

Cavitation, SCAs and the Proper Maintenance of Diesel Engine Cooling Systems

Would you believe me if I were to tell you that the presence of a few tiny bubbles, some so small that you need a microscope to see them, could destroy a diesel engine? One problem that has been plaguing the owners of diesel rigs for years is cavitation.

Cavitation is the formation and collapse of air bubbles on the outside of the cylinder walls during combustion (does not apply to dry-liner engines). These air bubbles implode repeatedly against the surface of the liner and can cause erosion of the liner that may progress into the combustion chamber.

Cavitation is further aggravated by vibration of the cylinder liner. The movement of the piston causes the cylinder liner to vibrate at a high frequency. When the cylinder liner vibrates, bubbles are formed in the water passages next to the liner. These bubbles then implode against the cylinder liner. The implosion of the bubbles will ultimately form pinholes in the liner.

UNDERSTANDING CAVITATION

In elastic media such as air and in most solids, there is a continuous transition as a sound wave is transmitted. In non-elastic media such as water and in most liquids, there is continuous transition as long as the amplitude or "loudness" of the sound is relatively low. As amplitude is increased, however, the magnitude of the negative pressure in the areas of rarefaction (pockets of low pressure) eventually becomes sufficient to cause the liquid to fracture, causing a phenomenon known as cavitation.

Cavitation bubbles are created at sites of low pressure as the liquid fractures or tears because of the negative pressure of the sound waves in the liquid. As the wave fronts pass, the cavitation bubbles oscillate under the influence of positive pressure, eventually growing to an unstable size. Finally, the violent collapse of the cavitation bubbles results in implosions, which cause shock waves to be radiated from the sites of the collapse. The collapse and implosion of myriad cavitation bubbles throughout an ultrasonically activated liquid result in the effect commonly associated with ultrasonics. It has been calculated that temperatures in excess of 10,000°F and pressures in excess of 10,000 psi are generated at the implosion sites of cavitation bubbles.

EFFECTS ON ENGINE COMPONENTS

Air can enter the system through leaks or through a faulty radiator cap. This leakage reduces cooling system pressure and increases the potential for the formation of bubbles in the coolant. These bubbles will eventually cause an increase in pitting of the metal surface in the cooling system. Water pump impellers and the housing itself can be the victim of cavitation caused by low system pressure or by air trapped in the system. Radiators and heater cores can also be damaged by cavitation caused by the same condition(s).

PREVENTING CAVITATION

Since cavitation cannot be prevented entirely, the use of supplemental coolant additives (SCAs) is necessary to provide a continuous protective coating on the metal surfaces in the cooling system. This coating will aid in controlling and limiting the damage done to the engine as a result of cavitation.

The single most important procedure in controlling damage caused by cavitation is keeping the cooling system clean with periodic flushing. The use of clean water combined with flushing agents will scrub the system of impurities, scale or other build-up allowing for a "fresh start" with the introduction of the new anti-freeze/water mixture.

When servicing the cooling system, always check for leaks or faulty pressure caps. These conditions can cause air leakage into the cooling system, reduce system operating pressure and allow the formation of bubbles.

MORE ON SUPPLEMENTAL COOLANT ADDITIVES

Supplemental coolant additives (SCAs) expand the protection abilities of the coolant in terms of both time and amount. Over time, however, the concentration of SCAs will gradually deplete during normal engine operation. Although SCAs provide protection for the cooling system components, it's just as important that the coolant have them in proper concentration.

The proper application of SCAs will provide:

- PH control to prevent corrosion
- Water-softening to deter formation of mineral deposits
- Cavitation protection to reduce the effects of cavitation

Check the operator's manual for the diesel engine you are working on, as the proper dosages for initial cooling system fill and proper maintenance are required.

The concentration of SCAs will gradually deplete during normal engine operation. Check the SCA concentration during normal engine operation and at regular intervals. Additional SCAs must be added to the coolant when it becomes depleted below the specified level. Maintenance dosages of SCAs must only be added if nitrite concentration is less than 800 ppm. If nitrite concentration is greater than 800 ppm, do not add additional SCAs.

A nitrite concentration of 2400 ppm or greater on most diesels requires immediate draining and flushing of the cooling system. Refill the system with new coolant and the proper SCA dosage, and be sure and check the concentration level at the next maintenance interval.

Silicate Gelation

Sodium silicate is added to the antifreeze to protect the aluminium surfaces from corrosion and pitting. Silicate gelation is the tendency for silicate that is added to antifreeze to drop out of the solution and form a jelly like substance that will plug radiators, heaters, after coolers and other parts of the cooling system.

This drop out of silicate can be attributed to a combination of factors and cooling system interactions, including:

- Higher amounts of silicate and phosphate in coolant
- Hotter running engines
- After coolers
- Additive packages

When antifreeze is over concentrated with SCAs, the excess silicate will drop out of the coolant and form silicate gel on heat transfer surfaces. This results in reduced coolant flow and engine overheating. It is also possible for silicate to drop out at low coolant temperature and plug radiator tubes. The reduction of the sodium silicate in the coolant makes the solution evaporate in a shorter period of time.

Additionally, coolant that has evaporated due to the drop out of silicates will leave a white, caked, powder-like substance.

LONGER DIESEL ENGINE LIFE THROUGH PROPER COOLING SYSTEM MAINTENANCE

A schedule of periodic maintenance will provide for efficiency of the cooling system and extended engine life. Daily visual inspections of the coolant and the overall condition of the cooling system components should be performed. The items listed below should be checked for any signs of wear or damage, and if necessary, corrective action must be taken. Anytime a coolant gauge, warning, shutdown, or low level device is malfunctioning, it must be repaired immediately to factory specifications.

Water and Coolant Inhibitors

Water will produce a corrosive condition in the cooling system and the mineral content may permit scale deposits to form on the internal cooling systems surfaces. Chlorides, sulphates, magnesium and calcium make up the dissolved solids in water and may cause scale deposits, sludge or corrosion. Therefore, coolant inhibitors must be used to control corrosion and scale deposits.

Antifreeze Inhibited Ethylene Glycol (IEG)

Ethylene glycol is used for freeze protection of the coolant. IEG, commonly referred to as antifreeze, also contains chemicals that provide limited protection against corrosion. The use of an IEG product with a low silicate formulation that meets either the TMC RP 329 performance or ASTM D 4985 requirements is recommended for use in diesel engines.

Inhibited Propylene Glycol (IPG)

An IPG/water mixture also provides freeze protection. Propylene glycol is approved for use in the greatest majority of diesel engines. When working on a diesel engine, consult the engine operator's manual to see if PG antifreeze is approved for use. Propylene glycol must meet the performance requirements of TMC RP-330 and the physical/chemical requirements of ASTM D5216. The maintenance procedures for propylene glycol are the same as for IEG coolant.

For best overall performance, a 50% concentration of IEG (1/2 IEG, 1/2 water) is recommended. An IEG concentration over 67% (2/3 IEG, 1/3 water) is not recommended because of poor heat transfer, reduced freeze protection and possible silicate dropout. An IEG concentration below 33% (1/3 IEG, 2/3 water) offers little freeze or corrosion protection and should be avoided.

IEG and IPG coolants require the addition of SCAs to provide cooling system corrosion and deposit protection. The SCAs added should match the chemistry of the additive package included in the coolant. If this precaution is not observed, coolant monitoring can become difficult, making over-inhibiting more likely. IEG formulations available in the market may contain from zero to the full amount of the required SCAs. A basic IEG without SCAs must have additional SCAs added at the time of the initial fill. A "Fully Formulated" or "Precharged" IEG such as Detroit Diesel Power Cool(r) already contains the required SCAs. Over concentration will result if SCAs are added to a fully formulated IEG coolant at the time of initial fill. This can result in solids dropout and the formation of deposits.

Coolants Not Recommended

Methyl alcohol-based antifreeze should not be used in diesel engines because of its effect on the non-metallic components of the cooling system and its low boiling point.

Similarly, methoxy propanol-based antifreeze should not be used because it is not compatible with fluoro-elastomer seals found in the cooling system. Glycol-based coolants formulated for heating/ventilation/air conditioning (HVAC) should not be used in diesel engines. These coolants generally contain high levels of phosphates, which can deposit on hot internal engine surfaces and reduce heat transfer.

Proper cooling system maintenance combined with the correct or recommended antifreeze and SCA will provide protection for the internals of a diesel engine for thousands upon thousands of highway miles

