

REINHOLD ENVIRONMENTAL Ltd.

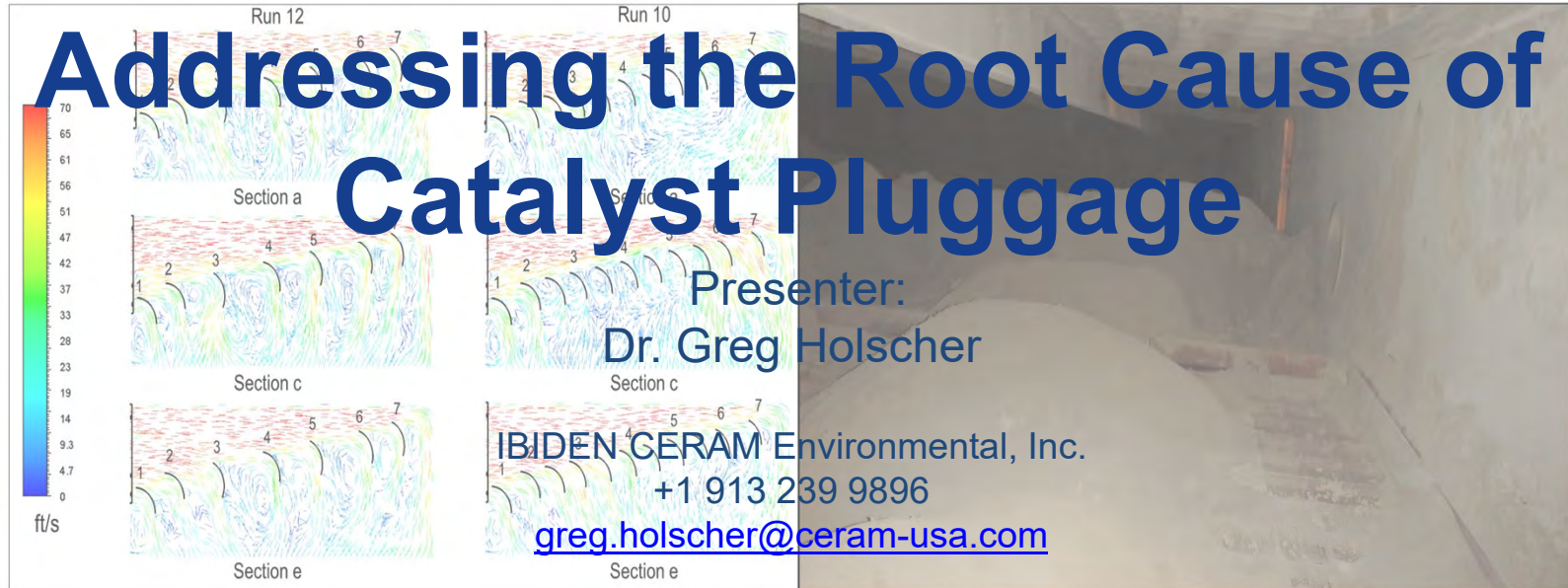


**2018 NO<sub>x</sub>-Combustion Round Table  
& Expo Presentation**

February 19-20, 2018, in St. Louis, MO / Hosted by Dynegy

All presentations posted on this website are copyrighted by Reinhold Environmental, Ltd (RE). Any unauthorized downloading, attempts to modify or to incorporate into other presentations, link to other websites, or obtain copies for any other uses than the training of attendees to RE's Conferences is expressly prohibited, unless approved in writing by RE or the original presenter. RE does not assume any liability for the accuracy or contents of any materials contained in this library which were presented and/or created by persons who were not employees of RE.

# Reinhold Environmental NOx Round Table February 19, 2018



Prepared by  
Greg Holscher and Stacy Steinhauer  
IBIDEN CERAM Environmental, Inc.

**CERAM**

# Presentation Topics

- Midwest Utility Pluggage Project
  - Unit and SCR Overview
  - Reactor Inspection Review
  - CFD Modeling Review & Implementation of Results
    - Phase I Study
    - Phase II Study
  - Affects of System Modifications to AIG Tuning
  - Catalyst Management Planning Affects
  - Summary



Flow  
Direction  
"Cleaned"

# “Midwest Utility” Overview

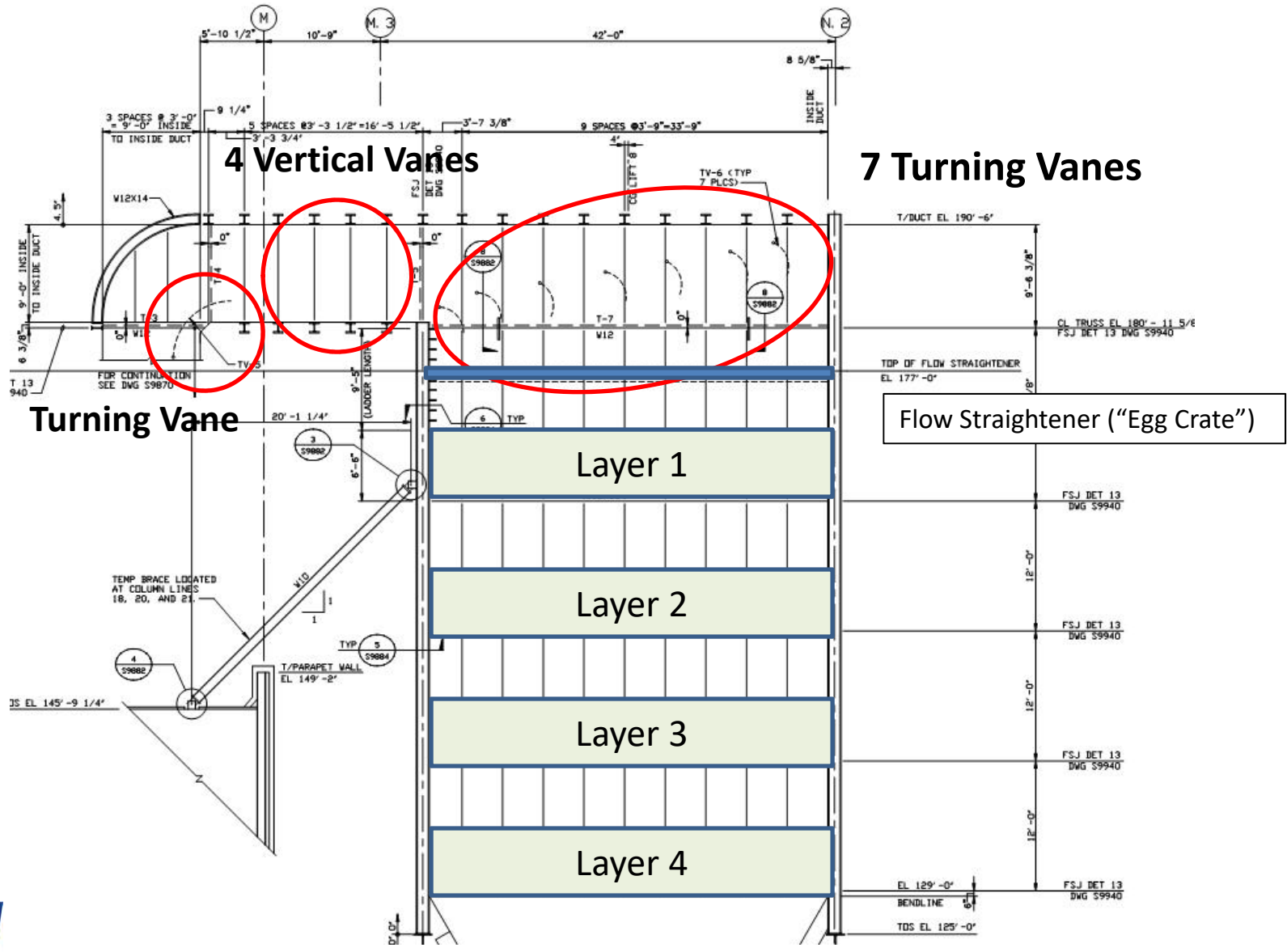
- 500 MW<sub>g</sub>
- B&W Cyclone Boiler (4,588 MMBtu/hr)
- PRB Blended Coal Fired
  - 90% PRB / 10% Bituminous
  - Sulfur  $\approx$  0.5%; Ash  $\approx$  6%; CaO  $\approx$  20%;  
P<sub>2</sub>O<sub>5</sub>  $\approx$  0.6%
- SCR in Service 2003
  - 3 + 1 Reactor
  - 12 x 11 Module Arrangement Per Layer
  - CERAM Honeycomb 7.4 mm Pitch Catalyst (9.2 mm Pitch Installed 2006; 8.2 mm Pitch Installed 2009)
  - Fuel Tech NO<sub>x</sub>Out Ultra System
- Originally Sootblowers Installed L1 & Sonic Horns Installed L2 & L3 (Sonic Horns All Layers)
- Physical Flow Model Demonstrated All Distributions Achieved and No Ash Drop Out







# SCR System Layout



# Reactor Hood Guide Vanes



7 Reactor Hood Vanes “Clean” Condition

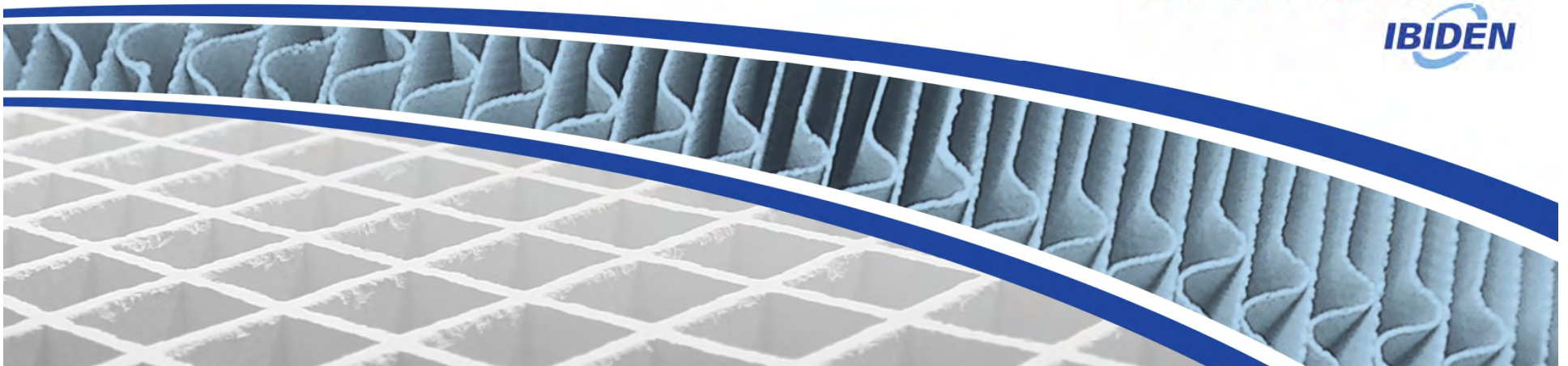


Ash Buildup “Dirty” Condition

# 2018 Reinhold Presentation

## “Midwest Utility” Reactor Inspection Review

**CERAM**  
IBIDEN



# Reactor Inspection Overview

- Annual Reactor Inspection Performed Over Past 14 Years
  - Frame by Frame Assessment of Pluggage
  - Inspect Catalyst Baffle Plates/Seals, Ammonia Injection Grid (AIG), Flow Correction Devices (Guide Vanes, Mixers, etc.), Accessible Duct Work (e.g., Crossover Duct, Inlet Duct, etc.)
  - Historically Pluggage Observed Due to Ash Dropout (Velocity Maldistribution?) and Unburned Carbon
    - Ash Piles (3-10 ft) Observed In L1, L2 & L3 (West (AIG Side) and Central Locations). More Run Time Piles Propagated to East Side. L4 Installed in 2013 with Same Results.
    - Severe Pluggage Across Central Section of Reactor. At Times Module Pluggage 5-100% in L1, L2, L3 & L4. Propagated to Lower Levels.
    - Catalyst Management Ensured Target Emissions Always Achieved
  - Ash Buildup in Crossover Duct (Large Gusset Plates Perpendicular to Flow)
  - CFD Modeling Recommended; Early 2000s CFD Not Quite Driving Design, But Technology Improving.

# Reactor Inspection (In the Beginning...)

- During Ozone Season. Average Pluggage 43% (L1), 27% (L2) and 18% (L3) After 16,000 Hours
- Unburned Carbon in Ash Piles (Reported to be 1-5% in ESP Hoppers)



Sintered Catalyst from Ash Pile

Pile disturbed revealing unburned carbon



# Reactor Inspection (In the Beginning...)



Ash buildup in crossover duct

Are these vanes clean?  
“Nature of PRB ash”



# Reactor Inspection (In the Beginning...)

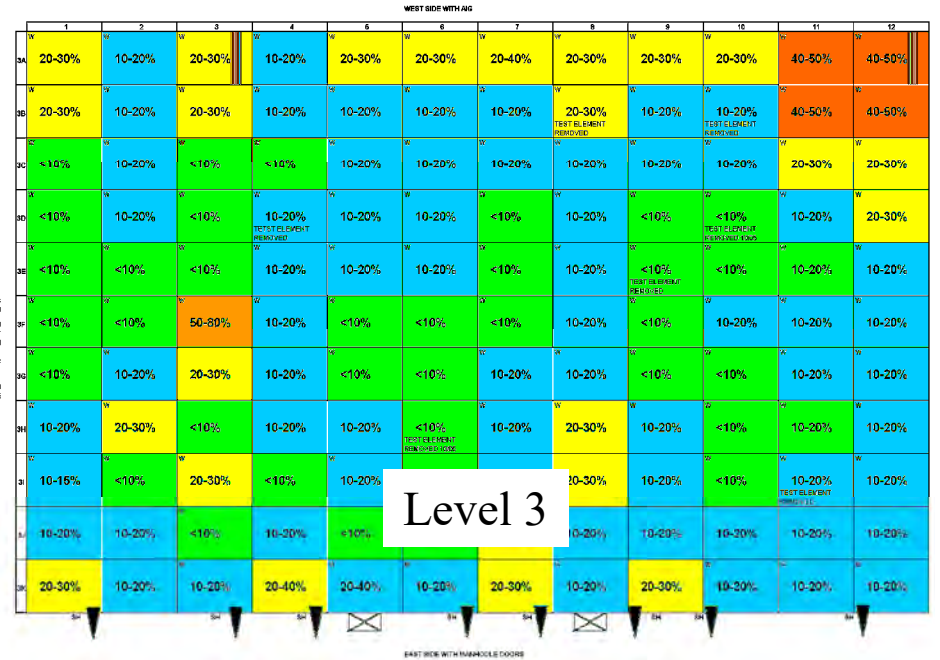
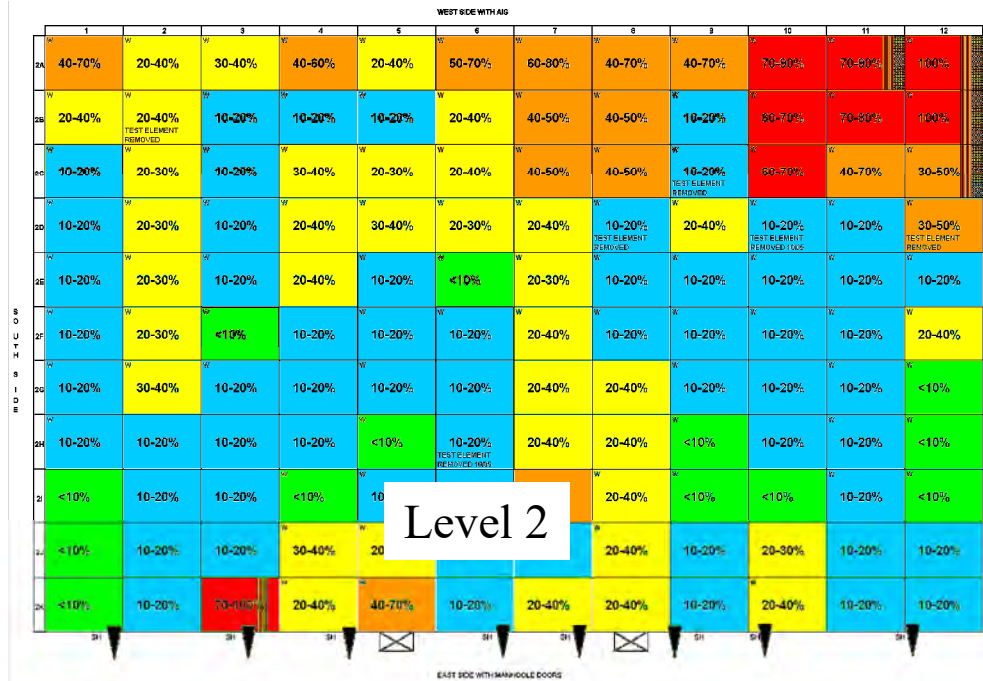
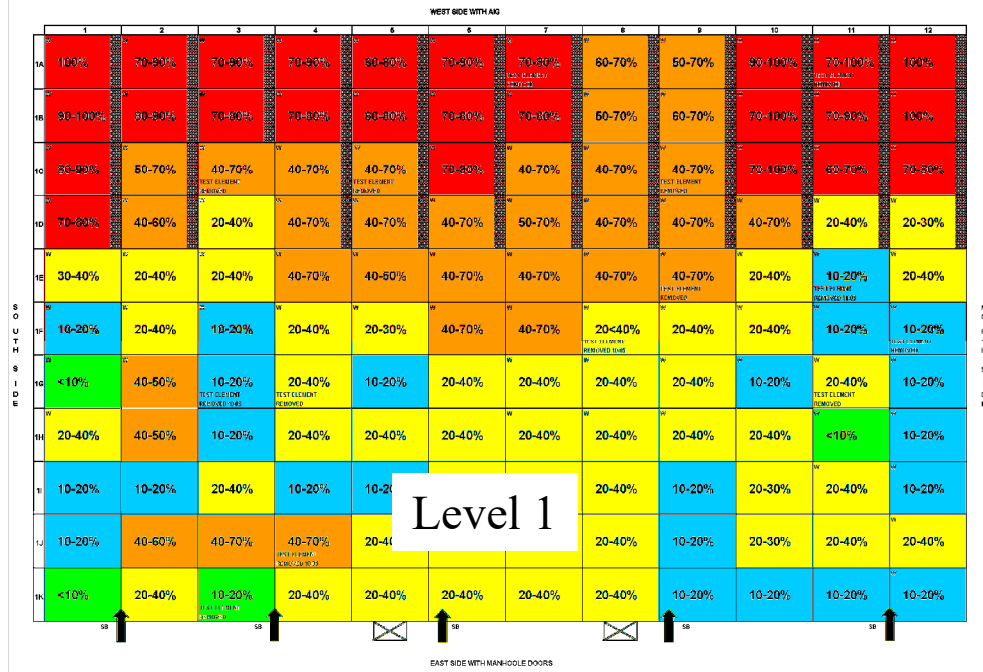


Ash Buildup on Vanes

Affects of Ash Shear

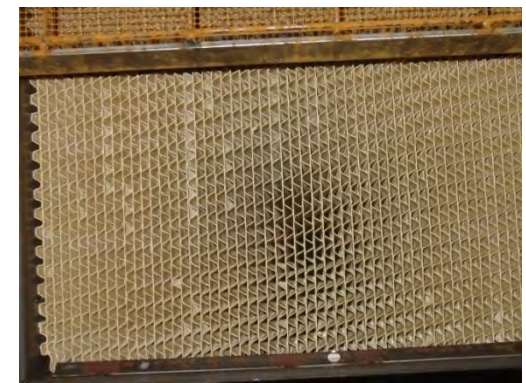
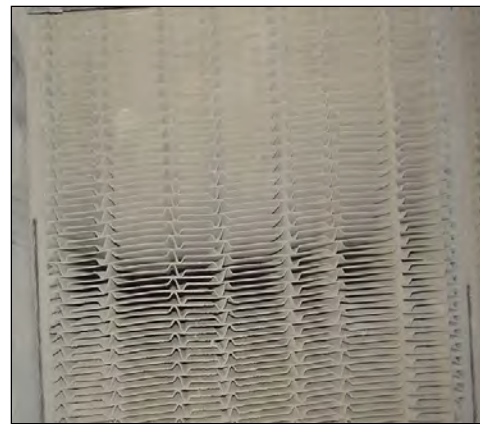
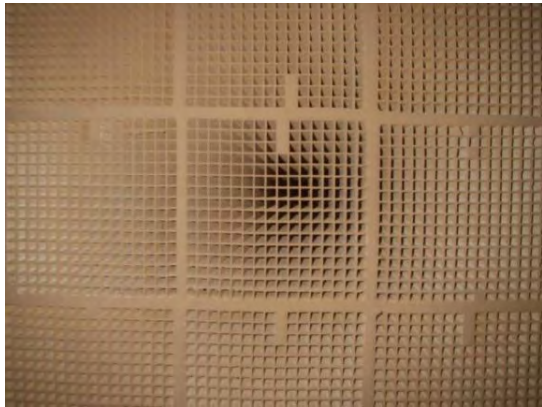


# Reactor Inspection (In the Beginning...)



# Why Not Just Use a Larger Pitch Catalyst?

- Larger Pitch May Remedy Some Flow Deficiencies and Reduce Pluggage and Pressure Drop
- Poor Flow Distribution Will Not Be Solved Solely By Using Larger Pitch (True for Honeycomb, Plate or Corrugated Fiber)
- Loss of Active Surface Area With Larger Pitch = Increased Life Cycle Costs



# Reactor Inspection (Larger Pitch)

- 2006 9.2 mm Pitch Honeycomb Catalyst Installed. Best-of-the-Best Modules from L1 to L2 and L3. Average Pluggage by 2007 was 50% L1, 34% L2 & 31% L3.
- Larger L1 Pitch Improved Flow Vectors; Short Lived Due to Ash Shear and Low Flow Areas
- Average Pluggage 18% (L1), 27% (L2) and 27% (L3); Lower in L2 & L3 Best –of-the-Best Modules Reused. **Year Round Operation in 2009!!!**
- Spring 2009, 8.2 mm Pitch Honeycomb Catalyst Installed L2; Best-of-the-Best from L2 into L3. **BIG NEWS WAS CFD MODELING BUDGETED FOR 2010!**



Ash Piles Eventually in L1

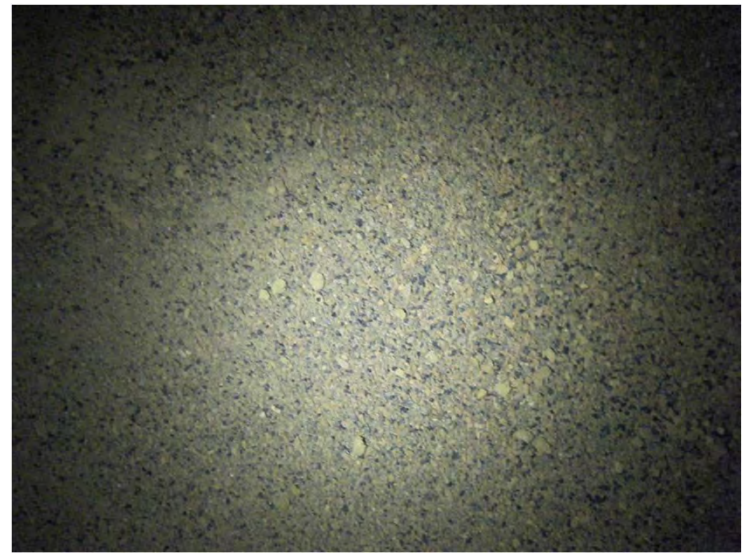


Larger Piles in Lower Levels

# Reactor Inspection (Larger Pitch)



Still Have Ash Dropout in Crossover Duct



Ash Piles Exists

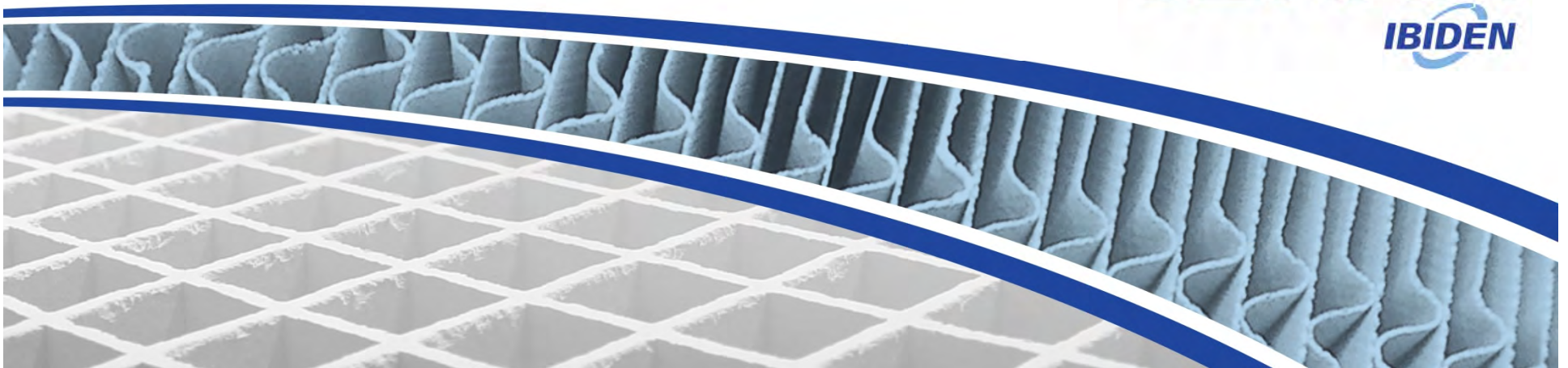


Unburned Carbon  
Sintering Concerns

# 2018 Reinhold Presentation

## “Midwest Utility” CFD Phase I Study

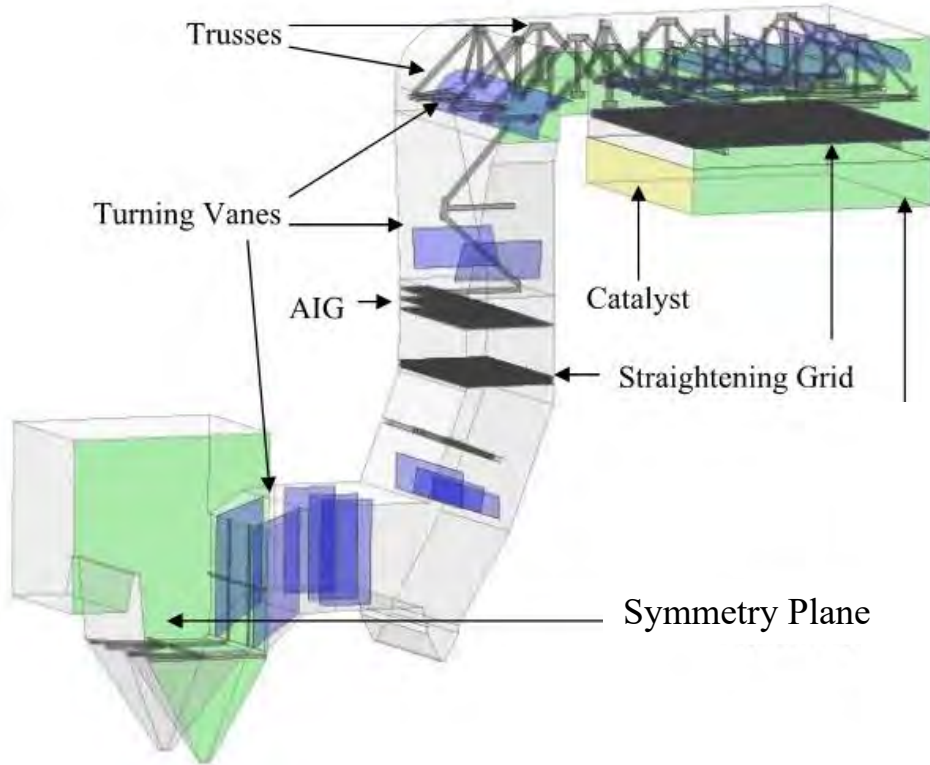
**CERAM**  
IBIDEN



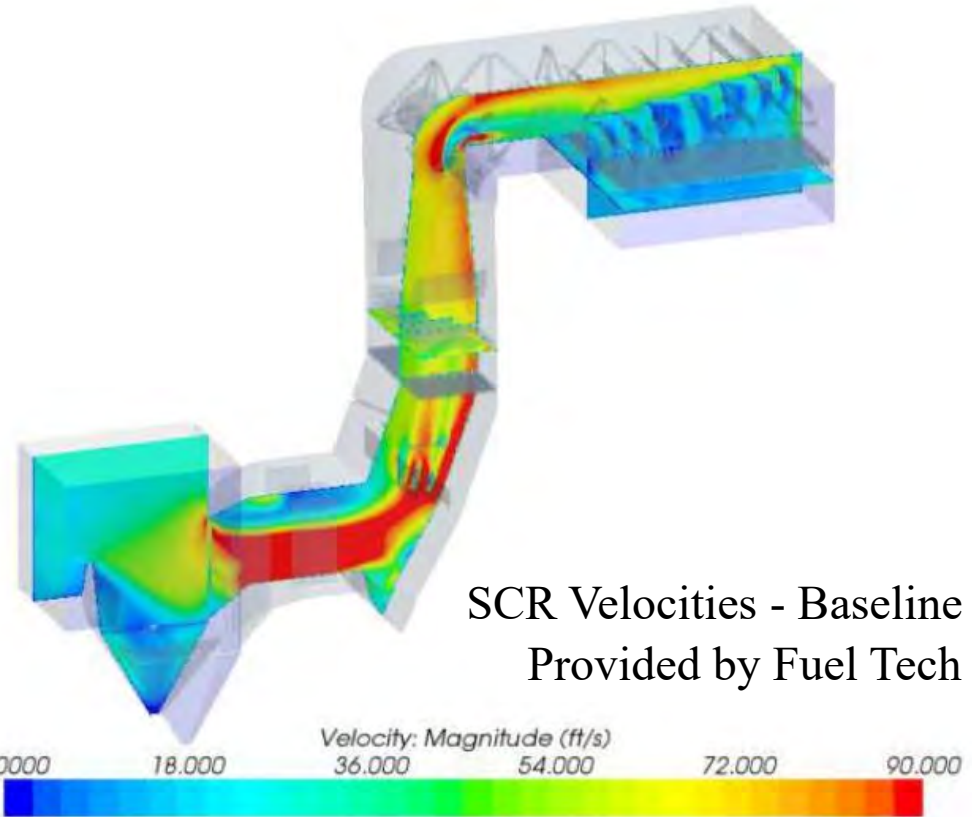
# CFD Modeling Study – Try to Improve Flow Distribution and Reduce Ash Dropout

- CFD Modeling Performed by Fuel Tech, Inc. in 2010
  - Velocity Profile at Economizer Outlet and SCR Outlet Used for Boundary Conditions
- Model From Economizer Outlet to SCR Reactor (Assumed Symmetry Plane about Economizer and Reactor Centerline)
- CFD Baseline Demonstrated Low and High Velocity Areas at Economizer Outlet
  - Ash Bridging in Economizer Hopper (e.g., Not Removing Ash Prior to SCR)
- CFD Modeling Revealed Low Flow Areas in Crossover Duct to SCR Due to Internal Trusses and Gusset Plates
- CFD Baseline Demonstrated High Velocity Distribution (Design = 100% Within 15% of Mean)
  - Velocity Distribution Upstream of AIG = 62% of Points Within  $\pm 15\%$  of Mean
  - Velocity Distribution Upstream of Catalyst = 51% of Points Within  $\pm 15\%$  of Mean (25% RMS)
- CFD Validated Ash Drop Out Observed in the Field

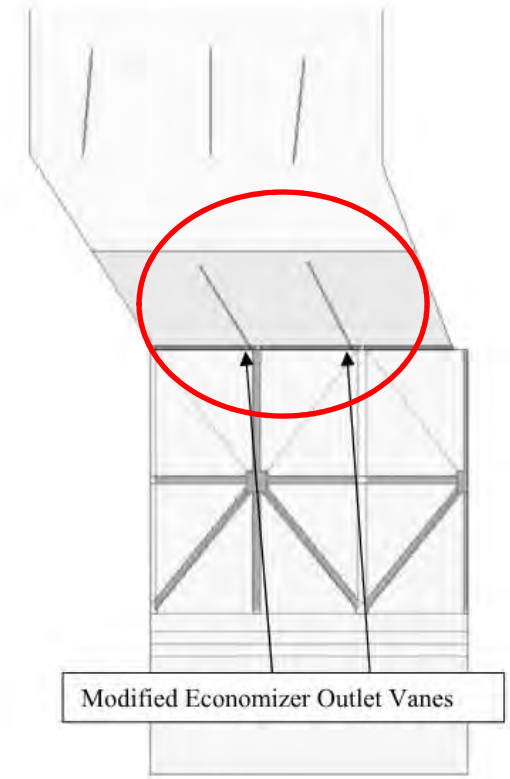
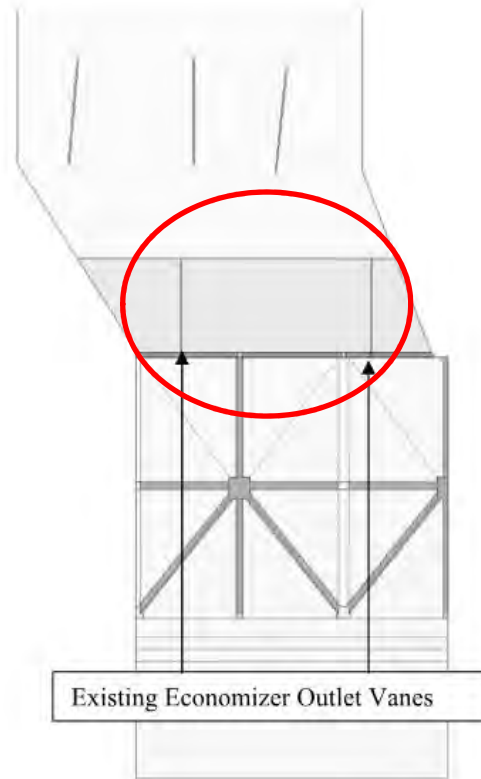
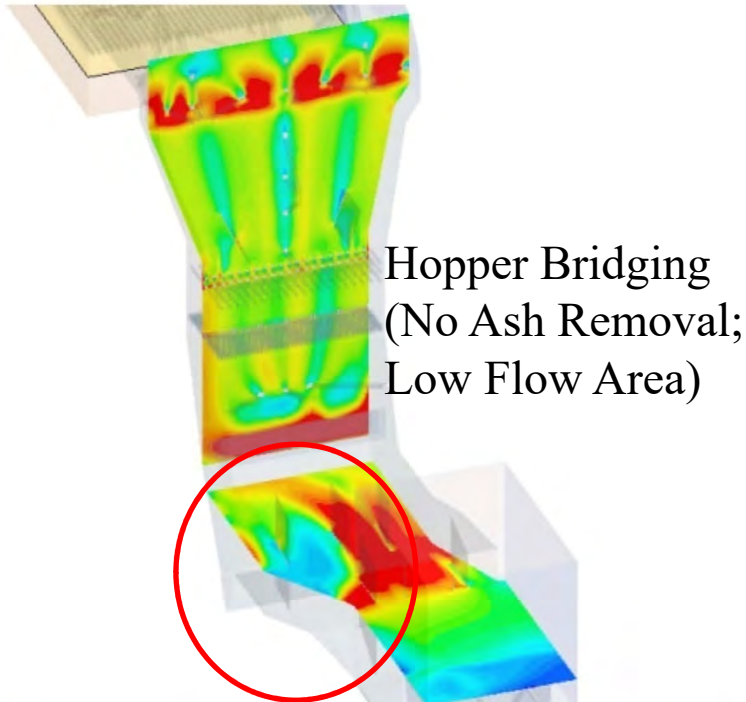
# CFD Modeling Study (2010)



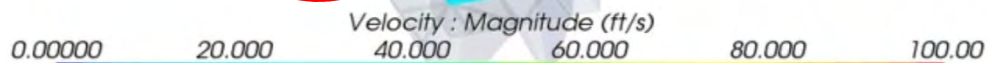
Module Arrangement



# CFD Modeling Study (2010)



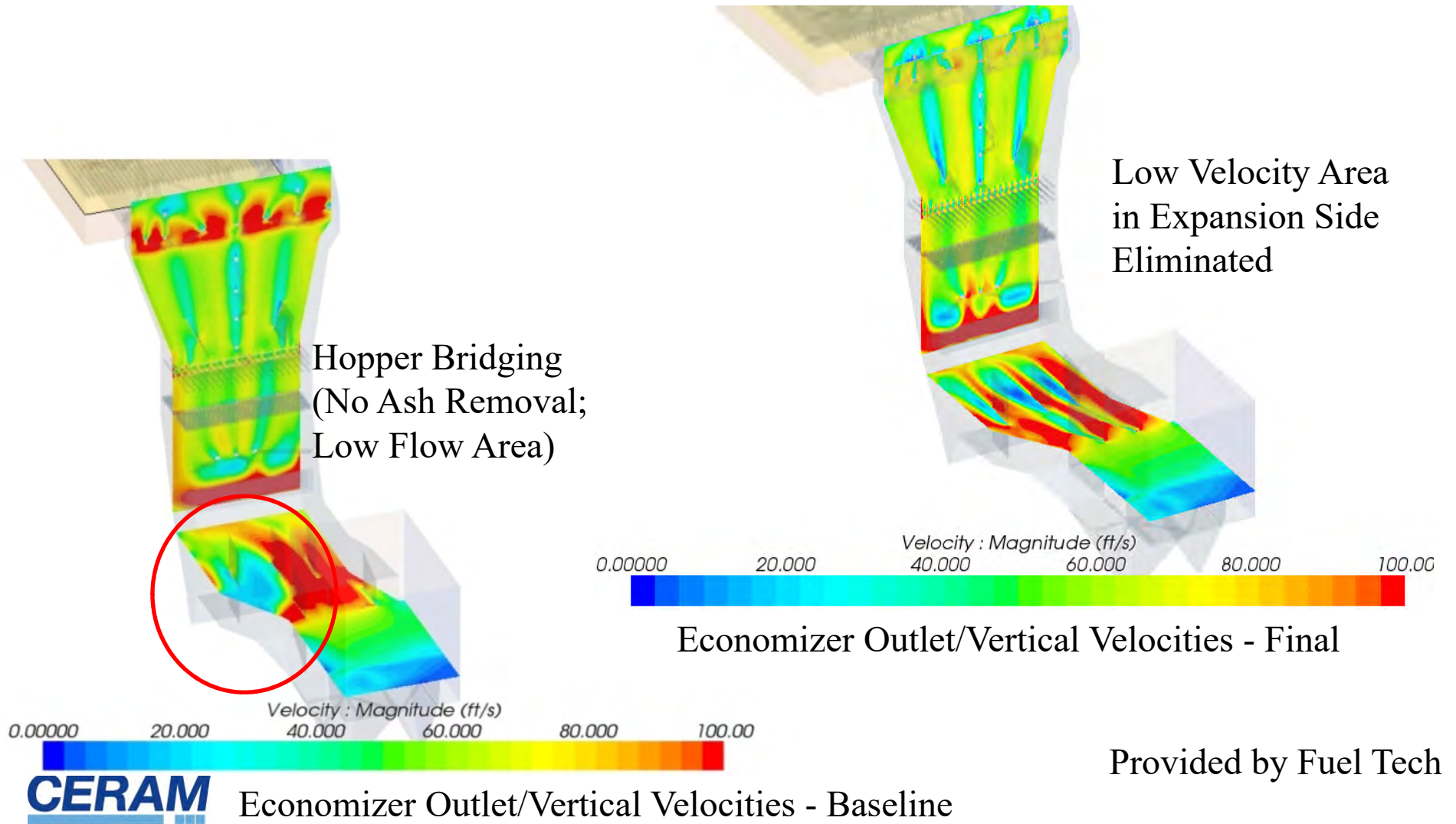
Economizer Outlet Existing & Modified Vanes



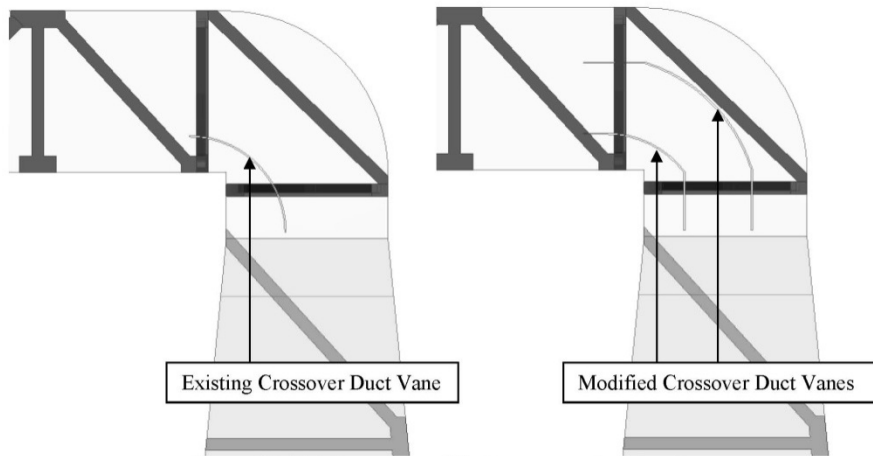
Economizer Outlet/Vertical Velocities - Baseline

Provided by Fuel Tech

# CFD Modeling Study (2010)

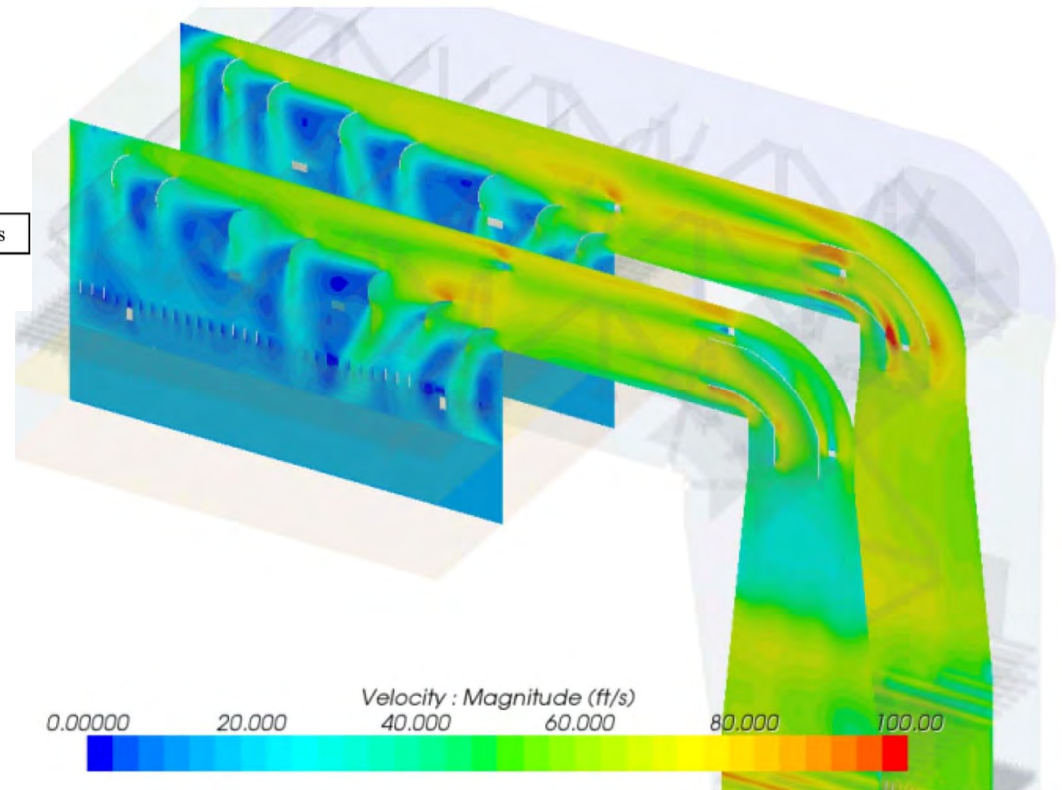


# CFD Modeling Study (2010)



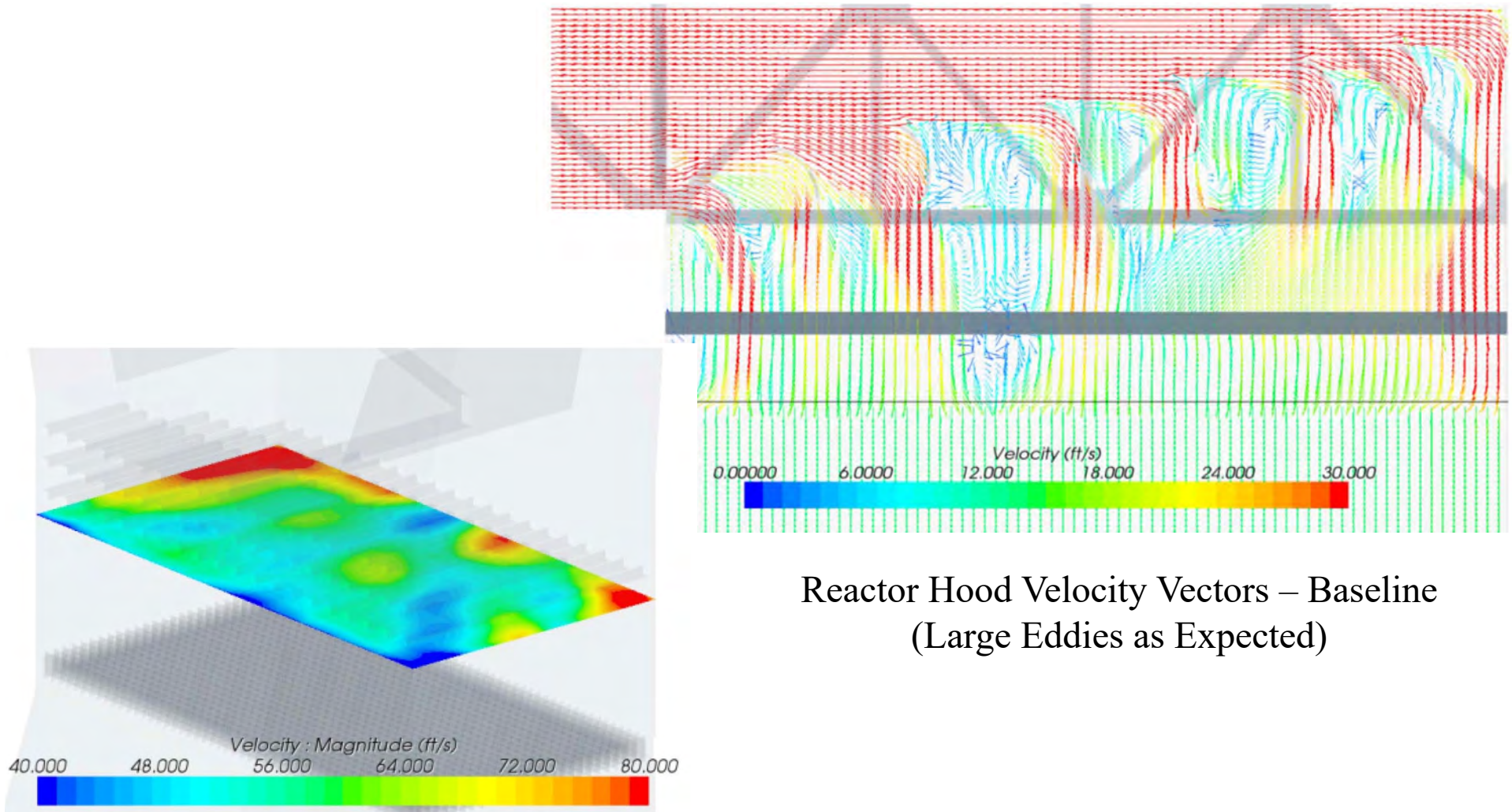
Existing and Modified Crossover Duct Turning Vanes

- LHS = One Vane with Curved Duct
- RHS = Modified Using Two Vanes with Leading and Trailing Edge Extension
- Flow Improved at Top of Duct, But Size and Spacing of Internal Structures Still Lead to Ash Buildup



Crossover Duct Turning Vane Velocity Profile

# CFD Modeling Study (2010)

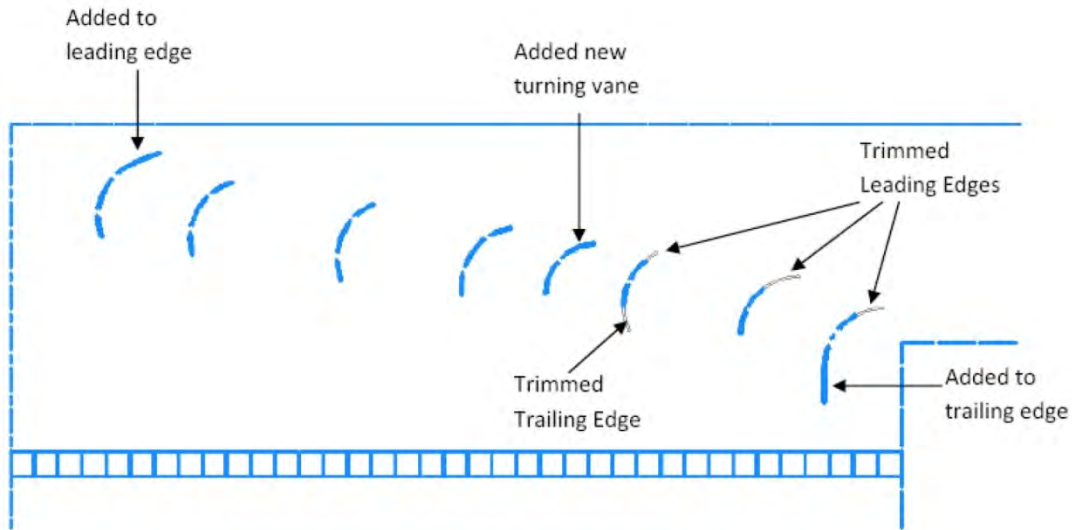


Reactor Hood Velocity Vectors – Baseline  
(Large Eddies as Expected)

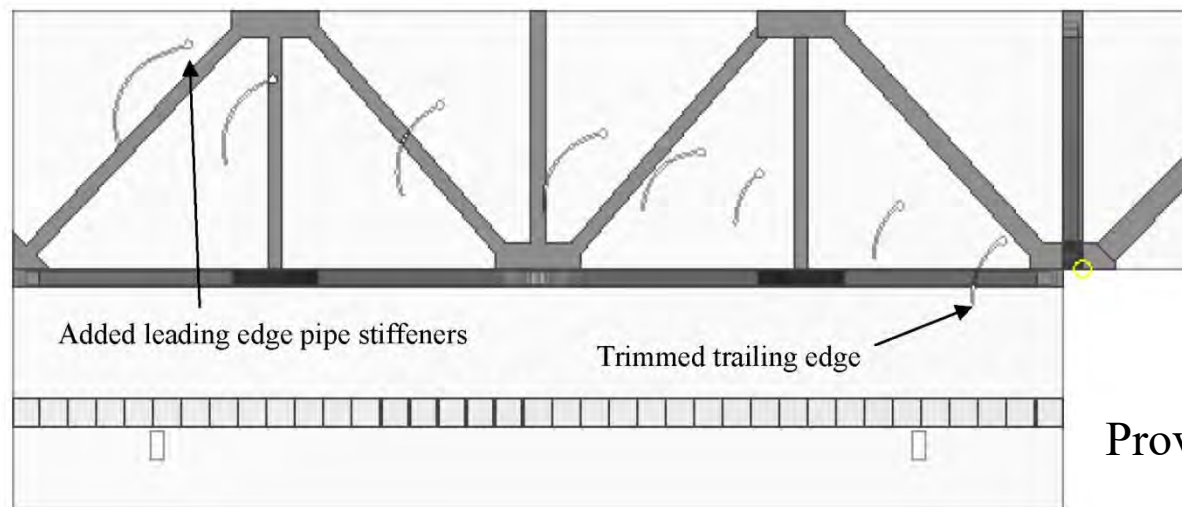
AIG Velocity Profile Baseline = 62% of points  
within 15% of Mean Velocity (18% RMS)

Provided by Fuel Tech

# CFD Modeling Study (2010)



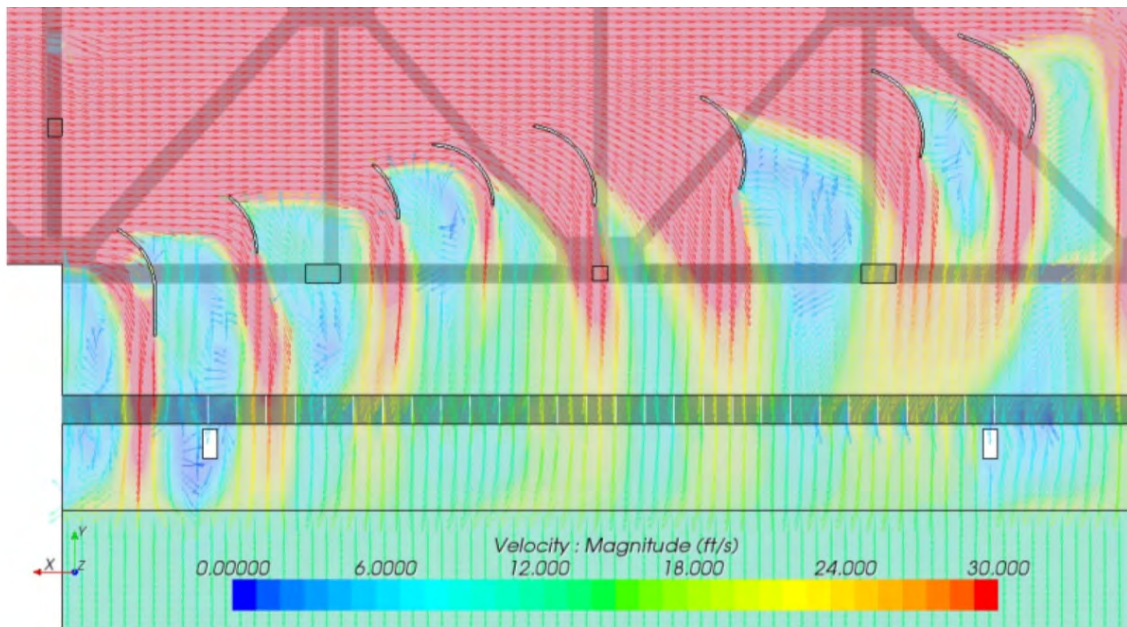
Tried “Novel” Approach(s) by Adding Leading Edge Pipe Stiffeners, Trimming Vanes and Added New Vane



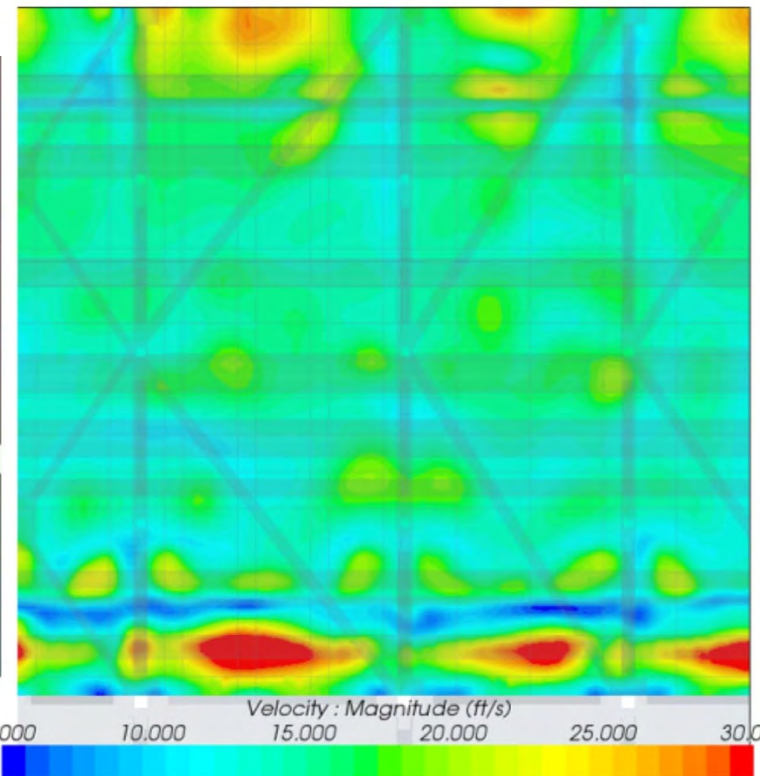
Provided by Fuel Tech

# CFD Modeling Study (2010)

- Reduce Flow Behind 3<sup>rd</sup> Turning Vane
- Increase in Low Flow Behind 1<sup>st</sup> Vane
- 51% of points within 15% of mean velocity (25% RMS)
- Flow Mal-Distribution Result of Poor Flow Into Reactor Hood, Vanning and Large Internal Trusses



Velocity Vectors at Reactor Hood



Velocity Profile at Reactor Hood

- “Novel” Solution Did Not Exist
- Multiple Changes to Vanes Required
- Decided Cost Prohibitive
- Only Change Would Be Vanes at Economizer Outlet

Provided by Fuel Tech

# Reactor Inspection (After CFD)

- Installation of New Vanes at Economizer Outlet Reduced Ash Loading to SCR
  - Smaller Piles Observed in L1 (Coincidence?)
- Erosion Starting to Show on Catalyst
  - Mechanically Last Longer Than Chemical Life (Wall Thickness L1=1.2 mm; L2=L3=1 mm). High Localized Velocities Due to Pluggage.
- Average Pluggage 31% (9.2 mm L1), 20% (8.2 mm L2) and 41% (7.4 mm L3)



Larger Piles in L1-L3



Smaller Ash Piles in L1-L3

# Reactor Inspection (After CFD)



Moderate Erosion in L1 after 18,500 hrs

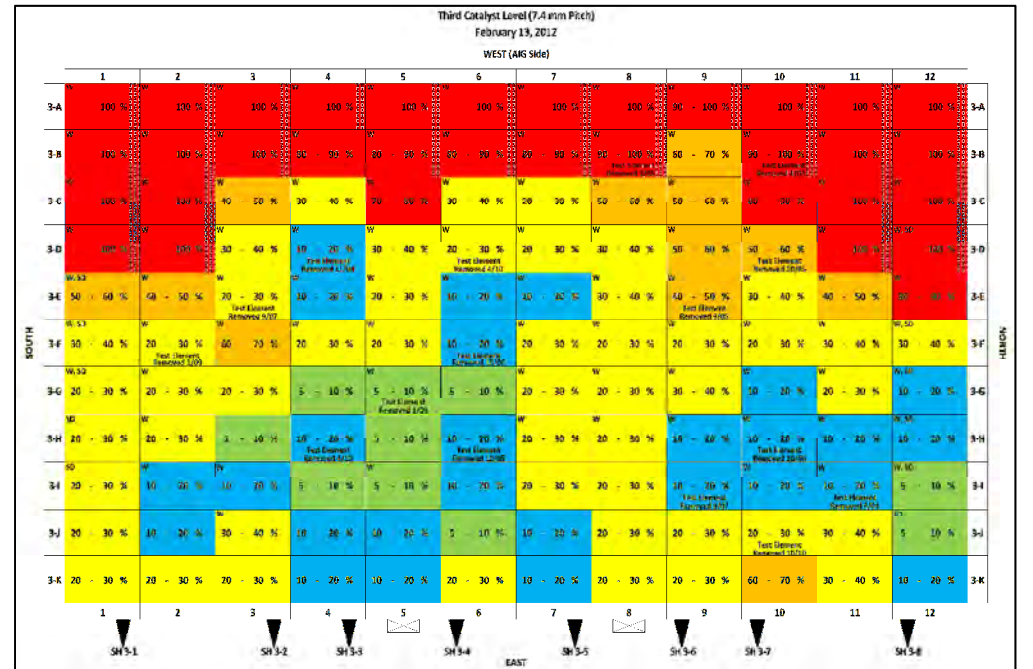
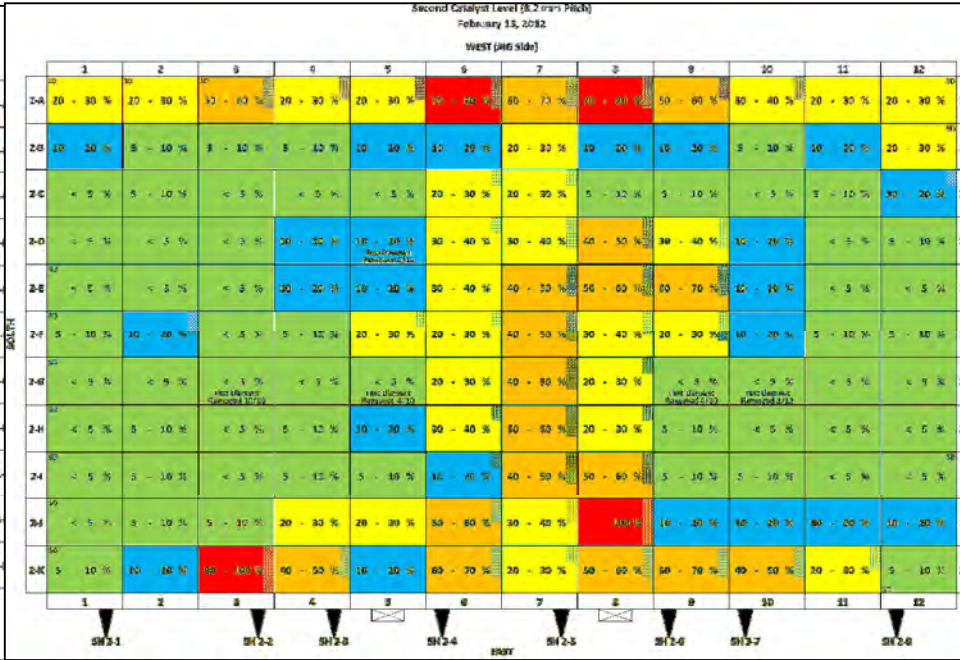
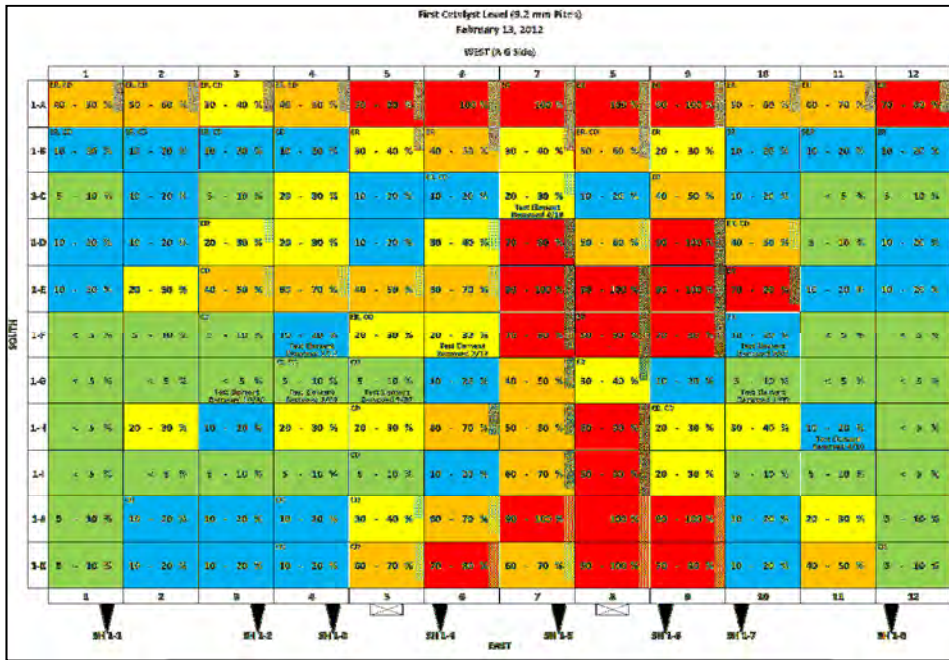


Mechanical Cleaning (Not Recommended)



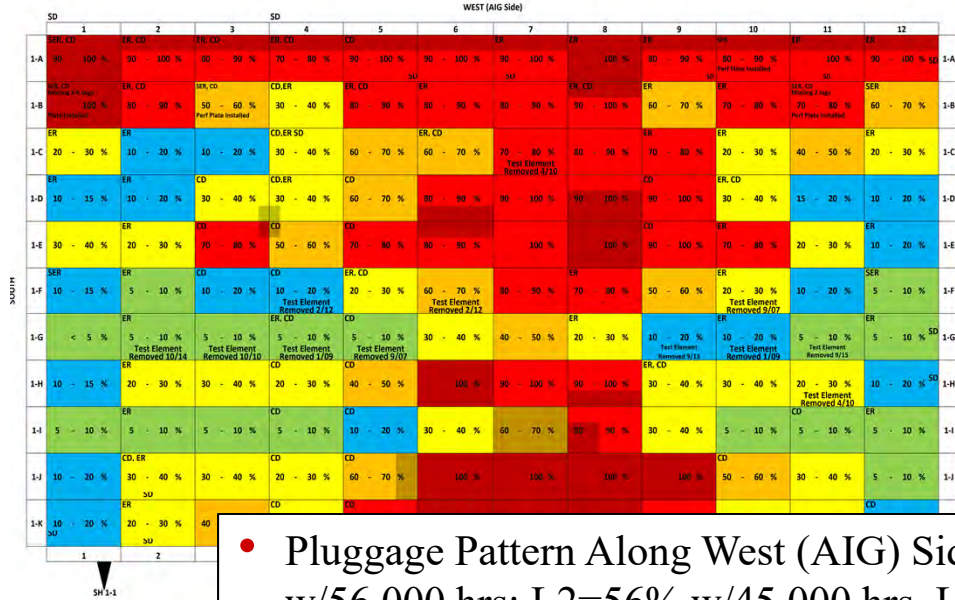
Before and After CFD



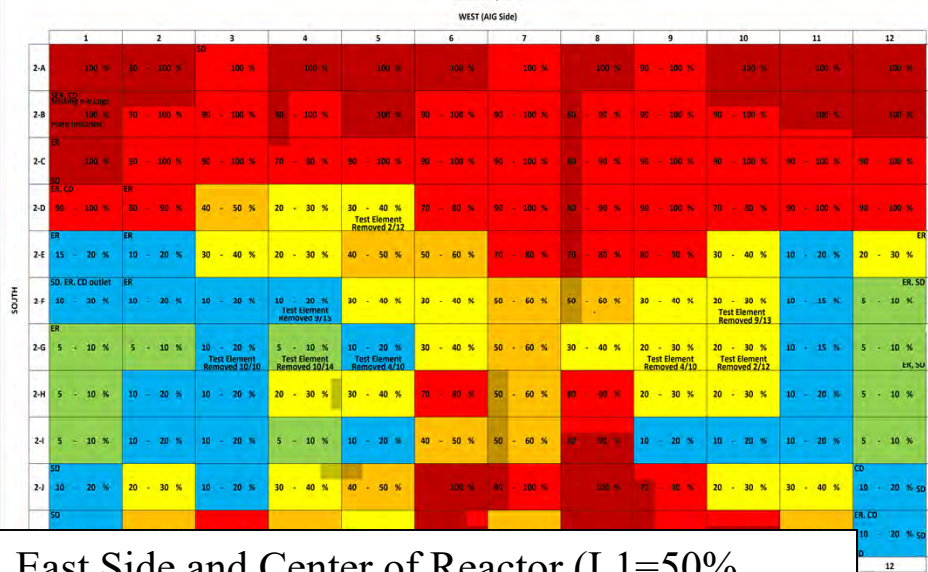


- Pluggage Pattern Along AIG Side and Center of Reactor (L1=34%, L2=20%, L3=44%)
- High Pressure Drop (5-6 in. w.g.)
- Erosion Will Increase
- 8.2 mm Pitch HC Installed in L4 in 2013. Accelerated Events Due to Pluggage
- Further CFD Modeling Recommended

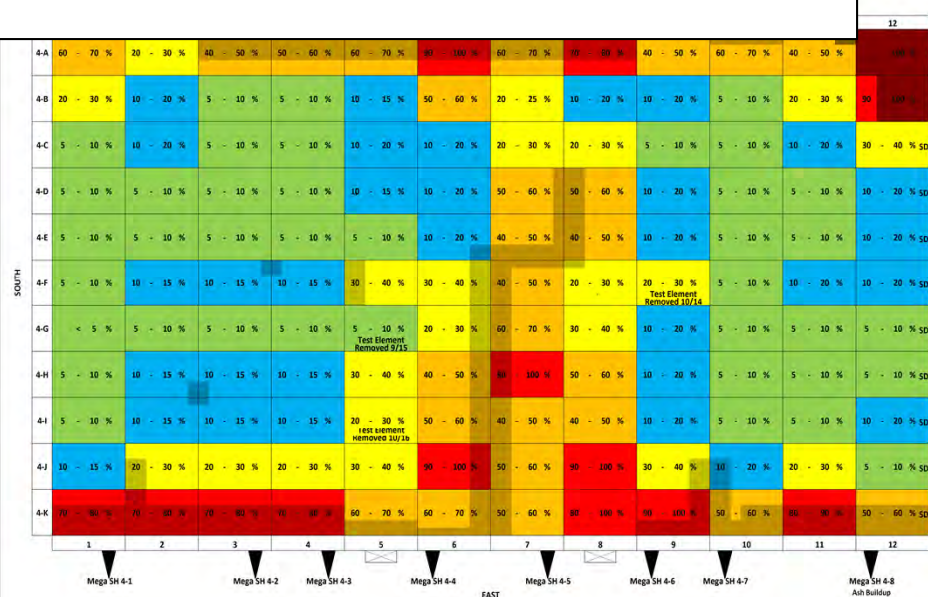
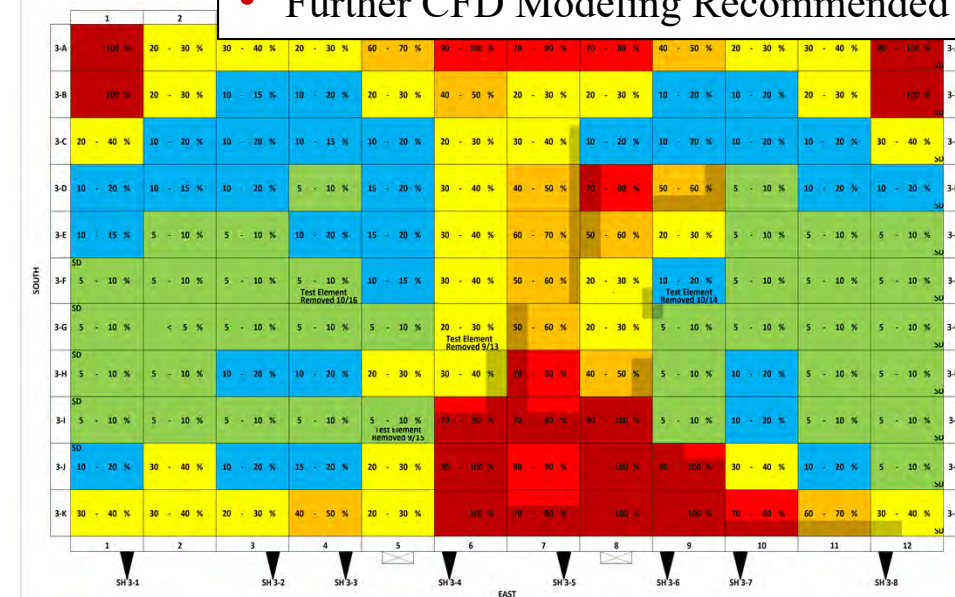
First Catalyst Level (9.2 mm Pitch)  
October 5, 2016



Second Catalyst Level (8.2 mm Pitch)  
October 5, 2016



- Pluggage Pattern Along West (AIG) Side, East Side and Center of Reactor (L1=50% w/56,000 hrs; L2=56% w/45,000 hrs, L3=31% w/27,000 hrs and L4=30% w/17,000 hrs)
- High Pressure Drop (6-8 in. w.g.)
- Erosion Will Increase
- Further CFD Modeling Recommended



# Reactor Inspection (2016 From L1)



Severe Erosion in L1 after 56,000 hrs



Unburned Carbon in Ash Piles



Larger Ash Piles From AIG to Far Side Through Center of Reactor

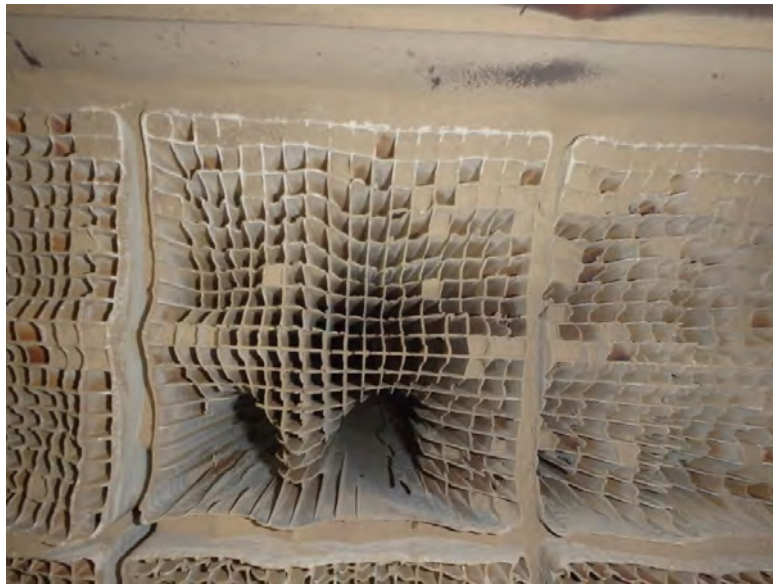
# Reactor Inspection (2016 From L2)



“Mud Daubers” on Outlet in L1



Large Accumulations on Trusses/Beams



**CERAM**

Erosion in L2 After 45,000 hrs



Ash Piles in L2

# Reactor Inspection (2016 From L3 & L4)



Ash Piles in L3



Pluggage on L3 Outlet (Hard & Compact)

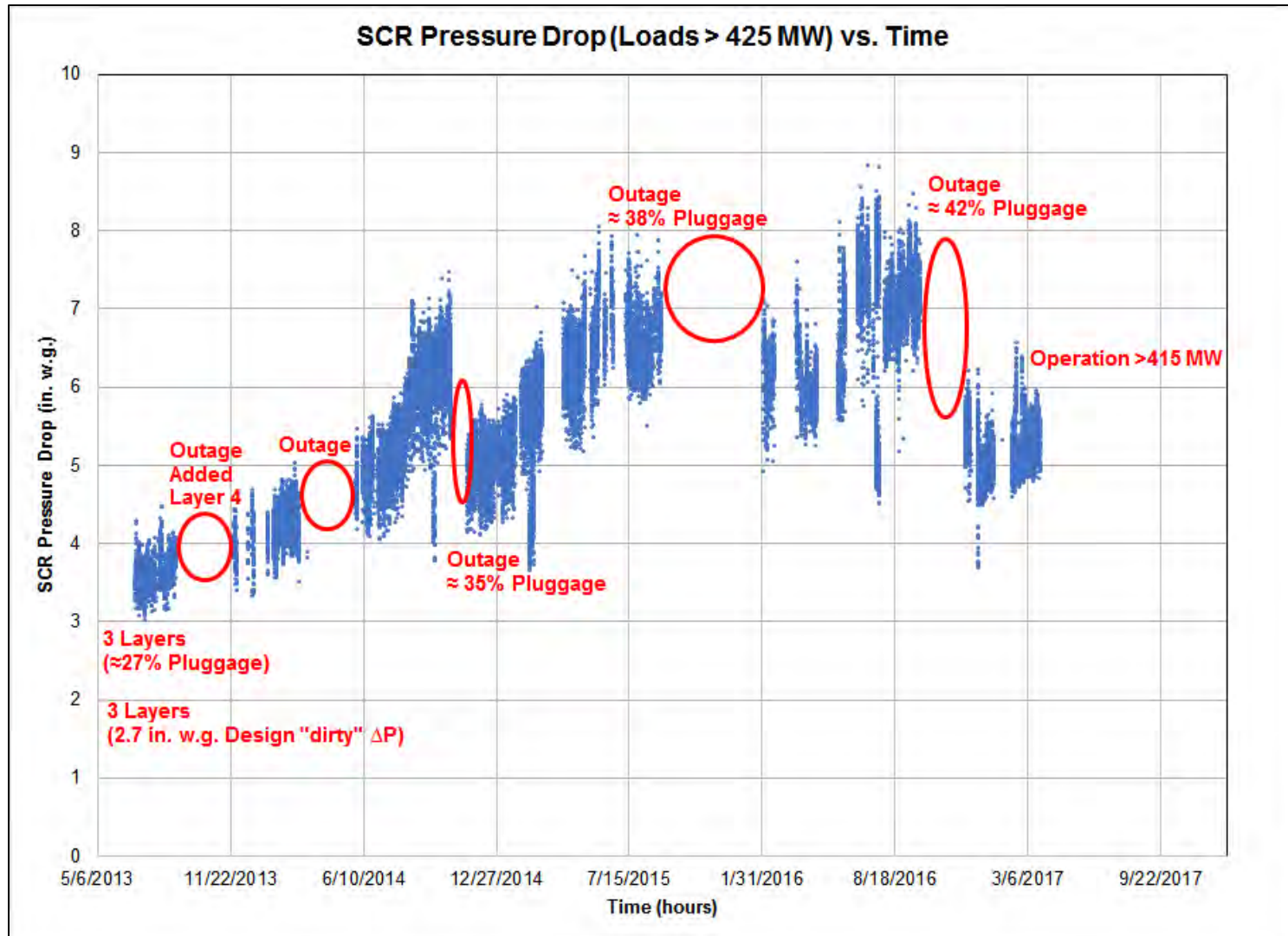


Ash Piles in L4



Unburned Carbon in Ash Piles

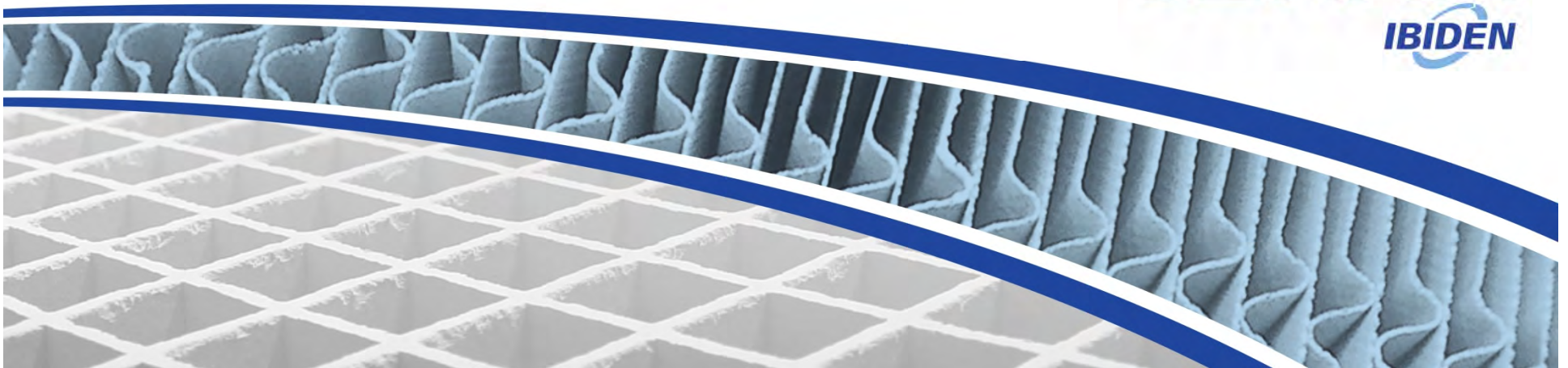
# Pressure Drop Across SCR



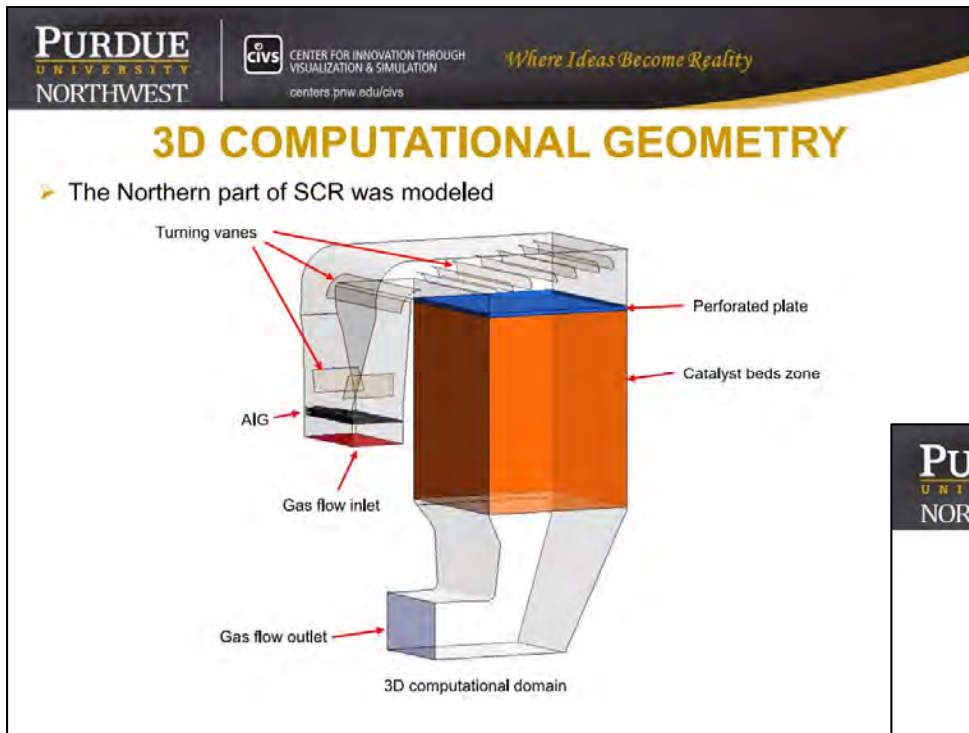
# 2018 Reinhold Presentation

## “Midwest Utility” CFD Phase II Study

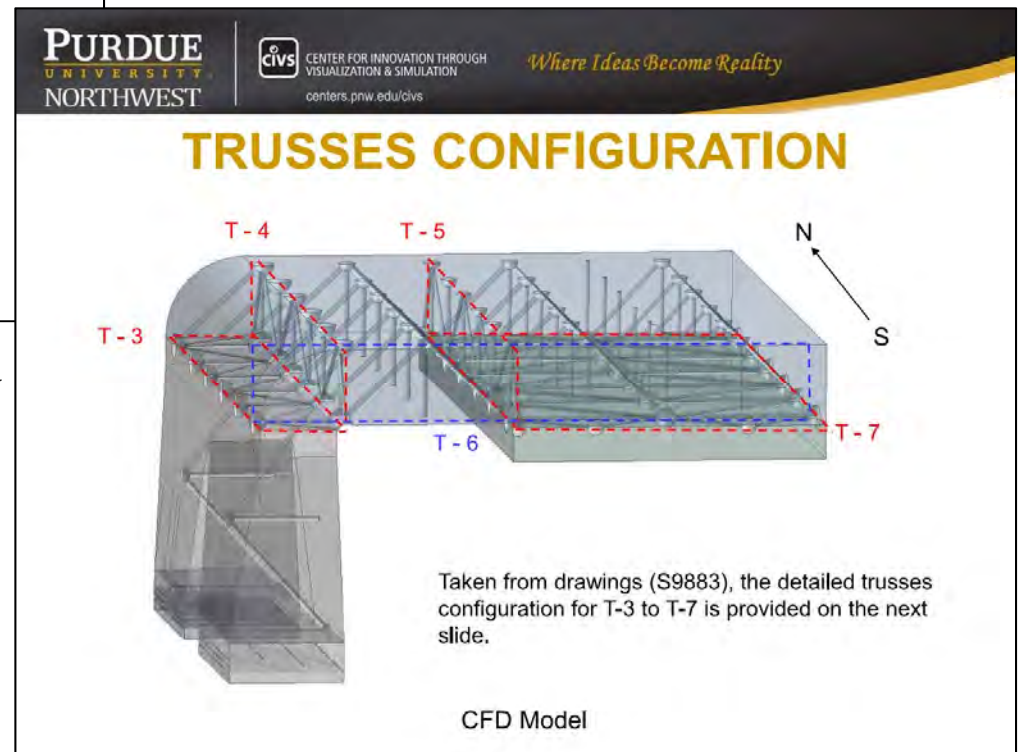
**CERAM**  
IBIDEN



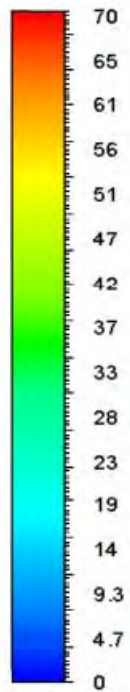
# CFD Modeling Study (2016-17; Phase II)



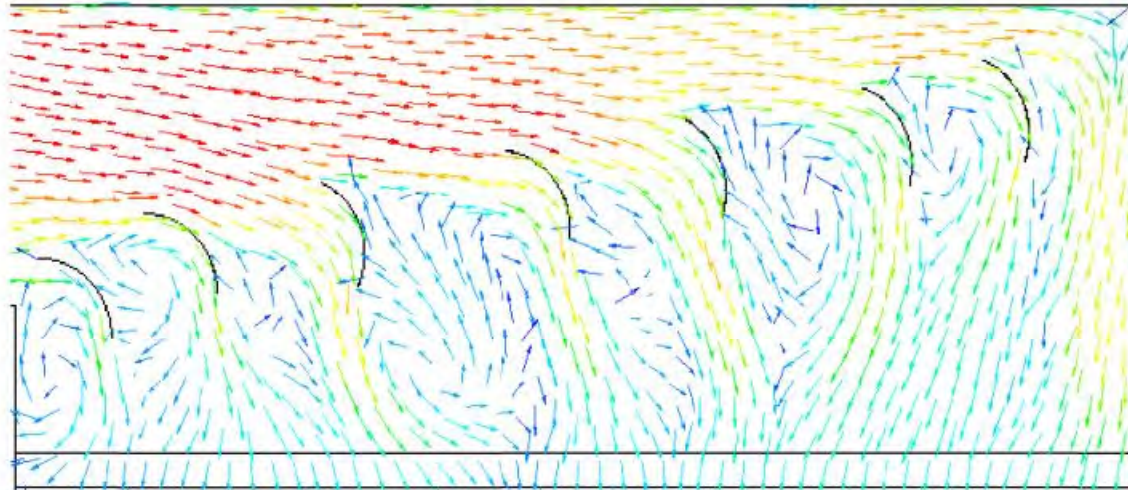
- Originally Would Model Assuming Symmetry
- Decided to Model Both North and South Reactors



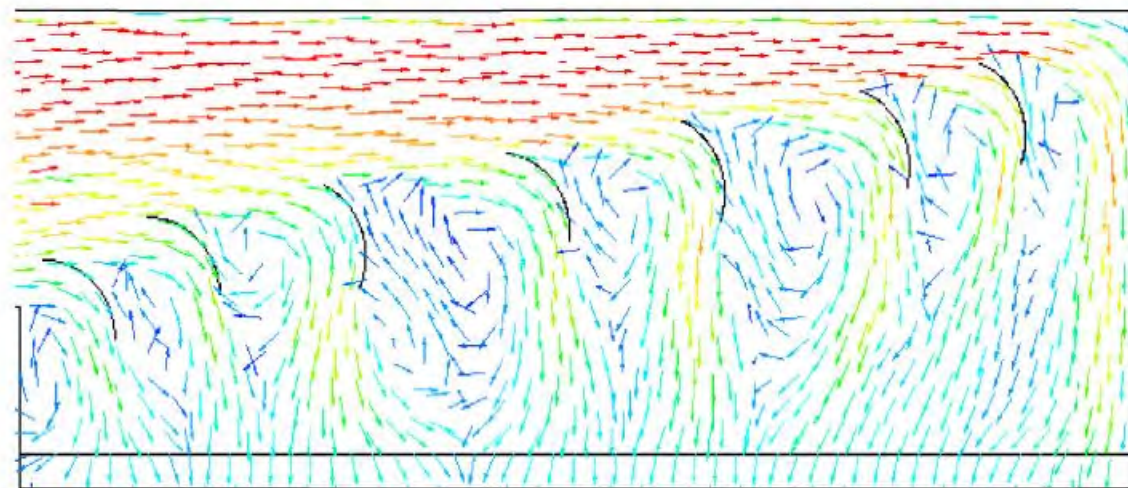
# GAS VELOCITY DISTRIBUTION



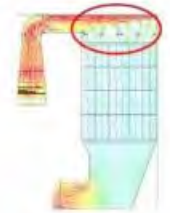
ft/s



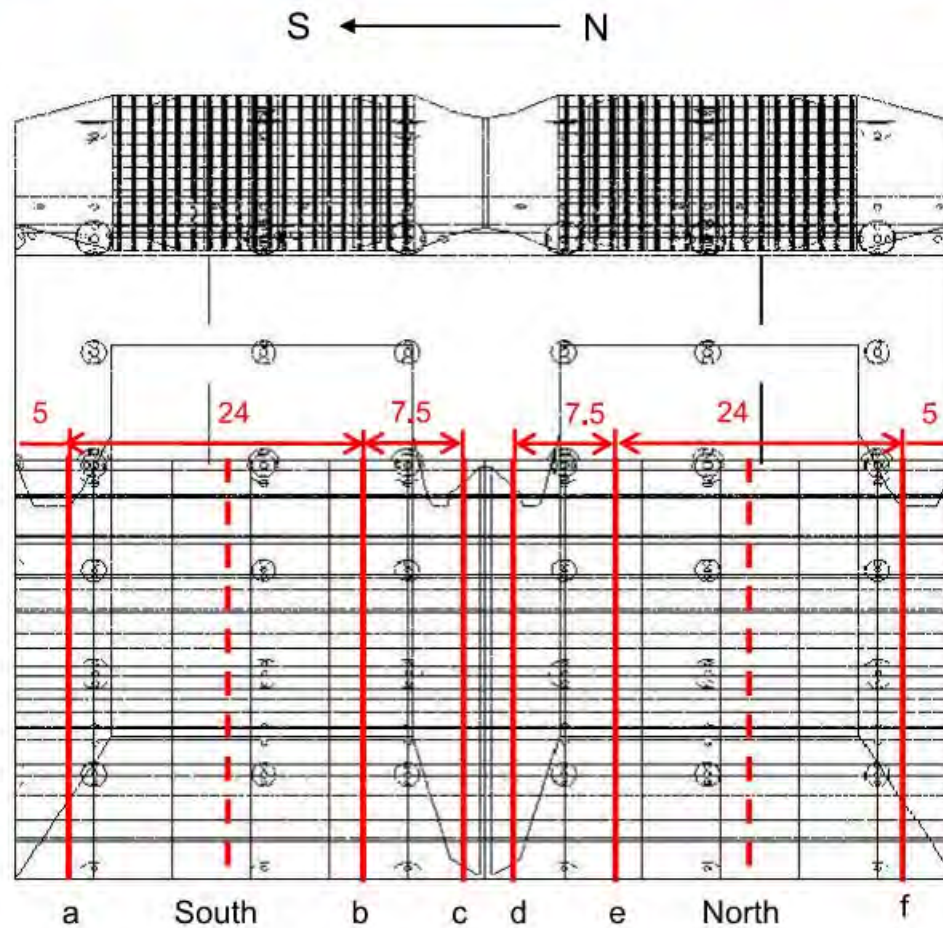
North SCR



South SCR



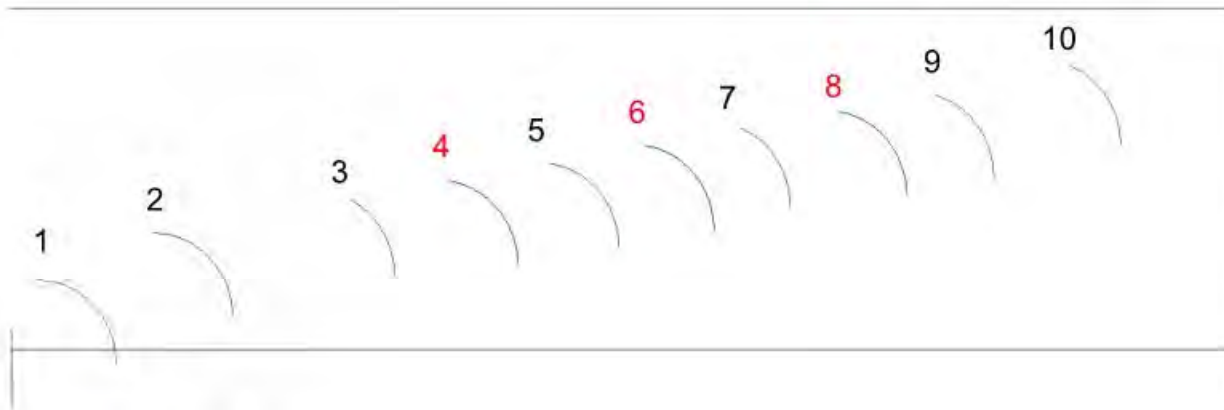
# SIDE VERTICAL SECTIONS SETTING



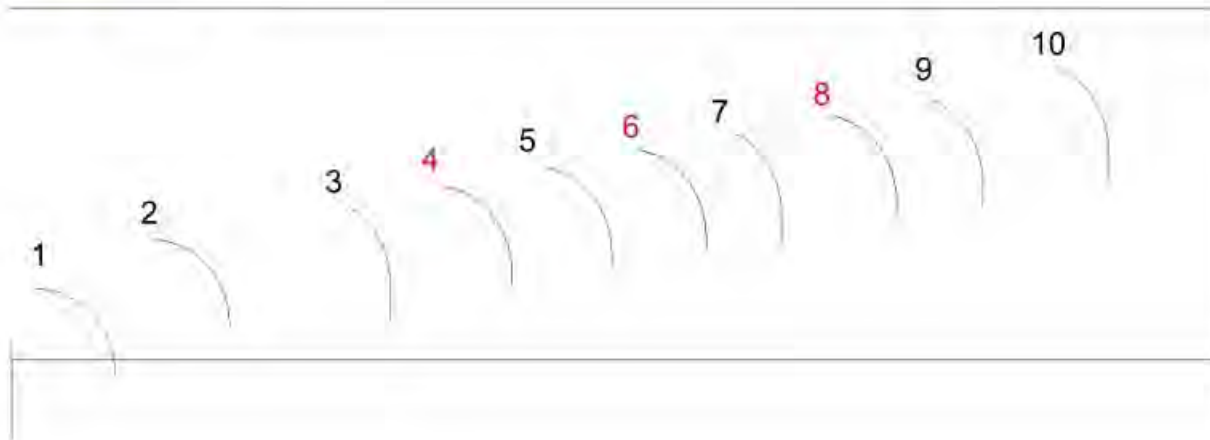
- Six more sections are created at different locations showing above

# U12 SCR TURNING VANE DIMENSIONS

## ➤ Run 1:

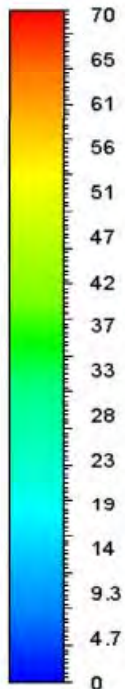
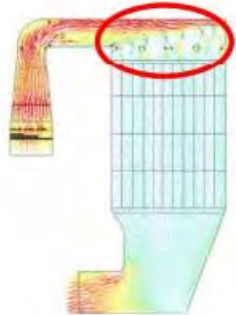


## ➤ Run 2:

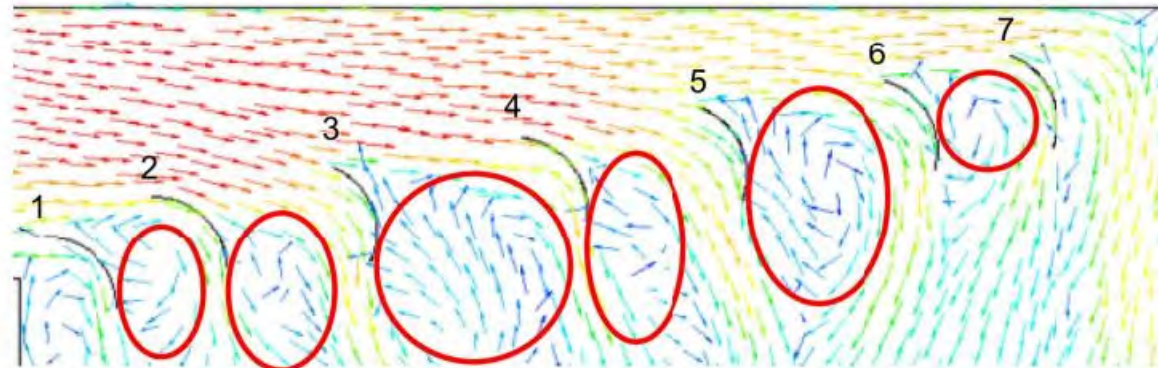


- Vanes 4, 6, and 8 were added in the middle between two adjacent vanes.
- Vanes 4, 6, and 8 have the same dimensions as vane 5.
- For Run 1, the trailing edges of vanes 3, 5, 7, 9, and 10 were trimmed to be vertical
- For Run 2, the trailing edges of vanes 3, 5, 7, 9, and 10 were trimmed to be vertical and were extended to the current trailing edge elevation

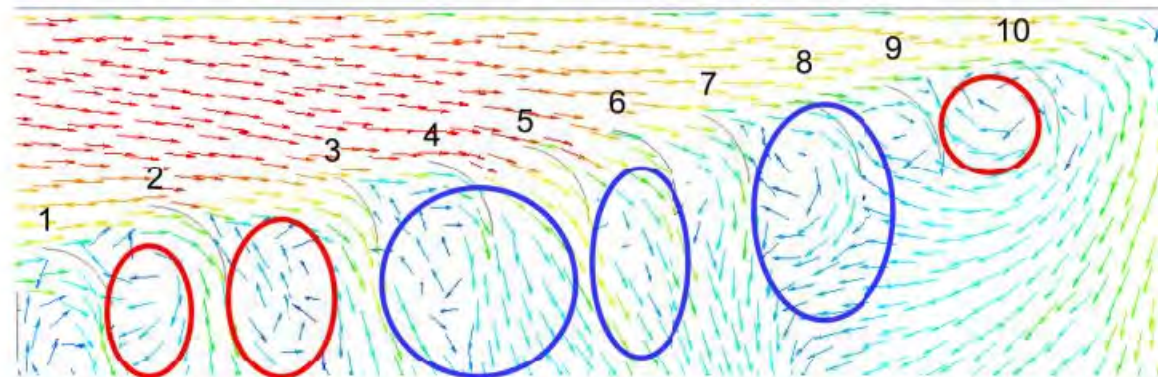
# FLOW DISTRIBUTION – NORTH SECTION



ft/s



Original SCR

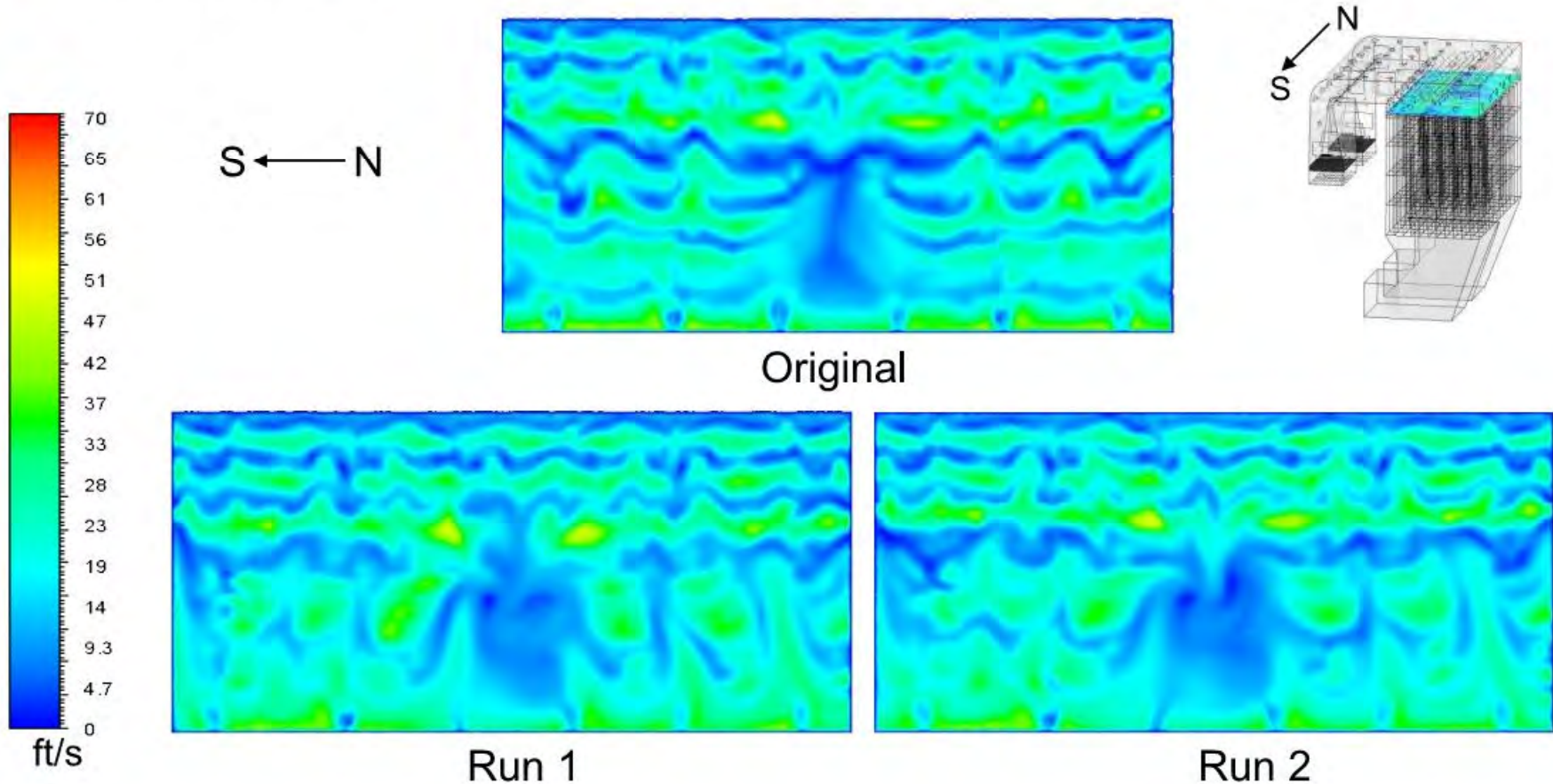


Run 1

- The recirculation areas behind vanes 3 and 5 decrease, but the recirculation area behind vanes 2 and 6 do not change.

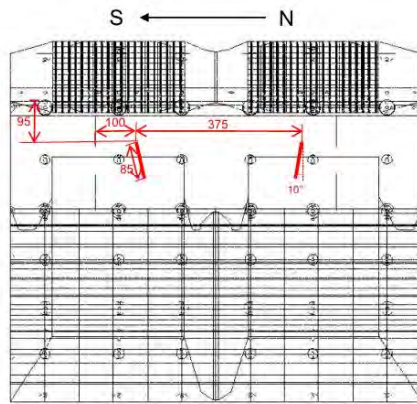
# HORIZONTAL SECTION OVER PERFORATED PLATE

➤ The section shown below is located 3ft above the perforated plate

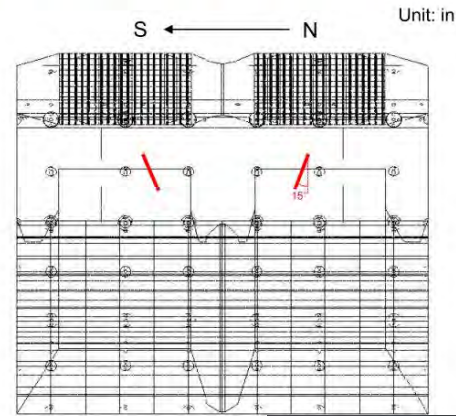


## TURNING VANES DIMENSIONS

### ➤ Modified Run 7 turning vanes



Run 7a

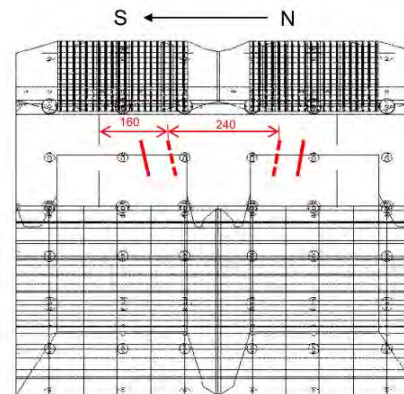


Run 7b

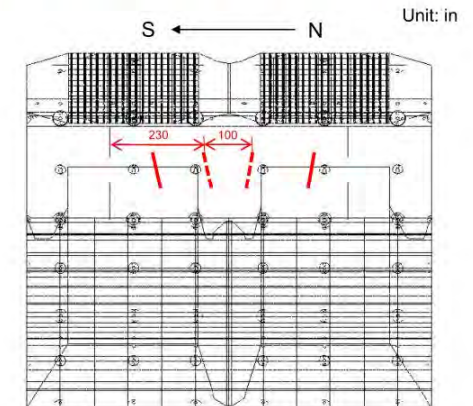
- Two vertical vanes were added to concentrate the flow to the center.
- The length of the new vertical vanes are the same as vane 8 (85 in) oblique angle. One more run (Run 7b) with 15° angle was set for comparison.

## TURNING VANES DIMENSIONS

### ➤ Modified Run 8 turning vanes



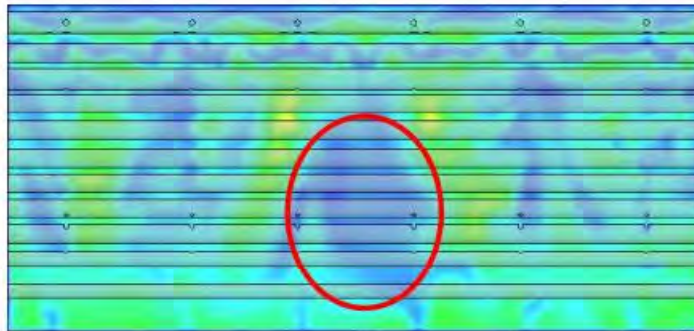
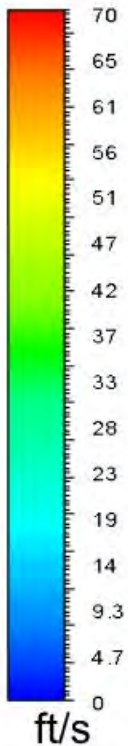
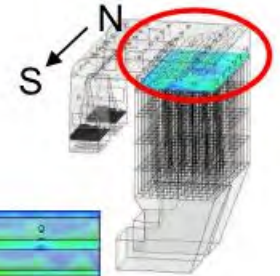
Run 8a



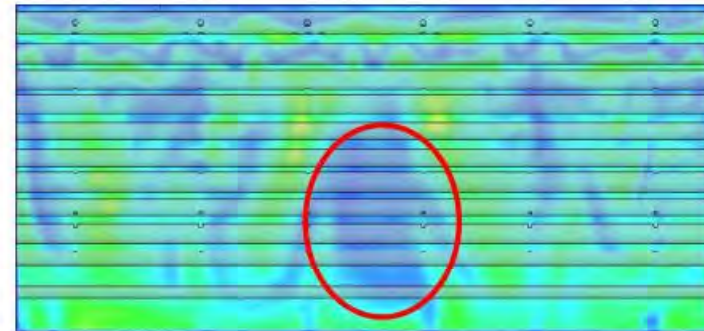
Run 8b

- The length of the new vertical vanes are the same as vane 8 (85 in).
- Two more vertical vanes were added based on Run 7a (10°) with the distance of 240 in.
- One more run (Run 8b) with the new vertical vanes closer (100 in) was simulated.

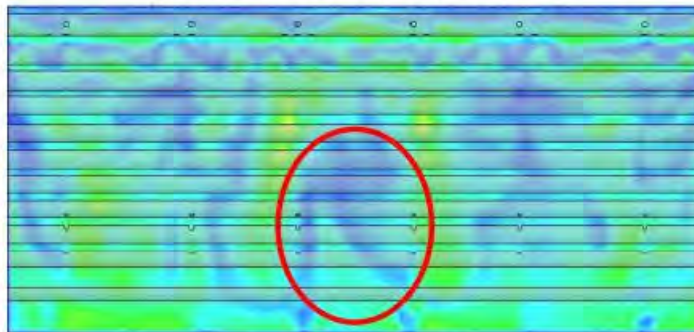
# HORIZONTAL SECTION OVER PEFORATED PLATE



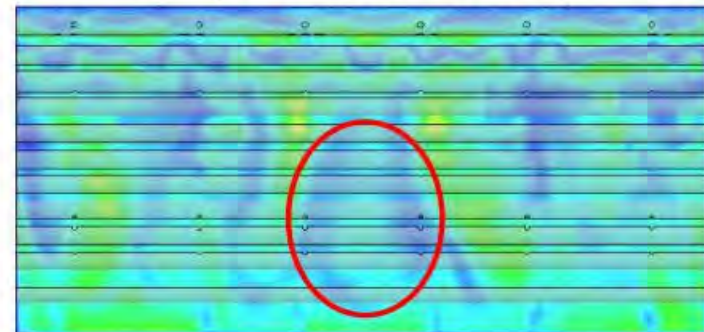
Run 7a  
(10°, 2 vertical vanes)



Run 7b  
(15°, 2 vertical vanes)



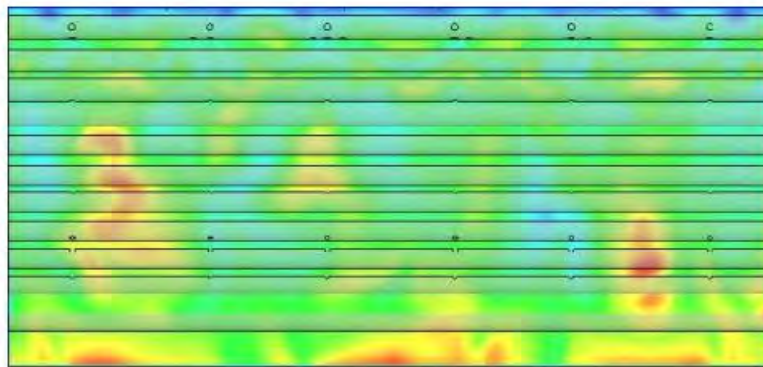
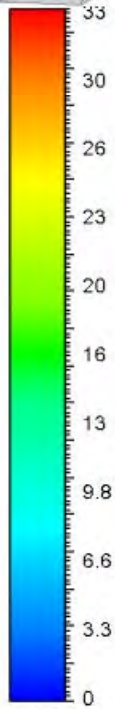
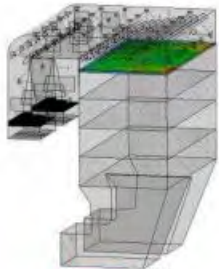
Run 8a  
(4 vertical vanes, 240 in)



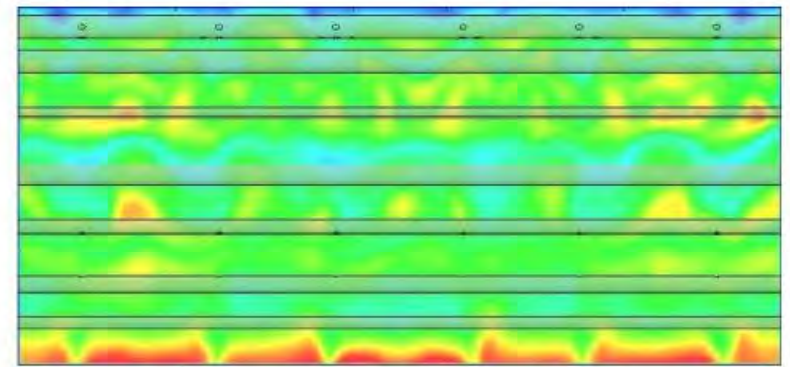
Run 8b  
(4 vertical vanes, 100 in)

- From the flow distribution over the perforated plate, the 4 vertical vanes help reduce the low velocity zone in the center area.

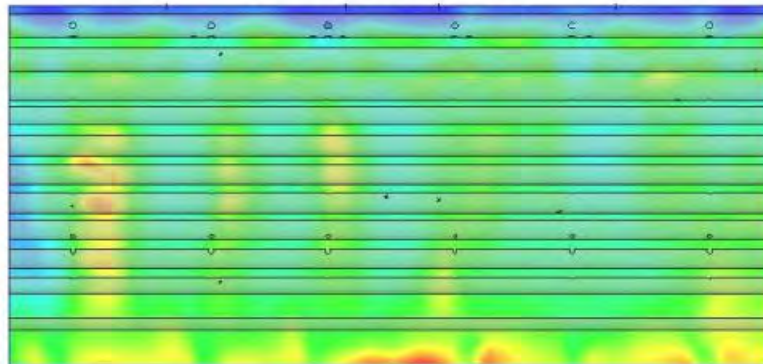
# HORIZONTAL SECTION AT THE PEFORATED PLATE



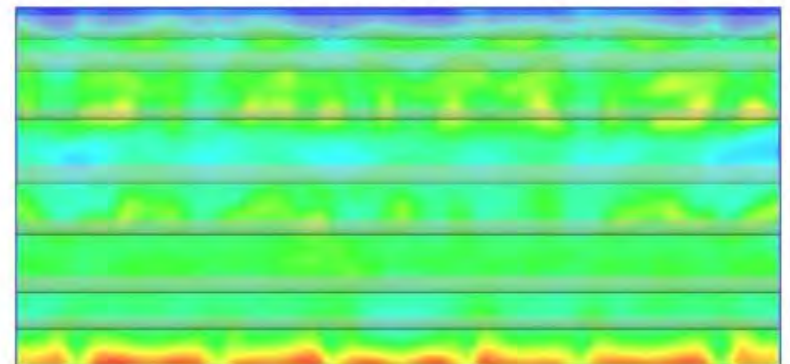
Run 10  
(4 vertical vanes)



Run 12  
(4 vertical vanes)

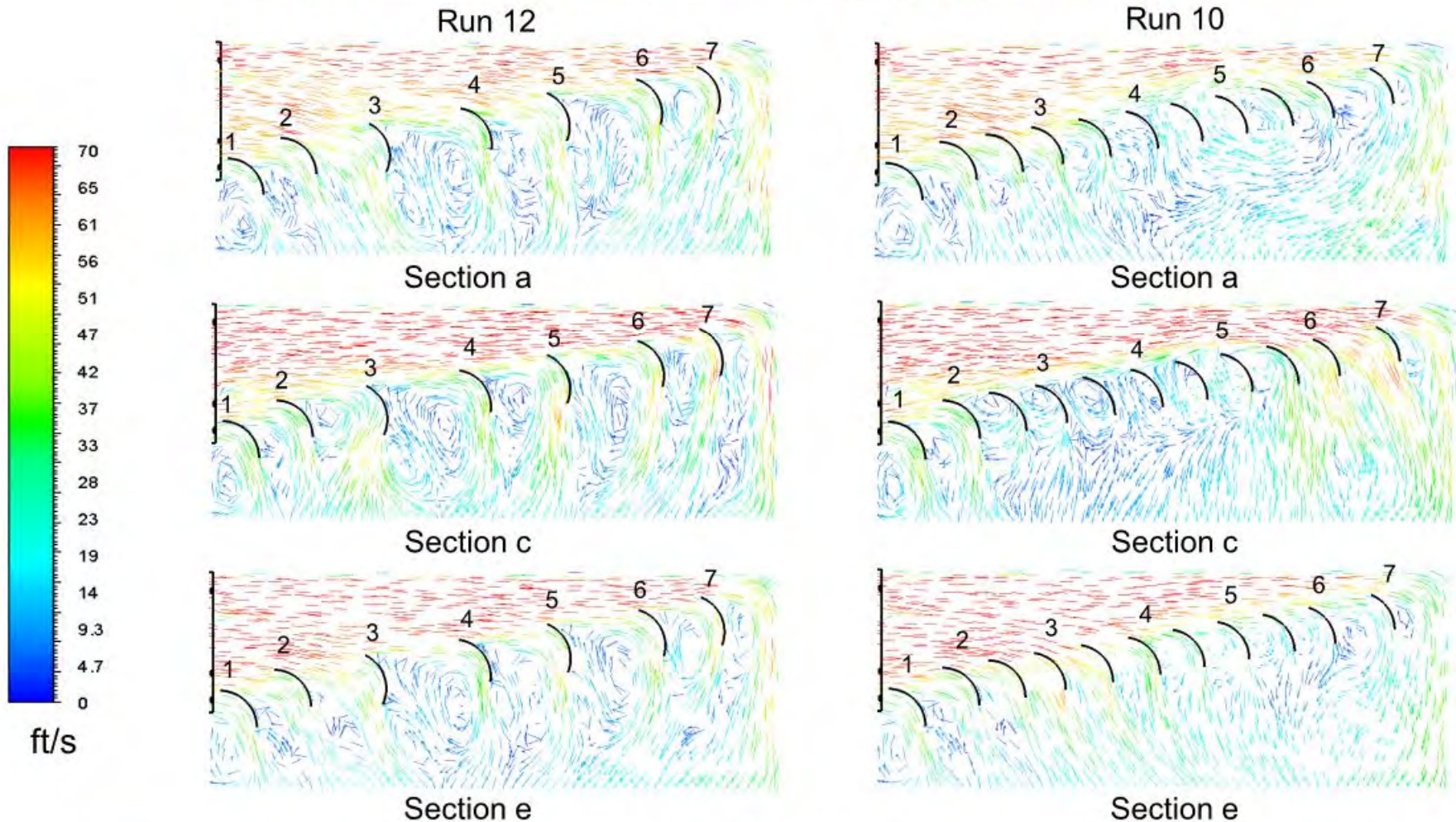


Run 13  
(6 vertical vanes)



Run 14  
(6 vertical vanes)

# SIDE BY SIDE COMPARISON

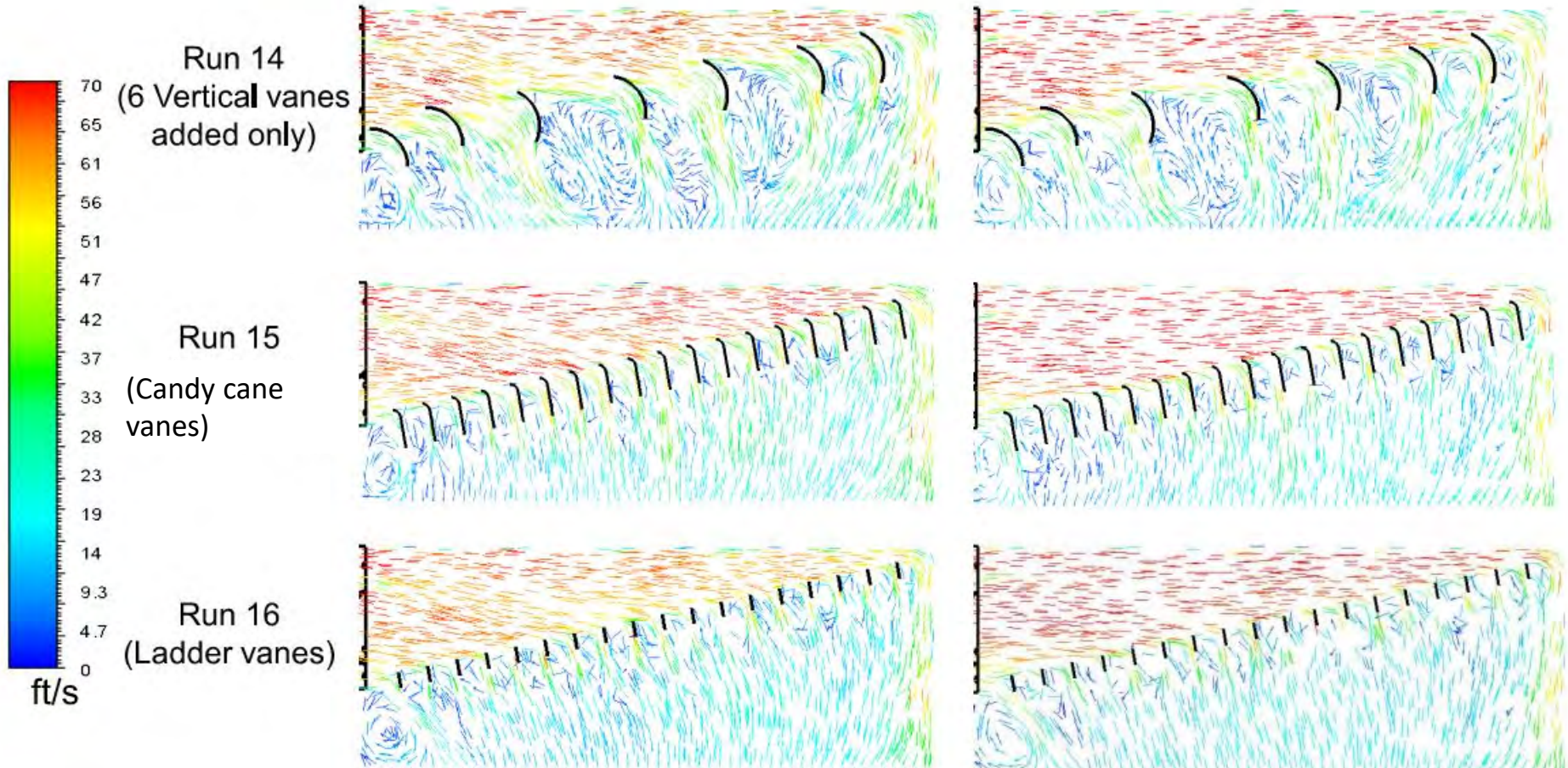


- The recirculation size in the Run 10 is smaller in section a and section e, but many small recirculation formed near vanes 3 - 5

# SIDE BY SIDE COMPARISON

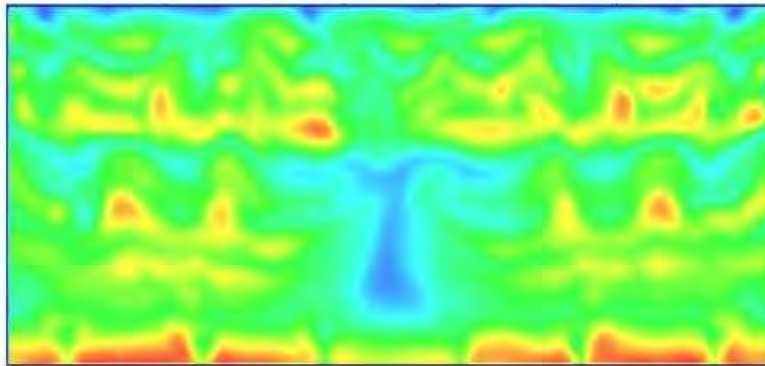
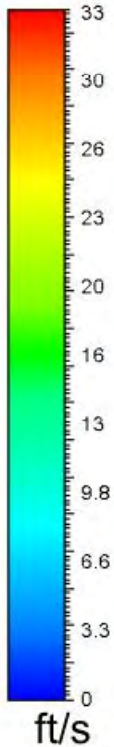
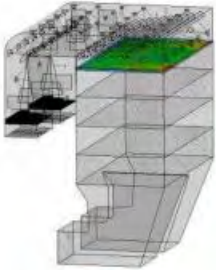
Section a

Section b

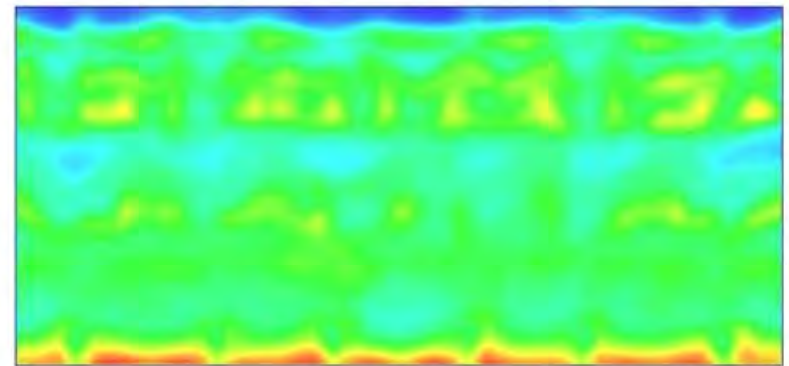


Note, Larger recirculation zones near wall across reactor (a through f) with ladder vanes

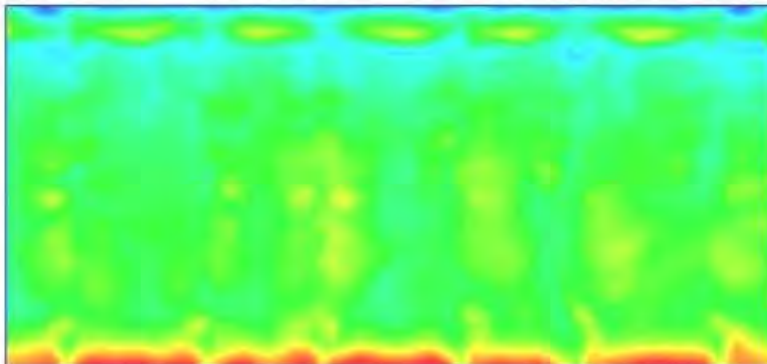
# HORIZONTAL SECTION AT THE PERFORATED PLATE



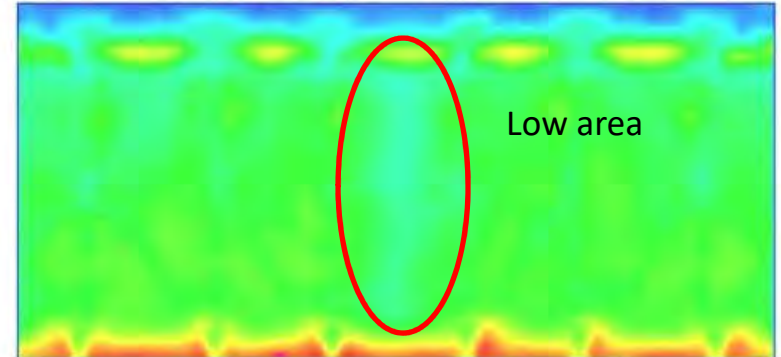
Baseline case  
(Current configuration)



Run 14  
(6 Vertical vanes added only)



Run 15  
(Candy cane vanes)

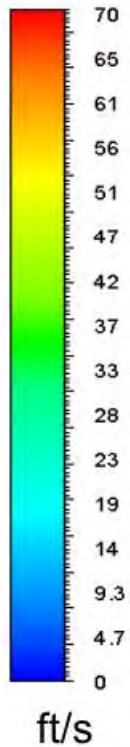


Run 16  
(Ladder vanes)

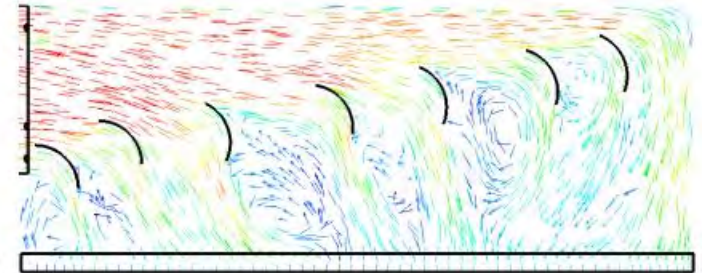
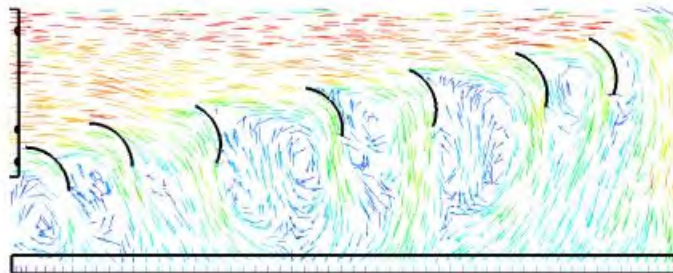
# SIDE SECTION VECTORS DISTRIBUTION

Section a

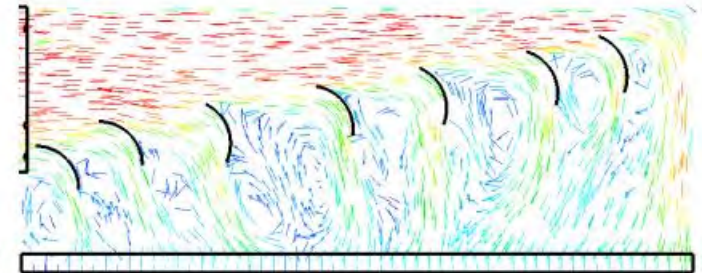
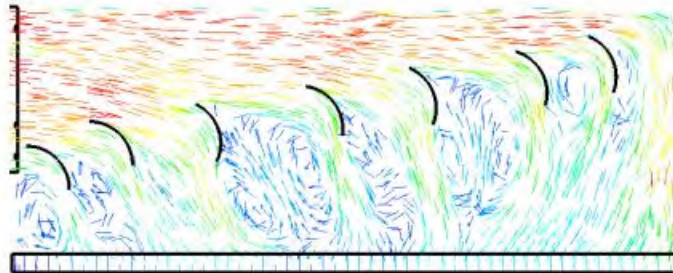
Section b



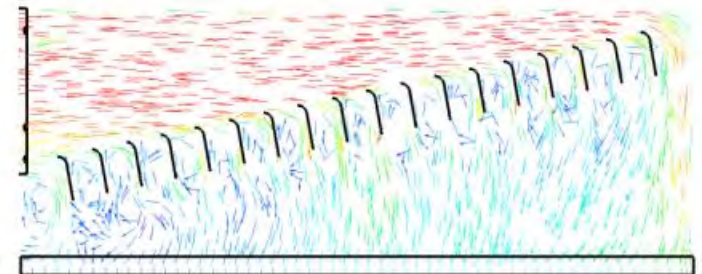
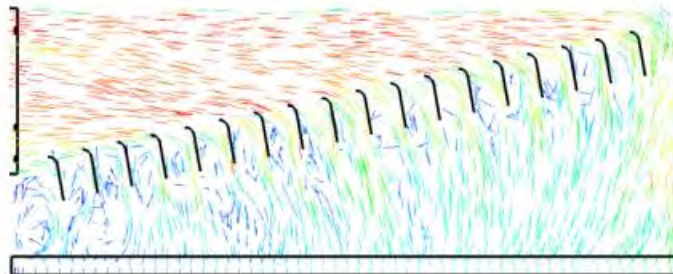
Baseline  
(Current vanes  
pattern)



Run 14  
(Six new vertical  
vanes)



Run 18  
(Six new vertical  
vanes, candy cane  
vanes )

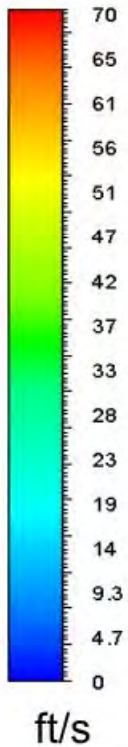


➤ Section a-f are located from south to north

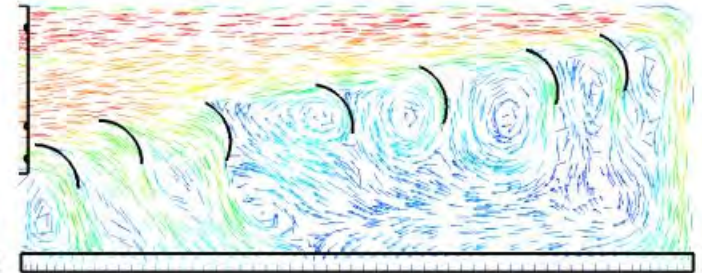
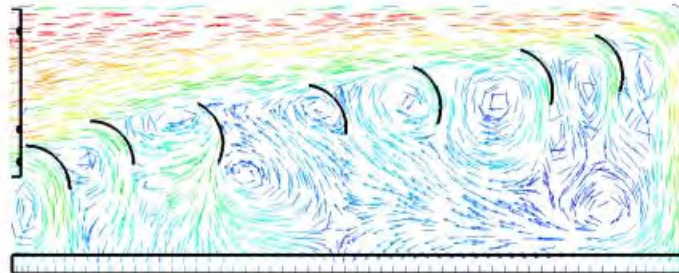
# SIDE SECTION VECTORS DISTRIBUTION

Section c

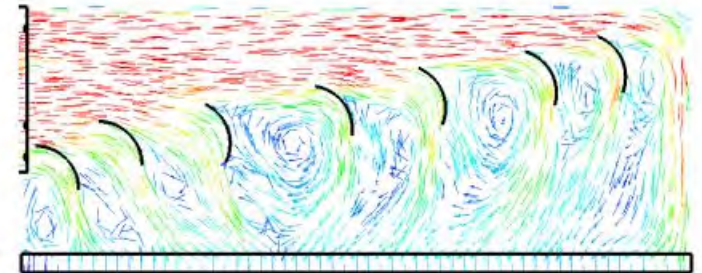
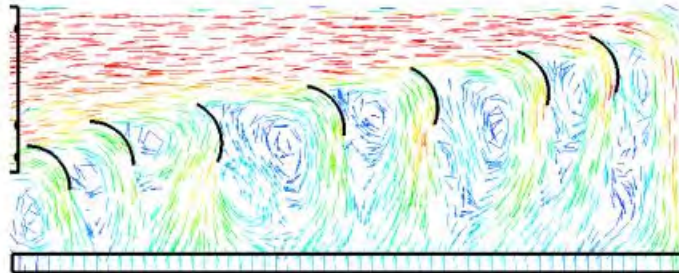
Section d



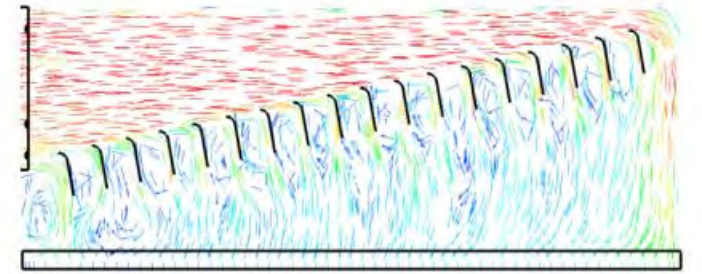
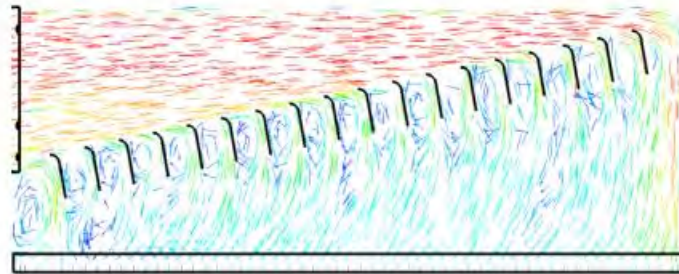
Baseline  
(Current vanes  
pattern)



Run 14  
(Six new vertical  
vanes)



Run 18  
(Six new vertical  
vanes, candy cane  
vanes)

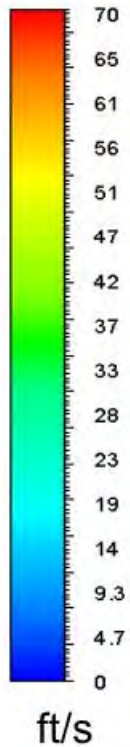


➤ Section a-f are located from south to north

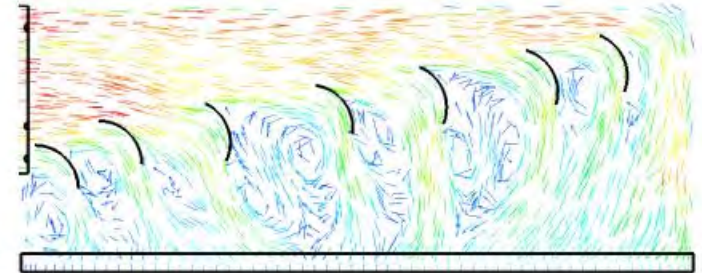
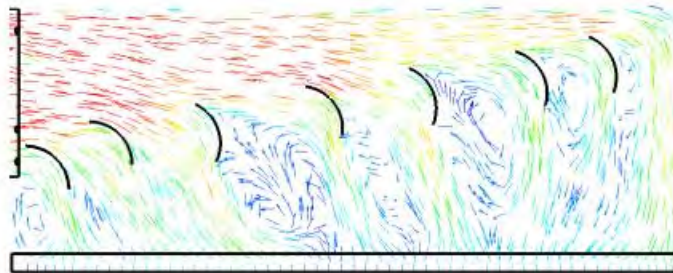
# SIDE SECTION VECTORS DISTRIBUTION

Section e

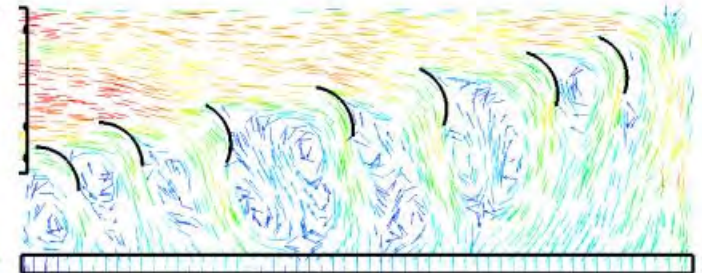
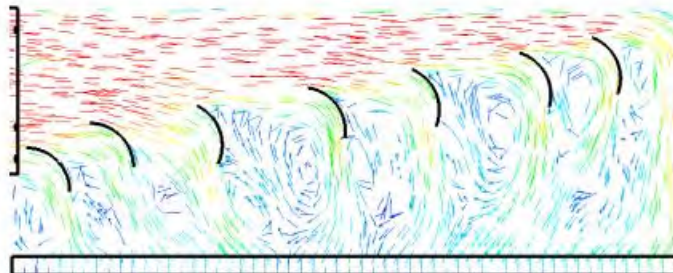
Section f



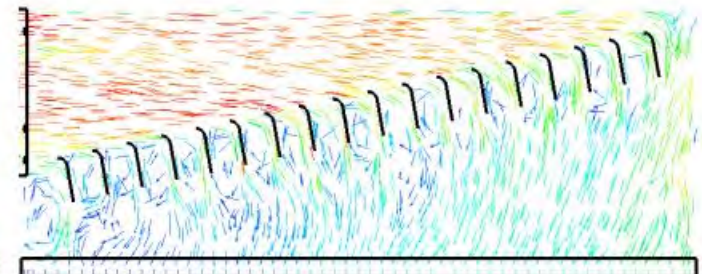
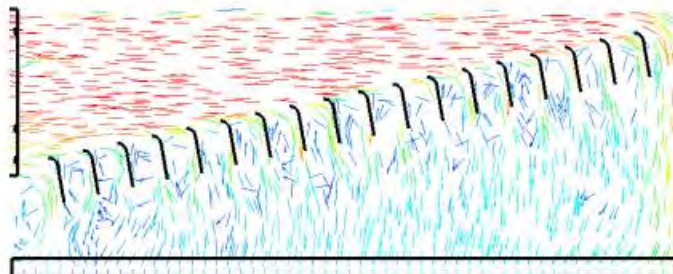
Baseline  
(Current vanes  
pattern)



Run 14  
(Six new vertical  
vanes)



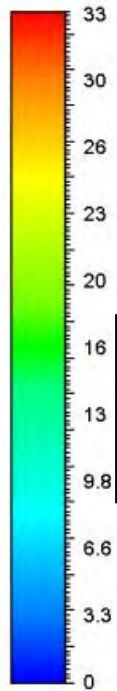
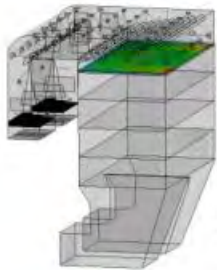
Run 18  
(Six new vertical  
vanes, candy cane  
vanes)



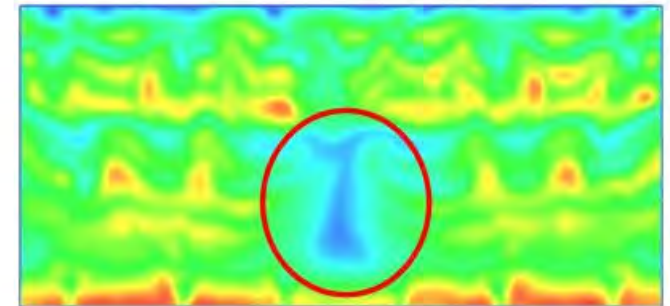
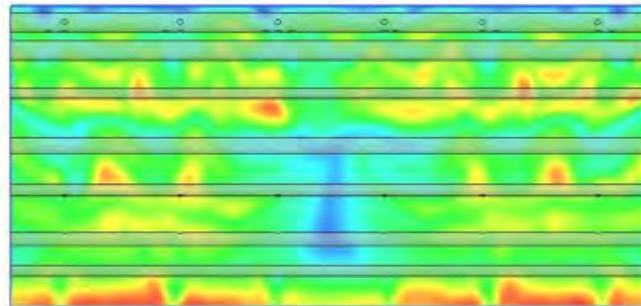
➤ Section a-f are located from south to north

# VELOCITY MAGNITUDE DISTRIBUTION

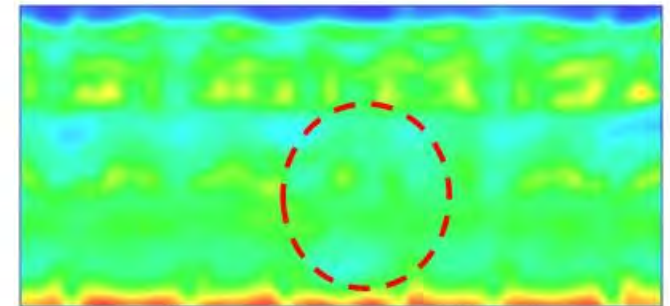
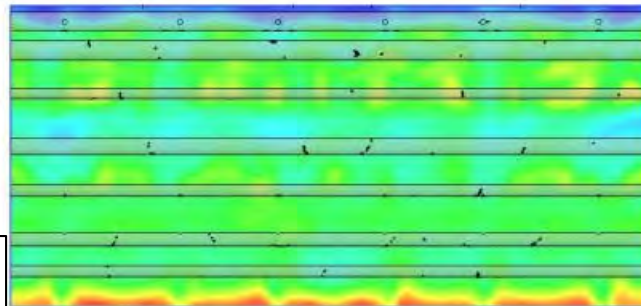
➤ Incoming flow velocity magnitude above the flow straightener



Baseline  
(Current vanes  
pattern)

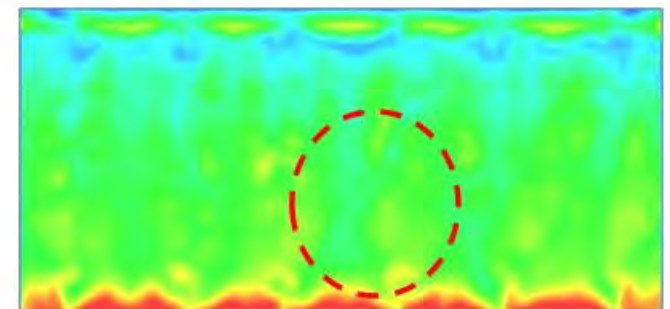
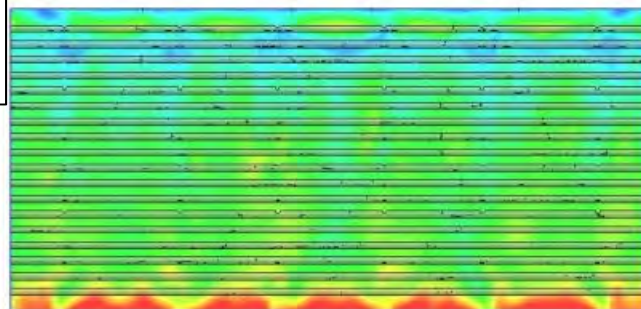


Run 14  
(Six new vertical  
vanes)



Low areas near wall  
due to inadequate  
free board height

Run 18  
(Six new vertical  
vanes, candy cane  
vanes )

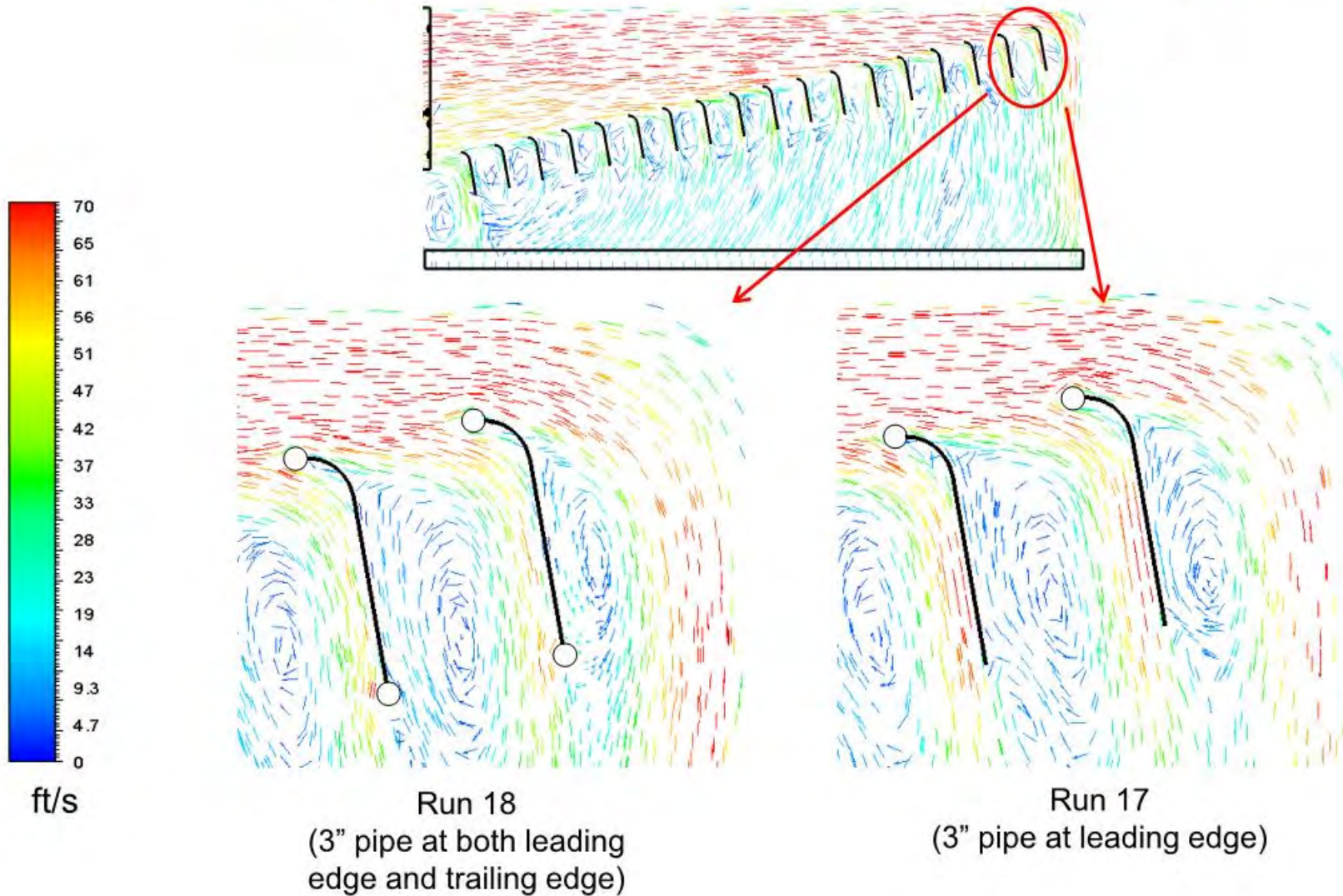


ft/s

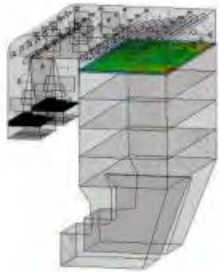
With vanes shadow

Without vanes shadow

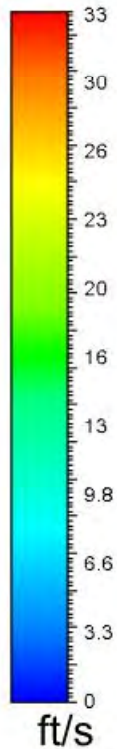
# EFFECT OF THE 3" PIPES



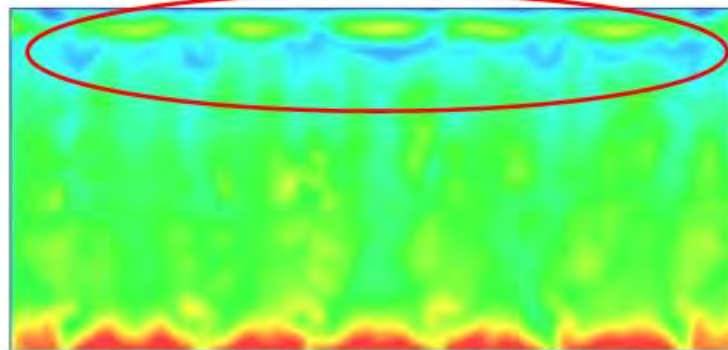
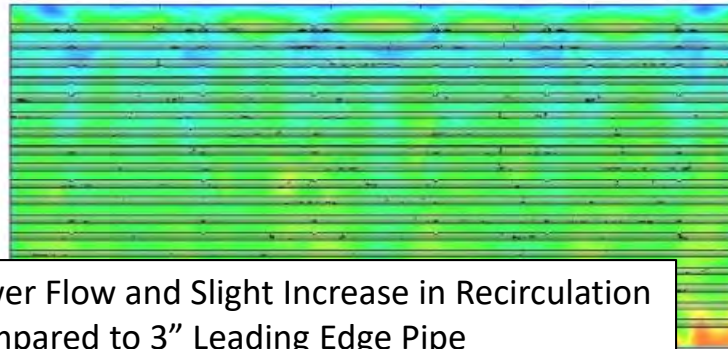
# HORIZONTAL SECTION AT THE PERFORATED PLATE



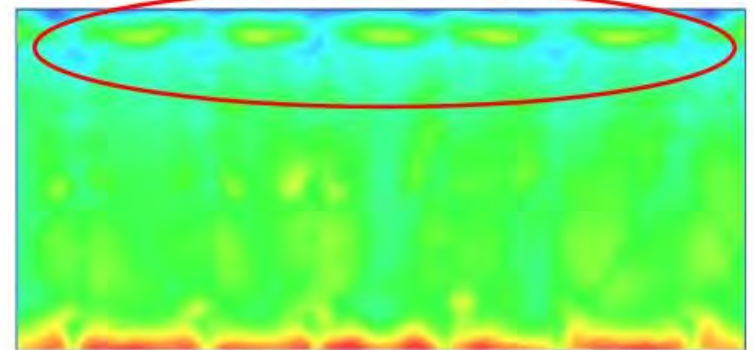
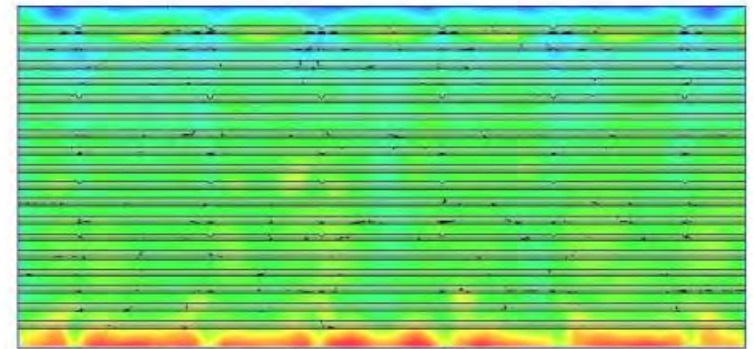
- Incoming flow velocity magnitude above the flow straightener



Lower Flow and Slight Increase in Recirculation  
Compared to 3" Leading Edge Pipe



Run 18  
(3" pipe at both leading edge  
and trailing edge)



Run 17  
(3" pipe at leading edge)

# DIFFERENT DESIGN LIST

	Number of vertical vanes	Turning vanes type
Baseline	4	Traditional turning vanes (current pattern)
Run 14	10	Traditional turning vanes (current pattern)
Run 18	10	Candy cane vanes (3-in pipe at leading edge & trailing edge)



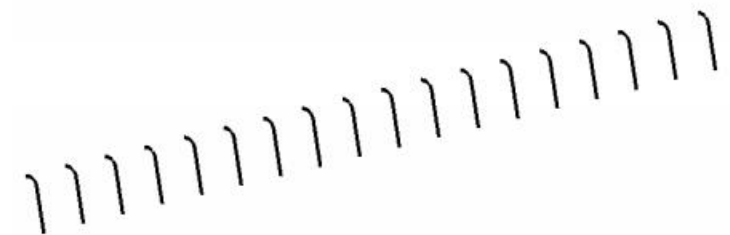
4 vertical vanes  
(current pattern)

10 vertical vanes

Top view

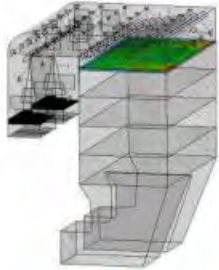


Traditional turning vanes  
(current pattern)



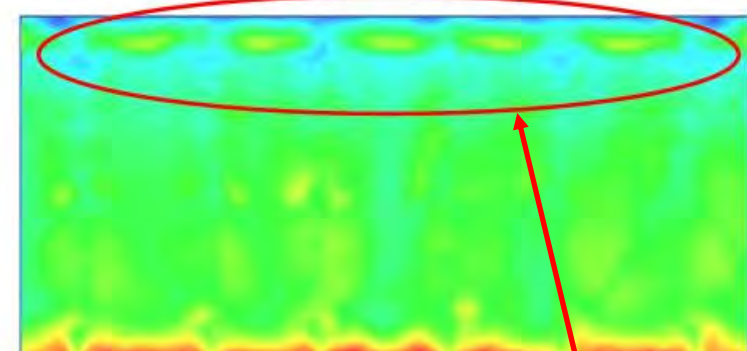
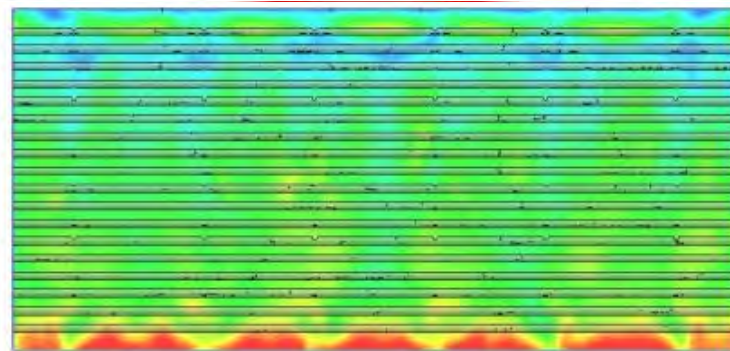
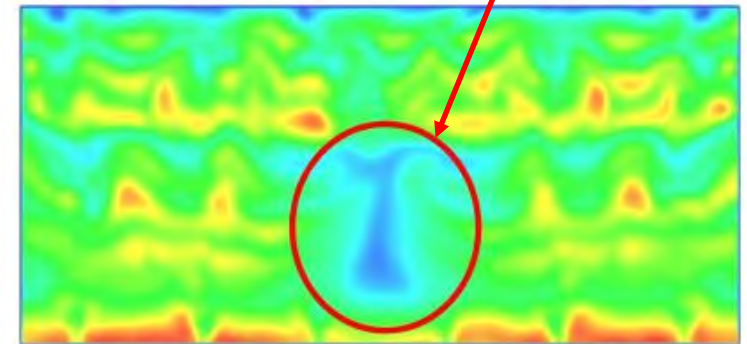
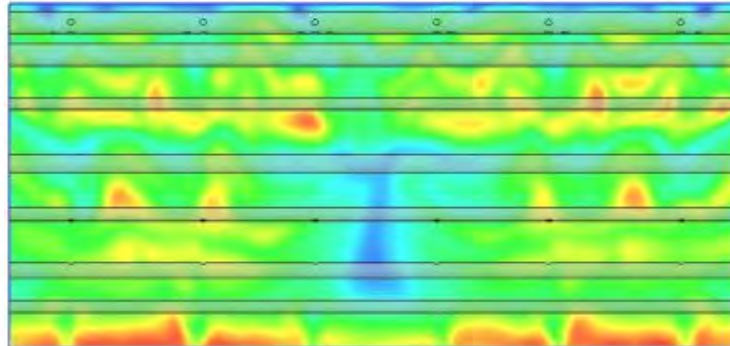
Candy cane vanes

# HORIZONTAL SECTION AT THE PERFORATED PLATE

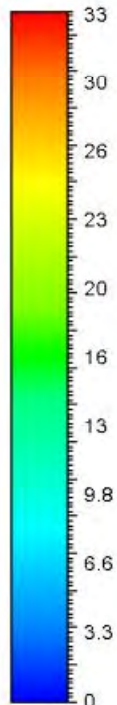


- Incoming flow velocity magnitude above the flow straightener

Removed Center  
Low Flow Area



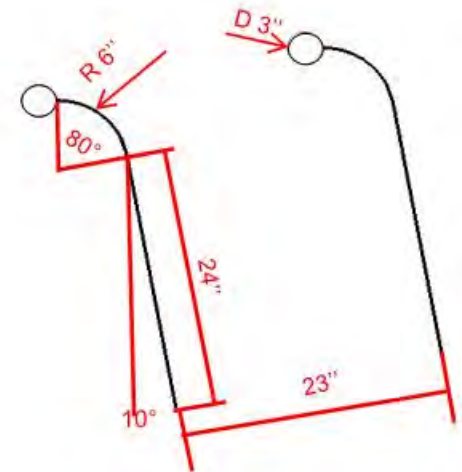
Recirculation Area ( $\approx 8$  ft down)



- Baseline (Current Vane Pattern) => Top Plots
- Final (6 New Vanes Crossover Duct & 18 New Vanes Reactor Hood) => Bottom Plots

# Reactor Inspection Results

- Reactor Inspection Performed May 11, 2017
- L1 & L2 Replaced in Spring 2017
  - Damage Occurred to Two Modules;
    - One Module had Forklift Damage to Elements (Elements Replaced)
    - Second Module Not Replaced; Re-Used Module w/80-90% Pluggage, Located Northwest Corner); Monitor for Increase in Pluggage in Adjacent Modules; May Need to Remove
- Leading Edge Sintering (Discoloration) Observed on Catalyst Modules With Former Ash Buildup
- Installed New Acoustic Cleaners on L1, L2, and L3
- Six New Turning Vanes Installed in Crossover Duct
- Eighteen New Vanes Installed in Reactor Hood (Work Around Existing Trusses)
  - Vane #10 (from AIG side) Appeared Lower Than Adjacent Vanes. May Capture Less Flow
  - Vane #16 (from AIG Side) Appeared Higher Than Adjacent Vanes. May Capture More Flow than Vanes #17 & #18, Resulting in Drop Out in East Side of Reactor
  - Will Monitor in the Future for Signs of Damage Due to Thermal Movement
- Center Section of Egg Crate was Replaced Due to Warpage
  - Warped Egg Crate Above Module 1-B11 was Not Replaced. Monitor Catalyst Below.
  - Will Monitor in the Future for Signs of Damage Due to Thermal Movement



# Reactor Inspection (After CFD Phase II)



General Condition (New Catalyst)  
Will Install New Sonic Horns



New Sonic Horn L2 & Condition of  
L2 (New Catalyst)

Second Catalyst Level (8.2 mm Pitch)  
May 11, 2017  
WEST (AIG Side)

	1	2	3	4	5	6	7	8	9	10	11	12	
2-A	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-A
2-B	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-B
2-C	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-C
2-D	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-D
2-E	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-E
2-F	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-F
2-G	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-G
2-H	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-H
2-I	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-I
2-J	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-J
2-K	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	2-K
	SH2-1		SH2-2		SH2-3		SH2-4		SH2-5		SH2-6		SH2-8

EAST



Aged Catalyst Module Left  
Installed in Unit (2-A12)

# Reactor Inspection (After CFD Phase II)

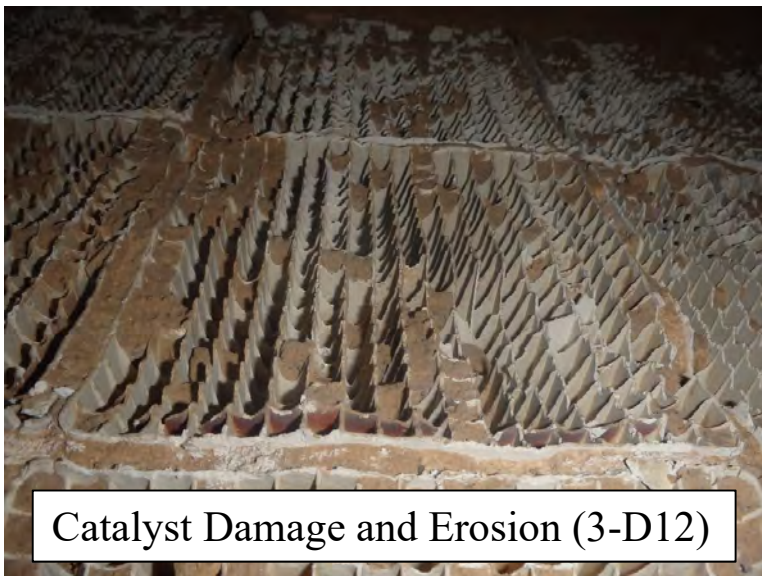


General Condition "Clean" Inspection



Localized Sintering (3-B12)

Level 3

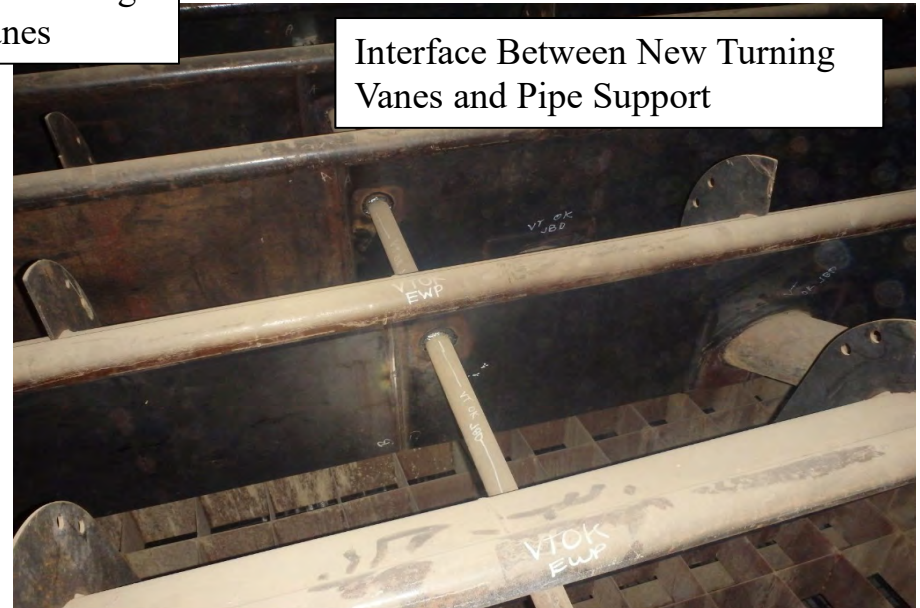
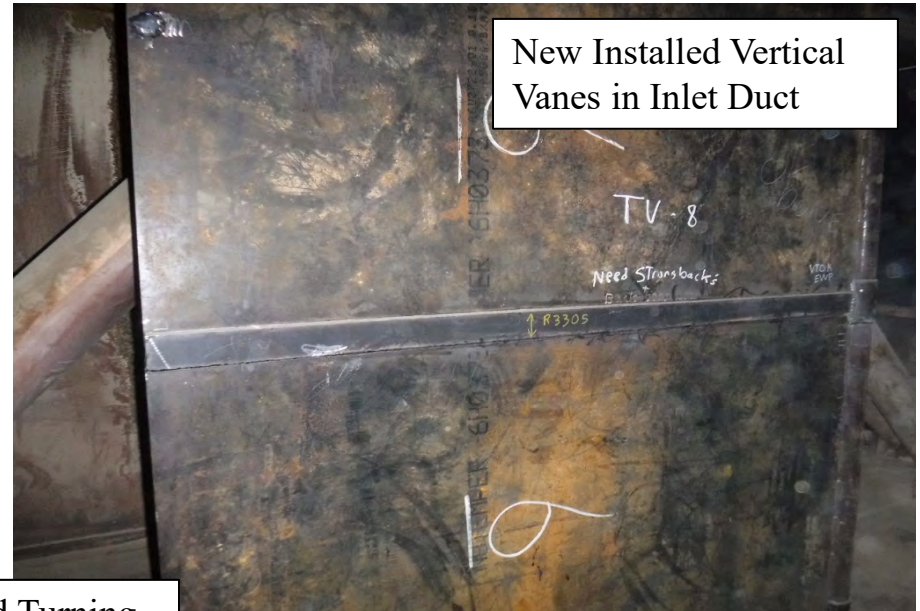
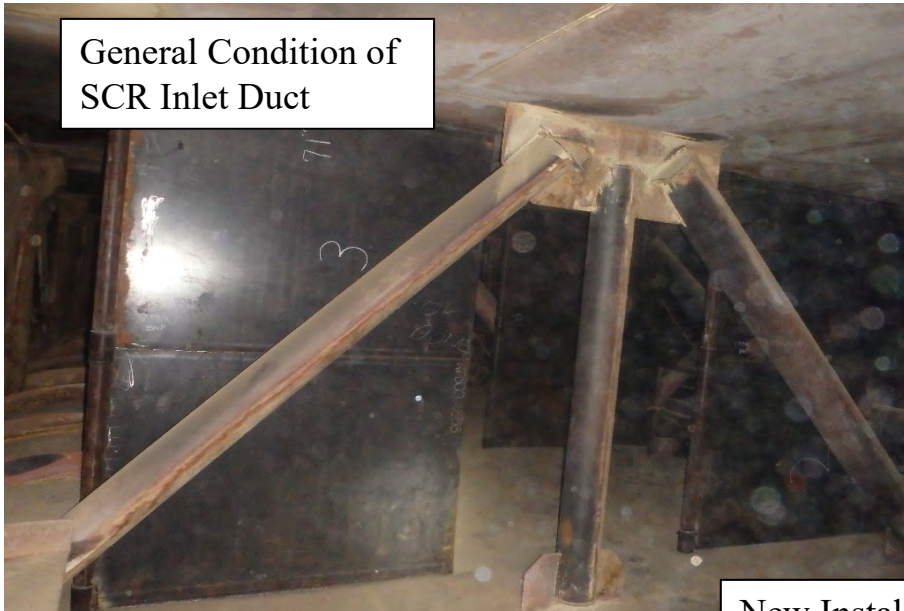


Catalyst Damage and Erosion (3-D12)

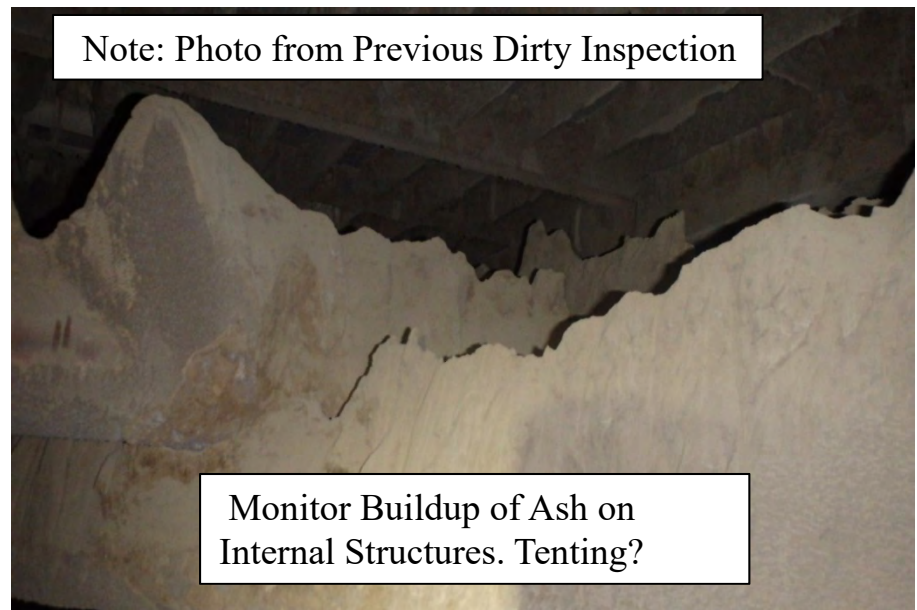
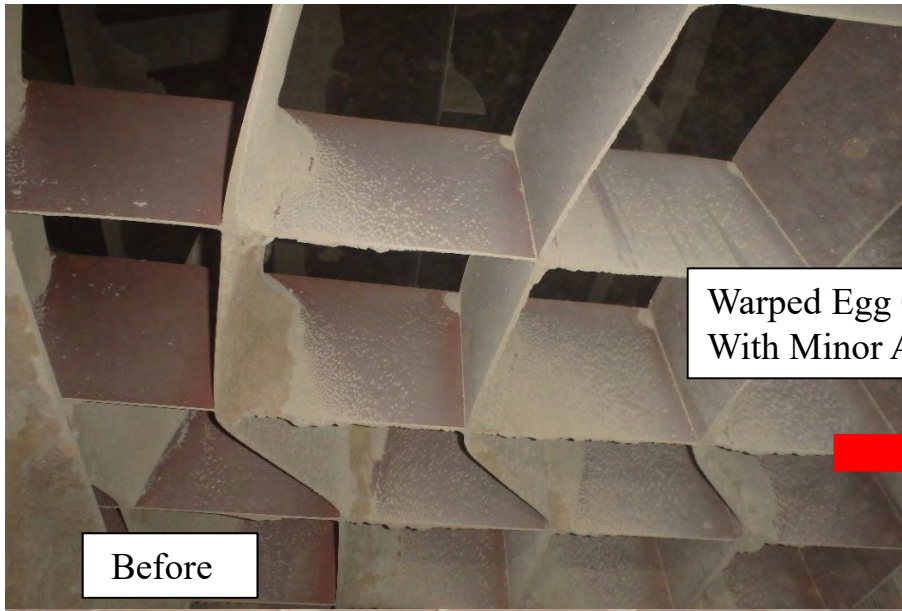


Catalyst Damage Possibly from Cleaning (3-C9)

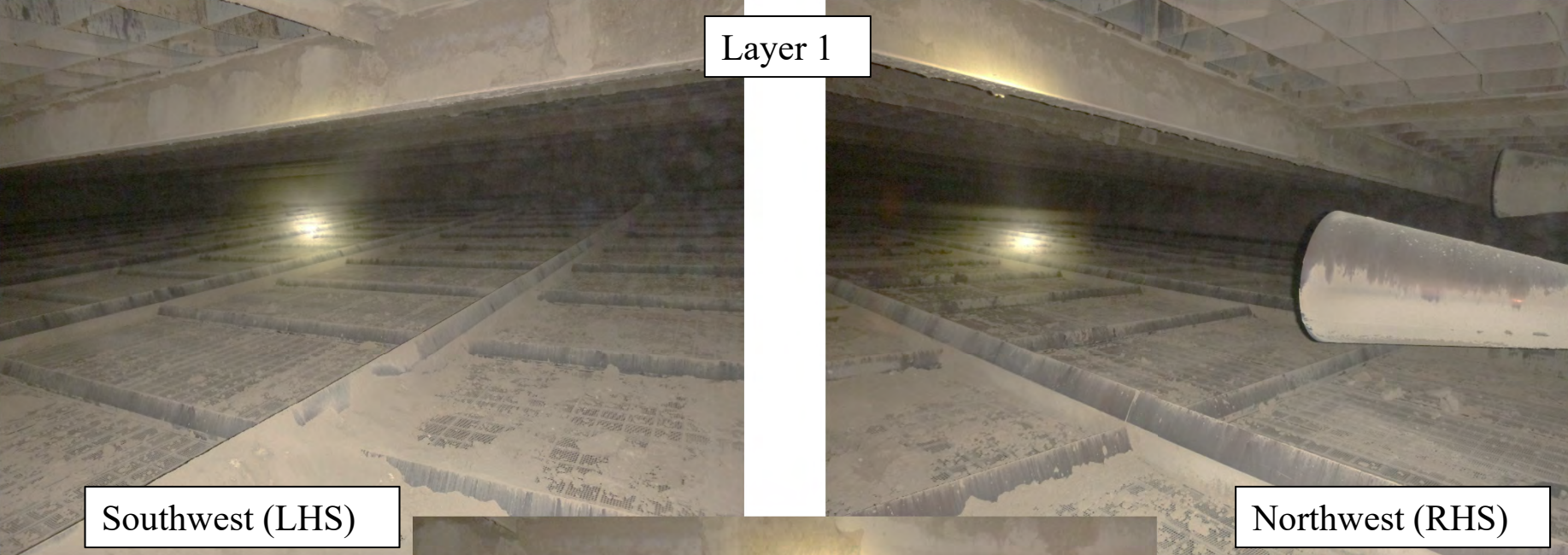
# Reactor Inspection (After CFD Phase II)



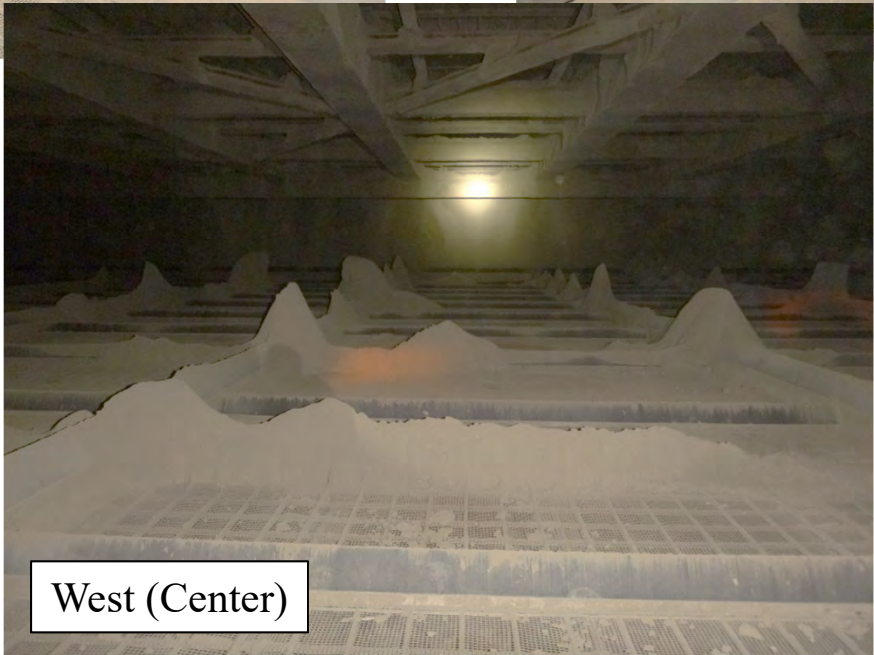
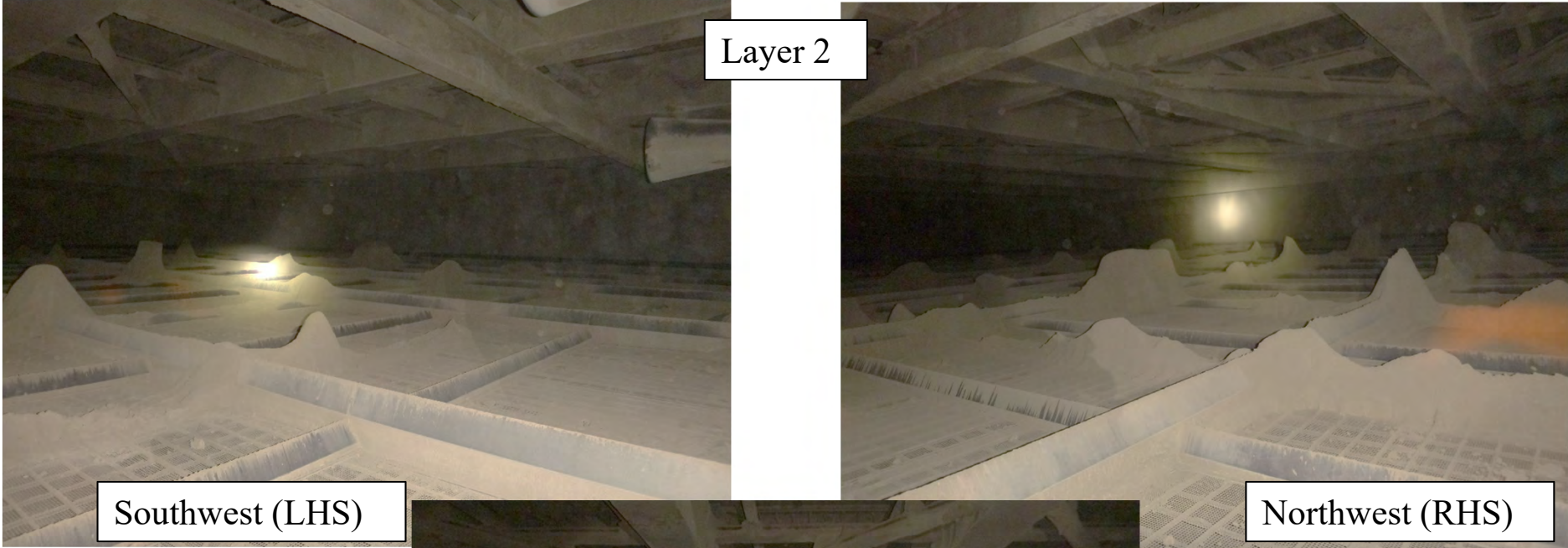
# Reactor Inspection (After CFD Phase II)



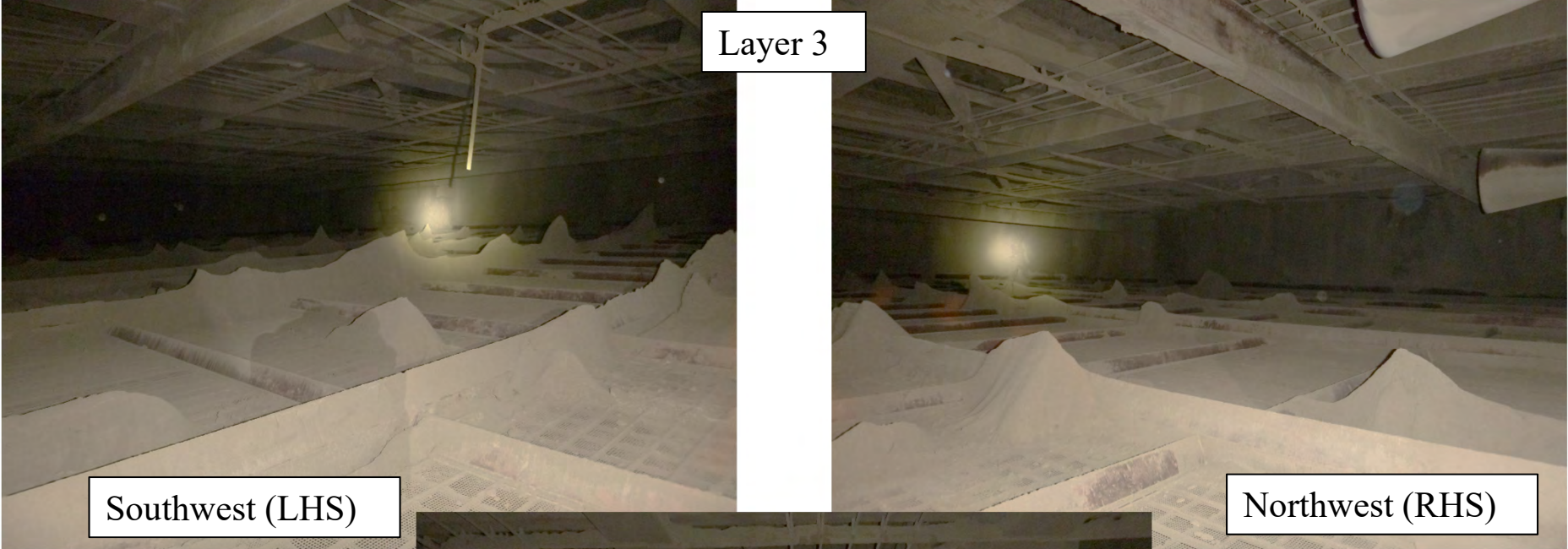
# Reactor Inspection (After Approx. 3,600 hrs)



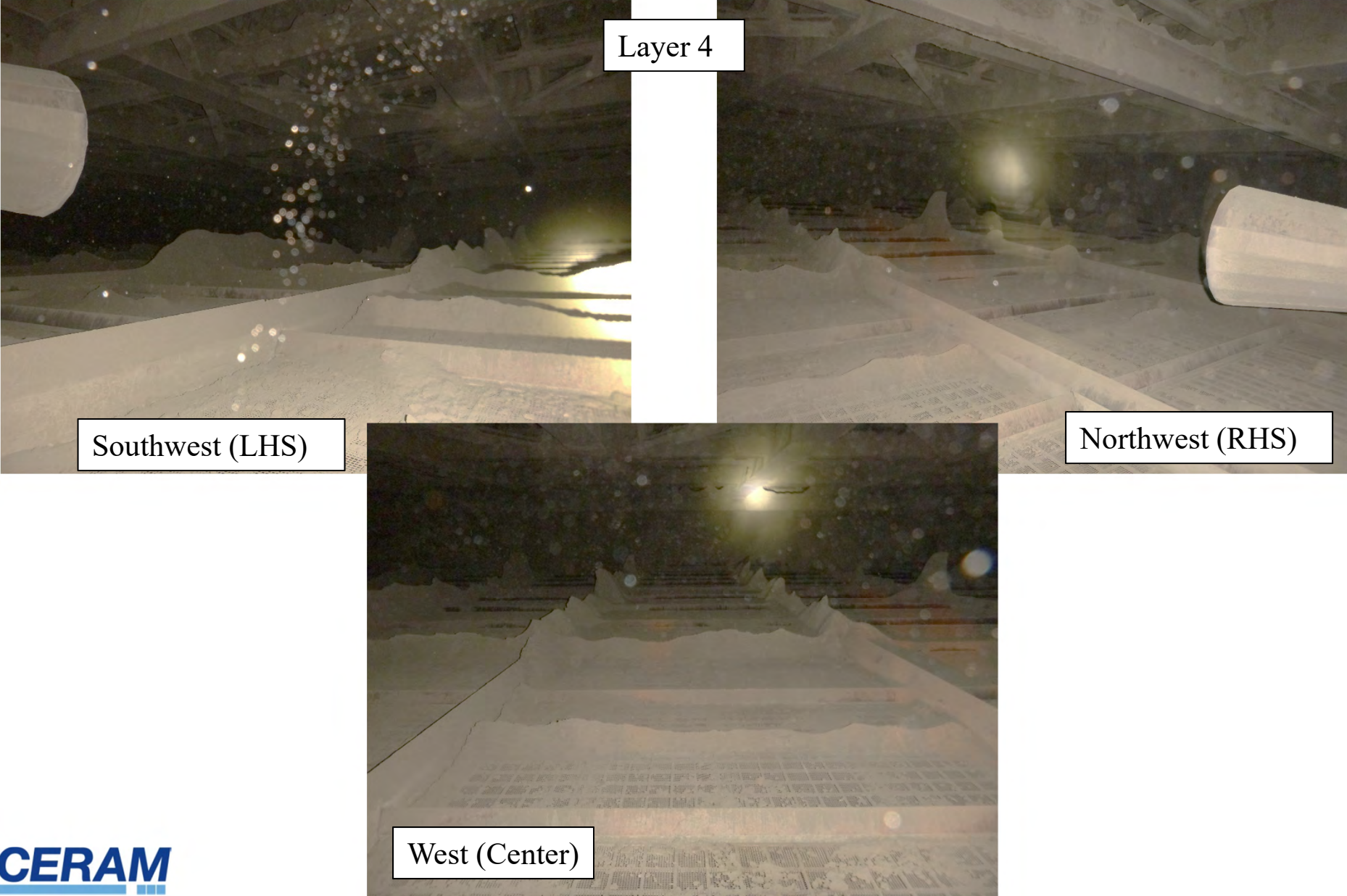
# Reactor Inspection (After Approx. 3,600 hrs)



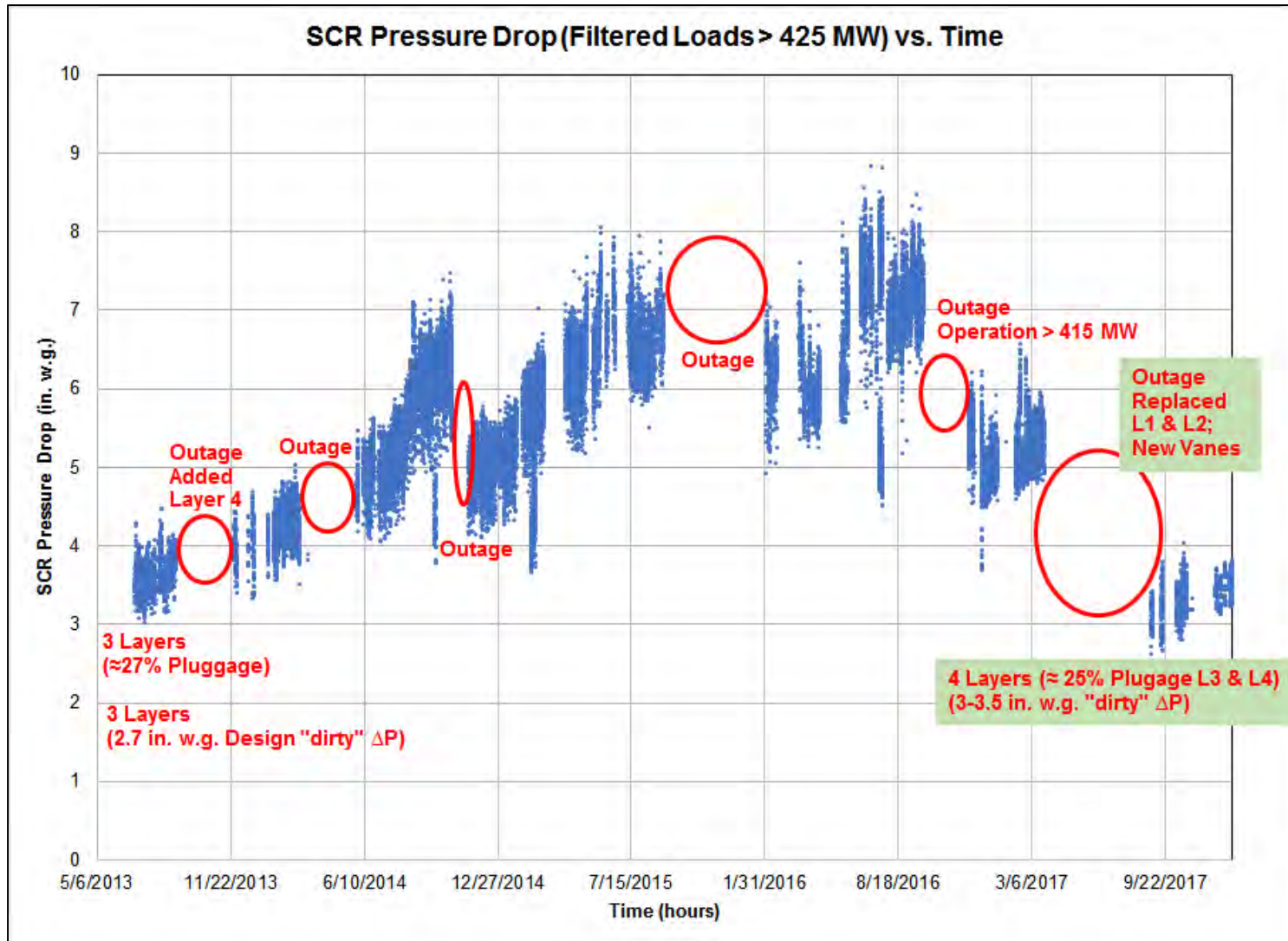
# Reactor Inspection (After Approx. 3,600 hrs)



# Reactor Inspection (After Approx. 3,600 hrs)



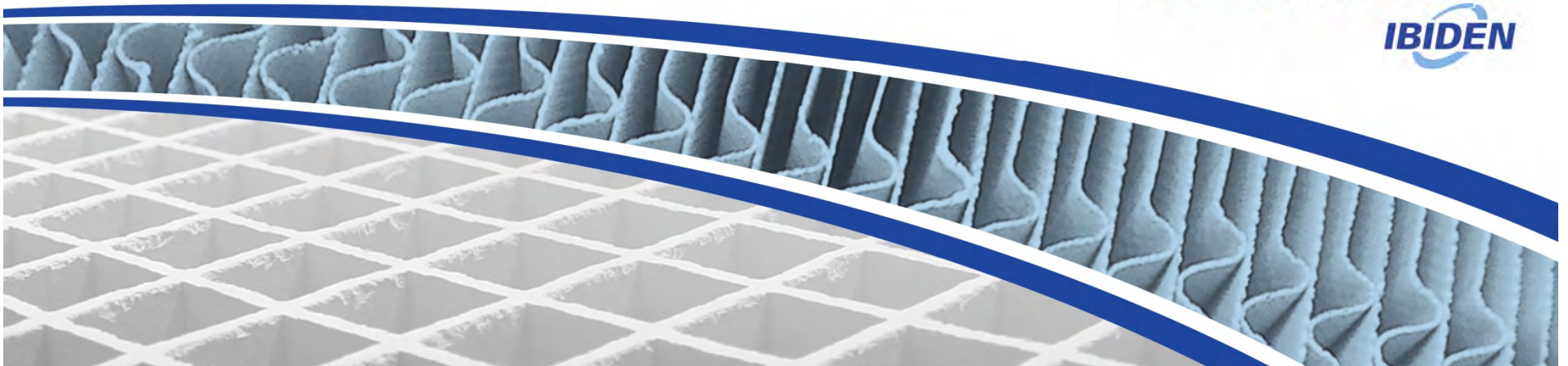
# Pressure Drop After CFD Phase II



# 2018 Reinhold Presentation

## Affects of System Modifications to AIG Tuning

**CERAM**  
IBIDEN



# AIG Tuning (Sept. 2017)

	Baseline	Final
<b>Target Distribution:</b>		
<b>Points within <math>\pm 15</math> ppm</b>	49 of 60	59 of 60
<b>Points within <math>\pm 20</math> ppm</b>	49 of 60	59 of 60
<b>Points within <math>\pm 25</math> ppm</b>	49 of 60	59 of 60



Missing tags on valves

# AIG Tuning (Sept. 2017)

Baseline SCR Outlet NOx Distribution Results							
Port Number	Parameter	1-A	2-B	3-C	4-D	5-E	6-F
11	Deviation (±)	-13	-3	10	28	44	67
12	Deviation (±)	2	3	15	5	-7	-2
13	Deviation (±)	-4	-5	-10	-29	-29	-31
14	Deviation (±)	1	-2	-2	-5	-2	4
15	Deviation (±)	-2	-7	-7	-7	-5	1
16	Deviation (±)	7	4	-1	-4	-1	-5
17	Deviation (±)	2	1	1	-8	-7	-11
18	Deviation (±)	0	-7	-14	-14	-30	-33
19	Deviation (±)	4	2	0	2	8	29
20	Deviation (±)	29	32	10	10	8	3

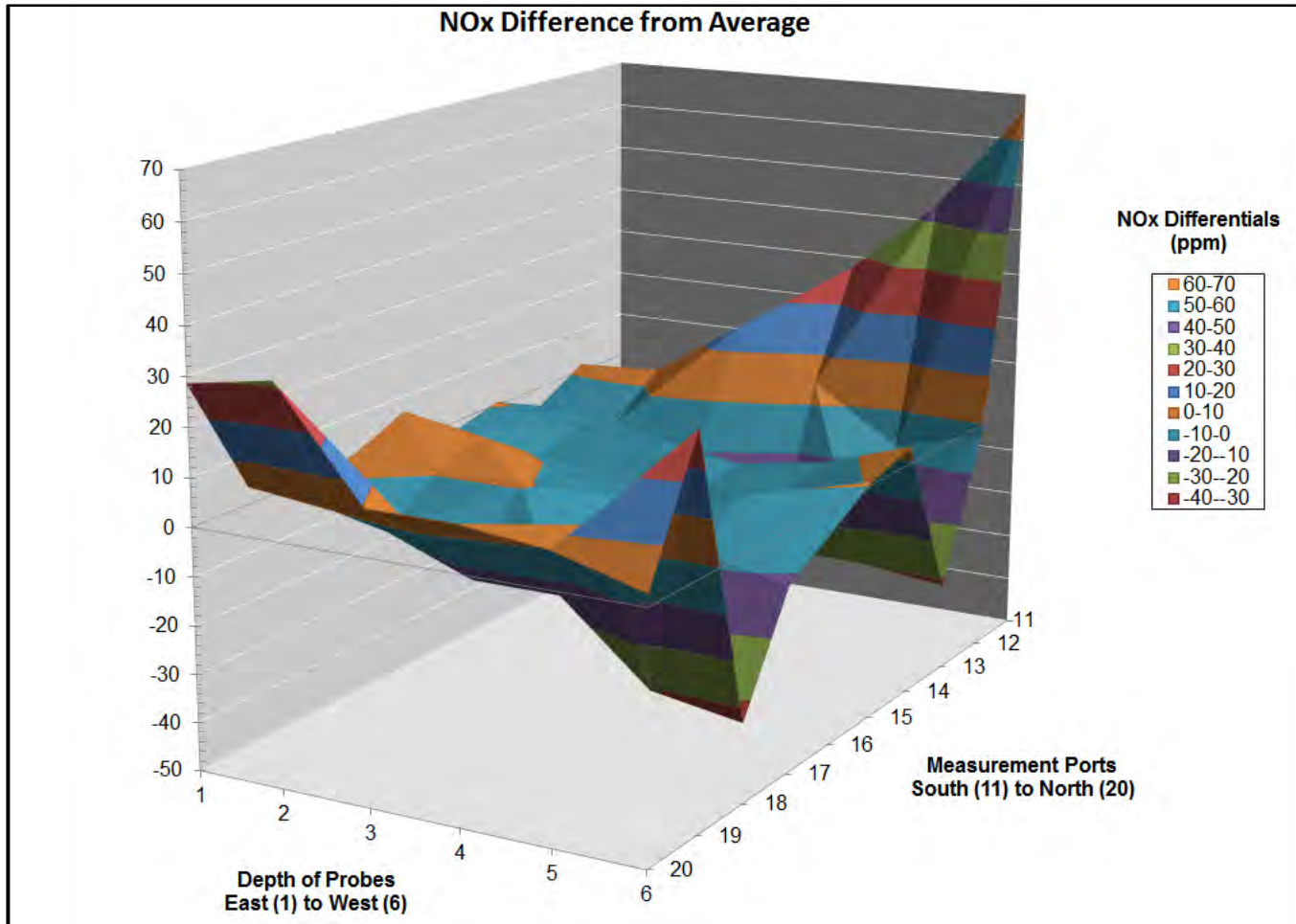
Negative numbers < -25 ppm = Over Injection  
 Positive numbers > +25 ppm = Under Injection

# AIG Tuning (Sept. 2017)

Final SCR Outlet NOx Distribution Results							
Port Number	Parameter	1-A	2-B	3-C	4-D	5-E	6-F
11	Deviation (±)	-7	-10	1	4	19	44
12	Deviation (±)	6	17	19	9	4	9
13	Deviation (±)	1	2	0	-6		
14	Deviation (±)	0	-2	-4	-2	-6	-6
15	Deviation (±)	2	0	1	4	7	9
16	Deviation (±)	6	9	3	-1	0	3
17	Deviation (±)	3	-4	-7	-9	-11	-12
18	Deviation (±)	7	1	-10	-8	-14	-12
19	Deviation (±)	7	1	-2	-7	-5	-5
20	Deviation (±)	-2	-3	2	0	-3	-10

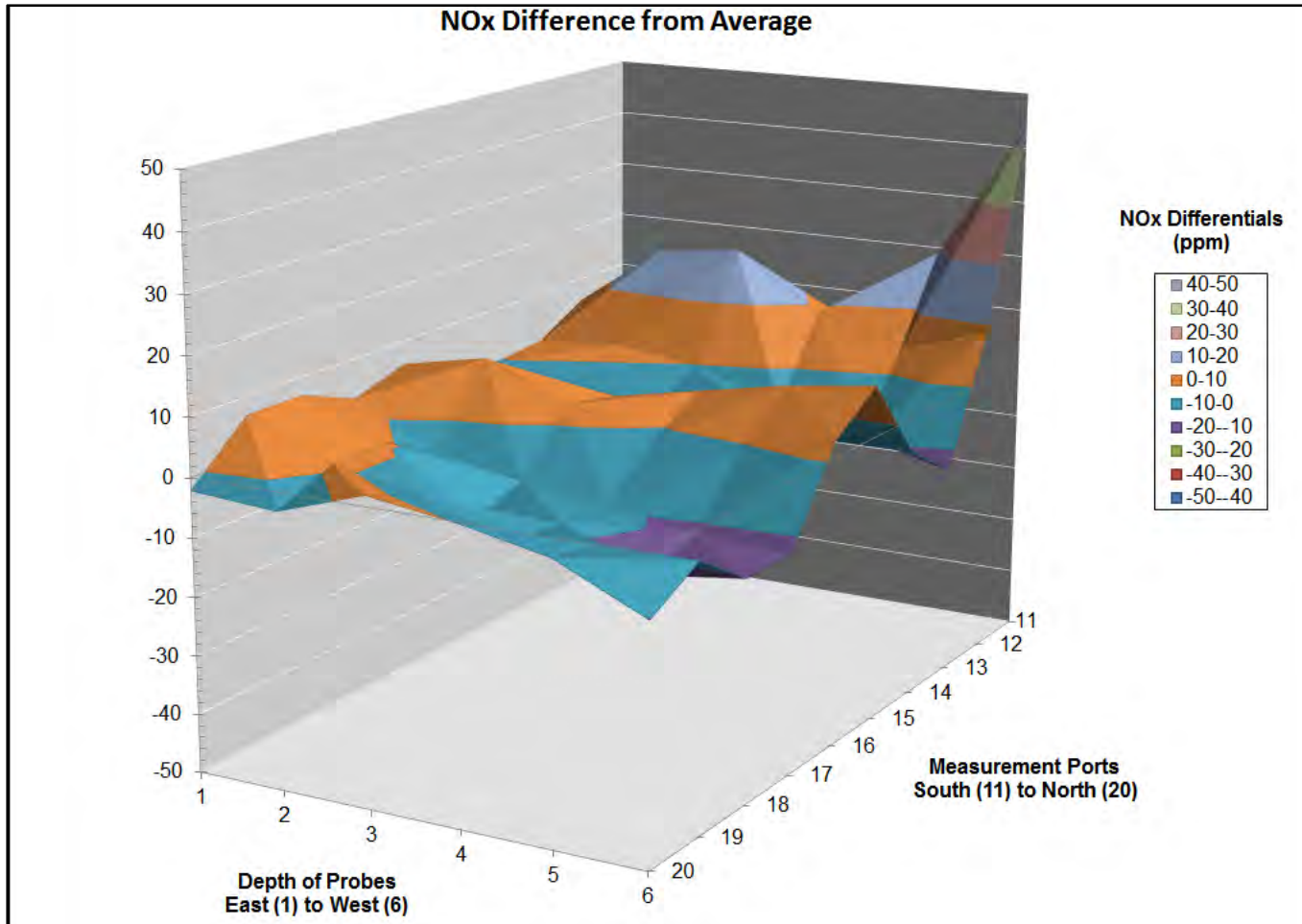
Valve #15 south side 100% open. May be plugged.

# AIG Tuning Baseline (Sept. 2017)



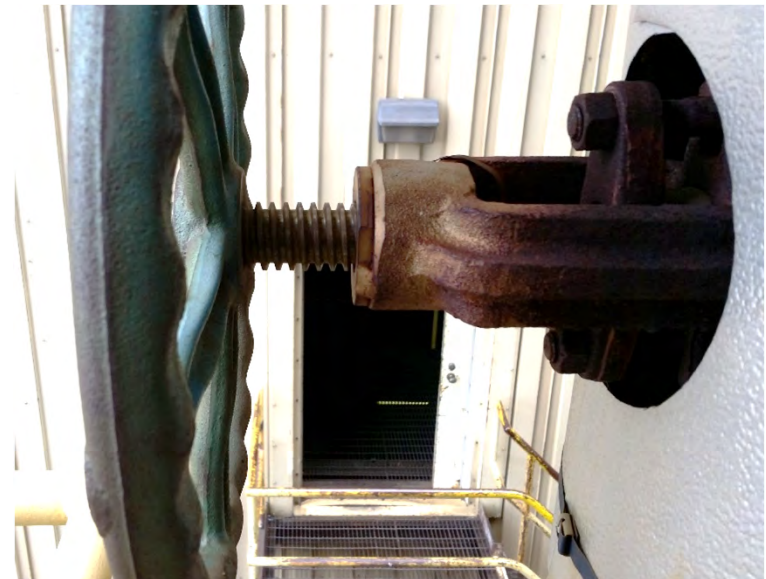
Measurement point 2160-5 had high O<sub>2</sub> (5-6%). Hooked compressed air line and no major improvement. Used avg 2.4% O<sub>2</sub> for point.

# AIG Tuning Final (Sept. 2017)



# AIG Tuning

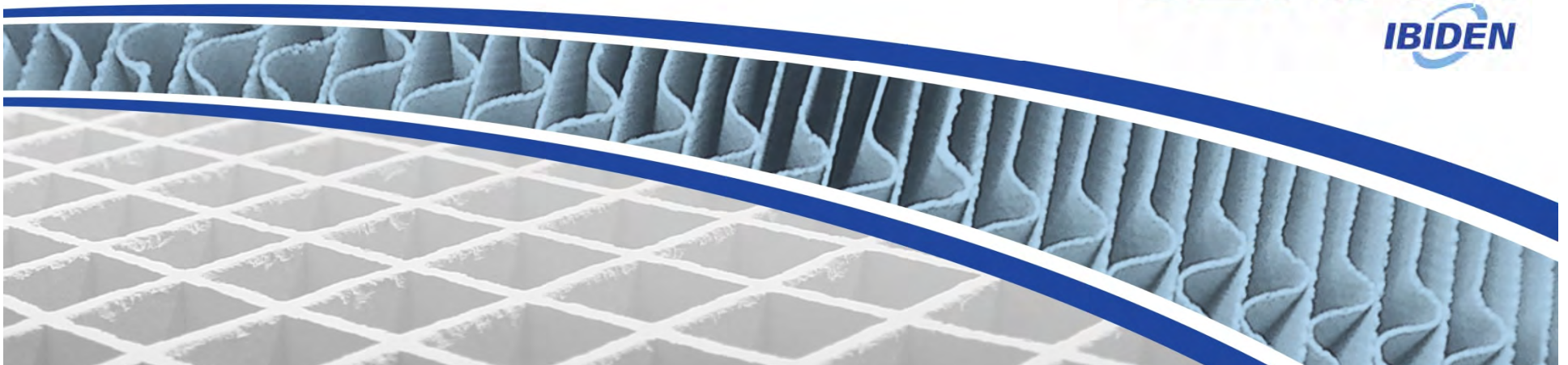
- Pressure Drop Measurements
- Historically Pressure Taps and Lines Are Plugged.
- Urea Salt's Out and Plugs Taps and Lines. Maintaining Clean Lines Extremely Difficult
- Recorded Number of Threads Exposed for All 30 Valves



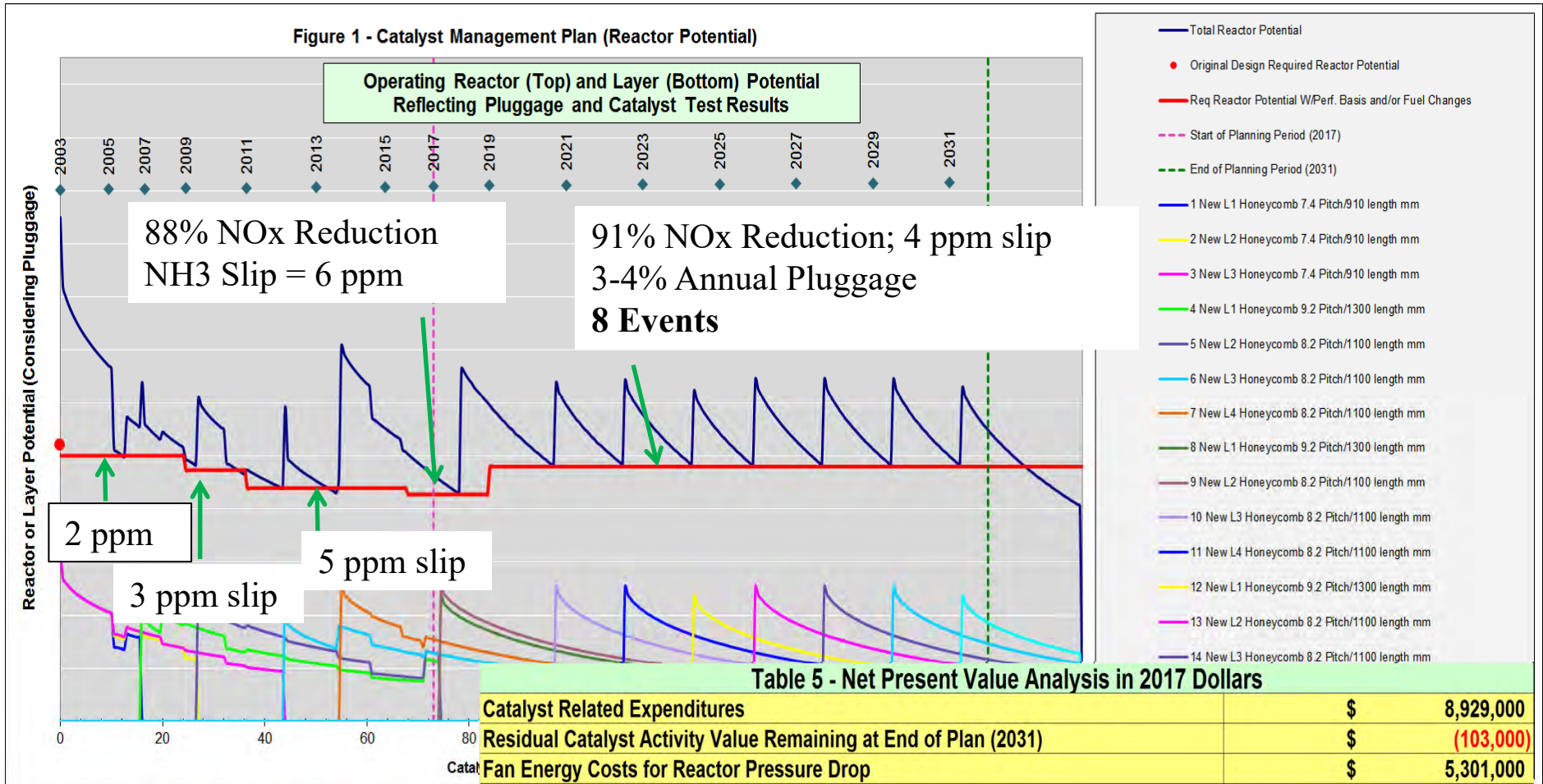
# 2018 Reinhold Presentation

## Catalyst Management Planning Affects

**CERAM**  
IBIDEN



# 15 Year Catalyst Management Plan Install L1 & L2 Spring 2017 with Reduced Pluggage



# 15 Year Catalyst Management Plan Install L1 & L2 Spring 2017 with No Modifications to Vanes

Figure 1 - Catalyst Management Plan (Reactor Potential)

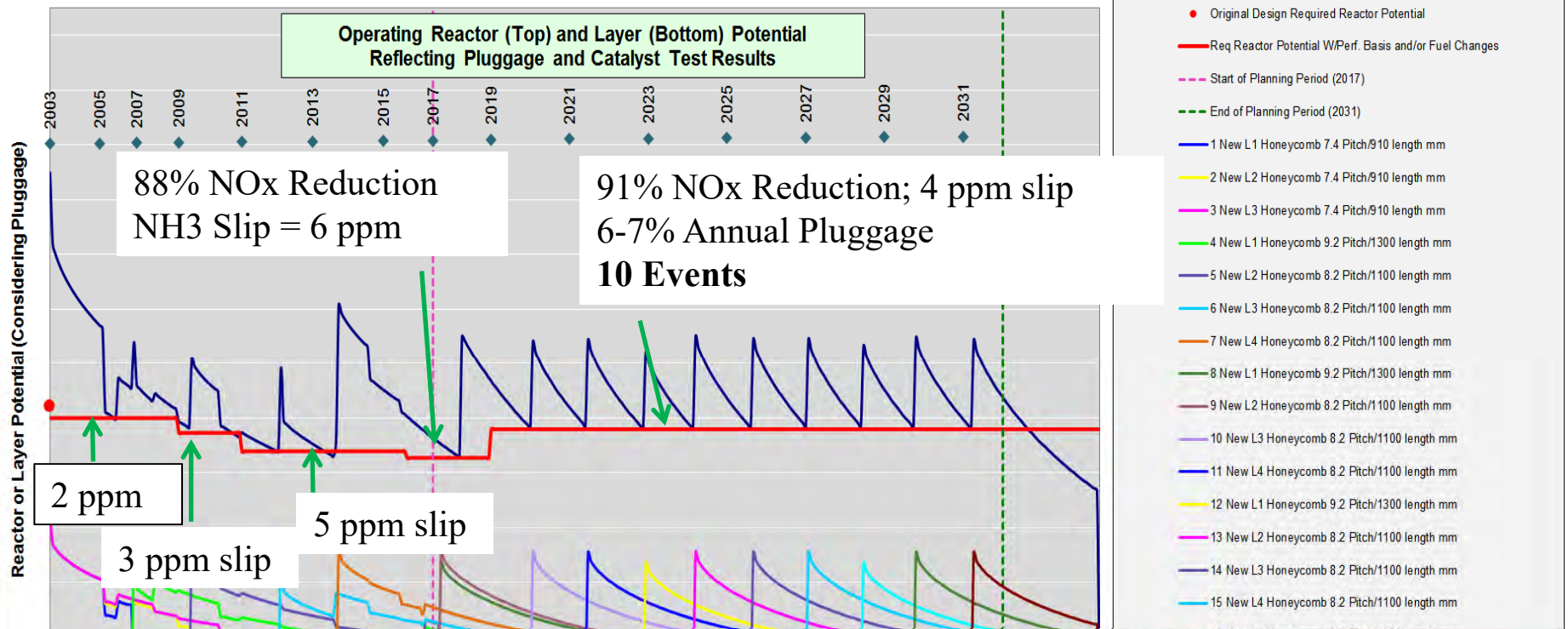


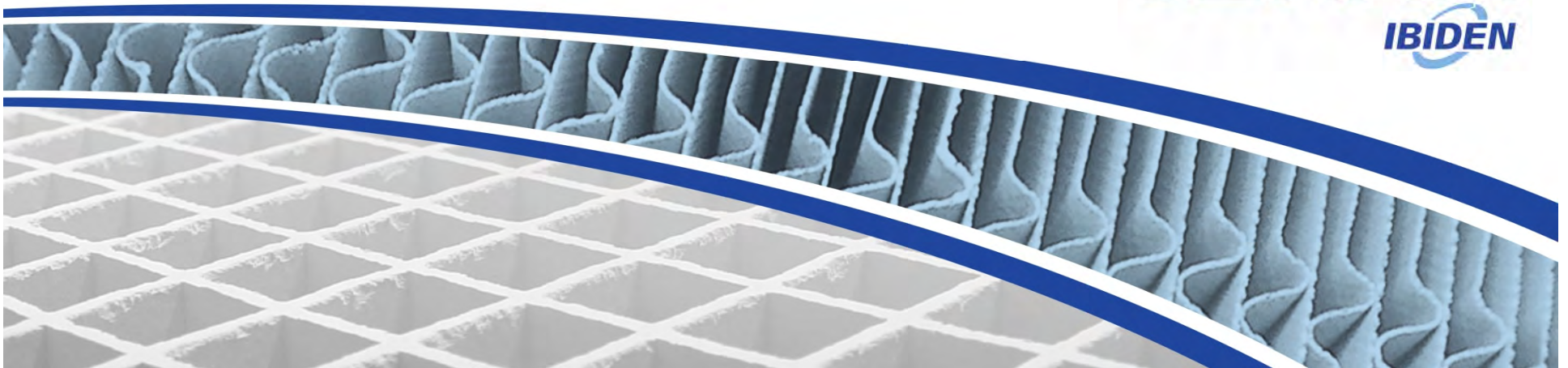
Table 5 - Net Present Value Analysis in 2017 Dollars

Catalyst Related Expenditures	\$	10,695,000
Residual Catalyst Activity Value Remaining at End of Plan (2031)	\$	(69,000)
Cat Fan Energy Co DeNO <sub>x</sub> System		5,959,000
<b>Plan 1 and Plan 2 Difference = \$2,548,000</b>		53,087,000
SO <sub>3</sub> Removal System Ammonia Cost	\$	Not Considered
Total Net Present Value of Plan (2017 to 2031)	\$	69,672,000
NPV NO <sub>x</sub> Removal Cost of Plan (2017 to 2031)		437 \$/ton

# 2018 Reinhold Presentation

## Summary of Modifications and Results

**CERAM**  
IBIDEN



# Summary

- Annual Reactor Inspection Performed Over Past 14 Years
- Historically Pluggage Observed Due to Ash Drop Out (Velocity Maldistribution) and Unburned Carbon
  - Ash Buildup in Crossover Duct and 3-10 ft of Ash in Layers
- Catalyst Management Ensured Target Emissions Always Achieved
- Solutions Have Been Developed and Implemented to Eliminate Pluggage
  - Installed Larger Catalyst Pitch. Slowed Down Pluggage, Still Had Increase.
  - CFD Modeled System in 2010 (Phase I).
    - Installed New Economizer Outlet Vane. Hopper Operable (No Bridging). Reduced Size of Ash Piles to SCR, but Pluggage Still Increased
    - Tried Varying Degrees of “Novel” Solutions to Vanning in Reactor Hood, But No Large Scale Improvements. Further Changes Possible, But Considered Not Cost Effective.

# Summary

- Solutions Have Been Developed and Implemented to Eliminate Pluggage (Cont.)
  - CFD Modeled System in 2016-17 (Phase II)
    - 6 New Vanes Installed in Crossover Duct to Work with Existing 4 Vanes
    - 18 New Vanes Installed in Reactor Hood (Work Around Existing Trusses; Will Monitor Affects of Vanes #10 & #16)
- Center of Egg Crate Section Replaced (Will Monitor)
- Will Monitor All Layers for Pluggage, Ash Accumulation, etc.
  - Especially Northwest Corner (Re-Used Module)
  - Ash Buildup and Ash Shear From Trusses and Beams
- Ash Buildup in Crossover Duct Still Present
- New Acoustic Cleaners Installed in L1, L2 and L3
- Reactor Pressure Drop Substantially Lower (Approx. 8 in. w.g. vs. 3 in. w.g.)
- Working to Keep Unburned Carbon Levels Lower
- **CFD Modeling and Implementation of Solutions Fixed “Major” Root Cause of Catalyst Pluggage**

**Thank You!**

**Questions?**

**CERAM**  
**IBIDEN**

