



Fuel Tank Capacity and Filling Performance

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. The purpose of this procedure is to determine the total fuel capacity, usable capacity, and vapor space of vehicle fuel systems. Also evaluate the fuel filling performance under various fill conditions.

1.2 Applicability. Fuel systems for passenger cars and trucks with gasoline (including ethanol fuel blends) or diesel engines.

1.3 Remarks. This is a system level test of the fuel storage system, including the fuel tank assembly, fuel fill pipe assembly, and the complete venting system.

Within this test procedure, several appendices are referenced from CG4191 which includes fill conditions to simulate the unique conditions of the North American, European/Australian, Korean, Brazilian and Chinese markets. Fuel systems designed to meet regional requirements should be tested with all of the tables that are applicable.

The tables of fill conditions specify minimum and maximum values for test inputs, as well as maximum allowable values for premature shutoffs, spitback, and liquid carryover. All fill tests must comply with these specifications, even if such details were not given in the subsystem or component technical requirements. Refer to Table 1 for the list of tables and titles.

Table 1: CG4191 Appendix List

Appendix	Table/Data Sheet Number	Title
A	A1	Fuel Dispensing Nozzles
A	A2	Unleaded Gasoline Fill Conditions – North America
A	A3	Unleaded Gasoline Fill Conditions – Europe/Australia
A	A4	Unleaded Gasoline Fill Conditions – Korea/India
A	A5	Unleaded Gasoline Fill Conditions – Brazil
A	A6	Unleaded Gasoline Fill Conditions – China
B	B1	E85 (85% Ethanol, 15% Unleaded Gasoline) Fill Conditions – North America
B	B2	E85 (85% Ethanol, 15% Unleaded Gasoline) Fill Conditions – Europe/Australia
B	B3	E100 Fill Conditions – Brazil
C	C1	Diesel Fill Conditions – North America
C	C2	Diesel Fill Conditions – Europe/Australia
C	C3	Diesel Fill Conditions – Korea/India

GM Confidential

© Copyright 2017 General Motors Company All Rights Reserved

May 2017

Page 1 of 21

Appendix	Table/Data Sheet Number	Title
C	C4	Diesel Fill Conditions - Brazil
D	D1	Recirculation Orifice Diameter Equivalent Chart
D	D2	Tank Volume and Vapor Space – Volume Method
D	D3	Fill Performance Evaluation

2 References

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

2.1 External Standards/Specifications.

21. BlmSchV	ASTM D93	ASTM D4806	ISO 9158
ABNT NBR 7148	ASTM D323	EN 12	SAE J285
ABNT NBR 7974	ASTM D975	EN 228	SAE J398
ABNT NBR 14483	ASTM D1298	EN 590	
ASTM D56	ASTM D1500	EN 13012	

2.2 GM Standards/Specifications.

GMW14474	GMW14859	GMW15696
----------	----------	----------

2.3 Additional References.

- CG4191
- Franklin Fueling Systems, Madison, Wisconsin (www.franklinefueling.com)
- GM Test and Validation Fuels Handbook, Specification of Testing and Validation Fuels, (<https://documents.naeng.gm.com/gdm3/drl/objectId/0b0163bd80390f2c>) (ID)
- Goodyear Rubber Products, Incorporated, Brandenton, Florida (www.goodyearrubberproducts.com)
- Grabner Instruments (Ametek Petrolab Company), Broken Arrow, Oklahoma, (www.grabner-instruments.com)
- Husky Corporation, Pacific, Missouri, (www.husky.com)
- OPW Retail Fueling Corporation, Hamilton, Ohio (www.opwglobal.com)
- State of California Air Resources Board (CARB), Section 2235 Title 13, Attachment A-8: Specifications for Fill Pipes and Openings of 2015 and Subsequent Model Motor Vehicle Fuel Tanks

(ID) = These references are intended for internal access within General Motors and shall not be distributed outside this company. Contact the GM Lead Engineer for further instructions.

2.3.1 Fuels.

- E85 Fuel (85% Ethanol, 15% Unleaded Gasoline)
- E100 (100% Ethanol)
- GMPT-2-022-B
- GMPT-2-023-B
- GMPT-3-017-A
- GMPT-3-018-B
- GMPT-3-032-C
- GMPT-4-019-B
- GMPT-4-020-A

GM Confidential

© Copyright 2017 General Motors Company All Rights Reserved

May 2017

Page 2 of 21



Documents
Document Sharing Hub

3 Resources

3.1 Facilities. Testing should be performed at a facility free of ignition sources. If indoors, the test facility should be an explosion-proof room with adequate ventilation to meet all local safety codes.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Nozzles. In CG4191, Appendix A, Table A1 specifies a minimum list of fuel dispensing nozzles to be used for this test procedure. While this list represents a variety of popular fuel dispensing nozzles in North America, Europe/Australia, Korea, Brazil, and China, it is only a small sample of the models that are available to fuel retailers. Specific concerns about fuel system interaction with nozzles other than those listed in CG4191, Appendix A, Table A1, or unique market requirements may require testing with additional nozzles.

Any nozzles used to represent the North American market must comply with SAE J285. Any nozzles used to represent the European/Australian, Korean and Chinese markets must comply with European Standard EN 13012. Any nozzles used to represent the Brazilian market must comply with Associação Brasileira de Normas Técnicas (ABNT) - the Brazilian Association of Technical Standards (based on ISO 9158).

3.2.2 Fuel Dispensing Pumps. Fuel dispensing pumps shall be capable of delivering the following flow rates to simulate service station fuel dispensers in North America, Europe/Australia, Korea, Brazil and China.

Note: For other markets, the requesting engineer must specify the nozzles and flow rates to use based on the countries in which the vehicle(s) will be sold.

3.2.2.1 Non-Vapor Recovery Nozzles for Gasoline or Ethanol Fuel Blends. For testing to simulate the North American market, regulate the dispensing pump to deliver 15.0 L/minute to 45.4 L/minute (4.0 gal/minute (gpm) to 12.0 gpm), as required, when the nozzle is set at the fast fill rate detent on the hold-open rack.

For testing to simulate the European/Australian, Korean and Chinese markets, regulate the dispensing pump to deliver 20 L/minute to 50 L/minute (5.3 gpm to 13.2 gpm), as required, when the nozzle is set at the fast fill rate detent on the hold-open rack.

For testing to simulate the Brazilian market, regulate the dispensing pump to deliver 20 L/minute to 50 L/minute (5.3 gpm to 13.2 gpm), as required, when the nozzle is set at the fast fill rate detent on the hold-open rack.

The allowable tolerance on the fill rate is ± 0.8 L/minute (± 0.2 gpm).

3.2.2.2 Vapor Recovery Nozzles for Gasoline or Ethanol Fuel Blends. For testing to simulate the North American market (California Air Resource Board (CARB) nozzles (see reference in 2.3)), regulate the dispensing pump to deliver 15 L/minute to 38 L/minute (4.0 gpm to 10.0 gpm) when the nozzle is set at the fast fill rate detent on hold-open rack.

For testing to simulate the European/Australian, Korean and Chinese markets, regulate the dispensing pump to deliver 20 L/minute to 44 L/minute (5.3 gpm to 11.6 gpm), as required, when the nozzle is set at the fast fill rate detent on the hold-open rack.

The allowable tolerance on the fill rate is ± 0.8 L/minute (± 0.2 gpm).

3.2.2.3 Conventional Diesel Fuel Nozzles. For testing to simulate the North American market, regulate the dispensing pump to deliver 20 L/minute to 50 L/minute (5.3 gpm to 13.2 gpm), as required, when the nozzle is set at the fast fill rate detent on hold-open rack.

For testing to simulate the European/Australian market, regulate the dispensing pump to deliver 20 L/minute to 60 L/minute (5.3 gpm to 15.9 gpm), as required, when the nozzle is set at the fast fill rate detent on the hold-open rack.

For testing to simulate the Korean market, regulate the dispensing pump to deliver 20 L/minute to 60 L/minute (5.3 gpm to 15.9 gpm), as required, when the nozzle is set at the fast fill rate detent on the hold-open rack.

For testing to simulate the Brazilian market, regulate the dispensing pump to deliver 20 L/minute to 50 L/minute (5.3 gpm to 13.2 gpm) as required, when the nozzle is set at the fast fill rate detent on the hold-open rack.

The allowable tolerance on the fill rate is ± 0.8 L/minute (± 0.2 gpm).

GM Confidential

© Copyright 2017 General Motors Company All Rights Reserved

May 2017

Page 3 of 21



Documents

Document Sharing Hub

3.2.2.4 Truck Stop Diesel Fuel Nozzles. For testing to simulate the North American market, regulate the dispensing pump to deliver 20 L/minute to 98 L/minute (5.3 gpm to 26.0 gpm), as required, when the nozzle is set at the fast fill rate detent on the hold-open rack.

For testing to simulate the European/Australian market, regulate the dispensing pump to deliver 60 L/minute (15.9 gpm) when the nozzle is set at the fast fill rate detent on the hold-open rack.

For testing to simulate the Indian market, regulate the dispensing pump to deliver 20 L/minute to 80 L/minute (5.3 gpm to 21.0 gpm), as required, when the nozzle is set at the fast fill rate detent on the hold-open rack.

The allowable tolerance on the fill rate is ± 0.8 L/minute (± 0.2 gpm).

3.2.3 Fuel Dispensing Hoses. Service station type hoses and connectors must be used between the nozzle and the floor to ensure that a realistic and consistent weight is suspended from the nozzle. The hose must hang vertically from the nozzle and travel directly to the floor. Either the floor or the fuel dispensing pump (but not the nozzle) must support all other equipment attached to the hose.

An incorrectly weighted hose suspended from the nozzle can change the position of the nozzle spout inside the fill pipe and affect test results.

3.2.3.1 Hoses and Connectors for Non-Vapor Recovery Nozzles, Gasoline and Ethanol Fuel Blends.

Testing to simulate the North American market requires the following equipment to be connected to the nozzle:

- Swivel Connector: Husky VI-0350, Husky VI-0352 (available from Husky Corporation), or Ohio Pattern Works (OPW) 241TPS, 19 mm ($\frac{3}{4}$ in) (available from OPW Retail Fueling Corporation).
- Hose: 19 mm ($\frac{3}{4}$ in) Inner Diameter (ID), 28.7 mm ($1\frac{1}{8}$ in) Outer Diameter (OD), 19 mm ($\frac{3}{4}$ in) fitting.

Testing to simulate the European/Australian, Korean and Chinese markets requires the following equipment to be connected to the nozzle:

- Connector: 25 mm (1 in) $\times$ 19 mm ($\frac{3}{4}$ in) reducer fitting, as needed.
- Hose: 19 mm ($\frac{3}{4}$ in) ID, 28.7 mm ($1\frac{1}{8}$ in) OD, 19 mm ($\frac{3}{4}$ in) fitting.

3.2.3.2 Hoses and Connectors for Vapor Recovery Nozzles. Testing to simulate the North American market requires the following equipment to be connected to the nozzle:

- Swivel Connector: Husky 4605.
- Hose for Vacuum Assist Nozzles: Goodyear Flexsteel factory coupled assembly (available from Goodyear Rubber Products, Incorporated), 19 mm ($\frac{3}{4}$ in) ID, M34 coupling.
- Hose for Balance Nozzles: Goodyear Maxxim Premier factory coupled assembly, 15.9 mm ($\frac{5}{8}$ in) ID, 47.6 mm ($1\frac{7}{8}$ in) coupling.

Testing to simulate the European/Australian and Chinese markets requires the following equipment to be connected to the nozzle:

- Swivel Connector: None.
- Hose for Vacuum Assist Nozzles: Factory coupled assembly, 19 mm ($\frac{3}{4}$ in) ID, M34 coupling.
- Testing to simulate the Brazilian market requires the following equipment to be connected to the nozzle:
- Swivel Connector: OPW 45-1, 19 mm ($\frac{3}{4}$ in).
- Hose for gasoline and ethanol blends: Goodyear 559N, 25.4 mm (1 in) ID, 34.9 mm (1.37 in) OD.

3.2.3.3 Hoses and Connectors for Diesel Nozzles. Testing to simulate the North American market requires the following equipment to be connected to the nozzle:

- Swivel Connector – None. Use a 25.4 mm $\times$ 19 mm (1 in $\times$ $\frac{3}{4}$ in) straight fitting to attach the nozzle to the hose.
- Hose: 19 mm ($\frac{3}{4}$ in) ID, 28.7 mm ($1\frac{1}{8}$ in) OD, 19 mm ($\frac{3}{4}$ in) fitting.

Testing to simulate the European/Australian and Korean markets requires the following equipment to be connected to the nozzle:

- Connector: 25 mm (1 in) $\times$ 19 mm ($\frac{3}{4}$ in) reducer fitting, as needed.
- Hose: 19 mm ($\frac{3}{4}$ in) ID, 28.7 mm ($1\frac{1}{8}$ in) OD, 19 mm ($\frac{3}{4}$ in) fitting.

GM Confidential

© Copyright 2017 General Motors Company All Rights Reserved

May 2017

Page 4 of 21

Testing to simulate the Brazilian market requires the following equipment to be connected to the nozzle:

- Swivel Connector: OPW 45-1, 19 mm (¾ in).
- Hose for gasoline and ethanol blends: Goodyear 559N, 25.4 mm (1 in) ID, 34.9 mm (1.37 in) OD.

3.2.4 Fuel.

3.2.4.1 Unleaded Gasoline. Unleaded gasoline used for this test procedure must be purchased from a GM approved supplier.

3.2.4.1.1 The minimum required fuels for testing to simulate the North American market are:

- GMPT-3-018-B, Reformulated Gasoline (RFG), Tier 2 United States Emission Certification Fuel (62.1 kPa (9.0 psi) Reid Vapor Pressure (RVP)) per GM Test and Validation Fuels Handbook, Specifications of Testing and Validation Fuels.
- GMPT-3-017-A, Evaporative Evaluation Blend Fuel – High Volatility (103.4 kPa (15.0 psi) RVP) per GM Test and Validation Fuels Handbook, Specifications of Testing and Validation Fuels.

3.2.4.1.2 The minimum required fuels for testing to simulate the European/Australian, Korean and Chinese markets are:

- Unleaded gasoline complying with the volatility Class B summer fuel specification from European Standard EN 228.
- Unleaded gasoline complying with the volatility class F/F1 winter fuel specification from European Standard EN 228.

3.2.4.1.3 The minimum required fuels for testing to simulate the Brazilian market are:

- GMPT-2-022-B, Brazil Gasohol High Volatility Fuel per GM Test and Validation Fuels Handbook, Specifications of Testing and Validation Fuels.
- GMPT-2-023-B, Brazil Gasohol Low Volatility Fuel per GM Test and Validation Fuels Handbook, Specifications of Testing and Validation Fuels.
- GMPT-3-032-C, Brazilian E22 Certification Fuel per GM Test and Validation Fuels Handbook, Specifications of Testing and Validation Fuels.

Deviations from these fuel types can be used with approval from regional Design Engineer or Test Engineer.

3.2.4.2 Ethanol Fuel Blends.

3.2.4.2.1 Testing for the North American market requires that E85 fuel be blended as follows:

- 85% by volume E100 ethanol per ASTM D4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasoline for use as Automotive Spark-Ignition Engine Fuel.
- 15% by volume GMPT-3-018-B RFG Tier 2 United States Emission Certification Fuel (62.1 kPa (9.0 psi) RVP) per GM Test and Validation Fuels Handbook, Specifications of Testing and Validation Fuels.

3.2.4.2.2 Testing for the European/Australian market requires that E85 fuel is to be blended as follows:

- 85% by volume E100 ethanol.
- 15% by volume unleaded gasoline complying with volatility Class B summer fuel specification per European Standard EN 228.

3.2.4.2.3 The minimum required fuels for testing to simulate the Brazilian market are:

- GMPT-4-019-B, Brazil E100 Certification Fuel per GM Test and Validation Fuels Handbook, Specifications of Testing and Validation Fuels.
- GMPT-4-020-A, Brazil E100 Durability and Calibration Fuel per GM Test and Validation Fuels Handbook, Specifications of Testing and Validation Fuels.

Deviations from these fuel types can be used with approval from regional Design Engineer or Test Engineer.

3.2.4.3 Methanol Fuel Blends, Leaded Gasoline. For vehicle programs requiring fill tests with methanol fuel blends or leaded gasoline, the minimum required fuels are to be specified by the requesting engineer.

3.2.4.4 Diesel.

3.2.4.4.1 Testing for the North American market requires that diesel fuel must comply with ASTM D975-05, Standard Specification for Diesel Fuel Oils. The required fuel is ASTM D975 No. 2-D S15 Ultra-Low Sulfur.

GM Confidential

© Copyright 2017 General Motors Company All Rights Reserved

May 2017

Page 5 of 21



Documents

Document Sharing Hub

3.2.4.4.2 Testing for the European/Australian and Korean markets requires that diesel fuel must comply with fuel specifications for Temperate Climate Grade B, D, E, or F from European Standard EN 590.

3.2.4.4.3 Testing for the Brazilian market requires that diesel fuel must comply with the following fuel test specifications:

- ABNT NBR 14483/ASTM D1500.
- ABNT NBR 7148/ASTM D1298.
- ABNT NBR 7974/ASTM D56/ASTM D93.

Note: Anti-foaming additive should not be used for any grades of diesel.

Deviations from these fuel types can be used with approval from regional Design Engineer or Test Engineer.

3.2.5 Fuel Heating and Cooling Equipment. Testing requires that fuel dispensing equipment must be capable of heating the fuel to 39 °C (102 °F) and cooling the fuel to 3 °C (37 °F).

If methanol fuel blends are required, the fuel(s) are to be heated or cooled as specified by the requesting engineer.

3.2.6 Environmental Chamber. Testing requires an environmental chamber capable of cooling the fuel system to -11 °C (13 °F). Specified fills at 26 °C (79 °F) may also require an environmental chamber, depending on the room temperature of the testing facility.

If methanol fuel blends are required, the fuel system is to be heated or cooled as specified by the requesting engineer.

3.2.7 Vacuum Source and Air-to-Liquid (A/L) Test Equipment for Vapor Recovery Nozzles. An artificial vacuum source capable of safely transporting fuel vapor is required for vacuum assist nozzles. The same artificial vacuum source may also be used in place of an actual balance system, if so desired, when testing with balance nozzles.

For balance nozzles used in testing for the North American market, the vacuum source must be capable of maintaining a constant vacuum of 0.05 kPa (0.2 in H₂O) inside the fill pipe at the fill cap interface during steady state flow under all test conditions for which a balance nozzle is to be used. With mechanical seal fill pipes, balanced nozzles vacuum level should be set statically. See GMW14859 for rationale for vacuum level. The allowable tolerance on the vacuum level is ± 0.03 kPa (± 0.1 in H₂O).

For vacuum assist nozzles used for testing for the North American and Korean markets, the vacuum source must be capable of maintaining an A/L ratio of 1.00 to 1.10. Use a Hasstech VacuCheck (available from OPW) A/L tester for setting the A/L ratio on vacuum assist nozzles. The Franklin Healy 900 nozzle (available from Franklin Fueling Systems) requires a vacuum setting of 14.94 kPa to 19.9 kPa (60 in to 80 in H₂O). The Franklin Healy 900 nozzle does not require testing with the Hasstech VacuCheck.

For vacuum assist nozzles used for testing the European/Australian and Chinese markets, the vacuum source must be capable of maintaining an A/L ratio of 0.95 to 1.05. Use test equipment that complies with German Directive 21. BImSchV for setting the A/L ratio on vacuum assist nozzles.

3.2.8 Pump to Drain Tanks, Vapor Recirculation. A pump capable of safely transporting liquid fuel is to be used for draining the fuel tank after the fill test is complete.

Air that displaces rapidly drained fuel from the fuel tank often does not have enough time to become saturated with fuel vapor prior to starting the next fill test. Install a fuel vapor recirculation hose during the draining process to allow vapor from the bulk fuel storage tank, rather than fresh air, to enter the fuel tank and replace the volume of the drained fuel.

3.2.9 Reid Vapor Pressure Measuring Equipment. To measure the RVP of the test fuel, a RVP bomb and water bath, Grabner MiniVap RVP tester (available from Grabner Instruments), or other equivalent method may be used.

3.2.10 Miscellaneous. The following equipment is also required:

- Graduated cylinder: To measure fill volume, liquid carryover and spitback.
- Level protractor: To adjust test fixture attitude for fills on 6% grade.
- Container for spilled fuel: To catch fuel during failed nozzle fills.
- Liquid trap: To capture liquid carryover during failed nozzle fills.

GM Confidential

© Copyright 2017 General Motors Company All Rights Reserved

May 2017

Page 6 of 21



Documents

Document Sharing Hub

- Ground straps: To ground any components in contact with fuel.

3.3 Test Vehicle/Test Piece.

3.3.1 Test Vehicle/Fixture. A test buck that simulates fuel tank mounting in an actual vehicle is required for this test. All contact points between the fuel tank and the vehicle body or frame, as well as the fill pipe mounting location and orientation, should be correctly simulated. Be sure to use the correct fuel tank straps and mounting hardware to achieve the proper amount of tank compression.

For Onboard Refueling Vapor Recovery (ORVR) fuel systems, the mounting location for the evaporative emissions canister can influence the amount of liquid carryover (especially during “failed nozzle” fills) and should simulate as closely as possible the mounting location in an actual vehicle.

Fuel tank orientation with reference to ground is critical and must be correct.

As an alternative, an actual production-intent vehicle may be used in place of the test buck. The vehicle should be set to curb mass and vehicle heights should be within specification.

3.3.2 Test Piece. Fuel tank assembly (including fuel pump assembly), fill pipe assembly, fill cap, evaporative emissions canister, evaporative emissions hoses, and canister vent solenoid.

A minimum of three (3) fuel tank assemblies, one (1) fill pipe assembly, one (1) fill cap, minimum of three (3) evaporative emissions canisters (if applicable) and one (1) canister vent solenoid (if applicable) are required for this test. For plastic tanks, it is recommended that one (1) tank from each mold cavity or cooling fixture be tested for volume verification purposes.

3.4 Test Time.

Calendar time: 20 days to 30 days

Test time: 120 hours to 160 hours

Coordination time: 1 hour to 8 hours

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. Lab testing personnel with fuel system test experience.

4 Procedure

4.1 Preparation.

4.1.1 Special Instructions. Tests requiring methanol fuel blends or leaded gasoline will require special instructions from the requesting engineer regarding fuel types and temperatures to be used.

Tests for vehicles that will be sold outside North America, Europe/Australia, Korea, Brazil or China will require special instructions from the requesting engineer regarding fuel dispensing nozzles, fuel types, flow rates, and temperatures to be used.

4.1.2 Instrumentation. Real time data is to be recorded at a 10 Hz (or faster) sample rate during each fuel fill, unless otherwise instructed by the requesting engineer.

The minimum required data channels are:

- Tank bulk fuel temperature. The thermocouple location must allow the temperature of a static undrainable prefill to be measured.
- Tank bulk vapor temperature. The thermocouple location must be in the upper most vapor dome.
- Dispensed fuel temperature, at or near the nozzle inlet.
- Tank vapor pressure in each vapor dome having one (1) or more vents.
- Fill pipe pressure near the fill cap interface, to be used for setting vapor recovery nozzle vacuum levels (gasoline systems only).

GM Confidential

© Copyright 2017 General Motors Company All Rights Reserved

May 2017

Page 7 of 21

Documents
Document Sharing Hub