


Combustion Optimization & SNCR Technology for coal fired power stations and retrofit experience

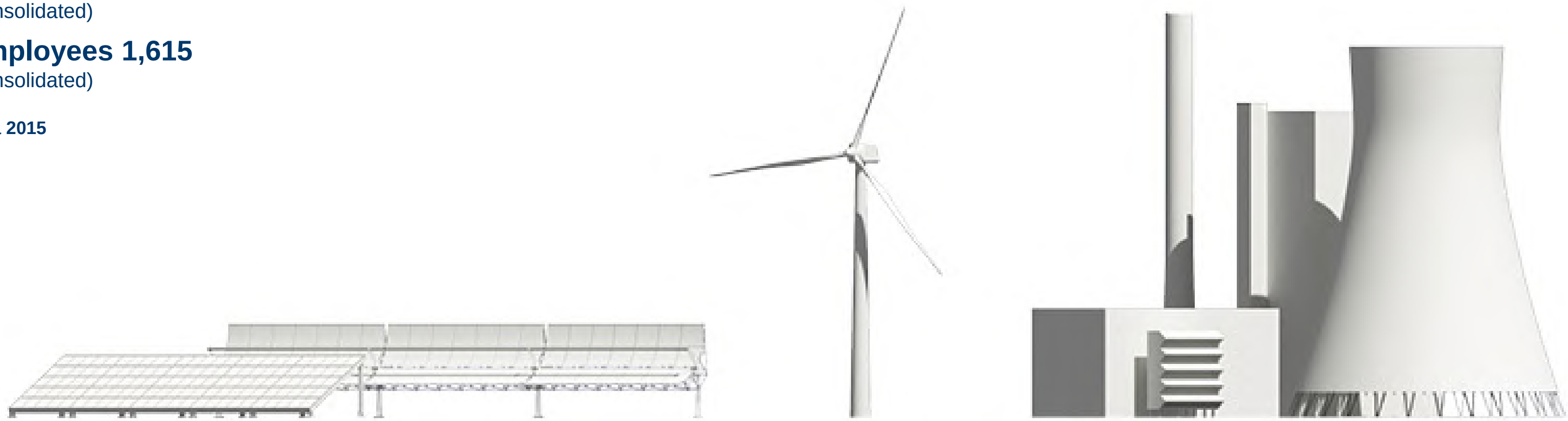
Matthias Schneider / STEAG Energy Services GmbH
Kolkata, Raipur, Hyderabad - November 2016

STEAG Energy Services Group

Revenue € 167 million
(consolidated)

Employees 1,615
(consolidated)

data 2015



STEAG Energy Services

Energy Technologies

Design, site supervision and commissioning of power plants

Plant Services

Operation & Maintenance, catalyst management and –regeneration, personnel services

Nuclear Technologies

Decommissioning and dismantling of nuclear plants, safety, radiation protection and realization of final disposal sites

System Technologies

Energy Management Systems, process optimization by sensor-based solutions, user trainings

Information Technologies

Operation Management Systems, Communication Technologies, Site IT

Energy Technologies Engineering

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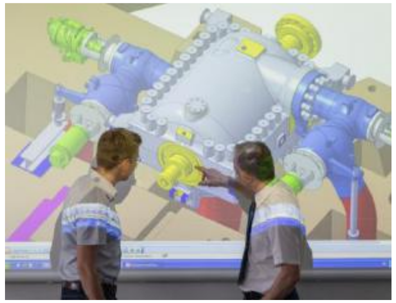
- **Conceptual design**
- **Basic Engineering**
- **Tendering**
  - Preparation of tender documents
  - Management of tender processes
  - Bid evaluation, contract negotiation
- **Detail engineering**
- **Site services**
  - Site Management
  - Supervision / Management of erection and commissioning
  - Performance tests
- **Project Management (technical, related to EPC / supply contracts)**



Experience is essential

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Which type of boiler?

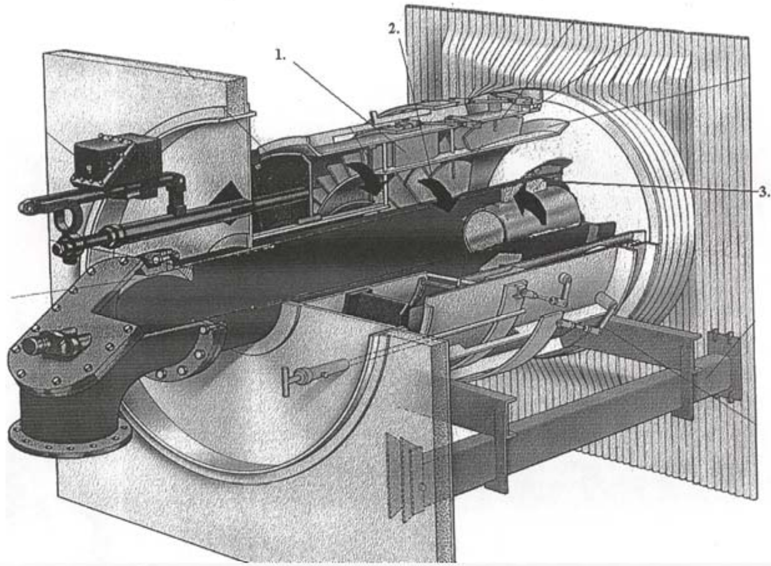
Which type of burner?

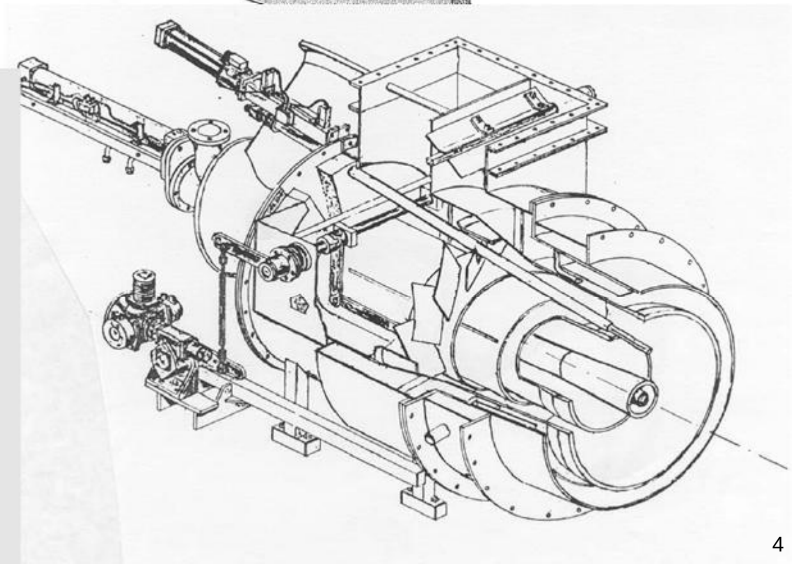
Which type of mill?

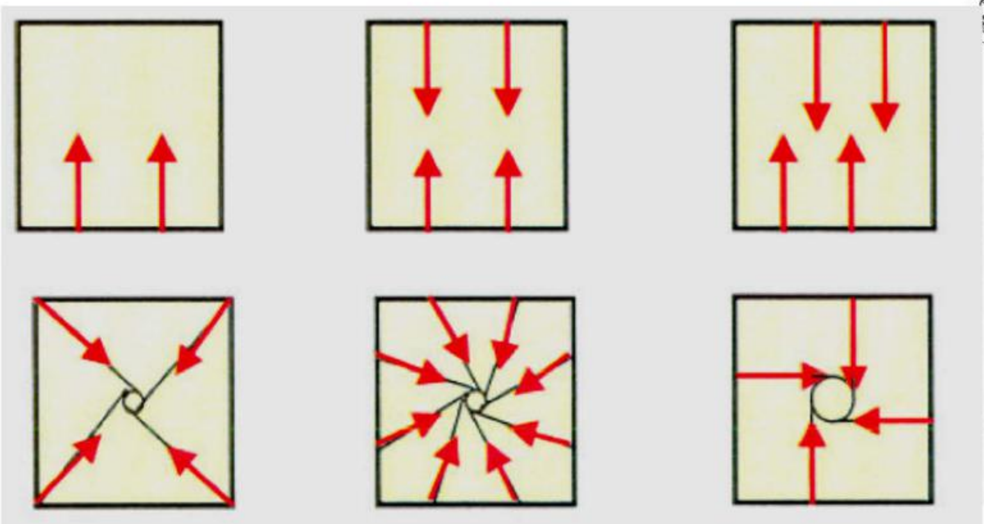
How many mills and burners?

How to connect the systems?

- **Windbox or individual air supply?**
- **Common coal pipe or individual?**







Steag optimization experience with own and 3rd parties for more than 75 years

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Bergkamen A 780 MW

Bergkamen

Bexbach 1 780 MW

Bexbach

Walsum 7/9/10 1350MW

Duisburg-Walsum

Herne 2/3/4 960 MW

Herne

Iskenderun 1/2 1,320 MW

Iskenderun

Voerde A/B 1,522 MW

West 1/2 712 MW

Voerde

Weiher 3 724 MW

Weiher

Lünen 6/7 507 MW

Lünen

Mindanao 1/2 232 MW

Mindanao

Termopaipa IV 165 MW

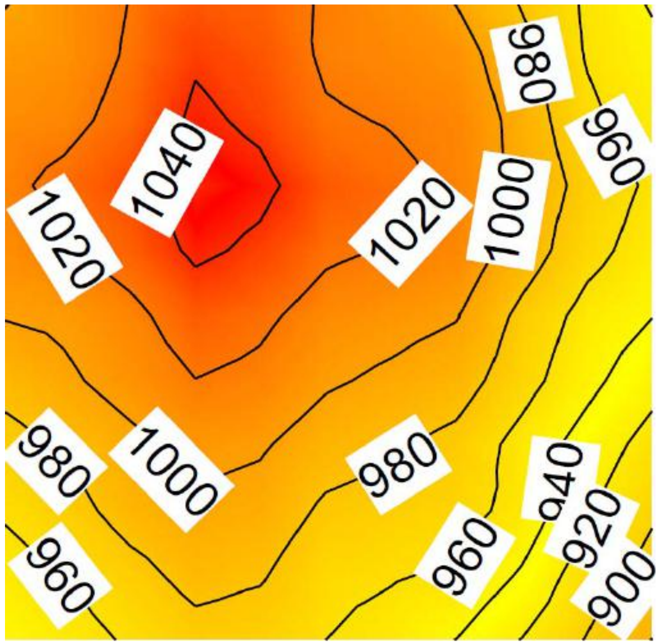
Paipa

MKV, HKV, MHK *) 466 MW

Völklingen-Fenne

What is the goal

- **Stable, monitorable flame**
- **High efficiency**
  - **low air ratio, even O_2 ratio**
  - **Low un-burnt carbon in ash**
  - **Low RH spray**
  - **Low exhaust gas temperature**
- **Low emissions (NO_x)**
- **Even distribution of flue gas temperature at furnace exit**
- **Avoidance of flame impingement on the walls**
- **Avoidance of slagging and fouling**
- **Applicability of a wide coal range**

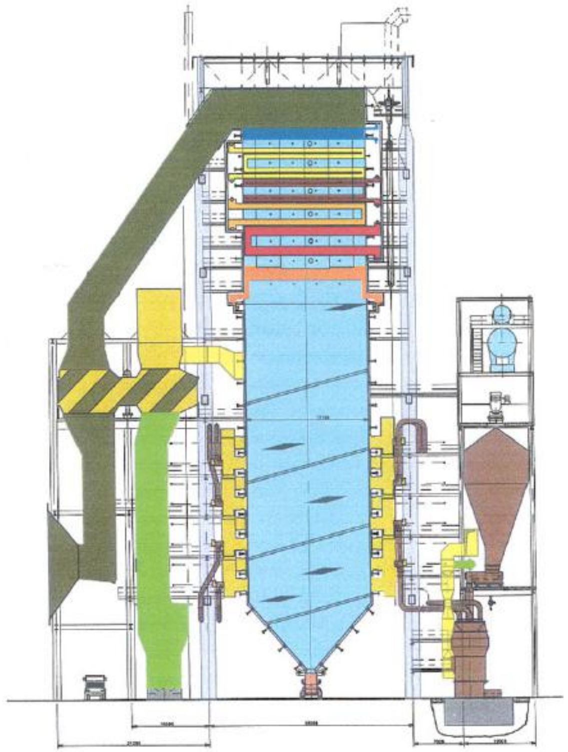


What is the reality

- **Uneven distribution of coal to the individual burners (deviation up to 30 to 40%)**
- **As a consequence high air ratio necessary**
- **Uneven distribution of flue gas temperature entering the convective path**
- **Lower steam output**
- **Slagging, Fouling, Corrosion**
- **High NO_x values**
- **No low load operation possible**

What is possible

- **Max deviation of coal about 5 % to 10 %**
- **NO_x depending on coal 350 to 450 mg/m³**
- **Air ratio 1.15 to 1.17**
- **Minimum load 10 to 15 % of MCR**

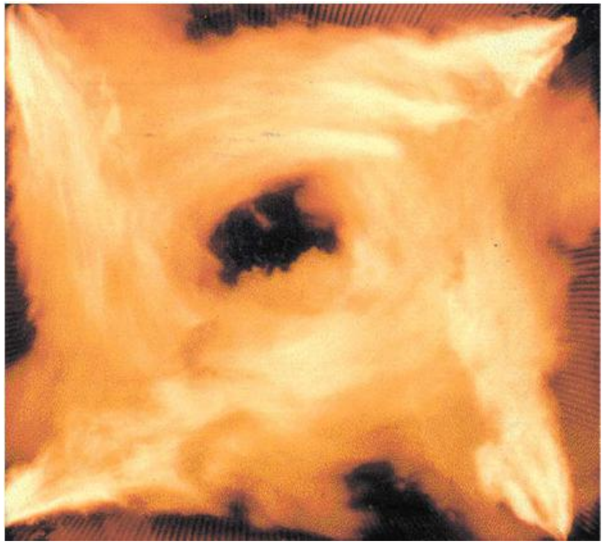


What are the tools beside software

- **Rotating classifier**
- **Balancing of the coal flow to the burners**
- **Balancing pressure drop of the coal pipes**
- **Fine grinding**
- **Single burner air control offers more possibilities for optimization than wind box design**

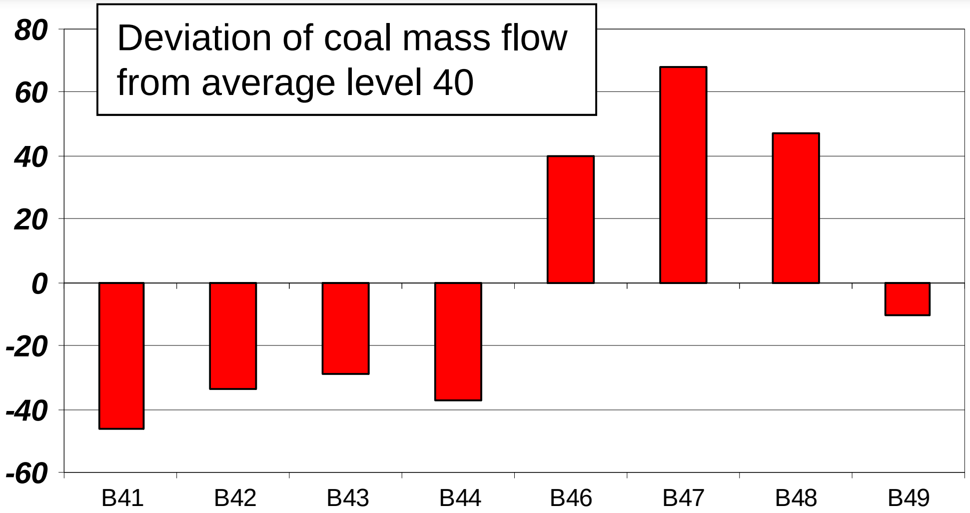
Combustion optimization
Primary NO_x-Measures

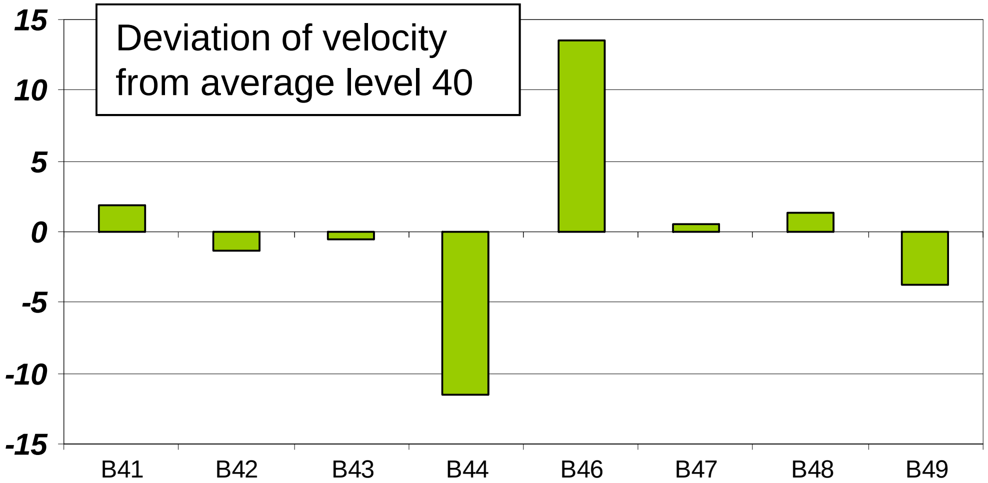
“ Reduce the air ratio in certain zones as far as possible. But avoid: poor flame stability, too high amount of unburnt carbon in filter ash, corrosion risk for evaporator walls, slagging and so on. “

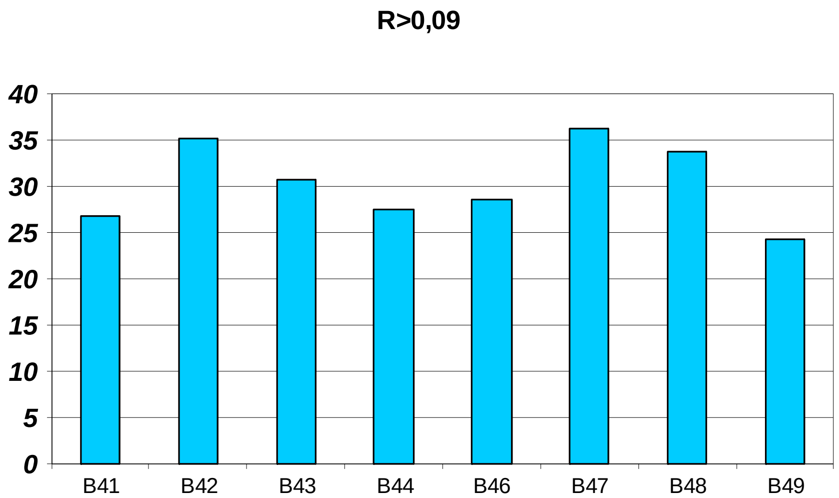


It is the art of engineering to reach low NOx-values while avoiding those unwished side effects

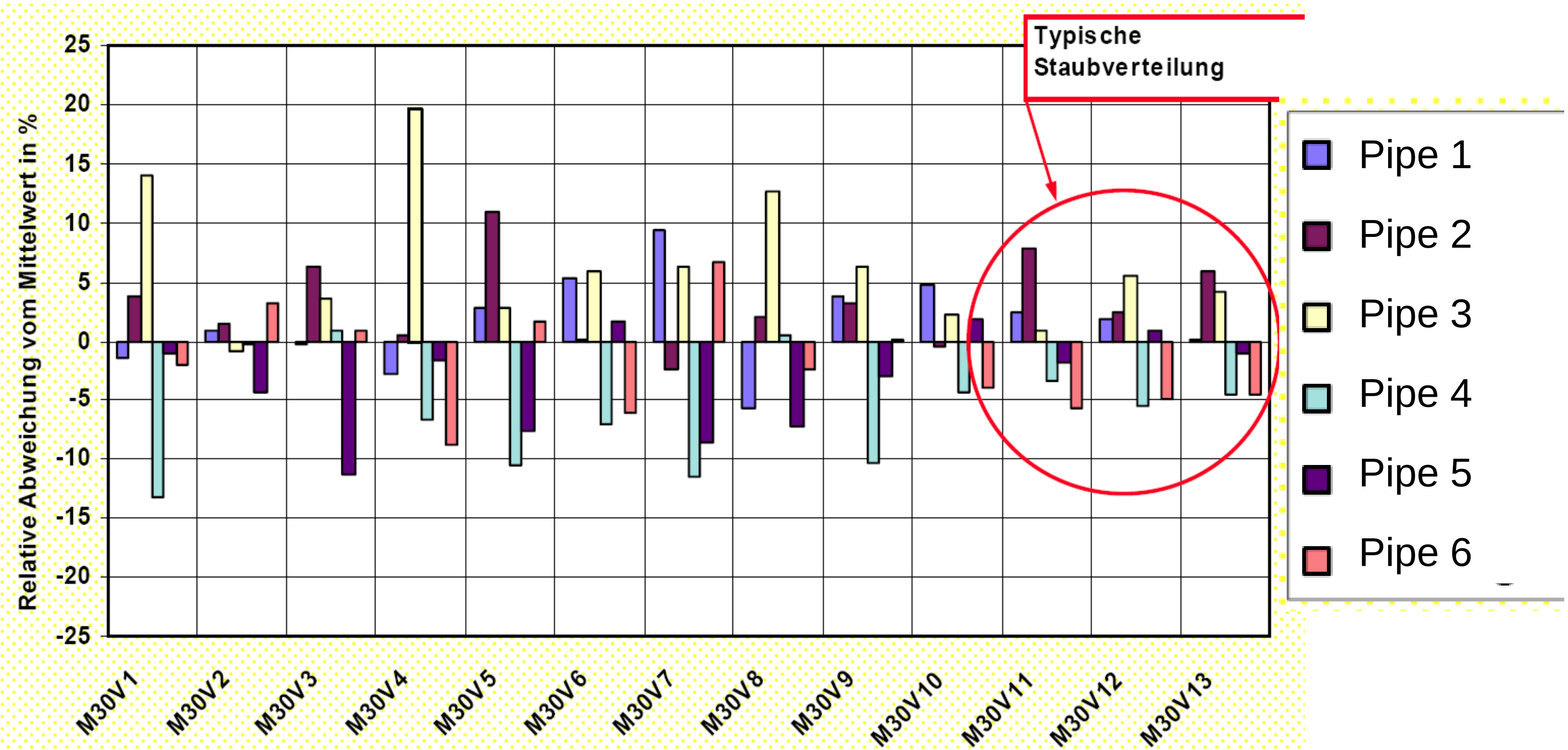
Example for bad coal distribution





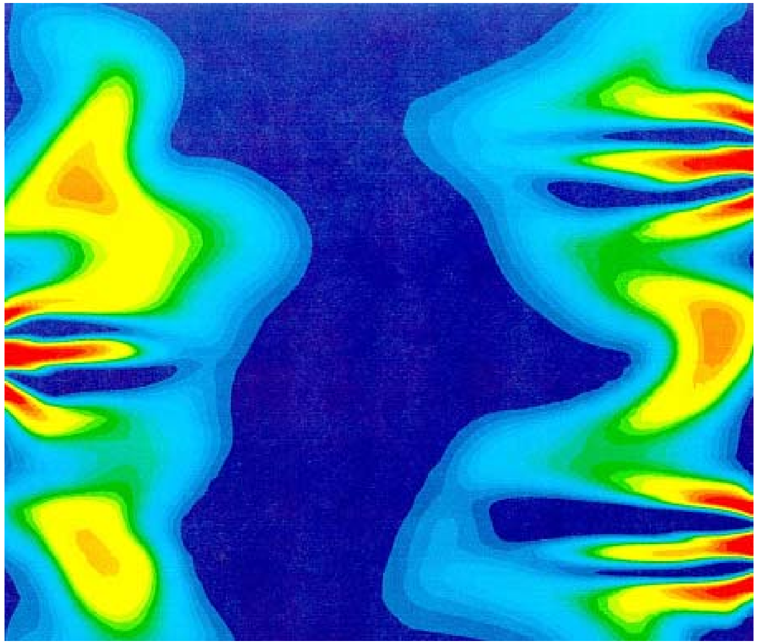


Better coal distribution
other example



What can be achieved by CFD?

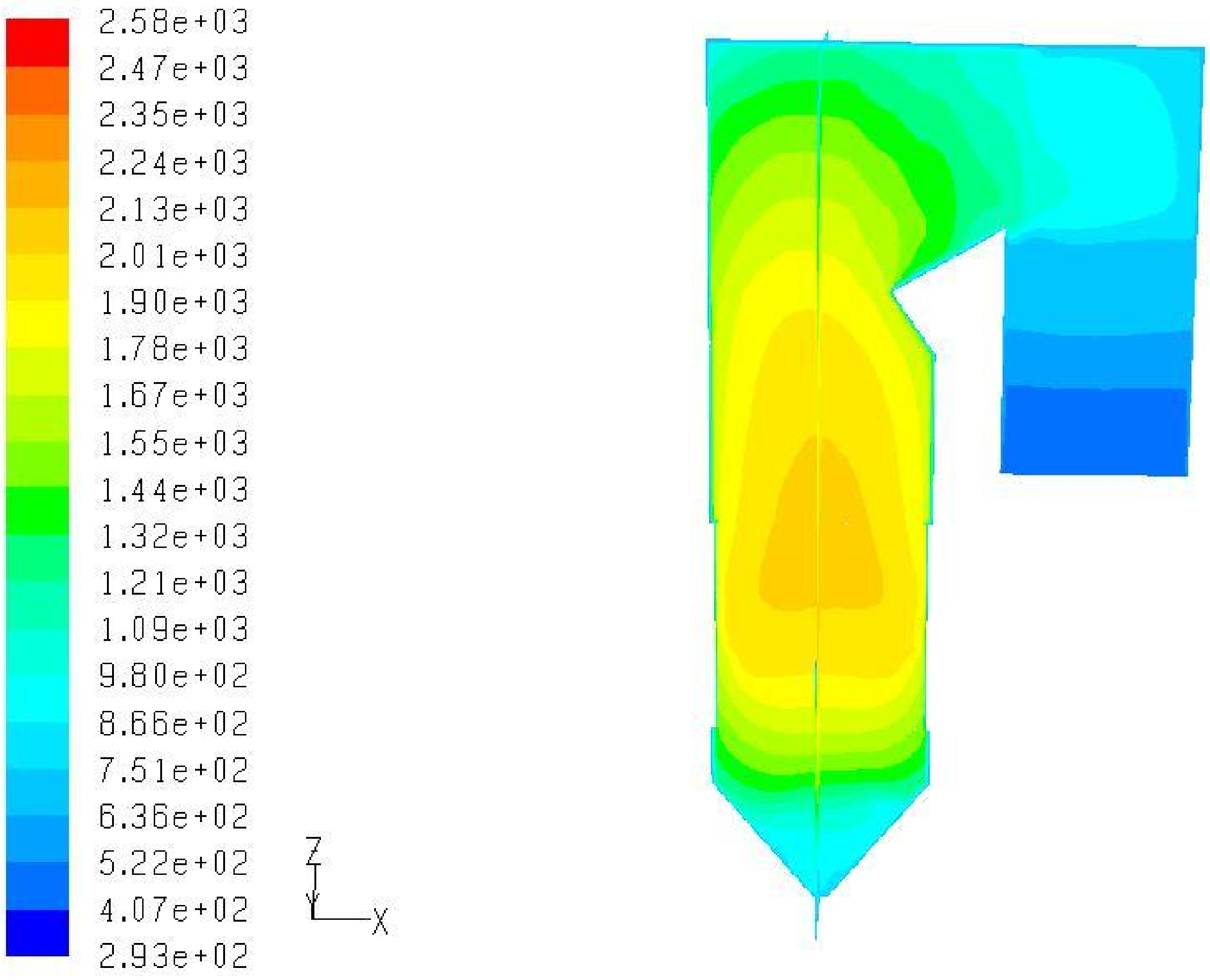
- Optimum furnace design
- Even distribution of coal and air
- Avoiding wall corrosion by avoidance of air lean areas close to the wall
- Optimized arrangement of burners inside the boiler
- Simulation of flow field and combustion at various loads
- Simulation of radiative and convective heat transfer



Limited:

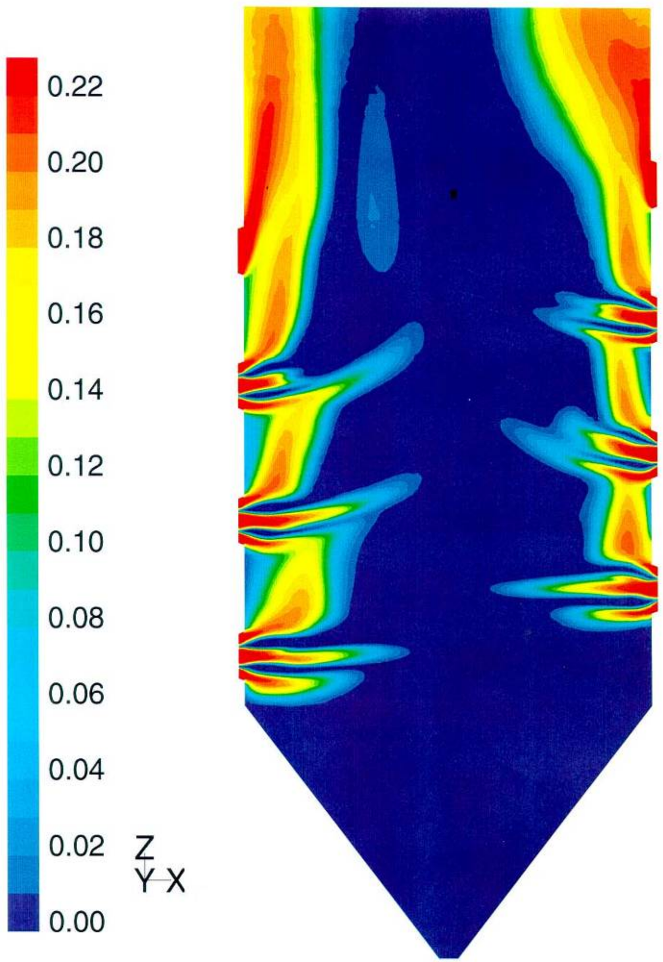
- Increase of flame stability
- Avoidance of slagging and fouling

Example for temperature distribution furnace mid plane

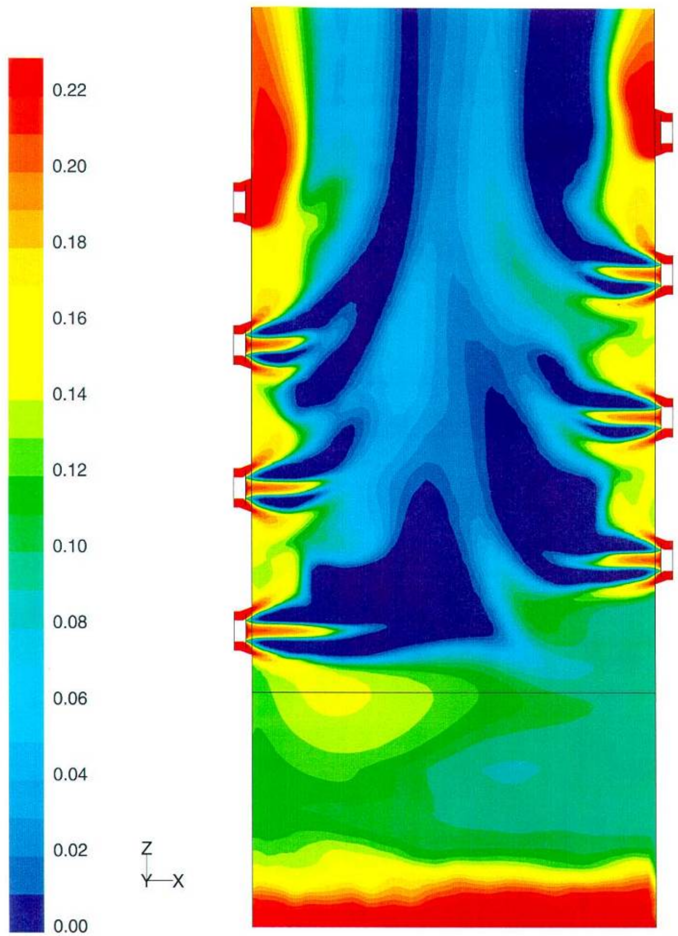


CFD Simulation of furnace and hopper design - O_2 plots

Old arrangement of hopper

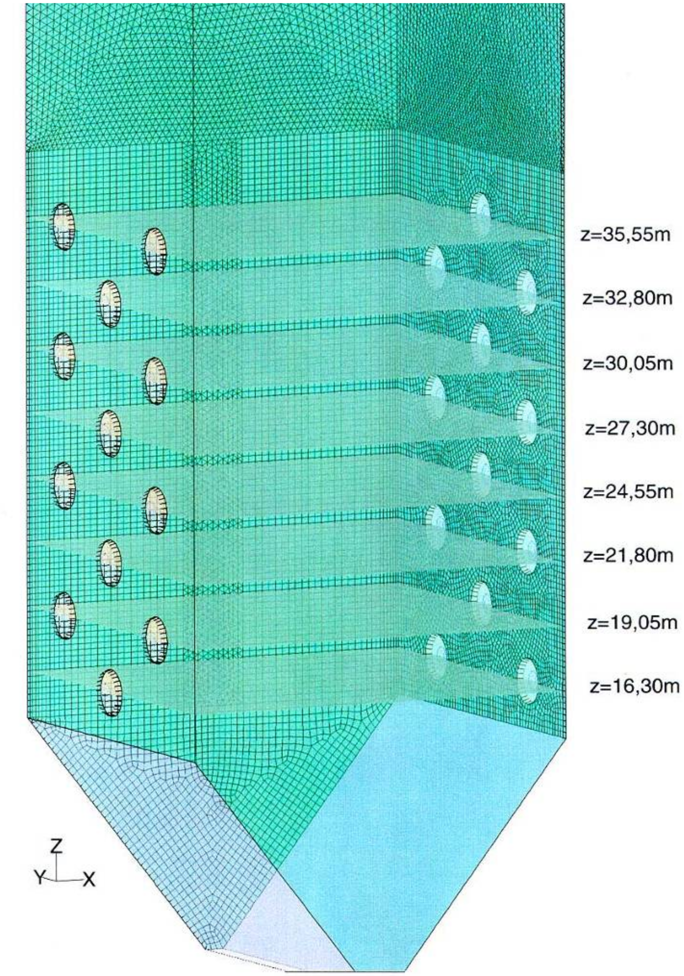


Optimized arrangement of hopper

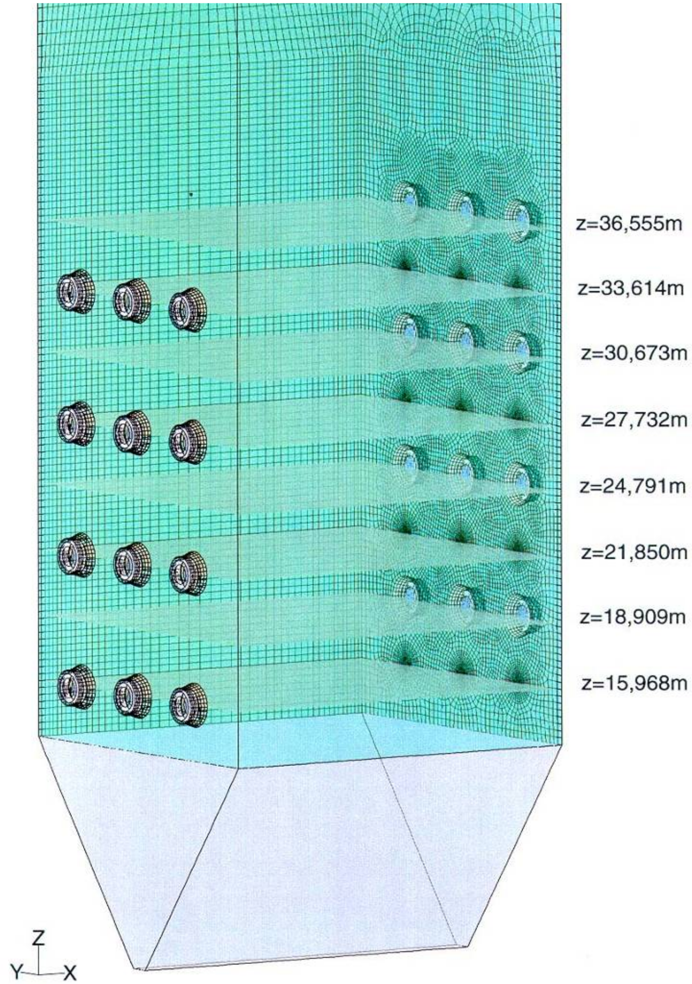


Optimized furnace and hopper design based on CFD Simulation

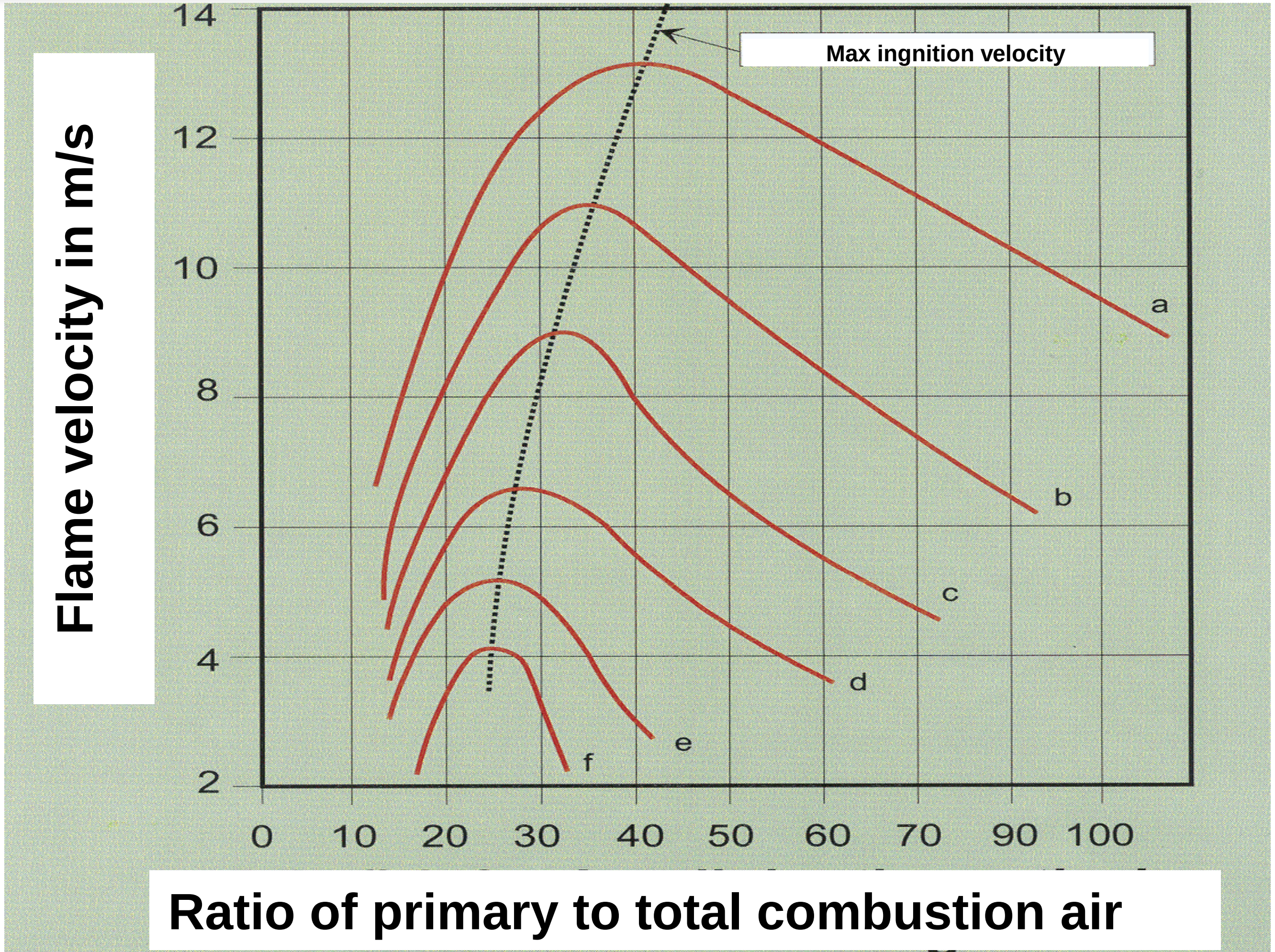
Old arrangement of hopper



Optimized arrangement of hopper

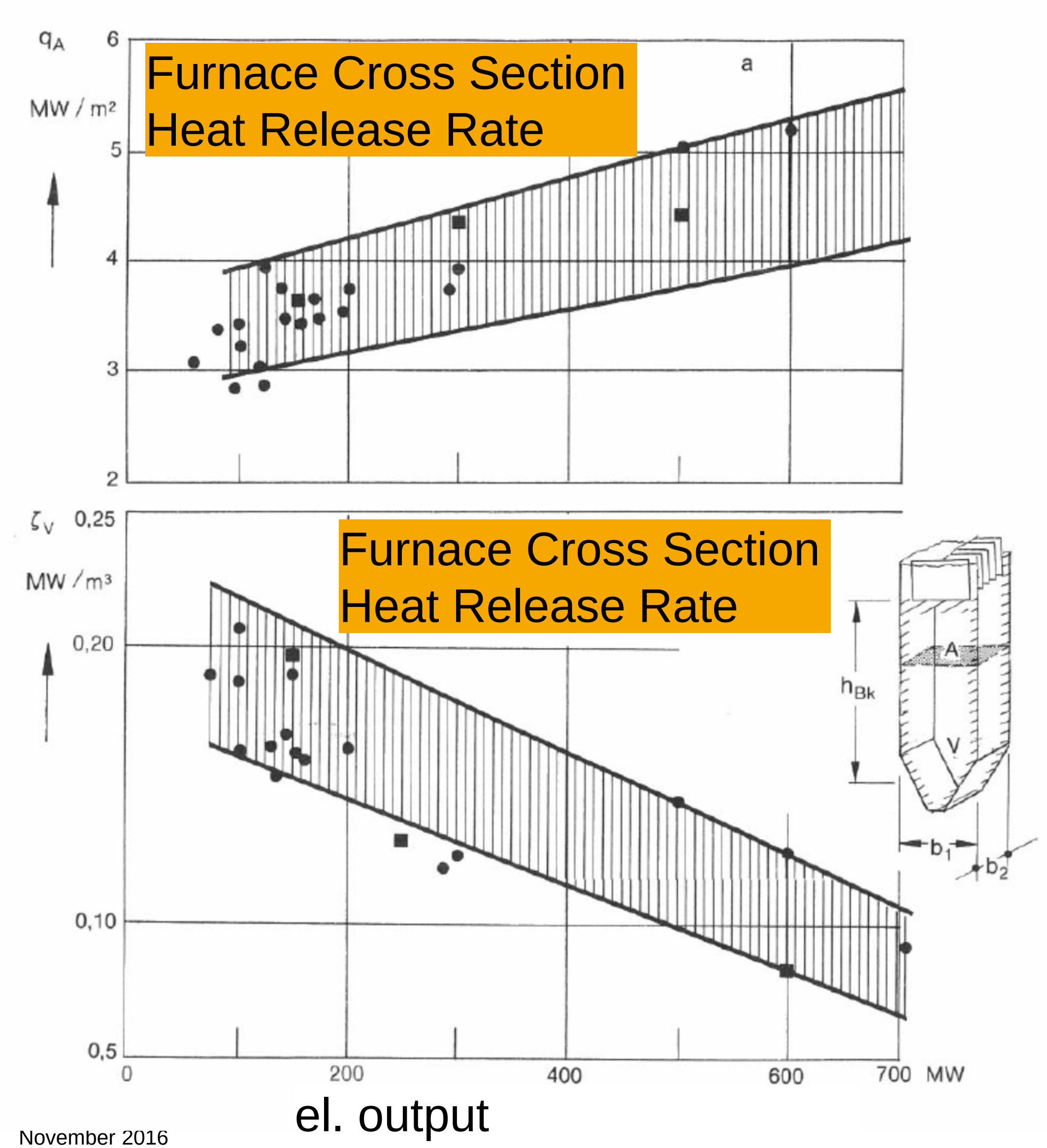


Coal parameters are influencing the combustion behavior
Propagation velocity of coal flame



	a	b	c	d	e	f
Volatiles in%	30	30	30	20	30	15
Ash in %	5	15	30	5	40	5

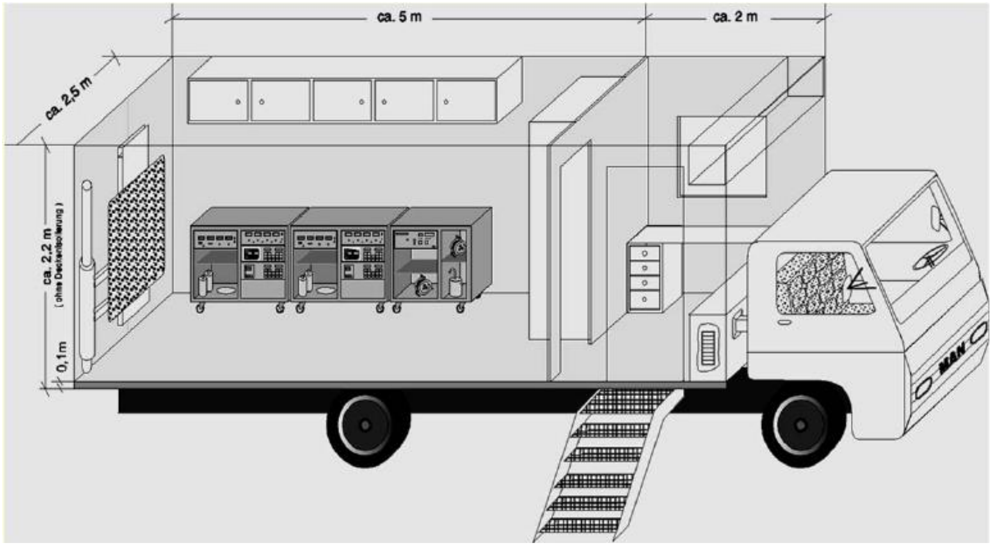
Furnace Cross Section Heat Release Rate in MW/m²
Furnace Volume Heat Release Rate MW/m³



Source: Zelkowski

Mobile measuring vehicle

- Pulverized-coal measuring module
- Fly ash measuring module
- PC / fly ash analysing module
- Extensive gas analyzing module
- Portable gas analyzing module
- Calibration module for gas analyzers
- Temperature measuring module
- Volume flow rates measuring module
- Measuring module for turbines
- Measuring module for pumps
- Measuring module for condensers
- Measuring-value data logging and processing module



Length	8.000 m overall
width	2.500 m
height	3.200 m
gross vehicle weight	8.990 kg

Key Statements

⇒ Most important is to ensure an even distribution of coal to the individual burners

⇒ Reduction of NO_x values depending on quality of the coal blend

⇒ Air ratio between 1.15 and 1.17 is a goal for a new boiler

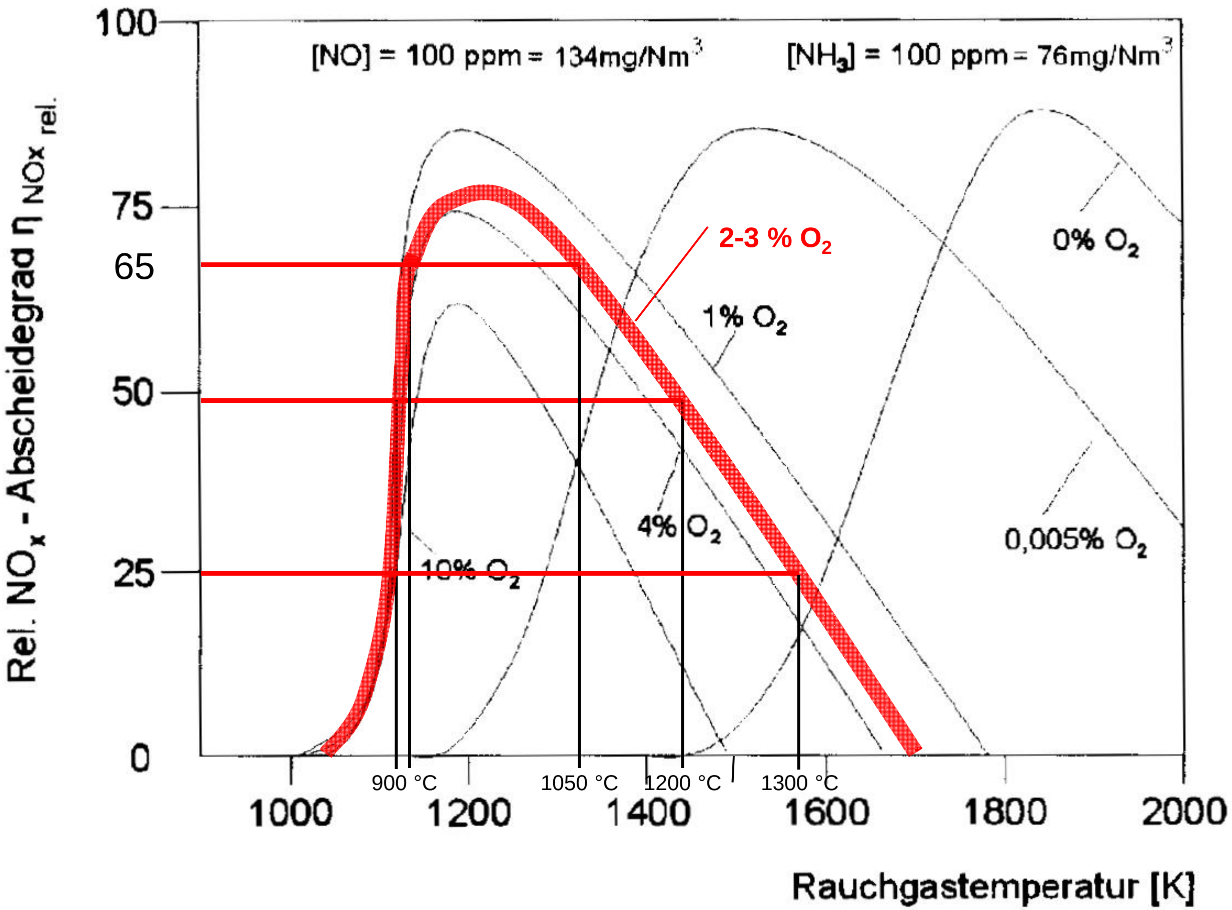
⇒ Tools to reach these goals : Balancing of the coal ducts, individual control of the air ratio of single burners, fine grinding

⇒ All of this can be a solid foundation for the use of software tools for further optimization of the entire combustion system. By software an optimization is possible but it cannot correct mistakes in design of the hardware.

Selective Non-Catalytic Reduction (SNCR) Systems

- **18 Installations**
- **Boiler types include stokers, front wall fired, roof fired, tangential fired, cyclone and opposed wall fired units**
- **Unit size from 15 to 620 MW**
- **Coal and Wood**
- **35-50% urea reagent and 19% aqueous NH_3 systems**
- **Achieve NO_x reductions in the range of 25% to 35%, with STEAG POWITECH up to 40 – 45% Turnkey Installation**
- **Current Projects:**
  - **PNM San Juan (350 & 650 MW)**
  - **Iberdrola Lada Station, Spain (350 MW)**
  - **Völklingen Power Station (195 MW)**

NOx reduction as a function of temperature and oxygen



- **NOx reduction = function of O_2**
- **Optimal temperature window between 2 – 3 % O_2 and 900 – 1050 °C**
- **Actual temperature window between 2 – 3 % O_2 and 900 – 1200 °C**

Urea	$NH_2CONH_2 + 2\ NO + ½\ O_2$	→	$2\ N_2 + CO_2 + 2\ H_2O$
	or for		
Ammonia	$4\ NH_3 + 4\ NO + O_2$	→	$4\ N_2 + 6\ H_2O$

Measures for SNCR range adjustment

Temperature measurement:

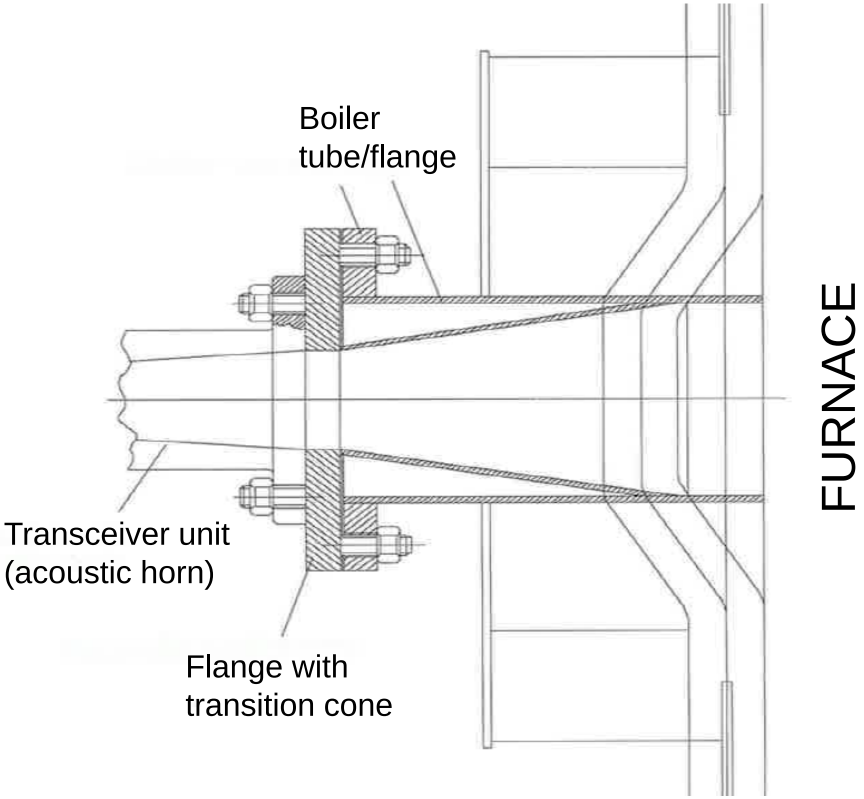
- with suction type pyrometer:
  - at different levels and depths of indentation
  - using existing ports / hatches
- with acoustic temperature measurement:
  - measurement at one level
  - preparation of boiler (see next slide)

Ammonia (urea) test injection:

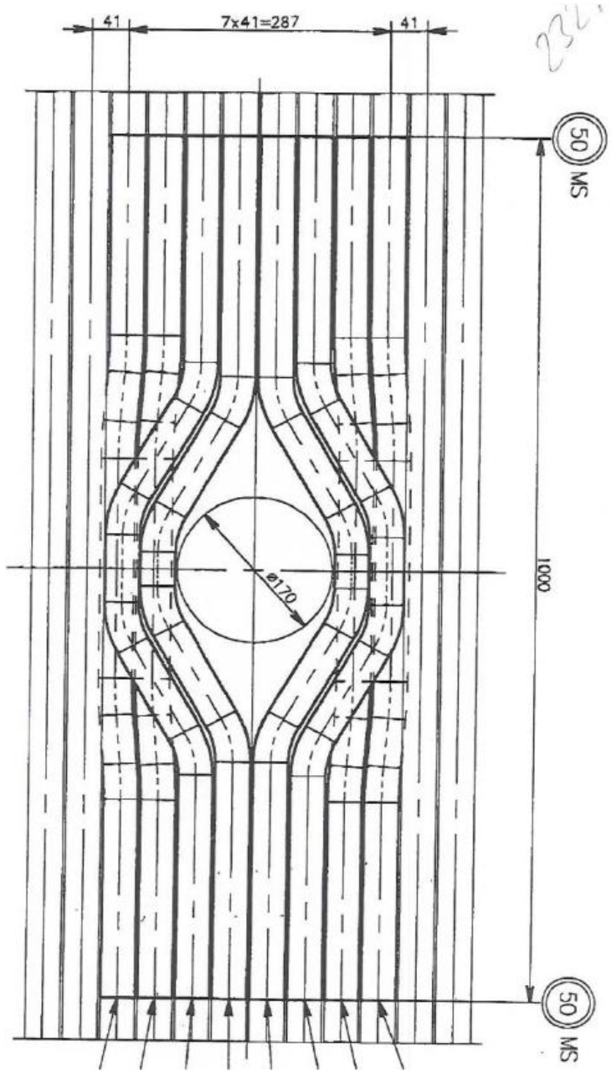
- test injection with urea solution:
  - at different boiler loads (typical load profile)
  - at different levels and with (arrangement on basis of the temperature measurements

Acoustic temperature measurement – Preparation of boiler

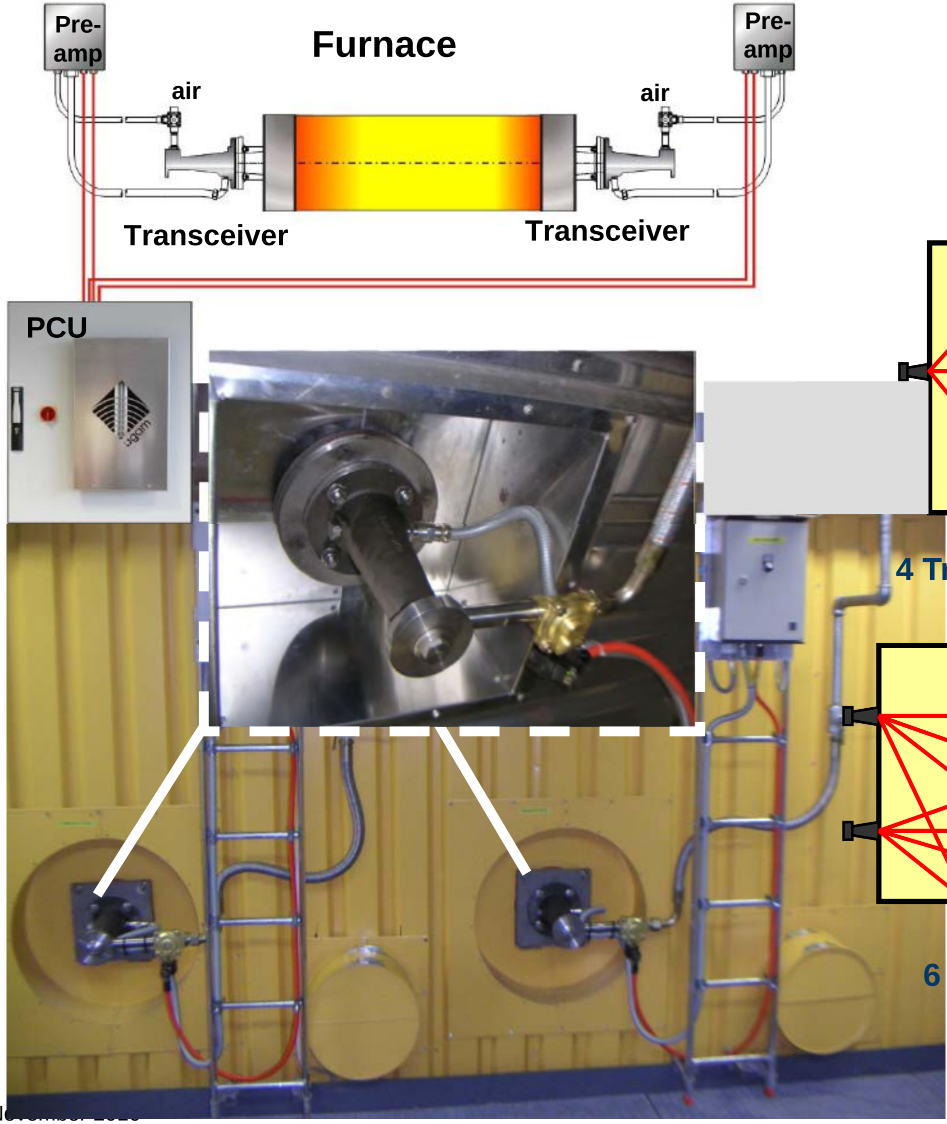
Opening for transceiver unit:



Lateral buckling in boiler wall:

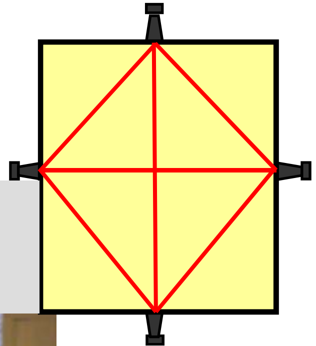


Acoustic temperature measurement – Arrangement

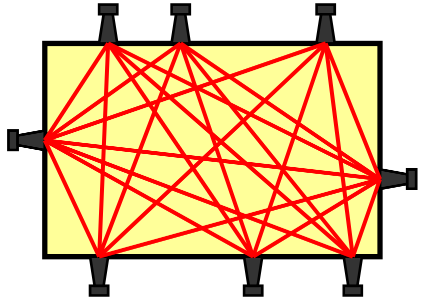


$$C = \sqrt{\frac{æ \, . \, R}{M} \, . \, T}$$

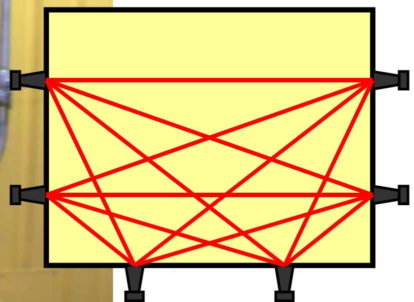
Air pressure:
80 - 120 psig
(5.5 - 8.3 bar)



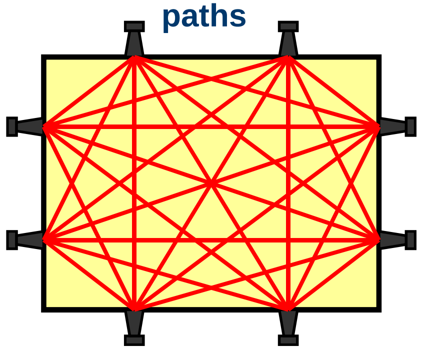
4 Transceiver, 6 paths



8 Transceiver, 21 paths



6 Transceiver, 12 paths



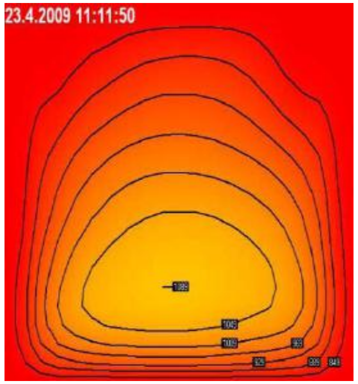
8 Transceiver, 24 paths

Source: Bonnenberg & Drescher

Acoustic temperature measurement –
Temperature profiles at 195 MW Power Station

65 MW with Mills 1+2

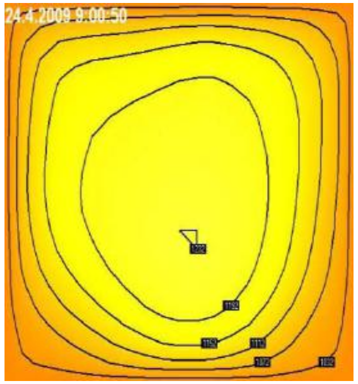
80 MW with Mills 3 + 4



82 MW with Mills 2+3

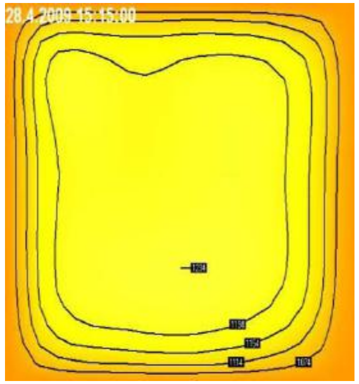
85 MW with Mills 1+2

121 MW with Mills 1,2 and 3



130 MW with Mills 1 to 4

160 MW with Mills 1 to 4



185 MW mit with Mills 1 to 4

Source: Bonnenberg & Drescher

Acoustic temperature measurement – Equipment

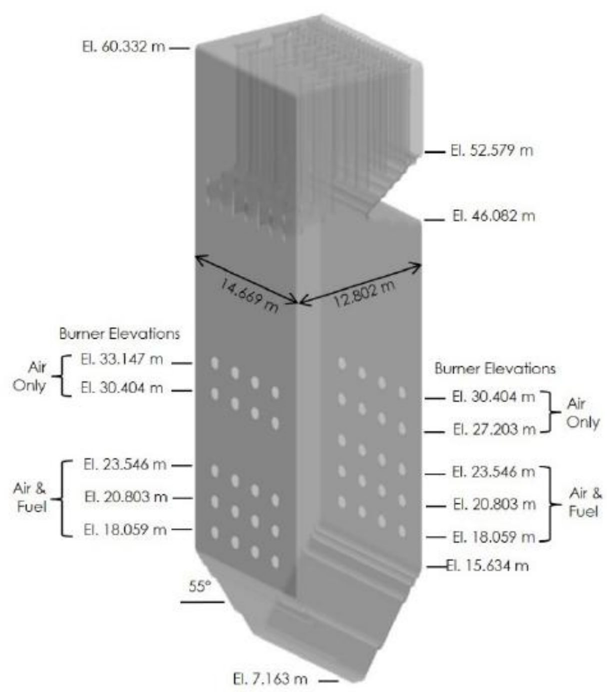
Transceiver unit

Transition cone

Source: Bonnenberg & Drescher

Iberdrola Lada Station
SNCR Project

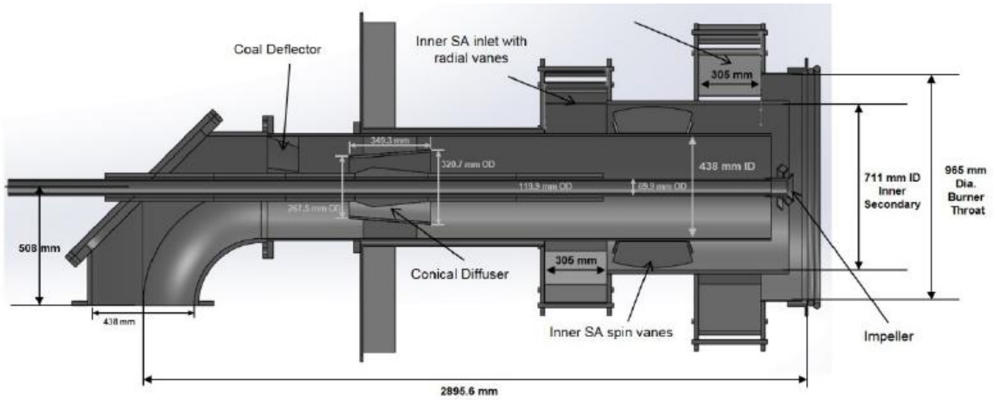
- **Unit Particulars:**
  - **Opposed fired unit with 2 levels of OFA**
  - **Full load 360 MW**
  - **B&W DRB Burners (early generation)**
- **Partnership between EPC company**

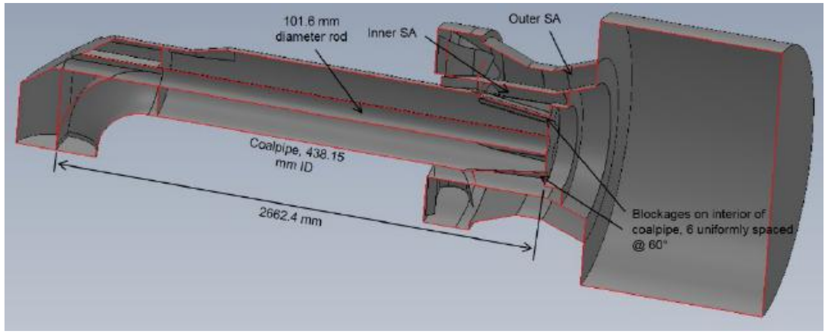


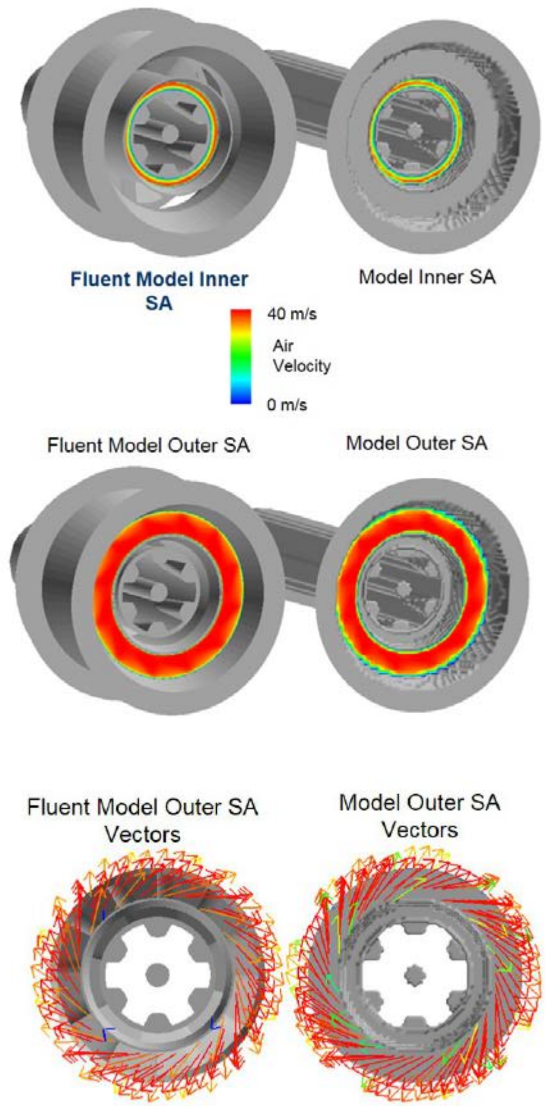
- **Project Scope**

	STEAG SCR-Tech	INERCO
• Urea Storage System	All Process Design & Assistance in Purchasing	All Supply and A&E System
• SNCR Zone	All Process Design, Equipment Design & Purchasing Assistance	All equipment Supply
• Burner Design		Design and Supply
• CFD Modeling	All Modeling, Burner through Boiler	
• BOP		Design and Supply

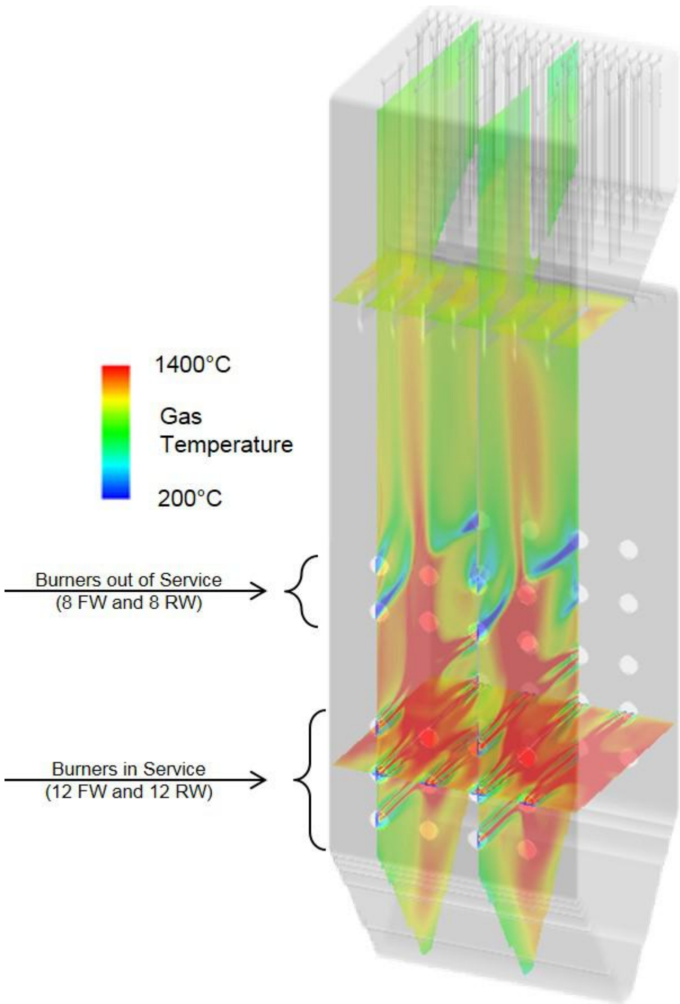
Iberdrola Lada Station
SNCR Project

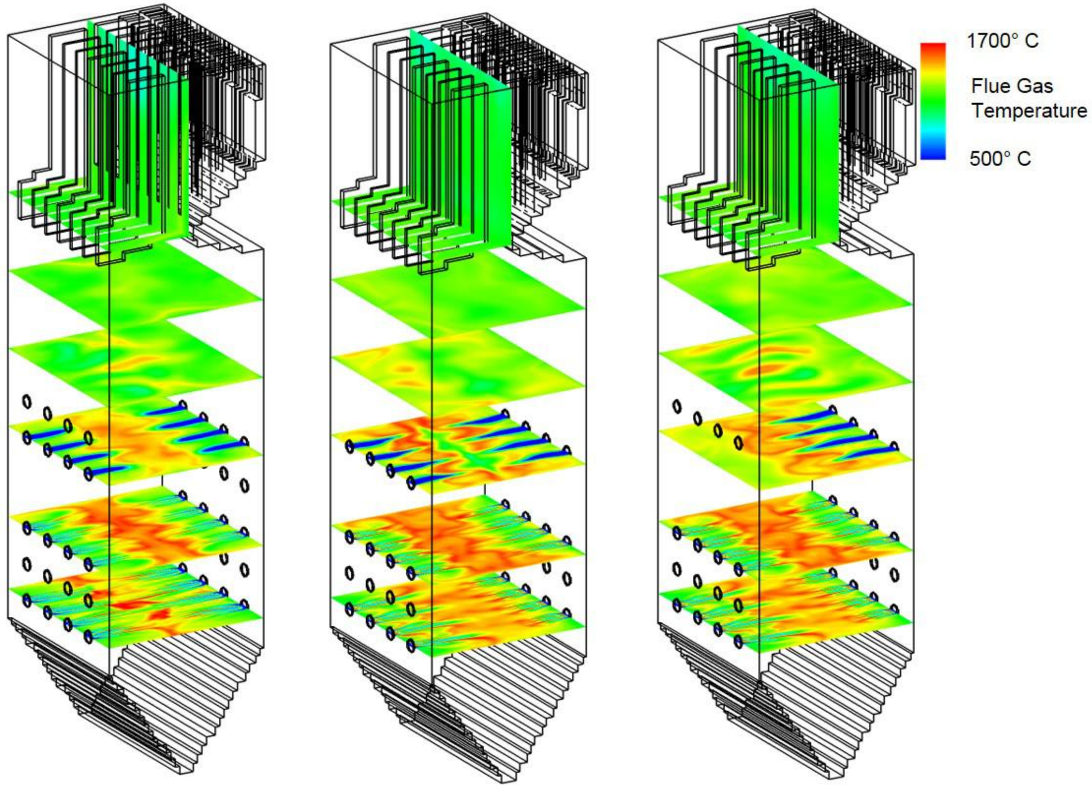




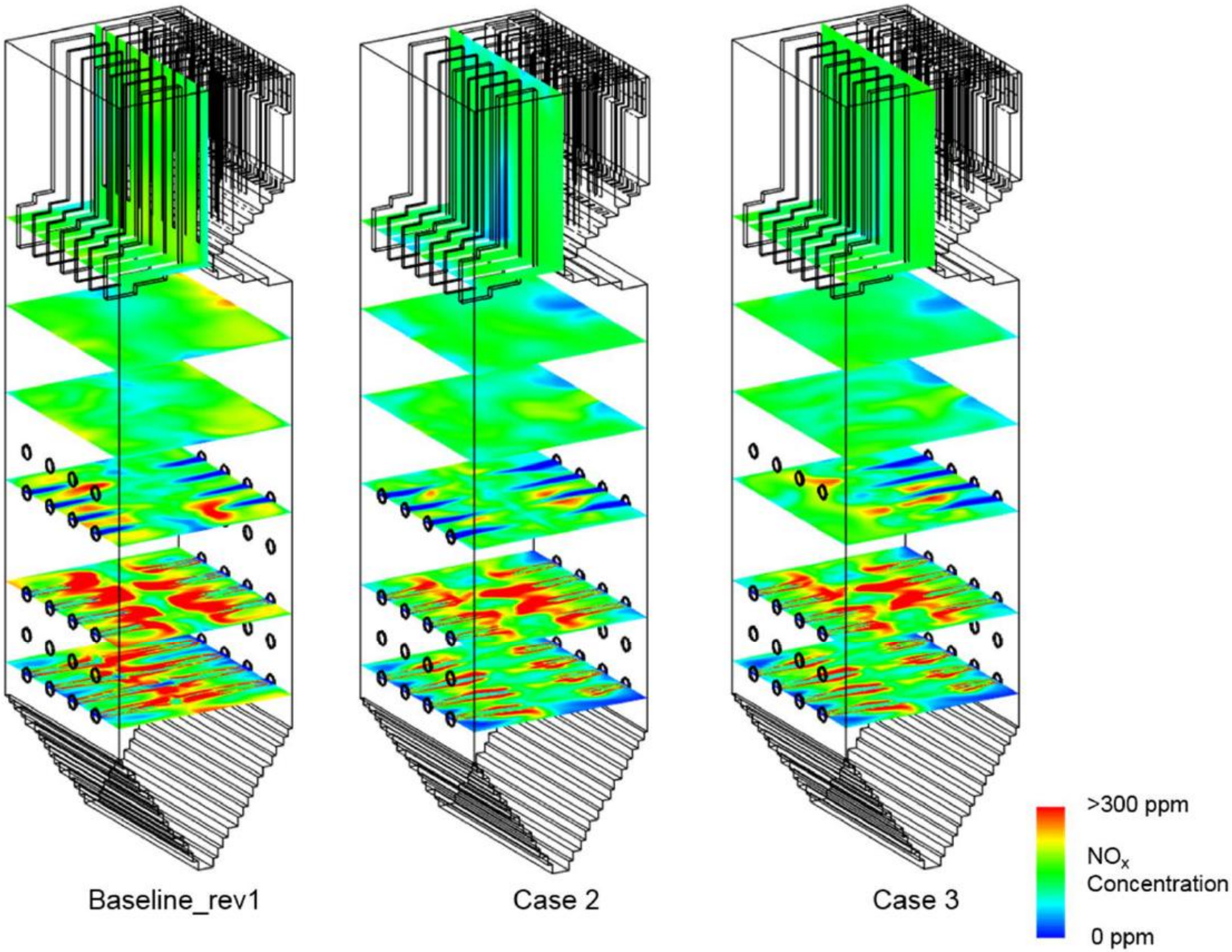


Iberdrola Lada Station
Temperature

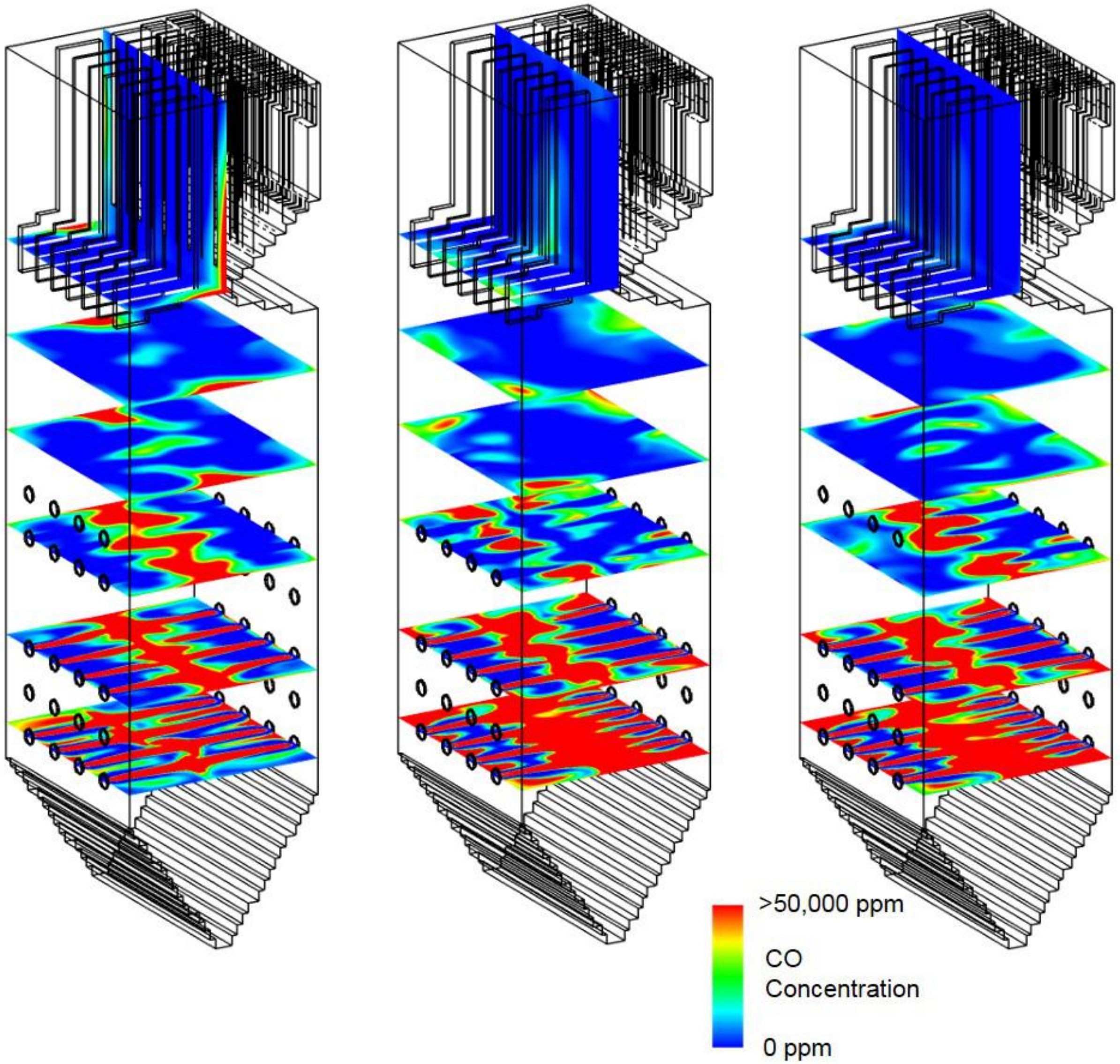




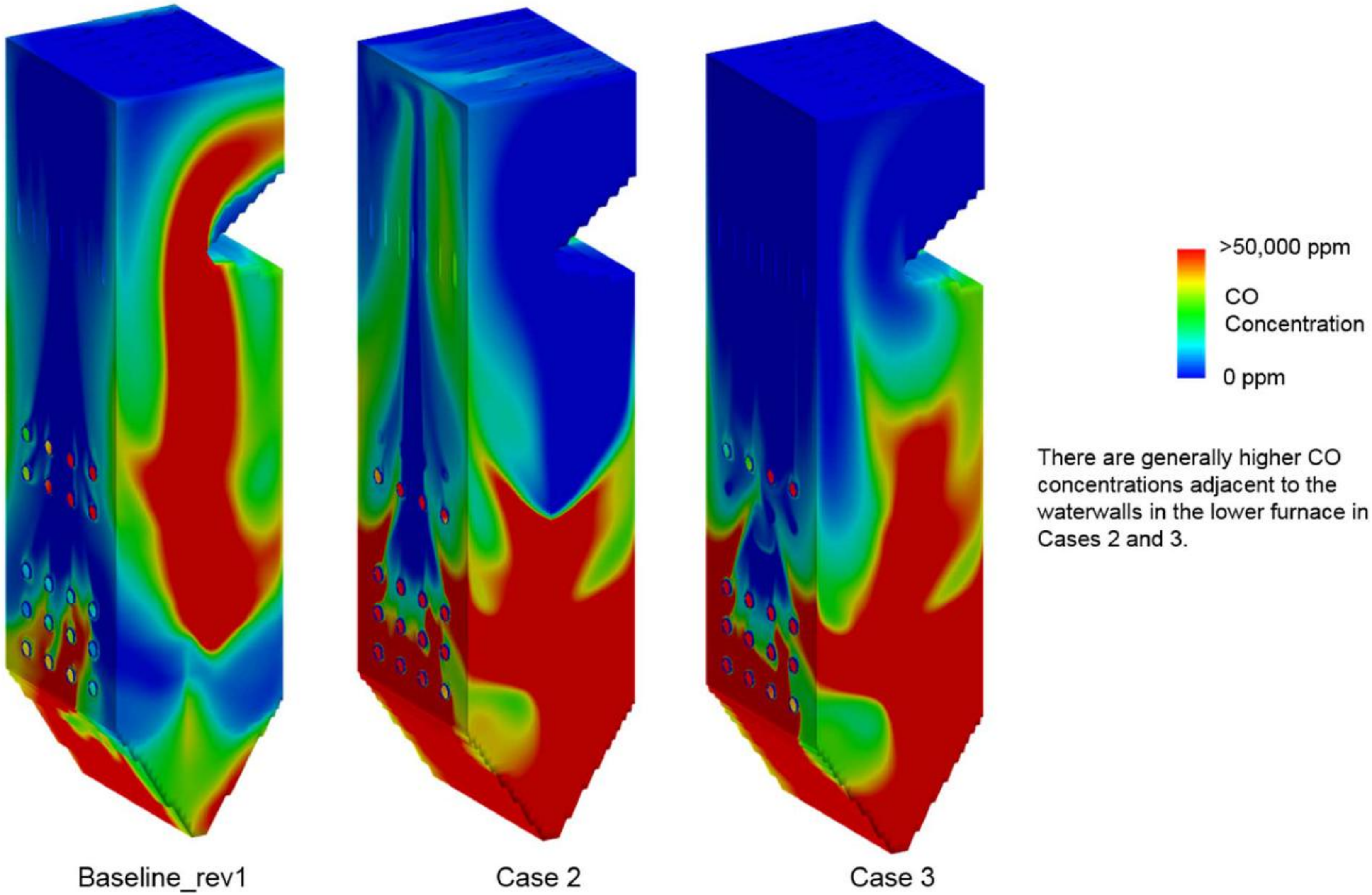
Iberdrola Lada Station
NO_X Profiling



Iberdrola Lada Station
CO Profiling

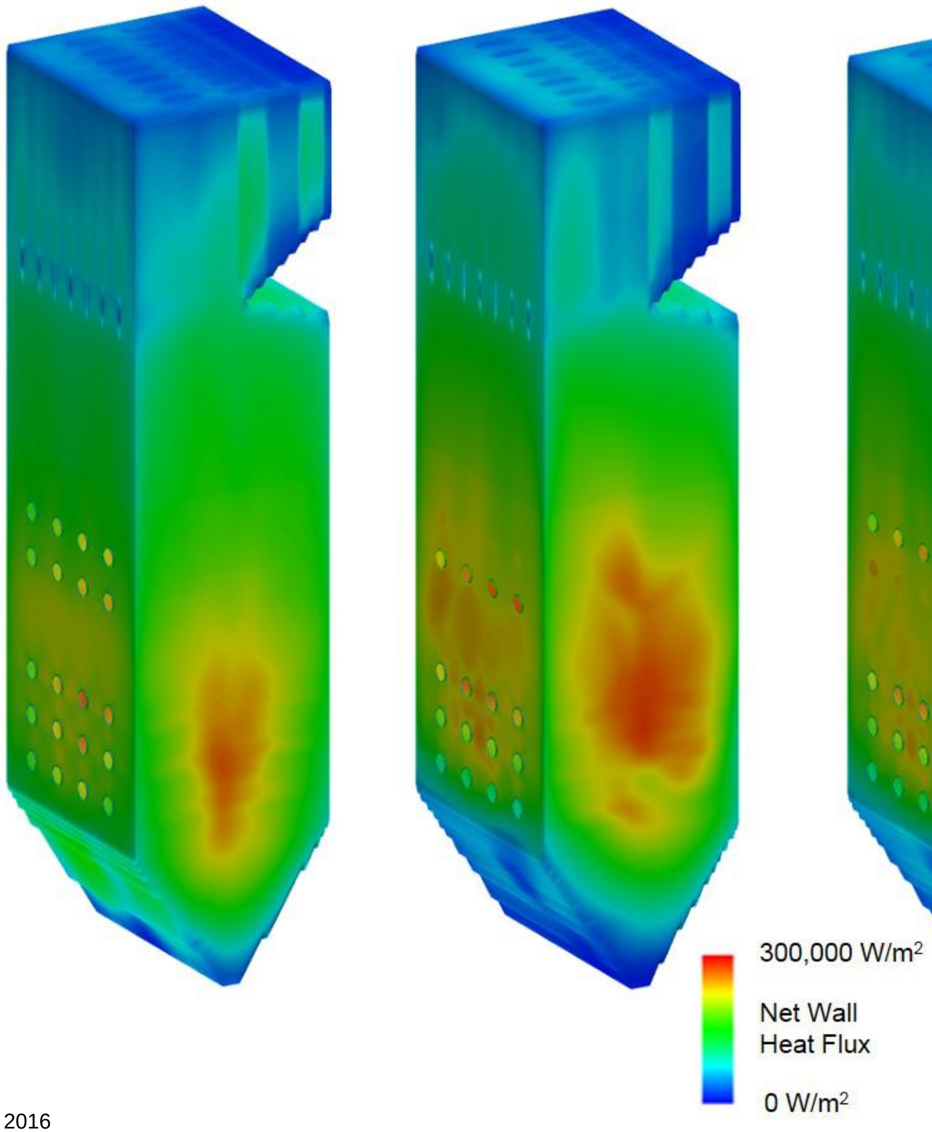


Iberdrola Lada Station
CO Profiling



There are generally higher CO concentrations adjacent to the waterwalls in the lower furnace in Cases 2 and 3.

Iberdrola Lada Station
Heat Flux



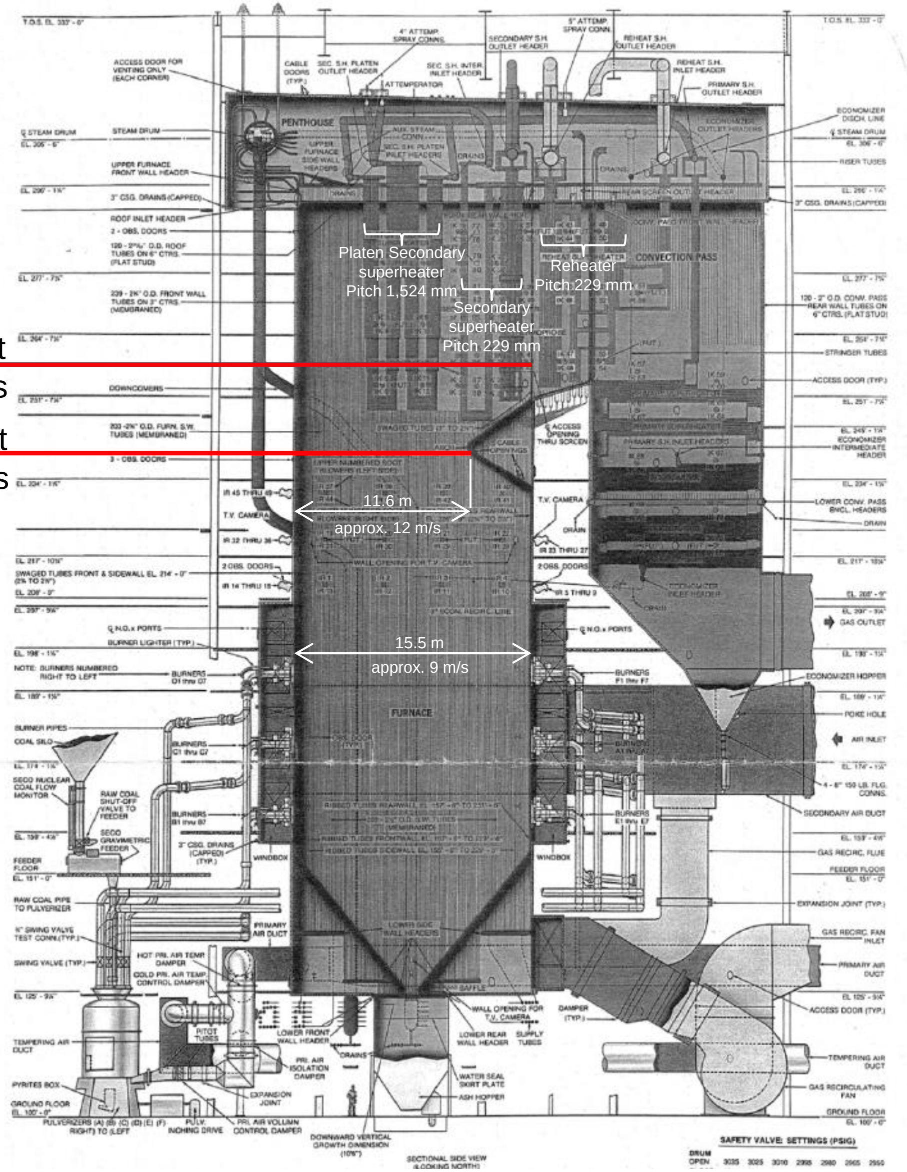
PNM – San Juan Station

- **San Juan Station Units 1 & 4**
  - **San Juan Unit 1 - 360 MW's**
  - **San Juan Unit 4 – 550 MW's**
- **Performed a Demonstration Test with Urea**
- **SNCR System**
  - **Urea Storage**
    - Single Storage for both Units
    - Wet or Dry supply
    - Solutionizing System (converting dry urea to wet)
  - **Urea Circulation System**
  - **Water Boost System**
  - **Chemical Hardness System**
  - **Urea Injection System**
    - 3 elevations with 6 injectors each (Unit 1)
    - 2 elevation with 10 injectors each (Unit 4)

SNCR plant on San Juan PP Unit 4

+ 258 feet
10 x Injection points

+ 238 feet
10 x Injection points

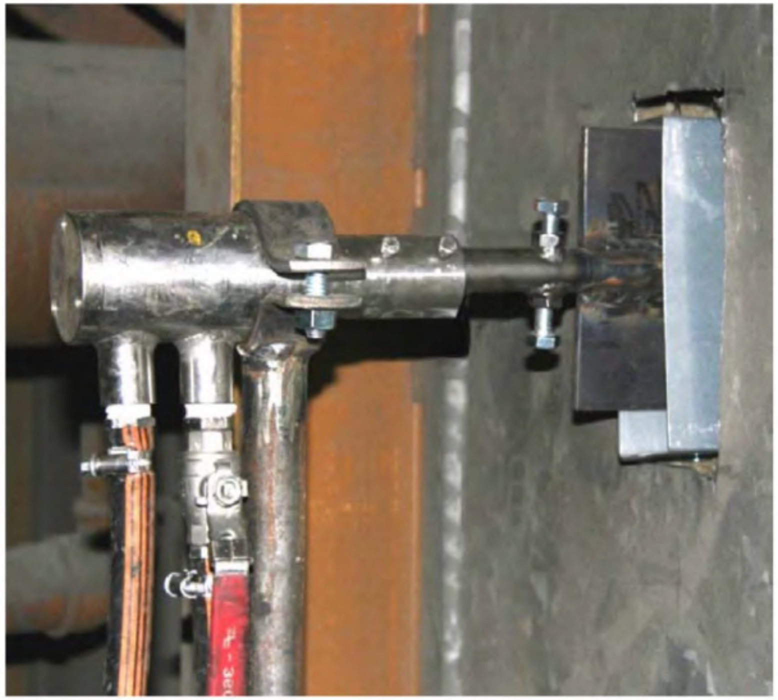


- **Two path boiler**
- **550 MW**
- **Boiler cross section 15.5 m x 18.3 m**

Ammonia (urea) test injection

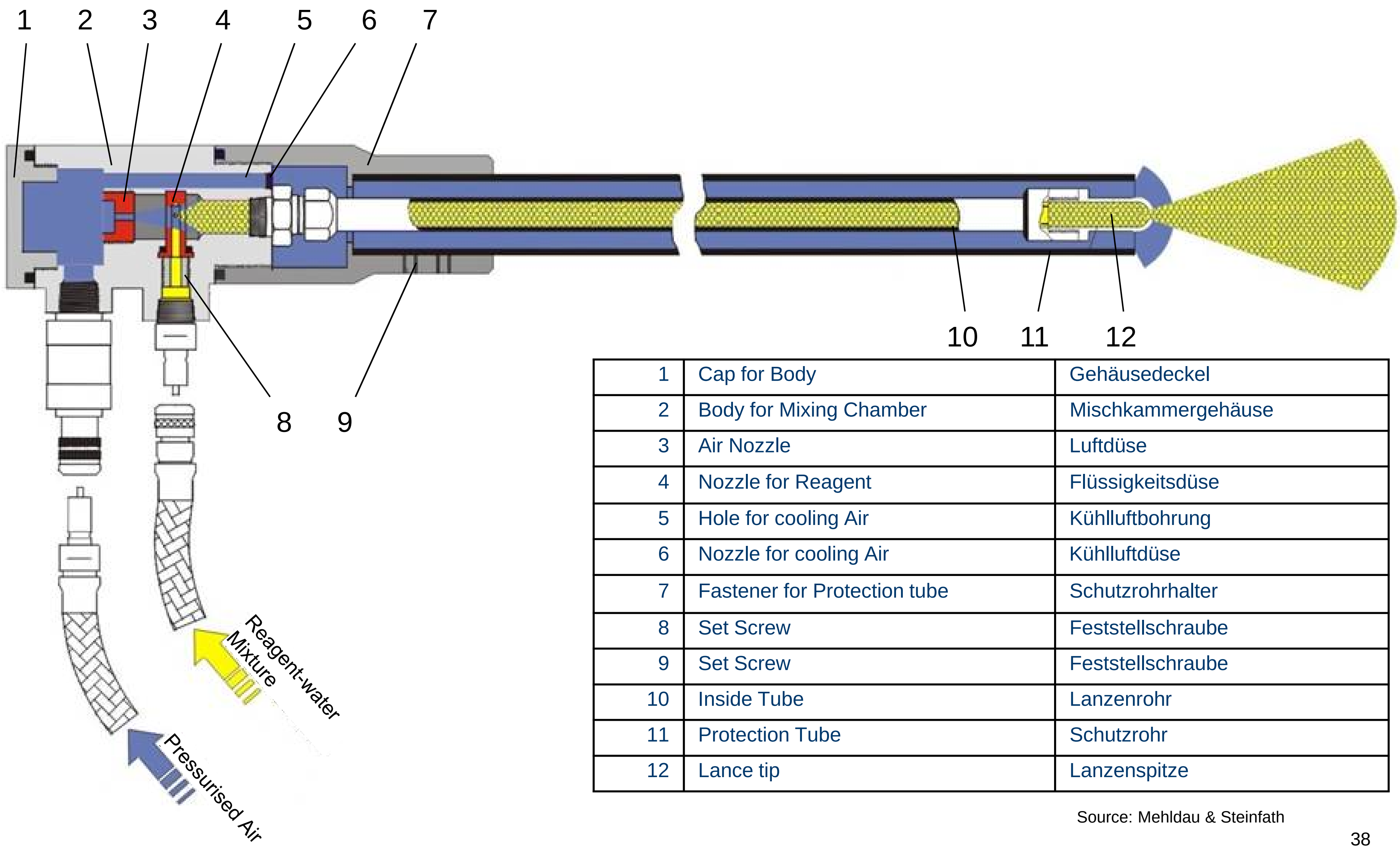
Testing plant with:

- metering and mixing module
- pumping module
- storage container for urea solution and
- temporary installation of injector



Source: Mehldau & Steinfath

General SNCR process basics – Injection lance

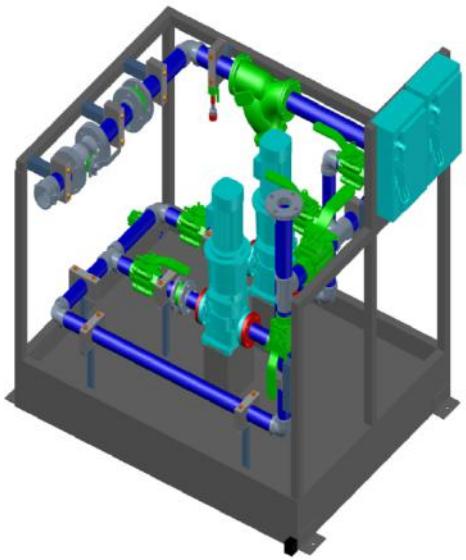


1	Cap for Body	Gehäusedeckel
2	Body for Mixing Chamber	Mischkammergehäuse
3	Air Nozzle	Luftdüse
4	Nozzle for Reagent	Flüssigkeitsdüse
5	Hole for cooling Air	Kühlluftbohrung
6	Nozzle for cooling Air	Kühlluftdüse
7	Fastener for Protection tube	Schutzrohrhalter
8	Set Screw	Feststellschraube
9	Set Screw	Feststellschraube
10	Inside Tube	Lanzenrohr
11	Protection Tube	Schutzrohr
12	Lance tip	Lanzenspitze

Source: Mehldau & Steinfath

STEAG's Ammonia Systems

- STEAG's experience brought to the US in the early 1990's.
- Have designed the Ammonia Systems many US utilities.
- Have O&M of systems since the mid-1980's.
- Full Scope, EPC capabilities.
- Aqueous or Anhydrous ammonia
- Design of both pressurized and atmospheric systems



PNM San Juan Station

Urea Storage / Solutionizing System

Dilution Water

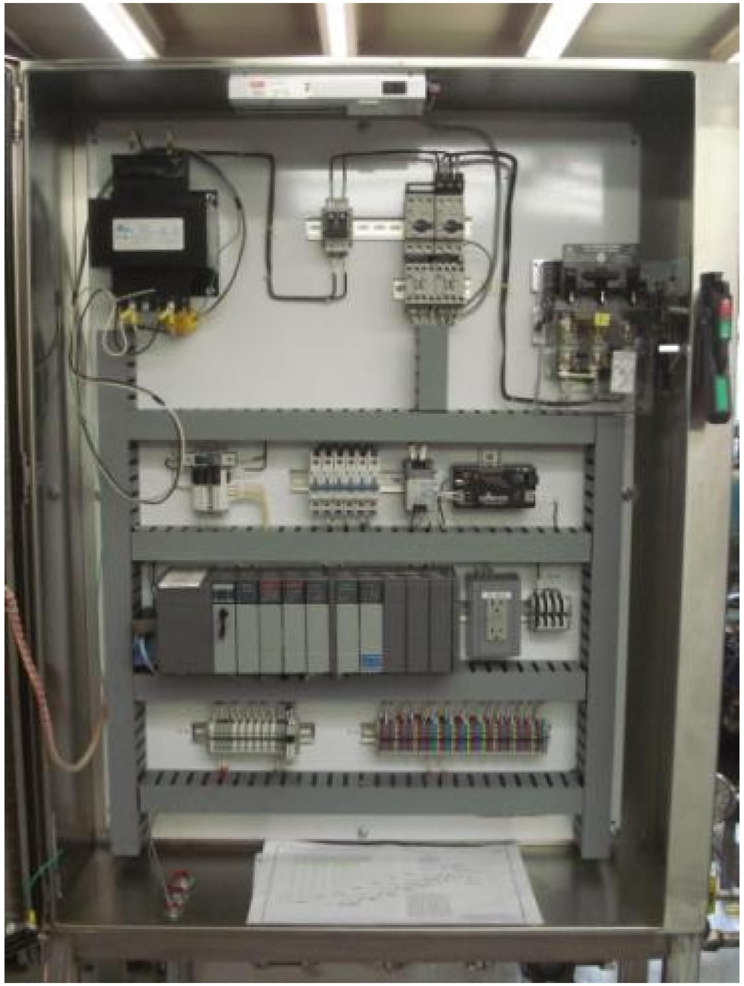
PNM – San Juan Station

SNCR Injectors

Chemical Mixing Skids (2 units)

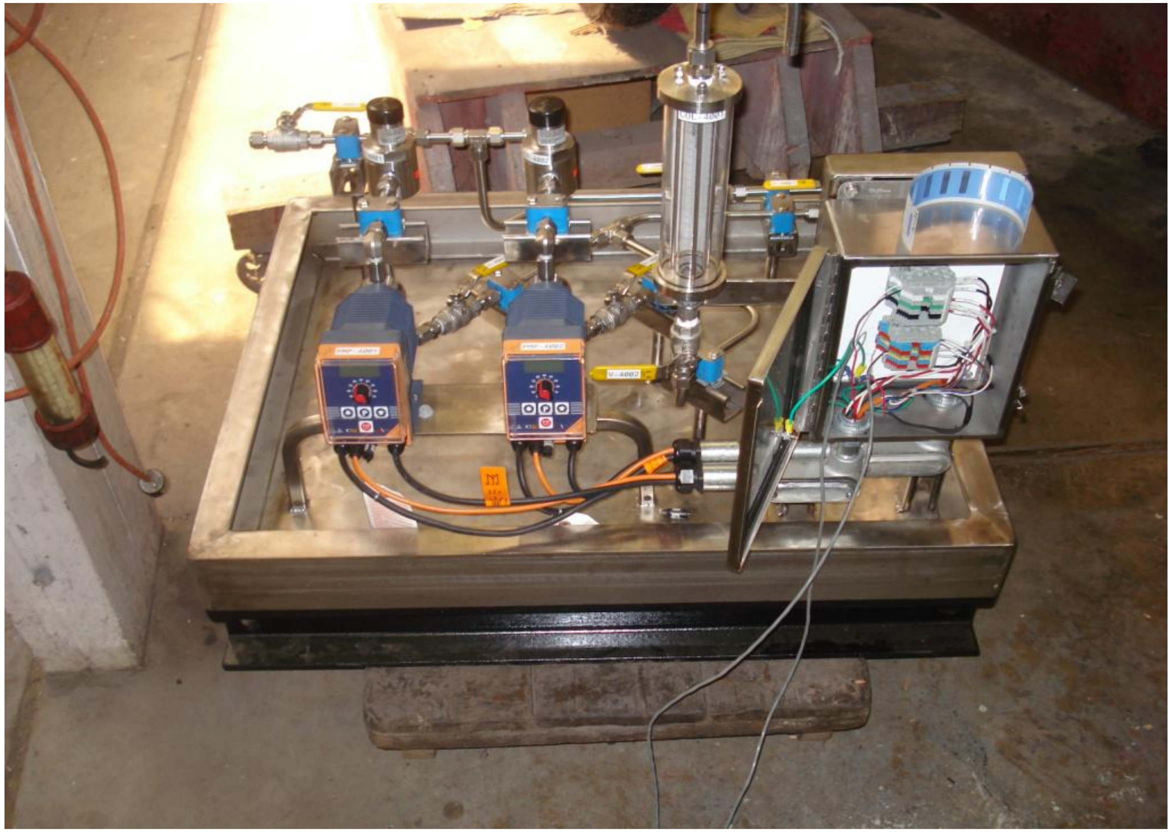
PNM San Juan Station

Local DCS Indication Panel



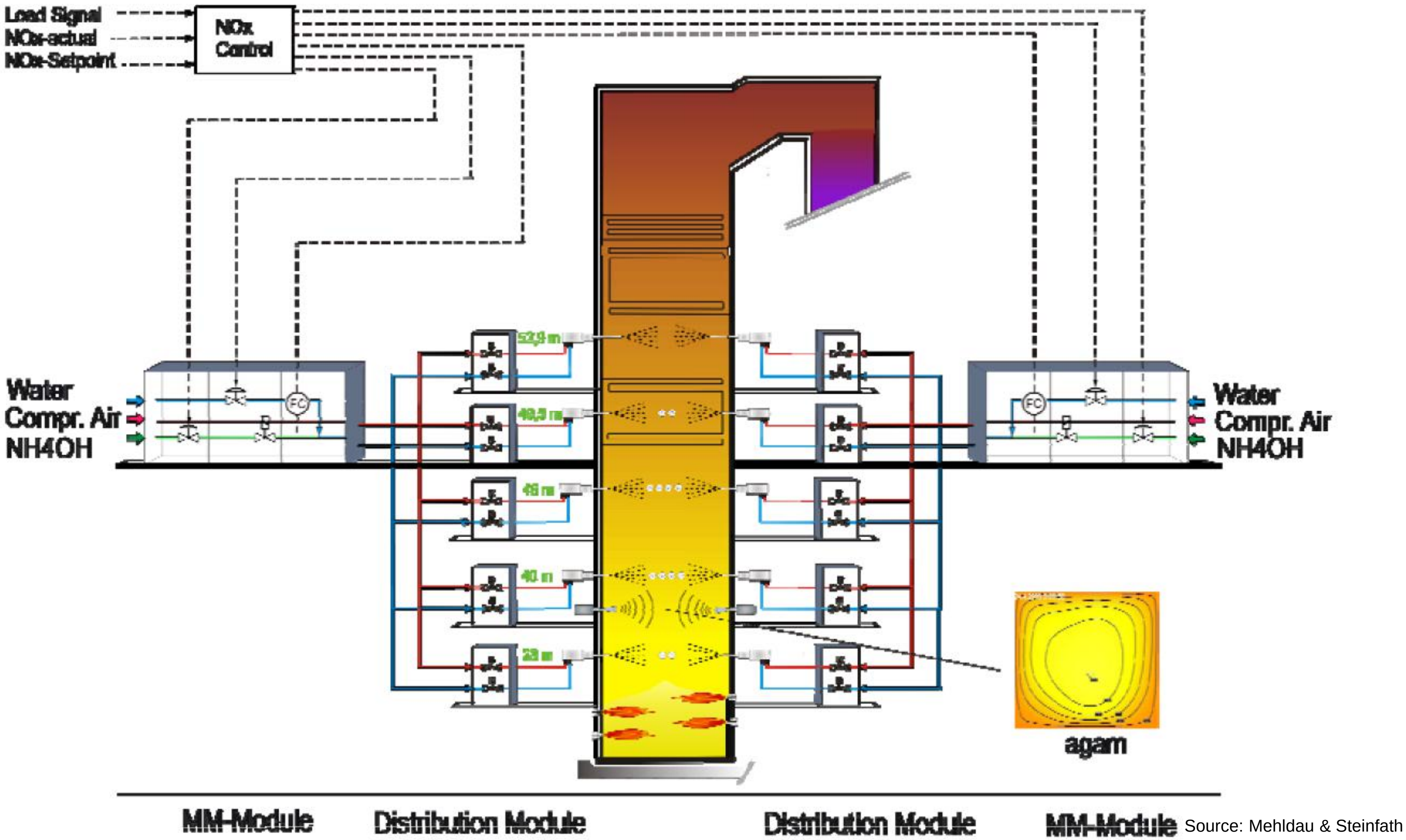
Sample PLC Based System

PNM San Juan



Chemical Hardness Skid

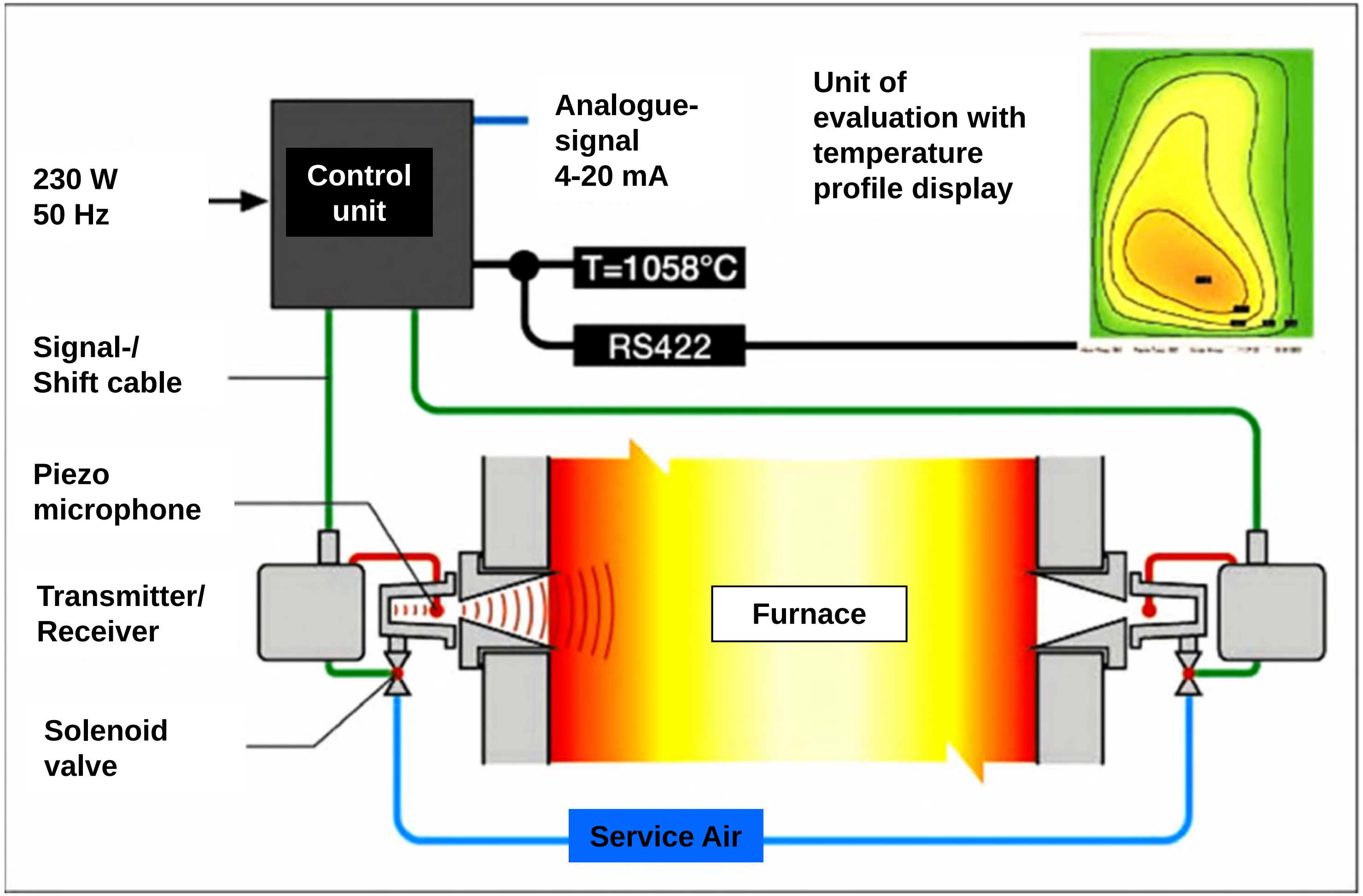
MKV Fenne –
General process flow



Source: Mehldau & Steinfath

Acoustic temperature measurement – control

Principal Design of an acoustic Gas temperature measurement system agam



Source: Bonnenberg & Drescher

General comparison of SCR and SNCR

SCR	SNCR

▪ NOx removal efficiency > 80%
▪ NH_3-Slip < 3 mg/Nm^3
▪ Additional fan capacity due to pressure loss at the catalyst, mixing, heat transfer system, flue gas ducts
▪ Additional energy input for the heating of the flue gas (only with Tail-end SCR)
▪ SO_3 react at low temperature cat. to Ammonium-bi-sulfate:
    ▪ Increasing of the pressure loss due to deposits
    ▪ Corrosion by Ammonium-bi-sulfate
    ▪ Negative impact on availability
▪ Investment cost (app. 5-10 times higher as for SNCR)
▪ High operation costs
▪ High maintenance costs (fan, heat transfer system, Cat.-Regeneration/exchange)
▪ Negative impact on the availability of the complete plant
	▪ NOx removal efficiency max. 40-50%
	▪ NH_3-Slip < 20 mg/Nm^3
	▪ higher reducing agents supply
	▪ Sometimes pollution of the fly ash or the by-product of the flue gas cleaning with ammonia
	▪ Lower susceptible to faults because operating critical components are redundant implemented
	▪ Low Investment- and operation costs
	▪ Nearly no expense for maintenance

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