REINHOLD ENVIRONMENTAL Ltd.

2012 Coal to Gas Conversion Round Table & Expo Presentation

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SCR Catalyst for Coal to Gas Conversions

Johnson Matthey Catalysts

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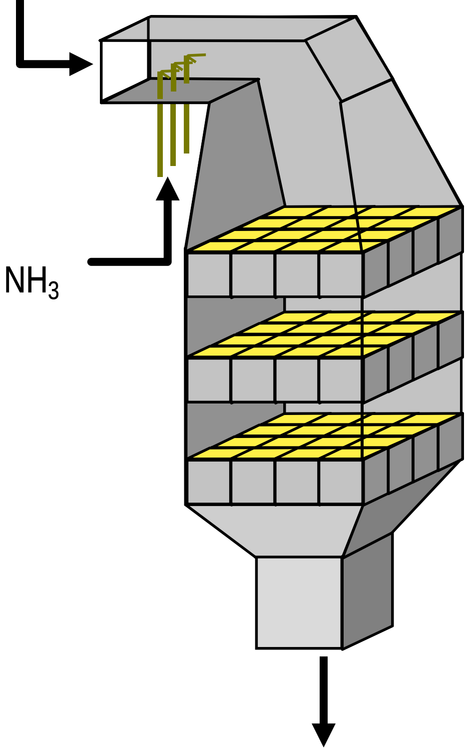
ENVIRONMENTAL CATALYSTS AND TECHNOLOGIES

Topics

- Catalyst Performance
- Catalyst Maintenance
- SCR Catalyst and Coal-to-Gas Conversions

SCR



- SCR = Selective Catalytic Reduction
- Purpose is to reduce NO_x (NO & NO_2) from combustion exhaust
- Ammonia (NH_3) is injected into flue gas as reducing agent. Flue gas passes through catalyst layers installed in a reactor
- NH_3 reacts with NO_x on the catalyst surface to form nitrogen and water

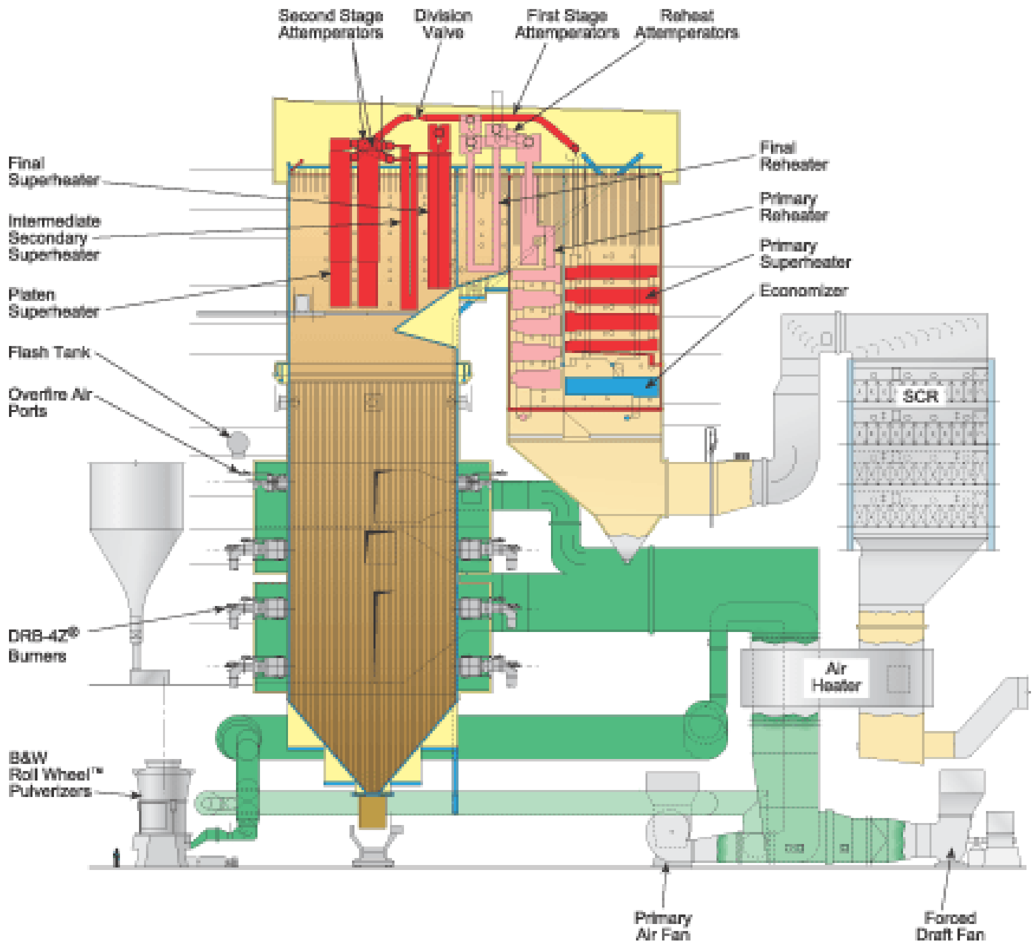
$$4NO + 4NH_3 + O_2 \xrightarrow{\text{Catalyst}} 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 \xrightarrow{\text{Catalyst}} 3N_2 + 6H_2O$$

Fossil Fuel Air Emissions Comparison (lb/MMBTU of Energy Input)

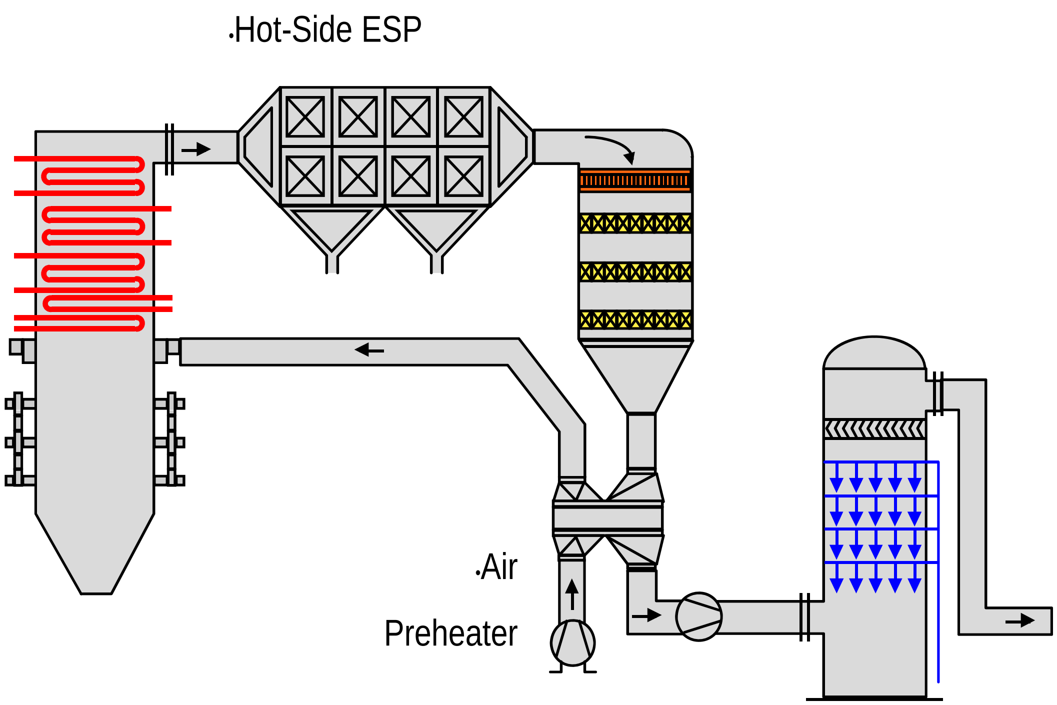
Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	120	160	200
Carbon Monoxide	0.09	0.03	0.20
Nitrogen Oxides	0.09	0.40	0.40
Sulfur Dioxide	0.001	1.0	2.5
Particulates	0.007	0.08	2.7
Mercury	0.000	0.007×10^{-3}	0.016×10^{-3}

SCR Configuration with Coal-fired Boilers – “High Dust”



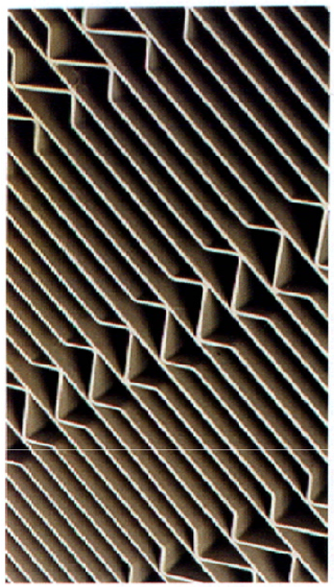
Source: The Babcock and Wilcox Company – www.babcock.com/products

SCR Configuration with Coal-fired Boilers – “Low Dust”

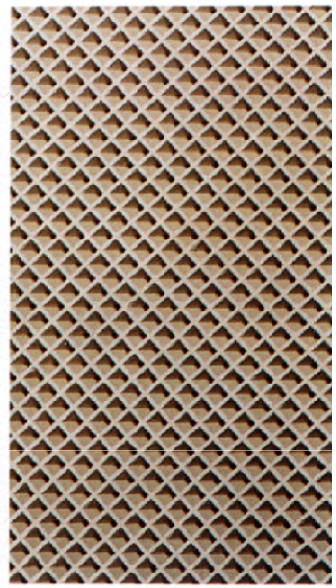


SCR Catalyst Types

Plate



Honeycomb



Corrugated

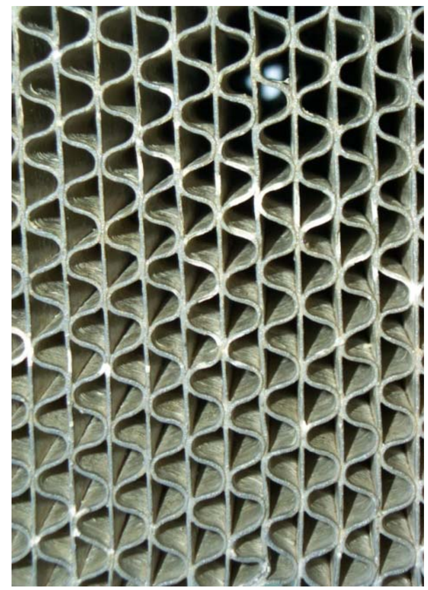
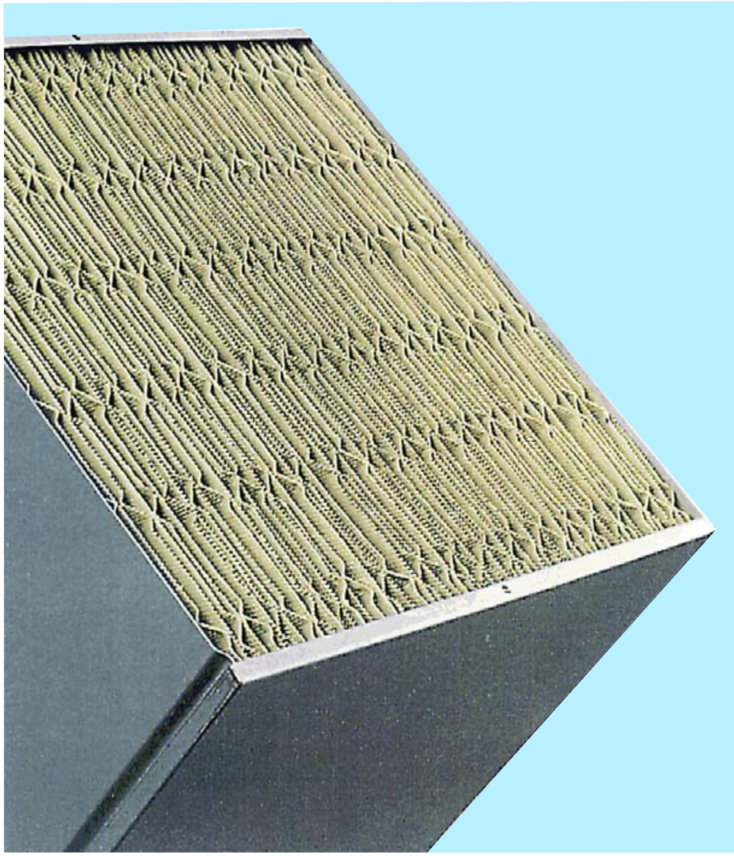


Plate-type Catalyst



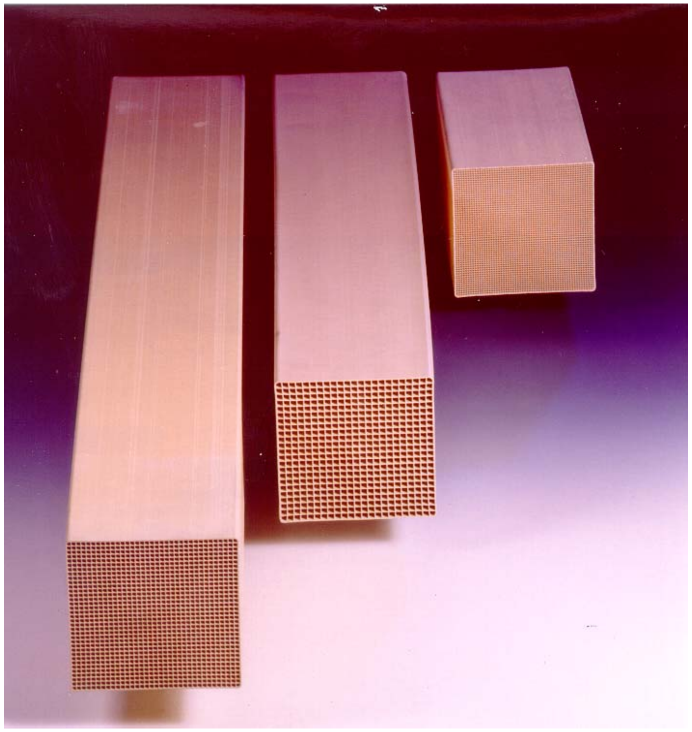
Composition

- Stainless steel expanded mesh substrate, coated with ceramic material
- TiO_2, V-oxide/W-oxide/Mo-oxide
- Notches formed into plates provide separation
- Inserted in element boxes with variable spacing: 60 to 90 plates
- Variable plate height up to 700 mm

Advantages

- Ideal for high dust configurations
- Plugging, erosion resistance
- Low pressure loss

Honeycomb Catalyst



Composition

- Homogeneously extruded ceramic with square-opening cell structure
- TiO_2, V-oxide/W-oxide
- Variable block height up to 1300 mm
- Pitch: 2.1 mm – 9.2 mm

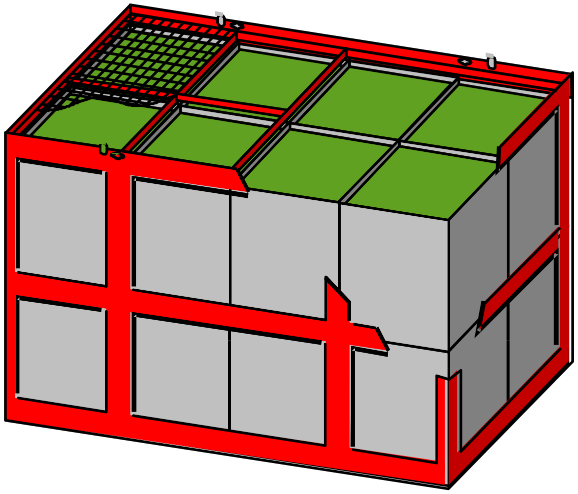
Advantages

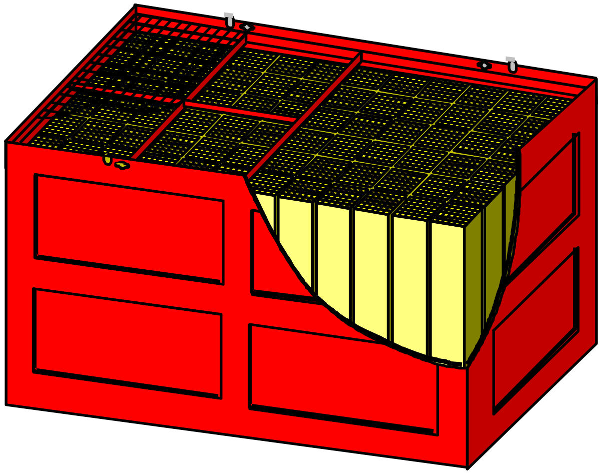
- Ideal for low/no-dust applications
- High active surface area per unit volume

SCR Catalyst Pitch Selection by Application

Application	Plate Pitch	Honeycomb Pitch
Natural Gas, Diesel	-	2.1 mm (70 x 70 cell) – 3.2 mm (47 x 47 cell)
Tail-End, Low-dust	5.0 – 5.6 mm	3.7 mm (40 x 40 cell) – 7.1 mm (21 x 21 cell)
Fuel Oil	5.0 – 5.5 mm	4.9 mm (30 x 30 cell) – 6.4 mm (23 x 23 cell)
Bituminous Coal	5.5 – 5.8 mm	6.7 mm (22 x 22 cell) – 8.2 mm (18 x 18 cell)
PRB Coal	5.7 – 6.0 mm	8.2 mm (18 x 18 cell) – 9.2 mm (16 x 16 cell)
Lignite	6.0 – 7.0 mm	Not Used (no US data)

Catalyst Modules for Utility SCRs

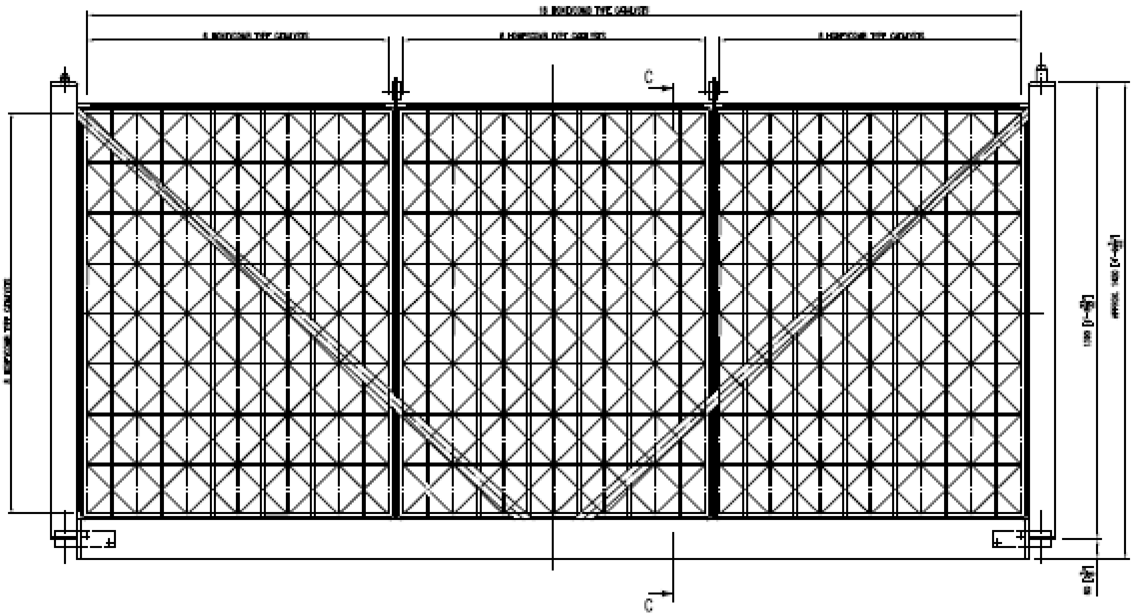




- Catalyst elements arranged in steel frames
  - Plate – 2 levels of 8 element boxes
  - Honeycomb – 72 monoliths
- Standardized cross-section
- Possible to interchange catalyst types within reactor
- Module height varies with catalyst height

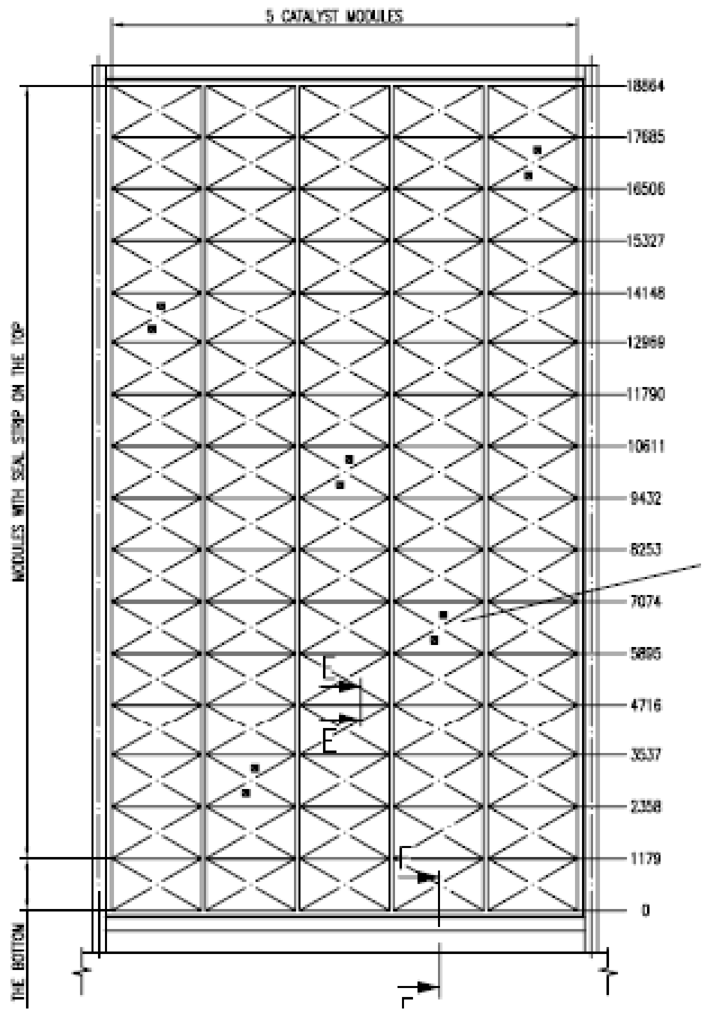
SCR Flow Requirements

- NH3/NOx: 5-10% RMS
- Flow Velocity: 10-15% RMS
- Temperature: +/- 25 °F
- Typical Linear Velocities: 5-8 m/s
- Accommodations may be possible for atypical conditions



SCR Catalyst Performance

- Fuels – Suitable for NG, Oil or Coal
- NOx Reduction
  - ✓ 50 - 90+% Range
  - ✓ 80 - 90% Typical
- Maximum Ammonia Slip
  - ✓ 2-10 ppm Typical
- Pressure Drop
  - ✓ ≤1.0 iwg Typical for Plate
  - ✓ ≤2.5 iwg Typical for Honeycomb
- Performance Guarantee Period
  - ✓ 3 years or 5 years Typical



Catalyst Lifetime

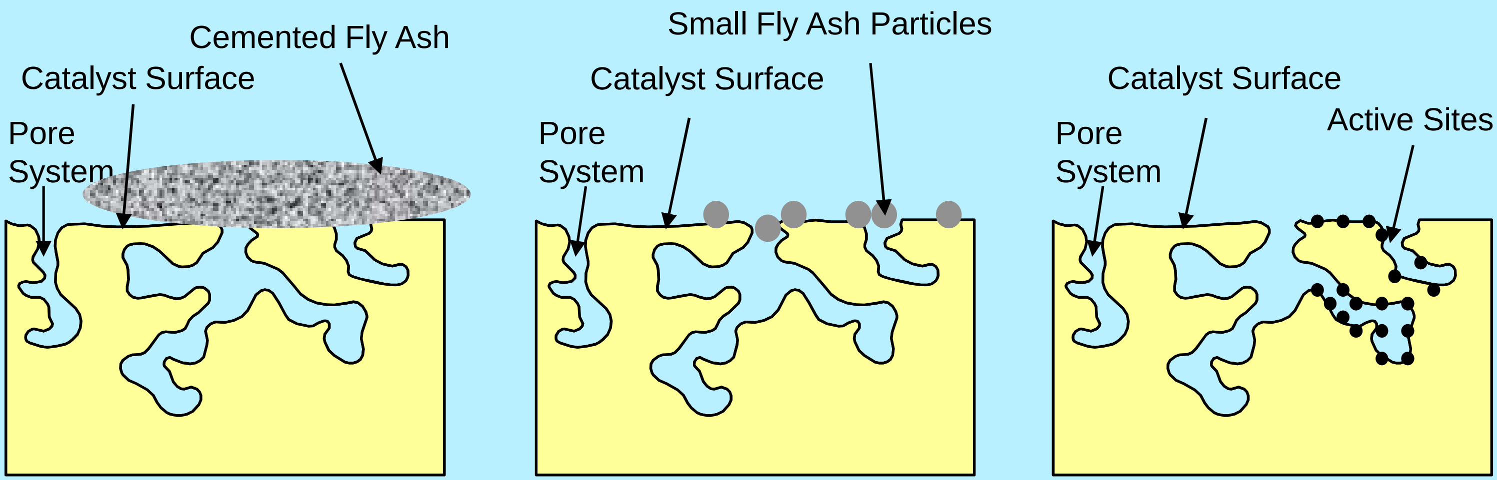
- Catalysts exhibit very high ‘fresh’ activity when first prepared/installed
- Over time, catalysts may be exposed to high temperatures and various chemical species that can reduce activity
- Catalyst activity will ‘age’ with operating time, eventually reaching a level at which the catalyst must either be regenerated or replaced

Catalyst Deactivation Mechanisms

Masking:
Macroscopic blockage of catalyst surface by cemented fly ash

Plugging:
Microsopic blockage of pore system by small fly ash particles

Poisoning:
Deactivation of active sites by chemical attack



Catalyst Deactivation Mechanisms

- Thermal deactivation**:** *(typically irreversible)*
  - Failure of substrate material
  - Sintering of support/Phase Change
  - Reaction of catalyst materials
  - Catastrophic thermal event
- Poisoning: *(typically reversible)*
  - Chemical (selective) contamination of active sites
  - Physical (non-selective) contamination
    - *masking, fouling, plugging of cells/pores, washcoat attrition*

Catalyst Poisons

- Arsenic, Phosphorous, Potassium, Sodium, Calcium – Active Site Poisons
- Silica, Alumina, Magnesium, Sulfates - Masking Agents
- Dust and Particulates
- Natural gas firing produces much lower concentrations of all catalyst poisons compared to a coal firing high dust SCR

Catalyst Regeneration or Cleaning Options

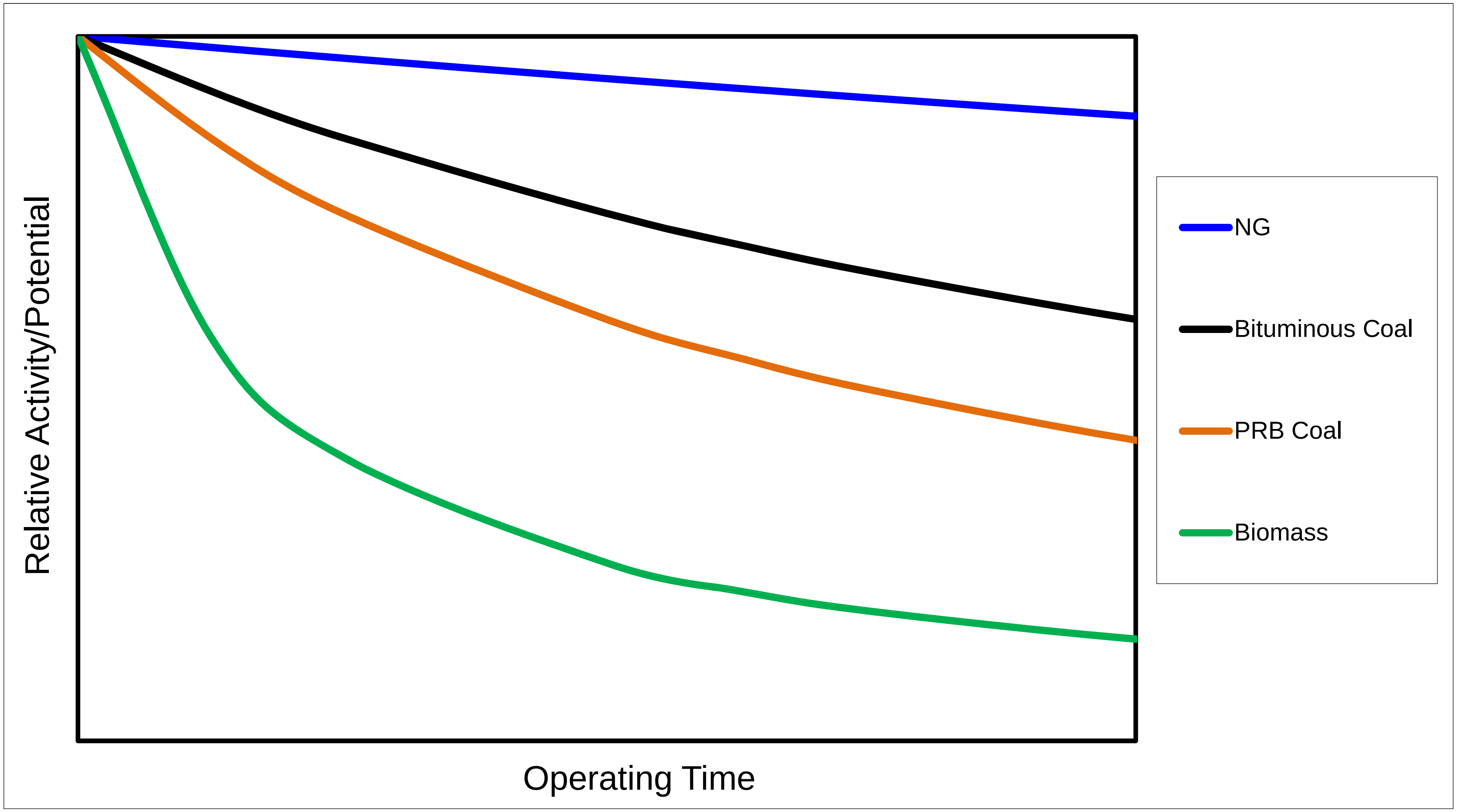
- **Physical**
  - **Vacuuming or Compressed Air Blowing**
    - *Removes dust and debris*
- **Chemical (including DI Water)**
  - **Washing/Regeneration**
    - *Removes masking agents*
    - *Restores surface area*
    - *Reduces poison concentration*

Coal to Gas Conversion

Advantages with Gas-firing

- Catalyst Selection For Coal . . .
  - Large pitch to avoid ash plugging
  - Minimized SO_2-SO_3 oxidation
  - Frequent replacement – every 2 years
- For Natural Gas firing . . .
  - Much slower catalyst deactivation – longer catalyst life
  - Fewer catalyst replacements
  - No fly ash plugging
  - No Sulfur → no ABS, can tolerate higher NH_3 slip, lower temp
  - Possible reduced NO_x reduction requirements
  - If 100% gas, can use higher cell density catalyst – reduced volume requirement

SCR Catalyst Deactivation



SCR Catalyst Options for Coal to Gas Conversion

For Units already having SCR with coal-fired catalyst

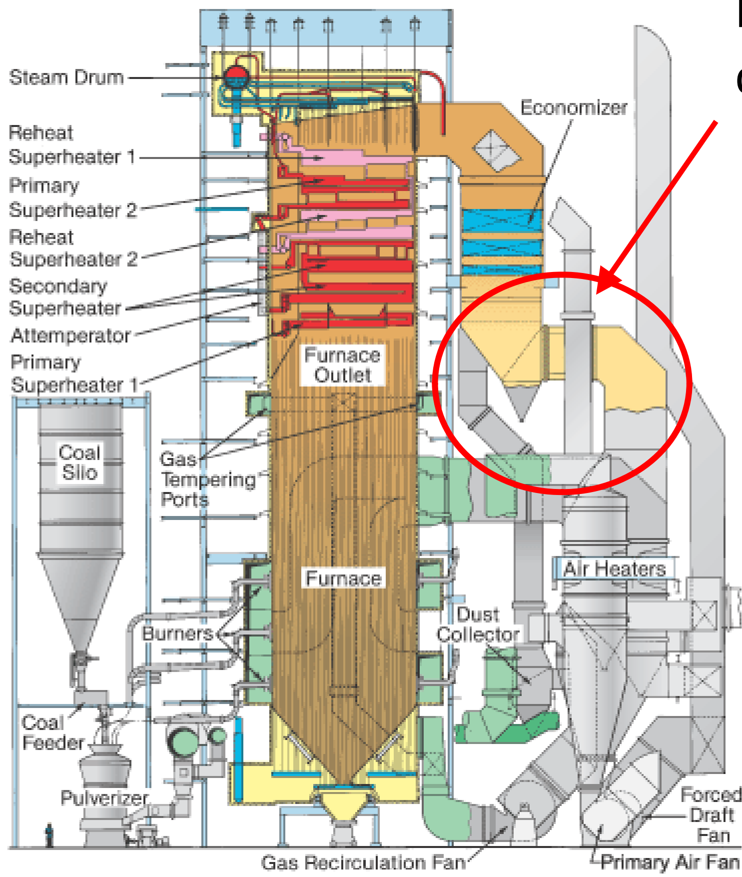
- Conversion to 100% Gas firing is OK
  - Remove portion of coal-fired catalyst for reuse in other coal units
  - Replace all coal-fired catalyst with gas-fired catalyst
- If coal will be backup fuel or co-fired, gas-specific catalyst is not suitable
  - Fly ash plugging
  - High SO_2 – SO_3 oxidation

If SCR required on unit after conversion

- Conversion to 100% Gas firing – install gas-fired catalyst
- Conversion to Gas with Coal backup or co-firing gas and coal – need catalyst suitable for coal-firing.

Catalyst Placement in a Boiler

Possible SCR catalyst location



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Sizing Examples

	Base Bit Coal Case	NG – equal NO_x load	NG – reduced NO_x load
NO_x in	300 ppmvd	300 ppmvd	240 ppmvd
NO_x out	40 ppmvd	40 ppmvd	40 ppmvd
NO_x Reduction	87%	87%	83%
NH_3 slip	2 ppmvd	2 ppmvd	5 ppmvd
Rel P0	1.00	0.83	0.77
Catalyst Pitch	5.6 mm plate	3.7 mm HC	3.7 mm HC
Relative Volume	1.00	0.26	0.21
Pressure drop	1.7 iwg	1.9 iwg	1.5 iwg

Coal to Gas Conversion – Summary Points

- Gas-firing has many advantages for SCR
  - Slower deactivation – longer lifetime
  - Low/No Sulfur → No ABS, higher NH_3 slip tolerable
  - No fly ash/particulate plugging
  - May result in Lower NO_x load, lower deNOx requirement
  - Low pitch, high cell density catalyst elements – lower volume requirement as compared to coal applications
- Catalyst sized for natural gas not suitable for coal-firing

Thank You!

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