Hot Gas Filtration GdPS

A route map and summary of options available and merits of each based on purchasers unique circumstances

Modified for AFS April 29 Discussion

THE McILVAINE COMPANY

Revision 4-1-2015

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    - Ceramic
      - Catalytic filter
    - Metal

Program Overview

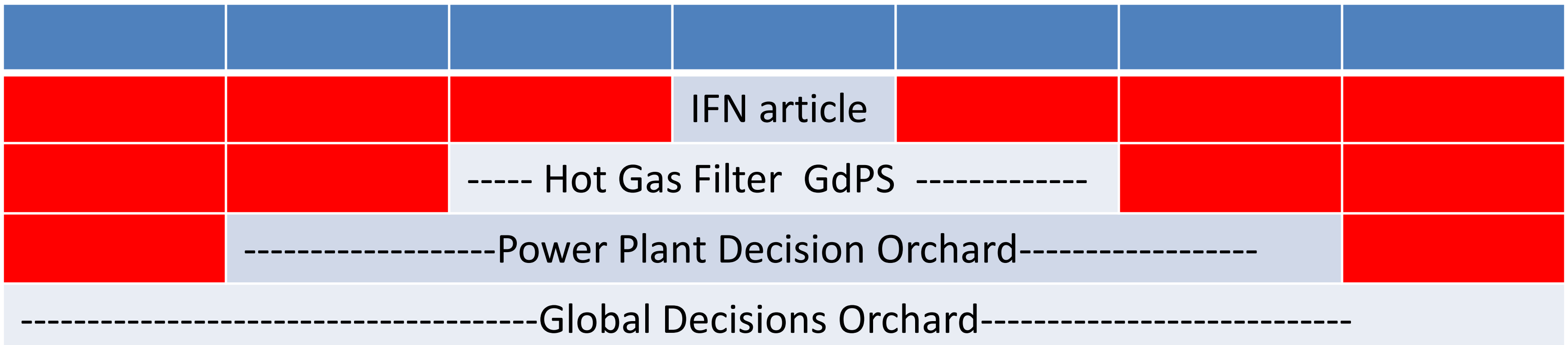
General

- The 90 minute session will be focused on a slide by slide display of the summary power points.
- As each slide is displayed there is the opportunity for discussion. It would start with the slide author if he so wishes
- Designated panelists as well as the entire group will be encouraged to ask questions and make observations
- Panelists and participants are encouraged to submit power points to be included in the summary
- Anyone is encouraged to submit articles and presentations for inclusion in the Power Plant Decision Orchard
- The Filtration News article in June will be based on the conclusions reached in the session
- The summary and the intelligence system will be continually updated

“Specific

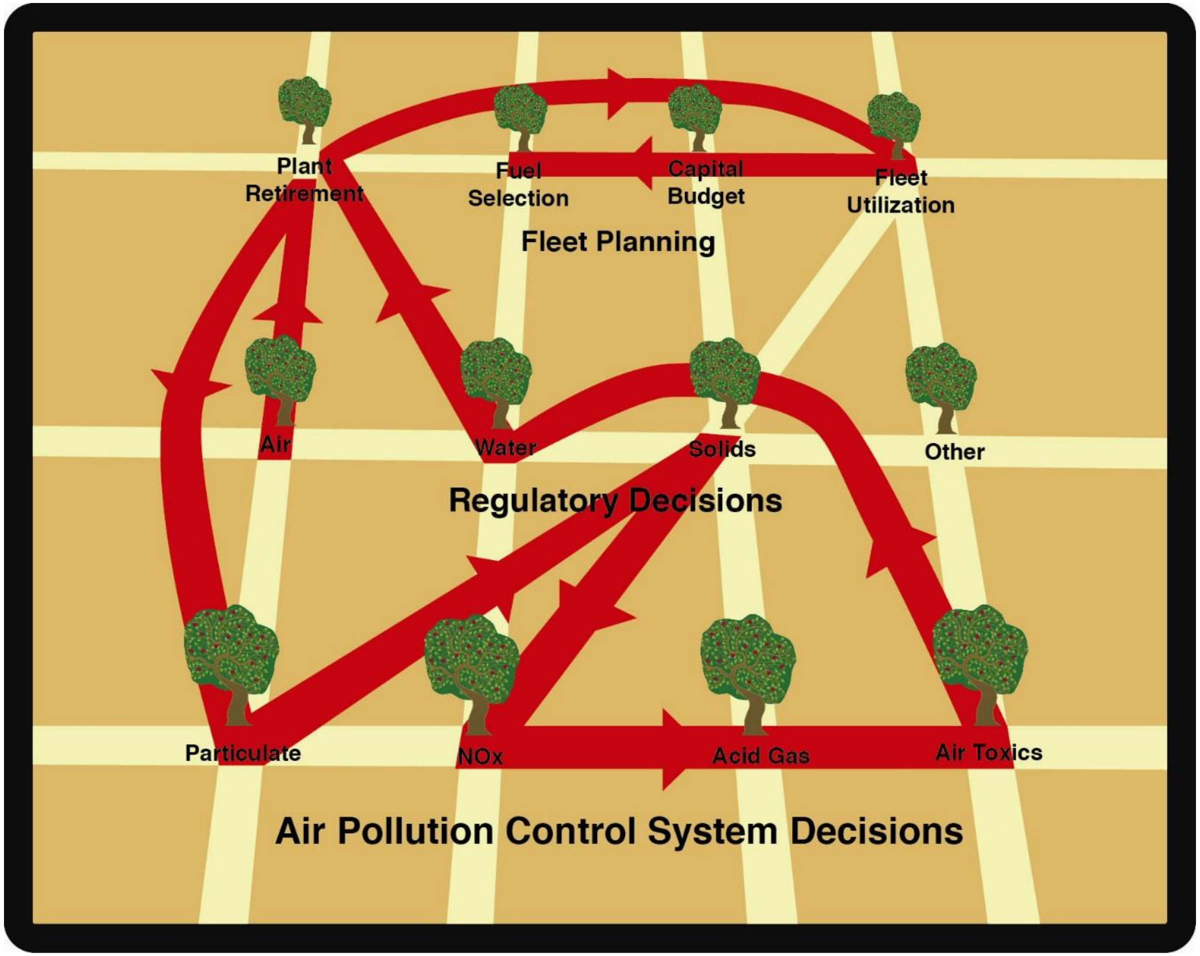
- Provide access to hot gas filter GdPS upon registration
- Provide updated version of HGF GdPS prior to the event
- Provide contact among presenters and attendees before , during and after the event.
- Conduct the program as a series of panels
- Presenters sit at designated tables during lunch and continue discussions
- Continuing upgrading of Hot Gas Filter GdPS and articles in IFN

Hot Gas Filter Summary is part of a whole system



The GdPS is part of a whole system. It is route map to the larger database display (Power Plant Air Quality Decisions) This in turn is part of a complete service for coal fired power plant operators- *Power Plant Systems and Components.* The June Filtration news article will be a compressed version of the revised summary as shaped by the AFS session.

Global Decision Positioning System (GDPS) to select hot gas media



Panelists

Company	Name
AEP	Tom Hart
Consultant	Rich Miller
Donaldson	Eddie Ricketts
Durr	Martin Shroter
ETS	John McKenna
F.L. Smidth	John Johnson
Haldor Topsoe	Nate White
Purolator	Pavlos Papadopoulos
SEI	Mick Chambers or Hardik Shah
Testori	Clint Scoble

Regulatory, Economic and plant specific impacts on filter choice

Subject	Author	Relevant decision
Regulations and Technology	Mcilvaine	**Many Different Options created**
Emission limits-World	Mcilvaine	**New approaches needed to meet new regulations**
China limits	Mcilvaine	**Will new rules here influence rules for you?**
U.S. regulations	Hot topic	**Multiple pollution control requires multiple decisions**
Cement and other	Mcilvaine	**Other industries have the same multiple decisions**
PM 2.5 ambient	Troutman -Sanders	**Need to evaluate future requirements due to ambient State limits**
Condensibles	Hamon	**Need to consider small sulfuric acid particle diameter**
Method 5 catch	Hamon	**Standard method shows large condensable fraction and may not be valid**

Regulations and technology are changing the hot gas filter choices

- China and the U.S. are leading the way with tough particulate emission requirements for power plants.
- Ambient regulations in U.S. states and counties as well as stack regulations for certain cities and provinces in China are much tougher than the national requirements
- The definition of particulate involves size fractions e.g 2.5 microns and physical state (discrete or condensable)
- Requirements involve new and existing installations each with a different set of site specific conditions
- The need to reduce mercury, other toxic metals, HCl, and SO2 changes the particulate reduction decisions.
- Upgrading dry precipitators with new electricals is one option
- One very active retrofit option is replacing the internals of precipitators with fabric bags.
- Wet precipitators are being used in some of the newer U.S. and Chinese installations
- Various dry scrubber/ fabric filter combinations are popular
- The ceramic catalytic filter offers potential of small foot print and with DSI can also capture acid gases.
- Metal filters offer an alternative separation at temperatures of 850F and extraction of heat from the clean gas.
- **Many different options based on new regulations and new filter designs**

Emission limits for coal plants around the world in mg/Nm3

pollutant	China Guangzhou, Shanxi	Sinopec Guangzhou	Zhejiang with SCR and WESP	China national regional l	U.S Existing/new	EU Existing/new
NOx	50	1.4 to 28.5	23,7	200/100	1060-640/117	200/200
SO2	35	2.85 to 7.6	15	200-400/100	350/65	400/200
PM	5	3.4 to 4.6	3.08	30	45/8	50
SO3	5	0.08				
Hg	0.003	0.0004 ug		.03	0.002/0.001	

New approaches needed to meet tough new regulations

China now has the most stringent particulate limits

- Due to pressure from citizens due to smog, the Chinese government is initiating the toughest air regulations of any country
- Tough national standards have now been followed by even more stringent standards in a number of cities and even provinces
- the new national standard of 30 mg/Nm3 for particulate was already tougher than the regulation for existing U.S. coal plants or for plants in the EU.
- The new regulation in Guangzhou and Shanxi limits dust to only 5 mg.
- Existing precipitators will not be able to meet these limits. Zhejiang is meeting the new requirements with a wet precipitator.
- Sinpoec Guangzhou is meeting the standards with a dry scrubber fabric filter system complete with activated carbon injection installed by Longking
- **Will Chinese rules influence rules elsewhere**

U.S regulations will dictate new hot gas filter approaches

McILVAINE

MATS and CSAPR

Mercury and Air Toxics Standards (MATS)

- Limits emissions of toxic air pollutants from coal and oil fired power plants
- Primary pollutants of concern are mercury, hydrogen chloride (HCl) and fine particulates ($PM_{2.5}$)
- FINAL RULE: Compliance by April 2015 with possible extensions of up to 2 years

Cross State Air Pollution Rule (CSAPR)

- Referred to as the "Good Neighbor" rule
- Regulates emissions from one state that may have a negative impact on air quality in a downwind state
- 28 states in the eastern half of the U.S. must limit state-wide emissions of precursors to ozone formation (NOx, SO_2 and $PM_{2.5}$)
- FINAL RULE issued August 2011 with first phase to begin in 2012
  - But, the rule did not take effect as scheduled due to litigation
  - August 2012: US Court of Appeals vacated the rule and remanded it to EPA
  - April 2014: US Supreme Court reversed Court of Appeals and reinstated CSAPR
  - November 2014: EPA issued new compliance dates of 2015 to 2017

Together, MATS and CSAPR will require coal plants to install:

- FGD or Dry Sorbent Injection (DSI) to control SO_2 and acid gases (HCl)
- SCR or SNCR to control NOx
- Fabric filters or electrostatic precipitators to control particulate matter
- Activated carbon injection units to reduce mercury

Control of multiple pollutants requires multiple decisons

Cement, power and other industries have tight emission standards

- Waste to energy plants have been subjected to tight particulate limits for some time
- Cement plants are finding that precipitators are inadequate to meet regulations in most countries
- The new MACT regulations in the U.S. provide tough requirements for industrial boilers and cement plants
- The MATS regulations in the U.S. provide particulate challenges related to using particulate as a surrogate for toxic metals
- Mining operations, pulp mills and other industries are also facing the necessity of improving particulate capture
- Particulate removal GDPS™ has to take into account the requirements for reduction of other pollutants

PM 2.5 ambient standards will require reduction

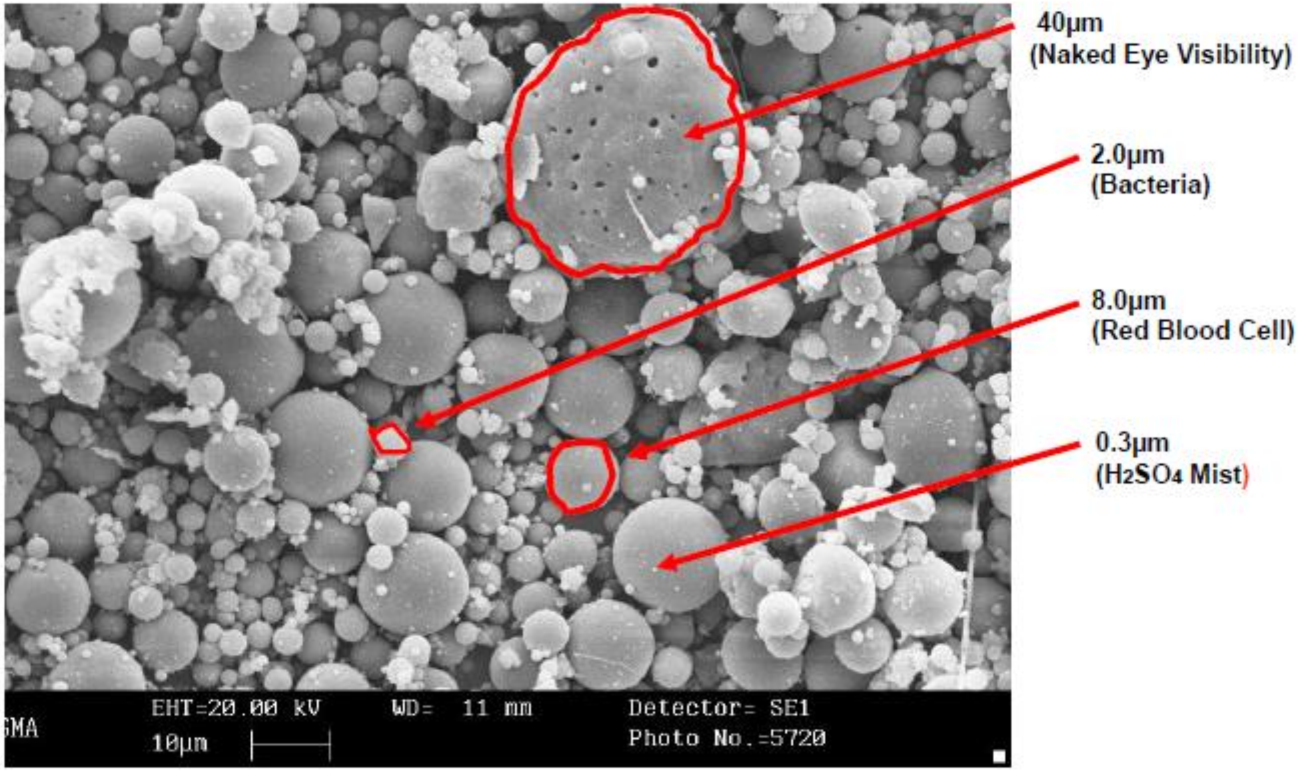
TROUTMAN SANDERS
ATTORNEYS AT LAW

Fine Particulate Matter ($PM_{2.5}$)

- Lowered annual standard to 12 ug/m^3 in December 2012
- EPA expects all areas to attain without new control requirements (except CA)
- Vacatur of de minimis levels (SILs and SMCs) could make permitting difficult
  - w/o SMCs, could require onsite monitoring
  - w/o SILs, could make modeling more difficult
- EPA's implementation rule also vacated
- EPA resets the baseline date; NC objects

Sulfuric acid mist is only 0.3 um in dia.

Particle Sizes



Supplied by Hamon

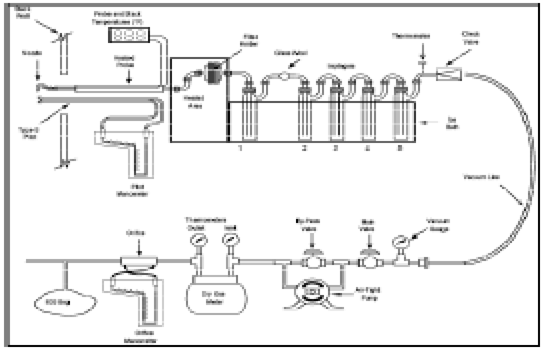
Choose collector to remove very small particles

PM includes both discrete and condensable aerosols

What is $PM_{2.5}$?

Filterable Particulate

- <2.5 microns in size
- Exists as solid particulate at temperatures of $250^{o}F$ or higher
- Collected in "front half" filter of PM test apparatus



Condensable Particulate

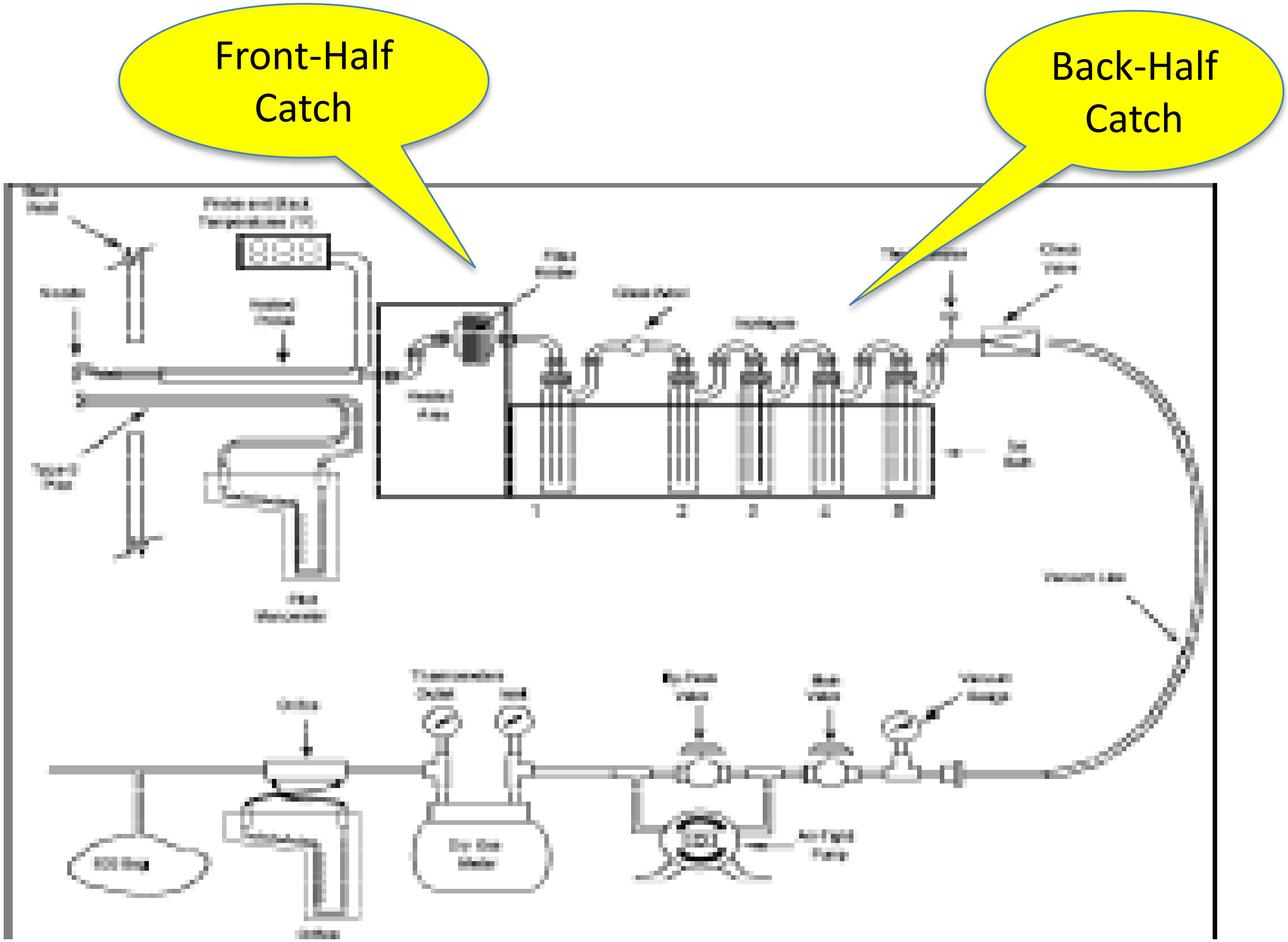
- <2.5 microns in size
- Vapors that condense
- Primarily SO_3 (H_2SO_4) sulfuric acid
- Toxic metals
- Collected in "back half" impingers in PM test apparatus

50%- 75% of PM2.5 is Condensable PM

Supplied by Hamon

Choice may have to include condensibles

Condensibles captured in back half of Method 5 train (Hamon)

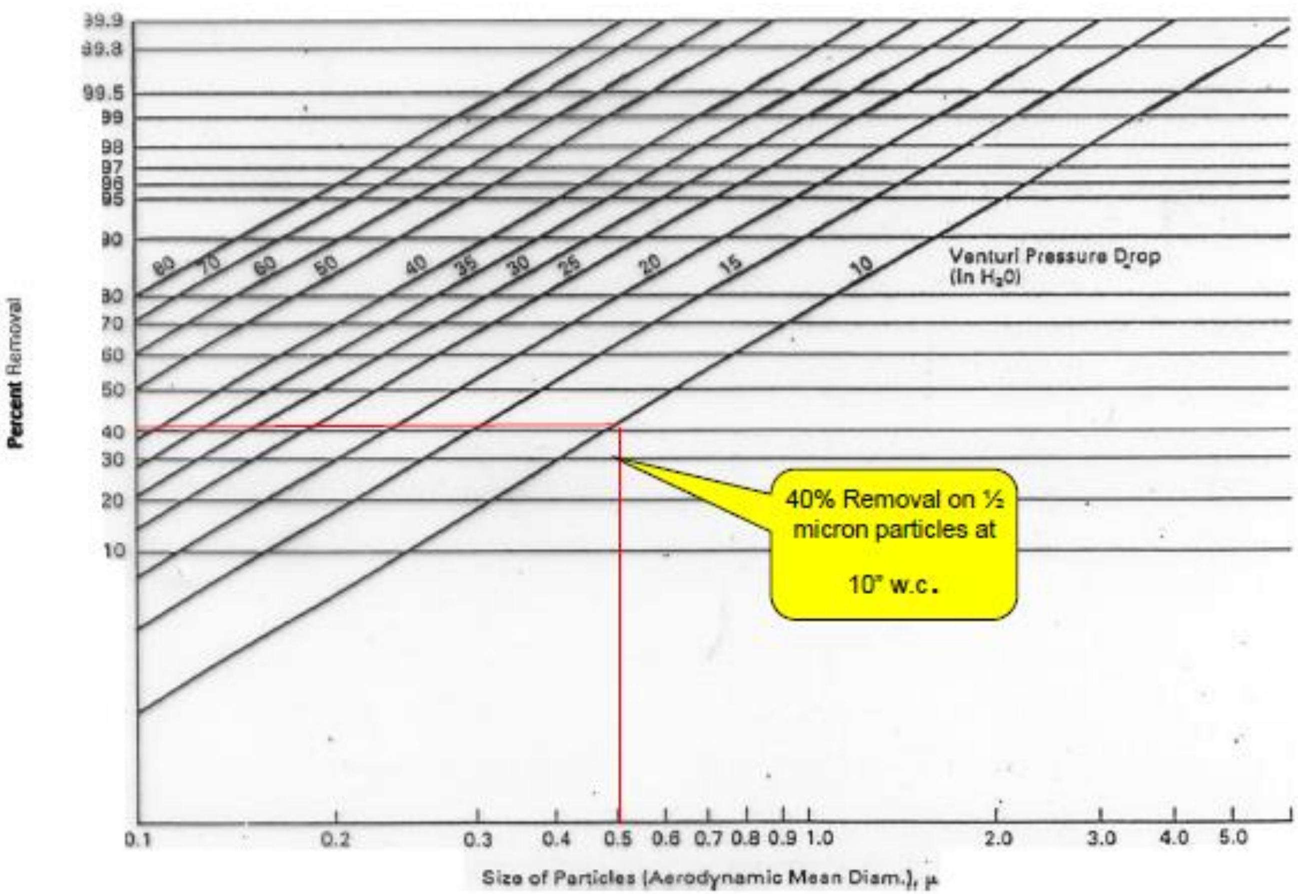


EPA Method 8 Sampling

Will you have to deal with this uncertain measurement ?

Scrubber limitations (Hamon)

Limitations on WFGD PM2.5 collection



Will you have to find alternative for H2SO4

Decision Route – Reasons to address hot gas alternatives

Webinars (subscriber only)

DATE	SUBJECT
March 5, 2015	**Mercury Measurement and Capture (Session 2)** 105 minutes **MORE**
February 26, 2015	**Mercury Measurement and Capture** 106 minutes **MORE**
January 29, 2015	**MATS Compliance Choices** 91 minutes **MORE**
INTERWEBVIEWS™ (FREE)	
August 2014	Mercury in Mandarin (*available in Mandarin and English by Bobby Chen of CBI*
Chinese youtube version	http://youtu.be/ldq33k5UWTs
中国能以低成本除汞得益于美国的技术发展	

Decision Orchard key words

Free to end users but subscription for others)

categorys	keywords
regulatory	CSAPR. Industrial Boiler MACT Legislation MATS NAAQS
Analysis by consul-ants	AECOM, Burns & McDonnell, Farber Golder, Kiewit, Sargent & Lundy
Other organiz-ations	EPRI, EERC, Reaction Engineering, Troutman-Sanders

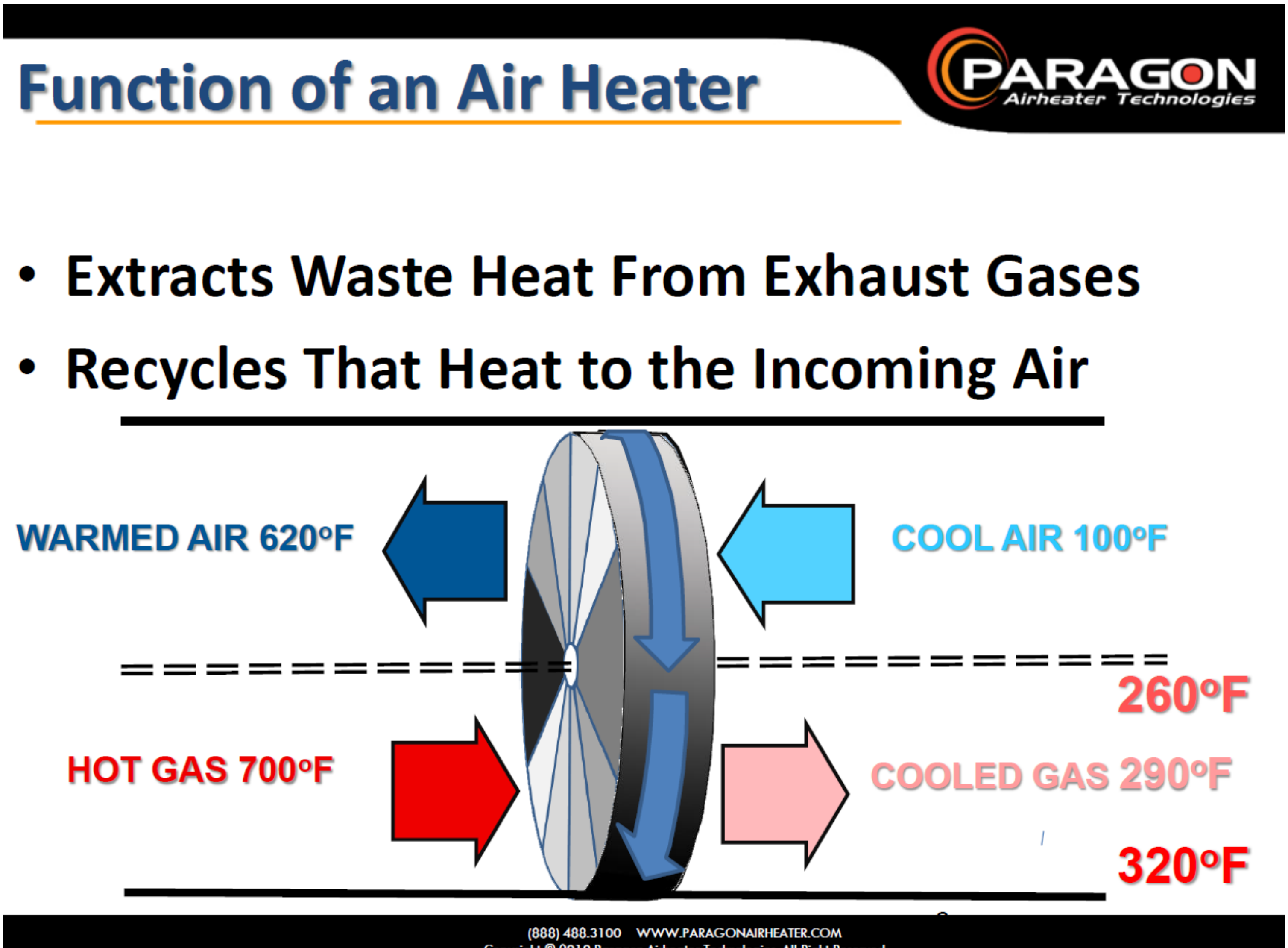
System and APC impacts on filter choice

Subject	Author	Relevant decision
System Impacts	Mcilvaine	**Many process and site specific impacts have to be considered**
Boiler efficiency-APH	Paragon	**The air heater outlet temperature is variable and impacts the filter selection**
Mercury Considerations	CBI	**The filter decision must be viewed along with the many options to reduce mercury and prevent –re-emissions**

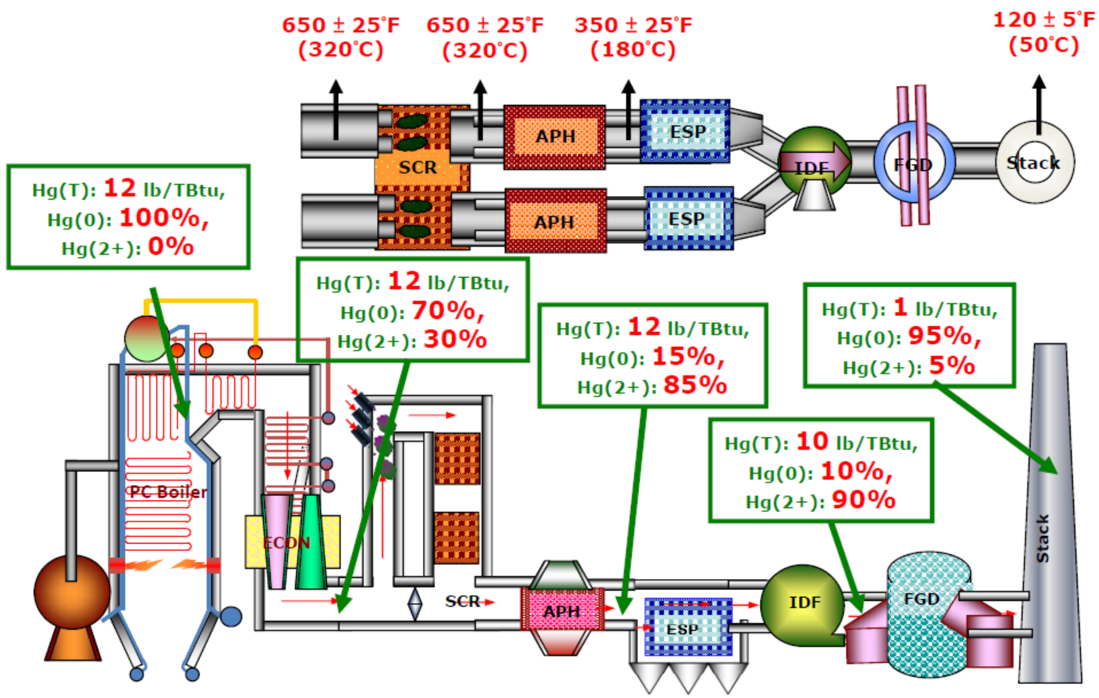
System impacts

- Heat extraction decisions must be made simultaneously with particulate control because of the inter-relationships
- The precipitator efficiency increases as the inlet temperature is reduced.
- The ability to use lower cost bags is enhanced by reducing both the gas temperature and the acid dew point
- Reduction of precipitator or baghouse inlet temperature to the acid dew point will cause corrosion and plugging problems
- Clean hot gas offers a big potential for energy recovery
- Existing rotary air heaters have inlet air leakage of 10% making the dust collectors larger than need be
- The SCR increases SO3 which will lead to more condensable particulate
- Activated carbon for mercury control increases particulate emissions
- Halogen addition to the coal causes potential corrosion problems
- Dry scrubbers increase the particulate load and potential emissions and wear on bags
- Wet scrubbers downstream of a precipitator can improve total particulate capture

Boiler efficiency is a function of heat transfer in the air heater but limited by the acid dew point



Mercury considerations in many locations



- If more than **1.0** lb/TBtu of stack Hg emission is observed, there is Hg reemission across the FGD

Decision Route – System impacts

Webinars

March 5, 2015	**Mercury Measurement and Capture (Session 2)** 105 minutes **MORE**
February 26, 2015	**Mercury Measurement and Capture** 106 minutes **MORE**
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中国能以低成本除汞得益于美国的技术发展	

Intelligence system key words

category	keywords
products	Air heater, SCR, SO3, PM 2.5, mercury, bromine
Suppliers	Babcock & Wilcox, Chemtura, Hamon,
Analysis by consul-ants	AECOM, Burns & McDonnell, Farber Golder, Kiewi, MHPS, Paragon, Sargent & Lundy, CBI
Other organiz-ations	EPRI, EERC, Siemens

Precipitator –Scrubber Options -1

Subject	Author	Relevant decision
All options	Mcilvaine	
Upgrade precipitator	KC Cottrell	
Component upgrade	KC Cottrell	
Recent SEI designs	SEI	
Wet precipitators	Mcilvaine	
Wet ESPs	Hamon	
WESP and SO3	Mcilvaine	
Recent installations	Hamon	

R Precipitator –Scrubber Options -2

Subject	Author	Relevant decision
Scrubber PM capture	Mcilvaine	
Dry scrubber, baghouse	longking	
Dry sorbent injection	Lhoist	
Reagents create PM 2.5		
TBD		
TBD		
TBD		
TBD		
TBD		

Options to meet tough particulate emission limits

- Upgrade existing precipitator with new more efficient electricals
- Buy a larger precipitator- may have to double size
- Use sorbent injection prior to the air heater to reduce the acid dew point and then make the air heater bigger to reduce the precipitator inlet temperature and improve efficiency
- Install a wet precipitator after the existing precipitator and scrubber
- Replace the precipitator with a fabric filter
- Add precipitator after the fabric filter
- Replace the precipitator with a hybrid fabric filter/ESP
- Combine particulate and scrubbing in one system with a dry scrubber and fabric filter
- Install a catalytic filter or hot gas filter to meet 850 F.

Upgrade ESP to meet MATS

ESPs for MATS Compliance

KC Cottrell Inc.

- Many existing power stations use ESPs for particulate collection.
- A properly designed ESP can achieve the required MATS limit for PM.
- Existing ESPs designed for previous limits may not need to be replaced.
- A variety of upgrade options can be employed, many in parallel, to improve performance.
- There is no single solution.

Specific upgrade options-KC Cottrell

ESP Upgrade Options

KC Cottrell Inc.

- Improve gas distribution
- Change Internals – collectors, electrodes
- Improve Rapping
- Modern control systems
- Increased power: more T/R sets
- High Frequency T/R sets
- Raise the roof
- Additional inlet/outlet fields
- New parallel ESPs
- Conversion to baghouse

Recent SEI Designs

Wet precipitators can be part of the most elaborate or simple system

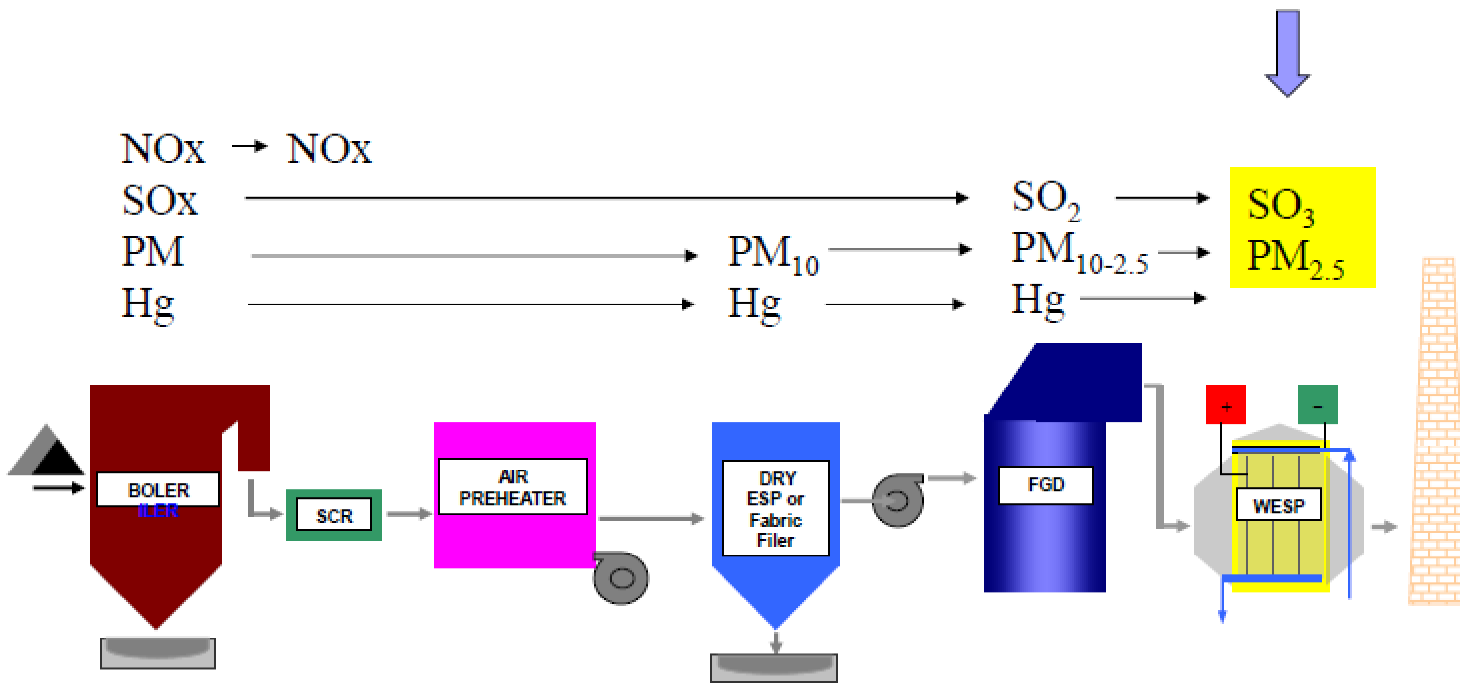
- The ultimate system has an SCR, fabric filter, wet scrubber, and then a final wet electrostatic precipitator
- Often overlooked is the simple option as follows
  - A lime wet scrubber captures particulate and SO2
  - A downstream Wet Esp removes the remaining particulate
  - The two can be combined in one tower
- Advantages
  - Low cost and easy retrofit
  - Flyash/lime/gypsum encapsulates the mercury and toxic metals
  - Good landfill material
  - High efficiency

Wet ESP Utility Installations

Facility	Size	Fuel	APC
AES- Deepwater	155 MW	Pet Coke	WFGD / WESP
Dakota Gasification	420 MW	Waste Liquids	WFGD/ WESP
Dalhousie 1 & 2	315 MW	Orimolsion	WFGD / WESP
Xcel- Shirco	2 x 750 MW	PRB Coal	WFGD/ WESP
NBP- Coleson Cove	3 x 350 MW	#6 Oil	WFGD / WESP
WE- Elm Road	2 x 615 MW	Pittsburgh #8	FF / WFGD / WESP
CWLP - Dallman	200 MW	Coal Blend	FF / WFGD / WESP
LGE - Trimble	820 MW	Coal Blend	DESP / FF / WFGD / WESP
Prairie States	2 x 880 MW	Southern Il. Bit.	DESP / WFGD/ WESP
EKPC - Spurlock	525	Coal Blend	WFGD/ WESP

Wet ESP is effective after a wet scrubber (Hamon)

Possible Alternative = WFGD + Wet ESP



Wet ESPS for SO3 and fine particulate

- Several WESPS were installed in U.S. to reduce the SO3 plume in the period around 2000
- Subsequently the solution to SO3 was determined to be dry injection
- However, WESPS have been installed on new plants to capture both the SO3 and fine particulate
- Siemens was the major supplier (now Foster Wheeler)

Scrubber capture of fine particulate

- Typical spray tower wet scrubbers do not remove much particulate if there is an efficient precipitator ahead of it
- A tray tower scrubber is slightly more efficient
- During an exceedance the scrubber can remove most of the particles
- At an emission of 0.2 lbs /mm btu from the precipitator, the scrubber will capture more than 0.l lbs/mm btu
- Wet scrubbers do not remove much SO3 when it is converted to sub micron hydrochloric acid aersosols
- With the new mass monitoring requirements particulate must be measured in the wet stack following the scrubber
- If the scrubber adds to or reduces the particulate it will now be recorded. Previously opacity monitors prior to the scrubber were the basis of determining excedances

Decision Route – Scrubber , Precipitator

Webinars Protected

Date	Recording tile
October 23, 2014	**Dry Scrubbing** 104 minutes **MORE**
October 2, 2014	**Precipitator Improvements** 84 minutes **MORE**
InterWebViews™) free	
Date	Subject; company date, language
(continuing opportunity for suppliers to provide more comprehensive information)	

Decision Orchard key words
(access to full data on protected site)

category	keywords

Fabric Filter Synthetic Media 1

Subject	Author	Relevant decision
Depends on locatiion	Mcilvaine	
Influence of conditions	KC Cottrell	
Media selection parameters	Mcilvaine	
Fiber shape	Testori	
Media characteristics		
Fiber blends	Testori	
Finishing /treatment	Testori	
Membrane comparison	Donaldson	

Fabric Filter Synthetic Media 2

Subject	Author	Relevant decision
Surface vs Depth	Donaldson	**Membrane vs non woven**
Clean filter efficiency	Donaldson	**Efficiency requirements at all times**
Fine fibers	Gutsche	**Fine fibers for higher efficiency**
P84/PPS blend	Gutsche	**Blends for higher performance**
cake build up	Gutsche	**Porous cake reduces pressure drop**
High temperature media options	IEA	**Media choice impacted by cost and performance**
Relative bag costs	ETS	**Differences in bag cost are significant**
Media selection	Testori	**Need to consider, acids, alkali, hydrolysis, oxidation**

Fabric Filters for hot gas filtration

- Fabric filters can be prior to or after the SO2 scrubbing device
- Various cleaning mechanisms impact bag and media selection
- A range of fibers and media is available depending on widely varying site specific condtions

Bag material considerations-KC Cottrell

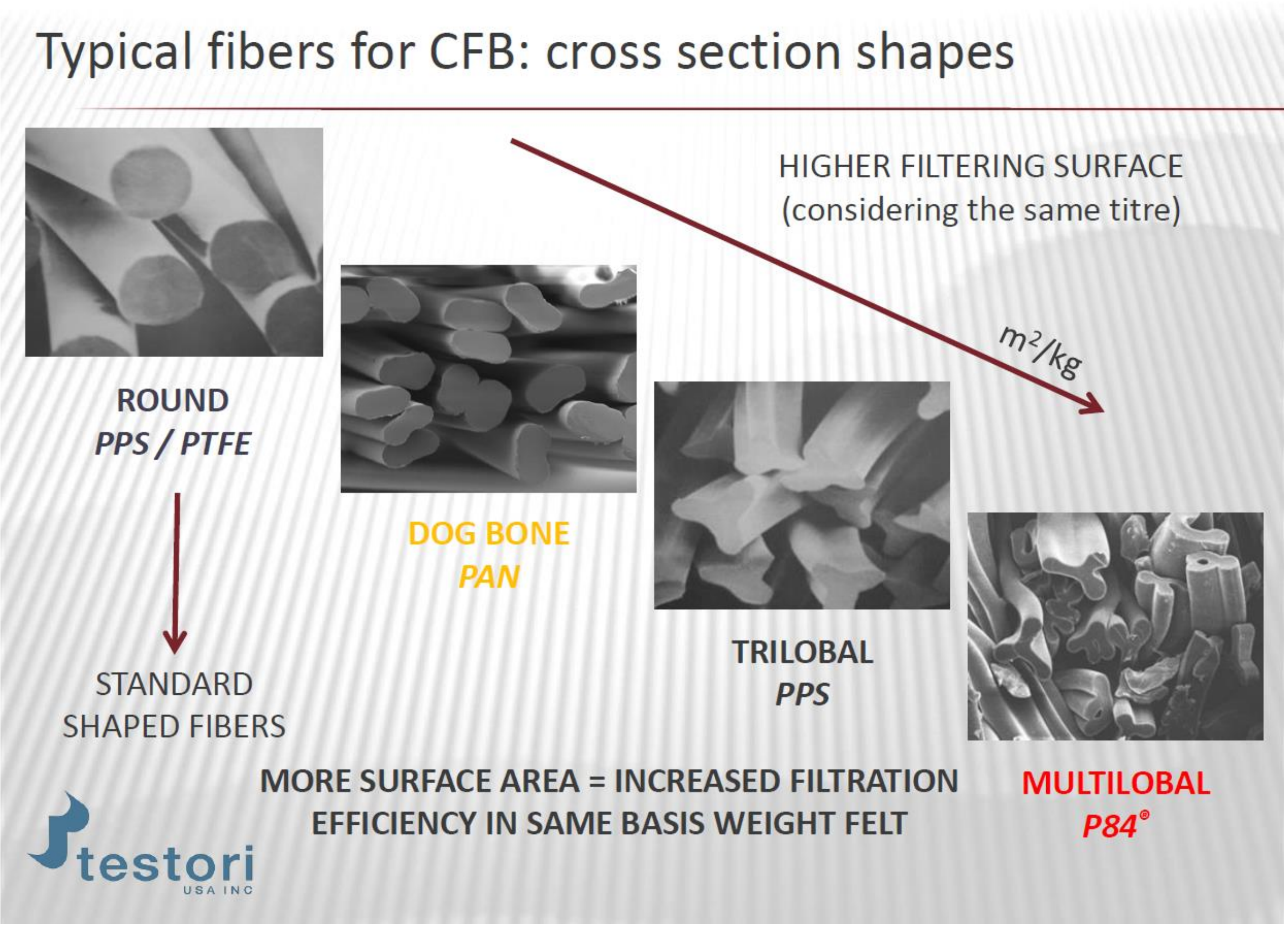
Bag Material Considerations KC Cottrell Inc.

- Operating temperature
- Moisture
- Chemistry
- Abrasion resistance
- Filtering Mechanism
  - Depth vs. Surface Filtration

Parameters affecting media selection

Subject	options					
fiber	pps	P84	ptfe	glass	ceramic	acrylic
media	Non woven	Membrane laminate	woven	sintered		
Plant conditions	Emission limit	Area available	Fan lmits	Mercury removal	SCR	FGD
gas	Flyash load	Sulfuric acid	Sulfates/	Activated carbon	temperatu re	Other acid gases
Bag shape	Tubular	Pleated	cartridge			
cleaning	Hi vol med Pressure air	High pressure air	Reverse air	shaker		

Fiber shape-Testori



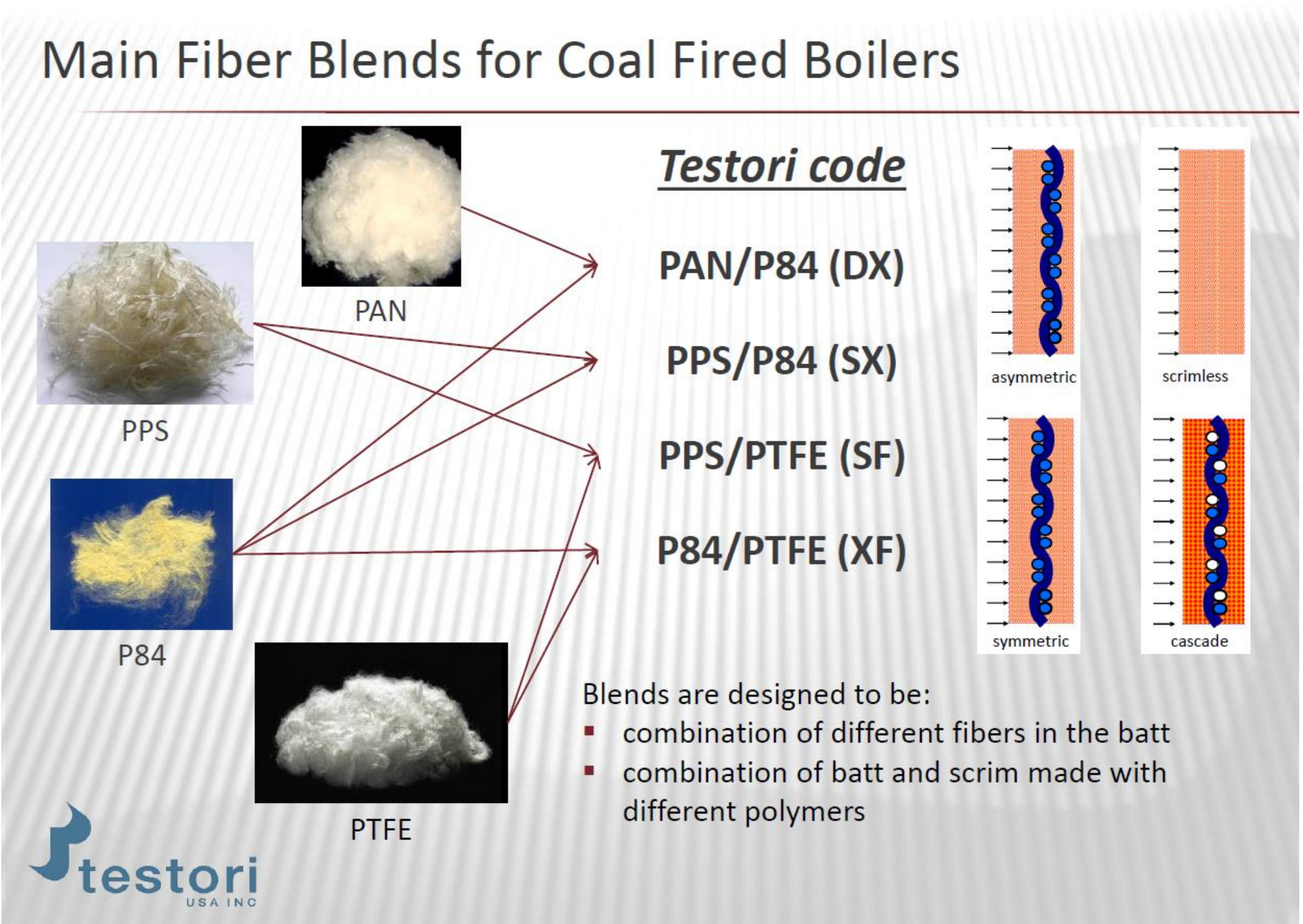
Dust Collector Fiber Options

Material Characteristics

Fiber Type	Maximum Operating Temperatures Degrees F (C) Dry Heat	Moist Heat	Chemical Resistance Strong Acids	Weak Acids	Strong Alkalis	Weak Alkalis	Solvents	Oxidizing Agents	Hydro-lysis
UHMWPE	176 (80)		****	****	****	****	****	****	****
Polypropylene	200 (93)	200 (93)	****	****	****	****	****	***	****
Polyester	275 (135)	200 (93)	***	***	*	**	***	****	*
Nylon (Polyamide)	250 (121)	225 (107)	*	***	***	***	***	***	**
PTFE	500 (260)	500 (260)	****	****	****	****	****	****	****
Glass	500 (260)	500 (260)							

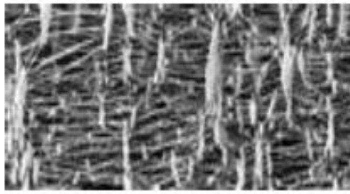
Hydrophobic versus Hydrophilic
Oleophobic versus Oleophilic

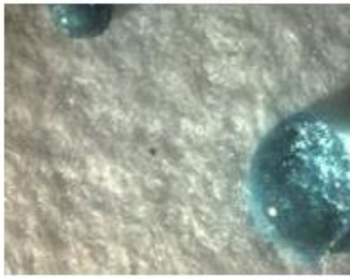
Fiber Blends for coal fired boilers

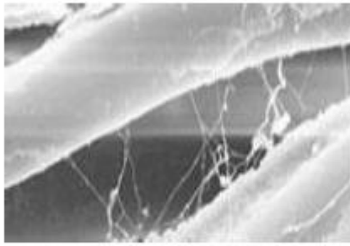


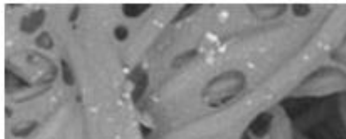
Needlefelts: Finishing and Treatments for CFB

	Description	Fibers	Benefit
ePTFE MEMBRANE	Expanded PTFE membrane laminate on the dust side	PAN, PPS, P84, GLASS, PTFE	- Controlled low emissions - Better efficiency - Cleanability - **Disadvantage**: abrasion, oils, special install, tight fit
KLEENTES	- Fluorinated resins for bath impregnation of the felt	PAN	- Water repellency - Better cake release - Suitable for sticky dust
MANTES	-PTFE resins for bath impregnation of the felt	PAN, PPS, P84, PTFE	-Water and oil repellency - Very good cake release - Increased bag lifetime - Adds surface area
RHYTES	-Fluorinated and PTFE resins (high concentration) for bath impregnation of the felt	PAN, PPS, P84	- Water and oil repellency - Better cake release - Suitable for sticky dust
SUPERNOVATES	- Copolymer foam deep coating suitable for temperature up to 200°C	PPS	- Better filtration efficiency - Very low emissions below 5mg/Nm^3

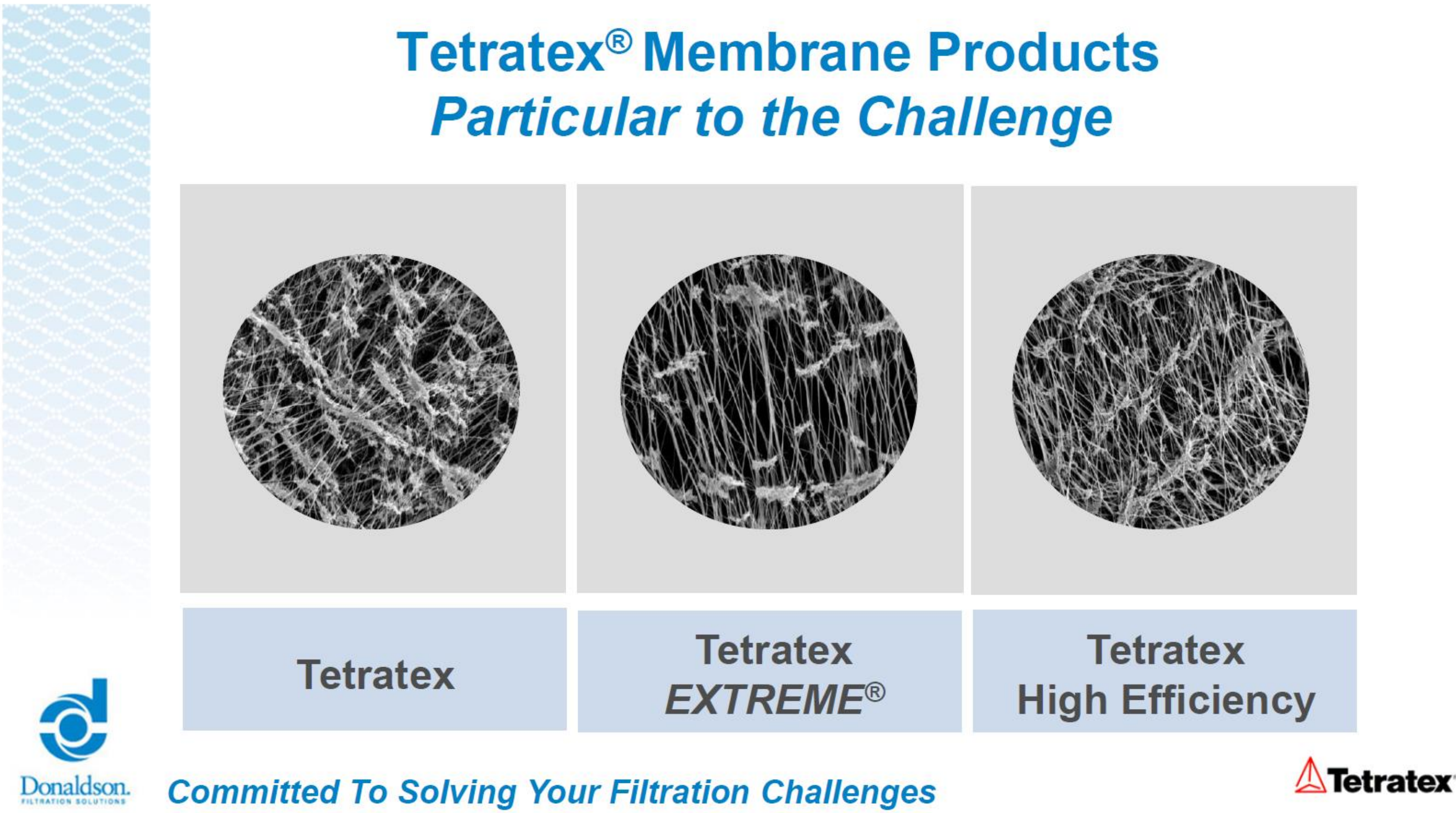






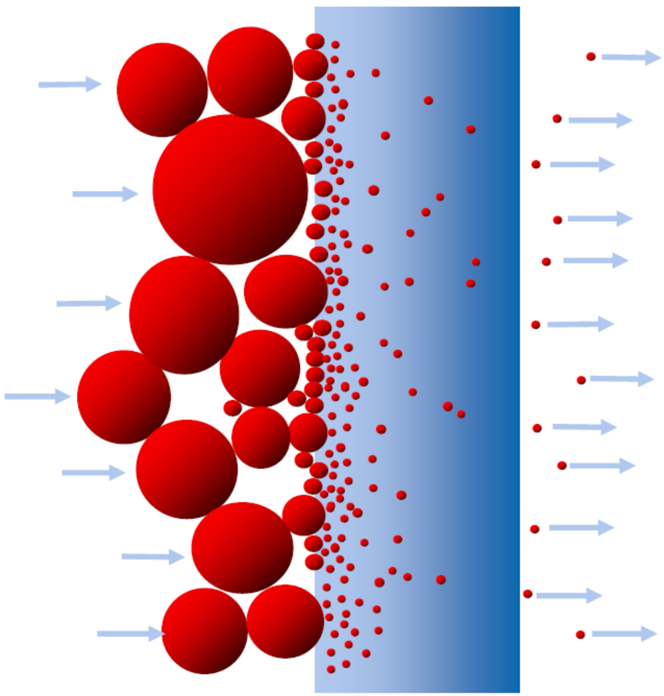


Range of membrane efficiencies



Donaldson cites depth filtration disadvantages

Conventional Filter Media: Depth Filtration



- Efficiency relies on primary cake formation
- Dust cake restricts airflow
- Requires high cleaning energy, which impacts mechanical stresses
- Fine particles migrate into media causing abrasion damage
- Leads to blinding - High pressure drop

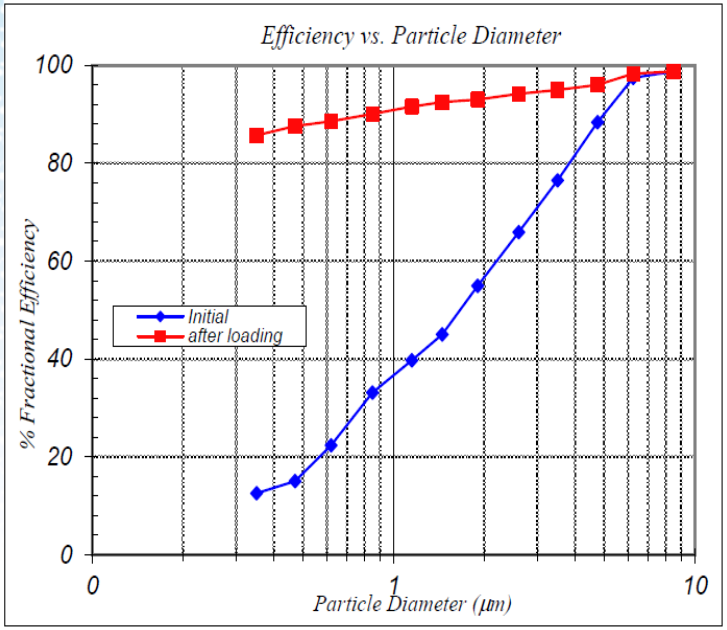
Donaldson. FILTRATION SOLUTIONS

Tetratex

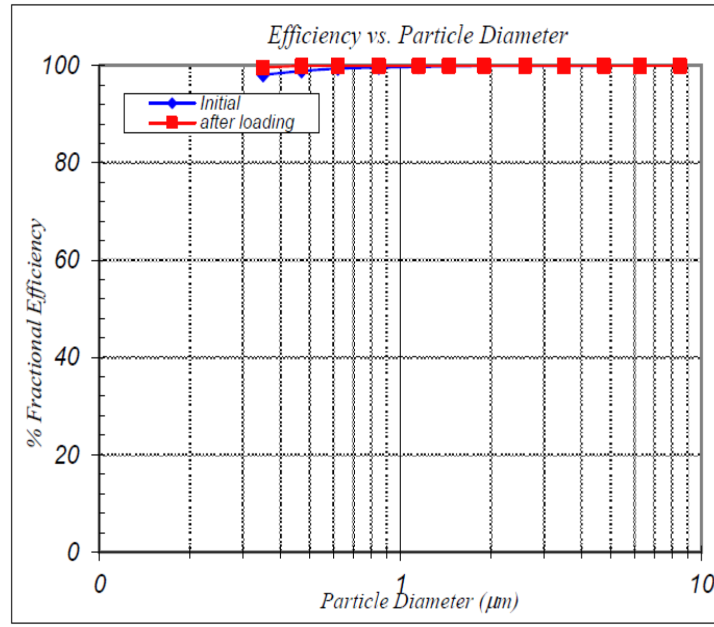
Membrane laminate has higher efficiency on smaller particles particularly prior to loading

Efficiency Comparison: 16oz PPS

Conventional Media



Tetratex Laminate (8162)



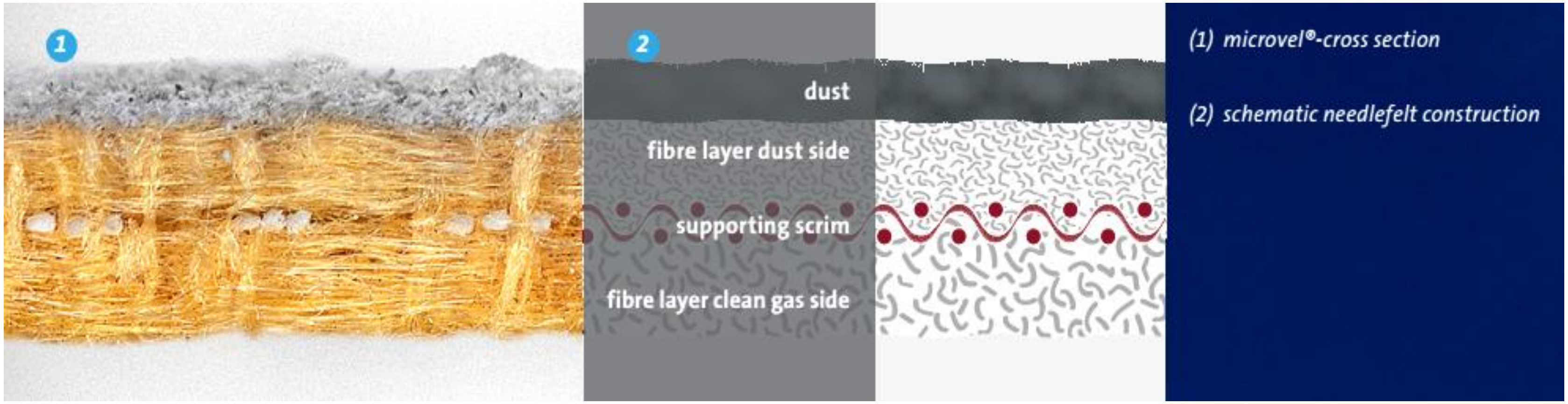
Independent test results conducted by LMS Technologies Inc. May 2012

Donaldson. FILTRATION SOLUTIONS

Committed To Solving Your Filtration Challenges

Tetratex

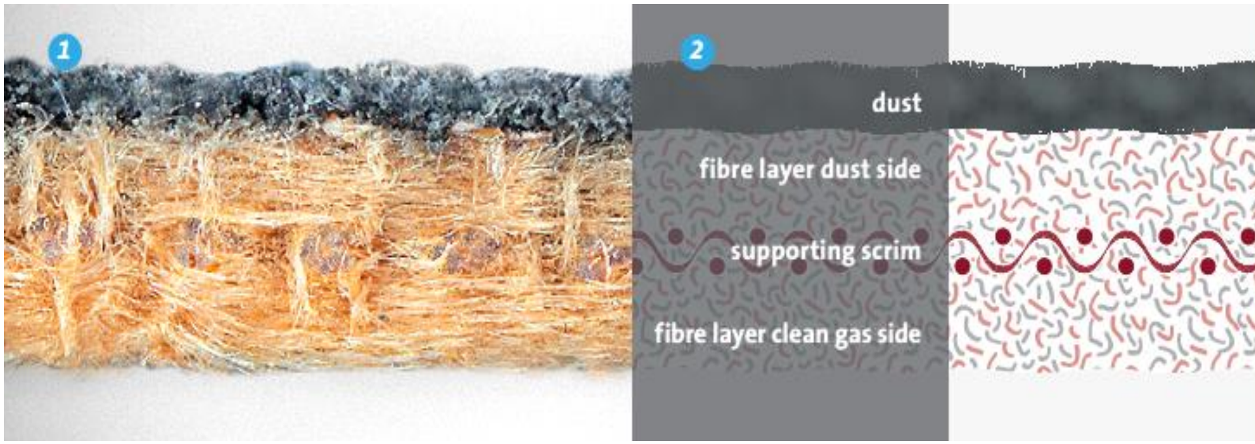
microvel® - Near zero emissions and low dp using fine fibres and Gutsche manufacturing expertise



***microvel*®- overview of advantages:**

- extremely low outlet emissions
- very good regeneration capabilities leading to low dp
- high mechanical stability
- problem free installation with no special tools
- optimal cost-benefit ratio
- excellent case histories and references

optivel® - An optimal combination blending different polymers to achieve the best results



(1) optivel®-cross section

(2) schematic needlefelt construction

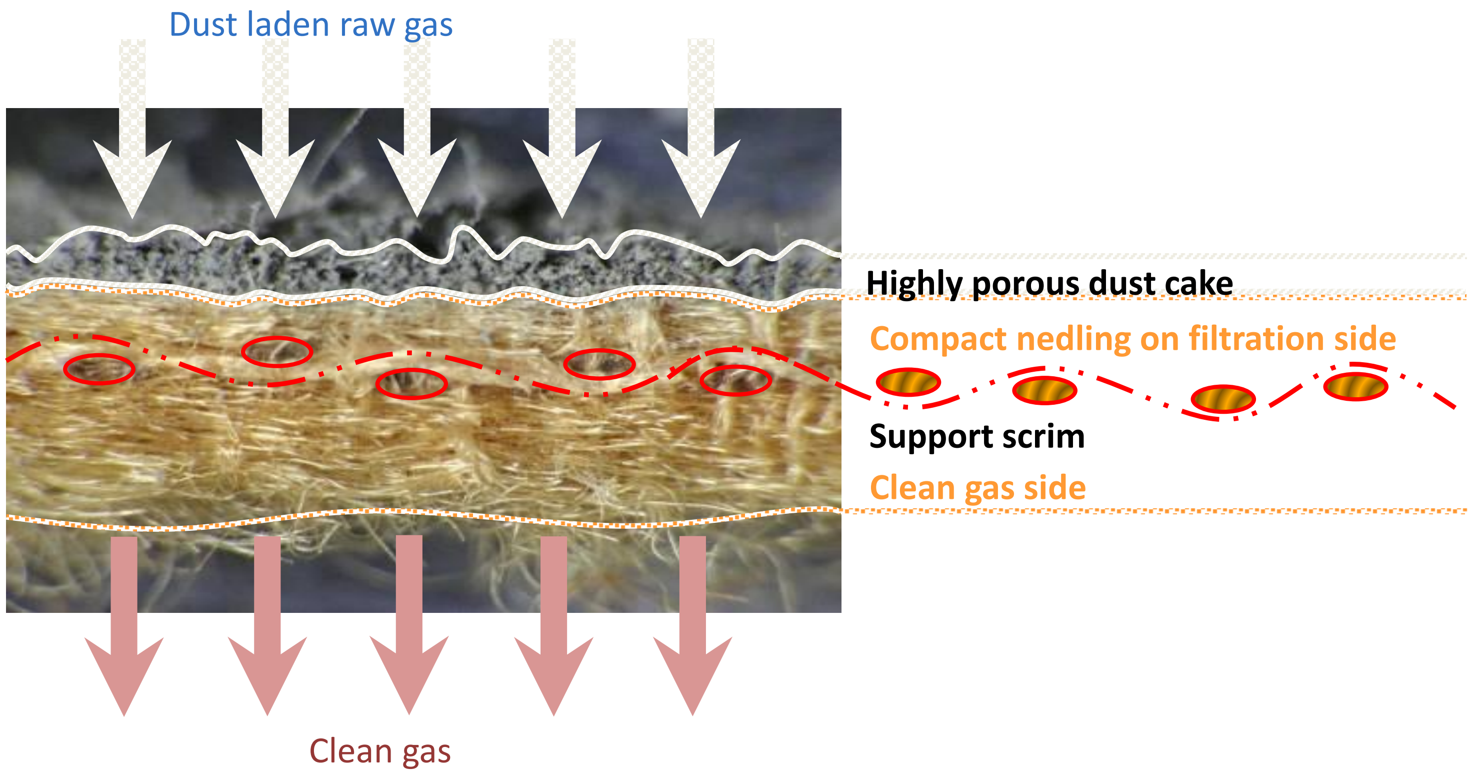
***optivel®*- overview of advantages:**

- improved separation efficiency
- optimal cost-benefit ratio
- combination of fibre strengths

- high mechanical stability
- optimal filter cake build-up
- world class reference list
- low dp and emissions

microvel® & *optivel*® - Filter media in filtration mode

Optimal filter cake build-up



High temperature fiber options

FF: Fabric types

Table 3 Fabric types (Stark, 2012; Popovici, 2011; Johnson and McMenus, 2011)

Name	Maximum operating temperature	Remarks	Relative cost
Acrylic felt (PAN or polyacrylnitrile)	130°C	Lowest maximum operating temperature.	£
PPS felt (Polyphenylenesulphide)	190°C	Degrades at higher temperatures with >12% oxygen. Resist chemical and thermal attack. Effective when laminated with ePTFE.	££
Aramid felt	204°C	Not as capable as PPS in chemically active flue gas	£££
Woven fibreglass	260°C	Fragile, require tight tolerances. Suitable with reverse-air cleaning systems.	£
P84 felt by Evonik Fibres (polyimide, PI, multi-lobal, tri-lobal)	260°C	Dimensional stability over 204°C but requires oversizing of filter to maintain proper bag to cage fit. Small pore size of 0.5-1 μm (traditional needle felt scim have a pore size of 15-20 μm).	£££
Pleated elements	Dependant on scim fabric	A/C <3.5:1. Applicable only when additional cloth area is needed to lower A/C ratio and eliminate inlet abrasion.	£££££

Relative bag costs

Cost Considerations

- Current pricing per bag, 33′ long by 5″ diameter:
  - PPS Felt ~ $81-90
  - P-84 Felt ~ $143-158
  - WFG/Membrane ~ $73-81

Media selection-Testori

Selecting Media

FILTER MEDIA SELECTION CHART FOR POWER						
FIBER TYPE	COMMON BRAND NAMES	TEMP LIMITS* F/C	RESISTANCE TO ACIDS	RESISTANCE TO ALKALIS	RESISTANCE TO HYDROLYSIS	RESISTANCE TO OXIDATION
COTTON	NA	180°/85°	Poor	Good	Good	Good
PVC	Rhovyl, Clevyl	150°/65°	Excellent	Excellent	Excellent	Excellent
POLYPROPYLENE	Herculon	190°/90°	Excellent	Excellent	Excellent	Poor
NYLON	Enka, Antron	230°/110°	Poor	Excellent	Poor	Good
HOMOPOLYMER ACRYLIC	Dolanit, Aksa	257°/125°	Good	Fair	Good	Good
POLYESTER	Fortrel, Dacron, et al.	300°/150°	Good	Poor	Poor	Good
PPS	Torcon, Procon, et al.	375°/190°	Excellent	Excellent	Excellent	Fair
ARAMID	Nomex, Conex, et al.	400°/205°	Poor	Excellent	Poor	Fair
POLYIMIDE	P84	450°/235°	Fair	Poor	Good	Good
PTFE	Profilen, Toyoflon, et al.	500°/260°	Excellent	Excellent	Excellent	Excellent
FIBERGLASS	NA	550°/285°	Good	Fair	Excellent	Excellent

*Dry heat only

Testori USA, Inc.
www.testori-usa.com

Decision Route – Fabric filter Media

Webinars Protected

Date	Recording tile
October 23, 2014	**Dry Scrubbing** 104 minutes **MORE**
January 8, 2015	**Fabric Selection for Hot Gas Applications** 120 minutes **MORE**
InterWebViews™) free	
Date	Subject; company date, language
(continuing opportunity for suppliers to provide more comprehensive information)	

Decision Orchard key words
(access to full data on protected site)

category	keywords

Bags and Filters 1

Subject	Author	Relevant decision
Tubular bags	Mcilvaine	
Pleated and other	TBD	
Leakage at seams	Mcilvaine	
P-84 for ESP retrofit	Mcilvaine	
Enel has converted ESPs	*ENEL	
Russia , Chile	*ENEL	
Eskom	* Eskom	
* At Evonik conference		

Bags and Filters 2

Subject	Author	Relevant decision
Money point Dry FGD	N.A	
Low pressure , long bag	KC Cottrell	

Tubular bags

Tubular bags remain the major choice for higher temperature conditions and heavy dust loadings.

Pleated bags are more expensive and are generally used where space is tight

The main use of wovens is in glass bags with reverse air cleaning.

Most tubular bags are non-woven felts.

Pleated and other bag designs

- TBD

Leakage at bag seams

- Power plants are reporting activated carbon on the clean side of bags. It is an emission problem and causes bag wear
- W.L Gore says that their new taped seam prevents this problem
- Suppliers of synthetic laminates say this only applies to glass bas with membranes and not synthetic bags where seams can be fused
- W.L. Gore cites specific comparisons in the cement industry where the new seam has measurably different outlet emissions.
- NFM has a taped bag which they apply in some but not all situations
- The longer a bag is pulsed the more the sewing holes can expand
- With the new requirements which are as low as 5 mg/Nm3 or even lower, this is a problem which needs to be addressed
- The general attachment of the bag and potential leaks at interfaces is also a matter to be considered

P 84 and high performance fibers for ESP retrofits

- A huge market is developing for substituting filter bags for ESP internals
- The low installation cost vs. a new stand alone baghouse justifies higher bag costs
- Existing precipitators are subject to greater temperature variations and other conditions which can be controlled in a new installation
- P84 and other high performance fibers are being embraced for this retrofit application
- Enel and Eskom are two examples

ENEL has converted ESPs

Fabric Filters running in Enel's national fleet

Enel
ENERGY TO LIFE

Plant	Capacity (MWe)	FF type	Installation	Supplier	Year	Bag Lenght [m]	Comp.	Emissions guarantees [mg/Nm3] (°)	Expected FF Emiss. in Operation [mg/Nm3]
Fusina 1&2	2 x 160	PJ, HP/LV	Conversion	TMK	1999	8,5	2	<30	<15
Genova 6	160	PJ, HP/LV	Conversion	TMK	2003	9	4	<30	<15
Sulcis 2 (*)	340	PJ, HP/LV	New (**)	Aster	2005	8,5	16	<25	<15
Torrevald. 1÷3	3 x 660	PJ, HP/LV	New (**)	TMK	2005	8	16	<10	<9
Brindisi S.# 3&4	2 x 660	PJ, HP/LV	Conversion	TMK	2010-12	8	4	<20	<10

(*) Circ.Fluid.Bed Boiler (CFB) (**) Over the existing Electr. Precip. ESP foundations (°) hourly basis

- Italian references regarding conversions from electrostatic precipitators (ESPs) to fabric filter (FFs) are all "brown field" installations.
- "Conversion" means "transformation" from an electrostatic precipitator to a fabric filter using the previous casing.
- "New" fabric filters → to use only the existing foundation of the old previous electrostatic precipitator and to design new filter steel structure and casing.
- There is in addition a small fabric filter installed in a ~ 30 MWe Biomass PP in Calabria (South of Italy)

Acronym: PJ pulse jet; HP/LV high pressure low volume type; ESP Electrostatic Precipitator; TMK Termokimik spa ; Torrevald.: Torrevaldaliga North power plant.

Enel has FF on boilers in Russia, Chile, Spain (Evonik presentation)

Fabric Filters in Enel's abroad fleet and programs

Enel
ENERGY TO LIFE

Plant	Country	Capacity (MWe)	FF type	Installation	Supplier	Year	Bag Lenght [m]	Comp.	Emissions guarantees [mg/Nm3]	Expected FF Emiss. in Operation [mg/Nm3]
Alcudia	Spain	2 x 125	PJ, HP/LV	New	Fisia Babcock	n.a.	8	6	<20	<15
Alcudia	Spain	2 x 130	PJ, IP/IV	New	ABB/BWE	n.a.	7	6	<20	<15
Tarapacà	Chile	158	PJ, IP/IV	New	ALSTOM	2013	10	8	<10	<10
Bocamina I	Chile	128	PJ, IP/IV	New	ALSTOM	2007	8	6	n.a.	20
Bocamina II	Chile	350	PJ, HP/LV	New	Slavex	2012	6,5	20	<30	<15
Reftinskaya 5	Russia	300	PJ, IP/IV	Conversion	ALSTOM	2013	8	4	<50	<20
Reftinskaya 7	Russia	500	PJ, HP/LV	Conversion	Clyde Bergmann	2014 (°)	8,5	16	<50	<20
Reftinskaya 4	Russia	300	PJ, IP/IV	Conversion	ALSTOM	2015 (°)	8	4	<50	<20

(°) Note: expected date / schedule to be confirmed.

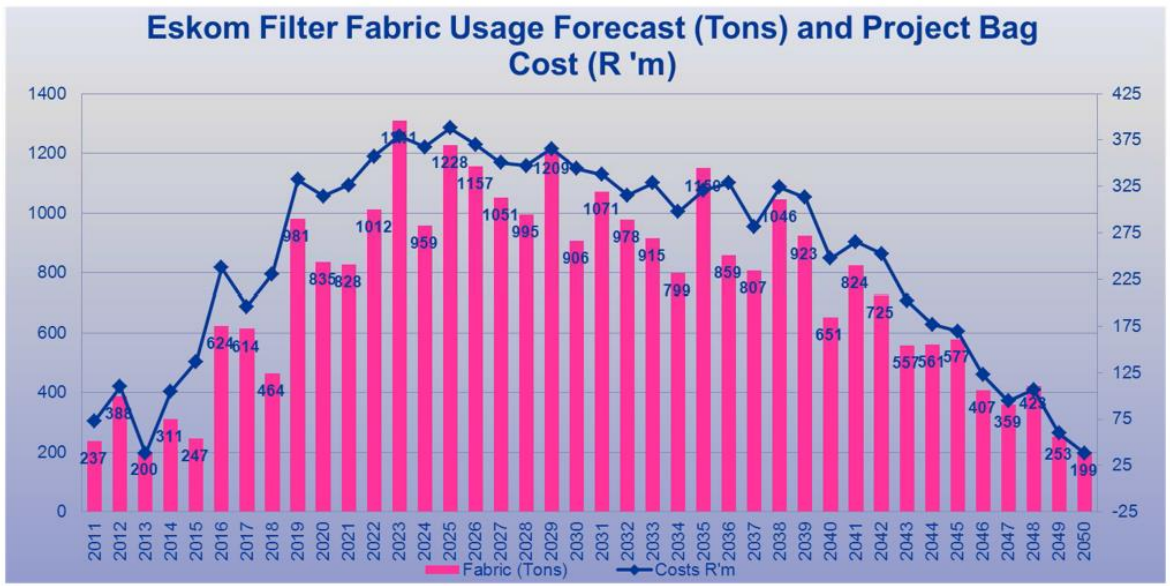
- The filters in Russia could be taken as the more challenging in terms of operation and maintenance considering the very high dust content of the coals (up to 40%) and the high NOx inside the flue gas.
- About the remaining units in Russia: #1÷ 4 and #8 ÷ 10 the conversion of the existing electrostatic precipitators ESP to fabric filters FF are today foreseen before the end of this decade.

Other Acronym: HP/LV High Pressure Low Volume type, IP/IV intermediate Pressure - Intermediate Volume, n.a. not available

Eskom will be spending $ 100 million/yr for bags (Evonik Presentation)

Fabric Usage Forecast following FFP Retrofit

Eskom



This equates to an average consumption of approx. 350 000 bags per year.
Currently all bags are disposed of in a Class H:H Hazordous Waste Dump at Holfontein (350 000 bags = +1 000 000 m² of fabric)

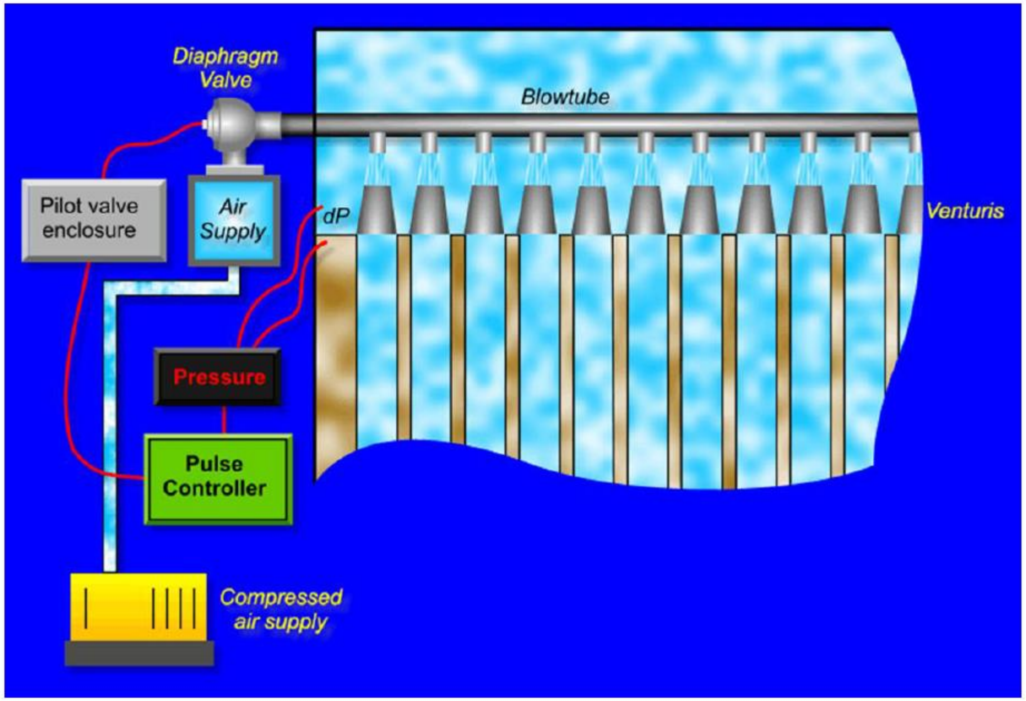
1923-2013

Money point Dry FGD P84/PPS

- N.A.

Cleaning impacts bag life and energy consumption (Pentair)

Principle of RPJ Filter Cleaning



The configuration of the filter cleaning system is crucial to effective filter cleaning and dP control

Multiple parameters for cleanining design (Pentair)

Cleaning system design considerations for Hot Gas

Some key considerations when configuring cleaning systems for Hot Gas applications:

Pulse valve choice

- What is the temperature at the valve; will high temperature seals (eg Viton) be required?
- Are aggressive chemicals in contact with the valve?
- Do we need stainless steel components rather than cast aluminium (standard).

Media dP

- What will the filter media be? Can we expect higher than usual differential pressures?
- What is the dP required to maintain the dust cake at the appropriate levels?

Waste gas and dew point

- Does the waste gas contain contaminants that may turn to an acid when the system passes through the dew point (eg during shut down periods)?
- Acid condensation on pulse system components will considerably shorten the life of these.

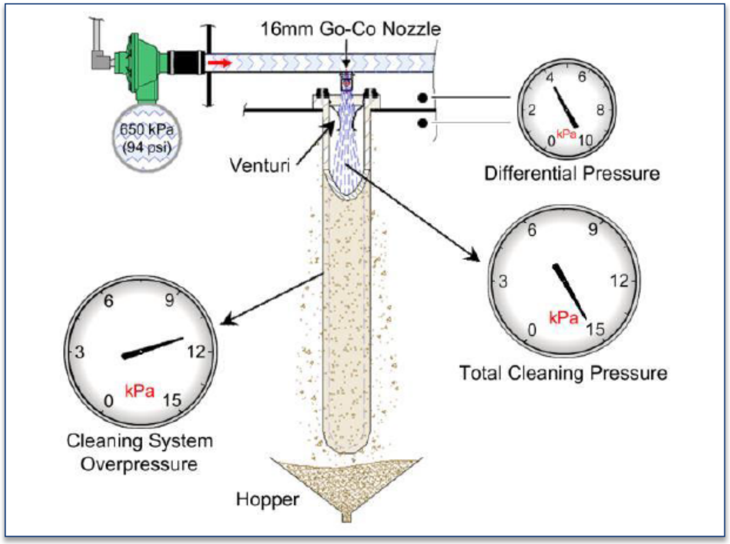
Cleaning makes the difference in tough application (Pentair)

Case Study: Australian Alumina Plant

Cleaning system was modified:

Goyen evaluated several changes to improve the cleaning performance using the GOCO software, computational fluid dynamics, and the test facility. Testing and modelling showed that the combination of the GOCO nozzles and venturis increased the cleaning overpressure so significantly that the pulse cleaning system operating pressure could be reduced.

The plant was able to resolve the high dP problem and reduce the electricity consumption of the liquor burner (via fan power reduction and air compressor savings), and eliminate downtime.



Ample cleaning power, easily adjusted by compressed air pressure level.

One option is a low pressure long bag design

Recent Trends in Fabric Filters

KC Cottrell Inc.

- Low pressure pulse, long bag design
- Online cleaning
- No bypass on start-up
- Filter as reactor (primary or secondary)
- Increasingly lower emission rates
- Use of PTFE membranes

Decision Route – Bags and Filters

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Decision Orchard key words
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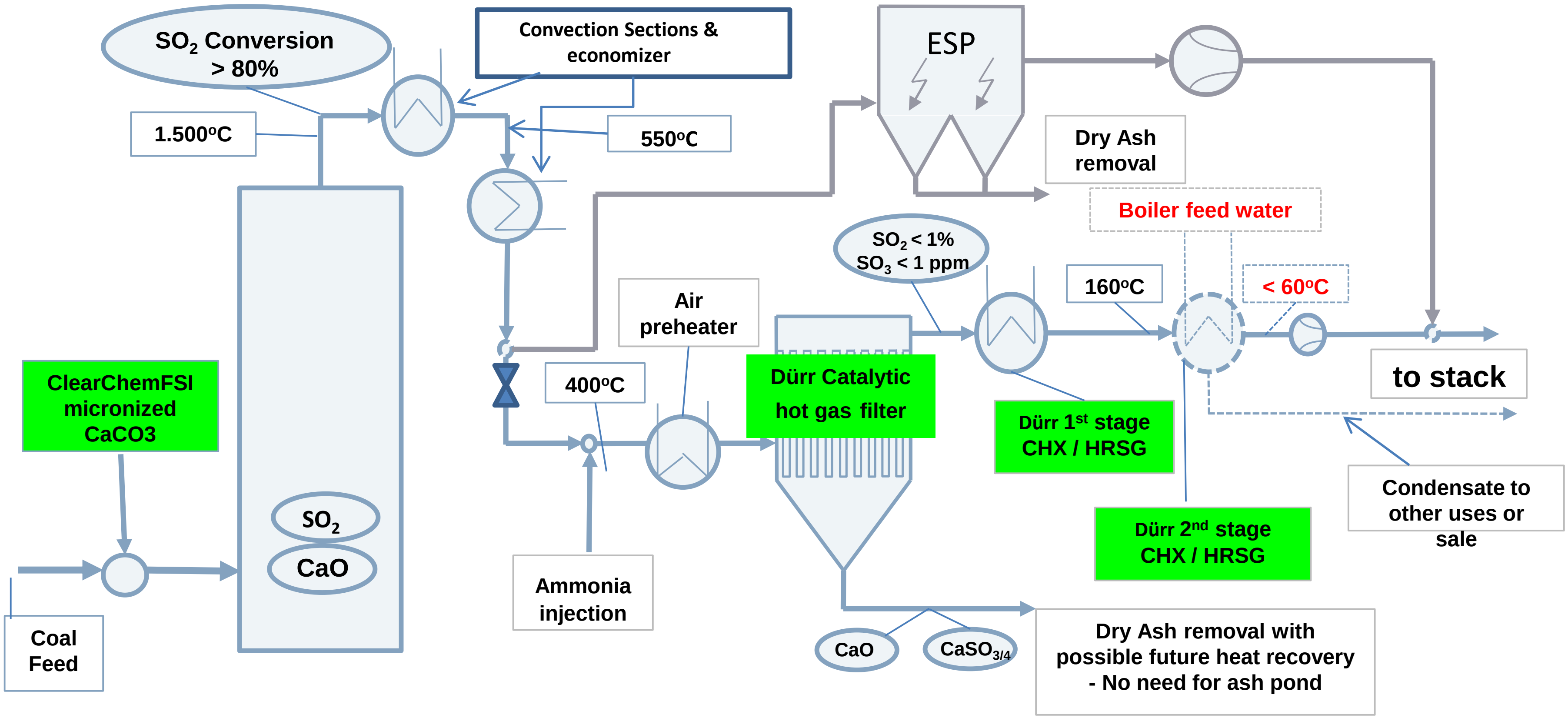
category	keywords

Ceramic and Metal Filters

Subject	Author	Relevant decision
Catalytic filter with powdered limestone	Durr	
Catalytic filter- ceramic and 3 layer	Haldor Topsoe	
Catalytic filter	Tri-mer	
Metal filters	Purolator	

ClearChemFSI™ Existing U.S. Coal-Fired Boilers

Side Stream Application – Example existing ESP



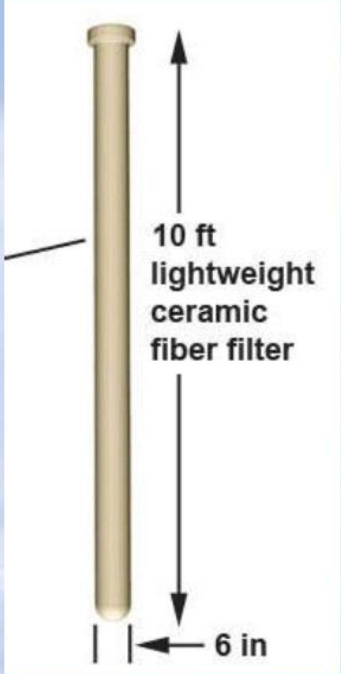
Input from Haldor Topsoe

TBDF

Catalytic filter with embedded catalyst

Filter Element

UltraCat Catalyst Filter: Structure and Size



Nano-bits of NOx, CO, VOC catalyst are embedded into the walls and adhere to the fibers.

Tri-Mer® CORPORATION

50 2010 YEARS

Input from Purolator

- TBD

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Decision Orchard key words
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category	keywords
Product	Catalytic filter, metal, ceramic
companies	Durr, Filtration Group, Haldor Topsoe, Purolaor