Latest Developments in Ceramic Filter-based Hot Gas Filtration

Tim Benstead - RATH Filtration GmbH

IEA Bioenergy Workshop - Task 33 | KIT Campus North, Eggenstein-Leopoldshafen (DE) | 6.June 2019

125 YEARS RESPONSIBILITY & PASSION

RATH Rath extends Hot Gas Filtration

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Hot Gas Filtration
- Key Points

1	**What is fine particulate - *and how can this be controlled?***
2	
3	
4	
5	

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Introduction to RATH AG

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RATH AG: Technology & Tradition

- Austrian family-owned business
- Established in 1891 by August Rath Jr.
- Head Office in Wien (Vienna)
- Specialised in the development, manufacture and supply of sophisticated refractory materials for thermal insulation and hot gas filtration
- 550 employees / 7 production locations
- 31 representative sales offices worldwide
- Annual turnover ca. 86 Mio.€ (2017)

RATH: Refractory Materials - Product Portfolio

RATH – Comprehensive Range of Refractory-based Products & Services

Unshaped Products	Pre-cast Blocks	Dense Bricks	Insulating Fire Bricks	High-Temperature Insulation Wools	Vacuum-formed Parts
					

RATH Filtration GmbH – Hot Gas Filtration (HGF)
Catalytic & Non-catalytic Ceramic Filter Elements

HGF - RATH Filtration GmbH (RFI)

- RATH has been involved in the development, manufacture and sale of rigid, low density filter elements for hot gas filtration applications for more than 20 years
- Spring 2016, **RATH Filtration GmbH (RFI)** was established as a new business unit within RATH AG
- The CF product portfolio was renamed **FILTRATH®** and then expanded to include **FILTRATH®CAT**
- A new HGF "Center of Excellence" was established in Meißen and in Dec 2016 the new **FILTRATH®** (CF) production line was inaugurated
- The new **FILTRATH®CAT** (CCF) production line in Meißen is currently undergoing final commissioning

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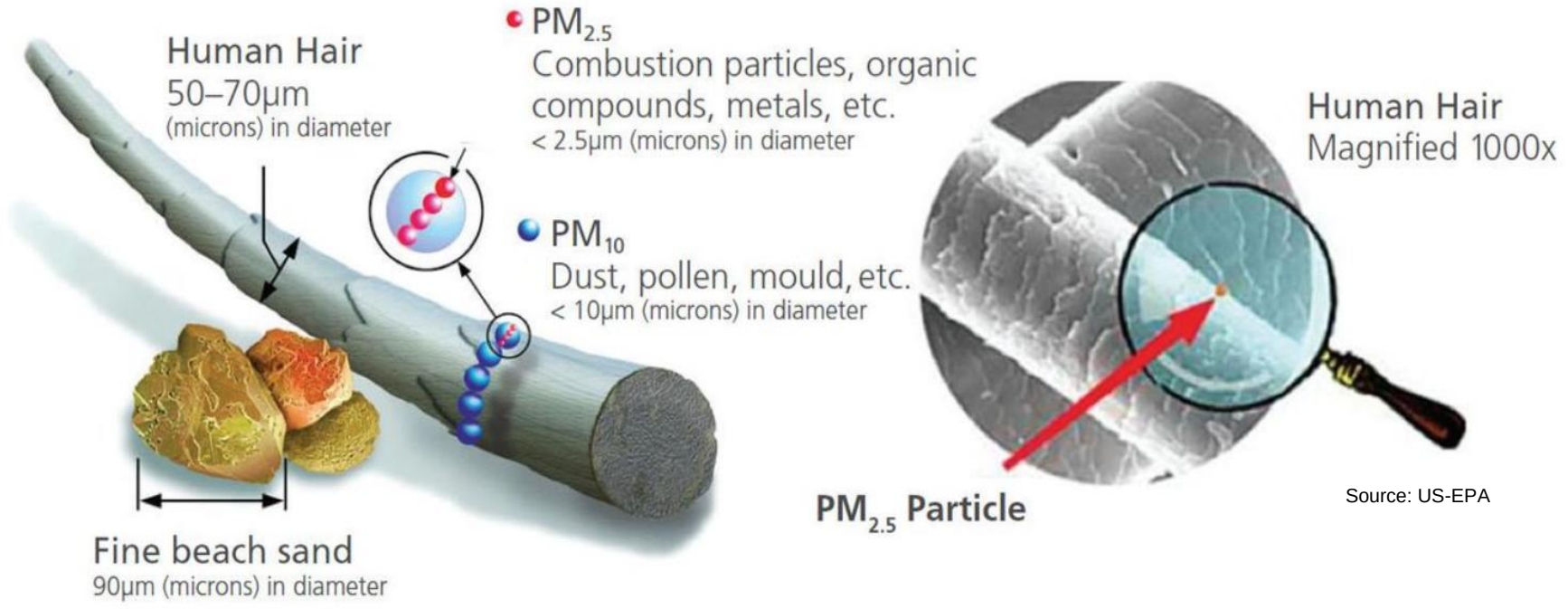
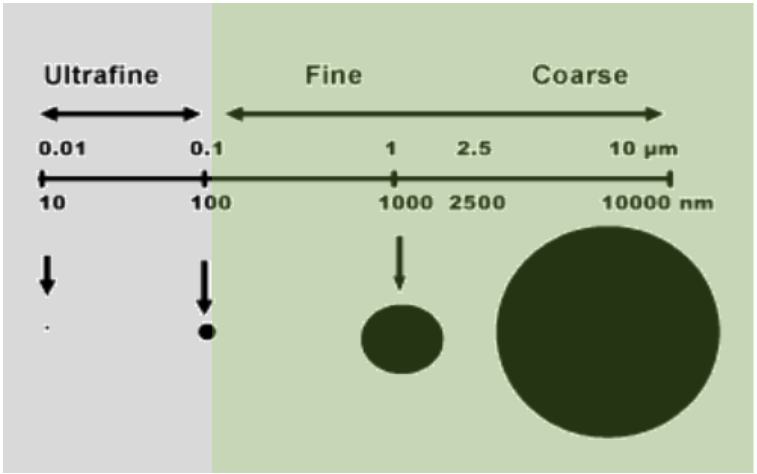
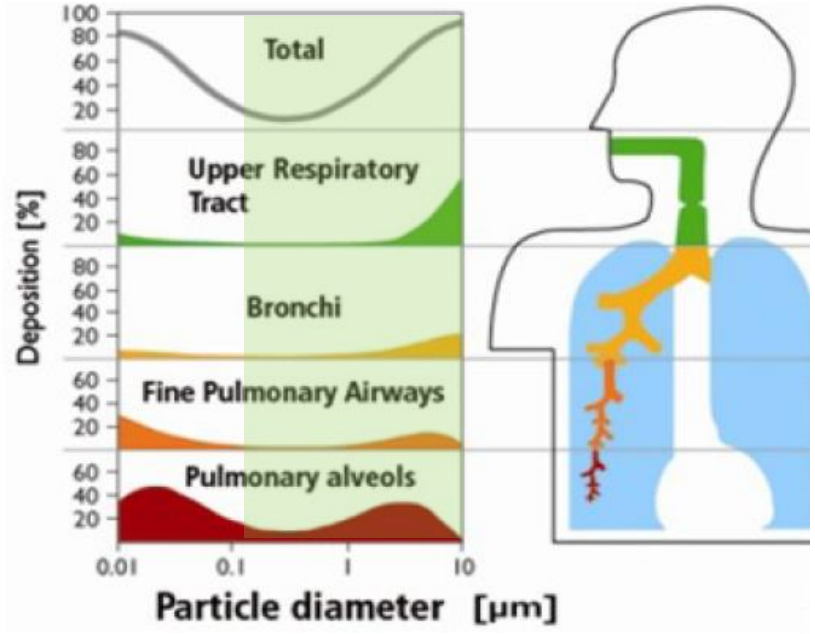
What is Fine Particulate (Particulate Matter)?



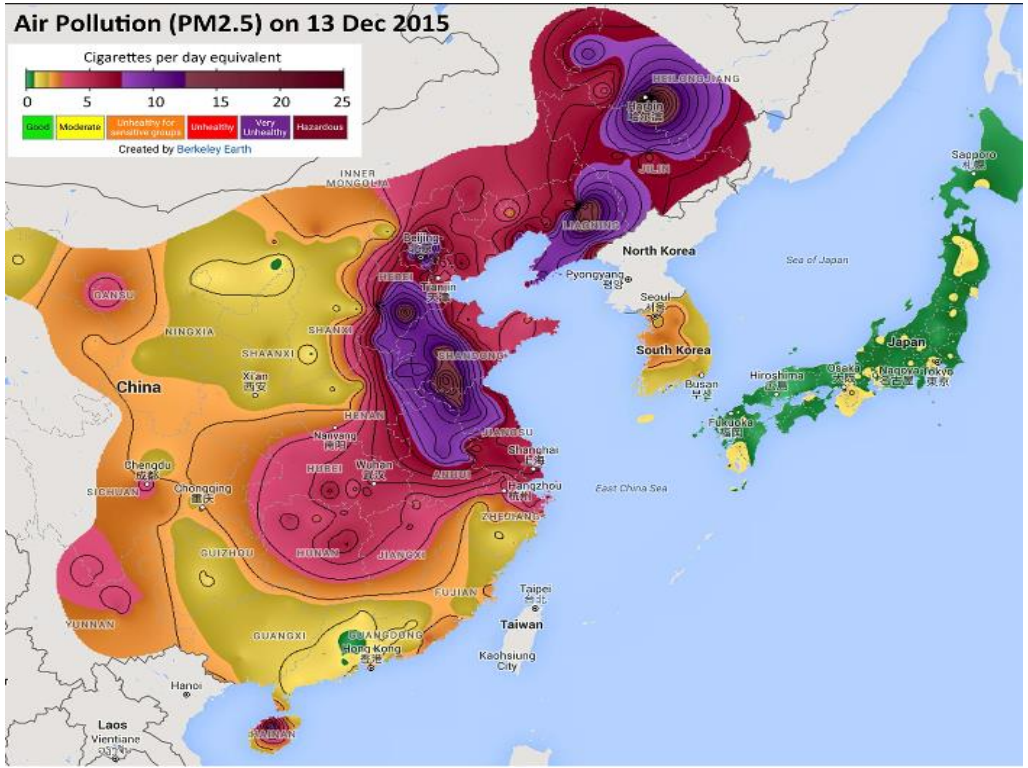
Source: US-EPA

Impact of PM on Human Health





Example: NE China - Chronic Air Quality

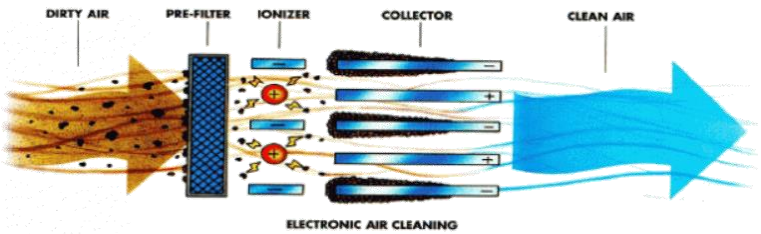


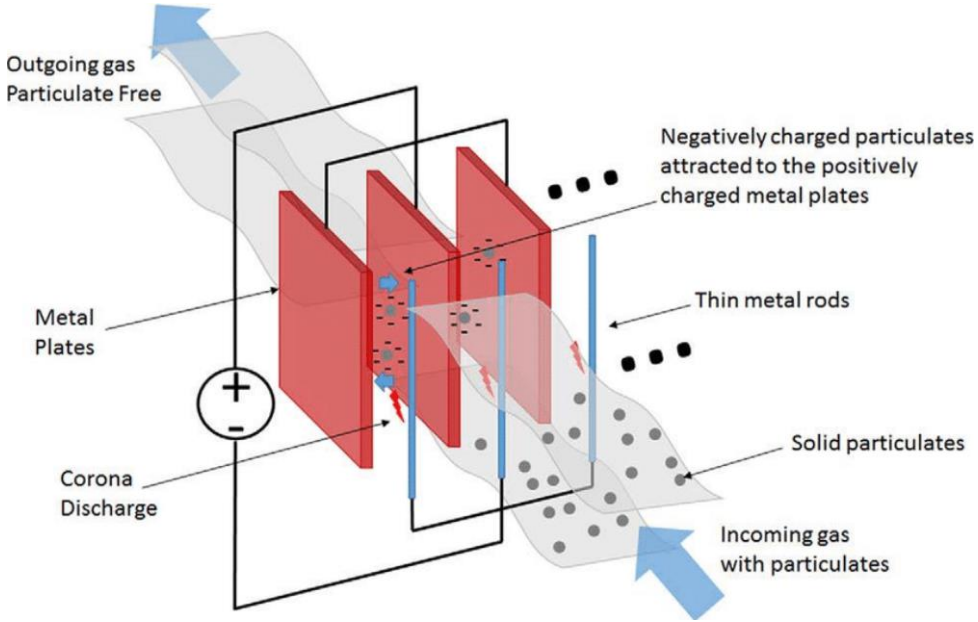
Particulate Matter - Air Pollution Control

- Particulate emissions from industrial appliciations have been subject to control for over 100 years
- During this time, various different filtration methods have been developed and implemented
- The two most common techniques used today are:
  - ***Electrostatic Precipitator / Precipitaton (ESP)***
    - In use since the 1920s ("non-barrier")
  - ***Bag Filter / Baghouse Filter (BHF)***
    - in use since the 1970s ("barrier")

Dry ESP - Principle of Operation

- Dry electrostatic precipitation is a non-barrier filter process in which fine dust particles are removed from the contaminated gas stream. The positively-charged (ionised) particles flow over negatively charged collector plates to which they are attracted

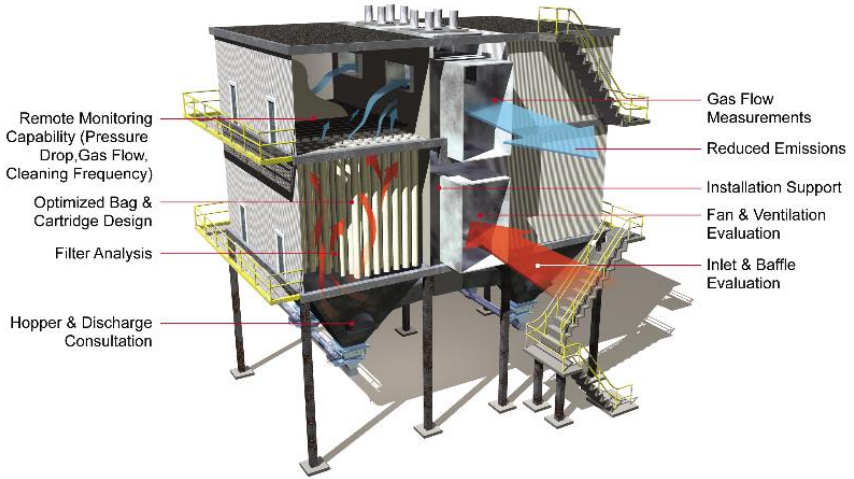




Limitation: Max. Outlet PM ca.20mg/Nm^3

Baghouse Filter - Principle of Operation

- The baghouse filter system is a barrier filter process in which fine dust particles are removed from the contaminated gas flow. Filtration occurs when the raw gas is passed through the wall of a long, cyclindrical bag filter made of woven or felt material
- The fine particulate trapped on the outer surface of the fabric filter is then removed via a shaking, sonic horn or "reverse jet-pulsed air" process



Limitation: 230°C Max. Temperature of Operation

Hot Gas Filtration
- Key Points

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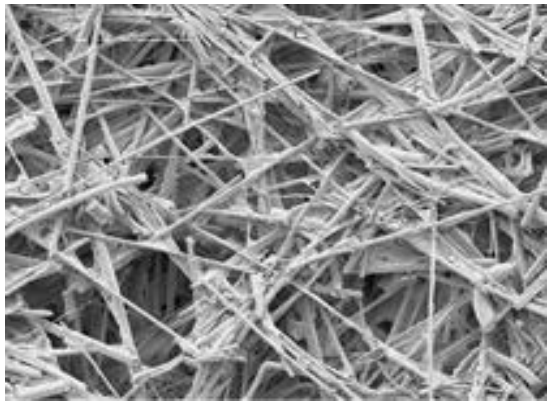
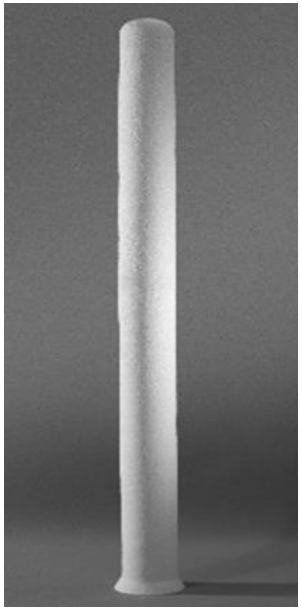
DeDusting - Hot gas Filtration (HGF)

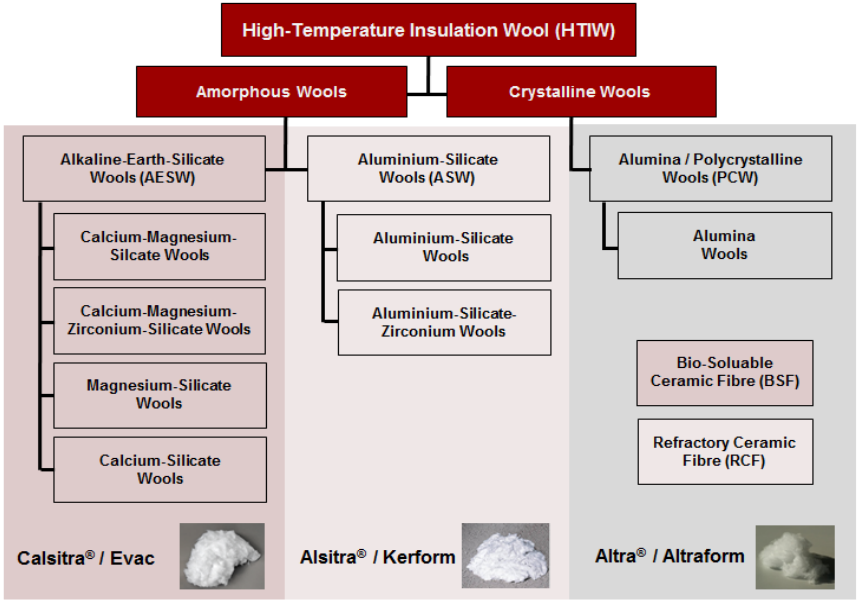
- **Hot Gas Filtration (HGF)** is generally taken to refer to the use of a barrier filtration technique to control process or exhaust emissions in the temprature range 250-1000°C
- Developed in the 1980s, rigid, low density ceramic filter (CF) element technology - typically in candle form - is particularly suited to HGF applications





High Temperature Wool - Werk Mönchengladbach

- High temperature wool (HTIW) is a mineral-based material comprising a collection of synthetically produced fibres of various lengths and diameters

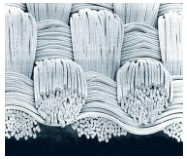


Vacuum-formed Parts - Werk Meißen

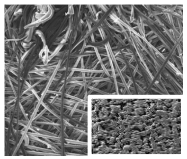
- Temperature-resistant VFP are playing an increasingly important role in thermal insulation thanks to their variety of shapes and outstanding properties
- The moldings are made from high-quality mineral, alkaline or polycrystalline wool with a high aluminium oxide content
- VFP made from high purity PCW (i.e. with an aluminium oxide content > 72% are not classified according to "EU-REACH“) and offer very high corrosion and temperature resistance

HGF: Filter Media - Dry Filtration

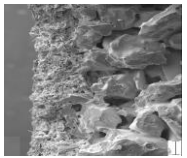
- Flexible Polytetrafluorene (PTFE) Fabric

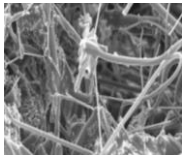
- Rigid Sintered Metal

- Rigid High-Density Ceramic

- Rigid Low-Density HTIW Fibre

Type of Filter Material	Max. Operating Temperature (°C)
Polypropylene (PP)	90
Polyacrylnitrile (PAN)	120
Polyester (PES)	150
Aliphatic Polyamide (PA)	110
Aromatic Polyamide [Aramide] (PA)	180
Polytetrafluorene (PTFE)	250
Sintered Metal (Fibre & Granulate)	600
Ceramic (High Density & Low Density fibre)	1000 (800)

HGF

FILTRATH® Ceramic Filter (CF) Elements

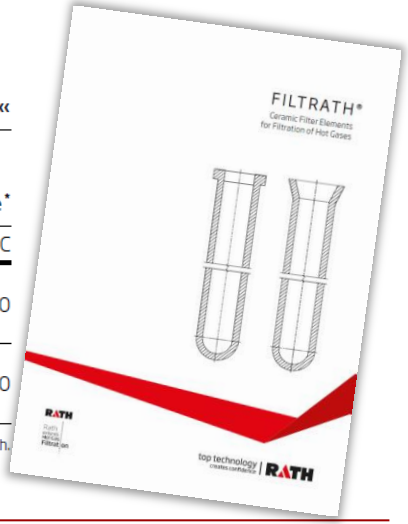
- Candle-shaped filter elements (produced in MEI) uing HTIW (supplied by MGB)
- Specially-developed fibres with ultra high-surface area
- Available in ASW ceramic fibre (RCF) and AES-biosoluble fibre (BSF) forms

FILTRATH® filter elements are available in two grades

Information «

Grade	Raw Material Base	Chemical Analysis		Max. Application Temperature*
		weight %		°C
FILTRATH® ASW	Aluminum Silicate Wool	Al_2O_3 SiO_2	44 56	1,000
FILTRATH® AES	Calcium/Magnesium Silicate Wool	CaO/MgO SiO_2	25 75	1,000

*the maximum temperature limit depends on the application conditions. For support/clarification please contact Rath.



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HGF: Manufacturing Process - HGF Elements

1. Emulsion

2. Vacuumforming

3. Vacuum-formed

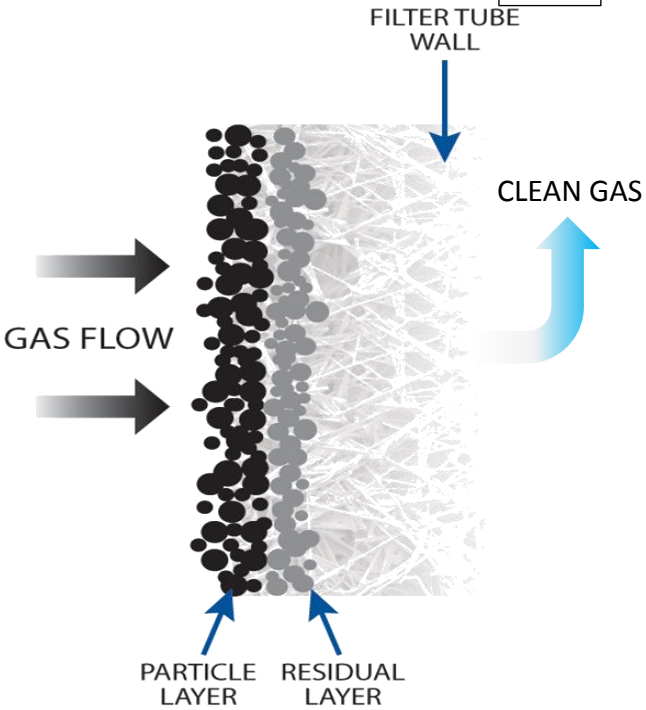
4. Drying

5. Finishing

6. Final QC / Packaging

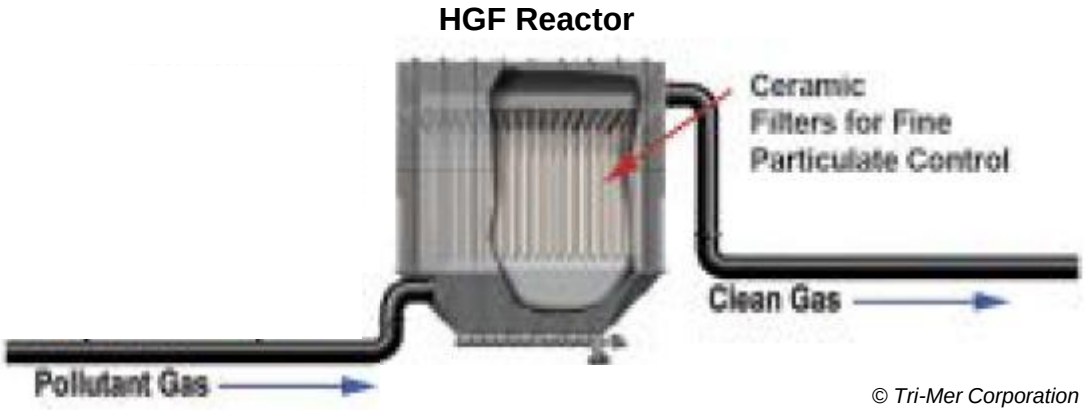
Ceramic Filter Elements - Surface Filtration

- High efficiency dedusting (HEPA*-rated)
- Filtration efficiency further enhanced via residual „primary“ dust layer (>99,99%)
- Negligible penetration of dust into the filter body
- Primary dust layer provides greater resistance to blockage, masking and poisoning and hence to an overall improvement in filter performance and durability
- Rigid, low density ceramic filter elements are not subject to expansion or bending
- Dedusting via “reverse jet-pulsed air” system
- Suitable for operation with variable dust loads



* High-Efficiency Particulate Air-filter

HGF: Particulate Control



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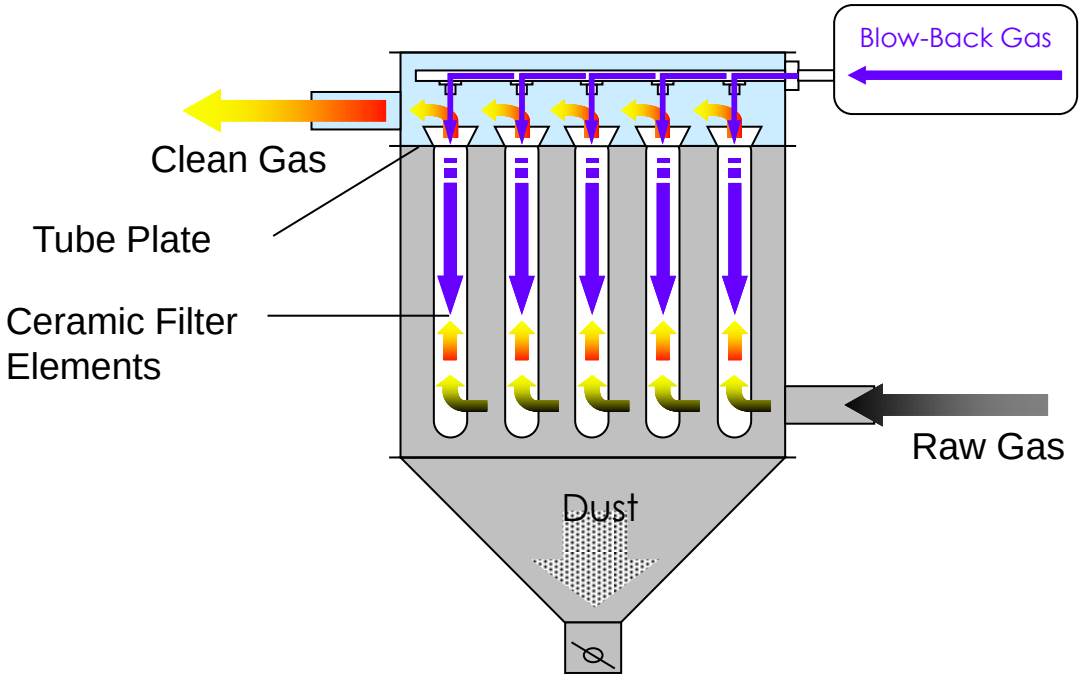
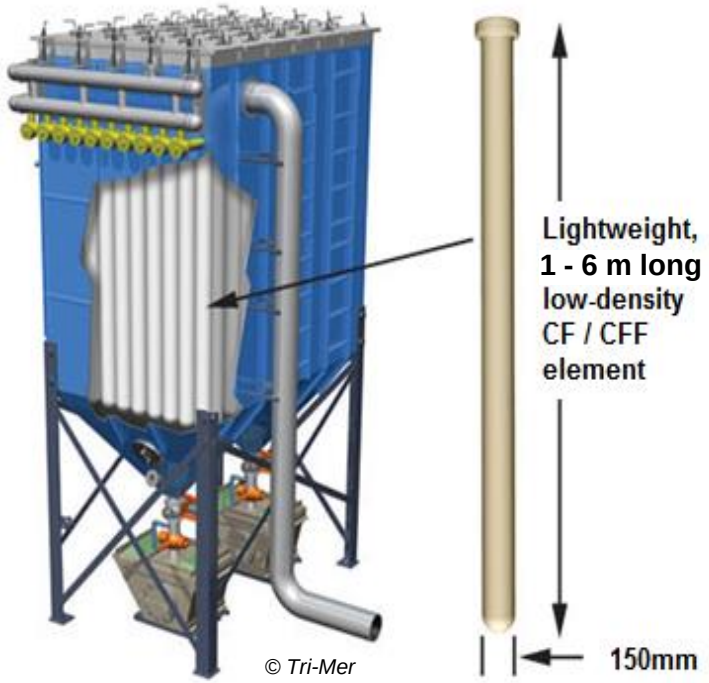
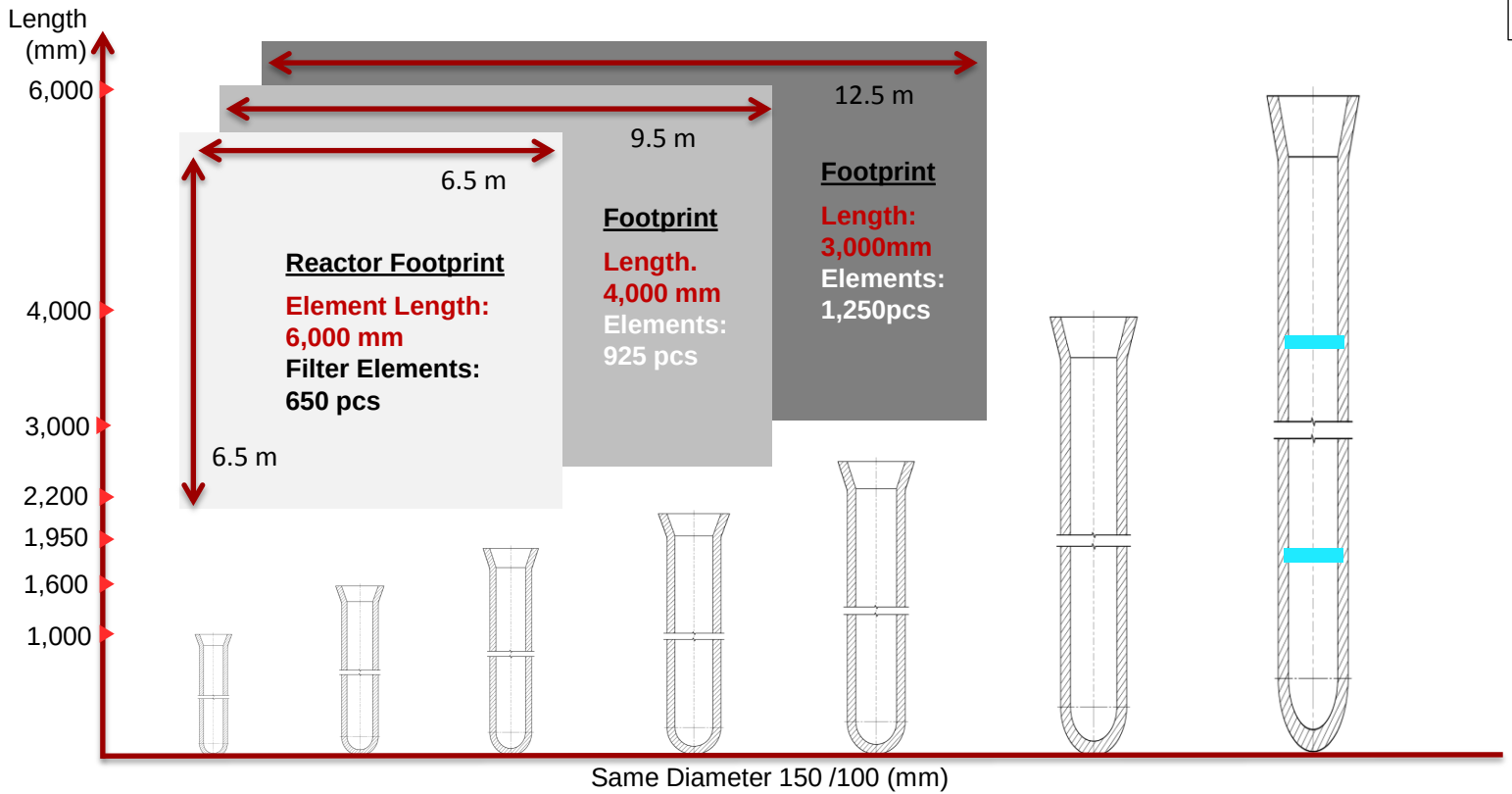
DeDust => *Particulate Matter (PM)* *Control*

Hot Gas Filtration - Reactor / Process





HGF: CF Element Length vs. Reactor Footprint



HGF: Extending Hot Gas Filtration

- Use of 6m long elements ensures a smaller system footprint and, hence, lower CAPEX costs
- Innovative multi-section concept with novel “Glue & Screw“ threaded joint system especially suited for large gas volumes
- Accurately machined screw joint sealed (during installation) using RATH-developed high temperature adhesive
- All RATH Filter elements >4m now supplied with screw joint
- Multi-section filter elements now installed at three (3) cement plant applications in Europe

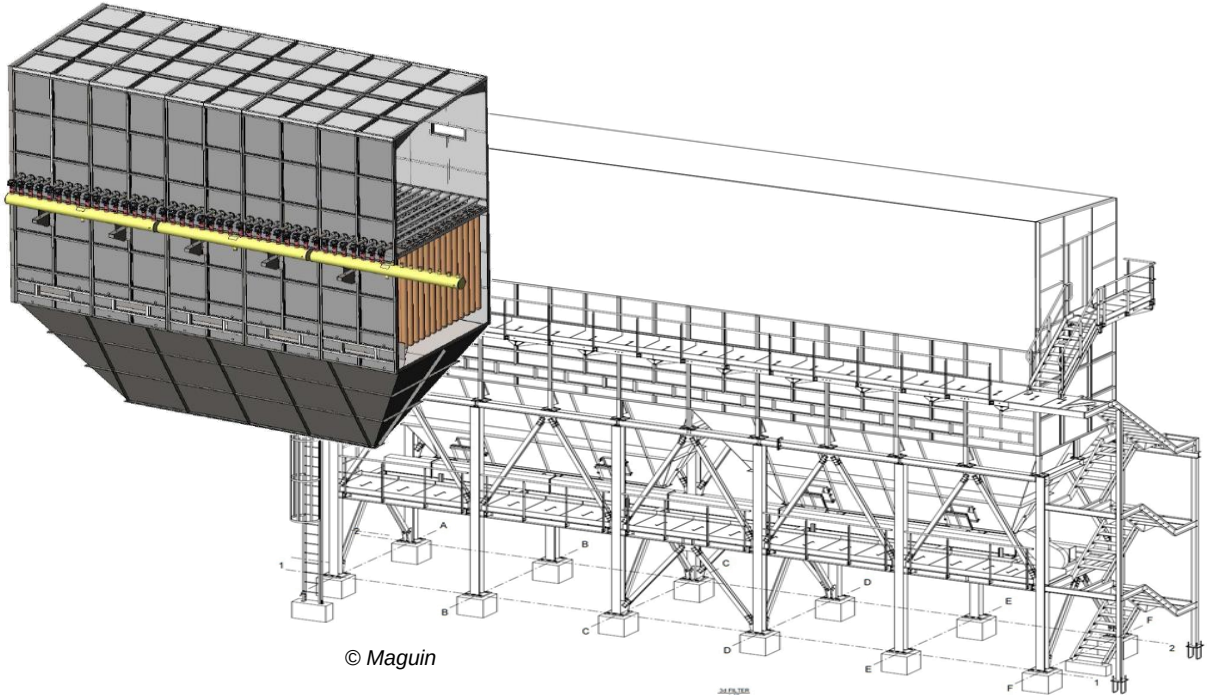
HGF: FILTRATH® CF - Flange Design

- Filter elements are held in position (clamped) via a flange (or “collar“) at the open end
- Both “V“ and “T“ forms are available for 150/110mm diameters – and “T“ only for 60/40mm diameters
- Use of “T“ form is more widespread, typically requiring:
  - *Strengthening of area around neck area*
  - *A ring gasket*
  - *Use of protection cone or venturi*
  - *Top plate, spacers and nuts to clamp it in postion*
- The “V“ form is simpler to manufacture, typically requiring:
  - *Conical (inner and outer) gaskets*
  - *Special ratcheted clamping system welded into positon*
  - *Greater distance between tube plate holes*

Rectangular “T“-Collar

Conical “V“-Collar

Multi-HGF Reactor - Redundancy Concept



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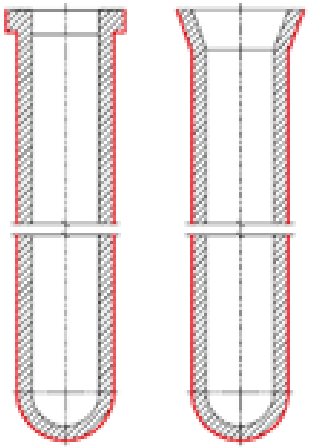
What is Catalytic Hot Gas Filtration?

- **Hot Gas Filtration (HGF)** is generally taken to refer to the use of a barrier filtration technique to control process or exhaust emissions in the temprature range 250-1000°C
- **Catalytic HGF** takes this concept one step further with the addition of an **SCR-Catalyst**-coating to the filter fibres. This enables "multi-pollutant control" of the particulate, acid gases[1] (SO_2, HCL, HF) and oxides of nitrogen[2] (NOx)
- SCR Technology is limited to a max. inlet temperature of 420°C
- It is similar to the technology in use on today's "Euro 6" Diesels cars which employ similar "DeDust & DeNOx" techniques…. albeit with some subtle differences!



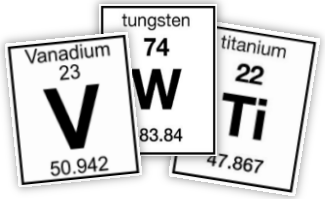
[1] in Verbindung mit einem alkali-basierten Sorbensmitte; [2] in Verbindung mit einem NH_3-basierten Reduktionsmittel.

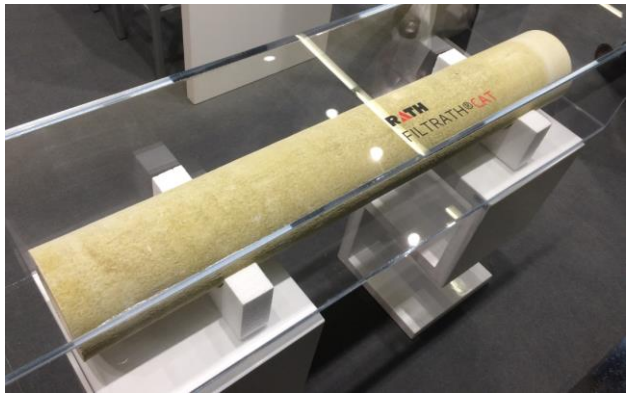
Catalytic Hot Gas Filtration

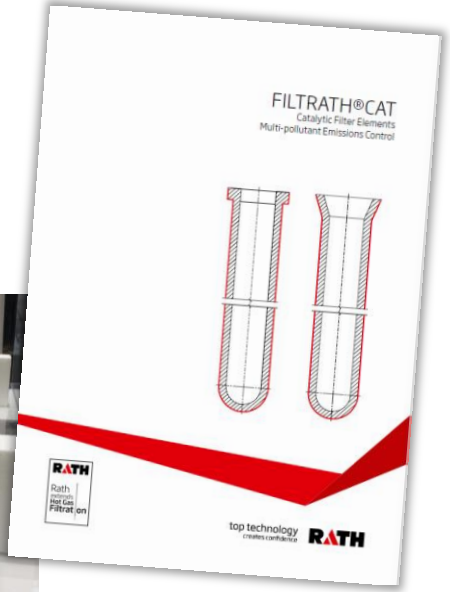
- FILTRATH®CAT = Catalytic Ceramic Filter (CCF) element

  => FILTRATH® CF (DeDust, DeSOx) + SCR Catalyst (DeNOx)

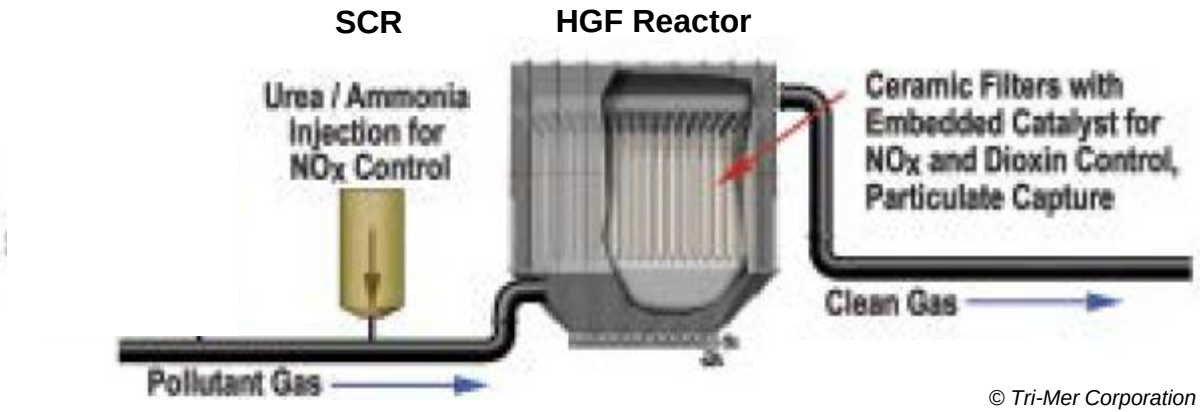
- FILTRATH®CAT enables high efficiency “3-in-1“multi-pollutnant control (DeDust, DeSOx, DeNOx) over a hot gas temperature range of 250-420°C







HGF: Multi-pollutant Control



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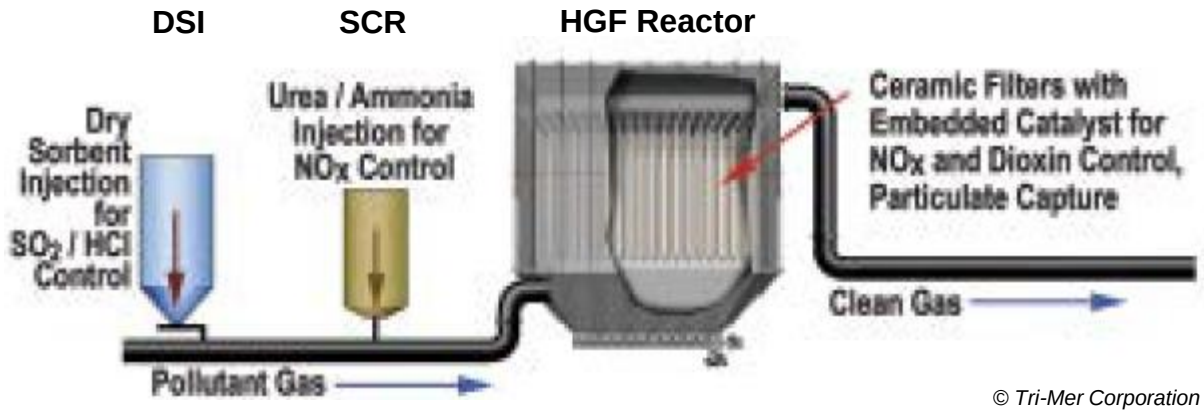
DeDust + DeNOx => *PM + NOx/Dioxin* Control

HGF: Multi-pollutant Control



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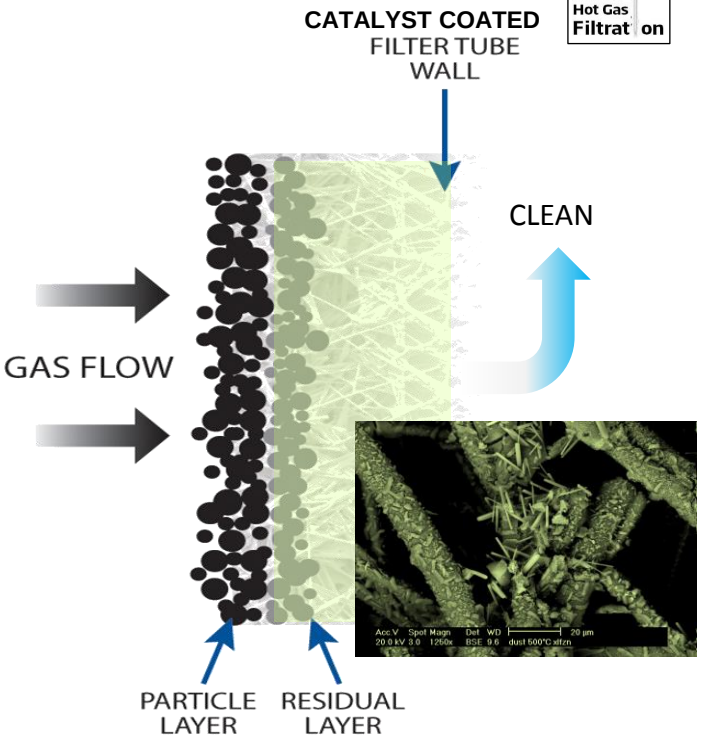
DeDust + DeSOx + DeNOx => *PM + Acid Gas + NOx/Dioxin Control*

Catalytic Hot Gas Filtration

- SCR Catalyst distributed finely across entire filter body (fibres)
- Exhaust gas flows in a tortuous (turbulent) path over the filter body *(i.e. no laminar flow)*
- High catalyst surface area and long residence time
- Not diffusion-limited *(as with extruded Honeyomb SCR)*
- Primary filter cake layer protects the catalyst from blockage, masking and poisoning, improving both performance and durability
- Dedusting of the secondary filter layer via “reversed jet-pulsed air”



* High-Efficiency Particulate Air-filter

Limitations of Honeycomb SCR Technology

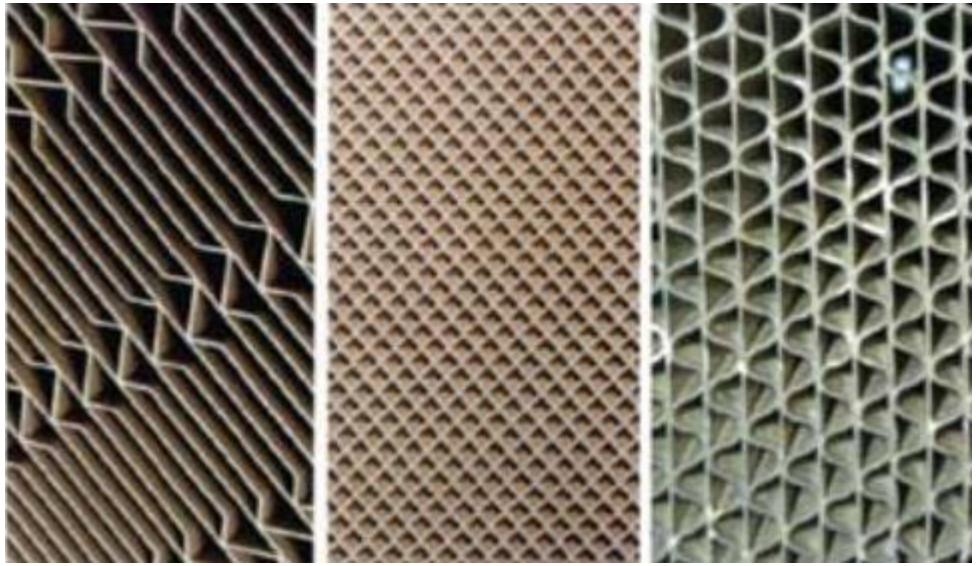
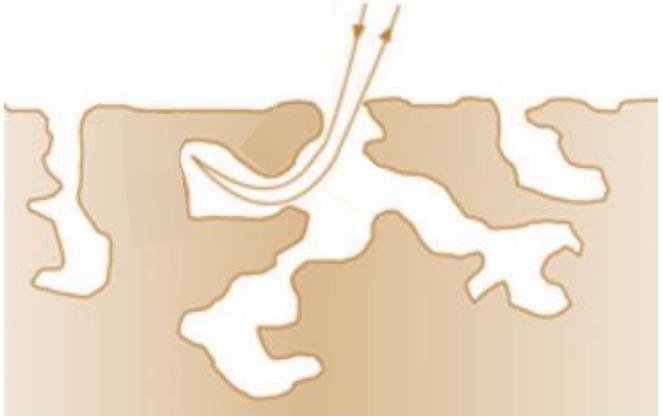


Plate Honeycomb Corrugated

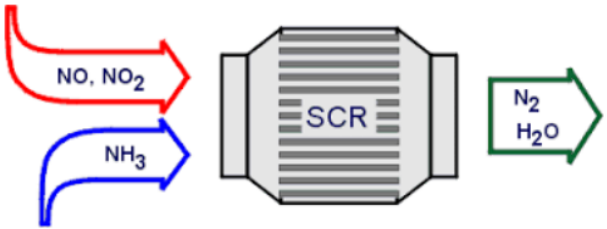
Laminar Flow

Diffusion-limited Reaction



SCR-Cataylst (Honeycomb)

SCR Process Chemistry



Selctive

Catalytic

Reduction of NOx

SCR reduction reactions for oxides of nitrogen (NOx: NO, NO_2) with **anhydrous ammonia** or **ammonium hydroxide** can occur as follows:

$$\mathbf{6NO} + 4NH_3 \rightarrow 5N_2 + 6H_2O$$

$$\mathbf{4NO} + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O \textit{ (dominates)}$$

$$\mathbf{6NO_2} + 8NH_3 \rightarrow 7N_2 + 12H_2O$$

$$\mathbf{2NO_2} + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$$

$$\mathbf{NO} + \mathbf{NO_2} + 2NH_3 \rightarrow 2N_2 + 3H_2O \textit{ (fast)}$$

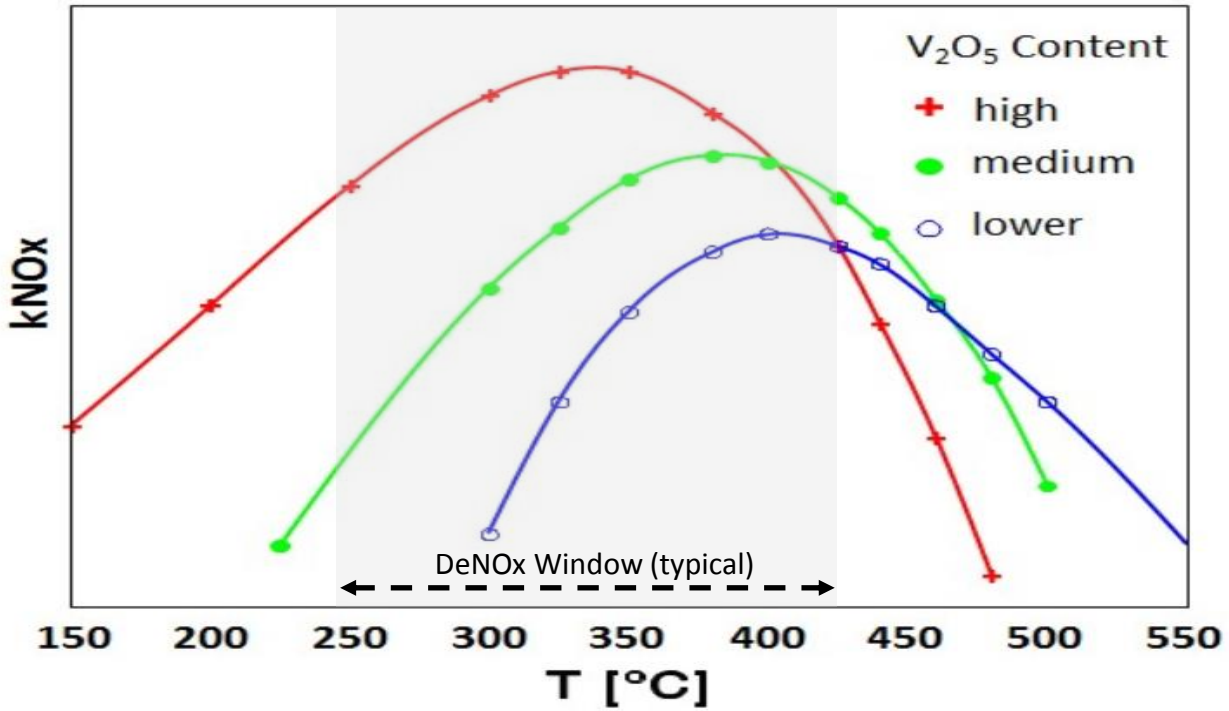
SCR Reaction with **Urea is as follows:**

$$\mathbf{4NO} + 2(NH_2)_2CO + O_2 \rightarrow 4N_2 + 4H_2O + 2CO_2$$

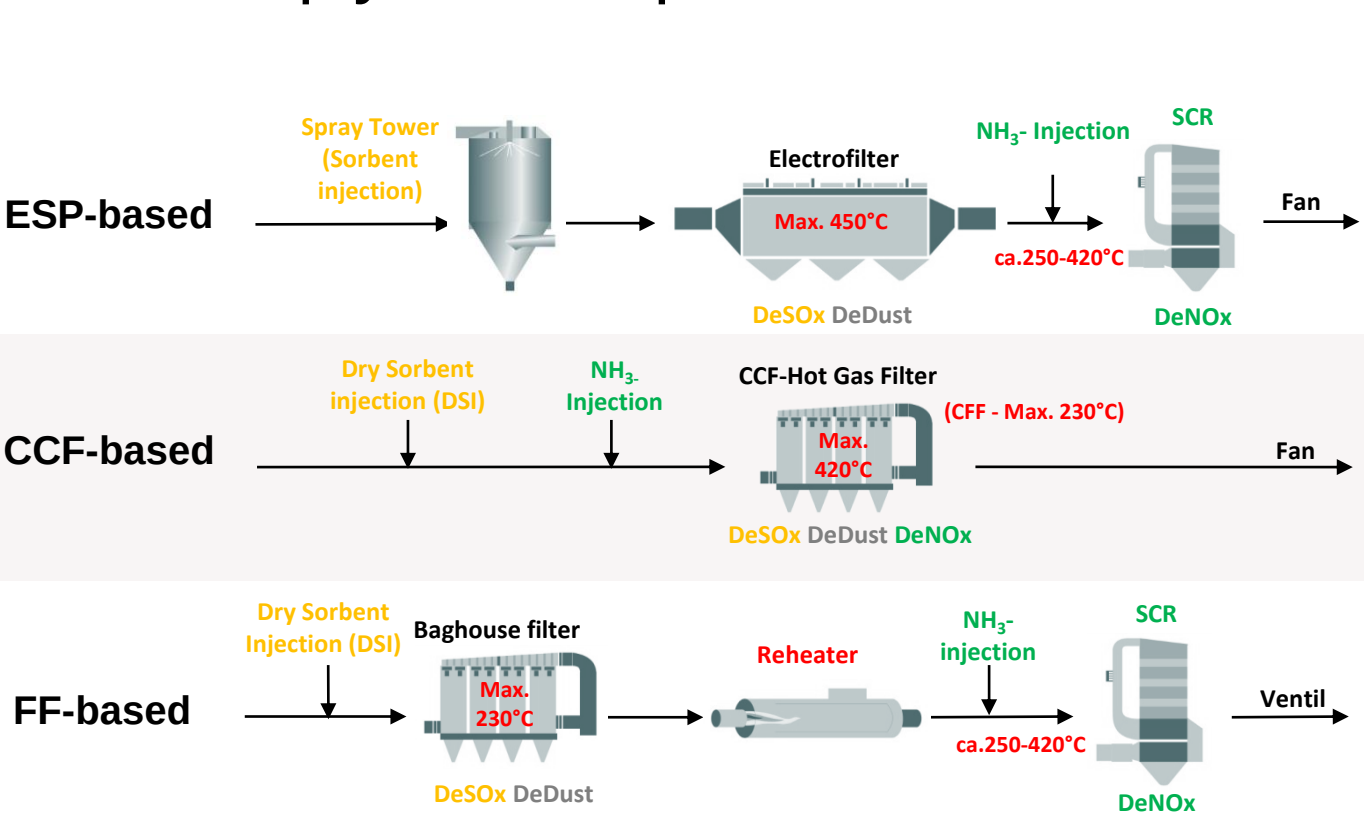
Limitation: AS/ABS-Build-up (at low temp.); Loss of SCR Performance (at high temp.)

Typcial Window of Operation: SCR Process

Highest Nox Conversion
(with lowest NH_3-slip)



CCF: Simply the Simplest Solution!



	CAPEX Saving	25.000 Nm³/h	50.000 Nm³/h
ESP-based	CaO Dry-ESP SCR/NH_3	100 %	165 %
CCF-based	$NaHCO_3$ CCF-HGF NH_3	80 %	110 %
FF-based	$NaHCO_3$ FF-BHF Burner SCR/NH_3	90 %	150 %

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Hot Gas Filtration
- Key Points

1	What is fine particulate - *and how can this be controlled?*
2	What is hot gas filtration (HGF) - *and how does this work?*
3	What is catalytic HGF - *and how does this work?*
4	**What is driving market demand - *and what are the applications?***
5	In a nutshell – summary

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Prinicipal Market Drivers for HGF

- **COMPLIANCE** *with most stringent exhaust emissions limits*

- **PROTECTION** *of downstream processes and equipment*

- **RECOVERY** *of energy and / or vaualbe process /scrap materials*

=> BENEFITS: End-user CAPEX &OPEX Savings

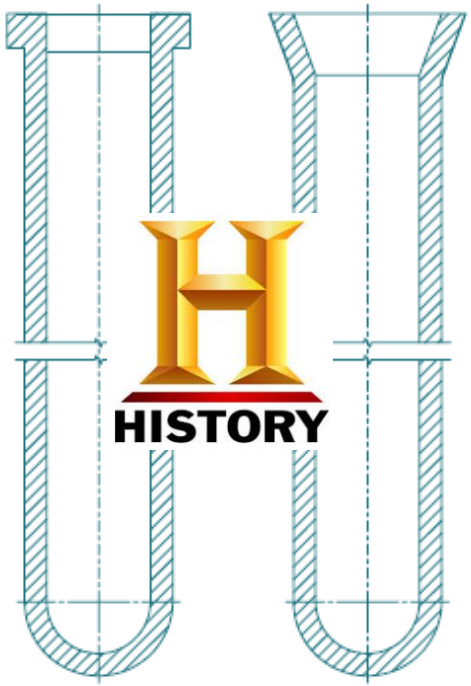
HGF: Industrial Applications

Industry		Sector / Branch	Potential Pollutants	Demand
	**Glass Manufacturing**	Container Glass, Flat Glass, Tableware Glass, Special Glass, etc.	Dust, acid gases, NOx / NH_3, CO, heavy metals	*2017+*
	**Cement & Lime Manufacturing**	Main Furnace, Clinker Cooler, Alkali-Bypass, „xmercury“	Dust, acid gases, NOx / NH_3, dioxins / furans, CO, Hg, heavy metals	*2018+*
	**Chemical & Petrochemical Industry**	Catalysts, Pigments, usw.	Dust, acid gases, NOx / NH_3, dioxins / furans, CO, VOC, Hg, heavy metals	*2019+*
	**Metal Processing Industries**	Iron & Steel, Non-Ferrous	Dust, acid gases, NOx / NH_3, CO, VOC, heavy metals	*2020+*
	**Biomass & Waste Incineration**	Also Gasification, Recycling, Remediation	Dust, acid gases, NOx / NH_3, CO, dioxins / furans, Hg, heavy metals	*2021+*
	**Energie / Power Generation**	Power Plants, Stationary / Marine Engines, Gas Turbines, usw.	Dust, acid gases, NOx / NH_3, CO, VOC	*2022+*

CCF Technology: Application Milestones

Today: >50 CCF applications *(>30 in Glass industry)*

- **2018:** 1st full scale Cement application worldwide (US)
- **2016:** 1st full scale application in China - *Glass*
- **2014**: 1st Biomass CHP worldwide (CL)
- **2013:** 1st full scale application in Middle East - *Glass (UE)*
- **2013:** 1st full scale application in Central America - *Glass (CR)*
- **2012:** 1st full scale application in North America - *Glass (US)*
- **2009:** 1st glass furnace application worldwide (ES)
- **2008:** 1st waste incineration applciation worldwide (JP)
- **2008:** 1st full scale application – *Meat rendering (FR)*
- **2005:** 1st pilot trials (FR)



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Conclusions

- Excellent refractory properties and shape diversity mean that FILTRATH® ceramic-based HGF element technology has now become state-of-the art for many high temperature APC applications
- Highest gas purification efficiency up to operating temperatures of 1000°C without the need (as in bag filter systems) to reduce the filter inlet temperature to below 250°C
- Dry gas purification process eliminating the costs associated with water consumption and wastewater treatment - hence, an ideal replacement for ESP and gas scrubbers
- FILTRATH® CAT filter element technology enables multi-pollutant control in one system eliminating interfaces and ensuring high adaptability to operating conditions
- Modern HGF systems with highly porous, multi-section, filter elements up to 6m long are robust and space-saving and, hence, highly cost-effective

Thank You For Your Attention !

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