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LUAT

Lehrstuhl für Umweltverfahrens-technik und Anlagentechnik

Univ.-Prof. Dr.-Ing. habil. Klaus Görner

Course

Waste to Energy and Recovered Materials from Waste

Helsinki University of Technology

30.01.-01.02.2008

Espoo, Finland

Folie 1

Thermal Treatment of Wastes in Practice

Klaus Görner

Univ.-Prof. Dr.-Ing. habil.

Environmental Process Engineering and Plant Design LUAT

University of Duisburg-Essen, Germany

Course

Waste to Energy and Recovered Materials from Waste

30th January - 1st February 2008

Helsinki University of Technology

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Folie 2

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Chair of Environmental Process Engineering and Plant Design

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Surrounding Area

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Networks

University of Duisburg-Essen

Structure 00-01

more Details 00-02

Energy research Ruhr ef.Ruhr

Organisation and Topics 00-03

Projects 00-04

CC Coal and Power Plants 00-00

CC Biomass and Wastes 00-00

Competence Net Work Power Plant Technology NRW 00-00

Technology Transfer

General 00-90

InPro-Consult 00-91

Other 00-00

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Pictures 00-09

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Working Areas

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Working Areas

Power Plant Technology
- thermodynamic system analysis, carbon capture technologies

Combustion Technology
- Coal, Gas, Special fuels

Thermal Treatment of Biomass and Wastes
- Municipal wastes, Biomass, Special wastes

Gas cleaning
- Dust removal, De-SOx, De-NOx, Removal of trace elements

Process Technology
- Particle generation, Calcination in cement industry, chemical processes

Plant Technology
- CFD-Simulation (FLUENT®)
- Process-Identification by Neural Nets (Process Insights®)

Environmental Management
- Mass and energy flow management (Umberto®)
- DIN ISO 14001

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Power Plant Technology 01

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Power Plant System Analysis

Thermodynamic Analysis 01-00
Cycle Analysis (Flow sheeting) 01-02

Studies

Power Plant Concepts (overview)..... 01-50
Power Plant Concepts (RKW NRW – BOA) 01-51
Thermal Processes (Geothermal PP, ..) 01-52

Carbon Capture and Storage

Post-Combustion Carbon Capture 01-10
Cycle Analysis (Flow sheeting) 01-11

Modelling and Simulation

Flame and Furnace Simulation (see Combustion Techn.) 02-00
Simulation of Flue Gas Cleaning (see Gas Cleaning) 04-00
Slagging and Fouling 01-60

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Combustion Technology

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Combustion Technology 02

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Modelling and Simulation

Mathematical Modelling (CFD) 00-20
Flow Model 00-00
Reaction Model 00-21
Heat Transfer Model 00-00

Simulation Studies

Natural Gas Combustion 02-01
CO Gas Combustion 02-02
Special Waste Vombustion 02-07
Hard Coal Cpmbustion 02-04
Brown Coal Combustion 02-05
Pre-dried Brown Coal Combustion 02-06
Petrol Char Combustion 02-09
$TiCl_4$-Erhitzer 02-08

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Gasification Technology

Gasification Technology 02

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Gasification

Puertollano / Spain
300 MW IGCC-Demo-Plant
Source: Siemens

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Modelling and Simulation

Mathematical Modelling (CFD) 00-10
Flow Model 00-00
Reaction Modell (Gasification Reactions) 00-30
Heat Transfer Modell 00-00

Technology

Coal Gasification 02-50
Reaction Modelling 02-51
Influence of Swirl 02-52

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Process Technology

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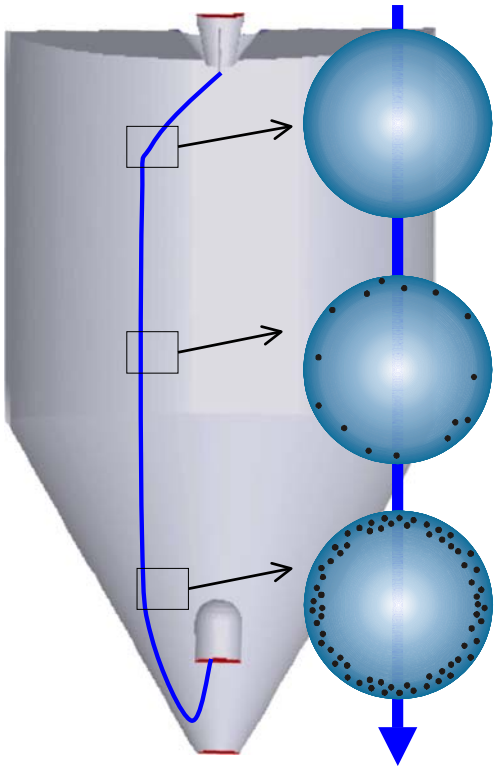

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Process Technology 05

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Modelling and Simulation

Calcinating – Process and Models 05-20
Spray Drying – Basics / Models 05-00
Chem. Reactor – Basics / Models 05-21

Applications

Calcinator in the Cement Industry 05-01
Spray Dryer in the Food Industry 05-02
Stirred Reactor in the Chem. Industry 05-07

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Gas Cleaning

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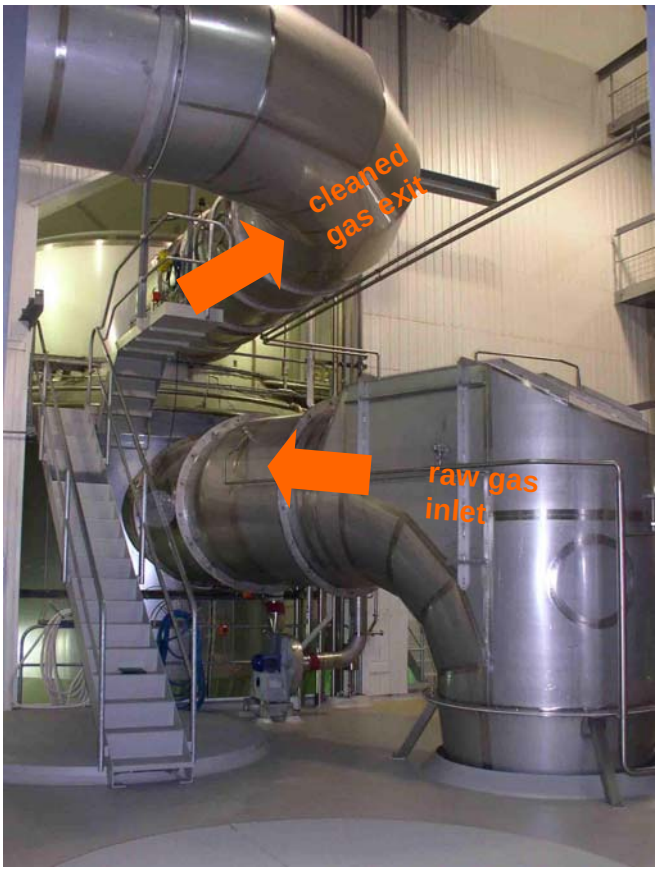

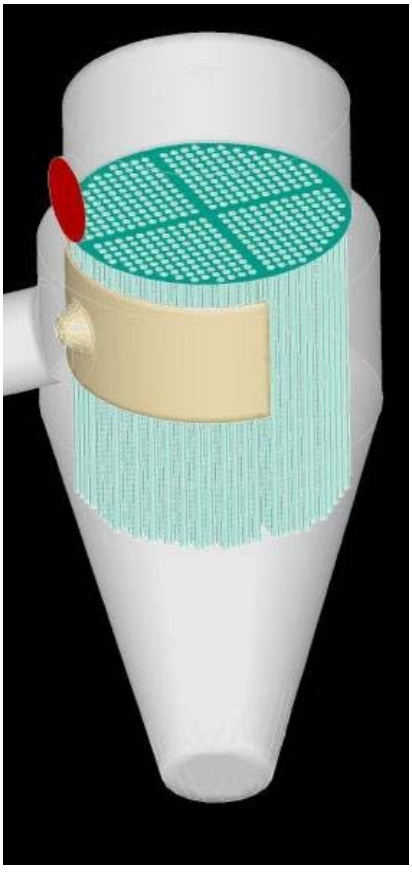

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Modelling and Simulation
- Mathematical Modellig (CFD) 00-20
- Empirical Modelling 00-00

Applications
- Bag Filter 04-21
- Cyclone 04-00

Experimental Rigs
- Determination of Pressure Losts 04-01
- Electrical Resistance 04-02
- Hot Gas Filtration 04-07

Experimental Results
- Bag Filter 04-04
- Cyclone 04-05

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Thermal Waste Treatment

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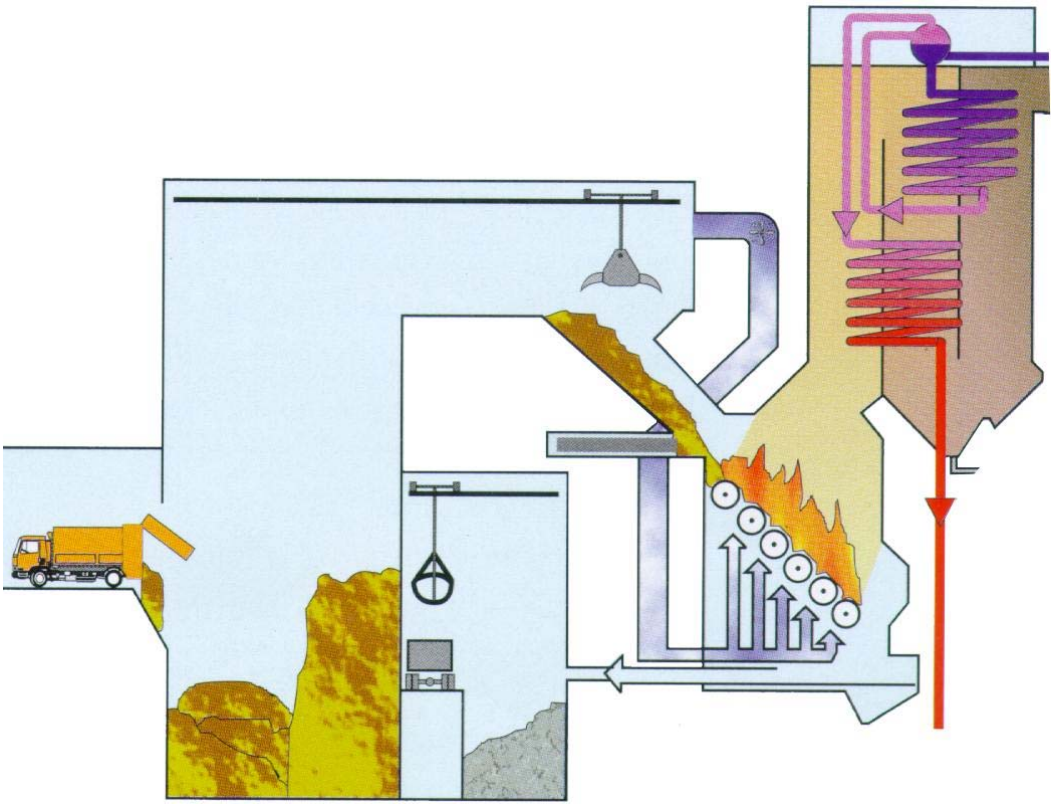
Thermal Waste Treatment Plant



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Waste throughput:
260.000 t/year

Products:
40.000 MWh Electricity
500.000 MWh Heat
6.000 t Scrap iron metal
60.000 t Slag, ash, filter cakes

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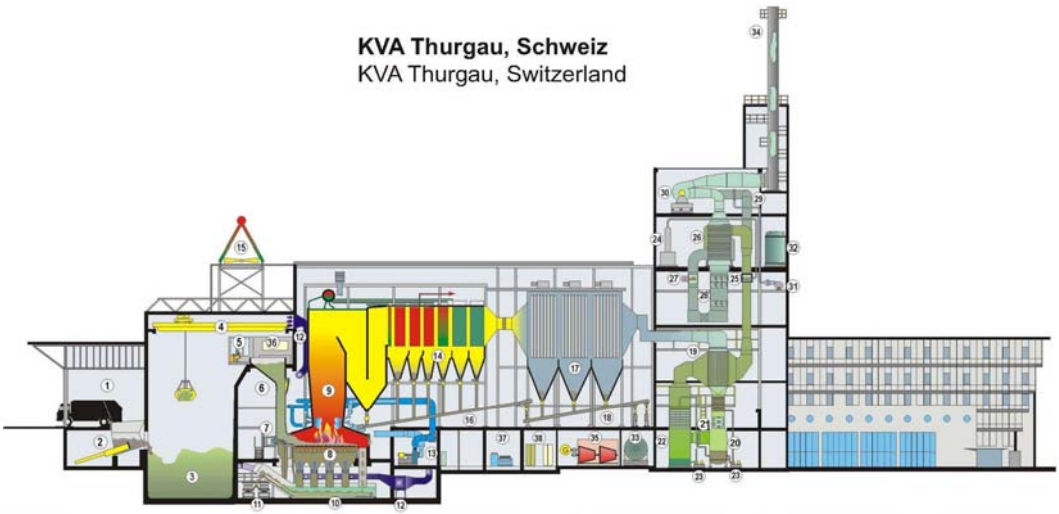
KVA Thurgau, Schweiz
KVA Thurgau, Switzerland



Technische Daten									
Jahresdurchsatz ca.:	120'000 t	1 Entladehalle	8 MARTIN Horizontal-Rost	16 Flugaschetransport (Kessel)	24 NH_4OH-Sprühverdampfer	32 Notwassertank
Anzahl Verbrennungslinien:	2	2 Sperrmüllschere	9 Feuerraum	17 Elektrofilter	25 NH_4OH-Eindüsung	33 Abwasserstapeltank
Verbrennungsleistung pro Linie:	8 t/h	3 Abfallbunker	10 Stösselentschlacker	18 Flugaschetransport (E-Filter)	26 Gas-/Gas Wärmetauscher	34 Kamin
Thermische Leistung pro Linie:	28 MW	4 Krananlage	11 Schlackenband	19 Gas-/Gas Wärmetauscher	27 Kanalbrenner	35 Turbine / Generator
Dampfleistung pro Linie:	31 t/h	5 Kranführerkabine	12 Primärluftsystem mit Luvo	20 Saurer Wäscher	28 DeNOx-Katalysator	36 Kontrollraum
Dampfdruck:	43 bar	6 Einfülltrichter	13 Sekundärluftsystem	21 Tropfenabscheider	29 DeNOx-Bypass	37 Notstromaggregat
Dampftemperatur:	400 °C	7 Beschickung	14 Dampfkessel	22 Basischer Wäscher	30 Saugzug	38 NS-/MS-Schaltanlage
			15 Luftkondensationsanlage	23 Wäscherpumpen	31 Spenluftgebläse	
Technical data						
Annual throughput approx.:	*120,000 t*	*1 Tipping hall*	*8 MARTIN horizontal grate*	*15 Air-cooled condenser*	*23 Scrubber pumps*	*31 Sealing air fan*
Number of lines:	*2*	*2 Bulky waste cutter*	*9 Furnace*	*16 Fly ash transport (boiler)*	*24 NH_4OH-spray evaporator*	*32 Emergency watertank*
Waste capacity per line:	*8 t/h*	*3 Waste bunker*	*10 Ram-type discharger*	*17 Electrostatic precipitator*	*25 NH_4OH-Injection*	*33 Waste water storage tank*
Thermal capacity per line:	*28 MW*	*4 Waste crane*	*11 Bottom ash conveyor belt*	*18 Fly ash transport (electr. prec.)*	*26 Gas/gas heat exchanger*	*34 Stack*
Steam output per line:	*31 t/h*	*5 Crane control cabin*	*12 Underfire air system with air preheater*	*19 Gas/gas heat exchanger*	*27 Duct burner*	*35 Turbine / Generator*
Steam pressure:	*43 bar*	*6 Feed hopper*	*13 Overfire air system*	*20 Wet scrubber (acidic)*	*28 DeNOx catalytic converter*	*36 Control room*
Steam temperature:	*400 °C*	*7 Feeder*	*14 Steam boiler*	*21 Droplet separator*	*29 DeNOx-bypass*	*37 Emergency power unit*
				22 Wet scrubber (alkaline)	*30 ID fan*	*38 Switch gear LV/MV*

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Topics

- Legislation (EU) 03-100
- State of the Art 03-200
- Watercooled grate 03-210
- Mathematical Modelling 00-300
- Model Validation 00-310
- Secondary Air Injection 03-400
- Corrosion 03-500
- Refractory Lining 03-600
- Advanced Control 03-800
- Decentralized Concepts 03-900

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Thermal Waste Treatment 03

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Experimental Rigs

- Field Pipe Reactor 00-20
- Micro-MWI 00-00
- MARS® Plant 00-21
- Real MWI 00-00

Experimental Results

- Field Pipe Reactor 03-01
- Micro-MWI 03-02
- MARS® Plant 03-07
- MARS® Plant (PowerGen) 03-04

Contact

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End

thank you
for
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Thermal Waste Treatment Plants

Waste Management Legislation

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Thermal Waste Treatment – Waste Management Legislation

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Thermal Waste Treatment – EU-27 Countries

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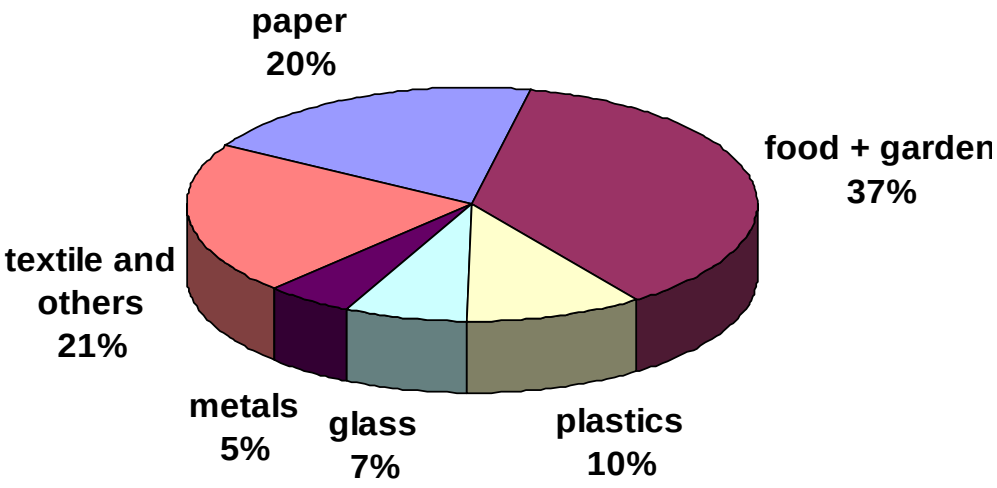
Estimated mean composition of the municipal waste in the EU15 countries



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Thermal Waste Treatment – Waste Management Legislation

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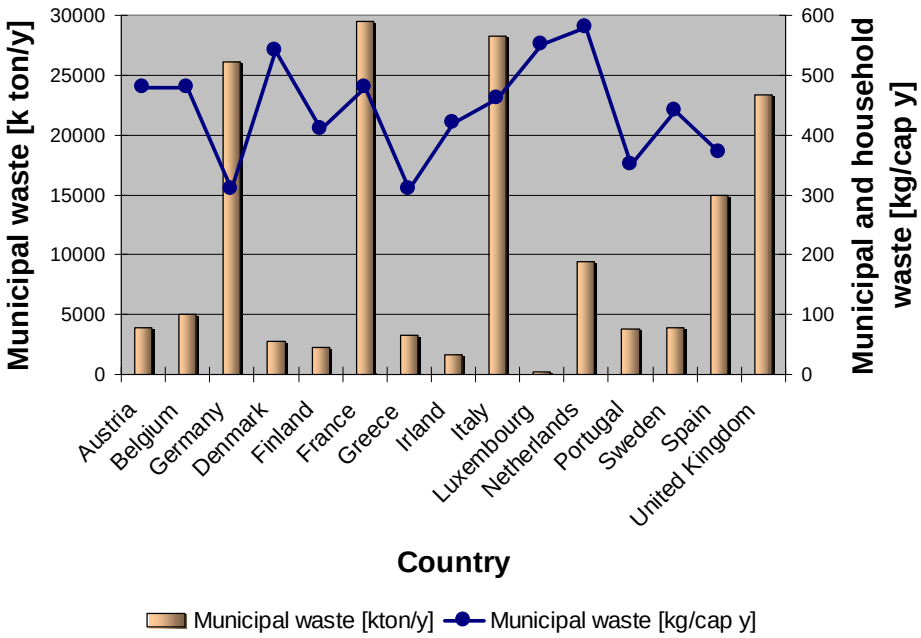
Amount of municipal waste in the EU15 countries



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Number of Municipal Waste Incineration Plants
with energy recovery in the EU15 countries (1993)

country	numb.	capacity [1000 Mg/y]
Austria	2	340
Belgium	24	2240
Germany	49	12020
Denmark	30	2310
Finland	1	70
France	225	11330
Greece	0	-
Ireland	0	-

country	numb.	capacity [1000 Mg/y]
Italy	28	1900
Luxembourg	1	170
Netherland	10	3150
Portugal	0	
Sweden	2115	1860
Spain	315	740
United Kingdom	31	3670

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Thermal WasteTreatment – Waste Management Legislation

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Operation conditions
for municipal waste incineration plants

Temperature	
in the after-burning chamber	
for municipal wastes	> 850 °C
for hazardous wastes	> 1,100 °C

Residence time	
in the after-burning chamber	> 2 sec

Level of incineration	
as total organic carbon TOC	< 3 %
as loss on ignition	< 5 %

Emissions	
see next table	

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Emission values
for municipal waste incineration plants

species	emissions limits in mg/m³		
	EU-standards 2005	ARN Nether-lands (1989)	BImSchV Germany (1990/ 1999)
dust	10	5	10
TOC	10	10	10
HCl	10	10	10
HF	1	1	1
SO_2	50	40	50
NO_X	200/400	70	200

species	emissions limits in mg/m³		
	EU-standards 2005	ARN Nether-lands (1989)	BImSchV Germany (1990/ 1999)
NH_3	10	5	-
CO	50	50	50
Cd+Tl	0,05	0,05	0,05
Hg	0,05	0,05	0,05/ 0,03
metals	0,5	1	0,5
dioxins +furans	0,1 ng TE/m³	0,1 ng TE/m³	0,1 ng TE/m³

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	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Municipal waste incinerated (kg per capita)											
EU (27 countries)	65	66	70	71	76	79	82	85	85	88	91
EU (25 countries)	69	70	75	76	81	84	87	90	91	94	97
EU (15 countries)	82	83	88	89	95	99	102	106	106	110	113
Municipal waste landfilled (kg per capita)											
EU (27 countries)	296	290	288	285	288	289	279	271	257	243	233
EU (25 countries)	294	290	292	286	287	286	277	267	253	238	227
EU (15 countries)	293	285	286	280	281	280	275	264	249	234	221

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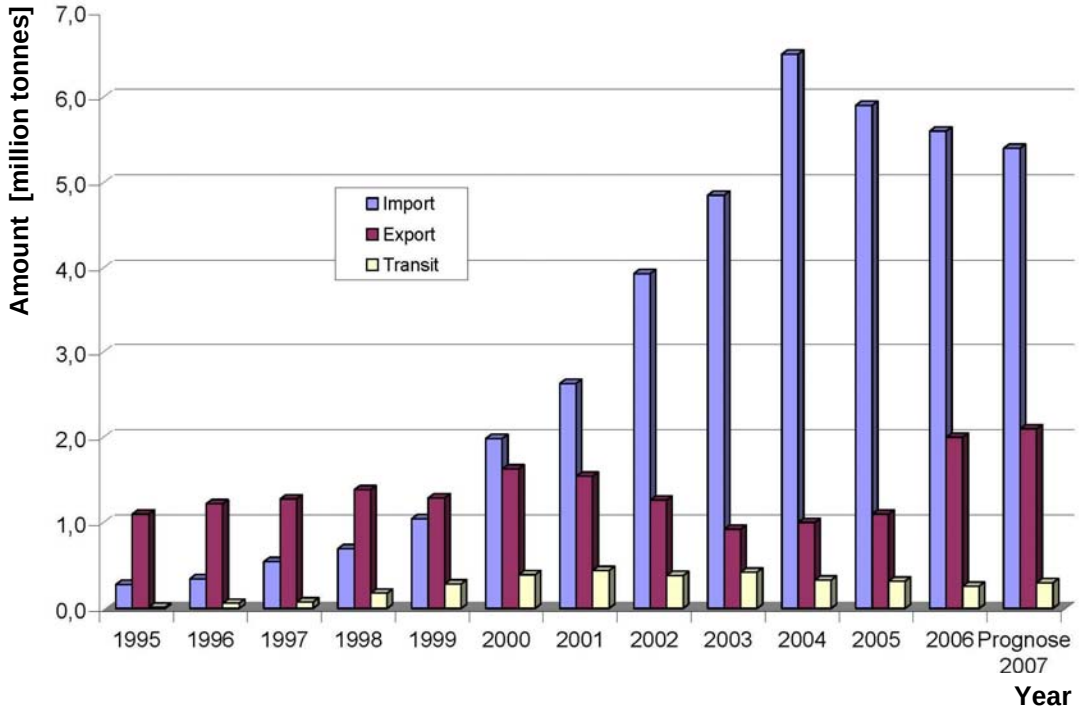
Waste Import, Export and Transfer in Germany
for municipal waste



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Thermal Waste Treatment Plants

State of the Art

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Typical Parameters of Waste

- Lower calorific value (LCV)
- Content of combustibles (B)
- Content of water (W)
- Content of non-combustibles (Ash, A)
- Content of polutants
- Particle size and distribution
- Slag melting behaviour
- Bulk density of the waste layer on the grate
- Flow resistency of the waste layer on the grate

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Proximat and Elementary Analysis

Proximat Analysis

- Content of water (W)
- Content of volatile material (VM)
- Content of combustible material (B)
- Content of ash (non-combustible material, A)

Elementary Analysis

- Carbon (C)
- Hydrogen (H)
- Oxygen (O)
- Nitrogen (N)
- Sulfur (S)

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Thermal Waste Treatment – Waste Qualities

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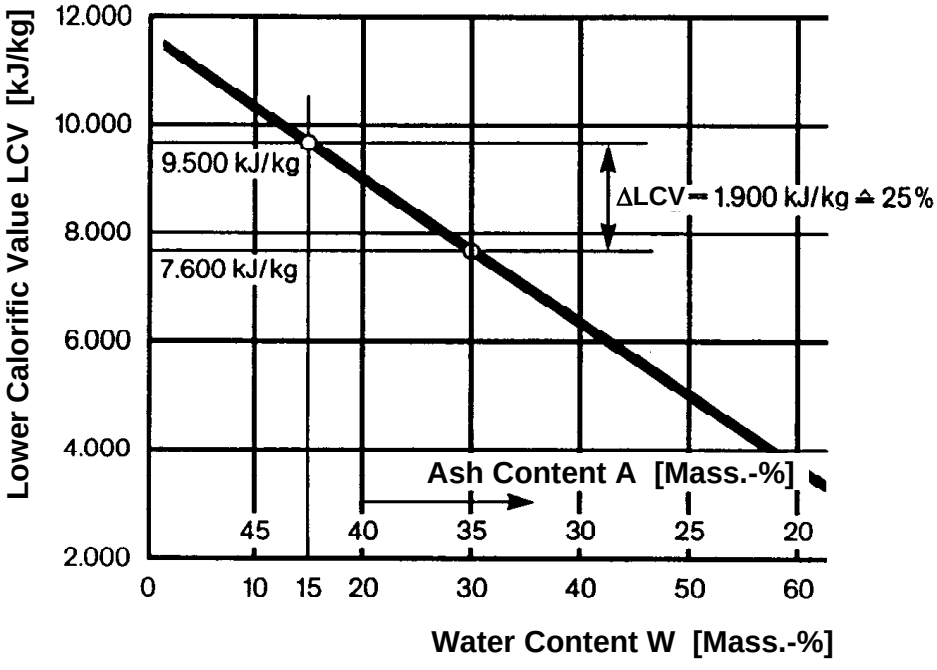
Influence of the water content on the Lower Calorific Value



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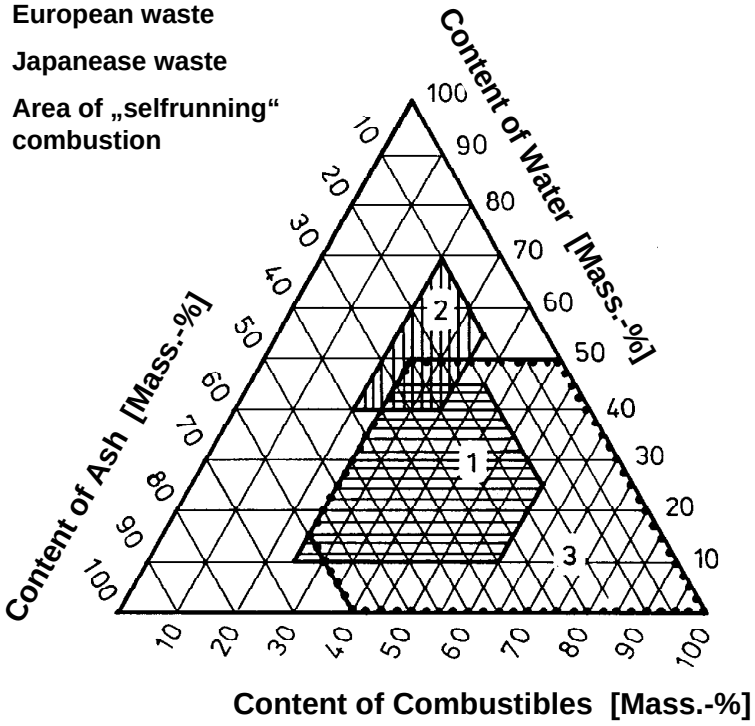
Combustion Triangle and Area of „Self-running“ Combustion

1 European waste
2 Japanease waste
3 Area of „selfrunning“ combustion



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Thermal Waste Treatment – Waste Treatment Processes

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Course
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„Hot“ Processes

Combustion Processes
- Grate firing processes
- Fluidizes bed firing processes
- Rotary kiln processes (special wastes)

Pyrolysis and Gasification Processes for an Energetic Usage
- Big number of processes

Pyrolysis and Gasification Processes for a Matarial Usage
- Big number of processes

„Cold“ Processes

Composting
- for a product compost
- for conditioning to landfill

Fermentation

Landfill

Landfill for Household Wastes
Landfill for Special Wastes

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Zones on the Grate and ongoing Processes

Drying Zone

- Temperature < 100°C
- Water content of the waste 30-40 %
- Vaporisation enthalpie 2260 kJ/kg

Pyrolysis / Gasification Zone

- Production of gases :
  - Hydrocarbons (gaseous)
  - Tars
- Production of resiual matarials:
  - Fixed Carbon (ignition temperature 750-800 °C)
  - Unburnable Material

Main Combustion Zone

- Main reactions

$$C + O_2 \rightarrow CO_2$$
$$C + CO_2 \rightarrow 2CO$$
$$C + 1/2O_2 \rightarrow CO_2$$
$$H_2 + 1/2O_2 \rightarrow H_2O$$

Burnout Zone

- Unburnt carbon < 3 bzw. 5 %
- Residence time (total) 0,75 - 1,5 h

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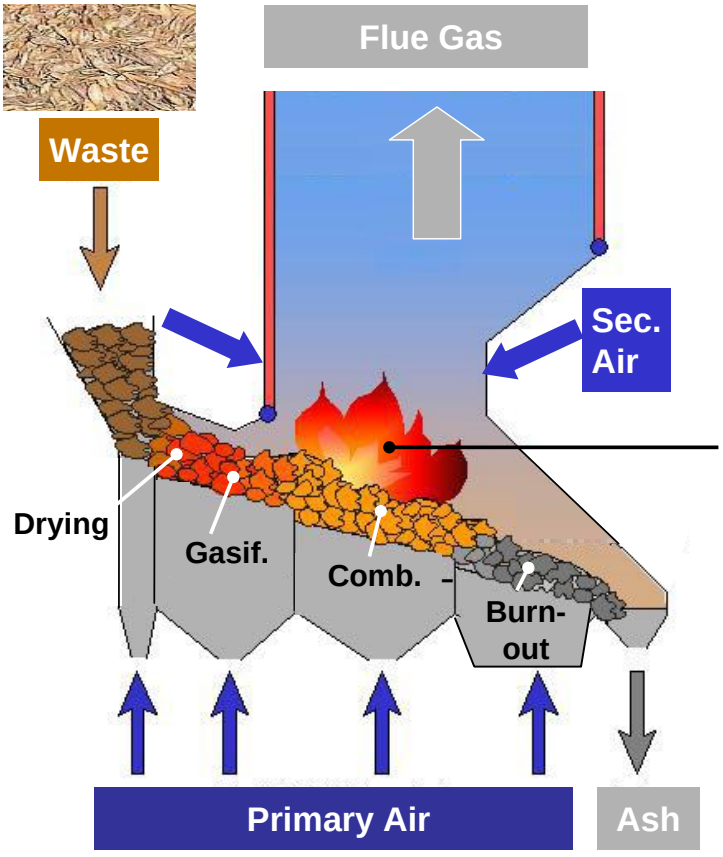

Main Combustion

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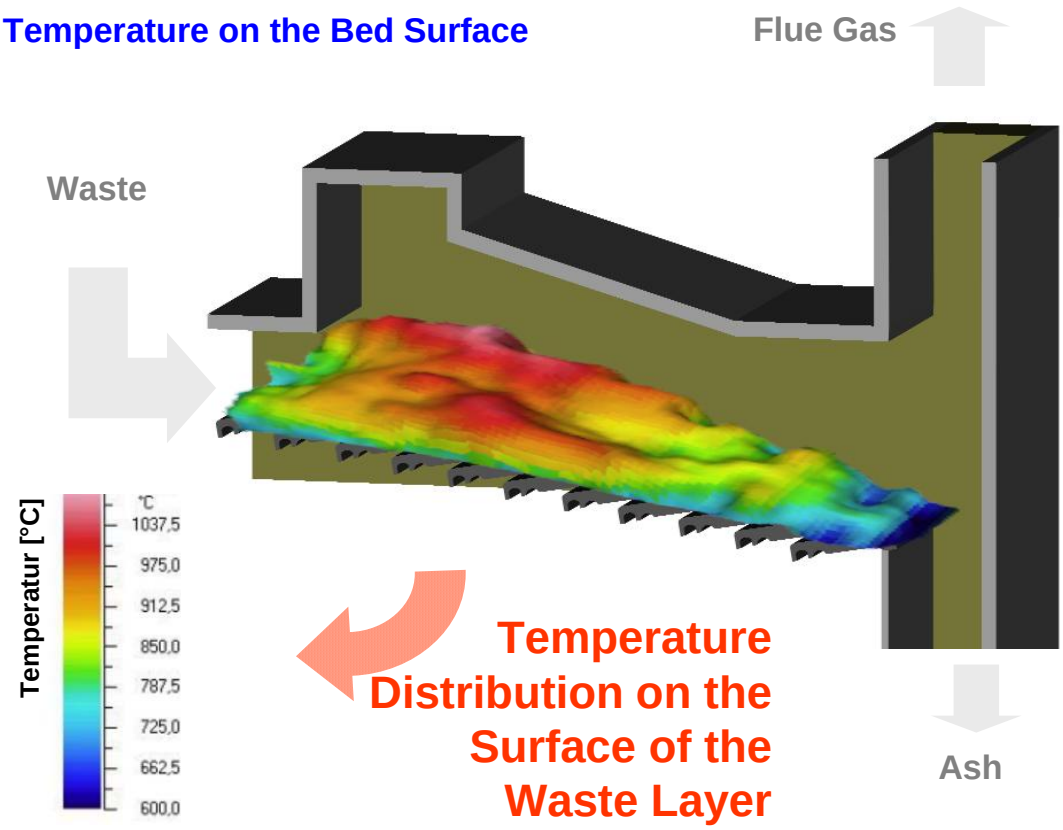
Temperature on the Bed Surface



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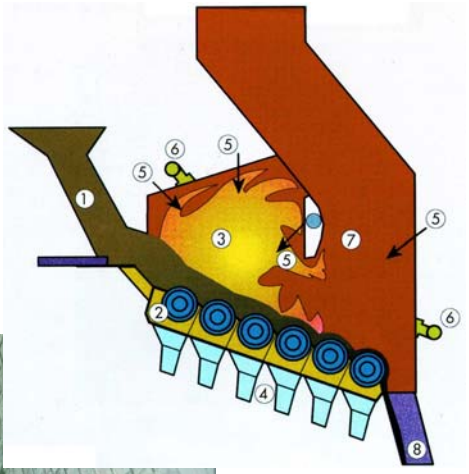
Roller Grate System



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Thermal Waste Treatment – Waste Treatment Plants

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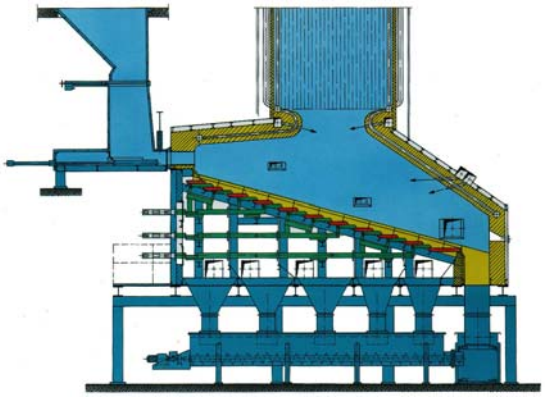
Forward Reciprocating Grate System



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Constructive Factors of Influence

- Geometry of furnace and boiler (parallel, counter, center flow)
- Grate firing system (roller grate, forward reciprocating grate, backward reciprocating grate, combinations)
- Cooling of grate bars (air or water cooled)
- Secondary air injection (nozzle arragement, distance, diameter)
- Flue gas recirculation to primary air
- Flue gas recirculation to secondary air
- Wall insulation concept (material, thickness, partial areas)
- Radiational pass insulation concept (material, thickness, partial areas, cladding)

Operational Factors of Influence

- Primary to secondary air ratio
- Primary air distribution to grate distribution zones
- Secondary air distribution to front/rear wall nozzles
- Air preheating (primary and secondary air)
- Flue gas recirculation to primary and/or secondary air

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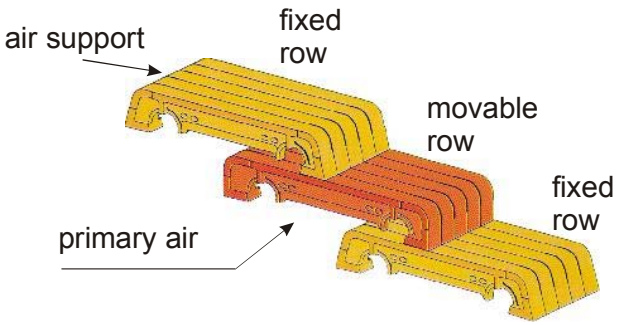
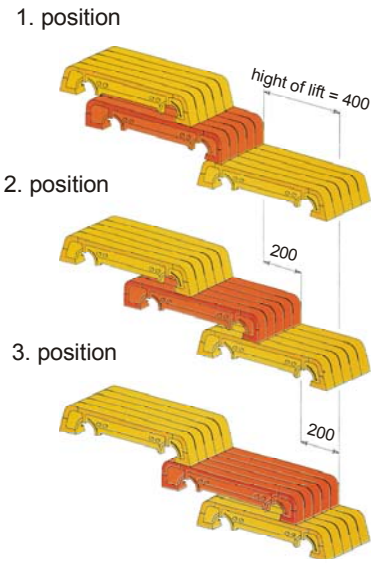
Forward Reciprocating Grate System (schematic)
for municipal waste incineration plants

grate bars (air cooled)



grate movement



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Forward Reciprocating Grate system (schematic)
for municipal waste incineration plants

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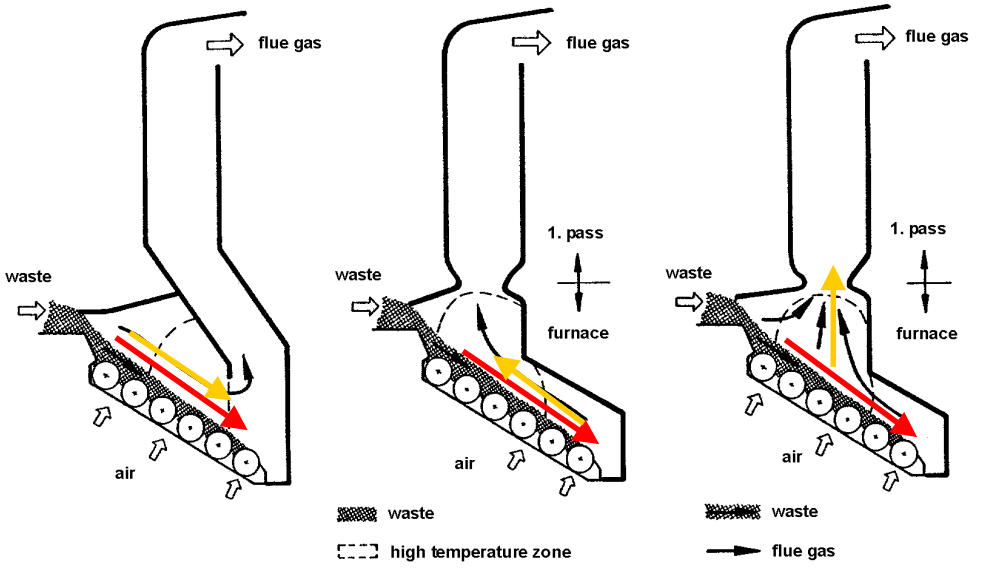
Furnace Geometries (schematic)
for municipal waste incineration plants



parallel flow | counter flow | center flow

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Advantages and Disadvantages of the different furnace geometries

parallel flow	counter flow	center flow	
pyrolysis gases pass the hottest area and therefore are burnt out suitable for lower LCV	energy transfer from main combustion area to the drying and gasification area suitable for higher LCV	very flexible for different heat release distributions on the grate suitable for a wider range of LCV	**advantages**
energy transfer from main combustion area to ignition area just by radiation	pyrolysis gases can bypass the hottest area and may cause burnout problems	flow and mixing pattern after the passage to the 1. pass sensible to disturbances	**disadvantages**

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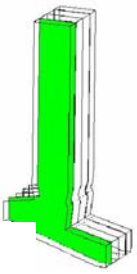
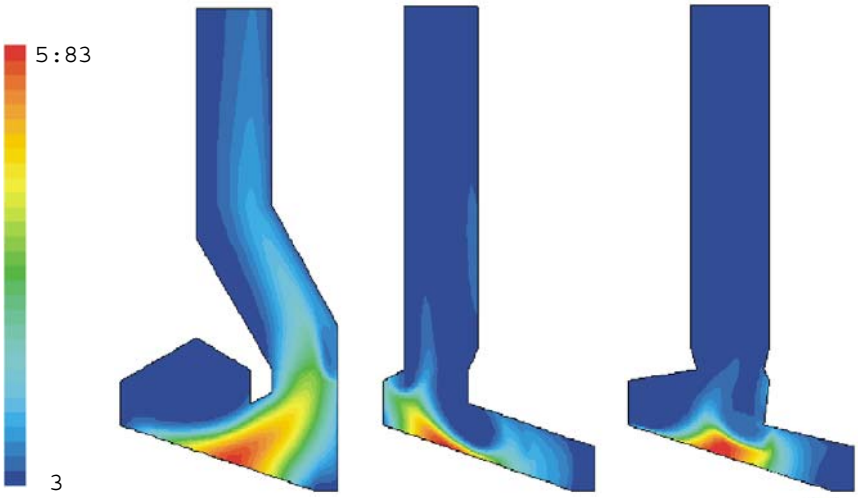
Influence of the Furnace Geometry

CO-concentration [mg/m³]





parallel flow firing | counter flow firing | center flow firing

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Influence of the Furnace Geometry

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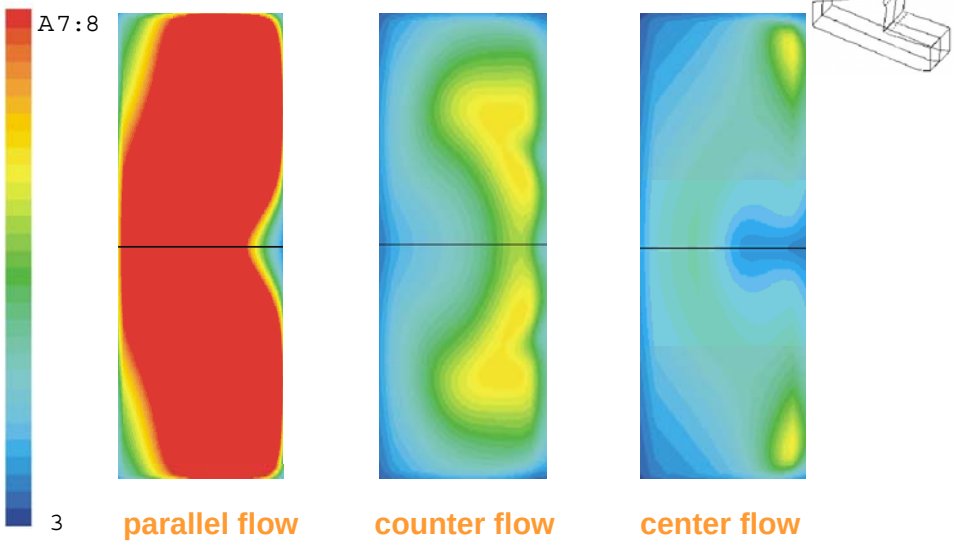

parallel flow firing | counter flow firing | center flow firing

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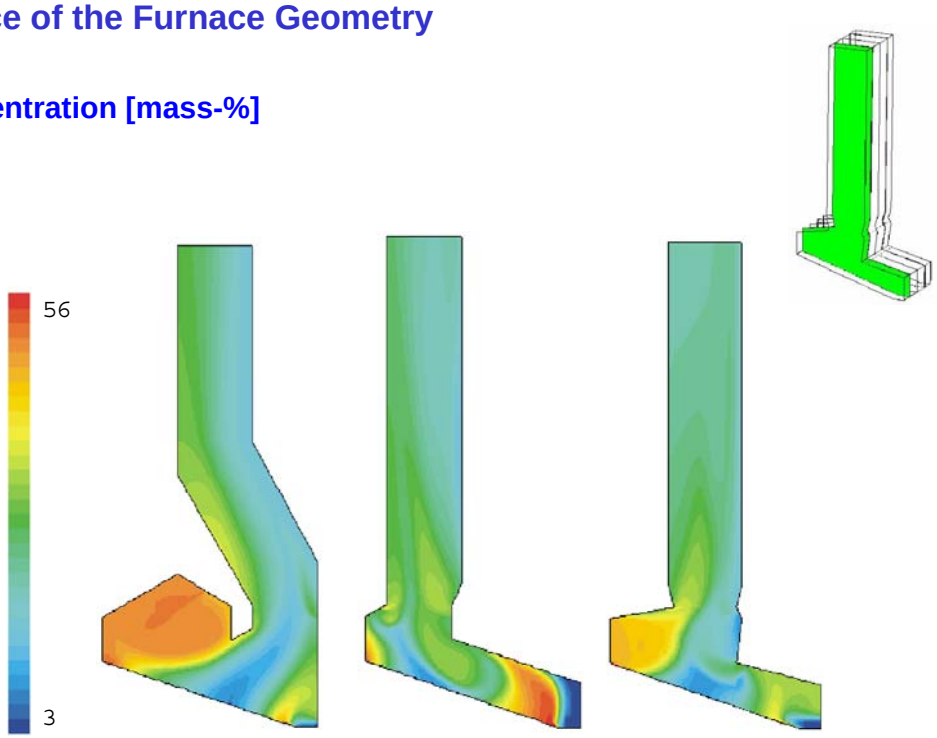
Influence of the Furnace Geometry

O_2-concentration [mass-%]



parallel flow firing | counter flow firing | center flow firing

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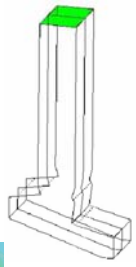
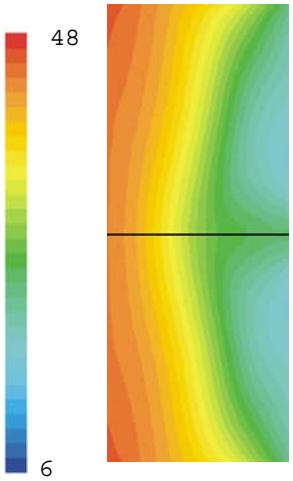
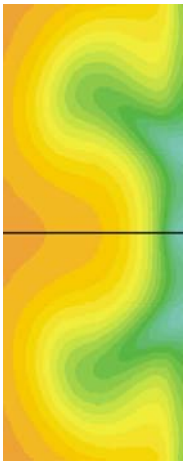
Influence of the Furnace Geometry

O_2-concentration [mass-%]





parallel flow firing



counter flow firing

center flow firing

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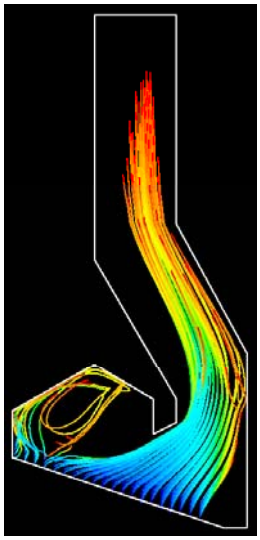
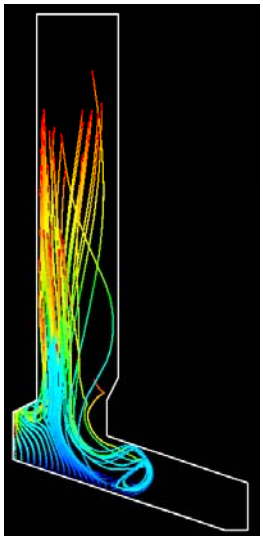
Influence of the Furnace Geometry

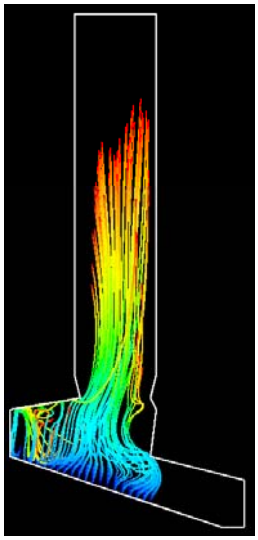
Streaklines



parallel flow firing



counter flow firing



center flow firing

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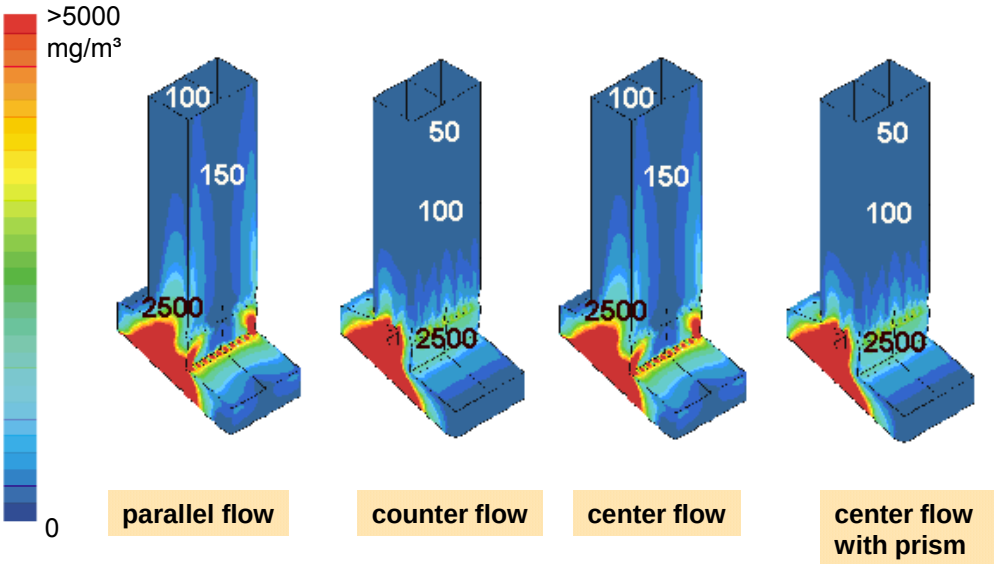
CO Distributions near the Walls
for the different furnace geometry concepts



parallel flow | counter flow | center flow | center flow with prism

Thermal Waste Treatment – State of the Art

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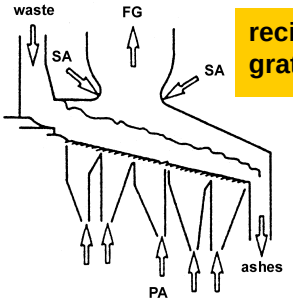
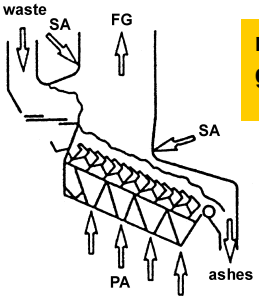
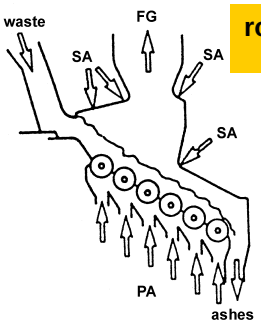
Secondary Air Injection (schematic)
for municipal waste incineration plants



reciprocating grate



reversed feed grate



roller grate

PA	primary air
SA	secondary air
FG	flue gases

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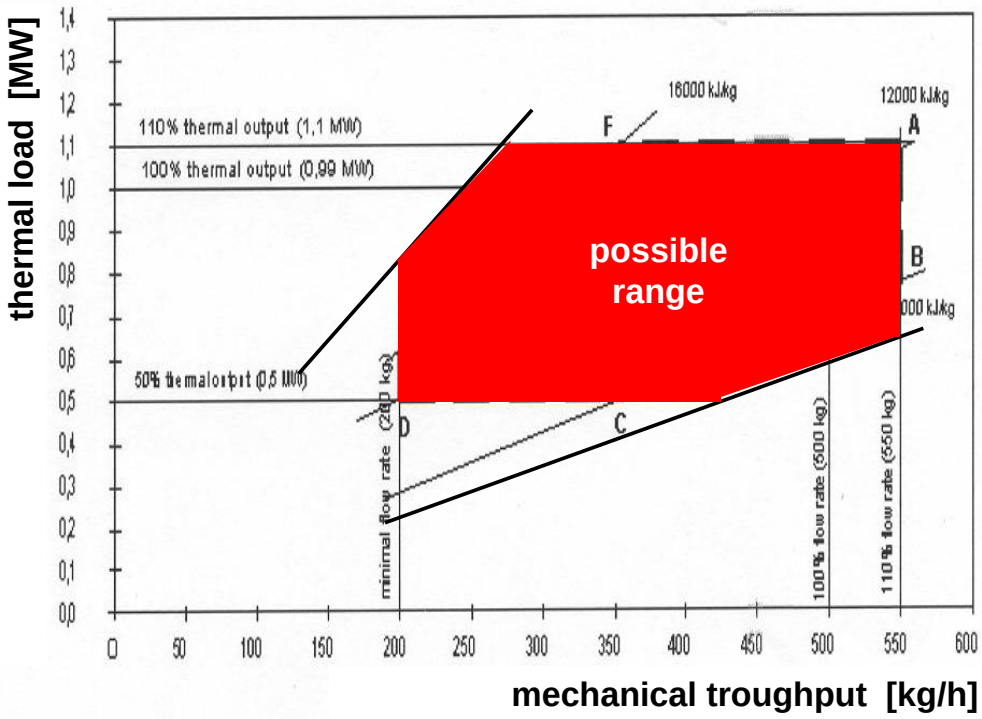
Firing Capacity Diagram for the MARS Test Rig



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Thermal Waste Treatment Plants

Mathematical Modelling

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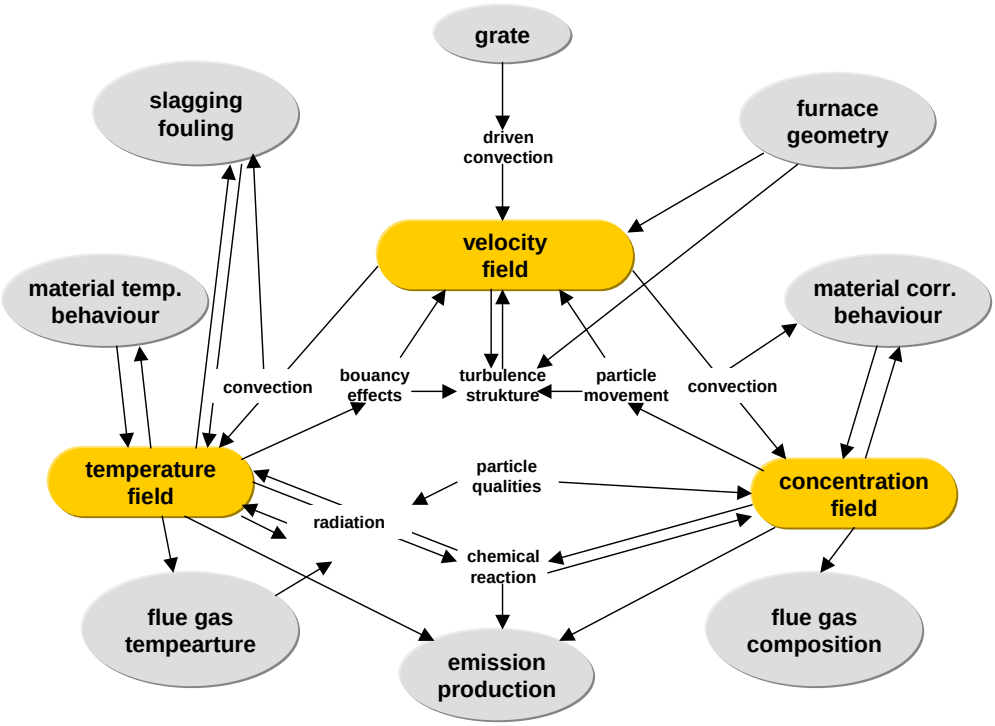
Interactions in a flame fired by solid fuels



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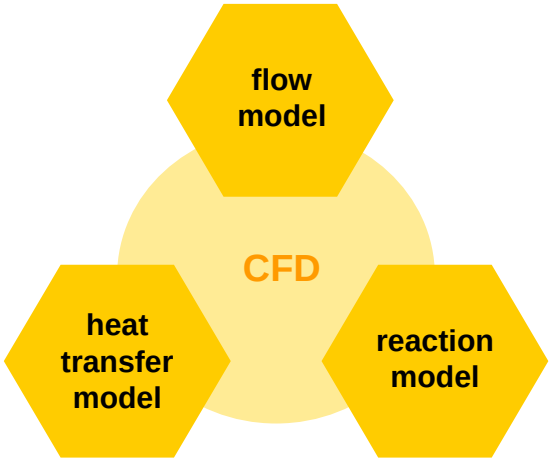
Interaction of the main sub-models



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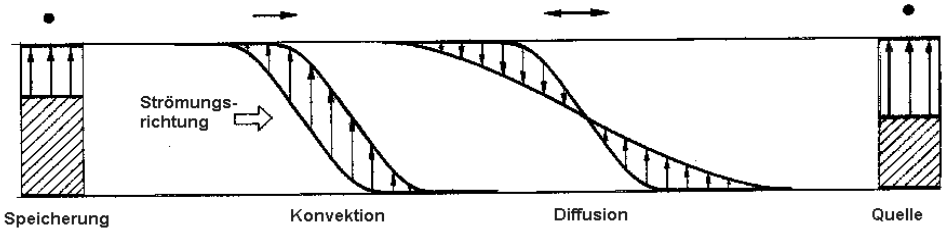
Transport-Equation

for a specific state variable φ

$$\frac{\partial}{\partial t}\left(\overline{\rho}\cdot\overline{\varphi}\right)+\frac{\partial}{\partial x_j}\left(\overline{\rho}\cdot\overline{\varphi}\cdot\overline{u}_j\right)=\frac{\partial}{\partial x_j}\left(D_\varphi\cdot\frac{\partial}{\partial x_j}\left(\overline{\varphi}\right)\right)+S_\varphi$$

transient term | convective net transport | diffusive net transport | source-/ sink term

Effect



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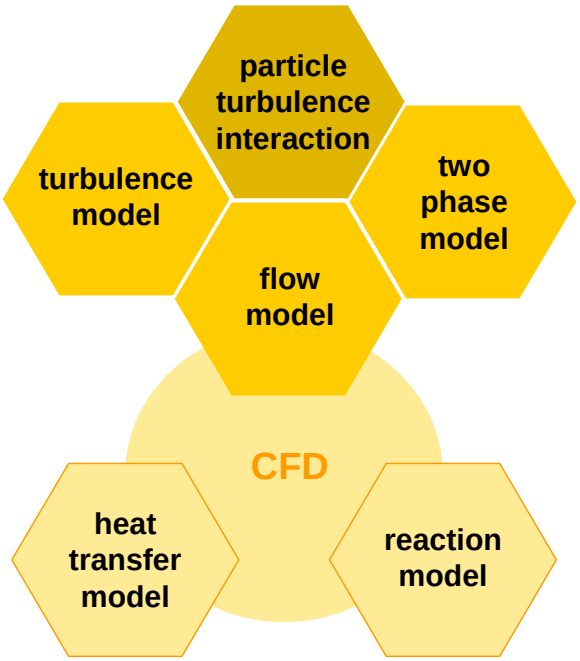

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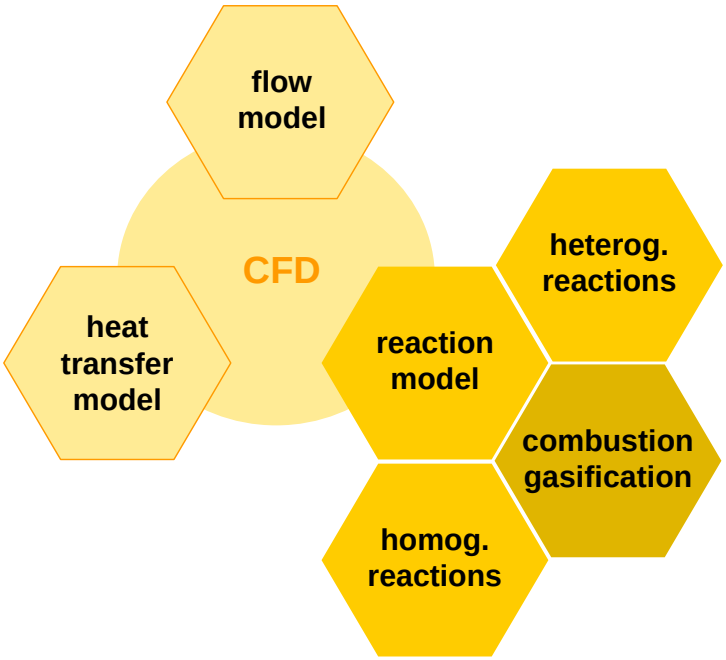

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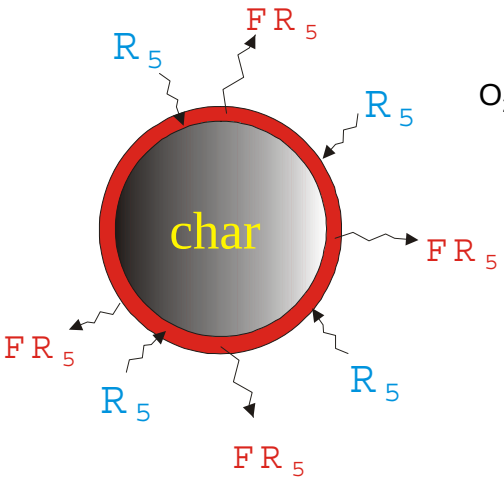
Reaction model with control by diffusion / reaction*

* Baum, Street and Field



O_2-diffusion

$$R_1 = C_1 \frac{\left[\left(T_p + T_\infty\right)/2\right]^{0.75}}{D_p}$$

reaction

$$R_2 = C_2 \exp\left(-E/RT_p\right)$$

Intrinsic reaction

$$\frac{dm_p}{dt} = -\pi D_p^2 p_{O2} \frac{R_1 R_2}{R_1 + R_2}$$

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Parameter set = model + parameter

- pyrolysis model
- reaction model gas
- reaction model char
- turbulence model
- radiation model
- particle size distribution
- particle tracking

- kinetic data for coal
- balanced species
- composition of the coal
- physical properties of coal (e.g. density, c_p)
- particle sizes
- gas pahse properties in the high temperature range
- eddy-breakup-parameters
- radiation parameters
- turbulence parameters

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Modelling of the gas phase

state and process variable to be balanced

- **reaction (mass transfer, chemical reaction)**

c (C_xH_y)	hydrocarbons	($C_xH_y + O_2 \rightarrow CO + H_2O$)
c (CO)	carbon monoxide	($CO + O_2 \rightarrow CO_2$)
c (CO_2)	carbon dioxide	
c (H_2O)	water	
c (O_2)	oxygen	

- **flow (momentum transfer)**

u_1, u_2, u_3	velocity components
k, ε	turbulence model

- **energy (heat transfer)**

h	velocity components
q_1, q_2, q_3	turbulence model

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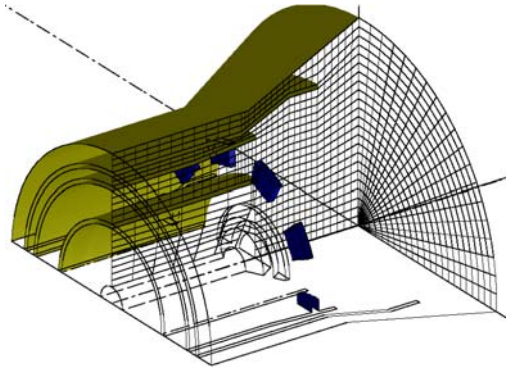
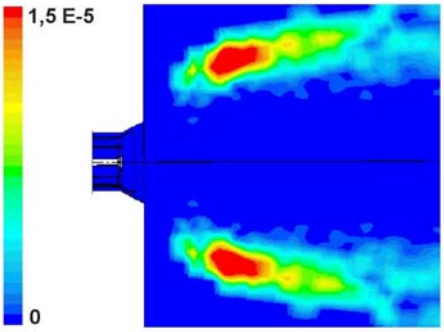
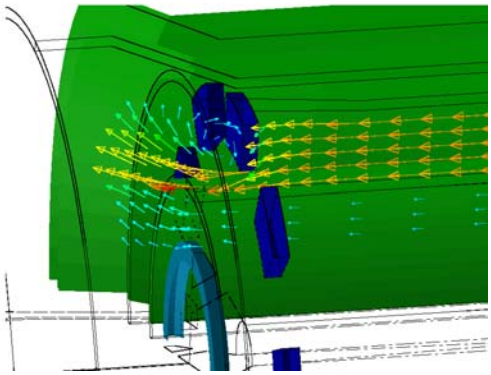
geometry



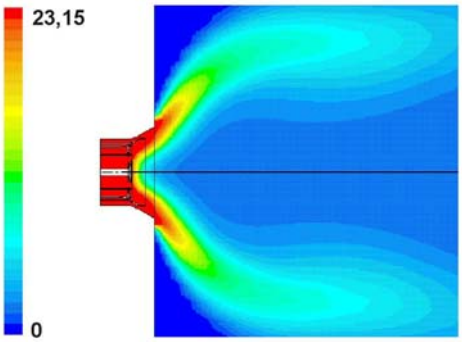
char combustion rate [kg/s]



velocity



O_2-concentration [Ma.-%]



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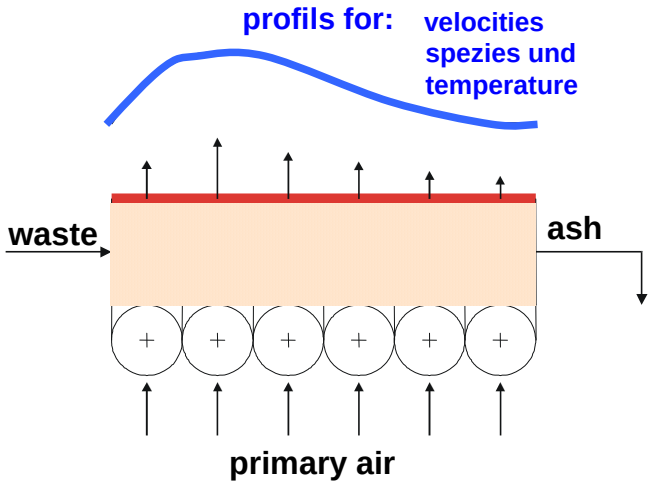
Modelling of the fixed bed (waste layer)

heterogeneous combustion in the waste layer



$$T = \frac{\dot{H}_{sensitive}}{c_p \cdot \dot{m}_{gas}}$$

$$\dot{H}_{sensitive} = \dot{Q}_{in} - \dot{H}_{latent} = \dot{m}_{waste} \cdot LCV_{waste} - \dot{H}_{latent}$$

$$\dot{H}_{latent} = (LCV_{CxHy} \cdot \mu_{CxHy} + LCV_{CO} \cdot \mu_{CO}) \cdot \dot{m}_{gas}$$

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Thermal Treatment – Mathematical Modelling

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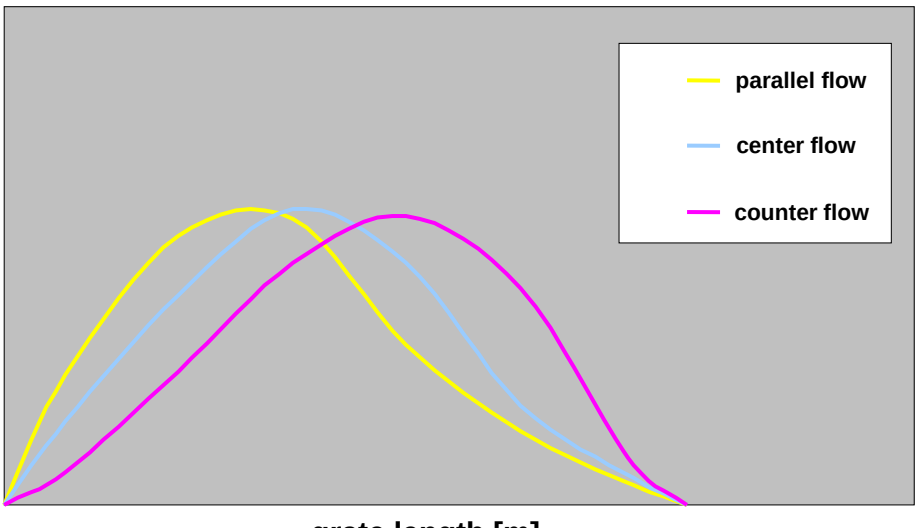
Modelling of the fixed bed (waste layer)

heterogeneous combustion in the waste layer

heat release profile



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Thermal Waste Treatment Plants

Model Validation

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Thermal Waste Treatment – Model Validation

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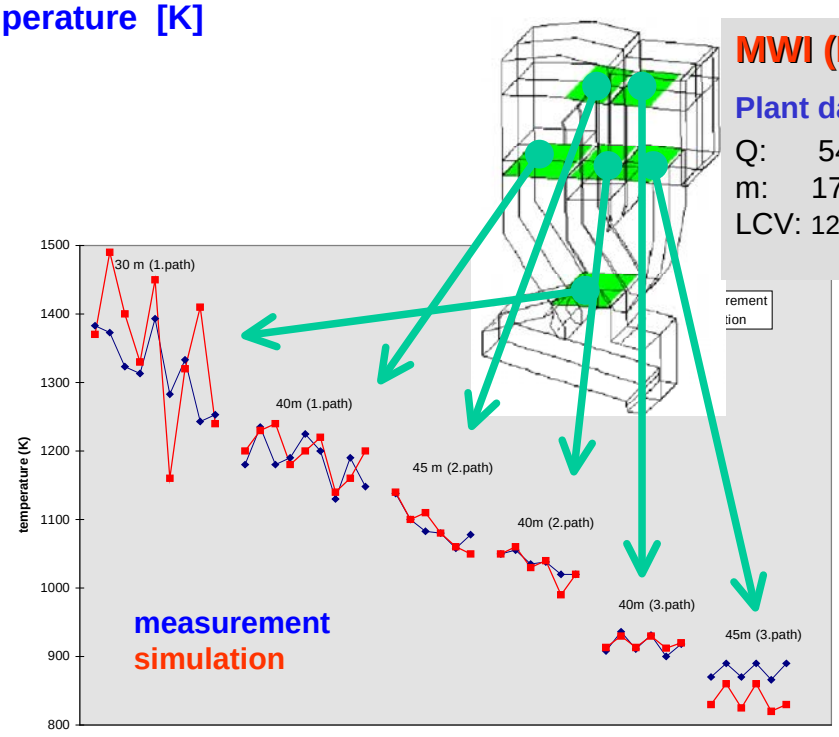
Comparison measurement - simulation

temperature [K]



MWI (Europe)

Plant data:

Q: 54 MW,
m: 17,8 t/h,
LCV: 12.000 - 20.000 kJ/kg

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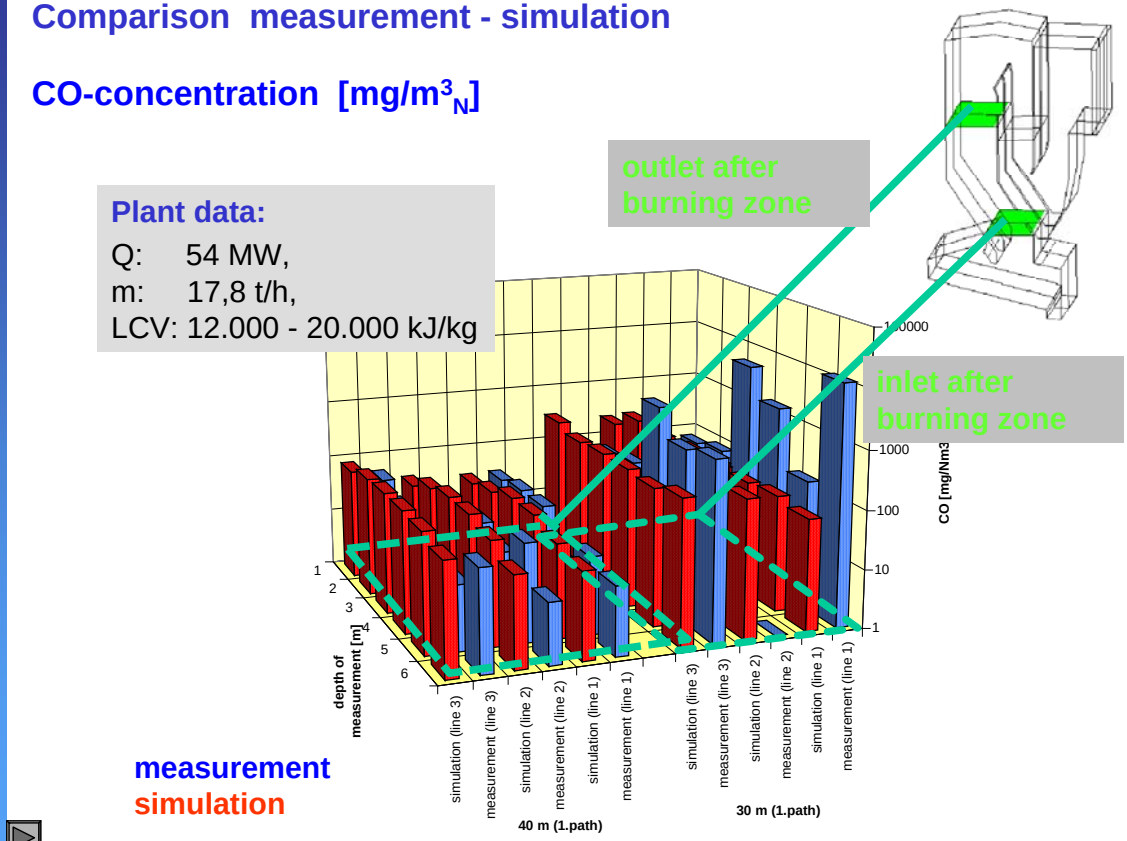
Comparison measurement - simulation

CO-concentration [mg/m^3_N]

Plant data:

Q: 54 MW,
m: 17,8 t/h,
LCV: 12.000 - 20.000 kJ/kg



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Thermal Waste Treatment Plants

Secondary Air Injection

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Thermal Waste Treatment – Secondary Air Injection

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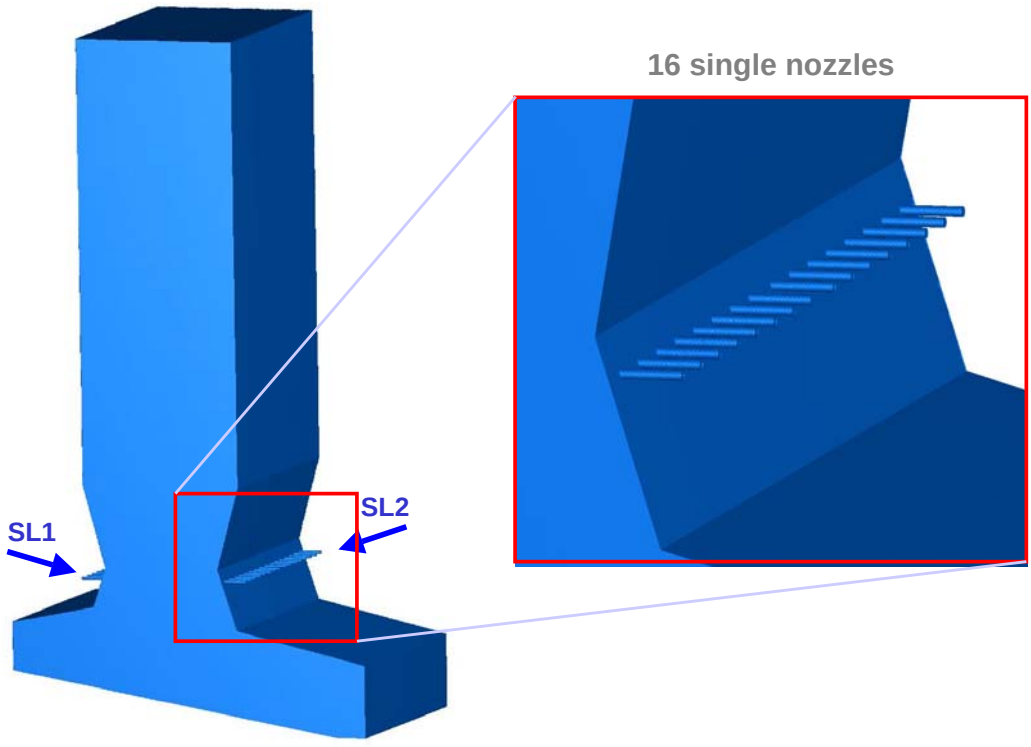
Geometry of the furnace and the radiational pass



Center flow firing

Detail of the rear wall nozzles

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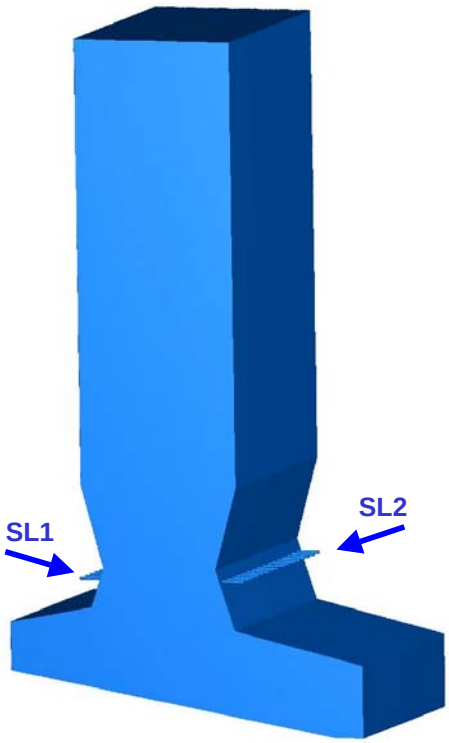
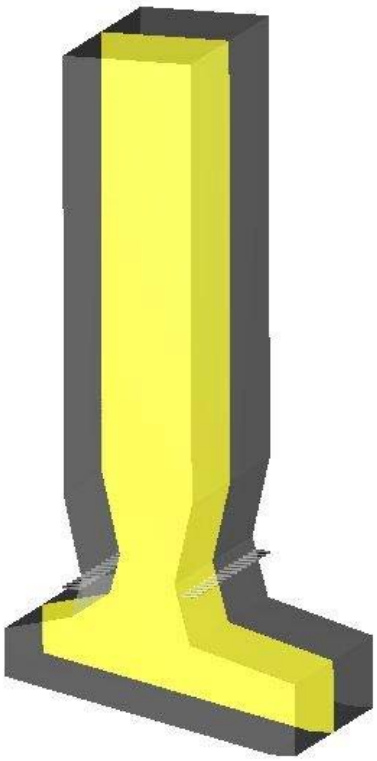
Geometry of the furnace and the radiational pass



Center flow firing



Results on the symmetry plane

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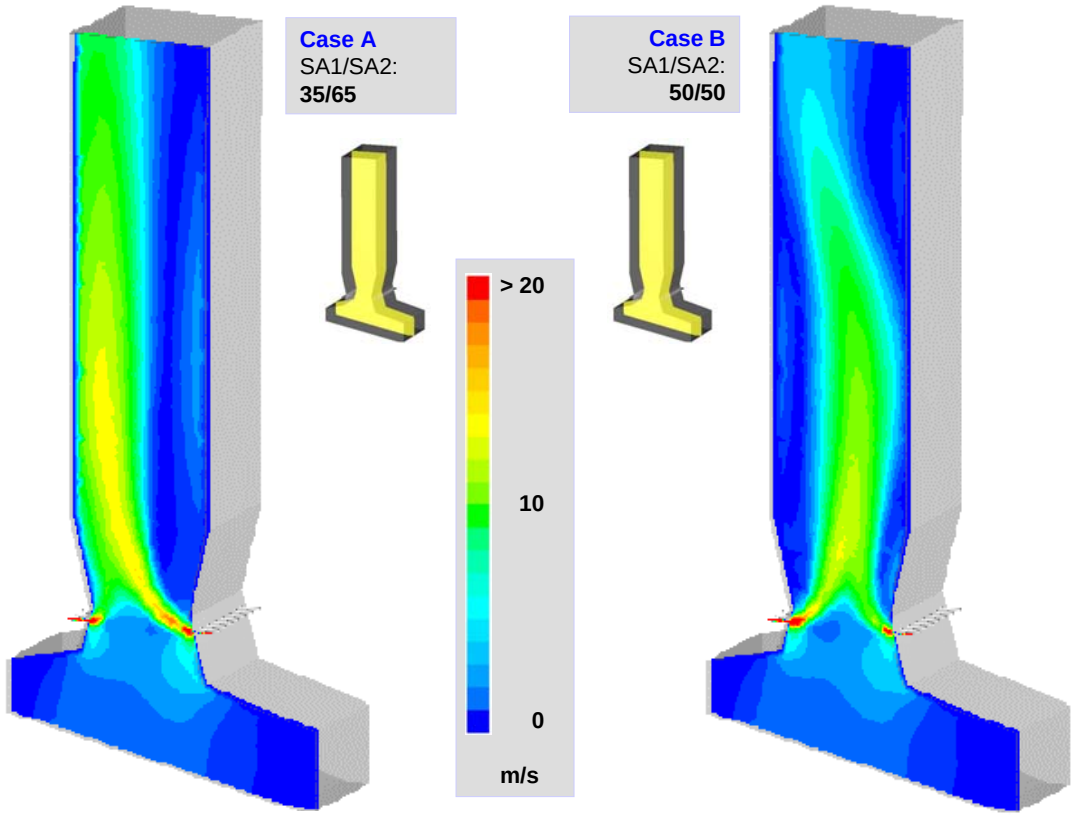
Folie 4

Velocity distribution



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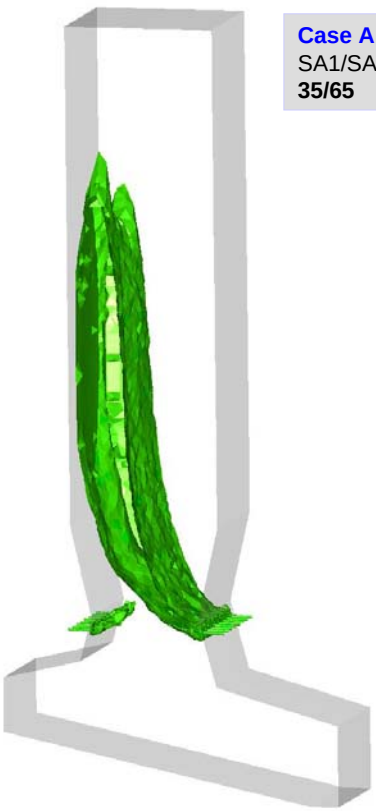
Velocity distribution

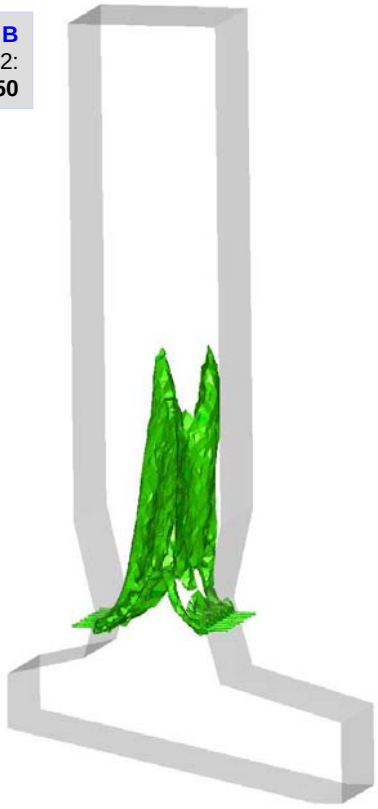


Case A
SA1/SA2:
35/65

Case B
SA1/SA2:
50/50

Iso-plane

11 m/s



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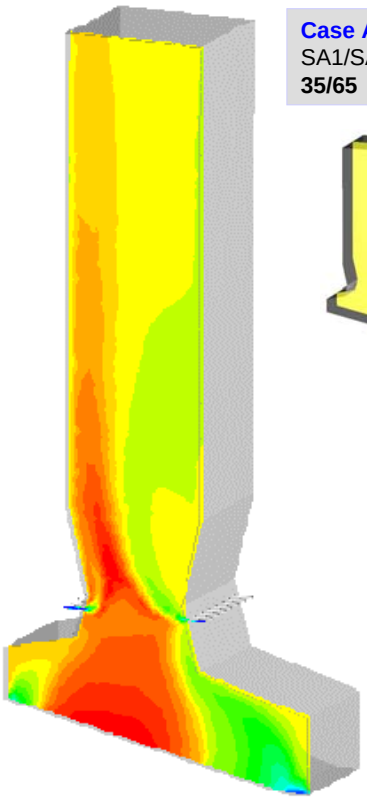
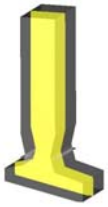
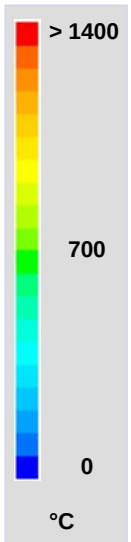
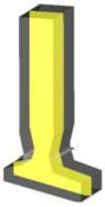
Temperature distribution



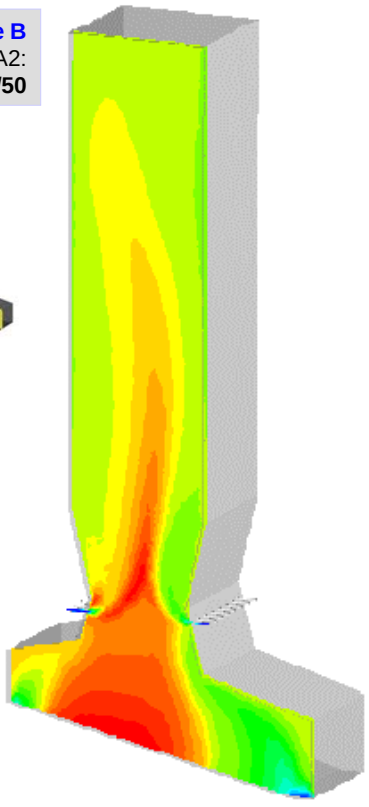
Case A
SA1/SA2:
35/65







Case B
SA1/SA2:
50/50



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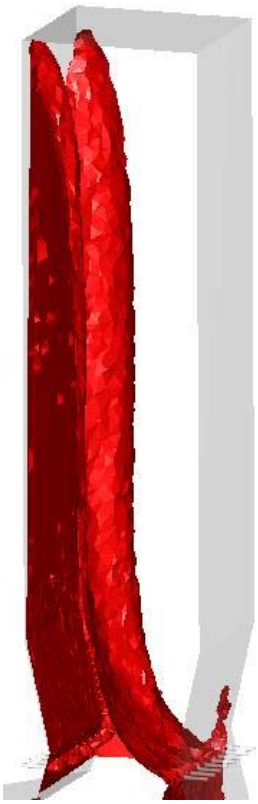
Temperature distribution

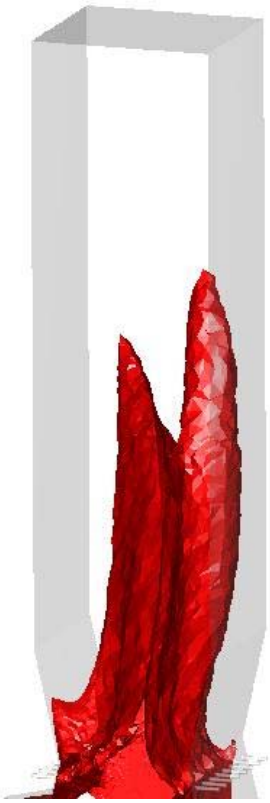
Case A
SA1/SA2:
35/65

Case B
SA1/SA2:
50/50



Iso-plane

1.000 °C



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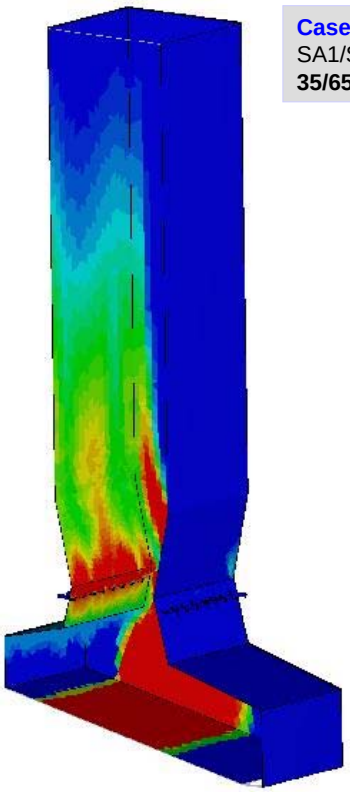
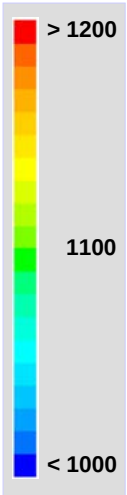
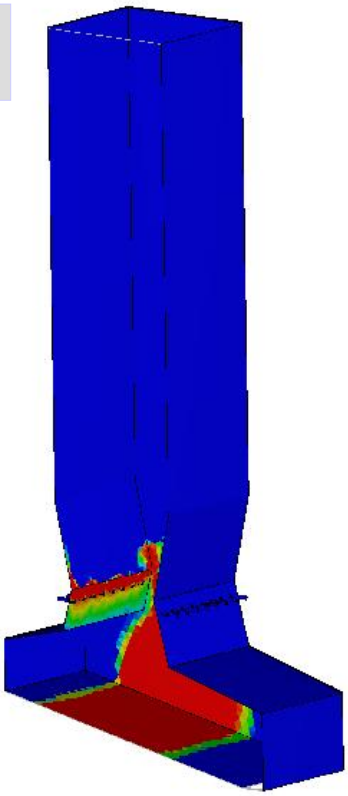
Temoerature distribution near the walls –flue gas side

Case A
SA1/SA2:
35/65

Case B
SA1/SA2:
50/50







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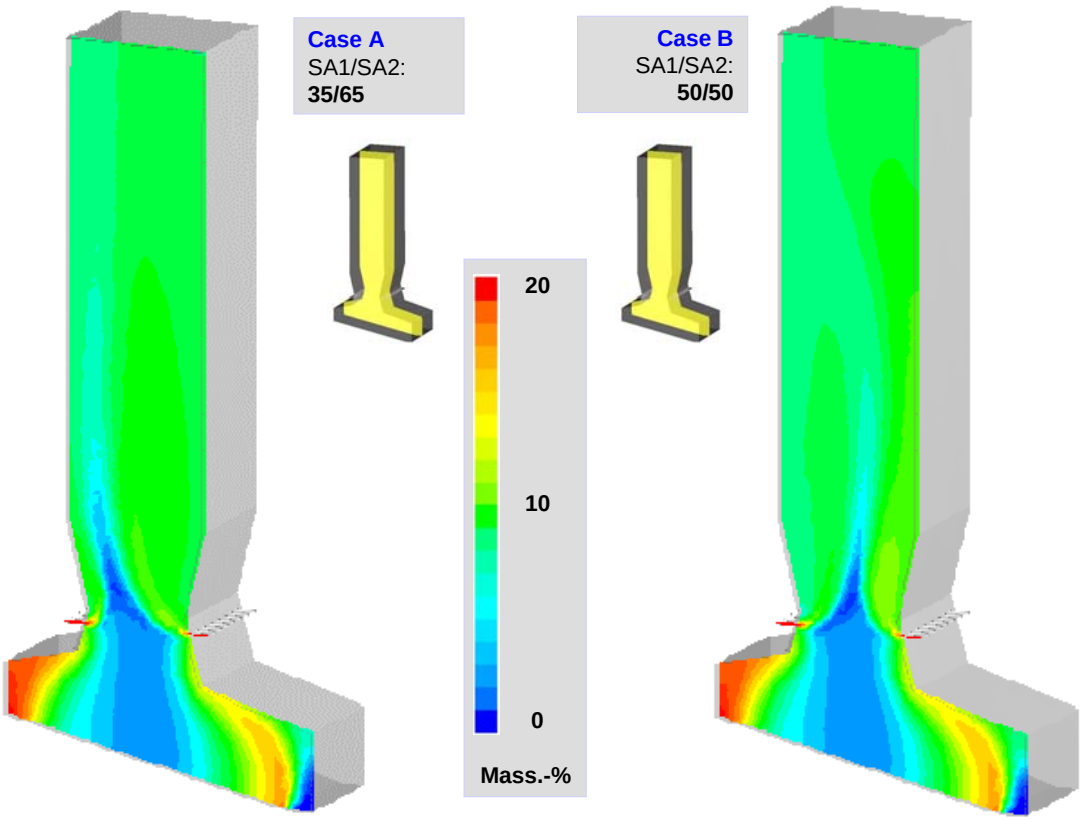
Oxigen distribution



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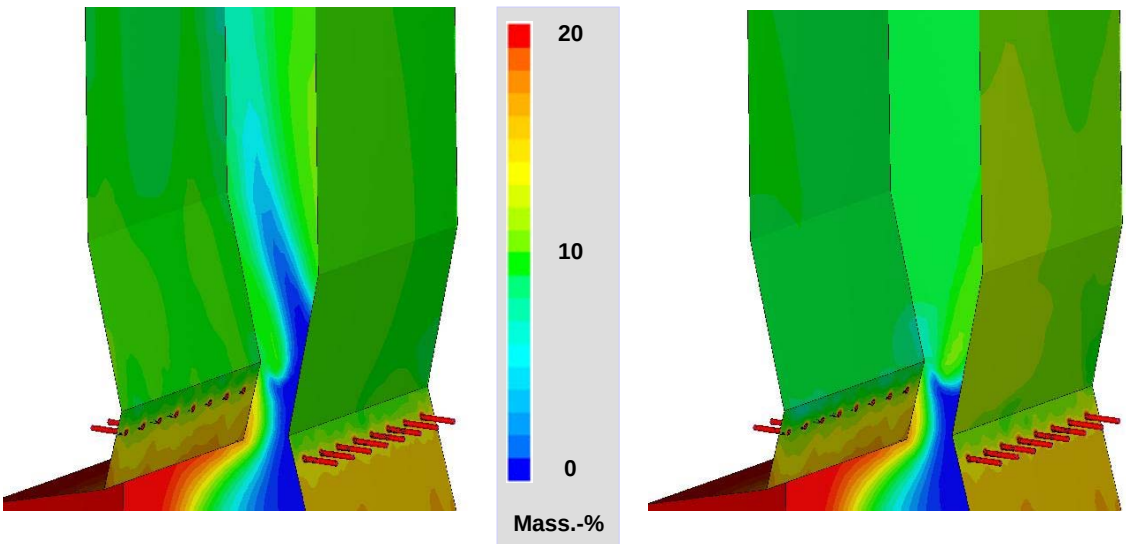
Oxigen distribution near the walls – flue gas side



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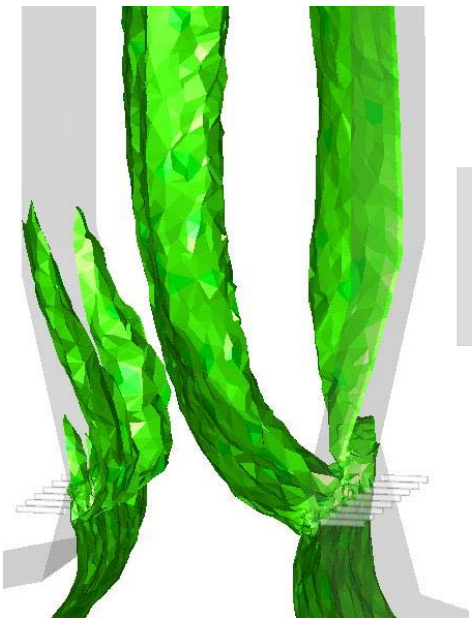
Oxigen distribution

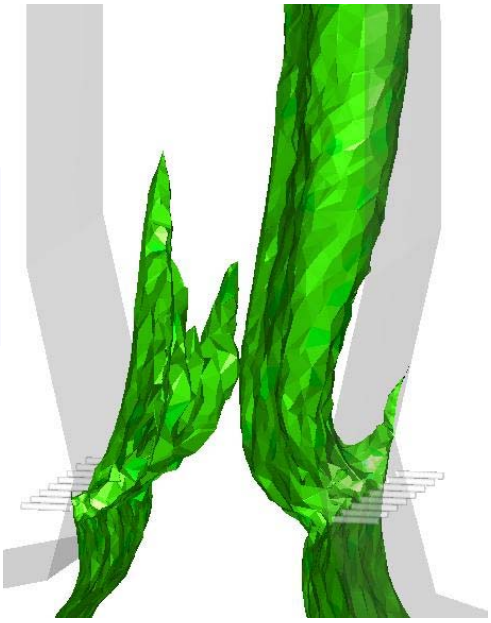
Case A
SA1/SA2:
35/65

Case B
SA1/SA2:
50/50



Iso-plane

10 Mass.-%



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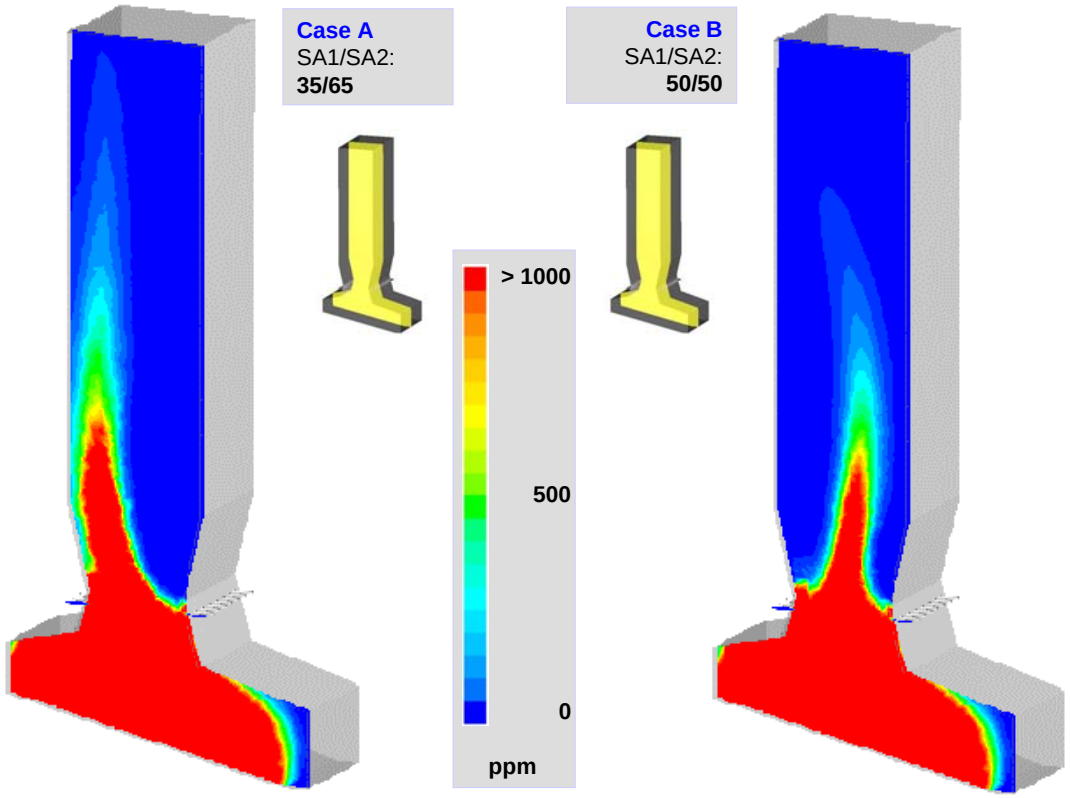
Carbon monoxide distribution

Case A
SA1/SA2:
35/65

Case B
SA1/SA2:
50/50



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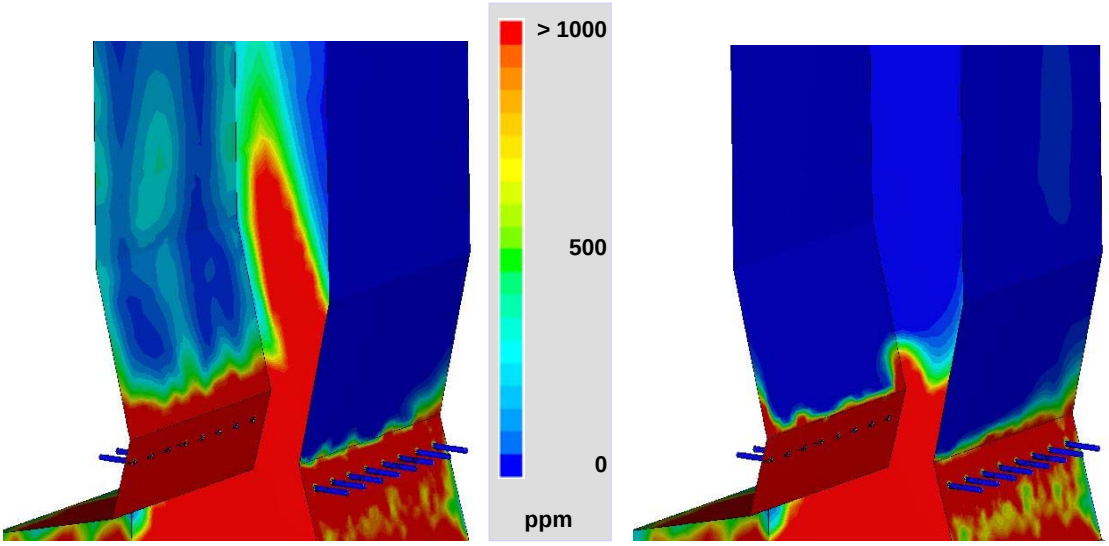
Carbon monoxide distribution near the walls – flue gas side

Case A
SA1/SA2:
35/65

Case B
SA1/SA2:
50/50



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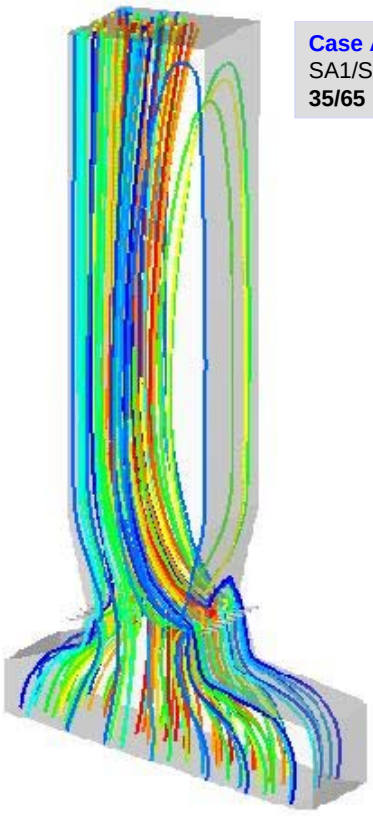
Steam lines

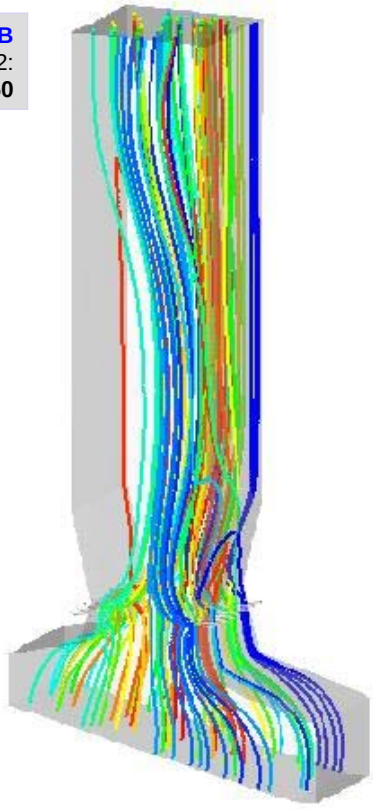
Case A
SA1/SA2:
35/65

Case B
SA1/SA2:
50/50



Stream lines

-



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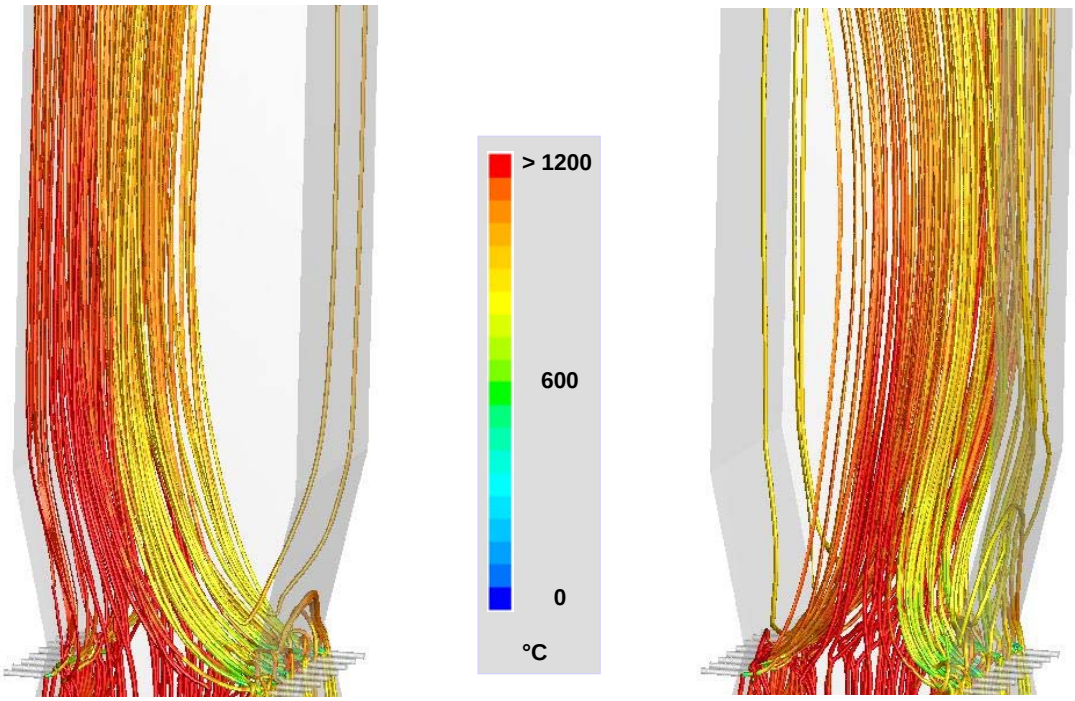
Stream lines colored by particle temperature

Case A
SA1/SA2:
35/65

Case B
SA1/SA2:
50/50



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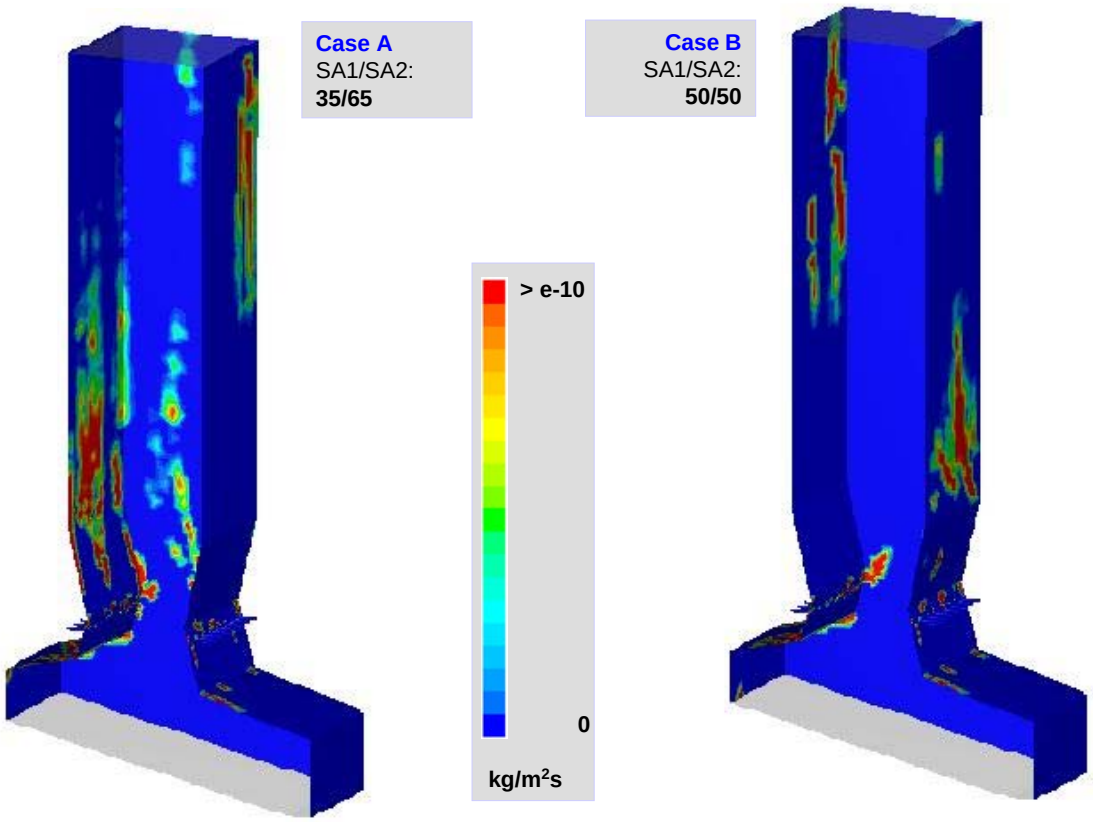
Abrasion attack

Case A
SA1/SA2:
35/65

Case B
SA1/SA2:
50/50



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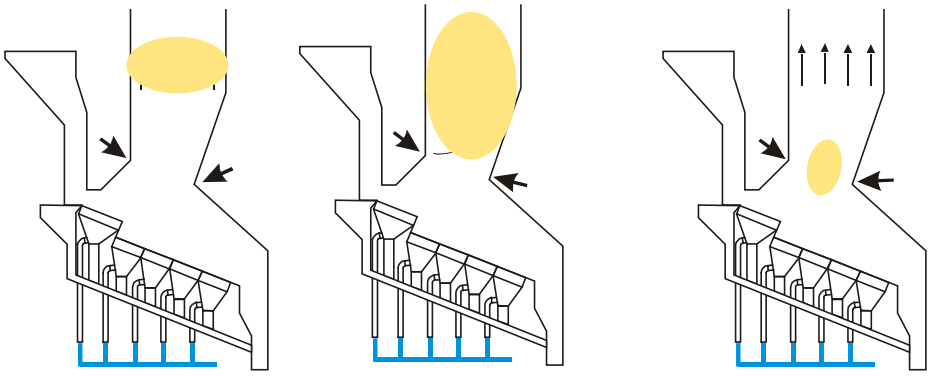
Different secondary air injection concepts



normal configuration | tangential injection | static mixing device

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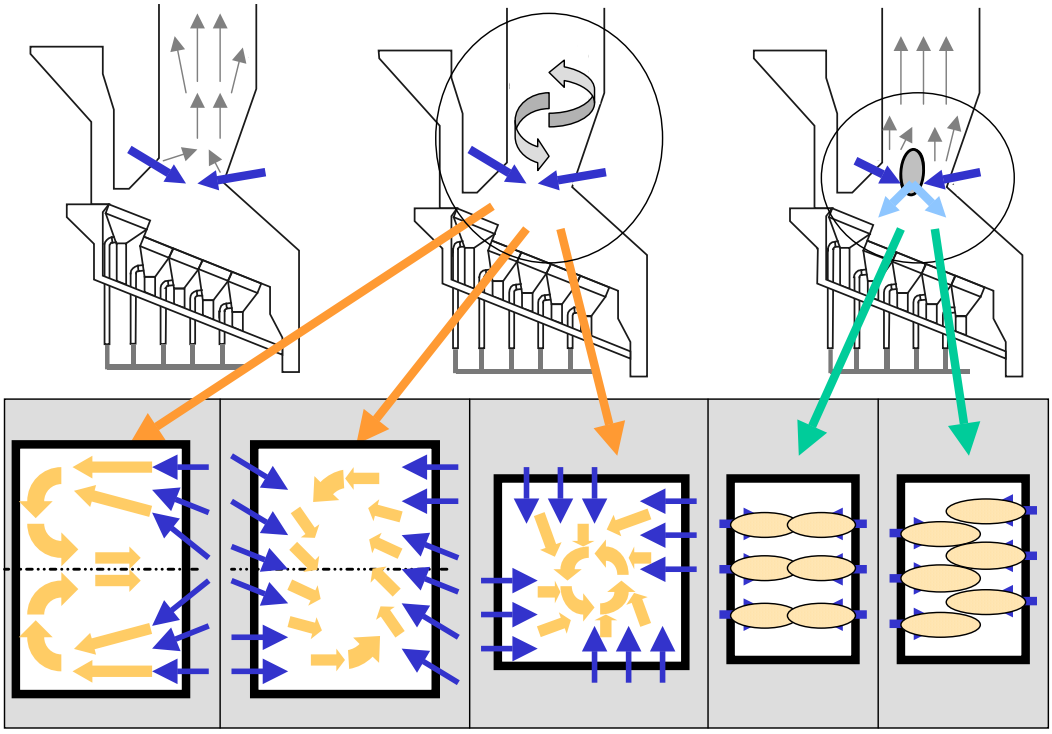
Secondary Air Injection Concepts

classically | swirl concept | displacement body



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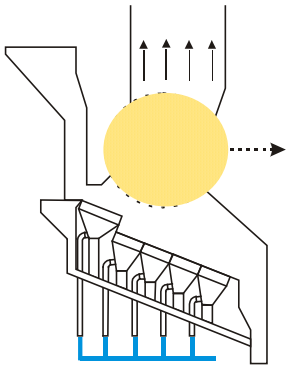
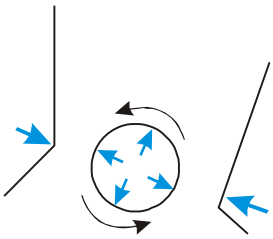
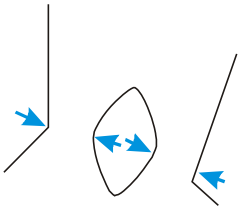
Advanced secondary injection concepts



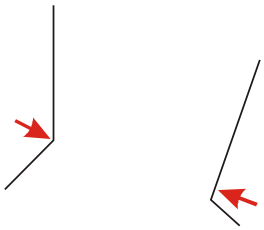
overall view of furnace and transition area



rotating cylinder + air



prism + air



steam instead of air

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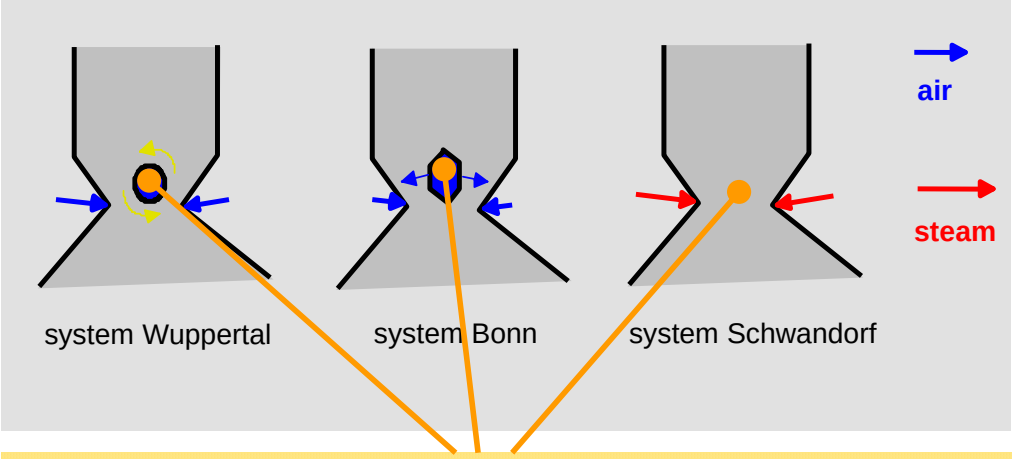
Advanced secondary injection concepts

System: Temelli**,** Kümmel, Krüger



Effect: Static mixing device and/or higher momentum

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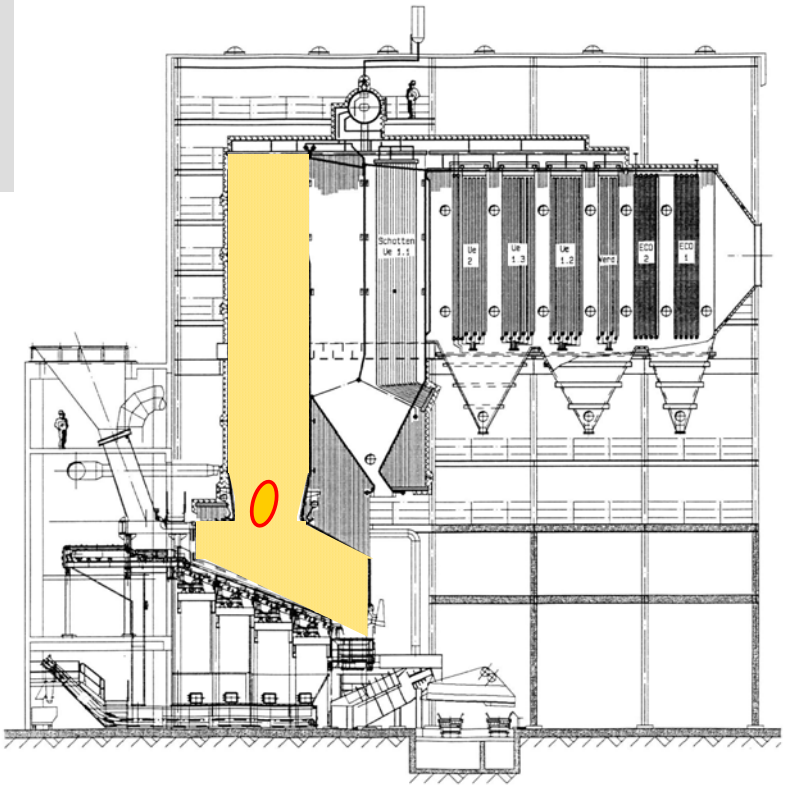
MWI Bonn

Plant Data:

Q: 24 MW,

m: 9,3 t/h,

LCV: 9.000 kJ/kg



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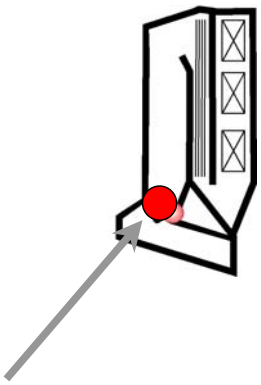
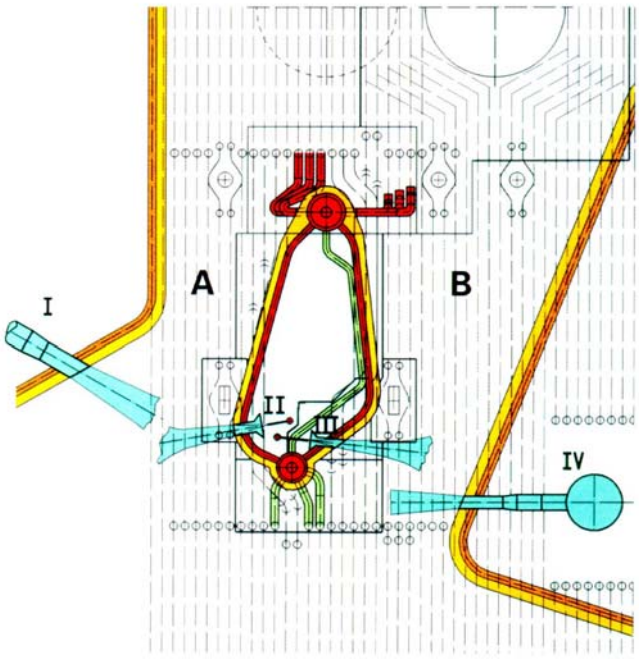
prism - system Bonn





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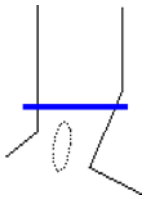
Comparison measurement - simulation

temperature [°C] - inlet after-burning zone



Plant data:

Q: 24 MW,
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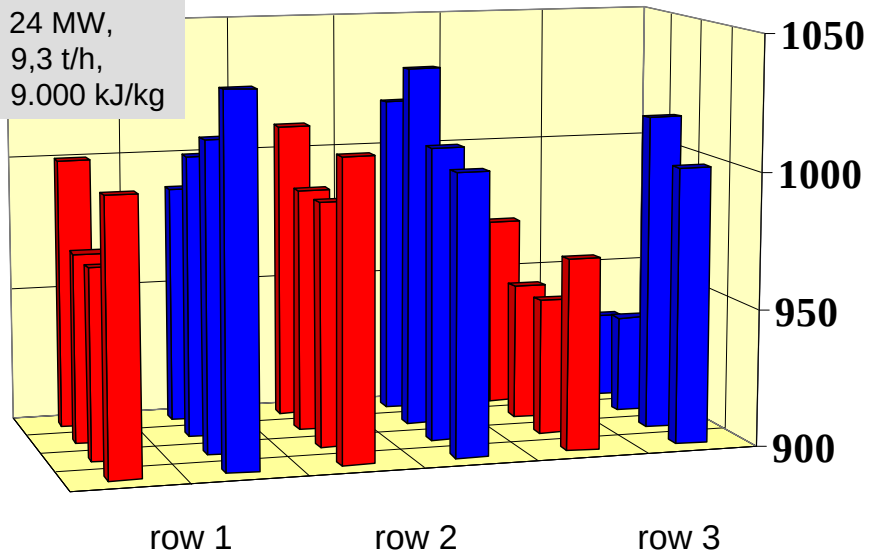
LCW: 9.000 kJ/kg



simulation measurment

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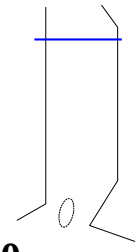
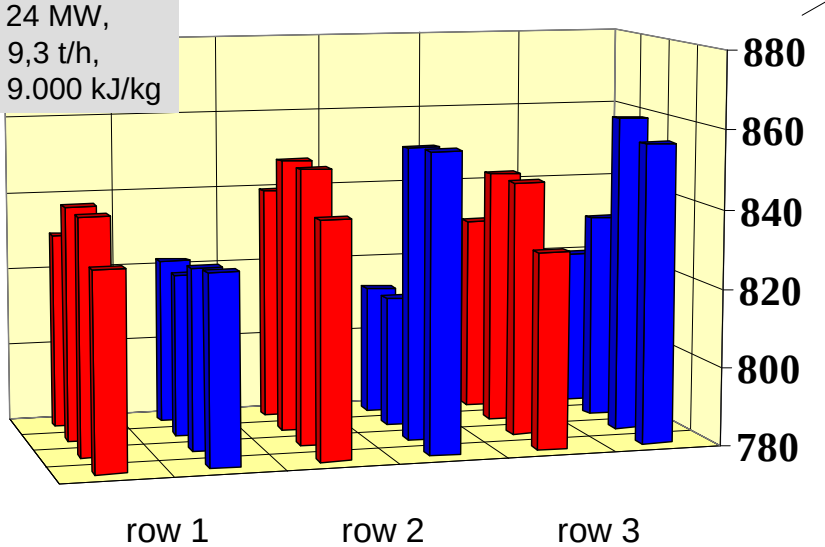
Comparison measurement - simulation

temperature [°C] - outlet after-burning zone



Plant data:

Q: 24 MW,
m: 9,3 t/h,
LCV: 9.000 kJ/kg



simulation measurement

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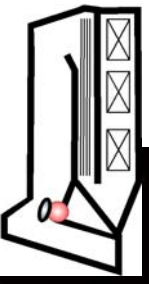
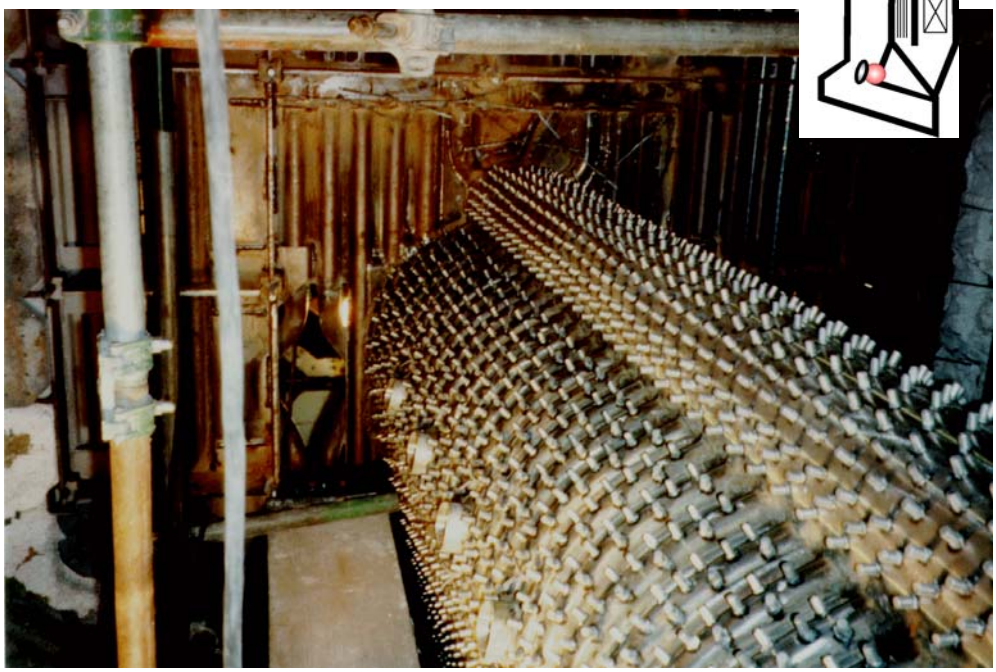
Advanced secondary injection concepts

prism - system Bonn





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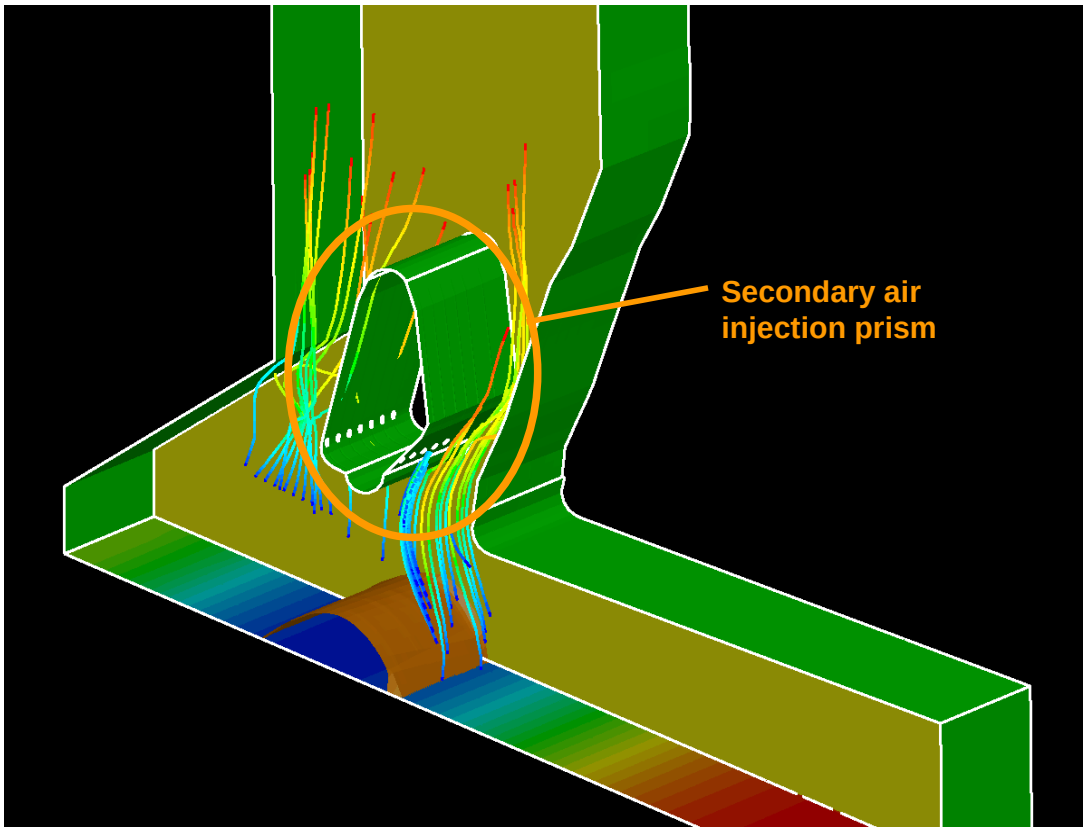

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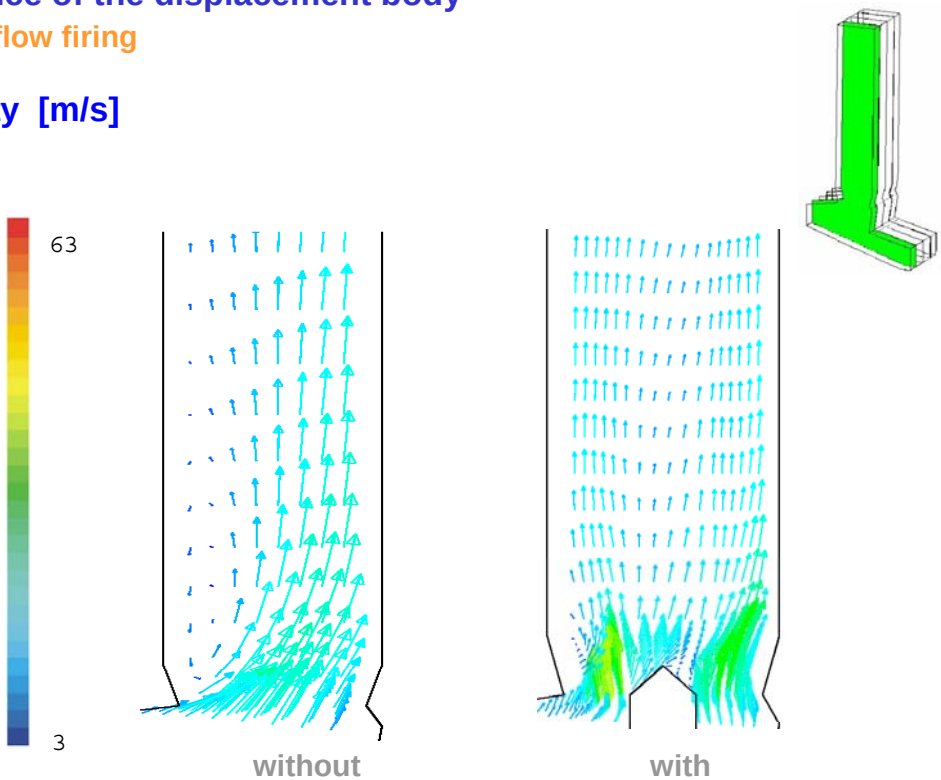
Influence of the displacement body

center flow firing

velocity [m/s]



without displacement body (prism) | with displacement body (prism)

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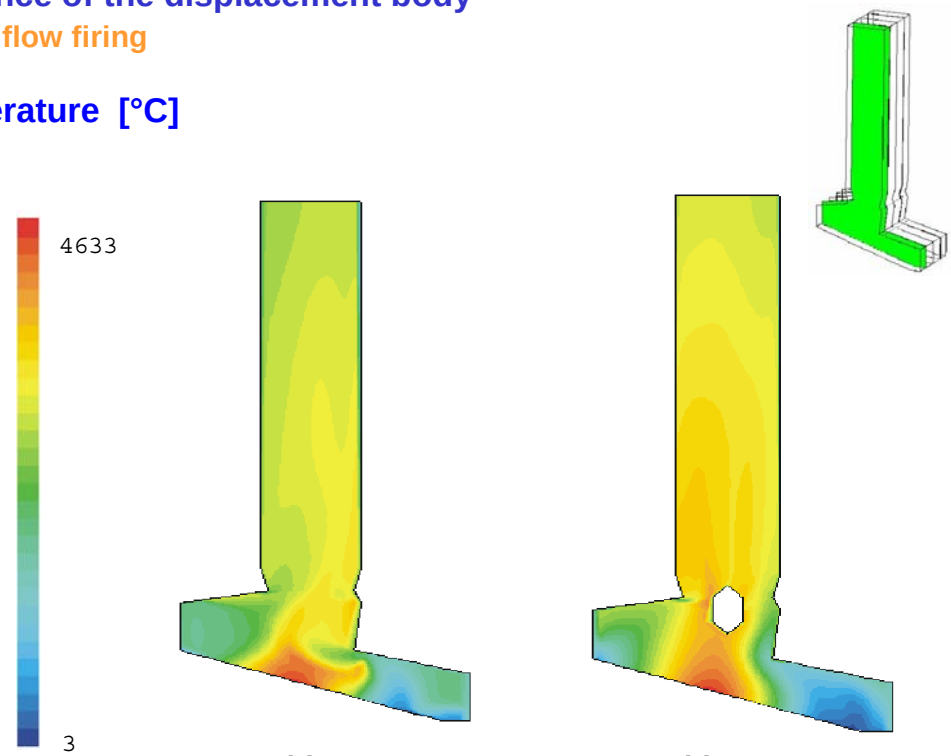
Influence of the displacement body

center flow firing

temperature [°C]



without displacement body (prism) | with displacement body (prism)

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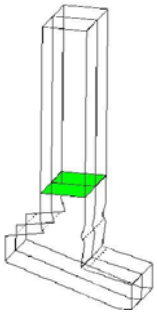
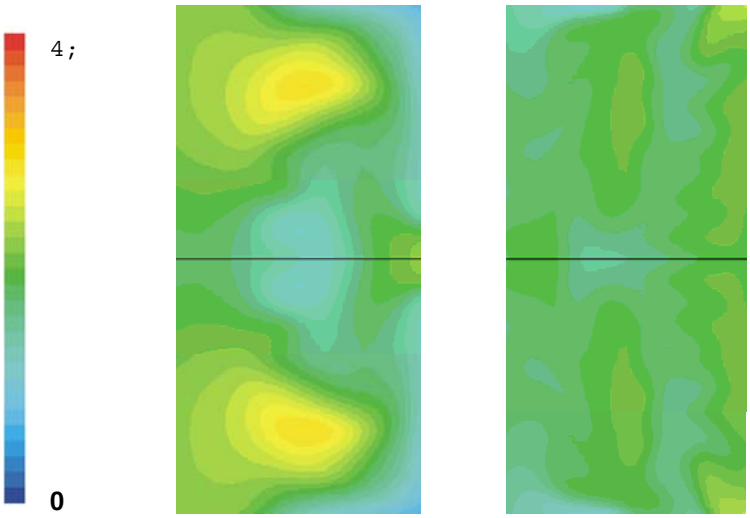
Influence of the displacement body

center flow firing

O_2-concentration [Massen-%]





without displacement body (prism) with

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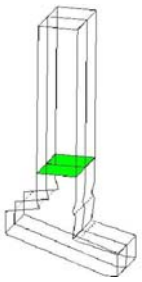
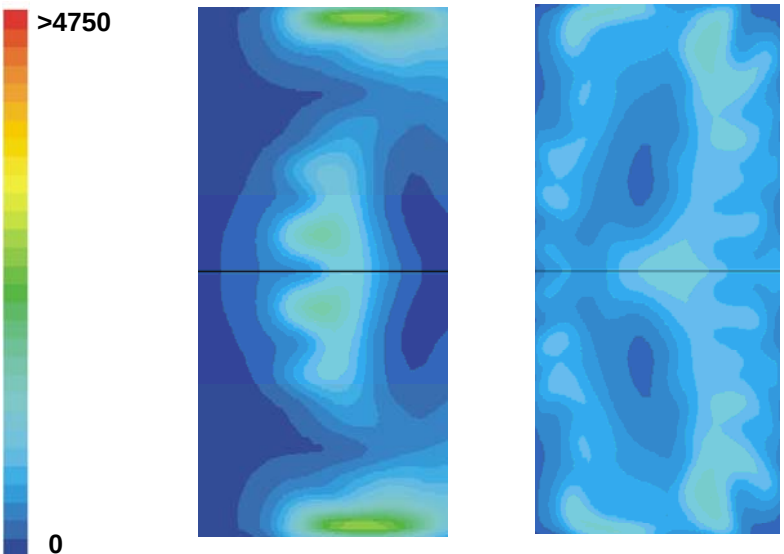
Influence of the displacement body

center flow firing

CO-concentration [mg/m³]





without displacement body (prism) with

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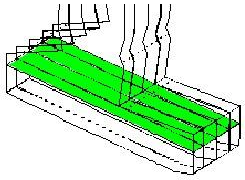
Influence of the displacement body

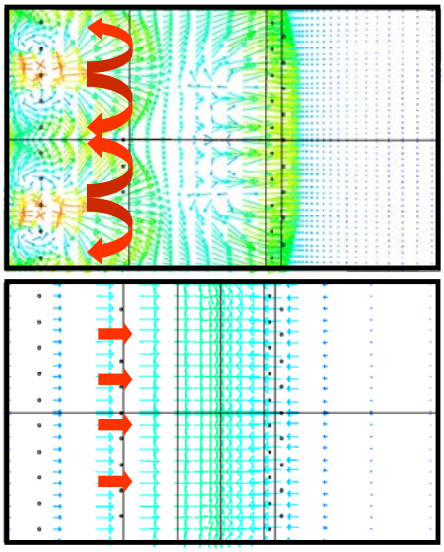
center flow firing



velocity [m/s]

without displacement body (prism)

with displacement body (prism)



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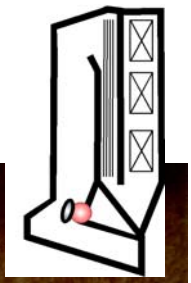
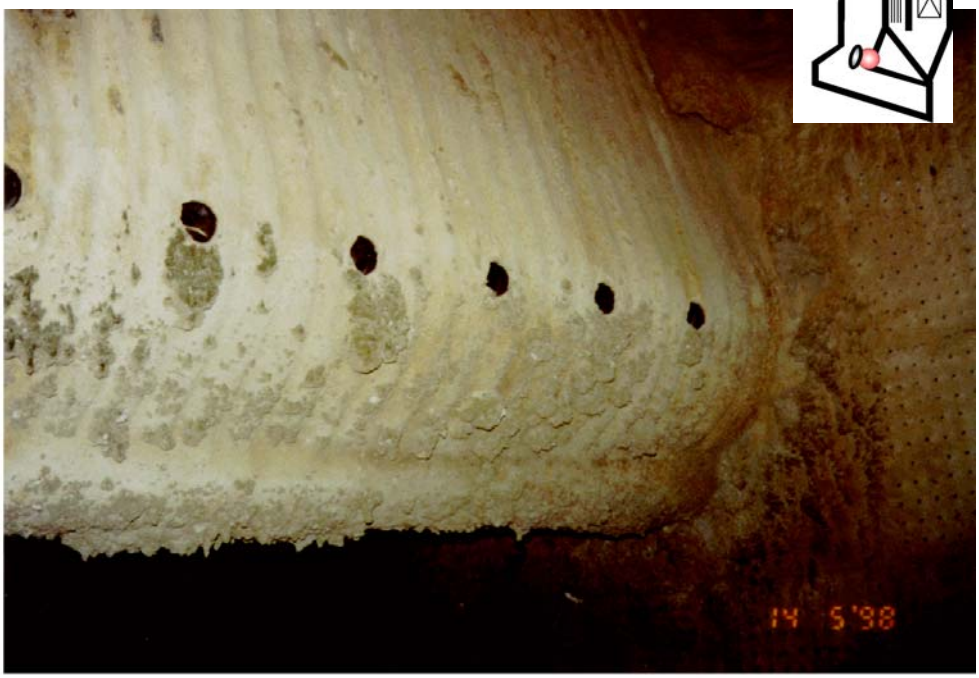
Displacement body

after 3,300 hours of operation





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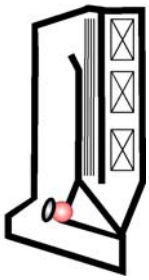
Displacement body

after 9,000 hours of operation



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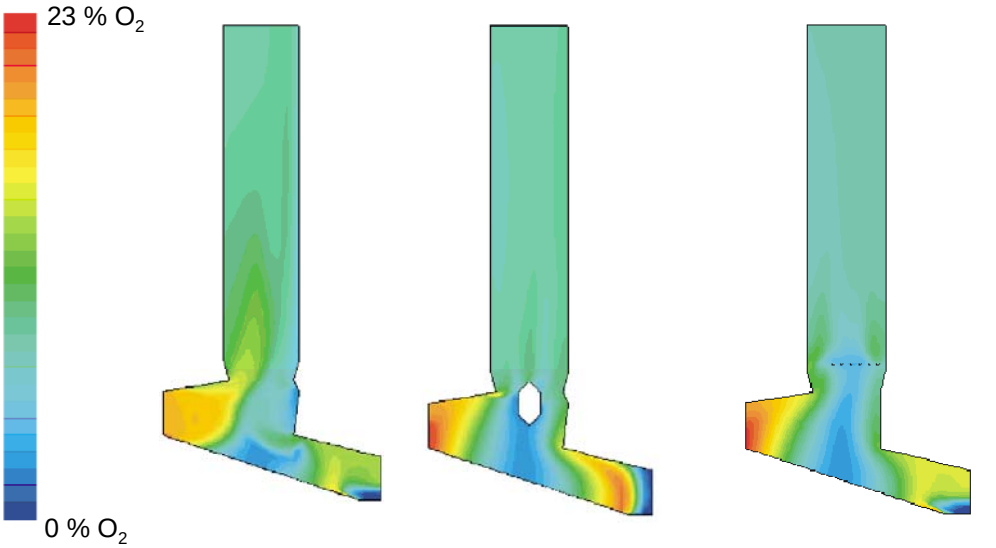
Influence of a tangential injection

center flow firing

O_2-concentration [mg/m³]



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Thermal Waste Treatment Plants

Refractory Lining

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Thermal Waste Treatment – Refractory Lining

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Variations for wall insulation (chem. and therm.)

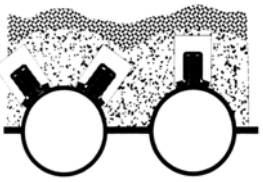
Metallic pipe and metallic protected pipe

metallic pipe
+
dust layer

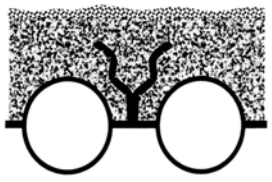
cladding
+
dust layer

SiC-Mass

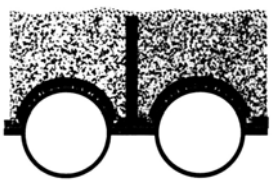
castable SiC (bound by phosphate)
+
dust layer



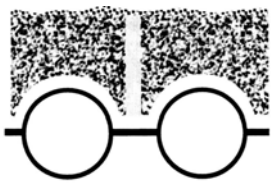
SiC-Beton (bound by water)
+
dust layer



SiC plates, bound by phosphate, luted
+
dust layer



SiC plates, (bound by phosphate, air cooled
+
dust layer



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Thermal heat conductivity
of different refractory linings

refractory lining material	thermal heat conductivity [W/(mK)] at 800 °C
Refrax 20 plates	20
SiC 70 refractory castable	4 - 6
SiC 90 refractory castable	6.3 - 7.5
Sillimanit (Andalusit) plates	1.74
compact refractory castable	1.83

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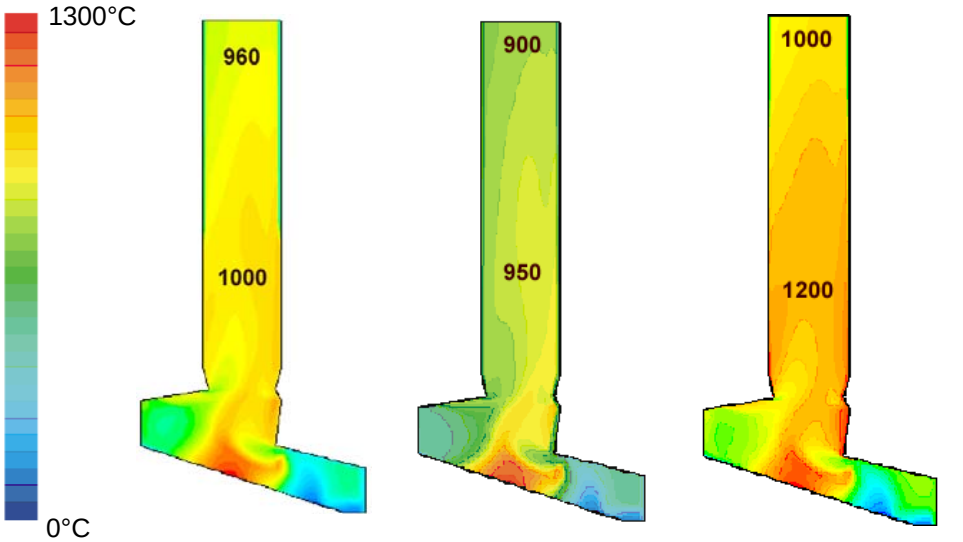
Influence of the refractory lining
center flow firing

temperature [°C]



castable SiC | luted SiC-plates | air cooled SiC-plates + dust

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Welding materials for cladding purposes

welding material	composition	
	element	partition [%]
NiCr625 2.4831 Inconel 625	C	<0,03
	Cr	22
	Mo	9
	Fe	<3
	Nb	3,5
	Ni	rest

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Thermal Waste Treatment Plants

Corrosion

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Thermal Waste Treatment - Corrosion

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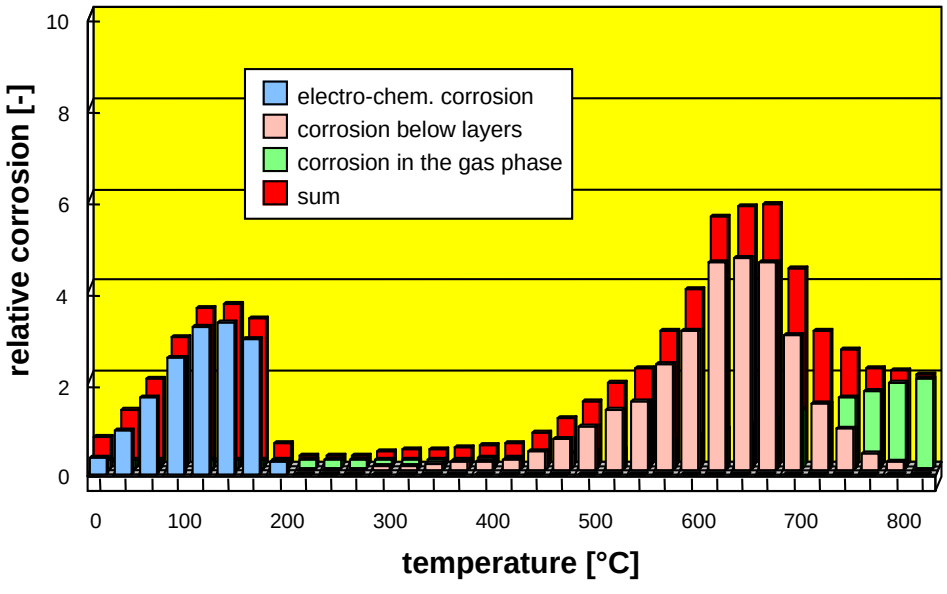
Low and high temperature corrosion
as a function of temperature



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Corrosion

Super-heater pipe under strong dust / slag layer

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Causes for corrosion

Mechanisms

- transition of alkali chlorid in dust layers
- direct attack by CO (just at very high concentrations)

Attack of alkali chlorids

Sulfatisation in the flue gas at temperatures below 700 °C:

- alkali chlorid + SO_2 + O_2 $\Leftrightarrow$ alkali sulfate + Cl_2/Cl
- Cl_2/Cl + Fe $\Leftrightarrow$ $FeCl_2$

At higher temperatures no **sulfatisation** in the gas phase,
transition in the dust layer and
release of chlorine near the metallic pipes.

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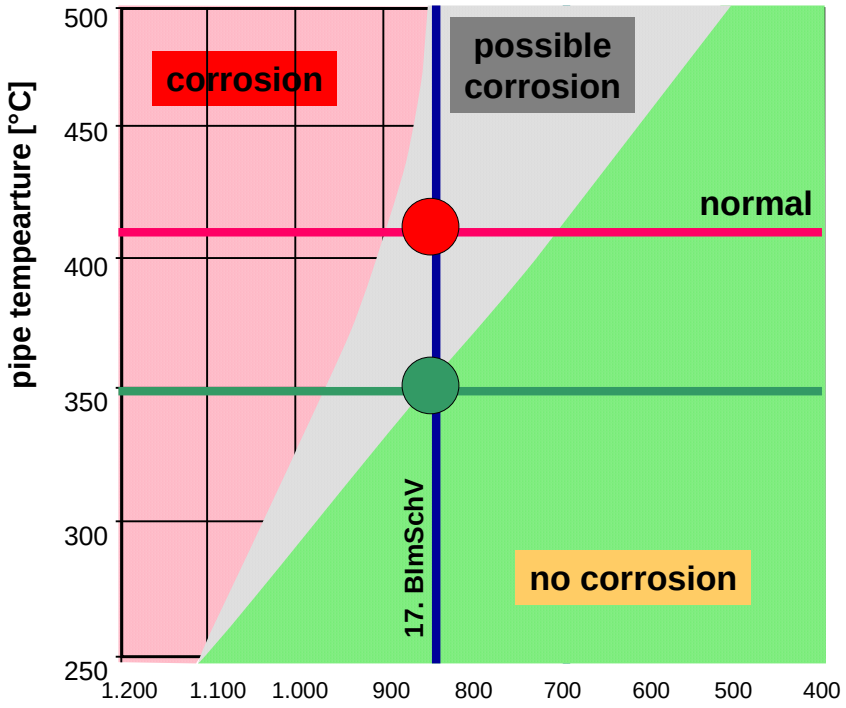
Critical temperatures



Source: Born, Seifert (Freiberg)

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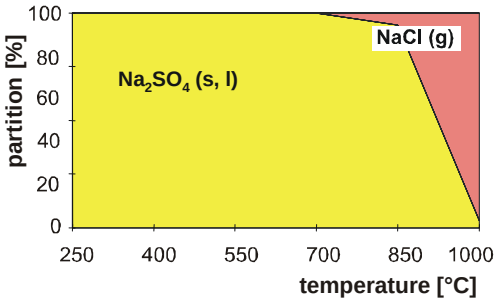
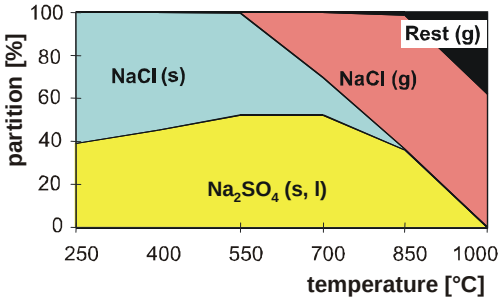
Phase equiliblium

as a function of CO- resp. O_2-concentration



Oxidizing atmosphere
(3 Vol-% O_2)

Reducing atmosphere
(1 Vol-% CO)



Source: Born, Seifert (Freiberg)

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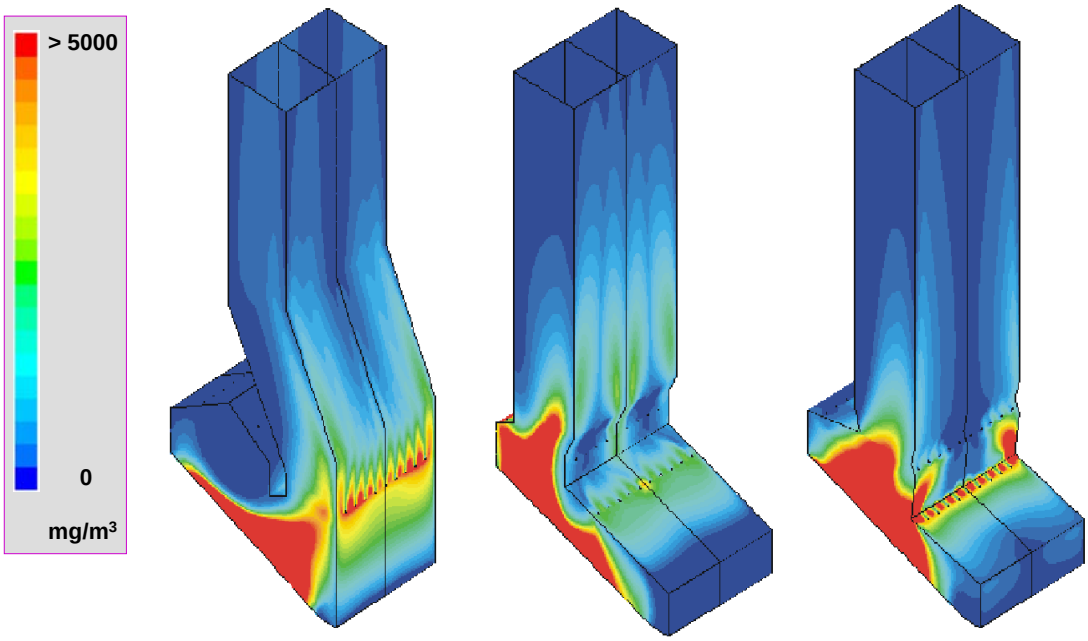
Furnace Geometry

CO-concentration [mg/m^3] near the walls



Parallel flow firing

Counter flow firing

Center flow firing

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Ash melting temperatures for different species

Pure species	melting temperature °C
NaCl	801
KCl	772
$MgCl_2$	714
$CaCl_2$	772
$FeCl_2$	676
$FeCl_3$	303

Eutectic systems mol-%	melting temperature °C
25 NaCl – 75 $FeCl_3$	156
55 $ZnCl_2$ – 45 KCl	230
60 KCl – 40 $FeCl_2$	355
58 NaCl – 42 $FeCl_2$	370
58 NaCl – 42 $FeCl_2$	460
49 NaCl – 51 $CaCl_2$	500

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Biomass Usage and Thermal Treatment of Wastes

Decentralized Plant Concept

Course

Waste to Energy and Recovered Materials from Waste

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Biomass usage very attractive in many EU-countries

- garanteed revenues for power production
- CO_2-neutrality gives advantages concerning emission trading

Thermal treatment of industrial wastes is interesting for production sites

- mono-graded wastes from production processes allow a well specified plant
- costs for the treatment can be reduced
- power and heat can be used internally

Treatment with power/heat production for municipal wastes for isolated areas is a challenge

- rural areas
- islands
- developing countries

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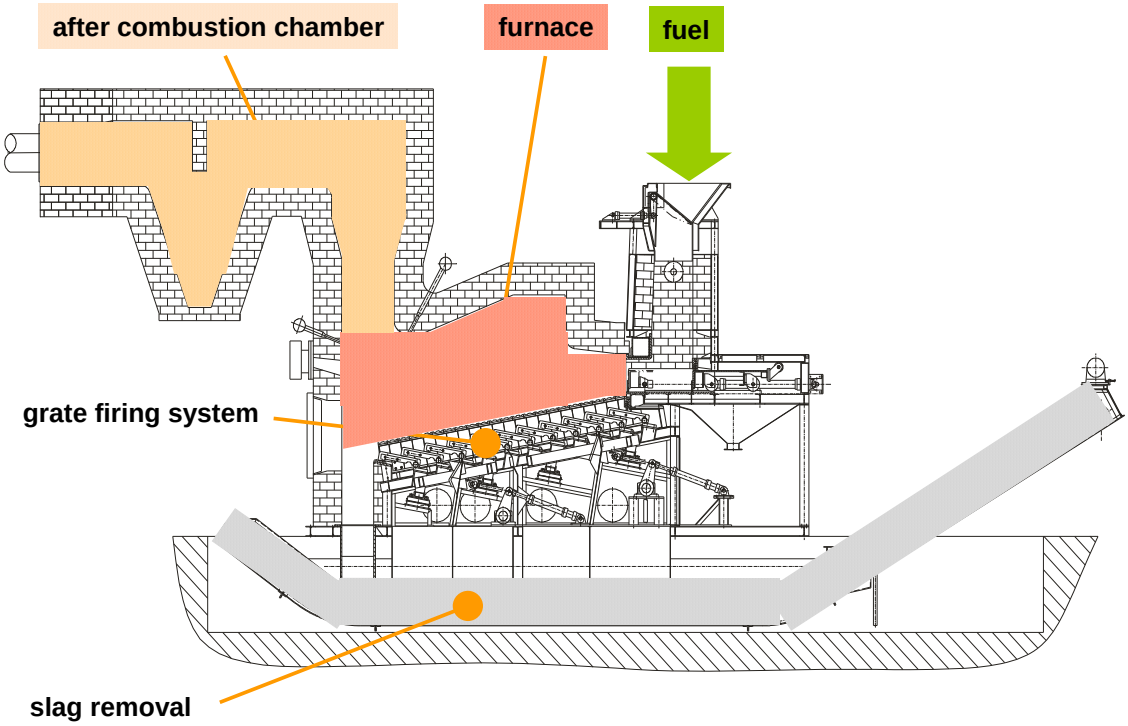

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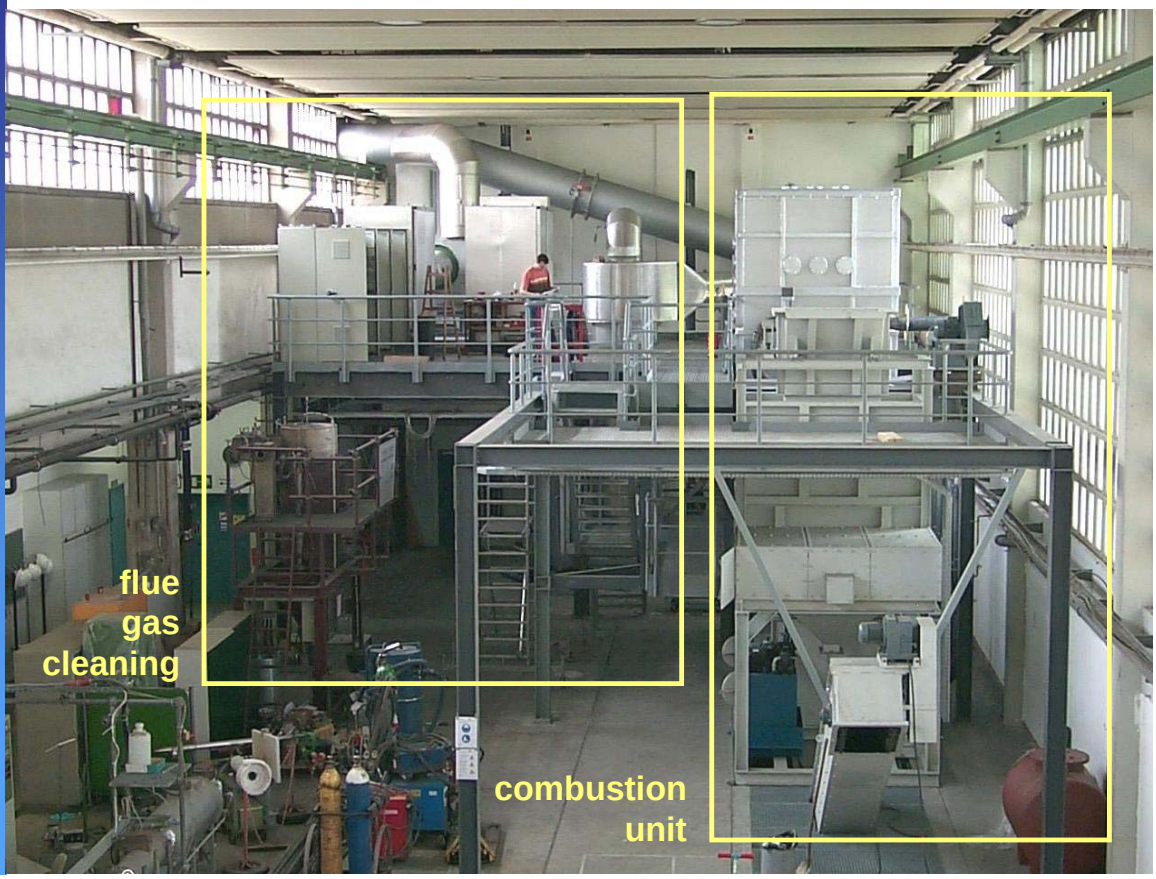

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Gas analysis – species and ranges

FTIR gas analysis (ranges for the different spezies)

species	raw gas	cleaned gas
CO	0 - 1000 mg/m³	0 - 300 mg/m³
CO_2	0 - 20 mg/m³	0 - 20 mg/m³
O_2	0 - 25 Vol-%	0 - 25 Vol-%
NO	0 - 2000 mg/m³	0 - 390 mg/m³
NO_2	0 - 2000 mg/m³	0 - 60 mg/m³
HCl	0 - 1000 mg/m³	0 - 90 mg/³
SO_2	0 - 3000 mg/m³	0 - 300 mg/m³
H_2O	0 - 40 Vol-%	0 - 40 Vol-%
NH_3	0 - 500 mg/m³	0 - 15 mg/m³
HF	0 - 100 mg/m³	0 - 25 mg/m³
N_2O	0 - 1000 mg/m³	0 - 200 mg/m³

FID gas analysis

$C_{ges.}$	0 - 1000 mg/m³	0 - 100 mg/m³

Hg CEM gas analysis

Hg^0		0 - 75 µg/m³

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Investigated fuels

The following fuels/wastes have been investigated:

- wood pellets
- wood chips
- scrap of paper + plastic scraps in different mixture fractions
- industrial wastes
- wastes similar to municipal wastes
- residual materials
- residual wastes

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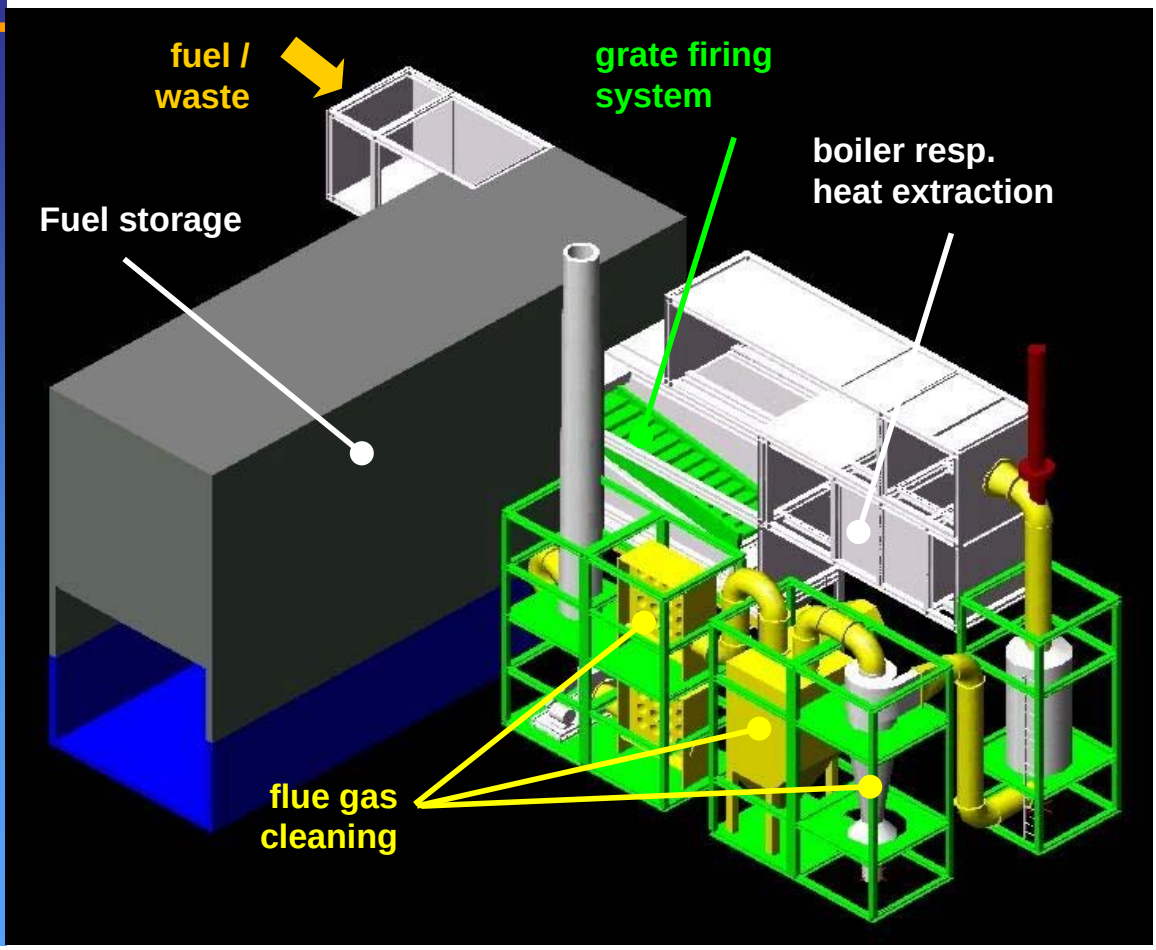

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