Energy Saving Improvements for Industrial Ovens

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5/26/2011

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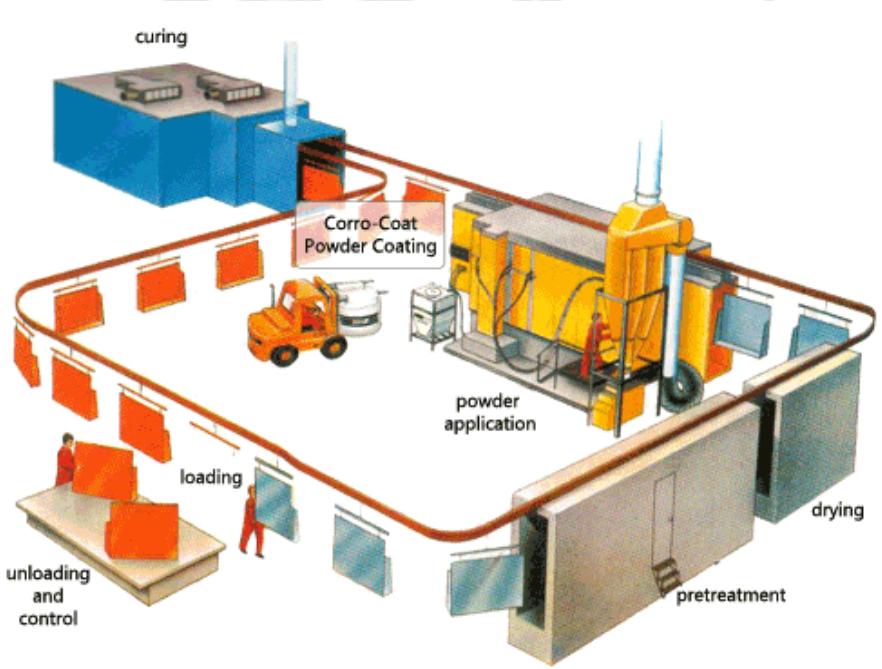
Project Overview

- Background
- Problem description
- Project goals
- Research methodology
  - Benchmarking
  - Development and validation of oven model
  - Parametric study
- Instrumentation requirements
- Budget
- Anticipated outcomes

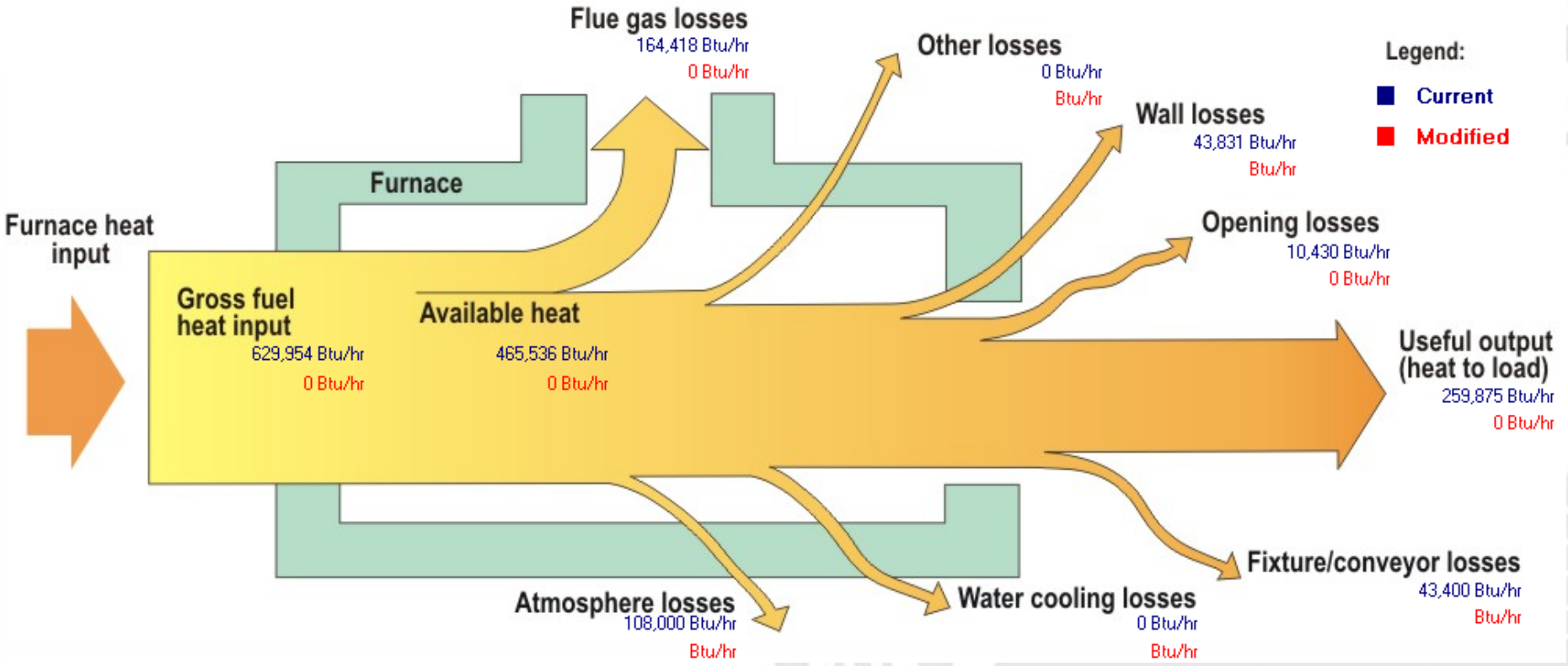
Background

- Continuous oven types
  - Curing
  - Drying
  - Annealing
  - Baking
- Energy sources
  - Fuel fired
  - Infrared



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

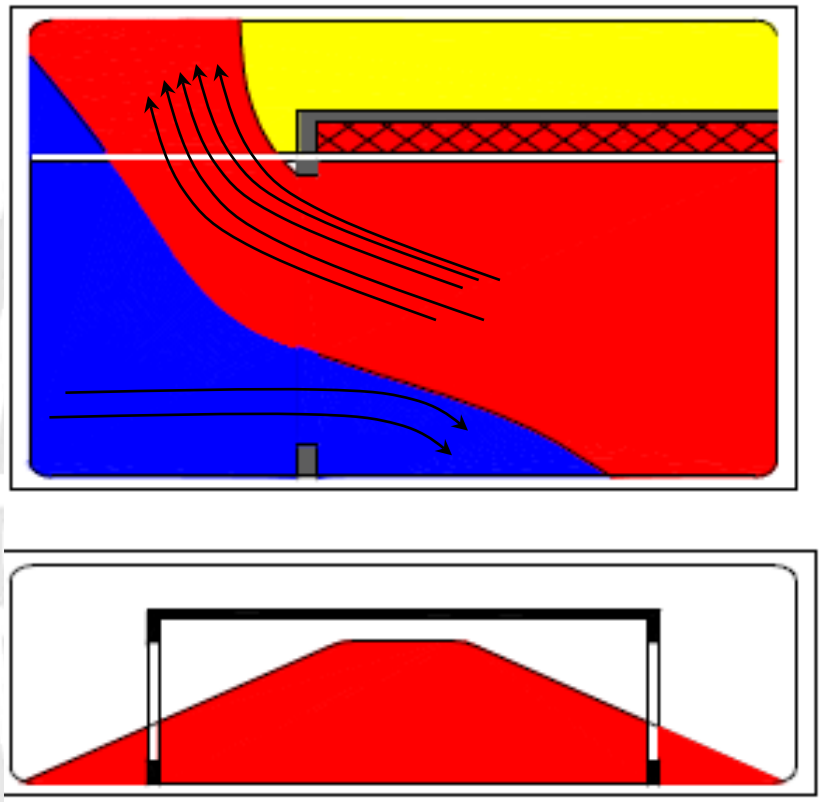
Pathways for Energy Loss



Senkey diagram of oven losses for powder coating cure oven using PHAST

Problem Description

- Heat escapes through oven door openings
- Current solutions lack analytical foundation



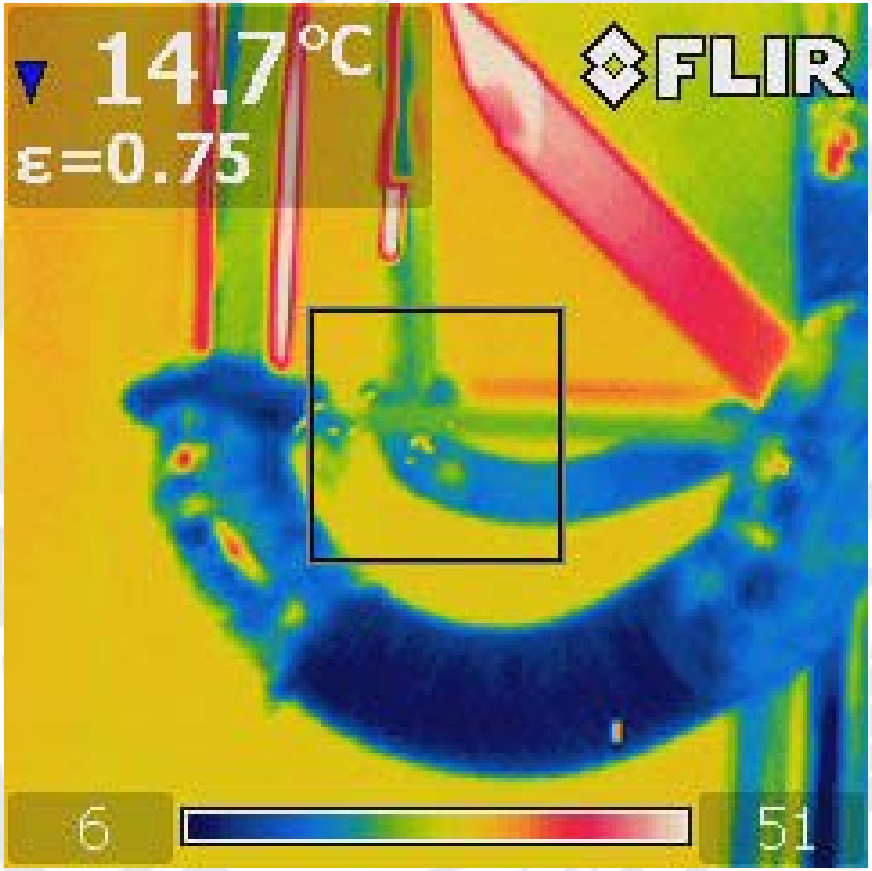
Picture courtesy of Industrial Technologies Midwest

Green Manufacturing Initiative

Pursuing Environmental, Energy and Economic Opportunities

Photo courtesy of Rapid-Line Manufacturing

Implemented Solutions



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

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

Goal and Objectives

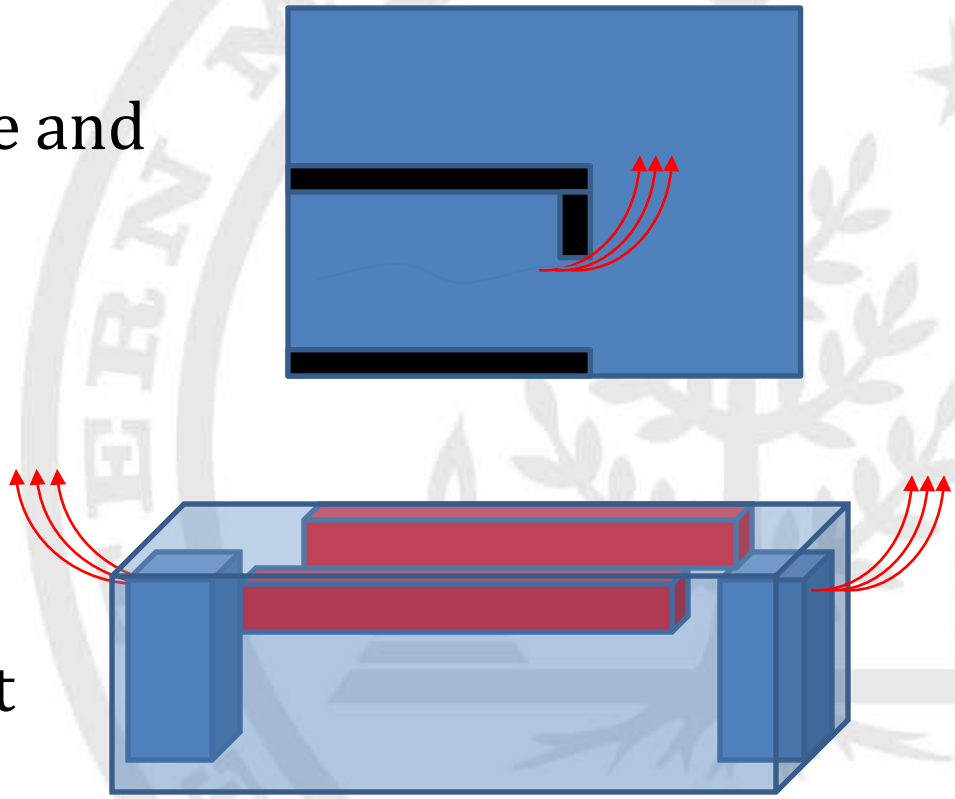
- Goal:
  - Devise a method for reducing energy consumption in industrial ovens
- Objectives
  - Develop an analytical approach to predict oven performance
    - Computational tools
  - Validate the proposed model with field data
    - Experimental tools
  - Evaluate changes to oven configuration
    - Design of experiments
    - Minimize energy use and cost of implementation

Benchmarking

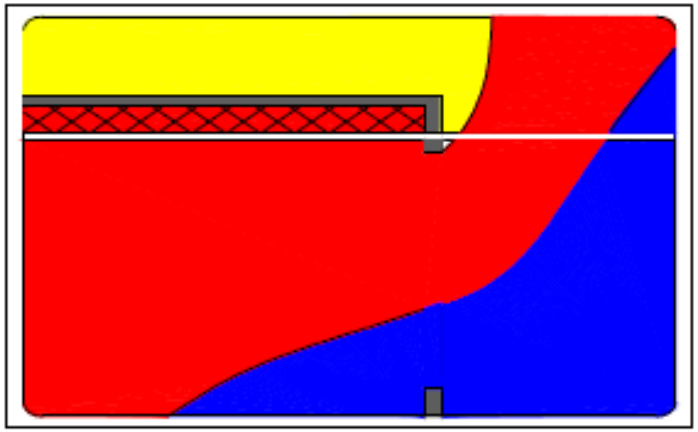
- Literature reviews
  - Ovens
    - Heat loss mechanisms and solutions
  - Modeling software
- Heat loss estimates
  - Case studies
    - Geometry
    - Energy consumption
    - Temperature and velocity profiles
  - PHAST analysis tool

Oven Model Development

- 2D
  - Simple geometry
  - Simulate temperature and velocity distribution
  - Concept validation
- 3D
  - Detailed geometry
  - Energy supply characteristics
  - Quantification of heat losses

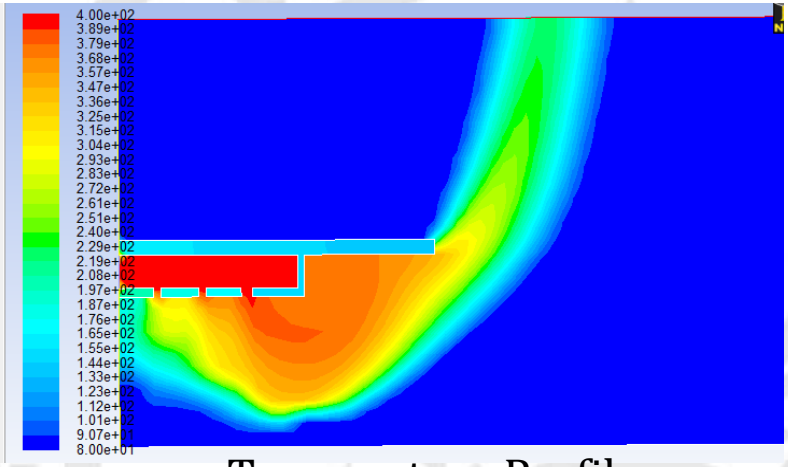


Initial 2D Results

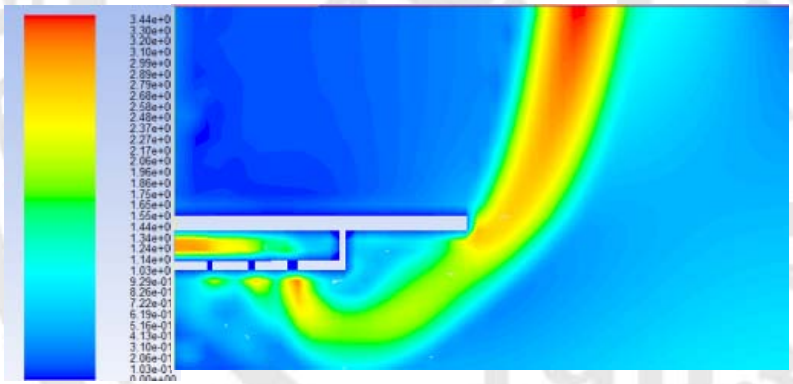


Picture courtesy of Industrial Technologies Midwest

2D Computational Fluid Dynamics (CFD) Oven Simulation



Temperature Profile



Velocity Profile

Model Validation and Use

- Validation by benchmark comparison
  - Spatial distribution of temperature and velocity
  - PHAST results
- Parametric study
  - Design of experiments approach
  - Oven seal geometry
  - Boundary conditions
- Improvement metrics
  - Energy usage
  - Temperature profile

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Instrumentation

Outline

- Measurements needed
- Potential measurement types
- Data acquisition system
- Budget Summary

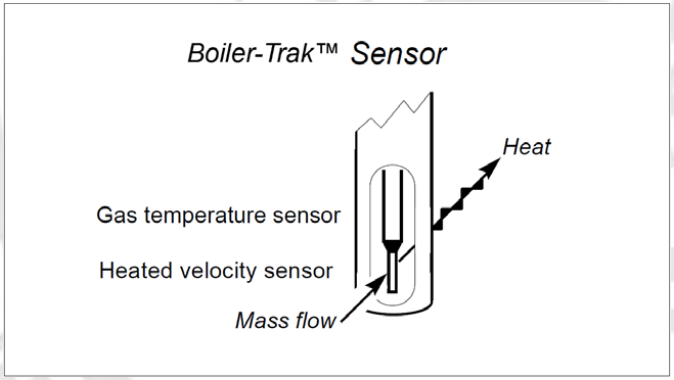
Measurements Needed

- Measurements needed
  - Flow rate
    - Natural gas
    - Up to 80 SCFM
    - Up to 150 ˚F
  - Temperature
    - Air
    - Up to 450 ˚F
  - Velocity
    - Mean air velocity (up to 50 ft/s)
    - Turbulence

Natural Gas Metering

- Invasive
  - FTB937 Gas Turbine
    - 6 – 100 ACFM
    - ~$1300 plus installation
  - Boiler-trak
    - Mass flow rate
    - ~$1500 plus installation

Photo courtesy of omega.com



Photos courtesy of sierrainstruments.com

Natural Gas Metering

- Non-Invasive
  - GE Panametrics PT878 Portable Ultrasonic Flow Meter
    - $700/wk
    - $1,500/mo.
    - $7,500 purchase

Photos courtesy of ge-mcs.com

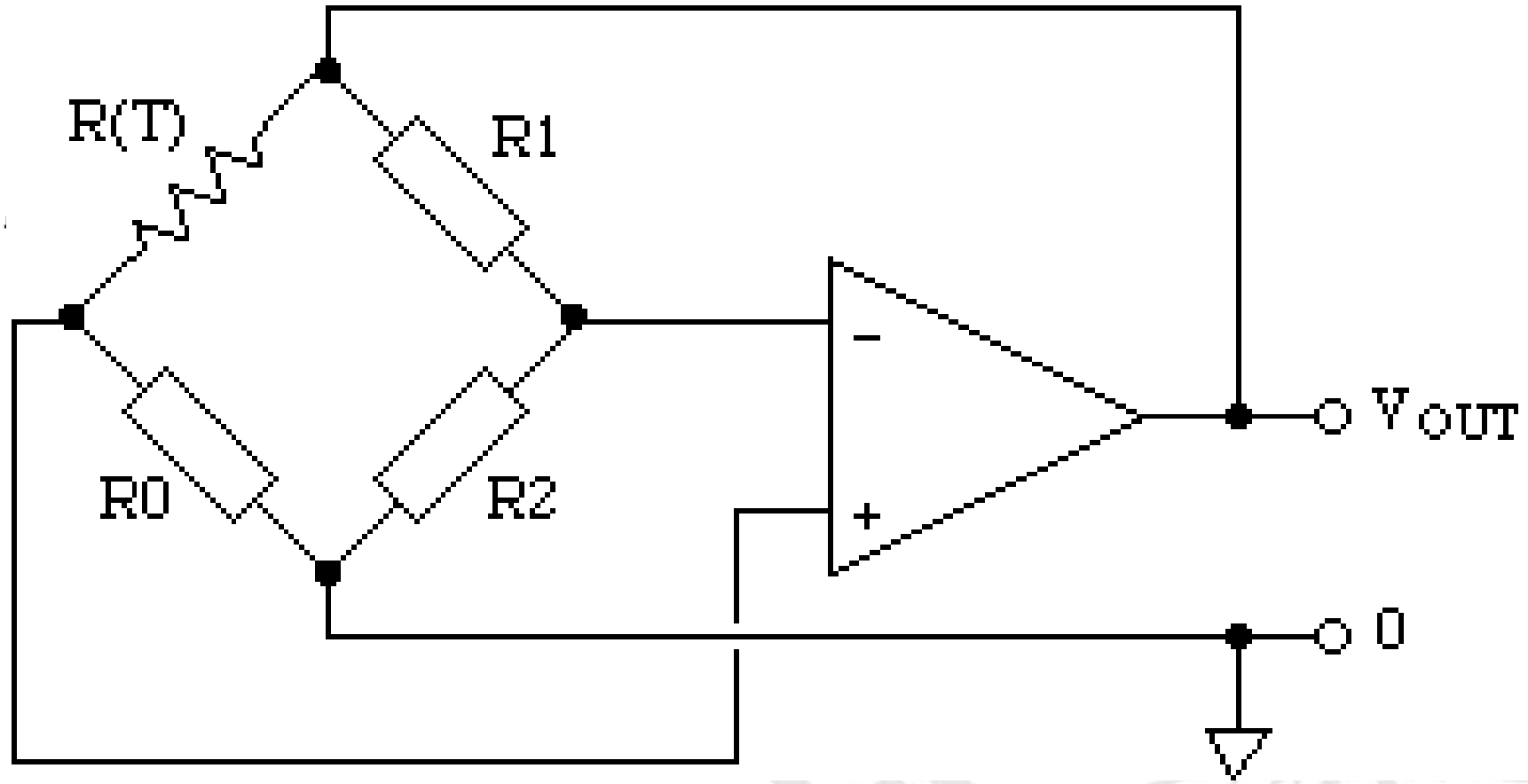
Measuring Temperature

- Thermocouples

Model No. ANSI Color Code	# of Thermocouples	Diameter mm (in)	Insulation	Total Cost	Unit Cost
5TC-GG-K-24-240	5	0.51 (0.020")	Glass Braid	$113.00	$22.60

- (20) Thermocouples needed: $452 min.

Measuring Air Velocity

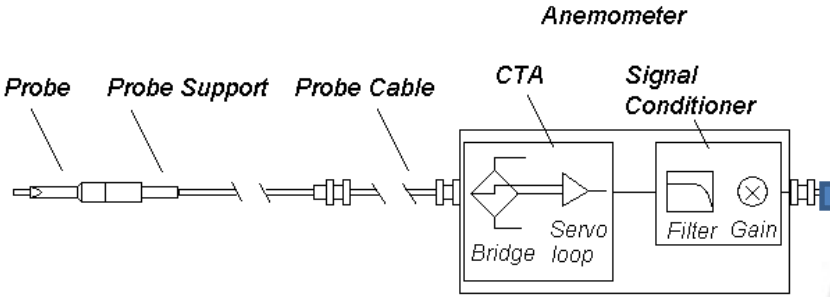


Photos courtesy of Dantec Dynamics

Measuring Air Velocity

- Hot Wire Anemometry Equipment Cost
  - Probe: $700
  - Probe support: $350
  - Electronics: $5,600

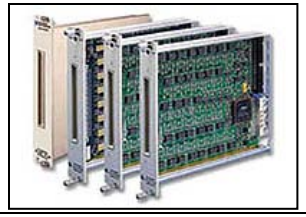
Data Acquisition System



Terminal Block

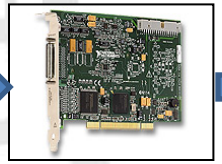
Adapter

Thermocouples, Gas Metering

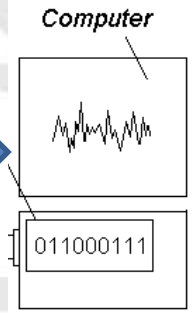


NI SCXI-1102
32-Channel
Thermocouple/Voltage
Input Module

SCXI 1000 Chassis



PCI-6221 DAQ Card



Data Acquisition System

DAQ card (NI PCI 6221)	$1,050.00
SCXI Chassis (SCXI 1000)	$900.00
32-Channel Thermocouple/Voltage Input Module (NI SCXI -1102)	$1,600.00
Isothermal terminal block (SCXI 1304)	$300.00
SCXI Adaptor (SCXI 1349)	$110.00

Low Cost Budget

Instrument	Cost	Subtotal	Supplier	NOTES/ASSUMPTIONS	Objective
Flow meter	$1,500.00		Boiler Trak	INVASIVE. Measures mass flow rate, does not include installation costs	Benchmark oven energy consumption
	Energy/flow meter	**$1,500**			
Thermocouples	$450.00		Omega.com		Measure temperature at oven outlet
Thermocouple wire	$200.00		Omega.com		
	Temperature	**$650**			
DAQ card (NI PCI 6221)	$1,050.00		NI		
SCXI Chassis (SCXI 1000)	$900.00		NI		
32-Channel Thermocouple/Voltage Input module (NI SCXI -1102)	$1,600.00		NI		
Isothermal terminal block (SCXI 1304)	$300.00		NI		
SCXI Adaptor (SCXI 1349)	$110.00		NI		
	Data Acquisition	**$3,960.00**			
Two hot film probes	$1,400.00		Dantec or TSI	Assumes we can use electronics in fluids lab	Measure air velocity at oven outlet
Probe support	$700.00		Dantec or TSI		
	Velocity	**$2,100.00**			
Material for traverse mechanism	$600				
Laptop	$1,200.00			If not available through GMI	
Labview license	$ -			Assumes it's available for student Master thesis	
FLUENT license	$ -			Assumes it's available for student Master thesis	
	Other	**$1,800**			

GRAND Total $9,360.00

Alternative Budget

Instrument	Cost	Subtotal	Supplier	NOTES/ASSUMPTIONS
Flow meter for energy consumption	$7,500.00	$1600 monthly rental/$700 per week	GE	NON INVASIVE. Velocity, need temperature measurement
	Energy/flow meter	**$7,500**		
Thermocouples	$850.00		Omega.com	
Thermocouple wire	$200.00		Omega.com	
	Temperature	**$1,050**		
DAQ card (NI PCI 6221)	$1,050.00		NI	
SCXI Chassis (SCXI 1000)	$900.00		NI	
32-Channel Thermocouple/Voltage Input module (NI SCXI -1102)	$1,600.00		NI	
Isothermal terminal block (SCXI 1304)	$300.00		NI	
SCXI Adaptor (SCXI 1349)	$110.00		NI	
	Data Acquisition	**$3,960**		
Two hot film probes	$1,400.00		Dantec or TSI	
Probe support	$700.00		Dantec or TSI	
Electronics	$5,600.00		Dantec or TSI	
	Velocity	**$7,700**		
Material for traverse mechanism	$600			
Laptop	$1,200.00			
Labview license	$ -			Assumes it's available for student Master thesis
FLUENT license	$ -			Assumes it's available for student Master thesis
	Other	**$1,800**		

Minimum **$15,910.00**

Maximum **$22,010.00**

Gas meter rented twice for a week each time

Purchase non invasive gas meter

Funding Options

- Grants
  - DOE Basic Energy Sciences
  - CE and DTE Foundations
  - WMU Research
- Interested companies

Anticipated Outcomes

- Documented, measurable and cost justifiable improvements at two or more installations
  - 3D CFD Model
    - Verifies problem
    - Illustrates solution to oven heat loss problem
    - Quantifies improvement
    - Provides a robust approach for evaluating other solutions
  - Solution Evaluation
    - Effectiveness in solving current problem
    - Cost of implementation

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Questions?