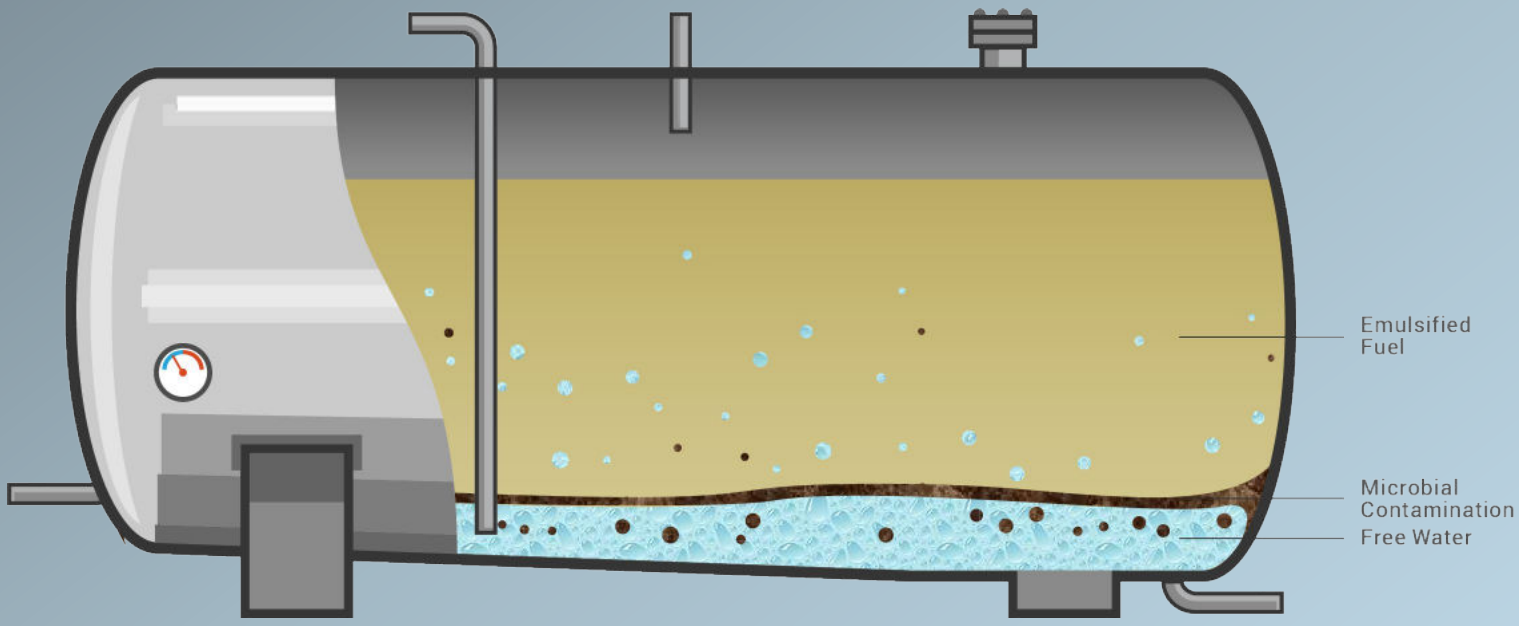
Conidia Bioscience



WHITE PAPER:

Guide to the Effects, Detection and Removal of Water in Diesel Fuel Tanks

Water in fuel tanks poses a serious risk to engine performance, lifespan and safety of stored Diesel fuel tank systems. Changes to fuel chemistry to meet environmental objectives can worsen these potential issues.

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Background

Fuel stored for prolonged period in storage tanks combined with certain environmental conditions such as hot and humid temperature or large temperature swing between seasons present the right condition for the generation of water via condensation, with the potential for the generation of microbiological growth, tank corrosion, poor efficiency, and engine failures.

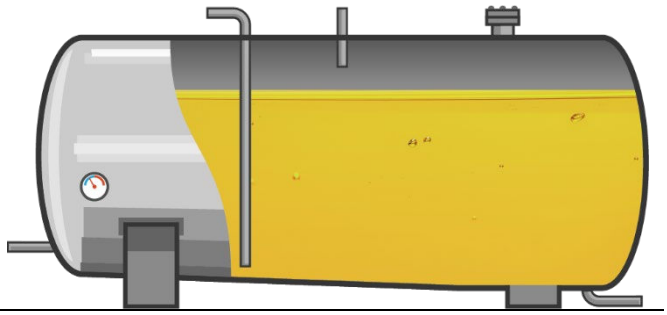
Fuel Performance

The stability and quality of fuel from time of production until it is consumed is critical to equipment performance. To ensure stability and quality, the fuel total water content must be monitored and controlled.

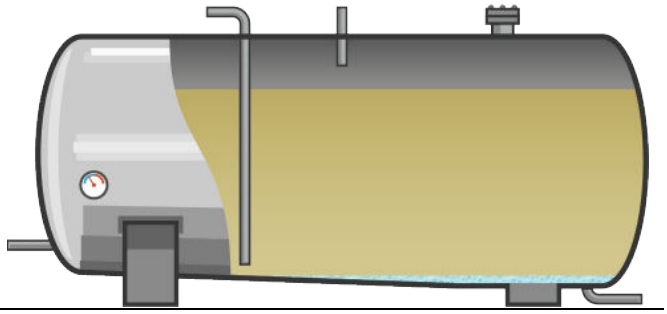
This is key to a healthy fuel handling process. The presence of excess water will deteriorate the fuel, promote microbial contamination, affect fuel performance, and deteriorate storage tanks, filtration system and ultimately the equipment in which it is used. Preventing tank precipitate and free water generation by controlling the total water content is the cure for fuel quality.

The Process of Water Ingress into Fuel Tanks

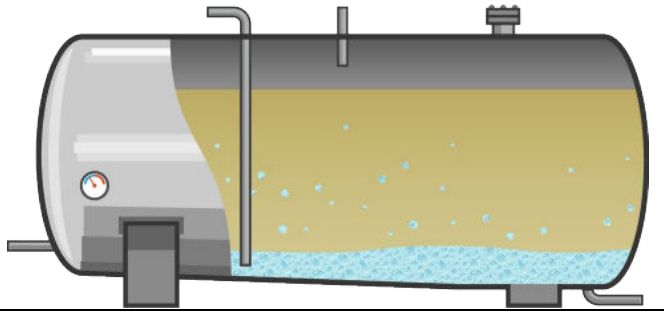
1. Fuel is delivered on-spec “clear & bright” and filled into a clean fuel tank.



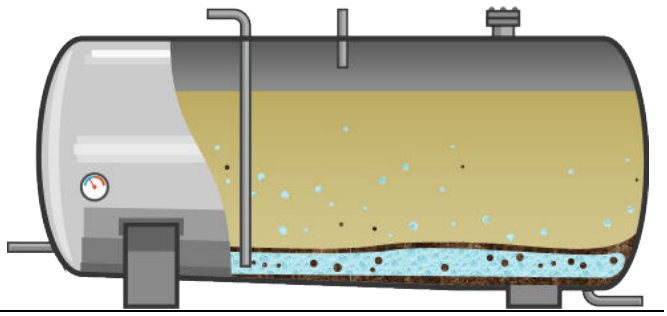
2. Through a combination of high air humidity, condensation, bad fuel quality delivery and tank leaks, water enters the fuel as both free water, or emulsified/bound within the fuel.



3. As the fuel reaches the saturation point for emulsified water, any additional water generated into the tank will settle as free water at the bottom of the tank, since fuel is less dense than water.



4. Microbes (e.g. “diesel bug”) require the presence of water to grow and feed on the fuel. This microbial contamination causes the formation of biomas predominanently at the fuel/water interface, as well as waste material (sludge) at the bottom and sides of the tank



Microorganisms are invisibly small organisms that are everywhere in nature. They are present in your fuel system in the likes of spores and bacteria. They will grow and develop in mixed communities over time if proper environmental conditions are created. These conditions are not limited to the following but are aggravating factors: low turn-over of stock, tanks not being filled for prolonged period which will allow condensation and free water to accumulate at the bottom of the tanks, no regular drainage of water-bottoms and regular verification or testing of the fuel.

The Impact of Microbial Contamination in Fuel Tanks

There are many possible outcomes from contamination in fuel systems:

- Filter plugging
- Pump failures
- Plugging of small orifices and lines
- Sluggish response of servo-valves and equipment having small orifices
- Nozzle fouling
- Engine stalling
- Sealant and elastomeric materials being deteriorated
- Epoxy material being deteriorated
- Corrosion of tank floors, sidewalls, and tubing
- Fiberglass material being deteriorated

Biofouling of Fuel in Storage Tank



These situations are combined with direct impact on fuel properties such as:

- Appearance, i.e., not being Clear & Bright
- Acidity number
- Oxidative stability
- Viscosity and viscosity index,
- Water separability

Fuel Tank Corrosion



It is essential therefore for companies to adopt a fuel maintenance programme that not only monitors and addresses the effects of these contamination issues, but also the cause of these problems in the first place, i.e. water in fuel.

Be Aware of the Impact of Changes to Fuel Chemistry

In order to contribute to the global reduction of CO_2 emissions, a great effort over the last two decades have been placed in changing the chemistry of fuels. However, increased bio-content in fuels also increases the ability to entrain emulsified water within the fuel.

The chemistry of some of these new bio-components has different characteristics and can react differently in presence of environmental element such as water. Biodiesel molecules are more polar, hence have greater affinity with water rendering the fuel more susceptible to water retention.

The nature of its chemistry can provide a challenge in keeping emulsified water at bay. The picture below shows clean diesel fuel with and without free and emulsified water.

Dissolved water in diesel fuel | Free water in diesel fuel | Emulsified water in diesel fuel



Fuel Specifications and Total Water Content

Different fuel specifications will have significantly varying saturation points for emulsified water in fuel.

ASTM D975 and EN 590 diesel fuel specifications is designed to not exceed 200 ppm of total water content. Biodiesel (B6-100) specifications such as ASTM D7467 and ASTM D6751 specifies a 500 ppm maximum, however due to the chemistry of biodiesel (FAME); biodiesel blends can absorb up to 25 times more moisture than petroleum diesel.

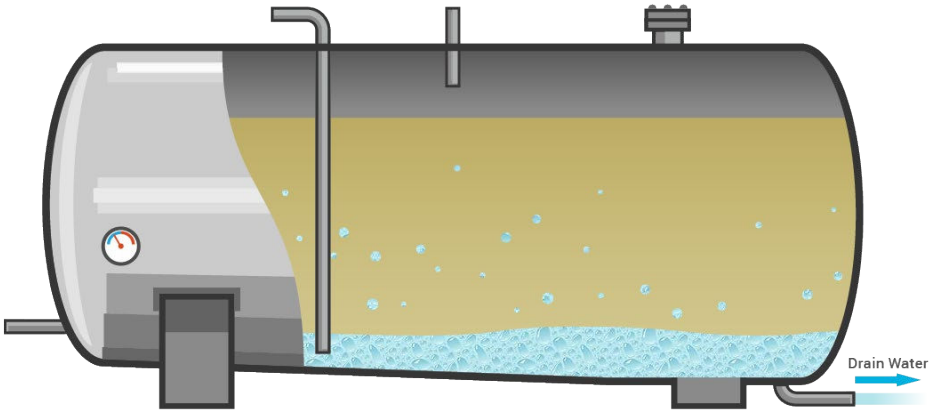


Further information can be found in the White Paper: **"Protecting Equipment from Microbial Contamination When Changing Fuel Chemistry"**[1]

[1] https://conidia.com/white-paper-protecting-equipment-from-microbial-contamination-when-changing-fuel-chemistry/

Testing for Water

In fuel, water may be free water at the bottom of the tank beneath the fuel, emulsified water (small droplets in suspension may make fuel hazy), or suspended water (so finely dispersed as to be invisible to the naked eye).





Detection of Free Water

Regular draining from the lowest point in the fuel tank is the easiest method for both detection, and removal, of free water from the fuel tank. In most cases a sample taken in this way can be left to settle and a clear separated layer of water would be seen.

Detection of Free Water (Using Water Finding Paste). The procedure for the Detection of Free Water test is to apply water finding paste (as per directions on package/container) to the bottom end of a dip stick, (approximately 15 to 20 cm) and insert the dip stick until it reaches the bottom. The length of the paste discolouration indicates the depth of the water in the tank. The paste changes colour in the presence of water. Water finding paste, does not detect emulsified, or water-alcohol mixtures.

Detection of Emulsified Water

Samples should also be taken regularly from within the mid-level of the fuel stored in the tank to check for the presence of emulsified water in the fuel.

Visual Inspection. Although Visual inspection is one of the simplest procedures in the quality control of fuels, it is also one of the best indications of suitability for use. Failure of this inspection indicates that the fuel is unsuitable and points to a breakdown in fuel handling equipment or procedures. The method for this inspection consists of two parts: visual colour and clear and bright.



- "Clear" assesses particulate contamination and means the absence of visible particles, sediment, solids, or dye (unusual fuel colour). Clear fuel has no floating or suspended matter.
- "Bright" assesses water contamination and means no water present either as liquid in bottom, drops on jar or haze (air bubbles causing haze usually clear within one minute after drawing sample).

Aquafighter® Dipstick Indicator. A simple and quick test method is to lower an Aquafighter® Dipstick Indicator into the tank to check for free or emulsified water content.

Emulsified water tests. For a more accurate answer these samples can be either sent to a laboratory, or some equipment have entered the market for the mobile measurement of total water content. Both should give a result for the parts per million (ppm) content for water in your fuel, this should be checked against the fuel specification to check that it is below stated limits for use.

Testing for Microbial Contamination

Since microbial contamination requires the presence of water to grow, samples for testing should be collected when performing water draining from the bottom of the fuel tank.

pH test indication. If present, microorganisms will concentrate in the water phase. Typically, this will render the water more acidic. One quick indication of bacterial infection is to assess the pH of the water phase. Using a pH sensitive paper assess the pH level, if the water as a pH value lower than 3, this can be indicative of microbial concentration.



Visual Inspection. Fungi (i.e. yeasts and moulds) typically grow at the water/fuel interface, when taking samples, you should visually assess for the presence of biofilms or biomasses while conducting the Clear & Bright test.

Neither of these methods will provide a conculsive answer to the presence of microbial contamination in your fuel

FUELSTAT® test kits. Traditionally, fuel testing methods have depended on fuel samples being sent to laboratories for analysis. Sending the fuel samples away for testing isn't simple. ASTM D6469 highlights that if a sample is to be tested for microbial contamination and cannot be tested on-site, it should be transported on ice and tested within 24hrs, or the sample may no longer be a true representation of the environment from which it came. Delays cause varying results which may cause an increased risk to your asset.

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FUELSTAT®: the simple on-site test

FUELSTAT® is a simple on-site test to detect microbes that thrive and do damage in fuels with a total time from start to production of detailed electronic report in 15-30 minutes. Advanced lateral flow testing technology means that FUELSTAT® is the only true on-site test that gives dependable results even in the dirtiest of conditions.

Unlike most other tests, FUELSTAT® test kits can be used at the tank, wherever it is located. The process is self-contained, requiring no additional equipment—just a single FUELSTAT® One fuel testing kit for each test. It's so easy to use, that a single individual can carry out the tests with only minimal training. Added to which, the FREE FUELSTAT® Result app will guide users through the whole process with simple to follow step-by-step video instructions.



The total process for FUELSTAT® is four easy steps and is very suitable for solo working. All equipment needed for the test is included in the test kit, barring a clean sampling container. The online training videos can be viewed on your smartphone before conducting the test. The test itself is simple and can be conducted under wing. All the tester has to do is put four drops of sample fluid into each test well.

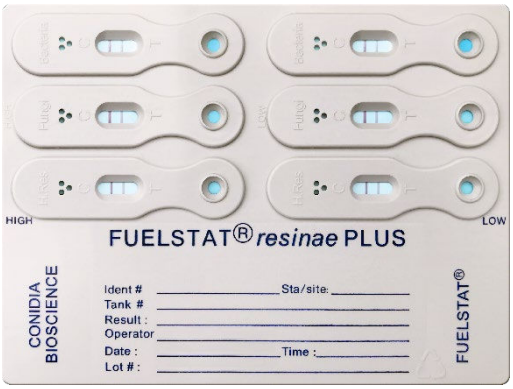
FUELSTAT® Result is an app available on iOS and Android that verifies the result and users have option of saving results to a central portal for record keeping and longer- term analysis. It makes the

use of FUELSTAT® a 100% paperless exercise cutting down both on cost, time taken and potential mistakes.

This all translates to FUELSTAT® being the most accurate, fastest and most simple test on the market. Treating microbial contamination at the earliest stage is both good practice and good business and FUELSTAT® helps all users and suppliers to ensure this.

FUELSTAT® is now available in 2 variants giving extra choice to fuel management operators:

FUELSTAT® Plus



FUELSTAT® Plus is an immunoassay antibody lateral flow fuel test kit for microbe detection.

FUELSTAT® Plus test kits target only specific micro-organisms that do damage to fuel. The tests are read by eye, but can be verified using the FUELSTAT Result app.

With FUELSTAT® Plus, tests take as little as 15 minutes, with easy-to-understand alert levels, you instantly know whether you need to take further action.

NEW FUELSTAT® One



FUELSTAT® One test kits are a new innovation in lateral flow fuel testing for microbe detection.

FUELSTAT® One test kits are a simpler, smaller format, advanced design which detect a broader range of microbial contamination found in fuel.

The test is designed to be read by the FUELSTAT Result app to provide a fully quantitative test result and report in just 20-30 minutes.

For more information visit: www.conidia.com/fuelstat

SOLUTIONS FOR THE CONTROL OF WATER IN FUEL TANKS

As with most situations, prevention is always better than cure. Operators should be aware of the importance of maintaining stored fuel tanks in conditions where water ingress cannot occur and that steps are taken to keep fuel on-spec, below stated ppm water levels. A regular test regime should be instigated, with swift and thorough remedial action taken.

Fuel filling

When receiving a delivery of fresh fuel a Certificate of Analysis (CoA) or Delivery Note report should be obtained from your supplier reporting the tested water content of that fuel batch to ensure that it is below specified water concentration. Where this is not possible a sample of fuel should at least be visually inspected to ensure that it is “clear & bright”. If supplying into an empty tank then the tank should be visually inspected for any signs of contamination or corrosion and throroughly clenaed if necessary prior to fuel filling.

Fuel levels ideally should be maintained at near full levels to reduce the volume of air within the tank, which may lead to condensation occuring.

Contaminated fuel

If the results of tests show the presence of either emusified water, free water and/or microbial contamination then the follow steps should be taken immediately:

Free water. All free water should be removed from the bottom of the tank, this is ideally achieved via a drain port sited at the lowest point of the tank. If there is no suitable drain point then this water can be removed via a scavenger drain pump with the extraction tube aimed at the lowest point in the tank (It is recommended that drained water is tested for microbial contamination).

Emulsified water. Water emulsified within the fuel can be removed over time with the installtion of Aquafighter® water removal filters. This negates the need to drain, dispose of and replace this fuel, at significant expense (see next section).

Microbial contamination. This can be removed by a combination of fuel polishing filtration and the use of appropriate biocides, if they are available. It should be noted that heavy contamination usually requires the complete draining and thorough cleaning of fuel tanks to remove the sludge waste material and prevent re-growth.

Treatment and Prevention of Water in Fuel using Aquafighter®

Aquafighter® is effective in reducing and removing water inside the fuel tank. These uniquely work by removing both **free** and **emulsified** water from the fuel.

Aquafighter® filters actively remove bound, suspended and emulsified water out of diesel fuel directly in the tank and keeps it water-free at all times. This is accomplished through 3 indispensable actions that are necessary to achieve the desired fuel purity and consequently provide tank protection:

- **Demulsifies water** by physico-chemical adsorption of water molecules to less than 65ppm total fuel water content with maximum efficiency. (Aquafighter causes water to release naturally from fuel and it achieves this without adding to or altering the fuel, unlike certain fuel additives would do. After market additives can cause corrosion themselves)
- **Attracts & Captures water** immediately upon release from the fuel molecules
- **Isolates water** in its protective gel to permanently segregate it from the fuel & tank environment so your fuel & tank is protected at all times. (Aquafighter will encapsulate the water preventing corrosion, microbial growth & re-emulsification until it is removed from the tank)Aquafighter® products come in various sizes and shapes to adapt to tank-size openings and tank configurations.

Aquafighter® filters consist of a reinforced filter membrane containing a specially formulated polymer powder which chemically absorbs the water, swelling in size to the maximum capacity of the filter, with indication by changing colour to a dark reddish-pink. Aquafighter® is designed to sit partially suspended from the bottom of the tank to absorb any trace of free water that might be present in addition to the emulsified water.

Aquafighter® is both a prevention insurance and a remedial tool for water issues. For optimum stored fuel quality it is advised to install an Aquafighter® into all new fuel tanks when clean fuel is delivered, keeping the fuel on-spec, water and contamination free.

Aquafighter® products are available in a range of sizes and configurations, each with a different maximum water capacity to suit different tank sizes and openings, some of the Aquafighter® products can capture and remove up to 60 litres of water.



For more information visit: http://www.conidia.com/aquafighter

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Aquafighter® tank opening & product fit guide



Tank Capacity / Tank Opening	0-100 L 0-25 US gal	100-500 L 25-125 US gal	500-1000 L 125-250 US gal	1000-1500 L 250-400 US gal	1500-2000 L 400-525 US gal	2000-5000 L 525-1250 gal	5000-10000 L 1250-2500 gal	10000-15000 L 2500-4000 gal	15000-20000 L 4000-5250 gal	20000-30000 L 5250-8000 gal	30000+ L 8000+ gal
38-90mm 1.5-3.5"	Finger (0-12 months)										
50-100mm 2-4"	Finger (0-12 months)	Snake (0-12 months)	Snake (0-6 months) Twin Snake (0-12 months)	Snake (0-4 months) Twin Snake (0-8 months) Triple Snake (0-12 months)	Snake (0-3 months) Twin Snake (0-6 months) Triple Snake (0-9 months) Quad Snake (0-12 months)						
90-150mm 3.5-6"	Anaconda (0-24 months)					Anaconda (0-12 months)	Anaconda (0-6 months) Twin Anaconda (0-12 months)	Anaconda (0-4.5 months) Twin Anaconda (0-9 months)	Anaconda (0-3 months) Twin Anaconda (0-6 months)		
150-300mm 6-12"	Medium Canvas (0-12 months) Large Canvas (0-24 months)					Medium Canvas (0-6 months) Large Canvas (0-12 months)	Large Canvas (0-6 months)	Large Canvas (0-4.5 months)	Large Canvas (0-3 months)		
300-600mm 12-24"	Large Canvas (0-24 months)					Large Canvas (0-12 months)	Large Canvas (0-6 months)	Large Canvas (0-4.5 months)	Large Canvas (0-3 months)	Fuel Station Mat (0-12 months)	2+ Fuel Station Mats (0-12 months)
600mm+ 24"+							Fuel Station Mat (0-24 months) Depot				

- Check the opening size of the tank first, and then the capacity of the tank. Choose an Aquafighter that suits your maintenance schedules.
- The period shown is the maximum time that the Aquafighter should be left in place between changes.
- These are estimates and needs could differ based on fuel quality, tank conditions and fuel quantity.

Choosing the correct size Aquafighter® for your tank

A wide variety of filter sizes are available, from long and thin to fit through smaller diameter tank ports, to larger format filters suitable for installation through the top manhole tank inlet. Check the opening size of the tank first, and then the capacity of the tank. Choose an Aquafighter that suits your maintenance schedules.

Note: The period shown is the maximum time that the Aquafighter should be left in place between changes. These are estimates and needs could differ based on fuel quality, tank conditions and fuel quantity.

Understanding the type of fuel you are using, its capacity for water entrainment, and the on-spec specifiaction for ppm of that fuel, gives you an even greater control of the correct size Aquafighter® filter for your tank. Since any free water should be drained completely from the tank before installation of your Aquafighter®, your calculations should be based on the potential maximum quantity of **emulsified** water within a full fuel tank.

Aquafighter®	Designed for	Maximum Water Capacity*	50% Water Capacity
Finger	small machines and tanks	0.2 litres	0.1 litres
Snake	machines, boats and tanks	0.5 litres	0.25 litres
Twin Snake	machines and tanks	1 litres	0.5 litres
Triple Snake	storage tanks	1.5 litres	0.75 litres
Quad Snake	storage tanks	2 litres	1 litres
Anaconda	machines and tanks	4 litres	2 litres
Twin Anaconda	fuel stations and other large tanks	8 litres	4 litres
Medium Canvas	storage tanks	2.5 litres	1.25 litres
Large Canvas	storage tanks	4.5 litres	2.25 litres
Fuel Station Mat	fuel stations and other large tanks	40 litres	20 litres
Depot	depot and terminal tanks	60 litres	30 litres

*Note: the above figures are for maxium water capacity for each filter. Aquafighter® filters should be replaced when they have reached 50% of their maximum capacity to ensure that they are working efficiently at all times, keeping fuel free from emulsified and free water.

Here are 2 examples showing the appropriate filter sizing based on the total potential water content:

Tank Size	Diesel Fuel (<200 ppm water)*		Biodiesel (<2000 ppm water)*	
	Potential Water Content	Aquafighter®	Potential Water Content	Aquafighter®
100 L	20 ml	Finger / Snake	200 ml	Snake
500 L	100 ml	Finger / Snake	1 L	2 x Twin Snake
1000 L	200 ml	Snake	2 L	2 x Triple Snake / 2 x Quad Snake / 2 x Medium Canvas
1500 L	300 ml	Twin Snake	3 L	Twin Anaconda / Large Canvas
2000 L	400 ml	Twin Snake	4 L	Twin Anaconda
5000 L	1 L	Quad Snake / Anaconda / Medium Canvas	10 L	2 x Twin Anaconda / Fuel Station Mat
10000 L	2 L	Anaconda / Large Canvas	20 L	Fuel Station Mat
15000 L	3 L	Twin Anaconda / Large Canvas	30 L	Fuel Station Mat / Depot
20000 L	4 L	Twin Anaconda	40 L	2 x Fuel Station Mat / 2 x Depot
30000 L	6 L	Fuel Station Mat	60 L	2 x Depot

Notes: *200 ppm ~ 0.2 ml/L *2000 ppm ~ 2 ml/L

For the Biodiesel example where multiple filters are shown, only one product should be installed at a time, but should be monitored and changed when the filter has exceeded 50% of its water capacity.

Who we are

Conidia Bioscience research, design, develop, manufacture and globally distribute innovative solutions for maintenance of fuel systems. Our products are designed to offer practical and easy to use, industry leading solutions to both maintain and monitor the stored fuel in your system, whether that be a fixed ground installed diesel fuel tank, or in an aircraft wing. Through simple steps of ensuring water doesn't develop within stored fuel, and instant testing at the tank, we keep fuel contamination free and ready to use, avoiding costly remedial action and fuel system failures.

FUELSTAT® fuel tests are developed, manufactured and marketed by Conidia Bioscience Limited. Based in UK, Conidia Bioscience Limited was founded in early 2000's by experts in immunoassay techniques and holds the internationally patented intellectual property for FUELSTAT®.

Conidia Bioscience manages the global distribution of Aquafighter® water removal filters for Diesel and middle distillate fuels.

Where to find us

FUELSTAT® and Aquafighter® are distributed globally by a network of specialist distributors covering the major sectors. Contact info@conidia.com who will arrange for a distributor to support you.

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