Reinhold Environmental Ltd.

2010 NOx-Combustion Round Table & Expo Presentation

February 8 & 9, 2010 Chattanooga, TN

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Design Considerations for SCR Systems on Cycling Units

2010 Reinhold Environmental Conference
February – 8 & 9, 2010

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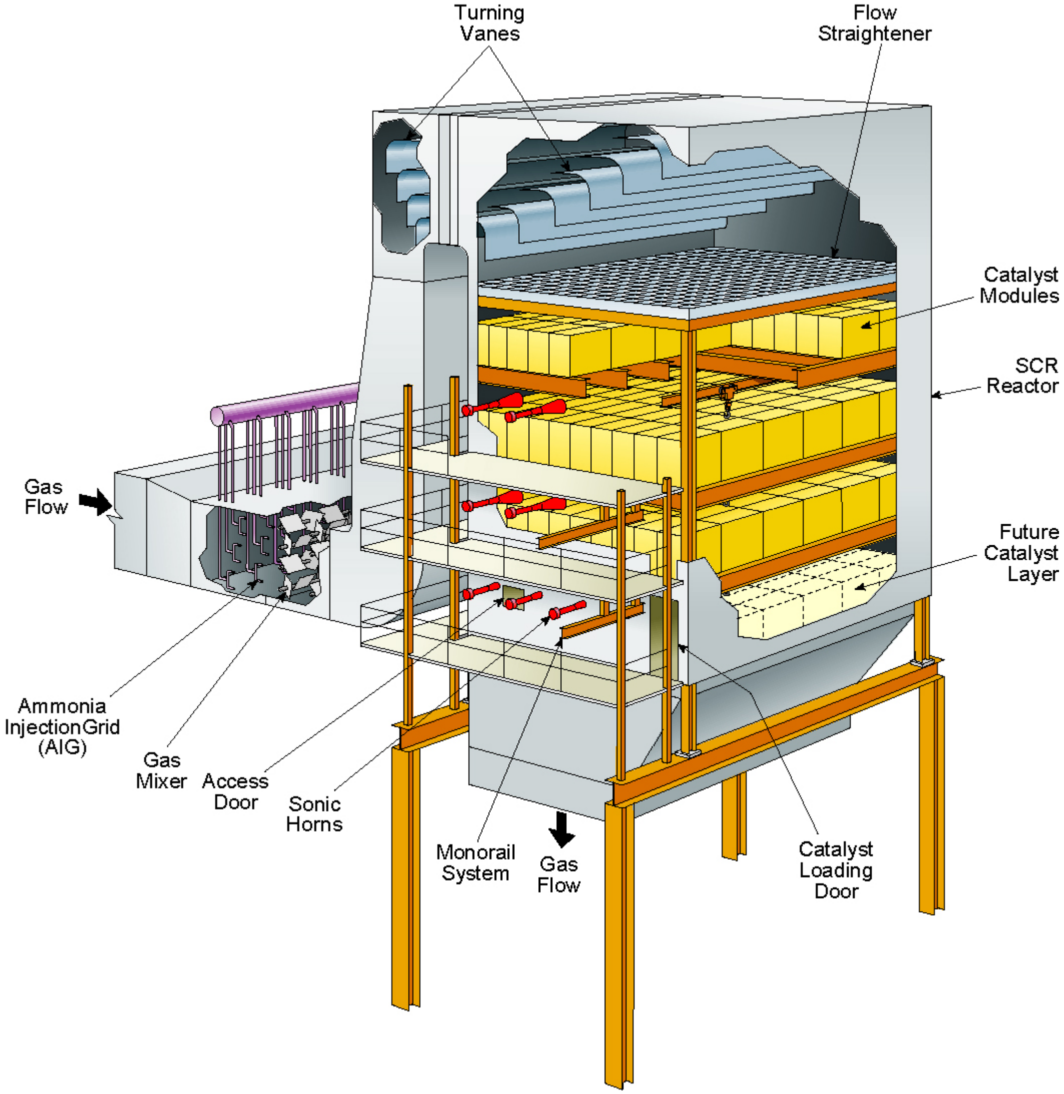
SCR Design

- Design parameters
  - Fuels burned
  - Flue gas flow
  - Flue gas temperature
  - Flue gas composition
  - NOx removal
  - Allowable NH3 slip
  - Catalyst life



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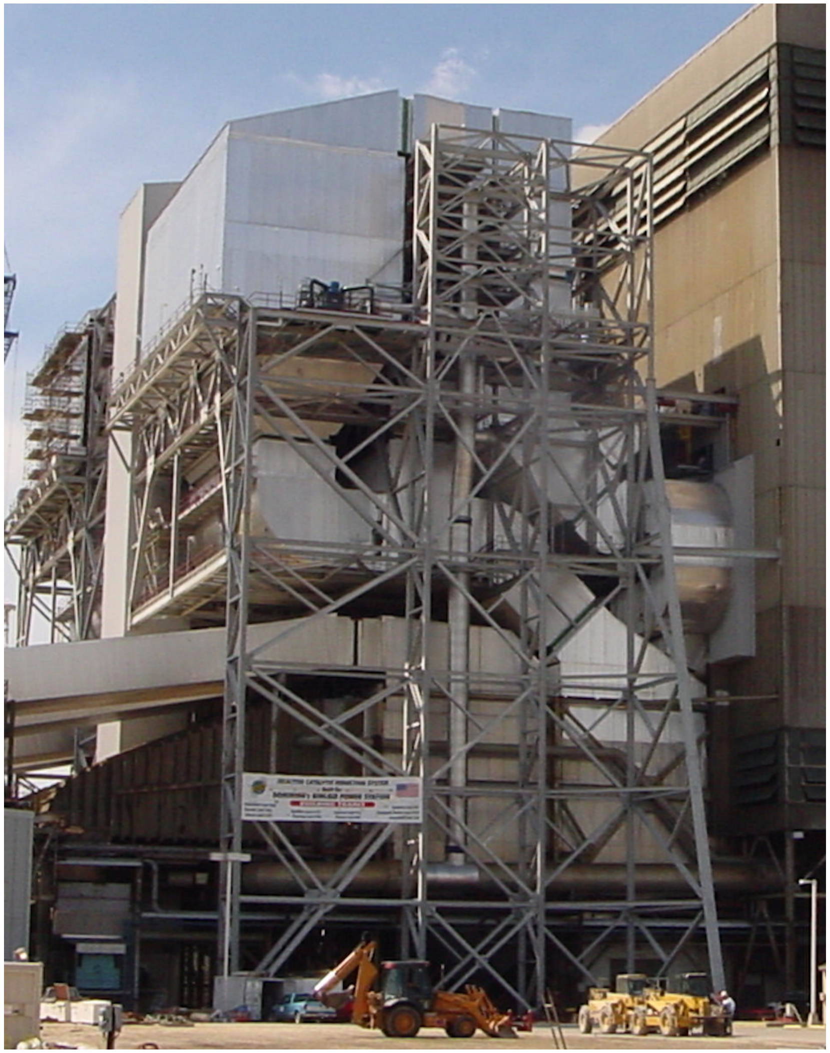
Flue Gas Flow



- Flue sizes
  - Draft loss
  - Erosion
  - Ash entrainment
- Reactor cross-section
  - Draft loss
  - Erosion
  - Ash entrainment

Velocity

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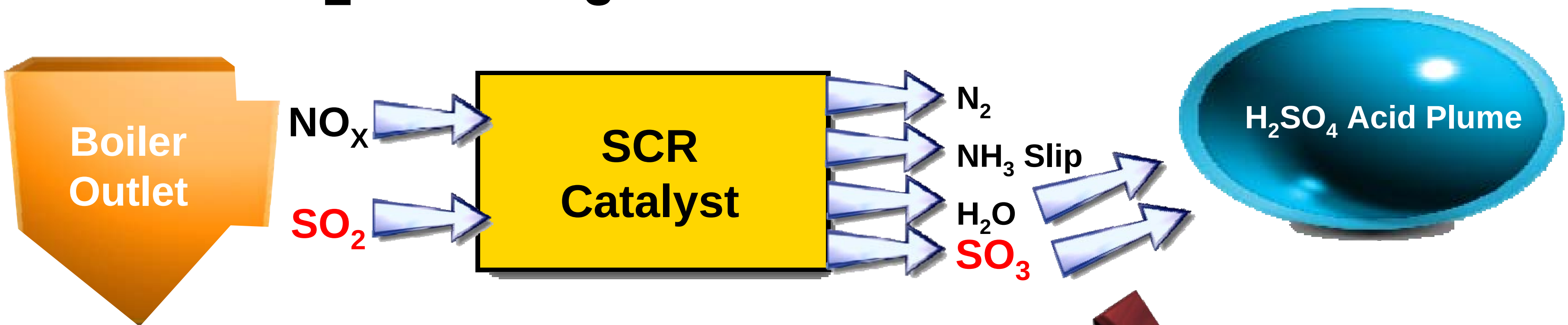
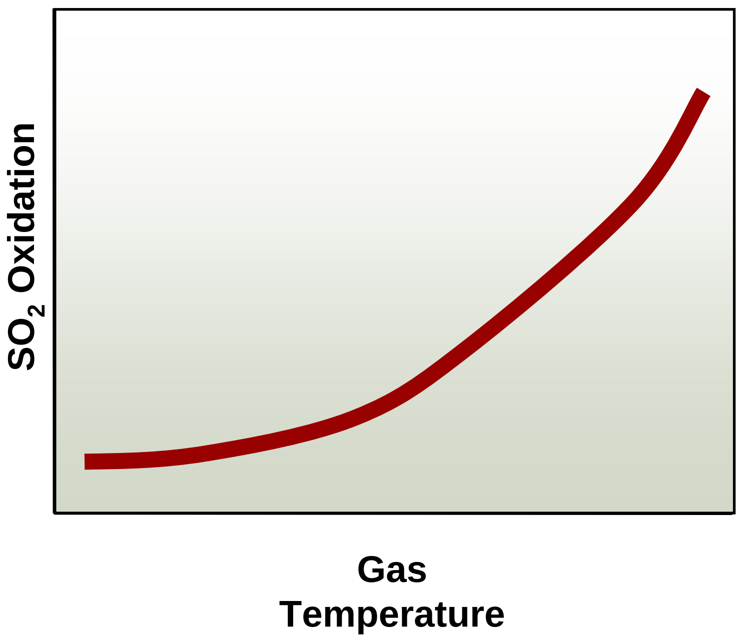
SO_2 to SO_3 Conversion Issues





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Minimum Ammonia Injection Temperature

- SO_3 reacts with NH3 to form $(NH_4)_2SO_4$ (ammonium sulfate)
  - Forms a fine particulate
  - Not formed at typical SCR outlet conditions
- SO_3 also reacts with NH_3 to form NH_4HSO_4 (ammonium bisulfate)
  - Forms a sticky solid
  - Forms at 400 - 450F in the bulk gas phase
- Formation of ammonium sulfate compounds in pores of catalyst via capillary precipitation
  - Temperature range for formation - 550-600F
  - Greatly reduces NO_X removal
  - Condition reverses after short term lower temperature operation when temperature is raised above 600F and compounds vaporize

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Economizer Exit Gas Temperature Conditioning

Ammonia is best introduced into the SCR reactor when flue gas temperatures are above ~ 600ºF.

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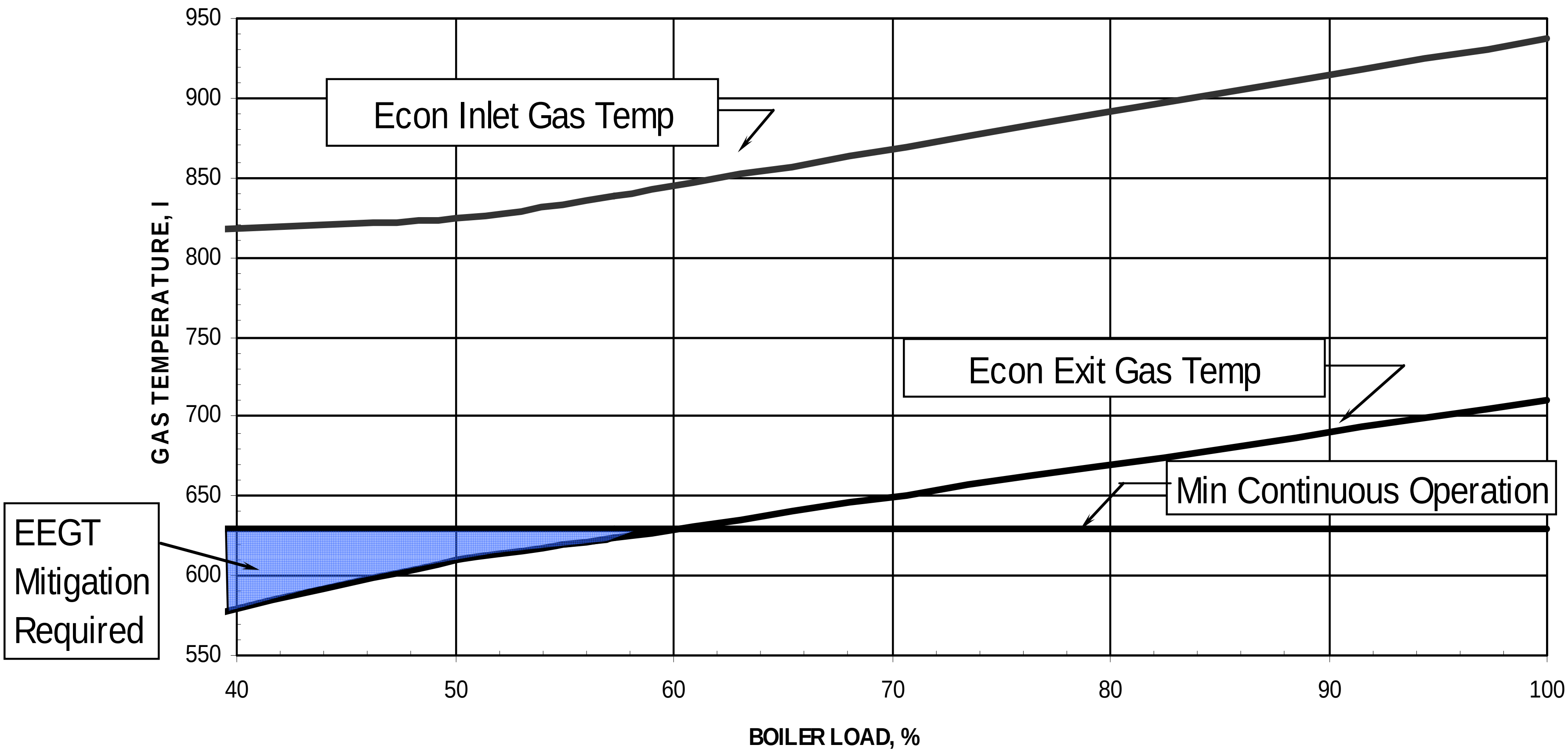
Example Case – Economizer Exit Temp. vs. Load



Note: **Minimum temperatures vary per catalyst manufacturers**

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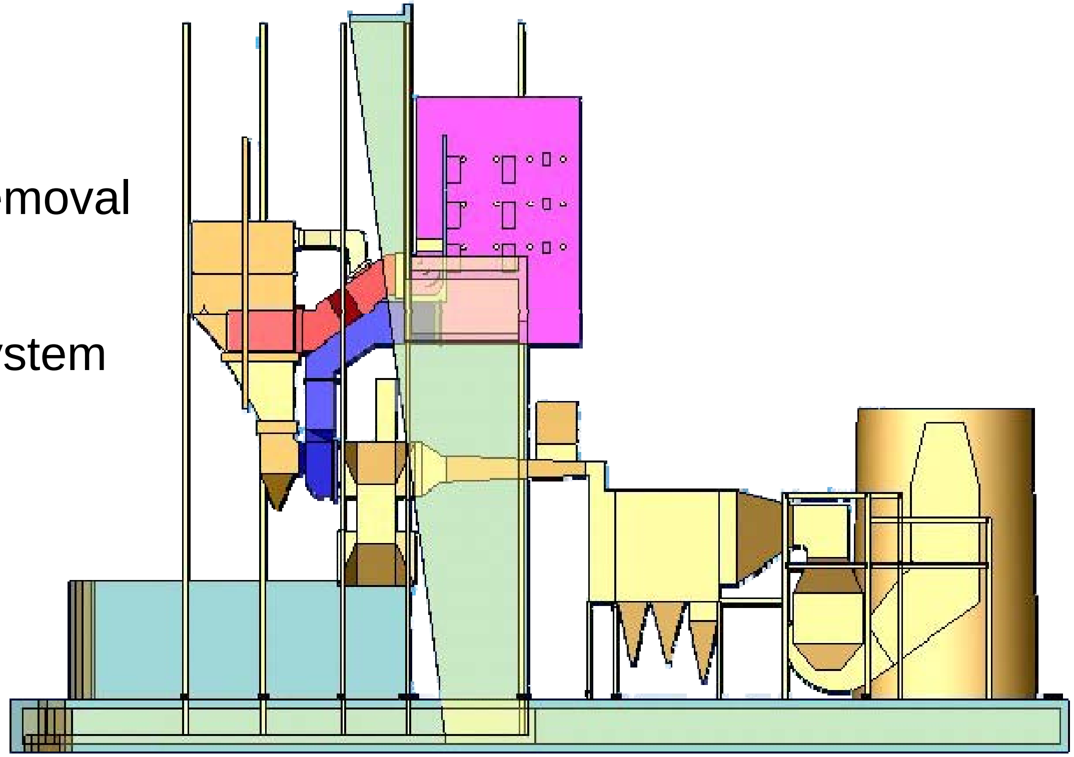
Options to Raise SCR Inlet Temperature

Wide load operating temperature can be achieved through:

- Economizer flue gas bypass
- Economizer heating surface removal
- Split economizer
- Feed water/boiler water mix system
- Economizer water bypass
- V-Temp™ Economizer



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SCR Gas Temperature Control Alternatives

Economizer Flue Gas Bypass

Advantages	Disadvantages
Quick gas temperature change	Expensive
Simple control	CP tie-in point
Minimal η penalty @ MCR	CP wall structure
Wide load range, w/Econ Out Damper	Buckstay / truss issues
No steaming economizer	Hot gas temp. flue design
	Ash accumulation
	Expansion
	Dampers & exp. joints
	Bypass Gas Mixing

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SCR Gas Temperature Control Alternatives

Economizer Surface Removal

Advantages	Disadvantages
Least expensive	Increased EEGT design
Predictable load range	Limited load range
No control loop	No gas temp. adjustment
No dampers & exp. joints	Loss of η across load range
No CP breach	
No gas mixing	
No ash accumulation	

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SCR Gas Temperature Control Alternatives

Split Economizer

Advantages	Disadvantages
No control loop	No gas temp. adjustment
Predictable load range	Limited load range
No loss of η across load range	Increased EEGT design
No dampers & exp. joints	Increased draft loss
No CP breach	
No gas mixing	
No ash accumulation	

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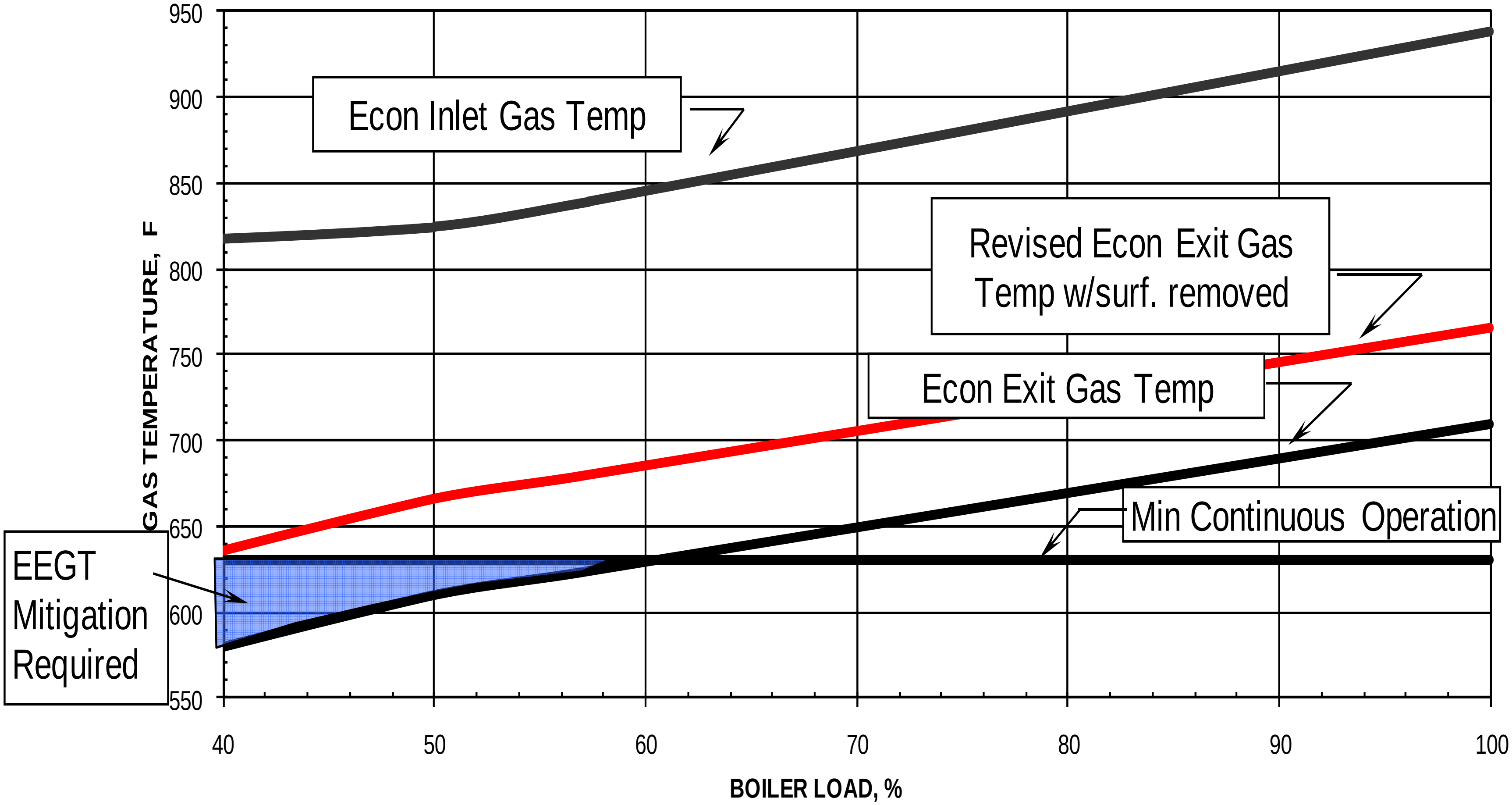
Example Case – Economizer Exit Temp. vs. Load



Note: **Minimum temperatures vary per catalyst manufacturers**

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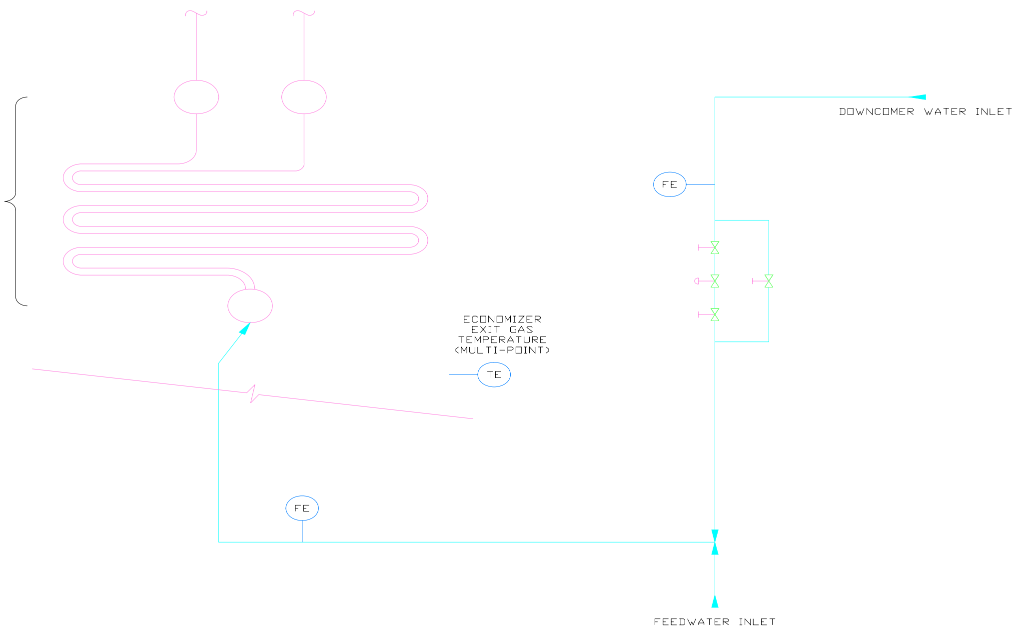
Feedwater Temperature Control



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SCR Gas Temperature Control Alternatives

Feedwater Temperature Control

Advantages	Disadvantages
Extended control range	Controls
Predictable load range	Limited load range w/o steaming
No loss of η @ MCR	Circulation analysis
No dampers & exp. joints	Additional piping & valves
No CP breach	Steaming economizer possible
No gas mixing	
No ash accumulation	

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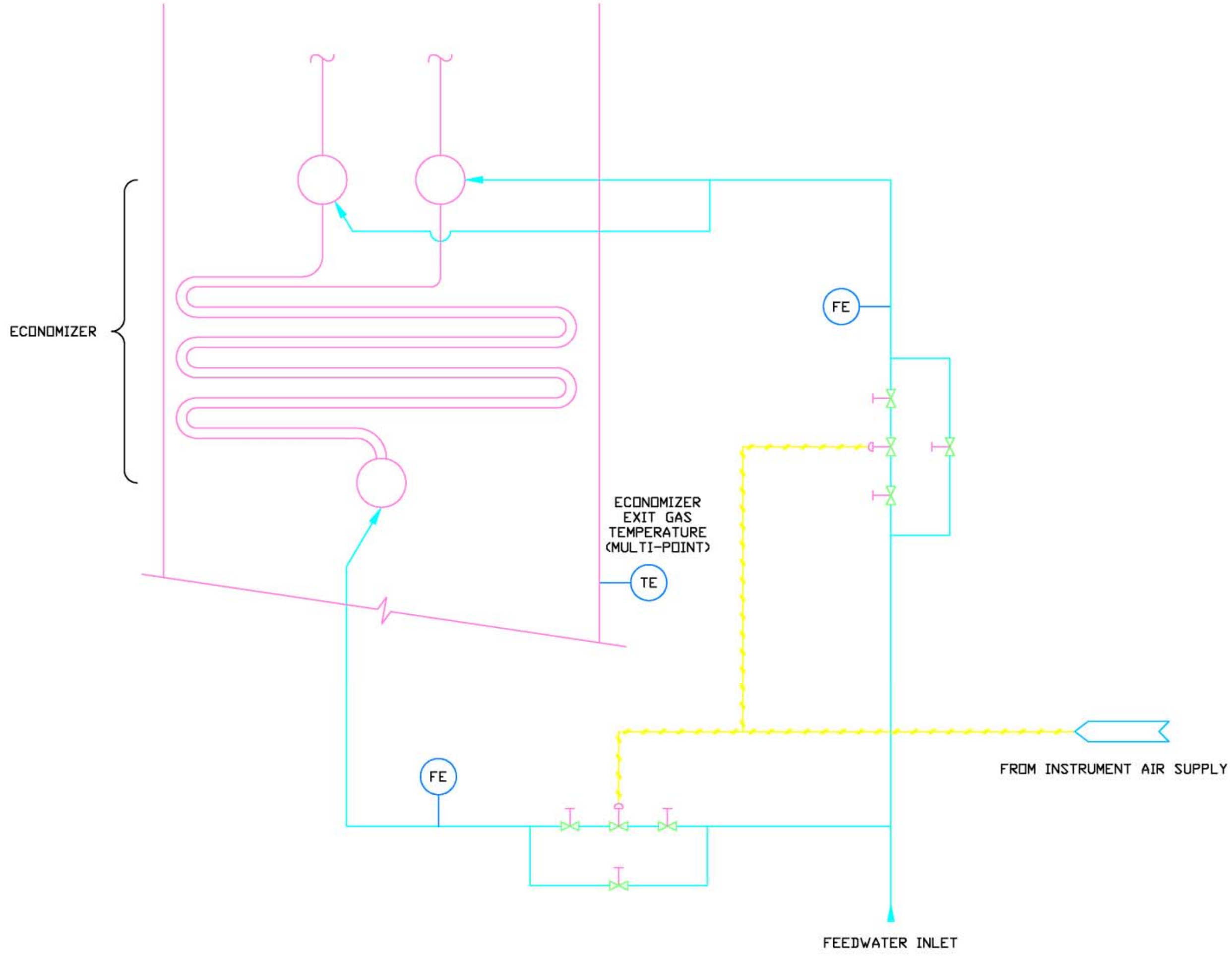
Water Side Bypass



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SCR Gas Temperature Control Alternatives

Economizer Water Bypass

Advantages	Disadvantages
Extended control range	Controls
Predictable load range	Limited load range w/o steaming
No loss of η @ MCR	Circulation analysis
No dampers & exp. joints	Additional piping & valves
No CP breach	Steaming economizer possible
No gas mixing	Uneven temp. distribution to the stringer tubes
No ash accumulation	Dead leg when O/S

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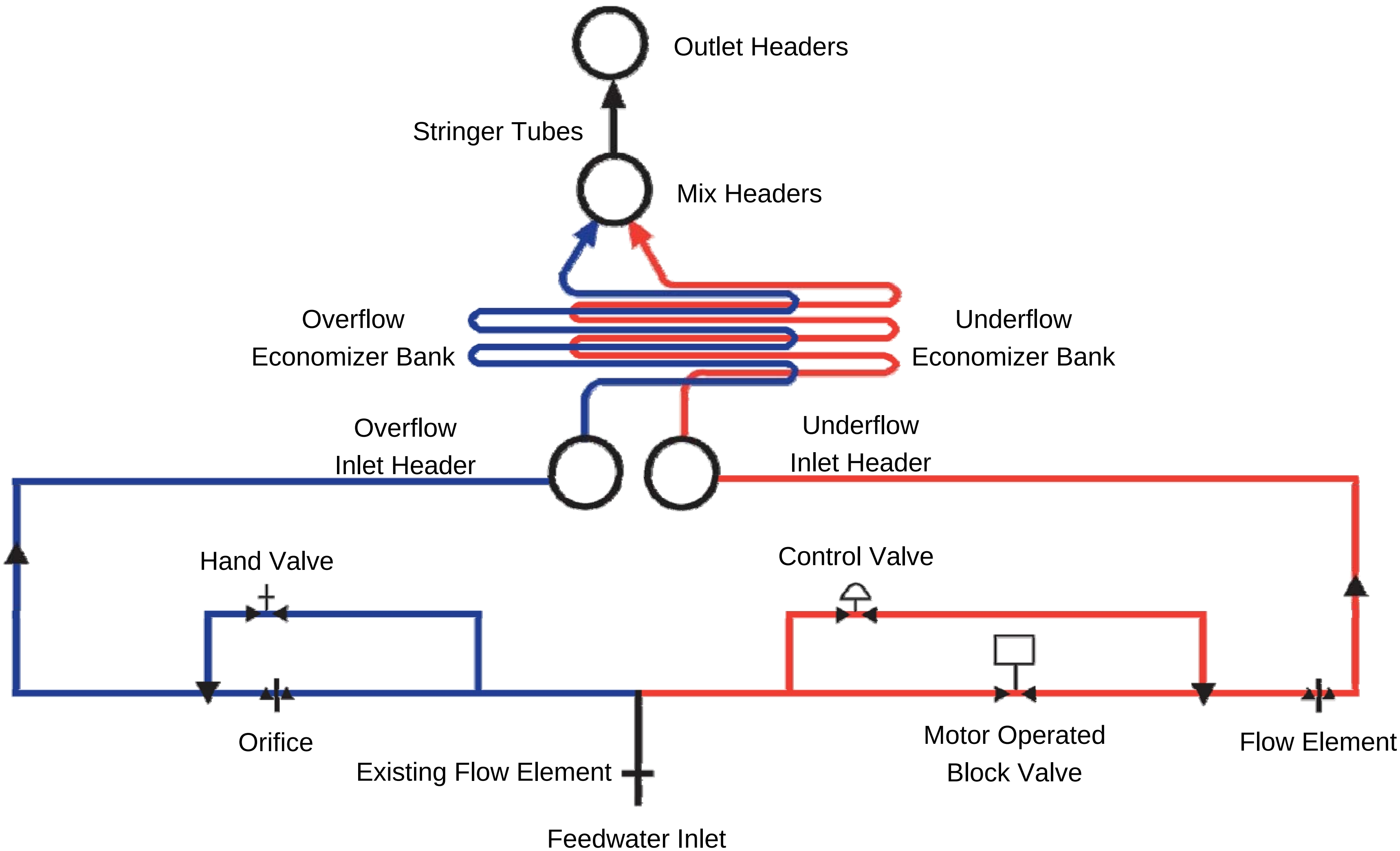
V-Temp™ Economizer



SCR Gas Temperature Control Alternatives
V-Temp™ Economizer

Advantages	Disadvantages
Extended control range	Controls
Predictable load range	Limited load range w/o steaming
No loss of η @ MCR	Circulation analysis
No water bypass	Additional piping & valves
No dampers & exp. joints	Steaming economizer possible
No CP breach	Intermediate headers?
No gas mixing	
No ash accumulation	
Even water temp. to stringers	

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V-Temp^{TM} Design Overview

- **Custom Designed for Particular SCR Application**
- **2nd inlet header added to the economizer**
  - Essentially two economizers operating in parallel
- **Valves added to feedwater piping**
  - Used to bias flow from overflow circuits to underflow circuits
- **Mix header to provide a uniform water temperature entering the stringers**

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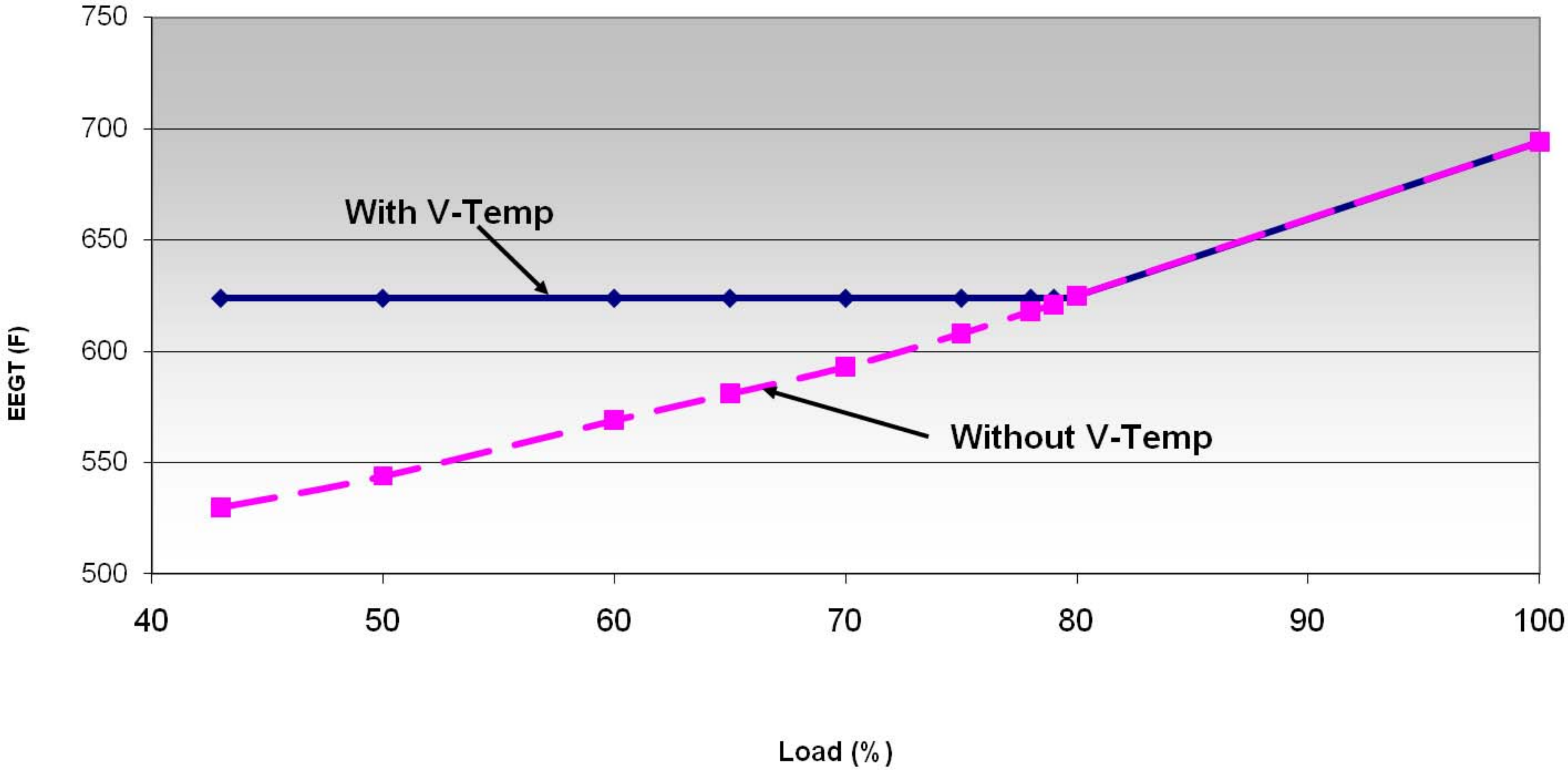
Predicted Economizer Exit Gas Temperature – With and Without V-Temp TM Economizer



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Benefits

Reducing/eliminating Ammonia Bisulfate (ABS) formation on catalyst

- Longer Catalyst Life
- Reduced Outages to Water Wash Catalyst
- Reduced Ammonia Slip
- Maintain Thermal Efficiency Across the Load Range with Select Solutions

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Catalyst Outage Protection

- Required to keep catalyst dry during
  - Non-ozone season
  - Extended outages

- Source of heated air required for protection system
  - Secondary air (alternative means required during boiler outages)
  - Heated ambient air
  - Rented dehumidification system

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Ammonia Slip

Ammonia slip is the result of:

- The need to have a slight excess of ammonia present to achieve the highest NO_X removal possible
- Imbalances in the NO_X distribution across the flue
- Imbalances in the ammonia distribution grid

Ammonia slip increases over time as the catalyst deteriorates

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Catalyst Management Process

Goals:

Maximize catalyst performance

Minimize O&M costs

Recommended four step process:

- Monitor system performance in terms of ammonia slip, ammonia consumption, NO_X performance
- During yearly unit outage, inspect reactor and catalyst
  - Assess condition of reactor (ash deposits)
  - Test sample catalyst for remaining activity – compare to original catalyst
- Tune ammonia injection equipment at least once a year
- Implement management method

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Catalyst Management

Management Methods

- Replacement with new catalyst
- Replacement with washed/regenerated catalyst
    - Washing can be on-site or even in-situ
    - Regeneration must be done in the service supplier's shop

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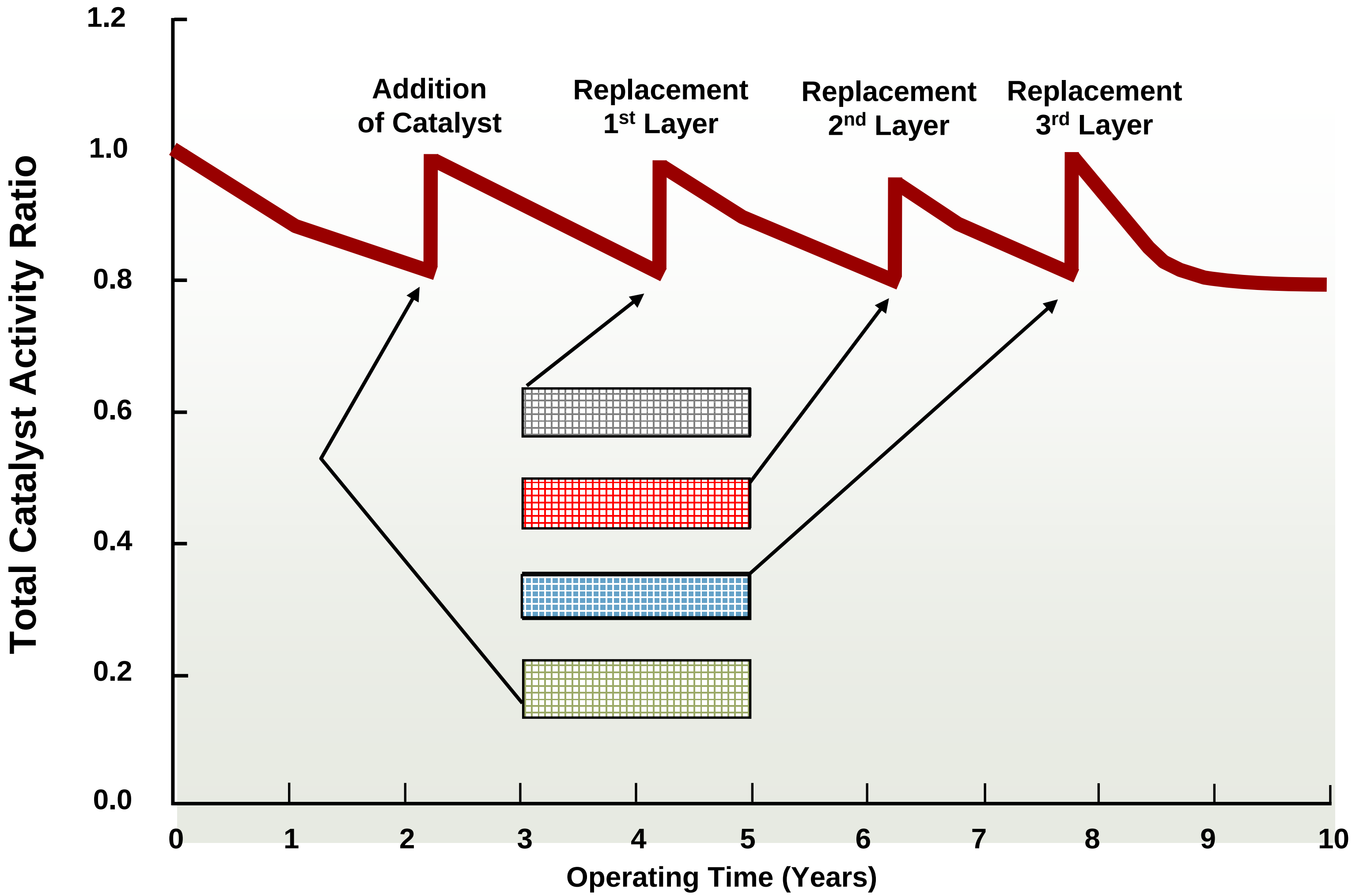
Typical Catalyst Management Plan



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