REINHOLD ENVIRONMENTAL Ltd.

# 2014 APC Round Table & Expo Presentation

July 14-15, 2014, in Louisville, KY / Hosted by LG&E/KU

# *Results of Performance Improvements: OUC Stanton Energy Center - Unit 1 FGD System*

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# Acknowledgements


- Co-Authors:
  - Gordon Maller – URS
  - Carsten Jensen – URS
- Upgrade Design Engineer: URS Process Technologies Office, Austin, TX
- OUC Owner Engineer: Black & Veatch

# Presentation Organization

- Project background
- Upgrade design approach
- CFD engineering results
- FGD upgrade results
- Conclusions

# Project Background (continued)

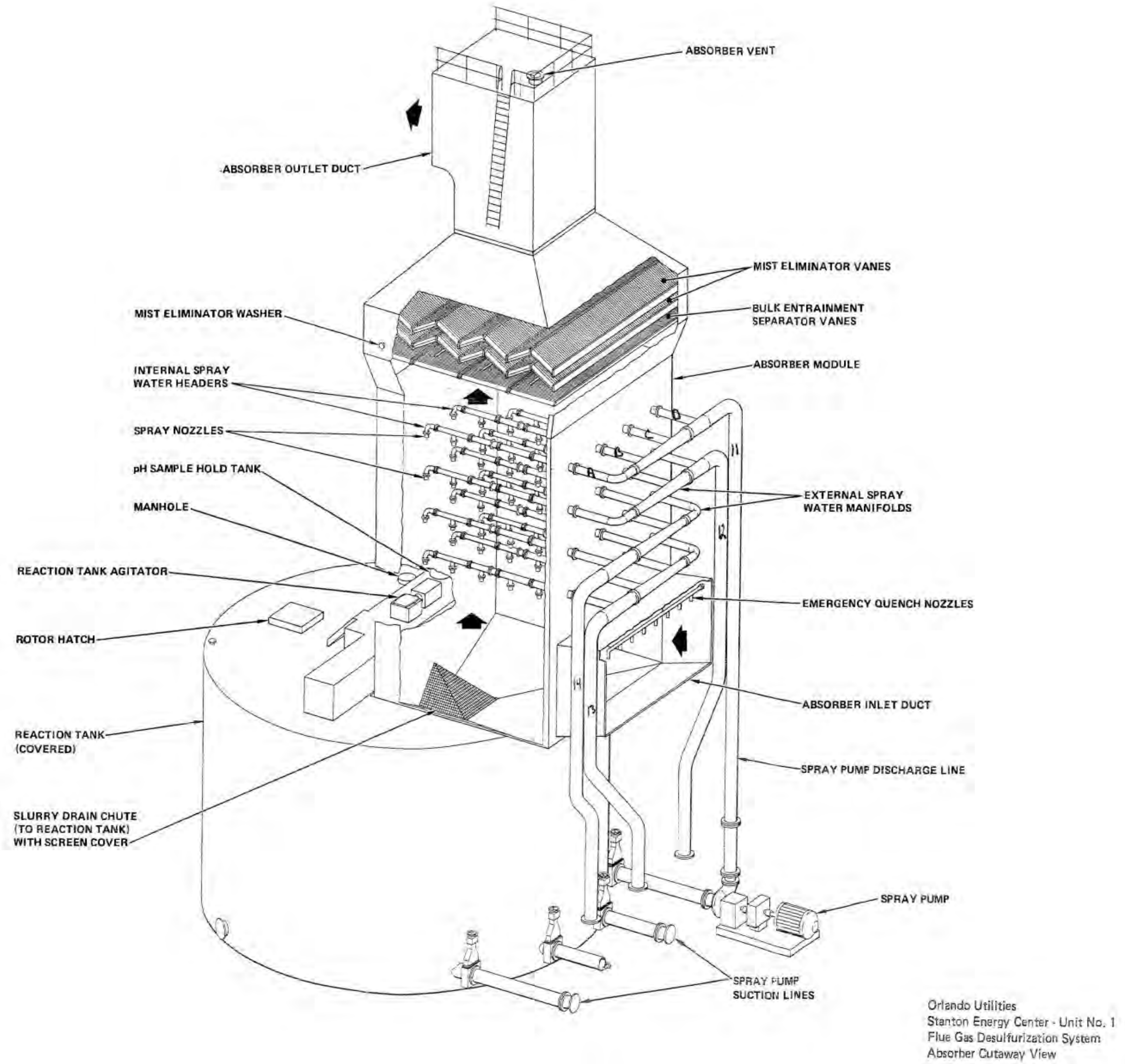
- Orlando Utility Commission (OUC):
  - Created in 1923 by an act of the state legislature
  - 3,280 acre Stanton Energy Center consists of two coal units, Units 1 and 2, two NGCC units, Units A and B, and a large solar farm
- Stanton Unit 1:
  - Balanced draft, natural circulation wall-fired unit rated at 456 MW
  - FGD is wet-limestone process installed by Combustion Engineering (CE), consists of three 50% absorber modules and four spray levels and recycle pumps per module
  - FGD recently converted to forced oxidation process

# Project Background

- Project Drivers:
  - Anticipated fuel sulfur increase
  - Desire to improve scrubber operating reliability
- Upgrade Design Objectives:
  - Increase removal efficiency
    - $SO_2$ removal efficiency: >96.0%
    - $SO_2$ emissions: <0.2 lb/MM Btu
  - Minimize any increase in pressure drop
    - Increase in dP over base: <2.0 in w.g.
- Current permit limits for Unit 1:

| UNIT 1 LIMITS | S02 | |
|---|---|---|
| | 1.20 LB/MMBTU MAXIMUM 2HR. AVG. | |
| | 1.14 LB/MMBTU MAXIMUM 3HR. AVG. | |
| | 70% REMOVAL AT LESS THAN OR EQUAL TO .60 LB/MMBTU | |
| | 30 DAY ROLLING AVERAGE | |
| | 90% REMOVAL AT GREATER THAN .60 LB/MMBTU | |
| | 30 DAY ROLLING AVERAGE | |

# Design Basis and Operating Conditions for Upgrade

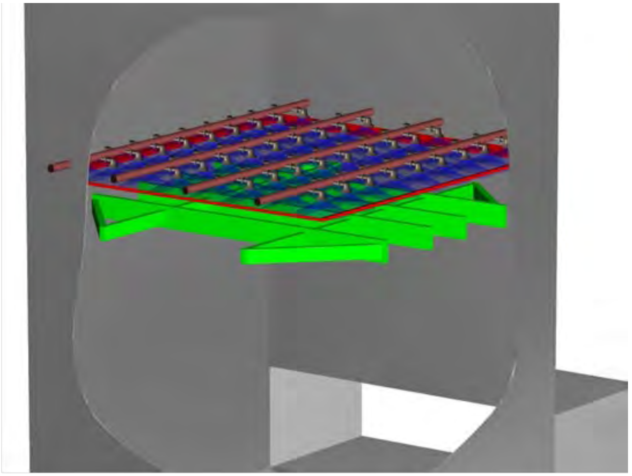


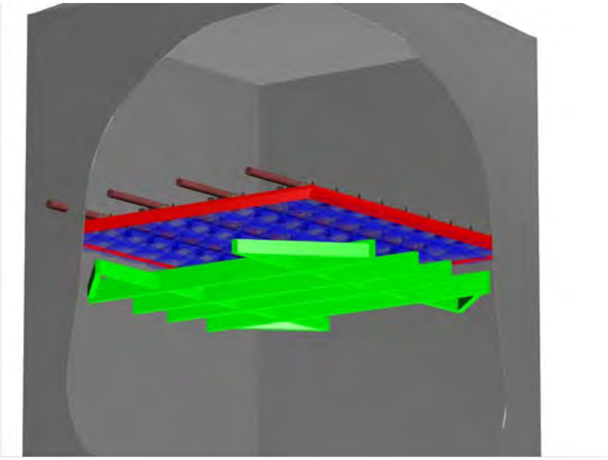
# Design Basis and Operating Conditions for Upgrade

| Parameter | Design, 100% MCR | Minimum | Maximum |
|---|---|---|---|
| Inlet $SO_2$, lb/MM Btu | 5.04 | -- | 5.04 |
| Inlet $SO_2$, lb/hr | 20,898 | 9,830 | 21,552 |
| Inlet Gas Flow Rate, ACFM | 1,614,879 | 1,021,000 | 1,650,000 |
| Inlet Temperature, °F | 338 | 350 | -- |
| Inlet Gas Pressure, in. wg | 12.39 | -- | -- |
| Outlet Gas Pressure, in. wg | 2.8 | 2.8 | 2.8 |
| Recycle Slurry pH | 5.5 | 5.5 | 6.0 |
| Recycle Slurry Solids Concentration | 10–13 wt.% | 10–13 wt.% | 10–13 wt.% |
| Recycle Slurry Chlorides, ppm | 20,000 | -- | 50,000 |
| Source of Limestone | Ground limestone | Ground limestone | Ground limestone |
| Limestone $CaCO_3$ | | 85% | 97% |
| Limestone $MgCO_3$ | | | 5% |
| Limestone Inerts | 10% | -- | 10% |
| Limestone Grind Size | 80% thru 200 mesh | 80% thru 200 mesh | 80% thru 200 mesh |
| Recycle Pump Capacity, gpm | 15,470 | 15,470 | 15,470 |
| Recycle Pump Head, ft | 72 – 90 | 72 – 90 | 72 – 90 |
| Operating Recycle Slurry Spray Levels Per Module | 4 | 4 | 4 |
| Operating Absorbers | 2 | 2 | 2 |

# Upgrade Design Approach

- Installation of new high performance spray headers
- Installation of Lechler high efficiency dual-down hollow cone spray nozzles
- Evaluated installation of sieve tray and increasing recycle flow rate

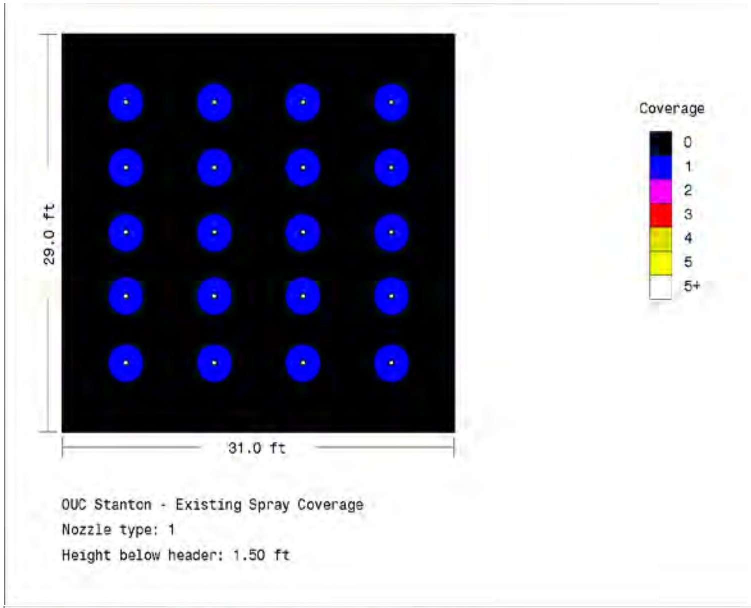




# Absorber Spray Header Before Upgrade

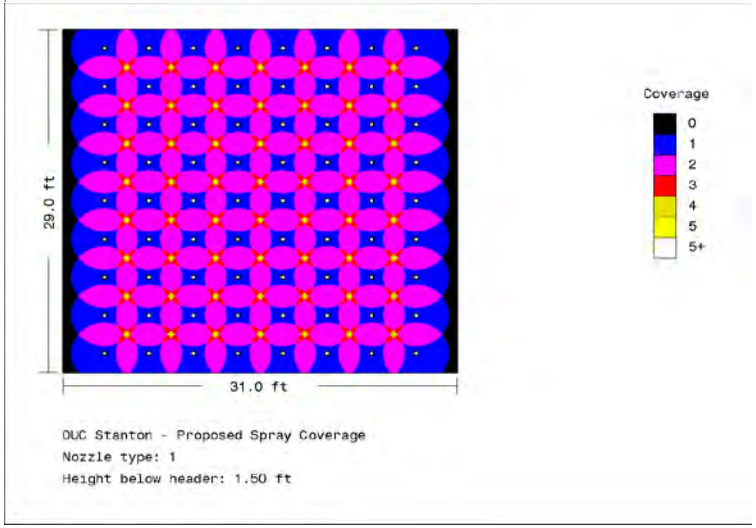
# Absorber Spray Header Coverage

Before Upgrade




Average Spray Coverage – 31%

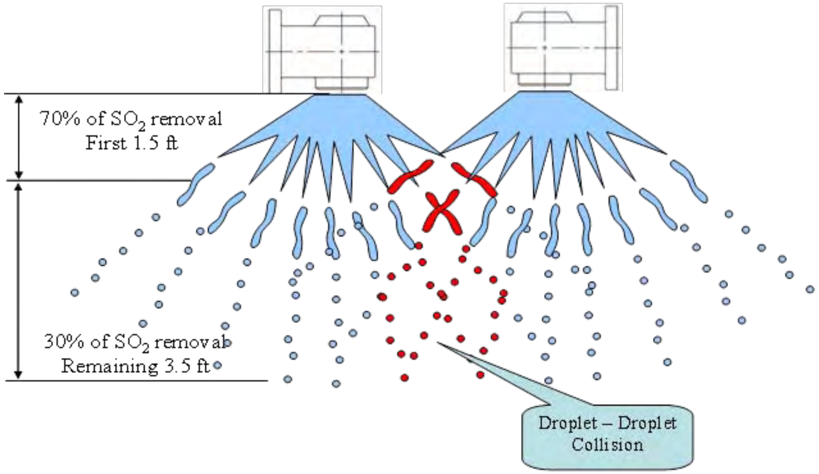
Following Upgrade



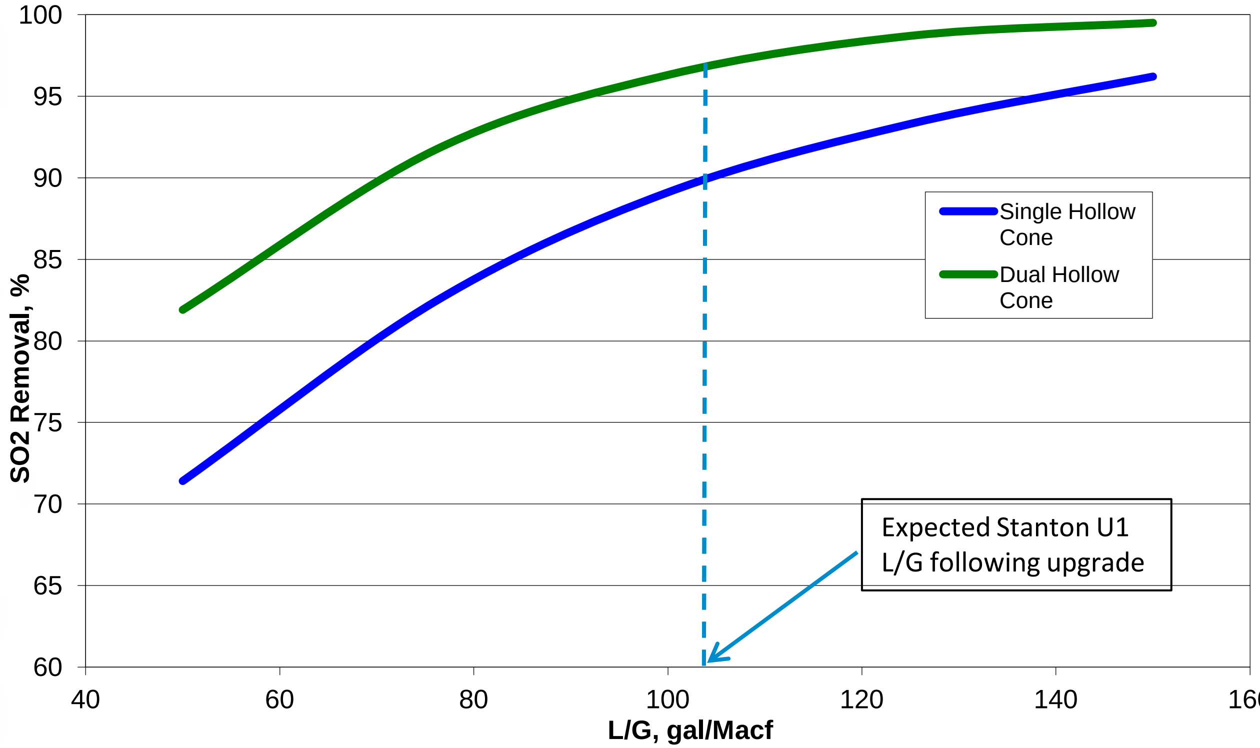

Average Spray Coverage – 203%

# Lechler Dual Down Spray Nozzles

- Enhanced performance result of droplet interactions and collisions where two spray cones overlap
  - Collisions create finer droplets and more spray surface area
  - Make droplets more reactive
  - Phenomena referred to as “secondary atomization”



# Expected Removal Enhancement Due To Spray Nozzles

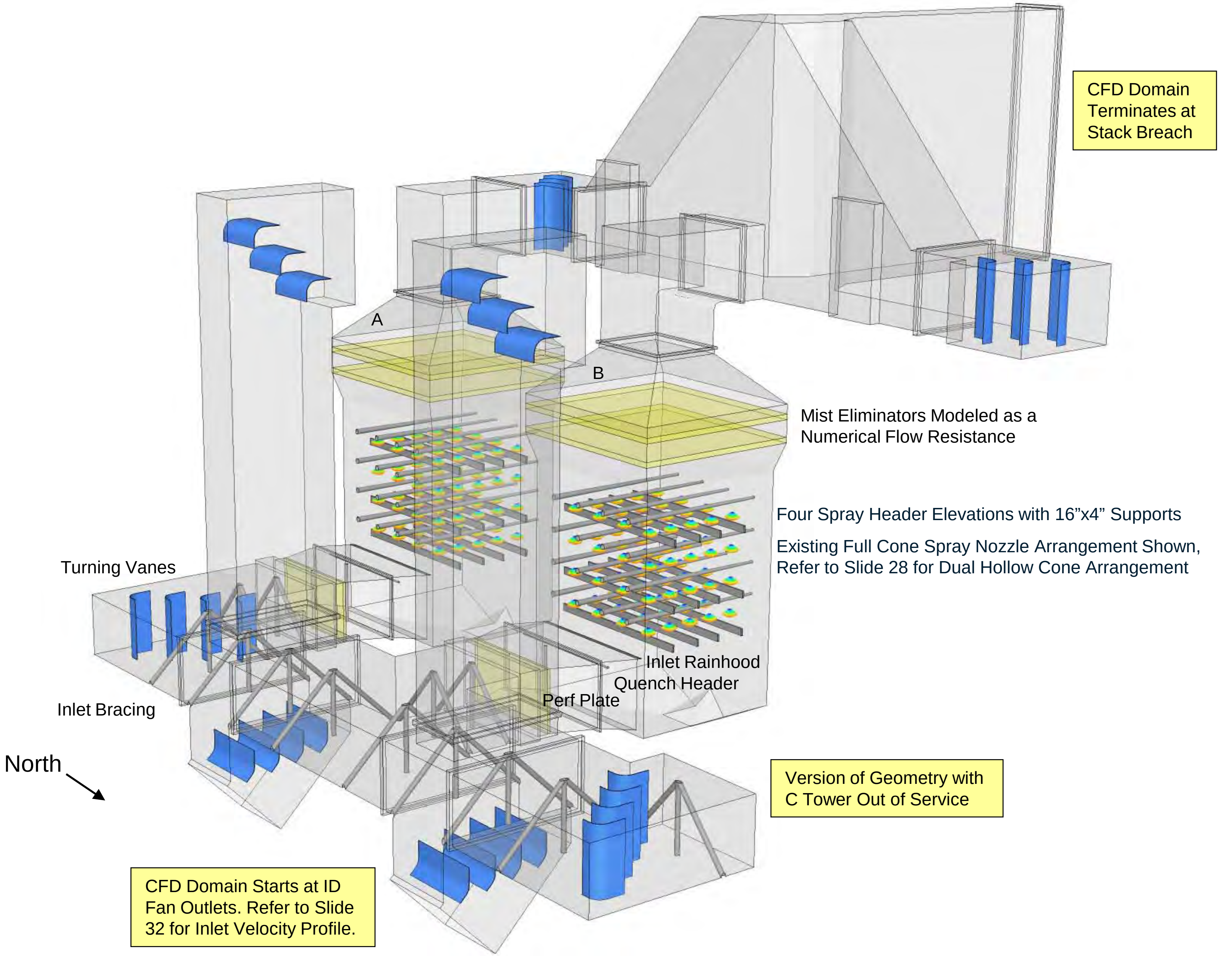


# CFD ENGINEERING RESULTS

# Objectives for CFD Study

- Evaluate the gas flow split between towers.
- Evaluate the gas velocity profile at the tower inlet breach.
- Determine the potential for scaling and buildup in the tower inlet ducts.
- Evaluate velocity profile through the recycle slurry spray zone.
- Evaluate if a perforated plate will improve velocity profile at both high and low load conditions
- Evaluate increase in pressure drop for recommended FGD upgrade

# Summary of CFD Model Geometry

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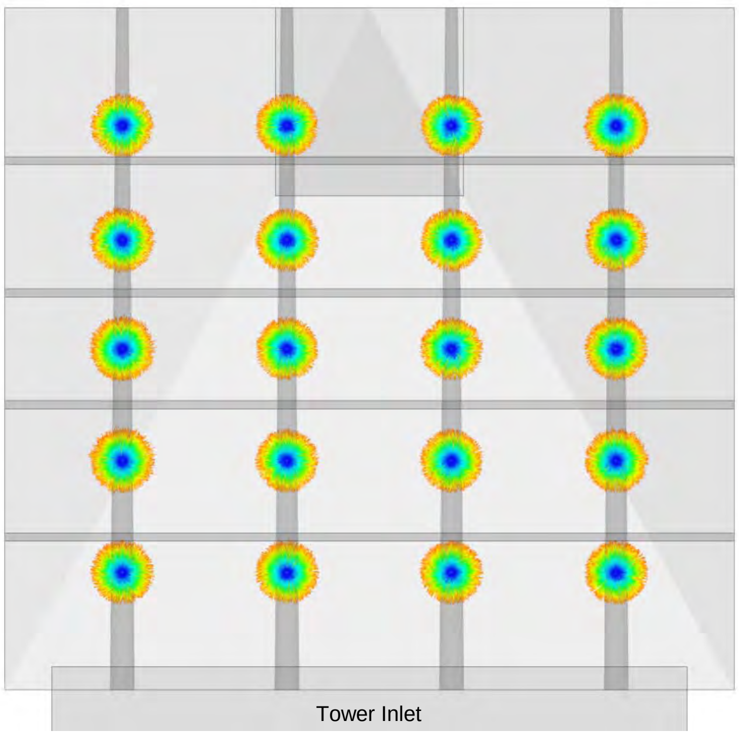
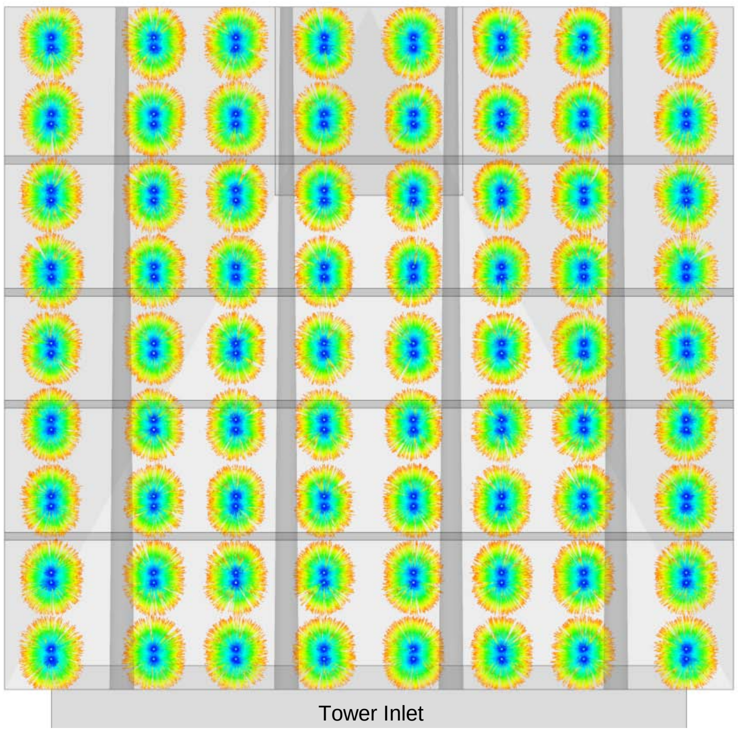
# CFD Model Geometry

Plan View of Spray Nozzle Layout




Cases 1, 2, 5, 6, 9-12: Existing Full Cone Layout




Cases 3, 4, 7, 8: Dual Hollow Cone Upgrade

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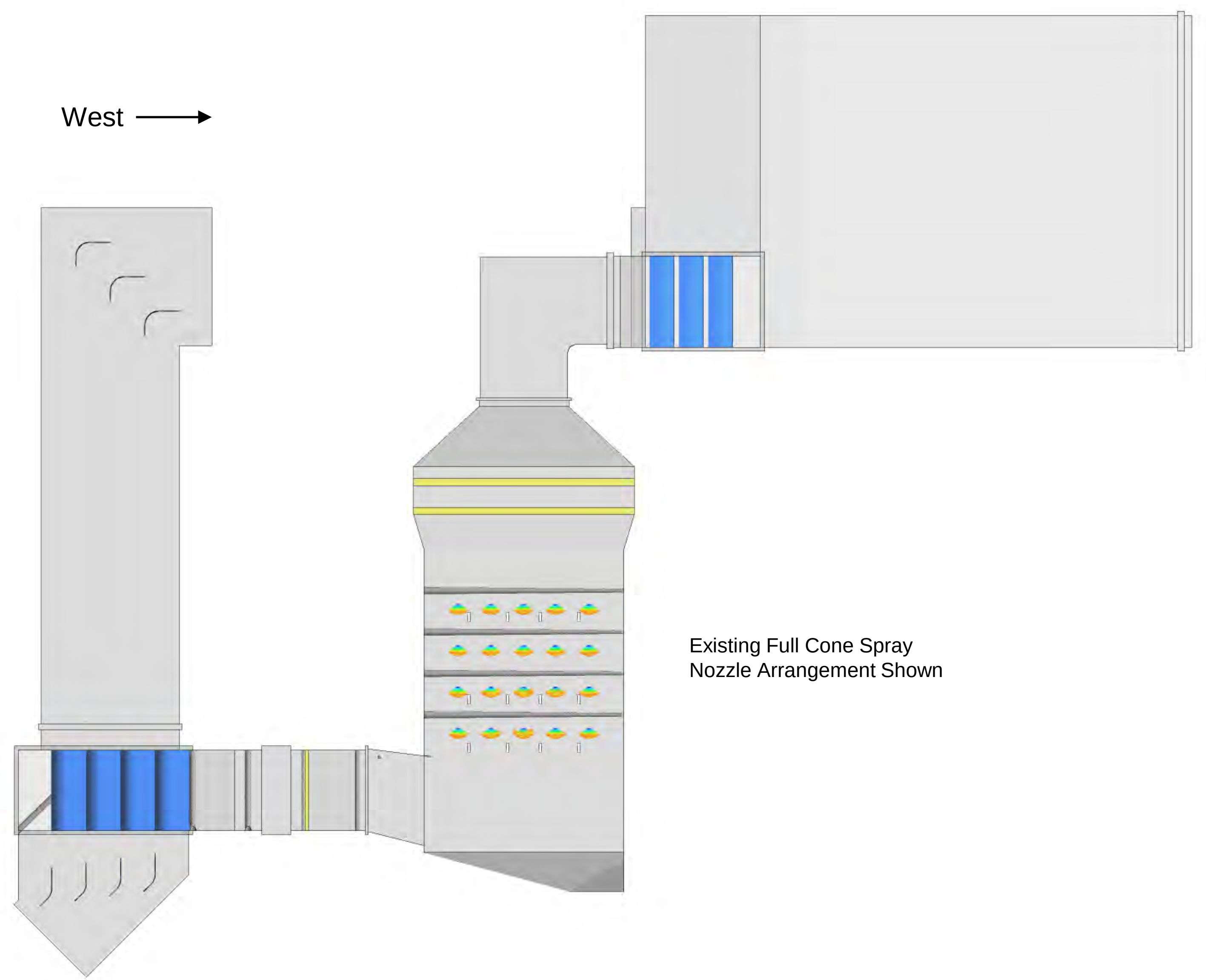
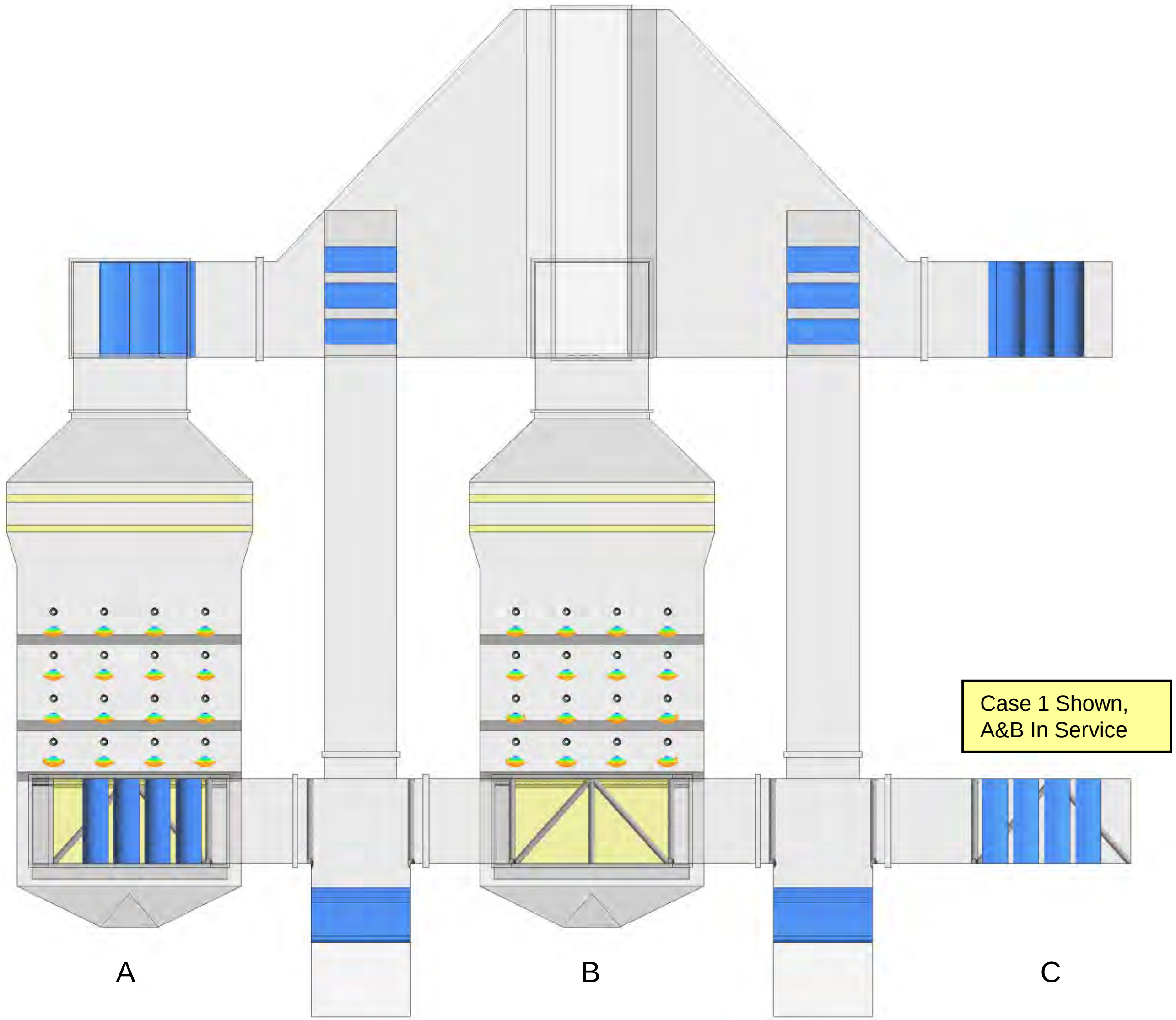
# CFD Model Geometry

Side Elevation View



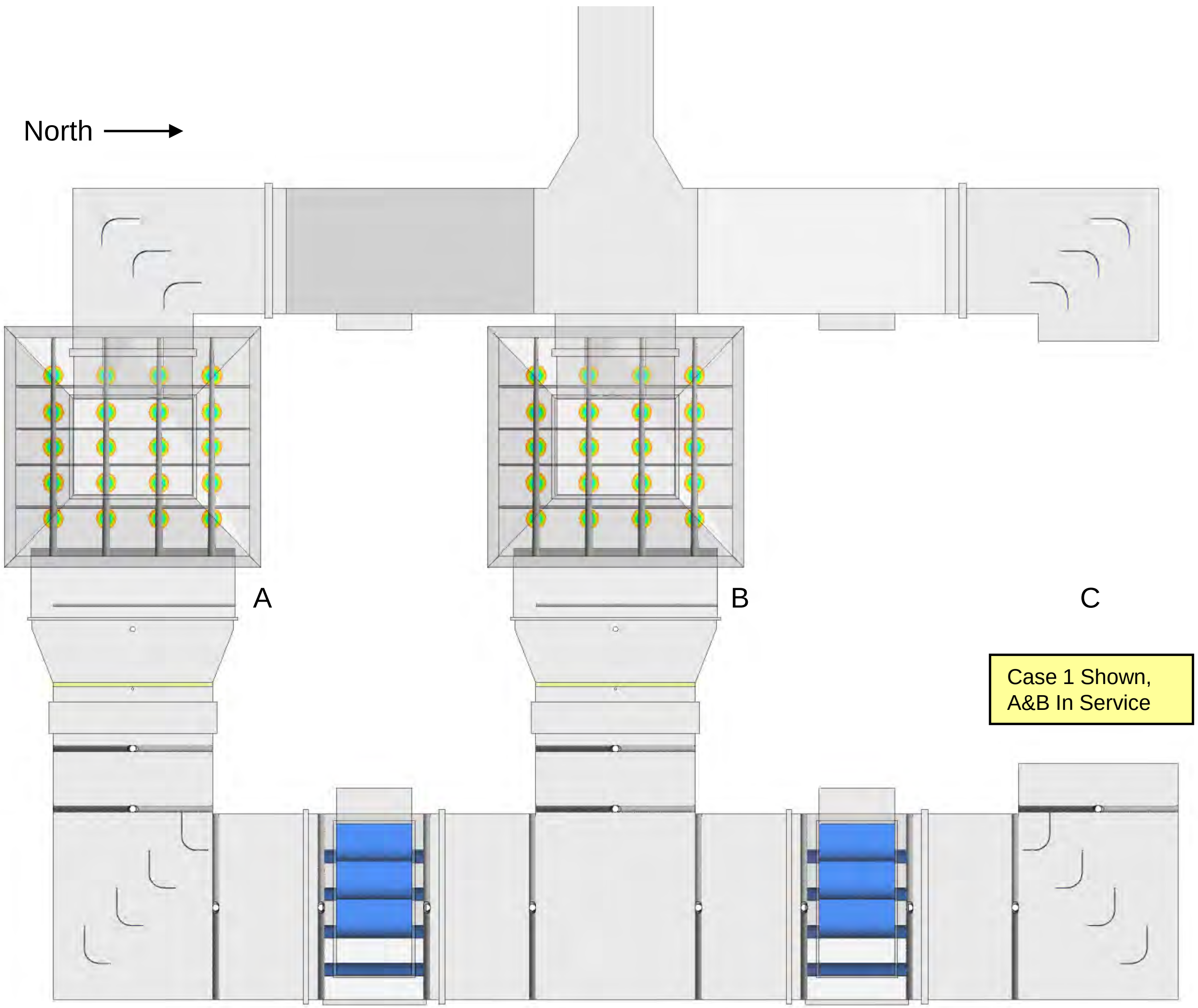
# CFD Model Geometry

End Elevation View, Looking West



# CFD Model Geometry

Plan View

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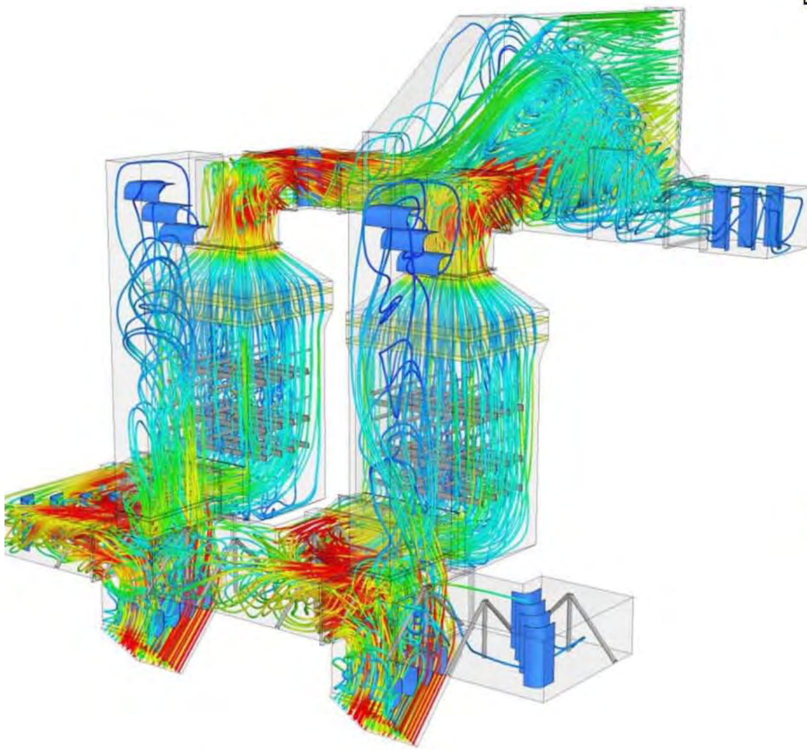
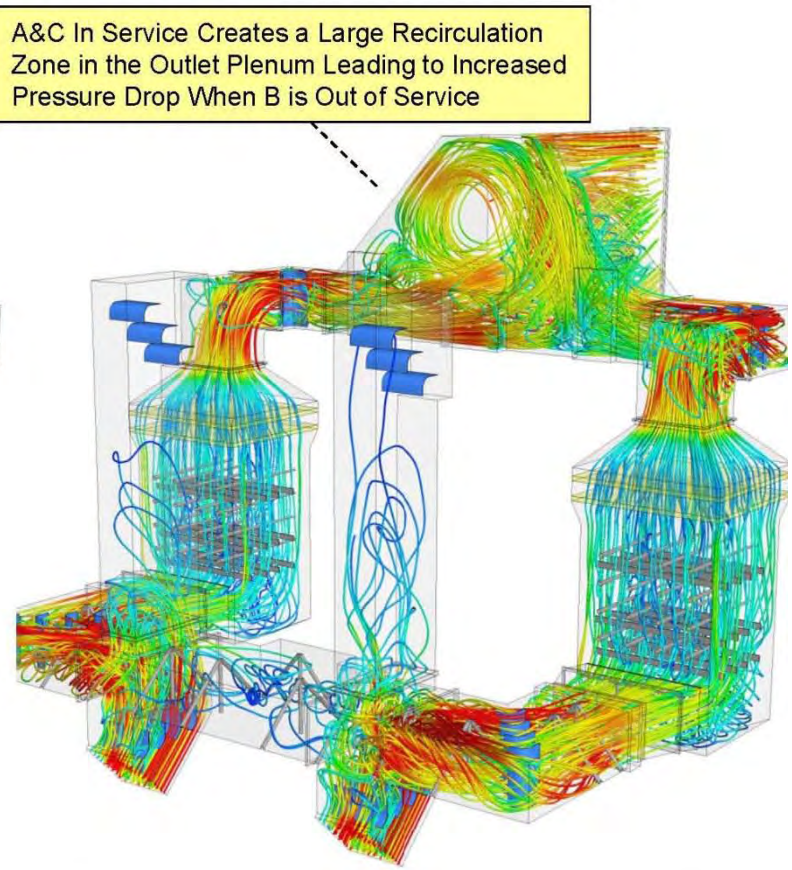
# Gas Streamlines

## Colored by Velocity Magnitude



Typical, All Full Load Cases with A&B In Service




Typical, All Cases Full Load with A&C In Service

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# Summary of Results – Flow Split Between Towers In Service

| Case | Towers In Service | | | Ductwork and Flow Control Device Configuration | Spray Nozzle Configuration | Spray Elevations in Service | Unit Load | Flow Split Between Towers (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | | | | A | B | C |
| 1 | ● | ● | | Existing | Existing Full Cone | 4 | Full Load | 48.5 | 51.5 | |
| 2 | ● | | ● | Existing | Existing Full Cone | 4 | Full Load | 50.3 | | 49.7 |
| 3 | ● | ● | | Perf Plate Mod | DHC Upgrade | 4 | Full Load | 48.8 | 51.2 | |
| 4 | ● | | ● | Perf Plate Mod | DHC Upgrade | 4 | Full Load | 50.2 | | 49.8 |
| 5 | ● | ● | | Existing | Existing Full Cone | 4 | Low Load | 49.8 | 50.2 | |
| 6 | ● | | ● | Existing | Existing Full Cone | 4 | Low Load | 50.5 | | 49.5 |
| 7 | ● | ● | | Perf Plate Mod | DHC Upgrade | 4 | Low Load | 49.9 | 50.1 | |
| 8 | ● | | ● | Perf Plate Mod | DHC Upgrade | 4 | Low Load | 50.2 | | 49.8 |
| 9 | ● | ● | | Existing | Existing Full Cone | 3 | Full Load | 49.5 | 50.5 | |
| 10 | ● | | ● | Existing | Existing Full Cone | 3 | Full Load | 51.0 | | 49.0 |
| 11 | ● | ● | | Existing | Existing Full Cone | 3 | Low Load | 49.9 | 50.1 | |
| 12 | ● | | ● | Existing | Existing Full Cone | 3 | Low Load | 49.9 | | 50.1 |

- Although the model predicts B tower receives slightly more flow on average due to the shortest path to the stack, the primary conclusion is that the flow split is uniform within the error limits of the model.

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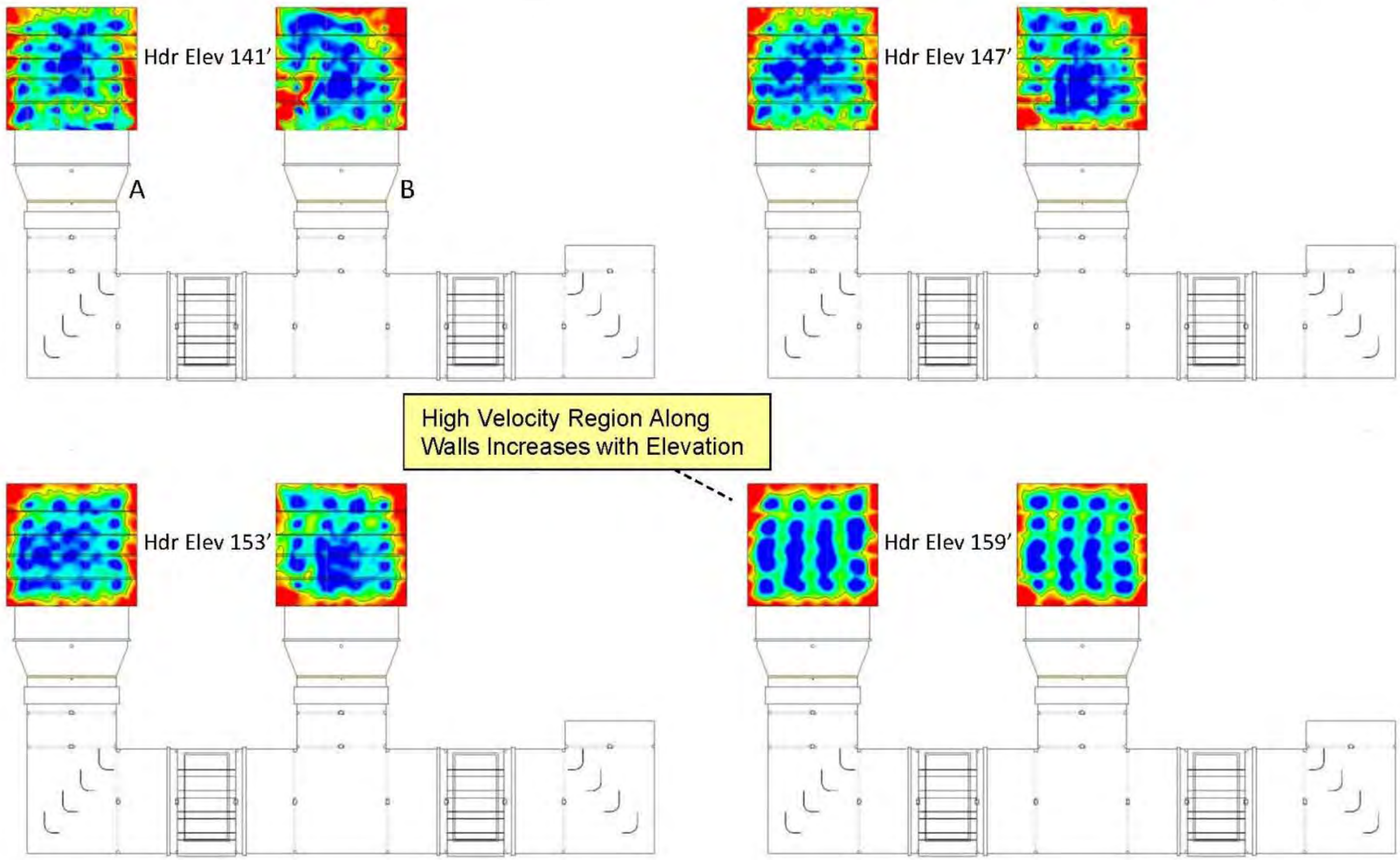
# Vertical Velocity Through Slurry Spray Zone

## Plan View

## Colored by Velocity Magnitude

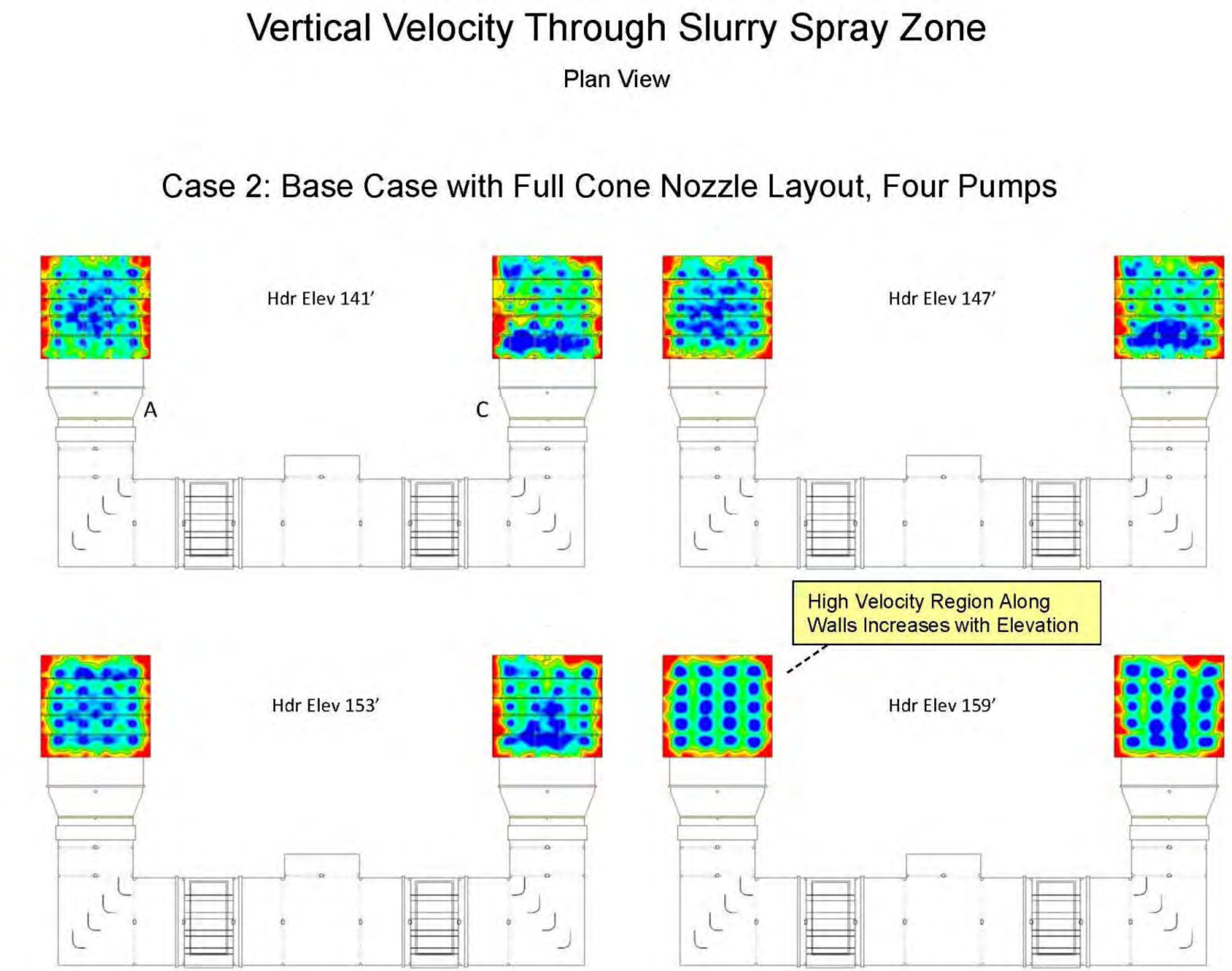
Case 1: Base Case with Full Cone Nozzle Layout, Four Pumps



# Vertical Velocity Through Slurry Spray Zone

# Plan View

# Colored by Velocity Magnitude

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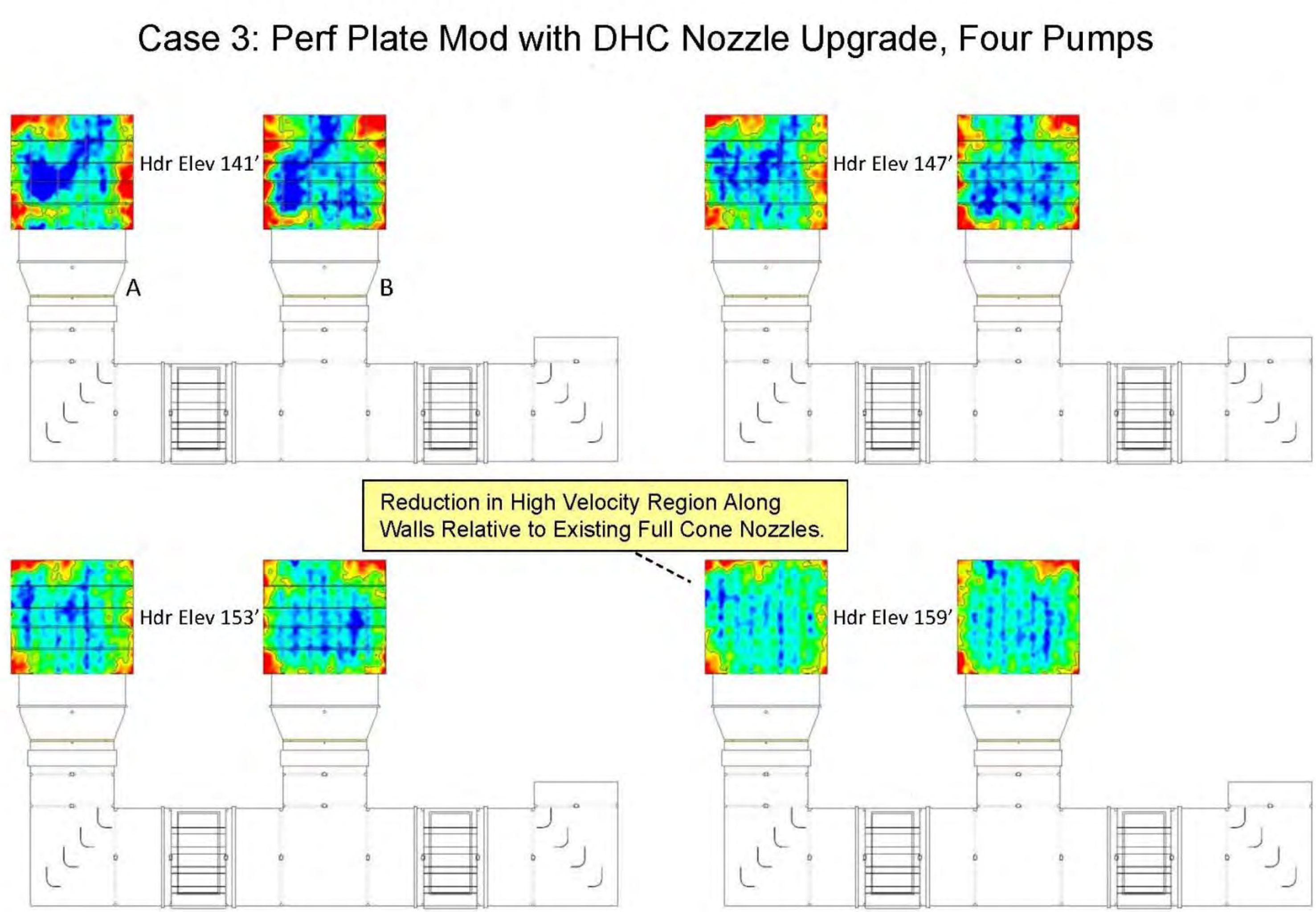
# Vertical Velocity Through Slurry Spray Zone

# Plan View

# Colored by Velocity Magnitude

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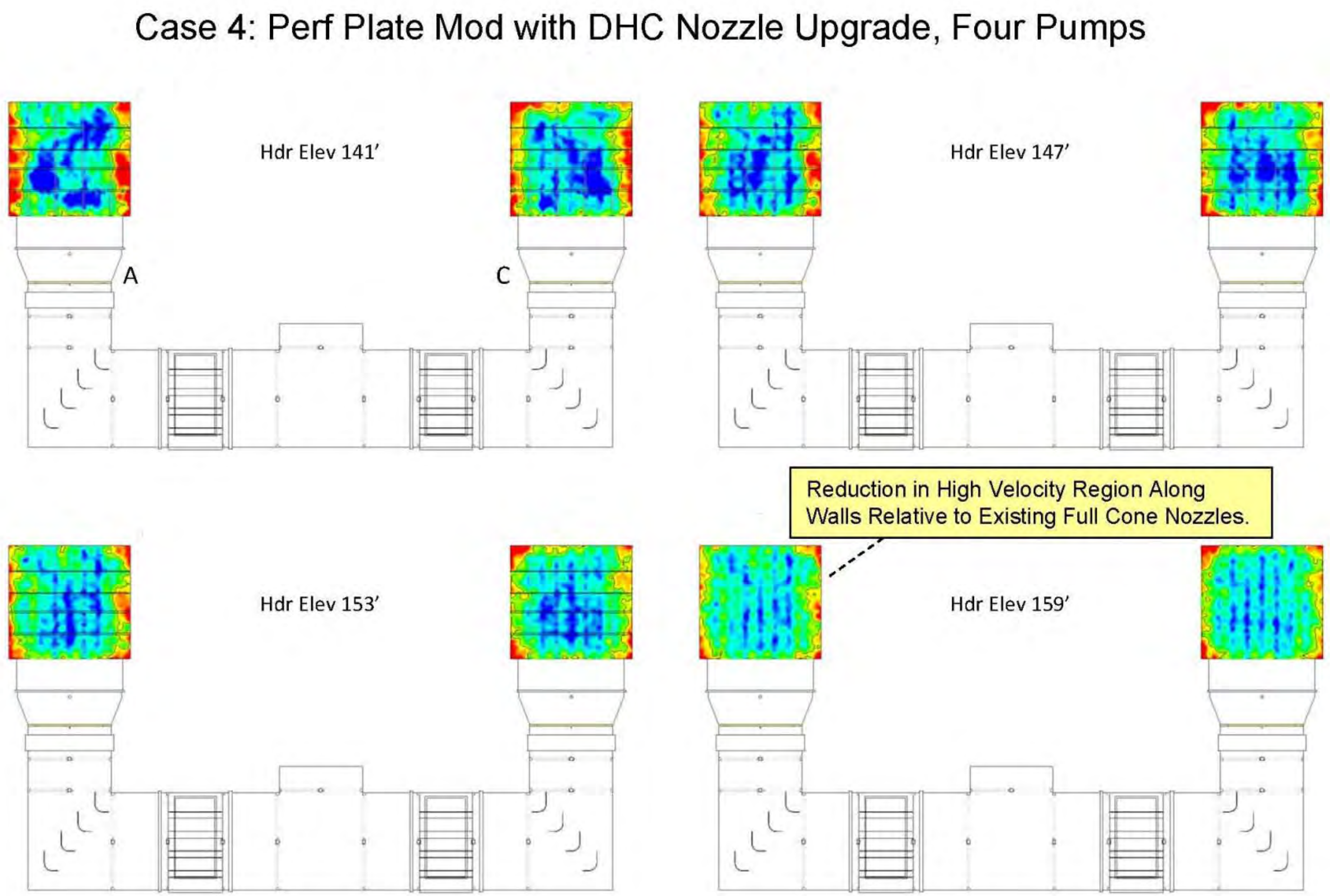
# Vertical Velocity Through Slurry Spray Zone

# Plan View

# Colored by Velocity Magnitude



# Summary of Results – Velocity Profile at Spray Header Elevations

| Case | Towers In Service | | | Ductwork and Flow Control Device Configuration | Spray Nozzle Configuration | Spray Elevations in Service | Unit Load | % Tower Area with Gas Velocity > 20 ft/sec at an Elevation 18" Below Header Centerline | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | | | | Hdr Elev 141' | Hdr Elev 147' | Hdr Elev 153' | Hdr Elev 159' | |
| 1 | ● | ● | | Existing | Existing Full Cone | 4 | Full Load | 25.4 | 25.6 | 26.1 | 26.8 | |
| 2 | ● | | ● | Existing | Existing Full Cone | 4 | Full Load | 20.8 | 21.5 | 22.5 | 23.9 | |
| | | | | | | | | **23.1** | **23.6** | **24.3** | **25.4** | **Avg** |
| 3 | ● | ● | | Perf Plate Mod | DHC Upgrade | 4 | Full Load | 23.7 | 19.4 | 14.0 | 11.6 | |
| 4 | ● | | ● | Perf Plate Mod | DHC Upgrade | 4 | Full Load | 22.5 | 19.3 | 16.0 | 12.6 | |
| | | | | | | | | **23.1** | **19.4** | **15.0** | **12.1** | **Avg** |
| 5 | ● | ● | | Existing | Existing Full Cone | 4 | Low Load | 8.3 | 8.8 | 9.6 | 11.7 | |
| 6 | ● | | ● | Existing | Existing Full Cone | 4 | Low Load | 10.5 | 10.8 | 11.9 | 14.0 | |
| | | | | | | | | **9.4** | **9.8** | **10.8** | **12.9** | **Avg** |
| 7 | ● | ● | | Perf Plate Mod | DHC Upgrade | 4 | Low Load | 10.1 | 7.1 | 4.1 | 2.8 | |
| 8 | ● | | ● | Perf Plate Mod | DHC Upgrade | 4 | Low Load | 8.6 | 6.2 | 4.4 | 2.8 | |
| | | | | | | | | **9.4** | **6.7** | **4.3** | **2.8** | **Avg** |
| 9 | ● | ● | | Existing | Existing Full Cone | 3 | Full Load | 26.1 | 25.0 | 24.0 | 24.1 | |
| 10 | ● | | ● | Existing | Existing Full Cone | 3 | Full Load | 24.6 | 22.2 | 22.0 | 23.0 | |
| | | | | | | | | **25.4** | **23.6** | **23.0** | **23.6** | **Avg** |
| 11 | ● | ● | | Existing | Existing Full Cone | 3 | Low Load | 7.2 | 8.9 | 11.0 | 12.9 | |
| 12 | ● | | ● | Existing | Existing Full Cone | 3 | Low Load | 6.4 | 9.1 | 10.9 | 13.2 | |
| | | | | | | | | **6.8** | **9.0** | **11.0** | **13.1** | **Avg** |

- **Cases 1, 2, 5, 6, 9-12:** The gaps in spray coverage from the full cone nozzle layout allow flue gas to escape the spray zone by traveling up the walls, especially in the corners. The region of high-velocity gas along the walls and corners increases as the gas travels upward past each spray elevation, with an average of 25.4% of the tower area exceeding 20 ft/s at the top spray elevation under full load with four pump operation. Similar flow profiles are observed for three pump operation.
- **Cases 3, 4, 7, 8:** The improved spray coverage from the dual hollow cone upgrade significantly decreases the high-velocity regions along the walls, especially at the top two header elevations, with an average of 12.1% of the area exceeding 20 ft/s at the top spray elevation under full load.
- The guaranteed $SO_2$ removal efficiency of 96.5% is within the demonstrated performance of other URS modified absorbers without wall rings. Following the recycle header upgrade, additional improvement in the overall $SO_2$ removal efficiency can be realized with the installation of wall rings. Wall rings will reduce the higher gas flow along the wall and in the corners by forcing the gas back into the spray contact zone. Wall rings are only effective in combination with a high performance header that provides good spray coverage.
- Refer to the plot on the next slide and images of velocity at each header elevation on slides 44-49, 70-75.

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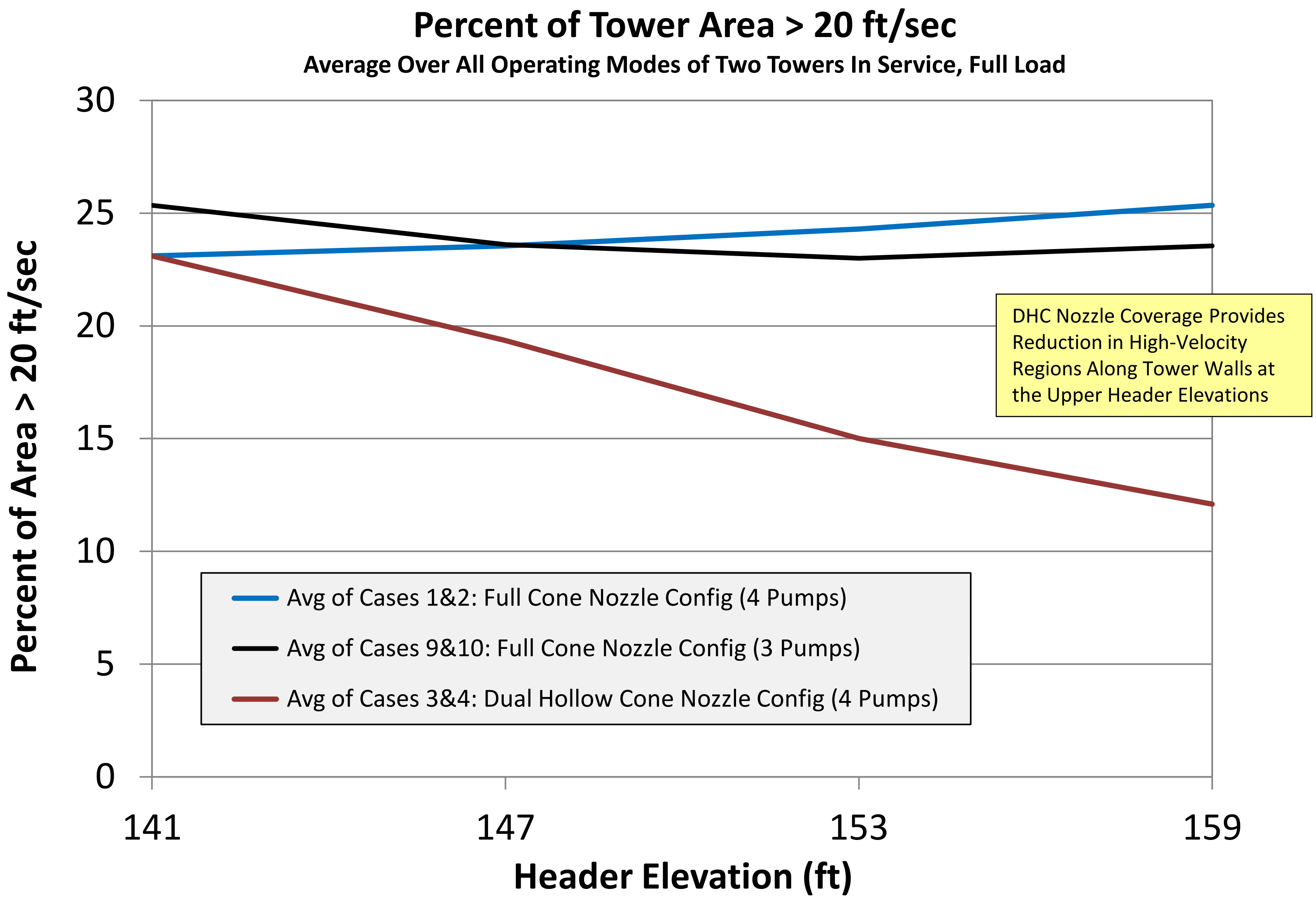
# Summary of Results – Velocity Profile at Spray Header Elevations




- This plot and the summary table on the previous slide show that the dual hollow cone upgrade significantly decreases the intensity of high-velocity regions along the walls, especially at the top two header elevations. This is due to the improved spray coverage from the dual hollow cone nozzle arrangement.

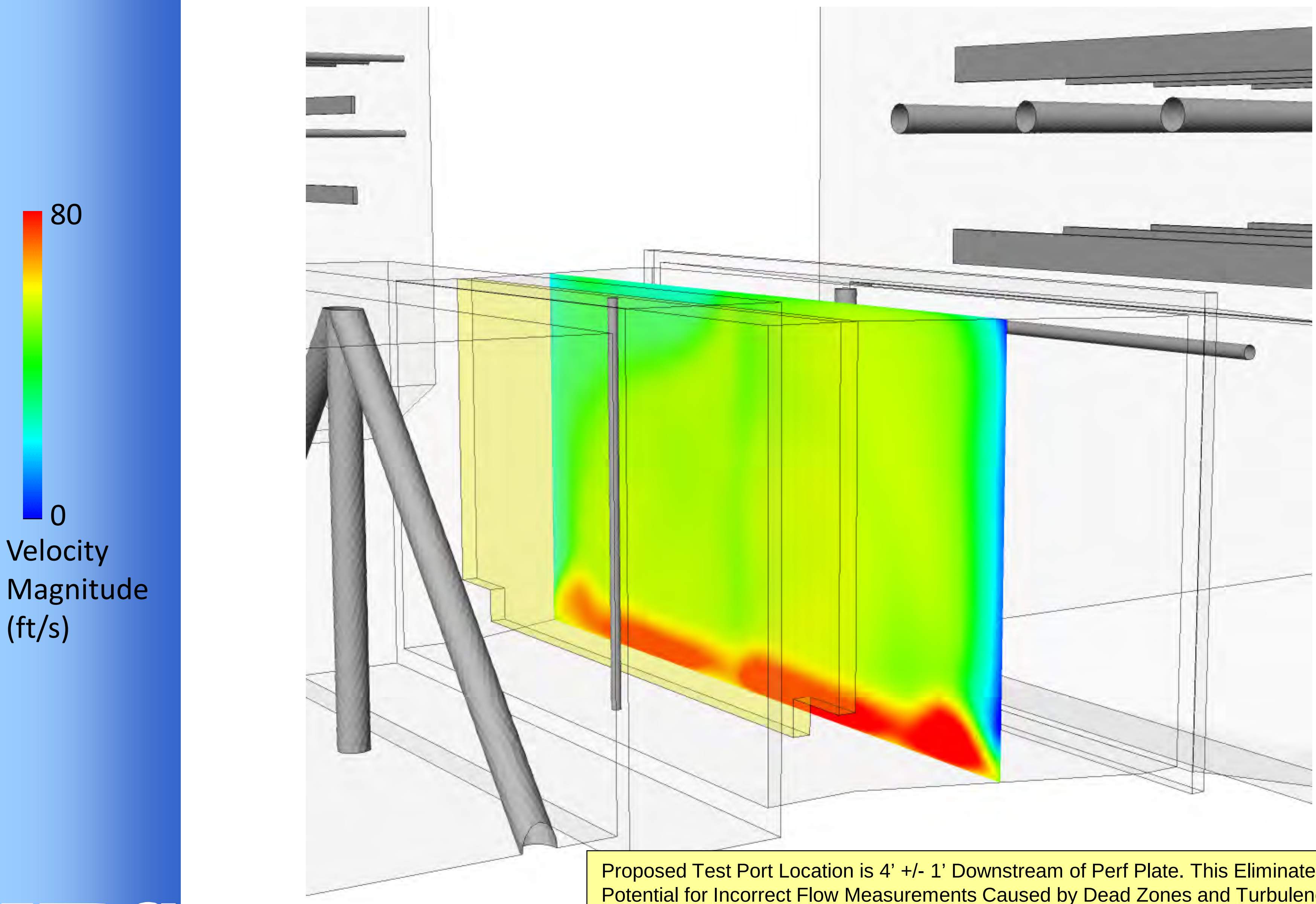
# Summary of Results – Pressure Drop

| Case | Towers In Service | | | Ductwork and Flow Control Device Configuration | Spray Nozzle Configuration | Spray Elevations in Service | Unit Load | Pressure Drop Summary, ID Fan Outlet Flange to Stack Breach (iwc) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total Pressure Drop (Static + Dynamic Head) | | | Static Pressure Drop | | |
| | A | B | C | | | | | A&B | A&C | **Average** | A&B | A&C | **Average** |
| 1 | ● | ● | | Existing | Existing Full Cone | 4 | Full Load | 5.8 | | **6.2** | 6.1 | | **6.5** |
| 2 | ● | | ● | Existing | Existing Full Cone | 4 | Full Load | | 6.5 | | | 6.8 | |
| 3 | ● | ● | | Perf Plate Mod | DHC Upgrade | 4 | Full Load | 6.9 | | **7.3** | 7.2 | | **7.6** |
| 4 | ● | | ● | Perf Plate Mod | DHC Upgrade | 4 | Full Load | | 7.6 | | | 7.9 | |
| 5 | ● | ● | | Existing | Existing Full Cone | 4 | Low Load | 2.9 | | **3.0** | 3.1 | | **3.2** |
| 6 | ● | | ● | Existing | Existing Full Cone | 4 | Low Load | | 3.0 | | | 3.2 | |
| 7 | ● | ● | | Perf Plate Mod | DHC Upgrade | 4 | Low Load | 3.9 | | **4.0** | 4.1 | | **4.2** |
| 8 | ● | | ● | Perf Plate Mod | DHC Upgrade | 4 | Low Load | | 4.0 | | | 4.2 | |
| 9 | ● | ● | | Existing | Existing Full Cone | 3 | Full Load | 5.3 | | **5.7** | 5.6 | | **6.0** |
| 10 | ● | | ● | Existing | Existing Full Cone | 3 | Full Load | | 6.0 | | | 6.3 | |
| 11 | ● | ● | | Existing | Existing Full Cone | 3 | Low Load | 2.6 | | **2.7** | 2.8 | | **2.9** |
| 12 | ● | | ● | Existing | Existing Full Cone | 3 | Low Load | | 2.8 | | | 3.0 | |

- The pressure drop values are reported between the ID fan outlet flange and the stack breach.
- For two-tower operation, the model predicts a lower FGD system pressure drop when the middle tower is in service. This effect is more pronounced at full load and is caused by
  1. The shorter duct run from ID fan to stack through the middle tower,
  2. The large recirculation zone in the outlet plenum when B is out of service.
- At full load, the recommended FGD upgrade configuration of Cases 3 and 4 with four pumps in service will increase the FGD system pressure drop by 1.6 iwc relative to the existing FGD configuration with three pumps in service. The increased pressure drop is a consequence of the improved spray coverage and the additional pump in service.

# Summary of Results – Velocity Profile at Proposed Inlet Duct Test Port Location

Typical of Cases 3 and 4: Recommended FGD Upgrade Configuration with Perf Plate Mod




Proposed Test Port Location is 4’ +/- 1’ Downstream of Perf Plate. This Eliminates the Potential for Incorrect Flow Measurements Caused by Dead Zones and Turbulence Upstream of the Perf Plate. Note High Velocity Along Floor at Proposed Test Port Location.

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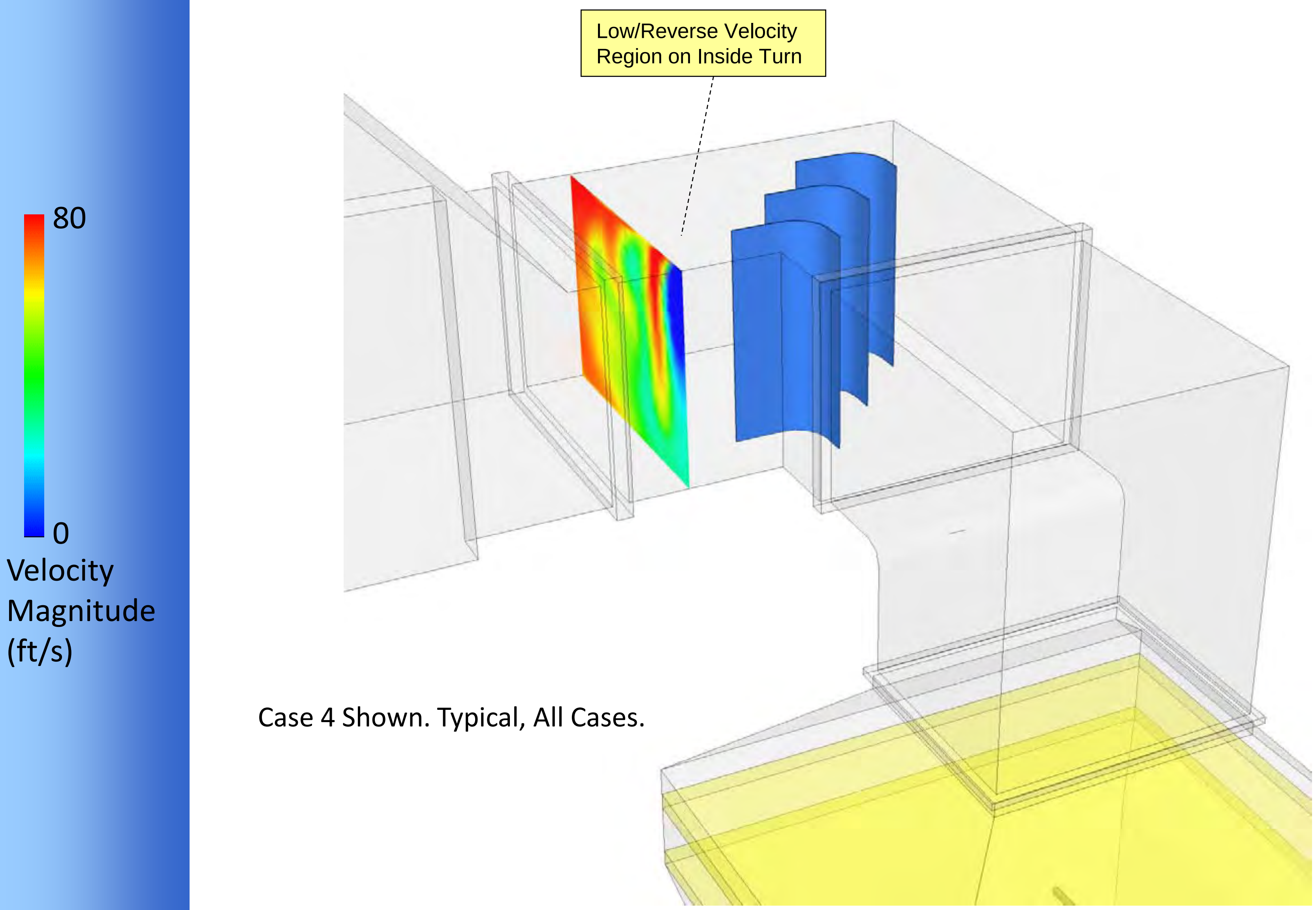
# Summary of Results – Velocity Profile at Tower Outlet Test Port Location




Case 4 Shown. Typical, All Cases.

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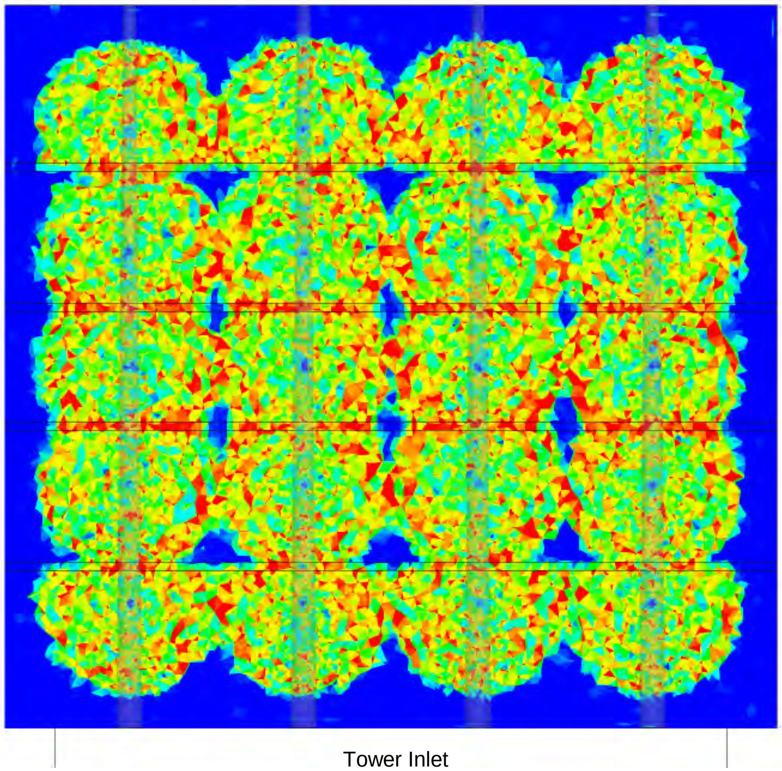
# Summary of Results – Spray Coverage Below Top Header Elevation

20 or >

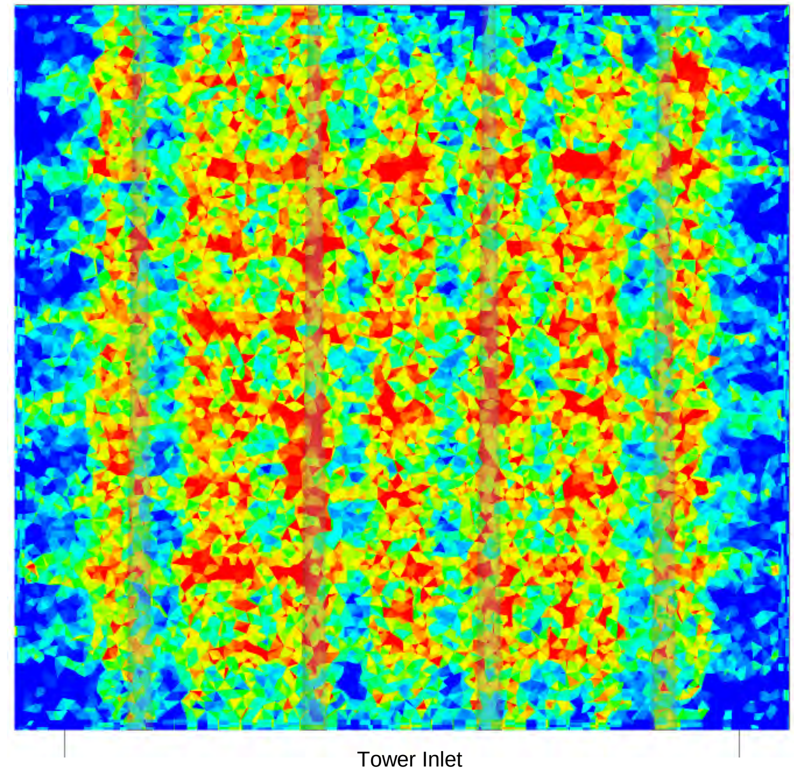
0

Liquid Loading Rate (gpm/sq. ft.)

Cases 1&2: Existing Full Cone Layout




Cases 3&4: Dual Hollow Cone Upgrade




- The dual hollow cone nozzle upgrade significantly improves the spray coverage, especially at the walls.

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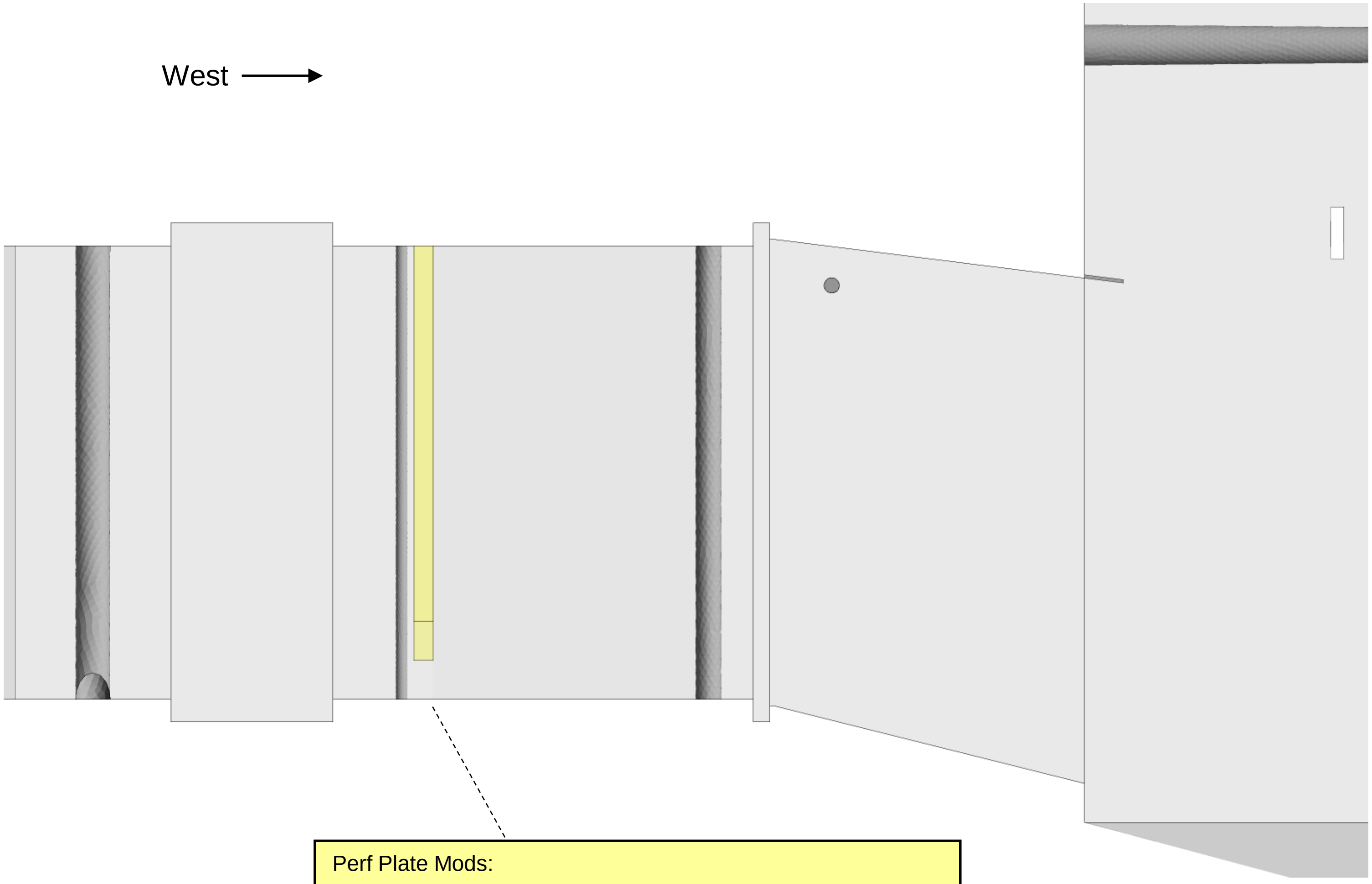
# CFD Model Geometry – Perf Plate Mod

Side Elevation View




Perf Plate Mods:

1) Remove Bottom 12” of Plate Across Entire Width of Duct.

2) Remove 24”x24” Square in Each Lower Corner.

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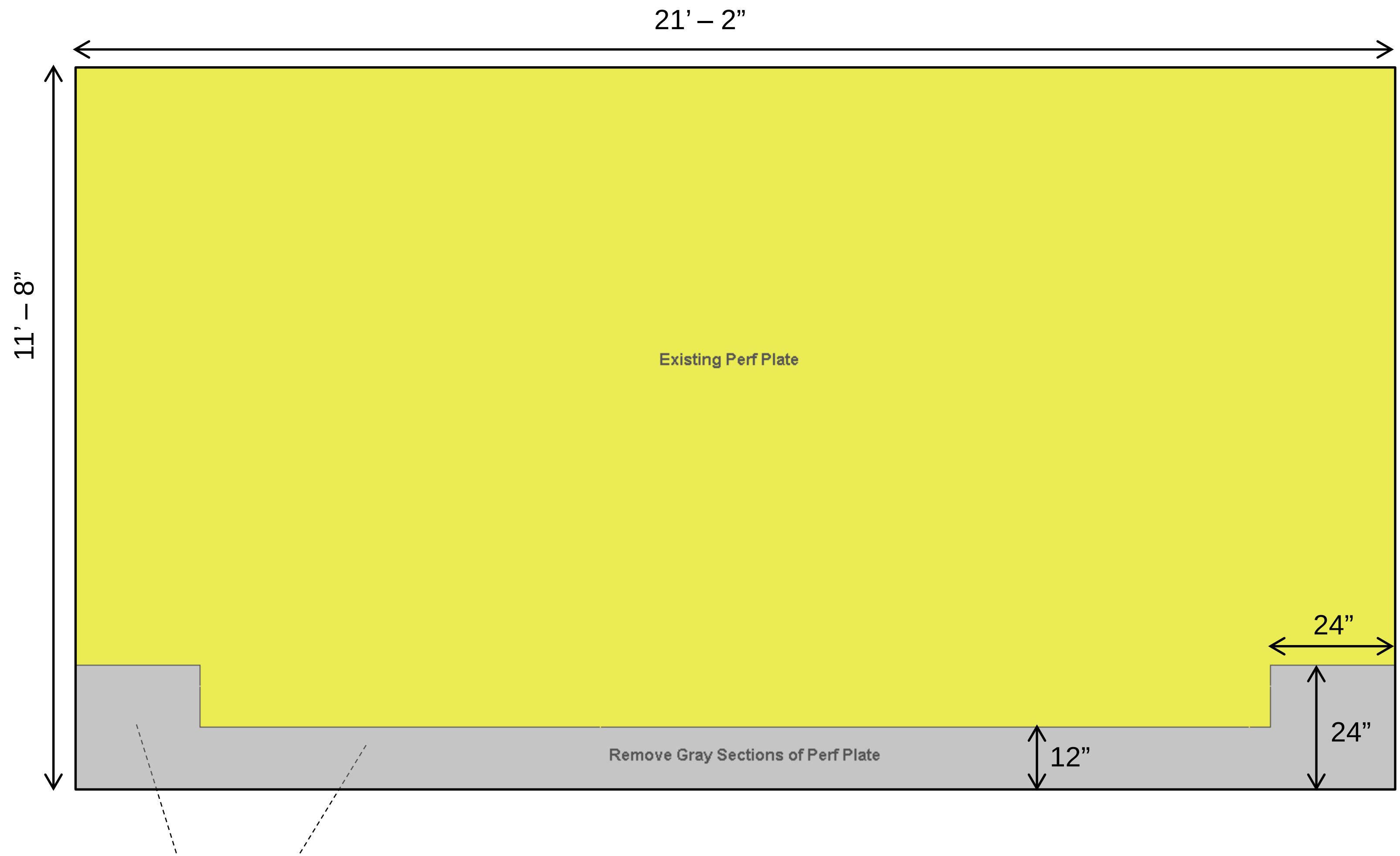
# CFD Model Geometry – Perf Plate Mod

Elevation View, Looking West In Direction of Gas Flow

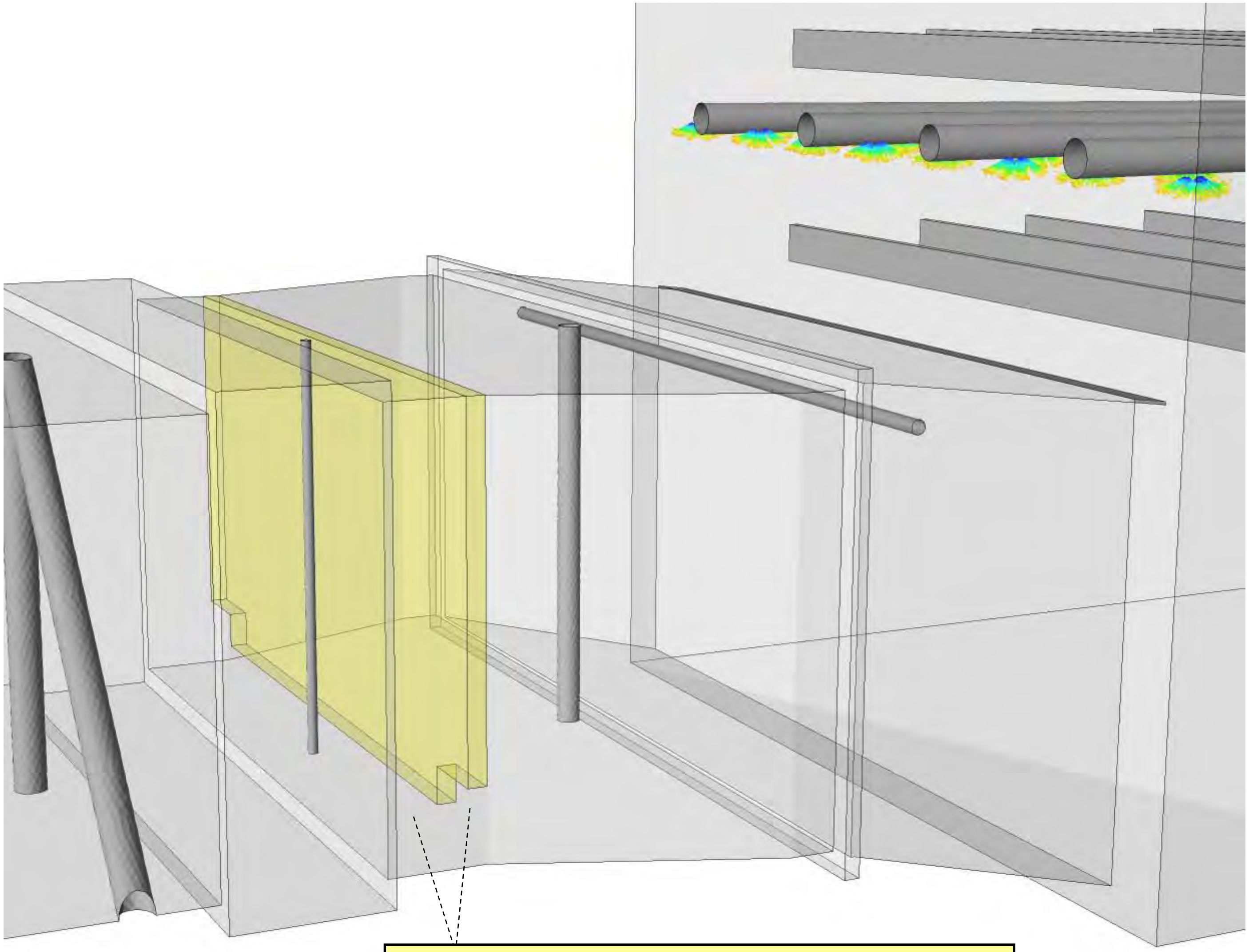



Perf Plate Mods:

1) Remove Bottom 12" of Plate Across Entire Width of Duct.

2) Remove 24"x24" Square in Each Lower Corner.

# CFD Model Geometry – Perf Plate Mod

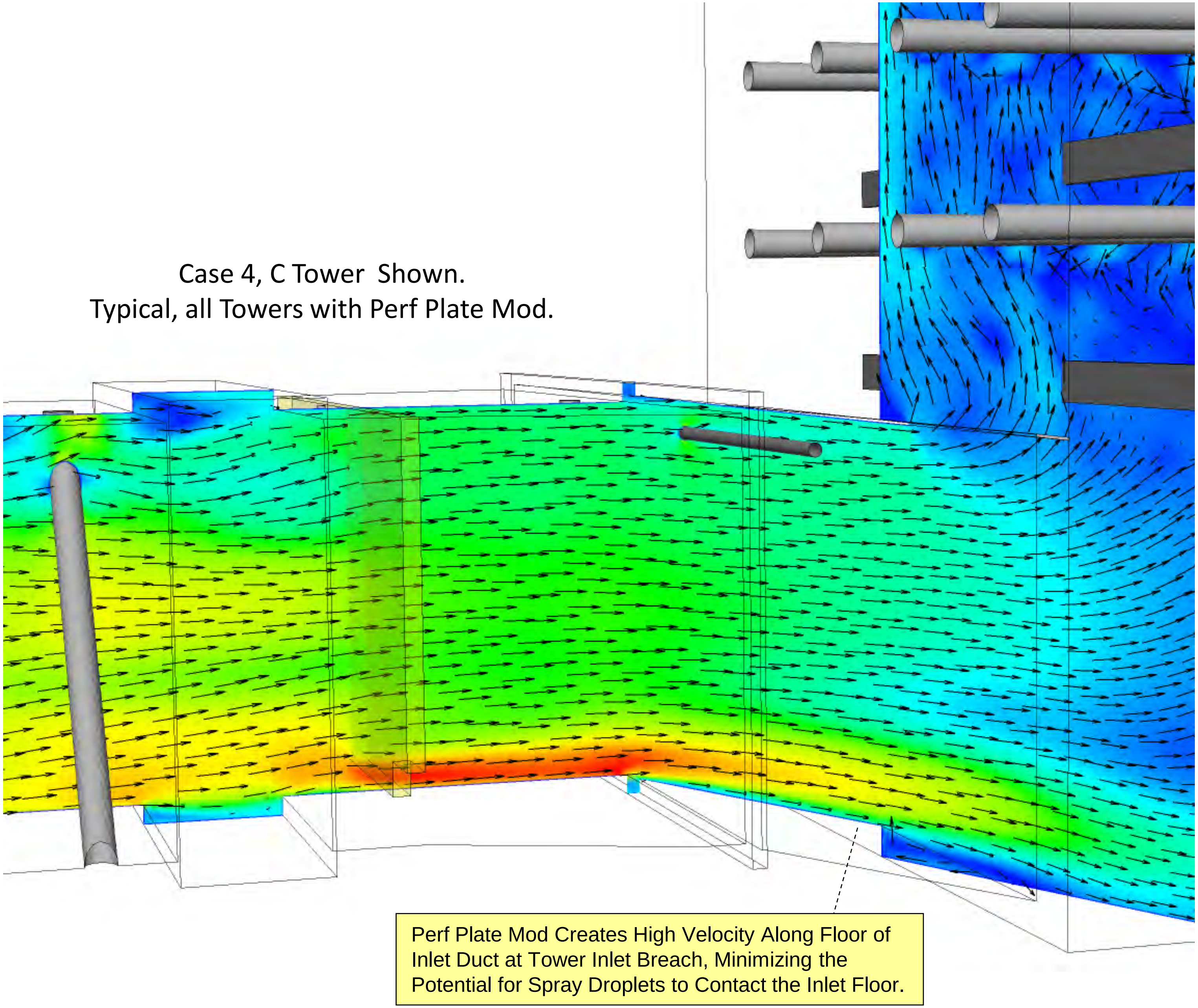


Perf Plate Mods:

1) Remove Bottom 12" of Plate Across Entire Width of Duct.

2) Remove 24"x24" Square in Each Lower Corner.

# Summary of Results – Performance of Perf Plate Mod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# FGD UPGRADE RESULTS

# Spray Test Video

# Performance Testing

| Parameter | Target Value | Tested Value | |
|---|---|---|---|
| $SO_2$ Removal, (%) | >96.0 | 96.2 | Pass |
| $SO_2$ Emissions, (lb/MM Btu) | 0.20 | 0.17 | Pass |
| Increase in Pressure Drop, (in-w.g.) | 2.0 | 1.13 | Pass |
| Limestone S.R. | 1.10 | 1.37 | Fail* |
| 30-day Reliability | | | Pass |

*Operating issues during test:

- Poor pH and density control
- Limestone reactivity lower than design
- Incomplete forced oxidation

Overall, URS deemed to have achieved performance requirements

# Conclusions

- Unit 1 FGD removal performance upgraded with minimal (<2 in w.g.) increase in system pressure drop and no increase in recycle flow rate
- Project completed on schedule and on budget
- URS performing additional work to address FGD reliability and operation problems
- 30 Day Reliability Test Successful – 30 day average $SO_2$ emission level .108 lb./mmbtu with 96% removal efficiency
- Stoichiometry improved to 1.25

# Inspection after six months

# Inspection after six months

# Inspection after six months

# Results of Performance Improvements: OUC Stanton Energy Center - Unit 1 FGD System

## Thank You

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