THERMAL IMAGING CONTROL OF FURNACES AND COMBUSTORS

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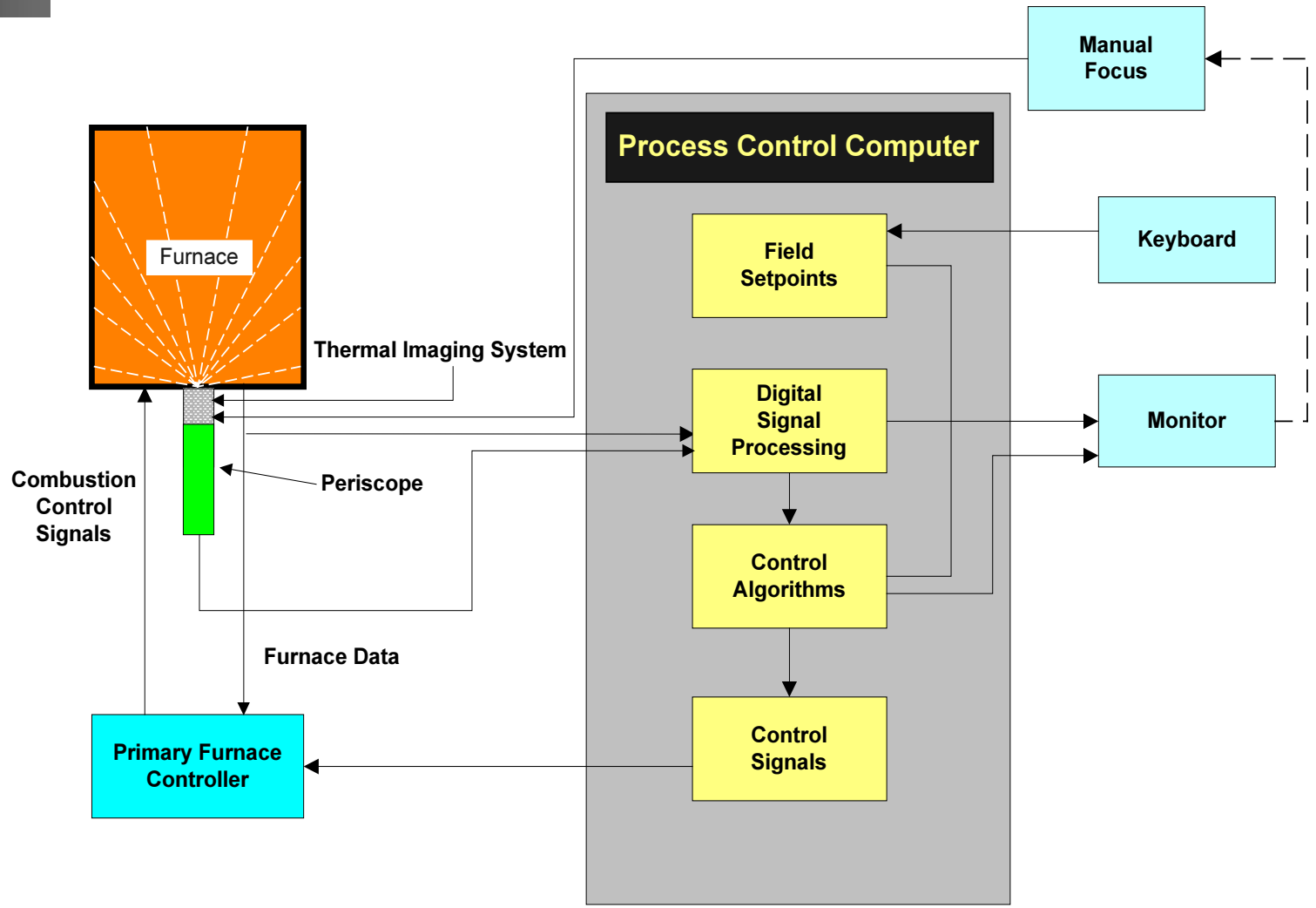
Project Description



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Project Team

- **Gas Technology Institute**
  - control system development and testing
- **U. of Illinois at Chicago**
  - control algorithm development and control system design
- **Owens Brockway Glass Containers**
  - End user guidance, potential host site
- **IEM, Corp.**
  - Potential licensee
- **Gas Research Institute (GRI)**
  - direction and funding support
- **U.S. DOE**
  - direction and funding support through OIT Sensors and Controls

Project Objectives/Goal

- **IOF need(s) addressed by this technology**
  - Higher energy efficiency -- lower emissions
  - Improved product quality -- longer furnace life
- **Objectives**
  - Demonstrate technology in the laboratory
  - Design and fabricate an industrial demonstration unit
  - Test the thermal imaging and control technology industrially
  - Find a partner to commercialize the technology
- **Overall goal**
  - The objective of this project is to demonstrate and bring to commercial readiness a near-infrared thermal imaging control system for high temperature furnaces and combustors.

Technical Risks/Innovation

- **Technical risks**
  - Hardware – reliable, low cost dual wave IR imaging system
  - Software – fast processing to give temperature map and information in the format needed for control
- **Innovation**
  - Thermal imaging of multiple surfaces at any angle to the camera over a wide temperature range of 500 to 2000°C
- **Advancement of state-of-the-art; over competition**
  - Advanced data handling and display
  - Near-real time (1-2 sec) with no emissivity data required
  - Data presentation in format for control
  - User interface for multi-point setpoints

Task Performance

Past Technical Milestones

Milestone	Due Date	Completion Date	Comments
Select furnace types for thermal imaging / control	Apr 99	Apr 99	Done
Survey available sensors and thermal imaging systems	May 99	May 99	Done
Survey furnace control systems	Jun 99	Jun 99	Done
Select thermal imaging control system components	Sep 99	Sep 99	Done
Review control algorithms	Oct 99	Oct 99	Done
Set up and conduct laboratory tests	Dec 99	Dec 99	Done

Task Performance

Past Technical Milestones

Milestone	Due Date	Completion Date	Comments
Design complete bench-scale thermal imaging / control system	Nov. 00	Mar 01	Done
Install thermal imaging / control system on bench-scale furnace	Mar. 01	May 01	Done
Complete lab-scale testing and data analysis	May 01	Aug. 01	Done

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Laboratory Test Furnace

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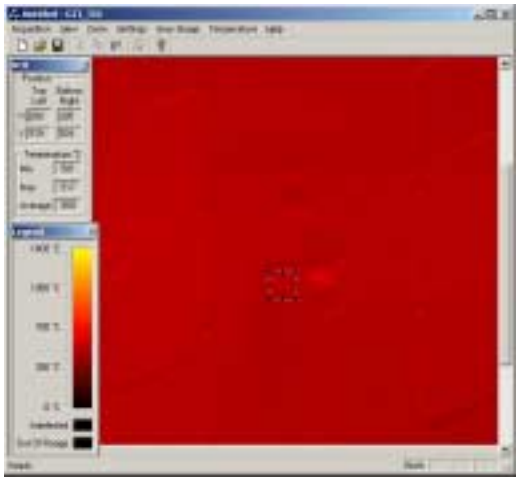
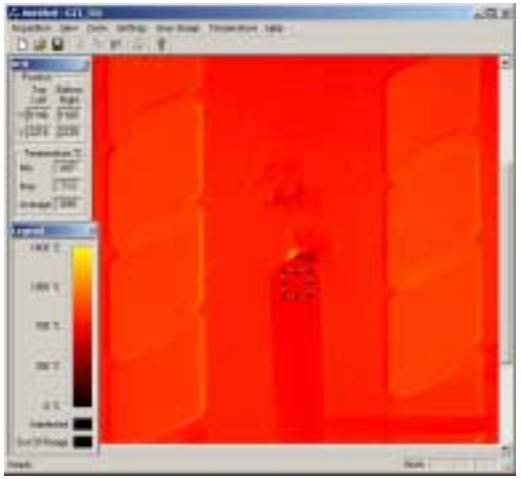
Expanded Temperature Range

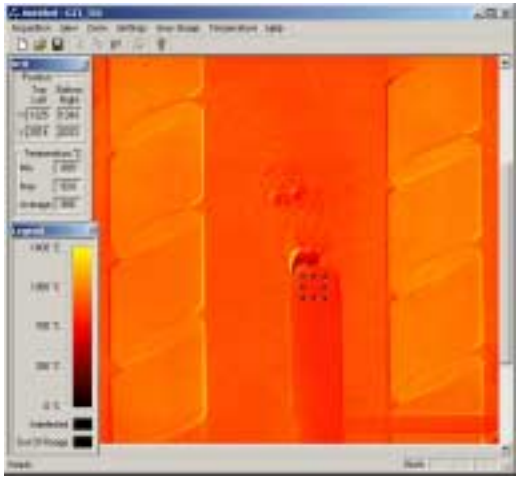
500°C
932 F



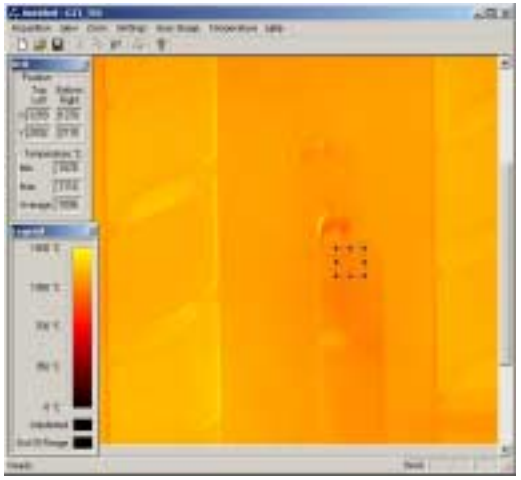
700°C
1292 F



900°C
1652 F



1100°C
2012 F



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Thermal Imaging System –
Bench-Scale Testing

GTI Heat Treating Furnace

Bench-Scale Thermal Imaging System Hardware

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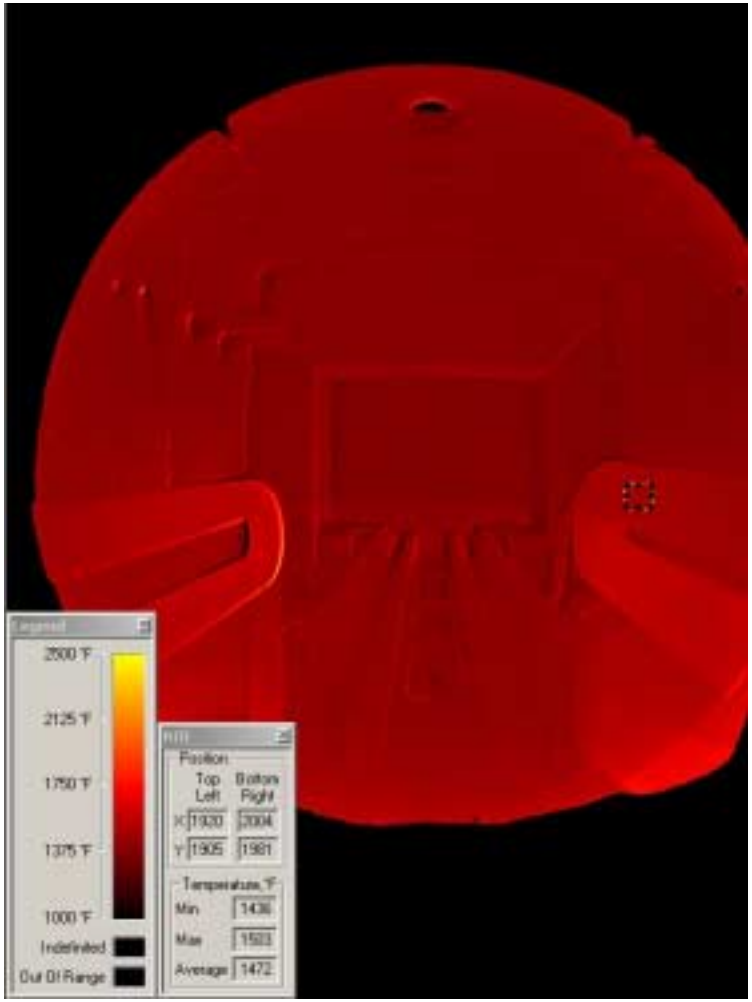
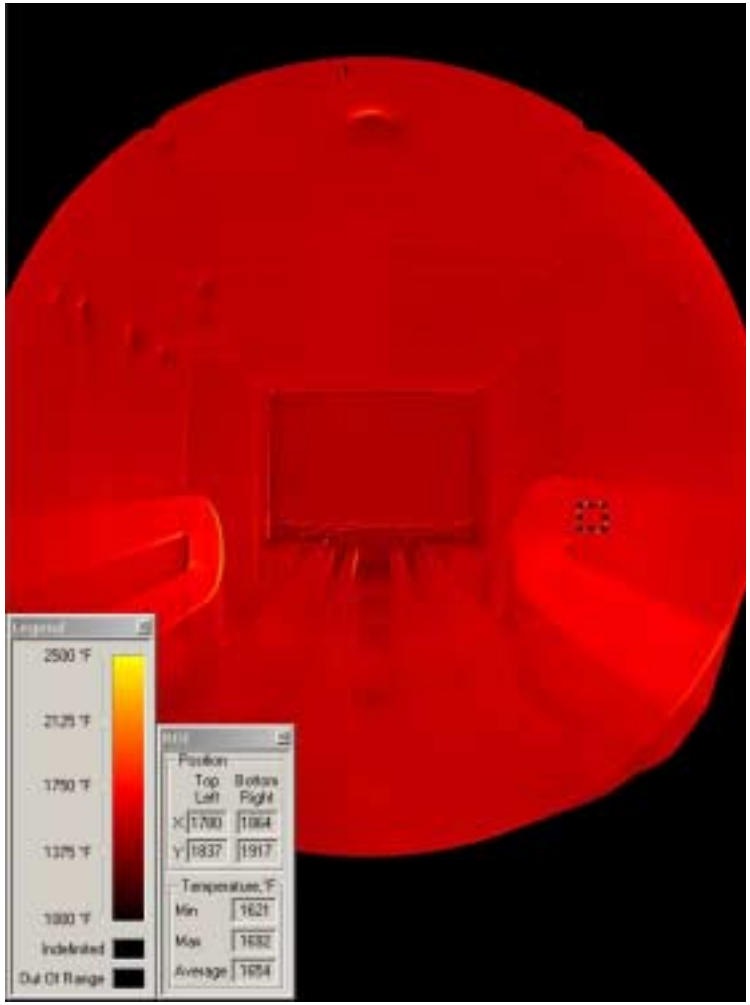
Heat Treat Tube Thermal Images





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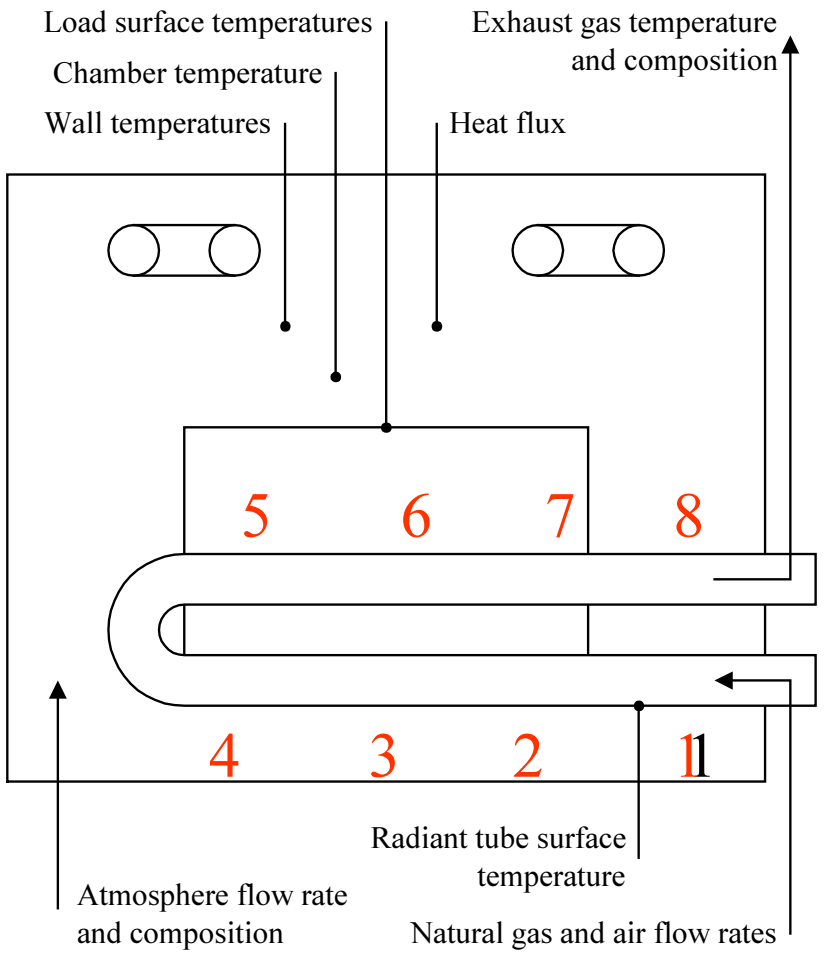
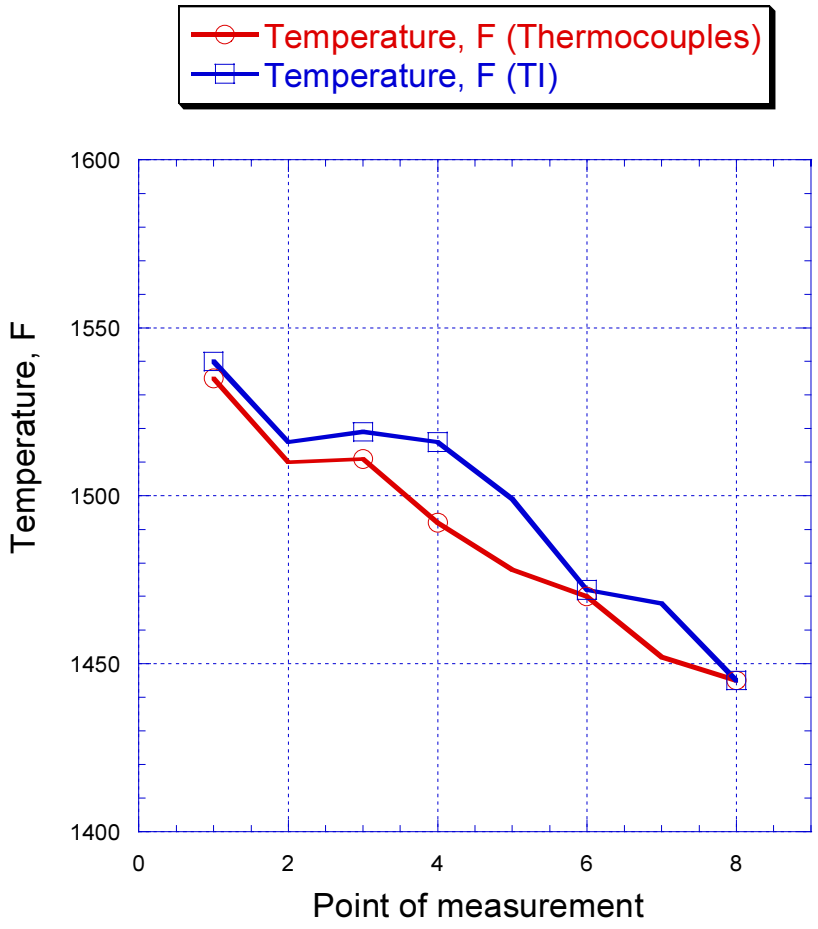
Radiant Tube Temperature Profile





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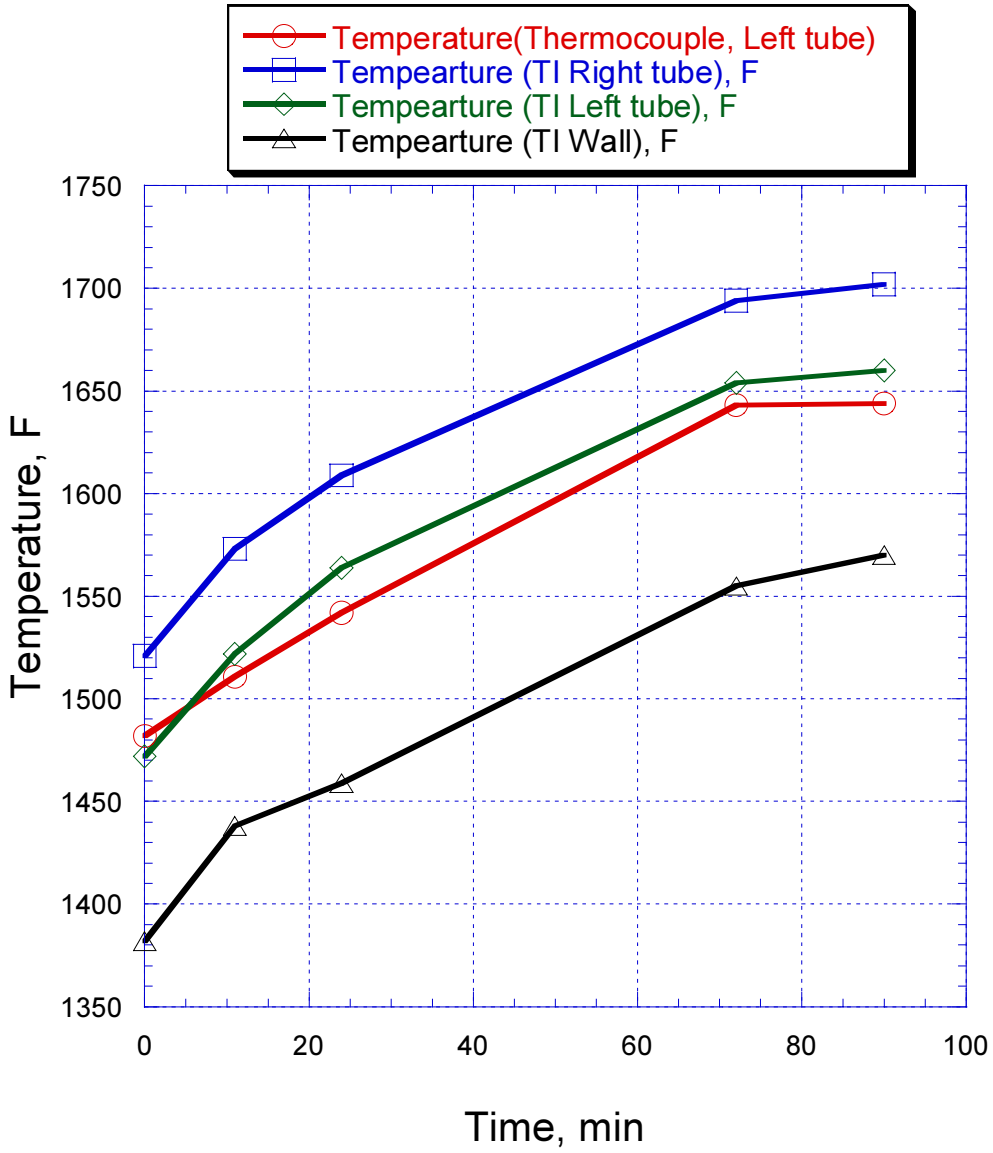

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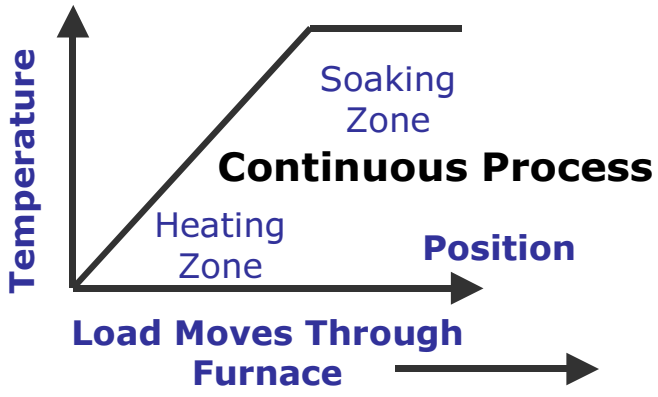
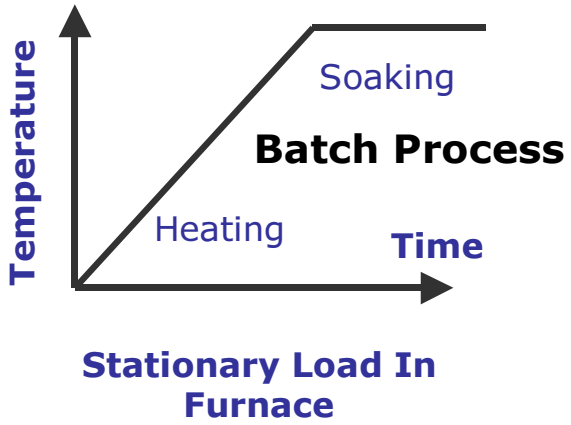
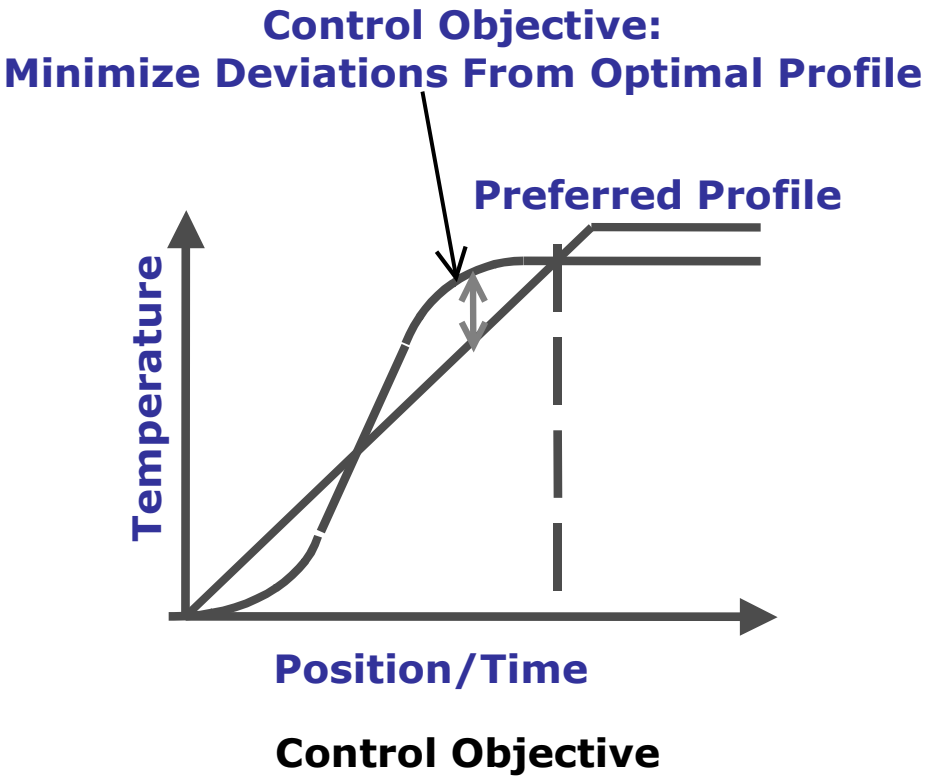
Process Types and Control







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Process Heating and Control

- **Continuous furnaces**
  - Load experiences desired thermal profile in passing through furnace
- **Batch furnaces**
  - Load experiences desired thermal profile by adjusting heat input to the furnace as needed
- **Control loop**
  - Sensor – field thermal imaging data acquired in near real time for input as multi-point data into control loops
  - Process tracking – following the thermal profile of the full load and comparing with the desired thermal profile
  - Feedback to independent inputs – air/fuel to individual burners, distribution of fuel between burners, speed of valve opening/closing, etc.

Sensor and Control Approach

- **Thermal imaging sensor**
- **Controlled**
  - Performance index – temperature, etc.
  - Instabilities, turn-down ratio
- **Control approach**
  - Identify constraints on performance indices
  - Minimize performance indices
    - Locally – for all cells – inner loop
    - Globally – for the furnace – outer loop
  - Develop control configuration in terms of output feedback using sweeping and singular-value decomposition

Commercialization

- **Proposed plant tests/deployments, and planned use in IOF manufacturing plant(s)**
  - Demonstration of pilot version of TIS on heat treating or forging furnace during 2002, with support from IEM, Corp. and UIC
- **Commercialization path & partners**
  - Partner – IEM, Corp. of Albany, NY
  - International Electronic Machines develops, manufactures, and markets rugged multimedia solutions, cameras, industrial computers, gauges, internet solutions, data acquisition, communications and data processing equipment for a variety of industries.
  - GTI and IEM will conduct an industrial field test
  - IEM will begin work of converting TIS to a commercial product
  - Gas industry funds are assisting transfer of TIS from lab to commercial product

Performance Merits

- **Reducing energy consumption and emissions**
  - Energy savings will be realized from lower heat losses with exhaust gases and operation of burners at optimum heat transfer conditions
  - Emissions will be reduced by operating furnaces and process heaters at optimum conditions over the full turn down ratio
  - High CO and NO_x production regimes can be avoided
- **Reduction levels**
  - NOx – up to 30%
  - Energy consumption – 5%
  - CO – up to 5%
  - CO2 – up to 5%
  - These levels will vary between furnaces since the TIS technology can be applied to many different industrial furnaces

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Performance Merits

				Reductions, 20% of market			
Industry	Application	Production, 10^6 ton/y	Total Fuel, 10^{12} Btu/y	Fuel, 10^{12} Btu/y	CO_2, Ton/y	CO, ton/y	NO_x, ton/y
Steel	Reheating	90	144	1.44	83,600	13.6	2,160
Steel	Continuous Anealing	22	19.8	0.2	11,600	1	99
Steel	Batch Annealing	8	8	0.08	4,600	0.4	12
Aluminum	Remelting	3.5	7	0.07	4,100	0.2	4
Glass	Melting	30	120	1.2	69,700	22.4	600
Chemicals	Ethylene Cracking	6	50.4	0.5	29,000	1.2	27
Metal Casting	Heat Treating	60	60	0.6	34,800	12	360
	Total		410	4.1	237,400	50.8	3.262

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Performance Merits

- **Improving product quality**
  - Product quality will be improved by optimizing the time-temperature profile of ALL elements of the load in either a continuous or a batch process
- **Quantifying the improvement**
  - Product properties altered by time-temperature history will be measured
  - Fraction of product not meeting specifications will be recorded over time

Performance Merits

- **Improving productivity**
  - Operation at optimum furnace or process heater conditions allows less down time
  - Furnace life is extended by reduction of hot and cold spots on furnace walls
- **Quantifying productivity improvements**
  - Recording furnace or process heater production over extended periods of time
  - Furnace and/or refractory life between rebuilding

Performance Merits

- **Reducing costs**
  - Less waste – more product processed to specifications
  - Lover energy consumption (up to 5%)
  - Lower emissions treatment costs (CO and NO_x reductions)
  - Longer furnace and refractory life

- **Cost savings**
  - Up to 5% of fuel costs
  - Other savings are furnace and process specific and difficult to quantify as a group

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Performance Merits

- **Minimizing waste**
  - The thermal imaging control technology can reduce wastes in a number of different industrial furnaces
  - More product can meet quality specifications and waste is minimized because furnaces and process heaters can be operated at optimum conditions over the full processing cycle

- **Quantifying waste reductions**
  - During field testing, product quality and amount of product waste not meeting specifications will be monitored
  - The percentage of waste minimized will be quantified relative to furnace operation without the TIS system

Path Forward

Future Technical Milestones

Milestone	Due Date	Completion Date	Comments
Complete control component for bench-scale furnace	Aug. 2001	Jun 02	In Progress
Demonstrate thermal imaging and control on bench-scale furnace	Sept. 01	May 02	Done – In Progress
Complete field system design	Nov. 01	Aug 02	In Progress
Install thermal imaging control system on industrial furnace(s)	Jan. 02	Oct 02	Later
Complete field testing and data analysis	Mar 02	Nov 02	Later

Path Forward

- **Next steps**
  - Joint GTI – IEM industrial field test
  - Submission of proposal to NYSERDA for New York state demonstration project
  - Conversion of hardware to commercial components by IEM
  - Integration of control algorithms into a commercial PLC-type unit capable of interfacing with furnace controllers
  - Demonstration of commercial prototype TIS in New York state
  - Possible field test sites are heat treating and forging furnaces
  - Final licensing arrangements made between GTI and IEM
  - Marketing, sale, and installation of TIS by IEM
- **Go/no-go consideration(s)**
  - The project team is requesting a no-cost time extension from DOE (until 12/31/02) to complete field testing and analysis

Coordinated Projects

- **GTI, with gas industry FERC support, is developing a suite of combustion sensors**
  - Thermal imaging
  - Flame rich and lean zones
  - Flame temperature
  - Flame species
- **All sensors utilize passive spectroscopic methods to monitor characteristics of combustion performance in real time inside the furnace or process heater**
- **For each industrial process**
  - The best 'multi-point' sensor is selected to work with GTI-developed control algorithms and the furnace controller
  - The objective is local and global optimization