Energy Saving Improvements for Industrial Ovens

Oven Air Seal

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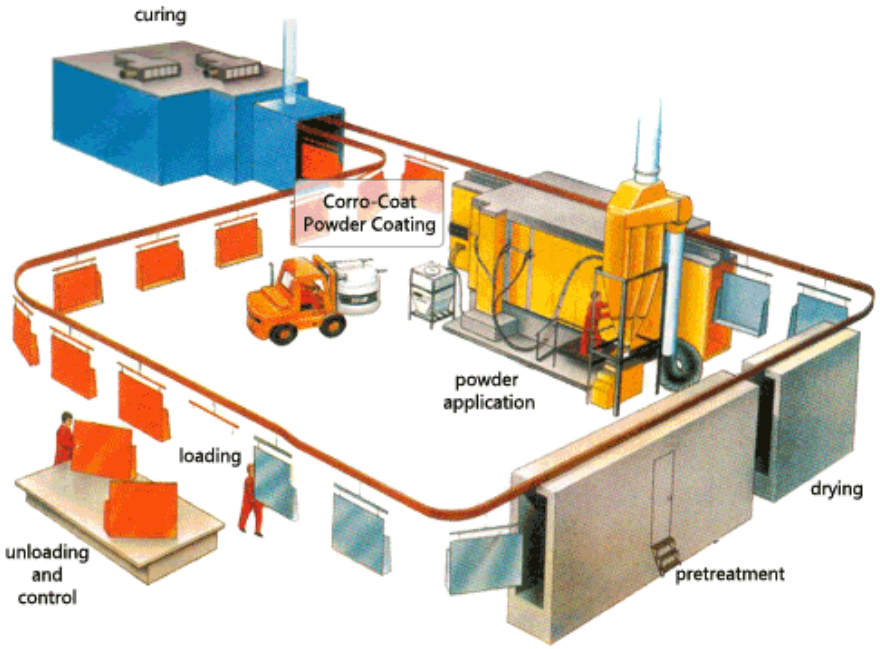
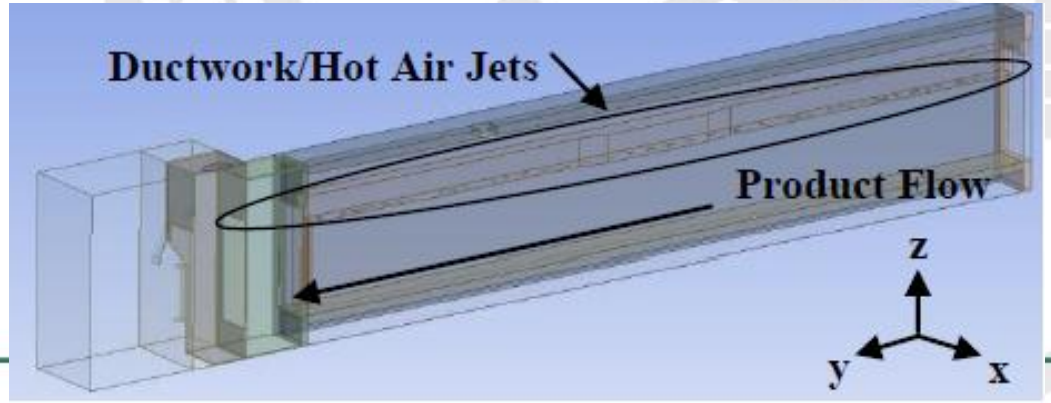
Background

- Continuous oven uses
  - Curing
  - Drying
  - Annealing
  - Baking
- Energy sources
  - Natural gas
  - Electricity

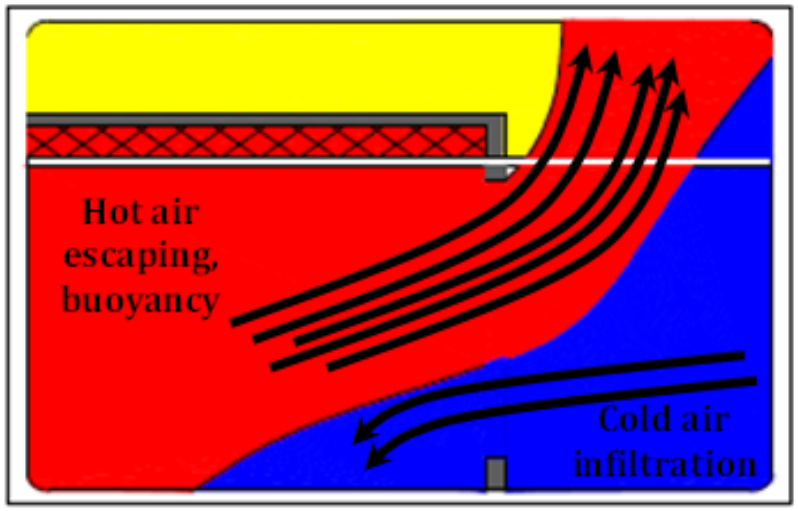


"Industrial Powder Paint Line." Photo. http://www.corrocoat.com.ph/powdercoating101.htm . Retrieved 4/8/2011



Problem Description

- Hot air escapes through oven door openings due to buoyancy effects
- Cold air infiltrates oven interior lowering average temperature



Implemented Solution – Air Seal

- Modest improvements achieved with trial-and-error approach
- Need better understanding of the problem to optimize solution

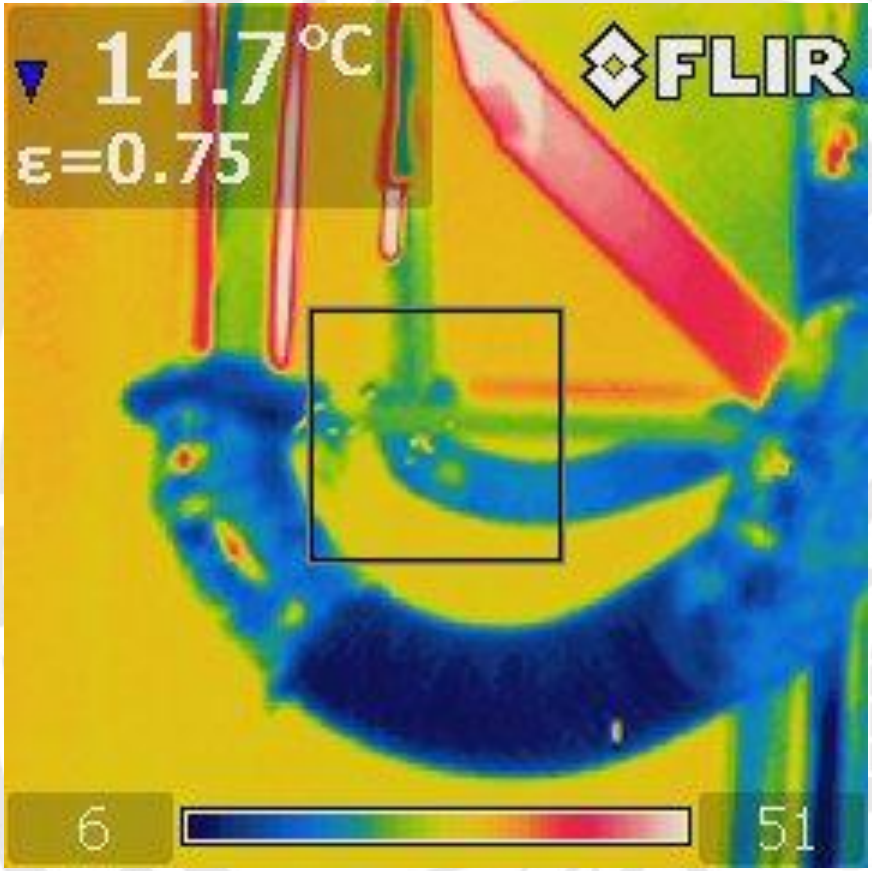


Photo courtesy of Rapid-Line Manufacturing, taken using a FLIR ThermaCAM™

Goal and Objectives

- Goal:
  - Optimize implementation of air seals to reduce energy consumption in industrial ovens
- Objectives
  - Develop an analytical approach to predict oven performance
    - Computational tools
  - Validate the proposed model with field data
    - Experimental results
  - Evaluate changes to oven configuration
    - Minimize energy use and cost of implementation
    - Increased production via higher throughput

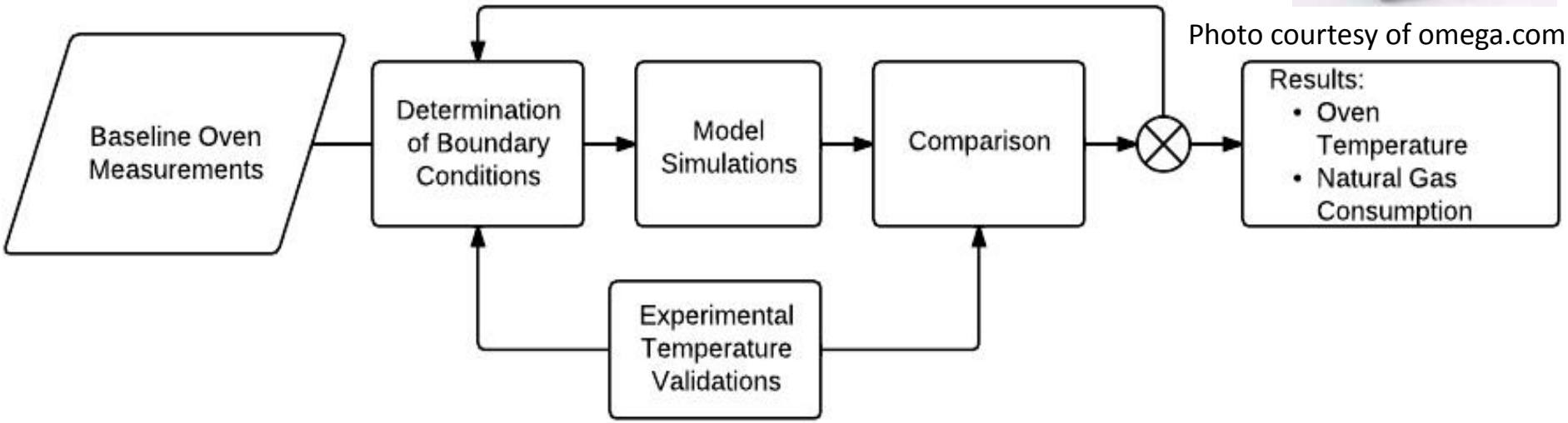
Benchmarking

- Focus areas
  - Ovens
    - Types, operation, heat loss mechanisms and solutions
  - Theory of turbulent buoyant jets
  - Experimental measurement techniques
- Methodology
  - Literature reviews
  - Site visits

Baseline Measurements

- Energy consumption
  - Invasive Natural gas meter well suited to low line pressure conditions
  - Provides quantitative measurement of energy use

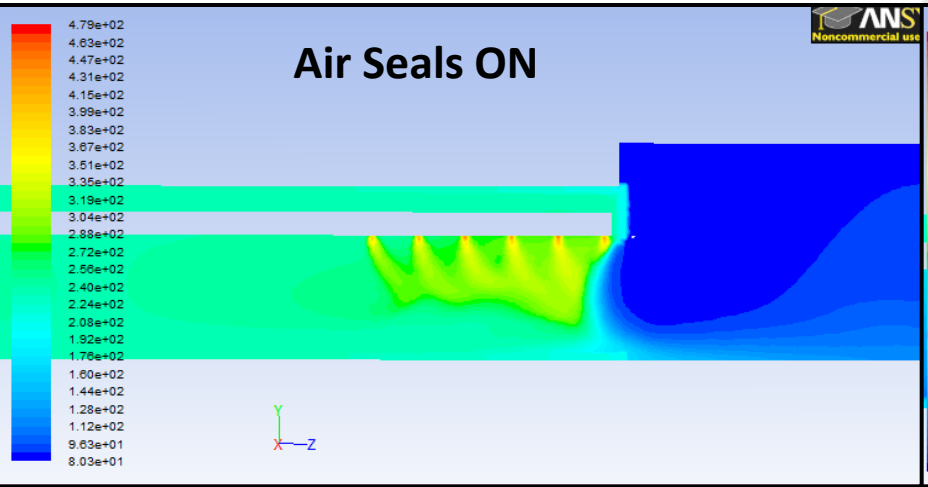
Photo courtesy of omega.com

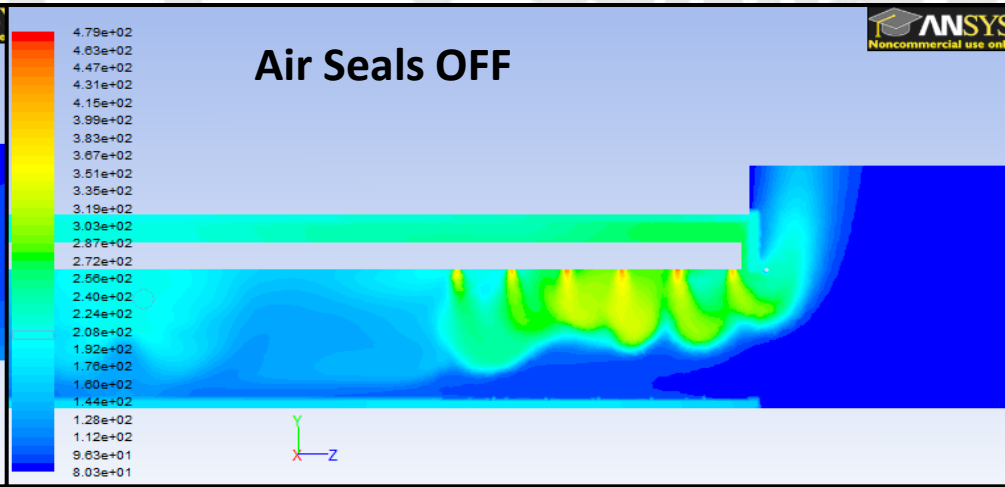


Model Simulations

- Model capable of reproducing physical trends
  - Buoyancy and non-uniform temperature distribution
  - Energy loss out door opening
- Model requires experimental validation to ensure accuracy

Modeled Temperature Profile

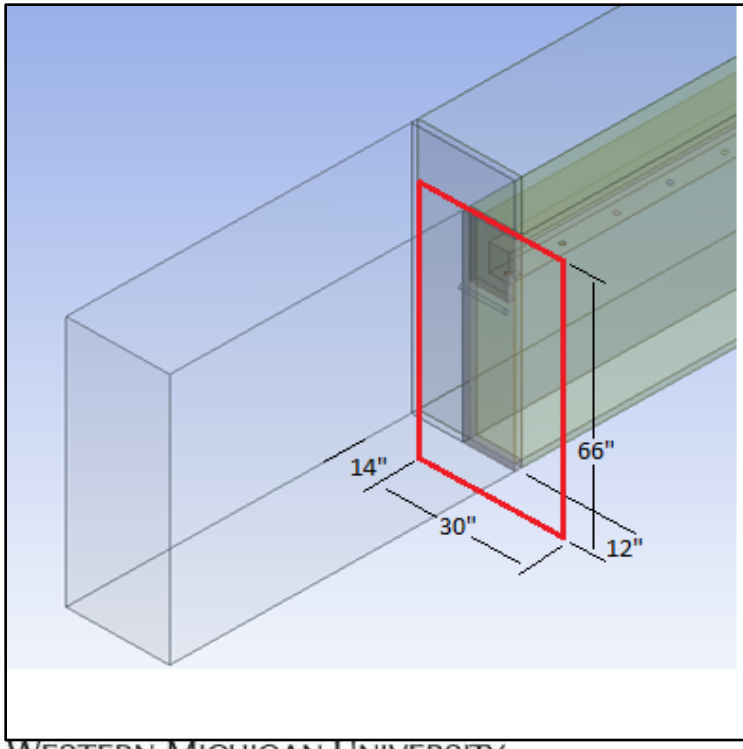


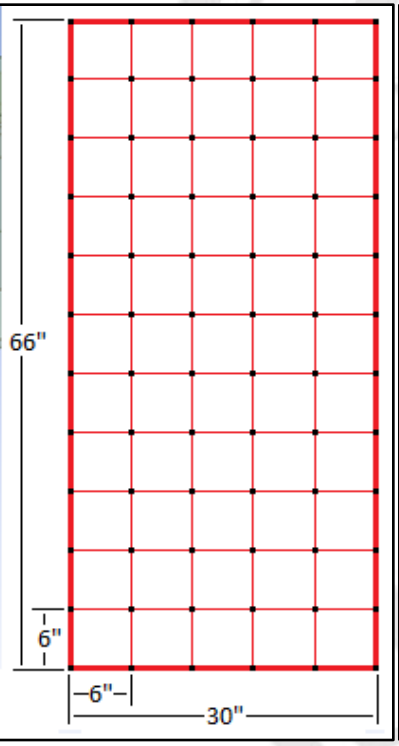


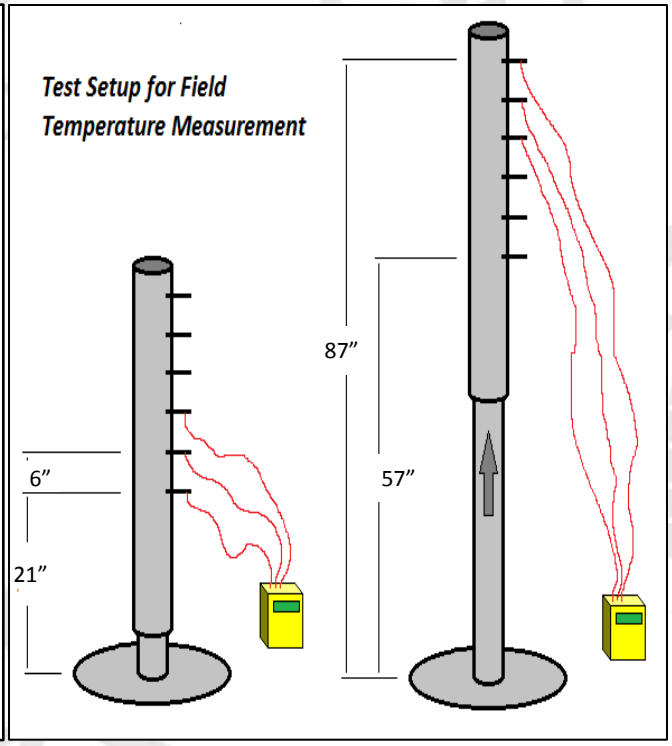
Experimental Validation

Profile Temperature Measurement

- Multi-point thermocouple test
  - Requires specialized data acquisition tools
  - Setup built for 6” spatial resolution

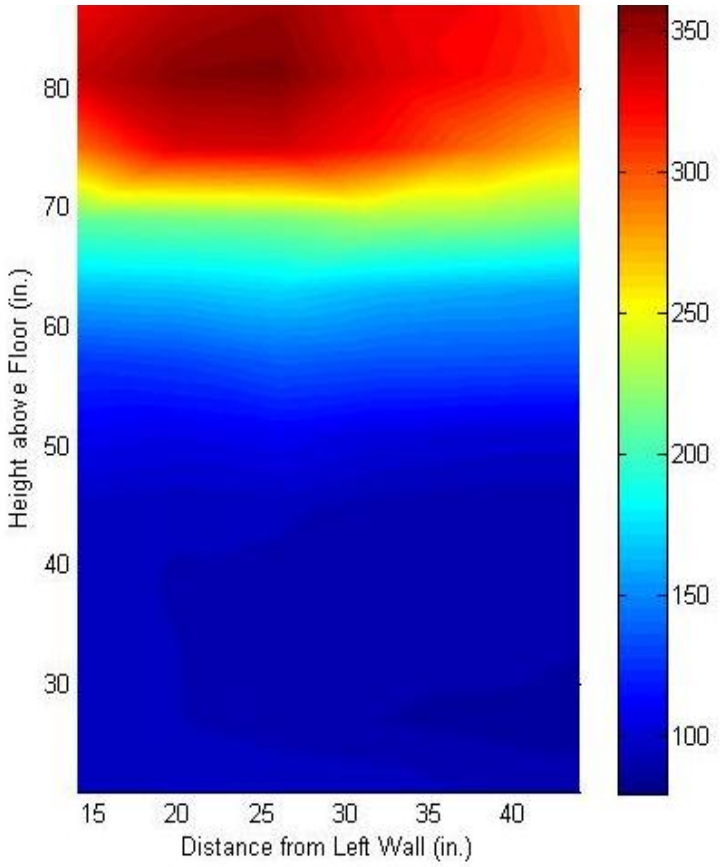




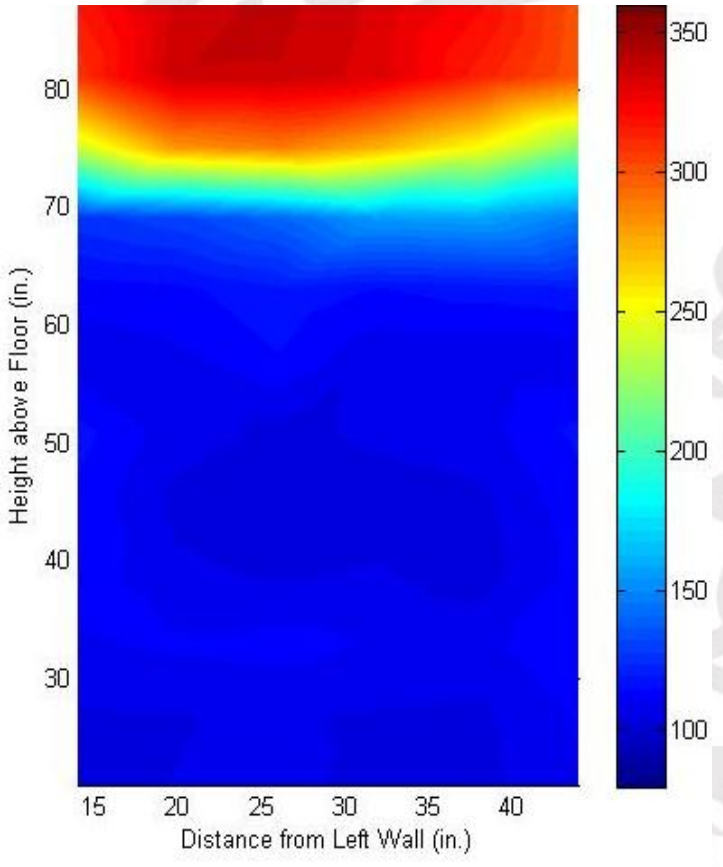


Experimental Validation

Temperature Profile Results



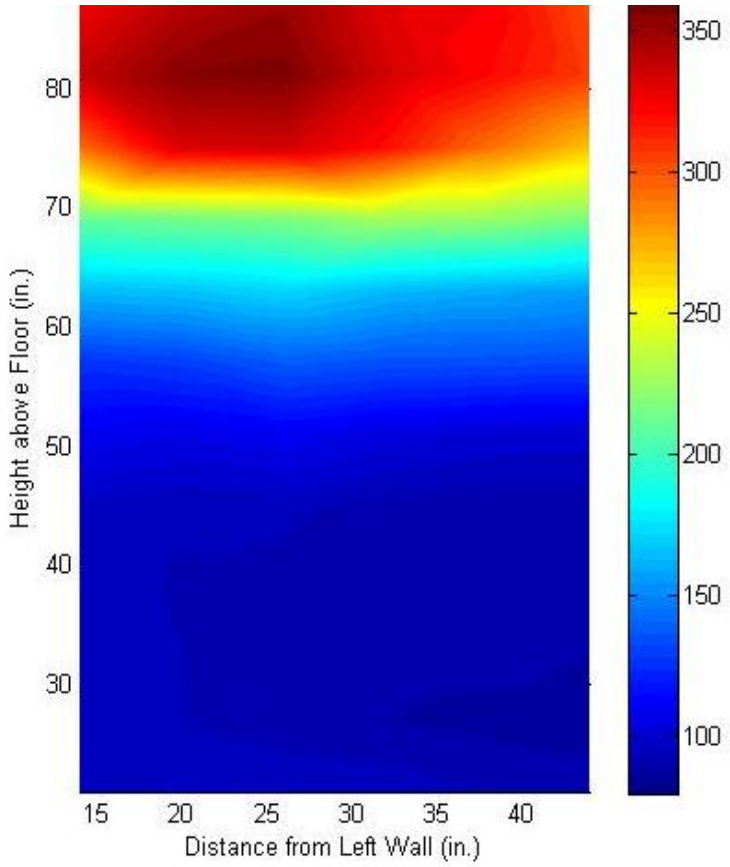
Air Seals OFF



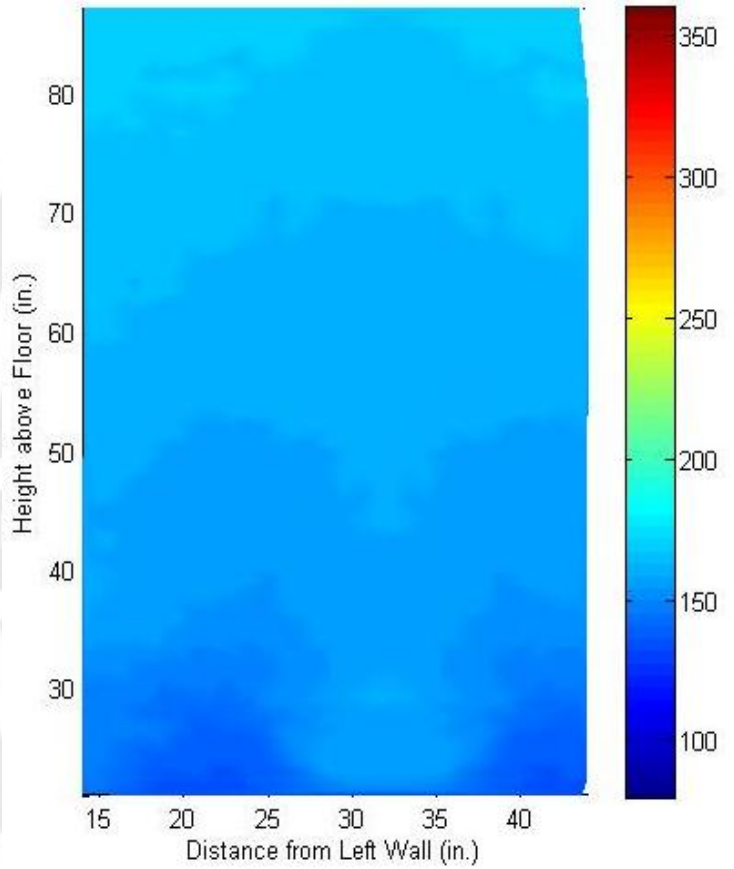
Air Seals ON

Experimental Validation

Profile Comparison, Air Seals OFF



Experimental data



Model results

Conclusions

- Designed and built test setup for accurate measurement of oven temperatures
- Quantified effects of current air seal solution:
  - Raised temperatures in lower regions of exit by as much as 20°F
  - Decreased peak temperatures in upper region of exit by around 10°F
  - Reduced temperature gradient across lower 75% of oven exit
- Present model requires refinement
- Boundary condition assumptions must be studied and reevaluated to improve accuracy

Future Work

Investigation of Boundary Conditions

- Hot air nozzle velocity and turbulence
  - Affects heat diffusion throughout oven
  - Difficult to measure directly
- Particle image velocimetry (PIV)
  - Utilizes high speed photography to gather images of illuminated particles entrained in flow
  - Statistical analysis of particle positions between images provides local fluid velocity vectors
- Laboratory model
  - Build a physical model representative of actual oven nozzle to side step difficulty of direct measurement issue

Acknowledgements

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Questions?


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Future Work

Investigation of Boundary Conditions

Example of PIV test setup for determining field flow characteristics

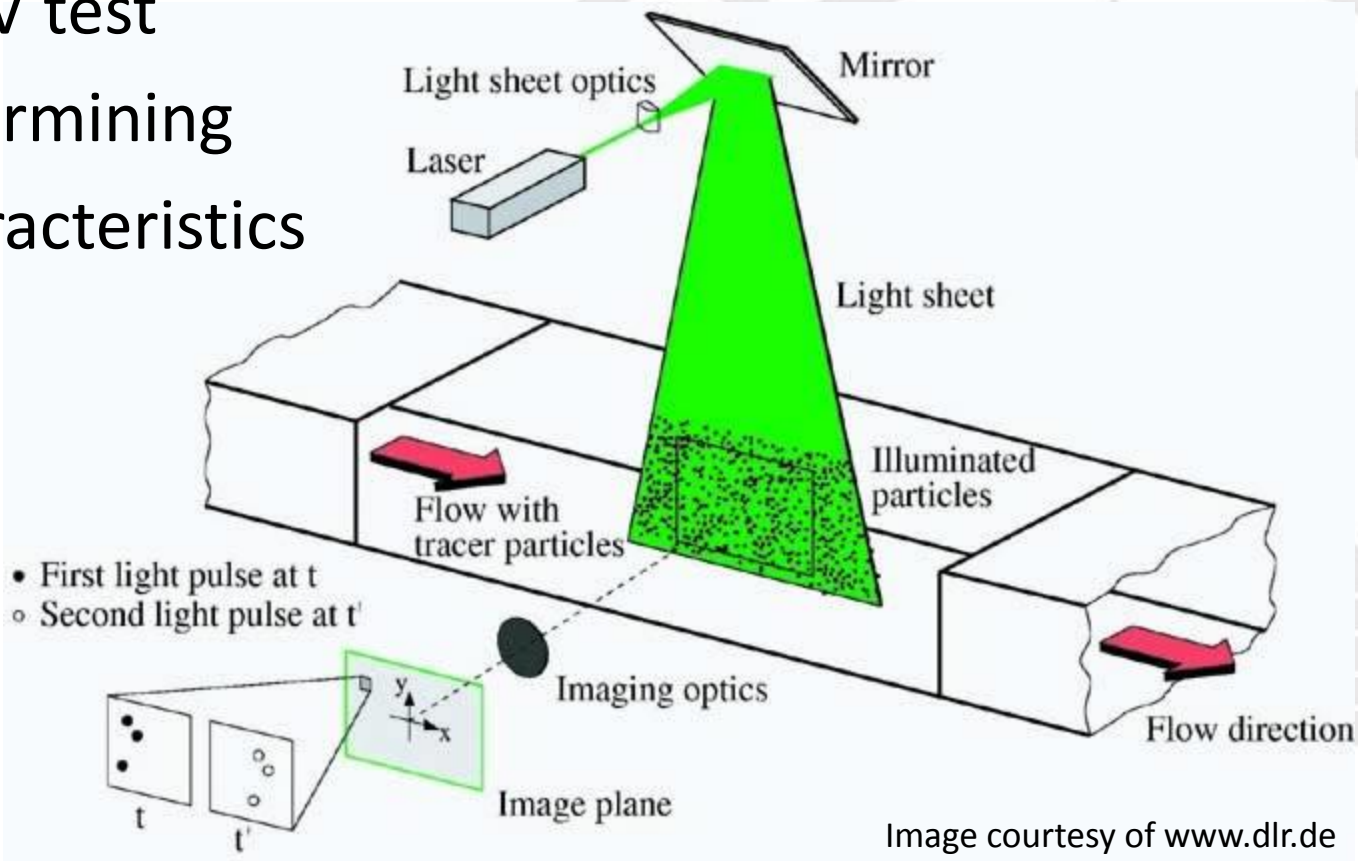
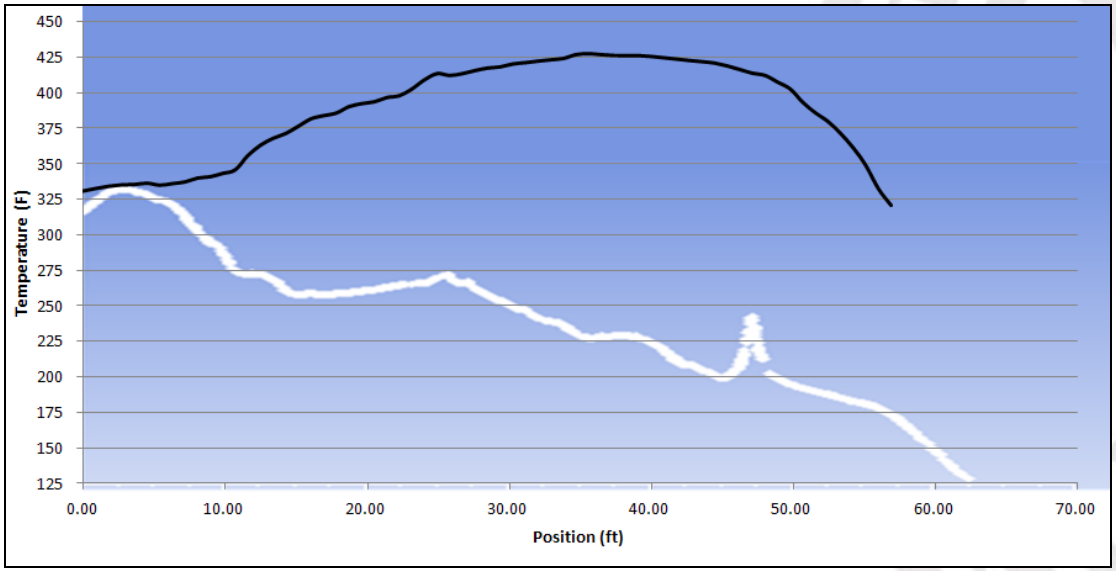


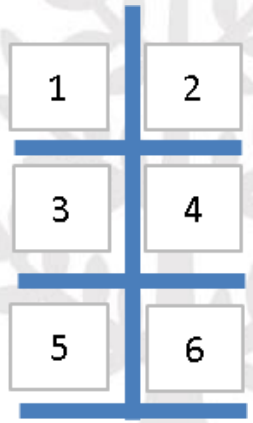
Image courtesy of www.dlr.de

Experimental Validation

End-to-End Temperature Measurement

- Lengthwise temperature through oven
  - Datapak DAQ system – provides temperature vs. time measurements
  - Experimental data compared with simulation results

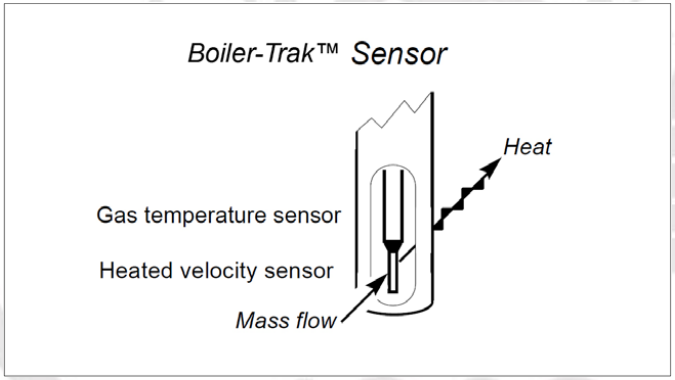




Temperature probe orientation; attached to product conveyor system

Energy Consumption Measurement

- Natural Gas Metering
  - Provides quantitative results of energy use
- Methods
  - Non-invasive
    - Convenient and portable
    - Low gas pressure limits use
  - Invasive
    - Single station use
    - Suited for current application



Photos courtesy of sierrainstruments.com and omega.com