



Critical Metal Temperatures

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 test is intended to define the extreme operating temperatures in critical areas and also, where possible, to define the sensitivity of those temperatures to coolant flow and system pressure.

1.2 Applicability. All liquid cooled Spark Ignition (SI) or Compression Ignition (CI) engines. This test is particularly useful in the development stage when changes to the head, block, and cooling system are possible. It may also be used to validate the head, block, and engine cooling system design.

1.3 Remarks. Temperatures in the engine block and head depend on the engine operating condition, and on the interaction between the coolant flow and the structure. The cooling flow through the engine should be sufficient to limit temperatures to acceptable levels under all conditions, including peak engine power. Of particular interest are the temperatures at the valve bridge in the head, at the spark plug boss in the head, and between the bores near the deck face in the block. If additional locations can be included, bore temperature on the exhaust side of the engine should be added first, followed by bore temperatures on the intake side of the engine.

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

GMW16169 (ID)

GMW16228 (ID)

GMW16230 (ID)

(ID) = This standard is limited to internal distribution within General Motors and shall not be distributed outside this company. Contact the GM Lead Engineer for further instructions.

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.

3.2 Equipment.

3.2.1 Fully capable engine dynamometer test facility with a combustion air supply capable of maintaining the standard air inlet pressure, temperature, and humidity. The dynamometer shall be capable of testing to the maximum speed and torque of the engine under investigation (see GMW16230, for details).

3.2.2 Instrumentation.

3.2.2.1 At a minimum, a coolant flow meter appropriately sized to measure total engine out flow for the engine being tested is required. Additional coolant flow meters may be added to other circuits if requested by the test engineer. Review of Computational Fluid Dynamics (CFD) data can help in the selection of properly sized flow

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meters. Magnetic flow meters are recommended because of their low restriction and robustness to contamination.

3.2.2.2 Thermocouple recording device with enough channels to record all requested thermocouple location simultaneously.

3.3 Test Vehicle/Test Piece.

3.3.1 Test Engine. An operational, representative engine with thermocouples installed at the locations described in 4.1.1.

3.3.2 Accessories. During the test, the auxiliary equipment necessary for engine operation shall be installed on the test engine as in the production-intent application.

3.3.3 Certain vehicle accessories necessary only for the operation of the vehicle and which may be mounted on the engine, may be removed for the test (e.g., alternator, power steering pump, Air Conditioning (A/C) compressor, etc.) Where these accessories cannot be removed, these parts shall be maintained in an unloaded condition (e.g., de-vaaned Power Steering (PS) pump, de-clutched A/C compressor).

3.3.4 Operation of fans or blowers that are often used for additional cooling of components exterior to the engine should be avoided. If this is not possible, it is recommended that the additional cooling only be active when required to maintain critical temperatures. Blowers or fans should be directed to move air parallel to the engine crankshaft axis and not directly at the engine block or oil pan.

3.3.5 Intake System. Full vehicle (platform specific) intake system, orientation according to vehicle setup is preferred.

3.3.6 Exhaust System. The engine exhaust system through the converter shall be the production vehicle system if possible. Also, the vehicle exhaust beyond the converter may be used. If a complete vehicle exhaust system is not used, the vehicle system at least through the first major restriction or reflection point (e.g., close-coupled catalytic converter) shall be used. Use of an inert catalytic converter is permissible or the converter substrate closest to the engine may be replaced with a perforated plate to serve as the first reflection point.

If production components are not used, care shall be taken to match the exhaust tuning to the greatest possible extent and to match the backpressure and temperature characteristics of the vehicle exhaust.

It is common for the output of engines in a dynamometer laboratory to be connected to a facility exhaust that operates at a pressure below atmospheric. When a test engine exhaust is connected to such a system, care shall be taken that the engine exhaust pressure at low flow rates is held at levels that reflect the intended application through the use of a backpressure valve if necessary.

3.3.7 Coolant Temperature. The thermostat shall be pinned open to the nominal full open value. The coolant temperature is to be controlled as specified in 4.3.

3.3.8 Engine Oil Temperature. For engines without a production oil cooler, oil gallery temperature shall be determined by the engine operating point and not by external controls. For engines with a production oil cooler, the oil temperature will be controlled by that oil cooler and the coolant temperature. If the engine utilizes a control device to manage oil heating and or cooling modes, the device shall be controlled to represent operation of the fully warmed up condition.

For any configuration, the oil temperature shall not be allowed to exceed the limit temperature intended for the particular engine application being tested.

3.3.9 Engine Management System. The Engine Management System (EMS) shall be the application specific system as prescribed by the test engineer and/or test procedure. Alternatively, a development system may be used with real time controllers.

Use the vehicle specific EMS according to the appropriate build phase. The base calibration (e.g., for a gasoline engine: ignition advance, air/fuel ratio, etc.) shall be updated to the latest development status. Document significant updates made to the calibration. In any case, non-engine codes (e.g., transmission, vehicle control module, etc.) may need to be masked, and routines that affect engine performance for non-engine related reasons (e.g., traction control) shall be disabled.

3.3.10 Engine Fluids.

3.3.10.1 Oil. Oil of the production intent type and viscosity for the model year of system being tested shall be used. The fill amount shall be the service fill amount.

3.3.10.2 Coolant. Use coolant that meets GMW3420 (dexcool®) mixed at a 50/50 volume ratio with water.

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3.3.10.3 Fuel. Use fuel corresponding to the region of the application. Use the same grade of fuel recommended for customer use. For dynamometer testing, it is permissible to use fuel of a higher octane number, provided that control settings are those that would be achieved when operating on customer recommended fuel with active knock control. This exception is allowed to protect engines running on the dynamometer for extended periods at conditions not typically encountered in steady-state vehicle operation.

3.4 Test Time.

Calendar time: 3 days

Test time: 24 h

Coordination time: 160 h

3.5 Test Required Information.

3.5.1 Instructions and prints/diagrams for machining of components so that thermocouples can be installed as outlined in 4.1.1 or other desired location.

3.5.2 Temperature limits appropriate for the material type (i.e., iron or aluminum) and thermocouple locations are required. It is important to note that the areas of highest metal temperature may not be accessible for thermocoupling. To determine suitable limits for thermocouple locations available, analytical results should be consulted. These limits must be agreed upon by the engineer responsible for the component design.

3.6 Personnel/Skills. Properly trained engine dynamometer test cell technician.

4 Procedure

4.1 Preparation.

4.1.1 Thermocouples. Thermocouples should be installed as described in 4.1.1.1 through 4.1.1.4. Clearly label the leads and/or connectors in a consistent manner. Alternate or additional locations are permissible based on input from the design and analysis engineers. Thermocouple locations must be agreed upon by the users of the resulting data sets.

4.1.1.1 Cylinder Head Valve Bridge. In the cylinder head bridge material, $2.0 \text{ mm} \pm 0.1 \text{ mm}$ from the combustion chamber surface, between the intake and exhaust valves on two (2) valve engines and between exhaust valves on four (4) valve engines.

4.1.1.2 Cylinder Block Major and Minor Thrust Axis. Install thermocouples from the coolant surface side of the bore to within $2.0 \text{ mm} \pm 0.1 \text{ mm}$ of the combustion chamber, at depths of $11 \text{ mm} \pm 0.5 \text{ mm}$, $20 \text{ mm} \pm 0.5 \text{ mm}$, $55 \text{ mm} \pm 0.5 \text{ mm}$, and $85 \text{ mm} \pm 0.5 \text{ mm}$ from the deck surface. Thermocouples should be placed along both the major and minor thrust axis.

4.1.1.3 Cylinder Block Siamese Area. Locate the thermocouples in the Siamese area of the block, in the same planes as the cylinder bore thermocouples.

4.1.1.4 Cylinder Head Spark Plug Boss. Locate the thermocouples in the cylinder head metal between the second and third thread from the combustion chamber. (This location may be replaced by a thermocouple spark plug, if sufficient data exists to support the replacement.)

4.1.2 Engine Installation. Install engine as described in GMW16230.

4.1.2.1 Bleed air out of the cooling system until all signs of air are gone. A sight glass, if present, shall show transparent coolant at all engine speeds, not opaque.

4.1.2.2 Stabilize the engine according to GMW16228.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 Standard inlet air conditions are common to SAE International (SAE) and International Organization for Standardization (ISO) procedures. Testing shall be done at standard conditions when possible. Deviations will affect results. Reference Table 1.

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