Introduction

Fluidized Bed Combustion

at the

Dresden University of Technology

Co-combustion

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Investigation (with) system

TU Dresden Pilot Rig

Co-fuels

Mathematical modelling

Calculations for optimising of combustion

- **Secondary air distribution**
- **Mixture proportions**
- **Charge spots of Co-fuels**

Modelling Data sheets 1D

Experimental Profiles 2D

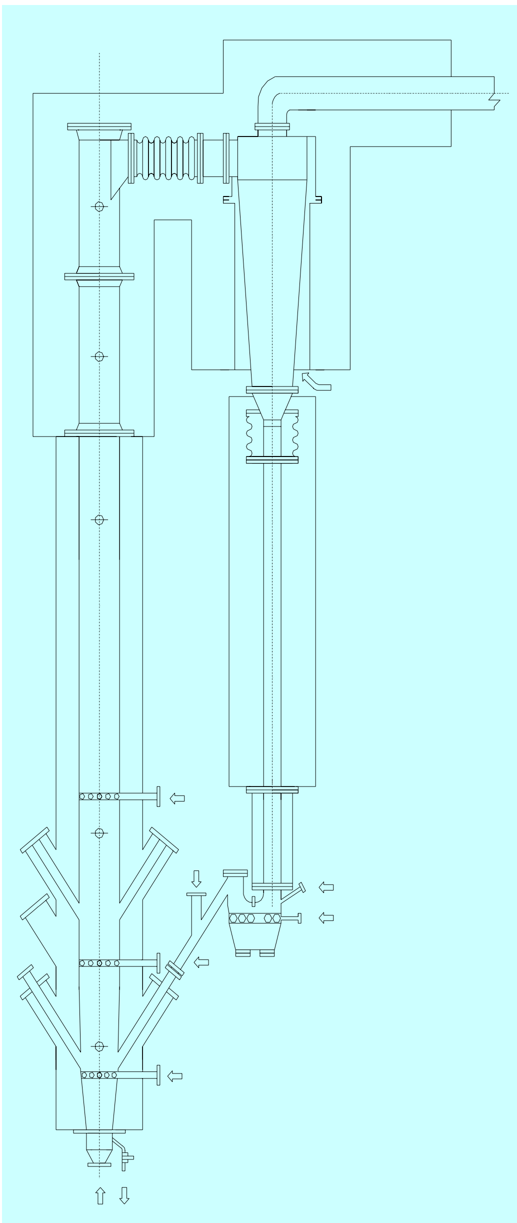
Outlook

Test Rig Circulating Fluidized Bed II

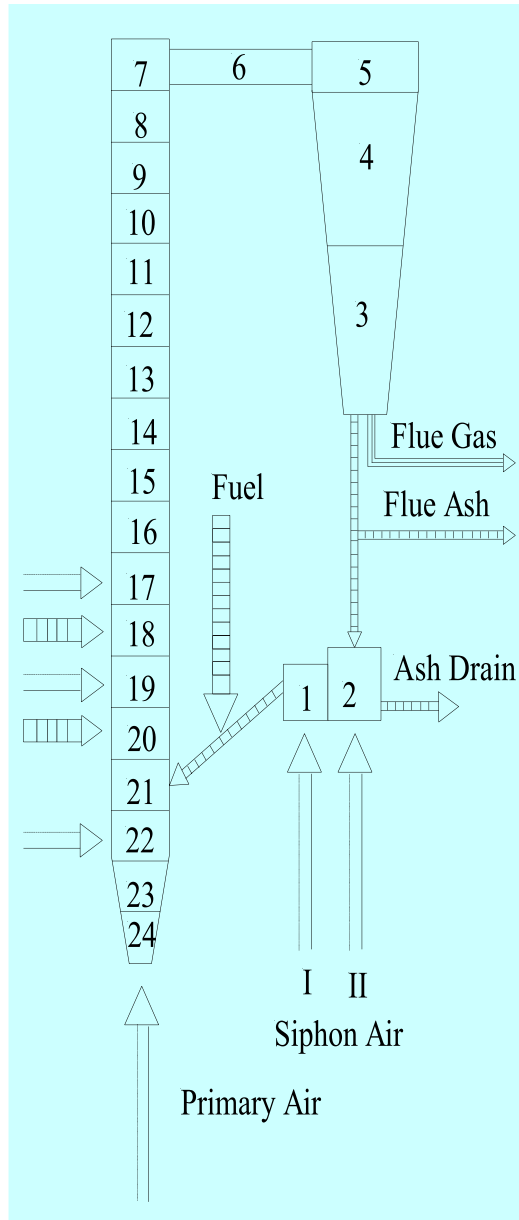
System height: 6,7 m
ø: 0,32 m

24 Elements
thermal Load: 300 kW

Sectional view



Cell Distribution for Modelling



Outline of substances, processes and reactions concidered in the simulation model

Air $O_2 + N_2$

Fuels: Coal + Waste
Elementary Analysis: C,H,O,N,S,A,W
Caloric Value: H_u ; H_{ul}
Particle Size Distribution: $p_0(d_C)$; $p_{0a}(d_{Ca})$

Limestone
Elementary Analysis
$CaCO_3$, H_2O, Minerals
Particle Size Distribution: $p_{0k}(d_{Ck})$

Drying Process (Water Outlet, kinetic)
Dry Fuels + Water

Calcination
CaO, CO_2, H_2O, Ash

Degassing (kinetic)
Coke
CO, CO_2, H_2, CH_4, C_xH_y, H_2O, NH_3, $\underline{HCN}$, H_2S

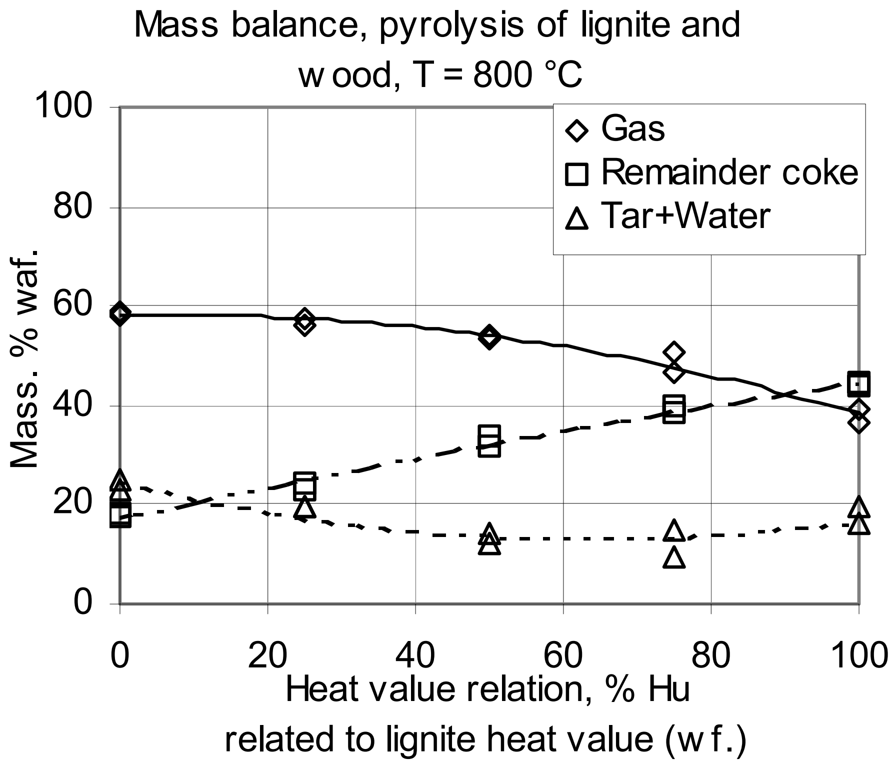
Particle Size Modification
(Contraction, Fragmenting, Attrition, Burning Rate)
$p_0(d_C) \rightarrow p_1(d_{C1})$; $p_{0a}(d_{Ca}) \rightarrow p_{1a}(d_{C1a})$

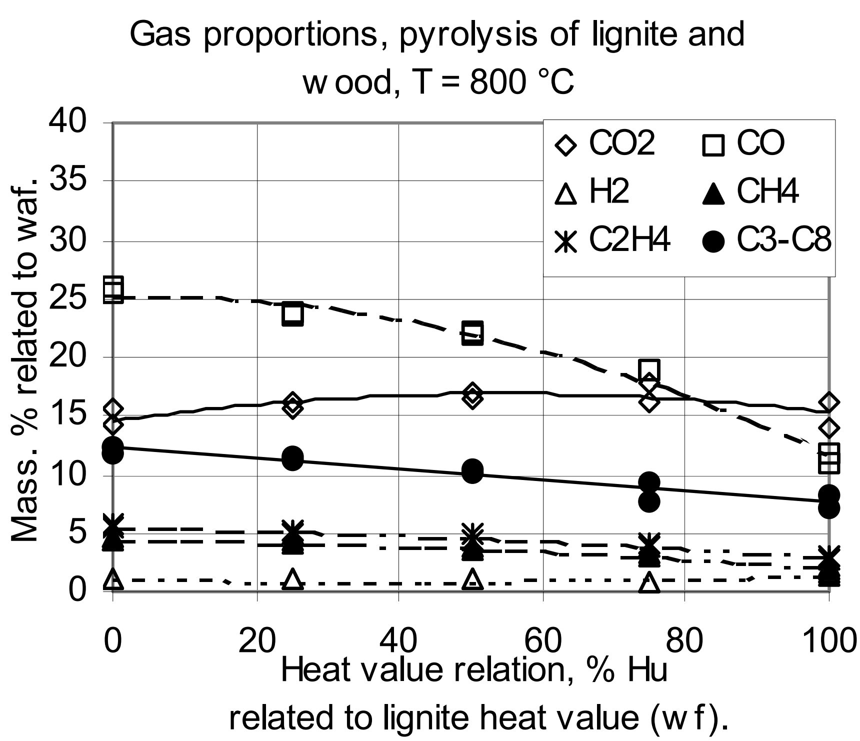
Particle Size Modification
(Abrasion)
$p_{0k}(d_{Ck}) \rightarrow p_{1k}(d_{C1k})$

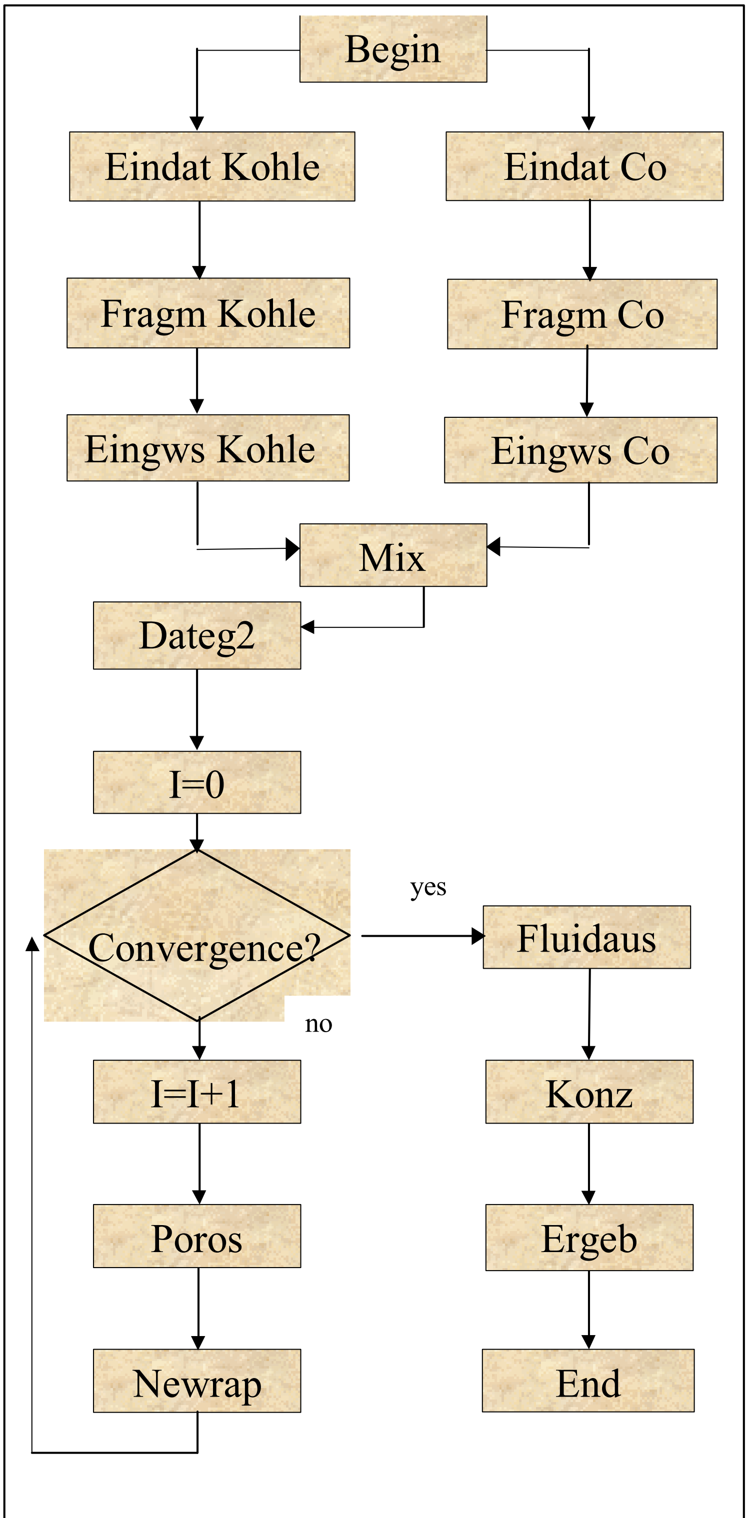
Combustion Reactions (stoichiometrically)
$1\ H_2 + 0,5\ O_2 \rightarrow 1\ H_2O$
$1\ H_2S + 1,5\ O_2 \rightarrow 1\ H_2O + 1\ SO_2$
$1\ CH_4 + 1,5\ O_2 \rightarrow CO + 2\ H_2O$
$1\ HCN + 1,25\ O_2 \rightarrow NO + CO + 0,5\ H_2O$

Sulphation(kinetic, Chemical Balance)
$1\ SO_2 + 0,5\ O_2 \rightarrow 1\ SO_3$
$1\ CaO + 1\ SO_3 \rightarrow 1\ CaSO_4$

Combustion Reactions (kinetic)
$1\ C + 1/\phi\ O_2 \rightarrow (2-2/\phi)\ CO + (2/\phi-1)\ CO_2$
$1\ CO + 0,5\ O_2 \rightarrow 1\ CO_2$
$1\ NH_3 + 1,25\ O_2 \rightarrow 1\ NO + 1,5\ H_2O$
$1\ NH_3 + 0,75\ O_2 \rightarrow 0,5\ N_2 + 1,5\ H_2O$
$1\ NO + 1\ CO \rightarrow 0,5\ N_2 + 1\ CO_2$
$1\ NO + 2/3\ NH_3 \rightarrow 5/6\ N_2 + 1\ H_2O$
$1\ NO + 1\ H_2 \rightarrow 0,5\ N_2 + 1\ H_2O$
$1\ NO + 1\ C \rightarrow 0,5\ N_2 + 1\ CO$
$1\ C_xH_y + (0,5x+y/4)\ O_2 \rightarrow x\ CO + y/2\ H_2O$


Mass balance, pyrolysis of lignite and
w ood, T = 800 °C
Gas
Remainder coke
Tar+Water
Mass. % waf.
0
20
40
60
80
100
0
20
40
60
80
100
Heat value relation, % Hu
related to lignite heat value (w f.)


Gas proportions, pyrolysis of lignite and
w ood, T = 800 °C
CO2
CO
H2
CH4
C2H4
C3-C8
Mass. % related to waf.
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
Heat value relation, % Hu
related to lignite heat value (w f).



Eindat
Sub for reading input data

Fragm
Sub for calculation of particle distribution in the feed for both fuels

Eingws
Sub for converting and precalculation of degassing, solid distribution and solid flow

Mix
Precalculation of mixture

Dateg2
Output of data

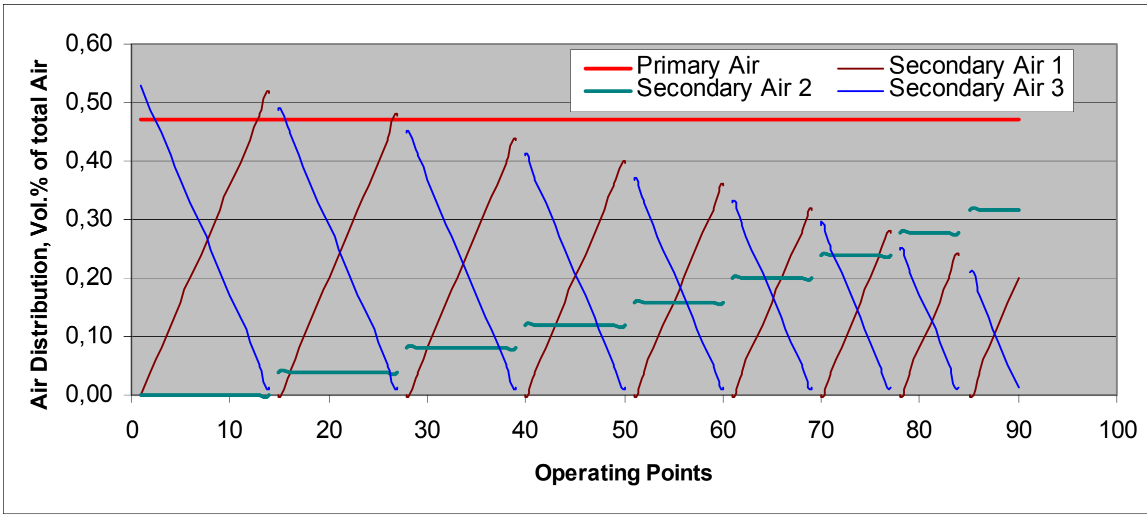
Poros
Sub for calculation of porosity along the reactor

Konz
Calculation of gaseous flows and concentrations for all elements (cells)

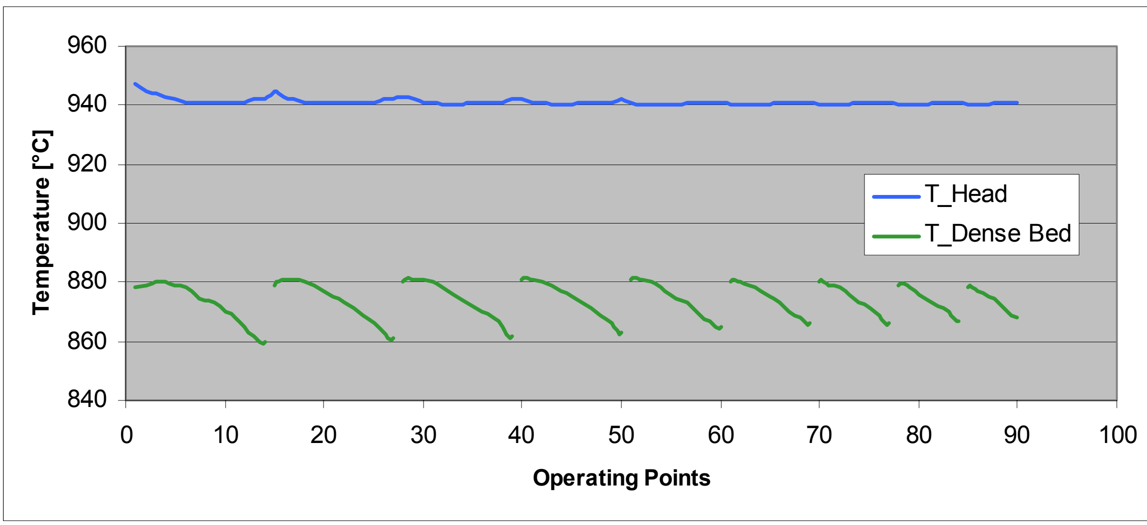
Newrap
Sub for Iteration of the nonlinear set of equations consist of 22 variables for 24 elements (cells)

Fluidaus
Output of the flowmechanical calculation

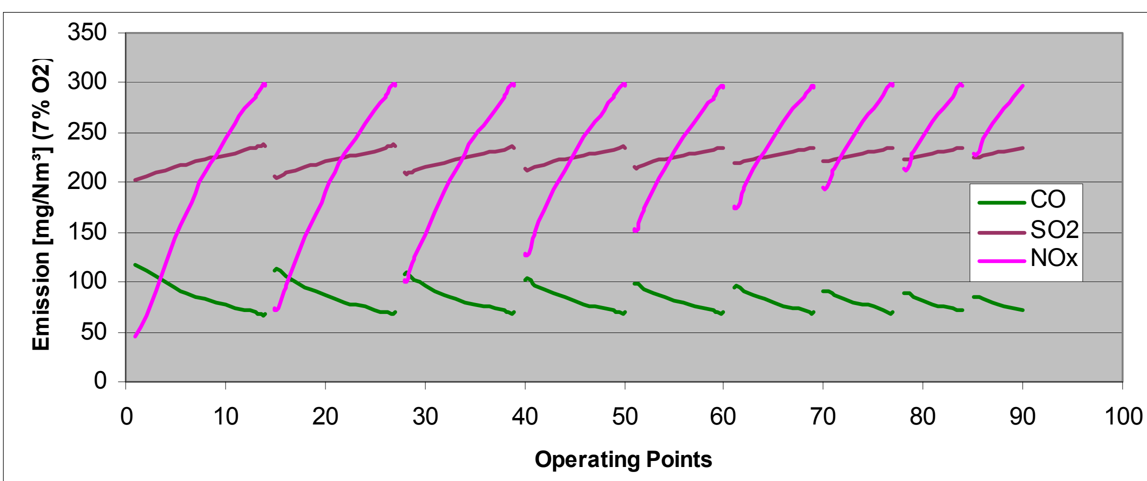
Ergeb



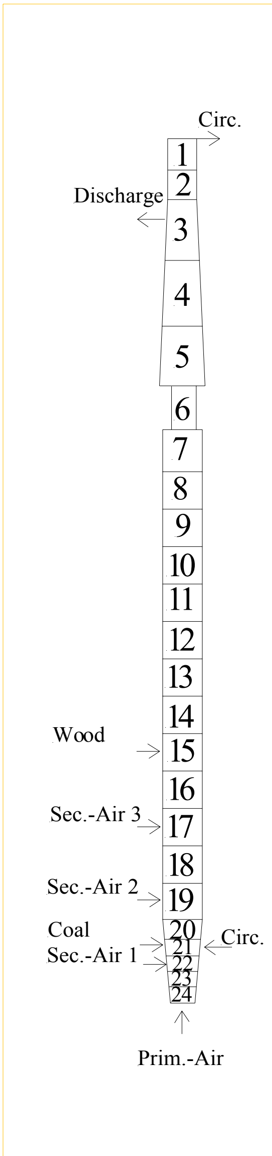
Air Distribution, Vol.% of total Air
0,60
0,50
0,40
0,30
0,20
0,10
0,00
0
10
20
30
40
50
60
70
80
90
100
Operating Points
Primary Air
Secondary Air 1
Secondary Air 2
Secondary Air 3

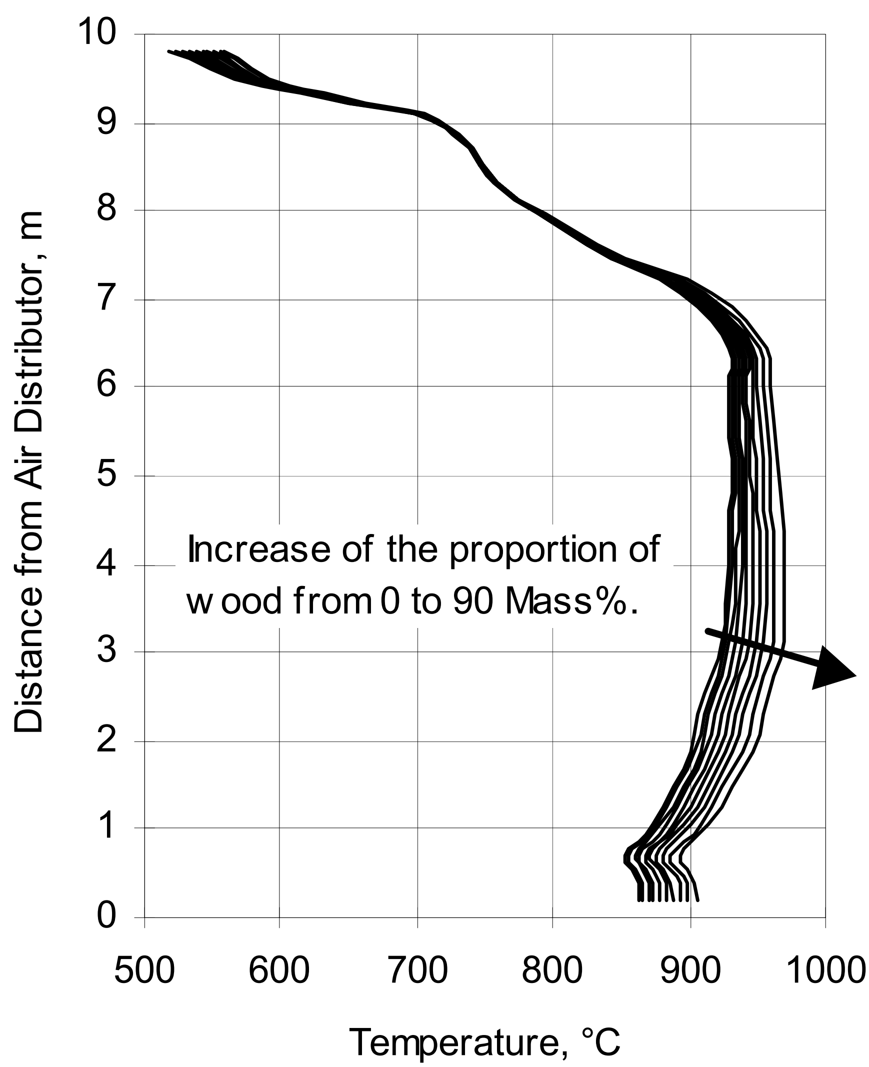


Temperature [°C]
960
940
920
900
880
860
840
0
10
20
30
40
50
60
70
80
90
100
Operating Points
T_Head
T_Dense Bed

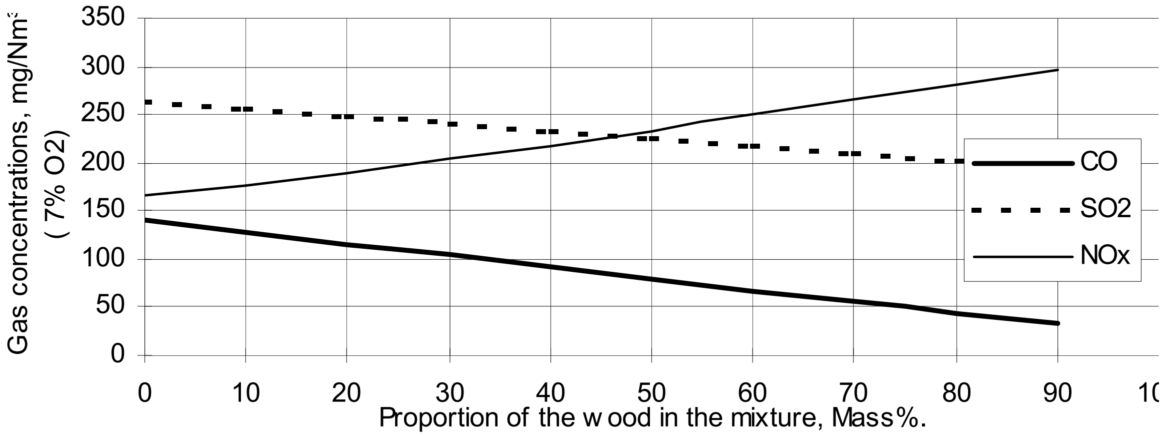


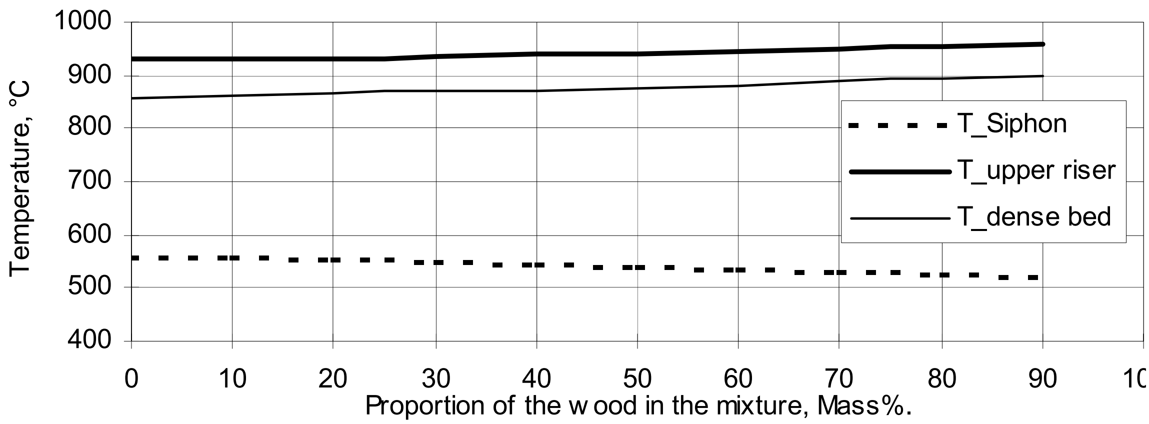
Emission [mg/Nm³] (7% O2)
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
100
Operating Points
CO
SO2
NOx

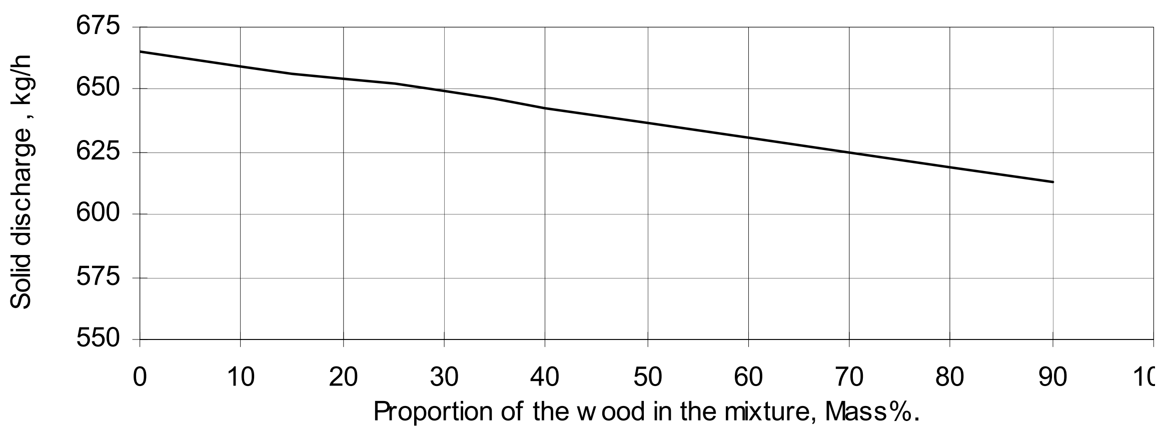


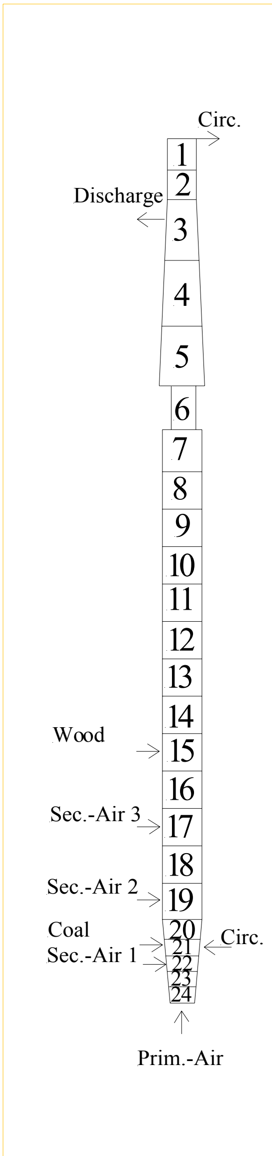


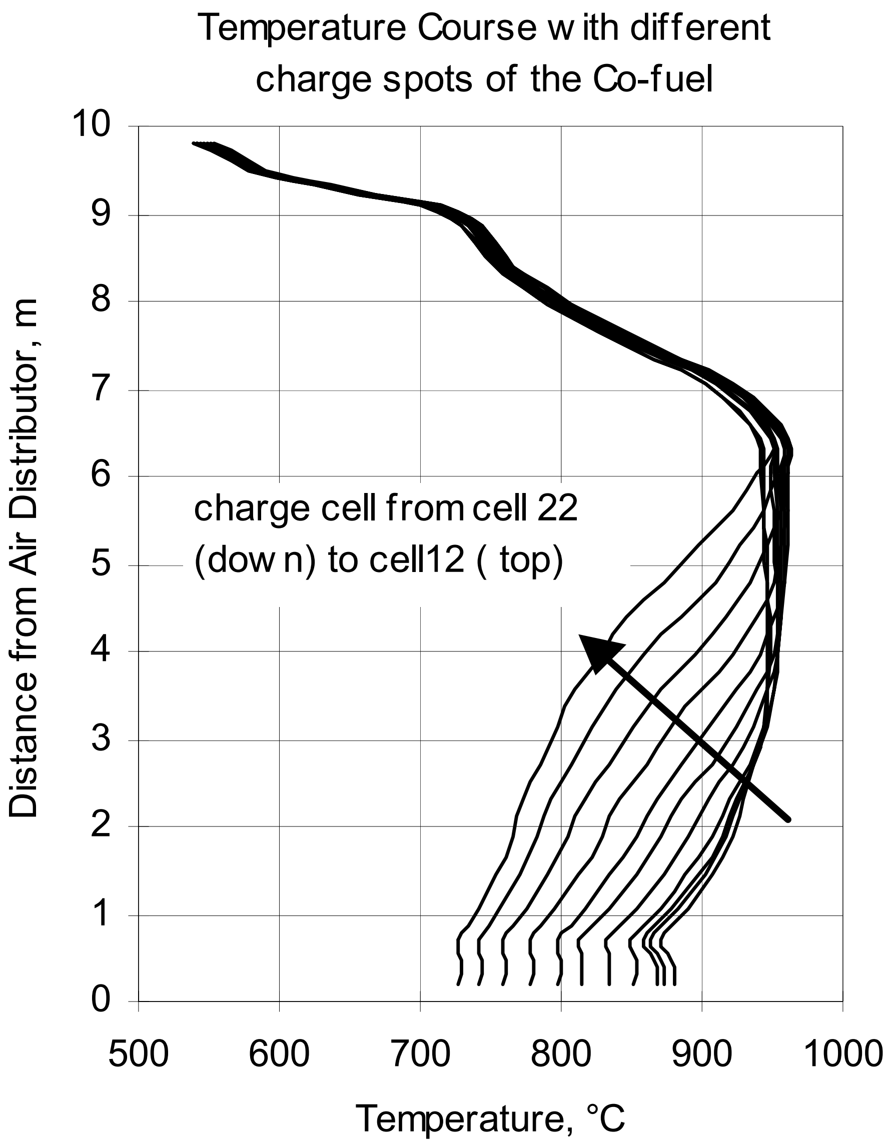
with superproportional wood application the danger of agglomerations is given, special with the Co-fuel waste wood appears this with 950 °C occur by the higher alkali contents, those the ash melting point lower

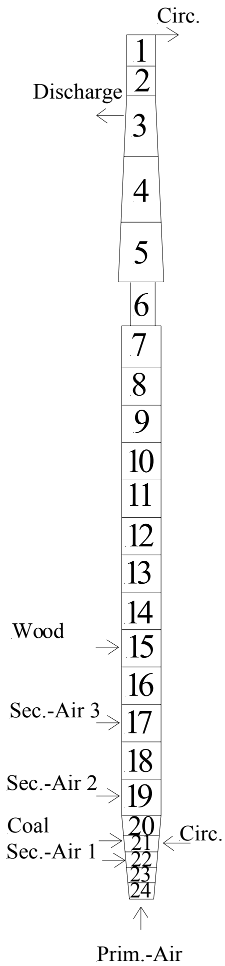

Gas concentrations, mg/Nm³ (7% O2)
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
10
Proportion of the w ood in the mixture, Mass%.
CO
SO2
NOx

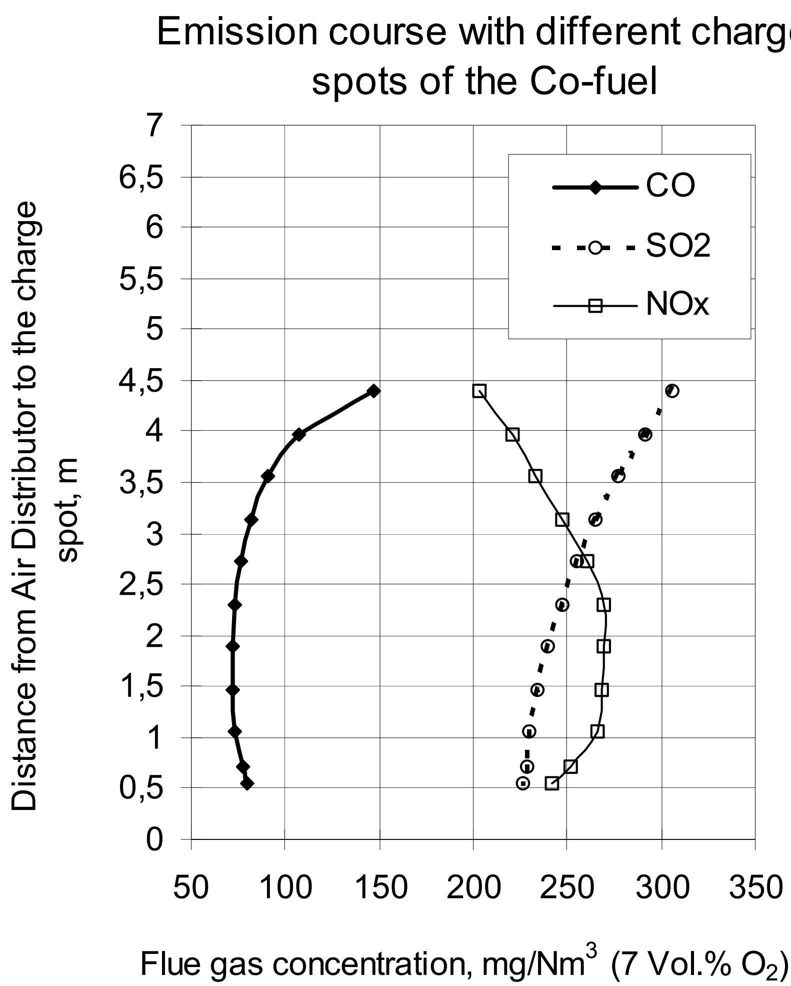

Temperature, °C
1000
900
800
700
600
500
400
0
10
20
30
40
50
60
70
80
90
10
Proportion of the w ood in the mixture, Mass%.
T_Siphon
T_upper riser
T_dense bed

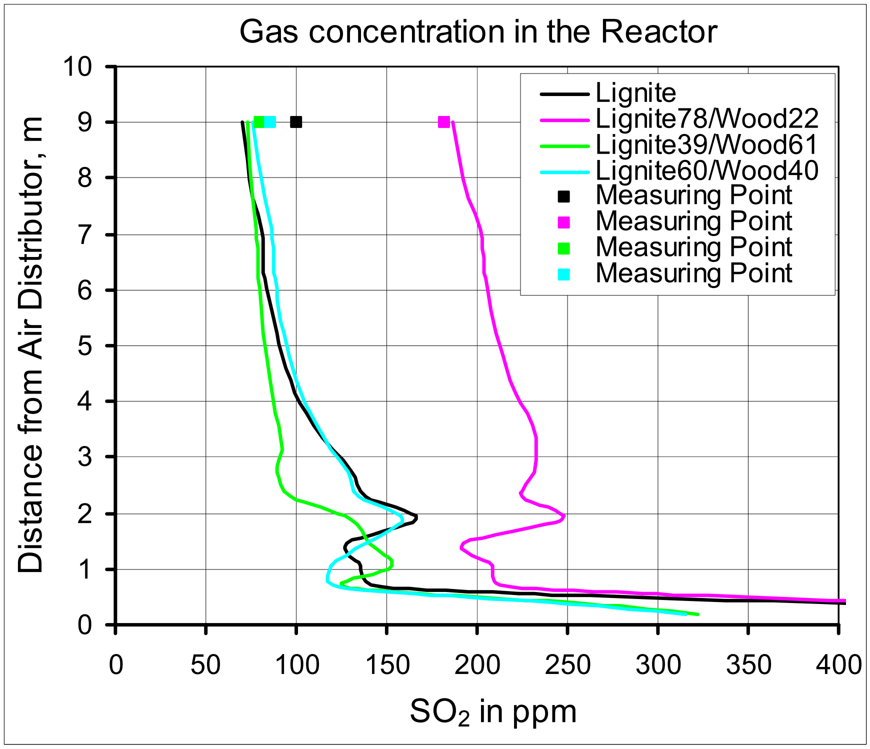

Solid discharge , kg/h
675
650
625
600
575
550
0
10
20
30
40
50
60
70
80
90
10
Proportion of the w ood in the mixture, Mass%.


Circ.
1
2
Discharge
3
4
5
6
7
8
9
10
11
12
13
14
Wood
15
16
Sec.-Air 3
17
18
Sec.-Air 2
19
Coal
20
Circ.
21
Sec.-Air 1
22
23
24
Prim.-Air

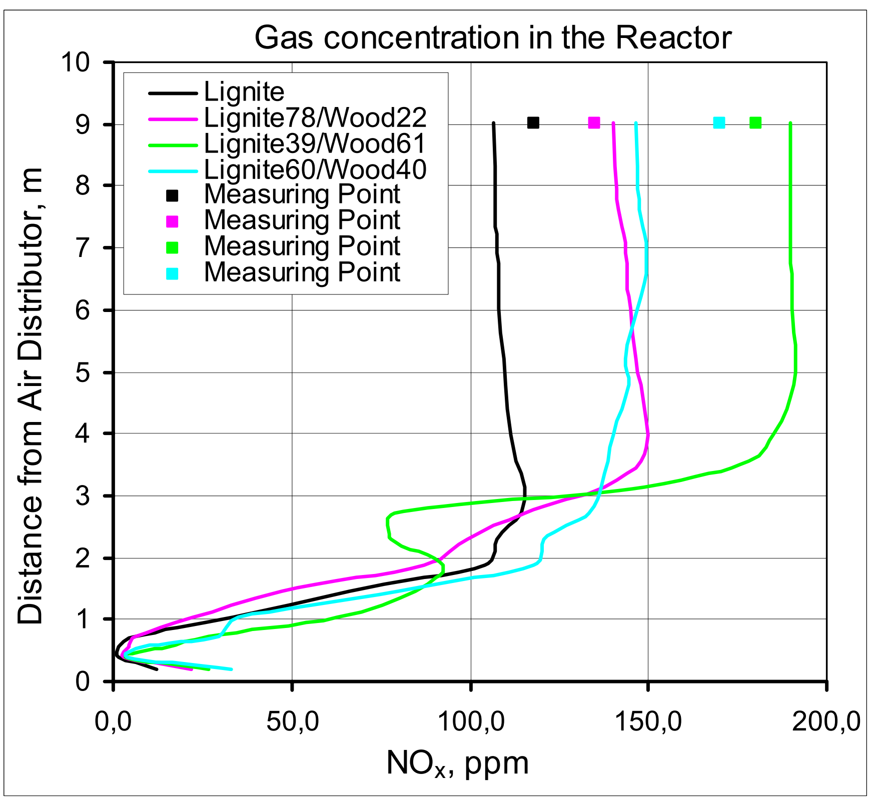

Temperature Course w ith different charge spots of the Co-fuel
Distance from Air Distributor, m
0
1
2
3
4
5
6
7
8
9
10
charge cell from cell 22 (dow n) to cell12 (top)
500
600
700
800
900
1000
Temperature, °C


Circ.
1
2
Discharge
3
4
5
6
7
8
9
10
11
12
13
14
Wood
15
16
Sec.-Air 3
17
18
Sec.-Air 2
19
Coal
20
21
Circ.
Sec.-Air 1
22
23
24
Prim.-Air

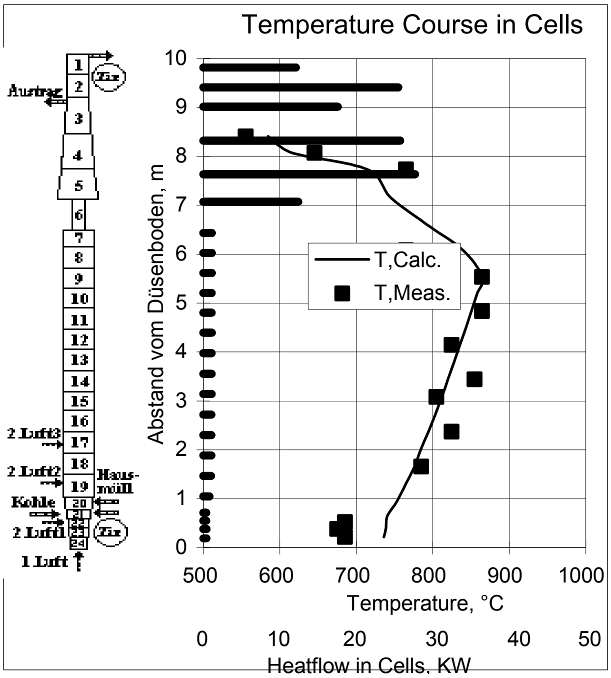

Emission course with different charge spots of the Co-fuel
CO
SO2
NOx
Distance from Air Distributor to the charge spot, m
Flue gas concentration, mg/Nm3 (7 Vol.% O2)
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
50
100
150
200
250
300
350

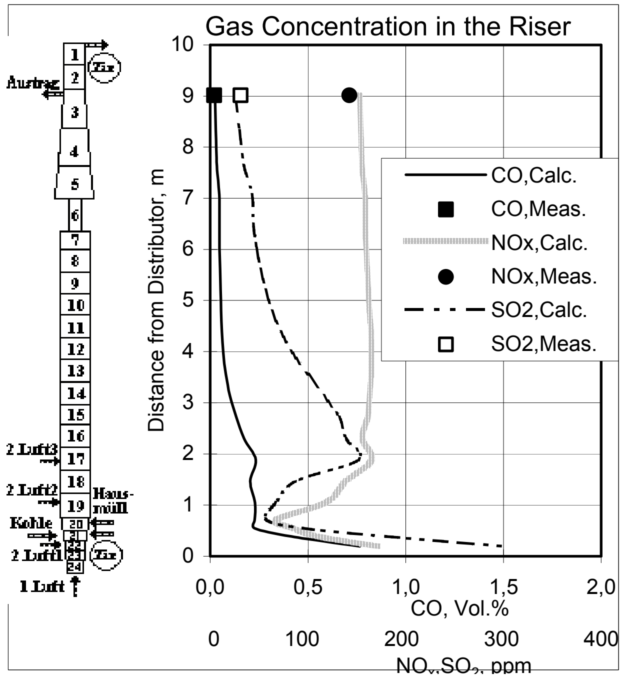


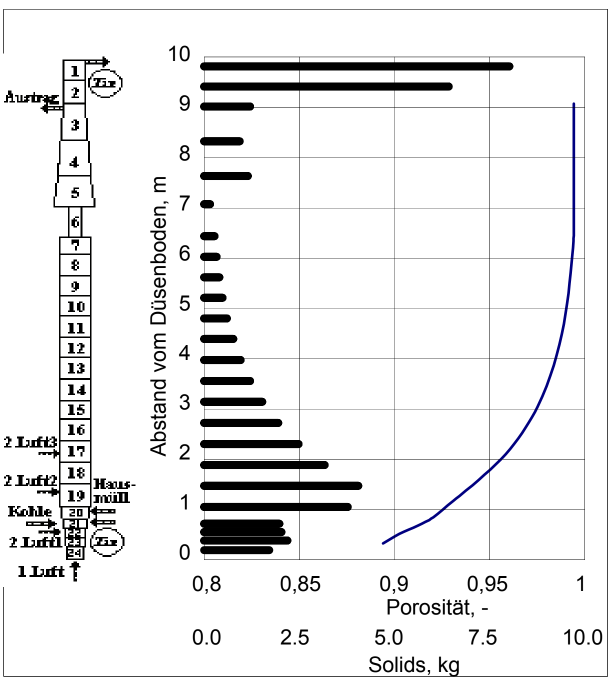
Gas concentration in the Reactor
Distance from Air Distributor, m
SO2 in ppm
Lignite
Lignite78/Wood22
Lignite39/Wood61
Lignite60/Wood40
Measuring Point
Measuring Point
Measuring Point
Measuring Point
0 1 2 3 4 5 6 7 8 9 10
0 50 100 150 200 250 300 350 400

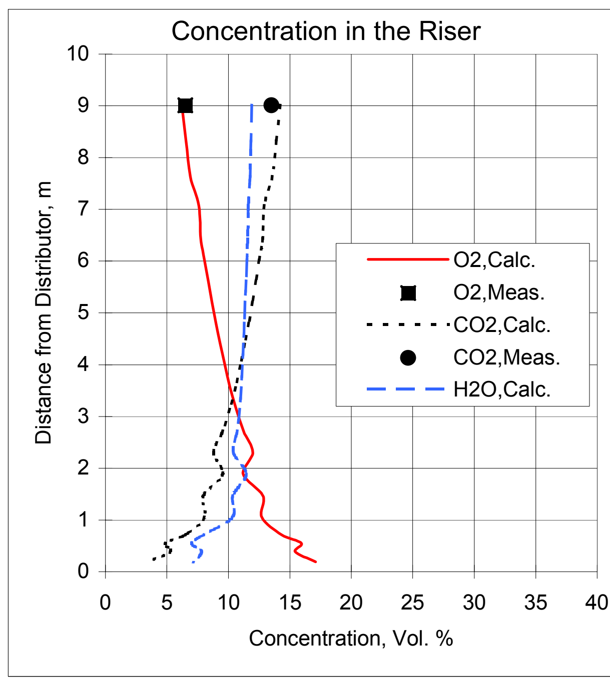


Gas concentration in the Reactor
Distance from Air Distributor, m
NOx, ppm
Lignite
Lignite78/Wood22
Lignite39/Wood61
Lignite60/Wood40
Measuring Point
Measuring Point
Measuring Point
Measuring Point
0 1 2 3 4 5 6 7 8 9 10
0,0 50,0 100,0 150,0 200,0

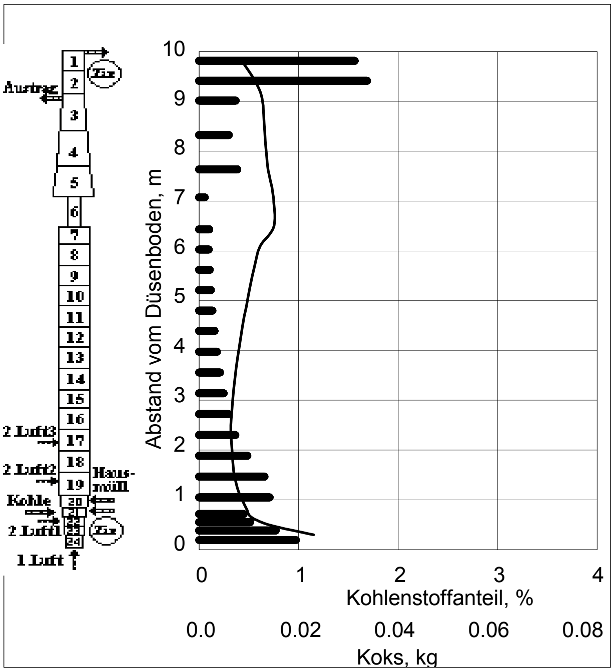


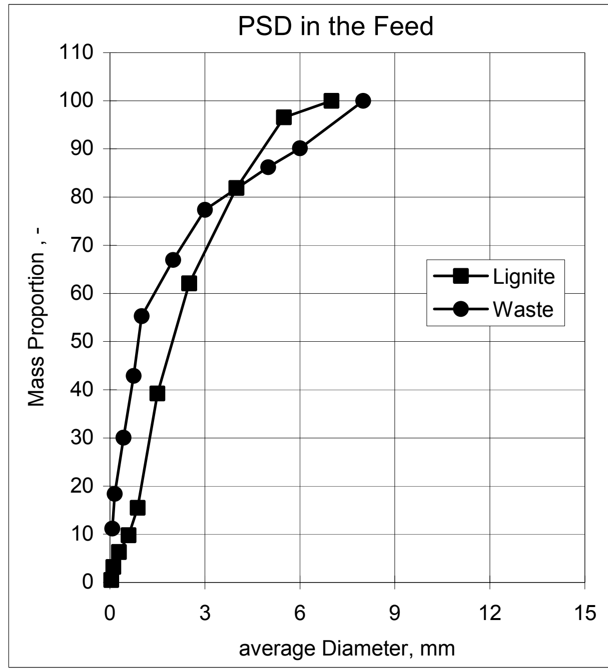


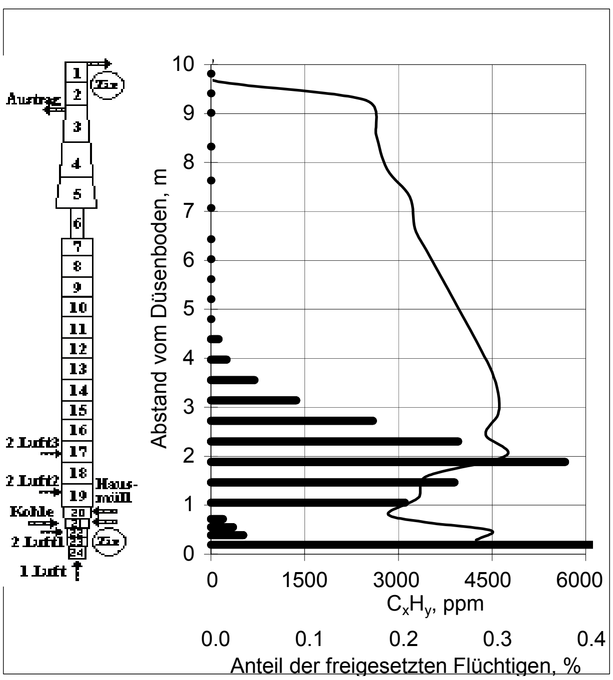


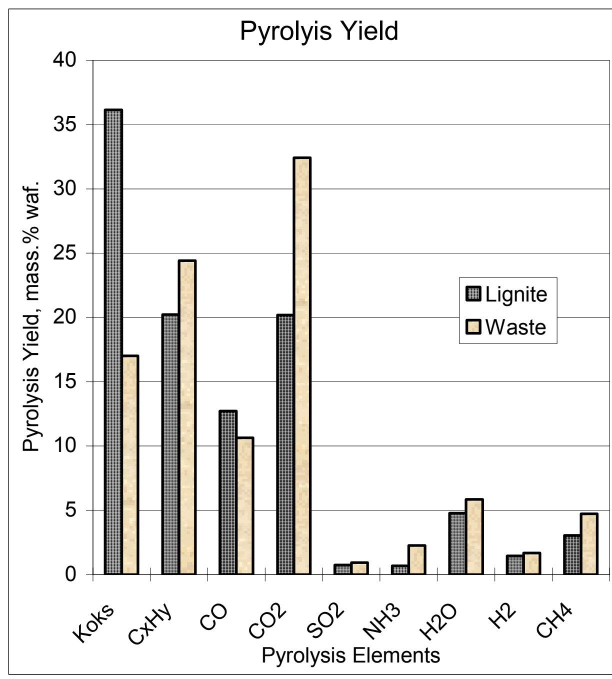


Combustion in ZWSF II			Versuch: tkhm254		Date:	02.07.98
Participants:		Nr.	Parameter		Unit	Input Cell
Brunne, T.	*Number:*	1	Lignite	50,0	kg/h	21
Hiller, A.		2	Waste	13,4	kg/h	20
Quang, N.T.	50	3	Air Ratio	1,18	-	-
		4	Th. Load	285	KW	-
		5	Primary Air	128	Nm^3/h	24
TU Dresden		6	Second. Air 1.	45	Nm^3/h	22
Institut für Energietechnik		7	Second. Air 2.	52	Nm^3/h	19
Lehrstuhl Kraftwerktechnik		8	Second. Air 3.	58	Nm^3/h	17
Prof. Dr. -Ing. habil. W. Bernstein		9	Siphon Air	37	Nm^3/h	1: 28; 2: 9





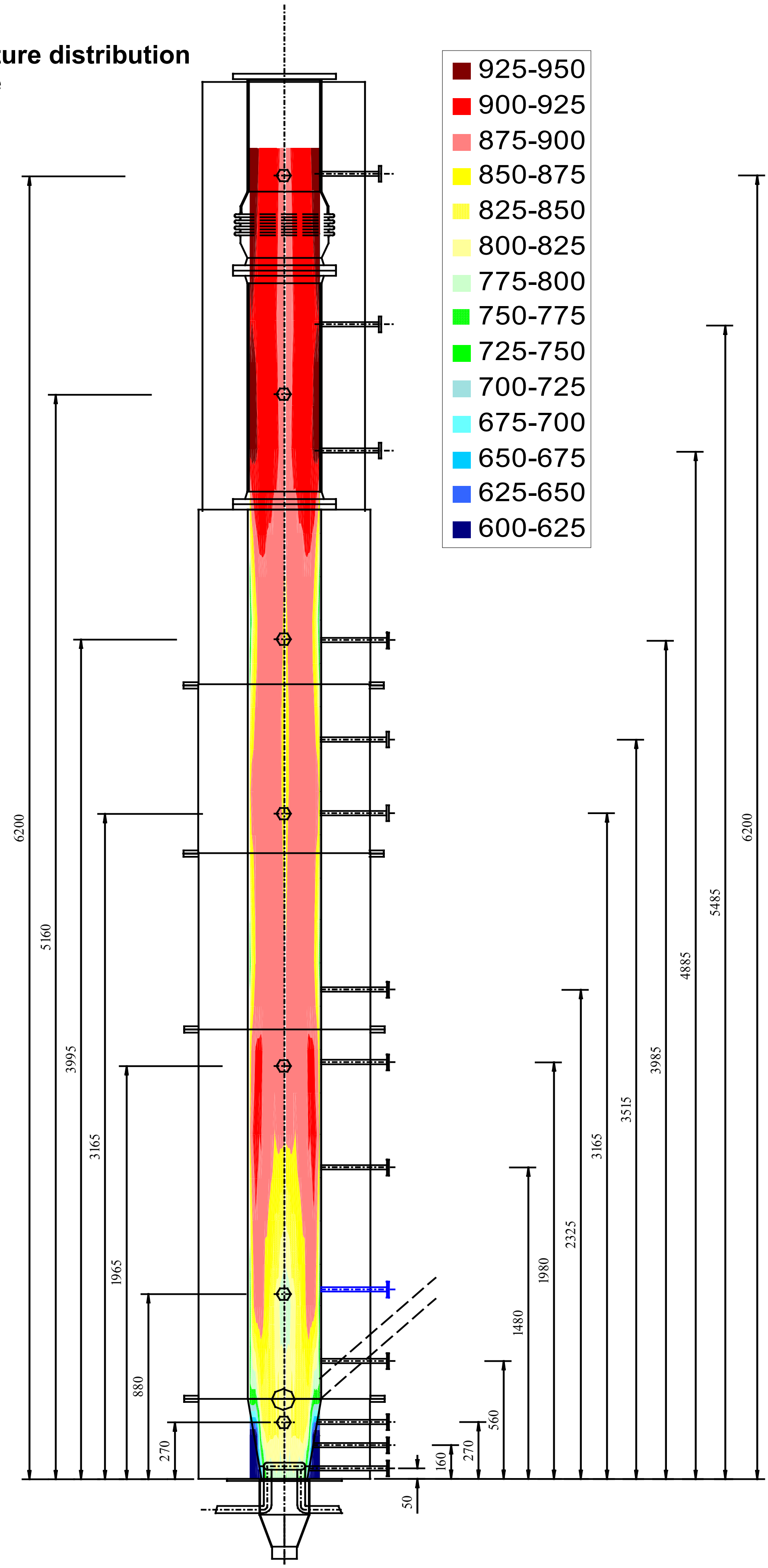




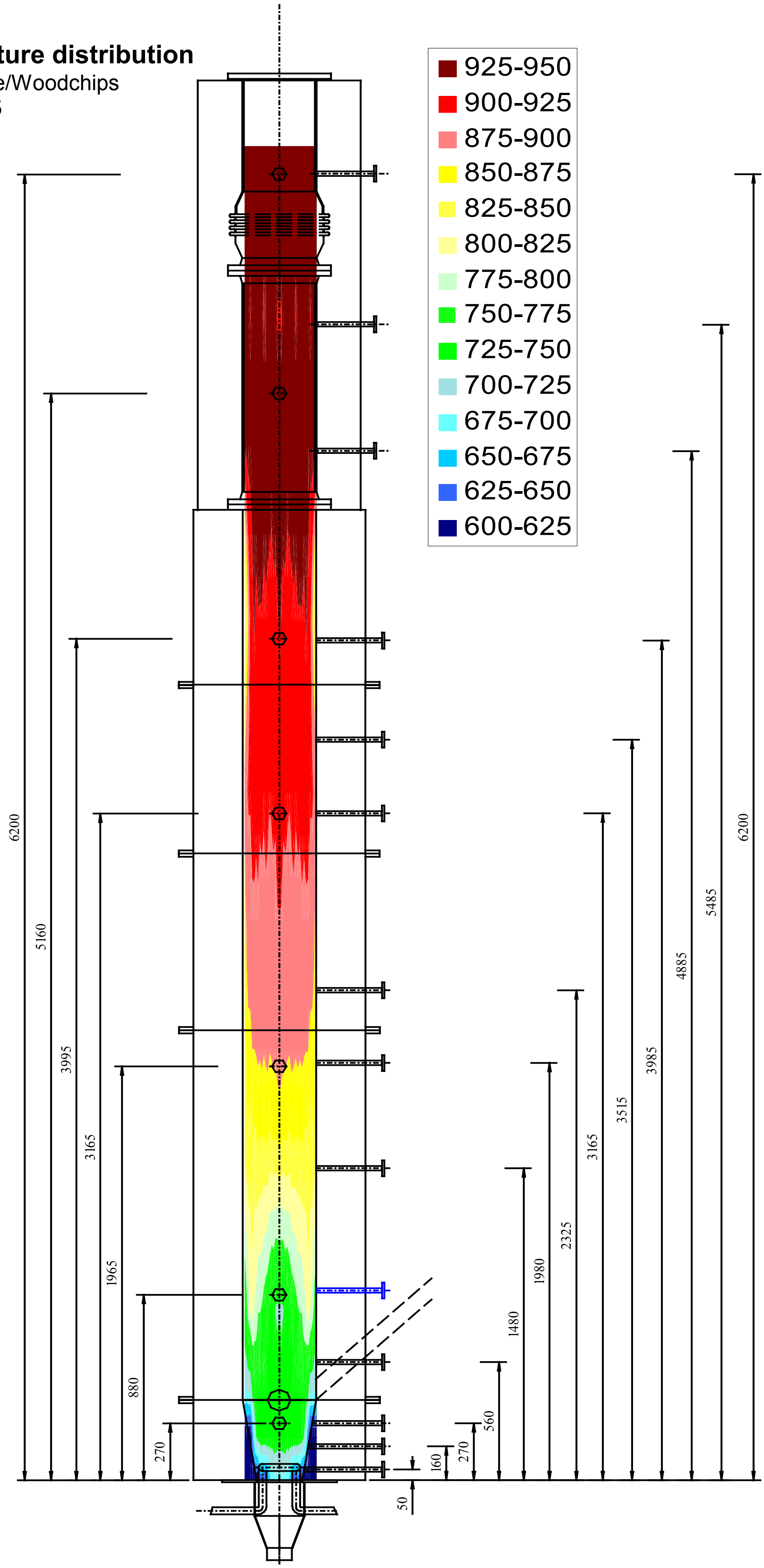
Combustion in ZWSF II			Versuch: tkhm254		Date:	02.07.98
Participants:		Nr.	Parameter	Größe	Unit	Input Cell
Brunne, T.	*Number:*	1	Lignite	50	kg/h	21
Hiller, A.		2	Waste	13,4	kg/h	20
Quang, N.T.	50	3	Air Ratio	1,18	-	-
		4	Th. Load	285	KW	-
		5	Primary Air	128	Nm3/h	24
TU Dresden		6	Second. Air 1.	45	Nm3/h	22
Institut für Energietechnik		7	Second. Air 2.	52	Nm3/h	19
Lehrstuhl Kraftwerktechnik		8	Second. Air 3.	58	Nm3/h	17
Prof. Dr. -Ing. habil. W. Bernstein		9	Siphon Air	37	Nm3/h	1: 28; 2: 9

Temperature distribution

Fuel: Lignite



Temperature distribution
Fuel: Lignite/Woodchips
Load: 85/15
260 kW

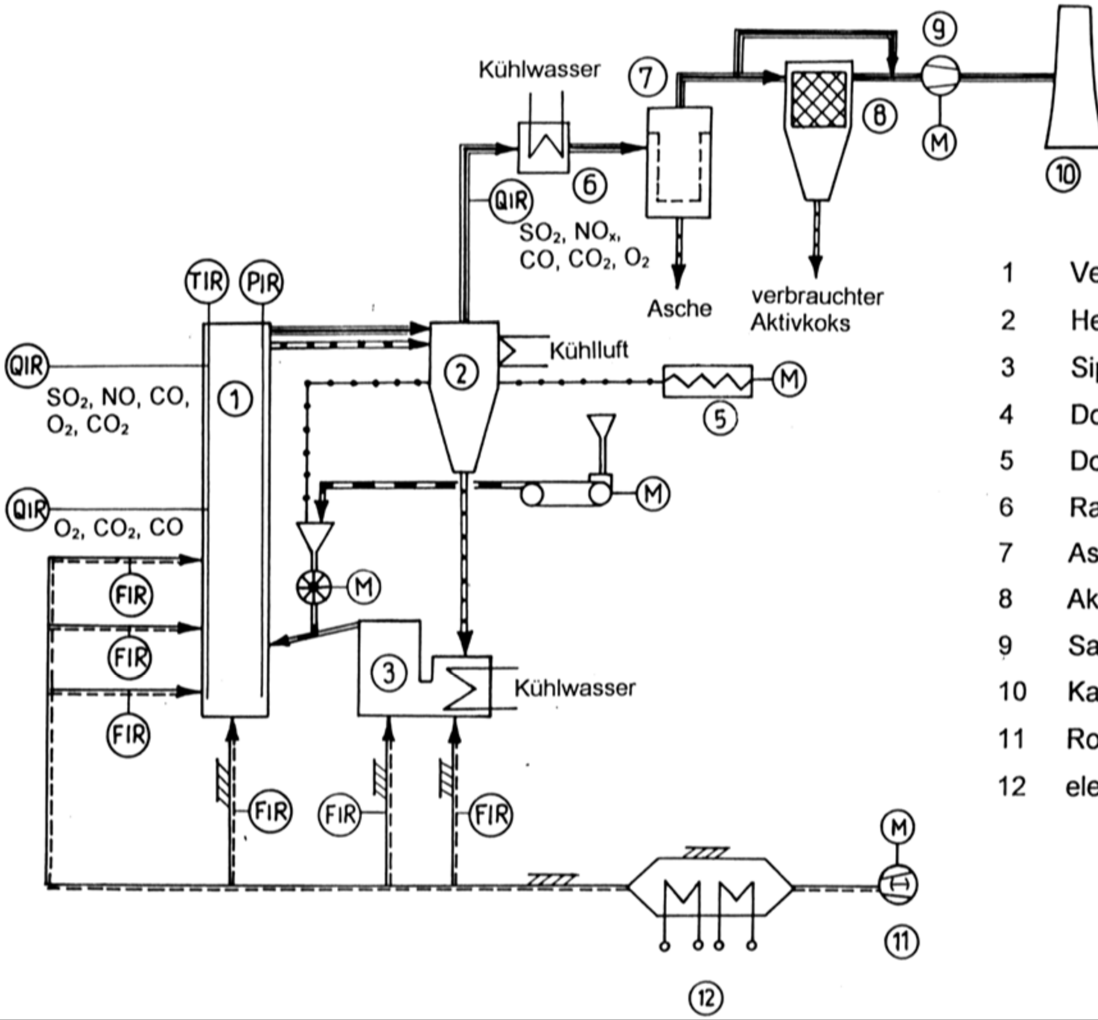


Outlook

- Determine emission profiles of NO_x and later NH_3,
- In result: optimisation of input spots for co-fuel (reburning),
- Consider dissymmetries as consequence of the charge spots (back-leg and co-fuel),
- Modelling of hard coal,
- Use of further Different Co-fuels: oil sludge, communal waste...,
- Development of the integration of CFB and Gasification (use our co-current fixed bed gasifier),
- Estimate of aspects of economy (and sense ...... electronic waste),
  - Combination of disposal with side effects:

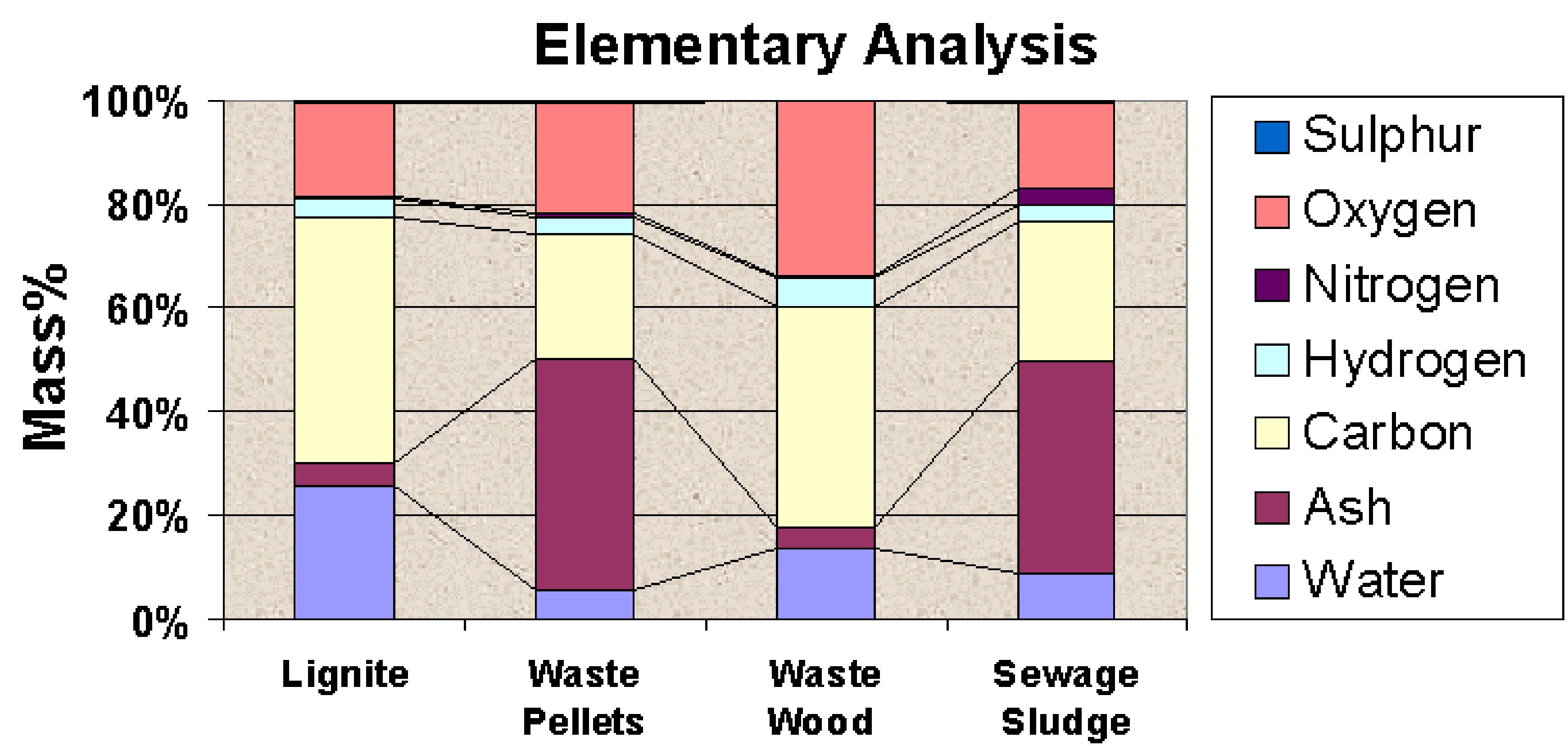
Elementary Analysis	Limestone	?
SiO_2	2,1 %	2,3 %
Fe_2O_3	0,4 %	3,6 %
Al_2O_3	1,2 %	0,6 %
CaO	53,8 %	46,6 %
MgO	0 %	0,2 %
H_2O	0,1 %	6,2 %
S	< 0,01 %	< 0,01 %
Ignition loss 900 °C	43 %	40,5 %

(Limestone and Arrears of the water purification of the power station)



1 Verbrennungsreaktor
2 Heißgaszyklon
3 Siphon
4 Dosierbandwaage
5 Dosierschnecke
6 Rauchgaswärmetauscher
7 Aschepatronenfilter
8 Aktivkoksfilter
9 Saugzug
10 Kamin
11 Rootsgebläse
12 elektr. Luvo (64 kW)

Fuels			Co-Fuels											
			Ba-gasse	Sewage Sludge (dry)	Sewage Sludge (humid)	Com-munal Waste	Natural Wood	Waste Wood	Wood Pellets	Oil Sludge	Waste Sludge (Water Station)	Paper Sludge	Paint Sludge	Elec-tronic Waste
			7	9										
Basic Fuels	Lignite (dry)	18	2	14	15	16	14	10				2	1	2
	Hard coal	10				4			8	8	9			
	Lignite (crude)	6												



	Lignite	Waste Pellets	Waste Wood	Sewage Sludge
Volatiles [%]	38,8	41,7	67,3	42,7
Hu [MJ/kg]	17,4	8,7	15,4	10,7