

VERT Standards and Procedures for Retrofit to reduce Diesel Engine Emissions

Transport and Clean Air

December 11-12, 2013

Moscow, Russia



Agenda

- History of VERT
- VERT testing of diesel particulate filters
- Durability testing and check of field capability
- Recommended procedure for a retrofit program
- Examples of global successful retrofit programs
- Summary

History of VERT

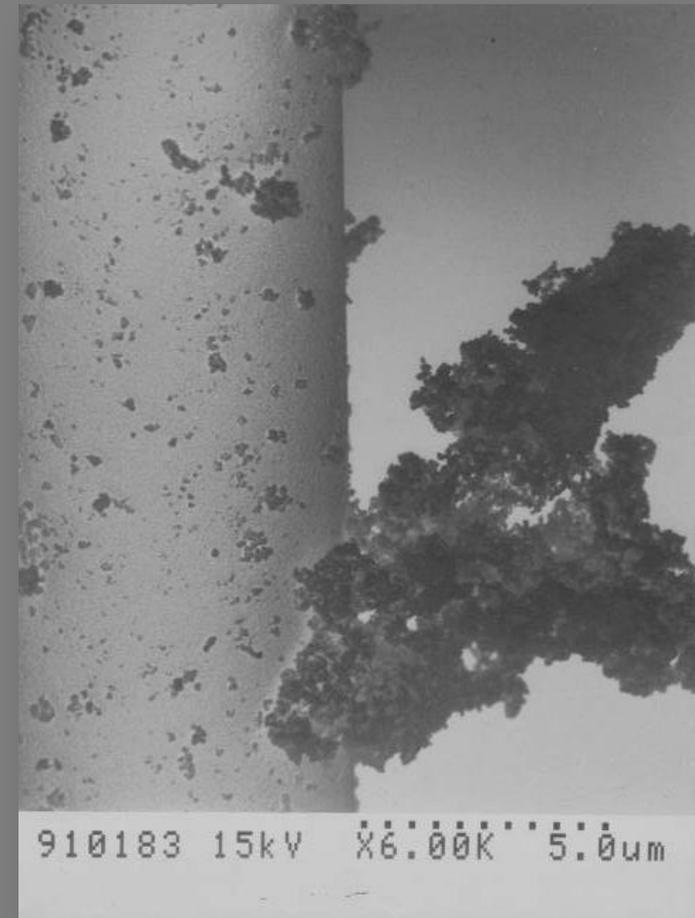
What stands VERT for?

- VERT = **V**erification of **E**mission **R**eduction **T**echnologies
- VERT=
 - Diesel particle filter testing procedure
 - Certification of exhaust after treatment systems
 - Quality control system
- VERT is a Trade Mark for Particle Filters of **B**est **A**vailable **T**echnology
- VERT is a global acting non-profit Association of filter manufacturers, engine builders and associates based in Switzerland

History of VERT

Soot particles a double risk because of:

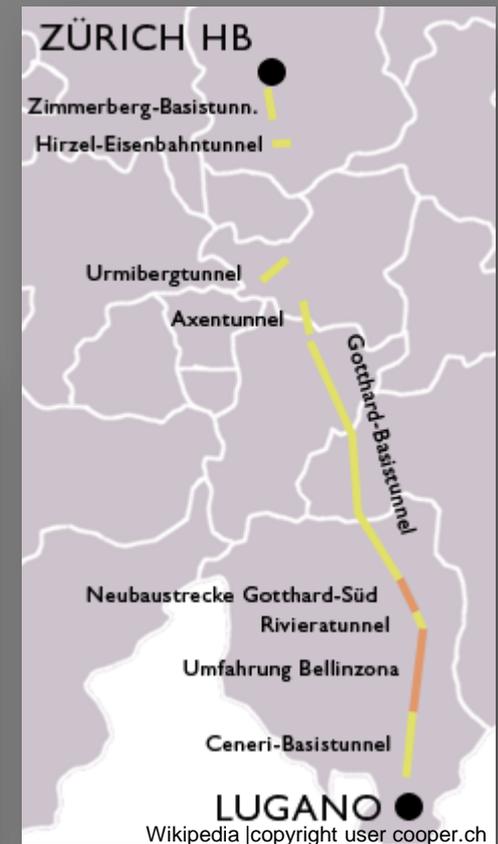
- Very small < 100 nm
 - High surface > 100 m²/g
 - Transporting toxics persistent in organism
 - Carcinogenic
 - Black color | global warming effect
-
- Long life toxic aerosol (weeks to month)
 - Defined by WHO 1988 as probably carcinogenic
 - **Since 2012 as evidenced carcinogenic (class 1 like asbestos)**



History of VERT

The roots are the NEAT New Transalpine Railways Program:

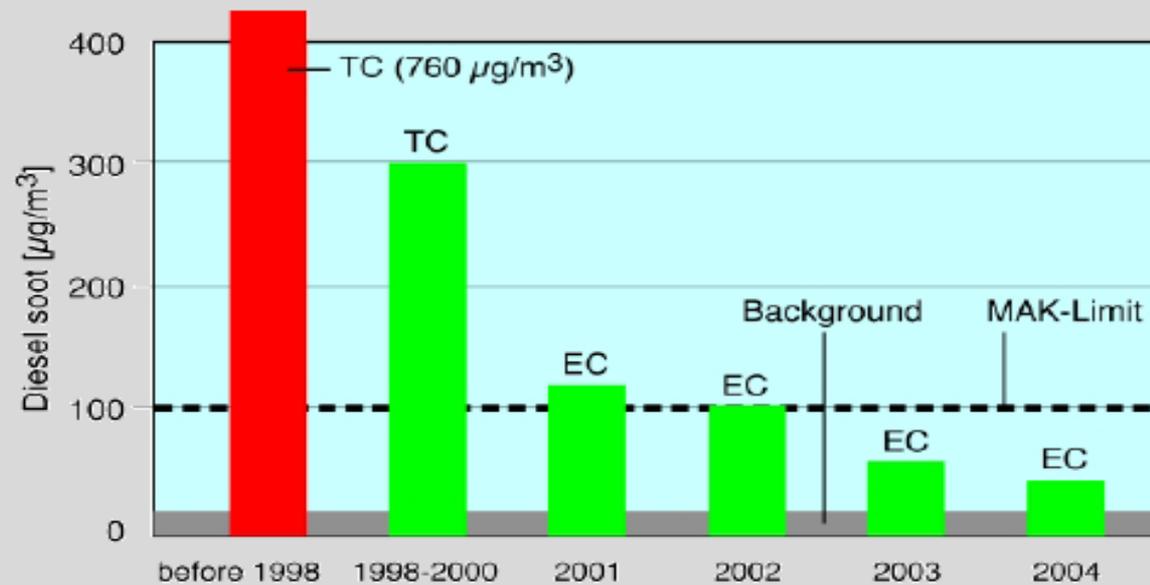
- One of the biggest tunneling project in Europe
- Maximum admissible workplace concentration of $100 \mu\text{g}/\text{m}^3$ diesel soot due to the carcinogenic
- Diesel particulate filter obligation to reach this value
- With finalizing the planning 1993 - start of VERT



History of VERT

Improvement of air quality in Swiss tunneling

SUVA:Tunnel-Luftqualität 1998-2004



VERT testing of diesel particulate filters

Concept of VERT-Filter Testing

- In-depth testing of exhaust gas filter structures for nanoscale filtration (Physical Properties)
- In-depth testing chemical phenomena in exhaust gas filter structures
- Testing a complete DPF system
- Type approval of one filter per filter family
- Endurance testing on typical vehicle application
- Testing is worst case oriented
- **B**est **A**vailable **T**echnology is the moving target



Testing the Combination Filter + Engine not required

VERT testing of diesel particulate filters

VERT-Requirements (total 21)

- Filtration efficiency > 97% for **solid particles 20-500 nm**
- Reduction of all toxic components
- No secondary toxic compounds
- Back pressure < 200 mbar
- Safe and complete regeneration
- No negative impact on noise
- No additional risks (heat radiation, visibility,...)
- Filter life = engine life
- Effects on fuel economy < 2 %
- ...



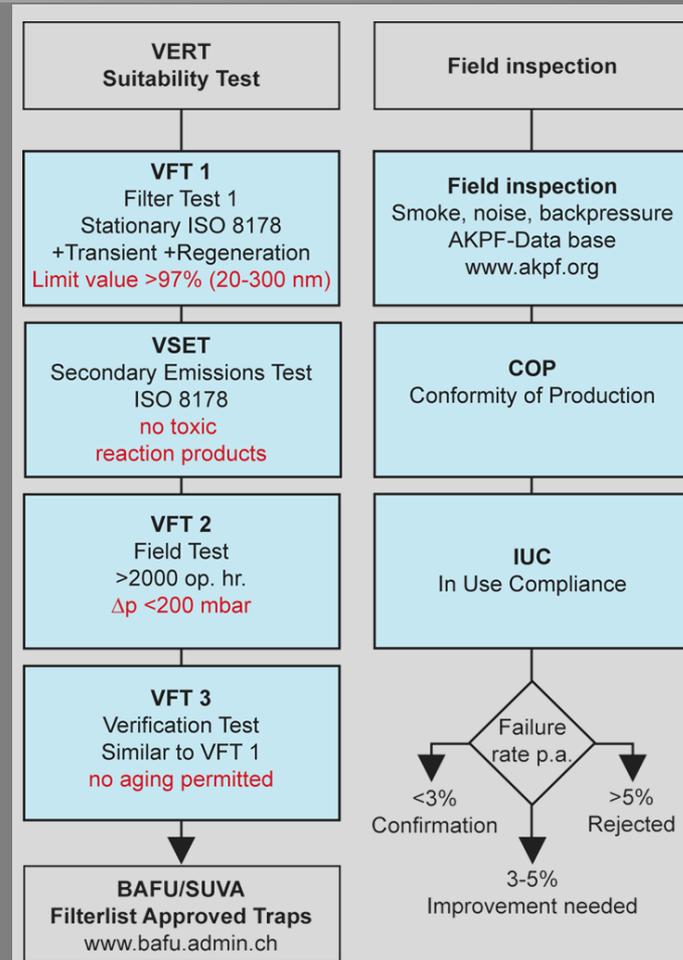
VERT testing is recognized worldwide by

BAFU, SUVA, ASTRA, BAV – Switzerland | AUVA, Wien, Tirol – Austria | BG Bau, UBA, TRGS 554 –Germany | CARB, MSHA, NY City – USA | VROM – Netherlands | Alto Adige – Italy | Santiago de Chile | DEEP – Canada | London LEZ – UK | Denmark LEZ | Beijing –China

VERT testing of diesel particulate filters

VERT verification process

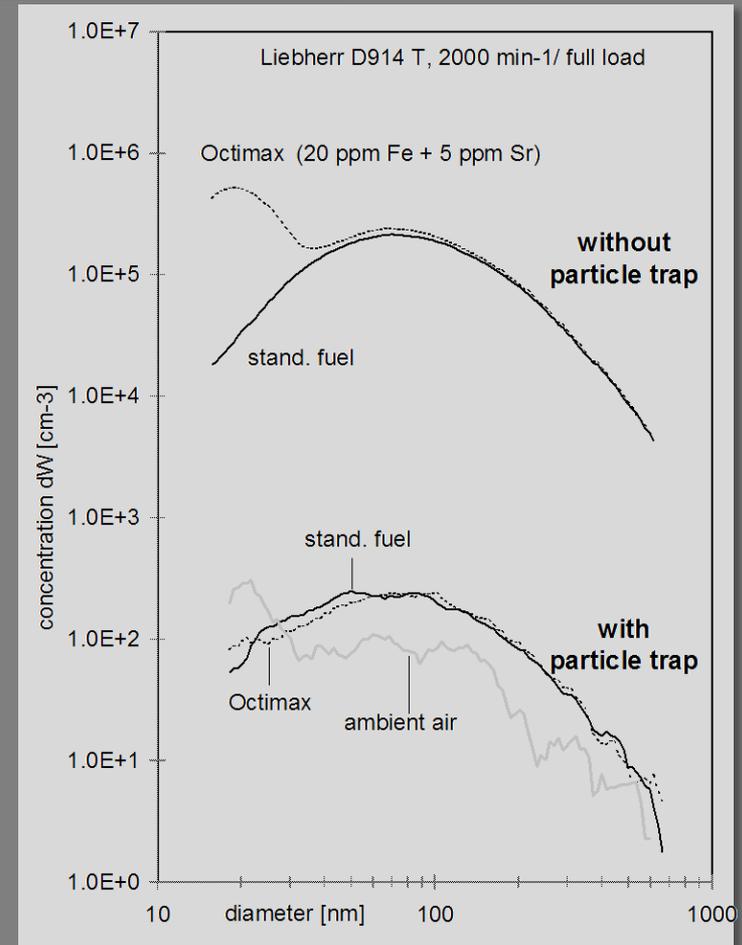
- Filter Testing acc. to SN277206 Certification and Quality Control since 1998



VERT testing of diesel particulate filters

Measurement must be by number and size

- DPF System has to show that filtration efficiency is > 99 % between regeneration



VERT testing of diesel particulate filters

Secondary Emissions

- VERT approved DPF systems do not release secondary emissions in relevant amounts, e.g.
- NO₂, Dioxins/Furans, PAH, Nitro-PAH etc.
- Sulfuric acid aerosols
- Metal oxide (Ash) particles, mineral fibers etc.

Durability testing and check of field capability

Durability Test (Field test)

- VERT approved DPF systems must undergo a field test of at least 2000 operating hours
- To be done in a typical application of the specific DPF system (i.e. stationary or mobile application resp.)
- With periodic tests of filter performance, back pressure, regeneration, control and alert systems, mechanical construction etc.



Durability testing and check of field capability

VERT-Certificate

- 1. VERT-testing successfully completed
- 2. Application per System duly signed - directed to VERT coordination office
- 3. Examination by VERT Scientific Committee - unanimity required
- 4. Stamp “Valid” VERT-CEO
- 5. Filter listed
- 6. Certificate to manufacturer

Valid only with VERT-stamp and validity date

VERT[®]-Certificate

No	B159C3.05	
Product	HJS Particle-Filter System: Filter Module	SMP [®] -CRT [®] HJS Sinter metal filter with upstream DOC
	Regeneration: Electr. Filter Control	NO _x from oxidation catalytic converter HJS (ECU V1.43se), E13 039018
Manufacturer	HJS Fahrzeugtechnik GmbH & Co KG Dieselweg 12 D - 58706 Menden	

We herewith apply to be listed in the VERT[®] filter-list and accept the rules and conditions

Manufacturer	Date	Signature
HJS Fahrzeugtechnik GmbH & Co KG	March 03 2010	Klaus Schewe

Certified by the VERT[®]-Scientific Committee

Andreas C.F. Mayer	Prof. Dr. Jan Czerwinski	Jacques Lemaire
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The report of the manufacturer is confidential

Durability testing and check of field capability

Applications of DPF

Exhaust of a diesel vehicle equipped must stay perfectly clean even after 85'000 km like with this bus



Recommended procedure for a retrofit program

Pre retrofit phase | Information needed

- Operation cycle (temperature log)
- Raw emission: CO, HC, CO2, O2, NOx, Opacity
- Fuel and lubrication oil properties
- Fuel and lubrication oil consumption
- Typical daily work schedule
- Vibration level at silencer location
- Installation space (photos and silencer drawings)
- Engine specs, age, mileage. Last maintenance



- Fact sheet for all vehicles during the test phase

Checklist 3.1

Test phase: → 3.1 Selection of Test Vehicles
Subject: → → Vehicle Description and Evaluation

Test vehicle name: 闽 D51660	Test fleet code: XM001a
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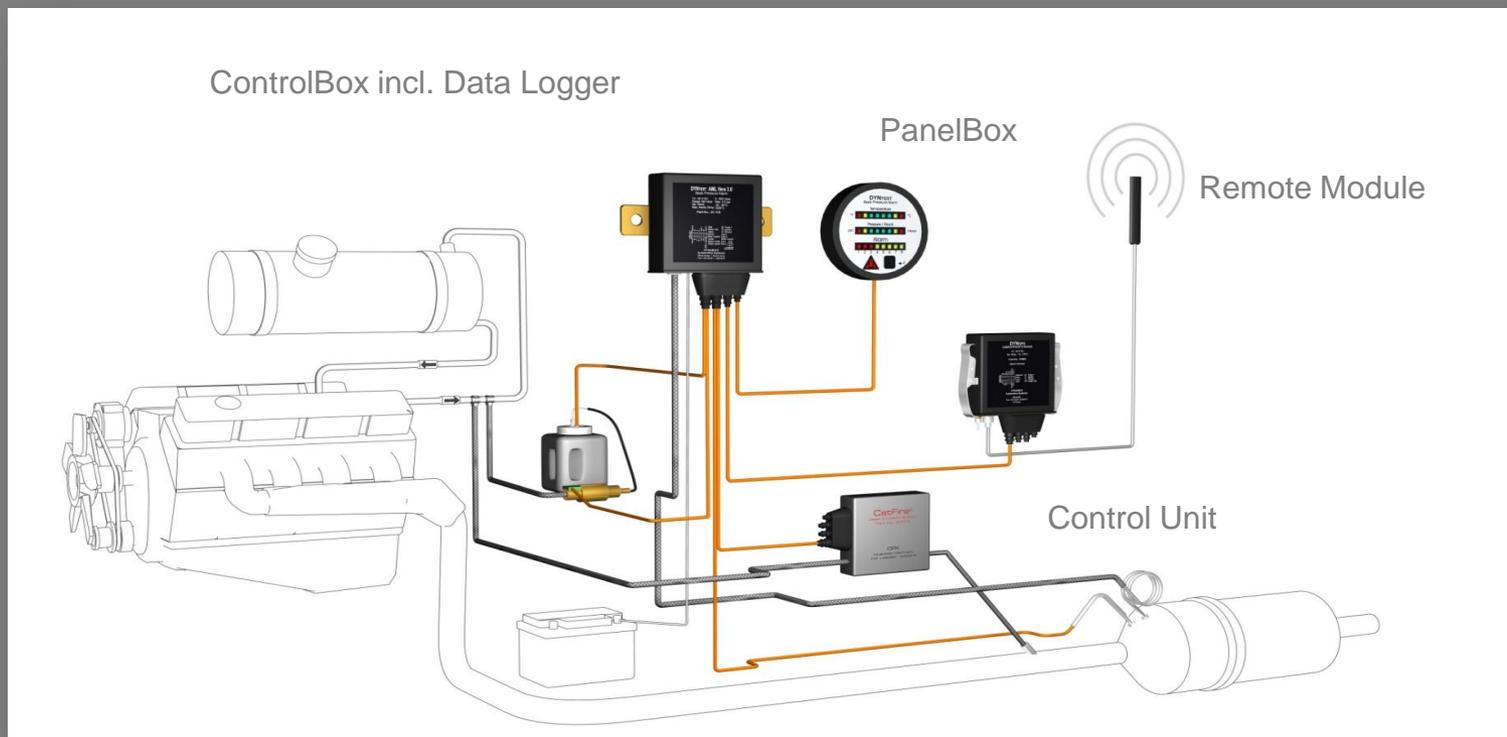
Contacts	
Owner company	Xiamen Xirunfa Company
contact person / e-mail / mobile phone	Chenyonglai 13860160025 --1269566572@qq.com
Operator company	Xiamen Xirunfa Company
contact person / e-mail / mobile phone	Chenyonglai 13860160025 --1269566572@qq.com
Operation site	Xiamen
Inspection date and site	Xiamen 2012 Nova

Vehicle Specifications	
Type of usage	<input type="checkbox"/> stationary 固定 <input checked="" type="checkbox"/> mobile 移动
Vehicle manufacturer ("brand") and vehicle type	Yutong ZK6113H, large passenger vehicle
Vehicle identification or registration number	闽 D51660; LFNJSRDKX41014800
Engine manufacturer and engine type	Wuxi Diesel Engine Works, CA6110
Engine emissions standards	China II
Engine displacement & cylinder number	7127ML 6-cylinder
Engine production year & op. time [hrs] or [km]	2002-May, 320000KM
Rated power [kW] at nominal RPM [1/min]	125KW
Fuel injection (common-rail, unit-pump?)	Unit-pump
Turbocharging & intercooling	Turbocharging
EGR, water-cooled?	No
Fuel supplier, type & sulfur content [ppm]	350ppm
Fuel consumption [l/h] or [l/100km]	30 l/100km
Lube-oil supplier, type, TBN & sulfur content [ppm]	YuChai Lube-oil CH-4; Shell; Gear oil GL-5
Lube-oil consumption [l/h] or [l/100km]	0.007 l/100km; Gear-oil none
Exhaust after-treatment	None

Vehicle History: 车辆历史信息	
First owner?	Xiamen Xirunfa Company
Vehicle or engine modified? When and what?	NO
Repairs? Replacements? When and what?	NO
Operation range: inside and/or outside city area	Inside city
Actual number of operators (drivers) or shifts	Fixed driver (One day off each week)
Operation time total per day [hrs/day]	8 hrs/day
Expected operation time for next 6 month [hrs]	1200 hrs
Location: fixed or mobile?	Inside Xiamen

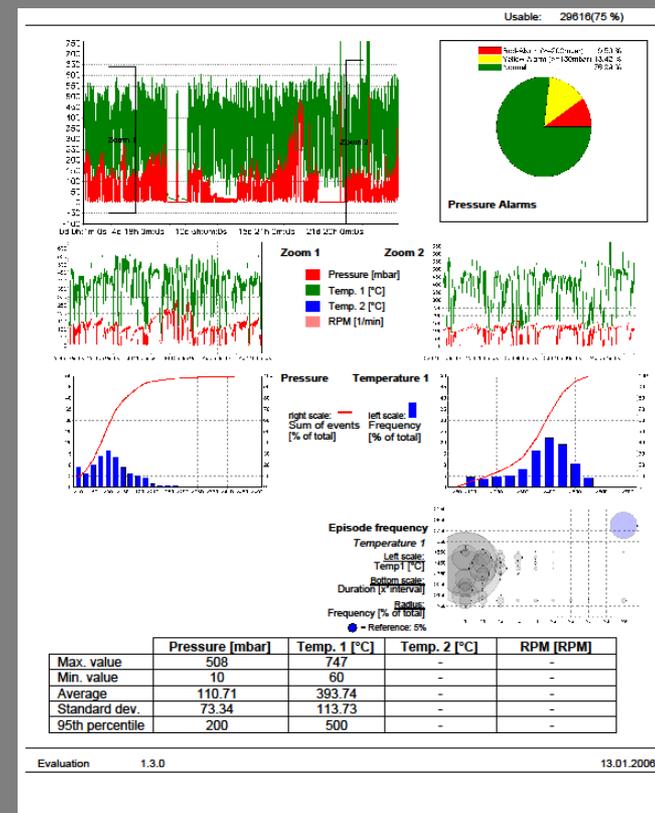
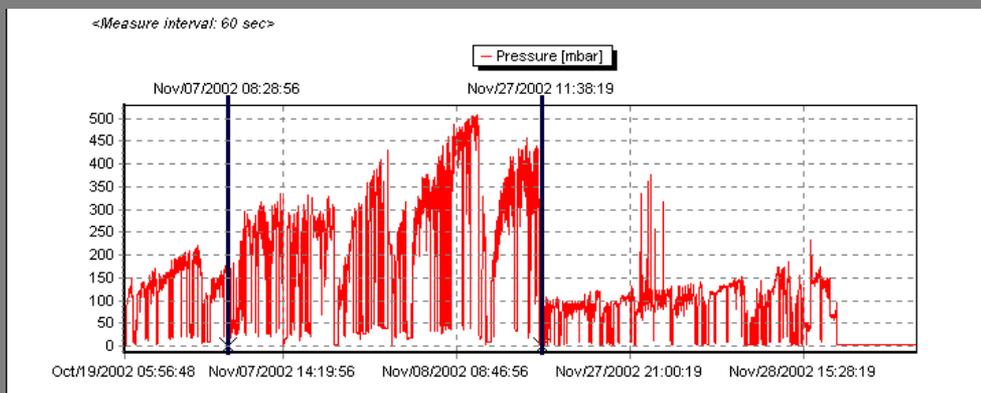
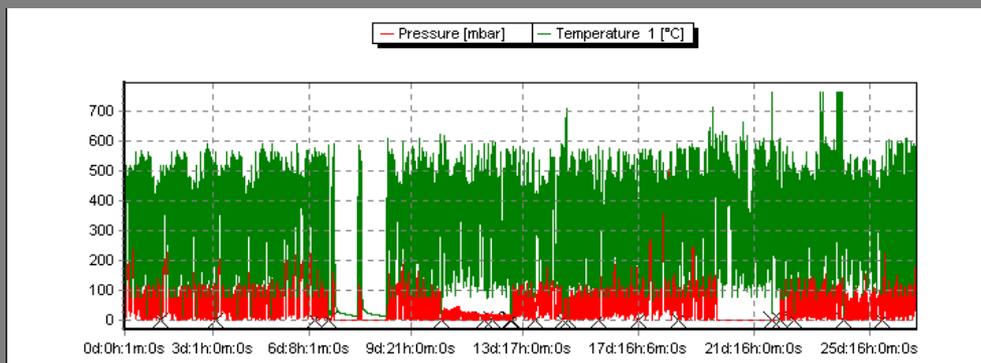
Recommended procedure for a retrofit program

multifunctional system is used in the VERT
Retrofit programs



Recommended procedure for a retrofit program

Compiled analysis and statistical results



Recommended procedure for a retrofit program

Prepare a pilot phase

- Agree on filter specifications
- Select from certified filter systems only
- Look for similar cases in data bases
- Think about cost optimization
- Merge DPF technologies with vehicles
- Install, measure and sign acceptance protocol
- Decide about fuel, lubricant and maintenance
- Plan periodic checks



Recommended procedure for a retrofit program

Start commercial retrofit program

- In Depth Filter Certification (worst case oriented)
- Electronic Filter Control onboard
- Stepwise build-up
- Public Support
- Periodic Checks and Sanctions
- Financing by Incentives or strict laws
- Subsidies will not work



Recommended procedure for a retrofit program

Key success factors

- Use only BAT Filter Quality
- Electronic Filter Control OBC
- Experienced consultancy for selection and installation
- Implement a database for the applications
- Periodic control and emission document
- Sanctions
- Financing by tender incentives
- Three stage responsibility:
 - Government → filter manufacturer → operator



Examples of global successful retrofit programs

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Examples of global successful Retrofit programs

Germany

- **Phase I** 1990/92
- Test: 1,500 trucks and buses
- **Phase II** from 1996 on
- **20,000 city buses**
- Regulation for in-house constructions according TRGS 554, VERT Recognized
- **Phase III** bonus malus system for trucks – Incentives due to the maut “maut= road tax”
- **Phase IV** 2008
- Low Emission Zones: Berlin y Munich starts to reduce BC (soot) by 60 % diesel driven cars without filters can not enter



 total apr. 80,000 retrofits

Examples of global successful Retrofit programs

London, UK



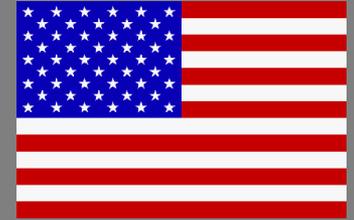
- EST: Energy Saving Trust : 30 Mio £ yearly since 2000
- DPF-retrofits financially supported up to 75 %
- London Transport started large scale retrofit 2000
- New concessions only under condition: DPF
- 2004: ca 6,000 retrofits – 2005: all **8,500 busses in London**
- 2007 London Low Emission Zone 3 phases – total > 100,000
- 2011 DPF for Construction Machines in London cross rail



en total apr. 35,000 retrofits

Examples of global successful Retrofit programs

USA



- EST: Energy Saving Trust : 30 Mio £ yearly since 2000
- 1998: DPF for construction machines in Boston “big dig”
- 2002: DPF for Diesels in all metal mines
- 2002: California Risk Reduction Plan, on-road and non-road
- 2005: New York and New Jersey
- Many activities in cities and counties under local law
- Large funds for school buses and transit buses
- EPA 2007: all new HDV with DPF



en total apr. 55'000 Retrofits

Examples of global successful Retrofit programs

Netherlands

- 2006/7 Low Emission Zones in all major cities, starting with onroad HDV,
- offroad vehicles following 2008
- based on VERT

Today > 12,000 Retrofits (+ 25,000 pDPF)



Italy

- 2005 DPF for LDV in Südtirol
- 2006/7 DPF for Construction Machines in public construction , 2007 Low Emission Zones in Lombardia and Emilia
- 2008 New „Decreto“ for retrofit of HDV
- Retrofits in the Milan and Turino area
- en total apr. 15,000 retrofits



Examples of global successful Retrofit programs

South Korea

- Retrofit activity starting 2004 busses and trucks in Seoul
- 2008 intensified
- Apr. 140,000 Retrofits



Chile

- 2005 retrofit Euro1+2 buses in Santiago – small scale
- 2008 retrofit Euro 3 buses - large scale -3500 vehicles
- 2013 continuation in Santiago and other cities
- Apr. 3,000 retrofits



Examples of global successful Retrofit programs

China

- retrofit activity starting 2004 bus and truck in Seoul
- 2006 retrofit for the Olympics (8,000 buses)
- 2008 retrofit guide
- Swiss cooperation with Beijing, Nanning and Xiamen 2010
- other cities start LEZ (Nanning, ...)
- VERT recognized
- 2,000 bus retrofits for 2014 in Nanjing announced
-



Examples of global successful Retrofit programs

Bogota, Columbia

- Just started – S < 30 ppm
- Pilot Fleet 18 buses
- 300 buses spring 2014
- 10.000 buses mid 2014-mid 2015
- 10 year plan for retrofit of all HDV



Examples of global successful Retrofit programs

Tehran, Iran

- Just started – sulfur 50 - 8000 ppm
- Pilot Fleet 10 buses
- 1000 buses 2014/2015
- 2000 buses 2015/2016
- 4000 buses 2016/2017



Summary

- Retrofit can reduce carcinogenic particles from diesel exhaust with an efficiency of $> 97\%$
- Best available retrofit technology should be used always
- The technology is world wide available
- By taking the right steps retrofit is successful
- An intelligent finance plan has to be put in place
- There is a lot of experience out in the market with retrofit of busses and chance to learn from experience in the past

 **No Diesel without a filter**

Summary

Thank you for your attention

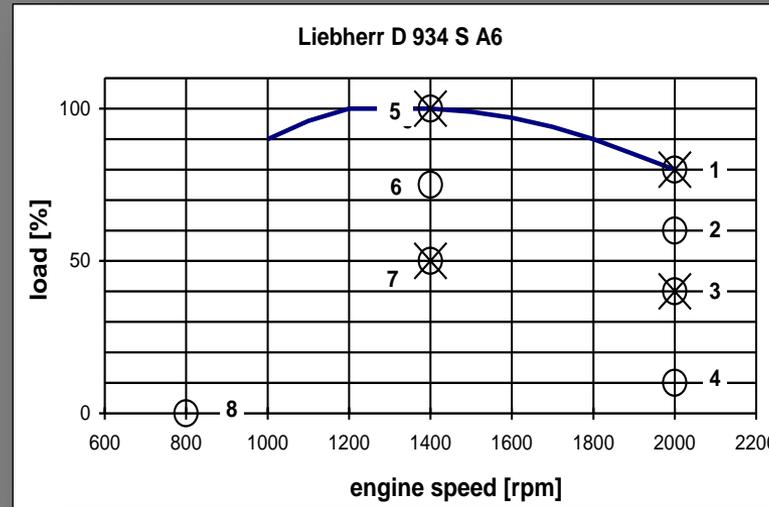
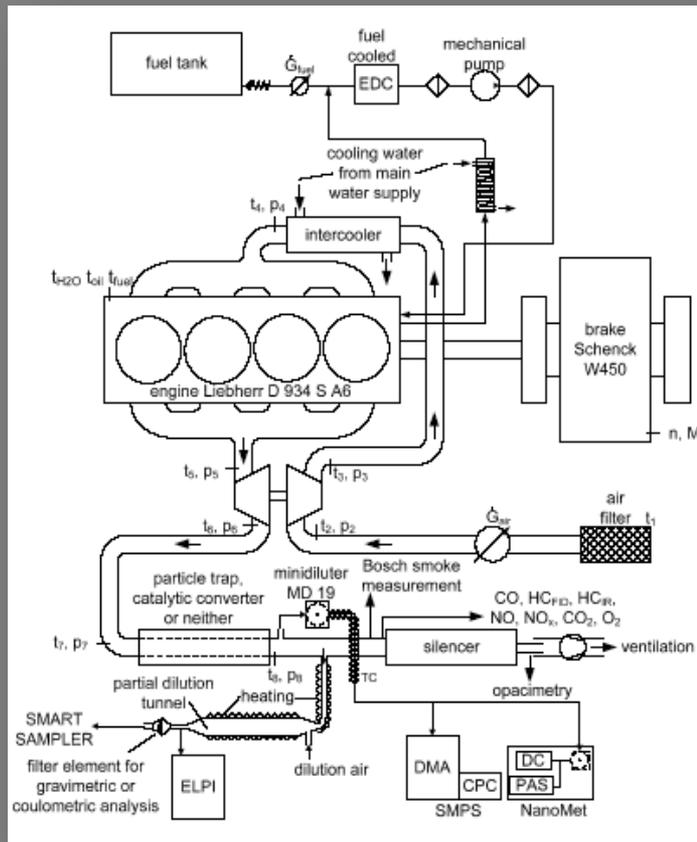


You will find a lot of information on the website
www.vert-dpf.eu

Backup

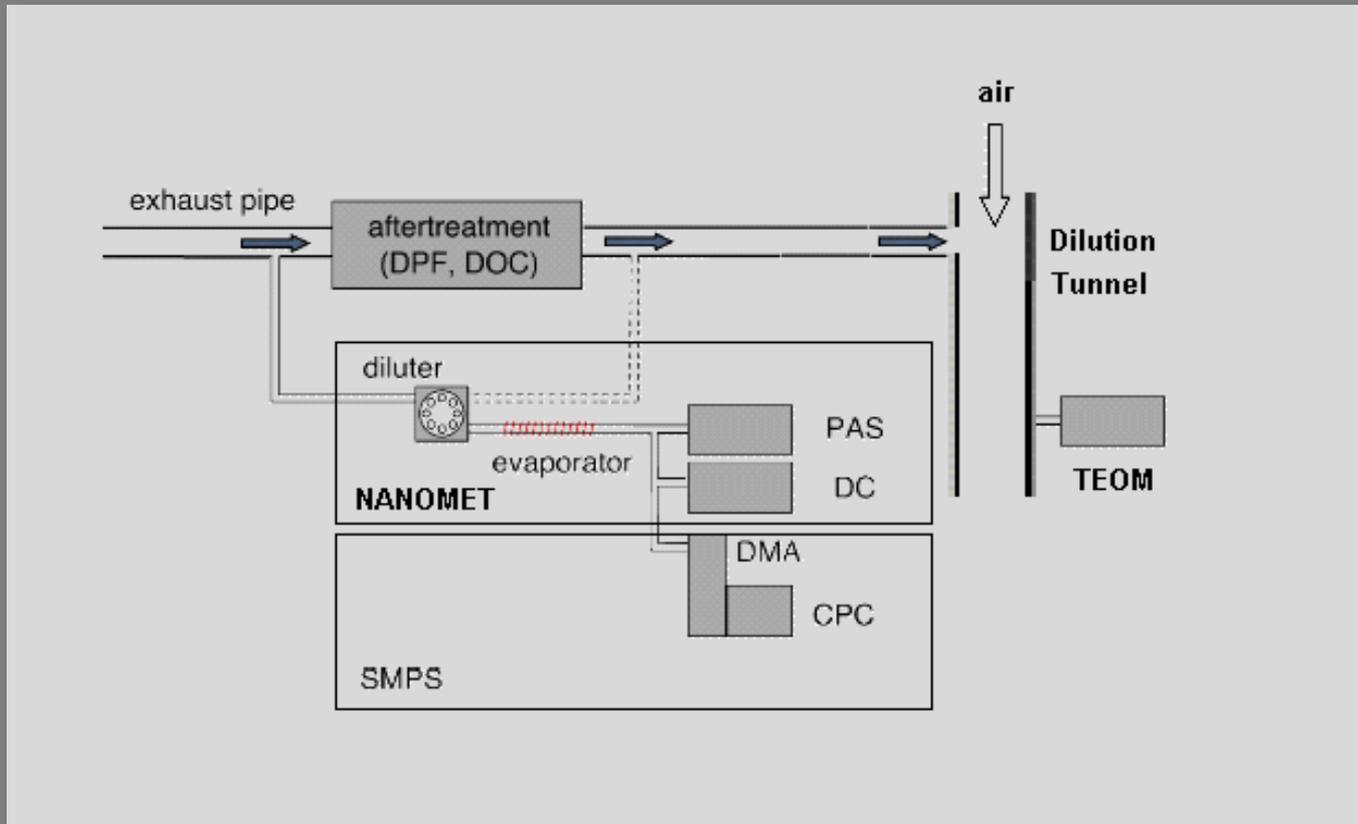
VERT testing of diesel particulate filters

Initial filter testing



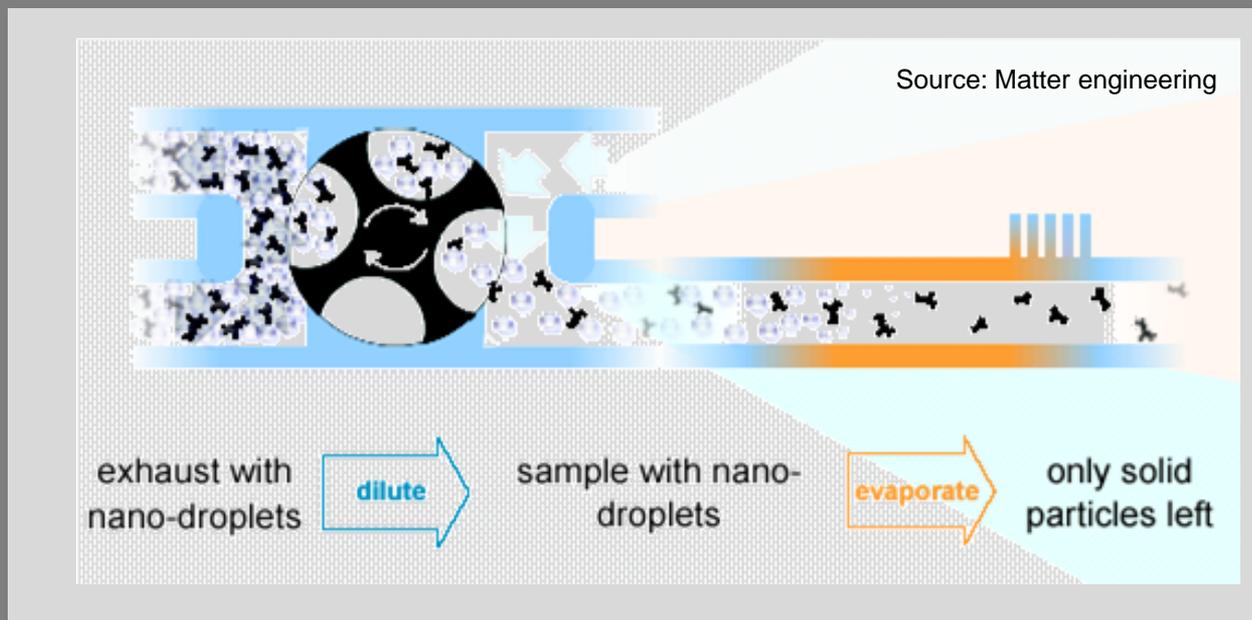
VERT testing of diesel particulate filters

Particle Number Testing



VERT testing of diesel particulate filters

Measuring the right values – removing droplets from aerosol sample



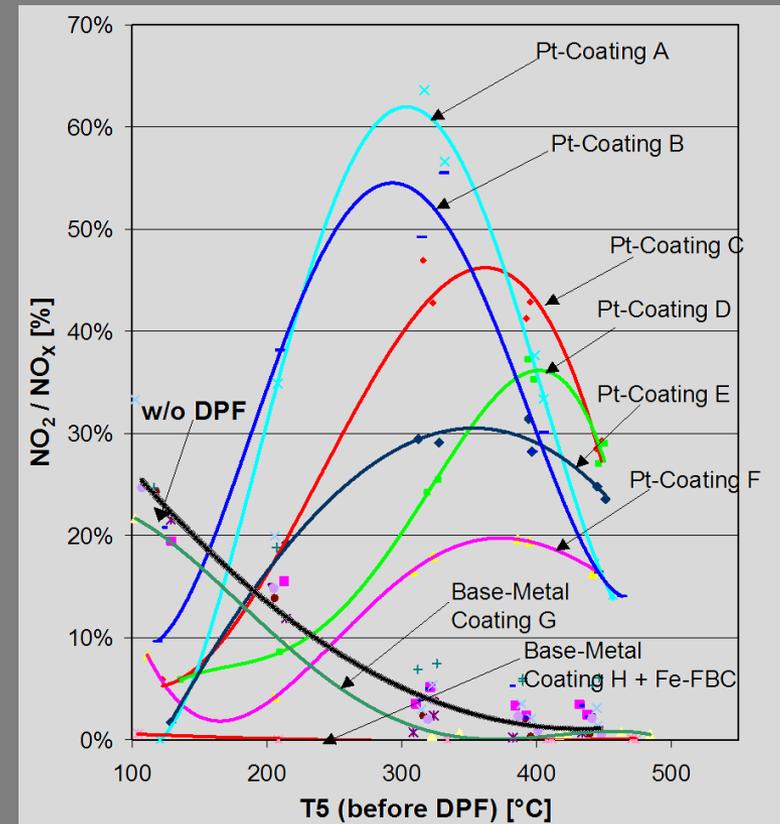
- Combination of diluter and heater is used to eliminate droplet from the aerosol

VERT testing of diesel particulate filters

NO₂/NO_x ratio increase

- Platinum coated filters use NO₂ for the regeneration process
- The diesel particulate filters (most passive systems) are tested against NO₂ increase
- The value for newly certified systems is

$$\Delta \text{NO}_2/\text{NO}_x < 20\%$$

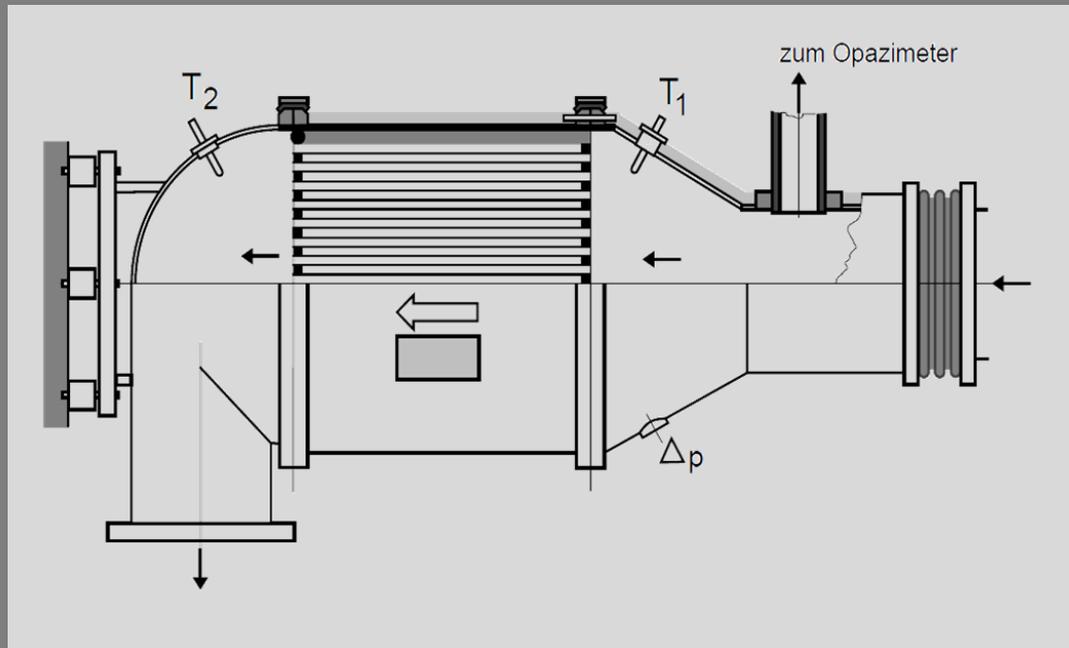


With Pt-coating and FBC at 10 ppm S

Durability testing and check of field capability

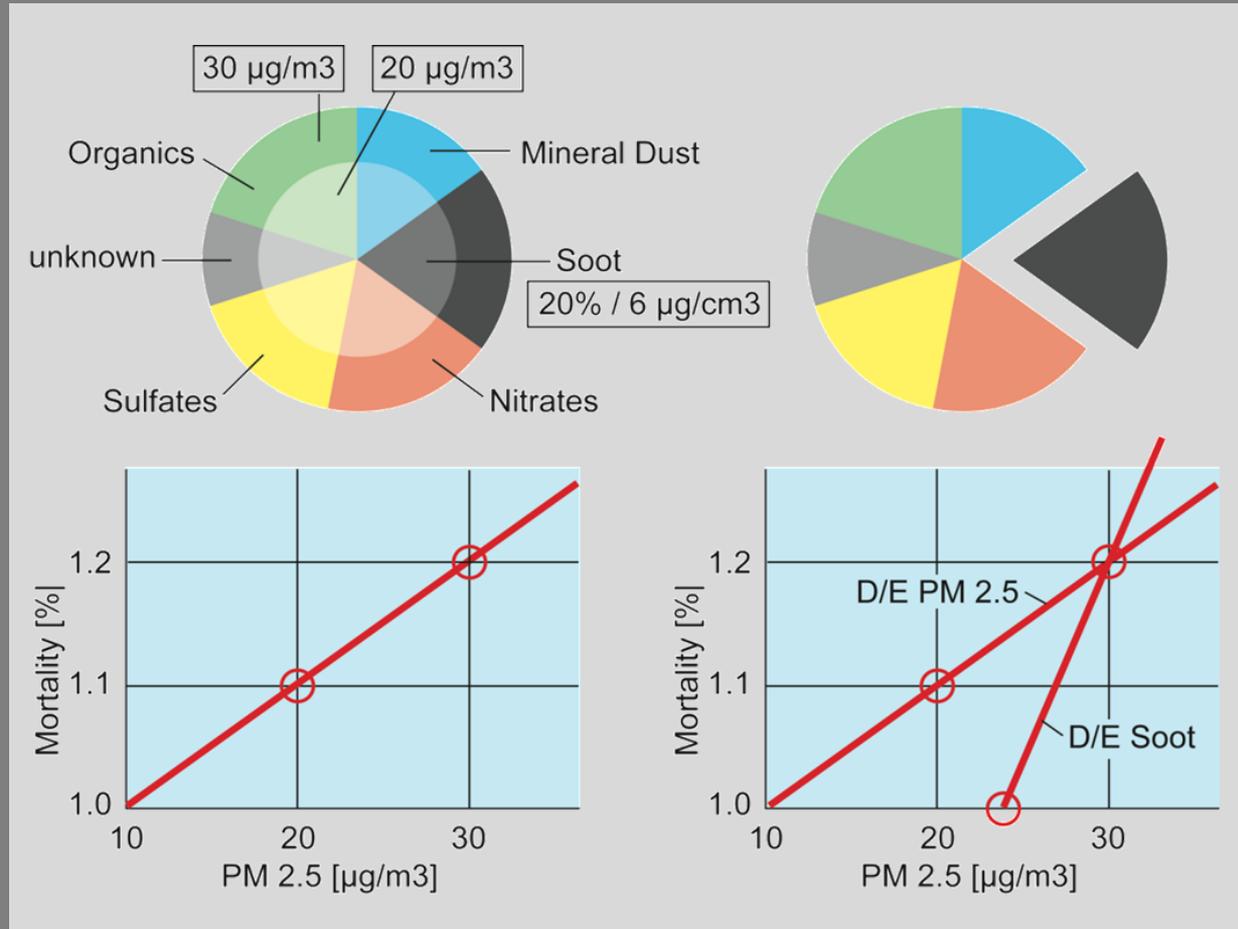
Emission measurement in the field

- VERT-Filters have an exhaust gas access port upstream of the DPF
- Emission measurement upstream and downstream filter is possible in situ



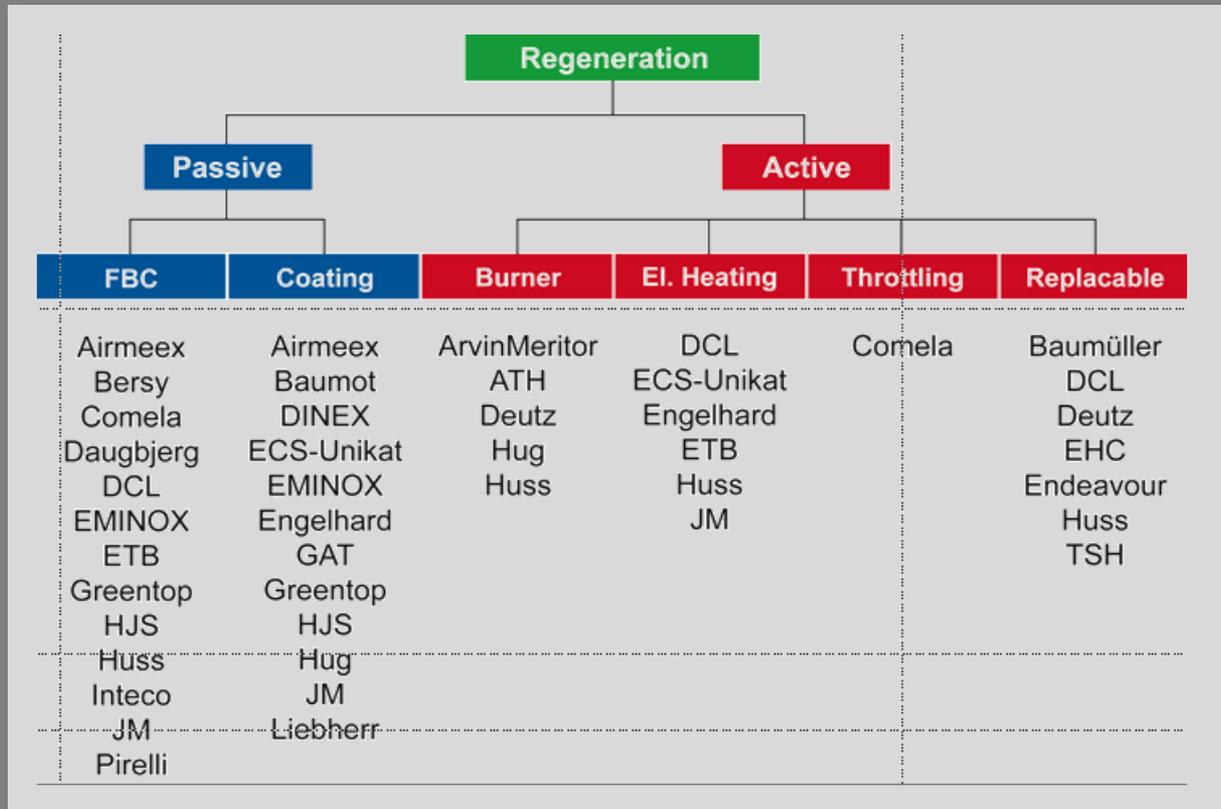
History of VERT

Dose/Effect by PM2.5 or Soot ?



History of VERT

Today's VERT certified DPF Systems



65 DPF systems verified from 31 manufactureres

