Smoke Alarm Research at NIST

Thomas Cleary
Fire Research Division, Engineering Laboratory
National Institute of Standards and Technology

NIST conducts research on the performance of smoke alarms with the aims of improving smoke alarm designs and strengthening requirements in the appropriate codes and standards. Recent research has focused on performance criteria for proposed new fire tests, and characterizing cooking nuisance sources

Although smoke alarms provide a substantial level of safety to households, reducing the risk of dying in reported fires by 50 % in homes with working smoke alarms, improved smoke alarm performance could further reduce fire risk. Earlier alarm activation by increasing the sensitivity of smoke alarms to risk-significant fire scenarios is one approach to improving performance. Flaming and smoldering upholstered furniture fires have been identified as risk-significant scenarios that are not adequately addressed in current standards. New polyurethane foam smoldering and flaming fire tests have been suggested to address this shortcoming, but need scientifically sound performance criteria to be complete.

An analysis methodology, based on the available safe egress time/required safe egress time (ASET/RSET) concept, is used to estimate the probability of escape given smoke alarm activation at specific smoke concentrations in flaming and smoldering polyurethane foam chair mock-up fire experiments to provide guidance in selecting new smoldering and flaming fire test performance criteria. The tenability limits were defined by a fractional effective dose value of 0.3 for toxic gas and heat exposure, and two smoke optical density limits used in previous studies, 0.25 m^{-1} and 0.43 m^{-1}, were considered. Analysis assumptions and limitations included:

- interconnected smoke alarms that alert occupants regardless of initial fire location,
- occupant pre-movement time treated as a distribution for distinct populations,
- travel speed as a function of smoke density,
- occupants traversing a range of equally frequent pre-determined egress routes,
- considering only one apartment-sized residential space,
- one location for the responsive smoke alarm, and
- three flaming and three smoldering scenarios, and a total of 18 full-scale tests.

Results have been presented to provide guidance in selecting performance criteria for new smoldering and flaming polyurethane foam fire tests proposed for ANSI/UL 217 and ANSI/UL 268[i]. This study provides a rationale for how to strengthen the requirements in a manner that considers commensurate improvement for flaming and smoldering alarm performance.

Ultimately, the Standards Technical panel for ANSI/UL 217 and ANSI/UL 268, other regulatory bodies and/or standards development organizations need to make a judgment on the addition of any new tests or performance requirements. This is an active area for proposals to the Standards Technical Panel for changes in ANSI/UL 217 and ANSI/UL 268.

NIST has conducted experiments to assess the performance of various residential smoke alarms to kitchen fires and nuisance alarm cooking scenarios[ii]. A structure representing a kitchen, living room and hallway was constructed to conduct the experiments. Eight different residential smoke alarms types, two photoelectric models, two ionization models, two dual sensor photoelectric/ionization models, and two multi-sensor, intelligent models were used in this study. The data gathered provided insight into the susceptibility of alarm activation from exposures to typical cooking events and alarm times for actual kitchen fires. The effects of alarm technology and installation location on the propensity of an alarm to activate were examined. In the kitchen fire experiments, all smoke alarms responded before hazardous conditions developed. One ionization alarm tended to respond first compared to other co-located alarms. Results show some smoke alarms placed greater than 6 m from the kitchen range may provide less than 120 s of available safe egress time, which suggests the importance of a more central alarm location closer to the kitchen for this configuration. Experiments were conducted to determine an alarm's propensity to activate when exposed to particulates generated from eight typical cooking activities including toasting, frying, baking and broiling. In most cases, the propensity to nuisance alarm decreased as the distance from the cooking source increased. Two alarms, an ionization alarm and a dual sensor alarm, experienced more nuisance alarm activations across the eight cooking activities than the other alarms. The remaining alarms experienced about the same combined nuisance alarm frequency when averaging all cooking events for installation locations outside the kitchen.

From the kitchen nuisance alarm tests the following conclusions are drawn:

1. For the conditions studied here, the propensity to nuisance alarm decreased as the distance from the cooking source increased.
2. Alarms (ionization alarm I1 and dual sensor alarm D2) that rely on sensitive ionization chambers experienced significantly more nuisance alarm activations for cooking activities and locations tested in this study.
3. All alarms except I1 and D2 experienced about the same nuisance alarm frequency for the locations outside the kitchen for the cooking scenarios tested.

Results from the nuisance cooking experiments have been used to explore potential nuisance resistance tests for ANSI/UL 217. Specifically, toasting, broiling and frying hamburger patties tend to produce cooking aerosols over a wide range of particle sizes and concentrations, and have been down-selected for further test development.

---

[i] http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1837.pdf

[ii] http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1784.pdf