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Glossary of Engine Cooling System Terms

RATIONALE

Five-Year Review. The terms "Auxiliary Pumps," "Logarithmic Mean Temperature Difference," and "Rotary Valves" have been added.

1. SCOPE

The objective of this glossary is to establish uniform definitions of parts and terminology for engine cooling systems. Components included are all those through which engine coolant is circulated: water pump, engine oil cooler, transmission and other coolant-oil coolers, charge air coolers, core engine, thermostat, radiator, external coolant tanks, and lines connecting them.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

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 J631 Radiator Nomenclature

SAE J814 Coolants for Internal Combustion Engines

SAE J1393 Heavy-Duty Vehicle Cooling Test Procedures

SAE J1436 Requirements for Engine Cooling System Filling, Deaeration, and Drawdown Tests

SAE J1468 Oil Cooler Application Testing and Nomenclature

SAE J1726 Charge Air Cooler Internal Cleanliness, Leakage, and Nomenclature

SAE J2914 Exhaust Gas Recirculation (EGR) Cooler Nomenclature and Application

SAE J3136 Low-Temperature Coolant Circuit Nomenclature and Applications

SAE J3142 Thermal Flow Control Valve Nomenclature and Application

3. DEFINITIONS

3.1 AERATION

The entrainment of gas (air, combustion gas, or both) in the coolant.

3.2 AFTERBOIL

Boiling of the coolant after engine shutdown. It is caused by an engine's local metal surface heat flux into adjacent coolant. Heated coolant would reach a superheated state for its local additive concentration and pressure.

3.3 AFTERBOIL VOLUME

The quantity of coolant forced from the engine by afterboil. The volume is a combination of liquid coolant and coolant vapor created by high heat flux from the engine liner and cylinder head reaching boiling point at the lower pressure seen locally after engine shutdown. This may or may not be displaced from the system, depending upon the system design, coolant level, or both.

3.4 AIR-TO-BOIL (ATB) TEMPERATURE

The ambient air temperature (°C or °F) at which the 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, the term is also quite 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.

3.4.1 Air-to-Boil Temperature = Boiling temperature of the system coolant - highest coolant temperature during specified test + ambient temperature.

3.5 AIR RECIRCULATION - FAN

The recycling of air already discharged by the fan back to the fan inlet. Recirculation raises air-fan temperature and reduces air mass flow.

3.6 AIR RECIRCULATION - RADIATOR

The recycling of hot air already passed through the radiator, usually caused by engine enclosure pressure. Recirculation can be minimized with well-placed recirculation baffles.

3.7 AMBIENT CAPABILITY

Similar to ATB temperature (see 3.4) but refers to an air ambient temperature at which any of the fluids being cooled exceed their design temperature limits under a specified operating cycle. For example, if four fluids are being cooled, the ambient temperature at which the first fluid reaches its design limit determines the ambient capability of the entire system.

3.8 AMBIENT TEMPERATURE

The environmental air temperature (°C or °F) in which a unit is operating. In general, the temperature is measured in the shade (no solar radiation) and represents the air temperature for engine cooling system performance measurement purposes. Air entering the radiator will usually be above ambient temperature due to the heat gained passing by hot surfaces on its way to the core or from recirculation.

3.9 APPROACH TEMPERATURE DIFFERENTIAL

The temperature difference between hot-side fluid (coolant, oil, or charge air) and cold-side fluid (air or coolant) entering the heat exchanger. This is a quantity indicating the temperature potential driving heat transfer in data supplied by the heat exchanger supplier along with the heat transfer capacity of the heat exchanger (see 3.48).

3.9.1 Supplier data usually comes in the form: $q' = (U \times A) \times \Delta T$

where:

q' = heat transferred (kW or Btu/min)

U = overall heat transfer coefficient (kW/m^2/°C or Btu/min/ft^2/°F)

A = effective core heat transfer area (m^2 or ft^2)

ΔT = temperature difference (°C or °F) expressed as either entering temperature difference or temperature potential (common definition for radiator performance)

3.10 AUXILIARY PUMPS

Typically run on 12 V electric power, may be used to supply coolant flow for heater cores flow during stop/start, for low temperature loops, and for charge air coolers and for electrification components.

3.11 AUXILIARY TANK

A separate tank in the cooling system provided to perform one or more of the following functions:

a. Filling

b. Coolant reservoir

c. Deaeration

d. Retention of coolant expelled from radiator by expansion, afterboil, or both

e. Visible fluid level indication, including add and full markings

f. A warning of low coolant level, either by an electronic fluid level indicator or low coolant warning sensor

The terms “burp bottle” and “overflow bottle” are sometimes used synonymously with this type of recovery system, which is non-pressurized.

3.12 BLOCKED OPEN THERMOSTAT

A thermostat mechanically blocked open to the position representing its maximum open position; usually used during cooling tests.

3.13 BLOWER FAN MODE

A cooling system configuration where the fan is positioned such that the air passes through the fan before entering the heat exchanger(s). This configuration is sometimes called a forced air, blower, blow through, or pusher system.

3.14 COOLANT

In the context of this standard, coolant is the fluid circulated through a cooling system by the pump that absorbs heat from the hot surfaces of heat exchangers from the hot side fluid, as well as absorbing engine heat rejection from hot internal surfaces as a result of fuel combustion at high temperatures. The heat is then dissipated to ambient air circulated through the core of the radiator by the fan. The coolant has other purposes in the case of engine cooling systems. At a minimum, the coolant consists of water plus a rust inhibitor, which protects iron parts of the engine and cooling system from oxidation. Antifreeze is most commonly added to water, either ethylene glycol or propylene glycol, to provide additional cooling system protection by:

- Lowering the freezing point temperature for low ambient temperature conditions when the engine is off.
- Raising the boiling point temperature to prevent localized boiling in areas of high temperature and low pressure inside the engine when operating a high load, high ambient temperature, or both.
- Adding galvanic corrosion protection for protection of cooling system parts containing copper, brass, and solder; and a surface coating on aluminum parts of the system to prevent oxidation.
- Providing added lubrication for seals in the coolant pump.

3.15 COOLANT RECOVERY SYSTEM

A subsystem for the purpose of containing the coolant which is expelled from the system when it expands due to an increase in the coolant's bulk temperature. The recovery system consists of a tank that is partially filled and attached using a vent line to the vent on a filler neck of a full and pressurized radiator. As the coolant heats and expands, it forces the radiator cap to open and allow fluid flow into the auxiliary tank. When the coolant cools, a vacuum is created, forcing the radiator cap to open, and that draws fluid from the tank back into the radiator. A pressure-vacuum cap is required for this type of system.

3.16 COOLING SYSTEM

A group of interrelated components that effectively transfer heat for the purpose of keeping components and cooling fluids below specified design temperature limits.

3.17 COOLING SYSTEM CAP

Device that seals the opening used to add coolant to the pressurized section of the engine cooling system and regulate the cooling system's pressure level. A relief spring will move enough to open the seal above a specified pressure, allowing coolant or pressurized air to flow out of the opening (either to the environment or an auxiliary tank), and prevent over-pressurization of the system that would cause structural damage or leakage elsewhere in the system. The opening system pressure is determined by the OEM. Note that once the cap is installed and sealed, pressure is only created when either (1) the coolant temperature rises above the value when the cap is sealed, (2) the volume expands thermally as in coolant recovery systems, or (3) there is another source of gas entering the coolant circuit. Simply installing and sealing a cap does not create pressure. In the case of recovery tank systems, a second spring reacting to vacuum will also be included in the cap to allow flow to return to the cooling system from the auxiliary tank when the coolant cools and contracts and reaches a specified negative pressure below ambient atmospheric pressure.

3.18 COOLING SYSTEM CAPACITY (VOLUME)

The amount of coolant designated (liters or quarts) to completely fill a cooling system to its designated cold full level mark. This includes filling all heat exchangers, lines, and a dry engine.

3.19 CORE

The section of a heat exchanger assembly that is comprised of the heat transfer surfaces.

3.20 DEAERATION

The removal or purging of gases (air, combustion gas, or both) which have been entrained in the coolant.

3.21 DEAERATION BAFFLE

A barrier used to separate chambers in a top tank or auxiliary tank to form a deaerating tank. The purpose is to provide low coolant velocity and surface area where entrained air can buoyantly separate from the liquid without being reintroduced into the active cooling system. This reduces the susceptibility of the coolant pump to cavitation and maintains the coolant's ability to transfer heat from the engine.

3.22 DEAERATION CAPABILITY

The ability of the cooling system to deaerate the coolant expressed in terms of time, volume flow rate, or both, under specified test procedures.

3.23 DEAERATING TANK

A specially designed tank capable of removing entrained air, combustion gas, or both, from the circulating coolant.

3.24 DEGAS SYSTEM

A subsystem that consists of a pressurized deaerating tank, cooling system cap, and the hoses that connect the tank to the cooling system. The degas system provides a volume for expansion of the coolant as it is heated, as well as a means of deaerating the coolant.

3.25 DRAWDOWN

The volume (liters or quarts) of coolant which can be lost before impairing the cooling system performance at grade cooling level, by initiating pump cavitation and loss of pump rise, under normal operating conditions. Drawdown is often expressed in the volume of coolant below the add mark where pump rise is a specified percentage below its normal pressure rise with a full system at a temperature below thermostat opening temperature.

3.26 EXPANSION VOLUME

The volume of space in a cooling system (such as in the radiator top tank or auxiliary tank) that allows for the expansion of coolant resulting from temperature rise.

3.27 FAN AIR FLOW

The rate of air flow (m^3/s or ft^3/min) that a fan can deliver at standard air temperature and pressure at a given static pressure rise (also called air system resistance) (kPa or inches water gauge) and rotating speed (rpm).

3.28 FAN PROJECTION

The fan's penetration into the shroud. Projection is defined as the fan's projected width which lies upstream of the shroud as a percentage of the total fan projected width in the case of a knife edge fan shroud.

3.29 FACE AREA

The core area (m^2 or ft^2) defined by the radiator width times height through which the air flow passes.

3.30 FACE VELOCITY

The velocity of air approaching the heat exchanger core (m/s or ft/min). Face velocity is used for determining the core's heat transfer performance and must be stated at standard temperature and pressure (STP), called standard face velocity. This is because the radiator supplier's performance is provided as a function of coolant flow and face velocity at STP.

3.31 FAN DRIVE

A set of components between the engine and fan hub which causes the fan to rotate. Drive types include:

a. Belt drive with fan speed proportional to engine speed

b. Belt drive with a clutch attached between the driven pulley and fan hub

c. Hydraulic pump and motor

d. Electric motor

3.32 FAN DRIVE - TEMPERATURE CONTROLLED

A fan drive which can be turned on or off or whose speed can be modulated in accord with an input signal (i.e., can be passive operation based on temperature conditions of the circulated air, actively commanded on such as a call for air conditioning operation or other fluid temperatures requiring cooling). The purpose of the drive is to operate the fan as required for cooling, but when cooling demands permit, allows the fan speed to be reduced or the fan to freewheel to reduce fan input power and noise. Viscous clutches control fan speed by controlling the flow of viscous fluid within the shear area (labyrinth). Some fan drives are magnetic or pneumatic on/off devices whose function is controlled by either the engine or other controller. There are various types of variable speed drives independent of engine speed that can use inputs such as coolant temperature, A/C refrigerant pressure, ambient air temperature, vehicle speed, transmission oil temperature and/or gear state, charge air cooler (CAC) inlet or outlet temperature, turbo boost pressure, or others to determine the input to the variable speed fan drive. Types of fan drives include:

a. Dry clutch

b. Wet clutch

c. Viscous shear coupling

d. Dump and fill

e. Hydraulic pump and motor

f. Electric motor

3.33 FAN DRIVE - TORQUE LIMITING

A fan drive system which limits the maximum fan speed when the fan's power absorption exceeds the drive's torque transfer ability. A means of torque limiting is accomplished with a hydraulic drive utilizing fixed displacement pump and motor, with a pressure-relief valve at the motor. Since motor displacement times pressure is converted into torque, and fan input torque is proportional to the square of speed, maximum fan speed is clipped when the required pressure reaches relief pressure. The same holds true for an electrically driven system when the required power exceeds the fan motor size for a given speed, or the torque limit is reached on a conventional viscous clutch drive system.

3.34 FILL RATE, MAXIMUM

The coolant flow rate (L/s or gal/min) that an empty cooling system will accept up to the full mark without overflowing.

3.35 FLOW RATE, CHARGE AIR

The rate of flow of high-temperature compressed air from a turbocharger compressor under specified operating conditions, expressed as either volumetric flow rate (L/s or ft^3/min) or mass flow rate (kg/s or lb/min).

3.36 FLOW RATE, COOLANT

The rate of flow of coolant through a cooling system component or group of components under specified conditions, expressed as either volumetric flow rate (L/s or gal/min) or mass flow rate (kg/s or lb/min).

3.37 FLOW RATE, LIQUID

The flow rate of non-coolant liquid through a cooling system or group of components under specified conditions expressed as either volumetric flow rate (L/s or gal/min) or as mass flow rate (kg/s or lb/min). Examples are engine oil, transmission oil, hydraulic oil, brake oil, etc. These fluids may be cooled by engine coolant in coolant-liquid heat exchangers, or by fan air flow, in the case of liquid-air coolers.

3.38 FREE FLOW

Water flow rate expressed as volume flow rate (L/s or gal/min), at a specified water temperature, through a radiator tested in its installed position while maintaining water at atmospheric pressure at seat of pressure cap (or pressure-relief valve) for a downflow radiator, or at highest point on inlet tank for a crossflow radiator. This rate is used for manufacturing quality control purposes and for checking radiators that have been in service which may be clogged internally.

3.39 GRADE COOLING LEVEL

The cooling differential or air-to-boil value obtained while maintaining a specified speed of ascent on a steep and lengthy grade.

3.40 HEAT DISSIPATION

The heat transfer rate (kW or Btu/min) that a component dissipates under specified conditions of hot and cold side mass flow rates and temperature differential.

3.41 HIGH AMBIENT COOLING PACKAGE

The standard product equipped with a cooling system will be advertised to operate up to a maximum ambient temperature without overheating or reliability problems. The standard design will assume an ambient air temperature and altitude. A low percentage of product sales may be sold in higher ambient temperatures, higher altitude, or more severe operating conditions where the standard cooling package will run hotter. Rather than adding the cost of a cooling system on the standard product to meet these more demanding conditions, a higher capacity cooling package may be offered as an option and priced accordingly. In the automotive case, this may be called a “Heavy Duty Cooling Package.” In the case of off-highway equipment, it may be called a “High Ambient Cooling Package.”

3.42 HIGH TEMPERATURE COOLANT CIRCUIT

A high temperature coolant circuit is generally a jacket water circuit cooling the core of the engine and other heat exchangers in that circuit.

3.43 IDLE TIME TO BOIL

The time required to boil the coolant while idling following other specified conditions.

3.44 INLET RESTRICTION (COOLANT PUMP)

The difference between the pressure (Pa or inches of water) of the coolant at the pump inlet under no flow conditions, and the pressure under full flow conditions with the thermostat blocked fully open. Inlet restriction values are given with the cooling system cap removed.

3.45 INLET TANK TEMPERATURE

The temperature (°C or °F) of coolant entering the radiator inlet.

3.46 INLET TEMPERATURE DIFFERENTIAL (ITD)

The inlet temperature difference (°C or °F) between the hot and cold fluids entering a heat exchanger.

3.47 LIMITING AMBIENT TEMPERATURE (LAT)

The ambient air temperature at which the engine coolant outlet temperature reaches the maximum allowable design temperature (see 3.7).

LAT = Maximum engine coolant outlet temperature - engine coolant outlet temperature + ambient air temperature.

3.48 LOGARITHMIC MEAN TEMPERATURE DIFFERENCE (LMTD)

The logarithmic mean temperature difference between the two fluids, where:

LMTD = (ΔT at inlet - ΔT at outlet)/(ln ΔT at inlet - ln ΔT at outlet)

3.49 LOW FLOW COOLING SYSTEM

A cooling system which under normal conditions operates at a coolant flow through the radiator of significantly less than full engine coolant flow rate. This increases the ΔT of the coolant across the radiator, which can permit a reduction in radiator size, and also provides a low temperature coolant circuit to beneficially cool other liquid-cooled heat exchangers in the engine cooling system, such as a CAC (see 3.50).

3.50 LOW TEMPERATURE COOLANT CIRCUIT

A low temperature coolant circuit simply means that the heat sources require coolant temperatures colder than values available in the high temperature circuit. So, the lower temperature circuit is created by a low flow cooling system, splitting some of a single pump flow to a separate heat exchanger with lower air-core temperature, or adding a second pump with flow dedicated to the lower temperature core. Examples of components that require low temperature circuit flow include CACs; hydrostatic propulsion; and motors, generators, and alternators in the propulsion system.

3.51 MULTI-PASS HEAT EXCHANGER

A heat exchanger that is configured so that either fluid passes across or through the core more than once in a counterflow, parallel flow, or crossflow direction to the other fluid.

3.52 OPEN RADIATOR TANK

A radiator tank that is open to atmospheric pressure.

3.53 OUTLET TANK TEMPERATURE

The temperature (°C or °F) of the coolant leaving the radiator outlet. This would include any temperature gain or loss from any device located in the radiator outlet tank.

3.54 OVERFLOW BOTTLE

See 3.11.

3.55 OVERHEATING

An operating condition where coolant, other liquid, or a component exceeds its design temperature limit. This may be caused by a deficiency in the cooling system or by operating conditions that exceed the design point conditions of the cooling system.

3.56 PRESSURE DROP

The difference in pressures (Pa, inches of water, or psi) measured between the inlet and outlet of a heat exchanger or any other component in the cooling circuit at a given flow rate through that component.

3.57 PRESSURE-RELEASE MECHANISM

A device that, when activated, allows the pressure in a cooling system to be released; synonymous with pressure-relief valve. In the case of the radiator cap, the pressure relief is intended to protect the entire engine cooling system from exceeding a specified pressure. Bypass-relief valves between the inlet and outlet of individual heat exchangers, particularly on the oil side of a liquid-liquid heat exchanger (engine, transmission, etc.), allow flow to bypass the heat exchanger and prevent structural damage or outside leakage in conditions where the oil is cold and viscosity high.

3.58 PUMP CAVITATION

The formation of coolant vapor bubbles in the pump's inlet cavity up to and on the impeller, which reduce the pump mass flow. Cavitation occurs when the local static pressure of the coolant drops below the vapor pressure of the coolant for a given local temperature. This usually occurs in areas of high coolant velocity where the increase in dynamic pressure results in an equivalent drop in static pressure.

3.59 PUMP CAVITATION PRESSURE

The static pressure (Pa or inches of water) of the coolant at the pump inlet at which the optimum pressure rise across the pump at a given speed, coolant temperature, and flow rate is reduced by a specified percentage (e.g., 10%). It is also defined as NPSHR (Net Positive Suction Head Required). The pressure requirement will vary based on pump design, operating speed, coolant temperature and physical properties, and pump inlet piping geometry.

3.60 PUMP CAVITATION TEMPERATURE

The temperature (°C or °F) of coolant at the pump inlet at which the optimum pressure rise across the pump at a given speed, pump inlet pressure, and flow rate is reduced by a specified percentage (e.g., 10%). The temperature requirement will vary based on pump design, operating speed, coolant temperature and physical properties, and pump inlet piping geometry.

3.61 PUSHER FAN

A cooling system configuration used in some automotive applications where an additional fan is positioned upstream of the heat exchanger(s) and downstream of the grille. This configuration is sometimes called a boost fan.

3.62 RADIATOR AIR RESTRICTION

The fan cooling air pressure drop (Pa or inches of water) across a radiator core at a specified rate of air flow and air density.

3.63 RADIATOR AIR BAFFLE

Various types of barriers used to enclose or direct air through the radiator to minimize air recirculation.

3.64 RADIATOR CAP

A cooling system cap that is located on the radiator. It seals coolant within the cooling system. It usually incorporates pressure relief and vacuum valves unless these functions are addressed by an auxiliary tank.

3.65 RADIATOR COOLING POTENTIAL

The temperature differential (°C or °F) between the air temperature entering the radiator and the average temperature of coolant in the radiator, usually under stabilized conditions. The average temperature is defined by the radiator inlet and outlet temperatures.

3.66 RADIATOR SHUTTERS

These devices are located ahead of or behind the heat exchangers and were used in the past to (a) speed warm-up of the engine coolant and/or (b) control coolant temperature by restricting or regulating air flow through the radiator. Shutters are typically actuated today by electric actuators (cars) or by hydraulic or pneumatic actuators (heavy-duty trucks and off-road equipment). The blockage of air flow is intended to prevent overcooling of the engine by heat loss off the surface of the engine and keep coolant temperature up for the heater circuit. This is especially useful in cold ambient conditions when the engine thermostat spends much of the operating time regulating coolant to fully bypass the radiator. More recently, shutters have been used to block air flow through the vehicle grille (and over the rough under hood and underbody surfaces) to improve fuel economy by reducing drag coefficient (C_D). For this function, the shutters are used, especially at highway speed, to limit the grille airflow to only the minimum that is required to satisfy the needs of various vehicle systems.

3.67 RADIATOR TANK BAFFLE

A partition or divider in a radiator tank to direct coolant to a particular section of that radiator.

3.68 RAM AIR FLOW

The amount of air passing through the radiator as a result of vehicle forward motion. On-highway vehicles commonly include ram air flow along with fan pressure rise-induced flow during high-load and high-speed operation design conditions.

3.69 ROTARY VALVES

Electrically actuated flow control valve that may act as a diverting or mixing thermostat or be used for more complex distribution of coolant among multiple branches.

3.70 SHUNT OR SURGE TANK

A shunt tank cooling system is used on most passenger car, light truck, and heavy-duty truck applications, and on many off-highway construction equipment machines. The shunt tank performs many of the functions of auxiliary tanks (see 3.11), such as receiving and recovering coolant expansion flow, locating system add and full marks, and deaeration. But unlike the other auxiliary tanks, the fill neck and pressure cap are also located on the top of the shunt tank. The unique feature of the shunt tank is that a small coolant line from the radiator top tank continually shunts a small amount of flow to the shunt tank. The flow leaves the tank through a large line and returns flow to the pump inlet. This type of system routing is also referred to as an “active degas” system. The shunt tank minimum fill line is ideally located above the top of the radiator. The purpose of the system is, with the low velocity flow in the large diameter shunt line to the pump, to maintain a positive pressure at the pump inlet equivalent to a column of coolant the height of the shunt tank above the pump inlet and improve cavitation performance of the pump. This is most beneficial when the radiator bottom tank is located at lower elevation than the pump inlet, or the radiator bottom tank to pump inlet line requires small diameter and/or sharp bends, resulting in increased inlet restriction.

3.71 SINGLE PASS HEAT EXCHANGER

A heat exchanger that is configured so that fluid passes across or through the core only once.

3.72 SPECIFIC HEAT REJECTION

The heat rejection of the engine expressed as a ratio of heat entering the fluid handling circuits (directly to the coolant, oil, and charge air) from the engine relative to flywheel brake power (kW/brake kW, hp/brake kW, hp/brake hp, or Btu/h/brake hp). It should be further defined at a given engine load, speed, and ambient air temperature.