

# ***Reinhold Environmental Ltd.***

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***2007 APC Round Table & Expo  
Presentation***

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***July 8-10, 2007  
Chattanooga, TN  
Hosted by TVA***

# APC Round Table & Expo

Chattanooga, 8 - 10 July 2007

## Filtration Materials for PJFFs

by Florin Popovici

*Inspec Fibres*

a RAG / Degussa company

# Index Filtration Materials for PJFFs

- Theory of dry filtration
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- References - Eskom

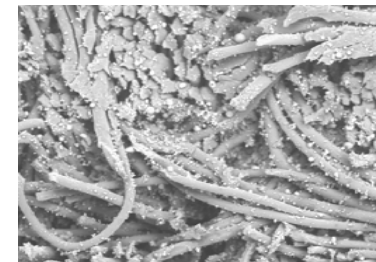
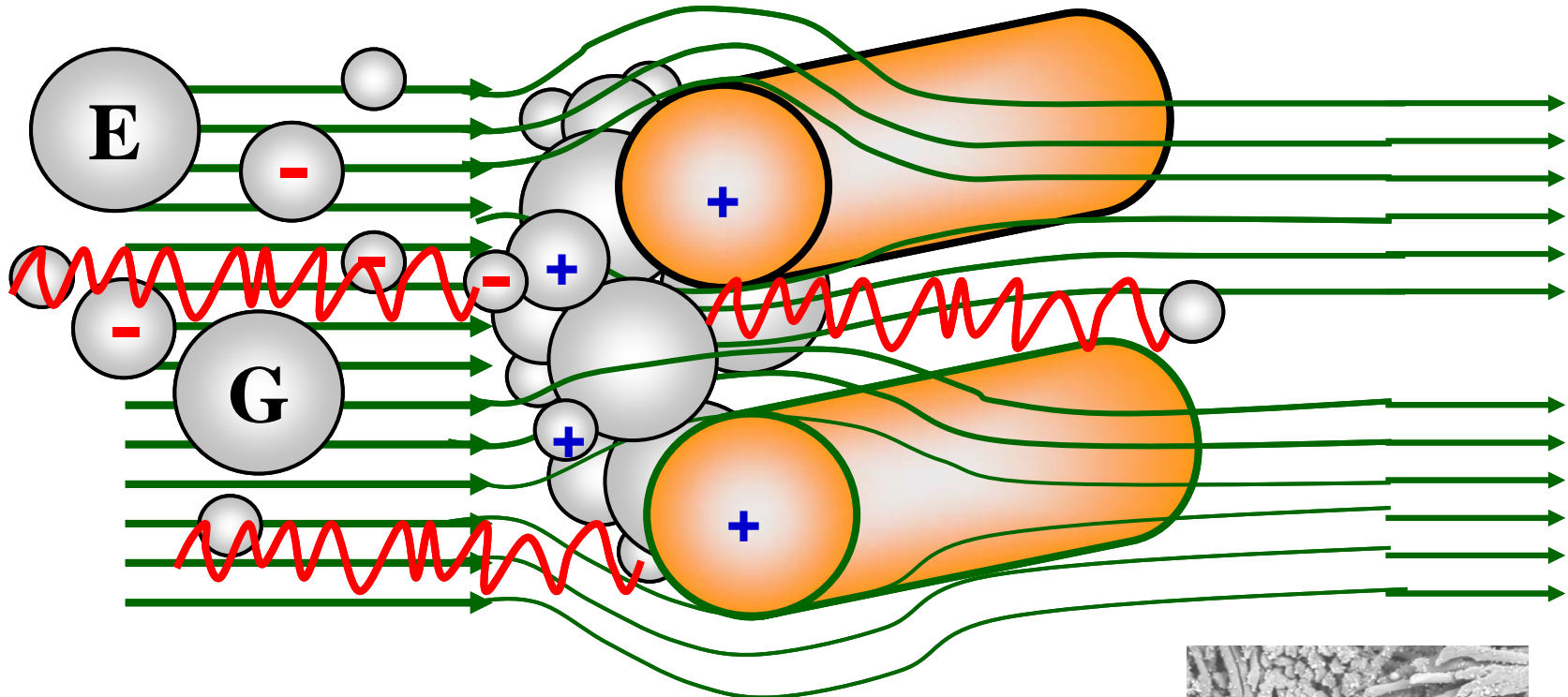
# Theory of Dry Fabric Filtration

# Filtration Mechanisms

- Sieving
  - by fibres
  - by dust filter cake, pre-coating of filter bags
- Impaction
  - collision with other dust particles and fibres
- Electrostatic charge
  - prevents diffusion caused by Brownian movement
  - important for the collection of fine particles, smaller than 5 microns
- Agglomeration
  - larger particles, gravitational forces , inertia

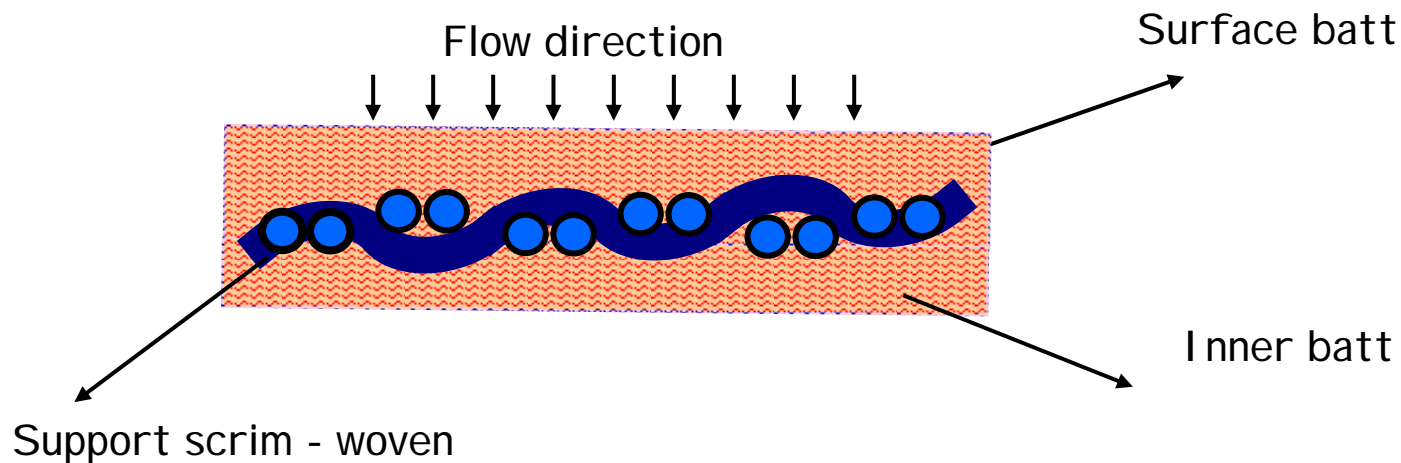
# Filtration Mechanism

➤ Sieving, impaction, agglomeration, electrostatic, cake filtration



# Construction of Filtration Materials

# Needlefelt Filtration Materials



## The Scrim:

- is the backbone of the filter medium (supporting scrim)
- provides dimensional stability.
- scrims are made from either staple fibre or multifilament yarn.

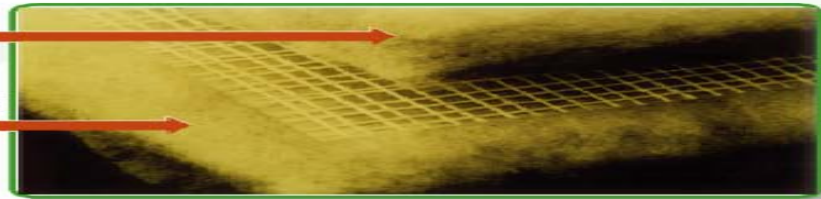
## Needlefelts:

- High filtration efficiency
- Lower cloth area in relation to volume flow
- Pulse jet cleaning plant
- Special coatings / finishes
- All types of fiber materials
- Mechanical / abrasion resistance

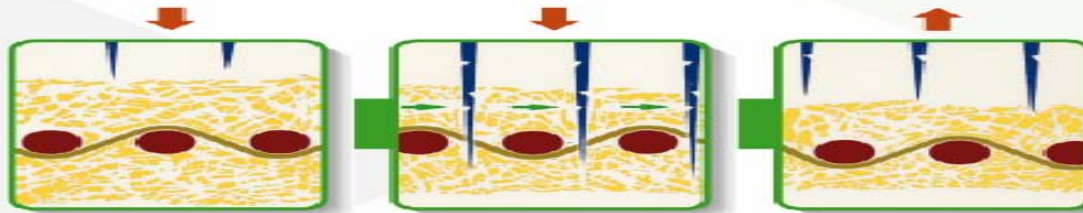
# FABRIC CONSTRUCTION - NEEDLE FELT

Consist of a web of fibres

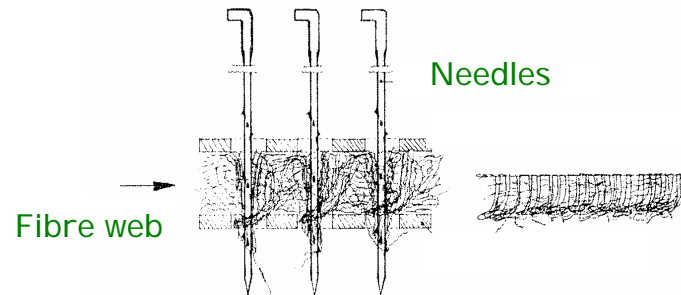
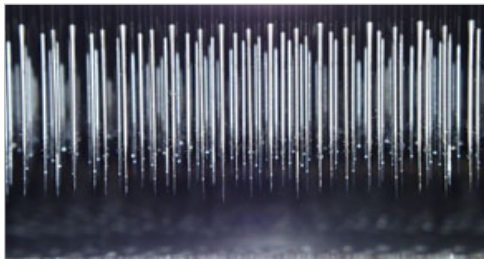
Scrim between webs



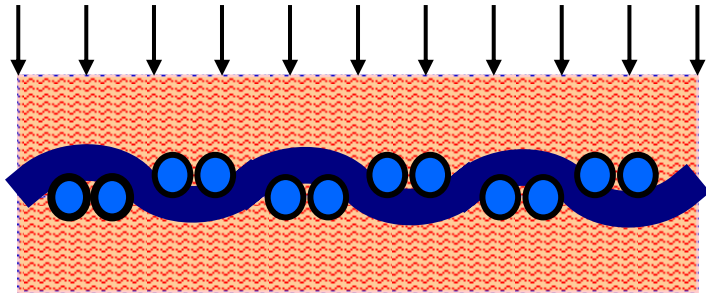
Called "NEEDLE FELT" because needles are used to entangle the fibres



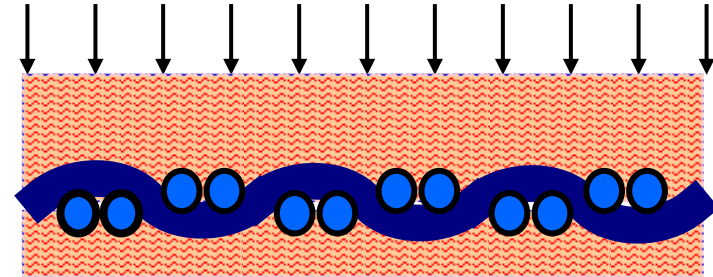
Courtesy of Beier-Albany



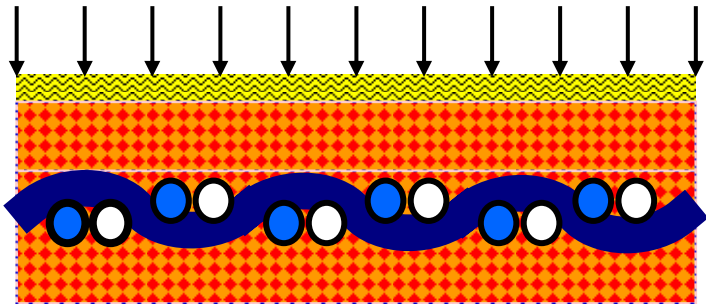
# Type of Needlefelt Constructions



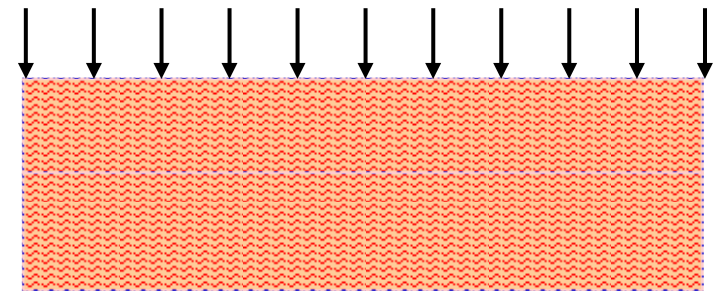
Symmetric



Asymmetric



Cascade, blends, hybrid scrim,  
composites

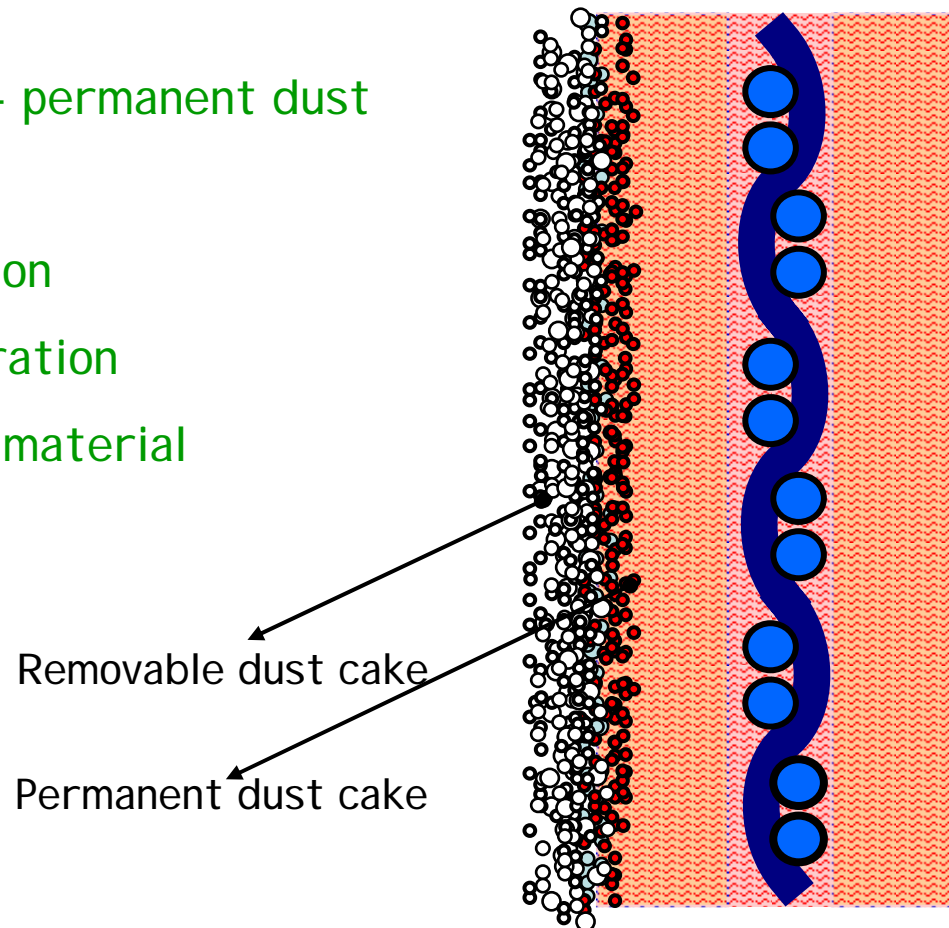


Self supported-no scrim

# Filtration Process

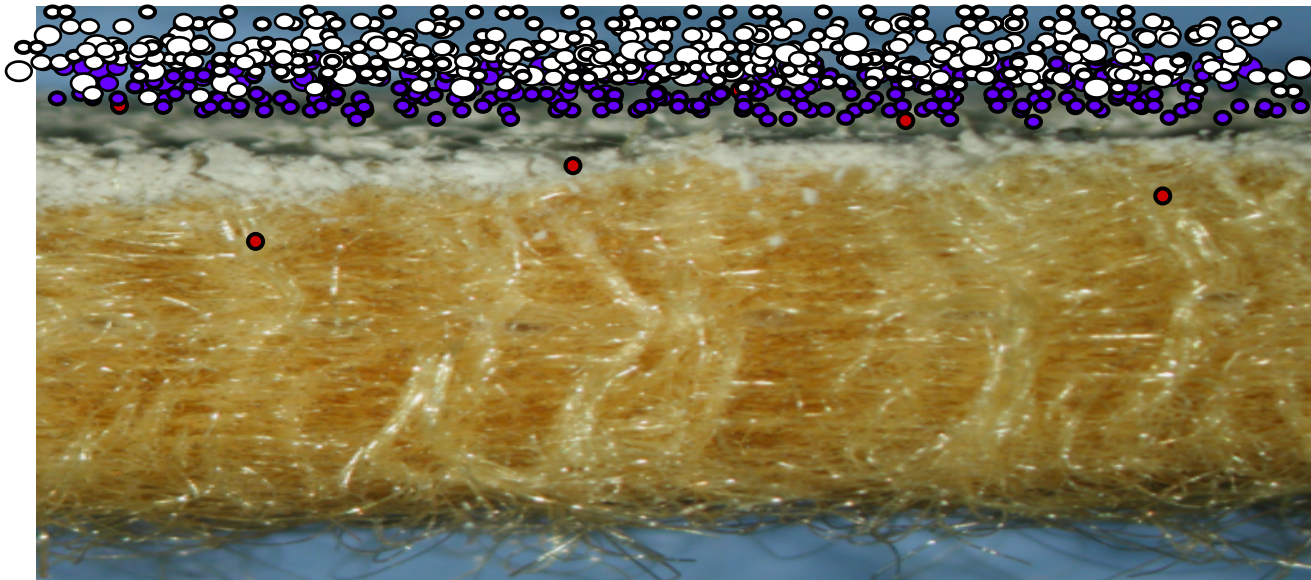
## Dust Cake Characteristics

- Adhesion to fabric - permanent dust cake
- Dust particle cohesion
- Porosity - Good filtration
- Protection of filter material
  - Abrasion
  - Chemical attack



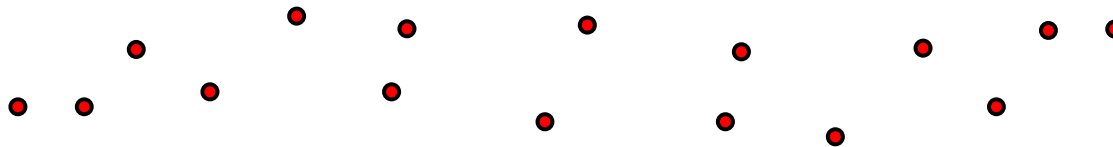
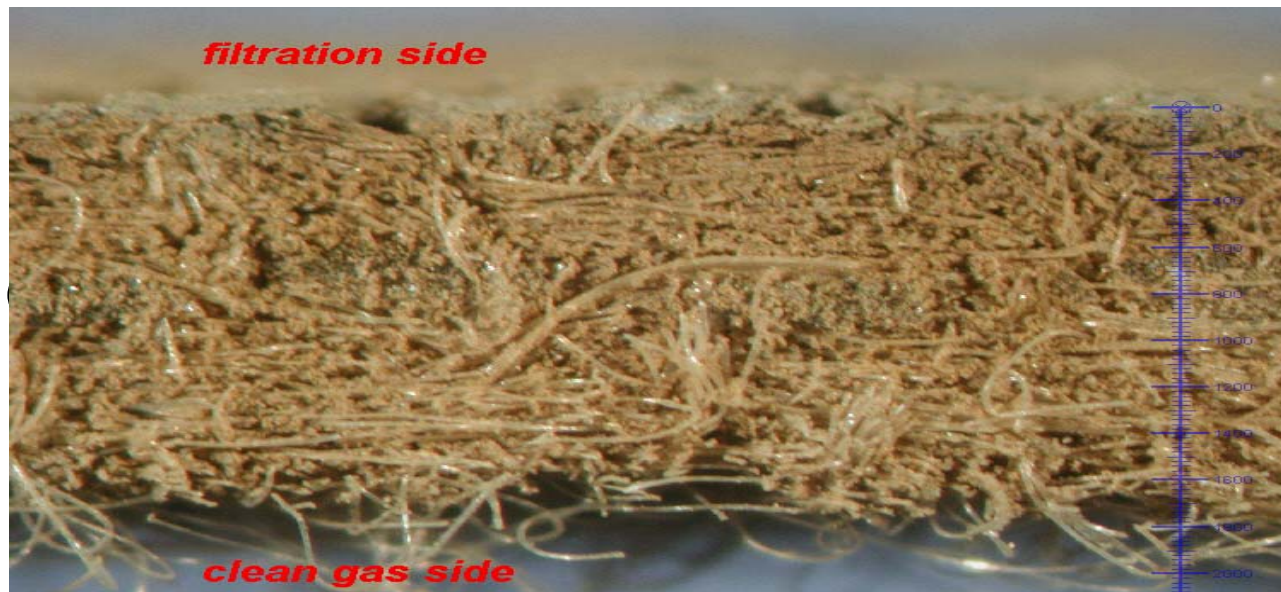
## Dust Cake Formation - Filtration

➤ Filtration process - normal needlefelt



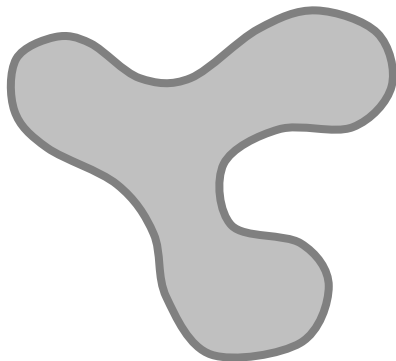
## Depth Filtration – Blinding of fabric

➤ Dust penetration into the fabric – long time process?

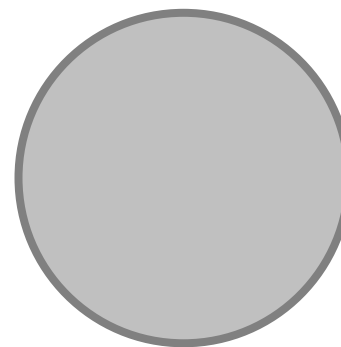


## Fibre cross-section comparison

Fibres with different cross sections are used for the manufacturing of non woven filter materials; multilobal fibres as well as circular fibres

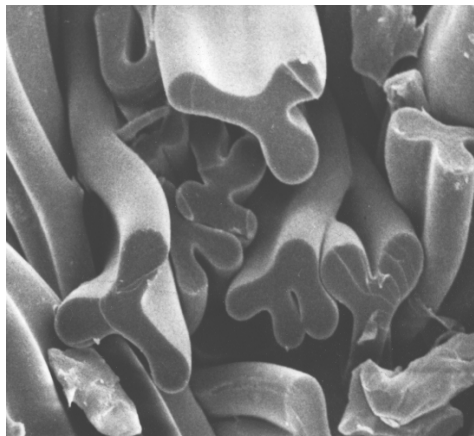


Multilobal fibre cross section



Round fibre cross section

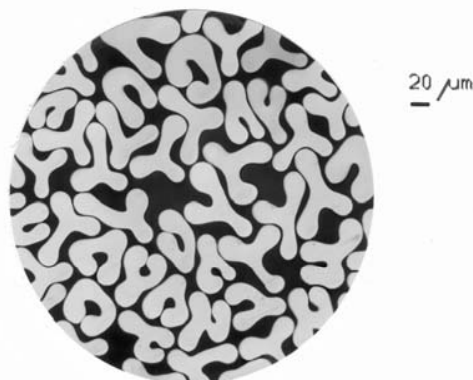
## Examples of different fibre cross sections



SEM image of multilobal / trilobal fibres

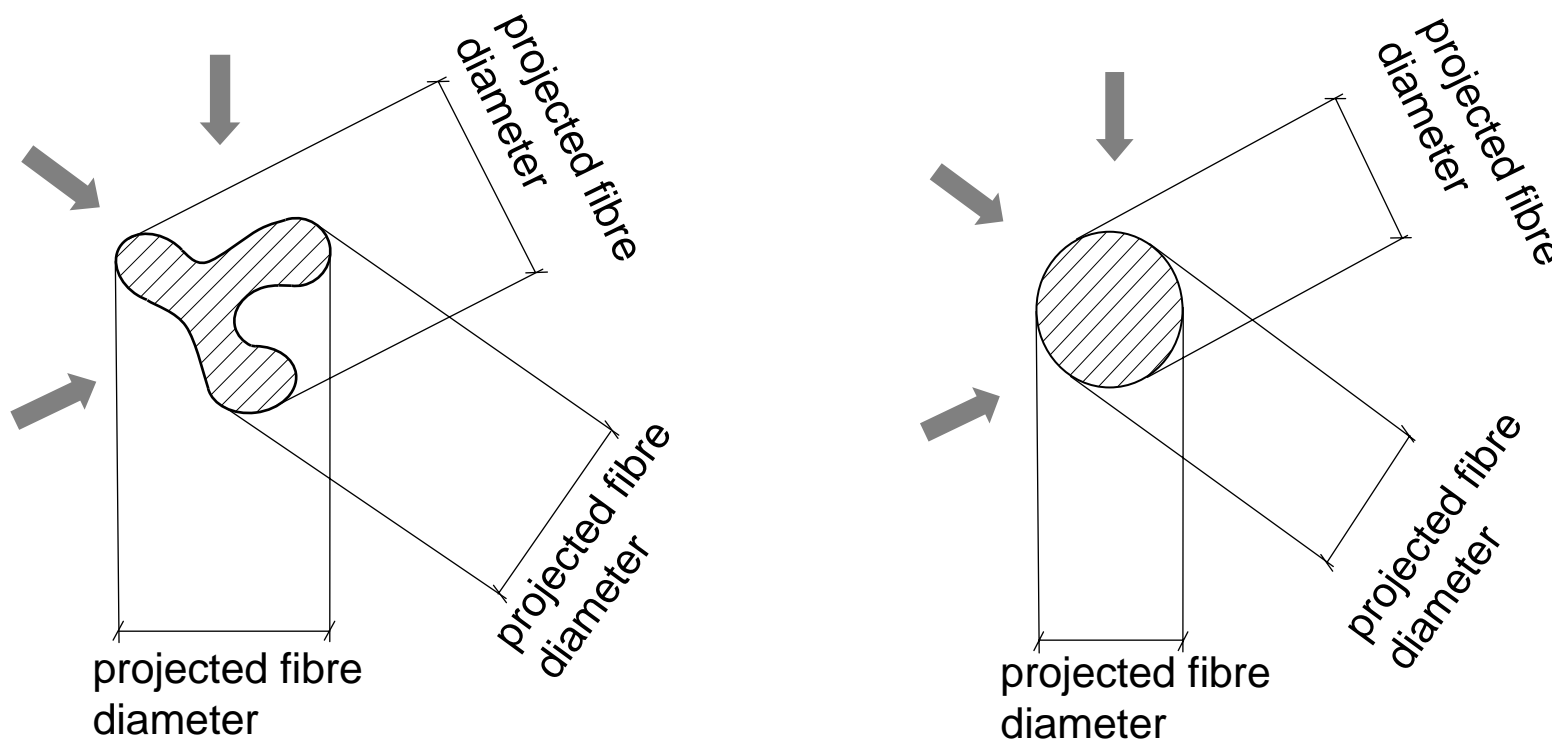


SEM round fibre image



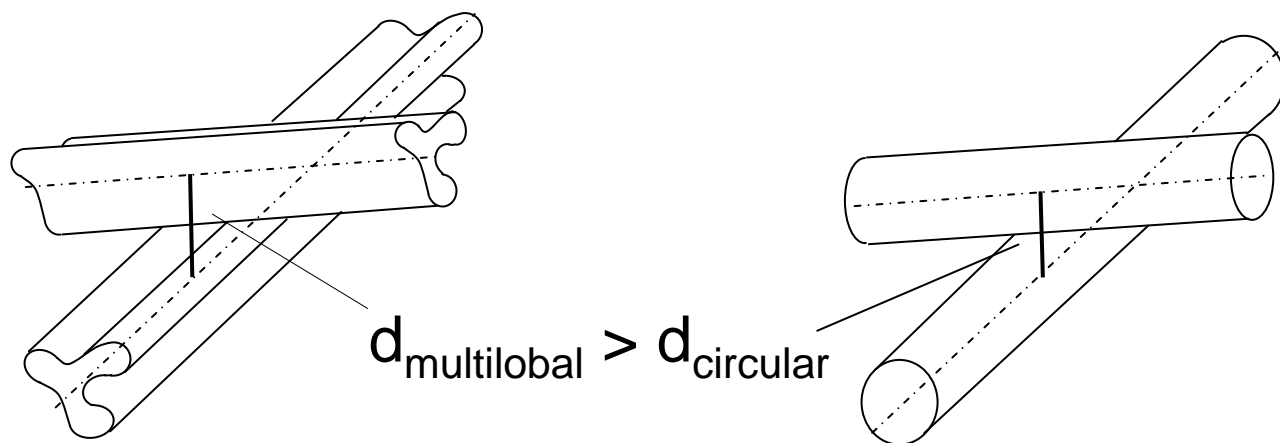
LM image of multilobal fibres

## Explanation for the differences in the felt thicknesses



Multilobal fibres with the same fibre titre show larger projected fibre diameters (~ + 30%).

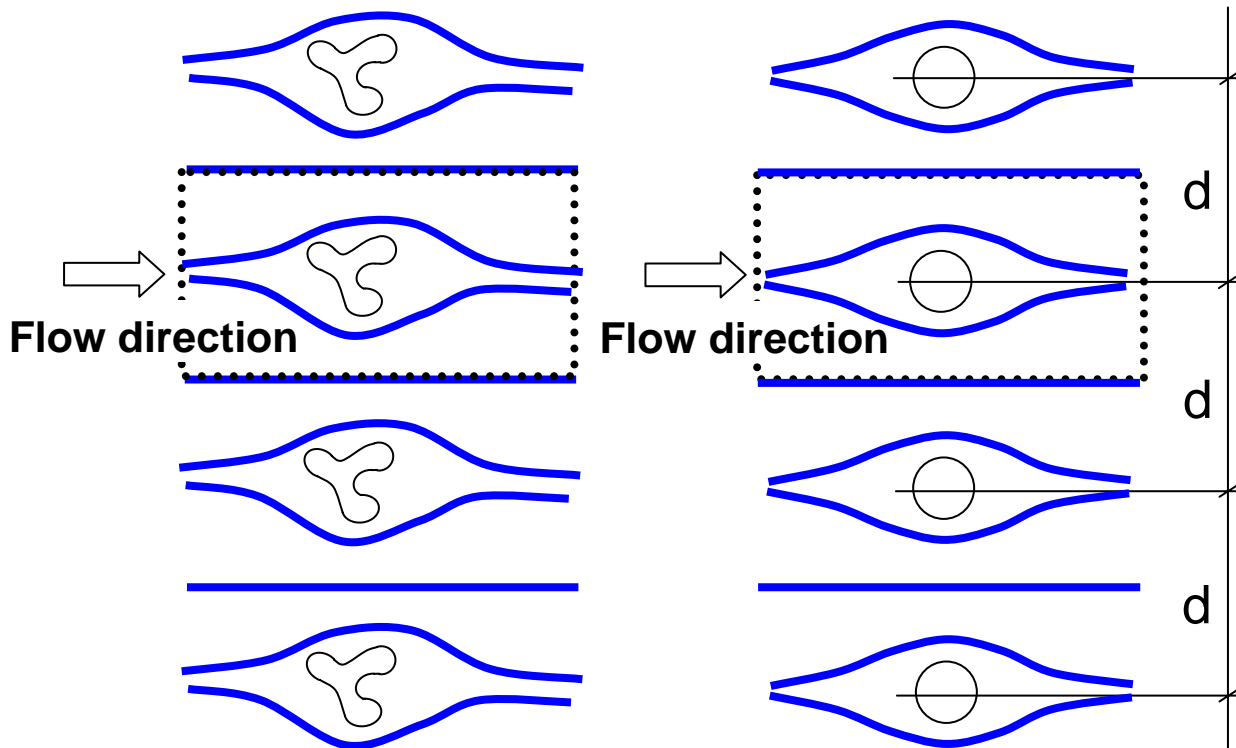
## Influence of fibre cross section on sample thickness



Due to the larger projected fibre diameters of multilobal fibres the distances  $d$  between fibres are also larger.

=> Filter materials built of multilobal fibres are more porous and thicker than felts manufactured of circular fibres.

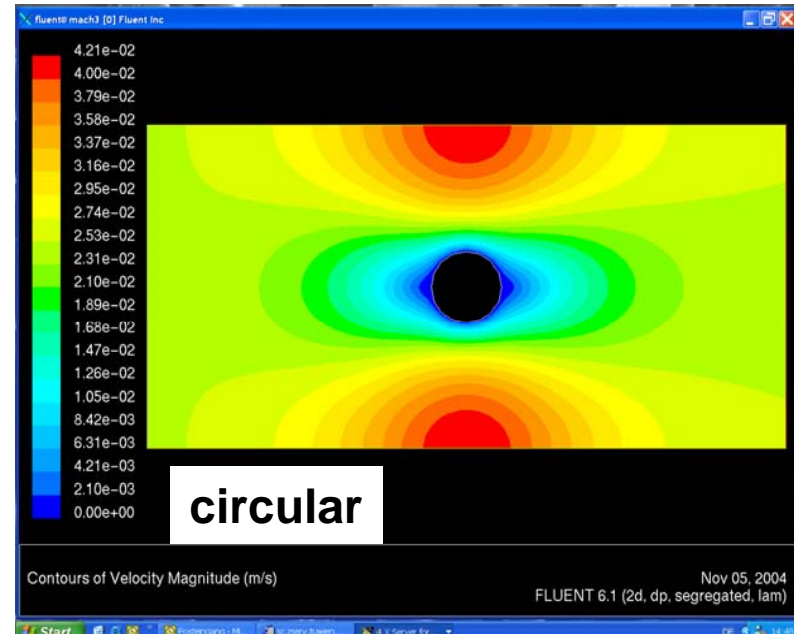
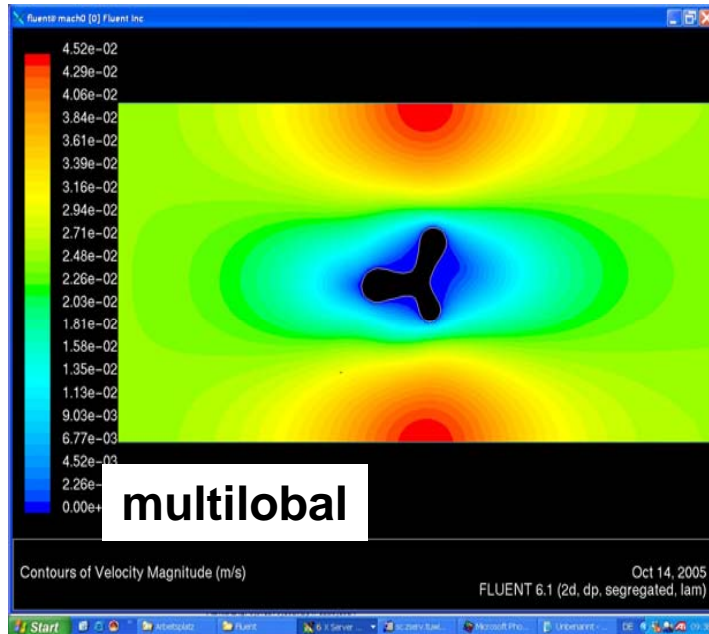
## Flow simulations: Comparison of the flow field around circular and multilobal fibres



- Lanes of laminar flow paths with a  $d$  width are considered.
- A grid of lanes (fibres) results.
- Filter face velocity 1.5 m/min (4.92 ft/min)

## Flow simulations: Results

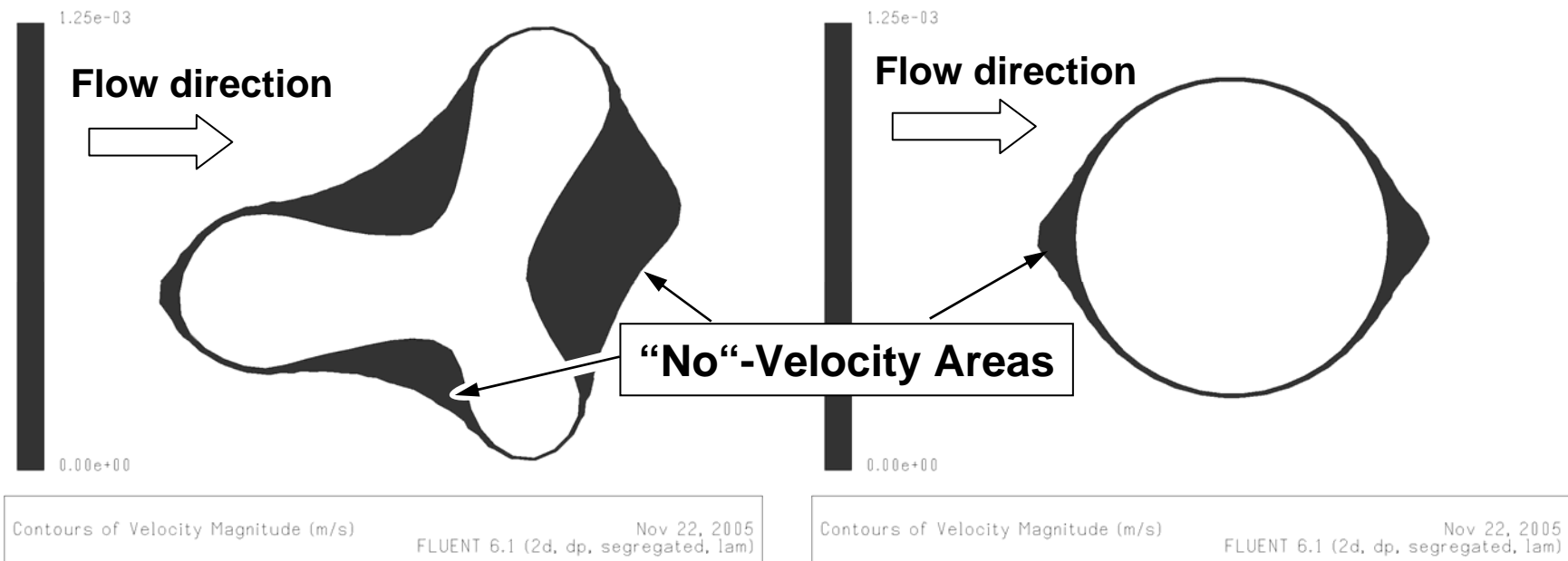
- Comparison of flow fields around multilobal and circular fibres.



- Multilobal fibres show larger areas with low flow velocity (called: **"No"-Velocity Areas**) compared to circular fibres.

## Definition of "No"-Velocity Areas

Areas with flow velocities below five percent of the filter face velocity are defined as "No"-Velocity Areas.

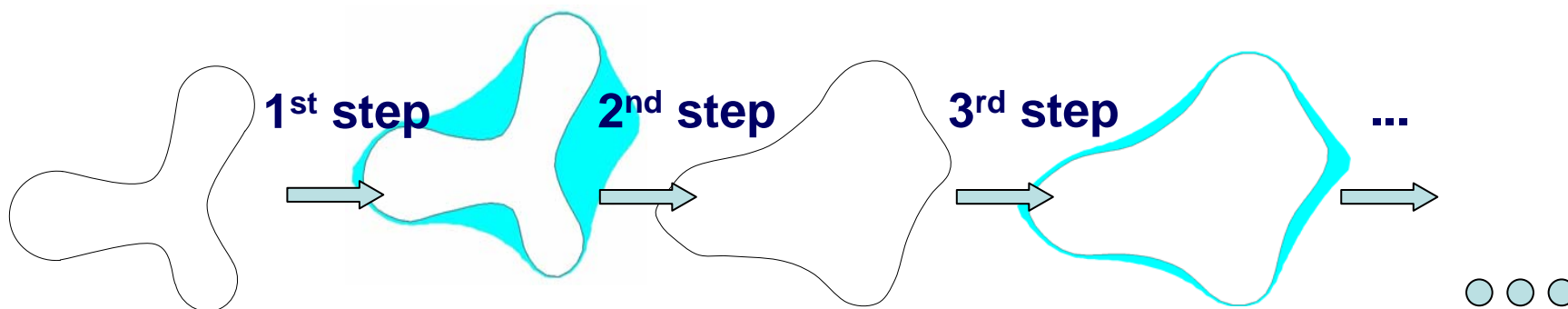


## Observations

- The “No”-Velocity Areas around multilobal fibres are larger compared to conventionally circular shapes.
- These areas represent extra storage spaces for particles which are separated within the filter medium during the initial phases of filtration (pre-coating).

## Simulation sequence of dust separation in the No"-Velocity Areas

Calculation of the resulting friction force



Simulation sequence :

**1<sup>st</sup> step**

Determination of the "No" Velocity Area.

**2<sup>nd</sup> step**

Filling up the whole "No" Velocity Area with particles.  
The fibre cross section changes.

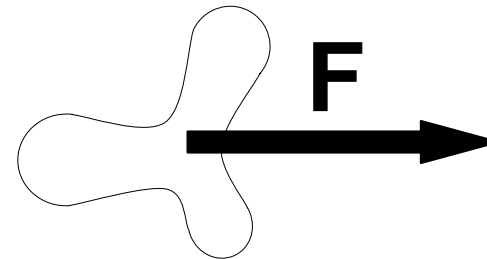
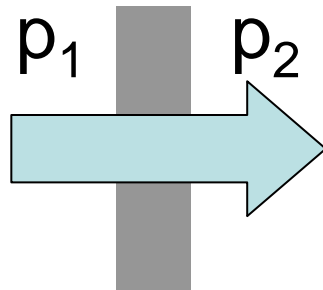
**3<sup>rd</sup> step**

Another determination of the "No" Velocity Area.

## Pressure drop of a fibre layer

The pressure loss  $\Delta p$  across a filter medium is the sum of fibre forces divided by the filter face area.

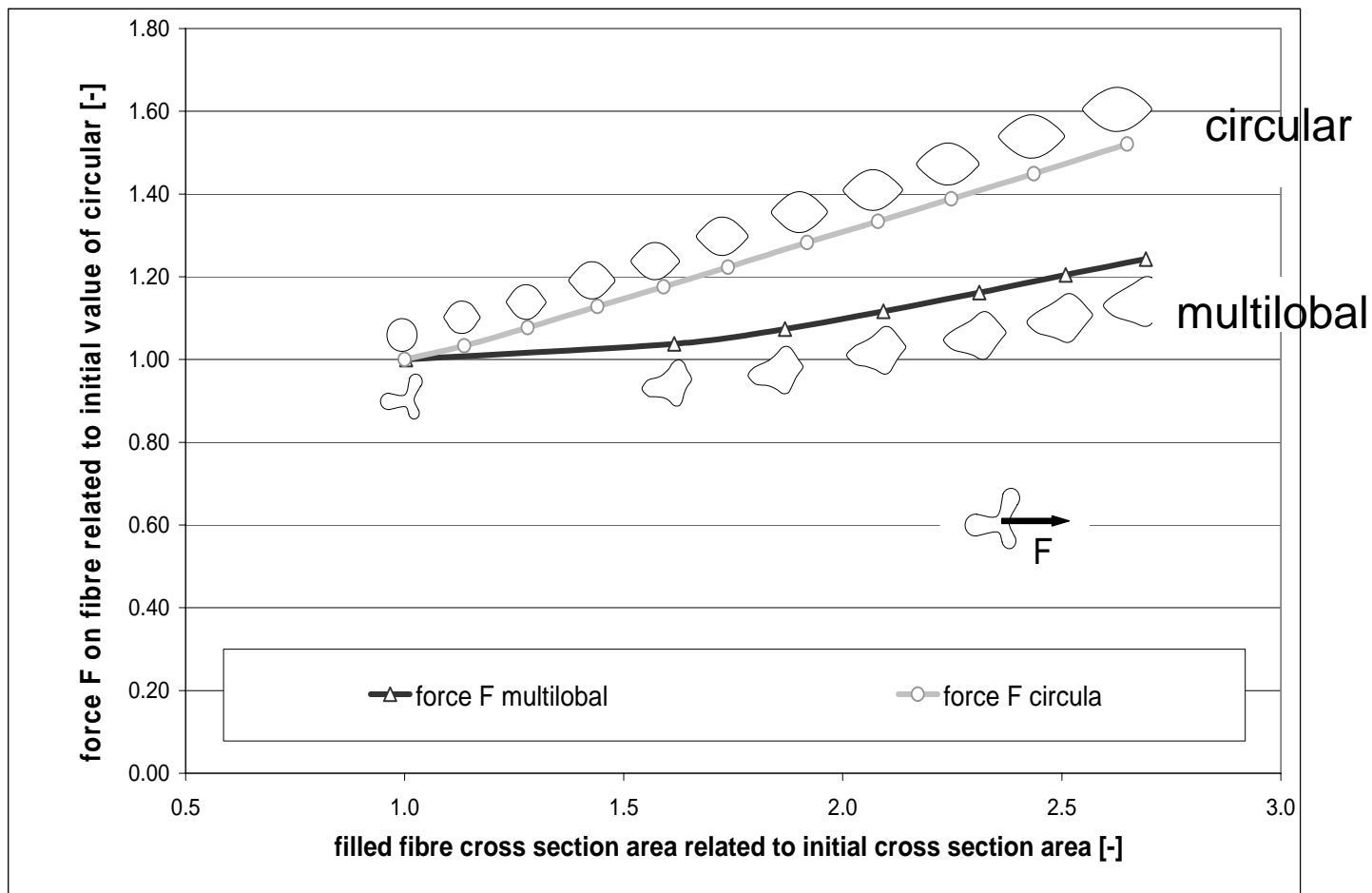
$$\Delta p = p_1 - p_2 = \frac{\sum F_i}{A} \approx \frac{n * F}{A} \sim F$$



Flow within filter medium  $\Rightarrow$  force on fibres (dust)

The force  $F$  on a fibre is a measure for the pressure drop  $\Delta p$ .

## Development of the force $F$ in the simulation sequence for multilobal and circular fibres (equal air permeability)

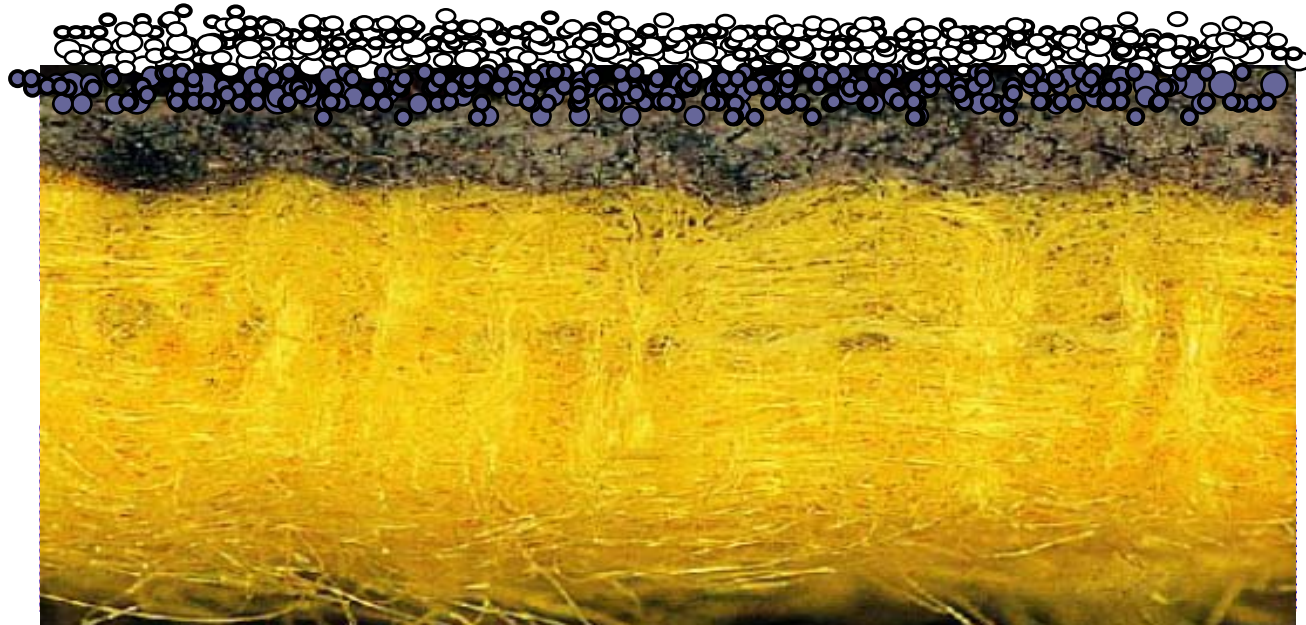


## Conclusions

- Dust separates in the low velocity zones of the multilobal fibres.
- The felt constructed from multilobal fibres – irregular / porous
- The dust cake formed by multilobal fibres is irregular – porous
- The dust cake formed by multilobal fibres is **stable** as compared to the dust cake formed by round fibres.
- The dust cake has a labyrinth like configuration derived from the irregular shape of the multilobal fibres – more dust pockets of collection.
- Multilobal felts can collect finer dust particles than felts based on similar titre round fibres.

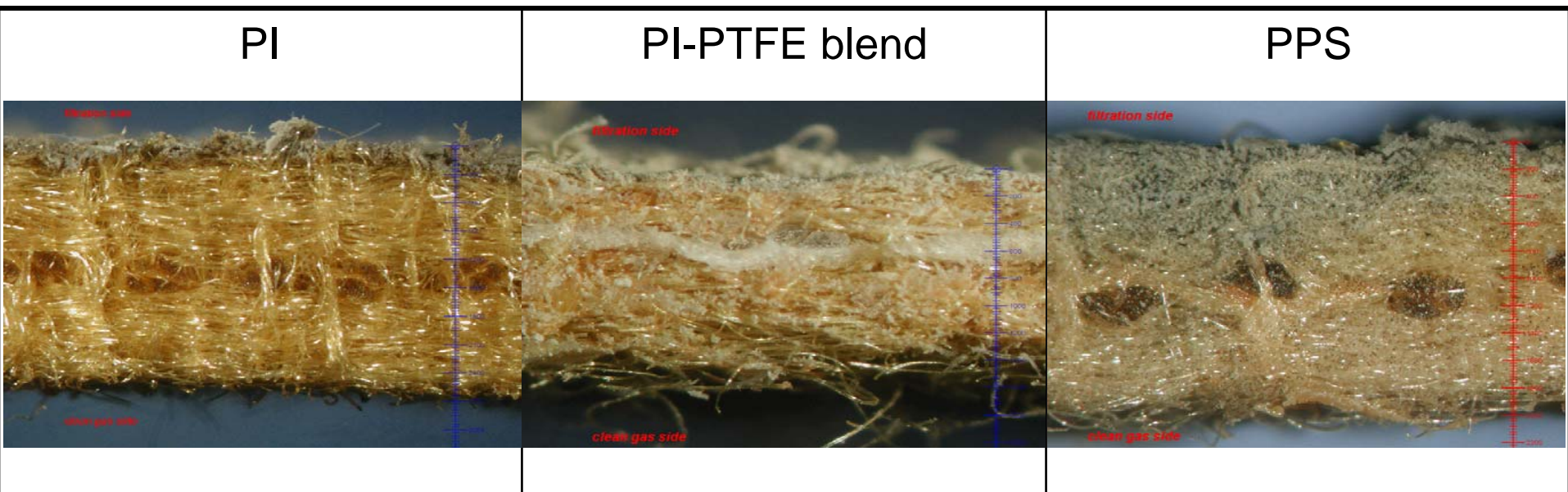
## Dust Cake Formation – Surface Filtration

- Surface filtration process – fine, multilobal fibres

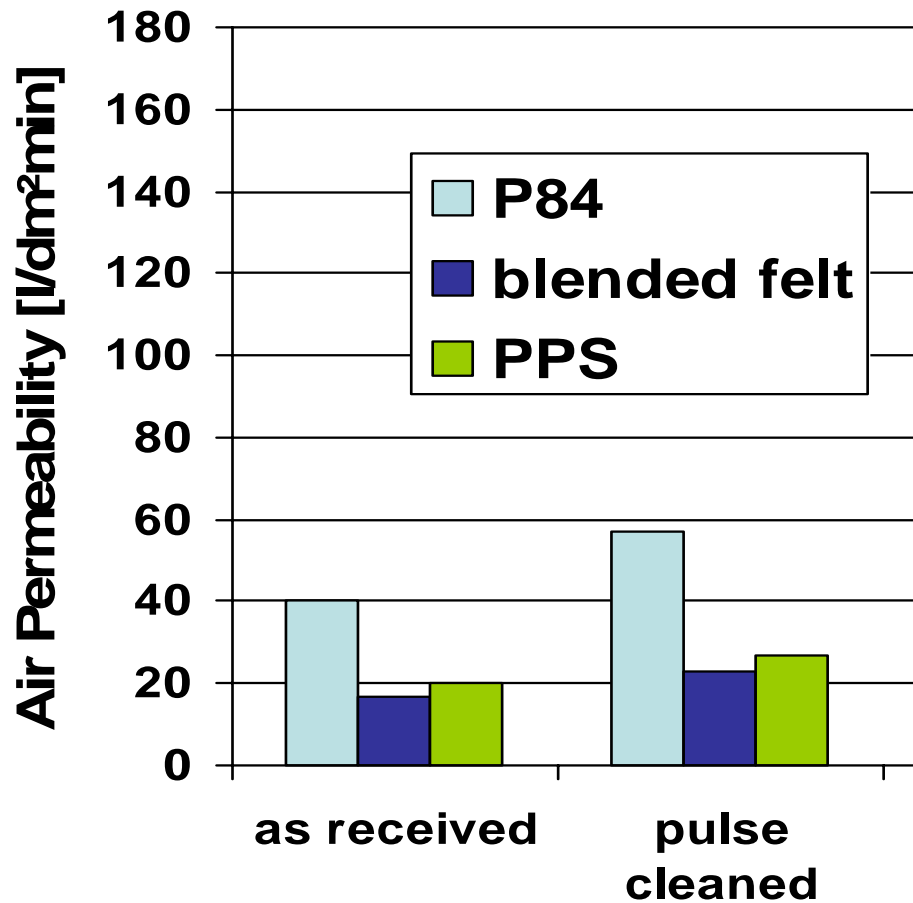


- The multilobal permanent dust cake is stable during the pulsing phase preventing the fine particles to migrate through the felt.
- The round shape of fibres associated with a low friction coefficient (i.e. PTFE) increases the dust penetration rate.

# Test bags installed for 1 year - FFP Stockholm



## Test bags installed for 1 year - FFP Stockholm



# Selection of Filtration Materials

## Selection of the Filtration Material

- Type of material; to suit the process environment
- Gas temperature: average, maximum, minimum, distribution
- Gas chemistry
- Dust chemistry
- Dust particle size distribution
- Dust particle shape
- Fibre profile: multilobal or round
- Fabric construction - composite
- Fabric treatment: singeing, coating, calendering
- Electrostatic properties of the fabric; to create a suitable dust cake
- Strength, weight, permeability, dimensional stability
- Type of cage
- Type and amount of pre-coating agent
- Type of bag house: design features



# Filter Materials for Coal Fired Boiler Bag Houses

- Polyacrylic (PAN): low temperature bag houses
- Polyphenylenesulfide (PPS): high temperature bag houses
- Polyimide (PI): high and low temperature bag houses
- PTFE: high temperature bag houses

## Fibre Blends:

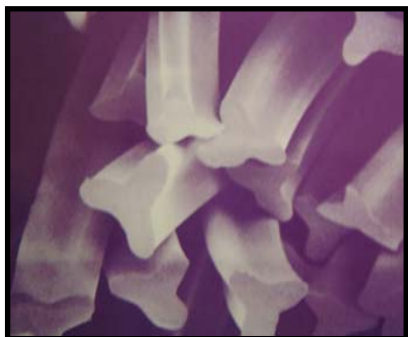
- PI + PAN;
- PI + PPS;
- PI + PTFE
- PI + PPS + PTFE

# Characteristics of Polyphenylenesulfide Fibre



- Developed in 1973 in the USA, is now distributed as a high grade fibre.
- Production: melt spinning process
- Shape: round and trilobal
- Application: boilers and incinerators.

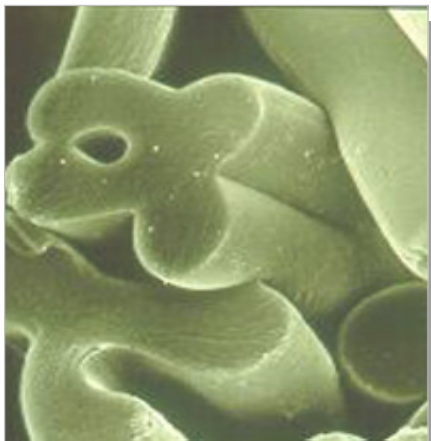
- Thermostability: constant: 190°C (374°F)  
maximum: 200°C (392°F)  
280°C-290°C (536°F- 554°F)
- Melting Point: 280°C-290°C (536°F- 554°F)
- Recommended continuous operating temperature: 130 - 160°C (266°F- 320°F)
- Density: 1,37 g/cm<sup>3</sup>
- Tensile Strength: 50 cN/tex
- Resistance to hydrolysis: excellent
- Resistance to acids: excellent
- Resistance to alkalis: excellent
- Resistance to oxidation: moderate



# Coal fired boilers: PPS offers these advantages

- economical solution with long term track records for filtering flue gases in the largest power stations
- can withstand typical gas conditions with 6 to 8 % moisture content and up to 2000 mg/m<sup>3</sup> SO<sub>x</sub>
- PPS meets additional requirements with regard to chemical resistance such as:
  - frequent dew point crossings when plant is operated for peaks only
  - change of coal sources
- good filtration efficiency with air to cloth ratios up to 1,0 m/min (3.3ft/min)
- the use of trilobal Procon on the surface improves filtration performance
- a fibre blend of Procon and P84 further more increases filtration efficiency, keeps low differential pressures and long cleaning cycles
- standard 10-12 wire cages can be used

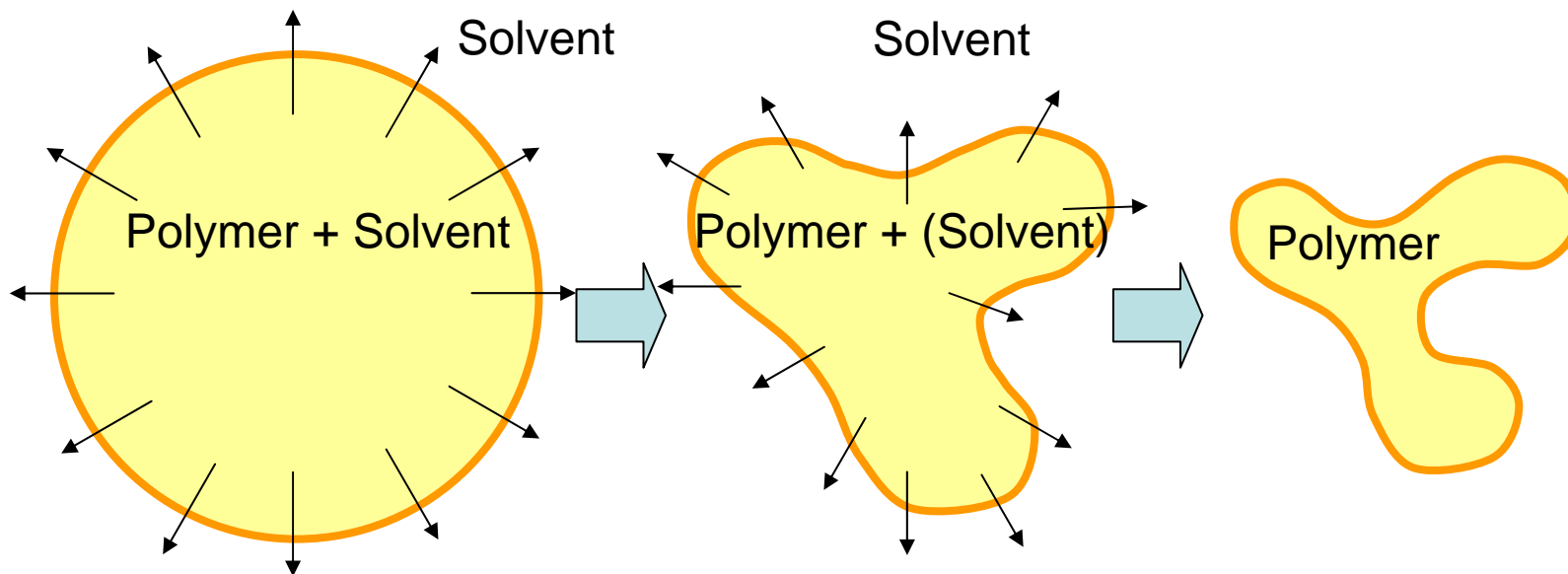
## Characteristics of Polyimide Fibre



- Developed during 1984, P84 (PI) proved to be very good for filtration.
- The fibres are produced in a dry spinning process.
- Shape: multilobal
- Applications: Coal fired boilers, steel works, cement plants, waste incinerators, etc.

- Thermostability:
  - constant: 240°C (464°F)
  - maximum: 260°C (464°F)
- Recommended continuous operating temperature: 130 - 190°C (266°F-374°F)
- Melting Point: does not melt
- Density: 1,41 g/cm<sup>3</sup>
- Tensile Strength: 38 cN/tex
- Resistance to hydrolysis: good
- Resistance to acids: good
- Resistance to alkalis: moderate
- Resistance to oxidation: good

## Generation of multilobal fibres - PI



Fabrication: Spinning

By vaporisation of the solvent the fibres shrink during the fabrication process. Irregular or regular lapped fibre cross sections are generated.

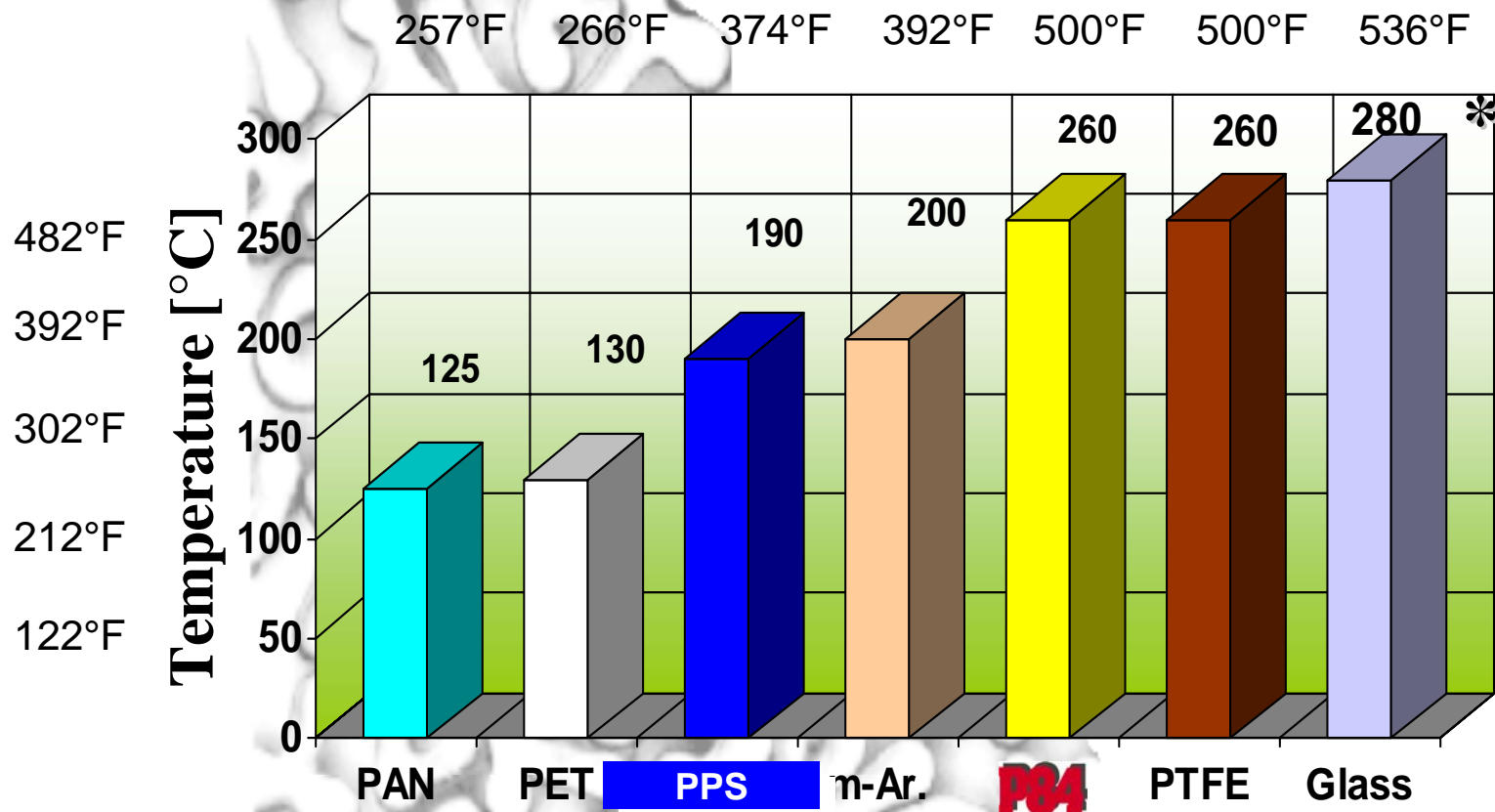
## High temperature filtration; PI offers these advantages

- PI filter media is capable to build up the required dust cake to filter the finest particles, neutralize acidic flue gases, capture dioxins and heavy metals when active carbon is added.
- suitable for a broad range of flue gas compositions
- can withstand temperature upsets if scrubbers are off
- good filtration efficiency, air to cloth ratios up to 4,6 ft/min (1.4 m/min) require small bag houses
- soluble salts are not effecting the filtration efficiency ("chicken effect" with PTFE membranes)
- standard 10 -12 wire cages can be used

## Guidelines for using PI continued

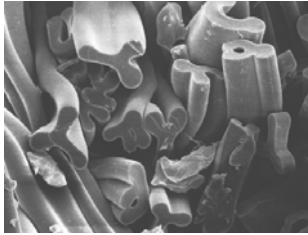
- short term peaks of 260°C (500°F) do not cause problems for PI , however longer periods around 260°C (500°F) may lead to fabric shrinkage. Short peaks of 10 minutes at 260°C (500°F) may be limited to 100 - 400 hours/year to achieve requested bag life.
- proper heat treatment of the needle felt in production is necessary.
- operation at or below the acid- and water - dew point should be avoided at any time
- condensation as well as operation close to the dew point may result in problems in case the pH of the dust is extremely acidic ( pH < 3 )
- zinc coated wire cages under acidic conditions may attack PI filter bags.

# Maximum Service Temperatures

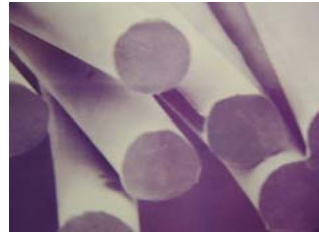


\* Actual application temperature may vary to the shown maximum, depending on the flue gas composition!

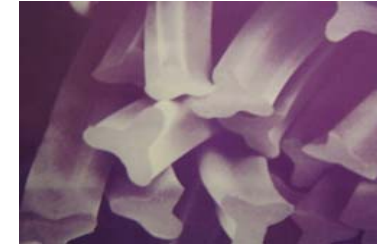
# Fibre Surfaces



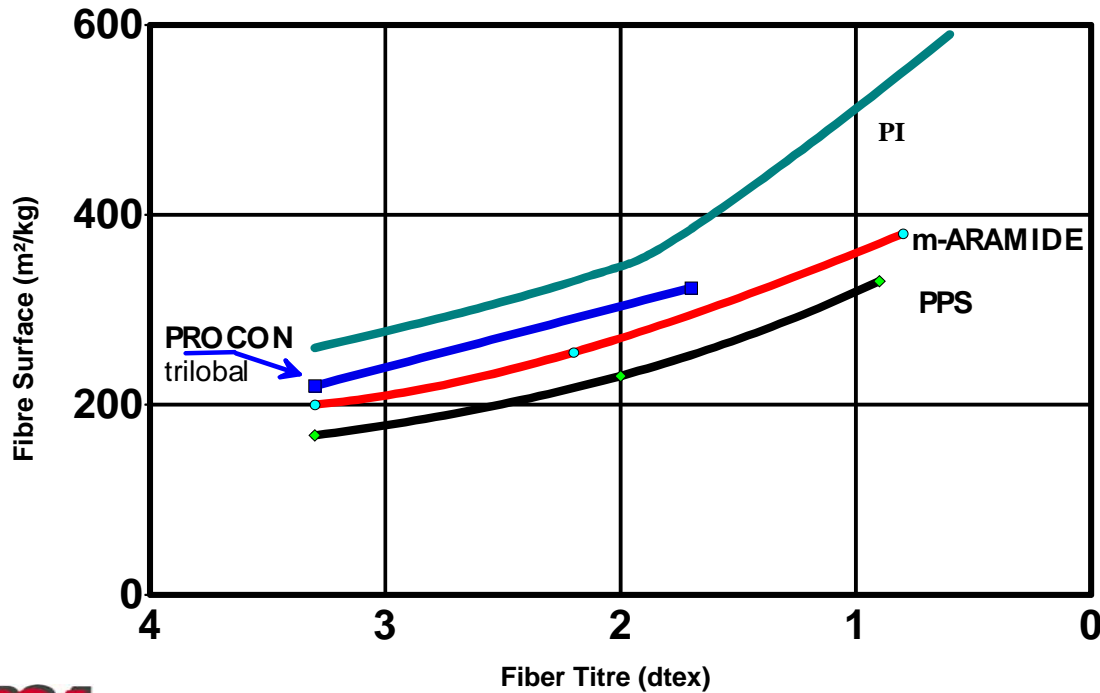
PI 2,2 dtex



PPS 2,2 dtex round (206 m<sup>2</sup>/kg)

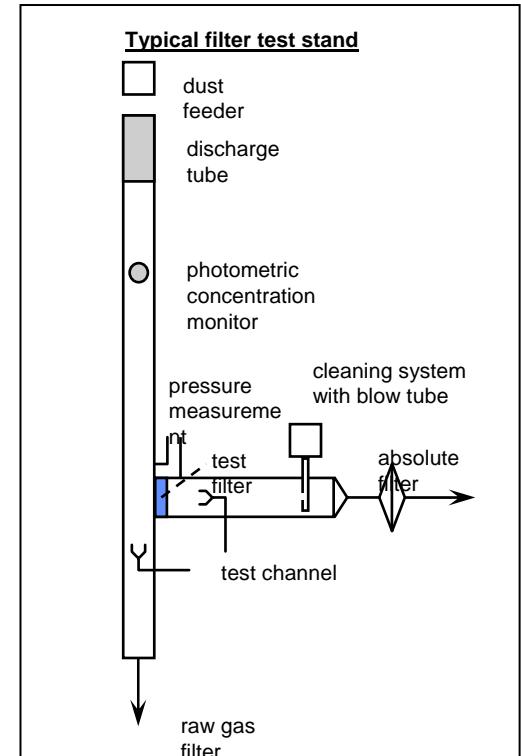
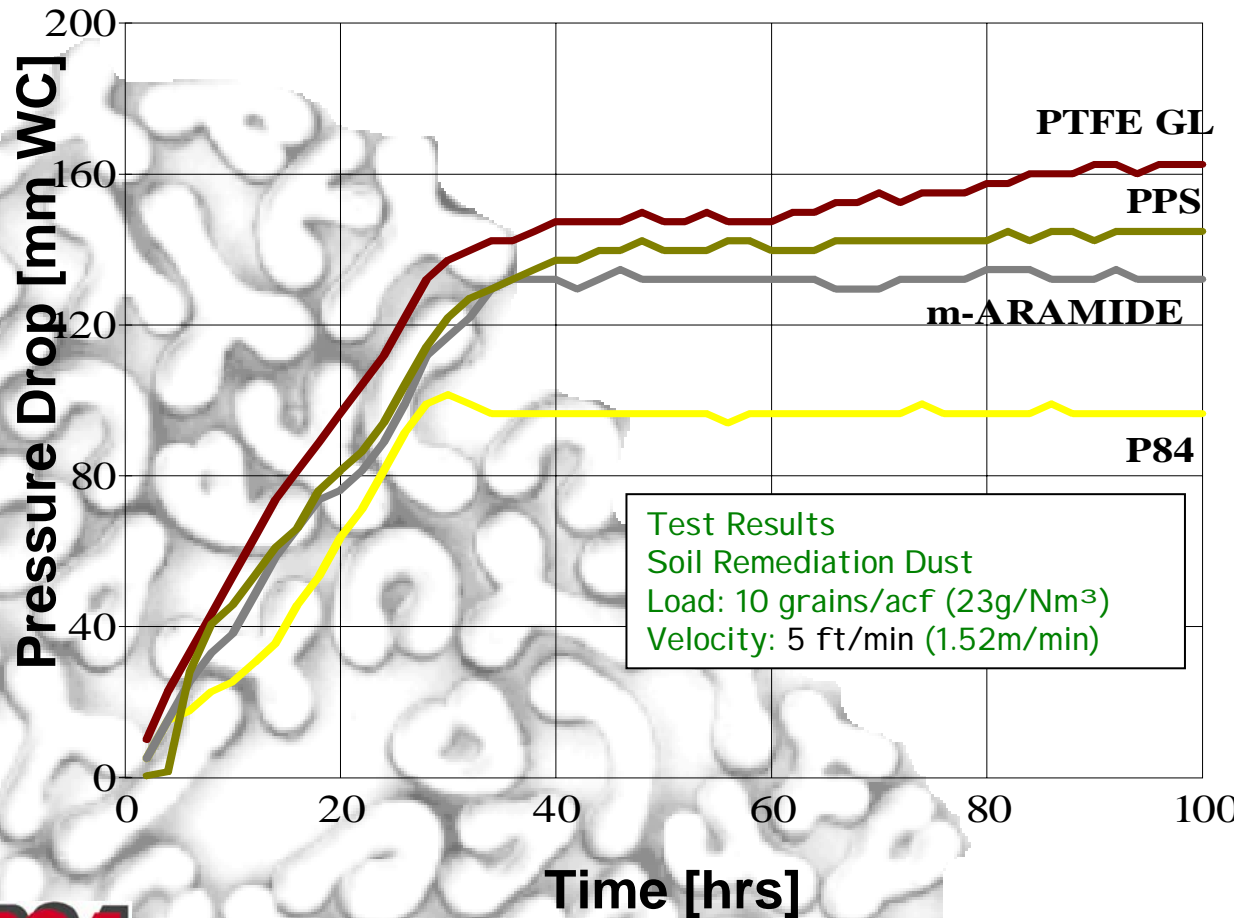


PPS 1,7 dtex trilobal (317 m<sup>2</sup>/kg)

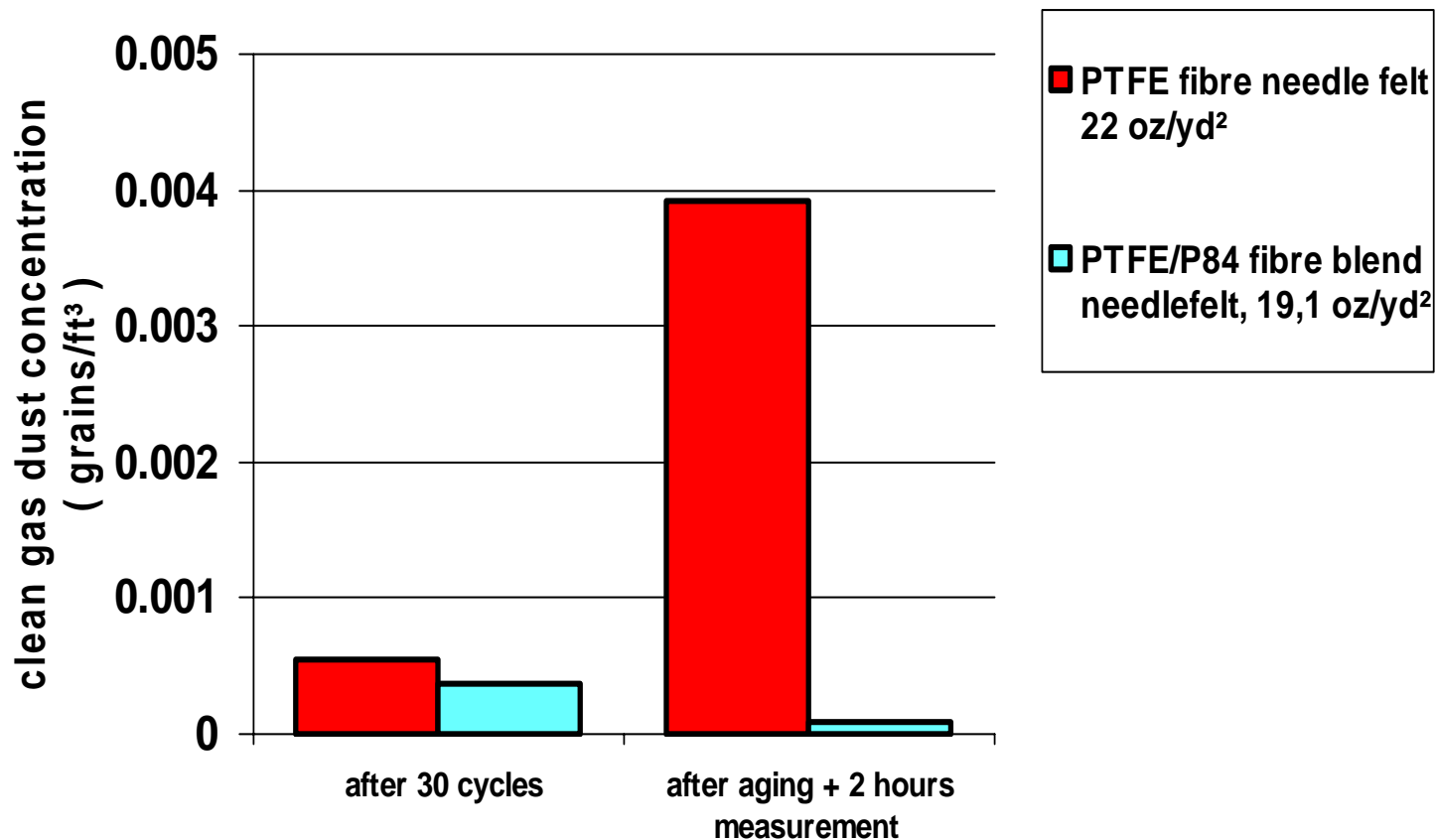


m-Aramid

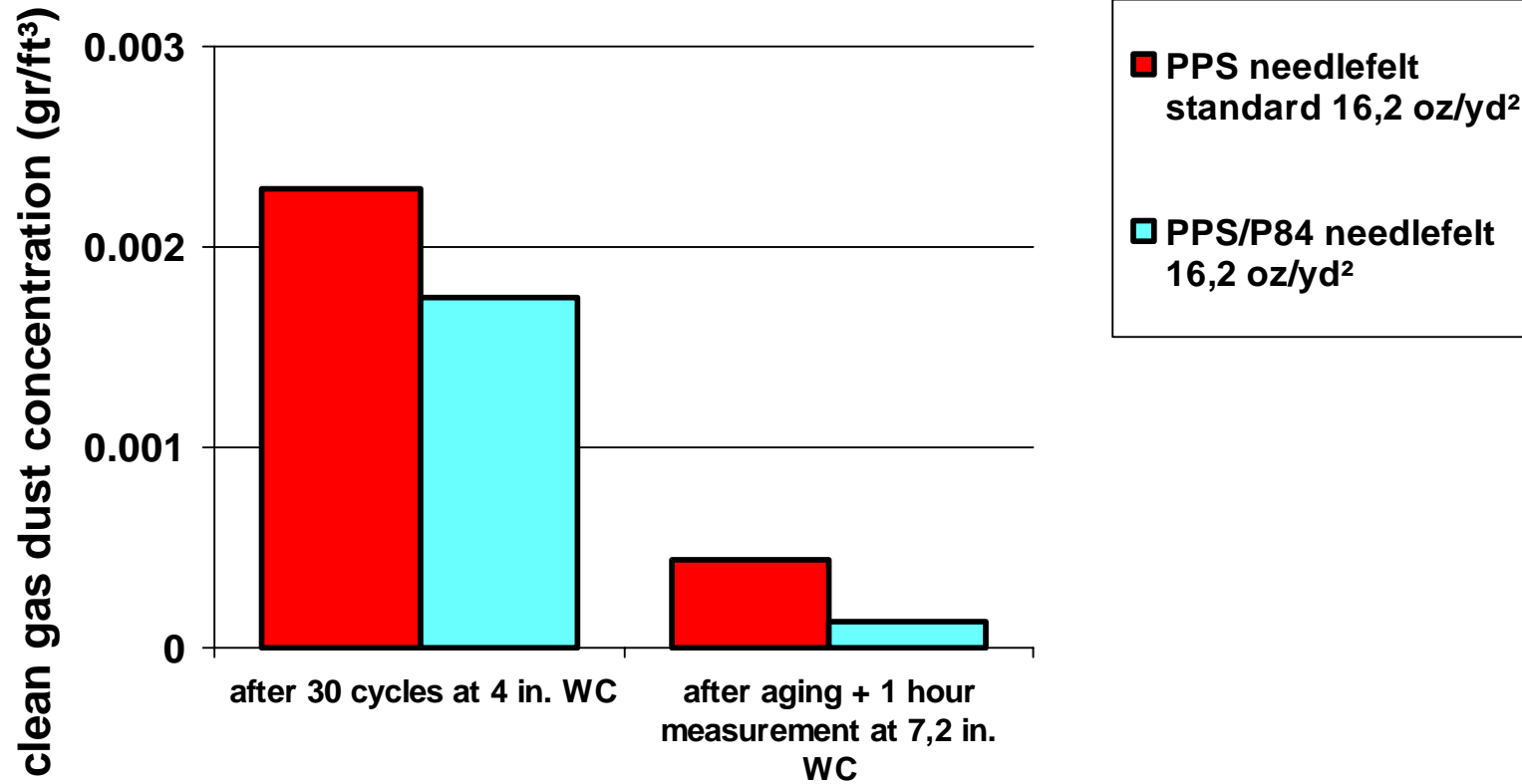
# Differential Pressure of Filter Fabrics



## Clean gas dust concentration of filter media



## Clean gas dust concentration of filter media





Thanks!