Electrostatic Precipitator Performance Improvement Through Computational Fluid Dynamic Modeling

PowerGen International
December 11, 2002

Authors:
Brian J. Dumont
Robert G. Mudry, P.E.

Airflow Sciences Corporation

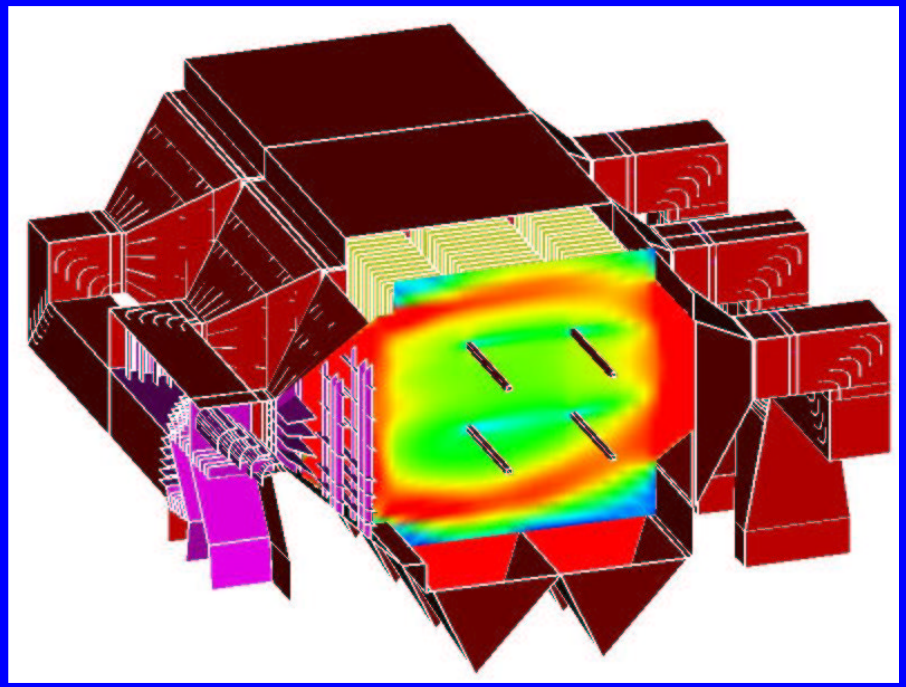
Airflow Sciences Corporation

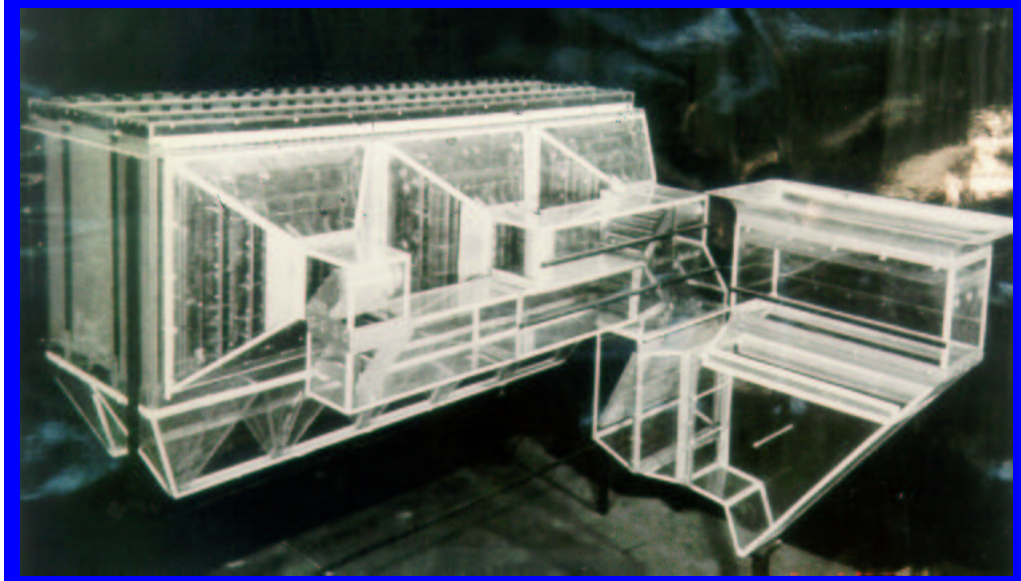
Introduction

- Flow modeling is an established practice to optimize gas flow patterns within industrial equipment
- Little published data exists on the accuracy of flow models, particularly for electrostatic precipitators (ESPs)
- Available data was analyzed in detail to compare model results to actual plant test data

Fluid Flow Modeling

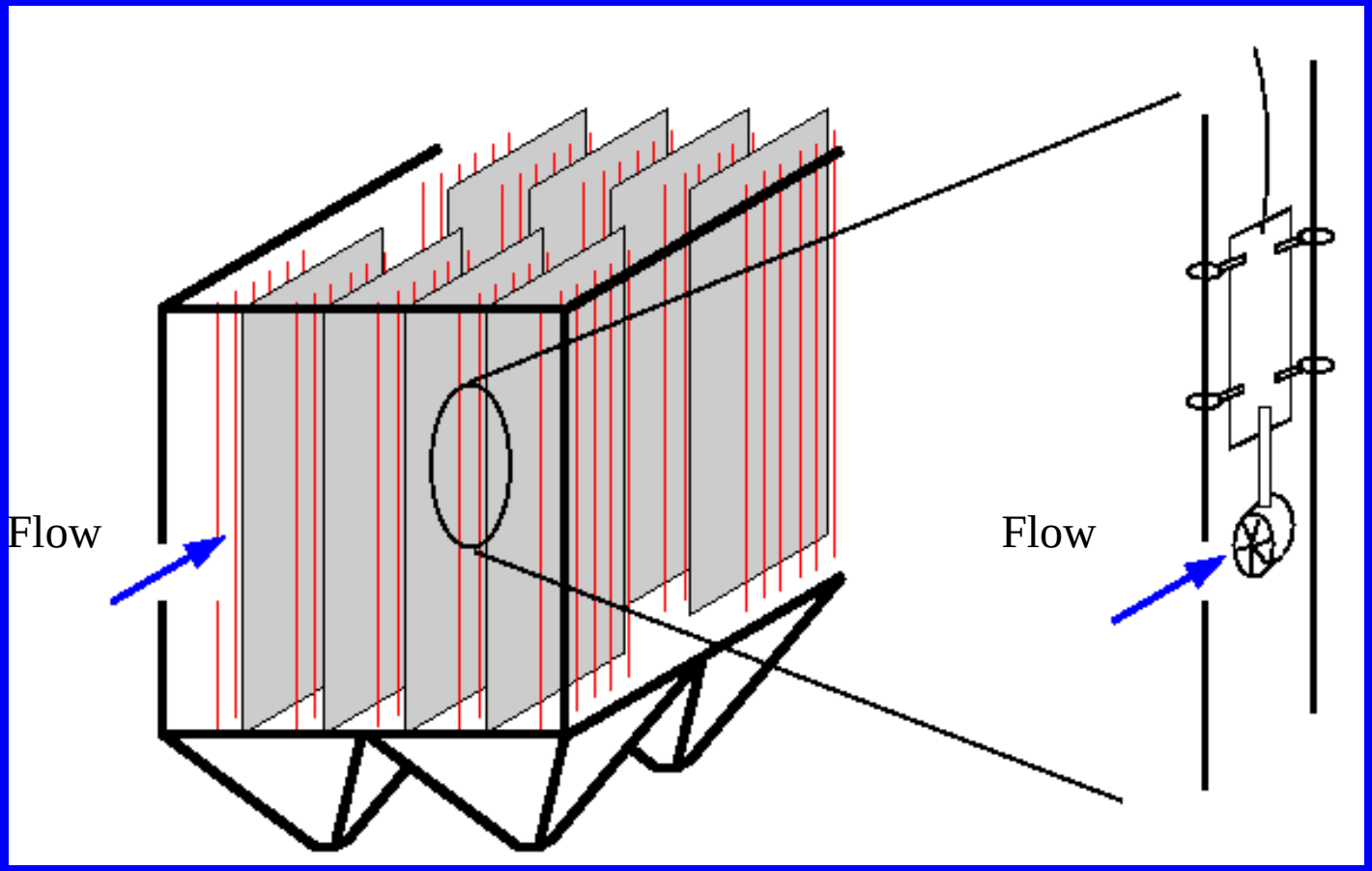
- Computational Fluid Dynamics (CFD)
- Physical scale modeling





Testing Methods

- ESP cold-flow velocity distribution measurement



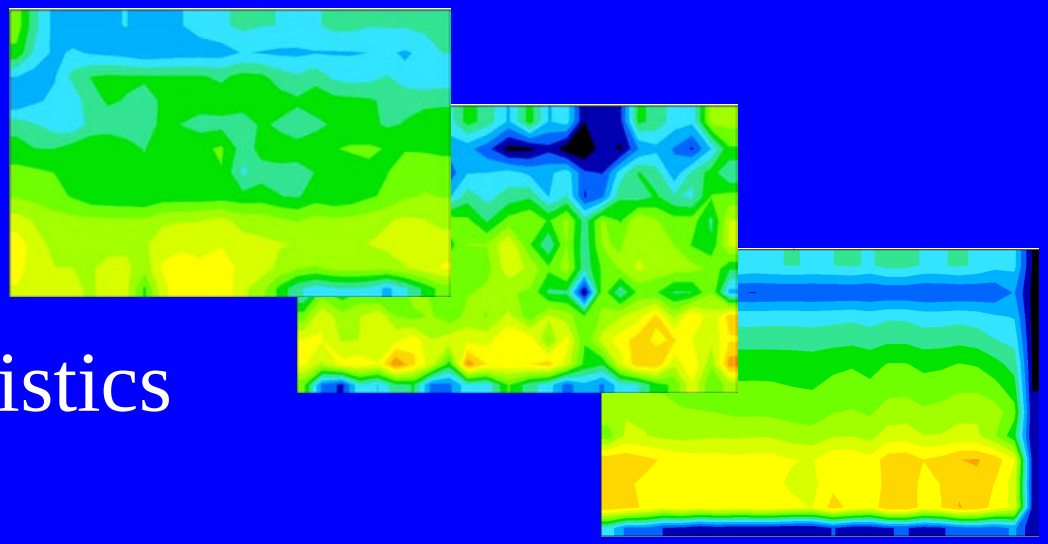
Objectives of Analysis

- Assess all available data for ESP testing and modeling acquired over the past 7 years
  - ESP field test data
  - CFD model results
  - Physical model results
- Perform statistical comparisons of the data
- Obtain <u>quantitative</u> information relating model correlation to test data

Cases Analyzed

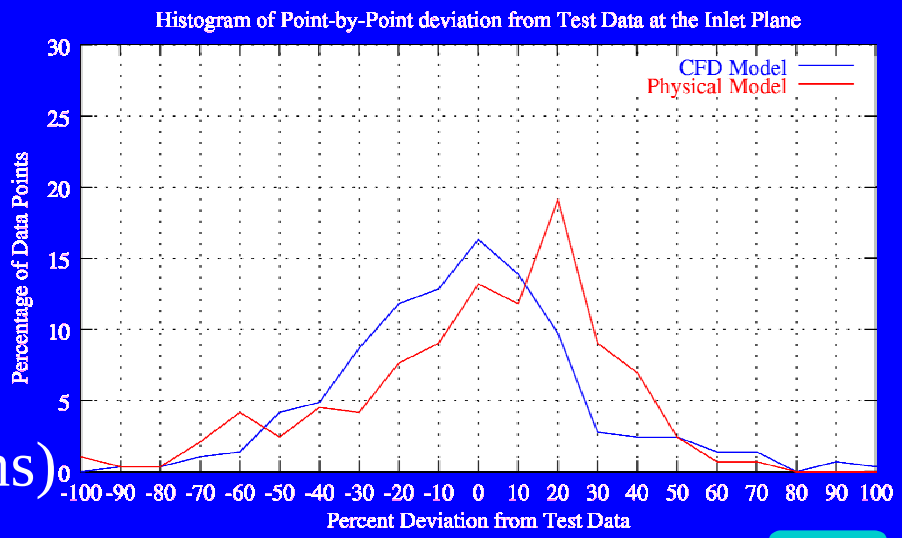
- Ten cases where field data and CFD data exist for the same configuration
- Five cases where corresponding physical model data also exist
- All cases from coal-fired electric power stations
  - U.S. and Canadian plants
  - Unit size ranges from 326 MW to 952 MW
- One case study is presented in detail, 326MW Unit in the Western U.S.
- All cases are summarized

Data Comparisons



- Contour plots
- Flow distribution statistics
  - % RMS
  - ICAC Standards
- Point-by-point deviations
- Overall Correlation Factor

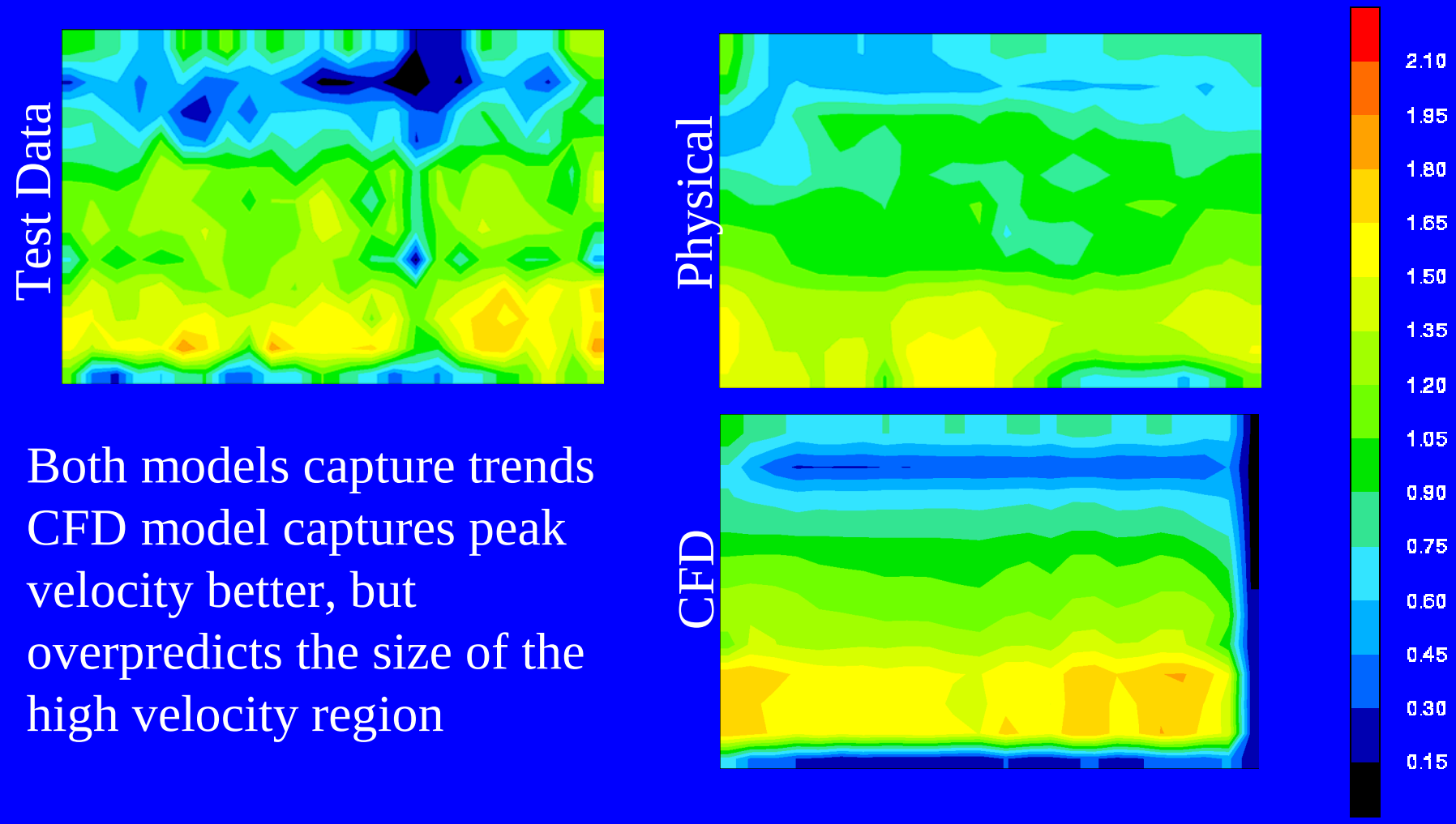
  (%RMS of point-by-point deviations)



Airflow Sciences Corporation

Case Study 2 - Inlet Plane

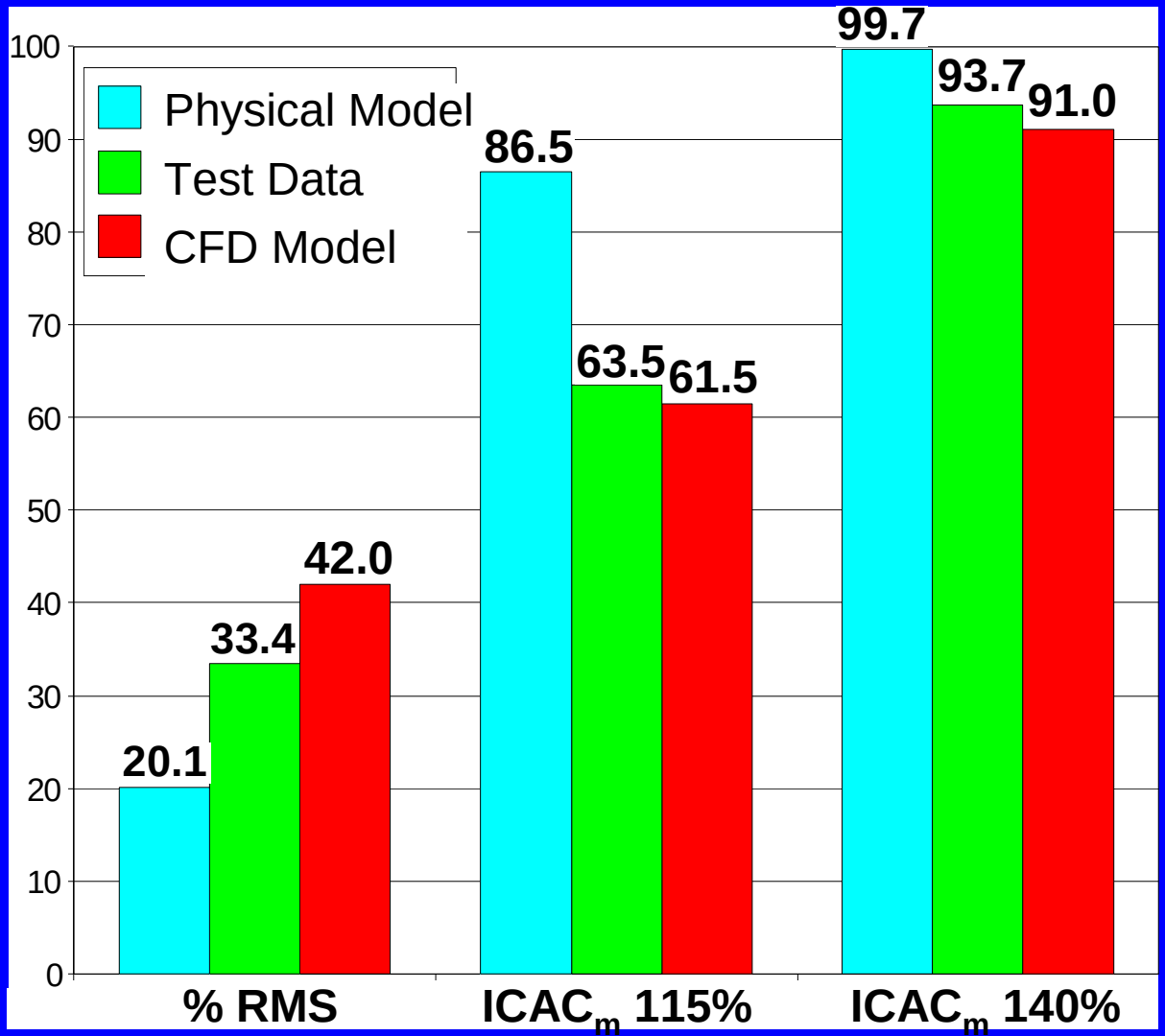
Normalized Streamwise Velocity Component



- Both models capture trends
- CFD model captures peak velocity better, but overpredicts the size of the high velocity region

Case Study 2 - Inlet Plane

Flow Statistics - Deviations from Goal Velocities



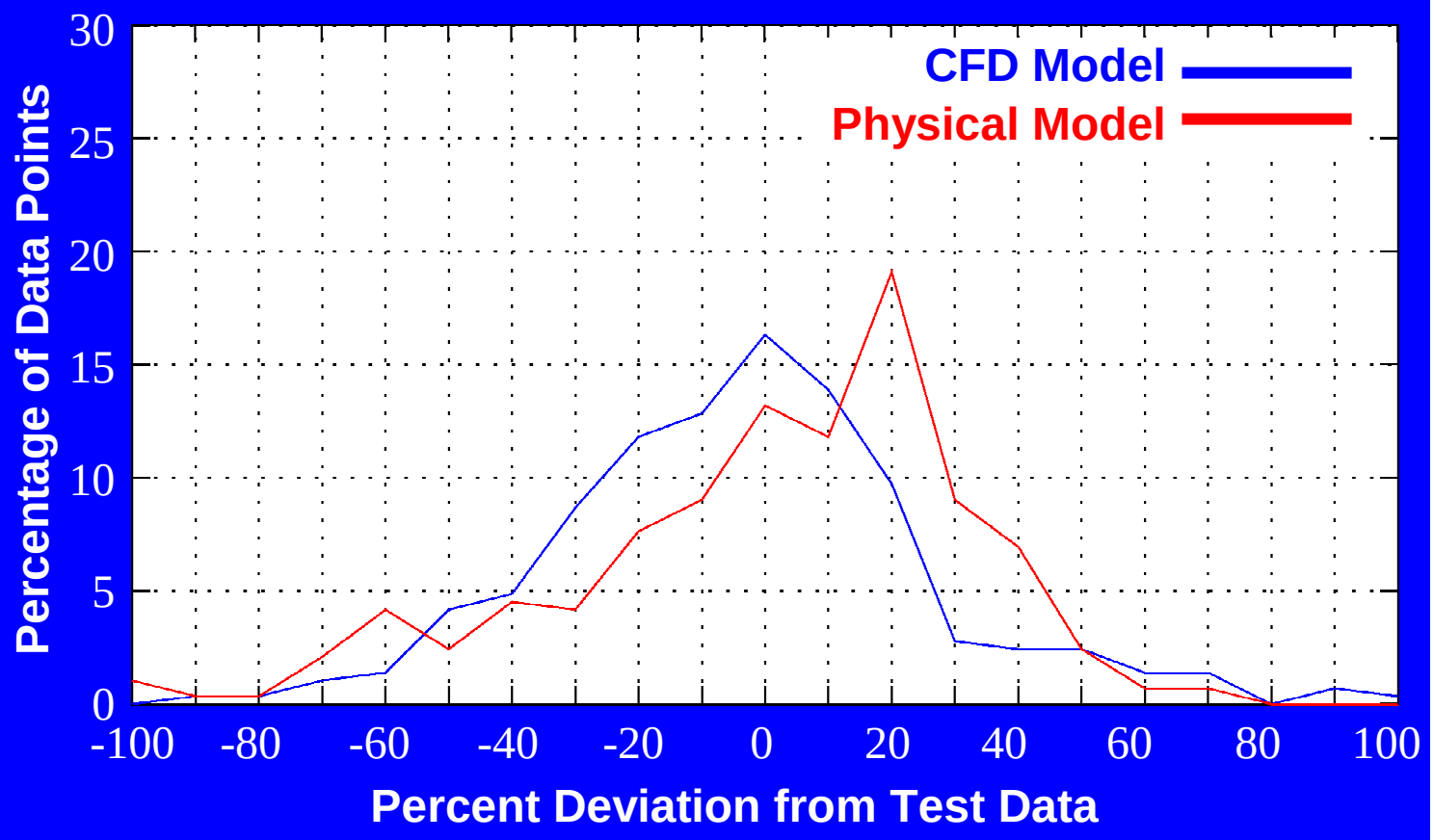
- Physical model overpredicts flow compliance to goal as shown by all 3 analyses
- CFD model underpredicts flow compliance to goal as shown by all 3 analyses

Airflow Sciences Corporation

Case Study 2 - Inlet Plane

Histograms – Point-By-Point Deviations from Test Data

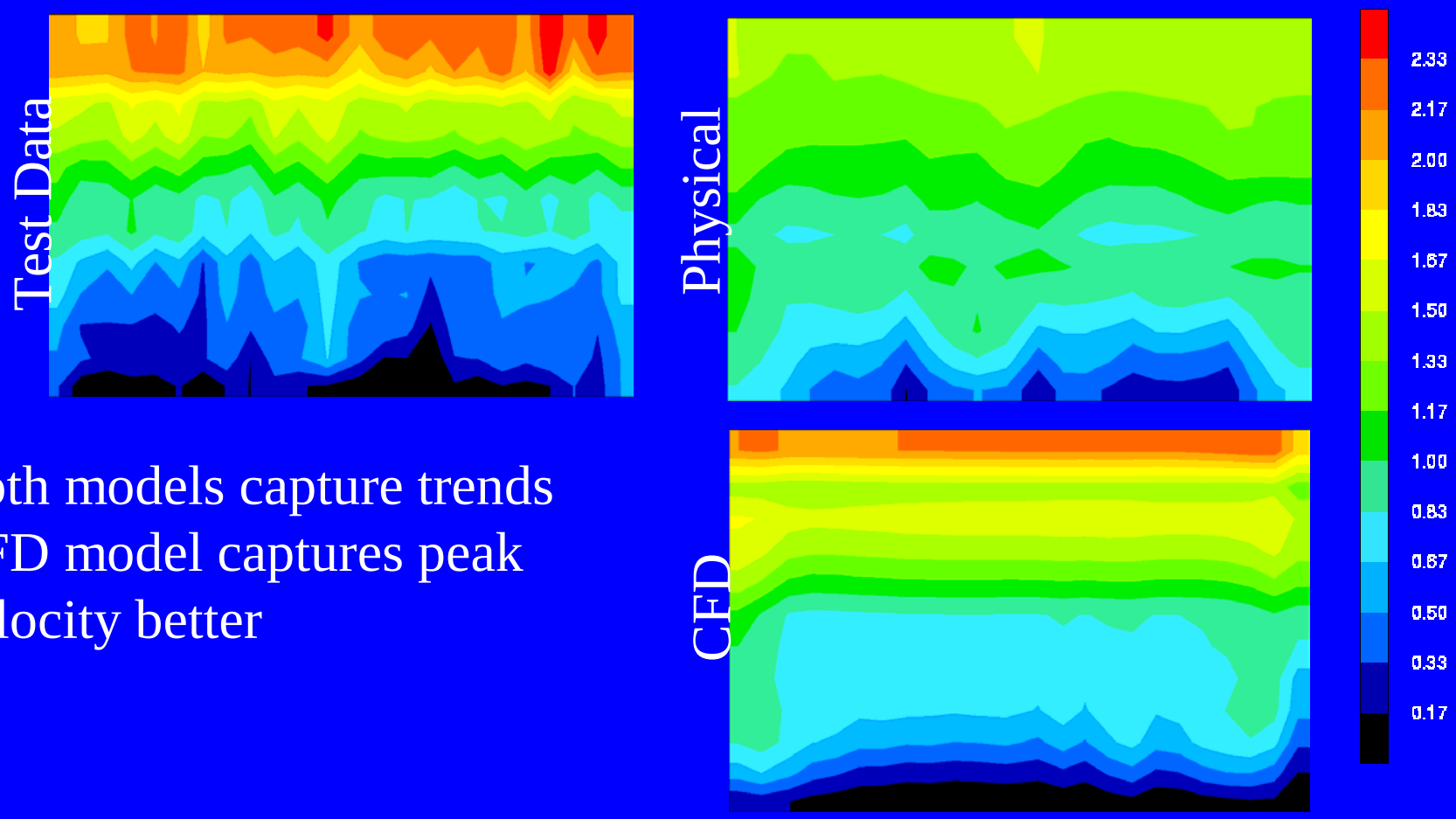
- Correlation Factors:
  CFD: 37.0
  Physical: 32.4
- 65% of CFD points within +/-25% band
- 61% of physical model points within same band



Airflow Sciences Corporation

Case Study 2 - Outlet Plane

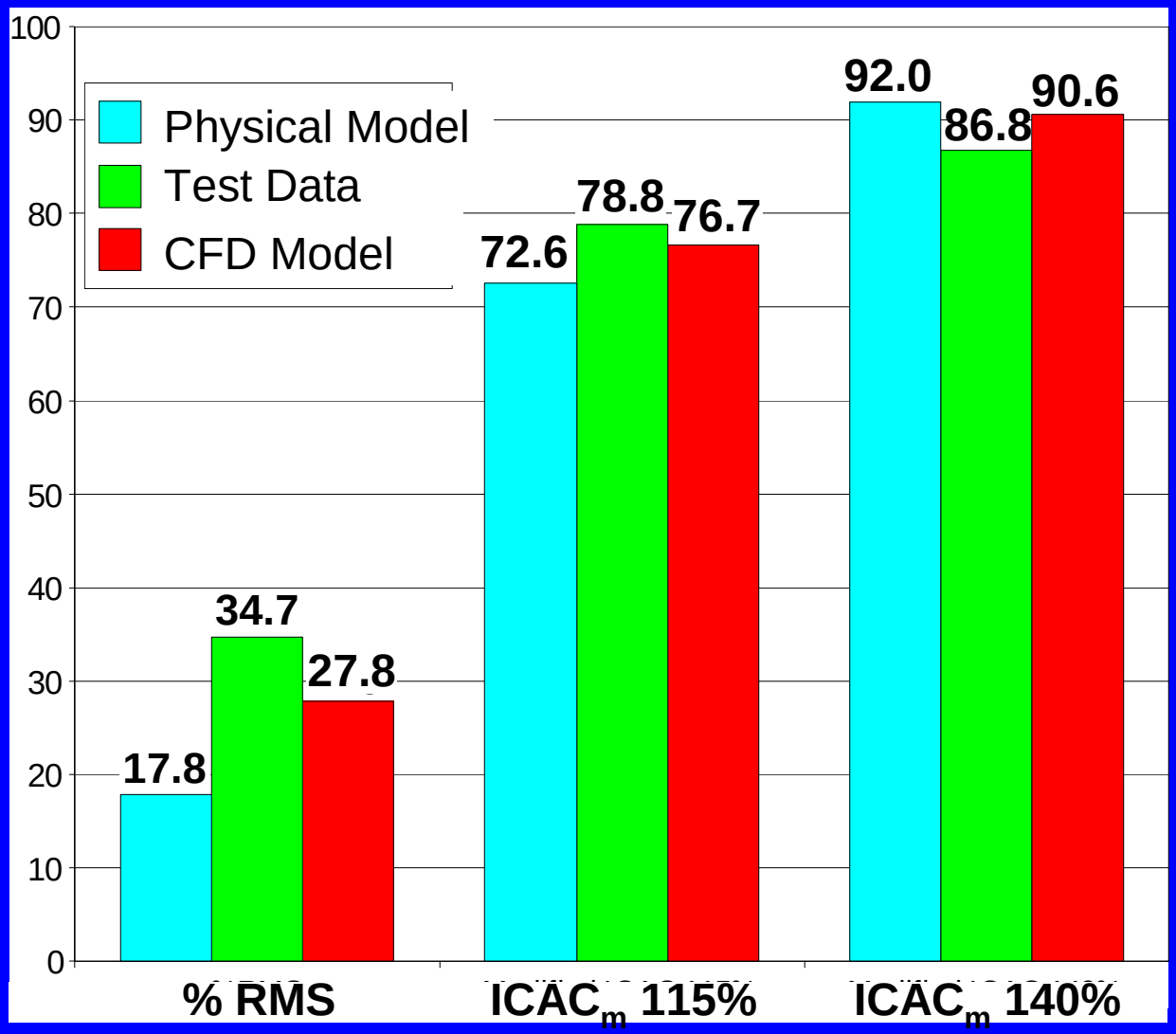
Normalized Streamwise Velocity Component



- Both models capture trends
- CFD model captures peak velocity better

Case Study 2 - Outlet Plane

Flow Statistics - Deviations from Goal Velocities

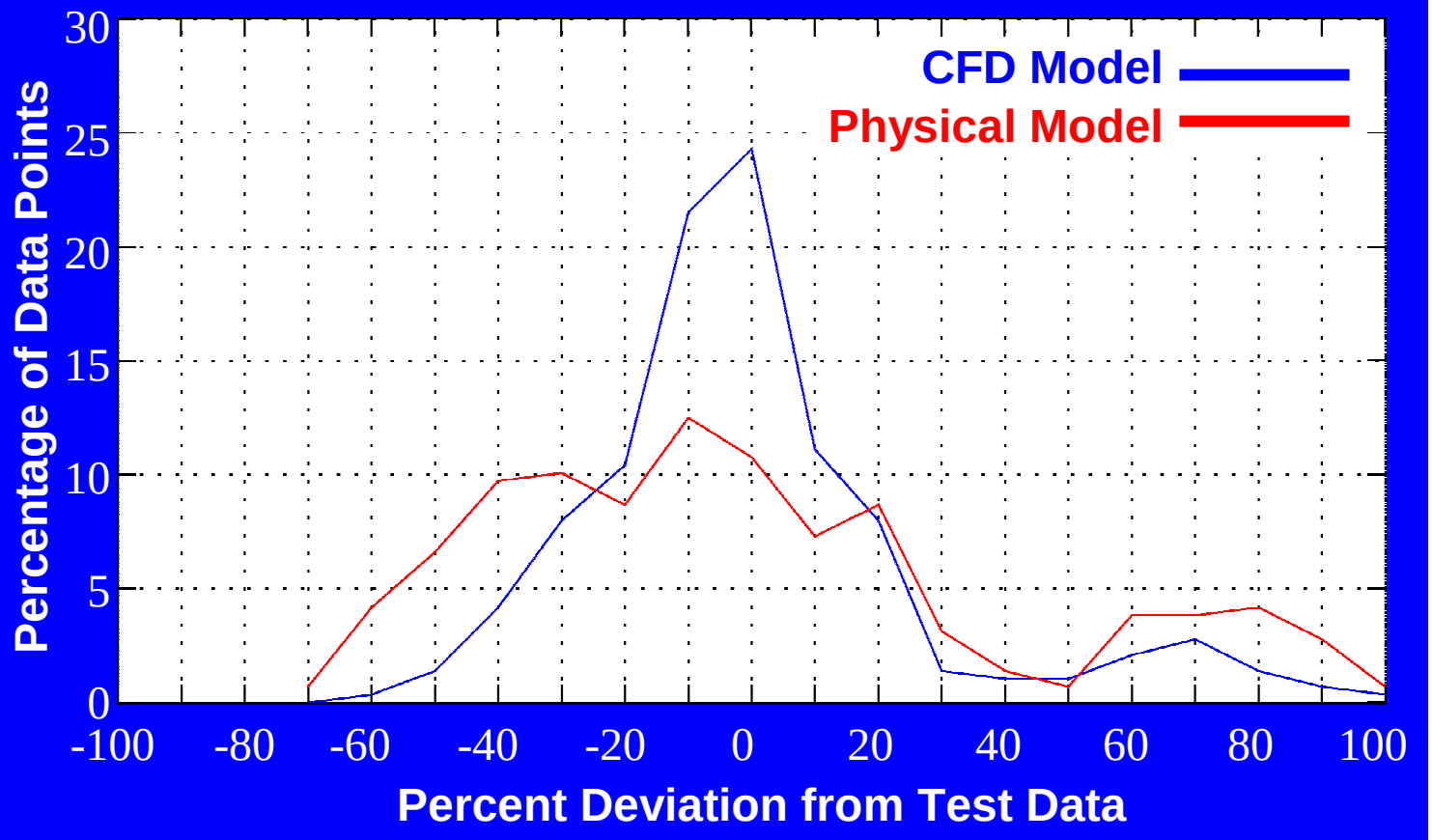


- Both models underpredict %RMS, especially the physical model
- Both models predict modified ICAC conditions fairly well

Case Study 2 - Outlet Plane

Histograms - Point-By-Point Deviations from Test Data

- Correlation Factors:
  CFD: 27.2
  Physical: 40.8
- 75% of CFD points within +/-25% band
- 48% of physical model points within same band



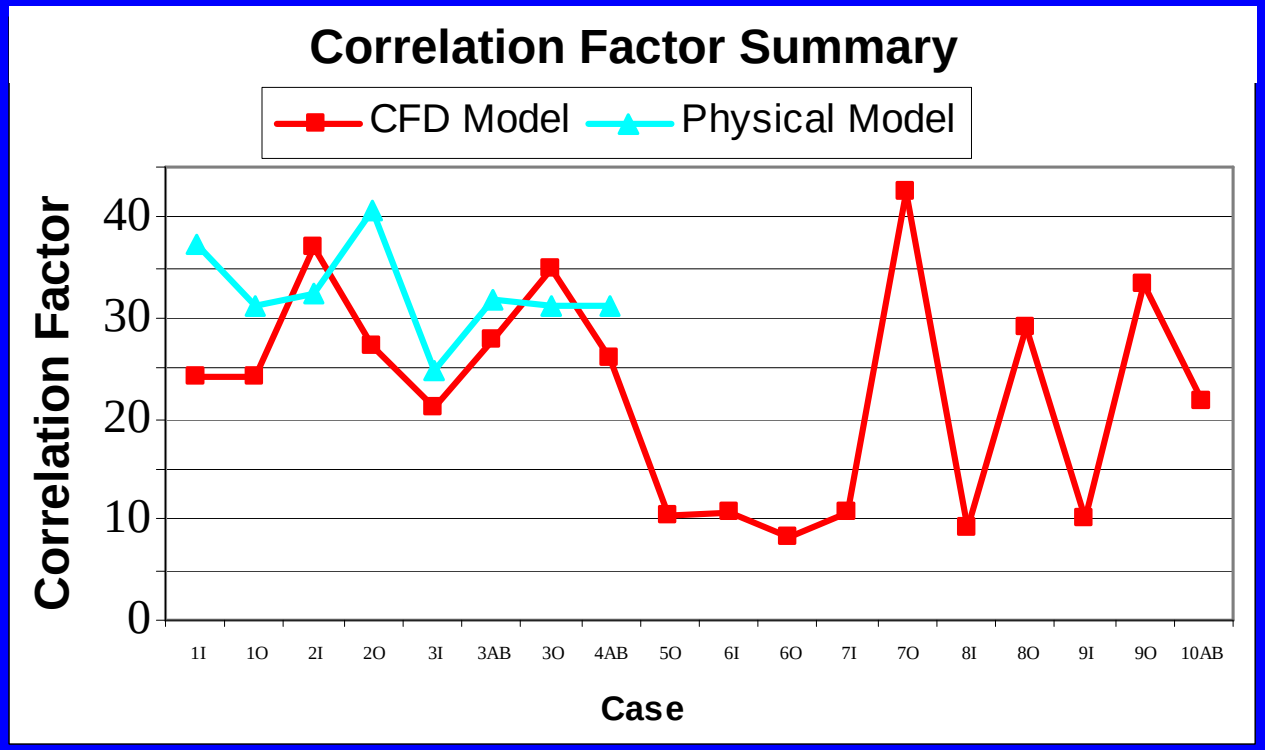
Airflow Sciences Corporation

Case Study 2 - Summary

- ESP Inlet
  - Both models correlate fairly well
  - Physical model has a lower correlation coefficient
  - CFD model matches flow statistics better and has a larger number of points within +/-25% deviation band on histogram
- ESP Outlet
  - CFD model agrees better with test data under all comparisons
  - Both models capture correct trends

All Case Studies - Correlation Factor

- In some cases, the CFD model has a better correlation factor
- In others, the physical model is better
- There is no clear trend as to why this occurs
- The CFD model correlates better on average



Airflow Sciences Corporation

All Case Studies - Overall Summary

- On average, the Correlation Factor for CFD models is 23.5 (27.8 using only studies where the physical model also existed)
- On average, the Correlation Factor for physical models is 32.6

Analysis Conclusions

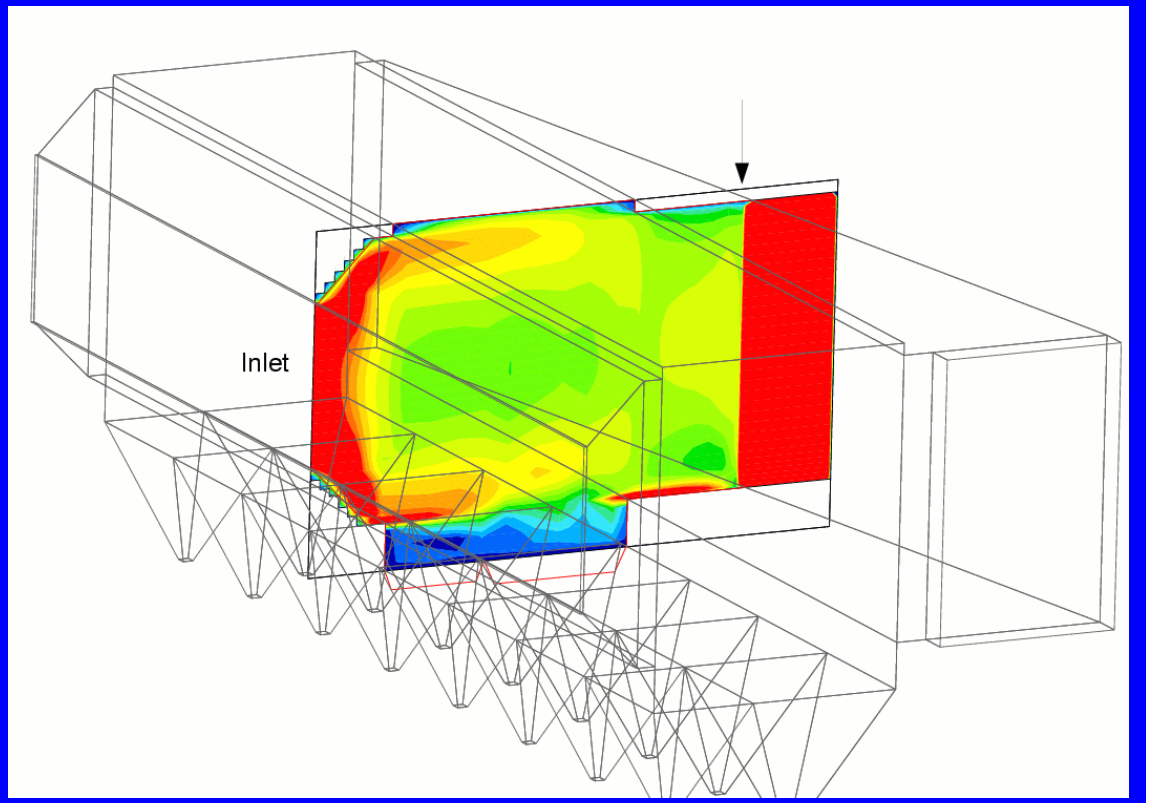
- On the whole, correlation is not as strong as desired
- Experience indicates that this level of correlation is enough to make CFD modeling a useful engineering tool for ESPs
- Additional research and development in CFD technology will allow for increased accuracy

Case Study

- Two identical 790 MW units
- Western U.S.
- Cold side chevron ESPs
- SCA=125
- Avg. vel 7.2 ft/s
- Both units regularly derated by 240 MW to operate within opacity limits

Baseline CFD Model Results

- Velocity pattern at ESP inlet shows non-uniform
  - High velocity on top and bottom, low velocity in center
  - RMS deviation = 26 %



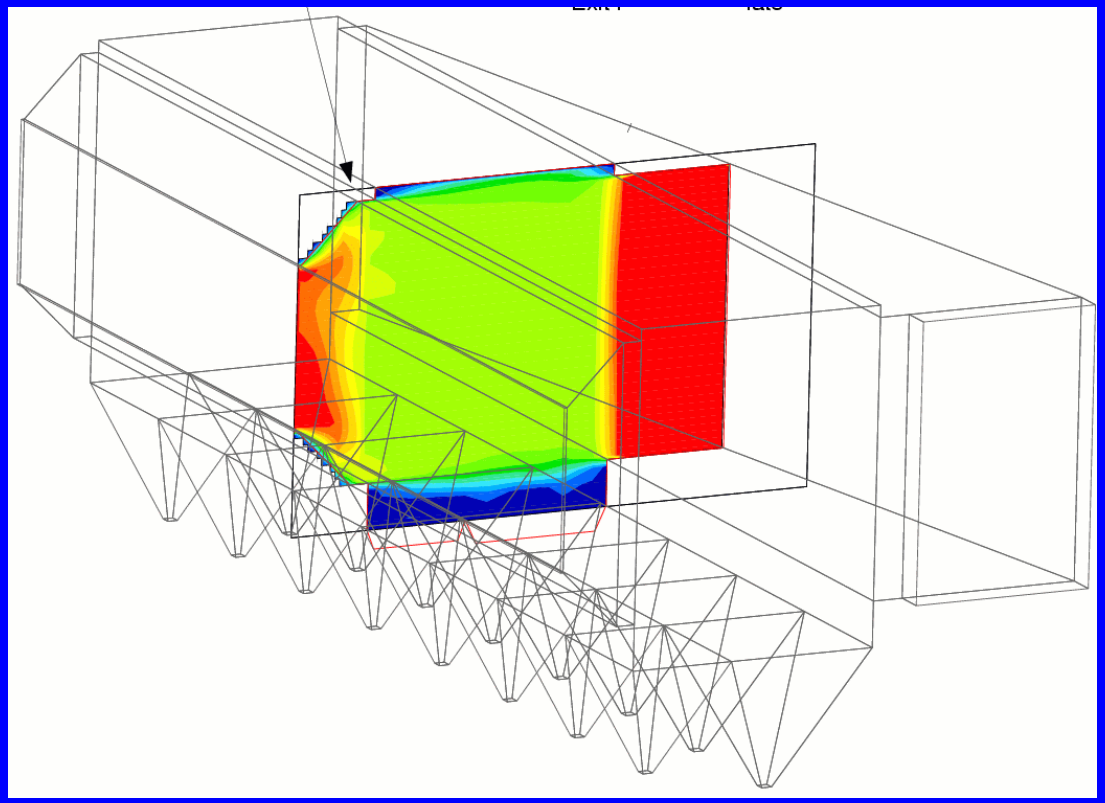
- Outlet plane poor distribution as well
  - RMS deviation = 20 %

Design Optimization

- Design modifications developed using CFD model
  - New inlet and outlet perforated plates
  - Slight alteration to inlet duct turning vanes

Final Design CFD Model Results

- ESP inlet velocity profile now uniform
  - RMS deviation = 7 %
- Outlet plane also improved
  - RMS deviation = 7 %
- Change to system pressure drop = +0.3 ”H_2O



Resulting ESP Performance

- ESP efficiency testing performed
  - 23% reduction in particulate emissions compared to original ESP geometry
- At same opacity, plant output increases by 150 MW per unit
- Payback for model study and installation costs = 1 year

Questions