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Book of Abstracts
November 2-5, 1998

Kellie Ann Beall, Editor

Building and Fire Research Laboratory
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NIST

United States Department of Commerce
Technology Administration
National Institute of Standards and Technology

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U.S. Department of Commerce
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National Institute of Standards and Technology
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For Presentation at the NIST Annual Conference on Fire Research
Gaithersburg, MD, November 2-5, 1998

A New Fire Detection System Using FT-IR Spectroscopy and Artificial Neural Networks

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Introduction

Future fire detection systems should have the ability of discriminating signatures between fire and non-fire sources as nuisance alarm problems have plagued existing smoke detectors. In high value installations, such as semiconductor clean rooms and telephone central offices, it is obvious that reliable fire detection systems are needed. In most cases, these detection systems are used to activate fixed fire suppression systems, and false discharges of the suppression agents are certainly undesirable. False alarms can cause unnecessary down time and undermine the operator's confidence in the detection system.

A new fire detection system using infrared diagnostics (FT-IR spectroscopy) together with advanced signal processing techniques (artificial neural networks) has been developed at Advanced Fuel Research, Inc. This new fire detection system promises to provide an early warning of hazardous conditions and has the ability to determine whether the hazardous conditions are from fire or nuisance/environmental sources.

Approach

It has been shown that multi-parameter fire detection systems are inherently more reliable than any single parameter measurement and can be made robust by the use of artificial intelligence methods (1-4). The objective of our research efforts is to use an advanced Fourier Transform Infrared gas analyzer to develop an intelligent fire detection system that can be used in high value facilities such as telephone central offices and semiconductor cleanrooms.

We have made extensive FT-IR gas measurements of flaming (2) and smoldering fires, as well as environmental/nuisance sources (5). The FT-IR measurements were made in open-path, cross duct, and extractive modes for flaming fires, while measurements of smoldering fires and environmental/nuisance sources were performed in the extractive mode. The extractive mode was selected in the latter case because most of the current fire detection technologies (e.g. VESDA and AnaLaser) for cleanrooms and telephone central offices are based on air sampling techniques in which the air samples from multiple locations of the rooms are drawn and delivered through an extensive piping network to a particle analyzer. The FT-IR system can be easily incorporated in this type of fire detection system, and comparison can be made with existing technologies.

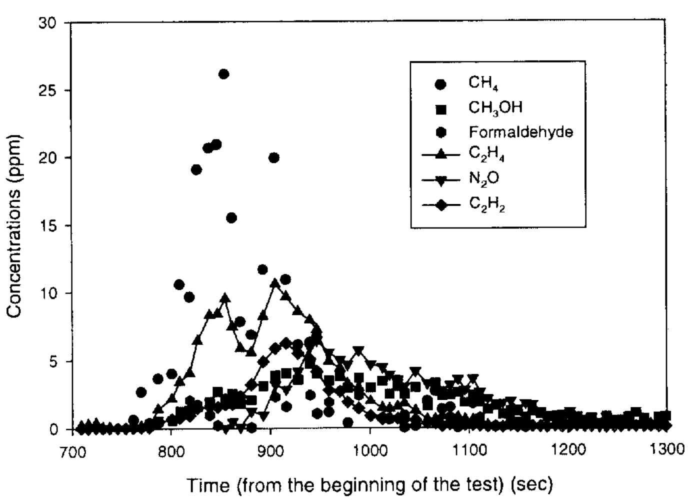

Figure 1 Gas concentrations of a Douglas fir fire test

Numerous materials were tested, including Polyurethane (PU), Polyvinylchloride (PVC), Polymethylmethacrylate (PMMA), Polypropylene (PP), Polystyrene (PS), Douglas Fir wood (DF), low density Polyethylene (LDPE), aqueous Ammonia (NH_3), Tetrafluoromethane (CF_4), Isopropyl alcohol (IPA), cables, etc

Figure 1 shows concentrations of some fuel specific species measured by an FT-IR spectrometer from a smoldering-flaming Douglas fir fire test. N_2O and formaldehyde were clearly observed in the figure. Similar observations can be made for other materials tested.

The species concentrations measured by a FT-IR, together with a neural network or fuzzy logic model, can be used to identify whether there is a fire or nonfire (environmental/nuisance) event, and to classify whether it is a flaming or smoldering fire if the event is indeed a fire. A commercially available neural network software package, NeuralWorks Professional II/Plus (6), was chosen to build the needed neural network. A so-called Learning Vector Quantization (LVQ) network has been built and tested (Figure 2). The inputs in the current version are concentrations of CO_2, CO, H_2O, CH_4,

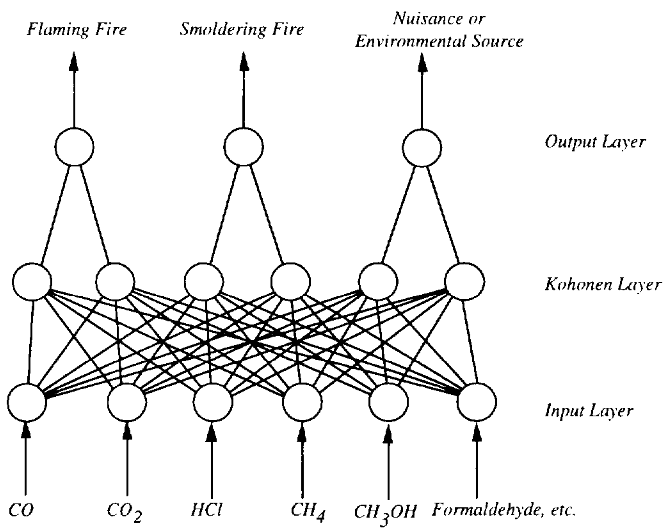

Figure 2 A Learning Vector Quantization (LVQ) network to characterize fire and non-fire events.

CH_3OH, Formaldehyde, HCl, C_2H_4, N_2O, NH_3, CF_4, NO, Methyl Methacrylate, Isopropyl alcohol, C_2H_6, C_3H_6, C_6H_{14}, C_2H_2, C_6H_6 (18 species from FT-IR measurements). The outputs of the network are classification of the input data as a flaming fire, smoldering fire, or nuisance/environmental source. The results of the above experiments look quite promising. From among the 248 cases tested, only 12 events were misclassified, most due to the difficulties in classifying the modes of combustion during a transition from smoldering to flaming fire.

We have incorporated the above-trained LVQ network into the data acquisition system for an On-Line 2010 Multi-Gas spectrometer. A real-time fire detection system has been constructed. Preliminary tests of this integrated software have been satisfactory using the test data described above.

Conclusions

FT-IR measurements of numerous fire (flaming and smoldering) and nonfire sources have been conducted. The combustion and fuel specific species have been identified and quantified. The species concentrations together with a neural network model were used to successfully distinguish fire and nonfire (environmental/nuisance) events as well as identify the modes of combustion (flaming or smoldering). The neural network model has been incorporated into the advanced FT-IR measurement system and a prototype fire detection system has been constructed.

Acknowledgement

The support by the National Institute of Standards and Technology under grant No. 50-DKNB-5-00174 with Dr. William Grosshandler as Technical Monitor is greatly appreciated.

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