CFD Evaluation of Air Distribution Systems for Residential Forced Air Systems in Cold Climates

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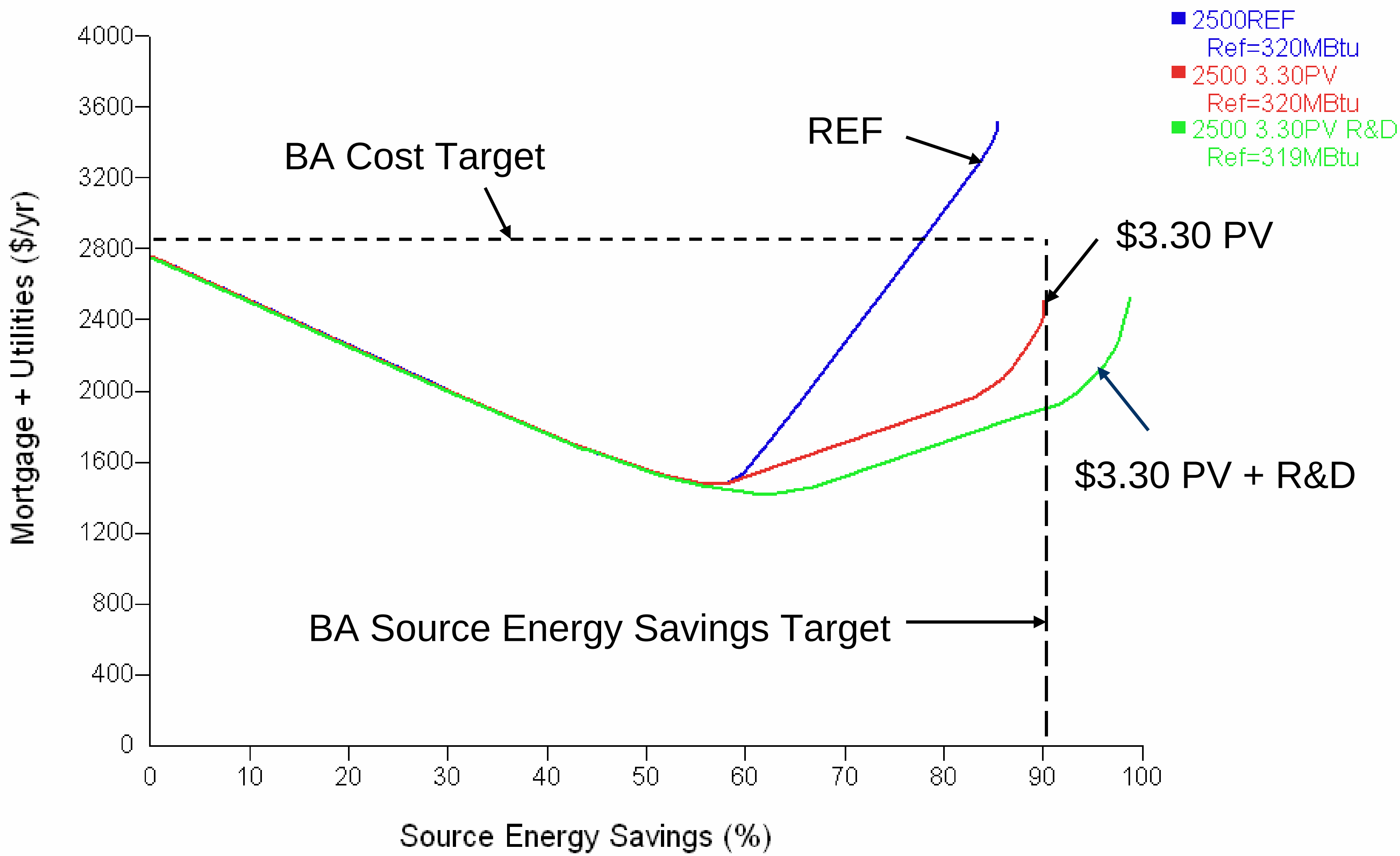
Outline

- Context of this project
- Review of past simulation work
- Results and correlation development
- Comparisons between test and simulation

Background

- Neutral cost of ZEH by 2020
- Improved shell (R30-R60-R5) + best available equipment = 50% by 2015
- ZEH shell + PV + ZEH systems by 2020

Scenarios and Performance Targets



How to maintain comfort?

- ZEH shells:
  - 50% less HVAC capacity
  - 50% smaller duct cross sections and registers
  - 50% less CFM
- Need integrated comfort conditioning for thermal, odor, humidity control

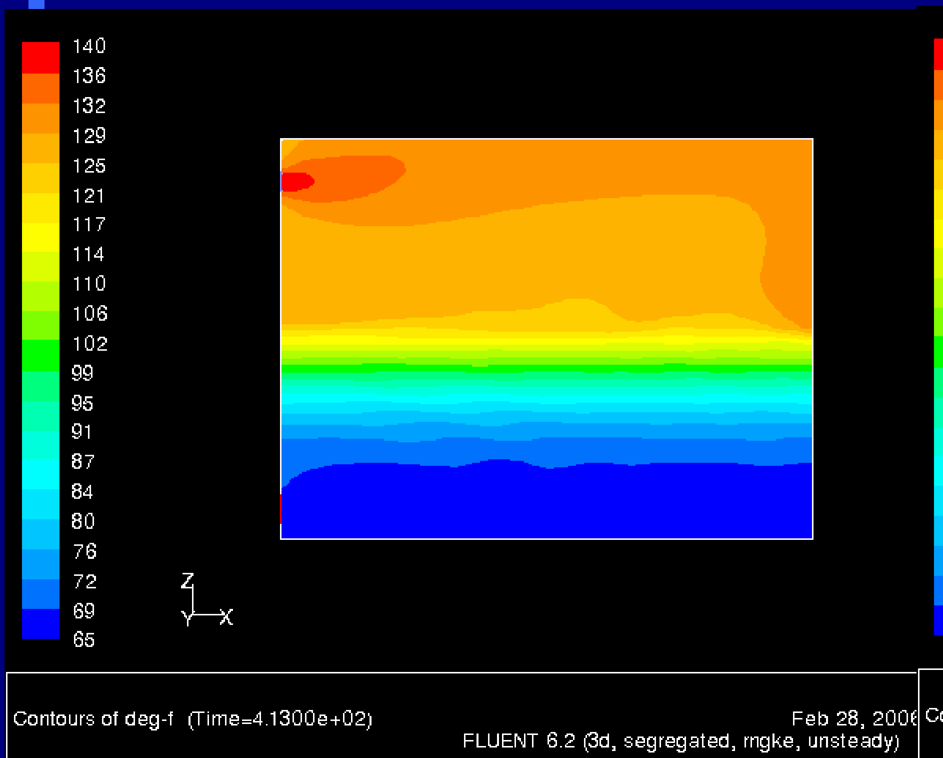
A low cost option

- 80% market penetration of A/C, so systems available
- Use A/C system for integrated comfort conditioning
- Obtain uniform distribution of ventilation air

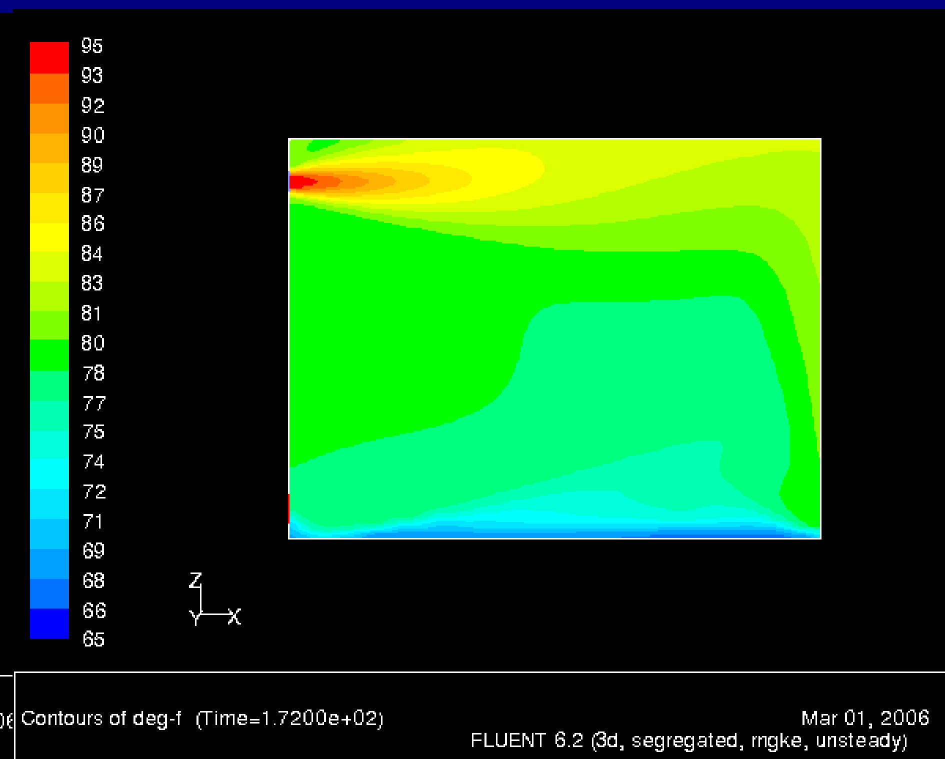
Major barriers

- Heating airflows less than cooling airflows
- Good supply air mixing not assured in heating mode unless carefully designed
- Stratification possible

Good air mixing required



Stratified



Well mixed

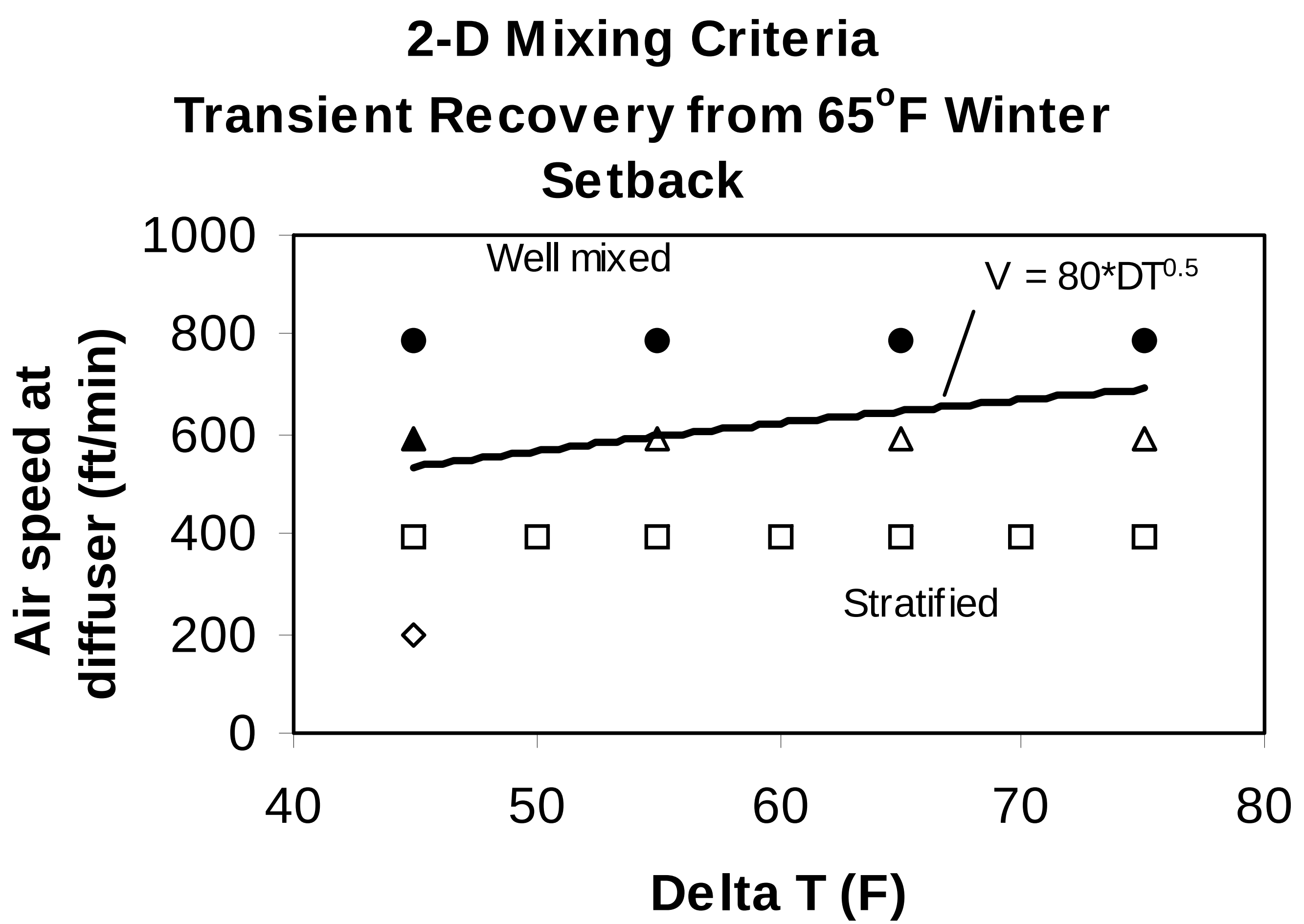
Objective

Develop demonstrated numerical models to provide initial design guidance on mixing performance and to direct experimental plans

CFD approach

- Recovery from 65ºF setback
- Variety of room sizes, diffuser sizes, air flowrates, supply temperatures
- 2D and 3D models
- Performance parameters defined
- Correlation developed

Initial 2D models



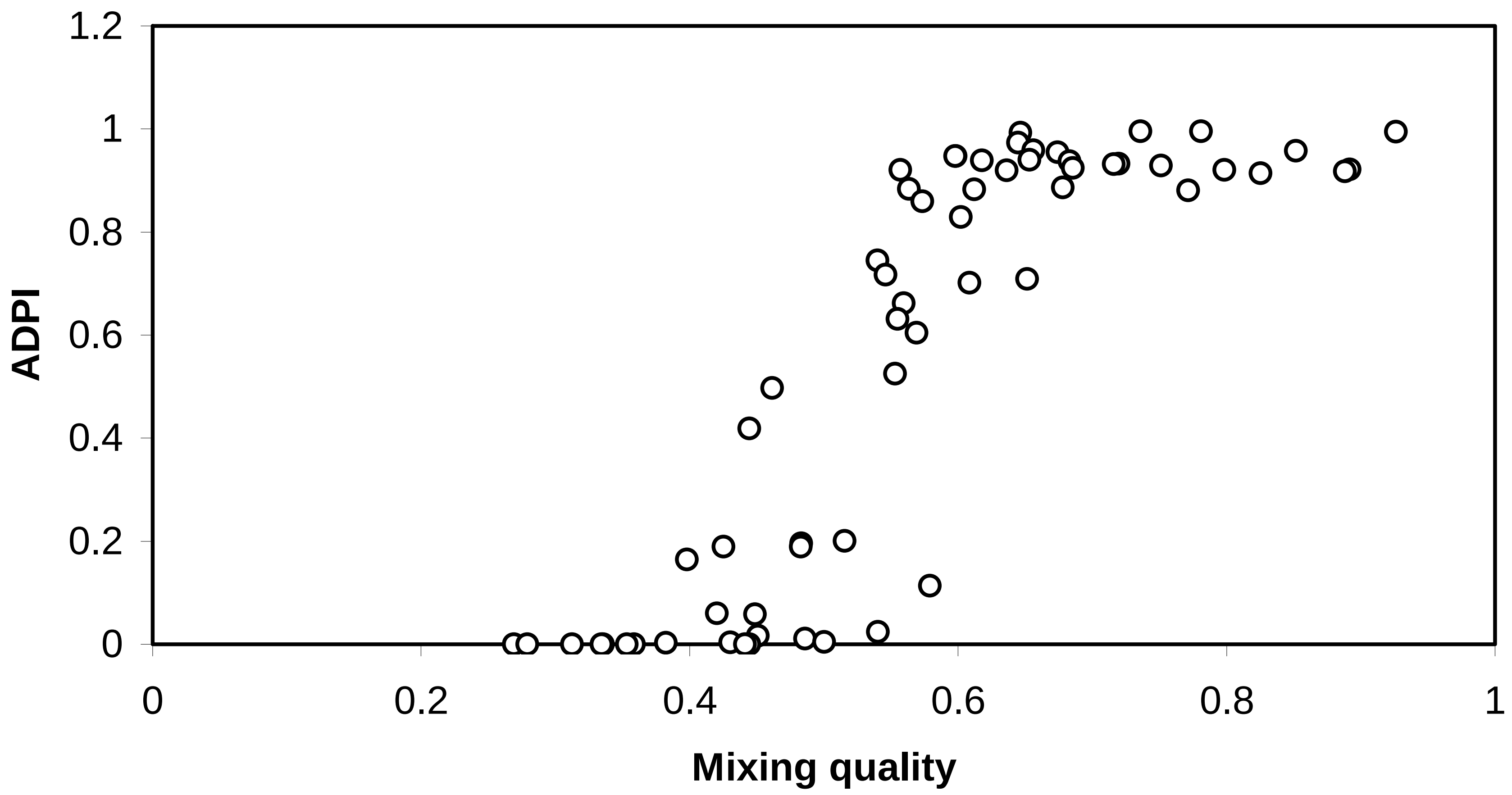
Performance criteria

- Displacement efficiency, η_d
- Mixing quality $Q = (1 - \eta_d)/(0.368)$
- Air diffuser performance index (ADPI)
  - Draft temperature between -1.5^o and 1^{o}C

$$\theta = T - T_{avg} - 8(V - 0.15)$$

  - Air speed less than 0.35 m/s

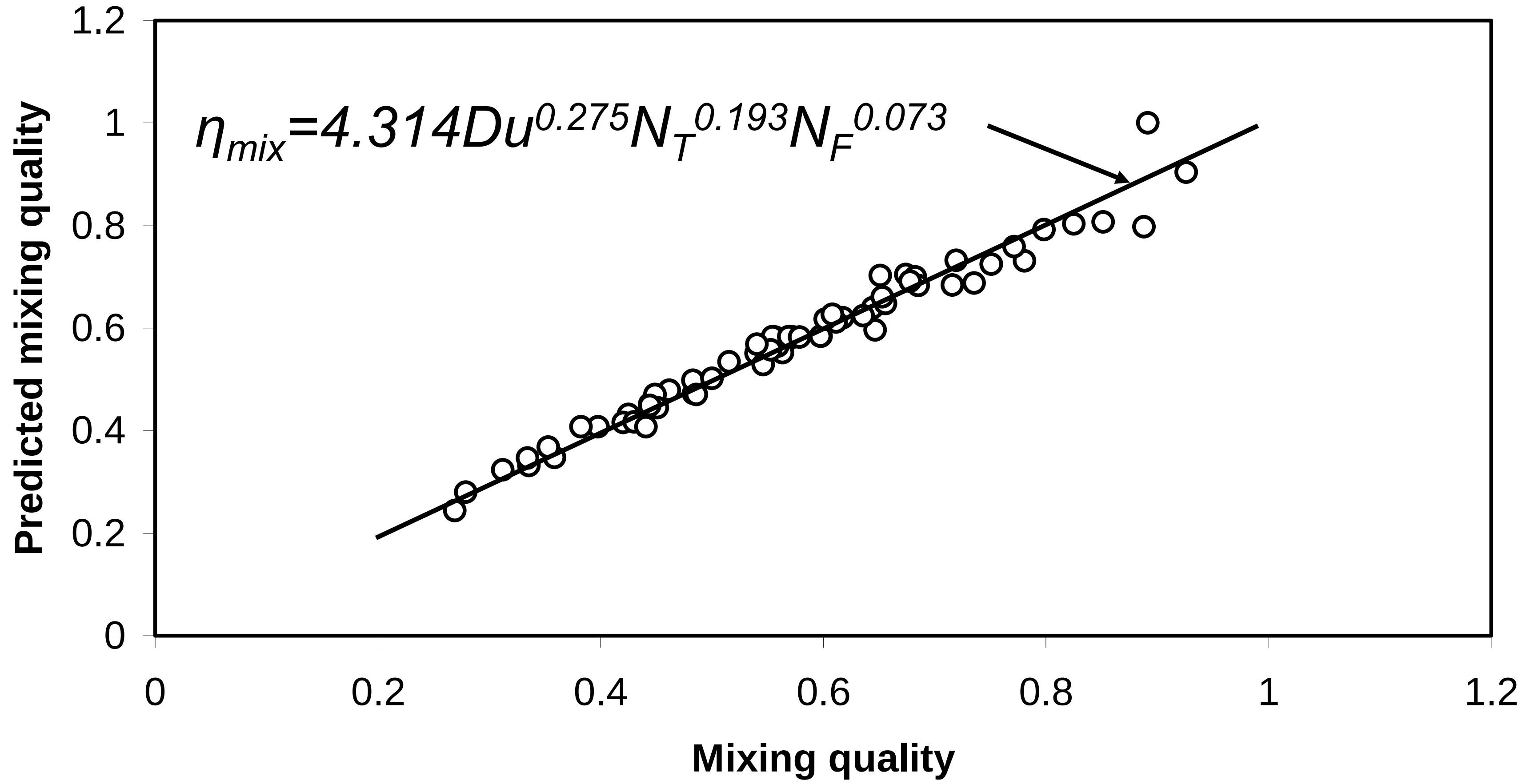
3D model results



Correlation development

- Geometry
  - Duct fineness ratio, N_F = *(height/width)*
  - Isothermal throw ratio, N_T = *(X/L)*,
- Air kinetic energy / thermal energy, $Du = V^2/\{c_p(T-T_o)\}$

Correlation development

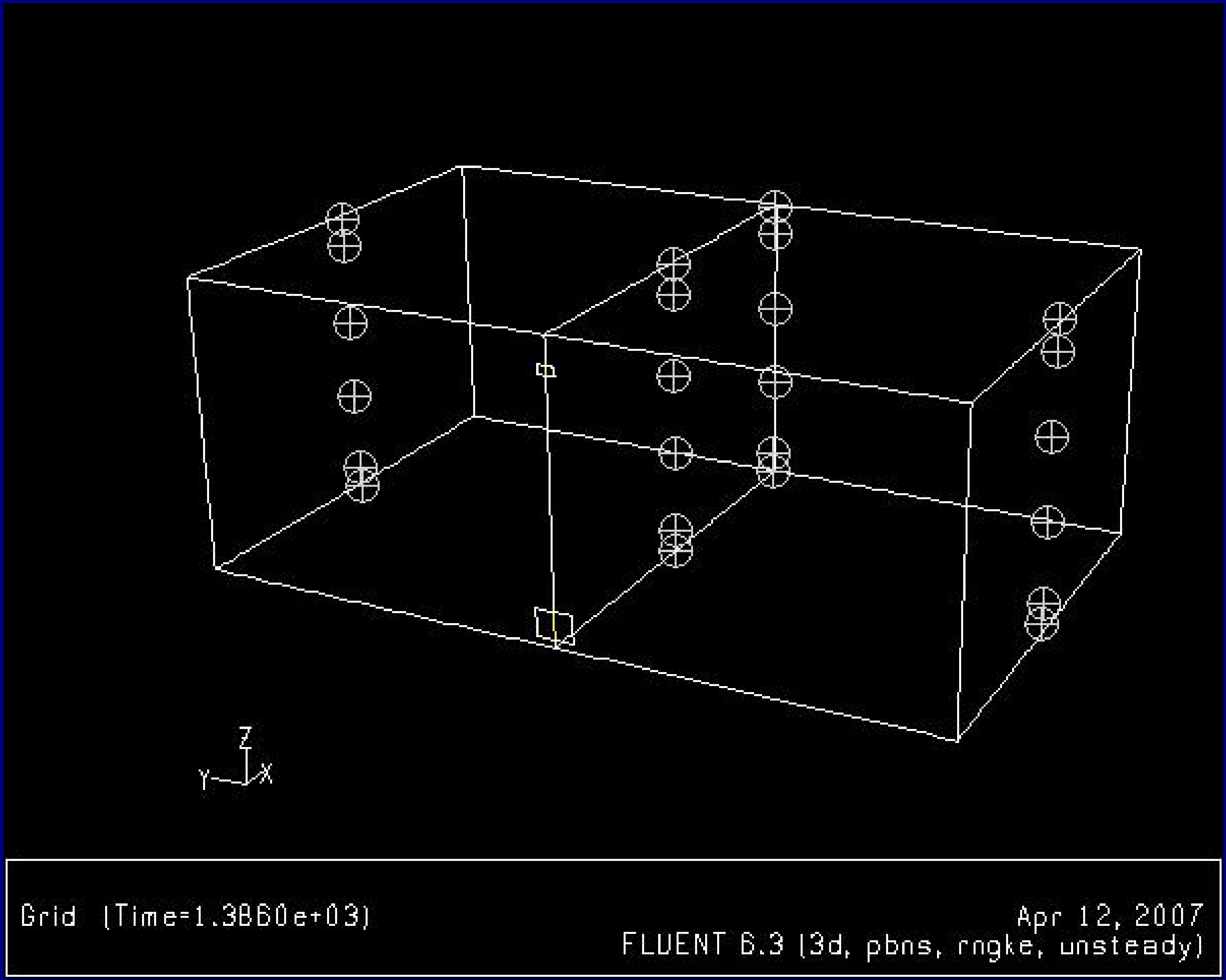


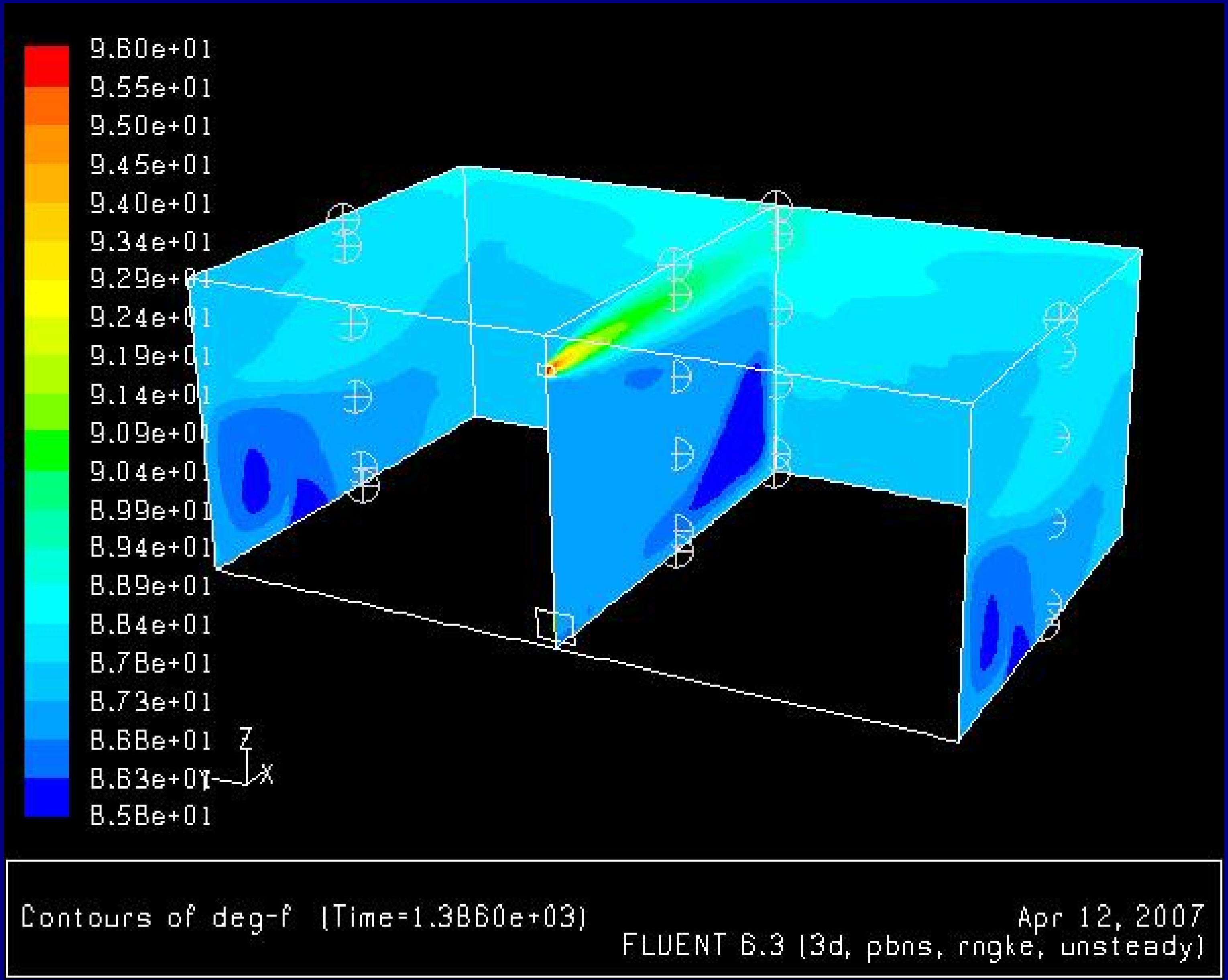
Comparison between test and simulation

- Experimental data from Ventilation Test Facility
- Field test data from IBACOS and Cardinal Glass house in Ft. Wayne

NREL Ventilation Test Room

- Two cases chosen for modeling
- Low flow, high temp. (L3)
  - 87 cfm, 102ºF SAT
- Medium flow, low temp. (M2)
  - 122 cfm, 96ºF SAT


Z
Y
X
Grid (Time=1.3860e+03)
Apr 12, 2007
FLUENT 6.3 (3d, pbns, rngke, unsteady)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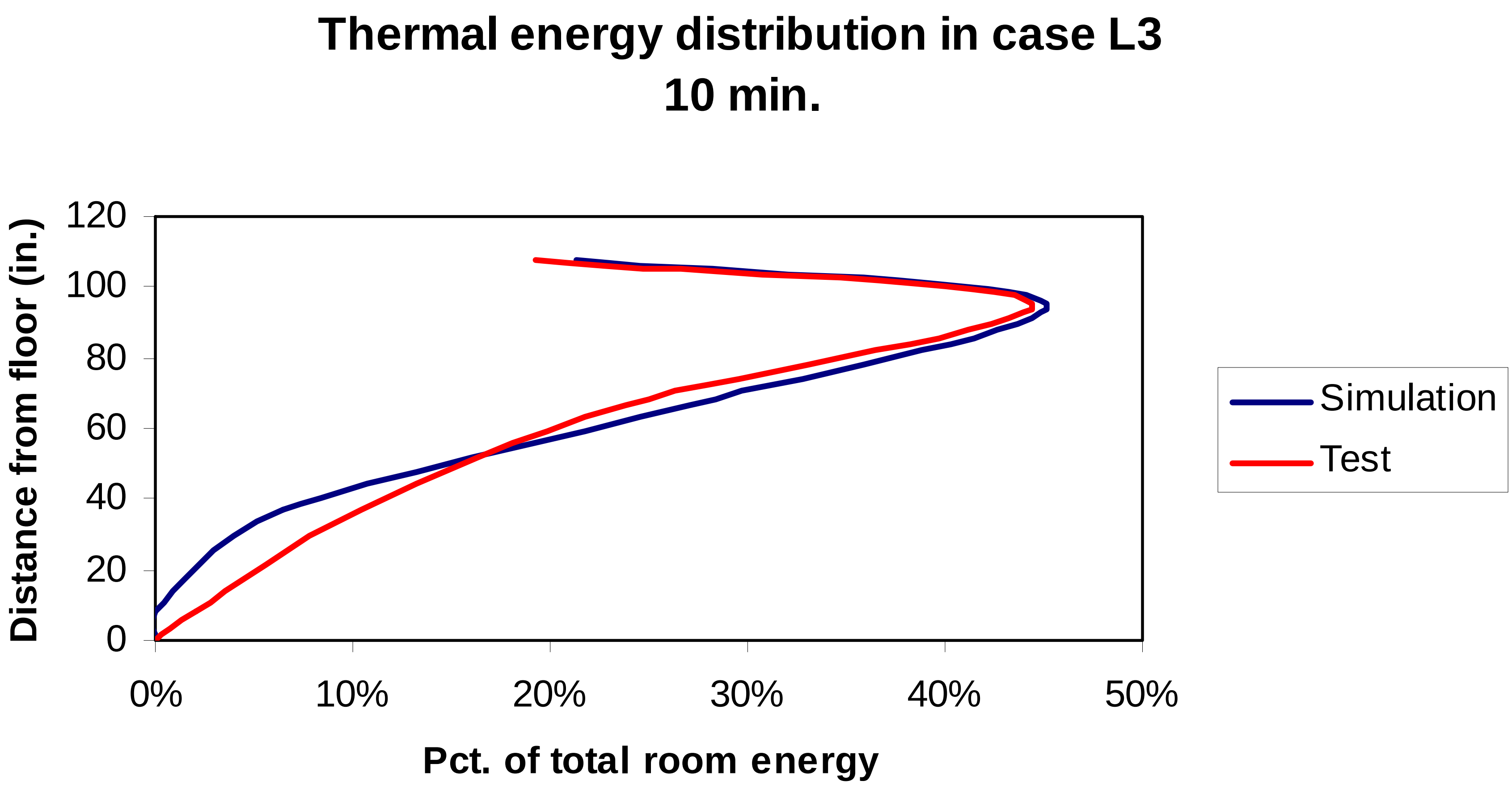
Contours of deg-f (Time=1.3860e+03)
Apr 12, 2007
FLUENT 6.3 (3d, pbns, rngke, unsteady)

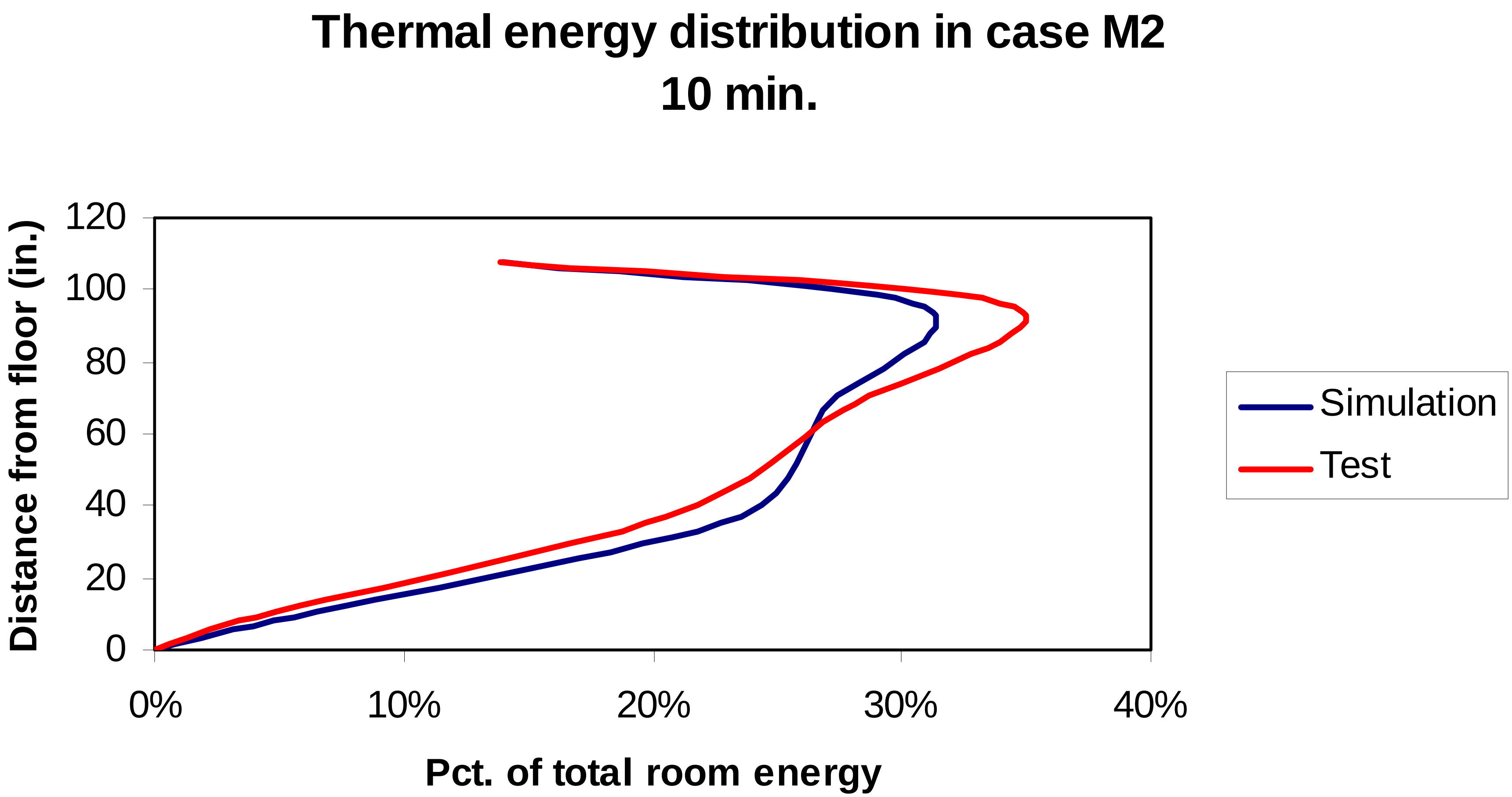
NREL Ventilation Test Room

- Stratification effects explored via relative energy content in room

NREL Ventilation Test Room



NREL Ventilation Test Room



NREL Ventilation Test Room

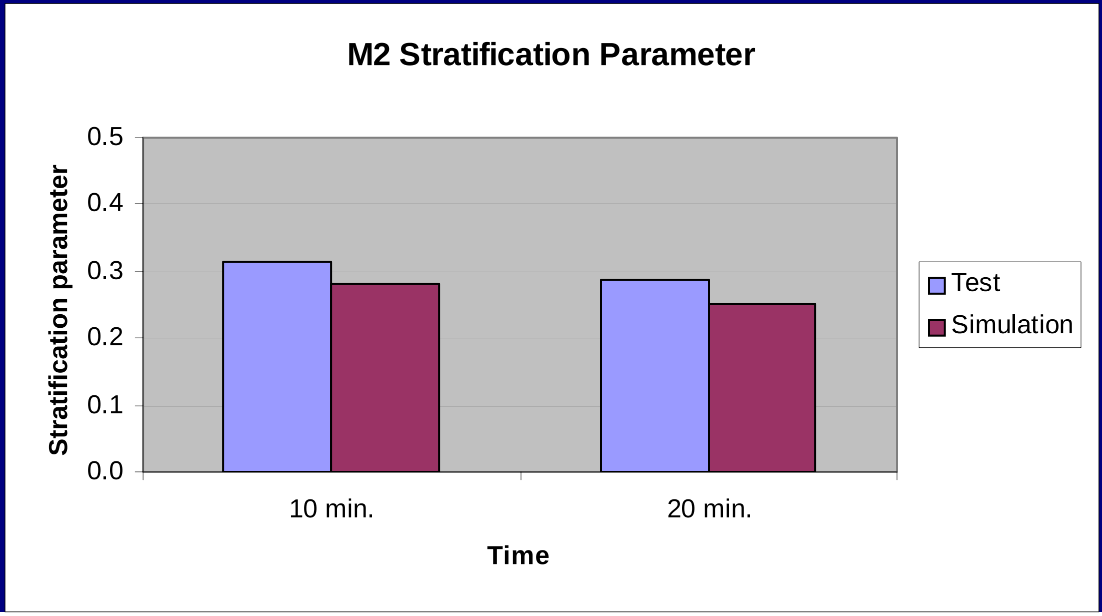
- Stratification parameter:

$(T_{ceiling} - T_{floor})/T_{weighted\ average}$

0: perfectly mixed

>1: extremely stratified

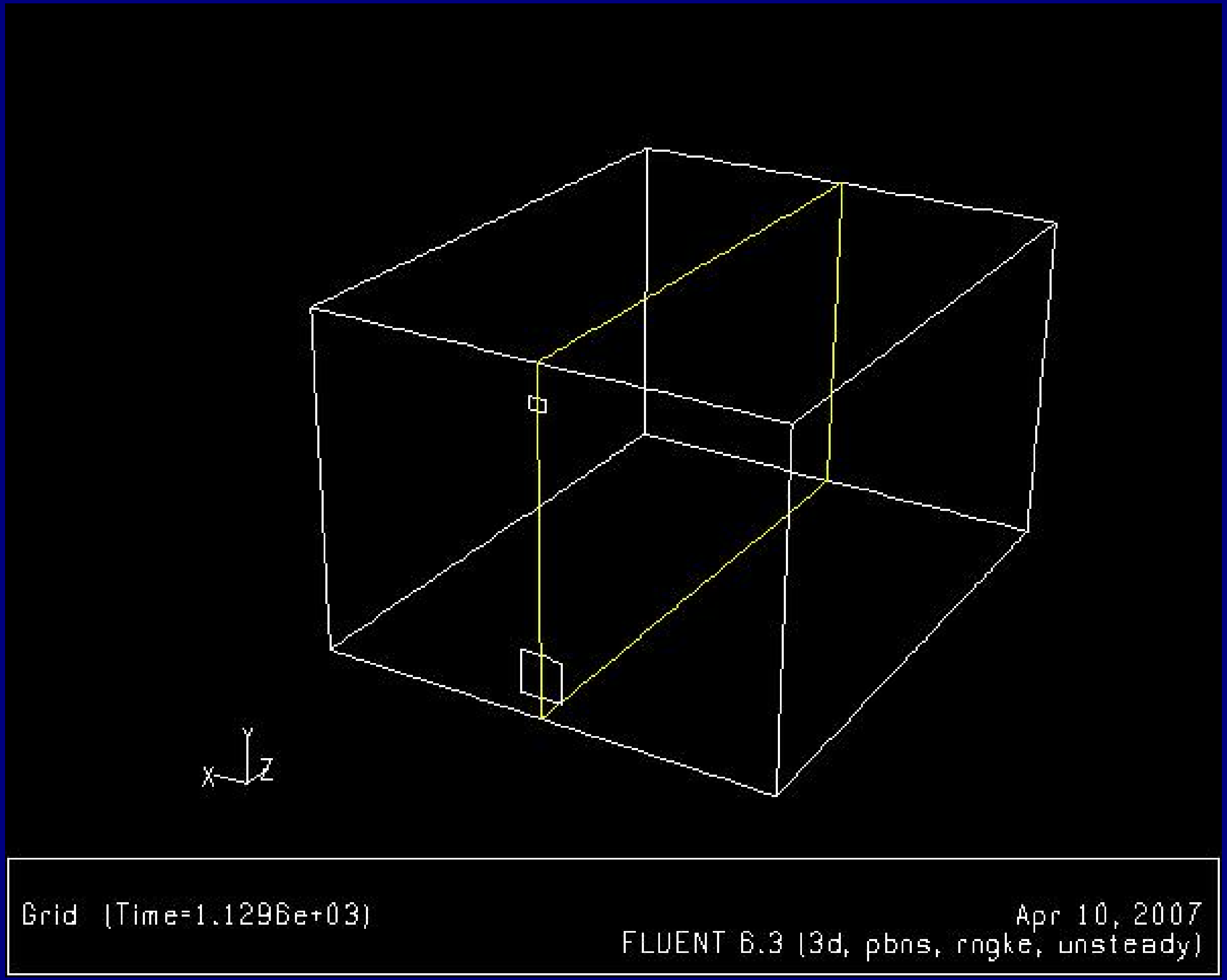
L3: 3 % diff. at 10 min.



M2: -11 % diff. at 10 min.

Ft. Wayne Test Room

- Bedroom supplied by single 6" by 4" high sidewall diffuser
- Range of flowrates modeled (design 71 cfm)
- Supply temperatures fixed and functions of return temperature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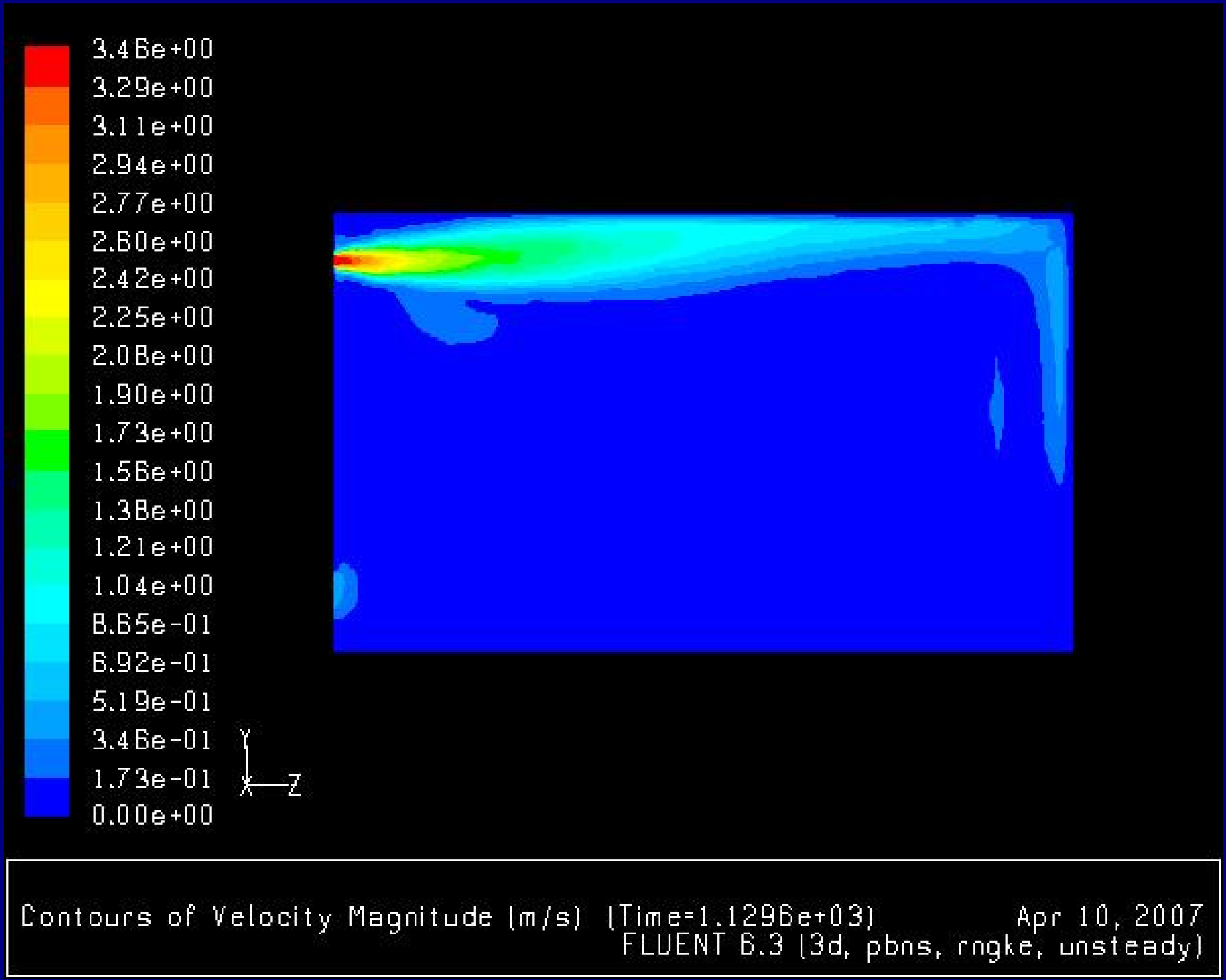
Grid (Time=1.1296e+03)
Apr 10, 2007
FLUENT 6.3 (3d, pbns, rngke, unsteady)



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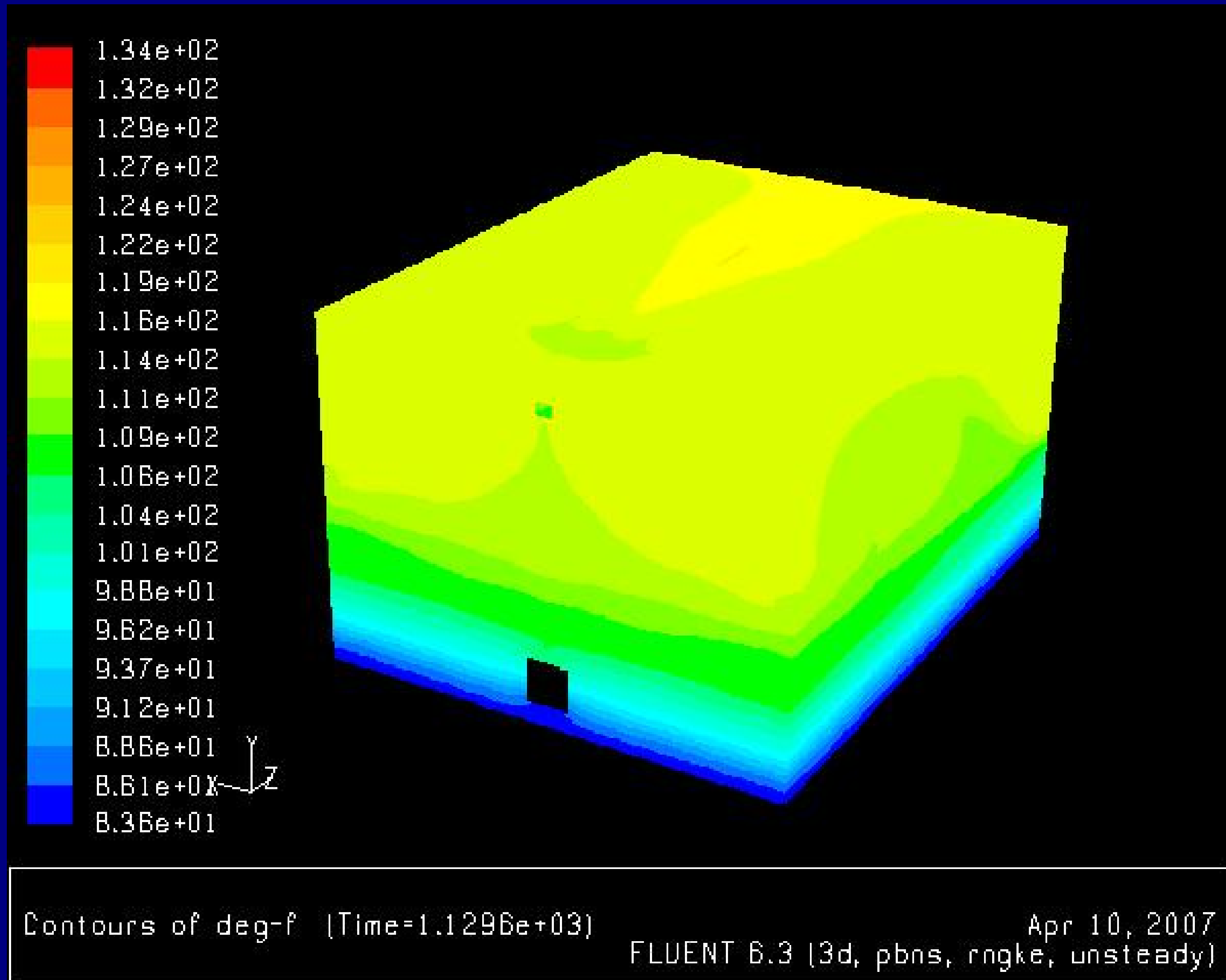
X
Contours of Velocity Magnitude (m/s) (Time=1.1296e+03) Apr 10, 2007
FLUENT 6.3 (3d, pbns, rngke, unsteady)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Contours of deg-f (Time=1.1296e+03)
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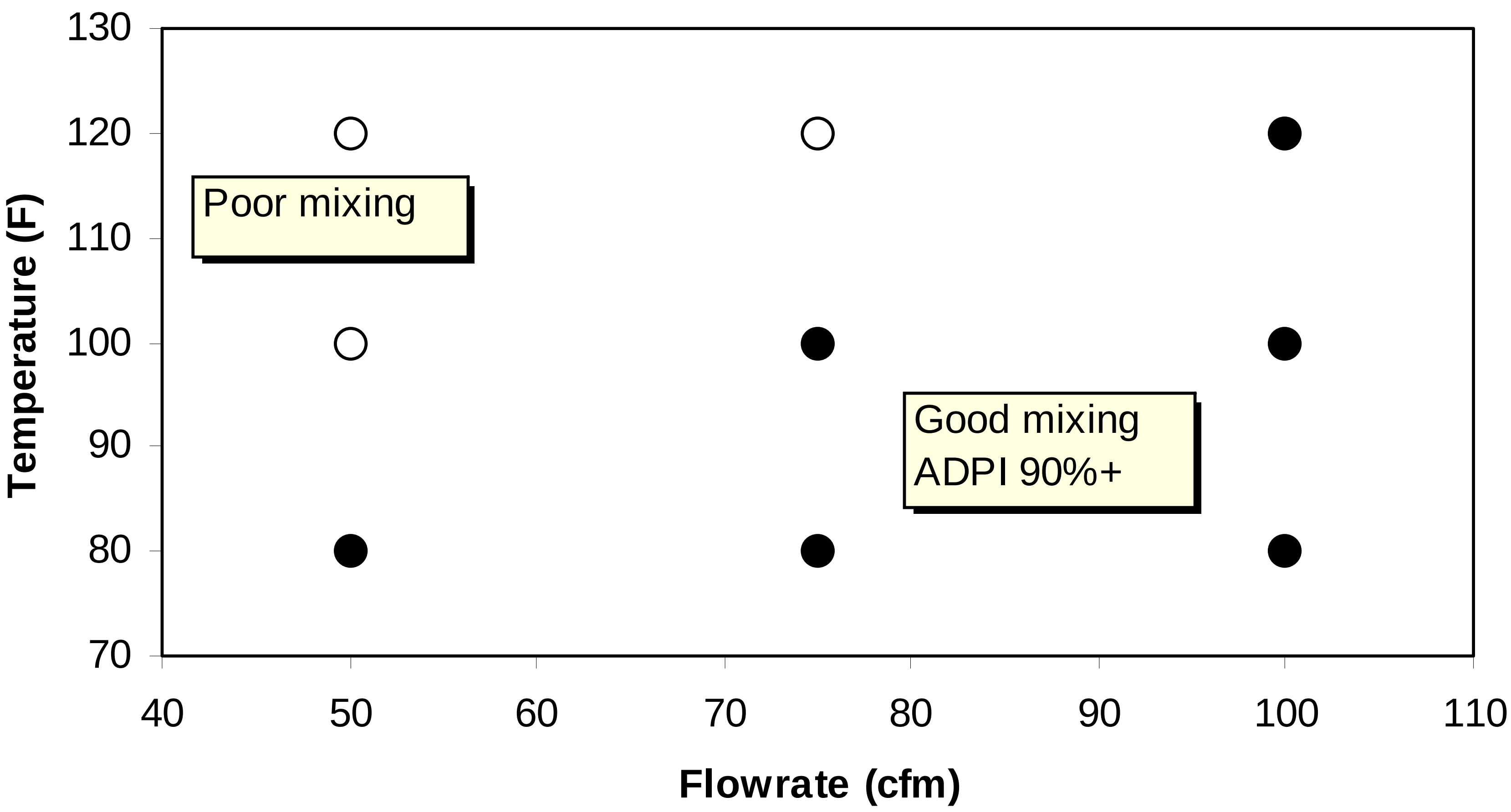
Ft. Wayne Test Room



Summary

- 2D and 3D models developed and used to predict mixing performance
- Good agreement between simple model and ventilation test room data

Future work

- Compare model to Ft. Wayne data
- Determine thermostatic control effects for select cases
- Develop design guidelines