

REINHOLD ENVIRONMENTAL Ltd.



2019 NO_x-Combustion-CCR Round Table Presentation

February 11 & 12, 2019, in Salt Lake City, Utah / Hosted by PacifiCorp

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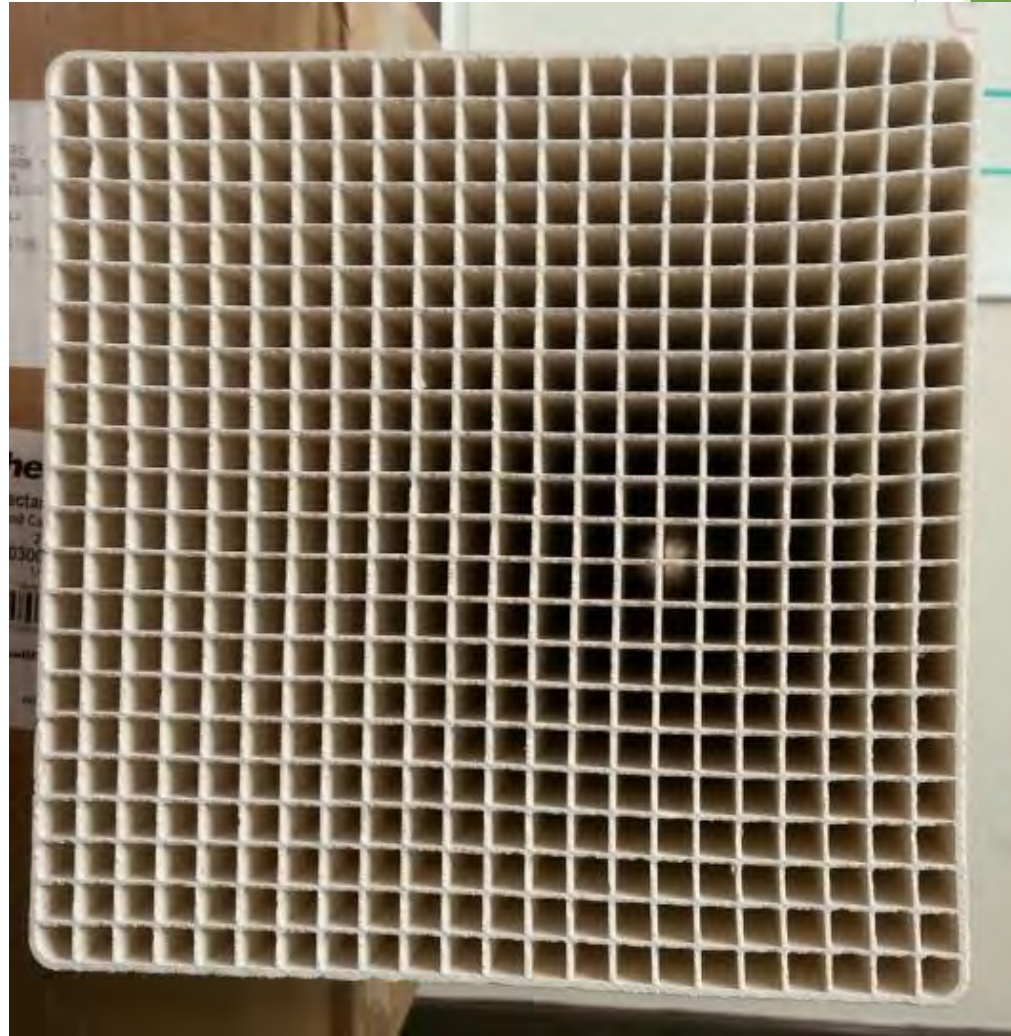


Innovative Combustion Technologies, Inc.

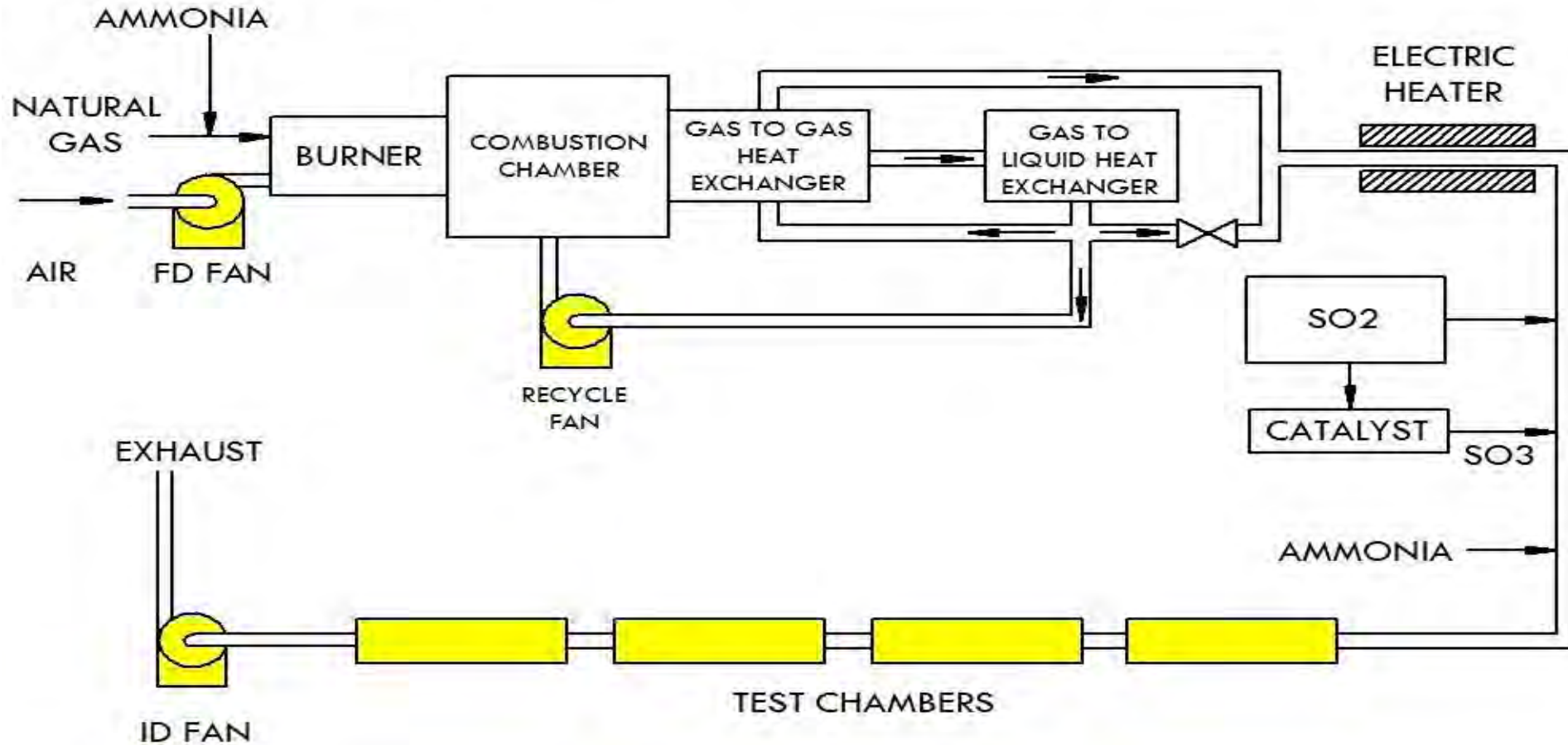
Maximizing the Value from
Catalyst Sampling and Testing

Catalyst Performance Testing: Typical Test Methods

- ▶ deNO_x Activity, k
- ▶ SO₂-SO₃ Conversion
- ▶ Chemical Composition
- ▶ Physical Properties



Pilot-Scale Schematic

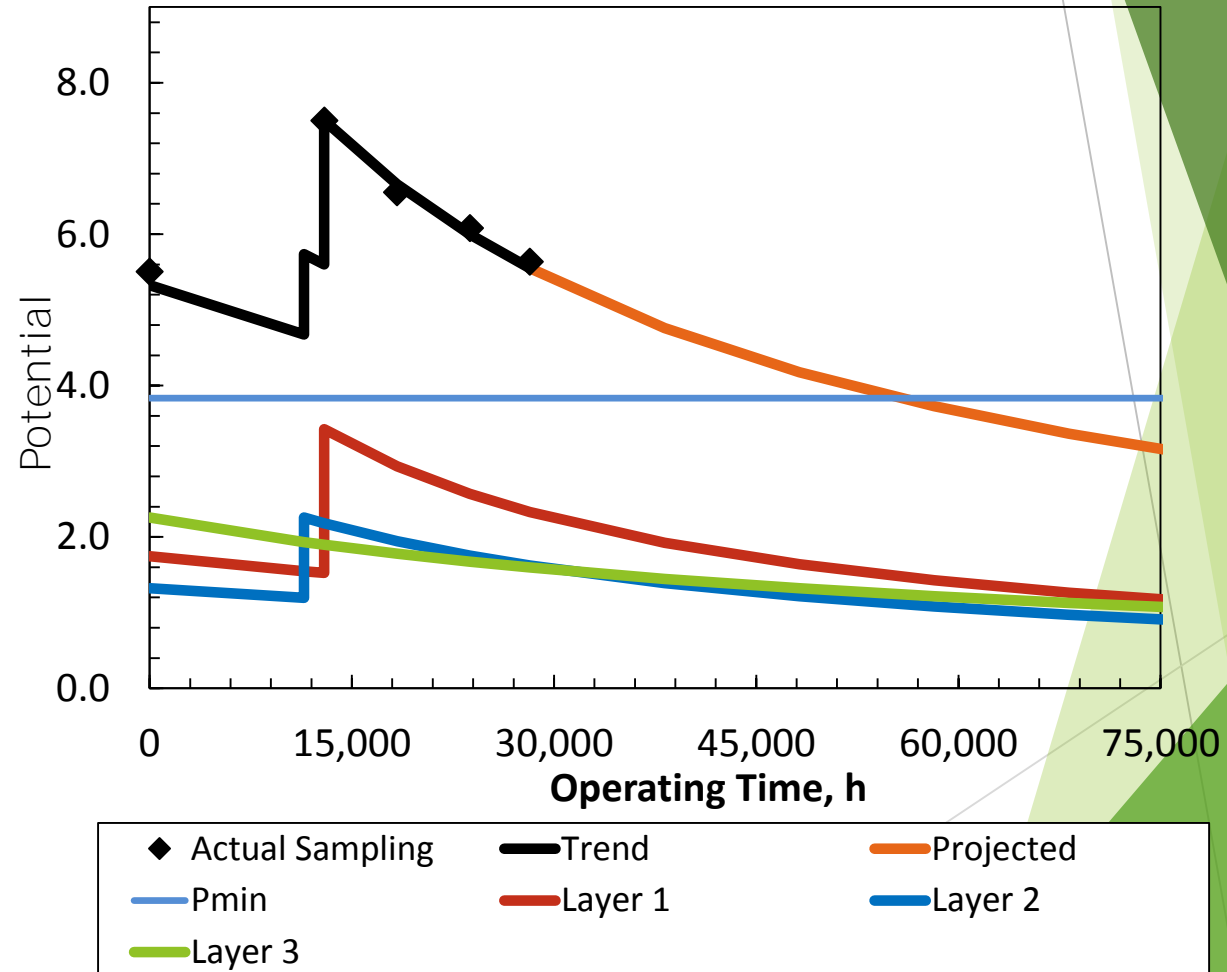


Catalyst Testing Facility



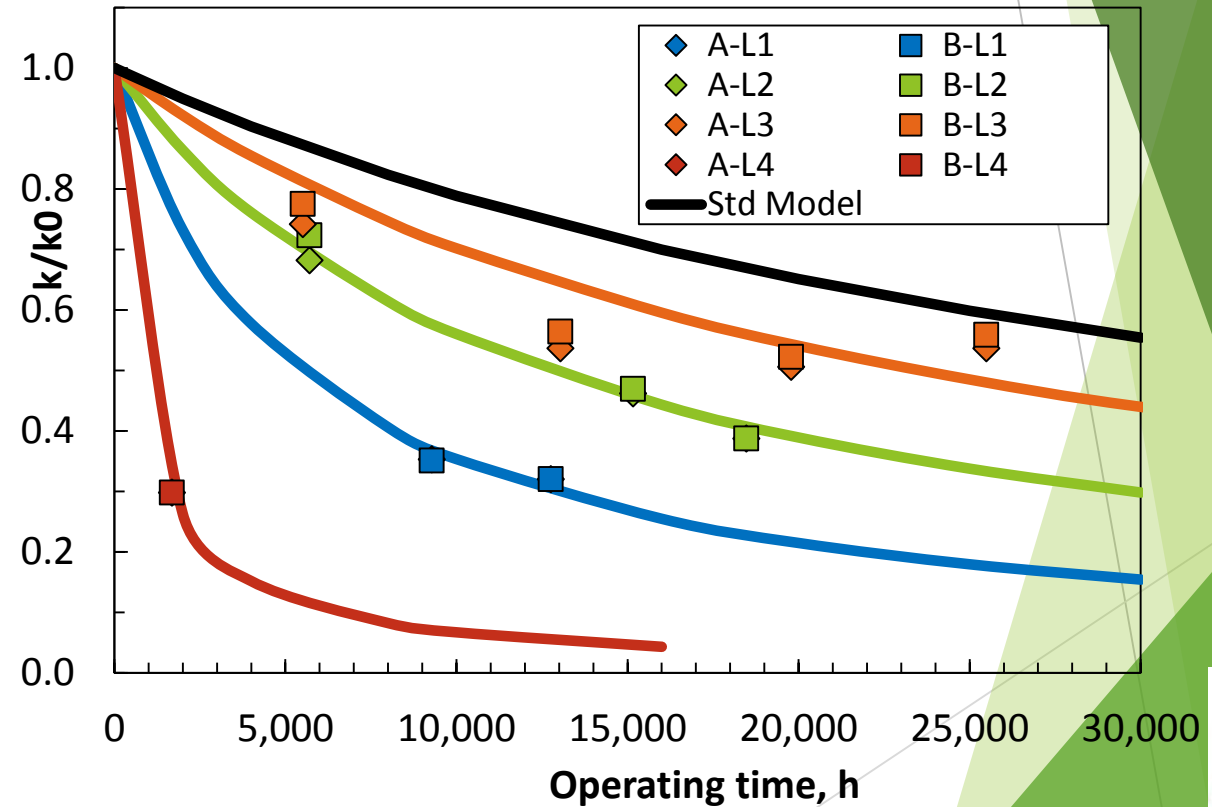
Catalyst Performance Testing: Value of Data

- ▶ deNO_x Activity (k)
 - ▶ Track deactivation trends
 - ▶ Calculate reactor potential
 - ▶ Project catalyst lifetime
- ▶ SO₂ - SO₃ Conversion
 - ▶ Prevent major corrosion/ABS event
- ▶ Chemical Composition
 - ▶ Determine primary deactivation mechanisms
 - ▶ Evaluate impact of operational changes

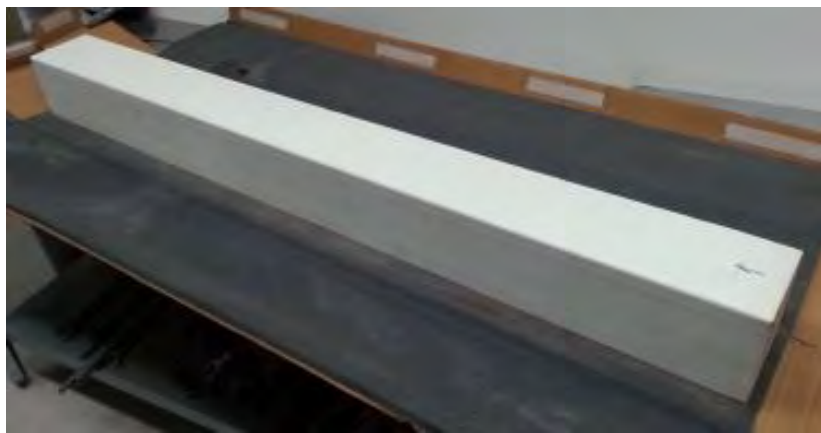


Factors Influencing SCR Catalyst Deactivation

- ▶ Primary deactivation mechanisms
 - ▶ Active site poisoning
 - ▶ Pore structure blinding/fouling
- ▶ Type of fuel fired
 - ▶ Bituminous (As, alkali)
 - ▶ Sub-bituminous (Si, Ca, P)
 - ▶ Blend (?)
- ▶ High vs. Low dust

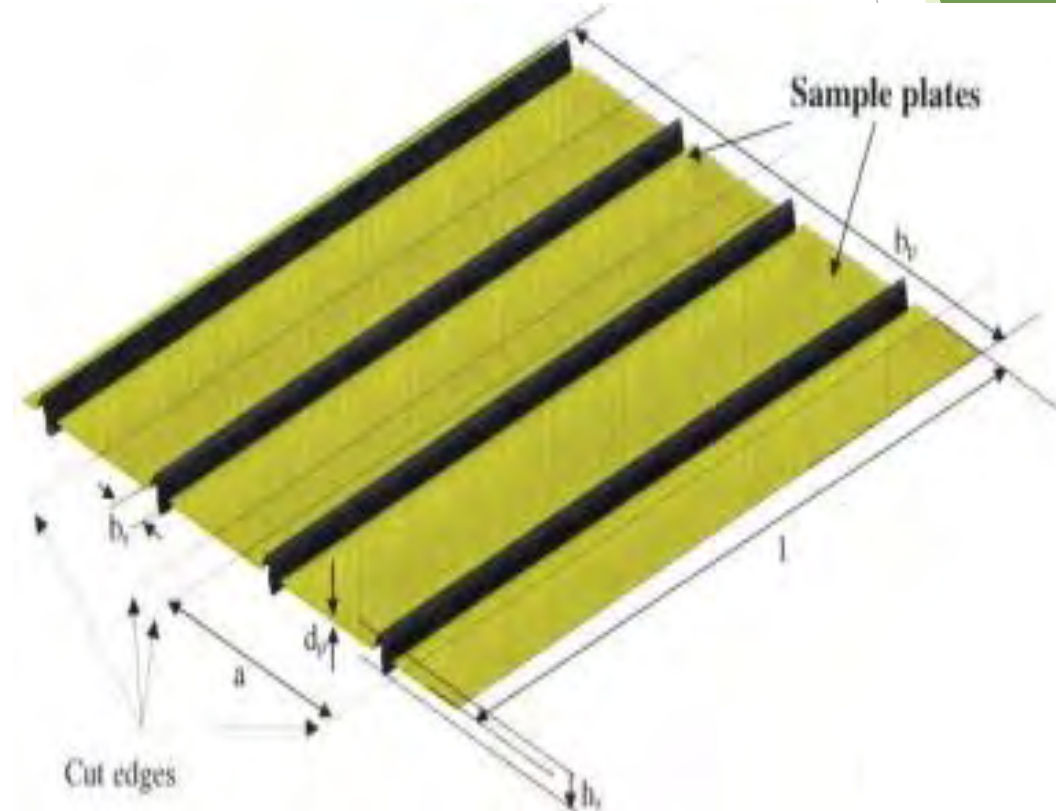


Catalyst Sample Prep: Intro



Catalyst Sample Prep: Plates

- ▶ Typical plate elements are 450 mm wide by full sub-layer length
- ▶ Plates are sampled in pairs
 - ▶ 14-16 plates for each test element
- ▶ Plates cut into 150 mm wide coupons for testing

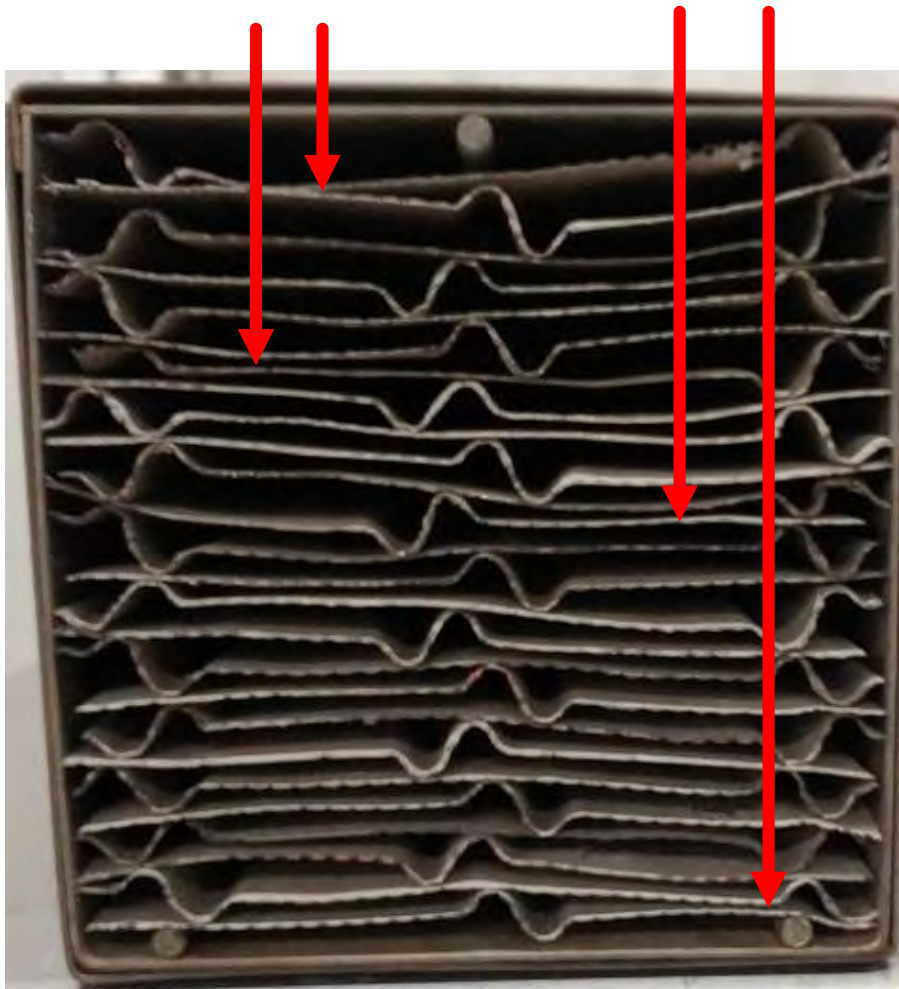


Catalyst Sample Prep: Plates

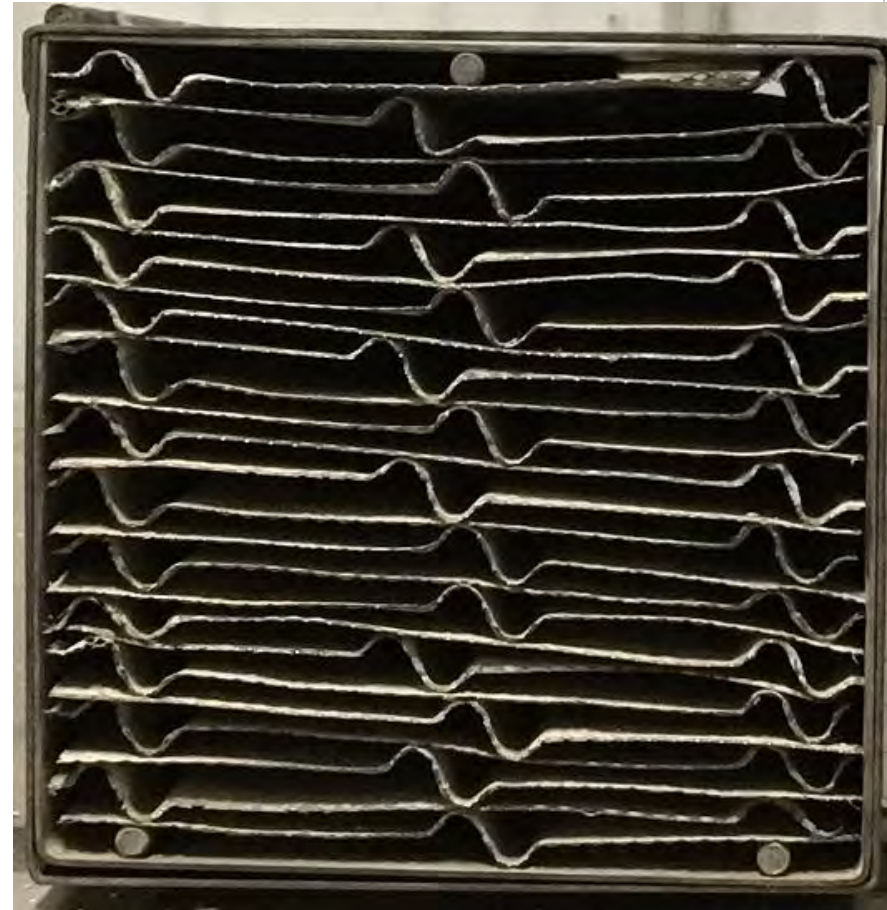
- ▶ 22-26 coupons required
 - ▶ 5.7 mm: 26 coupons
 - ▶ 7.0 mm: 22 coupons
- ▶ Test element closely matches full-scale
- ▶ Poor stacking, damaged plates impact results
 - ▶ Non-uniform flow
 - ▶ Unexposed surface area



Catalyst Sample Prep: Plates



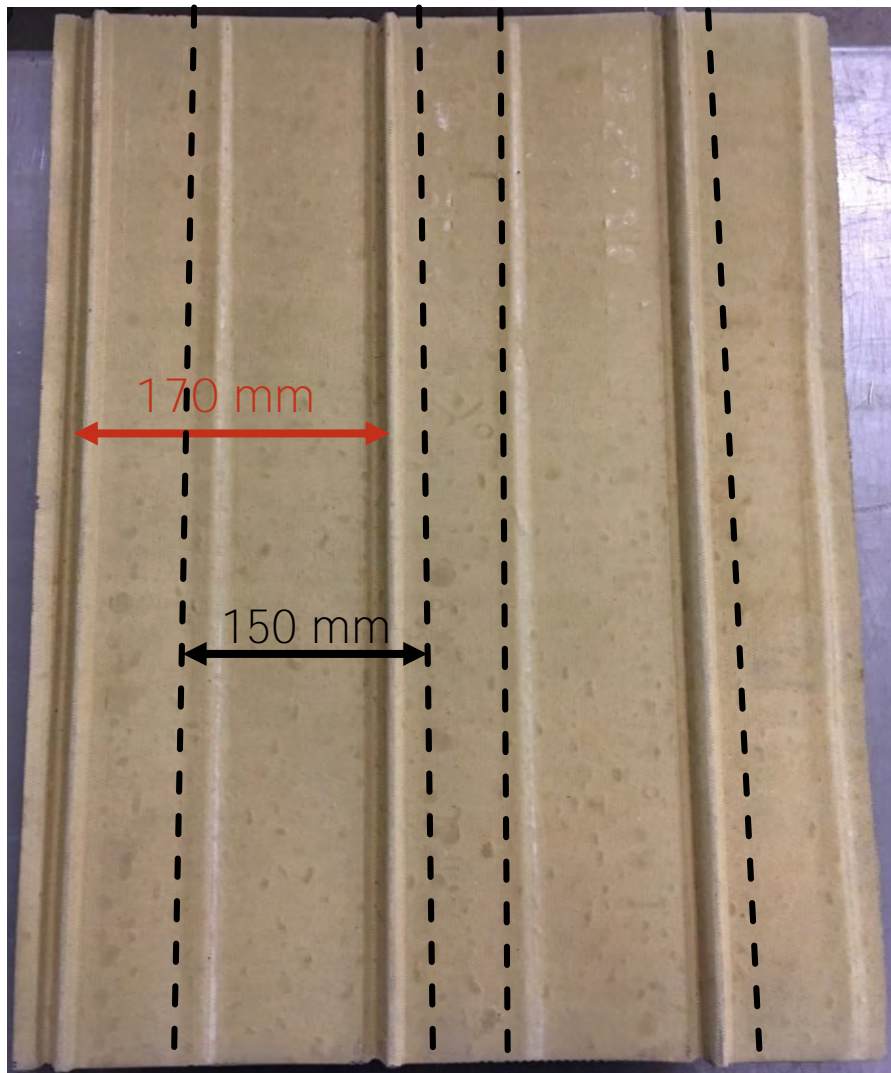
Initial Stacking



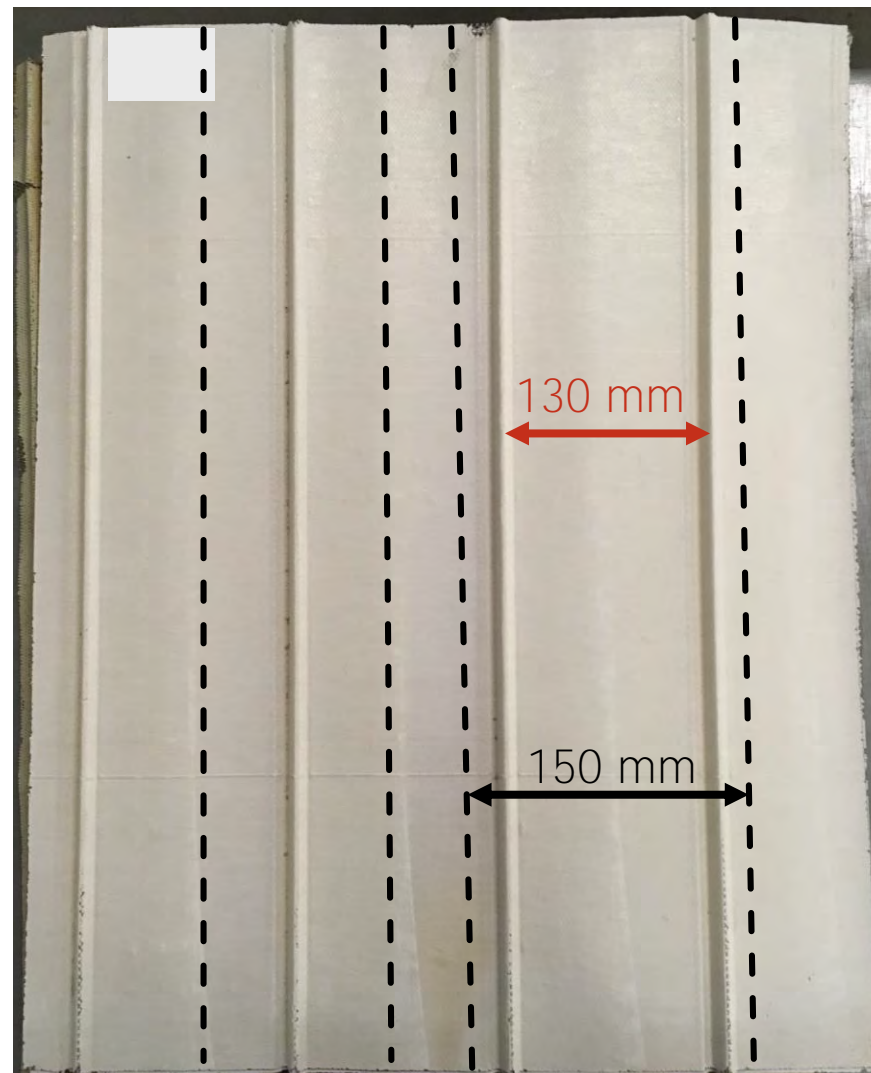
Restack

Catalyst Sample Prep: Plates

3-Notch Plate



4-Notch Plate



Catalyst Sample Prep: Plates

3-Notch Plate



4-Notch Plate



Catalyst Sample Prep: Plates

- ▶ Four-notch plates require additional considerations for stacking
- ▶ Must weigh importance of flow direction vs. notch orientation
 - ▶ Double amount of plates pulled
 - ▶ Ignore flow direction
- ▶ Not an issue with new material



Catalyst Sample Prep: Plates

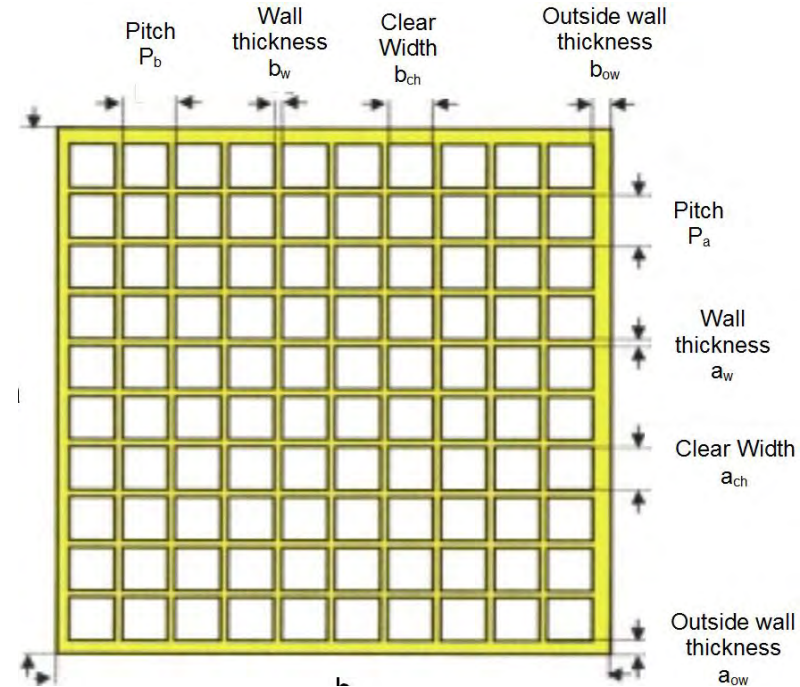


Catalyst Sample Prep: Plates



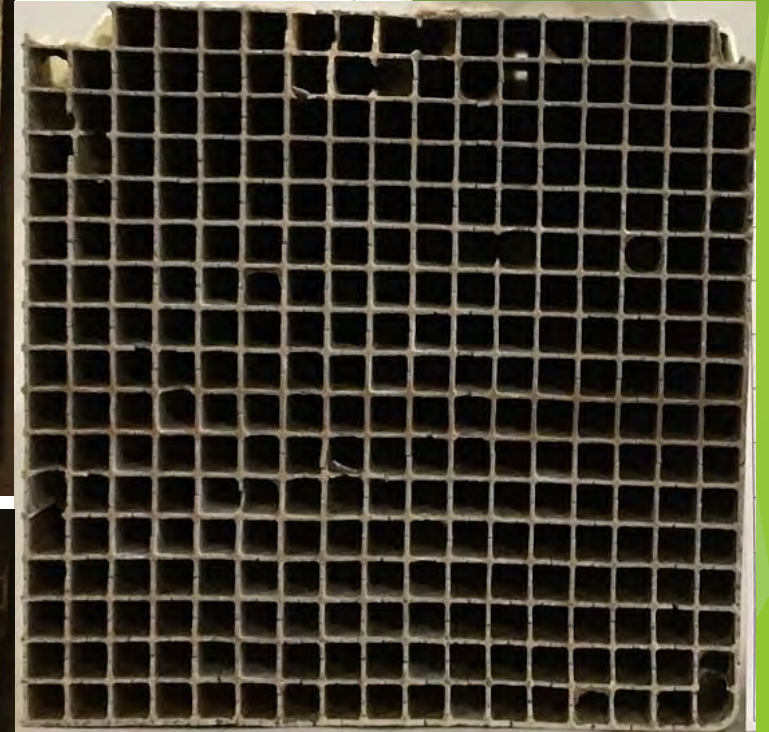
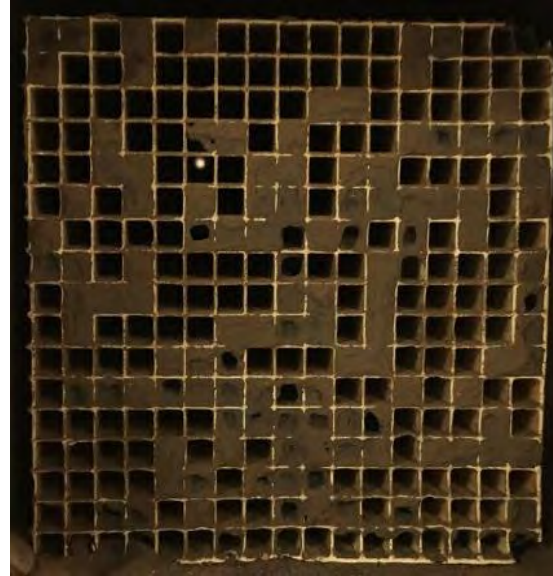
Catalyst Sample Prep: Honeycombs

- ▶ Test blocks installed in each layer
- ▶ Shaved on two sides
- ▶ Must be removed from metal casing for testing
 - ▶ Samples very brittle
 - ▶ Minimize shock
 - ▶ Ash caking makes removal difficult



Catalyst Sample Prep: Honeycombs

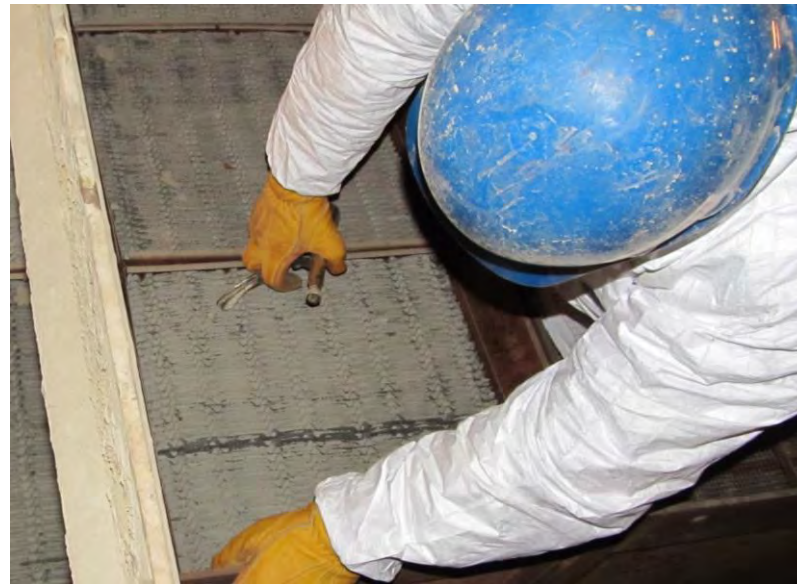
- ▶ Must clean sample to reduce plugging below 20%
 - ▶ Necessary to achieve desired channel velocity during testing
 - ▶ Plugging not just at catalyst face; within channels as well



Catalyst Sample Handling/Shipping: Plate Catalyst

Sampling Notes:

- ▶ Minimize damage to leading edges
- ▶ Avoid tearing/ripping material
 - ▶ Older/regenerated material more fragile
 - ▶ Discard if excessively damaged
- ▶ Immediately ID each plate
- ▶ Pull from randomly distributed modules
- ▶ Collect reference material before installation



Catalyst Sample Handling/Shipping: Plate Catalyst

Shipping Notes:

- ▶ Carrying material in garbage bags leads to bowing
- ▶ Protect material from damage/contamination
 - ▶ Wrap in plastic/bubble wrap
 - ▶ Avoid excessive stacking
 - ▶ Line up notches
- ▶ Select/construct right size crate/box
 - ▶ Pack with paper/bubble wrap

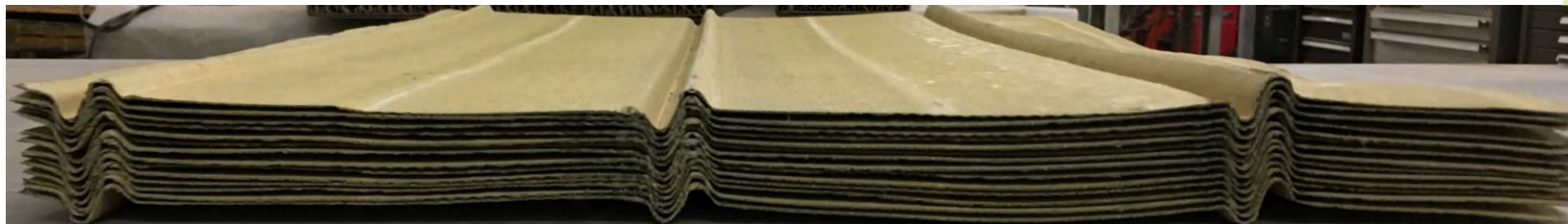


Catalyst Sample Handling/Shipping: Plate Catalyst

Notches Not Aligned



Notches Aligned



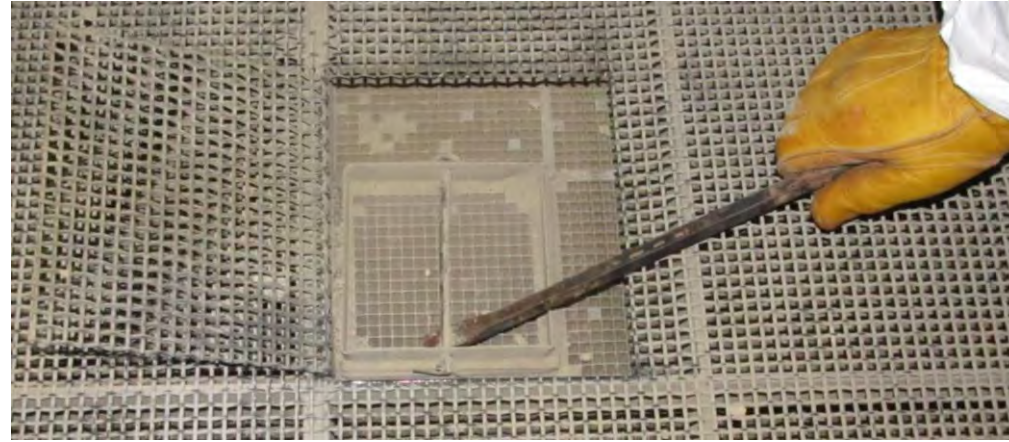
Catalyst Sample Handling/Shipping: Plate Catalyst



Catalyst Sample Handling/Shipping: Honeycomb Catalyst

Sampling Notes:

- ▶ Very fragile
- ▶ Avoid physical shock
- ▶ Select elements with minimal plugging
- ▶ Immediately ID element



Catalyst Sample Handling/Shipping: Honeycomb Catalyst

Shipping Notes:

- ▶ Less labor intensive
- ▶ Wrap elements in plastic
- ▶ Package in crate/box such that elements will not shift/fall
- ▶ Sheath vs. cuff



Catalyst Sample Handling/Shipping: Honeycomb Catalyst



Keys to Getting the Most from Bench-Scale Testing

1. Proper sample handling and shipping
2. Maintaining accurate data records
3. Sampling after operational changes
4. Testing baseline material
5. Test conditions = operating conditions

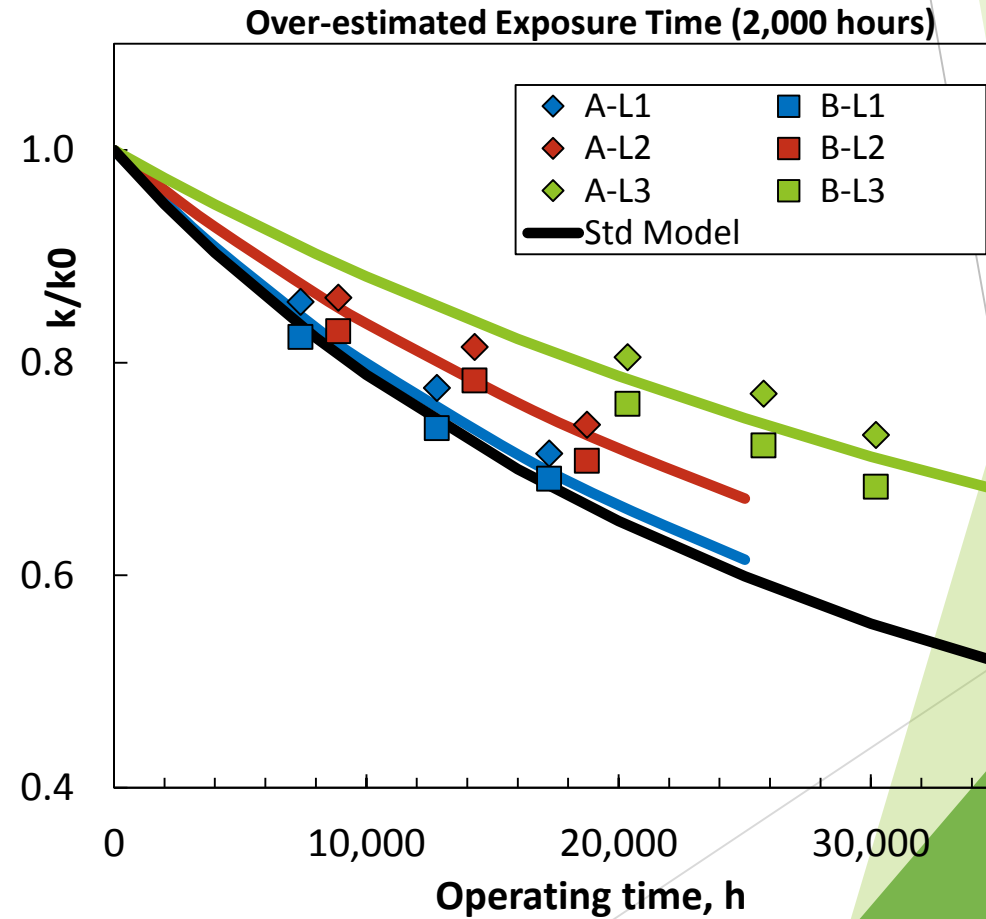
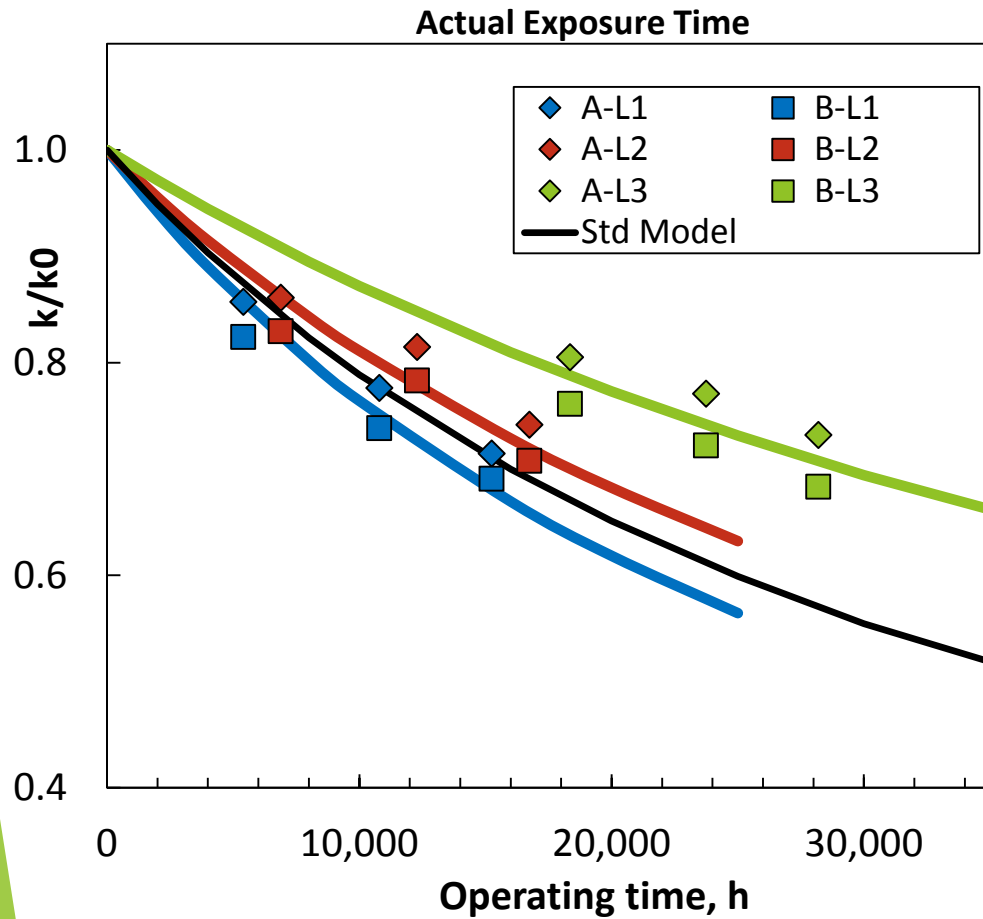


Value of Good Recordkeeping: Intro

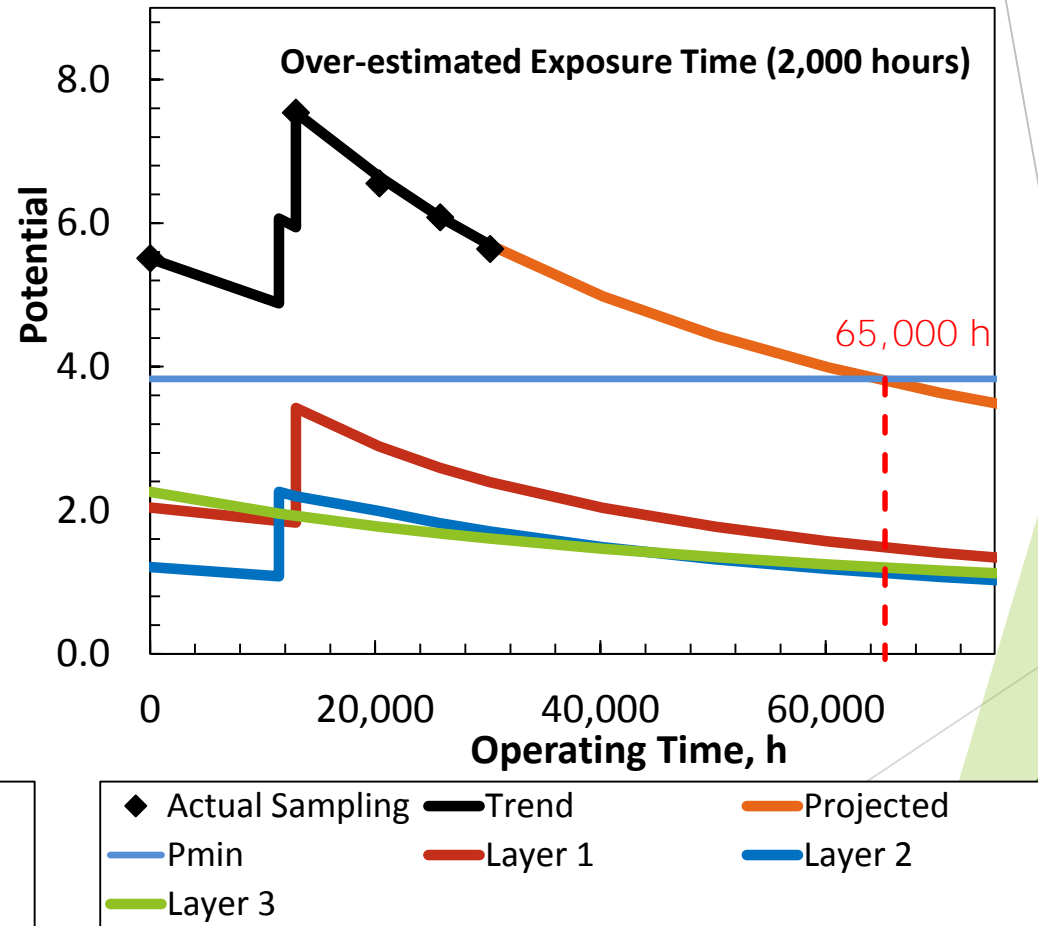
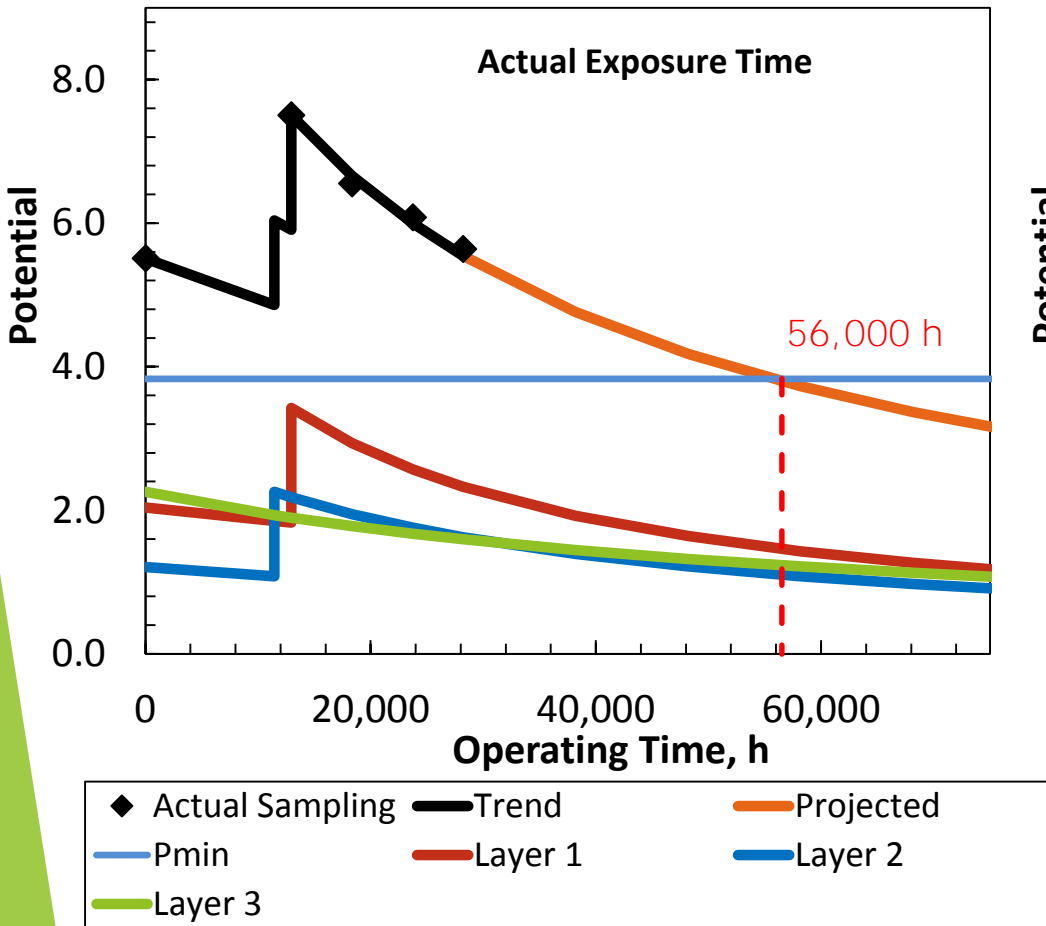
- ▶ Catalyst exposure hours
 - ▶ Date of install to sampling date
 - ▶ Consistent checkpoints each sampling
- ▶ Catalyst design parameters
- ▶ Reactor design vs. field tests
- ▶ Historical catalyst testing results



Value of Good Recordkeeping: Activity Trend (Over-estimate Time)

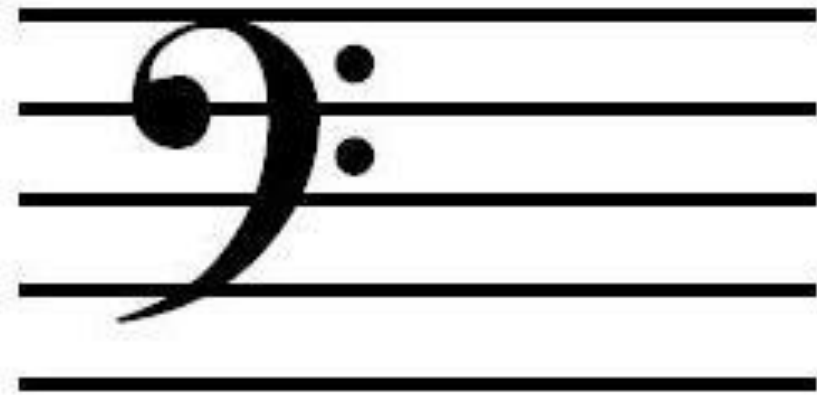


Value of Good Recordkeeping: Reactor Potential Trend (Over-estimate)

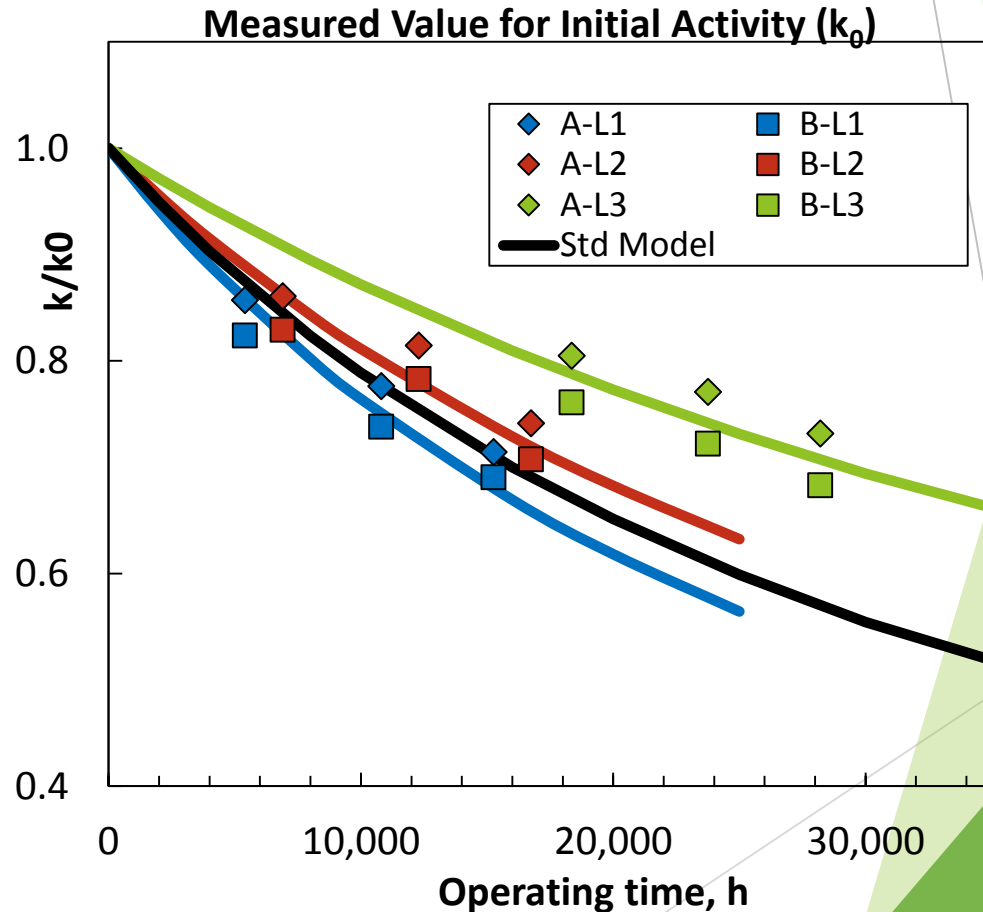
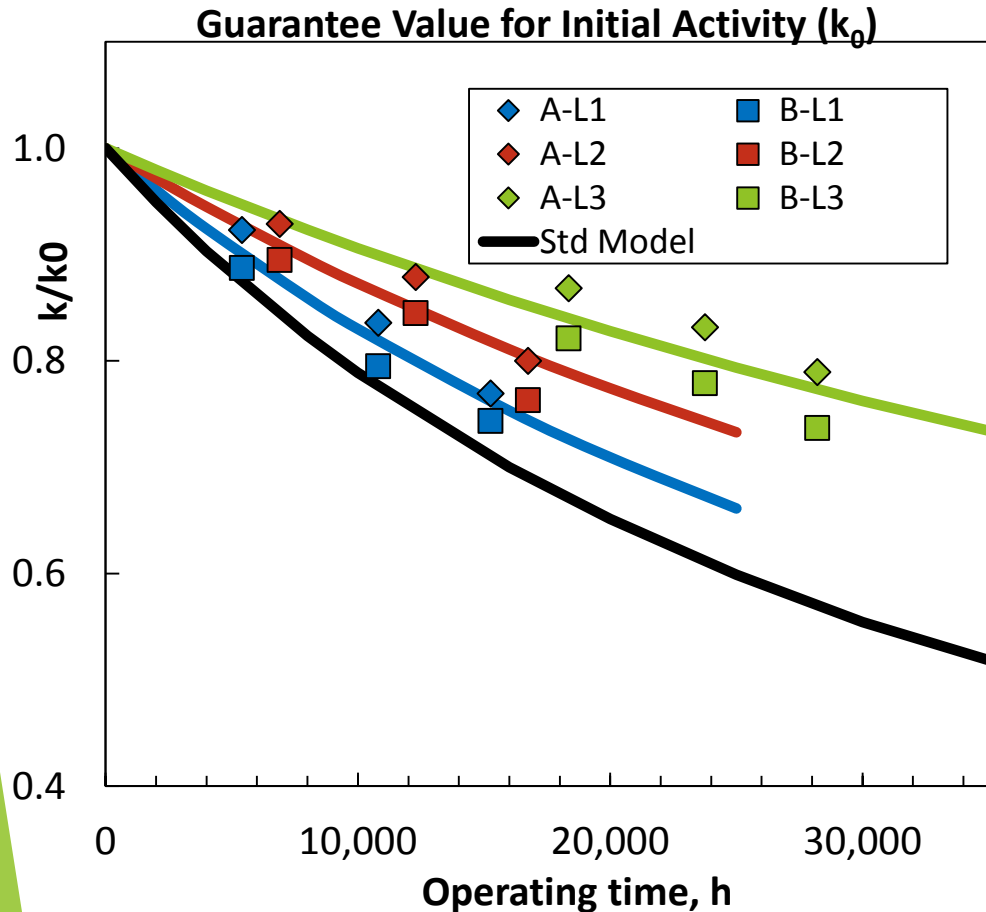


Importance of Baseline Testing: Intro

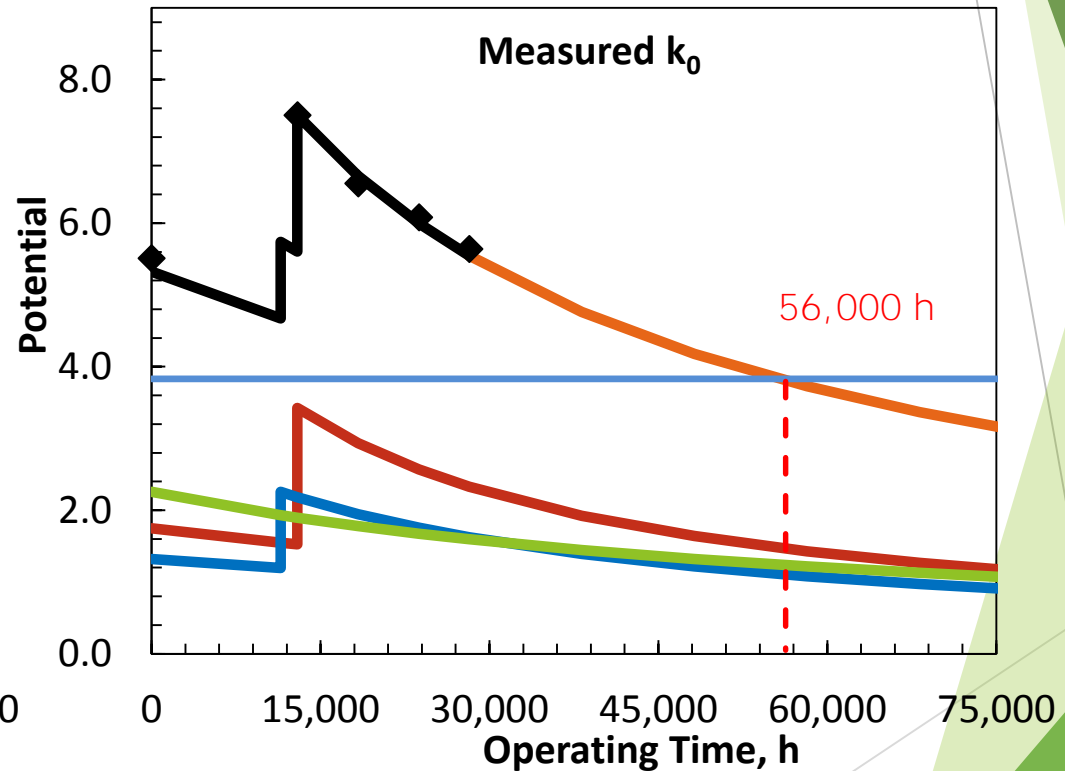
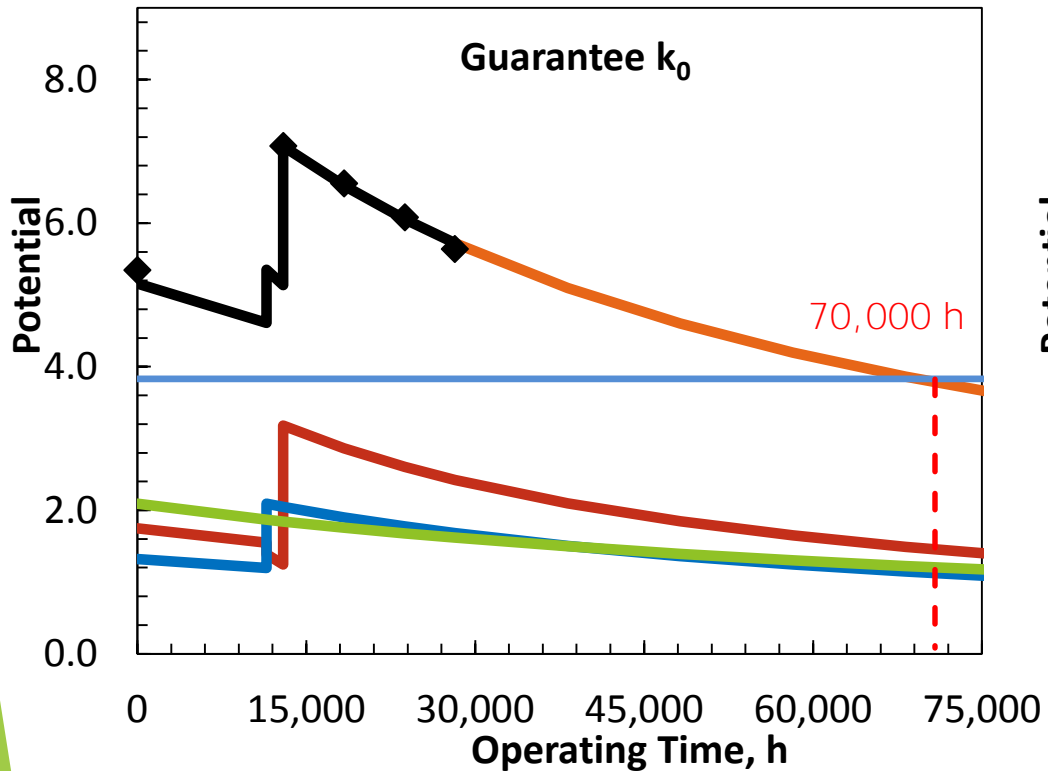
- ▶ Test new material for accurate baseline
- ▶ Initial activity guarantees can be underestimates
- ▶ Forgoing baseline testing potentially:
 - ▶ Underestimates deactivation rates
 - ▶ Overestimates remaining lifetime
- ▶ Multiple baseline tests more representative



Importance of Baseline Testing: Activity Trend



Importance of Baseline Testing: Reactor Potential Trend



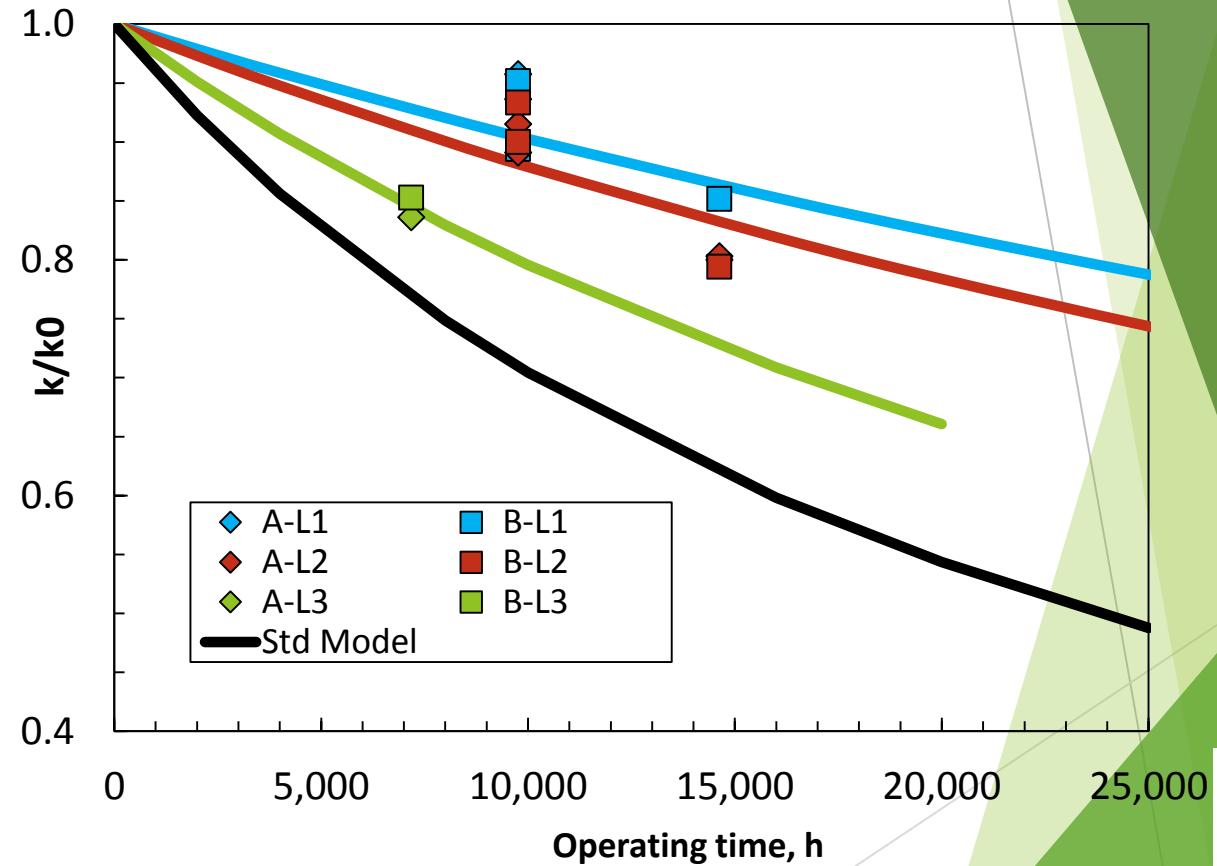
Southern Company Case Studies: Intro

- ▶ Prior to 2017:
 - ▶ All plans based on same general tool
 - ▶ Less emphasis on applying actual operating conditions
- ▶ Currently, more rigorous model:
 - ▶ Considers OIS data
 - ▶ Unique plans tailored to each plant
 - ▶ Can implement more aggressive catalyst management strategies
 - ▶ Significant savings by deferral of catalyst replacements and unit outages



Case Studies: Plant A

- ▶ Generation capacity: 818 MW
- ▶ PRB coal fired application
- ▶ Only units in Southern Co fleet utilizing SCRs on seasonal basis
 - ▶ Limited flue gas exposure on annual basis
 - ▶ Typically longer catalyst lifetime
 - ▶ Allows for more aggressive catalyst replacement strategies



Case Studies: Plant A

- ▶ Deactivation rates slower than standard trend
- ▶ Adjusting previous catalyst management plan deferred >\$2MM in cost between 2017-2020
- ▶ Regular catalyst testing ensures viability of more aggressive catalyst replacement plan

Description	Cost
New Catalyst Layer	\$1,556,749
Catalyst Removal	\$217,600
Catalyst Installation	\$272,000
Total Savings	\$2,046,349

- ▶ Four-year catalyst testing program = ~\$200,000
- ▶ ROI = ~1,000%

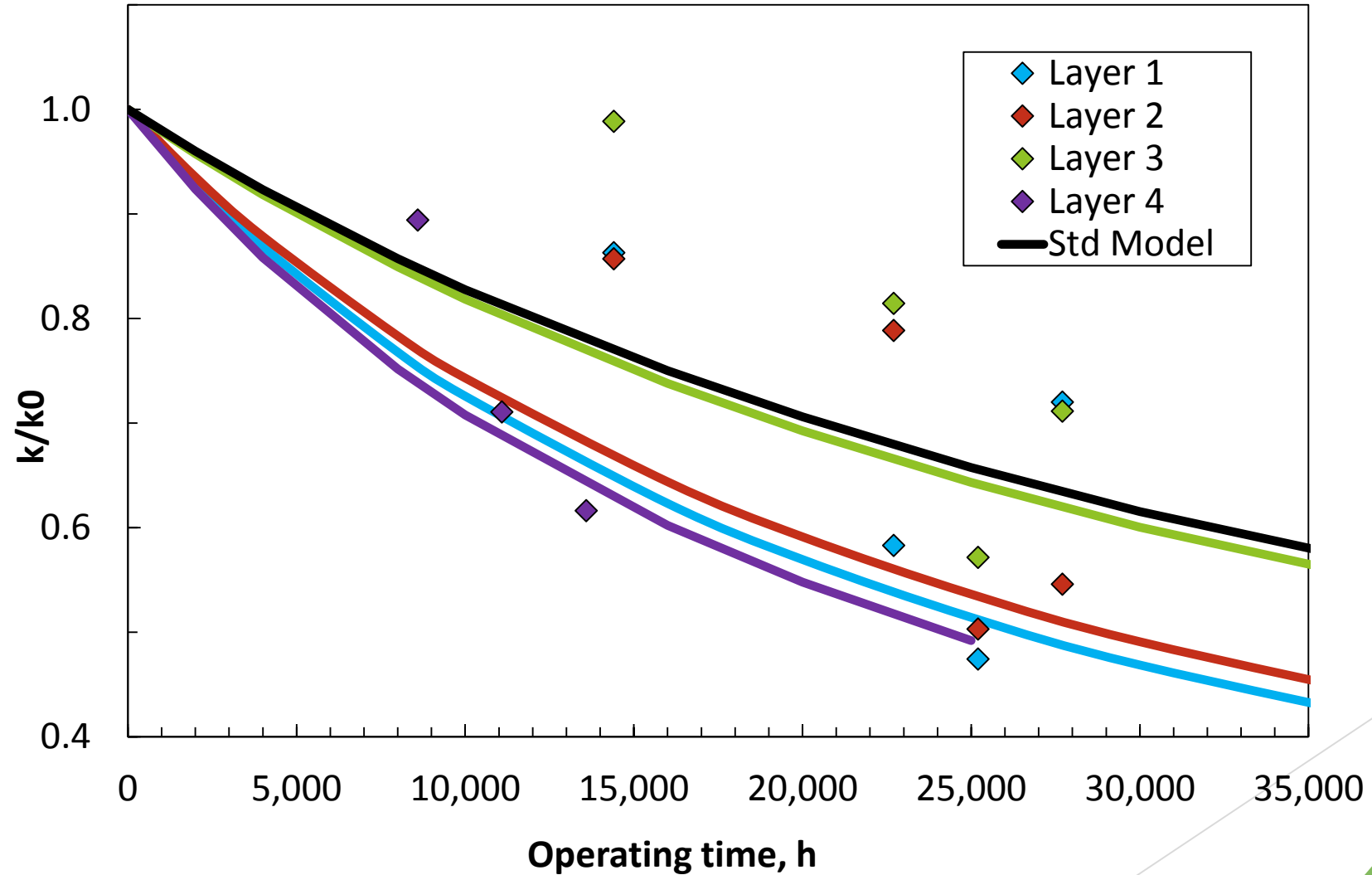


Case Studies: Plant B

- ▶ Generation capacity: 320 and 550 MW
- ▶ High-dust, bituminous coal-fired application
- ▶ In 2017, plant switched to cheaper coal with much higher arsenic content



Case Studies: Plant B



Summary

- ▶ Sample handling/prep can have significant impact on results
- ▶ Small inaccuracies impact analytical value of data
- ▶ Regular catalyst testing program allows for optimization of catalyst management plans
- ▶ Testing provides early diagnosis of impact on SCR function following operational change



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