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Application of Advanced Computational Technologies in the Fossil-Fired and Nuclear Electric Power Generation Industries

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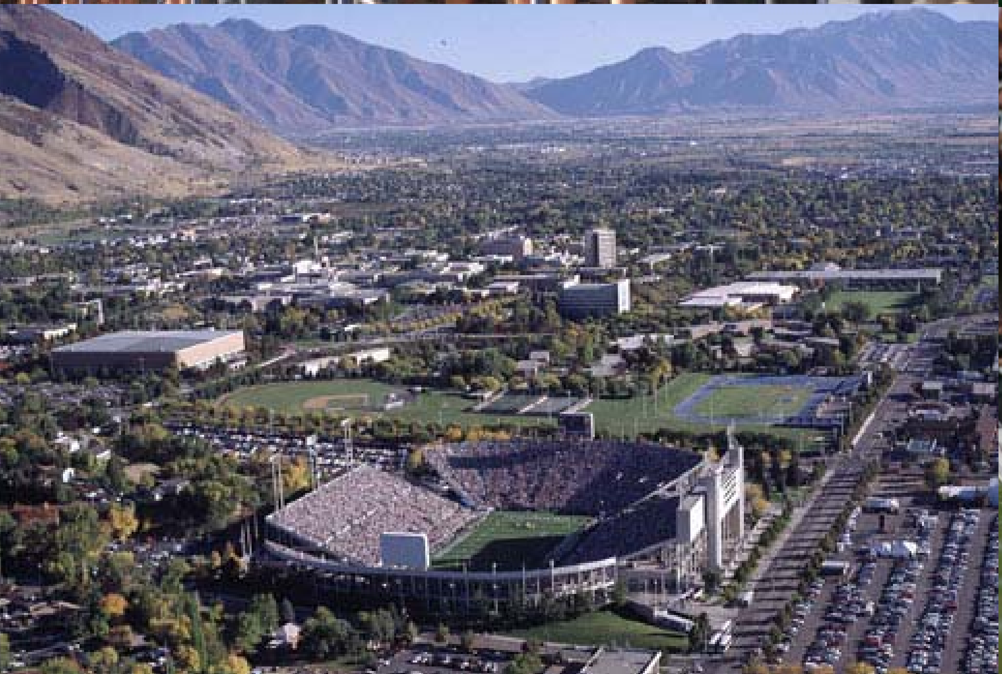


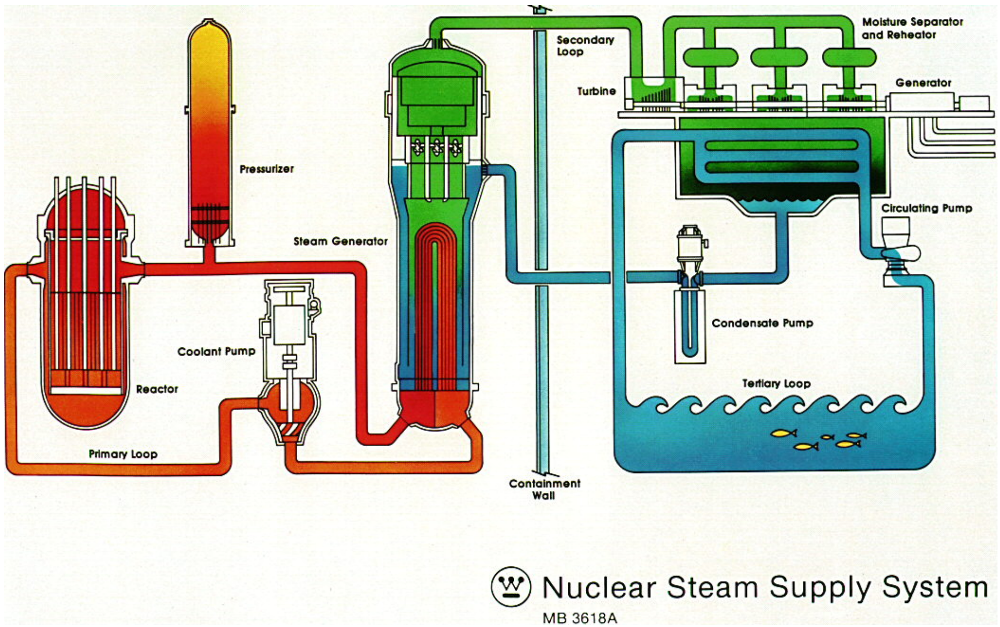
OUTLINE

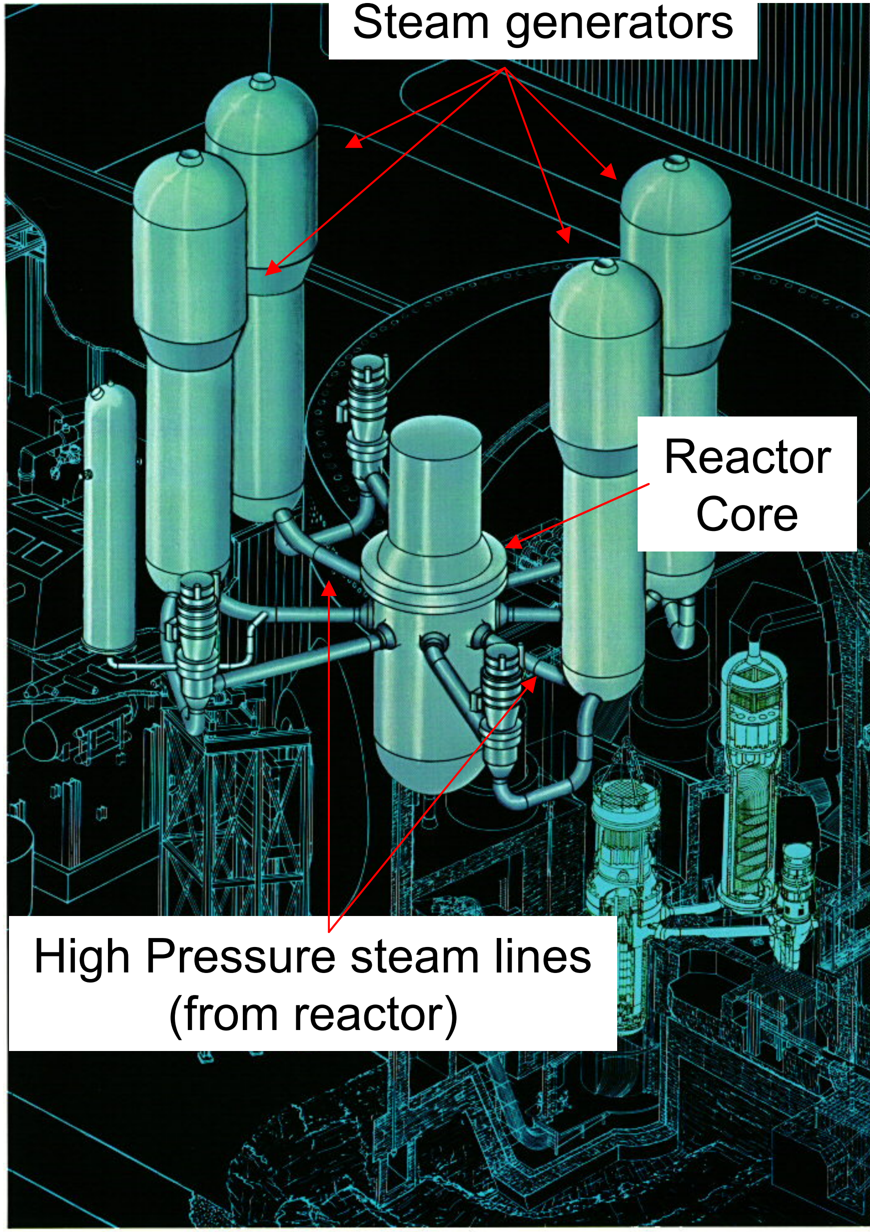
- Background and Introduction
- Application – Developing an Optimal Design to Reduce Temperature Mal-distribution from a 450 MW Air Preheater
- Application – Meeting 316(b) regulations by Identifying HZOI for Fitzpatrick Nuclear Power Plant
- Conclusions and Summary

Alion’s Experience In Electric Power Industry

- ## Fossil Fired Plants
  - Assessment and development of “best” NOx abatement strategies
  - Optimization of flow balancing in Combustion air supply ductwork
  - Multi-fuel modeling of combustion systems
  - Inspection and testing for plant performance
  - Plant design services
  - Coal blending analysis
  - Installation services
  - Fuel Conversion analysis
  - Cooling water intake analysis
  - Mitigation of Coal Slagging
- ## Nuclear Power Plants
  - GSI-191 LOCA Analysis
  - ECCS Strainer Design/evaluation
  - 316 (b) Cooling Water Usage
  - Fire Protection
  - Chemical Effects in Recirculation Pool

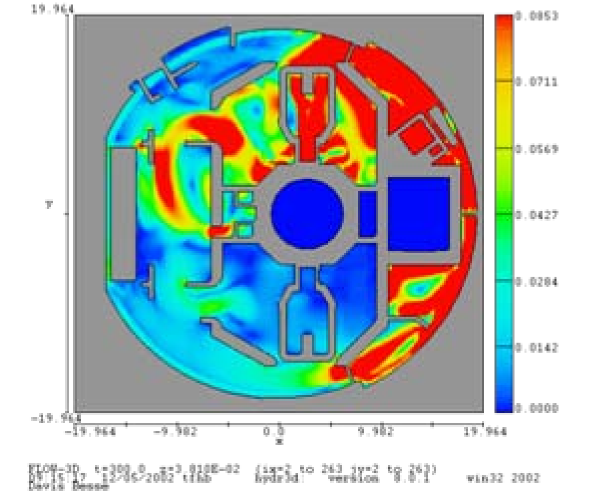
GSI-191: Loss of Coolant Accident (LOCA) in a High Pressure Steam Line in a PWR

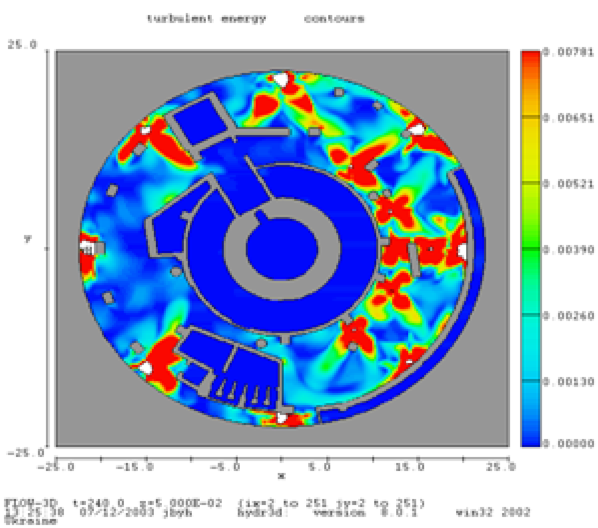




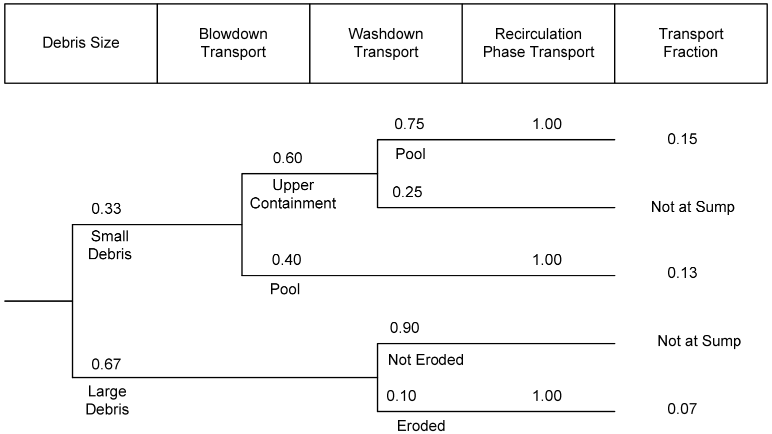
Westinghouse NUCLEAR STEAM SUPPLY SYSTEM

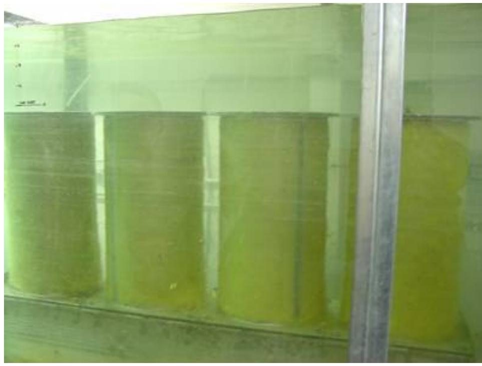
Analytical Tools Used





- o Debris Generation
- o Transport Logic Charts
- o CFD Analysis
- o Testing





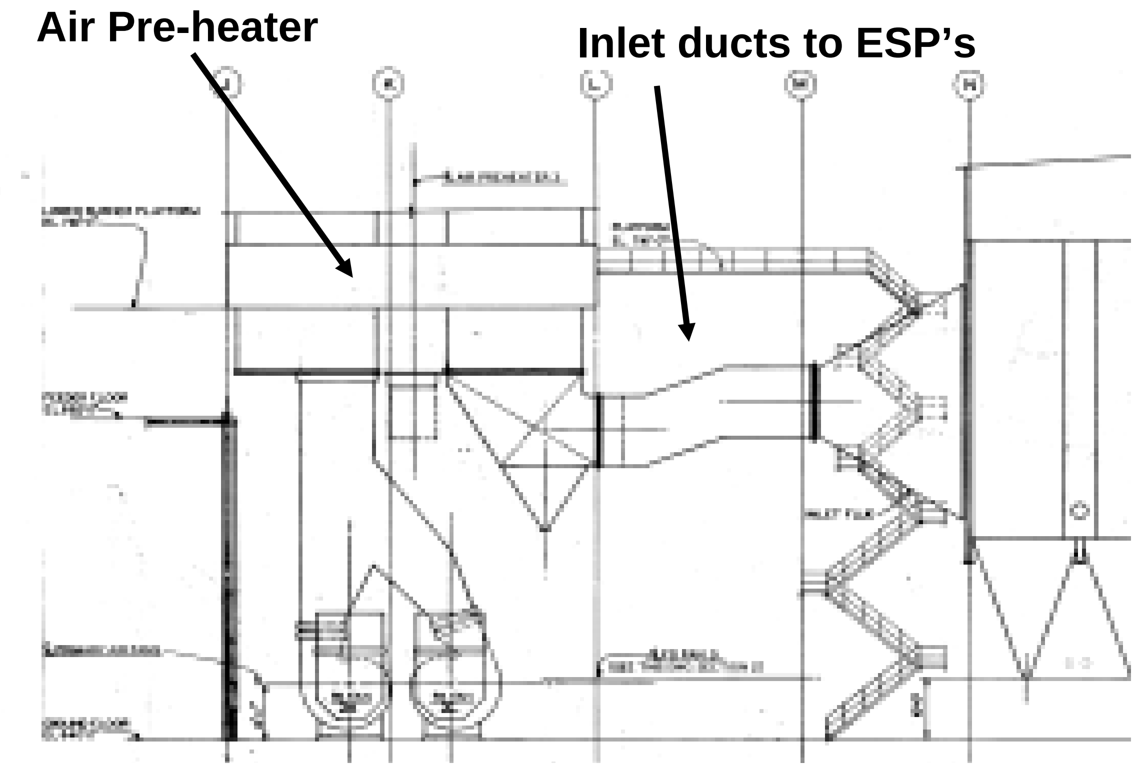
Strainer Array with Fiber Testing

Test Flume with Strainer Array

Application – Air Preheater on T-Fired Boiler

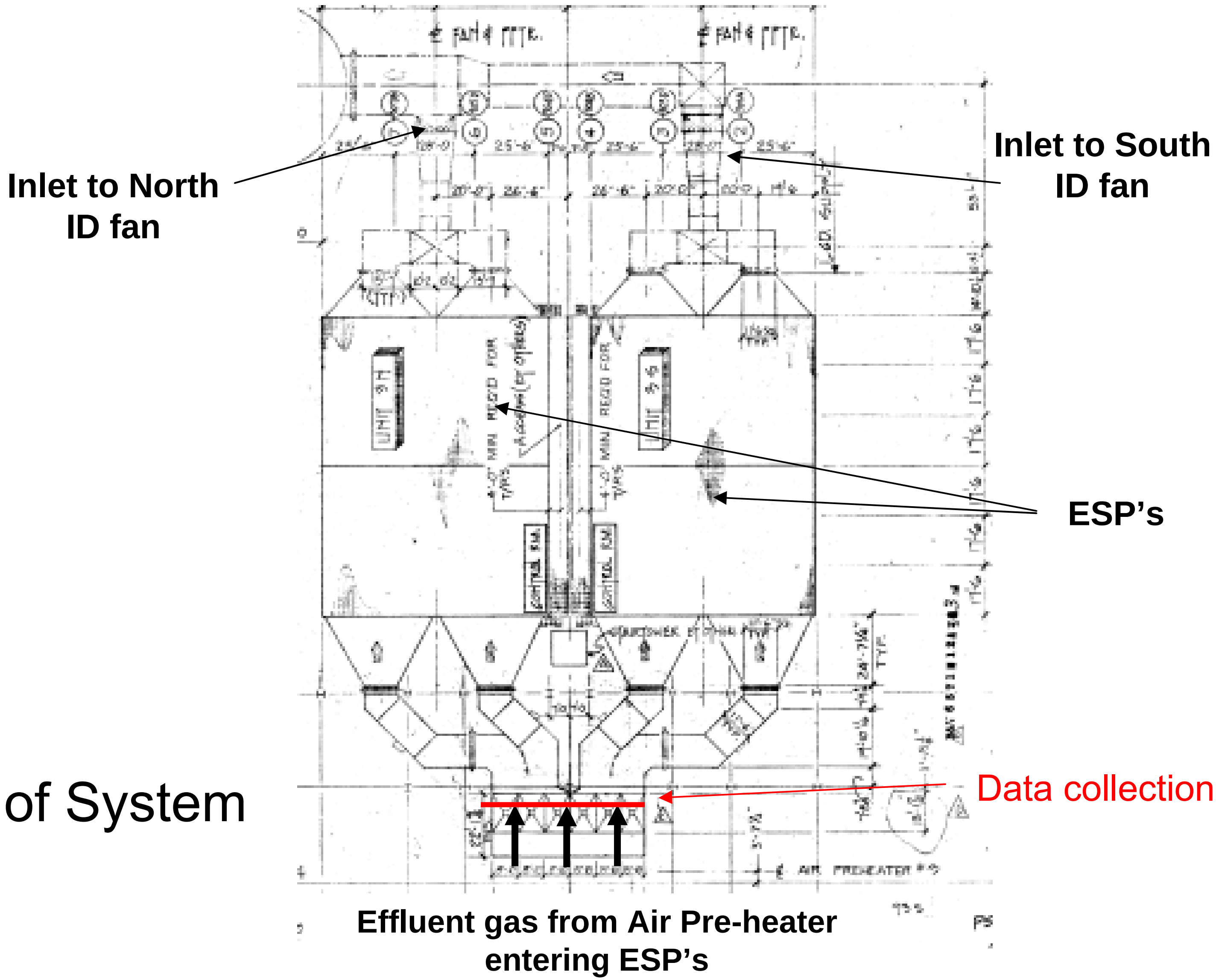
- Fuel Type: PRB Coal
- Furnace Type: T-Fired Boiler (450 MW)
- Analysis Tool: FLUENT version 6.2
- Main Task: Develop solution to rebalance measured temperature mal-distribution coming from air-preheater to ESP's/ID fans
- Customer: American Electric Power Oolagah Plant (reference available)

Application – Air Preheater on T-Fired Boiler



Side View of System Geometry

Application – Air Pre-heater on T-Fired Boiler

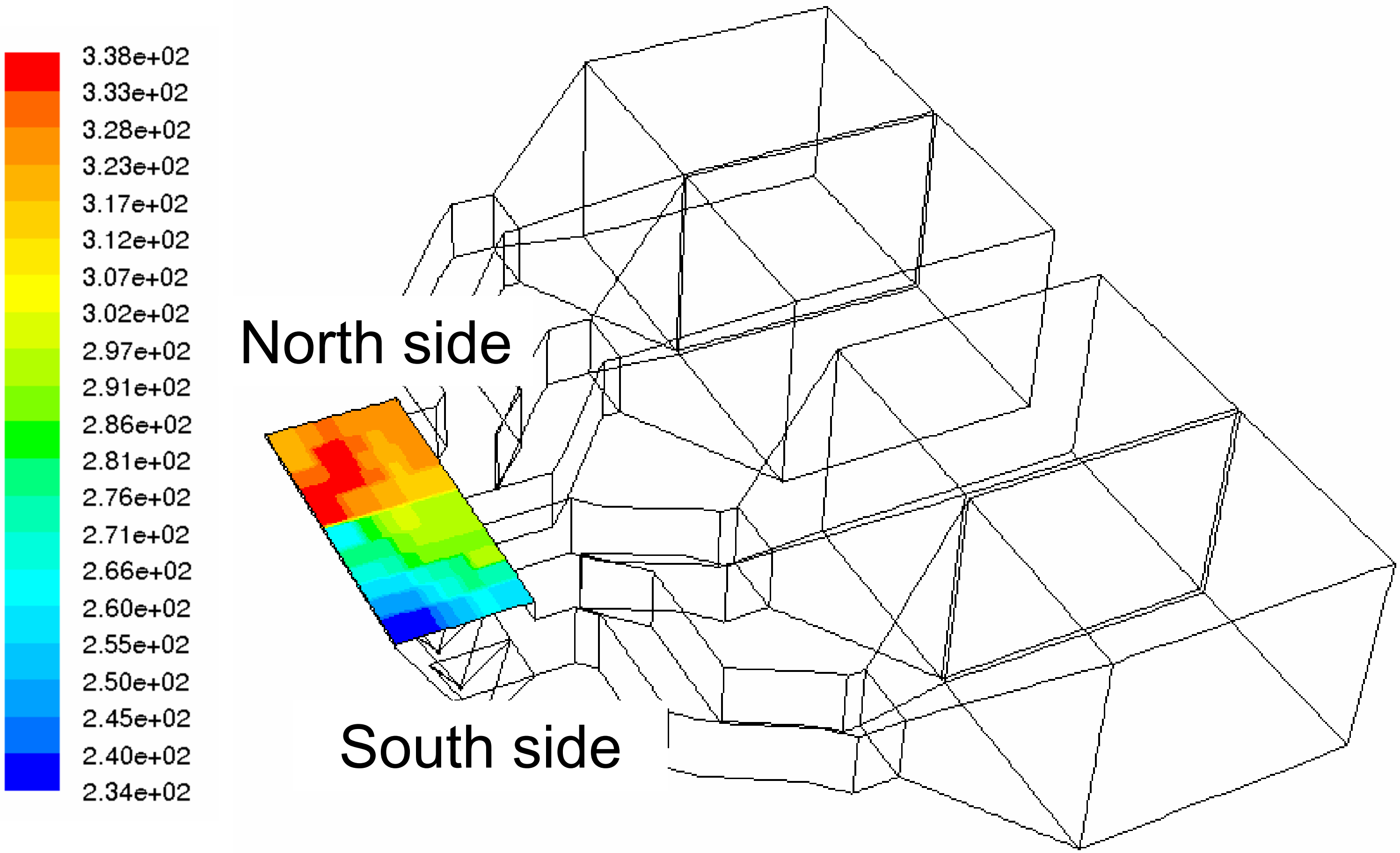


Plan View of System Geometry

Air Pre-heater Outlet Gas Temperatures (˚F)

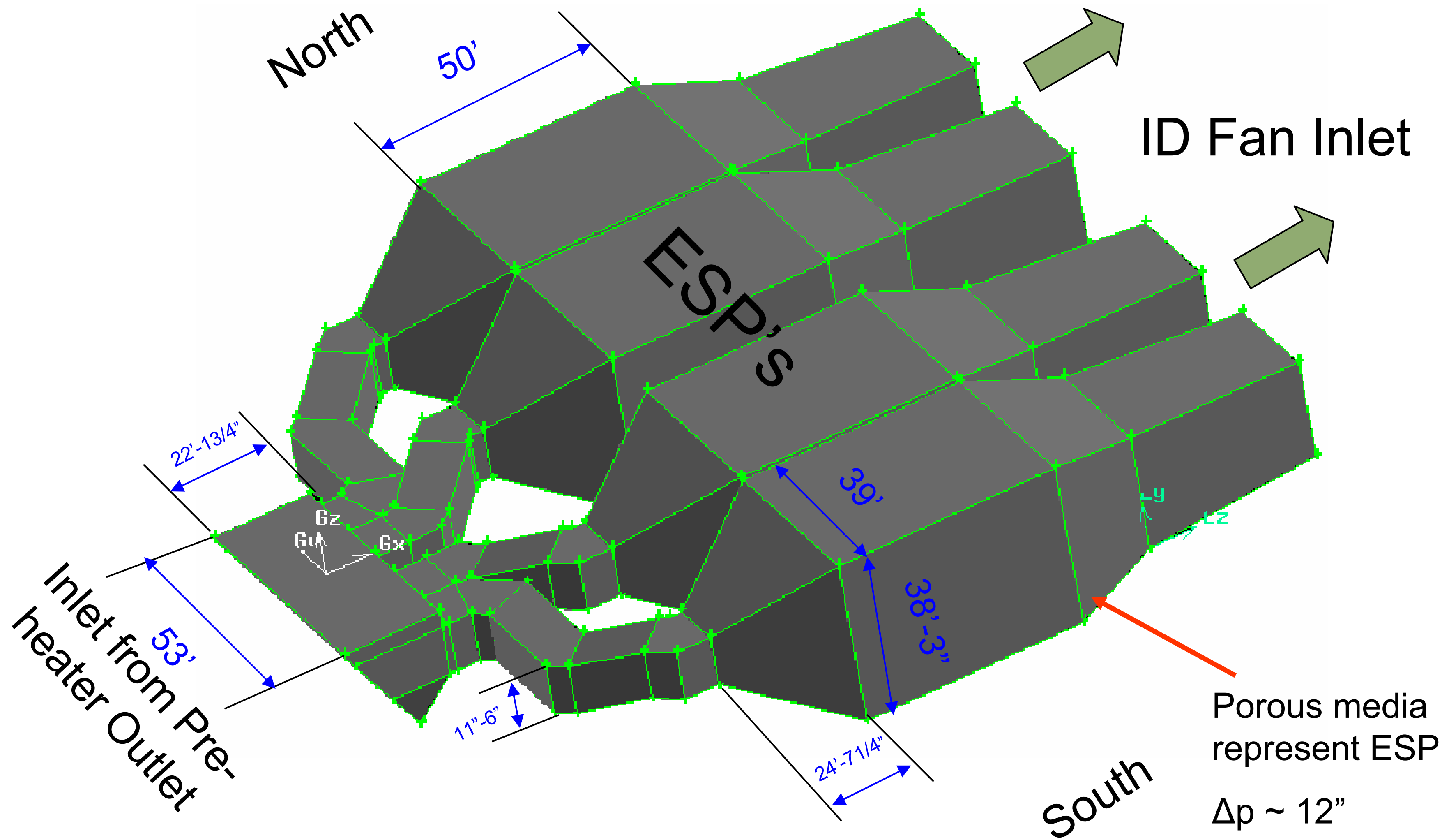
	Point 1 (nearest floor)	Point 2	Point 3	Point 4	Point 5	Point 6 (nearest ceiling)
Port 1 (North)	321.20	325.65	332.80	326.30	325.75	322.80
Port 2	319.65	335.30	336.85	329.75	320.55	327.35
Port 3	329.05	333.45	338.25	325.60	318.15	323.00
Port 4	333.70	335.80	333.40	328.05	317.25	323.40
Port 5	334.70	326.80	322.95	321.10	315.75	315.55
Port 6						
Port 7	265.05	285.40	292.50	300.90	293.40	293.70
Port 8	277.25	277.20	288.40	291.60	292.60	293.90
Port 9	266.45	273.75	285.65	286.85	288.60	286.90
Port 10	256.80	260.30	269.10	272.55	279.00	295.15
Port 11	244.80	249.75	258.90	267.40	277.20	274.10
Port 12 (South)	234.35	239.50	246.00	254.75	262.35	257.85

Application – Air Pre-heater on T-Fired Boiler



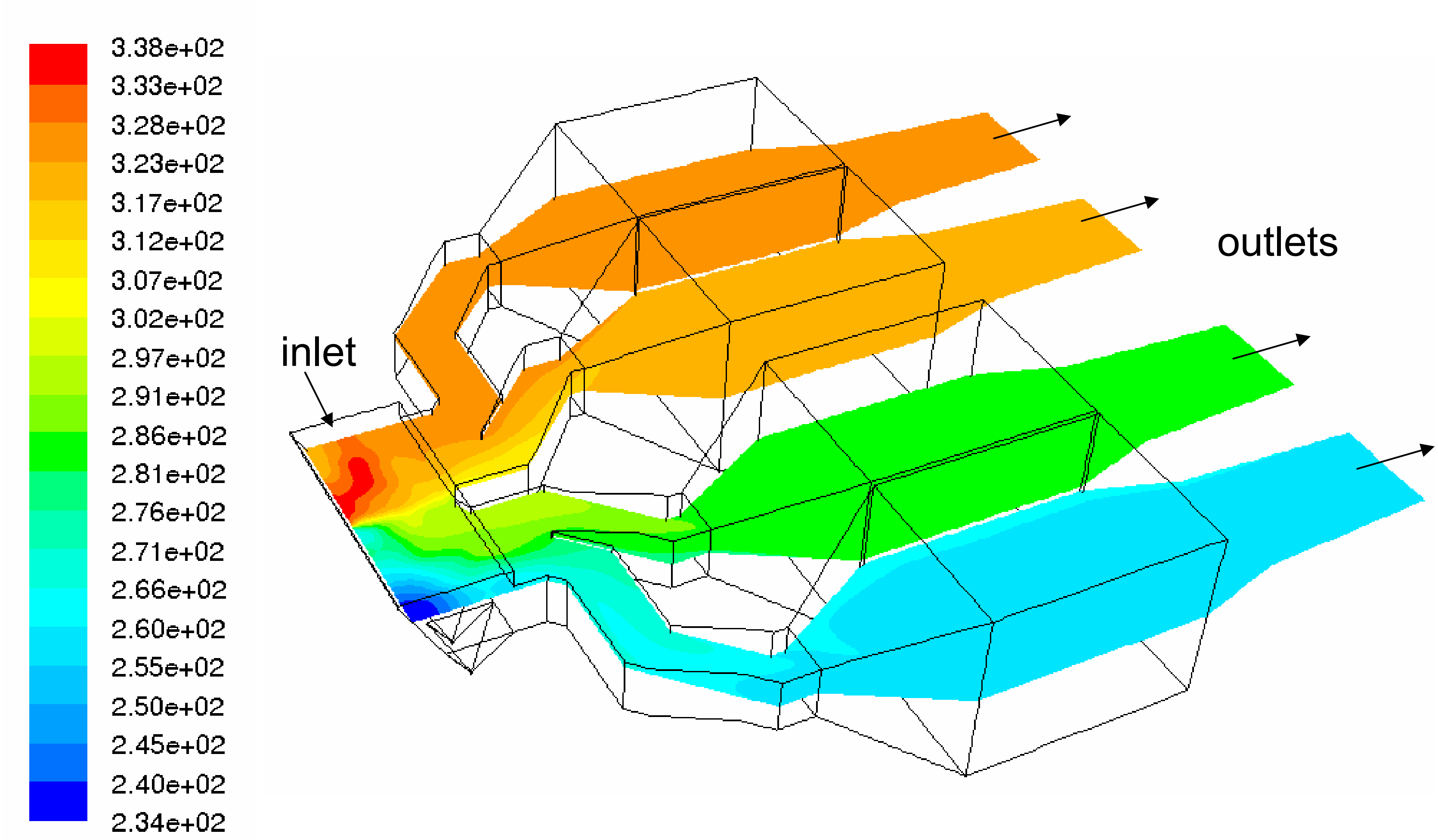
Measured outlet gas temperature (˚F) from pre-heater (boundary condition)

Application – Air Pre-heater on T-Fired Boiler



Air Pre-heater Model Geometry

Predicted Duct Temperature Profile (˚F)
(Plan view 5 ft below inlet elevation 699'- 9 ½")



Application – Air Pre-heater on T-Fired Boiler

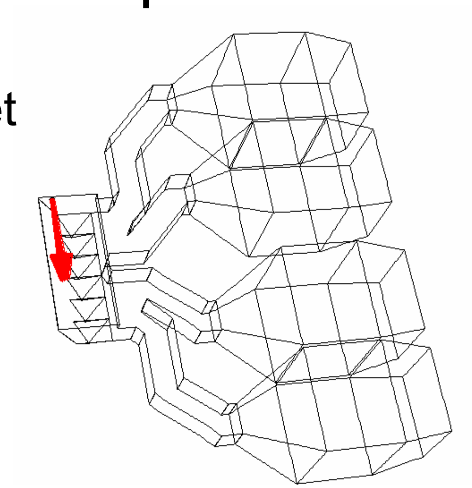
Summary

- Inlet flow rate: 1512.29 lbm/s
- Predicted ID fan temperature (˚F)
  - North
    - Average: 323.04 (data is 321.26)
    - Minimum: 317.34 (data 312.67)
    - Maximum: 326.35 (data 331.71)
  - South
    - Average: 271.99 (data is 259.68)
    - Minimum: 257.38 (data is 252.28)
    - Maximum: 287.56 (data is 268.36)
- Predictions high on South end (likely due to air leak)
- How to fix?

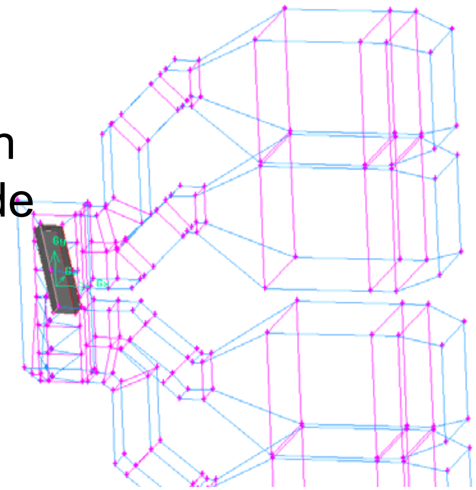
Application – Air Pre-heater on T-Fired Boiler

Proposed Modifications

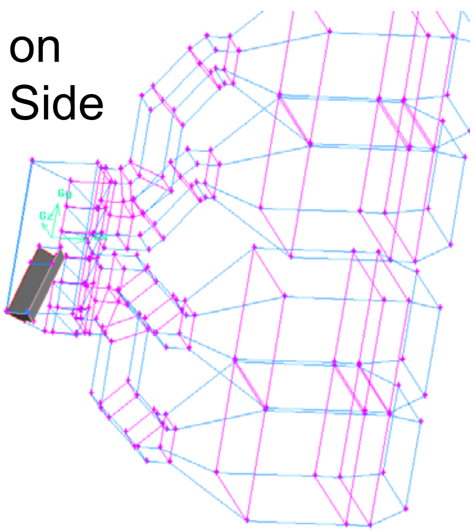
Free Jet



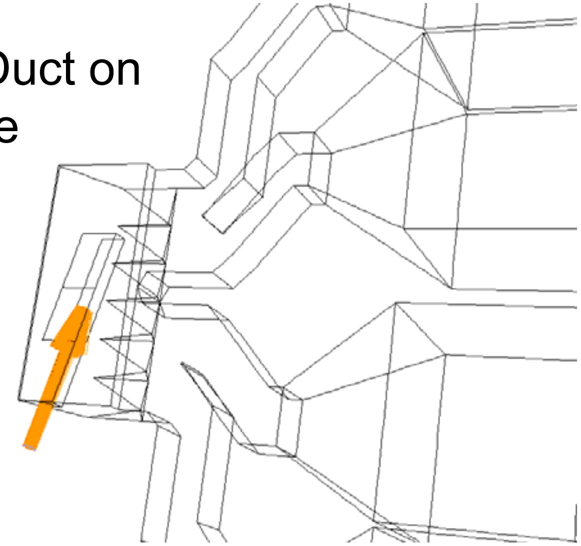
Duct on
Hot Side



Duct on
Cold Side

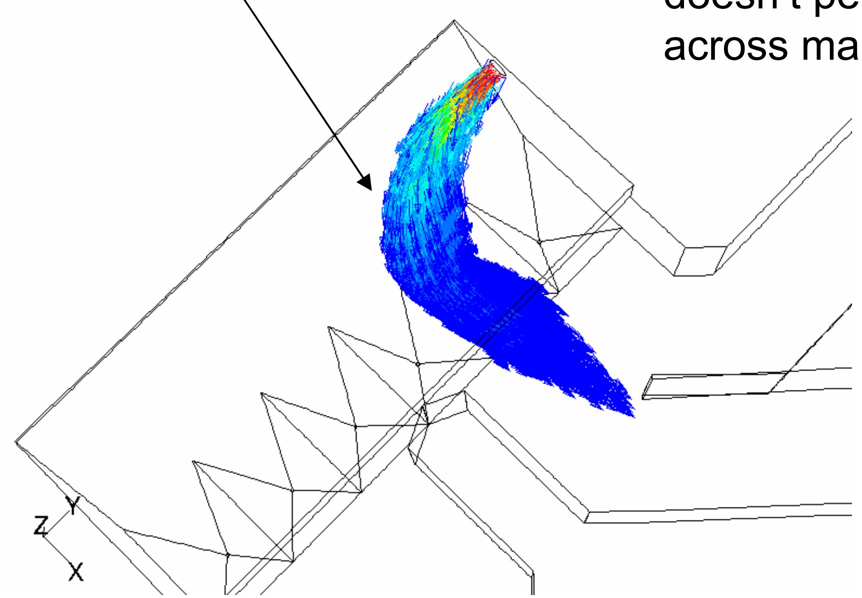


Venturi Duct on
Cold Side

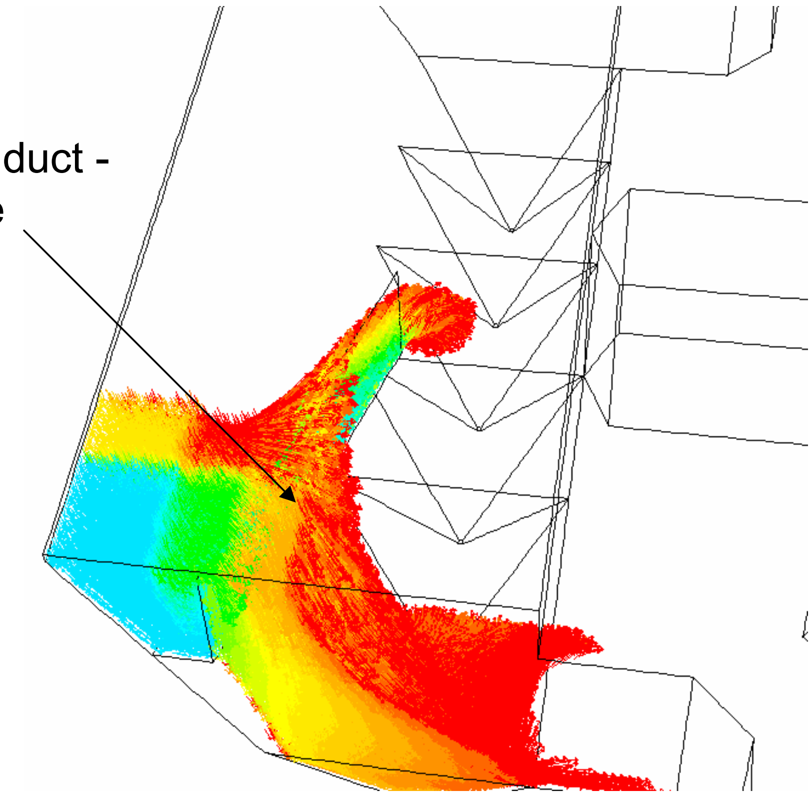


Analysis of Proposed Modifications

Insufficient momentum -
jet doesn’t penetrate
across manifold



Flow spills out of duct -
doesn’t penetrate
across manifold



Free Jet into
Hot Side

Duct on Cold (Hot)
Side

Analysis of Proposed Modifications

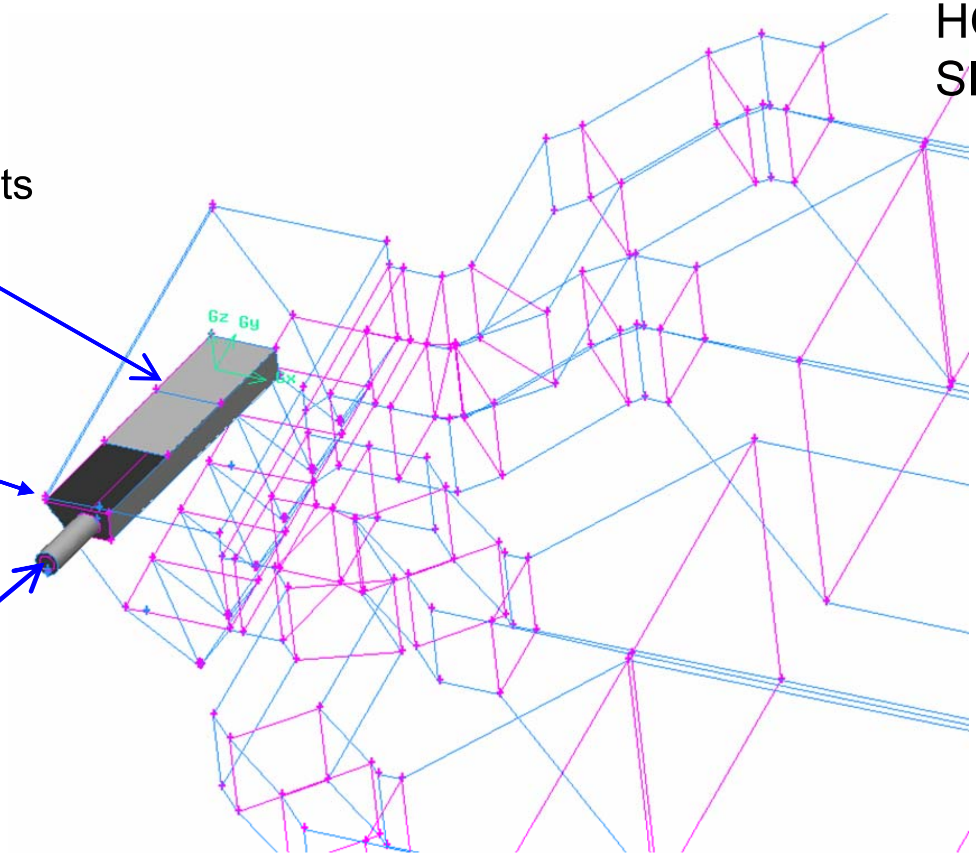
- Combine Proposed Modifications

“Venturi” Duct

Closed top prevents interaction

Open end entrains cold air – pushes to hot side

Cool Air Inlet

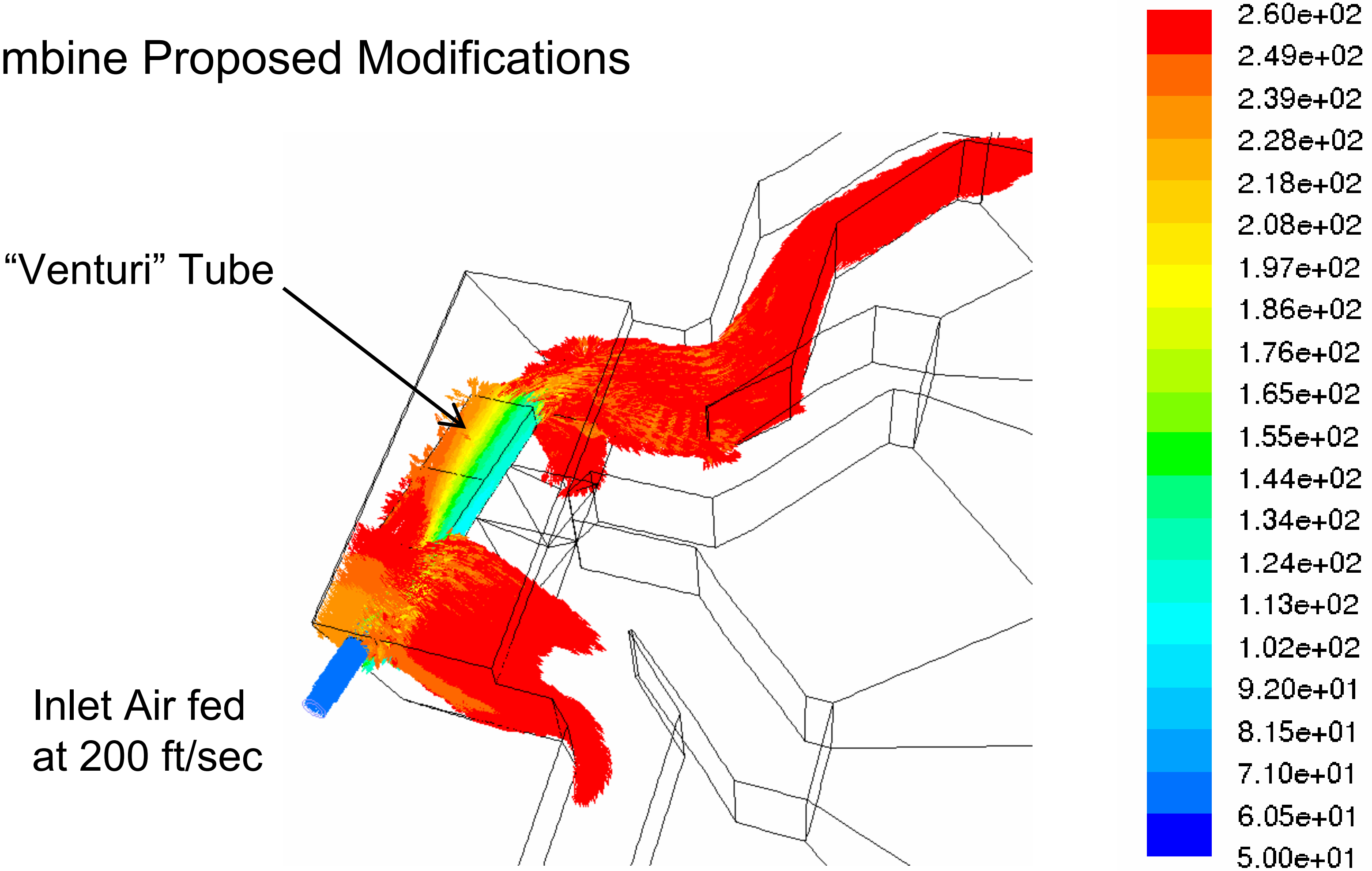


HOT SIDE

COLD SIDE

Analysis of Proposed Modifications

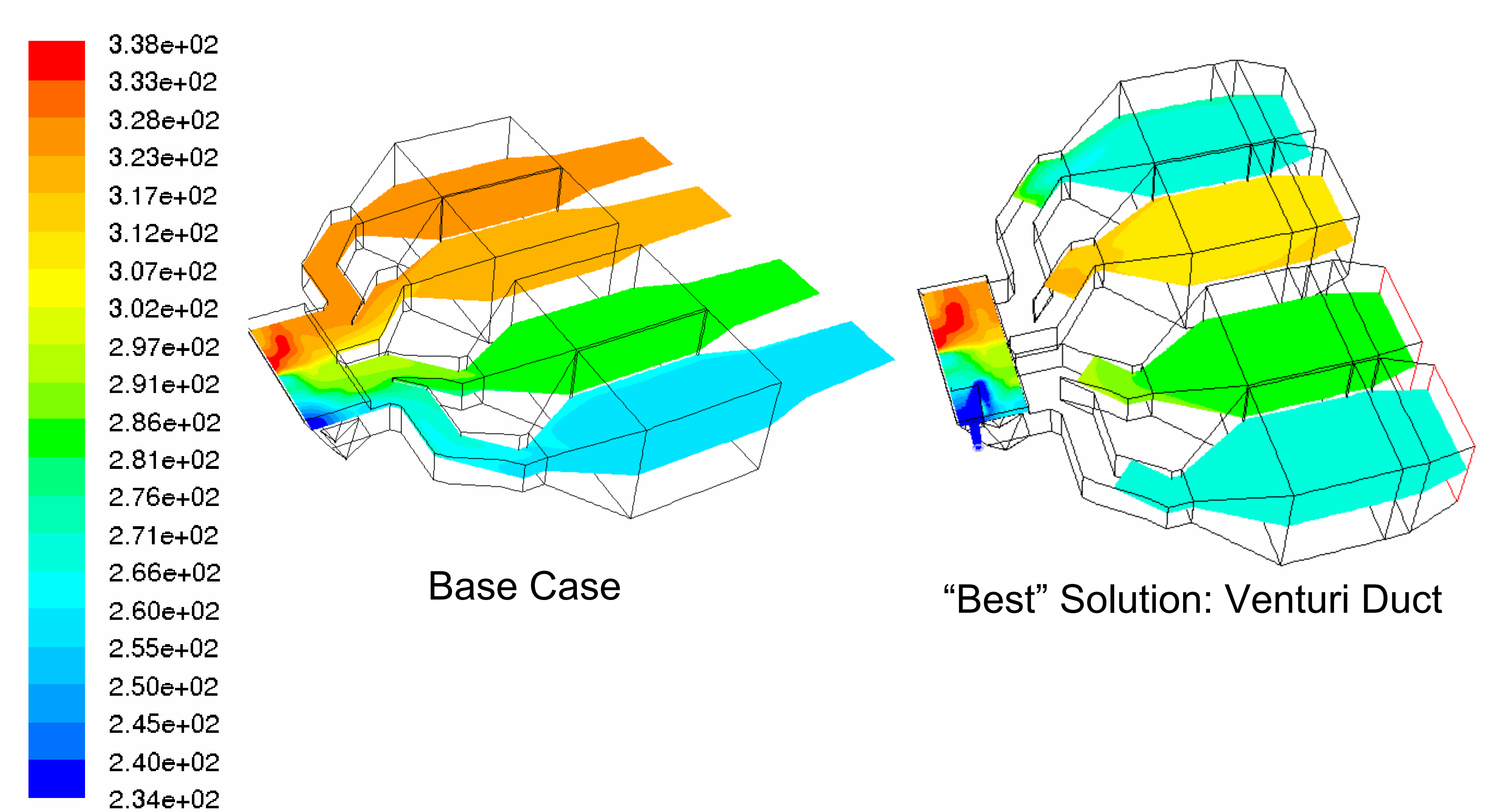
- Combine Proposed Modifications



Summary of Proposed Modifications

	North Temp (^{0}F)	South Temp (^{0}F)	Temp Range (^{0}F)
Data	321.3	259.7	61.6
Base – CFD	**323.0**	**272.0**	**51.0**
Free jet	309.7	272.6	37.1
Hot Duct	319.9	275.3	44.6
Cold Duct	319.9	274.4	45.5
Cold Duct - Venturi	**290.4**	**276.2**	**14.2**

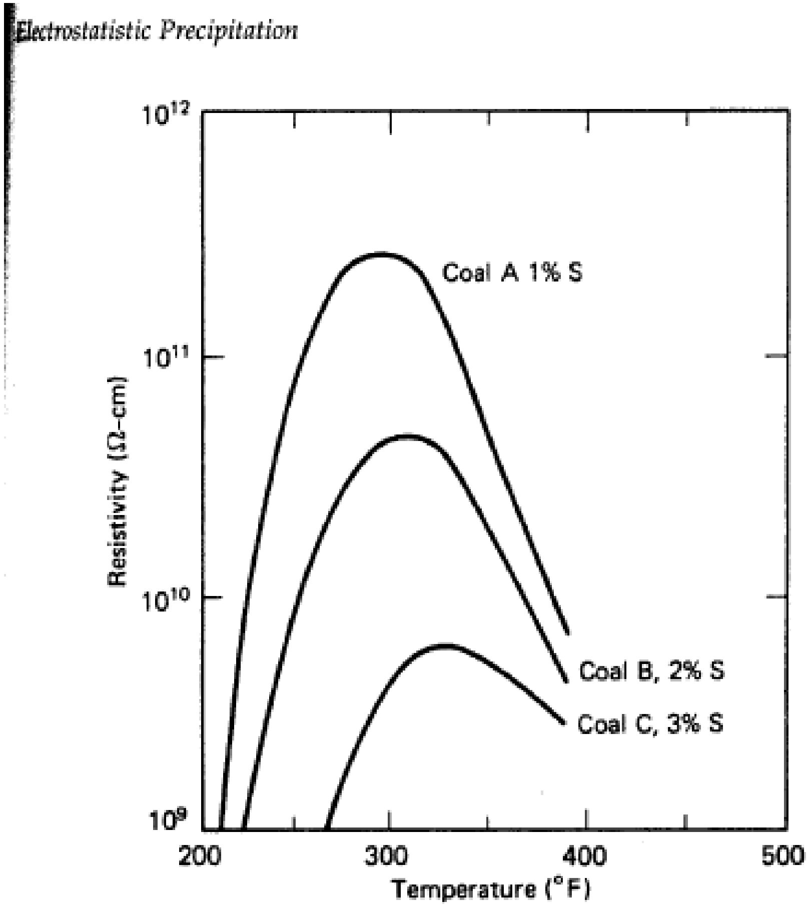
Predicted Temperature Profile (˚F) Comparison
(Plan view 5 ft below inlet elevation 699’- 9 ½”)



Base Case

“Best” Solution: Venturi Duct

Added Benefit?
Influence of Temperature on ESP Performance



NOTES:

1. Resistivity > 10^{11} makes ESP operation difficult
2. Resistivity < 10^{7} allows re-entrainment of particles
3. Current System can not tolerate additional mass flow to ESP/ID fans
4. Cold air added upstream of ESP may create "cement" inside ESP duct work

p. 177, Handbook of Environmental Engineering. (Vol 1) "Air Pollution Control Engineering". Wang, Pereira, Hung – Editors, Humana Press (2004).

Plant Solution:

- Plant to design/install FGR system (can't use outside air) to push cooler gas to hot side through Venturi duct.

- Update CFD model to include turning vanes at ESP's inlet.

- Evaluate louver downstream of ESP's to add "temperating" air (added mass will increase fan amps/power usage).

Application – HZOI for CWIS at Fitzpatrick Nuclear Power Plant

- Motivation: 316 (b) environmental regulations
- Approach: Apply CFD to Analyze HZOI
- Analysis Tool: Flow3D version 9.0
- Main Task: Predict HZOI for plant's environmental impact on how intake effects fish population in water body
- Customer: Fitzpatrick Nuclear Power Plant (reference available)

Approach:

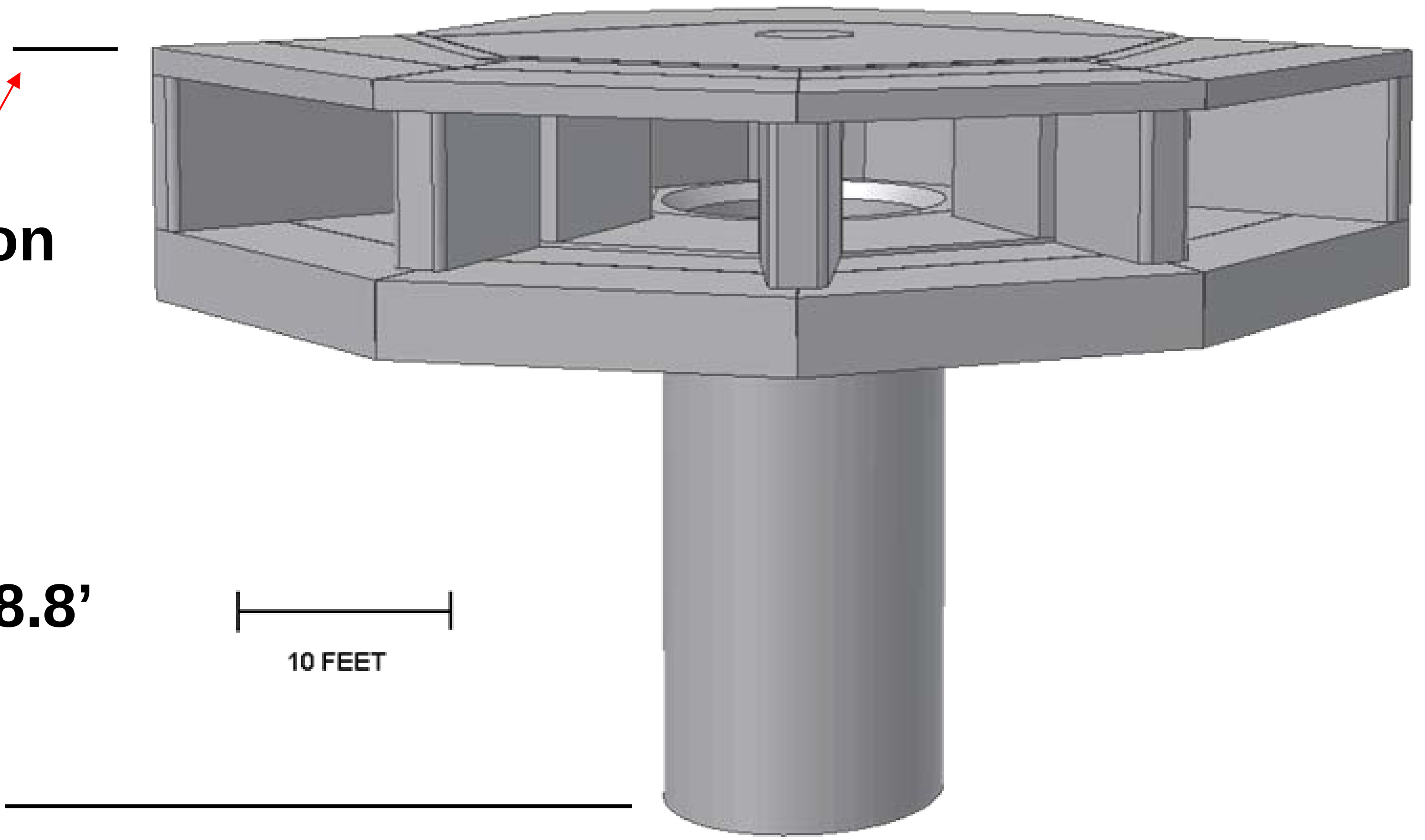
- CAD model developed for CWIS submerged in Lake Ontario with assumed 2° slope to lake bed
- CFD used to predict velocity currents around CWIS considering ambient lake currents (0.29 ft/s)
- HZOI defined as region with a 5% deviation in water currents from ambient lake currents
- HZOI shown at lake bottom, through CWIS centerline, and at lake surface

Existing Cooling Water Intake Structure Design

Intake structure view from shore looking North

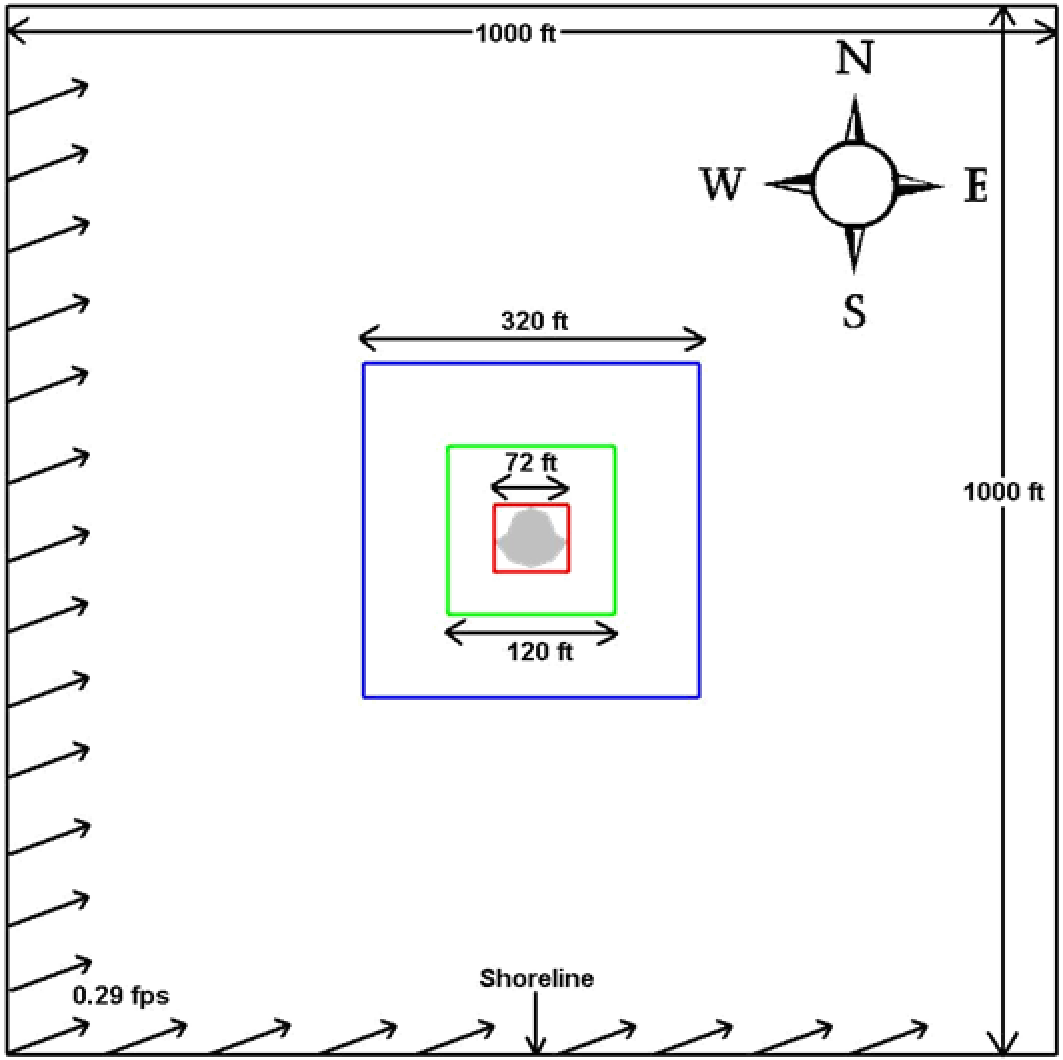
top elevation 232.8’

bottom elevation 218.8’



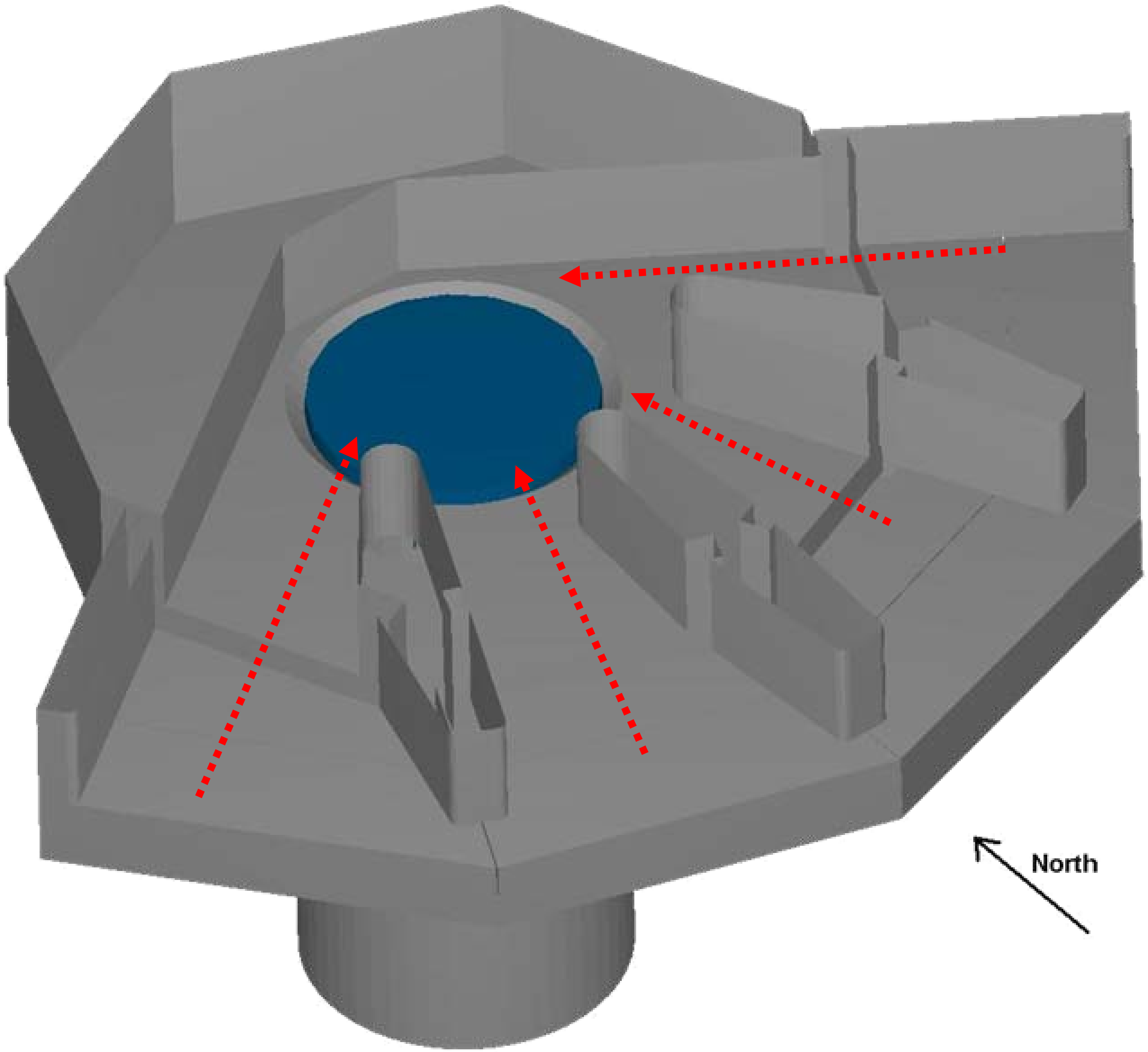
Model boundaries and initial conditions

- **Ambient Lake Ontario water currents used as initial condition**
- **Flow around and through CWIS modeled using finer meshes**

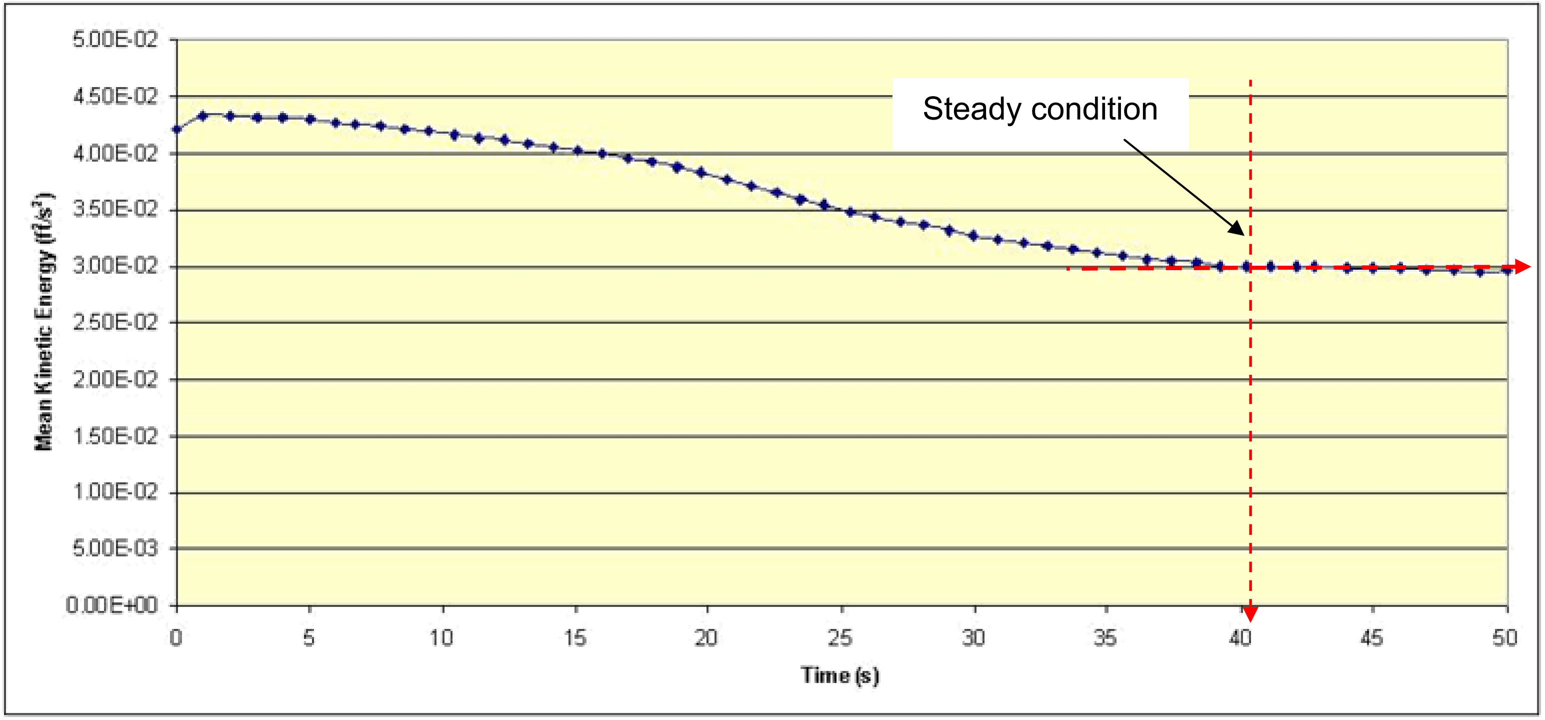


Cooling Water Intake Flow Rate withdrawn as mass sink

388,600 GPM outlet flow withdrawn through CWIS center as mass sink

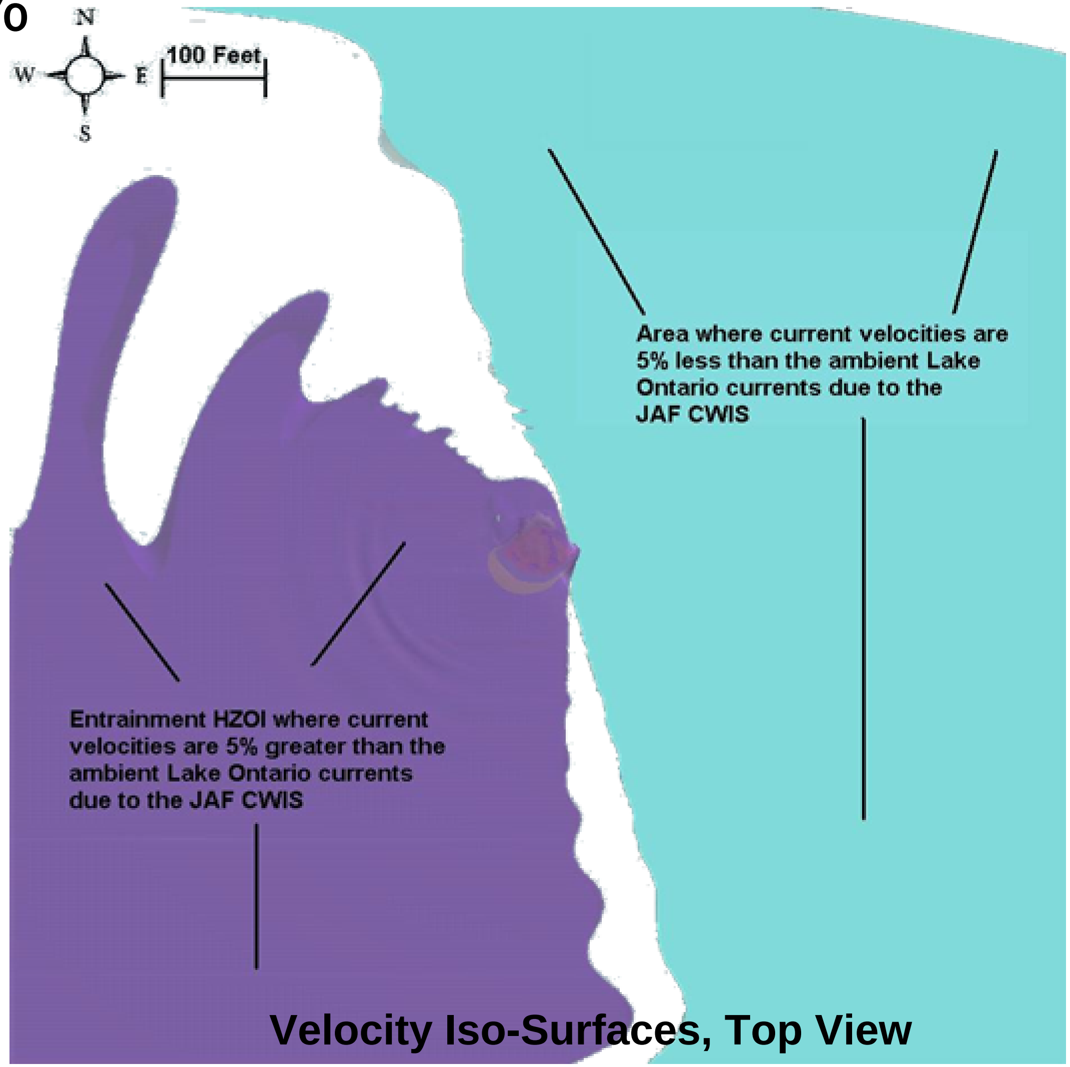


Flow-3D™ software used for transient simulation



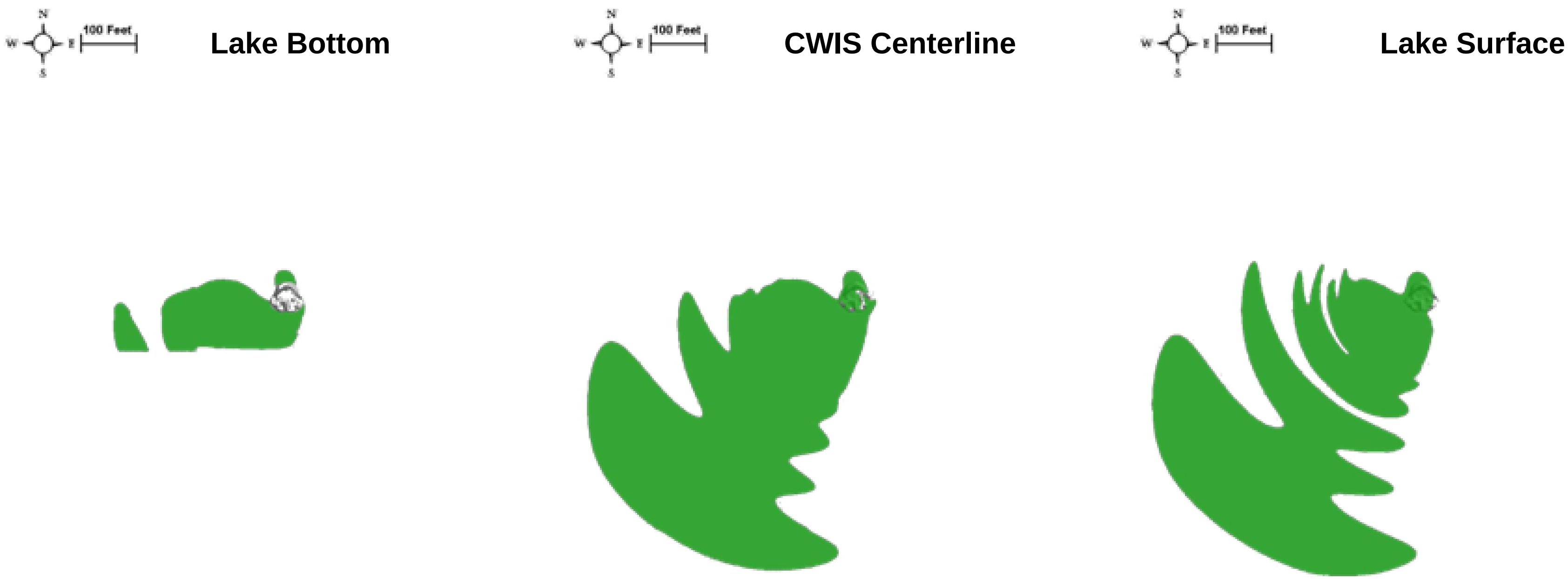
Mean-Kinetic-Energy change over time quantifies steady state conditions

Predicted HZOI – regions where predicted flow currents deviate from ambient flow currents by more than 5%



Velocity Iso-Surfaces, Top View

Predicted HZOI: Areas where predicted velocity magnitude > 5% ambient flow current



Summary

Entrainment HZOI (> 0.01 fps above ambient) size varies with lake elevation:

- *Lake bottom - 30,011 ft^2 (3.0% domain) has velocity magnitude > 5% ambient lake current (0.29 fps)*
- *CWIS centerline - 163.043 ft2 (16.3% domain) has velocity magnitude > 5% ambient lake current*
- *Lake surface - 162.716 ft2, (16.3% domain) has velocity magnitude > 5% ambient lake current*

High velocities concentrated directly in front of intake structure

- *1 fps > ambient current extends in front of intake structure ~1.5 ft*
- *0.5 fps > ambient current extends in front of intake structure ~5 ft (impingement HZOI)*
- *0.4 fps > ambient current extends in front of intake structure ~6 ft*

Summary cont.

Low velocity region:

- *concentrated on east and west sides of CWIS represent good sampling regions near CWIS intake*
- *on west side of CWIS attributed to water current being drawn toward CWIS which then stalls in "wedge" section of intake*
- *on east side of CWIS attributed to intake suction slowing ambient current downstream of CWIS leading to a "shadow" effect*
- *centered 10' from far eastern point of CWIS*

- *CFD clearly identified expected HZOI for general CWIS geometry with general bathymetry and topography data in a typical water body*

Conclusions

- *Alion provides Advanced Analysis to Fossil and Nuclear Electric Power Industries*
- *Application of comprehensive CFD based Engineering tools (Fluent and Flow3D) to complex industrial problems*
- *Developed "right" solution for AEP to balance Air Pre-heater temperature mal-distribution*
  - *plant designing system based on results)*
- *Identified CWIS HZOI for Fitzpatrick Nuclear Power Plant*
  - *Plant used this as part of their application to environmental regulatory agency*
- *Alion is committed to helping clients meet difficult challenges generating electric power in clean, safe, and environmentally friendly way*