REINHOLD ENVIRONMENTAL Ltd.

2013 NOx-Combustion Round Table & Expo Presentations

February 18 & 19, 2013, in Salt Lake City, UT / Hosted by PacifiCorp

Reinhold Environmental NOx Round Table
February 19, 2013

The Trials and Tribulations of SCR O&M

Presenters:
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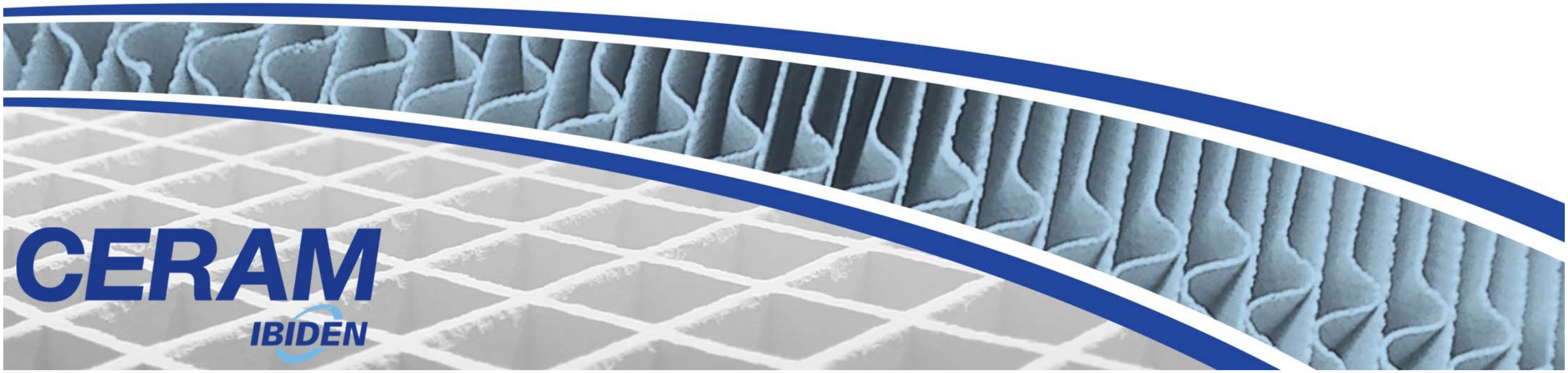


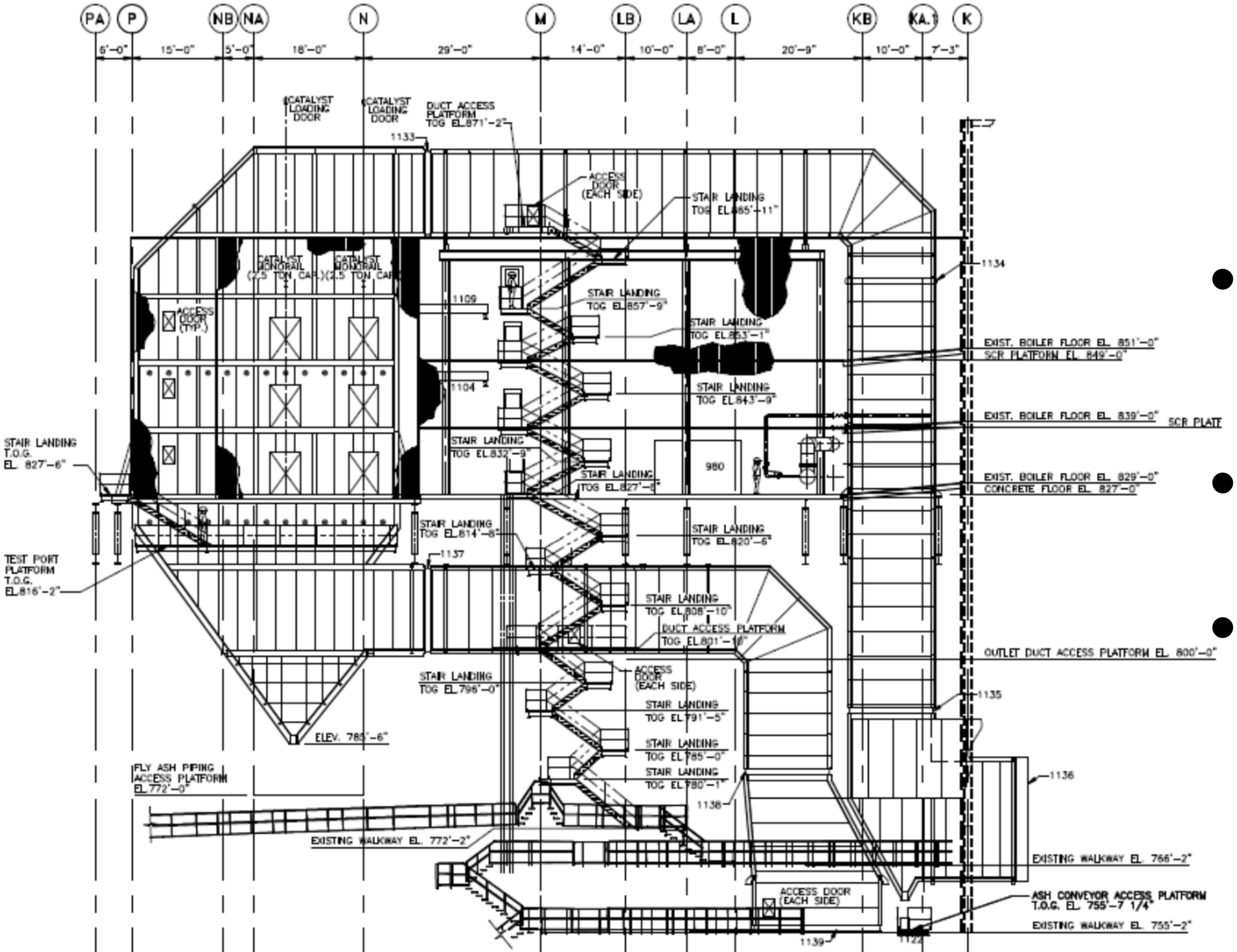
Presentation Topics

- Xcel Energy A.S. King Plant Case Example – by Noel Rosha
  - Unit and SCR Overview
  - DeNOx Demand and Reactor Potential
  - SCR Operations and Performance
  - Catalyst Management Planning Beyond Guarantee Life
- NIPSCO Bailly Unit 8 Case Example – by Greg Holscher
  - Unit and SCR Overview
  - Reactor Inspection Review
  - CFD Modeling Review
  - Affects of System Modifications to AIG Tuning
  - Summary

Xcel Energy A.S. King Unit 1

- 588 MW in service beginning 1968
- PRB coal fired
- B&W cyclone boiler
- 2004 – 2007 Rehabilitation Project
  - Steam turbine replacement
  - Steam generator overhaul
  - AQC additions
- SCR in service beginning 2007

A.S. King Unit 1 SCR Design



ELEVATION LOOKING NORTH

- B&W Cyclone Boiler
- High Dust SCR
- 2+1 Layer Arrangement

Original Catalyst Supply (By Others)

NOx Reduction	89% (0.74 to 0.08 lb/Mbtu)
SO_2 to SO_3 Conversion Rate	0.5% per Layer (1% for 2 Layers)
Honeycomb Catalyst Pitch	7.1 mm (21 x 21 cell)
Catalyst Length	1,315 mm
Module Arrangement per Layer	13 x 11
Design Catalyst Deactivation Rate	K/Ko = 0.73 after 24,000 hrs Equiv. K/Ko = 0.78 after 16,000 hrs

Xcel Energy King Plant SCR
Key Concerns

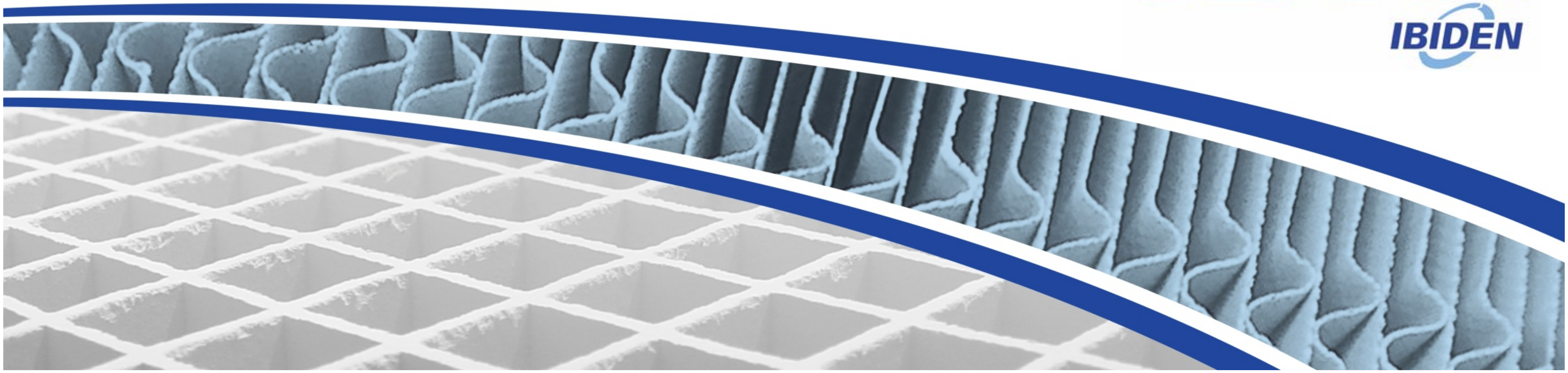
1) Aggressive Catalyst Design by Supplier
    - 7.1 mm Pitch Catalyst (Very Aggressive for PRB)
    - Aggressive Catalyst Deactivation Rate Assumption (0.73 K/Ko at 24,000 hr)
2) Small Pitch →→ 35% Catalyst Pluggage (5% Was Design)
3) Result was 2 Initial Catalyst Layers (2+1 Reactor)
    - Operates as 3+0 With More Frequent Changeouts
    - Proper Catalyst Design Would have Required a 4-Layer Reactor

1 + 2 + 3 = Very high ammonia slip and frequent catalyst changeouts

SCR Conditions as of 2010

- **NH_3 Slip of ~30 ppm** measured in June 2010 after ~20,000 hours
- Pluggage estimated to be >30%
- Emergency **summer 2010 outage** required to install the third layer of catalyst
- CERAM begins discussing catalyst management services with King Plant
- King Plant begins catalyst procurement to replace the existing top layer
- CERAM begins developing a catalyst management plan to achieve King's desired 2-year catalyst layer changeout cycle

DeNOx Demand and Reactor Potential



Reactor Potential

$$P = K/A\nu$$

P = Reactor Potential

K = Catalyst Activity, Nm^3/m^{2}h or Nm/h

Aν = Area Velocity, Nm/h
(normal gas flow, Nm^3/h divided by total installed catalyst surface area, m^2)

The Magnitude of Reactor Potential Determines the Amount of SCR System Performance Possible (DeNOx & Ammonia Slip Control)

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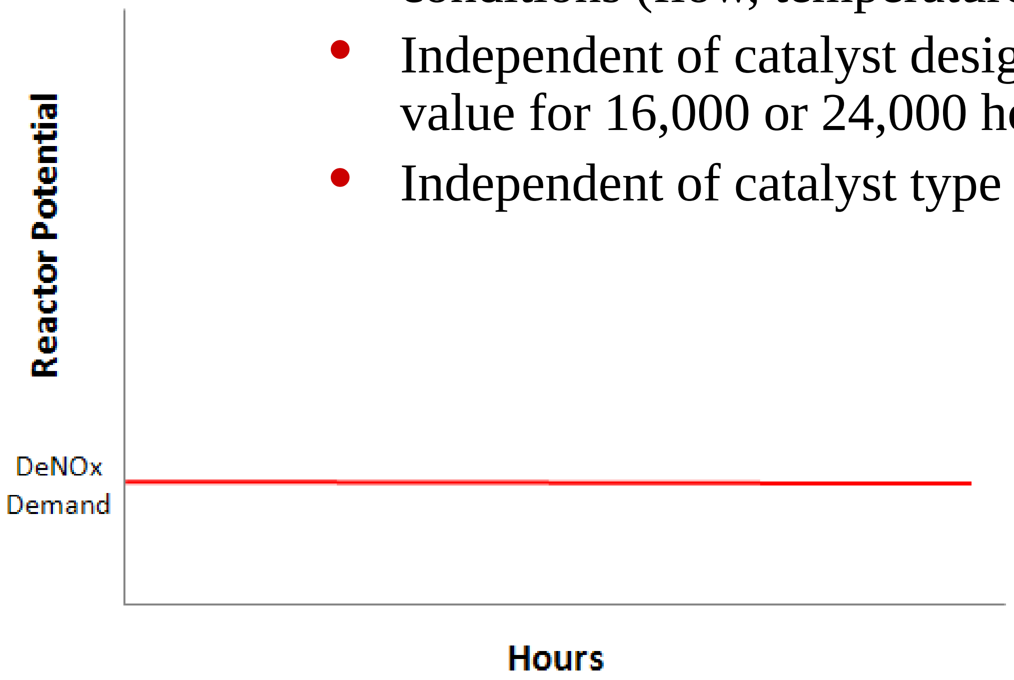
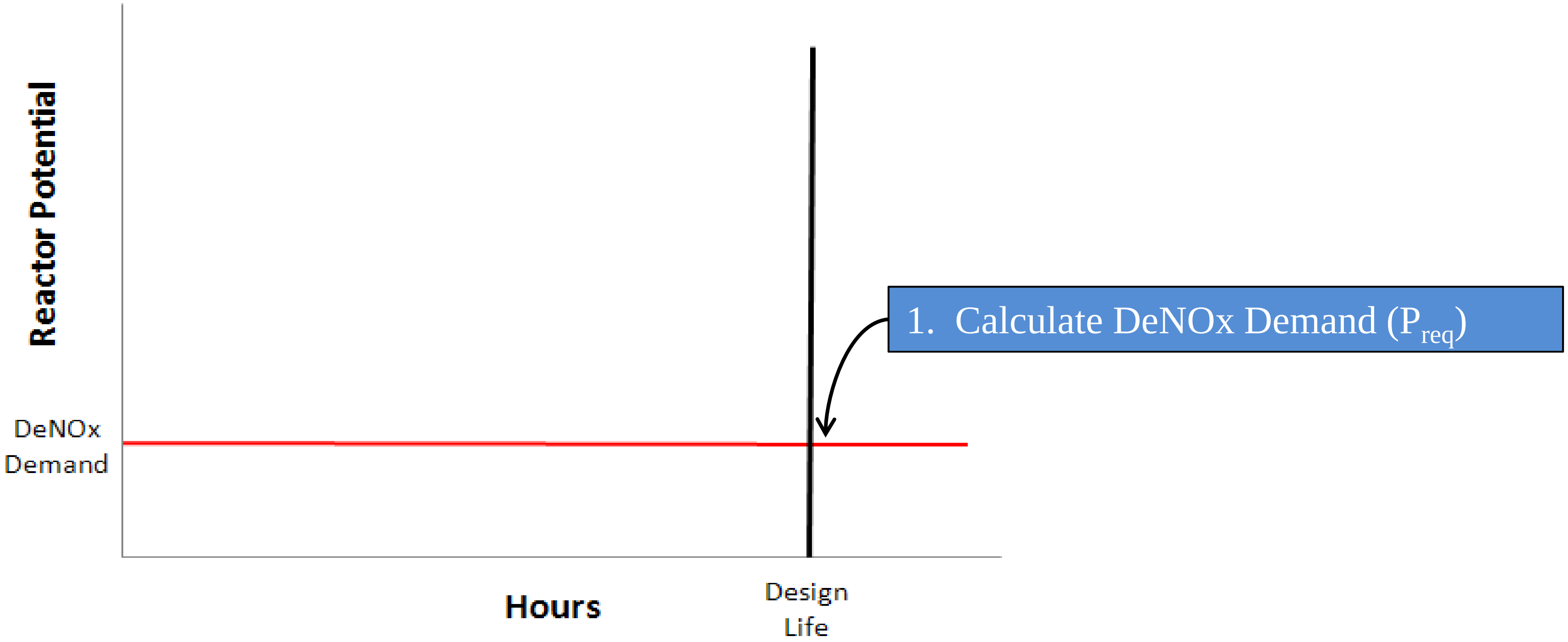
DeNOx Demand

- DeNOx Demand = The reactor potential required to meet NOx removal requirements at the specified operating conditions
- *Calculated* based on NO_X removal requirements, NH_3 slip, and boiler operating conditions (flow, temperature, pressure, etc.)
- Independent of catalyst design life (i.e. same value for 16,000 or 24,000 hour catalyst lifes)
- Independent of catalyst type or manufacturer



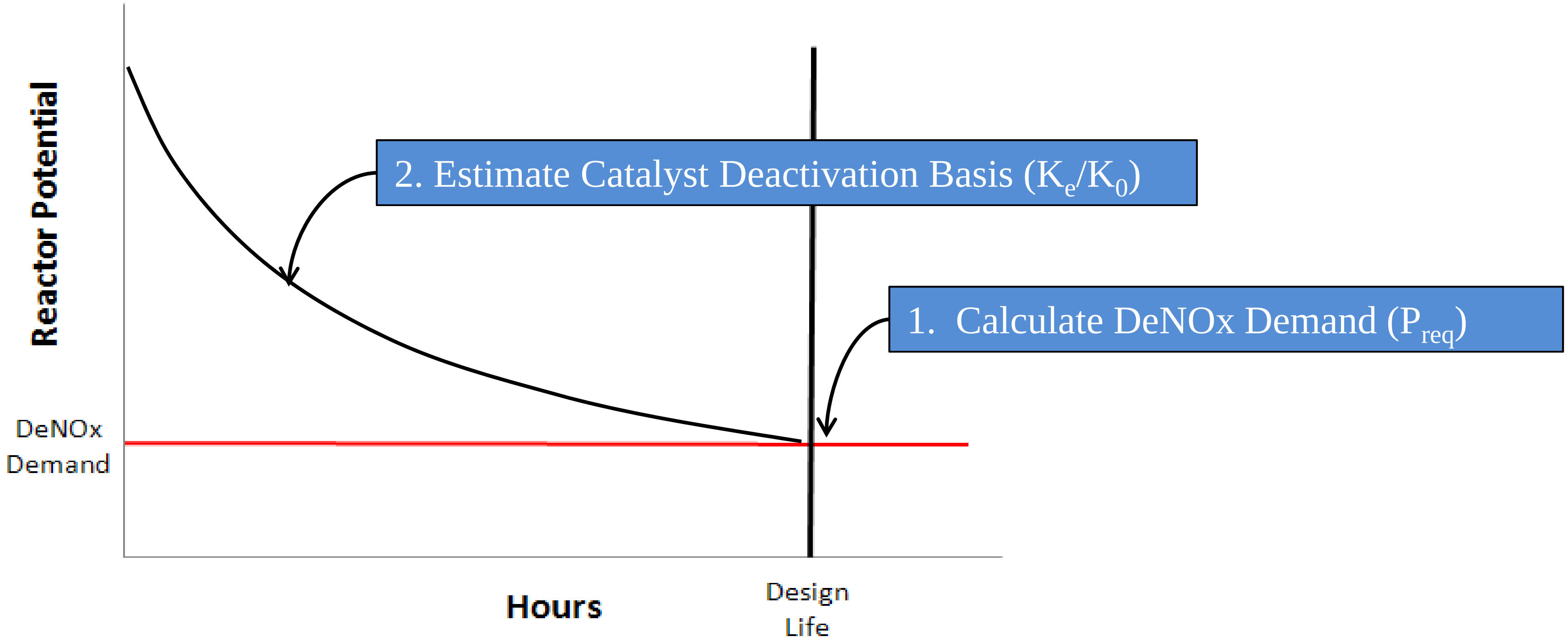
$$P_{req} = K_{req} / Av$$

Catalyst Design Process



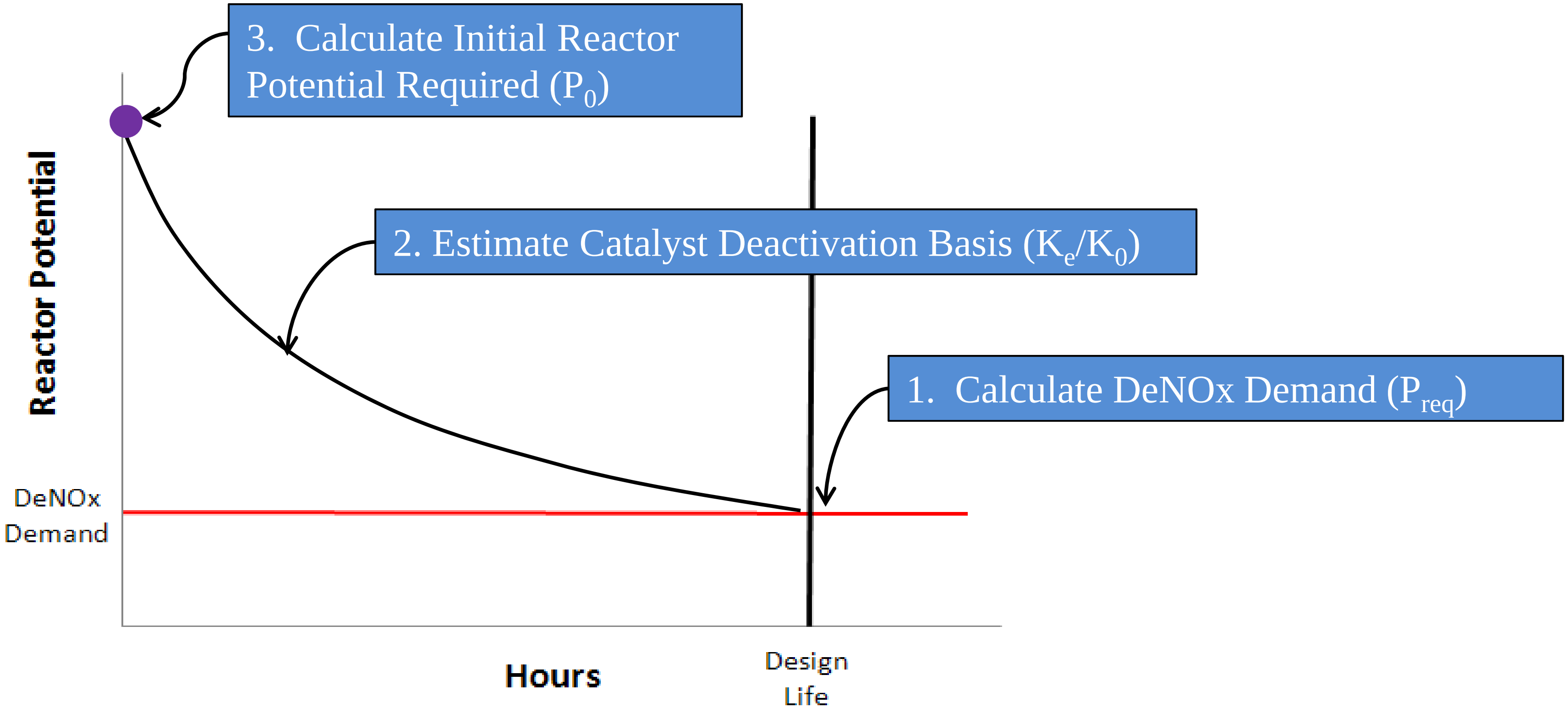
1. Calculate DeNOx demand (P_{req}) required

Catalyst Design Process



1. Calculate DeNOx demand (P_{req}) required
2. Estimate catalyst deactivation basis (K_e/K_0) based on fuel quality, combustion practices, unit duty, and design life

Catalyst Design Process



3. Calculate Initial Reactor Potential Required (P_0)

2. Estimate Catalyst Deactivation Basis (K_e/K_0)

1. Calculate DeNOx Demand (P_{req})

1. Calculate DeNOx demand (P_{req}) required
2. Estimate catalyst deactivation basis (K_e/K_0) based on fuel quality, combustion practices, unit duty, and design life
3. Calculate initial reactor potential [$P_0 = P_{req}/(K_e/K_0)$]

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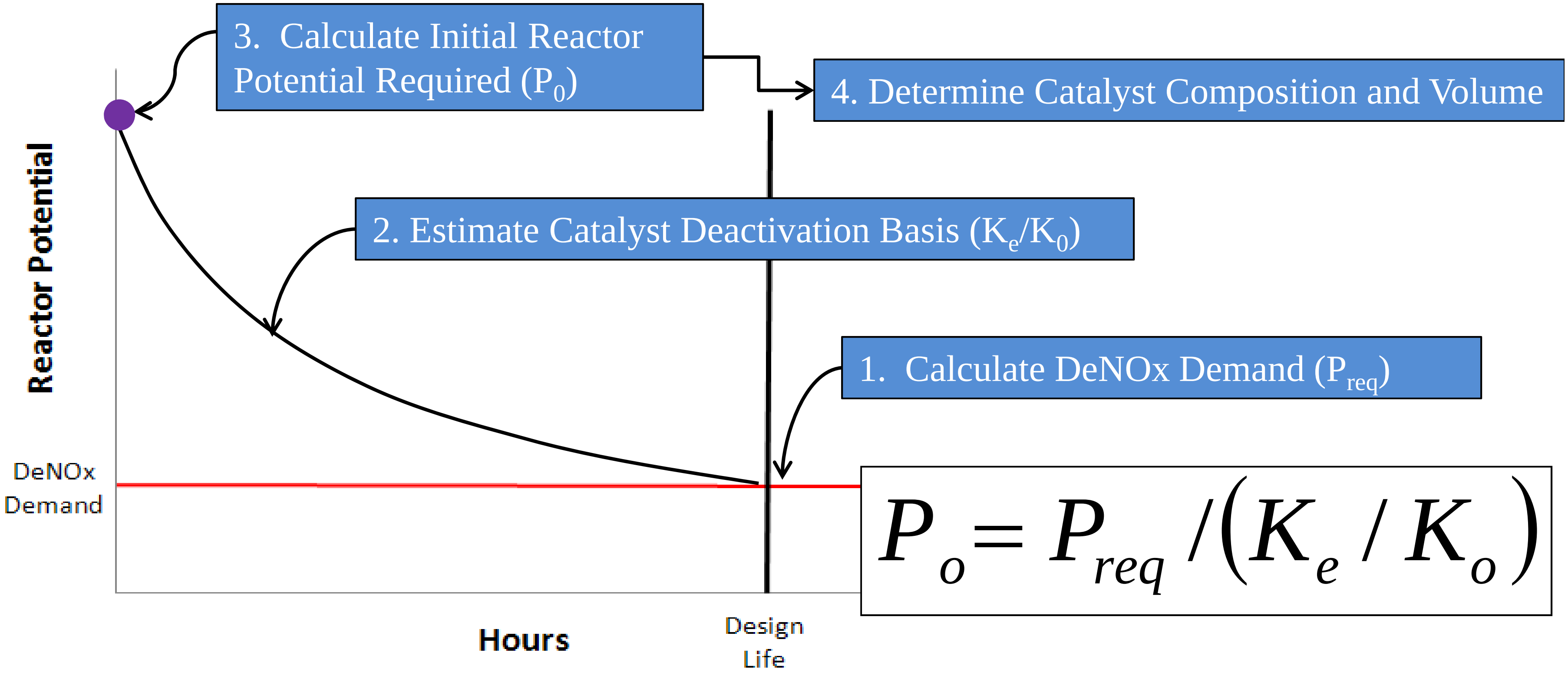
Catalyst Design Process



3. Calculate Initial Reactor Potential Required (P_0)

4. Determine Catalyst Composition and Volume

2. Estimate Catalyst Deactivation Basis (K_e/K_0)

1. Calculate DeNOx Demand (P_{req})

$$P_o = P_{req} / \left(K_e / K_o \right)$$

1. Calculate DeNOx demand (P_{req}) required
2. Estimate catalyst deactivation basis (K_e/K_0) based on fuel quality, combustion practices, unit duty, and design life
3. Calculate initial reactor potential [$P_0 = P_{req}/(K_e/K_0)$]
4. Catalyst volume determined based on P_0, SO2:3 conversion rate requirement, and catalyst geometry

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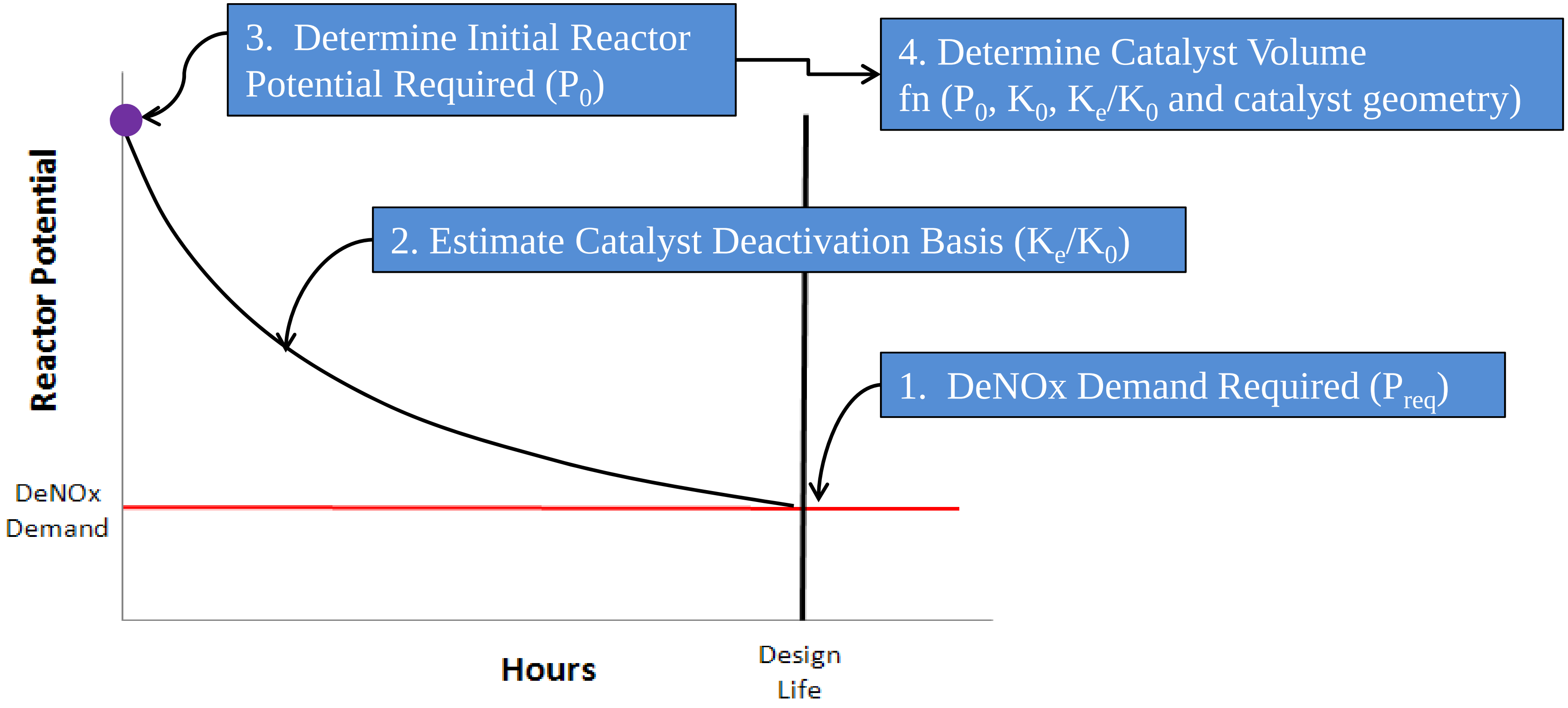
It is Essential That Initial Catalyst Design Consider a Reasonable Catalyst Deactivation Assumption



3. Determine Initial Reactor Potential Required (P_0)

4. Determine Catalyst Volume fn (P_0, K_0, K_e/K_0 and catalyst geometry)

2. Estimate Catalyst Deactivation Basis (K_e/K_0)

1. DeNOx Demand Required (P_{req})

- Examples Will Help Illustrate the Importance of the Catalyst Deactivation Rate Assumption

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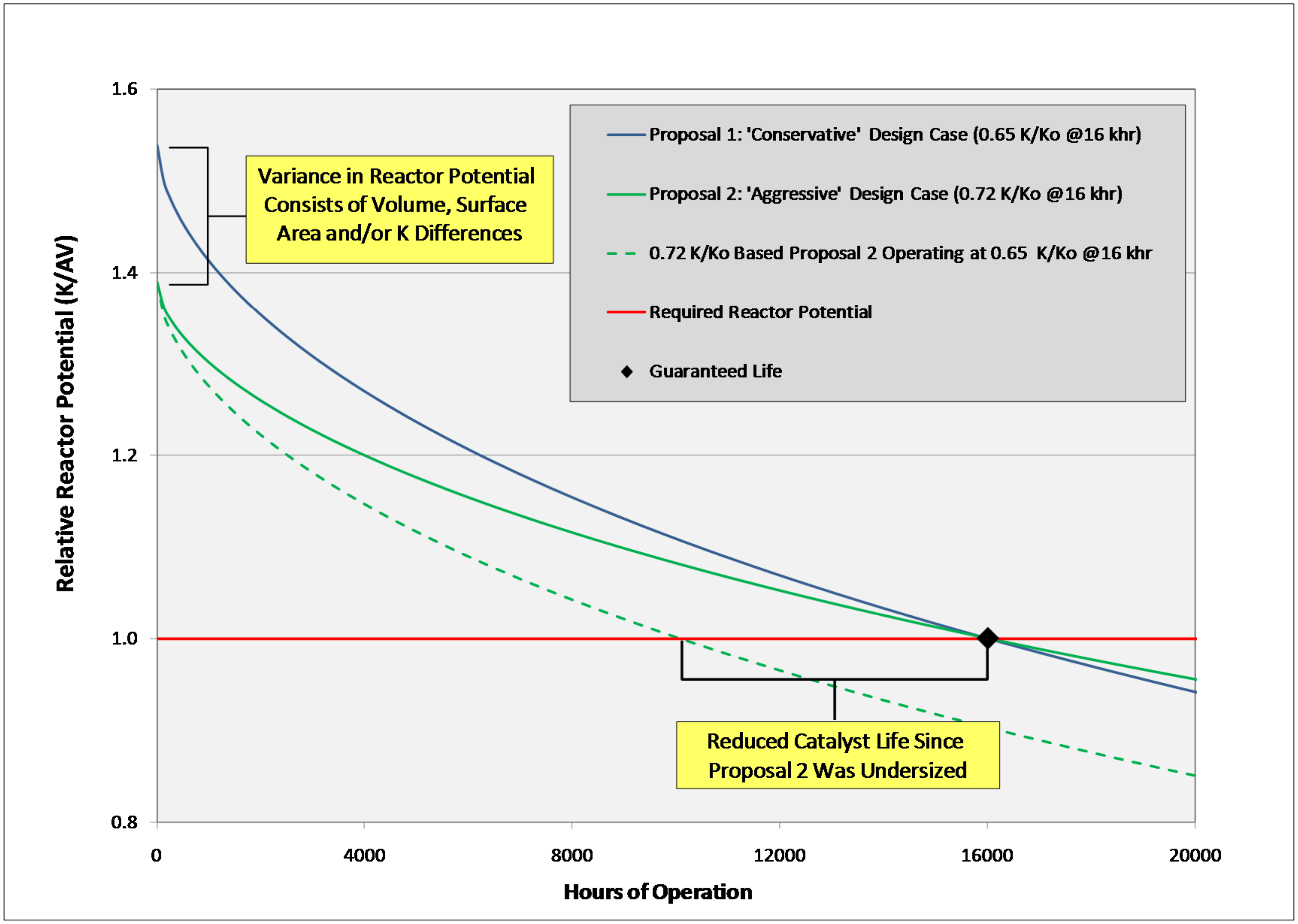
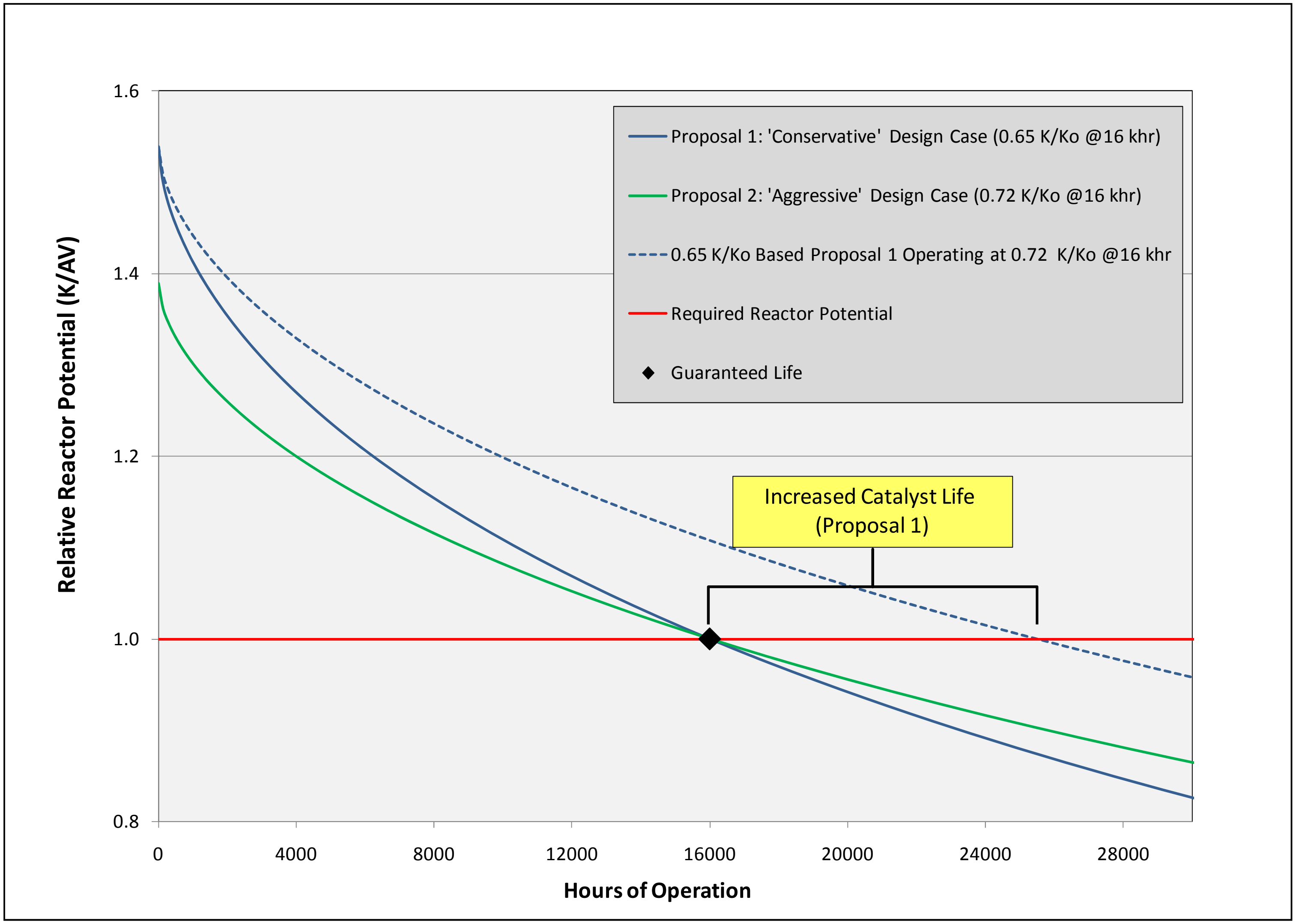
Catalyst Design Comparison – Case 1 High Deactivation



- A Catalyst Designed for a Deactivation Rate K/Ko =0.72 @16khr Will Require a Catalyst Addition at Approximately 11,000 Hours if a Deactivation Rate K/Ko = 0.65 Occurs (see dashed line above)

Catalyst Design Comparison – Case 2 Low Deactivation



- A Catalyst Designed for a Deactivation Rate K/Ko = 0.65 @16khr Will Not Require a Catalyst Addition Until Approximately 26,000 Hours if a Deactivation Rate K/Ko = 0.72 Occurs (see dashed line above)

A.S. King Unit 1

SCR Operations and Performance

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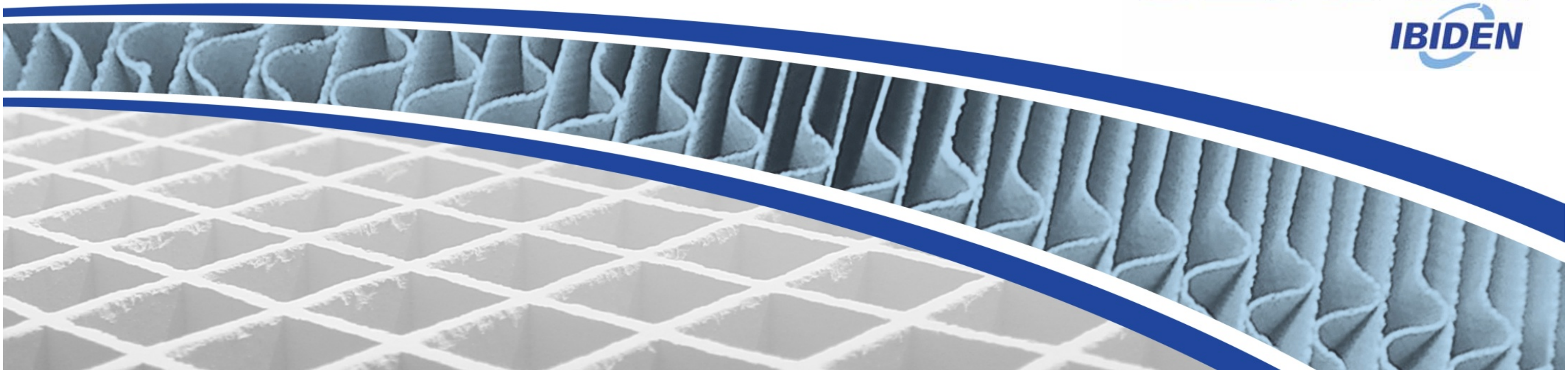
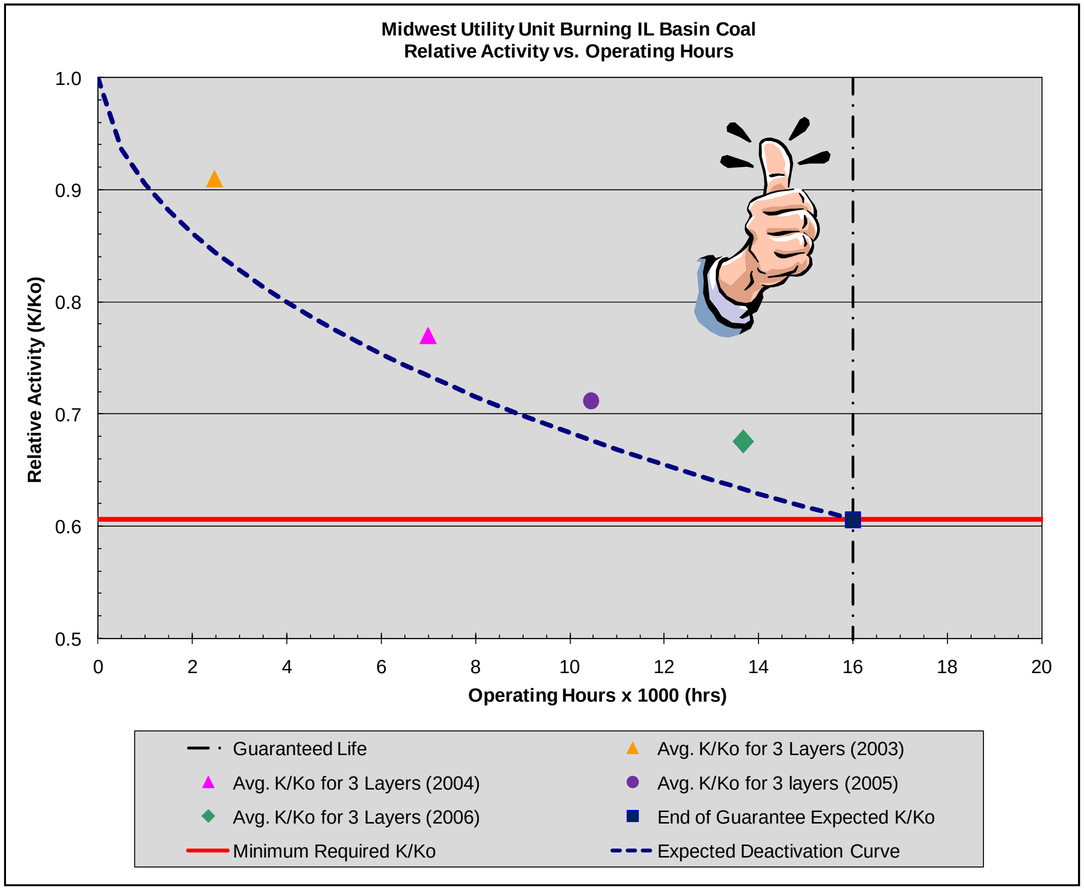


Traditional Catalyst Management

- Utility Pulls Test Elements
- Test Elements Sent to Laboratory
- Laboratory Tests Elements
- Laboratory Indicates if K/Ko is Above Original Sizing Basis
- Is This Catalyst Management Planning?

This Approach:

- Neglects Reactor Mechanical Condition
- Neglects SCR Operations Differences from Original Design/Specification Basis



Catalyst Testing is Only One Part of Effective Catalyst Management

Activity	**Objectives**
AIG Checks and Tuning	Optimize NH_3/NOx Distribution (Check/Tune Annually)
Monitor Ammonia in Ash	Test Frequently and Track Ammonia Slip Trends
Operations Data Assessment	Evaluate DeNOx Demand (NOx, T, Flow, Delta P, etc.)
Monitor Fuels Data	Evaluate Possible Effects on Catalyst
Reactor Inspections	Assess Pluggage and Mechanical Condition
Catalyst Testing	Assess Current Activity Levels and Deactivation Trends
Catalyst Management Planning	Evaluate Near Term SCR System Performance Capabilities
	Predict Next Need for Catalyst Addition
	Evaluate Options for Catalyst Addition (New vs Regen, etc.)

CERAM's Manage CATLife® Model Integrates All Considerations and Results to Assure Effective Catalyst Management Plan

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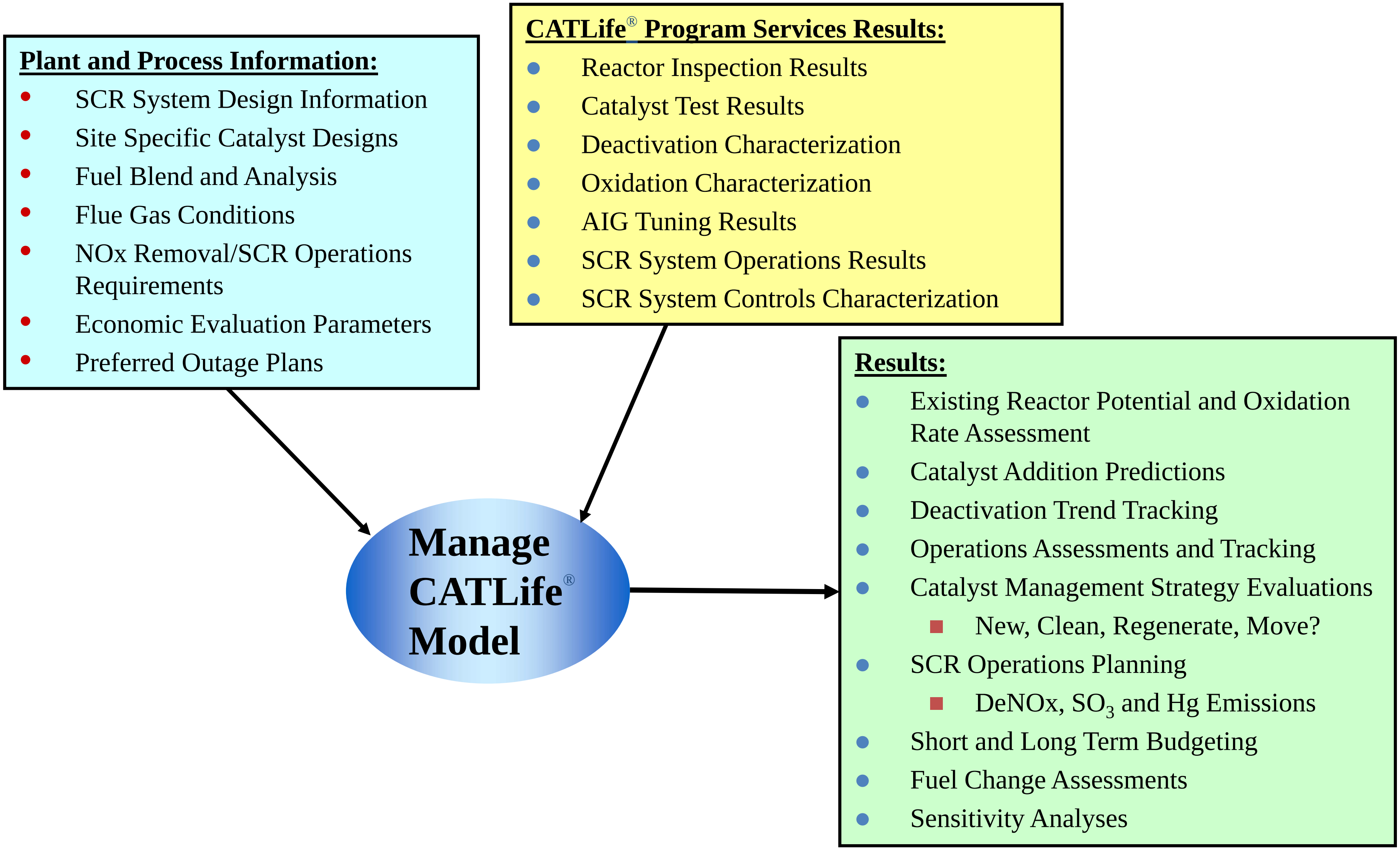
CERAM's Manage CATLife® Model



Plant and Process Information:

- SCR System Design Information
- Site Specific Catalyst Designs
- Fuel Blend and Analysis
- Flue Gas Conditions
- NOx Removal/SCR Operations Requirements
- Economic Evaluation Parameters
- Preferred Outage Plans

CATLife® Program Services Results:

- Reactor Inspection Results
- Catalyst Test Results
- Deactivation Characterization
- Oxidation Characterization
- AIG Tuning Results
- SCR System Operations Results
- SCR System Controls Characterization

Manage CATLife® Model

Results:

- Existing Reactor Potential and Oxidation Rate Assessment
- Catalyst Addition Predictions
- Deactivation Trend Tracking
- Operations Assessments and Tracking
- Catalyst Management Strategy Evaluations
  - New, Clean, Regenerate, Move?
- SCR Operations Planning
  - DeNOx, SO_3 and Hg Emissions
- Short and Long Term Budgeting
- Fuel Change Assessments
- Sensitivity Analyses

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CERAM's 20+ Years of SCR System and Catalyst Know How and Experience is Incorporated Into the Model

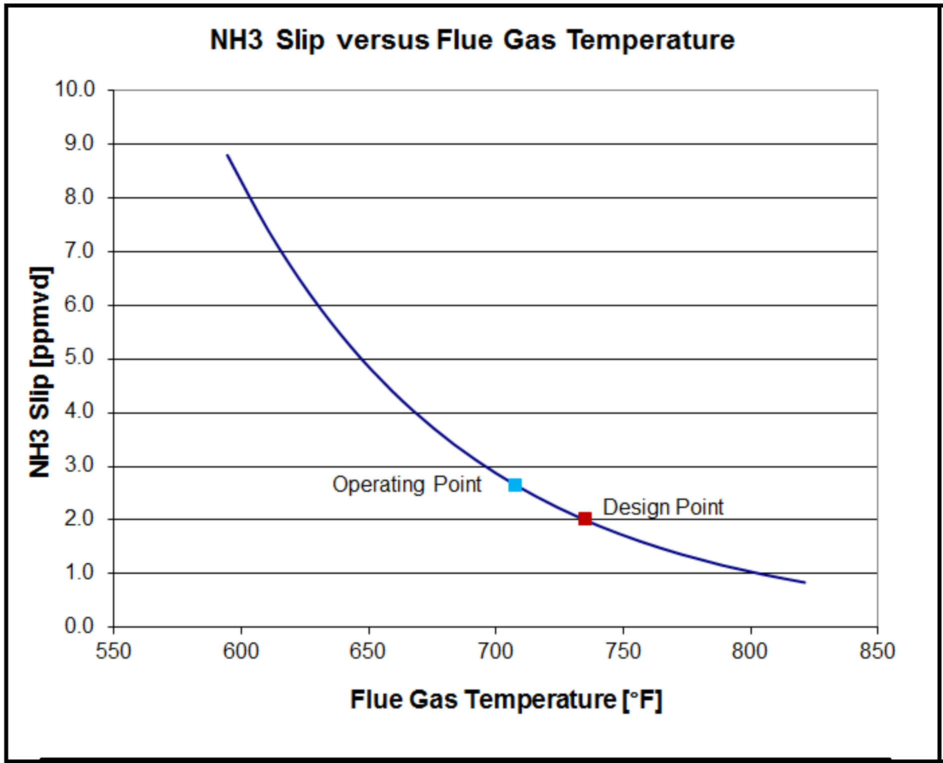
CERAM Working with King Plant

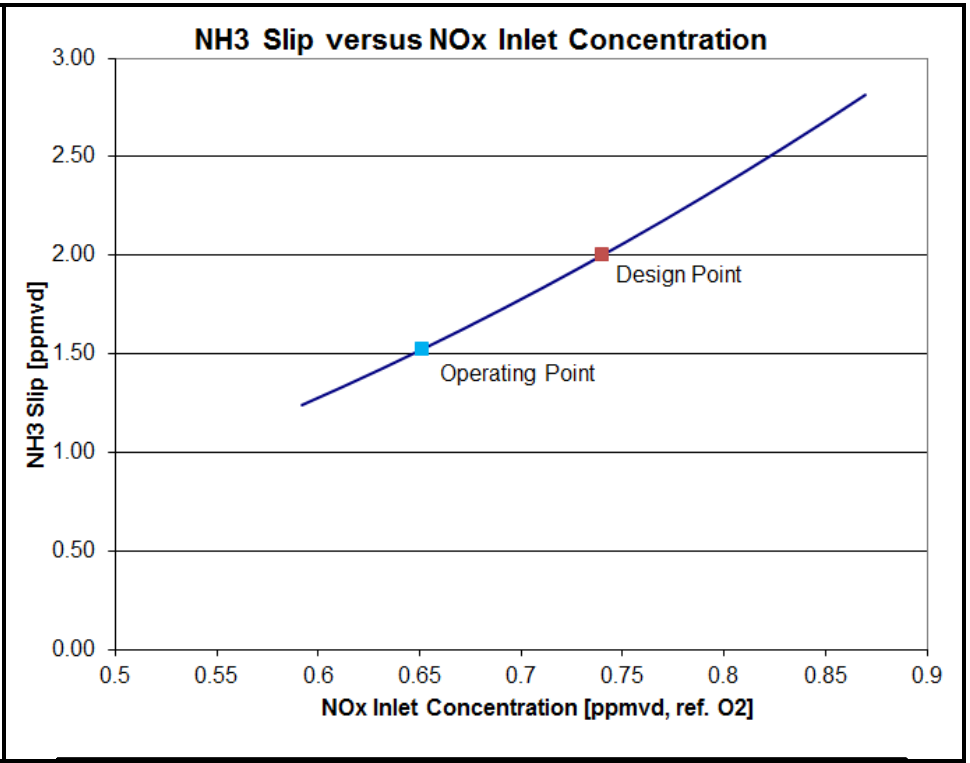
- **Develop Long Term Catalyst Management Plan to Fit Desired Outage Schedule**
  - **Replace One Layer Every 2 Years**
- Transition to Larger Catalyst Pitch
  - 8.2 mm CERAM replaced original 7.1 mm first layer in Spring 2011
  - 7.4 mm CERAM replaced original 7.1 mm second layer in Spring 2012
- Future 2 Year Replacement Cycle Achievable

King Plant
SCR Design Basis vs. Actual Operations

	Original Design Basis	**2011 Operating Data Basis**
Inlet NOx	**0.74 lb/MBtu**	**0.65 lb/Mbtu**
Outlet NOx	0.08 lb/Mbtu	0.08 lb/MBtu
Ammonia Slip	2.0 ppm	>2.0 ppm
Flue Gas Temperature	**735° F**	**705° F**
Catalyst Life	24,000	**Future Catalyst Events Occur Every 2 Years**

Effects of Temperature and Inlet NOx





Reduced Temperature →
0.65 ppm NH_3 Slip Increase

Reduced Inlet NOx →
0.48 ppm NH_3 Slip Decrease

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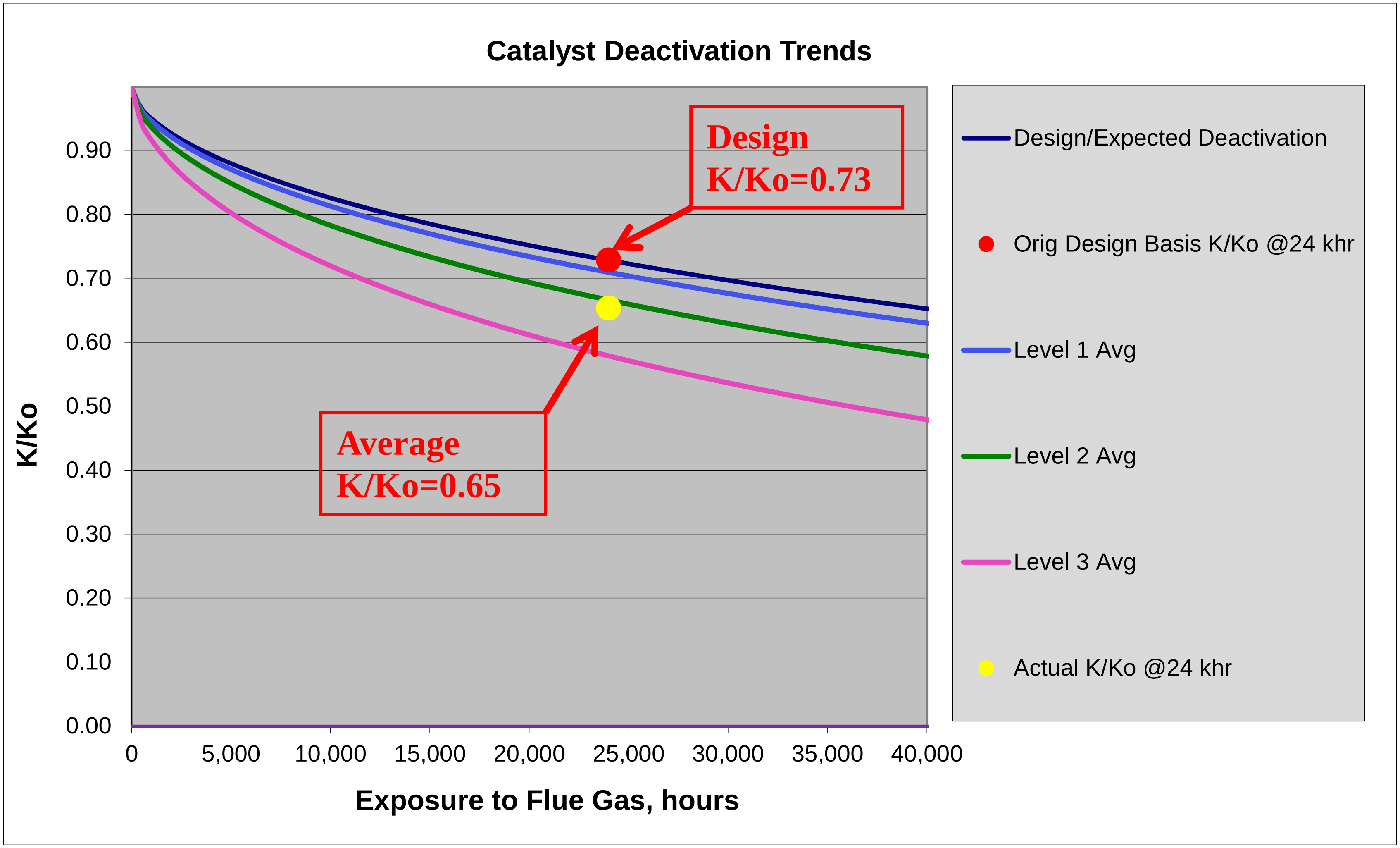
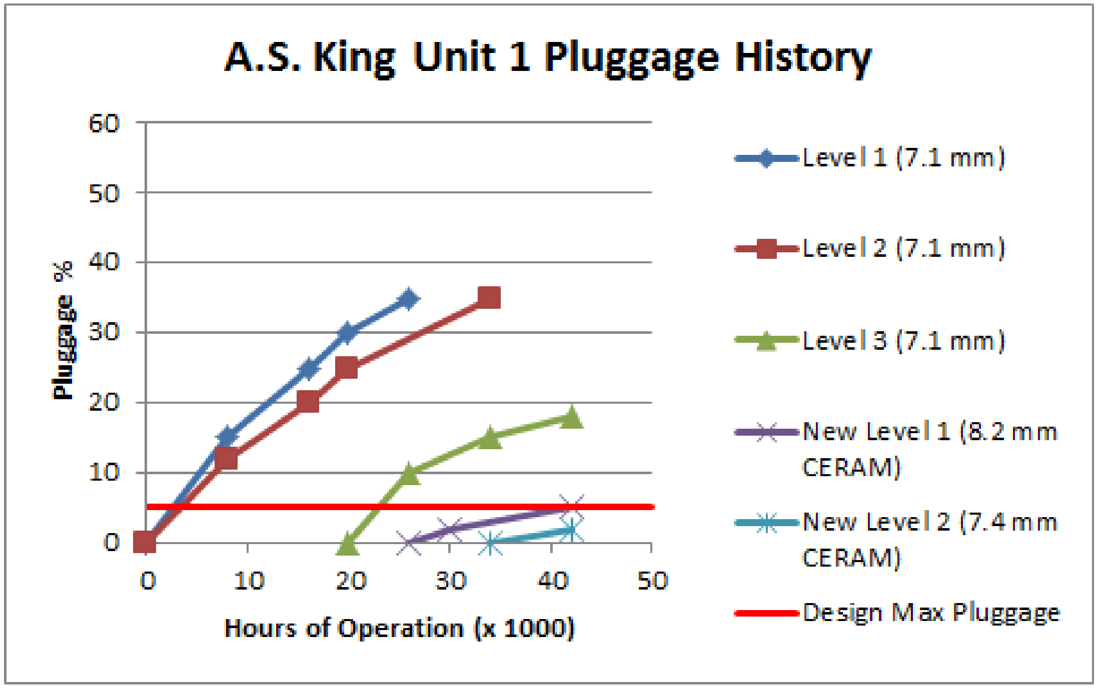
King Plant Catalyst Deactivation Rate

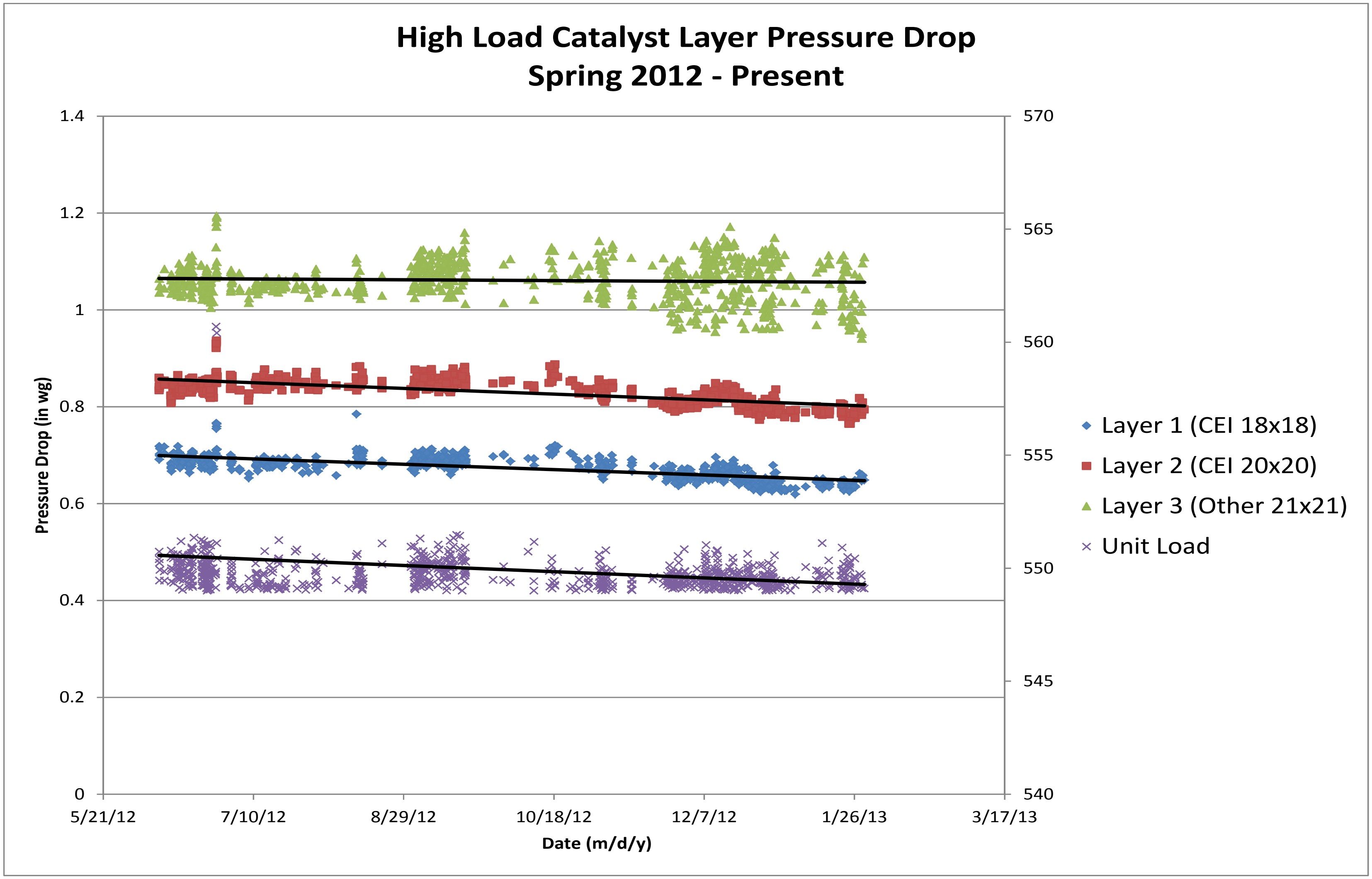


King Plant Catalyst Pluggage History

- 5% Design Pluggage
- 7.1 mm Pitch
  - >35% plugage in 1st and 2nd levels
  - >15% pluggage in 3rd level
- 8.2 mm Pitch CERAM
  - Installed in 1st level Spring 2011
  - <5% pluggage after 2 years
- 7.4 mm Pitch CERAM
  - Installed in 2nd level Spring 2012
  - <5% pluggage after 1 year



Catalyst Pluggage Trends



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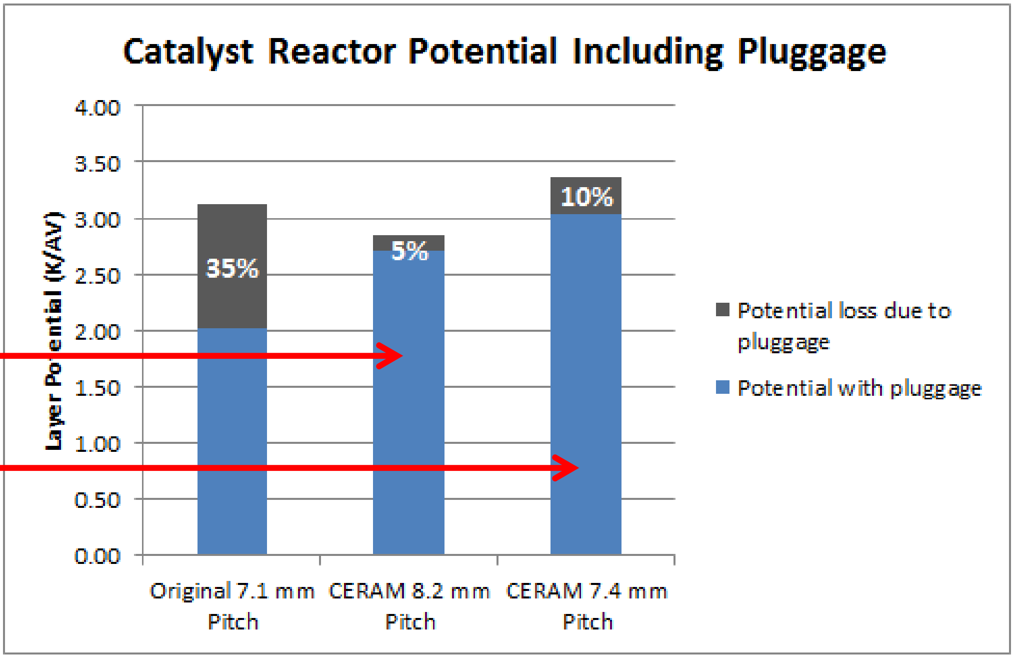
Proper Catalyst Selection – Geometry and Chemistry

- Catalyst Pitch Selection
  - We know 7.1 mm honeycomb is not the answer
  - Transitioning to larger pitch – reduced surface area must be offset by reduction in catalyst pluggage
  - 8.2 mm pitch has 16% less specific surface area compared to 7.1 mm
  - 7.4 mm pitch has 7% less specific surface area compared to 7.1 mm
- Catalyst Chemistry Selection
  - Existing catalyst is 0.5% $SO_{2/3}$ conversion rate per layer
  - Increasing the $SO_{2/3}$ conversion to 1.0% per layer will increase activity by approximately 10%



34% More Potential

49% More Potential

A.S. King Unit 1

Catalyst Management Plan Comparison

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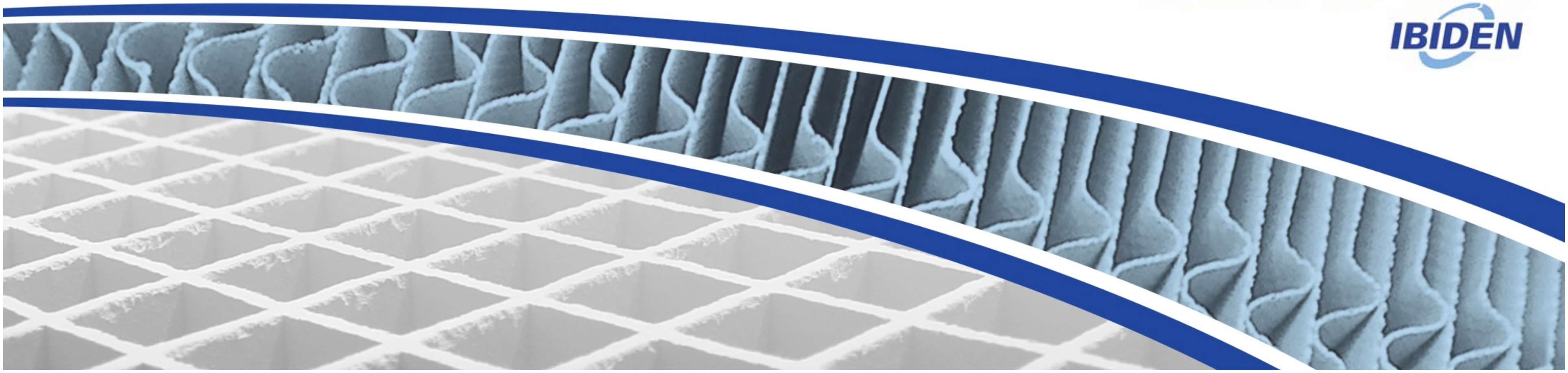
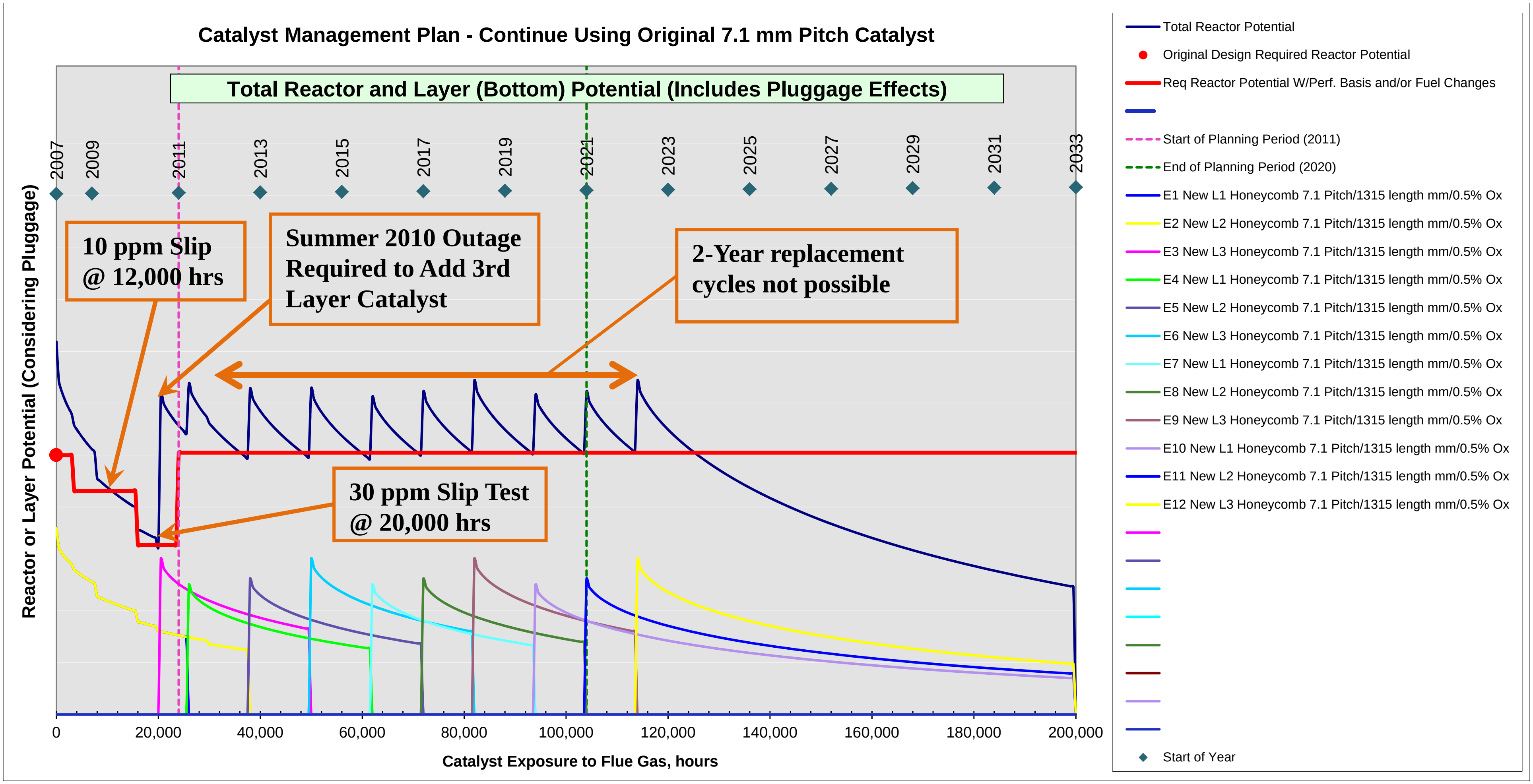


CMP Assuming Status Quo



10 ppm Slip
@ 12,000 hrs

Summer 2010 Outage
Required to Add 3rd
Layer Catalyst

2-Year replacement
cycles not possible

30 ppm Slip Test
@ 20,000 hrs

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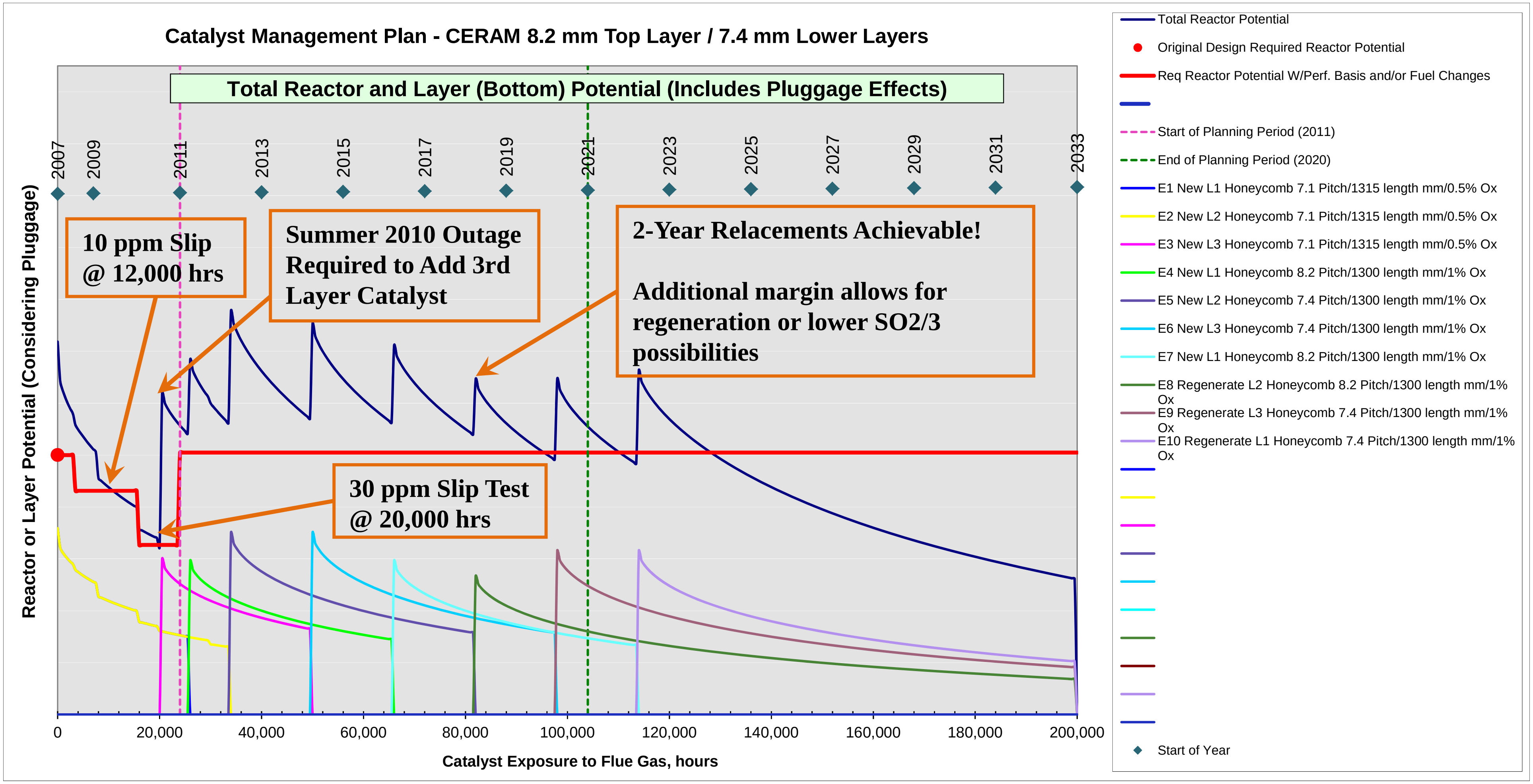
CERAM Working with King Plant

- **Develop Long Term Catalyst Management Plan to Fit Desired Outage Schedule**
  - **Replace One Layer Every 2 Years**
- Transition to Larger Catalyst Pitch
  - 8.2 mm CERAM replaced original 7.1 mm first layer in Spring 2011
  - 7.4 mm CERAM replaced original 7.1 mm second layer in Spring 2012
- Future 2 Year Replacement Cycle Achievable

Current CMP with Recommended Changes



Catalyst Management Plan - CERAM 8.2 mm Top Layer / 7.4 mm Lower Layers

Total Reactor and Layer (Bottom) Potential (Includes Pluggage Effects)

10 ppm Slip
@ 12,000 hrs

Summer 2010 Outage
Required to Add 3rd
Layer Catalyst

2-Year Relacements Achievable!

Additional margin allows for
regeneration or lower SO2/3
possibilities

30 ppm Slip Test
@ 20,000 hrs

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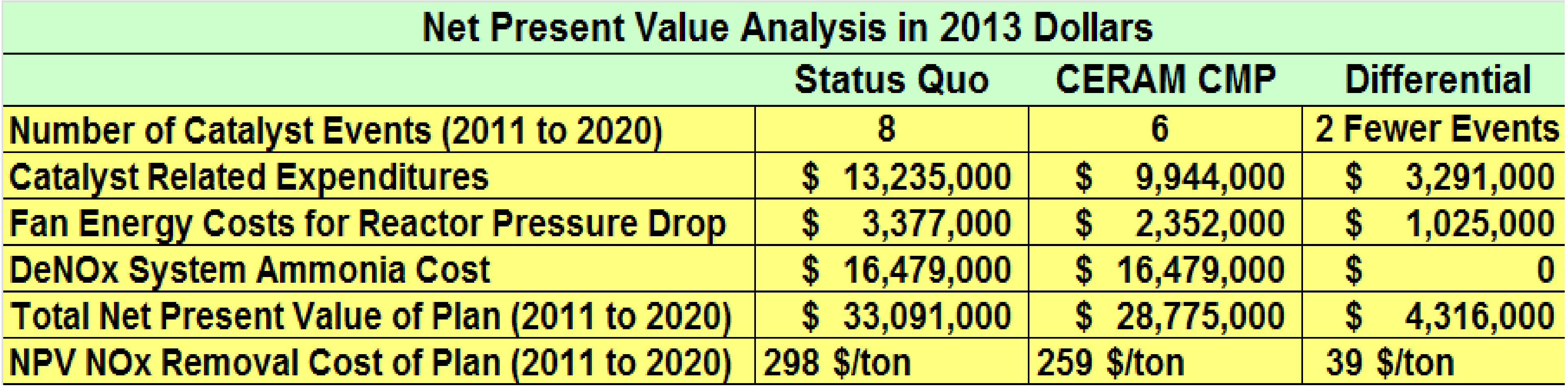
10 Year CMP Economics (2011-2020)



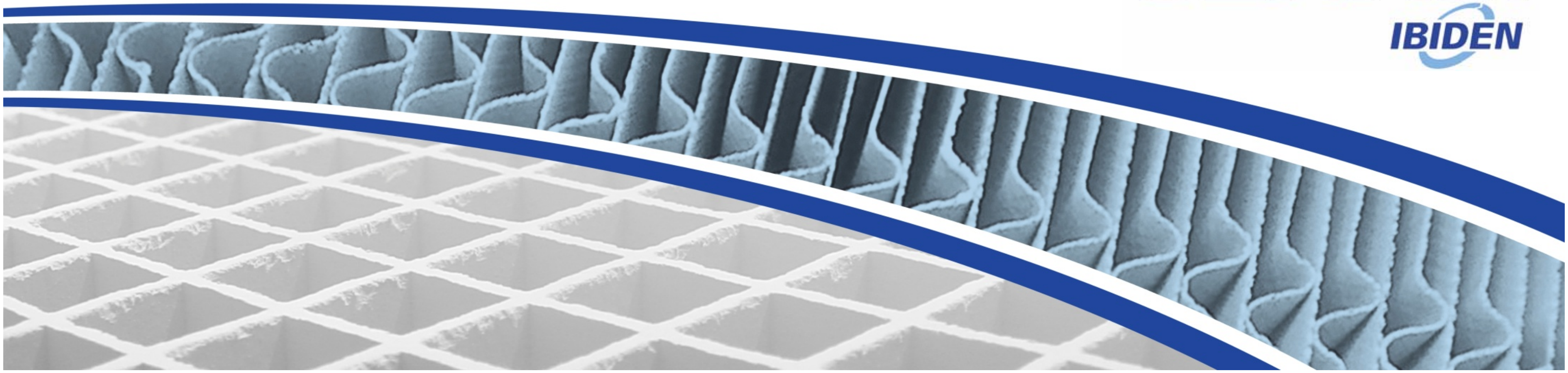
Net Present Value Analysis in 2013 Dollars

	Status Quo	CERAM CMP	Differential
Number of Catalyst Events (2011 to 2020)	8	6	2 Fewer Events
Catalyst Related Expenditures	$ 13,235,000	$ 9,944,000	$ 3,291,000
Fan Energy Costs for Reactor Pressure Drop	$ 3,377,000	$ 2,352,000	$ 1,025,000
DeNOx System Ammonia Cost	$ 16,479,000	$ 16,479,000	$ 0
Total Net Present Value of Plan (2011 to 2020)	$ 33,091,000	$ 28,775,000	$ 4,316,000
NPV NOx Removal Cost of Plan (2011 to 2020)	298 $/ton	259 $/ton	39 $/ton

Note: Economics <u>do not</u> consider replacement power costs associated with untimely outages!

2013 Reinhold Presentation

NIPSCO Bailly Unit 8
“Trials and Tribulations”



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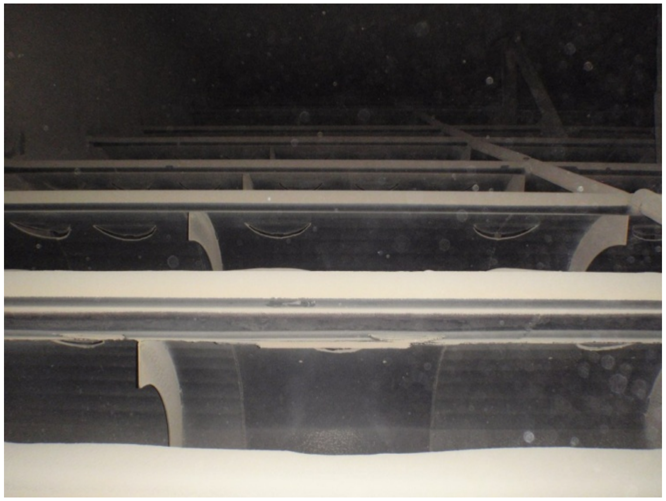
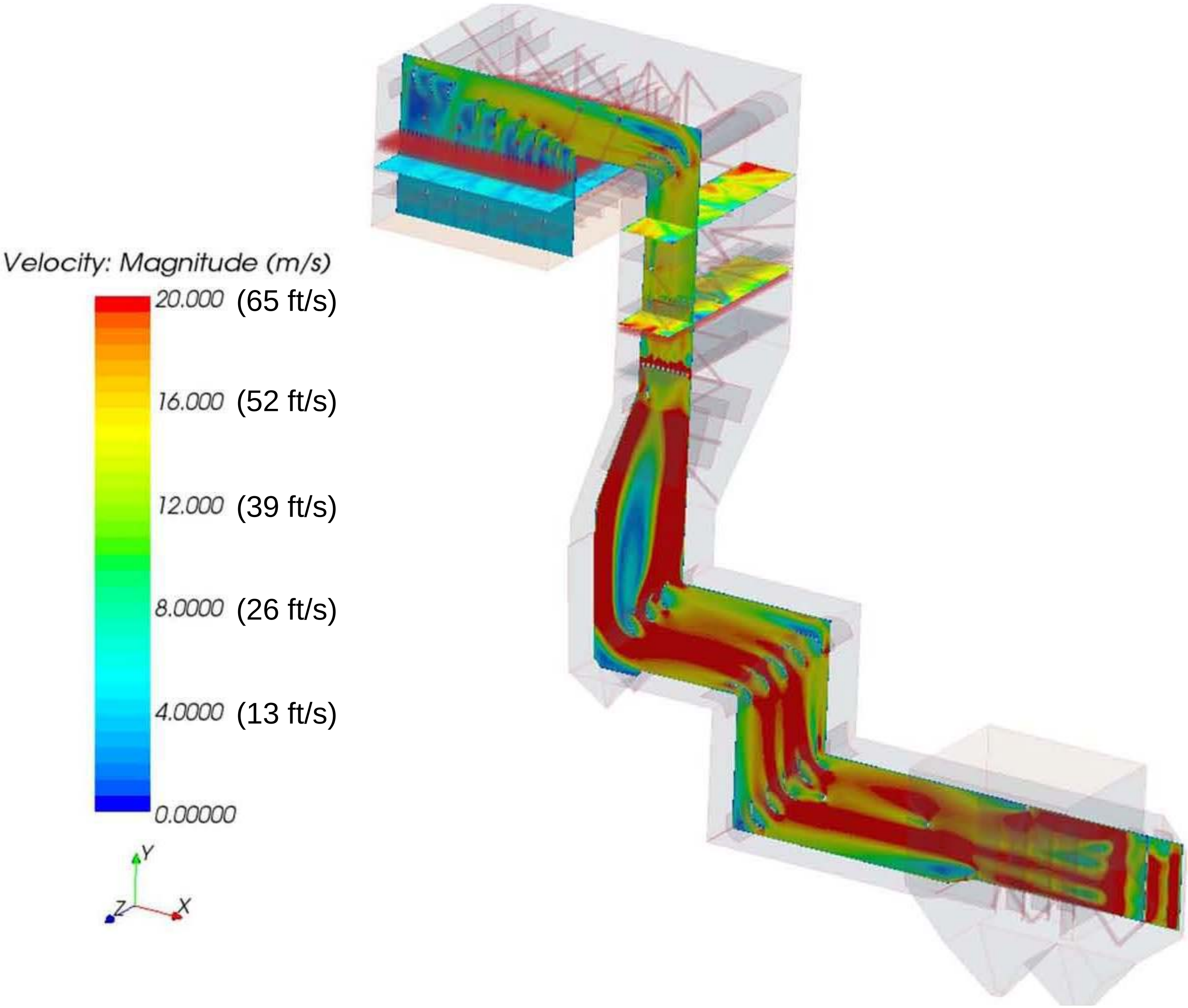
Bailly Unit 8 Overview

- 360 MWg
- B&W Cyclone Boiler (3,400 MMBtu/hr)
- Eastern Bituminous Coal Fired
  - Sulfur ≈ 2.5-3.5%
  - Ash ≈ 9-10%
- SCR in Service 2004
  - 3 + 1 Reactor
  - 12 x 7 Module Arrangement Per Layer
  - CERAM Honeycomb 6.7 mm Pitch Catalyst
  - Fuel Tech NOxOut Ultra System
- Originally Sootblowers Installed L1 & Sonic Horns Installed L2 & L3
- Physical Flow Model Demonstrated All Distributions Achieved and No Ash Drop Out

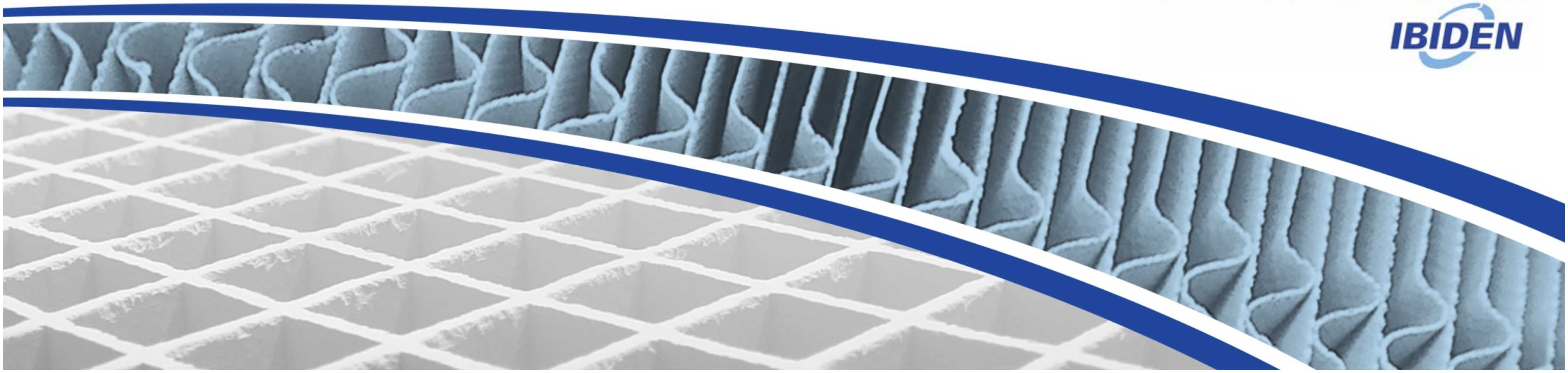


Bailly Unit 8 Schematic



2013 Reinhold Presentation

NIPSCO Bailly Unit 8
Reactor Inspection Review

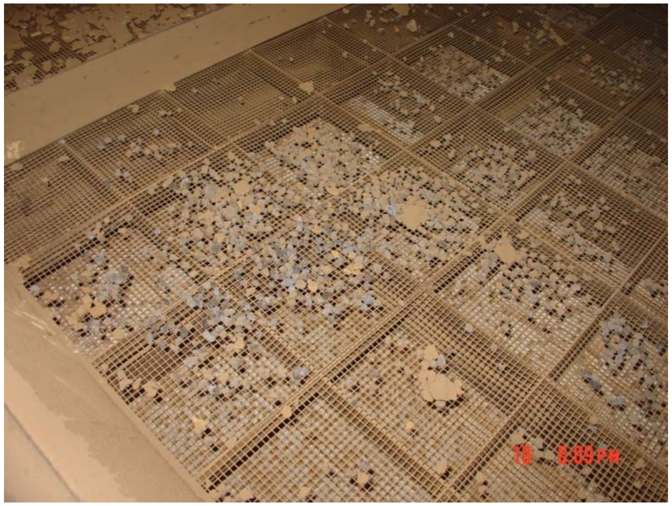


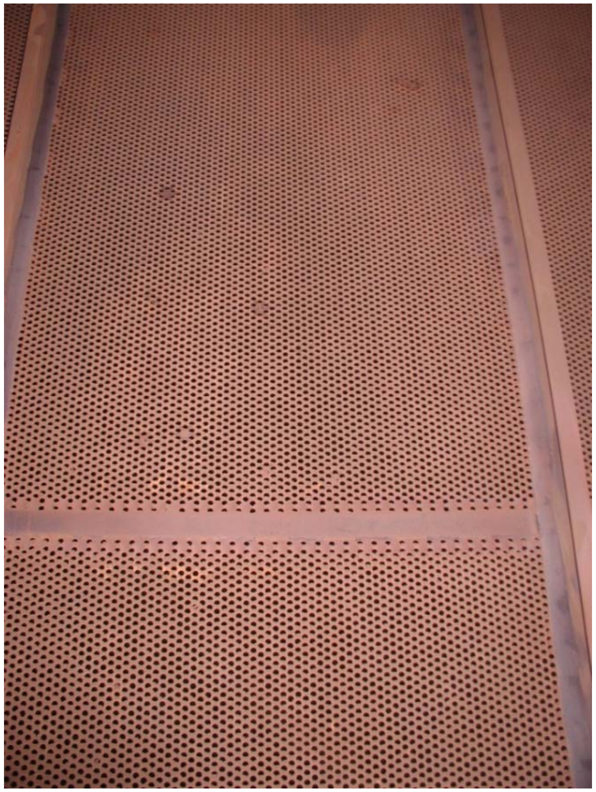
Bailly Unit 8 Reactor Inspection Overview

- Annual Reactor Inspection Performed Over Past 8 Years
  - Frame by Frame Assessment of Pluggage
  - Inspect Catalyst Baffle Plates/Seals, Ammonia Injection Grid (AIG), Large Particle Ash (LPA) Screen, Flow Correction Devices (Guide Vanes, Mixers, etc.), Accessible Duct Work (e.g., Crossover Duct, Inlet Duct, etc.)
  - Historically Pluggage Observed Due to LPA, Unburned Carbon and Ash Dropout (Velocity Maldistribution?)
    - Ash Piles (3-8 ft) Observed In L1, L2 & L3 (East Side)
    - Severe Pluggage Across East & South/Southeast Side Of Reactor
    - At Times Module Pluggage 5-100% in L1, L2 & L3
    - Catalyst Management Ensured Target Emissions Always Achieved
  - Solutions Developed and Implemented to Eliminate Pluggage
  - Ash Buildup On North Section of AIG Lances; Nozzle Pluggage
  - Vanes 2 & 3 In Reactor Hood Missing Flow (e.g., Appear “Dirty”)

Bailly Unit 8 Reactor Inspection Overview

- LPA (Popcorn Ash) Attributed to Plugging
- Original LPA Screen Design
  - 50% Open Perforated Plate (1/2” Diameter Holes)
  - Installed At Non-Inverted Angle Above Economizer Outlet Hoppers
  - Significant Quantities of LPA Deposited On/In Catalyst
  - Recommended Alternative Design





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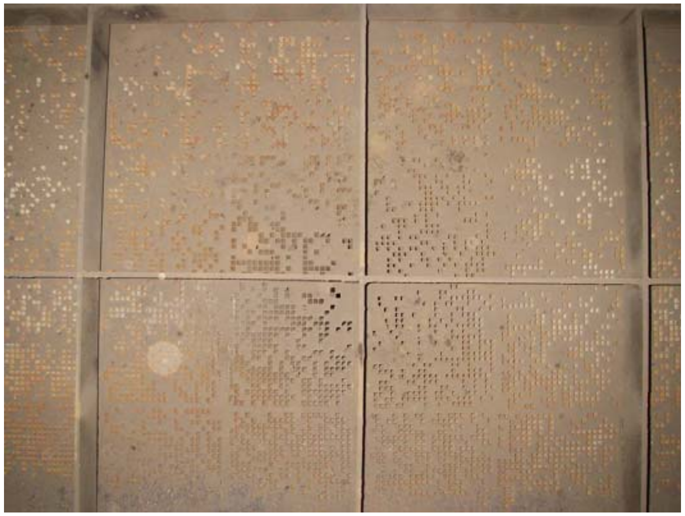
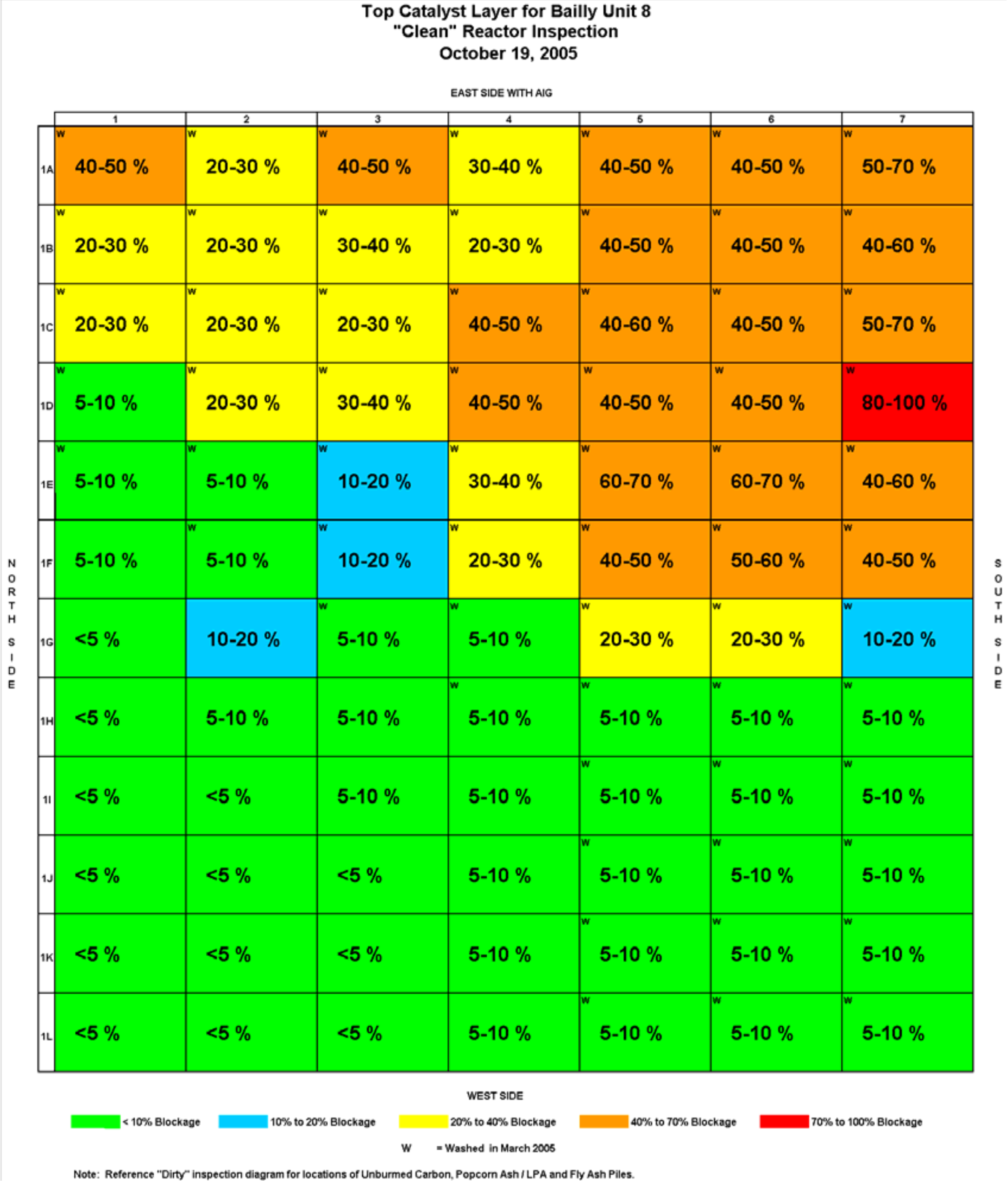
Bailly Unit 8 Reactor Inspection Overview





Top Catalyst Layer for Bailly Unit 8
"Clean" Reactor Inspection
October 19, 2005

EAST SIDE WITH AIG

NORTH SIDE

	1	2	3	4	5	6	7
1A	W 40-50 %	W 20-30 %	W 40-50 %	W 30-40 %	W 40-50 %	W 40-50 %	W 50-70 %
1B	W 20-30 %	W 20-30 %	W 30-40 %	W 20-30 %	W 40-50 %	W 40-50 %	W 40-60 %
1C	W 20-30 %	W 20-30 %	W 20-30 %	W 40-50 %	W 40-60 %	W 40-50 %	W 50-70 %
1D	W 5-10 %	W 20-30 %	W 30-40 %	W 40-50 %	W 40-50 %	W 40-50 %	W 80-100 %
1E	W 5-10 %	W 5-10 %	W 10-20 %	W 30-40 %	W 60-70 %	W 60-70 %	W 40-60 %
1F	5-10 %	W 5-10 %	W 10-20 %	W 20-30 %	W 40-50 %	W 50-60 %	W 40-50 %
1G	<5 %	10-20 %	W 5-10 %	W 5-10 %	W 20-30 %	W 20-30 %	W 10-20 %
1H	<5 %	5-10 %	5-10 %	W 5-10 %	W 5-10 %	W 5-10 %	W 5-10 %
1I	<5 %	<5 %	5-10 %	5-10 %	W 5-10 %	W 5-10 %	W 5-10 %
1J	<5 %	<5 %	<5 %	5-10 %	W 5-10 %	W 5-10 %	W 5-10 %
1K	<5 %	<5 %	<5 %	5-10 %	W 5-10 %	W 5-10 %	W 5-10 %
1L	<5 %	<5 %	<5 %	5-10 %	W 5-10 %	W 5-10 %	W 5-10 %

SOUTH SIDE

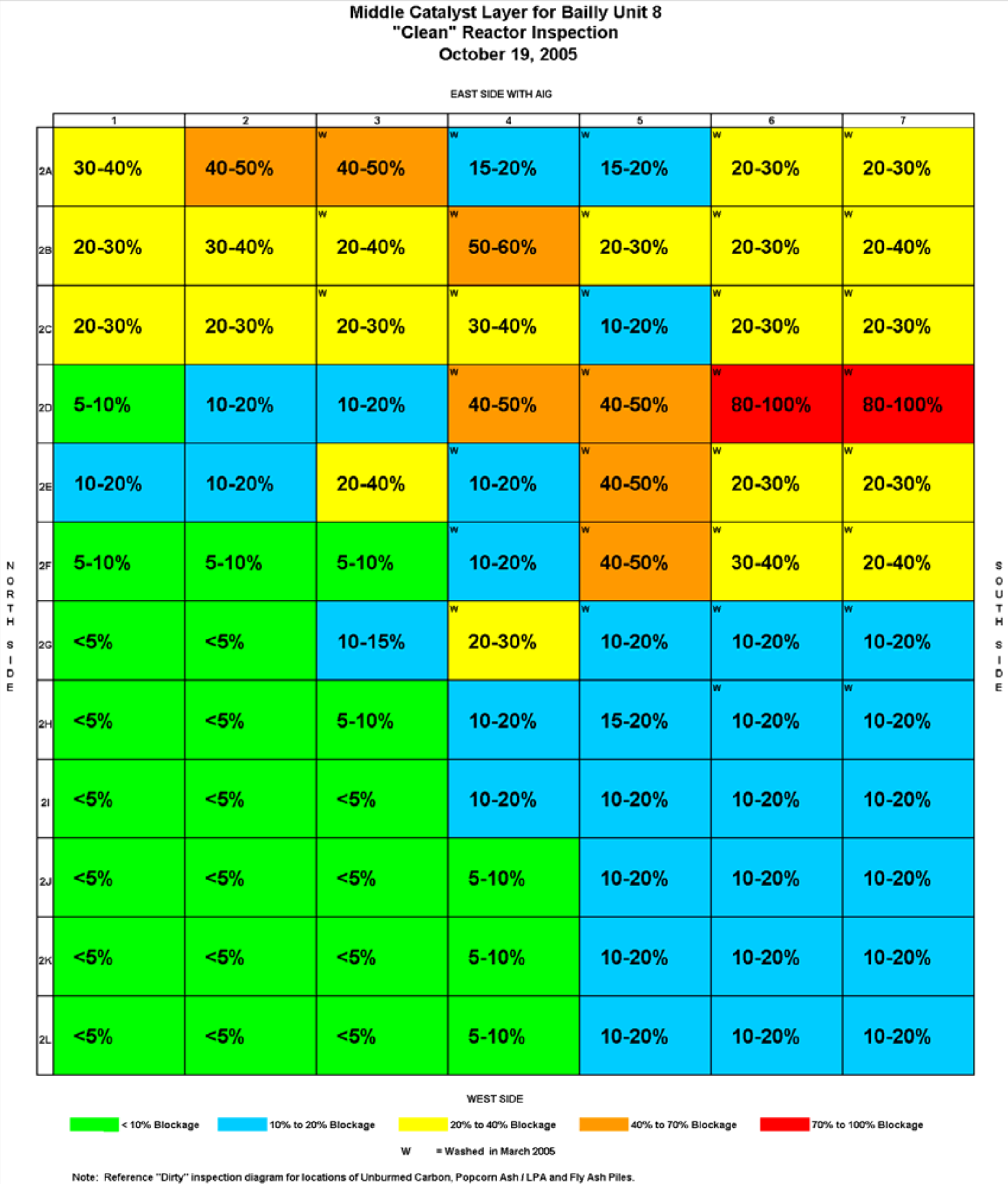
WEST SIDE

🟩 < 10% Blockage 🟦 10% to 20% Blockage 🟨 20% to 40% Blockage 🟧 40% to 70% Blockage 🟥 70% to 100% Blockage

W = Washed in March 2005

Note: Reference "Dirty" inspection diagram for locations of Unburned Carbon, Popcorn Ash / LPA and Fly Ash Piles.

Bailly Unit 8 Reactor Inspection Overview



Middle Catalyst Layer for Bailly Unit 8
"Clean" Reactor Inspection
October 19, 2005

EAST SIDE WITH AIG

	1	2	3	4	5	6	7
2A	30-40%	40-50%	W 40-50%	W 15-20%	W 15-20%	W 20-30%	W 20-30%
2B	20-30%	30-40%	W 20-40%	W 50-60%	W 20-30%	W 20-30%	W 20-40%
2C	20-30%	20-30%	W 20-30%	W 30-40%	W 10-20%	W 20-30%	W 20-30%
2D	5-10%	10-20%	10-20%	W 40-50%	W 40-50%	W 80-100%	W 80-100%
2E	10-20%	10-20%	20-40%	W 10-20%	W 40-50%	W 20-30%	W 20-30%
2F	5-10%	5-10%	5-10%	W 10-20%	W 40-50%	W 30-40%	W 20-40%
2G	<5%	<5%	10-15%	W 20-30%	W 10-20%	W 10-20%	W 10-20%
2H	<5%	<5%	5-10%	10-20%	15-20%	W 10-20%	W 10-20%
2I	<5%	<5%	<5%	10-20%	10-20%	10-20%	10-20%
2J	<5%	<5%	<5%	5-10%	10-20%	10-20%	10-20%
2K	<5%	<5%	<5%	5-10%	10-20%	10-20%	10-20%
2L	<5%	<5%	<5%	5-10%	10-20%	10-20%	10-20%

NORTH SIDE

SOUTH SIDE

WEST SIDE

🟩 < 10% Blockage 🟦 10% to 20% Blockage 🟨 20% to 40% Blockage 🟧 40% to 70% Blockage 🟥 70% to 100% Blockage

W = Washed in March 2005

Note: Reference "Dirty" inspection diagram for locations of Unburned Carbon, Popcorn Ash / LPA and Fly Ash Piles.

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Bailly Unit 8 Reactor Inspection Overview

Bottom Catalyst Layer for Bailly Unit 8
"Clean" Reactor Inspection
October 19, 2005

EAST SIDE WITH AIG

	1	2	3	4	5	6	7
3A	W 10-20%	W 40-70%	W 40-60%	W 40-60%	W 70-100%	W 70-100%	W 90-100%
3B	W 10-20%	W 20-30%	W 20-30%	W 50-60%	W 70-80%	W 70-100%	W 50-60%
3C	W <5%	W 10-20%	W 10-20%	W 60-70%	W 40-50%	W 40-50%	W 50-60%
3D	<5%	10-20%	10-20%	W 10-20%	W 20-30%	W 20-30%	W 20-40%
3E	<5%	10-15%	10-15%	W 10-20%	W 20-30%	W 20-30%	W 20-30%
3F	<5%	<5%	<5%	10-20%	10-20%	W 10-15%	W 10-15%
3G	<5%	<5%	<5%	10-15%	10-20%	10-20%	W <5%
3H	<5%	<5%	<5%	<5%	<5%	10-20%	10-20%
3I	<5%	<5%	<5%	<5%	<5%	5-10%	5-10%
3J	<5%	<5%	<5%	<5%	<5%	5-10%	5-10%
3K	<5%	<5%	<5%	<5%	<5%	<5%	<5%
3L	<5%	<5%	<5%	<5%	<5%	<5%	<5%

WEST SIDE

🟩 < 10% Blockage 🟦 10% to 20% Blockage 🟨 20% to 40% Blockage 🟧 40% to 70% Blockage 🟥 70% to 100% Blockage

W = Washed in March 2005

Note: Reference "Dirty" inspection diagram for locations of Unburned Carbon, Popcorn Ash / LPA and Fly Ash Piles.

Bailly Unit 8 Reactor Inspection Overview

- Replaced Perforated LPA Screen with STEAG LPA Screen
  - Significantly Less LPA Observed After New LPA Screen
  - Eliminate LPA From Reactor?
    - Design Allowed “Cleaning” by Pulling Chain To Move Screen
    - Release Screen; Strike Stoppers; Force Drops LPA To Hoppers
    - Seal Installation Around Screen Resulted In LPA Present In Reactor
  - “Fixed” Position of LPA Screen (Does Not Move
    - Eliminated LPA From Reactor

Bailly Unit 8 Reactor Inspection Overview

- High Levels of Unburned Carbon Typically Observed In Reactor
  - Contributed to Pluggage and Localized Sintering
  - Recommended To Reduce LOI Levels to <15% Measured Upstream of Reactor

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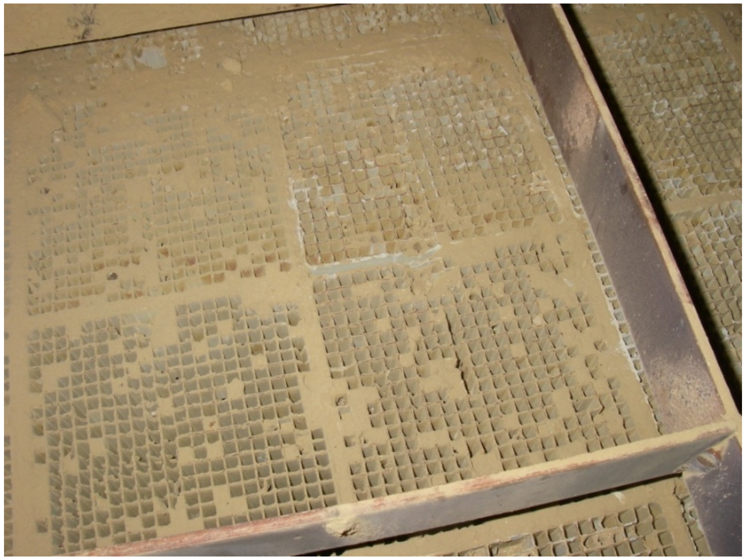
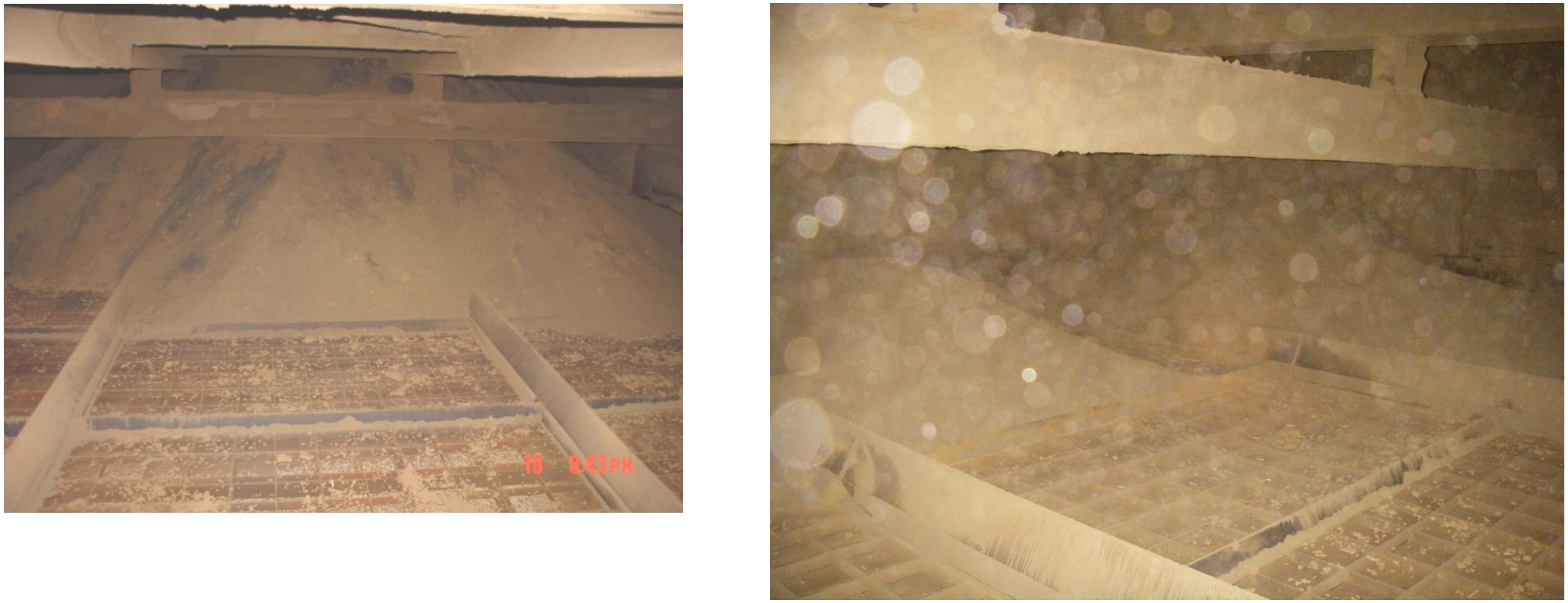
Example of “Mechanical” Cleaning Not Recommended



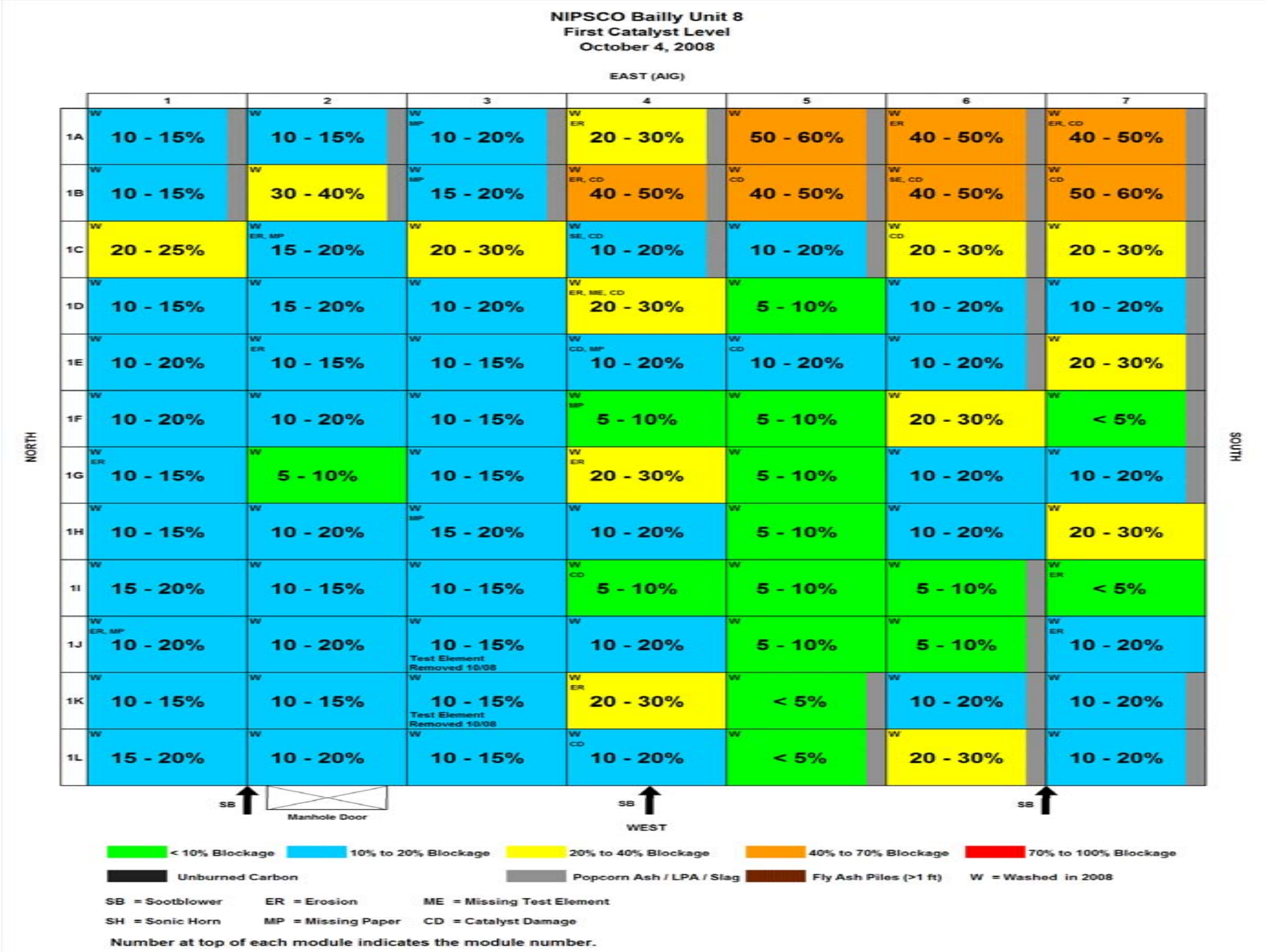
Discontinued by NIPSCO

Bailly Unit 8 Reactor Inspection Overview

- Ash Dropout In Reactor Severe Along East Side & Southeast Corner
- Ash Piles 3-8 ft Observed (Modules 80-100% Plugged)
- “Normal” Pluggage L1 = 18% (L1 Washed; was 64%), L2 pluggage = 40%, L3 pluggage = 35%



Bailly Unit 8 Reactor Inspection Overview



NIPSCO Bailly Unit 8
First Catalyst Level
October 4, 2008

EAST (AIG)

	1	2	3	4	5	6	7
1A	W 10 - 15%	W 10 - 15%	W MP 10 - 20%	W ER 20 - 30%	W 50 - 60%	W ER 40 - 50%	W ER, CD 40 - 50%
1B	W 10 - 15%	W 30 - 40%	W MP 15 - 20%	W ER, CD 40 - 50%	W CD 40 - 50%	W SE, CD 40 - 50%	W CD 50 - 60%
1C	W 20 - 25%	W ER, MP 15 - 20%	W 20 - 30%	W SE, CD 10 - 20%	W 10 - 20%	W CD 20 - 30%	W 20 - 30%
1D	W 10 - 15%	W 15 - 20%	W 10 - 20%	W ER, ME, CD 20 - 30%	W 5 - 10%	W 10 - 20%	W 10 - 20%
1E	W 10 - 20%	W ER 10 - 15%	W 10 - 15%	W CD, MP 10 - 20%	W CD 10 - 20%	W 10 - 20%	W 20 - 30%
1F	W 10 - 20%	W 10 - 20%	W 10 - 15%	W MP 5 - 10%	W 5 - 10%	W 20 - 30%	W < 5%
1G	W ER 10 - 15%	W 5 - 10%	W 10 - 15%	W ER 20 - 30%	W 5 - 10%	W 10 - 20%	W 10 - 20%
1H	W 10 - 15%	W 10 - 20%	W MP 15 - 20%	W 10 - 20%	W 5 - 10%	W 10 - 20%	W 20 - 30%
1I	W 15 - 20%	W 10 - 15%	W 10 - 15%	W CD 5 - 10%	W 5 - 10%	W 5 - 10%	W ER < 5%
1J	W ER, MP 10 - 20%	W 10 - 20%	W 10 - 15% Test Element Removed 10/08	W 10 - 20%	W 5 - 10%	W 5 - 10%	W ER 10 - 20%
1K	W 10 - 15%	W 10 - 15%	W 10 - 15% Test Element Removed 10/08	W ER 20 - 30%	W < 5%	W 10 - 20%	W 10 - 20%
1L	W 15 - 20%	W 10 - 20%	W 10 - 15%	W CD 10 - 20%	W < 5%	W 20 - 30%	W 10 - 20%

🟩 < 10% Blockage 🟦 10% to 20% Blockage 🟨 20% to 40% Blockage 🟧 40% to 70% Blockage 🟥 70% to 100% Blockage

⬛ Unburned Carbon ▨ Popcorn Ash / LPA / Slag 🟫 Fly Ash Piles (>1 ft) W = Washed in 2008

SB = Sootblower ER = Erosion ME = Missing Test Element

SH = Sonic Horn MP = Missing Paper CD = Catalyst Damage

Number at top of each module indicates the module number.

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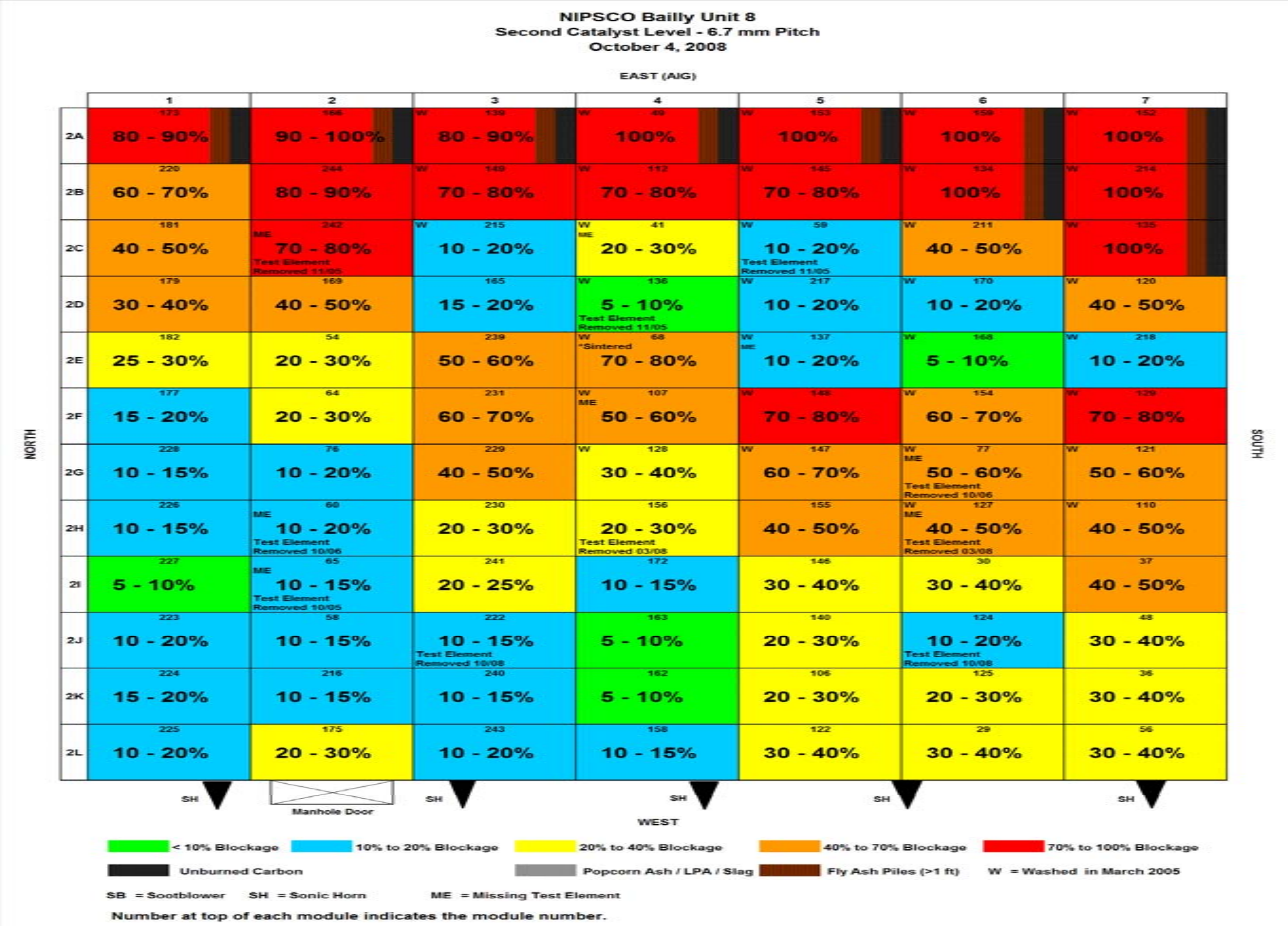
Bailly Unit 8 Reactor Inspection Overview



NIPSCO Bailly Unit 8
Second Catalyst Level - 6.7 mm Pitch
October 4, 2008

EAST (AIG)

	1	2	3	4	5	6	7
2A	173 80 - 90%	166 90 - 100%	W 139 80 - 90%	W 49 100%	W 153 100%	W 159 100%	W 152 100%
2B	220 60 - 70%	244 80 - 90%	W 149 70 - 80%	W 112 70 - 80%	W 145 70 - 80%	W 134 100%	W 214 100%
2C	181 40 - 50%	242 ME 70 - 80% Test Element Removed 11/05	W 215 10 - 20%	W 41 ME 20 - 30%	W 59 10 - 20% Test Element Removed 11/05	W 211 40 - 50%	W 135 100%
2D	179 30 - 40%	169 40 - 50%	165 15 - 20%	W 136 5 - 10% Test Element Removed 11/05	W 217 10 - 20%	W 170 10 - 20%	W 120 40 - 50%
2E	182 25 - 30%	54 20 - 30%	239 50 - 60%	W 68 *Sintered 70 - 80%	W 137 ME 10 - 20%	W 168 5 - 10%	W 218 10 - 20%
2F	177 15 - 20%	64 20 - 30%	231 60 - 70%	W 107 ME 50 - 60%	W 148 70 - 80%	W 154 60 - 70%	W 129 70 - 80%
2G	228 10 - 15%	76 10 - 20%	229 40 - 50%	W 128 30 - 40%	W 147 60 - 70%	W 77 ME 50 - 60% Test Element Removed 10/06	W 121 50 - 60%
2H	226 10 - 15%	60 ME 10 - 20% Test Element Removed 10/06	230 20 - 30%	156 20 - 30% Test Element Removed 03/08	155 40 - 50%	W 127 ME 40 - 50% Test Element Removed 03/08	W 110 40 - 50%
2I	227 5 - 10%	65 ME 10 - 15% Test Element Removed 10/05	241 20 - 25%	172 10 - 15%	146 30 - 40%	30 30 - 40%	37 40 - 50%
2J	223 10 - 20%	58 10 - 15%	222 10 - 15% Test Element Removed 10/08	163 5 - 10%	140 20 - 30%	124 10 - 20% Test Element Removed 10/08	48 30 - 40%
2K	224 15 - 20%	216 10 - 15%	240 10 - 15%	162 5 - 10%	106 20 - 30%	125 20 - 30%	36 30 - 40%
2L	225 10 - 20%	175 20 - 30%	243 10 - 20%	158 10 - 15%	122 30 - 40%	29 30 - 40%	56 30 - 40%

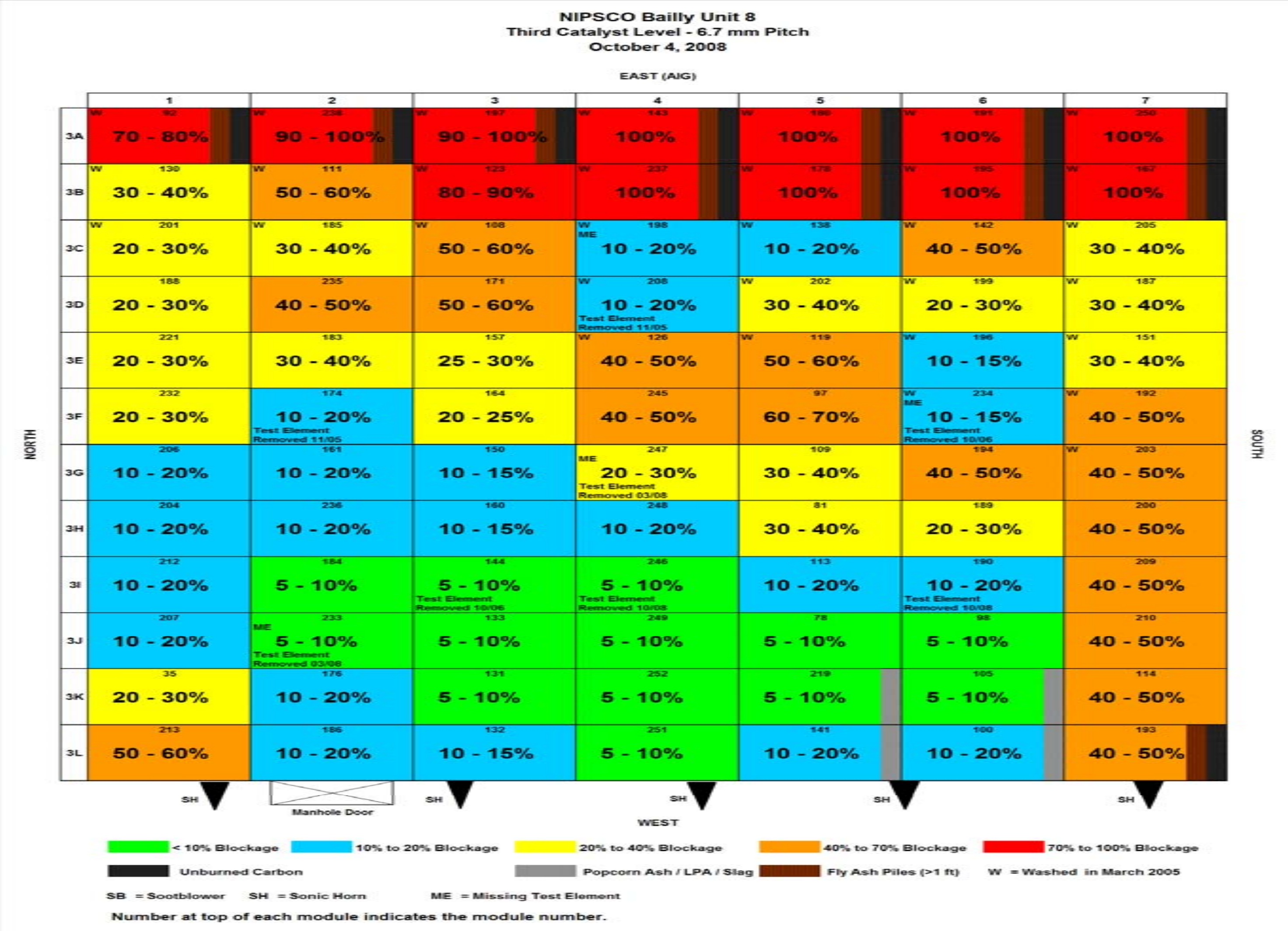
🟩 < 10% Blockage 🟦 10% to 20% Blockage 🟨 20% to 40% Blockage 🟧 40% to 70% Blockage 🟥 70% to 100% Blockage

⬛ Unburned Carbon ▨ Popcorn Ash / LPA / Slag 🟫 Fly Ash Piles (>1 ft) W = Washed in March 2005

SB = Sootblower SH = Sonic Horn ME = Missing Test Element

Number at top of each module indicates the module number.

Bailly Unit 8 Reactor Inspection Overview



NIPSCO Bailly Unit 8
Third Catalyst Level - 6.7 mm Pitch
October 4, 2008

EAST (AIG)

	1	2	3	4	5	6	7
3A	W 92 70 - 80%	W 238 90 - 100%	W 197 90 - 100%	W 143 100%	W 180 100%	W 191 100%	W 250 100%
3B	W 130 30 - 40%	W 111 50 - 60%	W 123 80 - 90%	W 237 100%	W 178 100%	W 195 100%	W 167 100%
3C	W 201 20 - 30%	W 185 30 - 40%	W 108 50 - 60%	W 198 ME 10 - 20%	W 138 10 - 20%	W 142 40 - 50%	W 205 30 - 40%
3D	188 20 - 30%	235 40 - 50%	171 50 - 60%	W 208 10 - 20% Test Element Removed 11/05	W 202 30 - 40%	W 199 20 - 30%	W 187 30 - 40%
3E	221 20 - 30%	183 30 - 40%	157 25 - 30%	W 126 40 - 50%	W 119 50 - 60%	W 196 10 - 15%	W 151 30 - 40%
3F	232 20 - 30%	174 10 - 20% Test Element Removed 11/05	164 20 - 25%	245 40 - 50%	97 60 - 70%	W 234 ME 10 - 15% Test Element Removed 10/06	W 192 40 - 50%
3G	206 10 - 20%	161 10 - 20%	150 10 - 15%	247 ME 20 - 30% Test Element Removed 03/08	109 30 - 40%	194 40 - 50%	W 203 40 - 50%
3H	204 10 - 20%	236 10 - 20%	160 10 - 15%	248 10 - 20%	81 30 - 40%	189 20 - 30%	200 40 - 50%
3I	212 10 - 20%	184 5 - 10%	144 5 - 10% Test Element Removed 10/06	246 5 - 10% Test Element Removed 10/08	113 10 - 20%	190 10 - 20% Test Element Removed 10/08	209 40 - 50%
3J	207 10 - 20%	233 ME 5 - 10% Test Element Removed 03/08	133 5 - 10%	249 5 - 10%	78 5 - 10%	98 5 - 10%	210 40 - 50%
3K	35 20 - 30%	176 10 - 20%	131 5 - 10%	252 5 - 10%	219 5 - 10%	105 5 - 10%	114 40 - 50%
3L	213 50 - 60%	186 10 - 20%	132 10 - 15%	251 5 - 10%	141 10 - 20%	100 10 - 20%	193 40 - 50%

🟩 < 10% Blockage 🟦 10% to 20% Blockage 🟨 20% to 40% Blockage 🟧 40% to 70% Blockage 🟥 70% to 100% Blockage

⬛ Unburned Carbon ▨ Popcorn Ash / LPA / Slag 🟫 Fly Ash Piles (>1 ft) W = Washed in March 2005

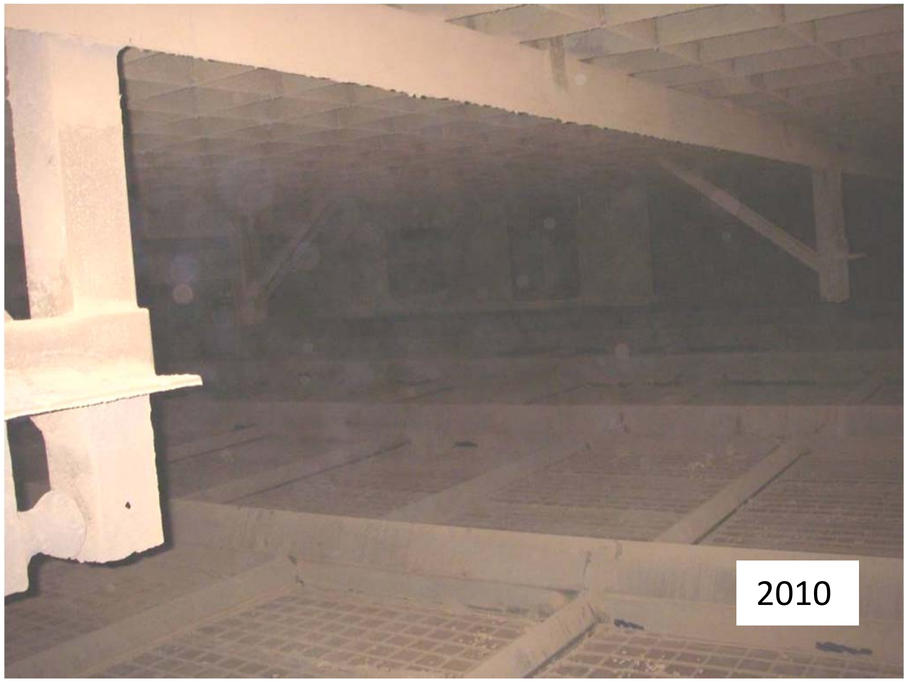
SB = Sootblower SH = Sonic Horn ME = Missing Test Element

Number at top of each module indicates the module number.

Bailly Unit 8 Reactor Inspection Overview

- Recommended CFD Modeling From Economizer Outlet to SCR Outlet
  - Original Flow Model Did Not Include CFD (Not Performed by Fuel Tech)
  - Physical Test Results Aided in Guide Vane Design & Location (Circa 2002-03)
  - Assumed Plug Flow From Economizer; ±15% Vel. Distribution
  - Reactor Internals Available Modeled (Gussets Perpendicular To Flow, etc.)
  - Height From Crossover Duct To Top of Catalyst In Level 1 Approx. 6 ft (Swirls & Eddies Present Based on Inspections)
  - Vanes 2 & 3 In Reactor Hood Missing Flow (e.g., Appear “Dirty”)
  - Ash Buildup on North Section of AIG Lances; South Side Clean; Southeast Side of Reactor Had Highest Pluggage
- 2009 L1 Replaced With 9.2 mm Pitch To Act As Catalyst/Flow Rectifier “Band-Aid” Until CFD Model
  - Piles On Lower Levels Not As Severe But Present
  - Best-of-Best Made in Lower Levels
  - 2008-09 Sonic Horns Installed L1; Sootblower Pipes Removed

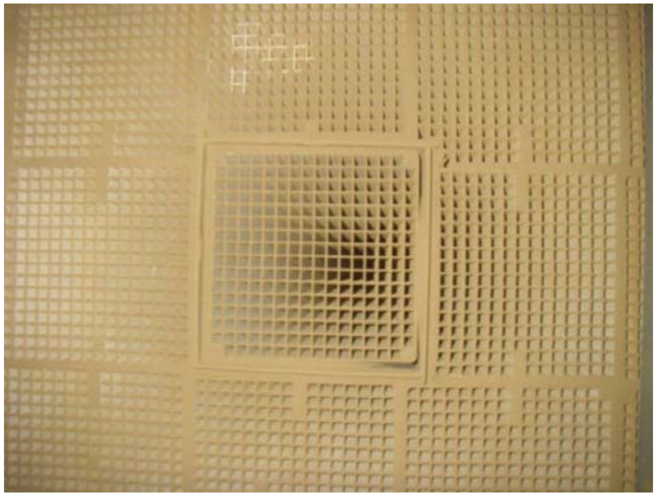
Bailly Unit 8 Reactor Inspection Overview



2010

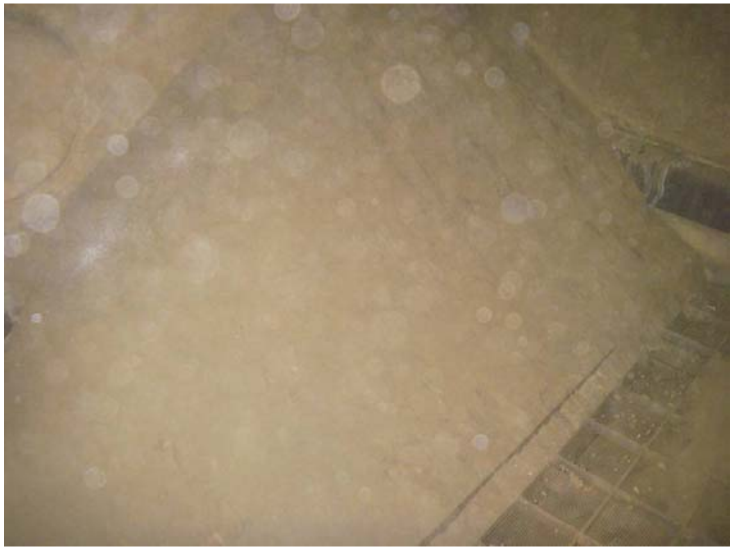
Avg pluggage:
L1 = 5% (9.2 mm),
L2 = 35% (6.7 mm),
L3 pluggage = 25% (6.7 mm)
(End of 2009; L1 (18%), L2 (40%) & L3 (35%))

9.2 mm Pitch
Level 1

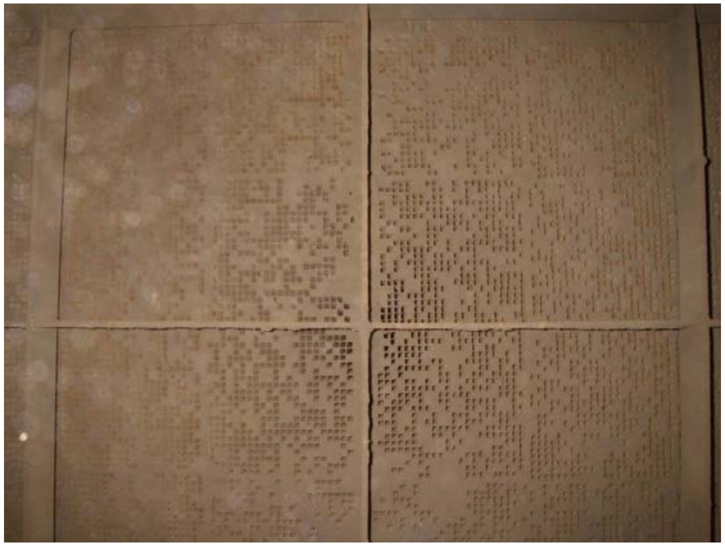


02.14.2011 14:27

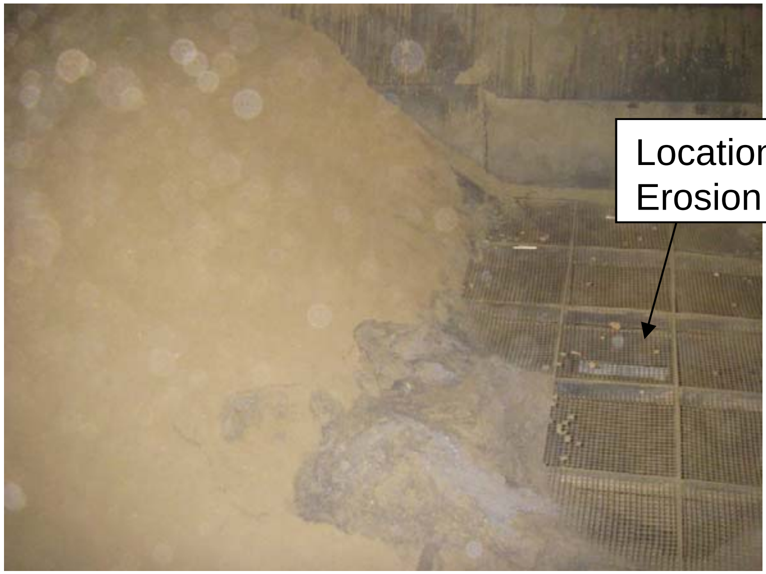
Bailly Unit 8 Reactor Inspection Overview



Level 2
6.7 mm Pitch



Bailly Unit 8 Reactor Inspection Overview



Location of Erosion (2010)

Level 2

02.14.2011 14:24

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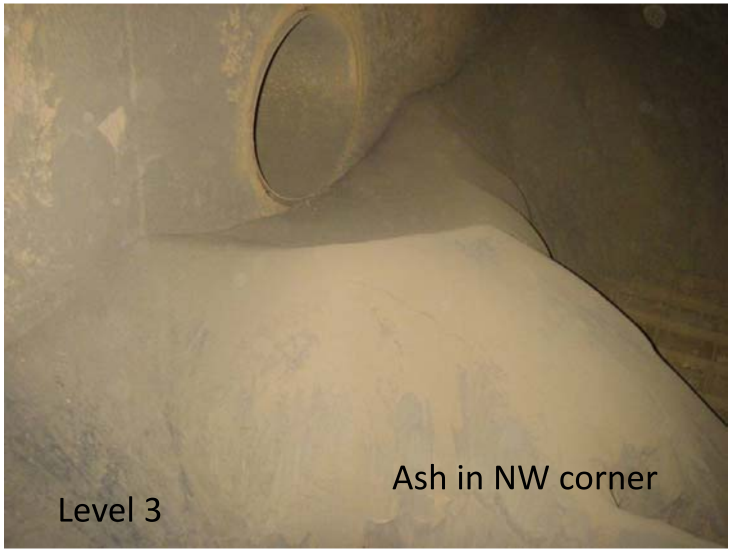
Bailly Unit 8 Reactor Inspection Overview

Level 2

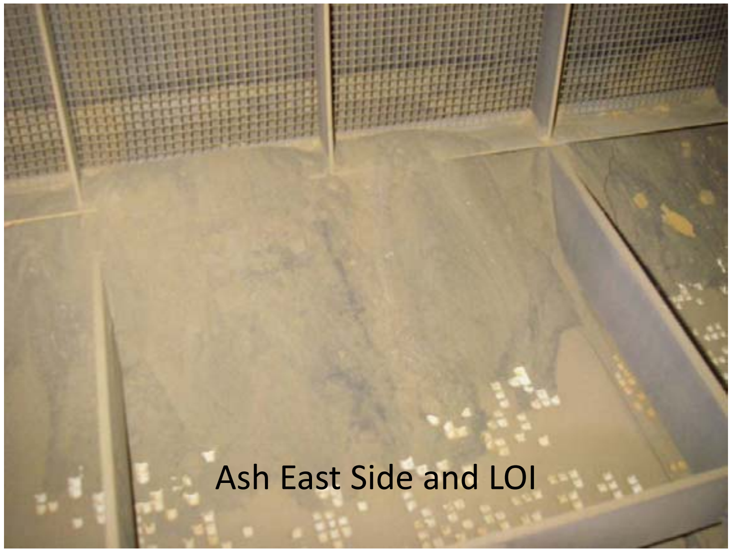
Seal damage (material type)



Level 3

Ash in NW corner

Mechanical cleaning and erosion



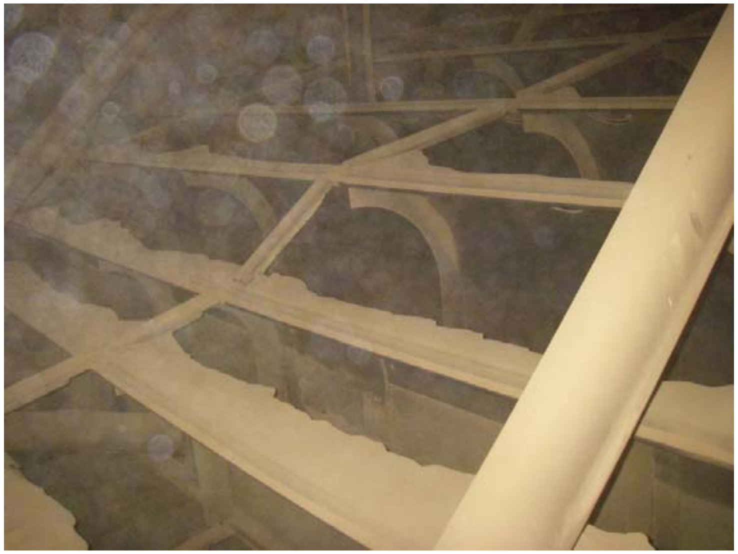
Ash East Side and LOI

Bailly Unit 8 Reactor Inspection Overview

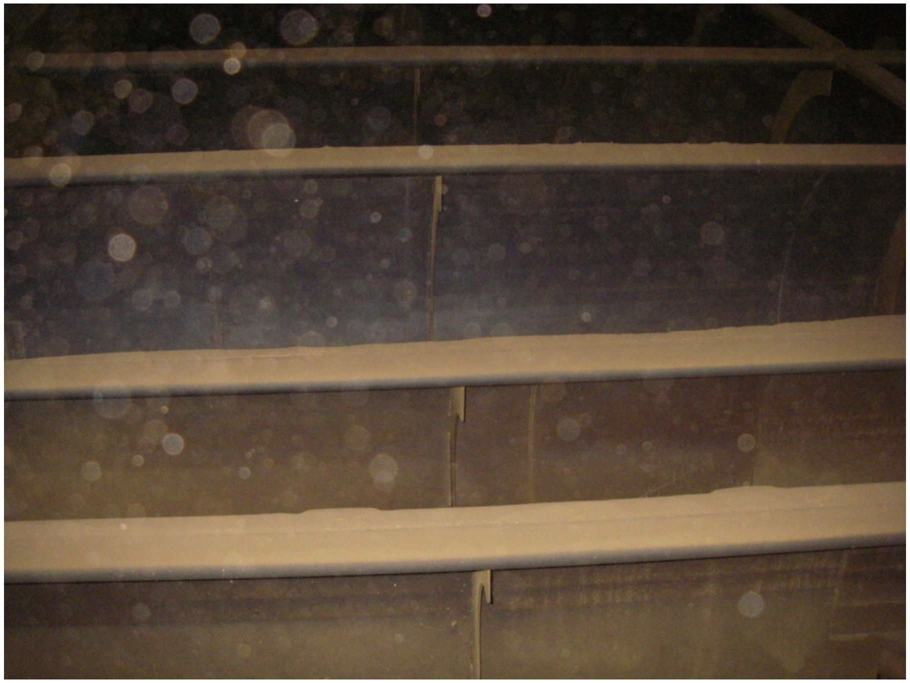
AIG

Valves all insulated

Bailly Unit 8 Inspection Results Overview



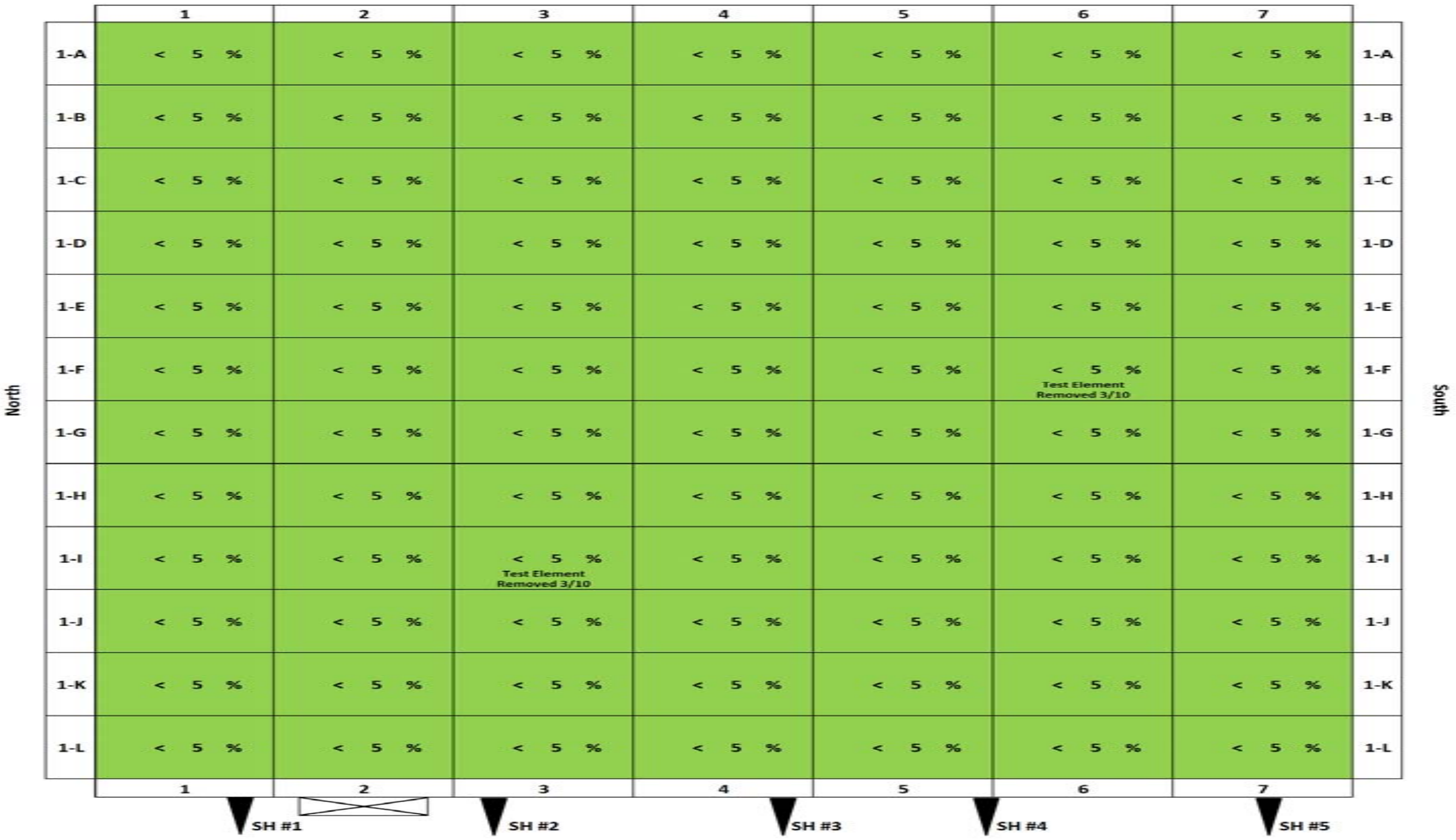
“Clean” vs. “Dirty” Vanes



Scallops Used

Bailly Unit 8
Pluggage Diagram
First Catalyst Level (9.2 mm Pitch)
March 3, 2010

East Side (AIG)



	1	2	3	4	5	6	7	
1-A	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-A
1-B	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-B
1-C	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-C
1-D	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-D
1-E	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-E
1-F	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 % Test Element Removed 3/10	< 5 %	1-F
1-G	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-G
1-H	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-H
1-I	< 5 %	< 5 %	< 5 % Test Element Removed 3/10	< 5 %	< 5 %	< 5 %	< 5 %	1-I
1-J	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-J
1-K	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-K
1-L	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-L
	1	2	3	4	5	6	7	

West Side

🟩	< 10% Blockage	🟥	70 - 100% Blockage	LPA = Large Particle Ash/ Slag
🟦	10 - 20% Blockage	▨	Fly Ash Pile	LOI = Unburned Carbon
🟨	20 - 40% Blockage	▼	SH = Sonic Horn	W = Washed
🟧	40 - 70% Blockage	☒	Man Hole	ER = Erosion

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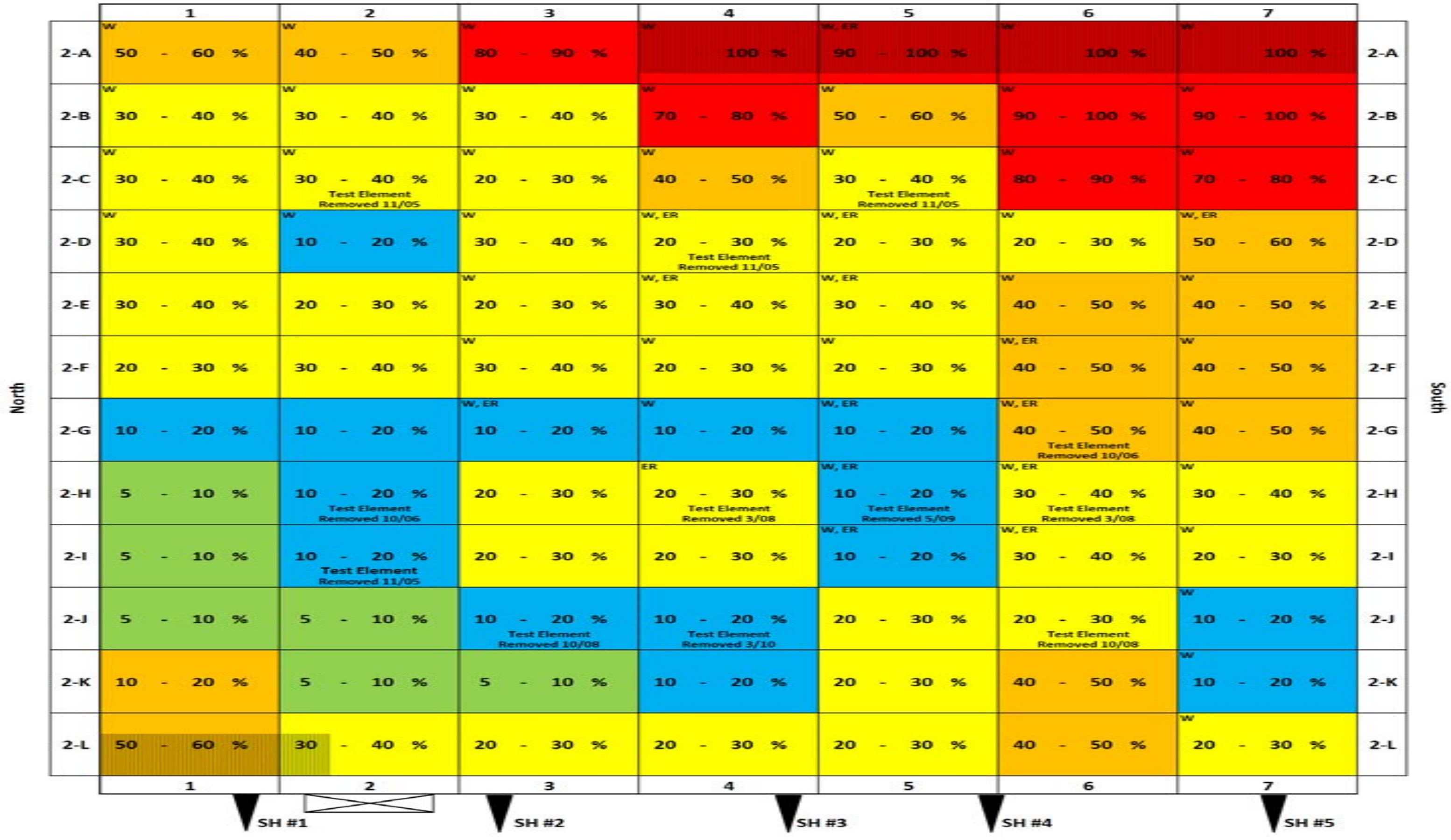
Bailly Unit 8
Pluggage Diagram
Second Catalyst Level (6.7 mm Pitch)
March 3, 2010



East Side (AIG)

	1	2	3	4	5	6	7	
2-A	W 50 - 60 %	W 40 - 50 %	W 80 - 90 %	W 100 %	W, ER 90 - 100 %	W 100 %	W 100 %	2-A
2-B	W 30 - 40 %	W 30 - 40 %	W 30 - 40 %	W 70 - 80 %	W 50 - 60 %	W 90 - 100 %	W 90 - 100 %	2-B
2-C	W 30 - 40 %	W 30 - 40 % Test Element Removed 11/05	W 20 - 30 %	W 40 - 50 %	W 30 - 40 % Test Element Removed 11/05	W 80 - 90 %	W 70 - 80 %	2-C
2-D	W 30 - 40 %	W 10 - 20 %	W 30 - 40 %	W, ER 20 - 30 % Test Element Removed 11/05	W, ER 20 - 30 %	W 20 - 30 %	W, ER 50 - 60 %	2-D
2-E	30 - 40 %	20 - 30 %	W 20 - 30 %	W, ER 30 - 40 %	W, ER 30 - 40 %	W 40 - 50 %	W 40 - 50 %	2-E
2-F	20 - 30 %	30 - 40 %	W 30 - 40 %	W 20 - 30 %	W 20 - 30 %	W, ER 40 - 50 %	W 40 - 50 %	2-F
2-G	10 - 20 %	10 - 20 %	W, ER 10 - 20 %	W 10 - 20 %	W, ER 10 - 20 %	W, ER 40 - 50 % Test Element Removed 10/06	W 40 - 50 %	2-G
2-H	5 - 10 %	10 - 20 % Test Element Removed 10/06	20 - 30 %	ER 20 - 30 % Test Element Removed 3/08	W, ER 10 - 20 % Test Element Removed 5/09	W, ER 30 - 40 % Test Element Removed 3/08	W 30 - 40 %	2-H
2-I	5 - 10 %	10 - 20 % Test Element Removed 11/05	20 - 30 %	20 - 30 %	W, ER 10 - 20 %	W, ER 30 - 40 %	W 20 - 30 %	2-I
2-J	5 - 10 %	5 - 10 %	10 - 20 % Test Element Removed 10/08	10 - 20 % Test Element Removed 3/10	20 - 30 %	20 - 30 % Test Element Removed 10/08	W 10 - 20 %	2-J
2-K	10 - 20 %	5 - 10 %	5 - 10 %	10 - 20 %	20 - 30 %	40 - 50 %	W 10 - 20 %	2-K
2-L	50 - 60 %	30 - 40 %	20 - 30 %	20 - 30 %	20 - 30 %	40 - 50 %	W 20 - 30 %	2-L
	1	2	3	4	5	6	7	

West Side

🟩 < 10% Blockage	🟥 70 - 100% Blockage	LPA = Large Particle Ash/ Slag
🟦 10 - 20% Blockage	▨ Fly Ash Pile	LOI = Unburned Carbon
🟨 20 - 40% Blockage	▼ SH = Sonic Horn	W = Washed
🟧 40 - 70% Blockage	☒ Man Hole	ER = Erosion

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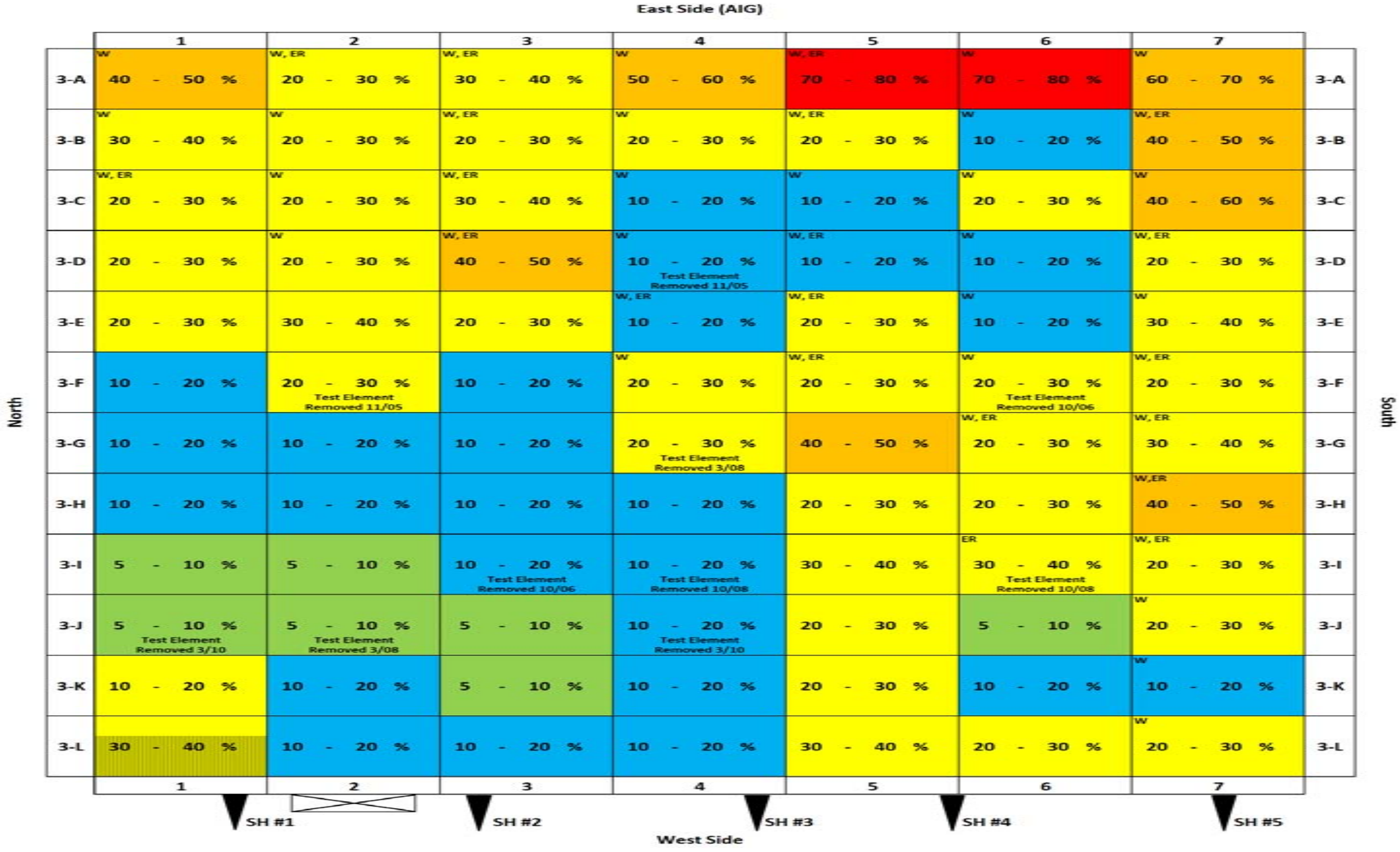
Bailly Unit 8
Pluggage Diagram
Third Catalyst Level (6.7 mm Pitch)
March 3, 2010



	1	2	3	4	5	6	7	
3-A	W 40 - 50 %	W, ER 20 - 30 %	W, ER 30 - 40 %	W 50 - 60 %	W, ER 70 - 80 %	W 70 - 80 %	W 60 - 70 %	3-A
3-B	W 30 - 40 %	W 20 - 30 %	W, ER 20 - 30 %	W 20 - 30 %	W, ER 20 - 30 %	W 10 - 20 %	W, ER 40 - 50 %	3-B
3-C	W, ER 20 - 30 %	W 20 - 30 %	W, ER 30 - 40 %	W 10 - 20 %	W 10 - 20 %	W 20 - 30 %	W 40 - 60 %	3-C
3-D	20 - 30 %	W 20 - 30 %	W, ER 40 - 50 %	W 10 - 20 % Test Element Removed 11/05	W, ER 10 - 20 %	W 10 - 20 %	W, ER 20 - 30 %	3-D
3-E	20 - 30 %	30 - 40 %	20 - 30 %	W, ER 10 - 20 %	W, ER 20 - 30 %	W 10 - 20 %	W 30 - 40 %	3-E
3-F	10 - 20 %	20 - 30 % Test Element Removed 11/05	10 - 20 %	W 20 - 30 %	W, ER 20 - 30 %	W 20 - 30 % Test Element Removed 10/06	W, ER 20 - 30 %	3-F
3-G	10 - 20 %	10 - 20 %	10 - 20 %	20 - 30 % Test Element Removed 3/08	40 - 50 %	W, ER 20 - 30 %	W, ER 30 - 40 %	3-G
3-H	10 - 20 %	10 - 20 %	10 - 20 %	10 - 20 %	20 - 30 %	20 - 30 %	W,ER 40 - 50 %	3-H
3-I	5 - 10 %	5 - 10 %	10 - 20 % Test Element Removed 10/06	10 - 20 % Test Element Removed 10/08	30 - 40 %	ER 30 - 40 % Test Element Removed 10/08	W, ER 20 - 30 %	3-I
3-J	5 - 10 % Test Element Removed 3/10	5 - 10 % Test Element Removed 3/08	5 - 10 %	10 - 20 % Test Element Removed 3/10	20 - 30 %	5 - 10 %	W 20 - 30 %	3-J
3-K	10 - 20 %	10 - 20 %	5 - 10 %	10 - 20 %	20 - 30 %	10 - 20 %	W 10 - 20 %	3-K
3-L	30 - 40 %	10 - 20 %	10 - 20 %	10 - 20 %	30 - 40 %	20 - 30 %	W 20 - 30 %	3-L
	1	2	3	4	5	6	7	

🟩	< 10% Blockage	🟥	70 - 100% Blockage	LPA = Large Particle Ash/ Slag
🟦	10 - 20% Blockage	▨	Fly Ash Pile	LOI = Unburned Carbon
🟨	20 - 40% Blockage	▼	SH = Sonic Horn	W = Washed
🟧	40 - 70% Blockage	☒	Man Hole	ER = Erosion

2013 Reinhold Presentation

NIPSCO Bailly Unit 8

CFD Modeling & Modifications

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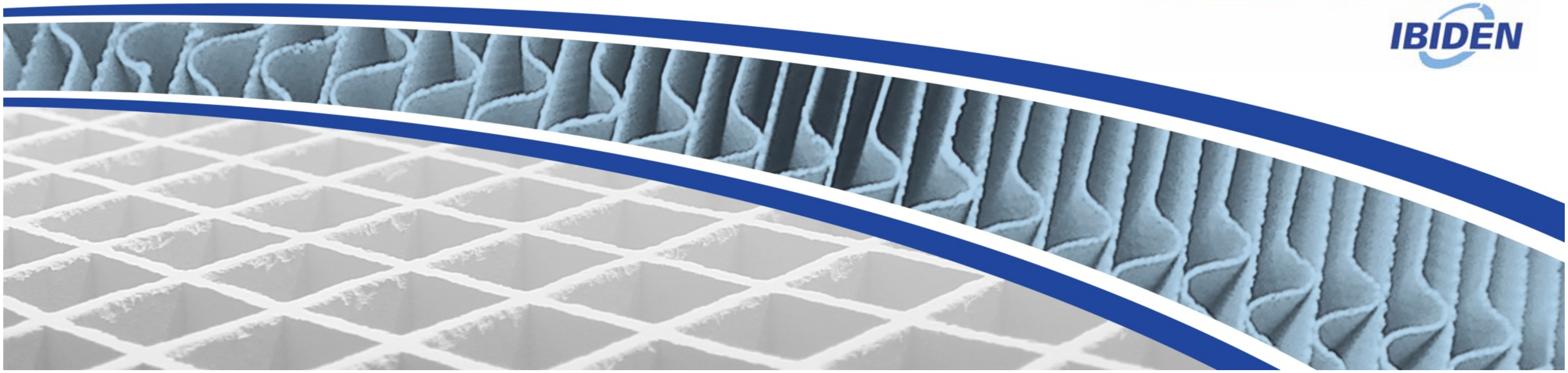
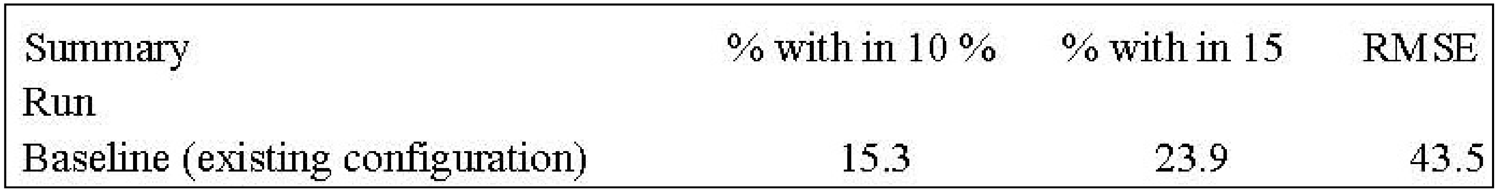


Bailly Unit 8 CFD Modeling Study – Goal of Study to Improve Flow Distribution

- CFD Modeling Performed by Fuel Tech, Inc.
- CFD Baseline Demonstrated High Velocity Distribution (Approx 43%)
  - Flue Gas Distribution Upstream of AIG = 100% of points within 15% of the mean
  - Flue Gas Distribution Upstream of Catalyst = 100% of points within 15% of the mean



Summary Run	% with in 10 %	% with in 15	RMSE
Baseline (existing configuration)	15.3	23.9	43.5

- Examine "Finger-Vanes" in Vertical Riser Duct; Ash Buildup On North Side of AIG; No Ash Buildup On South Side of AIG
- Dirty vs. Clean Vanes in Reactor Hood
- Ash Dropout East and Southeast Side of Reactor

FUEL TECH

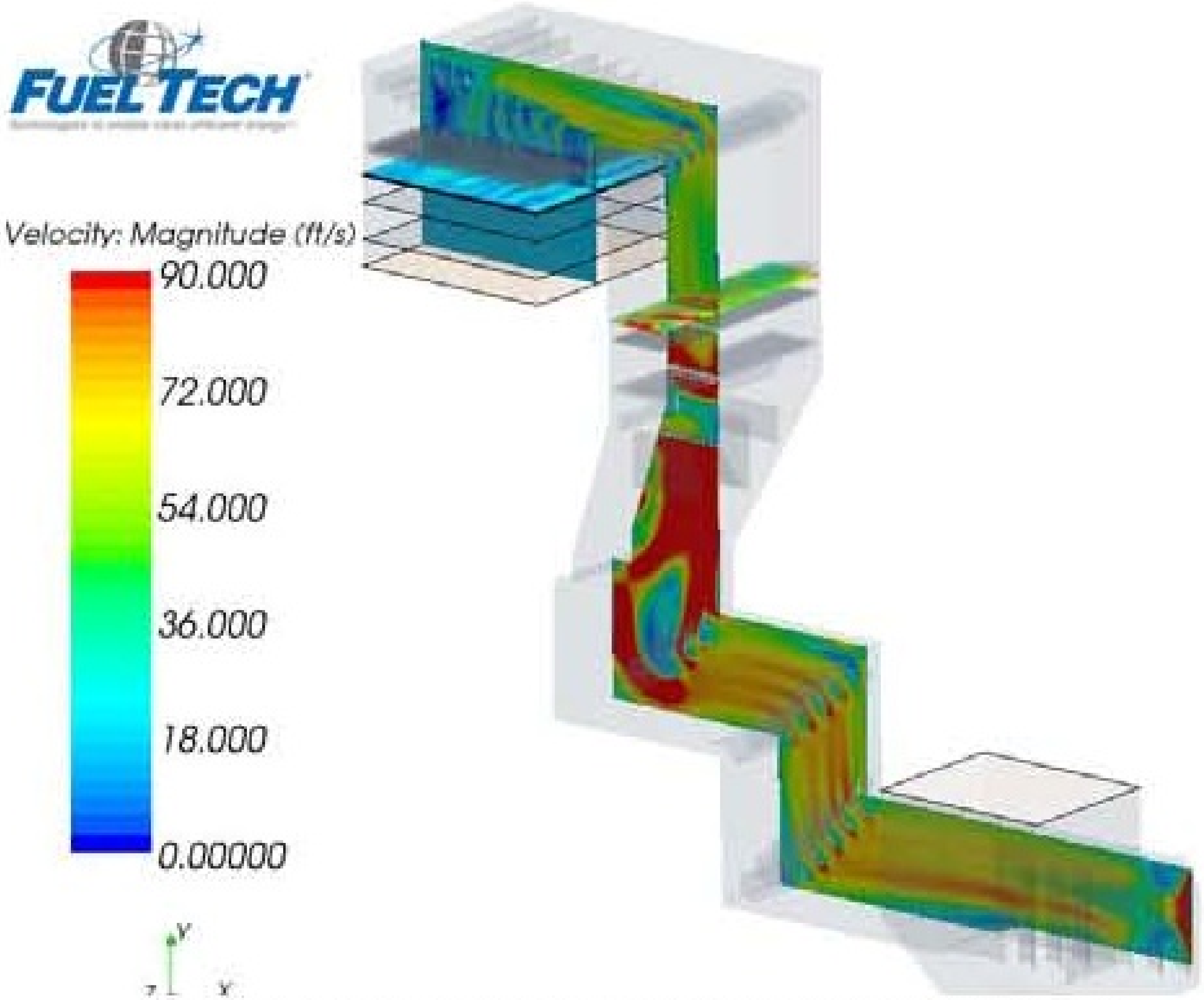


Figure 1: Baseline System Velocities

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Bailly Unit 8 CFD Modeling Study

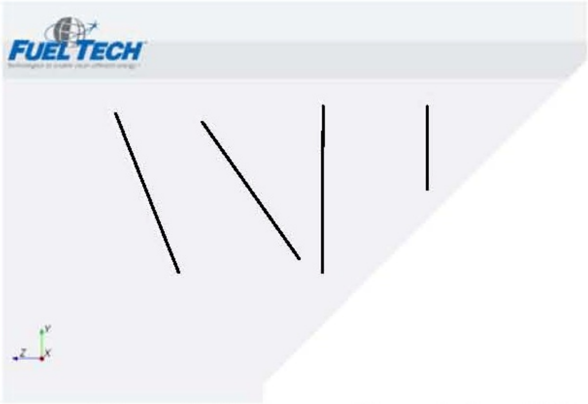


Figure 3: Expansion Vanes below AIG

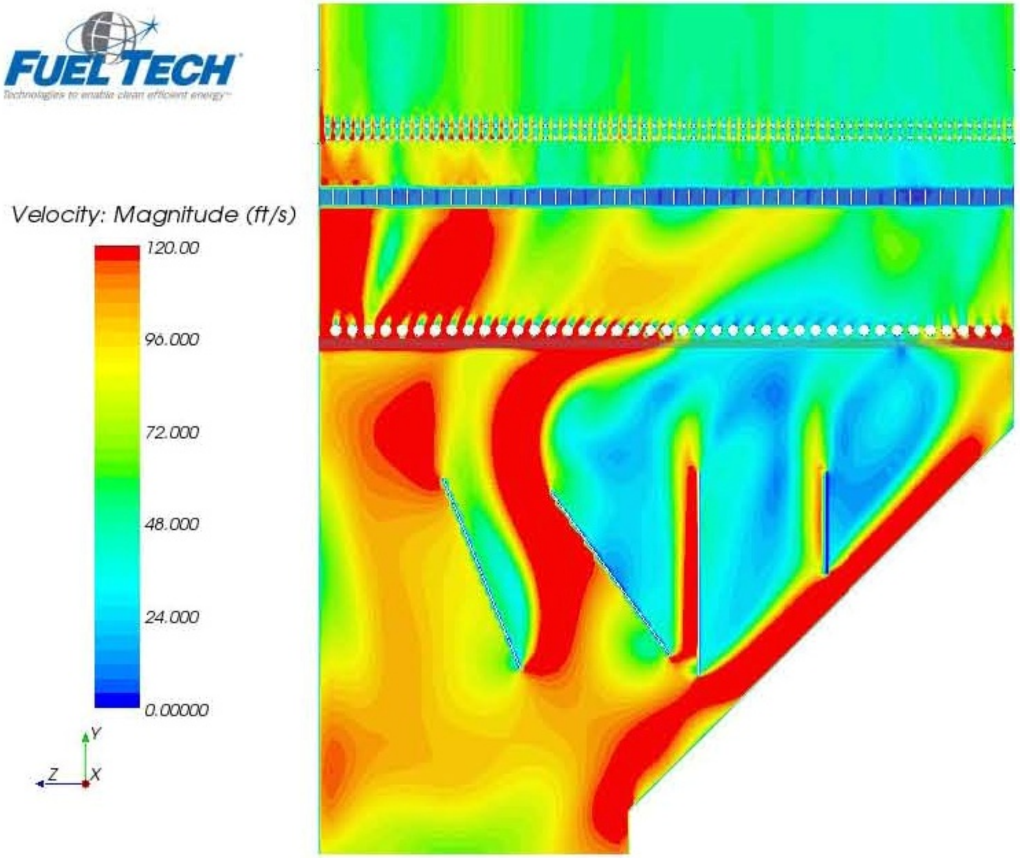


Figure 4: Velocities at Expansion Vanes Scale of 0 to 120 ft/s

Bailly Unit 8 CFD Modeling Study

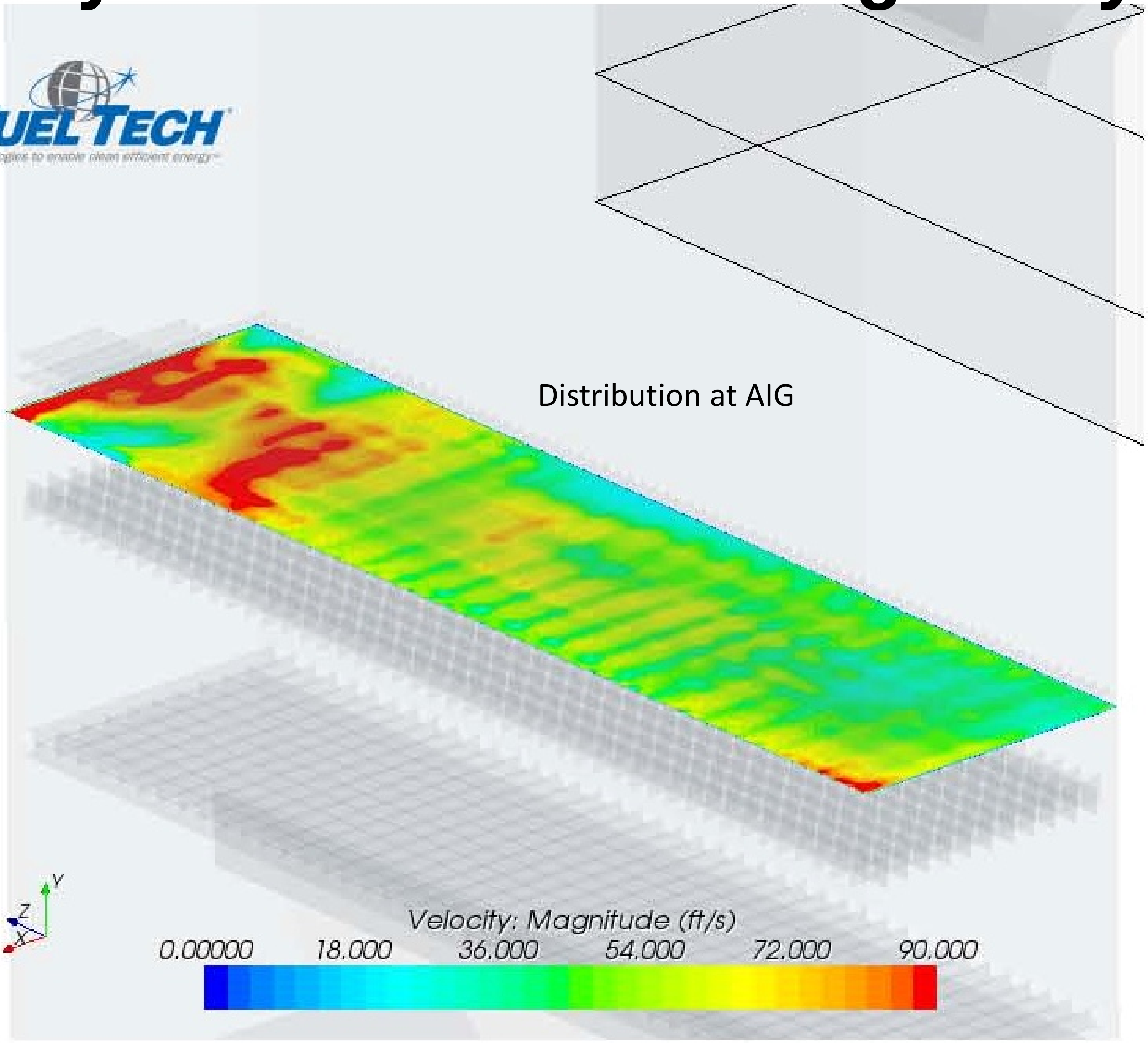
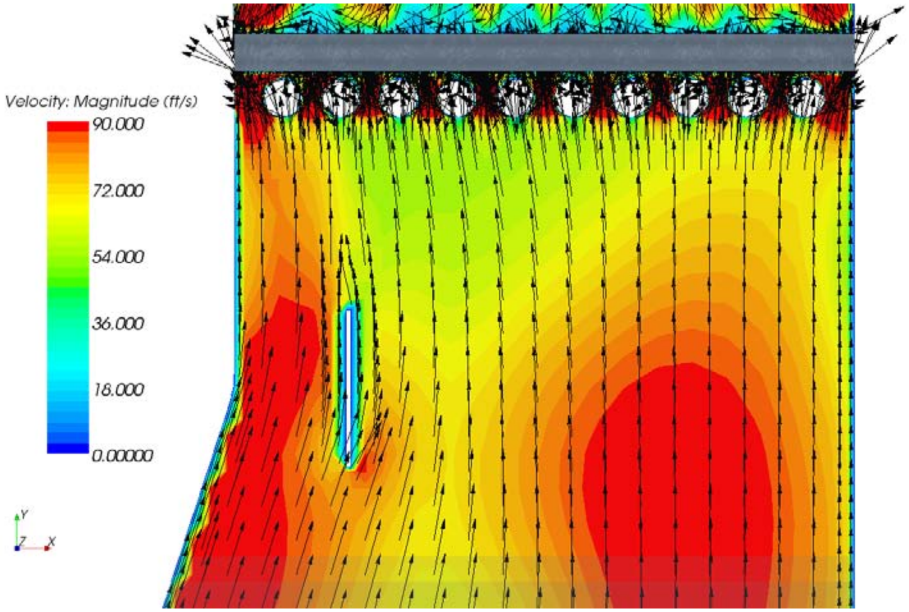


Figure 5: AIG Velocity Distribution

Bailly Unit 8 CFD Modeling Study



Bailly Unit 8 CFD Modeling Study

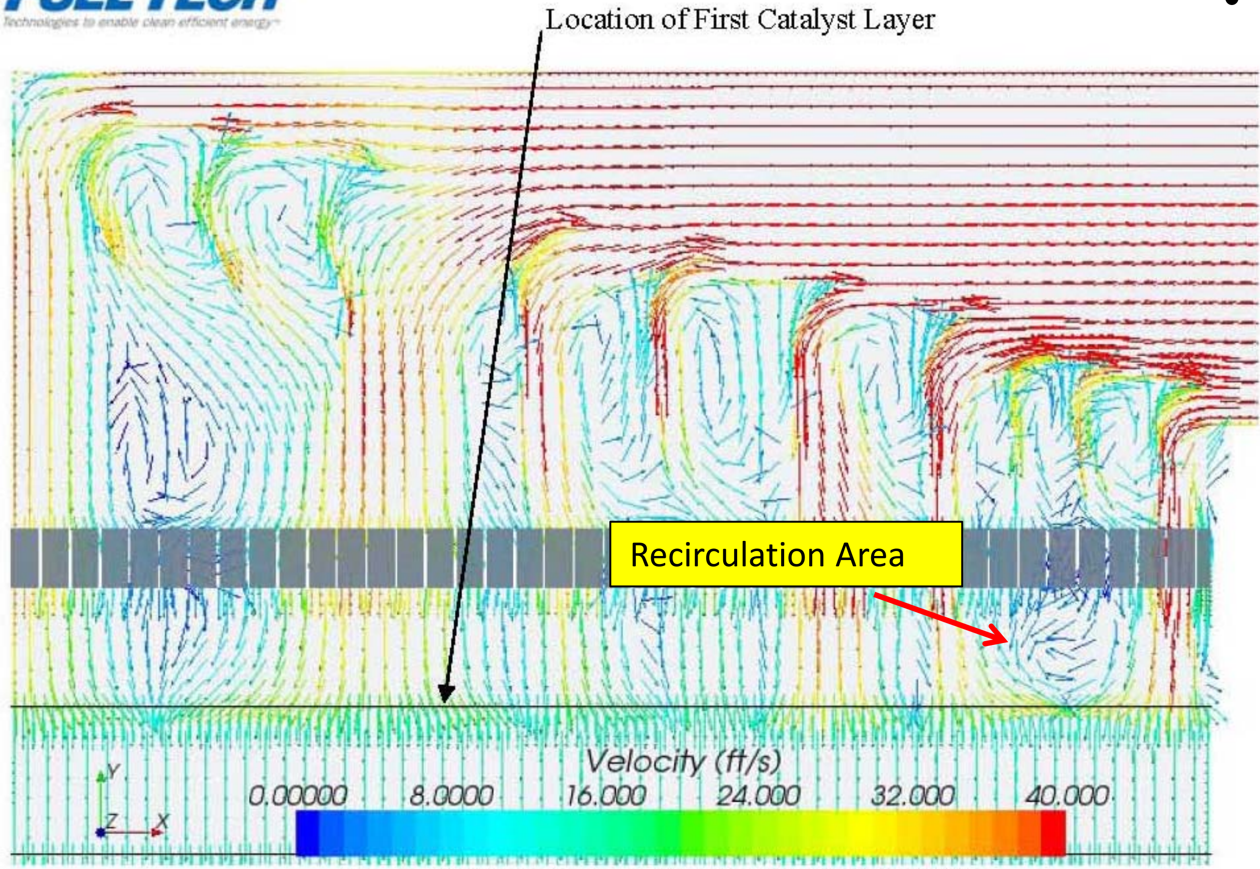
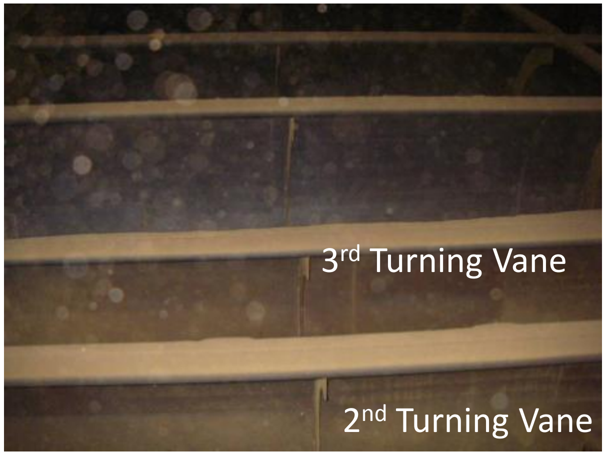


Figure 7: Vectors above Catalyst Scale 0 to 40 ft/s

- Flow Eddies Abundant Into L1 (Recirculation)



Bailly Unit 8 CFD Modeling Study

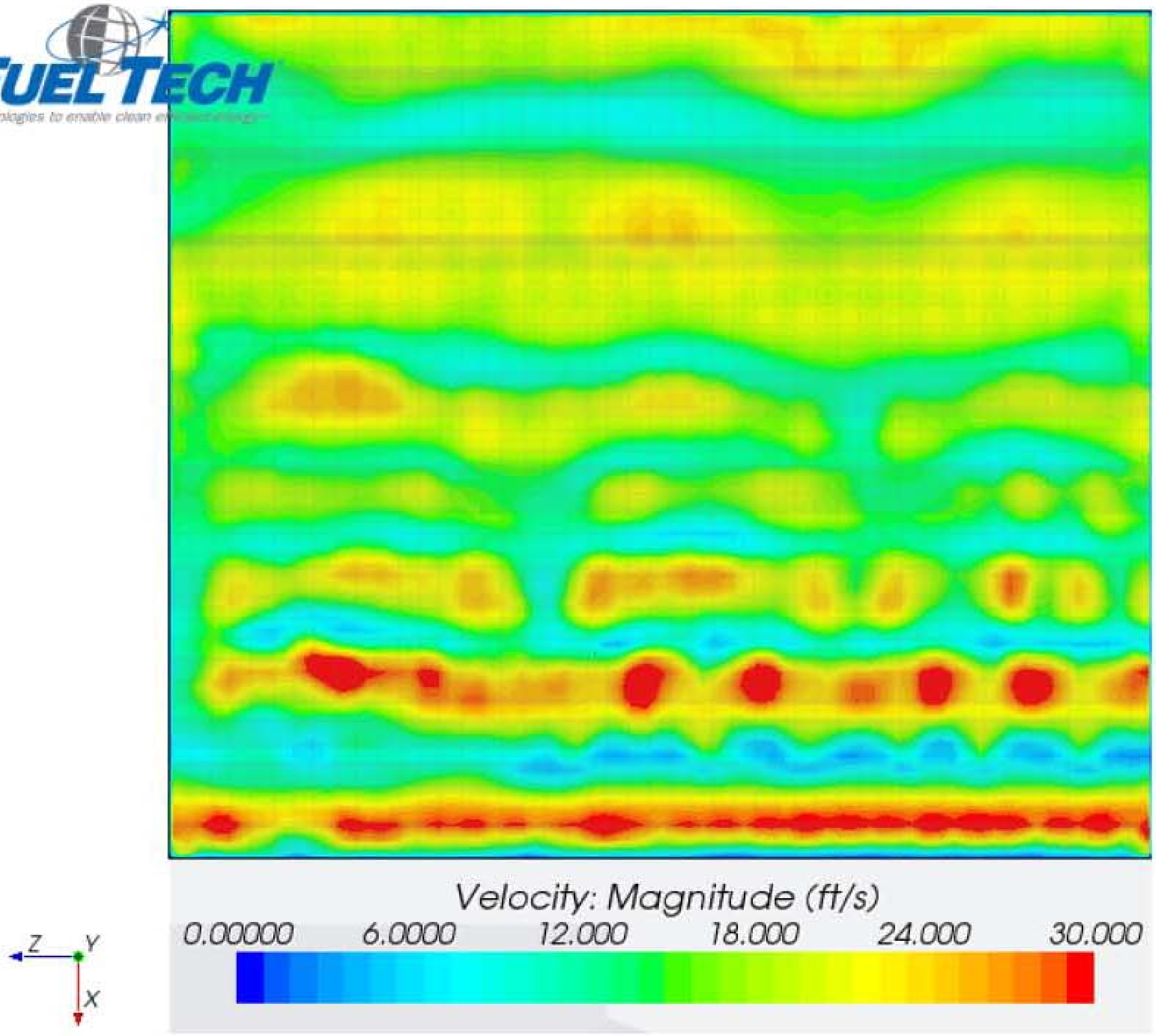


Figure 8: Velocity Distribution 6 inches above the Catalyst Face Scale 0 to 30ft

Bailly Unit 8 CFD Modeling Study

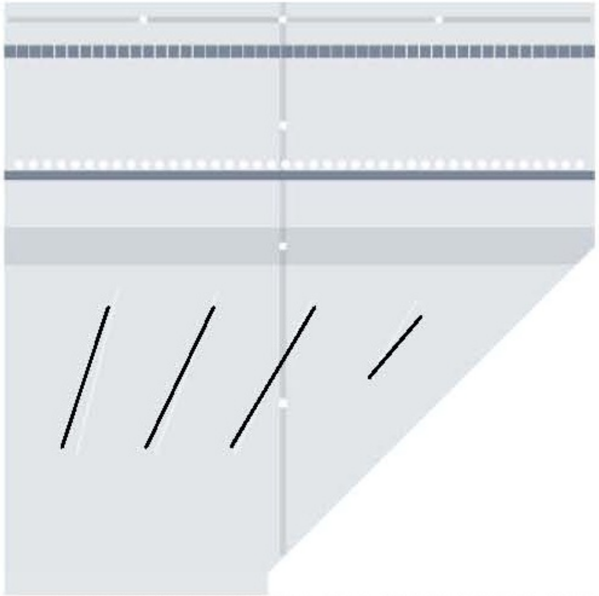


Figure 12: New Expansion Vane Geometry

- Relocated “Finger-Vanes” in Vertical Riser Duct

Figure 12: New Expansion Vane Geometry

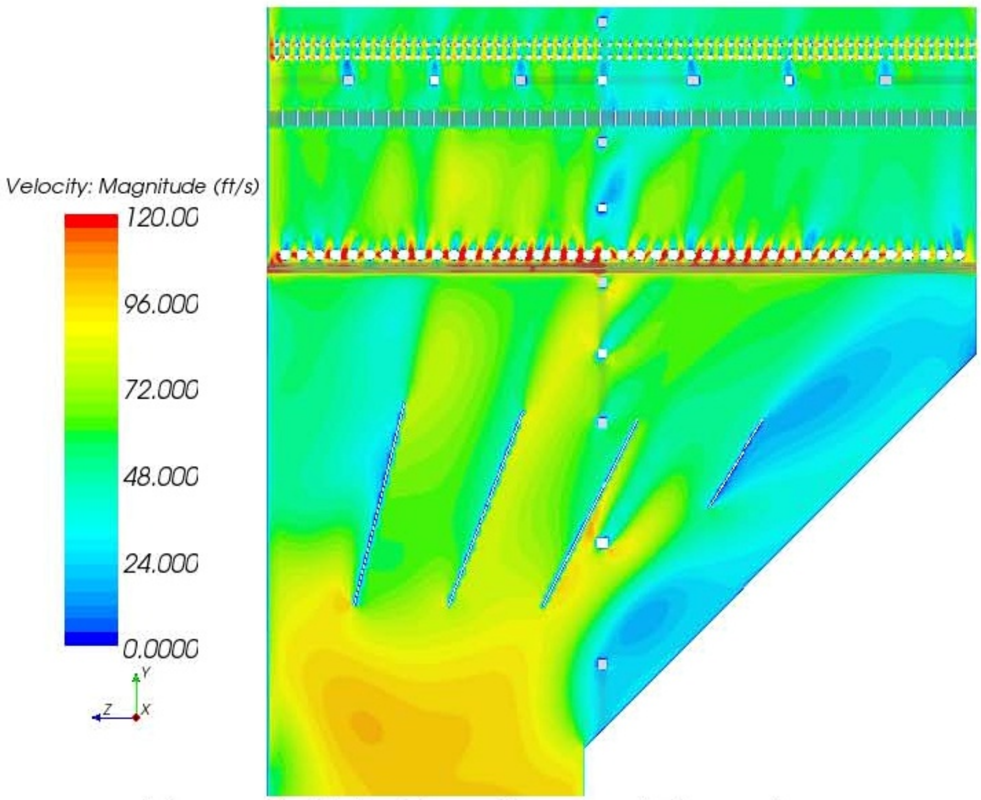


Figure 13: Velocities at Improved Expansion vanes

Bailly Unit 8 CFD Modeling Study

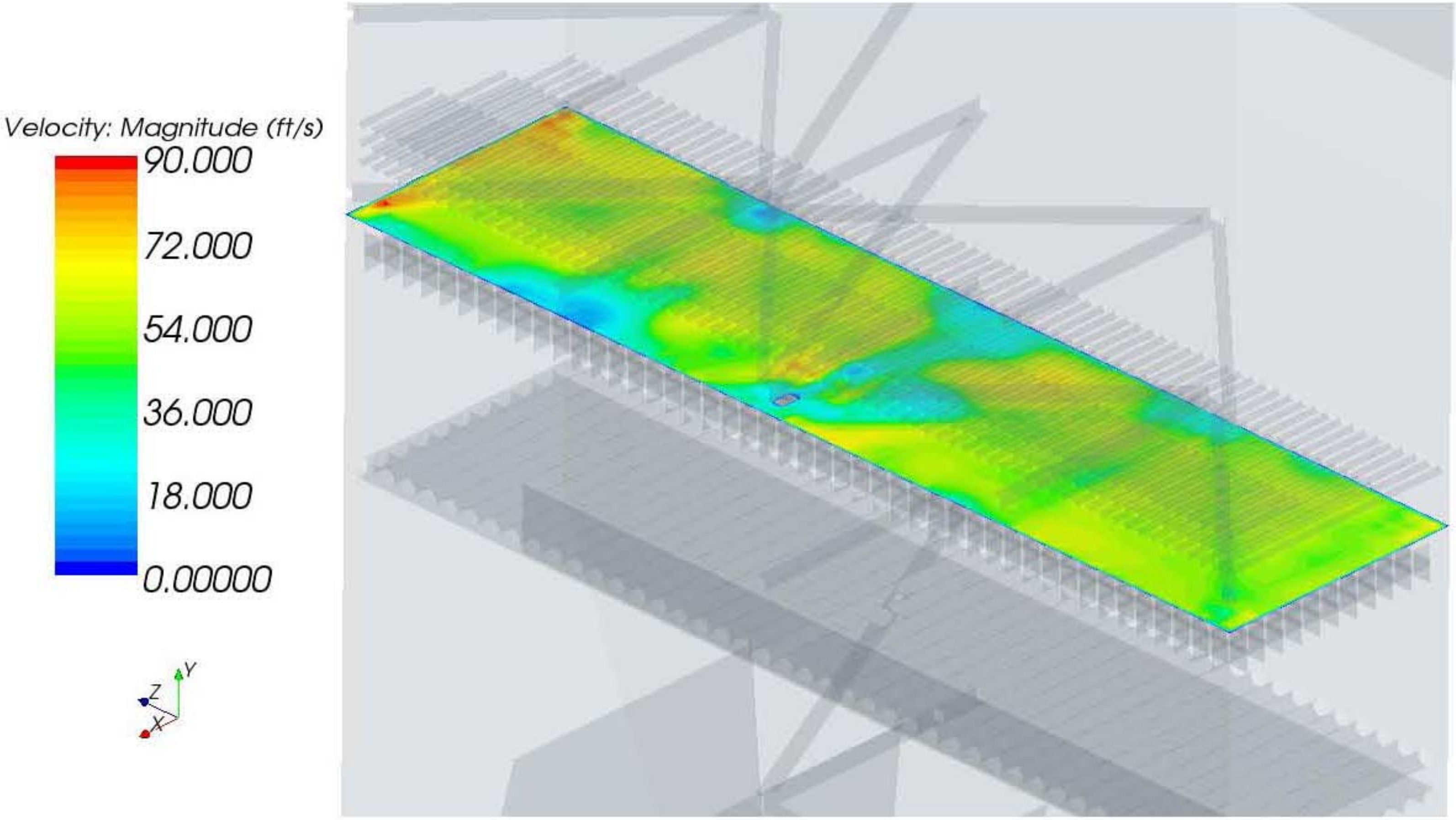
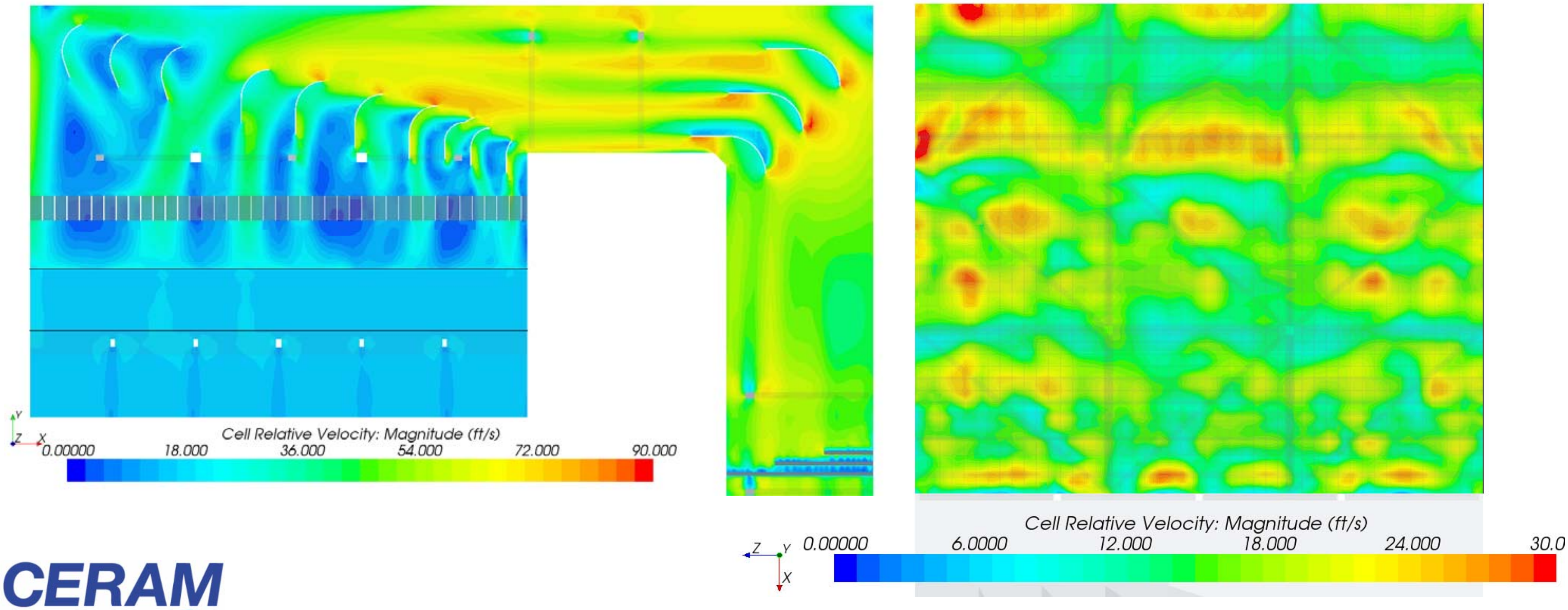


Figure 14: AIG Velocity Distribution

Bailly Unit 8 CFD Modeling Study

- Examined Change In Vanes Upstream of Crossover Duct
- High Velocity Exists That Sweeps Ash From Floor
- Relocated 2 Vanes; Improved Distribution By Minor Amount
- 35% of Points Within +/-15% of Average
- Expensive For Payback (Not Considered Any Further)



Bailly Unit 8 CFD Modeling Study

- Novel Solution: Trim 1st Vane and Extend 3rd Vane in Reactor Hood

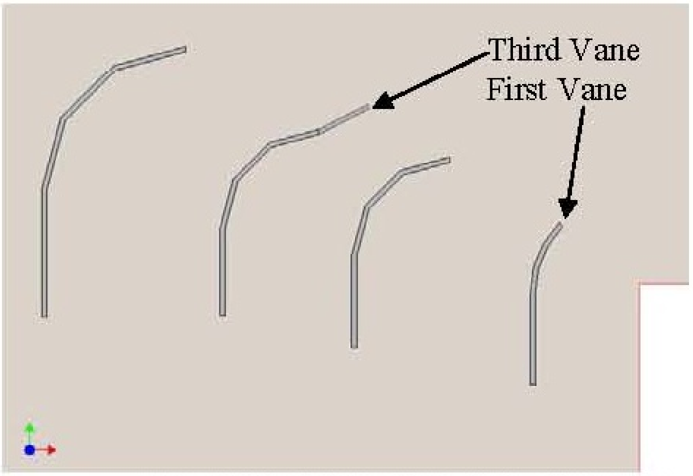


Figure 17: Vane Geometry Changes

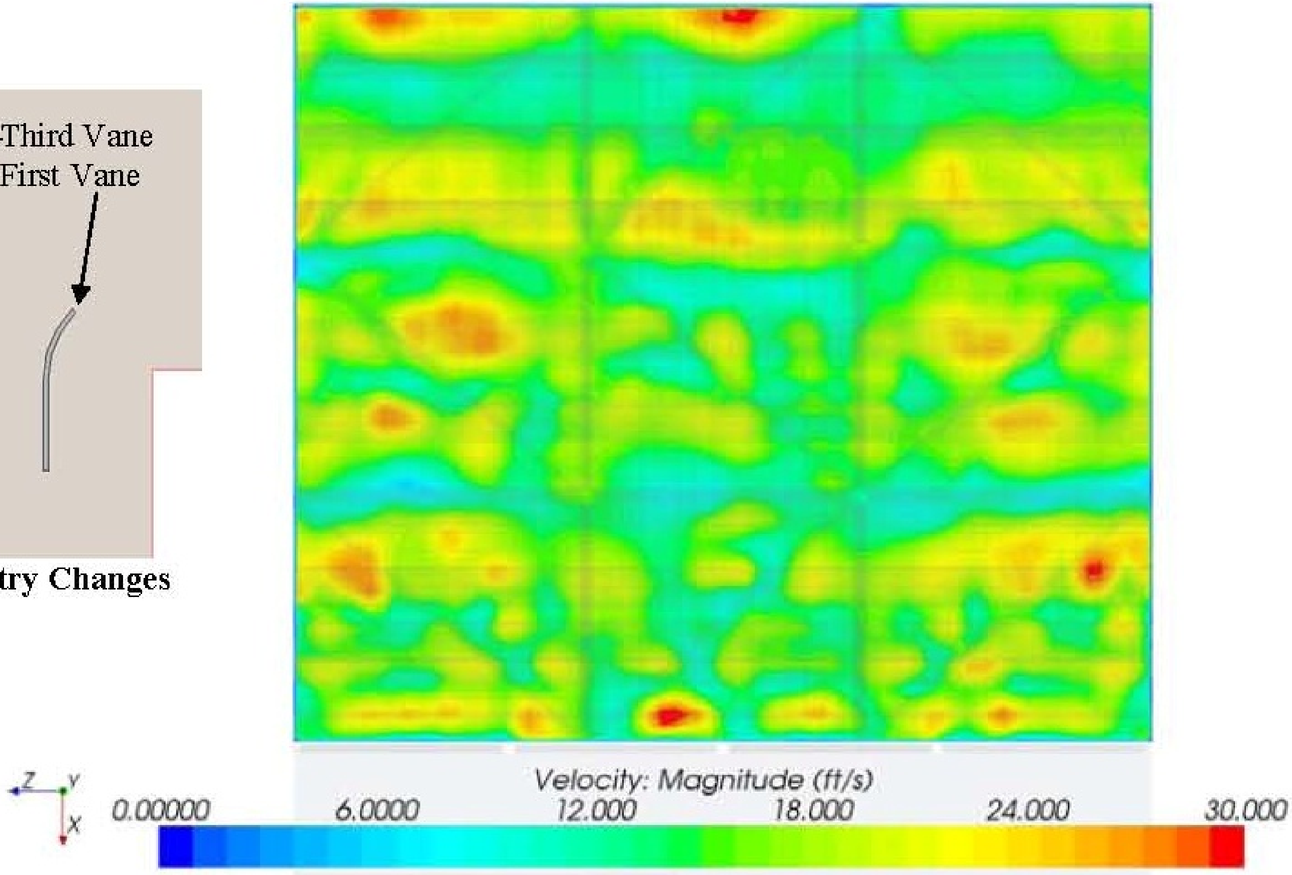


Figure 19: Velocity Distribution at Catalyst

Bailly Unit 8 CFD Modeling Study

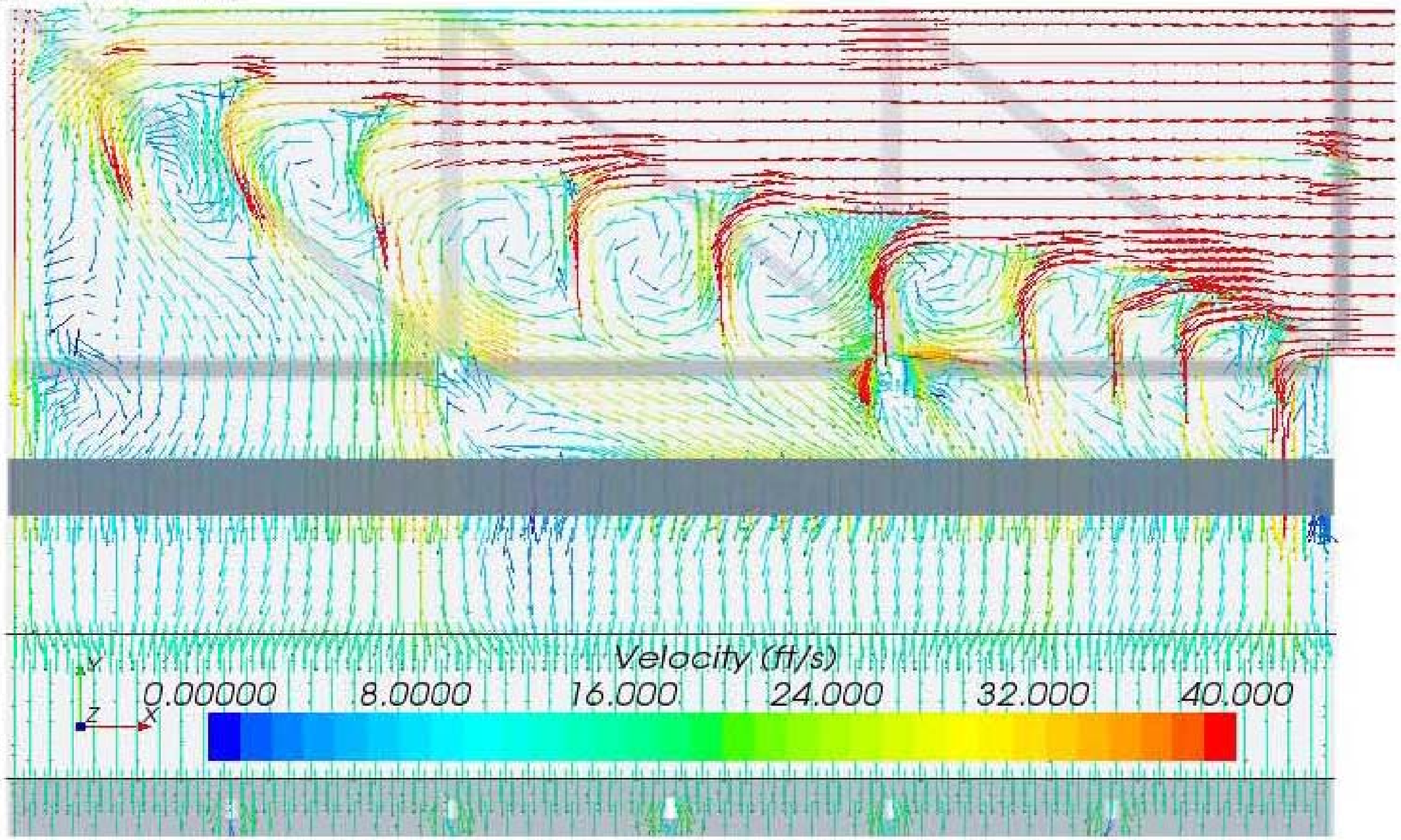


Figure 18: Vectors above Catalyst

Bailly Unit 8 CFD Modeling Study

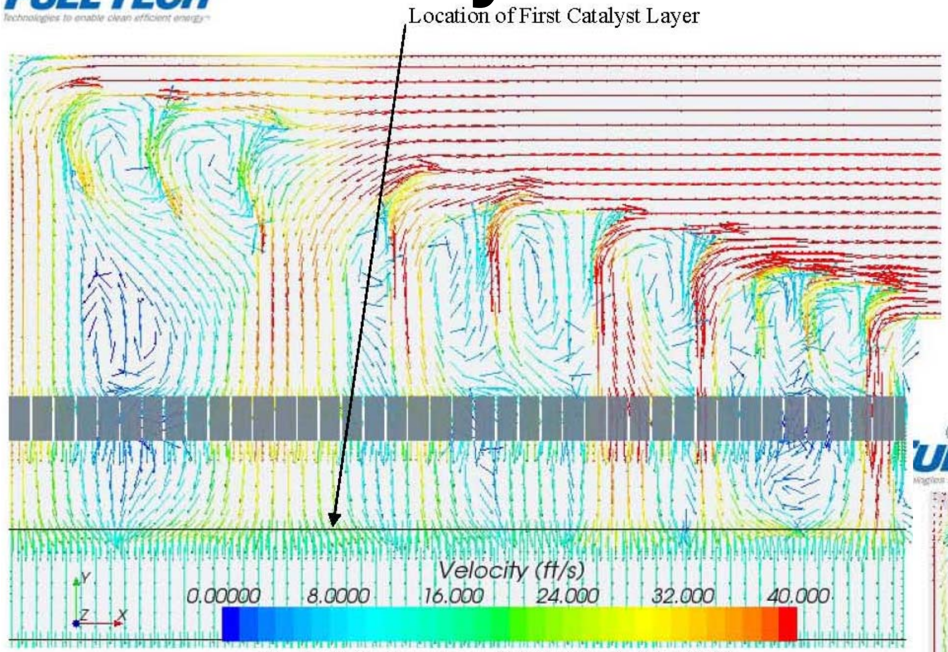


Figure 7: Vectors above Catalyst Scale 0 to 40 ft/s

Baseline

With Vane Modifications

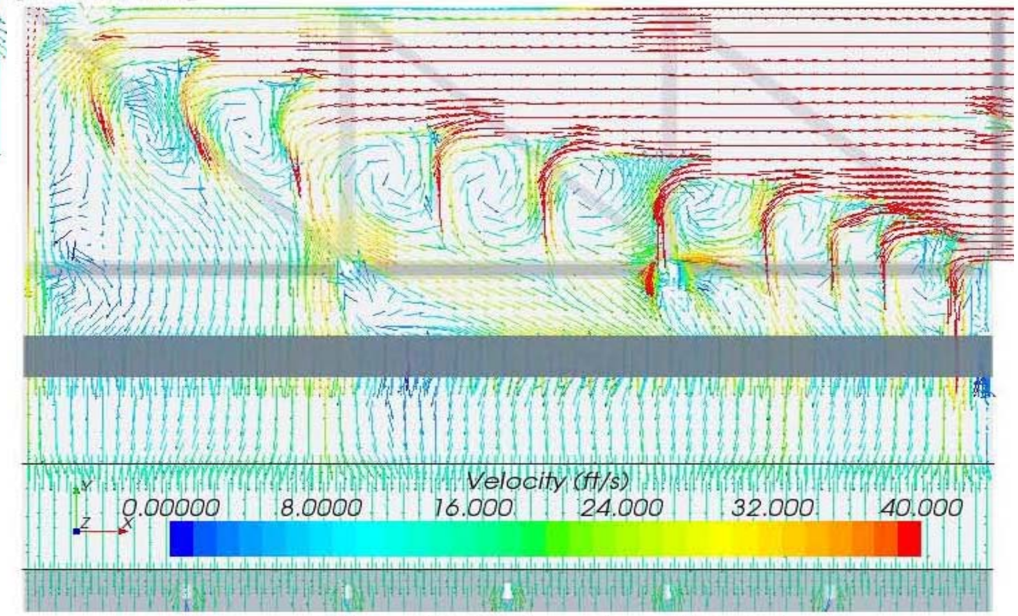
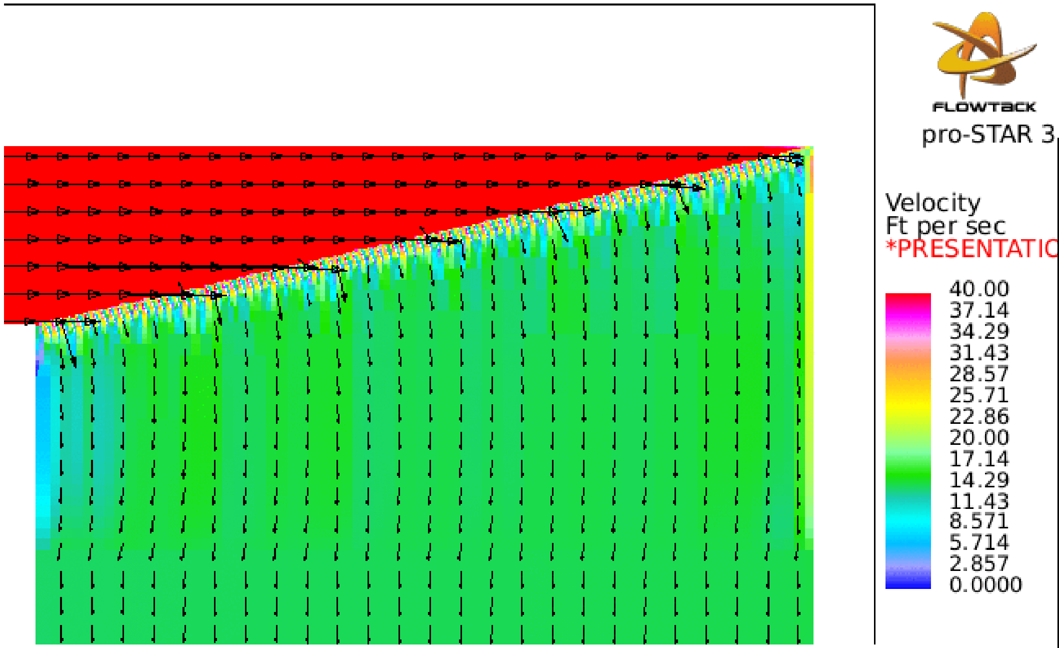


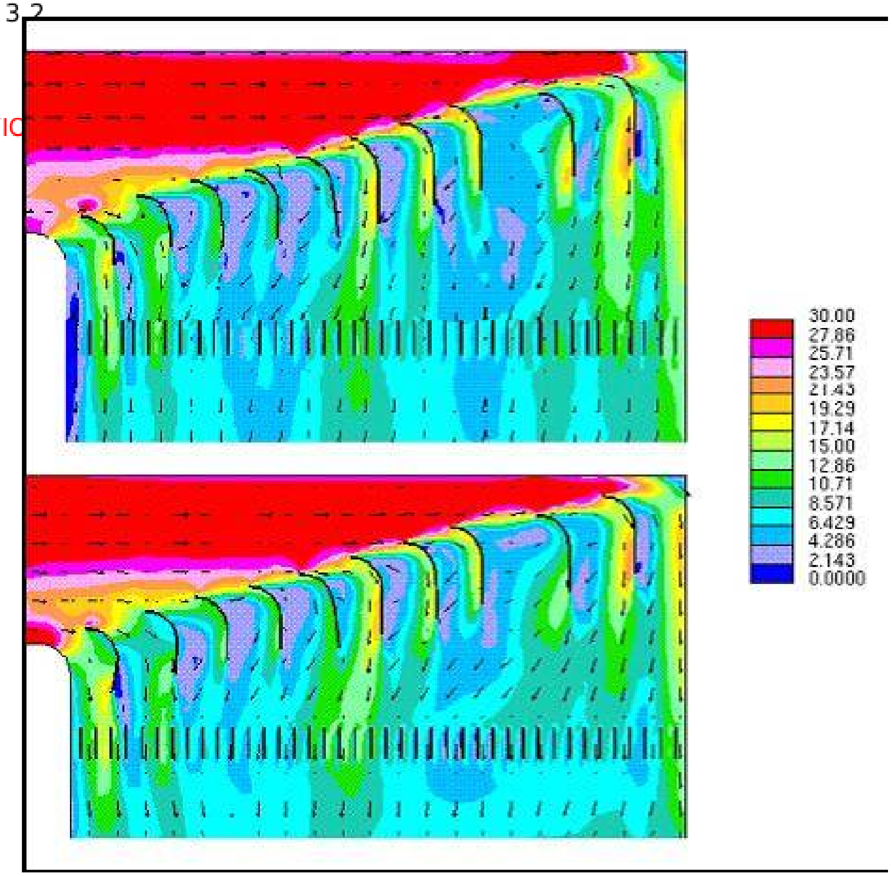
Figure 18: Vectors above Catalyst

Recirculation Area Removed

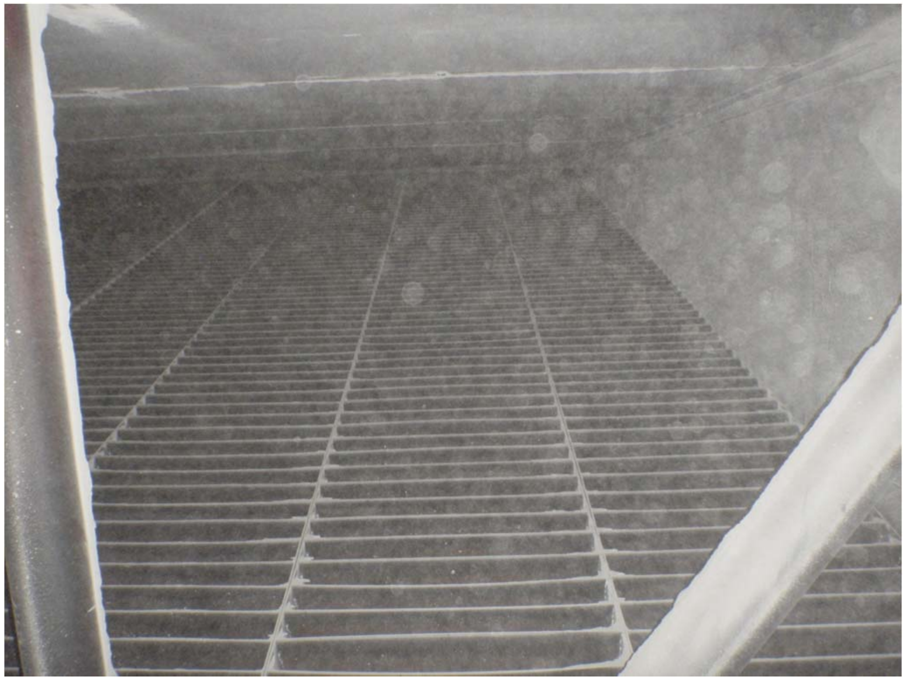
Example of GSG from CFD Modeling

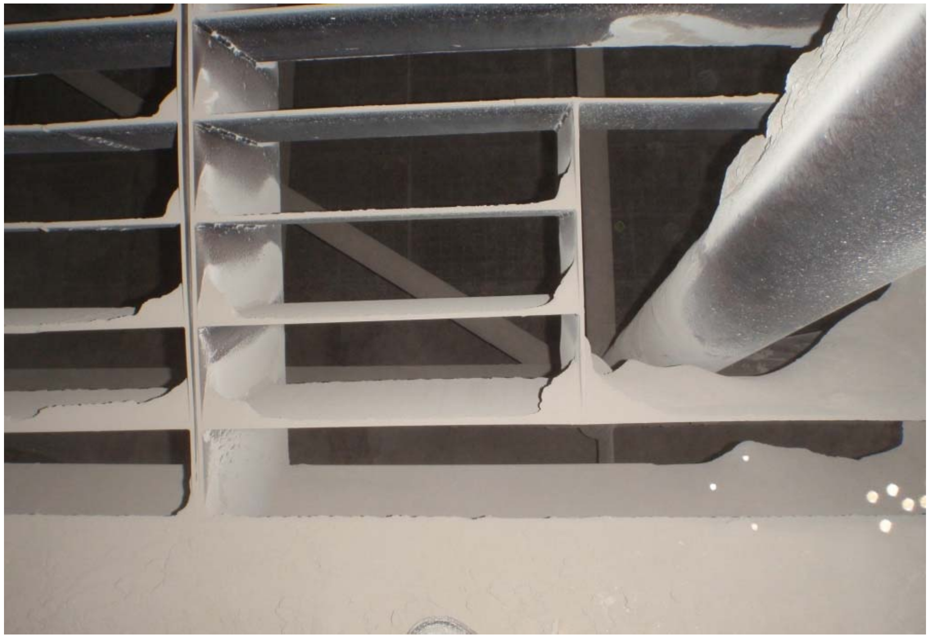


GSG = Graduated Straightening Grid
Patent Pending by Fuel Tech



Example of GSG from PRB Fired Unit

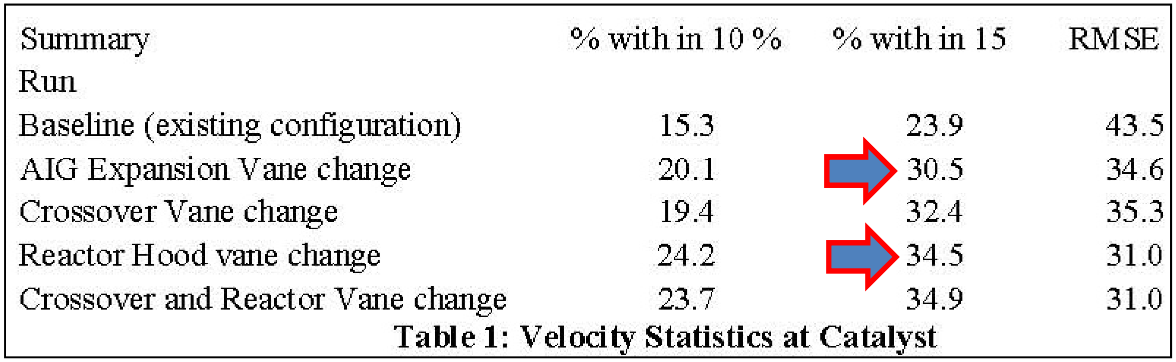




GSG = Graduated Straightening Grid
Patent Pending by Fuel Tech

Bailly Unit 8 CFD Modeling Study – Goal of Study to Improve Flow Distribution

- CFD Modeling Performed by Fuel Tech, Inc.
- CFD Baseline Demonstrated High Velocity Distribution (Approx 43.5%)
  - Flue Gas Distribution Upstream AIG = 100% of points within 15% of mean
  - Flue Gas Distribution Upstream Catalyst = 100% of points within 15% of mean
- Relocated "Finger-Vanes" in Vertical Riser Duct
- Trim 1st Vane and Extend 3rd Vane in Reactor Hood ("Economical Solution")
- Relocate Greater Number of Vanes or Install Graduated Straightening Grid (GSG) or Similar Device (Options Results in Substantial Cost Increase)
- Low Load Checked & CFD Showed No Issues



Summary Run	% with in 10 %	% with in 15	RMSE
Baseline (existing configuration)	15.3	23.9	43.5
AIG Expansion Vane change	20.1	➡ 30.5	34.6
Crossover Vane change	19.4	32.4	35.3
Reactor Hood vane change	24.2	➡ 34.5	31.0
Crossover and Reactor Vane change	23.7	34.9	31.0

Table 1: Velocity Statistics at Catalyst

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Bailly Unit 8 Inspection Results Overview

- Avg pluggage L1 = 5% (9.2 mm; 17.2k hrs), L2 pluggage = 3% (8.2 mm; 8k hrs), L3 pluggage = >25% (6.7 mm; 35.4k hrs) (L3 Removed in Fall 2012)
  - Larger Pitch Effective in Mitigating Pluggage in Combination to Guide Vane Modifications Upstream of AIG and Reactor Hood
- Top 9.2 mm Acting as Catalyst/Flow Rectifier. 1-2 ft Piles Observed L1 Northwest Corner For First Time (Approx. 17,200 hrs)
- Large Particle Ash (LPA) Observed On L1 and L2
  - LPA Screen Sections Are Worn (Replacement Recommended)
  - LPA Screen; “Fixed” Into Position & Does Not Move
- Unburned Carbon Observed in Reactor
- Fly Ash Piles (3-4 ft) observed on L3 (East side and NW side); L3 Removed
- Fly Ash Buildup Minor North Side of AIG Lances
- Erosion On East Side of L1 Due to High Velocities & Off Axis Velocity Vectors; Examine CFD Results For Solution

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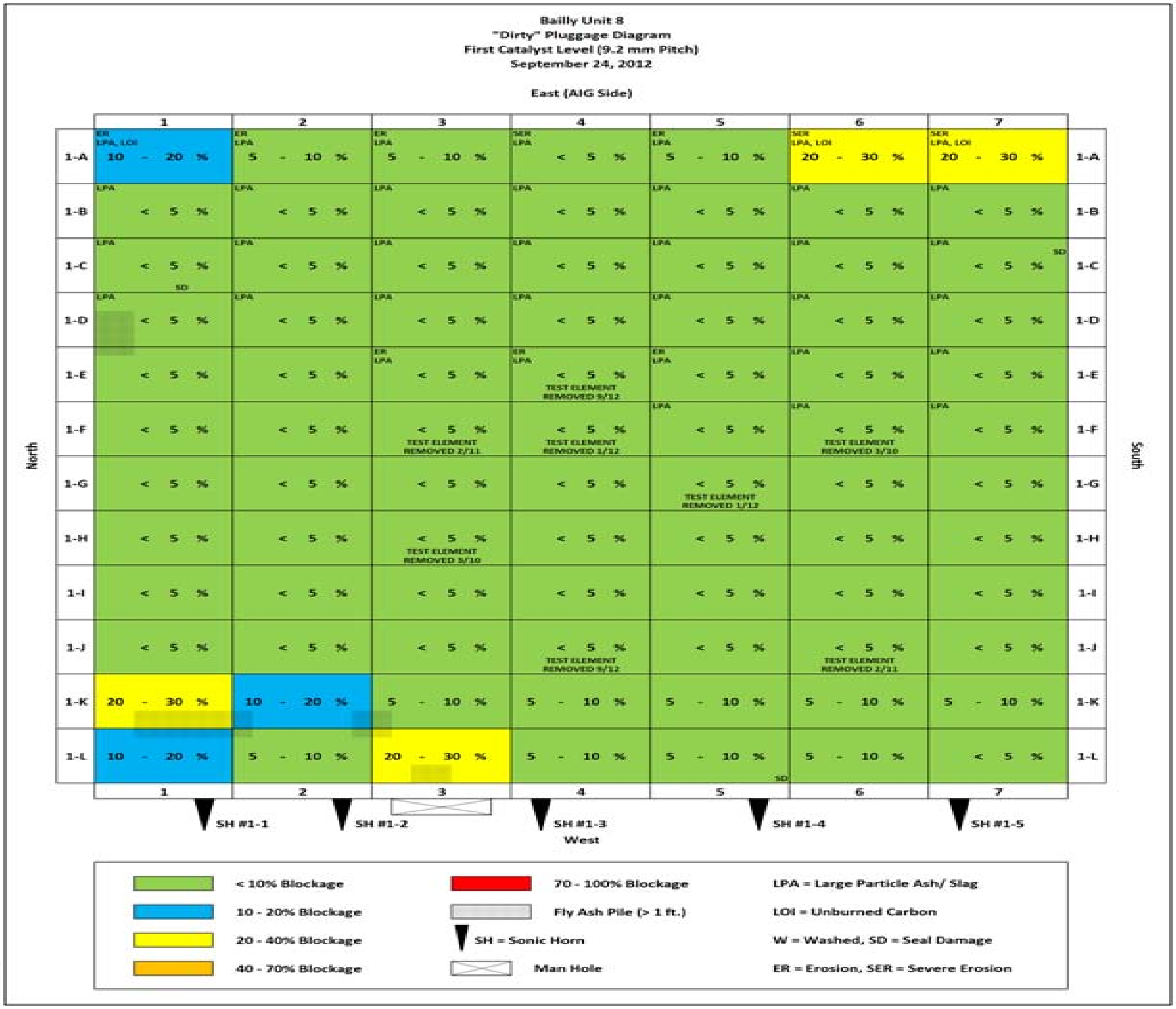
Bailly Unit 8 Reactor Inspection



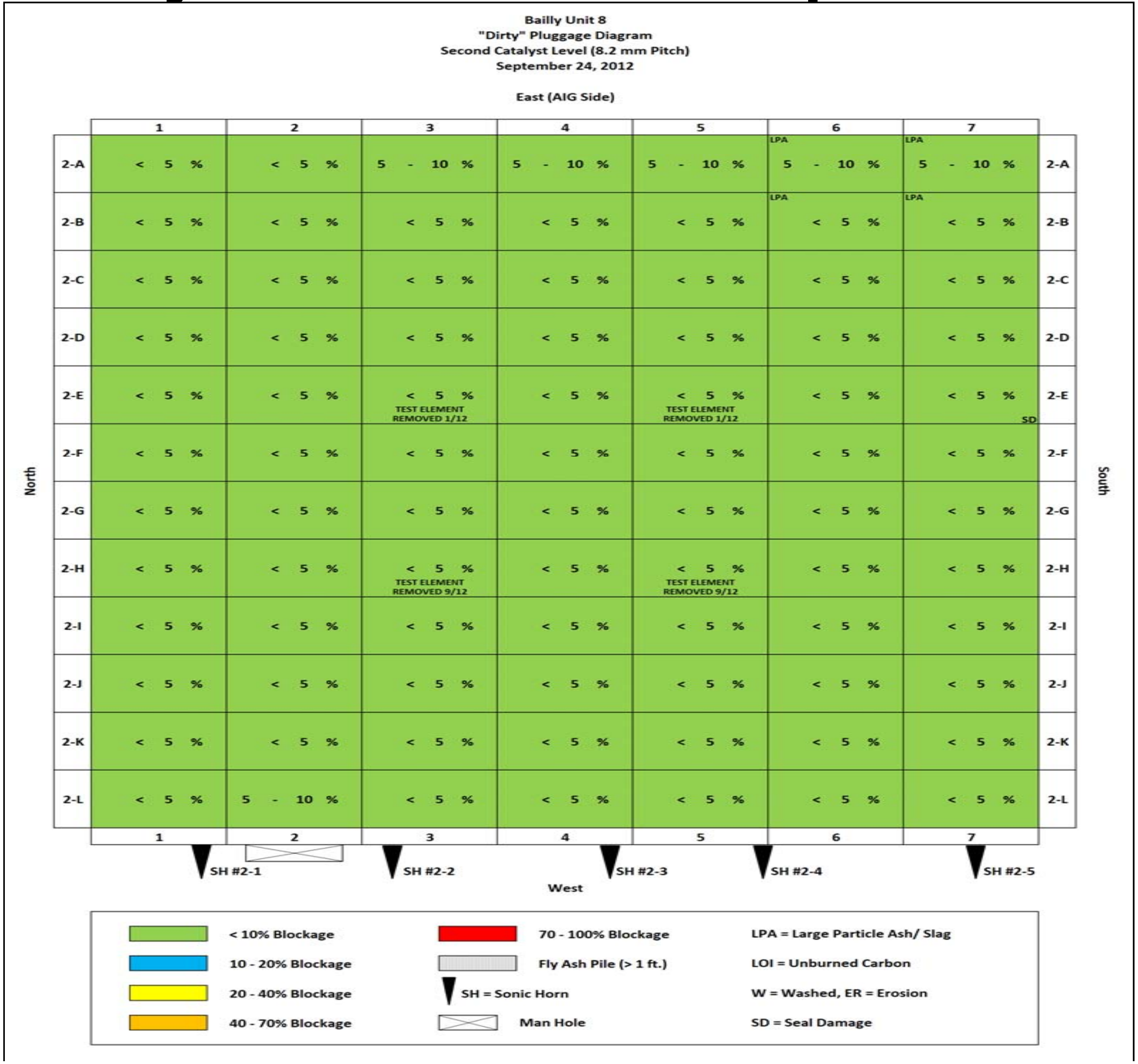
Bailly Unit 8
"Dirty" Pluggage Diagram
First Catalyst Level (9.2 mm Pitch)
September 24, 2012

East (AIG Side)

	1	2	3	4	5	6	7	
1-A	ER LPA, LOI 10 - 20 %	ER LPA 5 - 10 %	ER LPA 5 - 10 %	SER LPA < 5 %	ER LPA 5 - 10 %	SER LPA, LOI 20 - 30 %	SER LPA, LOI 20 - 30 %	1-A
1-B	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	1-B
1-C	LPA < 5 % SD	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA SD < 5 %	1-C
1-D	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	LPA < 5 %	1-D
1-E	< 5 %	< 5 %	ER LPA < 5 %	ER LPA < 5 % TEST ELEMENT REMOVED 9/12	ER LPA < 5 %	LPA < 5 %	LPA < 5 %	1-E
1-F	< 5 %	< 5 %	< 5 % TEST ELEMENT REMOVED 2/11	< 5 % TEST ELEMENT REMOVED 1/12	LPA < 5 %	LPA < 5 % TEST ELEMENT REMOVED 3/10	LPA < 5 %	1-F
1-G	< 5 %	< 5 %	< 5 %	< 5 %	< 5 % TEST ELEMENT REMOVED 1/12	< 5 %	< 5 %	1-G
1-H	< 5 %	< 5 %	< 5 % TEST ELEMENT REMOVED 3/10	< 5 %	< 5 %	< 5 %	< 5 %	1-H
1-I	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	1-I
1-J	< 5 %	< 5 %	< 5 %	< 5 % TEST ELEMENT REMOVED 9/12	< 5 %	< 5 % TEST ELEMENT REMOVED 2/11	< 5 %	1-J
1-K	20 - 30 %	10 - 20 %	5 - 10 %	5 - 10 %	5 - 10 %	5 - 10 %	5 - 10 %	1-K
1-L	10 - 20 %	5 - 10 %	20 - 30 %	5 - 10 %	5 - 10 % SD	5 - 10 %	< 5 %	1-L
	1	2	3	4	5	6	7	

🟩 < 10% Blockage
🟦 10 - 20% Blockage
🟨 20 - 40% Blockage
🟧 40 - 70% Blockage
🟥 70 - 100% Blockage
⬜ Fly Ash Pile (> 1 ft.)
▼ SH = Sonic Horn
☒ Man Hole
LPA = Large Particle Ash/ Slag
LOI = Unburned Carbon
W = Washed, SD = Seal Damage
ER = Erosion, SER = Severe Erosion

Bailly Unit 8 Reactor Inspection



Bailly Unit 8
"Dirty" Pluggage Diagram
Second Catalyst Level (8.2 mm Pitch)
September 24, 2012

East (AIG Side)

North

	1	2	3	4	5	6	7	
2-A	< 5 %	< 5 %	5 - 10 %	5 - 10 %	5 - 10 %	LPA 5 - 10 %	LPA 5 - 10 %	2-A
2-B	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	LPA < 5 %	LPA < 5 %	2-B
2-C	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	2-C
2-D	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	2-D
2-E	< 5 %	< 5 %	< 5 % TEST ELEMENT REMOVED 1/12	< 5 %	< 5 % TEST ELEMENT REMOVED 1/12	< 5 %	< 5 % SD	2-E
2-F	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	2-F
2-G	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	2-G
2-H	< 5 %	< 5 %	< 5 % TEST ELEMENT REMOVED 9/12	< 5 %	< 5 % TEST ELEMENT REMOVED 9/12	< 5 %	< 5 %	2-H
2-I	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	2-I
2-J	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	2-J
2-K	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	2-K
2-L	< 5 %	5 - 10 %	< 5 %	< 5 %	< 5 %	< 5 %	< 5 %	2-L
	1	2	3	4	5	6	7	

South

West

🟩 < 10% Blockage	🟥 70 - 100% Blockage	LPA = Large Particle Ash/ Slag
🟦 10 - 20% Blockage	▨ Fly Ash Pile (> 1 ft.)	LOI = Unburned Carbon
🟨 20 - 40% Blockage	▼ SH = Sonic Horn	W = Washed, ER = Erosion
🟧 40 - 70% Blockage	☒ Man Hole	SD = Seal Damage

Bailly Unit 8 Reactor Inspection

Bailly Unit 8
"Clean" Pluggage Diagram by NIPSCO
First Catalyst Level (9.2 mm Pitch)
October 23, 2012

East (AIG Side)

North — South

	1	2	3	4	5	6	7	
1-A	ER LPA, LOI 5 %	ER LPA 5 %	ER LPA 5 %	SER LPA 5 %	ER LPA 2 %	SER LPA, LOI 7 %	SER LPA, LOI 10 %	1-A
1-B	LPA 5 %	LPA 2 %	LPA 2 %	LPA 2 %	LPA 2 %	LPA 2 %	LPA 5 %	1-B
1-C	LPA 2 % SD	LPA 2 %	LPA 2 %	LPA 2 %	LPA 2 %	LPA 2 %	LPA SD 2 %	1-C
1-D	LPA 2 %	LPA 2 %	LPA 2 %	LPA 2 %	LPA 2 %	LPA 2 %	LPA 2 %	1-D
1-E	2 %	2 %	ER LPA 2 %	ER LPA 2 % TEST ELEMENT REMOVED 9/12	ER LPA 2 %	LPA 2 %	LPA 2 %	1-E
1-F	2 %	2 %	2 % TEST ELEMENT REMOVED 2/11	2 % TEST ELEMENT REMOVED 1/12	LPA 2 %	LPA 2 % TEST ELEMENT REMOVED 3/10	LPA 2 %	1-F
1-G	2 %	2 %	2 %	2 %	2 % TEST ELEMENT REMOVED 1/12	2 %	2 %	1-G
1-H	2 %	2 %	2 % TEST ELEMENT REMOVED 3/10	2 %	2 %	2 %	2 %	1-H
1-I	2 %	2 %	2 %	2 %	2 %	2 %	2 %	1-I
1-J	2 %	2 %	2 %	2 % TEST ELEMENT REMOVED 9/12	2 %	2 % TEST ELEMENT REMOVED 2/11	2 %	1-J
1-K	10 %	2 %	2 %	5 %	5 %	2 %	5 %	1-K
1-L	5 %	2 %	2 %	5 %	2 % SD	2 %	5 %	1-L
	1	2	3	4	5	6	7	

West

🟩 < 10% Blockage
🟦 10 - 20% Blockage
🟨 20 - 40% Blockage
🟧 40 - 70% Blockage
🟥 70 - 100% Blockage
▨ Fly Ash Pile (> 1 ft.)
▼ SH = Sonic Horn
☒ Man Hole
LPA = Large Particle Ash/ Slag
LOI = Unburned Carbon
W = Washed, SD = Seal Damage
ER = Erosion, SER = Severe Erosion

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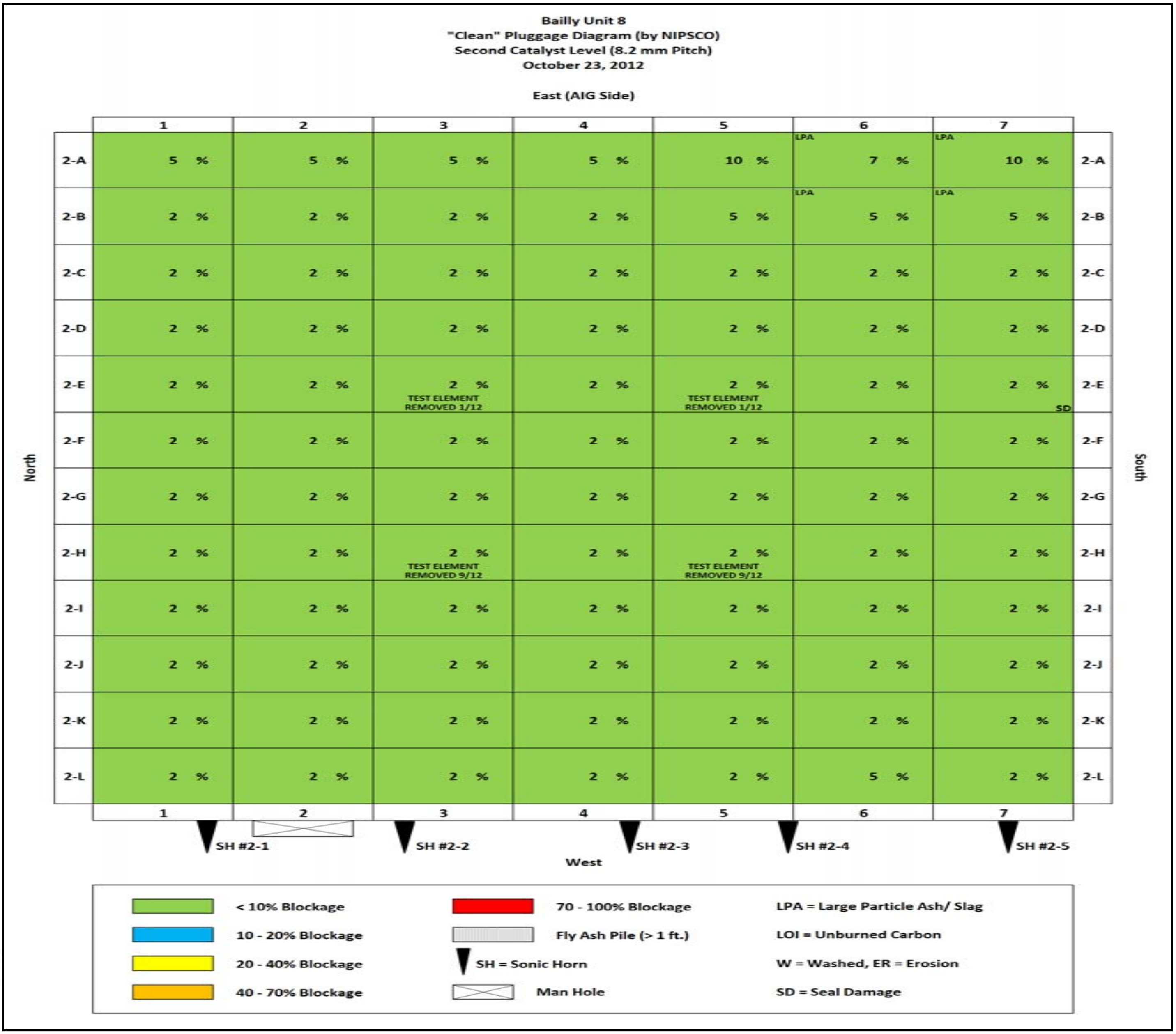
Bailly Unit 8 Reactor Inspection



Bailly Unit 8
"Clean" Pluggage Diagram (by NIPSCO)
Second Catalyst Level (8.2 mm Pitch)
October 23, 2012

East (AIG Side)

	1	2	3	4	5	6	7	
2-A	5 %	5 %	5 %	5 %	10 %	LPA 7 %	LPA 10 %	2-A
2-B	2 %	2 %	2 %	2 %	5 %	LPA 5 %	LPA 5 %	2-B
2-C	2 %	2 %	2 %	2 %	2 %	2 %	2 %	2-C
2-D	2 %	2 %	2 %	2 %	2 %	2 %	2 %	2-D
2-E	2 %	2 %	2 % TEST ELEMENT REMOVED 1/12	2 %	2 % TEST ELEMENT REMOVED 1/12	2 %	2 % SD	2-E
2-F	2 %	2 %	2 %	2 %	2 %	2 %	2 %	2-F
2-G	2 %	2 %	2 %	2 %	2 %	2 %	2 %	2-G
2-H	2 %	2 %	2 % TEST ELEMENT REMOVED 9/12	2 %	2 % TEST ELEMENT REMOVED 9/12	2 %	2 %	2-H
2-I	2 %	2 %	2 %	2 %	2 %	2 %	2 %	2-I
2-J	2 %	2 %	2 %	2 %	2 %	2 %	2 %	2-J
2-K	2 %	2 %	2 %	2 %	2 %	2 %	2 %	2-K
2-L	2 %	2 %	2 %	2 %	2 %	5 %	2 %	2-L
	1	2	3	4	5	6	7	

West

🟩 < 10% Blockage	🟥 70 - 100% Blockage	LPA = Large Particle Ash/ Slag
🟦 10 - 20% Blockage	▨ Fly Ash Pile (> 1 ft.)	LOI = Unburned Carbon
🟨 20 - 40% Blockage	▼ SH = Sonic Horn	W = Washed, ER = Erosion
🟧 40 - 70% Blockage	☒ Man Hole	SD = Seal Damage

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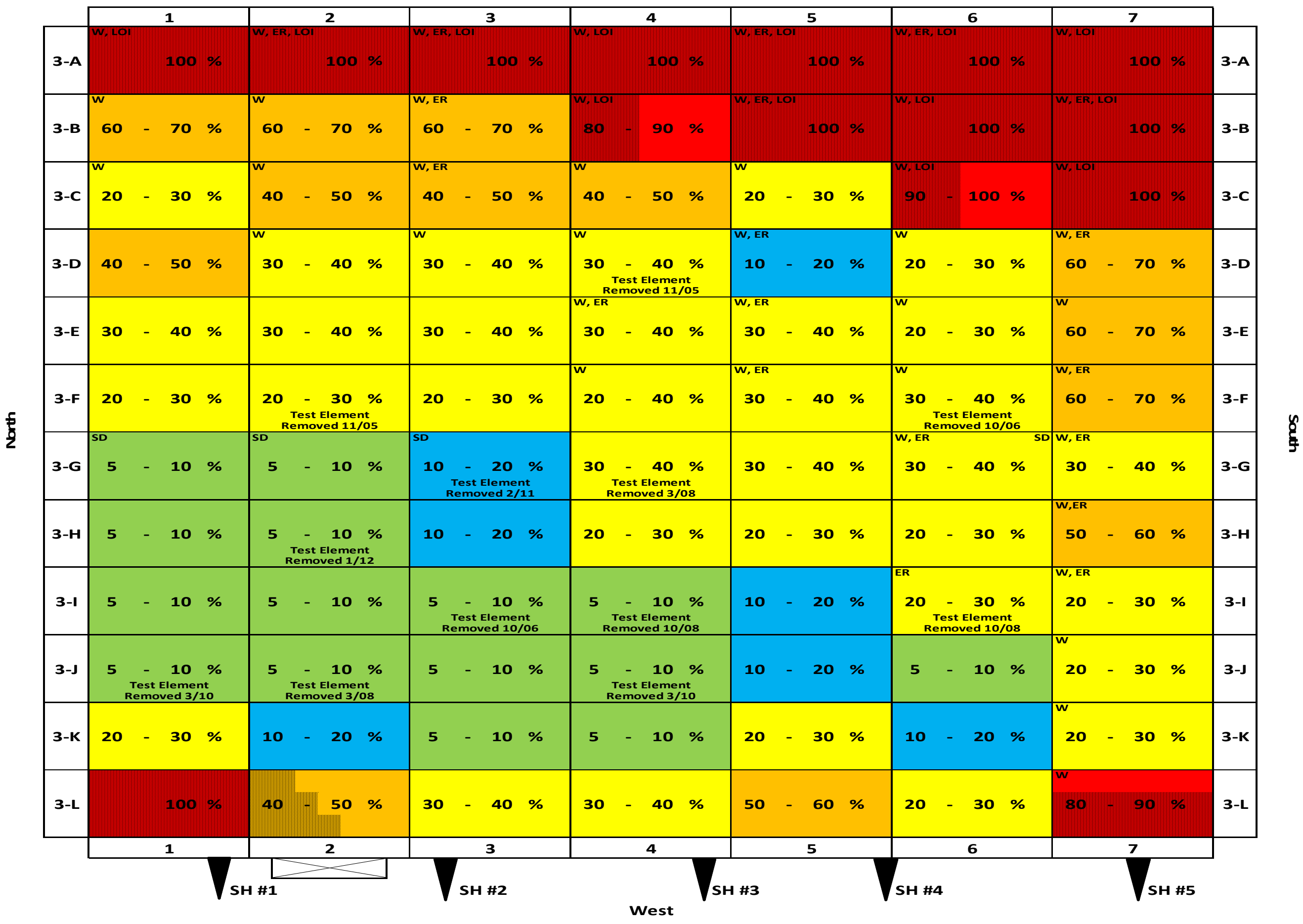
Bailly Unit 8 Reactor Inspection

Bailly Unit 8
Pluggage Diagram
Third Catalyst Level (6.7 mm Pitch)
January 30-31, 2012

L3 Removed Fall 2012
Lower Pressure Drop



	1	2	3	4	5	6	7	
3-A	W, LOI 100 %	W, ER, LOI 100 %	W, ER, LOI 100 %	W, LOI 100 %	W, ER, LOI 100 %	W, ER, LOI 100 %	W, LOI 100 %	3-A
3-B	W 60 - 70 %	W 60 - 70 %	W, ER 60 - 70 %	W, LOI 80 - 90 %	W, ER, LOI 100 %	W, LOI 100 %	W, ER, LOI 100 %	3-B
3-C	W 20 - 30 %	W 40 - 50 %	W, ER 40 - 50 %	W 40 - 50 %	W 20 - 30 %	W, LOI 90 - 100 %	W, LOI 100 %	3-C
3-D	40 - 50 %	W 30 - 40 %	W 30 - 40 %	W 30 - 40 % Test Element Removed 11/05	W, ER 10 - 20 %	W 20 - 30 %	W, ER 60 - 70 %	3-D
3-E	30 - 40 %	30 - 40 %	30 - 40 %	W, ER 30 - 40 %	W, ER 30 - 40 %	W 20 - 30 %	W 60 - 70 %	3-E
3-F	20 - 30 %	20 - 30 % Test Element Removed 11/05	20 - 30 %	W 20 - 40 %	W, ER 30 - 40 %	W 30 - 40 % Test Element Removed 10/06	W, ER 60 - 70 %	3-F
3-G	SD 5 - 10 %	SD 5 - 10 %	SD 10 - 20 % Test Element Removed 2/11	30 - 40 % Test Element Removed 3/08	30 - 40 %	W, ER SD 30 - 40 %	W, ER 30 - 40 %	3-G
3-H	5 - 10 %	5 - 10 % Test Element Removed 1/12	10 - 20 %	20 - 30 %	20 - 30 %	20 - 30 %	W,ER 50 - 60 %	3-H
3-I	5 - 10 %	5 - 10 %	5 - 10 % Test Element Removed 10/06	5 - 10 % Test Element Removed 10/08	10 - 20 %	ER 20 - 30 % Test Element Removed 10/08	W, ER 20 - 30 %	3-I
3-J	5 - 10 % Test Element Removed 3/10	5 - 10 % Test Element Removed 3/08	5 - 10 %	5 - 10 % Test Element Removed 3/10	10 - 20 %	5 - 10 %	W 20 - 30 %	3-J
3-K	20 - 30 %	10 - 20 %	5 - 10 %	5 - 10 %	20 - 30 %	10 - 20 %	W 20 - 30 %	3-K
3-L	100 %	40 - 50 %	30 - 40 %	30 - 40 %	50 - 60 %	20 - 30 %	W 80 - 90 %	3-L
	1	2	3	4	5	6	7	

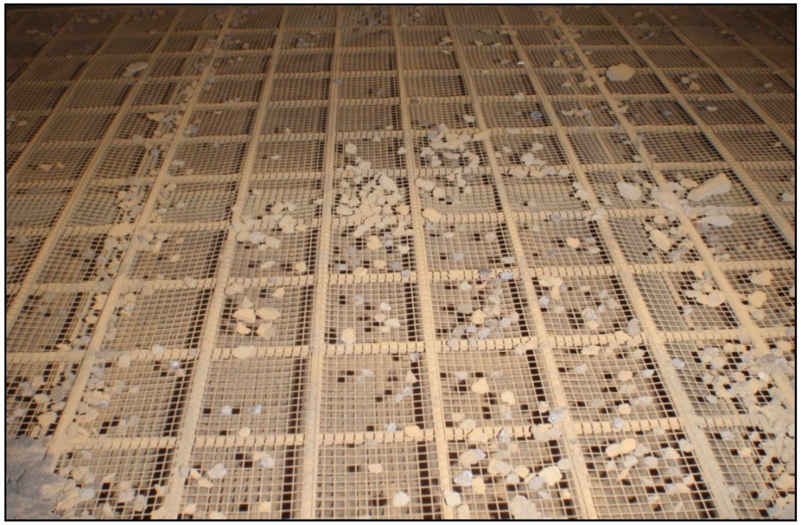
🟩 < 10% Blockage
🟦 10 - 20% Blockage
🟨 20 - 40% Blockage
🟧 40 - 70% Blockage

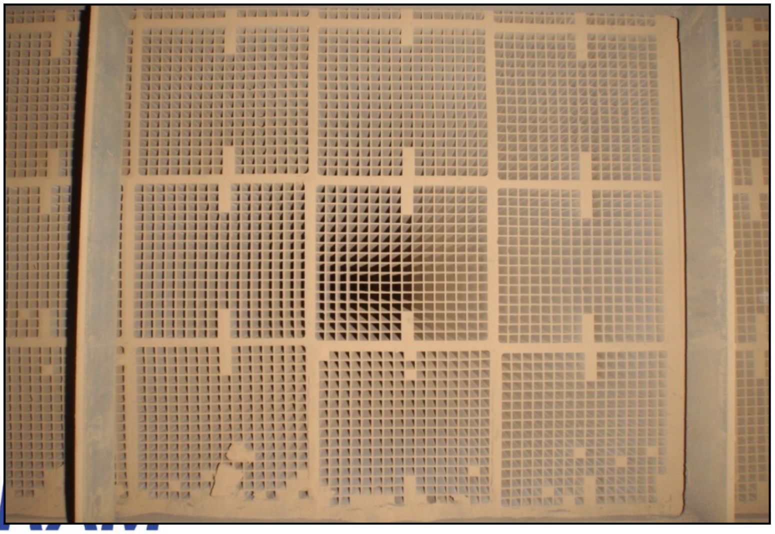
🟥 70 - 100% Blockage
▨ Fly Ash Pile
▼ SH = Sonic Horn
☒ Man Hole

LPA = Large Particle Ash/ Slag
LOI = Unburned Carbon
W = Washed, ER = Erosion
SD = Seal Damage

Bailly Unit 8 Inspection Results Overview

Level 1





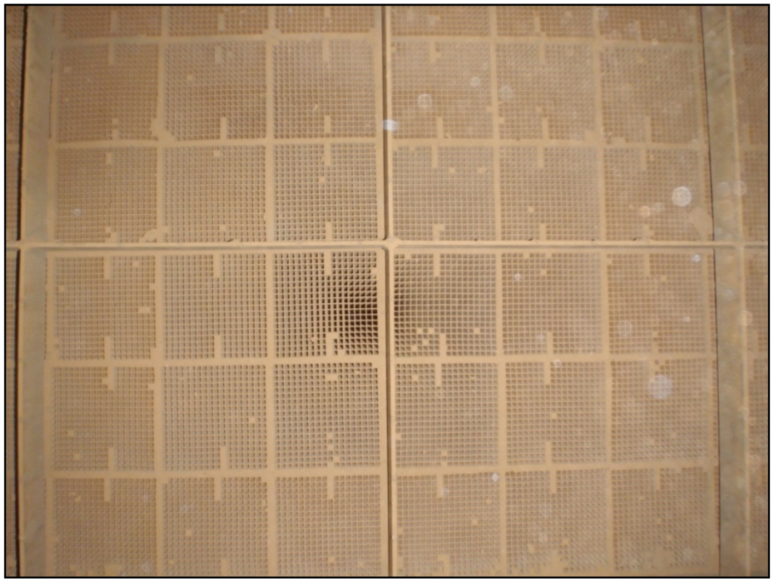
Bailly Unit 8 Inspection Results Overview

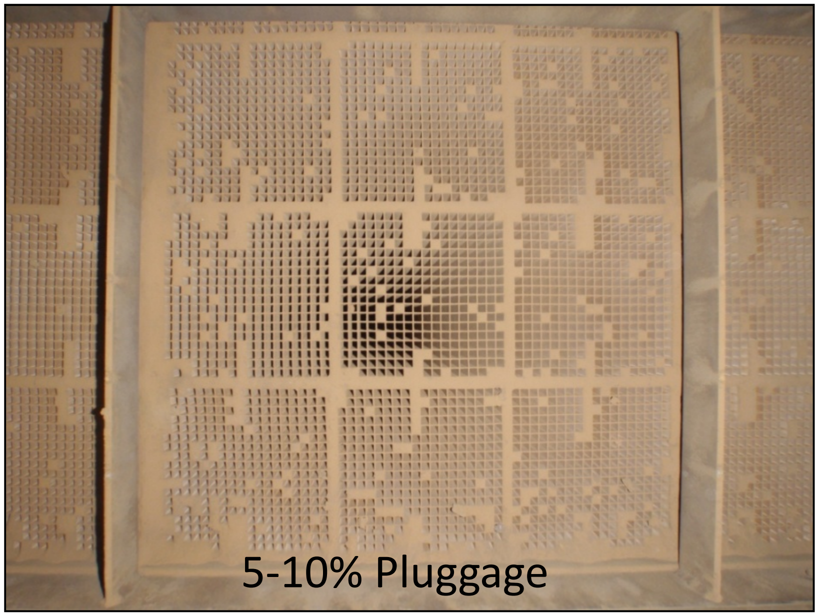
Level 1 (17,200 hrs)

Erosion on East Side (AIG Side)

Bailly Unit 8 Inspection Results Overview

Level 2





5-10% Pluggage

Bailly Unit 8 Inspection Results Overview

Level 3

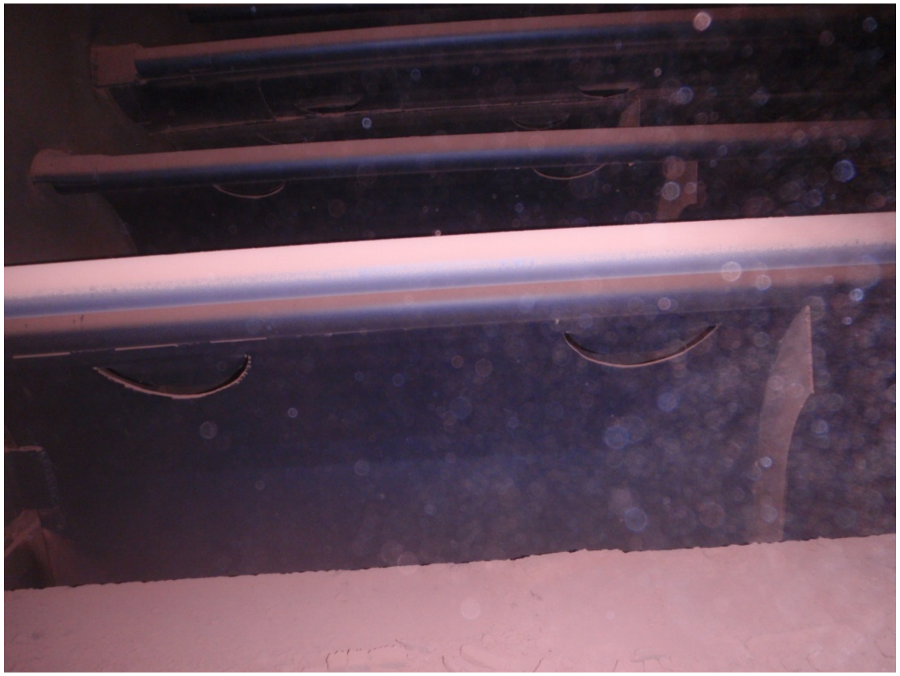
Bailly Unit 8 Inspection Results Overview

AIG

North Side

South Side

Bailly Unit 8 Inspection Results Overview



“Clean” Vanes

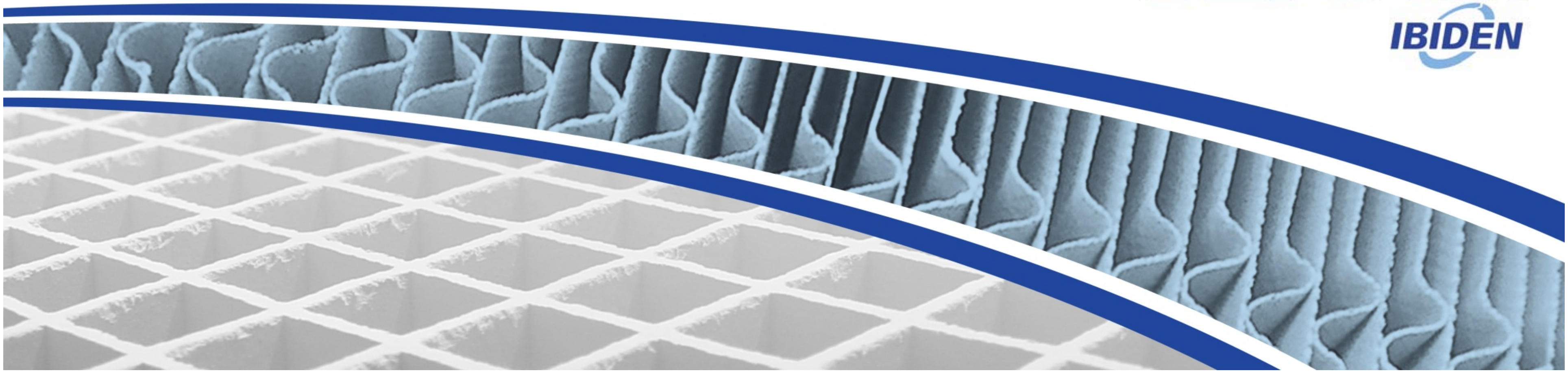
Bailly Unit 8 Inspection Results Overview

Repair LPA Screen

2013 Reinhold Presentation

NIPSCO Bailly Unit 8

Affects of System Modifications to AIG Tuning



AIG Tuning Bailly Unit 8

Bailly Unit 8	**Baseline**	**Final**
Target Distribution:		
Points within ±20 ppm	4 of 42	38 of 42
Points within ±25 ppm	5 of 42	42 of 42

Bailly Unit 8 Baseline SCR Outlet NOx Distribution Results

1	Grid Pt #	**501**	**504**	**502**	**505**	**503**	**506**
	Deviation (±)	**99**	**184**	**40**	**102**	**76**	**100**
2	Grid Pt #	**507**	**510**	**508**	**511**	**509**	**512**
	Deviation (±)	**124**	**126**	**155**	**139**	**168**	**119**
3	Grid Pt #	**513**	**516**	**514**	**517**	**515**	**518**
	Deviation (±)	**63**	23	**61**	16	**37**	**49**
4	Grid Pt #	**519**	**522**	**520**	**523**	**521**	**524**
	Deviation (±)	**74**	-4	**32**	-17	3	**37**
5	Grid Pt #	**525**	**528**	**526**	**529**	**527**	**530**
	Deviation (±)	**-37**	**-84**	**-66**	**-130**	**-68**	**-52**
6	Grid Pt #	**531**	**534**	**532**	**535**	**533**	**536**
	Deviation (±)	**-115**	**-118**	**-105**	**-123**	**-115**	**-103**
7	Grid Pt #	**537**	**540**	**538**	**541**	**539**	**542**
	Deviation (±)	**-127**	**-131**	**-132**	**-80**	**-94**	**-106**

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AIG Tuning Bailly Unit 8 (Rebalancing)

Bailly Unit 8	**Baseline**	**Final**
Target Distribution:		
Points within ±20 ppm	4 of 42	38 of 42
Points within ±25 ppm	5 of 42	42 of 42

Bailly Unit 8 Final SCR Outlet NOx Distribution Results							
1	Grid Pt #	**501**	**504**	**502**	**505**	**503**	**506**
	Deviation (±)	**7**	**15**	**-8**	**22**	**10**	**14**
2	Grid Pt #	**507**	**510**	**508**	**511**	**509**	**512**
	Deviation (±)	**-12**	**22**	**0**	**-4**	**-11**	**0**
3	Grid Pt #	**513**	**516**	**514**	**517**	**515**	**518**
	Deviation (±)	**-4**	**-3**	**-5**	**8**	**6**	**0**
4	Grid Pt #	**519**	**522**	**520**	**523**	**521**	**524**
	Deviation (±)	**13**	**1**	**-11**	**-3**	**-3**	**2**
5	Grid Pt #	**525**	**528**	**526**	**529**	**527**	**530**
	Deviation (±)	**-3**	**-8**	**-1**	**-25**	**-5**	**-10**
6	Grid Pt #	**531**	**534**	**532**	**535**	**533**	**536**
	Deviation (±)	**-10**	**9**	**8**	**3**	**7**	**6**
7	Grid Pt #	**537**	**540**	**538**	**541**	**539**	**542**
	Deviation (±)	**-21**	**1**	**1**	**20**	**-3**	**-16**

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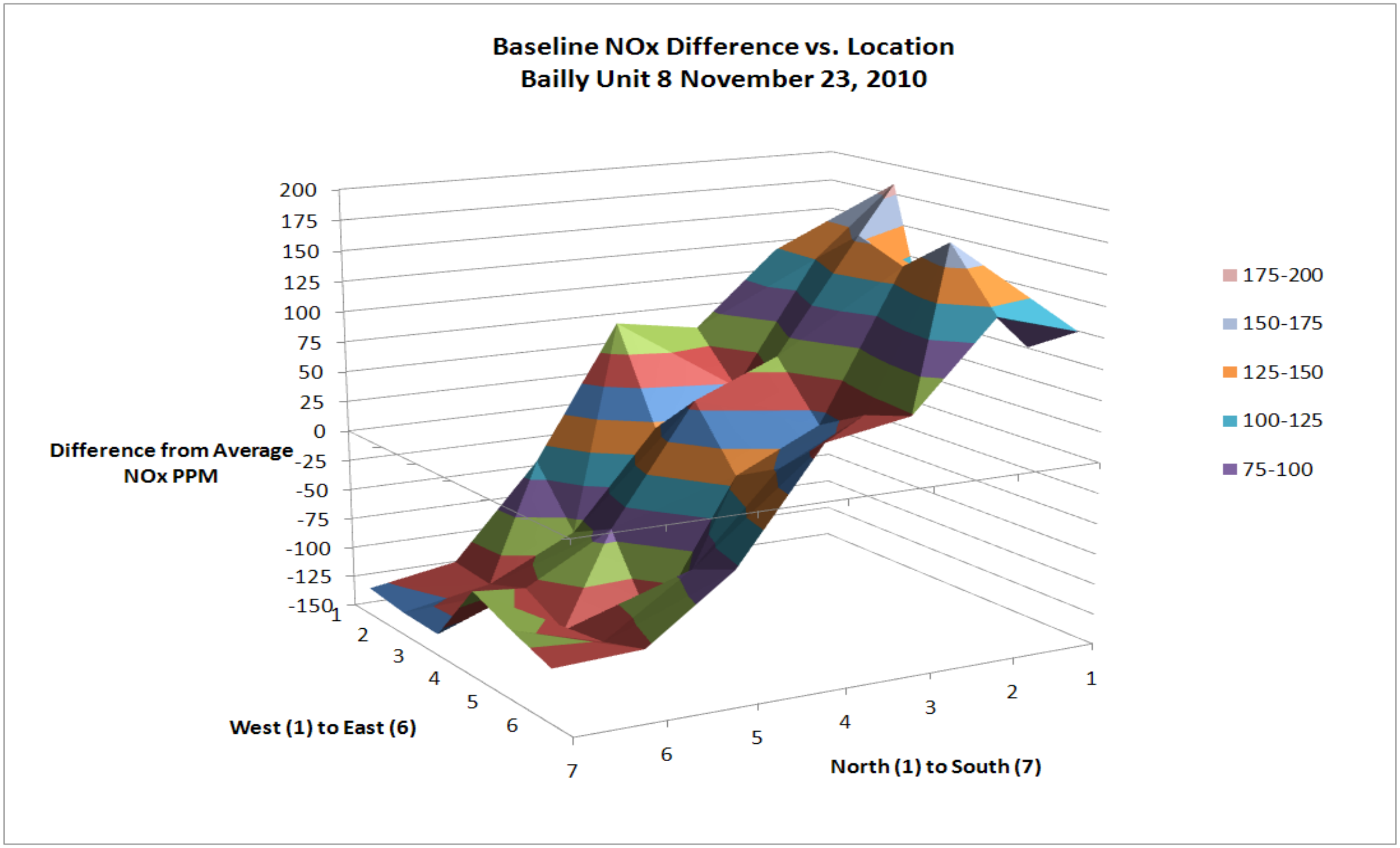
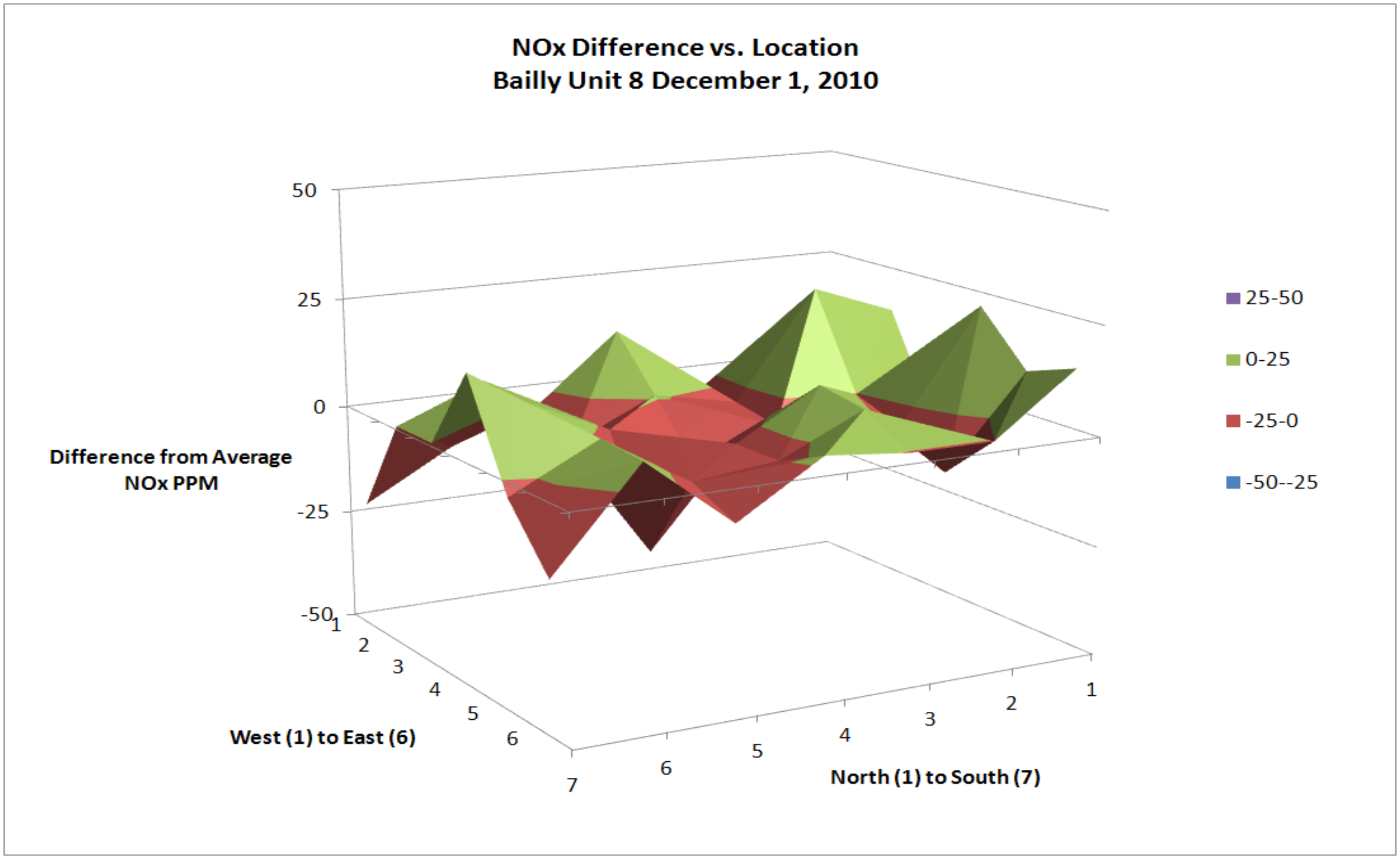
AIG Tuning Bailly Unit 8



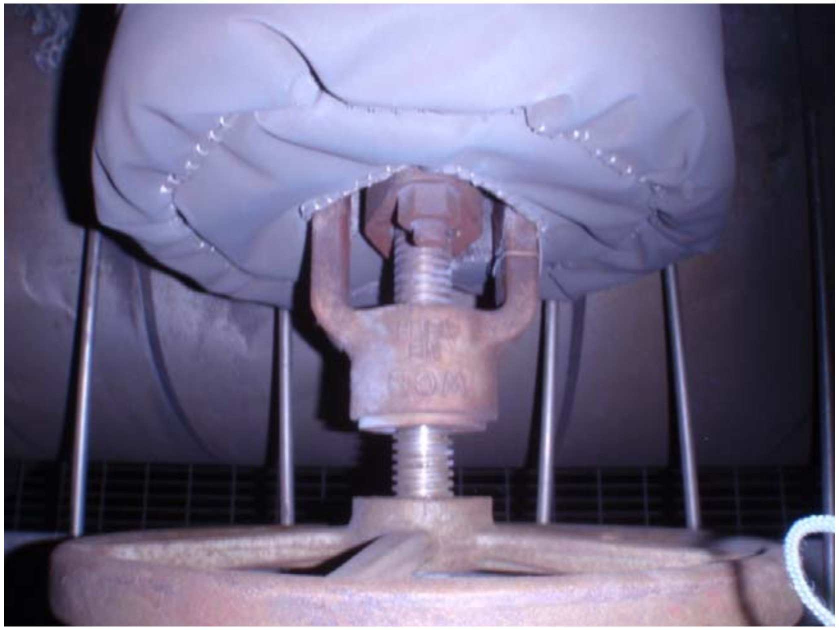
Baseline NOx Difference vs. Location
Bailly Unit 8 November 23, 2010

AIG Tuning Bailly Unit 8



AIG Tuning Bailly Unit 8

- Pressure Drop Measurements
    - Historically Pressure Taps and Lines Are Plugged.
    - Urea Salt's Out and Plugs Taps and Lines. Maintaining Clean Lines Extremely Difficult
    - Recorded Number of Threads Exposed for All 42 Valves



2013 Reinhold Presentation

NIPSCO Bailly Unit 8

Summary of Modifications and Results

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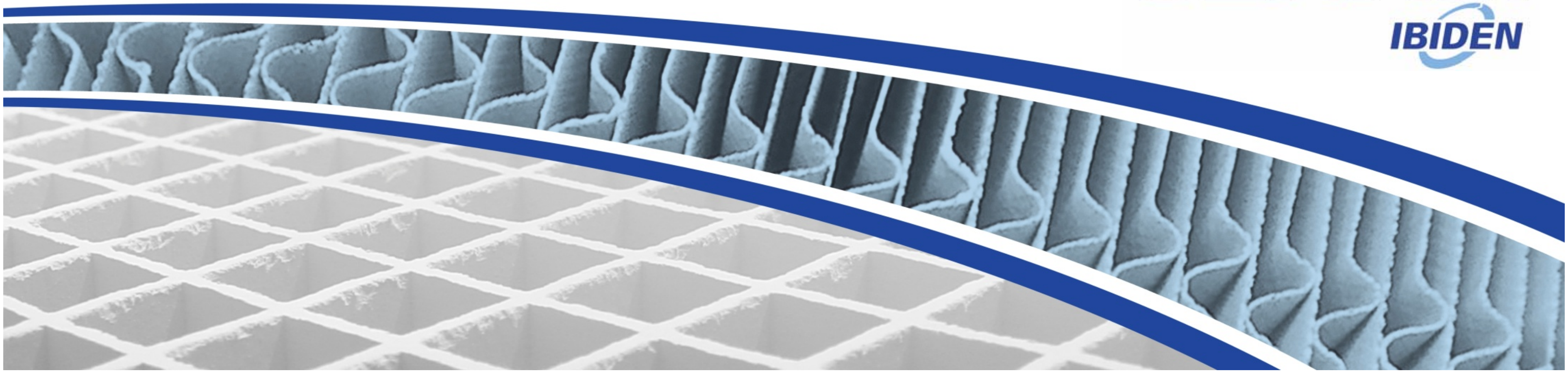

Bailly Unit 8 Summary

- Annual Reactor Inspection Performed Over Past 8 Years
- Historically Pluggage Observed Due to LPA, Unburned Carbon and Ash Dropout (Velocity Maldistribution)
- Solutions Have Been Developed and Implemented to Eliminate Pluggage
  - Installed STEAG LPA Screen; Screen Stationary; Repair Screen Panels
  - Working to Keep Unburned Carbon Levels Lower
  - CFD Modeling Used to Improve Velocity Distribution
    - 43.5% Baseline to 31% With “Novel” Economical Solution (15% Design); Further Changes Possible, But Considered Not Cost Effective
    - Localized High Velocity Areas More Prevalent (Examine CFD & Develop Solution)
  - Installed Larger Pitch to Mitigate Pluggage and Increased Operations/Fuels Flexibility
  - Reactor Pressure Drop Substantially Lower (7 in. w.g. vs. 3 in. w.g.)
  - Pressure Drop Lower From Decomposition Chamber to AIG

Thank You!

Questions?