

# **Spray Dry Absorber Conversion to a Dry Sorbent Injection System Coupled with Flue Gas Humidification**

Rudi Karpf

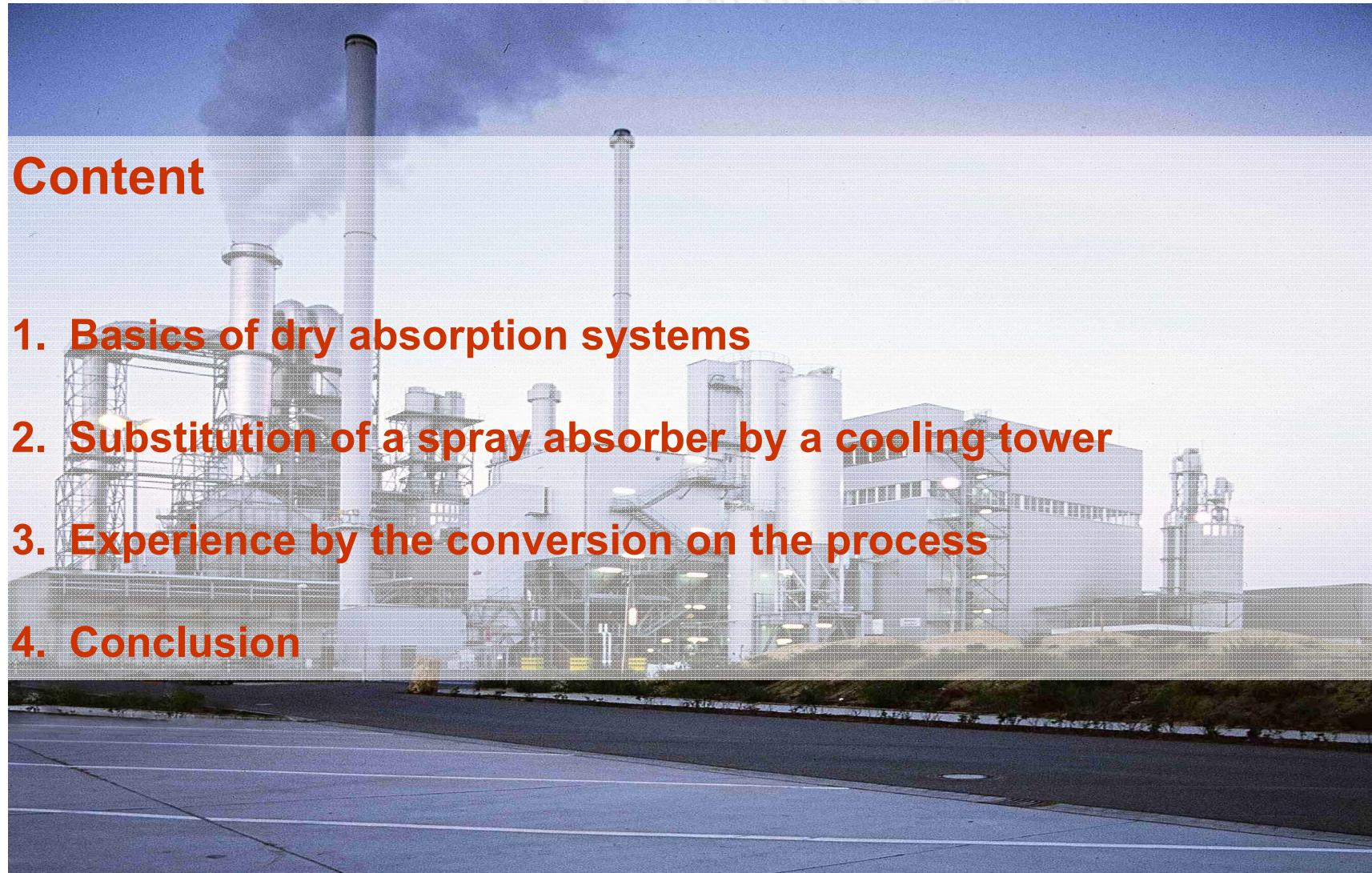
ete.a Ingenieurgesellschaft mbH, Lich (Germany)

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## Content

1. Basics of dry absorption systems
2. Substitution of a spray absorber by a cooling tower
3. Experience by the conversion on the process
4. Conclusion



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## Basics of dry absorption systems

objects to influence the efficiency and stoichiometry

- concentration and reactivity of gas pollutants
- concentration and reactivity of reagents
- contact of reaction partner
  - (e.g. distribution, mixture and surface of reaction partner)
- temperature und humidity

### reactivity at dry absorption with lime



## Basics of dry absorption systems

objects to influence the efficiency and stoichiometry

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## Basics of dry absorption systems

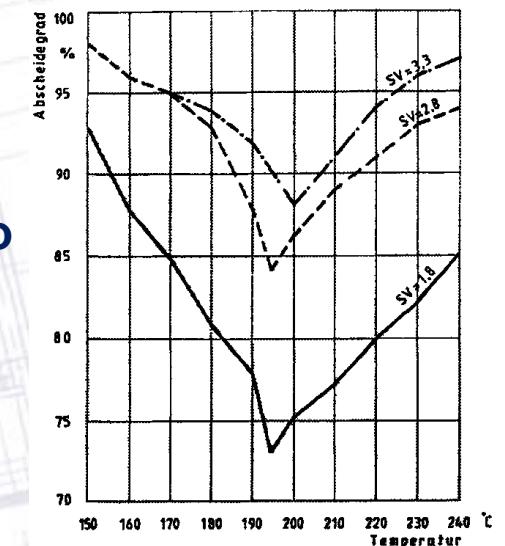
### HCl-efficiency rate

- relative humidity  $\varphi$

→ with increase of relative humidity  
the removal efficiency of HCl increase too

- flue gas temperature

→ up to appr. 200 °C decrease the HCl efficiency rate in respect of a lower relative humidity.  
> 200 °C the HCl efficiency rate will increase in respect of the positive influence of Kinetic



## Basics of dry absorption systems

### ***SO<sub>2</sub>-efficiency rate***

- relative humidity  $\varphi$

→ the influence of the relative humidity for the SO<sub>2</sub>-removal is much more higher as for the HCl-removal; that means if higher the relative humidity as higher the SO<sub>2</sub>-removal

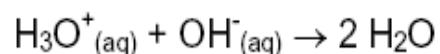
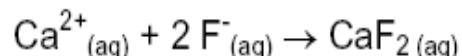
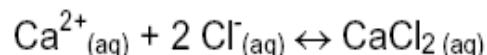
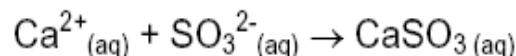
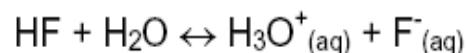
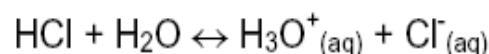
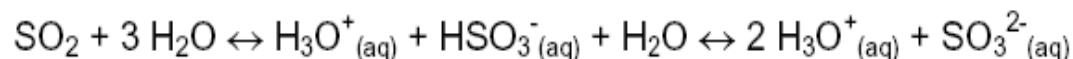
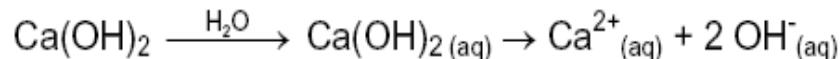
- flue gas temperature

→ in the opposite to the HCl-removal increase of the temperature occur a decrease of the SO<sub>2</sub>-removal based on a decrease of humidity

## Basics of dry absorption systems

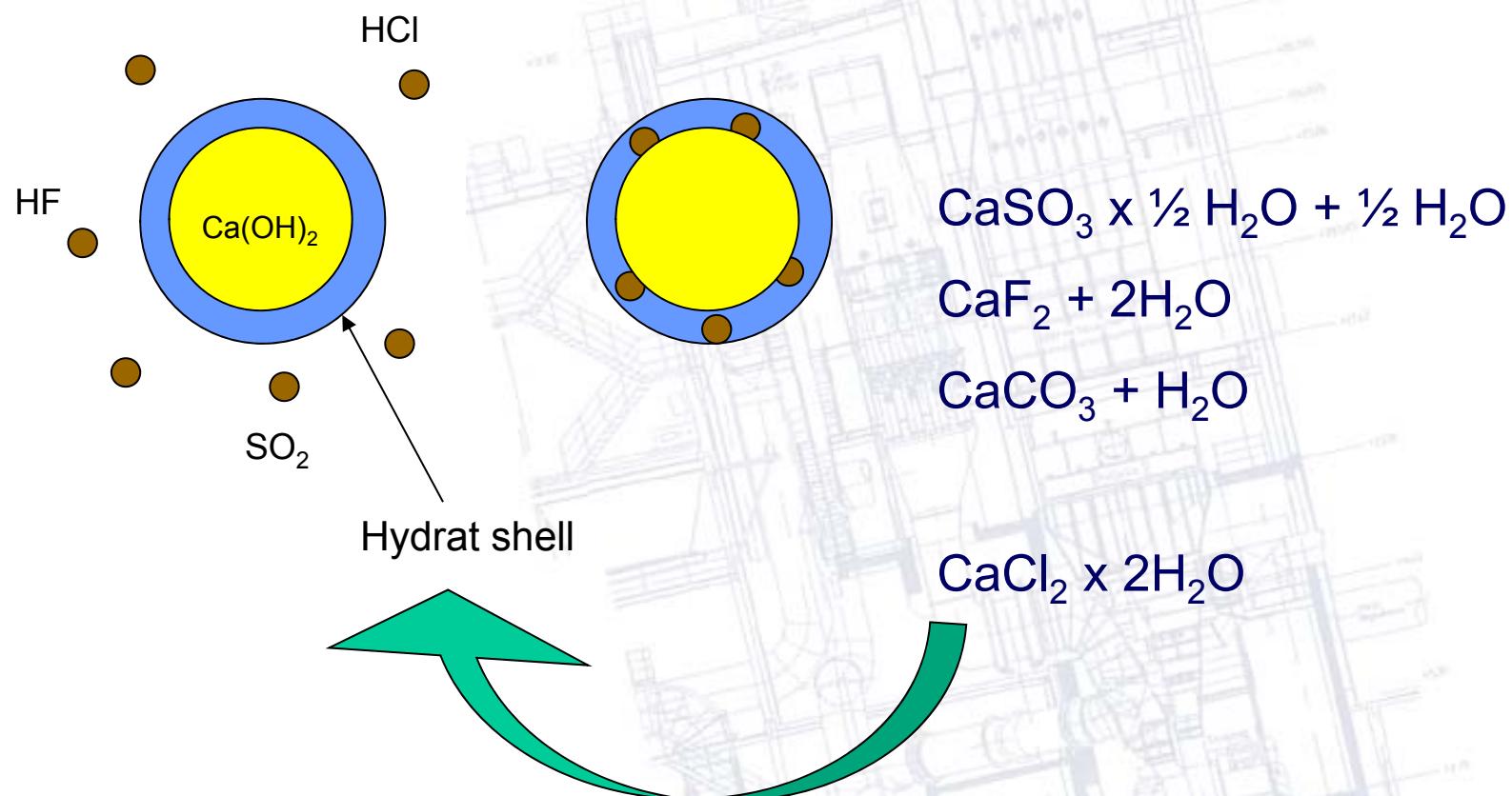
The presence of liquid water increase the reactivity of lime

→ The reaction velocity in the wet phase are much more higher as in a solid phase concerning the ionic formation



## Basics of dry absorption systems

### Separation process



## Basics of dry absorption systems

### Influence of the HCl content to the efficiency

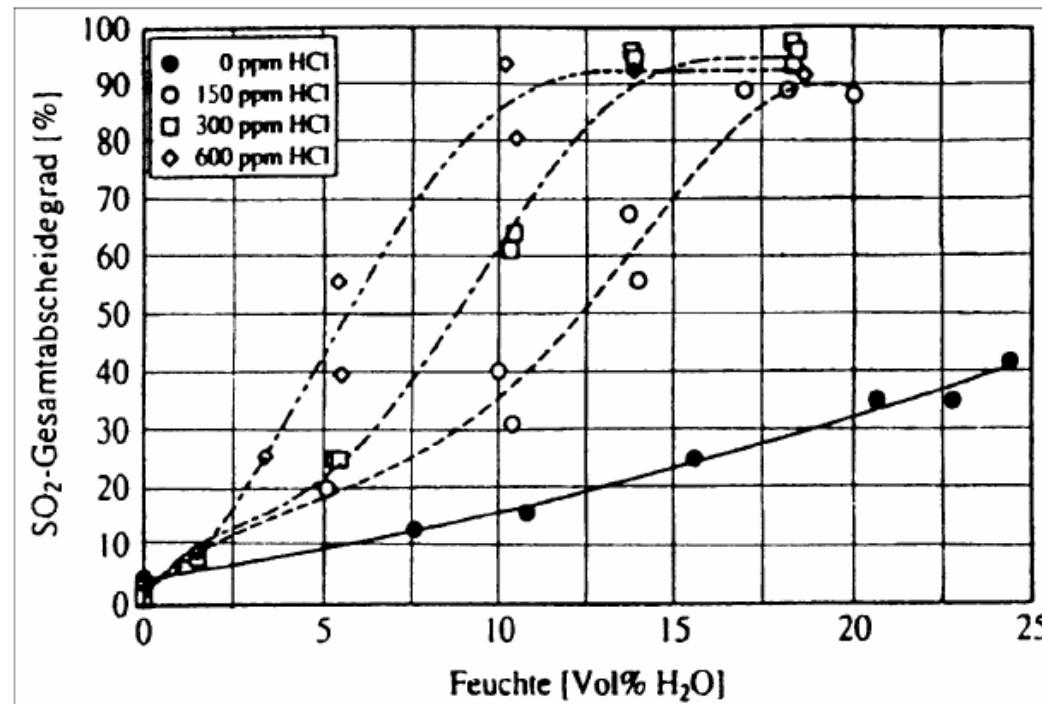
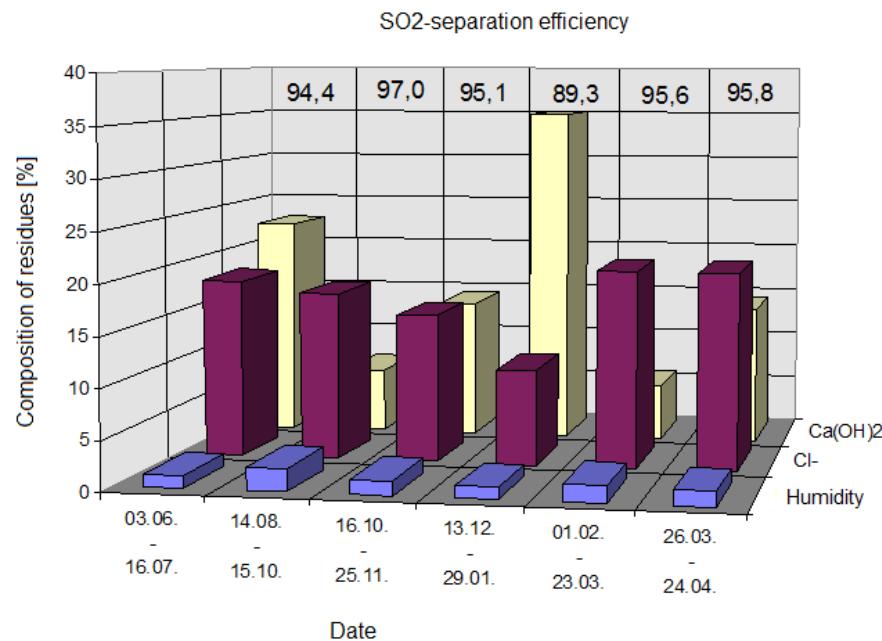


Abb.4 Einfluss der HCl-Konzentration und der absoluten Feuchte auf den  $\text{SO}_2$ -Gesamtabscheidegrad,  
Rohgaskonzentrationen:  $\text{SO}_2 = 750 \text{ ppm}$ ,  $\text{HCl} = 0 \text{ bis } 600 \text{ ppm}$ ,  $\text{Ca/S-Verhältnis} = 2$  (Quelle: [1] S.507)

## Basics of dry absorption systems

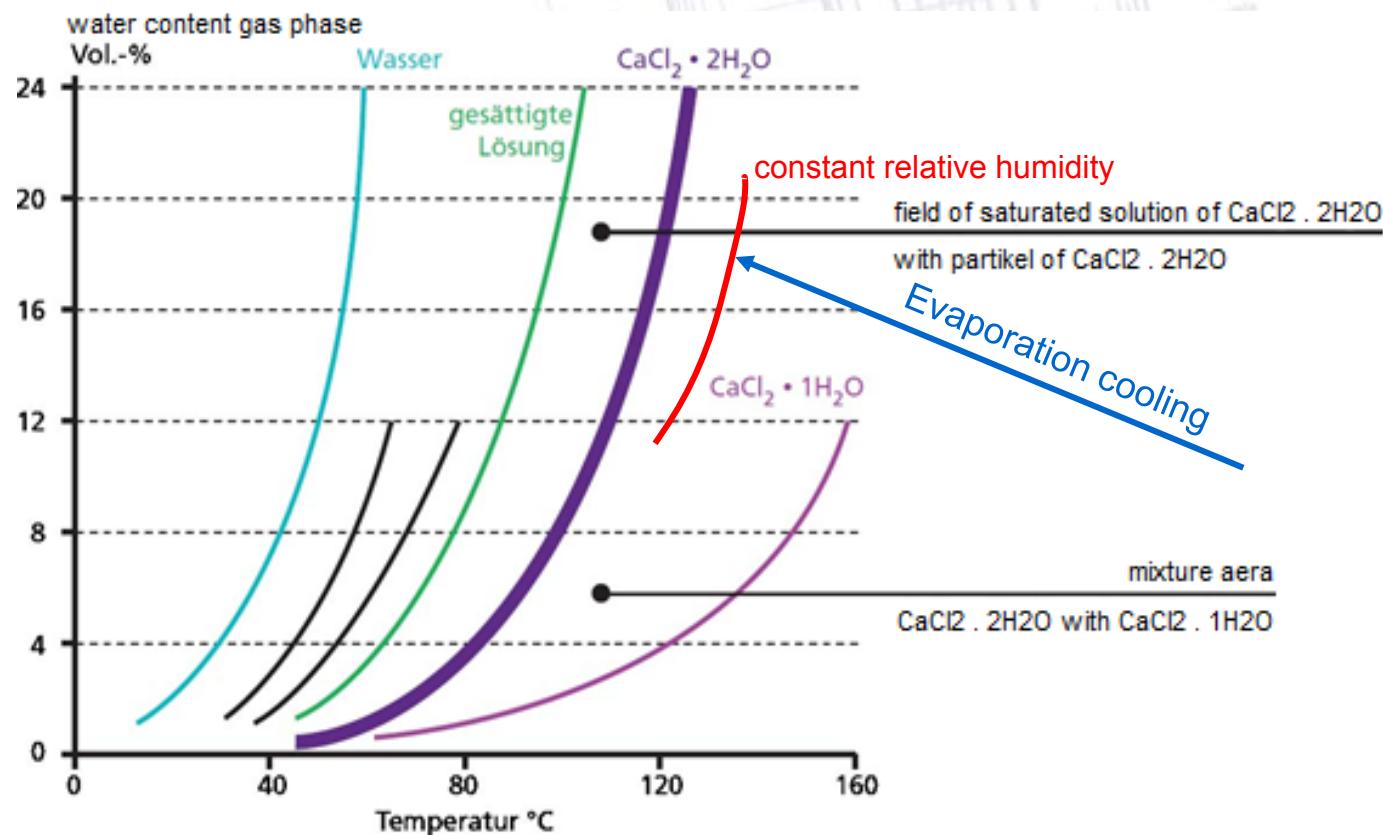
### Influence of the HCl content to the efficiency



measurement of ITU, SVA(hazardous waste combustion) Schöneiche(Berlin), 03.06.91 - 24.04.92

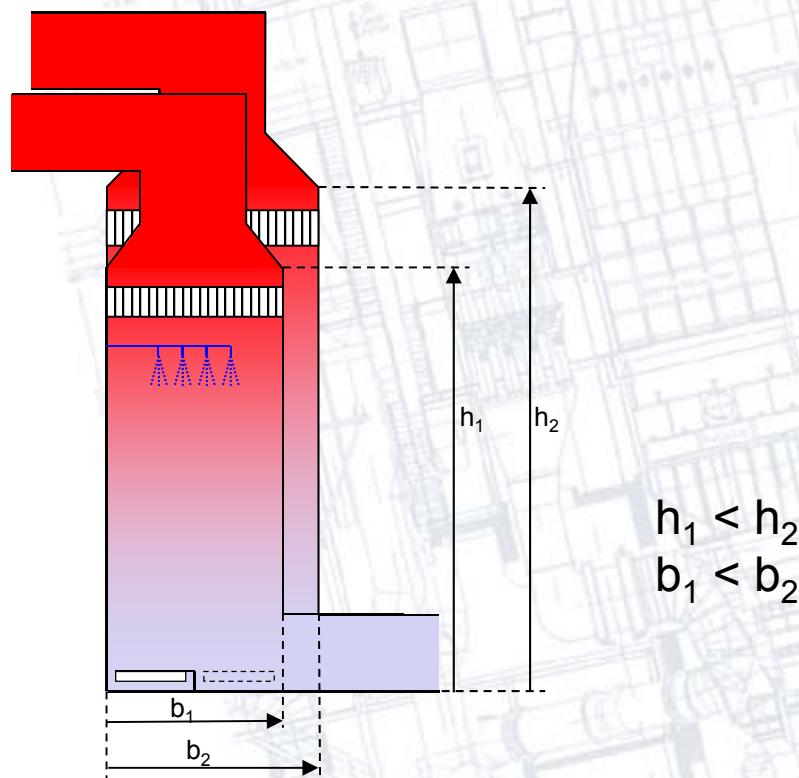
## Basics of dry absorption systems

### Section of phase diagram $\text{CaCl}_2/\text{H}_2\text{O}$



## Dimensions of spray absorber and cooling tower

Spray Absorber



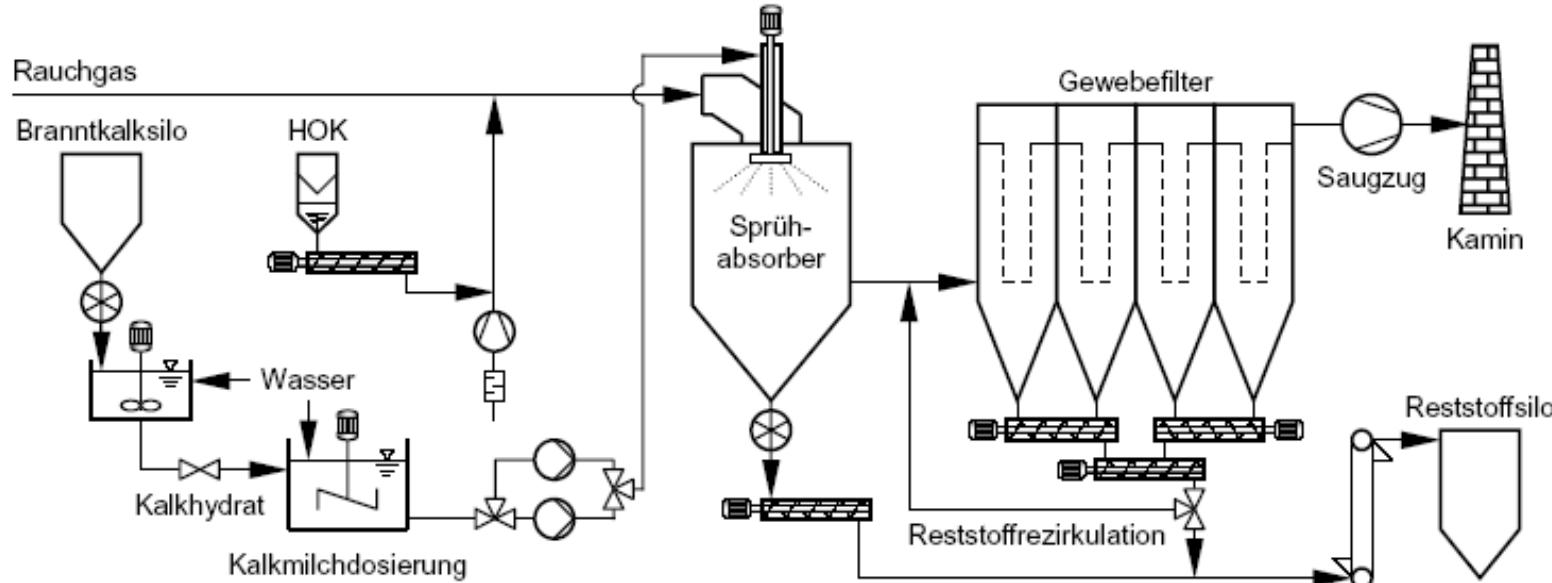
## Dimensions of spray absorber and cooling tower

The residence time must be longer at a spray absorption, based on the solid drying compare to a pure water evaporation.

Depend on,

- Heat and mass transfer at the phase boundary liquid/gas (convection, radiation, thermal conduction)
- Heat and mass transfer inside the droplets (thermal conduction, diffusion, convection)
- chemical reaction between liquid and gas
- Phase transition of dissolved substance inside the droplets (Crystallisation)

## Special conditions of spray absorption



The lime will inject in a reactivity kind, together with water!

→ that means with a high expectation of a very good efficiency rate

## Special conditions of spray absorption

The experience of existing plants shows

*at waste to energy plants*

- high enough separation of acid gas but with a SR-values >2,5  
(sometimes with an additional injection of high sophisticated lime)

*at fossil power station*

- high enough separation of acid gas with a SR-values  $\geq 1,4$



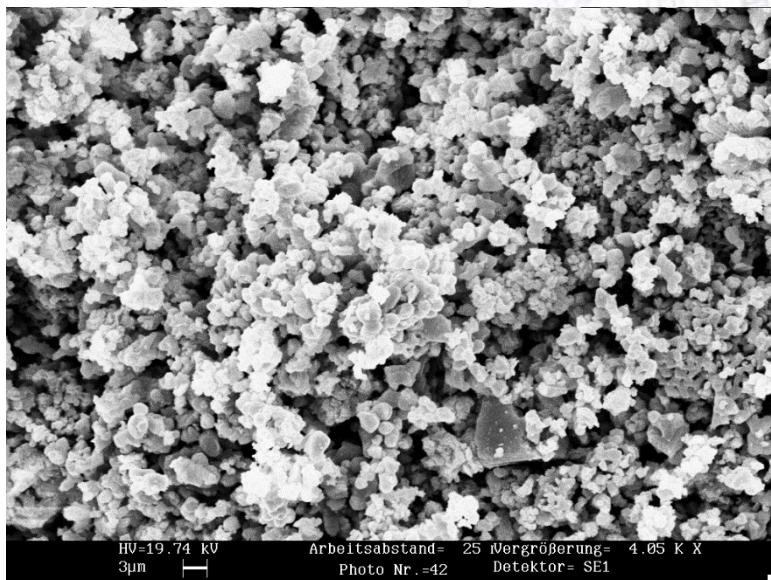
**Wherfrom comes the difference**

## Special conditions of spray absorption

### 1. The surface- structure of the lime which was injected as lime slurry

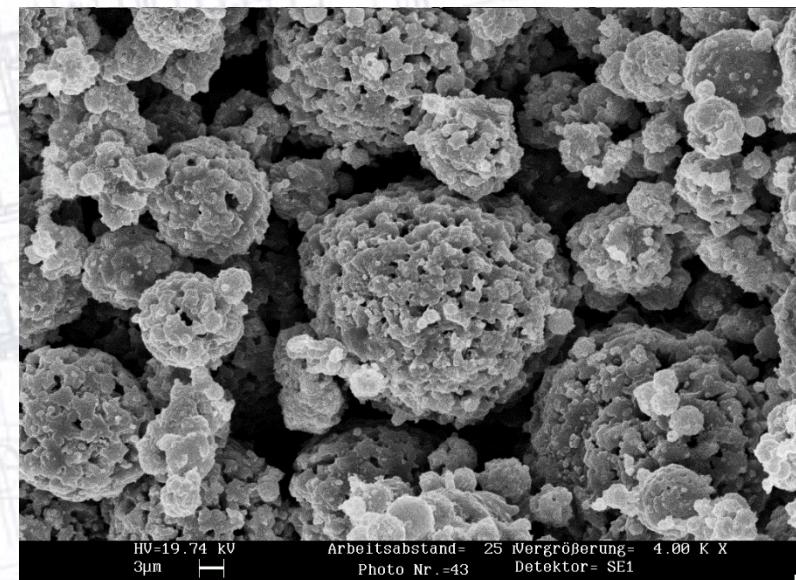
The necessary reaction surface is reduced in respect of the agglomeration, which occur during the evaporation of the lime slurry

fresh hydrated lime



$\text{Ca}(\text{OH})_2/\text{CaCO}_3$  from a wte

spray absorption system with lime slurry



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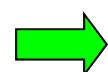
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## Special conditions of spray absorption

### 2. High carbonate content / low residence time at a liquid phase

lime slurry has a very alkaline milieu

Schadstoff	Einheit	CO <sub>2</sub>	HCl	SO <sub>2</sub>	HF
Rohgaskonzentration	[Vol.-%]	10			
	[mg/m <sup>3</sup> _N RG,tr.]		1.000	300	10
Molekülanzahl	[mol/m <sup>3</sup> _N RG,tr.]	4,492	2,74·10 <sup>-2</sup>	4,68·10 <sup>-3</sup>	5,00·10 <sup>-4</sup>
Molekülverhältnis	[mol/mol HF]	8.987	55	9	1



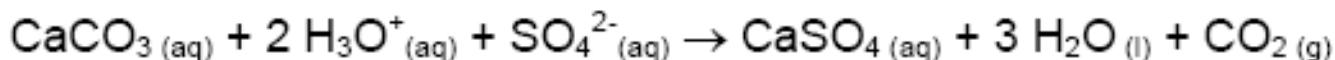
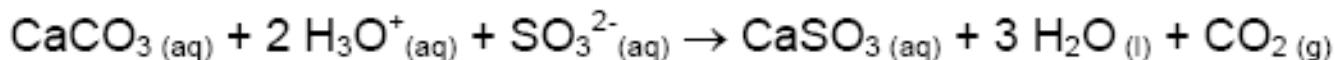
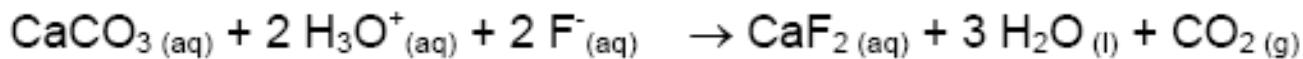
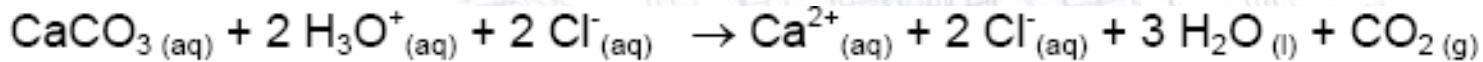
Formation of a high amount of carbonates

## Special conditions of spray absorption

### 2. High carbonate content / low residence time at a liquid phase

In a dry condition calcium carbonate is relatively inert (limestone) based on a high lattice energy and a compact surface structure.

In an acid milieu the carbonates decompose by elimination of CO<sub>2</sub>. Therefore reactions with the acid pollutants HCl, HF und SO<sub>2</sub> will take place in a liquid phase.



→ If calcium carbonate exists as long as possible in a solution (slurry), the separation efficiency will increase

## Special conditions of spray absorption

### 2. High carbonate content / low residence time at a liquid phase

*at fossil power station*

- process temperature  $\sim 80 \text{ }^{\circ}\text{C}$
- relative humidity  $\sim 70\%$



Long residence time

*at waste to energy plants*

- process temperature of  $135 - 160 \text{ }^{\circ}\text{C}$
- relative humidity of 4 -7%

## Optimizing capability

### Substitution of Spray Absorption by a simple cooling tower

- Comparison of operation costs

#### flue gas composition

- flue gas stream	<b>9,322 SCFM wet</b>
- HCl	<b>631 ppm</b>
- SO <sub>2</sub>	<b>105 ppm</b>
- HF	<b>22 ppm</b>
- H <sub>2</sub> O	<b>15 Vol.%</b>

## Optimizing capability

### Substitution of Spray Absorption by a simple cooling tower

- Comparison of operation costs  
operating resource consumption

Operation costs	Unit	Cond. dry absorption	Spray absorption
<b>Operation resource consumption</b>			
Lignite coke	kg/h	12	12
Activated coke	kg/h	0	0
Ca(OH) <sub>2</sub>	kg/h	235	157,3
CaO	kg/h		119
Water	m <sup>3</sup> /h	4,98	4
Pressurised air	m <sup>3</sup> /h	800	800
<b>Electrical Power</b>			
Consumer	kWh/h	110	150
ID fan	kWh/h	170	170
<b>Residues</b>			
	kg/h	513	611

## Optimizing capability

### Substitution of Spray Absorption by a simple cooling tower

#### - Comparison of operation costs

Lignite coke	\$/t	287,5
Activated coke	\$/kg	2,7
CaO	€/t	101,9
Ca(OH) <sub>2</sub> (18 m <sup>2</sup> /g)	\$/t	101,9
Ca(OH) <sub>2</sub> (40 m <sup>2</sup> /g)	\$/t	192,4
Water	\$/m <sup>3</sup>	0,6
Pressurised air (bei 8 bar)	\$/m <sup>3</sup>	0,1
Electrical power	\$/kWh	0,1
Residues	\$/t	135,8

The prices are based on German market

## Optimizing capability

### Substitution of Spray Absorption by a simple cooling tower

#### - Comparison of operation costs

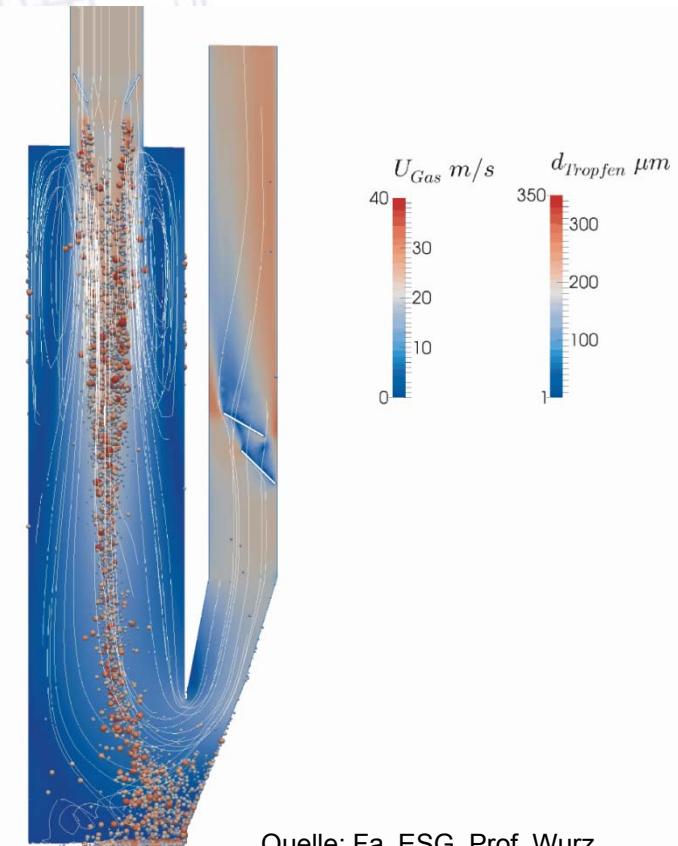
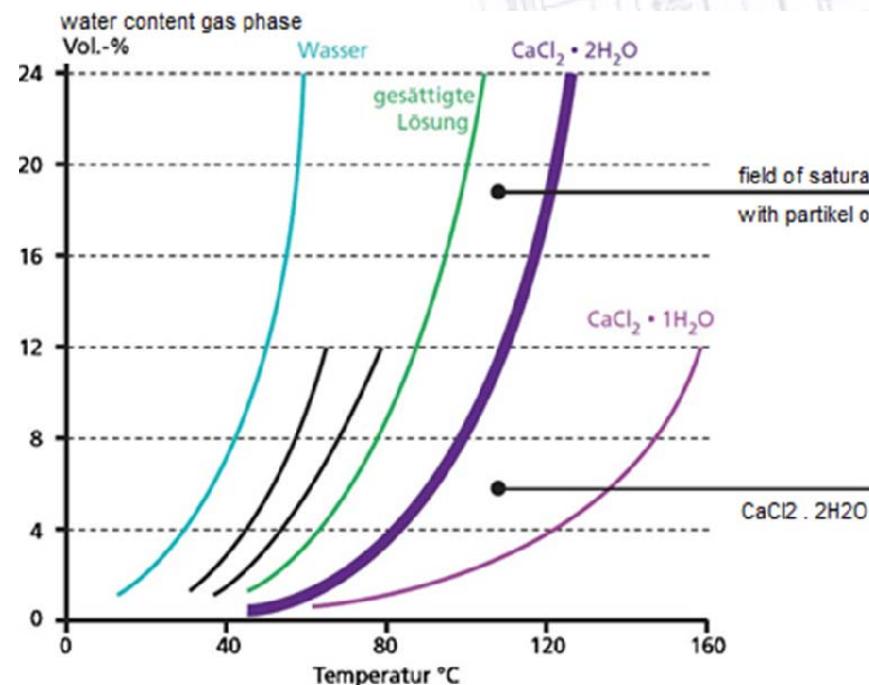
Operation costs	Unit	Cond. dry absorption	Spray absorption
Lignite coke	\$/h	3,4500312	3,4500312
Activated coke	\$/h	-	-
Ca(OH) <sub>2</sub>	\$/h		12,122649
CaO	\$/h	23,939685	30,268138
Water	\$/h	2,818431	2,501499
Pressurised air	\$/h	61,57536	61,57536
Electrical power	\$/h	18,382056	21,008064
Residues	\$/h	69,679764	82,990908
Sum operation cost	\$/h	179,84759	213,91778
Difference	\$/h	0	34,081509
Difference	%	0	18,95
Annual costs at 8000 h/a	\$/a	1.438.740	1.711.351
Difference	\$/a	-	272.611

## Optimizing capability

### Substitution of Spray Absorption by a simple cooling tower

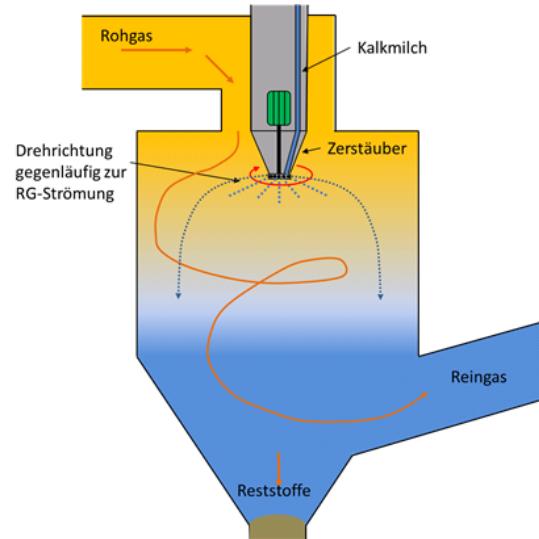
#### - SO<sub>2</sub>-Separation

#### Section of phase diagram CaCl<sub>2</sub>/H<sub>2</sub>O



Quelle: Fa. ESG, Prof. Wurz

## Rotary atomizer



Source: Lechler

Droplet size  
depend of

- 1) The material properties of the injected fluid:

$$\text{Material consistency} \quad \rho \text{ [kg/m}^3\text{]} \rightarrow \rho^t \sim D$$

$$\text{Surface tension} \quad \sigma \text{ [kg/s}^2\text{]} \rightarrow \sigma^s \sim D$$

$$\text{Dynamic viscosity} \quad \eta \text{ [Pa s]} \rightarrow \eta^r \sim D$$

- 2) The process oriented construction and mode of operation

$$\text{Revolution} \quad n \text{ [1/min]} \rightarrow n^p \sim D$$

$$\text{Diameter of the rotary atomizer} \quad d \text{ [m]} \rightarrow d^{-u} \sim D$$

$$\text{Mass flow} \quad \dot{m} \text{ [kg/h]} \rightarrow \dot{m}^q \sim D$$



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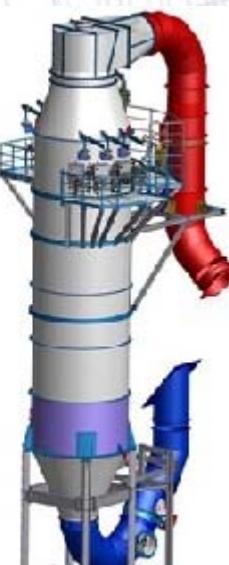
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## Dual media nozzles

The pressure of the pressurized air ( $\Delta p$ ) is proportional to the kinetic energy and only a small part of the pressure energy is used for overcoming the shear force of the surface tension.

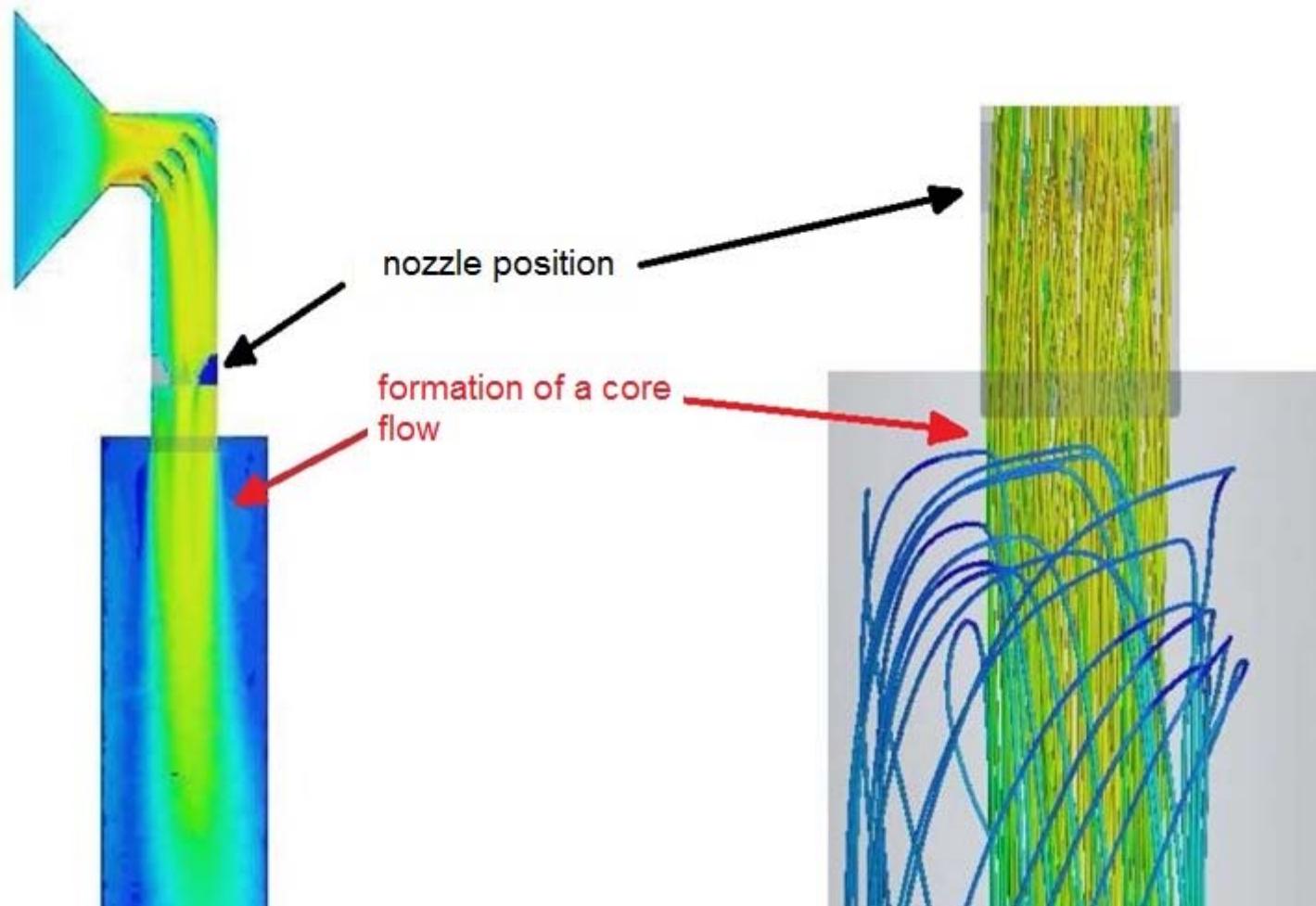


Quelle: Lechler



$$v_{Tr} = 0,88 \cdot \sqrt{\frac{2 \cdot \Delta p}{\rho_L}}$$

## Substitution of Spray Absorption by a simple cooling tower



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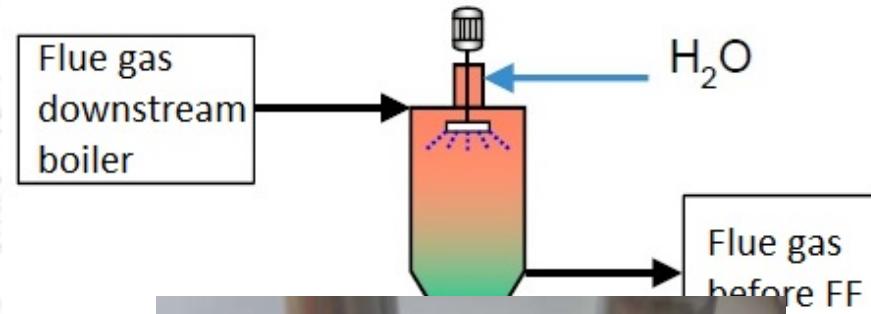
## Experience with the Substitution of Spray Absorption by a simple cooling tower at MHKW (wte) Wuppertal



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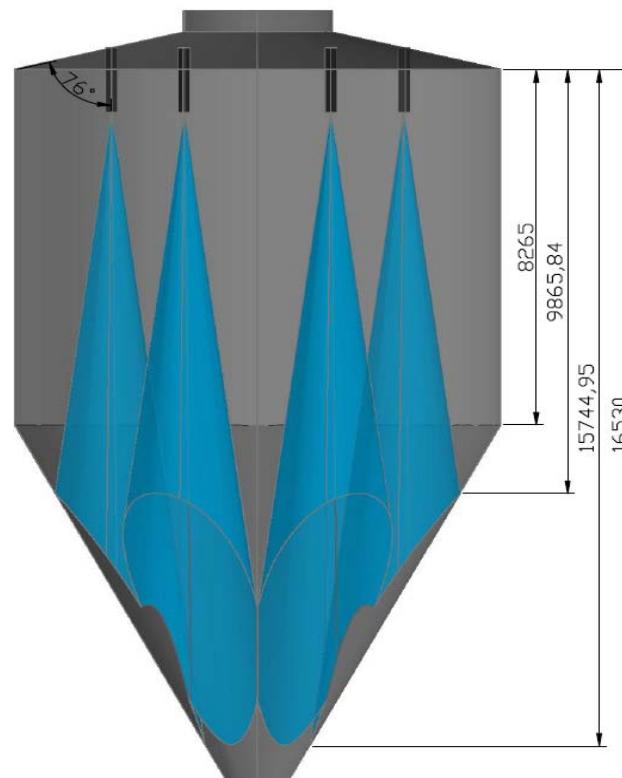
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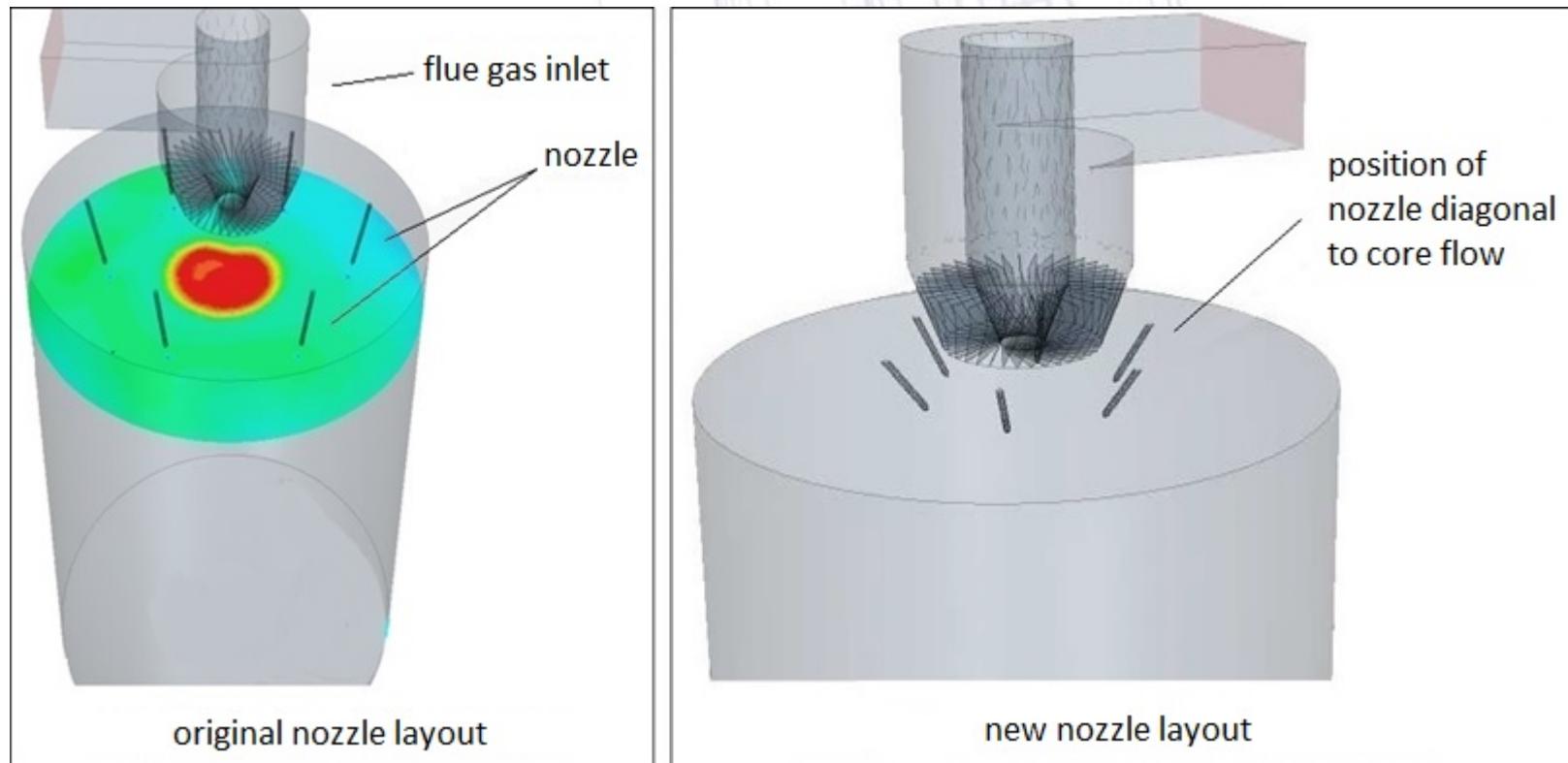
## Experience with the Substitution of Spray Absorption by a simple cooling tower at MHKW (wte) Wuppertal

### What can be done?

The customer investigate with a support by Lechler to substituted the rotary atomizer by dual media nozzles.



## Experience with the Substitution of Spray Absorption by a simple cooling tower at MHKW (wte) Wuppertal



## Conclusion

- a change from a spray absorption system to a pure cooling tower operation is in either case possible in consideration of the presented aspects
- a main focus should be on the fluid flows, droplet sizes and the residence time
- MHKW Wuppertal could realize a electricity savings of 75 kW only by the substitution of the rotary atomizer by dual media nozzles



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## Conclusion

- Spray absorption in waste incineration is not so effective and economical
  - ➡ the retrofit/optimization to a conditioned dry absorption system need not so significant modifications
- the substitution have two significant advantages
  - Save and good SO<sub>2</sub>-separation
  - Saving of operation costs of ~270,000 US \$ per anno  
(based on German price conditions)

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**Thank you for your attention**



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