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| GM | WORLDWIDE ENGINEERING STANDARDS | General Specification | GMW15390 |

# Brake Apply Booster and Master Cylinder Assembly Technical Specification

## 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 Scope.** This specification is derived from the Brake Subsystem Technical Specification (SSTS). The boosters and master cylinders as defined in this specification will be applied to passenger cars and light trucks up to 6800 kg Gross Vehicle Weight Rating (GVWR).

This document must only be used when invoked by a program-specific technical specification. References to the program-specific technical specification are included in this document where program-specific requirements are expected to exist.

**Note:** The program-specific technical specification may include additional program-specific requirements that are not referenced in this document and may supersede any requirements included in this document. In the case of any conflicts between this document and the program-specific technical specification, the program-specific technical specification takes precedence.

**1.2 Mission/Theme.** The brake apply system is to quickly, repeatedly, and efficiently convert the driver's pedal force and travel inputs into hydraulic fluid displacement and pressure. The brake apply system works in conjunction with the foundation brakes to provide the vehicle with smooth, safe deceleration, retardation and retention performance under all driving conditions, as specified in this document.

The GM apply system family is intended to provide world class performance from right-sized components with interfaces flexible enough to support the diverse packaging and processing requirements of the corporation.

Consideration will be given to the selection of recyclable materials.

**1.3 Classification.** Not applicable.

## 2 References

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

**2.1 External Standards/Specifications.**

| | |
|---|---|
| CMVSS 105 | FMVSS 105 |
| CMVSS 135 | FMVSS 135 |

**2.2 GM Standards/Specifications.**

| | | | |
|---|---|---|---|
| GM123M | GMW14178 | GMW14934 | GMW16072 |
| GMW3059 | GMW14375 | GMW15110 | GMW16177 |
| GMW3172 | GMW14547 | GMW15272 | GMW16331 |
| GMW3356 | GMW14562 | GMW15494 | GMW16808 |
| GMW4700 | GMW14573 | GMW15585 | GMW16881 |
| GMW4707 | GMW14590 | GMW15827 | GMW17000 |
| GMW8518 | GMW14671 | GMW15862 | |
| GMW14089 | GMW14872 | GMW15962 | |



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**2.3 Additional References.**

**Note:** The supplier shall work with the GM responsible engineer to comprehend the Best Practice requirements.

- Best Practice Brakes 50 Brake Booster Vacuum Hose/Pipe Interfaces – Revised
- Best Practice Brakes 179 Design Guidelines for Plastic Brake Booster Vacuum Tubes
- CG1832 Brake System Key Characteristics Designation System Additional Care Items
- CG2556 Body Structure Subsystem Technical Specification
- FCI Electronics Drawing 120-S-002-1-Z02
- Global Machinery and Equipment Specification - Safety and Ergonomics
- GM Global Legal Database V2.4 or current version
- GM Math Data File ACT79100.001.0001
- GM Part Number 13503566
- GM Part Number 18019500
- GM Squeaks and Rattles Noise Glossary
- Program-Specific Technical Specification
- Program Statement of Requirements (SOR)

## 3 Requirements

**3.1 Subsystem Definition.** The booster and master cylinder subsystem transforms force and travel of the pedal pushrod into hydraulic pressure and displacement. The booster amplifies the pedal pushrod force. The master cylinder provides brake fluid under pressure to the wheel cylinders and allows for fluid transfer between the storage reservoir and pressure chambers during temperature changes, lining wear, and lining change. The assembly will include booster (and check valve if vacuum powered), master cylinder, failure warning device, and fluid reservoir. For vehicles equipped with a traction control system, the Antilock Braking System (ABS) and Traction Control System (TCS) will draw and return brake fluid through the master cylinder.

Master cylinders are required for both diagonal split and front/rear split hydraulic systems.

Most applications will not require integral proportioning valves; however integral proportioning valves will be required on some applications. The incremental cost for proportioning valves should be itemized separately.

Assembly plant requirements may dictate that the booster and master cylinder be processed separately in the assembly plant.

**3.1.1 Appearance.**

**3.1.1.1 Color.** The check valve shall be black. The booster shall be black. (See note in 3.2.1.22 regarding aluminum boosters.) The master cylinder reservoir shall be clear or white and translucent. The master cylinder body shall be silver or gray.

**3.1.1.2 Fluid Visibility.** The fluid reservoir shall provide the ability to determine the fluid level without removing the fluid reservoir cap and be visible by the customer. Reference regulatory requirements in 3.3.3.1.1.

**3.1.1.3 Master Cylinder Port Marking.** The ports of the master cylinder shall be marked **P** for Primary and **S** for Secondary to coincide with the primary and secondary circuits of the master cylinder.

**3.1.2 Content.**

**3.1.2.1 Physical Content.** The assembly includes the booster, booster input and output, dash mounting provision, master cylinder body, failure warning device, fluid reservoir, reservoir cap, and all necessary hardware. The assembly also includes the booster check valve for vacuum powered boosters. As specified in the program-specific technical specification, the assembly may also include vacuum sensors or switches and/or hydraulic pressure or travel transducers. If the assembly will utilize a vacuum sensor, the sensor shall be approved by the sensor Bill of Material family owner with the Corporate Common sensors used wherever possible.



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**3.1.2.2 Functional Content.** The booster and master cylinder assembly operates with the pedal assembly, brake fluid via brake pipes and hoses, and calipers to transform pedal pushrod force and travel into hydraulic pressure and displacement resulting in vehicle deceleration. The assembly will provide a signal to the chassis electrical subsystem in the event of a primary or secondary circuit hydraulic failure via a reservoir fluid level sensor. Other signals may be provided by additional sensors or switches as detailed in the program-specific technical specification. The master cylinder shall allow venting of pressure from the chassis control modulator to the fluid reservoir.

**3.1.3 Ambient Environment.**

**3.1.3.1 Temperature and Humidity Range.** The booster and master cylinder assembly shall be designed to operate under the temperature and humidity ranges shown in Table 1. The temperature profile listed in Table 2 is to be used for all laboratory validation unless otherwise stated. The listed temperature should be confirmed during program development.

**Table 1: Temperature and Humidity Range**

| | Booster Assembly | Master Cylinder Assembly |
|---|---|---|
| Minimum Temperature (TMIN) | -40 °C | |
| Maximum Sustained Temperature (>10 minutes) | 100 °C | 120 °C |
| Maximum Excursion Temperature (TMAX) (≤ 10 minutes) | 120 °C | 140 °C |
| Relative Humidity Range | 0 to 100% | |

**Table 2: Cycles at Temperature**

| Percentage of Cycles at each Level of Temperature (%) | Temperature (°C) |
|---|---|
| 84 | 70 |
| 5 | 100 |
| 1 | 120 |
| 10 | -20 |

**3.1.3.1.1** The TMIN is the minimum temperature at which a component will be expected to operate. Assisted vehicle starting shall be permitted. Temporary degradation of the component function shall be permitted, but must be reviewed by engineering through Design Validation (DV) and Product Validation (PV) testing. Where not explicitly called out, the supplier shall test at the minimum temperature and present the results in the Analysis/Development/Validation Plan and Report (ADVP&R). Permanent loss of function shall not result in a walk-home situation. Temperature effects shall be included in the supplier's Design Failure Modes Effects Analysis (DFMEA).

**3.1.3.1.2** The maximum sustained temperature is the maximum temperature a component will experience on a continuous basis and be expected to maintain design functional life. The vehicle shall be able to experience 1200 h/12 000 cycles per 160 000 km of operation during continuous thermal conditions. Occupant safety shall not be compromised during continuous thermal conditions. Performance must be reviewed by engineering through DV and PV testing. Where not explicitly called out, the supplier shall test at the maximum sustained temperature and present the results in the ADVP&R. Temperature effects shall be included in the supplier's DFMEA.

**3.1.3.1.3** The maximum excursion temperature is the maximum temperature the component will experience on an infrequent basis and be expected to maintain functional life. The vehicle shall be able to experience 60 h/400 cycles per 160 000 km of operation during excursion thermal conditions. Occupant safety shall not be


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compromised during excursion thermal conditions. Performance must be reviewed by engineering through DV and PV testing. Where not explicitly called out, the supplier shall test at the maximum excursion temperature and present the results in the ADVP&R. Temperature effects shall be included in the suppliers DFMEA.

**3.1.3.1.4** If the vehicle target life is >160 000 km, as specified in the program-specific technical specification, the hours and cycles in paragraphs 3.1.3.1.2 and 3.1.3.1.3 should be adjusted accordingly. See program-specific technical specification. (Stakeholders: 0D.02 Thermal; 20.04 Brakes.)

**3.1.3.2 Temperature Shock via Water Splash.** The booster and master cylinder assembly will be exposed to five temperature shocks which occur when they encounter splash from freezing level salt water solution (1% sodium chloride by weight) for 60 s while at an operating temperature T = (TMAX -20 °C), where TMAX is the worst-case maximum excursion temperature from Table 1 Temperature and Humidity Range for the component assembly.

**3.1.3.3 Mechanical Vibration.** The booster and master cylinder combined assembly shall encounter 16 h of mechanical vibration along each axis for passenger car, 36 hours per truck, using the specified power spectral density in Figure A1. (Reference GMW3172 sprung mass profile.) A sample size of 6 should be used to demonstrate 97% reliability at 50% confidence. The master cylinder cap shall not rotate in the disengagement direction. All components shall remain functional. All assembled components shall remain assembled/retained. The test shall be conducted with at least one sample at the minimum brake fluid level and one sample at the maximum (MAX) brake fluid level. The brake fluid level switch shall not be activated, and there shall be no leakage of brake fluid.

**3.1.3.4 Mechanical Shock.** The booster and master cylinder combined assembly shall be exposed to 40 half sine wave mechanical shocks in each of the upward, rearward, and both lateral directions based on Table 3.

**Table 3: Mechanical Shock**

| Component Location | Maximum G Level (Zero-to-Peak) | | Total Duration |
|---|---|---|---|
| | Upward, Rearward | Left, Right | (ms) |
| Underhood | 14 | 7 | 10 |

**3.1.3.5 Component Drop.** The booster/master cylinder assembly must not be dropped from any height. Components that are dropped from any height are to be considered scrap and not shipped to the customer.

**3.1.3.6 Atmospheric Pressure.** The booster and master cylinder will be exposed to between 45 and 115 kPa during operation and storage. Before any testing, the parts are to be exposed to these pressure limits for 0.5 h. The DFMEA shall include this exposure and a one month duration exposure to identify any potential effects.

**3.1.3.7 Shipment.** Boosters and master cylinders shipped by air shall be exposed to a temperature of -50 °C and to a pressure of 15 kPa. Before any testing, the parts are to be exposed to these temperatures and pressure limits for 0.5 h. The DFMEA shall include this and one month duration exposure to identify any potential effects.

**3.1.3.8 Corrosion.** The booster and master cylinder assembly will be exposed to the 95$^{th}$ percentile corrosive environment which occurs in the north east United States of America (USA) and southeast Canada. This environment is composed of appropriate combinations of temperature, humidity, salt, splash, dust, mud, and component usage. See 3.2.1.23.2 for validation requirements.

**3.1.3.9 External Contaminants.** See 3.2.1.22 for fluid contaminant resistance. The booster and master cylinder shall be designed to prevent water entry from the engine compartment during normal driving or maintenance. The supplier's DFMEA shall consider water entry and contaminants.

**3.1.3.10 Internal Contaminants.** The master cylinder assembly must withstand brake fluid contaminants which include water (up to 10% by weight) and assembly lubricants. A vacuum booster must withstand contaminants which include humidity and fuel vapors. The supplier's DFMEA shall include the possibility of internal contaminants and add required testing to the AVDP&R and inputs into the Process Failure Mode Effects Analysis (PFMEA) where necessary.



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**3.1.4 Interfaces.** The booster and master cylinder assemblies shall be designed to interface with the subsystems and components described in the following paragraphs and shown in Figure A2. The packaging emphasis is on reducing the overall packaging size. See program-specific technical specification for math environment packaging file and applicable interfaces. The booster and master cylinder shall come as one assembly as shipped to the assembly plant unless otherwise specified in the program-specific technical specification. In either case, the master cylinder vacuum seal (interface to booster) shall be designed to ensure sealing throughout all tolerances. Also, this seal shall be retained to the master cylinder in such a manner that it may not be dislodged during shipping, assembly, or service handling. The seal should require a tool for removal. The seal shall stay retained to the master cylinder body when the master cylinder sub-assembly is subjected to 3.1.3.3.

**3.1.4.1 Booster and Master Cylinder Assembly to Other Subsystem Interfaces.** See Figure A2 Booster and Master Cylinder Interface Diagram.

**3.1.4.1.1 Sealing.** The booster shall have a sealing gasket that shall provide noise insulation between the engine and the passenger compartments. The sealing gasket will also provide sealing of the booster mounting to prevent water, dirt, dust, etc., entry into the passenger compartment. The gasket shall be designed to accommodate surface flatness variation of the mounting surface after full assembly (post torque-down) and be considered in the torque specification development of the booster stud to dash joint. The booster gasket shall be minimized while the passenger compartment insulation maximized to reduce pass-through noise. There shall be no direct open path between the engine and passenger compartment. See section 3.2.1.25.

**3.1.4.1.2 Body Structure.**

**3.1.4.1.2.1 Booster Mounting.** The preferred booster mounting is a 72 x 72 mm 4 stud pattern fastened to the cockpit module or front of dash structure. Engine compartment booster installation (through bolt/front bolt design) is permissible if specified by the program-specific technical specification (but is a cost penalty vs. a 4 stud mounting). The booster mounting shall be possible with or without the master cylinder installed to the booster. The program-specific technical specification shall specify the assembly method for the booster and master cylinder.

**3.1.4.1.2.2 Booster Mounting Modes.** The brake booster mounted on the vehicle shall have no structural, Rigid Body, modes below 30 Hz.

**Note:** This needs to be coordinated with the CG2556 Body Structure Subsystem Technical Specification, in 3.1.2.2.1 of that document, or superseding paragraph of that document, to ensure adequate stiffness of the body at the Brake

Booster attachment locations. (Stakeholders: 20.04 Brakes; 0C Noise and Vibration.) The program-specific technical specification shall detail the mounting condition which the supplier's brake apply must meet to be compliant with this specification. The supplier shall provide Finite Element Analysis (FEA) results during the DV phases demonstrating compliance.

**3.1.4.1.3 Power Source.**

**3.1.4.1.3.1 Vacuum Supply.** If the booster is vacuum powered, the brake apply assembly shall meet all performance requirements up to 100 kPa of vacuum and 36 kPa/s rate of change. There shall be no unintended brake pressure during these conditions. These conditions shall be considered in the supplier's DFMEA.

**3.1.4.1.3.2 Vacuum Hose.** If the booster is vacuum powered, the booster check valve will interface with the vacuum system using the appropriate sized vacuum hose For nylon vacuum tubes, the check valve and/or sensor normally will be part of the tube assembly. Retention of the hose must meet GM hose and best practice specifications (Brakes 179; Brakes 50). The supplier shall work with the GM responsible engineer to comprehend this requirement. See program specific technical specification for more information.

**3.1.4.1.3.3 Electric.** If the booster is electric powered, the source limitation is 70 A peak draw, 25 A continuous draw (during braking) in a range of 9 to 16 V.

**3.1.4.1.3.4 Hydraulic.** If the booster is powered by the power steering pump or a central hydraulic system, the available flow capacity is to be as specified in the program-specific technical specification.

**3.1.4.1.4 Chassis Electronics and Controls.**

**3.1.4.1.4.1 Brake Fluid System Failure Warning Sensor.** The connector for the brake fluid system failure warning sensor shall be a sealed connector for a 2 wire circuit following FCI Electronics Drawing



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120-S-002-1-Z02, keying option A. The associated wiring connectors are 120-S-002-1-A02, GM Part Number 13503566. The sensor shall meet the mechanization as illustrated in Appendix D. Reference program-specific technical specification paragraph for connection orientation. The supplier must submit a validation plan for the switch which must include a) a mechanical shock test, b) thermal shock test, c) vibration test, d) switch set points test, and e) a drop test.

**3.1.4.1.4.2 Electrical Grounding.** The booster and master cylinder components shall not be used for electrical ground paths.

**3.1.4.2 Interfaces to Other Brake System Assemblies.**

**3.1.4.2.1 Pedal Assembly.** The booster will interface with the brake pedal assembly as detailed for each platform application. See program-specific technical specification paragraph.

**3.1.4.2.2 Brake Pipes.** The master cylinder shall be designed to have fluid outlets located on the outboard side for both left and right hand drive vehicles if possible. See Figure A3 for pipe and fitting specifics. Double inverted flare fittings are required. The recommended installation torque shall exceed the +3 sigma torque-to-seal by 50%. The -3 sigma torque-to-fail must exceed the recommended installation torque by 50%. The values for +3 sigma torque-to-seal, -3 sigma torque-to-fail, and recommended installation torque shall be determined and reported by the supplier to the platform. See program-specific technical specifications paragraph. **Note:** It is recommended that the master cylinder assembly **not** be proliferated in order to accommodate multiple brake pipe port sizes. Instead the master cylinder pipes should be commonized between ABS, Electronic Stability Control (ESC), etc. variants.

**3.1.4.2.3 Brake Fluid.** The master cylinder shall be compatible with Department of Transportation (DOT) 3, and DOT 4, (glycol based) brake fluids. Validation testing shall be performed with one DOT 3 fluid meeting GMW16072, and one DOT 4 fluid meeting GMW3356. The program-specific technical specification shall specify the exact fluid for the particular application, which shall be used as one of the validation fluids.

**3.1.4.2.4 Antilock Brake System/Traction Control System Interface.** The booster and master cylinder shall be compatible with the ABS/TCS hydraulic modulator and the associated control system. The ABS/TCS usage is defined in paragraph 3.1.5.3. For TCS, the master cylinder fluid flow rate capability requirements are defined in paragraph 3.2.1.12.

**3.1.4.2.5 Brake Circuit Compliance.** The nominal total primary and secondary circuit compliance curve shall be provided by the platform for each application. The primary circuit apparent piston displacement (500, 5000, 12 000 kPa) detailed in the program-specific technical specification shall be used for all booster and master cylinder performance testing and fluid displacement calculations except where specified otherwise.

**3.1.4.2.6 Primary Brake Circuit Compensation.** Both the primary and secondary brake circuit shall provide brake fluid in reserve to accommodate lining wear, rotor/drum wear, and shoe adjustment, if applicable. The required amount will be provided by the platform for each application. See program-specific technical specification.

**3.1.5 Usage Definition.** The passenger car customer usage data given in this section are for high levels of usage in 160 000 km of USA retail customer driving. The truck customer usage data given in this section are for high levels of usage in 320 000 km of USA retail customer driving. Note that low levels of usage may be more appropriate for certain failure mechanisms, such as corrosion. This section and its subsections are the required conditions for paragraph 3.2.3.2.

**3.1.5.1 Line Pressure Distribution and Component Durability.**

**3.1.5.1.1 Passenger Car Pressure Distribution.** The master cylinder pressure distribution will be generated by the platform for each individual application. The total number of applications for the life validation for passenger car applications is 767 000. See Table A1 for an example of passenger car pressure distribution. See program-specific technical specification.

**3.1.5.1.2 Truck Pressure Distribution.** The master cylinder pressure distribution will be generated by the platform for each individual application. The total number of applications for the life validation for truck applications is defined by the platform. See program-specific technical specification.

**3.1.5.2 Pedal Pushrod Force Distribution.** The pedal assembly pushrod force distribution will be generated from the line pressure distribution information referenced in paragraph 3.1.5.1.

**3.1.5.3 System Durability.** The booster and master cylinder shall be tested per GMW15494. For vehicles in high usage regions such as China or India, extension of the test cycle may be required based on field



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experience. If the application uses a mechanical vacuum pump, the test should be run at an appropriate vacuum level (up to 95 kPa vacuum). See program-specific specification for more information.

**3.2 Product Characteristics.**

**3.2.1 Performance Requirements.** The following performance requirements apply to the booster and master cylinder assembly as per GMW14590. The requirements must be met with vacuum level of 67.7 kPa (where applicable) in addition to the program-specific vacuum level. See program-specific technical specification for the apparent piston displacements for each circuit and for preferred calibrations per model related to the below sections. The supplier test facility shall be GM Test Improvement Process (TIP) accredited to the requirements in Appendix E.

**3.2.1.1 Initial Travel Loss.** The initial travel loss of the booster and master cylinder shall be <2.0 mm. Travel loss is defined in Appendix B and is graphically displayed in Figure B1. The initial travel loss should be sufficient to accommodate all component tolerances, the power source in 3.1.4.1.3 impacts to the booster, the mount sealing provisions in 3.1.4.1.1, the mechanical vibration in 3.1.3.3, and the temperature and humidity requirements of 3.1.3.1 and must include the brake pad and other brake system expansion due to temperature. The supplier shall provide a lost travel correlation between GMW14590 and their production line audit criteria before sourcing to ensure 100% compliance during production. The brake apply lost travel per GMW14590 shall not increase >0.4 mm post durability cycling per GMW15494. The supplier shall present FEA results during technical reviews showing compliance to this requirement and a deformation vs. force graph up to the maximum functional input pushrod force as specified in 3.2.3.2.3.

**3.2.1.2 Travel Efficiency.** The travel efficiency of the booster and master cylinder assembly shall be >85%. Travel efficiency is defined in Appendix B and is graphically displayed in Figure B1.

**3.2.1.3 No-Power-Assist Force Loss.** The no-power-assist force loss shall be <320 N for a single diaphragm booster and <400 N for a tandem diaphragm. During production the no-power-assist force loss shall never be greater than +1.23 sigma (supplier's process) from the component utilized during regulatory (e.g., Federal Motor Vehicle Safety Standard (FMVSS) 135 failed power unit testing. The supplier shall demonstrate the variation of their force loss from a production process and adjust the nominal production target accordingly. The component used for regulatory testing shall be measured before assembling to the vehicle. No-power-assist force loss is defined in Appendix B and is graphically displayed in Figure B3.

**3.2.1.4 No-Power-Assist Force Efficiency.** The no-power-assist force efficiency shall be >95%. No-power-assist force efficiency is defined in Appendix B and is graphically displayed in Figure B3.

**3.2.1.5 Cut-In.** The cut-in shall be <90 N. Cut-in is defined in Appendix B and is graphically displayed in Figure B2.

**3.2.1.6 Initial Rise.** Initial rise is considered to be a tunable item and should be evaluated on a representative vehicle to determine the final value. The booster initial rise shall be tunable within a range of 25 to 800 N. The tolerance on initial rise shall be no greater than ± 50 N or 15% of the nominal rise, unless otherwise noted. Reaction pistons should incorporate rounded tips or similar features to improve modulation (the transition between the initial rise and the power slope portion of the curve). Initial rise is graphically displayed in Figure B2. (For initial pedal feel tuning of a vehicle, it may be advisable to order several boosters with different tunings to allow subjective evaluations to occur.)

**3.2.1.7 Power Slope.** The power slope shall be between ± 2.5% of the nominal gain. The power slope (master cylinder pressure/booster input force) is measured as defined in Appendix B and is graphically displayed in Figure B2. The power slope shall be of a single ratio unless otherwise stated in the program-specific technical specification as required to meet Brake Feel Index (BFI) vehicle requirements. For dual ratio boosters, the 2$^{nd}$ slope shall also have a tolerance of ± 2.5% of the nominal gain, with the origin of the 2$^{nd}$ slope line as the measured end point of the first slope line.

**3.2.1.8 Return Cut-Out.** The booster and master cylinder shall provide a force of 45 to 75 N to the brake pedal to return the pedal to the rest position. The return force shall accommodate all component tolerances including the pedal system, the power source in 3.1.4.1.3 impacts to the booster, the mount sealing provisions in 3.1.4.1.1, the mechanical vibration in 3.1.3.3, and the temperature requirements in 3.1.3.1. The pedal math data and brake pedal position sensor or switch information shall be provided in the program-specific technical specification. The brake apply supplier is responsible for ensuring sufficient pedal return with the information provided in the program-specific technical specification. The return cut-out is defined Appendix B and is graphically displayed in Figure B4. The return force requirement should be met at vacuum levels up to 95 kPa



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if required by the program specific technical specification. (This may require a different spring tuning for a mechanical vacuum pump system vs. an engine manifold application). The values shown are for an application without a pedal return spring. If a pedal return spring is used, the booster return force may be lower; refer to the program-specific technical specification.

**3.2.1.9 Total Output Efficiency.** The Total Output Efficiency (TOE) of the apply system shall be >80%. The TOE calculation (effective area/maximum booster area) is defined in Figure B5.

**3.2.1.10 Pressure Response Time.** The apply subsystem shall achieve pressure response times as specified in Table 4. Pressure response is evaluated with the apply system under a similar stroke/pressure relationship as during vehicle operating conditions. (Stakeholders: 20.04.04 Brake Apply; 0B.03 Deceleration.) Pressure response is to be evaluated at the expected vehicle power source level during a stopping distance test (warmed vehicle, all hardware including vacuum pumps installed and functioning as intended for production). Vacuum powered boosters shall also meet this requirement at 67 kPa. The expected vehicle power source level shall be provided in the program-specific technical specification. This pressure response time requirement must be met in conjunction with 3.2.1.14 noise requirement and throughout 3.2.1.1 initial travel loss range. The supplier shall present data at the technical review demonstrating compliance.

**Table 4: Pressure Response Time**

| Booster Subsystem | Apply (s) | Release (s) |
|---|---|---|
| Single Vacuum Booster | 0.13 (67 kPa vacuum)<br>0.10 (95 kPa vacuum) | 0.08 |
| Tandem Vacuum Booster | 0.15 (67 kPa vacuum)<br>0.12 (95 kPa vacuum) | 0.08 |
| Hydraulic Boosters | 0.15 | 0.08 |
| Electric Boosters | See program-specific technical specification. | |

**3.2.1.11 Pressure Hysteresis.** The average pressure hysteresis of the booster and master cylinder assembly shall be <27% of the maximum pressure when evaluated with a sinusoidal input force to the booster at a frequency of 0.5 Hz and a magnitude of 80% of the input force at booster run out when the source vacuum level is at 67.7 kPa.

**3.2.1.12 Master Cylinder Fluid Flow Rate Capability.** The master cylinder assembly shall provide fluid for the chassis control hydraulic pump during operation and allow for brake fluid expansion due to TMIN to TMAX expansion of the fluid and the brake system components. Refer 3.1.3.1 for TMIN and TMAX values. During chassis control events, the pump shall draw fluid from the master cylinder brake circuit ports. The internal pressure drop at fluid flow from the reservoir to the brake line connection shall meet the requirements in Table 5. The program-specific technical specification shall detail: 1) The amount of brake fluid volume in the system and expected expansion from TMIN to TMAX; 2) The thickness change of all brake pads from their respective TMIN and TMAX values and the corresponding fluid displacement through the master cylinder ports. Fluid flow rate shall be measured after a minimal brake application which seals the brake system (as defined by travel loss calculation) and during normal static unapplied conditions. These factors shall all be included in the DFMEA and ADVP&R. The fluid flow rate shall be measured in accordance with GMW15585. Minimum travel loss parts shall be assembled to durability, chassis controls, and base brake thermal abuse/fade development vehicles (minimum 3 vehicles) in the DV and PV phases.


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**Table 5: Minimum Master Cylinder Fluid Flow Rate**

| | | |
|---|---|---|
| Temperature | 25 °C | -20 °C |
| Delta Pressure | <2 kPa | <6 kPa |
| Flow | 5.0 cc/s | 2.8 cc/s |
| Pipe Diameter | 6 mm Outer Diameter | 6 mm Outer Diameter |
| Port Diameter | 4.6 mm | 4.6 mm |

**Note:** Typical flow values are shown in Table 7. Actual required flow may be higher or lower depending on vehicle GVWR and chassis controls functions. See program-specific technical specification for additional information.

**3.2.1.13 Proportioning Valve Characteristics.** Some applications will require integral proportioning valves and shall have an independent technical specification detailing their requirements. See program-specific technical specification and the program Statement of Requirements (SOR) document for the brake system. Proportioning valve performance characteristics are defined in Appendix C.

**3.2.1.14 Air Rush (Whoosh) and Stick Slip (Grunt) Noise.** Brake apply system noise shall be <35 sonesGF during a step apply and <10 sonesGF during a ramp apply when evaluated according to GMW14934 unless otherwise indicated in the program-specific technical specification. This includes, but is not limited to, check valve noise, air rush noise, master cylinder squeak, and stick-slip noise. This requirement must be met in conjunction with 3.2.1.10 pressure response time, 3.2.1.1 throughout entire initial travel loss range, and 3.1.4.1.3 throughout power source supply range. The supplier shall present data at the technical review demonstrating compliance. At least one durability and one base brake vehicle shall be equipped with a maximum travel loss brake apply assembly. The supplier shall submit with the DV test report the travel loss limit where booster grunt can be produced.

**3.2.1.15 Reservoir Water Permeability.** The reservoir material water permeability shall be such that the brake fluid picks up <3% water when exposed to 38 °C temperature and 100% humidity for one year.

**3.2.1.16 Leakage.** The master cylinder shall have no internal or external leakage up to 15 MPa fluid pressure. Input travel increase due to internal leakage shall be <0.1 mm in 30 s at any fluid pressure up to 21 MPa. Supplier must also demonstrate resistance to leakage from particle contamination and surface finish imperfections. Design must be tested with particles of 0.5 mm by 0.5 mm size in the seal groove and must either seal or purge the particles out.

**3.2.1.17 Reservoir Design.** Reservoir fluid volumes will vary by application. The volume requirements shall be specified for each application. Reserve volume is the volume below the Reservoir Communicating Point. See program-specific technical specification for brake component sizing to calculate the reservoir volumes. See Appendix K, Table K1 for the reservoir volumes that should be specified and shown on the part drawing. The reservoir shall be tested in accordance to GMW15962 to verify sufficient volume. The reservoir shall have baffles to:

1. Reduce volume due to acceleration forces.
2. Avoid fluid level switch flicker due to float movement caused by chassis controls pump activity.
3. Avoid unwanted pressure builds during evacuation and fill.
4. Minimize fluid splash on the underside of the master cylinder cap to prevent leakage through the diaphragm.

For item 4, the neck should be closed off except for a 10 mm diameter hole in the neck centerline for fluid fill. (This baffle shall be located below the MAX fill line of the reservoir.) A vent hole of at least 2 mm in diameter should be located in the upper neck to prevent air from being trapped in the top of the bottle. The baffle design should allow for insertion of a 6 mm suction tube for fluid removal. See Figure 1 for a typical execution of this baffle. For applications sharing the reservoir with the manual transmission clutch system, the reservoir shall be common for all transmissions on the program unless otherwise stated in the program-specific technical specification. The default design to accommodate this commonality shall be to have a port that can be trimmed/opened for the manual transmission clutch hose interface and remain unaltered and meet specifics in 3.2.3.2.1 reservoir burst requirements for automatic transmission equipped models. These factors should all be


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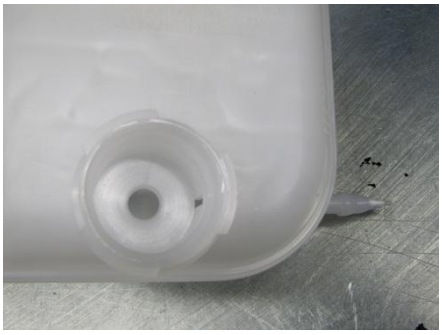
considered in the DFMEA. The master cylinder reservoir shall be sized to be no more than 5% greater than the required volume to meet the requirements of this section. The reservoir sizing shall meet all regional regulatory requirements (FMVSS 135 for USA, etc.) The reservoir shall also be sized in accordance with GMW15110. The master cylinder assembly shall indicate a partial system hydraulic failure through a reservoir fluid level switch. The fluid level switch connection shall be protected from or confirmed to not be in the direct path of water splash in the engine compartment. See program-specific technical specification for brake dimensions related to reservoir sizing.

The 'Max Fill' line shall be at the same location relative to the fill opening on all reservoirs, regardless of design if possible. This distance (shown as 'Y' in Figure F1) is to be 27 mm. This is to minimize the number of fluid fill heads and enable flexibility in building multiple platforms in a facility. Final dimension should be confirmed with the Manufacturing Engineering department to insure compatibility with existing plant equipment and platforms.

The reservoir neck shall be designed to accommodate a "bayonet" style cap. See Appendix J for the GM global standard fill neck dimensions.

**Figure 1: Reservoir Neck Baffle Example**



**3.2.1.17.1 Maximum Trip Point.** The fluid level switch shall not activate prior to the volume of fluid being reduced by the amount needed for statistically complete wear of all four brakes.

**3.2.1.17.2 Minimum Trip Point.** The point at which the switch activates shall occur before the fluid reaches the level of the dedicated fluid compartments.

**3.2.1.17.3 Component Variation.** The supplier shall indicate the increase in total reservoir volume (over the minimums specified by the platform) required to accommodate master cylinder assembly build variation.

**3.2.1.18 Brake Fluid System Failure Warning Sensor Diagnostics.** The brake fluid system failure warning sensor shall have diagnostic capability. Diagnostics must include a means to determine if the sensor is not connected. Refer to Appendix D, Figure D1 for sensor mechanization and Table D1 for switch electrical requirements.

**3.2.1.19 Reservoir Cap Performance.** Refer to the GM global reservoir cap specification GMW16808 for details on master cylinder cap performance.

**3.2.1.20 Check Valve.** If the booster is a vacuum booster, the check valve shall be tested in accordance to GMW14562.

**3.2.1.20.1 Check Valve Vacuum Loss.** The check valve vacuum loss shall be <1 kPa.

**3.2.1.21 Vacuum Retention (For Vacuum Boosters).** A vacuum booster shall retain vacuum as shown in Table 6. When tested, the measured vacuum must be adjusted for temperature changes to a testing target of 23 °C. The vacuum is measured at the check valve outlet (interface to hose).



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**Table 6: Vacuum Retention**

| | | Post-Durability Test/ Durability Cycling | |
|---|---|---|---|
| Time (h) | Vacuum (kPa) | Time (h) | Vacuum (kPa) |
| 0 | 67.7 | 0 | 67.7 |
| 168 | ≥30 | 27 | ≥0 |

**3.2.1.22 Booster and Master Cylinder Coating.** The booster and master cylinder (if applicable) must meet GMW14671-Type A paint, Underhood, suffix Z modified oil, brake fluid and fuel resistance. Test Modification: Test pieces shall be immersed in engine oil (GMW15827 and GMW16177) and Brake Fluid (GMW3356 and GMW16072) then exposed for 24 ± 5 h in a drying oven at +100 ± 3 °C. After cooling to +23 ± 5 °C, the paint film shall show no separation or softening.

**Note:** Aluminum boosters and master cylinders do not require coating unless required for cosmetic reasons by the program specific technical specification.

**3.2.1.23 Corrosion.**

**3.2.1.23.1 Cosmetic Corrosion.** The booster and master cylinder assembly shall be capable of passing 2 years corrosion exposure with <5% red rust or with <5% base metal corrosion (e.g., white corrosion). The booster and master cylinder assembly must meet the requirements specified in GMW15272 for both functional and cosmetic corrosion performance. Validation testing shall be to GMW14872: Underhood; all mounting locations; 4 salt sprays per cycle; Methods Severe-High (SH) and Severe-Moderate (SM); Exposures A and D. See program-specific technical specifications.

**3.2.1.23.2 Functional Corrosion.** The brake apply system shall remain functional after being subjected to 10 equivalent years Corrosion Test. Proper materials shall be selected to avoid corrosive interaction at component interfaces. Components and/or subsystems shall meet the requirements found in GMW15272. If the targeted marketing region includes North America and Europe (Visibility for Brake Apply: High), the corrosion requirements should be specified as follows: The component shall meet the corrosion and validation requirements of GMW15272. Cosmetic corrosion performance, as well as overall corrosion validation requirements, are based upon part/subsystem location on the vehicle. For this part/subsystem the corrosion classification is SH; the location is Underhood High Visibility.

**3.2.1.24 Squeaks and Rattles.** There shall be no customer annoyance due to squeaks and rattles of brake components during vehicle test procedure GMW8518. The final authority for the determination of whether a noise is objectionable lies with the Buyer Lead Engineer and/or the Squeaks and Rattles (S&R) Engineer. Squeaks and rattles include, but are not limited to, all the noises described in the GM S&R Noise Glossary. (Stakeholders: 20.04 Brakes; 0C.03 Noise and Vibration.)

**3.2.1.24.1 Master Cylinder Squeak.** Post DV and PV parts shall not exhibit any master cylinder squeak. This phenomenon shall be considered in the supplier's DFMEA and PFMEA (including grease application).

**3.2.1.25 Acoustic Performance.** Acceptable acoustic levels are a critical element to customer satisfaction. Any design that can impact these levels shall be reviewed with the design engineer, interior acoustic integrator, and acoustic treatments design engineer.

**3.2.1.25.1 Brake System Pass-Through.** The sound transmission loss of any component passing through the body structure shall meet or exceed the requirement from 400 to 10 000 Hz as specified in the program-specific technical specification per GMW14178. Refer 3.1.4.1.1 Sealing. (Stakeholders: 20.04 Brakes; 0C Noise and Vibration.)

**3.2.1.25.2 Pass-Through Interface.** The modular plate sheet metal or front of dash sheet metal shall remain in the same plane for at least 25 mm radially outward from the perimeter of any pass-through.

**3.2.1.25.3 Pass-Through Overlap.** The overlap of the pass-through grommet to the insulator mat shall be a minimum of 9.5 mm to ensure proper sealing.

**3.2.1.26 Label Durability.** Labeling must be in accordance with GMW14573.



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**3.2.2 Physical Characteristics.** The required physical characteristics for the booster and master cylinder are specified in the following paragraphs.

**3.2.2.1 Dimensions and Capacity.**

**3.2.2.1.1 Master Cylinder Sizing.** The program-specific technical specification shall specify the bore and stroke required to meet brake system performance requirements with the booster total boost force specified in 3.2.2.1.2 and the packaging envelope. The primary/secondary split shall be 50/50 unless otherwise specified in the program-specific technical specification. (Also see Figure A2.) The vehicle shall be equipped with a diagonally split system unless otherwise stated in the program-specific technical specification.

**3.2.2.1.2 Booster Sizing.** The program-specific technical specification shall specify the minimum total boost force required to meet brake system performance requirements and the packaging envelope. The supplier shall propose a booster size to accommodate these requirements. The minimum booster stroke shall be greater than the master cylinder maximum stroke.

**3.2.2.1.3 Reservoir Cap.** The reservoir cap shall be designed to the Global Reservoir Cap Specification, GMW16808 which specifies a bayonet (1/4 turn) style cap.

**3.2.2.1.3.1 Reservoir Cap Orientation.** The reservoir and cap shall provide cap orientation such that the cap text and symbols are aligned with the X-Y vehicle axis to ensure horizontal reading when viewed by a person in front of the vehicle looking into the engine compartment.

**3.2.2.1.4 Check Valve (For Vacuum Boosters).** The booster interface shall accommodate check valve barb dimensions that match check valve GM Part Number 18019500.

**3.2.2.1.5 Packaging.** The supplier shall provide the maximum packaging envelope for the booster and master cylinder assembly, including any expansion or growth under maximum apply conditions. The program maximum underhood packaging requirements shall be specified in the program-specific technical specification.

**3.2.2.1.6 Crashworthiness.** The brake system shall complement the ability of the vehicle to conform to the corporate and legal requirements for crashworthiness.

**3.2.2.1.7 Plastic Deformation.** The brake system components shall show plastic deformation prior to fracture in a crash.

**3.2.2.1.8 System Mechanical Return Stop.** The booster assembly shall contain the system mechanical return stop feature. When installed on the Front-of-Dash module plate and assembled to the pedal, the pedal shall assume the fully released position in the vehicle. This function is necessary in order to perform brake switch installation and adjustment on the cockpit module.

**3.2.2.2 Mass Properties.** See the program specific specification for the mass target. The assembly includes the booster, master cylinder, fluid reservoir and cap, fluid failure warning sensor, and booster/master cylinder interfacing hardware.

**3.2.3 Reliability.**

**3.2.3.1 Reliability Evaluation Point.** See program-specific technical specification for any Vehicle Technical Specification requirements different than 3.1.5.

**3.2.3.2 Reliability Requirements.** The demonstrated reliability of the subsystem through its target life under the environmental and usage conditions given in 3.1.3 and 3.1.5 shall be at least 98% reliability with 50% confidence.

**3.2.3.2.1 Reservoir Validation and Burst Strength.** The reservoir shall be tested to GMW16881. Exceptions require the approval of the program-specific design engineer.

**3.2.3.2.2 Master Cylinder Burst Pressure.** The master cylinder burst pressure shall exceed 34.5 MPa when applied to the outlet ports with the cutoff hole closed with input travel.

**3.2.3.2.3 Maximum Pushrod Input and Retention Force.** With power assist functioning, the booster and master cylinder assembly shall withstand a 10 700 N pedal pushrod force at all pushrod stroke conditions without catastrophic failure. Some truck applications shall require up to 17 100 N pedal pushrod force. See program-specific technical specification for applicability of 17 100 N force requirement. The pushrod must withstand a 2000 N pullout (tensile) force without disengaging or change of functional length.

**3.2.3.2.4 Spike Pressure to Simulate Antilock Brake System Recirculation.** With a properly filled and bled master cylinder, the unit shall be stroked to a position to close off the pressure relief holes (or close the center



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valve) at a rate of 80 ± 10 mm/s for 200 ± 2 strokes and shall not fail any seals or seats. A pressure leak test at 15 MPa for 3 minutes shall not increase piston travel >0.5 mm.

**3.2.3.2.5 Water Intrusion.** If the brake booster has any open chambers within the engine compartment, GMW14547 Dynamic Exterior Vehicle Water Ingestion Test shall be conducted to verify water does not affect the brake booster performance; including electrical, hydraulic, and vacuum assist. This exposure shall be included in the supplier's DFMEA. For this test, the program-specific technical specification shall specify the classification of vehicle usage and exposure as Moderate, Severe, or Fording.

**3.2.3.3 Quality.** For vacuum boosters and master cylinders, the supplier shall meet all of the quality control specifications as stated in Appendix G, Table G1, including the cleanliness audit. For boosters equipped with a vacuum sensor, the Responsibility Assignment Matrix (RASIC) in Appendix H, Table H1 and the testing in Appendix I, Table I1 shall be followed. For other brake assist systems see quality requirements in the program-specific technical specification.

**3.2.3.3.1 Hydraulic Booster Lot Control.** Randomly selected final assemblies (4 per shift) shall be assessed for acceptable performance before that lot of parts is shipped to the GM vehicle assembly plant. There shall be <5% change in performance and no external leakage after each part has experienced 1000 cycles at full stroke between 25 °C and 55 °C. In addition, each assembly shall be disassembled and inspected according to an inspection list including high Risk Priority Number (RPN) PFMEA items and past quality concerns including, but not limited to, proper seal seating, critical machined surface quality (e.g., piston outer diameter and bore), and contamination. Once acceptable part quality and performance is confirmed, that lot of parts may be shipped to the GM vehicle assembly plant.

**3.2.4 Serviceability.** The following paragraphs define the constraints and requirements associated with serviceability of the Brake Apply subsystem. Serviceability is the ease and cost of performing the maintenance, diagnosis, and repair operations necessary to preserve the original performance level of the vehicle throughout its target life.

**3.2.4.1 Design for Serviceability.**

**3.2.4.1.1 New Essential Tools.** The subsystem should not require the development of any new essential tools, as defined below, for the performance of diagnosis, maintenance, and repair procedures. Essential tool = a tool called out in the manufacturer's service manual diagnosis or repair procedure which is required to perform that operation.

**3.2.4.1.2 Fasteners/Fittings/Connectors/Seals.**

**3.2.4.1.2.1** Fasteners with a service specification of torque plus angle should be avoided in the areas where customer performed maintenance or service is recommended.

**3.2.4.1.2.2** Use of torque to yield fasteners is not permitted.

**3.2.4.1.2.3** All serviceable fasteners that are considered reusable shall withstand a minimum of 5 remove and replace procedures.

**3.2.4.1.2.4** Fasteners requiring a back-up wrench for removal shall have adequate clearance for back-up tools.

**3.2.4.1.2.5** The system shall use fasteners that are readily available from the GM Fastener Catalog.

**3.2.4.1.2.6** Dynamic torque values shall be provided for service publications.

**3.2.4.1.2.7** Quick connectors/fittings and seals should be reusable a minimum of 5 times and serviceable separately.

**3.2.4.2 Maintenance.**

**3.2.4.2.1 Performance of Scheduled and Unscheduled Maintenance.** System components shall not interfere with normal maintenance procedures.

**3.2.4.2.1.1** Visual inspection of brake fluid level must be possible immediately from engine compartment without removing any parts.

**3.2.4.2.1.2** During scheduled underhood service (e.g., oil change), the inspection of the brake booster/master cylinder assembly (for leaks and/or physical damage) shall be completed by visual means only.

**3.2.4.2.1.3** The brake hydraulic system shall adhere to the following fluid replacement intervals (unless otherwise specified in the program-specific technical specification):

**3.2.4.2.1.3.1** North America – DOT 3 - 10 years, DOT 4 - 2 years.



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