Online-CFD - a new approach for temperature-controlled SNCR in large scaled steam generators

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Introduction: MKV Völklingen (Evonik Power Saar GmbH)

MKV: Modellkraftwerk Völklingen

- located near Saarbrücken (Germany)
- built in 1982
- fires imported hard coal with varying qualities
- 4 mills feeding 2 low-NOx-burners each, at a shifted boxer design
- 195 MWel + 150 MW district heating
- NOx-limit: 290 mg/Nm³
- DeNOx-Options:
  - primary activities
  - SNCR or SCR

Introduction: MKV Völklingen (2)

External Conditions:

- Low-NOx burners installed
- NOx-limit: 290 mg/Nm³
- wide operational load range (40% -100%)
- many load changes (8 per day > 10% load)

Task:

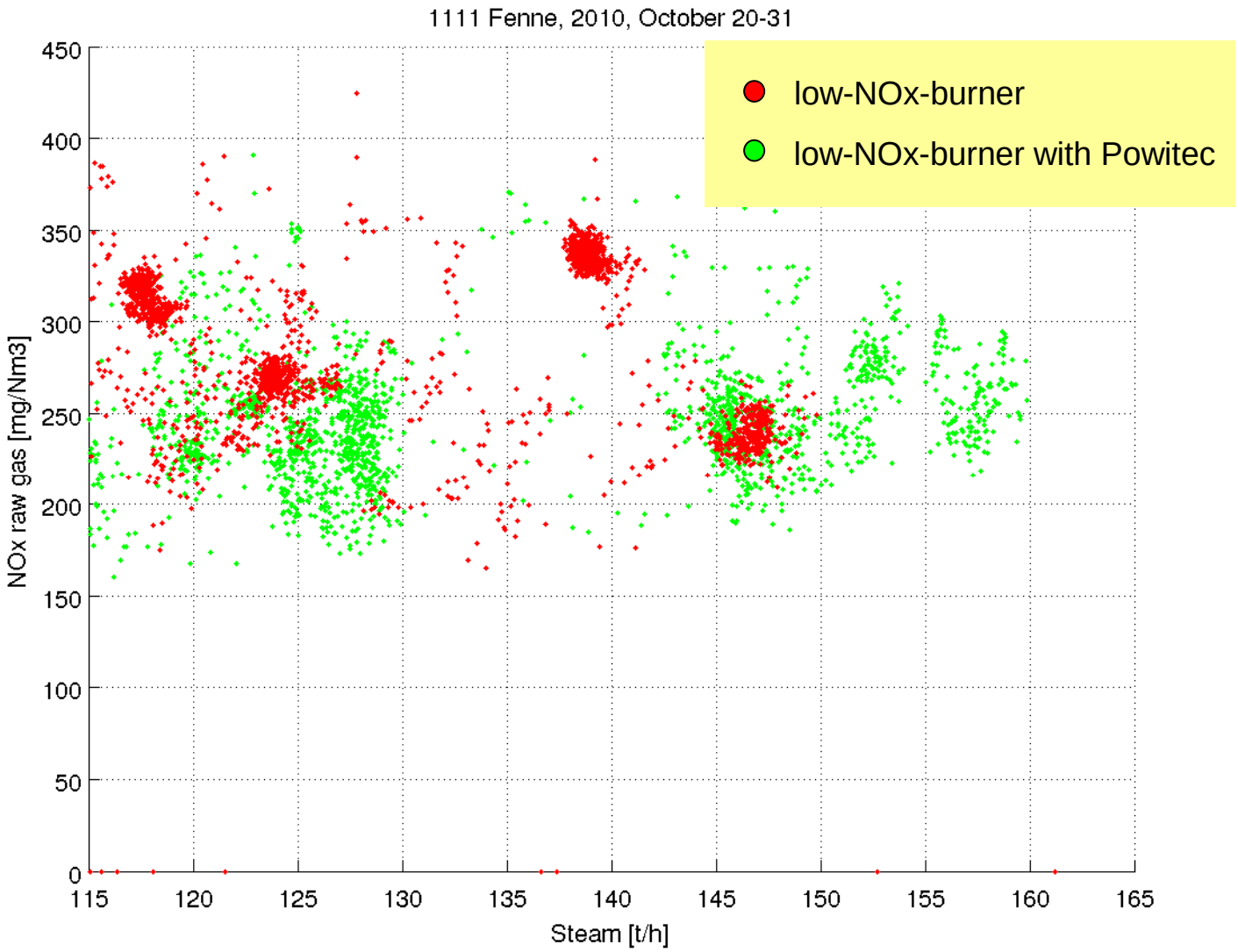
- control of NOx-level for all load cases with minimal NH3 slip and minimal ammonia consumption

Primary Activities for NOx-Reduction

- Low-NOx-Burners already installed

In Addition:

- optimization of local air/fuel ratios at each burner
- reduction of excess air by approx. 1% O_2
- 1% O_2 equals about 20mg/Nm^3 NOx



Introduction: SNCR vs SCR in large scaled boilers

SNCR-Advantages

- lower space requirements
- lower investments
- no costs for catalysator regeneration
- no flue gas pressure loss
- easy commissioning

SNCR-Drawbacks:

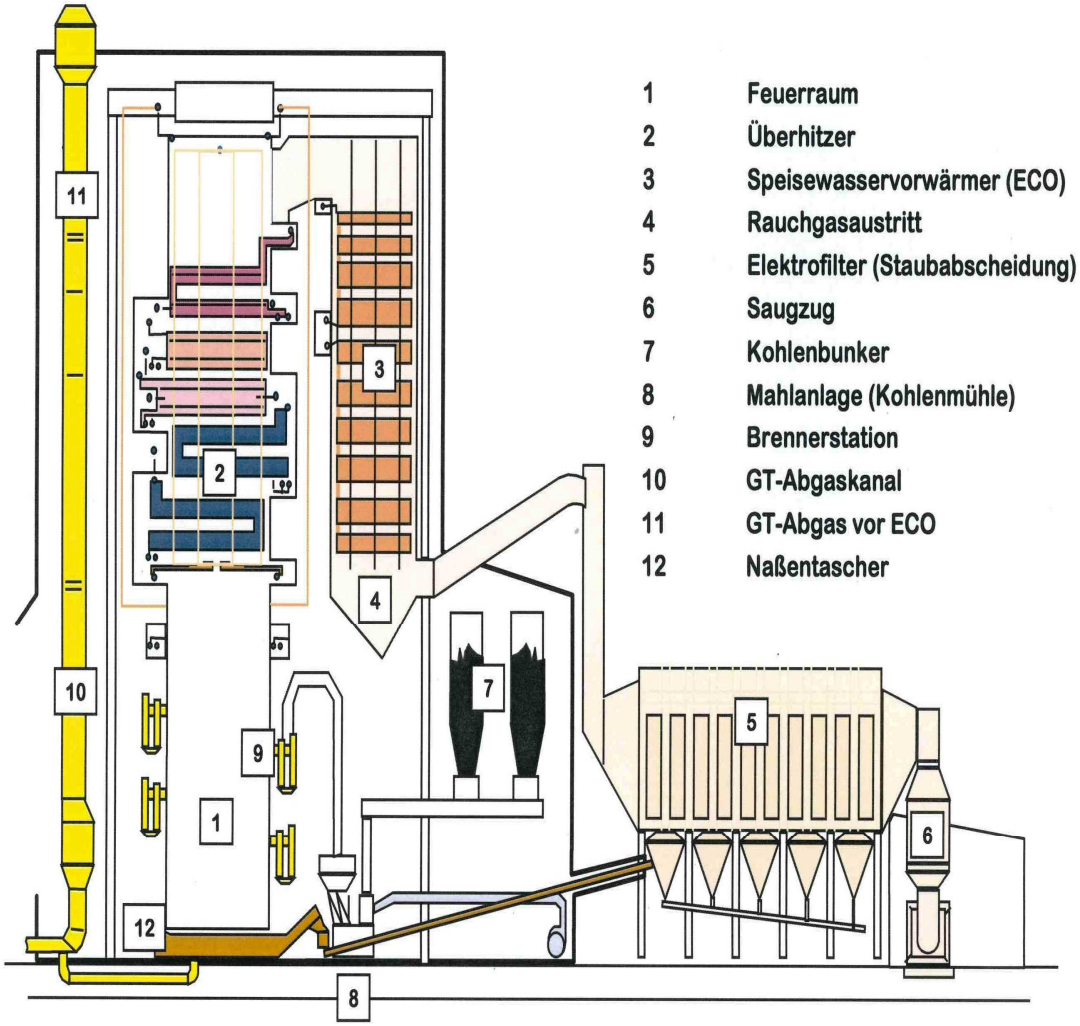
- advanced control system required
- high consumption of ammonia
- ammonia slip

Introduction: Why SNCR in large scaled boilers?

SCR or SNCR?

- very large economizer
  too low flue gas temperature for high-dust-SCR, limited space
- flue gas desulphurization in cooling tower
  not enough space for low-dust-SCR

➔ SNCR as best choice!



src: MKV Völklingen

Introduction: Why SNCR in large scaled boilers?

SNCR-Principle:

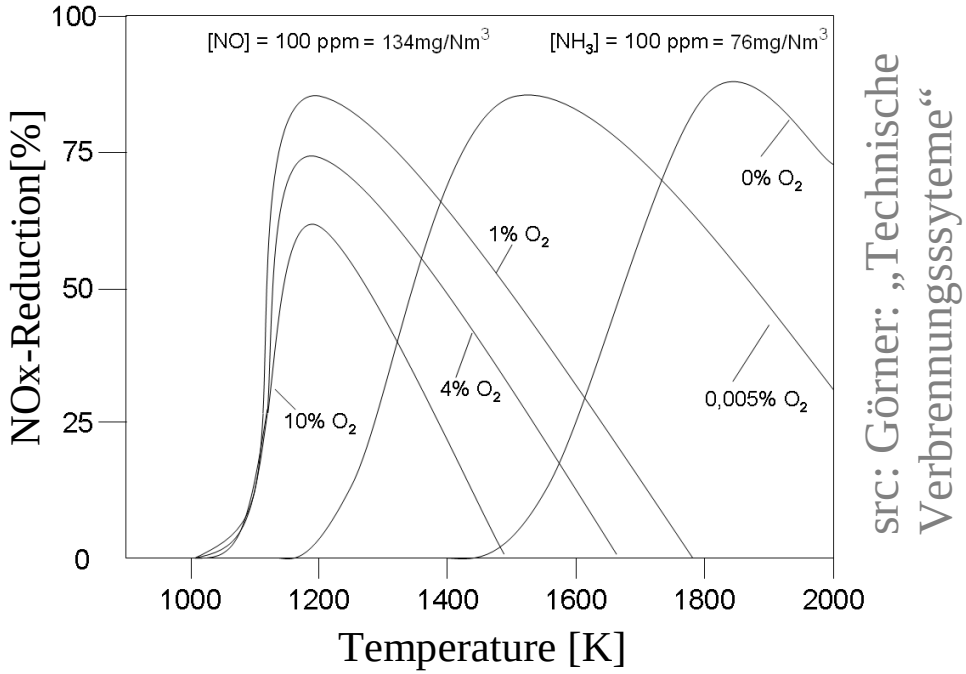
- injection of ammonia into flue gas:
  $4NO + 4NH_3 + O2 \rightarrow 4N_2 + 6H_20$

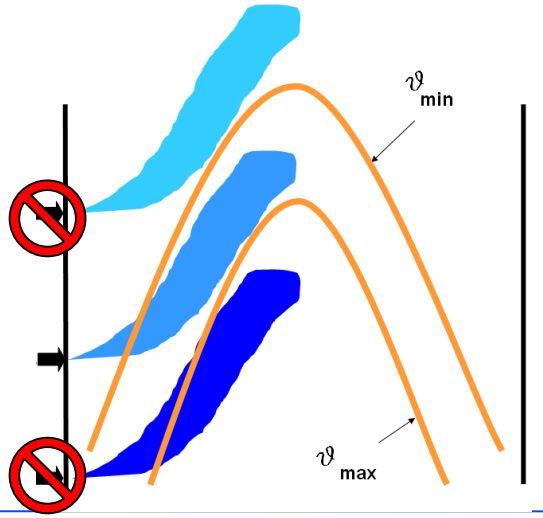
Challenges for SNCR:

- SNCR-reaction bound to specific flue-gas tempertures
- cold injection causes ammonia slip, hot injection causes even more NO
- many load changes

Task:

inject the right amount of ammonia at the right place at the right temperature of flue gas

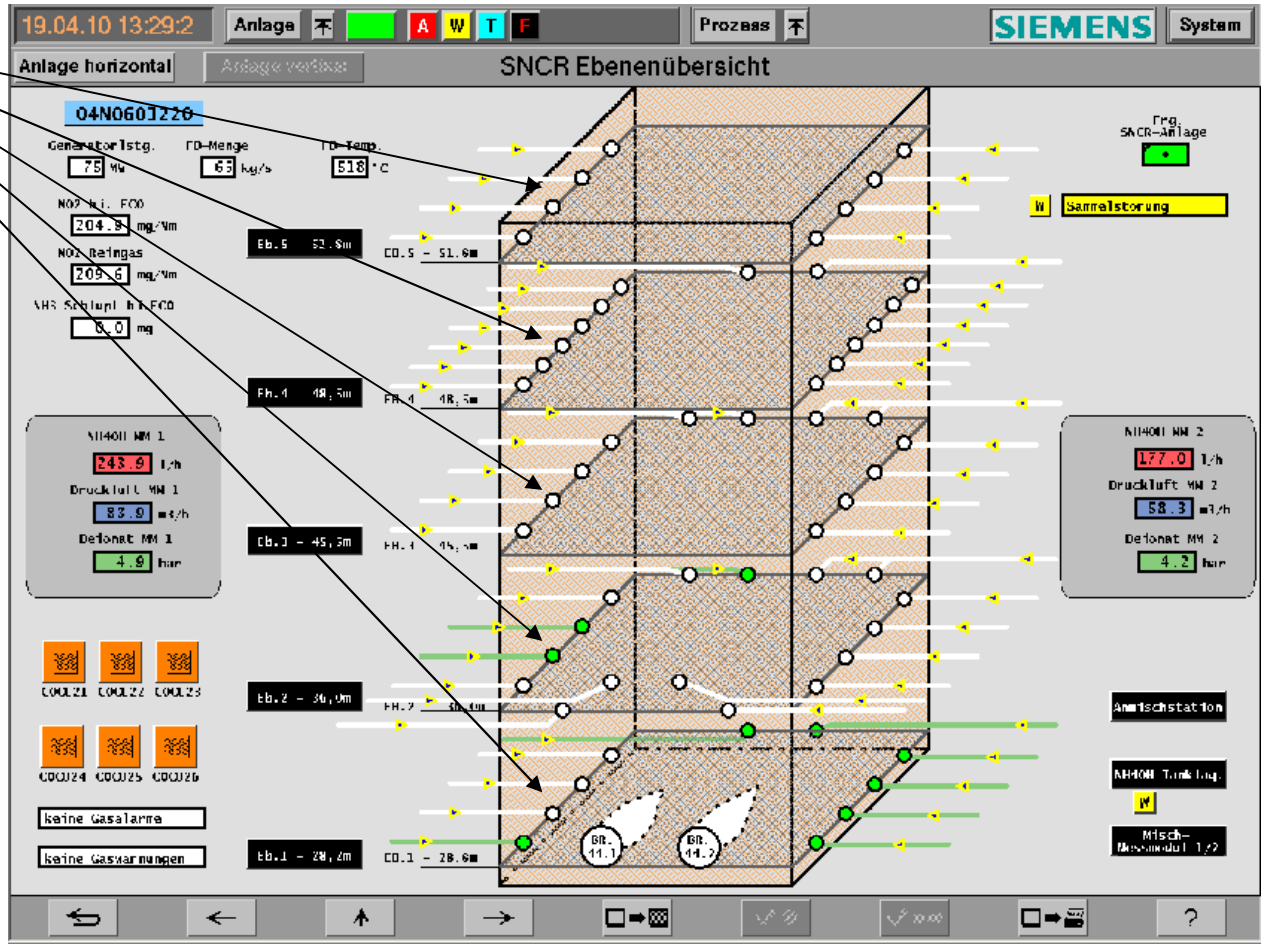




Introduction: Why SNCR in large scaled boilers?

SNCR-hardware installed by a third-party:

- 60 nozzles at five elevations incl. control system
- every nozzle can be opened or closed separately
- injection of ammonium water with groupwise controllable concentrations (max 25% NH3)

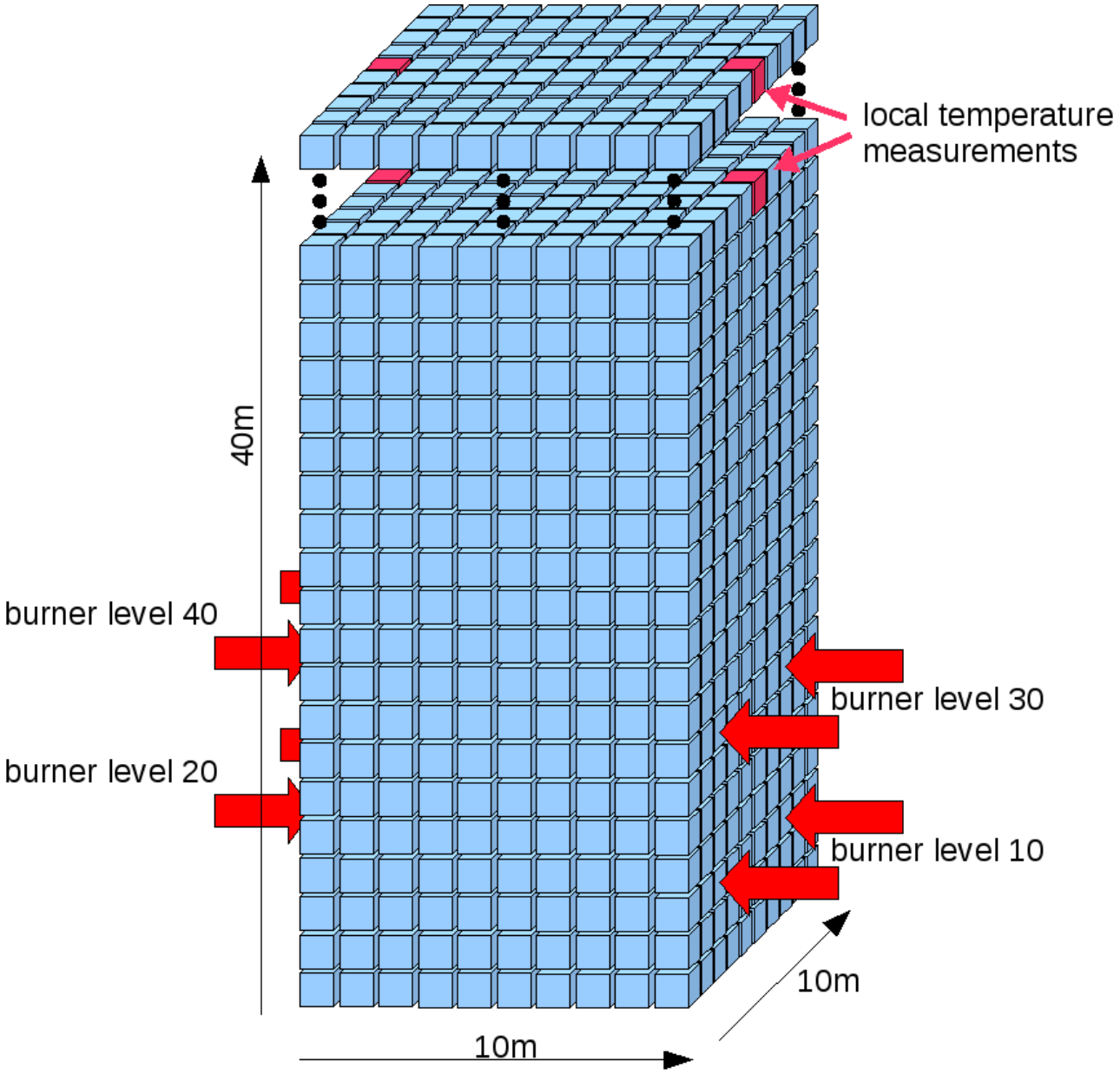


src: MKV Völklingen

Online - CFD

Basic-Principle:

- split furnace volume into 10*10*40 boxes
- integrate all available information (coal & air flows, flame temperature)
- solve RANS-equations (Reynolds Averaged Navier Stokes)
- online calibration with local measurements (temperatures, heat release, ...)



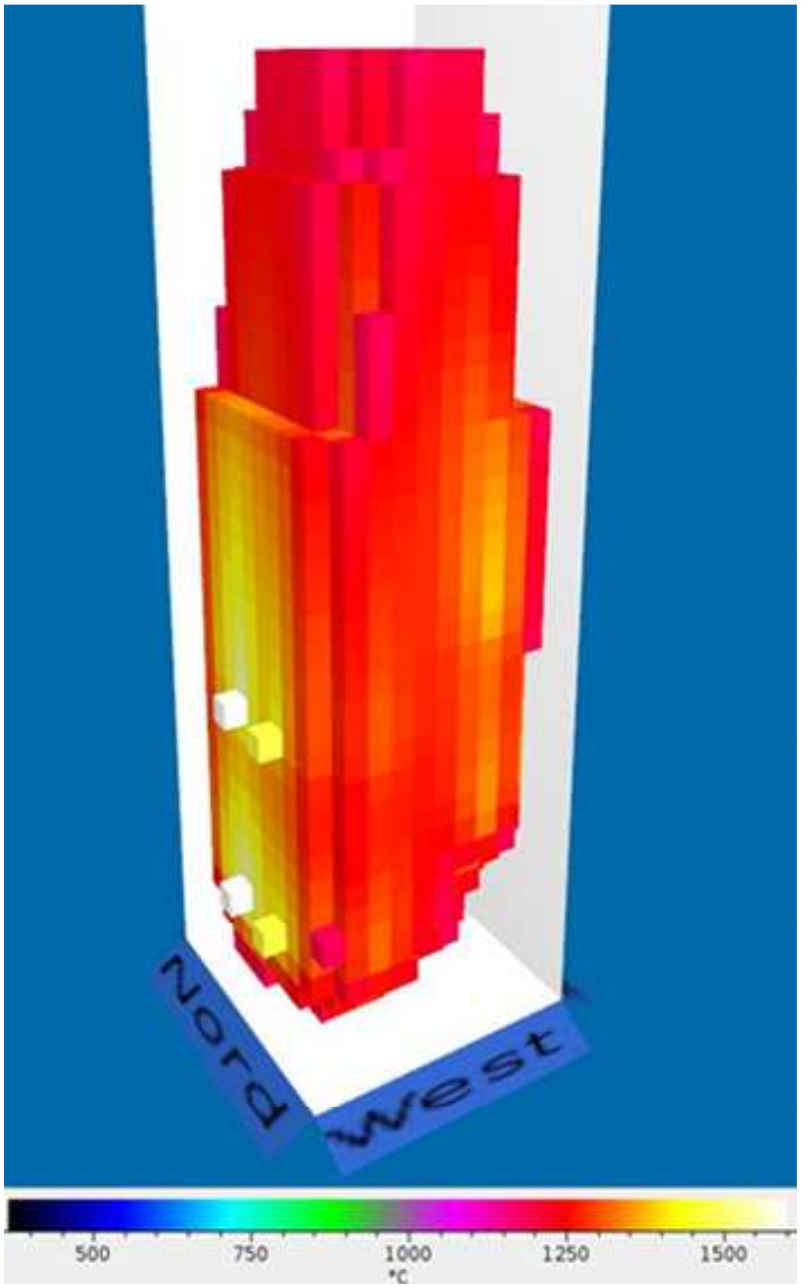
Online - CFD

Result:

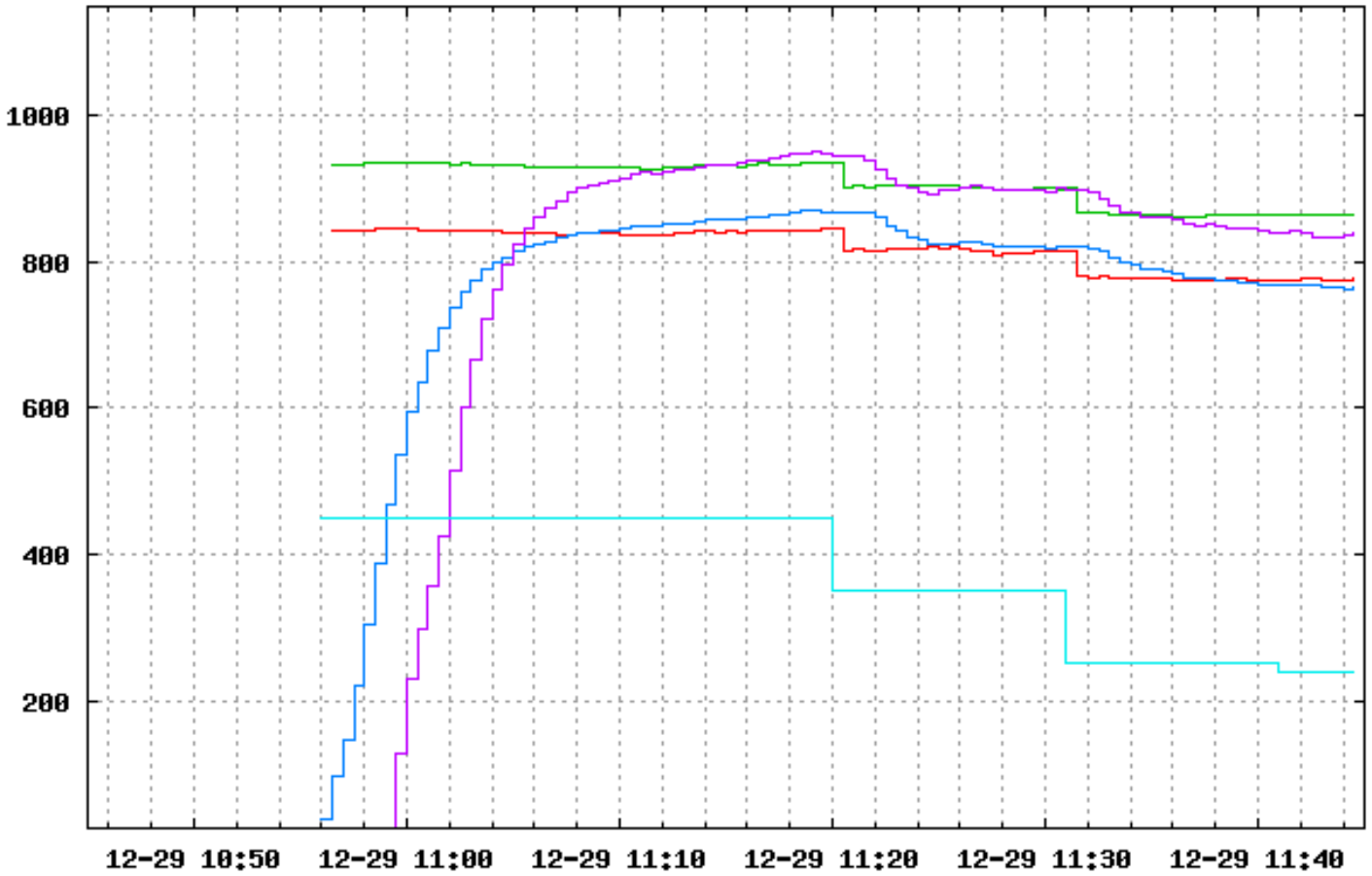
- Online-CFD provides 3D-temperature distribution of flue gas
- update every 20s
- online calibration with existing local temperature measurements

Plausibility Check:

- gas extraction pyrometer with 2 lances (2 positions at 1 elevation, 1 position at 2 elevations)



Online-CFD: Plausibility check by gas-extraction pyrometer



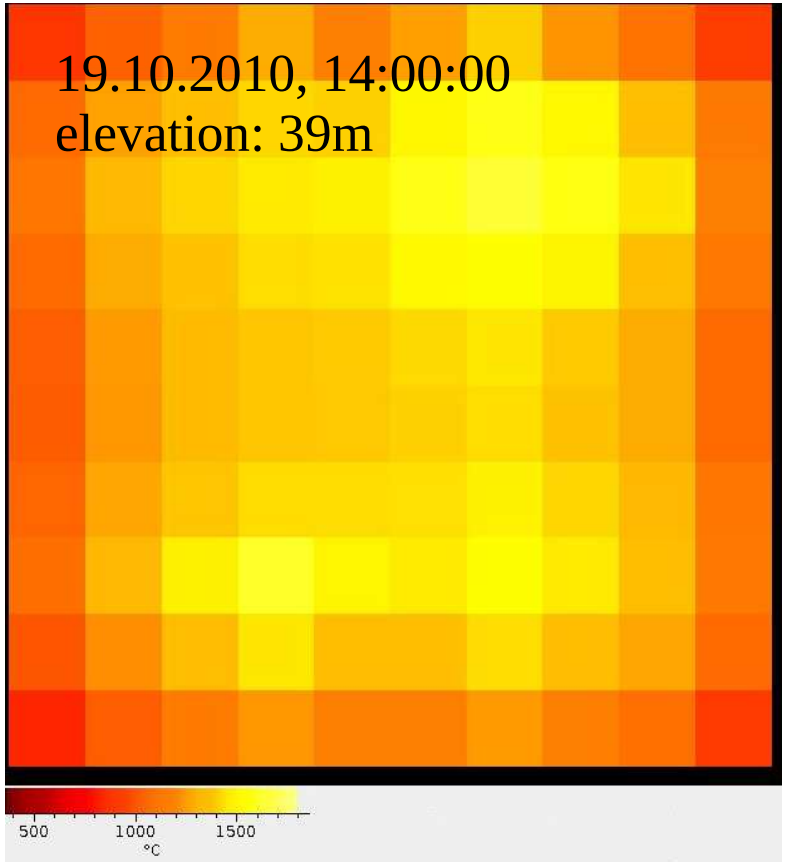
simulation 46m [°C]
measurement 46m [°C]
simulation 49m [°C]
measurement 49m [°C]

measurement depth [cm]

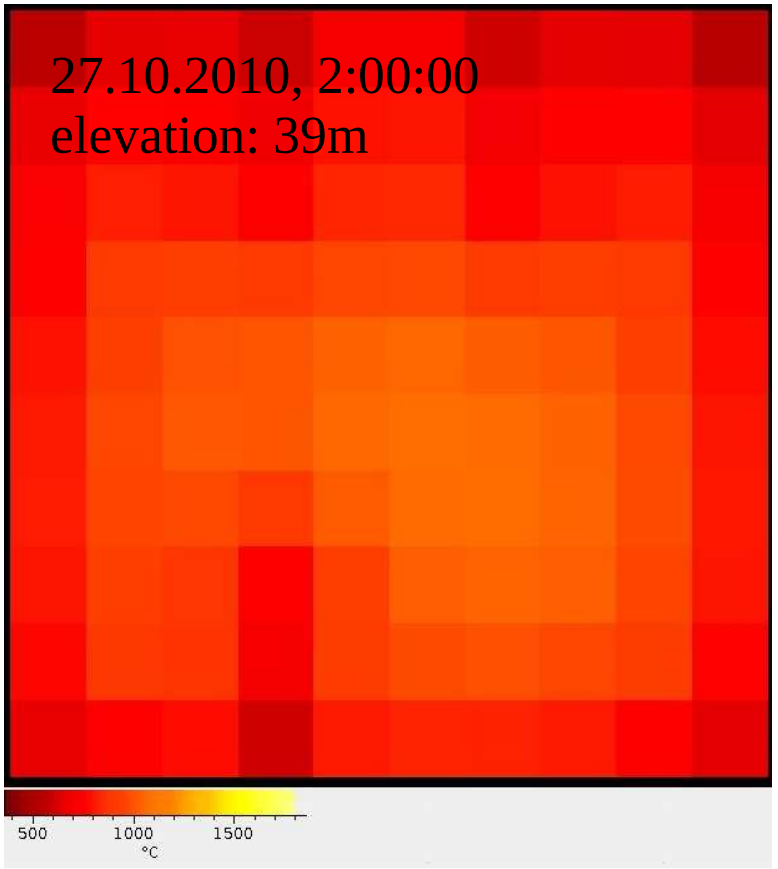
only small deviations between online-CFD and pyrometer!

Online-CFD: Plausibility check for horizontal profiles

full load



part load

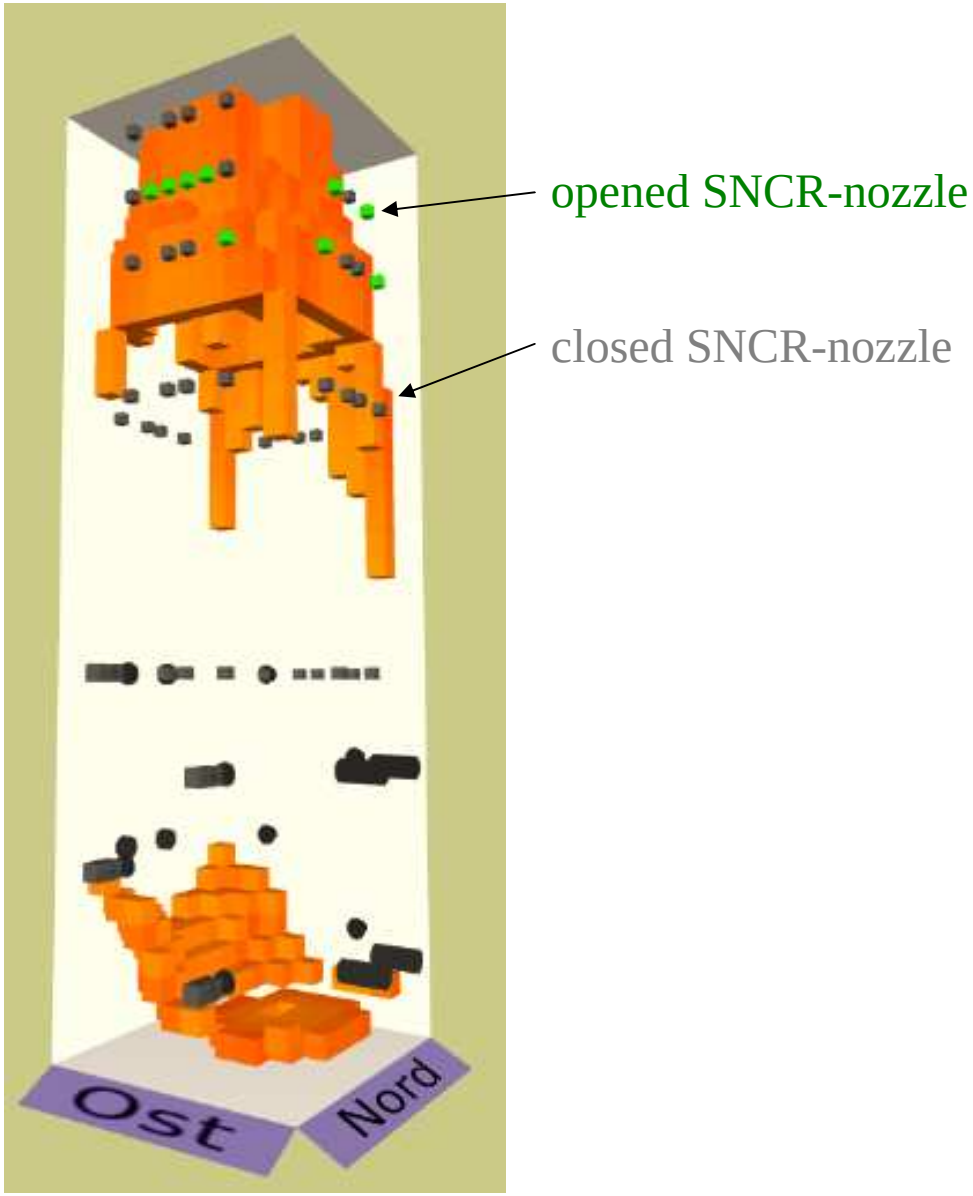


Online-CFD shows plausible temperature profiles

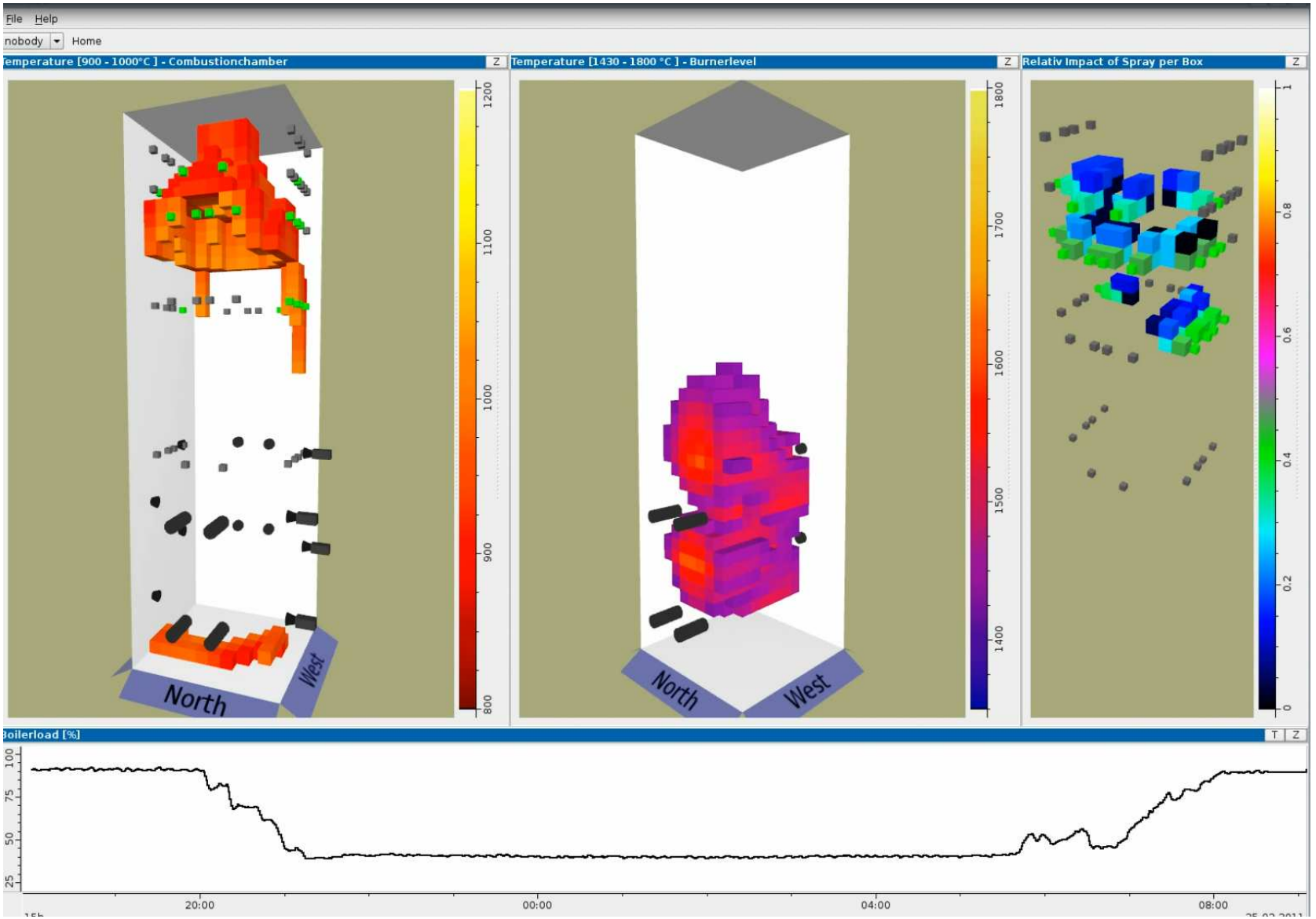
Secondary Activity for Reduction of NOx-Emissions

How to control SNCR-nozzles?

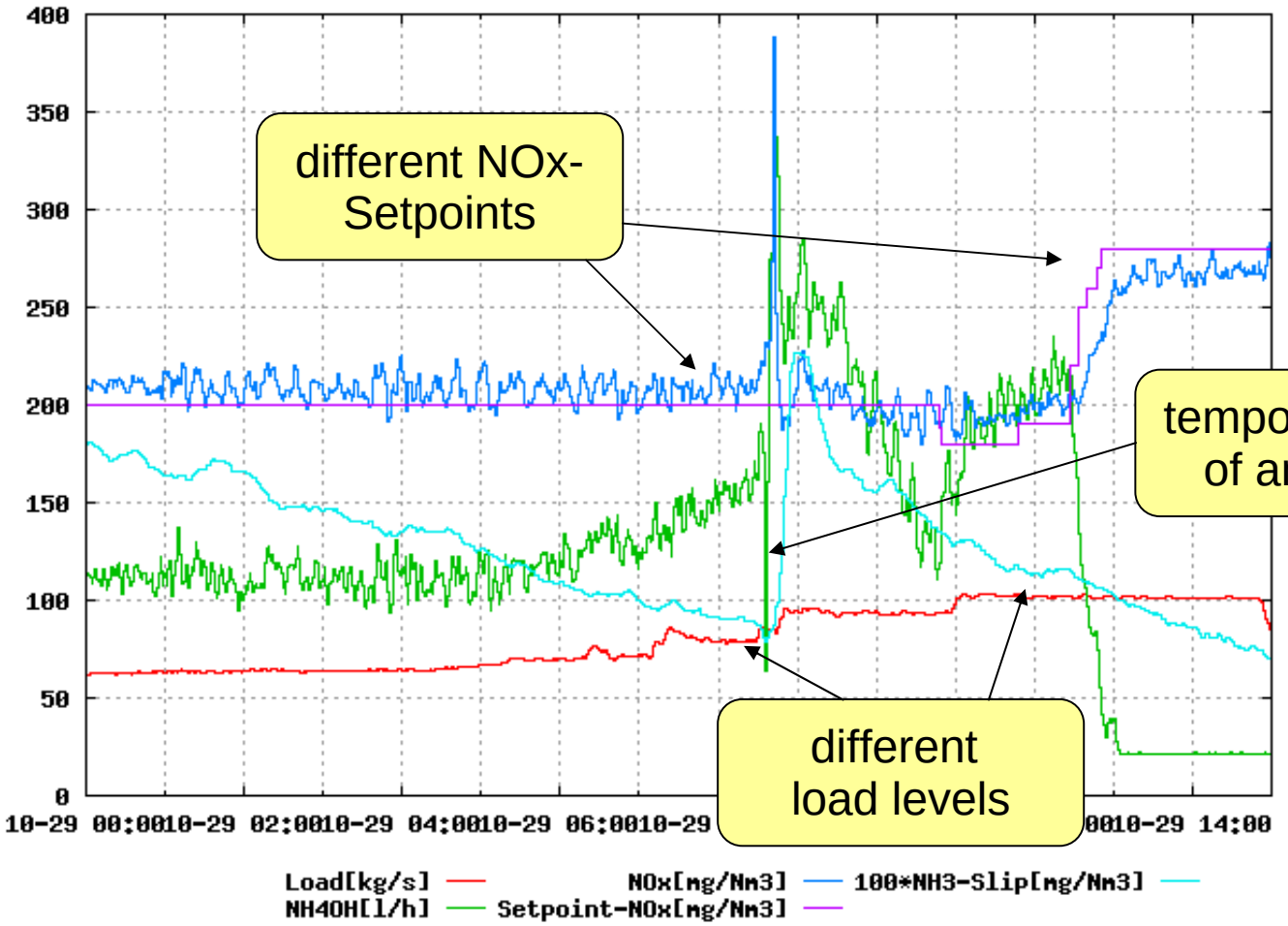
- calculation of flue-gas temperature reachable by each SNCR-nozzle
- open, if temperature within optimal range
- closed otherwise



Example:


File Help
nobody Home
Temperature [900 - 1000°C] - Combustionchamber
Temperature [1430 - 1800 °C] - Burnerlevel
Relativ Impact of Spray per Box
North
West
North
West
Boilerload [%]
20:00
00:00
04:00
08:00

SNCR-Results: Exemplary Time Plot



SP NOx [mg/Nm3]

NOx [mg/Nm3]

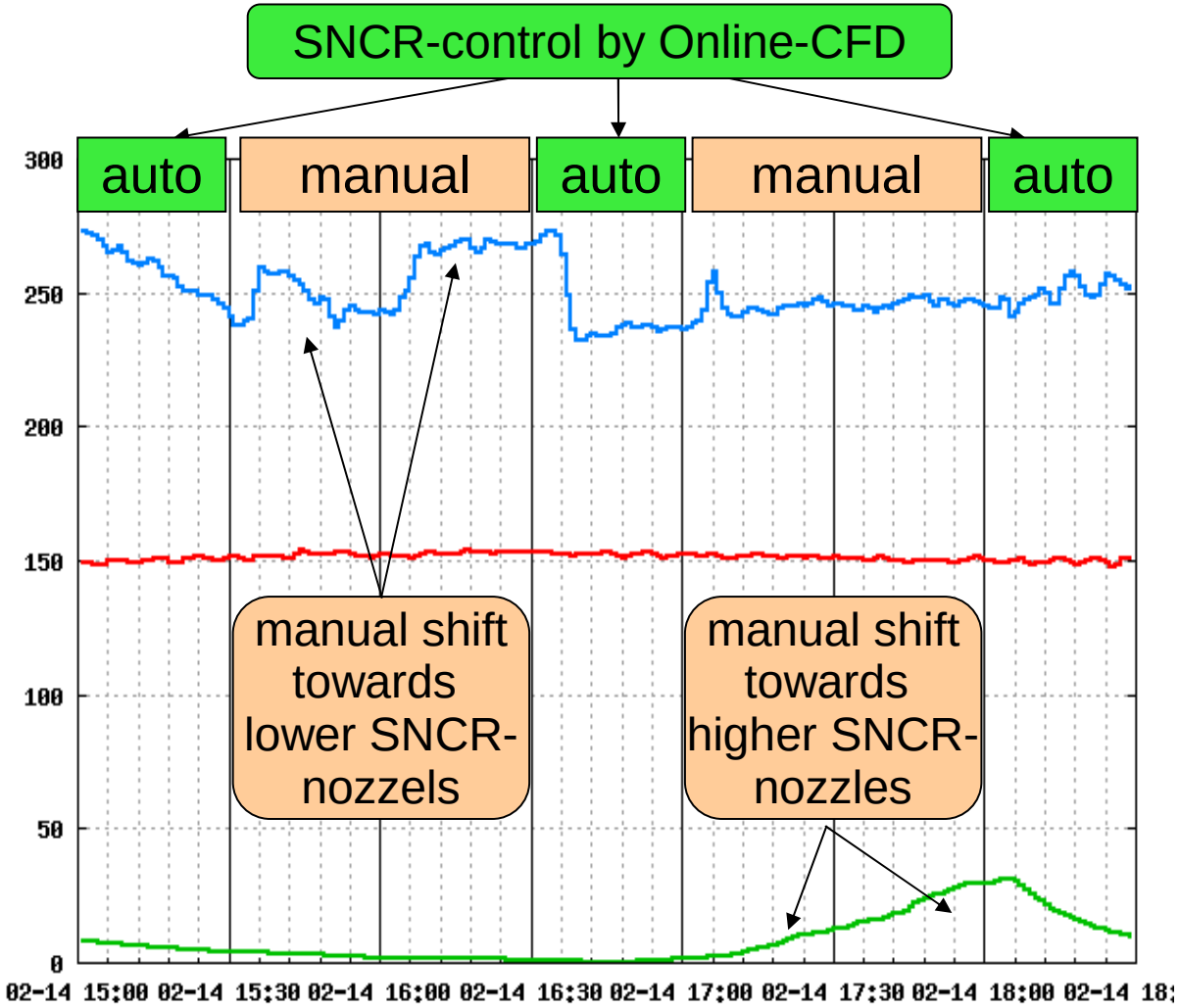
Steam [kg/s]

Slip*100 [mg/Nm3]

NH4OH [l/h]

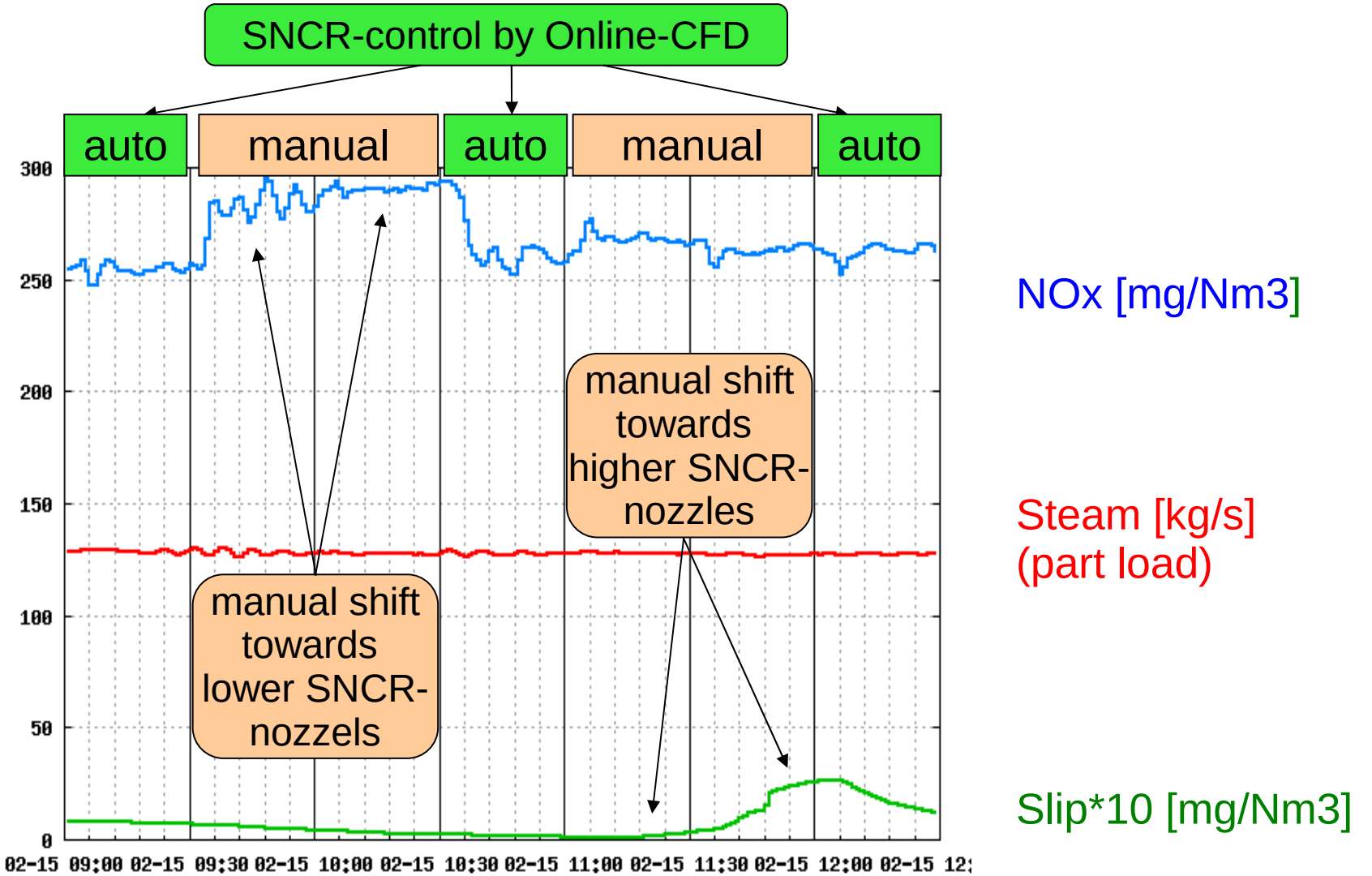
NOx-control works for different load levels

SNCR-Results: Manual Test to improve SNCR



Online-CFD finds optimal injection locations at full load

SNCR-Results: Manual Test to improve SNCR



Online-CFD finds optimal injection locations at part load

Summary

Powitec-approach for SNCR-Control:

- burner-side primary NOx-reduction on top of low-NOx-burners (third party) by optimization of air distribution and reduction of excess air
- 3D- online CFD of flue-gas temperatures
- modelling of mass, temperature and speed by solving RANS-equations (Reynolds Averaged Navier-Stokes-Equations)
- online calibration using plant measurements every 20s
- automatic nozzle-activation following online-CFD-temperatures

Summary

Results:

- burner-side primary NOx-reduction by 20mg/Nm^3 and increase of boiler efficiency
- automatic SNCR nozzle activation in suitable flue-gas temperature ranges
- safe NOx-limit compliance at 290mg/Nm^3 at all load cases

Evaluation (1.1.-18.5.2011):

load	40-60%	60-80%	80-100%
NOx in raw gas [mg/Nm^3]	370	316	320
NOx in clean gas [mg/Nm^3]	265	253	256
mean ammonia consumption [l/h]	202	226	324
mean ammonia slip [mg/Nm^3]	2.1	2.4	1.5

Thanks to

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Thank you very much

for your attention!