REINHOLD ENVIRONMENTAL ®

2025 Reinhold/PCUG Round Table Presentation

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Simple Cycle Hot SCRs

Design considerations, tradeoffs, and constraints for a hot application

Areas of Discussion

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- What Hot SCRs Offer
- Overview of SCR Components
- Design Considerations:
  - Ambient Temperature Range
  - Fan Turndown, Margin, and Filters
  - General Catalyst Temperature Ranges
  - CFD Modeling
- Tradeoffs:
  - High Efficiency vs Standard Efficiency
  - Catalyst Type vs Fan Size
  - Fan Redundancy Options
  - Future Upgrades
- Summary & Questions

What Hot SCRs Offer

- Speed: <5 minutes to base load
- Emissions Compliance: NO_x reductions up to 95%, NO_x emissions <2 ppm, NH_3 slip <2 ppm
- Simplicity: No steam turbines, condensers, cooling towers, or pumps.
- Delivery: As little as 50 weeks to build and ship.

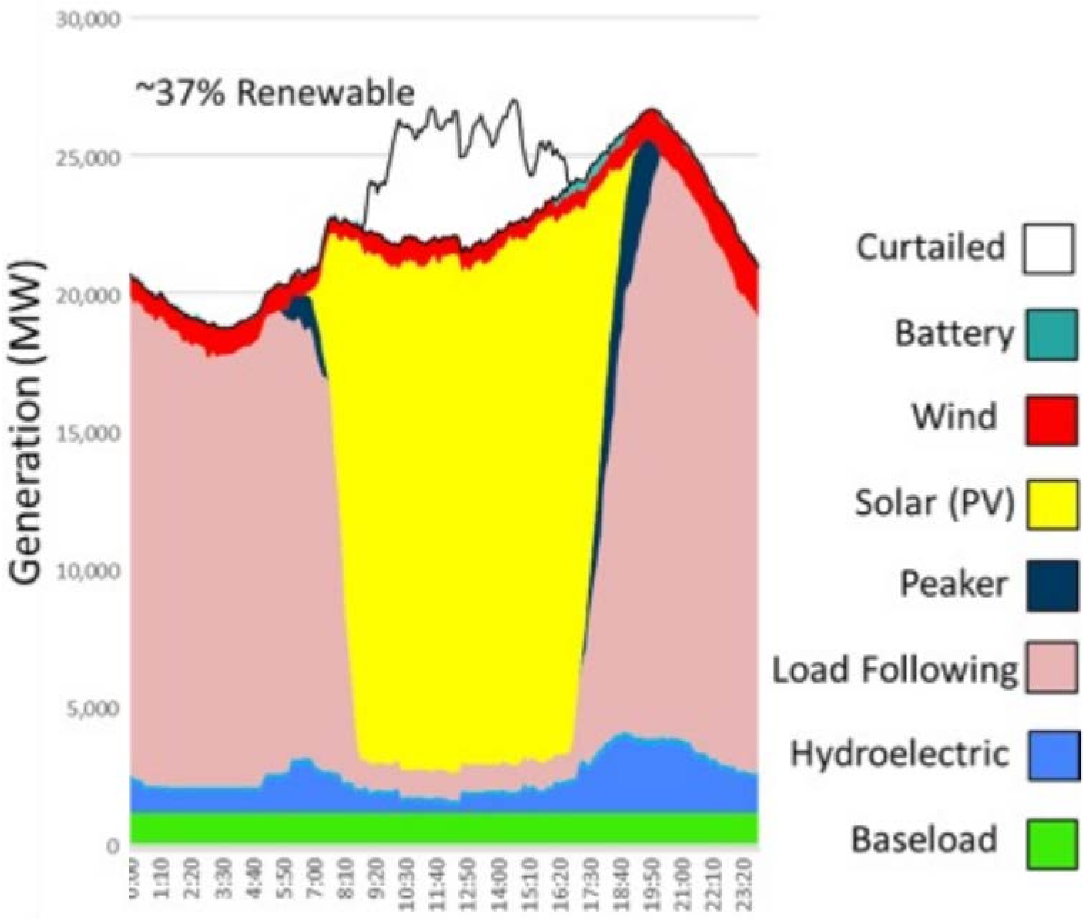
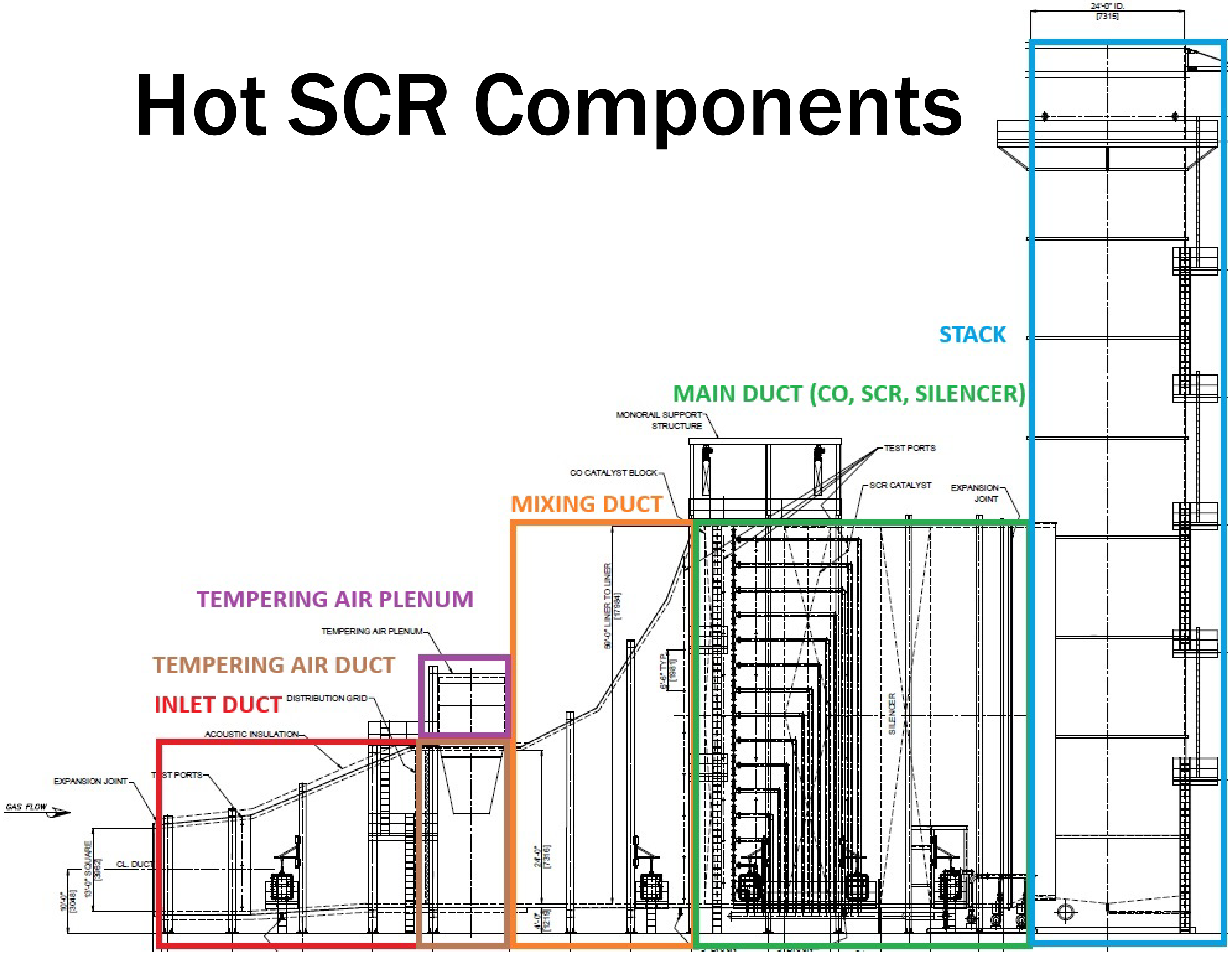


Image courtesy of Stephen Storm, EPRI, Reinhold Conference 2024

Hot SCR Components



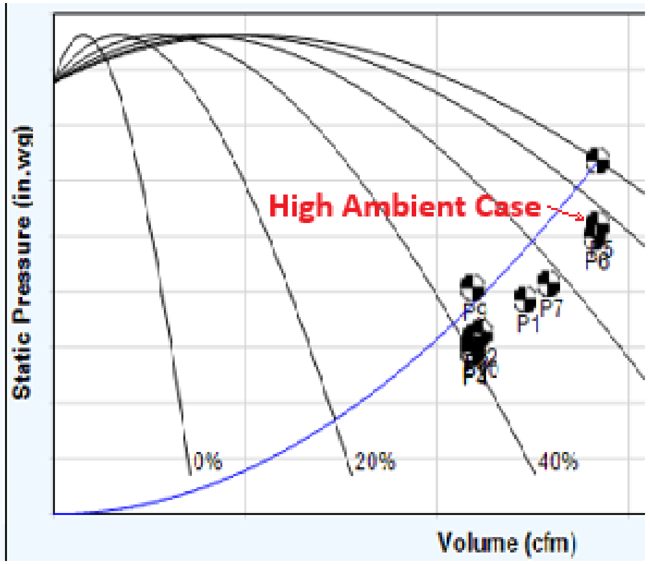
Not shown:

- Ammonia Injection Grid
- Ammonia Flow Control Unit
- Tempering Air Pipes*
- Tempering Air Fans

* Tempering air pipes are not actually pipes according to ASME B31 or Section I.

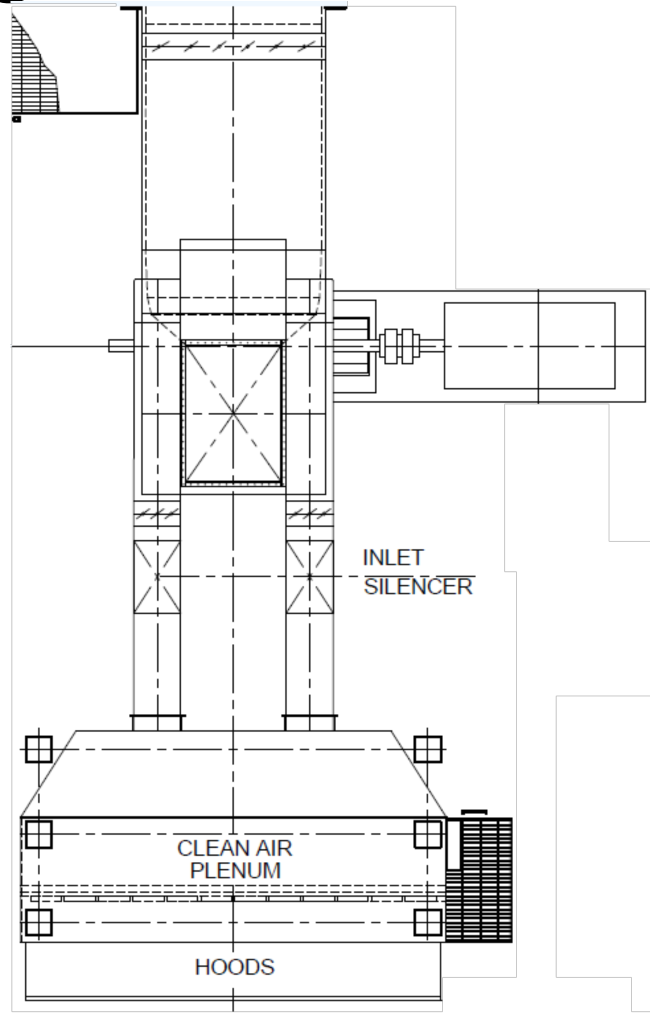
Design Considerations – Ambient Temperature Range

- Generally, Gas Turbines have lower exhaust temperatures on colder days and higher ambient temperatures on warmer days.
- The target mix temperature for safe catalyst operation is the same year-round, so the maximum temperature reduction will occur on the hottest day.
- The density and cooling capacity of the ambient air will both be at their minimums on the hottest day.
- Therefore, the maximum fan capacity will likely be determined by the high ambient condition.



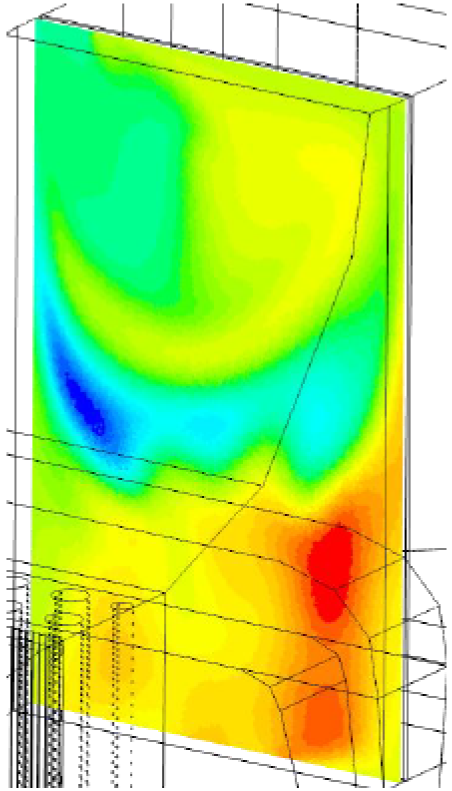
Design Considerations – Fan Turndown, Margin, and Filters

- We have found that for Hot SCR applications, the minimum volumetric fan flow rate is greater than 60% of the maximum volumetric fan flow rate (1.7 : 1 turndown). Therefore, for low ambient, part load, and startup cases the actual mix temperature can be well below the target.
- We suggest the fan design should be capable of 21% more discharge pressure and 10% more volumetric flow than is required in the worst-case conditions.
- We suggest a minimum mix temperature should be determined assuming the inlet vane position 5% above their minimum position for controllability.
- We suggest MERV 8 fan filters. It is preferred if a maximum filter pressure drop can be given based on a reasonable cleaning schedule and site conditions.



Design Considerations – General Catalyst Temperature Ranges

- SCR Catalysts generally operate most efficiently around 700 °F. Maximum design temperatures vary from 800 °F to above 1000 °F, with higher-temperature formulations requiring higher costs.
- CO Catalysts operate well over a wide temperature range. We follow a best practice of avoiding operating temperatures below 600 °F due to the risk of sulfur poisoning.
- At temperatures above 700 °F, ammonia can spontaneously break down increasing the required consumption to achieve the target NO_x reduction. This effect increases with temperature.
- Therefore, the SCR catalyst formulation defines the maximum allowable gas temperature, and the CO catalyst defines the minimum allowable temperature. CFD modeling can help determine the expected temperature distribution, from which a target mix temperature can be derived.



Design Considerations – Computational Fluid Dynamics Modeling

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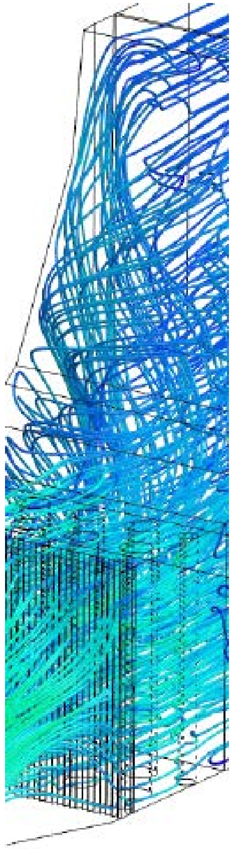
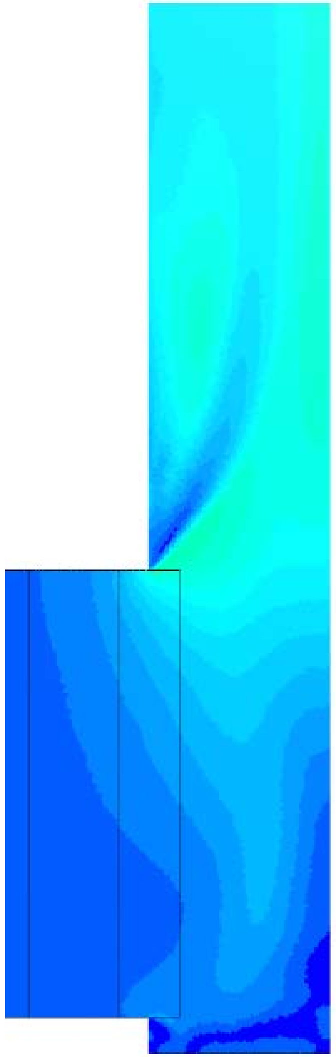
- CFD modeling is a resource-intensive and time-consuming process that is essential to a well design Hot SCR.
- Project-specific CFD requirements seem to vary widely.
- We recommend three conditions should be modeled using CFD:
  - Maximum fan flow conditions (usually the high ambient temperature case)
  - Maximum GT backpressure conditions (often the low ambient temp case)
  - Minimum mix temperature case (often the low ambient temp MECL case)
  - All these cases should consider the worst-case fan arrangement and should only consider natural gas operation.
- We have found that cold flow modeling is not a good substitute due to difficulty accounting for temperature related effects in the GT profile and mixing duct.



Other Design Considerations

- Startup time: A Hot SCR can startup in as little as 60 seconds, however the startup emissions control capabilities can vary from 5 - 15 minutes based on the design of the Ammonia Flow Control Unit. This should be determined by the hot start GT startup profile.
- Transient controls: The emissions control capabilities during load following operation are the result of multiple site-specific factors. If transient emissions limits are required, additional instrumentation and tuning should be considered.
- Silencer location: If a stack height of less than about 130 ft is required or if the far field noise requirements are particularly stringent, a duct silencer may be required. This increases the overall Hot SCR length and may carry an additional cost compared to a more typical stack silencer.



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Other Design Considerations

- Acoustic treatment: The largest gas turbines will often require an acoustic treatment of the inlet duct to meet near field noise requirements. This is more likely in a Hot SCR than a HRSG because the smaller gas path cross section results in a higher velocity and less noise attenuation. There are multiple types of acoustic treatments (shroud, panels, etc.) each with their own design and installation costs.
- Catalyst test blocks: Specifying spare test blocks to be delivered with the catalyst could be helpful during operation along with a well-defined record keeping and testing process.

Design Tradeoffs – High Efficiency vs Standard Efficiency

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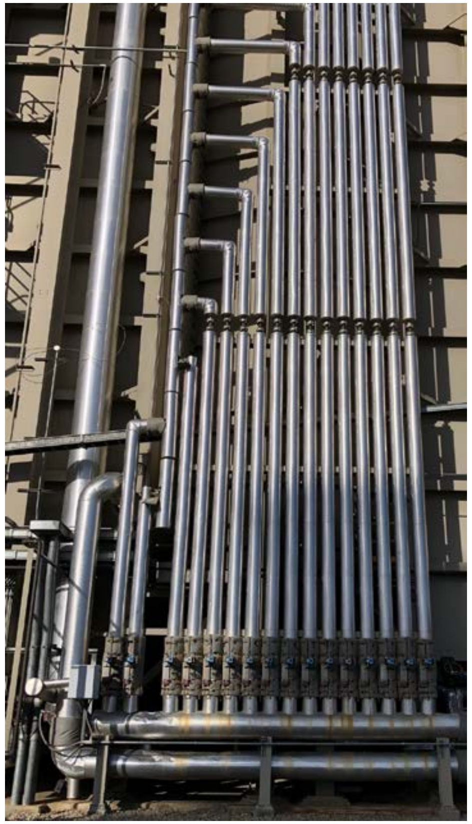
- Based on our HRSG experience, we use two distinct SCR system designs: A standard efficiency design and a high efficiency design.
- Generally, the standard efficiency design is used for applications where all three of the following criteria are true:
  - NO_x reduction <90%
  - Outlet NO_x > 2 ppmvd @ 15% O_2
  - Outlet NH_3 slip > 5 ppmvd @ 15% O_2
- The high efficiency design includes multiple system improvements that require additional detailed engineering, material, and equipment.
- This is a tradeoff between capital cost and required emissions levels



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Design Tradeoffs – Catalyst Type vs Fan Size

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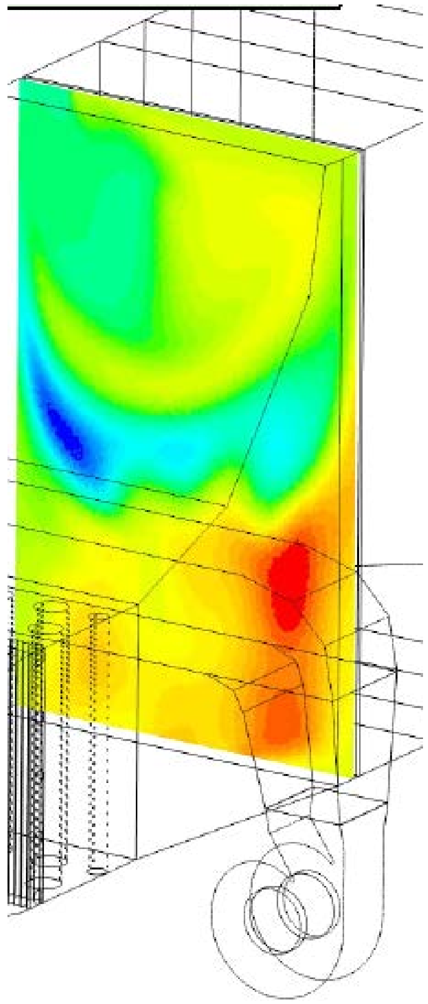
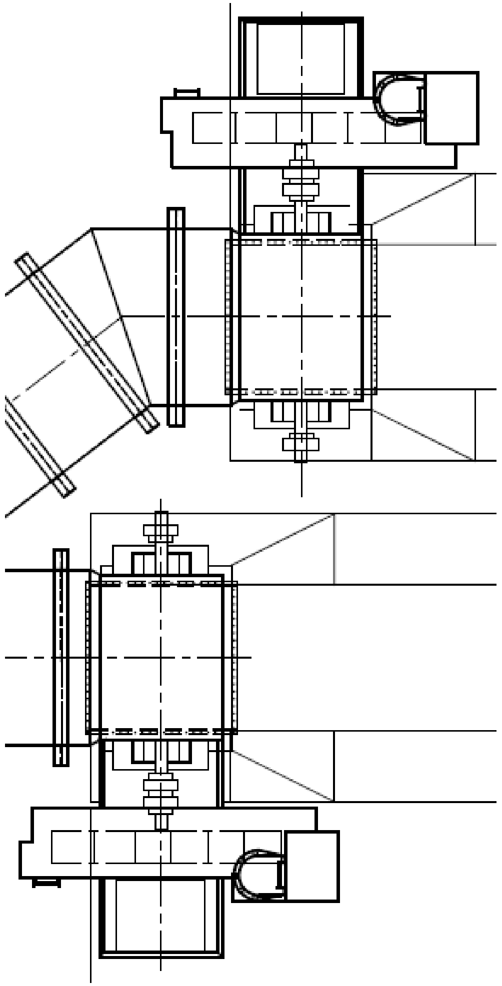
- Because SCR catalysts can be provided with different maximum temperature formulations, each formulation would have a corresponding fan designed for that maximum temperature.
- The highest temperature catalyst would correspond to the smallest fan, and the highest ammonia consumption. The lowest temperature catalyst would correspond to the largest fan, and the lowest ammonia consumption.
- The incremental cost increase for a higher temperature catalyst is more than for a larger fan. However, a larger fan puts a larger auxiliary load on the system.
- Therefore, this is a tradeoff between capital costs and operating costs.
- The risk of sulfur poisoning in the CO catalyst also limits the low temperature side of this tradeoff.



Design Tradeoffs – Fan Redundancy

- We consider the following five fan configurations to be the most popular for use in Hot SCR system design:
  - 1x100% (non-redundant)
  - 2x50% (non-redundant)
  - 2x100% (redundant)
  - 3x50% (redundant)
  - 4x33% (redundant)
- This is a tradeoff between capital costs and system reliability.
- For a non-redundant system, a spare impeller could help limit down time.
- For a redundant system, provisions could be made to operate the redundant fan if necessary, as an added layer of risk management.



Design Tradeoffs – Future Upgrades

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- Some applications consider reserving space in the site layout for the future addition of a HRSG. This is a tradeoff between current capital costs and future system flexibility.
- Provisions can be made to mitigate the additional GT backpressure created by this tradeoff provided the request is communicated during the design process.
- Other applications require including additional space or capacity in the individual equipment (SCR, CO, AFCU, Silencer, etc.). This is also a tradeoff between current capital costs and future system flexibility.
- The impact to system footprint of additional space requirements should be considered. It can also be helpful to discuss the potential performance impacts of additional equipment for cost-benefit purposes.

Summary

- The maximum fan capacity will likely be determined by the high ambient condition.
- Suggested fan design considerations:
  - 21% more discharge pressure and 10% more volumetric flow
  - Minimum mix temperature assumes inlet vane position 5% above their minimum
  - MERV 8 fan filters. Provide maximum filter pressure drop if possible
- We recommend three conditions should be modeled using CFD:
  - Maximum fan flow conditions (usually the high ambient temperature case)
  - Maximum GT backpressure conditions (often the low ambient temp case)
  - Minimum mix temperature case (often the low ambient temp MECL case)
  - All these cases should consider the worst-case fan arrangement and should only consider natural gas operation.
- Include spare catalyst test blocks
- Consider tradeoffs for SCR system efficiency, fan size, redundancy, and future upgrades

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Thank You!

Please email any further questions to mallen@vogtpower.com