

EXECUTIVE SUMMARY

Cooking range top fires account for over 91,000 home fires each year, causing over 300 and 3,700 annual deaths and injuries, respectively, based on data from 2006–2010 [1]. In addition, many cooking fire incident and injuries go unreported to fire departments and are not included within the data. Technologies potentially capable of preventing these fires have been considered and reviewed for the past 30 years. Beginning in 2010, Hughes started working with the Fire Protection Research Foundation (FPRF) to review the potential effectiveness of various technological options [2]. A workshop conducted as part of that project considered the emergence of commercial products on the market and identified the need to develop standardized tests and criteria to evaluate the performance and effectiveness of such devices. This report has summarized and analyzed the results of two live fire test series conducted to form the basis for such a test protocol.

The tests conducted were intended to: 1) develop the basic protocols for conducting standardized tests; 2) develop performance criteria for conduct of valid tests; and, 3) develop performance criteria for assessing fire protection performance of prevention technologies. The scope of this work was limited to assessing only fire preventing technologies, not those that would contain or alert after ignition.

Fire tests were conducted to assess the pre-ignition conditions for cooking oils in pans on electric surface cooktops of ranges. The pan temperatures, oil temperatures, effluent temperatures, and gas concentrations were measured continuously from the start of heating until ignition. Tests evaluated the impacts of oil types, oil brands, oil age and usage, oil depth, pan materials, pan sizes and thicknesses, range power, and range type (glass ceramic radiant element and coil element). It was intended to identify the test conditions that would present the greatest potential challenges to prevention devices and select them for inclusion in the recommended standard testing.

It was found that the type/age/use of oil only had a strong influence on the production of smoke, and not on the temperature of ignition. The percent free fatty acid (% FFA) of the oils tested were measured and correlated with the smoke and ignition temperatures. The % FFA varied for oils of different types (low for canola, vegetable, peanut oils, high for pork lard). The % FFA was also increased by artificially aging oils by sustaining them at high temperatures or using oils by repeatedly cooking food in them. Oils with increased % FFA produced smoke at lower temperatures, but ignited at approximately the same temperatures. Oils that produced smoke at lower temperatures were considered less challenging to detect before ignition. Fresh canola oil (lowest % FFA) was selected for continued testing and is recommended for a test standard. The brand of oil used (tested commercial grade and multiple consumer brands) did not affect the ignition properties, and no specific brand need be specified for testing.

Numerous criteria were used to identify “challenging” scenarios. Some examples include: 1) the total heating time to reach ignition; 2) the window of time available between a fixed pan temperature threshold (e.g. 300 °C) and ignition, 3) the window of time available between a measured smoke obscuration (e.g. 1.6 %/ft) and ignition; 4) the temperature of the pan at ignition; and, 5) the temperature of the oil at ignition. In general, the total heating time and available fixed pan temperature/smoke obscuration windows scaled proportionally, and were decreased by increasing the element power, decreasing the oil depth/volume, reducing the pan mass/specific heat capacity, and increasing the pan/element contact area. Conversely, the measured pan and oil temperatures at ignition were reduced inversely with the length of the test, presenting potential challenges for tests taking long periods to reach ignition.

The criteria used to identify challenging tests were directly related to the total heating time required to reach ignition. It is recommended that both fast and slow tests be conducted to challenge all

potential detection technologies. The fastest tests ignited in less than 7 minutes of heating. The slowest tests required as much as 1 hour of heating before ignition occurred (if at all). Several combinations of test variables were capable of producing heating times in these ranges by varying the range power, oil depth, etc. If a prevention device requires the use of a specific test variable (e.g. pan type, range type, etc.), it should be possible to produce a fast or slow test including this condition. The specific conditions producing fast/slow ignitions need not be specified or limited for standardized testing. The slowest tests were much more variable, with ignition times ranging from 20 minutes to over 1 hour for the same test conditions. A second set of "slow" tests (15-20 minute heating times) were also included in the recommendations to potentially provide a slow test but with more consistent results.

In order to demonstrate that a proposed test setup will meet the fast or slow test criteria, a heating test must be conducted without the prevention device activated or present. For safety reasons, the demonstration tests need not be conducted up to ignition. It has been proposed that the tests be run until an oil temperature of 350 °C (662 °F) has been reached and then the heating source turned off. Acceptable boundaries for allowable pan and oil temperatures and smoke obscuration have been developed from the test data for fast, slow, and the slowest test cases.

Pan and oil temperatures were measured in multiple locations in the tests conducted. Data showed that pan and oil temperatures measured at the center of the pan and at half of the initial oil depth above the pan surface provide a good representation of the spatial average. The oil temperature did not vary by more than 1–2 °C (3–4 °F) as a function of depth, and placement of the oil temperature measurement at the half oil depth ($\pm 1/16$ inch) should be adequate for standardized testing.

The smoke obscuration need only be measured and demonstrated within the test bounds if the prevention device to be tested uses smoke as an activation criteria. The current test design measured the smoke in a 4 ft x 4 ft hood over the range. Evaluation of real smoke measuring devices would require a more realistic kitchen type installation to provide the proper smoke concentrations for activation. Development of a smoke test room has not been evaluated as part of this effort and will require subsequent analysis.

Performance criteria has been developed to evaluate the performance of prevention devices based on proposed limits to the measured oil temperature in the pan. For the tests utilizing the final recommended instrumentation, ignitions did not occur until the oil temperatures reached 374–406 °C (705–763 °F) and pan temperatures reached 385–432 °C (725–810 °F). Based on the available test data a threshold in the range of 300 to 350 °C (572 to 662 °F) should be sufficient for prevention of ignition. If a more conservative threshold is desired, such as 250 °C (482 °F) oil temperature, the minimum time to ignition increases to 130 seconds and the resulting pan surface temperatures decrease to 263–312 °C (505–594 °F). An oil temperature threshold of 300 °C is currently used by the Japanese Industrial Standard (JIS) 2103 and 2093 [6,7].

Some cooking methods may require the temperature of foods to reach as high as 260 °C (500 °F) [9]. Inclusion of a minimum oil temperature prevents devices from severely limiting the ability to cook. It is also suggested to include a maximum allowable deviation in heating rate. Tests conducted without the device operating (demonstration of acceptable fast/slow test) must heat the pan and oil within specified bounds. The inclusion of the device should not reduce the heating rate by more than a defined threshold, for example, 10% of the average temperature increase per minute.

The recommendations for the performance criteria would include a device that can: 1) operate after the desired minimum oil temperature is reached; 2) operate before the maximum oil temperature is reached; and, 3) does not drastically reduce the heating rate measured without the device present,

it should be considered acceptable. These three criteria would be required for achieving a passing test result.