A REVIEW OF MEASUREMENTS AND CANDIDATE SIGNATURES FOR EARLY FIRE DETECTION

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The current generation of fire detection systems is designed to respond to the smoke, heat, or the electromagnetic radiation generated during smoldering and flaming combustion. Smoke is sensed either by measuring, with a photodetector, the light which is scattered from a controlled light source, or by the change in current created by charged particles passing through an ionizing radiation field. Heat can be easily sensed by a number of conventional devices, such as compensated thermocouples and thermistors. Both the absolute temperature and rate of temperature rise are used to define alarm conditions. The ultraviolet and infrared portions of the electromagnetic spectrum are typically detected with vacuum tube and solid state photodiodes, photoconductive and photovoltaic cells, thermopiles and pyroelectric cells [1].

Future developments in early warning fire detection are incumbent upon knowing what is unique about a fire as well as the means to measure those characteristics. The concept of a "fire signature" was defined by Custer and Bright [2] in their in description of the state of fire detection in the early 1970s. Advances in sensing and signal processing have been many over the last two decades, but relatively little new information on what occurs early in a fire has been revealed. The purpose of this paper is to reexamine the physical and chemical transformations associated with a burgeoning fire, to summarize the results of past experimental measurements of these transformations, to identify holes in the data which need to be filled, and to suggest a means by which these data can be used for developing new detection systems and evaluating their performance under realistic and unbiased conditions.

The literature has been reviewed to determine the extent to which fires have been characterized in their early phase (smaller than 100 kW). In particular, measurements of CO, CO_2, H_2O, H_2, O_2, smoke and temperature have been examined from tests performed by other laboratories simulating the UL and EN test protocols. Figure 1 is a plot of CO concentration measured in the six standard European fires (TF1 through TF6), a UL test, and a test performed with a transformer fire (CERB) [3,4]. Not surprisingly, the variation in magnitude and rate of growth vary dramatically with fuel type and geometry. The variation is also large between repeat runs of the same tests (TF1, TF2 and TF3). When scaled by estimated mass consumed of fuel (Figure 2), the different standard fires can be seen to group a bit more systematically. The measuring location for one series of TF1, TF2 and TF3 fires was three meters off the centerline, while the others were made directly above the center of the fuel. Additional measurements of species, temperature and velocity just above the flame are ongoing to get a more complete footprint of each fire type. Similar measurements of non-fire nuisance sources are required in order to discriminate between a fire and non-threatening situation with a high degree of certainty.

The concept of a universal fire emulator/detector evaluator (FE/DE) is being developed to supplement existing UL and EN standards involving prescribed full-scale room fires or smoke-flow boxes, and to develop an environmental chamber in which velocity, individual gas species, particulate matter and temperature can be controlled as a function of time. A detector would be placed inside the chamber and the desired environmental program would be selected to emulate either a fire or interfering signal. The objective is to have a facility in which alternative systems can be compared and new concepts evaluated on a level playing field. It will eliminate the run-to-run variation which is unavoidable in full-scale tests and allow more well controlled environments with realistic multiple stimuli. Computational fluid dynamics could be used to insert the fire source into the space being protected to guide detector placement and to predict system performance. Support for such a facility and the general approach is sought from the fire protection industry and regulating organizations.

[1] Cholin, J.M., *Industrial Fire Safety 2*, No. 5, p. 22, September/October 1993.
[2] Custer, L.P., and Bright, R.G., *Fire Detection: The State of the Art*, NBS TN 839, June 1974.
[3] Jackson, M.A., and Robins, I., "Gas Sensing for Fire Detection: Measurements of CO, CO_2, H_2,

O_2, and Smoke Density in European Standard Fire Tests," *Fire Safety Journal* 22, 181-205 (1994).

[4] Pfister, G., "Detection of Smoke Gases by Solid State Sensors - A Focus on Research Activities," *Fire Safety Journal* 6, 265-174 (1983).

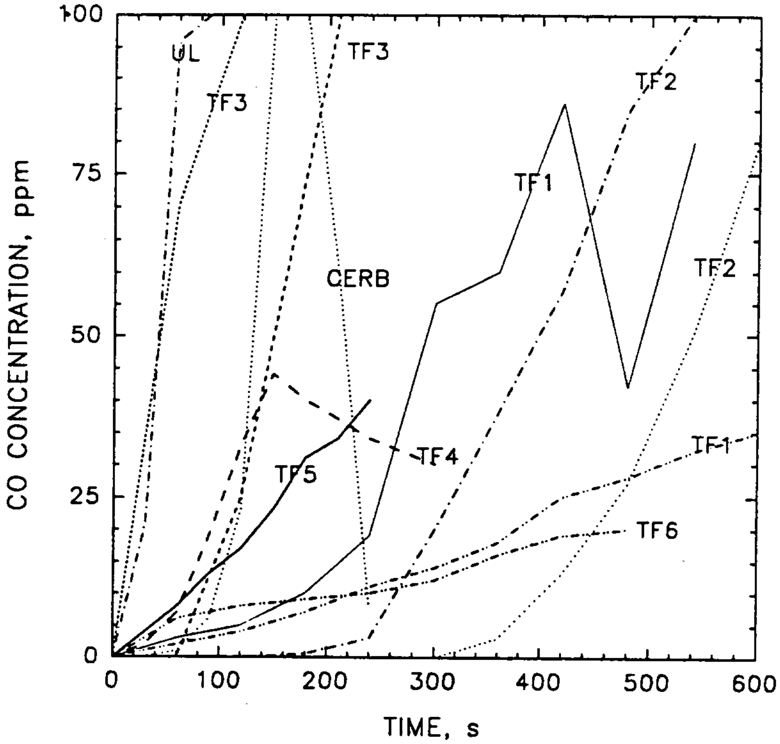

Figure 1. CO concentrations vs time in standard fire tests [3,4]

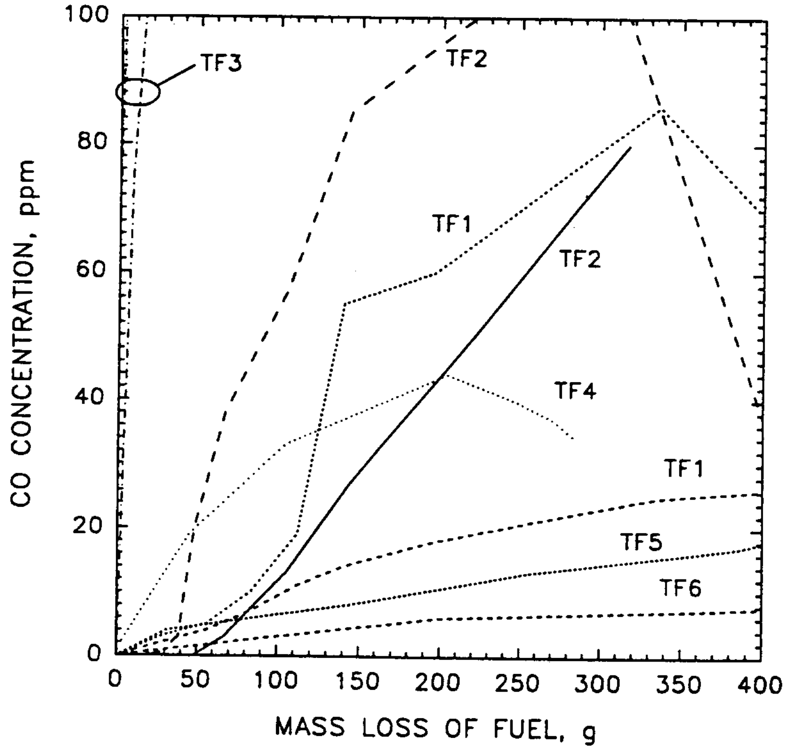

Figure 2. CO concentration vs mass loss in standard fire tests [3,4]