



Brake Pedal Emulator 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 Purpose. This standard establishes the mechanical and electrical requirements for a Brake Pedal Emulator (BPE) to be used in a brake system in which mechanical dash push-thru is eliminated. The BPE provides the driver with pedal feedback and sends the driver's deceleration request to the Brake Controller(s).

1.2 Applicability. All vehicles that use an Electrical Back-Up (EBU) brake system that do not include a mechanical linkage between the brake pedal and boosting/actuating mechanism (i.e., Mechanical Back-Up (MBU)) and still require the ability to have a driver decelerate the vehicle (full-time or part-time) by pressing a brake pedal.

1.3 Remarks. This standard does not define the specific pedal feel requirements (e.g., Pedal Travel vs. Pedal Force curves) of the BPE since this is vehicle specific and will appear in the program-specific Component Technical Specification (CTS); however, generic pedal feel curves are provided in this specification as a reference.

2 References

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

2.1 External Standards/Specifications.

ADR 31/03	FMVSS 105	GB 16897-1997	SAE USCAR 25
ADR 35/05	FMVSS 106	IATF 16949	SANS 1207/20013
Article 12, TRIAS 11	FMVSS 108	IPC J-STD-001	TIS 2540
CMVR 1989	FMVSS 126	ISO 1431-1	TRIAS 11-2
CMVSS 105	FMVSS 135	ISO 12103-1	TRIAS 12
CMVSS 135	GB 4094	ISO 26262	UN R13.09
CONTRAN RESOLUTION 519/2015	GB 7258	KMVSS 15, 90	UN R13.11
EWCAP-001	GB 12676-1999	SAE J2716	UN R13H

2.2 GM Standards/Specifications.

GMW3059	GMW3205	GMW14377	GMW15335
GMW3091	GMW3600	GMW14551	GMW15396
GMW3097	GMW7293	GMW14872	GMW15862
GMW3172	GMW14264	GMW15272	

2.3 Additional References.

- Appendices G1, G2, and G3 of program electronic Statement of Requirements (eSOR)
- Brake System Technical Specification (STS)
- Statement of Requirements (SOR) Appendix F
- GM1724

GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

August 2018

Page 1 of 27

- GM1738
- GM1797
- GM1829
- Program-specific CTS (found in SOR Appendix C2)
- Safety and Industrial Hygiene (S&IH) Technical Standard (TS), S&IH TS 3.4-160-02
- SCS-033-SA Hardware Integrity Metrics
- SCS-055 Design Failure Mode and Effects Analysis (DFMEA) Report Template
- SOR Material Decision Tree
- Validation Cross Reference Index (VCRI) in Appendix G3 of electronic Statement of Requirements (eSOR).

3 Requirements

3.1 System/Subsystem/Component/Part Definition. The BPE operates in between the Brake Pedal Arm and Pedal Bracket. When the driver applies force at the brake pedal pad, the BPE senses this with redundant sensors of diverse technologies and provides the signals to the Brake Controller(s). The Brake Controller(s) translates the driver's input to a deceleration request and sends the corresponding command to the brake apply system.

3.1.1 Appearance. All components of the BPE that are visible when it is fully assembled shall have a uniform color: black if plastic (0848 Black) and an as-finished non-painted color if metal (surfaces painted for corrosion resistance are acceptable). No supplier logo shall appear on the outside of the part. Final appearance approval shall be made by GM Engineering. See Appendix F5 of SOR for program-specific appearance details.

3.1.2 Content.

3.1.2.1 Physical Content. The BPE shall contain all the mechanical and electrical hardware necessary to perform the requirements set forth in this document. The BPE includes the emulating mechanism, housing, sensors and Printed Circuit Board (PCB), electrical connectors, interfacing hardware (i.e., to Pedal Arm and Pedal Bracket), and any other associated hardware (e.g., fasteners, seals). The physical content of the BPE must satisfy the functional safety requirements in 3.1.2.2.1, which may drive physical redundancy for some of the mechanical and electrical components.

3.1.2.1.1 Emulating Mechanism. The device or component contained within the BPE assembly is known as the emulating mechanism and it must produce the pedal feel requirements in 3.2.1.1.

3.1.2.1.2 Sensors and PCB. The BPE sends the driver's deceleration intent to the Brake Controller(s) by means of force and travel sensors. The BPE shall be able to sense the driver's intent (i.e., movement of pedal or change in force) from two (2) different locations within the BPE to prevent common cause failures. Sensor redundancy shall exist to the extent that it takes to satisfy the functional safety requirements in 3.1.2.2.1 and dependability requirements specified in 3.2.3. Redundancy in software alone will not be sufficient to satisfy these requirements; physical redundancy will be required with respect to the sensors and mechanical components. The BPE shall prevent common cause failures that cause all four (4) signals to be incorrect. The level of redundancy shall be reviewed by GM System Safety Engineering.

3.1.2.1.2.1 Travel Sensor. The travel sensor is the primary mechanism used to translate the driver's deceleration intent to the Brake Controller(s). The travel sensor shall detect movement of the pedal to the detail specified in 3.2.1.2.

3.1.2.1.2.2 Force Sensor. The force sensor shall be capable of sensing the driver's deceleration intent to a similar level of capability as the travel sensor. In addition, the use of a force sensor allows the driver to modulate vehicle deceleration under high-g braking (where there is minimal pedal travel) and also to sense rapid brake pedal applies. The type of sensor technology used is unrestricted as long as the signal fidelity, resolution, accuracy, etc. are capable of meeting the requirements specified in 3.2.1.2.

3.1.2.1.2.3 Wake-Up Switch. Only if directed by the program-specific CTS, the BPE shall be capable of providing a discrete signal to wake-up the Brake Controller(s) when the brake pedal is applied and the vehicle is off. If this feature is desired by GM, the discrete switch must be integrated into the BPE assembly and abide by the requirements specified in 3.2.1.1.5.

GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

August 2018

Page 2 of 27

3.1.2.1.3 Electrical Connectors. The electrical pins inside the connector shall be mechanically fixed to the connector itself (e.g., press fit, overmolding, etc.) See 3.1.4.2 for electrical connector interface requirements. Connector shrouds may be molded into the Housing (see 3.1.2.1.4) or an electrical connector header may be mechanically fastened and sealed to the Housing.

3.1.2.1.4 Housing. The BPE housing shall contain the emulating mechanism and sensor PCB. The purpose of the housing is to provide structure and stiffness to the system and provide attachment and protection for the components which it encloses. The housing shall be designed with consideration of the distribution of loads into the Pedal Bracket.

3.1.2.1.5 Interfacing Hardware. The BPE must have a means to attach to the Brake Pedal Module's Bracket. This may be accomplished with features integrated into the BPE's Housing or with a separate component. The BPE must also have a means to connect to the Pedal Arm to receive the driver's inputs. See 3.1.4.1 for details.

3.1.2.1.6 Ancillary Hardware. All ancillary hardware, including, but not limited to, fasteners and seals, shall be reviewed and approved by GM Engineering.

3.1.2.1.7 Lubrication. While not desirable, it is permissible to use lubrication (e.g., grease) to reduce friction and alleviate any Noise, Vibration, and Harshness (NVH) resulting from moving components. The lubricant must be in a sealed environment within the BPE and not leak out. Silicone is not allowed in any lubricant used. Any lubrication used shall be certified for acceptable performance with minimum and maximum tolerance quantities applied and in all environments stated in 3.1.3. Any form of lubrication used is subject to review and approval by GM Engineering.

3.1.2.2 Functional Content. The BPE has two (2) primary functions. The first is to send the driver's deceleration request to the Brake Controller(s) and the second is to provide the driver with pedal feedback since there is no longer a mechanical connection between the brake pedal and the apply system. The BPE may emulate the pedal travel and force characteristics of a traditional brake system or any other characteristics stated in the program-specific technical specification. A tertiary function of the BPE is to wake-up the Brake Controller(s) in the event of a pedal apply while the vehicle is off, but the need for this will be clearly stated in the program-specific CTS.

3.1.2.2.1 Functional Safety Content. The BPE shall support vehicle system functionality that meets Automotive Safety Integrity Level (ASIL) D requirements according to ISO 26262 without any exceptions; deviation requests based on sufficient analysis to be reviewed and approved by GM System Safety Engineering. The fault-tolerant design of the BPE supports continued operation of its functions in the presence of any single point, plausible dual point, or common cause malfunction without resulting in a hazardous situation. The BPE shall enable full diagnostic coverage and be diagnosable for any single point failure within its boundaries. The physical content of the BPE must satisfy the aforementioned functional safety requirements, which may drive physical redundancy for some of the mechanical and electrical components.

3.1.3 Ambient Environment. GMW3172 is referenced throughout this section. When referenced, the code for the BPE is ACCDB IP5K4K. This specifies the type of environmental conditions the BPE will be tested to when validating per GMW3172.

3.1.3.1 Operational Environment. The BPE shall meet all performance requirements (see 3.2.1), without loss of function or degradation of service life and shall not exhibit any undesirable operating modes when exposed to the environments listed in this section. Undesired operating modes include incorrect driver intent output or any other deviation from performance requirements stated in 3.2.1. When constructing a program-specific CTS, refer to the Vehicle Technical Specification (VTS) for program-specific environments.

3.1.3.1.1 Temperature. The BPE, at any time during its service life, shall meet all performance requirements when exposed to the temperatures in Table 1. For the extreme temperature range that goes beyond the operating temperature (i.e., -40 °C to -54 °C and 60 °C to 85 °C), the BPE must maintain functionality in these extreme temperatures ranges; however, adhering to performance requirements is not necessarily required. The BPE shall return to meeting all performance requirements once the environment's temperature returns to within the operating range (i.e., -40 °C to 60 °C).

GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

August 2018

Page 3 of 27



Documents

Document Sharing Hub

Table 1: BPE Temperature Requirements

Occurrence	Temperature
Operating Temperature	-40 °C to 60 °C
Extreme Temperature	-54 °C to 85 °C
Shipping/Assembly Temperature	-65 °C to 48 °C
National Highway Traffic Safety Association (NHTSA) Federal Motor Vehicle Safety Standards (FMVSS)/Canadian Motor Vehicle Safety Standards (CMVSS) 135 Temperatures	0 °C to 40 °C

3.1.3.1.2 Pressure. The BPE, at any time during its service life, shall meet all performance requirements when exposed to the pressures in Table 2.

Table 2: BPE Pressure Requirements

Occurrence	Absolute Pressure
Atmospheric	57 kPa to 106.3 kPa
Extreme Pressure	20 kPa to 106.3 kPa
Shipping/Assembly Pressure	20 kPa to 106.3 kPa

3.1.3.1.3 Radiation.

3.1.3.1.3.1 Total Solar Radiation. The BPE, at any time during its service life, shall meet all performance requirements when exposed to 775 MJ/m² per year.

3.1.3.1.3.2 Ultraviolet Radiation. The BPE, at any time during its service life, shall meet all performance requirements when exposed to 34.6 MJ/m² per year. Ultraviolet radiation is defined as wavelengths between 295 nm and 385 nm.

3.1.3.1.4 Humidity. The BPE, at any time during its service life, shall meet all performance requirements when exposed to relative humidity in the range of 0% to 100%.

3.1.3.1.5 General and Road Contaminants. The BPE, at any time during its service life, shall meet all performance requirements when exposed to cleaners, fluids, general contaminants, and road contaminants, as specified in Table 3. The BPE should not necessarily be capable of being submerged in the fluids mentioned in Table 3; see GMW3172 (code: ACCDB IP5K4K) to understand required level of dust and water protection.

Table 3: Contaminants

Contaminant	Content	Exposure Area and Time
Water, Snow, Ice	Common	Entire Assembly, 168 h
Sand, Dust	ISO 12103-1 A2 Fine Grade Dust	See 3.1.3.1.7
Brake Fluid	Commercially available	Entire Assembly, 168 h
Engine Coolant	Commercially available	Entire Assembly, 168 h
Windshield Washer Fluid	Commercially available	Entire Assembly, 168 h
Sap, Insects, Animal, Animal Waste	No test needed	Entire Assembly

Note: Some contaminants may come through a leaky Front of Dash or Heating, Ventilation, Air Conditioning (HVAC) unit.

3.1.3.1.6 Ozone. The BPE, at any time during its service life, shall meet all performance requirements when exposed to ozone concentrations and durations specified in Table 4.

GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

August 2018

Page 4 of 27

Table 4: Ozone Contaminants

Time: At ambient temperature and ozone concentration										
Total Time: 10 years = 87 600 h for Passenger Cars, 12 years = 105 120 h for Trucks.										
Total Ozone Exposure: 27 700 PPM for Passenger Cars, 33 324 PPM for Trucks, Location: Los Angeles, California										
Temperature (°C)	Ozone concentration (PPM)									
	0.00	0.01 to 0.05	0.06 to 0.10	0.11 to 0.15	0.16 to 0.20	0.21 to 0.25	0.26 to 0.30	0.31 to 0.35	0.36 to 0.40	
	Percent Total Vehicle Life									Percent Total Time In Band
38 to 43	0.01	0.07	0.08	0.08	0.07	0.02	0.02	0.01	0.01	0.35
32 to 38	0.07	0.72	0.97	0.74	0.56	0.29	0.09	0.02	0.01	3.46
27 to 32	0.92	3.32	3.03	2.34	1.13	0.35	0.07	0.01	0	11.18
21 to 27	4.53	8.97	4.44	1.23	0.17	0.01	0	0	0	19.38
16 to 21	10.23	16.02	1.07	0.01	0	0	0	0	0	27.34
10 to 16	10.73	14.25	0.03	0	0	0	0	0	0	25.01
4 to 10	4.82	7.32	0	0	0	0	0	0	0	12.13
-1 to 4	0.38	0.76	0	0	0	0	0	0	0	1.14
Total	31.70	51.43	9.62	4.40	1.93	0.67	0.17	0.03	0.01	100
Source: Purchaser Validation Center, Product Usage Measurements and Application, Los Angeles Area Ozone Data										

3.1.3.1.7 Particulates. Tables 5 and 6 list particulates and concentrations of which the BPE may see repeated exposure to during its service life.

Table 5: Particulates

Contaminant	Content	In Passenger Compartment
Dirt, Grit, and Sand	See Table 6	X
Mud	Various percent of water with Dirt, Grit, and Sand	X
Dust	See Table 6	X

Table 6: Sand and Dust Exposure Times

Concentration (milligrams per cubic meter)	Exposure Time (hours)
70	74.5
350	25.0
1600	5.0
3900	1.0

3.1.3.1.8 Vehicle Deceleration. The BPE, at any time during its service life, shall meet all performance requirements when exposed to up to 13.36 m/s² (1.5 G) vehicle decelerations.

3.1.3.1.9 Impact. The BPE, at any time during its service life, shall meet all performance requirements when exposed to an impact equivalent to being dropped from 1 m onto a concrete surface. This requirement applies to the BPE by itself (i.e., not assembled in pedal module).

GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

August 2018

Page 5 of 27

3.1.3.1.10 Vibration. The BPE shall successfully complete the Random Vibration – Mounting Location Sprung Masses vibration profile of GMW3172. In addition, in a severe vibration environment, no incidental signal shall be sent from the BPE to the Brake Controller(s) thus commanding unintended vehicle deceleration.

3.1.3.1.11 Electrical Requirements.

3.1.3.1.11.1 Supply Voltage. For the travel and force sensors, the BPE shall utilize 5 V regulated reference voltages, 0 V to 5 V outputs, and 0 V returns. Voltage input may vary between 4.9 V and 5.1 V. For the wake-up switch (if required) the BPE shall receive a nominal 12 V input with variation between 9 V and 16 V.

3.1.3.1.11.2 Extreme Voltage. The BPE shall be able to withstand the extreme voltage conditions listed in 3.2.1.2.6. Moreover, the BPE must return to 100% of its performance specifications after being exposed to these voltage conditions.

3.1.3.1.11.3 Electromagnetic Compatibility (EMC). The BPE, at any time during its service life, shall meet all performance requirements when exposed to EMC environments per GMW3091 and GMW3097. See 3.2.2.1.1 for best practices with regards to minimum clearances to surrounding electrical currents.

3.1.3.1.11.4 Electrical Environmental Durability Testing. The BPE, at any time during its service life, shall meet all performance requirements when exposed to the environmental conditions per GMW3172.

3.1.3.2 Manufacturing/Shipping Environment. The BPE shall not exhibit any permanent failure modes or undesirable operating modes after being subjected to manufacturing environments that include component shipping and vehicle assembly and shipping. Undesired operating modes include incorrect driver intended output.

3.1.4 Interfaces. The BPE shall support a modular pedal box system and shall be capable of being integrated into the same Pedal Module assembly that is used for a mechanically backed-up (e.g., vacuum-boosted) brake system without causing significant modifications.

3.1.4.1 Mechanical Interfaces. The BPE shall integrate and package into a Pedal Module assembly that adheres to GMW15396 as well as any characteristics stated in the program-specific Brake Pedal Module CTS. It shall fit between the Brake Pedal Arm and the Bracket where the Pedal Bracket may be mounted to the Dash Panel, the Instrumental Panel Structure, or a combination thereof. See Figure 1 for a rudimentary sketch of the BPE's approximate location. The precise vertical position of the BPE relative to the pedal arm's pivot point will dictate the pedal ratio. The BPE Supplier may be granted the ability to dictate the vertical position of the BPE between the pedal arm and bracket and thus the pedal ratio in order to optimize force and travel within the BPE. Alternatively, however, the pedal ratio may already be determined for the particular vehicle program. See program-specific CTS for direction. In either case, the BPE must abide by packaging and dimensional requirements specified in 3.2.2. The type of interface (e.g., clevis joint, ball and socket connection, etc.) between the BPE and the Pedal Arm will also be specified in the program-specific CTS. In the event that a ball and socket style connection is used, an acceptable range of relative motion between the input rod and the input rod retainer on the pedal arm will be specified in the program-specific CTS. The BPE shall be mechanically fastened to the pedal bracket. The BPE interface design may require a means of accommodating the arc path of the pedal arm connection point during pedal stroke depending on the design of the BPE's internals and its side-load compliance capability. In the event of a disconnection between the BPE and the Pedal Arm, the BPE must maintain its position such that, upon re-application of the pedal, the mating interfaces remain aligned to allow the Pedal Arm to apply force to the BPE's input rod and thus allow vehicle deceleration to be commanded.

GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

August 2018

Page 6 of 27



Documents

Document Sharing Hub

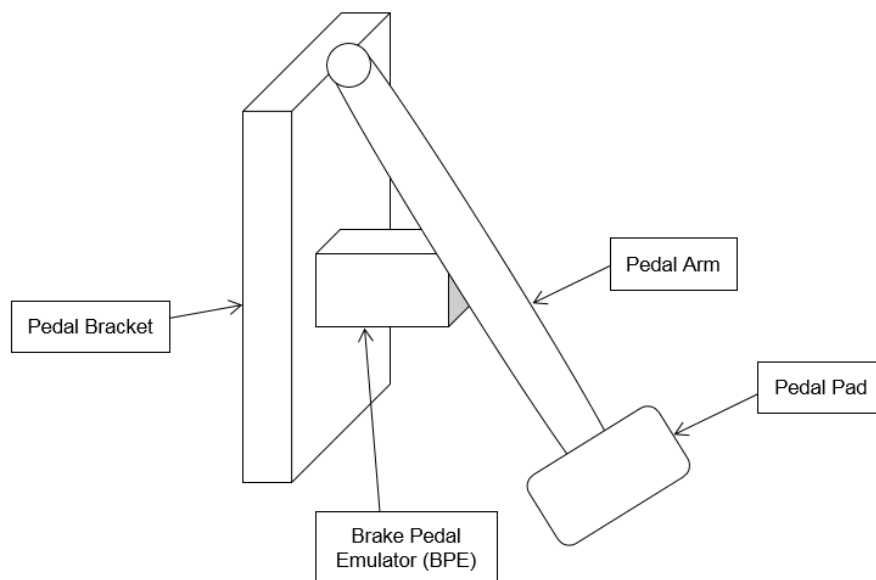


Figure 1: BPE Position in Brake Pedal Assembly

3.1.4.2 Electrical Interfaces. The BPE shall be compatible with the electrical system architecture for the given vehicle application; see program-specific CTS for particular requirements. The BPE shall meet ASIL B connector /harness/splice integrity requirements. The BPE shall have redundant, sealed electrical connectors which transmit pedal travel and force information in a fault-tolerant manner (meaning no degradation in sensor output performance). One electrical connector shall transmit primary travel and force signals and the redundant electrical connector shall transmit the redundant pedal travel and force signals. The connectors shall comply with the latest edition of SAE United States Council for Automotive Research (USCAR) 25, which specifies the ergonomic design criteria for electrical connections. The connectors shall have Connector Position Assurance (CPA) with a visual indicator as well as tactile feedback to indicate that a connection has been made. The redundant connectors shall be poke-yoked (i.e., keyed differently) to provide protection against incorrect assembly during original vehicle assembly or service. Each connector on the vehicle wiring harness will be a unique color and the mating connector shrouds on the BPE must have ink markings with the matching corresponding color. See program-specific CTS for color requirement. The connectors shall conform to USCAR 120-S-XXX-X-XXX with straight blades that are 1.2 mm in width and silver-plated conforming to EWCAP-001. Silver plating details shall be discussed and agreed upon with GM Engineering, but a matte (non-glossy) finish is required. The voltage and ground pins shall be furthest away from each other on pin out. After ten (10) connect/disconnect cycles the contacts shall still function normally. Connectors shall be reviewed for acceptance by the GM Electrical Connector Design Release Engineer (DRE) and/or the Electrical Connector BFO (Bill of Material (BOM) Family Owner).

3.1.4.2.1 Wake-Up Switch. If required, the wake-up switch shall have an electrical interface to the battery and to the Brake Controller(s). These interfaces may be integrated into the aforementioned redundant electrical connectors (see 3.1.4.2) or a separate (tertiary) electrical connector may be used. See program-specific CTS for further requirements.

3.1.5 Usage Definition.

3.1.5.1 Minimum Typical Usage Profile. The plot shown in Figure 2 shows the typical number of pedal applies for a given brake pedal force; see Table 7 for explicit data, which corresponds to Figure 2. The minimum typical operational hours for the BPE's electronics is 8800 h, but the program-specific CTS must be referenced for the particular vehicle application. This information is provided as a reference; the precise use case and minimum expected service life shall be defined in the program-specific CTS. Performance requirements stated in 3.2.1 are expected to be met for the entire usage profile of the BPE as well as for the aforementioned operational hours for the electronics.

GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

August 2018

Page 7 of 27



Documents

Document Sharing Hub

Table 7: Typical Number of Brake Pedal Applies for Given Pedal Force (Reference Figure 2)

Brake Pedal Force [N]	Number of Brake Pedal Applies
28.0	707 857
30.4	797 888
34.3	278 352
38.0	116 000
39.8	88 500
44.7	63 100
47.5	31 500
50.6	9000
61.2	4610
69.6	1490
78.2	1070
86.8	340
91.1	60
99.7	40
108.8	20
118.5	18
128.9	15
139.9	10
145.6	10
157.6	10
170.2	10
176.7	30
190.3	70
	<i>Total Number of Applies: 2 100 000</i>

GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

August 2018

Page 8 of 27

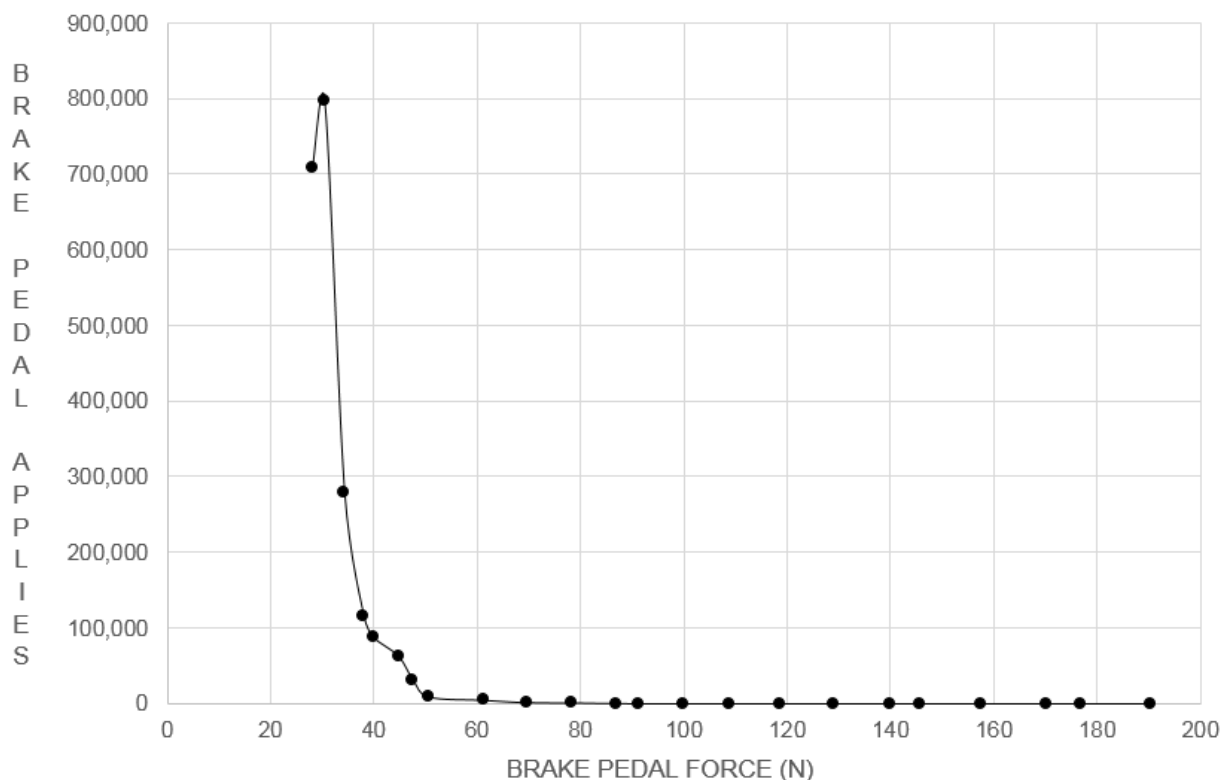


Figure 2: Typical Number of Brake Pedal Applies for given Pedal Force

3.1.5.2 Methods of Pedal Release. The BPE may see repeated exposure to the operator brake pedal pad release conditions during its service life. The following release speeds are at the brake pedal pad:

- Gentle (very slow, < 1 mm/s).
- Sidestep (instantaneous release), see 3.2.1.1.4.
- Release speeds between gentle and sidestep.

The speed of the BPE's Input Rod will actually be slower than this and will be dependent upon the vertical location of the BPE relative to the pedal arm pivot point.

3.1.5.3 General Durability. The BPE must survive the Brake Pedal Module's durability test requirements according to GMW15335 for structural strength testing. For fatigue testing, the BPE shall run a modified version of GMW14551 that is specific to the BPE (see program-specific CTS for number of cycles). In these procedures, the BPE is assembled into the program-specific Brake Pedal Module. The maximum force applied to the brake pedal during testing shall not exceed those listed in 3.2.1.3 of this specification. Additional requirements for cycling may be included in the program-specific CTS.

3.1.5.4 Regulatory Standards including FMVSS/CMVSS Compliance. The BPE shall comply with all regulatory standards as specified in the VTS for countries of sale, and also must comply with all requirements stated in 3.2.

3.2 Product Characteristics.

3.2.1 Performance Requirements.

3.2.1.1 Mechanical Output Characteristics. The following subsections specify requirements for force, travel, damping, and hysteresis that the BPE must exhibit to achieve quality brake pedal feel. The requirements and guidelines provided are all assessed and specified from the reference point of the brake pedal pad and not the BPE itself. When physically measuring pedal feel (e.g., during testing), the rubber pedal cover shall be included on the brake pedal pad. Pedal application shall be made at the center of the pedal pad and pedal force and travel shall be measured from the center of the pedal pad (see Appendix A, Figure A1 for more information). All

GM Confidential

© Copyright 2018 General Motors Company All Rights Reserved

August 2018

Page 9 of 27



Documents

Document Sharing Hub