Caterpillar Inc.
Cat® Marine Power
Diesel fuel feature story
187-P-2-004-98

Special to Seaway Review

HEADLINE: **Fuel for Thought**

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Why is it that breakdowns associated with diesel engines often seem to be directly related to poor fuel and inadequate fuel system maintenance? The answer to that question requires a close look at diesel fuel itself and some of the measures you can and should take to avoid unnecessary delays on your next trip.

The Nature of Diesel Fuel

Fuel oils range from highly refined distillates (ASTM No. 1) to the heaviest residual fuel classified as ASTM No. 6. Caterpillar recommends ASTM No. 2 or an equivalently graded fuel to ensure optimum engine performance and fuel efficiency.

Using a fuel that falls outside the requirements of an ASTM No. 2 fuel can result in shortened component life, poor fuel efficiency or low power, to name just a few problems. However, there are things to consider when using the recommended No. 2 fuel:

Buyer Beware

When you fill your tank, the fuel you're pumping may have been handled numerous times during transportation and distribution. The more it's handled, the better the chance for it to become contaminated. Water is a common contaminant that can be introduced into the fuel during shipment, typically via condensation. If not removed, it will cause costly damage to a diesel engine's fuel system.

High and Low Sulfur Side Effects

In addition to water and sediment, diesel fuels contain some sulfur. Refineries will remove enough of it to meet ASTM standards or the "national" standards for the specific fuel grade before marketing it. However, if a diesel fuel with a "high" sulfur content is used, it can cause problems. Sulfur levels for marine diesel should be less than 0.5 percent. In some areas of the world, particularly Mexico and other South American regions, sulfur levels may be as high as 1.5 percent. Sulfur in fuel, when combined with water vapor formed during the combustion process, forms sulfuric acid. The result is corrosive wear on valve guides and cylinder liners, which could ultimately lead to a premature overhaul. The use of proper lubricants and correct oil drain intervals reduces the degree of corrosive damage. Using the proper lubricant depends on your engine's fuel injection system (See illustration 1). To help combat the effects of sulfur with a direct injection diesel engine, use an American Petroleum Institute (API) CF-4 or CG-4 class oil that has a minimum "total base number" (TBN) equal to ten times the fuel's sulfur level. TBN is a measure of an oil's ability to neutralize sulfur byproducts. For

older precombustion chamber diesel engines, use an API CF-4, CG-4 or CF class oil that has a minimum TBN equal to twenty times the fuel's sulfur level. Keep the normal operating temperature in your cooling system above 180 degrees F (74 degrees C). This will limit the condensation of sulfur compound vapors that are formed during the combustion process on cylinder liner walls and the associated corrosive damage.

If you don't know the fuel's sulfur content, use an oil with the highest TBN available of the correct API class. Consider using a reliable oil analysis service to define the oil drain interval.

Be aware that "low" sulfur fuel can also cause problems. The process refineries use to remove sulfur in ASTM No. 1 and 2 fuels also removes compounds that contribute to a fuel's lubricity. (Lubricity describes the ability of a fluid to minimize friction between, and damage to, moving parts.) The effects of lowered lubricity on a fuel system can be compared to running an engine without oil. Without proper lubricity, the steel in a fuel injector becomes very hot, causing the fuel injector plunger to weld itself to the barrel, seizing the injector. Caterpillar recognized this problem and now provides fuel lubricity specifications, as has the International Standards Organization (ISO). (See attached sidebar for specifics.)

There are many additives available to increase fuel lubricity. However, not all additives perform well in all fuels or fuel systems. Some lubricity improvers may form deposits in the fuel injection system, so ask your fuel supplier for the proper additive recommendation.

Easy Starting

When purchasing fuel, you should also be aware of cetane ratings. The cetane number is a measure of diesel fuel ignition quality -- how easily the fuel will ignite under pressure -- which affects engine starting and acceleration. Check your engine manufacturer's recommendation, but usually diesel fuel should have a minimum cetane rating of 40 for direct injection diesel engines and 35 for precombustion (old) diesel engines. Fuel with cetane ratings below that recommendation contribute to harder starting, ignition delay, power loss and decreased fuel economy. Using a cetane improver additive, when required, can improve ignition and reduce white smoke during cold weather startups.

Go With the Flow

Another important fuel characteristic is viscosity, a measure of a diesel fuel's resistance to flow. Fuel with either too high or too low viscosity can cause system damage. The main concern with lighter fuels is low viscosity, and whether they provide adequate lubrication to plungers, barrels and injectors. Fuel, as delivered to the injection pump or unit injectors, should have a kinematic viscosity between 1.4 centistokes (cSt) and 20 cSt. Your fuel supplier can provide the typical kinematic viscosity of the fuel they supply.

Waxing Woes

Other important diesel fuel characteristics are cloud and pour points. Cloud point is the temperature at which fuel turns hazy or cloudy. When the temperature drops to a fuel's cloud point, paraffin waxes that occur naturally in fuel crystallize and cling together. This is known as "waxing" which plugs filters and stops fuel flow to the engine. The pour point of a fuel is typically 5 degrees F above the temperature at which the fuel fails to flow or turns solid. Those working in cold climates can prevent waxing by using fuel with a low cloud point or by providing some source of heat to the tanks. Lower cloud point fuels can better handle colder temperatures without waxing than those with a higher cloud point. Or, consider using a cloud point improver, which separates the clinging wax particles so they can pass through the filters. If you plan to go from a warm climate (where waxing isn't an issue), to a cold climate, consider installing a heater on your tank. Or, use a "wintergrade" fuel blended by the supplier for cold weather operation. You can also make your own winter blend by mixing a No. 1D fuel with low cloud point with a No. 2D fuel. A 50/50 blend covers most areas, unless you operate in extreme cold. In northern climates, some fuel marketers only handle "winterized" diesel fuel during late fall and winter.

In the Tank

The best way to make sure you're getting good fuel is to be informed. Ask other boat owners about their experiences. Choose a reliable fuel supplier, not necessarily based on lowest price. Your fuel supplier should be able to tell you how much water,

sediment and sulfur is in the fuel -- at least as delivered to him by his supplier. Make sure the amounts are no more than the maximums recommended by your engine manufacturer. If they exceed the limits, avoid them. But, you're not out of the woods yet because once it's in your tank, even top quality fuel can be subject to demise when condensation, sediment and microorganisms invade your fuel tank.

Water Contamination

Water can get into your fuel if it's mishandled by your fuel supplier. Most often, however, water gets into fuel tanks by condensation from the atmosphere. As the tank empties, air enters the tank. Water condenses on the walls and runs down the sides. The water never evaporates because it's heavier than fuel and goes to the bottom of the tank. After this process is repeated several times you may have a significant amount of water in the bottom of your tank.

Water in your fuel can cause injector seizures and failures at sea. It also accelerates wear of expensive fuel system components. Add salt spray and wear increases rapidly.

Water separators are critical to fuel treatment and should be used on all marine diesel installations. Operators of large vessels often install centrifuges which continuously recycle the fuel to remove water and sediment.

Sediment

Sediment consists of items like rust, scale, weld slag, dirt and other debris that can often get into fuel tanks. As sediment levels increase, fuel filters clog and deposits form, resulting in reduced power and excessive fuel system wear if not trapped by the fuel filter.

All marine installations should combat water and sediment contamination with a fuel filter/water separator. This device is usually installed between the fuel tanks and the engine fuel system inlet connection and contains a coalescer and separator. The coalescer filters 5-micron (large) pieces of sediment, algae and gums, while the separator separates the water from the fuel and drains it into a water collection bowl. Some fuel filter/water separators include a feature that can activate an alarm when the water reaches a maximum level.

Microorganisms

Water and fuel offer a habitat for bacteria, algae and other organisms. Because water is heavier than fuel, it settles at the bottom of the tank. The organisms live in the water and actually feed off the fuel. Bacteria is generally black, brown or green, grows in long strings and has a slimy appearance. As they reproduce, masses of bacteria and their excrement clog filters, cause corrosion and impose costly repairs on a diesel engine's fuel system -- if not stopped by the engine's fuel filters.

You can check for bacterial contamination by using commercially available test kits. Ask your local fuel supplier for recommendations concerning test kits and biocides. Biocides are chemical additives that kill microorganisms. As the organisms die, they fall

into the fuel stream and plug the fuel filters, so be prepared to replace the filters regularly. Eventually, the microorganisms may develop resistance to the biocide, which means you'll need to switch to a different brand. The best way to prevent microorganisms from growing in the fuel tank is to limit storage periods and keep your tank as water-free as possible.

Contacting the Pros

If your fuel filters become plugged one operating day after changing them, you have a problem that needs expert attention before serious fuel system or engine problems occur. In this case, contact a fuel treatment specialist who will clean out the tank by "recycling" your fuel.

Fuel recycling is done with a portable filtering device. Generally, one end of an electrical or air pressurized pump will be inserted into the fuel tank. The contaminated fuel is drawn into the recycling device and filtered to remove solid impurities, then routed back into the fuel tank. At the same time, any excess water is separated from the fuel. A healthy dose of additives usually follows to help treat microorganisms, enhance engine combustion and eliminate any hint of moisture. The process is repeated until the fuel filters no longer clog prematurely and no water collects in the reservoir. Boats with limited access tanks are a challenge for the fuel experts. But as long as fuel tanks are accessible, the fuel tank can be cleaned.

Poor quality and contaminated fuels are the culprits of many fuel system and engine-related problems. But they can be avoided if you follow some simple preventive

maintenance procedures, such as limiting water in the tank and filtering your fuel. A clean fuel tank is the first step toward a trouble-free trip.

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187-P-2-004-98 (articles/swy.doc)

Illustration 1

Engine Type	API Oil Class		
	CF-4	**CG-4**	**CF**
Direct-Injection Engine	Minimum TBN: 10 times fuel's sulfur level	Minimum TBN: 10 times fuel's sulfur level	(Not recommended)
Precombustion-Chamber Engine	Minimum TBN: 20 times fuel's sulfur level	Minimum TBN: 20 times fuel's sulfur level	Minimum TBN: 20 times fuel's sulfur level

Sidebar

Lubricity Specifications

There are three recognized lubricity bench tests available:

- High Frequency Reciprocating Rig (HFRR)
- Scuffing Load Ball On Cylinder Evaluator (SLBOCE)
- Modified ASTM D5001 Scuffing Bocle (SBOCLE)

The International Standards Organization (ISO) has recently approved a fuel lubricity specification. ISO specifies fuel lubricity using the HFRR test, operated at 60°C (140°F). Fuel test results must meet a maximum wear scar of .45 mm (.018 in.). The Engine Manufactures Association (EMA) has included a preferred diesel fuel lubricity specification. The new EMA FQP1 Fuel Specification measures fuel lubricity by the proposed ASTM SBOCLE test. The FQP1 Specification must meet the 3100 g minimum limit. Alternately, the HFRR test at 60°C (140°F) may be used with a .45 mm (.018 in.) maximum wear scar limit or 25°C (77°F) .38 mm (.015 in.) maximum wear scar limit.