Particle precipitation in medium- and large-scale biomass combustion plants

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TECHNOLOGY FOR CLEAN AIR

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Content

- Characterisation of particles to be precipitated
- Technological description of different dust precipitation technologies
- Evaluation of the aerosol precipitation efficiencies of different dust precipitation technologies
- Recommendations concerning the application of different dust precipitation technologies in biomass combustion plants

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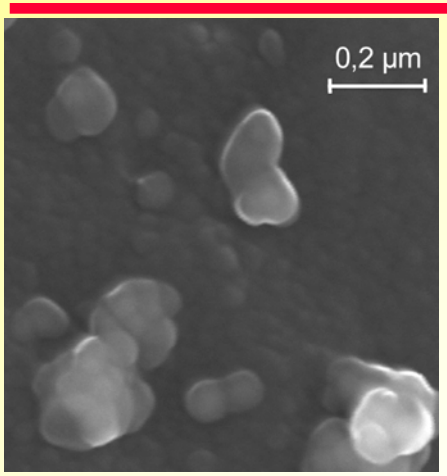
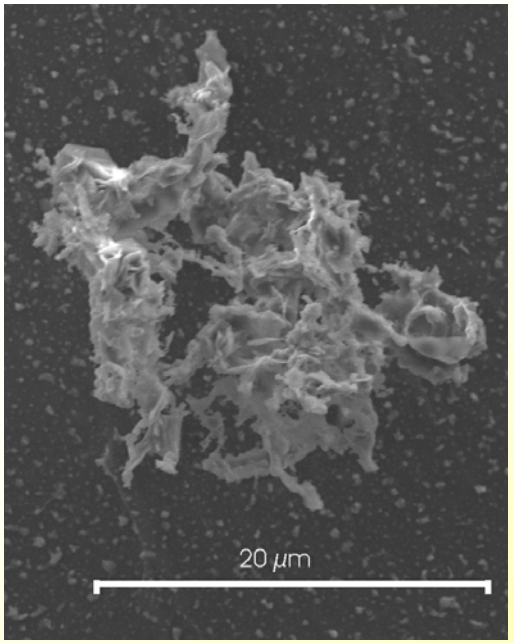
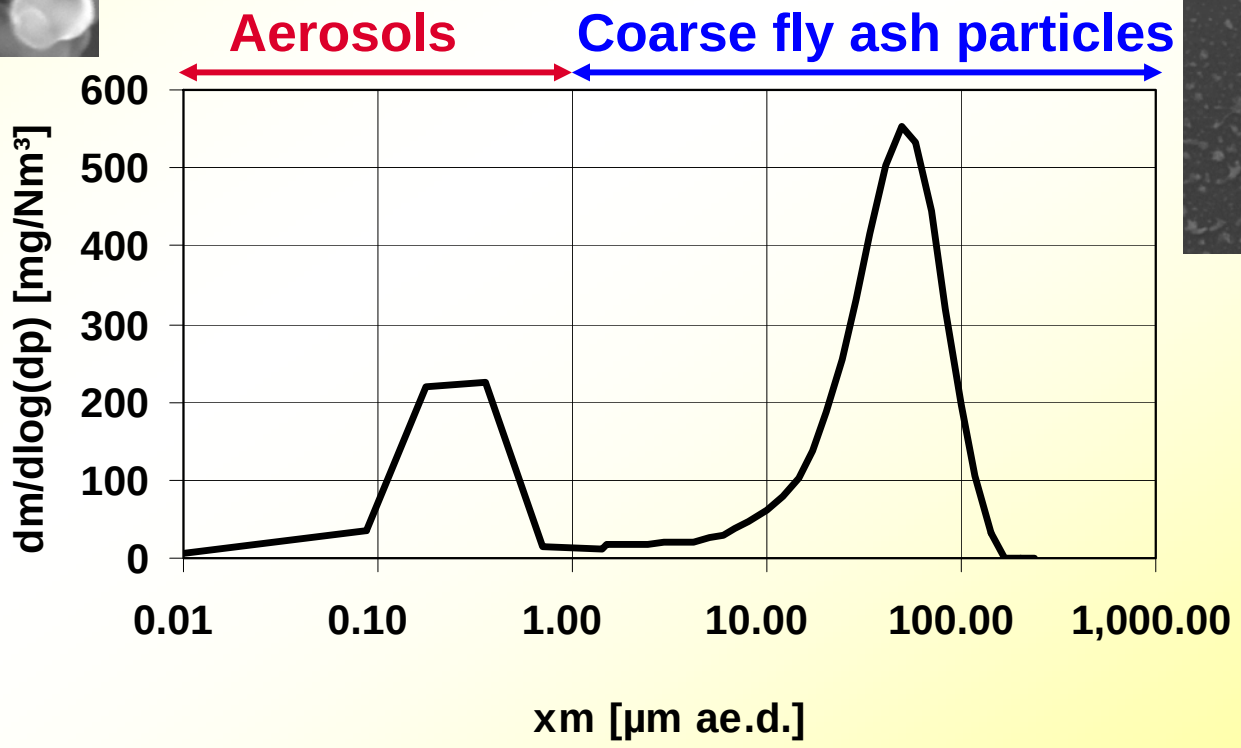
Typical particle size distributions of fly ashes formed during biomass combustion







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Dust precipitation technologies – overview

- **Cyclones**
- **Multi-cyclones**
- **Flue gas condensation units**
- **Electrostatic precipitators (ESP)**
  - **dry ESP**
  - **wet ESP**
- **Baghouse filters**

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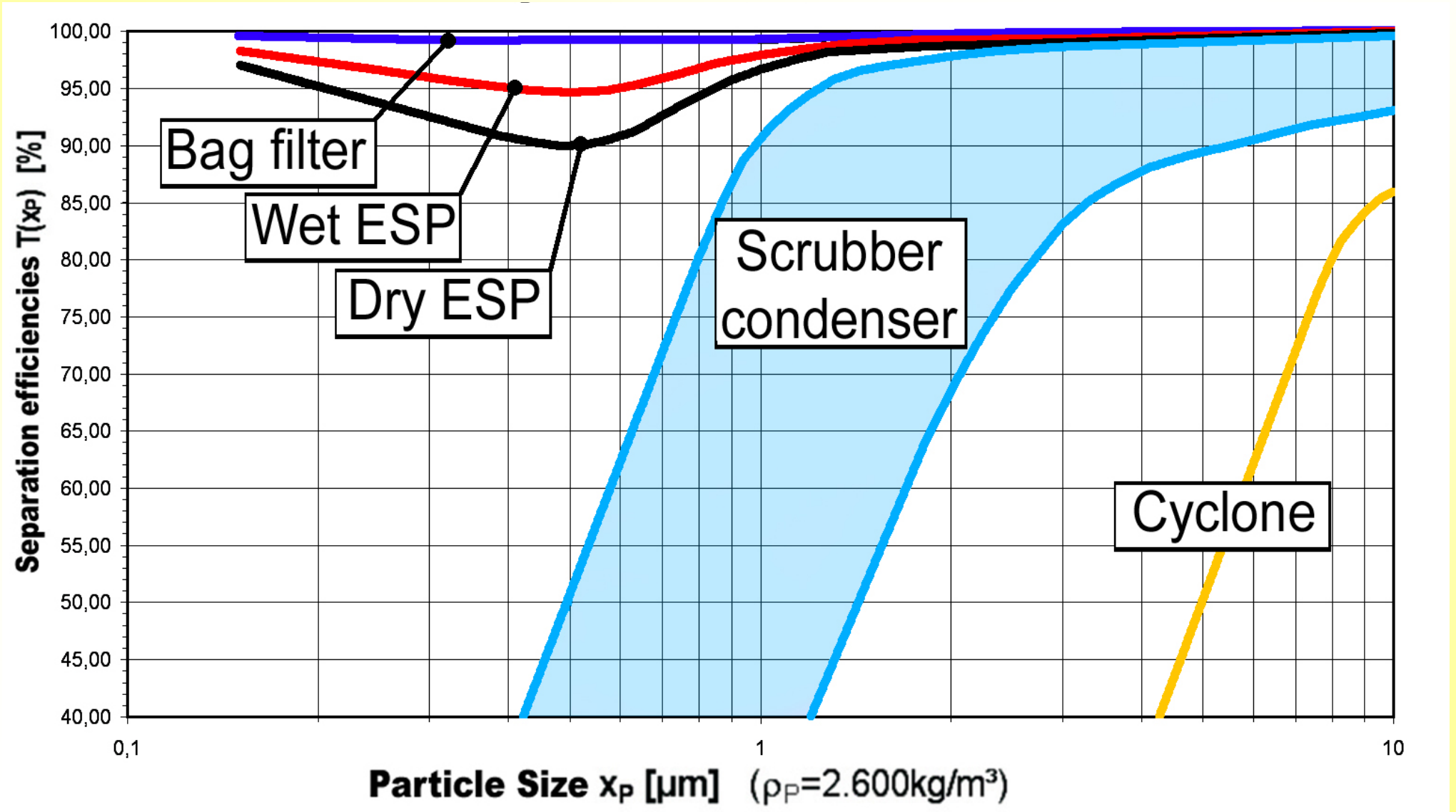
Precipitation efficiencies of different dust precipitation technologies



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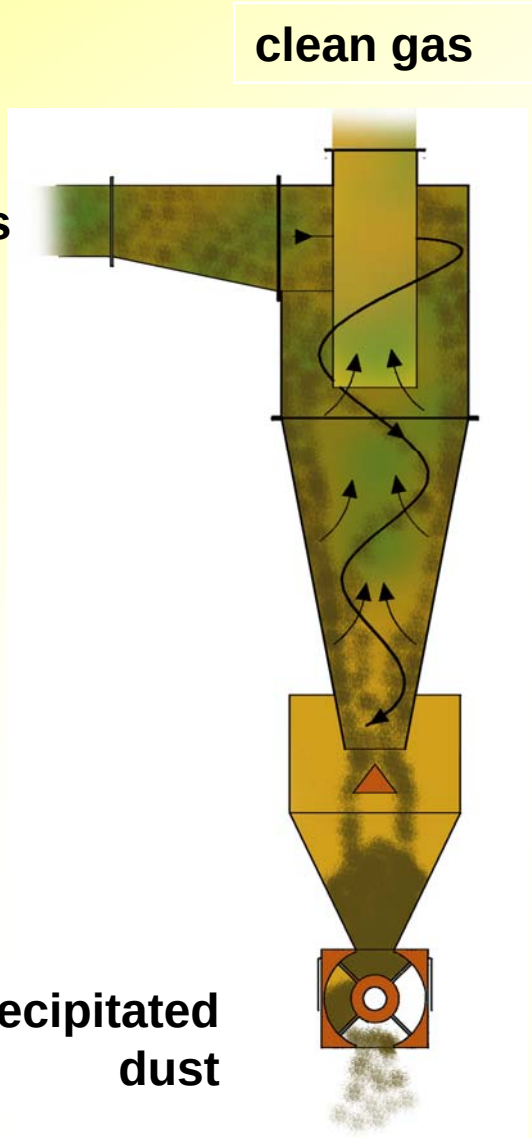
Cyclones and multi-cyclones



Principle:
precipitation by centrifugal forces

Cut diameters:
~ 5 µm

Operation temperature:
- up to 1,300 °C
- usually 150 - 250°C

Operation pressure:
- up to 100 bar
- usually atmospheric

Only suitable for coarse fly ash precipitation

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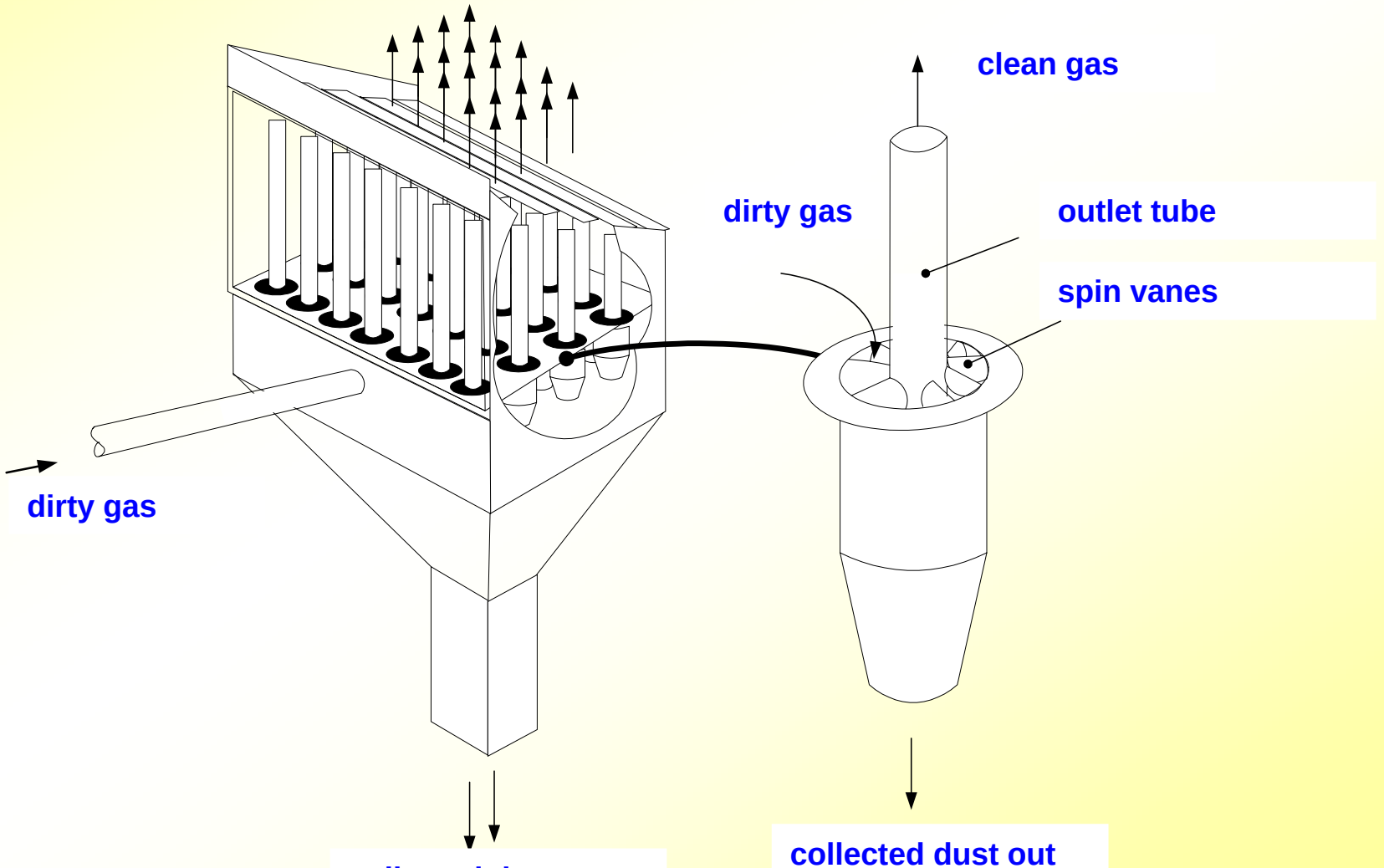
Scheme of a multi-cyclone



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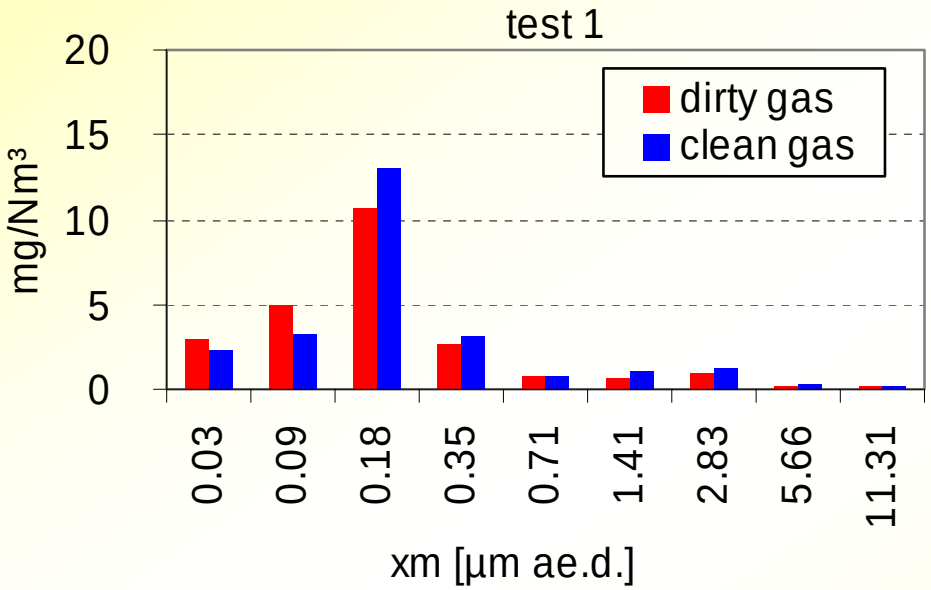
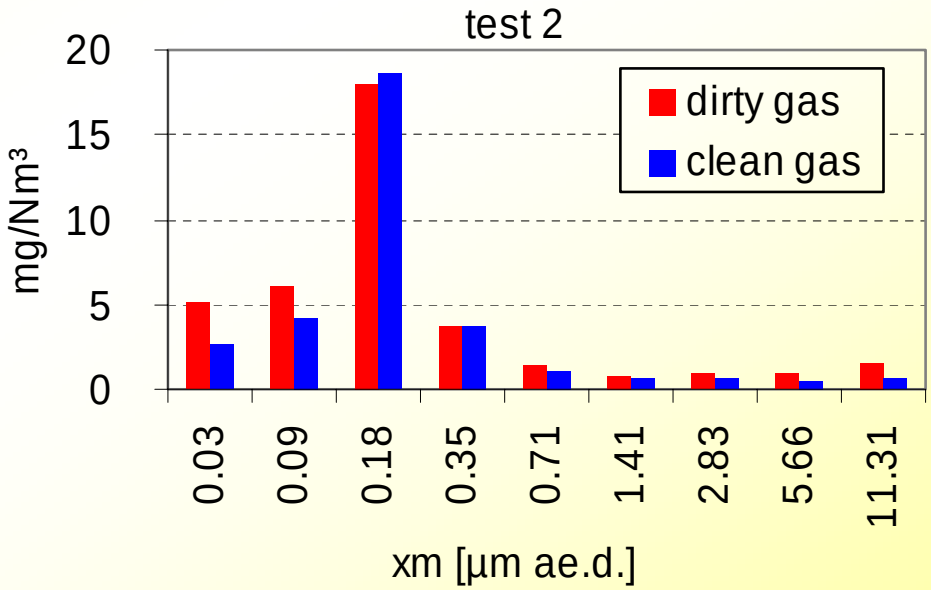
Multi-cyclones – aerosol separation

Measured particle size distributions of aerosols upstream and downstream a multi-cyclone

(coarse fly ashes are not considered)





Almost no separation of aerosol particles

Explanations: all data related to dry flue gas and 13 vol.% O_2
ae.d.: aerodynamic particle diameter
underfeed stoker, full load
fuel: hardwood (wood chips and sawdust)

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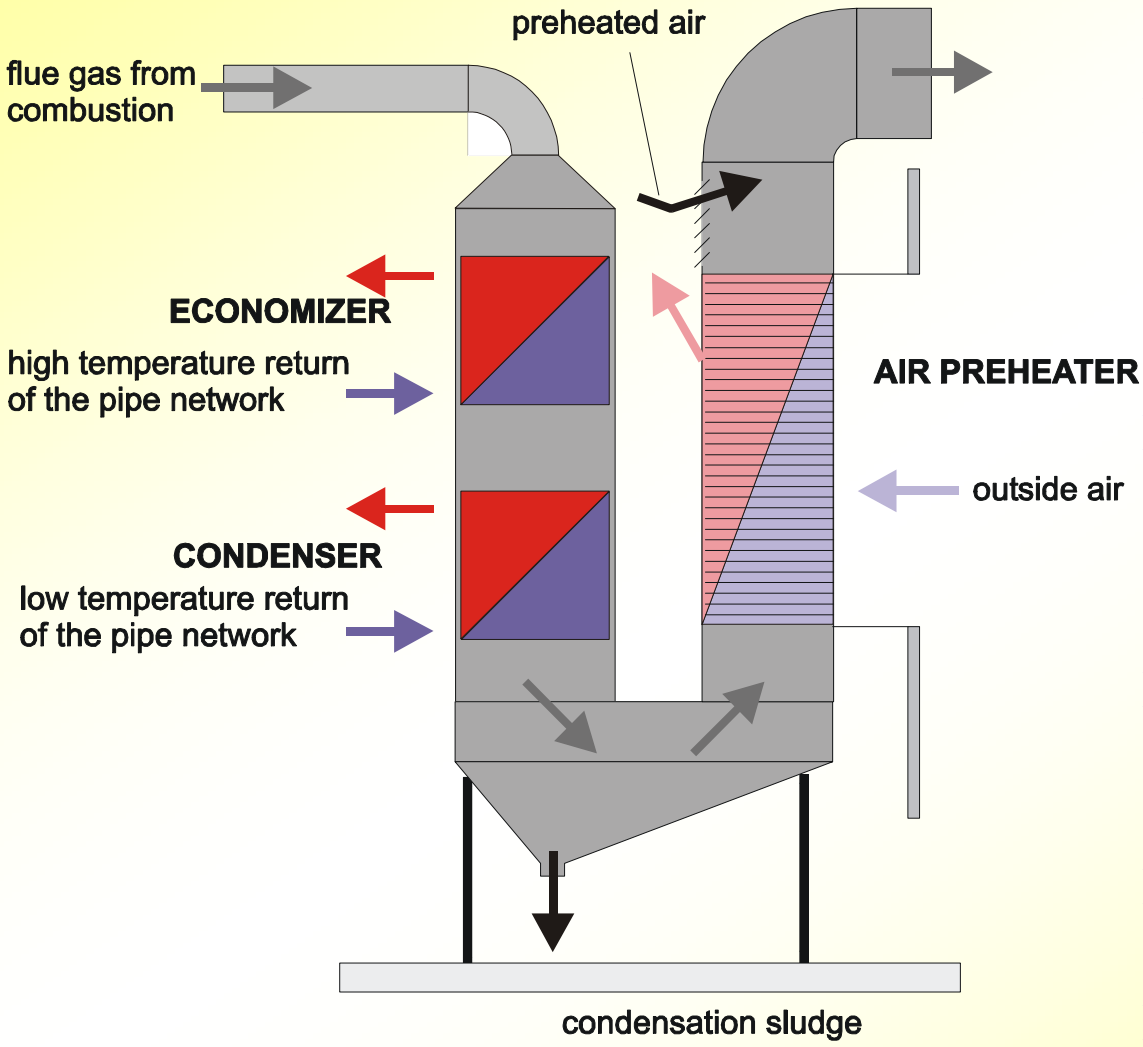
Flue gas condensation units



- Combined dust precipitation and recovery of sensible and latent heat
- Not applicable in all biomass combustion units.
  Constraints for application are:
  - low temperature of return
  - high moisture content of fuel
- Particle separation efficiency
  coarse fly ashes: almost 100%
  aerosols: depends on amount of condensed water vapour
- Pre-separation of coarse fly ash particles is recommended to avoid plugging of tube pipes
- Sludge/water separation is necessary
- Heat exchanger tubes can be cleaned by water injection

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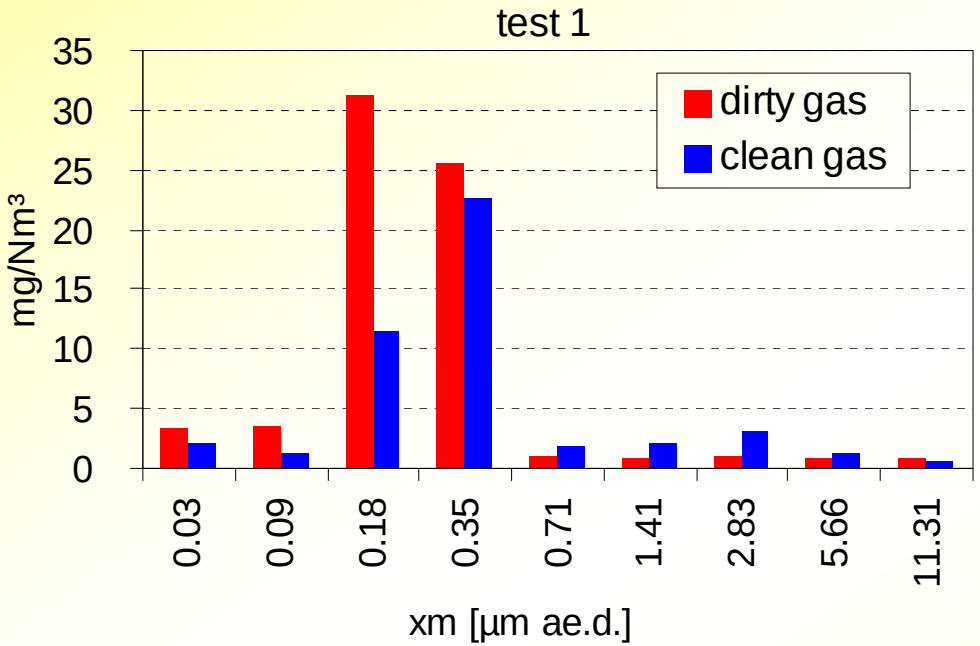
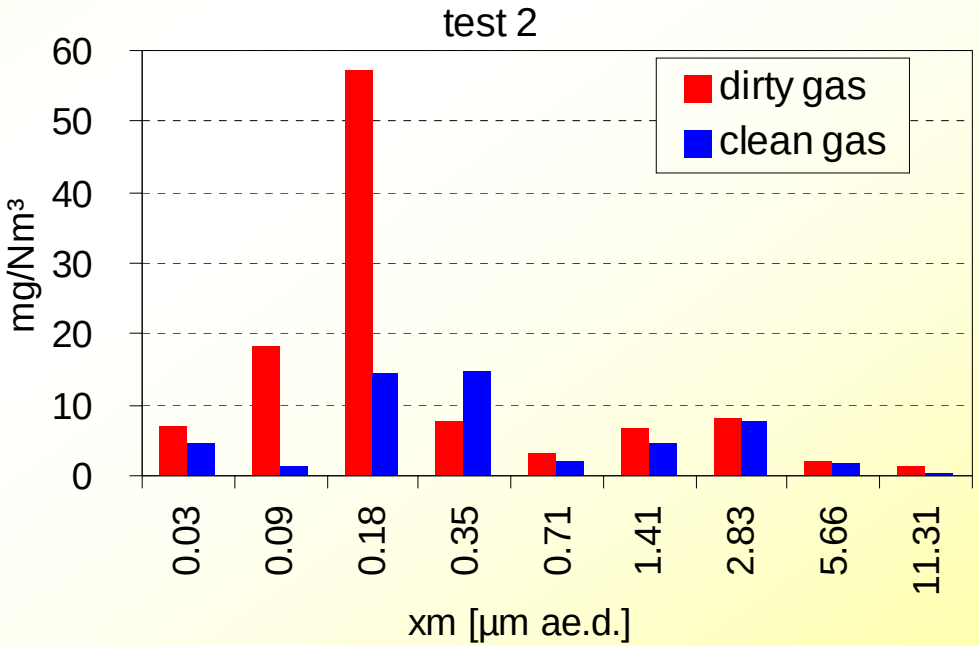
Flue gas condensation units – aerosol precipitation

Measured particle size distributions of aerosols upstream and downstream a flue gas condensation unit





Aerosol precipitation efficiency: test 1: 39%, test 2: 60%

Explanations: all data related to dry flue gas and 13 vol.% O_2; ae.d.: aerodynamic particle diameter; grate-fired combustion unit, 70% load; fuel: bark

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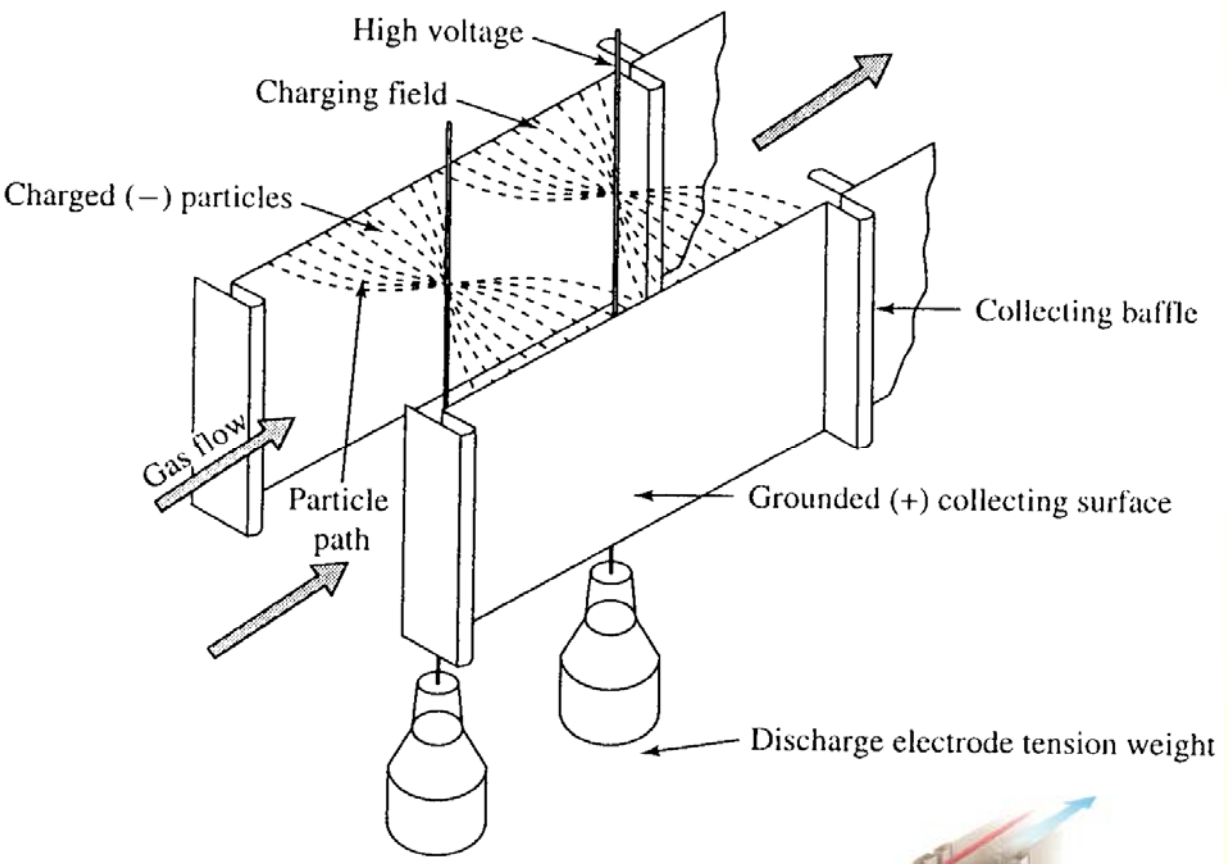
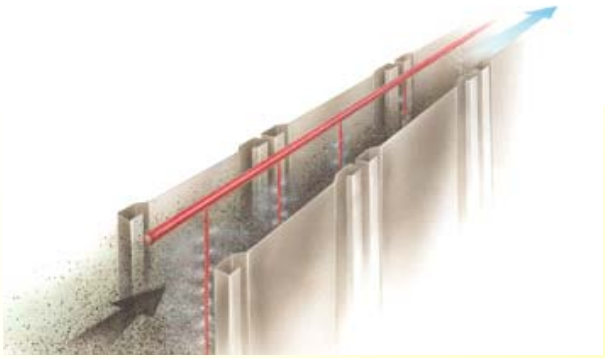
Electrostatic precipitators - principle of dry ESP





Principle:

(1) Particles are charged and
(2) precipitated at collection electrodes (plates)
(3) particles are removed from electrodes by rapping

Required properties of dust:

Specific electric resistivity between 10^7 and 10^{11} Ohm*cm

Operation temperature

up to 480°C, usually <250°C

Operation pressure

up to 20 bar, usually atmospheric

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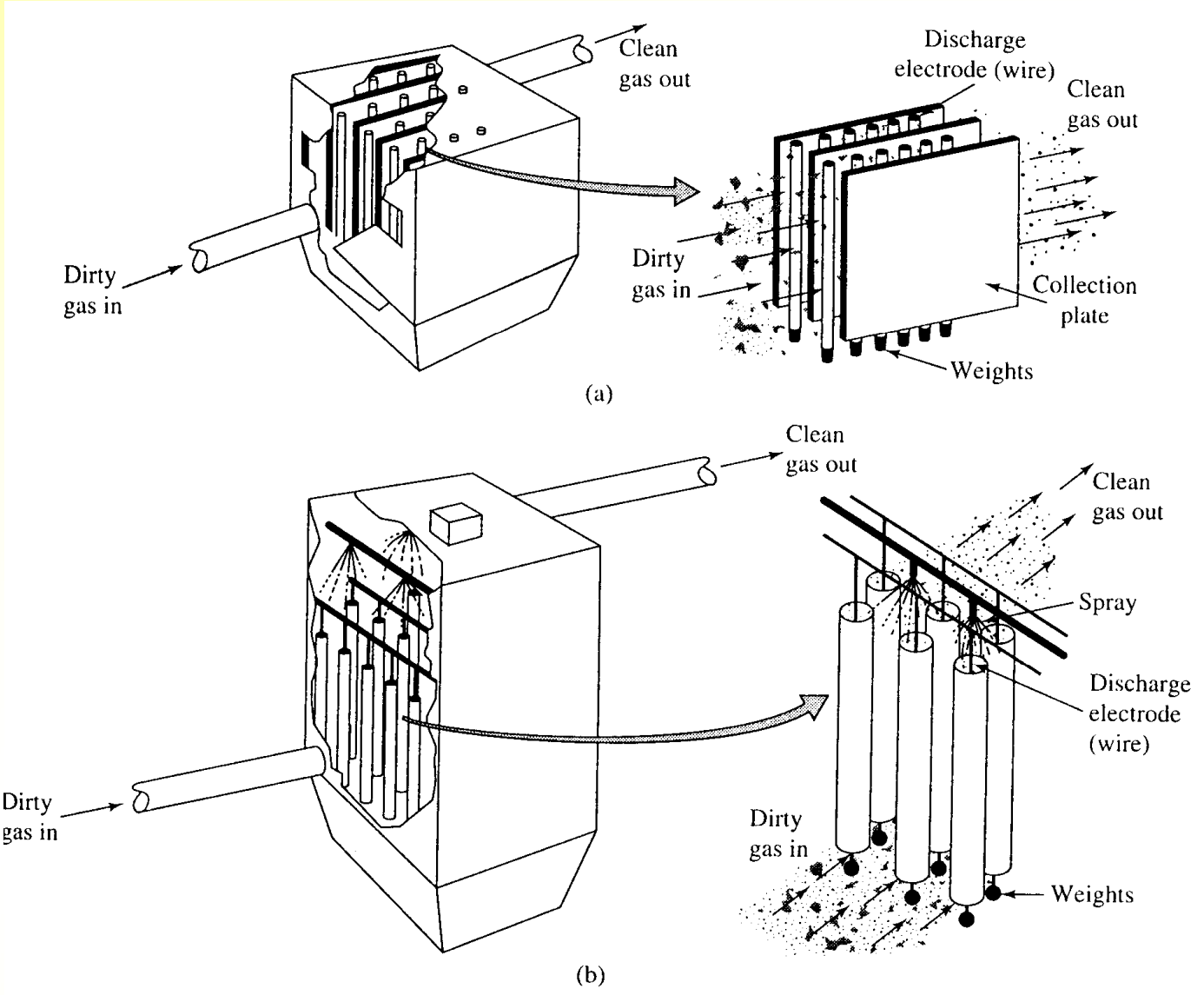
Electrostatic precipitators - plate and tube-type ESP



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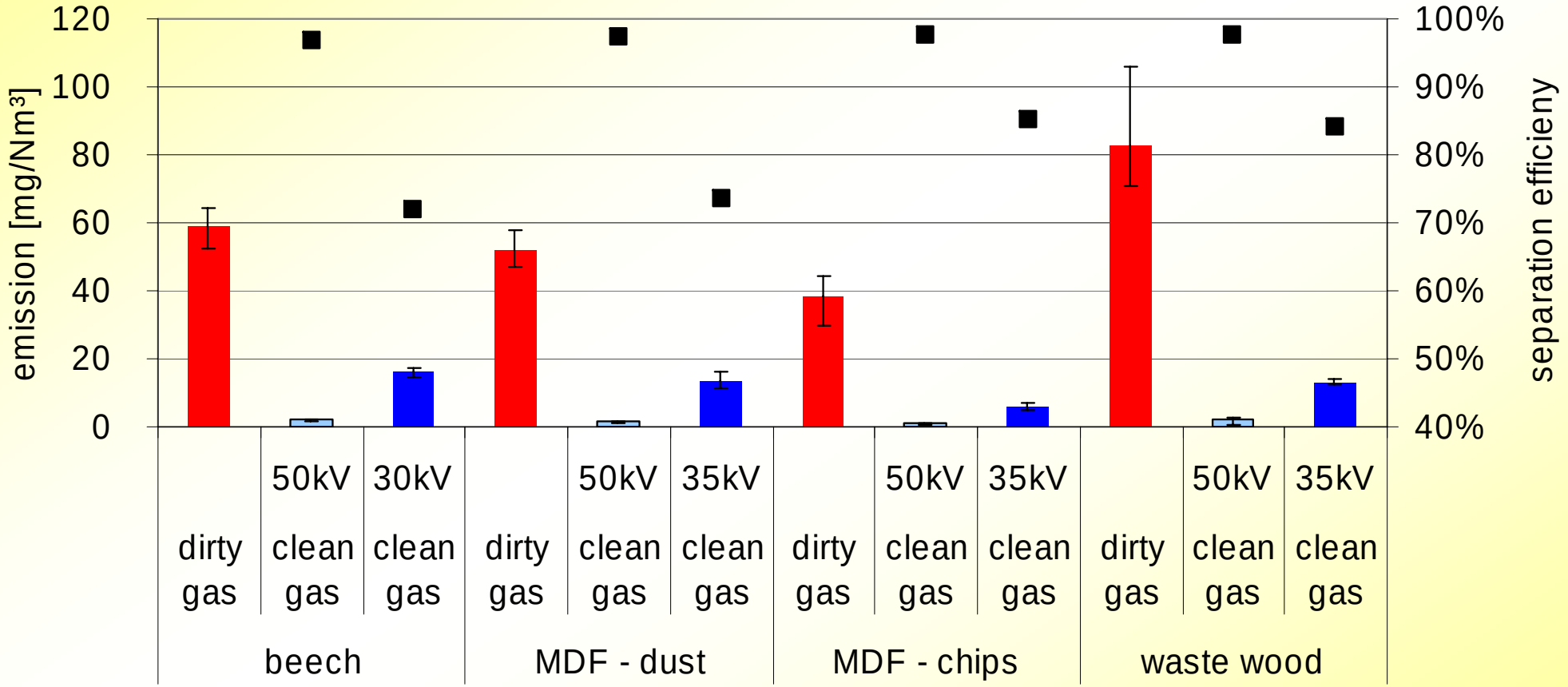
Dry electrostatic precipitators – aerosol precipitation vs. voltage



Explanations: results from impactor measurements; only particles <1µm considered
all data related to dry flue gas and 13 vol.% O_2
grate-fired combustion unit; filter current: <2 mA

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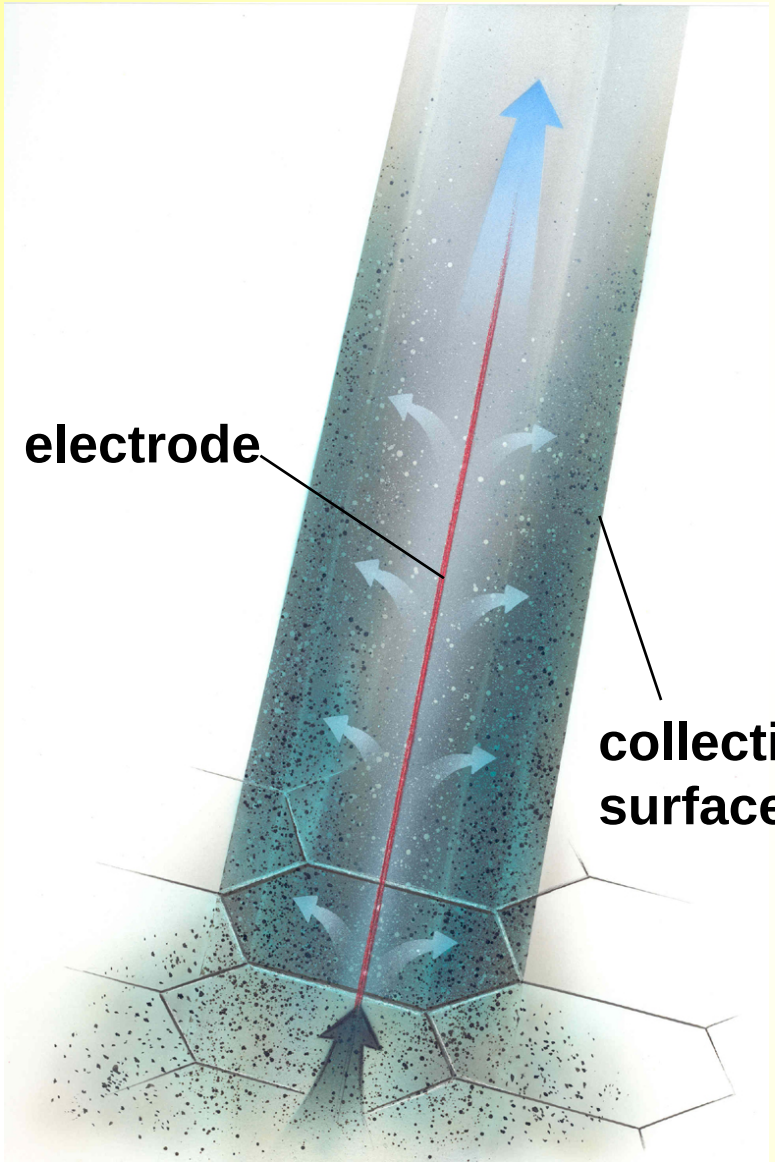
Electrostatic precipitators - principle of wet ESP (I)



Principle:

- The flue gas flows vertically through honeycomb-shaped collection surfaces.
- An emission electrode is located in the centre of the honeycombs.
- Before entering the wet ESP, the flue gas is cooled by a quenching process and saturated with water.
- Increasing the amount of moisture in the flue gas reduces the electrical resistance of the dust, making it easier to charge and remove the particles.

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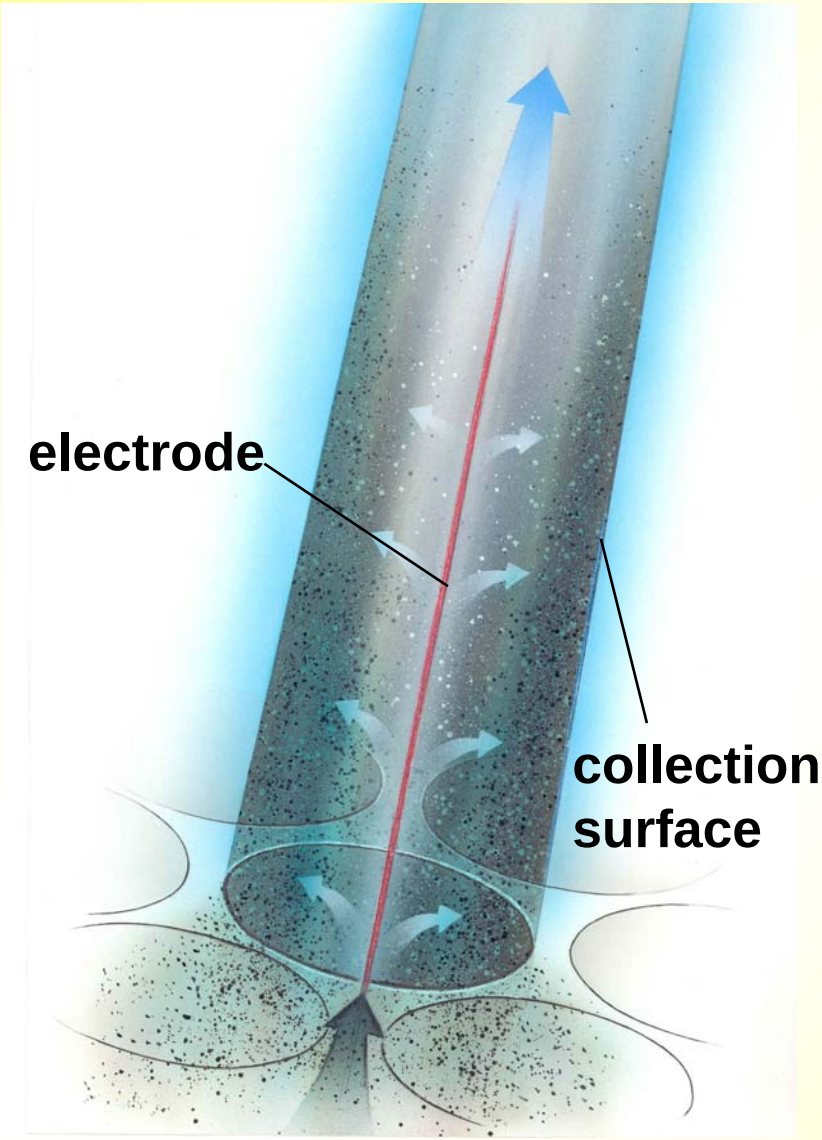
Electrostatic precipitators - principle of wet ESP (II)



Principle:

- **Collection surfaces are configured as circular pipes**
- **These collection surfaces are cooled on the outside by a surrounding flow of ambient air, which causes a layer of condensed vapour on the inside of the pipes**
- **Disadvantage: larger overall size**
- **Advantage: enhanced self-cleaning effect** (as the condensate drains off, it creates a film of water that carries away the separated particles)

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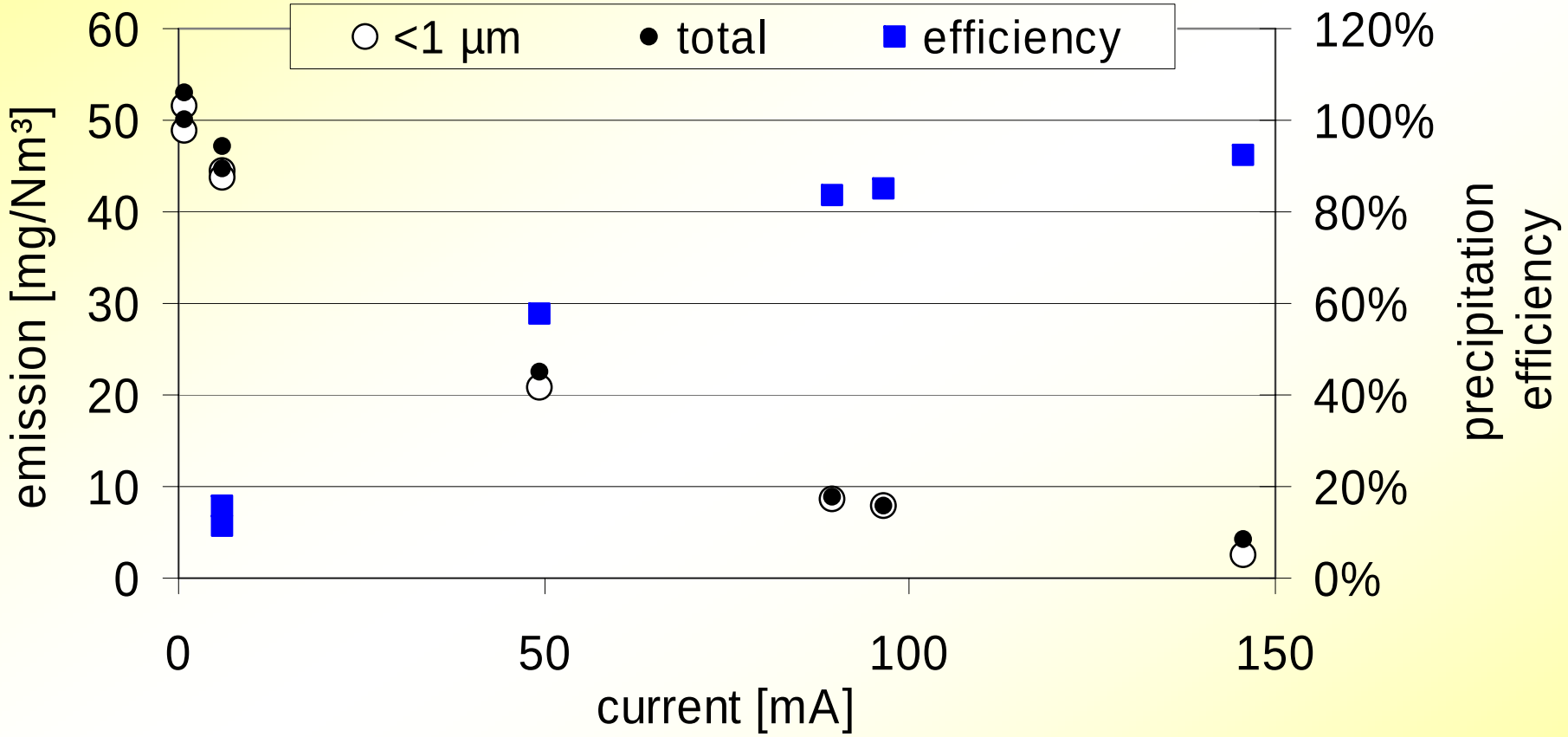
Wet ESP – aerosol precipitation vs. filter current



Explanations: results from impactor measurements; <1µm ... particles collected on impactor stages with a cut diameter <1µm; total ... total amount of particles collected with the impactor; all data related to dry flue gas and 13 vol.% O_2;
grate-fired combustion unit; fuel: mixture of bark, wood chips and sawdust;
filter voltage: <60 kV

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Baghouse filters

Principle:

- Flue gas is filtered on the surface of filter media by cake generation
- The cake is periodically removed from the surface by pressurised air

Operation temperature

- up to 850°C (depending on filter material)
- usually in the range between 160 and 220°C

Operation pressure

- up to 50 bar
- usually atmospheric

Additional advantage

- Combination with dry sorption in order to decrease HCl, SO_x, Hg and PCDD/F emissions

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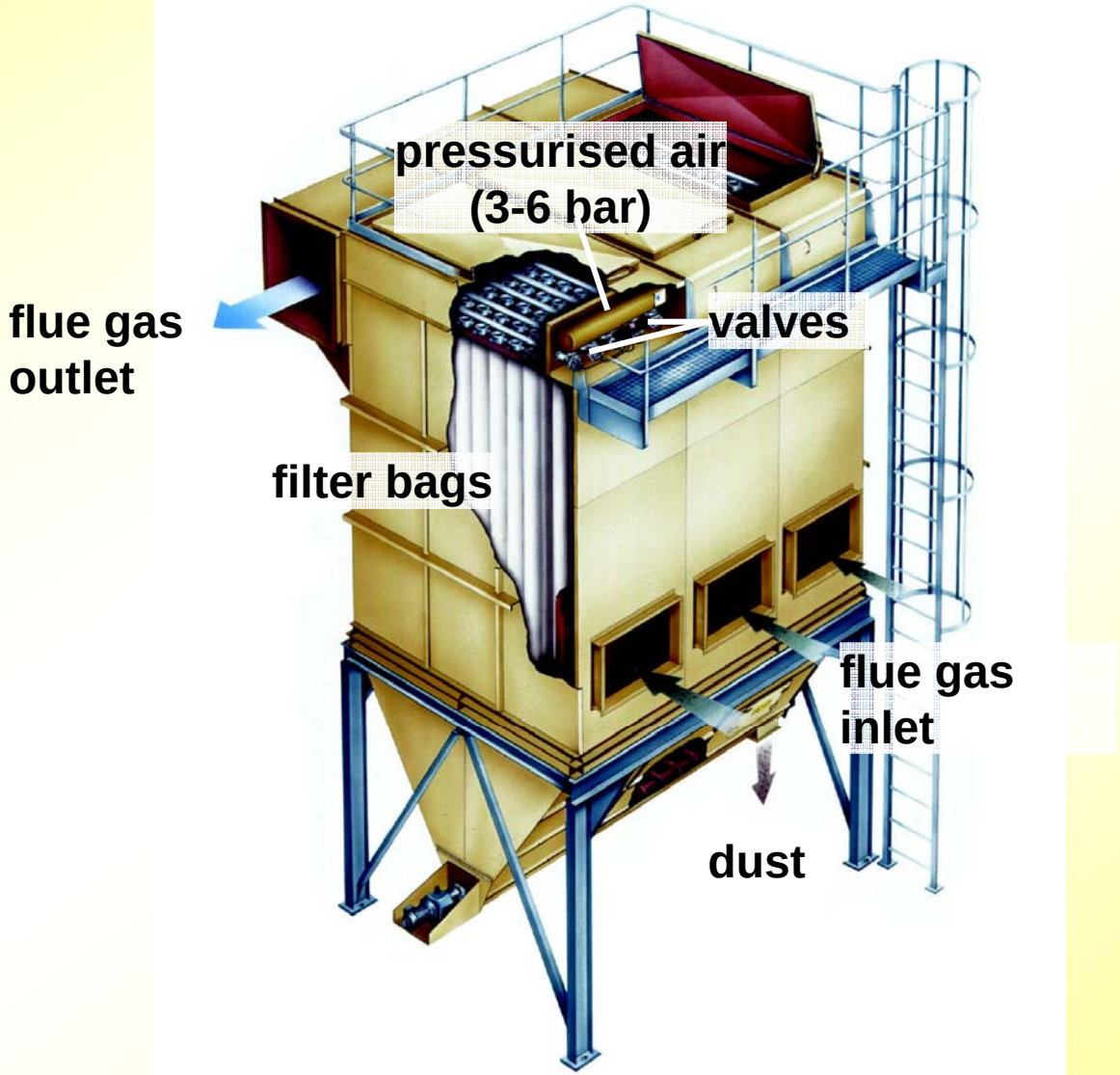
Baghouse filters – scheme



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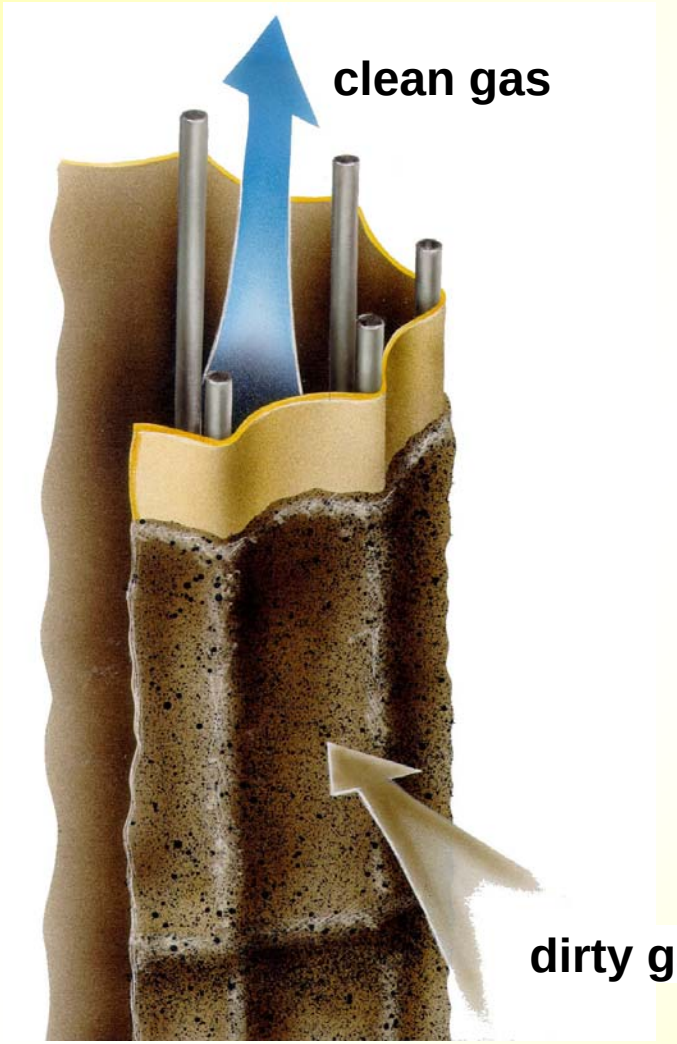
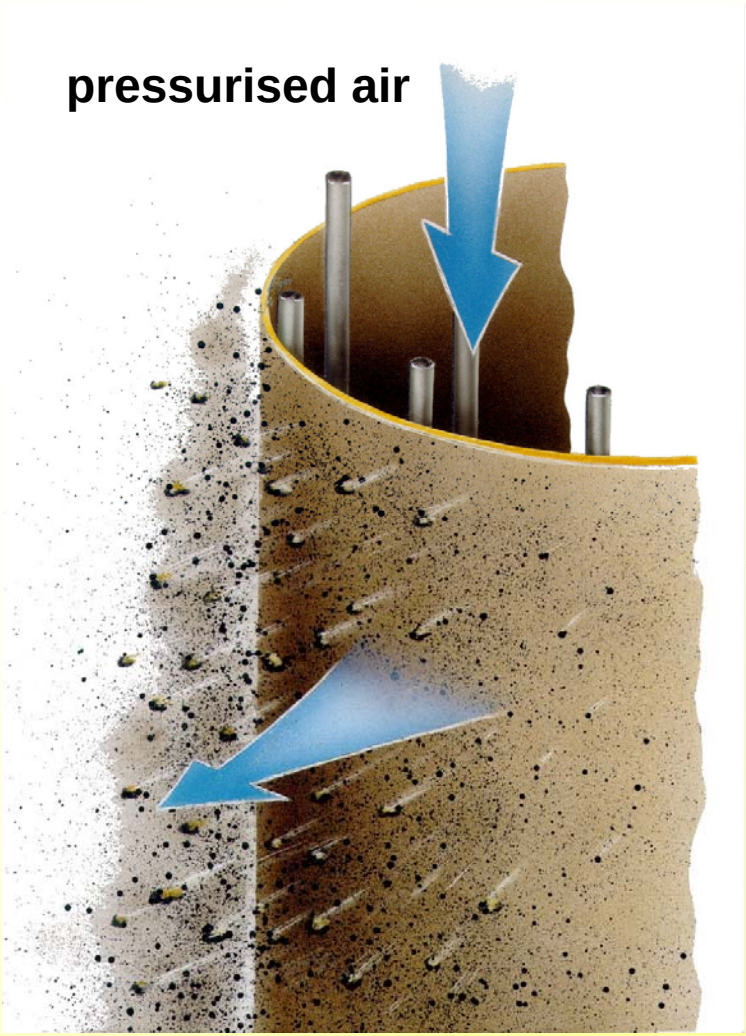
Baghouse filters – filter bag cleaning

filtration



cleaning



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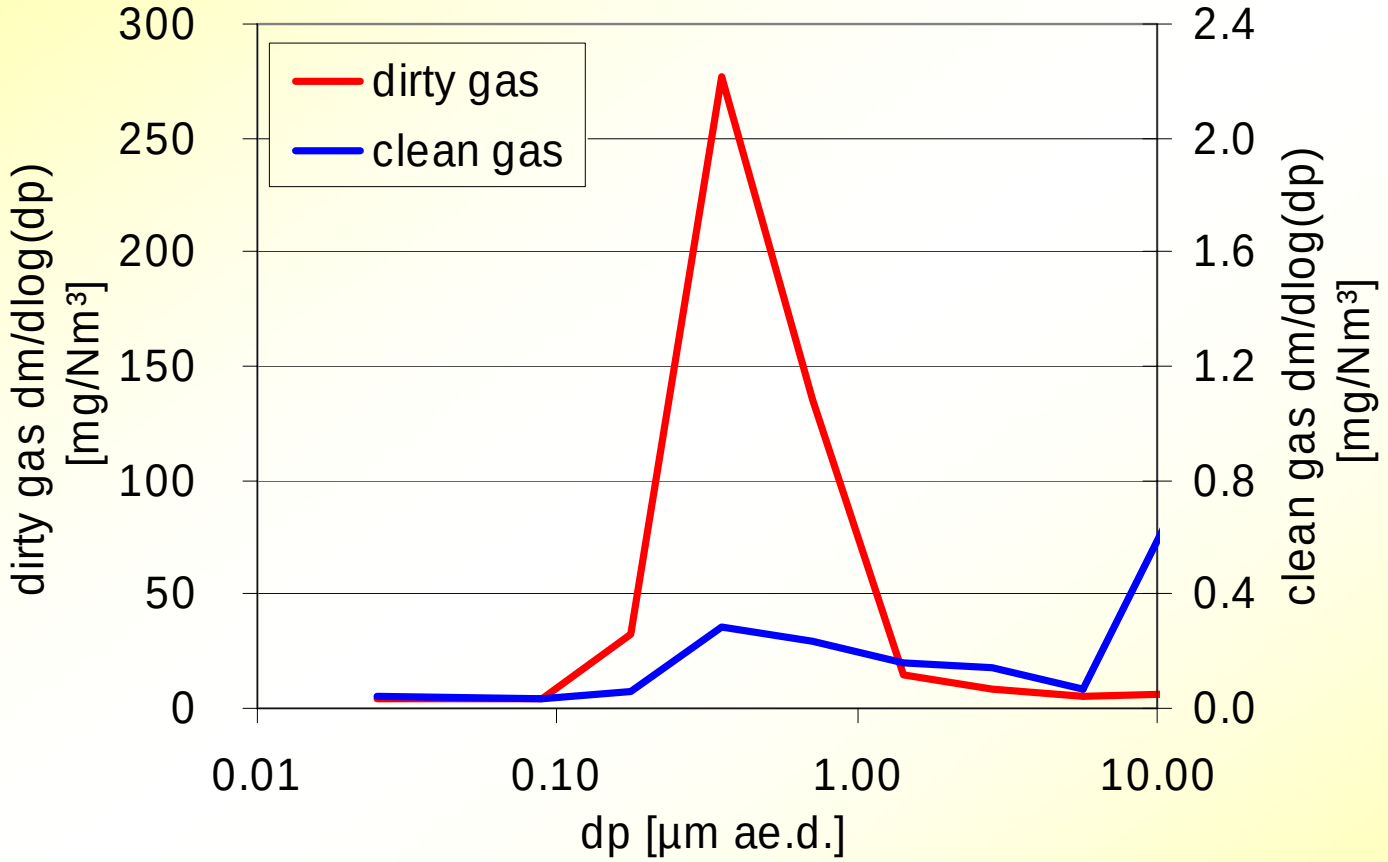
Baghouse filters – aerosol precipitation



Aerosol precipitation efficiency: >99%

Explanations: results from impactor measurements; all data related to dry flue gas and 13 vol.% O_2; grate-fired combustion unit; fuel: waste wood

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Particle separation in biomass combustion units – results from measurements

	multi-cyclone	flue gas cond. unit		ESP 1	ESP 2	baghouse filter
combustion technology	underfeed stoker	moving grate	moving grate	underfeed stoker	moving grate	moving grate
fuel	hardwood	bark	hardwood	hardwood	ind. waste wood	waste wood
load (% nominal capacity)	90	70	50	25	80 - 100	60 - 85
av. total fly ash, dirty gas	109		113	260	132	433
av. total fly ash, clean gas	74		24	<10	32	<2
coarse fly ash precipitation	☒☒☐	☒☒☒	☒☒☒	☒☒☒	☒☒☒	☒☒☒
aerosols, dirty gas	22 – 35	60 – 110	26 – 36	90 – 120	35 – 58	72 – 98
aerosols, clean gas	22 - 35	36 – 55	22 - 26	<10	6 – 8	0.4 – 0.7
aerosol precipitation	☐☐☐	☒☒☐	☒☐☐	☒☒☐	☒☒☐	☒☒☒

Explanation: all data in mg/Nm³ related to dry flue gas and 13 vol.% O_2

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Conclusions and recommendations

Best applicable precipitation technology with respect to the capacity range and fuel used

Emission limit: >150 mg/Nm³	**multi-cyclone**
Emission limit: 50 mg/Nm³	**flue gas condensation units, dry ESP**
Emission limit: 20 mg/Nm³	**dry or wet ESP**
Emission limit: 10 mg/Nm³	**baghouse filters, wet ESP**
Waste wood fired plants	**highly efficient baghouse filters**

Generally, a cyclone or multi-cyclone should be implemented upstream an ESP, baghouse filter or flue gas condensation unit in order to remove the coarse fly ash particles