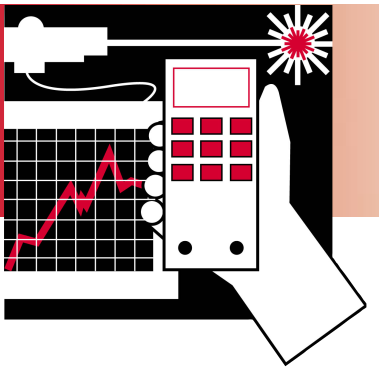
SENSORS & CONTROLS

Project Fact Sheet



Diagnostics and Control of Natural Gas Fired Furnaces via Flame Image Analysis

Benefits

- Improved burner balancing would allow operation at reduced excess air levels resulting in improved thermal efficiencies, reduced fuel consumption, and reduced NO_x emissions.
- For a large gas fired boiler (5.4 x 10^9 BTU/hour), a 10-percent reduction in nitrogen oxide emissions would result in savings of about $1 million per year from NO_x credits.
- A small reduction in fuel consumption of 0.5 percent would result in fuel savings of more than $250,000 per year for a large gas fired boiler.

Applications

Applications for the on-line system include:

- Real-time process control of multi-burner, natural gas fired furnaces for melting scrap and recycled materials in the aluminum industry.
- Direct flame reading sensors for continuous control of NO_x and other pollutants in natural gas fired furnaces for reheating steel for rolling operations, furnaces for forging, and furnaces for heat treating. Improved temperature uniformity should improve product quality in the steel industry, particularly for heat treating furnaces.
- Low-cost retrofit for implementing advanced process control for gas fired furnaces used in the glass industry. Advanced glass melting process control would result in improved burner efficiency, reduced emissions, and improved product quality because of greater temperature uniformity.

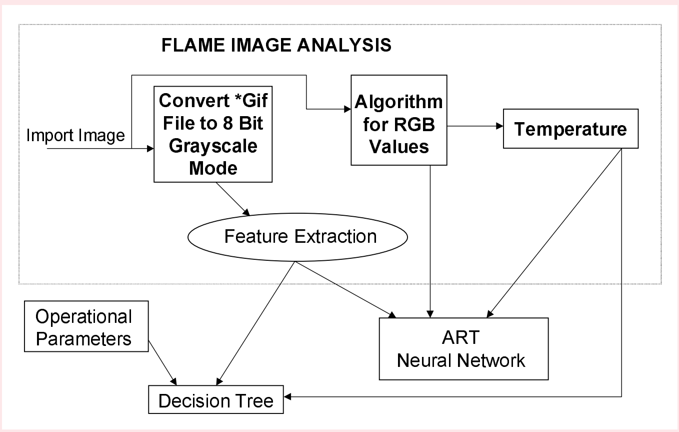
Video images and artificial intelligence techniques will be used to obtain information for optimal control of natural gas fired furnaces

A new approach for the detection of real-time properties of flames will be used in this project to develop improved diagnostics and controls for natural gas fired furnaces. The flame image sensing involves the use of both video cameras and optical spectroscopic observations along with advanced image analysis and pattern recognition techniques. These techniques will be used to identify flame features that can be correlated with the air/fuel ratio, level of nitrogen oxide emissions, and flame temperature.

This on-line system will provide guidance for balancing air/fuel ratios between individual burners on multi-burner furnaces. Identifying and correcting fuel rich burners should result in improved fuel efficiency. In addition, if flame temperatures can be carefully controlled, the NO_x emissions from a natural gas flame can be reduced to extremely low values. Flame temperature is therefore a very important control variable, and the temperature in various regions of the flame can be obtained from the continuous optical measurements. Another important aspect of combustion control for the glass and aluminum industries is product quality. Temperature uniformity in the furnace is important for both industries for achieving high product quality and for reducing scrap losses.

Thus, it is anticipated that this on-line diagnostic and control system will offer great potential for improving furnace thermal efficiency, lowering NO_x and carbon monoxide emissions, and improving product quality.

Flame Image Analysis



The flowchart above shows the flame image analysis components.

Project Description

Goal: Formulate a method for extracting features from flame images that can be correlated with combustion parameters such as the air/fuel ratio, nitrogen oxide and carbon monoxide emissions, and flame temperature.

Features that are important for NO_x formation may exist in different regions of the flame from those features that are most useful for correlating with the air/fuel ratio, for example. The flame images should readily identify regions associated with the highest radiation intensities and hence the highest temperatures.

The feasibility study will involve the collection of flame data from fiber-optic detectors or spectrometers along with flame images obtained by video cameras. A pilot-scale natural gas fired furnace and a bench-scale, oxy-fuel glass furnace will be used for these studies. After some preliminary data treatment, adaptive resonance theory neural networks will be examined for recognition of flame patterns as a function of operational conditions. This information, along with virtual temperature sensing of the flame, will then be used to develop control strategies for optimal control of gas fired furnaces.

Progress and Milestones

- This project was selected through the Sensors and Controls Program FY00 solicitation and was awarded in January 2000. All tasks are scheduled for completion in 36 months.
- The Phase I feasibility study is to be completed at the end of the first year of the project. Three majors tasks will be carried out:
  a) Data/Image Acquisition. This will include the natural-gas-fired furnace experiments using a combustor at Pennsylvania State University, oxy-fuel-fired experiments at University of Missouri – Rolla, and preliminary data processing.
  b) Flame Image Analysis. This will involve on-line digitization of input images, image processing to reduce the dimensionality of the data to a few salient features that are most clearly correlated with operating conditions and flame characteristics, and color temperature calculations using the red, green, blue values of the flame video image.
  c) Pattern Recognition. A neural network will be trained to use the image features to determine the conditions of the combustion process and to provide diagnostic information. Another neural net will be used for unsupervised pattern recognition using these same image features, and the results of the two pattern recognition techniques will be compared.
- The success of the Phase I feasibility study will be determined by the results for estimating operating parameters using replicate data taken at the original operating conditions as well as using data obtained over a range of operating conditions. Phase II will start with comprehensive data acquisition by video image and by spectrometer for the natural gas combustor along with flame image analysis by decision tree. If successful, similar data from the oxy-fuel furnace and glass manufacturing plants will be used to develop the system for furnaces used for glass production.

Project Partners

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