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(R) Heavy Duty Vehicle Cooling Test Code R**1. Scope**

This document supersedes SAE J819—Engine Cooling System Field Test. The purpose of this SAE Recommended Practice is to establish a testing procedure to determine the performance capability of the engine cooling systems, including charge air coolers on heavy-duty vehicles with liquid-cooled internal combustion engines. The definition of heavy vehicles for this document includes, but is not limited to, on and off highway trucks, cranes, drill rigs, construction, forestry and agricultural machines. Vehicles equipped with side or rear-mounted radiators may require an alternate procedure of a towing dynamometer because of peculiar aerodynamics.

Testing is generally conducted to determine compliance with cooling criteria established by the engine manufacturer or the end product user to meet a desired engine reliability goal.

2. References**2.1 Applicable Publication**

The following publication forms a part of the specification to the extent specified herein. Unless otherwise indicated the latest version of SAE publication shall apply

2.1.1 SAE PUBLICATION

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J2676—Transit Bus Cooling Systems Performance Testing (This document is in the process of being written and has not been published yet.)

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3. Definitions

3.1 Ambient Air Temperature

For lab conditions, the ambient air temperature should be measured at a specified distance, at least 2 meters away from the vehicle being tested, in front of the cooling system inlet grille or screens and reported. For field conditions, the ambient should be measured near the test vehicle and its location relative to the test vehicle should be recorded.

3.2 EOTD—Engine Outlet Temperature Differential

The difference between the coolant temperature at the engine outlet and the ambient air temperature.

3.3 Terms Used by the Industry Related to EOTD

3.3.1 AIR-TO-BOIL (ATB)

The ambient temperature at which the engine coolant outlet temperature reaches 100 °C (212 °F), the boiling point of water at standard conditions.

3.3.1.1 $ATB = 100\text{ °C} - \text{engine coolant outlet temperature} + \text{ambient air temperature}.$

3.3.2 AMBIENT CAPABILITY

Similar to ATB, but refers to a coolant temperature other than the boiling point of water.

3.3.3 AIR-TO-REDLINE (ATR)

The ambient temperature at which the engine coolant outlet temperature reaches the coolant overheat warning temperature.

3.3.3.1 $ATR = \text{Coolant overheat activation temperature} - \text{engine coolant outlet temperature} + \text{ambient air temperature}.$

3.3.4 LIMITING AMBIENT TEMPERATURE (LAT)

The ambient temperature at which the engine coolant outlet Temperature reaches the maximum allowable temperature.

3.3.4.1 $LAT = \text{Maximum engine coolant outlet temperature} - \text{engine coolant outlet temperature} + \text{ambient air temperature}.$

3.3.5 AMBIENT DESIGN TEMPERATURE (ADT)

The ambient temperature at which the engine coolant outlet temperature reaches the design coolant temperature.

3.3.5.1 $ADT = \text{Design coolant temperature} - \text{engine coolant outlet temperature} + \text{ambient air temperature}.$

3.3.6 TOP TANK TEMPERATURE DIFFERENTIAL (TTTD, ALSO KNOWN AS TOP TANK DIFFERENTIAL, TTD)

The difference between the coolant temperature at the radiator top tank and ambient air temperature. For a cross flow radiator, this would be the difference between the radiator inlet temperature and ambient air temperature.

3.3.7 AIR-TO-WATER (ATW)

The temperature differential between ambient air and engine outlet. The terminology assumes water as the coolant.

3.3.8 INTAKE MANIFOLD TEMPERATURE DIFFERENTIAL (IMTD)

The difference between the temperature of the air in the intake manifold and the ambient air.

3.3.9 CAC OUTLET TO AMBIENT

The difference between the charge air cooler outlet temperature and the ambient temperature.

3.3.10 INSTALLED CHARGE AIR COOLING SYSTEM EFFECTIVENESS

The effectiveness of the CAC system using the temperatures at the turbocharger outlet and intake manifold inlet rather than the temperatures at the CAC inlet and CAC outlet. See 3.3.10.1.

3.3.10.1 CAC System Effectiveness = $(\text{Turbocharger outlet temperature} - \text{Intake manifold temperature}) / (\text{Turbocharger outlet temperature} - \text{Ambient air temperature})$

4. Facility Requirements

4.1 Laboratory facilities should include the following:

4.1.1 POWER ABSORBING DEVICE

A chassis or drivetrain dynamometer capable of absorbing rated horsepower and peak torque of the engine/vehicle.

4.1.2 COOLING AIR

Constant air velocity and air temperature to the face of the radiator within the range recommended by the engine manufacturer.

4.1.3 INSTRUMENTATION

Ability to measure the required test data and test conditions. If the use of a controlled laboratory is not feasible, the test vehicle should be evaluated in a test course that is representative of typical field operating conditions that imposes worst case customer attainable and maintainable vehicle loading. Instrumentation similar to that used in the laboratory is still required.

5. Test Preparation and Set Up

5.1 Engine and Vehicle

- 5.1.1 It is preferable to perform tests at ambient air temperatures between 27 °C (81 °F) and 46 °C (115 °F). Avoid performing cooling tests if the ambient air temperature is below 18 °C (65 °F). This will minimize the effects of changes in air density.
- 5.1.2 For field tests of off highway vehicles, it is preferable to test at wind speeds below 10 km/h (6 mph) unless wind is 90 degrees to the test course.
- 5.1.3 Prior to start of the test, the machine shall be inspected to assure that:
- 5.1.3.1 It is serviced as specified by manufacturer.
- 5.1.3.2 It delivers specified power. This can be checked by monitoring fuel consumption, turbocharger outlet temperature and pressure or application of the Drawbar Test Procedure for Construction, Forestry, and Industrial Machines, or other suitable means.
- 5.1.3.3 All items directly related to the cooling system performance, such as: fan speed, fan belt adjustment, fan to core spacing, air recirculation baffling or air recirculation shields, coolant and other fluid levels, radiator pressure cap, etc. are properly adjusted and the heat exchangers are clean inside and out, and the fins are straight and in good condition.
- 5.1.4 The engine coolant thermostats should be blocked to the manufacturer's specified opening for the maximum design operating ambient air temperature condition.
- 5.1.5 The fan drive, if unit is so equipped, should be fully engaged using the manufacturer's recommended procedure.
- 5.1.6 All shutters should be fixed in the fully open position.
- 5.1.7 Air conditioning should be on "normal", coldest temperature setting, and fan speed on "high." Cab windows and vents are to be open to assure that the A/C compressor does not cycle during stabilization.
- 5.1.8 Cab heater fan should be "off" if different from air conditioning fan.
- 5.1.9 Block the coolant flow through the cab heater hoses at engine without affecting the flow of other auxiliary coolant circuits if equipped.
- 5.1.10 The air compressor on vehicles so equipped should be held in the disengaged mode. This can readily be accomplished by applying sufficient shop air to the air compressor discharge or wet tank to prevent the governor from turning on the compressor. This is very important when the air compressor inlet is taking clean air from the intake manifold.
- 5.1.11 Engine coolant should be 50/50 glycol solution concentration or 100% water as required by the engine manufacturer's test procedure.

5.2 Instrumentation and Data Log

5.2.1 REQUIRED

5.2.1.1 *Time Interval*

5.2.1.2 *Engine Speed*

5.2.1.3 *Fan Speed*

5.2.1.4 *Fuel Flow Rate Measurement and Temperature*

Follow the engine manufacturer's recommended procedure if one exists. The temperature of the fuel delivered to the engine should normally be maintained at or near 38 °C (100 °F).

5.2.1.5 *Ambient Air Temperature and Relative Humidity*

Shade thermometers and thermocouples from sun or other sources of non-pertinent radiated heat.

5.2.1.6 *Test Site Altitude and Observed Barometric Pressure*

5.2.1.7 For on-highway vehicles, velocity and temperature of ram air measured 1.0 m (3.3 ft) in front of the grille and on the approximate centerline of the grille opening (may or may not coincide with the centerline of the fan and/or the engine).

5.2.1.8 *Coolant Temperature at the Engine Outlet to the Radiator*

This temperature should be measured as close to the engine coolant outlet as reasonably possible.

5.2.2 Optional test information for the analysis of the cooling system may be obtained by measuring the following:

5.2.2.1 *Dimensional Relationship of Fan to Core, Shroud, and Engine*

5.2.2.2 Fan to shroud tip clearance at top, at bottom, and at both sides. This is to determine the centering of the fan in the shroud.

5.2.2.3 Back of fan to back of shroud at top, at bottom, and at both sides. This is required for fan penetration into the shroud.

5.2.2.4 Front of fan to back of radiator at top, at bottom, and at both sides. This is to determine the proximity of the fan to the core.

5.2.2.5 Front of fan to closest point on engine or engine-affixed hardware. This will help the decision-making process when it becomes desirable to change the fan penetration into the shroud.

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5.2.3 OPTIONAL DATA TO RECORD

5.2.3.1 *Ground Speed*

5.2.3.2 *Transmission Gear*

5.2.3.3 *Dynamometer Power*

5.2.3.4 *Axle Lubricant Temperature*

5.2.3.5 *Oil Temperature and Pressure of:*

5.2.3.5.1 Engine for monitoring stabilization and abort purposes

5.2.3.5.2 Transmission

5.2.3.5.3 Hydraulic System

5.2.3.6 *Water Pump Inlet and Outlet Pressures*

5.2.3.7 *Coolant Temperature at Engine Inlet from the Radiator*

5.2.3.8 *Coolant Flow Rate at Engine Outlet to Radiator*

5.2.3.9 *Engine Compartment Temperatures*

5.2.3.10 *Combustion Air Temperature at:*

5.2.3.10.1 Entrance to air induction system

5.2.3.10.2 In air cleaner before element

5.2.3.10.3 Turbo inlet for turbocharged engines

5.2.3.10.4 Intake manifold inlet or in the manifold

5.2.3.10.5 Exhaust gas at the turbo outlet

5.2.3.11 *Combustion Air Pressures*

5.2.3.11.1 Air cleaner exit measured at the location provided for the air cleaner restriction gage.

5.2.3.11.2 Turbo Outlet Pressure (Turbocharged Engines Only)

A port location in the turbo outlet should be specified by the engine manufacturer if accurate data is critical.

5.2.3.11.3 Intake Manifold Pressure (Turbocharged Engines Only)

A port location in the intake manifold should be specified by the engine manufacturer if accurate data is critical.

5.2.3.12 Cooling Air Temperature Entering and Exiting the Faces of Heat Exchangers

5.2.3.12.1 Radiator

At least four locations determined by splitting the core into equal areas

5.2.3.12.2 CAC

At least four locations determined by splitting the core into equal areas

5.2.3.12.3 On Air-to-Coolant Charge Air Coolers (if so equipped)

It is advisable to measure the temperature of the coolant entering and exiting the heat exchanger.

6. Procedure

6.1 For Lab Conditions

6.1.1 With vehicle engine off, adjust the ram air velocity to maintain the test speed specified by the engine manufacturer, for example, 24 km/h (15 mph).

6.1.2 Start engine and run at rated power and speed until stabilization occurs. Stabilized conditions exist when (a) engine speed and load have remained constant (within reason) for at least 15 min and (b) the EOTD does not change more than ± 0.3 °C (0.5 °F) between three consecutive sets of readings taken at 5 min intervals. The temperature of the engine lubricant in the sump should also be stabilized to within ± 0.3 °C (0.5 °F) between three consecutive sets of readings taken at 5 min intervals.

6.1.3 Record data documenting stabilization.

6.1.4 Adjust load to run engine at peak torque and speed or other specified cooling check points until stabilization occurs.

6.1.5 Record data documenting stabilization.

6.2 For Field Conditions

6.2.1 Operate machine under steady load conditions, which represent typical field operating conditions for the machine being tested. Continue operating and recording data until stabilization of the cooling system is achieved. Stabilization shall be considered achieved when a) engine speed and load have remained constant within reason for at least 15 minutes and b) the EOTD does not change more than 1 °C (2 °F) of two consecutive readings taken 5 minutes apart. The temperature of the engine lubricant in the sump should also be stabilized to within ± 1 °C (2 °F) between two consecutive sets of readings taken at 5 min intervals.

6.2.2 Record data documenting stabilization.

7. Test Data Evaluation

7.1 Engine Outlet Temperature Differential (EOTD)

Test data is used to determine the cooling system performance capability referred to as EOTD. It is defined in section 3.2.

7.2 Air-to-Boil Temperature (ATB)

The EOTD is used to determine the cooling system performance capability commonly referred to as air-to-boil temperature (ATB). It is defined in section 3.3.1.

7.3 Air-to-boil capabilities are calculated for each combination of ram air velocity, engine load, and engine speed specified by the engine manufacturer or the end user:

8. Test Result Extrapolation and Adjustment Guideline

8.1 Due to facility limitations or existing ambient air temperature conditions, actual test conditions may deviate from those specified by the acceptance criteria. EOTD temperatures based on test results may be adjusted for variations.

8.1.1 ALTITUDE

When the test is conducted at an altitude above the base of 152 m (500 ft), the calculated EOTD should be adjusted downward 1 to 2 °C (2 to 4 °F) per 305 m (1000 ft) of elevation.

8.1.2 COOLANT

When a test is conducted with water instead of an engine manufacturer specified 50/50 ethylene glycol-water mixture coolant base, the calculated EOTD temperature should be adjusted upward 3 to 4 °C (5 to 7 °F). The inverse will be true if a test is conducted with a 50/50 ethylene glycol-water mixture coolant base when the engine manufacturer specifies water as the test coolant medium. Increased EOTD adjustments for coolant type may be required in a cooling system where the coolant velocity through the radiator tubes is extremely low.

8.1.3 FUEL RATE VARIATION

When the test is conducted at a fuel rate different than the specified value, the EOTD should be corrected (see Equation 1). Corrections should not be applied to fuel rates grossly differing from the specified fuel rate.

$$EOTD_{\text{corr}} = EOTD_{\text{test}} \left(\text{Specified Fuel Rate} / \text{Test Fuel Rate} \right) \quad (\text{Eq. 1})$$