

REINHOLD ENVIRONMENTAL Ltd.



# **2017 NO<sub>x</sub>-Combustion-CCR Round Table Presentation**

February 27 & 28, 2017, in Cleveland, OH / Hosted by FirstEnergy

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# 2017 NO<sub>x</sub>-Combustion-CCR Round Table

Feb 27-28, 2017  
Cleveland, Ohio

## SNCR Retrofits for Cost-Efficient NO<sub>x</sub>-Control – International Case Studies and Experiences

Dr.-Ing. Wolfgang Schüttenhelm, ERC Emissions-Reduzierungs-Concepte GmbH, Germany

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- **Matra Power Plant, Hungary**

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- **Yangcheng Power Plant, China**

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# ERC Emissions-Reduzierungs-Concepte GmbH



**Headquarters: Buchholz i. d. Nordheide / Germany**

**Production site Additives: Wahlstedt / Germany**

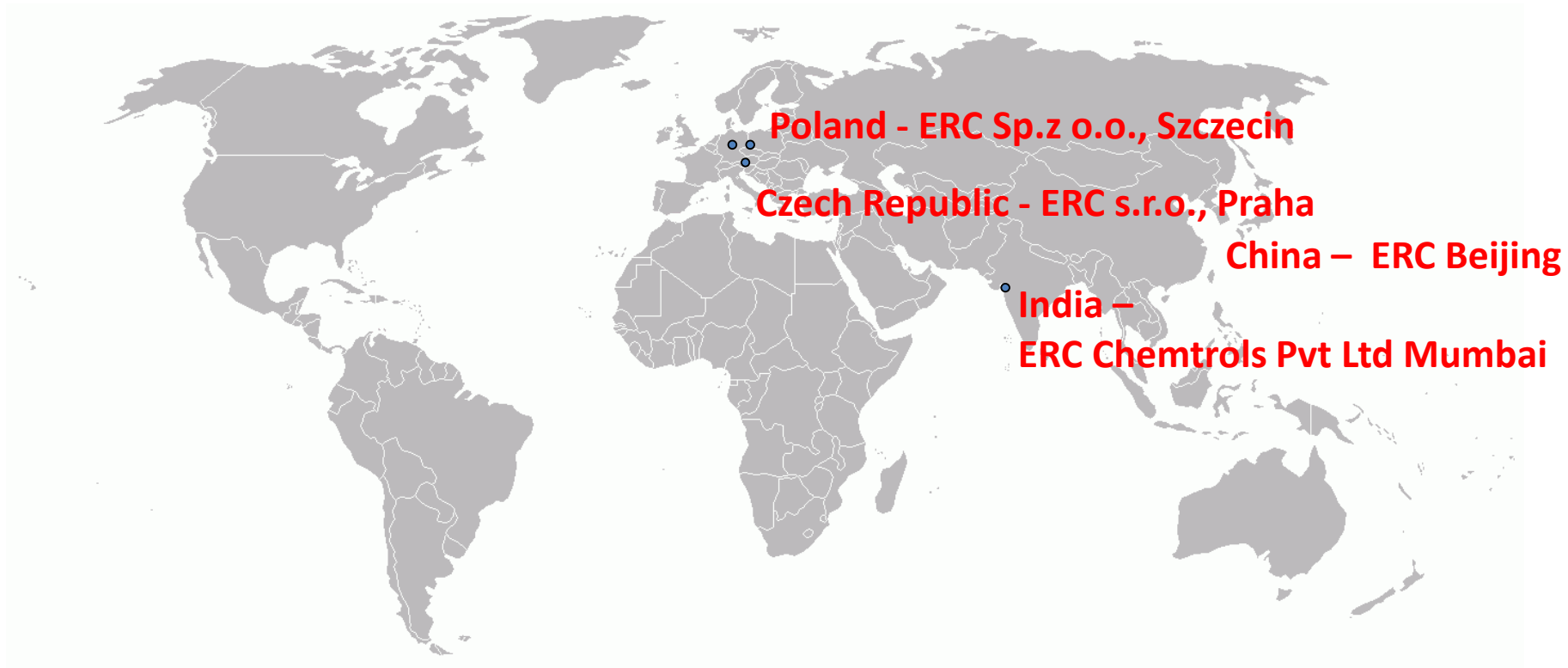
**Associated companies outside Germany: ERC s. r. o. Prague / Czech Republic**

**ERC sp. z o.o. Szczecin / Poland**

**ERC Chemtrols Ltd. / Mumbai, India**

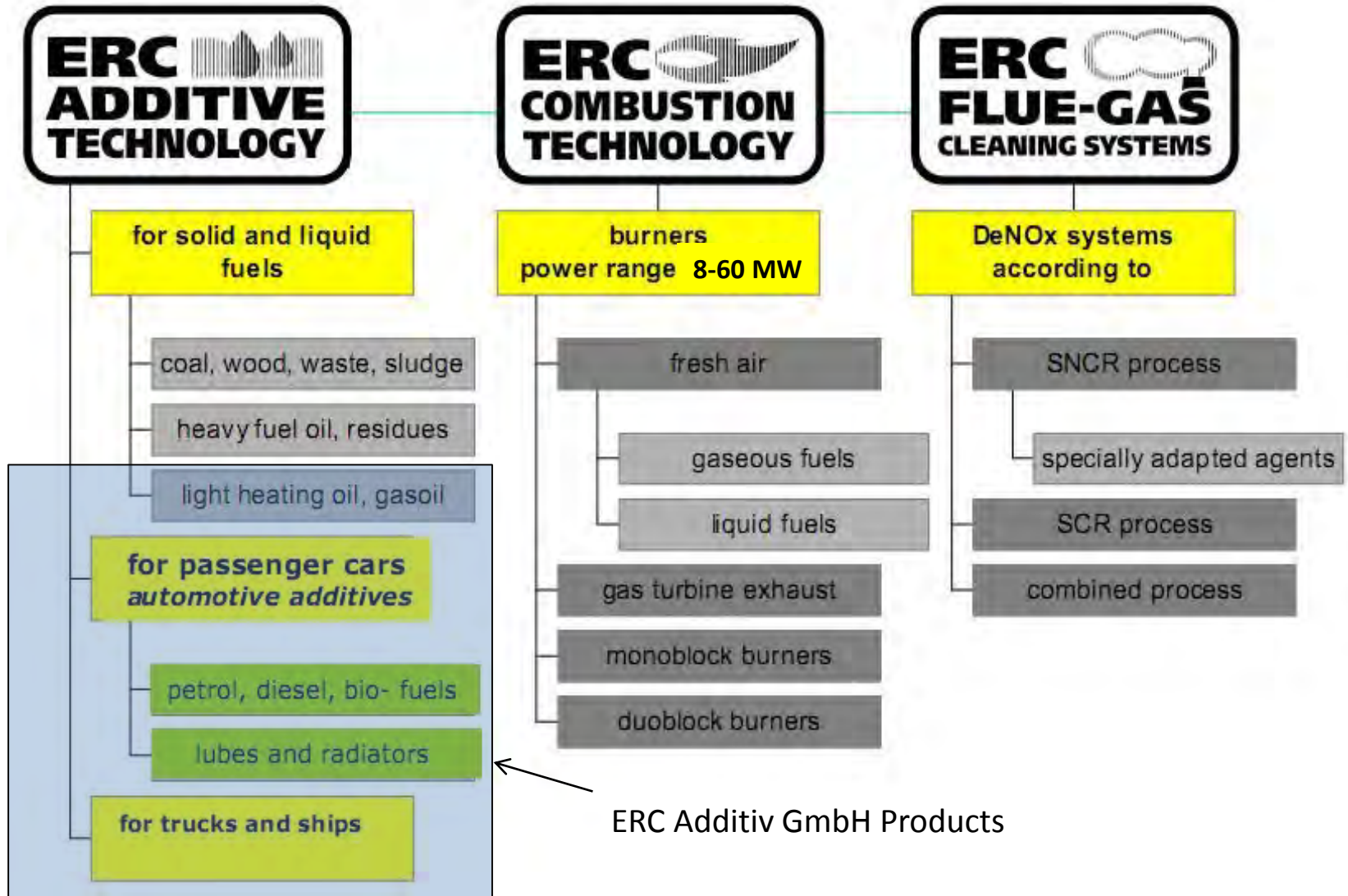
**ERC Beijing / China**

**Germany – ERC GmbH,  
ERC Technik GmbH, ERC Additiv GmbH, ERC MSR GmbH**



**References on all Continents**

# ERC Technik GmbH - Products



**NO<sub>x</sub>-Reduction for Coal-Fired  
Power Plants**



**Waste and Biomass  
Incineration**



Waste-to-Energy Facility Magdeburg, Germany

**NO<sub>x</sub>-Reduction for  
Cement Plants**



SNCR Reference Holcim Dotternhausen

# 1. Introduction

## Driving Forces promoting SNCR in Europe and Asia

- More stringent emission guidelines
- Age of the fleet / restricted remaining lifetime
- Policy of increasing the share of renewable energy sources
- Restricted operational time per year – large overcapacities
- Increased part load factors
- Lower CAPEX compared to SCR
- Less industrial customers requiring steam and heat (Eastern Europe)
- Decentralized heat supply
- Co-Firing of biomass or switching to biomass completely
- High-ash concentrations / erosion of catalysts

# 1. Introduction: International NO<sub>x</sub> Emission Limits for Large Combustion Plants (I)

## EC Directive 2001/80/EG

Year	Until 31.12.2015	From 01.01.2016	From 2021/22 Expected 1)
NO <sub>x</sub> limit / daily av. [mg/Nm <sup>3</sup> , dry, 6%O <sub>2</sub> ]	< 500 exist. < 200 new	< 200	< 150 bit. coal < 175 lignite
[Lb / MBtu]		< 0.13 bit. Coal < 0.15-0.22 lignite	< 0.1 bit. Coal < 0.13-0.18 lignite

1. Revision of BREF (Best Available Technologies Reference Emission Values, Sevilla Process – 4 years transition time from Summer 2017

## 13. BImSchV, Germany, May 02, 2013

Year	From 01.01.2016	From 01.01.2019	From 2021/22 Expected
NO <sub>x</sub> limit / daily av. [mg/Nm <sup>3</sup> , dry, 6%O <sub>2</sub> ]	< 200 lignite < 150 others	< 100 new (annual average)	< 150 bit. coal < 175 lignite
[Lb / MBtu]	< 0.1 bit. Coal < 0.15 lignite	< 0.065 bit. Coal < 0.08 lignite	< 0.1 bit. Coal < 0.13 lignite

# 1. Introduction: International NO<sub>x</sub> Emission Limits for Large Combustion Plants (II)

New Notification for Thermal Power Plants in India, dated December 7, 2015

Existing boilers	Start until 31.12. 2003	Start until 31.12. 2016
NO <sub>x</sub> limit / daily av. [mg/Nm <sup>3</sup> ,dry/ppm,6%O <sub>2</sub> ]	< 600	< 300
New boilers (Started-up from 01.01.2017 and those ones under construction)		
NO <sub>x</sub> limit / daily av. [mg/Nm <sup>3</sup> ,dry/ppm,6%O <sub>2</sub> ]		< 100

## Lower Emission Limits for Thermal Power Plants in China

Existing and new boilers	Start until 2016	Start from 2016 / 2017
NO <sub>x</sub> limit / daily av. [mg/Nm <sup>3</sup> ,dry/ppm,6%O <sub>2</sub> ]	< 100	< 50
[Lb / MBtu]	< 0.65 bit. coal	< 0.33 bit. coal

# Approach to meet the new EC NO<sub>x</sub> Emission Limit of 200 mg/Nm<sup>3</sup> (approx. 0.13 lb/mmBtu for bit. Coal)

- Primary Measures:**
- Optimization of mills
  - Optimization / Retrofit of burners
  - Staged Combustion
  - Overfire Air
  - Optimization of the firing control system
  - Combustion additives

**Target:** NO<sub>x</sub> Reduction to 250 - 350 mg/Nm<sup>3</sup>

## **Secondary Measures: SNCR (Selective Non Catalytic Reduction)**

**Target:** NO<sub>x</sub> Reduction to < 200 mg/Nm<sup>3</sup>

**If SNCR not applicable, apply SCR**

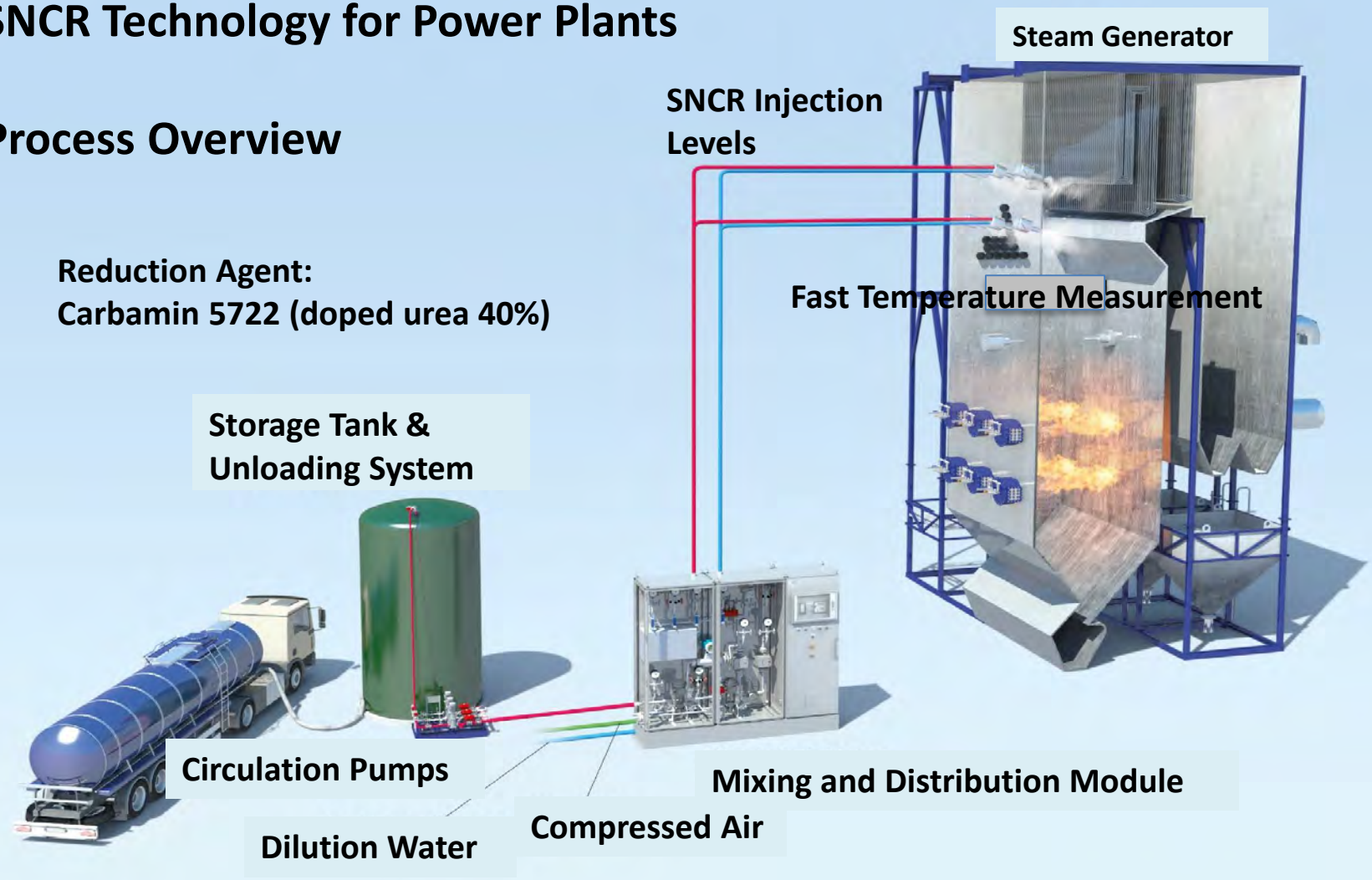
# Benefits of the SNCR-Process for Large Combustion Plants

- In combination with primary measures the new EC NO<sub>x</sub> emission limit of < 200 mg/Nm<sup>3</sup> / 0.13 lb/MMBtu can be met
- SNCR is not requiring additional space for e. g. structures, reactor and ductwork
- Pressure drop of catalyst have not to be anticipated which in many cases offsets operational cost for compressed air and increased amount of reduction agent
- No requirement of modifications of existing equipment (e. g. ductwork, ESP, fan) due to increased pressure drop
- No risk of catalyst poisoning or erosion resulting in high catalyst management cost – especially when burning lignite or biomass
- Urea based SNCR systems do not require hydrolysis systems to externally produce ammonia
- Much lower CAPEX compared to SCR

# SNCR Technology for Power Plants

## Process Overview

Reduction Agent:  
Carbamin 5722 (doped urea 40%)



# BASICS OF NO<sub>x</sub>- REDUCTION (I)

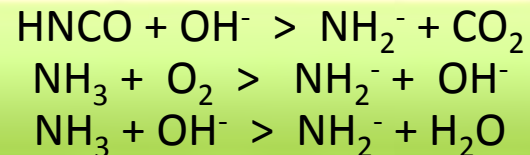
## OVERALL REACTION WITH UREA



## DECOMPOSITION



## RADICAL FORMATION



## DEGRADATIVE REACTION



# BASICS OF NO<sub>x</sub>- REDUCTION (II)

## Undesired Reactions / Parallel Reactions

### NH<sub>3</sub> Oxidation



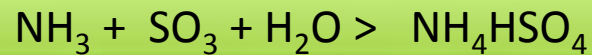
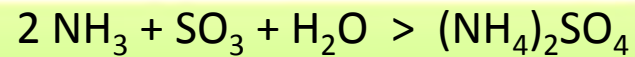
### NO<sub>x</sub>-Formation



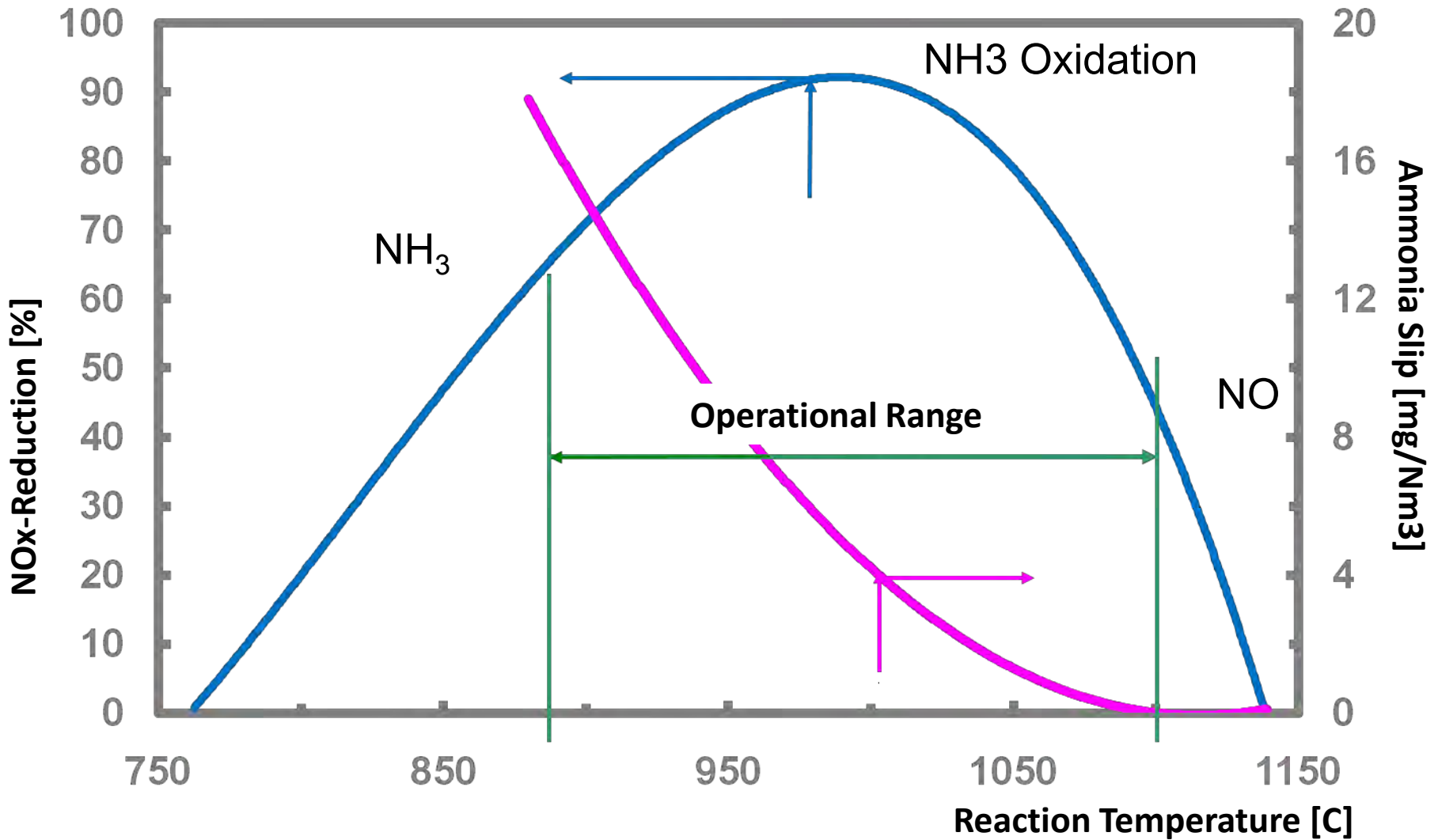
### CO Oxidation



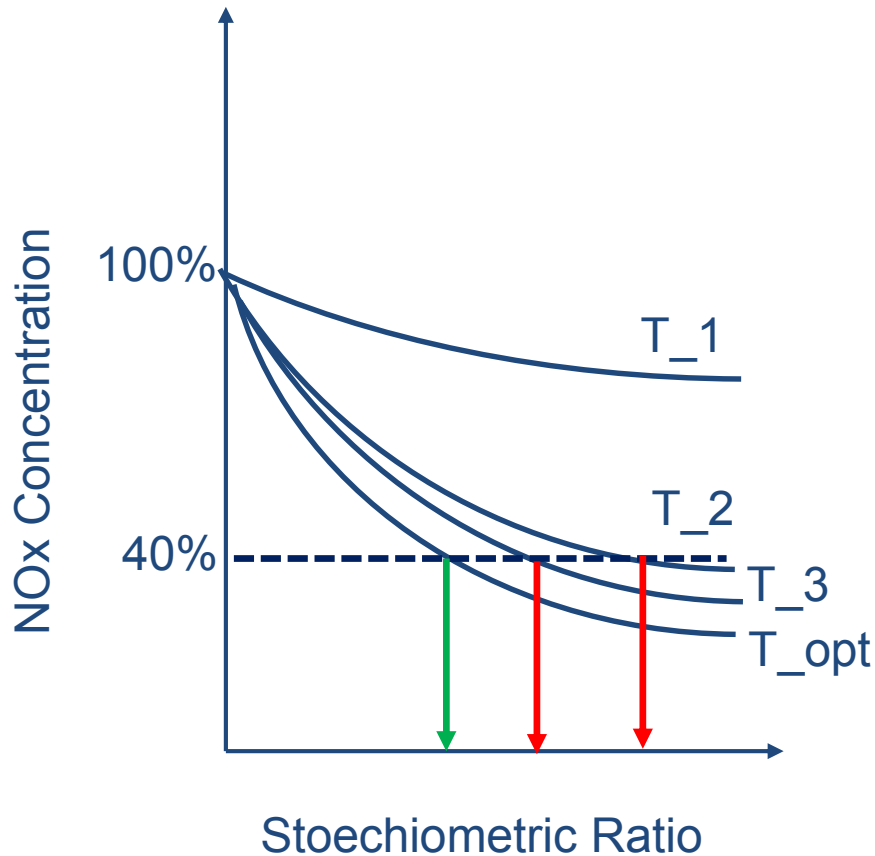
### Ammonia Sulfate & Ammonia Hydrogen Sulfate Formation



# Typical SNCR NOx Reduction versus Ammonia Slip



# SNCR Performance & Reagent Consumption



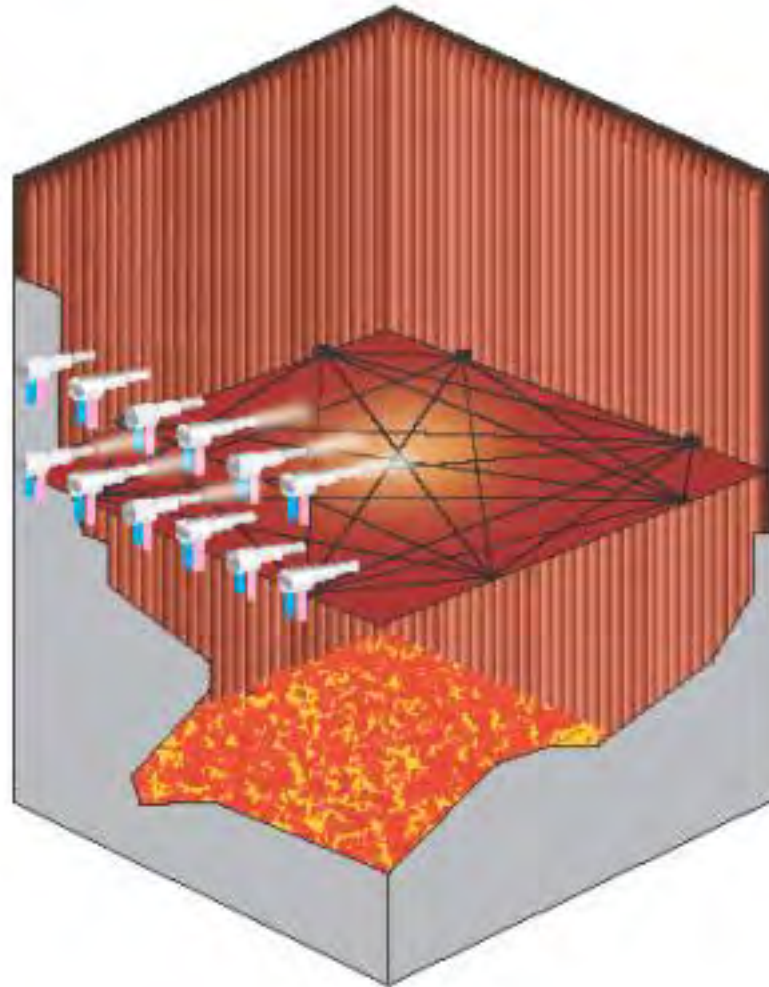
The required NO<sub>x</sub> performance and stoichiometric ratio of reduction agent to NO<sub>x</sub> depends on:

- Flue gas temperature
- Required reduction efficiency
- Permissible ammonia slip
- CO concentration
- O<sub>2</sub> concentration
- Residence time (flue gas velocity) in the SNCR temperature window
- **Precondition: appropriate design of injection points, injection lances / nozzles as well as control concept**

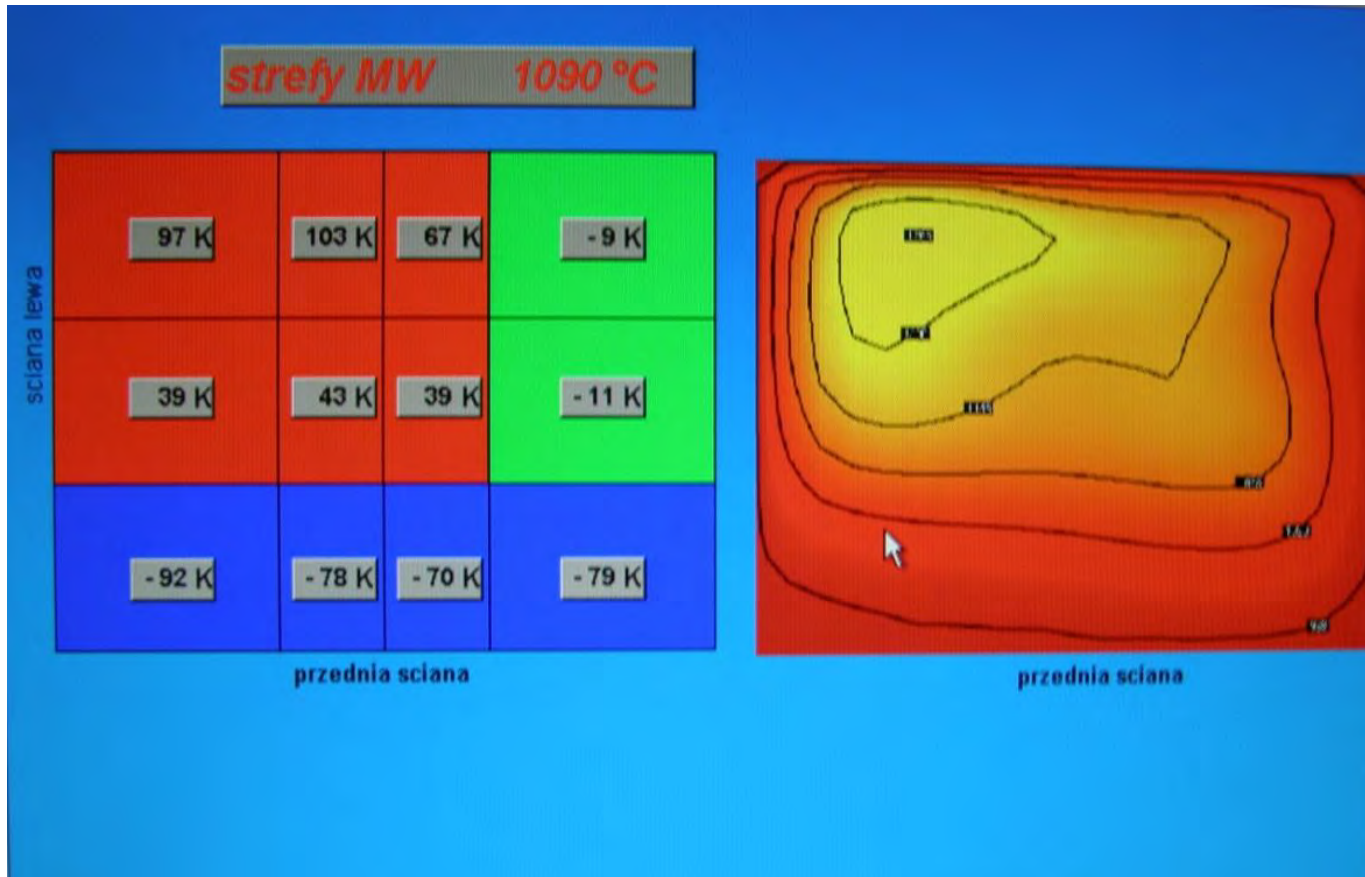
# Spray of ERC Proprietary SNCR Nozzles for Large Combustion Plants



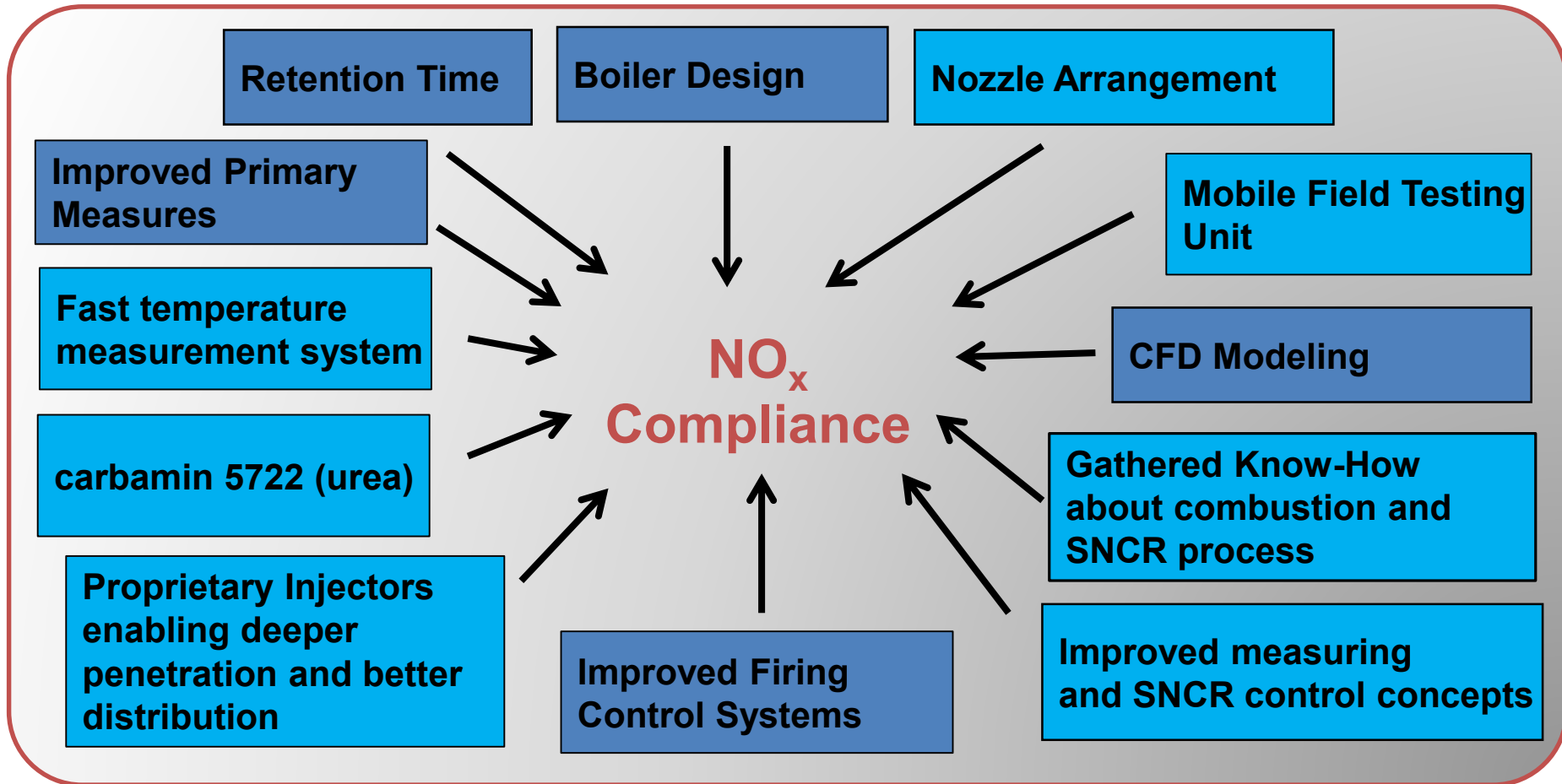
# Position of Lances and Temperature Measuring System



# Temperature Measurement and Injection Control – Split of the Combustion Cross Section in Temperature Zones



# Key Elements of ERC's SNCR Technology for Large Combustion Plants



## NO<sub>x</sub>-Reduction of Coal-Fired Power Plants



# Mátrai Erőmű Visonta / Hungary



NOx Emissions reduced below the new EC Limit Value at all of the 5 Units in only 2.5 years

## Reference Plant Introduction

### Worth to be known:

- Largest Hungarian Lignite-Fired Power Station
- Supplies approx. 15 % of Hungary's Electricity (approx. 6200 GWh/a)
- 5 Units commissioned 1969 – 1972
- Total installed capacity: 950 MW<sub>el</sub>
  - Units no. 1, 2: 100 MW<sub>el</sub> each
  - Units no. 3, 4, 5: 220 MW<sub>el</sub> each
  - 2 gas turbines: 45 MW<sub>el</sub> each
- Fuel: Lignite from adjacent surface mining

# Matra Unit III, Design Data

Estimation of Heat Input				
Coal Source	Visonta 2, Open Lignite Mining			
Calorific Value	7164 kJ/kg	3250 kJ/lb	3080 Btu/lb	
Capacity	220 MW <sub>el</sub>			
Steam Production	670 metric t/h	540°C, 140 bar(g)	Enthalpy	3448 kJ/kg
	738.7 stons/h			
eta <sub>th</sub>	90%			
Heat Input	2,566,844 MJ/h	corresponding steam production		
	2432.9 MMBtu/h	713,0	MW <sub>th</sub>	
Coal mass flow rate	358.3 t/h			
Estimation of NOx mass flow rate depending on heat input				
Flue Gas Volume	1,154,040 Nm <sup>3</sup> /h @ 6% O <sub>2</sub> , dry basis		729,004 scfm @ 6% O <sub>2</sub> , dry	
				NOx Reduction
Baseline NOx, average	300 mg/Nm <sup>3</sup>	763,27 lb/hr	0.314 lb/MMBtu	33,3%
Baseline NOx, max	350 mg/Nm <sup>3</sup>	890,48 lb/hr	0.366 lb/MMBtu	42,9%
Clean Gas NOx	200 mg/Nm <sup>3</sup>	508,84 lb/hr	0.209 lb/MMBtu	

## Matra Units 3 – 5, Warranties

**Reduction Agent to be used to meet warranties: Carbamin 5722 (Urea Based)**

**NO<sub>x</sub> < 200 mg/Nm<sup>3</sup>, @ 6 Vol. % O<sub>2</sub>, dry 1)  
approx. 0.209 lb/MMBtu**

**NH<sub>3</sub> < 5 mg/Nm<sup>3</sup>, @ 6 Vol. % O<sub>2</sub>, dry 1)  
approx. 6.58 ppm**

**NH<sub>3</sub> in Ash < 100 mg/kg (100 ppm by wt.)**

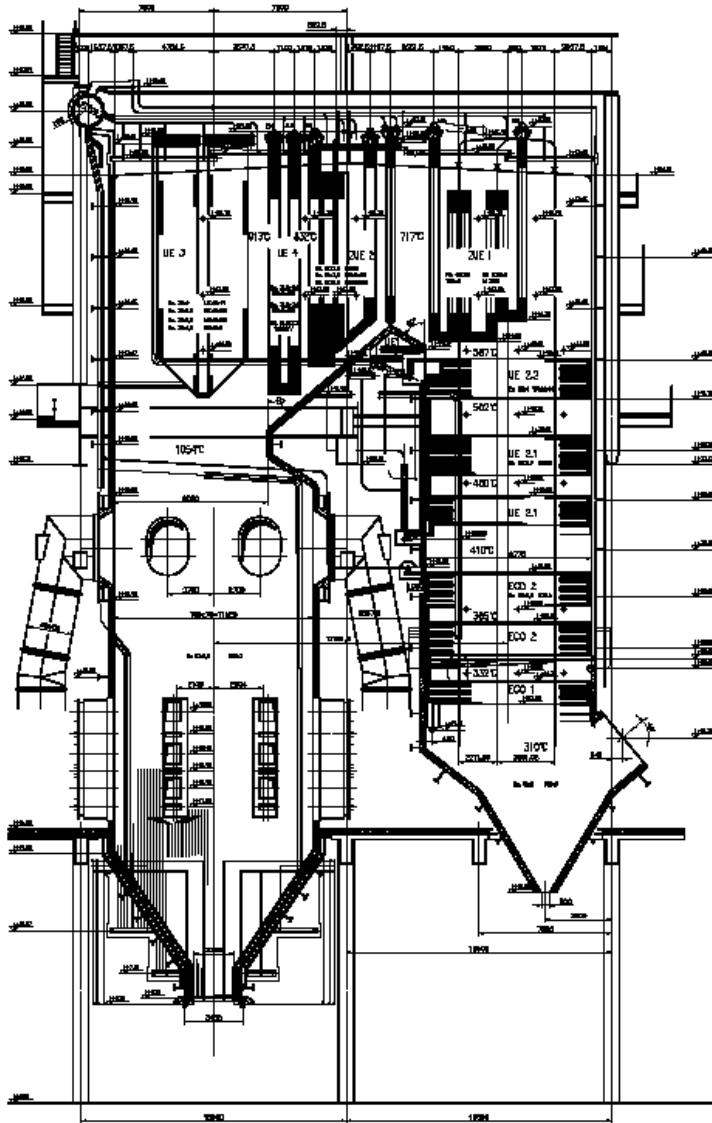
**NH<sub>3</sub> in Gypsum < 10 mg/kg (10 ppm by wt.)**

**1) Measured at the emission monitoring system downstream of the ESP**

## **History SNCR Project Matra Units 3 - 5**

<b>Trial / Testing SNCR at Unit 3:</b>	<b>November 2011</b>
<b>Pre-Engineering SNCR Unit 3 &amp; Storage Sytem:</b>	<b>April 2013</b>
<b>Contract SNCR Unit 3, Options for Units 4 - 5:</b>	<b>Juni 2013</b>
<b>Commissioning of Unit 3:</b>	<b>December 2013</b>
<b>Outages Unit 5 &amp; Unit 4:</b>	<b>April 2014 / May 2014</b>
<b>Commissioning of Units 4 &amp; 5:</b>	<b>August 2014</b>
<hr/>	
<b>Commissioning of Units 1 &amp; 2:</b>	<b>2015 / 2016</b>

# SNCR – Reference Matrai, Ungarn



## Unit III, Design Data

**Manufacturer:** Babcock

**Steam Production:** max. 670 t/h

**Steam Temperature:** 540 °C

**Steam Pressure:** 140 bar(g)

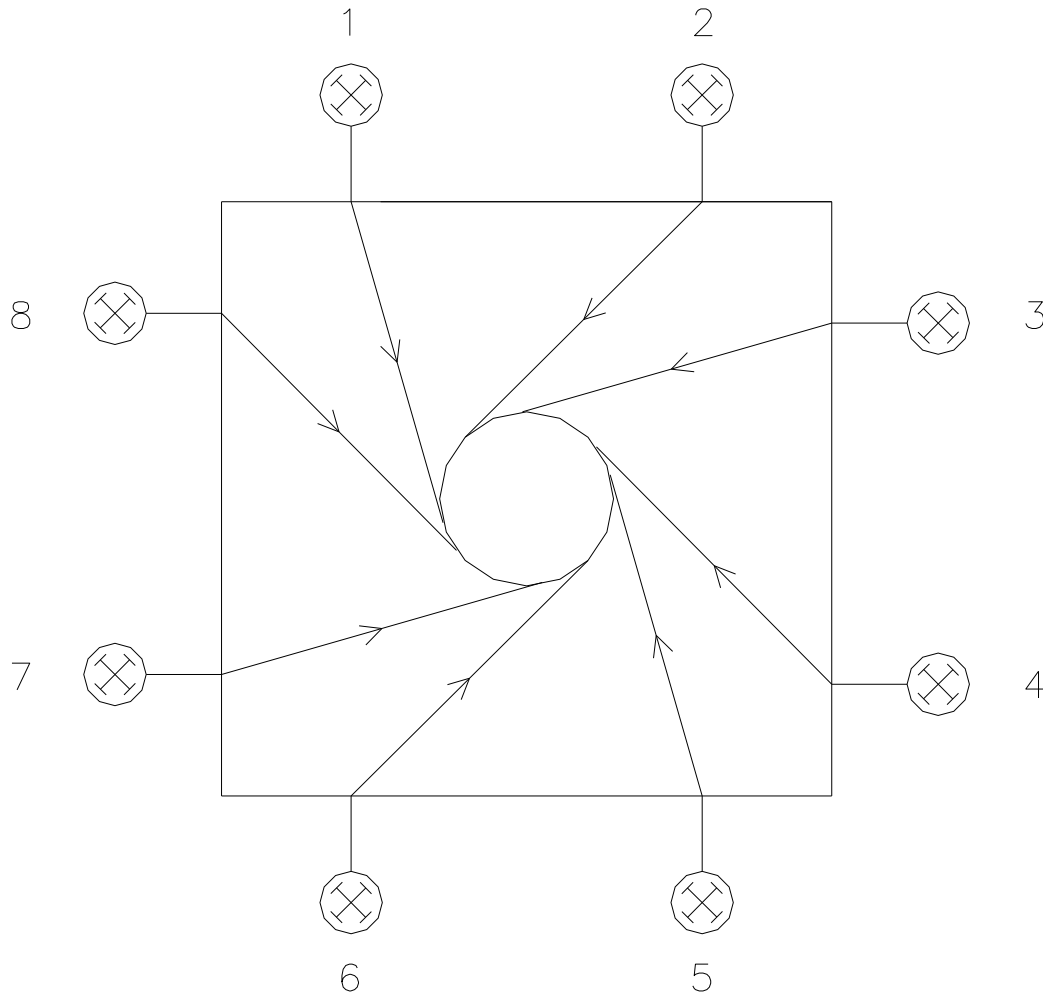
**Fuel:** Lignite & Biomass (max. 10%)

**Boiler Load:** min. 110 Mw<sub>el</sub>  
max. 220 MW<sub>el</sub>

**Flue Gas Volume:** min. 800,000 Nm<sup>3</sup>/h  
(dry, 6 % O<sub>2</sub>) max. 1,300,000 Nm<sup>3</sup>/h

**NO<sub>x</sub>-Emission:** approx. 300 mg/Nm<sup>3</sup> dry, 6 % O<sub>2</sub>  
max. 350 mg/Nm<sup>3</sup> dry, 6 % O<sub>2</sub>

## Arrangement of Mills and Burners



### SNCR Trial at Unit 3

Targets:

NO<sub>x</sub>: < 200 mg/Nm<sup>3</sup>, at 6 % of vol. O<sub>2</sub>, dry <sup>1)</sup>

NH<sub>3</sub> slip: < 5 mg/Nm<sup>3</sup>, at 6 % of vol. O<sub>2</sub>, dry <sup>1)</sup>

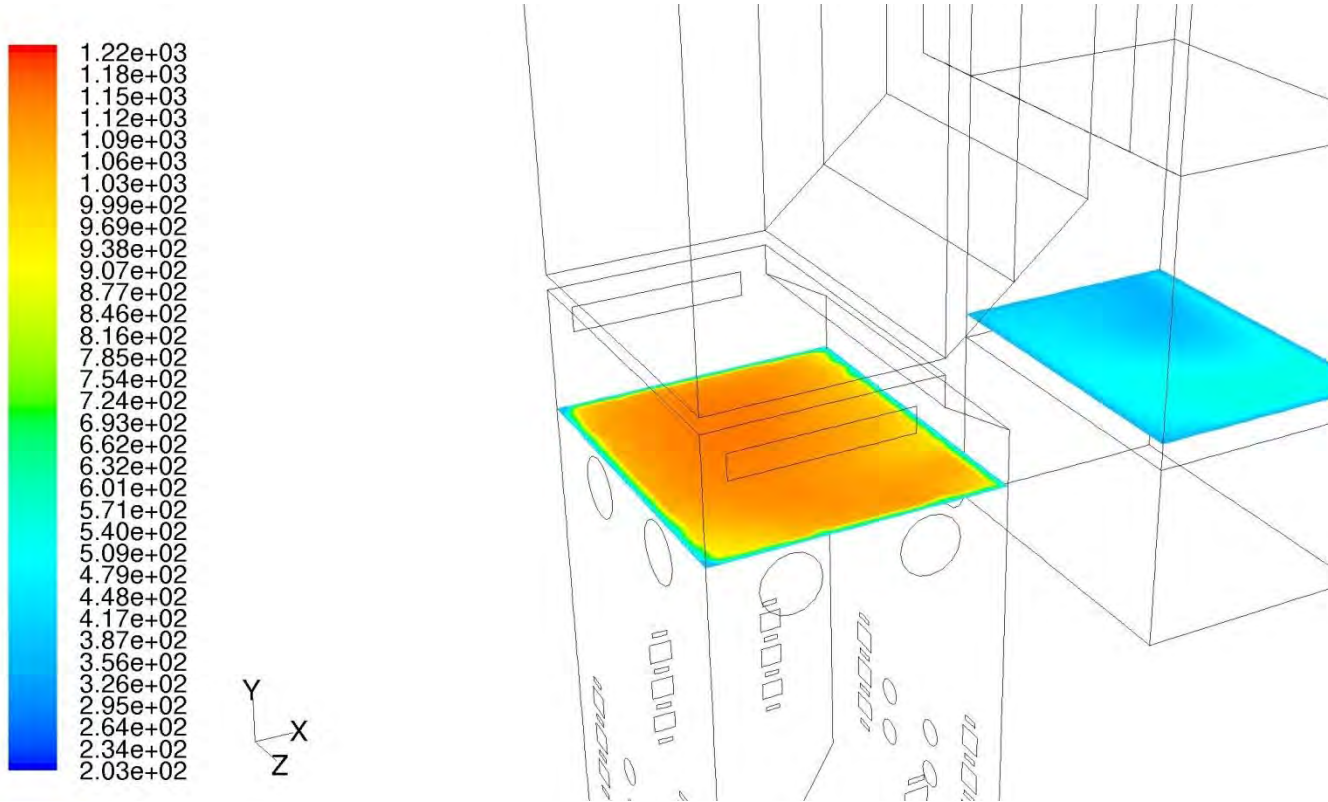
NH<sub>3</sub> in the ash: < 100 mg/kg

NH<sub>3</sub> in the gypsum: < 10 mg/kg

reduction agent: carbamin 5722 (urea based)

<sup>1)</sup> measured with the emission monitoring system, downstream ESP

## CFD Simulation of Temperature Distribution at Unit 3



## Temporary Storage for NO<sub>x</sub> Reduction Agent



NO<sub>x</sub> reduction agent: carbamin 5722, urea based

## SNCR Testing Equipment



## Injection Lances



left



right



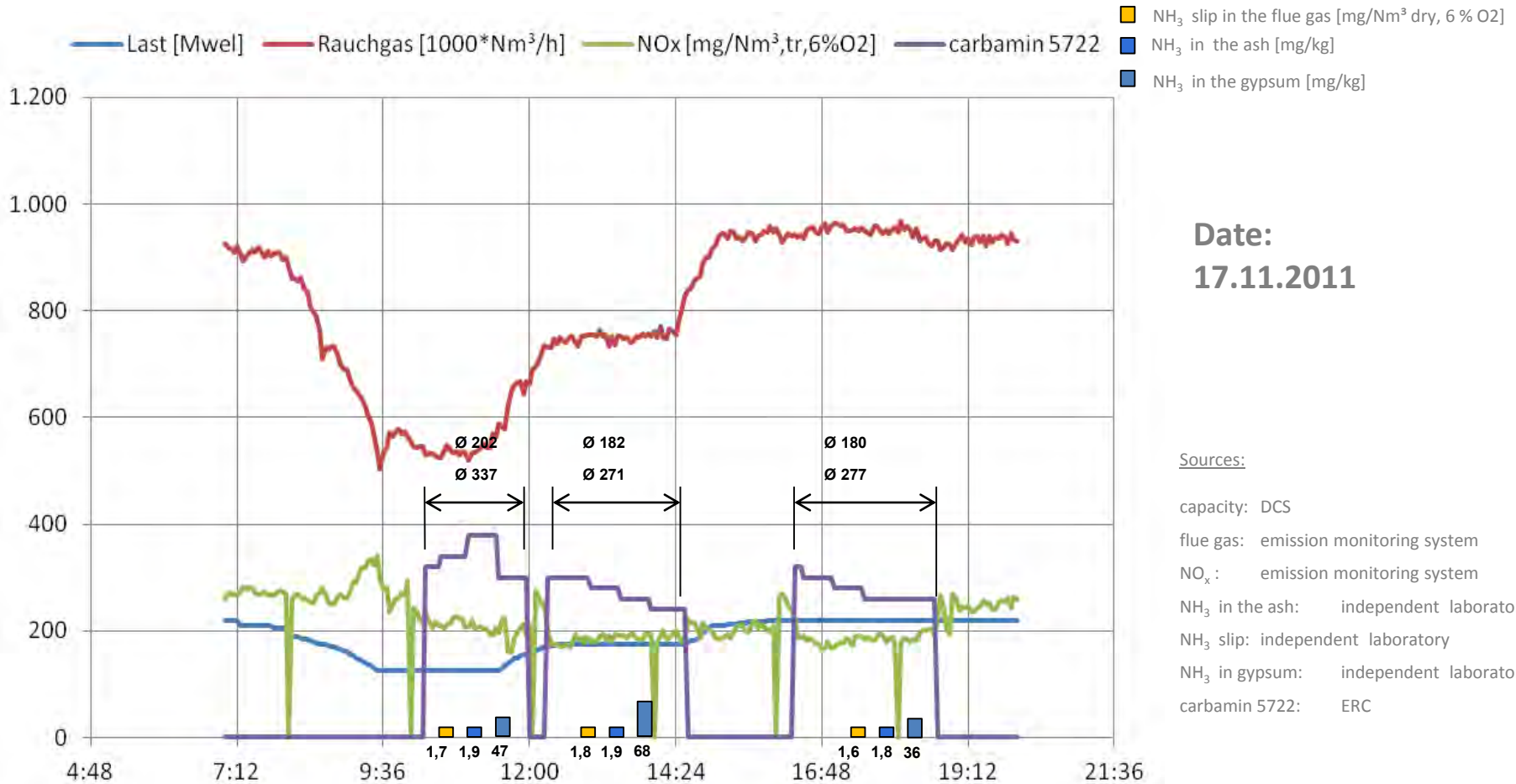
front left



front right

# SNCR – Reference Matrai, Ungarn

## Test Results at 110 MW<sub>el</sub>, 175 MW<sub>el</sub> and 220 MW<sub>el</sub>



Date:  
17.11.2011

Sources:

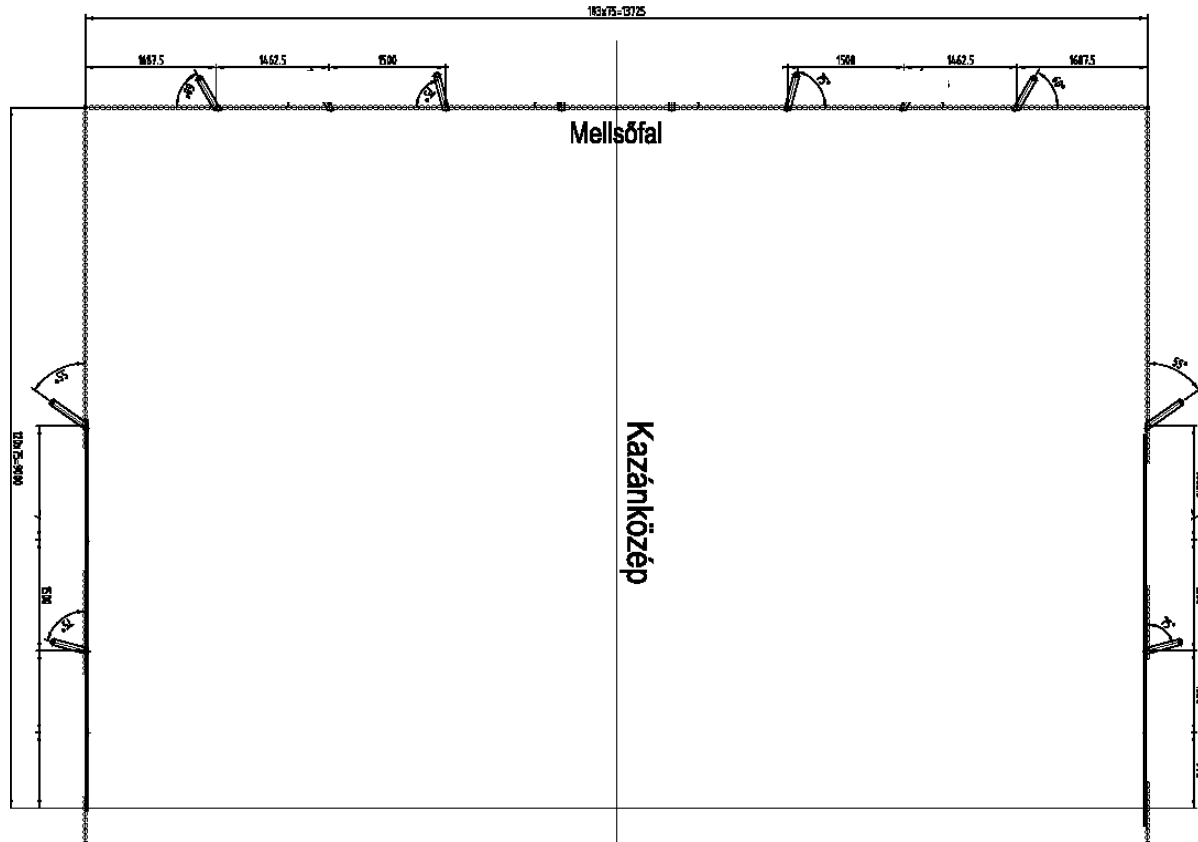
- capacity: DCS
- flue gas: emission monitoring system
- NO<sub>x</sub>: emission monitoring system
- NH<sub>3</sub> in the ash: independent laboratory
- NH<sub>3</sub> slip: independent laboratory
- NH<sub>3</sub> in gypsum: independent laboratory
- carbamin 5722: ERC

## Main Equipment of the Commercial SNCR Plant

<u>Component</u>	<u>No. of pieces</u>	<u>Remarks</u>
Tanks for NO <sub>x</sub> reduction agent	2	common, volume 100 m <sup>3</sup> / tank
Urea unloading pump station	1	common
Dosing station for carbamin 5100	1	common, incl. storage, volume 1.25 m <sup>3</sup>
Circulation pumps for NO <sub>x</sub> reduction agent	4	common, 2 submersible pumps / tank
Pump station for dilution water	1	common
Mixing and measuring modules	9	3 per unit
Injection lances	72	24 per unit, 2 levels
Temperature measuring systems	3	one per unit, 8 optical pyrometers
Control cabinets	3	one per unit



## Arrangement of the Injection Lances Lower Level, + 35.5 m for Low Loads up to 110 MW<sub>e1</sub>



## NO<sub>x</sub> Reduction Agent Storage Plant



## Urea Discharging Pump Station



carbamin 5100 Dosing Station



## Booster Pump Station for Dilution Water



## Injection Lance



Mixing and Distribution Modules Special Design for Extremely Dusty Areas



**Mixing and Distribution Module**  
**for Dilution Water and NO<sub>x</sub> Reduction Agent**



## Distribution Cabinets

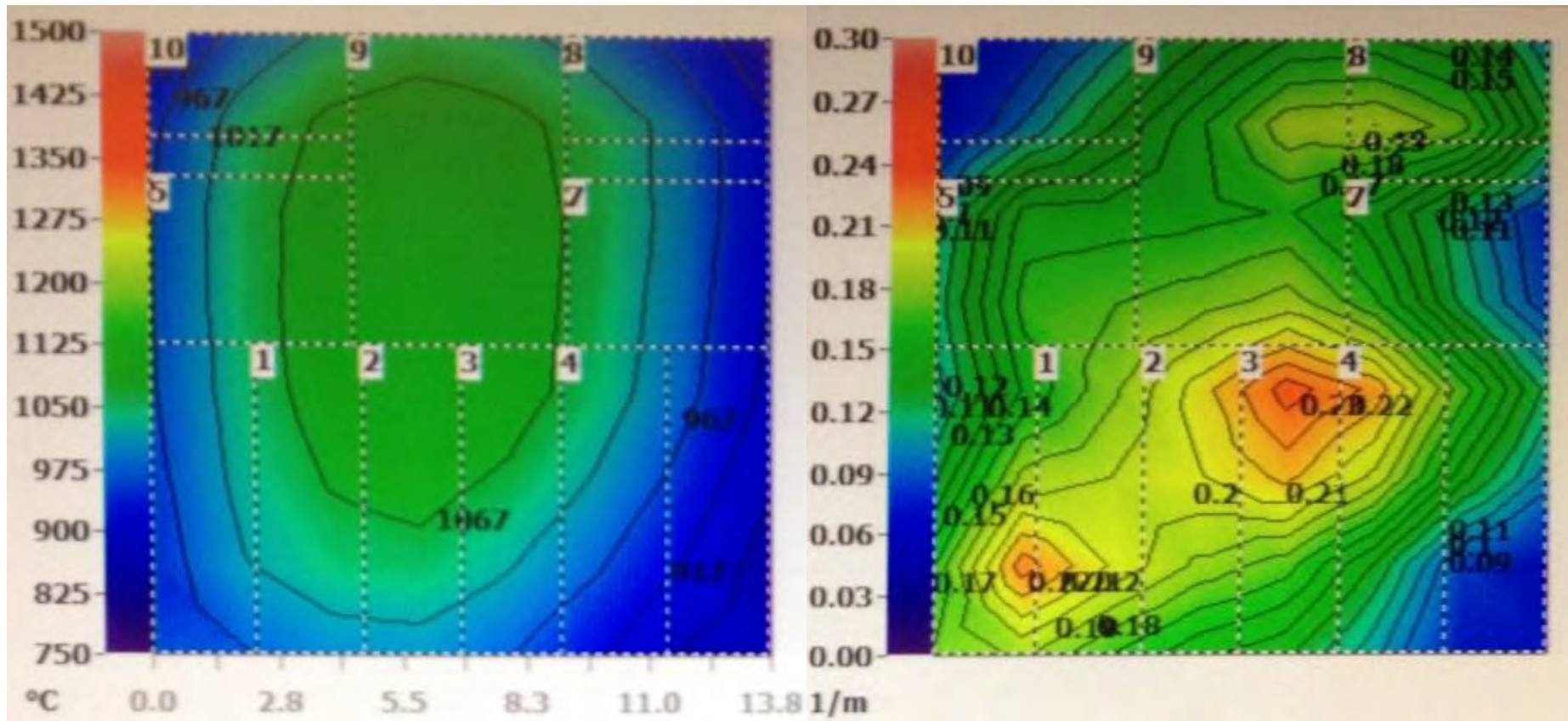
for Atomisation Air and Diluted NO<sub>x</sub> Reduction Agent



## Optical Pyrometer



## Furnace Temperature and Combustion Quality Mapping

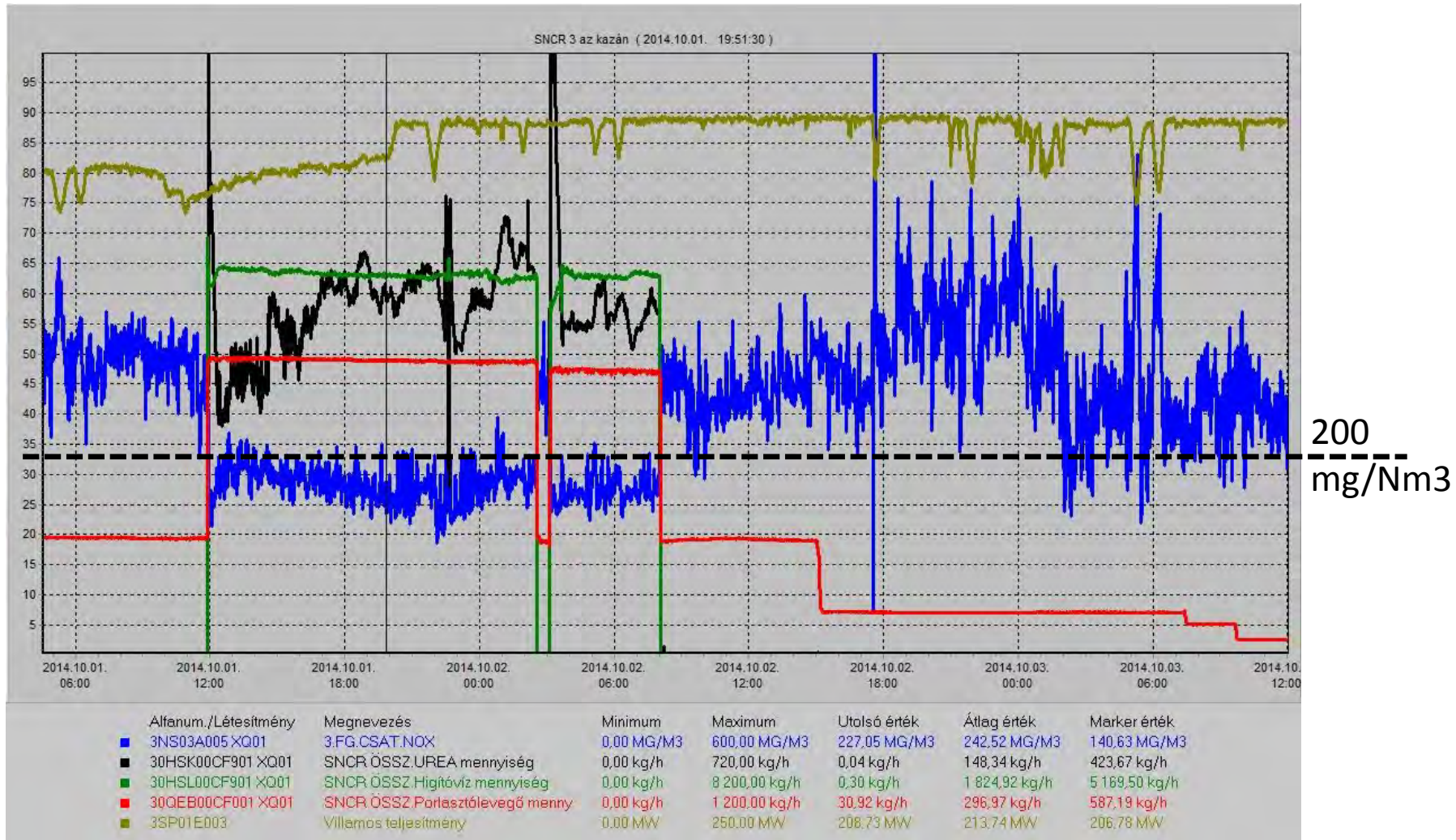


## Control Cabinets: SNCR and Temperature Measuring System



# SNCR – Reference Matrai, Ungarn

## Unit 4: Operational Parameters with the Commercial SNCR Plant



## Elektrownia Bełchatów – World-wide Largest Lignite-Fired Power Plant



Unit 3: 380 MW<sub>el</sub>, approx. 1.5 Mio. Nm<sup>3</sup>/h

Meeting the expected new BREF Emission level of 150 – 175 mg/Nm<sup>3</sup>

## Bełchatów Power Plant

- commissioned in 1981
- located close to Łódź
- largest lignite Power Plant world-wide
- produces more than 1/3 of Poland's electricity
- total capacity of 5420 MW<sub>el</sub>
- 12 Units, steam production 1150 t/h (380 – 390 MW<sub>el</sub>)
- Unit 14, over-critical steam parameters (858 MW<sub>el</sub>), el. Efficiency > 42 %



## Project Time Schedule

<b>Contract Award:</b>	<b>December 2015</b>
<b>Boiler modifications / openings:</b>	<b>Mid February 2016</b>
<b>Supply of SNCR Equipment:</b>	<b>March 2016</b>
<b>Erection:</b>	<b>until End of March 2016</b>
<b>Commissioning:</b>	<b>until End of April 2016</b>
<b>Delays of customer:</b>	<b>until June 2016</b>
<b>Trial Run:</b>	<b>until End of August 2016</b>
<b>Performance Measurements:</b>	<b>September 2016</b>
<b>Hand-over to customer:</b>	<b>End of September 2016</b>

## Design Data

### Design Basis SNCR Unit 3

Max. steam production:	1150 t/h
Load range:	60 – 100 %
Max. fuel mass flow:	460 t/h
Lower Heating Value Guarantee Coal:	7750 kJ/kg / appr. 3700 Btu/lb HHV
Max. Flue Gas Volumetric Flow Rate:	1,445,000 Nm <sup>3</sup> /h (dry, 6 % O <sub>2</sub> )
Max. Flue Gas Temperature End of Combustion:	1086 °C / 2012 °F
<b>NO<sub>x</sub> Base Line:</b>	<b>200 mg/Nm<sup>3</sup> (approx. 0.2 lb/MMBtu)</b>
Target:	$\Delta$ NO <sub>x</sub> $\geq$ 50 mg/Nm <sup>3</sup> NH <sub>3</sub> Slip $\leq$ 5 mg/Nm <sup>3</sup> NH <sub>3</sub> in Ash $\leq$ 100 mg/kg



## Boiler Modifications



SNCR Equipment



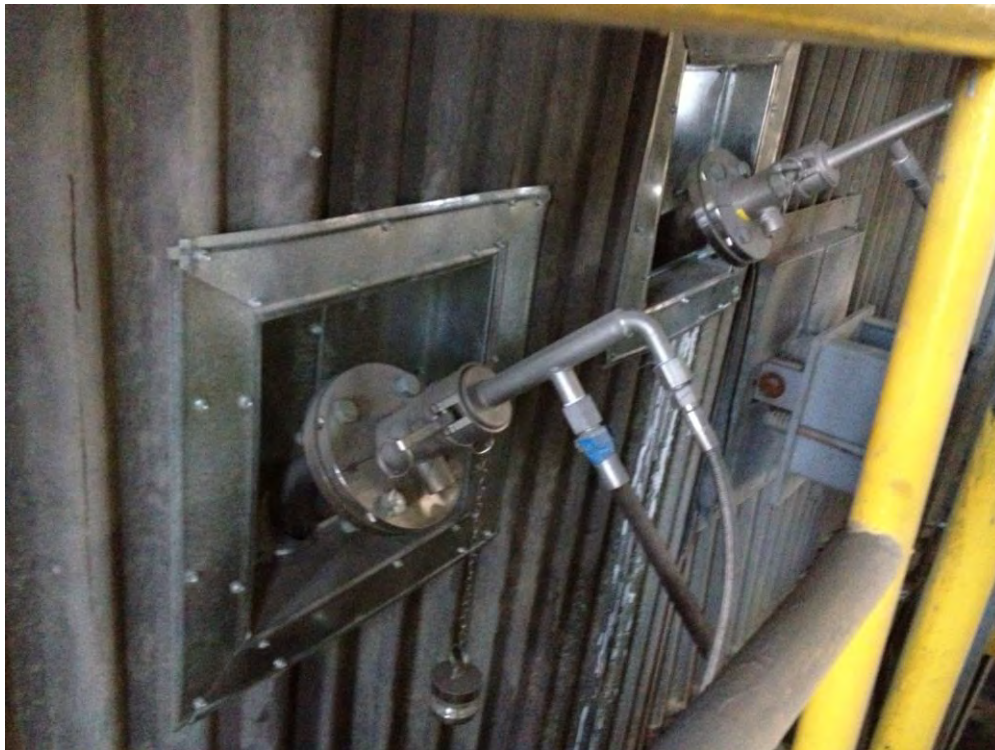
Dosing and Mixing Module

Valve Station for Injector Control



SNCR Equipment

Injection Lances

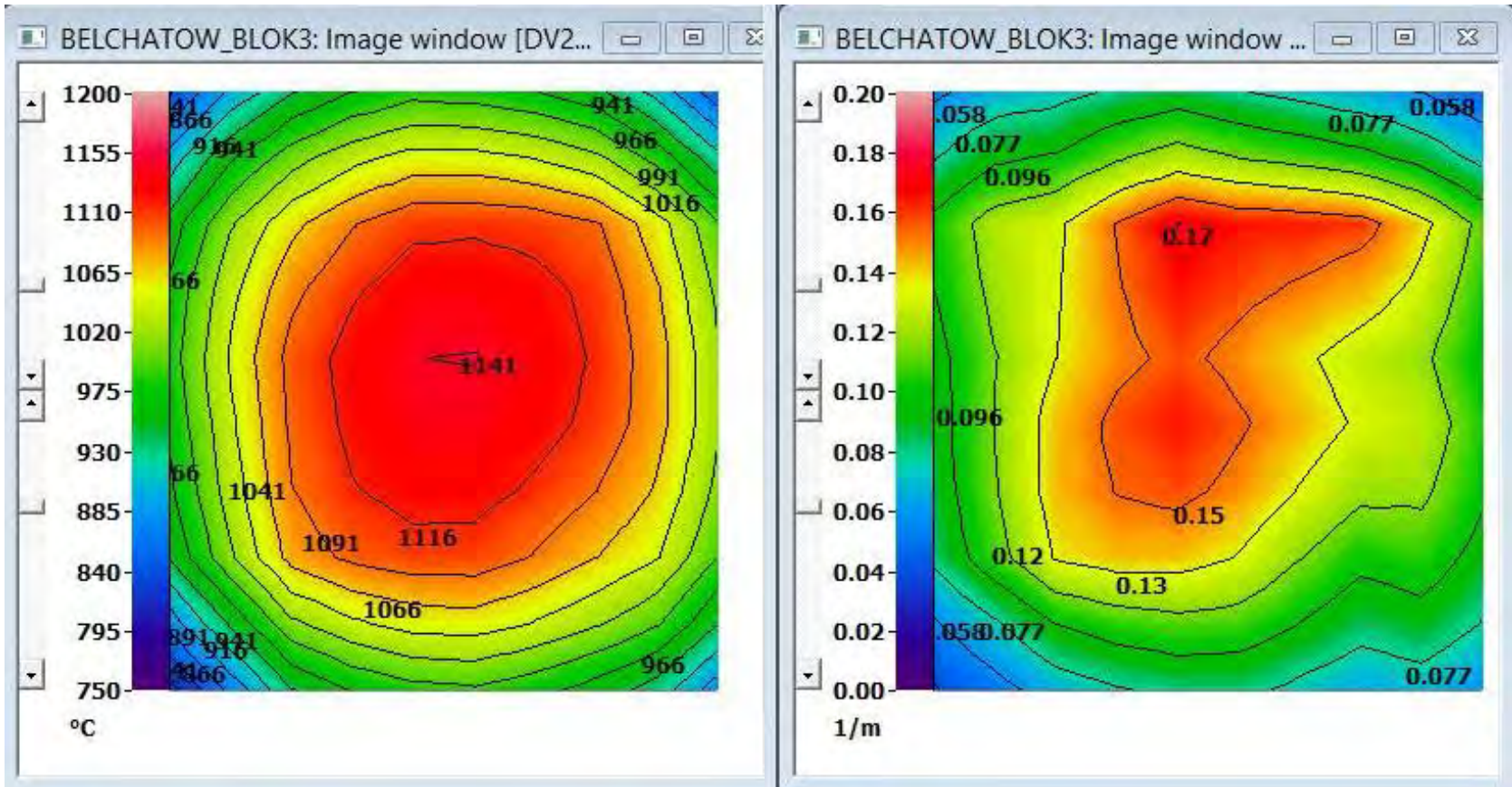


Optical Pyrometer and Shock Blower

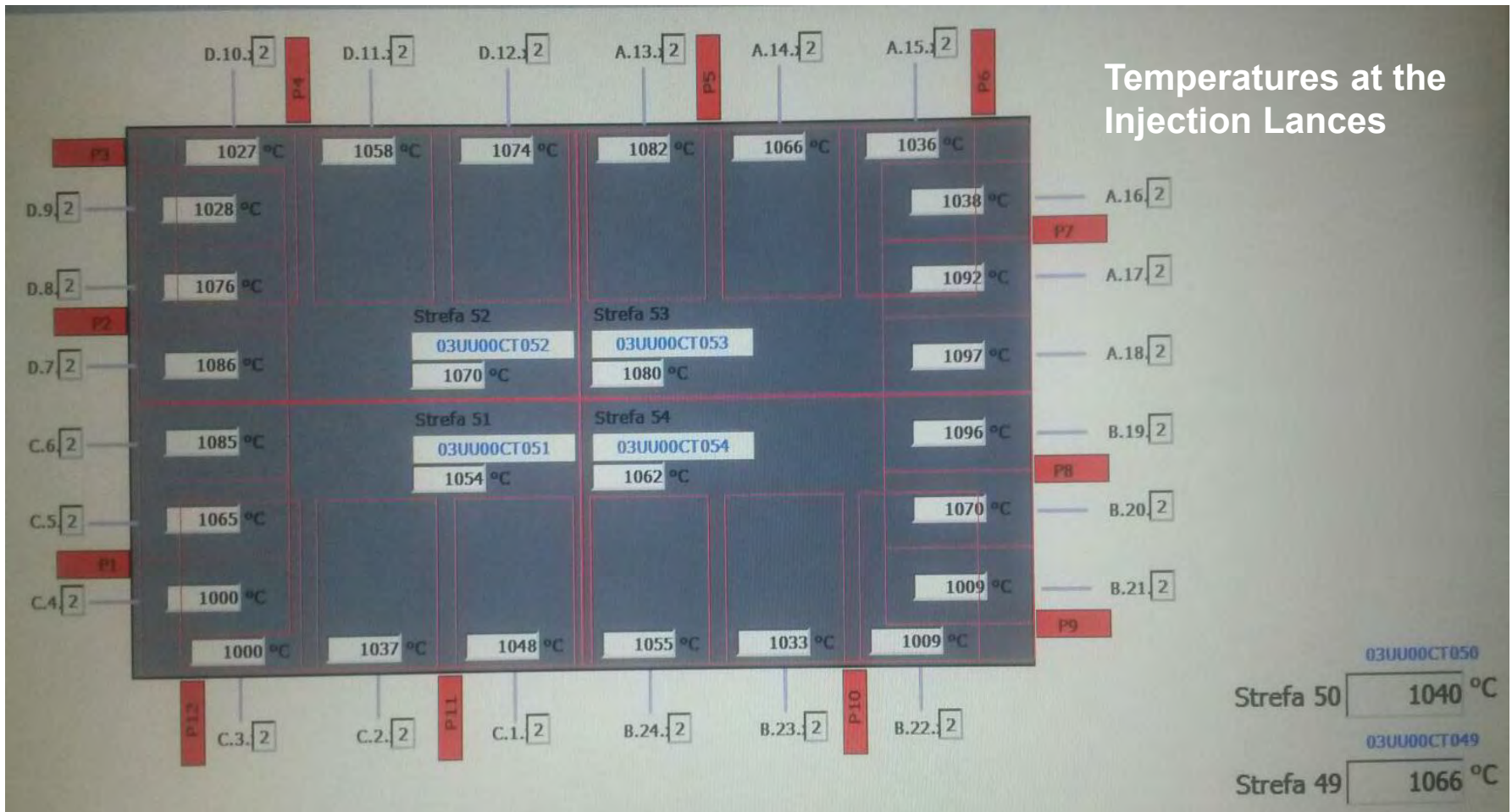


# Online Temperature Measurement

## Temperature Field and Optical Flue Gas Density



# Injectors and Temperature Field

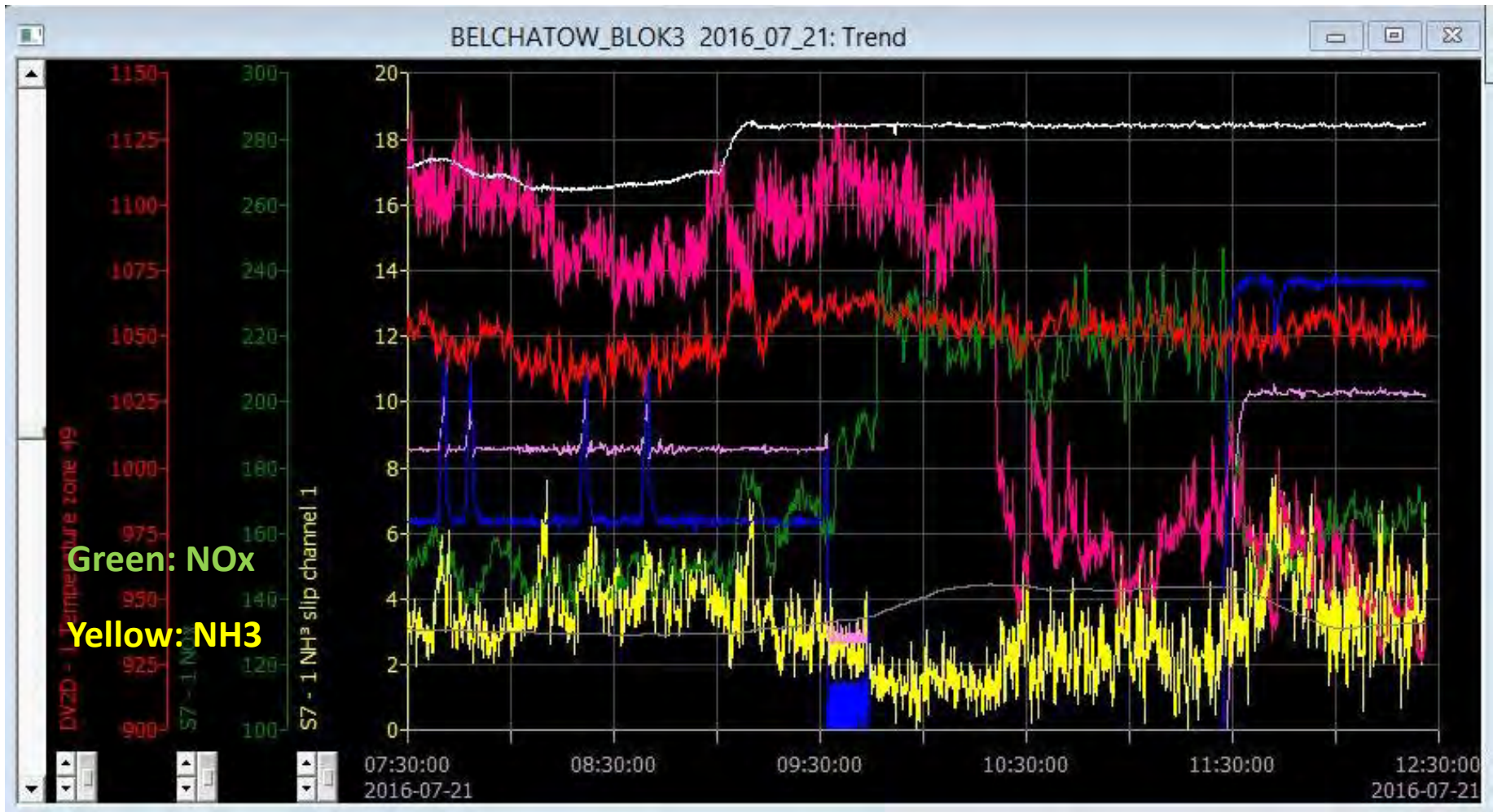


## Instrumentation and Control

### In Situ $\text{NH}_3$ Measuring Device upstream of Air Preheater



# Operational Results



## Yangcheng Power Station, China



Unit 1 - 6: 350 MW<sub>el</sub>      Unit 7 - 8: 600 MW<sub>el</sub>

**NO<sub>x</sub> Emissions reduced below 50 mg/Nm<sup>3</sup> by means of combining SNCR and SCR**

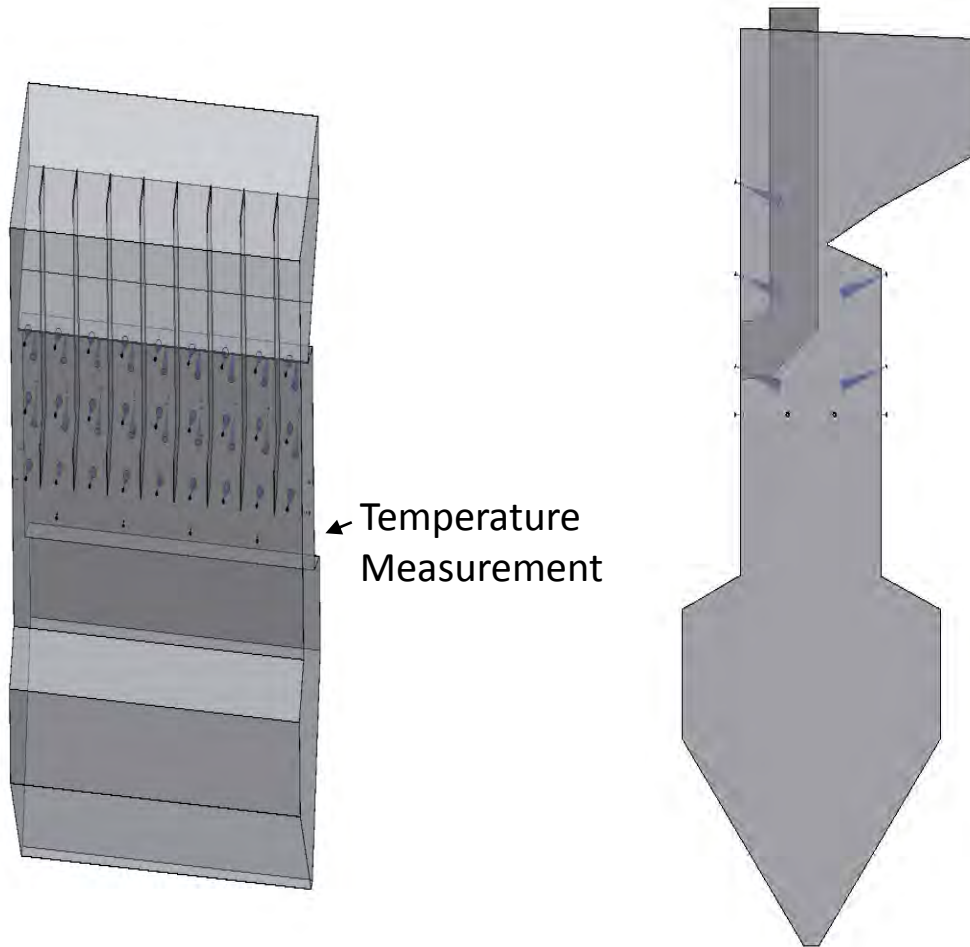
## Design Data SNCR Yangcheng Units 1 - 4

<b>Operation Point</b>	<b>MW</b>	<b>350</b>
Flue gas flow	$\text{m}^3_{\text{n}}/\text{h}$	1,550,000
Flue gas flow (dry)	$\text{m}^3_{\text{n}}/\text{h}$ (dry)	1,410,500
Flue gas quantity (dry)	$\text{m}^3_{\text{n}}/\text{h}$ / scfm @ 6 % $\text{O}_2$ (dry)	1,685,367 / 990,000
$\text{O}_2$ (average/assumed)	Vol.-% (wet)	2.8
$\text{H}_2\text{O}$ (assumed)	Vol.-%	9.0
<b><math>\text{NO}_x</math> emission (baseline), daily average</b>	<b><math>\text{mg}/\text{m}^3_{\text{n}}</math> @ 6 % <math>\text{O}_2</math> (dry)</b>	<b>1000 (approx. 0.65 lbs/MMBtu)</b>
<b><math>\text{NO}_x</math> emission downstream SNCR, daily average</b>	<b><math>\text{mg}/\text{m}^3_{\text{n}}</math> @ 6 % <math>\text{O}_2</math> (dry)</b>	<b>550 (approx. 0.3 lbs/MMBtu)</b>
<b><math>\text{NO}_x</math> emission downstream SCR (existing), daily average</b>	<b><math>\text{mg}/\text{m}^3_{\text{n}}</math> @ 6 % <math>\text{O}_2</math> (dry)</b>	<b>50 (approx. 0.033 lbs/MMBtu)</b>

## Design Data SNCR Yangcheng Units 7 - 8

<b>Operation Point</b>	<b>MW</b>	<b>600</b>
Flue gas flow	m <sup>3</sup> <sub>n</sub> /h	2,000,000
Flue gas flow (dry)	m <sup>3</sup> <sub>n</sub> /h (dry)	1,820,000
Flue gas quantity (dry)	m <sup>3</sup> <sub>n</sub> /h / scfm @ 6 % O <sub>2</sub> (dry)	2,174,667 / 1,280,000
O <sub>2</sub> (average/assumed)	Vol.-% (wet)	2.8
H <sub>2</sub> O (assumed)	Vol.-%	9.0
<b>NO<sub>x</sub> emission (baseline), daily average</b>	<b>mg/m<sup>3</sup><sub>n</sub> @ 6 % O<sub>2</sub> (dry)</b>	<b>1000 (approx. 0.65 lbs/MMBtu)</b>
<b>NO<sub>x</sub> emission downstream SNCR, daily average</b>	<b>mg/m<sup>3</sup><sub>n</sub> @ 6 % O<sub>2</sub> (dry)</b>	<b>550 (approx. 0.3 lbs/MMBtu)</b>
<b>NO<sub>x</sub> emission downstream SCR (existing), daily average</b>	<b>mg/m<sup>3</sup><sub>n</sub> @ 6 % O<sub>2</sub> (dry)</b>	<b>50 (approx. 0.033 lbs/MMBtu)</b>

## Arrangement of SNCR Injection Levels and Online-Temperature Measurement, Units 1 - 4



## SNCR – Reference Yangcheng Power Station, China



**Yangcheng Power Station,  
Urea Storage**



## SNCR – Reference Yangcheng Power Station, China



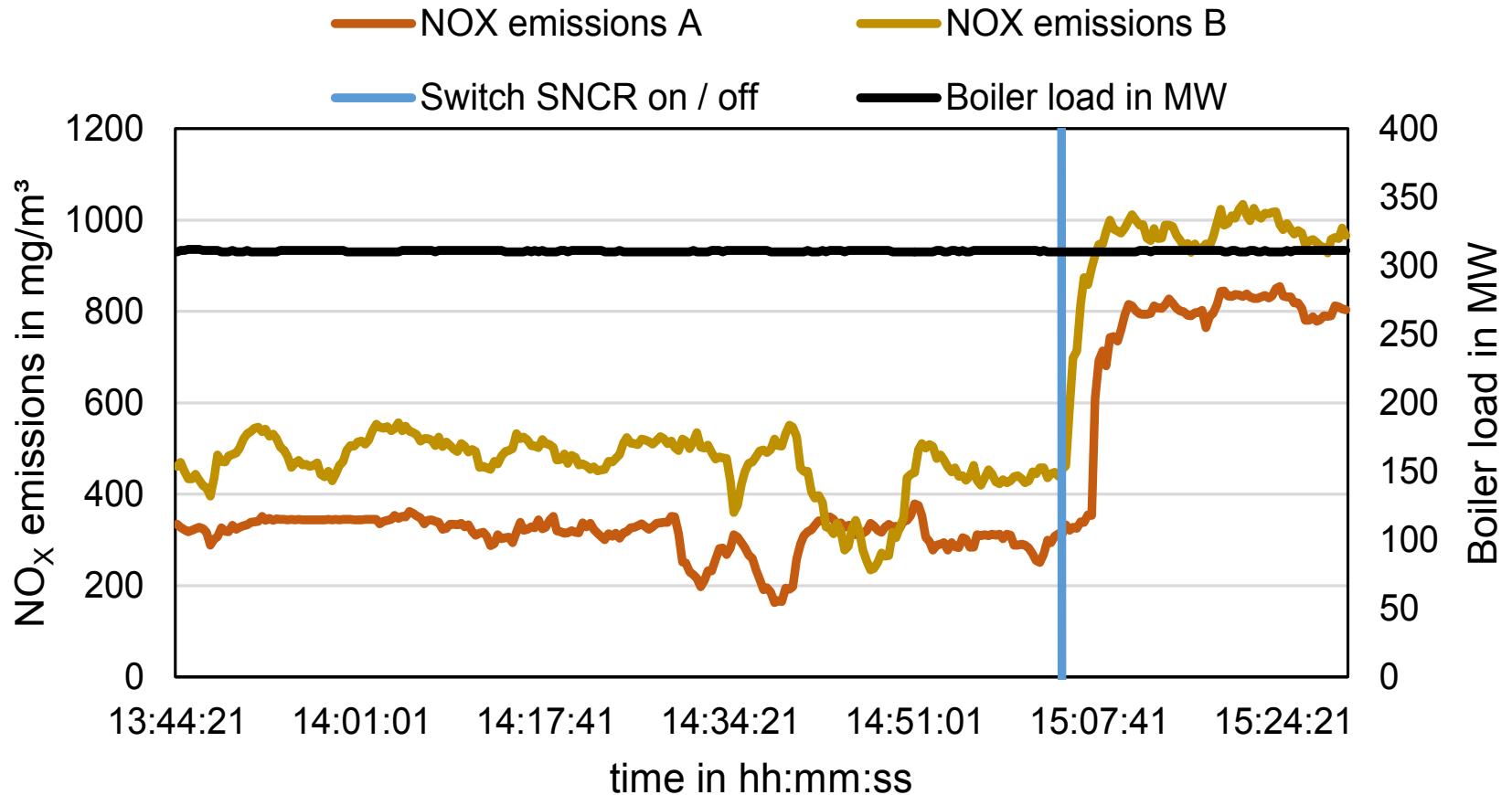
## Yangcheng Power Station Boiler 4, Mixing and Distribution Modules

## SNCR – Reference Yangcheng Power Station, China



**Yangcheng Power Station Boiler 4,  
Injection System**

## Yangcheng Power Station Boiler 4 – SNCR Results



## Yangcheng Power Station Boiler 4 – SNCR Results



NOx downstream  
SNCR & SCR  
(left / right Reactors)

## Dhekelia Power Station Units I – III, Cyprus



**Turn-Key High-Pressure SCR Retrofit downstream 3 x 18 MW<sub>el</sub> Two-Stroke-Engines, Fuel: HFO**

# Summary / Conclusions

- SNCR is an efficient and cost-effective technology for NO<sub>x</sub> control in large power stations
- ERC's proven technology is based on advanced SNCR injection systems in combination with online temperature measurements to achieve a high NO<sub>x</sub> control efficiency and a low ammonia slip
- NO<sub>x</sub> < 200 mg/Nm<sup>3</sup> / 0,13 – 0,2 lb/MMBtu and NH<sub>3</sub> slip < 5 mg/Nm<sup>3</sup> / 6.6 ppm or less are met in combination with modern LNBs
- The presented projects were executed in the agreed time schedule
- The combination SNCR and SCR provides very high NO<sub>x</sub> removal rates while maintaining a very low ammonia slip.
- A urea dissolving plant is a proven means to reduce reduction agent costs and increasing the overall economics
- ERC has gathered a huge experience which will be applied in favor of our customers in order to grant cost-effective compliance

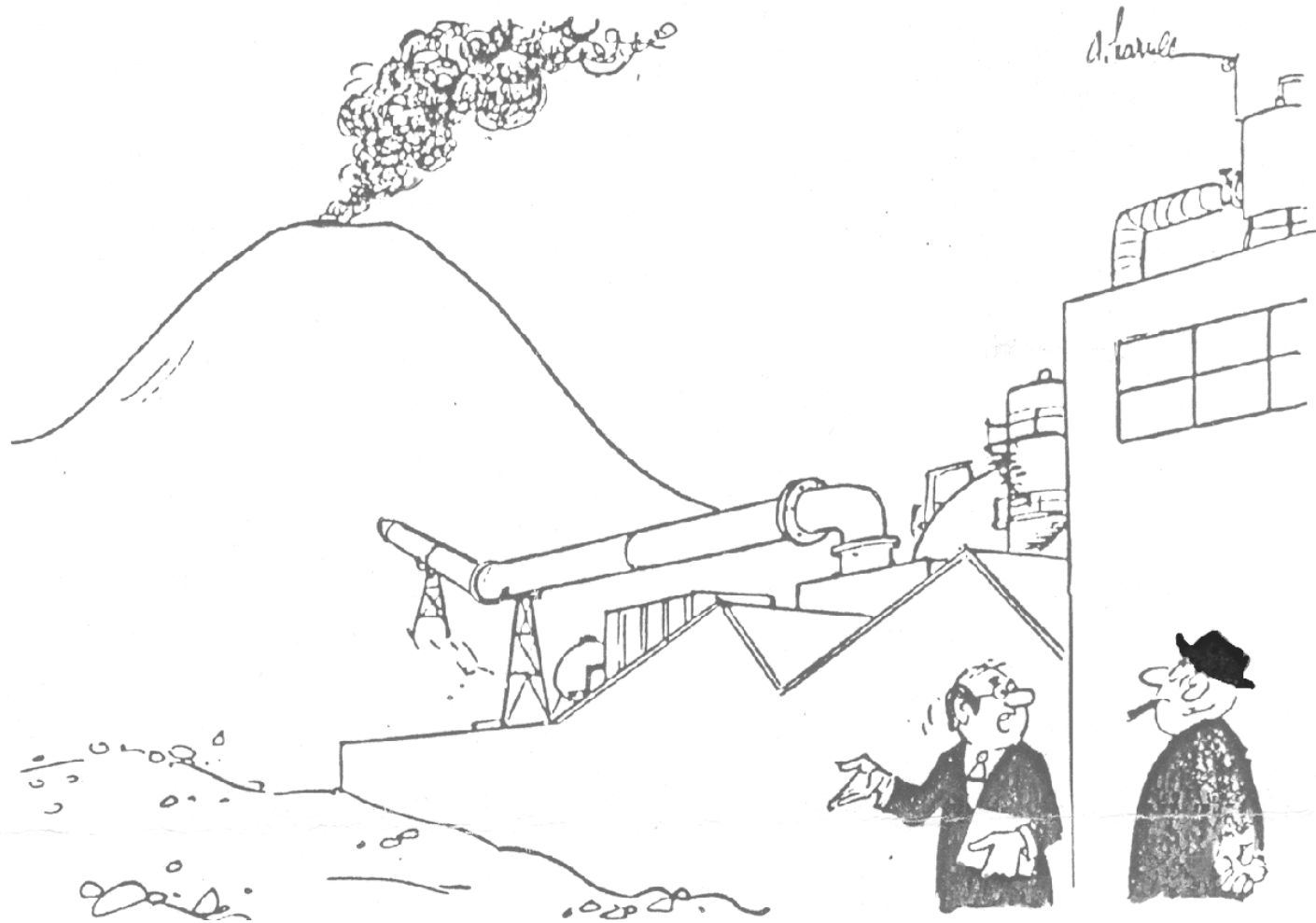


**Thanks for your attention – Questions???**

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If it wouldn't have worked we had a backup plan ...



since we lead the flue gas into the crater nobody complains about emissions any more