



Active Thermal Management Flow Bench System Flow Determination

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 intent of this standard is to determine the cooling system circuit flow rates of an active thermal management system for a variety of pump flow rates and flow control valve positions.

1.2 Applicability. This test applies to all liquid cooled engines with cooling systems capable of active control of coolant flow rates.

1.3 Remarks. Active thermal management systems can employ electric coolant pumps and control valves that can regulate coolant flow throughout the powertrain cooling circuits. These control valves can consist of a Main Rotary Valve (MRV), Block Rotary Valve (BRV), or other similar devices. Proper system control requires a thorough understanding of the interaction of these valves and the associated system flow rates. Production cooling systems typically do not contain a means for direct measurement of coolant flow. Flow rates must be inferred from the rotational speed of the water pump. By measuring cooling flow rates at a variety of pump speeds and control valve positions, a clear understanding of the system interactions can be developed. The procedure described here is similar to GMW17691 Active Thermal Management Dynamometer Coolant System Flow Determination and is closely related to GMW15808 Coolant System Bench Evaluation.

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

GMW15808

3 Resources

3.1 Facilities. A flow bench test facility as described in GMW15808 with a test controller and data acquisition system.

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 Basic Machine. A speed controlled electric motor with capacity to drive the water pump to approximately 1000 Revolutions per Minute (RPM) above the equivalent peak engine speed. This is required for applications that use a mechanically driven water pump. A 10 kW at 10 000 RPM motor is recommended, however, some North American applications may require as much as 12 kW at 10 000 RPM.

3.2.2 Fixturing. T-slot table to hold an engine block, heads, water pump, radiator, heater core, hoses, any additional cooling circuit components and instrumentation.

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3.2.3 Coolant Heater. An electric coolant heater may be required to raise the coolant temperature to 95 °C for testing. If an external heating circuit is used, it must have valves to isolate the heater during test operation.

3.2.4 Instrumentation.

3.2.4.1 Flow meters sized for appropriate flow rates with minimum pressure drop. Flow rates in various branches of the cooling circuit can range from > 200 Liters/minute (LPM) to < 5 LPM. Review of Computational Fluid Dynamics (CFD) data can help in the selection of properly sized flow meters. Magnetic flow meters are recommended because of their low restriction and robustness to contamination.

3.2.4.2 Pressure transducers or differential pressure transducers may be added to allow for pressure drop determination in the various cooling circuit branches. At a minimum, pressure transducers should be installed at the coolant pump inlet and outlet. Typical pressure ranges of -60 kPa to +800 kPa, with respect to atmosphere, should be expected.

3.2.4.3 If the engine utilizes an electric water pump in addition to coolant control valves, a power supply capable of providing the necessary voltage and current to operate the pump at maximum rated capacity is required. Also, instrumentation necessary to measure both voltage and current for the electric water pump is required so that power consumption can be determined. In addition, a control system and instrumentation is needed to control the devices and record both the command and feedback signals.

3.2.4.4 Thermocouples may be added in the various cooling circuit branches. Temperatures ranges of 15 °C to 120 °C should be expected.

3.3 Test Vehicle/Test Piece.

3.3.1 Test Engine. A test engine built to the specifications provided by the requesting engineer is required.

3.3.2 Test Components. A representative block, cylinder head(s), water pump, and any additional cooling circuit components from the engine are required. Any other cooling components that will be used to complete the active thermal management system circuit are also needed. These components may include, heater core, radiator, surge tank, engine oil heat exchanger, and transmission oil heat exchanger. If any of these components are not available, a representative restriction may be substituted. For system components that are electrically powered, an appropriate power supply is needed. For components that are actively controlled, a means for providing control of the devices is required.

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

3.4 Test Time.

Calendar time: 5 d
Test time: 15 h
Coordination time: 25 h

3.5 Test Required Information. A cooling system layout diagram and/or photographs of the test setup.

3.6 Personnel/Skills. Test cell operator(s) trained in the setup, use, and maintenance of engine test cell control and data acquisition systems.

4 Procedure

4.1 Preparation.

4.1.1 Mount the engine and platform released components onto the test fixture. Mount the platform components in relative height to design intent with respect to the water pump centerline. Avoid sharp bends, abrupt transitions, and flow restrictions in the hoses.

4.1.2 Install flow meters in the following coolant circuits (if applicable):

- Primary heat exchanger
- Primary heat exchanger bypass
- Engine bypass
- Engine oil heat exchanger
- Transmission oil heat exchanger

- Integrated Exhaust Manifold (IEM)
- Cabin heater
- Turbocharger
- Surge tank

Additional flow meters may be added if other circuits of interest are present. The intent is to accurately map out the flow characteristics of the entire coolant system with as much detail as realistically possible. An example flow diagram is shown in Figure A1 in Appendix A.

4.1.3 Install pressure transducers at the water pump inlet and outlet. Pressure transducers may also be installed in each of the circuits to determine the pressure drop associated with each heat exchanger or restriction.

4.1.4 Fill the system with GMW3420 compliant coolant. Be sure to measure the installed volume of coolant. The pressure cap may be disabled to allow pressure regulation with an external air source.

4.1.5 Bleed air out of the cooling system until all signs of air are gone. Controlling the MRV and BRV to their full open positions may help remove air from the system. A sight glass, if present, shall show transparent coolant at all engine speeds, not opaque.

4.2 Conditions.

4.2.1 Environmental Conditions. The test is to be run under ambient test cell air temperature conditions ($25^{\circ}\text{C} \pm 5^{\circ}\text{C}$).

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.

4.2.2.1 Coolant Temperature. The coolant temperature shall be controlled to an outlet temperature of $95^{\circ}\text{C} \pm 3^{\circ}\text{C}$ if possible. Coolant temperature control may be difficult for test points with low pump flow and/or certain flow control valve positions. Additional or alternative temperatures may be used depending on the intended operating temperatures for the application.

4.2.2.2 Cooling System Pressure. The cooling system pressure shall be controlled to the nominal system relief value for the intended application by means of an appropriate pressure regulation device. This pressure regulation device shall be located at a position in the coolant circuit that corresponds to the pressure control location in vehicle.

4.3 Instructions.

4.3.1 Electric or Variable Speed Water Pump Applications. Testing must be performed at maximum pump speed with a minimum of two (2) additional pump speeds. These additional speeds should be evenly spaced across the pump operating range, and provide flow rates that are within the measurement capability of the flow meters. The intent is to gather enough data points to develop linear relationships between pump speed and flow at constant valve positions.

The actual position of the control valve required to achieve the desired test points will be dependent on valve design. Consult the design specifications for the valve being tested to determine the appropriate values. However, the control valve must start at the upper mechanical stop location and be moved in decrementing direction between design of experiment test points. This ensures mechanical lash has been taken up and is aligned with software/calibration control strategy for handling mechanical lash. An example of the relationship between valve position and the distribution modes is shown in Figure B1 in Appendix B.

If the system has a separate valve to control coolant flow through the block, testing should also be performed with the valve in the closed and full open positions along with two (2) intermediate positions. These intermediate positions are not applicable for a block valve with only open and closed capability.

An example test matrix for system with a BRV is shown in Table C1 in Appendix C.

4.3.2 Fixed Drive Ratio Water Pump Applications. For applications with a fixed water pump drive ratio, pump speed will need to be varied to achieve the desired pump speeds. The selection of test speeds and valve positions should be as outlined in 4.3.1.

4.3.3 Stabilization and Data Sampling. Once the desired pump speed and valve positions have been achieved, wait 30 s to allow flow rates to stabilize before recording data. When stabilized, data shall be averaged for a minimum of 10 s.