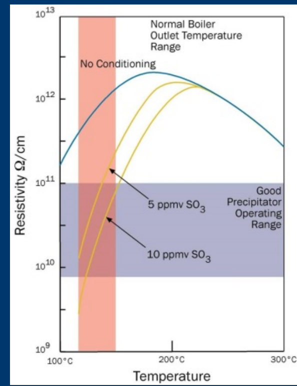
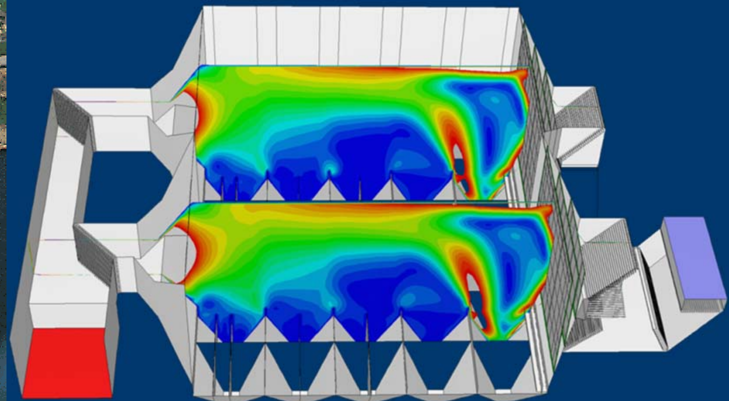




ESP and Fabric Filter Technology for Dedusting - Comparison and Optimization -

Matthias Schneider / STEAG Energy Services GmbH
Kolkata, Raipur, Hyderabad - November 2016

Criteria and background for selection of dedusting equipment for power stations

steag

What could be the background for improvements?

- New coal qualities
- More stringent environmental standards
- Changed economic criteria

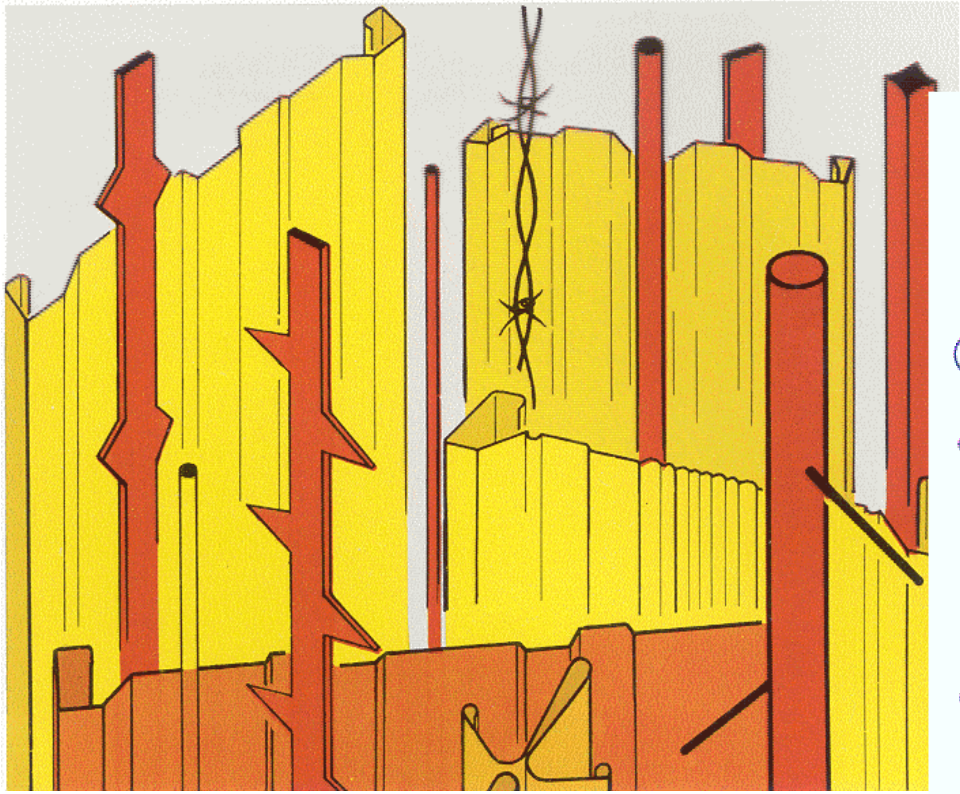
What has to be observed?

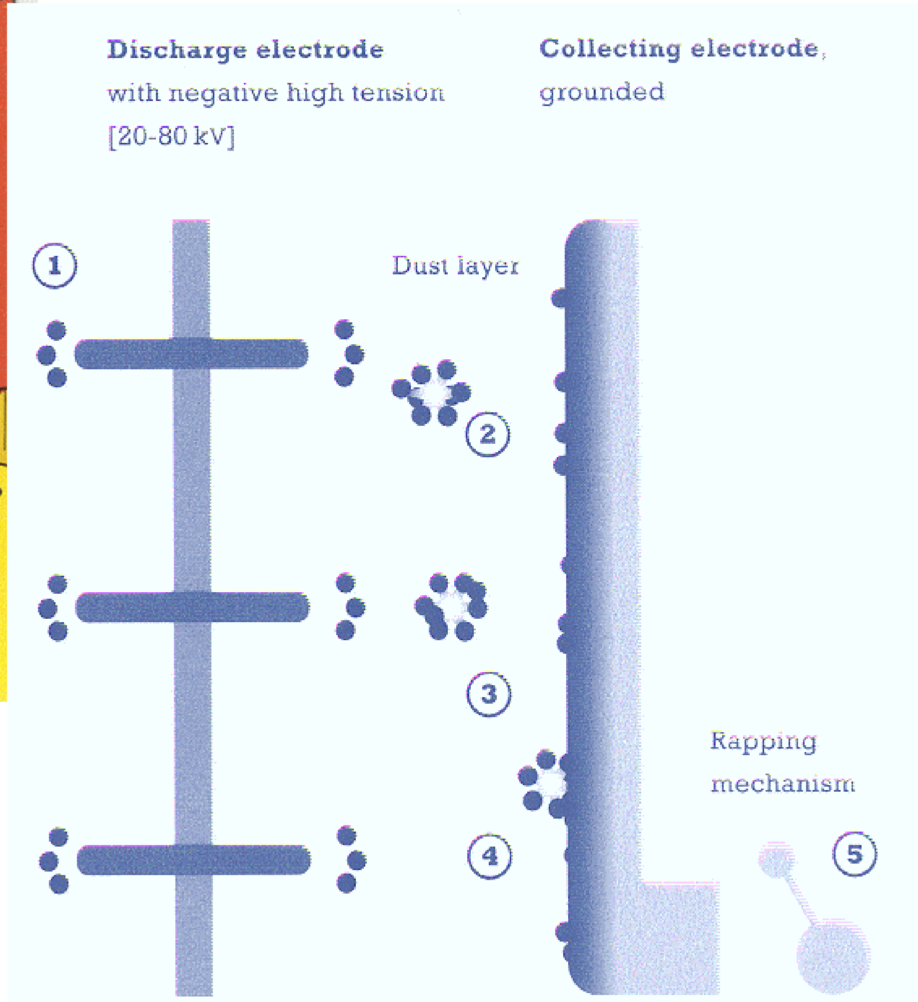
⇒ Investment

⇒ Operating costs

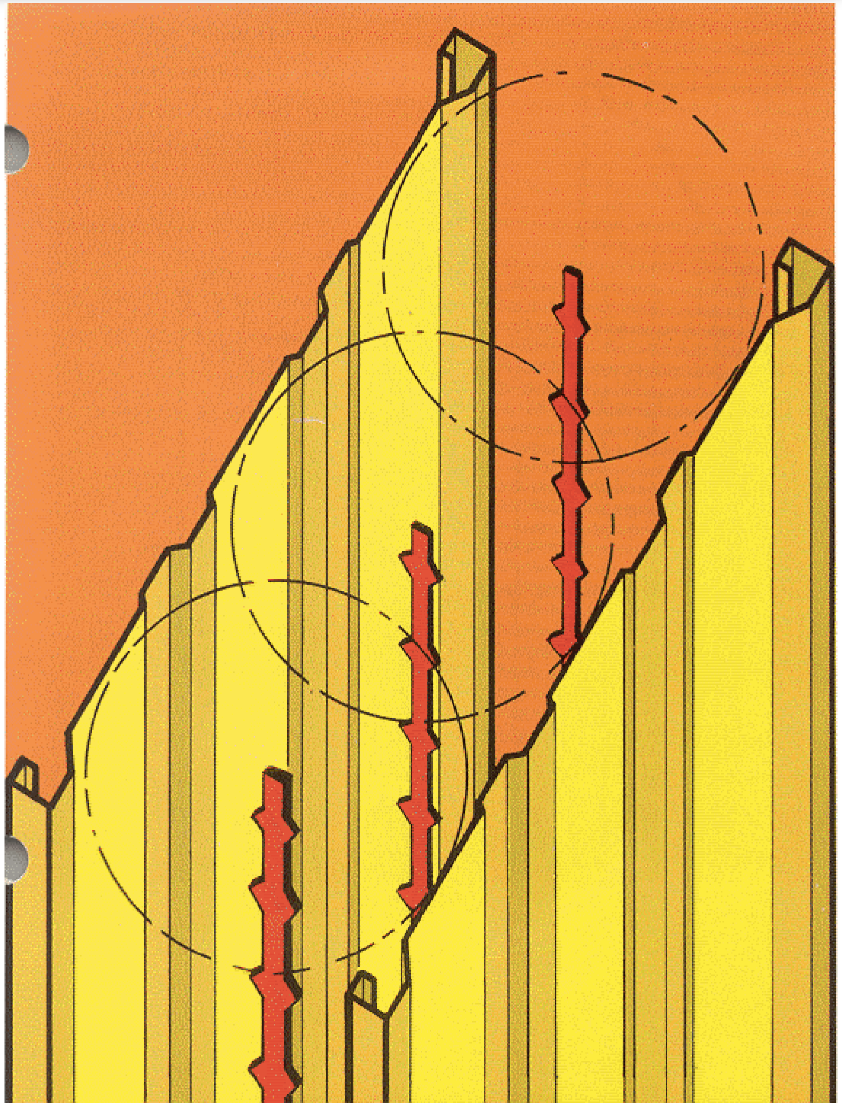
⇒ Maintainability

The Principle of Electrostatic Precipitation

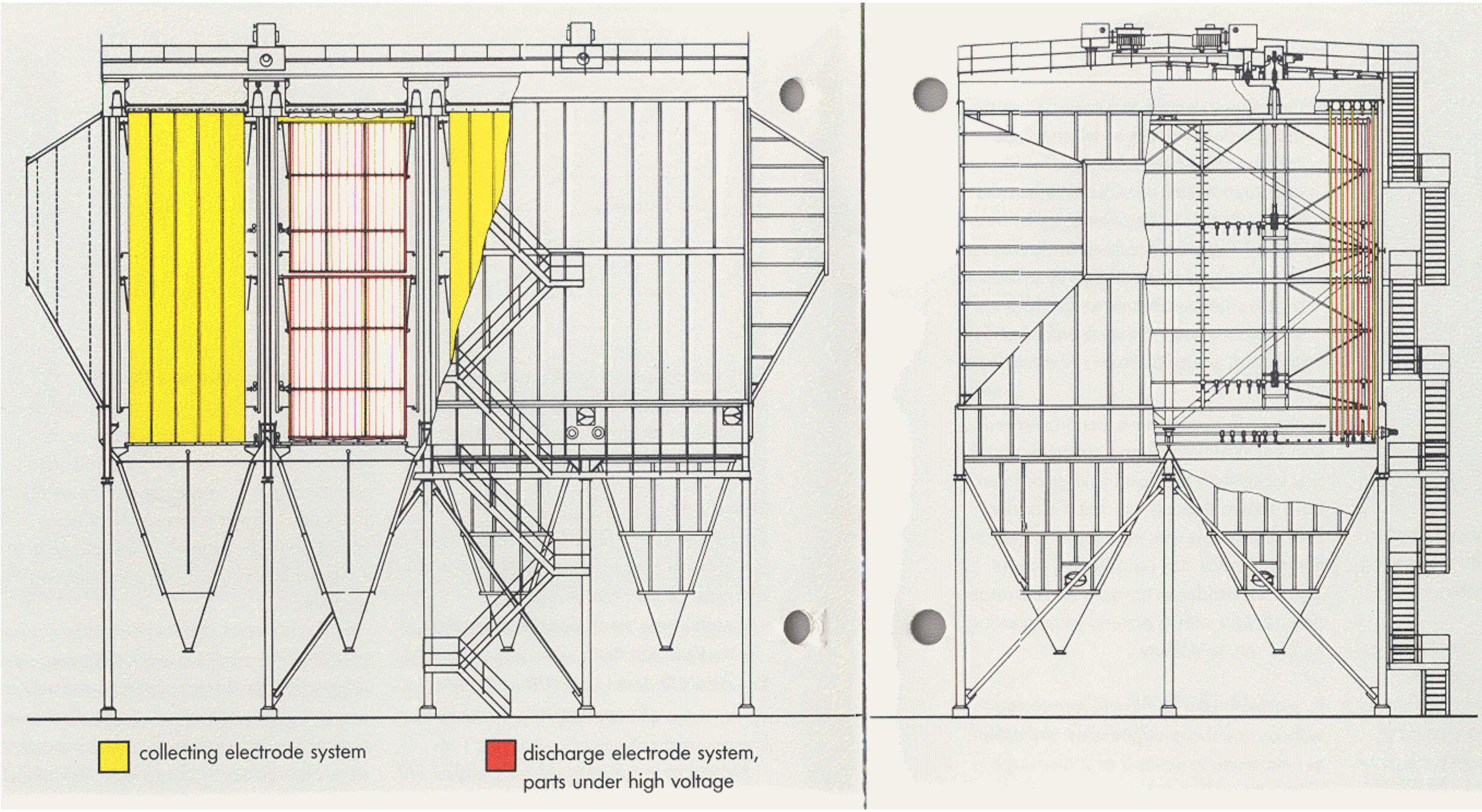




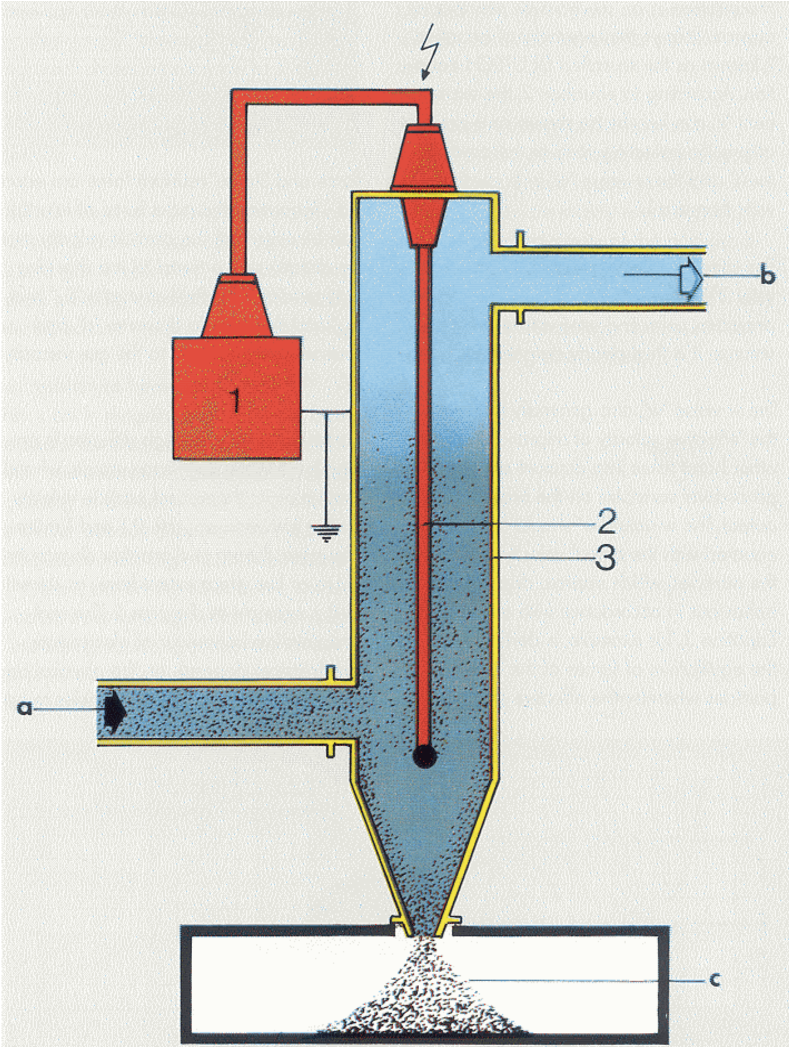
Saw-Edge-Shaped-Discharge-Electrode between Collecting Electrode



Example for Electrostatic Precipitator



Functional principle electrostatic precipitation



1 High Voltage Generator

2 Discharge Electrode

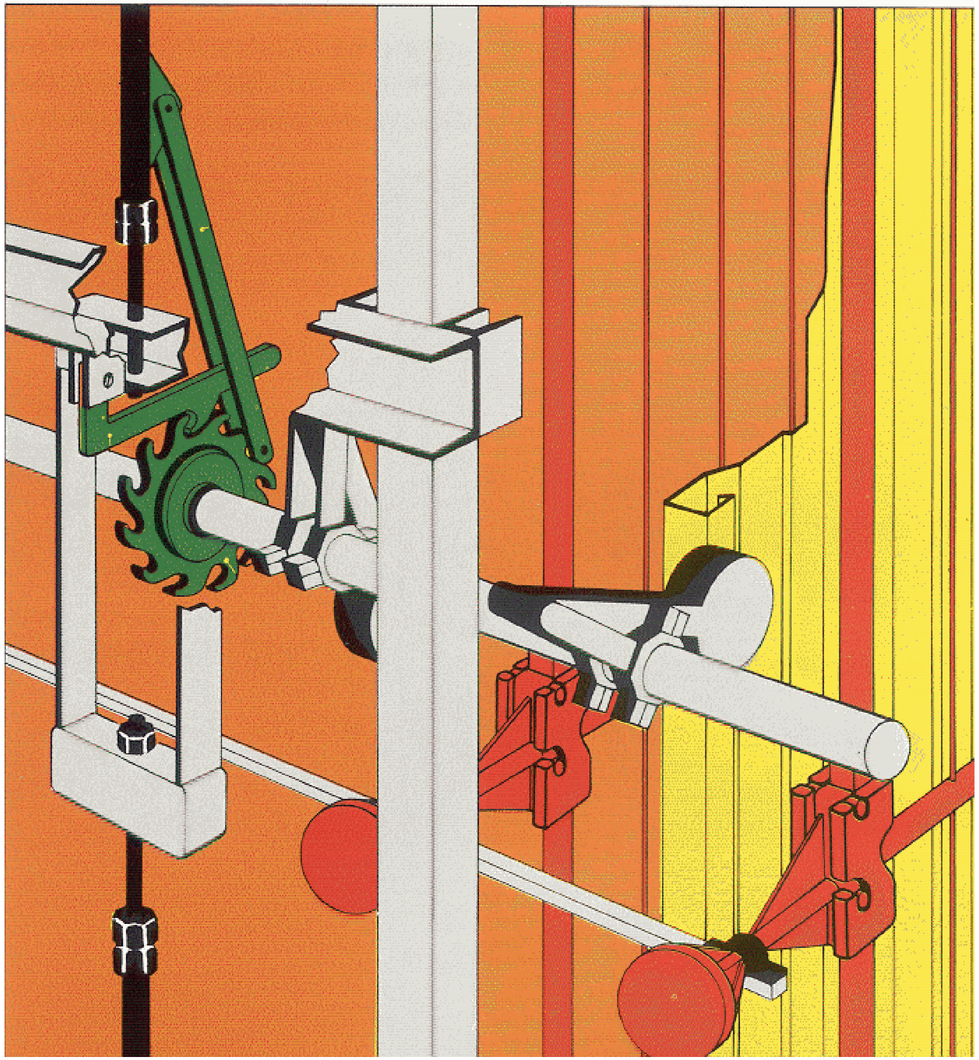
3 Collecting Electrode

a Raw Gas

b Clean Gas

c Precipitated Particulates

Discharge Electrode Rapping



DEUTSCH-Equation
Influence of different parameters on w-value

steag

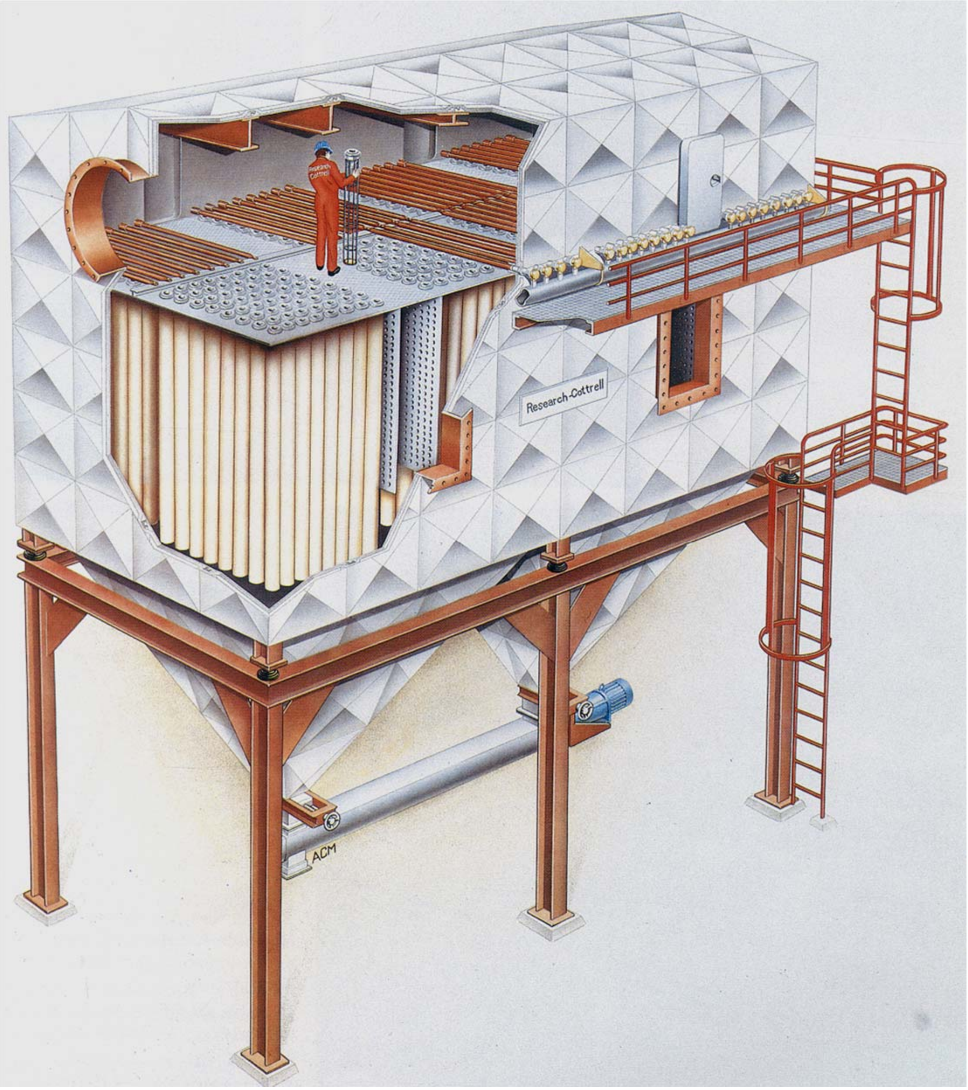
$$\varepsilon = \left(1 - e^{-\frac{wxf}{100}}\right) x100[\%]$$

$$f = F / V \left[m^2 / \frac{m^3}{s} \right]$$

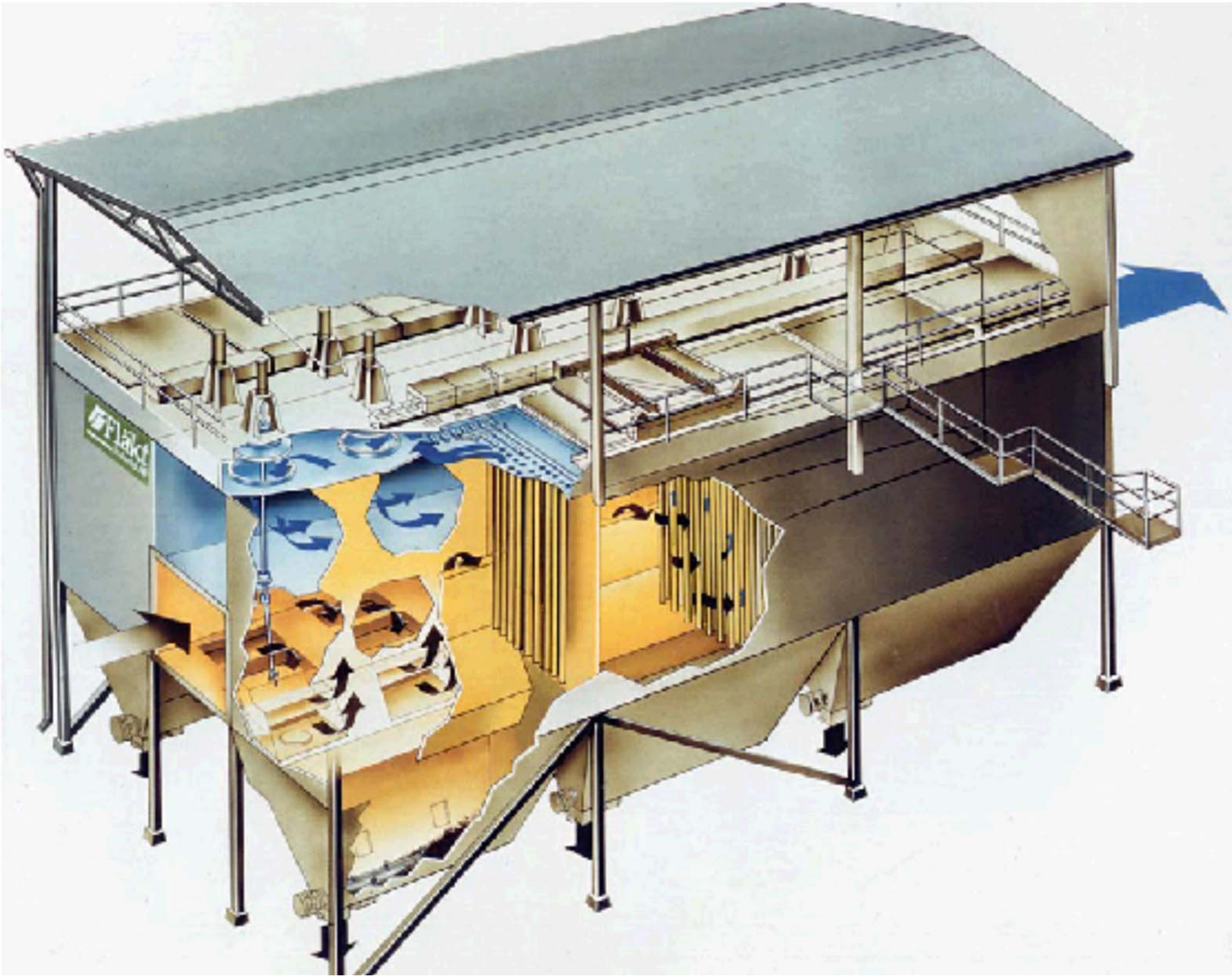
$$w[cm/s]$$

➢ Fuel	S	+
	Volatiles	+
	water	+
➢ Combustion temperature		
	high	-
➢ ash	Na_2O	+
	Fe_2O_3	+
	K_2O	+
	V_2O	+
	SiO_2	-
	CaO	-
	Al_2O_3	-
	MgO	-
➢ unburnt carbon	1-10%	+
➢ number of zones	high	+
➢ separation efficiency	high	-
➢ electrode height	high	-
➢ plate spacing	high	+

Fabric Filter in Comparison

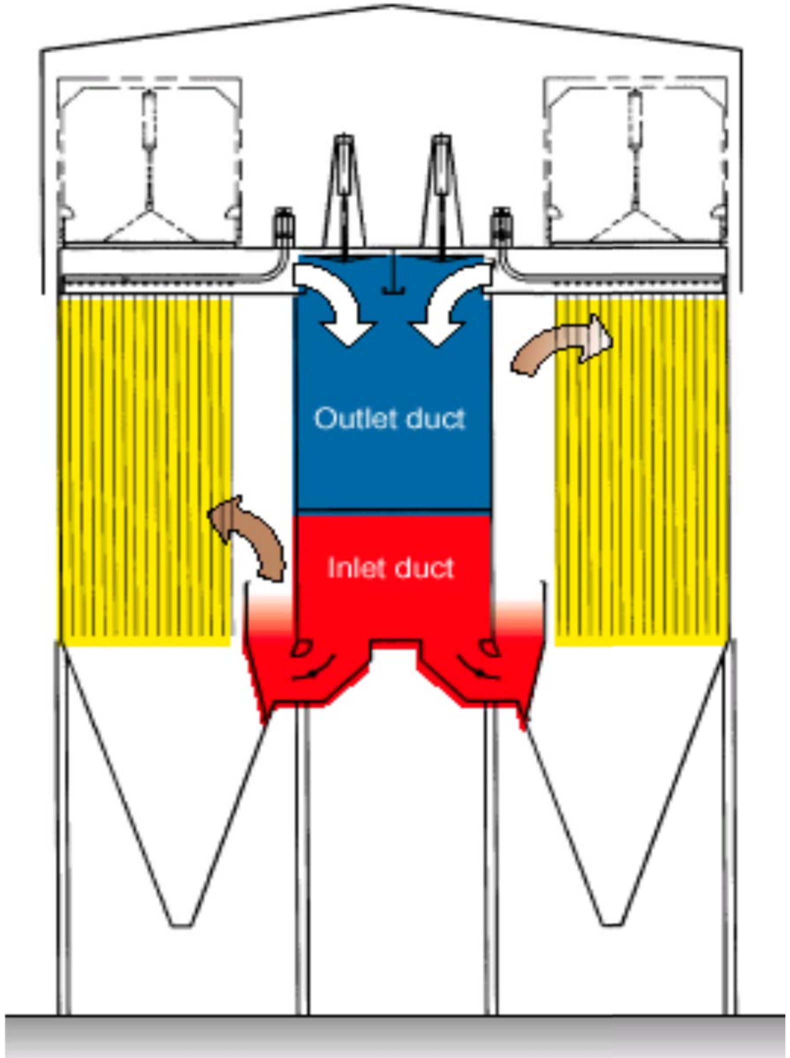


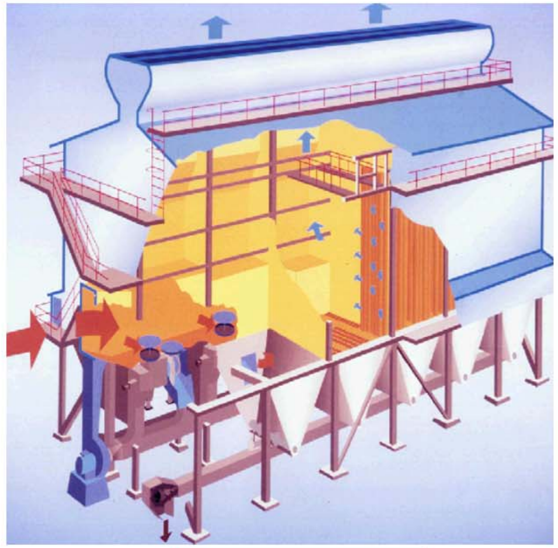
Fabric Filter House

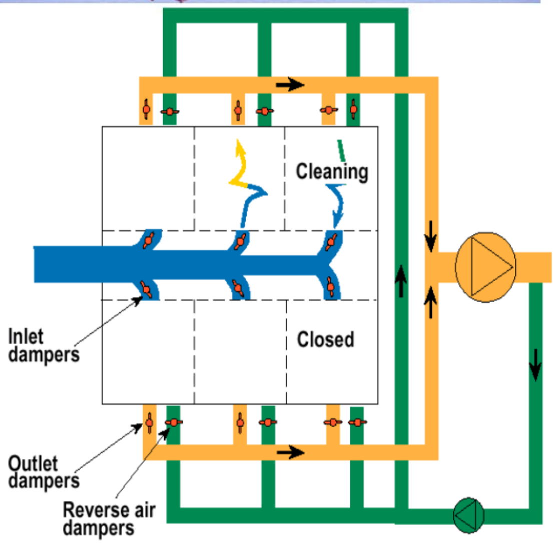


Source: Alstom

Details of Fabric Filter

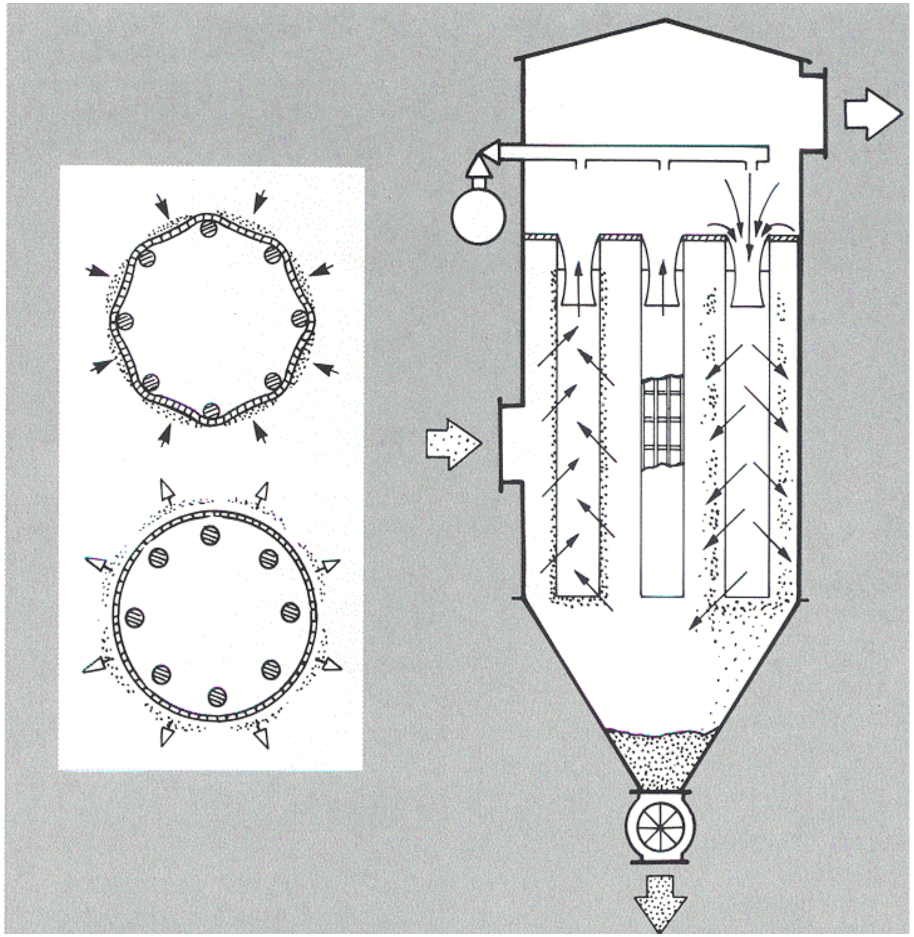


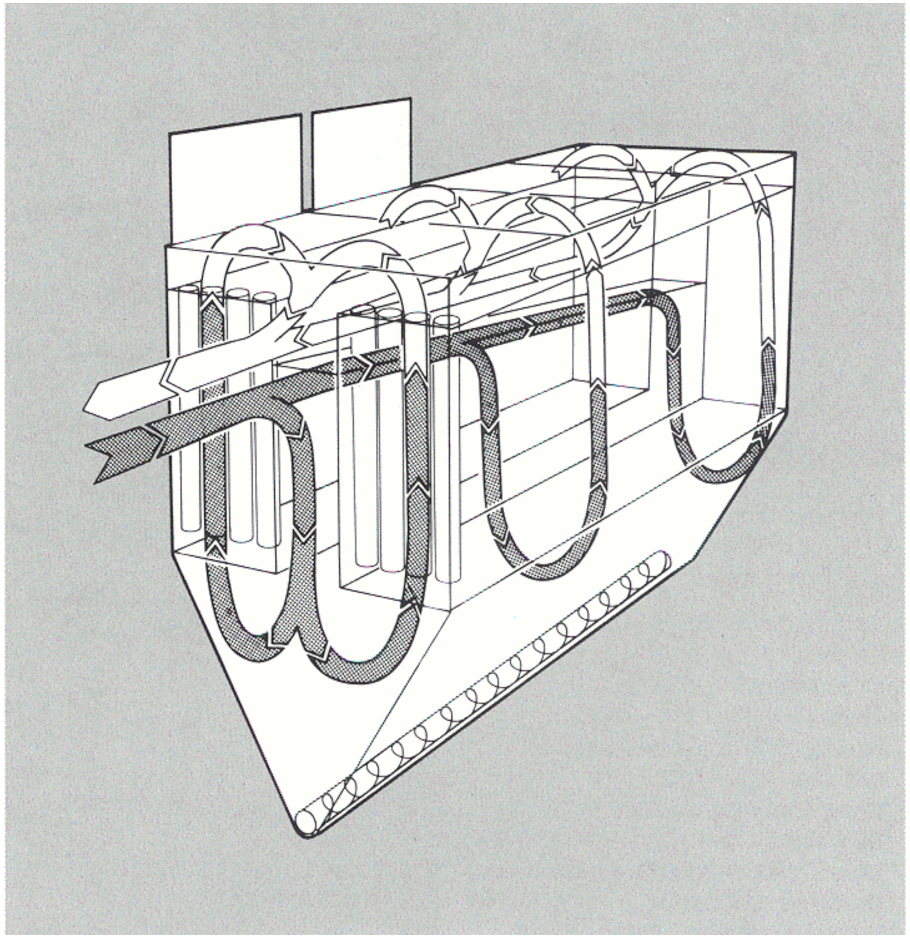




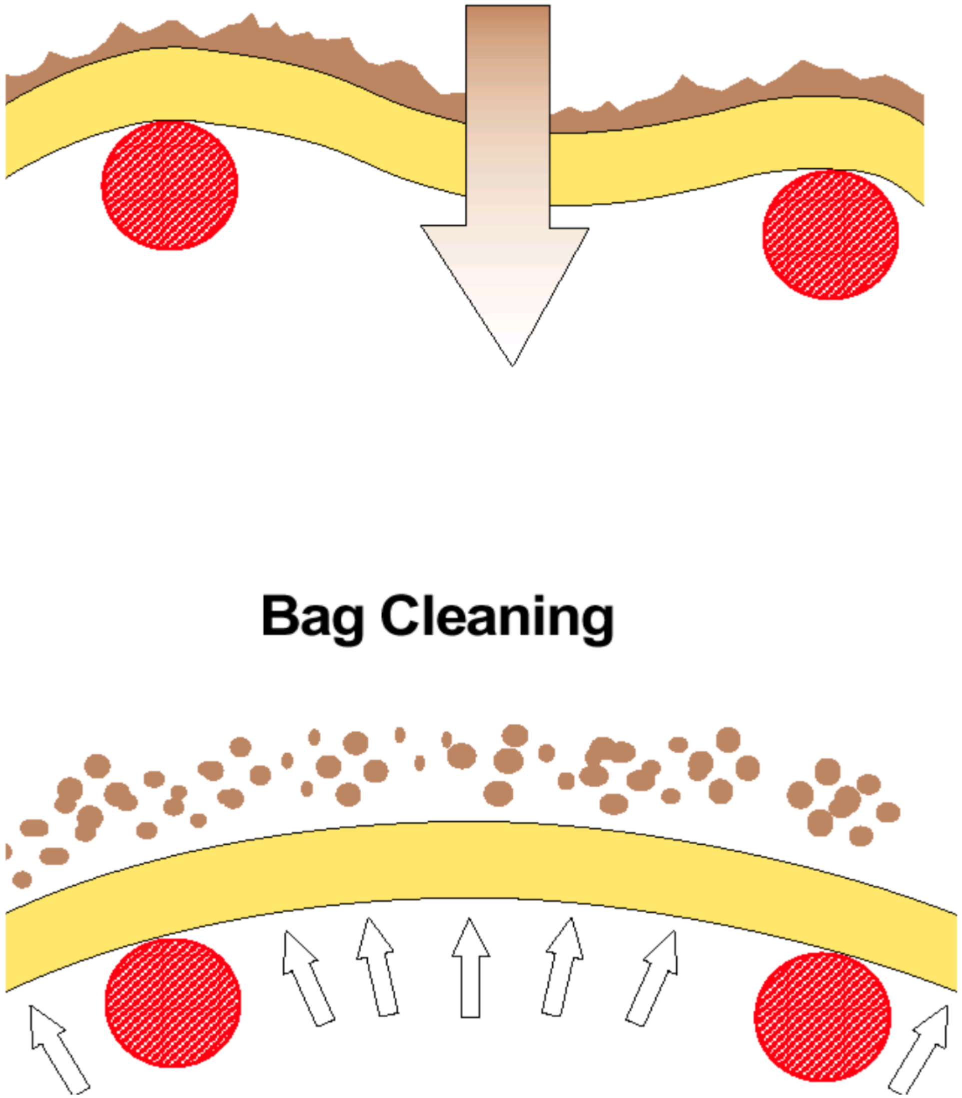
Source: Alstom

Principle Function of a Fabric Filter





Bag cleaning



Filter Media

Fibre	PP	PES	PAC	PPS	APA	PI	PTFE	GLS
Polymer Common trade name	Poly-propy-lene	Poly-ester	Dolanit Ricem	Ryton Procon Toray	Nomex	P84	Teflon	Fibre-glass
Temperature °C								
continuous	90	135	125	180	200	240	230	240
peak	95	150	130	210	220	260	260	280
Resistance								
Acid	5	3	4	4	2	3	5	4
Alkali	5	2	3	4	4	3	5	3
Hydrolysis (H_2O)	5	1	4 - 5	5	2	2	5	5
Oxidation (O_2)	3	5	3	3	3 - 4	–	5	5
Abrasion	5	5	3 - 4	3 - 4	5	4	3	1
Price rel. to PES	1	1	1.3	4.5	5	6	15	2-3

Source: Alstom

1 = Bad, 2 = Mediocre, 3 = Generally good, 4 = Good, 5 = Excellent

Comparison of Fabric Filter / ESP

Parameter	Fabric Filter (Pulse Jet Type)	ESP (Horizontal Flow Type)
Gasflow	No limitation	No limitation
Flue Gas Temperature	Critical for bag material; bag clogging may occur, if close to dewpoint	< 450 °C Critical if close to dewpoint because of corrosion
Dust concentration	No limitation; precautions to be made if dust is abrasive	No limitation; precollecting and gas distribution devices easy to combine
Dust resistivity	No influence	Most critical parameter for ESP-sizing

Quelle: Rothemühle

Comparison of Fabric Filter / ESP

steag

Parameter	Fabric Filter (Pulse Jet Type)	ESP (Horizontal Flow Type)
Particle Size Distribution	Sensitive for very fine particles because of possible bag penetration, then surface treatment required	Sensitive because of increasing resistivity, particle cohesion and re-entrainment, Corona suppression with submicron particles
H_2O-dewpoint	Sensitive for specific fabrics (not PPS)	Positive influence if dewpoint is high (Conditioning effect)
Acid Dewpoint	Sensitive for specific fabrics; Critical if close to dewpoint because of bag blockage	Positive influence because of conditioning effect Critical if close to dewpoint because of corrosion

Quelle: Rothemühle

Parameter	Fabric Filter (Pulse Jet Type)	ESP (Horizontal Flow Type)
Specific Collection Area (SCA)	60 - 72 $m^2/(m^3/s)$; depending mostly on inlet dust concentration and max. pressure drop	60 - 150 $m^2/(m^3/s)$ at 400 mm spacing; depending on efficiency required and coal type (ash resistivity)
Specific Active Volume	appox. 6 m^2/m^3 based on bags with 150 mm diameter	approx. 5 m^2/m^3 based on 400mm spacing

Quelle: Rothemühle

Comparison of Fabric Filter / ESP

Parameter	Fabric Filter (Pulse Jet Type)	ESP (Horizontal Flow Type)
Reqd. Base Area	approx. 43 m^2/m^2 (7 m bags) approx. 65 m^2/m^2 (8 m bags)	approx. 80 m^2/m^2 (16 m active CE height)
Clean Gas Dust	<< 20 mg/m^3	Typical <= 20 - 50 mg/m^3
Total Pressure Drop	<= 15 - 20 mbar	<= 3 mbar
Spec. Power Consumption	1,5 - 3,0 kW(m^3/s) (incl. ID-fan)	0,2 - 1,5 kW/(m^3/s) depending on specific ash properties (resistivity)
Life Time of Internals	5 years for bags 15 years for cages	15 - 20 years

Quelle: Rothemühle

Comparison of Fabric Filter / ESP

	Fabric Filter	ESP
seperation efficiency	higher	high
dependency on coal quality (see also seperation efficiency of ESP)	low	high
dangers	risc of fire at high fluegas temp. and high unburnt carbon content	electricity
maintanance	online	offline
additional rections	yes in dust layer	no
wet flu gases	fouling	corrosion

Example for economic comparison of Fabric Filter / ESP

steag

1. **Capital Cost**

   no big difference

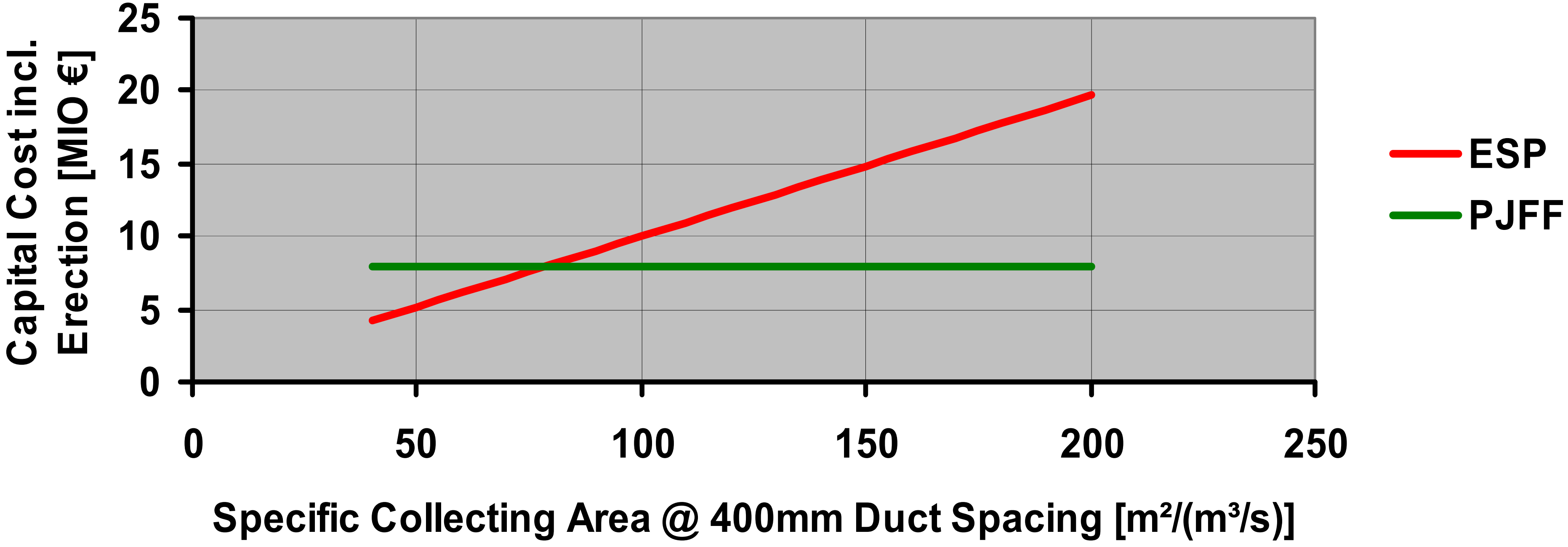
Example 350 MW unit
4000 operation hours a year
volume 40x40x20 m

2. **Operating Costs**

		ESP	Fabric Filter
pressure loss	mbar	2,2	16
equivalent electricity consumption	kW	130	960
electricity consumption	kW	650	80
total consumption	kW	780	1040
difference in consumption	kW	-	260
maintenance	%/a	1	6 +)
difference maintenance	%/a	-	5

+) change of filterbags every 3-4 years
capital cost of bags 15-20 % of total investment

Capital Cost of Pulse Jet Fabric Filters vs. ESP



Quelle: Rothemühle

Comparison of Fabric Filter / ESP
Electrostatic Precipitator

Pro

1 Low pressure drop
(< 2,5 mbar)

2 Low maintenance effort

3 High lifetime expectancy (>15-20 years) without any major overhaul

4 Insensitive against boiler tube leakage

5 Low total energy consumption and operation cost

6 Low maintenance time required

7 High reliability

Contra

1 Dependence of collection efficiency and ESP-size on changing fly ash properties

2 Relatively big installation volume

3 Relatively high investment cost

4 Low $DeSO_x$-effect behind FSI- or Spray Dryer installations

Comparison of Fabric Filter / ESP
Fabric Filters

Pro

1 Clean gas dust content independent from boiler load and ash type (less than 30 mg/Nm³)

2 Clean gas dust content less than 10 mg/m³ without problems

3 Safe and simple sizing procedure

4 $DeSO_x$-effect in ash layer on filter bag behind FSI- or Spray Dryer installations

5 Relatively low investment cost

Contra

1 High pressure drop (15 - 20 mbar)

2 Limited lifetime of filter bags dependent on bag material

3 Low emergency operation temperature

4 Sensitive to flue gas temperature lower than dew point

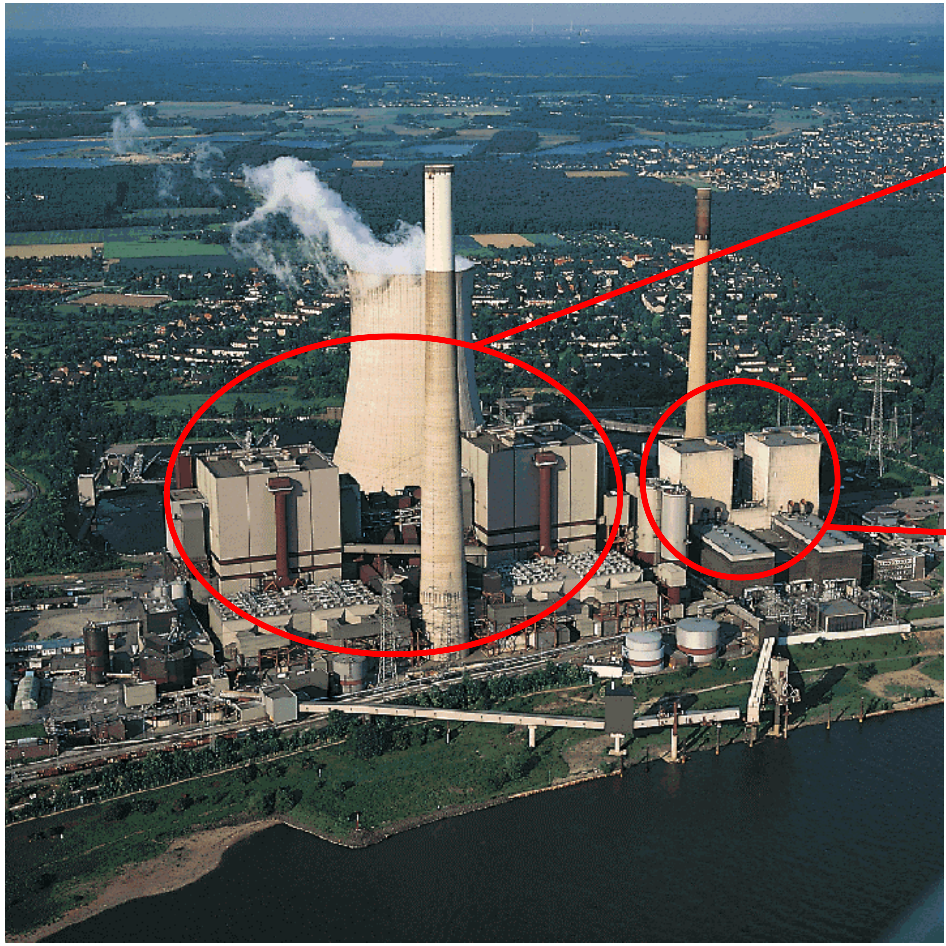
5 Sensitive to boiler tube leakage

6 Maintenance time needed for changing of filter bags
(approx. 1.000 hrs per FF every 5 years)

7 Pre-coating needed for commissioning

CFD Modelling for ESP Optimisation
Power Plant Voerde

steag



Unit Voerde A/B

Net capacity: **2 x 760 MW**

Fuel: **Hard coal**

Unit West I/II

Net capacity: **2 x 350 MW**

Fuel: **Hard coal**

Reasons for Retrofit Project – Project aims

- Improvement of environmental norms
  - FGD retrofit: SO_2 clean gas concentration 400 → 200 mg/m³ (STP) dry
  - ESP optimization: fly ash concentration 50 → 20 mg/m³ (STP) dry
- Boiler load increase 2 x 710 MW_{gross} → 2 x 760 MW_{gross} (+ 2 x 50 MW_{gross})

  → (Utilization of max. possible rated thermal input)
- Increase of efficiency
- Improvement of profitability
- Reduction of maintenance costs
- Improvement of competitiveness

CFD Modelling for ESP Optimisation

steag

Initial situation
New FGD without Bypass

Boiler/Turbine: Utilization of existing reserve capacity

DeNOx: Utilization of existing reserve capacity

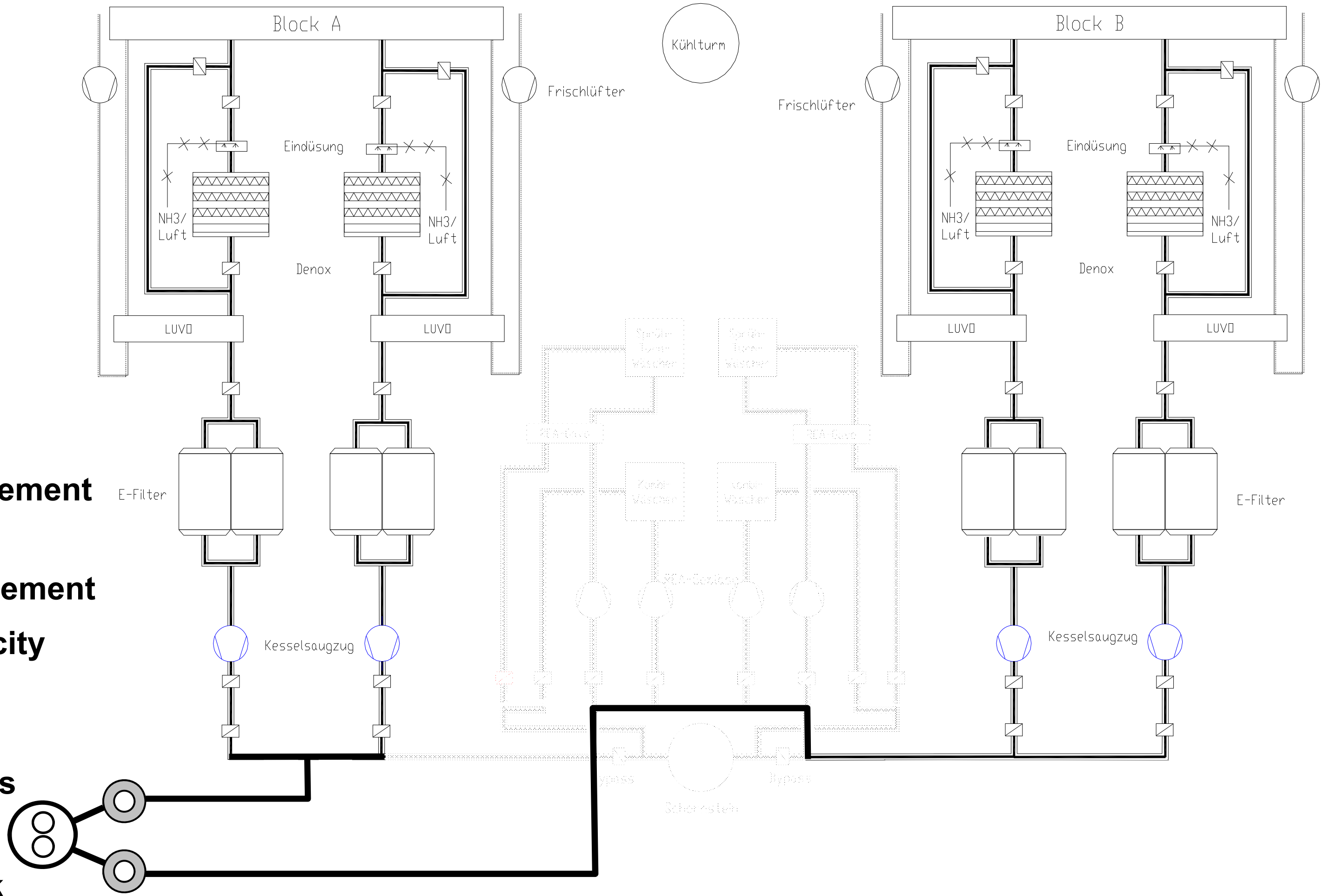
ESP: <u>Optimisation</u>, static reinforcement

Raw gas ducts: Static reinforcement

ID-Fans: Retrofit, capacity increase

FGD: New scrubbers

Stack: New wet stack

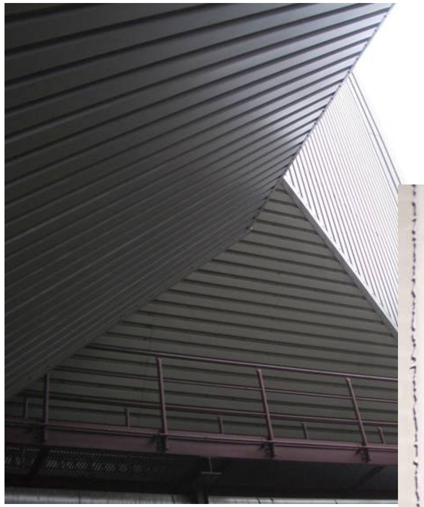


CFD Modelling for ESP Optimisation

steag

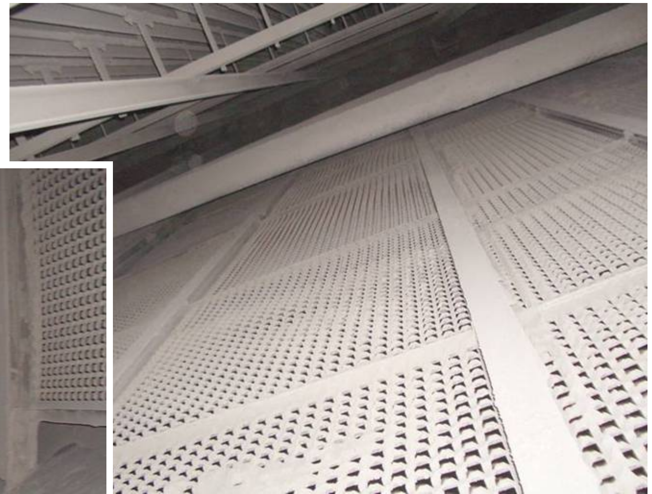
Prior to modification

ESP inlet and outlet sections

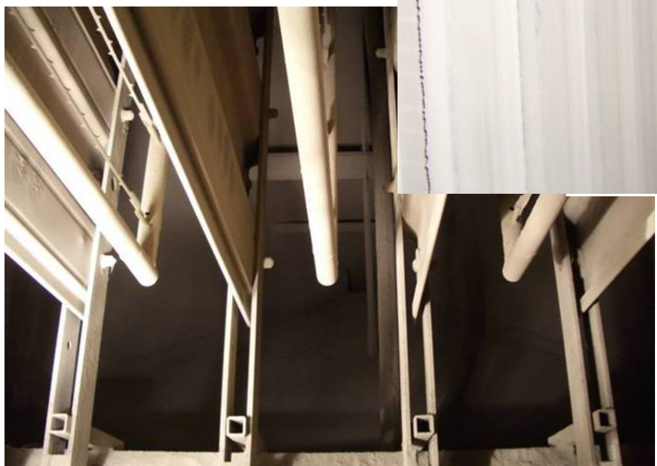


Inlet section diffuser

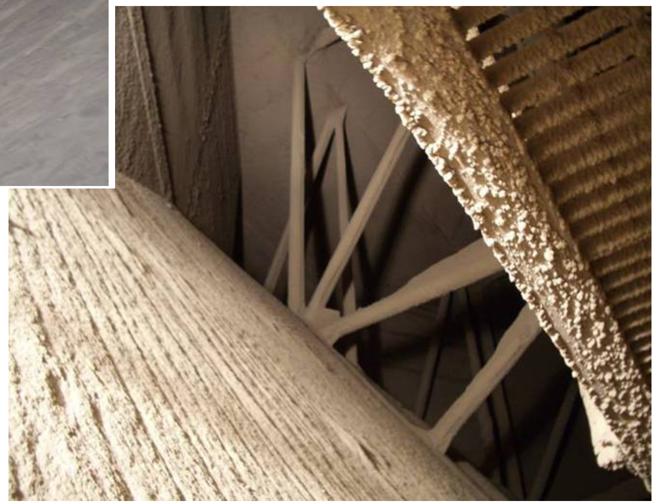
"X-Richtblech" flow-directing plates



View of the aisle upstream of the first bay of collecting electrodes



Collecting and spray electrodes with supports



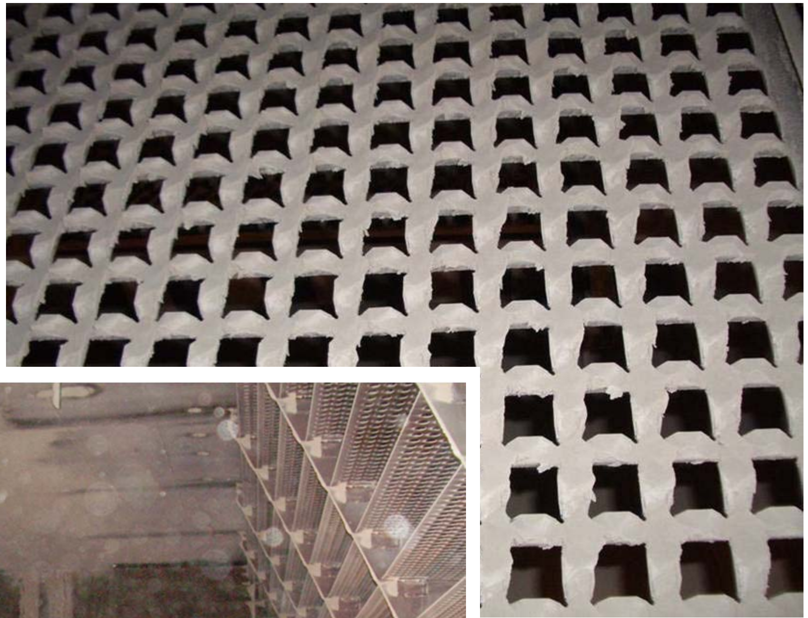
Outlet section

CFD Modelling for ESP Optimisation

Prior to modifications

Ductwork and guiding arrangements

Gas distributing wall made of "X-Richtblech" flow-directing plates

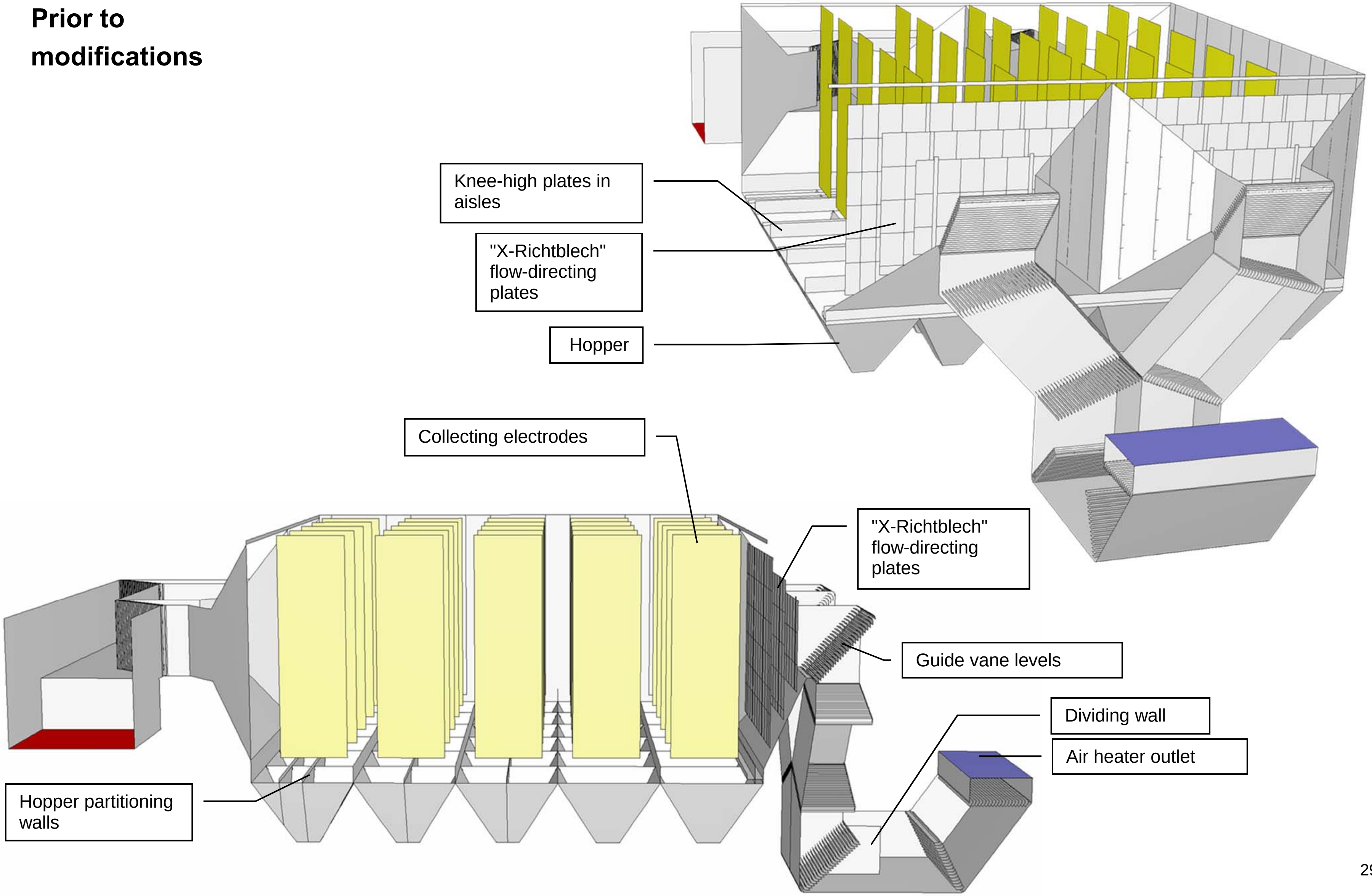


Guide vane level in duct section between air heater and ESP

Perforated guide vanes and dividing wall for distribution to two ESP trains

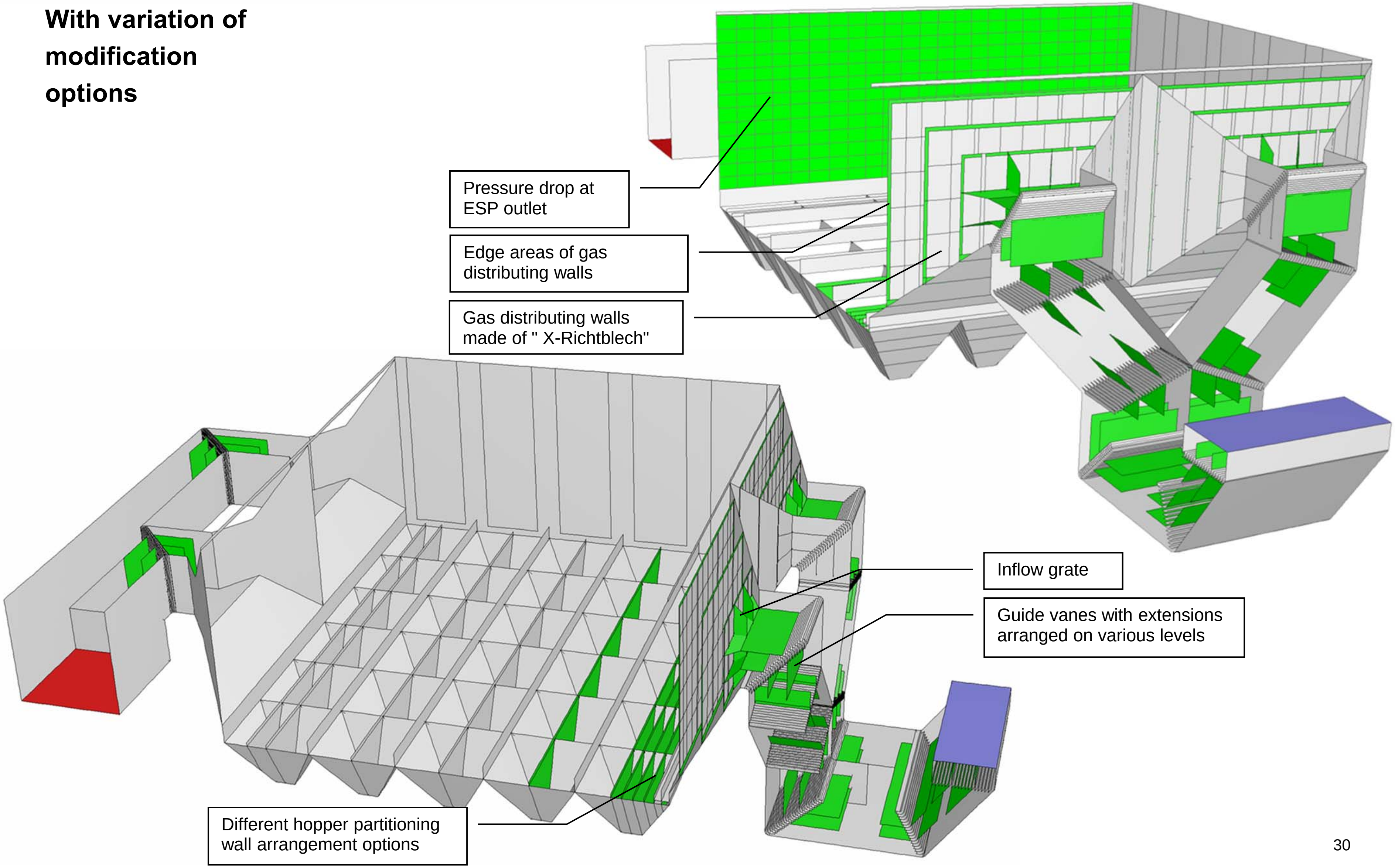
CFD Modelling for ESP Optimisation
FLUENT model of the ESP

Prior to modifications



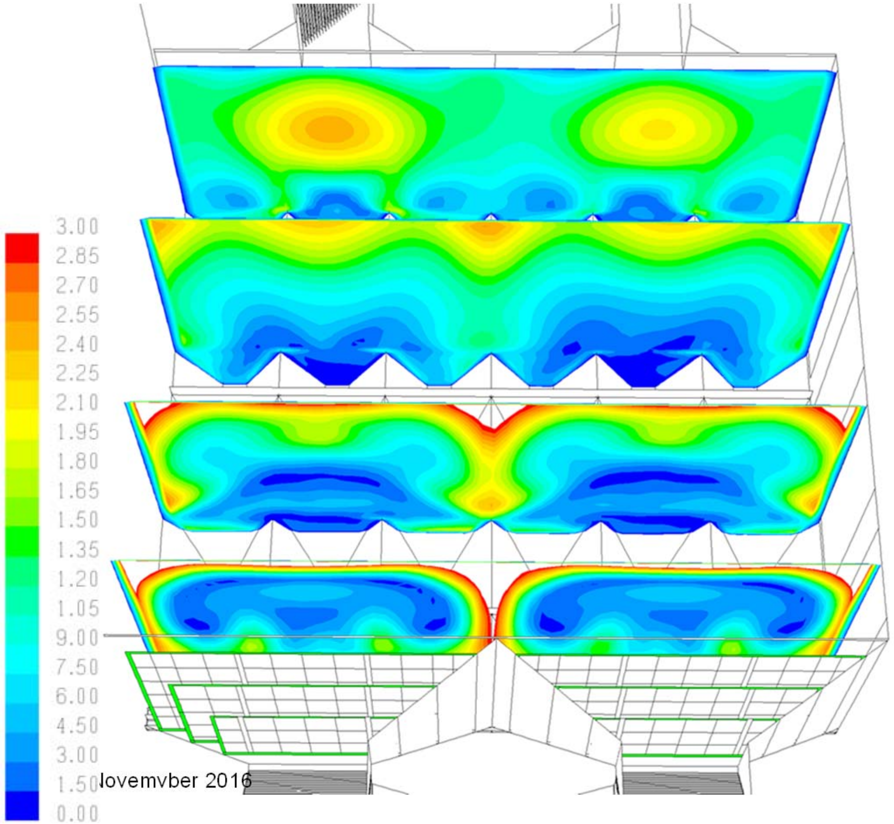
CFD Modelling for ESP Optimisation
FLUENT model of the ESP

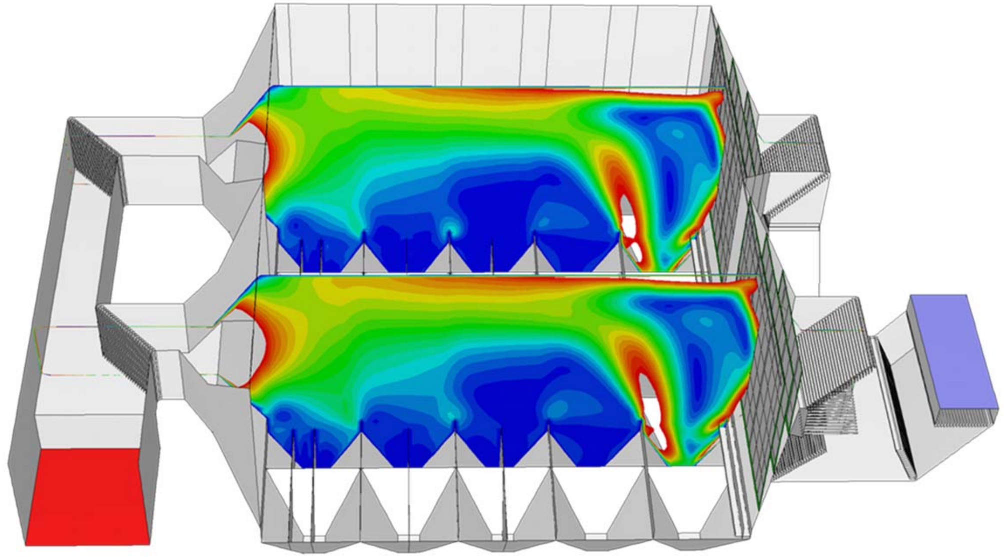
With variation of modification options

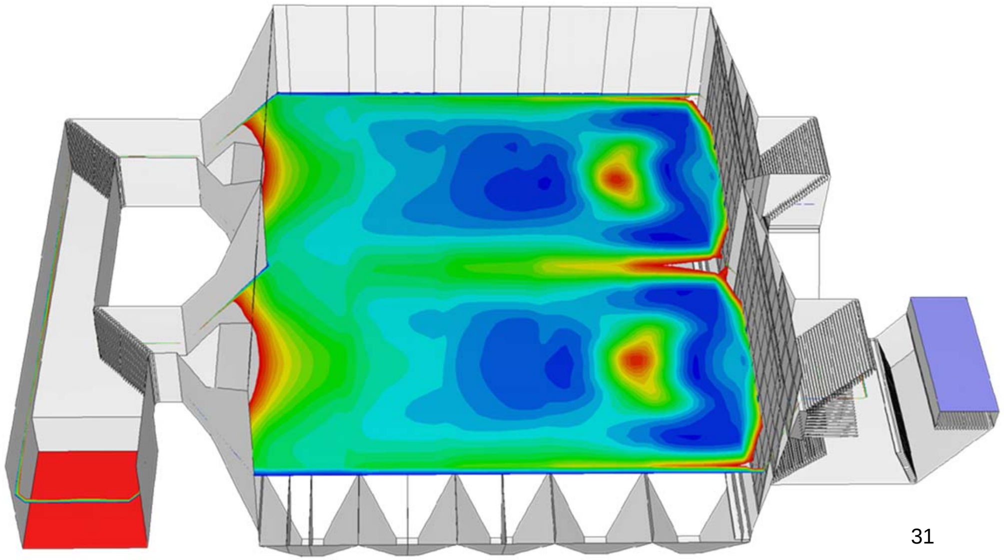


CFD Modelling for ESP Optimisation velocities before modification

Velocity pattern

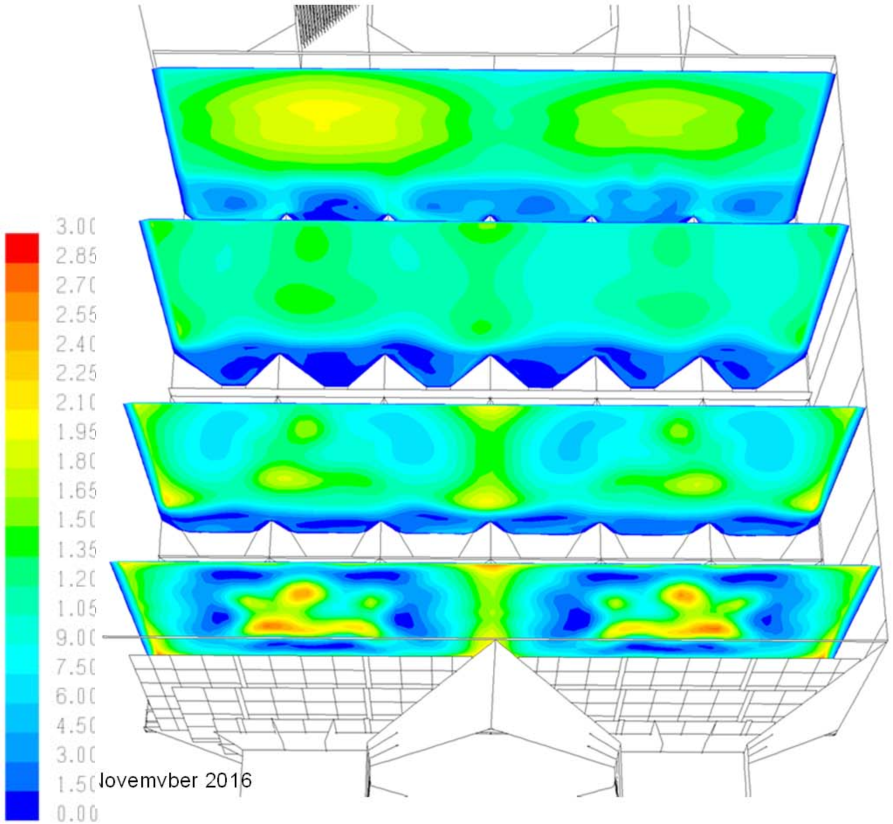


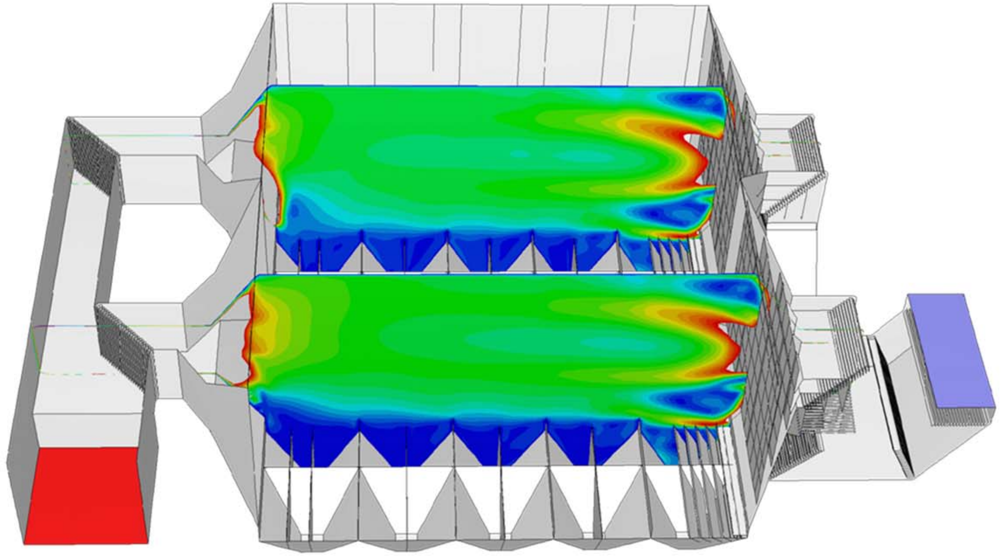


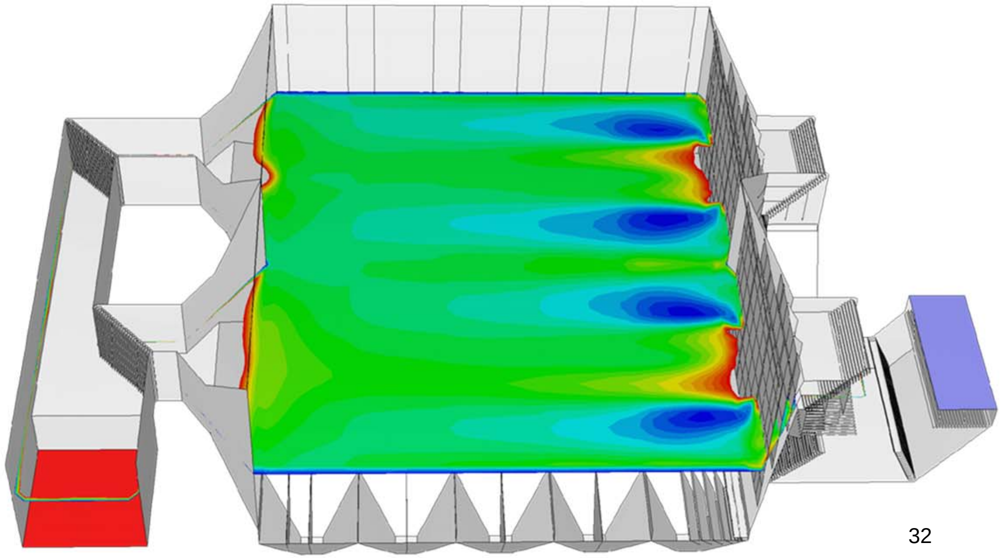


CFD Modelling for ESP Optimisation Velocities after modification

Velocity pattern

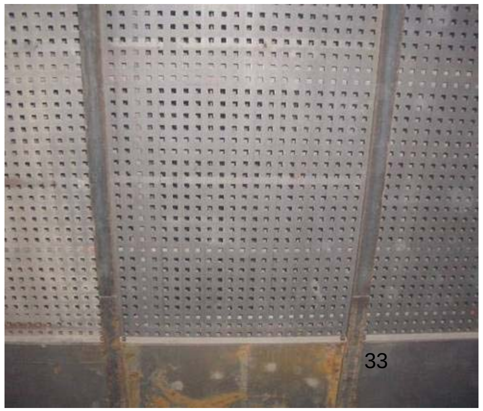






CFD Modelling for ESP Optimisation Modifications

- **Hopper interior**
  - grid of sloping plates in the first hopper row
  - standard separation wall in the second hopper row
- **Extension of guide vanes and inlet flow grate**
  - extension of two guide vanes
- **Gas distributing walls**
  - partial replacement of plates to implement the determined pressure drop coefficients
- **Outlet pressure drop**
  - Installation of an outlet wall with vertically staggered pressure drop coefficients



CFD Modelling for ESP Optimisation
Results

steag

The Emission limit value for dust of 20 mg/m³(i.N.)$_{dr}$ will be observed under all conditions.

SO_3-Conditioning Background: Resistivity - Coal & Ash Properties

steag

Charge Carriers improve **performance**

Charge Carrier: Sulfur trioxide (from SO_3 conversion)

Charge Carrier: Water Molecules

Charge Carrier: Sodium (Na_2O), Potassium (K_2O)

Iron(III) oxide (Fe_2O_3): catalytic action to convert SO_2 to SO_3

low resistivity → high particle migration velocity

Positive Properties

neutral particles reduce **performance**

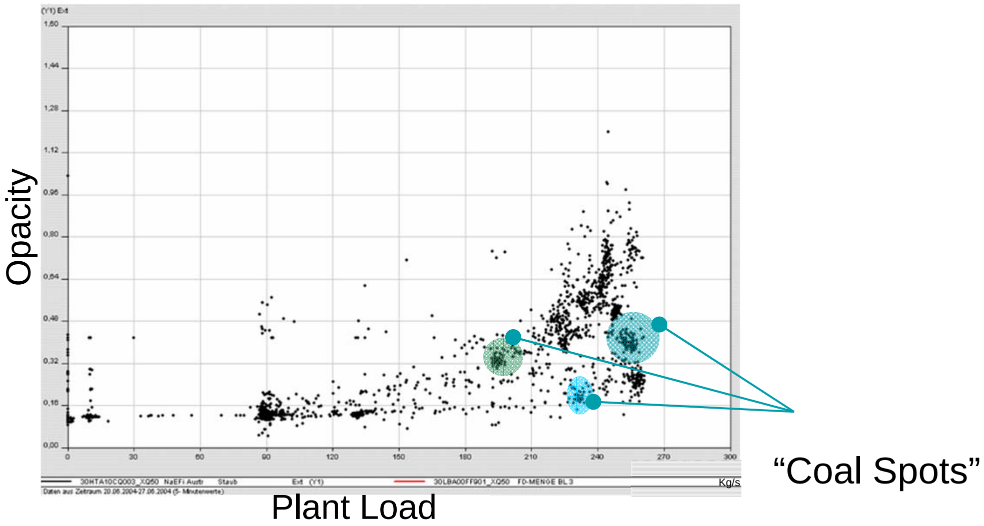
Natural Insulators: Silica (SiO_2), Alumina (Al_2O_3)

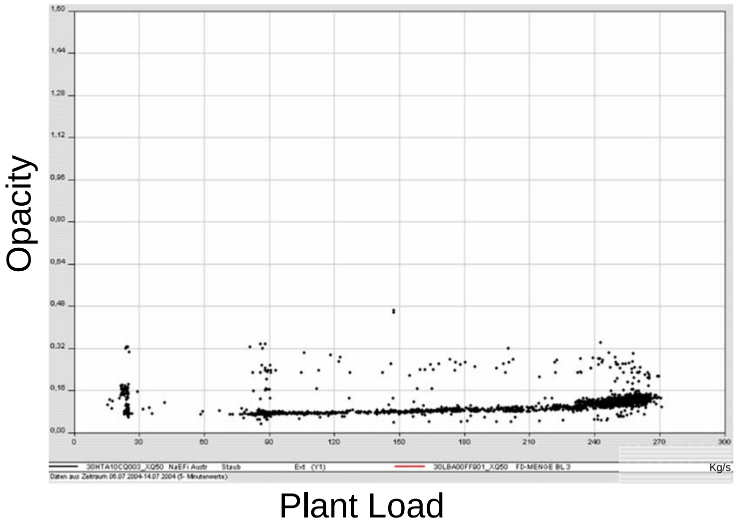
Tend to neutralize SO_3: Lime (CaO), Magnesia (MgO)

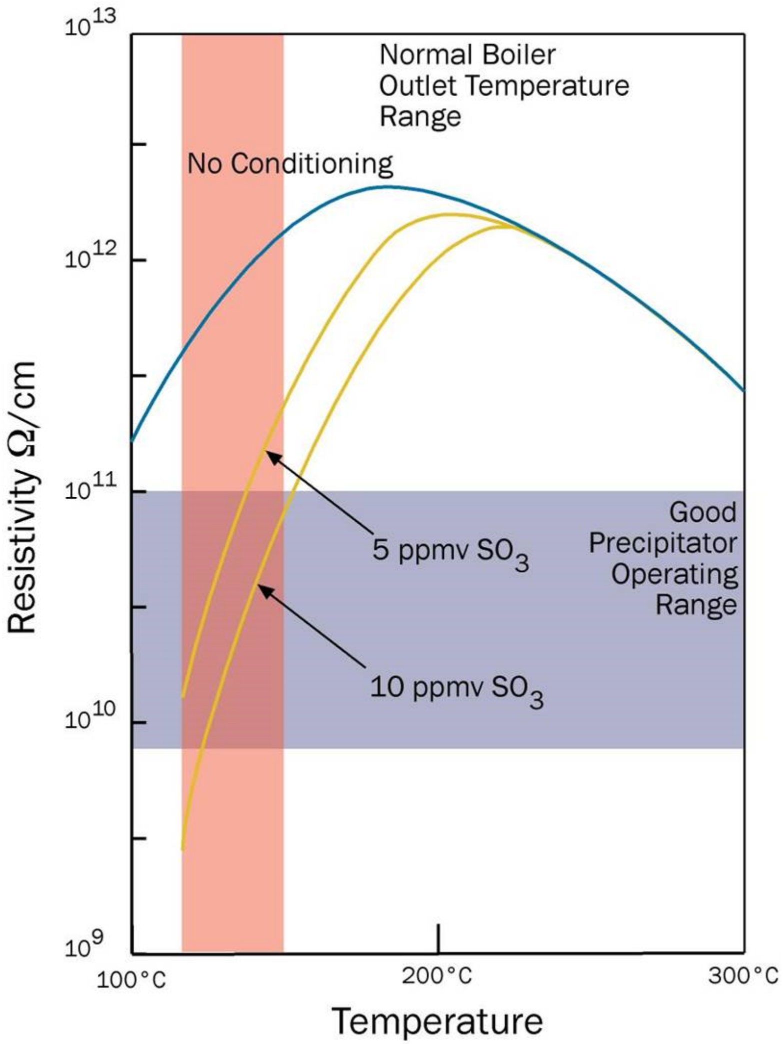
high resistivity → low particle migration velocity

Negative Properties

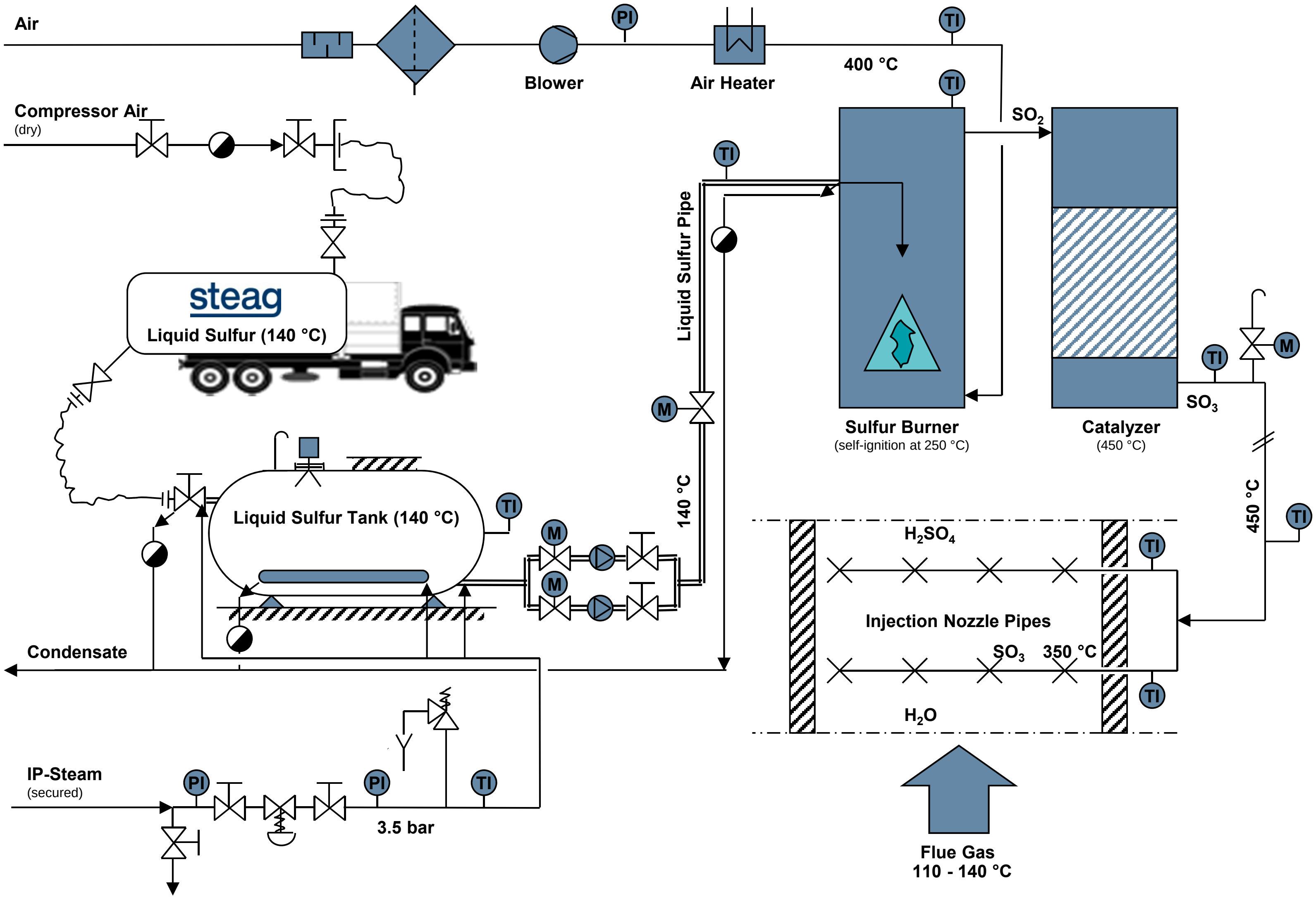
SO_3-Conditioning
Theory & Operating Results with/without SO_3-Conditioning







SO_3-Conditioning Plant Layout

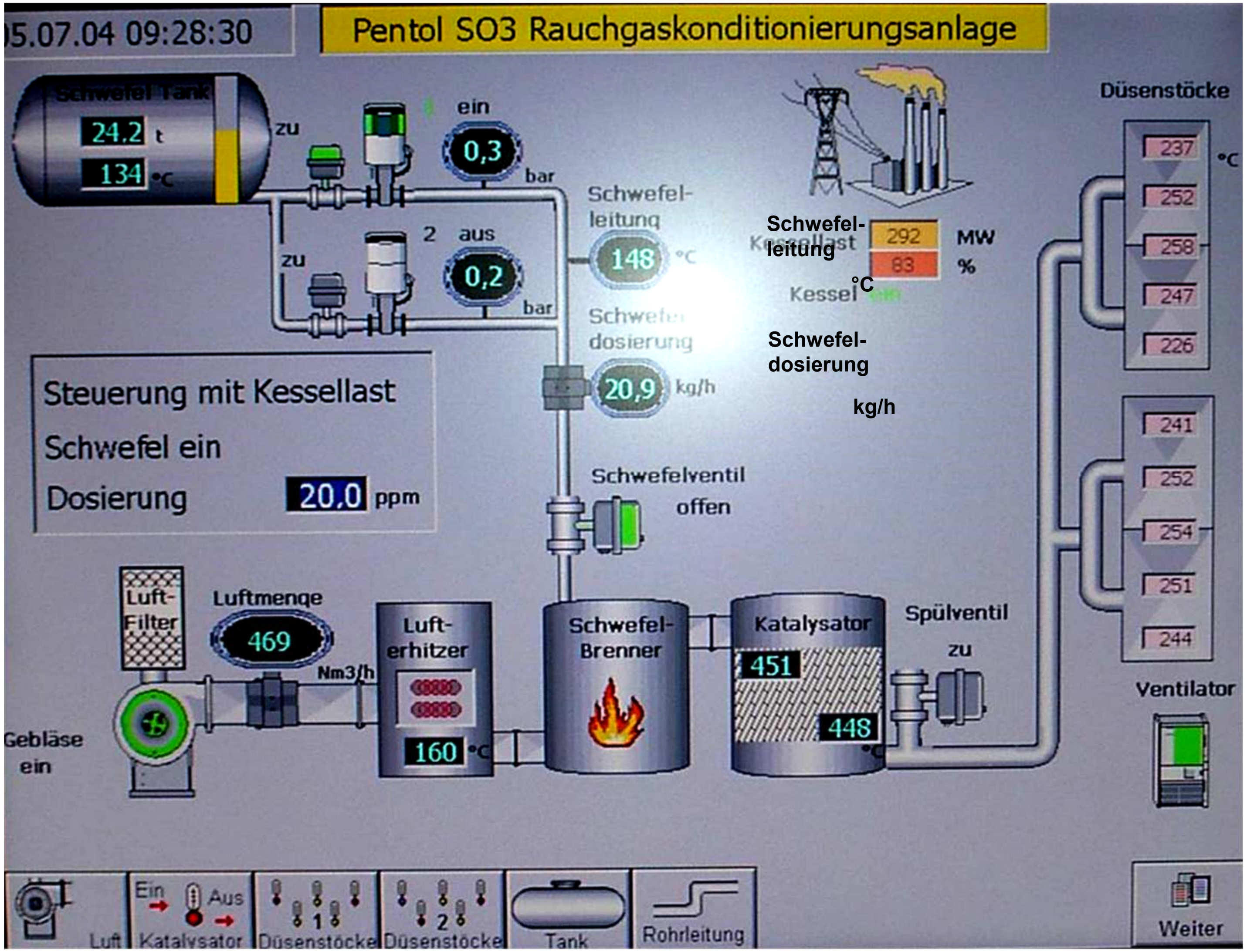


SO_3-Conditioning
Sulfur Tank & SO_3 Pipe
Operation temperature: 135 °C, content: 36 metric tons

Sulfur Pumps

SO_3 Pipe to the injection point

SO_3-Conditioning
Control Panel (Container)



SO_3-Conditioning Summary

- Great Flexibility for Coal Quality
- Keeping the future Emission-Limit of 20 mg/Nm³ without expensive ESP-Extension
- Installation of the SO_3-Conditioning Plant during Operation. Only short outage necessary for assembly of the injection tube and nozzles
- Investment costs relatively low
- Operation and maintenance costs relatively low
- SO_3-Conditioning Plant fully integrated in the DCS

Contact:
Dipl.-Ing. Matthias Schneider
STEAG Energy Services GmbH
Ruettenscheider Str. 1-3
45128 Essen / Germany
Phone: +49 201 801-2859
Mobile: +49 171 566-9263
E-Mail: matthias.schneider@steag.com