apparatus described for the expansion test may be used when it conforms to these requirements.

3.1.2.2.2 Test Procedure. Eighteen (18) assemblies are to be tested; six (6) at minimum hose compression, six (6) at nominal hose compression, and six (6) at maximum hose compression. Connect the specimen to the pressure system and fill completely with water, allowing all air to escape. Moving the hose back and forth may facilitate removal of air bubbles. Apply (41.4 +2.1/-0) MPa ((6000 +300/-0) psig) pressure at the rate specified in 3.1.2.2.1 and hold for 2 minutes (+0/-10) s. At the expiration of this hold period, increase the pressure at the rate specified in 3.1.2.2.1 until the hose bursts. Read the maximum pressure obtained on the calibrated gage to the nearest 0.7 MPa (100 psig) and record as the burst strength of the hose assembly. For hose assemblies preconditioned by temperature or fluid exposure, the hold pressure shall be (27.6 +2.1/-0) MPa ((4000 +300/-0) psig), instead of (41.4 +2.1/-0) MPa ((6000 +300/-0) psig).

3.1.2.2.3 Acceptance Determination. There must be no leaks or blisters in the hose assembly at the hold pressure of 41.4 MPa (6000 psig) or 27.6 MPa (4000 psig). The minimum bursting pressure for new hose assemblies shall be 78.0 MPa (11 300 psig). For hose assemblies which have been preconditioned per 3.1.2.5, 3.1.2.9 and 3.3.2.9, the minimum bursting pressure shall be 70.0 MPa (10 145 psig). For hose assemblies which have been preconditioned per 3.1.2.11 and 3.3.2.6, the minimum bursting pressure shall be 65.5 MPa (9493 psig). For hose assemblies which have been preconditioned per 3.3.1.1, the minimum bursting pressure shall be 50.0 MPa (7250 psig). No more than 50% of the samples may have a burst location within 20 mm of the crimp ferrule.

3.1.2.3 Volumetric Expansion. See Tables 8 thru 11.

Table 8: Volumetric Expansion (Low Pressure, Ambient Temperature)

Low Pressure	
Pressure	Volumetric Expansion
1.0 MPa (145 psig)	≤ 0.16 cm ³ /m (0.009 in ³ /ft)
2.8 MPa (400 psig)	≤ 0.23 cm ³ /m (0.007 in ³ /ft)

Table 9: Volumetric Expansion (High Pressure, Ambient Temperature)

High Pressure	
Pressure	Volumetric Expansion
6.9 MPa (1000 psig)	≤ 0.39 cm ³ /m (0.024 in ³ /ft)
10.4 MPa (1508 psig)	≤ 0.52 cm ³ /m (0.032 in ³ /ft)
20.0 MPa (2920 psig)	≤ 0.89 cm ³ /m (0.054 in ³ /ft)

Table 10: Volumetric Expansion (Low Pressure, Elevated Temperature)

Low Pressure	
Pressure	Volumetric Expansion
1.0 MPa (145 psig)	≤ 300% of measured ambient value
2.8 MPa (400 psig)	≤ 300% of measured ambient value

Table 11: Volumetric Expansion (High Pressure, Elevated Temperature)

High Pressure	
Pressure	Volumetric Expansion
6.9 MPa (1000 psig)	≤ 300% of measured ambient value
10.4 MPa (1508 psig)	≤ 300% of measured ambient value
20.0 MPa (2920 psig)	≤ 300% of measured ambient value

3.1.2.3.1 Test Procedure for Ambient Temperature Condition. Six (6) assemblies crimped at nominal hose compression shall be tested. Hose assemblies shall be tested to the requirements of GMW16837. Each actuation cycle, as defined in GMW16837 shall consist of pressurization from 0 MPa (0 psig) to each of the five (5) measurement pressures, 1.0 MPa (145 psig), 2.8 MPa (400 psig), 6.9 MPa (1000 psig), 10.4 MPa (1508 psig) and 20.0 MPa (2920 psig).

Volumetric Expansion test methods equivalent to GMW16837 may be used to meet the requirements of this test, upon the review and approval of the test method by the GM Materials Engineer issuing the Engineering Source Approval to the GMW3056 specification.

3.1.2.3.2 Acceptance Determination for Ambient Temperature Condition. The volumetric expansion at 1.0 MPa shall be ≤ 0.16 cm³/m (0.009 in³/ft). The volumetric expansion at 2.8 MPa shall be ≤ 0.23 cm³/m (0.007 in³/ft). The volumetric expansion at 6.9 MPa shall be ≤ 0.39 cm³/m (0.023 in³/ft). The volumetric expansion at 10.4 MPa shall be ≤ 0.52 cm³/m (0.032 in³/ft). The volumetric expansion at 20.0 MPa shall be ≤ 0.89 cm³/m (0.054 in³/ft).

3.1.2.3.3 Test Procedure for Elevated Temperature Condition. Six (6) assemblies crimped at nominal hose compression shall be tested. Hose assemblies shall be tested to the requirements of GMW16837. The test specimen shall be immersed in an 80 °C atmosphere for 30 minutes prior to actuation. Each actuation cycle, as defined in GMW16837, shall consist of pressurization from 0 MPa (0 psig) to each of the five (5) measurement pressures, 1.0 MPa (145 psig), 2.8 MPa (400 psig), 6.9 MPa (1000 psig), 10.4 MPa (1508 psig), and 20.0 MPa (2920 psig).

3.1.2.3.4 Acceptance Determination for Elevated Temperature Condition. The volumetric expansion at all pressure levels shall be < 300% of the comparable ambient values.

3.1.2.4 Hot Plate. See Table 12.

Table 12: Hot Plate

Test	Requirement	Pass Criteria
Hot Plate	T = 200 °C or 160 °C	No leakage or seepage
Burst Test	30.0 MPa (4350 psig)	Must meet 30.0 MPa (4350 psig) minimum Burst Pressure

3.1.2.4.1 Test Procedure. Eighteen (18) hose samples are to be tested; six (6) at minimum hose compression, six (6) at nominal hose compression and six (6) at maximum hose compression to each of the two (2) test procedures, Procedure A and Procedure B (see 3.1.2.4.4), using DOT 4 brake fluid meeting GM specification GMW16955, Fluid A1. Therefore, the total number of samples to be tested is 36.

3.1.2.4.2 Test Equipment. Brake hydraulic supply and pressure pump that can supply up to 150 MPa (22 000 psig). The hotplate will have adaptation for copper block, hose and temperature sensor. There shall be a control unit for temperature regulation, introduction of pressure and measured-data acquisition.

3.1.2.4.3 Preparation. The brake hose shall be mounted and fully extended in the test stand. The hose fitting that is not being tested shall be connected to the pressure supply. When testing the banjo fitting (brake caliper side), the fitting shall not rest on the hotplate. The hose fitting being tested will have a vent nipple, and will be positioned on the test stand, as shown in Appendix A, Figure A1. The female fitting (brake pipe side), shall be

tested by inserting the fitting into the copper block according to Appendix A, Figure A2. The preparation is applicable to both Procedures A and B (see 3.1.2.4.4).

3.1.2.4.4 Test Instructions.

3.1.2.4.4.1 Procedure A.

- Starting at room temperature $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, the hotplate shall be heated to the measuring point temperature (T) of $200\text{ }^{\circ}\text{C}$ for banjo fittings, $160\text{ }^{\circ}\text{C}$ for female fittings, within time $t_1 = 20$ minutes.
- The temperature shall be maintained at temperature T. Simultaneously, a constant pressure of $p = 10\text{ MPa} \pm 0.2\text{ MPa}$ shall be applied for time $t_3 = 60$ minutes within maximum time $t_2 = 20\text{ s}$ of temperature T being attained.

Subsequently, the complete brake hose shall be depressurized followed by immediate repressurization at the specified test temperature until burst. (The pressure and time curve is shown in Appendix A, Figure A3.)

3.1.2.4.4.2 Procedure B.

- Starting at room temperature $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, the hotplate shall be heated to the measuring point temperature T of $200\text{ }^{\circ}\text{C}$ for banjo fittings, $160\text{ }^{\circ}\text{C}$ for female fittings, within time $t_1 = 20$ minutes.
- The temperature shall be maintained at temperature T. Simultaneously, a constant pressure of $p = 10\text{ MPa} \pm 0.2\text{ MPa}$ shall be applied via a pressure ramp within time $t_2 = 20\text{ s}$ of temperature T being attained. The pressure shall be maintained for at least time $t_3 = 40\text{ s}$. The complete brake hose shall be depressurized. The pressure sequence during time $(t_2 + t_3) = 60\text{ s}$ corresponds to a single cycle. This cycle will be repeated $20\times$ with a no pressure apply time $t_4 = 1$ minute between cycles.

Subsequently, the complete brake hose shall be depressurized followed by immediate repressurization at the specified test temperature until burst. (The pressure and time curve is shown in Appendix A, Figure A3.)

3.1.2.4.5 Acceptance Determination. Hose assemblies must record Burst Test result equal to or $> 30.0\text{ MPa}$.

3.1.2.5 Low Temperature Resistance. See Table 13.

Table 13: Low Temperature Resistance

Test	Requirement	Pass Criteria
Low Temperature Resistance	$-44\text{ }^{\circ}\text{C}$ to $-50\text{ }^{\circ}\text{C}$ ($-47\text{ }^{\circ}\text{F}$ to $-58\text{ }^{\circ}\text{F}$)	No cracks when hose is flexed
Leak Test (3.1.2.1)	10.3 MPa to 14.5 MPa (1494 psig to 2103 psig)	No leakage at coupling or hose
Burst Test (3.1.2.2)	70 MPa ($10\text{ }150\text{ psig}$)	Minimum burst pressure

3.1.2.5.1 Test Procedure. Six (6) assemblies crimped at nominal hose compression shall be tested. Select the proper size test mandrel, as specified in Appendix A, Table A1. Remove the hose armor, if any, and condition the hose and the cylinder in a straight position in air at $-44\text{ }^{\circ}\text{C}$ to $-50\text{ }^{\circ}\text{C}$ for 70 h. While the parts are still at this temperature, bend the hose at least 180 degrees around the cylinder at a steady rate in a period of 3 s to 5 s. Allow the parts to return to room temperature $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$. Conduct Leak Test per 3.1.2.1, followed by Burst Test per 3.1.2.2.

3.1.2.5.2 Acceptance Determination. There shall be no cracks when hose is flexed at $-44\text{ }^{\circ}\text{C}$ to $-50\text{ }^{\circ}\text{C}$. Hose assemblies will pass the requirements of the Leak Test and the Burst Test.

3.1.2.6 Tensile Test. See Table 14.

Table 14: Tensile Test

Test	Requirement	Pass Criteria
Tensile	1750 N (389 lb)	Hose shall not break or pull from crimped fitting at $< 1750\text{ N}$ (389 lb)

3.1.2.6.1 Test Apparatus. A tension testing machine, conforming to the requirements of ASTM E4 or ISO 7500-1 Methods, and equipped with an indicating device to give the total pull in Newtons (N) (pounds (lb)) at the conclusion of the test. (A machine capable of 4.5 kN (1000 lb) capacity would be suitable).

3.1.2.6.2 Fixtures. The machine shall have suitable fixtures attached to it so the hose assembly shall have a straight centerline corresponding to the direction of the machine pull.

3.1.2.6.3 Test Procedure. Eighteen (18) assemblies are to be tested, six (6) at minimum hose compression, six (6) at nominal hose compression and six (6) at maximum hose compression. Apply an increasing tensile load at a speed such that the moving head of the testing machine travels at the rate of 25 mm/minute $\pm$ 3 mm/minute (1.0 in/minute $\pm$ 0.1 in/minute) until separation. Record the total load at the time of separation, and note if the hose breaks, or if the hose separates from the coupling.

3.1.2.6.4 Acceptance Determination. The hose shall not break, or pull from the crimped fitting at < 1750 N (389 lb) force.

3.1.2.7 Whip Test. See Table 15.

Table 15: Whip Test

Test	Requirement	Pass Criteria
Whip Test Duration	50 h	No leakage of hose or crimped assembly
Adhesion Test (3.1.3.6)	1.4 Nm (8.0 lbf-in)	Shall not delaminate

3.1.2.7.1 Test Apparatus. Mandatory hose motion is produced by the following device, or by its equivalent:

3.1.2.7.1.1 A movable header consisting of a horizontal bar mounted at each end on vertically rotating disks through bearings with centers placed 101.6 mm (4 in) from the disk centers, and an adjustable stationary header parallel to the movable header in the same horizontal plane as the centers of the disks. The headers are each provided with end connections in which the hose assemblies are mounted in parallel. The disks are rotated at a speed of 800 rpm $\pm$ 10 rpm, whereby the hose ends fastened to the moving header are rotated at this speed through a circle 203.20 mm $\pm$ 0.25 mm (8.000 in $\pm$ 0.010 in) in diameter while the opposite hose ends remain stationary. The end connections on the movable header are tightly capped, while those on the stationary header are open to a manifold through which water pressure is supplied by a suitable means. The hose assemblies are subjected during testing to a constant water pressure that shall be maintained between 1.55 MPa and 1.72 MPa (225 psig and 250 psig). A limit switch shall be used to stop the machine when the water pressure drops, as in the case of hose failure, since it is essential that the machine stop if the pressure drops. An elapsed time indicator shall be provided.

3.1.2.7.2 Test Procedure. Twenty-four (24) assemblies are to be tested, eight (8) at minimum hose compression, eight (8) at nominal hose compression, and eight (8) at maximum hose compression.

3.1.2.7.3 Hose External Attachment Requirements. All external appendages such as chafing collars, mounting brackets, date bands and spring guards shall be removed from the brake hose assembly prior to testing on the whip machine.

Note: Per National Highway Traffic Safety Administration (NHTSA) interpretation, hose assemblies incorporating intermediate collars or fittings (not external appendages such as brackets) which are located between the end fittings and are not readily removable are considered as having separate free lengths for the purposes of whip testing.

3.1.2.7.4 Hose Attachment to Apparatus. Equip the non-rotating header to permit attachment of each hose assembly with individual adjustment for length. When mounted in the whip test machine, the projected length of the hose assembly shall be less than the free length by the amount indicated as slack in Appendix A, Table A2.

3.1.2.7.5 Error Sensitivity. Inasmuch as the whip test results are very sensitive to error in setting this length, take measurements carefully. The reduction from free length to projected length, on the machine, shall be within the limits specified. Take the projected length parallel to the axis of the rotating head.

3.1.2.7.6 Installation and Bleed Procedure. Install the test specimen assemblies in the apparatus without any twist. Bleed all hoses and passages to eliminate air pockets or bubbles. Apply the water pressure and start the

motor rotating the movable head and set elapsed time indicator to zero to record the duration of the test. Periodically check the rpm. Failure of the specimen by water leakage and consequent loss of pressure within 50 h constitutes a failure of the test. At the completion of 50 h of testing, remove a section of hose from the center portion of each sample and conduct the Adhesion Test, per 3.1.3.6.

3.1.2.7.7 Acceptance Determination. There shall be no leakage of the hose or crimped assembly for 50 h of test duration. All hose samples must meet the adhesion requirements of 3.1.3.6.

3.1.2.8 Torsion Test, Center Fitting. See Table 16.

Table 16: Torsion Test, Center Fitting

Test	Requirement	Pass Criteria
Torsion Test for Center Fitting	0.8 Nm (7.08 lbf-in)	Center fitting shall not slip

3.1.2.8.1 Test Procedure. If the brake hoses include a center fitting, the center fitting shall be subjected to a torsion test. The center fitting shall not slip on the brake hose below a torque of 0.8 Nm (7.08 lbf-in). The hose shall be grasped and held within 5 mm of the center fitting before the torque is applied. Six (6) hose assemblies at nominal hose compression are to be tested.

3.1.2.8.2 Acceptance Determination. The center fitting shall not slip when a torque of 0.8 Nm (7.08 lbf-in) is applied.

3.1.2.9 Heat Age/Cold Bend. See Table 17.

3.1.2.9.1 Test Procedure. Six (6) assemblies crimped at nominal hose compression shall be tested. Assemblies are to be aged at $100\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ for $504\text{ h} \pm 2\text{ h}$. Assemblies are to be removed from the oven and conditioned at room temperature for 6 h to 12 h. Select mandrel per Appendix A, Table A1 and condition both mandrel and sample for $48\text{ h} \pm 1\text{ h}$ in a cold chamber at $-44\text{ }^{\circ}\text{C}$ to $-50\text{ }^{\circ}\text{C}$. Without removing the sample or mandrel from the chamber, bend the hose 180 degrees around the mandrel within 5 s. Remove the hose from the cold chamber and condition it at room temperature for 1 h to 6 h. Wrap the hose around the mandrel and inspect, with 7× magnification, for cover cracks. Conduct Leak Test per 3.1.2.1, followed by Burst Test per 3.1.2.2.

Table 17: Heat Age/Cold Bend

Test	Requirement	Pass Criteria
Heat Age Cold Bend	$100\text{ }^{\circ}\text{C}$, 504 h	There shall be no cracks visible at 7× magnification
Leak Test (3.1.2.1)	10.3 MPa to 14.5 MPa (1494 psig to 2103 psig)	No evidence of leakage at the coupling, or in hose member
Burst Test (3.1.2.2)	70 MPa (10 150 psig)	Minimum burst pressure

3.1.2.10 Fitting Rotation. See Table 18.

Table 18: Fitting Rotation

Test	Requirement	Pass Criteria
Fitting Rotation	$\geq 2.00\text{ Nm}$ (17.70 lbf-in)	Value must be $\geq 2.00\text{ Nm}$ (17.70 lbf-in)

3.1.2.10.1 Test Procedure. Twelve (12) assemblies are to be tested, six (6) at minimum hose compression and six (6) at nominal hose compression using DOT 4 brake fluid meeting GM specification GMW16955, Fluid A1.

3.1.2.10.2 Assembly Preparation. Assemblies are to be filled with brake fluid and aged $168\text{ h} \pm 1\text{ h}$ at $110\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$. Cool assemblies at room temperature for a minimum of 1 h. Cut each test assembly 50.8 mm

from the caliper (banjo) fitting skirt. Insert a mandrel of diameter equal to the nominal hose inner diameter (to prevent hose collapse) and secure in a vise such that the distance between the fitting skirt and the vise is approximately 6 mm. Using a calibrated torque wrench, measure the torque required to turn the fitting on the hose.

3.1.2.10.3 Acceptance Determination. Banjo fittings must record values of ≥ 2.00 Nm (17.70 lbf-in).

3.1.2.11 Brake Fluid Compatibility. See Table 19.

Table 19: Brake Fluid Compatibility

Test	Requirement	Pass Criteria
Brake Fluid Compatibility	504 h at 120 °C	See following tests
Constriction Test (3.1.3.1)	Probe must fall freely	Probe must fall freely through assembly
Leak Test (3.1.2.1)	10.3 MPa to 14.5 MPa (1494 psig to 2103 psig)	No evidence of leaks or blisters
Burst Test (3.1.2.2)	65.5 MPa (9500 psig)	Minimum burst pressure

3.1.2.11.1 Test Procedure. Twelve (12) assemblies are to be tested, six (6) at nominal hose compression and six (6) at minimum hose compression with each of two (2) brake fluids, DOT 3 brake fluid meeting GMW16955, Fluid A2 and DOT 4 brake fluid meeting GMW16955, Fluid A1. Therefore, the total number of samples to be tested is twenty-four (24). The hose assembly will be filled with brake fluid, capped and placed in an oven at $120\text{ °C} \pm 3\text{ °C}$ for 504 h. At completion of the aging period, the assembly shall be drained, conditioned at room temperature ($23\text{ °C} \pm 5\text{ °C}$) for a minimum of 30 minutes, checked for constriction of fluid path per 3.1.3.1, leak tested per 3.1.2.1, and then burst tested in accordance with 3.1.2.2. The Burst Test must be completed within 3 h of sample removal from the oven.

3.1.2.11.2 Acceptance Determination. There must be no constriction of the fluid path. Hose assemblies must meet the constriction requirement of 3.1.3.1. Hose assemblies must meet the leak test requirement of 3.1.2.1. Hose assemblies must meet the burst test requirements of 3.1.2.2.

3.1.3 Physical Requirements.

3.1.3.1 Constriction Test.

3.1.3.1.1 Test Procedure.

3.1.3.1.2 Probe Requirements. Select a spherical, or 25.4 mm to 76.2 mm, cylindrical Constriction Test Probe (Appendix A, Figure A4) having an **A** diameter of 64% of the nominal inside diameter of the test hose. Typical **A** diameters are listed in Appendix A, Table A3. The cylindrical probe is to be used except where impractical (e.g., curved tube and block assemblies).

3.1.3.1.3 Constriction Procedure. Hold the assembly vertically at one (1) fitting. Insert the specified probe into the end of the upper fitting. The probe shall fall through the assembly without assist. Manual straightening of the hose is permissible; no other manipulation of the assembly is allowed. Record whether or not the probe entered the full length of the hose.

3.1.3.1.4 Acceptance Determination. The probe must freely fall through the assembly.

3.1.3.1.5 Production Process Requirement. Constriction testing must be performed on 100% of production parts. The method of constriction testing shall be determined by the manufacturer and approved by the GM Materials Engineer issuing the Engineering Source Approval for the brake hose assembly.

3.1.3.2 End Fitting Corrosion Resistance.

3.1.3.2.1 Cyclical Corrosion Test. See Table 20.

3.1.3.2.1.1 Test Procedure. The Brake Hose Assembly shall meet the corrosion performance and validation requirements of GMW15272. Lab testing shall be to GMW14872, UB, All, 4sp, Methods 1/2, Exposure A (cosmetic) and E (functional). As invoked in this document, this test is run on standard test samples independent of in-vehicle orientation.