GM	WORLDWIDE ENGINEERING STANDARDS	Test Procedure	GMW14547

Dynamic Exterior Vehicle Water Ingestion Test

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. To determine if water degrades performance of any exterior, underbody or underhood component under multiple water exposures.

1.2 Applicability. All vehicles.

1.3 Remarks. This procedure includes the following tests and is recommended to be performed in the following order:

1.2.1 Flooded Road. Comprehends driving in flooded road conditions and standing water.

1.2.2 Powertrain Fluid Water Contamination Test. Evaluates fluids under several water exposures.

1.2.3 Rainstorm (Run Either Road or Laboratory). Evaluates engine air induction under wet road and rainstorm conditions.

1.2.3.1 High speed rainstorm road test.

1.2.3.2 High speed rainstorm laboratory test.

1.2.4 Boat Launch Test. Checks critical vehicle components are packaged above the static boat launch water line (math analysis only).

1.2.5 Universal Water Test Booth (UWTB). Comprehends automatic and manual exterior and underbody car washes. Comprehends snow melt conditions and driving in heavy rain and trailing mist.

1.2.6 Under Hood High Pressure Spray Wand. Evaluates under hood component performance while being washed with a high pressure spray wand.

1.2.7 Manual Hand Wash. Evaluates under hood and underbody mounted components and vents while being washed with a garden hose.

This procedure was developed to test exterior, under hood and underbody mounted components at the vehicle level (see Appendix A, Table A1 summary of critical components and subsystems being evaluated).

1.2.8 Steam Evaluation. Evaluates vehicle idle performance during an extended idle after a car wash event.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

None

2.3 Additional References.

- CG4160 Test Data Sheets
- Owner's Manual
- Subsystem Technical Specification (SSTS)
- Vehicle Technical Specification (VTS)

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3 Resources

3.1 Facilities.

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.

3.1.3 GM Water Troughs.

3.1.4 Universal Water Test Booth.

3.1.5 Climatic Wind Tunnel with Dynamometer.

3.1.6 GM Test Tracks.

3.2 Equipment.

3.2.1 Equipment to provide high pressure spray and garden hose.

3.2.2 Fire extinguisher.

3.2.3 Graduated beaker (250 mL capacity with milliliter increments).

3.2.4 Handheld digital fiber optics inspection camera.

3.2.5 Vehicle to push the test vehicle out of the water trough, if required.

3.2.6 Secondary Air Injection (SAI) pump activation switch (program specific).

3.2.7 Fresh clean powertrain fluids.

3.2.8 Use 125 mL fluid sample containers.

3.2.9 Stop watch.

3.2.10 GM Tech2 Diagnostic Scanner. (or equivalent diagnostic tool).

3.2.11 Syringe.

3.2.12 Empty fuel canister housing or fuel system water trap. (Splash engineer to obtain proper setup from fuel system development or release engineer. The fuel systems team is responsible for the specific vehicle setup and prepping for test).

3.2.13 Scale to determine the amount of water absorbed by the air filter elements if needed.

3.2.14 Suitable tools to dismantle the air induction system.

3.2.15 Water extractor to dry the intake manifold.

3.2.16 See-through horns.

3.2.17 Sufficient quantity of dry engine air filter elements.

3.2.18 Manual switch to enable 100% evaporation (EVAP) purge.

3.2.19 Clear intake tube installed on chassis load leveler compressor inlet.

3.2.20 Manual switch to activate air ride compressor.

3.2.21 See Appendix B, Figures B1 thru B19 for illustrations of all test setups.

3.3 Test Vehicle/Test Piece.

3.3.1 In the event that not all models are available to test, determine which vehicles are “worst test case” scenarios (i.e., lowest ride height, highest airflow engine, etc.)

3.3.2 Vehicle level validation requires all parts being evaluated to be of production design including production intent material properties. This includes production intent fasteners.

3.3.3 The test vehicle shall be fitted with all the production front end features (bumper, grille, front openings, etc.) and all the components in the engine compartment affecting flow, such as engine encapsulation, cooling module, etc.

3.3.4 For specific regions, a corresponding front license plate shall be mounted.

3.3.5 To protect the engine against water ingress, the following two (2) methods are recommended:

3.3.5.1 A twin walled wire grille shall be installed after the air mass sensor, which in the event of water ingress triggers a surge water detector in such a way that the ignition voltage to the engine is immediately cut off.

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3.3.5.2 Inspection camera or infrared night vision camera installed in the clean air side of the air intake system with a video monitor with or without a recording device in the passenger compartment to watch for water ingress past the air filter.

3.4 Test Time.

Calendar time:	Not applicable
Test time:	40 to 56 hours (Milford Proving Ground) 120 hours (all other regions)
Coordination time:	20 hours

3.5 Test Required Information. Complete data sheets available in Global Document Management (GDM) as CG4160.

3.6 Personnel/Skills. Trained personnel shall be used.

4 Procedure

4.1 Preparation.

4.1.1 General Vehicle Preparation Requirements (All Tests).

4.1.1.1 Install clean dry engine air filter.

4.1.1.2 Install water trap to inlet hose of air ride suspension compressor (if equipped). Coordinate with Chassis Control Systems Development for installation.

4.1.1.3 Add manual switch to enable air ride compressor for maximum run time as reported by chassis development engineer.

4.1.1.4 Install empty fuel canister housing or water trap. (Splash engineer to obtain proper setup from fuel system development or release engineer).

4.1.1.5 Verify that fuel system water trap functions properly (vacuum check).

4.1.1.6 Add dry canister vent solenoid (CVS) and canister.

4.1.1.7 Add switch to enable manual 100% purge full time and vehicle controlled purge rate (the fuel system team is responsible for setting up and verifying vehicle for splash testing).

4.1.1.8 Install engine protection device described previously.

4.1.1.9 Procure dry, clean engine air filters.

4.1.1.10 Equip vehicle with SAI pump if required for special markets. Add manual switch to enable SAI pump to run for 30 s intervals (secondary air injection reaction pump).

4.1.1.11 The water level in the trough shall be checked before each data point.

4.1.1.12 The water level shall be allowed to settle to (h water = x ± 5 mm) between the first half of the individual passages. All remaining passages will contain a wake moving in direction of the vehicle motion. For remaining passages, wake should be allowed to settle to (h water = x ± 20 mm).

4.1.1.13 Use GM Tech2 Diagnostic Scanner (or equivalent diagnostic tool) to check pretest diagnostic trouble codes (DTC). Record codes on data sheets. Clear all powertrain and body DTCs if any are present.

4.1.1.14 After all tests, check for DTCs and record on data sheet. Verify DTCs do not reset. Execute five (5) key starts with 30 s run time after every data point to verify codes/DTCs cleared or set. Open driver's door and wait for 1 minute minimum between key cycles.

4.1.1.15 Turn engine compartment cooling fans on for test duration if possible (Electric).

4.1.1.16 Remove vehicle interior carpeting and floor padding prior to water testing.

4.1.1.17 Verify vehicle has the latest powertrain, chassis and body calibrations and record identification numbers on data sheet (do not test prior to 80% calibrations).

4.1.1.18 Install see-through horn without electrical hookup. Waterproof the open electrical connections (see Appendix C "Water in Horn Measurement Instruction").

4.1.1.19 Fill fuel tank(s) at start of test. Do not allow fuel level to get below 50%.

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4.1.1.20 Set vehicle mass to curb, plus driver and full fuel. Record mass.

4.1.1.21 Measure and record vehicle trim and air dam heights (measured vertically through the center of each wheel, from the ground to fender/quarter panel flange). If the actual trim heights differ from the theoretical trim heights, the vehicle springs may be corrected to adapt the height.

4.1.1.22 Remove all camouflage that can impact testing. Obtain all required permissions for camouflage removal PRIOR to testing.

4.1.1.23 Document vehicle configuration with digital photos of the following views: front, side, rear, ¾ front, ¾ rear, underbody front, underbody rear, induction inlet, SAI, CVS, air ride compressor and any other critical components.

4.1.1.24 Disable traction control (if feasible).

4.2 Conditions. Vehicle shall be driven straight and centered in the water troughs. Limit steering motions to those required to maintain direction.

Note: Tests should be run only with driver to improve test repeatability (validation only).

Note: Manual Transmission, use 1st gear for speeds up through 40 km/h if possible. Use 2nd gear for speeds over 40 km/h if possible. Record gear on CG4160.

4.2.1 Environmental Conditions. Not applicable.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions.

4.3.1 Flooded Road Laboratory Test. For subsystems and components to be analyzed during this procedure, see Appendix A, Table A1.

4.3.1.1 Test Procedure.

4.3.1.1.1 Set Water trough to desired depth from “Global Flooded Road Exposure Chart” located in specific Vehicle Technical Specification (VTS) paragraph.

4.3.1.1.2 Turn on SAI switch for maximum run time in water trough.

4.3.1.1.3 Turn on EVAP. Purge solenoid while in water only.

4.3.1.1.4 Enter the water trough at initial depth and target speed as shown in Program VTS (paragraph 3.2.1.6.2.1) Global Flooded Road Chart.

4.3.1.1.5 Maintain maximum achievable vehicle speed closest to initial entry speed without wheel spin. In order to achieve optimum reproducibility, only moderate changes to the accelerator pedal position are permitted. Erratic (non-constant) accelerator pedal operation shall be avoided to prevent uneven bow waves at the front of the vehicle.

4.3.1.1.6 During the individual passages, both the surge water detector display and/or camera shall be observed.

4.3.1.1.7 Exit trough at constant speed not greater than entry speed and maintain speed until the turn around. Turn around and drive through the water trough as soon as the level is ± 5 mm for the first 50% of passes. The remaining passes are to be driven with a wake traveling with the direction of the vehicle and water level ± 20 mm. In the period between the individual passages while waiting for the water level to settle, the engine speed shall be kept at idle. Continue to drive through the water trough until 150 m (or as close to 150 m as possible) total exposure has been reached for a specific speed and depth. Do not accelerate out of the water trough upon completion of the last passage. Maintain entry speed if possible until a safe level area is reached and stop vehicle. Complete two (2) 3 s Wide Open Throttle (WOT) maneuvers after the last passage of each data point. After leaving the water trough, execute the 3 s WOT maneuvers after 10 s wait.

Warning: If engine stalls as a result of surge water, the clutch on manual transmission vehicles shall be operated immediately. If surge water is noticed on any vehicle during a run, take foot off of accelerator immediately and key off the ignition. No attempts shall be made to restart the engine before the induction system has been dried and all cylinders checked for water.

4.3.1.1.8 Stop at inspection site. Turn off SAI switch and EVAP purge switch when not in the water trough.

4.3.1.1.9 Fully turn steering wheel lock to lock and note belt squeal. Record on data sheet (5 cm, 10 cm depths only).

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4.3.1.1.10 Shut off engine.

4.3.1.1.11 Restart two (2) more times and check for warning lights. Record codes and lights on CG4160.

4.3.1.1.12 Inspect the induction system for water entry. Record observations on CG4160.

4.3.1.1.13 Dry out air induction system completely and replace any wet absorbent components.

4.3.1.1.14 Inspect the fuel system by draining test canister or trap and measure the amount of water collected after each data point. Record on CG4160.

4.3.1.1.15 If water is present in **clean** air portion of the induction system, SAI system trap, CVS trap, load leveler compressor inlet or other critical subsystems, **abort** validation test. At this point development begins and/or subsystem limits can be determined using 1 cm depth increments.

4.3.1.1.16 If any performance degradations occur as defined in the VTS, abort the test. Otherwise repeat for remaining water depths and speeds.

4.3.1.1.17 The filter element can be weighed to compare the results of different runs.

4.3.1.1.18 Record all data on CG4160.

4.3.1.1.19 Continue on to next test speed and test depth. When executing the 30 km/h impact, stop and reverse data point, stop vehicle using brakes when rear wheels first enter the level portion of the trough. Reverse out at 10 km/h.

4.3.1.1.20 After all flooded road exposures, inspect horn(s) for water intrusion (see Appendix C “Water in Horn Measurement Instruction”).

4.3.1.1.21 For any vehicle with plug in charging capabilities, charge vehicle per the instructions in the owner's manual after each specific depth and speed. Vehicle must charge for a minimum of 60 s. If vehicle does not start charging process, charging process is interrupted, or Message Information Light (MIL) is set, contact appropriate Rechargeable Energy Storage System (RESS) validation engineer for root cause investigation.

4.3.2 Powertrain Fluid Water Intrusion Procedure.

4.3.2.1 Additional Vehicle Preparation. Drain and flush powertrain fluids (transmission, transfer case, power transfer unit (PTU) and differentials).

4.3.2.2 Install transmission oil tap in transmission oil cooler (TOC) lines.

4.3.2.3 Instructions.

4.3.2.3.1 Take 63 mL baseline (prior to test) transmission fluid, transfer case, PTU, differential fluid samples and record on CG4160.

4.3.2.3.2 Replace with 63 mL fresh fluids to top off levels.

4.3.2.3.3 Set water trough to lowest required depth per data points called out in program specific VTS 3.2.1.6.2.1 Global Flooded Road Matrix.

4.3.2.3.4 Transmission fluid temperature should be 87 °C minimum prior to each water exposure (driveline warm up procedure should be followed prior to each Powertrain Fluids Water Intrusion runs).

4.3.2.3.5 Enter water trough at required entry speed. Drive through water trough to achieve a total exposure of 75 m (as close to as possible). Driving technique as described in Flooded Road portion of procedure above.

Note: Powertrain fluid water intrusion testing requires only 75 m of Flooded Road exposure.

4.3.2.3.6 Exit trough and immediately drive approximately 5 km shifting through gears. Return to inspection area.

4.3.2.3.7 Put 63 mL fresh transmission fluid in a 125 mL bottle and add transmission fluid from the vehicle to the 125 mL level. Set bottle aside. Take a 62 mL vehicle transmission fluid sample and place in a clean bottle. Record fluid appearance on CG4160. Put the beginning 125 mL sample (63 mL fresh fluid plus 62 mL vehicle fluid) back into transmission to reset fluid level.

4.3.2.3.8 Complete all remaining required Global Flooded Road Matrix (VTS 3.2.1.6.2.1) data points and take transmission oil samples as described in 4.3.2.3.7.

Reminder: Warm up transmission oil to > 87 °C prior to each water exposure.

4.3.2.3.9 For vehicles with “fording” requirements, repeat sampling procedure for the maximum allowable water “fording” depth (see program specific Flooded Road VTS for fording depth).

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4.3.2.3.10 Warm up transmission oil to > 87 °C. Drive vehicle into UWTB. Attach exhaust duct. Set parking brake and start vehicle. Run vehicle at idle for one (1) complete water booth test (8 minutes duration) with underbody spray on.

4.3.2.3.11 Take transmission fluid sample per 4.3.2.3.7.

4.3.2.3.12 After all water exposures have been completed (Flooded Road, Underhood Powerwash, UWTB, Manual wash) take a 63 mL sample of differential, PTU and transfer case fluids. Mark samples "E.O.T." (end of test).

4.3.2.3.13 Send all clearly marked fluid samples to the laboratory for analysis. If transmission fluid samples are visually cloudy, they are over the requirement for water contamination. Do not send the cloudy samples to the laboratory for analysis.

4.3.2.3.14 Record percent water contamination on CG4160.

4.3.3 High Speed Rainstorm Road Test.

4.3.3.1 Facilities.

4.3.3.1.1 Circular track or other course where constant speed is obtainable.

4.3.3.1.2 Circular track with road surface that can be ideally sprayed is preferable to test air inlets located in fender cavities.

4.3.3.2 Equipment.

4.3.3.2.1 Water trailer with a 600 L water tank and a pump for a delivery of up to 10 L/minute. The pump is connected in front of the vehicle with a hose with a fine diffusing nozzle. For air inlets located in fender cavities, an additional nozzle is used to spray directly onto that specific tire against driving direction.

4.3.3.2.2 The water trailer should be equipped with a priority vehicle light.

4.3.3.2.3 Fine diffusing nozzle(s) with one (1) central and six (6) peripheral openings for generating a spray cone with a 130 degree angle (e.g., Lechler model number 502.748.30.BL.00.0).

4.3.3.2.4 Base frame for fixing and varying direction of the nozzle, mounted on the hood.

4.3.3.2.5 Pressure manometer for acquisition and monitoring of pump while driving.

4.3.3.2.6 Switch for turning on and off water supply from inside vehicle.

4.3.3.2.7 Measuring computer with monitor for the acquisition and documentation of 4.3.3.2.7.1 thru 4.3.3.2.7.3.

4.3.3.2.7.1 Pressure drop in clean air side of air cleaner box.

4.3.3.2.7.2 Pressure drop in dirty (raw) air side of air cleaner box.

4.3.3.2.7.3 Voltage or frequency signals from the Mass Air Flow Sensor (MAFS).

4.3.3.2.8 Video system with external, watertight miniature heads for the monitoring of the clean air side of the air filter and development of the air induction system during rain test.

4.3.3.2.9 Suitable tools to dismantle the air induction system.

4.3.3.2.10 Sufficient quantity of dry air filter elements.

4.3.3.2.11 Digital camera for documentation.

4.3.3.3 Additional Vehicle Preparation.

4.3.3.3.1 Front Induction. Before the first test run, the engine speed range in which a vehicle speed between 160 km/h to 180 km/h is achieved in the highest gear (highest driving position with automatic transmission (AT)) shall be ascertained with the trailer detached. A gear which allows this same engine revolutions per minute (rpm) should be used at 120 km/h test speed with the trailer attached.

4.3.3.3.1.1 The base frame with spray nozzle shall be mounted on the hood with the nozzle aimed in such a way that it sprays toward the center of the vehicle front. The distance from the nozzle to the vehicle shall be 1 m. The height of the center nozzle opening over the ground depends on the division level of the flow paths in front of the vehicle (part of the air flow goes to the vehicle underbody, i.e., in the lower cold air intake, part goes to the upper air intake, i.e., the hood) and shall be ascertained prior to the testing via testing in a wind tunnel or simulation. The spray nozzle shall be connected to the water trailer and its pump connection using a hose fastened to the vehicle. The pump pressure shall be controllable during the test and shall be displayed in the vehicle. During the test, it shall be possible to switch the spray nozzle on and off from within the vehicle.

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4.3.3.3.1.2 Before each test, the air induction system shall be dried and a new filter element fitted. The water tight camera head of the video system shall be installed in the clean air area of the intake muffler so that the exact moment of any droplet penetration can be ascertained.

4.3.3.3.2 Fender Cavity Induction. Preparation steps are identical to those for front induction, however, the nozzle in front of the vehicle shall be eccentrically offset to the induction side of the vehicle (offset approximately 250 mm to 300 mm from the center of the vehicle). Distance of the nozzle and height from ground are same as in previous description.

4.3.3.3.2.1 In addition to spraying the front, a spray shall be generated in the wheel housing that is similar to driving in heavy rain.

4.3.3.3.2.1.1 Ideally, the test track would be sprayed so that there is 2 mm to 3 mm water on the road surface.

4.3.3.3.2.1.2 If it is not possible to spray the road surface, a water hose, connected with an additional nozzle shall be positioned in front of the tire (a distance of 50 mm to 100 mm facing rearward) on the induction side and directed to centerline of the tire, so that there is a spray cloud generated below the fender cavity, comparable to that of tire spin on wet surfaces.

4.3.3.4 Instructions.

4.3.3.4.1 Condition all new air filter elements for 4 minutes at 120 km/h (test speed).

4.3.3.4.2 Activate the spray nozzle for 100 km or until abort criterion.

4.3.3.4.3 Water pressure to be 2.0 bar + 0.2 bar.

4.3.3.4.4 To facilitate evaluation, a time record shall be made as soon as water is supplied. During the test, the pressure drop on the clean air side indicates the water load status of the air filter element.

4.3.3.4.5 The test runs for 100 km. Monitor camera in clean air duct for signs of water during the exposure. Record stabilized Mass Airflow value on CG4160. Abort test if steady stream of water is visible. Record abort time or mileage on CG4160.

4.3.3.4.6 After running 100 km with no performance degradation, execute three (3) consecutive WOT accelerations to 50 km/h followed by one (1) WOT acceleration to 120 km/h.

4.3.3.4.7 After rainstorm exposure, inspect horn(s) for water intrusion (see Appendix C “Water in Horn Measurement Instruction”) and record on CG4160.

4.3.3.4.8 For any vehicle with plug in charging capabilities, charge vehicle per the instructions in the owner's manual after Rainstorm Test. Vehicle must charge for a minimum of 60 s. If vehicle does not start charging process, charging process is interrupted, or MIL is set, contact appropriate RESS Validation engineer for root cause investigation.

4.3.4 High Speed Rainstorm Wind Tunnel Test.

4.3.4.1 Facilities.

4.3.4.1.1 Climatic Wind Tunnel with Dynamometer Capable of Creating a Rainstorm Environment.

4.3.4.2 Equipment.

4.3.4.2.1 Fine diffusing nozzle(s) with one (1) central and six (6) peripheral openings for generating a spray cone with a 130 degree angle. (e.g., Lechler model number 502.748.30.BL.00.0). For air inlets located in fender cavities, an additional nozzle is used to spray directly onto that specific tire against driving direction.

4.3.4.2.2 Nozzle(s) to be connected to city water. Pressure to be 2.0 bar + 0.2 bar.

4.3.4.2.3 Base frame for fixing and varying direction of the nozzle, mounted to floor of tunnel.

4.3.4.2.4 Pressure manometer.

4.3.4.2.5 Switch for turning on and off water supply from control room.

4.3.4.2.6 Measuring computer with monitor for the acquisition and documentation of the following:

4.3.4.2.6.1 Pressure drop in clean air side of air cleaner box.

4.3.4.2.6.2 Pressure drop in dirty (raw) air side of air cleaner box.

4.3.4.2.6.3 Voltage and frequency signals from the hot film Mass Air Flow meter.

4.3.4.2.7 Video system with external, watertight miniature heads for the monitoring of the clean air side of the air filter and development of the air induction system during rain test.

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