Particulate Matter Overview

Dr. Dirk Porbatzki
Uniper Technologies GmbH

„PM“-Discussion

- Dust emissions of modern power plants show mostly particles < 10 µm.
- If FGD is installed, almost 100 % are <2.5 µm.
- Therefore in modern power stations ALL measures to improve the dust precipitation efficiency are measures to improve PM precipitation.

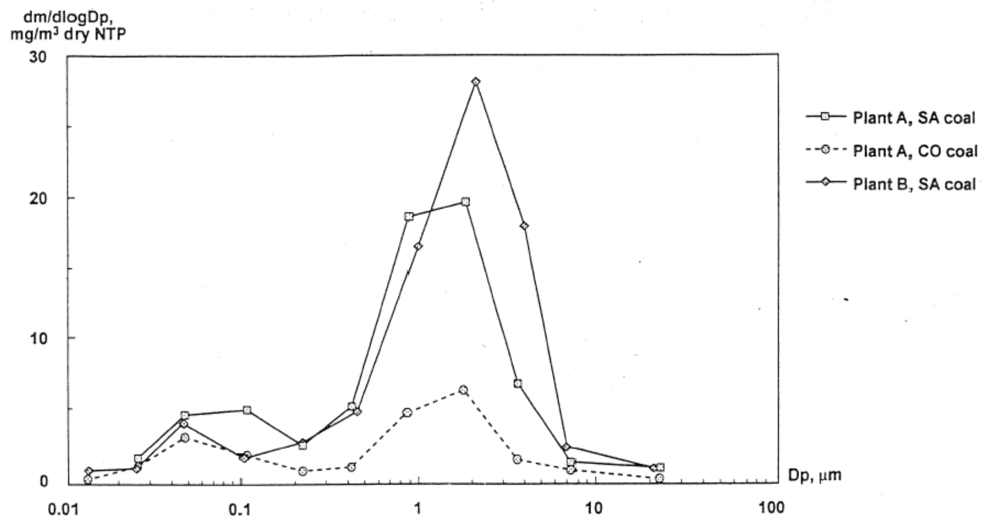
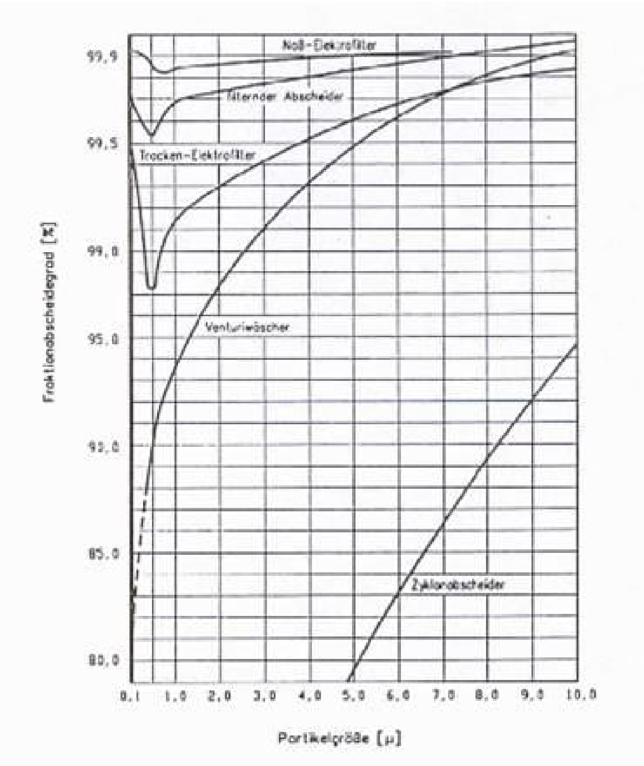


Figure 3: ESP outlet, mass based size distribution determined with BLPI and AI.



(One) Scientific Definition of „Particulate Matter“

- **Thoracic particulates, PM10, coarse fraction:** Particles with a diameter of ≤10 µm and particles that can pass by more than 50 % a selecting precipitator which is designed for an aerodynamic diameter of 10 µm. Particles of that size are respirable.

- **Respirable particulates, PM2.5, fine fraction**: Particles with a diameter < 2,5 µm and particles that can pass by more than 50 % a selecting precipitator which is designed for an aerodynamic diameter of 2.5 µm.. This fraction includes particularly the respirable particles.

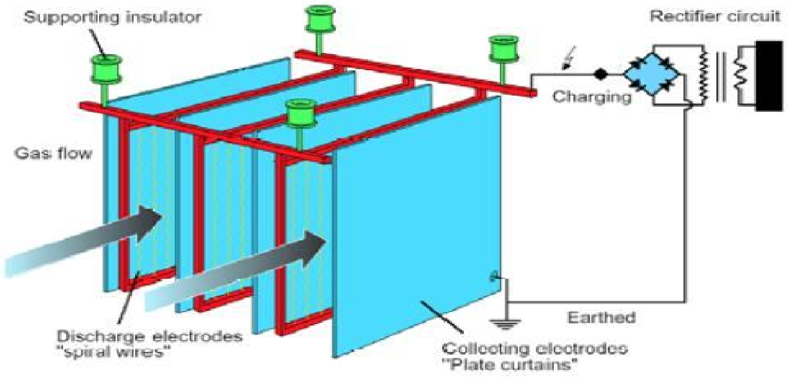
- **Ultra fine particulates UFP:** Particles with a diameter <0.1 µm which can penetrate to the bloodstream.

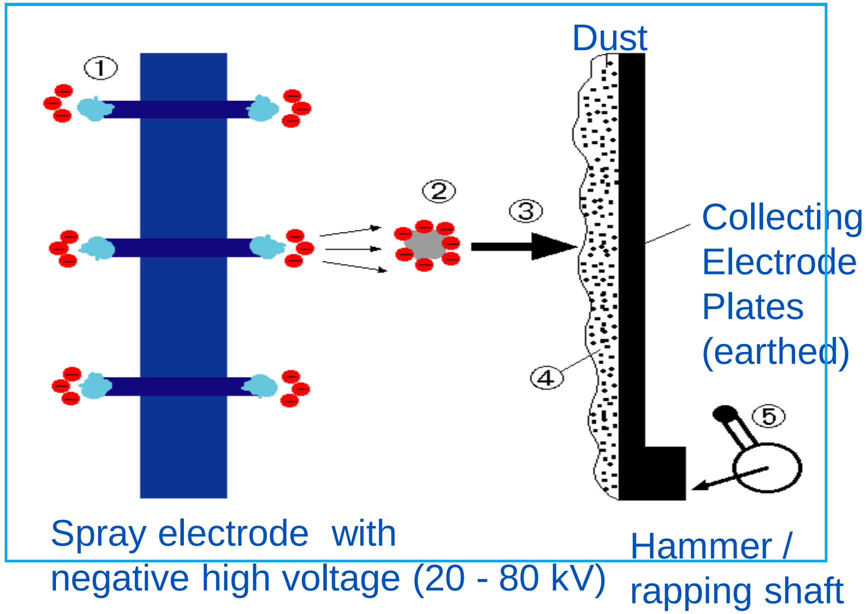
Electrostatic precipitators (ESP‘s)…

- ESP‘s are „intelligent“ precipitators due to the fact :
- …that the energy, necessary for precipitation, affects exclusively the particles but not the total flue gas flow.
- Therefore the specific energy demand is usually lower in comparison with other techniques .

Physical Fundamentals - ESP

1. Electron Emissions
   - (Negative) Corona Discharge
2. Particle Charging
   - Diffusion charging for particles < ca. 0.5 µm
   - Field charging for particles of > ca. 0.5 µm
3. Transport of charged particles: Velocity given by equilibrium between Coulomb Force (viscous drag of gas) and Field Force (Stoke's Law)
4. Dust agglomeration at Collecting Electrode Plates
   - Cohesion/ adhesion
   - electrostatic charging
5. Cleaning Collecting Electrode by hammers



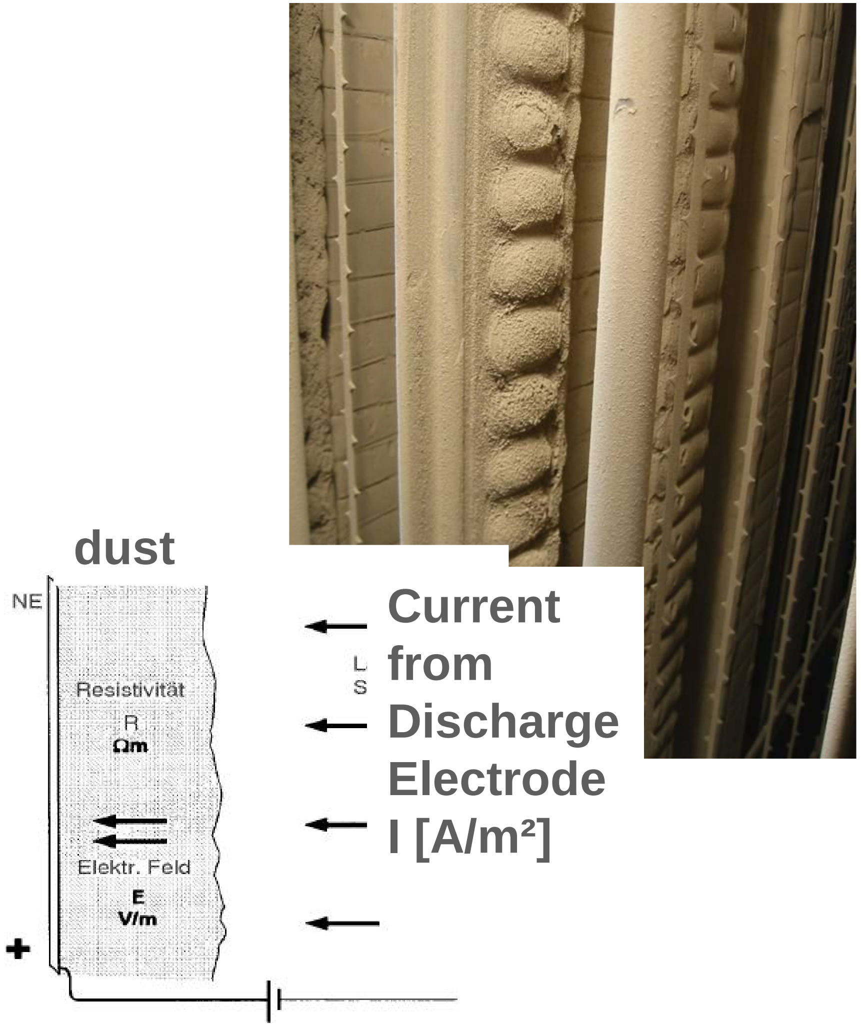


Grafik: Lurgi, Alstom

Ohm‘s Law helps to describe the process

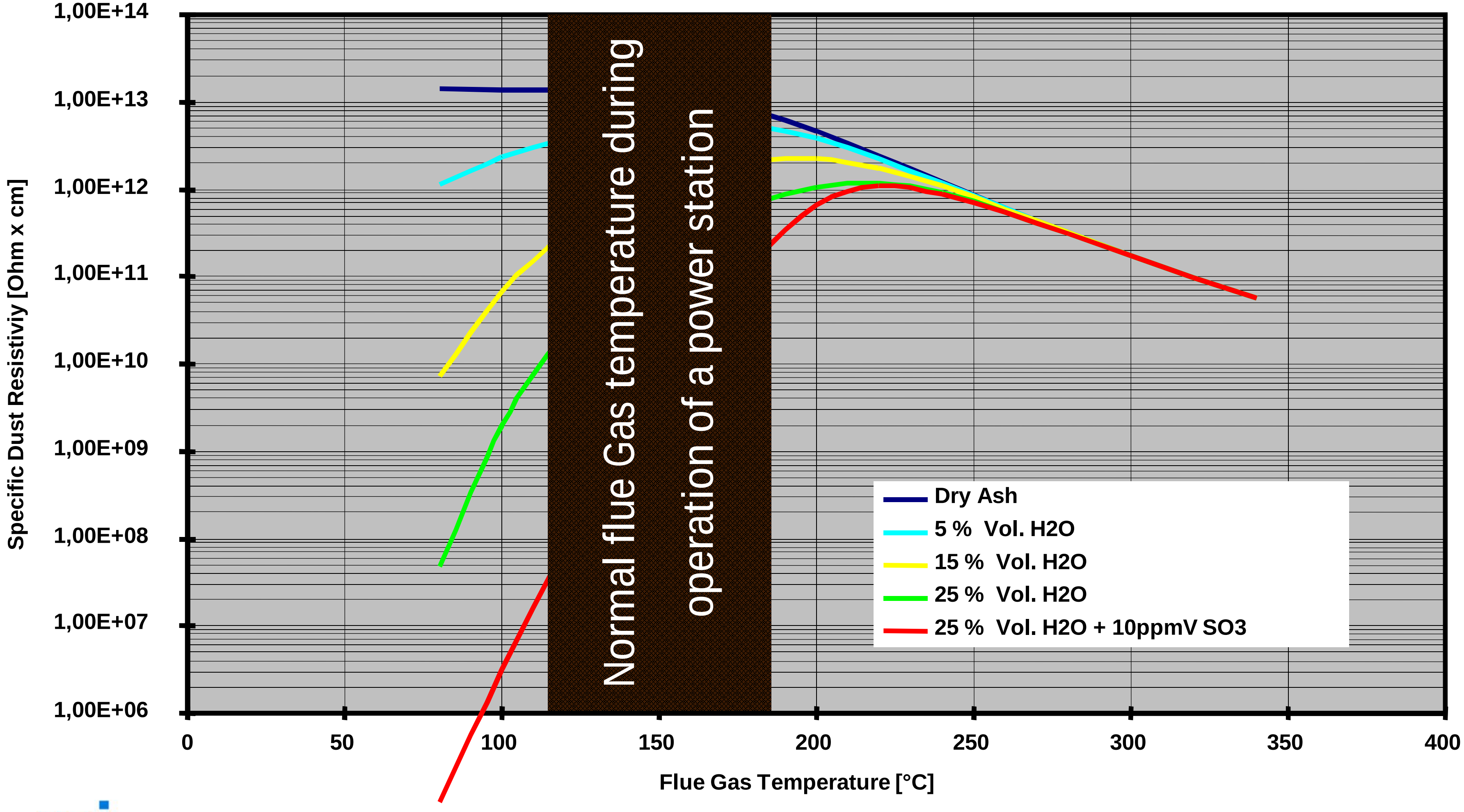
$E = R \times I$ [$V/m = \Omega m \times A/m^2$]

- Field Strength **E** (defines acceleration / adhesion): $E = 3 – 6\ kV_S/cm$
- Discharge current **I**: $I = 0{,}1 – 0{,}5\ mA/m^2$
- Dust resistivity **R**:
  Normal operation: $10^8 – 10^{11}\ \Omega xcm$
  Re-Entrainment : $< 10^7\ \Omega xcm$ (too high conductivity → may cause reverse polarity)
  Back corona: $> 10^{11}\ \Omega xcm$ (formation of positive charged ions)

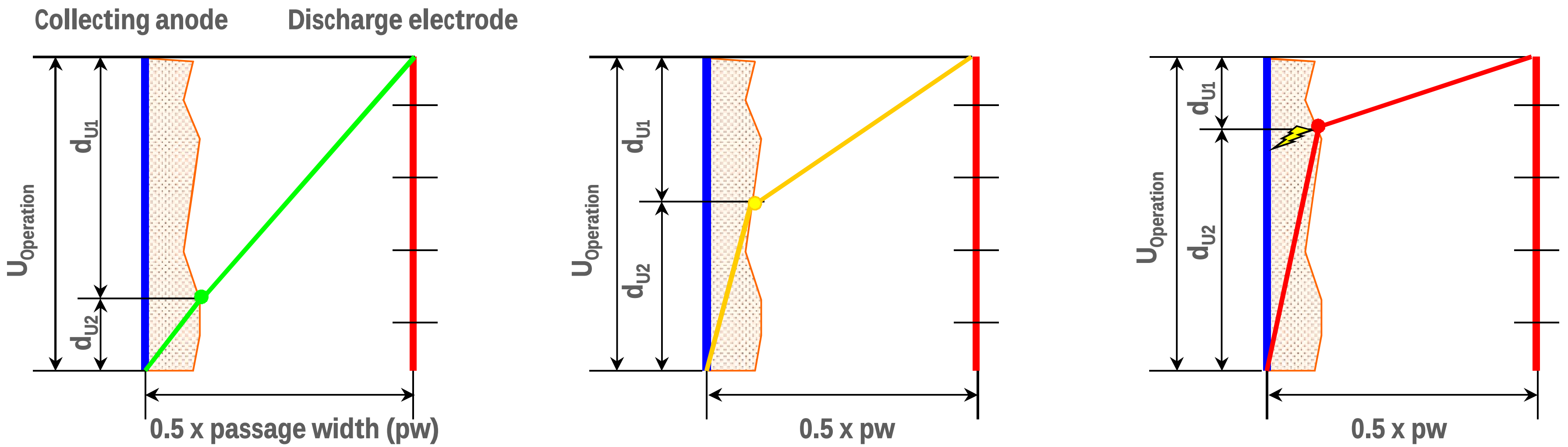


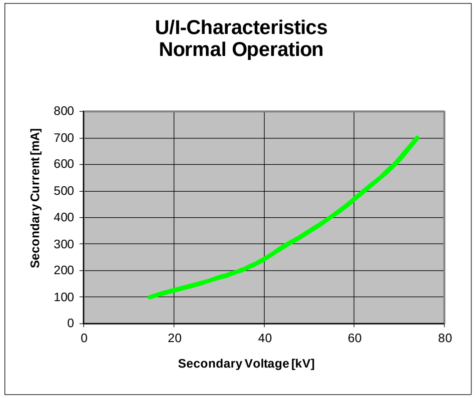
Grafik: Alstom, Foto: H.Schatton

Dust resistivity – most important parameter for ESP operation …

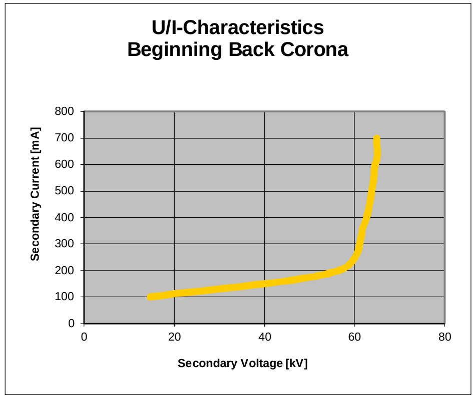


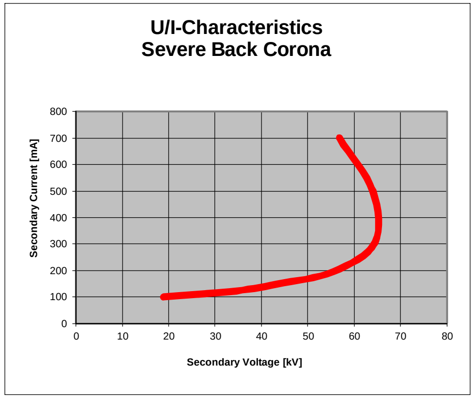
Current condition of the ESP can be detected by Current-/ Voltage diagrams…





Control Cabinet





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Conclusions from the process examination:

- A certain discharge current is necessary to charge the particles and to collect them at the anode
- Electric field strength must not be too high to allow a proper cleaning of the collecting electrode (anode)
- If dust resistivity is low, the current has to be increased
- If dust resistivity is high, current MUST be reduced to avoid back corona

→ maximum current entry can be counter productive! Reduced precipitation is possible.

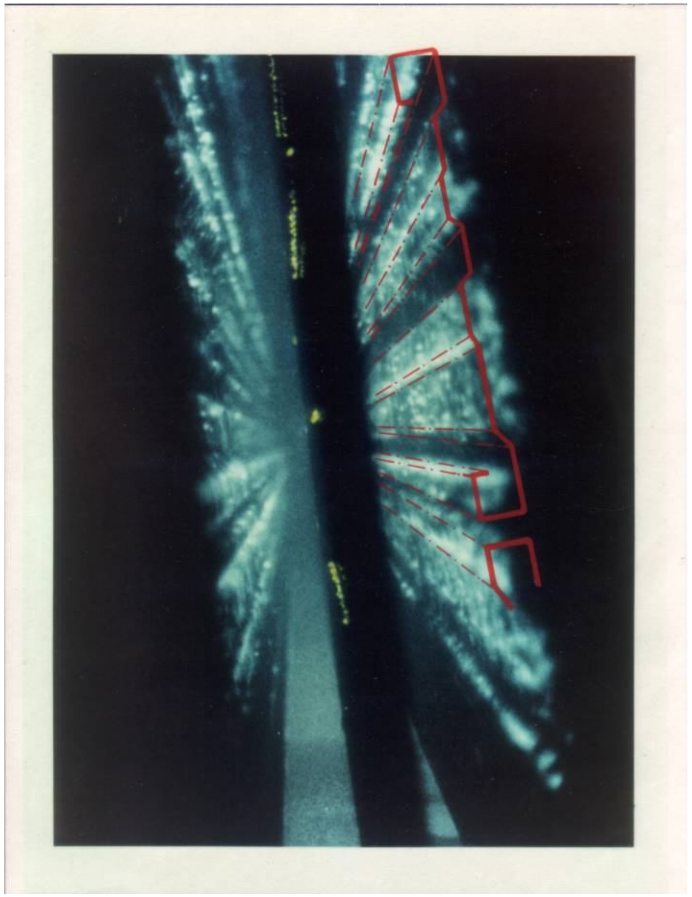


Bild: Walther & Cie.

ESP design is based on experience..

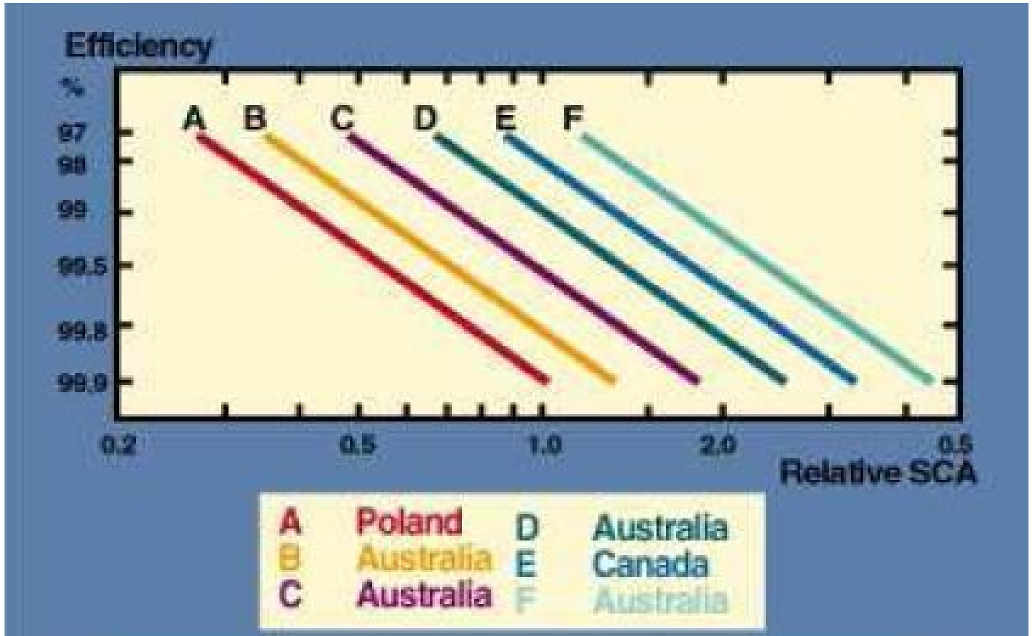
Classical „Deutsch“-equation:

$$\eta = 1 - e^{-(w_D \times f(SCA))} \times 100$$

f (SCA)	= A / V	[s/m]
η	= Collection efficiency	[%]
f (SCA)	= specific collecting area or „f-value“	[s/m]
w_D	= migration velocity	[cm/s]
A	= Collecting Area	[m^2]
V	= Flue gas volume	[m^3/s]

ESP Design is no exact science. References with comparable applications are necessary or the design margins are increased

Indian coals: >30 % ash, ~ 0.4 % S



Coal		A	B	C	D	E	F
Ash content, (dry basis)	%	10	16	31	19	18	28
Sulfur, total,	%	0.70	0.36	0.34	0.62	0.27	0.26
Na_2O in coal ash	%	0.80	0.65	0.50	0.10	0.30	0.10

Grafik: Alstom

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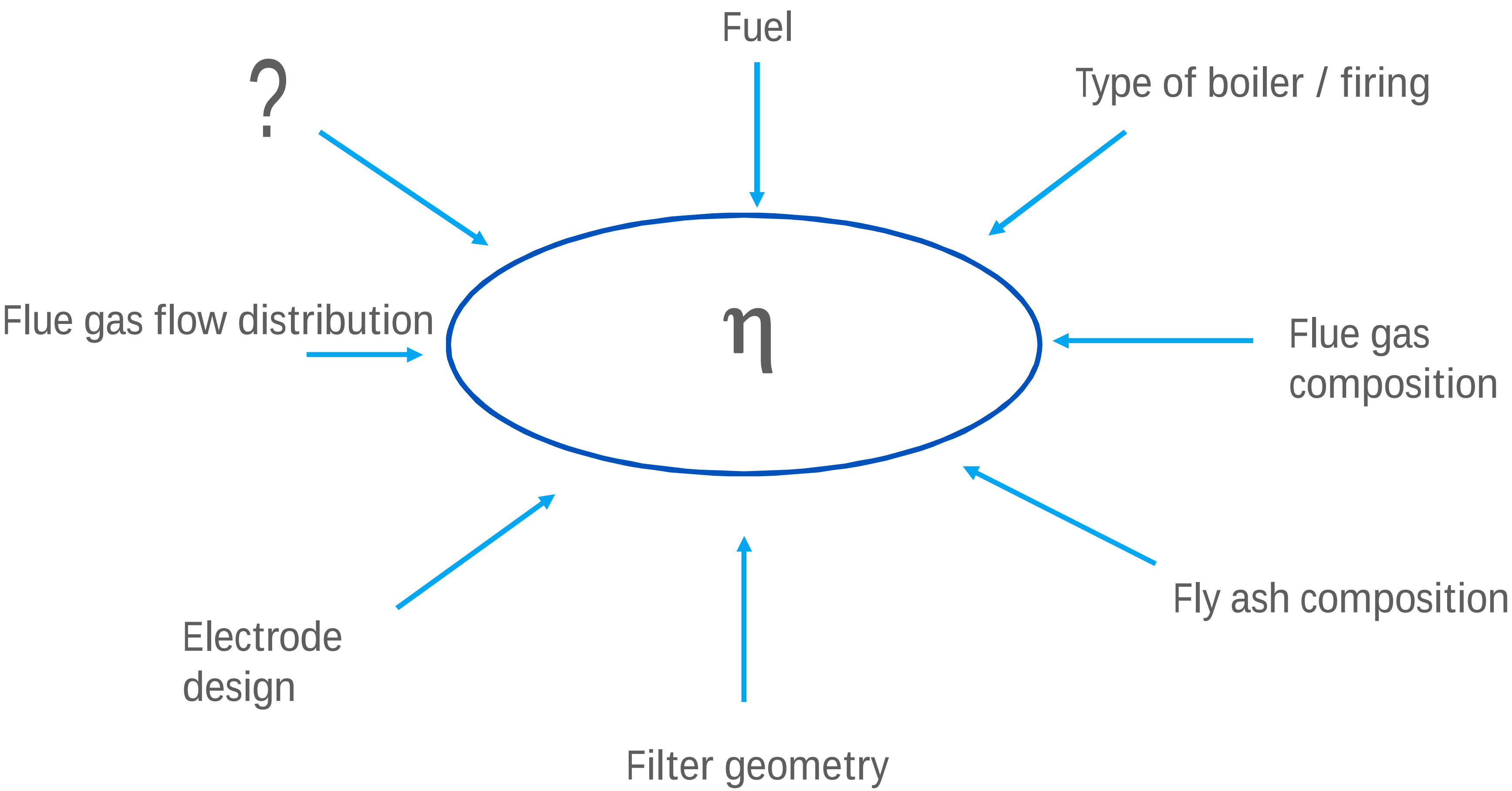
Several possible impact on dust precipitation efficiency…



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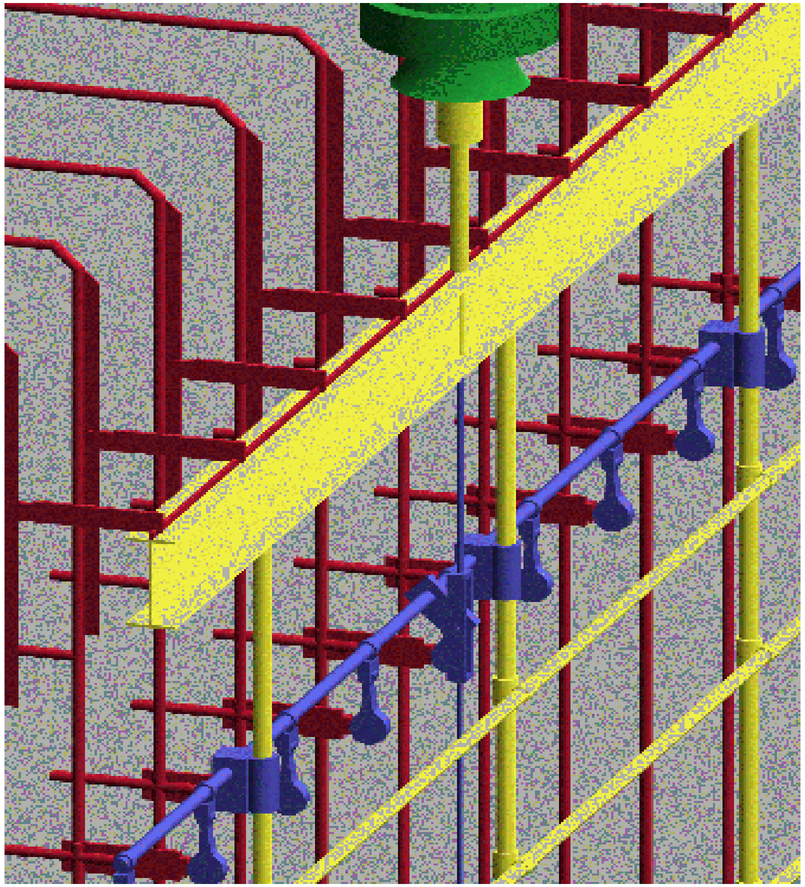
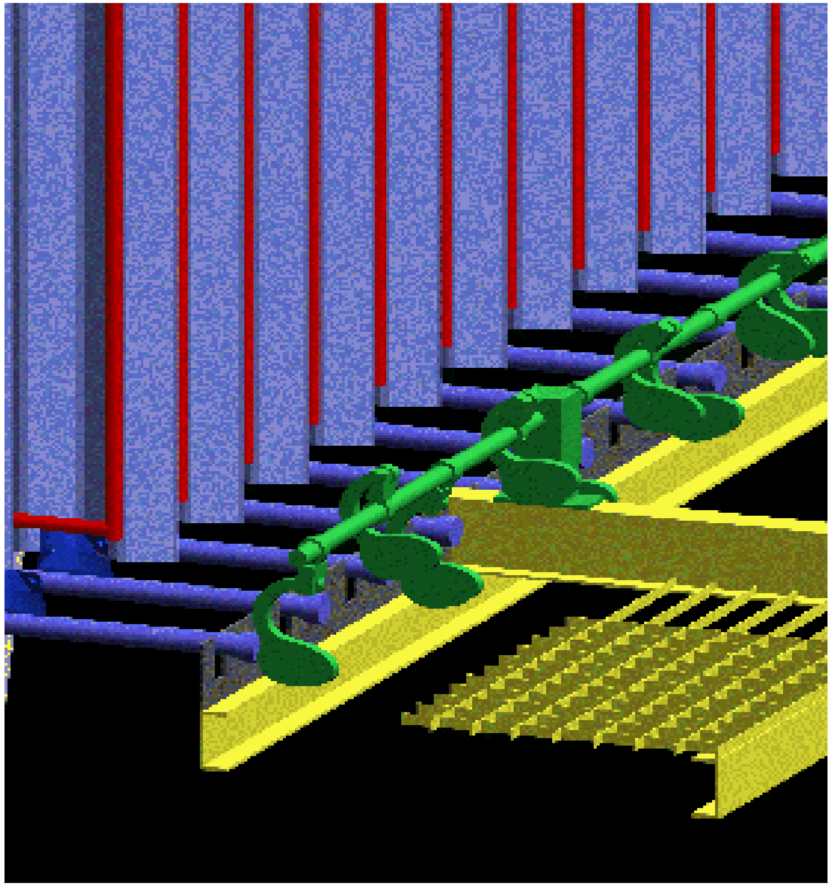
Electrode Cleaning…



SE-rapping Lurgi

(blue = shaft & hammers)



CE-rapping Lurgi

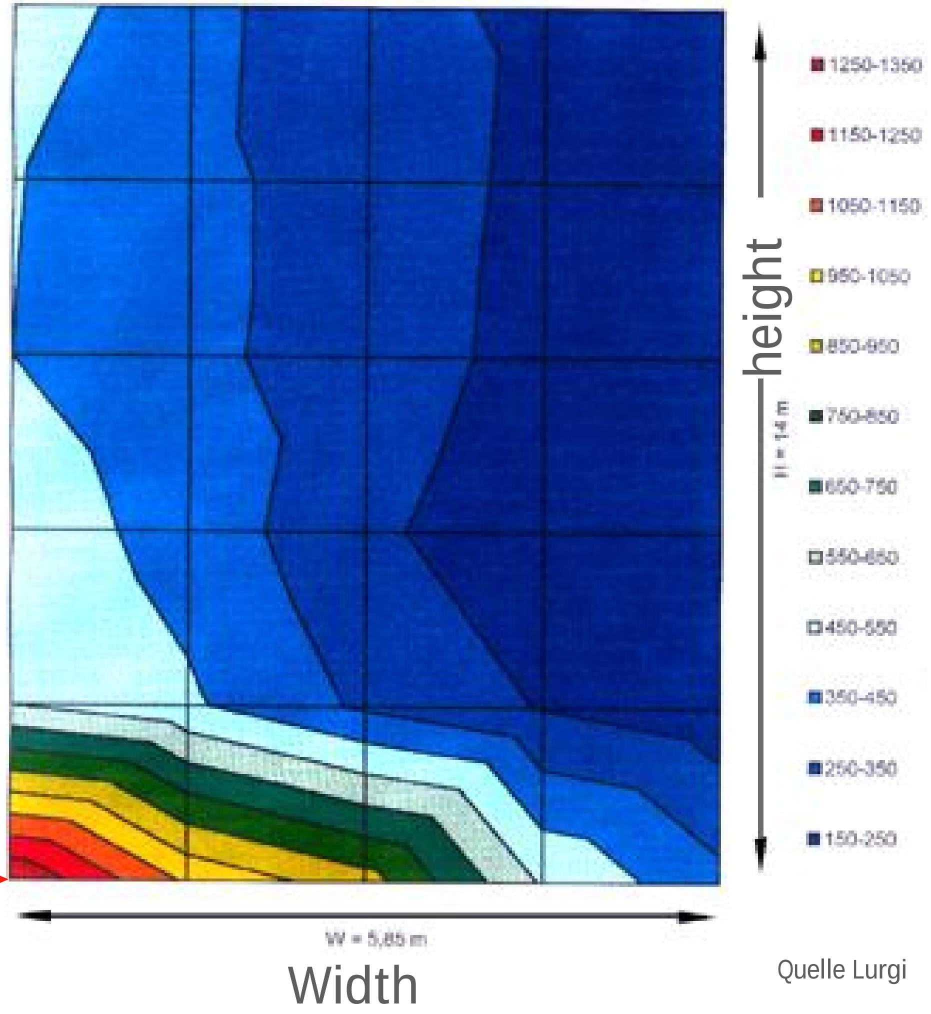
(green = shaft & hammers)

Rapping acceleration on collecting electrodes…

Minimum requirements:

Rapping acceleration > 100 g on the furthest point from the rap

Rap



Quelle Lurgi

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ESP –Optimization Possibilities…

1. Mechanical maintenance of the precipitator

2. Optimization of firing and boiler operation

3. Flue Gas Distribution

4. Optimization of high voltage units and controllers

5. Flue Gas Conditioning

6. New Interieur / Enlargement

7. Conversion to bag filter / hybrid precipitators (dry +wet)

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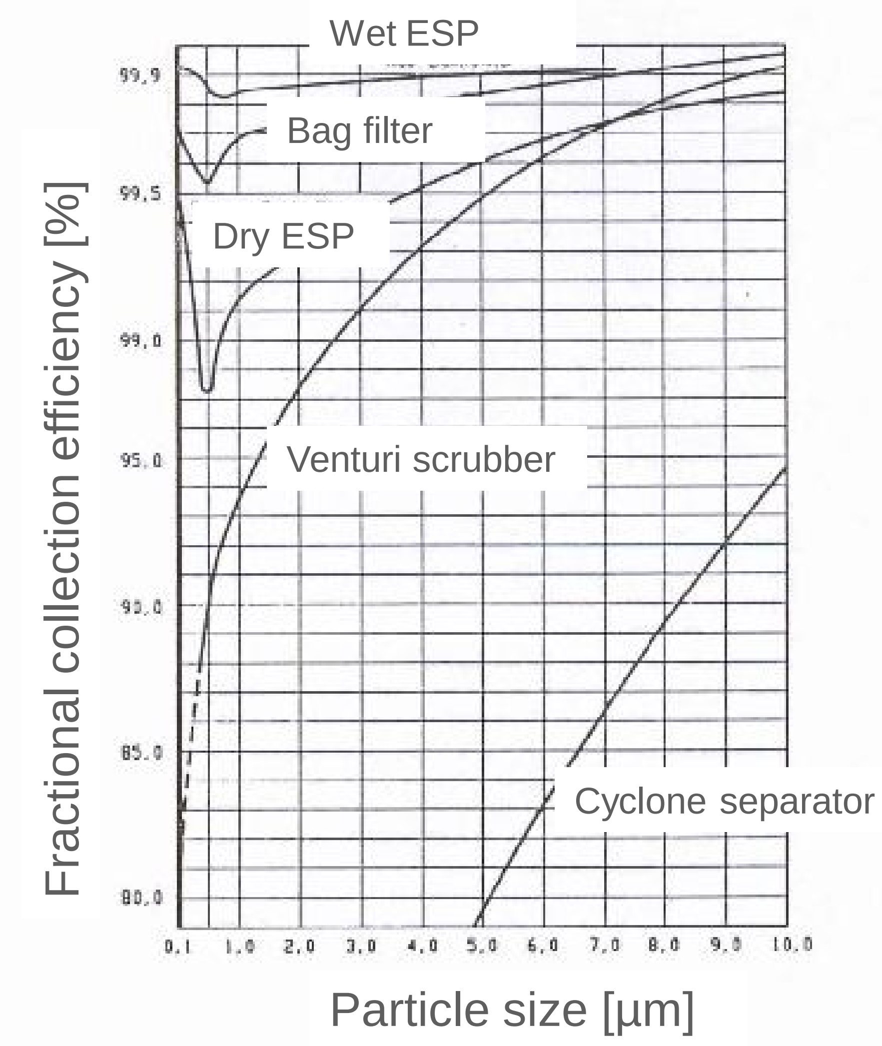
Fractional collection efficiency of different filter techniques…



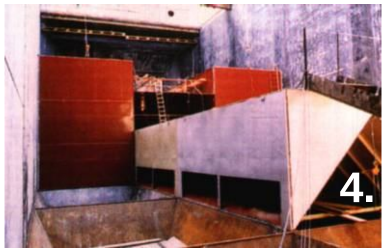
Retrofit ESP to baghouse filter

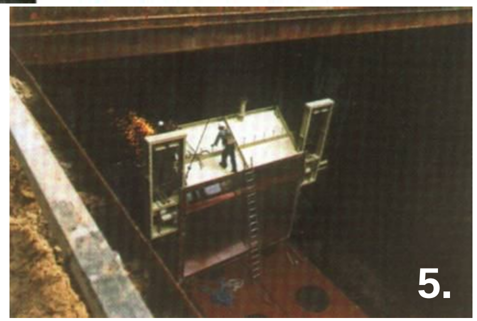
Pic 1
Assembly Area

Pic 2
Pre-mounted clean gas chamber

Pic 3
Empty baghouse filter casing

Pic 4
Assembly of the chamber walls

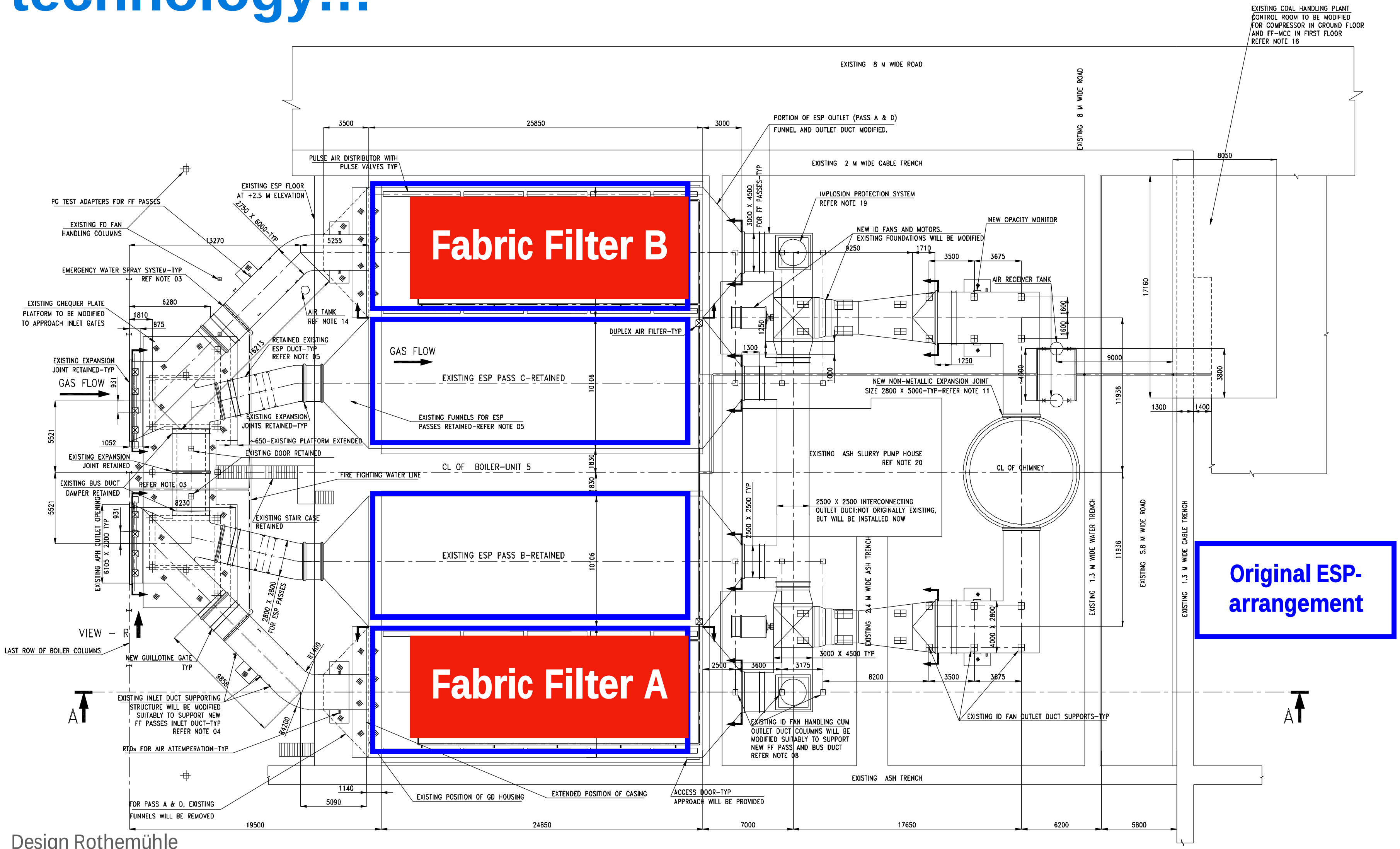




Pic 5
Installation of by-pass dampers

Bauart Fa. Walther

Baghouse filter retrofit in India shows the need of less specific space of this technology…



Design Rothemühle

Comparison Baghouse Filter- ESP (1)

Parameter	**Bag Filter (Pulse-Jet)**	**ESP (horizontal type)**
Volume Flow	No restriction	No restriction
Flue Gas Temperature	Critically for fabric, blockage can occur when dew point is undercut	< 450 °C Critically when dew point is undercut due to corrosion
Particle Concentration	No restriction but precautionary measures can be necessary if dust is	No restriction keine Begrenzung; Pre-separator and gas distribution should be combined well
Dust resistance	No influence	Most critical parameter for design

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Comparison Bag Filter- ESP (2)

Parameter	Bag Filter (Pulse-Jet)	ESP (Horizontal Type)
Particle size distribution	Sensitive to very fine particles due to possible penetration of the fabric and blockage	Sensitive to increasing dust resistivity, high cohesion, suppresion of discharge current
H_2O-dew point	Critical to some fabrics (not PPS), blockage	Positive influence at high dew point temperature dew point (electric field force, conditioning)
Acid dew point	Critical for some fabrics , blockage possible	Positive influence at high dew point temperature dew point (electric field force, conditioning) critical due to corrosion (SO_3 injection!!)

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Comparison Bag Filter- ESP(3)

Parameter	Bag Filter (Pulse-Jet)	ESP (horizontal)
Specific Precipitation Surface	60 - 72 $m^2/(m^3/s)$; depends on particle mass flow, particle size, pressure loss	60 - 150 $m^2/(m^3/s)$ @ 400 mm passage width; depends on required precipitation efficiency, dust resistivity,..
Specific Active Volume	ca. 6 m^2/m^3 @tube diameter 150 mm	ca. 5 m^2/m^3 @ 400mm passage width

Comparison Bag Filter- ESP (4)

Parameter	**Bag filter (Pulse-Jet)**	**ESP (Horizontal Type)**
Necessary building area	ca. 43 m^2/m^2 (7 m tubes) ca. 65 m^2/m^2 (8 m tubes)	ca. 80 m^2/m^2 (16 m active collecting electrode height)
Emission	<< 20 mg/m^3	Typically 20 - 50 mg/m^3
Total Pressure Loss	<= 15 - 20 mbar	<= 3 mbar
Specific Power Consumption	1.5 – 3.0 kW(m^3/s) (incl ID fan)	0,2 - 1,5 kW/(m^3/s) depends on dust resistivity
Lifetime	5 years tubes 15 years supporting cages	15 - 20 years and (much) more

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Retrofit of ESP under retention of existing parts…

Pic1

Existing parts removed

Pic 2

Expansion side wall

Pic 3

Expansion side wall /
support roof steel beam

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„As good as new“: ESP retrofit with higher electrodes…

Pic 1

Installation of new collecting electrode plates

Pic 2

Expansion of side- and dividing walls and new steel beams for the roof

Pic 3

Expansion inner steel work

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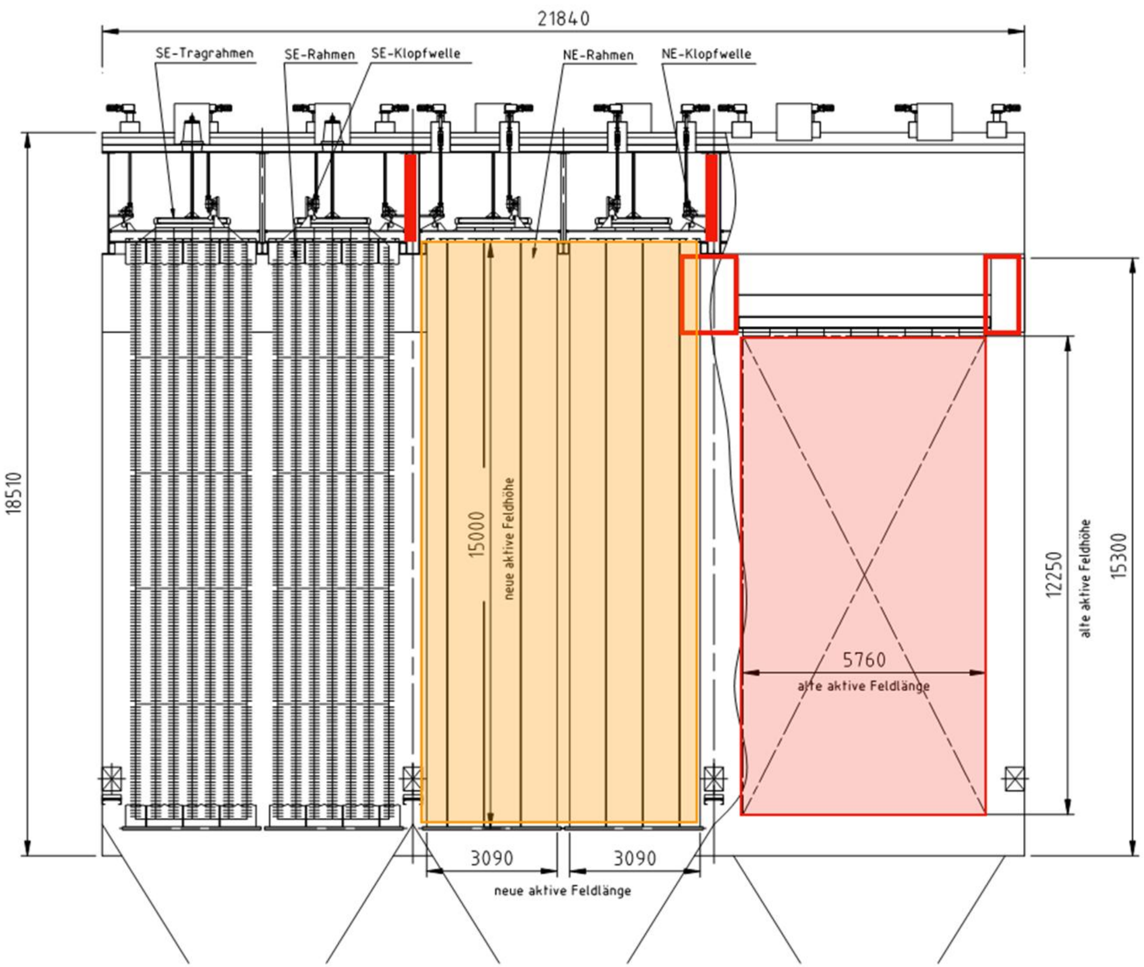
ESP enlargement with new electrodes and housing..

- New interior with
  400 / 500 mm passage width
- Rigid discharge electrodes
- Discharge electrode (NE)- Top rapping
- Collecting-electrode (NE) - Top Rapping
- Max. discharge electrode (15 – 16 m)
- Longer fields; possible due to new "roof" concept + top rapping
- further use of the old casing by extension of the existing side walls
- Doubled number of precipitator fields
- New High Voltage systems/controls



Construction Fa. Walther/Rothemühle

Dr. Dirk Porbatzki, Uniper Technologies GmbH

Dr. Dirk Porbatzki

Chemical & Environmental Services

Telefon: +49 209 601 6574
Telefax: +49 209 601 6403
Mobil: +49 151 16216733
dirk.porbatzki@uniper.energy