

# Catalytic Emissions control for coal and gas power plants



Johnson Matthey

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APGTF Workshop- “Power generation (coal, gas, and biomass) under increasingly stringent emissions regulations”

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EMISSION CONTROL TECHNOLOGIES



# JM – Divisions and Products

- Stationary Emissions Control business is a subdivision of the larger Emission Controls business



## Stationary Emissions Control (SEC)



### Power Industry

#### Catalyst and Equipment

- Coal Plant SCR
- Gas Turbine SCR and CO
- Engine SCR



### Oil, Gas, Marine, and Locomotive Industry

#### Catalyst and Equipment

- Modulux 3-Way & 2-Way Converters for Gas Compression and Oil Pumps
- HAPs Converters
- Selective Catalysts Reduction (SCR)



### Industrial Manufacturing

#### Catalysts

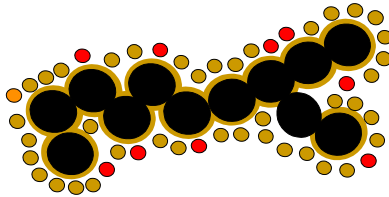
- PTA
- VOC
- NOx Abatement
- Selective Catalytic Reduction (SCR)



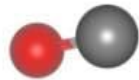
# Targeted Pollutants



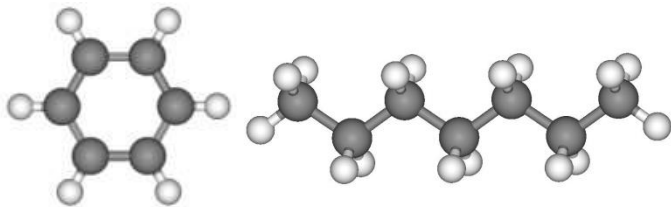
**Oxides of Nitrogen (NO<sub>x</sub>)**



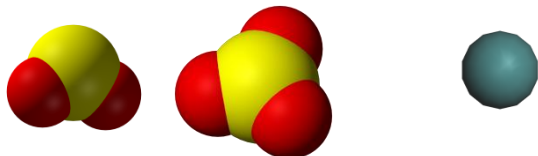
**Particulate Matter (PM)**



**Carbon Monoxide (CO)**



**Unburnt Hydrocarbons (HC)**



**SEC pollutants(Hg, SO<sub>3</sub>, SO<sub>2</sub>, ...)**

## Catalysts and Catalytic Systems for Emission Control

### Honeycomb Catalysts



Several pitches for applications such as WtE gas turbine, and engine, etc.

### Plate Catalysts



High dust applications coal fired power plants

### SCR Systems



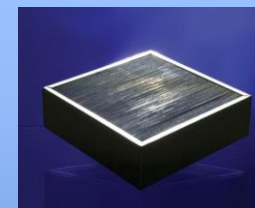
System soln inc. reactor, catalysts, dosing & controls

### Pellets



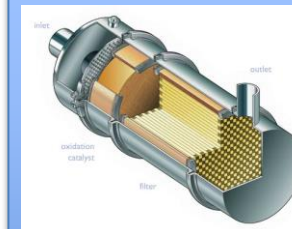
Removal of NO<sub>x</sub> or organic compounds

### Oxidation Catalysts



Removal of CO odor & VOCs

### DPF Filtration

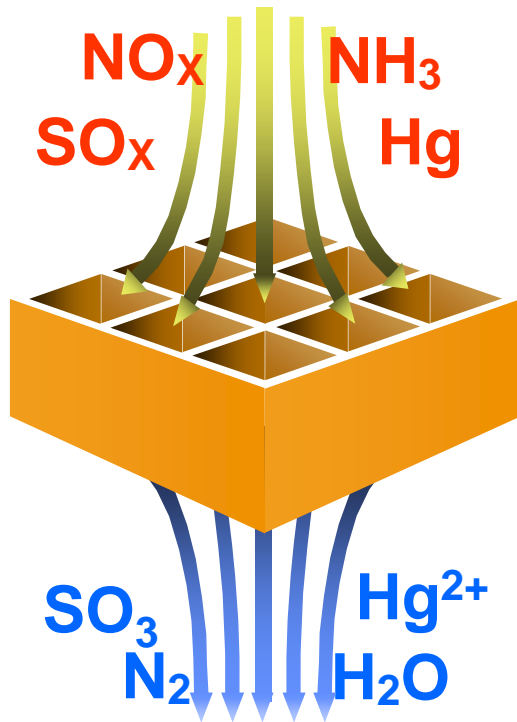


Removal of Particulate Material from Diesel Engines

❖ The majority of our products focus on the Selective Catalytic Reduction of NO<sub>x</sub> using NH<sub>3</sub> as the reductant



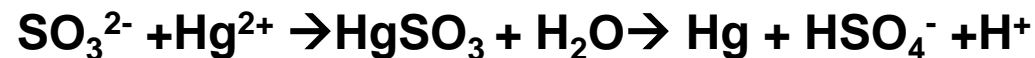
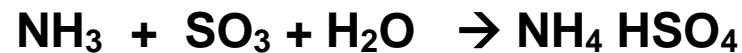
# SCR Process in a Coal Power Plant



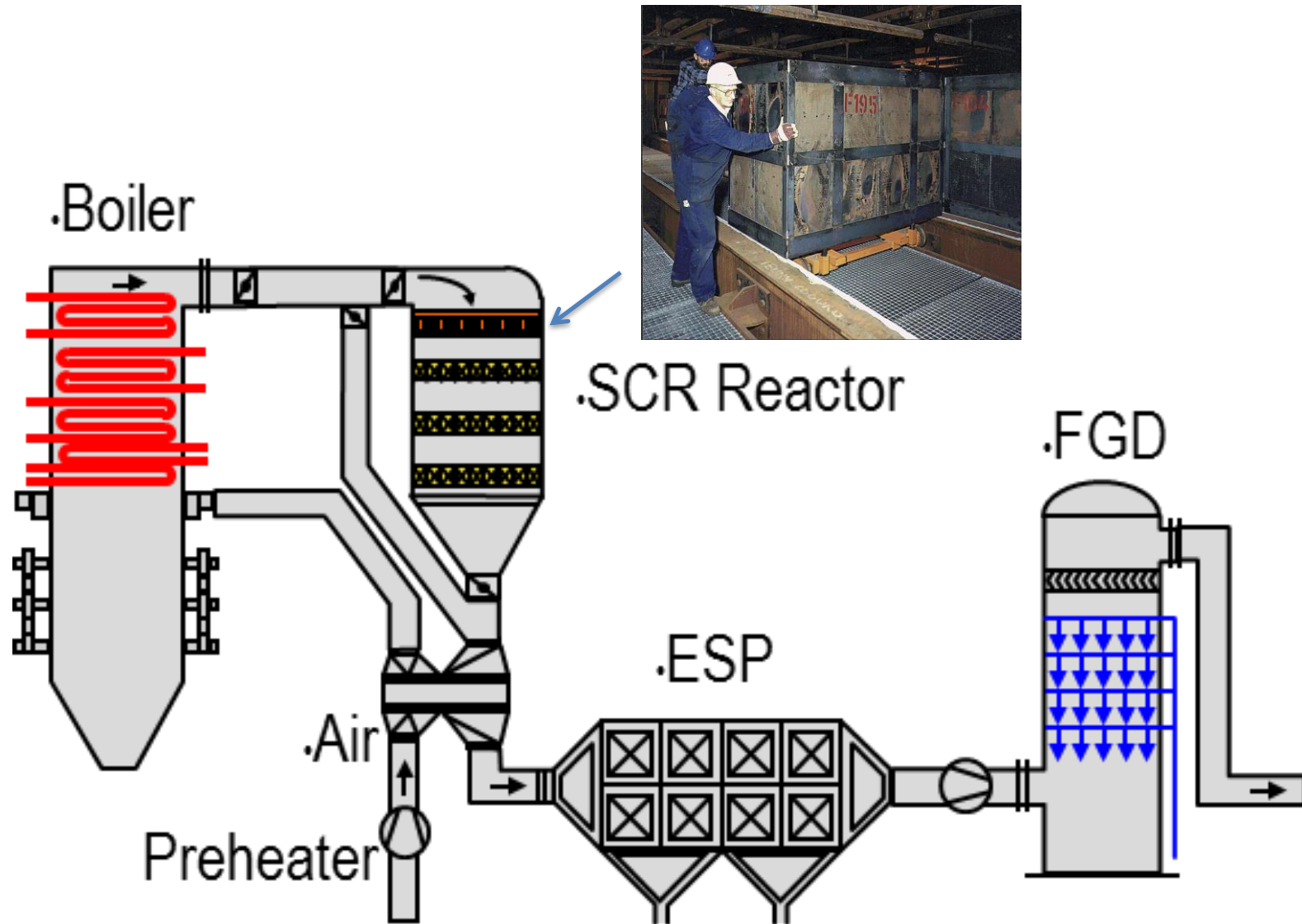
## Three main reactions of interest

- 1)  $4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}$  Maximize
- 2)  $\text{SO}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{SO}_3$  Minimize
- 3)  $\text{Hg} + 2\text{HCl} + \frac{1}{2}\text{O}_2 \rightarrow \text{HgCl}_2 + \text{H}_2\text{O}$  Maximize

## Undesired Parallel Reactions

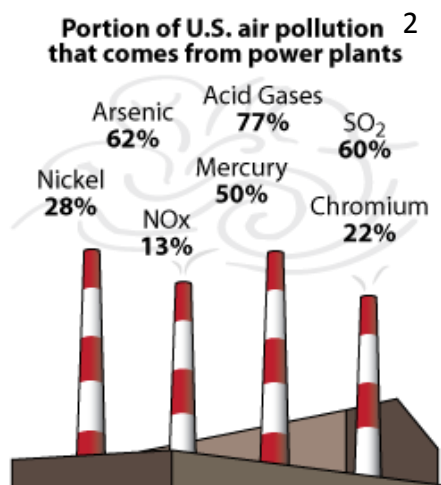


# Typical SCR Emissions Control in a Coal Power Plant



# Reduction of Hg emissions from Coal Power Plants

- Hg is one of the most volatile of all the heavy elements and is known for its toxicity particularly in the form of methylmercury.
- In the US, MATS regulations are currently enforced and existing plants are limited to 1.2 lbs Hg/TBtu(coal) and 4.0 lbs Hg/Tbtu(lignite) for a 30 day average.<sup>1</sup>
- In Europe the BAT conclusions of the LCP BREF should be adopted in 2017. All LCP permits in Europe will have to be updated accordingly within 4 years after publication of BAT conclusions. Only the higher end of the BAT-AEL range is legally binding at EU level.
- Generally preferred technology for Hg removal is “co-benefits”, in which Hg<sup>0</sup> is oxidized over the SCR catalyst to Hg<sup>2+</sup> which is then adsorbed in the downstream sulfur scrubber. Europe appears to be following the US lead in terms of technology approach.
- In light of this, a power generation facility intending to rely on the Hg oxidation properties of an SCR catalyst will need to ensure that property is reliably predicted under actual operating conditions.
- Advanced Hg oxidation catalysts are available and several different applications are being considered (Lignite vs. Hard coal).



BAT-AEL for coal plants				BAT-AEL for lignite plants			
Combustion plant total rated thermal input(MW <sub>th</sub> )	New Plants (µg/Nm <sup>3</sup> )	Existing plants (µg/Nm <sup>3</sup> )	Averaging period	Combustion plant total rated thermal input(MW <sub>th</sub> )	New Plants (µg/Nm <sup>3</sup> )	Existing plants (µg/Nm <sup>3</sup> )	Averaging period
<300	<1-3	<1-9	Average of samples obtained during one year	<300	<1-5	<1-10	Average of samples obtained during one year
≥300	<1-2	<1-4	Yearly average	≥300	<1-4	<1-7	Yearly average

1) Federal Register, Vol. 81, No. 66, April 6, 2016

2) <http://www.epa.gov/airquality/powerplanttoxics/powerplants.html>



# Challenges for Hg oxidation over SCR catalysts in Coal Power Plants



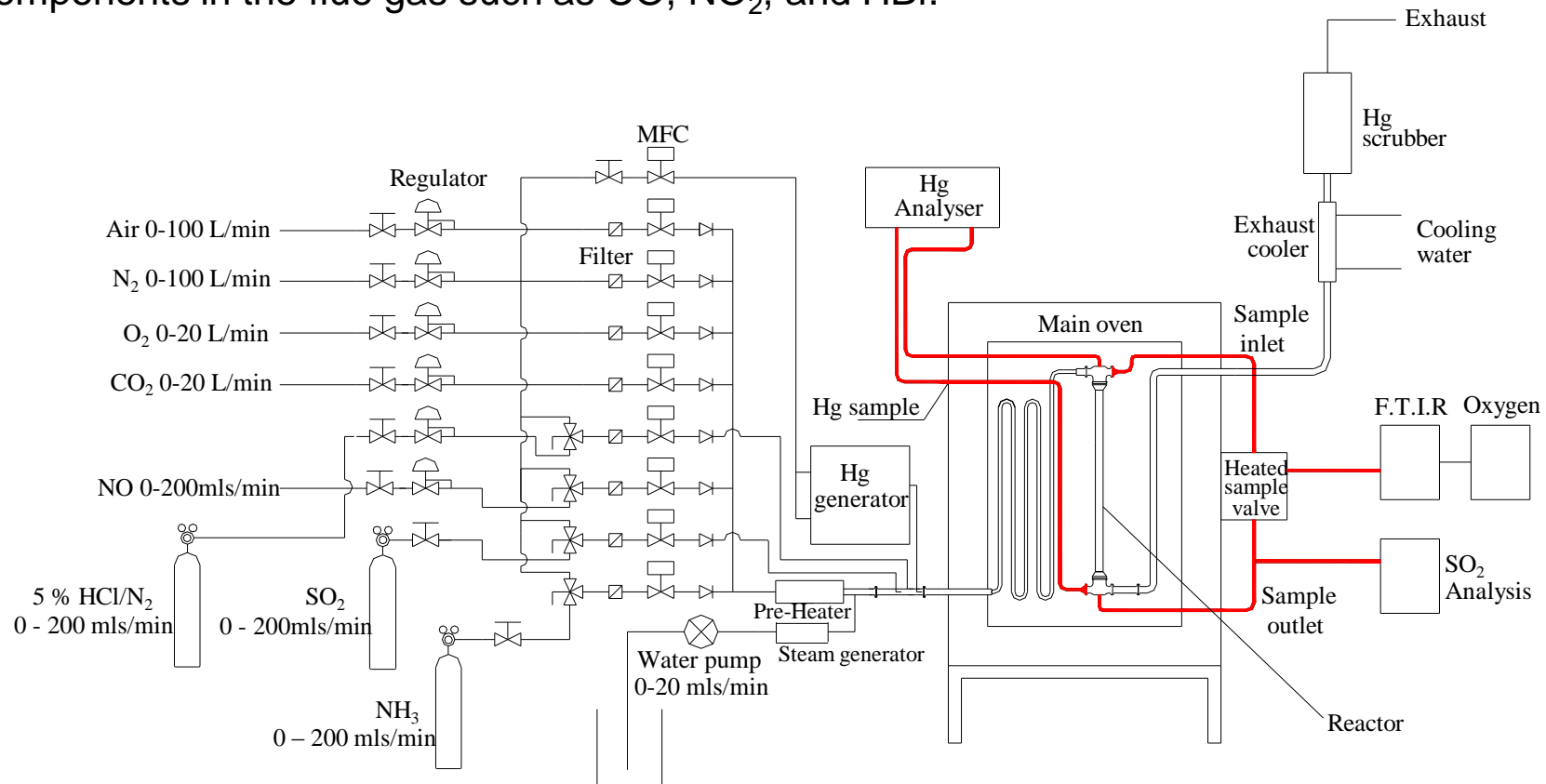
- Accurately measuring Hg oxidation under simulated power plant conditions in the lab and correlating activity measurements of the catalyst to performance in a plant or to third party tests. Hg concentrations are typically in the ppb level of the flue gas!
- Maximize Hg oxidation while maintaining the same SO<sub>x</sub> and NO<sub>x</sub> activity, particularly in the following tough conditions (equilibrium limited):
  1. Low halogen content
  2. High temperature
  3. High H<sub>2</sub>O content & Low temperatures (Lignite plants, which typically don't have SCR catalysts installed)
- Understand how the operating conditions affect Hg oxidation activity of SCR catalysts so that better Hg oxidation guarantees can be made and Utilities have more operational flexibility
- Understanding and minimizing the deactivation mechanisms (Plate/HC erosion, posions, etc) of these SCR catalysts both for Hg and for SCR.

Example Conditions	Sub-/Bituminous plants	Lignite plants
T (°C)	320-420	170-200
LV (Nm/s)	1.7-2.2	1.0-2.2
AV (Nm/h)	13-20	7-9
SO <sub>2</sub> conc (ppm)	400-3000	400-2000
NO <sub>x</sub> conc (ppm)	0-550	0-140
NH <sub>3</sub> conc (ppm)	0-500	-
HCl conc (ppm)	15-110	0-15
Inlet Hg (mg/Nm <sup>3</sup> )	5-45	10-20
O <sub>2</sub> (%)	2.5-6	3.5
H <sub>2</sub> O (%)	6-12	18-24



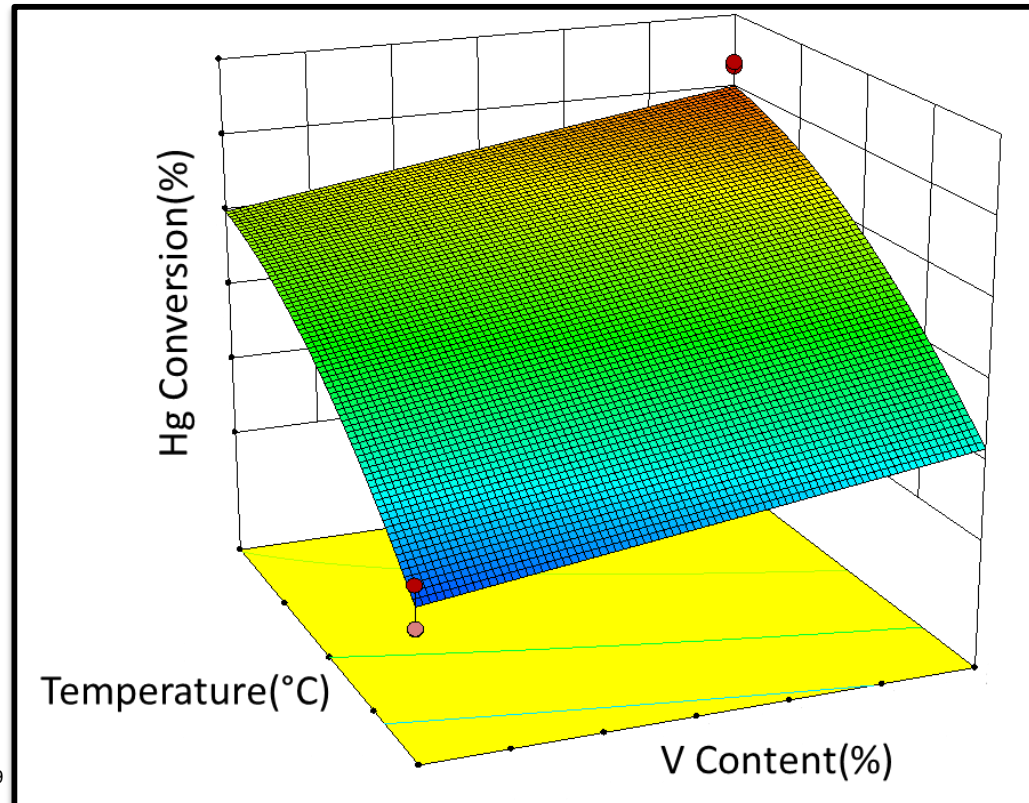
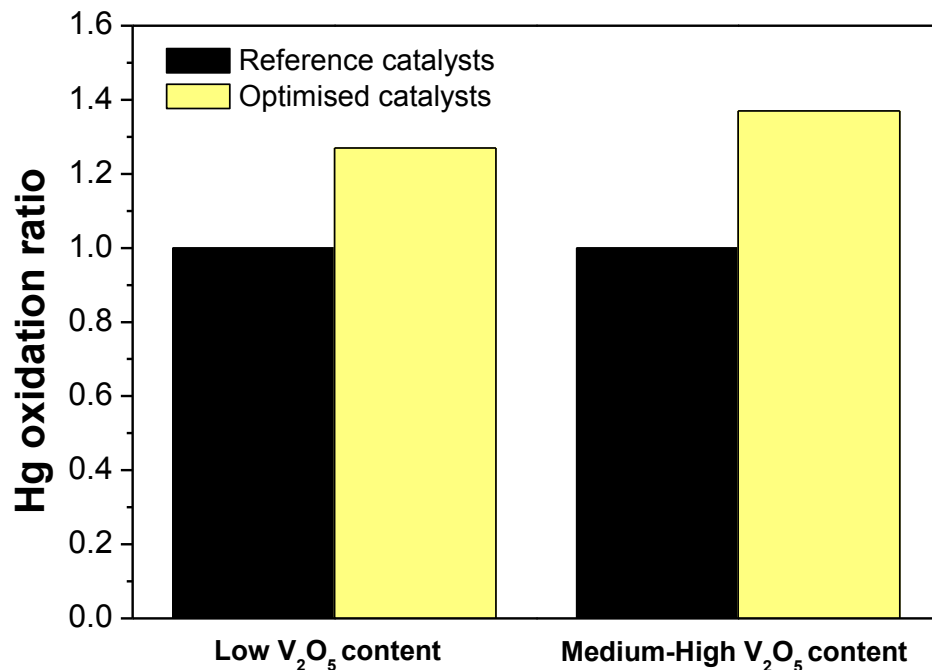


- In addition to our standard NO<sub>x</sub> and SO<sub>x</sub> testing facilities, JM has a dedicated lab for Hg oxidation research and has been involved with Hg oxidation since early 2000s.
- This Semi-Bench reactor system is unique since it can nearly match both the LV and AV in SCR reactors on typical coal power plants. It also has the ability to investigate the effects of lesser components in the flue gas such as CO, NO<sub>2</sub>, and HBr.



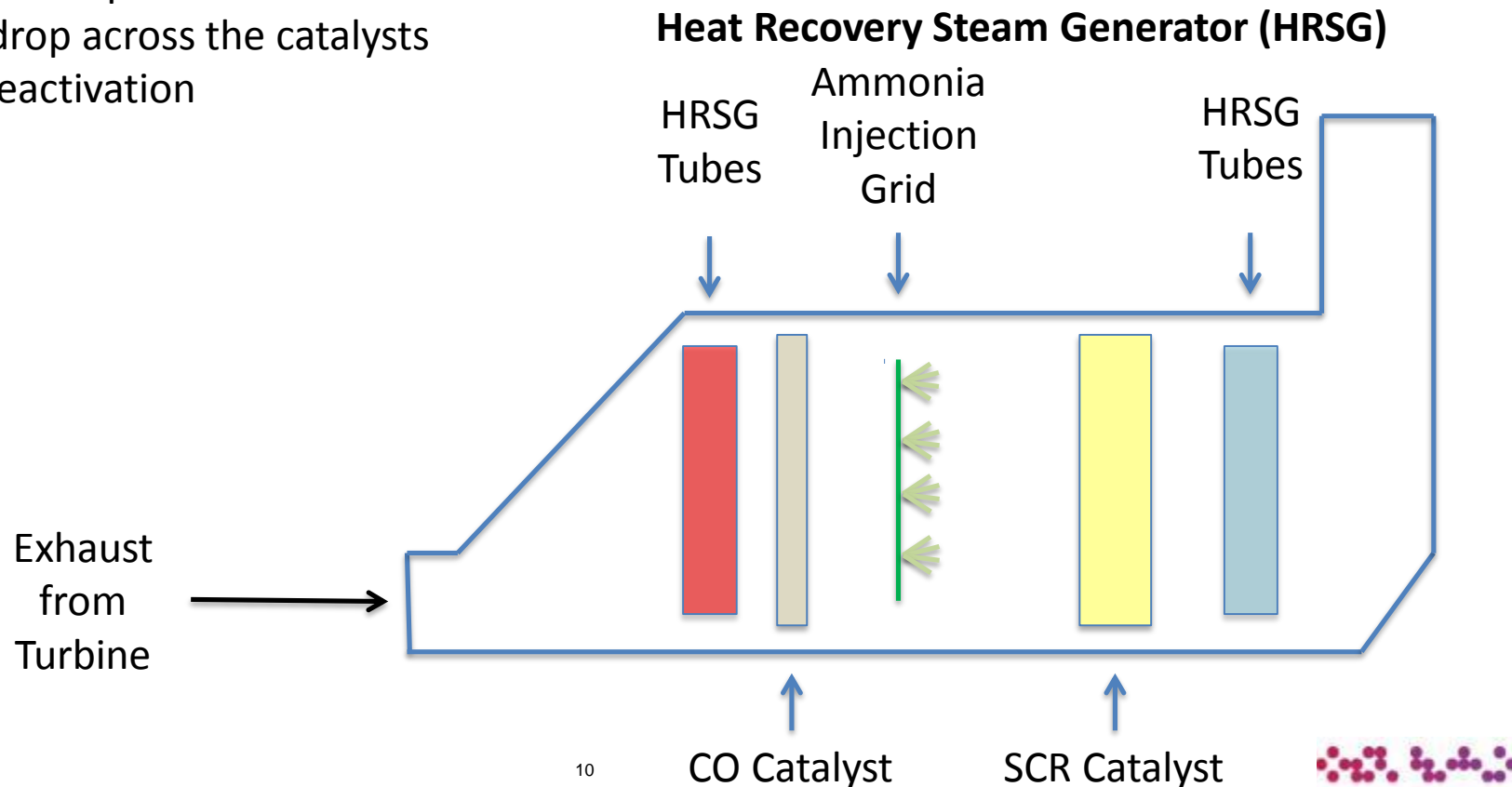
# Some of the Hg Oxidation developments at JM

- Developed a detailed model of the Hg oxidation performance of our SCR catalysts under a variety of operational conditions, which allows utilities to predict Hg oxidation performance.
- Developed advanced SCR catalysts with enhanced activity (Hg and NO<sub>x</sub>)
- Heavily involved in the development of Hg oxidation protocols for both the US and European markets
- Involved in several field trial applications for our catalysts(Europe & USA).
- Published mechanistic investigations on Hg oxidation over SCR catalysts



# Typical Emissions control for Combined Cycle Gas Turbine SCR

- Emissions control for gas turbines typically involve a CO and SCR catalyst installed in a HRSG
- There are strict emissions regulations from these units for CO, VOC, NO<sub>x</sub>, and NH<sub>3</sub>
- Some of the main concerns regarding emission control on Gas Turbines are:
  - Emissions at low temperature
    - Frequent start-ups/shut downs(Operational flexibility)
    - Low load operations
  - Pressure drop across the catalysts
  - Catalyst deactivation
  - Cost



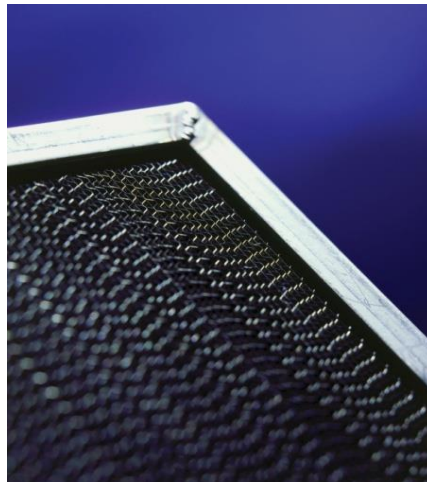
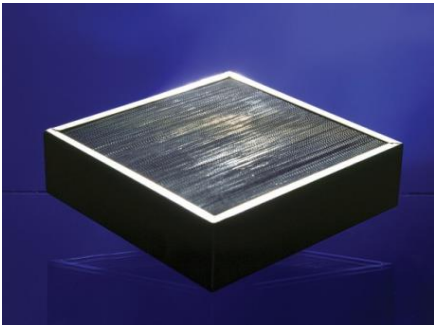
# Typical Catalyst products for Gas Turbines

## Oxidation Catalyst

- Typically used for CO and VOC oxidation on gas and Diesel engines
- Typically 200 CPSI
- Custom Block sizes that are fully brazed for strength
- Thin walls for low pressure drop
- Contains Precious Metals such as Pt

## SCR HC Catalysts

- Typically used for the reduction of Nox with  $\text{NH}_3$  as reductant
- High activity & specific surface area
- Variable length and number of cells
- *Typical*: 140 cpsi & 200 – 400 mm length
- Homogeneously extruded ceramic with square-opening cell structure
- $\text{TiO}_2$ , V-oxide/W-oxide



- Advanced Oxidation Catalyst
  - Improved activity(particularly at low temperatures)
  - Sulfur resistance
- Advanced SCR Catalyst
  - Thin wall geometry for lower pressure drop

Today we will focus on this development

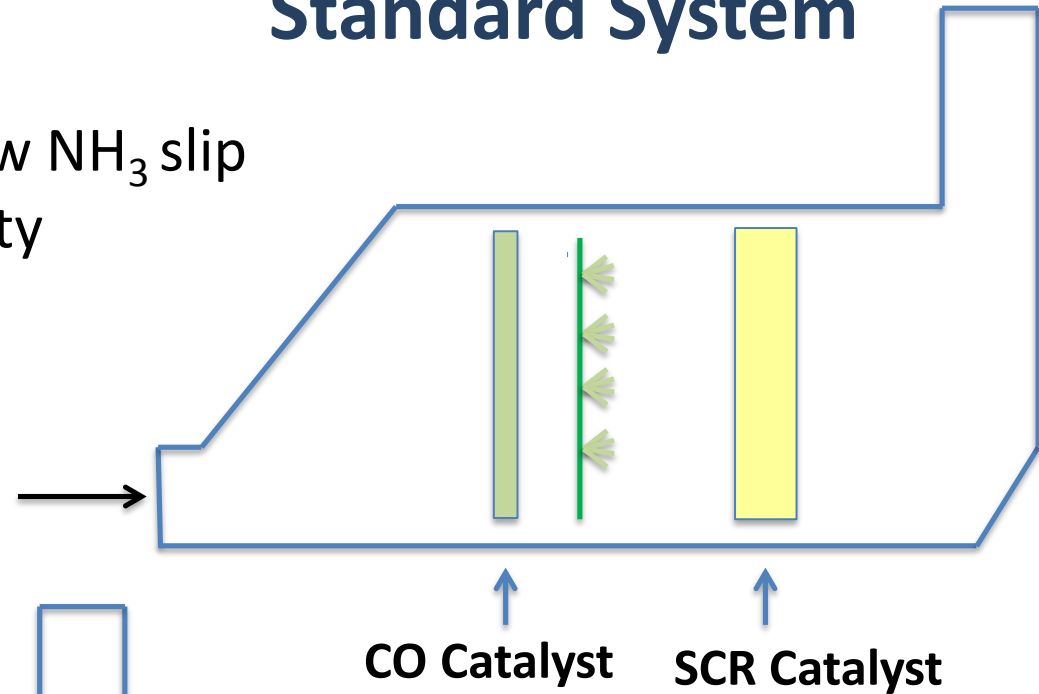
- Ammonia Slip Catalysts (ASC)
  - Ammonia slip control
  - Catalyst volume reduction for low pressure drop

# SCR-ASC Has a Number of Potential Advantages

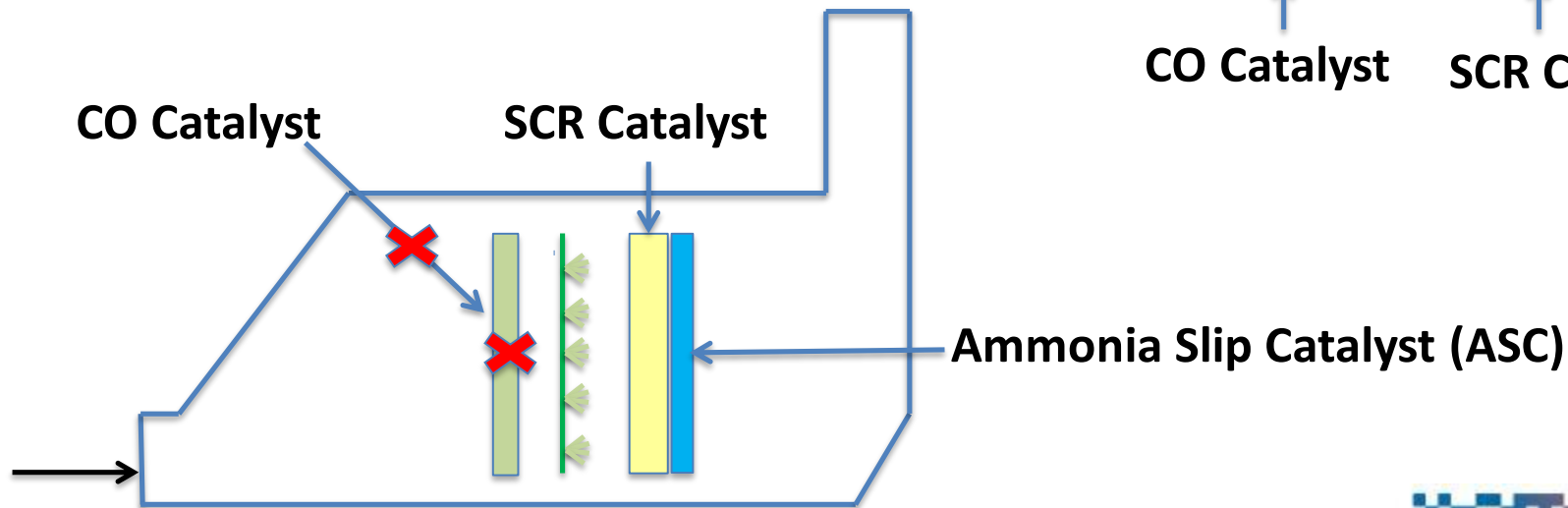
## SCR-ASC Advantages

- Reduced Volume, delta P
- High NO<sub>x</sub> Conversion, Low NH<sub>3</sub> slip
- CO Oxidation Functionality

## Standard System



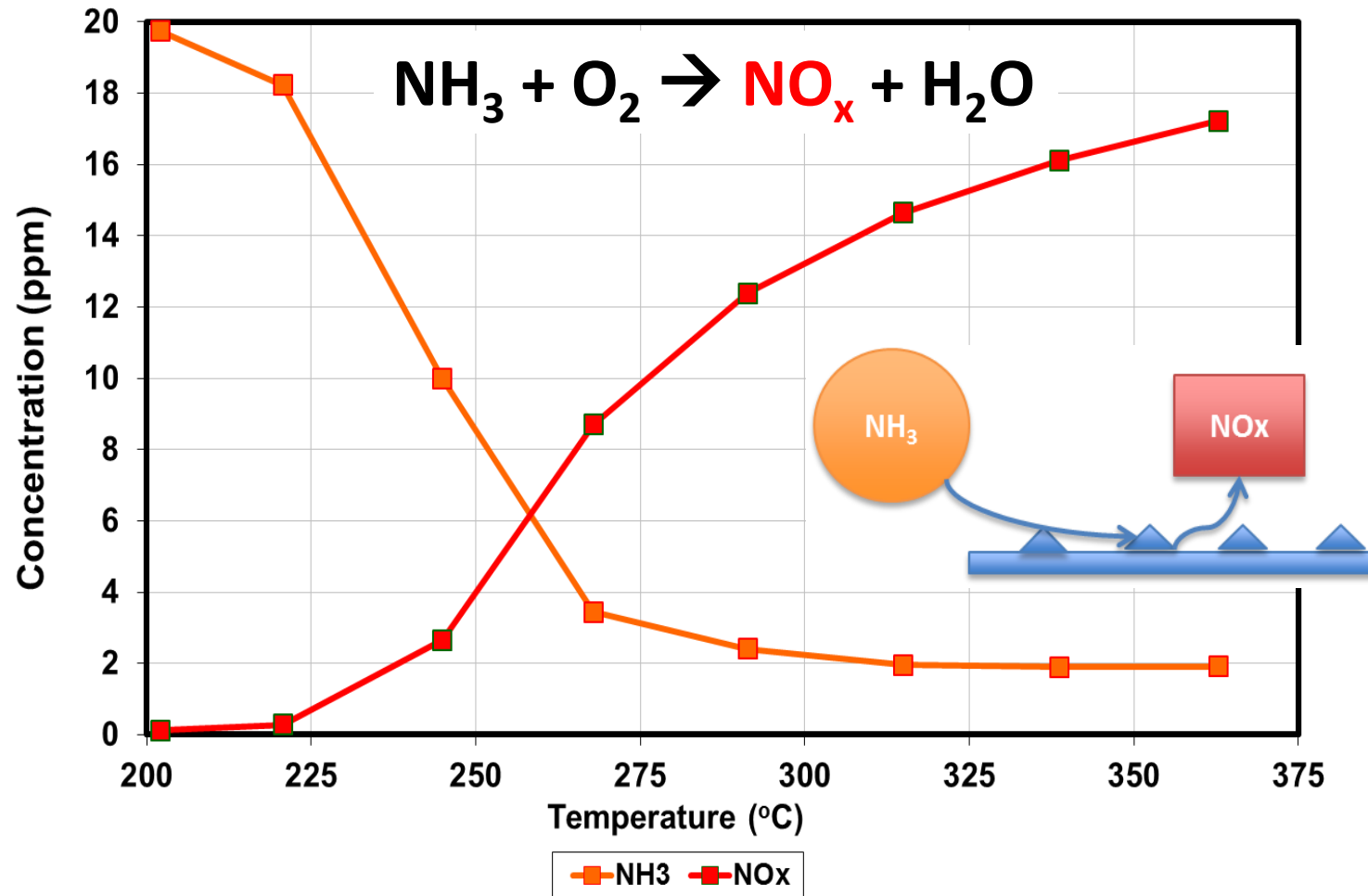
## SCR-ASC System



# Pt Based Ammonia Slip Catalyst Selective to NOx

$\text{NH}_3 = 20\text{ppm}$ ,  $\text{O}_2 = 15\%$ ,  $\text{H}_2\text{O} = 8\%$ ,  $\text{CO}_2 = 3\%$ , Balanced by  $\text{N}_2$

## Non-Selective Ammonia Slip Catalyst

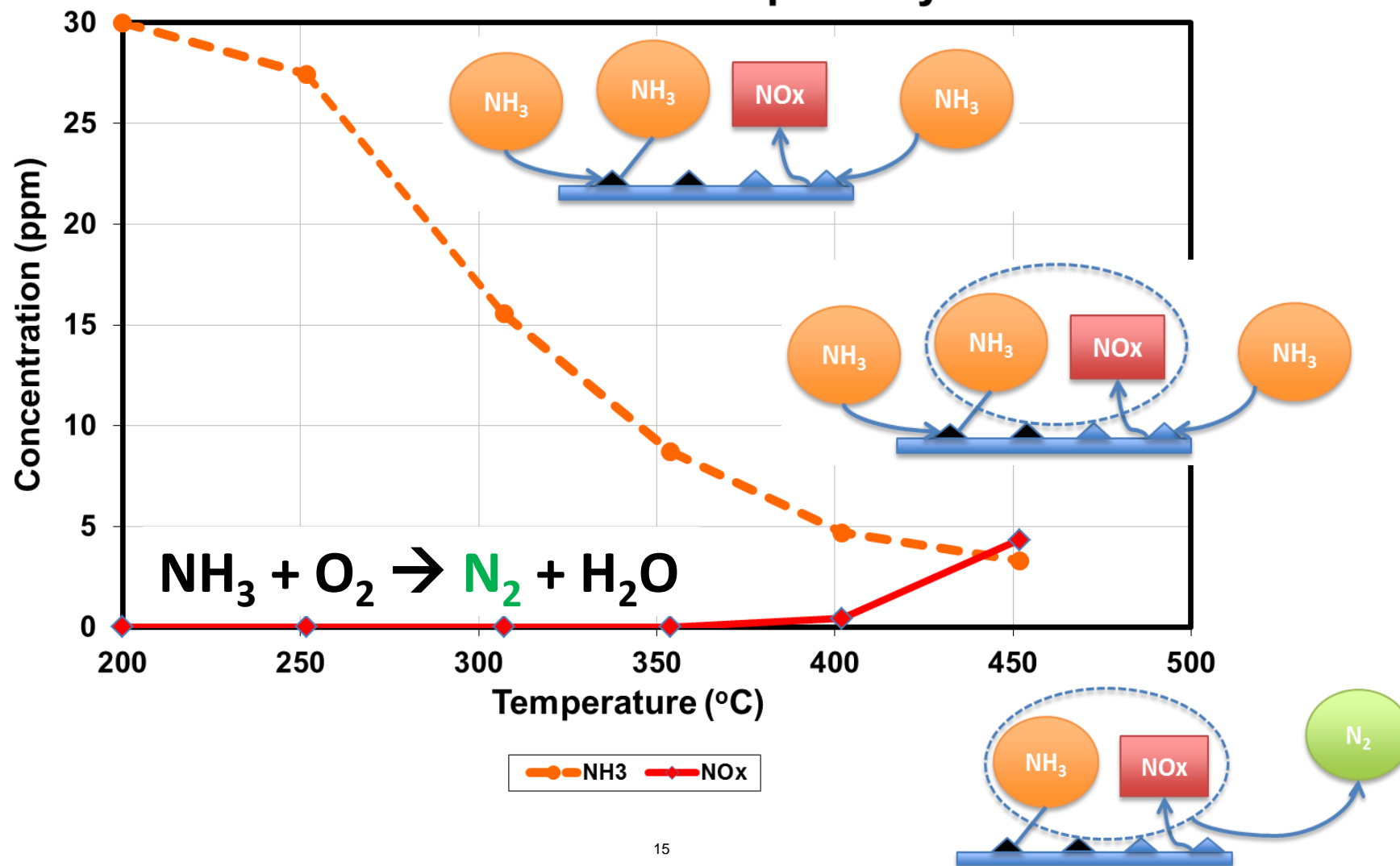




# New Ammonia Slip Catalyst Selective to N<sub>2</sub>

NH<sub>3</sub>= 30ppm, O<sub>2</sub>= 15%, H<sub>2</sub>O= 8%, CO<sub>2</sub> = 3%, Balanced by N<sub>2</sub>

## Selective Ammonia Slip Catalyst



# Conclusions

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- JM has several new technologies to help utilities deal with the increasingly stricter emissions controls legislation on both coal and gas turbine power plants.
- These technologies allow these plants to be emissions compliant and still economically competitive with other forms of power generation.
- JM has worked with many utility operators world-wide to develop standard or unique solutions that allow them to achieve their emissions limits.

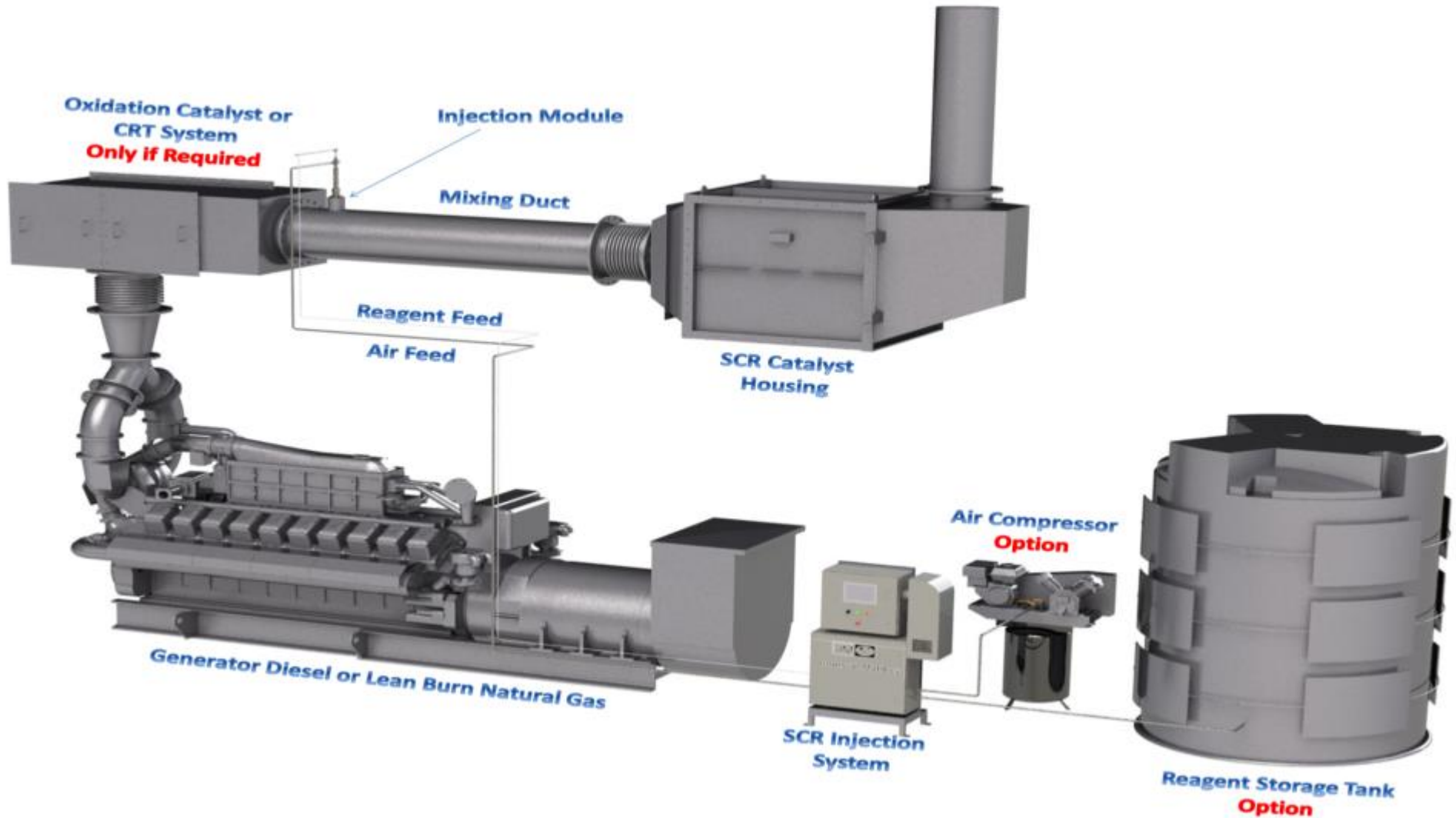
**Questions?**



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# Background Slides

# Engine SCR (Diesel or Natural Gas)





### Incinerator Kristiansand, N

- 120 000 t/a municipal waste
- Low-dust
- Reduction rate  $\text{NO}_x > 95 \%$
- Ammonia slip  $< 5 \text{ mg/m}^3$



### Incinerator Hameln, N

- 140 000 t/a municipal waste
- Low-dust
- Reduction rate  $\text{NO}_x > 88 \%$
- Ammonia slip  $< 3.8 \text{ mg/m}^3$



### Incinerator EVI Europark, D

- 365 000 t/a municipal waste
- Low-dust
- Reduction rate  $\text{NO}_x > 90 \%$
- Ammonia slip  $< 5 \text{ mg/m}^3$



### **EON, Ratcliffe, UK**

- 4 x 520 MW
- World-Market Coal
- Reduction rate  $\text{NO}_x > 85 \%$
- Ammonia slip  $< 2 \text{ ppm}$



### **Studstrupværket, DK**

- 2 x 350 MW
- Coal and Straw
- Reduction rate  $\text{NO}_x > 90 \%$
- Ammonia slip  $< 2 \text{ ppm}$



### **NUON, Amsterdam, NL**

- 660 MW
- World-Market Coal
- Reduction rate  $\text{NO}_x > 90 \%$
- Ammonia slip  $< 1 \text{ ppm}$