Technology Update

Cleaning of exhaust gases
from diesel engines using
silicon carbide ceramic filters

StobbeDPF

Exhaust gases from diesel engines are known to contain particles contributing to unacceptable high death and illness rates amongst the population in the industrialised world.

Serious efforts are made by manufacturers of diesel engines to reduce contaminating emission in the next generation of engines, but the most effective and fastest way to alleviate the problem is to install diesel particle filters (DPF).

LiqTech is proud to present this Technology Update on the latest development of our program for DPFs.

For several years LiqTech has been pioneering the development of silicon carbide (SiC) based DPFs, and today we are able to present a complete range of filters for all sizes of engines and duties.

Through cooperation with complete system suppliers the filters are produced both as retrofit and as original equipment.

LiqTech is working with some of the worlds leading suppliers of fuel born catalysts and solid catalytic systems for DPF. We offer cost effective filters with maximum rejection of particulate matter and reduction in exhaust gasses.

Our filters have been tested in many locations worldwide and have proved to comply with the general regulations in the field.

Through the development of the Stobbe DPF it is the ambition of LiqTech to contribute to a cleaner and better living environment.

Lasse Andreassen
Managing Director
LiqTech ApS

List of content

1 **Introduction**
2 **Background**
2 **The Stobbe filter**
2 Design characteristics
3 Filter sizes
4 Dimensioning
5 Catalytic coating
5 *Wash coat*
5 Stobbe filter benefits
6 **Why diesel?**
6 **The challenge**
6 Air pollution from diesel engines
7 Legislation
8 **Diesel particulate filters**
8 Regeneration
8 Environmental benefits
9 Operational considerations
9 *Engine wear*
9 *Noise attenuation and muffler warranty*
9 **Diesel filter construction material**
9 Cordierite
10 Silicon Carbide
10 *History*
10 *SiC Hexoloy*
11 **Areas of application**
11 **Track record**
11 Caterpillar excavators
12 London taxis
13 **Summary**

Introduction

The awareness of diesel engines as the cause of microscopic particles in diesel fumes has increased considerably during the last years.

A large number of investigations have pointed out the serious health consequences caused by particles from diesel engines.

Diesel particulate filters (DPFs) are devices installed in diesel engine vehicles that collect particulate matter without obstructing the flow of exhaust gas or damaging the vehicle.

A variety of technologies can be installed along with a DPF to reduce the amount of harmful exhaust gasses emitted.

The silicon carbide (SiC) based filters were developed by the Danish company Stobbe Tech A/S together with DTU, the Danish Technical University. Today, the filters (Stobbe filters) are produced and marketed by LiqTech ApS in Denmark.

The Stobbe SiC DPF provides the most durable filter available on the market today with high soot load capacity and a design, which allows regeneration at low temperatures. In cooperation with some of the major suppliers in the world for complete systems the Stobbe DPFs are applied to the widest range of vehicle types and ages providing significant environmental benefits and cost-effective operation.

The filters, which have replaced the muffler on some vehicles, can be installed as a retrofit or can be included as original equipment.

▸ A selection of our products

Background

Diesel fuel account for around 40% of all road fuels worldwide and roughly 25% of that is burned in urban areas. In France diesel is fuelling nearly 1/3 of all motorcars and virtually all trucks have surpassed gasoline as the dominant energy source. While the role of diesel as an efficient fuel has been questioned for automobiles in Europe, it certainly is the case for heavy vehicles that diesel occupies a position challenged only by compressed natural gas in a few markets for urban busses. Yet there are danger signs about the health effects of diesel exhaust and diesel's contribution to air pollution. This concern has been paramount in the USA, particularly in California. Recent studies also show that black carbon emitted by diesel engines and other combustion sources may also be contributing to global warming.

In an article in the highly esteemed British magazine the Lancet (September 2000) it is pointed out that in Austria, France and Switzerland, approx. 40.000 death on an annual basis can be related to pollution from vehicles corresponding to 6% of total mortality. In addition vehicle pollution was thought to have caused 300.000 incidents of bronchitis and 500.000 incidents of asthma.

The Stobbe filter

Design characteristics

The so-called Stobbe filter, originally designed by Stobbe Engineering in Denmark, is of the Wall Flow Filter type (WFF) produced with honeycomb geometry. In this geometry, the porous walls of the honeycomb act as the filter barrier, which retains the particulate material from the diesel exhaust gas. The honeycomb geometry gives a high filtration area per unit volume. This advantage is also used in the well known catalyst carriers for ordinary gasoline driven automobiles.

The particulate material mainly consists of carbon particles, but a small amount of ash from the lubrication oil is also present. The carbon particles are agglomerates of very small particles, of which a large part is breathable, and since they contain a large amount of hydrocarbons, the soot from the diesel exhaust has adverse effects on the health. The SiC diesel filters are able to retain more than 90% of the soot.

▸ A scanning electron microscopic picture of the silicon carbide structure on a monolith

After collection of the soot, the filter needs to be cleaned. This can be done using several methods, but usually, the filter is heated to a temperature, where the soot ignites at approx. 550 °C for the un-catalysed reaction, depending on oxygen content in the exhaust gas, and the soot simply burns to carbon dioxide and water. SiC has a very high decomposition temperature (above 2000 °C) and has long time stability in oxidizing atmosphere up to temperatures above at least 1400 °C. This is an advantage, since the working temperature of a diesel filter can be as high as 800-1400 °C for short periods of time. For comparison, another material cordierite melts at 1360 °C. Such high working temperature will, however, never occur due to the high heat capacity of SiC.

Together with Adastra, an Octel compagny, LiqTech has developed a SiC trap in combination with the fuel born catalytic regeneration technology using the Octel Octimax™ catalyst. This makes it possible to regenerate the filters at a temperature below 300 °C.

As another advantage, SiC has a very high thermal conductivity, approx.

10 W/mK for the porous material. Other types of ceramic materials (for example cordierite) with the same porosity, have thermal conductivities of less than 1 W/mK.

The thermal property of the filter material is important mainly because the soot burn-off process produces heat, which needs to be dissipated also throughout the filter body. If the thermal conductivity is too low, local „hot spots" arise, which in combination with fuel born catalysts, are known to create a eutectic, a situation where small amounts of the inorganic ash melt and block the filter surface. The high heat capacity and conductivity of SiC filters basically prevents the occurrence of hot spots.

The pores of the Stobbe filter are relatively large giving the filters the unique combination of in depth bed filtration and surface filtration with excellent permeability.

Our standard retrofit DPF filter program is designed with 40% porosity, 2 x 2 mm cells with 0.8 mm wall thickness, and 90 cpsi (cells per square inch). LiqTech also supplies DPFs with 150 cpsi, which has a reduced pressure drop across the filter element. The 150 cpsi elements are especially suited for new and smaller engines.

▸ Cross section of a Stobbe filter with seven sections and a volume of 23 litres

Large filters are segmented in order to avoid thermal stress caused by regeneration. The individual filter elements are bonded together with a flexible ceramic fiber bonding material.

The diesel filters have been tested on a laboratory diesel engine dynamometer in many locations around the world. Among other tests during the development are: bending strength testing, measurement of thermal conductivity, test of oxidation and corrosion properties at high temperatures, test of gas permeability, porosity measurements and measurements, of filtration efficiency.

Filter sizes

The Stobbe filter is manufactured in sizes from 1.0 to 40 litres in volume. The filter diameter is ranging from 80 mm for the smallest size to 381 mm for the largest size.

▸ A selection of different sizes of SiC based diesel filter elements with capacity up to 40 litres

Item #	Filter volume [Litre]	Diameter [mm]	Length [mm]	Diameter [inches]	Length [inches]	Number of sections
80010	1.0	80	205	3.2	8	1
80029	2.8	118	254	4.66	10	1
80030	3.3	118	305	4.66	12	1
80035-1	2.5	144	154	5.66	6	1
80037	3.3	144	205	5.66	8	1
80050	4.4	190	154	7.5	6	4
80060	5.8	190	205	7.5	8	4
800802	6.3	228	154	9	6	7
80080	8.4	228	205	9	8	7
800801	9.3	228	228	9	9	7
80100	10.4	228	254	9	10	7
80120	12.5	228	305	9	12	7
80130	12.9	254	254	10	10	7
80150	15.5	254	305	10	12	7
80170	16.4	286	254	11.25	10	7
80200	19.6	286	305	11.25	12	7
80230	22.8	286	355	11.25	14	7
80300	29.0	381	254	15	10	9
80350	34.6	381	305	15	12	9
80400	40.0	381	355	15	14	9
Length of square element is variable from 100 to 500 mm						
80540	8.8	140x140x450		5.5x5.5x17.4		1

90 cpsi (cells per square inch)
Cells 2 mm x 2mm for deep bed filtration with
20 – 25 µm pore size and 40% porosity

▸ Physical dimensions of the entire filter program

Material Specifications CPSI coding	90	150
Pore size [µm]	20-30	6-12
Porosity [%]	≈ 40	≈ 40
Air through wall permeability [10^{-12}/m² Darcy] at 20°C	0.70	0.40
Thermal conductivity [W/mk] at 25°C	≈ 40	≈ 40
Thermal conductivity [W/mk] at 650°C	≈ 15	≈ 15
Specific heat [J/kg/K] at 25°C	750	750
Specific heat [J/kg/K] at 800°C	1250	1250
Weight gained after 10.000 hours use in air at 1000°C	low	low
Weight gained after 10.000 hours use in air at 1200°C	low	low
Weight gained after 10.000 hours use in air at 1400°C	low	low
Expansion/radial [10^{-6} °C^{-1}] at 25°C	4.2	4.2
Expansion/radial [10^{-6} °C^{-1}] at 650°C	3.9	3.9
Thermal shock parameter, TSP 3	85-750	160-1400
Long life maximum temperature in air [°C]	1200	1200
Modulus of elasticity E [GPa]	50	50
Poisson's ratio [v]	0.10	0.10
Compress strength, longitudinal Qa [MPa]	50	60
Bending strength [MOR/a MPa]	> 40	> 50
Bending strength [MOR/b MPa]	1.70	3.20
Bending strength [MOR/c MPa]	2,6	4.9
Specific weight, wall density [gram/cm³]	1.8	1.8
Monolith weight, bulk density [gram/cm³]	0.92	1.43
Electrical resistance [ohm x cm]	1-2	1-2

▸ Specifications of the SiC material used for the construction of the carrier of the DPF filters

▸ SiC 2.5 and 3.3 litre filters with friction band. 144 mm Ø and 154/205 mm length

▸ SiC 8 - 23 litre filters, 7 sections

▸ Relation between the filter volume and the engines displacement

Square configurations are also available with a cross section of 140×140 mm and length variable from 100 to 500 mm.

In the table on page 3, the physical dimensions of the entire filter program is illustrated.

The standard configuration is based on 90 cpsi with a soot load capacity of >18 gram/litre, but LiqTech also supplies filters with 150 cpsi in sizes from 2 to 23 litres in volume with a soot load capacity of 12 gram/litre.

LiqTech is able to manufacture larger sizes upon requirement tailored to any length or diameter required.

In the top left table the specifications for the SiC material, used for construction of the carrier of the DPF filters, are illustrated.

Dimensioning

Selection of the appropriate size and type of Stobbe filter is done by using the left chart to select the filter volume based on the type and size of engine.

For more exact dimensioning information please contact LicTech.

Catalythic coating

Coating of filters with catalytically active coatings is used to lower the regeneration reaction temperature. The non-oxide ceramic SiC exhibit properties very different from the oxide ceramic monolith materials. LiqTech has excellent experience in producing SiC WFF with pore size of 23 µm. The pore size is determined by the composition of the mixture of SiC used in the extrusion process. The important pores, as manufactured by LiqTech, are created during the extrusion process, prior to the firing process, giving advantages such as:

- Pore size easier selectable
- Pore size distribution very narrow
- No loss of pores during firing
- No dead-end pores created during firing

Wash coat

A good gaseous phase oxidation catalyst is dependant on wash coat thickness often in the range of 20-60 µm, porosity, surface, etc. Wash coating the Cordierite flow-through monolith wall surface will block most of the pores causing no problems for the oxidation catalyst system. Wash coating a WFF is a challenge as blocking or decreasing the size of the important filtrating pores will increase the monolith pressure drop.

As an alternative to catalytic coating the fuel born catalytic system offers several benefits because a low regeneration temperature can be achieved without coating the filters with a solid catalyst.

Stobbe filter benefits

The Stobbe filters provide excellent properties for filtration of exhaust gas from diesel engines, and LiqTech offers a very comprehensive program of filters of different sizes for any desirable duty.

Some of the key benefits of the Stobbe filter are summarised in the table below.

More than 95% of the particulate matter is removed, and by catalytic coating it is possible to achieve additional PM reduction.

Applying the fuel born catalyst system gives the additional benefit of reduction in NO_x emission. Independent tests show that NO_2 gasses are actually reduced by 20-40%, while NO_x emission is cut by 5-10%.

The lower figure , shows the pressure drop for the Stobbe filter with 90 cpsi. Tests are made on a VW 1.9 TDI engine in a SuperFlow engine test bench. The tests were carried out in CPERI at Thessalonica University in Greece.

The graph below illustrates the superior performance of the LiqTech

Stobbe filter benefits
High soot loading capacity
Soot load mass limit >18 g/litre
> 95 % soot removal of fine and ultra fine particles
High heat capacity
High heat conductivity
Suppression of high temperature peaks, hot spots and ash sintering
High durability
Relatively large pores and high permeability enables successful use of coating solutions
Suitable for fuel born catalyst systems
Suitable for catalysed DPF systems
Independent on fuel sulphur content

▸ Key benefits of the Stobbe filter

▸ Pressuredrop as a function of mass loading

product in terms of pressure drop as a function of mass loading.

Why diesel?

Diesel plays a vital role in the world's economy, quality of life and supply security, and it offers a wide range of performance, efficiency and safety benefits as an energy source. The attributes that make diesel such an effective source of power include:

- *Safety* – Diesel is a safer fuel than gasoline or other alternatives. It is less flammable and explosive than gasoline

Particulate type:	Particle size:
Course	> 2.5 µm
Fine	< 2.5 µm
Ultra fine	< 0.1 µm

▸ Particles in exhaustion gasses

- *Energy content* – Diesel fuel contains more energy per unit volume as compared to gasoline

- *Efficiency* – Today's heavy duty clean diesel truck engines get 10-30% better fuel economy than those built in the last 10 years

- *Durability* – Diesel engines are renowned for their durability, lasting hundreds of thousands of miles. This helps conserve resources

- *Continuous improvements* – Significant progress has been made in reducing emissions from diesel engines of all kinds. Thanks to new, clean diesel technologies, today's trucks and buses are eight times cleaner than those built just a dozen years ago

The challenge

Scientists and health professionals have long believed that diesel engine emissions can be harmful to human health. Several investigations connect exhaust from diesel engines with lung inflammation and tissue damage along with potentially cancerous effects. While most research has been related to the risk of cancer, recent investigations indicate a more general concern also of non cancerous effects such as irritation, inflammation, lung tissue damage, and the things that contribute to asthma and other lung diseases.

Particulates are liquid or solid constituents in the air and are of very varied origin. In industrialized countries particulates originate from private household (32 percent), industry (31 percent), and diesel engines (20 percent). A high carbon content varying between 20 and 90 percent, commonly referred to as soot, is typical of the particulates in diesel engine emissions. Such soot particulates are formed in the so-called gas phase and are caused by incomplete combustion of the fuel.

Air pollution from diesel engines

Particulates in air caused by traffic vary in size and numbers. The particulates are usually divided into three categories as illustrated in the table on page 6.

Particulates with an aerodynamic diameter less than 10 µm can be collected from the air and measured according to its mass, normally designated as PM_{10}. Since PM_{10} is based on mass, the larger particulates will carry more weight than the ultrafine particulates.

Most investigations carried out in USA and Europe describes relations between PM_{10} and $PM_{2.5}$ and health effects. However, it is also recognized today that the ultrafine particulates can be a primary cause to adverse health effects, because these particulates may escape the natural „filter" system in the organism and penetrate into the alveoli of the lungs, where they may cause coagulation of blood, which may ultimately have cardiovascular effect.

Based on these considerations, it has been calculated that reduction of particulates from diesel engines are likely to reduce illness and mortality in large cities and in densely populated areas close to highways.

A special investigation was carried out in the State of California in the USA on school buses. The State has 24.000 school buses, out of which 70% are diesel powered. It is estimated that these buses are releasing 13 tonnes of soot into the sky on a daily basis near playgrounds, class rooms and bus stops frequented by children all over the state.

These considerations has caused the state to initiate a program to reduce diesel emission by 75% by the end of this decade, partly by replacing old buses by new natural gas powered buses, and reduce emission by diesel filters on others. Nearly USD 13 million has been allocated for installation of diesel filters.

Legislation

Most countries in the industrialized world are implementing legislation to limit emission from vehicles.

During the past years, Europe and the USA adopted new legislation regulating emissions from most heavy – and medium – duty diesel engines. Regulations in the USA require reductions of more than 90 percent of nitrogen oxides (NO_X) and particulate matter (PM) between now and 2007. European regulations require NO_X reductions of 60 percent and PM reductions of more than 75 percent by 2008. The first phase of regulations in both regions will begin over the next few years.

Looking back to the 1970s and 1980s there has been a remarkable reduction in both NO_X gasses and particulates as illustrated in the two tables on page 7.

Diesel particulate filters

Diesel particulate filters are devices installed on diesel engine mufflers that collect particulate matter without obstructing the flow of exhaust gases or damaging the vehicle. A variety of technologies can be installed along with a DPF to reduce the amount of harmful exhaust gases emitted. The filters, which have replaced the muffler on some vehicles, can be installed as a retrofit or can be included as original equipment.

All of the filters operate by a similar process of forcing the exhaust gases through a porous cell and this blocks the particulate in the gases on the inflow side of the cell. Using disposable filters and regeneration are two ways to remove the particulate that builds up.

Particulate-laden diesel exhaust enters the ceramic filter, but because the cell of the filter is closed at the opposite end, the exhaust cannot exit the cell. Instead the exhaust gases pass through the many porous walls of the cell. The particulate is trapped on the cell wall. The exhaust gases exit the filter through the adjacent cell.

Regeneration

Regeneration is the process of removing the collected particulate matter by means of oxidation. There are three different methods of regeneration:

- *Catalysed passive regeneration*
  The particulate is combusted, and the gases are oxidized, if there is a catalyst present. If exhaust gases do not exceed the temperature required for regeneration (approx. 380°C) – which often happens during operation – then an additional component, like a fuel born catalyst, is necessary

- *Fuel born catalytic regeneration*
  By adding a fuel born catalyst it is possible to burn off the soot deposits at reduced temperature. The addition of the catalyst is made with a dosing system, which delivers the catalyst to the fuel at precisely the rate required to ensure reliable filter regeneration. Furthermore it automatically compensates for driving in dense city traffic or at high motorway speeds

- *Un-catalysed passive regeneration*
  The particulate is combusted as a non-catalysed reaction at high temperature (approx. 650°C). In order to facilitate the process, it is common to add a diesel oil additive, which has proven to be an effective way of securing regeneration of the filter, when no catalyst is present

Environmental benefits

Diesel particulate filters are capable of reducing more than 95% of PM by destroying both the soluble organic fraction (SOF) of PM and the carbon particulates. Together, the carbon particulates and SOF make up the majority of the total PM emitted from diesel engines; however, engine wear metals and sulphate are also present. By application of

Principle for the air flow through the DPF

▸ Air flow through a DPP showing how every second inlet/outlet is capped and build in to a muffler

fuel born catalysts, it is also possible to achieve an interesting reduction in NO_X emission.

Operational considerations

A major consideration for equipment operators is how a retrofit program will influence engine performance. Diesel filters are typically optimised for the particular vehicle application. This ensures the maximum control efficiency possible, while minimising or eliminating adverse effects of the system on the engine or vehicle performance.

Engine wear

Filter systems do not appear to cause any additional engine wear or affect vehicle maintenance. Maintenance of the system itself will be minimal, because manufacturers are designing systems to minimise maintenance requirements during the useful life of the system.

Noise attenuation and muffler warranty

In almost all cases, retrofitting with a DPF will entail replacement of the existing muffler. In this case, noise attenuation for the replacement muffler will be the same as with the stock muffler. Mufflers normally include a warranty. Typically, if a muffler is under warranty, the manufacturer of the retrofit equipment will provide a warranty for the replacement muffler for the same amount of time as remains with the stock muffler.

Diesel filter construction material

Diesel filters may be produced from a range of different materials. High quality performance is required due to the extreme operating conditions especially in terms of temperature range.

Cordierite

Cordierite is a magnesium aluminia silicate material. It's most important feature is that it has a very low coefficient of thermal expansion and excellent resistance to thermal shock. The raw material is relatively low in cost. It has good electrical insulation properties, moderate mechanical properties and temperature resistance, and can readily be formed into a variety of shapes. In particular it can be made in high volume through cost-effective extrusion or dry-pressing methods.

Silicon Carbide

Silicon carbide, SiC, is a highly wear resistant material with good mechanical properties, including high temperature strength and thermal shock resistance. It has a high hardness, only surpassed by diamond. It offers excellent chemical resistance and has

Application of DPFs
City buses
Transit buses
School buses
Large over-the-road trucks
Fork-lifts
Mobile cranes
Tractors
River-freight towboats
Rail road freight locomotives

▸ Application of DPFs

a relatively low thermal expansion and high thermal conductivity. The high thermal conductivity and high temperature resistance makes it suitable as a construction material for special types of heat exchangers, which will be exposed to severe temperature and chemical conditions and abrasive products.

History

SiC was invented more than hundred years ago by Dr. Edward Goodrich Acheson, who made the first man-made abrasive and substance hard enough to cut glass. Acheson's discovery became Carborundum, the trademark for SiC and the name given to the company he started. Today the French company Saint-Gobain has continued the traditions and has earned a reputation for providing advanced, high-tech ceramic components to worldwide markets. These markets span multiple industries, requiring materials that are resistant to extreme temperature, thermal shock, abrasion and corrosion.

LiqTech is using SiC supplied from Saint-Gobain as the raw material for its diesel filters.

SiC Hexoloy

Hexoloy is the trade name of SiC produced by Saint-Gobain. The sintered alpha SiC is produced by pressure-less sintering of ultra-pure sub-micron powder derived from the original Acheson process. The powder is mixed with non-oxide sintering aids. The sintering process results in a single-phase, fine grain SiC product, that is very pure and uniform, with virtually no porosity. Whether sub-merged in corrosive environments, subjected to extreme wear and abrasive conditions, or exposed to temperatures in excess of 1400°C, the product out performs other commercially available ceramics or metal alloys.

Contributions of diesel to key transportation activities

▸ Contribution of diesel to key transportation activities

Contribution of diesel to key industrial activities

▸ Contribution of diesel to key industrial activities

Areas of application

LiqTech has supplied filters for a wide range of applications ranging from taxis in the streets of London to heavy duty CAT excavating machines.

Some of the most common applications of DPFs are illustrated in the table, at the top of page 10.

Diesel fuel is used in our every day life and is found in almost any activity we turn to. This is illustrated in the two tables on page 10.

The tables illustrate that diesel is the major source of energy for commercial transportation and for all major industrial activities both on land and at sea.

Track record

LiqTech has supplied the Stobbe filter to a wide range of applications for heavy duty engines in Europe.

Caterpillar excavators

Caterpillar (CAT) 325 excavating machine with a 26 ton service weight is equipped with a 6.6 litre, cyl 3116 TA turbocharged after-cooled diesel engine with power of 125 kW at 2000 RPM. The smaller CAT 320, with a service weight of 21 ton, has the same 3116 T engine, without after cooling, and a power of 96 kW at 1800 RPM. Both machines have essentially the same muffler and therefore can easily be equipped with a Stobbe DPF L13-Kat particle trap. The DPF system reduces the particulates by > 95%, and gaseous emission such as carbon monoxide by as much as 90%. Hydrocarbons are reduced by 80%.

The system is based on the Stobbe F-820 ceramic monolith SiC filter with a volume of 13 litres followed by a noble metal Catox ceramic catalyst with 5 litre volume supplied by Haldor Topsøe A/S. Both ceramic units are enclosed in a AISI 304 stainless steel cylinder as the original muffler. A two layer AISI 316 compensator is mounted on the 3.5" insulated stainless steel pipe between the turbo generator and filter system in order to adsorb thermal stress in equipment and turbocharger. Therefore, it is possible to mount the equipment in less than an hour on the original muffler support without any kind of modification to the vehicle. It is important that the catalyst module is mounted after the monolith filter to protect it from soot build-up.

The DPF principle is passive and demands no daily service and can operate 24 hours a day. The system lifetime is in excess of 8000 hours.

Oxford Street

London taxis

The taxi company in London has installed DPFs from LiqTech in the London „Black Cab" taxis. The filters were supplied trough Adastra, and a system was installed for dosing the Octel Octimax™ fuel born catalyst. This enabled the cab owners to return to the streets of London, collecting fare-paying passengers and completing distances of 12.000-20.000 kilometres. The vehicles were equipped with data logging systems confirming that reliable filter regeneration could be achieved at low exhaust temperature.

In summary the benefits of installing DPFs in Black Cabs were the following:

- Mass of particulates reduced by 85-90%
- Visible black smoke eliminated

Test results for the particulate reduction

- Typically 99% reduction in number of particles
- Ultra-fine particles below 0.1μ included
- Human health benefit
- Most cost effective single PM measure for black cabs

The test results for the particulate reduction are illustrated in the figure on page 10.

In summary the test gave excellent results, which has been confirmed with other trials. In addition to the results above there was also measured a reduction in emission of NO_2 of 20-40% and a reduction in NO_x emission of 5-10%.

Summary

A wide range of investigations and research has proven that particulates in the exhaust from diesel engines are causing unacceptable death and illness amongst the population in the industrial world.

Serious efforts are made by the manufacturers of diesel engines to reduce the emission, but the most effective way to solve the problem here and now is to install DPFs to remove particulates, and DPFs combined with catalyst units to remove also gases being part of the emission.

The technology to solve the problem is available, and it is basically a question of legislation to enforce a solution to the emission challenge. LiqTech is contributing to the development of efficient and cost effective DPFs, and together with suppliers of catalysts, we are developing a new generation of systems, which will contribute to reduction of diesel engine emission, and make a better living environment for the human beings.

LiqTech ApS
Grusbakken 12
DK-2820 Gentofte
Denmark

Tel. +45 4593 4993
Fax. +45 4593 4983

sales@liqtech.dk
www.liqtech.dk

LiqTech