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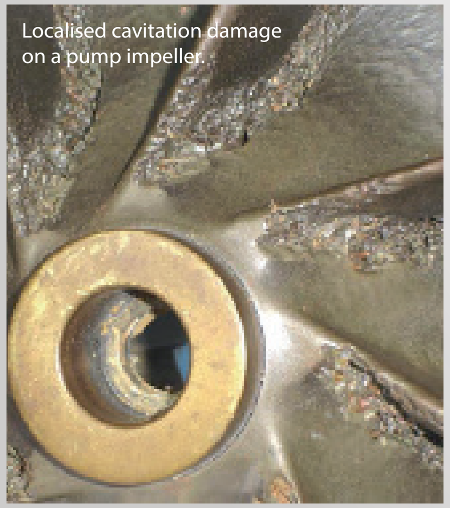
Keeping the cooling system cool

The table shows an energy balance for a commercial diesel engine based upon tests. The cooling system must absorb a whopping 38 per cent of the power flow coming from the fuel. So how can you check the condition of the cooling system? This article focuses on the coolant.

The cooling system should keep the diesel engine at an optimum temperature so that the engine achieves a long life and the fuel economy can be optimised. Under Australian long-distance conditions, the ideal operating temperature of the coolant returning from the engine is about 102°C. It gets cooled by the radiator. The oil will be hotter. When it returns to the sump the engine oil is probably 110°C+. It gets cooled by the sump and on some engine oil cooler bundles. The return fuel also plays its part by cooling the injectors. It is probably at 60-70°C coming out of the engine. It gets cooled by the fuel tank. If the engine has an EGR system, there may also be an EGR cooler that puts additional heat into the coolant.



Localised cavitation damage on a pump impeller.

Most of the cooling occurs in the radiator. There will be a thermostat in the radiator path to get the engine to working temperature quickly. The thermostat starts to open when the coolant temperature it experiences is in the range 80-90°C. There are two types of thermostats,' blockers' and 'bypass'. If the thermostat sticks open, then the engine will run cold when the engine operates under low power. The oil will be cold and more viscous, so the lubrication is substandard. The fuel burns slower and this results in oil and fuel deposits in the cylinders. The engine runs dirtier. In an extreme situation, the engine might bind. If the thermostat sticks closed, then the radiator is closed off and the engine will overheat. Thermostats are reliable but can fail when the truck has done more than 1,000,000km, so changing it is a preventative maintenance.

Coolant for heavy-duty diesel engines is typically a 50/50 solution of glycol with water. Glycol comes in two types, which are Ethylene Glycol and Propylene Glycol. These chemicals stop the coolant from freezing when the vehicle is parked during winter and boiling under high power conditions. Ethylene Glycol, which is the most common base for truck coolant, has good thermal properties so the heat can be efficiently transferred from the engine to the radiator. EG tastes bittersweet and causes inebriation. EG is toxic; it is also odourless. Wash coolant off if it gets spilt on you! EG will also burn as a powder if it is spilt on an exhaust pipe. The standard for coolant is Australian Standard AS2104:2004 and specifies two types, which are Type A (glycol + corrosion inhibitor) and Type B (corrosion inhibitor only). Ethylene Glycol coolant is usually died green-yellow but beware, colour is not a reliable indicator of the chemical type of coolant. Propylene Glycol is also used on Australian diesel engines. The best advice is to use a coolant type recommended by the engine manufacturer.

A typical diesel coolant has a boiling temperature of 128° C and a freezing temperature of -37° C. The pH is 8-9.

In Australia coolant is needed for the coolant system to operate at high temperatures and pressures. The cooling system is closed so pressure rises when the engine gets hot. Typically, the radiator cap will release pressure to protect the radiator at about 1 atmosphere gauge pressure (~100kPa). The cooling system is a ripe environment for metal corrosion.

Uniform corrosion is caused by chemical or electrochemical reaction that results in deterioration of the entire exposed metal. It can be caused by acid formation, combustion gas leaks, excessive flow velocities aeration or contamination.

Diesel coolant must contain corrosion inhibitors. They are called SCA (Supplemental Coolant Additives). SCAs get consumed and need to be topped up.

Pitting and Cavitation is caused by collapse of low-pressure bubbles due to mechanical forces or restriction of flow. The result is formulation of a small hole or cavity at one location in the metal.

Output Energy	% of Energy in Fuel	Power Out for 600 Net Engine Horsepower
Net mechanical flywheel power	29%	174 Hp (130 kW)
Coolant	38%	228 Hp (170 kW)
Exhaust gas	31%	186 Hp (139 kW)
Cooling air	1.8%	10.8 Hp (8.1 kW)
Return fuel	0.2%	1.2 Hp (0.9 kW)
Total Energy / Power	100%	600 Hp (447.4 kW)

Cavitation can be caused by mechanical vibration on a cylinder wall or cooling system temperature or pressure below design levels. Cylinder linings are vulnerable. Poor SCA concentration is a risk factor for cavitation. The photo shows cavitation corrosion of a pump impeller. Note how the cavitation damage is localised. Cylinder liners can be also attacked by stray electrical currents flowing through the coolant. Calcium and magnesium scale build-up inhibits heat transfer and chlorine in the water decarburises iron and softens it. Coolant is often supplied concentrated and needs to be mixed with water before use. Using chlorinated water introduces the chlorine additive, which is undesirable.

Crevice corrosion occurs at a place where there is a stagnant micro-environment such as under gaskets, washers or clamps. Acid conditions or a depletion of oxygen can lead to clevis corrosion. Galvanic corrosion occurs when two different metals are located together in a corrosive electrolyte. The anode metals deteriorate fast and the cathodic metal is protected. Galvanic corrosion should be avoided by correct design, but imbalanced coolant is a significant risk factor. Electrolysis occurs when stray electrical current flows through the coolant because of bad electrical connections in the grounding system. The cooling system is the likely path for stray current. Aluminium is the most likely target of electrolysis.

Additive and inhibitor packages are essential to suppress cavitation, scale build-up, rust and acid formation.

The key components are: Silicon is a corrosion inhibitor for aluminium. Phosphate is used for iron corrosion protection and pH control. Boron is also used with Phosphorous to protect the iron and keep the pH in the range 8-9. Molybdenum is used to protect solder, iron and aluminium surfaces. Nitrite is a key protection inhibitor as it forms a cavitation resistant layer on liner sleeves. Coolant analysis will report the Nitrite level with 800ppm a desirable number.

Heavy duty diesel engine cooling systems commonly have a coolant filter. This filters out particles of scale and imperfections. It is also loaded with corrosion inhibitor chemicals that are continuously absorbed as the coolant flows through to complement the SDA dosing. This is usually described as delivery of supplemental coolant extenders. There is a balance point with additives so it is sensible to follow the engine manufacturer's coolant specification. Otherwise there is a danger that the nitrate level in the coolant could be too high or too low, with adverse consequences for the liners in a wet cylinder system.

Glycol concentration can be measured using a refractometer, which is an optical instrument. A sample of the coolant is put into the refractometer and the reading is used with a conversion scale to measure the glycol concentration. It works for both Ethylene Glycol and Propylene Glycol. The instrument does not measure the SDA concentration. It is assumed that if the glycol level is adequate then so will be the SDA level. Coolant test strip kits are also useful for measuring the pH and the glycol concentration. A pH below 8 is a serious risk for metal corrosion in the cooling system. 8-9 is desirable.

Every workshop needs to be able to assess the quality of the coolant. The first step is visual inspection. Look for: Foam, as it hinders heat transfer and probably indicates the SCA level is low. Colour indicates whether there is iron contamination in the coolant. Use a colour chart to compare the coolant against a fresh sample. Oil and Fuel floating on the water can be an indication if a hole exists that is linking the oil path or fuel path with the coolant path. Urgent investigation is necessary as the engine is at risk. Suspended particles in a sample of the coolant should be resolved. Magnetic particles indicate corrosion attack of iron components is occurring. Non-magnetic particles may indicate the coolant dosing is incorrect. Suspended particles are associated with the risk of plugging of cooling system passages, which restricts heat transfer. Smell the coolant. It should not smell like ammonia, burnt, fuel, 'mechanical', or volatiles. The nose is a useful instrument for coolant analysis!

The cooling system is critical. Be critical of the coolant chemistry and contamination levels. Make observations, smell the coolant and use test strips to check acidity.

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