DIESEL FUEL - PERFORMANCE DETERMINING FACTORS

Diesel Fuels Compression-ignition engines run on middle-distillate fuels with boiling ranges higher than that of gasoline but lower than that of lubricating oil base stocks. The most stable diesel fuels are "straight run" stocks derived from simple distillation of crude oil; however, many commercial fuels contain a portion of catalytically cracked material. The most important properties of diesel fuels are volatility, heating value, ignition quality or cetane number, viscosity, low temperature flow, sulfur content, lubricity, deposit control, storage stability and component compatibility

Volatility
The volatility of a diesel fuel has little influence on engine performance, except as it affects exhaust smoking tendencies. The distillation range of a diesel fuel does not allow much flexibility in this regard because of the interrelationship and interdependence with other specification factors. The controlling factor is the ASTM D 86 distillation 90% evaporated temperature, or T90. Because diesel fuels are classified as nonflammable for freight purposes, minimum flash point restrictions are imposed.

Heating Value
Fleet operators, railroad and shipping companies are concerned about fuel economy. Provided other specifications are met, these companies prefer to use the fuel with the greatest heating value. Fuel density and mid-boiling point have been correlated with fuel heating value.

Ignition Quality or Cetane Number
This factor influences ease of starting, duration of white smoking after start-up, drivability before warm-up and intensity of diesel knock at idle. Studies have correlated ignition quality with all regulated emissions. As ignition delay is reduced, the combustion process starts earlier and emissions (primarily carbon monoxide and hydrocarbons) are reduced.

Ignition delay is measured by the Cetane Number (CN) test (ASTM D 613), which uses a single-cylinder, variable compression ratio engine analogous to the Octane Number engine. In this case, the ignition delay of the test fuel is measured at a fixed compression ratio. This result is compared with the results from standard reference fuels consisting of blends of n-cetane and heptamethylnonane.

Few laboratories are equipped with cetane rating engines, so a number of correlations between Cetane Number and physical properties have been developed. The ASTM D 976 method for Calculated Cetane Index uses the density and mid-boiling point of the fuel. This method can provide an accurate prediction of the ignition quality of the fuel; however, Cetane Index does not take into account the benefits of cetane improving additives. Cetane improving additives, usually organic nitrates, can boost the cetane number of a fuel and the fuel's performance in engines.

Diesel engines vary widely in their cetane requirements, and there is no commonly recognized way to measure this value. In general, the lower an engine's operating speed, the lower the CN of the fuel it can use. Large marine engines can tolerate fuels with CNs as low as 20, while some manufacturers of high-speed passenger car diesel engines specify 55 CN fuel.

Viscosity
Viscosity influences the spray pattern when the fuel is injected into the cylinder. Low-speed marine engines can use higher viscosity fuels than high-speed road transport engines and still run without excessive smoking. Minimum viscosity limits are imposed to prevent the fuel from causing wear in the fuel injection pump.

Low Temperature Flow
Unlike gasoline, which has a freezing point well below even the most severe winter conditions, diesel fuels have pour points and cloud points well within the range of temperatures at which they might be used. This can present a problem in many applications where heated storage is not available. In these situations, precautions must be taken to tailor the low temperature properties of the fuel to meet the ambient conditions.

Diesel fuels contain a class of hydrocarbons called paraffins that form waxes at lower temperatures. Cloud point is the temperature at which the wax first begins to separate from the fuel and the fuel appears cloudy. At a lower temperature, called the pour point, the fuel can no longer be poured. Other measures of operability that usually lie between the cloud point and the pour point have been developed to simulate actual vehicle conditions. These measures include the Cold Filter Plugging Point (CFPP) and the Low Temperature Flow Test (LTFT).

Refiners alter low temperature fuel properties seasonally to provide assurance against field problems. The low temperature flow properties of a diesel fuel can be altered by varying the fuel composition or through the use of additives. These additives, or flow improvers, are polymers that can affect the wax formation and wax structure of the diesel fuel as it cools. The result can be smaller, more compact, wax crystals that are able to flow through filters at lower temperatures than the untreated diesel fuel.

Storage Stability

In storage, diesel fuels are attacked by atmospheric oxygen, which can cause varnish deposition. Antioxidants and dispersants are added to prevent such problems, while copper metal deactivators reduce the catalytic effects of copper parts that may be present in the fuel system.

In the presence of water, bacterial action can cause a build up of "slime" near the fuel water interface in the storage system, leading to filter plugging. Biocides can be used to inhibit bacterial growth.

Component Compatibility

Diesel fuels are injected into the engine through precision pumps and fine injector nozzles. Dirt and water contamination must be avoided to protect these critical components. Specifications include tight limits on water and sediment, but some fuel marketers also install final filters at service station pumps to protect against dirt picked up in the distribution system.

Deposit build up in engines is influenced by fuel quality. Fuels that leave a heavy carbon residue and contain excessive amounts of high boiling point materials are prone to cause engine deposits. Therefore, limits are placed on carbon residue and ASTM D 86 90% evaporated temperature.

Sulfur Content

Sulfur naturally occurs in all crude oils and is present in refined products. During combustion, sulfur compounds oxidize to form SO_2 and SO_3, which form sulfates in the exhaust gas stream. These sulfates are part of the diesel engine's particulate emissions; therefore, reducing fuel sulfur levels can result in lower particulate emissions.

Diesel exhaust aftertreatment devices are being developed and optimized. These devices include particulate filters, oxidation catalysts and lean NOx reduction catalysts. Currently available lean NOx reduction catalysts are very sensitive to poisoning from sulfur in the fuel. To reduce particulate emissions and enable the use of aftertreatment devices, many countries have mandated reduced levels of sulfur in diesel fuel. In many refineries, low sulfur diesel fuel and ultralow sulfur diesel fuel is produced by hydrotreating diesel blend streams to reduce sulfur level. In addition to removing sulfur, these processes can also reduce other polar compounds that normally exist in the diesel fuel. As a result, these lower sulfur diesel fuels can exhibit poor lubricity, poor oxidative stability and poor static discharge properties.

Lubricity

In many diesel fuel systems, the fuel itself provides lubrication for the fuel pump and injectors. A poor lubricity fuel can result in excessive wear and premature failure of these components. With reductions in fuel sulfur level, lubricity is becoming a larger concern. Many refiners are using lubricity improver additives to restore the lubricating properties of the fuel. Many pump tests and bench tests have been developed to measure the lubricity of diesel fuels. The most widely used method is called the High Frequency Reciprocating Rig (HFRR).

Water Content

All diesel fuels contain small amounts of water. The amount of water that a fuel can hold is controlled by temperature and hydrocarbon type and distribution. As temperature decreases, the amount of water dissolved in the fuel will also decrease, which may lead to a water layer forming on the bottom of the storage container. This layer should be minimized by draining the tank regularly to prevent bacterial contamination and the entrainment of water in the fuel distribution system. Excessive water in a fuel system can cause corrosion, filter plugging and icing (under cold conditions).

Biodiesel

Agricultural products, such as soybean, rapeseed, palm and coconut can be used to make a biodiesel fuel that can be used in diesel engines. Normally, the plant oil is converted to the methyl ester for use as a fuel. Biodiesel fuel can be blended into normal diesel fuel, or used 100% pure in diesel engines. As the use of biodiesel fuel grows, there is continuing work to design standard specifications for it. In general, biodiesel fuel can have very good lubricity properties, even when used at only 2% in normal diesel fuel. However, it has also been observed that biodiesel has a higher viscosity than normal diesel fuel, can contribute to higher levels of injector deposits, and can exhibit poor cold flow properties.