SCR technology for NOx control

CCPP, power generation with highest overall efficiency at lowest emissions limits

Johannes Lind
ANDRITZ Energy & Environment

Christian Fauland
VERBUND Thermal Power

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- General
- Products of ANDRITZ air pollution control
- Best Available Techniques (BREF document)
- Emission Limits for CCPP in Europe
- Performance data for Mellach power plant
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General

- ANDRITZ has supplied secondary NOx emission control equipment for various types of firing and fuels (coal, oil, gas, biomass, waste, off gases etc.)
- ANDRITZ`s first reference for Selective Catalytic Reduction (SCR) of NOx was started up in the year 1986 at the coal fired power plant Mellach/ Austria.
- The strict Austrian emission limit for NOx leads to first integration of SCR for CCPP in Leopoldau, Linz Süd and Donaustadt Unit 03.
- ANDRITZ was awarded contracts for 2 x SCR at CCPP GaoAnTun in Beijing/China in 2012.
- SCR for Mellach CCPP Unit 10 & 20 was taken over in 2012

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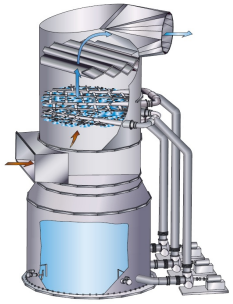
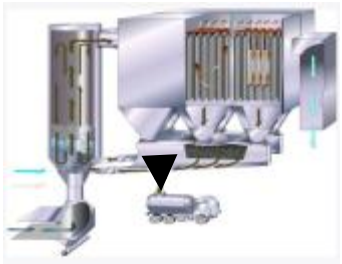
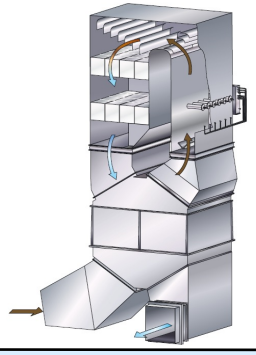
Products of ANDRITZ air pollution control

Wide product range for removal of SOx, dust, Hg, heavy metals, NOx, ….

	Wet method	Dry method	DeNOx
			
POWER STATIONS	Wet limestone FGD FGD plus Mercury removal Sea Water FGD CO2 absorption	Dry Sorption Turbo CDS / TurboSorp Mercury removal Dust removal	SCR (high dust application) SCR for combined cycle power plants (CCPP)
INDUSTRY **incl. EfW and biomass**	Wet FGC (calcium and NaOH based) Multistage scrubber Combined systems	Dry Sorption TurboSorp	SCR (low dust / clean gas application)

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BAT (Best Available Technique) for CCPP emission limits

Plant Type (new large combustion plants, LCP)	Emission level associated with BAT (mg/m³n)		O_2 level (%)	BAT options to reach this level
	NOx	CO		
New CCPP without supplementary firing	20-50	5-100	15	Dry low NOx premix burners or SCR
New CCPP with supplementary firing	20-50	30-100	Plant spec.	Dry low NOx premix burners and low NOx burners for the boiler part or SCR or SNCR

Dry Low NOx burner (DLN)

DLN basic characteristic: mixing of combustion air and fuel before combustion

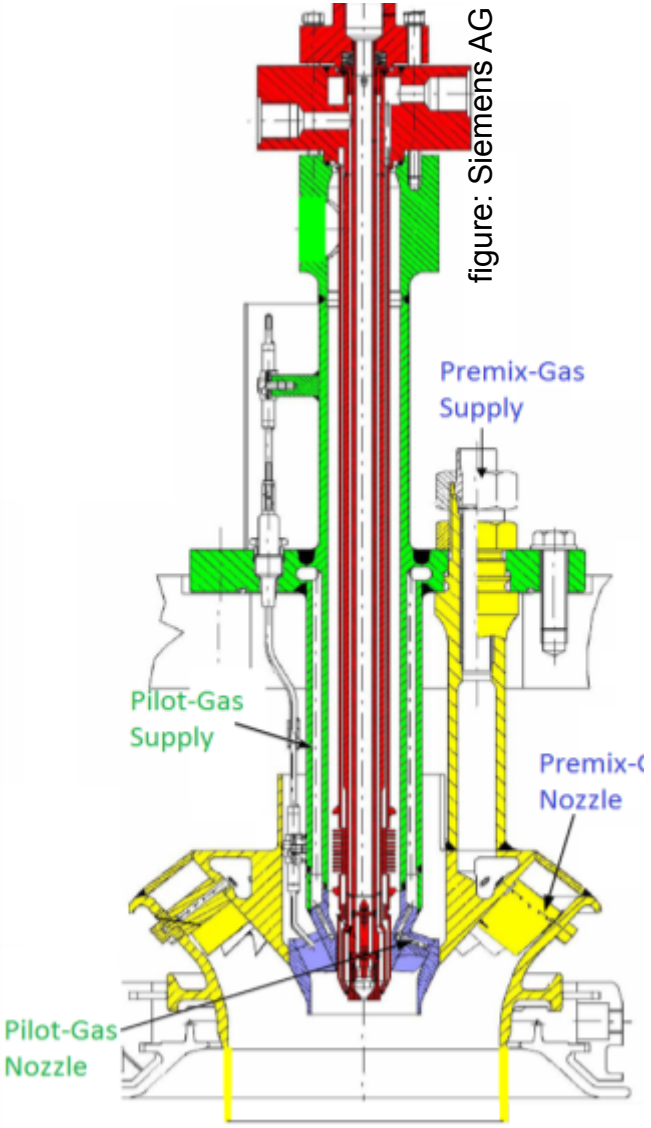
⇒ homogeneous temperature distribution

⇒ lower flame temperature

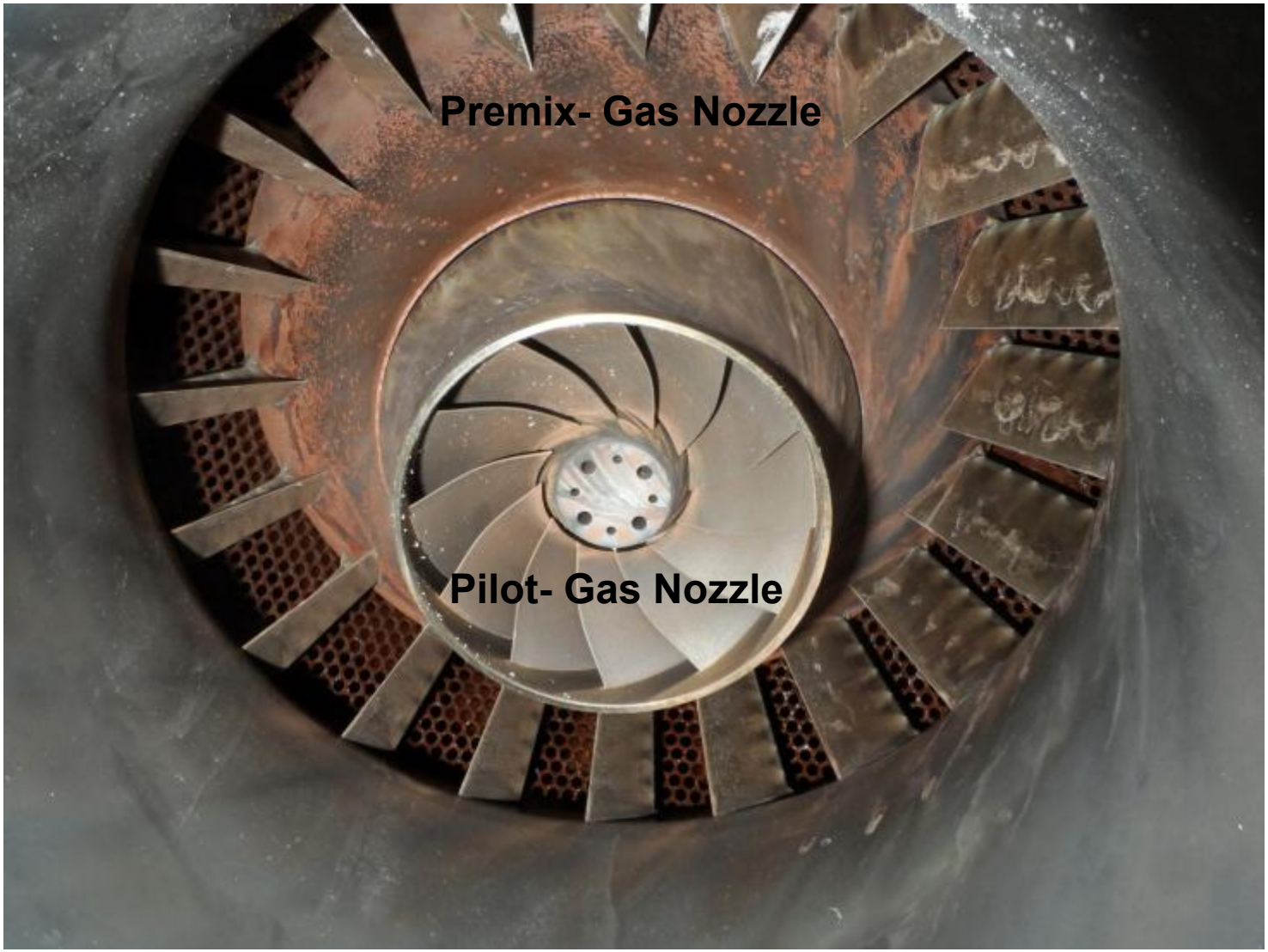
⇒ lower NOX emissions

CCPP Mellach:

- Siemens SGT5-4000F(6) with annular combustion chamber
- 24 HR3-burners (PMP)
  - 2-stage hybrid-burner
  - premix-pilotgas (PMP): mixing of pilotgas and air axial swirler => NOx-reduction
  - premix-gas: mixing of premix-gas and air in diagonal swirler => NOx-reduction



Dry Low NOx burner (DLN)



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Emission limits for CCPP in Europe

Plant	Emission limit (mg/m³n,dry)			O_2 level (%)
	NOx	NH_3	CO	
EU-directive LCP	50 *	-	-	15
Austrian Law (LRV-K)	35	10 (at 0 % O_2)	35 **	15
Permit for CCPP Mellach	20 ***	10 (at 0 % O_2)	35 **	15

*) valid for power output at ISO conditions > 50 MW thermal, the emission limits apply for loads higher than 70 % resp.:

NOx < 75 mg/Nm³ (efficiency of the gas turbine determined under ISO base load conditions) in the following cases :

- Gas turbines used in a combined heat and power generation with an overall efficiency higher than 75 %;
- Gas turbines used in combined cycle plants having an overall annual average electrical efficiency higher than 55 %.

**) at 100 % load

***) from minimum load to 100 % load

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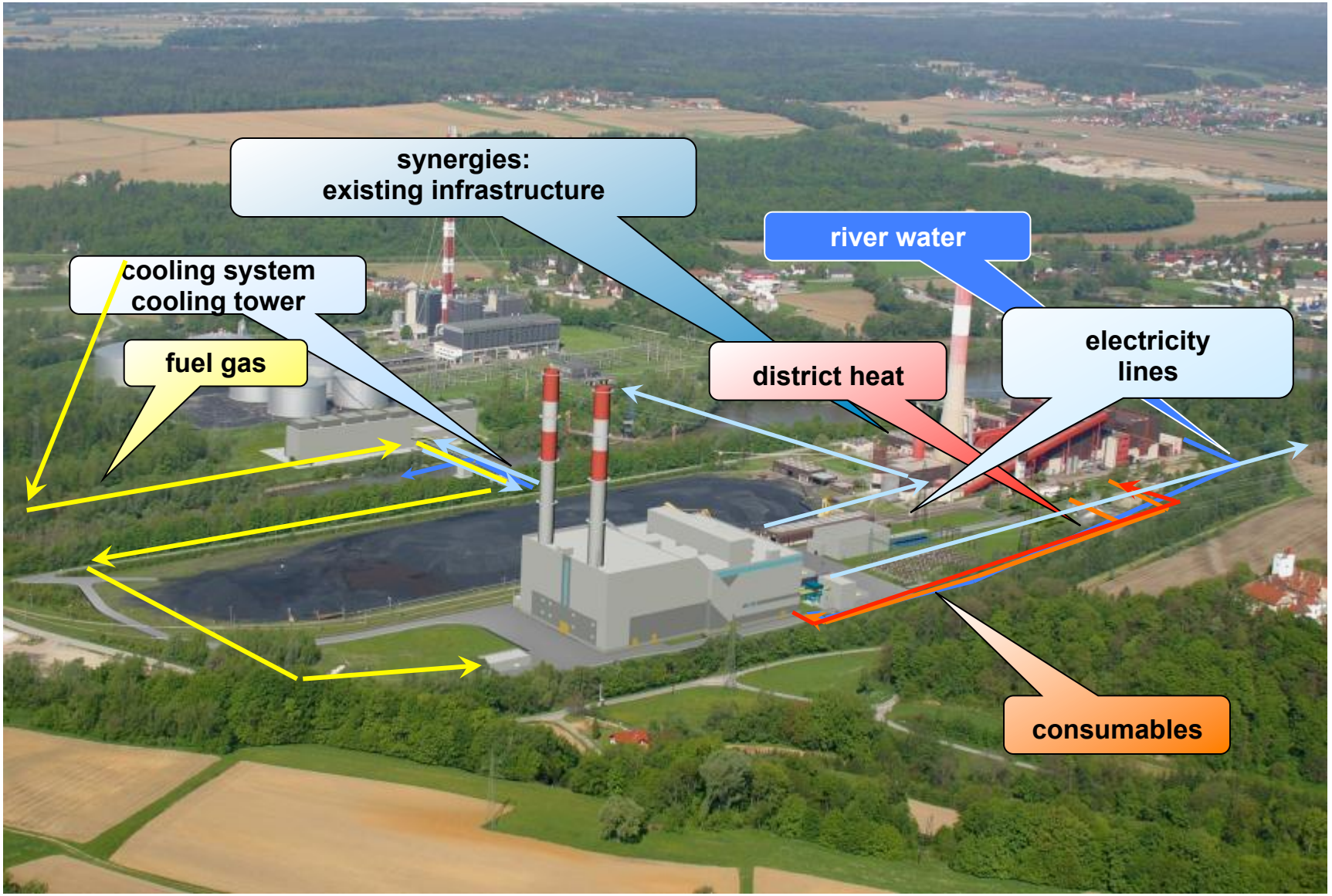
Performance data for Mellach power plant

Data	Unit	
Net electrical power output Unit 10	MWel	421
Net electrical power output Unit 20	MWel	417
Max. total district heating output	MWth	400
Net efficiency Unit 10 (river water cooling)	%	59,6
Net efficiency Unit 20 (cooling tower)	%	58,7
Fuel conversion efficiency (400 MW district heating)	%	81

Input/output of CCPP Mellach



Performance data for Mellach power plant

KEY DATA

UNIT: **2 x SCR for CCPP Mellach/AUSTRIA**
CUSTOMER: **VERBUND Thermal Power**
Start-Up 2011/12

TECHNOLOGY/SUPPLY:
2 x SCR integrated into HRSG

Fuel:	natural gas
Capacity:	total 838 MW_{el}
Flue Gas Flow:	2 x 2,110,000 m^3/h (std_{wet})
NO_x inlet:	61.6 mg/m^3 (std_{dry},15% O_2)
NO_x outlet :	<20 mg/m^3 (std_{dry},15% O_2)
NH_3- slip:	<10 mg/m^3 (std_{dry},0% O_2)
Reducer:	Anhydrous ammonia

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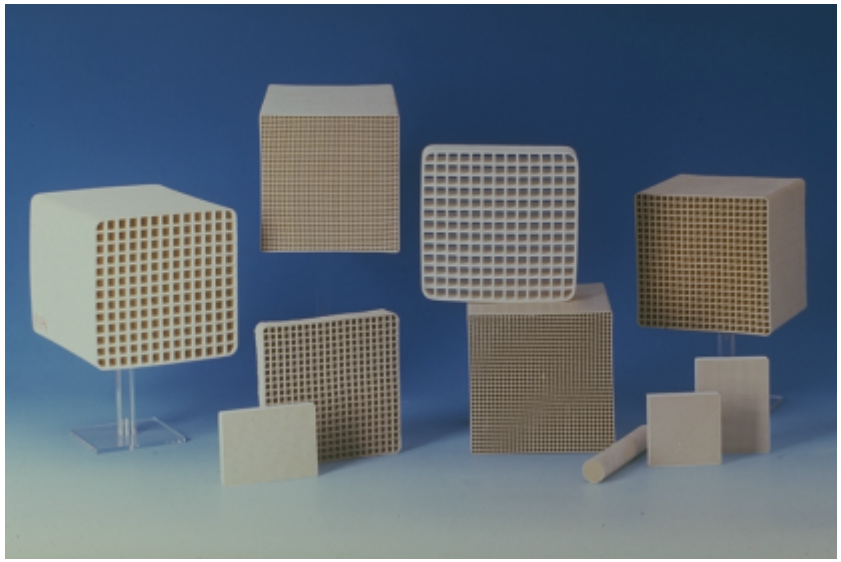
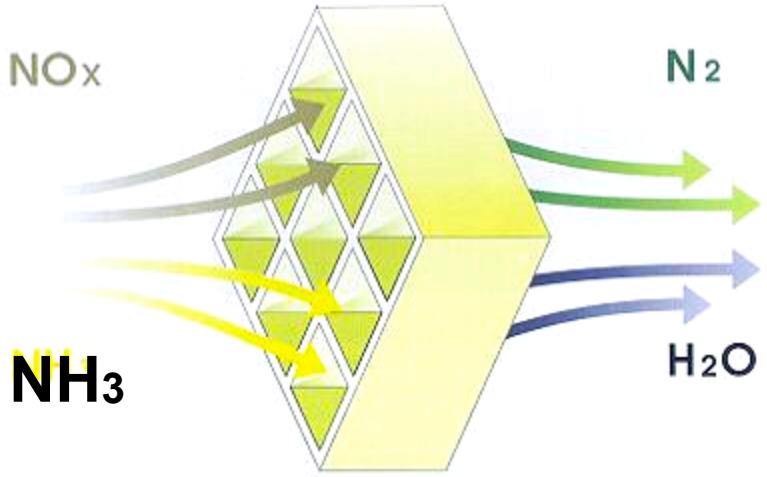
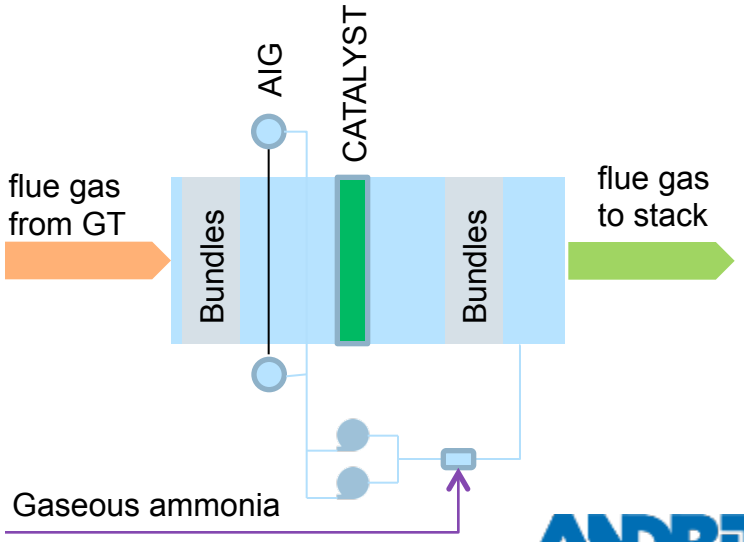
SCR for Mellach Power Plant





- With the following reactions on the catalyst surface
  - $4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$
  - $2\ NO_2 + 4\ NH_3 + O_2 \rightarrow 3\ N_2 + 6\ H_2O$
- Decomposition of dioxins and furans (PCDD, PCDF)
- Side reaction
  - $2\ SO_2 + O_2 \rightarrow 2\ SO_3$



SCR for Mellach Power Plant

AIG design:

- Low flue gas pressure loss (< 0,3 mbar)
- 32 adjustable AIG sections to meet the required NH_3/NOx molar ratio upstream catalyst
- Number of nozzles optimized according to distance between AIG and catalyst via CFD

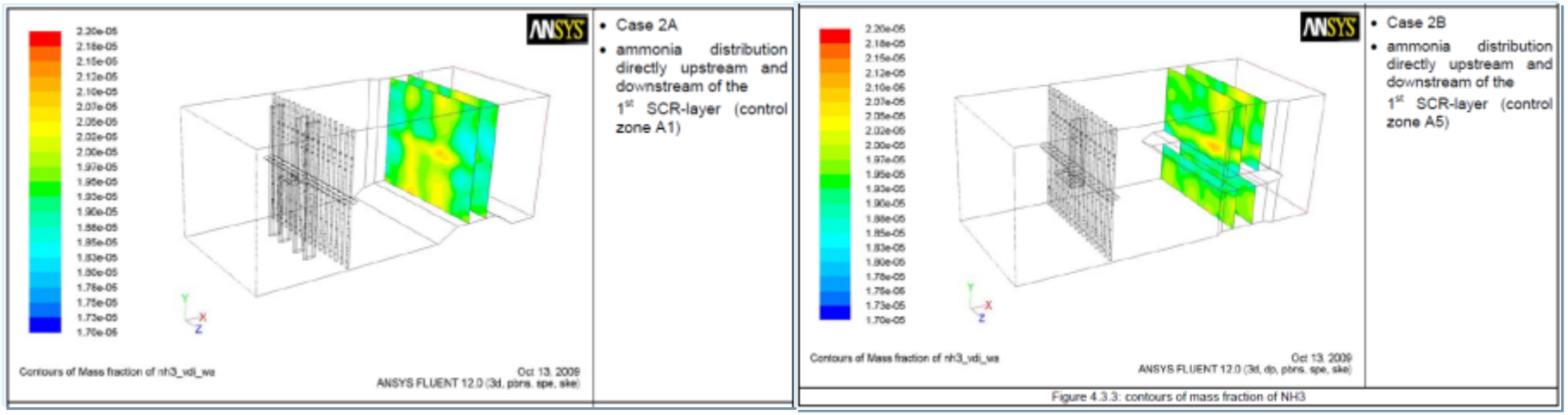


Figure 4.3.3: contours of mass fraction of NH3

Ammonia distribution upstream catalyst for two control zones (worst cases) acc. CFD study:

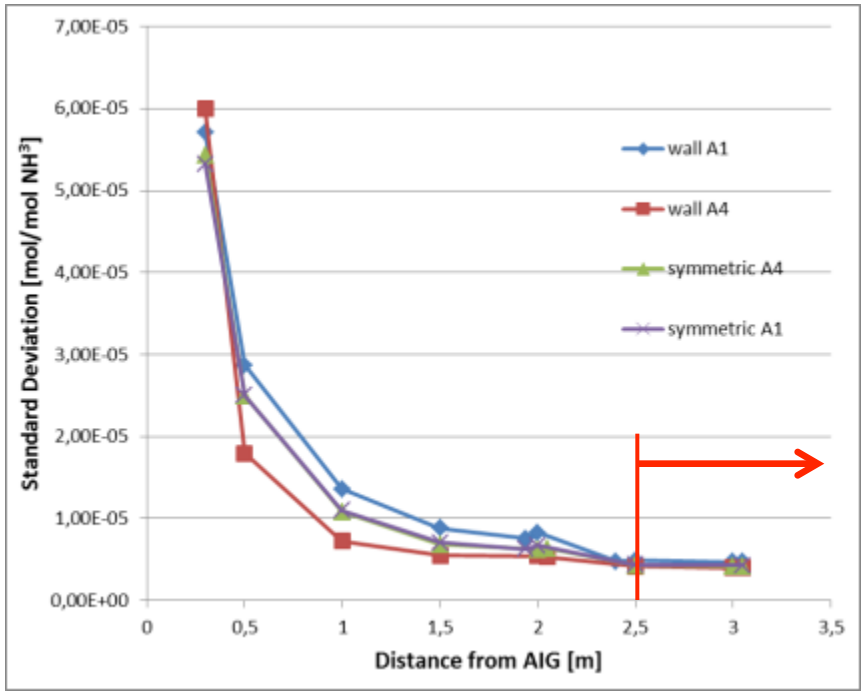
Description	Load	Location	Result	Minimum requirement acc. catalyst supplier
NH3 concentration deviation (Case 2A: control zone A1)	100%	1 st catalyst layer inflow cross sectional area	100% of the values within a range of -6.9% / +6.8% (CoV = 2.8%)	80% of the values within a range of +/-10% and the remaining 20% of the values within a range of +/-20%
NH3 concentration deviation (Case 2B: control zone A5)	100%	1 st catalyst layer inflow cross sectional area	100% of the values within a range of -4.9% / +8.1% (CoV = 2.1%)	80% of the values within a range of +/-10% and the remaining 20% of the values within a range of +/-20%

CoV = coefficient of variation = standard deviation / mean value

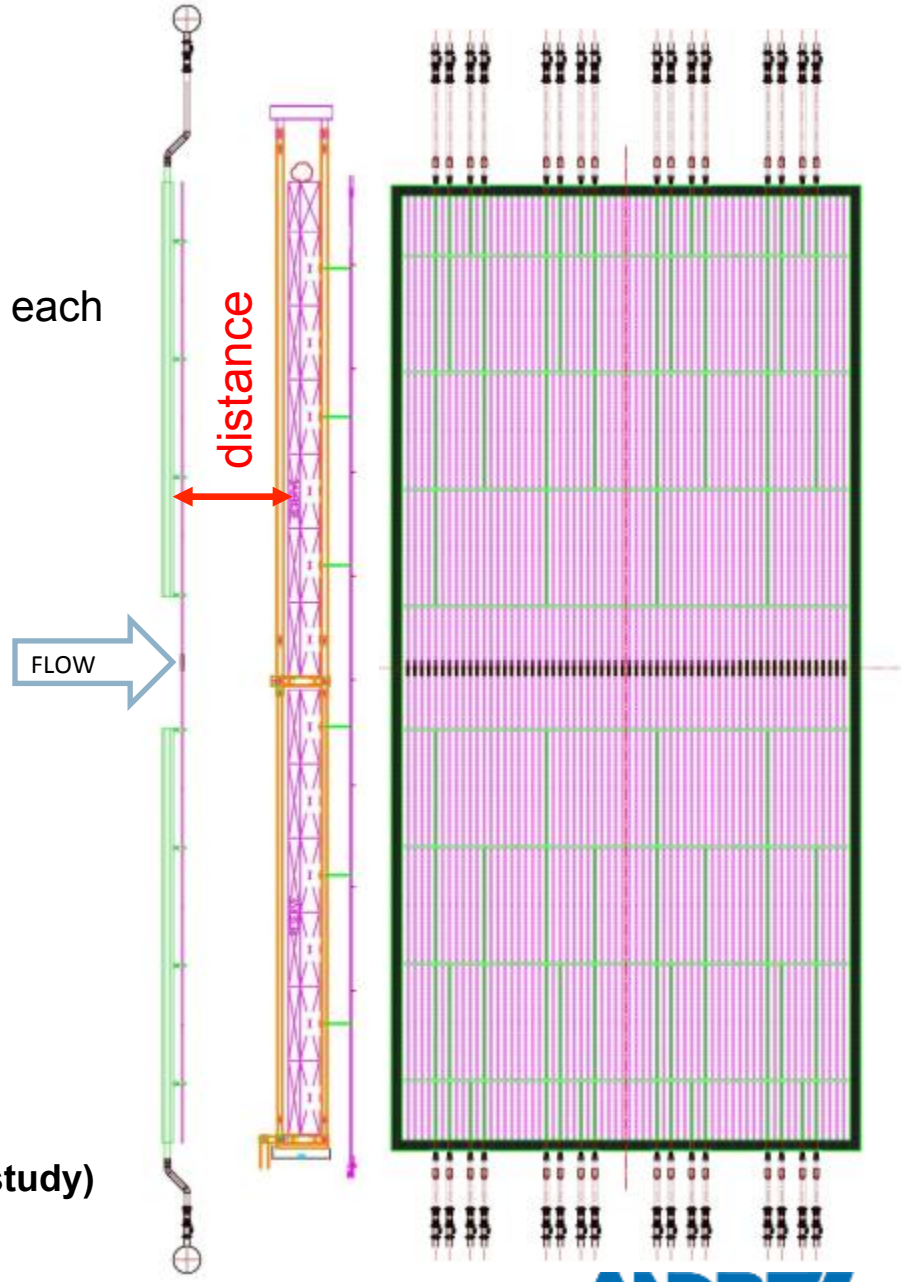
SCR for Mellach Power Plant

AIG design:

- Co- current injection of ammonia
- Duct dimension 21,9 x 11,6 m
- 32 adjustable AIG sections of approx. 8 m² each
- Distance from AIG to catalyst inlet > 2,5 m



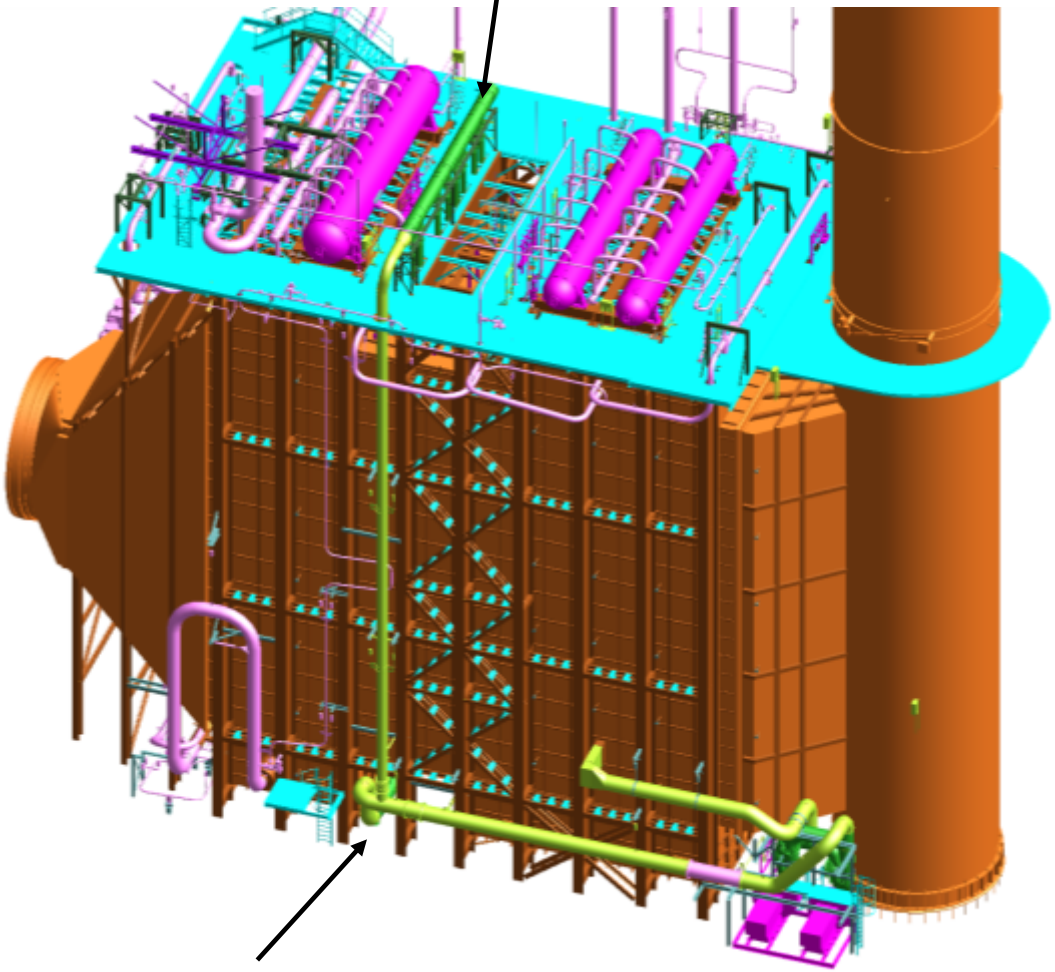
Standard deviation of NH_3 -concentration versus distance between AIG and catalyst (based on CFD study)



SCR for Mellach Power Plant

AIG tuning flaps:

Source: Fotostudio Pachernegg, Graz



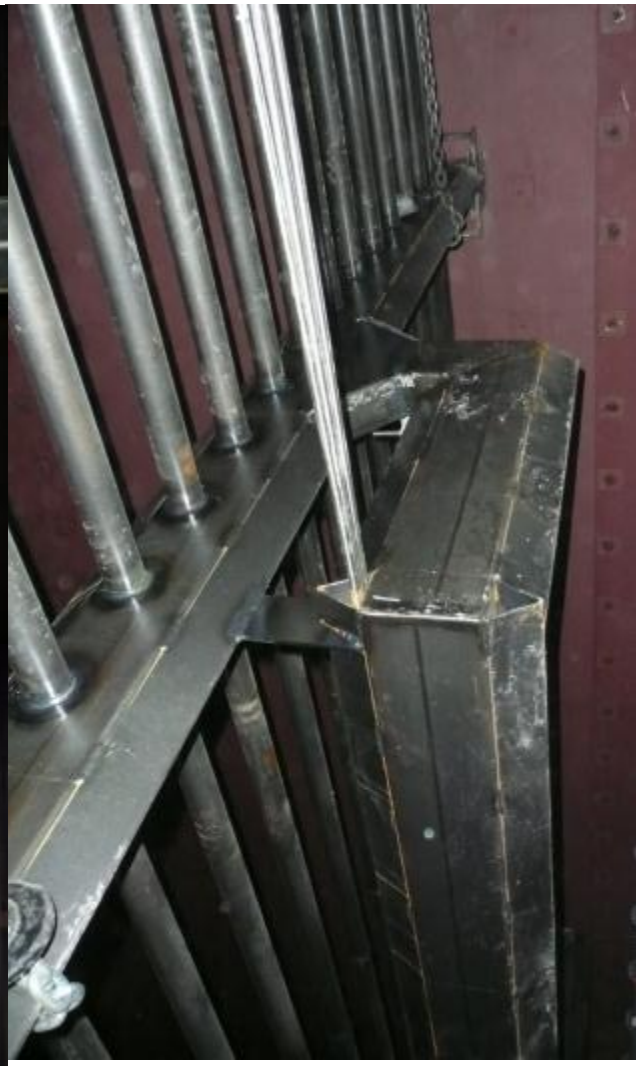
SCR for Mellach Power Plant

Catalyst design:

- Operation flue gas temperature from 300 to 350 °C
- GT operation with natural gas only
- Performance lifetime 24000 operational hours
- Catalyst pitch is 3 mm (50 x 50 cells per element)
- Catalyst length 285 mm
- Catalyst pressure loss < 3,4 mbar
- 132 (12 x 11) modules installed on steel frame, supported on top of HRSG
- 6 modules (12 x 6) are stapled on each other and screwed, then intermediate supporting frame is installed for further 12 x 5 modules
- Space between modules and HRSG duct is sealed by insulation pads , all modules are screwed together
- Space is kept free upstream for additional 50% catalyst

SCR for Mellach Power Plant

AIG erection (8 pieces per unit):



SCR for Mellach Power Plant

Catalyst module installation:

Insulation pad

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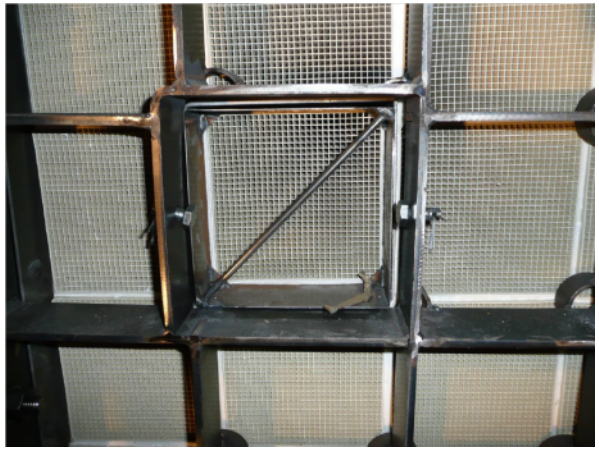
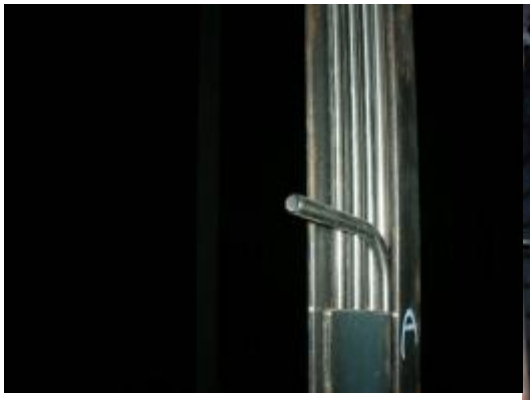
Catalyst module erection (132 modules per Unit):

Catalyst test elements



DeNOx System for HRSG

Catalyst modules installed:



Net measuring point

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Ammonia dosing station:

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Commissioning of unit 10 & 20:

- NOx downstream GT far below design figure (design 61 mg/m³n NOx,dry,15 vol% O_2)
- CO downstream GT at base load at 2 mg/mn³ far below emission limit (35 mg/mn³)
- NO_2/NOx ratio measured approx. 20% at 100 % GT load
- AIG with 32 adjustable fields, NOx profile can be adjusted accurately
- Ammonia flow control valve was changed to smaller dimension due to much lower ammonia mass flow than actually designed

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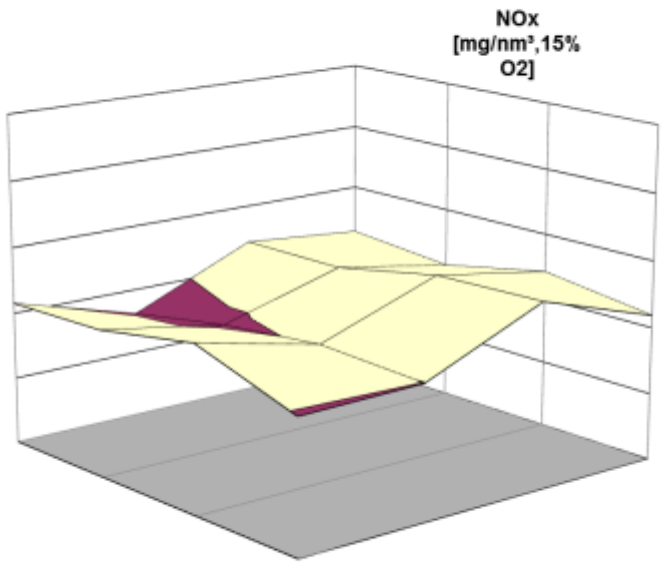
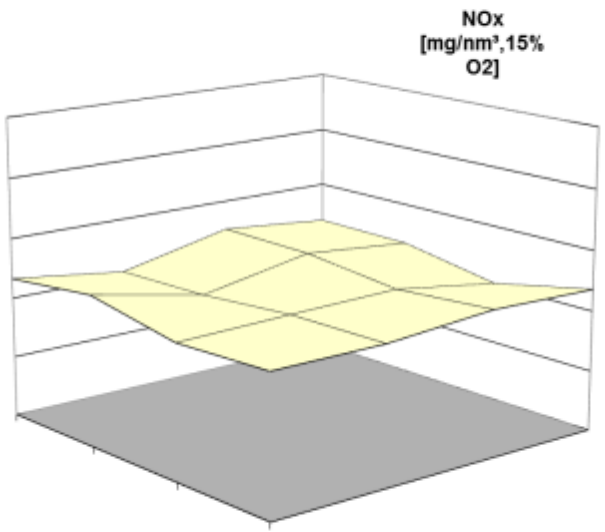
Commissioning of unit 10:

SCR Mellach Unit 10, Cleangas NOx-distribution across HRSG section before AIG tuning (GT load of 287MW)



Standard deviation 1,5 mg/nm³ NOx

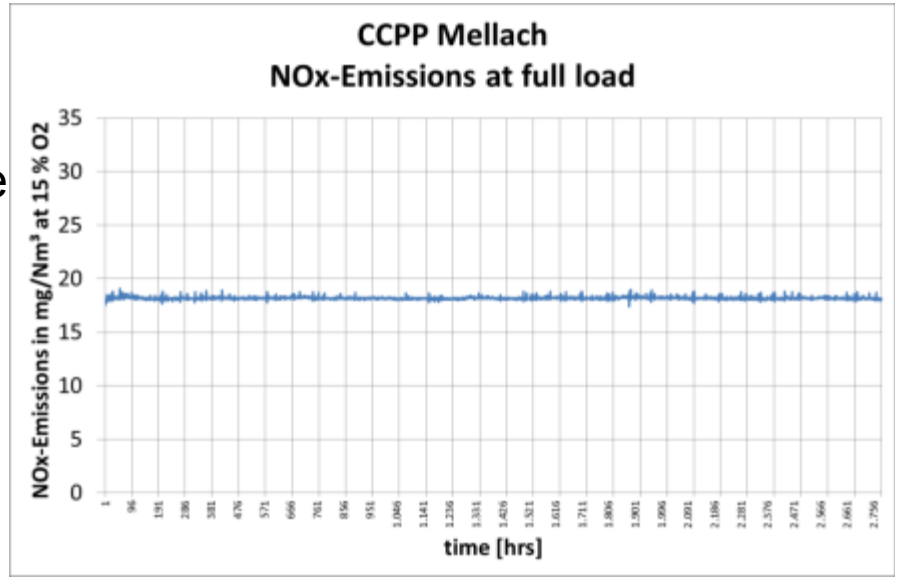
SCR Mellach Unit 10, Cleangas NOx-distribution across HRSG section after AIG tuning (GT load of 287MW)



Standard deviation 0,7 mg/nm³ NOx

First year operating experience with SCR CCPP Mellach

- NOx-value stable below 20 mg/Nm³
  - at 100 % load
  - over entire ambient temperature range
- NOx-value can be kept below 20 mg/Nm³ down to approx. 50 % load (min. load)
- pressure drop: approx. 3,2 mbar at 100% load (=> power output reduction due to pressure drop approx. 0,3 MWel / 0,1 %)



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Selected SCR References

PS Leopoldau (Austria)

Capacity:	170 MWel
Fuel:	Natural gas
Flue gas volume:	1,400,000 Nm³/h
NOx content:	170 mg/Nm³
Removal efficiency:	80 %
Start-up:	1988

PS Donaustadt (Austria)

Capacity:	350 MWel/ 250 MW district heating
Fuel:	Natural gas
Flue gas volume:	1,940,000 Nm³/h
NOx content:	68 mg/Nm³
Removal efficiency:	50 %
Start-up:	2001

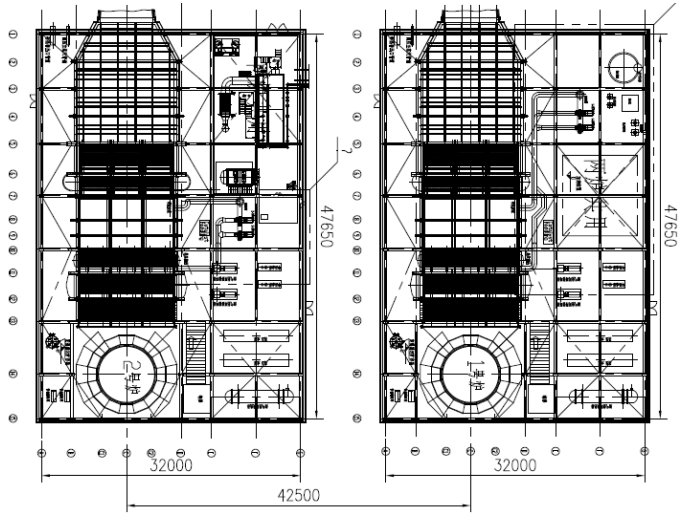
Selected SCR References

CCPP Mellach (Austria)

Capacity:	838 MWel
Fuel:	Natural gas
Flue gas volume:	2 x 2,110,000 Nm³/h
NOx content:	61,6 mg/Nm³
Removal efficiency:	67 %
start-up:	2012

PS GaoAnTun (China)

Capacity:	836 MWel
Fuel:	Natural gas
Flue gas volume:	2 x 2,055,000 Nm³/h
NOx content:	51,3 mg/Nm³
Removal efficiency:	85 %
Start-up:	2013 / 2014



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SCR technology for NOx control– perfect APC solution for HRSG's, Summary:

- Due to the strict NOx emission limit of 20 mg/m³n and the NOx raw gas guarantee given from GT supplier it was necessary to implement a SCR system in Mellach power station

- NOx raw gas concentration from GT are much lower than guaranteed values from SIEMENS, SCR system in Mellach is oversized but still necessary

- Latest AIG and catalyst design leads to lowest pressure loss of SCR system (<3,2 mbar at full load),this results in a loss of power output of not more than approx. 0.3 MW_{el}

- Distance between AIG and catalyst can be reduced from 3 m down to 2,5 m for further CAPEX reduction

- CCPP can meet lowest emission limits (CO < 2mg/m³n and NOx < 20 mg/m³n) and efficiency is still kept high, helping to cut down CO_2 emission (60 % less CO_2 emission compared to coal fired power plant)

ANDRITZ Energy & Environment GmbH

Contact:
DI Johannes Lind
Tel.: +43/316/501-373
johannes.lind@andritz.com
www.andritz.com/aee

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