REINHOLD ENVIRONMENTAL ®

2023 Reinhold/PCUG Round Table Presentation

Cohosted by Duke Energy and Vistra in The Westin Hotel, Cincinnati, OH on June 26-27, 2023

Future of SCR Technology

SCR DeNOx Catalyst and Technology

Agenda

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- SCR for new fuel applications
  - New Fuels (Hydrogen, Ammonia)
  - Larger Gas Turbines
- Ultra-low emissions System requirements
  - SCR reactors in series
  - Case Study
- Catalytic reduction of VOC’s
- Conclusions

SCR for Hydrogen Fuel Applications

H_2 Production

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- Most abundant element in the universe
- Does not exist on earth as a standalone molecule
- 90% of the worlds H_2 comes from CH_4 (natural gas) or coal
- Most common method is reforming (SMR) using natural gas
- Electrolysis of water – very energy intensive - expensive

Hydrogen Production Methods by "Color"

- Grey or Black: Gasification of coal or reforming of natural gas w/o carbon capture
- Blue: Reforming of CH_4 with carbon capture and storage
- Green: Electrolysis of water using renewable power
- Pink: Electrolysis of water using nuclear power
- Turquoise: Pyrolysis of CH_4 producing H_2 and solid carbon
- White: Gasification using 100% biomass as a feedstock

Transportation and Storage of H_2

Challenges

- Generally, H_2 gas stored at > 5000 psi requiring significant compression energy (~5 kWh/kg)
- Liquid storage requires - 424F, energy intensive @ (~12 kWh/kg) or 30% of LHV of H_2
- Storage tanks are double walled and very expensive
- World's largest tank holds only enough H_2 to operate a large gas turbine for 8 hours
- Salt dome, aquifer and non permeable rock cavern storage near point of use

H_2 Impact on SCR Performance & Design

Known and Unknown Impacts

- Currently must use “old” technology burners when firing H_2 – Results in high NOx emissions
- Inlet NOx concentration will increase significantly – short term high probability; longer term unknown but likely
- Deactivation rate of catalyst firing H_2 is expected to be the same as with natural gas
- Umicore has developed SCR designs that meets >98% DeNOx with very low NH_3 slip
- Will future firing of H_2 produce >50% NO_2/NOx ratio?

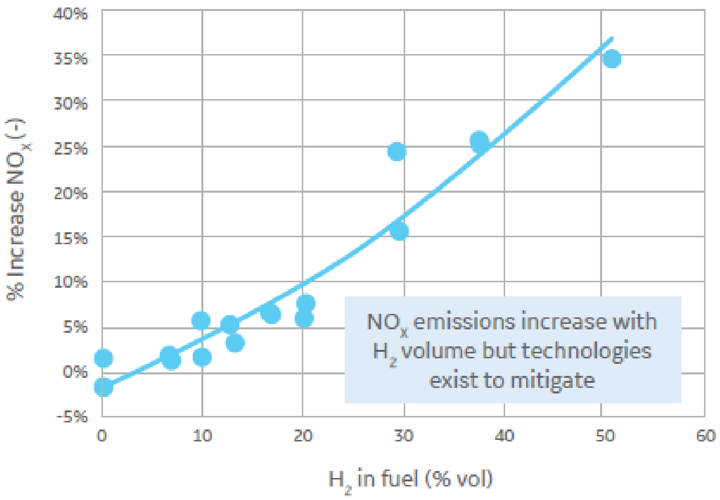

Table from GE Hydrogen for Power Generation

H_2 Impact on SCR Performance & Design

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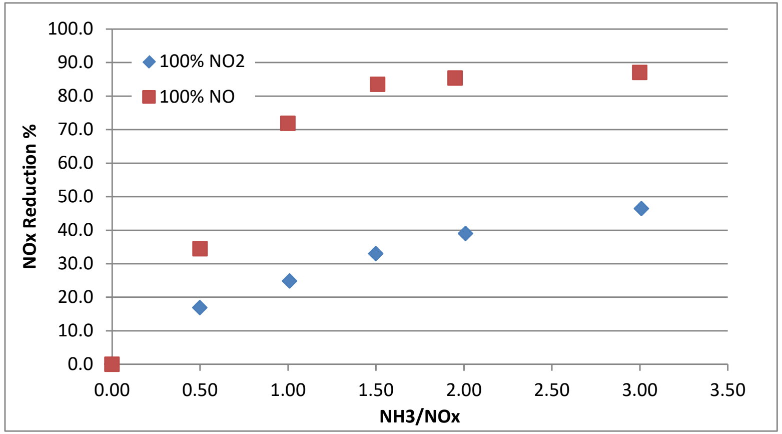
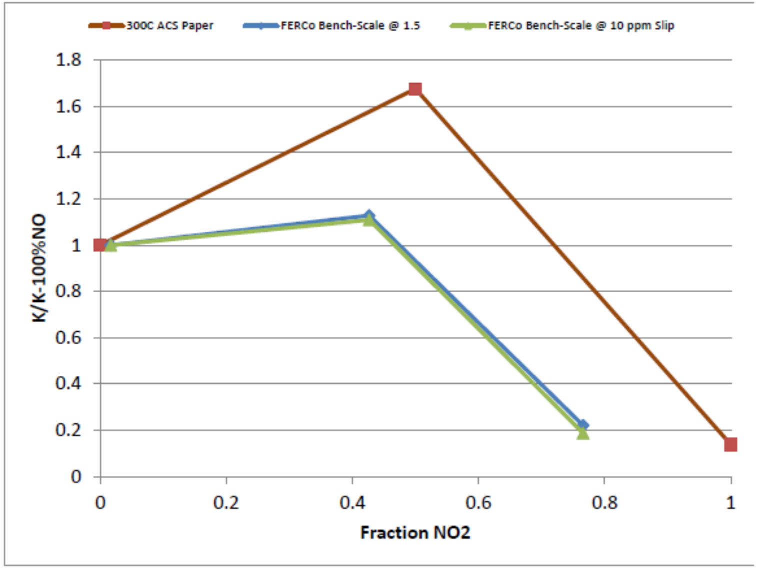
Impact of high NO_2 on DeNOx Reaction ????





Achieving Ultra-low Emissions

Sealing

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- High NOx reduction and low slip
  - Any amount of bypass makes this impossible

- In new units, failure to meet targets is likely a result of poor sealing (or higher than expected NH_3 to NOx maldistribution)

Ammonia Mixing

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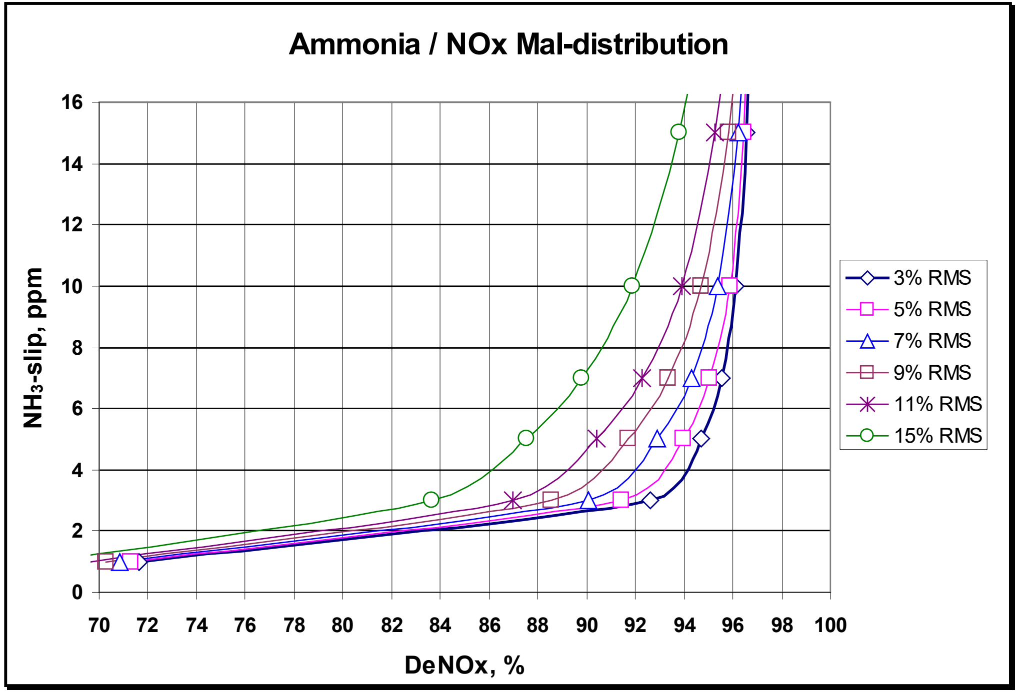
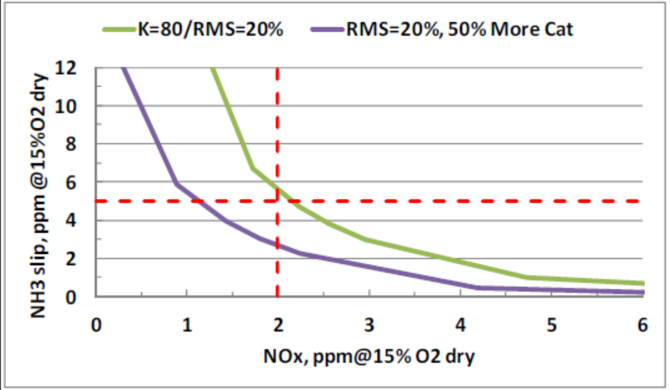
- For high NOx reductions, NH_3/NOx mixing is critical to meet performance targets
- NH_3 supplied
  - Anhydrous
  - Aqueous
  - Urea
- Ammonia slip is given for end of guarantee period – will generally increase over time
- What RMS is required to achieve 94% deNOx and 5 ppm slip?



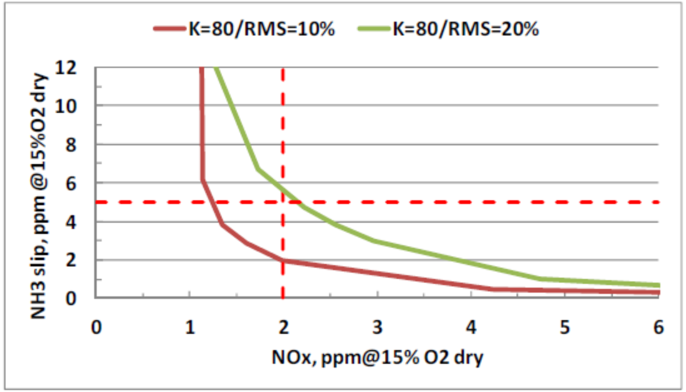
Ammonia Mixing

- SCAQMD is pushing NO_x from 5 to 2 ppm in So. Cal.
- Assumption is that just adding more catalyst will be the solution

RMS=20% Add Catalyst



Tune AIG To RMS=10%

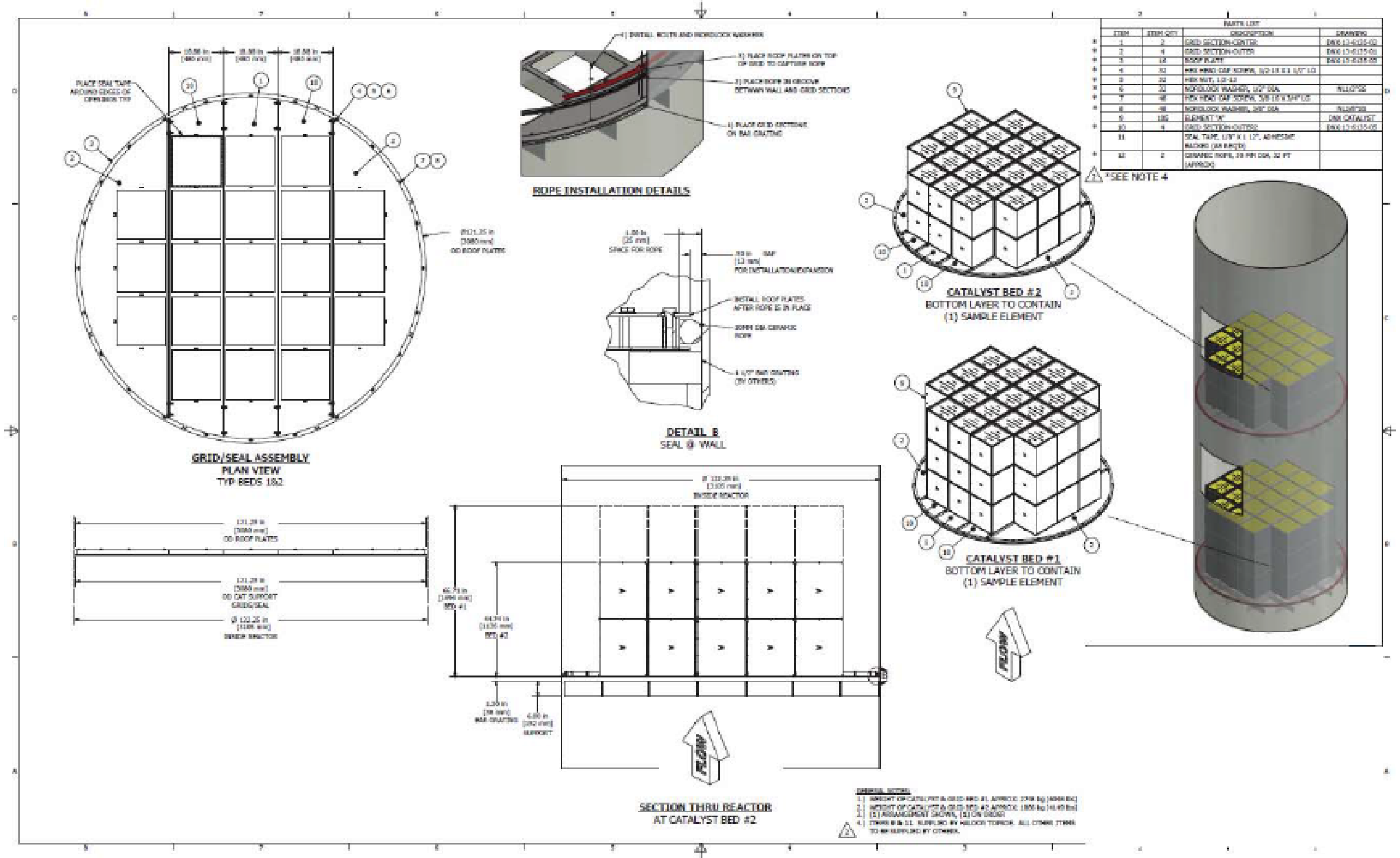


- Just tuning the AIG allows 2 ppm NO_x to be achieved
- Adding 50% more catalyst helps, but not as much as tuning

Typical Questions

1. When should you consider doing two SCR reactor in series?
2. When should I use two AIG's instead of mixers?
3. What can happen if I have extremely high NOx?

DNX® Elements – Round Duct



Covert Project Comparison

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	Traditional Dual Function	2 Reactor in Series
Total Volume, m3	85.4	75.1
SCR, m3	27.9	17.6
Dual Function, m3	57.5	57.5
DP Catalyst, in H2O	3.03	3.05
Ammonia to NOx maldistribution requirement	8% RMS	15% RMS AIG / 20% RMS Mixers
Denox, 96%	96%	96%
Ammonia Slip, ppmvd @ 15% O2	5.0	5.0
Outlet NOx, ppmvd @ 15% O2	2.0	2.0
Cast Calculation Numbers		
CO Oxidation	n8501	
Traditional	n8500	
2 Reactor in Series	n8507	
Bypass Comparison Outlet	Based on 1% bypass for the layer	Based on 1% bypass for both layers
1% Ammonia Slip, ppmvd @ 15% O2	0.53	0.1162
1% Nox, ppmvd @ 15% O2	0.5	0.0858

Formaldehyde & Other VOC’s

Formaldehyde Reduction

- Growing concern for regulators
- Results from unburned air/fuel
- Correlates with the amount of unburned hydrocarbons in the exhaust
- Formaldehyde is reduced via oxidation over a catalyst bed

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

Formaldehyde Reduction

- We have existing references for formaldehyde removal, specifically on gas turbine applications
- CH_2O can be removed alongside NO_x & CO in the same catalyst bed
- High removal of CH_2O is possible, >90% depending on exhaust gas temperature

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