



BIODIESEL, PARTICLES AND FUEL FILTER BLOCKING



Who We Are

Fuel Additive Science Technologies Limited (FAST) formulates, blends and distributes fuel additives under the exocet[®] brand and as own-brand products for a wide range of customers.

Our fuel additives use tried and tested chemistry and methodology from the world's most reputable suppliers.

Our staff includes recognised oil and fuel industry professionals of long-standing, with experience in fuels science, refinery processes and chemicals manufacture.

Our Philosophy

Whilst we don't expect to make all our customers and end-users into fuel scientists, we want them to understand, in the simplest terms, what are the potential problems, the actual problems, the possible solutions and the overall benefits of our products.

In this respect we are happy to use a bottom-up, field-based approach – indeed, experience has shown us that this is the best way for us to learn what the real issues are and how to overcome them.

We need our products to work for you – you need to see the benefits, whether these be technical or economic. Any claims we make, therefore, will be realistic, achievable and repeatable; and are based on the science.

What We Offer – What Are Fuel Additives?

Fuel additives are blends of one or more chemical compounds having a specific quality enhancement functionality related to either fuel storage, fuel handling or fuel combustion. They are typically added at low volumes measured in parts per million.

Adding chemicals to fuel in order to achieve a "different" or "desired" performance is a branch of the oil industry that goes back 100 years. It is not a new concept and need not be viewed with the scepticism that it is in some quarters. Only the very cheapest road fuels do not contain an additive "package" and, via the Worldwide Fuels Charter (see later), the majority of the world's engine and vehicle manufacturers now prescribe the use of additives to ensure that their equipment has the best chance of meeting the stringent performance and emissions controls being imposed.



What Happened in 2019?

Adding biodiesel (fatty acid methyl ester - FAME) to petroleum diesel as a means of increasing the renewable content of the fuel and advancing the green credentials of all the interested parties has been happening for some time. The FAME content of road diesel (EN590) has been steadily increasing for more than 10 years and until 2019 was typically in the range 4-5% by volume.

Historically, red diesel (BS2869:A2) contained only marginal, if any, volumes of FAME.

Both the on-road fuel standard (EN590) and the off-road fuel standard (BS2869:A2) allow for up to 7% by volume of FAME to be added. This standard was set in 2011 and has not changed.

Running in parallel to the fuel standards is the Renewable Transport Fuel Obligation (RTFO). This is the government's requirement of the fuel supply industry to include increasing volumes of renewable content in the UK's fuel pool – collectively both diesel and petrol. The expectations are as per the table below:

YEAR	RTFO RENEWABLE VOLUME (%)
2011	5.75
2018	7.25
2019	8.50
2020	9.75
2032	12.40

This does cause some confusion given that the maximum volume by the diesel and gas oil fuel standards is 7%, for example. The balance is made up by the volume of ethanol added to petrol as renewable content and the double counting of any recycled product used e.g. used cooking oil. Fuel suppliers can also pay for exemption certificates.

Regardless, in 2019 the need to comply with the RTFO became an industry imperative, and fuel suppliers – refiners and import terminals – pushed the FAME content towards its maximum permitted limit.

This was not so much of an issue in road diesel (EN590), where the turnover is relatively high and operators have been used to the higher FAME content for some time. For off-road fuel (BS2869:A2), however, the sudden increase in the FAME content caused many problems over a number of months nationwide with the main tangible issues being fuel starvation and equipment downtime resulting from fuel filter blockages. FAST was intimately involved in investigating the causes from the very earliest reports. The findings have proved very interesting and the fuel additive solutions cost-effective and sustainable.



Fuel Filter Blocking

Via our routine customer fuel quality management service, we saw a surge in field problems reporting fuel filter blocking in vehicles using red diesel (gas oil BS2869:A2). Initially the problems were confined to south east England, especially East Anglia, but the Bristol area and south Wales soon followed and then a line along the M4 corridor. Ultimately, the problems spread to the north east of England, Cumbria and much of Scotland over a seven-month period.



Over 100 fuel and fuel filter samples were received. Initially, the filters appeared black in colour after only a short time in operation.



In time, the fuel filter samples received varied in colour from black to brown to light brown, some had a sticky deposit.

The filter residues and deposits were analysed by FAST and by an external laboratory in order to chemically identify the material causing the fouling.

Results found the materials on the filter surface contained an unusually high amount of sterol glucosides and monoglycerides. FAST also identified stearic monoglyceride on a number of filters.

Biodiesel Precipitates

Sterol glucosides and monoglycerides are natural materials found in biodiesel (FAME) derived from plants. Once they have precipitated out of the fuel, these compounds will not readily dissolve back into solution with the bulk fuel unless the temperature is raised to around 40°C. Precipitation of sterol glucosides and monoglycerides is accelerated at lower temperatures, but, as experienced in 2019, can also occur at typical ambient temperatures during summer months.

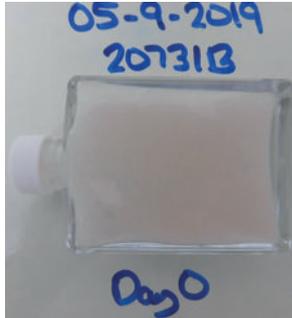
After much discussion with industry partners and further research, FAST concluded that the most likely cause of the spate of fuel filter blocking issues was the agglomeration of these FAME component precipitates. Although rumours of inappropriate blend regimes and a batch of "bad" FAME persist, it is still not clear why the precipitation was occurring and why some fuel suppliers were affected and not others, but our aim became (and still is) to provide additive solutions that be used to treat the problem and prevent it occurring.

Fuel Testing

Most of the fuels tested by FAST were found to be clear and bright with no free water or sediment present and, critically, met the fuel standard for gas oil in all respects (as below).



Clear and bright with no free water or sediment visible



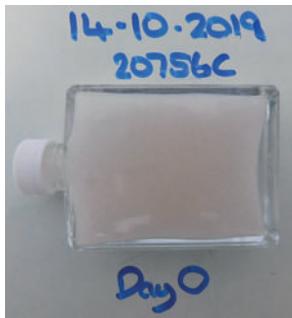
No microbiological growth observed



Approximately 15% of the fuels tested were in poor condition by appearance alone - they had free water and sediment visible and microbiological growth was observed in the sample. See below - hazy with free water and sediment present. 4,000,000 colony forming units/L of microbiological growth.



Hazy with free water and sediment visible



Microbiological growth observed; 4,000,000 cfu/L



It was concluded that for these 15% of fuel samples that were in poor condition, then filter blocking may have been due to microbiological growth and/or particulate and water contamination resulting from poor storage conditions.

As the fuel filter blocking issues became more widespread and fuel samples were continually being received without any obvious or consistent divergence from specification, FAST began to routinely measure the particle count distribution. This is analysed and reported using ISO4406 – in general, the lower the numbers the 'cleaner' the fuel.

Particle distribution analysis is only recently being phased into the EN590 standard and is not yet part of the BS2869:A2 standard. The hunch on the part of FAST to carry out this analysis did reveal a stark difference between fuel with filter blocking issues and problem-free fuel.

FAST uses a laboratory reference gas oil (Sample No. 20690); it contains 5.4% FAME (biodiesel). The table below compares some of the test results: total contamination, particle count code, FAME content and appearance, between our laboratory reference fuel, 20690, and five gas oils with filter blocking problems.

SAMPLE NO.	FUEL TYPE	APPEARANCE	FAME CONTENT [%]	TOTAL CONTAMINATION [MG/KG]	PARTICLE COUNT [ISO 4406 CODE]
20690	Gas Oil	Clear & bright	5.4	5.9	17/14/09
20731B	Gas Oil	Clear & bright	5.5	14.5	22/20/16
20739	Gas Oil	Clear & bright	6.7	12.6	21/20/16
20743B	Gas Oil	Clear & bright	6.5	15.2	20/18/14
20829	Gas Oil	Clear & bright	6.1	15.5	21/19/15
20734	Gas Oil	Clear & bright with free water and sediment visible	6.2	29.4	20/19/15

Sample No. 20690 is FAST laboratory reference fuel. The other fuels were being used in vehicles with filter blocking problems.

Sample No. 20734 had microbiological growth present due to the free water and both contaminants contributed to the total contamination result, which put the fuel outside the fuel standard. This fuel sample is an example of one of the 15% that were causing fuel filter blocking due to fuel contamination from poor storage conditions.

Sample Nos. 20731B, 20739, 20743B and 20829 (and Sample No. 20690, lab ref. fuel) are **within the fuel specification**.

The difference between the four fuels reported as causing filter blocking issues and the lab reference fuel lies in the total contamination and particle count results.

Clean gas oil typically has a total contamination result <6mg/kg. Particle count is not part of the fuel specification, but the Worldwide Fuel Charter 2019 (WWFC 2019) recommends a maximum value (ISO4406 code) of 18/16/13 for modern low emission engines.

Note. WWFC 2019 recommends a maximum value of 10mg/kg for total contamination. BS2869:A2 and BS EN590 have a maximum of 24mg/kg for this test parameter.

To this end, our experience at FAST now is to use total contamination and particle count results as a primary indication of the potential of a fuel to cause filter blocking due to precipitation of biodiesel components.



FAST exocet® Fuel Additive Field Trials

With this knowledge, FAST supplied dispersant-containing fuel additives for customers to carry out field trials with end users who were experiencing serious fuel filter blocking issues. At this stage it was still unclear if an acceptable solution could be found and degrees of intuition and faith came to the fore.

The field trials were immediately very successful and exocet® Sludgebuster (XO1067S) became the first additive recommended to treat the problem.

It also became apparent during 2019 that those customers who had been routinely using exocet® Gas Oil Supreme (XO1249G0) prior to the FAME content increase, did not experience any fuel filter blocking issues even though their near neighbours were. exocet® Gas Oil Supreme (XO1249G0), exocet® Gas Oil Conditioner (XO1258G0) and exocet® Diesel Supreme (XO1964D) became the additives recommended to prevent the problem by routine addition to the bulk fuel.

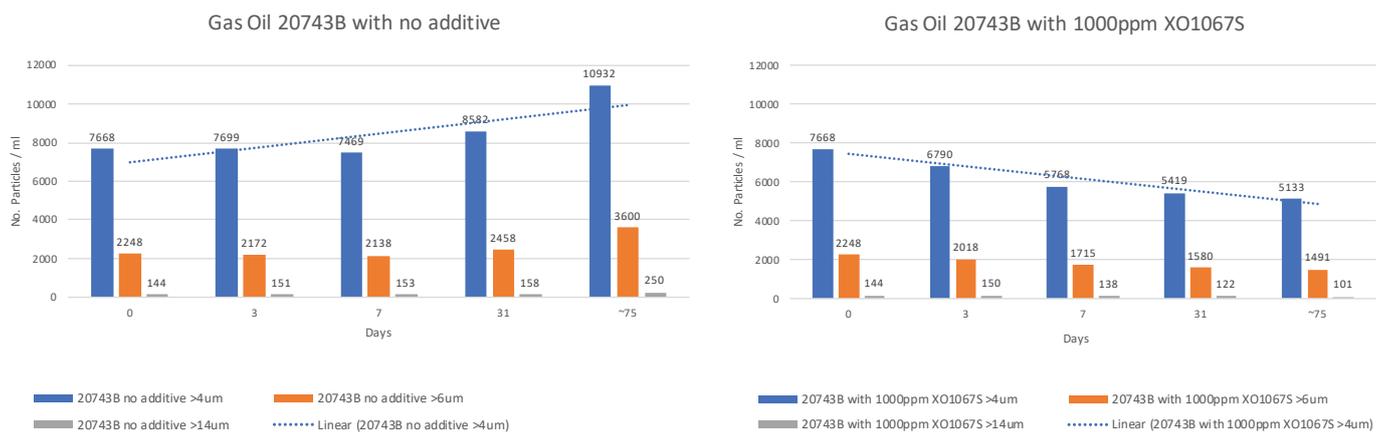
Additional Laboratory Testing

Samples that had been received in August 2019 were re-visited in December. Some were now found to be hazy in appearance, having been recorded as “clear & bright” initially. This indicated a solid material was precipitating out of the remaining fuel sample.

Particle Counting Tests (IP 565)

As a result of the observations above, a test was started to measure particle count during storage at room temperature over a period of time; one sample was stored in a clean vessel in the dark as received and one was treated with exocet® Sludgebuster and stored under the same conditions.

Results of Particle Counting



The first graph shows that the total number of particles **increased** during storage at room temperature. The second graph shows that with the addition of exocet® Sludgebuster the total number of particles > 4µm **decreased** over the same period under the same conditions. This simple test indicates that the dispersant effect of the additive has broken up the particles and prevented agglomeration during storage.

The conclusion we draw is that stored fuel, containing relatively high levels of FAME, continues to precipitate ‘particles’ over a short time frame and that these are unlikely to re-dissolve, leading to precipitate build-up in vehicle fuel tanks and bulk fuel tanks having the potential to cause fuel line and filter blockage fairly quickly. This can be alleviated (and even improved) by the addition of a dispersant-containing additive.

Filter Blocking Tendency Tests (IP 387)

Filter Blocking Tendency (FBT) is a parameter that is part of the EN590 standard applied during the winter months. The maximum value is 2.54 (no units).

A gas oil sample containing “bad” FAME was tested for FBT with and without exocet® fuel additives. The results are in the table below.

SAMPLE NO.	FUEL	ADDITIVE	DOSAGE [PPM]	FBT	FBT (REPEAT)
20829	Gas Oil	None	0	2.69	n/a
“	“	Sludgebuster	1000	1.6	1.53
“	“	Diesel Supreme	500	1.56	1.49
“	“	Gas Oil Supreme	500	1.69	1.69

The results show that the fuel containing the “bad” FAME had an FBT value higher than the winter maximum in the EN590 fuel specification. Use of exocet® fuel additives brought the FBT down to well below the maximum limit of 2.54.

FAST’s particle count and FBT work is now continual as we build a more complete picture of the characteristics of fuel from various sources in order to assess storage, handling and performance properties. We are also working to optimise our fuel additive recommendations.

Our results so far demonstrate that a well formulated fuel additive, containing dispersants, will prevent agglomeration of precipitated FAME (biodiesel) particulates, keeping them small and dispersed in the fuel and able to flow through the fuel filters, thus maintaining equipment operability.

Importantly, FAST’s fuel additives also contain a deposit control additive to protect fuel injectors and keep them clean.



exocet® Fuel Additives

FAST's exocet® fuel additives containing dispersants and deposit control additives, which prevent or inhibit the agglomeration of biodiesel components, leading to free-flowing fuel are:

exocet® Sludgebuster X01067S

- a concentrated product, used to treat an existing problem
- for the rapid dispersal and breakdown of already-formed 'clumps' of precipitate
- works best if circulated or stirred
- might have to accept 2-3 filter changes until the problem is cleared
- use only once before moving onto regular use products as below

exocet® Diesel Supreme X01964D

- regular use additive formulated for on-road diesel and having a high dispersant and deposit control content
- to be used in off-road fuel and on-road fuel when a high level of protection against FAME precipitates is required and allows fuel to meet the injector cleanliness parameters of the WWFC 2019
- will prevent agglomeration of particles and subsequent filter blocking

exocet® Gas Oil Supreme X01249G0

- regular use additive formulated for off-road diesel
- contains dispersant and deposit control chemistries
- will prevent agglomeration of particles
- provides protection against FAME precipitates AND allows fuel to meet the (injector cleanliness) fuel flow parameters of the WWFC 2019

exocet® Gas Oil Conditioner X01258G0

- used for low turnover fuel and fuel stored for more than 6 weeks
- regular use additive formulated for low throughput off-road diesel
- contains dispersant and deposit control chemistries
- will prevent agglomeration of particles
- provides protection against FAME precipitates AND allows fuel to meet the (injector cleanliness) fuel flow parameters of the WWFC 2019

These exocet® additives will treat and prevent filter blocking problems caused by precipitated biodiesel (FAME) particulates. FAST recommends the use of a 10µm filter on all bulk storage tanks.

The Economics - Replacement Filters vs. Fuel Additives

exocet® fuel additives, at the recommended dose rates, add around one penny to the price of a litre of fuel.

In this context, we ask you to consider the following:

- the price of new fuel filters for your vehicles
- the price of new filters for your bulk fuel storage tanks
- the labour charge to change these filters
- the number of times fuel filters were changed during the peak of the crisis
- the cost of downtime
 - people
 - lost production

FAST suggests that no matter what your volume of fuel use, using fuel additives regularly is far more cost-effective than continually replacing filters.

Product Summary

exocet[®] Sludgebuster X01067S

- Rapid solution to filter blocking issues caused by biodiesel dropout
- Contains concentrated hydrocarbon detergent
- Lifts and breaks down sludge in fuel tanks

1L treats 1,000L fuel



exocet[®] Diesel Supreme X01964D

- Prevents and disperses agglomeration of biodiesel precipitates that cause filter blocking
- Cleans and maintains injector and fuel system cleanliness and prevents corrosion
- Increases cetane number for smoother power delivery
- Reduces emissions

1L treats 2,000L fuel



exocet[®] Gas Oil Supreme X01249G0

- Prevents agglomeration of biodiesel precipitates that cause filter blocking
- Maintains injector and fuel system cleanliness and prevents corrosion
- Raises cetane number in-line with EN590
- Reduces emissions

1L treats 2,000L fuel



exocet[®] Gas Oil Conditioner X01258G0

- Prevents agglomeration of biodiesel precipitates that cause filter blocking
- Maintains injector and fuel system cleanliness and prevents corrosion
- Raises cetane number in-line with EN590
- Reduces emissions
- Stabilises fuel for longer storage
- Prevents microbial growth in a clean system

1L treats 2,000L fuel





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