



Compressed Natural Gas (CNG) Subsystem Technical Specification for Mono-Fuel and Bi-Fuel Vehicles

1 Introduction.....	4
1.1 Purpose	4
1.2 Applicability.....	4
1.3 Remarks	4
2 References	4
2.1 External Standards/Specifications.....	4
2.2 GM Standards/Specifications	5
2.3 Additional References	5
3 Requirements	6
3.1 System/Subsystem/Component/Part Definition	6
3.1.1 Appearance.....	7
3.1.2 Content	7
3.1.3 Ambient Environment.....	10
3.1.4 Interfaces	15
3.1.5 Usage Definition.....	18
3.2 Product Characteristics	19
3.2.1 Performance Requirements.....	19
3.2.2 Physical Characteristics.....	29
3.2.3 Reliability.....	30
3.2.4 Serviceability.....	31
3.2.5 User System/Subsystem/Component/Part Interface	33
3.3 Design and Construction	34
3.3.1 Materials, Processes and Parts Selection Guidelines	34
3.3.2 Design Guidelines and Constraints	35
3.3.3 Identification and Marking.....	39
3.3.4 Workmanship	40
3.3.5 Interchangeability.....	40
3.4 Documentation	41
3.4.1 Assembly Drawing	41
3.4.2 Detailed Drawings.....	41
3.4.3 Installation Drawings.....	41
3.4.4 Master Process Documents (MPD)	41

GM Confidential

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August 2017

Page 1 of 59



Documents
Document Sharing Hub

3.4.5 Service Manual Supplement.....	41
3.4.6 Owner's Manual Supplement.....	41
3.4.7 Process Failure Mode Effects Analysis	41
3.4.8 Design Failure Mode Effects Analysis	41
3.4.9 Process Control Plan	41
3.5 Support of System/Subsystem/Component/Part After Sale.....	41
3.5.1 Ease of Disassembly of Quick Connects in Fuel Lines	41
3.5.2 Venting and Removal of the CNG Fuel Container or System	41
3.5.3 Customer Care and Aftersales (CCA) Release	41
3.6 System/Subsystem/Component/Part Operator Training	41
3.7 System/Subsystem/Component/Part Characteristics	41
3.7.1 System/Subsystem/Component/Part Definition.....	41
3.7.2 Component Interface Description	46
4 Validation.....	49
4.1 General	49
4.1.1 Subsystem Validation Initiation.....	49
4.2 Validation Cross Reference Index.....	49
4.3 Supporting Paragraphs.....	49
5 Provisions for Shipping	49
5.1 Shipment.....	49
5.2 Packaging	49
5.3 Vehicle Transport	49
6 Notes	49
6.1 Glossary.....	49
6.2 Acronyms, Abbreviations, and Symbols.....	51
7 Additional Paragraphs	53
8 Coding System.....	53
9 Release and Revisions	53
Appendix A: Test Fuels	54
Appendix B: Contaminants.....	55
Appendix C.....	57
C1 Region Specific Standards and Regulations Depending from the Region of Sale	57
C1.1 Regulations– Global CNG.....	57
C1.1.1 Europe	57
C1.1.2 Czech Republic – Regulations	57
C1.1.3 Mexico – Regulations	57
C1.1.4 Thailand – Regulations	57
C1.1.5 India – Regulations.....	57
C1.1.6 Venezuela – Regulations	57

GM Confidential

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August 2017

Page 2 of 59


Documents
 Document Sharing Hub

C1.1.7 South Korea – Regulations	58
C1.1.8 United States (Federal and State) – Regulations	58
C1.1.9 Canada (Federal and Provincial) – Regulations	58
C1.2 Industry Standards – Global CNG	58
Appendix D: Filling Nozzle Tests for CNG and LPG Vehicles	59
D1 Test Criteria	59
D1.1 Nozzle Load Test	59
D1.2 Brake Away Force Test.....	59
D1.3 Static Force Test.....	59

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August 2017

Page 3 of 59



Documents

Document Sharing Hub

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 Chassis Compressed Natural Gas (CNG) Fuel Storage and Handling Subsystem ("CNG fuel subsystem" in the following) requirements for General Motors compressed natural gas fueled vehicles. Additionally, this standard serves as a template to be used for developing a CNG fuel subsystem specification for a particular platform or vehicle. In this form, this standard provides information required for developing a specification for a particular application, with only application specific addition, deletion, and modification.

1.2 Applicability. This standard applies only to Bi-fuel or Dedicated (Mono-Fuel, Mono-Fuel plus) CNG vehicles and is applicable to CNG system components only. It includes requirements for complete vehicles, complete vehicles requiring subsystem installation, becoming an altered or second stage manufactured vehicle, or, as an incomplete vehicle associated to the IVD (Incomplete Vehicle Document), which will be furnished with each incomplete vehicle. Vehicle assembly strategy will be specified by program specific statement of requirements (SOR).

Note: As defined within the Federal Motor Vehicle Safety Standards (FMVSS) in the United States, the supplier shall provide all necessary intermediate manufacturing (Altered or IVD) information, along with any applicable Environmental Protection Agency (EPA), California Air Resources Board (CARB) emission certification requirements and stated fuel economy requirements.

Note: The IVD is not a substitute for knowledge and understanding of the requirements of the Federal Motor Vehicle Safety Regulations (FMVSR) or the FMVSS. Intermediate and final stage manufacturers shall be familiar with the regulations and standards referred to above and be aware of their specific responsibilities as they relate to the final destination and sale of each incomplete vehicle.

For bi-fuel systems, the gasoline components will remain defined in GMW15311.

1.3 Remarks. The CNG fuel subsystem is a functional subsystem that receives fuel, stores fuel, delivers filtered fuel, regulates CNG fuel pressure to the CNG fuel rail and senses CNG fuel temperature and pressure. The CNG fuel subsystem is to carry out these functions while meeting specific requirements of the customer, other subsystem interfaces, mandated safety standards, mandated emission standards, and other company objectives/strategies.

Program-specific technical specification (SOR Appendix C2) will include additional program specific requirements that are not referenced in this standard and may supersede any requirements included in this standard. In the case of any conflicts between this standard and the program-specific technical specification, the program-specific technical specification takes precedence.

Bi-fuel CNG vehicles are designed to operate on gasoline as well as compressed natural gas. Dedicated (Mono-fuel) CNG vehicles are designed to operate on CNG alone. The functions, performance, design constraints, and validation required of the CNG fuel subsystem are directly defined in this standard or a reference is made to another standard. Vehicles containing a CNG Fuel subsystem are denoted by one of the two option codes below:

- FHV: Bi-fuel & Monovalent Plus CNG
- FHZ: Dedicated CNG

2 References

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

2.1 External Standards/Specifications.

49 CFR Part 172	CMVSS 103	FMVSS 304	ISO 527-2
ANSI NGV 1	CSA B109	ISO 11439	NFPA 52
ANSI NGV 2	CSA B51	ISO 14469	SAE J1344
ANSI NGV 3.1	DIN 51624	ISO 15500-13	SAE J1616
ANSI PRD 1	FMVSS 103	ISO 16750-4	SAE J1645

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Page 4 of 59



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California Code of
Regulation Title 13
CGSB 3.513

FMVSS 301
FMVSS 303

ISO 3167
ISO 527-1

SAE J902
UN R110

2.1.1 The Supplier is required to verify conformance to all applicable standards based upon the CNG Fuel Subsystem design and integration into the vehicle. The order of precedence of these regulations, requirements, codes and standards is shown in Figure 1.

Figure 1: Order of Precedence



2.1.2 In addition to the documents listed in 2.1, Program Specific Documents may apply to this specification and the supplier shall verify conformance to the standards and regulations listed in Appendix C if applicable. Additionally, region specific standards and regulations shall be fulfilled as noted in Appendix C for the Region of Sale.

2.2 GM Standards/Specifications.

9986467	GMW14089	GMW14889	GMW15727
GMW3059	GMW14234	GMW14890	GMW15753
GMW3091	GMW14264	GMW15184	GMW15756
GMW3097	GMW14510	GMW15272	GMW15862
GMW3103	GMW14547	GMW15311	GMW16776
GMW3116	GMW14555	GMW15357	GMW17000
GMW3172	GMW14573	GMW15358	GMW17144
GMW7699	GMW14854	GMW15531	GMW17867
GMW8518	GMW14859	GMW15570	
GMW8738	GMW14888	GMW15667	

2.3 Additional References.

- CG3546
- CG3547
- CG4996
- ELEC86-S5128
- FSH-189 (Best Practice)
- GM1927
- PPEI_GM8762_GenInfoElectricalSerialData
- PPEI_GM8763_Power_Ground

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August 2017

Page 5 of 59



Documents

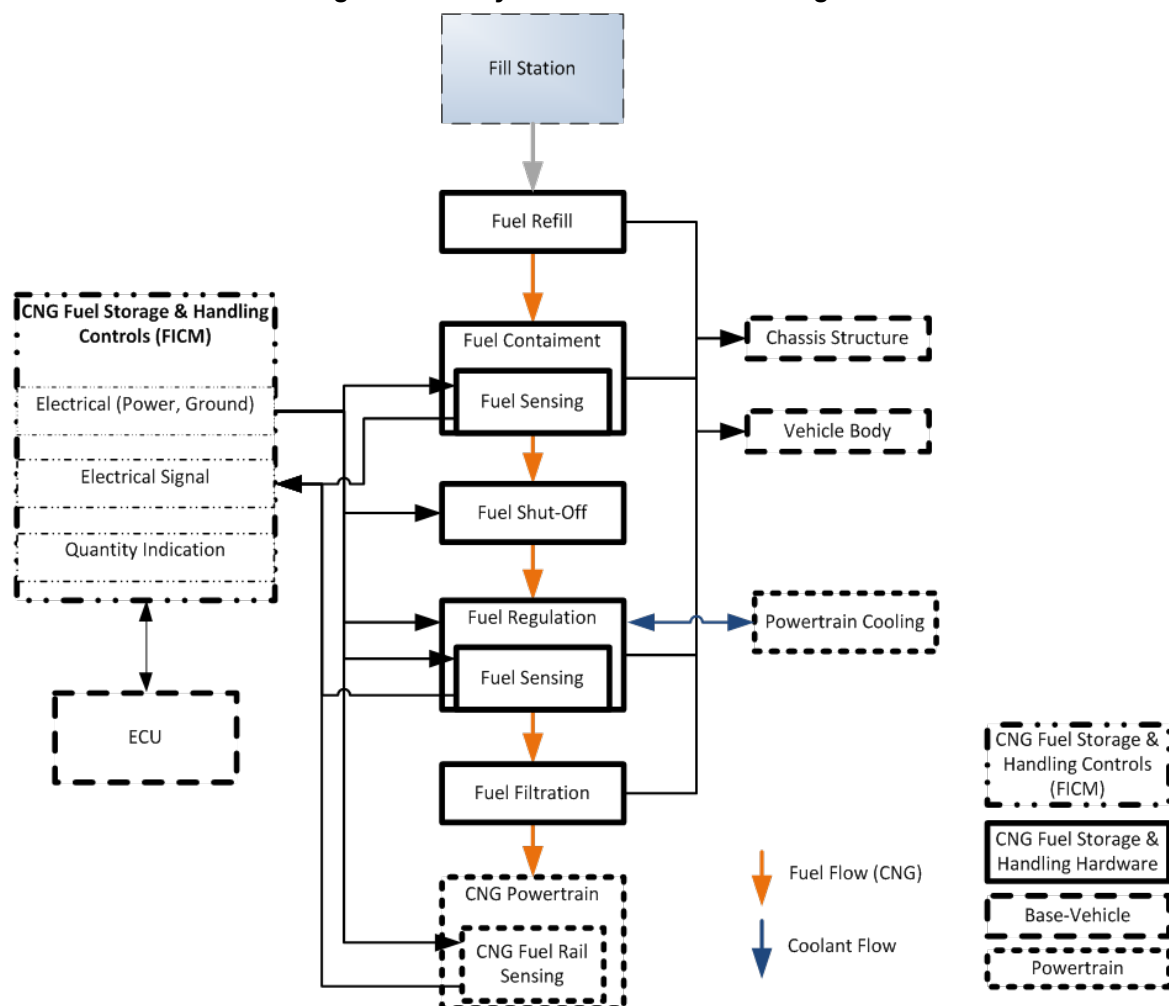
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- PPEI_GM8774_Addendum_B_FuelSystem_AltFuel_CNG_LPG
- PPEI_GM8774_Addendum_C_FuelSystem_BiFuel_Gas_CNG
- PPEI_GM8779_PostCollisionOperation
- GM Best Practices for Grounding.
- GM Bill of Process (BOP) Document Number/Rev: 35234.AH
- GMLAN Serial Data Signal Definitions and Framing Requirements
- GM Global Fastener Catalog (access when granted with GM Supply Power license)
- GM Upfitter Best Practice Manuals www.GMUpfitter.com
- US Department of Transportation Federal Hazardous Materials Transportation Law 103-311

3 Requirements

3.1 System/Subsystem/Component/Part Definition. The CNG fuel subsystem is to provide the capability to receive and store fuel, sense and calculate fuel quantity, deliver and meter fuel to the engine, and sense temperature and pressure parameters. The major subsystem content components and interfaces are depicted in Figure 2.

Figure 2: Subsystem Visual Context Diagram



ECU: Electronic Control Unit
FICM: Fuel Injector Control Module

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Page 6 of 59

3.1.1 Appearance.

3.1.1.1 Subsystem Color. In some Regions of Sale, a specific tank color is requested by the local Regulations. Therefore refer to the Program Specific Documents.

3.1.1.2 Filler Neck Color. Filler Neck Color is either stainless steel or black as required by Program Specific Documents.

3.1.1.3 CNG Subsystem Appearance. Appearance of CNG subsystem components in general shall be consistent with the look of the original vehicle (i.e. avoid bright colors).

3.1.2 Content.

3.1.2.1 Physical Content. The CNG fuel subsystem consists of, but is not limited to, the following components:

3.1.2.1.1 Fill Pipe – Assembly (High Pressure).

3.1.2.1.1.1 Receptacle.

3.1.2.1.1.1.1 Fill Cap.

3.1.2.1.1.1.2 Inlet Filter.

3.1.2.1.1.2 Valve – Check.

3.1.2.1.1.3 Fill Pipe.

3.1.2.1.2 Container – Assembly.

3.1.2.1.2.1 Container.

3.1.2.1.2.2 Container Valve – Assembly.

3.1.2.1.2.2.1 Valve - Automatic Shutoff.

3.1.2.1.2.2.2 Relief Device – Temperature Triggered Pressure Relief.

3.1.2.1.2.2.3 Relief Device – Pressure Triggered Pressure Relief.

3.1.2.1.2.2.4 Excess Flow Limiter.

3.1.2.1.2.2.5 Valve - Manual Shutoff.

3.1.2.1.2.2.6 Sensor – Pressure (optional).

3.1.2.1.2.2.7 Sensor – Temperature (optional).

3.1.2.1.2.3 Container Relief Plug with secondary Temperature and/or Pressure Triggered Pressure Relief (optional).

3.1.2.1.2.4 Labels.

3.1.2.1.3 Container Bracket – Assembly.

3.1.2.1.4 Container Strap – Assembly.

3.1.2.1.5 Isolator.

3.1.2.1.6 Container Shield.

3.1.2.1.7 Valve Protector or Helmet (optional).

3.1.2.1.8 Fuel Line - Assembly (High Pressure).

3.1.2.1.9 Regulator – Assembly.

3.1.2.1.9.1 Sensor – Pressure (optional).

3.1.2.1.9.2 Inlet Filter.

3.1.2.1.9.3 Regulator stage high pressure.

3.1.2.1.9.4 Valve – Shutoff High Pressure (optional).

3.1.2.1.9.5 Valve – Shutoff Low Pressure (optional).

3.1.2.1.9.6 Regulator Stage Low Pressure (exchangeable with Valve Low Pressure Regulation Electrical).

3.1.2.1.9.7 Valve – Low Pressure Regulation Electrical (exchangeable with Regulator Stage Low Pressure).

3.1.2.1.9.8 Valve - Pressure Relief.

3.1.2.1.9.9 Heat Exchanger.

3.1.2.1.9.10 Bracket.

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Page 7 of 59



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3.1.2.1.10 Fuel Line – Low Pressure (Hose/Pipe).

3.1.2.1.11 Filter – High Pressure (optional).

3.1.2.1.11.1 Filter Bracket.

3.1.2.1.12 Filter Assembly – Low Pressure (incl. oil separation).

3.1.2.1.12.1 Filter – Low Pressure (incl. oil separation).

3.1.2.1.12.2 Filter Bracket.

3.1.2.1.13 Alternative fuel system controller.

3.1.2.1.14 Alternative Fuel specific wiring harnesses (optional).

3.1.2.1.15 Safety device vent line assemblies.

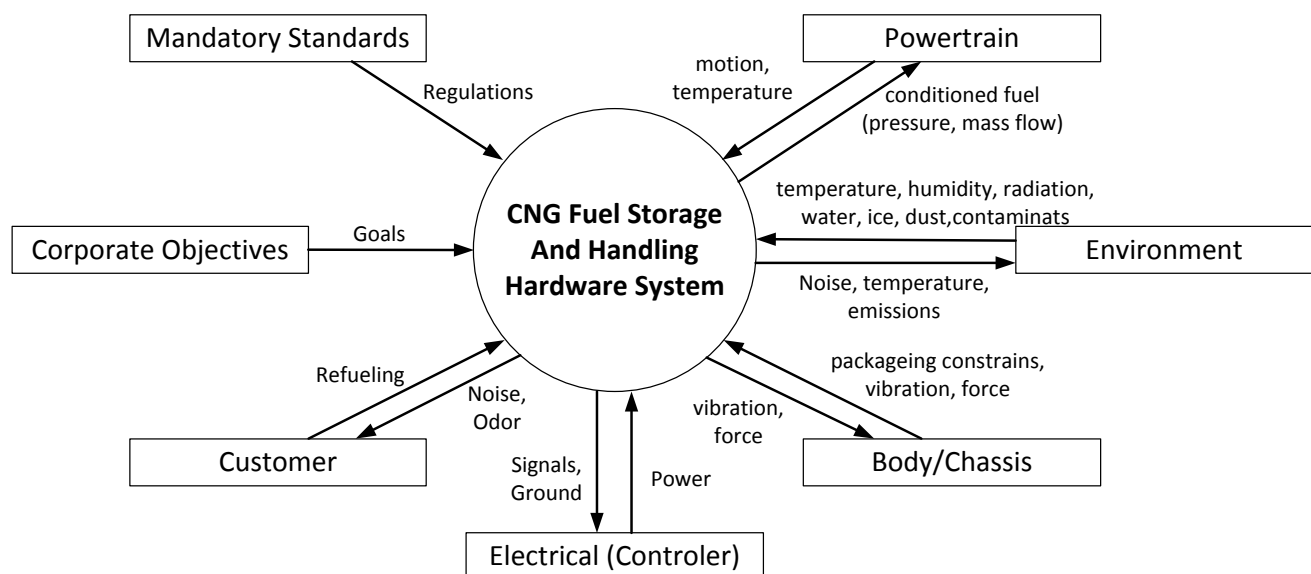
3.1.2.1.16 Vent boot (required for in trunk mounting).

3.1.2.2 Functional Content.

3.1.2.2.1 The subsystem shall meet all internal and external applicable performance objectives and regulations. The design and operation of the CNG fuel subsystem shall be in accordance with the applicable governmental safety regulations and company safety objectives.

3.1.2.2.2 A functional context diagram for the fuel subsystem is shown in Figure 3.

Figure 3: CNG Fuel Subsystem Functional Context Diagram



3.1.2.2.3 Receive Fuel. The CNG fuel subsystem shall receive fuel for storing up to the designed in-storage capacity.

3.1.2.2.4 Store Fuel. The CNG fuel subsystem shall store fuel in a safe, leak-free manner, as defined in 3.1.4.3.7.

3.1.2.2.5 Sense Fuel Level. The CNG fuel subsystem shall sense fuel levels and provide a proportional signal.

3.1.2.2.6 Supply Filtered Fuel. The CNG fuel subsystem shall supply filtered fuel to the engine upon demand according to the pressure and flow requirements of the powertrain.

The CNG fuel subsystem shall meet all performance requirements when supplied with fuel contaminated by the largest particle, which can pass through any filters used in the system. The usage of high and low pressure filtration depends on the regional required filtration specification dependent on the experience with the local fuel quality.

The default filter strategy is shown in Table 1:

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Page 8 of 59



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Table 1: Default Filter Strategy

Filter Strategy	Filter Size
Receptacle filter	50 µm minimum
High Pressure/Low Pressure Inline filter	50 µm minimum, but the smaller the better
Low Pressure Inline filter liquid removal	To be defined in the program specific powertrain interface request (compressor oil residual)
Low Pressure Inline filter liquid reservoir	The bigger the better, depending on the regional experience

3.1.2.2.6.1 Filter Design. Design choice shall incorporate the following assessment:

- Filter media shall support the maximum powertrain requested flow over the design life time of the filter/filter element.
- Filter media shall generate only a minimum pressure drop when supporting the powertrain requested flow over the design life time of the filter/filter element.
- The filter media shall withstand the total number of refueling impulses defined by the vehicle program (default stated in 3.1.5.1 without damage or reduction of performance).
- The filter media capacity and the durability shall support the least number of service exchanges possible.
- The unusable fuel mass of the CNG storage system shall not be elevated (by raising the switch over pressure) by > 15% compared to the value of the CNG storage system with a new filter media due to contamination.
- For low pressure liquid contaminant separator, the reservoir capacity shall be large enough to ensure service intervals that are in line with the regular vehicle maintenance schedule.
- Filter media exchange and/or filter cleaning procedure shall be similar to the regular vehicle maintenance schedule.

3.1.2.2.7 Manage Heat. The CNG fuel subsystem shall manage heat buildup in the fuel and components. The CNG Fuel subsystem shall also provide protection to subsystem assemblies and components from adjacent heat generating components as required.

3.1.2.2.8 Manage Internal Gaseous Fuel Temperature. The CNG fuel subsystem shall maintain full functionality over the target life (see 3.1.5) of this specification at temperatures as described in 3.1.3 in combination with the temperatures resulting from fuel flow dynamics in the fuel storage system as given in 3.1.2.2.8.1 through 3.1.2.2.8.2.

The CNG fuel subsystem shall manage chilling effects of the Joule Thomson Effect due to gas expansion in the fuel carrying components.

3.1.2.2.8.1 Low Temperature. At -40 °C (-40 °F) (ambient still air) the gas low temperature extreme is characterized by a fast fill refueling of an "empty" storage system and the fuel delivery to the engine at program specific flow rates taking the individual container material, container size and the number of containers, as well as the storage pressure range into account.

Initial fuel pressure shall be 500 kPa gauge. Deviations from this start pressure may be requested by the fuel container manufacturer and shall be approved by the Bill of Material (BOM) Family Owner (BFO) and the program team.

3.1.2.2.8.2 High Temperature. At maximum operating (still air) temperatures (as defined in 3.1.3) the fuel storage temperature will be established based on a "fast fill" condition. In this condition, fuel is delivered to the vehicle storage system from a supply reservoir with a volume of at least 20 times the vehicle storage system volume at an average fill rate of ≥ 6.0 GGE/minute (Gasoline Gallon Equivalent) for North America or 10 kg/minute for UN R110 regions, as defined in 3.2.1.1.4.

3.1.2.2.8.2.1 Initial fuel pressure shall be 500 kPa gauge. Deviations from this start pressure may be requested by the fuel container manufacturer and shall be approved by the BFO and the program team. The initial temperature of fuel within the vehicle storage system is defined to be the ambient temperature. The fuel temperature of supply reservoir is defined to be $\geq +32$ °C (≥ 90 °F).

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Page 9 of 59

3.1.2.2.9 Manage Noise. The CNG fuel subsystem shall manage all generated noise so that it falls below customer objectionable level.

3.1.3 Ambient Environment. The ambient environmental conditions that the CNG fuel subsystem may encounter during its life are defined in paragraphs 3.1.3.1 through 3.1.3.12.

3.1.3.1 The CNG fuel subsystem shall fulfill performance requirements as shown in Tables 2 and 3.

Table 2: Ambient Temperature

Region	Minimum Temp	Maximum Temp
Worldwide Default	-48 °C (-55 °F)	+52 °C (125 °F)
Russia (Siberia)	-51 °C (-60 °F)	Not applicable
Middle East	Not applicable	+55 °C (130 °F)

Table 3: Normal Operating Environment Note 1, Note 2

Underbody Air Temperature	(-40 to +90) °C
Underhood Air Temperature	(-40 to +180) °C
Trunk and Vehicle Interior Temperature (i.e. vans)	(-40 to +77) °C
Relative Humidity	(2 to 100) %
Barometric Pressure Note 2	(56.9 to 106.3) kPa
Precipitation	≤ 4.6 mm/minute
Electromagnetic	According to GMW3097
Ozone	≤ 0.40 ppm (part per million)

Note 1: Powertrain integration fuel storage and handling components shall be able to meet, or exceed, the minimum, continuous, and excursion temperature limits specified in 0.

Note 2: Regional requirements may require a lower barometric pressure due to their elevation. See the program specific document for clarification.

3.1.3.1.1 The constant maximum CNG temperatures inside the storage containers are limited by the major standards to +57 °C (North America, +135 °F; ANSI NGV2) or +65 °C (United Nations (UN) R110).

3.1.3.1.2 The constant minimum CNG temperatures inside the storage containers are limited by the major standards to -40 °C (-40 °F). (ANSI NGV2, UN R110).

3.1.3.1.3 All underbody components of the CNG fuel storage and handling system (except the CNG container) shall withstand a maximum temperature of +90 °C. For maximum CNG container temperatures (see 0).

3.1.3.1.4 All under hood mounted components of the CNG fuel storage and handling system shall withstand a maximum continuous temperature of ≥ +135 °C.

3.1.3.2 Extreme Operating Environment. The CNG fuel subsystem shall not exhibit any permanent failure modes (i.e. walk home) when subjected to the extreme operating environment as defined in 3.1.3.2.1 to 3.1.3.2.6.

3.1.3.2.1 The CNG fuel storage container shall withstand a maximum ambient temperature of +82 °C, according to the major standards maximum allowed CNG container surface temperatures. (UN R110 and ANSI NGV3.1).

3.1.3.2.2 The excursion duration shall not increase the CNG temperature inside the storage container to more than the allowed continuous CNG temperature limits (see 3.1.3.1).

Since there is a deviation of the maximum ambient temperature in the standards and the GM internal maximum temperature requirement of +90 °C, program dependent temperature requirements exceeding the applicable standards due to package position, shall be evaluated, documented and applied in validation testing.

3.1.3.2.3 To keep the surface and CNG temperatures within the regulatory requirements additional measures (i.e. shielding) maybe needed.

3.1.3.2.4 All underhood mounted components of the CNG fuel storage and handling system shall withstand an ambient temperature excursion up to +180 °C.

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Page 10 of 59



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3.1.3.2.5 Since there is a deviation of the maximum continuous ambient temperatures in the standards and the GM internal maximum temperature requirement of +180 °C, program dependent temperature requirements exceeding the applicable standards due to package position, shall be evaluated, documented and applied in validation testing.

3.1.3.2.6 For minimum, continuous and excursion examples of the ambient temperature, see Tables 5 through 7 and Figures 4 through 6.

Thermal performance terminology is defined in Table 4.

Table 4: Thermal Performance Terminology

Term	Definition
Continuous	Requirements designated as Continuous are considered conditions the vehicle will experience on a frequent basis and maintain design functional life. The vehicle shall be able to experience <i>1400 h/12 000 cycles per 160 000 km</i> of vehicle life under Continuous vehicle conditions. Occupant safety shall not be compromised during Continuous thermal conditions.
Excursion	Requirements designated as Excursion are considered conditions the vehicle may experience on an infrequent basis and maintain design functional life. The vehicle shall be able to experience <i>60 h/400 cycles per 160 000 km</i> of vehicle life under Excursion vehicle conditions. Occupant safety shall not be compromised during Excursion thermal conditions.
Extreme Event	Requirements designated as an Extreme Event are considered conditions of abuse or operation outside the limits specified in the owner's manual. Components may be damaged under Extreme Event conditions. The vehicle must be drivable after the event. Occupant safety shall not be compromised during an Extreme thermal event.

Note: Suggested values for continuous and excursion operating time and cycles for different regions are given in the Table 5. The values are based on a 160 000 km vehicle life:

Table 5: Suggested Values

		North America		European		Asia Pacific		Latin America/ Africa/Middle East
Driving Condition	Hours	Cycles	Hours	Cycles	Hours	Cycles	Hours	Cycles
Continuous	1400	12 000	1400	12 000	1750	15 000	1750	15 000
Excursion	60	400	60	400	60	400	60	400

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Page 11 of 59



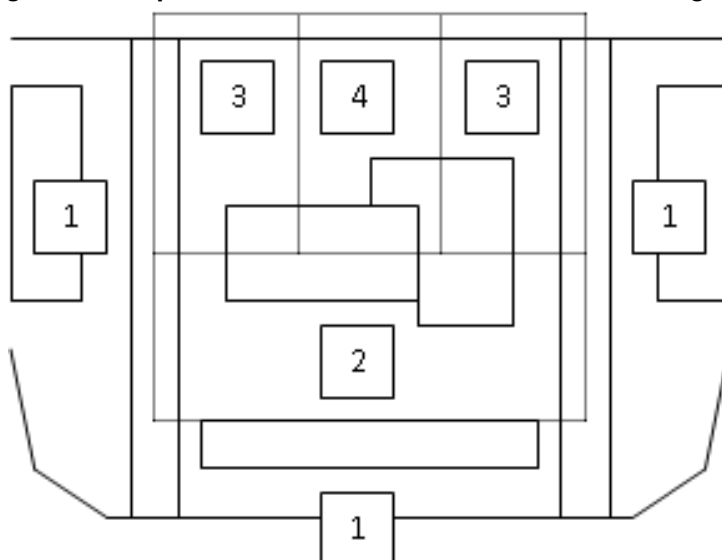
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Table 6: Temperature Zones Underhood Transverse Engines

Zone	Minimum, Continuous and Excursion Temperatures
Zone 1	Forward of the Radiator and outboard of the rails. Minimum = -40 °C Continuous = +80 °C Excursion = +100 °C
Zone 2	Forward of the centerline of the engine and rearward of the radiator. Minimum = -40 °C Continuous = +100 °C Excursion = +120 °C
Zone 3	Forward of the Front of Dash. From the rail to 125 mm from the exhaust pipe. Rearward of the centerline of the engine. Minimum = -40 °C Continuous = +120 °C Excursion = +140 °C
Zone 4	Forward of the Front of Dash. From center of exhaust to 125 mm left and right in car. Rearward of the Centerline of the engine. Minimum = -40 °C Continuous = +135 °C Excursion = +150 °C

Figure 4: Temperature Zones Underhood Transverse Engines



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Page 12 of 59



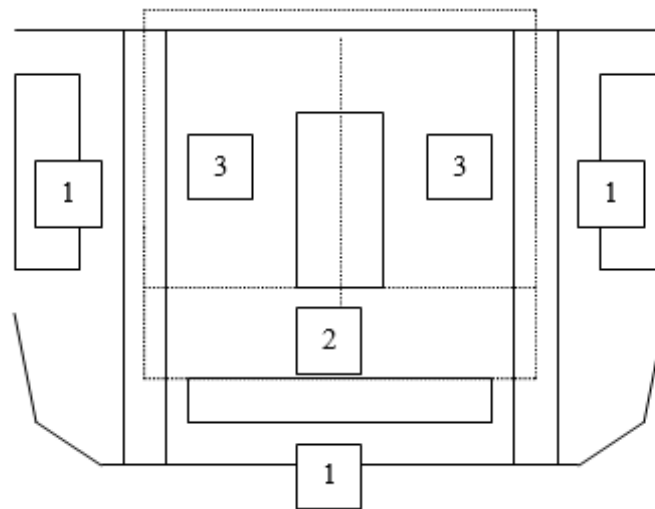
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Table 7: Temperature Zones Underhood Longitudinal Engines

Zone	Minimum, Continuous and Excursion Temperatures
Zone 1	Forward of the Radiator and outboard of the rails. Minimum = -40 °C Continuous = +80 °C Excursion = +100 °C
Zone 2	Forward of the engine and rearward of the Radiator. Minimum = -40 °C Continuous = +100 °C Excursion = +120 °C
Zone 3	From the centerline of engine to the rails. Forward of the Front of Dash to the front of the engine. Minimum = -40 °C Continuous = +120 °C Excursion = +140 °C

Figure 5: Temperature Zones Underhood Longitudinal Engines



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Page 13 of 59



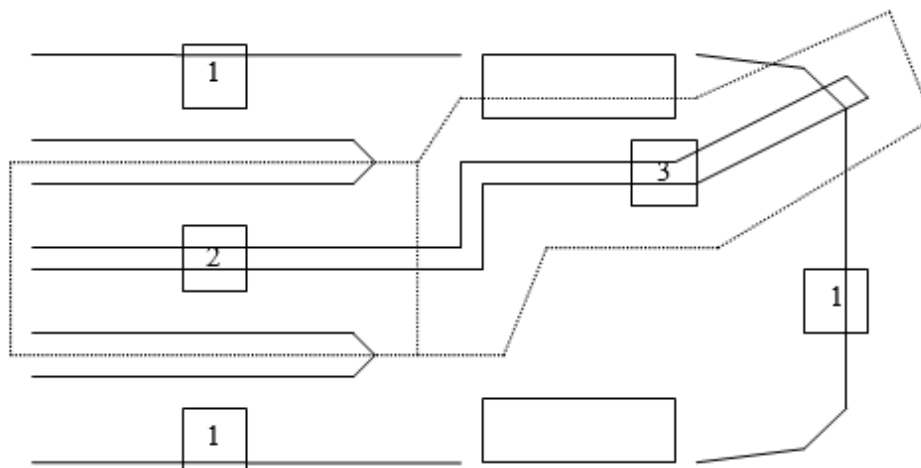
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Table 8: Temperature Zones Underbody

Zone	Minimum, Continuous and Excursion Temperatures
Zone 1	Rearward of the front of dash. Outboard of the exhaust. Minimum = -40 °C Continuous = +80 °C Excursion = +100 °C
Zone 2	Rearward of Front of Dash. Forward of kick up. Within 150 mm of exhaust. Minimum = -40 °C Continuous = +115 °C Excursion = +150 °C
Zone 3	Rearward of kick up. Within 150 mm of exhaust. Minimum = -40 °C Continuous = +115 °C Excursion = +140 °C

Figure 6: Temperature Zones Underbody



3.1.3.3 Total solar radiation is defined as wavelengths between 295 nm and 2800 nm. The CNG fuel subsystem shall meet all operating performance requirements, without loss of function or degradation of service life, under the operating environment defined in 3.1.3.1 after exposure to Solar Radiation. If the parts of the system are sensitive to Solar Radiation (e.g. Type 3 and 4 Containers), they shall be protected.

3.1.3.4 Ultraviolet radiation is defined as wavelengths between 295 nm and 385 nm. The CNG fuel subsystem shall meet all operating performance requirements, without loss of function or degradation of service life, under the operating environment defined in 3.1.3.1 after exposure to Ultraviolet Radiation. If the parts of the system are sensitive to Ultraviolet Radiation (e.g. Type 3 and 4 Containers), they shall be protected.

3.1.3.5 The CNG Fuel Storage system shall be capable of operation with gauge pressures ranging from 0 MPa (0 psi) to a maximum of 125% service pressure, or 31 MPa (4500 psi) for United States and Canada and maximum service pressure of 26 MPa for all systems with 20 MPa nominal working pressure for UN R110 regions. Low pressure section operating pressure shall be nominal CNG fuel rail working pressure + 100%.

3.1.3.6 Fueling Cycle Temperatures and Pressures. The CNG fuel subsystem shall meet all operating performance requirements, without loss of function or degradation of service life, under the operating environment defined in 3.1.3.1 after and during the exposure to the typical temperature dynamics of a "fast-fill" operation (see Table 9).

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Page 14 of 59



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Note: The typical temperature change shall be applied at all possible initial operating temperatures throughout the range of 3.1.3.1.

Table 9: Definition of Pressure Ramps and Temperature Dynamics at Fast-Fill

First Pressure Pulse at Fuel System Interface (upstream of the receptacle)	18 MPa (at empty container/remaining unusable fuel mass inside the container)
Pressure Pulse Duration	0.7 s
Number of Pulses	Two (2)
Average Fueling Rate	Flow rates in North America are up to 6 GGE/minute or up to 10 kg/minute for other regions.
CNG Temperature Data During a Fast Fill (Minimum temperatures of the gas inside components during refueling)	The average gas temperature can drop by -40 °C from the start fill gas temperature. Local minimum average gas temperature inside components can stay for as long as ≤ 20 s.

3.1.3.7 Fuel Contamination. The contamination of the CNG varies from region of sale. The Design Release Engineer (DRE) shall review the actual known fuel quality for each program. Supporting information about available test fuels and the region dependent fuel composition can be obtained at the System BFO and the GM Fuels Lab (e.g., see Appendix A).

3.1.3.8 Contamination (external). Appendix B, Table B1 identifies the potential contaminants which the CNG fuel subsystem must withstand prolonged exposure to or be located, packaged, or protected from to assure no degradation from its design function. Appendix B, Table B2 identifies additional potential contaminants, which also shall be considered.

3.1.3.9 Corrosion. CNG fuel subsystem components shall have no degradation of performance throughout the corrosion and durability target life, when exposed to the severe corrosive environments (e.g., Coastal areas or regions with high road salt usage).

3.1.3.10 Mechanical Shock. The CNG fuel subsystem and its components shall meet all operational performance requirements, without loss of function or degradation of service life, when exposed to mechanical shock derived from the mechanical load requirements in GMW3172 (these mechanical loads are also required for CNG Storage System Components without electrical functions).

3.1.3.11 Vibration. The CNG fuel subsystem shall meet all operational performance requirements, without loss of function or degradation of service life, when exposed to a spectrum of vibration load inputs for a duration representative of typical customer operation over its design service life. The magnitude and duration of the vibration loading inputs shall be determined by GMW15570 or by conducting platform specific Road Load Data Acquisition measurements based on proving ground vehicle durability schedules.

3.1.3.12 Impact. The CNG fuel subsystem and its components shall change into a failsafe state and stay leak tight when exposed to the standard fuel system crash loads as defined in GMW3172. In addition to these component requirements, the CNG storage system shall be subjected to the standard fuel system vehicle crash simulation.

The results of the program specific simulation analysis shall be converted into design requirements for the impact resistance of the components, as well as component impact test requirements (e.g., fall tower or sled tests) to assess the suitable component resistance. Finally the total CNG storage system shall be exposed to the standard fuel system vehicle crash tests.

3.1.3.12.1 Ice and Mud Exposure. For vehicles designed for rural areas (i.e., unpaved roads, elevated levels of snow) the design of underbody components of the CNG fuel storage system shall prevent the accumulation of mud or ice to prevent damage from mass build up (e.g., location: Lubbock Texas, Caliche build up (concrete like mud)).

3.1.4 Interfaces. The CNG fuel subsystem interfaces with several physical entities that will affect or constrain its functionality and design. These interfaces are described in 3.1.4.1 through 3.1.4.5.

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August 2017

Page 15 of 59



Documents

Document Sharing Hub

3.1.4.1 External-to-Vehicle to Subsystem. Descriptions of the associated major interfaces are given in the paragraphs 3.1.4.1.1 through 3.1.4.1.4.

3.1.4.1.1 Refueling Station. The CNG fuel subsystem will interface with compressed natural gas station pumps and /or compressed natural gas home refueling or vehicle refueling appliances during refueling. The design and operation of the subsystem must address and satisfy the requirements in paragraphs 3.1.4.1.1.1 through 3.1.4.1.1.4. Bi-fuel CNG applications shall maintain the interface to the base vehicle gasoline fuel subsystem.

3.1.4.1.1.1 Fill Nozzle. The subsystem fill valve shall accept fuel from any ANSI NGV 1 or ISO 14469 approved fill nozzle at an average fill rate of 6.0 GGE/minute minimum from (73 to 3600) psi for North America or 10 kg/minute minimum from (0.05 to 20) MPa for other regions.

3.1.4.1.1.2 Fill Receptacle. The CNG fuel fill connection or receptacle shall conform to ANSI NGV 1, UN R110 or ISO 14469 as applicable to the specific region.

3.1.4.1.1.3 Vehicle/Station Operator. The CNG fuel subsystem and its operation, if affecting the interfaces with persons fueling the vehicle, shall:

- Accommodate common practice operations, such as fuel fixture coupling insertion, retention and removal.
- Maintain a user-friendly interface (e.g., force, sound, and odor, with the fueling operator).

3.1.4.1.1.4 Ambient. Potential CNG fuel subsystem interfaces with the vehicle are:

- During the fill operation, natural gas leakage from the CNG Fuel Subsystem shall not exceed the limits defined in ANSI NGV 1 or ISO 14469.
- Some CNG fuel may escape into the ambient above/under/near the vehicle during fuel fixture nozzle removal from the fuel filler receptacle.

3.1.4.2 Subsystem to Subsystem. Interfaces between the CNG fuel subsystem and other vehicle subsystems are identified in the CNG Fuel Storage Subsystem Baseline Design Failure Mode, Effects, & Analysis (DFMEA). These interfaces may constrain or drive the design of the CNG fuel subsystem and therefore shall be addressed during subsystem design and development. The CNG fuel subsystem implementation and operation in the vehicle must also successfully accommodate the identified interfaces. The physical interface requirements are detailed in the fuel subsystem Interface Control Documents.

3.1.4.2.1 Brake Performance. The CNG fuel subsystem shall not affect the base vehicle brake performance.

3.1.4.2.2 Ride and Handling Evaluation. The mass and weight distribution of the CNG fuel subsystem should not negatively affect the base vehicle ride and handling characteristics.

3.1.4.2.3 Restricted Fuel Flow Condition. The CNG fuel subsystem shall be designed to not experience a sudden, abnormal reduction/loss of fuel flow.

3.1.4.3 Component to Component. Generic component to component interface requirements for the CNG fuel subsystem are identified in paragraphs 3.1.4.3.1 through 3.1.4.3.4.

3.1.4.3.1 Crashworthiness. The CNG fuel subsystem components shall not leak during and after crash test conditions. Any leak after or during standard crash testing causes the subsystem to fail crashworthiness requirements. The CNG fuel subsystem components shall stay attached to the vehicle during and after the crash test. Components must be designed to prevent unintended disconnection and damage to adjacent gasoline fuel system and non-gasoline fuel system components. In Bi-fuel CNG applications, the gasoline fuel subsystem crashworthiness requirements shall be maintained.

3.1.4.3.2 Noise. Component to component connections must minimize transmission of subsystem noise.

3.1.4.3.3 Electrical Environment. The applicable specifications for the electrical components of the CNG storage system are:

- GMW3091
- GMW3097
- GMW3103

The interface description to Powertrain (Controls) can be found in the following Powertrain - Platform Electrical Interface (PPEI) documents:

- PPEI_GM8762_GenInfoElectricalSerialData
- PPEI_GM8763_Power_Ground

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August 2017

Page 16 of 59



Documents

Document Sharing Hub

- PPEI_GM8774_Addendum_B_FuelSystem_AltFuel_CNG_LPG
- PPEI_GM8774_Addendum_C_FuelSystem_BiFuel_Gas_CNG
- PPEI_GM8779_PostCollisionOperation

Note: The requirements listed in 3.1.4.3.3.1 are a subset of what can be found in the PPEI documentation:

3.1.4.3.3.1 Electrical Voltage at the Component. The CNG fuel subsystem and components shall meet all operational performance requirements, without loss of function or degradation of service life, unless otherwise stated when supplied with the voltage levels listed in Table 10.

Table 10: Voltage Levels of Electrical Components

Voltage Operation	Voltage levels
Low Voltage Operation	(5.5 to 9.0) V
Normal Voltage Operation	(9.0 to 16.5) V
High Voltage And Jump Start Operation	(16.5 to 24) V
Load Dump Condition	33 V

3.1.4.3.4 Wiring/Connections/Connectors. The CNG fuel subsystem wiring, connections and connectors, and all CNG fuel subsystem wiring interactions with the base vehicle wiring shall meet the internal GM requirements for electrical systems, as well as the following requirements (as verified by a routing quality assessment):

- Original Equipment Manufacturer (OEM) ground wires shall not be used for power grounding. Power grounds shall be routed to engine or chassis locations. Use of OEM ground wires for signal returns is acceptable, per GM Best Practices for Grounding.
- All revisions or additions to OEM electrical wiring shall be color coded and labeled and be included in the wiring diagrams in a manner consistent with OEM practice.
- All additional underhood and underbody wiring shall be suitable for that type of application and suitably protected. Such wiring shall be wrapped in a conduit.
- Use of OEM style connectors (sealed mating connectors) shall be used for all underhood and underbody connections to the OEM harness.
- Wires shall be routed and firmly secured to avoid contact with sharp or abrading surfaces or moving parts (such as cooling fans, steering, transmission shift controls, and brake and accelerator pedals). In addition, wires shall be protected from or kept ≥ 125 mm from radiant heat sources.
- Wiring shall not be under tension between fixed points under vehicle static or dynamic conditions. Sufficient wiring slack should be included to maintain clearance under normal engine roll conditions.
- All electrical connections exposed to the elements shall be sealed for corrosion protection.
- Wiring shall be retained to prevent pinching, entrapment or misrouting, or protected to prevent squeaks and rattles.

3.1.4.3.5 Electrical and Information Controls. Refer to the Program Specific Subsystem Technical Specification.

3.1.4.3.6 Electrostatic Discharge. The CNG fuel subsystem shall not generate electrostatic charge, nor create Electrostatic Discharge (ESD) related incidents at any point in the subsystem for conditions as defined in SAE J1645.

Components must not create ESD or ESD related damage in adjacent or downstream components.

The electrostatic voltage build-up in the CNG fuel subsystem shall not exceed 500 V. Conductive material shall be used to ground the fuel filter, chassis lines, and fuel subsystem, to a ground source which has $< 10^6 \Omega$ at 1 kV resistance.

For components with heat sources (e.g. solenoids), higher operating surface temperatures can be reached. These components shall be tested separately for their maximum conditions as specified in the Program Specific Documents.

GM Confidential

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August 2017

Page 17 of 59



Documents

Document Sharing Hub

3.1.4.3.7 The CNG Storage System shall withstand periodic exposure to car wash without degradation of performance over the specified duration of service life.

3.1.4.3.8 System Tightness.

3.1.4.3.8.1 Exterior Leakage (100% Methane, 0 °C).

3.1.4.3.8.1.1 Over total service life: 5×10^{-5} mbar $\times$ L/s, per interface.

3.1.4.3.8.2 Interior Leakage (100% Methane, 0 °C).

3.1.4.3.8.2.1 New part: 5×10^{-5} mbar $\times$ L/s.

3.1.4.3.8.2.2 At specified end of life condition: 1×10^{-4} mbar $\times$ L/s.

3.1.4.3.8.3 High and Low Pressure section of the CNG Storage System shall be tested at the specific nominal working pressure of this section in vehicle End-Of-line test with CNG.

3.1.4.3.8.4 If any regional standard requires a bubble tight interface then a test procedure shall assure (in addition to the above mentioned thresholds) no bubbles in 3 minutes test period.

3.1.4.4 Fuels. All components of the CNG fuel subsystem shall be designed to support the Platform specific regional CNG fuel composition and quality as defined in Appendix A. Performance and quality of the vehicle shall not be affected due to incompatibility between the fuel subsystem components and the CNG fuel.

3.1.4.4.1 Test Fuels. See Appendix A.

3.1.4.4.2 Component Test and Other Fuels. See Appendix A.

3.1.5 Usage Definition. Usage conditions that the CNG fuel subsystem may encounter are captured in CG3546 and 3.1.5.1 through 3.1.5.2. Usage conditions along with reliability requirements are comprehended in General Motors component and vehicle validation test procedures.

Note: Suppliers of a component are required to comprehend vehicle usage conditions captured in CG3546, but the document itself is not to be published since it contains GM internal information. The DRE has to ensure that any conditions unique to the component under review are evaluated and/or verified according to the specific applicable conditions translated from the content of CG3546, in addition to the tests captured in General Motors standards and/or validation procedures.

3.1.5.1 Refueling Cycles. The refueling cycles pressure test for a subsystem is performed with CNG. The values shown in Table 9 shall be a guideline for testing the CNG storage system under real refueling station conditions using CNG. These values were calculated using an estimated conservative usage of a CNG vehicle with an average of one (1) refueling cycle per day. The values in Table 9 differ from mandatory component design approval testing since components are pressure tested using hydraulics and not CNG. In comparison, the applicable standards for component testing are much higher for components (ANSI NGV 2: 2250 cycles per service year; UN R110: 1000 cycles per service year). A subsystem test cycle takes much longer than a component test cycle because testing with CNG takes much longer than testing with hydraulics. Testing the subsystem with CNG is required as the system is subjected to different kinds of combined temperature and flow mechanics stresses not present in hydraulic testing. The subsystem refueling cycles testing will assure that the combination of components within the system is leak free during the filling procedure.

3.1.5.1.1 Real Refueling Cycles. The CNG fuel storage system testing shall have 1650 filling cycles per service life. Of the 1650 cycles, 1000 full filling cycles shall be tested from < 2 MPa to a temperature compensated service pressure, and 650 filling cycles shall be tested with different elevated storage system pressures according to Table 11.

Table 11: Refueling Cycle Fill Properties

Storage System Pressure Range	% Total Cycles	Cycles
Empty to full	61%	1000
25% to full	14%	225
50% to full	14%	225
75% to full	12%	200

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August 2017

Page 18 of 59



Documents

Document Sharing Hub