Czestochowa University
of Technology
Poland

Turow Power Plant S.A.

Sulfur capture in a 235 MW CFB boiler by mechanical activation of sorbents

- Prof. Wojciech NOWAK

47th IEA Meeting, Złotniki Lubańskie, 2003

Polish utility power plants

Power Plant	Capacity [MW]
1. Bełchatów	4320
2. Kozienice	2640
3. Turów	2036
4. Połaniec	1740
5. Dolna Odra	1674
6. Pątnów	1600
7. Rybnik	1600
8. Jaworzno III	1190
9. Łaziska	1040
10. Łagisza	769
11. Opole*	720
12. Siersza	705
13. Adamów	600
14. Ostrołęka	600
15. Skawina	535
16. Konin	478
17. Jaworzno	443
18. Stalowa Wola	357
19. Blachownia	244
20. Halemba	200
21. Pomorzany	112
22. Miechowice	101
23. Szombierki	44

*/ docelowa – 2160 MW

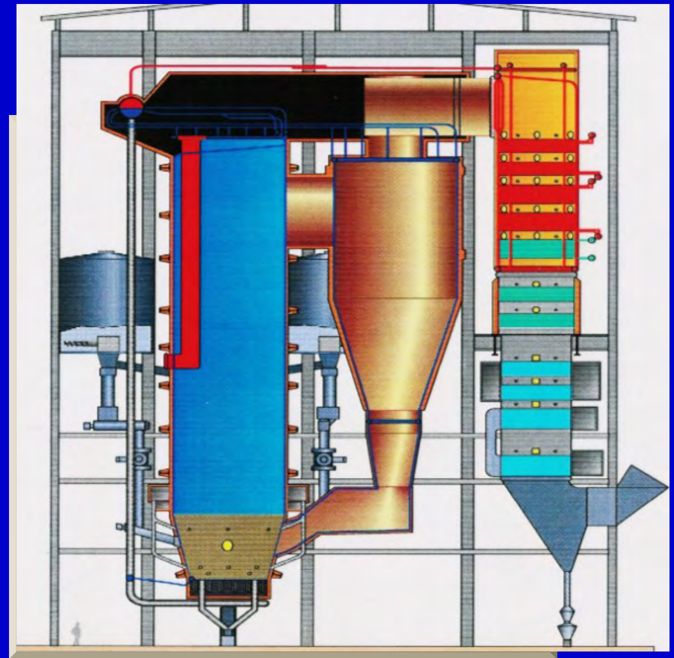
Polish CFB power dimension

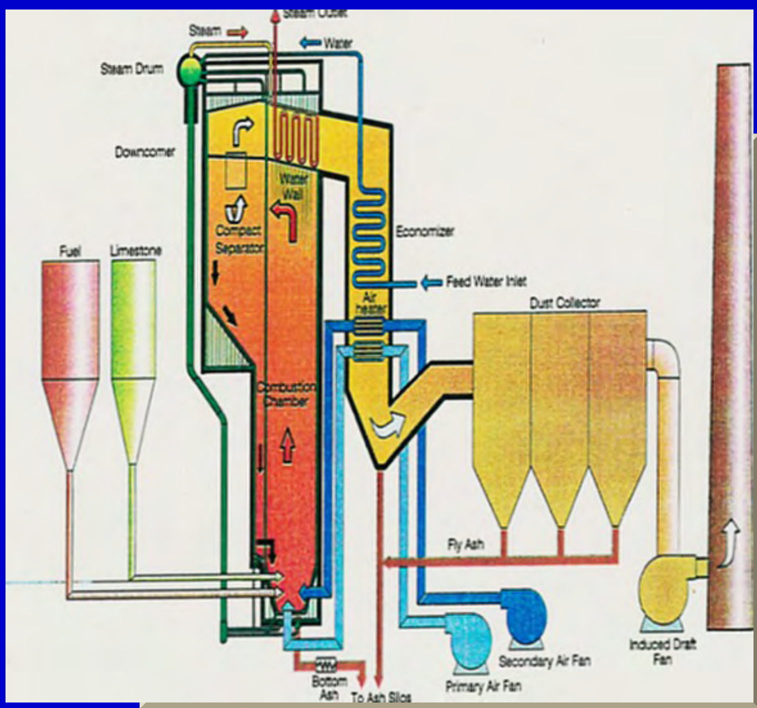
- Largest CFB market in Europe
- Pionier in supercritical OTH CFB boiler
- Extensive experience and knowledge
- Wide range of fuels
- Cofiring coal with slurry, biomass, animal wastes
- Very good emission performance
- Ambitious programs undertaken by power plants and universities
- CFB biomass/ waste gasification – new challenge

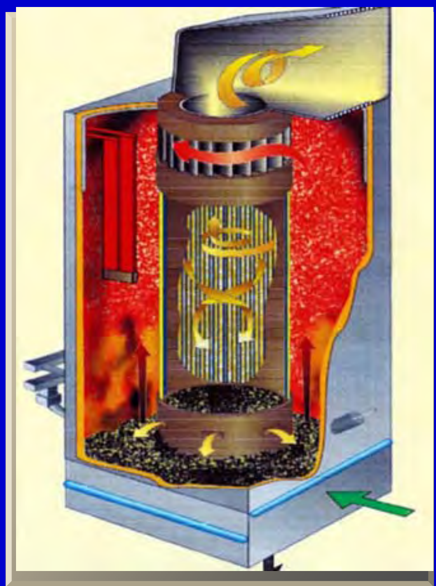
Commercial CFB boilers in Poland

OWNER/LOCATION	YEAR	TYPE	CAPACITY	FUELS
Turow Power Plant S.A.	1998	CFBC Unit 1 and 2 Hot cyclones	2 x 235 MWe	Brown coal, Lignite
Turow Power Plant S.A.	2000	CFBC Unit 3 Hot cyclones	235 MWe	Brown coal, Lignite
Turow Power Plant S.A.	2002-2004	CFBC Units 4, 5 & 6 Hot cyclones	3 x 260 MWe	Brown coal, Lignite
EC Katowice S.A.	2000	CFBC Steam-cooled cyclone	120 MWe	Bituminous coal, coal slurry
Power Plant PSE Jaworzno II S.A.	1999	CFBC Units 1 & 2 Compact CFB	2 x 70 MWe	Bituminous coal, coal slurry
EC Chorzow Elcho	2003	CFBC Units 1 & 2 Compact CFB	2 x 113 MWe	Bituminous coal
EC Zeran, Warsaw	1997	CFBC Unit A Hot cyclones	315 MWe	Bituminous coal
EC Zeran, Warsaw	2001	CFBC Unit B Steam-cooled cyclone	315 MWe	Bituminous coal
EC Bielsko-Biala	1997	CFBC Hot cyclones	177/165 MWe	Bituminous coal
Polpharma Starogard Gdański	1993	CFBC Hot cyclones	2 x 60.2 MWe	Bituminous coal
EC Tychy	1999	CFBC Cymic Internal cyclone	37 MWth electricity 70 MWth dictric heat	Bituminous coal
EC Ostroleka	1997	BFBC bubbling type	30 MWth	Bark, paper waste
EC Siersza	2001, 2003	CFBC Units 1 & 2 Hot cyclones	2 x 338.5 MWth	Bituminous coal

TYPES OF CFB BOILERS IN POLAND

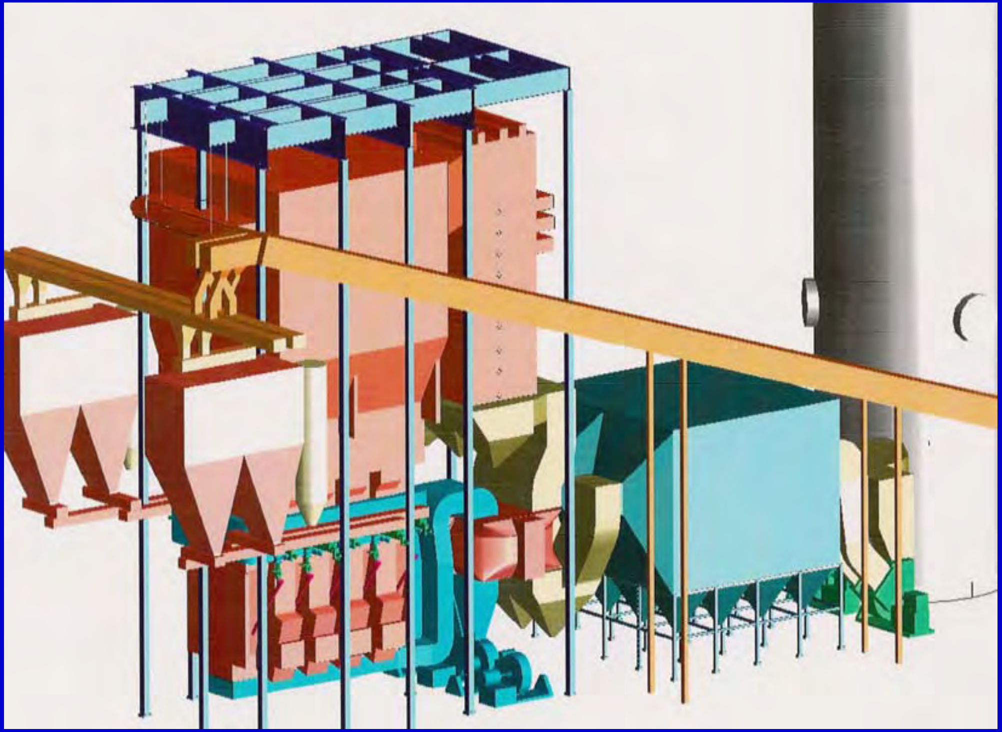




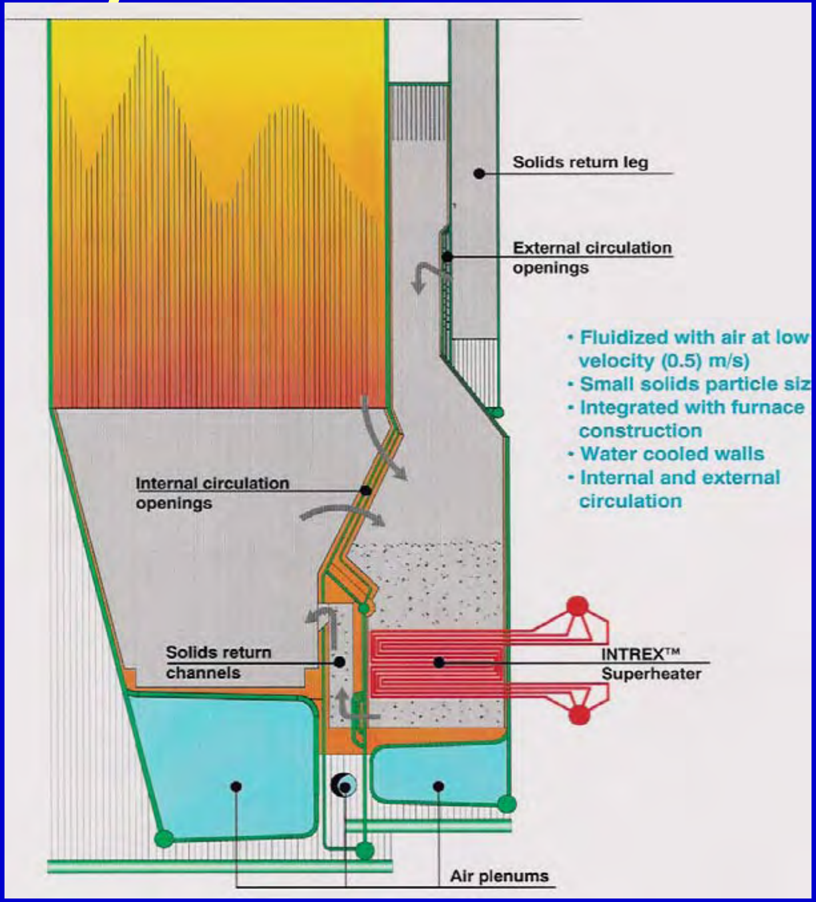


UNITS 4-6 CFB COMPACT IN ELEKTROWNIA TURÓW

Capacity	*260 MW_e*
Steam pressure	*16.7 MPa*
Steam temperature	*565 ^oC*
Efficiency (netto)	*39.1 %*



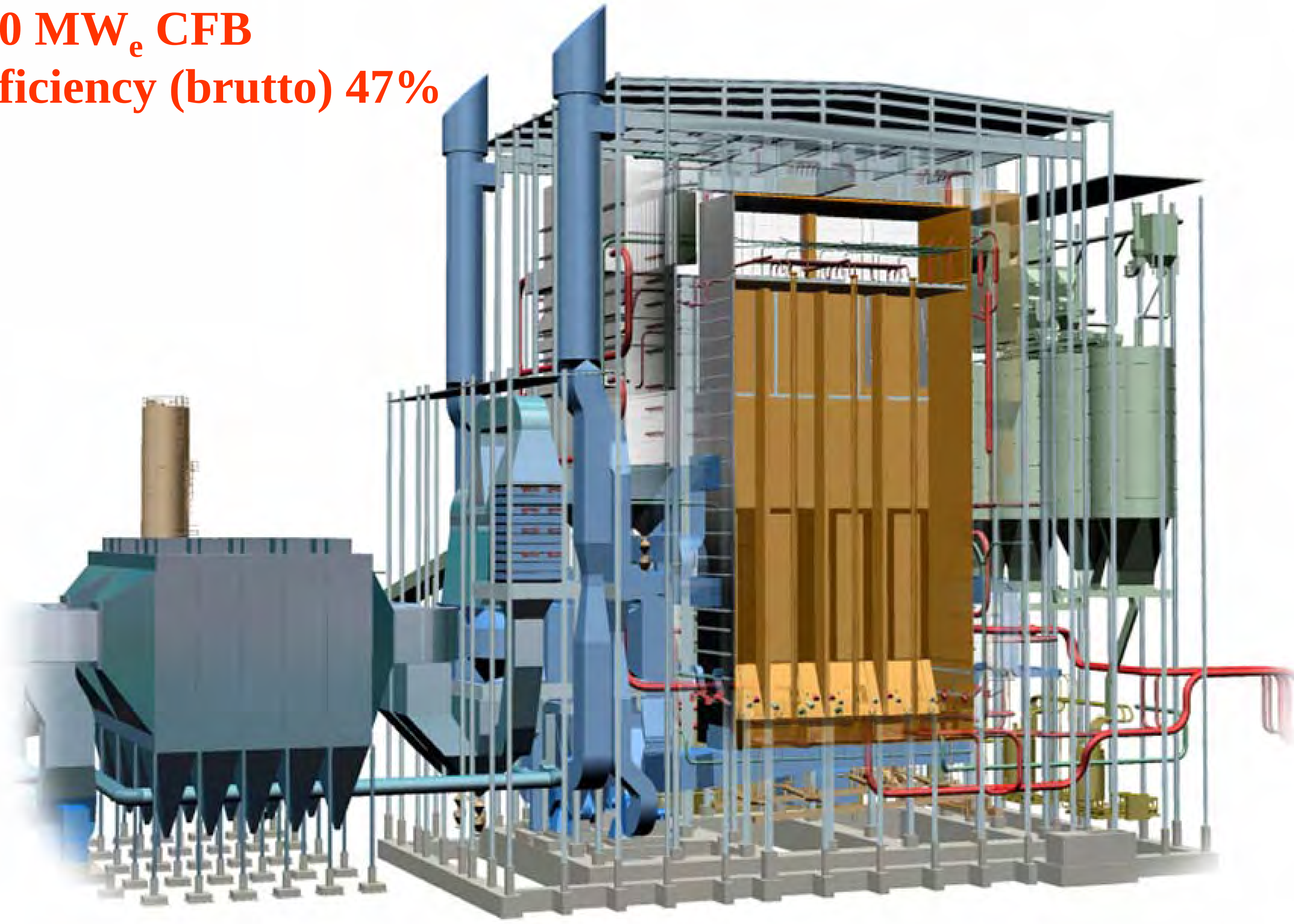
Superheater INTREX



Comparison of parameters for CFB boilers (235-260 MW_e) and 460 MW_e CFB

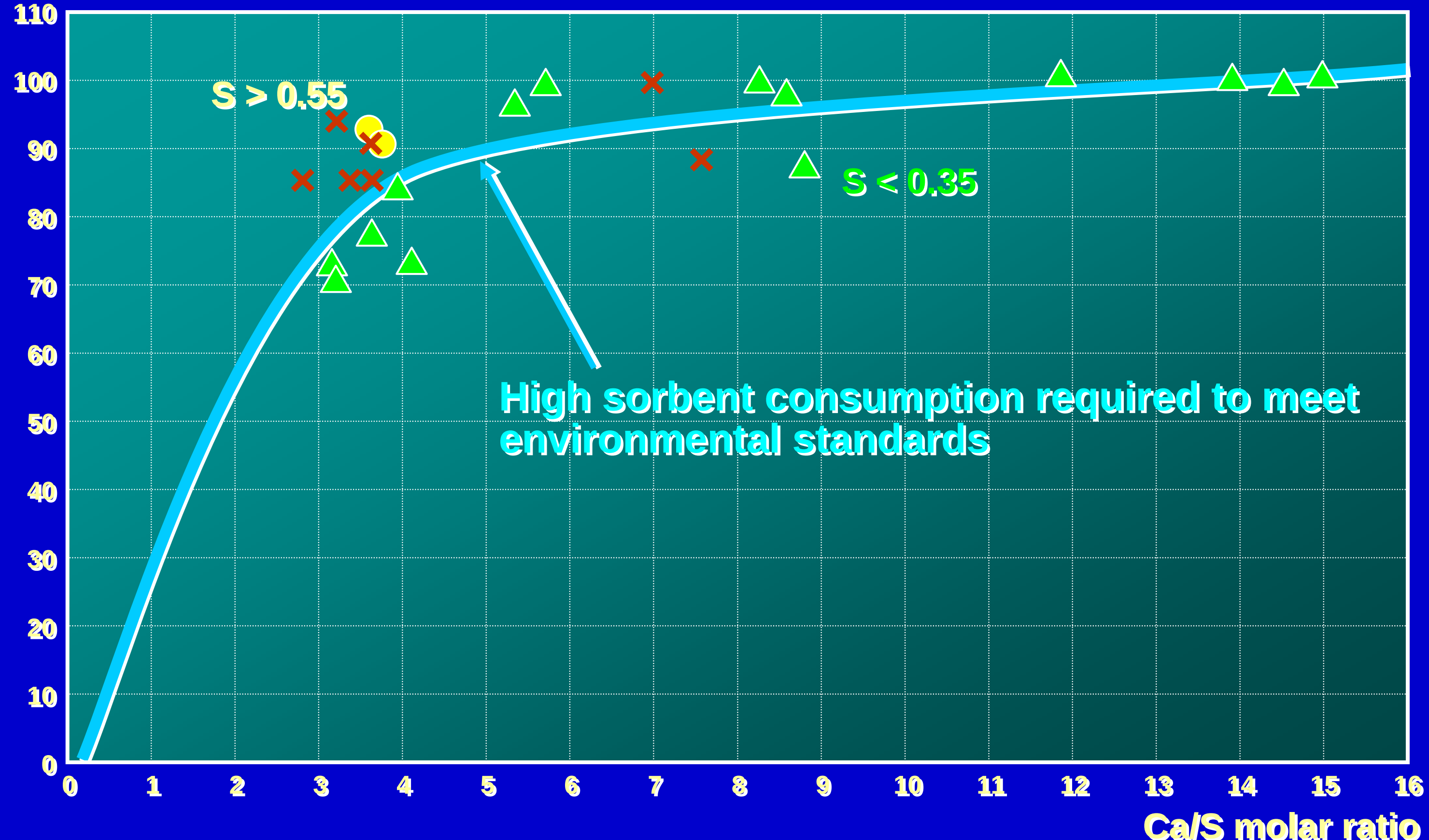
Specification	Blocks with cyclones CFB Turow No 1,2,3	Blocks 4-6 Compact type Turow	Block 460 MW PKE S.A. Lagisza
Electric capacity, gross, MW_e	235	262	460
Live steam flow, kg/s	185.4	200	359.8
Live steam pressure at turbine inlet, MPa	13.17	16.65	27.5
Live steam temperature at turbine inlet, ^oC	540	565	560 (+5/0)
RH steam temperature, ^oC	540	565	580
RH steam flow, kg/s	165.5	182	313.1
Cold reheat steam pressure, Mpa	2.8	4.2	5.3
Cold reheat steam temperature, ^oC	312	350	310.5
RH steam pressure at turbine inlet, MPa	2.5	3.8	4.88
Feed water temperature, ^oC	242.6	250	290
Flue gases outlet temperature, ^oC	157	138	122

460 MW_e CFB
Efficiency (brutto) 47%



Experience in the field of utilization of activated fly ash and sorbents in SO_2 capture in large-scale CFB boilers

Desulfurization efficiency at 235 MWe CFB boilers fired with brown coal



THE ADVERSE EFFECTS OF INCREASING Ca/S RATIO

Higher Ca/S ratio

↓

Higher operation costs
Higher NOx level
Loss of combustion efficiency
Increased ash disposal costs

DESIGNS FOR IMPROVING SO_2 REMOVAL

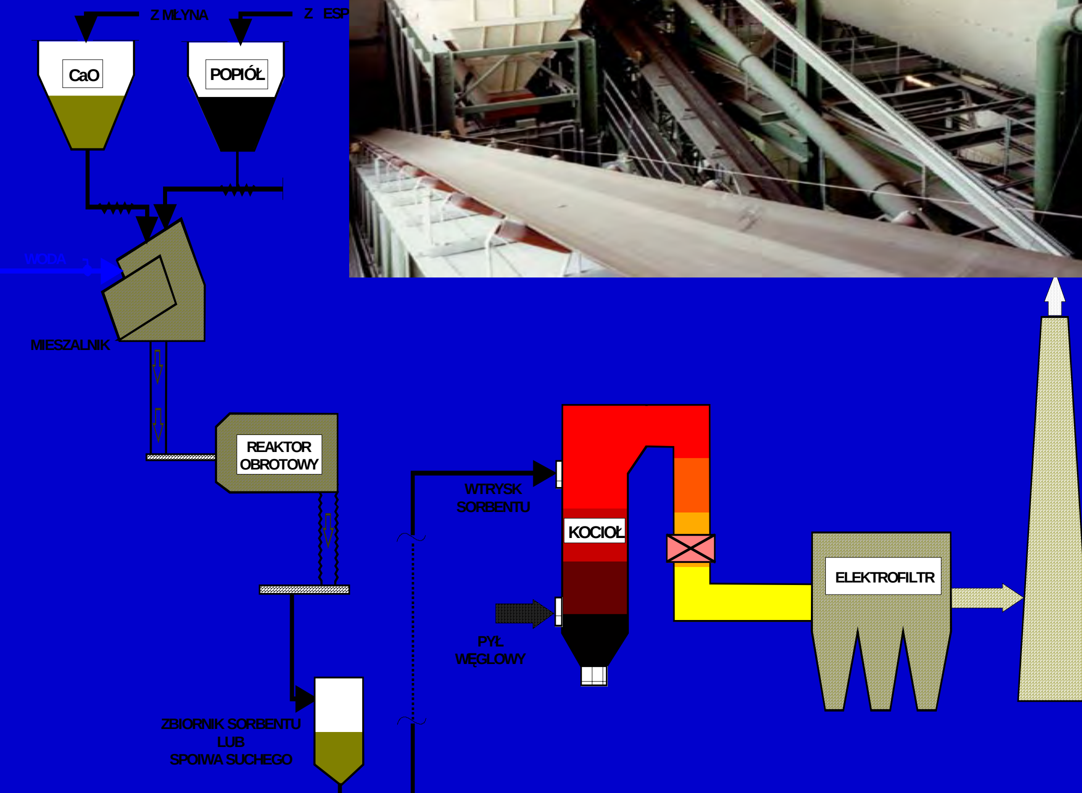
The following factors have their impact on obtaining higher levels of desulfurization efficiency:

- sorbent's granulation,
- sorbent's surface,
- amount of the active content,
- amount of inserted sorbent (mole ratio: Ca/S),
- time residence by sorbent in contact with combustion gas in a combustion chamber
- homogeneity of sorbent-combustion gas intermixity

DEVELOPMENT OF HIGH-REACTIVITY SORBENTS

Reactivity of the sorbent particles is an important parameter which dictates the effectiveness of sulfur capture in CFB boilers, similar to the other combustion technologies

SCHEMAT OF MODIFIED SORBENT PRODUCTION



CHEMICAL ACTIVATION

MECHANICAL ACTIVATION

Mechanical Activation

Patent number 180380 covers the technology and instalation for obtaining settings materials from CFB and PC boilers


URZĄD PATENTOWY RZECZYPOSPOLITEJ POLSKIEJ

Dokument patentowy

Przedsiębiorstwo Usługowo-Inwestycyjne Budownictwa i Energetyki "ENERGOMAR-NORD" Spółka z o.o., Warszawa, Polska

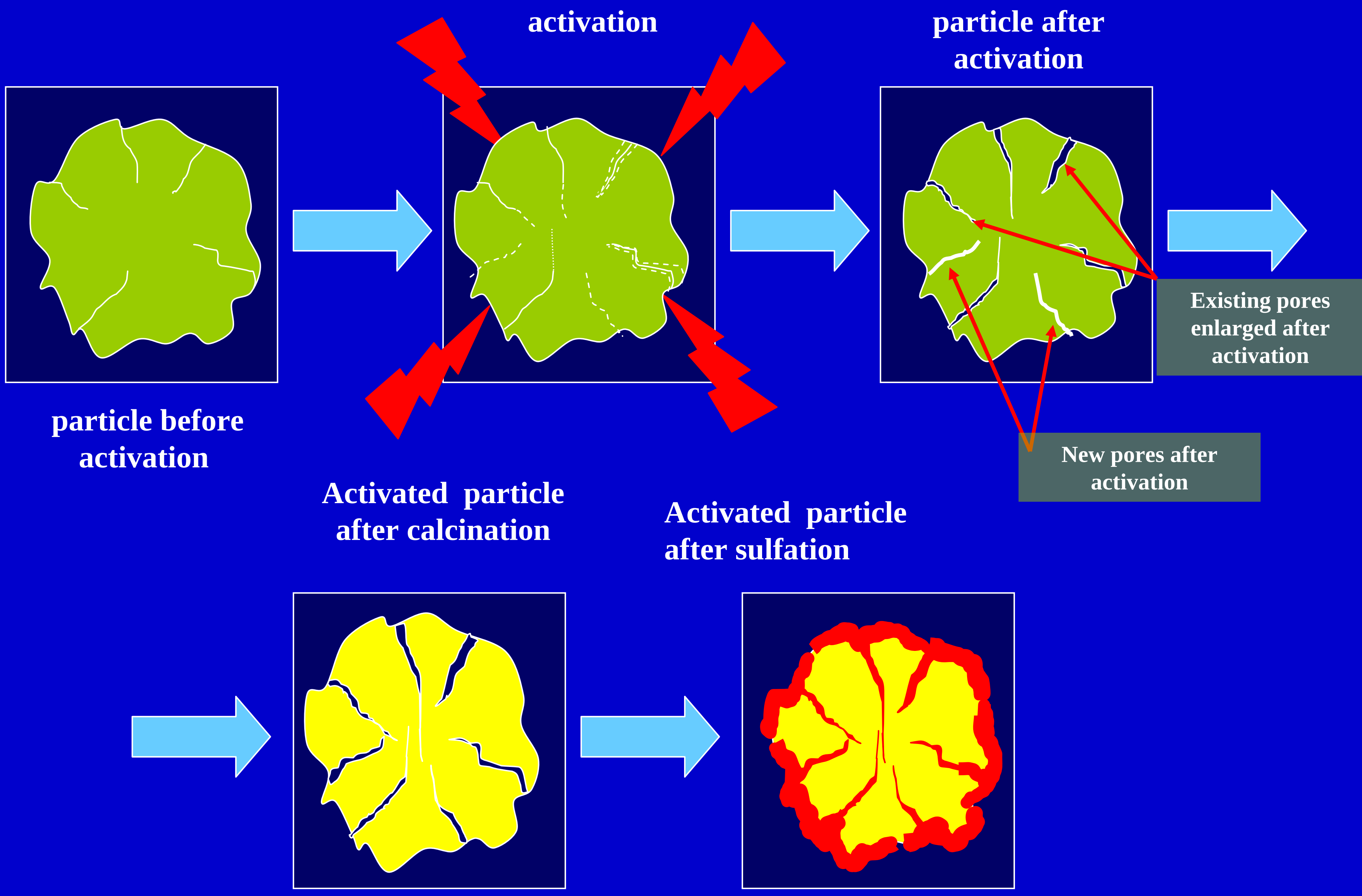
PATENT

NR 180380

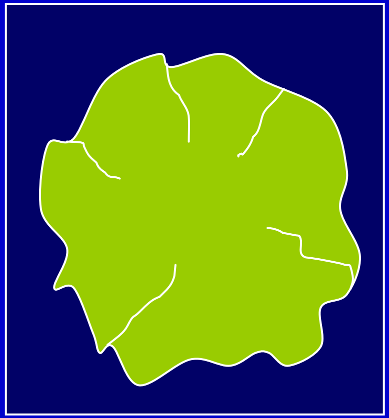
NA WYNALAZEK PT.

Sposób i urządzenie do otrzymywania materiałów wiążących z popiołów kotłów energetycznych, zwłaszcza z paleniskiem fluidalnym

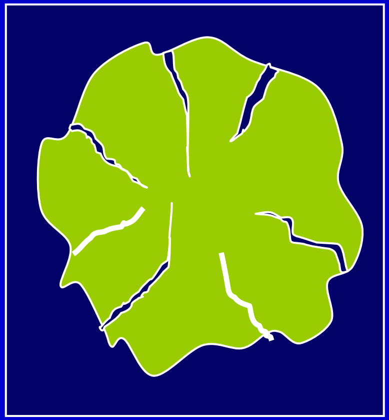
PRINCIPLE OF MECHANICAL ACTIVATION

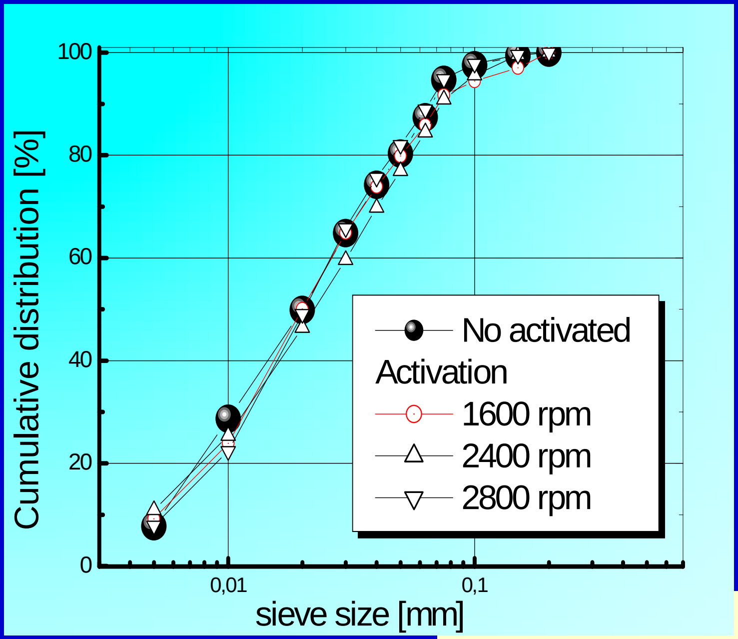


particle before activation



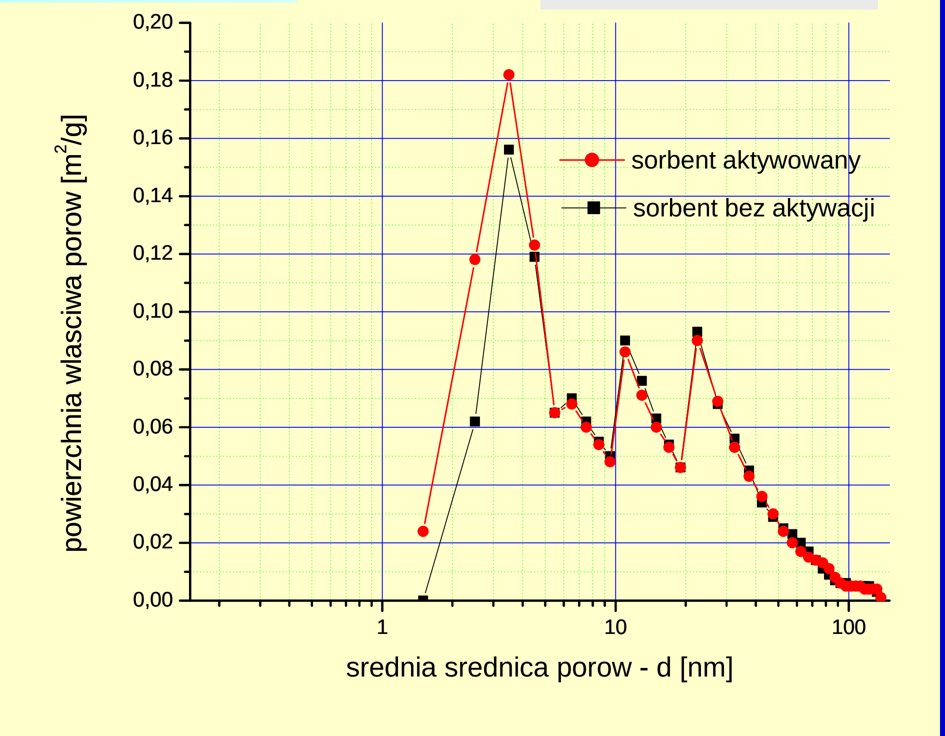
Activated particle



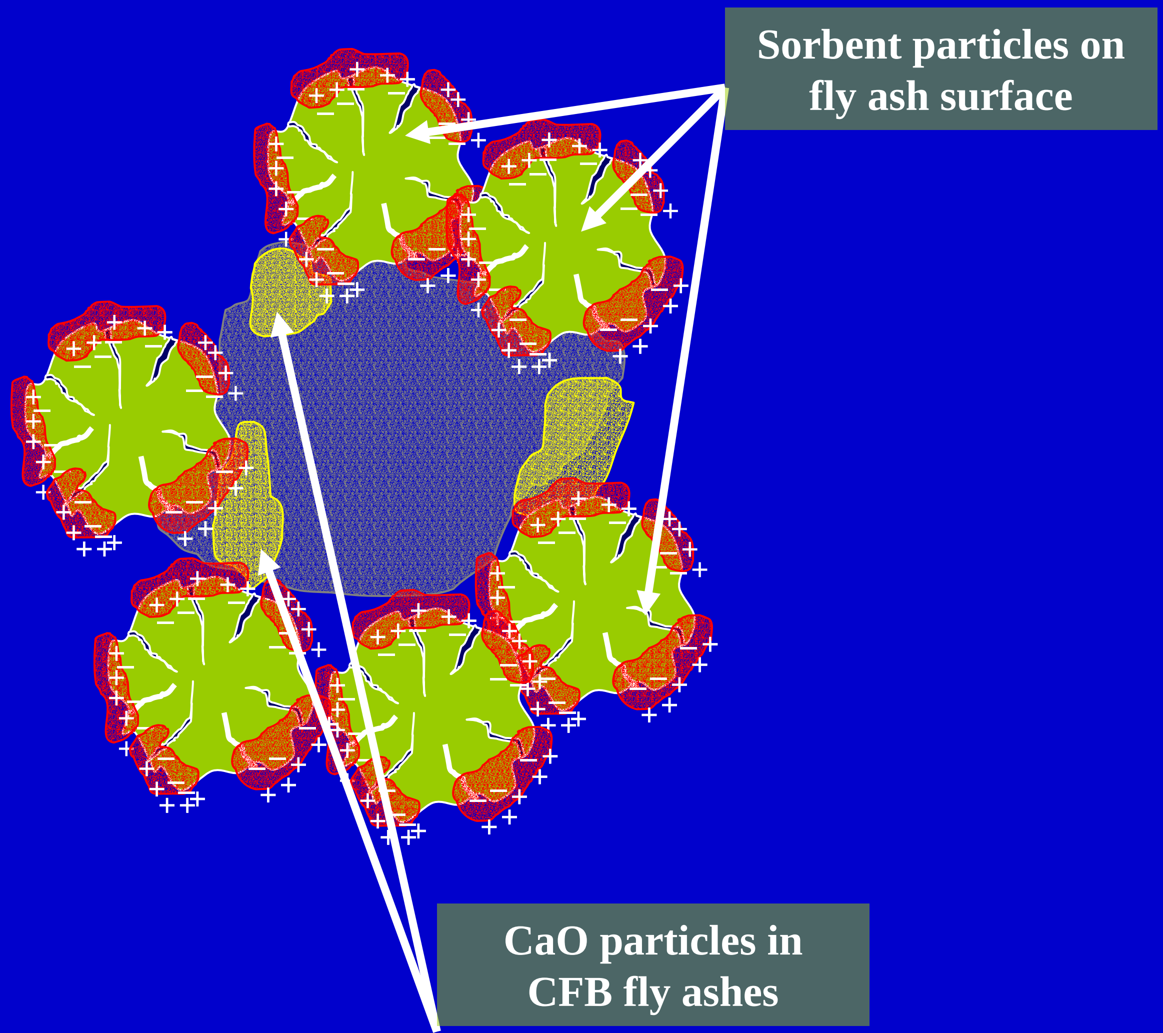


SURFACE AREA OF PORES

Activated \ Non activated



Addition of fluidized bed ashes to sorbent



Results of mechanical activation

- Larger specific surface area
- Shifting pore volume distribution to smaller pores
- Increasing gel pores (<10 nm)
- Formation of defects
- Fragmentation of aglomerates
- Desintagration of metakaloinite
- Spheroidizing CFB ash particles
- Separation of activated material from unactivated due to electrostatic charge on the surface

Activator elements capacity 3 t/h

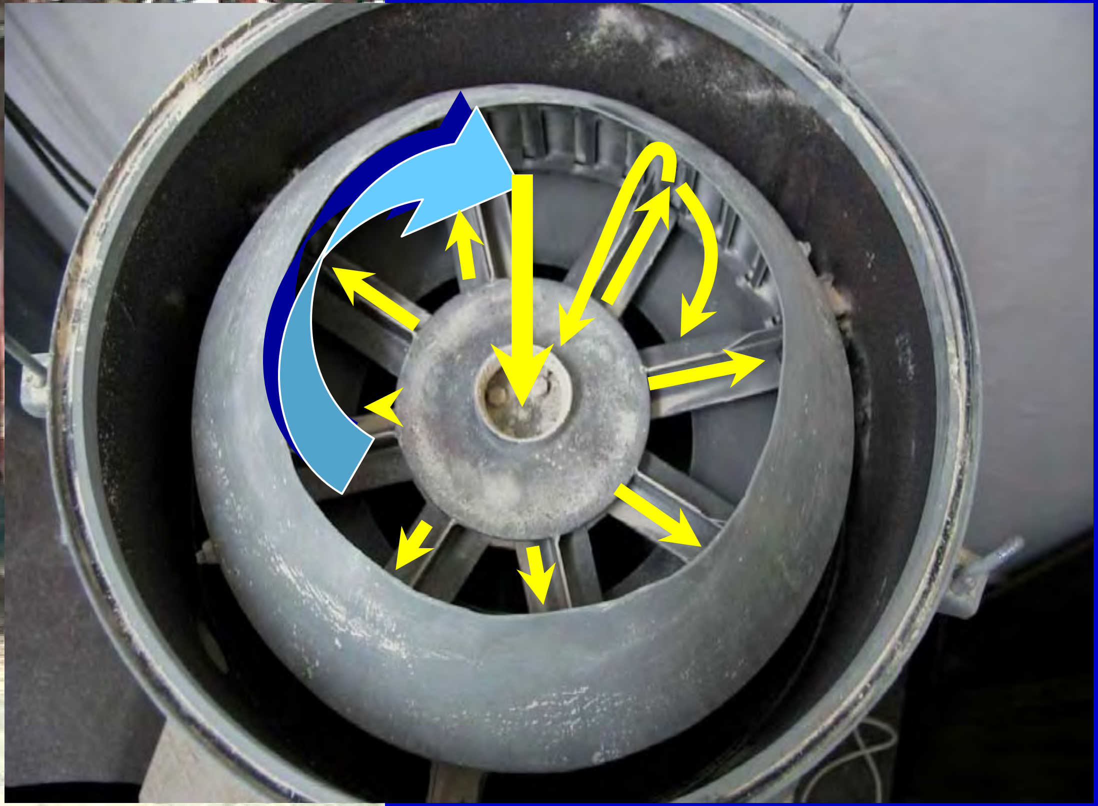
Rotor

Frame cover

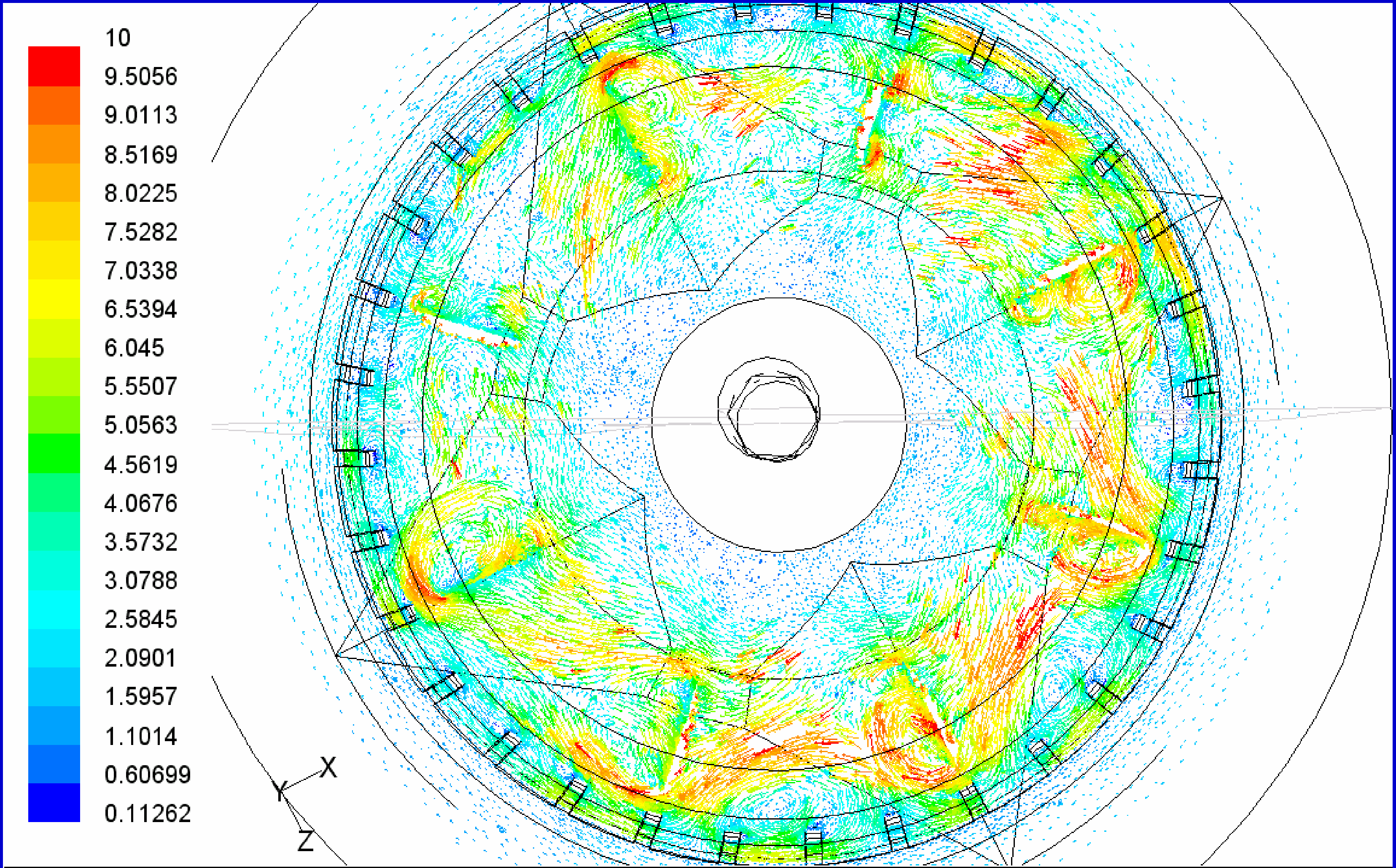
Activating chamber

CFB ash utilization: pilot plant at Turow Power Plant

Mechanical activation

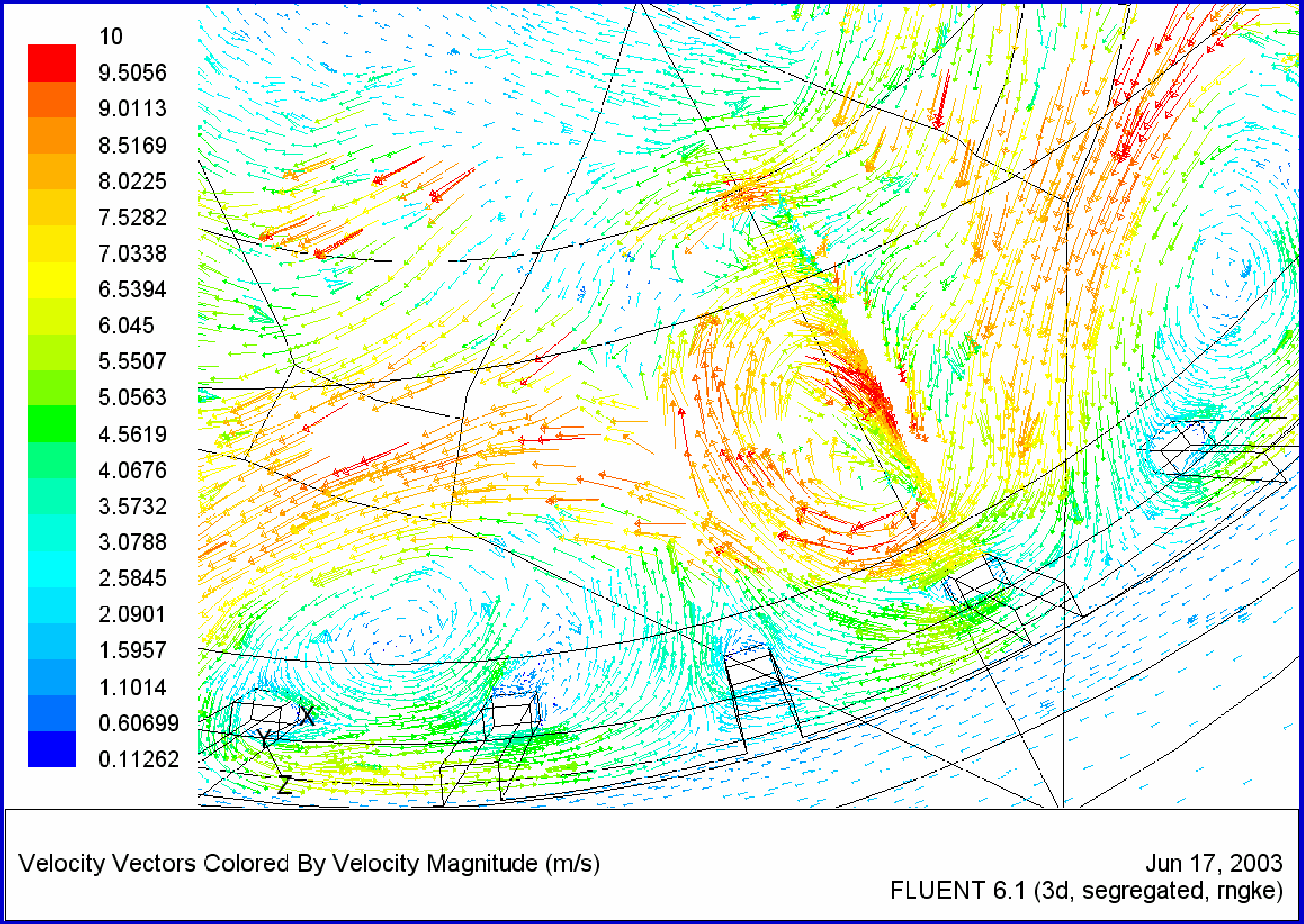


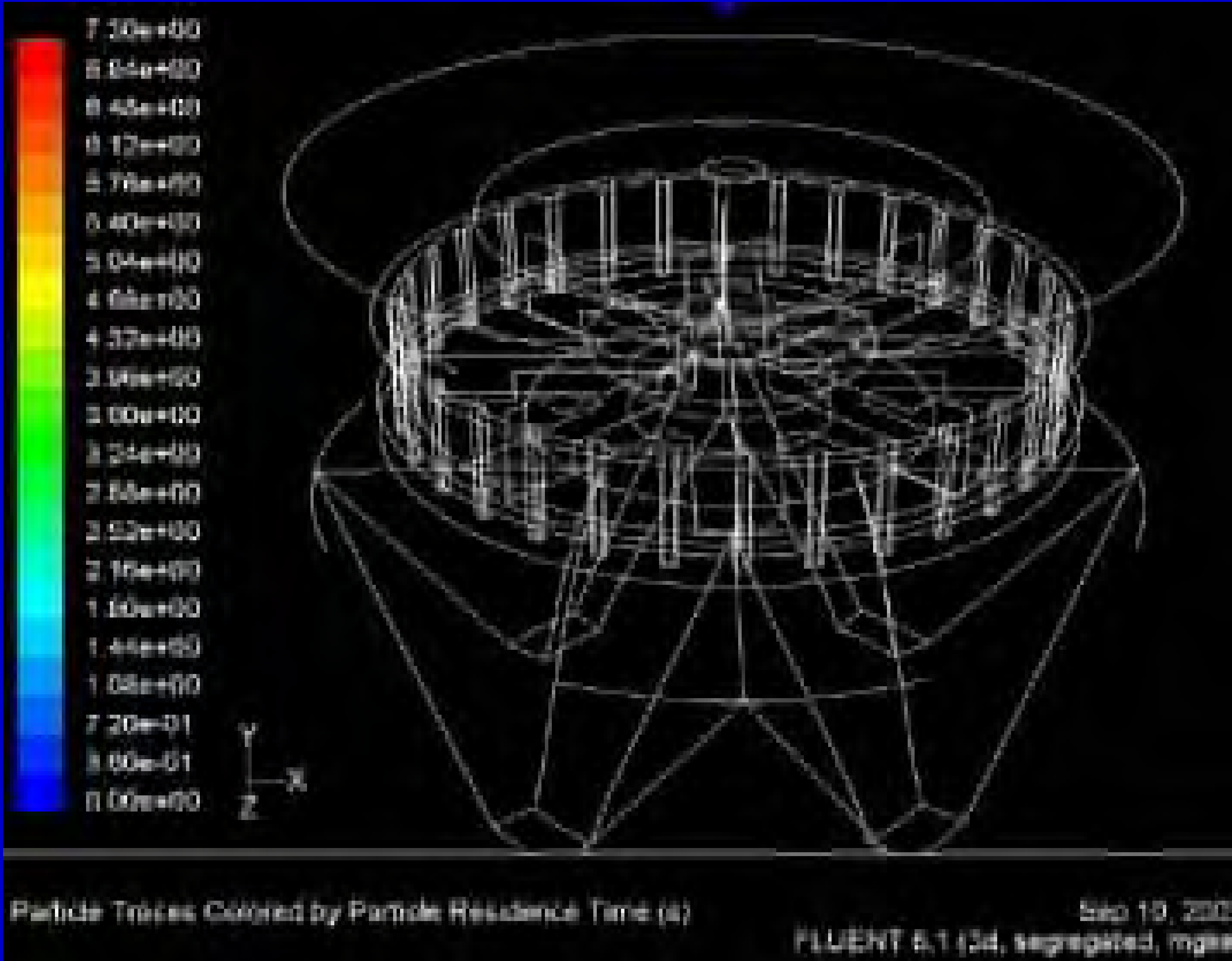
MOVEMENT OF ACTIVATED PARTICLES



Velocity Vectors Colored By Velocity Magnitude (m/s)

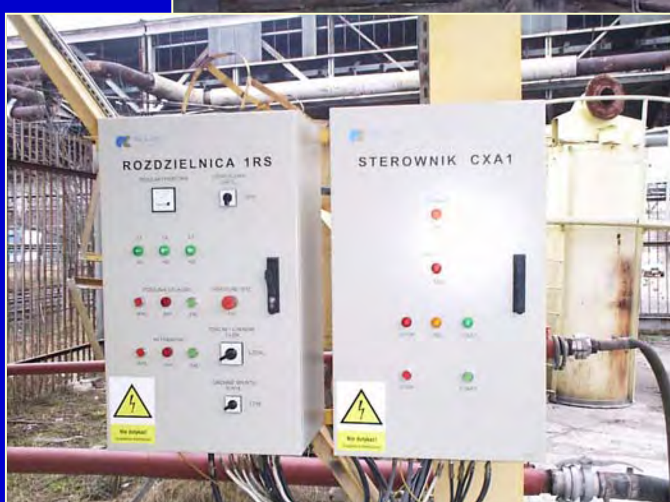
Jun 17, 2003
FLUENT 6.1 (3d, segregated, rngke)


10
9.5056
9.0113
8.5169
8.0225
7.5282
7.0338
6.5394
6.045
5.5507
5.0563
4.5619
4.0676
3.5732
3.0788
2.5845
2.0901
1.5957
1.1014
0.60699
0.11262
X
Y
Z
Velocity Vectors Colored By Velocity Magnitude (m/s)
Jun 17, 2003
FLUENT 6.1 (3d, segregated, rngke)


7.20e+00
6.84e+00
6.48e+00
6.12e+00
5.76e+00
5.40e+00
5.04e+00
4.68e+00
4.32e+00
3.96e+00
3.60e+00
3.24e+00
2.88e+00
2.52e+00
2.16e+00
1.80e+00
1.44e+00
1.08e+00
7.20e-01
3.60e-01
0.00e+00
Y
X
Z
Particle Traces Colored by Particle Residence Time (s)
Sep 10, 2003
FLUENT 6.1

Activator 5 t/h

Activator



Control panel

Loading sleeve

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ENERGY ENGINEERING
LABORATORY

TECHNICAL UNIVERSITY OF CZESTOCHOWA

DEPARTMENT OF HEATING,
VENTILATION AND AIR PROTECTION

Determination of the limestone reactivity should be somehow standardized and more uniform for all CFB boilers

RI stands for Ca/S molar ratio, which shows the amount of Ca before the test, and the amount of sulphur after. CI is defined as amount of sulphur (in grams), absorbed by kilogram of tested calcium

Reactivity Index and Sorption

Reactivity test	**RI**	**CI**
excellent	< 2,5	> 120
very good	2,5 - 3,0	100 -120
good	3,0 - 4,0	80 - 100
sufficient	4,0 - 5,0	60 - 80
low quality	> 5,0	< 60

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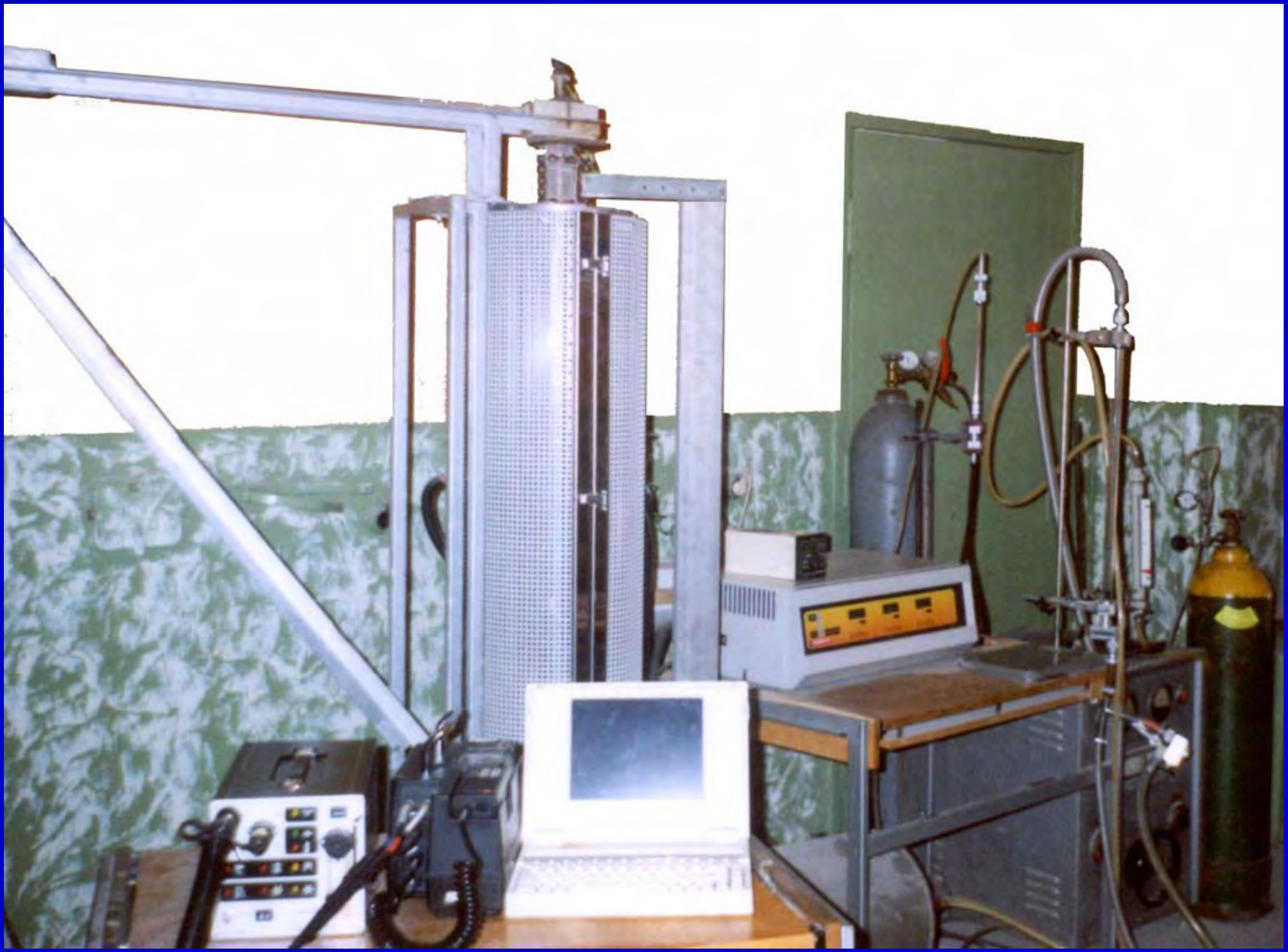
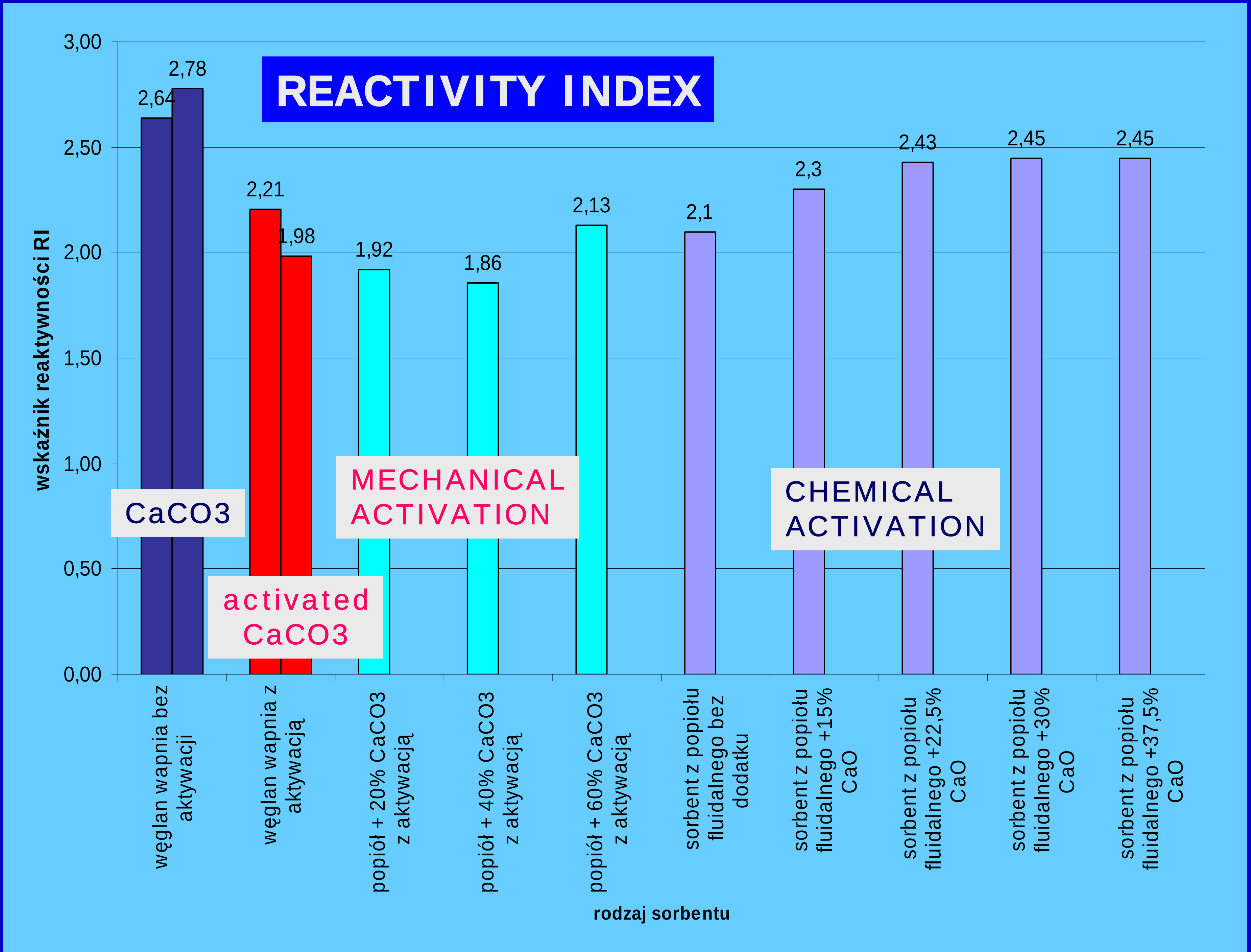
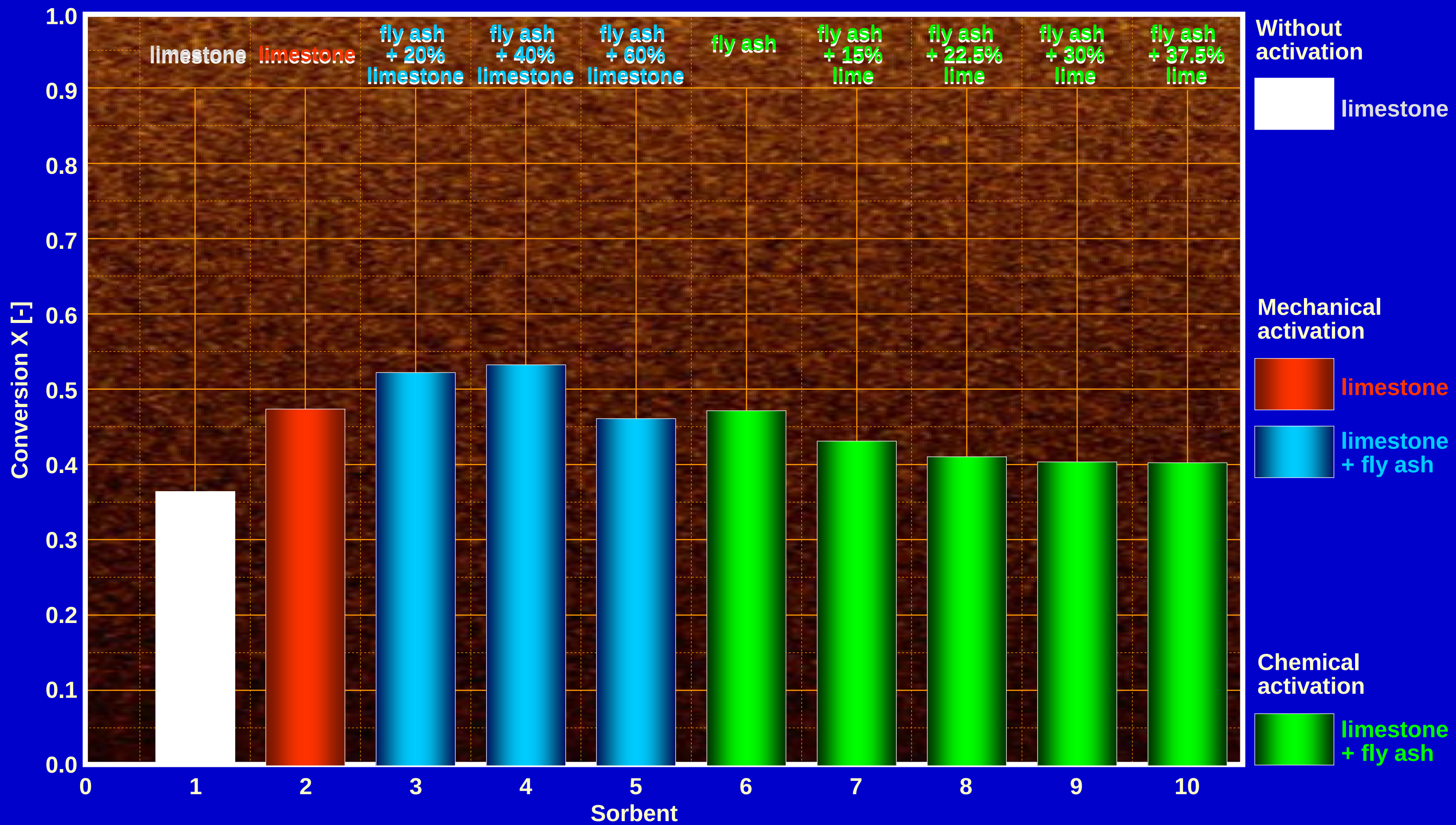
VENTILATION AND AIR PROTECTION

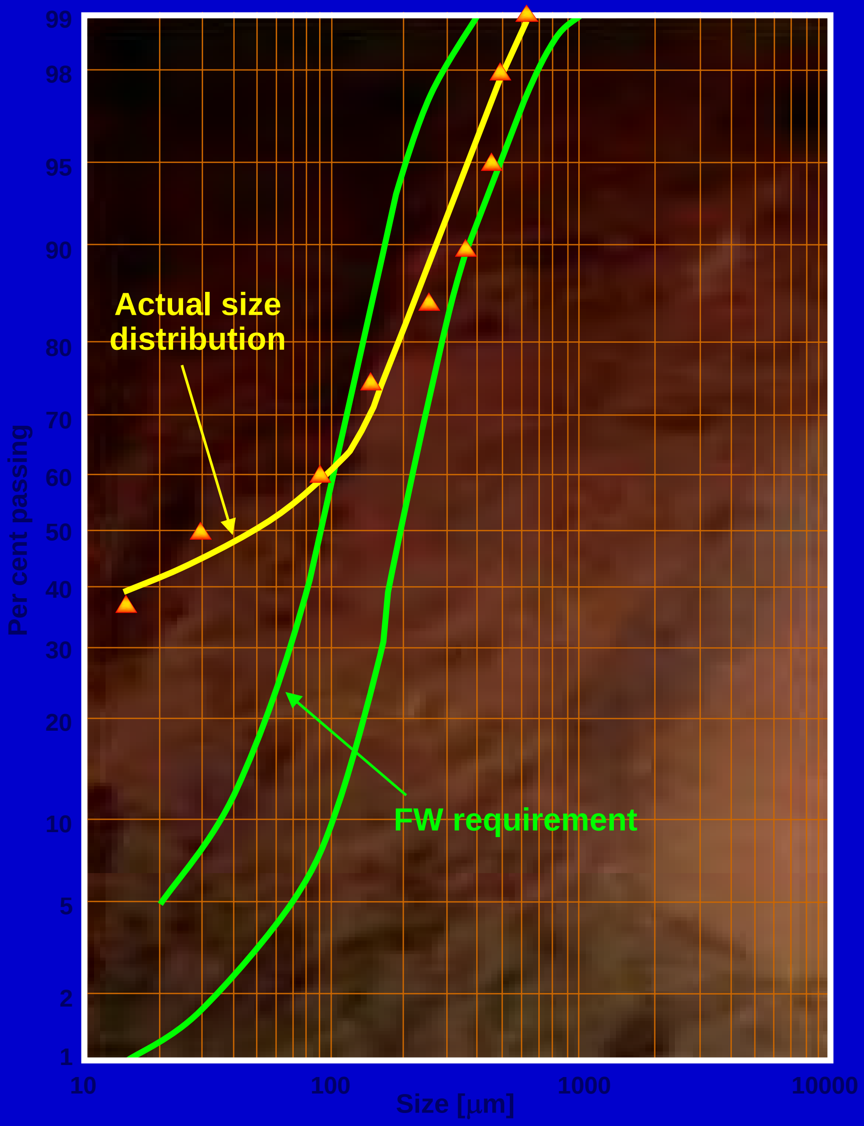
Test unit




REACTIVITY INDEX
wskaźnik reaktywności RI
3,00
2,50
2,00
1,50
1,00
0,50
0,00
2,64
2,78
2,21
1,98
1,92
1,86
2,13
2,1
2,3
2,43
2,45
2,45
CaCO3
activated CaCO3
MECHANICAL ACTIVATION
CHEMICAL ACTIVATION
węglan wapnia bez aktywacji
węglan wapnia z aktywacją
popiół + 20% CaCO3 z aktywacją
popiół + 40% CaCO3 z aktywacją
popiół + 60% CaCO3 z aktywacją
sorbent z popiołu fluidalnego bez dodatku
sorbent z popiołu fluidalnego +15% CaO
sorbent z popiołu fluidalnego +22,5% CaO
sorbent z popiołu fluidalnego +30% CaO
sorbent z popiołu fluidalnego +37,5% CaO
rodzaj sorbentu

Conversion

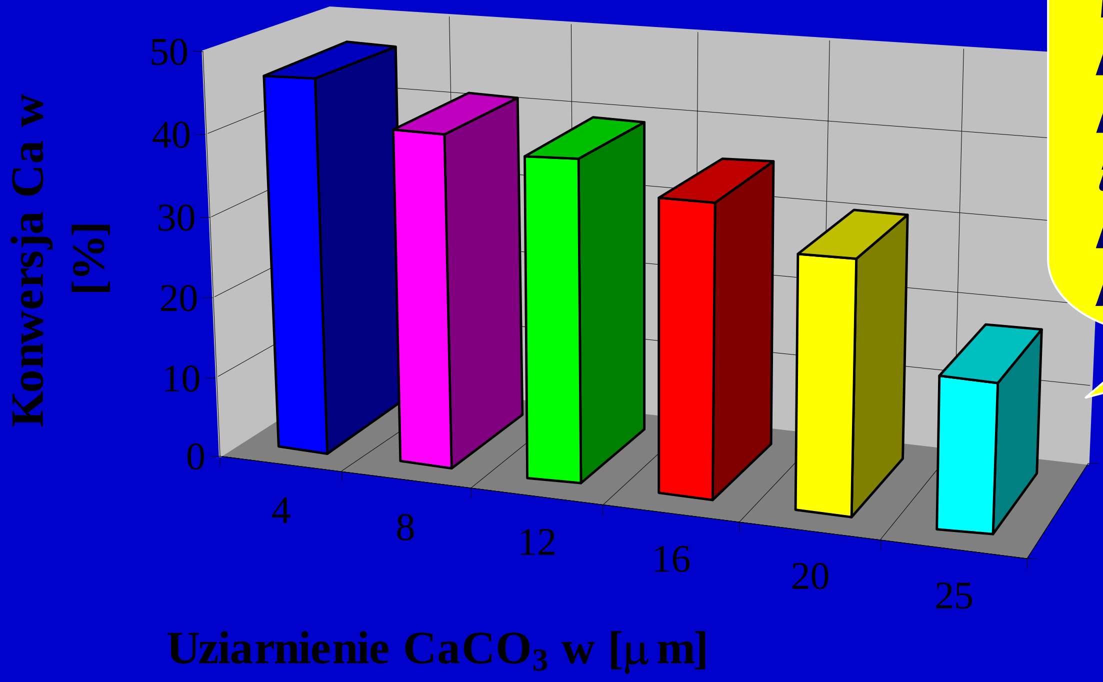

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Conversion X [-]
limestone
limestone
fly ash + 20% limestone
fly ash + 40% limestone
fly ash + 60% limestone
fly ash
fly ash + 15% lime
fly ash + 22.5% lime
fly ash + 30% lime
fly ash + 37.5% lime
0
1
2
3
4
5
6
7
8
9
10
Sorbent
Without activation
limestone
Mechanical activation
limestone
limestone + fly ash
Chemical activation
limestone + fly ash



LIMESTONE SIZE DISTRIBUTION FOR CFB BOILERS

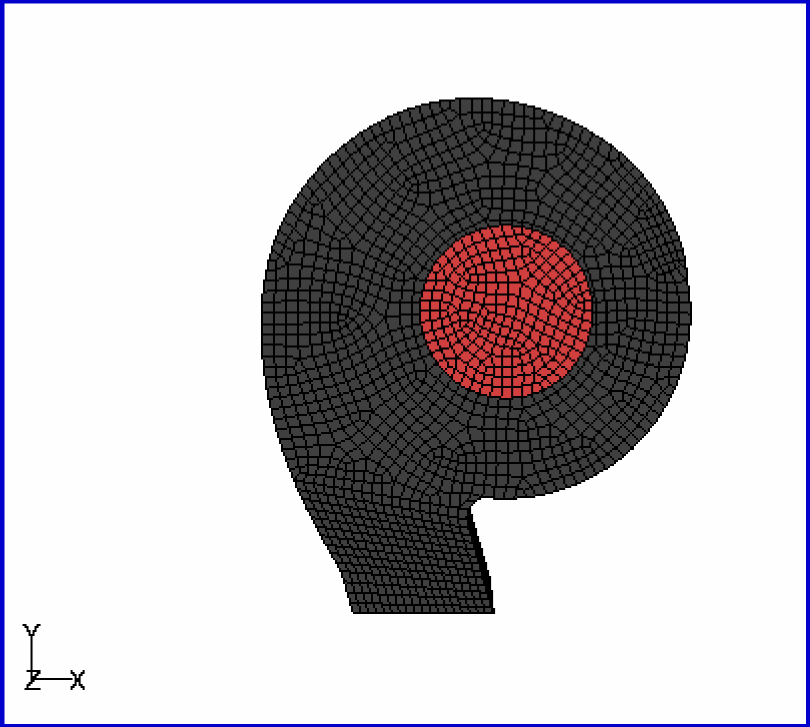
Since the limestone size distribution has a very important influence on the desulfurization efficiency, it has to be as close to the provided by supplier curves as possible. In our opinion the required characteristic is too restrictive and mill producers are not able to comply with such requirements in the full range.

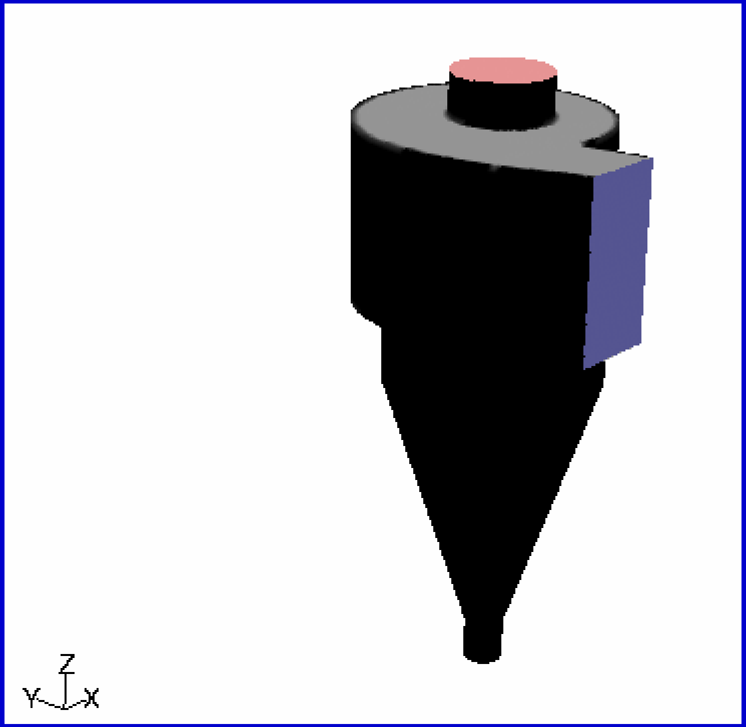
LIMESTONE EFFICIENCY CONVERSION



Conversion is improved when size of the limestone particles is reduced – a process that takes place naturally in the CFB boiler

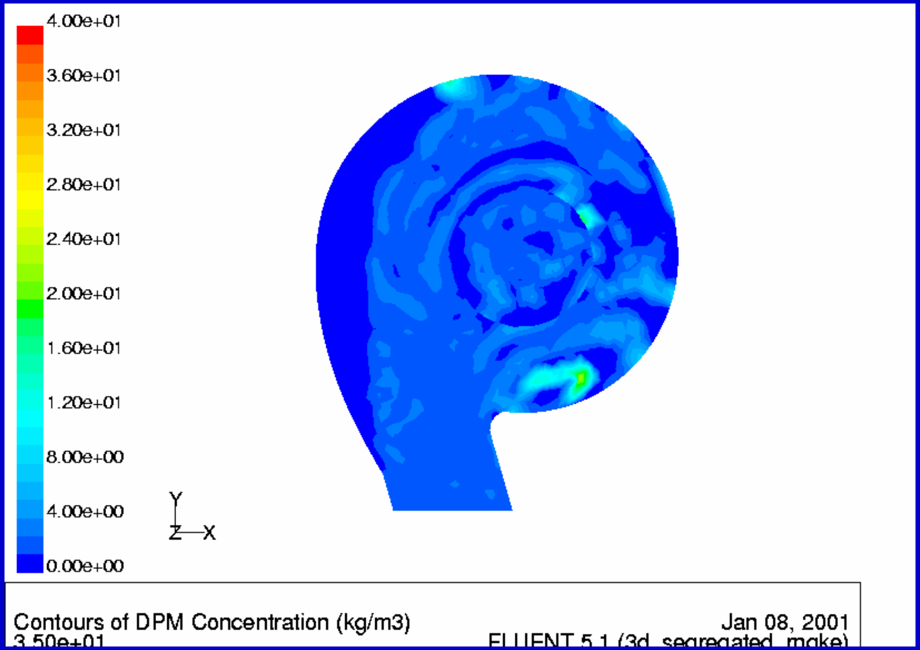
Cyclone inlet modification



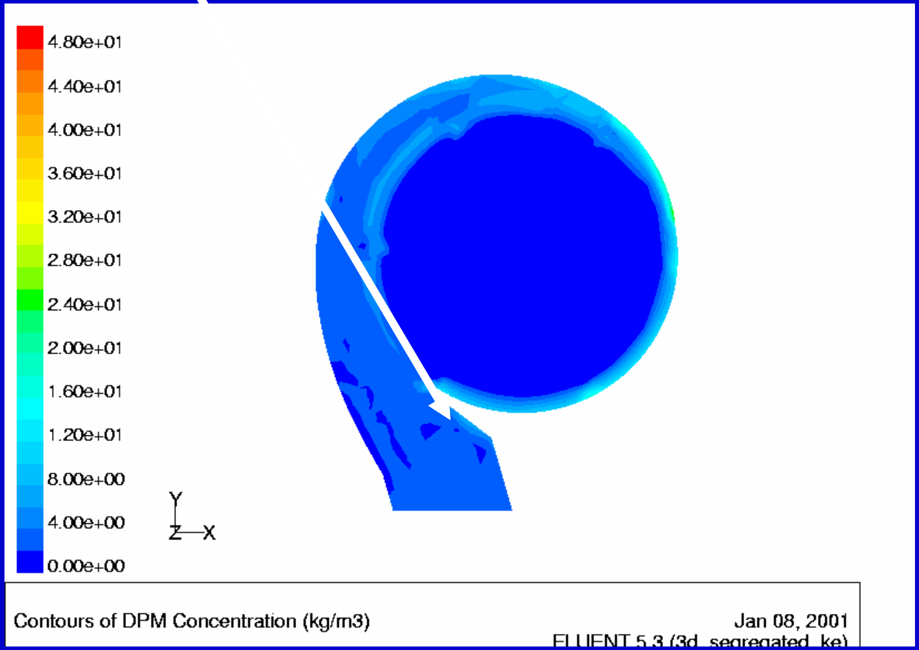


Solids concentration

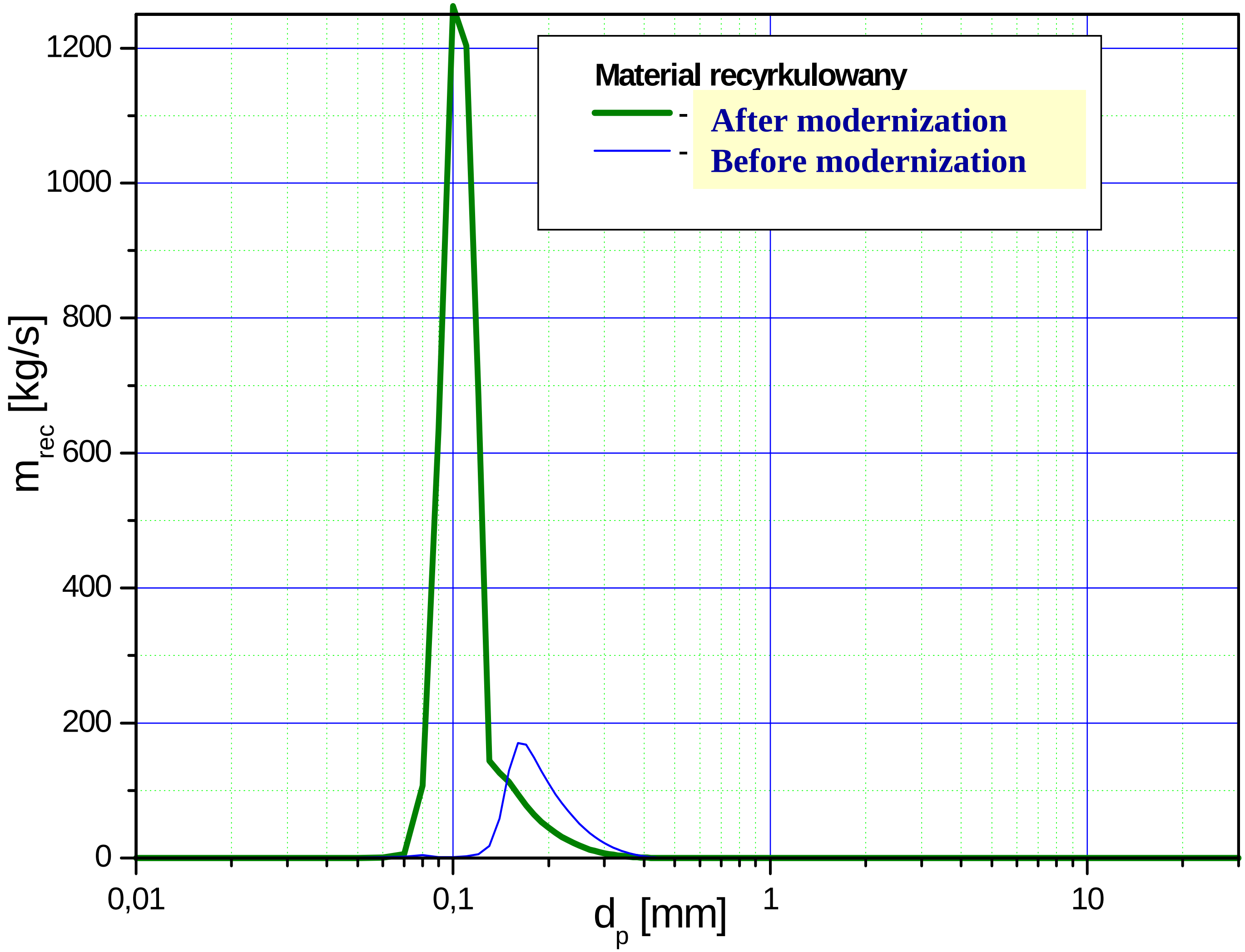
Before modification



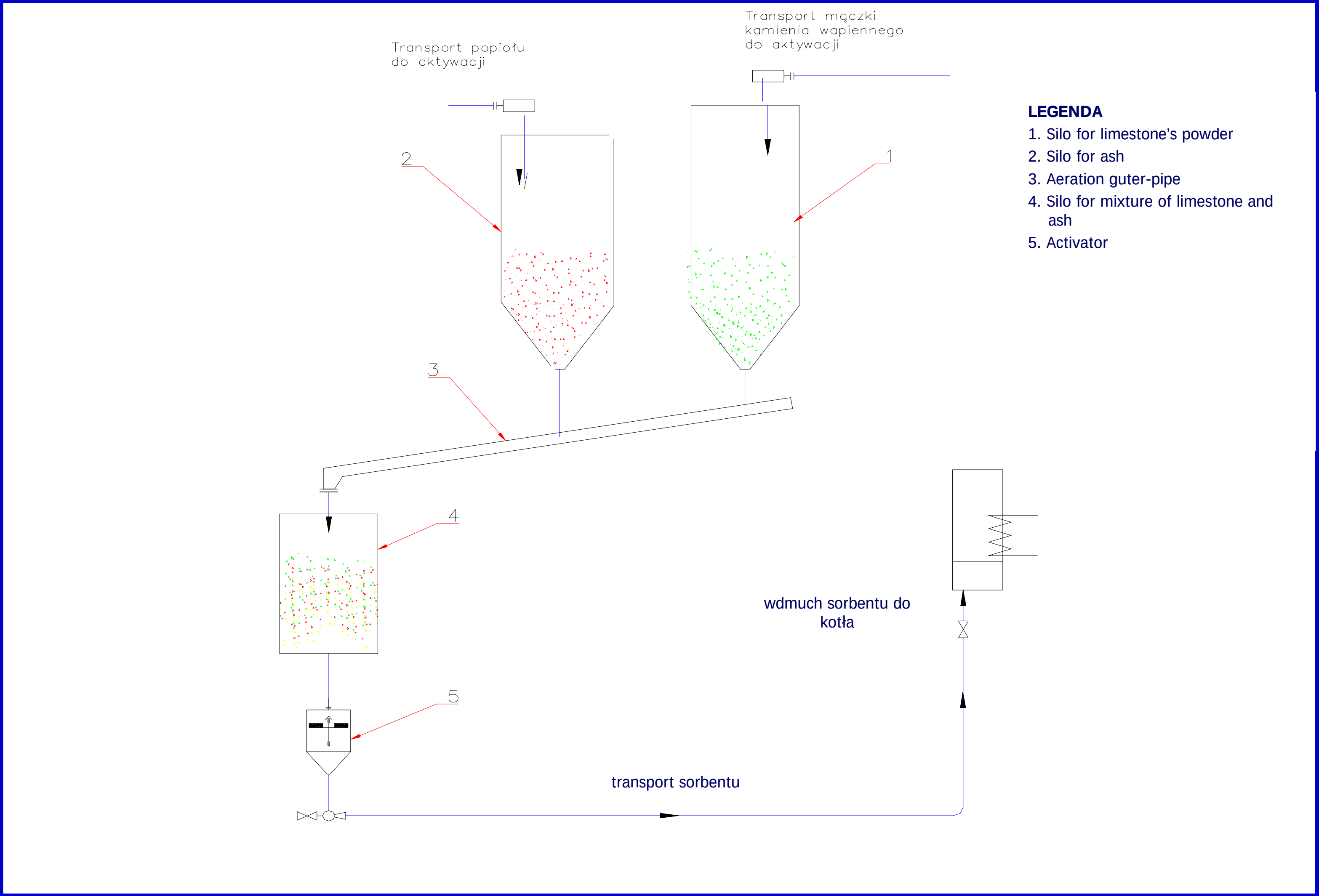
After modification



Cyclone inlet

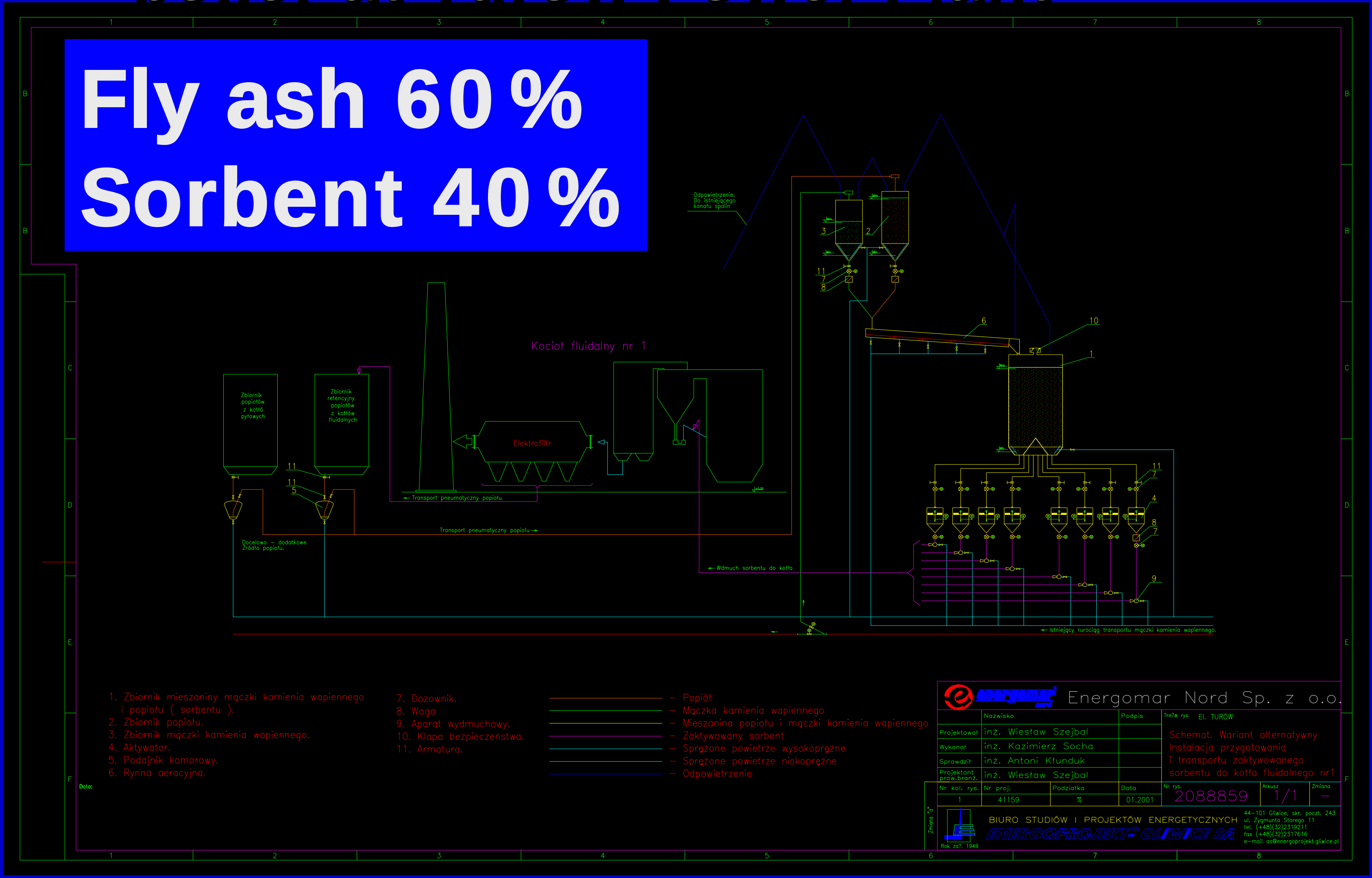

Material recyrkulowany
After modernization
Before modernization
1200
1000
800
600
400
200
0
m_{rec} [kg/s]
0,01
0,1
1
10
d_p [mm]

Pilot plant installation at the Turow Power Plant

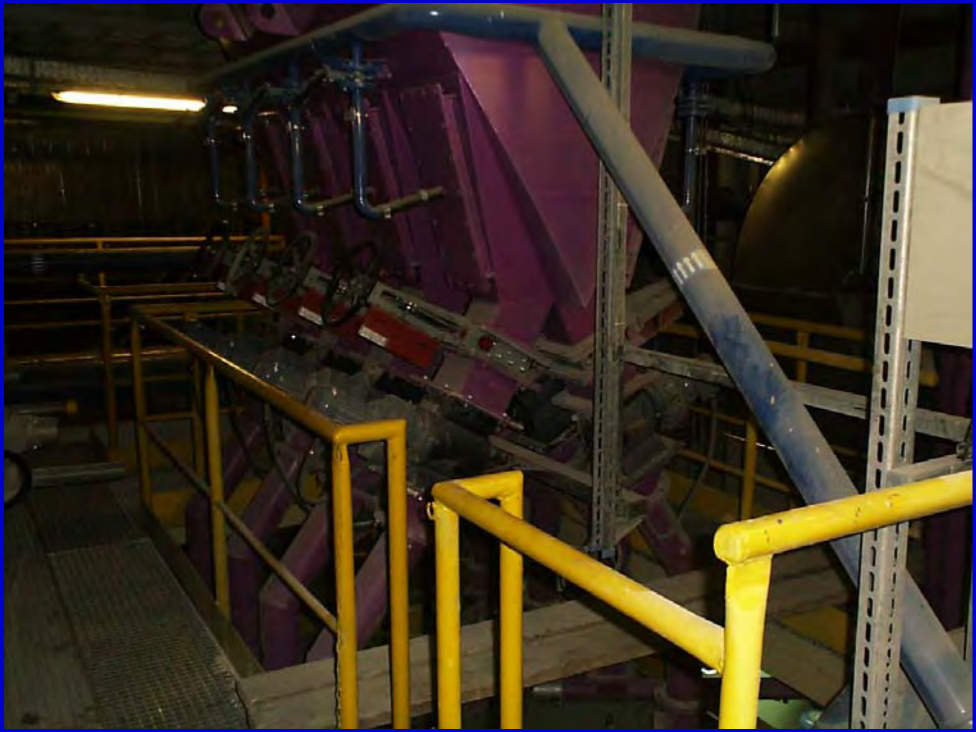


Sorbent activation in a 235 MW CFB boiler at Turow Power Plant

Fly ash 60 %
Sorbent 40 %



Installation for production of high-reactive sorbents



Performance tests

- Stable boiler operation
- 26% sorbent consumption reduction at 100% MCR and 26.3% at 80% MCR
- 99.2% availability
- Lower SO_2 and NO_x