REINHOLD ENVIRONMENTAL Ltd.

2012 NOx-Combustion Round Table & Expo Presentation

February 13-14, 2012, in Columbus, OH / Hosted by AEP

Reinhold NOx Conference
Regeneration and New Catalyst

Columbus, OH

February 13, 2012

Agenda

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- Factors to Consider
- Balanced Approach to Catalyst Actions
- Long-term View

Factors to Consider

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- Environmental requirements now and future
- Plant limitations now and future
- SCR performance
- Outage schedule
- Total costs
- Risks

Environmental Requirements

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- NO_x
- SO_2
- SO_3
- Particulate
- Mercury

Plant Limitations

- Pressure drop
- Inlet operating temperature
- Ammonia slip
- Number of layers
- Catalyst pitch and length
- Module weight

SCR Performance

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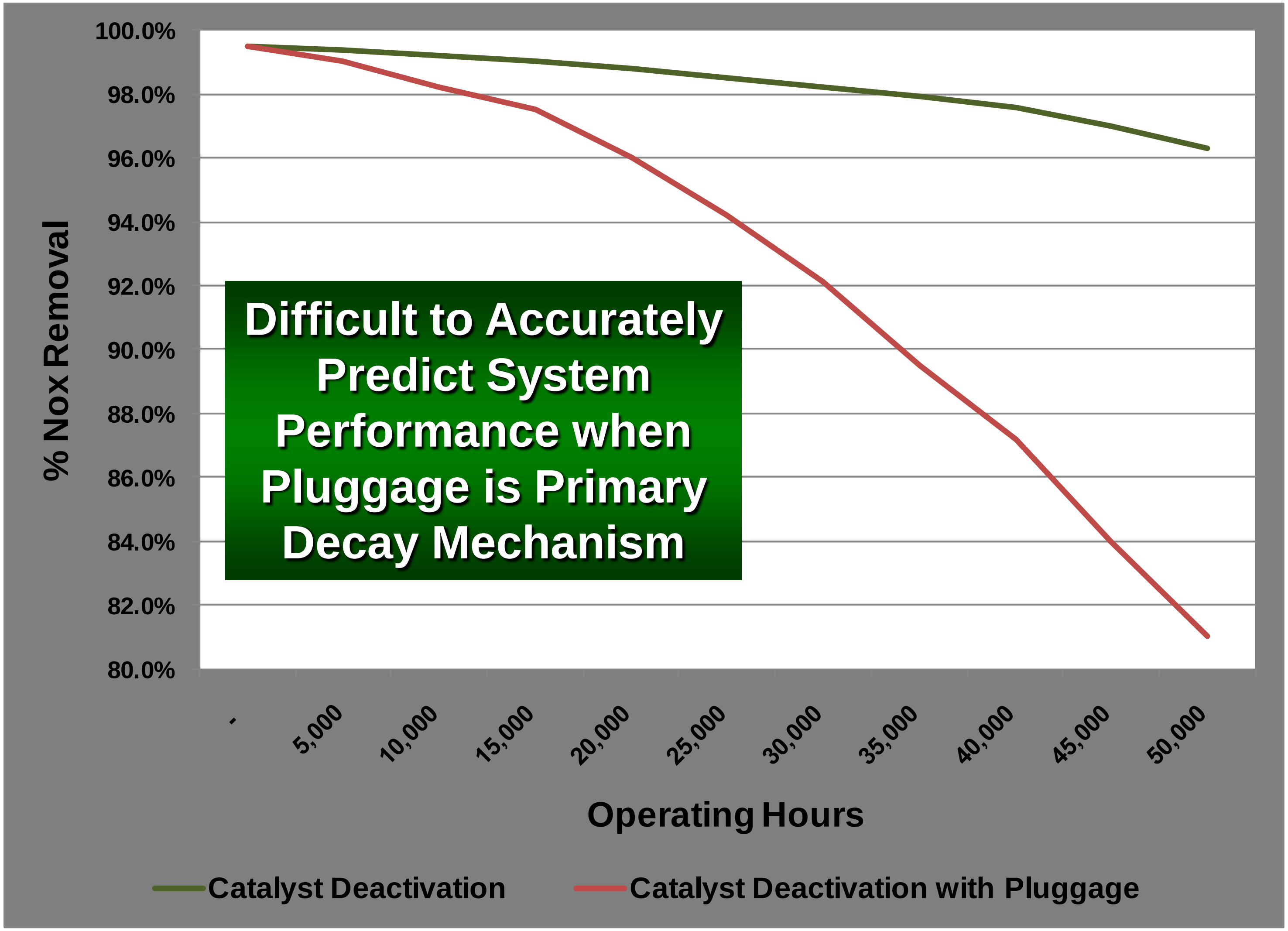
Primarily Affected By

- **SCR Performance**
  - **Catalyst Performance**
    - Catalyst Decay Rate
      - Flue Gas Impurities
      - Operating Conditions
    - Temperature
    - Flue Gas Velocity
    - SO_3 Concentration - 0 to 10ppm
    - NH_3 Concentration < 1.0 Mole Ratio
  - % Catalyst Pluggage
  - % Flue Gas By-pass

SCR Performance



Outage Schedule

- Frequency - Sets design
- Duration - Determines what actions can be considered
- Flexibility - Allows options to be evaluated
- Predictability – Factor into risk

Total Costs

- Catalyst purchase
- Labor to install and/or remove catalyst
- Disposal
- Mitigation reagents (Ammonia, trona, PAC)
- Capital
- Maintenance

Risks

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- **Cost of failure**
  - NO_x credits
  - Fines (NOVs)
  - Plant utilization
- **Chance of failure**
  - Low to high
  - Can it be monitored
  - What is back-up plan and costs

Balanced Approach

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- Must meet environmental requirements
- Must not exceed plant limitations
- Purchase new
  - Sell existing
  - Store for future use
  - Dispose
- Regenerate
  - “Hot” regeneration
  - Store for future use in same or different plant
  - Purchase from inventory

Balanced Approach

- Fleet vs. plant
- Add or replace a layer
- Non-homogeneous SCR reactor
  - New and regenerated
  - Multiple catalyst types
  - Multiple catalyst configurations

Requirements drive Catalyst Management

New or Regenerate?

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	Requirement	New	Regenerated
Price per Layer, $	< $2,500,0000	$ 2,000,000	$ 1,200,000
DeNOx K, m/hr	> 42	45	40
SO_2 Conversion, %	< 0.4%	0.30%	0.60%
Pressure Drop, inches water	< 0.75	0.5	0.5
Delivery Time	6 months	6 months	2 months

New or Regenerate?

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	Requirement	New	Regenerated
Price per Layer, $	< $2,500,0000	$ 2,000,000	$ 1,200,000
DeNOx K, m/hr	> 40	45	40
SO2 Conversion, %	< 0.7%	0.30%	0.60%
Pressure Drop, inches water	< 0.75	0.5	0.5
Delivery Time	2 months	6 months	2 months

Decision based on requirements & performance

Catalyst Strategy & Planning

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Considerations of New and Re-Use options
when managing
SCR Catalyst Layer Change-outs

- Balance use of New and Used Materials
- Carefully consider State of Catalyst Technology
- Get the Facts

Catalyst Layer Management

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Balance Use of New and Used Materials

- Invest in Long-term Suitability of Catalyst
- Plan for Impact of Next Layer Action(s) & Position
- Control Quality: Refurbish what you use
- Align Outage Timing with Contingency Plans

Build a Longer-Term Mgt Plan

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- Each Catalyst Change-out is an opportunity to reap benefits that multiply in future periods
  - Move to Higher Potential Layers, ↑ K/AV, Layer Height
  - Evaluate Suitability to Future Regeneration
  - Monitor and Anticipate Reactor Net SO_3
    - Locate the regenerated and/or aging plate layers in upper layers to benefit from ammonia suppression of SO_2 oxidation
  - Evaluate Advanced New Catalysts for benefits in NOx, SOx and Hg control

Advanced SCR Catalyst

DeNOx Activity (K) vs SO2 oxidation

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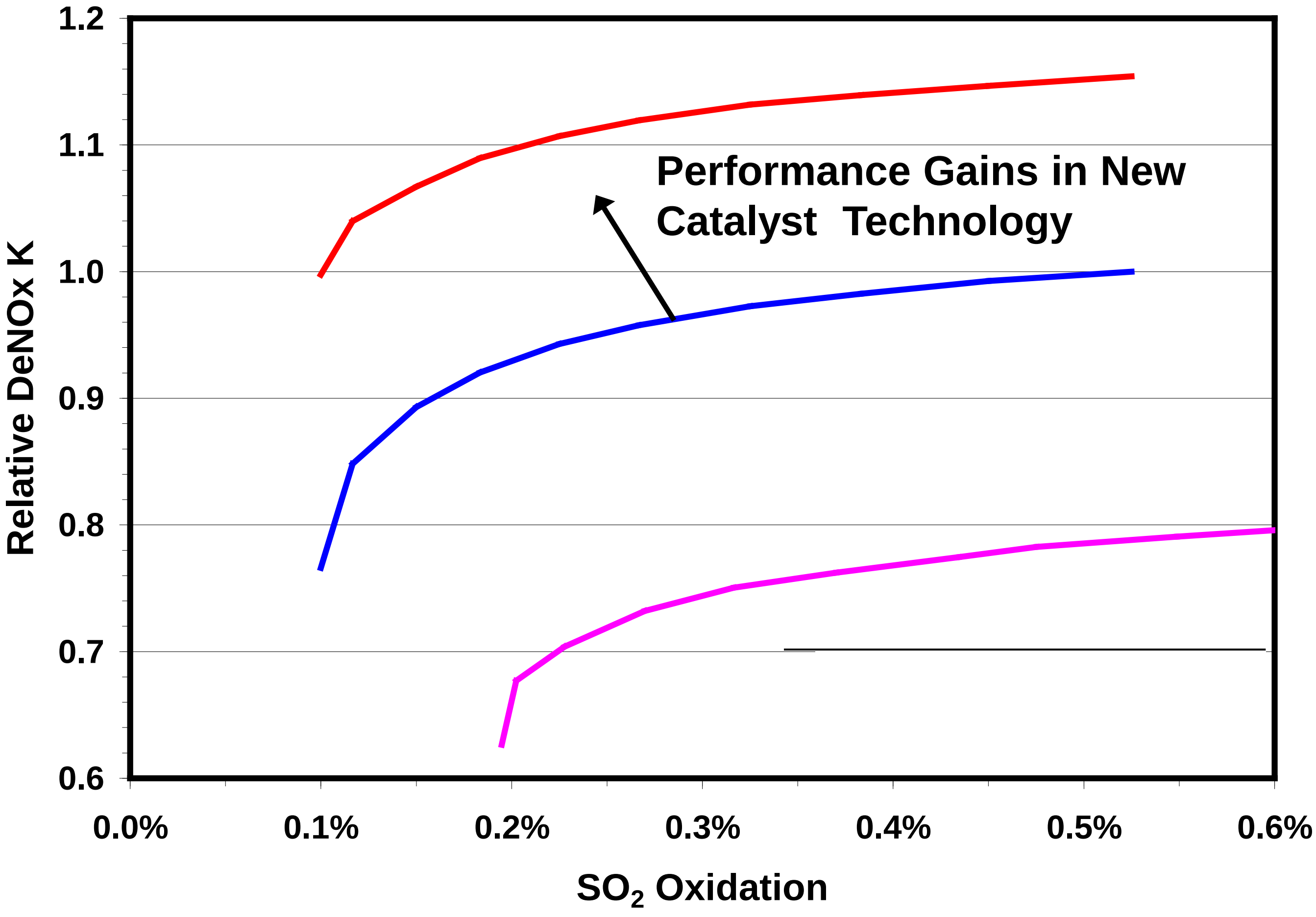

Step Changes in Performance from Advancements:
Both Physical & Chemical Changes in Catalysts

Restore when you Regenerate

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- Change-outs are Costly; Fixes aren't Fun
- Incorporate Thoughtful Selection Criteria when re-using catalysts. Establish contingencies.
- Dispose/Recycle materials damaged and compromised – especially heat-impacted and materials with catalyst mass loss
- Consider New Module Screens
- Repair and Replace Seals

SCR Catalyst Deactivation: Physical

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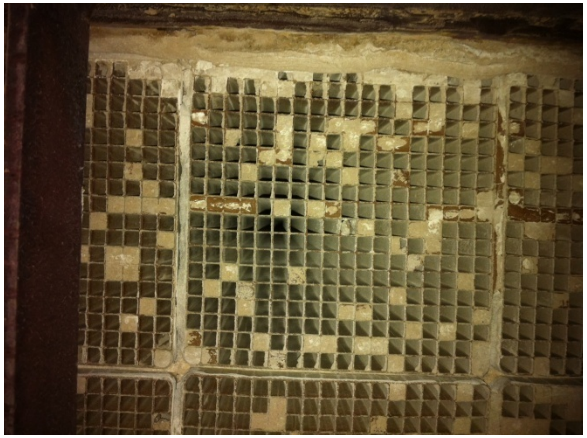
Regeneration Candidates



Not Regeneration Candidates

Catalyst Layer Management

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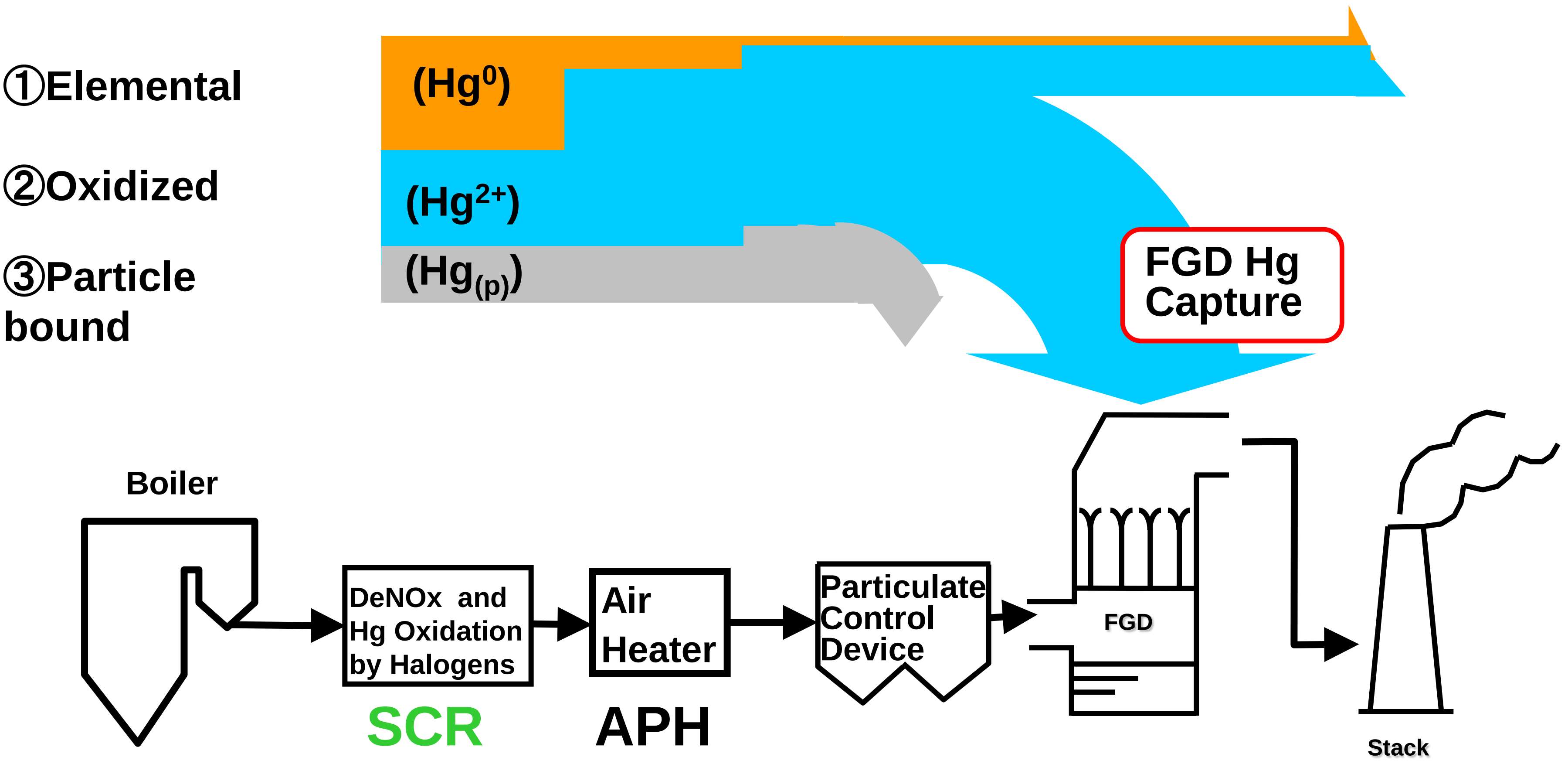
Carefully consider State of Catalyst Technology

- New — Regenerable from Original
- SO_3 Control by Additives or Avoidance
- Mercury Oxidation

SCR Co-Benefits of Hg Oxidation



Catalyst Technology Advancements: Mercury Oxidation

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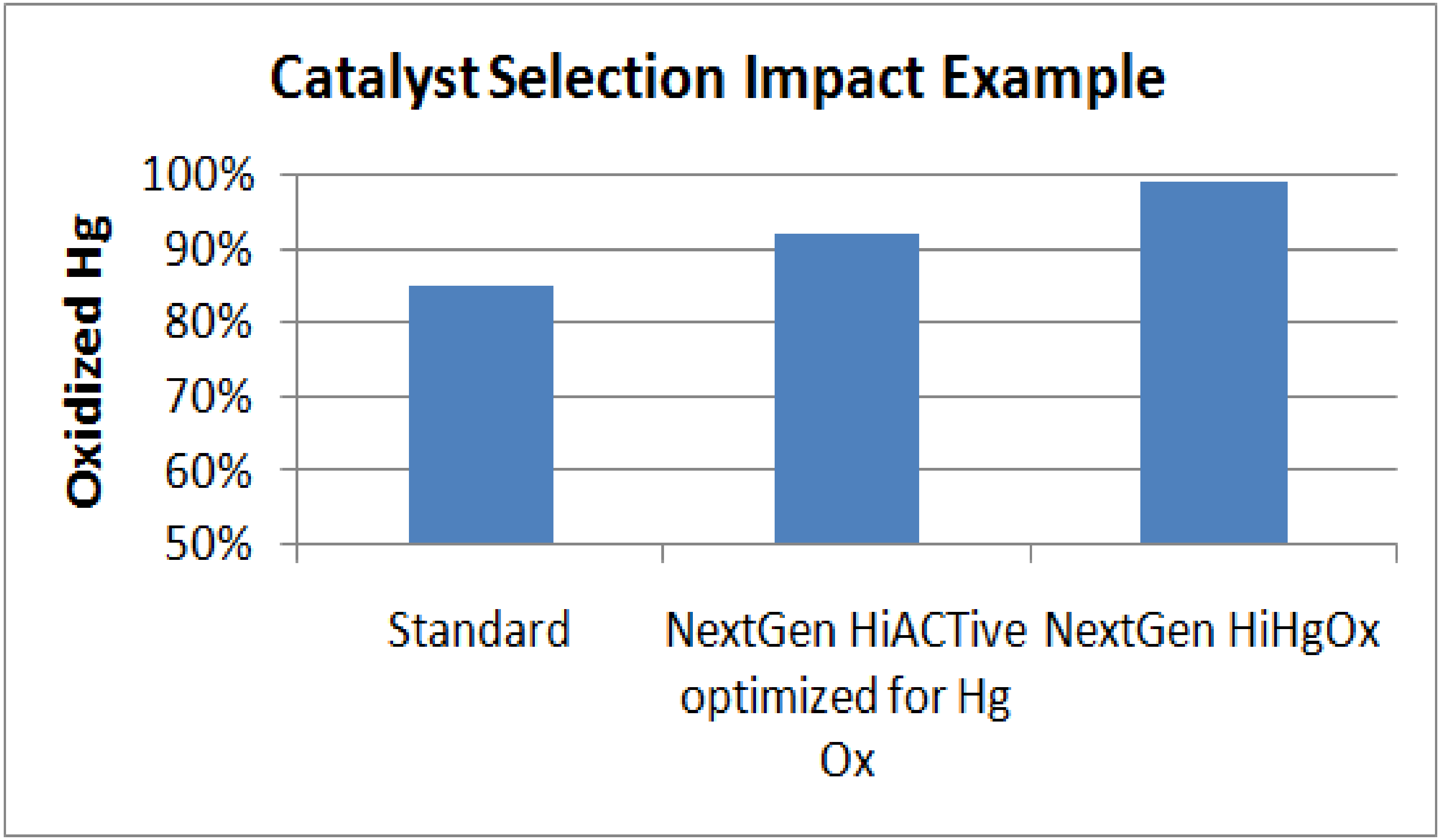

2009 → 2010 → 2012

Get the Facts

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Features of regeneration – evaluating the technology

- What performance can I plan for when targeting to regenerate and re-use? Multi-Plant Catalyst Measurements of NOx, SOx

- What about catalyst strength? Can I restore materials through “strength metal” re-impregnation and elevated heat treatment? A controlled experiment.

Restoring NOx & SOx Measured Performance from Original

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- Same-Plant Layer Regenerations
- Experiences of 8 North American Plants
- Mix of Projects by 2 U.S.-Regenerators
- Verified Cormetech-Produced catalysts with known histories
- Original and 1st-Regenerated, measured at the same conditions of performance for a given plant
- MR=1 for Activity, K

Activity Restoration, as Regenerated

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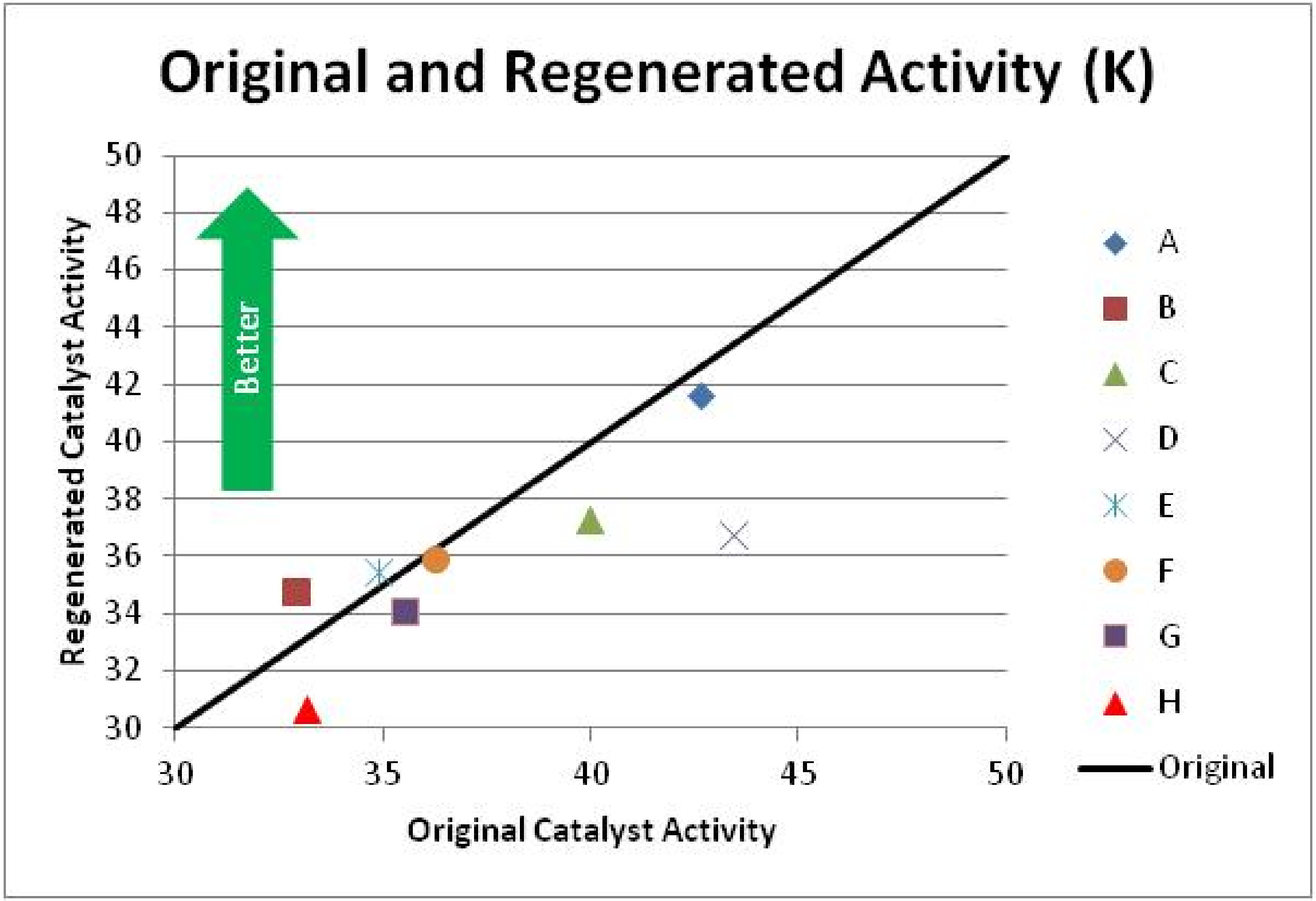

$SO_2 – SO_3$ Conversion, as Regenerated

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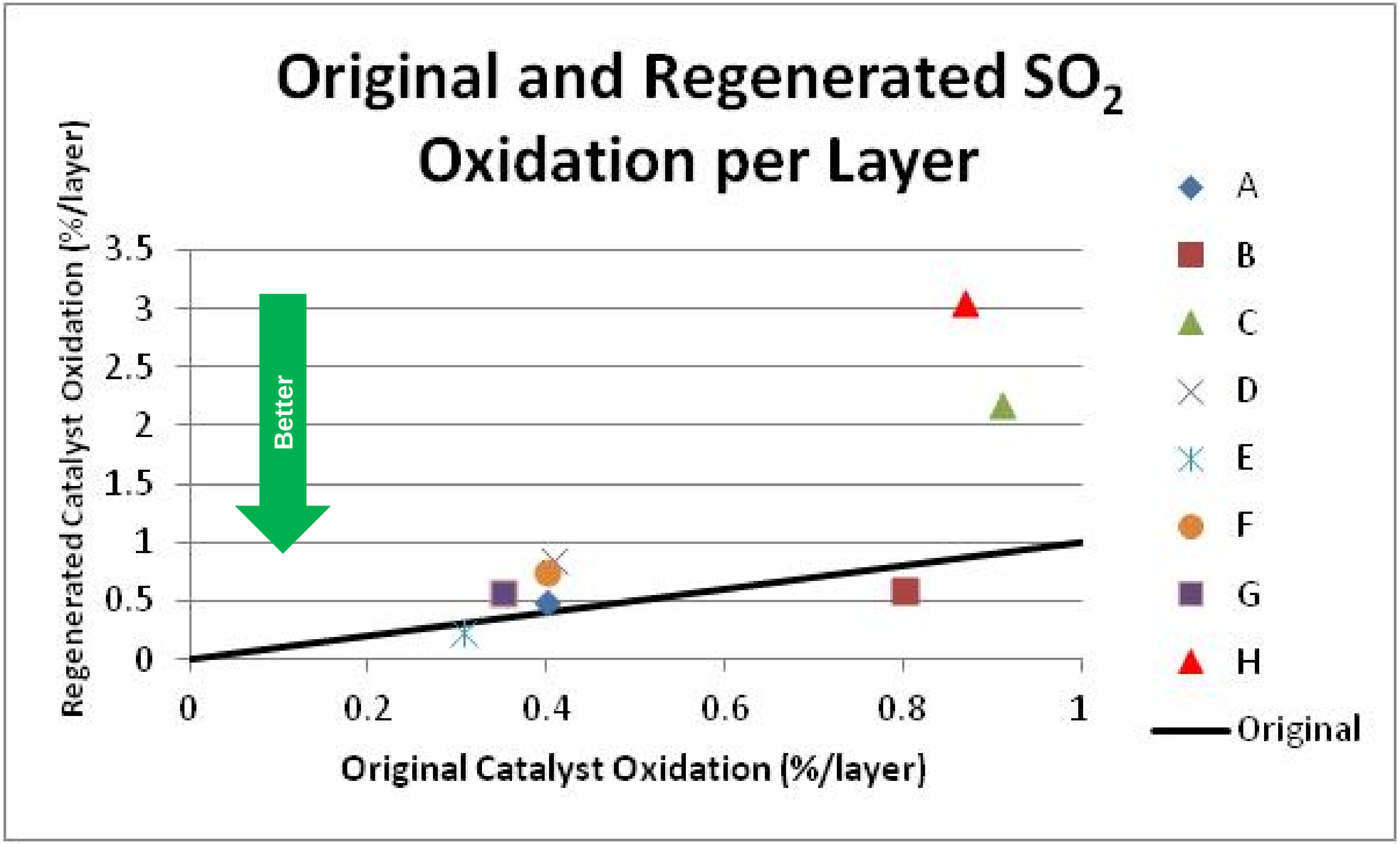
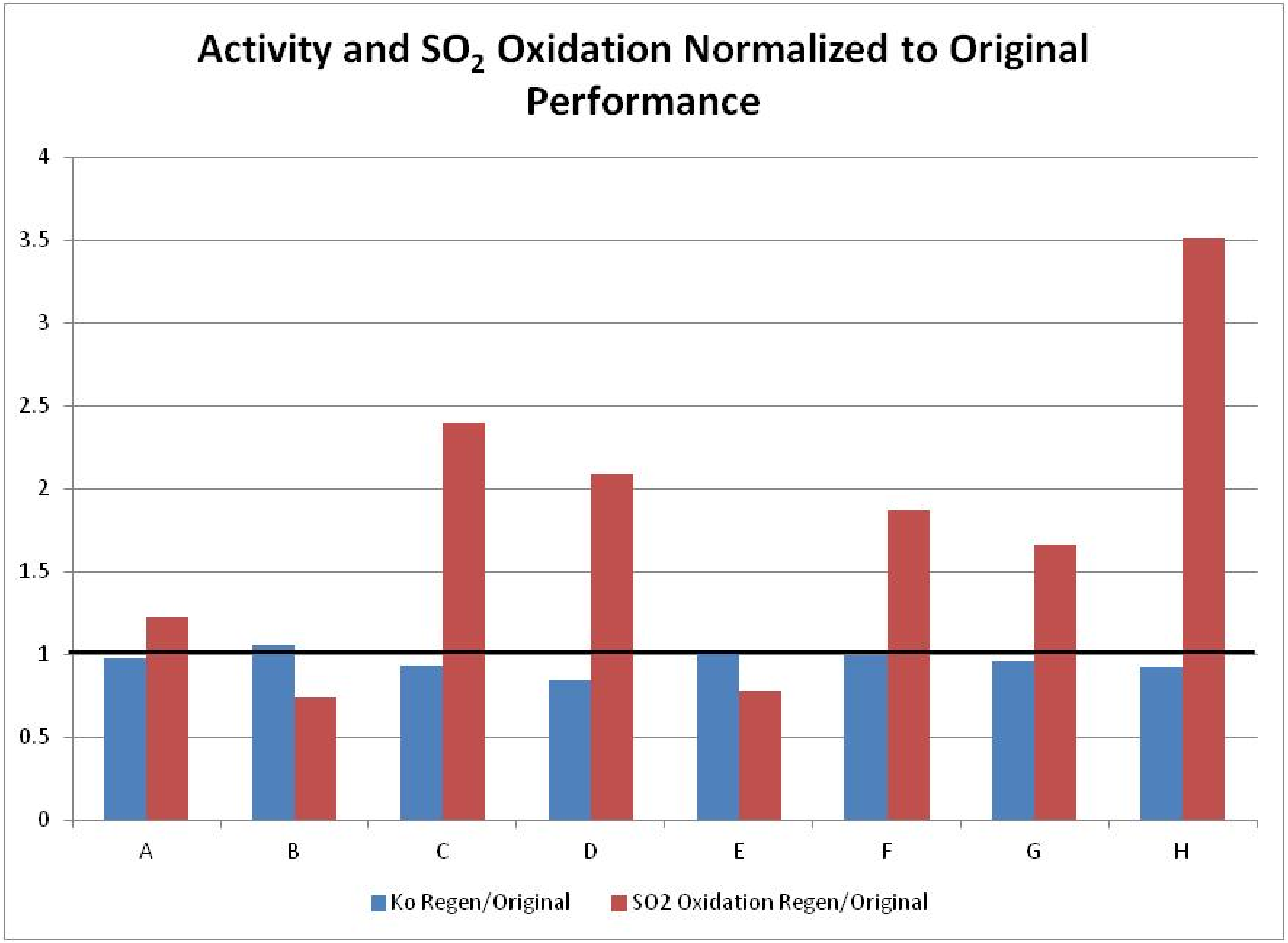


Balance of Performance by Plant, as Regenerated



Performance Restoration

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- Performance measurements reflect the outcome of Activity(K) at MR=1 and SO_2 – SO_3 Conversion Rate (%) for regenerated catalyst performance vs original new catalyst performance, at each plant's conditions
- Restoration of Activity for NOx control reflects consistent results of 90-100% across most of the tested plants, for PRB and E-Bituminous sources
- SO_2 – SO_3 Conversion varied widely and reflected no meaningful association within the scope of this study. More plant data is being gathered on this.

Metal Re-Impregnation and Secondary Heat Treatment for Strength Recovery

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- Cormetech Study, to address questions from Utility community
- CoaLogix, Inc. Processed Supplied Samples

  Regeneration, Metal Re-impregnation, Drying and Heat Treatments
- Sample Management, Tests and Analyses conducted in Durham, NC SCR Catalyst Performance Laboratory by Cormetech, using customary apparatus and methods to measure Transverse Crush Strength.

Experimental Process

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- All elements are marked and assembled into a single SCR module and treated to the appropriate cleaning process for regeneration.
- After processing and drying, each element is cut in half, directing an equal quantity to a Low and High concentration Tungsten impregnation process. Samples are marked and traced throughout the experiment.
- Elements are then separated by Tungsten Level and portioned for processing under 3 unique levels of Heat Treatment.
- Final elements are sectioned for suitability to apparatus and Crush Strength testing performed.
- Results are evaluated for statistical confidence and reported.

Transverse Crush Test Apparatus

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Test Matrix : 192 Crush Tests

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			Pitch		Field Operation		Tungsten Conc.		Temp of Heat Treat		
Sample #	Descrip.	# of Samples	6.9	8.2	New	Used	Low	High	150C (300F)	343C (650F)	450C (840F)
1	New 6.9	8	X		X		X		X		
2		8	X		X		X			X	
3		8	X		X		X				X
4		8	X		X			X	X		
5		8	X		X			X		X	
6		8	X		X			X			X
7	Field 6.9	8	X			X	X		X		
8		8	X			X	X			X	
9		8	X			X	X				X
10		8	X			X		X	X		
11		8	X			X		X		X	
12		8	X			X		X			X
13	New 8.2	8		X	X		X		X		
14		8		X	X		X			X	
15		8		X	X		X				X
16		8		X	X			X	X		
17		8		X	X			X		X	
18		8		X	X			X			X
19	Field 8.2	8		X		X	X		X		
20		8		X		X	X			X	
21		8		X		X	X				X
22		8		X		X		X	X		
23		8		X		X		X		X	
24		8		X		X		X			X

Catalyst Sources

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New: **Original Catalyst Retentions of the Field SCR, Unused**

Field: **SCR Catalyst Operated in the Plant Source**

Catalyst	Pitch, mm	Original Install	Plant Source
Cormetech Honeycomb	6.9	> 4 years	E-Bit 1
Cormetech Honeycomb	8.2	> 4 years	E-Bit 2

Measuring Strength

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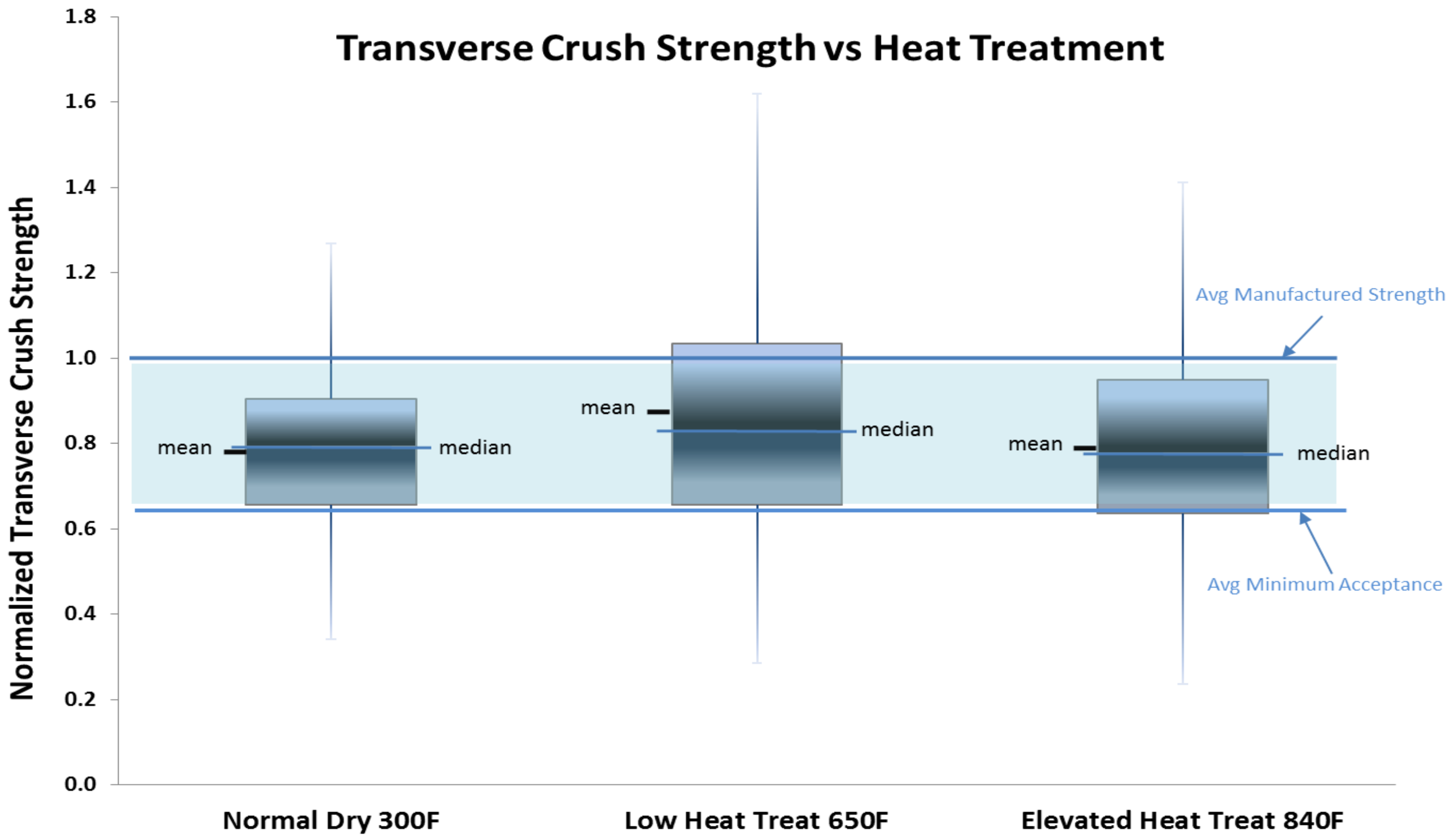
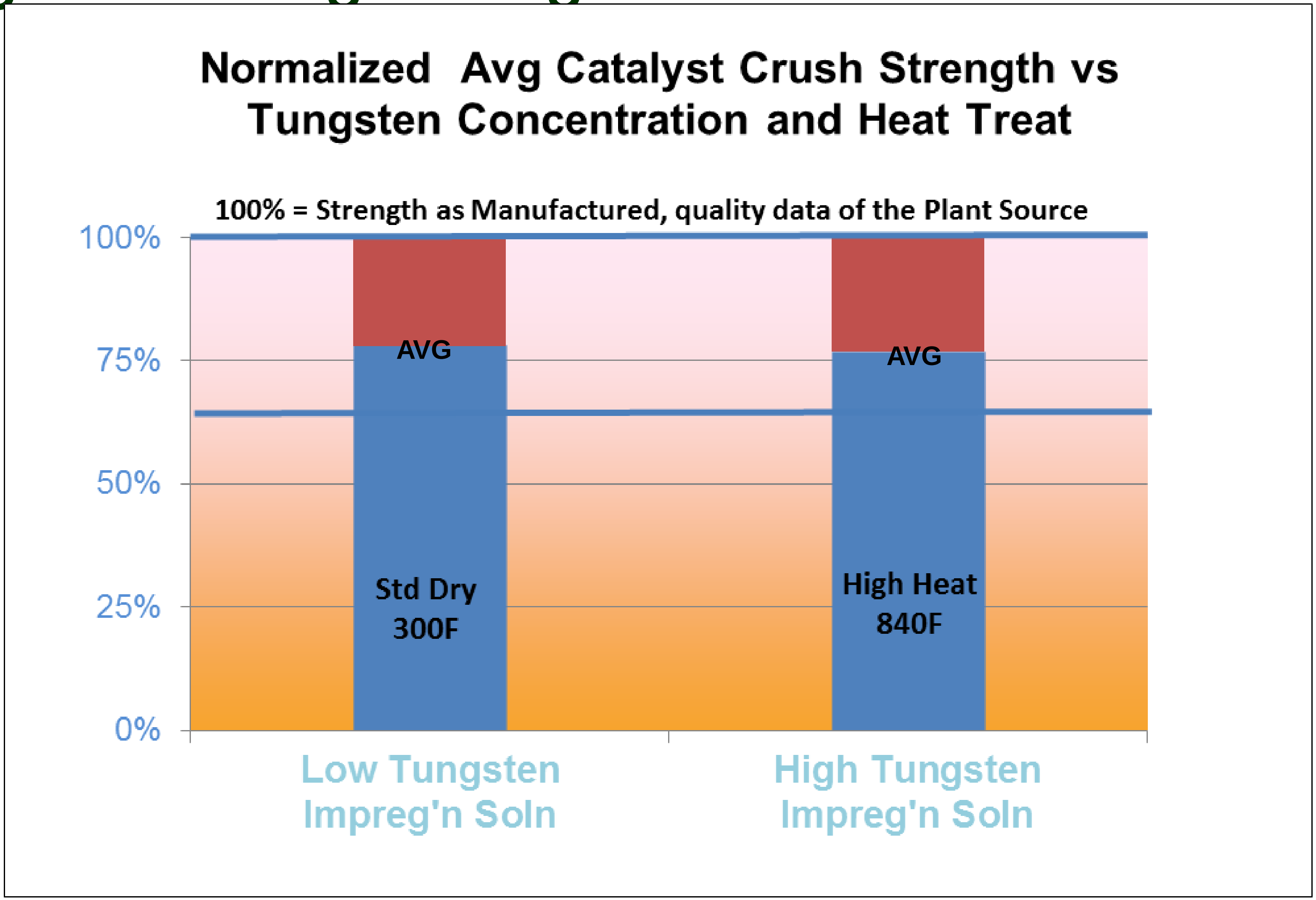
- This study was conducted as a controlled experiment with a large sample population.
- Measurements of transverse crush strength are impacted by the physical construction of the base material, therefore the experiment was run from a known source population and conducted to achieve sufficient data density. The test method is relevant to the primary material stresses of concern.
- Box Plots provide a meaningful view of the data and are included here to replace original Bar Graphs that reflected the Mean values only.

BoxPlot View: Heat Treatment



Low Heat/Low Tungsten
High Heat/ High Tungsten



BoxPlot: Heat Treatment & Tungsten Concentration

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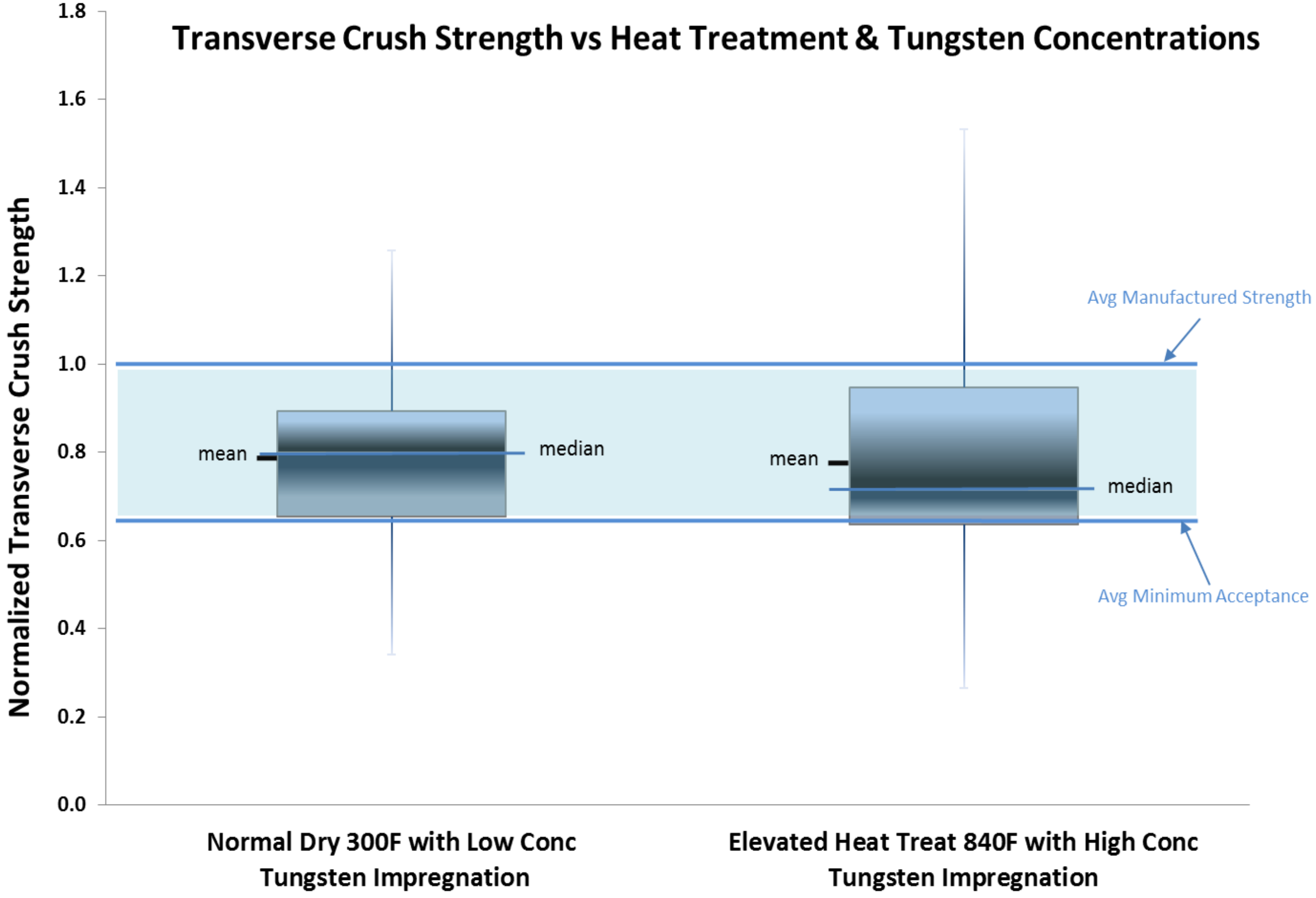

Metal Re-impregnation and Secondary Heat Treatment: Conclusions

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- Strength features were not impacted by the re-impregnation of tungsten.
- Heat treatments ranging from 300°F to 840ºF provided no measured benefit for crush strength at any metal re-impregnation concentration.
- Material strength after heat treatment that is typical of normal reactor temperatures produced the highest values, but are not statistically different from Dry and Elevated Heat conditions of test.
- The crush strength of all regenerated materials remained in an acceptable condition for strength after one regeneration cycle.
- Crush strength testing of once-regenerated catalyst samples from all other source plants tested by this method, outside of the experiment, produced results consistent with that reported here.

In Conclusion

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- Think *Reactor* Performance when making Layer Decisions

- Plan for Long-term Impacts at each Decision

- Consider the Fleet

- Incorporate the Benefits of both New & Regenerated Catalyst Technologies