Study of Technology for Detecting Pre-Ignition Conditions of Cooking-Related Fires Associated with Electric and Gas Ranges and Cooktops

Erik L. Johnsson
Building and Fire Research Laboratory
Gaithersburg, Maryland 20899
National Institute of Standards and Technology

Introduction

In 1994, 3,425 deaths, 19,475 injuries, and $4.2 billion in property damage were caused by 438,000 home fires in the United States.[1] The National Fire Protection Association estimated that between 1988 and 1992, range/oven appliance fires averaged about 20 % of all home fires and were responsible for approximately 20 % of the injuries, 5 % of the deaths, and 5 % of the property loss associated with home fires. A majority of these range/oven fires involved food.[2] The overall objective of the Consumer Product Safety Commission's Range Cooking Fire Project is to reduce the number of cooking-related fires in homes. The objective of this testing effort was to determine the possibility of detecting hazardous range-cooked food situations to allow alarm or shutoff of the range before ignition occurs. Feasibility of such a detection system also requires the availability of effective technology and its ability to differentiate normal and hazardous situations and thus not alarm falsely.

Phase I of this project revealed some insight into the pre-ignition conditions of food fires that might be monitored to indicate an incipient fire and the devices that might be used to detect and act upon such conditions. It was concluded that there are some common signatures of approaching ignition conditions for 3 foods (soybean oil, bacon, and sugar) cooked on electric and gas ranges. The conditions are high temperatures, high smoke particulate density, and high levels of hydrocarbon gases. Phase I also generated a list of devices with potential to detect these and other pre-fire conditions and to shut down and restart electric and gas ranges. A report of the findings of Phase I is available.[3]

The objective of Phase II of this project was the determination of whether there is any potential for devices, alone or in conjunction with others, to detect and warn of approaching ignition conditions for certain foods cooked on electric and gas ranges without false alarming under a variety of normal cooking conditions. The Phase II test plan focused on obtaining more data on cooking scenarios and potential sensors. The experiments conducted at NIST were designed to (1) establish that a set of safe cooking practices and a set of approaching ignition situations generate sufficiently different conditions to discriminate between them, and (2) select a few readily available detection devices with the ability to sense stimuli in the ranges established by (1), and analyze the consistency of their responses with that expected from contact with the stimuli.

Experimental

The kitchen laboratory is described in detail in the Phase I report.[3] The laboratory was equipped with a probe that carried sample gas to carbon dioxide, carbon monoxide, and total hydrocarbon analyzers. A HeNe laser was used in conjunction with 3 photodiode detectors to monitor attenuation and light scattering at two angles. Twenty-five tin-oxide gas sensors were located near the range. The gases sensed included carbon monoxide, volatile organic compounds, general hydrocarbons, and water. Eight photoelectric smoke detectors were placed near the range and on the ceiling. Four ionization type smoke detectors were placed on the ceiling adjacent to four of the photoelectric detectors. Forty-two thermocouples were used to thermally map the range area and monitor the temperatures at each sensor/detector site.

A total of forty-two tests were conducted on four ranges. Sixteen cooking scenarios were divided into fourteen base scenarios that were conducted on an open-coil element electric range and two additional scenarios which utilized an electric range with a self-cleaning oven and a downdraft range with grilling capability. Two of the fourteen base scenarios were also repeated using a gas range and three were conducted again on the open-coil electric range with the range hood active. Each test was repeated once. Of the sixteen scenarios, five were completely normal cooking procedures, six followed normal cooking procedures and then were allowed to continue to possible ignition to simulate unattended cooking, and five simulated unattended cooking from the beginning.

Results and Discussion

Figure 1 shows temperatures versus time for the pan and food within the pan for bacon cooked in an unattended fashion. Figure 2 shows the time trace for attenuation of the laser beam by the smoke generated by the cooking process. Figure 3 shows the voltage of a hydrocarbon gas sensor located on the range hood and the level of hydrocarbons measured above the pan by the hydrocarbon analyzer versus time.

For this particular test, ignition occurred at 605 seconds. Figure 1 shows that the temperature in the food stays about 80 degrees less than the pan bottom temperature, but follows its behavior reasonably well. The temperature of most food cooked on a range surface should not surpass 300 °C which occurred at 450 s during this test. From Figure 2, significant smoke of greater than 50% laser attenuation is generated after 450 s. Figure 3 shows that the sensor sharply rises after 350 s while the concentration measured by the analyzer rises only after 530 s. From these plots only, it appears that temperature, smoke, and hydrocarbon measurements begin to increase substantially when cooking has passed typical heating levels and allow for 1 to 4 minutes of time to alarm depending on which signal or combination of signals is used.

Conclusions

Initial analysis of the data from 42 tests of normal and hazardous cooking conditions points to feasibility of a pre-ignition detection system for most cases, but additional features such as a timed disable button would need to be designed into a system to prevent false alarms for some kinds of attended normal cooking.

References

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2. Miller, A. "U.S. Home Product Report, 1988-1992: Forms and Types of Materials First Ignited in Fires," National Fire Protection Association, Quincy, MA; February 1995. 105 p.
3. Johnsson, E. "Study of Technology for Detecting Pre-Ignition Conditions of Cooking-Related Fires Associated with Electric and Gas Ranges and Cooktops, Phase I Report," NIST IR 5729, National Institute of Standards and Technology, Gaithersburg, MD; 107 p., October 1995.

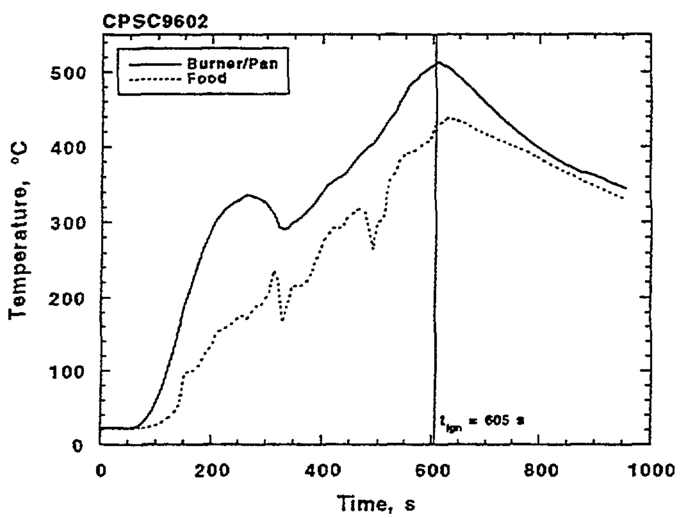

Figure 1. Temperatures vs. time for the burner/pan interface and the bacon cooked at high heat on an electric range.

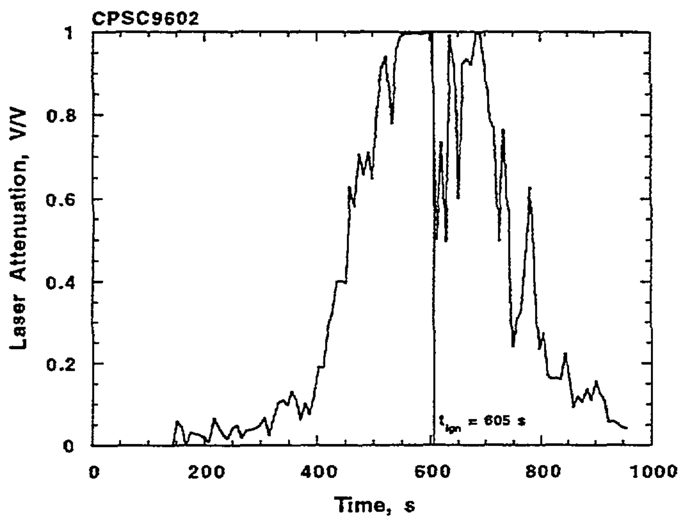

Figure 2. Laser light attenuation vs. time for bacon cooked at high heat on an electric range

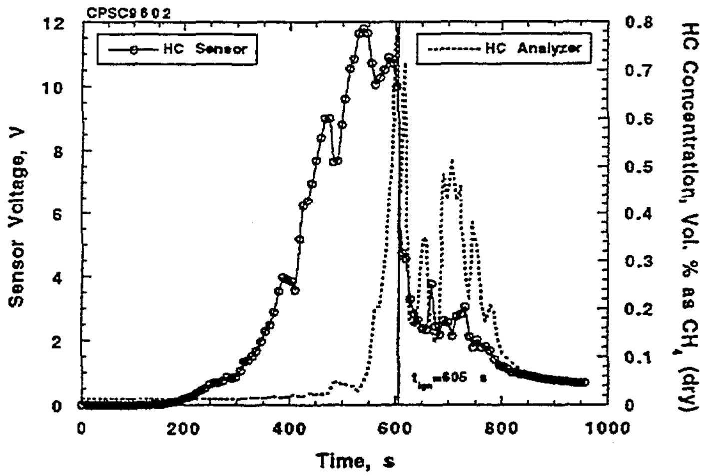

Figure 3. Hydrocarbon gas sensor voltage and analyzer concentration vs. time for bacon cooked at high heat on an electric range.