ELECTRIC POWER 2003

Computational Fluid Dynamic Modeling of Electrostatic Precipitators

05 March 2003

Authors:

Brian J. Dumont, P.E.

Robert G. Mudry, P.E.

Airflow Sciences Corporation

734-464-8900

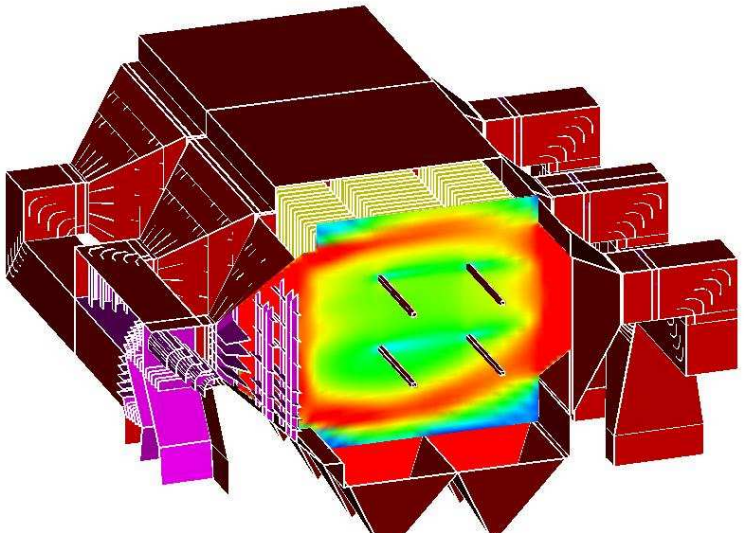
ELECTRIC POWER 2003

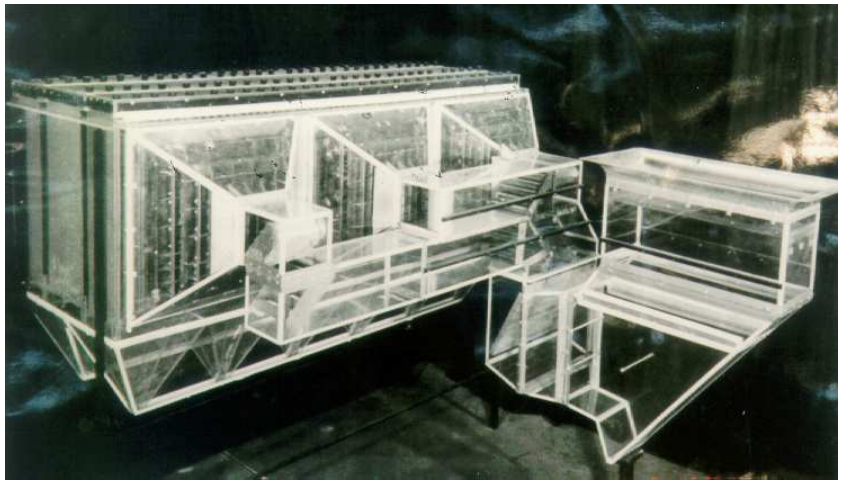
Objectives of Analysis

- Assess all available data for ESP testing and modeling acquired over the past 5 years
  - ESP field test data
  - CFD model results
  - Physical model results
- Perform statistical comparisons of the data
- Obtain quantitative information relating model correlation to test data

Fluid Flow Modeling

- Computational Fluid Dynamics (CFD)
- Physical scale modeling

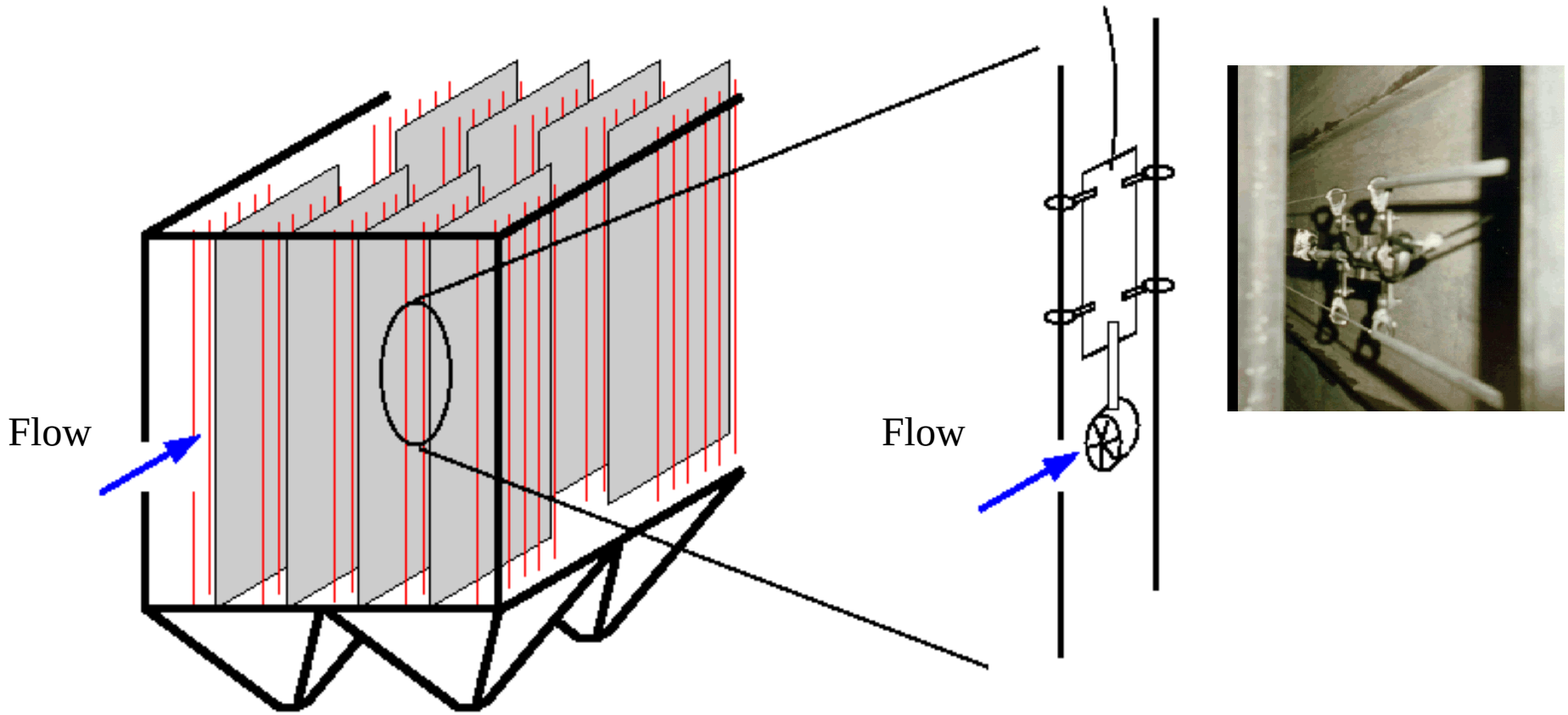




- How accurate are modeling methods?

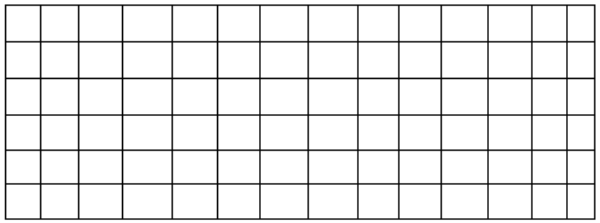
Testing Methods

- ESP cold-flow velocity distribution measurement

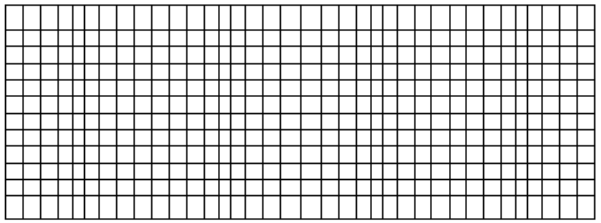


Data Comparisons

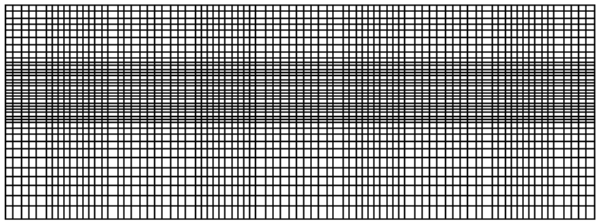
- Assess the quantity and spatial locations of available velocity data



Test Data
14x6 = 84 points



Physical Scale Model
36x12 = 432 points



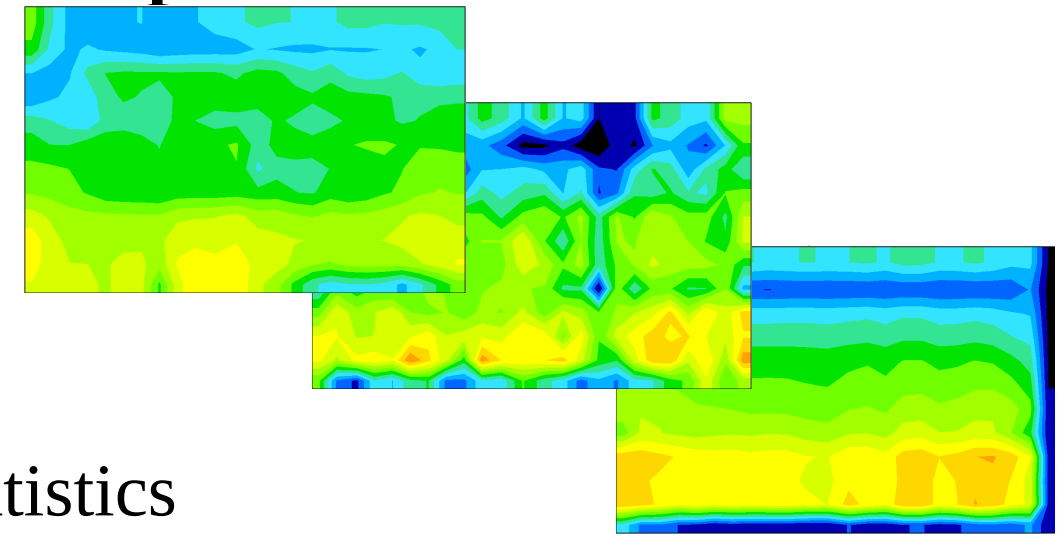
CFD Model
83x38 = 3154 points

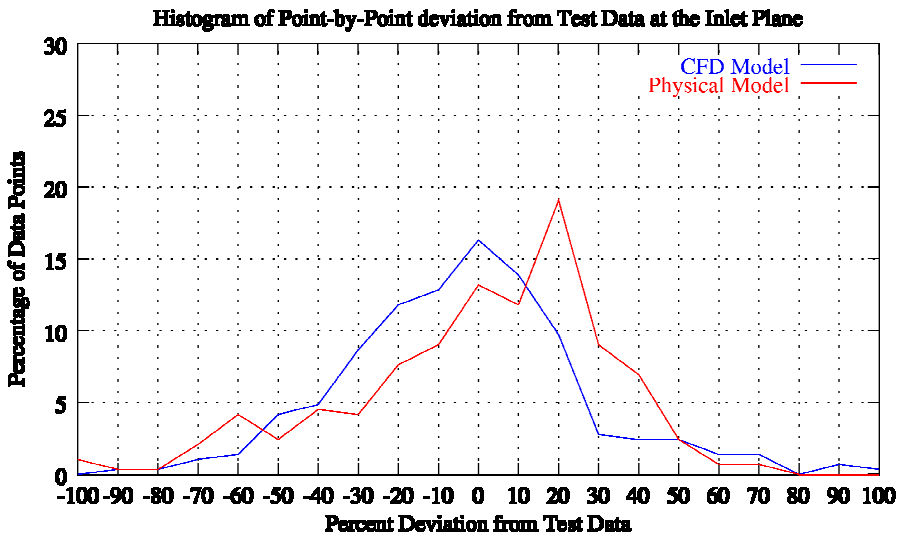
- Velocities interpolated onto the test data traverse grid

ELECTRIC POWER 2003

Data Comparisons

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



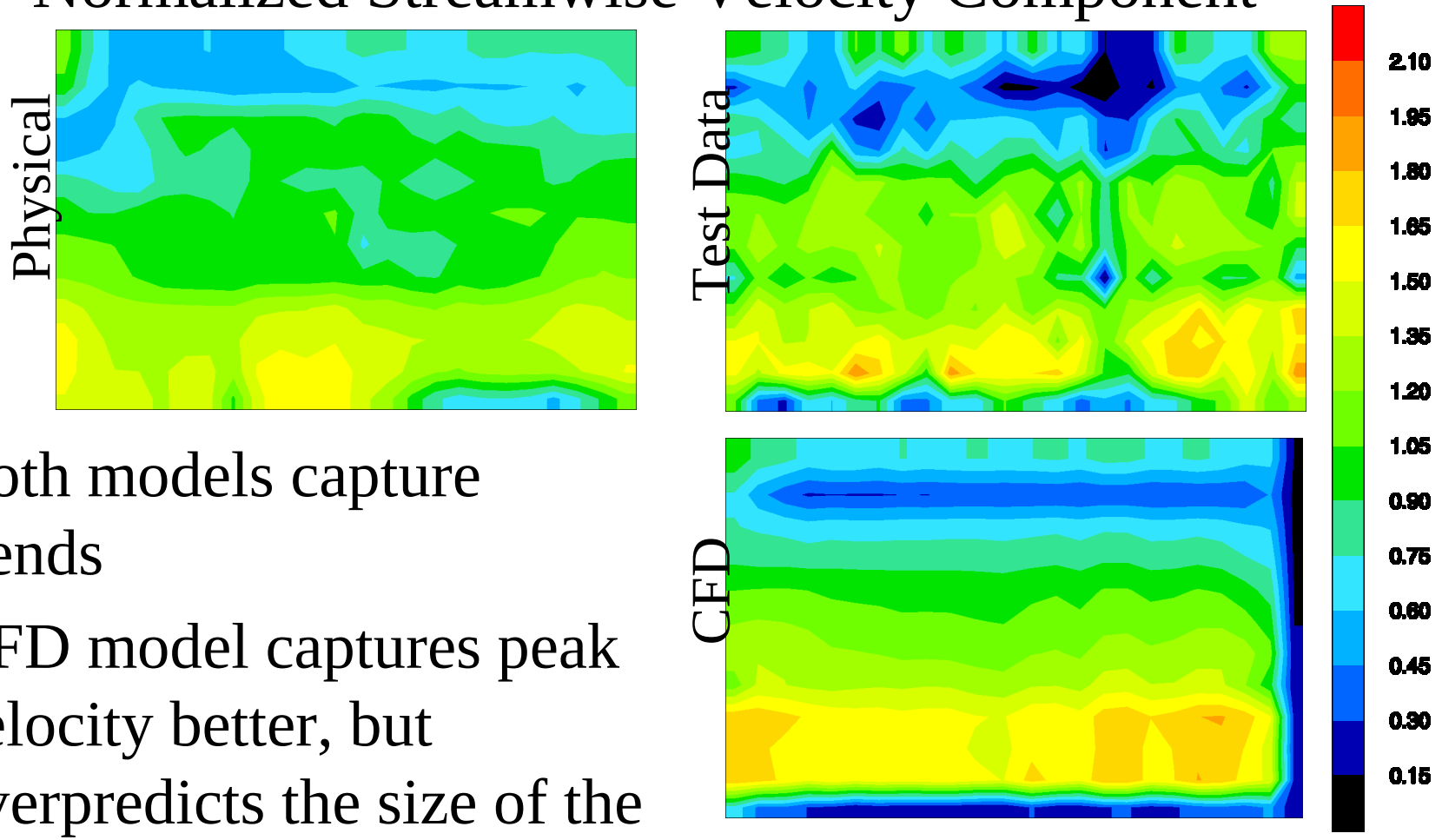


Case Studies

- 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. (three in the paper)
- All cases are summarized

Case Study 2 - Inlet Plane

Normalized Streamwise Velocity Component

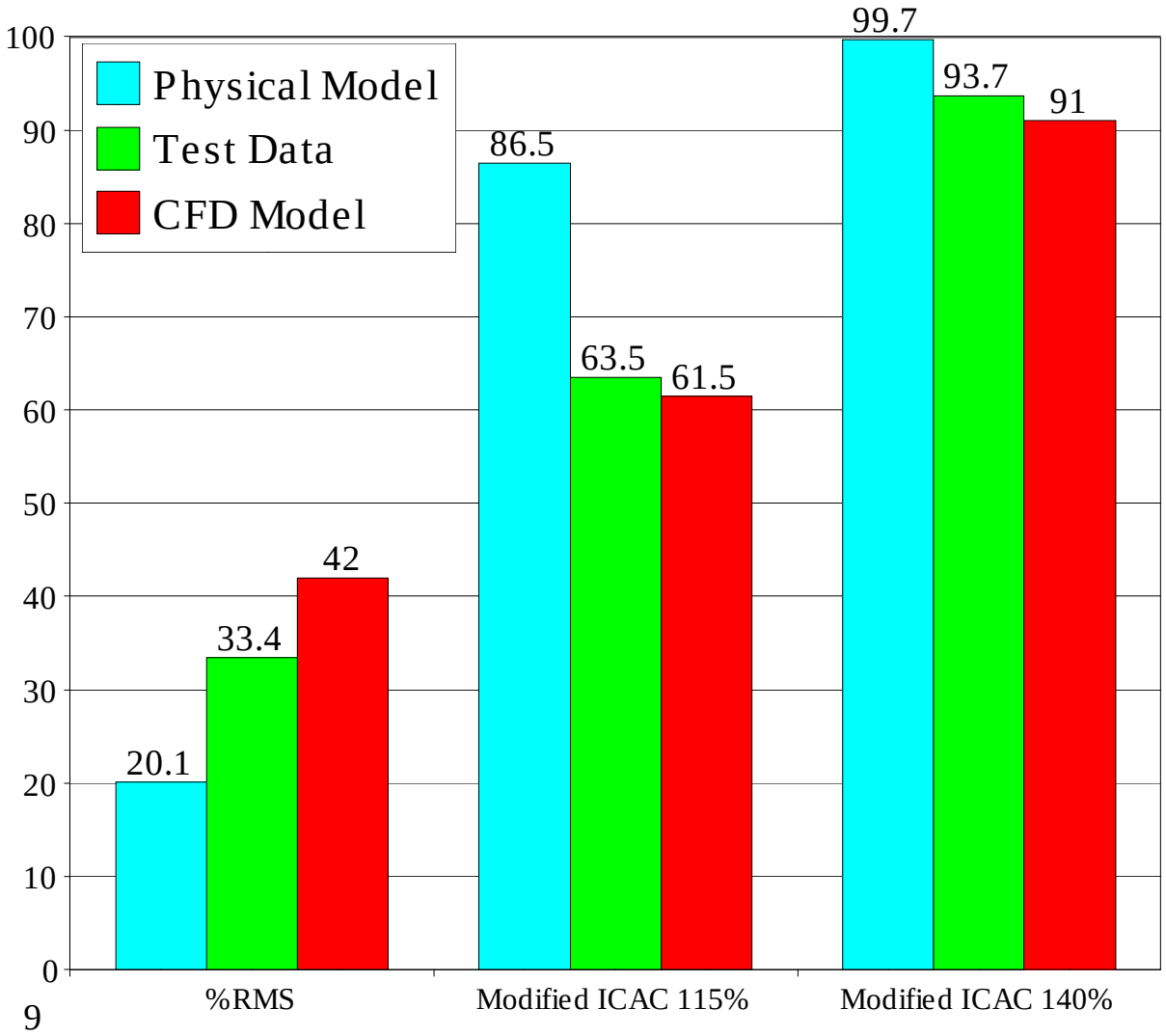


- Both models capture trends
- CFD model captures peak velocity better, but overpredicts the size of the high velocity region

ELECTRIC POWER 2003

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

ELECTRIC POWER 2003

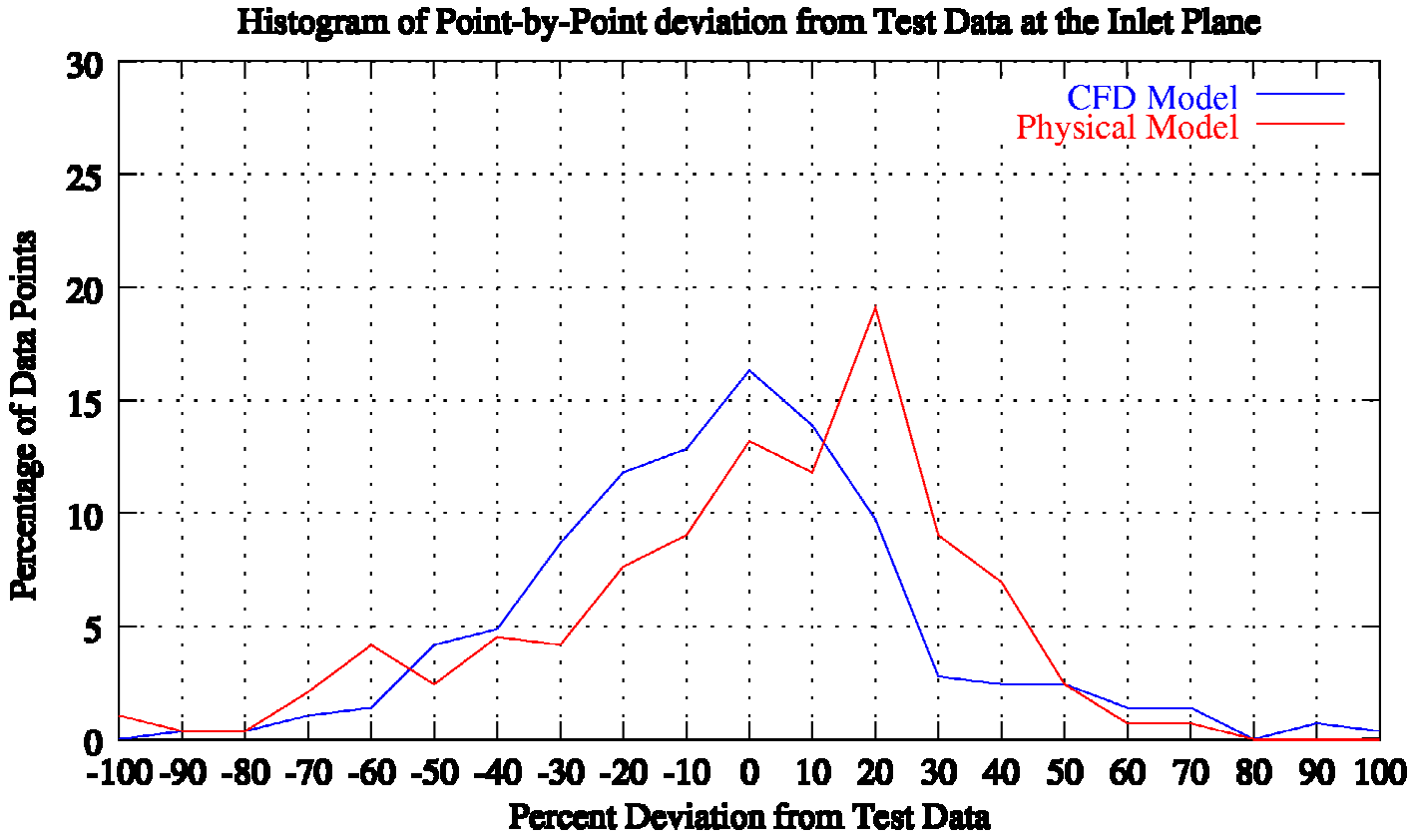
Case Study 2 - Inlet Plane

Histograms - Deviations from Test Data Velocities

- Correlation Factors:

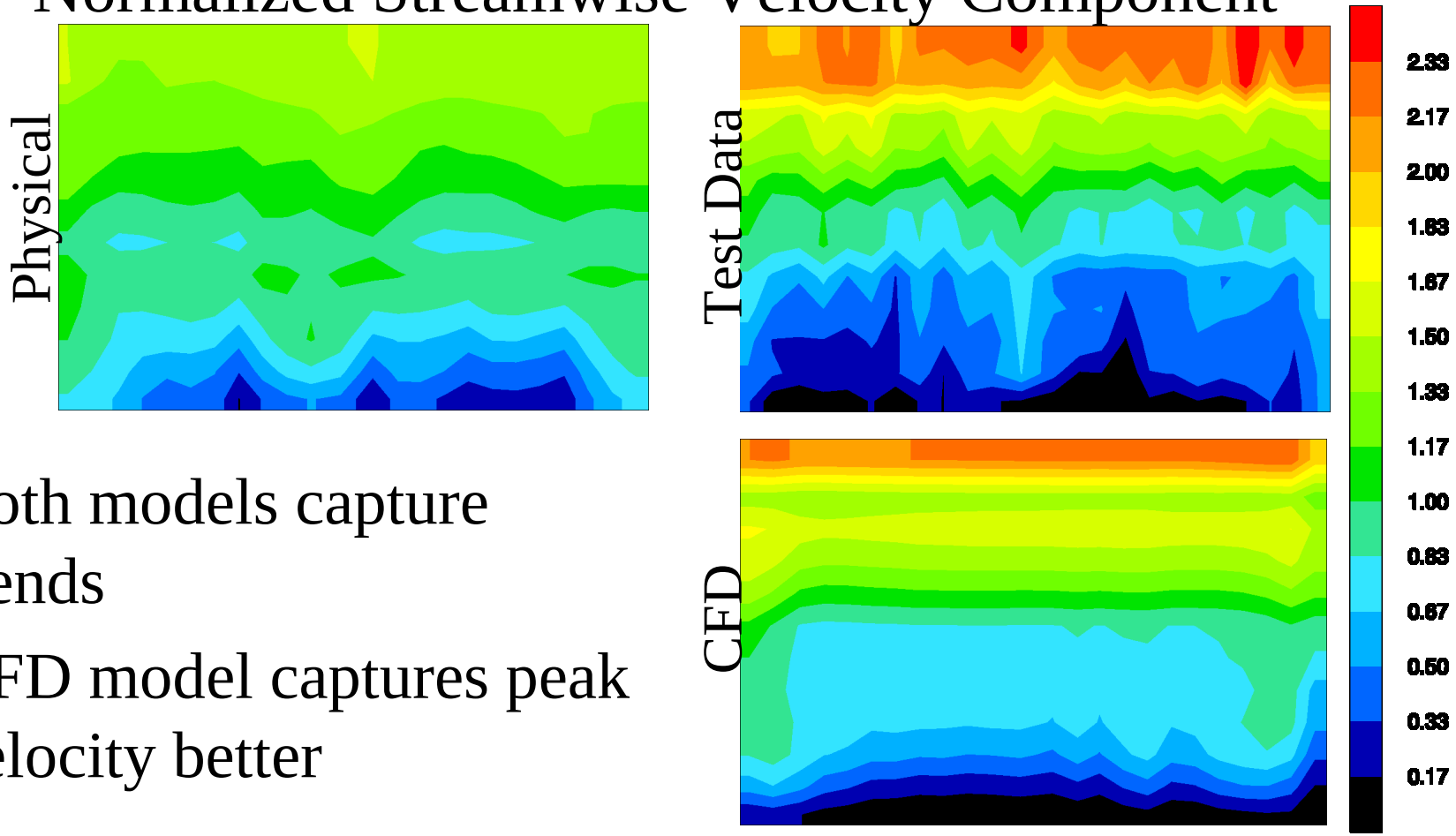
  CFD: 37.0

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



Case Study 2 - Outlet Plane

Normalized Streamwise Velocity Component

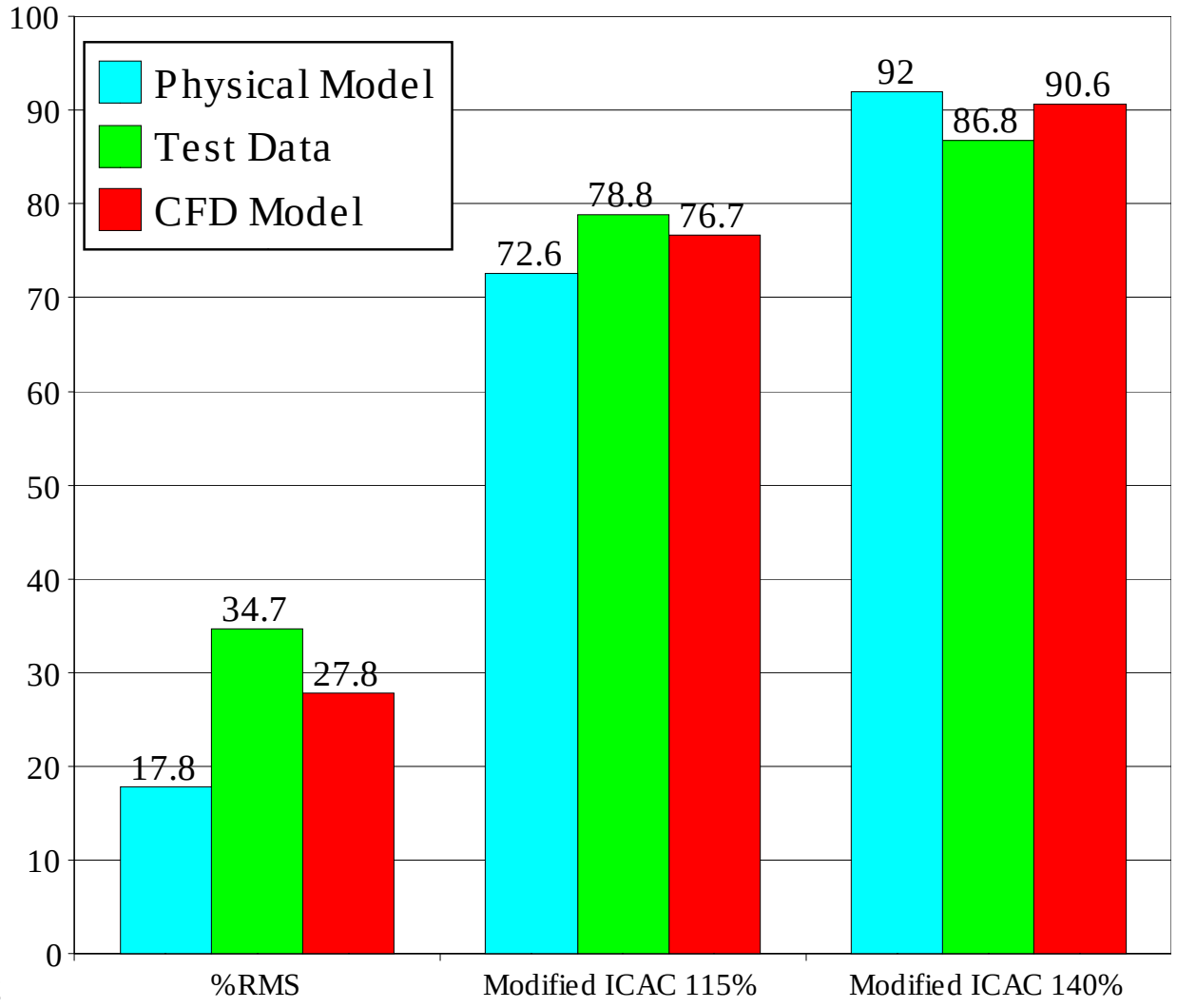


- Both models capture trends
- CFD model captures peak velocity better

ELECTRIC POWER 2003

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

ELECTRIC POWER 2003

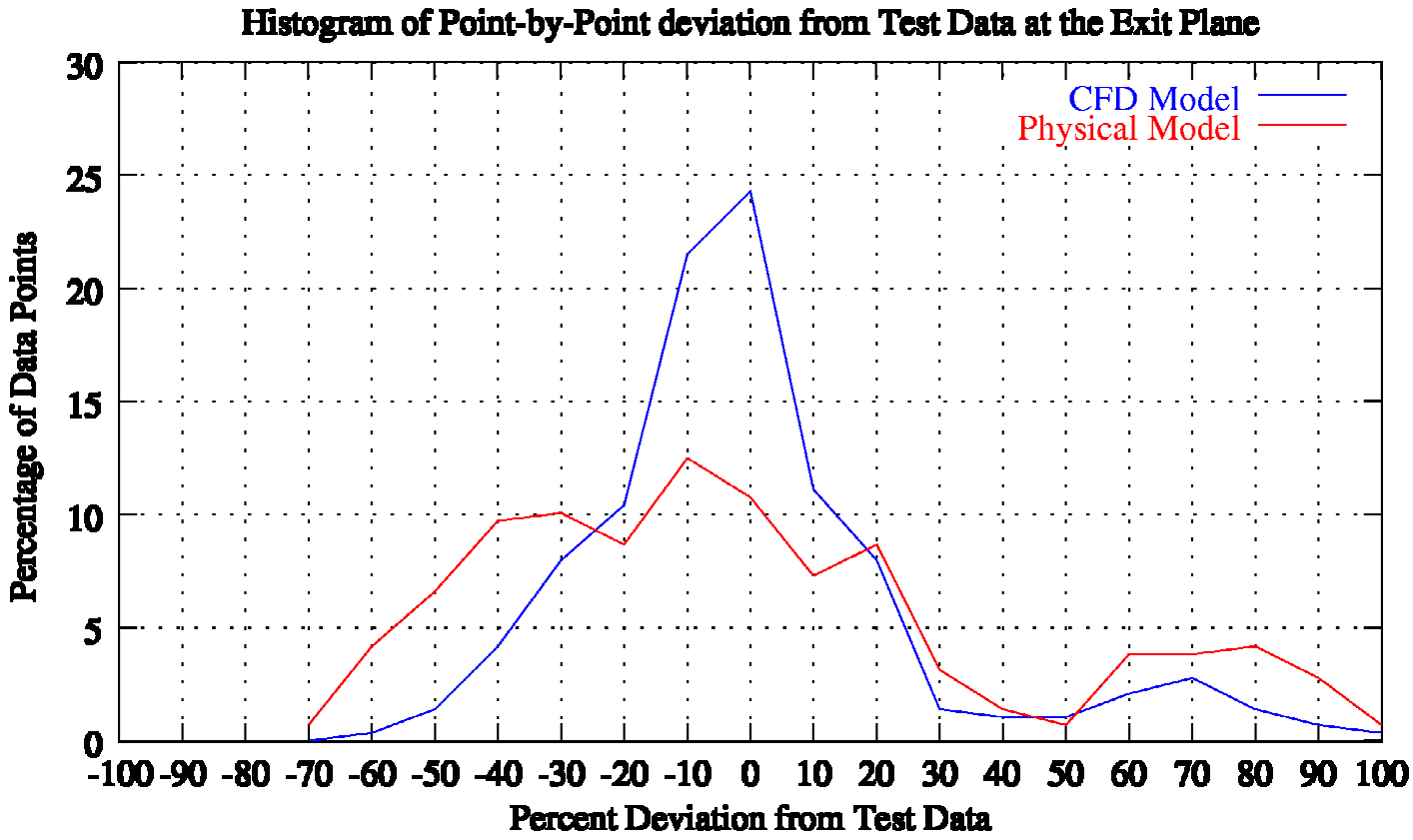
Case Study 2 - Outlet Plane

Histograms - Deviations from Test Data Velocities

- Correlation Factors:

  CFD: 27.2

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



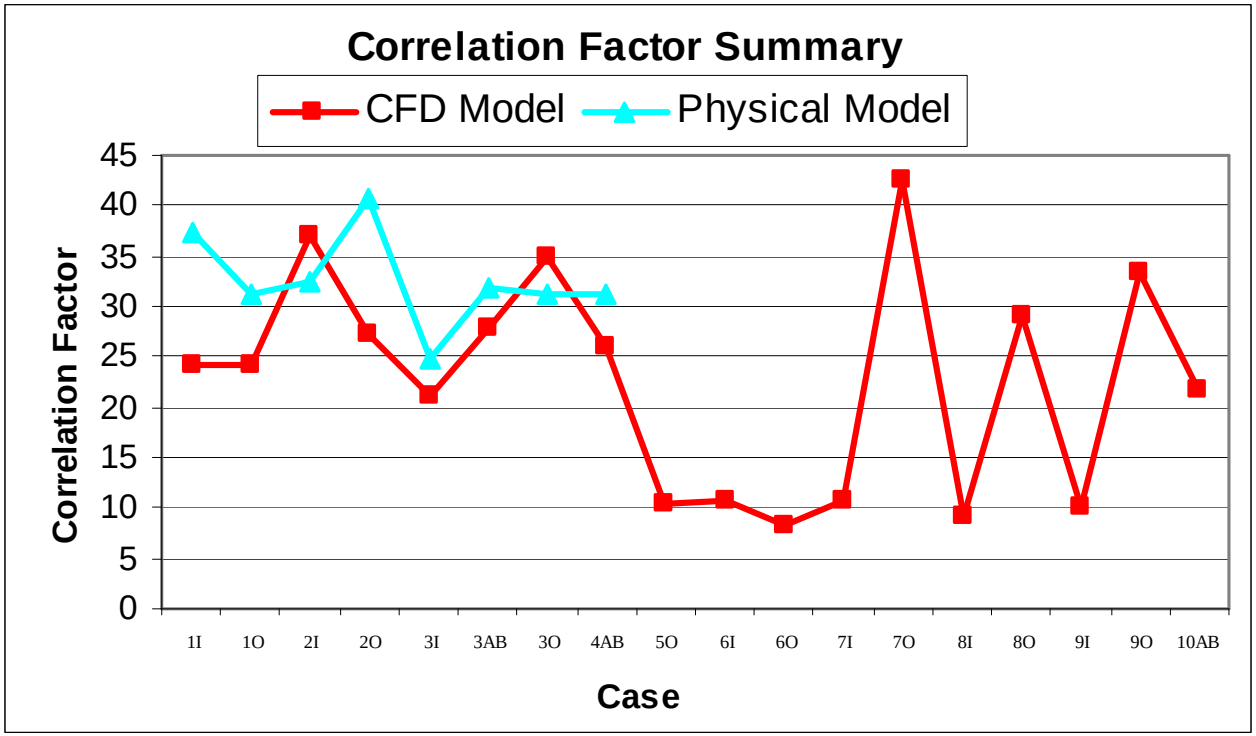
Case Study 2 - Summary

- 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



ELECTRIC POWER 2003

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

ELECTRIC POWER 2003

Conclusions

- On the whole, correlation is not as strong as desired
- Experience indicates that this level of correlation is enough to make flow modeling a useful engineering tool for ESPs
- It is believed that increased correlation is possible through careful attention to modeling methods
  - Inclusion of smaller structure as computer power allows
  - Details of mounting structure associated with flow control devices should be considered
  - Detailed inspections should be done to document as-installed geometry

ELECTRIC POWER 2003

Questions