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

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Executive Summary

A significant portion of residential fires stem from kitchen cooking fires. Existing fire data indicate that cooking fires primarily are unattended and most often involve oil or grease. The purpose of this investigation was to ascertain the existence of one or more common features or characteristics of the pre-ignition environment that could be used as input to a sensor in a pre-fire detection device. The ultimate goal of this continuing study is to evaluate the feasibility of incorporating such a device into the range that would react to a pre-fire condition and reduce the occurrence of unwanted kitchen fires.

The focus of the study was unattended foods placed in pans on burners set to high heat. Experiments were conducted with three different foods and with gas and electric ranges to investigate the pre-ignition environment of actual range-top cooking fires. Numerous temperatures in the near surroundings as well as local plume velocity and laser-attenuation measurements were recorded. A Fourier transform infrared spectrometer was used to observe significant species production above the food. Results of these experiments are presented and evaluated.

The second part of this study was a literature and patent search of technologies with the capability to act as either the sensor in a pre-fire detection device or as the automatic control that would respond to a detector warning signal by shutting off the gas or electricity supply. A broad range of potential detection technologies was reviewed because the pre-fire signatures had not yet been identified. A bibliography and comments on the applicability of different technologies are included.

The conclusions pertaining to the experiments are based on measurements and observations of combinations of specific ranges, pans, foods, and ventilation so extrapolation to other conditions should be performed with caution. The major conclusions of this research are as follows:

- Strong indicators of impending ignition were temperatures, smoke particulates, and hydrocarbon gases.
- Promising detection technologies include: tin oxide (SnO_2) sensors for hydrocarbon detection, narrow band infrared absorption for hydrocarbon detection, scattering or attenuation types of photoelectric devices for smoke particle detection, thermocouples for thermometry of the burner, pan, range surface (top and below), or range hood.
- Logical processing of signals from two or more of the detection technologies could be an important means by which false alarms of pre-ignition conditions are eliminated.
- Control technologies exist that are applicable to the safe shutdown and restart of gas and electric ranges upon detection of approaching ignition.

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1.0 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] Through analysis of the 1988-1992 data collected through the National Fire Incident Reporting System, NFIRS, the National Fire Protection Association estimated that in that period, 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] Currently, there is not an adequate understanding of the pre-ignition conditions of food fires that might be monitored to indicate an incipient fire nor of the devices that might be used to detect and act upon such conditions. The overall objective of this project is to identify pre-ignition conditions and the methods, materials, and devices that can be used to detect such conditions and alert, or intervene, to reduce the risk of cooking-related fires associated with electric and gas ranges and cooktops.

This objective was addressed through two major activities in Phase I. In order to identify the pre-ignition conditions, experiments were performed to monitor specific aspects of the environment and how they changed as ignition conditions were approached during heating of various foods using combinations of range types and range-hood status (active/inactive). Temperatures of the surroundings close to the pan as well as plume velocity and laser-attenuation measurements were recorded. A Fourier transform infrared, FTIR, spectrometer was used to determine if the production of any specific gas species was significant. Analysis of the experimental results has determined the conditions with potential, alone or in combination with one another, to provide input to a pre-ignition sensor.

The second activity was the identification of methods, materials, and devices with potential as means of detection and reaction to pre-ignition conditions. This was begun with a literature and patent search. The search focused on sensing devices and technologies capable of detecting one or more cooking-related conditions as well as control technologies capable of shutting off gas and electric ranges in the event of a detected threat. The bibliographical information on technologies related to these goals is provided with comments regarding their potential usefulness in a range pre-ignition detection system.

2.0 Experimental

2.1 General Design

The focus of this set of experiments was to characterize the environment immediately preceding ignition. Combinations of food type and cooking pan were chosen primarily to investigate cases in which the food can ignite after a relatively short time of heating and likely result in a serious fire hazard. High heating levels were chosen in order to ensure ignition, which at low or medium settings might not occur at all or might require hours.

Three variables were changed in order to establish their effects on the pre-ignition environment: (1) food type, (2) range style, and (3) hood operation. Different foods were studied because a candidate signature must exist for each type of food if it is to have potential as input to a universal pre-cooking-fire sensor. Diverse range types were of interest because of potential variation in ignition modes due to a proximate flame on the gas range, although in these experiments, the ranges functioned primarily as sources of heat. The use of the different ranges selected was expected to have some effect on the time lag of the behaviors of the recorded variables because of the varied levels of heat flux output associated with each range. The range-hood status was of interest for two reasons. First, the flow caused by an active range hood might obscure the signature(s) of interest preceding ignition. Second, the different flow patterns might alter entrainment of air which could effect the mechanism and location of ignition and thus the preceding set of signatures as well.

The selected foods and ranges were chosen because they were typically used for cooking in households and were representative of cooking fire scenarios that have actually been reported. More uncommon range models, food types, and styles of cooking could have been tested, but their results are less relevant at this stage.

2.1.1 Facility Construction

A small, stand-alone laboratory was built in Building 205, the Large-Fire Facility, at NIST to accommodate these experiments. A schematic of the room is shown in Figure 1. The interior dimensions of the room are as follows: 3.66 m (12 ft) width, 2.44 m (8 ft) depth, and 2.44 m (8 ft) height. The room was outfitted with double-wide doors, 163 cm (64 in) wide by 207 cm (81 in) high, and fluorescent lighting. Access holes were made for external supplies of electrical power and natural gas. The structure consists of 2.44 m (8 ft) lengths of 8.9 cm (3.5 in) by 3.2 cm (1.3 in) galvanized steel studding on the outside with 40.6 cm (16 in) centers supporting 1.3 cm (0.5 in) thick gypsum drywall with the interior painted white. A set of white wooden cabinets with overhead cupboards and a countertop with cupboards below were installed. A space in the center was reserved for range installation.

A range hood (described in Section 2.1.2) was installed above the range location. A 25.5 cm (10 in) wide by 8.9 cm (3.5 in) high rectangular hood duct passes through the wall directly behind the range hood to an elbow that transitions to a 15 cm (6 in) diameter round duct. The round duct is vertical for about 0.6 m (2 ft) where it connects to an elbow, traverses about 1.8 m (6 ft) horizontally to another elbow where the end is directed upwards and is positioned approximately 10 cm (4 in) below a large 41 cm (16 in) diameter duct which connects to the draft hood afterburner system.

A box hood, 188 cm (74 in) wide by 58 cm (23 in) deep by 91 cm (36 in) high, was constructed over the doorway to capture most of the smoke produced by the experiments. The hood was made of 9 mm (3/8 in) thick plywood. From 46 cm (18 in) above the bottom of the hood to 67 cm (26.5 in), the width of the box tapers from 188 cm (74 in) to 30 cm (12 in). The top 24 cm (9.5 in) of the hood is 30 cm (12 in) wide by 58 cm (23 in) deep. The hood is connected at the side of the top section to a 20 cm (8 in) diameter, 4.3 m (14 ft) long duct which leads to a fan which pulls the exhaust into the duct of the afterburner system.

Electrical power was provided from two sources. All of the instrumentation was supplied 120 V electricity from a portable electric sub-panel box with a 60 amp rating which split 240 V

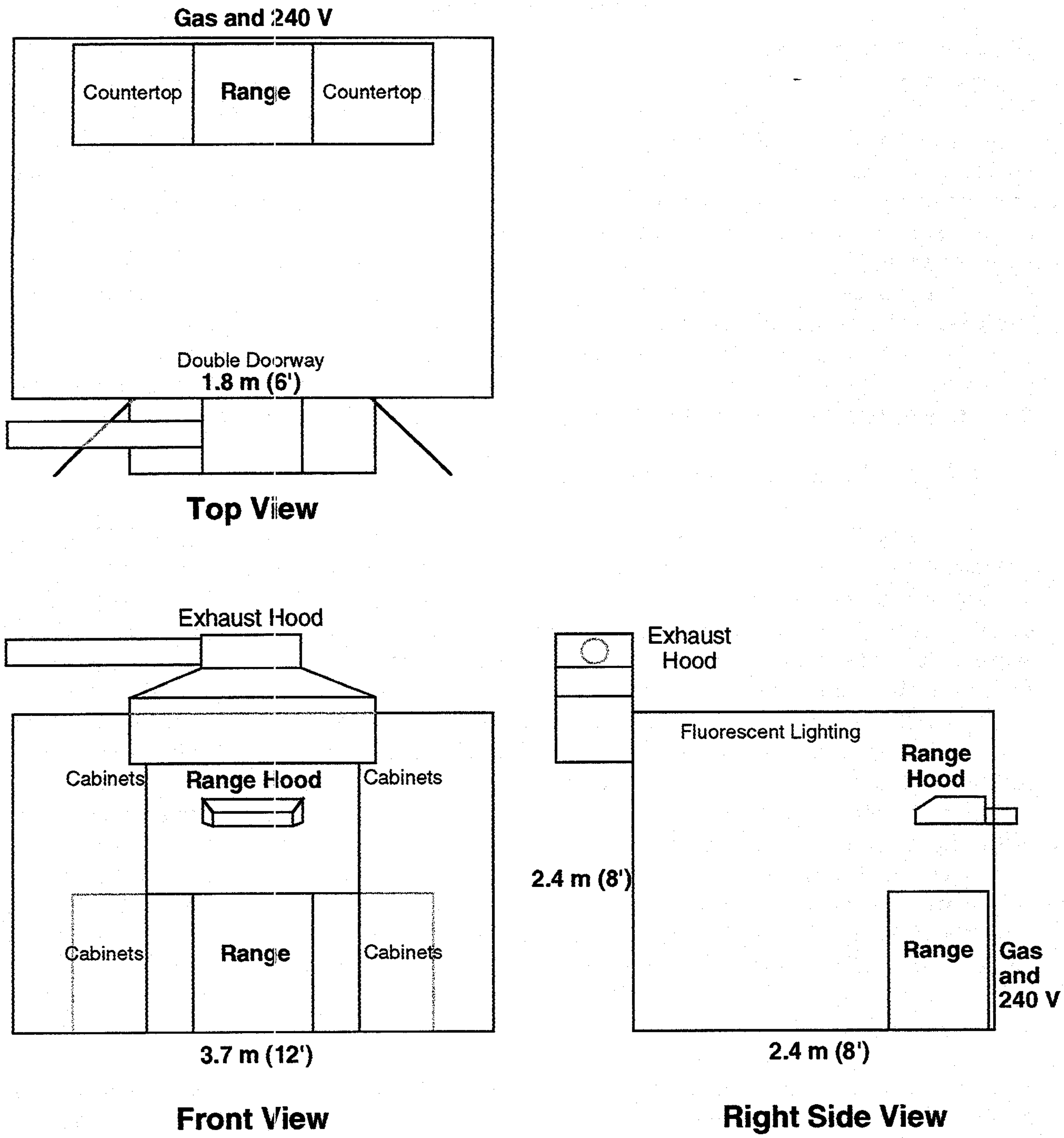

Figure 1. Schematic of Range-Fire Pre-Ignition Detection Facility.

electricity into eight separate circuits. Electric ranges require between 208 V and 240 V, and they are rated for each. Since 240 V provides approximately one-third more heating power than 208 V and it is the most common range voltage in single family homes, it was desirable as a both a typical and more hazardous case. The required 240 V usually consists of two lines of 120 V each and a neutral. The 220 V house circuit was boosted to 240 V by increasing one of the lines from approximately 115 V to about 130 V. A separate circuit breaker was installed particularly for the range. Current meters were used on the two lines to monitor the amperes drawn by the range, and a third meter monitored the power usage in kilowatts on the boosted line.

Natural gas was provided through a 1.3 cm (0.5 in) inside-diameter pipe connected to the low-pressure house supply. The low-pressure gas came into the pipe at 3.0-3.5 kPa (12-14 inches of H_2O). A pressure regulator in the line was adjusted to decrease the pressure to 1.74 kPa (7.0 inches of H_2O). The natural-gas pressure was monitored with a pressure gauge tapped into the line, and the flow was monitored with a 4.7 L/min (10 SCFH) rotameter.

2.1.2 Kitchen Ranges and Range Hood

Three different ranges were to be tested: A - electric with open-coil sheathed heating elements; B - gas; and C - electric with a smooth top. The first two were tested extensively, but the electric smooth top was used for only two tests. Each range is 76 cm (30 in) wide and free-standing. The electric range with open-coil elements has two 15 cm (6 in) and two 20 cm (8 in) burners. The 15 cm and 20 cm burner elements are rated at 1325 W and 2350 W, respectively, for 240 V electricity. The front burners facilitated the setting up of measuring instruments, so the right front 20 cm burner was utilized for the tests since it was the largest of the two front burners. The high-output gas range has two typical-power, 2.6 kW (9000 BTU/h) sealed burners and two high-power, 3.5 kW (12000 BTU/h) sealed burners. The left front burner was utilized for the tests since it was the only high-output burner in the front. The smoothtop electric range, including the oven and burners, is rated for 11.4 kW at 120/240 V and 8.6 kW at 120/208 V.

The range hood is a 76 cm (30 in) wide model made of stainless steel, and it has a 94 L/s (200 cfm) flow capacity. The hood opening extends 45 cm (18 in) out from the wall and tapers from about 75 cm (29.5 in) wide at the wall to 60 cm (24 in) at the front over the frontmost 15 cm (6 in). It was either off or engaged at maximum flow for each experiment.

2.1.3 Parametric Experiments

Parametric experiments were conducted so the results could be used to establish a test plan detailing the conditions of the instrumented experiments. The purpose of these preliminary experiments was to determine the effects of pan material, shape, and size, and the amount of food on the temperature of, time to, and mode of ignition of the food. These experiments (the first five; Table 1) were conducted on a typical, inexpensive gas range with four medium output, 2.6 kW (9000 BTU/hr) unsealed burners. The primary food tested was corn oil. One thermocouple in the oil monitored the temperature, and a stopwatch was used to time the observations.

Several tests were conducted with a simple procedure. The pan was secured with a ring stand clamp tightened on the pan handle to prevent spillage. Using a graduated cylinder, an amount of room-temperature corn oil was measured and poured into the pan. A stopwatch was started as the burner was turned on at the highest setting. The temperature of the corn oil was recorded every 30 or 60 seconds. Upon ignition, a lid was placed on the pan to snuff out the fire, and a CO_2 extinguisher was also available to assist with extinguishment.

Table 1 summarizes the conditions and results of the parametric tests, each of which was performed once. The test plan evolved as greater understanding of the parameter interactions was gained. The first five tests were performed on the inexpensive gas range with oil. The amount of oil and pan type were varied. Oil cooked in stainless steel ignited in each case with the greater amount of oil requiring more time. The combination of the average power output of the range and the heat transfer characteristics of the aluminum pans did not enable the oil to reach ignition temperatures. To aid in the selection of a carbohydrate test food, a sixth test was performed on the open-coil element electric range with baked beans. Temperatures inside the pan reached over 530 °C, but ignition did not occur. A seventh test was performed on the same electric range with corn oil in a non-stick aluminum frying pan. This test was primarily used to determine whether a fire could occur when the food was contained in an aluminum pan. The temperature was not measured, but the oil did eventually ignite.

The results from these experiments were helpful in deciding what materials to use in the instrumented tests. Aluminum was ruled out as a pan material because of the inability of the typical gas range to ignite corn oil. Stainless steel provided both ignition and short test duration which was desirable. The difference in oil volume for the tests conducted with stainless steel affected the time of ignition, but did not greatly affect the ignition temperature. Similarly, the temperature histories for the tests using two types of aluminum pans and two amounts of oil were different, but the final steady temperatures were comparable. Since the impact on test duration was not large and final temperatures were similar, pan sizes and food amounts were selected using reasonable cooking practices. The lack of ignition of the baked beans, although they were heated in an aluminum pan, discouraged the use of this food in the fully-instrumented tests since the ability to ignite was doubtful.

2.1.4 Instrumented-Test Parameters

Table 2 summarizes the food types, amounts, and the pans selected for testing. The rationale behind the selection of vegetable oil was that preheating oil in a pan before cooking a solid food item inside is a common practice and is a known circumstance leading to many cooking fires. Also, oils vaporize more readily than solid foods and thus cause more intense fires. Soybean oil was the particular oil chosen because it holds 75 % to 80 % of the cooking oil market.[3] Most commonly used vegetable oils are processed in order to have less than 2 % free fatty acid content. This translates into similar smoke (140 °C - 230 °C), flash (275 °C - 335 °C), and fire (350 °C - 365 °C) points.[4] The pan size was selected so that the 20 cm (8 in) burner area would most closely match the area of the bottom of the pan. The volume of oil was chosen to provide a reasonable depth for frying in the pan.

Bacon was chosen as the second food. The rationale behind the selection of bacon was that animal fats and greases are other commonly cooked foods, and grease and oil fires seem to be the most prevalent cooking fires. Another scenario that was considered was the frying of lard

Table 1. Conditions and results of parametric tests

Test No.	Food, Range	Pan	Volume or Mass	Time to Ignition	Ignition Temp.
1	Corn oil, D: typical-output, gas	2.9 L (3 qt) sauce stainless steel, copper clad bottom 18 cm diam., 11.7 cm ht. Model U	500 mL	14 min 15 s	373 °C
2	Corn oil, D: typical-output, gas	2.9 L (3 qt) sauce aluminum, ceramic coated Model V	500 mL	No ignition; Steady temp. at 33 min	None, T_{steady}= 336 °C
3	Corn oil, D: typical-output, gas	2.9 L (3 qt) sauce stainless steel, copper clad bottom 18 cm diam., 11.7 cm ht. Model U	250 mL	9 min 10 s	377 °C
4	Corn oil, D: typical-output, gas	2.9 L (3 qt) sauce cast aluminum, ceramic coated Model V	250 mL	No ignition; Steady temp. at 25 min	None, T_{steady}= 334 °C
5	Corn oil, D: typical-output, gas	25 cm (10 in) frying aluminum, non-stick Model W	250 mL	No ignition; Steady temp. at 28 min	None, T_{steady}= 332 °C
6	Baked beans, A: open-coil sheathed element, electric	1.9 L (2 qt) sauce aluminum, thin-gauge Model X	670 g	No ignition; Increasing temp.	None, Temp. exceeded 530 °C
7	Corn oil, A: open-coil sheathed element, electric	25 cm (10 in) frying aluminum, non-stick Model W	250 mL	approx. 12 min	not measured

Table 2. Food types, amounts, and the pans used

Food	Amount (Volume or Mass)	Pan
Soybean oil (Wesson brand)	500 mL	26 cm (10.3 in) diameter frying stainless steel, aluminum clad bottom 6.0 cm height Model Y
Bacon (Econovalue brand)	227 g	26 cm (10.3 in) diameter frying stainless steel, aluminum clad bottom 6.0 cm height Model Y
Table sugar (Weis Markets brand)	227 g	1.9 L (2 qt) sauce stainless steel, aluminum clad bottom 17.8 cm diameter, 9.1 cm height Model Z

which is sometimes preheated for the introduction of a vegetable, but cooking a meat which creates its own grease is more common. Like vegetable oils, greases vaporize easily and may cause intense fires. The mass was chosen as a reasonable amount to be cooked in a 26 cm (10.3 in) pan. This scenario would be especially appropriate for a cook who was in a hurry and therefore heated all the bacon at once on a high heat setting.

Table sugar was chosen as the third food as an example of a carbohydrate. Sugar contains almost no water or ash, and its low melting point allows faster vaporization than unprocessed vegetable matter. The rationale behind this selection included verbal evidence from several people who had experienced problems with sugar ignition. The preliminary experiment with baked beans and other tests performed at CPSC labs with pasta and potatoes all indicated difficulty or unlikelihood of igniting more commonly cooked carbohydrates.

The testing schedule was developed to streamline the test set-up and to lessen the possibility of systematic errors (through randomness) surfacing in the results. The test matrix is presented in Table 3. A total of twenty-two tests were conducted, of which only two used the smoothtop range. Six of the tests were repeated to determine consistency of results. The selection of tests to be repeated was random because all of the tests exhibited similar smoking and ignition phenomena. A general overview of the ignition behavior of the various scenarios was desired which would lead to more rigorous testing of a specific signature or signatures in Phase II under a variety of conditions to determine widespread applicability and reliability.

2.2 Instrumentation

A variety of instruments was implemented to attempt to characterize the pre-ignition cooking environment. Measurements focused on thermal aspects of the area with an attempt to gain chemical, plume smoke, and plume velocity information as well. The goal of the effort was to ascertain which measurements are effective for indicating approaching ignition conditions without regard to practicality which will be a subject of future studies. Figure 2 is a pictorial diagram of the layout of the instruments for these tests.

2.2.1 Thermocouples

Thermocouples were used to measure temperatures in three general areas: the plume, the pan, and the range. The buoyant plume above the pan which consisted of hot air, gases, and food aerosols generated by the heating process was equipped with a grid of thermocouples as shown in Figure 3. The vertical centerline, or axis of symmetry, of the pan was monitored with six thermocouples, and three heights were horizontally mapped with three additional thermocouples each. The thermocouples were Omega* model no. 5TC-GG-(K)-30-(72) [30 gauge, 0.25 mm (0.010 in) diameter, K-type (Chromel-Alumel), 183 cm (72 in) long, glass braid insulation].

*Certain commercial equipment, instruments, or materials are identified in this report to specify adequately the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

Table 3. Experimental test matrix. The numbers are consecutive-test designations.

Food	**Range**	**Range A** Electric with Open-Coil Elements		**Range B** High-Output Gas		**Range C** Electric with Smoothtop	
	Hood Status	On	Off	On	Off	On	Off
Soybean Oil		1,4,8	5	14,16	18	7	
Bacon		3,9	2,10	13,15	17,19		6
Table Sugar		11	12	20	21,22		

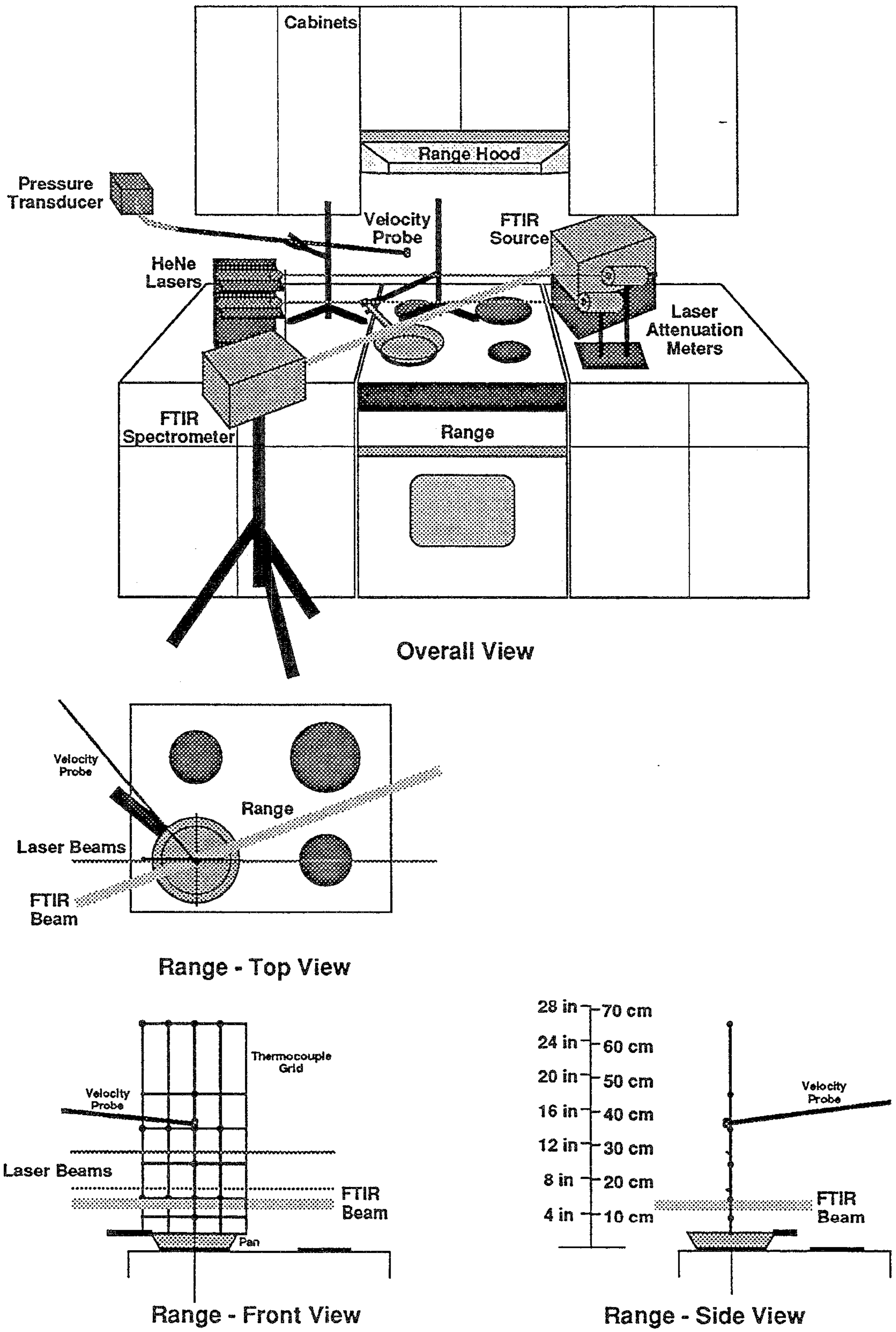

Figure 2. Pictorial diagram of the instrumented test area.

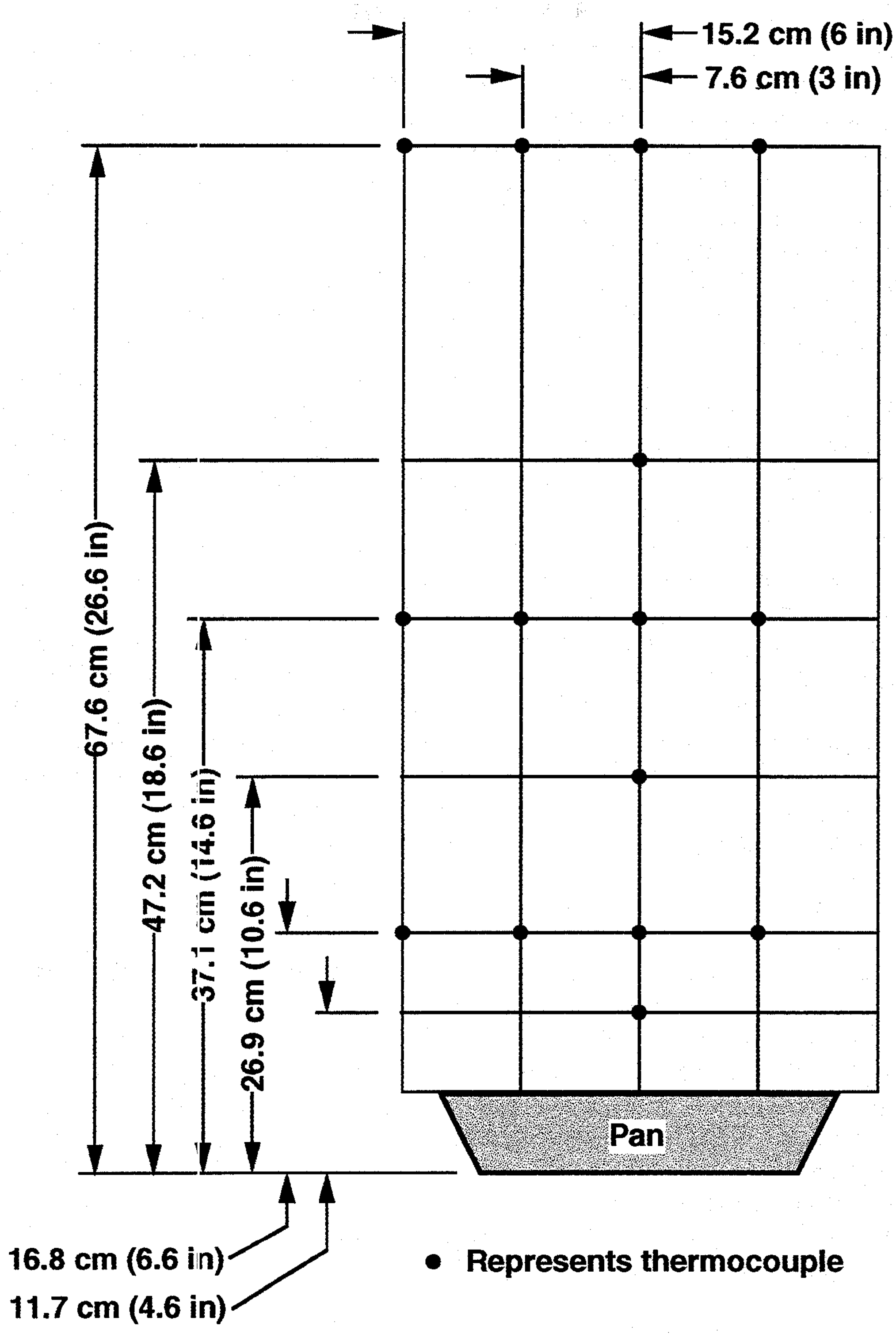

Figure 3. Schematic of the plume thermocouple grid.

The pan area was monitored with several thermocouples. Two thermocouples contacted the food inside the pan near the center at the bottom and approximately 7 mm (0.3 in) above the bottom. These thermocouples were Omega model number KMQSS-020(G)-12 [stainless-steel sheathed, 0.51 mm (0.020 in) sheath diameter, K-type (Chromel-Alumel), grounded, 30 cm (12 in) long]. The temperature interface between the cooking element and pan was measured with another 0.51 mm (0.020 in) sheathed thermocouple. In the case of the electric range, the thermocouple was sandwiched between the centermost ring of the resistive element and the pan. For the gas range, the thermocouple was located in the outer 2 cm (0.8 in) of the pan diameter so as not to be in the flame itself. The thermocouple was bent to cause contact with the pan bottom. A special washer thermocouple assembly (a thermocouple designed as a boltable washer) was attached to the inside of each pan using an 6-32 type screw and nut through a 3.6 mm (9/64 in) diameter through-hole 1.8 cm (0.7 in) above the bottom (inside) of the pan. This thermocouple was Omega model number WTK-6-60 [20 gauge, 0.368 cm (0.145 in) washer diameter, M3.5 (#6) screw size, K-type (Chromel-Alumel), 152 cm (60 in) long, glass braid insulation] and was used to estimate the metal temperature at ignition since the ignition location was most likely the hot metal surface where it interfaced with the food.

Thermocouples were placed at several other locations around the range and range hood where it would be relatively easy to locate a built-in sensor. The thermocouples were Omega model no. SA1-K [30 gauge, 0.25 mm (0.010 in) diameter, K-type (Chromel-Alumel), 91 cm (36 in) long, Teflon insulated, self-adhesive backing]. The locations were as follows: 17 cm from the center of the burner at the 2 and 8 o'clock positions (60 ° and 240 ° clockwise from rear of burner, respectively); mounted on the range hood's vertical front wall both inside and outside, centered above the active burner; below the range top under the burner area (electric only); and on top of the range back, directly behind the burner (gas only). The thermocouple below the electric range top was only implemented for a few tests.

2.2.2 Laser Attenuation Apparatus

In order to determine relative aerosol mass concentration above the cooking area, two He-Ne laser attenuation systems were arranged such that the beams passed through the axis of symmetry of the pan 17.8 cm (7 in) and 27.9 cm (11 in) above the burner surface. The He-Ne lasers were Melles Griot model number 05-LLR-811, and each generated a beam with 1 mW power. They were mounted on a vertical-translation stand which provided the ability to finely adjust their position. The transmitted light was received by two photodiodes which were mounted on optical rods and connected to a power source. The photodiodes (Hamamatsu S1337-1010BQ, 100 mm^2 active surface area), operational amplifier circuits, power source box, and mountings with connections for power input and signal output were the same as those used by Pitts et al.[5] The pre-test output of the devices with unobstructed laser light was 8 - 10 V.

2.2.3 Bi-directional Probe

The vertical gas velocity above the cooking area was measured through the use of a bi-directional probe and a sensitive pressure transducer. The probe was stainless steel with 14.3 mm

(9/16 in) inside diameter ends of 1.2 mm (3/64 in) wall thickness and 31.8 mm (1.25 in) height, and the support tubes were 113 cm (44.5 in) long. The probe end was located approximately 36 cm (14 in) above the burner surface and centered above the pan. Since most velocity measuring instruments are hindered by particle-laden flows, a bi-directional probe was implemented because of its ability to perform in smoke-laden flows such as are produced by pre-fire and fire conditions.[6] The probe was connected to a Setra model 264 pressure transducer for which the range was ±24.9 Pa (±0.1 inches of water) with an output of 2.5 Vdc for zero differential pressure and 10 Pa/Vdc sensitivity. The transducer excitation was accomplished with a Setra model 2195 regulated 12-28 Vdc power supply.

2.2.4 Fourier Transform Infrared Spectrometer

The spectrum of major gas species above the cooking area was measured using an open-path Fourier transform infrared spectrometer (FTIR). A MIDAC Corporation Model M2501-C detector and Model M2402-C source were placed approximately 1.6 m (63 in) apart with the burner of interest approximately centered between them. The two units were positioned at a height such that the center of the 3.8 cm (1.5 in) diameter infrared beam passed through the center axis of the pan approximately 15 cm (6 in) above the burner surface. The spectrometer spectral resolution was set to 4 cm^{-1}. Each set of sixty-four spectra was signal-averaged over 20 seconds to provide each data point.

2.2.5 Infrared Video

An infrared video camera was used to obtain thermal imagery of the cooking environment over time so comparisons could be made of maximum temperatures and temperature gradients in the period preceding ignition. The camera used was an Inframetrics model 525 camera and power supply. It was connected to a Canon VR-20 portable video recorder and a JVC TM-22U color video monitor. The camera was directed from an angle approximately 20° above the horizontal plane of the burner and was located at sufficient distance to focus on a view that included the burner, pan, some of the food, about 15-20 cm (6-8 in) on each side of the pan, and about 25 cm (10 in) above the pan. The area framed by each image was about 56 cm (22 in) wide by 39 cm (15 in) tall. The videotapes were reviewed, and individual IR image frames were digitally analyzed at 1 second, 45 seconds, and 90 seconds before ignition.

Two blackbody sources were utilized for calibration of the infrared video images. The Mikron model M-310 source was set at 300 °C, and the Barnes Engineering source was set at 511 °C. The Mikron source provided a continuous readout of the temperature, but a Fluke model 52 K/J thermometer was necessary to monitor the Barnes Engineering source while recording the calibration video.

2.2.6 Standard Video and Photographic Equipment

A VHS video camera, Panasonic AG-170 Proline, was approximately centered outside of the doorway of the laboratory enclosure and was focused to capture a view of the entire cooking scene including the range surface, cooking pan, range hood, and smoke plume. The abilities to zoom close to the pan as well as achieve panoramic views were important features of the camera. A Ricoh Mirrai zoom lens camera was used to take still 35 mm slide photographs of the apparatus and test behavior.

2.3 Data Acquisition, Reduction, and Plotting

2.3.1 Data Acquisition

An Intel 486 computer controlled the data acquisition process. The computer communicated with an HP3460 scanner box and HP3454A digital voltmeter. The data system has a capacity of 20 instrument channels and 60 thermocouple channels, but only 3 and 24 were used, respectively. Approximately one second of scan time is required for every 20 channels used. The data system was capable of scanning the 27 channels at two second intervals which was the setting for a few tests, but most of the tests used a three second time interval.

A data acquisition program developed at the Building and Fire Research Laboratory was executed on the computer. The program requires input of instrument channel range, thermocouple channel range, scan interval, display preference, and file name. The program allows the user to take sets of "zero" and "span" readings of the instrument voltages for purposes of calibration. For this series of tests, only a set of background zeroes, the output voltages for ambient conditions, was necessary. The data were stored on the computer hard disk in a format compatible with the data reduction program.

The FTIR spectrometer was controlled and the data were acquired with a dedicated Intel 386 computer. The FTIR scanned 64 times and produced average signals from the scans every 20 seconds. Initially, FTIR data were taken in the absorbance mode, but problems with data collection in this mode necessitated switching to collection of data in the single-beam mode which was then converted to the absorbance mode after each test using the data processing routines within the FTIR software.

2.3.2 Data Reduction

The reduction of data was accomplished with the RAPID software which was developed at NIST especially for fire tests.[7] RAPID consists of a set of FORTRAN subroutines that convert voltages from instrumentation and thermocouples into meaningful physical values. Subroutines are also available to further convert and combine basic variables into more useful forms. The main subroutines used for these experiments were TC to convert thermocouple voltages to temperatures, VELOCITY to convert the pressure transducer voltage into velocity, COMPUTE which combines any other channels arithmetically as desired, and SMOOTH which is described in Section 2.3.3.

Instrument descriptions and calibrations are entered and the subroutines are accessed through a control file with extension ".ctl". A sample control file is included in Appendix D. The control file specifies the treatment of the raw data and the output format. Each data file required a distinct control file for purposes of identification of the test and documentation in the output as well as for the input of specific zero calibration data that varied from test to test. Before processing each file, the zero scan and first minute of background data were inspected for anomalous readings, and the first five data points were averaged to provide the background zeroes for the laser-attenuation and velocity measurements. These numbers were typed into the control file. Applying RAPID.EXE produced two files, a reduced file with extension ".red" and a save file with extension ".sav". Each save file was inspected for reasonable output from each instrument. The next step was to apply a columnizing program COLUMN.EXE to the reduced file. This put the data into a format that could easily be pulled into a plotting software package.

The FTIR data were reduced separately from the other instrument data. The integrated areas for the hydrocarbon and water peaks were determined as a function of time using a MIDAC Grams/386 software program. Attempts were made to perform the same analysis on CO_2, but the results were found to be difficult to interpret. Carbon monoxide concentrations were below the detectable limits of the instrument.

Infrared camera images were processed and analyzed using customized software.[8]

2.3.3 Data Plotting

Data plotting was performed on a Macintosh Centris 650 with Kaleidagraph version 3.0 software. Kaleidagraph puts the data into columns and rows with each column associated with time or a channel of raw or processed data and each row representing a time step. Plotting of the data involves selecting one independent and the desired dependent variables from one or more data files. For comparison purposes, data were shifted in time for the few tests when background periods of longer than 60 seconds were required due to start-up difficulties. In this fashion, a variable from more than one test could be compared as if all of the tests were in the same time frame, or as if all the tests had a common burner activation time.

The set of data from each test was presented in 12 different plots for analysis and archival purposes. Two plots show the changes in velocity and laser-attenuation measurements in time. A third plot shows the FTIR hydrocarbon and water areas as a function of time. The rest of the plots are combinations of temperatures. Four vertical profiles of temperature and three horizontal profiles of temperature are plotted from the plume thermocouple grid. The last two plots are of those temperatures associated with the pan and food and those associated with other range and range-hood locations. The set of plots for one test will be presented in Section 3.0.

In some cases, actual fluctuations or noise in specific measurements obscured the overall trends. Smoothing of the data was used in these cases to clarify the trends. If "3 pt smooth" is noted on a plot, then each data point was replaced by one defined by a least-squares linear fit using three points consisting of the original point, the preceding point, and the following point. This type of smoothing was utilized in the application of RAPID to raw data. If "3 % smooth" is noted, then the same procedure was performed on the data, except 3 % of the total population was used to generate each linear fit and establish each new point. For a total population of 300 smoothed by 3 %, nine points would be used and would consist of the original point, the four preceding points, and the four following points. This type of smoothing was implemented using Kaleidagraph and was applied to reduced data when additional smoothing was deemed necessary.

2.4 Procedure

2.4.1 Experimental Operation

Each experiment began with no heat applied to the food and ended soon after ignition of the food. The duration of each test was determined by the time to ignition which varied from about 5 to 30 minutes, but was typically about 15 minutes. The steps involved in these experiments are described in the following paragraphs.

All of the power cords and strips were plugged in or switched on. The test identification and date labels were changed for photographic purposes. The pan-wall thermocouple was attached, and the pan, thermocouple, and lid were weighed together. After the food material equilibrated to room temperature, the appropriate amount was weighed and placed in the pan. Then the pan, food, thermocouple, and lid were reweighed to get an accurate mass of the food. The pan was placed on the burner, and the pan handle was secured with a clamp to a heavy ring stand to prevent spillage of the food during extinguishment with the lid. As the pan was placed on the burner, the burner-pan interface thermocouple was carefully positioned. The lid was not put on the pan, but the lowest thermocouples of the grid were checked for potential interference when the lid would be used to extinguish the fire. The pan-wall thermocouple was plugged into its data line, and the two food thermocouples were positioned in the food. The plume thermocouple grid was centered, and the He-Ne laser beams were turned on to check for interference by the grid. Any range or range-hood thermocouples that had been previously removed were repositioned.

The afterburner system and exhaust hood were turned on and allowed to equilibrate. If the test protocol called for an active range hood, it was also turned on. The data acquisition system was switched on, the program was initiated, and the required inputs were provided. The pressure transducer was switched on, and the height and centering of the bi-directional probe were checked. The photodiode circuits were powered, and the horizontal alignment of the He-Ne lasers was adjusted. For the electric range, the current meters and power meter were turned on as was the digital voltmeter used to read the AC signals.

The FTIR and its computer were operated separately from the rest of the experimental apparatus. The FTIR detector was filled with liquid nitrogen shortly before each test to cool the sensing element. An iterative alignment procedure was performed on the FTIR receiver using the spectrometer software. Initially the apparatus was aligned to give 90 % of the signal, but when some experiments experienced problems with flame radiation saturating the detector, it became necessary to decrease the signal alignment to roughly 80%.

The infrared camera also required liquid nitrogen. The camera was usually filled with nitrogen about 10 minutes before a test and topped-off immediately before the test to guarantee sufficient cooling for a test of long duration. The infrared camera and optical video camera were both checked for need of cassette replacement. The optical video camera was focused and the date and time labels were activated. The still photography camera was checked for slide film and loaded if necessary. The initial cooking scene was usually photographed.

When all of the previous activities were completed, the test was nearly ready to begin. Two zero scans were recorded with the data acquisition system and were checked for anomalies that might indicate reversed polarity, an open circuit, or power off to an instrument. After all adjustments were made inside, the operators vacated the room to allow the air currents to equilibrate, after which a background scan was recorded with the FTIR. The data acquisition operator then counted down to a start time at which moment the recording of general data, FTIR data, and the two videotapes was initiated. Two stopwatches were also started simultaneously. One minute of background data was recorded. The last five seconds of the background period were counted down to enable the burner or heating element to be set on the highest level at the one minute mark. Throughout the test, observations were made verbally and recorded on the test log sheet. A blank log sheet is included in Appendix C. Infrared camera settings were recorded as were times and numbers of photographs.

Upon ignition, the pan was covered with the lid to extinguish the fire, and the burner was shut off using an external circuit breaker (electric range) or valve (gas range). A CO_2 extinguisher was available in case of re-ignition which did occur in the case of oil heated on the electric range. Also, the sugar fires used only a CO_2 extinguisher and not the lid because the sugar tended to overflow the pan and prevent use of the lid. Each experiment was usually continued another five minutes in order to record the partial return of the variables to background conditions. The lid could not be lifted safely until sufficient time had passed to allow cooling of the pan below ignition temperatures.

While a pan was cooling, a calibration video was recorded for the infrared camera. The camera was lowered and moved close to two blackbody sources that were set up in a corner of the laboratory. The temperatures of the sources and the voltage level of the camera were noted while the camera recorded 10 - 30 seconds of images. If the voltage level drifted, usually lower, from pre-test levels, video was recorded under the current as well as reset conditions. Generally, a calibration was performed between two consecutive tests to allow its use for both.

After a pan was cool enough to handle safely, it was removed with the lid still in place and weighed to determine the mass loss due to heating and the brief period of flaming. For the soybean oil, the volume of the remaining material was also estimated, but this was somewhat difficult because of the increased viscosity of the oil and the difficulty of removing all of it from the pan into a graduated cylinder.

After each test was completed and materials were weighed, an already clean pan was prepared for immediate use while the just-used pan and lid were cleaned for future use. It was found that the pans could be adequately cleaned for multiple test usage with steel wool and strong detergent. The exception was the pans that were used to cook sugar which could only be cleaned sufficiently with excessive effort. The stainless steel surfaces were returned to smoothness with minimal debris, and only oxidative coloring remained after cleaning.

2.4.2 Safety Practices

A set of safety rules and precautions was developed because of the threats of smoke inhalation, fire spread, etc. No personnel were permitted in the laboratory enclosure after the cooking began to produce significant smoke and a layer of smoke developed unless breathing apparatus was utilized. All of the personnel conducting or observing the experiment had to wear safety shoes and safety glasses or goggles. Visitors were not allowed to pass the warning tape located on the floor at the door opening. At least one fire extinguisher was located near the doorway and someone trained in fire containment was always nearby when ignition was imminent.

3.0 Results and Discussion

3.1 General Experimental Results

The results of the parametric experiments are further discussed in this section. The main focus is on the instrumented experiments and the possibility that any of the measurements recorded can lead to pre-ignition detection.

3.1.1 Parametric Experiments

The parametric experiments were primarily of interest for assistance in the selection of the pans used in the instrumented tests. The temperature behavior of these tests is of some additional interest. Figure 4 depicts the temperature versus time curves of the parametric tests for which temperature was monitored. Both of the tests using stainless steel pans (shown as solid lines) ignited, while the others which used aluminum pans (dashed lines) did not. The two tests of different amounts of corn oil in a stainless steel sauce pan show similar temperature behavior, except the one using the smaller amount caused compression of the curve in time. The tests of different amounts of corn oil in a ceramic-coated aluminum pan also show similar behavior except the one using the smaller amount also caused time compression of the curve. The tests of 250 mL of corn oil in two kinds of aluminum pans show similar behavior. Oil heated in aluminum pans on this typical gas range fell short of ignition temperatures by at least 30 °C.

The last two parametric tests were conducted on the open-coil electric range. The baked beans test shows a very long water evaporation time, about 1500 seconds, until the temperature begins to rise sharply over 100 °C. Heating was continued for several minutes after smoke production had decreased to a low level. The bean residue consisted of a dry char and ash. The last test was conducted using an aluminum frying pan with 250 mL of corn oil which did ignite after approximately 12 minutes, but the temperature was not monitored. This test demonstrated the ability of the electric range to ignite oil in an aluminum pan.

3.1.2 Instrumented Experiments

A total of twenty-two tests, listed in Table 3 and consisting of twelve combinations of range, food, and hood status, were conducted of which eighteen produced ignition and did not experience problems with data collection or operational procedure. Seven of the test combinations were repeated. Test one was repeated twice because the initial heating level was too low. Tests six and seven were the only tests conducted on the smoothtop range because test six did not produce ignition, and additional unsuccessful tests were considered likely to occur.

The results of the instrumented experiments are provided primarily in graphical form. One test of oil heated on the electric range with the range hood off is used as a typical example

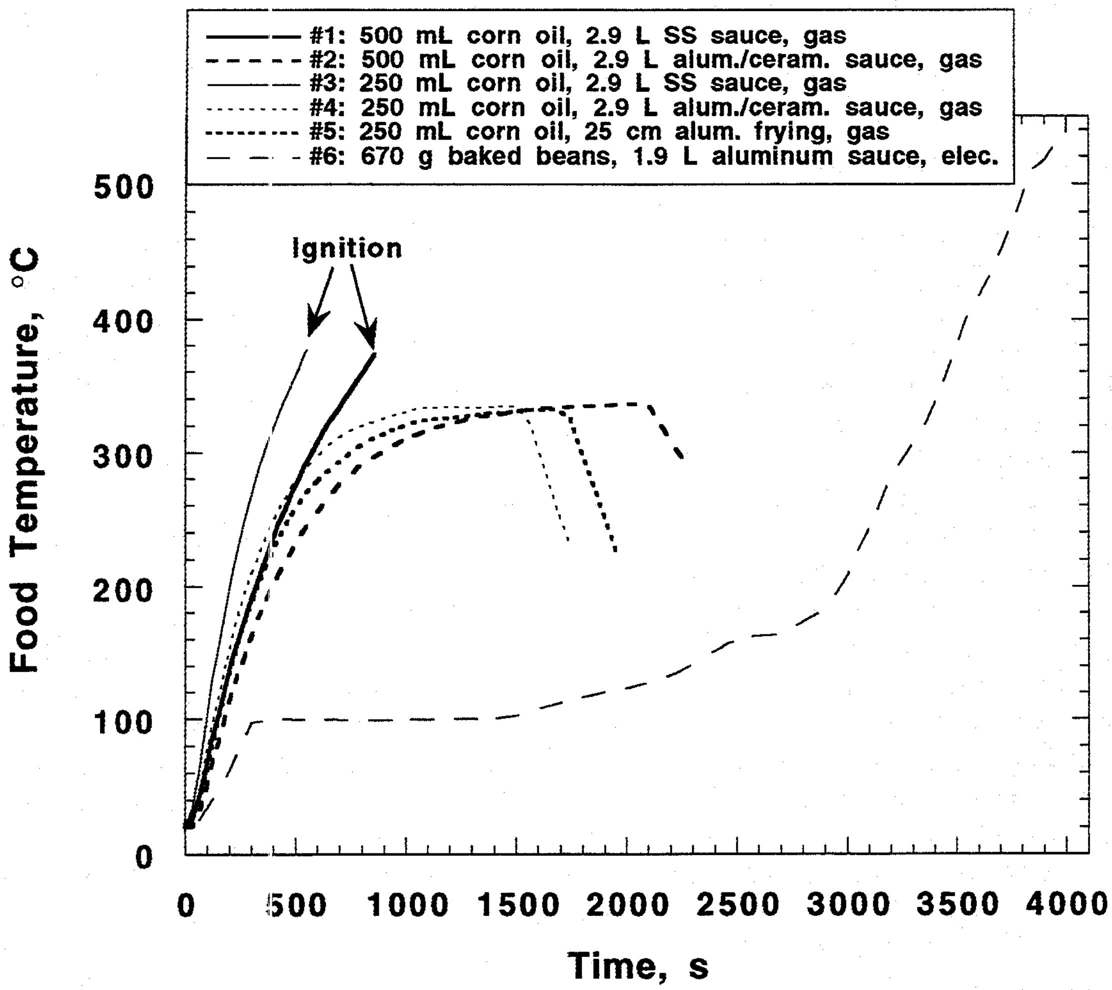

Figure 4. Parametric experiments temperature versus time curves.

throughout this section. The results and discussion focus primarily on comparing the same measurement from each different fire on the same plot and judging the potential use of that measurement as a universal pre-ignition signature. Not all of the measurements are compared, but certain measurements within each family of similar measurements were selected as both typical of the type of measurement and most practical for future implementation based on location. The comparison plot curves all begin at the time the burner was energized and end about two seconds before the ignition time. The oil and bacon in the electric-range tests ignited significantly faster than the same foods in the high-output gas-range tests. For this reason, the measurement comparisons are separated by range type. "On" and "off" in the comparison plots legends refer to the status of the range hood for each test.

3.2 Temperatures

3.2.1 Pan and Food

Figure 5 shows the temperatures from the pan and food thermocouples as a function of time for a test of oil heated on an electric range with the range hood off. There was apparently no temperature gradient within the oil since the two food curves coincide. The pan inside-wall temperature was also identical to the food temperatures until ignition when the thermocouples in the oil were displaced from the pan by the lid as it was used to extinguish the fire. After ignition, the food temperatures no longer indicated the temperature of the food since the thermocouples lost contact with the food and were on top of the lid. After ignition, the pan-bottom temperature gradually approached the pan-side temperature.

Figure 6 shows a comparison of the pan-bottom temperatures for all of the food and range-hood combinations heated on the electric range. The sugar results exhibit a much faster temperature rise because heat is transferred to sugar less efficiently than to oil which allows the metal pan to retain more of its heat in the sugar case. The oil and bacon curves are all similar to each other. Figure 7 shows a comparison of the pan-bottom temperatures for all of the food and range combinations heated on the high-output gas range. The tests of bacon and oil with the range hood off experienced much higher temperatures than the same foods with the range hood on. It is unknown whether this was due to the lack of heat extraction by the hood or some other reason. It could also have been a configuration effect because a minor change in the proximity of the thermocouple to the burner flame could greatly influence the measured temperatures.

Figure 8 shows a comparison of the pan-side temperatures for all of the food and range-hood combinations heated on the electric range. Except for the test of oil with the range hood on, all of the temperature curves are similar. Figure 9 shows a comparison of the pan-side temperatures for all of the food and range combinations heated on the high-output gas range. The oil tests' trends are similar, but the test with an inactive range hood does show faster heating. The sugar test results show a much faster temperature rise due to the initially dry state of the sugar, and the bacon test has a much slower temperature rise than either the sugar or oil.

The temperatures of the food and pan may show reproducible and predictable pre-ignition behavior, but the locations are quite inconvenient for measurements during cooking. On the electric range, the burner and pan bottom should experience similar conditions so the burner is

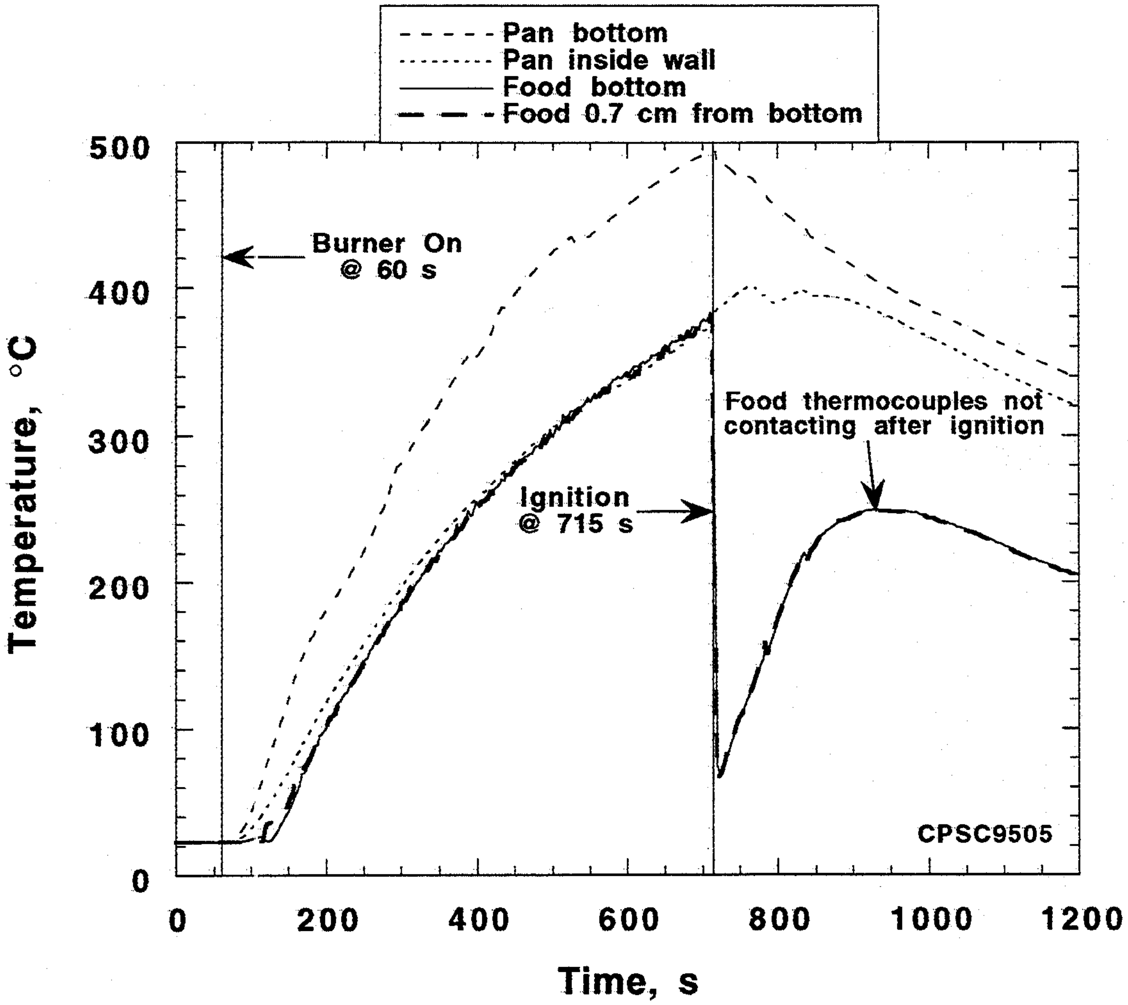

Figure 5. Plot of pan and food temperatures versus time for oil heated on the electric range with the range hood off.

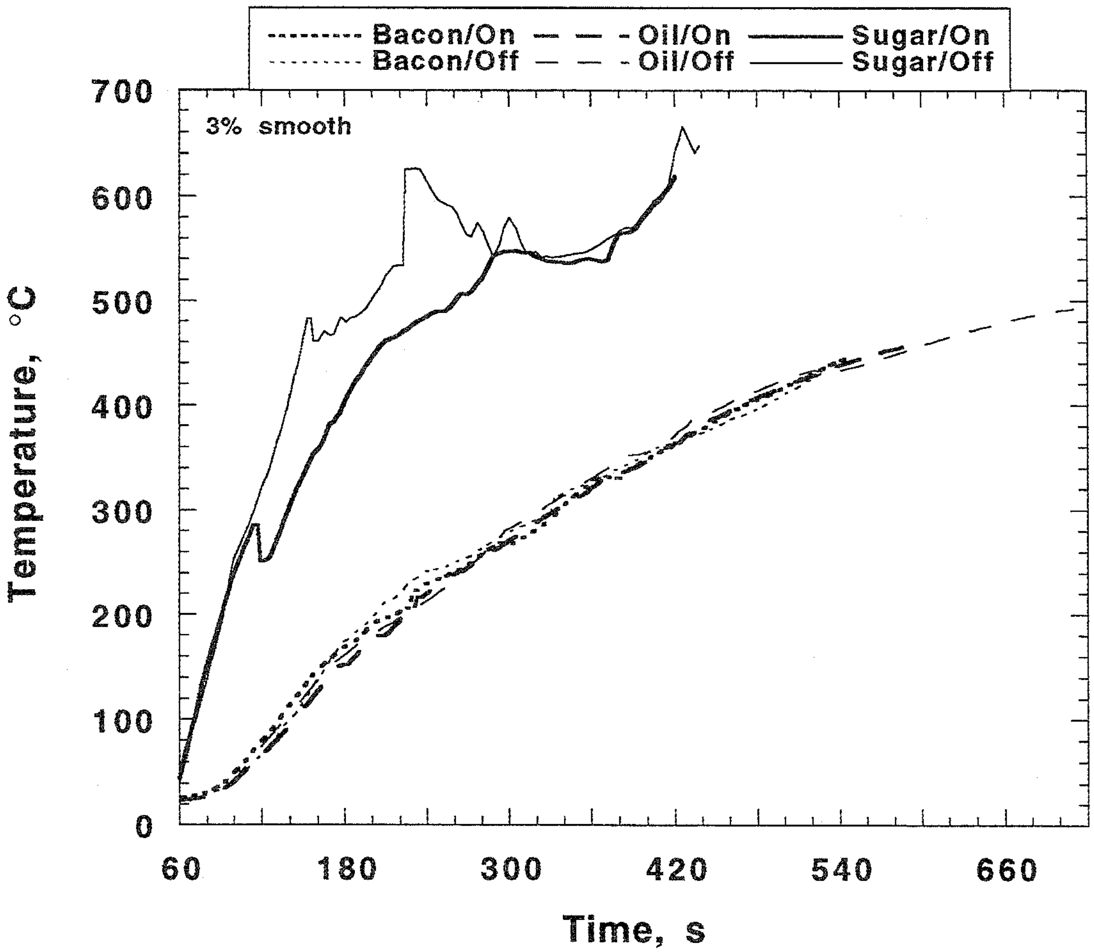

Figure 6. Plot of pan-bottom temperatures versus time for all tests on the electric range.

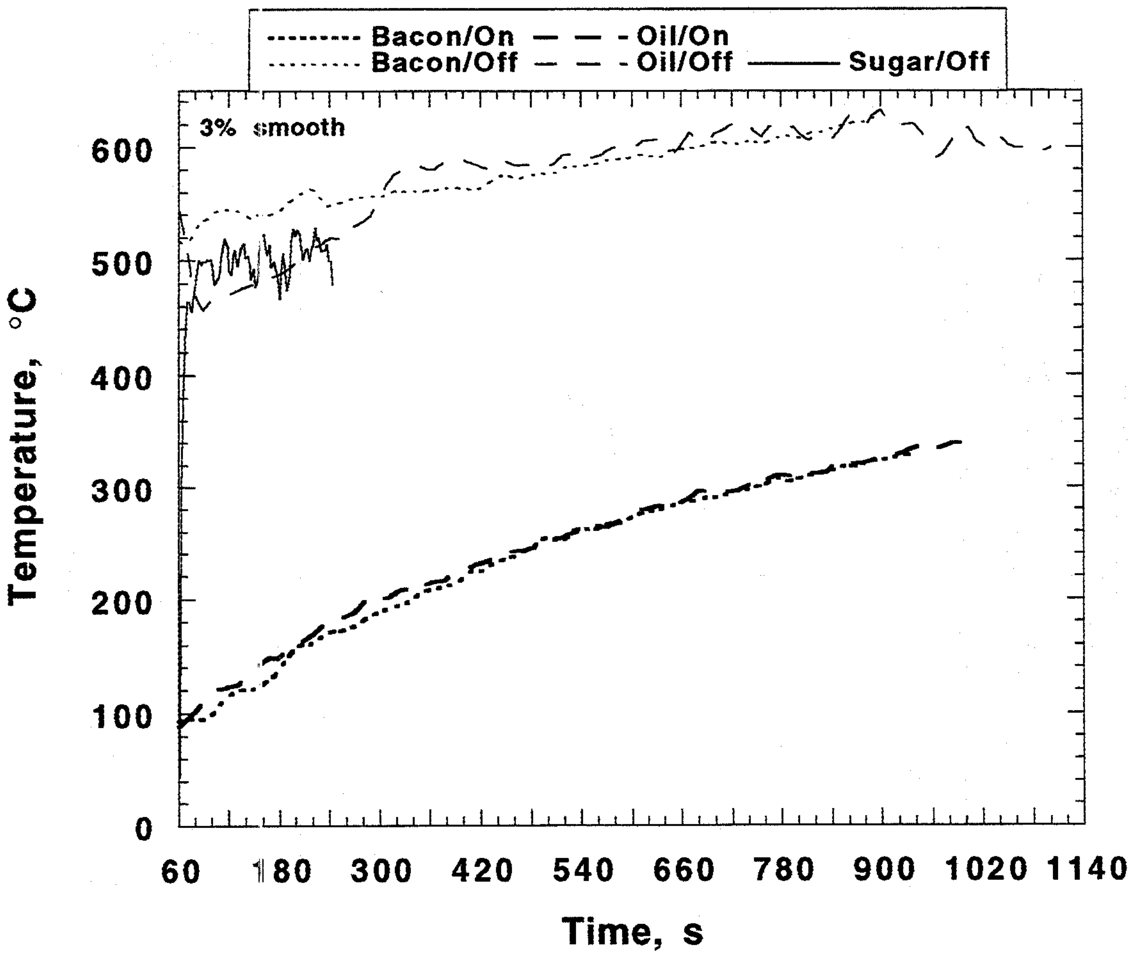

Figure 7. Plot of pan-bottom temperatures versus time for all tests on the high-output gas range.

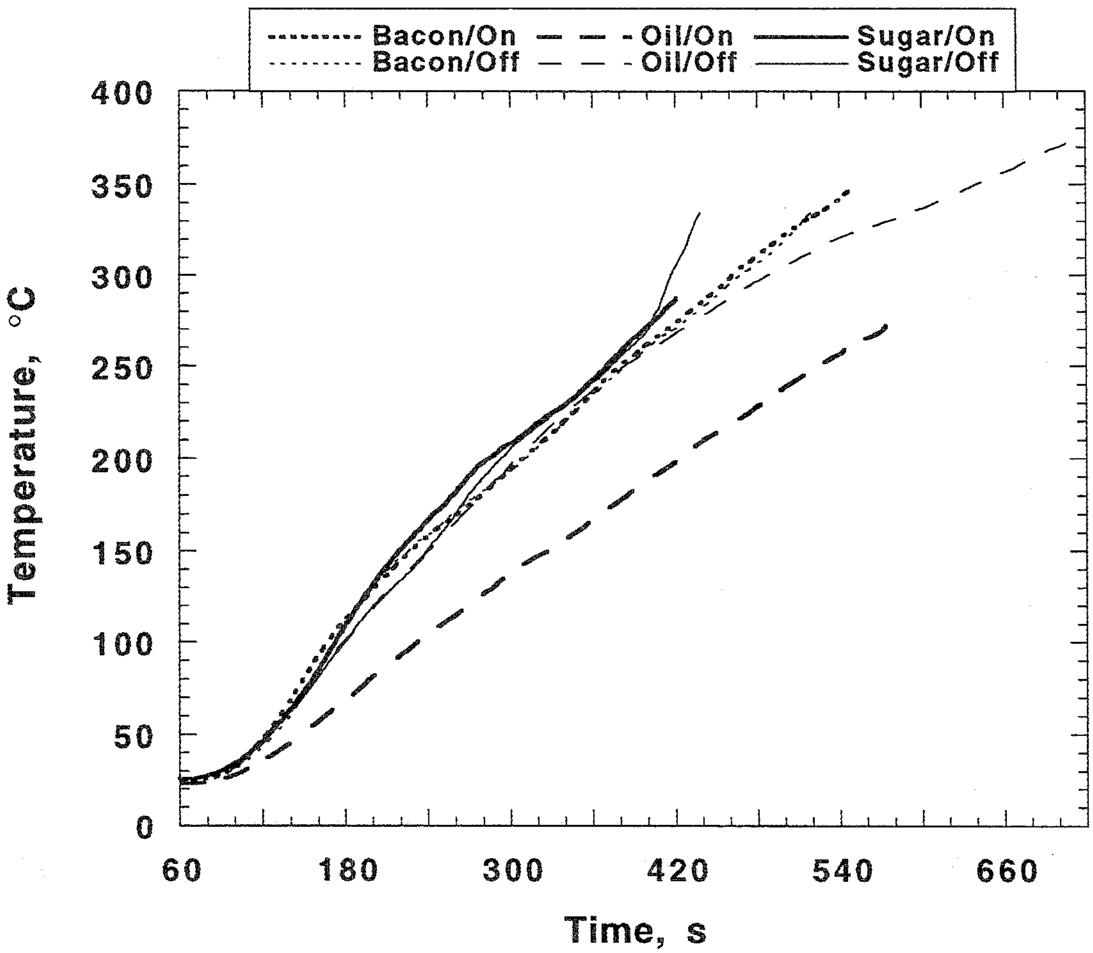

Figure 8. Plot of pan-side temperatures versus time for all tests on the electric range.

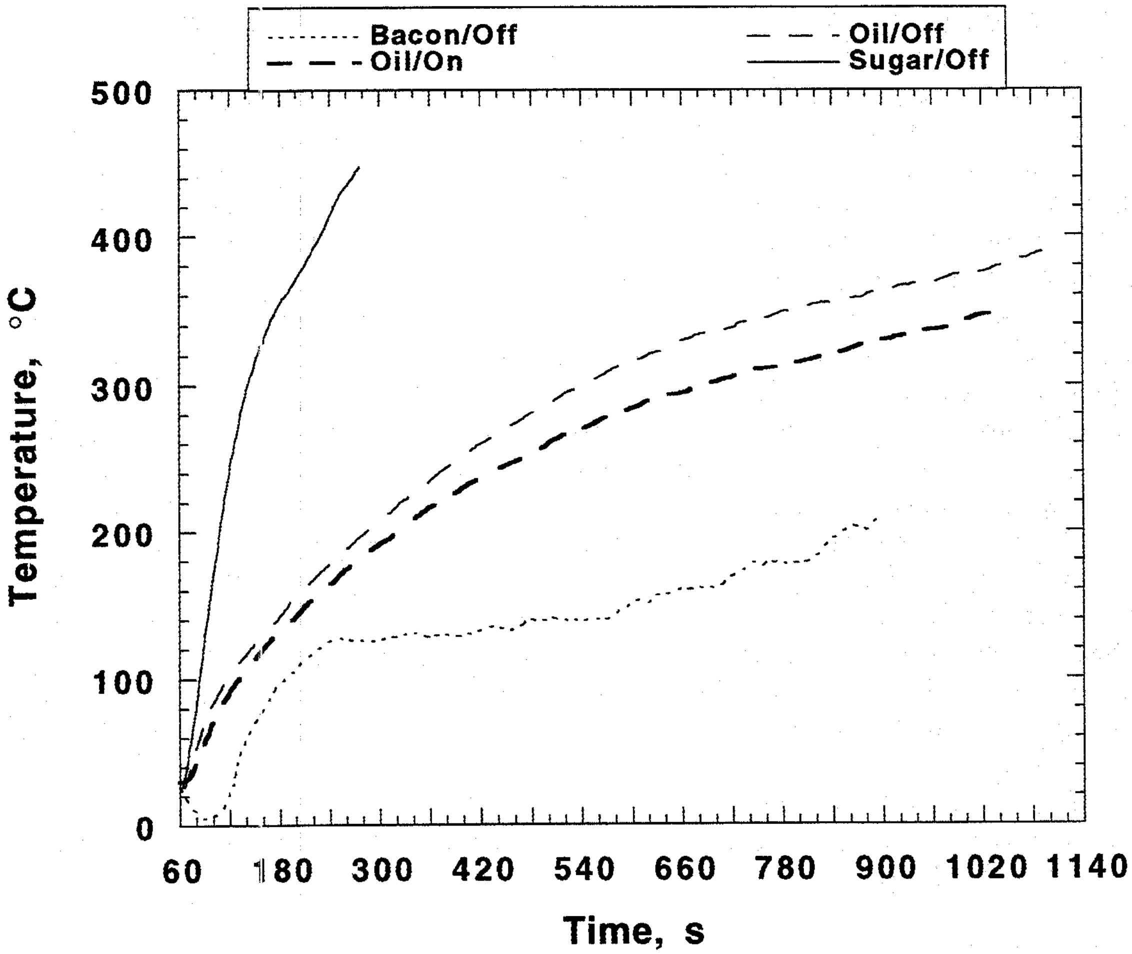

Figure 9. Plot of pan-side temperatures versus time for all tests on the high-output gas range.

a good candidate for such measurements. The burner or pan temperature on the electric range could be used in conjunction with other signatures if threshold temperature or integrated time and temperature behavior were utilized to detect pre-ignition conditions.

3.2.2 Plume

Figures 10 through 16 show the plume thermocouple grid temperatures as a function of time for a test of oil heated on an electric range with the range hood off. The grid diagram of Figure 3 helps in interpreting these figures. Figure 10 shows the vertical profile of the pan-centerline temperatures above the burner. Before ignition, none of the temperatures exceeded 100 °C. The plumes were relatively cool compared to the pans and food below. At the highest point above the burner, the temperature only reached about 40 °C. Figures 11 and 12 show the vertical temperature profiles 7.6 cm to the left and right (when facing the range) of the pan centerline. The temperatures left of center were much less than those right of center. This implies a high degree of asymmetry in the plume. At 16.8 cm above the burner, the temperature right of the pan centerline was even 10 °C greater than the centerline temperature. Figure 13 shows the vertical temperature profile 15.2 cm to the left of the centerline. Of all of the vertical temperatures, these were the coolest.

Figures 14, 15, and 16 show the changes in horizontal temperatures with time along lines 16.8 cm, 37.1 cm, and 67.6 cm above the burner, respectively. These figures also demonstrate that the plume temperatures were shifted to the right of center. The plumes in the tests conducted on the high-output gas range tended to shift to the left slightly. In every case, while the degree was different for each test, the plumes tended to lean away from the center of the range.

Figure 17 shows a comparison of the centerline temperature 37.1 cm above the burner for all of the food and range-hood combinations heated on the electric range. The behaviors of the same foods were similar. Figure 18 shows a comparison of the centerline temperature 37.1 cm above the burner for all of the food and range combinations heated on the high-output gas range. The bacon temperature curves are similar, but the oil curves differ by about 20 °C and show different trends. Sugar ignited very quickly, even relative to the parallel electric-range test. These figures show that the range hood affects the ignition process and the plume to a minor degree at most.

The plume may be a difficult location to position a temperature measuring device as a range pre-ignition detector. The temperatures are not very high in the plume and do not change significantly with time during heating.

3.2.3 Range and Range Hood

Figure 19 shows the temperatures of the range and range-hood thermocouples as a function of time for a test of oil heated on an electric range with the range hood off. The outside surface of the hood actually cooled prior to ignition. The range surface thermocouples equidistant from the burner have similar temperature curves. The temperature of the range beneath the burner surpassed 200 °C which means that the space beneath the burner is a relatively hot environment.

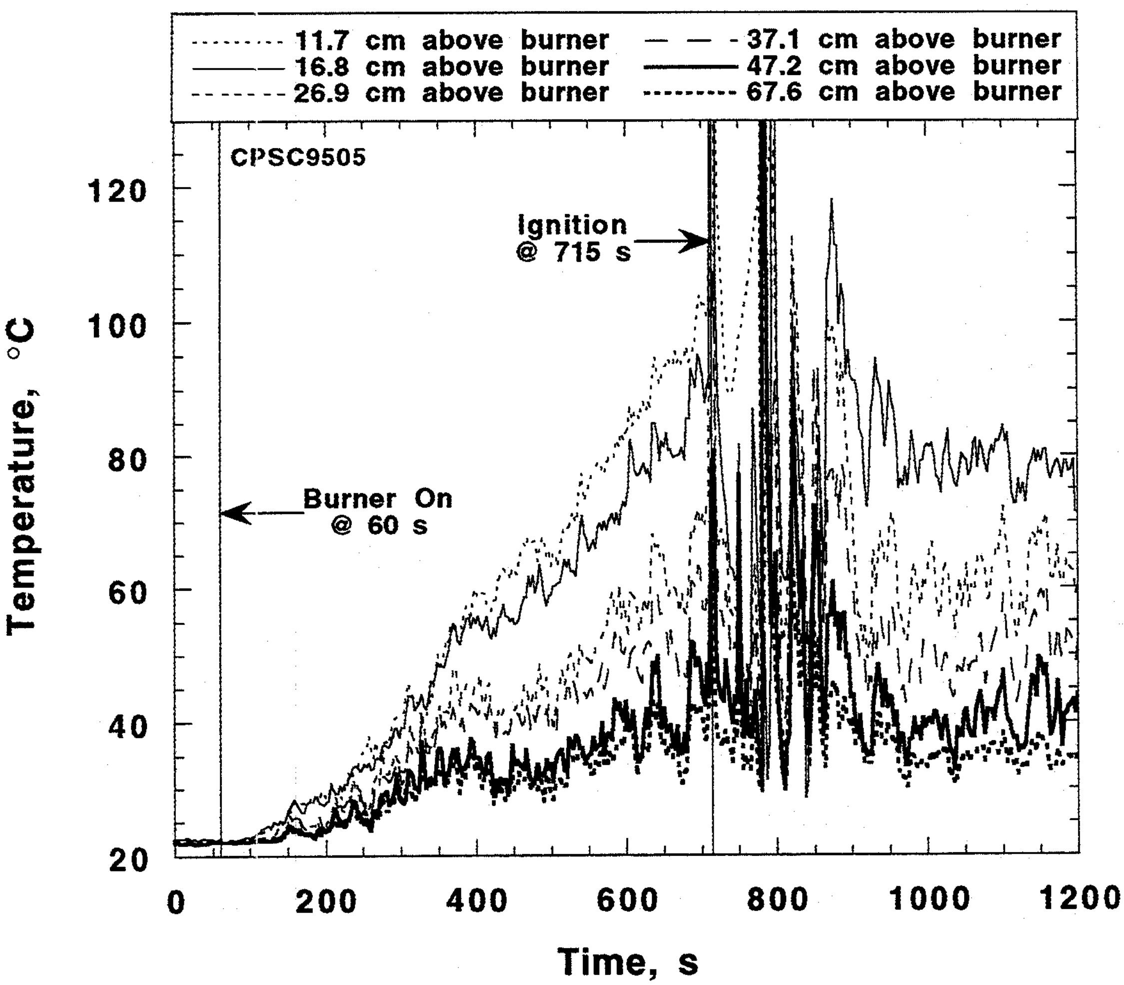

Figure 10. Plot of vertical profile of pan-centerline temperatures in the plume versus time for oil heated on the electric range with the range hood off.

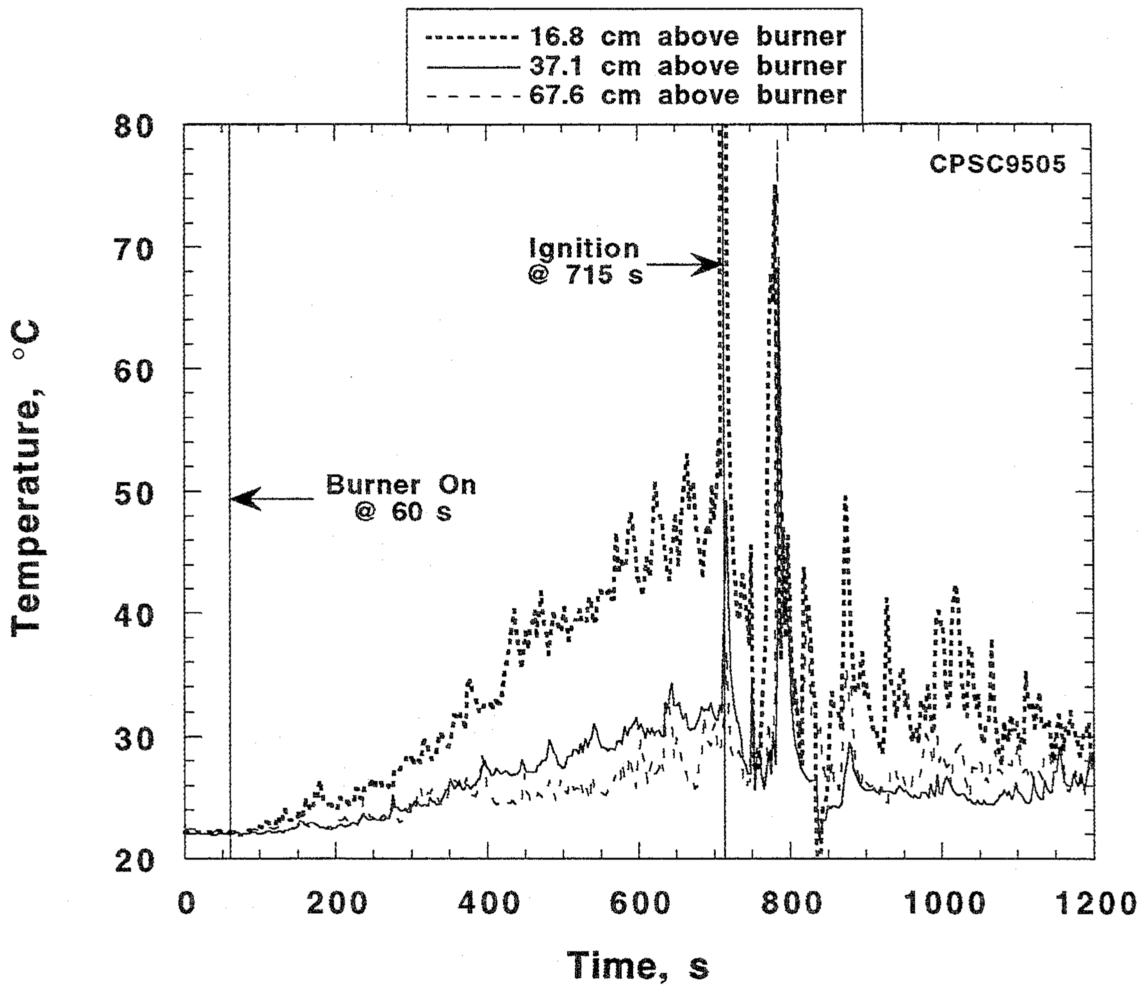

Figure 11. Plot of vertical profile of temperatures 7.6 cm left of the pan centerline versus time for oil heated on the electric range with the range hood off.

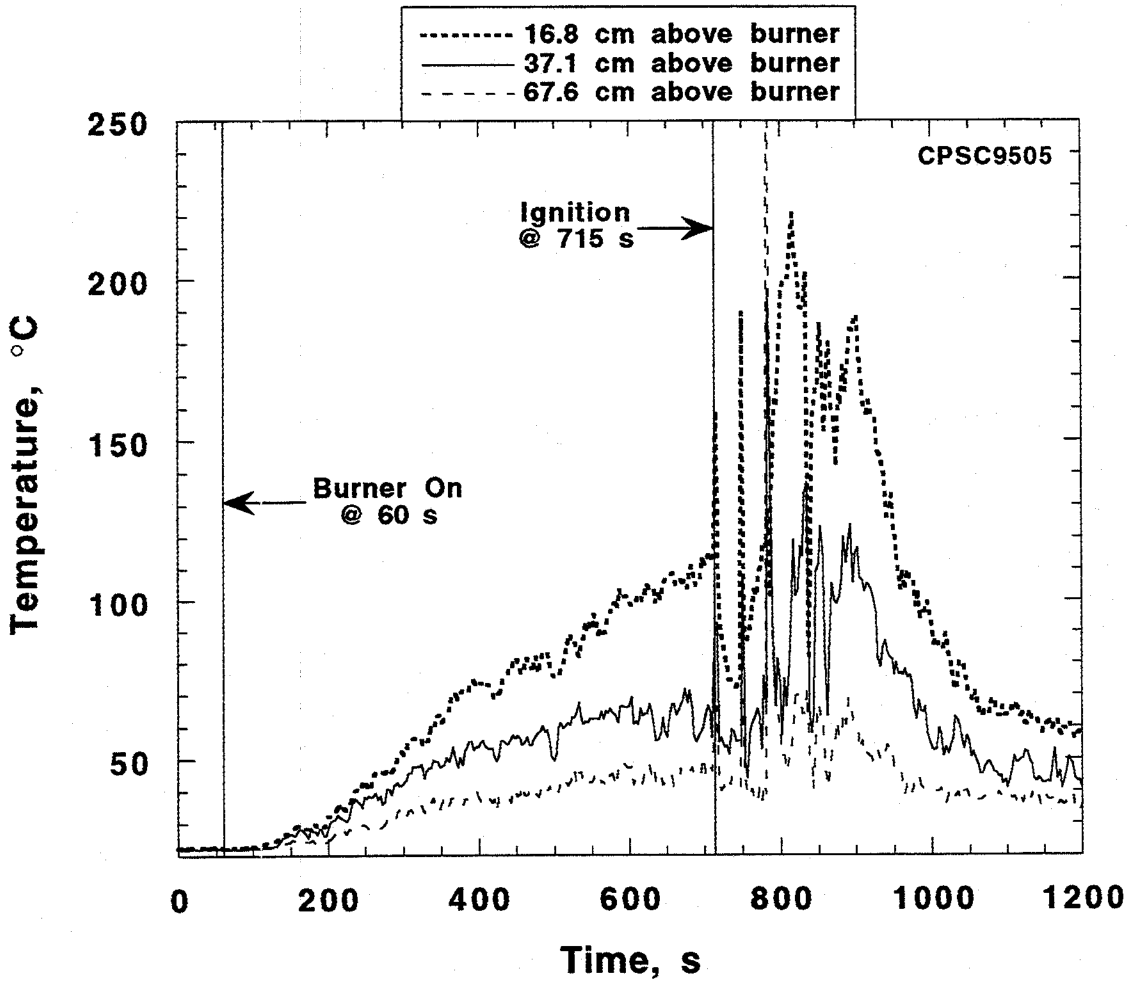

Figure 12. Plot of vertical profile of temperatures 7.6 cm right of the pan centerline versus time for oil heated on the electric range with the range hood off.

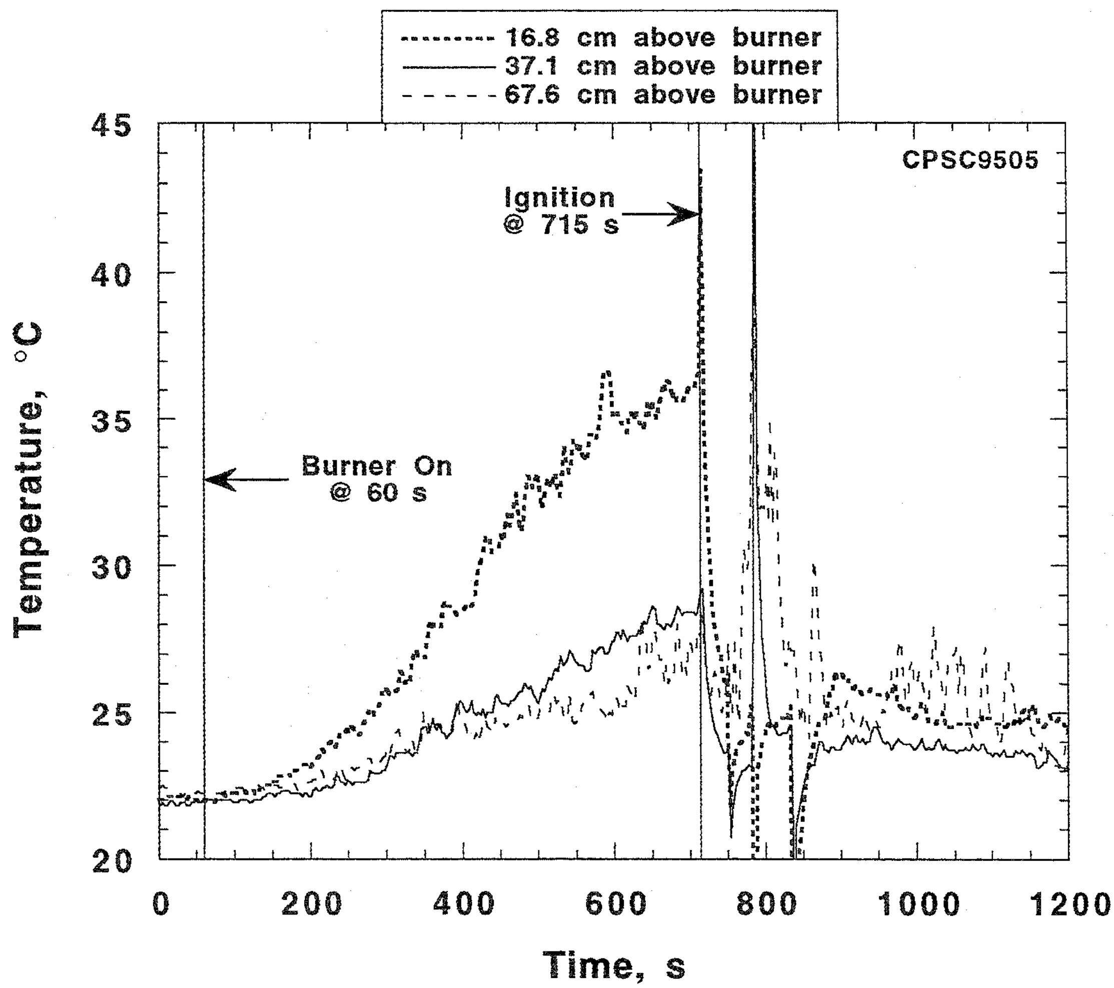

Figure 13. Plot of vertical profile of temperatures 15.2 cm left of the pan centerline versus time for oil heated on the electric range with the range hood off.

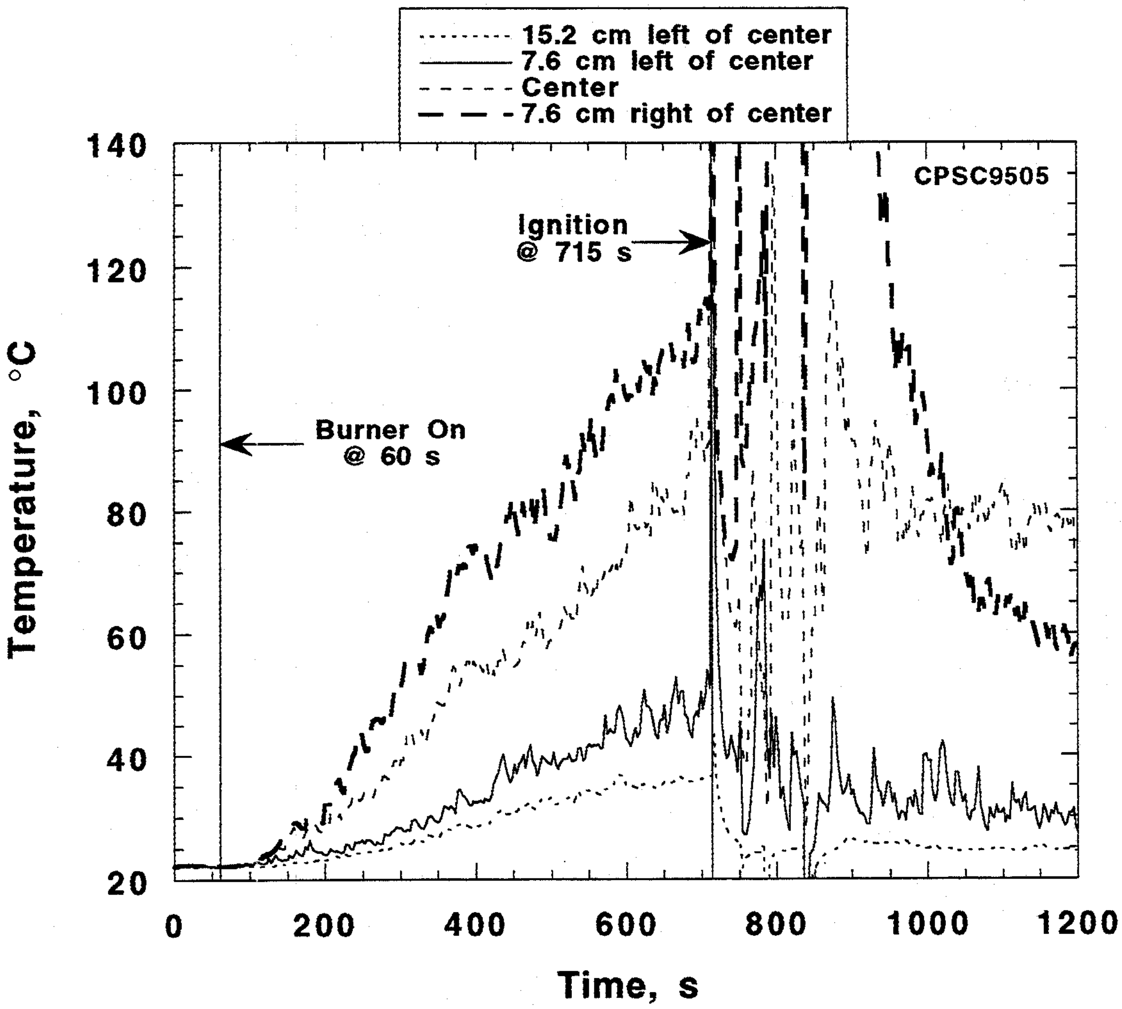

Figure 14. Plot of horizontal profile of temperatures 16.8 cm above the burner versus time for oil heated on the electric range with the range hood off.

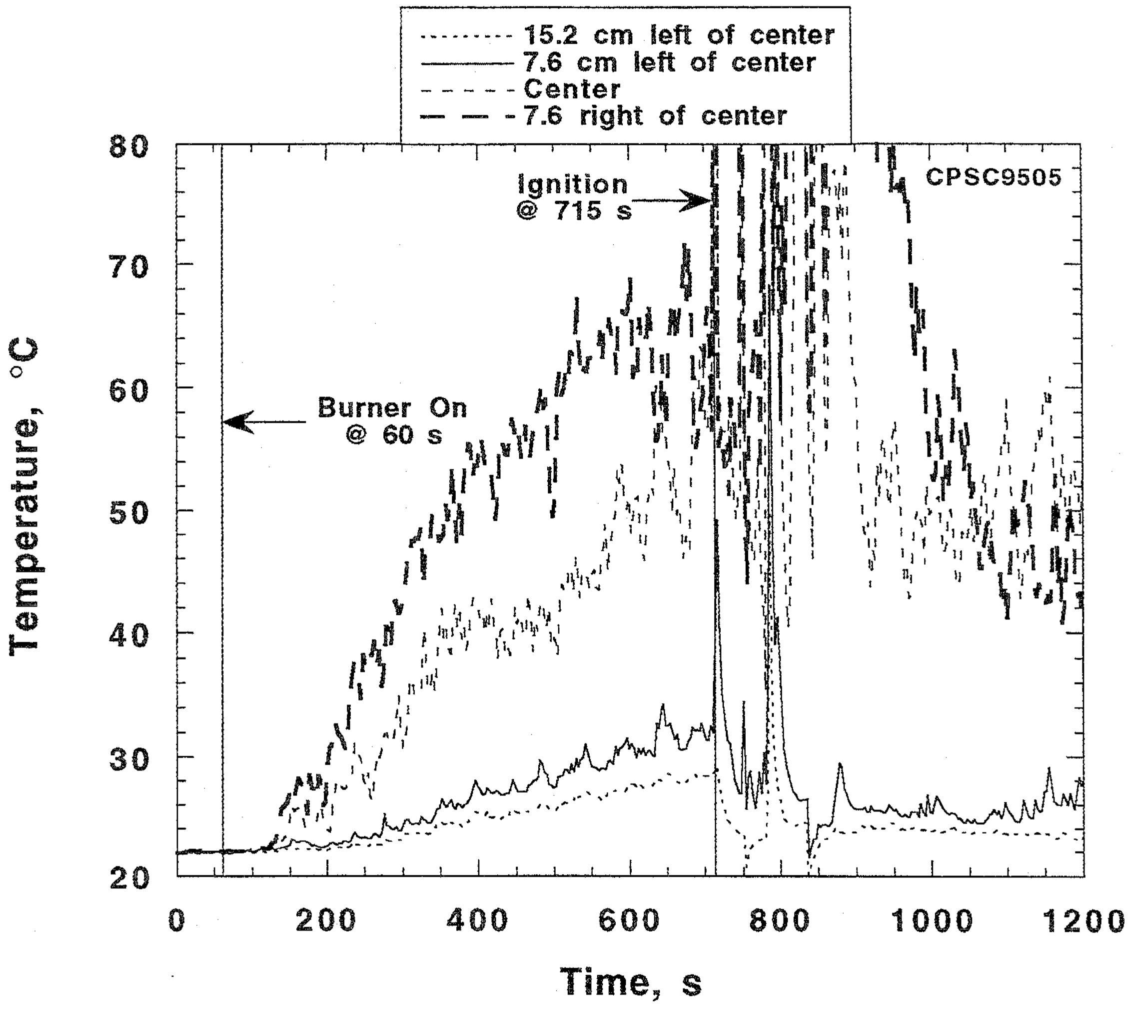

Figure 15. Plot of horizontal profile of temperatures 37.1 cm above the burner versus time for oil heated on the electric range with the range hood off.

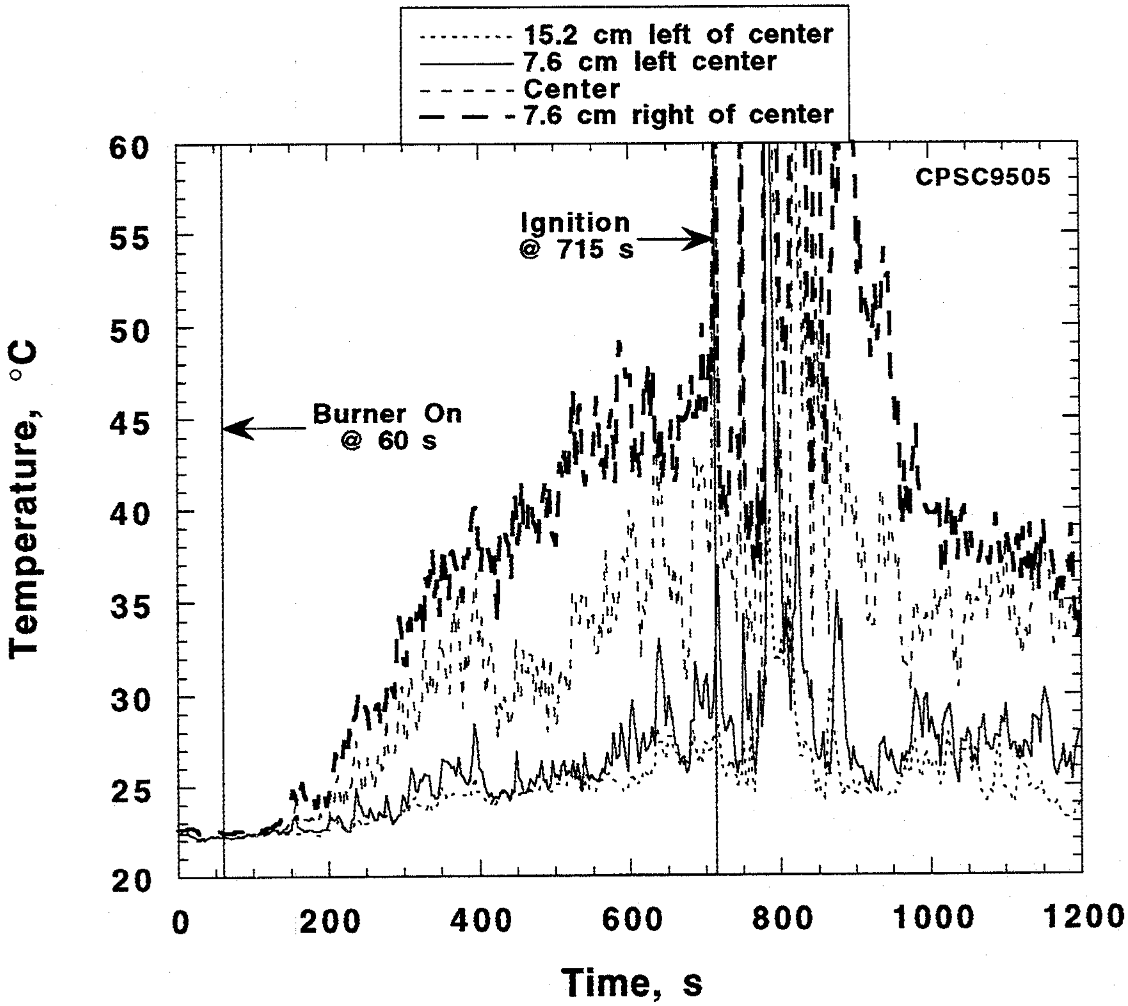

Figure 16. Plot of horizontal profile of temperatures 67.6 cm above the burner versus time for oil heated on the electric range with the range hood off.

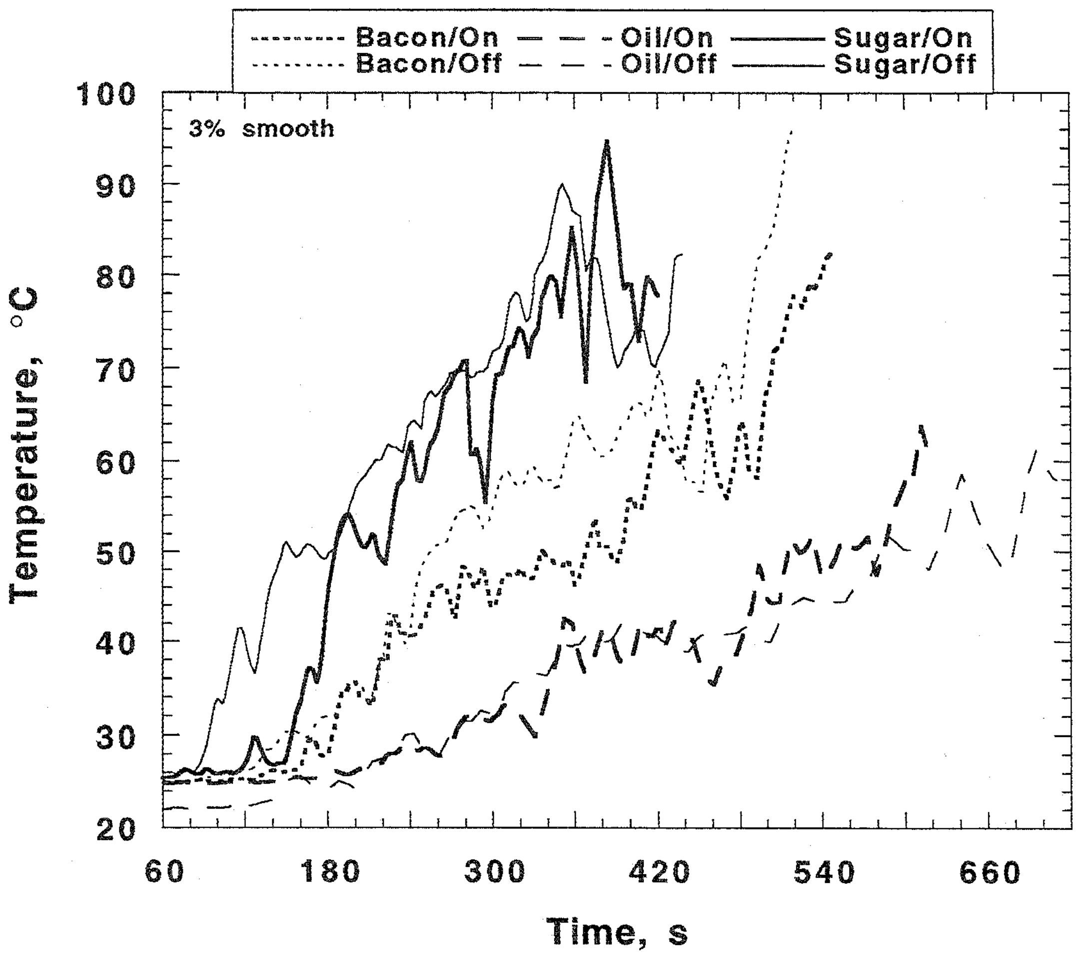

Figure 17. Plot of pan-centerline temperature 37.1 cm above the burner versus time for all tests on the electric range.

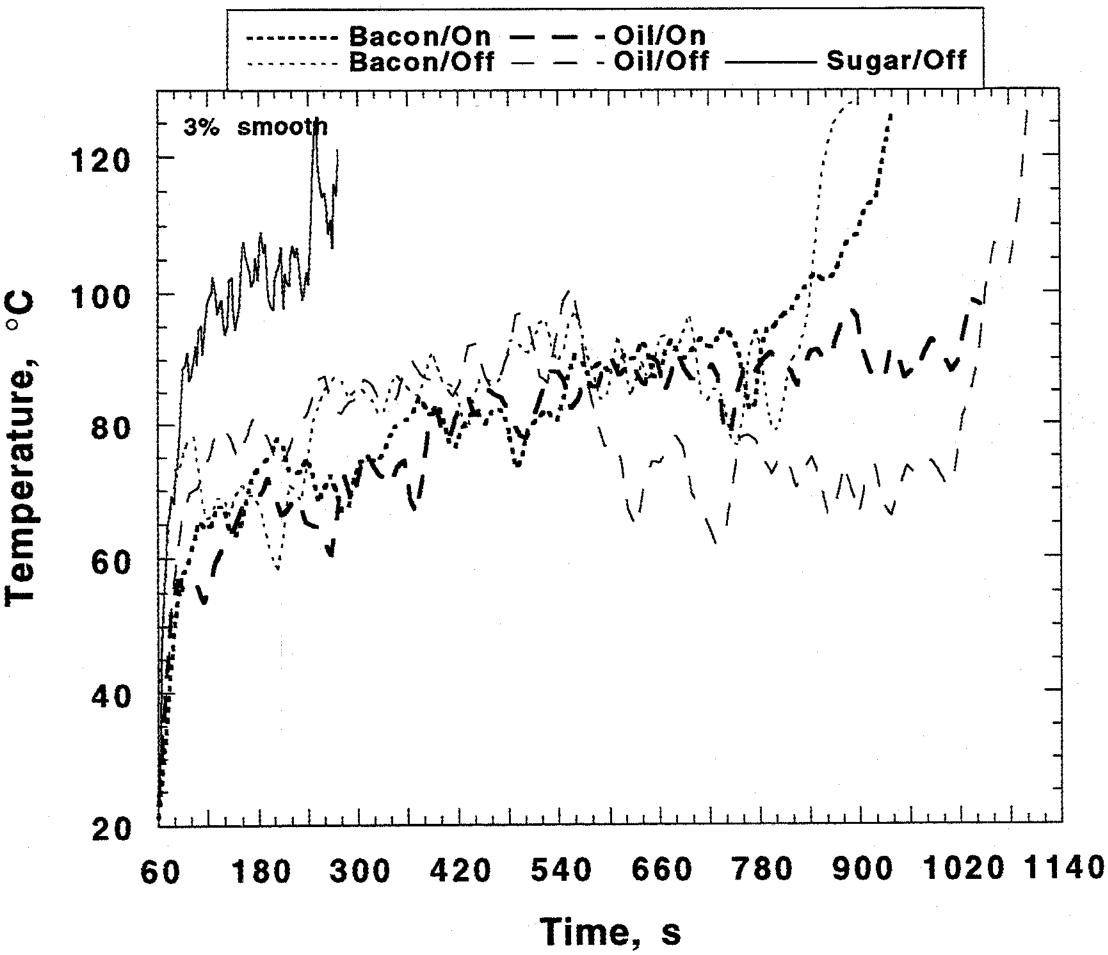

Figure 18. Plot of pan-centerline temperature 37.1 cm above the burner versus time for all tests on the high-output gas range.

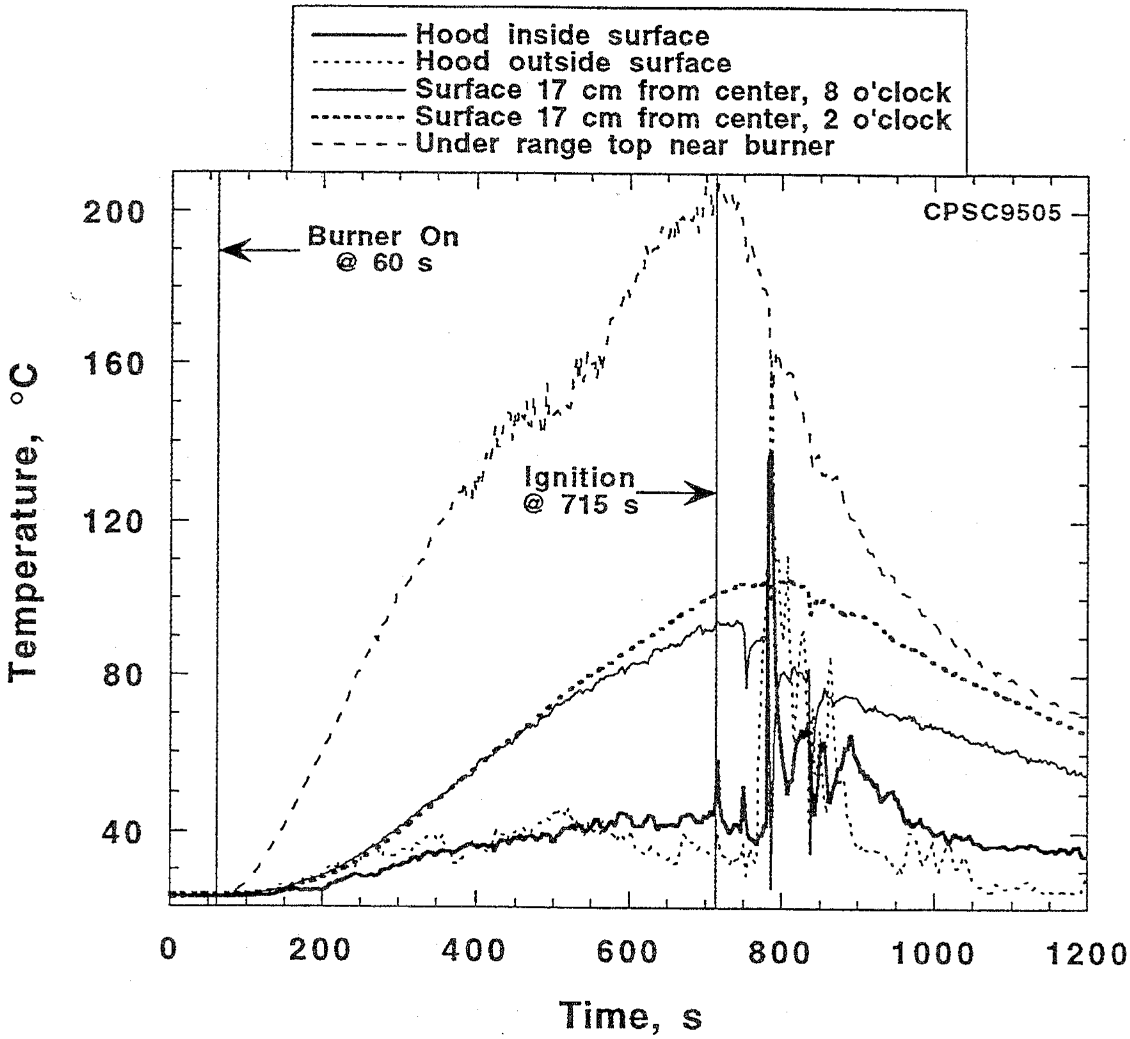

Figure 19. Plot of range and range-hood temperatures versus time for oil heated on the electric range with the range hood off.

Figure 20 shows a comparison of the range surface temperature 17 cm from the burner center at the 8 o'clock position for all of the food and range-hood combinations heated on the electric range. Figure 21 shows a comparison of the range surface temperature 17 cm from the burner center at the 8 o'clock position for all of the food and range combinations heated on the high-output gas range. All of the temperature curves are similar between food types and ranges except for the longer duration and slower heating of the gas-range tests.

Figure 22 shows a comparison of the inside range hood surface temperature for all of the food and range-hood combinations heated on the electric range. The curves appear quite different at first, but the temperatures differences are only between 2 °C and 5 °C. Figure 23 shows a comparison of the inside range hood surface temperatures for all of the food and range combinations heated on the high-output gas range. The gas range produced nearly 15 °C higher temperatures in the hood than the electric range. The temperature increased much faster during the gas-range tests compared to the electric-range tests due to the gas range's instant flame. The temperature curves are again very similar to each other.

A range-hood or range-surface temperature sensor has some potential as a pre-ignition device in conjunction with some other signal. A high-temperature threshold in these areas could theoretically be surpassed by cooking safely for a long time period or using multiple burners simultaneously so temperature would probably not function successfully as a lone signature of impending ignition. A high temperature in the presence of another, more discriminating pre-ignition signature might aid in decreasing false alarms that could occur if only one signal was monitored. The temperature of the space below the burner also has potential as a pre-ignition detection input. The area is convenient, and for the electric range, it reached relatively high temperatures that would clearly indicate the high heating conditions on the burner above.

3.3 Plume Velocity

Figure 24 shows the vertical plume-gas velocity measured by the bi-directional probe 35.6 cm above the burner as a function of time for a test of oil heated on an electric range with the range hood off. The initial minute of the test shows that the noise level associated with this measurement is approximately ± 0.08 m/s. After the heating process, the fluctuations are on the order of ± 0.2 m/s. There is a fairly sharp rise in velocity and then a leveling off.

Figure 25 shows a comparison of the vertical-velocity measurements 35.6 cm above the burner for all of the food and range-hood combinations heated on the electric range. The cooking of sugar, which heats fastest, produces the highest velocities due to early buoyancy. The cooking of oil produces a more quiescent flow, with bacon's behavior lying between that of sugar and oil. The tests with the range hood off actually show slightly higher velocities, but the differences are not great enough to draw any conclusions. Again, the influence of the range hood seems to be relatively inconsequential. Figure 26 shows a comparison of the vertical-velocity measurements 35.6 cm above the burner for all of the food and range combinations heated on the high-output gas range. These velocities are 20 % to 50 % higher than those for the same electric-range tests. All of the food curves are more similar for the gas range than for the electric range. The plume generated by the gas flame tends to dominate the velocity behavior and somewhat smear out food and range-hood effects. Velocity does not seem to be a universal signal of impending ignition.

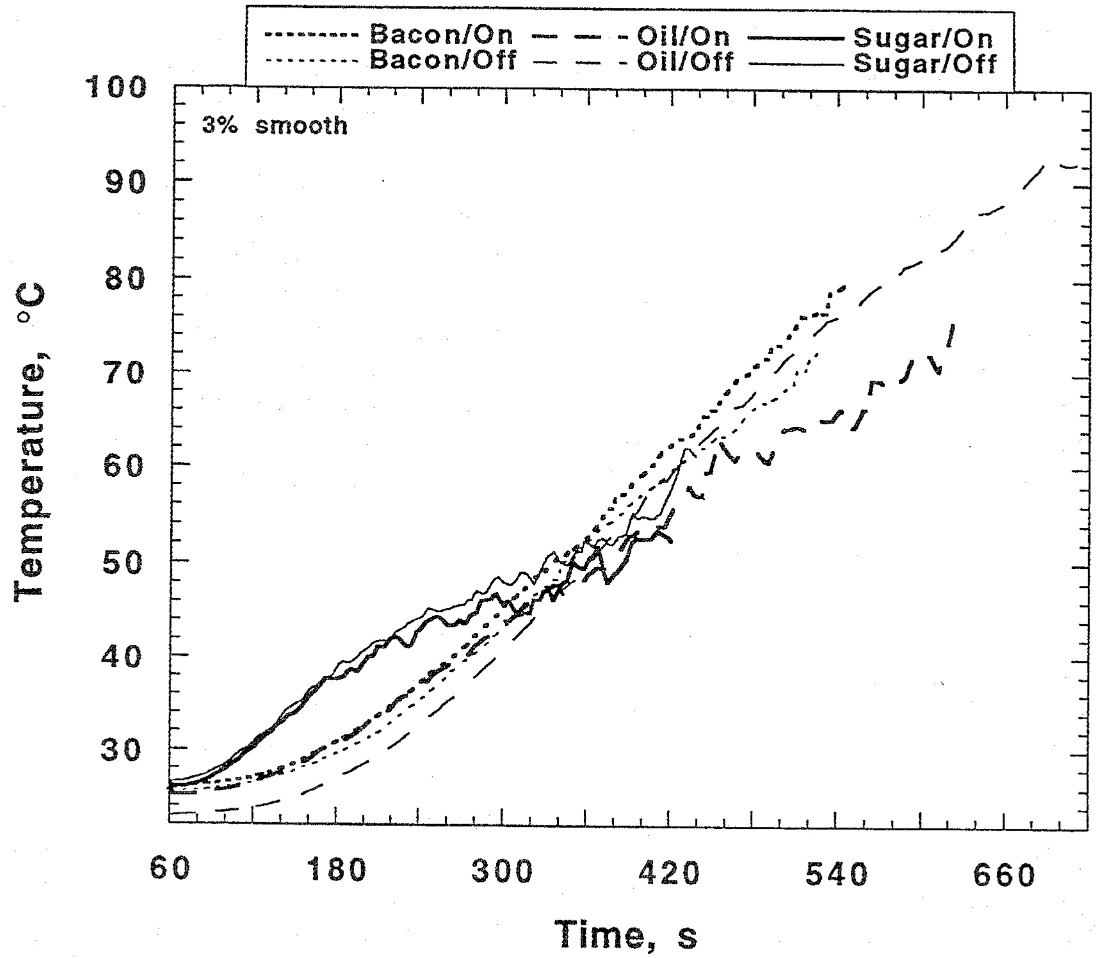

Figure 20. Plot of range "8 o'clock" surface temperature versus time for all tests on the electric range.

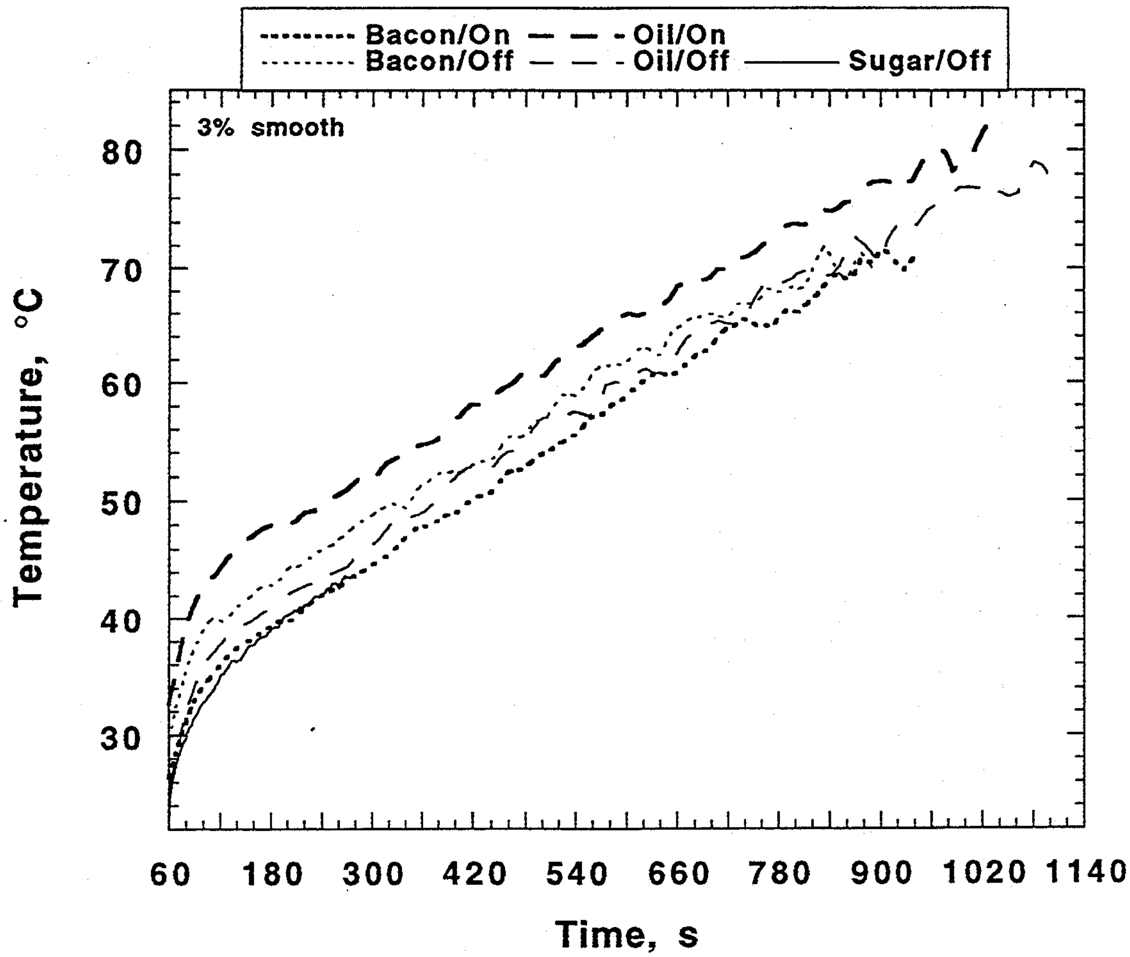

Figure 21. Plot of range "8 o'clock" surface temperature versus time for all tests on the high-output gas range.

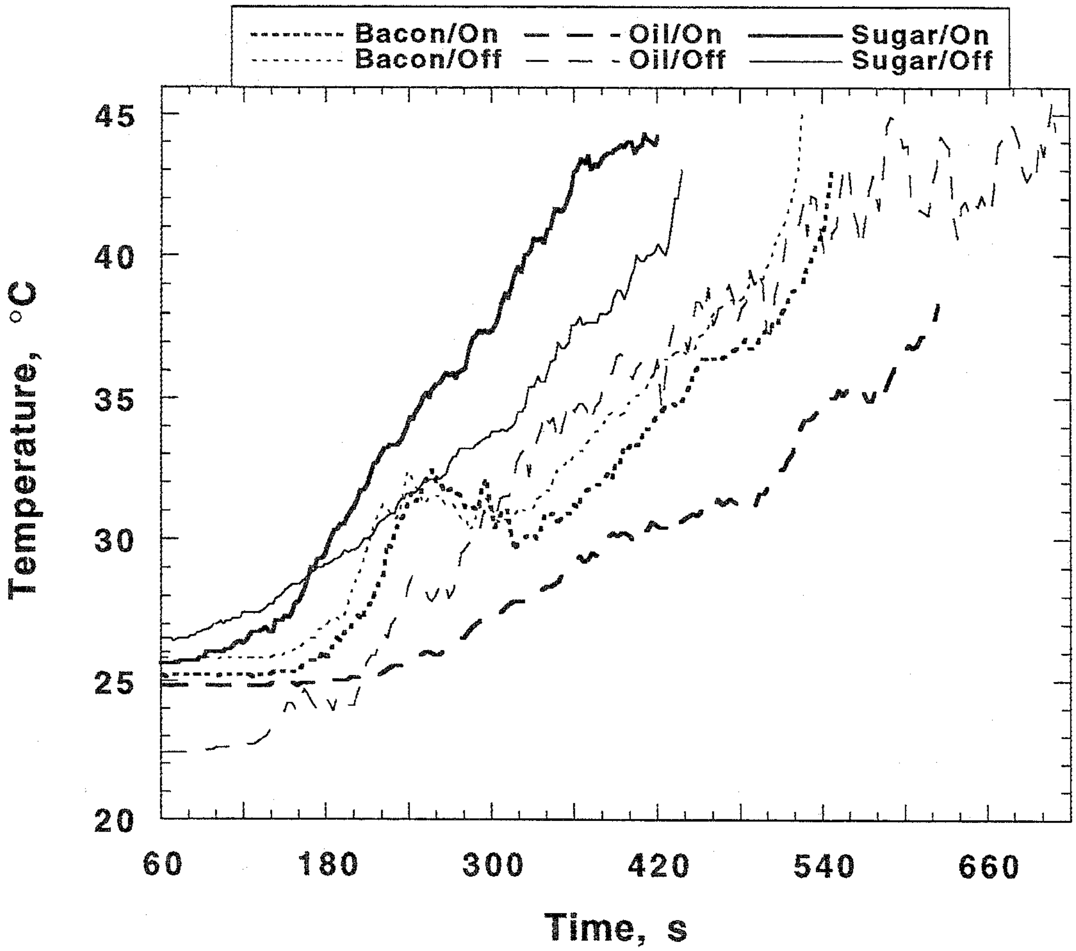

Figure 22. Plot of range hood inside surface temperature versus time for all tests on the electric range.

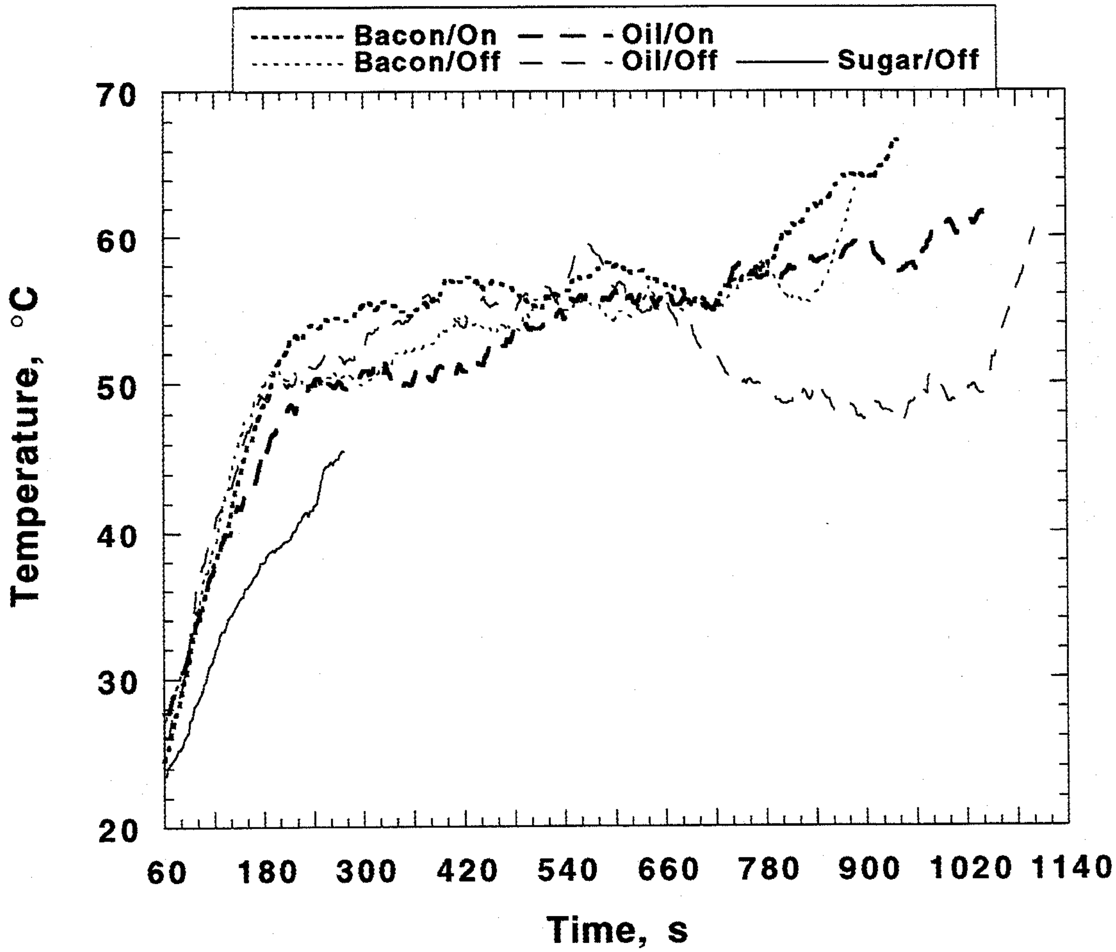

Figure 23. Plot of range hood inside surface temperature versus time for all tests on the high-output gas range.

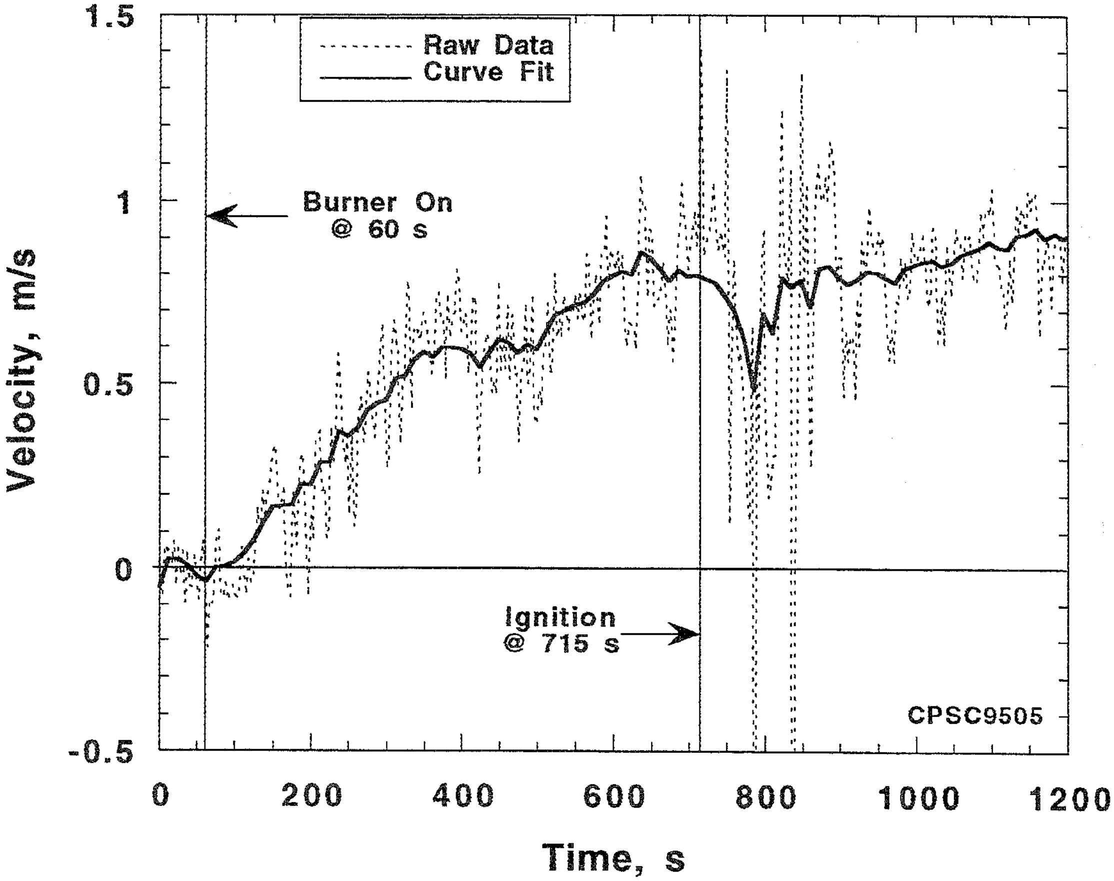

Figure 24. Plot of vertical velocity 35.6 cm above the burner versus time for oil heated on the electric range with the range hood off.

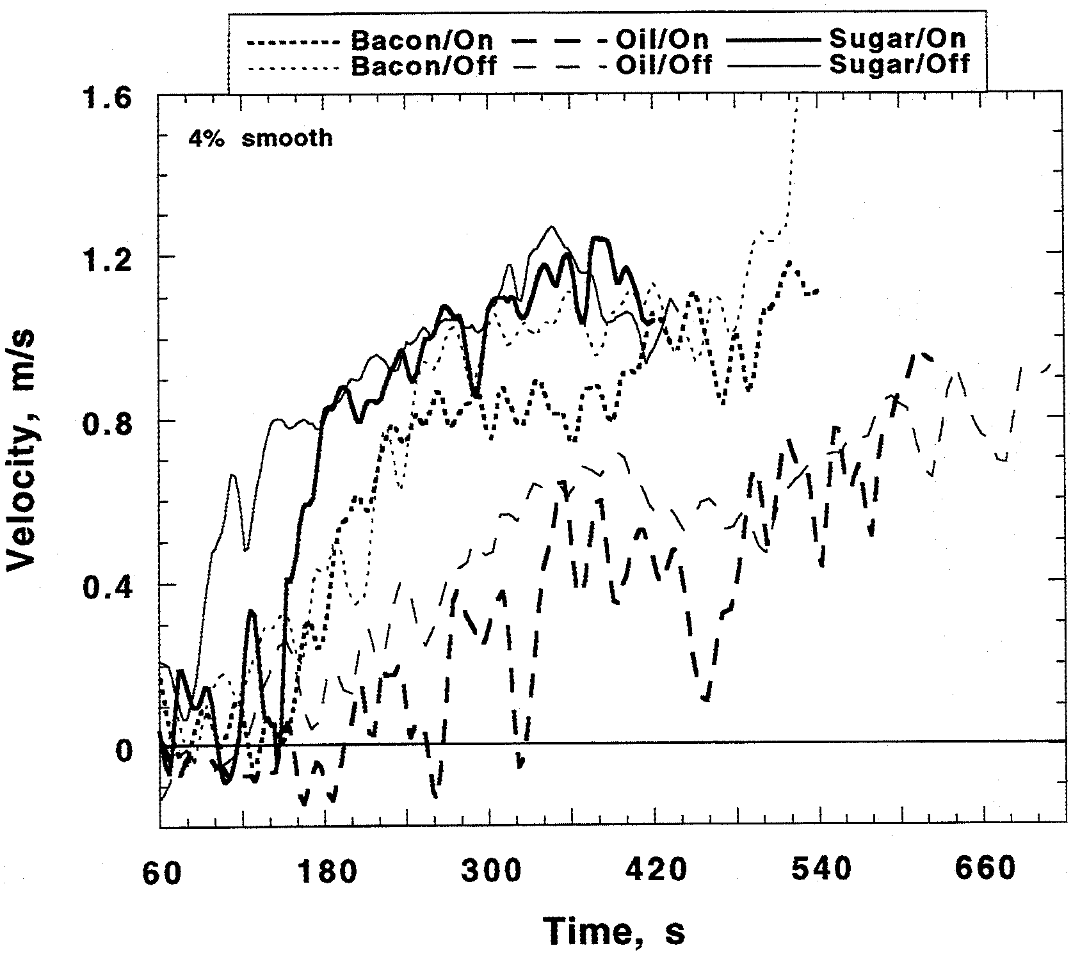

Figure 25. Plot of vertical velocity 35.6 cm above the burner versus time for all the tests on the electric range.

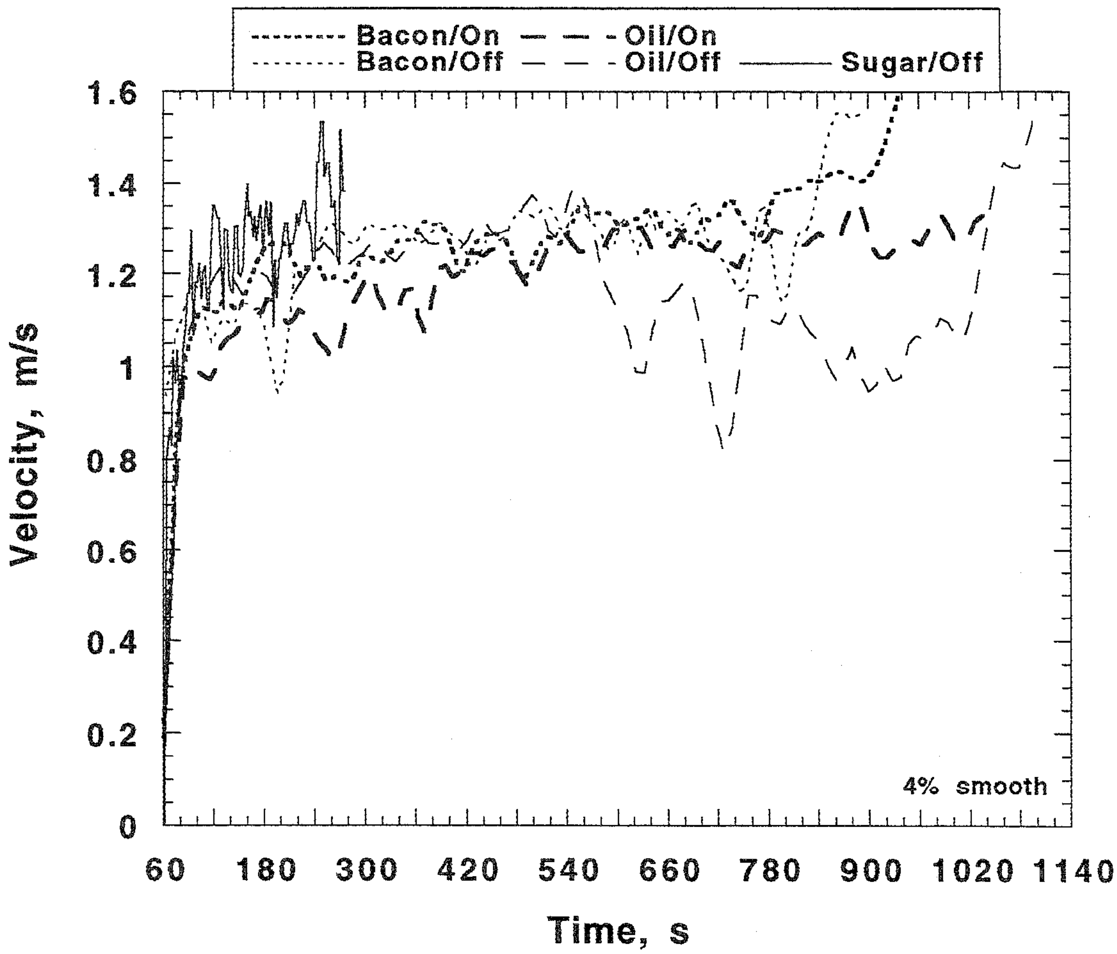

Figure 26. Plot of vertical velocity 35.6 cm above the burner versus time for all the tests on the high-output gas range.

3.4 Laser Attenuation

In these experiments, laser attenuation is the decrease in laser-light intensity due to interference or obscuration by particles in the path of the beam. Laser attenuation was calculated by subtracting the voltage measured during the test from the pre-test background-zero value and dividing the result by the same background-zero value. Figure 27 shows laser attenuation, with units of volts-per-volt, as a function of time for the two He-Ne lasers for a test of oil heated on an electric range with the range hood off. A sharp increase in attenuation begins at 450 seconds. The increase, while sharp, is fairly linear until ignition.

Figure 28 shows a comparison of the laser-attenuation measurements 17.8 cm above the burner for all of the food and range-hood combinations heated on the electric range. The sugar curves are different than those of oil and bacon in that they rise very sharply after two minutes of heating, but the rate of rise decreases within a minute to slopes similar to the other foods. The oil and bacon curves are similar except for the period of time after heating begins until the curves rise. Bacon requires about two minutes less to generate significant smoke levels.

Figure 29 shows a comparison of the attenuation measurements 17.8 cm above the burner for all of the food and range combinations heated on the high-output gas range. The sugar ignited much earlier than the oil and bacon. Local heating, melting, and charring was observed in the pan of sugar where the gas flame impinged on the pan. Less time was required for the gas range to cause a local area to ignite than the electric range required to heat all of the sugar. The bacon and oil curves are similar in shape to those for the electric range except that they are stretched in time.

All of the foods produced large quantities of smoke that created a smoke layer in the upper region of the room. The smoke layers were clearly visible, up to 60 cm in thickness, and noxious in odor. When this occurred, the room air became unbreathable and even caused discomfort in its diluted form outside of the room. Characteristics associated with these large quantities of smoke are important features of the pre-ignition environment. Light attenuation and the related phenomenon of scatter show considerable potential as pre-ignition signatures. Threshold levels of attenuation or scattering would be most appropriate since the slopes of the attenuation curves are similar for different foods on a given range.

3.5 FTIR Gases

Relative changes in concentration of general hydrocarbons, carbon dioxide, and water were obtained from the FTIR data analysis. Absolute concentrations were not calculated due to the difficulty associated with calibration of the FTIR with known quantities of the required gases over the range of plume temperatures encountered during testing. The qualitative trends of the species as ignition approached were determined. The area referenced in the following figures is the area under the curve of absorbance plotted versus frequency. The area is calculated by integrating between the wavenumbers (frequency units of cm^{-1}) that bound the spectral band, or peak, of a specific gas species. The area, with units resulting from the product of absorbance and frequency, has little quantitative meaning without calibration, but relative changes in an area reflect relative changes in the gas concentration.

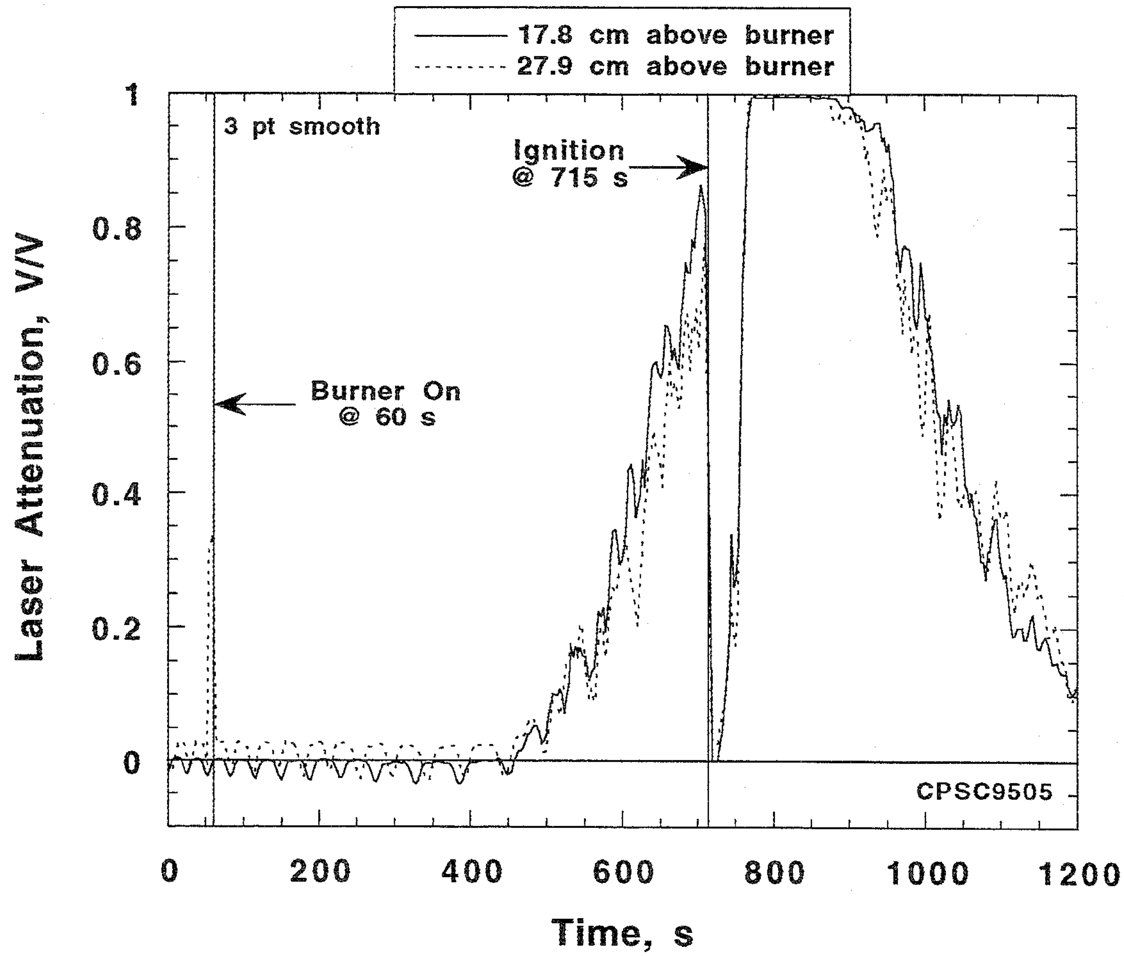

Figure 27. Plot of laser attenuation versus time for oil heated on the electric range with the range hood off.

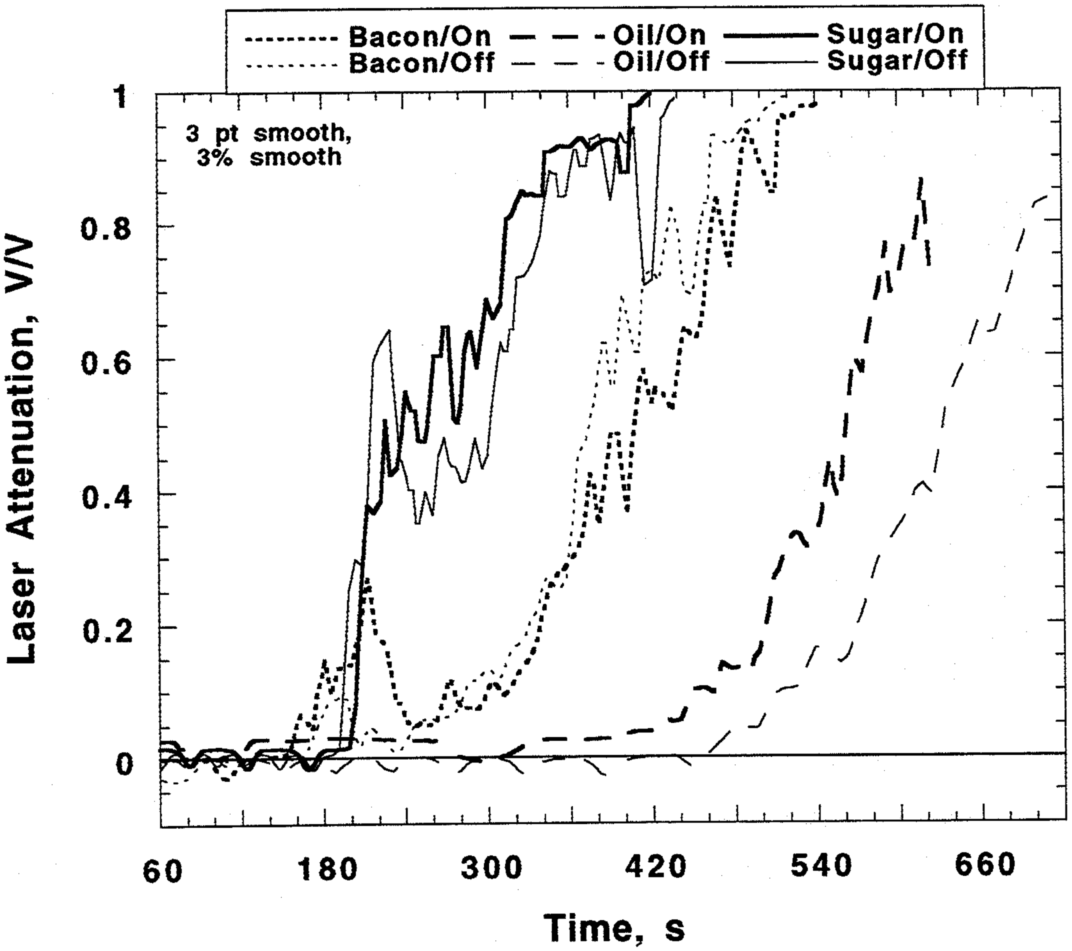

Figure 28. Plot of laser attenuation 17.8 cm above the burner versus time for all the tests on the electric range.

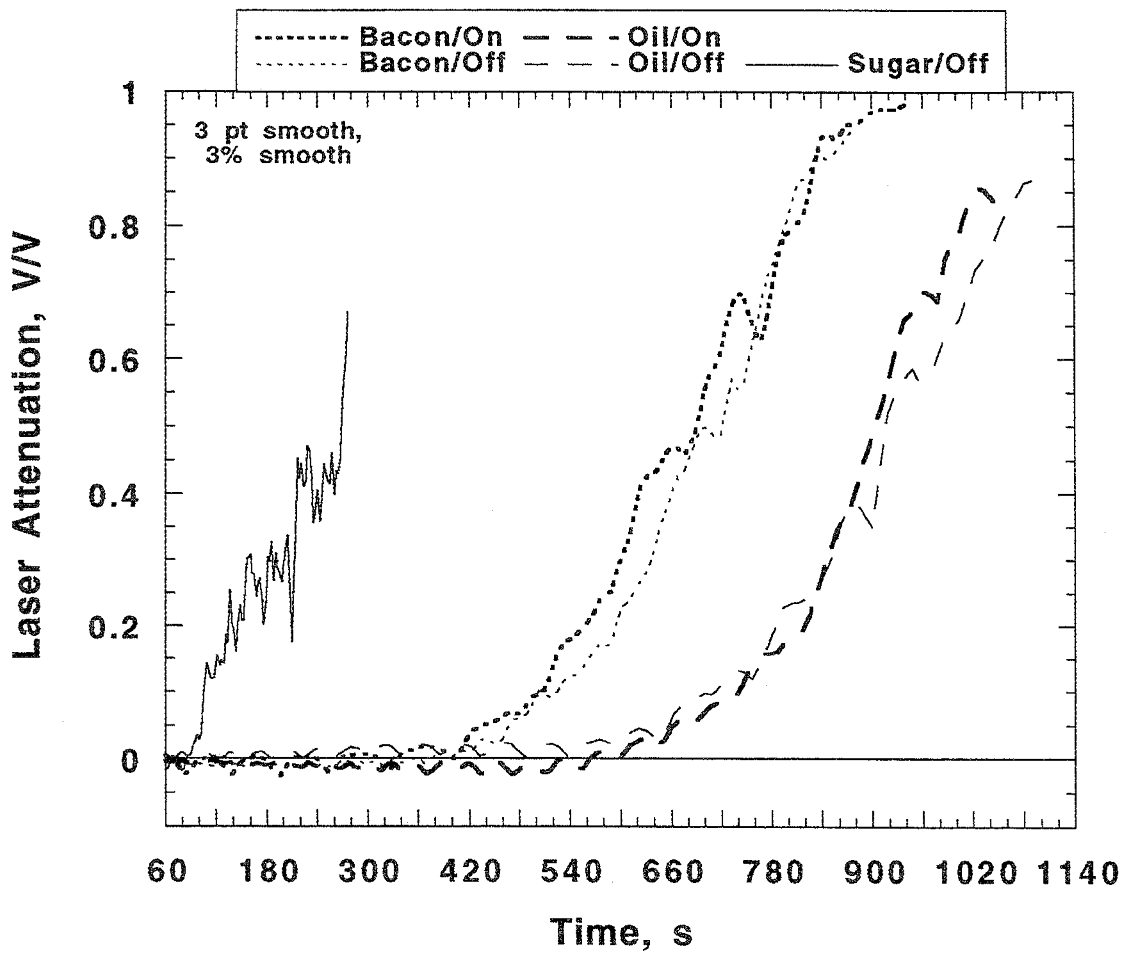

Figure 29. Plot of laser attenuation 17.8 cm above the burner versus time for all the tests on the high-output gas range.

Figure 30 shows the total hydrocarbon and water areas as a function of time for a test of oil heated on an electric range with the range hood off. Hydrocarbon area is the area under the hydrocarbon spectral peak integrated from 2782 cm^{-1} to 3029 cm^{-1}. This frequency range corresponds to the spectral band produced by the stretching of carbon-hydrogen bonds in alkanes, alkenes, and aromatic hydrocarbons.[9] The limited spectral resolution of the instrument and the likely overlap and interference of the spectra of many hydrocarbons prevented further identification of specific organic compounds within the broad peak. The hydrocarbon curve rises sharply in a manner similar to the laser attenuation curves. The water area is the area under the water spectral peak integrated from 1644 cm^{-1} to 1755 cm^{-1}. Water increases more gradually than the hydrocarbons and peaks at one fourth of the hydrocarbon amount.

Figure 31 shows a comparison of the hydrocarbon-area measurements for all of the food and range-hood combinations heated on the electric range. Sugar produces similar levels of hydrocarbons to those produced by the other foods, but in a shorter period of time. The curves closely resemble those for laser attenuation except sugar generates the most hydrocarbons, followed by bacon and oil.

Figure 32 shows a comparison of the hydrocarbon-area measurements for all of the food and range combinations heated on the high-output gas range. The gas range seems to produce similar levels of hydrocarbons from heating food to those produced by the electric range. The coarse time resolution of these measurements makes it difficult to accurately compare the maximum levels since the last spectral scans before ignition are averaged with scans after ignition. The data points shown are those averages that were not tainted by post-ignition scans.

Figure 33 shows a comparison of the water-area measurements for all of the food and range-hood combinations heated on the electric range. The heating of sugar produces much more water than either bacon or oil due to the breakdown of the chemical structure of sucrose. For bacon, water initially boils off due to the water content of the meat, and then more water vapor forms later as a pyrolysis product. Heating of the oil produces no water initially, but increasing amounts form as some components of the oil begin to break down.

Figure 34 shows a comparison of the water-area measurements for all of the food and range combinations heated on the high-output gas range. Water was measured immediately upon the start of each test using the gas range. This is due to the addition of a constant level of water vapor from combustion of the burner flame to the water contributed from the foods.

An effort was made to generate CO_2 area curves by integrating the CO_2 spectral band from 2320 cm^{-1} to 2383 cm^{-1}. The results initially seemed nonphysical because of negative areas which implied a decrease in CO_2 from ambient levels. One possible explanation is that little or no air, which contains CO_2 on the order of several hundred ppm, was entrained by the plume and passed by the FTIR beam in the section of the path length over the pan. This would cause less CO_2 to be measured during the experiments than was measured as background levels. Since the background data were subtracted from the experimental data, negative areas resulted. Another explanation is that the increased temperature of the plume relative to the cool background caused the CO_2 molecules to spread apart, and the decreased number density of CO_2 molecules was interpreted as an absolute decrease in CO_2 by the FTIR. A third possibility is that the increase in plume temperature during the test over the ambient background temperature produced enough additional infrared radiation from the plume to cause the relative absorbance by CO_2 in the hot

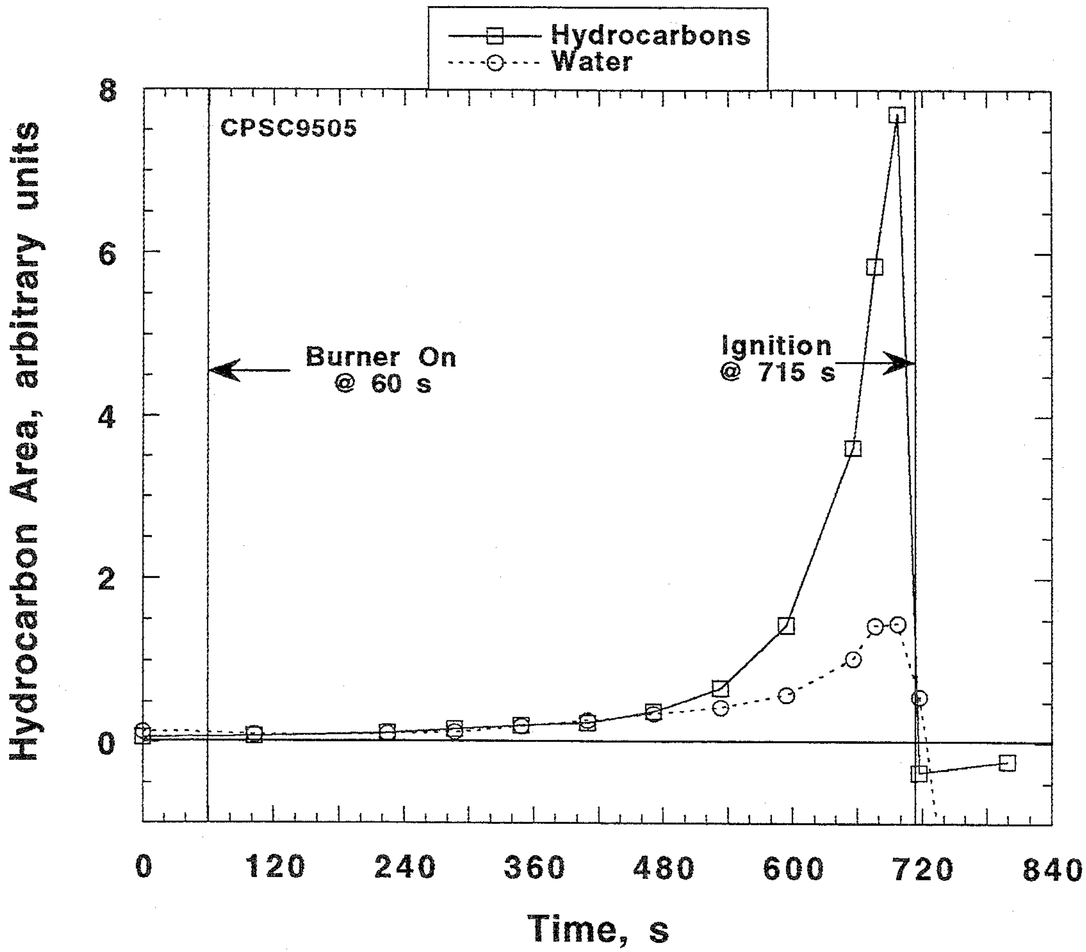

Figure 30. Plot of FTIR hydrocarbon and water areas versus time for oil heated on the electric range with the range hood off.

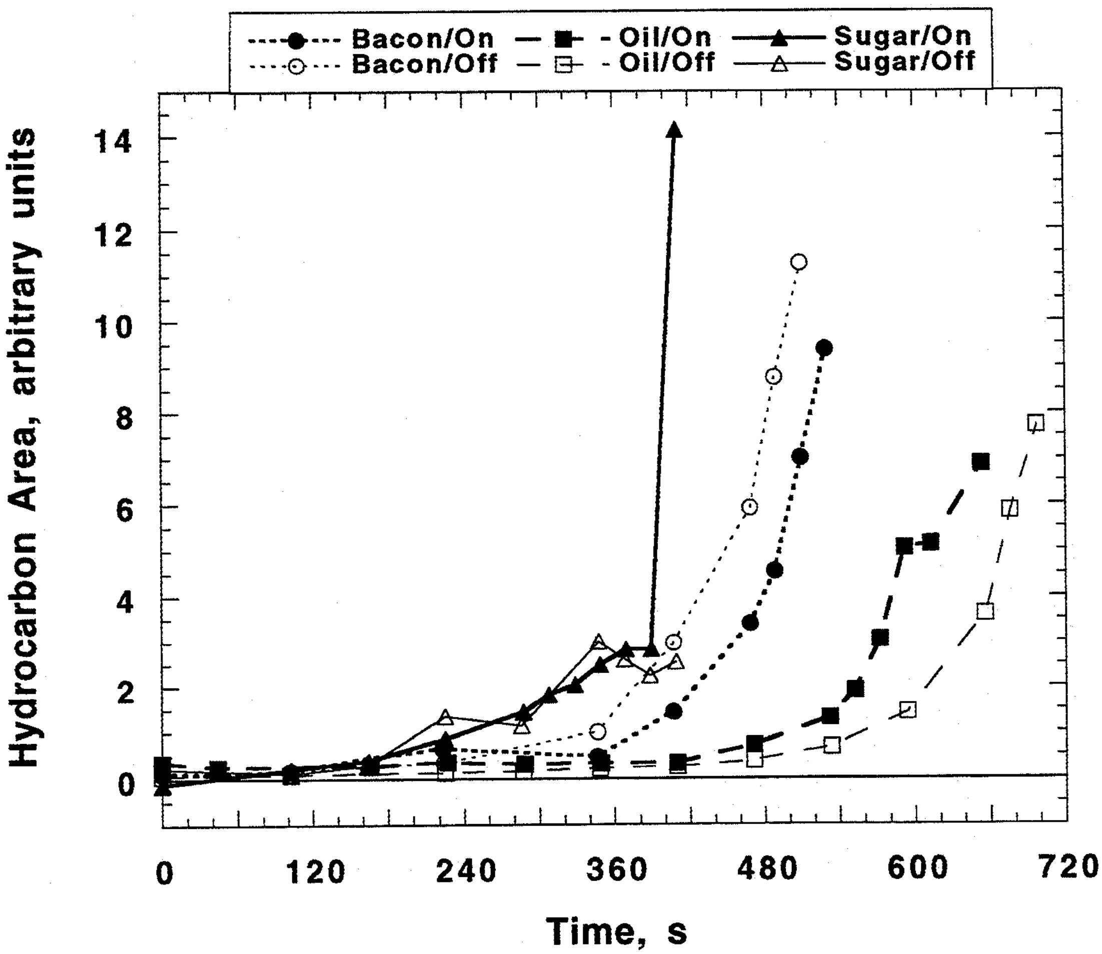

Figure 31. Plot of FTIR hydrocarbon area versus time for all the tests on the electric range.

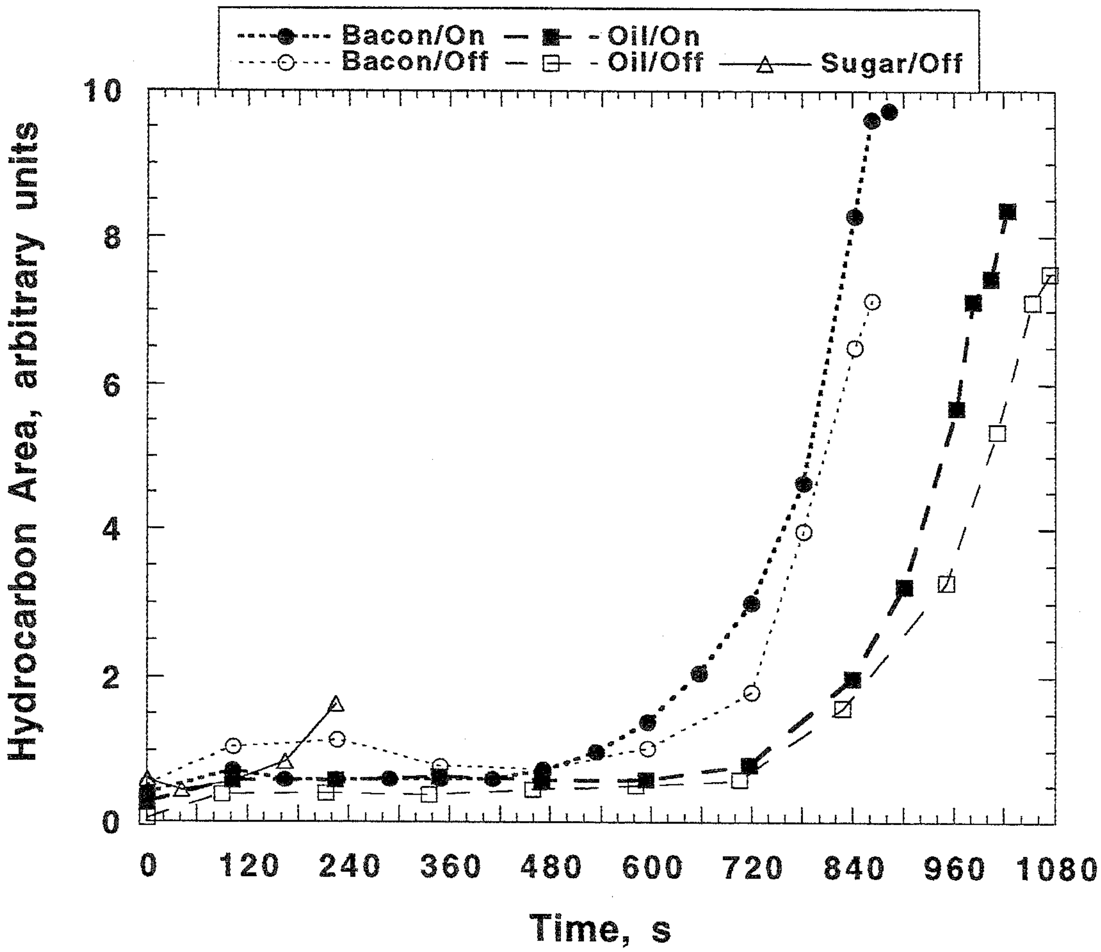

Figure 32. Plot of FTIR hydrocarbon area versus time for all the tests on the high-output gas range.

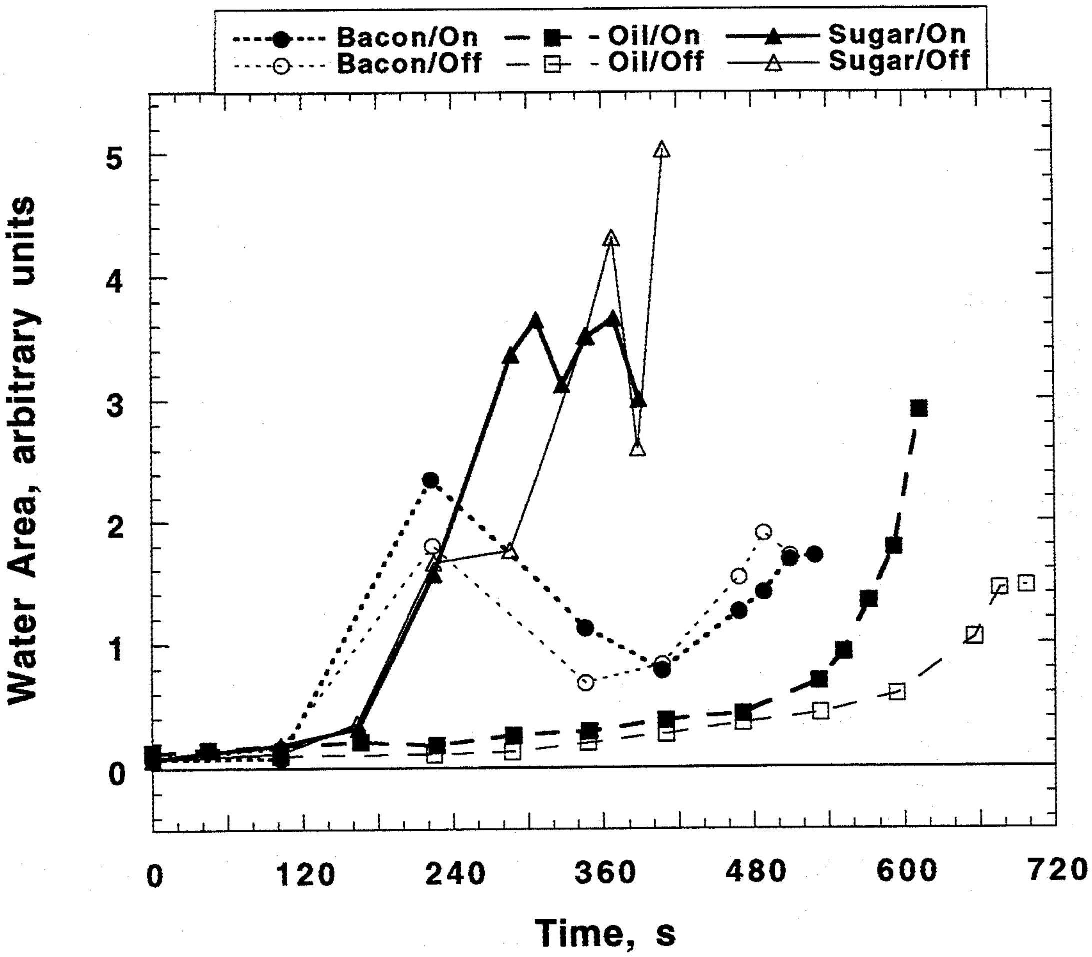

Figure 33. Plot of FTIR water area versus time for all the tests on the electric range.

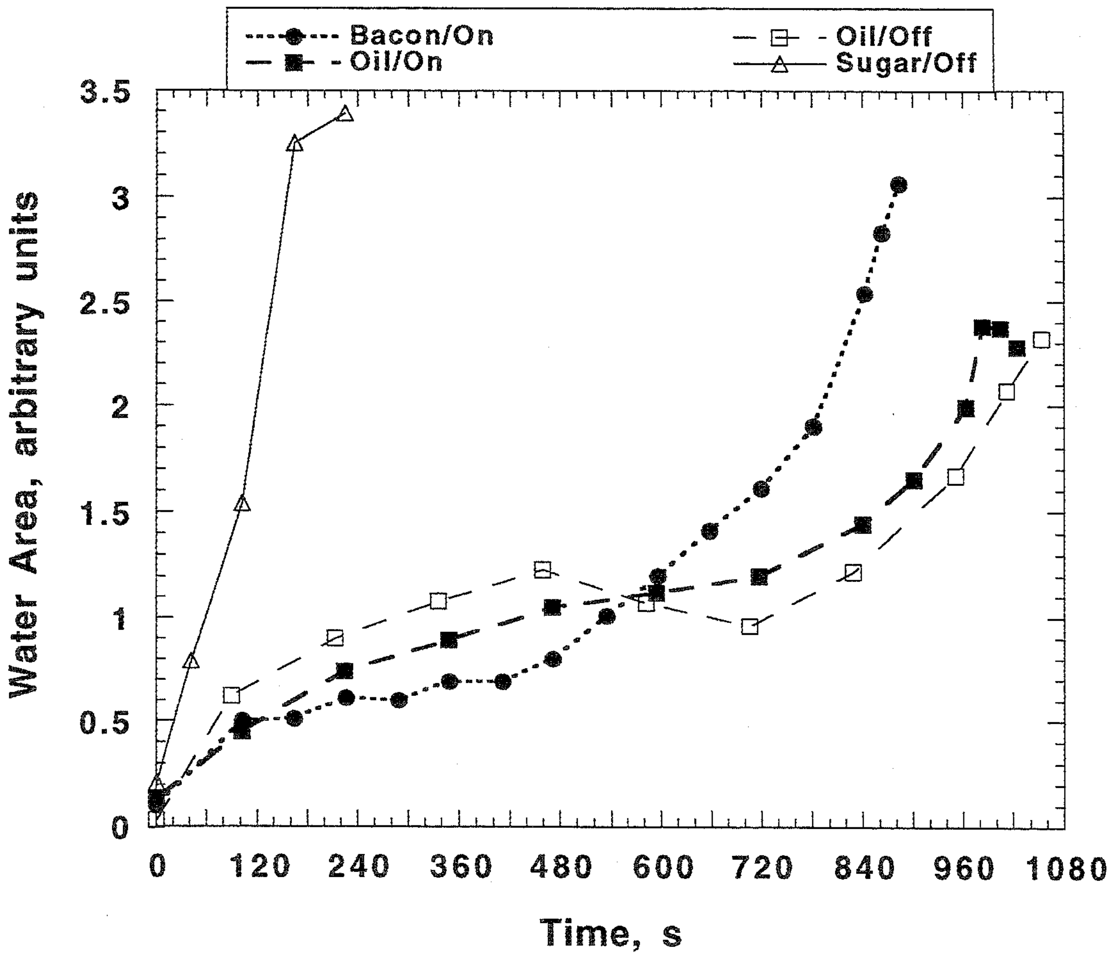

Figure 34. Plot of FTIR water area versus time for all the tests on the high-output gas range.

plume to seem less than the ambient CO_2 absorbance.

Total hydrocarbons or related phenomena have high potential as pre-ignition signatures. Attainment of a threshold level would warn of impending ignition. The high rate of change of hydrocarbon levels when they first begin to develop could also be used as an early warning of approaching ignition conditions if it can be shown to be a behavior uncharacteristic of normal cooking. Water and carbon dioxide are not good candidates for pre-ignition signatures because gas-powered ranges safely yield both gases through combustion of the hydrocarbon fuel. There are also numerous other household sources of CO_2 and water that would obscure those gases generated by cooking food.

3.6 Recorded Images

3.6.1 Infrared Video

Infrared images were captured from the infrared videotape recordings at approximately 1, 45, and 90 seconds before ignition. The images were calibrated using calibration images also captured from the infrared video. Figure 35 is the image one second before ignition for the test of oil heated on the electric range with the range hood off. Most of the images displayed slight to nearly imperceptible temperature changes over the 90 second period of time. The images of sugar cooked on the electric range showed more obvious changes because of the expansion of the material over the pan edge. Although the accuracy of the temperature calibration is poor because of the unknown emissivities of the materials in view, it is likely that if large changes in the thermal environment did occur, they would be seen in these images. Infrared imaging does not appear to be useful for pre-ignition detection.

3.6.2 Standard Video

The videotape recordings of the fires captured much of the observable phenomena, and the ignition behavior can be watched frame by frame to observe location of flame initiation. Audible comments made by the test personnel during the test concerning operational activities and observations are also included on the tapes.

3.6.3 Photographs

A total of 132 photographs were taken in the course of the experimental portion of this project. The subjects of the photographs are the experimental apparatus and test behaviors before, during, and after each test.

3.7 Effects of Variables

3.7.1 Range Type

The quantities and trends of most measurements are similar between the range types. The

CPSC RANGE COOKING FIRE PRE-IGNITION
DETECTION TEST SERIES

Test Conditions

Test Identification:	CPSC9505
Food Material:	Soybean Oil
Range Type:	Electric-Coil
Hood Status:	Off
Time before ignition:	1 sec

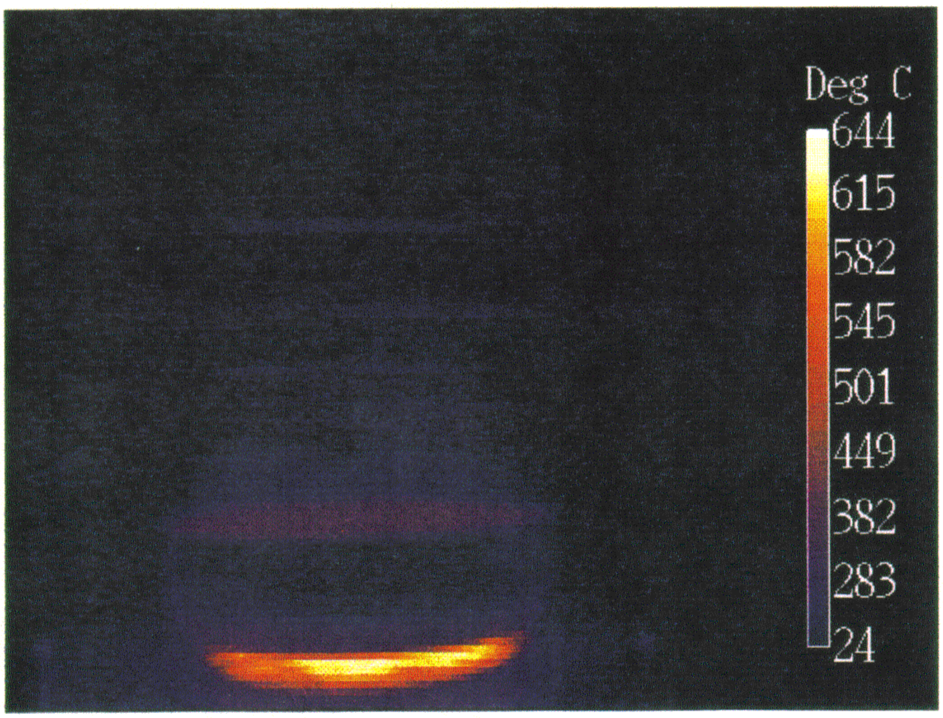

Figure 35. Infrared image of the thermal environment one second before ignition for oil heated on the electric range with the hood off.

primary effect of range type was the amount of time required to bring food to ignition. Although sugar very quickly ignited on the gas range, oil and bacon needed about 50 % more time to reach ignition conditions on the gas range compared to that needed on the electric range. Sugar required about 50 % less time to ignite on the gas range than it required on the electric range, but the reason for this is explained in Section 3.7.2. While the gas burner flame is at a higher temperature than the electric element, the heat transfer rate to a pan is less for this particular gas range compared to this electric range. One reason for this is that the flame contact area on the pan is less than the open-coil element contact with the same pan.

The measurements of velocity and temperature in the plume are higher at earlier stages for the gas range because of the instantaneous manner of burner ignition compared to the gradual temperature rise of an electric element. The burner post-flame gases themselves contribute to heating of the area above the burner more than the natural convection from an electric element.

3.7.2 Food Type

Oil and bacon require several minutes to reach boiling, and then smoking, conditions. The bacon fat must first liquify, as well, before boiling can begin, yet the lesser mass of liquid produced by the bacon compared to the oil requires less time to heat, vaporize, and produce smoke. Sugar requires less time than bacon and oil to begin generating smoke, and the production of smoke is more abrupt and less gradual than that of the other foods. Sugar and bacon seem to produce darker smoke than oil. Sugar has a unique behavior in that it melts, resolidifies, and then continues to pyrolyze as an intumescent (bubbling and swelling) char.

A reason for sugar's faster ignition behavior on the gas range as compared to the electric range is related to the ring-shaped gas flame and the failure of the heat to spread across the entire sugar mass equally. As liquids, oil and grease tended to conduct and convect heat more readily than sugar, and they equalized the temperature distribution. Sugar retained the heat unevenly in the local area above the burner flame which allowed the lesser amount of sugar to progress to ignition in less time than all of the sugar would have required. The aluminum clad bottom of the pan was not completely successful in distributing the heat evenly. It is possible that the test of sugar on the gas range with the range hood on failed to ignite because the remaining sugar acted as a heat sink and a barrier to plume generation which prevented the local area of sugar transformation from developing enough flammable vapor and high temperature.

3.7.3 Range-Hood Status

The range-hood capacity seemed to be overwhelmed by the plume behavior of the heated foods. When smoke generation was at steady, high levels, most of the smoke seemed to bypass the range hood. The largest hood available in our survey had about 75 % greater flow capacity than the hood used, but it is likely that such an increase would only partially alleviate the accumulation of smoke. The high-output gas-range test on sugar with the range hood active did not produce ignition conditions, while sugar cooked on the same range with the hood inactive did ignite. It is not known whether the hood played a significant role in this case, if the explanation in Section 3.7.2 is valid, or if a wide range of behaviors accompanies the heating of sugar. Since the status of the hood did not affect ignition conditions in a clear manner, the presence or absence of a range hood of similar capacity to this one or whether such a range hood is active or not should not significantly affect the inputs to a detector sensing any of the conditions measured in these experiments.

3.7.4 Pan Material

A flammable liquid food cooked in an aluminum pan tended to reach ignition conditions slowly, if at all, when compared to heating the same food in a stainless steel pan for the ranges used in this study. The use of stainless steel in the pans always produced ignition for oils and fatty meat under high heating for these particular ranges. The reason for this is the high thermal conductivity (170 W/mK) and thermal diffusivity (70×10^{-6} m^2/s) of aluminum which contribute to high heat losses to the sides of the pan. Thermal conductivity, $\boldsymbol{k}$, is a property of a material that describes the relative ease of heat conduction through it. The thermal diffusivity of a material, α, describes the relative ease of heat conduction through it compared to its capacity for energy storage. Stainless steel has much lower values of these thermal properties ($\boldsymbol{k}$ = 15 W/mK, $\alpha = 4 \times 10^{-6}$ m^2/s) which gives it a tendency to retain more heat than a material with higher property values. Heat easily conducted to the sides of an aluminum pan is then transferred to the air due to the much greater contact area between hot metal and air compared to the stainless steel case in which the walls are relatively cool compared to the bottom, and the pan's high temperatures are concentrated where air does not come into contact.

3.8 Reproducibility

Seven of the experiments were repeated with the same conditions to determine test-to-test variation of the recorded variables. The experiments were very reproducible. Differences between the maximum measurement values and the heating times required for ignition of repeated tests were typically less than 10 % and often under 5 %. Two figures are provided to illustrate these typical variations.

Figure 36 shows a comparison of the pan-centerline temperatures 16.8 cm above the burner and the pan-side temperatures between two tests of bacon cooked on the electric range with the hood off. The heating time required to produce ignition conditions for test 9510 was 31 seconds (6.7 %) greater than that required for test 9502. Just before ignition, the centerline temperature for test 9502 was approximately 20 °C (5.2 %) greater than that of test 9510. The pan-side temperature for test 9510 was approximately 33 °C (5.4 %) greater than that of test 9502. The maximum temperatures, temperature trends, and heating periods were similar for each of these tests.

Figure 37 shows a comparison of laser-attenuation measurements 17.8 cm above the burner between two tests of oil cooked on the gas range with the hood on. The heating time required to produce ignition conditions for test 9516 was 34 seconds (3.6 %) greater than that required for test 9514. Just before ignition occurred, the attenuation level for test 9514 was 4.8 % (5.5 %, relatively) greater than that of test 9516. The maximum attenuation levels,

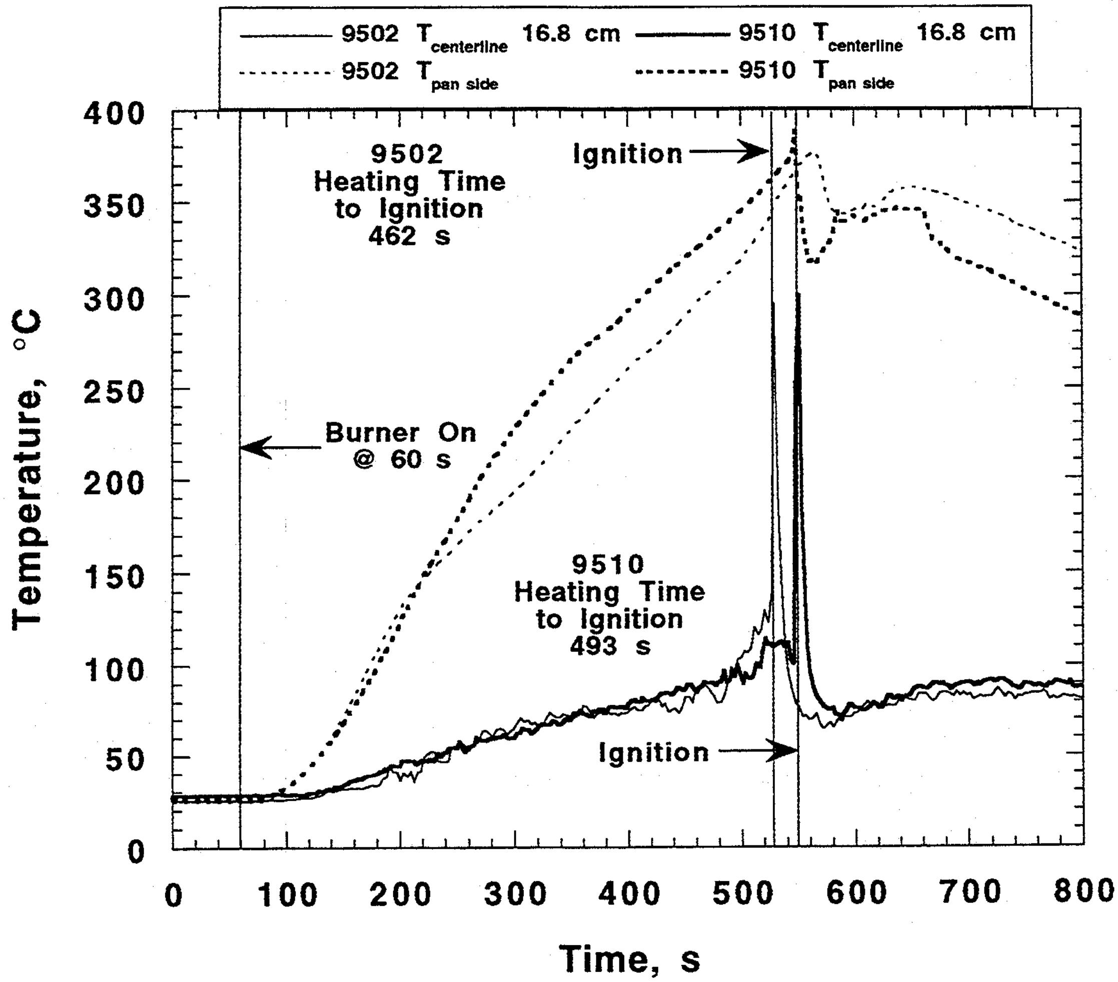

Figure 36. Plot of the 16.8 cm pan-centerline and pan-side temperatures versus time for repeated tests of bacon cooked on the electric range with the range hood off.

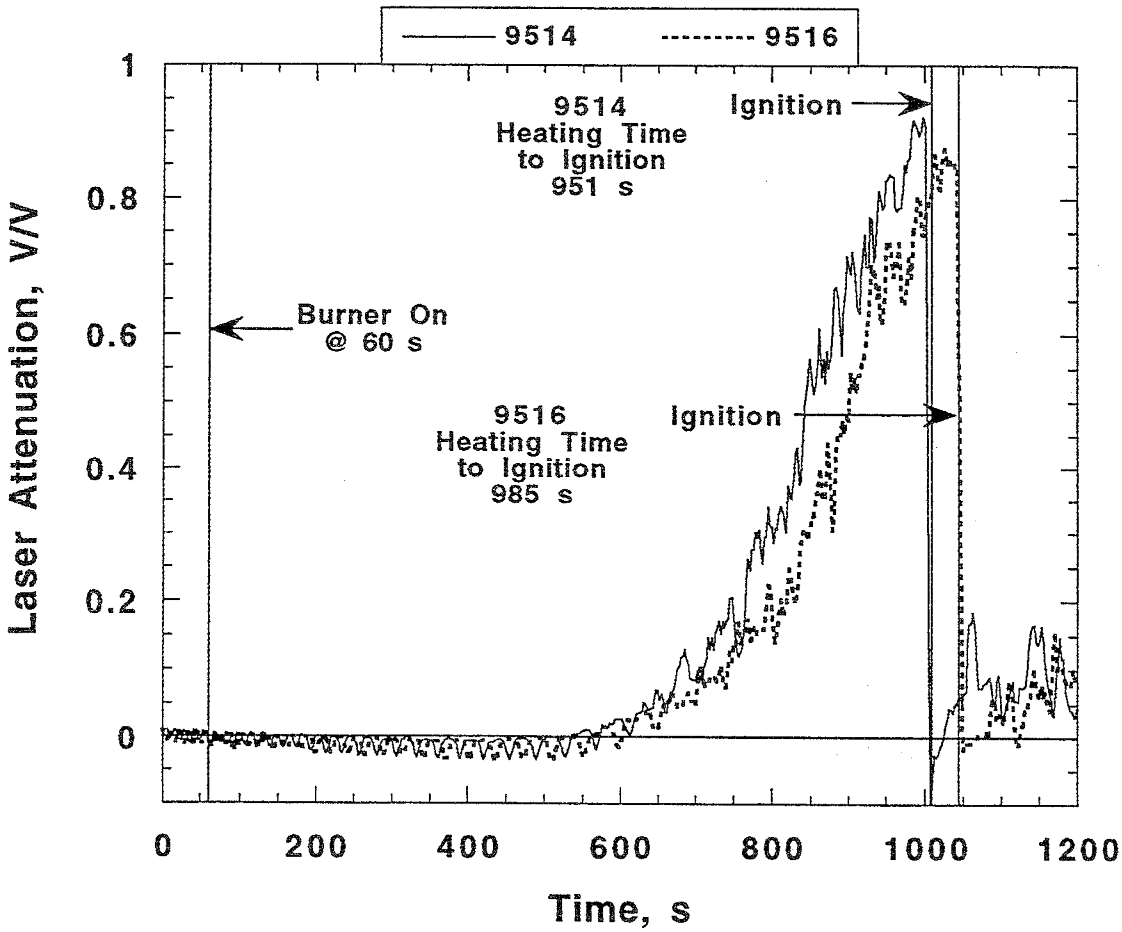

Figure 37. Plot of laser attenuation 17.8 cm above the burner versus time for repeated tests of oil cooked on the gas range with the range hood on.

attenuation trends, and heating periods were similar for each of these tests.

3.9 Re-Ignition Behavior

Re-ignition occurred frequently for the tests with oil cooked on the electric range in stainless steel pans after the oil was extinguished with the lid. The residual heating ability of the de-energized electric burner built up very high temperatures within the closed pans. Attention should be given to this phenomenon because current recommended safety practices may not take it into account. A high capacity fire extinguisher may be necessary to completely extinguish such a fire with or without initial extinguishment with the lid.

4.0 Literature Search

4.1 Objectives

The second major activity of this project was the identification of methods, materials, and devices with potential to detect and react to pre-ignition conditions. This was accomplished with a literature and patent search. The search focused on technologies capable of detecting one or more cooking-related signatures and the control technologies capable of shutting off gas and electric ranges in the event of a danger signal from a detector. The bibliographical reference information related to these technologies is provided in Appendix A.

4.2 Search Databases and Strategies

4.2.1 Databases

The databases that were searched were NIST's fire document collection (FIREDOC), Engineering Index (EI), National Technical Information Service (NTIS), and Derwent World Patent Index (WPI). FIREDOC is a database managed by the Fire Research Information Services at NIST. The documents contained in FIREDOC primarily are related to fire, smoke, flame, and combustion fields, although the database has started to include research literature associated with building technology as well. FIREDOC was the primary resource for investigating technologies related to smoke detection because the subject has been thoroughly researched and documented at NIST and elsewhere. FIREDOC was not helpful at all, however, in the investigation into control technologies.

The EI and NTIS databases, while covering the broad range of all scientific research, also contain several orders of magnitude more papers than FIREDOC. These databases were very helpful in finding research reports that are indirectly related to or unrelated to fire or smoke, but could have bearing on this project's objectives. NTIS also contains literature that has limited publication and distribution. EI and NTIS were more helpful than FIREDOC in obtaining controls references. The detector patent search was limited to smoke detectors. A controls search was also conducted using the patent database.

After generating each list, the documents were screened by title and abstract for any potential use related to the two goals. Selected documents were read for better understanding of novel methods and designs. The screened lists are provided in Appendix A.

4.2.2 Detector Strategies

The literature and patent search for detection and sensor technology was started without prior knowledge of what the pre-ignition signatures might be if they existed at all. Many conditions could be assumed based on common sense such as higher temperatures than those experienced during safe cooking, some amount of smoke, and some increase in velocity above the burner due to buoyancy. The other unknown signatures left the scope of the search very broad. The search strategies, located in Appendix B, were based on primarily looking for smoke and fire detector technologies and then expanding the inquiry to include other kinds of temperature, heat, radiation, velocity, and hydrocarbon gas sensor technology. Upon completing the present experimental measurements, plume velocity and infrared imaging were not found to be potentially useful signatures, so their related technologies are not included. In addition to papers on the sensed conditions, those on the topics of smart sensors, fuzzy logic, and artificial intelligence used in detectors were examined.

4.2.3 Controls Strategies

Control technology for shutting down gas and electric ranges upon receiving input from a detection device is not new or innovative. Gas burners in some appliances already have flame sensors that cause the gas valves to close upon a "no-flame" condition. Smoothtop electric ranges already have thermostat-controlled override technology that discontinues current to the heating elements when the ceramic top temperatures approach levels that could damage the material. Although these technologies are available in other applications than those proposed, and information was gathered from manufacturers on the current applications, additional searches were performed to look for novel methods and technologies that are applied to other equipment or apparatus, but may be utilized for these purposes.

4.3 Search Results

4.3.1 Detectors

The searches for detectors and sensors resulted in the discovery of many technologies with varying degrees of applicability to the range pre-ignition problem. Perhaps the most valuable resource as an overview of detector technologies is a paper by Grosshandler.[10] Some of the major detection technologies are compared in Table 4. Smoke detectors of the ionization, photoelectric, condensation nuclei, and electrostatic types were investigated. These common smoke detector technologies are fairly simple and are a logical choice for more in-depth inquiry since the experimental results point towards smoke-related phenomena as the most evident ignition precursors. Ionization detectors require a radioactive ionizing material which would

Table 4. Detection technology comparison.

Device or Method	Detection Effectiveness	Simplicity	Relative Cost	Other Problems or Features
Ionization smoke detector	Very high	Medium	Low	Too sensitive, Radioactive
Photoelectric smoke detector	High	Medium	Low	
Condensation nuclei detector	Very high	Medium	Medium	
Electrostatic Smoke Detector	Unknown	Low	Medium	May not work on non-combustion smoke
Tin oxide coated semiconductor	High	High	Medium	
Piezoelectric microbalance mass sensor	Very high	Low	Medium	Too sensitive, becomes overloaded
Catalytic gas sensor	High	High	Low	Confused by mixtures, can be poisoned
Electro-chemical sensors	High	Low	High	Requires high temperature, slow
Infrared imaging	Low	Medium	High	Interference of gas flame
Thermocouple	Medium	High	Low	

probably not be easy to market for use near food. Ionization detectors also provide much greater sensitivity than would be required for range use. Condensation nuclei type smoke detectors would respond properly to smoke levels, but these also are very sensitive and need humidification components that make the device overly complex. Electrostatic detectors measure the charge on soot particles, but they may not work well with smoke that is not a product of combustion.

Photoelectric detectors require only a light source and a light receiver to detect scattered or attenuated light. The moderate simplicity of this technology makes it attractive for potential use on ranges. A problem with point type photoelectric smoke detectors is that they require the smoke to come to the detector through ambient flows or diffusion. A point type detector installed on a range would not see smoke until too late because the buoyant plume carries smoke up and away from the range. A point type detector would function well in the range hood or installed somewhere above the range, but those locations are outside the scope of this project. Sampling type photoelectric detectors have similar difficulties as the condensation detectors because they require a flow system to carry the air and smoke inside.

Another kind of photoelectric smoke detector is the beam type which directs light from an emitter diode into the air and receives scattered light back from particles onto a detector diode. If particles from smoke reach a high enough density, a threshold level of received light is attained and the detector signals a danger condition. Complications with this device are the potential inadvertent blockage of the detector and large scale reflection of light back to the detector by nearby objects. These issues are addressable through a design process.

Another particle-based detector is the piezoelectric microbalance mass sensor which detects the changing particle loading on an oscillating quartz crystal by its frequency change, but it responds to only smaller particles and becomes loaded easily. Similar in concept to the FTIR spectrometer used in this project's experiments is the monitoring of specific infrared spectral bands to detect various gases.

Chemical detectors are a more recent addition to detector technology. Gas sensors using tin oxide (SnO_2) are sensitive to carbon monoxide as well as oxidizable hydrocarbons, so either would be detected if present as food ignition approaches. Platinum doping allows the sensor to operate at room temperature instead of 300 °C. Catalytic sensors heat when in contact with specific chemical gases, but the catalyst can become poisoned, and it can be confused by mixtures of gases. Electrochemical sensors change their electrical properties when an impinging gas causes a reaction, but these sensors are usually slow and require high temperatures.

Temperature could be monitored by many methods including infrared emission, but sophisticated thermometry is expensive. Temperature technology in the form of thermocouples, thermistors, or RTDs (resistance temperature devices) is inexpensive and versatile. One or more of these devices could be used in conjunction with a smoke detection device to prevent false alarms by providing additional checks on the possible approaching fire situation. Since sensing of a temperature threshold would be most appropriate, thermistors, which are very sensitive to changes, would probably not be the best choice. The platinum in RTDs can make their cost prohibitive depending on the size of the device. Thermocouples remain an effective and inexpensive method of thermometry.

The combination of smoke sensing and temperature sensing devices in a single detector requires a microprocessor of some sort to logically interpret the incoming sensor information.

Appendix A also contains a section on fuzzy logic, artificial intelligence, and smart sensors as applied to multi-parameter detection. The algorithms and hardware can range from simple to very sophisticated and would depend on the final design of the detector. The number of inputs to the smart system and how they should be interpreted would impact the complexity and cost of the detector. Costs of the individual components have not been assembled because they are so dependent on actual design and application.

4.3.2 Controls

Very few of the documents found in the NTIS and EI databases were directly related to the needed technology, but many of the patents were similar to or exactly the kinds of controls being sought. Several of the patents are for power disruption devices designed for smoke or fire alarm input. Other patents are for gas safety valves with detector inputs. Brochures that were obtained from companies advertise similar technology to that which was sought. The technology for shutting down gas and electric ranges as ignition conditions are approached is readily available and is relatively inexpensive since much of it is mass produced for application to ranges and other appliances.

5.0 Conclusions

The conclusions pertaining to the experiments are based on measurements and observations of combinations of specific ranges, pans, foods, and ventilation so extrapolation to other conditions should be performed with caution. The conclusions of this research are as follows:

- Food cooked in a stainless steel pan more quickly reached ignition conditions than the same food cooked in an aluminum pan.
- For the particular open-coil element electric and high-output gas ranges used in these experiments, food cooked on the electric range reached ignition conditions more quickly than the same food cooked on the gas range with the exception of sugar which reached ignition conditions more quickly on the gas range.
- For the particular ranges used in these experiments, cooking food on the electric range produced similar ignition conditions to those produced by cooking the same food on the gas range.
- The temporal heating and ignition behaviors of soybean oil and bacon were similar; however, sugar had a unique behavior.
- The particular range hood used was not found to have a significant effect on ignition conditions, and its active or inactive status appeared irrelevant to pre-ignition detection.
- Weak indicators and non-indicators of impending ignition were velocity above the burner and infrared imaging of the cooking area.
- Strong indicators of impending ignition were food, pan, range, and range-hood temperatures, smoke particulates, and hydrocarbon gases. Some pre-ignition temperature signatures will require more study since they may be mimicked by normal, safe use of the oven or multiple burners.

- Tin oxide (SnO_2) sensors are available that are sensitive to hydrocarbons including carbon monoxide. Although CO was below the detectable limits of-the FTIR spectrometer, hydrocarbons showed a significant increase preceding ignition, and a finite amount of CO is usually a pyrolysis product. Tin oxide sensors could be used to detect increasing pre-ignition levels of hydrocarbons.
- The magnitude of spectrally specific infrared absorption could be measured as a means of detecting hydrocarbon gases.
- The scattering or attenuation types of photoelectric smoke detectors could be applied to the detection of range pre-ignition conditions due to the large quantities of smoke produced as ignition approaches.
- Thermocouple thermometry of the burner, pan, range surface (top and below), or range hood is an easily implemented means of pre-ignition detection, especially in conjunction with another method.
- Logical processing of signals from two or more of the aforementioned sensors could be an important means by which false alarms of pre-ignition conditions are eliminated.
- Control technologies exist that could be applied to the safe shutdown and restart of gas and electric ranges upon detection of approaching ignition.

6.0 References

1. Karter, M. J., Jr. "Fire Loss in the United States in 1994," NFPA Journal, Quincy, MA; Vol. 89, No. 5, 93-100, September/October 1995.

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. "Food Fats and Oils," 7th Edition, The Institute of Shortening and Edible Oils, Inc., Washington, D.C.; 1994. 29 p.

4. Swern, D., editor. Bailey's Industrial Oil and Fat Products, Vols. 1, 2, and 3, 4th ed., John Wiley & Sons, Inc., New York, NY; 1985.

5. Pitts, W. M.; Yang, J. C.; Gmurczyk, G. W.; Cooper, L. Y.; Grosshandler, W. L.; Cleveland, W. G.; and Presser, C. "Fluid Dynamics of Agent Discharge," NIST SP 861, National Institute of Standards and Technology, Gaithersburg, MD; April 1994. In "Evaluation of Alternative In-Flight Fire Suppressants for Full-Scale Testing in Simulated Aircraft Nacelles and Dry Bays," Section 3, Grosshandler, W. L.; Gann, R. G.; Pitts, W. M., editors, 37-343 pp, 1994.

6. McCaffrey, B. J. and Heskestad, G. "Robust Bidirectional Low-Velocity Probe for Flame and Fire Application," Combustion and Flame Vol. 26, No. 1, 125-127, February 1976.

7. Peacock, R. D.; Breese, J. N.; and Forney, C. L. "User's Guide for RAPID, Version 2.3," NIST SP 798, National Institute of Standards and Technology, Gaithersburg, MD; 112 p., January 1991.

8. McMahan Research Laboratories. "MRL V1000 Image Controller," 1993.

9. Lide, D. R., editor; Frederikse, H. P. R., editor. CRC Handbook of Chemistry and Physics, CRC Press, Inc., Boca Raton, FL, 2579 p.

10. Grosshandler, W. L. "Assessment of Technologies for Advanced Fire Detection," American Society of Mechanical Engineers. Heat and Mass Transfer in Fire and Combustion Systems. HTD-Vol. 223. Winter Annual Meeting. November 8-13, 1992, Anaheim, CA, American Society of Mechanical Engineers, New York, NY; Cho, P.; Quintiere, J., editors, 1-10 pp, 1992.

7.0 Appendices

Appendix A. Literature and Patent Search Reference List

Gas Detectors

Anon
Making use of faster, more accurate leak detection
Gas Industries (Park Ridge, Illinois) v 38 n 3 Jan 1994. p 15-16
1994

Azad, A. M.; Mhaisalkar, S. G.; Birkefeld, L. D.; Akbar, S. A.; Goto, K. S.
Behavior of a new ZrO//2-MoO//3 sensor for carbon monoxide detection.
Ohio State Univ, Columbus, OH, USA
Journal of the Electrochemical Society v 139 n 10 Oct 1992 p 2913-2919
1992

Coles, G.S.V.
Selective semiconductor sensors for reducing and oxidizing gases
Univ of Wales, Swansea, Wales
Bulletin of Materials Science v 17 n 7 Dec 1994. p 1401-1409
1994

Dick, R. ; Schorb, K. ; Reichert, J.
Untersuchungen an Polymerbeschichtungen auf Surface-Acoustic-Wave-Sensore n zur Detektion organischer Loesungsmitteldaempfe. (Investigations of polymeric coatings on surface acoustic wave sensors for detection of gaseous organic solvents)
Kernforschungszentrum Karlsruhe G.m.b.H. (Germany, F.R.). Inst. fuer Radiochemie.
Kernforschungszentrum Karlsruhe GmbH (Germany). Projekt Schadstoffbeherrschung in der Umwelt (PSU).
Report No.: KFK--4985
NTIS Accession Number: TIB/B92-02295/XAB
Dec 91 30p
German
Germany, Federal Republic of

Florschuetz, P. ; Walther, J.
Erkennung von Gas- und Brandentwicklung in Lagern radioaktiver Abfaelle. Schlussbericht. (Detection of gas and fire in underground radioactive waste disposal. Final report)
Materialpruefungsanstalt fuer das Bauwesen Freistaat Sachsen, Freiberg (DE). Referat Brandschutz.
NTIS Accession Number: TIB/A95-00573/XAB
May 93 19p
German
Germany

Fryberger, T. B. ; Semancik, S.
Conductance Response of Pd/SnO2(110) Model Gas Sensors to H2 and O2 (Final rept)
National Inst. of Standards and Technology (NML), Gaithersburg, MD. Chemical Process Metrology Div.
NTIS Accession Number: PB95-125803
Sensors and Actuators B 2, n4 p305-309 1990.
1990 5p

Grace, R. ; Guzman, A. ; Portnoff, M. ; Purta, D.
Carbon Monoxide Monitor for Automobile Passenger Compartment (Final rept. Jul 0-Apr 91)
Carnegie-Mellon Inst. of Research, Pittsburgh, PA.
John A. Volpe National Transportation Systems Center, Cambridge, MA.
Report No.: DOT-VNTSC-NHTSA-91-3; DOT-HS-807 761
NTIS Accession Number: PB92-119056/XAB
Jul 91 75p

Harwood, J. A.; Moseley, P. T.; Peat, R.; Reynolds, C. A.
Use of Low Power Carbon Monoxide Sensors to Provide Early Warning of Fire.
Harwell Lab., Oxfordshire, UK
Home Office, UK
Fire Safety Journal, Vol. 17, No. 6, 431-443, 1991.
University of Duisburg. International Conference on Automatic Fire Detection "AUBE '89", 9th. September 26-28, 1989, Duisburg, West Germany, Luck, H., Editor, 433-447 pp, 1989.

Harwood, J.; Reynolds, C.
Development of New Fire Sensors.
Home Office Fire Research and Development Group, UK
Fire Research News, Vol. 13, 14-15, Spring 1991.

Hierlemann, Andreas; Weimar, Udo; Kraus, Gerolf; Schweizer-Berberich, Markus; Goepel, Wolfgang
Polymer-based sensor arrays and multicomponent analysis for the detection of hazardous organic vapours in the environment
Univ of Tuebingen, Tuebingen, Ger
Proceedings of the EUROSENSORS VIII Conference. Part 1 Toulouse, Fr
Air France; Air Inter; Centre National de la Recherche Scientifique; Commission of the European Communities; International Sciences Foundation; et al
Sensors and Actuators, B: Chemical v B26 n 1-3 pt 1 May 1995. p 126-134
1995

Kingon, A. I. ; Myers, E. R. ; Tuttle, B.
Ferroelectric Thin Films II. Materials Research Society Symposium Proceedings Held in Boston, Massachusetts on December 2 - 4, 1991. Volume 243
Materials Research Society, Pittsburgh, PA.
NTIS Accession Number: AD-A261 895/7
1992 694p

Lei, Yuanjin; Jiang, Zhufeng; Tao, Yuemei; Wu, Zhihong
Novel catalytic gas sensor has long-life and low power consumption
Inst of Precious Metals in Kunming, Kunming, China
Sensor Review v 15 n 1 1995. p 22-24
1995

Litton, C. D.; Conti, R. S.; Tabacchi, J. G.; Grace, R.
Evaluation of a Nitric-Oxide-Compensated Carbon Monoxide Fire Sensor.
Bureau of Mines, Pittsburgh, PA
IC 9339; 14 p. 1993.
This U. S. Bureau of Mines report describes the results of two large-scale tests conducted to evaluate a prototype nitric oxide (NO)-compensated carbon monoxide (CO) fire sensor, developed by Carnegie Mellon Research Institute (CMRI). In the tests, small coal fires were allowed to develop in the presence of diesel exhaust at relatively low ventilation airflows. These tests compared the response of the CMRI fire sensor with that of other fire sensors, including the Bureau's diesel-discriminating smoke detector. During the tests, CO, NO, and smoke levels were continuously monitored in order to determine the sensor alarm times and gas levels as the fire developed. The data indicted that the NO-compensated CO fire sensor was capable of suppressing the CO produced by a diesel engine and that the sensor responded reliably to the CO produced from the test fires. The tests also showed that the Bureau's diesel-discriminating smoke detector alarmed earlier than the prototype NO-comprnsated CO fire sensor.

Moye, C. H.
Development of a First Approximation of a Design Method for Combustible Gas Detection Systems.
Worcester Polytechnic Inst., MA
Thesis; 99 p. May 1991.
This paper reviews the basic design objectives for the use of fixed combustible gas detection systems, reviews the state-of-the-art in combustible gas detection technology, and reviews criteria used in the design and layout of fixed systems. A solution for sensor placement in a non-ventilated enclosure is presented. There is also a discussion regarding the development of a national consensus standard for the design and installation of combustible gas detection systems. There is no standard for the design and installation of combustible gas systems, although standards for system components do exist.

Munday, E. B.
Chlorofluorocarbon leak detection technology
Oak Ridge K-25 Site, TN.

Department of Energy, Washington, DC.
Report No.: K/QT-390
NTIS Accession Number: DE91006906/XAB
Dec 90 49p

Okayama, Y.; Handa, T.; Fukaya, H.; Maruyama, T.; Endo, K.
Carbon Monoxide Sensor Element Made of SnO2-Sb203-Pt Semiconductor.
; 2 p. 1990.

[ABSTRACT IN ENGLISH] Report of electric resistance characteristics in CO dense gas sensor element. This uses gas adsorption on a semi-conductor surface at a normal temperature, unlike other CO sensor elements which must be heated to maintain their particle surface temperature (200-300 deg C).

Outcalt, S. L. ; Ingham, H. ; Bruno, T. J.
Process Gas Chromatography Detector for Hydrocarbons Based on Catalytic Cracking (Final rept)
National Inst. of Standards and Technology (CSTL), Boulder, CO. Thermophysics Div.
Gas Research Inst., Chicago, IL.
NTIS Accession Number: PB95-141099
Process Control and Quality 2, p357-369 1992.
1992 13p

Plog, C. ; Maunz, W. ; Obermeier, E. ; Scheibe, C. Dornier G.m.b.H., Deutsche Aerospace A.G., Friedrichshafen (Germany).
Einsatzmoeglichkeit selektiver chemischer Sensoren zur Ueberwachung von KW/CKW - Emissionen sowie Prozesssteuerung. (Possibilities of application of selective chemical sensors to monitor emissions of hydrocarbons and chlorine hydrocarbons and process control)
NTIS Accession Number: TIB/A95-03403/XAB
Dec 94 117p
German
Germany

Stedman, D. H. ; Bishop, G. A. ; Peterson, J. E. ; Guenther, P. L. ; McVey, I. F.
On-Road Carbon Monoxide and Hydrocarbon Remote Sensing in the Chicago Area (Final rept)
Denver Univ., CO. Dept. of Chemistry.
Illinois Dept. of Energy and Natural Resources, Springfield. Office of Research and Planning.
Report No.: IL/ENR/RE/AQ-91/14
NTIS Accession Number: PB92-121490/XAB
Oct 91 96p

Stone, H. W. ; Ohm, T. R.
Emergency Response Mobile Robot for Operations in Combustible Atmospheres (Patent Application)
National Aeronautics and Space Administration, Pasadena, CA. Pasadena Office.
PAT-APPL-8-153 934; NAS 1.71:NPO-19020-1-CU
NTIS Accession Number: N94-29420/4/XAB
Filed 15 Nov 93 21p

Tournier, Guy; Pijolat, Christophe; Lalauze, Rene; Patissier, Bruno
Selective detection of CO and CH//4 with gas sensors using SnO//2 doped with palladium
Ecole Nationale Superieure des Mines de St.-Etienne, Saint-Etienne, Fr
Proceedings of the EUROSENSORS VIII Conference. Part 1 Toulouse, Fr
Air France; Air Inter; Centre National de la Recherche Scientifique; Commission of the European Communities; International Sciences Foundation; et al
Sensors and Actuators, B: Chemical v B26 n 1-3 pt 1 May 1995. p 24-28
1995

Tuebingen Univ. (Germany, F.R.). Inst. fuer Physikalische und Theoretische Chemie.
Chemische Sensoren in Duennschicht Technologie. Abschlussbericht. (Chemical sensors based on thin films. Final report)
NTIS Accession Number: TIB/A95-01643/XAB
9 Dec 91 41p
German
Germany, Federal Republic of

Zellers, E. T.
Selective Real-Time Detection of Olefin Gases and Vapors (Final rept)

Michigan Univ., Ann Arbor. Dept. of Environmental and Industrial Health.
National Inst. for Occupational Safety and Health, Cincinnati, OH.
NTIS Accession Number: PB93-217115/XAB
30 Mar 93 140p

Ziolkowski, C. J. ; Huebler, J. E. ; Rush, W. F.
Sensors for Advanced Gas Distribution Systems. Final Report, March 1987-February 1988
Institute of Gas Technology, Chicago, IL.
Gas Research Inst., Chicago, IL.
Report No.: GRI-90/0322
NTIS Accession Number: PB91-159566/XAB
Jan 91 43p

Artificial Intelligence, Smart Sensors, Fuzzy Logic

Beyreis, J. R.
State of Detection Technology.
Underwriters Laboratories, Inc., Northbrook, IL
U. S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 12th Joint Panel Meeting. October 27-November 2, 1992, Tsukuba, Japan, Building Research Inst., Ibaraki, Japan, 89-92 pp, 1994.

Fox, P.; Girling, K.
New Generation of High Sensitivity Smoke Detectors. Product Profile.
Air Sensor Technology Ltd.
Fire Surveyor, Vol. 22, No. 4, 22-26, August 1993.

Harvey, M.
Focus on Fire Detection: Sensing Intelligence.
Thorn Security Ltd., UK
Fire Prevention, No. 249, 27-29, May 1992.

Heskestad, G.; Newman, J. S.
Fire Detection Using Signal Cross Correlation Techniques. Technical Report.
Factory Mutual Research Corp., Norwood, MA
FMRC J.I. 0R0R8.RU; 129 p. May 1990.

Hosokawa, M.; Satoh, K.; Kouzeki, D.; Tamura, H.; Okuda, Y.; Kusanagi, S.; Fujioka, T.; Watabe, Y.; Kurio, T.; Nakanishi, S.
Study of Fuzzy-Reasoning Intelligent Fire Detection System.
Fire Research Institute, Tokyo, Japan
Matushita Electric Work, Osaka, Japan
U.S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 12th Joint Panel Meeting. October 27-November 2, 1992, Tsukuba, Japan, Building Research Inst., Ibaraki, Japan, 110-113 pp, 1994.

Ishii, Hiromitsu; Ono, Takashi; Yamauchi, Yukio; Ohtani, Shigeru
Algorithm for improving the reliability of detection with processing of multiple sensors' signal.
Nihon Univ, Tokyo, Jpn
9th International Conference on Automatic Fire Detection - AUBE '89 Duisburg, Ger Conference Date: 1989 Sep
Fire Safety Journal v 17 n 6 1991. p 469-484
1991

Ishii, H.; Ono, T.; Yamauchi, Y.; Ohtani, S.
Fire Detection System by Multi-Layered Neural Network With Delay Circuit.
Nihon Univ., Tokyo, Japan
Hochiki Corp., Tokyo, Japan
International Association for Fire Safety Science. Fire Safety Science. Proceedings. 4th International Symposium. July 13-17, 1994, Ottawa, Ontario, Canada, Intl. Assoc. for Fire Safety Science, Boston, MA, Kashiwagi, T., Editor, 761-772 pp, 1994.

Kouzeki, D.
Progress Report on Suppression and Detection Research in Japan.
Fire Research Institute, Tokyo, Japan

U. S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 12th Joint Panel Meeting. October 27-November 2, 1992, Tsukuba, Japan, Building Research Inst., Ibaraki, Japan, 81-82 pp, 1994.

Kozeki, D.; Satoh, K.; Takemoto, A.; Nomura, J.; Kurio, T.; Nakanishi, S.
Study of Fire Detection System Introducing AI Technology. Part 2. Role of Fuzzy Expert System to Reduce False Alarms.
Matsushita Electric Works, Ltd., Osaka, Japan
Report of Research Institute of Japan, No. 71, 21-31, March 1991.

[Abstract in English] The objective of this study is to develop a new fire detection system which is extremely reliable, i.e., far less alarming falsely, using modern Artificial Intelligence (AI) technology. In this study, the role of Fuzzy Expert System incorporated in our prototype AI fire detection system was examined to reduce false alarms. Fuzzy membership functions corresponding to flaming fires, smoldering fires, smoke of tobacco, and steam flowing out of a bathroom in a hotel guest room were defined in consistency with the rules of expert system. Experimental results showed that the Fuzzy membership functions defined in this study and the Fuzzy Expert System are useful to reduce false alarms. It was easy to identify flaming fires and steam from bathroom, but not always easy to identify smoldering fires of bed sheets with the tobacco smoke before and just when the smoke concentration reaches the value of 10%/m. However, in case of smoldering fires the fire growth rate is much smaller than in case of flaming fires. Therefore, the system can wait a little until the final decision of either fires or non-fires. By delaying the final decision a little, the system could judge either fires or non-fires clearly.

Lister, E.
Product Profile: An Introduction to Multisensor Technology.
ADT Security Systems, UK
Fire Safety Engineering, Vol. 2, No. 3, 14-17, June 1995.

Meacham, B. J.
Use of Artificial Intelligence Techniques for Signal Discrimination in Fire Detection Systems.
FireTech, Meilen, Switzerland
Journal of Fire Protection Engineering, Vol. 6, No. 3, 125-136, 1994.

Milke, J. A.
Application of Neural Networks for Discriminating Fire Detectors.
Maryland Univ., College Park
University of Duisburg. International Conference on Automatic Fire Detection "AUBE '95", 10th. April 4-6, 1995, Duisburg, Germany, Luck, H., Editor, 213-222 pp, 1995.

Research is being conducted to describe the characteristics of an improved fire detector which promptly reacts to smoke while discriminating between smoke and odors from fire and non-fire sources. This study is investigating signature patterns associated with fire and environmental sources via small- and large-scale tests toward the development of an improved fire detector. On the tests, smoke and odors are produced from a variety of conditions: flaming, pyrolyzing and heated samples, and nuisance sources, such as aerosols, household products and cooked food. Measurements include light obscuration, temperature, mass loss, CO, CO2, O2 and oxidizable gas concentrations. The feasibility of an elementary expert system to classify the source of the signatures from small-scale experiments was demonstrated in the first phase. In the recently completed second phase, a similar expert system correctly classified the source of the signatures in large-scale experimets in 85 % of the cases. Neural networks have been applied to both sets of data from the small- and large-scale tests providing an even greater successful classification rate.

Milke, J. A.; McAvoy, T. J.
Analysis of Signature Patterns for Discriminating Fire Detection With Multiple Sensors.
Maryland Univ., College Park
Fire Technology, Vol. 31, No. 2, 120-136, May 1995.

Incorporating intelligence into a fire detector so that it can recognize signature patterns is intended to permit prompt fire detection while allowing the detector to discriminate between signatures from fire and nonfire sources. The primary purpose of this preliminary study is to investigate the patterns of signatures associated with fire and environmental sources using small-scale experiments. We generated products from a wide range of conditions, from flaming or pyrolyzing samples, to heated samples and samples obtained with an atomizer. We also measured gas concentrations, light obscuration, and temperature to characterize the products. By analyzing the data, we identified trends from which an elementary expert system can be formulated to identify the source of the airborne products. Several patterns are evident. The maximum CO2 concentrations achieved during experiments with flaming fires are significantly greater than the maximum CO2 concentrations achieved during experiments with nonflaming fires (pyrolyzing fires, heated liquids, and environmental odors). The nonflaming sources can be identified based on the CO and metal oxide sensor peak measurements. Except for three experiments using pyrolyzing solids, the peak CO concentration is greater - though the Taguchi detector response is less - for nonflaming fires than for environmental sources. Subsequent application of a neural network properly classifies all except one pyrolyzing fire.

Oizumi, T.; Saito, K.; Gruver, W. A.
Fire Detection and Extinguishment System Using Fuzzy Inference and Neural Networks.
Kentucky Univ., Lexington

Interscience Communications Ltd.; National Institute of Standards and Technology; Building Research Establishment; and Society of Fire Protection Engineers. Interflam '93. Fire Safety. International Fire Conference, 6th. March 30-April 1, 1993, Oxford, England, Interscience Communications Ltd., London, England, Franks, C. A., Editor, 281-286 pp, 1993.

Okayama, Y.
Approach to Detection of Fires in Their Very Early Stage by Odor Sensors and Neural Net.
Nohmi Bosai Ltd., Tokyo, Japan
International Association for Fire Safety Science. Fire Safety Science. Proceedings. 3rd International Symposium. July 8-12, 1991, Edinburgh, Scotland, Elsevier Applied Science, New York, Cox, G.; Langford, B., Editors, 955-964 pp, 1991.

Okayama, Y.; Ito, T.; Sasaki, T.
Design of Neural Net to Detect Early Stage of Fire and Evaluation by Using Real Sensors' Data.
Nohmi Bosai Ltd., Tokyo, Japan
International Association for Fire Safety Science. Fire Safety Science. Proceedings. 4th International Symposium. July 13-17, 1994, Ottawa, Ontario, Canada, Intl. Assoc. for Fire Safety Science, Boston, MA, Kashiwagi, T., Editor, 751-759 pp, 1994.

Siebel, Rainer
Composite detection algorithm using signal trend information of two different sensors.
Duisburg Univ, Duisburg, Ger
9th International Conference on Automatic Fire Detection - AUBE '89 Duisburg, Ger Conference Date: 1989 Sep
Fire Safety Journal v 17 n 6 1991. p 519-534
1991

Tamura, H.; Satoh, K.; Kouzeki, D.; Hosokawa, M.; Kusanagi, S.; Fujioka, T.; Watabe, Y.; Kurio, T.; Nakanishi, S.; Shimomura, S.; Kirihata, S.
Study of Intelligent Fire Detection System: A System Consisting of Fuzzy Expert System and Two Sensing Elements.
Fire Research Institute, Tokyo, Japan
Report of Fire Research Institute of Japan, No. 75, 51-62, 1993.
[ONLY ABSTRACT IN ENGLISH]

Other Detectors and Sensors

Author (Inventor): ARAKAWA M; TERASAWA T; OGAWA M; KAMI H
Sensor in form of integrated circuit e.g. smoke detector - has integrated components mounted on dielectric insulating substrate
Patent Assignee: (MATW) MATSUSHITA ELECTRIC WORKS LTD
WPI Acc No: 90-133257/18
Patent (basic)
Patent No Kind Date Field of Search
DE 3934873 A 900426 (BASIC)

Author (Inventor): CAWLEY D CAWLEY R
Fire suppression system for decorative e.g. christmas tree automatically shuts down electrical system when tree catches fire using smoke detector
Patent Assignee: CAWLEY D
WPI Acc No: 91-177075 24
Patent (basic): - <BASIC> US 5018586 A 910528

D'Amico, A. (Ed.)
Proceedings of EUROSENSORS V
Proceedings of EUROSENSORS V Rome, Italy, 1991 Sep 30-Oct 2
Sensors and Actuators, A: Physical v 31 n 1-3 pt 3 Mar 1992.
Publ by Elsevier Sequoia SA, Subscription Department, Lausanne 1, Switz. 287p
1992

DePaula, Ramon P. (Ed.)
Fiber Optic and Laser Sensors XII
NASA Headquarters, Washington, DC, USA
Fiber Optic and Laser Sensors XII San Diego, CA, USA
SPIE - Int Soc for Opt Engineering, Bellingham, WA USA
Proceedings of SPIE - The International Society for Optical Engineering v 2292 1994.. 468p
1994

Egan, Margaret R.; Litton, Charles D.
Detector responses to both fire and non-fire contaminants.
Bur of Mines, Pittsburgh, PA, USA
New Technology in Mine Health and Safety, Phoenix, AZ, USA, 1992 Feb 24-27
New Technol Mine Health Saf. Publ by Soc of Petroleum Engineers of AIME, Richardson, TX, USA. p 69-80
1992

Fabricius, N. ; Guttmann, H.J. ; Hollenbach, U. ; Ingenhoff, J. ; Wolf, B.
Prozessmesstechnik mittels integriert optischer Sensoren auf Glasbasis. Teilvorhaben: Integriert optische Sensor- und Signalverarbeitungskomponenten in Glas. Abschlussbericht. (Process measuring practice by glass-based integrated optical sensors. Subproject: optical sensor- and signal processing components in glass. Final report)
IOT Entwicklungsgesellschaft fuer Integrierte Optik-Technologie mbH, Waghaeusel (DE).
NTIS Accession Number: TIB/A94-04429/XAB
1992 62p
German
Germany

Author (Inventor): FRITZ F V
WPI Acc No: 90-354757/47
Self-penetrating remote sensing smoke detector - with mast positioning sensor to provide signal to main alarm unit in presence of combustion products in space
Patent Assignee: (FRIT) FRITZ F V
Patent (basic)
Patent No Kind Date Field of Search
US 4968975 A 901106 (BASIC)

Gutierrez, F.J. (Ed.); Gracia, J. (Ed.)
Proceedings of EUROSENSORS VI
Proceedings of EUROSENSORS VI, San Sebastian, Spain
Sensors and Actuators, A: Physical v 37-38 n 2 Jun-Aug 1993. Publ by Elsevier Sequoia SA, Subscription Department, Lausanne 1, Switz. 804p
1993

Kersey, Alan D. (Ed.); Dakin, John P. (Ed.)
Distributed and Multiplexed Fiber Optic Sensors IV
Naval Research Lab., Washington, DC, USA
Distributed and Multiplexed Fiber Optic Sensors IV, San Diego, CA, USA
SPIE - Int Soc for Opt Engineering, Bellingham, WA USA
Proceedings of SPIE - The International Society for Optical Engineering v 2294 1994.. 175p
1994

Litton, Charles D.
Two faces of smoke.
Bur of Mines, Pittsburgh, PA, USA
New Technology in Mine Health and Safety, Phoenix, AZ, USA, 1992 Feb 24-27
New Technol Mine Health Saf. Publ by Soc of Petroleum Engineers of AIME, Richardson, TX, USA. p 95-104
1992

Litton, C. D.; Furno, A. L.; Opferman, J. J.
APPLICATION OF SUBMICRON PARTICULATE DETECTOR TO REAL MINE FIRES.
US Bur of Mines, Pittsburgh Research Cent, Pittsburgh, PA, USA
20 International Conference of Safety in Mines Research Institutes. Sheffield, Engl, 1983 Oct 3-7
Health & Safety Executive Available from Health & Safety Executive, Explosion & Flame Lab, Buxton, Engl I2, 12p
1983

Litton, Charles D.; Vinson, Robert P.
Application of the diesel discriminating fire sensor to the measurement of respirable coal dust
U.S. Dep of the Interior, Pittsburgh, PA, USA
Proceedings of the 29th IAS Annual Meeting. Part 3 (of 3), Denver, CO, USA
IAS Annual Meeting (IEEE Industry Applications Society) v 3 1994. IEEE, Piscataway, NJ, USA,94CH3452-0. p 2121-2125
1994

Naumaan, Ahmed (Ed.); Baixeras, Joseph M. (Ed.); Kreisler, Alain J. (Ed.); Corsi, Carlo (Ed.)
Infrared and Optoelectronic Materials and Devices.
E. F. Johnson Co., Bloomington, MN, USA
Infrared and Optoelectronic Materials and Devices, Hague, Neth, 1991 Mar 12-14
SPIE - Int Soc for Opt Engineering, Bellingham, WA, USA; EPS - European Physical Soc; Europtica - European Federation for Applied Optics; ANRT - Assoc Natl de la Recherche Technique; Assoc Elettrotecnica ed Elettronica Italiana; et al
Proceedings of SPIE - The International Society for Optical Engineering v 1512 1991. Publ by Int Soc for Optical Engineering, Bellingham, WA, USA. 299p
1991

Author (Inventor): PIEREN H, KUNZ P, PORTENIER M
Gas flow speed monitor for smoke detector uses cooling effect of gas flow on temp. sensitive resistance element
Patent Assignee: SECURITON AG
WPI Acc No: 85-062494/11
Patent (basic): BE 900472 A 850228

Schmidt-Ott, A.; Krull, W.; Burtscher, H.
Electrostatic Fire Detector.
AMT Univ., Duisburg, West Germany
NT Univ., Duisburg, West Germany
ETH-Zurich, Switzerland
Fire Safety Journal, Vol. 17, No. 6, 423-430, 1991.
University of Duisburg. International Conference on Automatic Fire Detection 'AUBE '89", 9th. September 26-38, 1989, Duisburg, West Germany, Luck, H., Editor, 215-225 pp, 1989.

Author (Inventor): TANGUAY W P
Variable level sensitivity smoke detector - diminishes sensitivity of detector for temporary time period by increasing predetermined level causing alarm generation
Patent Assignee: (SEAT) SEATT CORP
WPI Acc No: 89-015753/02
Patent (basic)
Patent No Kind Date Field of Search
US 4792797 A 881220 (BASIC)

Author (Inventor): TAYLOR H L EHRET C O
Air flow control system with smoke detector for building closes vent and disables recirculating air blower when fire, smoke, or high heat is detected
Patent Assignee: TAYLOR H L
WPI Acc No: 90-192421/25
Patent (basic): US 4928583 A 900529

Ionization Detectors

Author (Inventor): BEYERSDORF H
Ionisation smoke detector with measuring chamber - is operated by measuring potential of measuring electrode for extra electric field strength
Patent Assignee: (BEYE) BEYERSDORF H
WPI Acc No: 90-261718/35
Patent (basic)
Patent No Kind Date Field of Search
DE 3904979 A 900823 (BASIC)

Author (Inventor): HEBERLEIN G E; BRUSKI G P
Modular smoke detector for electrical equipment cabinet - has fan to induce air from interior of cabinet to ionisation detector via flow controller
Patent Assignee: (ALLB) ALLEN BRADLEY CO
WPI Acc No: 88-346055/48
Patent (basic)
Patent No Kind Date Field of Search
US 4785288 A 881115 (BASIC)

Author (Inventor): KAMINAKA Y; KOIZUMI S; NAGSHIMA T; HIRAI Y; SATO T

Ionisation type ceiling mounted smoke detector - has inner electrode and outer electrodes in ring and in line with gaps in casing
Patent Assignee: (HOCH) HOCHIKI CO LTD
WPI Acc No: 89-208002/29
Patent (basic)
Patent No Kind Date Field of Search
DE 3843297 A 890713 (BASIC)

Author (Inventor): MOCHZUKI M
Ionisation type smoke detector transmitting fire signal - derives sensor section output from junction between fixed resistor and constant current source having variable resistor to adjust output
Patent Assignee: (NOHM) NOHMI BOSAI LTD
WPI Acc No: 93-378784/48
Patent (basic)
Patent No Kind Date Field of Search
EP 571842 A1 931201 (BASIC)

Newman, J. S.
Modified Theory for the Characterization of Ionization Smoke Detectors.
Factory Mutual Research Corp., Norwood, MA
International Association for Fire Safety Science. Fire Safety Science. Proceedings. 4th International Symposium. July 13-17, 1994, Ottawa, Ontario, Canada, Intl. Assoc. for Fire Safety Science, Boston, MA, Kashiwagi, T., Editor, 785-792 pp, 1994.

Author (Inventor): SASAKI T
Ionisation type-smoke detector has radioactive source to ionise air within inner and outer chambers and electrical circuits for detecting potential
Patent Assignee: NOHMI BOSAI KOGYO CO LTD
WPI Acc No: 88-353624/49
Patent (basic): US 4786811 A 881122 (BASIC)

Takahashi, I.; Matsuzawa, T.; Sakaguchi, M.
Ionization chamber-type CO sensor
Nemoto & Co Ltd, Tokyo, Jpn
Proceedings of the Fourth International Meeting on Chemical Sensors. Part 2 (of 2), Tokyo, Japan
Sensors and Actuators, B: Chemical v B14 n 1-3 pt 2 Jun 1993. p 539-540
1993

Author (Inventor): THORP E J
Smoke detector having low height ionisation type sensor - has ion source which is perpendicular w.r.t. common electrode and divides cylindrical chamber into two target electrode regions
Patent Assignee: (PITT) PITTWAY CORP
WPI Acc No: 91-008847/02
Patent (basic)
Patent No Kind Date Field of Search
EP 405473 A 910102 (BASIC)

Willey, M.
Line Type Heat Detectors - Their Operation and Application.
Patol Systems, UK
Fire Surveyor, Vol. 21, No. 2, 8-12, April 1992.

Temperature Sensors

Brenci, Massimo; Guzzi, Donatella; Mencaglia, Andrea; Grazia, Anna
Optical fiber sensor system for fire detection in hazardous environments
Istituto di Ricerca sulle Onde Elettromagnetiche, Firenze, Italy
Measurement v 12 n 2 Dec 1993. p 183-190
1993

Bryant, J. E. ; Bennett, J. E. ; Pinkston, W. H.
Infrared Fiber-Optical Temperature Sensor (Patent)
Department of the Navy, Washington, DC.

Report No.: PAT-APPL-7-744 046; PATENT-5 145 257
NTIS Accession Number: AD-D015 495/5
Filed 12 Aug 91 patented 8 Sep 92 10p
Supersedes PAT-APPL-7-744 046.

Davis, R. M. ; Antoine, G. J. ; Diller, T. E. ; Wicks, A. L.
Measurement of a Surface Heat Flux and Temperature
Virginia Polytechnic Inst. and State Univ., Blacksburg.
National Aeronautics and Space Administration, Washington, DC. Apr 94 15p
In NASA. Langley Research Center, National Educators' Workshop: Update 1993. Standard Experiments in Engineering Materials Science and Technology p 203-218.
NTIS Accession Number: N94-36407/2/XAB

Furniss, C. Paul
Improved temperature measurement in heat treatment furnaces using special sensors
Incotherm Ltd
Industrial Heating v 60 n 3 Mar 1993. p 86-89
1993

Kuo, C. H.; Kulkarni, A. K.
Analysis of Heat Flux Measurement by Circular Foil Gages in a Mixed Convection/Radiation Enviornment.
Pennsylvania State Univ., University Park
Journal of Heat Transfer, Vol. 113, No. 4, 1037-1040, November 1991.

NERAC, Inc., Tolland, CT.
Fiber Optic Temperature Measurement, Sensors, and Thermometers. (Latest citations from the INSPEC Database) (Published Search)
National Technical Information Service, Springfield, VA.
Dec 93 180 citations minimum
NTIS Accession Number: PB94-857349/XAB
Supersedes PB93-851046

NERAC, Inc., Tolland, CT.
Fiber Optic Temperature Measurement, Sensors, and Thermometers. (Latest citations from the INSPEC Database) (Published Search)
National Technical Information Service, Springfield, VA.
NTIS Accession Number: PB95-877577/XAB
Apr 95 101 citations minimum
Supersedes PB94-857349

NERAC, Inc., Tolland, CT.
Sensors and Probes in Heat Treating. (Latest citations from METADEX) (NewSearch)
National Technical Information Service, Springfield, VA.
NTIS Accession Number: PB95-852331/XAB
Oct 94 191 citations minimum

Ng, D. ; Spuckler, C. M.
Non-Contact Heat Flux Measurement Using a Transparent Sensor
National Aeronautics and Space Administration, Cleveland, OH. Lewis Research Center.
NTIS Accession Number: N93-32330/1/XAB
Report No.: NAS 1.15:106252; NASA-TM-106252
Jul 93 13p

Photoelectric Detectors

Author (Inventor): APPLEBY D ELLWOOD S H
Point obscuration sensor smoke detector transmits IR radiation from at least two sources along different paths, measuring absorption coefft. to calculate concentration of species and thus detect fire
Patent Assignee: APPLEBY D (ELLW/) ELLWOOD S H
WPI Acc No: 93-388882/49
Patent (basic): GB 2267963 A 931222

Author (Inventor): BEST J A; ELLNER I L; KAPRELIAN E K
Optical smoke detector and alarm - directs light from IR LED into closed smoke chamber towards reflector, and detects scattered radiation to signal alarm condition
Patent Assignee: (CERG) CERBERUS AG
WPI Acc No: 90-123706/16
Patent (basic)
Patent No Kind Date Field of Search
US 4906978 A 900306 (BASIC)

Author (Inventor): BLAIR H V; MCLIN J; HALIK J F; COATES W J
Smoke detector with scattering discrimination - monitors scattered light at two angles and electronically discriminates between scattering to measure amount of smoke
Patent Assignee: (ALLC) ALLIED-SIGNAL INC
WPI Acc No: 92-399026/48
Patent (basic)
Patent No Kind Date Field of Search
WO 9219955 A1 921112 (BASIC)

Fibre-optic smoke sensor.
Brenci, M.; Guzzi, D.; Mencaglia, A.; Mignani, A. G.
CNR, Florence, Italy
Proceedings of Eurosensors V, Rome, Italy, 1991 Sep 30-Oct 2
Sensors and Actuators, B: Chemical v B7 n 1-3 Mar 1992. p 780-783
1992

Cole, M.
Alternative Strategy.
I.E.I. Group, London, England
Journal of Applied Fire Science, Vol. 2, No. 2, 105-117, 1992-1993.
AFPA Seminar. The Future of Halons. May 1991, 1993.

WPI Acc No. 90-126209/17
Light sensing air pollution or smoke detector - adapted to receive and amplify signals received from solid state photocell subjected to flashing light source
Patent Assignee: (COLE) COLE M T
Author (Inventor): COLE M T
Patent (basic)
Patent No Kind Date Field of Search
EP 365047 A 900425 (BASIC)

Author (Inventor): EDWARDS J
Particle detector e.g. for smoke detector - passes air over sensor which detects reflected radiation from walls and particles
Patent Assignee: (FIRE) FIRE FIGHTING ENTR; (FIRE) FIRESTONE TIRE & RUBBER CO
WPI Acc No: 91-022370/03
Patent (basic)
Patent No Kind Date Field of Search
WO 9016053 A 901227 (BASIC)

Egan, M. R.
Diesel-Discriminating Detector Response to Smoldering Fires.
Bureau of Mines, Pittsburgh, PA
IC 9353; 16 p. December 7, 1992.

Reliable fire detection is essential for both safe evacuation and containment or extinguishment. In order to increase reliability by reducing the number of nuisance fire alarms in underground mines that use diesel-powered equipment, the U.S. Bureau of Mines has developed a diesel-discriminating fire detector (DDD). It was designed to discriminate between smoke produced by a fire and the smoke-laden exhaust of a diesel engine. Experiments were conducted by the Bureau ot compare the smoke detection capabilities of the DDD with those of conventional fire detectors in response to smoldering coal and conveyor belting.

Fire Prevention
Detecting Alternatives.
Fire Prevention, No. 238, 26-28, April 1991.

Since their introduction in the late 1950's, ion-chamber smoke detectors have dominated the early warning fire detection market to the extent that today they probably account for over 90 per cent of installed detectors.

Fox, P.
Product Profile: Developments With the VESDA Aspirating Smoke Detectors.
IEI Ltd., UK
Fire Surveyor, Vol. 21, No. 3, 16-18, June 1992.

Author (Inventor): HAWKINSON D
Fast alignment system for projected beam smoke detector has A-D converter output turned to digital valves read by micro-controller to determine how many light emitting diodes to turn on
Patent Assignee: PITTWAY CORP
WPI Acc No: 93-368097/46
Patent (basic): US 5260765 A 931109

Author (Inventor): KAJII S; HONMA H H; NARUMIYA J F
Smoke detector with light emitting and receiving sections - has monitoring terminal to relay signal for set period which is shortened when connected to external meter
Patent Assignee: (HOCH) HOCHIKI CO LTD
WPI Acc No: 85-243606/40
Patent (basic)
Patent No Kind Date Field of Search
DE 3506956 A 850912 (BASIC)

Author (Inventor): KAPRELIAN E K
Combined scatter and light obscuration smoke detector - with output of each receptor subjected to bandpass filter, amplifier and comparator
Patent Assignee: ( ) KAPRELIAN E K; (KAPR) KAPRELIAN E K
WPI Acc No: 89-300521/41
Patent (basic)
Patent No Kind Date Field of Search
US 4857895 A 890815 (BASIC)

Author (Inventor): KAWAI H; SAWA H
Photoelectric e.g. scattered light smoke detector - has light emitter and sensor and smoke detector unit with base plate and peripheral wall passing air but not light and having insect net
Patent Assignee: (HOCH) HOCHIKI CO LTD
WPI Acc No: 88-286899/41
Patent (basic)
Patent No Kind Date Field of Search
DE 3809738 A 881006 (BASIC)

Author (Inventor): (TWKI) KIDDE GRAVINER LTD
High sensitivity smoke detector - has light source directing light beam along input path, and beam confining device preventing light from travelling backwards
Patent Assignee: (TWKI) KIDDE GRAVINER LTD
WPI Acc No: 92-009370/02
Patent (basic)
Patent No Kind Date Field of Search
EP 463795 A 920102 (BASIC)

Author (Inventor): KRAUTWALD H; KELLER W; HEINZEL
Compact optical smoke detector - has socket supporting rotational symmetric integral housing and labyrinth cover with recess in base receiving balancing resistor
Patent Assignee: (SIEI) SIEMENS AG
WPI Acc No: 89-016942/03
Patent (basic)
Patent No Kind Date Field of Search
EP 299410 A 890118 (BASIC)

Author (Inventor): MOCHIZUKI M
Light-scattering type smoke detector - has array of light-shielding columns each having dark light-reflecting surfaces and light-receiving elements

Patent Assignee: (NOHM) NOHMI BOSAI KOGYO CO LTD
WPI Acc No: 87-066544/10
Patent (basic)
Patent No Kind Date Field of Search
EP 213878 A 870311 (BASIC)

Author (Inventor): MOCHIZUKI M; ITO H; KOBAYASHI R
Smoke detector for fire alarm - detects smoke density in smoke chamber in accordance with signal which light receiving element outputs when receiving light emitted by lamp
Patent Assignee: (NOHM) NOHMI BOSAI LTD
WPI Acc No: 94-009353/02
Patent (basic)
Patent No Kind Date Field of Search
EP 577045 A1 940105 (BASIC)

Author (Inventor): MOCHIZUKI M; ITO H; KOBAYASHI R; MORITA T
Smoke detector with lamp and light receiver for fire alarm - calculates smoke density based on calibration values for two reference gases, with light from lamp scattered by smoke in detection chamber
Patent Assignee: (NOHM) NOHMI BOSAI LTD
WPI Acc No: 94-027751/04
Patent (basic)
Patent No Kind Date Field of Search
EP 580110 A1 940126 (BASIC)

Author (Inventor): MUELLER K; RYSER P; WIESER D; KUNZ R E; ROSSI M; GALE M T
Optical smoke detector using light diffraction principle - has planar optical element in light path between light source and cooperating radiation detector.
Patent Assignee: (CERG) CERBERUS AG
WPI Acc No: 94-093873/12
Patent (basic)
Patent No Kind Date Field of Search
EP 588232 A1 940323 (BASIC)

Author (Inventor): NAGAOKA A; SHIMOMURA S; ARAKAWA M; TERASAWA T; KAMI H; OGAWA M
Photoelectric smoke detector - uses light receiving element to detect smoke particles in projected light
Patent Assignee: (MATW) MATSUSHITA ELECTRIC WORKS LTD
WPI Acc No: 91-096394/14
Patent (basic)
Patent No Kind Date Field of Search
GB 2236390 A 910403 (BASIC)

Author (Inventor): NAGASHIMA T
Light scattering type smoke detector forms labyrinth members by taking dispersion of light emitting ranges of light emitting device and range caused by assembly device into consideration
Patent Assignee: HOCHIKI CO LTD
WPI Acc No: 94-050842/07
Patent (basic): GB 2270157 A 940302

Author (Inventor): NAGASHIMA T
Light scattering type smoke detector has number of labyrinth members for facilitating inflow of smoke from outside and cutting off light entering from outside
Patent Assignee: HOCHIKI CORP
WPI Acc No: 94-319021/40
Patent (basic): GB 2277376 A 941026

Author (Inventor): ORIOKA Y; MOCHIZUKI M
Photoelectric smoke detector - includes light emitter arranged so that emitted light is reflected from facing wall at given angle onto other walls
Patent Assignee: (NOHM) NOHMI BOSAI KOGYO CO LTD
WPI Acc No: 86-089021/14
Patent (basic)
Patent No Kind Date Field of Search

EP 175940 A 860402 (BASIC)

Author (Inventor): POORMAN R N
Forward and back scattering loss compensated smoke detector compares transmitted light with scattered light and includes two light photodetectors for detecting directly scattered light and ratiometric value is produced in accordance with transmitted versus scattered light
Patent Assignee: CUMMINS ELECTRONICS CO INC
WPI Acc No: 94-316279/39
Patent (basic): US 5352901 A 941004

Ryser, P.; Pfister, G.
Optical fire and security technology: Sensor principles and detection intelligence.
1991 International Conference on Solid-State Sensors and Actuators, San Francisco, CA, USA, 1991 Jun 24-28
IEEE Electron Devices Soc; Cerebus AG, Switzerland; Endress & Hauser, Germany; Ford Motor Co , USA; General Monitors, USA; et al
Transducers '91 91 Int Conf Solid State Sens Actuators. Publ by IEEE, IEEE Service Center, Piscataway, NJ, USA (IEEE cat n 91CH2817-5). p 579-583
1991

Author (Inventor): RYSER P WERNER J
Optical smoke detector for fire alarm system has 2 sources and 2 detectors connected in optical bridge circuit preceded by electrical time multiplex bridge
Patent Assignee: CERBERUS AG
WPI Acc No: 94-010074/02
Patent (basic): EP 578189 A1 940112

Whitesel, Henry K.; Overby, John K.; Ransford, Michael J.; Tatem, Patricia
Smoke and mirrors: a fiber optic smoke sensor
Naval Surface Warfare Cent., Annapolis, MD, USA
Fiber Optic and Laser Sensors XII, San Diego, CA, USA
SPIE - Int Soc for Opt Engineering, Bellingham, WA USA
Proceedings of SPIE - The International Society for Optical Engineering v 2292 1994. Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, USA. p 123-133
1994

General or Multiple Technologies

Ahola, H.
Performance of Smoke Detectors in Computer Rooms.
VTT-Technical Research Center of Finland, Espoo
VTT Research Reports 681; Project PAL6007; 33 p. May 1990.
Smoke detectors have been compared in an environment similar to a real computer room. Four different test fires were used: smoldering transformer coil, smoldering cable, smoke bomb producing white smoke and flaming polyurethane foam. The test samples included optical and ionization point-type detectors, optical beam detectors, channel detectors and sampling detectors.

Anon
Detecting alternatives.
Fire Prevention n 238 Apr 1991 p 26-28
1991

Budnick, E. K.
In Situ Tests of Smoke Detection Systems for Telecommunications Central Office Facilities.
Hughes Associates, Inc., Columbia, MD
International Symposium on Fire Protection for the Telecommunications Industry. May 14-15, 1992, New Orleans, LA, 1-27 pp, 1992.

Bukowski, R. W.; Jason, N. H.
International Fire Detection Bibliography, 1975-1990.
International Fire Detection Literature Review and Technical Analysis.
National Institute of Standards and Technology, Gaithersburg, MD
NISTIR 4661; 193 p. September 1991.
This bibliography was collected from numerous international sources and represents as complete a compilation of publications from the 15 years covered as could be collected. Nearly 1000 references are included, separated into one of 20 topics such as aerosols and smoke,

industrial occupancies, ships, smart detectors and systems, and system reliability studies. Each such section begins with a brief summary and cites the more important papers within. The bibliography ends with a commentary on what the overall literature shows, what research is needed to achieve more reliable detection system operation and reduced unwanted alarms. An author index and a key work index are provided.

Connolly, G. F., Jr.
Automatic Fire Detectors: A Specification Primer.
Factory Mutual Research Corp., Norwood, MA
Consulting-Specifying Engineer, Vol. 11, No. 5, 44-46, April 1992.

Conti, R. S.; Litton, C. D.
Response of Underground Fire Sensors: An Evaluation.
Bureau of Mines, Pittsburgh, PA
RI 9412; 17 p. 1992.

This U. S. Bureau of Mines report discusses the results of research conducted in the Bureau's experimental mine at Lake Lynn Laboratory on the response of fire sensors to simulated mine fires, which included (1) a slowly developing coal-conveyor belt fire, (2) a rapidly burning liquid fuel-belt fire, and (3) a liquid fuel-belt fire in the presence of diesel exhaust. During these tests, several mine fire sensors were evaluated with respoect to sensor placement, spacing, and type. The data indicate that smoke sensors alarm several minutes before CO sensors do; and that, in the prese3nce of diesel exhaust, a prototype diesel-discriminating smoke sensor can successfully function without being sensitive to the diesel contaminants. The vertical placement of sensors in the entry near the fire was also shown to be critical in terms of alarm times. Additional data showed that variations exist in response time and level of response for two brands of electrochemical CO sensor. Results also indicate that early detection of fires will improve the probability of miners' escape, because of reduced smoke concentrations during the incipient stages of the fire.

Author (Inventor): (FUIT) FUJITSU LTD
Firing smoke monitor system using detection, comparison and discrimination - has automatic alarming based on early smoke finding by smoke detector under any circumstances using two different monitors
Patent Assignee: (FUIT) FUJITSU LTD
WPI Acc No: 92-361600/44
Patent (basic)
Patent No Kind Date Field of Search
JP 4263394 A 920918 (BASIC)

Grosshandler, W. L.
Assessment of Technologies for Advanced Fire Detection.
National Institute of Standards and Technology, Gaithersburg, MD
American Society of Mechanical Engineers (ASME). Heat and Mass Transfer in Fire and Combustion Systems. HTD-Vol. 223. Winter Annual Meeting. November 8-13, 1992, Anaheim, CA, Am. Soc. of Mechanical Engineers, New York, NY, Cho, P.; Quintiere, J., Editors, 1-10 pp, 1992.

The majority of fires are sensed either by the heat or the smoke they produce at a set location in space, with an alarm signal being issued when a threshold temperature or particulate level is exceeded. Many of these sensors are inexpensive and perfectly suitable for certain applications, but issues such as false alarms and increased performance can necessitate alternative sensing techniques. Advances in sensor technology, in microelectronics, and in our understanding of ignition and flame spread provide an opportunity to greatly enhance the performance of fire detection systems in traditional applications. Technological advances have also led to new situations with unique protection requirements at a time when environmental considerations have eliminated our most effective suppressants (halons), making the early detection of a fire even more critical. This article describes some of these developments, suggests possible applications, and indicates limitations to the technologies which need to be overcome before exploitation is feasible.

Grosshandler, W.
Assessment of Technologies for Advanced Fire Detection (Final rept)
National Inst. of Standards and Technology (BFRL), Gaithersburg, MD. Fire Science Div.
1992 10p
NTIS Accession Number: PB95-126330
Pub. in Proceedings of a Conference on Heat and Mass Transfer in Fire and Combustion Systems, Anaheim, CA., November 8-13, 1992, p1-10.

Grosshandler, W. L.
Review of Measurements and Candidate Signatures for Early Fire Detection. [ABSTRACT ONLY]
National Institute of Standards and Technology, Gaithersburg, MD
NISTIR 5499; September 1994.
National Institute of Standards and Technology. Annual Conference on Fire Research: Book of Abstracts. October 17-20, 1994, Gaithersburg, MD, 137-138 pp, 1994.

The current generation of fire detection systems is designed to respond to the smoke, heat, or the elastromagnetic radiation generated during smoldering and flaming combustion. Smoke is sensed either by measuring, with a photodector, the light shich is scattered from a controlled light source, or by the change in current created by charged particles passing through an ionizing radiaiton 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.

Luck, H (Ed.)
9th International Conference on Automatic Fire Detection - AUBE '89.
Univ Duisburg, Dep of Communications, Electrical & Electronic Engineering, Duisburg, Ger Conference Title: 9th International Conference on Automatic Fire Detection - AUBE '89, Duisburg, Ger, 1989 Sep
Fire Safety Journal v 17 n 6 1991. Publ by Elsevier Science Publ Ltd, Barking, Engl. p 421-553
1991

Meacham, B. J.
Intremational Developments in Fire Sensor Technology.
FireTech, Meilen, Switzerland
Journal of Fire Protection Engineering, Vol. 6, No. 2, 89-98, 1994.

Morrow, G. S.; Litton, C. D.
In-Mine Evaluation of Smoke Detectors.
Bureau of Mines, Pittsburgh, PA
IC 9311; 17 p. 1992.

This report presents the results of a U. S. Bureau of Mines evaluation of smoke detectors placed in conveyor belt entries of underground coal mines. The selected mines are located in six different Mine Safety and Health Administration (MSHA) districts, are operated by seven different companies, and use atmospheric monitoring systems from seven different manufacturers. Principal concerns are early detection and warning of fires, reliability of operation, frequency of maintenance, and adaptability of detectors to monitoring systems and the mining environment. The data contained in this report provide for some comparisons between smoke detectors and CO sensors, specifically in the areas of early detection of fires and susceptibility to nuisance alarms due to diesel exhaust contaminants. Finally, recommendations for performance standards, sensitivity tests, detector classification, and maintenance are presented.

NERAC, Inc., Tolland, CT.
Fire Alarms and Fire Detectors. (Latest citations from the Ei Compendex*Plus database) (Published Search)
National Technical Information Service, Springfield, VA.
Jan 95 250 citations
NTIS Accession Number: PB95-868337/XAB
Supersedes PB94-879749

NERAC, Inc., Tolland, CT.
Smoke Detectors. (Latest citations from the U.S. Patent Database) (Published Search)
National Technical Information Service, Springfield, VA.
May 93 161 citations minimum
Accession Number: PB93-867844/XAB
Supersedes PB90-862756

Serio, M. A.; Bonanno, A. S.; Knight, K. S.; Newman, J. S.
FT-IR Based System for Fire Detection.
Advanced Fuel Research Inc., East Hartford, CT
Factory Mutual Research Corp., Norwood, MA
NISTIR 5499; September 1994.
National Institute of Standards and Technology. Annual Conference on Fire Research: Book of Abstracts. October 17-20, 1994, Gaithersburg, MD, 139-140 pp, 1994.

A major advance in fire safety technology during the past two decades is the availability of low cost smoke detectors based on either ionization or photoelectric detectors. However, these detectors have some drawbacks because of the high frequency of false alarms and maintenance problems. Other types of detector technologies have been developed for specific gases, such as CO2, CO, or O2, based on metal oxide semiconductors, electrochemical sensors, or optical sensors.

Author (Inventor): STETTER J R; PAN L
Modular component for a residential smoke detector alarm - comprises an amperometric sensor having a sensor electrode for CO and a counter-electrode, and a current-to-voltage converter circuit
Patent Assignee: (TRAN-) TRANSDUCER RES INC
WPI Acc No: 94-234032/28
Patent (basic)

Patent No Kind Date Field of Search
US 5331310 A 940719 (BASIC)

Stinshoff, D.
From 'Shouting' to 'Thinking': The History of Fire Detectors.
Fire International, Vol. 136, 24,26, August/September 1992.

Yea, Byeongdeok; Konishi, Ryosuke; Osaki, Tomoyuki; Sugahara, Kazunori
Discrimination of many kinds of odor species using fuzzy reasoning and neural networks
Tottori Univ, Tottori, Jpn
Sensors and Actuators, A: Physical v 45 n 2 Nov 1994. p 159-165
1994

Youngblood, W. W.
Increased Fire and Toxic Contaminant Detection Responsibility by Use of Distributed, Aspirating Sensors
Wyle Labs., Inc., Huntsville, AL.
National Aeronautics and Space Administration, Washington, DC.
1990 25p
NTIS Accession Number: N93-27722/6/XAB
In NASA, Washington, Technology for Space Station Evolution. Volume 2: Data Management System/Environmental Control and Life Support Systems p 517-541.

Control Technology

Author (Inventor): BADIN A N LOGUTOV V Y A
Thermal circuit breaker for low power appliances has stopper set in housing and larger bimetallic plate set on heat store
Patent Assignee: BADIN A N
WPI Acc No: 90-097407/13
<XRPX> N90-075214
Patent (Basic): SU 1485322 A 890607 9013
The circuit breaker comprises the housing (1) contg. two interacting contact bimetallic plates (2,3) with arms of different lengths. The larger bimetallic plate (3) has a heat storage cell (4), and is fixed in housing having freedom of its angular rotation in a bending plane. The housing (1) has a stopper (14) for its free end, and a switch containing lever hinged in the housing, bimetallic plate clamp with regulation screw contact spring and a contact. The bimetallic plate (3) has a reset spring (5) with regulation screw (6) for a fast resetting. USE - In thermal circuit breakers for electrical heaters. Service is extended and reliability is improved.

Bellinger, T. F.
RUNNING OVERLOAD PROTECTION FOR MOTORS -- 2.
Allis-Chalmers Engineering Review v 40 n 1 1975 p 28-31
1975

Benouar, M.
PYROTECHNIQUE CIRCUIT INTERRUPTER FOR THE PROTECTION OF ELECTRICAL SYSTEMS.
Carbone-Ferraz Inc, Parsippany, NJ, USA
IEEE Transactions on Power Apparatus and Systems v PAS-103 n 8 Aug 1984 p 2006-2010
1984

Benouar, M'Hamed
PYROTECHNIQUE CIRCUIT INTERRUPTER FOR THE PROTECTION OF ELECTRICAL SYSTEMS.
Carbone-Ferraz Inc, Parsippany, NJ, USA
CECON '83 Record, Cleveland Electrical/Electronics Conference and Exposition 1983.
Cleveland, Ohio, USA
1983 Oct 4-5
IEEE Cleveland Section, Cleveland, Ohio, USA Joint Chapter on Electronics & Measurements
Cleveland Electrical/Electronics Conference and Exposition 1983. Publ by IEEE, New York, NY, USA. p 36-39
1983

Benouar, M.
PROTECTING POWER SEMI-CONDUCTORS USING FAST ACTING AND CURRENT LIMITING INTERRUPTING DEVICES.
Carbone-Ferraz Inc, Parsippany, NJ, USA

Industrial & Commercial Power System Technical Conference 1984.
Papers presented at the 1984 Annual Meeting - IEEE Industry Applications Society.
Atlanta, GA, USA
1984 May 7-10
IEEE Industry Applications Soc, Static Power Converter Committee, New York, NY, USA IEEE, Atlanta Section, Atlanta, GA, USA
IEEE Conference Record of Industrial and Commercial Power Systems Technical Conference 1984. Publ by IEEE, New York, NY, USA. p 86-96
1984

Benouar, M.
PYROTECHNIQUE CIRCUIT INTERRUPTER FOR THE PROTECTION OF ELECTRICAL SYSTEMS.
Carbone-Ferraz Inc, Parsippany, NJ, USA
Technical Papers - IEEE Power Engineering Society 1984 Winter Meeting.
Dallas, TX, USA
1984 Jan 29-Feb 3
IEEE Power Engineering Soc, New York, NY, USA, 5 p.
Publ by IEEE, New York, NY, USA.
1984

Author (Inventor): BORELLI L FERRARI A TAGLIAFERRO B
Control and monitoring appts. for gas burners uses controller monitoring physical values, flame detection, gas safety solenoid valve, electric fan motor and relays with monitor logic
Patent Assignee: RBL RIELLO BRUCIATORI LEGNAGO SPA
WPI Acc No: 94-120073/15
<XRPX> N94-094049
<BASIC> EP 591910 A1 940413 9415

When the value of sensed characteristics exceeds predetermined limits, the feed to the motor (M) supplying air continues via contacts (B1,B2) if the flame continues to burn after the safety gas solenoid valve has been de-energised. A relay (B) is excited via the normally closed contact (1E) of a second relay (E) in the equipment logic. The second relay (E) is in series with a resistance (BLG) wound round a bi-metallic strip and in parallel with a closed contact (2RF) in the flame monitoring logic circuit (A.RF) interrupting feed to the motor. ADVANTAGE Has backup safety and operates in the transient period between end of pre-ventilation and flame ignition.

Borodenko, V. A.
MAGNETICALLY CONTROLLED CONTACT-VIBRATORS IN INSTALLATIONS FOR RELAY PROTECTION AND ANTIFAILURE AUTOMATION.
Soviet Power Engineering (English translation of Elektricheskie Stantsii) v 11 n 1 Jan 1982 p 78-84
1982

Author (Inventor): BOSQUI P Y PILLARD J C
Flame monitor for burner with reversibly movable screen closes safety valve when UV radiation ceases to excite photocell during variable periods of window opening
Patent Assignee: ENTR GEN CHAUFFAGE (GECH) ENTREPRISE GEN CHAUFFAGE IND PILLARD (GECH) ENTR GEN CHAUF IND
WPI Acc No: 92-073323/10
<XRPX> N92-055132
Patent (Basic): DE 4127425 A 920227 9210

Ultraviolet radiation from the flame is monitored by a photocell (3) on to whose cathode (3a) the radiation is conc. by a lens (5) through an axial bore (4) and window (8a). The opaque screen (18) interposed between the window (8a) and the photocell (4) is moved into and out of the optical path at intervals of about 1 second by a reversible stepping motor (16). The periodicity can be varied to suit the qualities of flame in various burners. USE/ADVANTAGE Esp. on gas-fired boilers. Failures arising from weakening of restoring spring conventionally fitted to sliding screen are avoided.

Buckland, I.G.
Use of fire and gas detection systems as part of the safety control package
Health and Safety Executive, Engl
Symposium on Major Hazards Onshore and Offshore
Manchester, Engl
Institution of Chemical Engineers Symposium Series n 130 1992. Publ by Inst of Chemical Engineers, Davis Building, Rugby, Engl. p 283-292
1992

Author (Inventor): / BURKHARDT R CESCHIA M PODBIELSKI M
Dynamic response monitoring circuit for burner flame monitor has flame relays controlled by respective frame sensor evaluation stages coupled to common output

Patent Assignee: (HBRA) HARTMANN & BRAUN LEIPZIG GMBH (GERT) VEB GERAETE & REGLERWERK TEL (GERT) GERAETE & REGLER WERK LEIPZIG
WPI Acc No: 89-279450/39
<XRPX> N89-213500
Patent No. (Basic): EP 334027 A 890927 8939
German

The dynamic response monitoring circuit has an evaluation stage (10,20) coupled to each flame sensor (41,42) controlling a flame relay (11,21) associated wtih a common output (A). A switch (13,23) connected in series with each flame relay (11,21) is connected to the respective evaluation stage (10,20) via a diode (17,27). Pref. each flame sensor (41,42) receives the emitted flame radiation via a clocked liquid crystal cell (31,32) switched between the opaque and transparent states in exact phase opposition. The flame signals provided by the evaluation stages (10,20) control an operating circuit (4). ADVANTAGE Provides back-up flame monitoring facility.

A dynamic self-monitoring circuit for automatic flame guards, comprising one or two frame monitoring in multi-burner plants, two transmission channels (2, 3) being provided and linked by an AND-circuit at an output (A) and alternately supplied via a clock-controlled device (7, 31, 32) with the flame signal delivered by the flame sensor (6, 41, 42) and each comprising a flame relay (11, 21) and a circuit (10, 20) for evaluating the flame signal, and switches (13, 23) are disposed in series with the flame relays (11, 21) and are actuated by actuating circuits (110, 210) connected respectively via diodes (17, 27) to the outputs of the two evaluating circuits (10, 20) and evaluating their switching state, and a starting circuit (4) is provided.

Author (Inventor): CHANG S
Cooking stove burner gas valve automatic controller has relay activating motor and closing valve when circuit is in conductive state
Patent Assignee: (CHAN/) CHANG S
WPI Acc No: 88-142230/21
<XRPX> N88-108635
Patent No. (Basic): GB 2197738 A 880525 8821

A rotatable shaft connected to the open valve is in one angular orientation and the sensor detects the presence of a gas flame at the burner. The switch is in its corresp. angular orientation maintaining its on position and a control circuit in its non-conductive state. When the sensor detects the absence of a flame at the burner with the gas valve open, the control circuit is changed to its conductive state to activate the motor. The shaft and switch are rotated to a second angular orientation, so that the switch is placed in its off position, thus deactivating the motor, with the valve closed. The circuit includes a relay activating the motor and closing the valve when the circuit is in its conductive state. Pref. the switch is a notched wheel, which when in the second angular orientation, receives a contact element of the switch. ADVANTAGE Burning period is set in advance, automatically switching gas supply off at predetermined time and if burning gas it extinguished i.e. blown out, gas supply is automatically and immediately turned off.

Author (Inventor): CHANG S
Automatic controller of master gas switch e.g. on cooker has flame induction rod monitoring gas burner flame and closing relay when flame stops
Patent Assignee: (CHAN/) CHANG S
WPI Acc No: 88-337942 47
<XRPX> N88-256129
Patent No. (Basic): US 4783600 A 881108 8847

The automatic controller comprises a valve controllinq the level of gas flow from a gas source to a gas burner. An electrical rotary motor is coupled to the valve for rapidly closing the valve. Electrical power is supplied to energise the motor. A flame-responsive circuit connects the motor to the power supply when a flame of the gas burner stops. A time-responsive circuit connects the motor to the power supply at the end of a user-selectable burner-on cycle. A motor stop means inactivates the power supply after the motor closes the valve to stop the motor. The stopper includes a drive shaft coupling the motor and the valve and a compressive wheel affixed to the drive shaft and havinq a notch on its circumference. A touch switch cooperates with the compressive wheel and has a release button arranged to move into the notch when the motor has rotated the drive shaft to close the valve.

Author (Inventor): DANJOU F BOIRON G
Safety device monitoring gas burner operation uses timed relay circuit to selectively switch thermocouple in and out of circuit to enable and disable its operation
Patent Assignee: (CSEL-) CONS ELEC R V SA (CSEL-) CONSTR ELECTRIQUES RV SA
WPI Acc No: 91-224816 31
<XRPX> N91-171620
Patent No. (Basic): EP 439417 A 910731 9131
French

The safety device has two relays. The first (41) has its coil connected in series with a capacitor (25) by a diode (42) to prevent relay excitation during capacitor charging and permit relay excitation during capacitor discharge. A second relay (48) supplied by this circuit has contacts (48a,48b) at the terminals of a thermocouple (11) to enable thermocouple operation when ignition is required and inhibit it when extinction is required. ADVANTAGE Prevents thermocouple holding supply valve open during hot starting and stopping of gas burner.

Safety device for the operation of a gas fuel burner (2), including a delayed control system (1b) comprising: a circuit (14) for producing a low-voltage d.c. supply, a capacitor (25) intended to be supplied by the circuit (14) on appearance of a control command, and a circuit (27) for discharging the capacitor (25) when the charging voltage of the capacitor (25) reaches a threshold voltage (Va) which is fixed by a means (29), such that the discharge time corresponds to at least the ignition duration (Ta) of the burner, the discharge of the capacitor making it possible to drive switching means (41,41a) which open a solenoid valve (4) allowing fuel to be fed to the burner, characterised in that the switching means include a first relay (41) mounted in series with the capacitor (25), via a diode (42) mounted to prevent energising of the relay during the charging of the capacitor and to allow energising of the relay during the discharge of the capacitor, and in that it comprises a second relay (48) supplied by the circuit (14) for producing a low-voltage d.c. supply, the two contacts (48a,48b) of which are mounted at the terminals of a thermocouple (11), so as to close the thermocouple circuit as soon as an ignition command intervenes and to disable operation of the thermocouple as soon as a command for extinguishing the burner intervenes.

Author (Inventor): ENTO K
Combustion controller comprises flame detection circuit, thermostat connected with electronic safety valve coil and generating electromotive force according to flame temp. of burner NoAbstract
Patent Assignee: (RINN) RINNAI CO (RINN) RINNAI KOREA CO (RINN) RINNAI CORP (RINN) RINNAI KOREA CO LTD
WPI Acc No: 93-402071/50
Patent No. (Basic): KR 9303902 B 930515 9350

Author (Inventor): ERDMAN J L
Digital controller component failure detection for gas appliance controlling operation of combustion air blower and gas valve as function of essentially square wave input signals from thermostat
Patent Assignee: (HONE) HONEYWELL INC
WPI Acc No: 92-032521/04
<XRPX> N92-024770
Patent No. (Basic): US 5076780 A 911231 9204

The control system for a gas-fired heating appliance comprises a number of sensors, including a combustion air pressure switch, in a serial energisation path for providing sinusoidal alternating current sensor signals indicative of conditions related to an ignition sequence of the appliance. A signal conditioner is connected to the number of sensors for converting the sensor signals to a set of periodically alternating input signals. A controller controls the appliance to initiate the ignition sequence as a function of the presence or absence of the periodically alternating input signals. A gas valve is connected in the serial energisation path; and a gas valve relay having a gas valve relay coil is connected between the serial energisation path and the controller. Gas valve relay contacts are connected in the serial energisation path between the gas valve relay coil and the gas valve. ADVANTAGE Safe operation and/or shutdown in event of failure.

Fallen, Manfred
Untersuchung von Stoerungen in Gasbrenneranlagen Beruecksichtigung des Schliessverhaltens von Magnetvengtilen.
Study of disturbances in gas-burner equipment . Taking into account the closure behavior of magnetic valves..
Univ Kaiserslautern, Kaiserslautern, West Ger
GWF, das Gas- und Wasserfach: Gas/Erdgas v 129 n 9 Sep 1988 p 432-443
1988
German

Author (Inventor): FROHLICH H KEMPA P ROLOFF H J
Protective device for light monitoring sensor in burner control unit comprises movable wall with slit to trap particles released from the light source being monitored
Patent Assignee: (ZIST) ZENT INST SCHWEISSTECHNI
WPI Acc No: 89-086324/12
<XRAM> C89-038271
<XRPX> N89-065774
Patent No. (Basic): DD 261318 A 881026 8912

Light sensitive element measuring the magnitude of an electromagnetic beam is protected from sparks, slag spray or dust emanating from the source by a movable wall having at least one slit in which the wall speed is given by a min. value of b/d x C where b is the length of the slit, d is the depth of the slit and C the max. speed of a spark or slag spray. USE/ADVANTAGE During welding or cutting esp. with burners. Prevents the measuring element giving false readings due to the sparks, slag spray or dust hitting the sensitive part of the element.

Author (Inventor): FROHLICH H KEMPA P ROLOFF H J
Protection device for light monitoring sensor in a burner control unit made of rotatable light permeable tubular cover to prevent sparks, dust etc. reaching sensor element
Patent Assignee: (ZIST) ZENT INST SCHWEISSTECHNI
WPI Acc No: 89-086325/12
<XRAM> C89-038272
<XRPX> N89-065775
Patent No. (Basic): DD 261319 A 881026 8912

Light sensitive element (1) measuring an electromagnetic beam is protected from sparks, spray etc. emanating from the source by a rotation body (5) made of light permeable material which is fitted into a housing (3). The body (5) rotates around the element (1) fixed into the housing by means of a gas stream (8) hitting conductor plates (10). USE/ADVANTAGE In welding and cutting esp. with burners. The permeable rotation body prevents sparks and dust etc. from hitting the element (1) and causing false readings of the light source

Glenn, D. J. Cook, C. J.
NEW FAULT-INTERRUPTING DEVICE FOR IMPROVED MEDIUM-VOLTAGE SYSTEM AND EQUIPMENT PROTECTION.
S&C Electric Canada Ltd, Rexdale, Ont, Can
Conference Record Industry Applications Society, IEEE-IAS-1984 Annual Meeting
Chicago, IL, USA
1984 Sep 30-Oct 4
IEEE Industry Applications Soc, New York, NY, USA
Conference Record IAS Annual Meeting (IEEE Industry Applications Society) 1984. Publ by IEEE, New York, NY, USA. p 335-342

Glenn, Douglas J. Cook, Carey J.
NEW FAULT-INTERRUPTING DEVICE FOR IMPROVED MEDIUM-VOLTAGE SYSTEM AND EQUIPMENT PROTECTION.
S&C Electric Canada Ltd, Rexdale, Ont, Can
IEEE Transactions on Industry Applications v IA-21 n 5 1985 p 1324-1332
1985

Glenn, D. J.
NEW FAULT-INTERRUPTING DEVICE FOR IMPROVED MEDIUM-VOLTAGE SYSTEM AND EQUIPMENT PROTECTION.
S&C Electric Canada Ltd, Rexdale, Ont, Can
IEEE Conference Record of 1984 Annual Pulp and Paper Industry Technical Conference.
Toronto, Ont, Can
1984 Jun 19-22
IEEE Industry Applications Soc, Technical Operations Committee Pulp & Paper Industry, New York, NY, USA
IEEE Conference Record of Annual Pulp and Paper Industry Technical Conference 1984. Publ by IEEE, New York, NY, USA. p 70-77
1984

Goldstein, M. Anderson, T.
Chemical CO Detector for an Automatic Gas Safety Shutoff Valve. Final Report, June 1984-September 1988
Quantum Group, Inc., San Diego, CA.
Gas Research Inst., Chicago, IL.
Report No: GRI-89/0033
NTIS Accession Number: PB91-243063/XAB
Jul 91
67p

Gubina, F. Orgorelec, A. Plaper, M. Hrovatin, J.
CONCEPT OF ELECTRIC POWER SYSTEM EMERGENCY CONTROL BY MEANS OF MULTIPURPOSE AUTOMATA.
Elektroinst Milan Vidmar, Yosl
International Conference on Large High Voltage Electric Systems (CIGRE), Proceedings of the 28th Session.
Paris, Fr
1980 Aug 27-Sep 4
CIGRE, Paris, Fr
International Conference on Large High Voltage Electric Systems v 2. Publ by CIGRE, Paris, Fr p 32. 08. 1-32. 08. 8
1980

Author (Inventor): HALL P J
Gas-filled heating unit has valved burner and ignition assembly removably mounted with thermostat and electronic automated control
Patent Assignee: (CARV-) CARVER & CO ENGIN
WPI Acc No: 87-137330/20
<XRPX> N87-102922
Patent No. (Basic): EP 222221 A 870520 8720

A burner, valve assembly, ignition electrode, flame sensor electrode, thermostat and electronic automatic control member are assembled together as a single replaceable unit. The unit is removably installed in a heater. The unit has separable electrical connectors for releasable securement to manual actuators. The unit is releasably connected to a fuel supply duct. The valve assembly controls a supply of combustible fuel to the burner. USE Esp. for caravan.

A heater unit comprising a thermally conductive main body (14), a burner (80), for burnign fuel in a combustion chamber (41, 42) for heating said body, a valve assembly (71) which is associated with control means to control a supply of combustible fuel to teh further and to operate ignition means (73) for initiating combustion in response to manually actuable electrical switch means connectable to the control means, to sensor means comprising a flame sensor (74), for sensing the presence of combustion, and to a thermostat (75); and characterised in that: (a) the body has an upstanding heat transfer main wall (34) which has a combustion chamber side exposed to heat in the combustion chamer, and has provided therein a fuel connector duct (53) to receive fuel from a supply pipe (115) connectable to the body (14); (b) the heater unit comprises an integrally replaceable unit (15) which incorporates the flame sensor (74), the thermostat (75), the burner ignition means (73), the valve assembly (71), the burner (80) and an electronic automatic control unit (72) of the control means fastened together to form the integrally replaceable unit (15); (c) the replaceable unit (15) is secured releasably by fastens (79) to the main wall (34) of the body (14) so that: (i) the burner and the valve assembly (71) are located on the combustion chamber side of the main wall (34); (ii) the valve assembly is releasably clamped to the body (14) to sealingly engage the body around the fuel connector duct (5), to receive fuel therefrom; (iii) the thermostat (75) is held in thermal contact with the main wall (34); and (iv) the electronic automatic control unit (72) is located in a space separated from the heated space in which the burner is disposed so that the electronic automatic control unit (72) is shielded from burner heat; (d) the flame sensor, ignition means, valve assembly and thermostat are electrically connected in the replaceable unit (15) to the electronic automatic control un

Heising, C. R. Patterson, R. C.
Reliability expectations for protective relays.
Associated Power Analysts Inc, USA
Fourth International Conference on Developments in Power System Protection
Edinburgh, Engl
1989 Apr 11-13
IEE Conference Publication n 302. Publ by IEE, London, Engl. p 23-26
1989

Hitchen, I. R.
PROCESS SAFETY BASED ON INSTRUMENT SUPERVISORY & SAFEGUARDING SYSTEMS: DESIGN & TESTING PHILOSOPHIES.
UKF Fertilizers Ltd, Chester, Engl
Process Measurement, Control and Applications.
Part of PROMECON Control & Instrumentation Exhibition and Conference. Part of PROMECON Control & Instrumentation Exhibition and Conference.
London, Engl
1984 Jun 19-22
Inst of Measurement & Control, London, Engl
Publ by Inst of Measurement & Control, London, Engl p 269-274
1984

HUBER, E. J.
Safety considerations in the selections of switches and relays.
Underwriters' Lab Inc, Melville, NY
ASME Pap 71-DE-33 for meeting Apr 19-22 1971, 5 p
1971

Author (Inventor): JENSEN G E
Temp. alarm partic. for kitchen use comprises small and easily handleable unit for direct application on cooking unit and incorporating inbuilt thermostatic contact NoAbstract
Patent Assignee: (JENS/) JENSEN G E
WPI Acc No: 93-259881/33
Patent No. (Basic): DK 9101844 A 930512 9333

Author (Inventor): JONES G E PRICE B L
Relay operation checking circuit for e.g. burner control has load and lockout relays to power and deactivate device respectively and generator for supplying short duration signals
Patent Assignee: (GASC) BRITISH GAS PLC
WPI Acc No: 89-124557/17
<XRPX> N89-094967
Patent No. (Basic): GB 2209076 A 890426 8917

The relay operation system includes a load relay RL2 for powering a device, a lockout relay RL16 for deactivating the device, a detector circuit Q1, R37, C17, D9 for sensing short duration signals, and generator R30, C16 for providing a succession of short duration signals for input to the detector circuit via the coil of the lockout relay. The system further comprises a supply for powering the load relay in response to the detected signal succession whereby a check on the continuity of the lockout relay coil and the powering of the output relay is effected by the same signal. The signals are normally insufficient to actuate the lockout relay. If the lockout relay fails to operate, the resistor R37 will eventually fail to disable the load relay. If the lockout relay becomes open circuit the load relay is de-energised.

Author (Inventor): KNUTSON A E

Electric kitchen stove safety shut-off uses smoke detector to actuate relay to interrupt supply of power to stove
Patent Assignee: (KNUT/) KNUTSON A E
WPI Acc No: 87-129221/18
<XRPX> N87-096575
Patent No. (Basic): US 4659909 A 870421 8718

The detector is mounted externally of the stove and supplies an electrical signal when smoke is detected. A power cutoff device is connected to and actuated by the signal-supply for automatically interrupting the supply of power through a power-conveyor to the stove when smoke is detected. The relay is interposed between the stove plug and its wall receptacle. The power cutoff device automatically grounds the power-conveyor upon receipt of the signal so as to actuate a circuit breaker and require manual resetting of the latter before the supply of power to the stove can be resumed. ADVANTAGE Lessens resulting damage should fire occur. No modification to internal stove circuitry required.

Laabs, John
TWO-CHIP THERMAL SENSOR/SWITCH PROVIDES CONTROL, WARNING, AND SHUTDOWN.
Haley Eng Syst, Pawcatuck, Conn
Electronic Design v 28 n 20 Sep 27 1980 p 150, 152
1980

Lakes, Larry S.
CIRCUIT PROTECTION IN AUTOMATIC TRANSFER SWITCH APPLICATIONS.
Diesel Progress North American v 51 n 2 Feb 1985 p 58-60
1985

Lauffer, Dietrich
Use of Electrically Ignited and Monitored Natural Gas Burners.
EINSATZ VON ERDGASZUENDBRENNERN MIT ELEKTRISCHER ZUENDUNG UND UEBERWACHUNG.
Hegwein GmbH, Stuttgart, West Ger
Gas Waerme International v 33 n 2-3 Feb-Mar 1984 p 63-66
1984
GERMAN

Lesin, N. M. Savin, S. N.
Estimation of the noise immunity of digital relay protection devices and automatic machines based on a microcomputer.
Electric Technology U.S.S.R. (English Translation of Elektrichestvo) n 2 1989 p 61-67
1989

Author (Inventor): MALIK S
Fire alarm system for domestic appliance comprises dedicated smoke sensor to supply signals to isolating relay for disconnecting power supply
Patent Assignee: (MALI/) MALIK S
WPI Acc No: 94-257294/32
<XRPX> N94-202751
Patent No. (Basic): GB 2275556 A 940831 9432

A dedicated smoke sensor unit (10, 15) is installed proximate the appliance and wired to a isolating relay unit (23) housed in a module that plugs into the mains socket (13). The appliance power lead in turn be connected into the mains circuit via the module. A remote alarm unit is connected through the mains wiring and the system draw power from the mains supply to drive each unit. Alternatively, the system can be battery powered and use radio frequency technology. When smoke is detected in the body of the appliance the remote alarm unit, battery or mains powered, is activated by coded signals and the circuit simultaneously isolates the mains power to the appliance whilst activating fire extinguishers (24) when fitted. USE/ADVANTAGE Appliance such as washer-driers and tumble driers which use heating elements and are prone to catching fire. Invariably, such appliances are installed in or close to kitchens where smoke detectors are impractical due to cooking fumes.

Author (Inventor): MATSUSHITA DENKI SANGYO KK
Cooking timer for domestic toasting appliance uses microcomputer controlled relay and has sensor to terminate operation if high temp. is detected
NoAbstract
Patent Assignee: (MATU) MATSUSHITA DENKI SANGYO KK
WPI Acc No: 94-291477/36
<XRPX> N94-229455
Patent No. (Basic): JP 6221577 A 940809 9436

Author (Inventor): MCGRATH P J
Flame detection circuit for electronically controlled gas-fired appliance applies alternating voltage across flame probe and indicates flame presence according to flame induced DC component
Patent Assignee: (BLAC-) BLACK TOMATIC CONTROLS LTD

WPI Acc No: 92-261455/32
<XRPX> N92-199954
Patent No. (Basic): GB 2252436 A 920805 9232

The flame detection circuit comprises the flame probe, a device for applying an alternating voltage across the flame probe, and a device responsive to the DC component induced by the flame probe in the presence of a flame to provide an indication of whether a flame is present in the vicinity of the flame probe. The device for applying the alternating voltage comprises a pair of terminals for connection to the two supply rails of an A.C. supply, an impedance device connected across the terminals, and an A.C. current path between a node in the impedance device and the flame probe such that the impedances between the node and each terminal are equal. USE/ADVANTAGE For monitoring flame presence to ensure safe operation of gas-fired appliance. Polarity of AC supply may be reversed and neutral pole not tied closely to local earth while need for isolating transformer is eliminated. Uses cheap compact components.

Author (Inventor): MIKHALKEVICH E P
Circuit breaker for domestic appliances has screw thread at one end of body and fixed contact interacting with body stop.
Patent Assignee: (MIKH/) MIKHALKEVICH E P
WPI Acc No: 93-349103/44
<XRPX> N93-269215
Patent No. (Basic): SU 1758692 A1 920830 9344

When the insulated insert (3), sitting on the screw thread (11) of one current conducting ring (5), is turned, the insert (4) engages with the screw thread (10). Ring is connected to one of the terminals (7) and the other ring to another terminal (7). The electric circuit is then completed. The speed of connection of the circuit breaker depends on the gap (a). Further movement of insert (3) of already closed circuit breaker takes place until the stop at the lid (2). USE/ADVANTAGE As circuit breaker suitable for building, e.g. switching on and off domestic appliances Reliability and noiseless operation

Author (Inventor): MITSUBISHI DENKI KK
Internal power supply circuit for electronic equipment has fault detection relay switch whose AND circuit contacts are short-circuited with power on
Patent Assignee: (MITQ) MITSUBISHI DENKI KK
WPI Acc No: 90-110959/15
<XRPX> N90-085821
Patent No. (Basic): JP 2060421 A 900228 9015

Morris, George V.
Safety Control for Electronic Circuits, Patent
Department of the Army, Washington, DC.
Report No: PAT-APPL-206 756 PATENT-4 201 136
NTIS Accession Number: AD-D007 884/0
Filed 19 Jan 51 patented 6 May 80
4p
Supersedes PAT-APPL-206 756-51.

Muller, R. S.
Solid-State Sensor and Actuator Workshop Held in Hilton Head Island, South Carolina on 4-7 June 1990, Final rept
California Univ., Berkeley.
Army Research Office, Research Triangle Park, NC.
NTIS Accession Number: AD-A224 850/8
Report No: ARO-27885.1-EL-CF
1990
196p

Ohtsu, Toshihide
MERCURY CONTACT RELAYS OVERCOME OPERATING PROBLEMS IN SWITCHING.
NEC, Jpn
JEE, Journal of Electronic Engineering v 20 n 199 Jul 1983 p 38-39
1983

Author (Inventor): RICHARDS D A
Electrical appliance esp. toaster having safety switching arrangement has relay and latch de-energised if fault detection is input from residual core balance, so that heating elements are turned off and bread carriage is returned to upper position
Patent Assignee: (PNEA-) PNE APPLIANCE CONTROLS PTE LTD
WPI Acc No: 94-048169/06
<XRPX> N94-094759

Patent No. (Basic): US 5283421 A 940201 9406

When a carriage of the toaster is in a lower position, a switch (21) is closed and power passes through a bridge rectifier circuit (22) to an integrated circuit (19), which, for the normal cooking operation, switches SCR (20) off so that a relay (7) is energised, switching switches (8) and (9) on to energise heating elements (2) and (3). Power is also supplied to a latch (27) to hold the carriage in the lower position. If, however, a fault detection is input from a residual core balance (12) to the integrated circuit (19), SCR (20) is switched on so that power from bridge rectifier (22) is shorted. This causes relay (7) and latch (27) to be de-energised so that the heating elements (2) and (3) are turned off and the carriage is returned to the upper position, causing switch (21) to open. ADVANTAGE Prevents unexpected energisation of appliance when power supply is re-connected.

Author (Inventor): RINNAI CO
Burner with flame failure safety circuit has detector and electromagnetic safety valve in fuel supply passage NoAbstract
Patent Assignee: (RINN-) RINNAI CO
WPI Acc No: 92-005007/01
Patent No. (Basic): KR 9007260 B 901006 9201

Sakai, Masayoshi Kato, Masakazu Futsuhara, Koichi Mukaidono, Masao
Safety control of power press by using fail-safe multiple-valued logic
Nippon Signal Co Ltd, Urawa, Jpn
IEICE Transactions on Information and Systems v E76-D n 5 May 1993. p 577-585
1993

Schukantz, Jr, James H.
Transient Protection Device Current Interrupter, Patent Application
Department of the Navy, Washington, DC.
NTIS Accession Number: AD-D009 016/7
Report No: PAT-APPL-6-314 592
Filed 26 Oct 81
12p

Author (Inventor): SEDORE G
Automatically activating or deactivating electrical appliance on presence of fire by placing secondary switch with fire sensing switch actuator e.g. heat or smoke sensor between operating components of appliance and power source
Patent Assignee: (WARN-) WARNAREST INC
WPI Acc No: 93-197553/25
<XRPX> N93-151984
Patent No. (Basic): CA 2052781 A 930405 9325

A The method involves placing a secondary switch between the operating components of an electrical appliance and a power source. The secondary switch has an open position and a closed position. In the closed position electrical current flows from the power source to the operating components of the electrical appliance. In the open position the flow of electrical current between the power source and the operating components of the electrical appliance is disrupted. The secondary switch has a fire sensing switch actuator in the form of a heat sensor or a smoke sensor, such that the position of the secondary switch is altered upon the presence of a fire being sensed. USE E.g. for deactivating electric stove if fire originated from that appliance, for activating radio/alarm clock in presence of fire as a warning to occupants of residence.

Author (Inventor): SHARP KK
Microwave oven has sensor having light emitting element and light receiver to detect smoke and condition of combustion to control relay and stop heating NoAbstract
Patent Assignee: (SHAF) SHARP KK
WPI Acc No: 93-331977/42
<XRPX> N93-256004
Patent No. (Basic): JP 5240447 A 930917 9342

Stein, H. L.
GROUND-FAULT CIRCUIT INTERRUPTERS AND PROTECTORS.
Specifying Engineer, Des Plaines, IL, USA
Specifying Engineer v 54 n 1 Jul 1985 p 87-90
1985

Sugimoto, Noboru Futsuhara, Koichi
Energy for safety information transmitted in safety control system.
Research Inst of Industrial Safety, Tokyo, Jpn
JSME International Journal, Series 3: Vibration, Control Engineering, Engineering for Industry v 35 n 2 Jun 1992 p 214-222

1992

Author (Inventor): TAKENAKA KOMUTEN CO
Heating element with protective device for domestic appliances or electric blanket uses temp. sensitive twisted wires to monitor main heating wires and has control circuit to interrupt supply if preset temp. is exceeded NoAbstract
Patent Assignee: (TKEN) TAKENAKA KOMUTEN CO
WPI Acc No: 95-096341/13
<XRPX> N95-076125
Patent No. (Basic): JP 7023529 A 950124 9513

Author (Inventor): TAYLOR J C JONES C E
Thermostatically-controlled electrical appts. e.g. domestic iron where switch interrupts power to appliance after preset number of thermostat operations to improve safety
Patent Assignee: (STRI-) STRIX LTD
WPI Acc No: 91-310751/42
<XRAM> C91-134609
<XRPX> N91-238196
Patent No. (Basic): WO 9115026 A 911003 9142

Thermostatically controlled electrical appts. e.g., domestic iron comprises a switch (100) disposed in the power supply circuit for interrupting the power after a given number of cycles, a bimetallic strip (106) heat uo and deflects while the power supply is activated and then returns to its original position as it cools thus moving an actuating member (117) via a rack (116) and a pawl (114) whereby after a given number of cycles the snap action blade (110) acts to ooen contacts (112, 104) and a rocker arm (120) mounted on the member (117) so that in one orientation of the switch the blade (110) will operate in a much smaller number of cycles. ADVANTAGE Switches off the power to the iron after a period of time.

Author (Inventor): TOKYO GAS CO LTD
Controller for clothes drier comprises thermostat installed at burner controlling device stopping operation until thermostat restarts, allowing drying operation when filter is only a little choked
Patent Assignee: (TOLG) TOKYO GAS CO LTD
WPI Acc No: 95-084460/12
<XRAM> C95-037953
<XRPX> N95-066851
Patent No. (Basic): JP 7008693 A 950113 9512

The device comprises a thermostat installed at a burner part, and a device to stop operation until actuation of the thermostat after starting the operation is smaller than a set value, and stop the operation only temporarily when the time is the set value or more and restart the operation when the thermostat is restored. USE Drying operation is continued when a filter is choked only a little.

Author (Inventor): UECKER R P
Gas valve assembly for burner control has one stage of operation controllable by thermostatic device and second stage initiated by pilot flame detected by ignition controller
Patent Assignee: (JOHV) JOHNSON SERVICE CO
WPI Acc No: 89-159811/22
<XRPX> N89-121860
Patent No. (Basic): GB 2210155 A 890601 8922

The control apparatus comprises a valve for permitting fuel to flow from an inlet to a main pressure chamber and to a pilot burner. A valve permits fuel to flow from the pressure chamber a first orifice to a first chamber adjacent the first side of a main valve diaphragm, thereby cusing a main valve to cmmence opening to supply fuel to an outlet. A pressure regulator is biased to a closed by a spring and includes a diaphragm having two sides the first side being in a pressure sensing relationship to said otulet and to a second side fo the main valve diaphragm. The seocnd side of the diaphragm is in a pressure sensing relationship to atmospheirc ambient. The pressure regulator is configured to be urged to open an exhaust passage at a pressure at the outlet, thereby permitting fuel to flow from the main pressure chamber the first orifice to the The flow of fuel results in a pressure differential across the main valve diaphragm to maintain the pressure at the outlet at a constant value.

A valve permits fuel to flow from an inlet to a main pressure chamber and to a pilot burner. A second valve bermits fuel to flow from the pressure chamber through a first orifice to a first chamber adjacent the first side of a main valve diaphragm, thus causing the main valve to commence opening to supply fuel to an outlet. A first pressure regulator is biased closed and includes a regulator diaphragm having a first side and a second side. The first side is in a pressure sensing relationship to the outlet and to a second side of the main valve diaphragm, while the second side of the regulator diaphragm is in a pressure sensing relationship to atmospheric ambient. The pressure regulator is configured to be urged to open an exhaust passage at a predetermined pressure at the outlet, thus permitting fuel to flow from the main pressure chamber through the first orifice to the outlet. ADVANTAGE Pressure differential across main valve diaphragm maintains outlet pressure at constant value. @(10pp)@

A step opening valve for controlling the flow of gaseous fuel to a burner and including: valve means configured for staged operation, said means being arranged for permitting fuel to flow from an inlet to a main pressure chamber and to a pilot burner during a first stage of operation; a main valve diaphragm for controlling the flow of fuel through a main valve to an outlet passage connectible to said burner; a first regulator for controlling the position of said main valve diaphragm during a low burner firing rate; a second regulator for conrolling the position of said main valve diaphragm during a high burner firing rate; a timing diaphragm coacting with a pressure blocking valve for controllably disabling said first regulator; said valve means being arranged for permitting fuel to flow, during a second stage of operation, from said pressure chamber to said main valve diaphragm, to said timing diaphragm and to the control areas of said first and second regulators; said main valve diaphragm thereby moving said main valve to a position for providing said low burner firing rate as set by said first regulator; said timing diaphragm thereafter urging said blocking valve to a position for disabling said first regulator after a time delay; following said time delay, said main valve diaphragm moving said main valve to a position for providing said high burner firing rate as set by said second regulator.

Author (Inventor): WESTPHAL N
Function monitoring circuitry for electrical appliance has current sensor parallel to circuit breaker with LED of connected to sensor
Patent Assignee: (GERT) GERATE & REGLER TEL VEB
WPI Acc No: 90-008153/02
<XRPX> N90-006240
Patent No. (Basic): DD 270596 A 890802 9002

The LED lights up if the triac is interrupted but not the heater or other appliance. The evaluation of the LED takes place depending on the control of the circuit breaker. USE/ADVANTAGE Monitoring electrical load circuits esp. heating elements. LED lights up if circuit breaker is interrupted and heater or its supply lines are not interrupted.

Appendix B. Search Strategies

Key:			
AND	=	*	= Logical AND, both arguements must be present
DC			= Patent class
DE			= Descriptor field
(F)			= Both arguements in same field
IC			= International patent class
ID			= Identifier field
KW			= Keyword field
NOT	=	-	= Logical NOT
OR	=	+	= Logical OR, one arguement must be present
PY			= Publication year
TI			= Title field
(W)	=	()	= Arguments must be adjacent
?			= Wildcard

Detector and Sensor Searches

EI Search 1

Set	Items	Description
S1	17317	DETECTORS/DE
S2	27324	SENSORS/DE
S3	17229	NEURAL/DE
S4	65480	NETWORKS/DE
S5	14310	NEURAL/DE(W)NETWORKS/DE
S6	57564	DETECTORS/DE OR SENSORS/DE OR NEURAL(W)NETWORKS/DE
S7	5897	SMOKE
S8	229280	HEAT
S9	1934	FLAMMABLE
S10	60395	GASES
S11	131	FLAMMABLE(W)GASES
S12	216847	THERMAL
S13	132562	RADIATION
S14	1604	THERMAL(W)RADIATION
S15	235163	SMOKE OR HEAT OR FLAMMABLE(W)GASES OR THERMAL(W)RADIATION
S16	28420	HYDROCARBONS
S17	12247	PYROLYSIS
S18	55	SMOULDERING
S19	51023	COMBUSTION
S20	11	SMOULDERING(W)COMBUSTION
S21	253	SMOLDERING
S22	51023	COMBUSTION
S23	78	SMOLDERING(W)COMBUSTION
S24	39117	HYDROCARBONS OR PYROLYSIS OR SMOULDERING(W)COMBUSTION OR SMOLDERING(W)COMBUSTION
	57564	S6
	235163	S15

	39117	S24
S25	1699	S6AND(S15ORS24)
S26	908939	PY=1990:1995
	2130	SMOKE/DE
	17317	DETECTORS/DE
	121	SMOKE/DE(W)DETECTORS/DE
	121	SMOKE DETECTORS/DE
S75	121	SMOKE(W)DETECTORS/DE OR SMOKE DETECTORS/DE
S76	1	IONIZATION DETECTORS/DE
	5897	SMOKE
	0	[D[D[D
S77	5897	SMOKE OR [D[D[D
	5897	SMOKE
	48035	DETECTOR?
S78	240	SMOKE(W)DETECTOR?
	240	78
	908939	26
S79	82	78AND26

EI Search 2

Set	Items	Description
S1	0	CHEMICAL DETECTORS/DE
S2	155	CHEMICAL SENSORS/DE
S3	1	GAS SENSORS/DE
S4	156	CHEMICAL DETECTORS/DE OR CHEMICAL SENSORS/DE OR GAS SENSORS/DE
S6	1934	FLAMMABLE
S7	2104	COMBUSTIBLE
S8	37262	HYDROCARBON?
S9	40940	FLAMMABLE OR COMBUSTIBLE OR HYDROCARBON?
	156	4
	40940	9
S10	10	4AND9

FIREDOC Search

Set	Items	Description
S1	1992	KW=(DETECT? OR SENS?)
S2	10776	PY=1990:1995
S3	1626	SMOKE(W)(DETECT? OR SENS?) OR FIRE(W)(DETECT? OR SENS?)
S4	5032	KW=(HEAT OR TEMPERATURE OR GAS OR HYDROCARBON OR AEROSOL)
S5	5905	S4 OR KW=(PARTICLE OR INFRARED OR COMBUSTIBLE OR FLAMMABLE)
S6	7907	S5 OR KW=(CHEMICAL OR (CARBON(W)MONO?) OR RADIAT? OR THERM?)
S7	1318	S6 OR KW=(SMOKE(W)CONTROL OR COMPUTER(W)PROGRAM? OR HOSPITAL?)
S8	2113	S7 OR KW=(NUCLEAR(W)POWER OR OFFSHORE(W)PLATFORM OR EGRESS)
S9	2695	S8 OR KW=(SURVEYS OR HANDICAPP? OR AIRCRAFT(W)ENGINE?)
S10	4676	S9 OR KW=(HALON? OR LEGISLATION? OR FIRE(W)INVESTIGAT?)
S11	5303	S10 OR KW=(DORMIT? OR CORRID? OR COMPUTERS OR HEALTH(W)CARE?)
S12	6045	S11 OR KW=(FIRE(W)MODEL? OR FIRE(W)PLUME? OR BOMBS)
S13	6644	S12 OR KW=(ZONE(W)MODEL? OR FIRE(W)LOSSES? OR AUTOMO?)

S14	7496	S13 OR KW=(BUILDING(W)CODE? OR COMPUTER(W)MODEL?)
S15	7952	S14 OR KW=(FOREST(W)FIRE? OR CIVIL(W)DEFENSE OR DETONATION)
S16	9652	S15 OR KW=(EVACUAT? OR EXPLOSI? OR BUILDING(W)DESIGN)
S17	9973	S16 OR KW=(AUDITORY OR ELDERLY OR GARMENT? OR INVESTIGATION?)
S18	13078	S17 OR KW=(FIRE(W)FIGHT? OR RESPIRATOR? OR STATISTICS)
S19	13781	S18 OR KW=(OFFICE(W)BUILDING? OR UPHOLSTER? OR OIL(W)SPILL?)
S20	14294	S19 OR KW=(CRUDE(W)OIL OR RESCUE OR WILDLAND OR RAILROAD?)
S21	14484	S20 OR KW=(CARE(W)HOME? OR CIGAR? OR MEDICAL(W)SERV?)
S22	15115	S21 OR KW=(SUBWAY? OR PRISON? OR FLOODING OR FIRE(W)DEPART?)
S23	15525	S22 OR KW=(ROCKET OR CASUALT? OR TRAINING OR WEATHER OR ESCAPE)
S24	420	S1 AND S6
S25	1814	S3 OR S24
S26	1197	S25 NOT S23
S27	261	S26 AND S2

NTIS Search

Set	Items	Description
S1	23580	DETECTORS/DE
S2	5669	SENSORS/DE
S3	2354	NEURAL/DE
S4	18504	NETWORKS/DE
S5	414	NEURAL/DE(W)NETWORKS/DE
S6	29408	DETECTORS/DE OR SENSORS/DE OR NEURAL(W)NETWORKS/DE
S7	4902	SMOKE
S8	100198	HEAT
S9	852	FLAMMABLE
S10	39026	GASES
S11	186	FLAMMABLE(W)GASES
S12	97181	THERMAL
S13	170125	RADIATION
S14	3586	THERMAL(W)RADIATION
S15	106925	SMOKE OR HEAT OR FLAMMABLE(W)GASES OR THERMAL(W)RADIATION
S16	18826	HYDROCARBONS
S17	6658	PYROLYSIS
S18	25	SMOULDERING
S19	61551	COMBUSTION
S20	2	SMOULDERING(W)COMBUSTION
S21	150	SMOLDERING
S22	61551	COMBUSTION
S23	38	SMOLDERING(W)COMBUSTION
S24	24786	HYDROCARBONS OR PYROLYSIS OR SMOULDERING(W)COMBUSTION OR SMOLDERING(W)COMBUSTION
S25	1378	6AND(15OR24)
S26	330480	PY=1990:1995
S27	287	25AND26
S28	101451	TEMPERATURE/DE
S29	91	27AND28
S30	18156	28AND26
S31	3223	6AND(15OR24OR28)

S32	723	31AND26
S33	707	2AND28
S34	177	33AND26
S35	432	34OR27

WPI Search 1

Set	Items	Description
S1	0	IC=G08B? OR[D[DAND
S2	7375	IC=G08B
S3	13280	DC=W05
S4	4847	IC=G08B AND DC=W05
S5	7375	IC=G08B?
	237252	PY=1990
	248468	PY=1991
	268804	PY=1992
	273511	PY=1993
	248061	PY=1994
	24283	PY=1995
S6	784716	PY=(1990 OR 1991 OR 1992 OR 1993 OR 1994 OR 1995)
	4847	4
	784716	6
S7	2570	4AND6
	1397	SMOKE
	18266	DETECTOR?
S8	203	SMOKE(W)DETECTOR?
	203	8
	2570	7
S9	60	8AND7

WPI Search 2

Set	Items	Description
1	4966	IC=G08B AND DC=W05
2	802484	PY=(1990:1995)
3	2608	S1*S2
4	208	SMOKE(W)DETECTOR?
5	62	S3*S4
6	91	4*2
7	29	6-5

Controls Searches

EI Search 1

Set	Items	Description
1	4751	SHUT()DOWN OR SHUTDOWN OR SHUT()OFF OR SHUTOFF
2	20773	DISCONNECT? OR STOP? OR POWER()DOWN OR SAFEGUARD?
3	3895	DUSDISCONTINU? OR DEACTIVAT? OR SAFE?()CONTROL?

4	17439	DISCONTINU?
5	155649	AUTOMAT? OR INTERRUPT? OR TURN()OFF OR TURNOFF_
6	199264	S1-S5/OR
7	513397	(GAS? OR ELECTRIC? OR ELECTRONIC)/DE,ID
8	80287	ELECTRONIC?/DE,ID
9	223110	(MACHINE? OR EQUIP? OR APPLIAN?)/DE,ID
10	54391	(KITCHEN? OR COOK? OR UTILIT? OR INSTRUMENT?)/DE,ID
11	210071	(POWER? OR CURRENT? OR VOLT?)/DE,ID
12	387586	(ENERG? OR HEAT? OR TEMPERATURE? OR OVEN?)/DE,ID
13	1097849	S7-S12/OR
14	70831	S6*S13
15	50817	S6/TI
16	18277	S13*S15
17	904958	CONTROL? OR COMPONENT? OR DEVICE?
18	199965	TECHNOLOG?
19	914641	DESIGN? OR ELEMENT? OR SWITCH? OR CIRCUIT?
20	27211	NECMECHANI? OR RELAY? OR BREAKER? OR FUSE?
21	412894	MECHANI?
22	143615	WIRING OR TRANSMISSION OR SURGE? OR THERMOSTAT?
23	87345	FAULT? OR BURNER? OR PILOT? OR VALVE?
24	1917534	S17-S23/OR
25	56331	S14*S24
26	207181	ALARM? OR WARN? OR EMERGENC? OR DANGER? OR HAZARD? OR SAFE? OR PROTECT?
27	7170	S25*S26
28	140082	NUCLEAR OR TELEPHONE?
29	5624	S27-S28
30	3494	S29/TI
31	4923	29/ENG
32	4923	6*31
33	1063	15*31
34	41108	S26/TI
35	281	33*34
36	539768	S24/TI
37	145	35*36
38	936794	PY=1990:1995
39	28	37*38
40	897268	PY=1969:1979
41	105	37-40
42	12347	PY=1959:1968
43	104	41-42

EI Search 2

Set	Items	Description
1	1389	(FIRESAFE OR PROTECT?)()DEVICE?
2	521	CIRCUIT()INTERRUPT? OR PROTECTIVE()EQUIPMENT
3	5640	CUTOFF()VALVE? OR CIRCUIT()BREAKER? OR THERMOSTAT?
4	76	CUTOFF()SWITCH? OR SAFE?()SWITCH? OR SHUTOFF()VALVE?
5	232331	ACTUATOR? OR SAFE?()VALVE? OR SAFE?()FUSE? OR RELAY? OR COMPONENT?

6	238701	S1-S5/OR
7	12837	EMERGENCY()SHUTDOWN OR SAFE()SHUTDOWN OR AUTOMAT?()CONTROL?
8	244532	SAFE?()CONTROL? OR DETECT? OR MONITOR? OR DEACTIVAT? OR INTERRUPT?
9	25890	DISCONNECT? OR STOP? OR POWER()DOWN OR ALARM? OR SHUTDOWN
10	7272	SHUT()DOWN OR SHUTOFF OR SHUT()OFF OR SAFEGUARD? OR TURN()OFF
11	281860	S7-S10/OR
12	3498	APPLIANCE? OR HOUSE?()EQUIPMENT OR RESIDEN?()EQUIPMENT
13	15953	HOME?()EQUIP? OR ELECTRONIC()EQUIPMENT OR POWER()EQUIPMENT
14	12388	KITCHEN? OR COOK?()EQUIP? OR BURNER? OR OVEN?
15	31295	S12-S14/OR
16	234943	INDUSTR? OR POWER()TRANSMISSION OR OIL()PRODUCTION
17	51496	TELECOMMUNICATION OR SUBSTATION? OR POWER()DISTRIBUTION
18	131028	COMMUNICATION()SYSTEM? OR POWER()PLANT? OR OIL()WELL? OR NUCLEAR?.
19	387475	S16-S18/OR
20	461	S6*S11*S15
21	360	S20-S19
22	117300	NUCLEAR?
23	355	21-22
24	136	S23/TI
25	18510	S6(F)S11
26	145	S25(F)S15
27	474819	19+22
28	108	26-27
29	0	S28/TI
30	145	S6(F)S11(F)S15
31	58042	S6/DE,ID
32	32	30*31
33	12894	HIGH()VOLTAGE?
34	27	32-33

NTIS Search 1

Set	Items	Description
1	4343	SHUT()DOWN OR SHUTDOWN OR SHUT()OFF OR SHUTOFF
2	15232	DISCONNECT? OR STOP? OR POWER()DOWN OR SAFEGUARD?
3	2006	DUSDISCONTINU? OR DEACTIVAT? OR SAFE?()CONTROL?
4	6690	DISCONTINU?
5	56587	AUTOMAT? OR INTERRUPT? OR TURN()OFF OR TURNOFF
6	82939	S1-S5/OR
7	199561	(GAS? OR ELECTRIC? OR ELECTRONIC)/DE,ID
8	37520	ELECTRONIC?/DE,ID
9	116095	(MACHINE? OR EQUIP? OR APPLIAN?)/DE,ID
10	42788	(KITCHEN? OR COOK? OR UTILIT? OR INSTRUMENT?)/DE,ID
11	122672	(POWER? OR CURRENT? OR VOLT?)/DE,ID
12	269056	(ENERG? OR HEAT? OR TEMPERATURE? OR OVEN?)/DE,ID
13	583562	S7-S12/OR
14	30277	S6*S13
15	17674	S6/TI
16	6071	S13*S15
17	654130	CONTROL? OR COMPONENT? OR DEVICE?

18	718482	TECHNOLOG?
19	448820	DESIGN? OR ELEMENT? OR SWITCH? OR CIRCUIT?
20	10958	NECMECHANI? OR RELAY? OR BREAKER? OR FUSE?
21	415123	MECHANI?
22	63741	WIRING OR TRANSMISSION OR SURGE? OR THERMOSTAT?
23	57433	FAULT? OR BURNER? OR PILOT? OR VALVE?
24	1353702	S17-S23/OR
25	27245	S14*S24
26	227156	ALARM? OR WARN? OR EMERGENC? OR DANGER? OR HAZARD? OR SAFE? OR PROTECT?
27	5851	S25*S26
28	262747	NUCLEAR OR TELEPHONE?
29	3161	S27-S28
30	1560	S29/TI
31	3161	S29/ENG
32	3161	S6*S31
33	519	S15*S31
34	48078	S26/TI
35	124	S33*S34
36	213621	S24/TI
37	51	S35*S36
38	340043	PY=1990:1995
39	14	S37*S38
40	620274	PY=1969:1979
41	32	S37-S40
42	188074	PY=1959:1968
43	31	S41-S42

NTIS Search 2

Set	Items	Description
1	1394	(FIRESAFE OR PROTECT?)()DEVICE?
2	3990	CIRCUIT()INTERRUPT? OR PROTECTIVE()EQUIPMENT
3	1470	CUTOFF()VALVE? OR CIRCUIT()BREAKER? OR THERMOSTAT?
4	75	CUTOFF()SWITCH? OR SAFE?()SWITCH? OR SHUTOFF()VALVE?
5	151076	ACTUATOR? OR SAFE?()VALVE? OR SAFE?()FUSE? OR RELAY? OR COMPONENT?
6	156698	S1-S5/OR
7	5922	EMERGENCY()SHUTDOWN OR SAFE()SHUTDOWN OR AUTOMAT?()CONTROL?
8	212708	SAFE?()CONTROL? OR DETECT? OR MONITOR? OR DEACTIVAT? OR INTERRUPT?
9	16643	DISCONNECT? OR STOP? OR POWER()DOWN OR ALARM? OR SHUTDOWN
10	6904	SHUT()DOWN OR SHUTOFF OR SHUT()OFF OR SAFEGUARD? OR TURN()OFF
11	234141	S7-S10/OR
12	2688	APPLIANCE? OR HOUSE?()EQUIPMENT OR RESIDEN?()EQUIPMENT
13	9346	HOME?()EQUIP? OR ELECTRONIC()EQUIPMENT OR POWER()EQUIPMENT
14	6501	KITCHEN? OR COOK?()EQUIP? OR BURNER? OR OVEN?
15	18193	S12-S14/OR
16	385704	INDUSTR? OR POWER()TRANSMISSION OR OIL()PRODUCTION
17	9408	TELECOMMUNICATION OR SUBSTATION? OR POWER()DISTRIBUTION
18	95328	COMMUNICATION()SYSTEM? OR POWER()PLANT? OR OIL()WELL? OR NUCLEAR?.
19	466635	S16-S18/OR

20	652	S6*S11*S15
21	444	S20-S19
22	256696	NUCLEAR?
23	374	S21-S22
24	65	S23/TI
25	15267	S6(F)S11
26	152	S25(F)S15
27	643731	S19+S22
28	65	S26-S27
29	0	S28/TI
30	152	S6(F)S11(F)S15
31	29165	S6/DE,ID
32	57	S30*S31
33	4458	HIGH()VOLTAGE?
34	56	S32-S33
35	783074	PY=1964:1979
36	28	34-35

WPI Search

Set	Items	Description
1	6785	(FIRESAFE OR PROTECT?)()DEVICE?
2	1005	CIRCUIT()INTERRUPT? OR PROTECTIVE()EQUIPMENT
3	21868	CUTOFF()VALVE? OR CIRCUIT()BREAKER? OR THERMOSTAT?
4	1347	CUTOFF()SWITCH? OR SAFE?()SWITCH? OR SHUTOFF()VALVE?
5	460014	ACTUATOR? OR SAFE?()VALVE? OR SAFE?()FUSE? OR RELAY? OR COMPONENT?
6	485710	S1-S5/OR
7	19490	EMERGENCY()SHUTDOWN OR SAFE()SHUTDOWN OR AUTOMAT?()CONTROL?
8	453788	SAFE?()CONTROL? OR DETECT? OR MONITOR? OR DEACTIVAT? OR INTERRUPT?
9	212326	DISCONNECT? OR STOP? OR POWER()DOWN OR ALARM? OR SHUTDOWN
10	20366	SHUT()DOWN OR SHUTOFF OR SHUT()OFF OR SAFEGUARD? OR TURN()OFF
11	652808	S7-S10/OR
12	20939	APPLIANCE? OR HOUSE?()EQUIPMENT OR RESIDEN?()EQUIPMENT
13	6679	HOME?()EQUIP? OR ELECTRONIC()EQUIPMENT OR POWER()EQUIPMENT
14	47309	KITCHEN? OR COOK?()EQUIP? OR BURNER? OR OVEN?
15	73591	S12-S14/OR
16	123233	INDUSTR? OR POWER()TRANSMISSION OR OIL()PRODUCTION
17	9660	TELECOMMUNICATION OR SUBSTATION? OR POWER()DISTRIBUTION
18	35106	COMMUNICATION()SYSTEM? OR POWER()PLANT? OR OIL()WELL? OR NUCLEAR?.
19	166590	S16-S18/OR
20	1552	S6*S11*S15
21	1480	S20-S19
22	31477	NUCLEAR?
23	1476	S21-S22
24	1138	S23/TI
25	71754	S6(F)S11
26	1034	S25(F)S15
27	192181	S19+S22
28	987	S26-S27
29	154	S28/TI

30	1034	S6(F)S11(F)S15
31	150496	S6/DE,ID
32	371	S30*S31
33	21045	HIGH()VOLTAGE?
34	360	S32-S33
35	17535	PY=1964:1979
36	360	S34-S35
37	1550458	PY=1978:1985
38	110	29-37
39	327511	S11/DE
40	107	38*39
41	150496	S6/DE
42	100	40*41
43	38930	S15/DE
44	100	42*43

Appendix C. Sample Test Log Sheet

CPSC Range-Cooking Fire Pre-ignition Detection Series

TEST ID CPSC95 ______ Date ____/ /1995

Pan Information

Size ______________ cm (in)
Type ______________
Material ______________
Previous Usage ______________
Mass Measurements:
- Pan+TC ______ kg
- Lid ______ kg
- Pan+TC+Lid ______ kg
- Pan+TC+Lid+Food (before) ______ kg
- Pan+TC+Lid+Food (after) ______ kg

Range Hood Active: YES / NO

Food Summary

Substance ______________
Initial Volume ______________ ml
Remaining Volume ______________ ml
Initial Mass ______________ kg
Remaining Mass ______________ kg

Experiment Operators

		Instrument(s)
Rik Johnsson	☐	
Dick Harris	☐	
Marco Fernandez	☐	
Mai Ngo	☐	
Nelson Caballero	☐	
Ted Gordon	☐	

Clock Time @ 0

Time(min)	Comments/ Observations	IR Camera Level	Voltage/Gas Flow Readings	Photos Time #	Temps Time °C
0	DATA ON - BACKGROUND				
1	BURNER ENERGIZED				
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
181					
9					
20					
	IGNITION				
	FIRE EXTINGUISHED				
	DATA OFF				

Additional Notes:

Appendix D. Data Analysis - Sample .CTL File

```
    5    0    0    0   20    1    0    0
    4    1    1    1    0    5
NIST/CPSC Pre-Ignition Detection Series: CPSC9502 27JUN95 227 g Bacon in 26.7 cm
 SS (Al base) Frying Pan, Range Hood Off
   00 1Time  Elapsed time                                               (s)
   57 2LExt1 HeNe laser and photodiode, lower                          (V)
   58 2LExt2 HeNe laser and photodiode, upper                          (V)
   59 2Vlcty Bi-directional velocity probe  .1" H20 = delta 2.5 V   (m/s)
   60 2T0/005Thermocouple Tree,         center, 11.7 cm fr. burner (Deg C)
   61 2T2/010Thermocouple Tree, 15.2 cm  left, 16.8 cm fr. burner (Deg C)
   62 2T1/010Thermocouple Tree,  7.6 cm  left, 16.8 cm fr. burner (Deg C)
   63 2T0/010Thermocouple Tree,         center, 16.8 cm fr. burner (Deg C)
   64 2T-/010Thermocouple Tree,  7.6 cm right, 16.8 cm fr. burner (Deg C)
   65 2T0/020Thermocouple Tree,         center, 26.9 cm fr. burner (Deg C)
   66 2T2/031Thermocouple Tree, 15.2 cm  left, 37.1 cm fr. burner (Deg C)
   67 2T1/031Thermocouple Tree,  7.6 cm  left, 37.1 cm fr. burner (Deg C)
   68 2T0/031Thermocouple Tree,         center, 37.1 cm fr. burner (Deg C)
   69 2T-/031Thermocouple Tree,  7.6 cm right, 37.1 cm fr. burner (Deg C)
   70 2T0/041Thermocouple Tree,         center, 47.2 cm fr. burner (Deg C)
   71 2T2/061Thermocouple Tree, 15.2 cm  left, 67.6 cm fr. burner (Deg C)
   72 2T1/061Thermocouple Tree,  7.6 cm  left, 67.6 cm fr. burner (Deg C)
   73 2T0/061Thermocouple Tree,         center, 67.6 cm fr. burner (Deg C)
   74 2T-/061Thermocouple Tree,  7.6 cm right, 67.6 cm fr. burner (Deg C)
   75 2TPnBtmThermocouple centered under, contacting pan           (Deg C)
   76 2TPnSdeThermocouple bolted to inside of pan at food level    (Deg C)
   77 2TFood1Thermocouple contacting food at center near bottom    (Deg C)
   78 2TFood2Thermocouple contacting food at center near surface   (Deg C)
   79 2THood1Thermocouple on inside of hood centered above pan     (Deg C)
   80 2THood2Thermocouple on outside of hood centered above pan    (Deg C)
   81 2TSurf1Thermocouple on top range, 17 cm from center, 8pm     (Deg C)
   82 2TSurf2Thermocouple on top range, 17 cm from center, 2pm     (Deg C)
   83 2TRangeThermocouple beneath range surface centered below pan(Deg C)
                                                                      999
    1.0
    1.0
                                                                      999
SKIP=(S1Z1)2
```

```
TC
1
60 83 X
COMPUTE
1
59-0.0  X  $1
VELOCITY
1
59  9.96  Z  3  1  68  X
COMPUTE
2
(8.507-57)/8.507  X  $2
(10.148-58)/10.148  X  $3
SMOOTH
2
$2  0  3  X  $4
$3  0  3  X  $5
RENAME
   $1   VelV  Bi-directional probe raw voltage                (V)
   $2   Extn1 Laser extinction for lower position            (V/V)
   $3   Extn2 Laser extinction for upper position            (V/V)
   $4   Extn1sLower laser extinction smoothed (3 pt)         (V/V)
   $5   Extn2sUpper laser extinction smoothed (3 pt)         (V/V)
                                                                  999
END
```

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A significant portion of residential fires stem from kitchen cooking fires. Existing fire data indicate that cooking fires primarily are unattended and most often involve oil or grease. The purpose of this investigation was to ascertain the existence of one or more common features or characteristics of the pre-ignition environment that could be used as input to a sensor in a pre-fire detection device. The ultimate goal of this continuing study is to evaluate the feasibility of incorporating such a device into the range that would react to a pre-fire condition and reduce the occurrence of unwanted kitchen fires. The focus of the study was unattended foods placed in pans on burners set to high heat. Experiments were conducted with three different foods and with gas and electric ranges to investigate the pre-ignition environment of actual range-top cooking fires. Numerous temperatures in the near surroundings as well as local plume velocity and laser attenuation measurements were recorded. A Fourier transform infrared, FTIR, spectrometer was used to observe significant species production above the food. Results of these experiments are presented and evaluated. The second part of this study was a literature and patent search of technologies with the capability to act as either the sensor in a pre-fire detection device or as the automatic control that would respond to a detector warning signal by shutting off the gas or electricity supply. A broad range of potential detection technologies were reviewed because the pre-fire signatures had not yet been identified. A bibliography and comments on the applicability of different technologies are included. The conclusions pertaining to the experiments are based on measurements and observations of combinations of specific ranges, pans, foods, and ventilation so extrapolation to other conditions should be performed with caution. The major conclusions of this research are as follows: (1) Strong indicators of impending ignition were temperatures, smoke particulates, and hydrocarbon gases. (2) Promising detection technologies include: tin oxide (SnO_2) sensors for hydrocarbon detection, narrow band infrared absorption for hydrocarbon detection, scattering or attenuation types of photoelectric devices for smoke particle detection, thermocouples for thermometry of the burner, pan, range surface (top and below), or range hood. (3) Logical processing of signals from two or more of the detection technologies could be an important means by which false alarms of pre-ignition conditions are eliminated. (4) Control technologies exist that are applicable to the safe shutdown and restart of gas and electric ranges upon detection of approaching ignition.

KEY WORDS (MAXIMUM OF 9; 28 CHARACTERS AND SPACES EACH; SEPARATE WITH SEMICOLONS; ALPHABETIC ORDER; CAPITALIZE ONLY PROPER NAMES)

appliances; fire detection; fire prevention; ignition prevention; kitchen fires; residential buildings; sensors; smoke detectors; smoke measurement

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