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Requirements for Engine Cooling System Filling, Deaeration and Drawdown Tests

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The Engineering Society For Advancing Mobility Land Sea Air and Space ®
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HIGHWAY VEHICLE REPORT

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REQUIREMENTS FOR ENGINE COOLING SYSTEM FILLING, DEAERATION AND DRAWDOWN TESTS

1. PURPOSE:

The purpose of this information report is to list the requirements which are in general use for filling, deaeration, and drawdown of engine cooling systems for heavy-duty and industrial applications. The material presented in this document is for information purposes only, and does not constitute an SAE Standard.

2. LEVELLING:

Before starting any test, the vehicle or the industrial equipment must be level.

3. FILLING:

With the engine off, thermostats closed, a completely drained system (including heater, other accessories and their lines) must fill with cold water at 5 gpm (19 L/min) with a hose until the filler neck overflows. Close shutters or block the airflow to the radiator with cardboard segments and run the engine at approximately rated speed without radiator cap until the thermostats open. The opening of the thermostats may be detected by observing the flow in the radiator inlet line sight glass, by noting a sudden rise in inlet line or top tank temperature, or by noting when the coolant temperature exceeds the thermostat rating by 5°F (3°C). Continue running the engine for 5 min, and then stop the engine and measure the amount of water required to refill the system to the 100% full point, which is defined to be at the bottom of the filler neck extension (cold-fill level) or to the recommended cold-fill "Full" mark if there is no filler neck extension.

3. (Continued):

The quantity of water added shall not exceed 10% of the total system capacity, defined in this information report.

The test applies in general to systems of up to 100 qt (95 L) capacity. However, lower fill rates [for example, 3 gpm (11 L/min)] may be required in special instances and will be specified by the engine manufacturer. For systems over 100 qt (95 L) capacity, the engine manufacturer may call for a higher fill rate in order to keep the total fill time to a reasonable period.

In addition, in certain instances where air entrapment in the fill line (shunt line) may be suspected, the engine manufacturer may call for a bucket fill test. In larger systems, particularly those with remotely mounted heaters, manual air bleed vent valves may be required.

4. EXPANSION VOLUME:

The radiator must provide an expansion volume equal to a minimum of 6% of the total system capacity. This expansion volume will remain empty during a cold fast fill, but provision shall be made to vent the air from this space to the filler neck during gradual engine warm up. The amount of water required to slow fill the radiator from the bottom of the filler neck extension to the breather hole [usually 0.12 in (3.2 mm) diameter] in the filler neck extension, expressed as a percent of the total system capacity, is the percent expansion volume.

Provision for a filler neck extension tube is the preferred construction for radiators for heavy-duty and industrial applications. However, if a filler neck extension is not provided, the amount of water required to fill the radiator from the recommended "Full" mark to the bottom of the filler neck, expressed as a percent of the total system capacity, is the percent expansion volume. Total system capacity is defined following the requirements for drawdown testing.

5. DEAERATION TESTS:

The engine manufacturers require tests of the cooling system deaeration capability to remove gases from the coolant during operation. These gases may originate from air entrainment during filling, from vortexing at the fill or shunt line connection when a vehicle is not operating on a level surface or due to centrifugal forces in a prolonged turn, or from combustion gases leaking across cylinder head seals.

Because of the differences in the approach and the test methods of the various engine manufacturers, it is important that these tests be performed strictly in accordance with the engine manufacturer's requirements.

A brief description of some of the deaeration tests required by various manufacturers is given in the information report for general information only. Refer to the engine manufacturer's requirements for details.

5. (Continued):

Deaeration tests are to be performed after determination of the expansion volume.

After determination of the expansion volume, replace the thermostats with blocked-open thermostats and refill the system with a hose until the filler neck overflows. Run the engine at approximately rated speed for 5 min and refill the system to the bottom of the filler neck extension or other "Full" mark. One or more of the following deaeration tests may then be required:

5.1 Test 1 (Deaeration of Fill-Entrained Air): Run the engine at an approximately rated speed with the shutters closed or the airflow to the radiator blocked with cardboard segments to maintain a top tank temperature of 150°F ± 10 (65°C ± 6) without a radiator cap. Run until a sight glass in the engine outlet (radiator inlet) runs clear of air bubbles. The time from refilling to the bottom of the filler neck extension until the sight glass runs clear of air bubbles shall not exceed 25 min.

5.2 Test 2 (Continuous Deaeration): Using a special vented radiator cap with the hose led to an inverted water-filled bottle set in a bucket of water for purposes of measuring the volume of vented air, run the engine at an approximately rated speed with blocked-open thermostats and with the shutters closed or the airflow to the radiator blocked with cardboard segments to maintain a top tank temperature of 150°F ± 10 (65°C ± 6).

Inject air into the system and measure the volume of air vented by the deaeration system while monitoring the pump pressure rise. The rate of air venting when a 35% loss in the pump pressure rise occurs must equal or exceed an amount specified for each engine model.

5.3 Test 3 (Continuous Deaeration): With the radiator cap on, run the engine at an approximately rated speed with blocked-open thermostats and with the shutters closed or the airflow to the radiator blocked with cardboard segments to maintain a top tank temperature of 150°F ± 10 (65°C ± 6).

Inject air at a rate specified for each engine model [approximately 0.1 cfm (2.8 L/min) per cylinder] and monitor the water pump flow. At a specified air injection rate, the water pump flow must not fall below 50% of the original value, and the coolant loss through the overflow line must not be more than the drawdown rating (determined in section 6).

5.4 Test 4 (Continuous Deaeration): Under the conditions of Test 3, inject air at increasing rates until bubbles are seen in a sight glass in the radiator inlet line. This rate of air injection is called the deaeration capacity and the minimum values are specified by the manufacturer for each engine model.

6. DRAWDOWN:

After the deaeration tests, run the engine at a governed no load speed, with blocked-open thermostats, and with the shutters closed or the radiator blocked with cardboard segments to maintain top tank temperature at 150°F ± 10 (65°C ± 6) without the radiator cap. When the temperature is reached, add or draw off water until the system is filled to the bottom of the filler neck extension or the other "Full" mark. Then draw off water slowly in 1 qt (1 L) increments from the system at a point of positive pressure and measure until air is seen in the engine outlet sight glass. The amount of water drawn off, expressed as a percent of total system capacity, is the drawdown rating. This must be equal to or greater than 11% of the total system capacity, but not less than a specified minimum, for systems up to 100 qt (95 L) capacity. For most manufacturers, this specified minimum drawdown rating is 3 qt (3 L). However, some engine manufacturers require higher minimums. For cooling systems with capacity above 100 qt (95 L), the required drawdown rating shall be 11 qt (10.5 L) plus 4% of the system capacity in excess of 100 qt (95 L).

7. TOTAL SYSTEM CAPACITY:

Following the drawdown test, drain and measure the water from the entire system, being careful that no fluid is trapped in the system. This volume of fluid drained, added to the amount drawn off during the drawdown test, is the total system capacity.

8. OTHER REQUIREMENTS:

Individual engine manufacturers may have additional cooling system tests or system parameters that they require. Refer to the engine manufacturer's requirements. A sampling of some of these requirements follows.

8.1 Pump Cavitation: Under the rated engine load and an engine outlet temperature of 210°F (99°C), which will provide a temperature equal to or greater than the highest coolant temperature expected at the pump, the loss of water pump pressure rise shall not exceed a specified amount, usually 10%.

8.2 Water Pump Suction: Suction at the inlet to the water pump shall not exceed 3 in Hg (10.2 kPa) at engine high idle, without a radiator cap, and with the thermostats open. Or, alternatively.

8.3 Water Pump Inlet Pressure: There shall be a positive pressure at the inlet to the water pump at all times.

9. SPECIAL CONSIDERATIONS FOR SYSTEMS WITH SURGE TANKS OR COOLANT RECOVERY SYSTEMS:

An engine cooling system which has a surge tank can be considered to have a remote mounted radiator top tank. For purposes of these tests, the surge tank shall be considered to be the radiator top tank. Filling should be accomplished through the filler neck on the surge tank. The surge tank will be provided with a filler neck extension or the other cold-fill "Full" mark. The expansion volume for the system is provided in the surge tank in the same manner as in the usual radiator top tank. The total system capacity includes the volume of the surge tank to the bottom of the filler neck extension or the other cold-fill "Full" mark.

An engine cooling system which has a coolant recovery system can be considered to have a remote mounted expansion volume only. For purposes of this test, filling should be accomplished through the radiator filler neck, filling to the bottom of the filler neck, and through the coolant recovery system tank inlet, filling to the recommended cold-fill level. The expansion volume for the system is provided in the coolant recovery system tank, and is equal to the volume from the recommended cold-fill level to the top of the tank.

RATIONALE:

Not applicable.

RELATIONSHIP OF SAE STANDARD TO ISO STANDARD:

Not applicable.

REFERENCE SECTION:

Not applicable.

APPLICATION:

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