**Diesel Tank Corrosion Mechanism, and Corrosion Control**

This article will cover the corrosion mechanism, and corrosion control, by the installation of a standards-based SAE J1488 filtration system that removes the majority of corrosion risk to tanks caused by MIC, (Microbiologically Influenced Corrosion).



The increased prevalence of corrosion in the storage tanks was first noticed in 2007, shortly after the introduction of ULSD (Ultra Low Sulfur Diesel) biodiesel blends. Intense study has followed, trying to answer the question of what has changed to cause the corrosion, and how to mitigate it.

The cost of corrosion is potentially immense. The lifecycle of tanks is reduced, normally tanks last for 30 to 40 years, now tanks have been replaced in as little as 10 years. The increased corrosion is affecting all parts of the diesel infrastructure, piping, fittings and seals, so environmental damage, and liability, is increasing. In addition, acidified fuel is damaging the injectors of emergency backup generators, putting at risk the safety and health of the public at hospitals and water treatment plants. Data centers face large liability issues if backup generators fail during a real emergency, causing disruption to business.

**The Corrosion Mechanism**

**Summary:** There are two parts to the corrosion mechanism. In **Part 1**, emulsified water moves permanently into the ULSD biodiesel fuel column and bonds to the biodiesel using a hydrogen bond, and in **Part 2**, microbes follow the bonded emulsified water into the fuel column; this greatly increases the microbe’s growth volume; more microbes, more acids, more corrosion.

In **Corrosion Control**, we will discuss the standards-based filtration method to remove this bonded emulsified water, filtration based on SAE J1488\_201010. SAE is the Society of Automotive Engineers. The removal of the bonded emulsified water in the fuel column denies the microbes the water they need for growth, thereby greatly reducing the number of microbes, and therefore reducing the acids produced.

**Part 1:** Emulsified water moves into the fuel column and has bonded to the biodiesel

We know from the research paper "Moisture Absorption in Biodiesel and its Petrodiesel Blends" that 100% biodiesel can hold 15 to 25 times more emulsified water compared to 100% diesel, and hits saturation quickly. This is because both water and biodiesel molecules are polar (they have a positive and negative end to the molecule), so the water molecules are attracted to, and bond quickly to, the biodiesel.

[https://biodieseleducation.org/Literature/Journal/2007\_He\_Moisture\_absorption\_.pdf](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=2ahUKEwjYtNq6q8riAhUPZd8KHYvCCioQFjABegQIAhAC&url=https%3A%2F%2Fbiodieseleducation.org%2FLiterature%2FJournal%2F2007_He_Moisture_absorption_.pdf&usg=AOvVaw3-r22bbfXsuhgsWAWPZ0T3)

The actual bonding mechanism of emulsified water to biodiesel is by a hydrogen bond. While weaker than a covalent or ionic bond, it still attaches multiple water molecules to a biodiesel molecule. The hydrogen atoms (positive charge) in the biodiesel bonds to the oxygen atom of water (negative charge). As seen in the biodiesel molecule pictured below, there are many hydrogen attachment points. This is why pure biodiesel can hold 15 to 25 times more water than pure diesel, and why bonded emulsified water is so difficult to remove. As well, additional water molecules continue to bond to the already attached water molecules, so the number of water molecules attached to the biodiesel will continue to grow.

**\**

Biodiesel Molecule Covalent Bond

**C**

**H3**

**C**

**H2**

**/**

**C**

**H2**

**/**

**\**

**C**

**H2**

**O**

**C**

**H2**

**/**

**C**

**||**

**O**

**\**

**CH3**

**/**

**C**

**H2**

**/**

**\**

**C**

**H2**

**C**

**H2**

**/**

**\**

**C**

**H2**

**C**

**H2**

**/**

**\**

**C**

**H2**

**C**

**H2**

**/**

**\**

**C**

**H2**

**\**

**C**

**H2**

**/**

**C**

**H2**

**\**

Water Molecule

**O**

**H**

**/**

**\**

**H**

Bonded Emulsified Water Hydrogen Bond

**C**

**H3**

**C**

**H2**

**/**

**C**

**H2**

**/**

**\**

**C**

**H2**

**O**

**C**

**H2**

**/**

**C**

**||**

**O**

**\**

**CH3**

**/**

**C**

**H2**

**/**

**\**

**C**

**H2**

**C**

**H2**

**/**

**\**

**C**

**H2**

**C**

**H2**

**/**

**\**

**C**

**H2**

**C**

**H2**

**/**

**\**

**C**

**H2**

**\**

**C**

**H2**

**/**

**C**

**H2**

**\**

**O**

**H**

**/**

**\**

**H**

**O**

**H**

**/**

**\**

**H**

**O**

**H**

**/**

**\**

**H**

**O**

**H**

**/**

**\**

**H**

**O**

**H**

**/**

**\**

**H**

**O**

**H**

**/**

**\**

**H**

**O**

**H**

**/**

**\**

**H**

Note: 100% pure ULSD and 100% pure gasoline are not polar, so do not bond to water. This is why, prior to the introduction of biofuels (biodiesel and ethanol), water was found mainly on the tank bottom. Microbial growth was mainly limited to the thin fuel/water interface.

**Part 2:** Microbes follow the water into the fuel column to greatly increase their growth volume, and produce more acids

Microbes permanently migrate into the fuel column, as they now have the water they need to live there. This migration has greatly increased the microbe’s growth volume, resulting in more microbes, more acids, acidified fuel, more corrosion. In addition, the microbes can create biofilms on surfaces that the diesel touches. This has led to the corrosion crisis we have now.

Biodiesel itself is a good source of nutrients for microbes. Think “fast food”, with the bonded emulsified water attached for convenience and enhanced growth.

Before 2006, microbes were limited to the fuel/water interface, close to the tank bottom. This interface is typically very thin, being described as the thickness of a sheet of paper. While microbes produced acids, their number were so low that acid production was also low.

**Corrosion Control**



SAE J1488 is the recognized diesel industry filtration standard for diesel: “To determine the ability of a fuel/water separator to separate emulsified or finely dispersed water from fuels. This test method is applicable for biodiesel fuel.”

[www.sae.org/standards/content/j1488\_201010/](http://www.sae.org/standards/content/j1488_201010/)

J1488 was updated in 2010 by SAE to account for the reduced interfacial tension (IFT) of ULSD biodiesel blends compared to the higher IFT of pure ULSD.

IFT is the ability of two fluids to repel each other. The high IFT in 100% pure ULSD means that water is easily repelled, and precipitates out to the tank bottom. The lower IFT of ULSD biodiesel blends means more water is bonded to the biodiesel molecule. With this hydrogen bond, the water is more difficult to remove using traditional filters.

There are two phases of the J1488 test procedure; in the first phase 100% pure ULSD, with its high IFT, is used. 2500 ppm emulsified water is added to a dry fuel sample. Since pure ULSD is not polar, the emulsified water is not attracted and is not bonded to the ULSD. Any filter should have as close to 100% efficiency in removing all the water.

In the second phase, the IFT is lowered to 15-19 mN/m, simulating a B20 ULSD biodiesel blend, and again 2500 ppm water added. In this setup, emulsified water is attracted to and bonds to the biodiesel, so it is much harder to remove. This is when the hydrogen bonds come into play. In order to reduce the water to 200 ppm or below, a filters efficiency in breaking the hydrogen bonds to remove water will need to be 92%, (2500 \* (1-.92)) = 200. 200 ppm controls the growth of microbes by limiting available water to the microbes; little water, little life, little MIC, corrosion controlled. As well, 200 ppm is the warranty level for emergency backup generators.

A new generation of filters have been developed since 2011 to remove the bonded emulsified water by breaking the hydrogen bonds as tested against SAE J1488.

The corrosion control mechanism is supported with field test results. Fuel samples from end users using SAE J1488\_201010 filtration consistently show storage tank water levels well below 100 ppm. Fuel samples that had been taken directly from the return lines after filtration, but before return to the tank, show as little as 10 ppm.

The only time the water is above 100 ppm is typically after a fuel delivery, which speaks to the quality of fuel delivered, or a water leak into a tank; in that instance the leak was found and fixed. These very low level of water content (< 200 ppm) will deny microbes the water needed for growth; little water, little life, little MIC, corrosion controlled.

A key point is that in order to identify the presence of bonded emulsified water, a Karl Fisher titration must be used. Other test methods will not pick up the presence of bonded emulsified water. For example, the visual “clear and bright” test will continue to be “clear and bright” with substantial bonded emulsified water, and no visible free water present.

An additional benefit of SAE J1488 filtration is that if properly installed, and run on an optimal schedule, the sludge and free water that normally deposits on the tank bottom is continually removed, such that storage tanks do not need to be cleaned again. The operational cost of keeping a tank clean is only the electricity used for the filtration system, and annual changeout of filters.

**Different Tank Corrosion Scenarios**

Storage tanks are used in different situations, and some are at a much greater risk to corrosion. Major factors affecting corrosion, in addition to the level of bonded emulsified water, are: age of the stored fuel, how often the fuel is turned over, and exposure of the tanks to the elements.

**Above Ground Storage Tanks (AST) or Underground Ground Storage Tanks (UST)**

The corrosion risk applies to both, and a case can be made that ASTs are more at risk due to the wider swings in temperature and humidity during the day/night cycle, thereby condensing more water to be absorbed into the stored ULSD biodiesel blends, and hence more corrosion.

**Emergency Backup Generator Storage**

The highest corrosion risk is for emergency backup generator storage tanks. The fuel is turned over very slowly; generators are typically tested on a monthly schedule for an hour or two. At this rate of fuel consumption, the tank is effectively never turned over, just topped off a few times a year. While NFPA 110 recommends the complete replacement the fuel on a regular basis, in reality this does not occur. Water is continually absorbed and bonded to the ULSD biodiesel blend, and microbial growth continues unabated, acidifying the fuel, and corroding the tank and components. The risk extends from the tank to the emergency backup generator itself, acidified fuel can corrode the injectors, greatly increasing the risk of failure during a time of emergency. In addition, excess water in the fuel flashes into steam at the injector, thereby increasing the damage to the injectors.

**Gasoline Stations**

Diesel storage tanks are replenished often during a year. The key factor in corrosion control therefore is the quality of the delivered ULSD biodiesel blended fuel. If the fuel is dry (little bonded emulsified water), the fuel will be dispensed before it has time to absorb much water, and before substantial MIC can occur. However, if the delivery tankers are delivering fuel already with significant water content, then MIC may have already started.

This was noted in the 2016 EPA report “Investigation Of Corrosion-Influencing Factors In Underground Storage Tanks With Diesel Service”:

*“Minimizing water presence is and has always been an important part of UST maintenance. However, diesel blended with biodiesel can hold in solution more water than diesel without a biodiesel component. This means more water is likely arriving in USTs entrained in fuel today since biodiesel is more common in diesel than prior to 2007. “*

<https://www.epa.gov/ust/investigation-corrosion-influencing-factors-underground-storage-tanks-diesel-service>

If the delivered fuel has substantial bonded emulsified water, the fuel may also have microbial growth, and acidified fuel.

**Terminal Storage Tanks**

100% pure ULSD is blended at various concentrations with 100% pure biodiesel at the terminal. 100% biodiesel is transported to the terminal from biodiesel manufacturing locations, and during its transport can absorb 15 to 25 times more water than pure diesel could. The 100% biodiesel should be filtered before being blended, to remove the bonded emulsified water that has been absorbed in transit.

The blended fuel is now stored in the large terminal tanks awaiting delivery to retail stations by delivery tankers. This blended fuel should be tested, and if significant bonded emulsified water is found, the fuel should be filtered prior to being transferred into the delivery tankers. As well, if the fuel is acidified, it should be treated before delivery.

**Ethanol**

While this article focuses on ULSD biodiesel blends, there are similarities between biodiesel and ethanol:

- both are biofuels, ethanol is based on plant material (corn), and biodiesel is based on both plant and animal material;

- both are involved in corrosion;

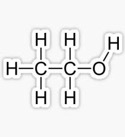
- both are polar in nature, that is the biofuel molecules has a positive and negative charge at either ends of the molecule

- both has a great affinity to absorb water

Ethanol can create hydrogen bonding similar to biodiesel. Ethanol has less hydrogen atoms to bond to water molecules than biodiesel, but has a higher percentage content (E15) at the pumps than biodiesel blends.

Note: both 100% ULSD and 100 % gasoline are not polar.

Ethanol molecule



**Industry Articles**

The following industry organizations have published articles describing the corrosion threat and SAE J1488 filtration as a solution.

**Biofuels Digest** -

|  |
| --- |
| [SAE J1488\_201010 needed for Diesel Infrastructure Corrosion, Prevention, says Dieselpure : Biofuels Digest](http://www.biofuelsdigest.com/bdigest/2016/11/27/sae-j1488_201010-needed-for-diesel-infrastructure-corrosion-prevention-says-dieselpure/)  www.biofuelsdigest.com  In Washington, a July 2016 EPA report has brought corrosion into the spotlight. What was not mentioned in the EPA report is that there is a simple preventative maintenance item that prevents corrosion, filtering biodiesel blends with filters tested against SAE J1488\_201010. Fuel experts have documented severe and rapid corrosion in our existing diesel infrastructure,… |

The **Uptime Institute**

The **Uptime Institute** focuses on datacenter, and issues Tier III and Tier IV certifications that address data center redundancy. Uptime suggests datacenter managers reconsider their diesel supply, and recognize that bonded emulsified water and acidifying fuel can introduce a single point of failure into a data center by effecting backup generators, and that SAE J1488 filtration is a solution.

<https://journal.uptimeinstitute.com/reconsider-your-diesel-supply/>

**EGSA:** The Electrical Generating Systems Association is the world’s largest organization exclusively dedicated to On-Site Power Generation, and includes most emergency generator manufacturers. http://www.egsa.org/AboutUs.aspx. EGSA has created a series of videos to educate their association members on the corrosion issues. This video references SAE J1488 specifically <https://www.youtube.com/watch?v=63PEmHg9Yns&list=PLG2-PE4wBFb2ybJI9T1LKE6a3bv17dTUP&index=8&t=0s>

For more information on this article, please contact the author Patrick Smyth [patsmyth@octanesystemsinc.com](mailto:patsmyth@octanesystemsinc.com) 613-794-6090