# McIlvaine Webinar Series - $NO_X$ (SCR, SNCR)
# Co-Coupling $NO_X$ Technologies – SNCR / SCR

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March 26, 2015

# STEAG Strategies

- STEAG has been an owner and operator of power plants since the mid 1930's.
- STEAG owns and operates 33 SCR reactors with most installed in the late 1980's to meet the environmental mandates.
- The current emission level in Germany is ~ 100 ppm moving down to 50ppm.
- Boiler / SCR's were originally designed for high ash mine mouth Brown coal fuels.  Today the fuel source is world sourced fuels (~ 300 different) with low / medium sulfur content.

# STEAG Reactors Designs

- **Late 1980 designs based on Japanese experience.**
- **Originally designed for high ash fuels; medium / low sulfur fuels.**
- **STEAG reactors do not have standard size catalyst modules.**
  - **Standard US Size ~2 meter X 1 meter  (6.6' X 3.3')**
  - **STEAG Module Size**
    - Small  Size: 1 meter X 1 meter (~3.3' x 3.3'
    - Large Size: 2.7 meters X 1.5 meters (~4.9' x 8.8')
    - Reactors designed for catalyst log length up to about 1.1 Meter (current size catalyst in industry up to 1.350 M)

STEAG – Weiher Station

STEAG – Bexbach Station

# What does this mean?
# STEAG Unidentified Unit

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- The current reactors have a 60% removal efficiency.
- Future reactor $NO_X$ removal will force the reactor to an 80 - 85% removal efficiency.
- Optimization of the catalyst can provide a little improvement in potential (Roughly a 5% increase).
- The SCR alone will not make it!
- Significant increase in replacements / modifications.

| | | Existing | Future | |
|---|---|---|---|---|
| Unit Configuration | | | | |
| Number of Modules | Per Layer | 96 | 96 | 96 |
| Layer per reactor | # | 3 | 3 | 3 |
| Catalyst Info. | | | | |
| Catalyst Pitch | mm | 7.1 | 7.1 | 7.1 |
| Cells | # | 21 | 21 | 21 |
| Catalyst length | | 1000 | 1000 | 1000 |
| Operating Conditions | | | | |
| Flow Rate | Nm3/h @ 0 °C | 1,234,365 | 1,234,365 | 1,234,365 |
| Temperature | F | 725 | 725 | 725 |
| Fluegas Conditions | | | | |
| NOx Inlet | ppmvd | 302 | 302 | 302 |
| SO2 Inlet | ppmvd | 242 | 242 | 242 |
| Oxygen | % | 3.1 | 3.1 | 3.1 |
| Moisture | % | 12.5 | 12.5 | 12.5 |
| Slip | ppm | 2 | 2 | 2 |
| | | | | |
| Nox Removal | % | 60% | 80% | 85% |
| Nox Outlet | ppm | 121 | 60 | 45 |
| | | | | |
| Potential Minimum | | 3.26 | 3.85 | 4.06 |
| Layer Potential | | 2.53 | 2.78 | 2.53 |
| Max Catalyst Potential | | 7.59 | 8.34 | 7.59 |
| Deactivation Amount | | 4.3 | 4.5 | 3.5 |
| De-activation Percentage | | 33% | 17% | -13% |

# What can be done to increase life

## The Dilema?

- **Reactors are at the maximum limit for catalyst additions.**
- **SCR Reactor foot print is set.**
- **Reactor designs is nearly 25 years old.**

## Possible Solutions

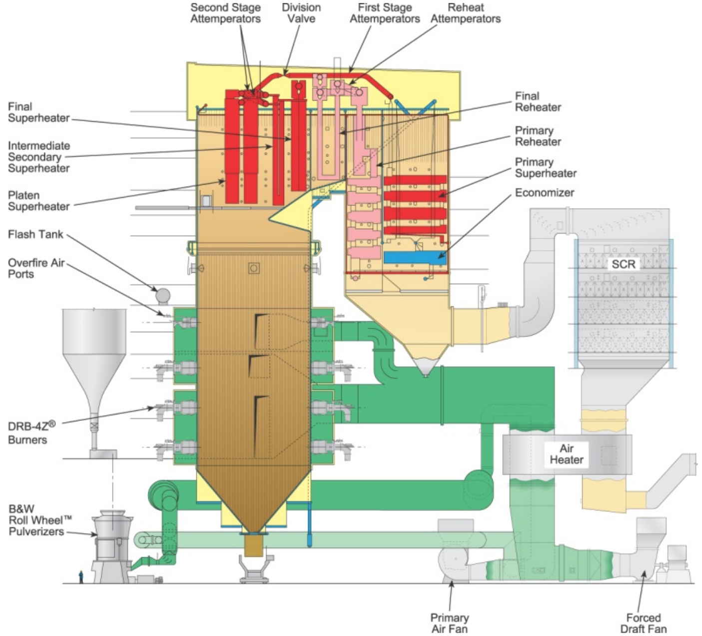
- **Adding a tailing end SCR.**
- **Modifying of the existing SCR.**
- **Adding of other $NO_X$ removal technologies.**

# Co-Coupling of Technologies

- **Modification or addition of SCR's is extremely capital intensive.**
- **Energy Market is completely de-regulated which requires more moderate expenditures.**
- **<u>S</u>elective <u>N</u>on-<u>C</u>atalytic <u>R</u>eduction (SNCR) is a viable alternative.**
  - Has been done and is a commercially available – STEAG has designed over 18 & have 2 units in the STEAG's fleet operational.
  - Low capital cost alternative.
  - Common reagent possible.

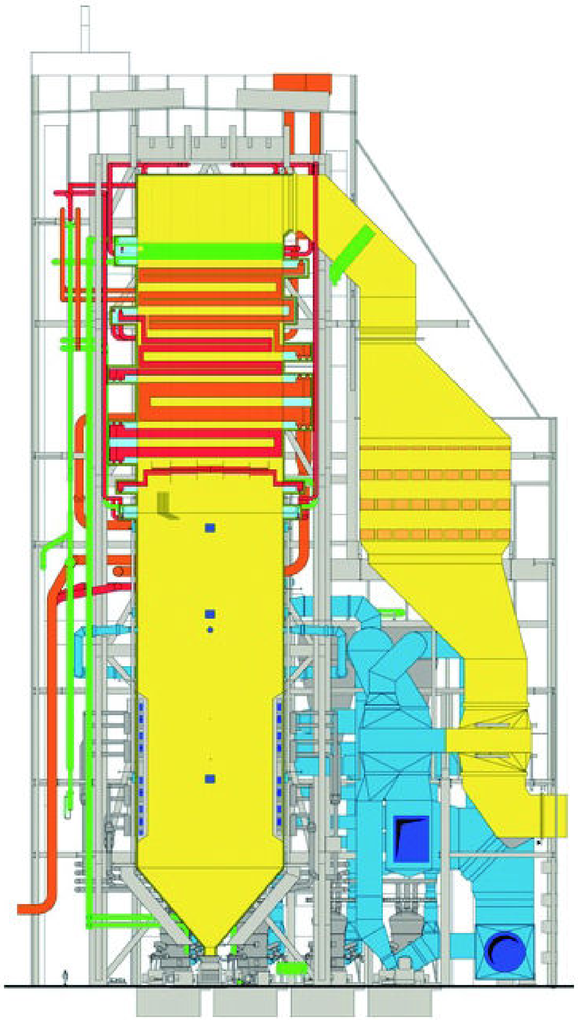
# STEAG Boiler configurations

- **Different Types of Boiler Designs.**
- **Most of STEAG newer higher efficiency boilers are tower design boilers.**




Typ. Backpass Boiler

Babcock & Wilcox Design



Typ. Tower Boiler

# SNCR Configuration

- **The SNCR Reactions:**

  **Aqueous Ammonia Reactions**

  $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$

  $2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$

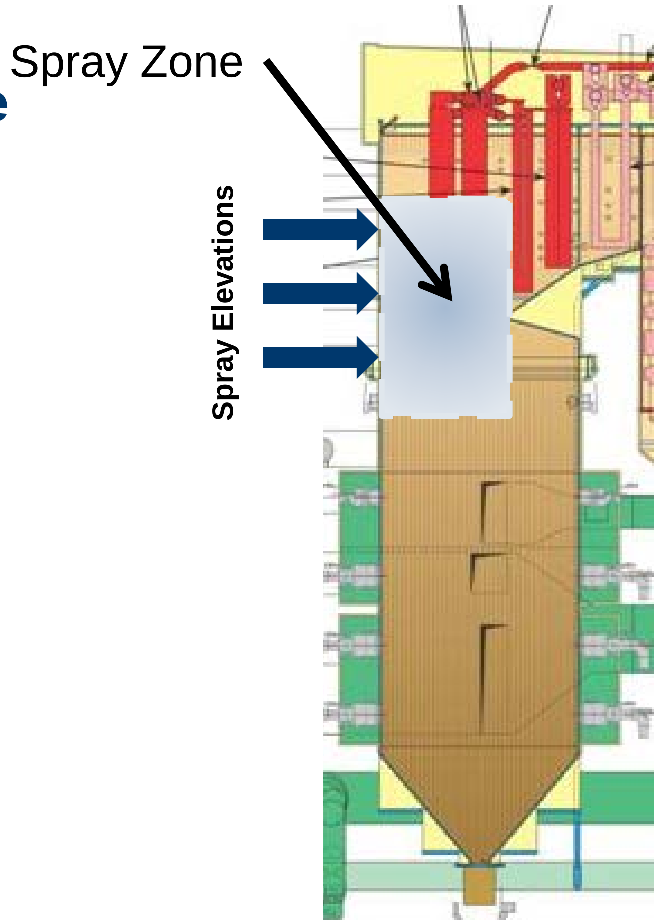
  **Urea Reactions**

  $2CO(NH_2) + 2NO + 1/2\ O_2 \rightarrow 2N_2 + CO_2 + 2H_2O$

- **Reagent Devolatilization**
  - **Aqueous Ammonia is a quick reaction.**
  - **Urea is a longer reaction.**
- **Ideal temperature zone for SNCR is 1600 $^{o}$F to 2200 $^{o}$F furnace Temperature. The temperature zone changes height with changing elevation.**

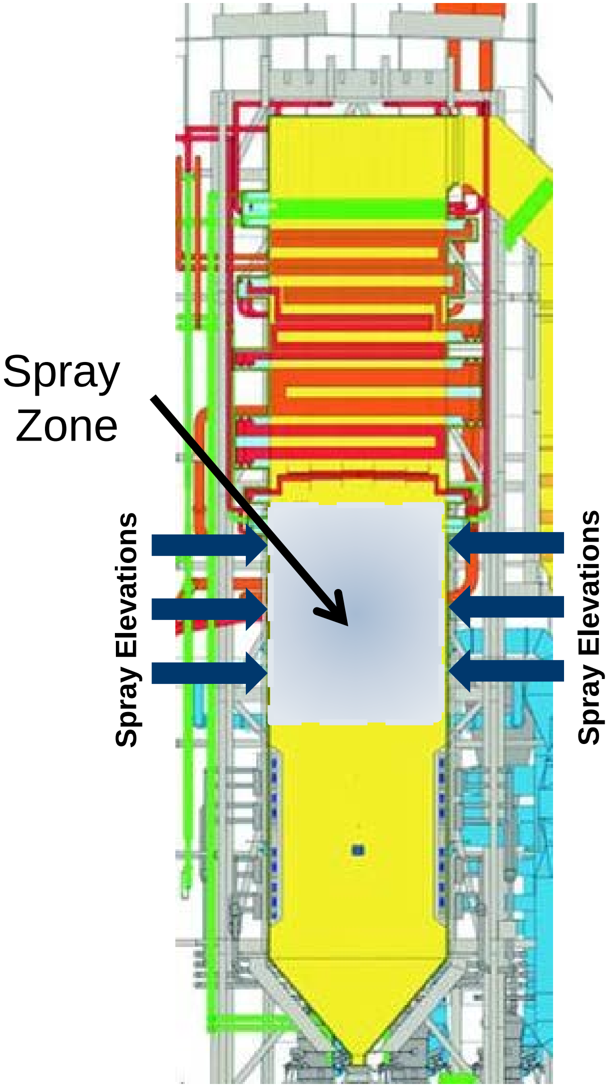
# SNCR Design – Backpass design

- **Normally in a Backpass boiler the spray zone is from the front wall of the unit and possibly on the front size walls.**
- **For depth of penetration, urea is normally utilized since the devolatilization takes longer.**
- **Normally four to eight probes across width of unit at 2 to 3 elevations (Low load versus higher load operation)**
- **Normally a 20 to 35% reduction. Greatly dependant upon on the spray distribution and temperature zones.**



# SNCR Design – Tower Boilers

- The zone is above the burners to below the high temperature superheater.
- Access can be from all four (4) walls of the unit.
- Better flow distribution for spray distribution.
- Spray needs to adjust elevation based on the load conditions.
- Typical 20 – 30% reductions with Ammonia can be achieved greater with urea.



# What is needed for reduction?

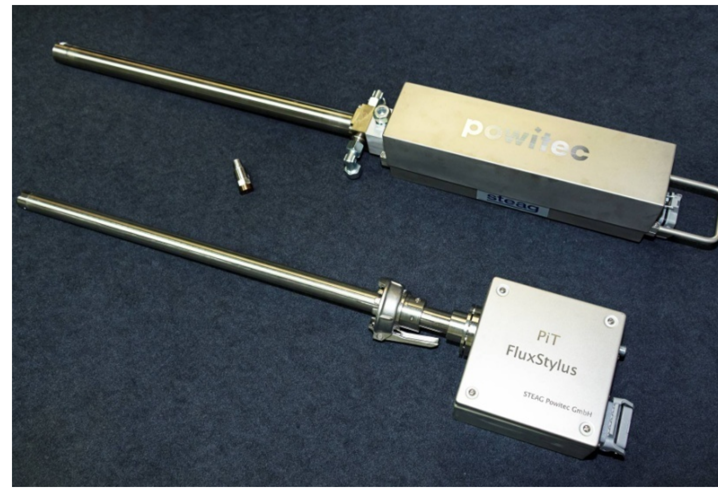
- **The objectives of the SNCR?**
  - Provide additional NOX removal margin.
  - Economical capital.
  - Economical reagent.
- **Referring back to the original example.**
  - Need a 39% SNCR reduction to obtain a similar outlet NOX level of 50 ppm.
  - The SCR performance would result in the following:

| | | Existing | Future (SCR Only) | | Future (SCR / SNCR) | |
|---|---|---|---|---|---|---|
| Nox Removal (SCR) | % | 60% | 80% | 85% | 79% | 74% |
| Nox Outlet | ppm | 121 | 60 | 45 | 45 | 45 |
| | | | | | | |
| Potential Minimum | | 3.26 | 3.85 | 4.06 | 3.58 | 3.32 |
| Layer Potential | | 2.53 | 2.85 | 2.85 | 2.78 | 2.78 |
| Max Catalyst Potential | | 7.59 | 8.55 | 8.55 | 8.34 | 8.34 |
| Deactivation Amount | | 4.3 | 4.7 | 4.5 | 4.8 | 5.0 |
| De-activation Percentage | | 33% | 22% | 11% | 33% | 52% |

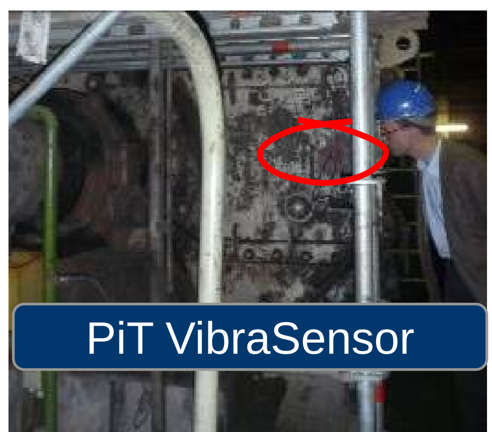
  - This is a stretch for the conventional SNCR performance.

# “Real Time” CFD Modeling

- **STEAG developed a system called STEAG Powitec which is “real time” CFD model.**
- **A CFD model is built for the unit and then inputs from the control room and sensor that are installed into the furnace.**
- **There are 150 references for Powitec realtime CFD systems.**








# Modeling of the parameters

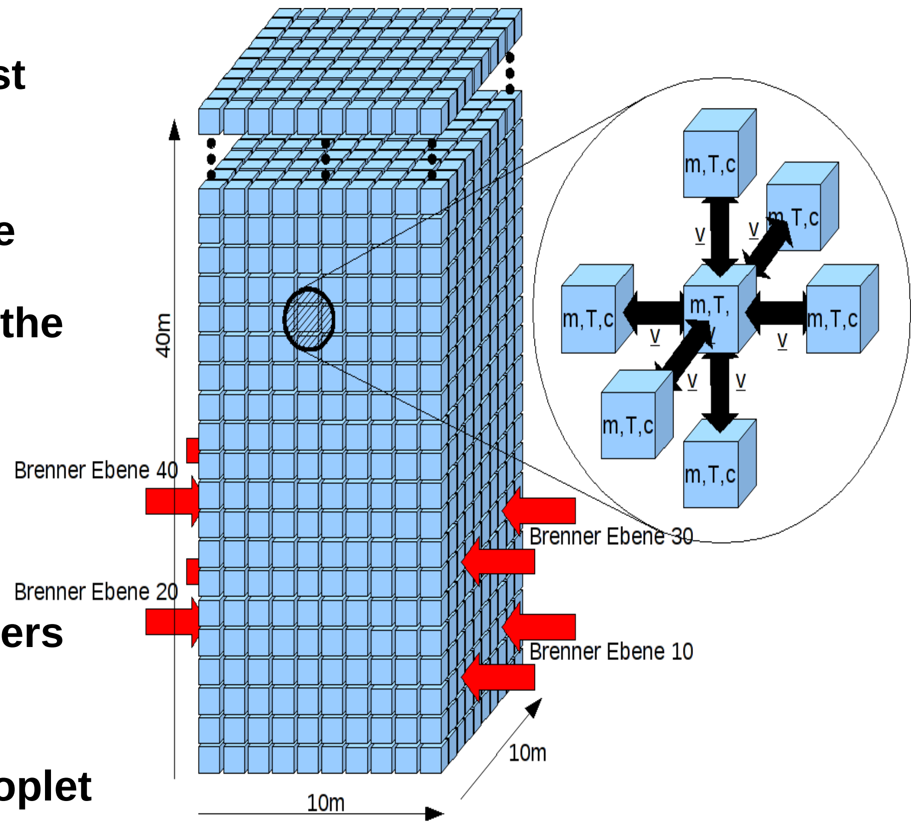
- **Model of the flames**
  - **Thermal and dynamical flame changes**
  - **In dependency of load changes, coal dust allocation, heating value**
- **Combustion Chamber Model**
  - **Separation of the relevant part in volume elements**
  - **For each volume element calculation of the flue gas parameters:**

    Temperature

    Mass Flow

    Density

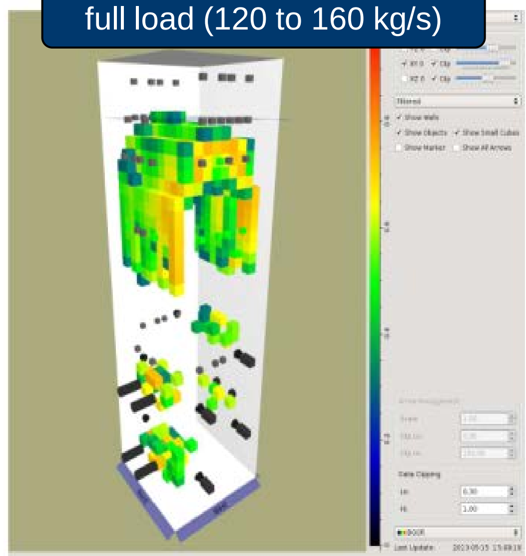
    Speed in x, y und z-Direction
  - **Modelling of over fire air and super heaters**
  - **Consideration of soot blowing**
  - **Modelling of wall slagging**
  - **Balancing of the injected $NH_4OH$ and droplet spectra**
- **Solving of RANS equation (Reynolds Averaged Navier Stokes)**
- **Online-Calibration**
- **Validation**



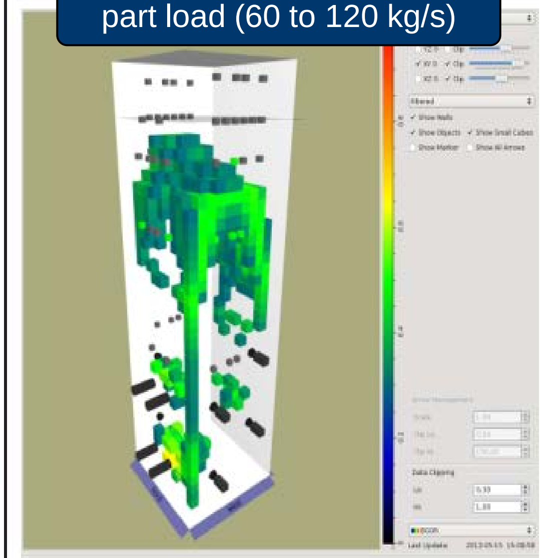
# Determination of SNCR

- **Frequency of occurrence of an optimal temperature window (980°C to 1020°C) over 1 month with several coal mixtures. Highest frequency would be indicated in red, lowest in blue.**
- **Results lances to be positioned at:**
  - **Full load: Level 47m**
  - **Part load: Level 43m**
  - **Low load: Level 38m to 40m**
- **Independent lances installed on all 4 walls**

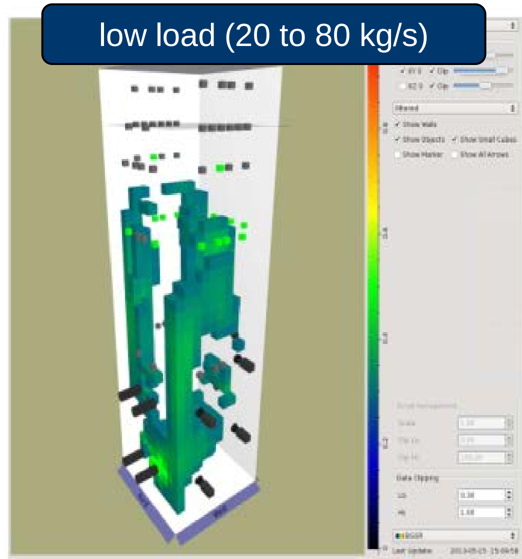
full load (120 to 160 kg/s)



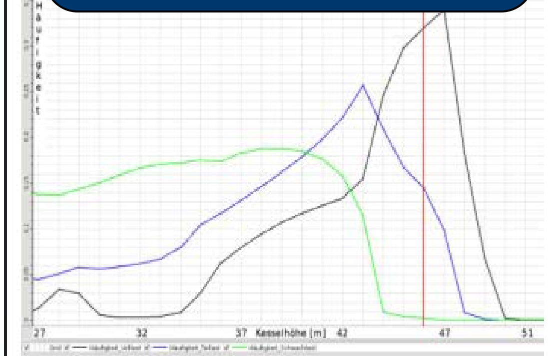
part load (60 to 120 kg/s)



low load (20 to 80 kg/s)

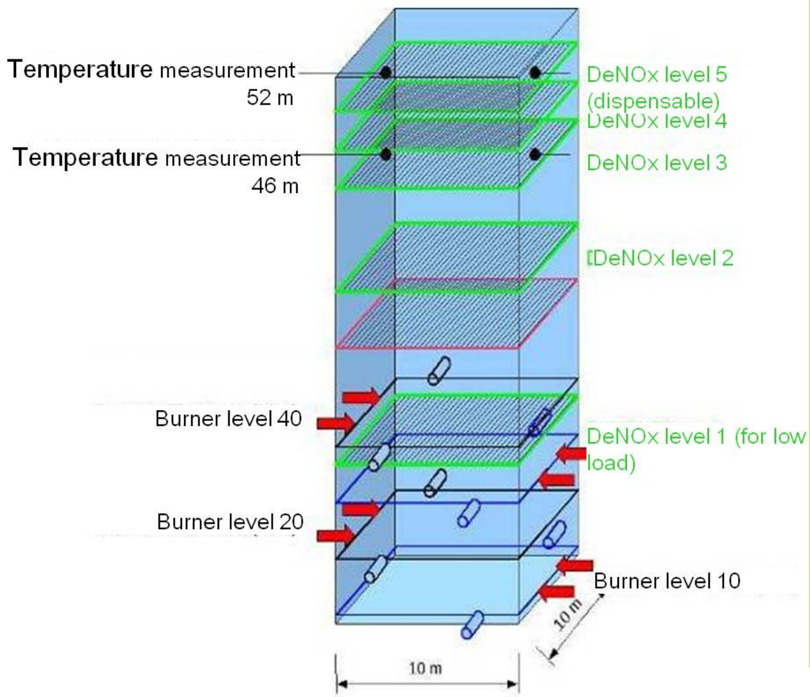


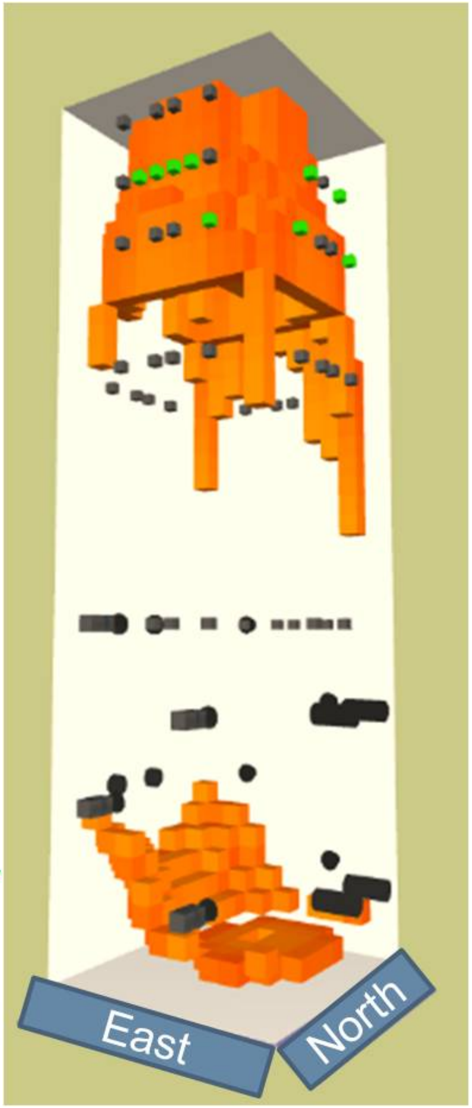
Graphs showing the injection rates at the under the various loads.
- full load in black
- part load in blue
- low load in green



# The SNCR Configuration

- **Based on the CFD Model, 5 elevations were selected.**
- **Probes on all four walls.**
- **Number of ports varied per elevation based on the CFD models.**



# Conclusions

- Co-coupling of the SCR and the SNCR can accomplish a low cost alternative to meet $NO_X$ objective.
- The SCR should be optimized before reviewing SNCR options.
- Elevated NOx reduction with the SNCR to achieve lower overall reductions.
- Combustion intelligence systems (Real time CFD modeling) will be required to achieve the greater removal levels.
- Ammonia Slip from the SNCR becomes less critical as it is destructed in the SCR.
- STEAG is working on SNCR / Higher intelligence systems to achieve 50% or greater reductions.

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