REINHOLD ENVIRONMENTAL Ltd.

2013 NOx-Combustion Round Table & Expo Presentations

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Simple Cycle SCR Design Issues

Presentation for

Reinhold Environmental

2013 NOx Combustion Round Table

Salt Lake City, UT

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Outline

- Simple Cycle SCR System Overview
- SCR Design Conditions & Specifications
- Ammonia Slip Monitoring
- Tempering Air
- Flow Modeling
- AIG Design & Ammonia Distribution
- Bypass and Structural Design

Simple Cycle SCR Systems Overview

- Common Misconception…Simple Cycle SCR is a Commodity..
  - Add-on to a GT package to meet emissions requirements
- When treated as a commodity, details can and have been overlooked
- Performance problems can result in $millions in lost generation (down time or de-rating), testing, investigations and repairs to get into compliance
- Proper specification and design is key to successful operation… **avoid "commoditization"**

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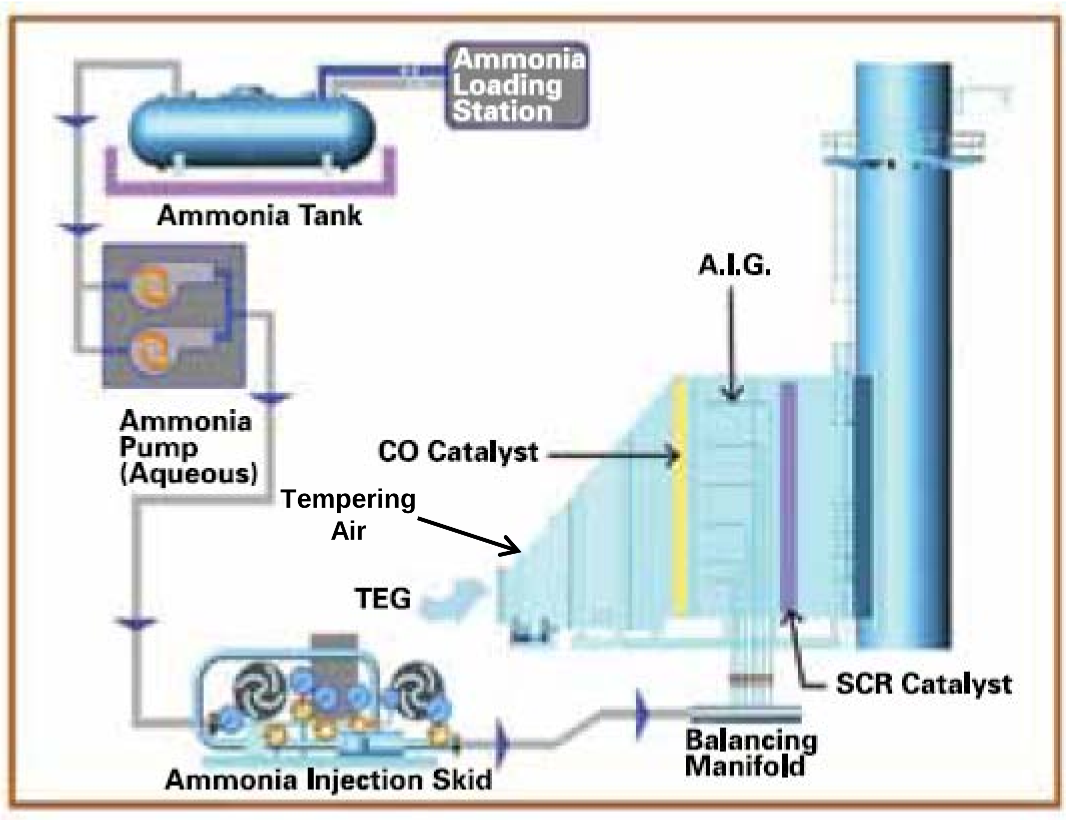
Simple Cycle SCR Design - Typical



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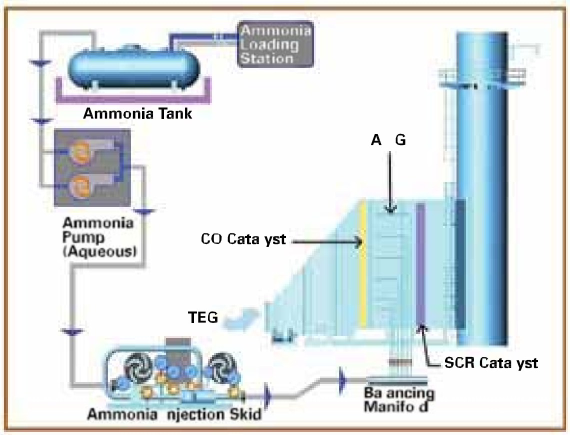
Simple Cycle SCR Design Conditions

- Several Factors Dictate Design of SCR
  - Gas Flow…depends on size of engine
  - Engine exhaust NOx
  - Stack NOx (DeNOx) and NH_3 Slip…Local permit requirements
  - Flue gas Temperature
  - Footprint Available
    - Back Pressure



Simple Cycle SCR Design Conditions

Typical Values – GE LM6000

Parameter	Units	Value
Gas Flow	lb/hr	1,100,100
SCR Inlet NOx	ppm	25 (Natural Gas)*
SCR Outlet NOx	ppm	<2.5
Temperature	°F	750-800
Ammonia Slip	ppm	<5

* Engine NOx can be adjusted by water injection

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Simple Cycle SCR – Water Injection for NOx Control

- Water Injection used to reduce engine NOx to 25 ppm
- GT Manufacturer sets limit on how much water can be added…~20 ppm may be lower limit
  - SCR Duty cannot be dramatically reduced
- Higher water injection will increase CO
- Balancing act between CO and NOx…and ammonia slip

Simple Cycle SCR – Maintaining Performance

Pollutant	Maintainability
NOx	Outlet NOx usually controlled below 2.5ppm
NH_3 Slip	Depending on monitoring, can be very difficult to maintain 5 ppm if system problems exist
CO	Can be difficult to maintain if engine NOx is reduced too low with water injection (i.e. to maintain NH_3 slip)

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Simple Cycle SCR – Design Specs

- Give yourself some breathing room…
- If NOx permit limit is 2.5 ppm, set design point for SCR to something lower
  - The operating setpoint will be something lower than 2.5 ppm to avoid exceedances.
  - If inlet NOx is 25 ppm, then DeNOx is above 90%...ammonia slip could be an issue from the start.
- Same for CO….if permit is 5 ppm, then set design to something lower
- Operators do NOT like to push the envelope!

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Simple Cycle SCR – Design Specs

	Units	Design	Actual Operation
SCR Inlet NOx	ppm	25	25
SCR Outlet NOx	ppm	2.5	2.2
DeNOx	%	90	91.2
Ammonia Slip	ppm	<5	<5

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Simple Cycle SCR – Ammonia Slip Monitoring

- Depending on the state/permit, ammonia slip may or may not be monitored
- When it's not monitored, it's usually measured periodically by CTM-027 or FTIR
- If it is monitored, control of NOx and CO is critical to stay in NH_3 slip compliance

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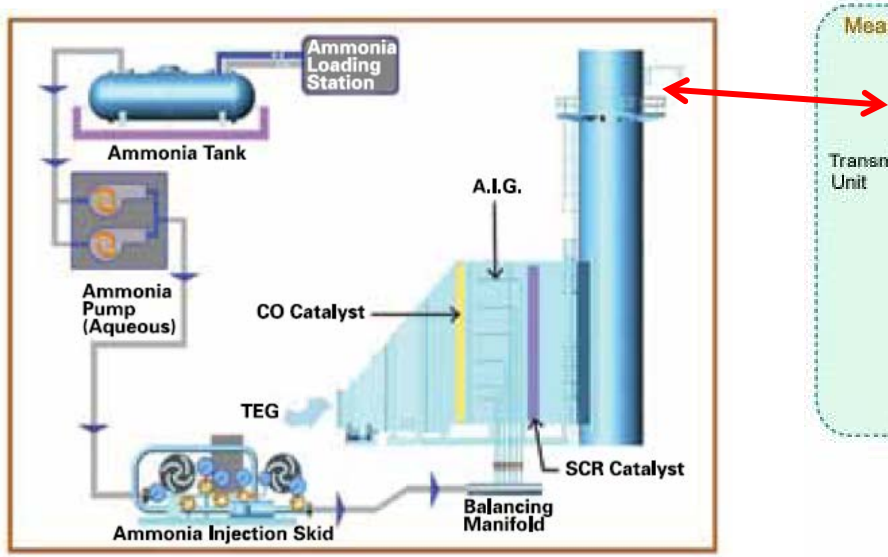
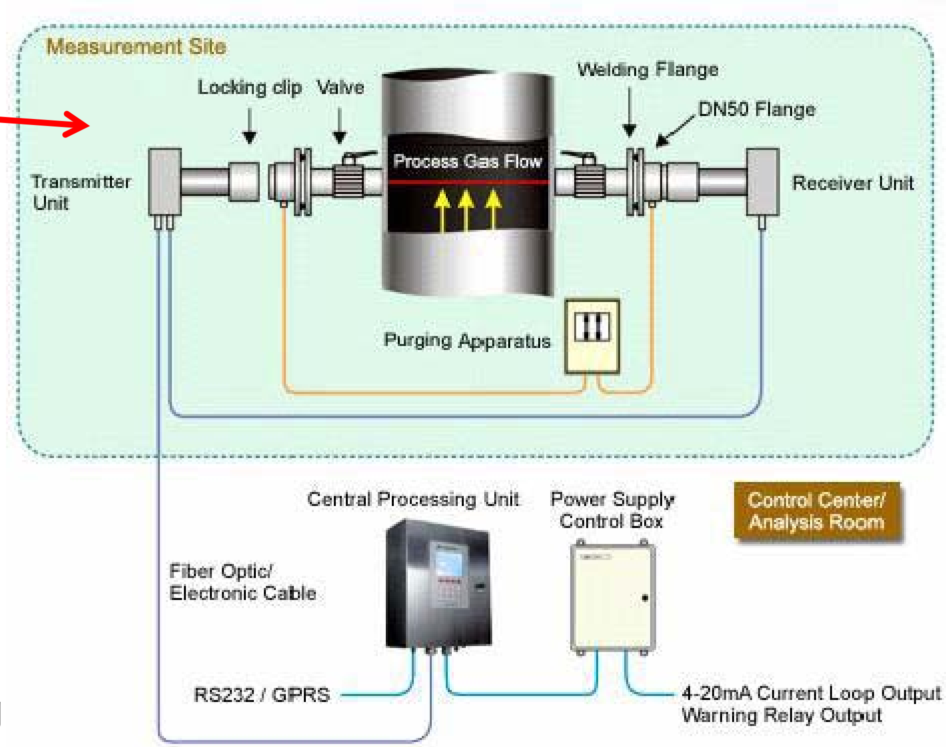
Simple Cycle SCR – Ammonia Slip Monitoring





Tunable Diode Laser Absorption Spectroscopy (TDLAS) Analyzers (using light absorption technology) are typically installed in the stack to continuously measure ammonia.

Simple Cycle SCR – Tempering Air

- Many systems utilize tempering air at the engine exhaust to reduce the flue gas temperature.
  - Done primarily for SCR to keep gas temperature < 800F
- Although in theory the systems work, the implementation, performance issues and O&M can be significant
  - Temperature Distribution
  - Parasitic loads for TA fans
  - TA Fan maintenance…more moving parts
  - Cooling Air Lance design…subject to high turbulence at GT exhaust

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Simple Cycle SCR – Tempering Air

- The need for tempering air should be reviewed
- High temperature catalyst (~850F) may be worth the investment
  - Would eliminate TA system entirely

The Need for Flow Modeling...

- Size of system should not dictate whether a system is modeled
  - Flow modeling should ALWAYS be done. "Duplicates" are not always the case
- Modeling should be done early, by OEM or catalyst supplier as required
- Detailed modeling can save time and $$ in the long run
- Physical or CFD are proven methods, but CFD has advantages…
  - Better simulation of GT exhaust
  - Thermal mixing

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Physical & CFD...Pros and Cons

- Physical Modeling - Pros
  - Proven Technique
  - Complex flow simulations and solutions
  - NH_3 distribution modeling
  - Visualization
- Physical Modeling - Cons
  - Iterations can be time consuming
  - Thermal mixing difficult
  - Measurement points limited
  - Crude, Static GT exhaust simulation

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Physical & CFD…Pros and Cons

- CFD Modeling - Pros
  - Iterations can be done quickly
  - Detailed representation of flow and mixing patterns
  - “Infinite” number of test points
  - Output can be very informative
  - More accurate GT exhaust simulation
- CFD Modeling - Cons
  - Large and complex models can be time consuming
  - NH_3 distribution modeling requires detailed mesh
    - Two models are often used

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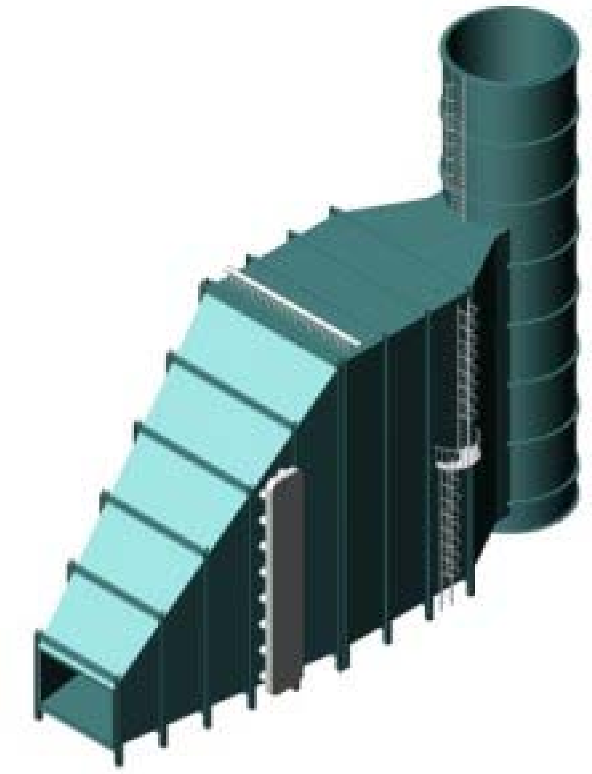
Simple Cycle SCR – Fluid Flow Design Considerations

- No Boiler Tubes!!
- Many systems with steep angles on Combined Cycle flues do not work in Simple Cycle applications
- High swirl and turbulence from GT…Single perforated plate may not be enough to improve distribution
- Burdens CO catalyst
  - CO Catalyst performance can be hindered
- Poor flow distribution ultimately results in poor ammonia distribution and degraded SCR performance



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Simple Cycle SCR – Ammonia Mixing

- AIG typically located directly downstream from CO Catalyst
- CO Catalyst will significantly reduce turbulence intensity
  - Metallic catalyst with 200 cells per square inch
- Even thought there may be plenty of injection points, there ammonia and flue gas blending is weak
- AIG will need a mixing "boost"

Simple Cycle SCR – AIG Design

- AIG should be designed with ability to tune as much as possible!
- Systems designed with no tuning capability have very limited flexibility
- Aspect Ratio comes into play

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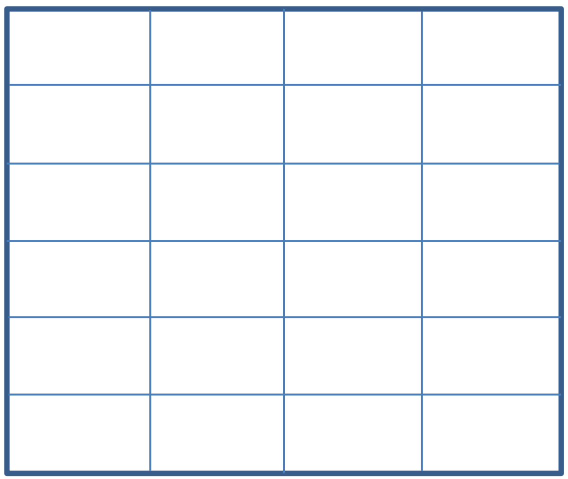
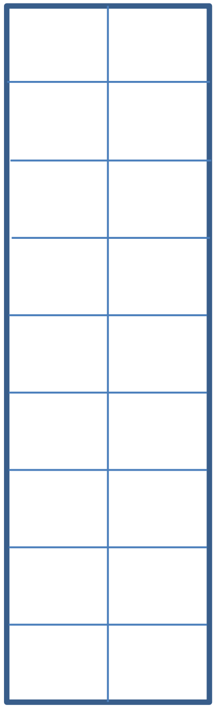
Simple Cycle SCR – AIG Design





High Aspect Ratio
More Vertical Zones

Low Aspect Ratio
More Zones Across Width

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Simple Cycle SCR – Ammonia Vaporization

- Numerous Design Options…electric or steam vaporizers
  - Use ambient air fans
- Many systems use the hot flue gas to vaporize the ammonia
  - Use of "hot fans" (>800F) prone to O&M issues…seals, bearings, etc.
  - Foreign material can plug AIG
  - Be cautious with liquid fuels (SO_3 and NH_3 reaction)

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Simple Cycle SCR – SCR Catalyst Design

- Plate, Honeycomb and Corrugated Catalyst all used successfully in simple cycle applications
- When properly specified, operated and maintained, catalyst should far exceed guarantee life
  - Less deactivation risks in natural gas applications
- Performance problems usually due to system issues..
  - Poor NH_3/NOx Distribution
  - Poor Velocity Distribution
  - Bypass

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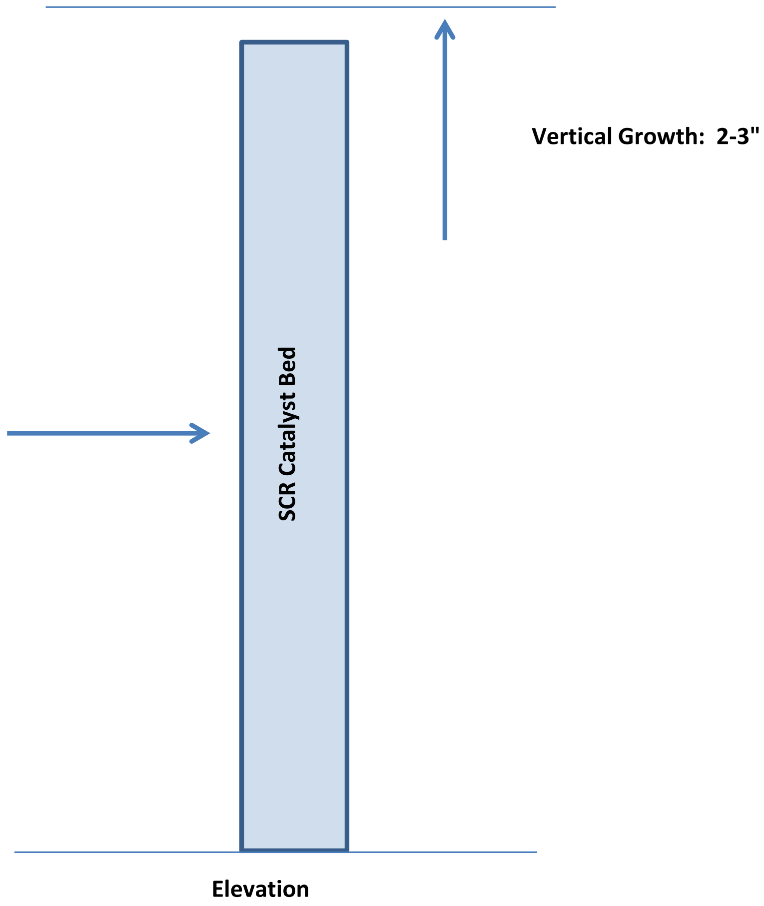
Simple Cycle SCR – SCR Structural Design

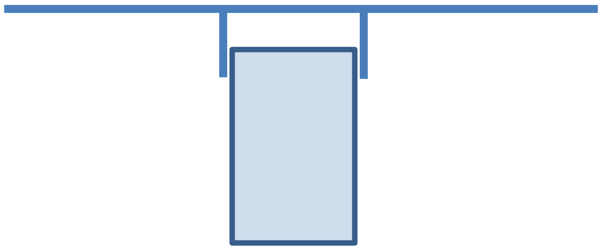
- ❑ Stainless Steel components…higher expansion coefficient than carbon steel
- ❑ System must be designed to accommodate growth vertically and horizontally
- ❑ Vertical growth could be 2-3”
- ❑ Sealing is critical to avoid bypass



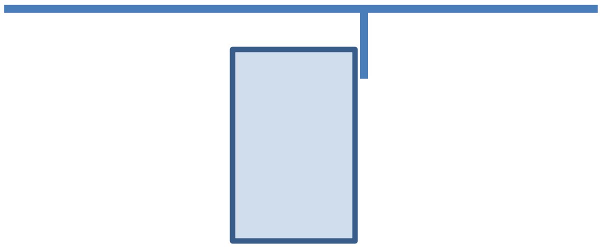
Simple Cycle SCR – SCR Structural Design

Top Seal Design

Good



Bad



Simple Cycle SCR – Additional Structural Considerations

- Insulation – Can release if not properly addressed
  - Liner gaps
  - Access Doors
- Catalyst Support Structure
  - Poor design can affect integrity of catalyst modules
  - Excessive column deflections can have significant effect on bypass
- Column Deflection
  - SCR Support Columns to be properly designed for pressure, seismic, etc.
- Structural Integrity near GT Exhaust
  - Any devices in this region must be robust…turbulence levels are very high

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Simple Cycle SCR Design - Summary

- Proper Design Specifications a Must
- Avoid Tempering Air if possible
- Flow Modeling a Must
- AIG and Ammonia Mixing are critical to performance
- Structural Design can impact Performance
- SCR not a Commodity!

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