

Diesel: A User Guide.



1. Diesel, What Is It? Diesel has become the generic name for fuel used to power compression ignition engines (designed by Rudolf Diesel and named after him) as oppose to spark ignition (petrol/gasoline) engines. Traditionally, diesel is a hydrocarbon fuel derived from crude oil by a refining process now starting to be known as petrodiesel. In recent years "BIO" diesel has appeared which is produced from a variety of vegetable oils and animal fats to provide an alternative fuel to traditional diesel. The word Diesel is used to generally describe a number of fuels:

- Diesel Road Fuel** (BS EN 590. 2009 DERV). The diesel available at the pump on garage forecourts for normal road use. Since 2008 this has been Ultra Low Sulphur Diesel (ULSD) that is blended with biodiesel by up to 7%. Sometimes this is also called white diesel.
- Marine Gas Oil** (BS ISO 8217) , only permitted for sea going vessels. These are commercial vessels going to sea in Category D waters. This fuel is not a low sulphur fuel and is regulated by the EU.
- Gas Oil/Red Diesel** (BS2869.2006 class A and D). It is called red diesel

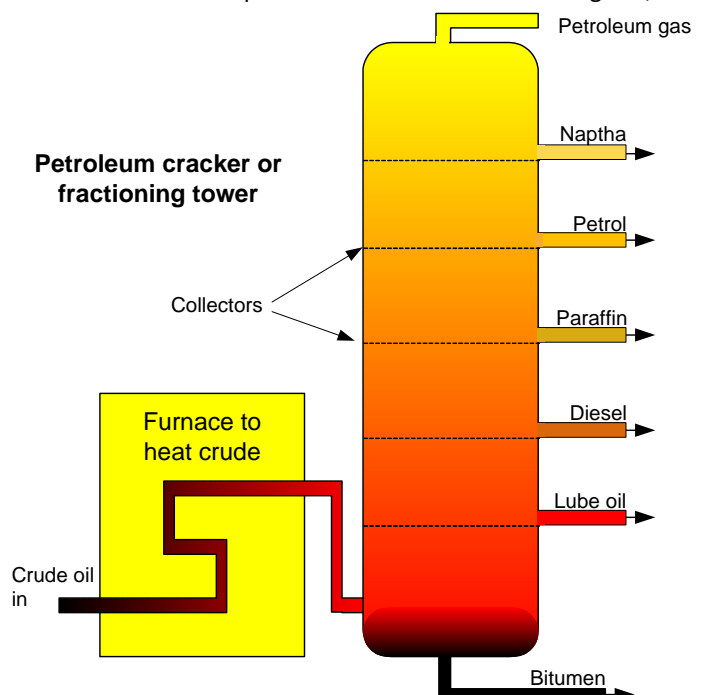


because it is red. Since January 2011 (EU Directive 2009/30/EC, Non Road Mobile Machinery (NRMM) effective January 2011) it is identical to diesel road fuel but with a red colour additive (excise marker for tax purposes) for use in the UK and is taxed at a lower rate because it is restricted to certain uses. Red diesel is also known as gas oil, medium diesel and heating oil. Red diesel in Ireland and Norway is green diesel (green dye instead of red dye) it is not green in the environmental meaning. This is the fuel that is put in our boats, plant and agricultural vehicles.



2. Environmental issues. In recent years, to reduce emissions produced from combustion engines, many changes have been brought into effect in both the engines and the fuels. How these changes affect the user are explained below:

- Hydrocarbon or Petro Diesel.** Diesel is distilled out of crude oil by a fractional distillation process and is known as petrodiesel to distinguish it from biodiesel. It contains a number of base chemicals, one of which is sulphur which helps the lubricating quality of the fuel. Sulphur is one of the emissions from engines that is damaging to the environment (causing acid rain). The sulphur content of diesel fuel sold for road vehicle use is regulated and decreased from 1000 milligrams/kg to a maximum of 10 milligrams/kg by EU law effective since 2008.



b. **Biodiesel.** Biodiesel is produced from plants or animal fats. The process results in a cleaner burning fuel. Biodiesel is also known as FAME (Fatty-acid methyl ester) and can be used as a fuel additive. Bio diesels contain more natural bacteria than petrodiesel. They are a better solvent. They can contain more contamination. Bio diesel contains more water due to its production process and is more hydroscopic, attracting up to 15 times more water than petro diesel.

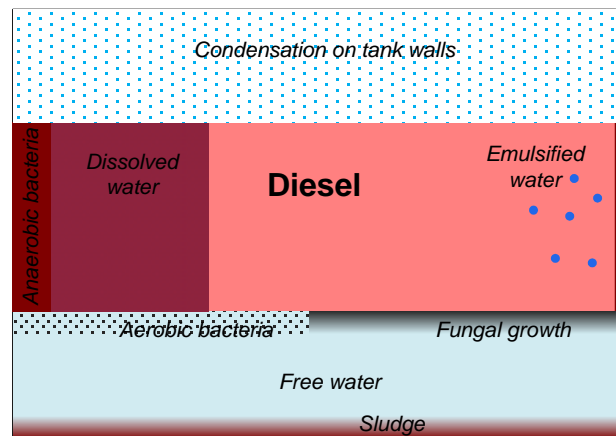


c. **Blended Fuels.** The reduction of sulphur in petrodiesel resulted in a loss of fuel performance primarily in the lubrication characteristics, in particular in fuel pumps and injectors. To bring the fuel performance back to what it was, biodiesel is now blended into petrodiesel in various percentages (currently in UK the blend is up to 7% biodiesel). FAME/Biodiesel is being blamed for a number of mechanical problems including seal failures, corrosion in injection systems, pump seizures, and a variety of other fuel system problems.

d. **Blended Fuel Implementation.** The use of FAME/Biodiesel was introduced in 2008 in white ULSD diesel to create a more environmentally friendly blended fuel and improve its performance. From January 2011 red diesel is made to the same specification as white diesel but with the addition of the red excise dye marker. This blended fuel appears to be more prone to the problems discussed below.

3. Diesel Fuel Problems. Diesel fuel is prone to a number of problems including, water, bacteria, fungus/moulds and chemical (instability and phase separation). These problems have always existed to some extent, but the blended fuels seem to be more prone to them.

a. **Blended Fuel.** The blended fuel is not a problem in road going vehicles that regularly use the contents of their tanks. Modern ULSD fuels with a biodiesel blend are not as stable in storage as the original diesel with high sulphur content. Applications that involve the blended fuel sitting undisturbed for long periods appear to suffer more from the problems mentioned below than pure petro diesel. Although some reports state that the fuel starts to break down after 28 days, in essences 6 months storage is acceptable. If fuel is being stored for more than 6 months some form of treatment should be considered as detailed in the treatment section below.



b. **Water.** Water and diesel do mix, but not to any advantage. Water contaminated fuel does not combust efficiently and can lead to mechanical damage to injectors and engines. In addition to corrosion issues, when the water is caught in the combustion process it can explode into superheated steam which can damage the injector tips. Water in the fuel can also result in "diesel bug".

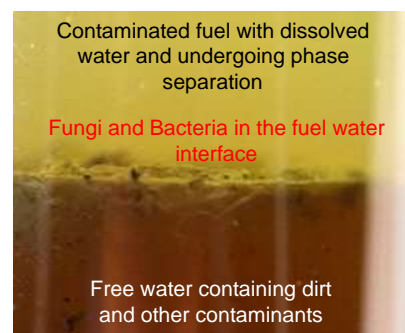


How does the water get there? Poor refining, bad handling or ill-fitting tank top fittings may allow rain water ingress. Biodiesel contains more water from its production process and can absorb up to 15 times more water from the atmosphere than petrodiesel. The new blends are more prone to water absorption in storage. However one of the main problems is diesel stored in a tank which is subject to temperature differentials. If the tank has empty space and the temperature changes, condensation can form on the inside. When the condensation droplets are large enough they will run down into the fuel. They are heavier than the fuel they will collect at the bottom of the tank. This cycle can be repeated with each temperature cycle. This can be cured by keeping the tank filled to stop condensation but this is not always feasible, especially given the

storage life constraints of blended fuels. The fuel delivery tanker is not maintained at a full level all the time, neither are the suppliers tanks. There could be in excess of 5 different storage tanks in the supply chain, all suffering condensation before the fuel arrives in the users tank. The biodiesel that is now blended with petrodiesel encourages absorption of more water into the fuel thereby increasing the problems.

The water can be present in the fuel in the following ways:

- i. **Dissolved water.** Where the water is mixed in the fuel at a molecular level.
 - ii. **Emulsified water.** Where there are droplets or globules of water suspended in the fuel. This will eventually sink and become free water.
 - iii. **Free water.** Water that has settled to the bottom of the tank and forms a distinctive layer with the fuel on top.
- c. **Diesel Bug (Biological Contamination).** Diesel bug can be either bacteria, mould, yeast or fungi or a combination of all of them.
- i. **Bacteria.** There are many different types of bacteria that can live in diesel tanks. As the bacteria goes through its life cycle it reproduces, produces waste and dies. The waste and dead cells end up on the bottom of the tank. Eventually if enough bacteria and water exist in the tank it will start to get sucked into the fuel intakes and clog the fuel filters.
There are two primary bacteria groups:
 1. **Aerobic Bacteria** require oxygen to live and reproduce. These bacteria generally live and breed in the interface between water and diesel where they can get oxygen from the water. If there is water in a tank it does not mean there is bacteria, however if the water is left for any length of time it could encourage bacterial growth.
 2. **Anaerobic Bacteria** live without oxygen. This type can form a layer on the tank wall which if not treated can start to grow in layers until it is millimetres thick. In pipelines it can grow enough to restrict fuel flow. This type of bacteria also produces acids which will cause structural damage and corrosion to steel tanks and pipes. Anaerobic bacteria can grow anywhere in the tank as it does not require water/oxygen to live. It can digest the sulphur (there is still a small amount in ULSD) in the fuel and produce hydrogen sulphide leading to a foul odour.
 3. **Bacteria growth.** In perfect conditions, each individual bacteria can reproduce or duplicate itself every 20 minutes. Based on that process a single bacteria can become almost 1.5 billion in 10 hours. Thankfully our tanks are not ideal conditions, but the bacteria can still reproduce at a rapid rate that can become a problem.
 - ii. **Fungi/moulds/yeasts.** A number of different spore types can be found in diesel and again they thrive at the water/fuel interface. They can form a dense biomass if left undisturbed. However thankfully most of them are slow growing so this would take a significant amount of time. This can eventually start to block filters and is difficult to break down and remove.
- d. **Algae.** Algae does not exist in diesel tanks despite common belief.. Algae requires light to grow and reproduce and diesel tanks are generally very dark therefore no algae can grow. Frequently fungi, bacteria and fuel degradation products clumping together are mistakenly diagnosed as algae.
- e. **Fuel degradation.** Although not commonly recognised as such, diesel does really have a best before date. In most applications where the fuel is used quickly, such as in road vehicles there are no problem. But in the leisure marine, plant and agricultural environment, fuel can sit in tanks undisturbed for many months or even years. Fuel in this environment can start to degrade and break down producing residues that will clog filters and result in poor combustion. The name for this breakdown is phase separation. In simplistic terms some of the molecules in the fuel start to separate out and clump together, where eventually the will become heavy enough to sink to the bottom of the tank. The result is a sludge in the tank and filters and fuel that does not combust



efficiently. Petrodiesel/biodiesel blending is also being blamed for making these problems more common because allegedly the blended fuel is more unstable than pure petrodiesel.

- f. **Sludge.** Sludge is not a problem in itself but a by-product of the above mentioned problems. Sludge is the layer of debris found at the bottom of the tank which is a mix of general dirt, living and dead bacteria, fuel degradation products and fungi or moulds. If there is no bacteria or fungi and the fuel is not degrading there is unlikely to be any sludge.
- g. **General comment.** If water, bacteria, fungi or fuel degradation is detected in a tank it has probably been there for some time. However there is always a risk that it came from the fuel supplier. Always buying from reputable sources will help reduce the chance of a delivery of bad fuel, but it does not eliminate it entirely. Cheap fuel from unknown sources are always a risk.

4. Symptoms and Consequences.

- a. **Symptoms.** The symptoms of bad fuel are also mistaken for symptoms of engine problems, and the first assumption is nearly always that the cause is something mechanical. Regular testing of fuel tanks will help eliminate many of the problems associated with diesel engines. When there is confidence in the fuel, diagnosing engine problems will be simpler. Symptoms that indicate a potential fuel problem are:
 - Clogged and slimy filters. Unfortunately this generally occurs in bad weather when the vessel is being thrown around. The fuel, sludge, water and bio mass all get churned up and sucked into the filters. This can frequently be the first indication of a fuel contamination problem.
 - Sludge in the tanks (although very difficult to see unless the tank is emptied).
 - Dark, hazy fuel that is difficult to see through. Good fuel should be very clear.
 - Loss of power and dropping RPM under load.
 - Excessive exhaust smoke.
 - Corroded or pitted injectors.
 - Bad smell from the fuel or exhaust. The result of anaerobic bacteria producing hydrogen sulphide.
- b. **Consequences.** The consequences of poor fuel are wide ranging from simple financial loss to total loss of vessel or loss of life:
 - Excessive fuel use due to poor fuel performance.
 - Excessive engine wear on pumps and injectors.
 - Excessive filter usage.
 - Engine failure at a critical time. Which could lead to the loss of the vessel, or loss of life in extreme conditions. Clogged filters due to contaminated fuel usually happens in rough weather when tank contents are shaken up. Engine failure even in force 6 conditions in a small boat can be frightening in the best case and catastrophic in the worst.

5. Detection. Regular checking of filters can help identify a potential problem, but a proactive approach to fuel management is a safer bet. Fuel samples can be extracted and sent to laboratories for analysis or a surveyor or marine engineer may be able to carry out the tests for you.

- a. **Visual inspection.** A visual check of the fuel when first sampled can give a good indication of any potential problems. The sample may show clear evidence of water or contamination such as the sample shown below.

- b. **Water detection.**

Regular checking for water in the tank can help eliminate some of the problems before they occur. Water testing is simple to carry out with a dipstick and water detecting paste. If water is detected it can be treated early to help eliminate other problems. Yachting Worldwide Ltd



Surveyors routinely check for water in the tank as part of a full survey.

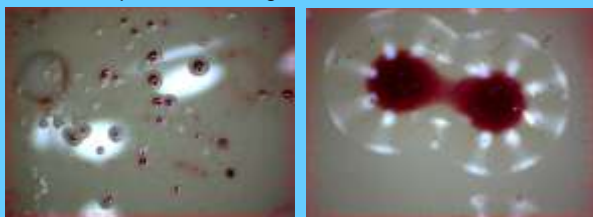
- c. **Bacteria and Biological Detection.** Bacteria, moulds, yeasts and fungi can be detected in a number of different ways.
- Laboratory analysis.** Samples can be taken and sent in sterile containers to a specialist laboratory for analysis. This generally takes 1 to 2 weeks after acquiring a test kit.
 - Culture test.** A specialist dip slide test can be carried out by your surveyor or marine engineer. Yachting Worldwide Ltd takes samples on site and puts them through a test regime, where any bacteria or fungi is incubated and cultured over a 5 day period. The cultures are then assessed and a report provided based on the findings. The slides shown below were taken from the contaminated sample of fuel shown above while the control slides were taken from the clean fuel sample.

Bacteria contaminated dip slide from a fuel sample.

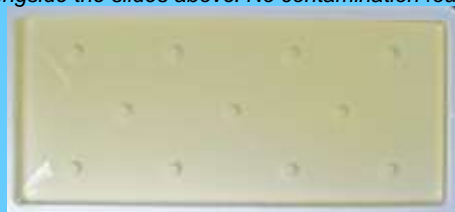
Each red spot on the slide represents a colony of bacteria. This test slide indicates 10^4 colony forming units per millilitre, or slight infection.



Close ups of bacterial growth from the slide above.



Control slide taken from clean fuel sample and incubated alongside the slides above. No contamination found.



Fungus contaminated dip slide from a fuel sample.

The bubbles appearing on the side show fungal/yeast growth is present. A large area of mould is seen growing on the right of the slide. This slide indicates heavy infection.



Close up of fungal and mould growth from the slide above.



Control slide taken from clean fuel sample and incubated alongside the slides above. No contamination found.



- Immunoassay test.** This is similar to a pregnancy test kit but takes multiple samples. The test can give a result on site within 10 minutes. The downside of this test is the cost which is over 3 times as much as a dip slide test. Yachting Worldwide Ltd surveyors can also carry out this test at the clients request.
- d. **Phase separation.** There is no simple, inexpensive on site testing for phase separation of fuels. If testing is required it should be sent to a specialist laboratory. However if a sample is taken and it looks cloudy or hazy then there is a good chance fuel degradation is taking place.

6. Treatment. The best treatment is prevention. Always buy from reputable sources. Don't be embarrassed to ask a fuel supplier or marina when they last tested their tanks for water or contamination.

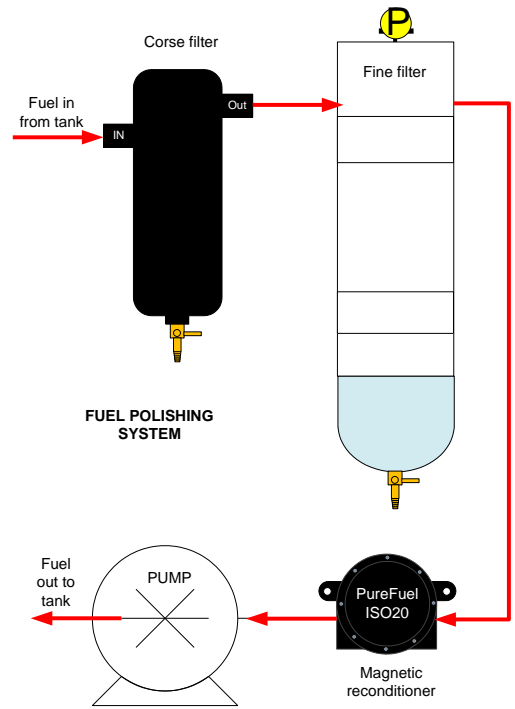
- a. **Water Contamination.** Water can be removed by the following methods:
- Chemical additives.** These can be added to the fuel to encourage the water to break down and be absorbed into the fuel and then burnt through combustion. This will remove water in a dissolved or emulsified state but is not efficient for free water.

- ii. **Water absorbing materials.** There are a variety of products on the market that generally look like a large fabric sausage that can be lowered to the bottom of the tank where they will absorb water but not fuel. They are suitable for removing free water but not dissolved or emulsified water.
 - iii. **Pump or siphon.** Put the suction end of a pipe in the lowest point of the tank and siphon out the contents until all free water is gone and only fuel is coming through. Best method if there is a significant amount of free water in the tank before treating with other methods. This does not remove dissolved or emulsified water.
 - iv. **Fuel polishing.** Fuel polishing will remove all water, dissolved, emulsified or free water providing it can be sucked from the tank. Explained in more detail below.
- b. **Biological Contamination.** The method used depends on how heavy the contamination is. The usual methods are:
- i. **Biocide fuel additives.** There are a variety of biocide additives that can be mixed with fuel to kill biological contamination. Once dead it will be filtered out by the fuel filters. The normal process is a shock treatment with a concentrated dose to kill the bulk of the contamination. This is followed by a lower preventative dose when refilling the tank to prevent regrowth. However if there is a heavy biofilm on the tank walls only the outer layers of bacteria will be killed and repeat shock dosing may be required.
 - ii. **Fuel polishing.** Removes biological contamination by filtration. If a magnetic fuel conditioner is fitted it will disrupt the life cycle of any living bacteria that pass through the system for at least 28 days.
 - iii. **Manual cleaning.** If the tank has heavy biological contamination, it may have to be drained then mechanically cleaned to remove the biofilm from the walls and pipes. This would normally be done in conjunction with a biocide treatment on refilling or fuel polishing.
- c. **Phase Separation.** This can be treated either by use of a fuel additive or by fuel polishing. For tanks used for long term storage a dedicated fuel polishing unit can be installed to automatically treat the fuel.
- d. **Treatment Methods.** The treatment methods available are shown in more detail below:
- i. **Additives.** There are a variety of fuel additives on the market for treating fuel problems. Some are more effective than others. In cases of heavy contamination it is better to opt for fuel polishing rather than additives. If additives are used whatever is in the tank has to pass through the filters and injectors to be removed. Some are designed to treat specific problems only, and some are designed as complete treatments. It is important to read the label to ensure you have the right product for your problem.
 - 1. Fuel enhancer/conditioner/stabiliser. Generally designed to boost fuel performance and will help with phase separation problems. Will not normally treat biological problems. Most contain cleaning agents to clean the fuel pumps, injectors and combustion chambers.
 - 2. Biocides. If it is a biocide only, it will only kill the biological contamination without improving the fuel or getting rid of water.
 - 3. Water removal. There are standalone chemicals designed for removing the water and sometimes they are combined with fuel enhancers.
 - 4. Multipurpose fuel treatments. There are a number of additives that will re condition the fuel getting rid of phase separation problems, will kill bacteria and fungi and help disperse water. The by-products still end up in the filters or being burnt in the engine. The effectiveness of multipurpose additives can vary.
 - 5. Other additives. There are a host of additives on the market that are designed primarily to improve fuel performance, reduce emissions and increase MPG. These are designed to improve cetene numbers and clean injectors and engines. Most of these additives are designed for a specific purpose as stated on the package, but many sales people will sell them as a “cure all” for any fuel problem. Read the package and ensure it clearly states that it will cure a particular problem before purchasing. If it doesn’t say it on the box it won’t do it.



- ii. **Fuel polishing.** A process known as fuel polishing can be used to clean and recondition the fuel. This process involves pumping the fuel out of the tank and through a special filtration unit to remove water, biological contamination and sludge. This is a specialist service that requires not only the equipment but the knowledge to use it effectively. The fuel is generally cycled from the tank through the filtration unit and back into the tank. The fuel must be cycled through the system a number of times to be effective unless a standby tank is used while the main tank is cleaned. To give a thorough clean the fuel can be pumped into a standby tank while the main tank is then mechanically cleaned before putting the reconditioned fuel back into it. This is the most efficient method of treating fuel problems because the water, biological contamination and sludge in the fuel is totally removed. Fixed polishing units can be installed on tanks to automatically process the contents on a regular basis.

- iii. **Tank cleaning.** If the tank has extremely heavy contamination it may be prudent to mechanically clean the tank after removing the fuel. This is a good idea with older tanks to ensure that existing contamination doesn't get passed into the newer fuels which are more susceptible to it. After cleaning the tank, only clean or polished fuel should be put in to it.



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