# NoTox<sup>®</sup> Silicon Carbide Diesel Particulate Wall Flow Filter

**Technical Product Information** 

Features: – No melting problems – High soot load tolerant – High permeability

# **4. EDITION**

**Notox Corporation** 

# Contents

NoTox products 4 NoTox 1,7 litre WFF base substrate 5 NoTox 2,6 litre WFF base substrate 6 NoTox 6 litre WFF base substrate 7 NoTox 8 litre WFF base substrate 8 NoTox 10 litre WFF base substrate 9 NoTox 10 litre WFF base substrate 10 NoTox 13 litre WFF base substrate 11 NoTox 20 litre WFF base substrate 12 NoTox 23 litre WFF base substrate 13

Semi-Finished-Heated 14

Material features 17

Channel closing 20

System technology 21

How to order 22

Sizing 23

The final NoTox product 24

NoTox Business Concept 26

References and Supporting Products 27

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# NoTox<sup>®</sup> Silicon Carbide Diesel Particulate Wall Flow Filter

**Technical Product Information** 

Features: – No melting problems – High soot load tolerant – High permeability



# Introduction

Constant improvements in the product lead to optimization of the specifications and broader understanding of implementation.

This fourth edition replaces all previous editions.

Please note the separate Canning Specification, available on special request and under a secrecy agreement, containing 28 pages of technical information and experience.

### The goal

Reducing particulate emissions from diesel engines is preferably done by separating the soot from the hot exhaust gas with high temperature stable barrier filters.

The Wall Flow Filter, WFF, is preferably constructed from an extruded square shaped cell honeycomb structure in which every second channel is closed at alternate ends in a chess board like pattern in order to force the gas through the porous wall. With the NoTox WFF, the filtration efficiency of a diesel engine's Total Particulate Matter, TPM, can easily be >85% initially with 25  $\mu$ m pore and >90% after just 10 minutes of operation without losing important permeability.

Either continuously or at appropriate intervals, the accumulated soot particles are oxidized and the filter is cleaned.

The basic material, Silicon Carbide, features exceptional thermal stability so that the diesel WFF is guarantied against any melting problems. Possible cracks caused by thermal stress are prevented by manufacturing techniques and filter design.



# **NoTox products**

NoTox Corporation offers a wide variety of ceramic diesel Wall Flow Filter substrates divided into specific groups, which can easily be matched to the specific needs of each emission control application.

### **Basic substrates**

The following standard substrate set volumes are currently available:

- NoTox L2
- NoTox L3
- NoTox L6
- NoTox L8
- NoTox L10
- NoTox L13
- NoTox L20
- NoTox L23

#### Semi-Finished

Semi-Finished modules available as base substrate set canned on the outside circumference with one or two layers 6,5 mm Interam XD 4200 gram/m<sup>2</sup> into AISI 304 1,5 mm wall thickness pipe app. 30 mm longer than the substrate: • NoTox L2-SF

- NOTOX L2-SF
- NoTox L3-SF
- NoTox L6-SF
- NoTox L8-SF
- NoTox L10-SF
- NoTox L13-SF
- NoTox L20-SF
- NoTox L23-SF



# NoTox 1,7 litre WFF base substrate

### Substrate product code NoTox L2-Ø118×L154-F820

# Substrate Dimension $\oslash~118 \times L~154~mm$

 $\varnothing$  4.66 × L 6 inch

When ordered as a Semi-Finished module, add SF to the product code, such as: NoTox L2-Ø118×L154-F820-SF

Semi-Finished dimension  $\varnothing~132 \times L~170~mm$ 

- Pore size
- Substrate alternatively 125 mm long, 1,4 litre
- One piece unit only
- Semi- or Fully-Finished



# NoTox 2,6 litre WFF base substrate

### Substrate product code NoTox L3-Ø144×L154-F820

#### **Substrate Dimension**

When ordered as a Semi-Finished module, add SF to the product code, such as: NoTox L3-Ø144×L154-F820-SF

Semi-Finished dimension  $\varnothing~158 \times L~170~mm$ 

- Pore size
- Four segments or one piece unit
- Semi- or Fully-Finished



# NoTox 6 litre WFF base substrate

### Substrate product code NoTox L6-Ø190×L205-F820-4

Substrate Dimension  $\varnothing$  190 × L 205 mm  $\varnothing$  7.5 × L 8 inch

When ordered as a Semi-Finished module, add SF to the product code, such as: NoTox L6-Ø190×L205-F820-4-SF

Semi-Finished dimension  $\varnothing$  222  $\times$  L 235 mm

- Four segments only
- Pore size
- · Semi- or Fully-Finished
- L8 four segments, two phase El-Heated module length 255 mm





# NoTox 8 litre WFF base substrate

### Substrate product code NoTox L8-Ø228×L205-F820-7

Substrate Dimension  $\emptyset$  228 × L 205

 $\varnothing$  9  $\times$  L 8 inch

When ordered as a Semi-Finished module, add SF to the product code, such as: NoTox L8-Ø228×L205-F820-7-SF

Semi-Finished dimension  $\varnothing$  252  $\times$  L 235 mm

- Pore size
- Semi- or Fully-Finished
- Four or seven segmented
- Seven segments, three phase El-Heated module





# NoTox 10 litre WFF base substrate

### Substrate product code NoTox L10-Ø228×L255-F820-7

Substrate Dimension  $\emptyset$  228 × L 255

 $\varnothing$  9  $\times\,L$  10 inch

When ordered as a Semi-Finished module, add SF to the product code, such as: NoTox L10-Ø228×L255-F820-7-SF

Semi-Finished dimension  $\varnothing$  252  $\times$  L 285 mm

- Pore size
- Semi- or Fully-Finished
- Four or seven segmented
- Seven segments, three phase El-Heated module





# NoTox 10 litre WFF base substrate

#### Substrate product code NoTox L10-Ø250×L205-F820-7

Substrate Dimension  $\emptyset$  250 × L 205

 $\emptyset$  230 × L 203  $\emptyset$  10 × L 8 inch

When ordered as a Semi-Finished module, add SF to the product code, such as: NoTox L10- $0250 \times L205$ -F820-7-SF

Semi-Finished dimension  $\varnothing$  282 × L 235 mm

- Pore size
- Semi- or Fully-Finished
- Seven segments, three phase El-Heated module





# NoTox 13 litre WFF base substrate

Substrate product code NoTox L13-Ø250×L255-F820-7

#### Substrate Dimension

When ordered as a Semi-Finished module, add SF to the product code, such as: NoTox L13-Ø250×L255-F820-7-SF

Semi-Finished dimension  $\varnothing$  282 × L 285 mm

- Pore size
- Semi- or Fully-Finished
- Seven segments, three phase El-Heated module



# NoTox 20 litre WFF base substrate

Substrate product code NoTox L20-Ø286×L305-F820-7

#### Substrate Dimension

 $\ensuremath{\varnothing}$  286  $\times$  L 305  $\ensuremath{\varnothing}$  11,25  $\times$  L 12 inch

When ordered as a Semi-Finished module, add SF to the product code, such as: NoTox L20-Ø286×L305-F820-7-SF

Semi-Finished dimension  $\varnothing$  326 × L 350 mm

- Pore size
- Semi- or Fully-Finished
- Seven segments only



# NoTox 23 litre WFF base substrate

Substrate product code NoTox L23-Ø286×L355-F820-7

#### Substrate Dimension

 $\ensuremath{\oslash}$  286  $\times$  L 355  $\ensuremath{\oslash}$  11,25  $\times$  L 14 inch

When ordered as a Semi-Finished module, add SF to the product code, such as: NoTox L23-Ø286×L355-F820-7-SF

Semi-Finished dimension  $\varnothing$  326 × L 390 mm

- Pore size
- Semi- or Fully-Finished
- Seven segments only



NoTox L6-STS - Prototype showing the individual components.

# Semi-Finished-Heated

Electrical heating is one of the many advantages of the NoTox Technology and is made possible by the exceptional thermal conductivity of SiC and the split-substrate design with internally placed heating elements. The supplied energy is used with maximum efficiency and heat loss to the surroundings is minimized. There are two basic system techniques which appear practical for electrical regeneration.

# Off-vehicle heating

One technique uses external power supply from the mains, usually 110 or 230-400 volt AC and heats the filter substrate with commonly available pipe heating elements for regeneration during a period when the vehicle is parked. Everything is controlled by very simple and low cost arrangements.

This principle has been shown to work rea-

sonably well with Cordierite WFF for city busses, Forklift Trucks and fleets of vehicles, all of which have a regular duty cycle and a regular period in which the vehicle is not driven. Heating time with the Cordierite material is from 2-6 hours in order to heat the substrate sufficiently to start the soot oxidation. The energy is rather in-efficiently used, due to the poor thermal conductivity of the Cordierite ceramic filter substrate. Also, a substantial amount of the supplied heat is lost to the surroundings due to the external position of the heating element.

In the case of vehicles with regular duty cycles, such as Forklift Trucks, use of the NoTox technology combined with mains connection will result in a connection time of app. 30 minutes for a complete regeneration. This is comparable to the length of the lunch break for most drivers. Thus the NoTox SF Heated WFF technique represents a substantial saving in electricity consumption and, maybe more important, the ve-



*NoTox*  $2 \times L6$ -STS - Prototype with one central inlet and dual outlet. Power and shop air connection on left side of box. Mounted on a Forklift Truck with 6 litre NA diesel engine.

hicle can be operated in a three shift cycle.

For Forklift Trucks accepting 30 minutes regeneration time, the illustrated NoTox prototypes show the value of this technology. The following examples explain physical size and necessary heating element power. All are based on regeneration every four hours.

### Small diesel engines

#### NoTox L6

Natural aspirated 3 litre diesel engines require a 6 litre capacity NoTox L6 STS filter rated at 3600 Watt in 230 VAC. The complete system is only 250 mm in diameter with an overall length of 380 mm, giving high filtration capacity/outside volume ratio. System weight is less than 20 kg as shown on photo.

### Larger diesel engines

Larger diesel engines require larger filter systems. Such may be based on Ø 250 mm substrate segments giving NoTox L13. Alternatively, two identical NoTox L6 or L8 STS units may be assembled over a central gas inlet section giving a slim-line system with two exhaust outlets, one in each side.

#### NoTox L13

NoTox L13 STS unit with 13 litre capacity and 6 kW/3-phase 230/400 VAC supply. This single module system is app. 320 mm in diameter and 400 mm long.

#### NoTox 2×L6

NoTox  $2\times$ L6-STS unit with 12 litre capacity and 7,2 kW/3-phase 400 VAC supply. This dual module slim-line design is only 250 mm in diameter and app. 800 mm long.

The only operation required by the driver is to

connect the power plug every four hours during a lunch break. An effective heating time around 20 minutes, six times a day in a three shift operation on a NoTox STS involves only 12 kWh/day energy consumption. Soot combustion air may be supplied either by an on-vehicle high voltage air pump, a 24 VDC on-vehicle air pump or, most cheaply, with shop compressed air. The operator can connect the electrical supply as well as the compressed air supply in the same connector.

### Heating time

The graph illustrates the heating time for NoTox L6 STS high voltage filter system. When connecting this NoTox STS to the mains just after finishing driving, the trap temperature will be app. 100-150°C which reduces further heating in order to reach the actual soot ignition temperature (either 350, 400 or 600°C) to less than 20 minutes. The soot oxidation takes



around 10 min. with a 20-100 litre/min. controlled combustion air supply.

The NoTox STS technology will show time and power savings when used with either:

- Fuel additive, regen. temp. at ~350°C or
- Noble metal catalyst coating, regen. temp. at  ${\sim}400^{\circ}\text{C}$
- No help from any active material, regeneration temperature app. 600°C.

This STS (Soot Trap System) technology is fully developed and ready for production by interested system manufacturers.

### **On-vehicle heating**

A variation of the electrically heated diesel filter system offers regeneration while driving and for an unlimited driving period. This PSTS (Passive Soot Trap System) technique takes advantage of:

- Power from only the vehicle's own 24 volt DC system
- Very efficient use of the limited power due to the heating element placing
- Intelligent controls and strategy to make efficient use of exhaust heat to preheat one trap before regeneration
- Catalytically active fuel additive to form intimate contact with all soot particles and reduce oxidation temperature to as low as ~350°C, during the soot accumulation in the trap,
- Alternatively, catalytically PM coated trap for combustion temperature  ${\sim}400^{\circ}C$  further resulting in oxidation of CO and HC

Therefore, vehicles with too low a load for simple filter systems will benefit from an optimum PSTS installation including: two individual traps in the same container to be sequentially isolated from the main exhaust flow using a special designed exhaust gas diverter valve and a fuel additive for <400°C regeneration temp.



*NoTox L13-STS model showing one of 3 heating elements.* 

# Material features

Initial filtration efficiency >98% with a 5  $\mu$ m pore decreasing to >95% with 15  $\mu$ m pore and >90% with 25  $\mu$ m pore. We strongly recommend the 25  $\mu$ m pore for outstanding flow behaviour.

**Filtration area** as high as 0,5 m<sup>2</sup>/litre filter which is the highest available ratio determined only by the honeycomb design and is similar to the known Cordierite WFF.



The **basic material** Silicon Carbide features exceptional thermal stability and easily exhibits a 10.000 hours use in oxidizing atmosphere at 1600°C. This is considerably higher than temperatures caused by exothermic reaction of even very large amounts of soot in the trap.

**Permeability** in NoTox WFF is two times higher compared to Cordierite WFF because:

- the number of pores per area is twice as high

- the NoTox powder technology completely eliminates commonly accepted blind pores.

**Thermal conductivity** is generally low for all ceramics but for SiC, as in the NoTox WFF, higher than 10 W/m-K, compared to Cordierite's less than 0,5 W/m-K.

Relatively high **thermal expansion of** SiC,  $\sim 4 \times 10^{-6}$  mm/°K as the origin of thermal stresses is controlled by manufacturing techniques and filter design in order to reach satisfactory safe soot limits.

High **corrosion resistance**, insured by the quartz surface on the porous structure, eliminates chemical reaction with accumulated ash from additives in the lubricating oil or diesel fuel. This allows 3-4 cleaning sessions of loose ash accumulation and by this the 250.000 miles lifetime.

**Material strength** for SiC is several times higher than for Cordierite, in the range of 25-40 MPa for the NoTox type of SiC compared to 2-5 MPa for Cordierite.

Silicon Carbide does not **melt** but the decomposing temperature >1800°C is considerably higher than any possible temperature peaks caused by any exothermic reaction of soot in the WFF.

The NoTox **channel closing** method is unique and a great improvement over traditional methods where 5-10 mm long plugs are pushed into every second channel. The NoTox method forms part of the substrate walls into a roof over the cell ends to close them, occupying no useful filtration surface area at the cell ends.

This reduces the need for a high canning pressure in order to prevent axial movement of the substrate. In multi-segmented substrate sets, telescoping of the centre segments is prevented with similar techniques.

The number of segments of the NoTox WFF influences the term »maximum safe soot load«. The higher the number of segments the higher the soot load before possible cracks may occur.

**Death-ring-area** in the front face circumference seen on some Cordierite WFF, generally used to help prevent axial movement, is not needed with the NoTox substrate technology.

**Monolith sizes** are identical to what the market by now accepts as being the standard for easy replacement.

NoTox substrate is manufactured with a technique that, in selected areas, increases the **friction** towards the insulating interface between substrate and canning metal container.

### Material Data Sheet

Specifications - ISO									
Filter name	NoTox L3	NoTox L6	NoTox L6	NoTox L6	NoTox L10	NoTox L10	NoTox L13	13 NoToxL20	
Substrate Code - segment numbers	F/760-1	F/780-5	F/780-9	F/820-5	F/760-5	F/760-5	F/780-9	F/820	
Filter size - radius x length	R70x150	R95x205	R95x205	R95x205	R115x255	R125x205	R125x255	R160x255	
Material - 0,8 mm wall thickness	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	
Material composition code	F/760	F/780	F/780	F/820	F/760	F/760	F/780 F/820		
Mean pore size - µm - 1/1000 mm	5	15	15	25	5	5	15 2		
Open porosity - %	45	45	45	45	45	45	45 4		
Permeability 10 -12/m2 Darcy	0,30	1,30	1,30	2,20	0,30	0,30	1,30	1,30	
Delta P, kPa, wall face velocity 2 cm/s	1,00	0,20	0,20	0,15	1,00	1,00	0,20	0,20	
Max safe soot limit - g/litre substrate	>10	6	>10	6	8	6	>10	>10	
Thermal conductivity - 25°C (W/mK)	11	11	11	11	11	11	11	11	
Thermal conductivity - 630°C (W/mK)	7	7	7	7	7	7	7	7	
Specific heat - 25°C - J/kg	750	750	750	750	750	750	750	750	
Specific heat - 800°C - J/kg	1250	1250	1250	1250	1250	1250	1250	1250	
Expansion/radial x10-6/°C - 25°C	4,20	4,20	4,20	4,20	4,20	4,20	4,20	4,20	
Expansion/axial x10-6/°C - 650°C	3,90	3,90	3,90	3,90	3,90	3,90	3,90	3,90	
Thermal shock parameter, TSP 3	160-1400	110-1100	110-1000	85-750	160-1400	160-1400	110-1000	85-750	
Decompose/Melting temperature - °C	>1800	>1800	>1800	>1800	>1800	>1800	>1800	>1800	
Modulus of Elasticity - E - GPa	50,00	50,00	50,00	50,00	50,00 50,00		50,00	50,00	
Poisson`s ratio - v	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	
Compress strength, longitu. Qa MPa	40	60	60	30	40	40	60	30	
Bending strength - MOR/a MPa	28	25	25	20	28	28	25	20	
Bending strength - MOR/b MPa	3,20	2,20	2,20	1,70	3,20	3,20	2,20	1,70	
Bending strength - MOR/c MPa	4,90	3,40	3,40	2,60	4,90	4,90	3,40	3,40 2,60	
Electrical resistance - Ohm x cm	1	1	1	1	1	1	1	1	
Availability according to MDS	standard	standard	standard		standard	standard	standard	standar	

Max. safe soot limit test was performed on NoTox L6-F820 traps with four, five or nine segments connected to a MB OM616 4 cyl. 2,4 litre diesel engine loading the trap at 1300 rpm/65 Nm, increasing to 3500 rpm/110 Nm for five minutes for steady 750°C temperature in the complete trap followed by idling and no load sequence until complete regeneration.

Test fuel: Danish Shell Automotive Gas Oil, City Diesel with <50 ppm S, residual ash content ,01%wt.

### Material Data Sheet

Geometry information								
Fllter name	NoTox L3	NoTox L6	NoTox L8	NoTox L10	NoTox L10	NoTox L13	NoTox L20	
Substrate Code - segment numbers	F/820-1	F/820-4	F/820-7	F/820-7	F/820-7	F/820-7	F/820	
Filter dimensions - radius x length	R70xL150	R95xL205	R115xL205	R115xL255	R125xL205	R125xL255	R140xL305	
Actual filter radius - mm - *	72	95	115	115	127	127	143	
Internal interface width - mm - *		6,00	3,00	3,00	3,00	3,00	3,00	
Unit diameter, incl interface - mm	144	190	230	230	254	254	286	
Substrate length - mm - *	154	205	205	255	205	255	305	
Channel effective length - mm	152	203	203	253	203	253	303	
Unit weight - kg - measured - *	2,28	5,90	8,70	10,70	10,60	13,00	20,20	
Specific weight - g/ccm	0,91	1,02	1,02	1,01	1,02	1,01	1,03	
Number of segments	1	4	7	7	7	7		
Filter substrate diameter - inch	5,67	7,48	9,06	9,06	10,00	10,00	11,26	
Filter length - inch	6,06	8,07	8,07	10,04	8,07	10,04	12,01	
Wall thickness - mm - fixed	1,00	0,80	0,80	0,80	0,80	0,80	0,80	
Wall thickness - 1/1 inch	0,039	0,031	0,031	0,031	0,031	0,031	0,031	
Total cells across the center line - *	50	65	79	79	87	87	107	
Cell spacing Center to Center - mm	2,88	2,74	2,84	2,84	2,85	2,85	2,56	
Open side Width per Cell - mm	1,88	1,94	2,04	2,04	2,05	2,05	1,76	
Inlet cell Cross Section - mm <sup>2</sup>	3,53	3,76	4,14	4,14	4,20	4,20	3,10	
Total Cell Cross section - mm <sup>2</sup>	8,29	7,50	8,04	8,04	8,13	8,13	6,56	
Filtration area per Cell - mm <sup>2</sup>	1.143	1.574	1.653	2.060	1.665	2.075	2.134	
Filter unit total front face - cm <sup>2</sup>	162,86	283,53	415,48	415,48	506,71	506,71	642,42	
Inlet cell frontal area - cm <sup>2</sup>	50	61	102	102	119	119	138	
Internal interface ring area - cm <sup>2</sup>	0,00	15,08	7,54	7,54	7,54	7,54	19,79	
Internal interface cross area - cm <sup>2</sup>	0	46	28	28	30	30	51	
Lost front face/total front face - %	0,00	21,40	8,46	8,46	7,50	7,50	11,09	
Interface volume - ccm	0,00	123,18	71,33	88,90	77,18	96,19	215,95	
Number of substrate cells - *	1.850	3.241	4.929	4.929	5.681	5.681	8.889	
Number of inlet filter cells -	925	1.621	2.465	2.465	2.841	2.841	4.445	
Inlet cells per cm <sup>2</sup> - numbers	12,06	13,34	12,44	12,44	12,31	12,31	15,25	
Inlet cells per inch <sup>2</sup> - numbers	77,78	86,03	80,25	80,25	79,40	79,40	98,39	
Inlet cell volume - ccm	497	1.236	2.073	2.583	2.425	3.022	4.175	
Effective total filtration area - cm <sup>2</sup>	1.057	2.551	4.073	5.077	4.730	5.895	9.485	
Filter Unit total volume - ccm	2.508	5.812	8.517	10.595	10.388	12.921	19.594	
Filter Unit effective volume - ccm	2.508	5.689	8.446	10.506	10.310	12.825	19.378	
Specific Filter Unit area - m²/litre	0,42	0,45	0,48	0,48	0,46	0,46	0,49	

1



Comparison of monolith front face inlet flow characteristics of Corning and NoTox channel closing methods. The NoTox channel closing, manifolding method causes less turbulens resulting in a 25% less pressure drop over the monolith inlet face, plotted against the linear filter wall face velocity.

# **Channel closing**

### **Innovative features**

Pressure drop which is one of the worst enemies of the soot trap is helped greatly with this simple, well proven and reliable technique. In order to convert the Flow Through Monolith to a Wall Flow Filter every second channel must be closed in order to comprise a coextending throughgoing passage separated by the wall.

The main principle of the NoTox design is to avoid relying on the insertion of additional material into the filter body, also known as a plug, but rather to close the passage by means of material already present in the form of parts of passage walls adjacent to the passage.

This technique insures that the effective substrate length is the same as the substrate. In other terms, the filtration area is not reduced by conventional plugging methods. Avoiding a loss of filtrating substrate length of two times app. 8 mm on a 205 mm long trap is equivelent to as much as 8% filtration area.

An extra feature is that comparison of Corning and NoTox monolith front face inlet flow characteristics with different channel closing methods shows a most interesting results. The NoTox channel closing and manifolding method causes considerably less turbulens resulting in a 25% less pressure drop over the monolith, plotted against the linear filter wall face velocity.

# System technology

### **Fuel Additives**

Catalytically active fuel additive tests on NoTox filters show very fine results. NoTox WFF has the advantage of having higher thermal conductivity and capacity which evens out the exothermal harmful reactions compared to Cordierite traps. The result is a gentle reaction giving a more uniform filter temperature and regeneration with absolutely no temperature peaks. There is no possible melting problem associated with the NoTox SiC trap.

- Iron oxide based additives are currently undergoing large scale tests in field trials with very good results.
- Cerium based additives have been tested in our engine lab with interesting results that depend on stochastic behaviour.
- Copper based additives have been tested in the engine lab as well as in many field trials and show very promising regeneration temperatures in the range of 300-380°C.

Corrosion resistance of NoTox SiC substrates is advantageous and different compared to Cordierite at elevated temperatures, important for long time use in connection with lubricating oil and fuel additives. All additives will eventually block up the filter and in high temperature spots react with themselves or the trap material. If any chemical reaction between powdered ash and trap material takes place, periodic cleaning of the trap becomes impossible. Problems associated with long time durability caused by non-removable ash accumulation in Cordierite filters are associated with the melting point (~950°C) of a typical ash composition. As the low thermal conductivity and thermal capacity of the Cordierite material cause high temperature spots during un-controlled regenerations, the ash melts in various places over a period of time forming a non-removable solidified surface on the filter wall.

NoTox SiC WFF with high thermal conductivity and capacity completely eliminates problems associated with hot spots. The NoTox trap has not experienced problems with molten ash.

### Multi-Trap

Retro-fit of filter systems to replace popular, relatively small diameter and long length, mufflers with a diesel particulate WFF system produces a problem associated with current WFF technology. The best one piece WFF substrate ratio diametre/length is between 1:1 and 1:1,4. Therefore, it is rather difficult to reach sufficient filtration area and substrate volume with limited muffler diameters.

Multi-Trap is a method and system set-up with nearly unlimited substrate volume designed to replace most slim-line mufflers.

# Oil burner heated system

For some vehicle set-ups a burner regeneration system performs best. A NoTox  $2\times$ L24 prototype with a total of 48 litre trap volume for off-duty diesel oil burner regeneration has been successfully mounted since 1994 and tested by DSB in Denmark on a Deutz V12 industrial engine powered Plasser Unimatic rail road construction vehicle. The system was produced with 25 µm pore size giving app. 40 hours of operation before off duty cleaning and offering >90% filtration efficiency.

### PM Coatings

Precious Metal catalytic coatings for reduction of the soot oxidation temperature have been tested in the laboratory. The largest effort was put into the important wash-coat where a basic alumina coating technique with good adhesion and large surface has been developed. NoTox Corp. will supply further information on request.

Further information about Delta and Carry on request.

# How to order

# Explanation of the product code

#### Example

NoTox L6-Ø190×L205-F820-4-SF

L6	=	subst	rate	volume	in	litı	re
a 1 0 0		1.		0.1			

- $\emptyset$ 190 = diameter of the substrate
- L205 = length of the unit
- F820 = material code describing the pore size 4 = number of segments selected to
- create the filter block
- SF = Semi-Finished
- FF = Fully-Finished

#### Present standards

- Material F-820 equivelent to 25 µm pore.
- Wall thickness either 0,8 mm or 1 mm.
- Channel width: 1,8 or 2,0 to 2,5 mm.

#### Soot limit:

The safe soot limit depends on several dimensional factors, the three most important being:

- Number of substrate segments
- Substrate segment length
- Ratio between diameter and length

Increasing segmentation numbers and decreasing substrate length easily increase the safe soot limit to above the possible amount of soot particles being possible to pack into the total channel volume. Currently NoTox substrate with diameter <190 mm has a maximum of four segments, and diameter >228 mm has preferably seven segments. Generally speaking, as the NoTox trap shows considerably more gentle or slower response to uncontrolled exothermic reactions, the maximum safe soot limit has a different meaning compared to the Cordierite trap.



Square root of permeability (Darcy) plotted as a function of pore sizes in different materials.

#### Darcy

# Sizing

### **Basics**

NoTox products feature half the clean trap pressure drop compared to equivalent Cordierite based WFF and just as important considerably less back presssure increase during the soot layer build up. All in all this will result in:

- Smaller traps or lower engine back pressure
- · Easier to fit into the engine compartment
- Because of the above less temperature drop before the trap

Mounting soot traps involves considerable knowledge and experience. Please seek further information in relevant SAE articles and from actual tests.

- Base the choise on the following four criteria:
- Is the vehicle suitable for the purpose
- Type of regeneration principle
- · Drive cycle, number of daily shifts
- Engine type, volume flow

# Additive based regeneration

The three commonly available additives show different properties and demand to trap / engine sizing. The following general rules are based on tests with prescribed Copper and Ferrum additive amounts in connetion with <50 ppm Sulphur content fuel.

#### **Small Engines**

Suitable trap size for natural aspirated diesel engine based on a NoTox WFF system with sequential regeneration is:

· One filter litre for one litre engine displacement

#### Large Engines

Suitable trap size based on a NoTox WFF system with sequential regeneration during operating on larger engines with displacement from 4-15 litre is:

- 1-1<sup>1</sup>/<sub>2</sub> filtre litre / litre engine displacement for natural aspirated engines
- 1½-2 filtre litre / litre engine displacement turbo charged depending on boost pressure / volume flow

• 21/2-3 filtre litre / litre engine displacement for 2-stroke blown and turbo charged engines



### Off duty regeneration

Based on accumulation of the soot during the total drive cycle and regeneration by external heating the filters must usually be twice the size described above.

#### Warning

In order to protect the engine and eliminate excess fuel consumption the following important cases must be avoided:

- Too large engine backpressure, no more than 250 mBar in absolutely worst case senario
- Too large distance from the engine, metre >1
- Worn out insulation, insure good insulation protection
- Vibration transfer to the filter, use flexible joints, pipes etc.





NoTox L13

NoTox L6-SF

# The final NoTox product

# Basic substrate product

Non-canned raw substrate set as delivered. Includes the internal interface in between the segments regardless of segment numbers.

Each set will be shipped covered in strained plastic wrap to be wrapped directly with the external interface without removing the plastic wrap. Cut off excessive wrapping prior to customer heat treatment. The remaining wrapping burns away during the heat treatment of the possible surrounding Interam interface.

This technique is used in order to prepare the canning processes and to insure substrate protection during handling.

# Semi-Finished product

Semi-Finished filter module canned with a suitable 12 mm external fibre insulating interface inside AISI 304 1,5 mm thick rolled sheet pipe with 2 pcs. MIG welded steel L-rings, the system being app. 30 mm longer than the substrate. The product is delivered heat treated in order to remove organic binder from the interface. This treatment oxidizes the outside face of the can to a light brown colour.





NoTox L8-SF-H

Notox L6 prototype

# **SF-Electrically-Heated Prototypes**

Semi-Finished-Heated prototype filter unit inside AISI 304 stainless steel 1,5 mm thick rolled sheet pipe with selectable length. L-ring may be removable, as shown also on STS picture, and is integrated with the inlet/outlet cones for easy system disassembling. This product is only available in close cooperation with the system manufacturer.

The supplied pre-shaped pipe heating element with AISI 316 or Inconel shield is retractable from the four, five or seven segments substrate set without any disassembling of the filter module. The segments are separated by profiled knitted wire mesh guides. The slots between the segments for the heating element are app. 7-9 mm wide.

# **Fully-Finished**

Fully-Finished units inside AISI 304 stainless steel 1,5 mm thick rolled sheet pipe with selectable length and inlet cone sizes, flanges / adaptors, extra insulation and heat shields. The L-ring is integrated with the inlet/outlet cones and diffuser. The product is delivered heat treated in order to remove organic binder from the interface.

# **NoTox Business Concept**

# **Company Strategy**

Together with the Danish Technical University over the past 10 years NoTox Corporation and Stobbe Technologies have developed methods, know-how, techniques, manufacturing techniques and production equipment for the manufacturing of a variety of barrier filters for hot gas cleaning.

NoTox Corp. offers the following »software«

- Innovation in hot gas filtration
- R & D collaboration
- Special substrate production
- Licensing of system design

NoTox Corp. offers the following »hardware«

- NoTox ceramic WFF substrate set
- NoTox Semi-Finished WFF modules
- NoTox Fully-Finished WFF modules

- in the area of diesel engine exhaust filter system parts for the diesel engine industry. Completely finished products are produced in cooperation with other parties.

#### **Customer Support**

As an extra service for OEM and system manufacturers, NoTox Corp. are proud to offer a series of patent protected methods, system designs and regeneration techniques. Please contact NoTox Corp. for CAD drawings, etc. and further discussion under a secrecy agreement. NoTox Corp. presents reliable technical information concerning the described products and the use of the products.

- The product is delivered according to specification
- · Delivery time depends on the actual product

#### However:

- All advice concerning the selection and the use of any products is provided with no warranty
- NoTox Corp., Stobbe Engineering A/S or Stobbe Technologies assumes no responsibility for any patent liability arising from the use of any product in a process, manner, or formula
- Nothing in the listed information shall be construed as an inducement or recommendation to use any process, procedure or product in conflict with existing or future patents
- All warranties of merchantability and fitness of purpose are disclaimed
- In certain countries NoTox WFF substrates with a mean pore size between 20 m and 55 m should not be used for passenger cars or passenger cars derivatives capable of seating 12 passengers or less, also know as light-duty vehicles, without the prior consent of Corning Inc.

### For further information contact

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# **References and Supporting Products**

# References

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# Supporting Products

Substrate interface Catalytic Support Systems Ltd Knitwire Products Phone: +44 925 265655 Fax: +44 925 264995

3M Europe GmbH Interam® products Phone: +49 2131 14-0 Fax: +49 2131 142626

Flame glow plugs BERU Ruprecht GmbH & Co. KG Phone: +49 7141 132-0 fax: +49 7141 132-350

Heating elements BACKER Elektro-Värme AB Phone: +46 451-661 00 Fax: +46 451-614 37

Connectors Electrical/pneumatic in one ODU Kontakt GmbH & Co Phone: +49 8631 6156-0 Fax: +49 8631 6156-49

Exhaust system insulation TIGHITCO Inc. Phone: +1 404 355 1205 Fax: +1 404 351 4458

Graphite/steel composite gaskets Elwis Royal A/S Phone: +45 45 87 72 55 Fax: +45 45 87 72 66

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