



SURFACE VEHICLE RECOMMENDED PRACTICE

J1436™

JUN2023

Issued 1983-09
Revised 2023-06

Superseding J1436 JUL2018

Requirements for Engine Cooling System Filling,
Deaeration, and Drawdown Tests

RATIONALE

SAE Five-Year Review and requirements clarification.

1. SCOPE

This SAE Recommended Practice is applicable to all engine cooling systems used in (1) heavy-duty vehicles, industrial applications, and (2) automotive applications.

There are two categories of coolant reservoir tanks covered in the document:

- a. Pressurized tanks
- b. Unpressurized tanks

1.1 Purpose

The purpose of this document is to list the requirements which are in general use for filling, deaeration, expansion volume, and drawdown of engine cooling systems for heavy-duty, industrial, and automotive applications. Due to the differences in heavy duty and automotive cooling systems, they are dealt with in separate sections of this recommended practice. In the case of heavy duty, these procedures apply to both the main jacket water pump and separate circuit water pumps. The material presented in this document is a recommended practice only and does not constitute a SAE standard.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

- SAE J151 Pressure Relief for Cooling System
- SAE J164 Cooling System Metallic Caps and Filler Necks
- SAE J1004 Glossary of Engine Cooling System Terms

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Documents

Document Sharing Hub

SAE J3096 Cooling System Non-Metallic Caps and Filler Necks - Threaded Construction

3. APPLICATIONS

3.1 Heavy Duty and Industrial Equipment

3.1.1 Leveling

Before starting any test, the heavy duty vehicle or equipment shall be in a plane parallel to the horizontal level.

3.1.2 Filling

With the engine off, thermostats closed, a completely drained system (including heater, other accessories, and their lines) must be filled with cold coolant (20 °C) at the manufacturer's recommended fill rate (for example: 19 L/min $\pm$ 2 L/min [5 gpm $\pm$ 0.5 gpm] or 11 L/min $\pm$ 1 L/min [3 gpm $\pm$ 0.3 gpm]) with hose until the filler neck overflows when system is equipped with reservoir tank; when the system is equipped with surge tank, fill it at the highest target cold fill level and follow the manufacturer's instructions on venting the engine and accessories.

Close shutters or block the airflow to the radiator with cardboard segments and run the engine at approximately rated speed without pressure 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 3 °C (5 °F). Continue running the engine for 5 minutes, and then stop the engine and measure the amount of coolant 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.

The quantity of coolant added shall not exceed 10% of the total system capacity defined in 3.1.6. An engine manufacturer may grant permission in a specific case to exceed 10% of total system capacity, but in no case shall the quantity of coolant added exceed the system drawdown rating, defined in 3.1.5.

The test applies in general to systems of up to 95 L (100 quart) capacity, although much larger systems in heavy duty applications will have similar requirements and test methods. However, unique fill rates may be required in special instances and will be specified by the engine manufacturer. If the system fills slower than desired, (<11 L/min), the manufacturer may require a low coolant warning sensor to detect poor initial fill or lack of top off. Most manufacturers now require a low coolant sensor regardless of fill performance. For systems over 95 L (100 quart) 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.

3.1.3 Expansion Volume

Coolant system filling may be done at the radiator top tank or through a remotely located tank such as an overflow tank or a surge tank. Radiator top tanks and surge tanks, being pressurized, and which include the expansion volume and the radiator pressure cap, will have a filler neck extension to limit the "cold full" level to avoid filling the expansion volume that is needed to accommodate the coolant volume change as it reaches operating temperature. The filler neck extension will incorporate a breather hole above the "hot full" level to allow air to escape while filling, and the size of the hole will depend on the required fill rate. Overflow tanks, being unpressurized, do not include filler neck extensions and require completely filling both the radiator top tank and the overflow tank up to the "cold full" level. As discussed above, expansion volume in the overflow tank must be provided to accommodate the coolant volume change as it reaches operating temperature.

The expansion volume needed above the “cold full” level will be dependent upon several parameters including the water-glycol ratio, the maximum allowable coolant temperature, the afterboil effect present at the top tank and the temperature of the coolant when filled cold. For example, if a system is filled cold at 21 °C (70 °F) with a 50% water-glycol mixture (based on volume), a 6% expansion volume above the “cold full” level accommodates a 110 °C (230 °F) maximum coolant temperature and an extra 1% expansion space beyond that will accommodate an additional 10 °C (18 °F) afterboil effect. Each manufacturer should account for coolant expansion volume according to their design requirements. It should be noted that excess expansion volume may preclude the system from pressurizing to the intended level, which could result in unintended boiling.

In some cases, a “full level” and “add level” may be marked on a pressurized tank using a sight glass or on the surface of a non-metallic remote tank. A typical volume between these levels is in the range of 4 to 6% of system volume. So, the total combined volume between “add level” and filler neck level may vary between 8 to 16%, depending on manufacturer's recommendations. Again, the more volume added for these volumes, the more challenging it is to pressurize the system and the more space required.

Most systems today will also include a low coolant level sensor, and it may be located in an unpressurized or pressurized tank, or in the coolant line upstream of the pump. The location of the sensor will often be synonymous with the “add level” in a pressurized tank and serve as the only indication of low coolant level. Independent of its location relative to the “add level,” the sensor location is generally located ~16% of system volume below the “full level.” The low coolant level sensor should always be located above the system's drawdown limit.

3.1.4 Deaeration

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 vortex formation at the fill line (shunt line) connection when a vehicle is not operating on a level surface, from centrifugal forces in a prolonged turn, or from combustion gases leaking across cylinder-head seals.

Also, deaeration capability is a measurement of the radiator inlet tank (or top tank) to remove air to the free surface of the coolant at a specified rate without passing enough air through the radiator assembly and into the pump inlet to reduce pump performance by a specified amount (e.g., 3% of the system flow rate without losing 10% in pump pressure rise with the coolant level starting at the full mark).

Because of the differences in the approach and test methods of the various engine manufacturers, it is important that these tests be performed strictly in accordance with the engine manufacturer's requirements. Be sure that the engine water pump is producing pressure within 15 seconds regardless of what test is being performed.

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

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

After determination of the expansion volume, replace the operating thermostat(s), with blocked-open thermostat(s) (except where noted) and refill the system with a hose until the filler-neck overflows. Run the engine at approximately rated speed for 5 minutes 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:

3.1.4.1 Test 1 (Deaeration of Fill-Entrained Air)

Run the engine at an approximately rated speed with blocked open thermostat(s), without a pressure cap, and with the shutters closed or the airflow to the radiator blocked with cardboard segments to maintain a top-tank temperature of 65 °C ± 6 °C (149 °F ± 11 °F). 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 bubbles shall not exceed the manufacturer's specification, e.g., 25 minutes.

3.1.4.2 Test 2 (Continuous Deaeration)

Using a special vented pressure cap with the vent hose led to an inverted coolant-filled bottle set in a bucket of coolant for purposes of measuring the volume of vented air, run the engine at 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 $65^{\circ}\text{C} \pm 6^{\circ}\text{C}$ ($149^{\circ}\text{F} \pm 11^{\circ}\text{F}$).

Inject air into the system via the heater return circuit or equivalent closed loop branch, from a pressurized air source adjusted to produce visible bubbles in a sight glass. Measure the time required to fill the inverted bottle with air vented from the system while monitoring the pump pressure rise. The pump pressure rise is plotted against air venting rate (volume of bottle/time to fill with air). Gradually increase the pressure of air injected into the system, allowing the filled system to stabilize for at least 3 minutes before each data point. Take several data points at increasing air injection pressures. The rate of air venting that gives a 35% loss in pump pressure rise must equal or exceed an amount specified by the engine manufacturer, e.g., 5% of engine displacement per minute.

3.1.4.3 Test 3 (Continuous Deaeration)

With the pressure 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 $65^{\circ}\text{C} \pm 6^{\circ}\text{C}$ ($149^{\circ}\text{F} \pm 11^{\circ}\text{F}$).

Inject air via the heater return circuit or equivalent closed loop branch at a rate specified for each engine model (e.g., 2.8 L/min [0.1 cfm] per cylinder) and monitor the water pump flow. At the specified air injection rate, the coolant pump flow (not pressure) must not degrade more than the manufacturer's required value, e.g., 50%, and the coolant loss must not be more than the drawdown rating (determined in 3.1.5).

3.1.4.4 Test 4 (Deaeration with Operating Thermostat(s))

Run the engine at high idle for 5 minutes with operating thermostat(s) and without pressure cap. Bring engine to low idle and fill system to appropriate full level. Install the pressure cap. With the shutters closed or the airflow to the radiator blocked with cardboard segments, run at high idle for 10 minutes more, keeping engine coolant outlet temperature between approximately 82°C (180°F) and 93°C (200°F). Run at 50 to 150 rpm higher than torque peak engine speed up to 20 minutes more, keeping engine coolant outlet temperature between approximately 82°C (180°F) and 93°C (200°F). The system has acceptable deaeration capability if a sight glass runs clear of bubbles in the manufacturer's specified time period.

3.1.5 Drawdown

This test determines the reserve quantity of the cooling system and the correct position of the low mark in the radiator top tank or expansion tank. Note that in all test cases, the drawdown volume must exceed that volume refilled during cold fill. If equipped, it is also convenient to evaluate the low coolant sensor operation and check engine light during the drawdown test.

3.1.5.1 Test 1 (Drawdown by Loss of Pump Pressure)

Run engine at rated engine speed with blocked open thermostats, without a pressure cap and with shutters closed or the radiator blocked with cardboard to maintain a top tank temperature of approximately 82°C (180°F). Add or remove coolant until the system is filled to the bottom of the filler neck extension or to the specified "Full" level. Install the pressure cap. Record the water pump pressure rise to establish a reference pump rise, then drain off coolant in increments of 1 L (1 quart) at a point of positive pressure and record pump pressure rise after each unit of coolant is removed. Remove coolant slowly until there has been a 15% loss in pump pressure rise from the reference pump rise. The water pump rise loss at the low coolant level mark must not be more than 10% from the reference pump pressure rise. The volume of coolant drawn from the system, expressed as a percent of the total system volume, is the drawdown volume. This volume is specified by the manufacturer, e.g., minimum of 12% of the total system volume including the expansion volume as described in 3.1.3 plus another 6% or more of the system volume between the full mark and low mark. This requirement may vary, or sometimes not apply to HD off highway construction and industrial equipment. It is suggested to review the design with the engine manufacturer.