July, 2010 200 Industrial Dr • Butner, NC 27509•(919)575-6711

Critical Fuel Systems
A division of BFS Industries, LLC

Fuel Oil Maintenance and Filtration Selection

"How do I size the fuel filtration set?" This is one of the most common fuel systems questions we hear. Iwill answer this question but before we get to the how, we should discuss the why. The "why" has a lot to do with the way in which diesel fuel, also referred to as fuel oil, is used in a modern facility as well as some specific properties of diesel fuel. The first thing you should know is that diesel fuel is "hydrophilic" which simply means that it actually attracts moisture, without regard to which process is used to produce the fuel oil.

The refining industry has two primary processes for producing diesel fuel; hydrogen cracking or catalyst cracking. Refiners in the USA use the catalyst cracking method most often because it is the most efficient way to produce gasoline (our primary fuel); in Europe and other areas abroad diesel is the primary fuel, so their refineries use the hydrogen cracking method. Unfortunately the catalyst method produces a somewhat unstable diesel fuel. This unstable fuel oil doesn't become an issue if the fuel is used quickly; it only becomes problematic if the fuel oil sits in storage for months.

The instability issue can dramatically affect the performance of diesel engines in both the ability for the engine to start reliably and to run efficiently. Fuel oil is produced to certain standards which include maximum allowable water content and minimum cetane ratings. Maximum acceptable water content and sediment is .05%. The minimal acceptable cetane number for diesel fuel is 40. Most fuel suppliers will add cetane booster to reach a level of 42-44 to allow for degradation and ensure the fuel doesn't cause any problems with the engines.

The cetane number represents the fuels ability to ignite. Cetane is an abbreviation for the hydrocarbon chain; 1-hexadecane **(** $C_{16}H_{34}$), a hydrocarbon chain that that ignites very readily under compression. Fuel oil contains very little actual $C_{16}H_{34}$ but the cetane scale is used in quantifying the quality of diesel fuel by measuring how well the fuel ignites in comparison to pure cetane. A cetane number of 10 indicates that the fuel will ignite 10% as readily as pure cetane. The maximum effective cetane rating for a diesel engine is 50, after that there is no improvement in engine performance and an engine can actually start encountering new problems. By adequately maintaining the stability of fuel oil you will improve efficiency, reliability and emissions of your engine generator.

One other way that instability of stored diesel fuel presents is that the oil will stratify in the storage tank. This stratification will occur, based on the density of the constituent parts of the fuel oil. Since the fuel suction line is at the bottom of the storage tank the heaviest components will get used first which may cause the engine to generate smoke or go out of emission compliance, but the

danger comes from the lighter components at the top, which burn faster causing preignition that can seriously damage the engine.

Another issue that has to be considered is that the refining process also creates residual water in the diesel fuel. Historically most of this water would separate out in a couple days as the fuel sat in refinery holding tanks before being loaded into tanker trucks or pumped out into pipelines. Since our refining capabilities haven't kept pace with demand the oil is transported almost as soon as it's refined. This means that the water can't settle out, so it is transported with the diesel fuel and ends up, on site, in storage tanks where the water does eventually settle out.

This transported water is the first water that enters the storage tank, additional moisture enters with the air through the atmospheric vent and more is actually produced by the microbial life that lives at the water line and feeds on the hydrocarbons. There are more than two dozen different types of fungi, algae, and bacterium that can live in a fuel oil tank, if the fuel oil is not treated this growth can actually develop to form a filter and nozzle clogging fibrous mat, to prevent this a comprehensive maintenance plan is required. Filtration is part of this maintenance program.

Fuel oil filtration or "polishing" is only one of three steps required to maintain the readiness of standby fuel oil in storage tanks.

1. Remove water and particulate through filtration.
2. Treat the fuel with cetane boosters, stabilizers and biocides.

   Minimum legal cetane rating for diesel fuel is 40, most fuel oil is refined to about 42, additives are often injected at the tank farms to raise the cetane number and stabilize the fuel oil.

   Stabilizers maintain the quality of fuel preventing the diesel fuel from stratifying into different density layers and forming varnishes while sitting in storage tanks.

   Biocides kill the bugs that increase fuel degradation, particulate formation, and water content.

3. After system start-up, test fuel quarterly until consistently positive results are achieved and then decrease frequency to no less than annually testing the storage tank. Require fuel supplier to provide analysis of fuel delivery. If in doubt test the tank after receiving a load.

Filtration basics, how it works.

Filtration is a fairly straightforward. Modern filtration units operate with 3 distinct filtration phases. Different manufactures may claim more phases of separation but these added "phases" most often offer nothing in regards to system reliability or fuel oil quality. The 3 true phases are;

1. Course Strainer- This section should be a full size basket strainer with a 100 mesh basket. These are typically simplex style and should be automatically monitored for plugging. On larger systems or continuous flow systems upgrading to a duplex basket strainer could be justified. Either strainer primary purpose is to remove large particulates to protect the filtration pump and extend the life of the primary filter.
2. Separator-Water separation and removal is the key function of the filtration system. A coalescing membrane causes the emulsified water to form into droplets as the contaminated fuel passes through it. The separator element repels the water droplets while allowing the free-flow of fuel oil through this element. The water falls to the bottom of the filter housing where it is collected for removal. Removal of the water can be automatic or manual.
3. Primary Filter-Removing particulate to meet the specified level is done by the primary filter. This filter is a fine element type of filter with a final production typically in the range of 4-10ppm. This filter is a disposable filter that is, by design, prone to fouling and must be monitored. The operators should keep a supply of replacement filters on hand. If the primary filter is plugging before the filtration system can complete a cycle the operator should replace the filter element with a courser one for a complete cycle and then revert back to a finer element for the next cycle.

In addition to the filtration phases a few other components are needed to complete the filtration system. These components are:

1. Filtration Pump-The sole purpose of the pump is to circulate oil from the storage tank through the filtration system and back to the storage tank. The filtration pump must be sized to meet the specified tank "turn-over" rate. On fuel systems with multiple storage tanks care must be taken to ensure that the suction and return valves are properly aligned to prevent a spill by flooding a storage tank.

2. Containment Basin-In cabinet style systems the bottom of the cabinet serves this purpose. Skid type systems are provided with a 3" containment wall that is seal welded around the perimeter of the base. In both instances these serve to contain any leakage and provide for a way to mount a switch to detect and annunciate leaks.

3. Filtration System Options
    a. Centrifugal separator-A centrifugal separator can be installed in high, continuous flow applications where excessive contamination is present. This component utilizes the velocity of fuel flowing through it to generate sufficient centrifugal force to separate water and dense particulate from the diesel fuel. The heavier contamination drops out in the low velocity section while the fuel flows through. The contaminants can be purged manually or automatically.

b. Secondary filter-This is typically installed in systems where existing storage tanks and piping are expected to be contaminated and the filtration system is run intermittently and/or a very high level of filtration is required. In either case the secondary filter is piped in series with the primary filter. The primary filter should be selected to filter at about 25% of the level of the secondary or final filtration required.
c. Waste holding tank-In large capacity systems the filtration set can remove several gallons of water from apparently clean diesel fuel in a single cycle, exceeding the storage capacity of most separator filters and require manual intervention to drain the filters and restart the system. The automated waste holding tank option would provide for automatic purging of the coalescing filters to permit the filtration set to cycle without interruption or human intervention.

4. Additive Injection Option-This option will change the fuel filtration system into a true fuel maintenance system. By properly treating the clean diesel fuel one can extend the life of the fuel dramatically. The process is simple and time tested; test the fuel, adjust the amount of additive injection accordingly and test again.

More about additives

The primary additives used in the mission critical market are stabilizers, cetane boosters and biocides. There are over 140 different manufacturers of fuel additives registered with the United States EPA and several of the manufacturers produce additives under many different trade names. The EPA doesn't certify the efficacy of the additives, all they care about is that they don't produce harmful gasses during combustion.

Due to the variety and concentration of the hundreds of different additives it is important for operators to follow the additive manufacturer's specific directions for use.

Cetane Boosters-Most cetane boosters use 2-ethylhexl nitrate (EHN) as a base. A concentration, added to the fuel, of about .04% EHN is optimal, raising the cetane a range of 3-7. The higher cetane yield comes when combined with higher quality fuel. The nitrates in cetane boosters are now shown to increase instability in diesel fuel and are no longer recommended.

Water Emulsification Agents-Some companies market chemicals that will cause water to emulsify into the fuel oil and prevent it from separating out. **Any** water in the fuel is bad, the **only** option for generator fuel systems is to remove this water; emulsifying agents will prevent the separators from effectively removing water and cause the water to be distributed throughout the entire fuel system. We do not recommend the use of any emulsification agents in your mission critical fuel systems.

Stabilizers-Fuel stability is affected by several factors such as moisture, temperature, and oxygen exposure. Heat will accelerate the degradation process, in fuel by-passing type generator systems the fuel gets heated drastically as it cools the engine fuel injectors and is returned to the tank. By heating up the fuel the degradation process is drastically accelerated, stabilizers help protect the fuel from this degradation.

Biocides-The biocides required to successfully treat diesel fuel should be solvent based with a broad spectrum blend that is designed to kill and prevent future growth of algae, bacteria, and fungi. The treatment chemical must be effective in both the fuel and accumulated water. Dosage should be tailored to the level of contamination present.

Testing Details

NFPA 110 8.3.8 requires annual testing of fuel oil to ASTM standards for generator fuel systems. Some of the tests are:

1. ASTM D-613 cetane/combustion test
2. ASTM D-1094 water test
3. ASTM D-2274 fuel stability test
4. ASTM D-500 lubrication quality test
5. ASTM D-97 cold flow test

How to select and size a fuel maintenance system.

The sizing and selection process is one of life's great mysteries. Typically filtration system sizes are based on flow rates. Flow rates are chosen based on how quickly the fuel needs to be cycled. Divide the storage tank capacity by the desired cycle time; this will give you the flow rate necessary to choose a specific size filtration unit.

Good engineering practices dictate that in multiple tank installations the fuel maintenance system should be sized, at a minimum, to cycle a tank within the amount time the tank can be off line. If the system doesn't have a waste holding reservoir then the filtration set should be timed to cycle while operators are on site to monitor the system and empty the separator filter.

If the fuel system has only a single storage tank then the filtration cycle time should be short to lessen the likelihood of getting caught with contaminated fuel if the generators are brought on line. A 4 hour turn-over is a good starting point in most instances. One other option is to size the unit for full system flow using the system transfer pump to circulate the fuel through the filtration system.

Conclusion-Circumstances have changed in the diesel fuel industry that requires operators to actively maintain their stored fuel oil. Including a fuel maintenance system in the construction of mission critical diesel fuel system will allow the operators to meet their commitment for operational readiness.