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Steinmüller Engineering GmbH
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Combustion optimisation, efficiency improvements and emission reduction by installation of modern LowNO_x firing systems at existing bituminous coal and lignite coal-fired steam generators

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1. Introduction

Siemens Energy Sector – Answers for energy supply

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Energy products and solutions - in 6 divisions

Oil & Gas	Fossil Power Generation	Renewable Energy	Energy Service	Power Trans-mission	Power Distribution

Energy Service Fossil
Region Europe and Africa (REU)

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1. Introduction

Actual requirements for power plant operation

- **Efficiencies, price pressure, lower operation costs**
- **Meet requirements of European Emission Directive (especially recently EU joining countries)**
- **Operational flexibilities, e.g. extended load range and fuel properties (coal blends)**
- **Reduced time of full load operation and optimisation of part load conditions, frequent plant start up and shut down**
- **Increased load change rates (Primary and secondary frequency control), lifetime extension**

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Three examples of executed Firing projects within last two years:

2. **Extension of Load Range**

3. **Flexibilty improvement and reduced operating costs**

4. **Emission reduction and increase of availability**

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2. Extension of load range

Main plant figures

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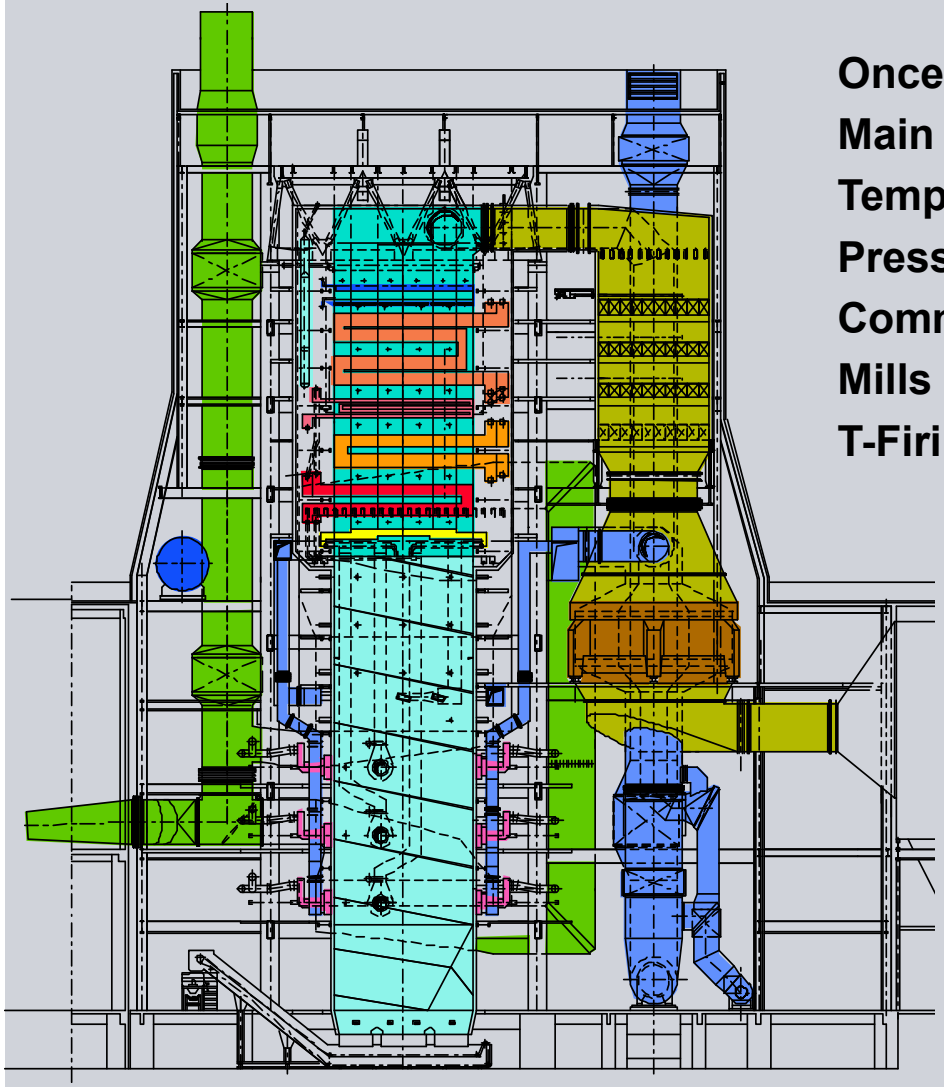


Once-through (Benson®) Type Boiler

Main steam flow	**260 kg/s (936 t/h)**
Temperature (SH/RH)	**545 °C / 568 °C**
Pressure (SH)	**260 bar**
Commissioning	**1996**
Mills for Bituminous Coal	**6 Roller Mills**
T-Firing, 12 SM-IV-Burner	**61 MWth each**

Bituminous coal:

	Unit	Coal before revamp	Coal after revamp
NCV	MJ/kg	25,0 – 29,3	23,6 – 26,7
Water (ar)	w. %	5,5 – 13	7,4 – 16,2
Ash (ar)	w. %	7,0 – 20	4,7 – 15,5
VM (daf)	w. %	25 – 42	28 – 43

2. Extension of load range

Goals and measures

Goal of retrofit:

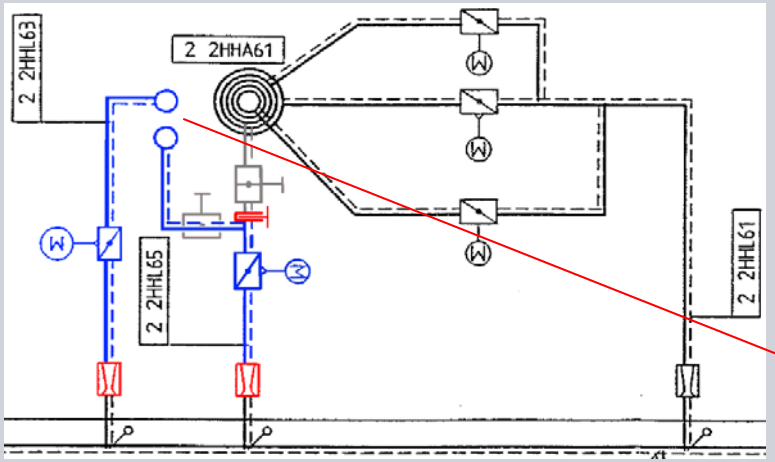
- **Boiler capacity increase 10 %**
- **Keep NO_x-Emissions ≤ 450 mg/Nm³**
- **Minimise slagging of furnace**
- **Corrosion protection of furnace walls (O_2)**
- **Use of import coals**

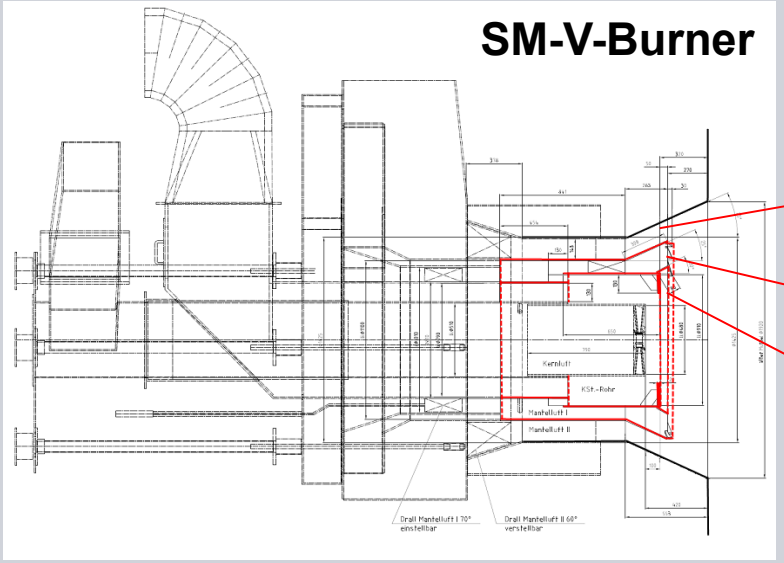
Measures:

- **Revamp to SM-V-Burner design (67 MWth)**
- **Modification of side wall air system**
- **Optimisation of OFA system**
- **Retrofit of mills**
- **Capacity increase of FD Fan**

2. Extension of load range

Firing concept





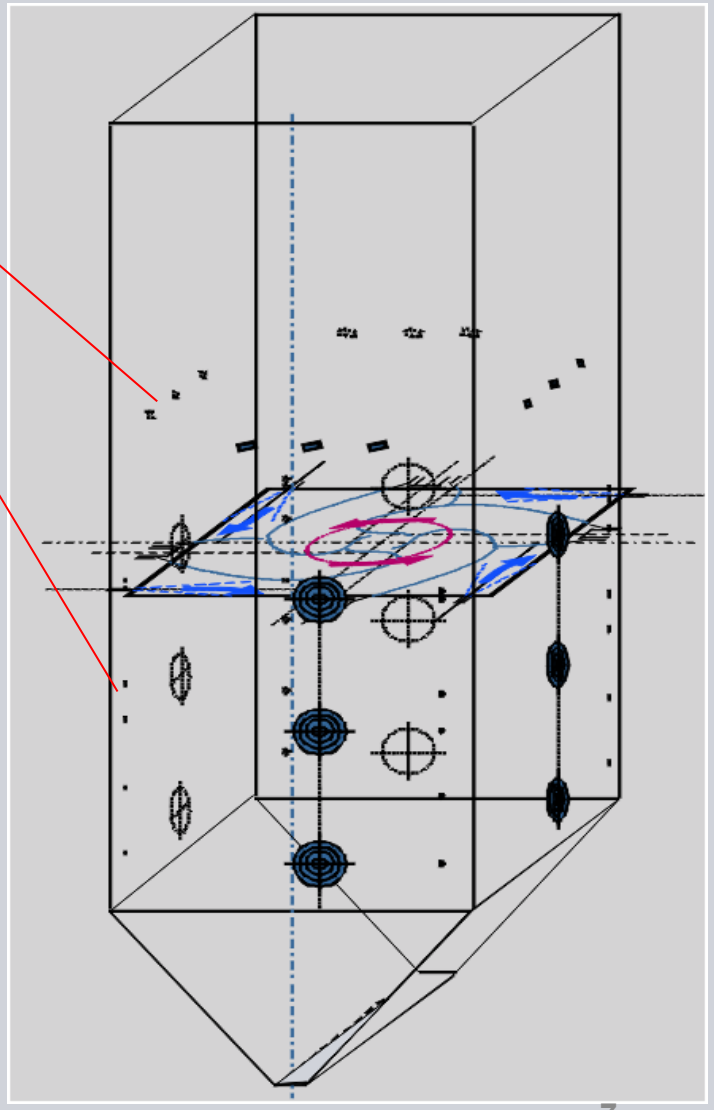
Over fire air

Side wall air

Secondary air 2

Secondary air 1

Primary fuel



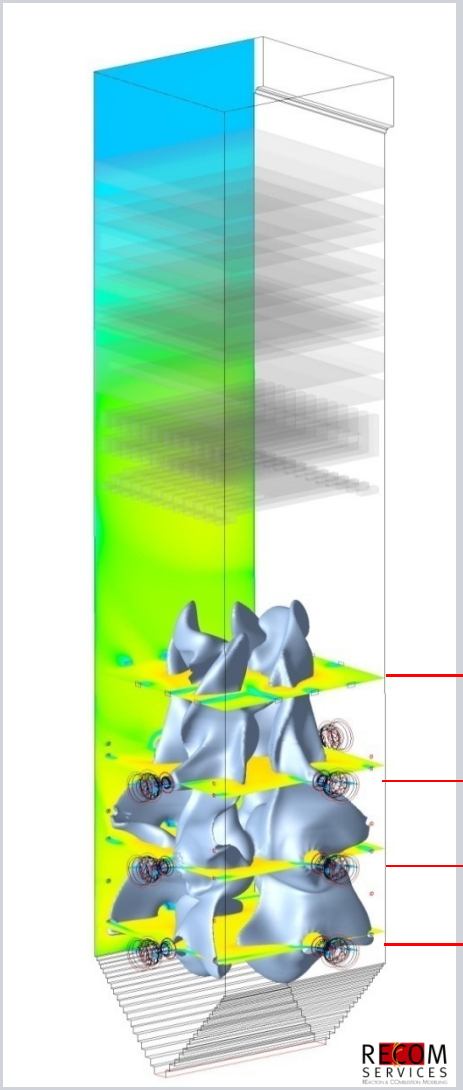
2. Extension of load range

CFD calculation of furnace

Temperature profile with isosurface 1500 °C

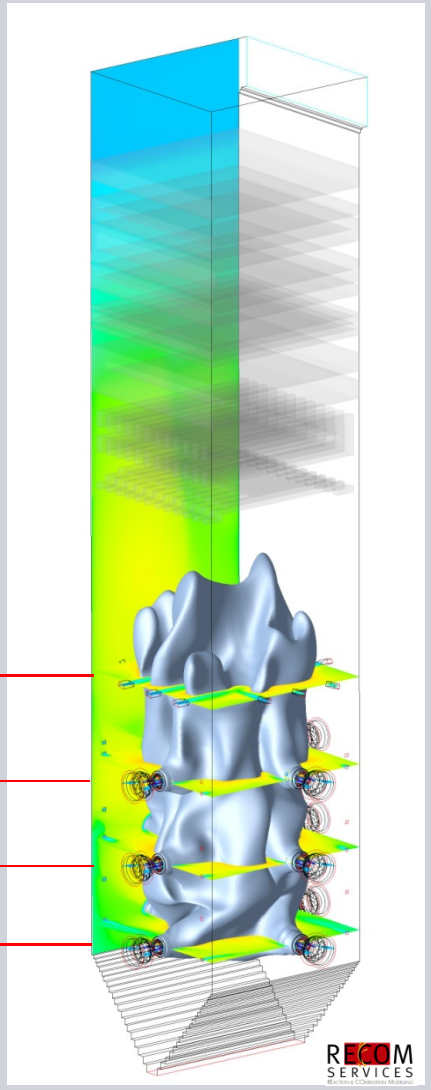
before revamp

Heat input 735 MW
Air ratio 1,18



after revamp

Heat input 799 MW
Air ratio 1,18



improved position of fireball

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2. Extension of load range

Measuring results

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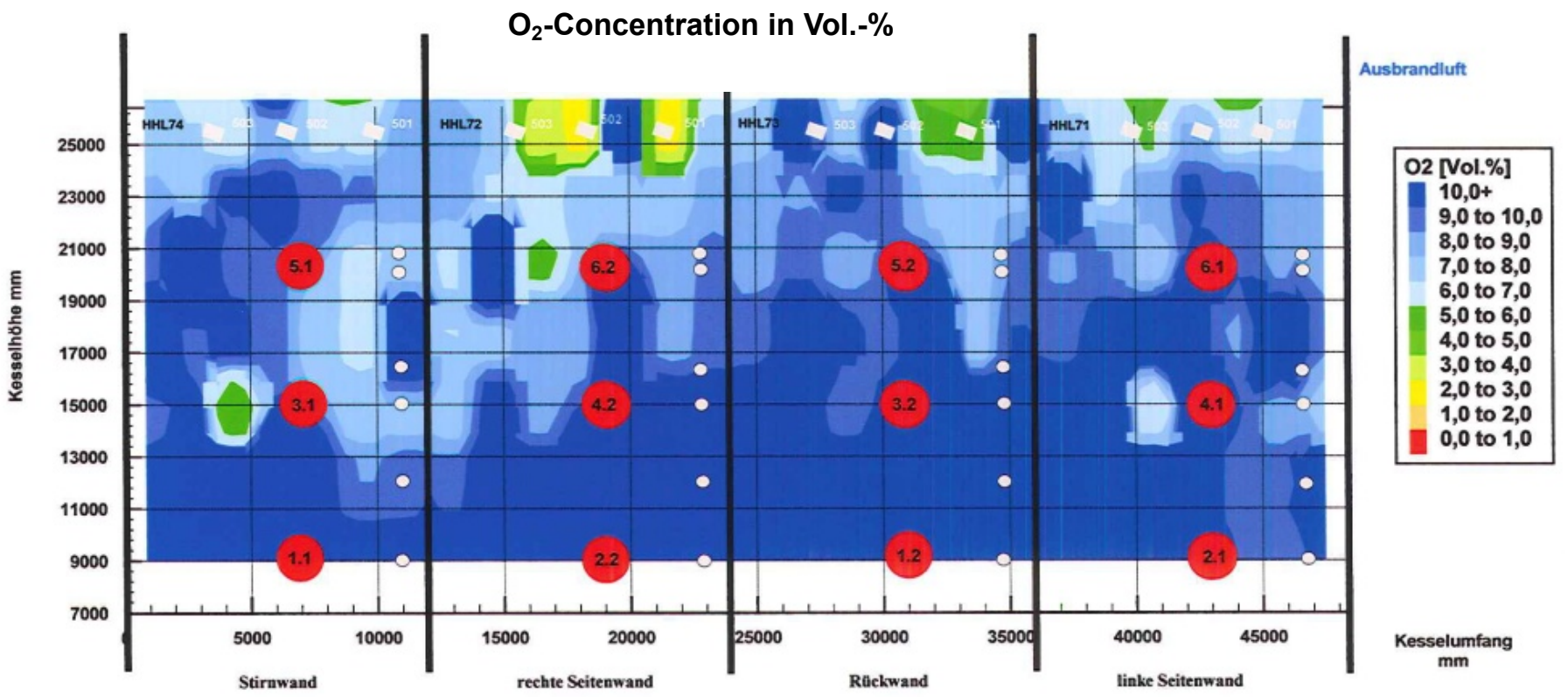
Measured wall atmosphere after revamp



100 % > 1 % O_2

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2. Extension of load range

CFD and measuring results

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	measured **before revamp**	CFD **after revamp**	measured **after revamp**
Load [%]	100	**109**	**109**
NO_x [mg/Nm³@6%O_2]	304	**290**	**297 – 320**
CO [mg/Nm³@6%O_2]	26	**16**	**0 – 50**
FEGT [°C]	1236	**1265**	**1267**
UBC in fly ash [w. %]	1,7	**2,1**	**1,6 – 3,4**
O_2 < 0,5 [Vol. %]	1,6	**0,4**	**1,2**
Excess-Air-Ratio	1,18	**1,18**	**1,18**

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2. Extension of load range

Life time experience

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SM-V-Ultra Low NO_x Burner

after 8 years of operation - 03/2005

after 13 years of operation - 05/2010

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Three examples of executed Firing projects within last two years:

2. **Extension of Load Range**

3. **Flexibilty improvement and reduced operating costs**

4. **Emission reduction and increase of availability**

3. Flexibilty improvement and reduced operating costs

Main plant figures

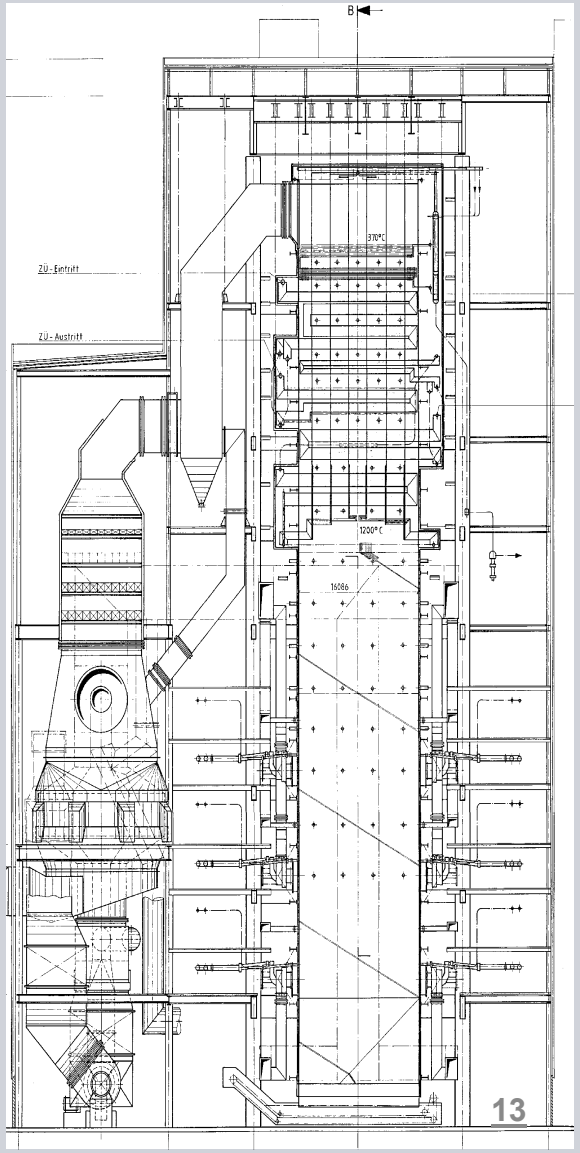
Benson type steam generator

Fuel:	**Bituminous Coal**
Steam flow:	**420 kg/s / 1512 t/h**
Temperature (SH/RH) :	**535 °C / 541°C**
Pressure (SH):	**254 bar**
Fuel heat input:	**1278 MWth**
FEGT:	**1250 °C**

Opposite firing system, 12 MSM-Burner, 100 MWth each

Mills:	**3 Tube Mills**
Commissioning:	**1989**

	Unit	Ref. coal before revamp	Coal range after revamp
NCV	MJ/kg	25,1	**16,7 – 26,4**
Ash (a.r.)	Mass -%	7,1	**6 – 30**
Moisture (a.r.)	Mass -%	13,5	**7 - 18**
Volatiles (a.r.)	Mass -%	32,9	**21 – 36,5**



3. Flexibility improvement and reduced operating costs

Goals and measures

Goal of retrofit:

- **Simplification of firing system by removing the secondary fuel system (reburning)**
- **Extension of coal quality range (Import Coal with high volatile matter)**
- **Keep / Slight Reduction of primary NO_x emissions**
  - **⇨ Reduction of ammonia consumption**
- **Reduction of excess air ratio from 1,25 down to 1,18**
  - **⇨ Reduction of flue gas losses and lower power consumption of fans**
- **Avoid furnace wall corrosion and slagging**

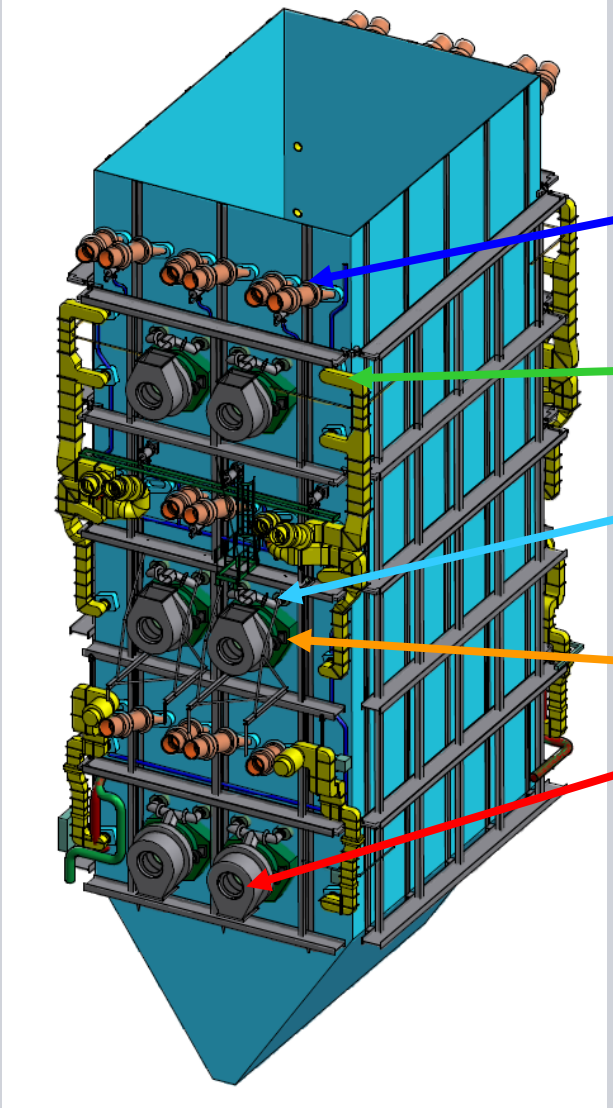
Measures:

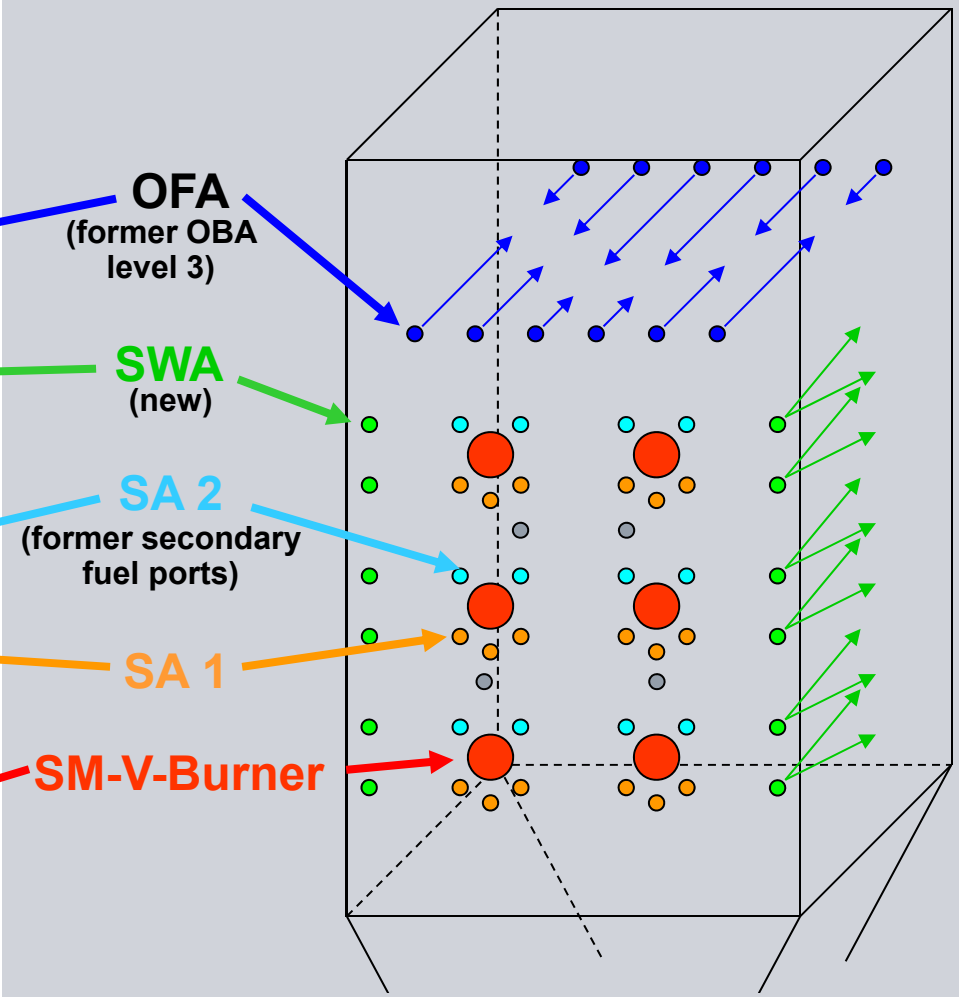
1. **Firing system**
- **New burners**
- **Adding a new side wall air system**
- **Implementation of Over fire air**

2. **Pulverising system (3 tube mills)**
- **Shut-off of secondary firing system (including flue gas recirculation system)**
- **Optimisation of PF distribution**

3. Flexibility improvement and reduced operating costs

Combustion air system



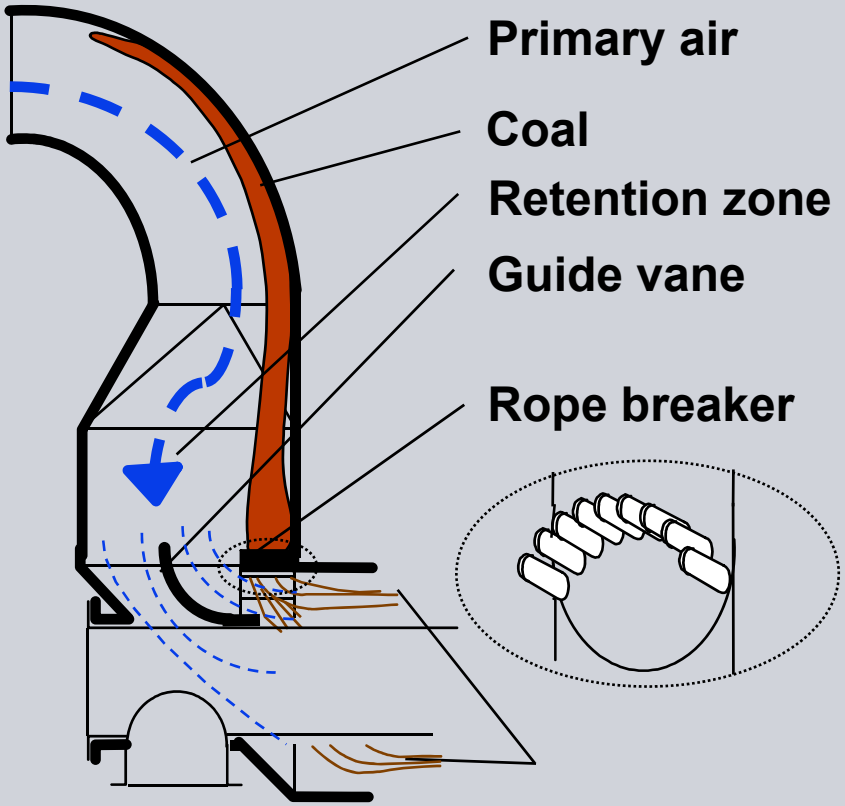


complex and flexible,

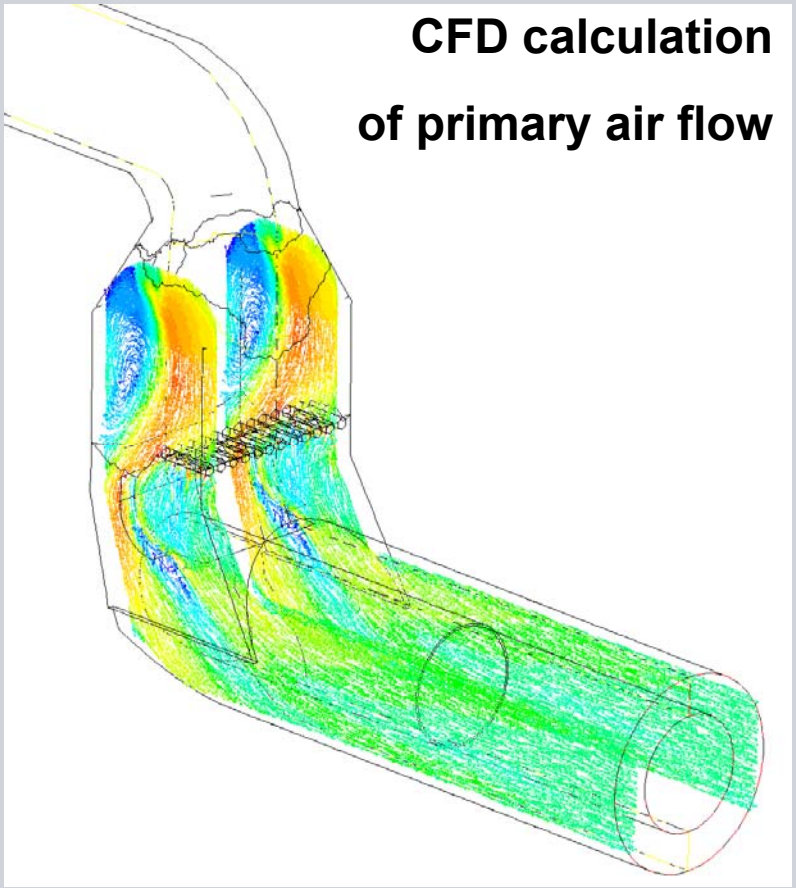
use of existing equipment as much as possible

3. Flexibility improvement and reduced operating costs

Burner design

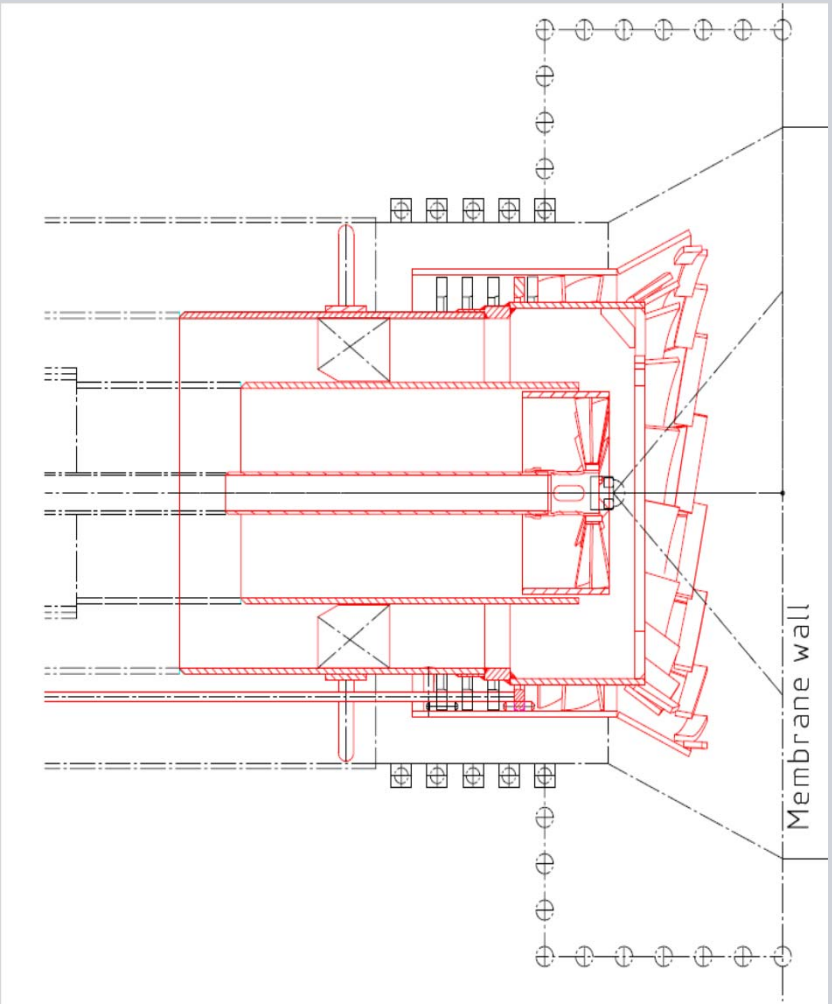


„Uniform“ coal - air mixture



3. Flexibility improvement and reduced operating costs

Burner modification



Burner modification

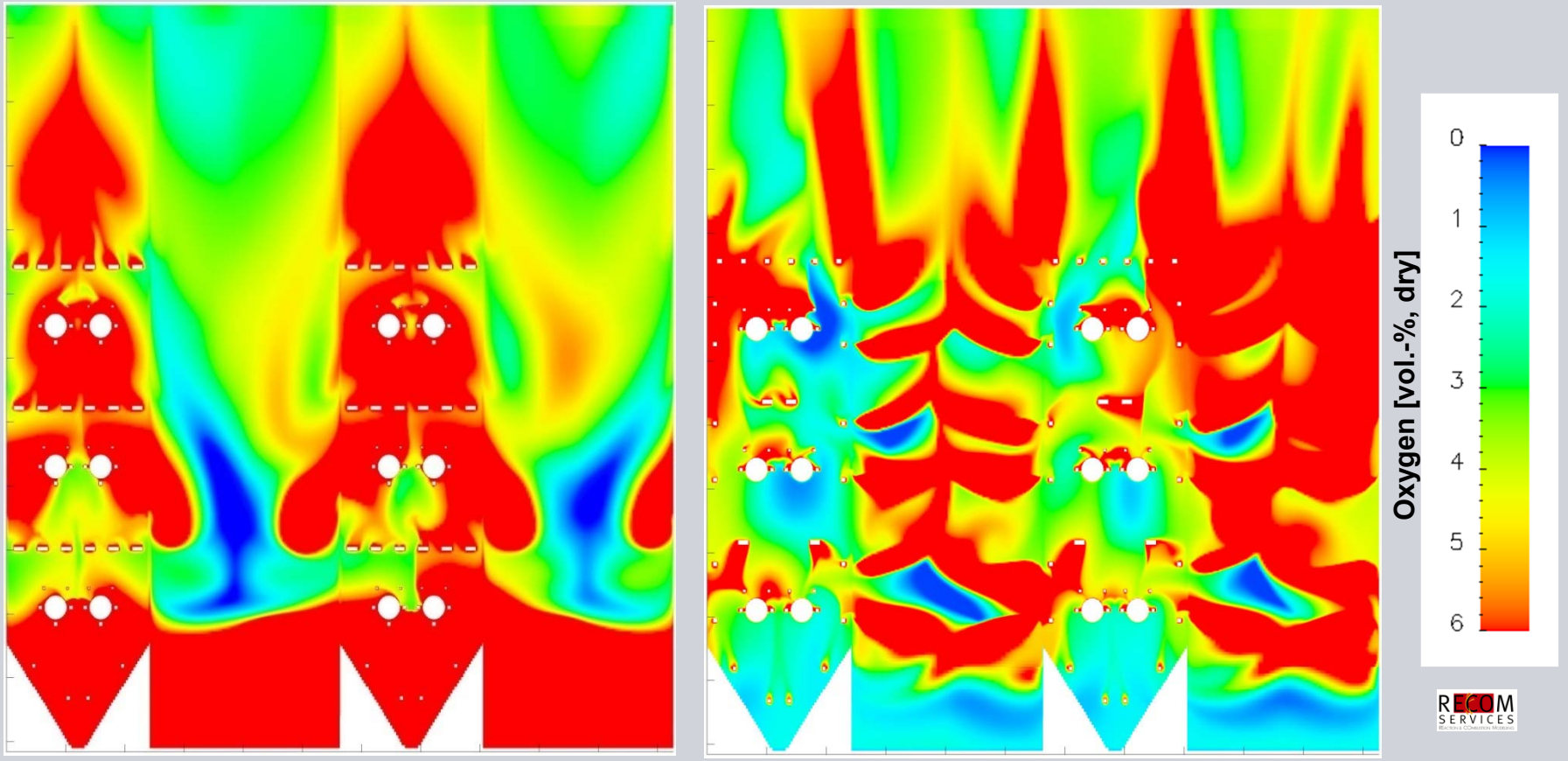
minimum hardware replacement and scope of work

3. Flexibility improvement and reduced operating costs

CFD calculation

O_2 concentration at furnace walls

before revamp ($\lambda_{tot} = \lambda_{BB} = 1{,}25$) **after** revamp ($\lambda_{tot} = 1{,}18$, $\lambda_{BB} < 1{,}0$)



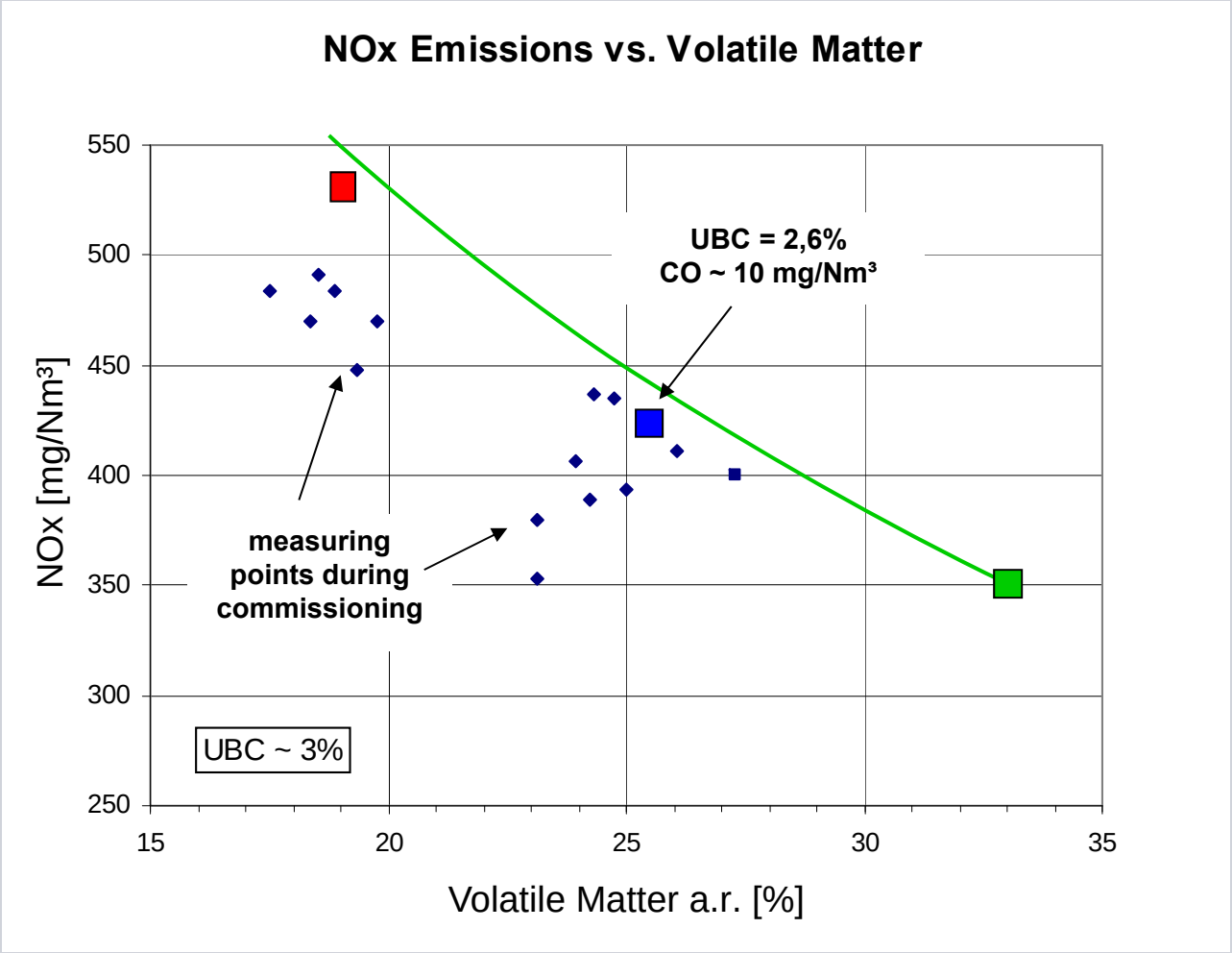
3. Flexibility improvement and reduced operating costs

CFD and measuring results

	measured **before revamp**	CFD **before revamp**	CFD No. 7 **after revamp**	measured **after revamp**
Coal	VM ~ 25% a.r.		**Colombian coal**	**blend with low cont. of VM**
FEGT [°C] (Mean / Maximum)	1211	**1215 (1320)**	**1209 (1312)**	**~ 1225**
Excess-Air-Ratio [-]	1,25	**1,25**	**1,18**	**1,18**
NO_x [mg/Nm³, @ 6%O_2]	520 (±30)	**528**	**315**	**350 – 480**
CO [mg/Nm³, @ 6%O_2]	< 10	**15**	**8**	**< 25**
UBC in Fly Ash [w. %]	ca. 3,2	**3,1**	**1,8**	**~ 2,5**

3. Flexibility improvement and reduced operating costs

Measuring results



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Three examples of executed Firing projects within last two years:

2. **Extension of Load Range**

3. **Flexibilty improvement and reduced operating costs**

4. **Emission reduction and increase of availability**

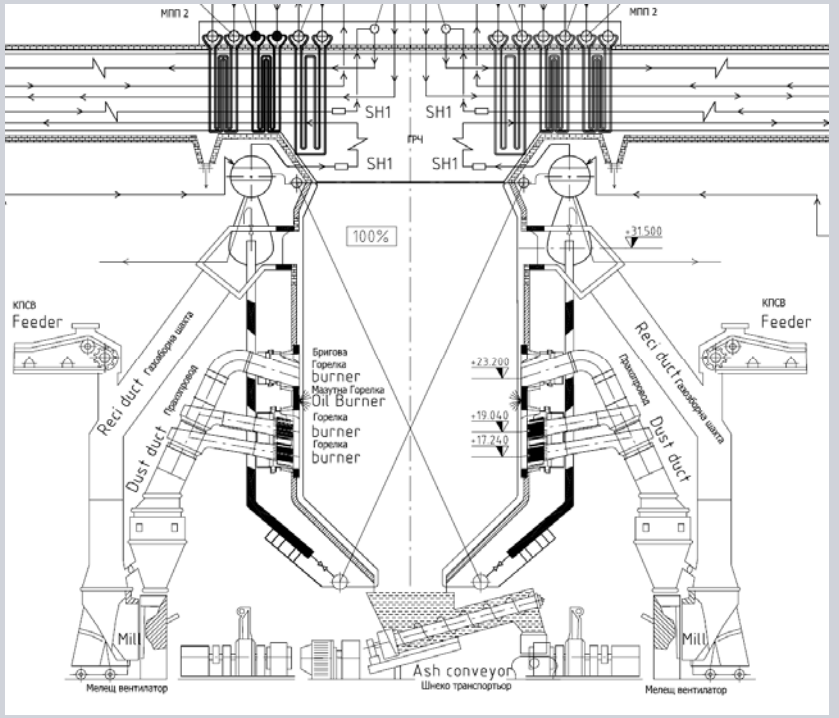
4. Emission reduction and increase of availability

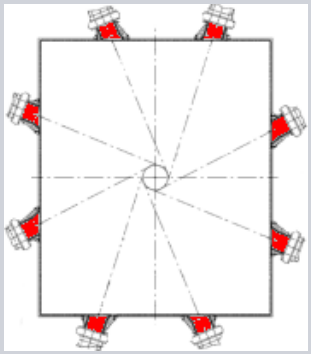
Main plant figures

Boiler type: Natural circulation

Fuel:	**Bulgarian lignite**
Steam flow*:	**192 kg/s / 690 t/h**
Temperature (SH/RH):	**540 °C/ 540°C**
Pressure (SH):	**130 bar**
Fuel heat input:	**660 MWth**
FGET:	**1100 °C**
Tangential firing, 8 mills	
Commissioning	**1981**
***Retrofit (8% load increase)**	**2009**

	Unit	Range
NCV (a.r.)	MJ/kg	6-7
Ash (a.r.)	w.%	10 – 20
Moisture (a.r.)	w.%	50 - 60
Volatiles (daf.)	w.%	~ 60





4. Emission reduction and increase of availability

Goals and measures

Goals:

- **Reduction of the NO_x emissions from 375 to below 180 mg/Nm³ @ 6% O_2**
- **Increase of effectiveness of the combustion chamber by reduction the excess air from 1,2 to 1,15 (at furnace outlet)**
- **CO emissions below 180 mg/Nm³ @ 6% O_2**
- **Preventing water wall corrosion**
- **Decreasing slagging formation -> increase of availability**

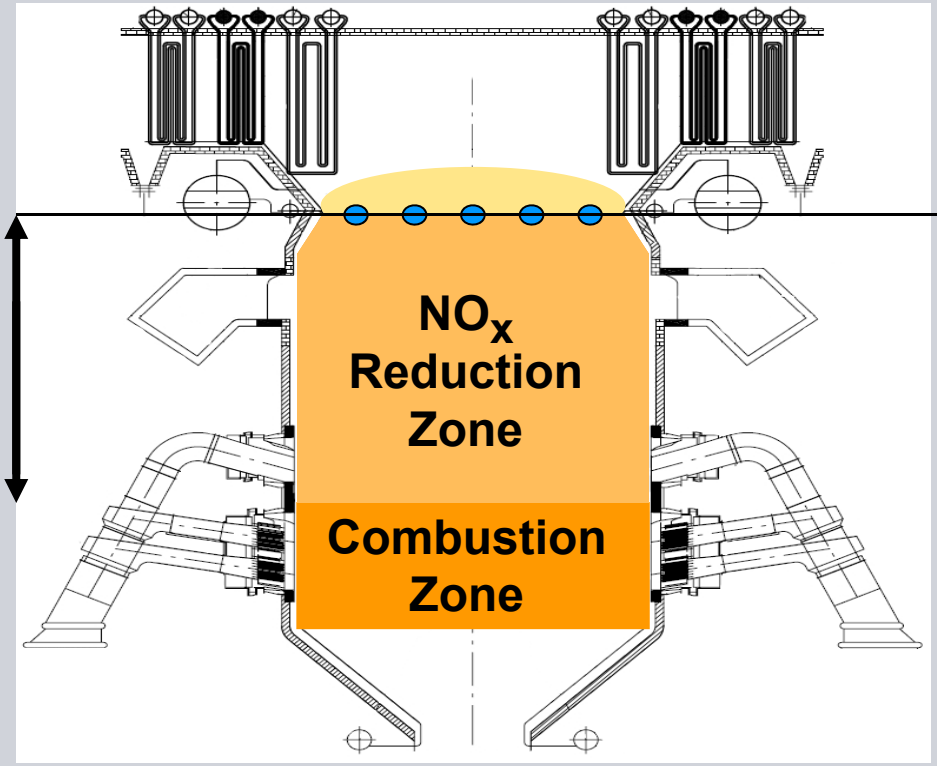
Measures:

- **Burner outlet modification**
  - **Stabilise the ignition close to the burner outlet**
  - **Improve the release of volatiles**
  - **Optimisation of the furnace cross-section air distribution**
  - **Protect membrane walls against corrosion**

- **Modification of burner PF distribution**
  - **Staging the combustion more effective, reduce burner belt Excess Air Ratio**
  - **Influence the residence time inside the furnace**

4. Emission reduction and increase of availability

New OFA system



Increase furnace burnout zone

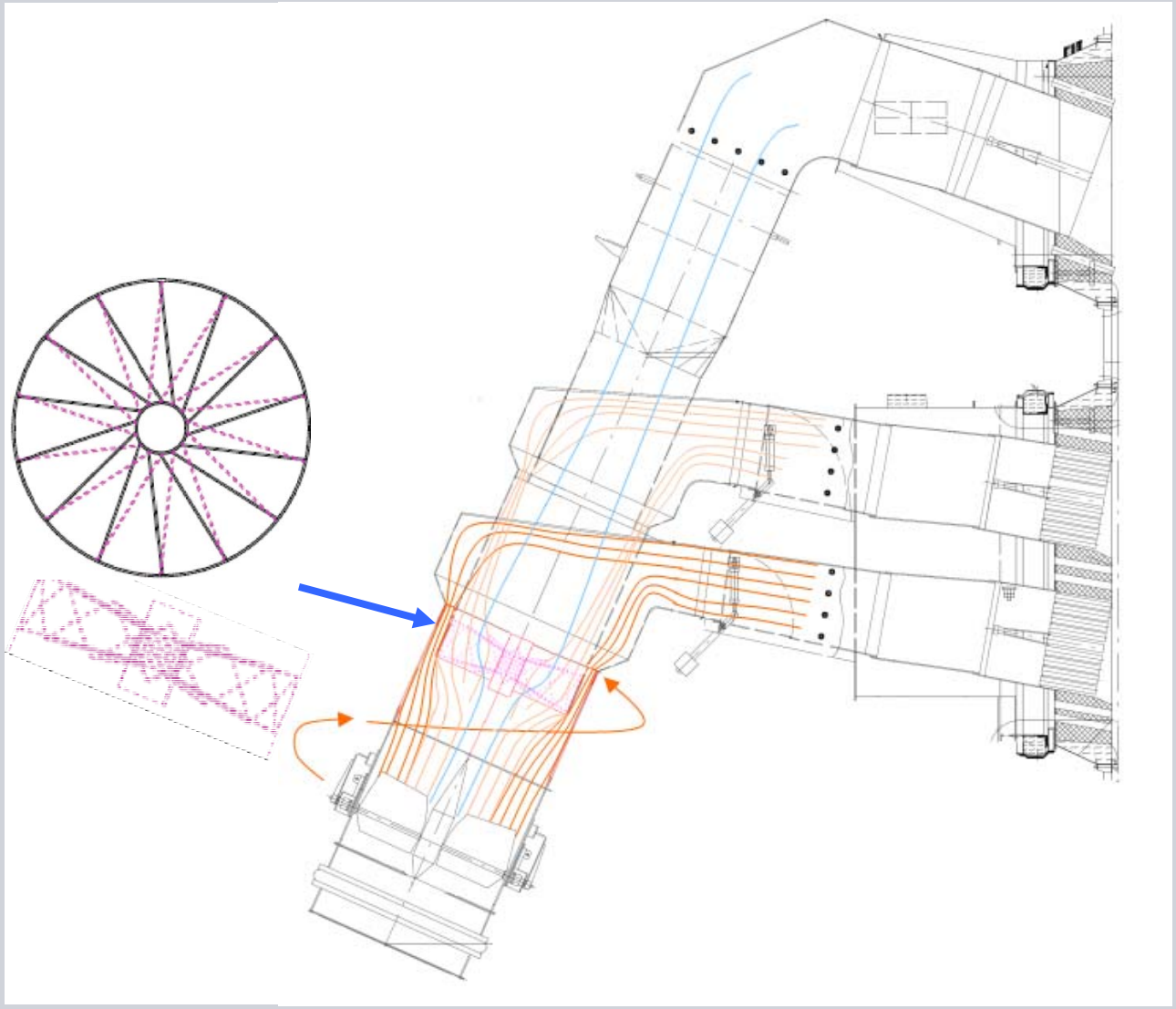
Decrease loss of ignition

Equalise furnace outlet temperature

Create downstream mixing of flue gas

4. Emission reduction and increase of availability

Additional PF concentrator



% of PF distribution

Vapor burner

Upper main burner

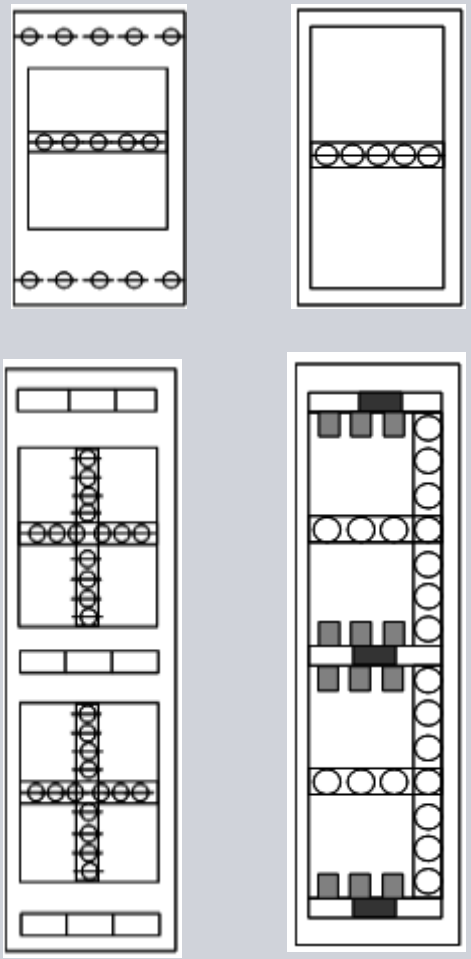
Lower main burner

before / after revamp

4. Emission reduction and increase of availability

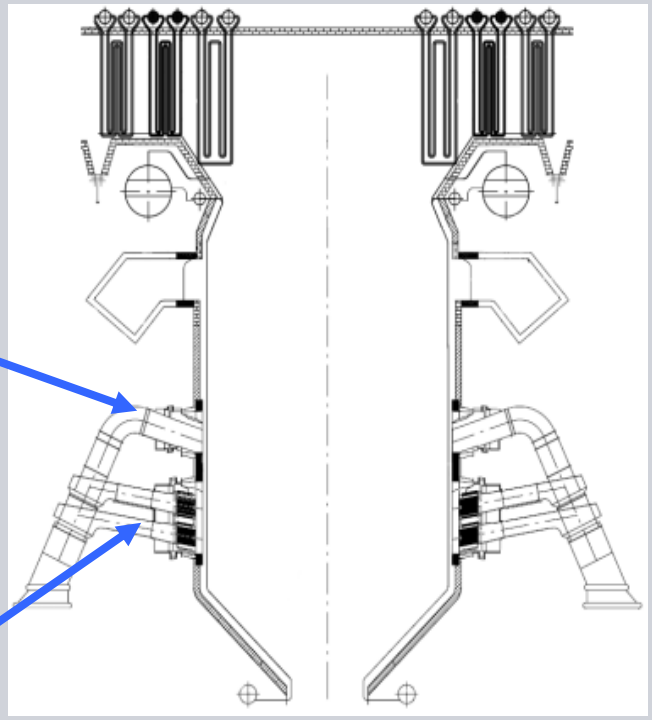
Burner modification

Stable and early ignition,
Preventing water wall corrosion



before revamp

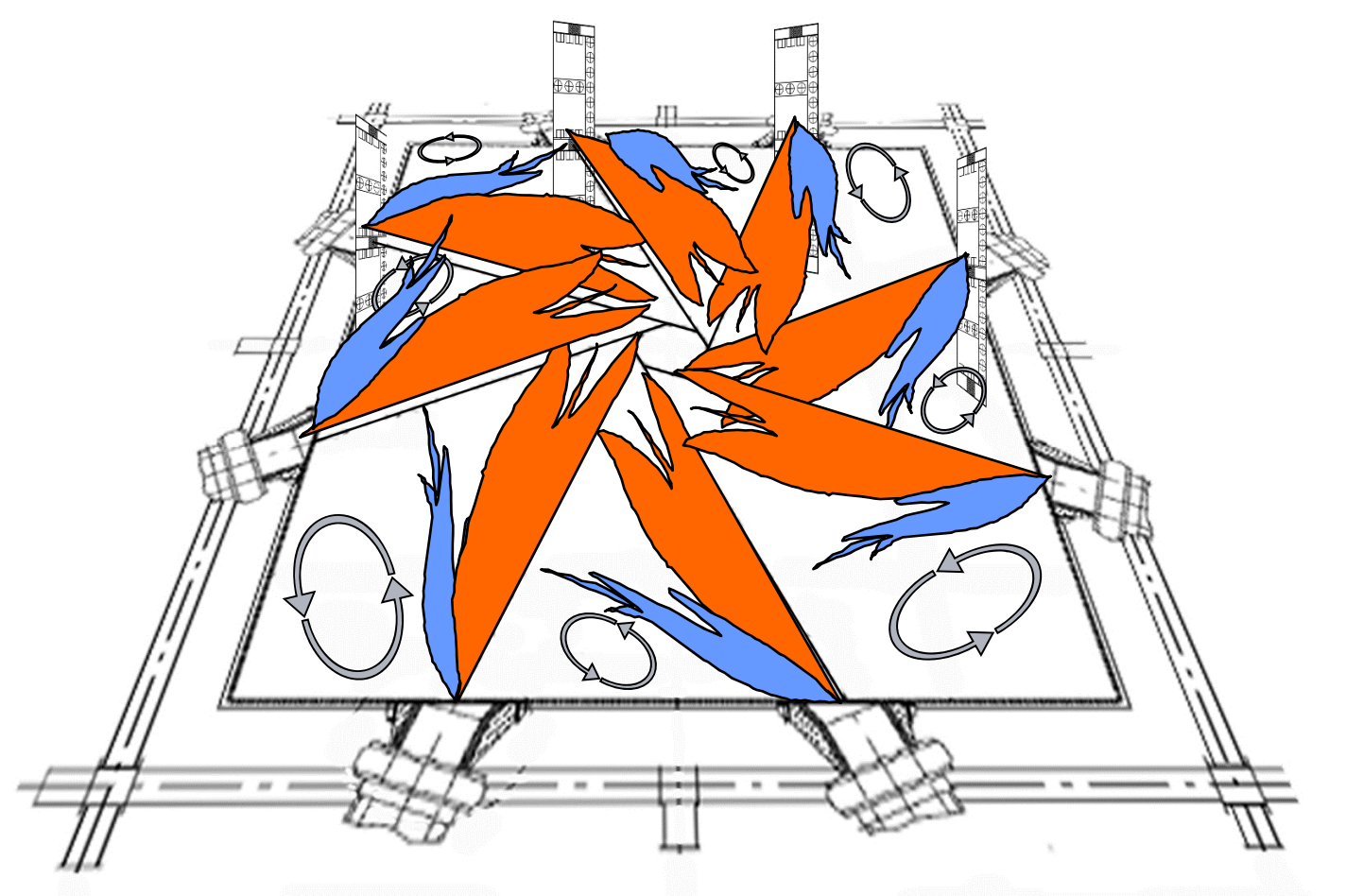
after revamp



4. Emission reduction and increase of availability

Air / Coal mixture, Radial Air Staging

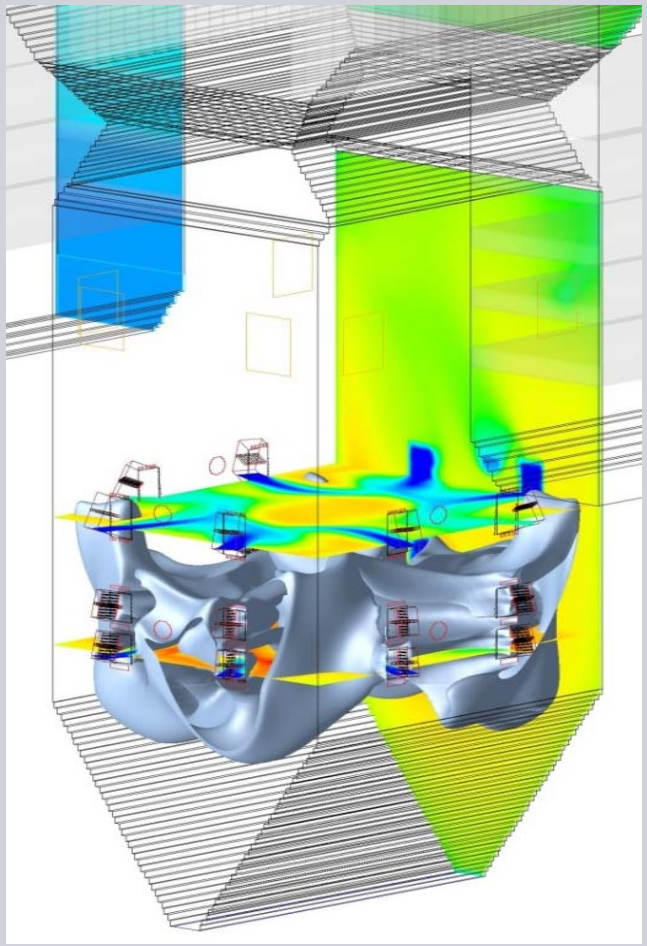
Preventing water wall corrosion



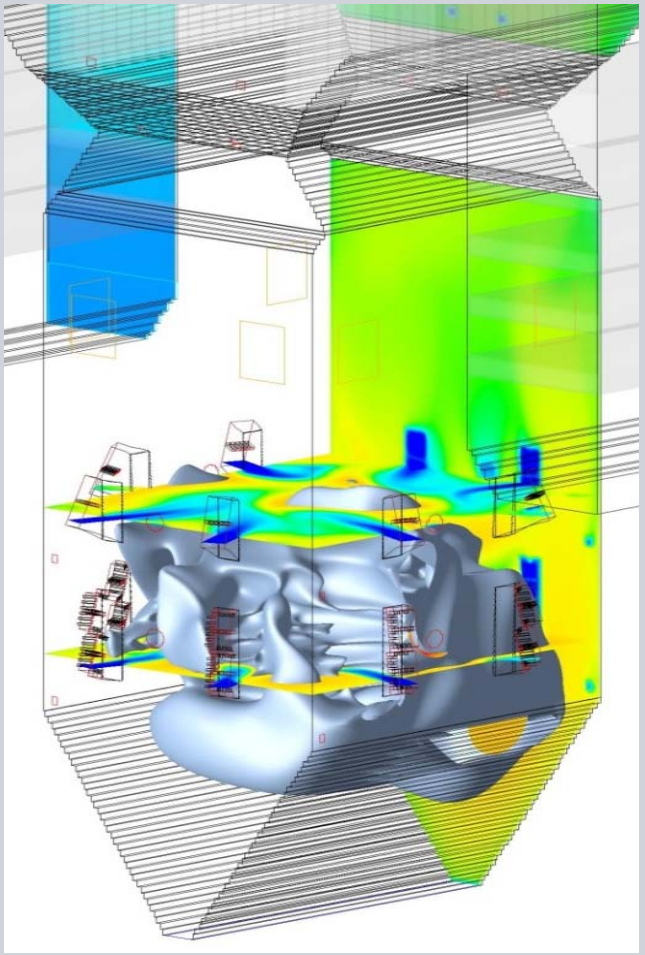
4. Emission reduction and increase of availability

CFD calculation of combustion temperatures

Isosurface 1200 °C



before revamp



after revamp

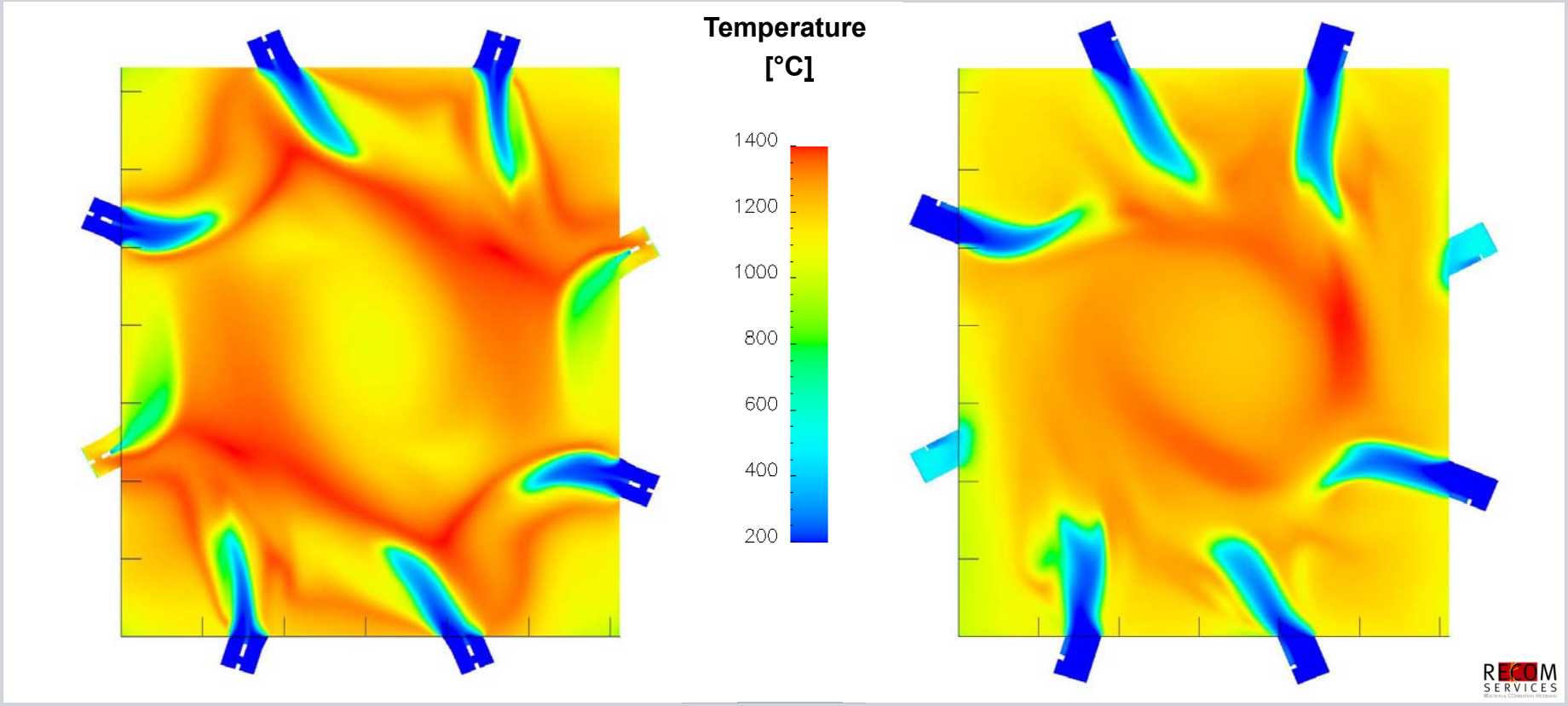
4. Emission reduction and increase of availability

CFD calculation of furnace temperature

Lower main burner

before revamp

after revamp



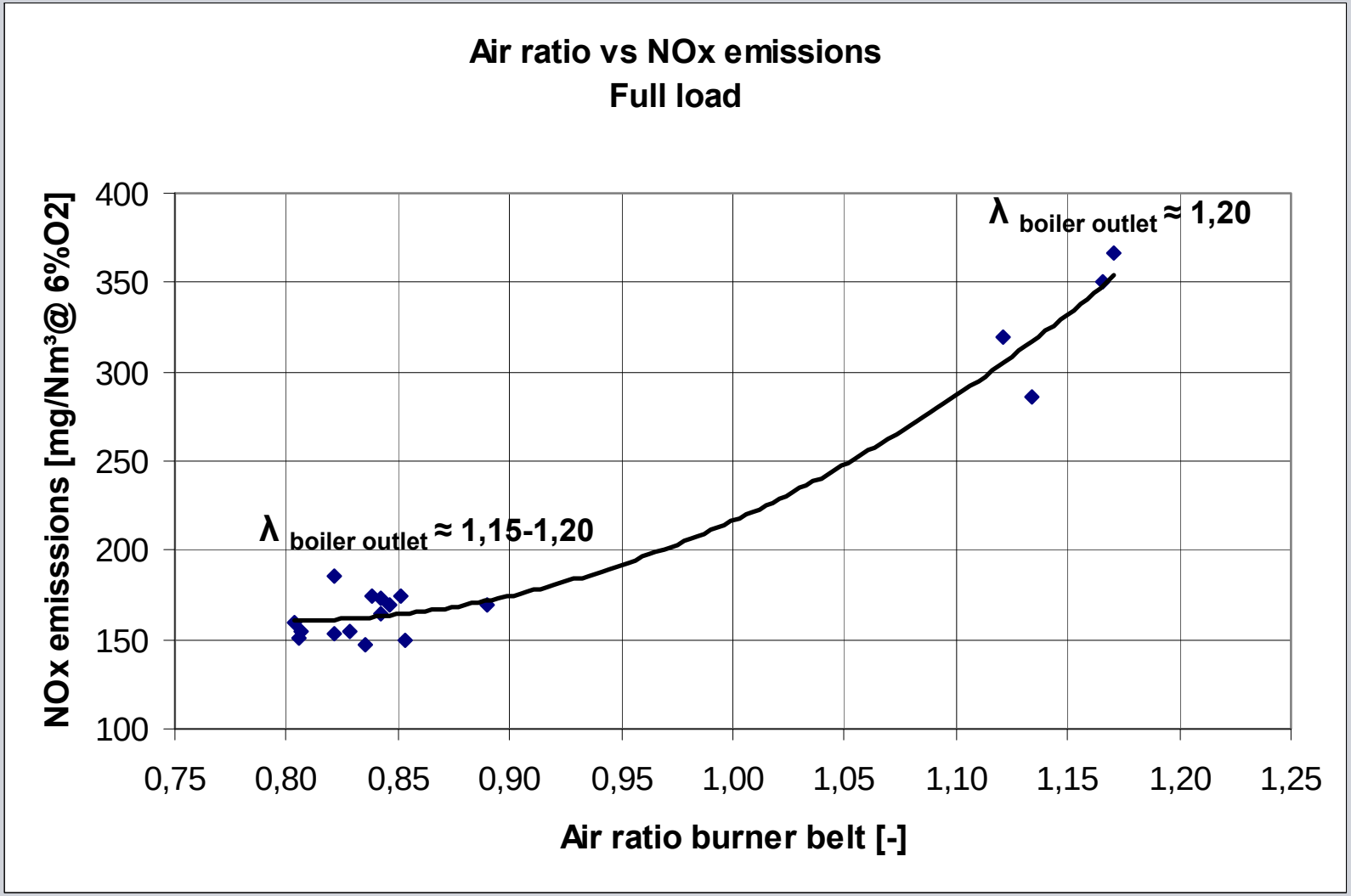
4. Emission reduction and increase of availability

CFD and measuring results

	measured **before revamp**	CFD **after revamp**	measured **after revamp**
Boiler efficiency	84		**84 + ~ 1,5**
NO_x [mg/Nm³, @ 6%O_2]	350 - 400	**195**	**150 – 180**
CO [mg/Nm³, @ 6%O_2]	< 50	**270**	**30 - 100**
Excess-Air-Ratio at Boiler Outlet [-]	1,2	**1,2**	**1,1**
UBC hopper [%]	15	**-**	**~ 12**
UBC fly ash [%]	3	**4,8**	**~ 2,5**

4. Emission reduction and increase of availability

Measuring results



5. Summary

The three presented retrofit projects show that the following goals were achieved:

- Load range extension
- Reduction of primary NO_x emissions
- Cost reduction by improved efficiency and simplification
- Increase of operating flexibility

Thank you for your attention