

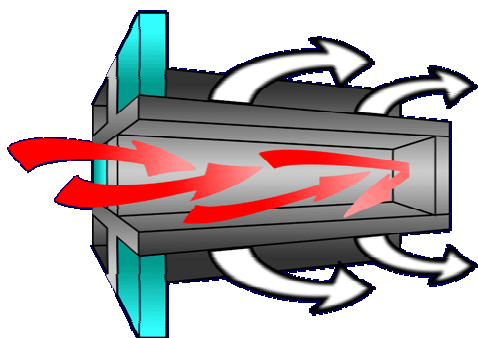


A guide to filter technology selection

Diesel Particulate Filter (DPF) technologies are well proven and highly effective in their ability to filter carbon particles. So called "wall flow" filter structures based on various extruded ceramic materials such as Cordierite or Silicon Carbide, commonly achieve in excess of 95% total particulate mass reductions.

Significantly, particle count or particle number reductions usually achieved by DPF's exceed 99%. In health benefit terms this adds strongly to the argument to apply filters to even modern engines. Though much has been achieved in engine design improvements to reduce total particle mass output, the application of filter technologies significantly reduces particle number output and in particular sub micron sizes of carbon particle.

Unquestionably, filters are very effective at removing soot (carbon) particles, from a diesel engine exhaust stream and can be easily packaged within the confines of a replacement exhaust silencer. More interesting questions centre on the methods employed to ensure that the filter is self cleaning during vehicle operation. This process is often called filter regeneration.



Filter regeneration methods

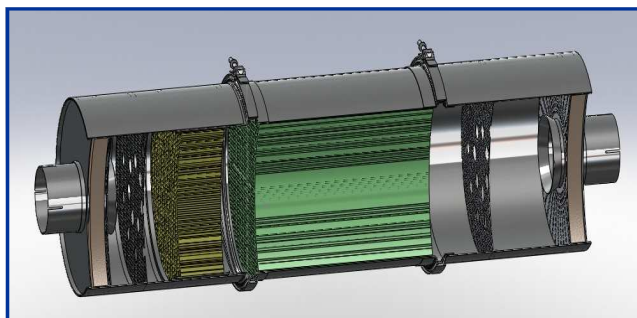
In basic terms, filter regeneration is the combustion of collected soot (carbon) particles collected within the filter during the operation of the vehicle. In full oxygen conditions without the presence of a catalytic reaction, carbon combustion occurs at approx 600°C. All filter regeneration strategies find means to combust collected soot at lower levels of temperature.

Most commonly one or more of three methods are employed, the first two being considered within these notes :-

1. Passive filter regeneration using "gas exchange" catalytic techniques
2. Fuel borne catalyst assisted regeneration
3. Active regeneration (several methods possible including Hydrocarbon injection or electrical heating elements)

1. Passive filter regeneration using gas exchange techniques

Often called a "continuously regenerating filter" or trap, this method is often considered to be a neat solution to filter regeneration as everything happens passively. With frequent high exhaust temperatures, the oxidation activity of a catalyst can ensure that soot particles combust as they are collected in the filter.



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Typically a highly active precious metal coated oxidation catalyst is positioned in advance of a ceramic wall-flow filter (various materials can be used). As the exhaust flow enters the inlet chamber, it hits a diffuser plate which distributes the gas evenly through a first stage or pre catalyst. This highly active, precious metal coated catalyst oxidises the CO and HC into CO₂ and H₂O, virtually eliminating them from the exhaust gas.

Importantly, in temperature ranges from 260 to 400 °C the pre catalyst also oxidises some of the NO to NO₂. Subsequently the wall-flow filter collects the particulate matter and trapped soot is continually oxidised by the NO₂, removing it from the exhaust gas. This is the key to the of soot collected by this type of filter system.

Continuously regenerating filters are an excellent solution for vehicles working regularly within higher operating temperature duty cycles, such as trucking vehicles or high load applications. This being so as these vehicles will typically experience frequent excursions to high exhaust temperatures and where average exhaust temperatures exceed 260° for 40% or more of the operating duty cycle.

Catalysed filter variant for gas exchange technologies

In the more demanding lower temperature applications a catalytic coating can also be applied to the filter itself. This is often called a Catalysed Continuously Regenerating Filter (cCRF). Adding a coating to the filter itself can extend the capabilities of gas exchange filter types, to cover a wider range of operating conditions, with lower exhaust temperatures or NO_x:PM ratio.

In the catalysed filter variant, after the NO₂ has reacted with soot particles trapped in the filter producing NO and CO₂, some of the NO is re-oxidised to NO₂ which then further reacts with any soot remaining in the filter.

Additionally zone coating of the filter can be added such as a base metal catalytic coating, which will further help to reduce the external emission of NO₂, which would be undesirable.

Supplier guidelines vary for the application of catalysed continuously regenerating filters. Astra cCRF filters are recommended for applications working with the following conditions:-

Temperature requirements for passive operation:-

Peak temperature	: 390°C or above
Ave cycle temperature	: 215°C or above
Time above 350°C	: 5% (recommended)
Time above 300°C	: 20%
Time above 240°C	: 30%

2. Fuel borne catalyst assisted filter regeneration

Typically the fuel borne catalyst assisted regeneration filter system (FBC DPF) consists of two major components, the high efficiency filter (DPF) and an FBC dosing and control system.

A fuel borne catalyst (FBC) regenerated filter system will normally utilise only a silicon carbide (SiC) filter material, due to the high thermal durability of this material. An FBC regeneration strategy employs a simple filter structure as it requires no precious metal catalyst substrate within the silencer. However, the filter itself can be catalytically coated if preferred, in order to specifically target gaseous emissions.

An FBC DPF utilises a fuel borne liquid catalyst injected into the fuel stream as it feeds the engine, to aid regeneration of the filter. FBC is injected into the fuel via a dosing system and a supply of liquid catalyst stored on board the vehicle. Initially, FBC aids the combustion process within the cylinder, reducing the total burden of soot produced and ensuring that only catalysed soot enters the filter.

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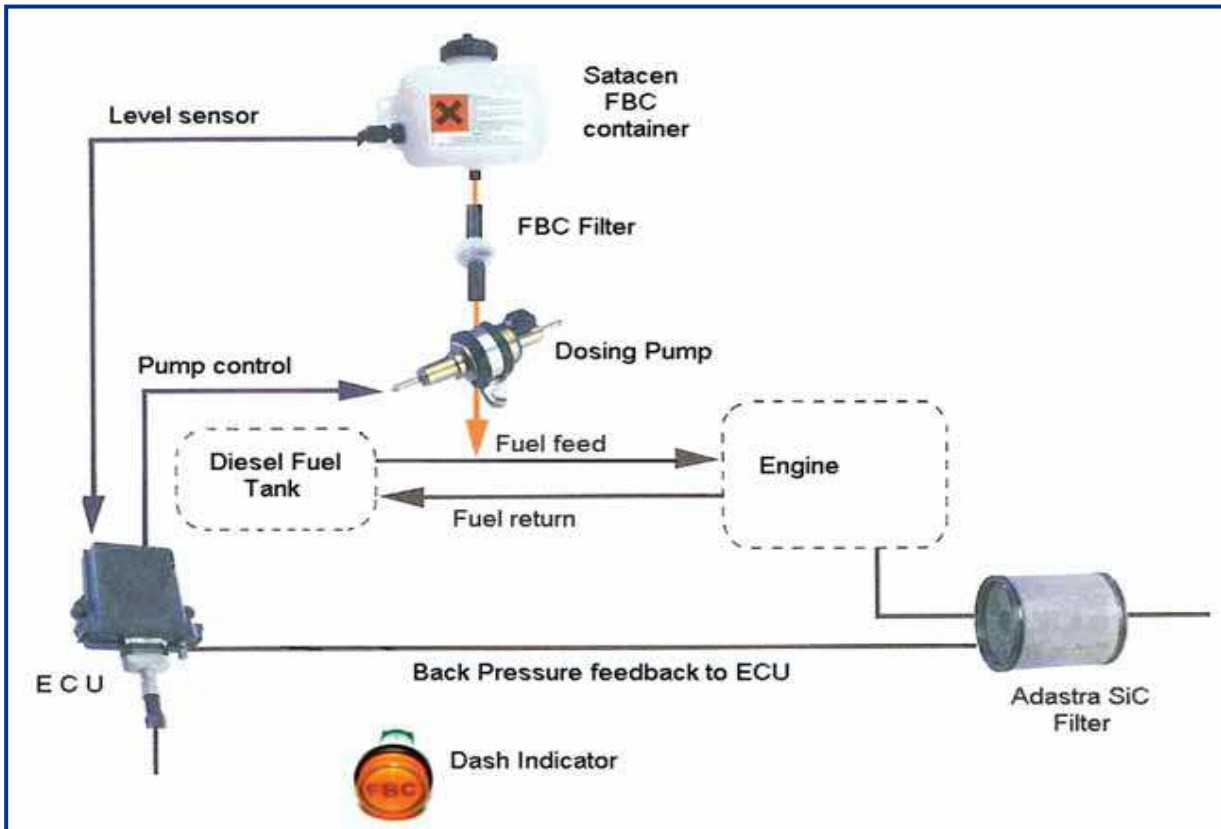
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Soot pre-catalysed with FBC will then combust at significantly lower temperature than would otherwise be possible. FBC DPF systems have been successfully employed on duty cycles where more than 80% of the operating cycle time is spent at lower than 250°C exhaust temperature.

FBC DPF systems are not described as continuous regeneration. Catalysed soot is stored within the filter until an excursion to temperature of approx 370°C occurs. As the catalyst used to combust the soot is not dependent on temperature of the exhaust for its production and is always present, the temperature of the duty cycle to which these systems can be applied is nevertheless wider than gas exchange systems.

Active regeneration for FBC assisted regeneration strategies

FBC based regeneration system employ electronic monitoring of back pressure and temperature. All Adastra FBC DPF systems employ secondary twin glow plug heaters which act as a secondary "active" trigger to aid filter regeneration following a period of low temperature operation. Glow plugs provide a localised high temperature heat source, sufficient to ignite pre catalysed soot, in order to achieve filter regeneration. Electronics store data on back pressures and temperatures which can be downloaded for duty cycle review.

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FBC Consumption

FBC is consumed during the operation of the vehicle at varying rates dependent on the system applied. However, the **Adastra** FBC DPF utilises Satacen 3 FBC which is an Iron/Strontium based catalyst, dosed at a rate of 1 litre FBC : 2200 litres of fuel consumed. Thus running costs are dependent on vehicle usage.

FBC Costs

- ✦ Assuming a 50,000 mile per annum average vehicle usage and
- ✦ Assuming a 13MPG average fuel consumption figure,
- ✦ FBC costs on average equate to:
- ✦ 1st year : £0.0018 per mile – as first fill included in sale price
- ✦ Thereafter : £0.005 per mile *

Conclusions

Choosing a filter technology appropriate to a specific vehicle application should be a more complex consideration than installation cost and convenience. The vehicle duty cycle has to be considered and understood in order to select a system type, exactly in the same manner as one would consider the type of tyre one would select, when comparing high speed with off highway service.

Ignoring duty cycle considerations can potentially result in filters providing shortened service intervals or blocking of the filter through insufficient temperature to regenerate. Selection should therefore be based on an informed understanding of the vehicle duty cycle.

Whilst much has been learned in the application of filter systems in the past, a careful approach should nevertheless be adopted and in mixed service circumstances Astra would recommend erring on the side of caution by employing an FBC based system. Alternatively involving a data logging exercise to map the exhaust temperature conditions, can help to verify the suitability of particular technology.

* as at 2010 prices

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