

	SURFACE VEHICLE RECOMMENDED PRACTICE	
	SAE	J1393 SEP2012
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Superseding J1393 NOV2004		
Heavy Duty Vehicle Cooling Test Code		

RATIONALE

This document has been reviewed and updated to correct spelling and grammatical errors, to clarify some technical specifications, and to meet new formatting requirements.

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 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 Documents

There are no referenced publications specified herein.

3. DEFINITIONS

3.1 AMBIENT AIR TEMPERATURE

For lab conditions, the ambient air temperature should be measured at a specified distance, at least 2 m away from the vehicle being tested, in front of the cooling system inlet grille or screens and reported. For field conditions, the ambient air temperature 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.

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3.3 Terms Used by the Industry Related to EOTD

3.3.1 AIR-TO-BOIL (ATB)

The ambient air temperature [$^{\circ}\text{C}$ or $^{\circ}\text{F}$] at which the engine coolant at the radiator inlet reaches its boiling point. The coolant boiling point is a function of the absolute pressure and the characteristics of the coolant. However, this term is also commonly used without consideration for the absolute pressure or the coolant characteristics. In the case of an open radiator at sea level pressure with water as coolant, a boiling point of 100°C (212°F) is assumed.

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

3.3.2 AMBIENT CAPABILITY

Similar to LAT (see 3.3.4), but refers to an ambient air temperature at which any of the fluids being cooled exceeds its design temperature limit under a specified operating cycle.

3.3.3 AIR-TO-REDLINE (ATR)

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

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

3.3.4 LIMITING AMBIENT TEMPERATURE (LAT)

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

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

3.3.5 AMBIENT DESIGN TEMPERATURES (ADT)

The ambient air temperature at which each fluid being cooled in the cooling system reaches its design temperature limit under specific operating conditions related to the equipment's application.

3.3.5.1 $\text{ADT} = \text{Fluid design temperature limit} - \text{max fluid temperature in system} + \text{ambient air temperature}.$

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 CHARGE AIR COOLER (CAC) OUTLET TO AMBIENT

The difference between the CAC outlet temperature and the ambient air 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 = (Turbocharger outlet temperature – Intake manifold temperature)/(Turbocharger outlet temperature - 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 with sufficient accuracy and repeatability. If the use of a controlled laboratory is not feasible, the test vehicle should be evaluated in an outside test course as described in section 4.2. Instrumentation similar to that used in the laboratory is still required.

4.2 Field testing requirement

4.2.1 In the case of large construction machinery too large for testing on a chassis or drivetrain dynamometer, power absorption can be created using a drag sled test, running an appropriate high-severity duty cycle for the machine, or both. Multiple cycles may be specified for cooling tests, as different cycles may be the more high-severity duty cycle for engine, transmission, and hydraulic systems. Operating conditions should be carefully considered and tailored to meet vehicle mission requirements that maintain vehicle reliability and are cost effective.

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 Test Parameters
 - 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.

5.2.1.9 Coolant temperature at engine inlet from the radiator

5.2.1.10 Coolant flow rate at engine outlet to radiator

5.2.1.11 Oil temperature and pressure of engine for monitoring stabilization and abort purposes

5.2.1.12 Combustion air temperature at:

5.2.1.12.1 Entrance to air induction system

5.2.1.12.2 In air cleaner before element

5.2.1.12.3 Turbo inlet for turbocharged engines

5.2.1.12.4 Intake manifold inlet or in the manifold

5.2.1.13 Cooling air temperature entering and exiting the faces of heat exchangers

5.2.1.13.1 Radiator

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

5.2.1.13.2 CAC

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

5.2.1.13.3 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

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 Axial distance fan projects out of shroud at top, at bottom, and at both sides. This is required for fan penetration into the shroud.

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

5.2.2.5 Distance between fan and 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.

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 Transmission

5.2.3.5.2 Hydraulic System

5.2.3.6 Water Pump Inlet and Outlet Pressures

5.2.3.7 Engine Compartment Temperatures

5.2.3.8 Exhaust gas temperature at the turbo outlet

5.2.3.9 Combustion Air Pressures

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

5.2.3.9.2 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.

5.2.3.9.3 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.

6. PROCEDURE

6.1 For Lab Conditions

6.1.1 For mobile equipment, 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 2% (or within capability of equipment) for at least 15 min, and

(b) the EOTD does not change more than $\pm 0.3^{\circ}\text{C}$ (0.5°F) between three consecutive sets of readings taken at 5 min intervals, and

(c) temperature of the engine lubricant in the sump is stabilized to within $\pm 0.3^{\circ}\text{C}$ (0.5°F) between three consecutive sets of readings taken at 5 min intervals.

If test equipment or machine is not capable of achieving engine speed and load variation within 2% as specified, a statement in the report shall be made listing the actual speed and load variations attained.

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, or a short repetitive cycle if that is more symbolic of machine operation. 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 2% (or within capability of equipment) for at least 15 min, and

(b) the EOTD does not change more than 1 °C (2 °F) between two consecutive readings taken 5 min apart, and

(c) temperature of the engine lubricant in the sump is stabilized to within ± 1 °C (2 °F) between two consecutive sets of readings taken at 5 min intervals.

If test equipment or machine is not capable of achieving engine speed and load variation within 2% as specified, a statement in the report shall be made listing the actual speed and load variations attained.

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 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 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.