SCR-Catalyst Management

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UTG / Catalyst & Oil Management

We are Uniper

Our operations:

Power Generation

Commodity Trading

Energy Storage

Energy Sales

Energy Services

Where we operate:

40+ countries around the world
4th largest generator in Europe

Employees: 13,000

Power generation - Europe

Power generation - International

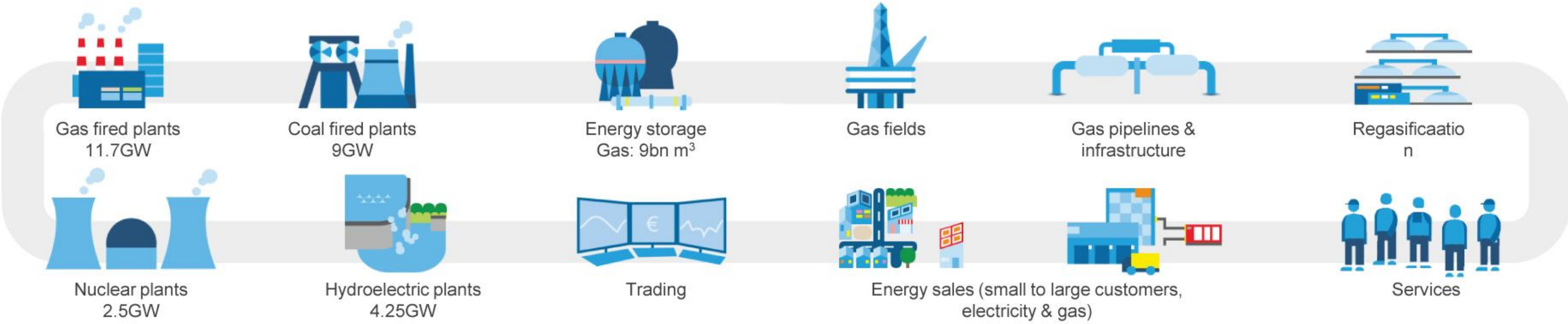
Commodity Trading

€1.71bn Turnover

100 years Experience

31.6 GW Total generation

Main activities:

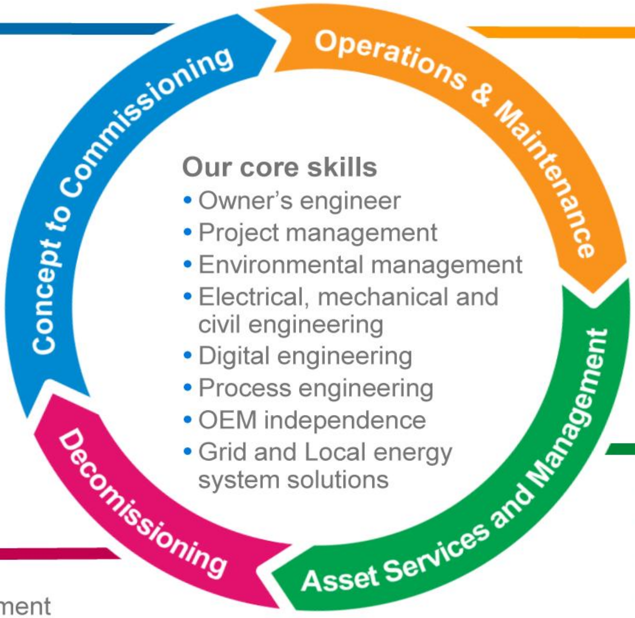


Company data: October 2016

Energy Services is bringing Uniper's competencies to the global stage

- Front end engineering design
- Commercial evaluation
- Engineering Procurement and Construction tendering and project management
- Construction and site management
- Commissioning

- Outage support
- Production support
- Maintenance and spares optimisation
- Field services
- Workshop services



- Benchmarking
- Asset lifetime assessment & extension
- Asset risk management
- Compliance and standards
- Technical operational excellence

- Planning, permit and impact assessment
- Decommissioning and dismantling
- Demolition

Value proposition

Leading one-stop-shop energy solutions provider with services across the value chain and life-cycle

Leveraging competencies in delivering bespoke customer solutions

Business at a glance

✓ Expertise across multiple technologies

✓ Services to more than 600 customers[1]

✓ Active in more than 40 countries[1]

1. Based on 2015

Uniper & India Power have formed a strategic partnership to develop and service the power sector

India Uniper Power Services

- 50:50 joint venture in power plant services
- A value-based service provider
- Offering a broad range of flexible and customised services
- Headquartered in Kolkata

The joint venture will combine strengths of strong partners with complementary scope and portfolio. Key service offerings:

- Plant operations and maintenance,
- Asset monitoring software and analytical tools,
- Fuel evaluation and optimisation (e.g. blending of Indian and Indonesian coals)
- Increasing flexibility of units; Lifecycle extension,
- Supply and integration of pollution control equipment and systems, etc.

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2. UTG Test Facilities
3. From Catalyst Testing to Catalyst Management
4. SCR-Impact on Downstream Equipment
5. Mercury Oxidation

SCR DeNOx Basics

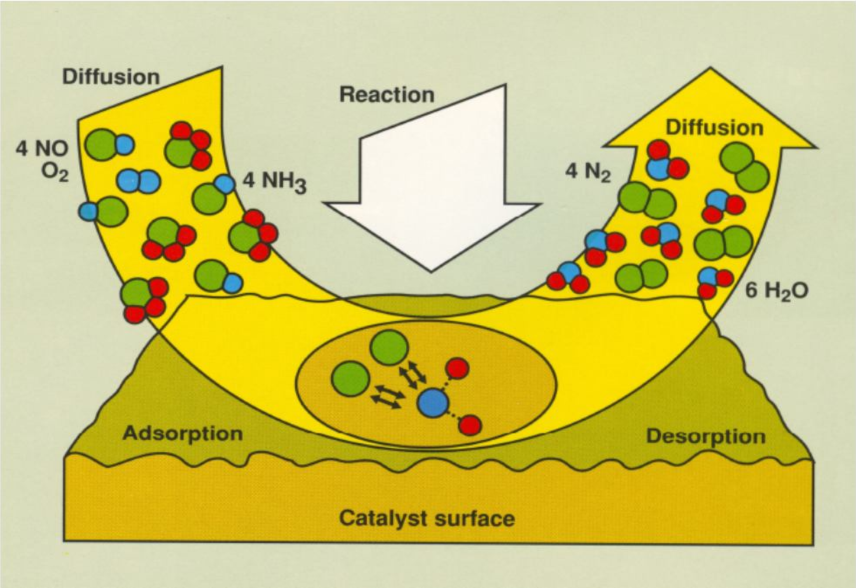
Desired Reactions

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

$NO + NO_2 + 2\ NH_3 \rightarrow 2\ N_2 + 3\ H_2O$

$6\ NO_2 + 8NH_3 \rightarrow 7\ N_2 + 12\ H_2O$

$Hg + 2\ HCl + ½\ O_2 \rightarrow HgCl_2 + H_2O$



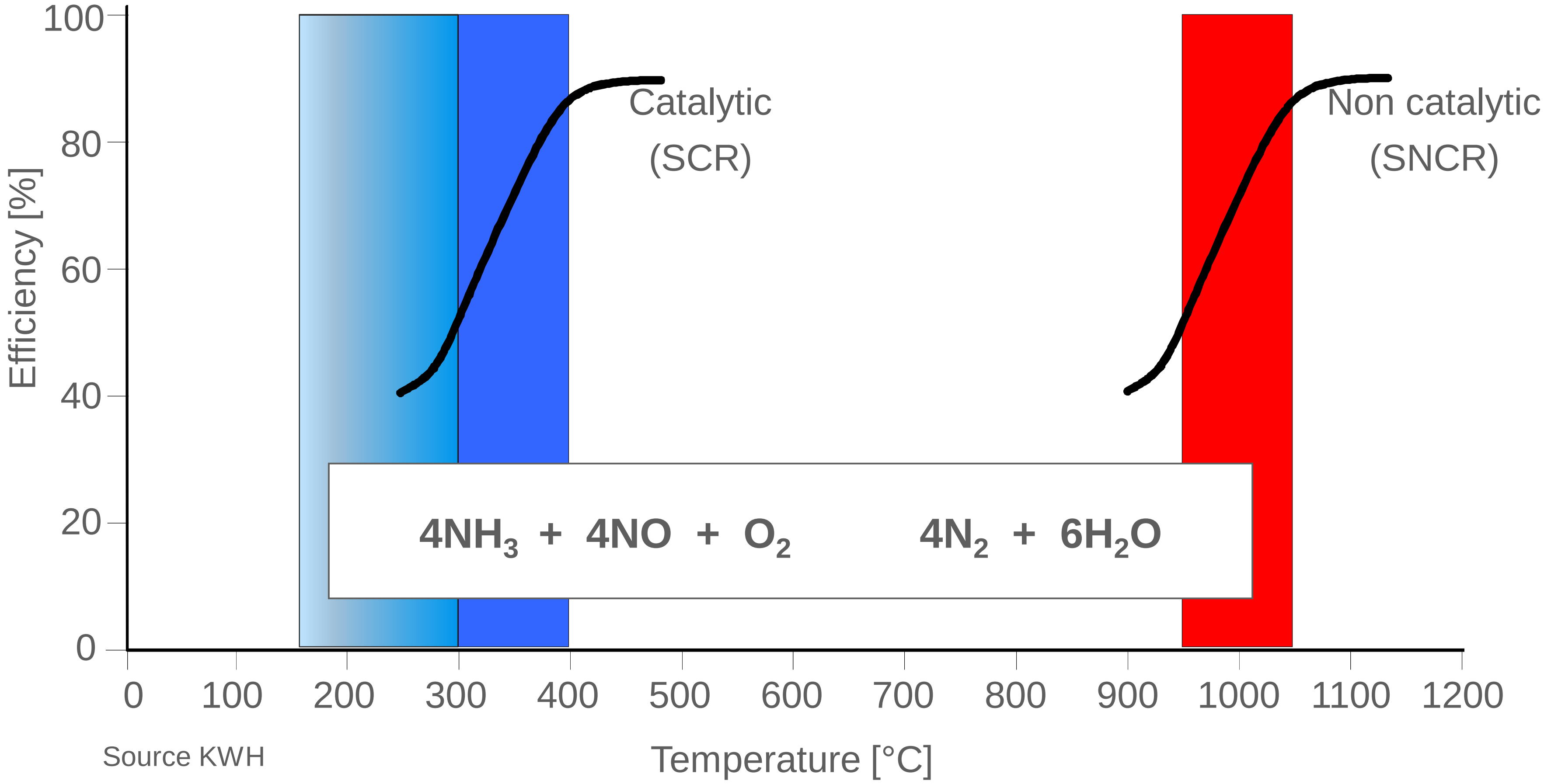
Undesired Reactions

$SO_2 + ½\ O_2 \rightarrow SO_3$ (SO_2 Conversion)

$NH_3 + SO_3 + H_2O \rightarrow NH_4SO_4$ (Ammonia Bisulfate Formation)

$HgCl_2$ reduction by NH_3 and SO_3

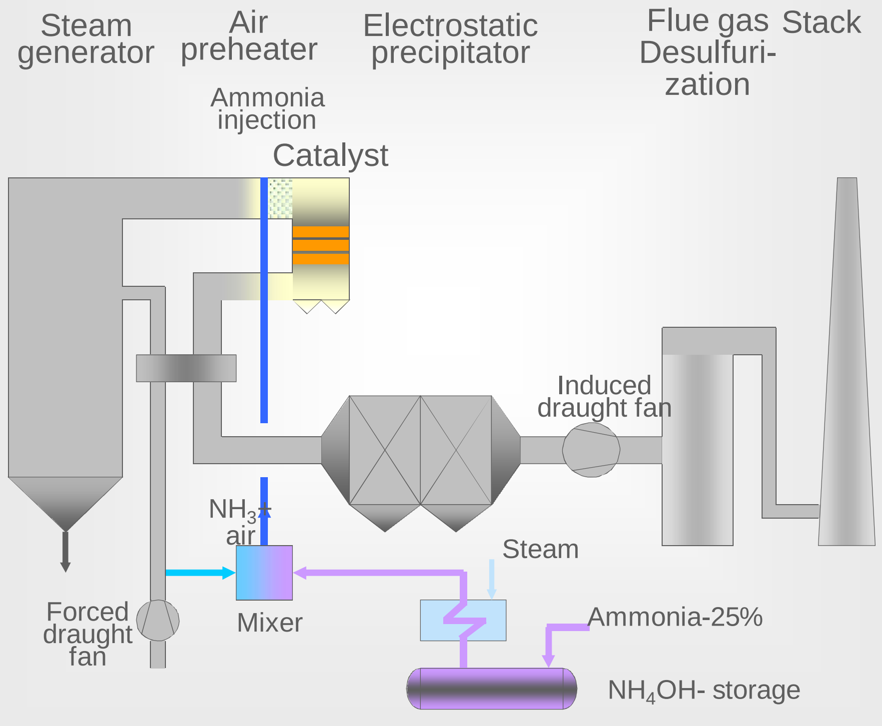
Operating Temperatures



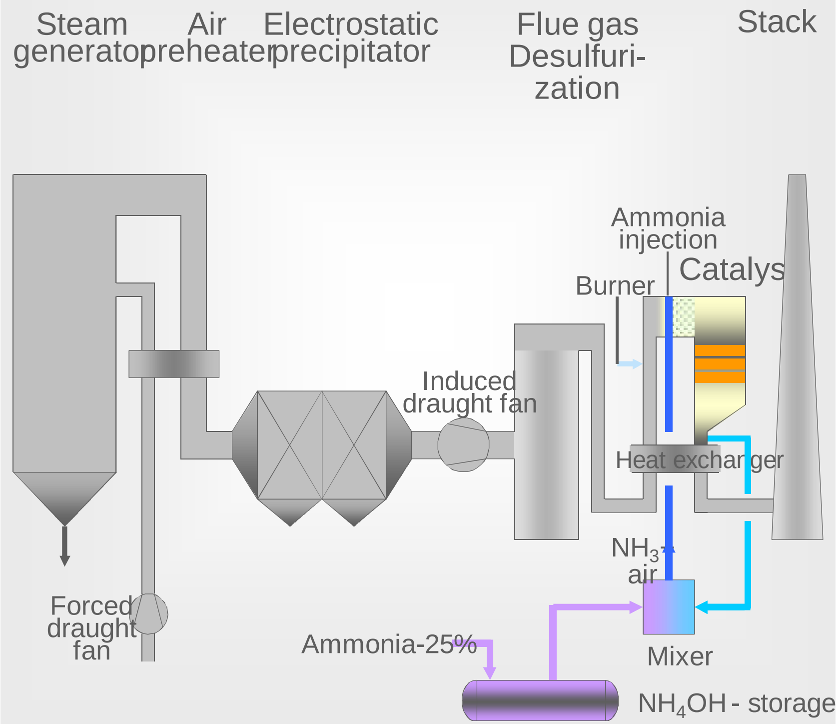
Source KWH

Typical positions for SCR system installions

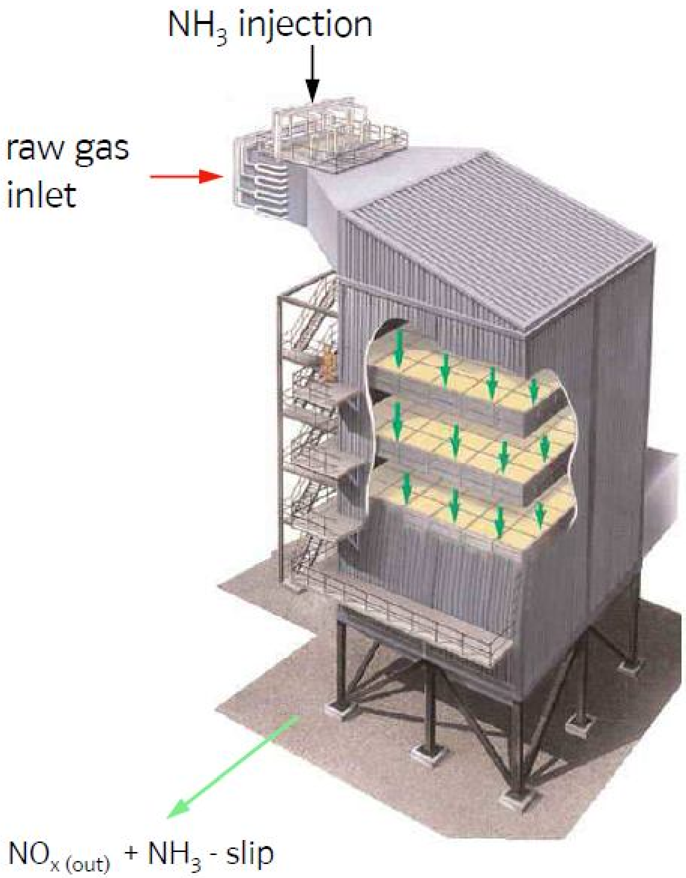
High Dust

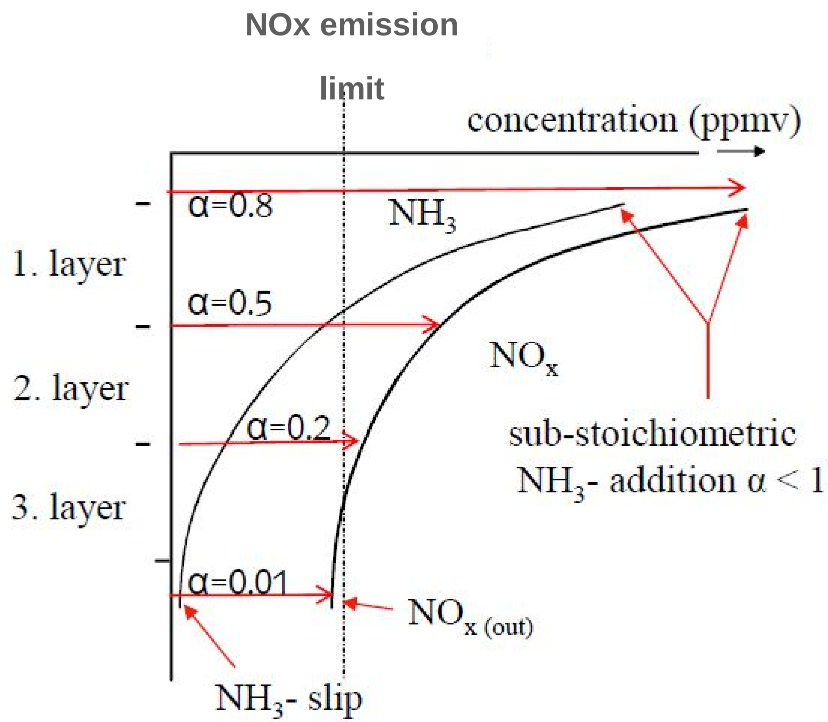


Tail End



SCR-Fundamentals





Characteristics

- NO_x- reduction below emission limit
- NH_3- consumption almost complete

Numerical example for NOx and NH_3 conversion

NO_x in : 243 ppmv

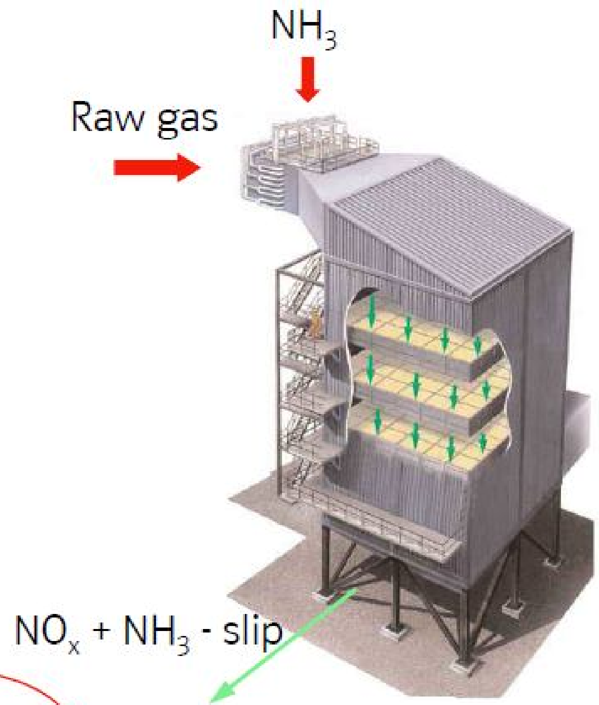
NO_x out : 29 ppmv

→ NO_x conversion : 88 %

NH_3 in : 215 ppmv

NH_3 out : 0,7 ppmv

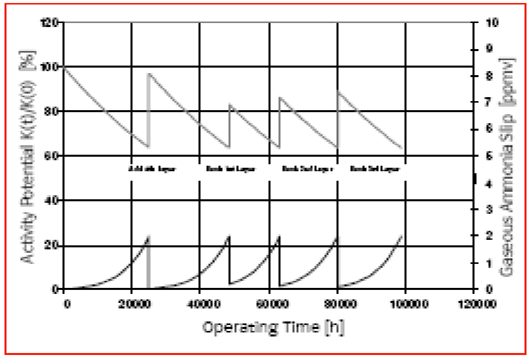
→ NH_3 consumption : 99,7 %



Uniper Technologies Know How for SCR Management

- Operation of 10 SCR pilot plants from 1985 - 1987
- Design and operation of a certified bench scale SCR test reactor since 1988
- Development of a MARA system for AIG tuning since 1989
- Design of a catalyst management system since 1990
- Commercial catalyst management services since 1992 at coal- and oil-fired units and waste incineration plants
- Experience from the operation of >40 SCR reactors in Uniper‘s power plants
- More than 150 customers worldwide, mostly with several SCR reactors
- Detailed test results of almost all commercially available catalyst materials
- Design and operation of a bench test reactor in Columbus/Ohio 2004-2011
- Implementation of a lifetime database / calculation tool (LEONID) since 2004
- 80% of coal fired power stations in Germany use Uniper‘s services

Why SCR Management?



- Catalyst in thermal power stations unavoidably deteriorate over time
- SCR catalyst is the most expensive "spare part" purchase in a power station
- Optimizing operation of installed catalyst volume by e.g. utilization of available design margins
- Forecasting the most economical catalyst replacement and regeneration schedules according to existing outage plans
- Best choice of appropriate catalyst material (price, technical properties)
- On time RFQ's and PO's for necessary new catalyst material or regeneration

→ **Make rational financial decisions independent of catalyst suppliers / catalyst regenerators**

Types of commercially available SCR catalyst

Honeycomb

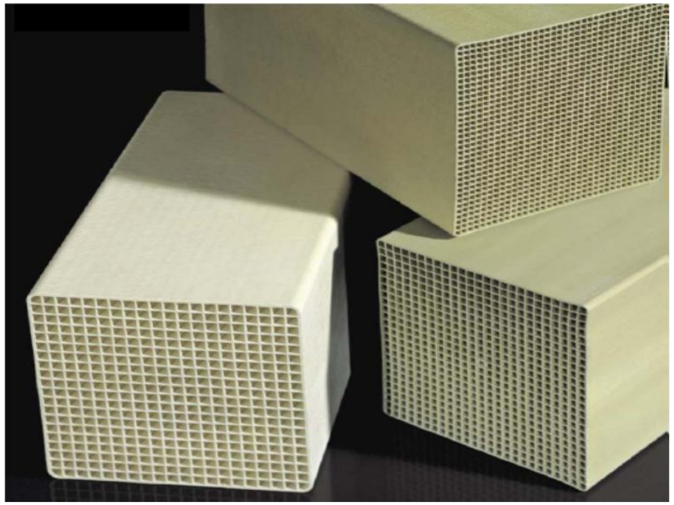
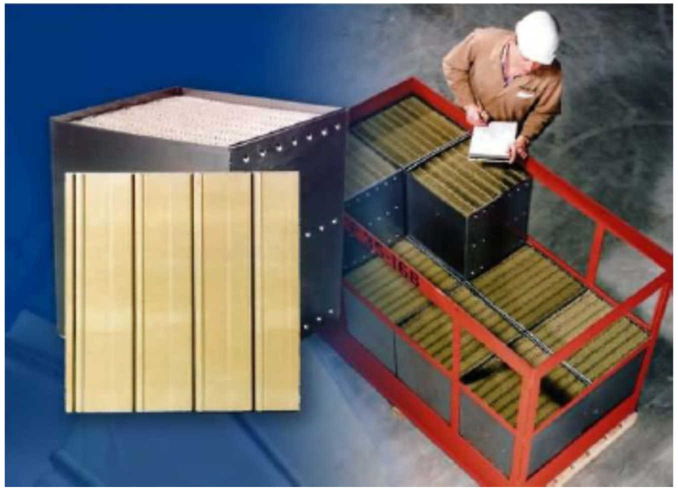
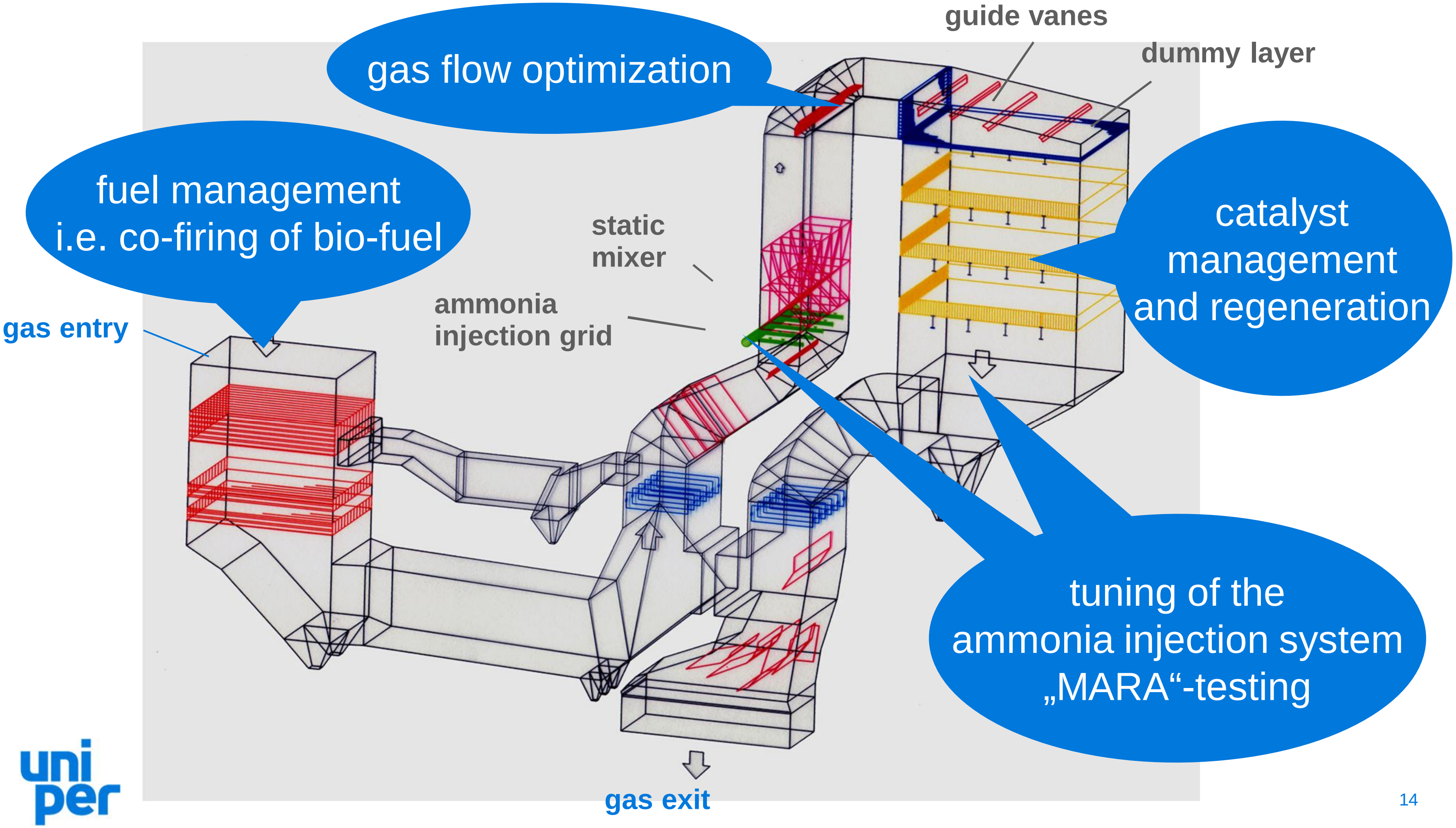


Plate-type
metal support
High Ash Content



Corrugated catalyst
glass fiber support

Focuses of modern SCR Management in support of plant operations



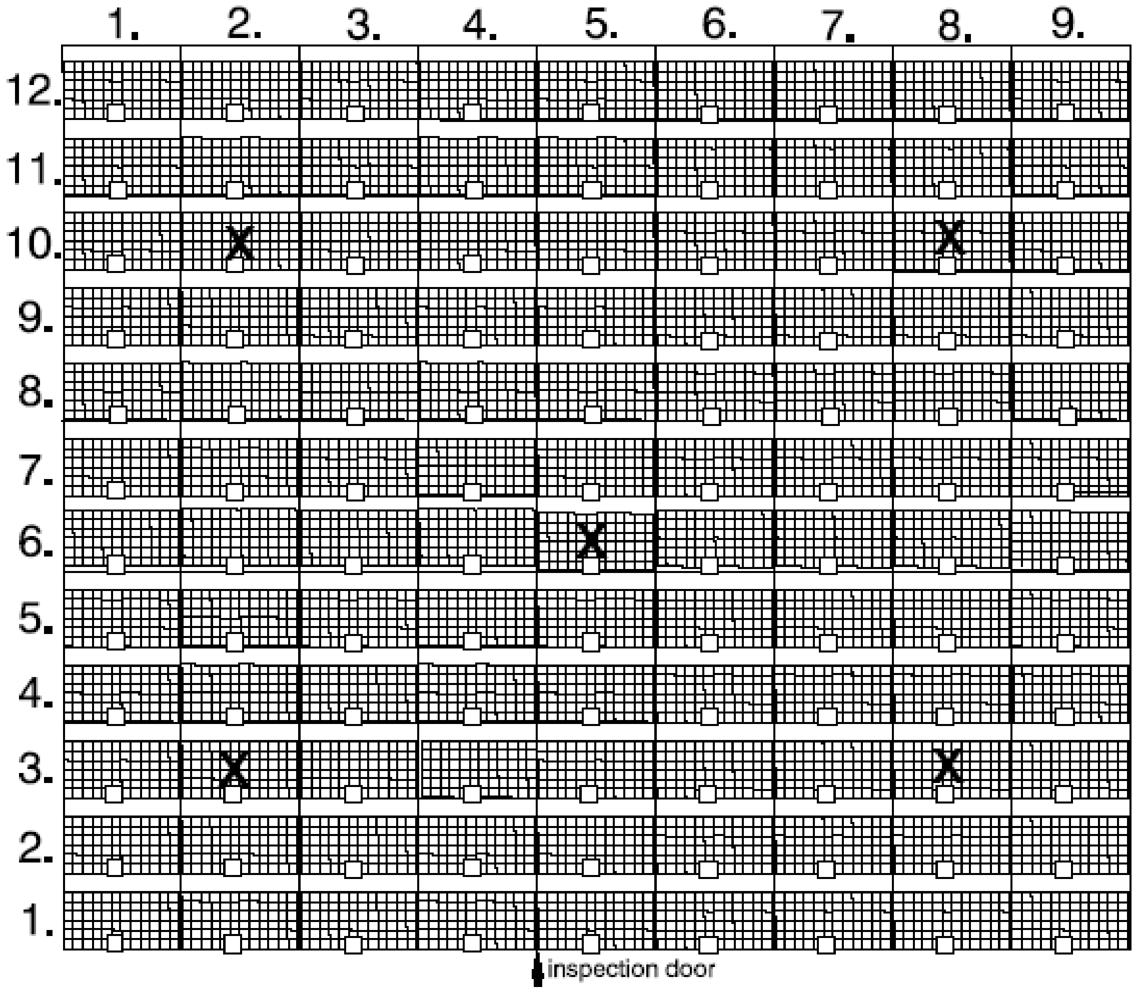
Uniper Kraftwerke GmbH - Scholven Power Station Unit F

• Unit Capacity	740 MW
• Fuel	Hard Coal

DENOx Plant

• Type of Process	High Dust SCR
• Capacity	2 x 1.200.000 m3/h STP
• Arrangement	High Dust
• Type of Catalysts	Honeycomb 7-pitch
• 4 catalyst layers x	314 m^3
• NOx removal	78%
• Commissioning	1989

Example: Catalyst Sampling (plates)



March 2005 | Dep. VAU | Bs

- One layer of catalyst modules
- 12x9 modules á 1x2x1 m³ ~216 m³

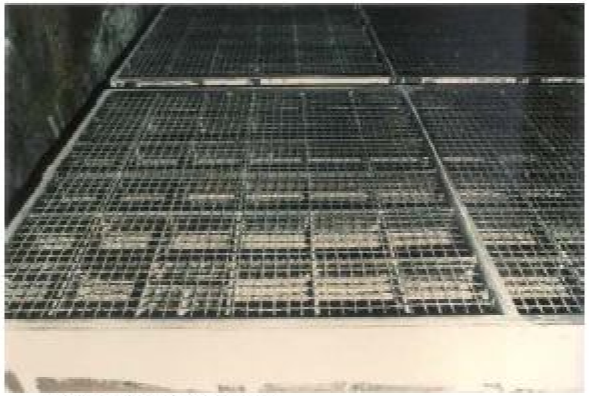
X: pull positions
(plates)

- Representative samples over the cross section

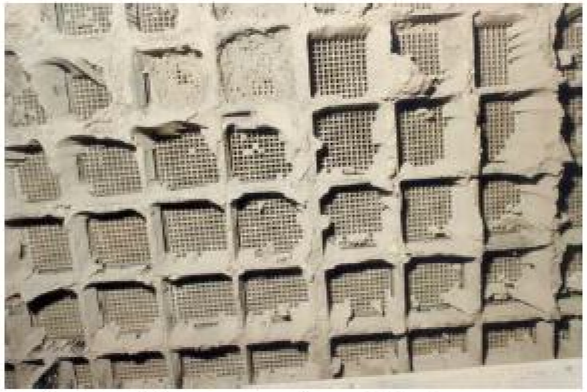
Visual Inspection of AIG, SCR Reactor

plugged NH_3-injection system

Visual reactor inspection and SCR catalyst sampling often provides valuable first hand information about the SCR reactor and reasons for potential performance problems



flue gas bypass



plugged honeycomb catalyst

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plugged plate-type catalyst

Example: Catalyst Inspection - Plugging & Piles

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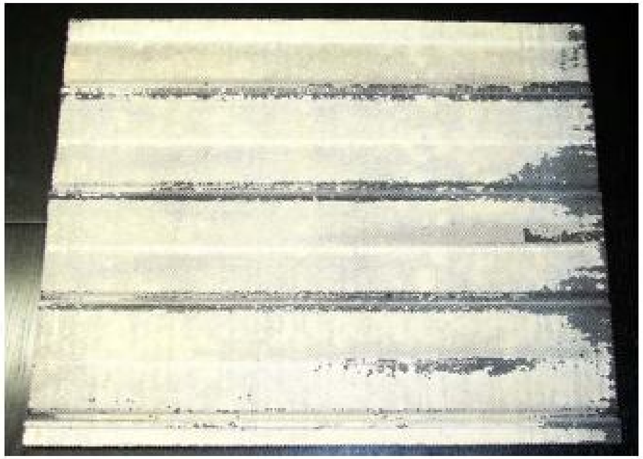
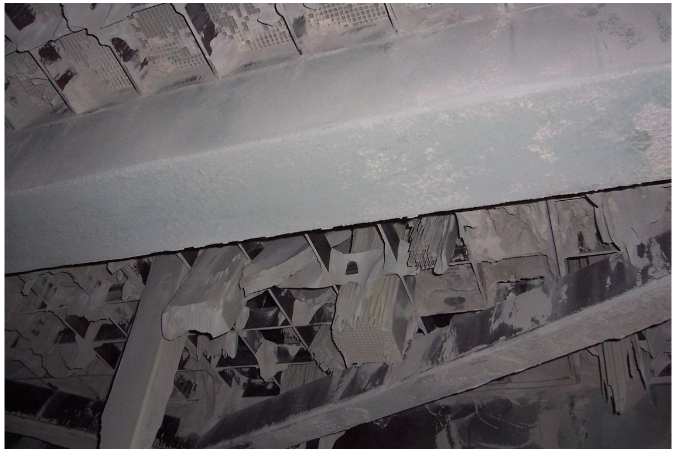
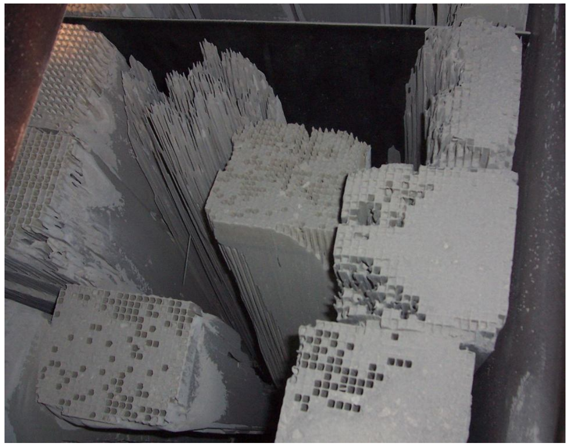
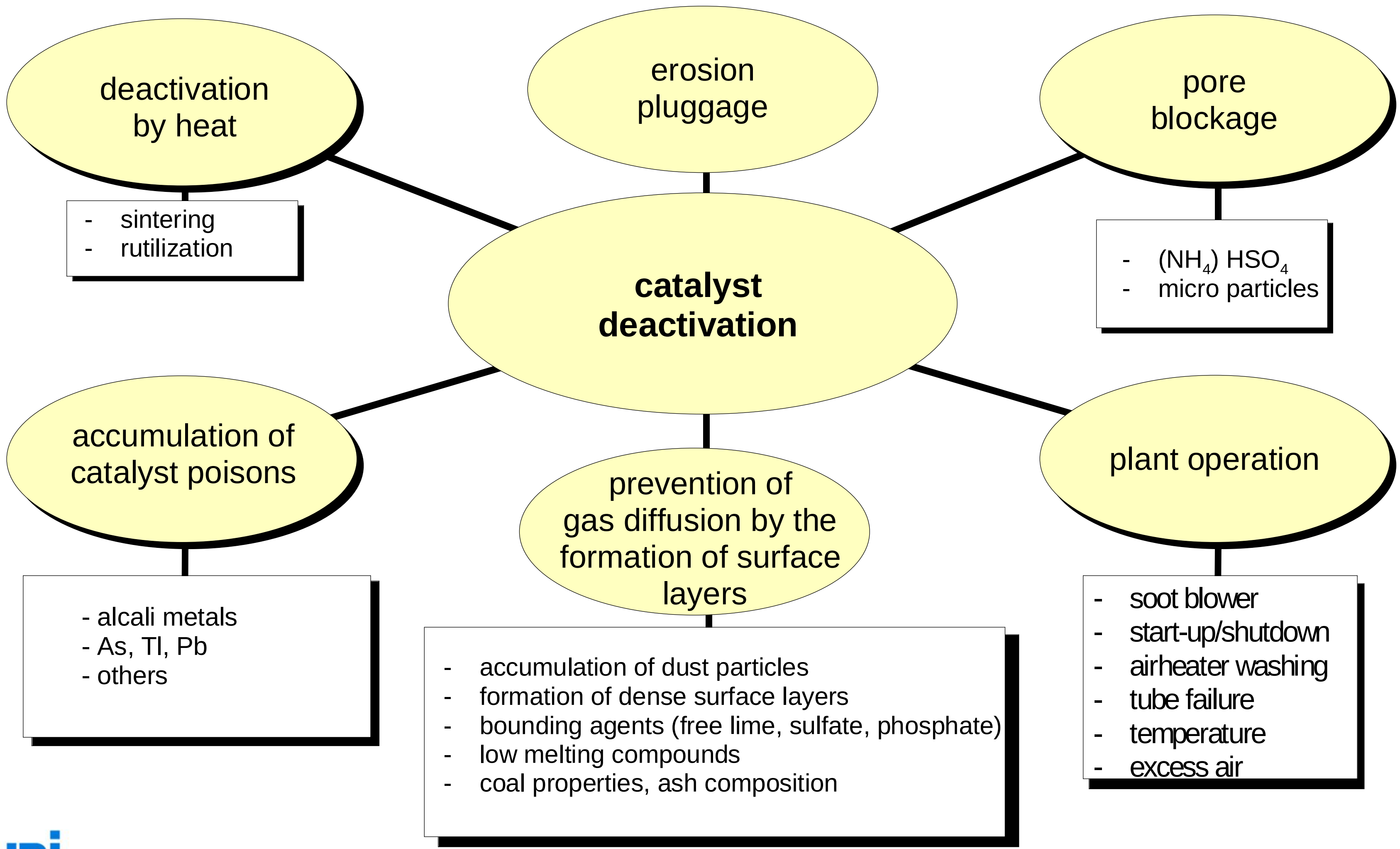
Example: Catalyst Inspection - Erosion







Catalyst Deactivation

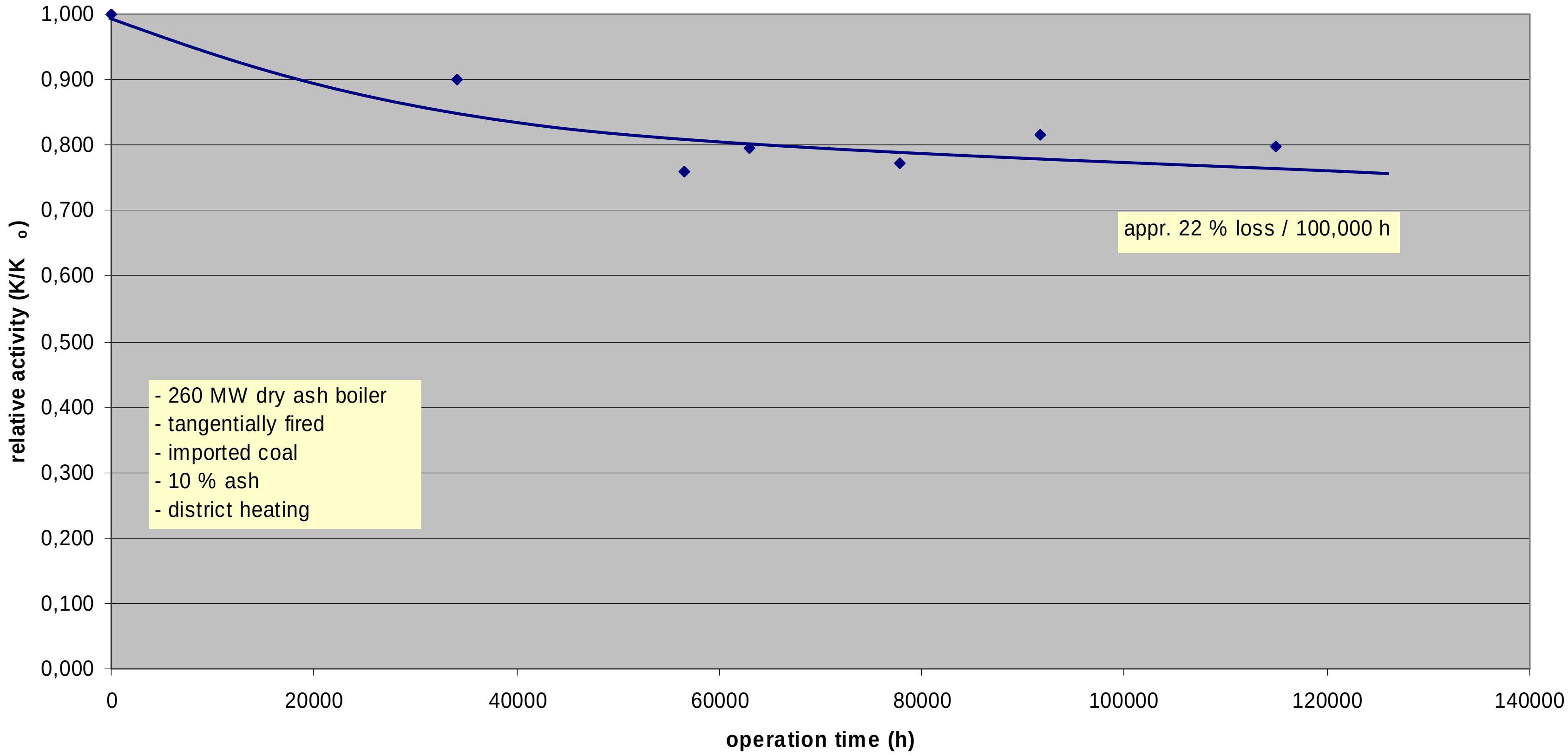


Catalyst Testing under power plant conditions

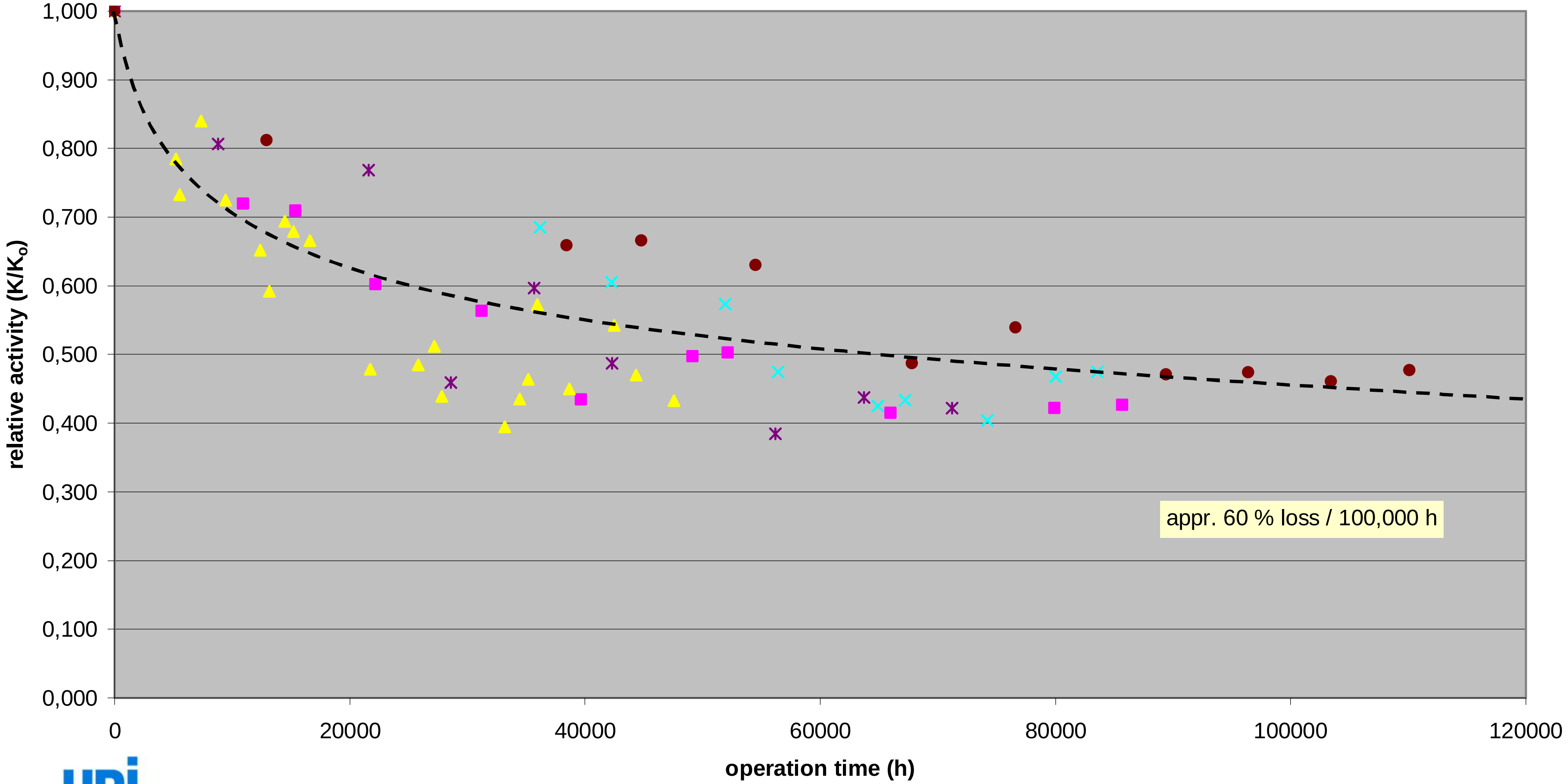
- Determination of the realistic NOx reduction capability fully transferable to the full scale plant according to VGB standard S302
- Calculation of catalyst activity and potential of each catalyst layer and whole SCR reactor
- Potential forecast in combination with the calculated minimum potential

ð optimized catalyst reloading / regeneration strategy

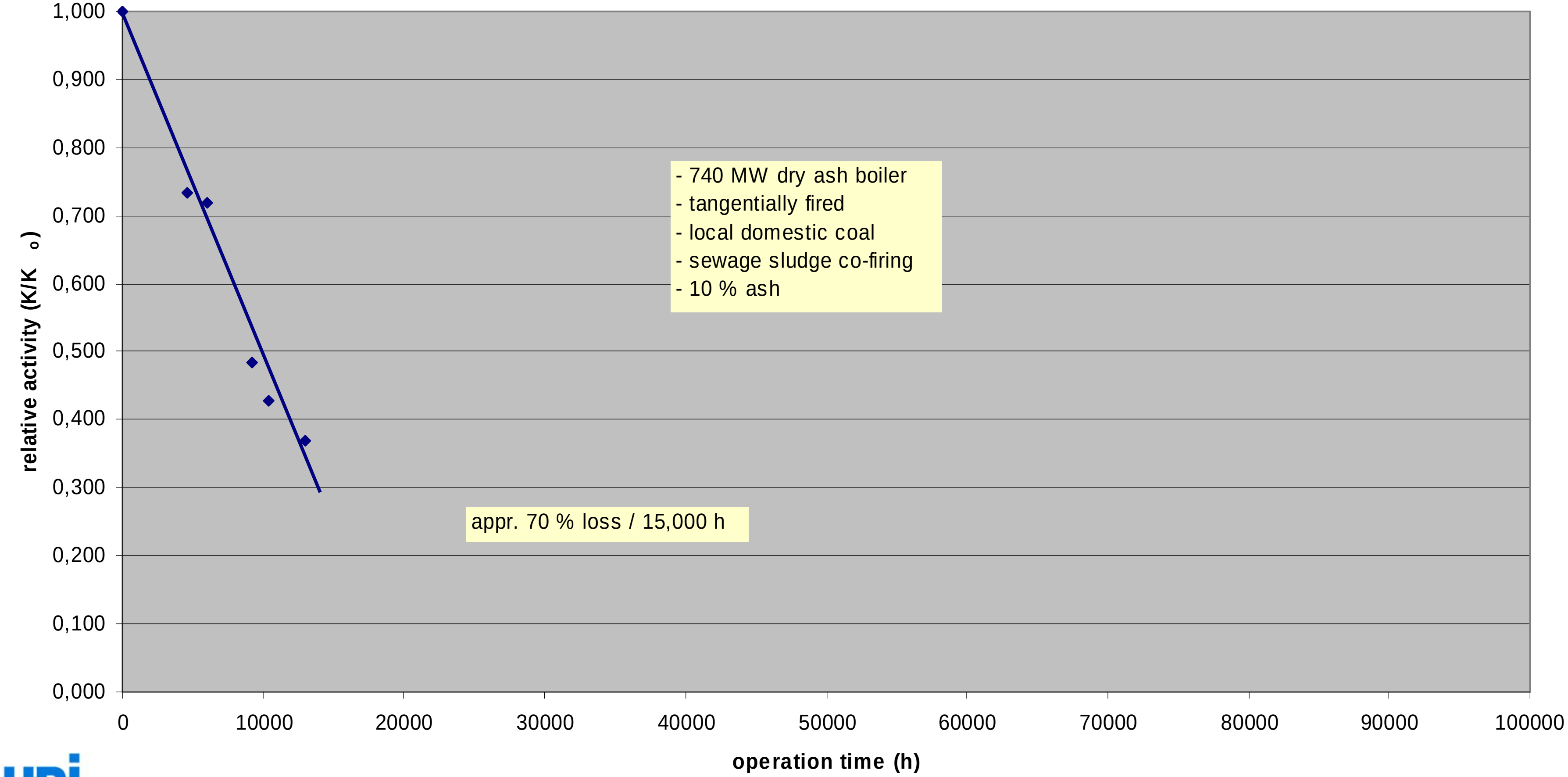
Example: Long Term Deactivation of High Dust Catalyst (best case)



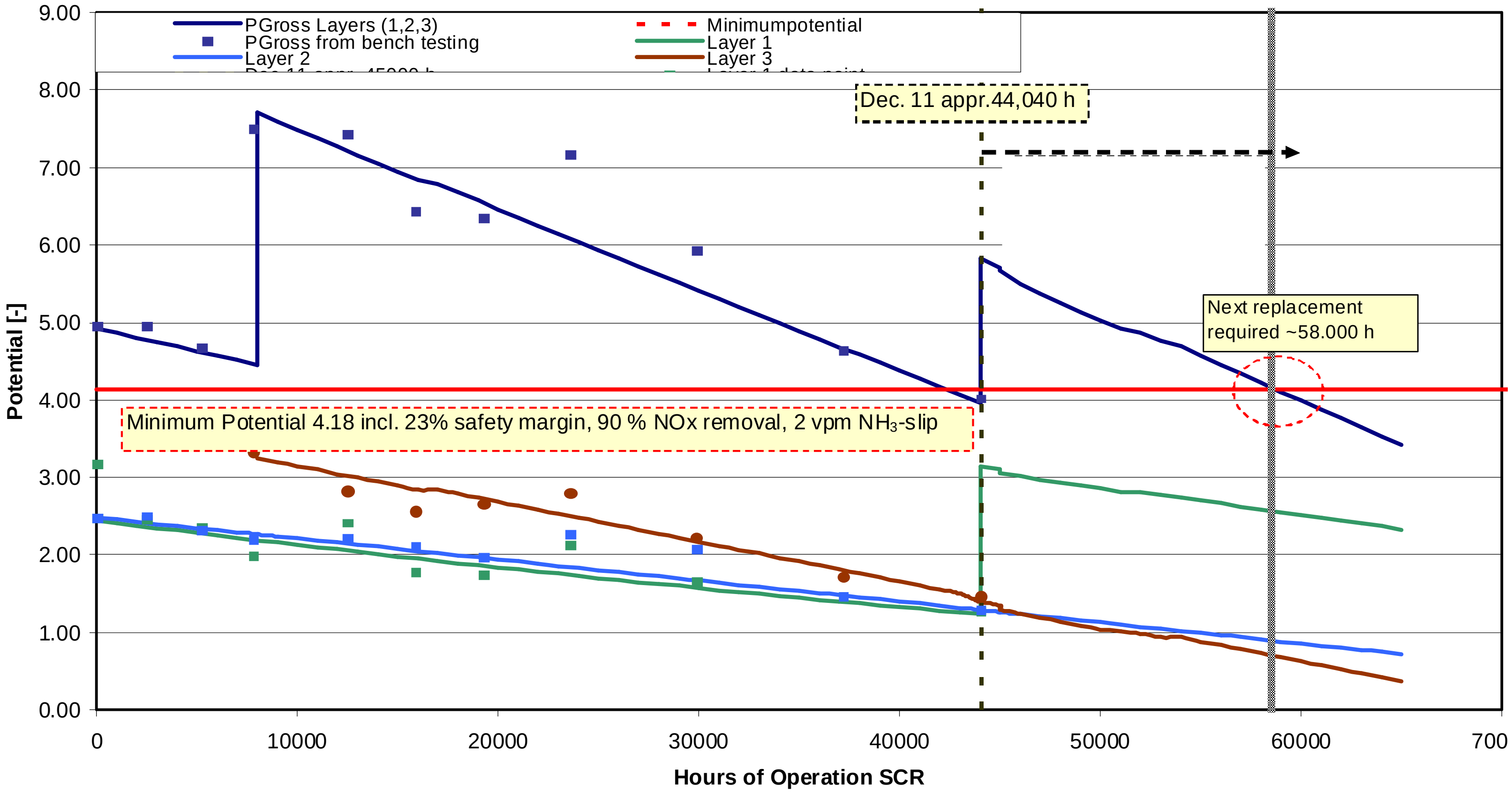
Example: Long Term Deactivation of High Dust Catalyst (real case)



Example: Long Term Deactivation of High Dust Catalyst (worst case)

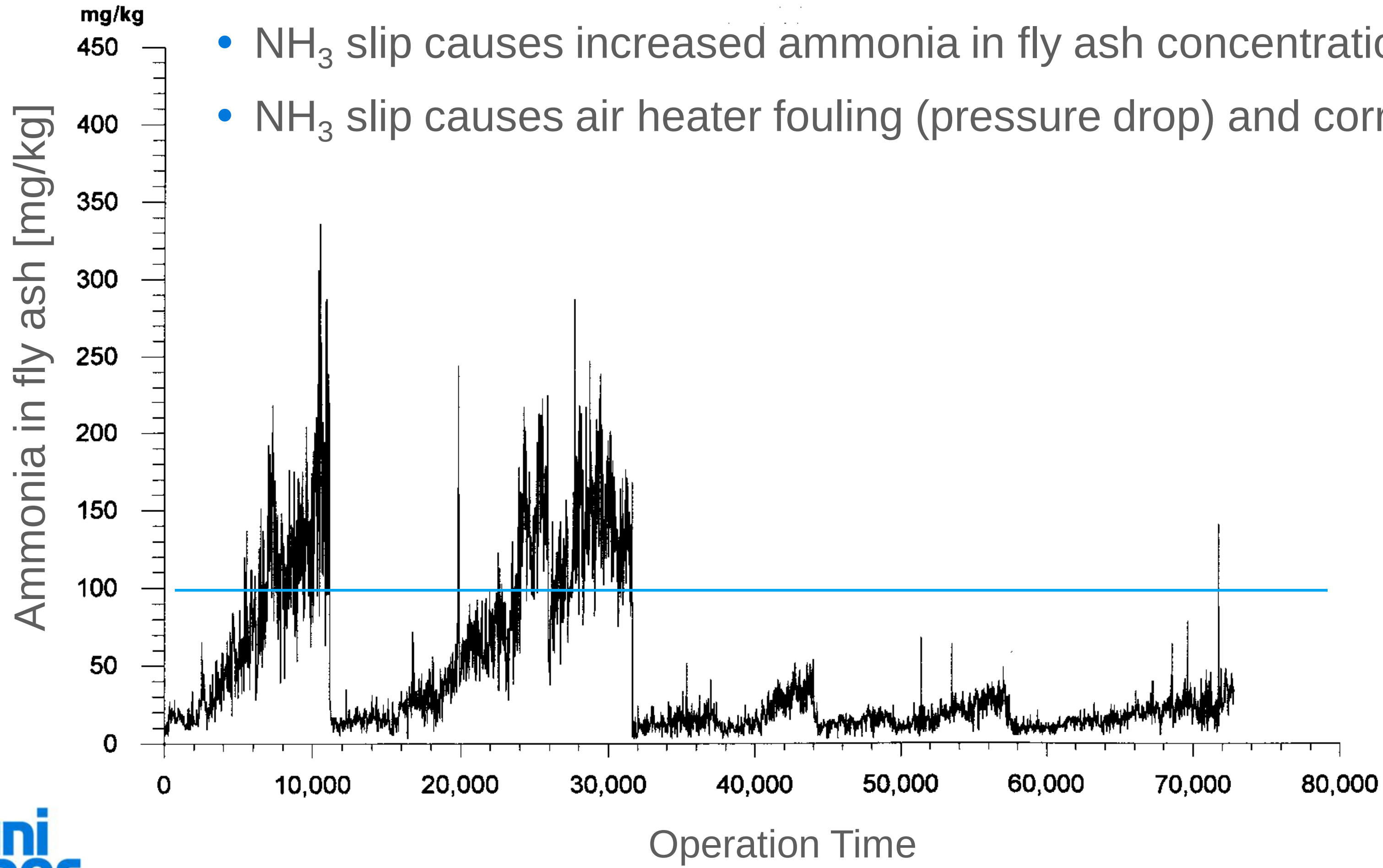


Potential forecast – compliance with NO_x and NH_3 limits



Catalyst Deactivation

- Catalyst deactivation causes ammonia slip
- NOx emission values remain stable
- NH_3 slip causes increased ammonia in fly ash concentrations
- NH_3 slip causes air heater fouling (pressure drop) and corrosion



Catalyst Deactivation - Detection of Mechanisms (e.g. XRF Analysis)

Honeycomb catalyst

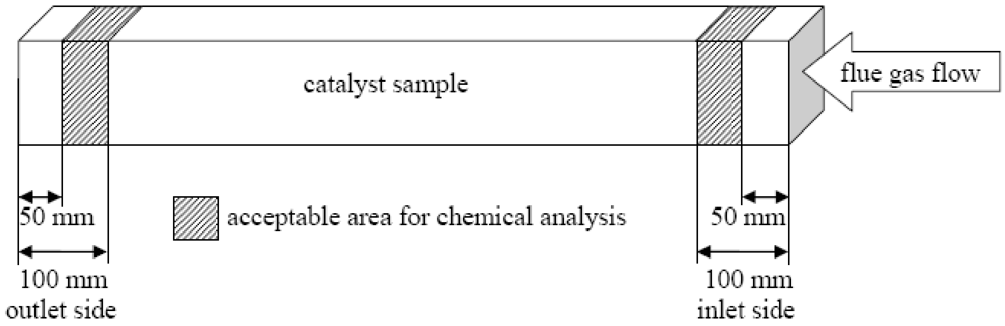
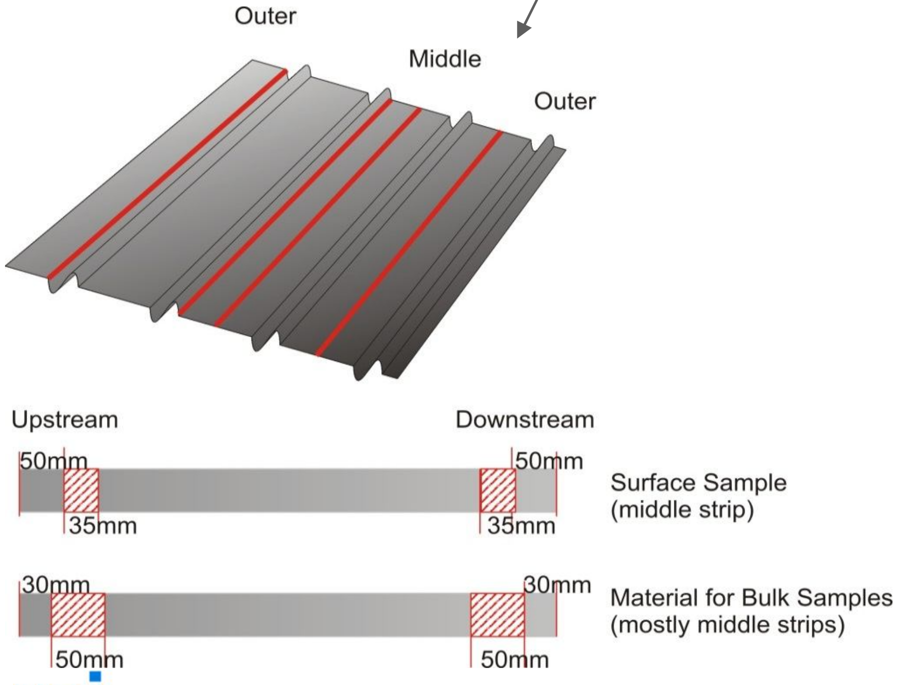
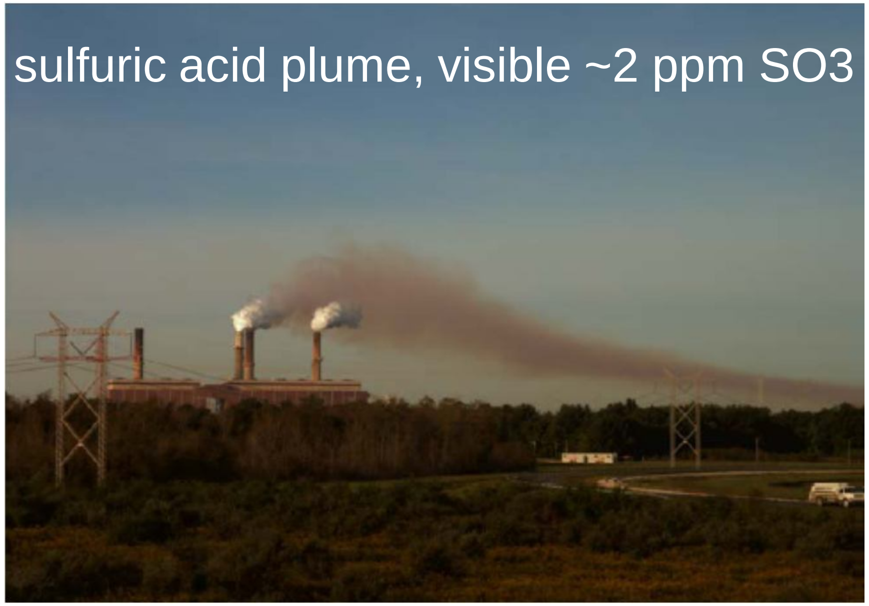


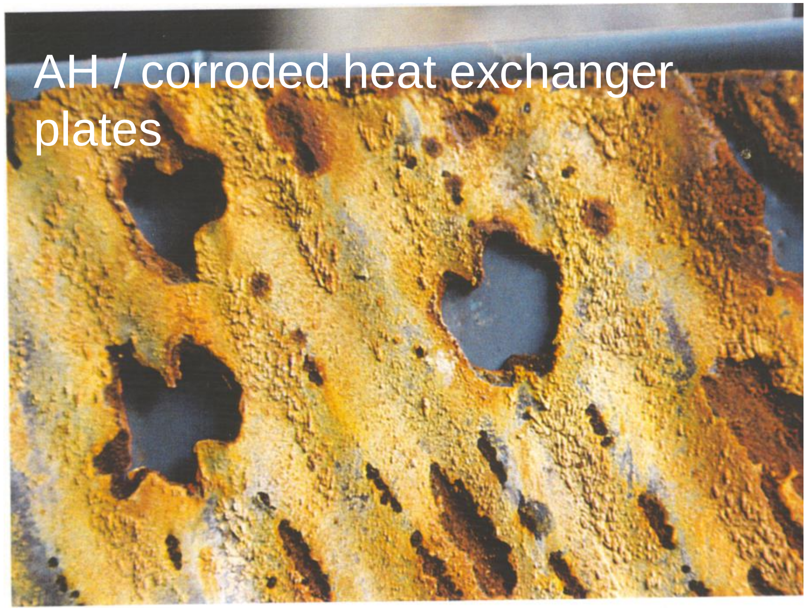
Plate type catalyst



- Chemical analysis of catalyst surface and bulk gives informations about the reasons for deactivation (e.g. poisoning, surface layer blinding)
- Understanding of catalyst deterioation mechanisms allows countermeasures! (e.g. CaO addition at arsenic poisoning)

SCR Impact on Downstream Equipment, example: SO_2 to SO_3 conversion





SO_2 conversion:

- acid emissions
- corrosion
- plugging (increasing pressure loss)

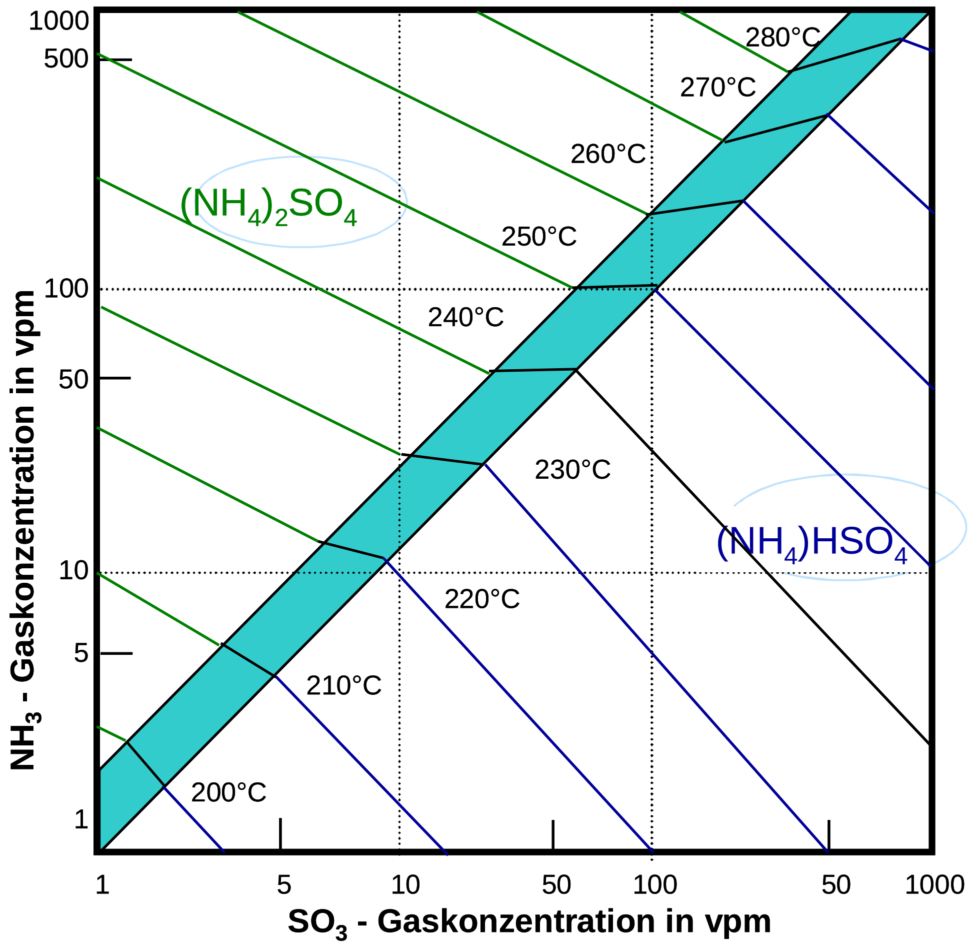
Example: SO_2 to SO_3 Conversion Rate throughout a Catalyst Lifetime

- Experience shows that SO_2 to SO_3 conversion does not decrease throughout a catalyst lifetime
- Conversion <u>can</u> increase if iron is present in/on the catalyst surface. Data has shown that conversion decreases in the presence of H_2SO_4 (originated by SO_3 and moisture) by mobilizing iron into the micropore system.
- The iron can have different sources: fly ash, metal grid (plate type catalysts), modules metal structure, corroded particles carried over by the flue gas, ...

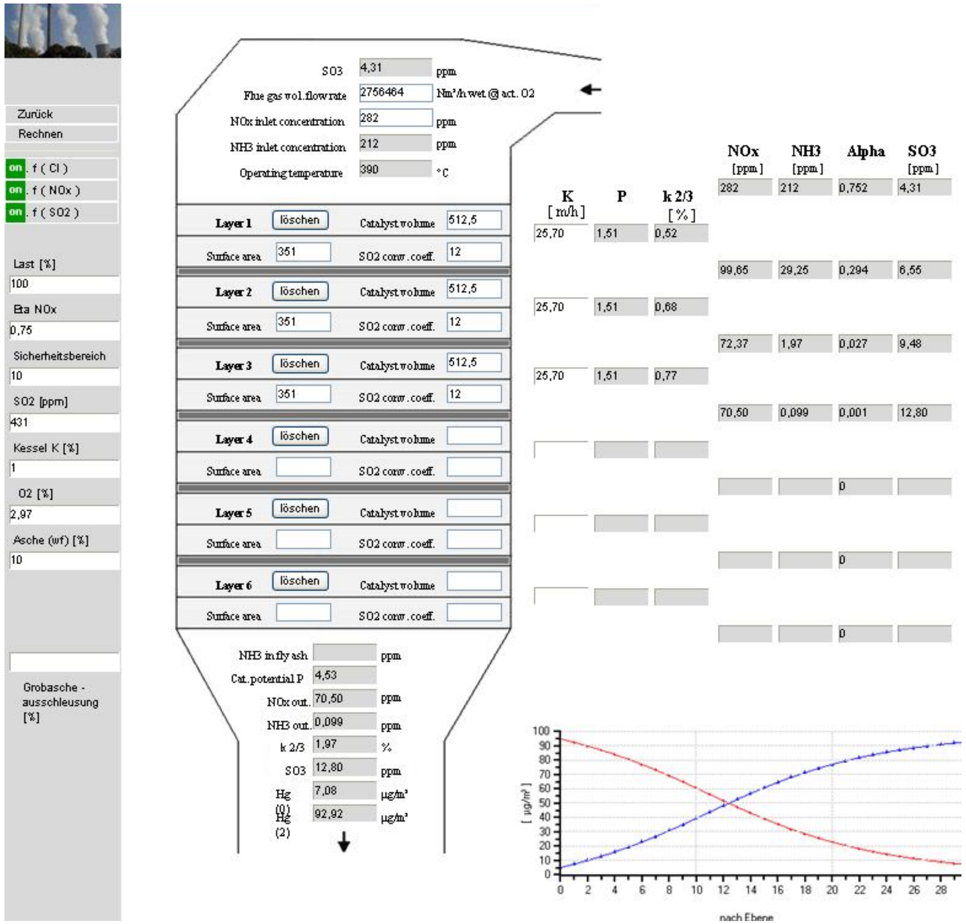
SO_2 conversion; Ammonia (bi)sulphates

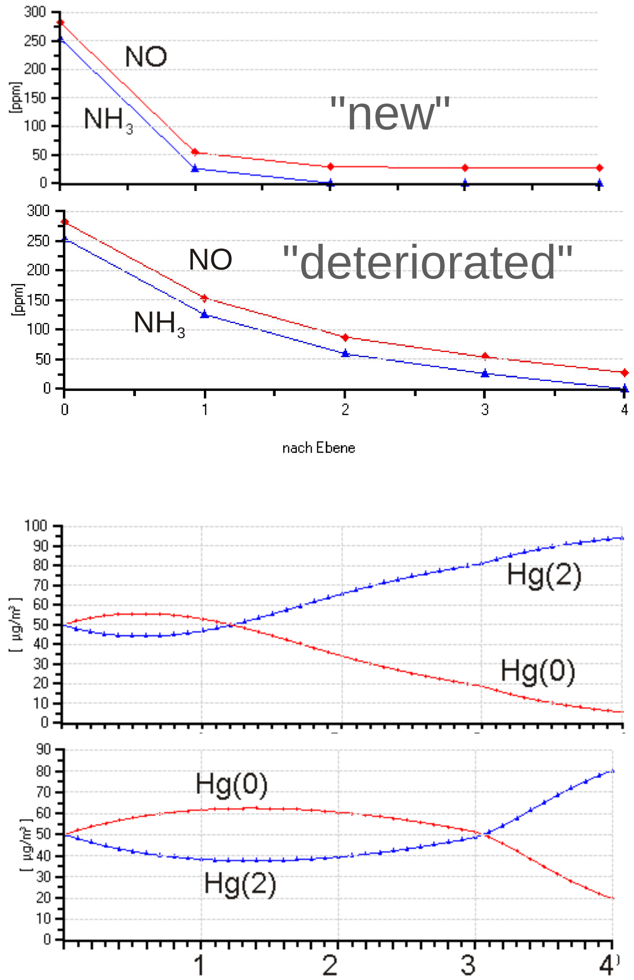
ABS dew point

- Important low load / partial situations
- Affected by partial pressures of NH_3 and SO_3, both can vary over lifetime
- Note: graph not valid for SCR-catalyst pore systems due to different conditions inside/outside the pores (pressure dependancy)

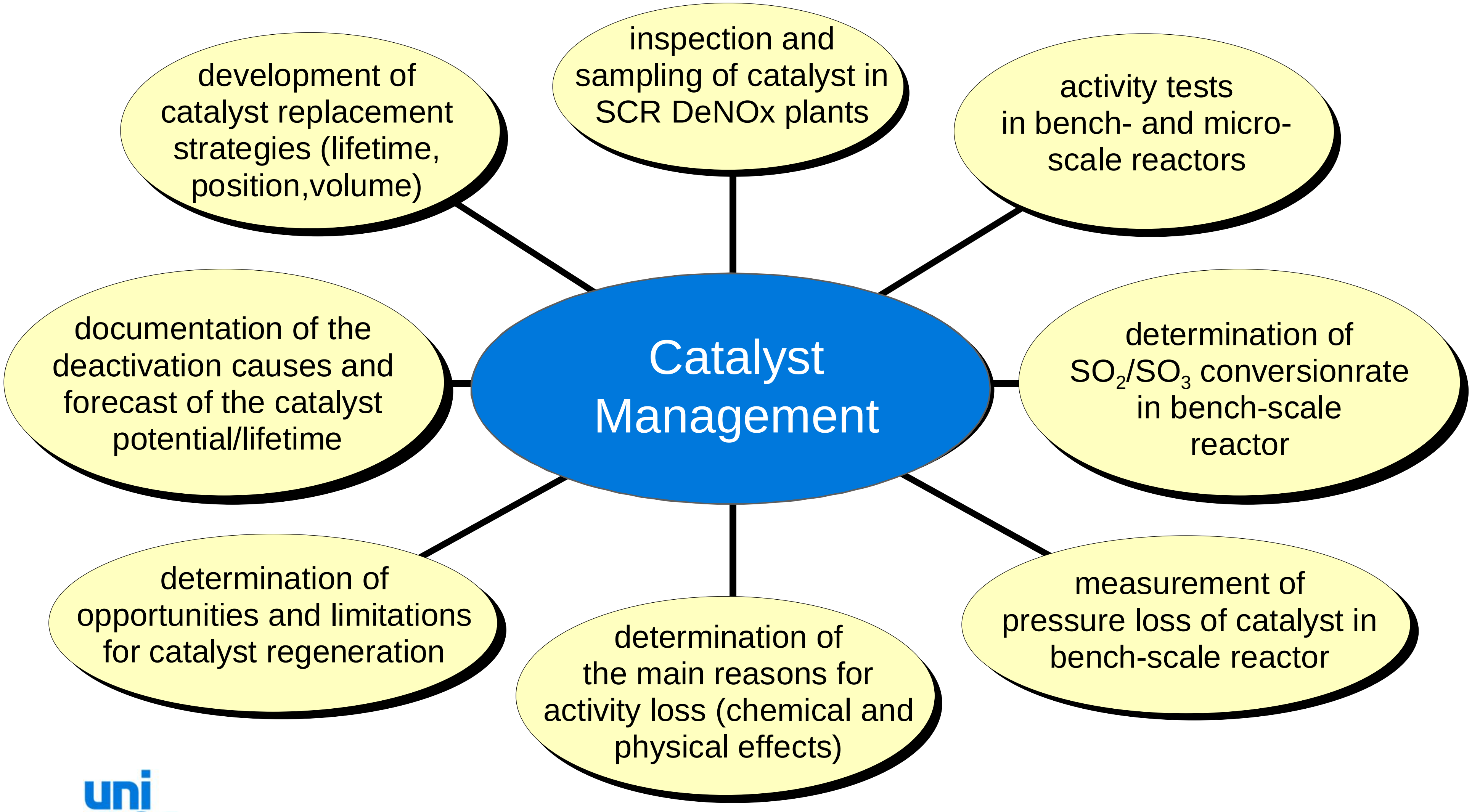


Catalyst management –
Leonid database and calculation tool





Summary


Catalyst Management
development of catalyst replacement strategies (lifetime, position,volume)
inspection and sampling of catalyst in SCR DeNOx plants
activity tests in bench- and micro-scale reactors
documentation of the deactivation causes and forecast of the catalyst potential/lifetime
determination of SO_2/SO_3 conversionrate in bench-scale reactor
determination of opportunities and limitations for catalyst regeneration
determination of the main reasons for activity loss (chemical and physical effects)
measurement of pressure loss of catalyst in bench-scale reactor

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Future Aim: Advanced catalyst management considering the Hg-oxidation on catalysts

- Example: Influence of catalyst deactivation (increased NH_3-slip) on Hg oxidation and possible effects (Leonid database and calculation tool)

  - Shifting Hg-active layers downstream

  - Effect: Possibly lower total Hg oxidation rate