S&A FY03 ANNUAL REVIEW MEETING

THERMAL IMAGING CONTROL OF FURNACES AND COMBUSTORS

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Project Overview

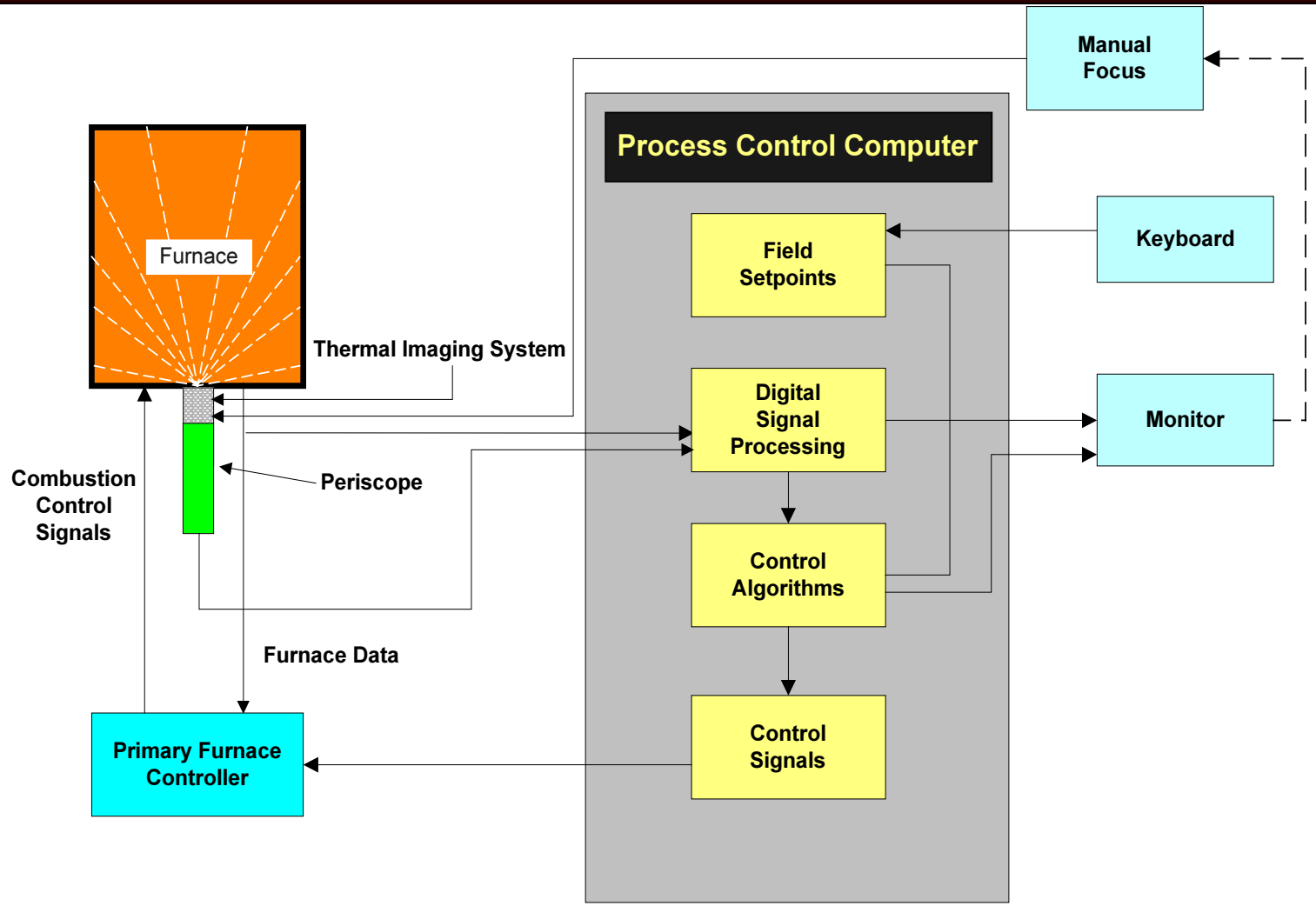
- **Project description**
  - Dual wavelength near-IR thermal imaging system developed in the laboratory, demonstrated in the lab, and demonstrated on several industrial furnaces

- **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.

Project Description



Technical Merit

- **Addresses technical need(s) of the S/C community and the S/C priorities of the IOFs**
  - Higher energy efficiency -- lower emissions
  - Improved product quality -- longer furnace life

Directly addresses industry needs

Glass, steel, aluminum – seeing and eliminating hot spots and improving temperature uniformity extends furnace life, improves efficiency, and lowers emissions

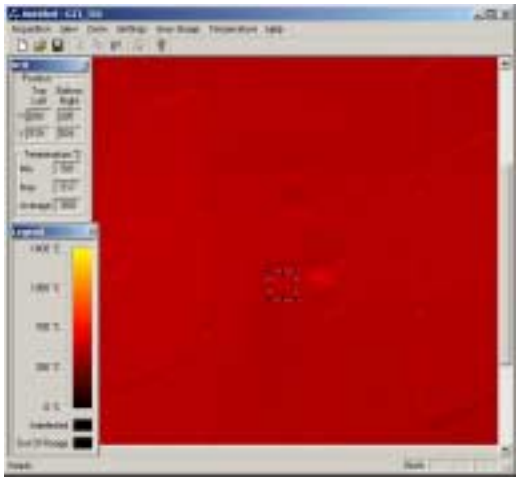
Chemicals – temperature uniformity in process heaters with many burners improves product quality while also extending furnace life and maintaining low NOx emissions from many burners at once

Technical Merit

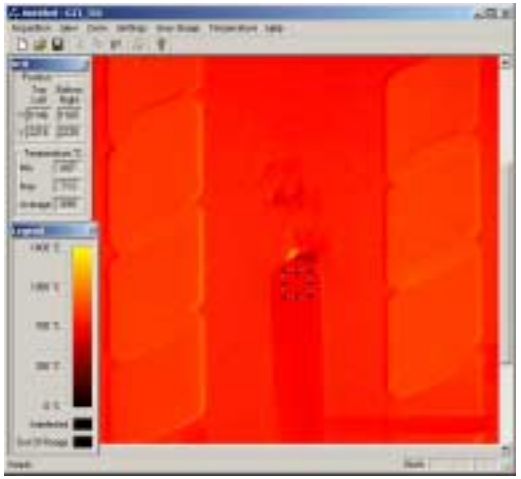
- **Contributes a critical, significantly advanced technology to the S/C community**
  - Increases the temperature range (500 to 2000°C) of industrial thermal imaging systems
  - Provides output in a format useful to furnace control systems because temperature information can be averaged, summed over defined areas, or compared directly with a desired temperature ‘map’
  - Temperature and video images can be obtained simultaneously, providing a dual sensor function, making the technology simultaneously more useful and more cost effective

Expanded Temperature Range

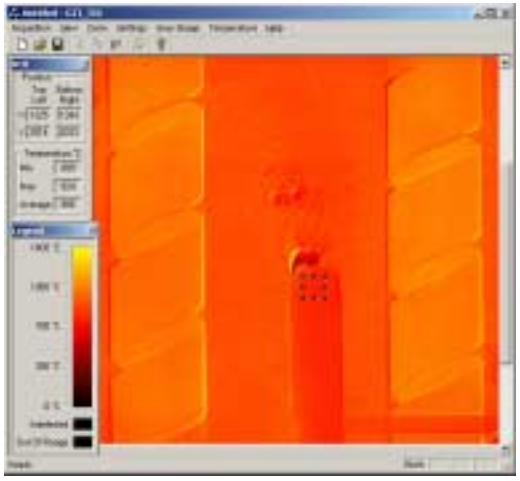
500°C



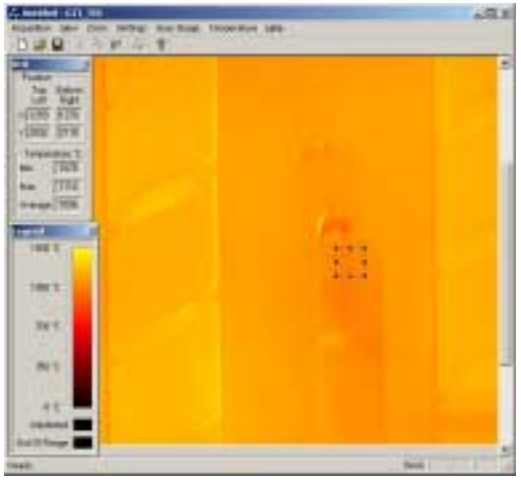
700°C



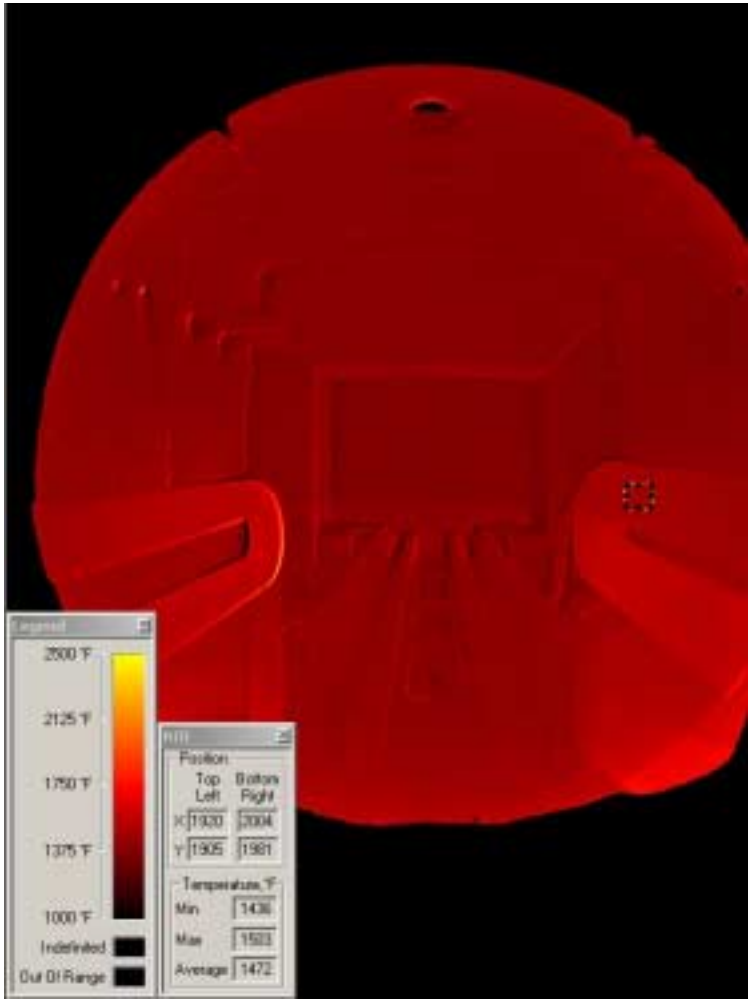
900°C

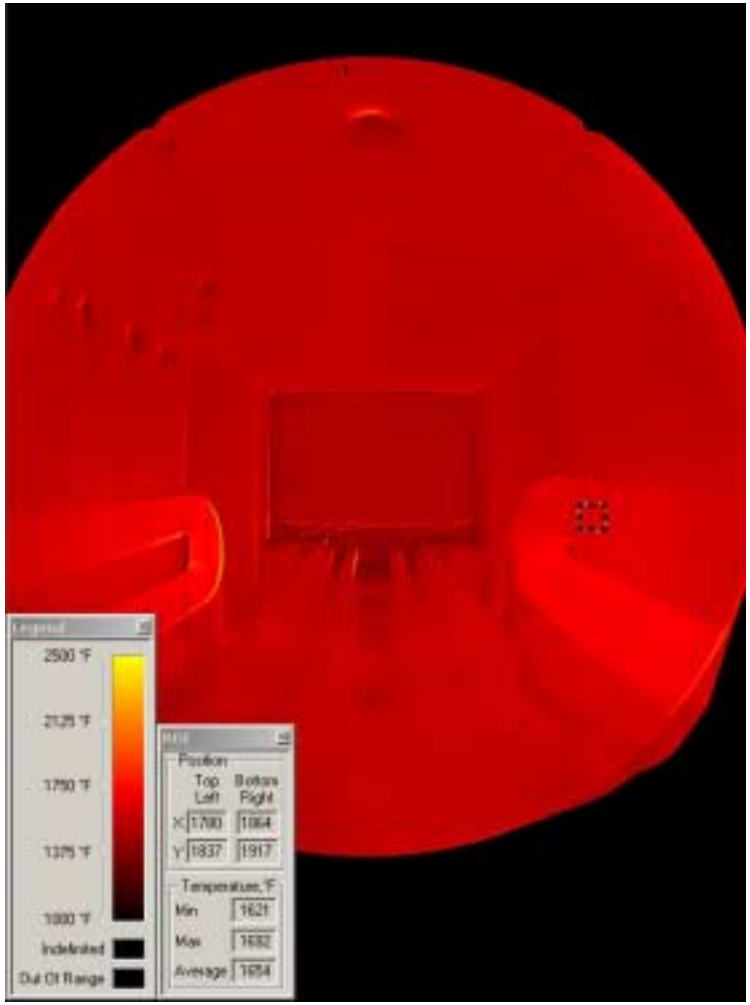


1100°C



Heat Treat Tube Thermal Images





Technical Progress and Outlook

Technical Milestones

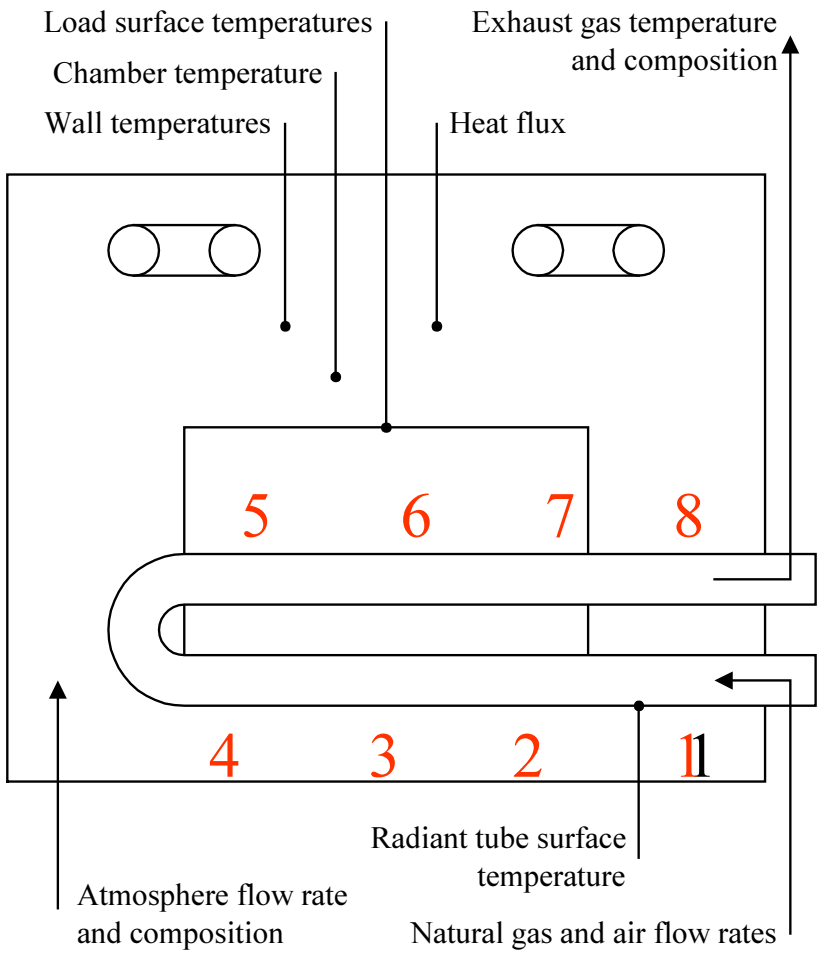
Milestone	Comments
Complete control component for bench-scale furnace	In Progress
Demonstrate thermal imaging and control on bench-scale furnace	Done on a GTI heat treating furnace
Complete field system design	Done
Install thermal imaging control system on industrial furnace(s)	Planned for summer 2003 on two Owens Illinois glass furnaces – a regenerative air-gas melter and an oxy-gas melter
Complete field testing and data analysis	Summer 2003

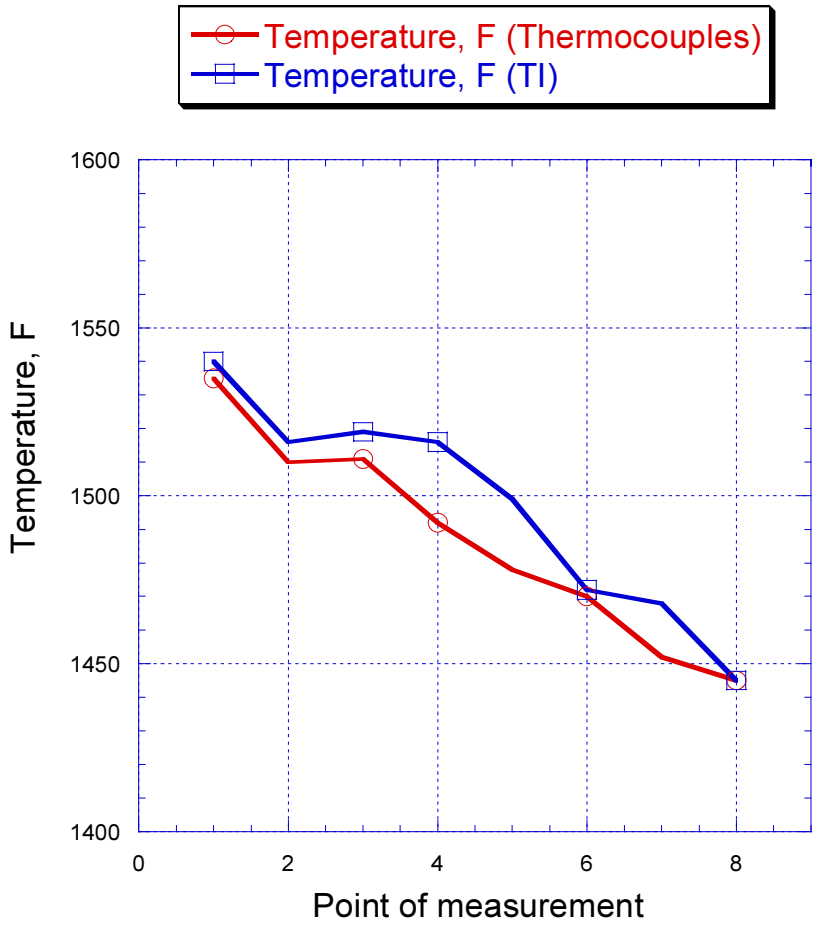
Thermal Imaging System – ***Bench-Scale Testing***

GTI Heat Treating Furnace

Bench-Scale Thermal Imaging System Hardware

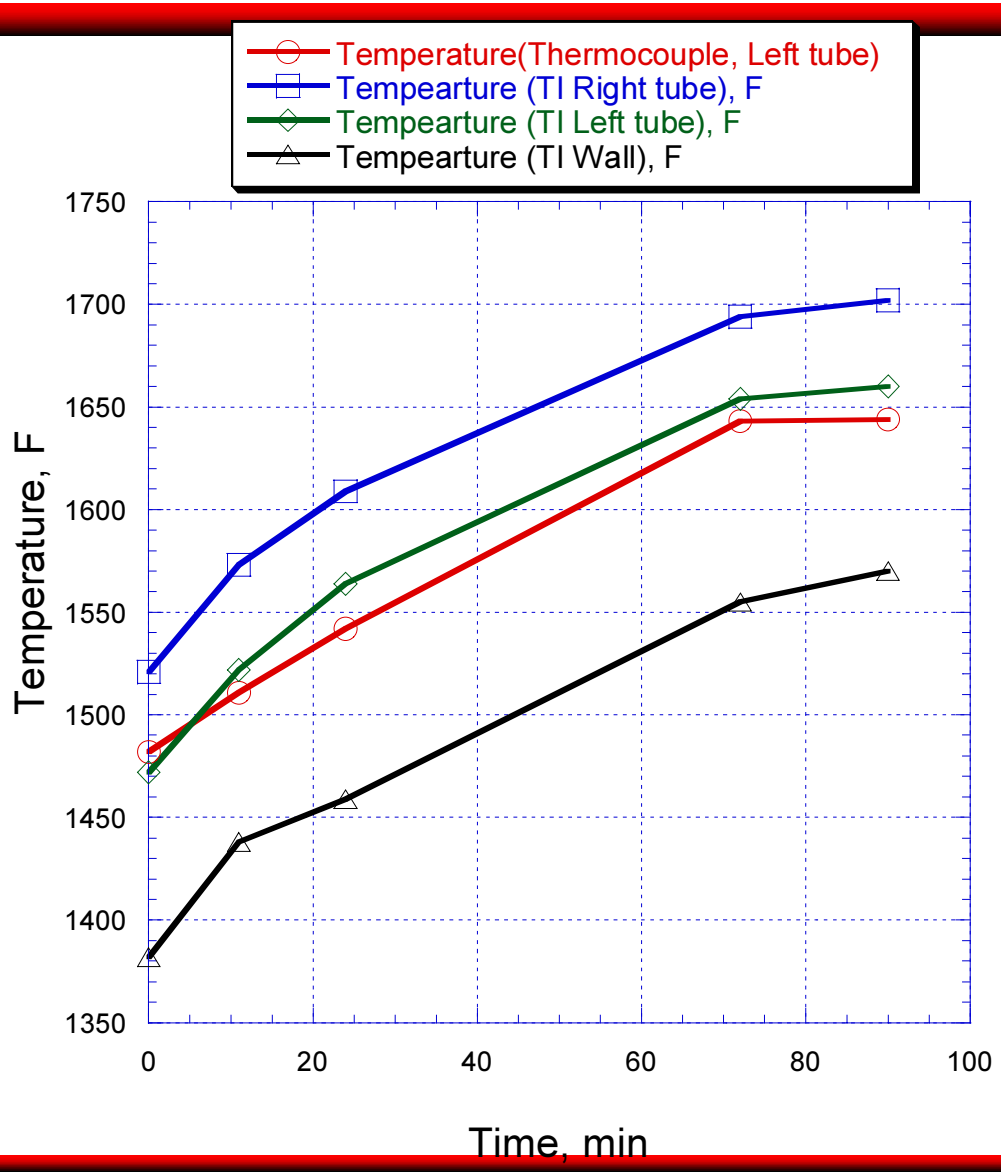
Radiant Tube Temperature Profile



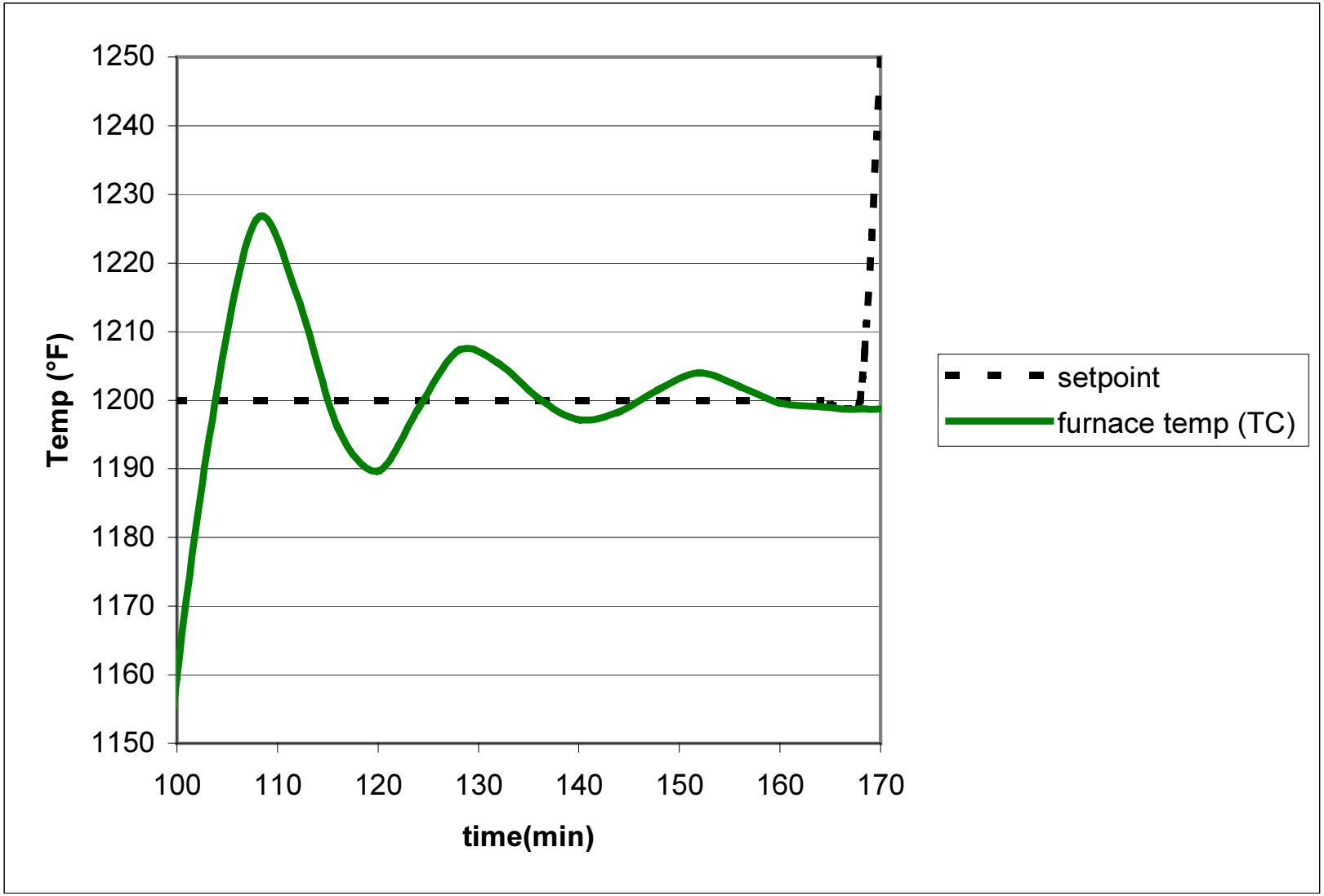


Temperature rise with time

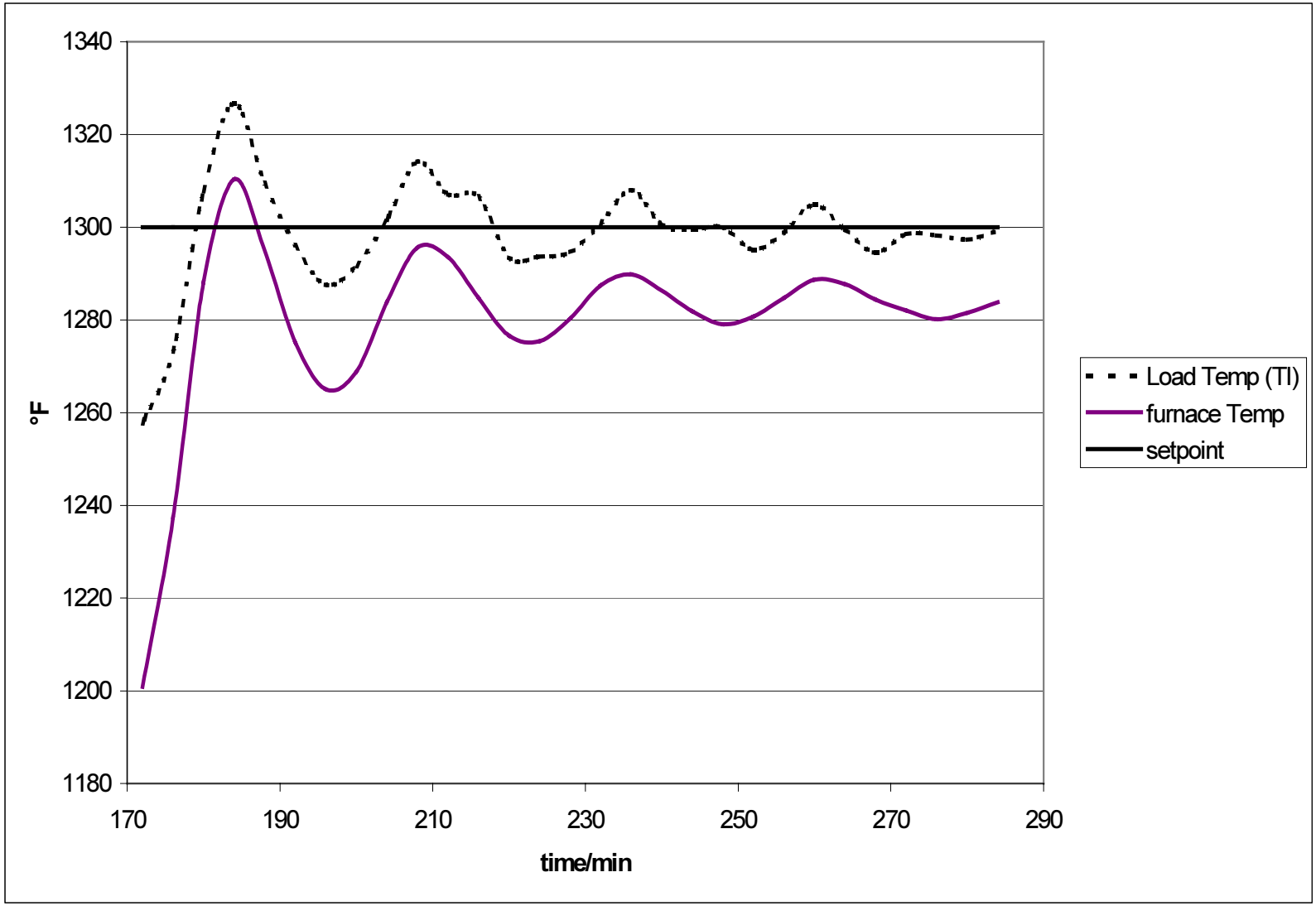
Thermal Imaging vs. thermocouple



Heat Treat Furnace Control - Traditional



Heat Treat Furnace Control – Thermal Imaging



Technical Progress and Outlook

Future Technical Milestones/Goals

Milestone/Goal	Expected Completion Date	Comments
Owens Illinois glass furnace (air-gas and oxy-gas) demonstrations	Summer 2003	Schedule being organized with OI Manager of furnace operations
NYSERDA funded project to develop an industrial prototype TI system	July 2003	18-month project with IEM and GTI
Invited paper on TI system published at 2003 Glass Problems Conference	Oct. 2003	One of 25 papers to 600-member glass industry audience
DOE Project Completion	Dec. 2002	Project complete – further development in prgress

NYSERDA Project Work Plan

Tasks	Thermal Imaging System Task Durations
	Q1 Q2 Q3 Q4 Q1 Q2
1. Define TIS Specs with GTI	
2. Software Technology Transfer	
3. Fabricate TIS Prototype	
4. Demonstrate and Test Prototype	
5. Refine and Solidify Commercial Design	
6. Prepare for Marketing and Production	
7. Project Management and Reporting	
Reports Meetings	

Technical Progress and Outlook

- ***Heat management.*** The camera lens must be inside the furnace; other parts are near the furnace exterior and will be subjected to heat, which must be removed if the system is to continue to operate. *This will be addressed* through with a *cooling shroud* which around affected components with a constant flow of coolant, usually water.
- ***Lens cleaning*****.** Even the cleanest furnace will inevitably release soot, dust, or something which could adhere to a lens. There must be a way to clean the lens, preferably without having to remove it from the furnace and without interfering with furnace operation. A *pressurized nitrogen cleaning system is planned* for the objective lens.
- ***Repair and maintenance.*** For severe service locations, the camera system will be on a *retractable mount* which will allow it to be removed from the furnace without interrupting operations.
- ***High-temperature optics.*** The objective lens must be made of a material which can transmit the near infrared spectrum needed and will not be harmed by temperatures of 3,000º or more. T*he properties* of candidate substances will be studied and most suitable selected.

Technical Progress and Outlook

- **Industrial end-user involvement**
  - Owens Illinois testing in summer of 2003
  - Blasch Precision Ceramics field testing for the industrial prototype in the upcoming NYSERDA project
  - IEM, Corp. development of the industrial prototype sensor and OEM marketer and supplier of final near-IR thermal imaging system

Industry Needs and TIS Benefits

Higher energy efficiency, lower fuel costs	Control of furnace instabilities and a more uniform temperature profile allows the less over-firing fuel and faster load processing
Lower exhaust gas emissions, including CO and NO_x	Better control provides more complete combustion (lower CO) and more uniform temperature profile with decreased peak flame temperature (lower NO_x)
Higher product quality and less solid waste	More uniform load temperature profile lowers product loss, raises product quality
Elimination of refractory hot spots	Field data indicates refractory hot spots. Burner conditions are modified to produce a more uniform temperature profile
Better furnace stability	Real-time field data enables system to focus on an instability and use controls to eliminate it in near real time

Market Potential

- **Commercialization plan**
  - After market review, product price evaluation, and industrial need assessment, the project team has found the best commercialization route to be a low-cost, reliable video and thermal imaging system
  - The original dual-wavelength near-IR approach will be used to collected thermal imaging data in real time
  - The same information will be used to create real-time video images of the process
  - The propreitary technique uses the same hardware and more sophisticated algorithms relative to the original thermal imaging system

Market Potential - IOF Industries

Industry	Application	Production, 10^6 ton/y	Total Fuel, 10^{12} Btu/y
Steel	Reheating	90	144
Steel	Continuous Anealing	22	19.8
Steel	Batch Annealing	8	8
Aluminum	Remelting	3.5	7
Glass	Melting	30	120
Chemicals	Ethylene Cracking	6	50.4
Metal Casting	Heat Treating	60	60
	Total		410

Programmatic Merit

- **Energy and environmental benefits**
  - Lower energy costs – for batch and continuous processes
  - Decreased NO_x abatement costs – by an estimated 30% for high temperature processes
  - More product meeting specifications – optimized process control
  - Less down time between loads
  - Longer furnace life – from elimination of hot spots and decreased furnace component wear with more heat applied directly to the load
  - Lower capital cost per piece or per pound of product – from higher furnace throughput (continuous furnaces) or faster cycling (batch furnaces
- **Economic benefit**
  - Annual savings of $17 million dollars with 10 percent market penetration

Energy and Environmental Benefits

				Reductions, 10% 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	0.43	25,100	4.1	1,100
Steel	Continuous Annealing	22	19.8	0.06	3,500	0.3	50
Steel	Batch Annealing	8	8	0.025	1,400	0.1	6
Aluminum	Remelting	3.5	7	0.02	1,250	0.1	2
Glass	Melting	30	120	0.36	20,900	6.7	300
Chemicals	Ethylene Cracking	6	50.4	0.15	8,700	0.35	13
Metal Casting	Heat Treating	10	10	0.03	1,750	0.6	30
	Total		410	**1.1**	**62,500**	**12**	**1,450**

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
  - Fuel gas BTU value
- **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