Sludge Contamination in Marine Diesel Fuel

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Marine diesel fuel systems are prone to fouling from sludge formed in fuel tanks. High humidity, condensation and contamination during fuel transfer allow the accumulation of water and bacteria in diesel systems. Two major groups of organisms contaminate fuel systems; bacteria and fungi. This article focuses on bacterial contamination only and does not address fungal infections.

Water and diesel fuel are the key ingredients in the formation of biomass often referred to as sludge *(Image 1)*. Many mariners use biocides as their first line of defense without really understanding what is happening in their fuel system.

Sludge is composed of water, degraded fuel, bacterial slime, and a variety of bacteria. Some of these bacteria biodegrade fuel to produce food while others excrete organic acid. The results are a decrease in the fuel's stability, an increase in a fuel's acid number, and an increase in corrosivity.

The presence of sludge in a fuel system has an economic impact often overlooked. Sludge leads to filter plugging, MIC (microbial influenced corrosion) and a breakdown of fuel and loss of properties (colour, pour point, cloud point, thermal stability)[2]. Sludge also results in the loss of additive performance.

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Despite all the potential issues with the presence of sludge, effective treatment and control is rarely employed. Some may use filtration and biocides but few really understand sludge and how to deal with it.

Cause and Dynamics

Bacteria are natural residents in diesel fuel. They are most commonly introduced through vent tubes, water intrusion, and fuel transfer. Chemicals from water in the fuel form a conditioning film on solid surfaces. This occurs within minutes after the fuel has been introduced to the tank. This film allows free-floating bacterial cells to attach to the surface, at which point some of them begin to generate a starch-like substance often referred to as "slime." This is the "glue" that holds the sludge or biomass together. Soon, other bacteria start to move into the slime layer. Some of these get their food from the fuel, while others get their food from the by-products of the fuel users. The result is a rather complex ecology of life forms growing in the sludge. Some of these bacteria produce organic acids, which may promote pitting corrosion of underlying steel. The pitting corrosion, only observed under sludge accumulations, accounts for most fuel tank failures.

As sludge builds up, bits of it slough off and travel downstream, where they adhere to surfaces — perhaps a filter — and start to grow new sludge. The most common indicator of a severely fouled fuel system is complete filter plugging resulting in engine shut-down.

Image 1: The forward day tank of a Lloyds + 100A1 Class Tug undergoing cleaning due to bio-mass contamination.

Operational Impact

MIC – (microbial influenced corrosion)

As described above, sludge in contact with steel or cast iron leads to corrosion. The exact role of the bacteria themselves is a matter of much research and conjecture, but it is clear that very high rates of metal penetration occur under biologically active sludge.

Filter Plugging

Bits of sludge that have landed on a filter will then grow and slowly blanket the filter, sealing it off and stopping the flow of fuel. These growths may initially appear as tiny specs and not readily visible to the naked eye *(Image*

2). As the sludge film matures, the filter takes on an overall slimy, black coating *(Image 3)*. At this stage the filter is plugged.

If corrosion of iron or steel is occurring in the fuel system, the corrosion by-products *(Image 4)* will also transfer to the filter medium, further accelerating filter plugging.

Treatment and Control

The typical preventative maintenance program for diesel systems is to change fuel filters at intervals based on hours of operation. When filters plug prematurely, filter changes are simply made more often and are usually based on engine warning devices.

There are preventative measures that one can take to help control the problem. These range from mechanical cleaning of the fuel, treatment with biocides, or the use of a novel filming amine technology.

Fuel Polishing

Mechanical cleaning of the fuel in the tank is often called fuel "polishing." This involves circulating the fuel through a bank of graded filters, perhaps including final filters as fine as 0.5 microns. Some polishing systems use a centrifuge as the first stage to remove larger particles and free water. The result, as proudly shown in little jars by the polisher operator, is that the fuel goes from looking dark and murky, to clear and bright.

The advantage of fuel polishing is that, if done right, most of the free water is removed from the fuel tank. The disadvantages are 1) it is expensive, 2) it requires system down time, and 3) much of the solid sludge is left in the tank. That residual sludge can grow again very rapidly once the system is returned to service. The bottom line: Fuel polishing alone is only a temporary solution.

Image 2: Filters from a boiler system operating on ULSD. Fuel Right® filming amine technology was used to treat the fuel and over a three-month period, the bio-film (opaque) was dissolved and filter plugging issues were eliminated. The fuel was sloughing deposits of bio-mass downstream and prematurely clogging filters. The bio-film is opaque. The weight of the filters reduced from left to right due to reduction of bio-film loss.

Image 3: A marine filter/water separator plugged with bio-film. Treatment of the fuel with Fuel Right® dissolved the existing sludge in the fuel tank.

Image 4: Filter with evidence of corrosion deposits (due to its brown colour). It is completely plugged with bio-film and corrosion particles.

Biocides

Biocides are commonly promoted in the marine market and can be somewhat effective if used properly. Biocides alone are rarely effective against established sludge, as they struggle to penetrate the biomass to directly contact the bacteria in order to kill them. Using certain dispersants along with biocides can give somewhat better results - but most systems simply treated with biocides continue to have some degree of sludge fouling and corrosion.

The advantages of biocides are that they require little or no system down time and do their job while the system is running. They can be very effective against certain bacterial or fungal problems caused by free-floating organisms. The disadvantages are that they are generally expensive, may provide operator exposure risks, can lead to reduced performance if used repeatedly, and they tend to give only marginal benefit against established sludge. In some laboratory studies, even the best biocides have produced only marginal benefit even when treating a clean system before introducing fuel contamination.

Once a tank has been treated with a biocide, the tank should be cleaned to remove any remaining dead debris or sludge - and then re-treated to address the sludge residues left after cleaning.

Filming Amines

Filming amines have been used as corrosion inhibitors in industrial water systems for several decades. They have also been used for that purpose in fuel additives by at least one major additive supplier. Research begun in the 1990s found that certain combinations of filming amines have other useful properties for fuel systems — for one thing they literally dissolve the bacterial slime, thus releasing the entrapped water and degraded fuel into the fuel. Because the released particles of solid fuel and droplets of water are miniscule, encapsulated and treated, they do not cause problems in the operating system and simply go through and burn harmlessly in the combustion process. Equally as important, the film formed on surfaces by the treatment defeats the conditioning film that precedes bacterial attachment, so no new biomass (sludge) forms. The results are a cleaner and trouble-free fuel system, long filter life, and no corrosion inside steel tanks.

The advantages of filming amine treatment are 1) it is relatively inexpensive, 2) less concern for handling safety and environmental effects if spilled than with biocides, 3) no down-time during or following treatment and 4) benefits do not decline with repeated treatment. The amine film remains on solid surfaces for perhaps many months, so treatment can be done at extended intervals. Because the combination of amines has potent cleaning power, diesel users typically notice smoother operation, easier starting, and greatly reduced exhaust smoking. The amine film also protects against metal wear, normally a concern with ULSD as compared to the higher sulphur fuels. Finally, the amines are alkaline by nature, so acidic by-products of fuel deterioration in storage are neutralized, resulting in enhanced storage stability.

Each of these corrective measures has certain advantages — and limitations. The best answer lies in using a combination of these schemes: Tank cleaning or fuel polishing to remove any free water in the system and at least some of the accumulated sludge and debris, biocides when needed to correct biological problems caused by free-floating microbes, and a filming amine treatment to finish the cleaning of the system and keep it that way. If only one of the solutions is to be used, the newer filming amine treatment offers the most cost-effective and lasting benefits.

Summary

The topic of bacterial colony formation in diesel fuel systems is far more complex than this article can cover. The research in this field is extensive and this paper provides a very basic overview.

Understanding the economic impact that biomass contamination can have on an operating budget is the first step to exploring ways to remediate the problem.

The use of modern filming amine chemistry to dissolve and control sludge is likely the most economical approach to managing contamination in fuel systems. The programmed use of amines as a preventative measure in ULSD systems has proven over the past 18 years to be a very effective and economical approach to the prevention of MIC and formation of sludge.

References

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Bob Tatnall spent 30 years as a materials engineer with DuPont, specializing in corrosion, linings and coatings. In 1968 he first observed a little-known phenomenon called microbiologically influenced corrosion, or MIC. Fascinated by this destruction of metals and alloys by bacteria, Tatnall spent the rest of his DuPont career learning how bacteria and other microorganisms interact in different environments. Through his collaboration with researchers at universities worldwide, he learned not only about bacteria, but also about biofouling, or the buildup of slime masses as a natural habitat for bacteria and fungi (yeasts and molds). Bob founded Fairville Products, Inc in the mid-1990s and began research to develop the Fuel Right® technology we know today.

Tim Rivard's first degree was in the Engineering Technologist, Mechanical and Material Science program from Northern College of Applied Arts and Technology. He also obtained a cross-disciplinary degree in finance and economics from the University of Western Ontario as well as his Master of Business Administration. Before taking on the role of President for Fuel Right (Canada) Limited, Tim's career included international business development in 21 countries.

For more information about Fuel Right®, visit: www.fuelright.ca or email info@fuelright.ca.