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Maintaining Diesel Engines for Reliable Operation

Risk Solutions

Hartford Steam Boiler
One State Street
P.O. Box 5024
Hartford, CT 06102-5024
Tel: (800) 472-1866
www.hsb.com

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Background

Whether used for continuous or intermittent service, diesel engines require maintenance if they are to perform as intended. This guide is intended for reference for ***high and medium speed diesel engines*** using 1-D and/or 2-D diesel fuel, and sets forth some important points to be observed.

Fuel and fuel system

Diesel engines can burn a wide range of fuels, depending on their design. Fuels specifically formulated for diesel engine use are commonly referred to as Number 1 (ASTM D975 No. 1D), and Number 2 (ASTM D975 No. 2D). Larger engines are also fitted with fuel systems for burning heavier products, referred to as heavy fuels. Regardless of classification, there are certain properties of the fuel which are important to the user of the engine.

Over the life of an engine, fuel represents about 75 perecent of the total operating cost. Moreover, if fuel quality is not maintained, it can cause premature engine failure or decreased performance. The suitability and condition of fuel for diesel engines is frequently overlooked as a maintenance item. There are several important aspects to be checked:

1. Know Your Fuel Quality

Engine performance specifications for diesel engines are based on a specific fuel type (basis fuel). The grades commonly available for use in medium and high speed diesels are shown in the table below. When considering engine output, it is always necessary to know the properties of the fuel being burned and how it compares to the basis fuel named in the performance specifications.

Fuel Grade	API Gravity	Heating Value (BTU/lb)
1-D	40-44	18,510-19,860
2-D	33-37	18,335-19,650

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In addition to the performance consequences of using an off-specification fuel, there are mechanical risks. Lighter fuels may reduce the life expectancy of fuel system components because its low viscosity will reduce lubricity. Heavier fuel can reduce the life of cylinder liners and rings due to increased combustion chamber deposits.

If it is necessary to correct the density of fuel, it must be done by blending existing stock with a heavier/lighter grade to achieve the desired characteristic. ***NEVER*** reduce fuel with alcohols or gasoline, and ***NEVER*** add gasoline or alcohol to diesel fuel **for any reason**. Damage to the fuel injection system will occur. Furthermore, such a mixture can create an explosive mixture (gasoline) in the tank or will result in stratification (alcohols).

Other important characteristics of all diesel fuels are:

- **Cloud Point:** The temperature at which a cloud or haze appears in the fuel. This is caused by solidification of paraffins in the fuel, and these solids can cause fuel filter plugging. Engine operation at or below the cloud point may be seriously affected by inadequate fuel flow because of filter blockage. If such operation is anticipated, fuel heaters should be installed. Dilution of the fuel with kerosene or addition of a flow improving additive (wax crystal modifiers) can also help.
  · If the fuel's cloud point is at least 10° F below the ambient temperature, engine performance will generally be satisfactory.
  · Grade 2D, has a cloud point of 10°F (-12°C), while the lighter grade 1D has a cloud point of -20°F.
- **Pour Point:** The temperature 5° F warmer than that at which the fuel will flow. Reliable operation of diesel engines requires a pour point at or below ambient. Dilution of the fuel with kerosene or addition of a flow improving additive (wax crystal modifiers) can also help. The pour point averages about 10º F lower than the cloud point.
- **Water Content:** Water in excess of .05 percent by volume (this water content is permitted in both type 1-D and 2-D fuels) is a contaminant in diesel fuel. Water separation by sedimentation or by a coalescing filter must be adequate to remove water from the fuel ***before it reaches the fuel injection pump.*** *Water concentrations in excess of .05% by volume will cause damage to the fuel injection system.* The presence of water in the diesel fuel can also promote bacterial growth, which is a serious hazard to the fuel filtration system. It is recommended that all diesel fuel be treated with a biocide . Consult your engine manufacturer for approved products.

2. Age of Fuel

Diesel fuel is more prone to oxidation than gasoline. It must never be kept in storage for more than 12 months. Arrangements should be in place to either consume the fuel or rotate it to oil burner stock.

3. Cetane number

This index ranks fuel as to its ability to ignite from pressure and heat. Low cetane number fuels will suffer from delayed ignition, increased exhaust emissions, and can cause starting difficulty and engine knock. Engine damage can result. White smoke and odor during cold weather starts indicate low cetane fuel.

A guideline for **minimum cetane index is 40** for all engines. Although some pre-combustion chamber engines will run on cetane index 35 fuel, a cetane index of greater than 40 is a good rule to observe for any diesel engine. Always follow the recommendations of the engine manufacturer.

Cetane improvers are available for supplementing existing stocks.

NOTE: Some engine manufacturers prohibit the use of fuel additives for the purpose of increasing cetane number alone.

4. Cleanliness

Diesel fuel injection systems depend on small flow passages and very close clearances. They cannot tolerate impurities in the fuel. This means that the fuel filters must be maintained per the manufacturers published schedule or more frequently if the condition of fuel stocks require it. All filters must be at least of the same quality as original equipment.

Air filters are equally important to the longevity of an engine. They serve to trap abrasives before they can enter the engine combustion chambers. Lack of proper air filtration will cause rapid wear of rings, pistons, and liners. Change air filters at least as often as the manufacturer recommends, and use a replacement filter of at least original equipment quality. If unusually dusty conditions prevail, air filters may require more frequent replacement or cleaning.

Coolant and cooling system

The cooling system of a diesel engine must be capable of continuously removing about 30% of the heat released by combustion of its fuel without overheating. Assuming a reasonably clean cooling system, this is usually not a problem. In addition to coolant level, there are several items which should be checked:

Coolant Level

Coolant level is critical to proper operation of a cooling system. If coolant level falls to the point where air is drawn into the cooling jackets, cooling capacity will be reduced, and serious mechanical damage, including cavitation corrosion, will result. ***Always check coolant level.***

Coolant Composition

Engine coolant is generally a mixture of ethylene or propylene glycol base antifreeze and water. The freezing point of the mixture will depend on the relative amount of glycol used. It is important to use the best available water ***blended with not more than 60% ethylene glycol base antifreeze or 50 percent propylene glycol base antifreeze.***

It is equally important never to use water alone as an engine coolant. *(Water is corrosive at engine operating temperatures.)* Measuring the freeze Point and chemical protection in your engine's cooling system is essential for protection against liner pitting, corrosion and coolant dilution. Coolant and water qualities can be test with available test strips and the use of a refractometer.

Water quality is important. The following table shows the recommended minimum acceptable characteristics for cooling system water, according to one manufacturer (Caterpillar Inc.):

Minimum Water Quality for Coolant Use:

Properties	Limits	ASTM Test Methods
Chloride (Cl) gr/gal (ppm)	2.4 (40) max	D512B, D512d, D4327
Sulfate (SO4) gr/gal (ppm)	5.9 (100) max	D516b, D516d, D4327
Total Hardness,gr/gal (ppm)	10 (170) max	D1126b
Total Solids, gr/gal (ppm)	20 (340) max	D1888a
pH	5.5 - 9.0	D1293

Recommended additives and inhibitors

Engine manufacturers will usually provide detailed guidance as to additives necessary to prevent corrosion or to provide supplemental lubrication of cooling system components. It is very important that the recommended concentrations of these not be exceeded. High concentrations can cause precipitation of solids, and can cause damage to seals and other internal parts. On the other hand, low concentration of coolant additives can cause cavitation pitting on the water side of the cylinder liners.

Sometimes, engine manufacturers will supply special filters which dispense additives into the coolant (controlled release filters). If an engine is fitted with these filters, then it is very important that additional additives NOT be separately added to the coolant. Conversely, if chemistry is controlled by specific additives then controlled release filters must NOT be used.

Cooling System Integrity

No check of the cooling system is complete unless it is reasonably apparent that the system is tight and free of air. Introduction of air into a cooling system for whatever reason is a serious matter. This can cause internal cavitation and spot corrosion in the water jackets, especially on higher temperature parts, such as the cylinder sleeves.

Particular attention should be paid to engines having silicone hose packages as the hoses may not always successfully adhere to the engine connections. Only constant tension spring clamps should be used to attach these hoses and their integrity should be routinely checked

If there is any doubt about system integrity, the engine manufacturer should be consulted, and further tests should be performed until such doubt is resolved.

Lubrication

Engine lubrication is perhaps the single most important element of a good maintenance program. Engine oil lubricates moving parts, provides corrosion

protection, absorbs and neutralizes contaminants, and serves as a coolant and a sealant. Through regular oil and filter changes (or cleaning of centrifugal oil filters, if equipped), the oil removes foreign matter from the engine, contributing to internal cleanliness and minimizing engine wear.

Engine lubricating oils are prepared from either petroleum or synthetic stocks, and are formulated with a number of additives which provide or modify certain characteristics of the base oil stock. Among these are detergents, alkalinity agents, oxidation inhibitors, dispersants, and anti-wear agents. These additives give the engine oil its desirable qualities.

Re-refined oils are acceptable provided that the oil meets the SAE viscosity and API specifications for new oils.

1. Selecting an Engine Oil – Classification

Perhaps no other property of engine lubricating oil properties causes more confusion that the classification systems promulgated by the American Petroleum Institute (API) and some European agencies. To avoid that confusion, one needs only consult the recommendations of the engine manufacturer and be aware that only a few of these classifications will apply to any given engine.

The API system of oil classification breaks into two broad classes; Service Station oils (API Class SA-SN as of this writing), and Commercial oils (API Class CA-CJ-4 at this writing). For the purposes of this discussion, it is assumed that only diesel engines are considered, and therefore, the service station oils intended for use in gasoline powered automobile type engines will not apply.

The current API Commercial Engine Oil Classifications are:

Service Category	Brief Description
CD-2	Severe Duty for 2 stroke diesel engine service, controls wear and deposits.
CE	Service for turbocharged heavy-duty diesel engine use. Can be a replacement for former CD class oils.
CF	Upgraded over API CD for high sulfur fuels. Replaces API CD.
CF-2	Upgrade over API CD-II for two stroke diesel engines. Replacing API CD-II
CF-4	1990 diesel engine service for high speed, four stroke diesel engine service. Exceeds requirements for API CE category.
CG-4	1995 diesel engine service for engine wear and deposit issues linked to fuel specs. and engine design features required to accommodate 1994 EPA regulations for low sulfur (0.05%) fuel.

CJ-4	Introduced in 2006 for high-speed four-stroke engines. Designed to meet 2007 on-highway exhaust emission standards. CJ-4 oils are compounded for use in all applications with diesel fuels ranging in sulphur content up to 500ppm (0.05% by weight).

It is important to note that any manufacturer may describe its products according to these classifications, but only licensed companies may use the API "doughnut " symbol on their packaging, Such licensees have been required to certify that their products meet the technical performance standards for each API service category.

2. Selecting an Engine Oil - Viscosity

Viscosity is the property of oil which resists flow. It is this property of the oil which provides it with the ability to form a load bearing film on adjacent moving parts. The greater the viscosity of the oil, the greater will be its film strength and ability to carry a pressure load. Unfortunately, that same higher viscosity will impede the flow of oil within oil piping and passages, and so viscosity needs to be chosen with these competing needs in mind. This selection is further complicated by the fact that for most oils, viscosity changes with temperature, and operation in warmer weather will require greater viscosity.

Fortunately, engine manufacturers are usually very thorough in their recommendations as to lubricating oil viscosity, and will usually have a recommendation to meet any condition. ***Follow their instructions.***

Engine oil testing

Engines which represent a significant investment and which perform critical functions should be on a program of regular oil testing. Test results will confirm the condition of the lubricating oil charge and will provide important information on the internal condition of engine as well.

Oil analysis can detect contaminants such as diesel fuel, soot, coolant, salt, airborne sand, dirt or dust, and, trace wear metals from internal components. **We recommend oil analysis as part of every Preventive Maintenance (PM) program for diesel engines.** Oil testing should include the following analyses:

1. Chemical and physical testing to determine presence of contaminants (water, fuel, antifreeze, etc.)

2. Wear analysis to identify metallic wear components in the oil.

3. Oil condition analysis to quantify soot, sulfur, nitration, and oxidation products in the oil.

4. Total Base Number

Total Base Number is an index of the sulfur by-product neutralization capacity of the engine oil. Since virtually all diesel fuels contain some sulfur, and since engine oils contain additives intended to neutralize the sulfur compounds produced by combustion, this index provides a convenient way of judging the extent to which that neutralization capacity has been reduced.

5. Ash of Sulfated Ash Content

Virtually all oils will leave a non-combustible residue if burned. That incombustible residue, if excessive, can build up in some high temperature areas within the engine, and they can be troublesome. The engine manufacturer will usually have good advice to offer regarding maximum ash in engine oils, and their recommendations should be followed.

Oil Condition is Important...If in Doubt, Change the Oil and Filter!