



Powertrain Cooling Low Load Stability for Passenger Vehicles

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 whether a powertrain cooling system is capable of operation at low loads without instability or flow control cycling, to avoid excessive thermal strain fatigue of vehicle heat exchangers, loss of coolant, or undesirable temperature gauge fluctuation.

1.2 Applicability. This procedure is applicable for all passenger vehicles with traditional wax thermostats and for all passenger vehicles with active thermal management controls (meaning electronically controlled water pump and/or distribution valve).

1.3 Remarks. Outlet side thermostats with robust seals are prone to undamped cycling in low temperatures. The low flow pulses of warm coolant through the radiator, and cold airflow over the radiator's exterior, create high strain, which when repeated can cause premature fatigue of tubes and tube/header braze joints. Software and calibration for electronically controlled pumps and valves have the potential to create similar cyclic flow and corresponding fatigue damage. The flow cycling observed in this procedure is compared to the limit defined in the Vehicle Technical Specification (VTS).

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW3420	GMW14191	GMW14193	GMW14960
GMW14167	GMW14192	GMW14328	GMW14961

2.3 Additional References.

Program Powertrain Cooling VTS

3 Resources

3.1 Facilities. This procedure is facility independent. Detailed information is provided to execute each test condition. However, this information may not be sufficient to ensure that the test results from each facility are equivalent. It is the responsibility of each facility to define the steps for executing this procedure based on the capability of their facility with consistency of test results from facility to facility being the primary objective. This procedure can be run at an on-road test facility or a climatic wind tunnel facility with the following capabilities.

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 Climatic Wind Tunnel. Climatic Wind Tunnel with ability to provide the vehicle speed (typical minimum 160 km/h), wind speed (typical minimum 160 km/h), vehicle loading using a chassis dynamometer (typical minimum tractive force of 5 000 N), and ambient temperature (controlled within a range of ± 1 °C) required for

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each condition. The tunnel should provide representative airflow through the heat exchangers, underhood, and underbody of the vehicle.

3.1.4 On-Road Facility. An on-road test facility shall be equipped with a designated test location (e.g., circular track) with defined procedure start and stop locations.

3.2 Equipment.

3.2.1 Temperature measuring and recording equipment as described in Appendix A.

3.2.2 Pressure measuring and recording equipment as described in Appendix A.

3.2.3 Measuring and recording equipment for the engine speed.

3.2.4 Measuring devices for mechanical fan and prop shaft speed (if applicable).

3.2.5 Measuring and recording equipment for voltage and current for compartment blower(s), battery(s), and engine cooling fans (if applicable).

3.2.6 Flow meter as described in Appendix A.

3.2.7 (Wind Tunnel) Device for operation and adjustment of accelerator pedal.

3.2.8 (On-road testing) Driver's trace for variable speed conditions.

3.3 Test Vehicle/Test Piece. Passenger vehicles equipped with liquid cooling system and configured with appropriate vehicle content.

3.4 Test Time.

Calendar time: 15 days

Test time: 24 h

Coordination time: 8 h

3.5 Test Required Information. Test conditions as specified by the VTS, inputs for road load calculations.

3.6 Personnel/Skills. One (1) climatic tunnel operator and/or one driver (if necessary) trained and proficient in operating the climatic wind tunnel or driving the procedure at the on-road facility. For all performance driving tests, the driver must be qualified and obtain the correct driving permits dictated by each test facility.

4 Procedure

4.1 Preparation. The vehicle shall be equipped with devices according to 3.2 and Appendix A. Ensure that a front license plate or blank equivalent (size is country specified per VTS) is installed. If the vehicle will be tested with camouflage, ensure that the airflow paths to the heat exchangers, underhood, and underbody of the vehicle are appropriate.

Prior to test, the powertrain must be preconditioned per one of the following:

- Engine Heat Rejection Test 9.
- Vehicle break-in procedure.
- At least 3000 km of general usage.

It is recommended to power check the engine. The engine or transmission should not be tested if it has > 50 000 km of total usage.

4.1.1 Calibrated Pressure Cap. Use of a calibrated pressure cap set at minimum pressure relief value is recommended.

4.1.2 Coolant. All test conditions shall use the released coolant and coolant to water ratio. Released coolant shall meet GMW3420.

4.1.3 Deaeration. Coolant system shall be deaerated to achieve the released coolant fill. Use service fill procedure plus two thermal cycles for vehicles not equipped with surge tanks.

4.1.4 Thermostat (if equipped). Use of a calibrated thermostat set at minimum stroke and at maximum temperature/set point opening value is recommended.

4.1.5 Fan Clutch (if equipped). Use of a fan clutch meeting the required performance when tested per GMW14328, GMW14960, or GMW14961 is recommended.

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4.1.6 Heat Exchangers. Use of a radiator, condenser, charge air cooler and oil coolers with the required performance values (heat rejection and pressure drop) when tested per GMW14193, GMW14192, GMW14191, or GMW14167 respectively is recommended. Components with over 50 000 km of in-vehicle use, damage, or debris present shall not be used.

4.1.7 Powertrain Calibration Level. Use vehicles with vehicle calibration levels at 80% or greater for validation. If significant calibration changes are made to engine cooling fan, aero shutter, engine (especially coolant control valve or water pump), or electronic climate controls operation, test results should be revisited.

4.1.8 Vehicle Fluid Levels. Use the released fill levels. Transmission fluid should be set to maximum fill level.

4.1.9 Electrical Power Supply. All vehicle electrical systems shall be supplied by the internal vehicle power supply. Instrumentation can be powered by non-vehicle power supply when possible.

4.1.10 Frequent Stop Warning Lights (On-road Testing). If the city traffic procedure will be conducted on a circular track, install frequent stop warning lights if required by the facility.

4.2 Conditions.

- **Condition 1** in Table 2 represents a combination of high thermal strain and system gain resulting from low ambient temperature, while retaining sufficient hours of operation to accrue meaningful fatigue damage. Several variables directly affect the severity of the condition specified. The primary variables are ambient temperature, vehicle speed, shutter/fan state, and Heating, Ventilation, and Air Conditioning (HVAC) heating power. The specified procedure is required at a minimum, but it is expected that if a variation in one of these variables is a reasonable possible selection, the effect of this modified condition should be evaluated. More specific considerations for these variables are given following.
- **Conditions 2 - 5** in Table 2 present transient control challenges to electronically controlled cooling systems, which may result in high thermal strain events, loss of coolant due to local boiling, or undesirable temperature gauge fluctuation. An example of local boiling is provided in Appendix B, Figure B2.

4.2.1 Environmental Conditions. The test shall be run at the environmental conditions listed in Table 1. For on-road testing, unless specified otherwise, the ambient temperature at the start of the test shall be within ± 3 °C of the temperature listed in Table 1. The test shall be conducted with winds < 24 km/h.

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.

4.2.3 Stability Sensitivity. The engine cooling system stability at low load is sensitive to high gain, feedback lag, and hysteresis. When the system response for cooling overshoots the required cooling power with some lag in feedback, the system can revert to no cooling power (zero flow) and oscillate indefinitely. An example of desired system control following initial thermostat opening is provided in Appendix B, Figure B1. Overall stability impacts of several variables are discussed as follows:

- **Ambient temperature:** Lower temperature increases both system gain (more severe for cycling) and absolute magnitude of thermal strain (more radiator damage). The specified conditions provide a moderately severe condition with significant customer exposure. Testing at lower temperatures can yield greater understanding of system stability and robustness but may not be realistic in terms of customer usage hours to accrue meaningful radiator damage.
- **Vehicle speed:** Higher vehicle speed increases system gain (more severe) but also engine load (less severe due to the larger cooling power needed). Often the net effect between the two is not linear in the tested range, resulting in the need for multiple speeds to be evaluated. For engine driven water pumps, engine speed should also be considered, as the system gain is directly dependent on water pump speed.
- **Shutter/fan state:** Closed shutters may reduce gain (less severe), particularly if upper and lower shutters are both present. However, the opposite response has also been observed. For this reason, each valid combination of shutters present/absent/open/closed should be evaluated. Engine cooling fan operation increases gain (more severe). For this reason, fan operation near the initial radiator flow control point (Start-To-Open (STO) or equivalent, plus applicable tolerances) should be calibrated with care on applicable engine cooling systems.
- **HVAC operation:** Maximum heater core(s) demand from the engine coolant will lower the engine cooling load, and consequently lower the required flow (more severe). However, steady-state operation at full hot/maximum blower HVAC settings is not realistic. The specified settings take this into account, but it is

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recommended to understand system sensitivity to settings, and manual system settings may be adjusted based on test engineer judgment regarding cabin comfort. When available, dual heater core systems are recommended as the tested configuration within a program.

- **Heavy-Duty cooling packages:** Added coolers for transmission and engine oil can have counterintuitive effects, and are not consistently better/worse for cycling stability. For this reason, all configurations should be evaluated, with the highest sales configuration taking priority.

4.2.4 Vehicle Climate Control Settings (Front and Rear if Equipped). Automatic climate systems shall use 22 °C full auto. For manual climate systems, the following settings are recommended unless otherwise specified:

Table 1: Manual System Climate Control Settings

Condition	Temperature	Blower	Mode	Source	A/C
-20 °C	Full Hot	Mid	Floor	Outside Air (OSA)	On
0 °C	$\frac{3}{4}$ Hot	Mid	Floor	OSA	On
10 °C	Mid	Low	Defog	OSA	On
25 °C	Mid	Off	Bi-level	OSA	Off
38 °C	$\frac{3}{4}$ Cold	Mid	Panel	OSA	On

4.2.5 Solar Load. No solar load is required for ambient temperature conditions tested at 25 °C or below. Testing above 25 °C ambient shall apply a minimum of 600 W/m². Climatic tunnel testing above 25 °C ambient should target 1000 W/m² when capable.

4.2.6 Transmission Gear. Except as noted, the transmission gear should be Drive for an Automatic Transmission (AT) or the highest possible gear that can maintain the specified vehicle speed for manual transmissions. If excessive gear shifting is required to maintain vehicle speed, the lower transmission gear should be manually selected (also see note on vehicle speed in 4.2.9). Excessive is defined as more than four downshifts/upshifts in 1 km. For manual transmissions, if two gears are possible selections for a typical driver, the more probable gear should be selected.

If both gears are equally likely, both should be considered, in accordance with other constraints of the condition. The gear which results in the more severe performance should be selected for validation purposes. If the severity of the results varies by vehicle systems, both gear choices should be run.

If the vehicle has tap mode, or other similar driver selectable gear shifting, the effect of manually selecting gears using tap mode must be considered. The choice of gears using tap mode should follow the same process as manual transmissions as described previously in 4.2.6.

If the vehicle has tow/haul mode, it should be selected if it is recommended in the owner's manual for the operating condition being tested.

4.2.6.1 Transmission Gear (Hybrid Vehicle Coast Down). When coasting down hybrid vehicles, it may be necessary to make sure the vehicle has a true neutral gear setting. If there is not a true neutral gear setting, it may be necessary to use the vehicle calibration to put the vehicle in a coast mode.

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Table 2: Vehicle Test Conditions

Condition	Ambient	Profile
Condition 1	-20 °C x any Relative Humidity (RH) 0 °C x any RH 10 °C x 40%RH	Stabilized speeds 50 kph, 75 kph, 100 kph, 130 kph
Condition 2	-20 °C x any RH 0 °C x any RH 10 °C x 40% RH	FTP75 City schedule
Condition 3	-20 °C x any RH 0 °C x any RH 10 °C x 40% RH	US06 Highway schedule 30 minute loop
Condition 4	-20 °C x any RH 0 °C x any RH 10 °C x 40% RH	Consecutive launch sequence
Condition 5	-20 °C x any RH 25 °C x 40% RH 38 °C x 40% RH	Positive/negative grade sequence

4.3 Instructions. A vehicle program may not need to run all of the conditions of this procedure. The required conditions and performance specifications are dictated by the program VTS. Unless otherwise specified, curb mass plus one occupant (as for heater performance testing) vehicle loading shall be used.

4.3.1 Condition 1 – Stabilized Speeds. Execute each condition specified in Table 2. Begin with all fluids soaked to 50 °C or lower. Start the vehicle, confirm HVAC settings are as specified in Table 1, and select Drive. Accelerate at 15 kph/s to 50 kph and hold speed for 30 minutes. Bring vehicle speed to a stop and turn off ignition. Soak fluids under 50 °C and repeat for 75 kph, 100 kph, and 130 kph. For each test point, the segment may be terminated prior to 30 minutes if any of the following conditions are met:

- Coolant stabilizes below intended flow control opening set point
- Coolant stabilizes above intended flow control opening set point, having damped out any cycling that resulted from initial opening
- Coolant flow control does not damp out and cycling repeats 10 times

4.3.2 Condition 2 – City schedule. Execute each condition specified in Table 2. Begin with all fluids soaked to 50 °C or lower. Start the vehicle, confirm HVAC settings are as specified, and select Drive. Execute the FTP75 speed trace as shown in Figure C1.

4.3.3 Condition 3 – Highway schedule. Execute each condition specified in Table 2. Begin with all fluids soaked to 50 °C or lower. Start the vehicle, confirm HVAC settings are as specified, and select Drive. Execute the US06 speed trace three (3) times in succession as shown in Figure C2.

4.3.4 Condition 4 – Consecutive launch sequence. Execute each condition specified in Table 2. Begin with all fluids soaked to 50 °C or lower. Start the vehicle and confirm HVAC settings are as specified. Accelerate to 160 kph at 15 kph/s, then immediately stop at a rate of 10 kph/s, this represents the first cycle. Subsequent cycles accelerate only to 80 kph. Repeat for a total of 15 cycles with 10 s dwell time between stop and subsequent launch.

4.3.5 Condition 5 – Positive/negative grade sequence. Execute each condition specified in Table 2. This condition uses Gross Vehicle Mass Rating (GVMR) Powertrain Cooling (PTC) vehicle loading. Begin with all fluids soaked to 80 °C or lower. Start the vehicle and confirm HVAC settings are as specified. Start the vehicle

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