2009 BFRL Project Description

Project Title: Smoke Alarm Performance Standards

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BFRL Program: Reduced Risk of Fire Spread in Buildings

Objective: To provide a technical basis for modifications and/or additions to standard test methods used to certify residential smoke alarms by developing performance metrics related to the hazards posed by fires, and to the susceptibility to nuisance alarms.

Problem:

What is the problem? Smoke alarms are now installed in 96% of all U.S. homes. While 4% of homes do not have smoke alarms, approximately 20% of homes with smoke alarms have non-operational smoke alarms[1]. It is estimated that if every home had working smoke alarms, U.S. residential fire deaths could drop by 36% (~1100 lives saved per year.)[1] U.S. fire statistics for home structure fires from Years 2000-2004 reveal that 34% of civilian deaths occurred in homes with operating smoke alarms, 22% of civilian deaths occurred in homes with smoke alarms present, but that failed to operate, and 43% of civilian deaths occurred in homes with no smoke alarms[2]. The statistics point to three major problems or obstacles to further reducing residential fire deaths through smoke alarm usage. First, how can 100 % of homes have smoke alarms? Second, how can the percentage of working smoke alarms be significantly increased? Third, how can smoke alarms, when they are functioning, be more effective in warning occupants?[3] Research points to two main reasons for non-working smoke alarms: missing or dead batteries and intentional power source interruption[4]. A reduction in nuisance alarms would tend to reduce intentional disabling of alarms. There is a need for research to improve the performance measurement of smoke alarms including performance for a range of fire scenarios, and the susceptibility to nuisance alarms.

Why is it hard to solve? The difficulty lies in the level of detail needed to fully characterize alarm performance. There is a lack of detailed data which could be used to more completely and objectively resolve current gaps in knowledge to succinctly quantify fire hazard and nuisance alarm susceptibility. Smoke alarms are non-specific to the origin of the aerosols

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[1] Ahrens, M., "US Experience with Smoke Alarms and Other Fire Detection/Alarm Equipment," NFPA, Quincy, MA, November, 2004.
[2] Ahrens, M. "Home Structure Fires," NFPA, Quincy MA, February, 2007.
[3] Home Smoke Alarms and Other Fire Detection and Alarm Equipment, Public/Private Fire Safety Council, April 2006. http://www.firesafety.gov/programs/
[4] Smith, C.L., "Smoke Detector Operability Survey – Report on Findings," U.S. Consumer Product Safety Commission, Bethesda ,MD, November, 1993.

they are exposed to. As long as the smoke or nuisance aerosol concentration reaches a fixed level, the alarm responds. Therefore, smoke alarm performance metrics must be tied to test results that reproduce realistic fire hazards and common nuisance alarm sources. Smoke and nuisance source characteristics in any new standard test need to match real-scale test smoke characteristics (size distribution, concentration, rate of production, etc.) and the environmental conditions (air flow, temperature, humidity and gas species.)

How is it solved today, and by whom? Currently, the National Fire Protection Association Standards Committee on the National Fire Alarm Code has task groups gathering and analyzing research on smoke alarm performance in order to assess the need to prepare revisions to the Standard, NFPA 72. Underwriters Laboratories, Inc. is conducting a research program to asses the needs for new fire sensitivity tests for smoke alarms. The NPFA task groups are working with limited data, while the UL effort does not consider fire hazard development, nor nuisance source performance

Why NIST? The proposed work addresses standards needs through measurement science research consistent with the BFRL and NIST missions. NIST should perform this research because it is the leader on smoke alarm performance research, formulating, directing, and carrying out the bulk of the research that has been used to develop and justify the consensus standards in the US. NIST has the technical expertise to develop scenarios and collect meaningful data including conducting relevant full-scale fire tests, measuring smoke and aerosol properties, and model development.

Approach:

What is the new technical idea? The new technical idea in this multi-year program is to develop sound performance measurements for smoke alarms that would be used to specify new detection requirements, would not be based on specific technologies, would not require stiff installation location mandates in addition to current requirements (every level plus bedrooms, plus interconnected), and would provide better overall performance in residential settings (including hazards to occupants in the room of fire origin.) In FY08, a set of full-scale experiments was conducted to provide insight into the hazard development from initially smoldering and initially flaming fires, and allowed for a performance assessment of smoke alarm technologies. A range of parameters was examined (specifically polyurethane foam density, fabric cover, fire room volume, and ignition scenario) so a sensitivity analysis of factors affecting residential smoke alarm performance was performed. In FY09, the full-scale data will be analyzed considering alternate egress scenarios, tenability criteria, and computational schemes to better quantify alarm performance. The smoke characteristics from the full-scale tests conducted in phase one will be compared to standard or proposed standard fire sources used in UL 217/268, and the results of the UL Smoke Characterization Project[5]. Previous nuisance source tests conducted in the Home Smoke Alarm Project[3] and additional testing will be used to develop design requirements and a test standard for a detector that would minimize false alarms due to steam, non-hazardous smoke (i.e., nuisance smoke from cooking activities),and dust while providing quick response to a range of fires. OA funding will be used to complete this objective (FY09).

Why can we succeed now? NIST can succeed now because the previous work conducted in the Home Smoke Alarm Project[3] laid a foundation to build a strong technical basis for smoke alarm performance, and the Codes and Standards organizations recognize the need for strong technically defensible requirements for smoke alarm performance. There is a push from fire officials, housing industry, and the public to make the best decisions related to smoke alarms which motivates the standards committees. The PI has the requisite technical expertise in all aspects of residential smoke alarm performance and aerosol measurements, and is recognized a leader in the field by the relevant codes and standards organizations.

What is the research plan? Experiments were conducted in a multi-room suite connected by a hallway to quantify the effects of ignition scenario, fire room volume, covering fabric, foam density and alarm location, on the development of untenable conditions, and alarm response (photoelectric and ionization, dual alarm and carbon monoxide.)

The full-scale experiments employed all the measurement hardware for determining combustion gases, temperatures, and smoke obscuration in each room, including the burn room. Visibility degradation was documented by video cameras. A number of smoke alarms and CO alarms were monitored for alarm condition and CO concentration. Smoke aerosol size distribution data were collected throughout the tests in order to quantify smoke properties for comparison to other experiments and additional smoke sources being considered for use in standard tests.

Photoelectric, ionization and dual sensor type residential smoke alarms from several manufacturers were purchased from retail outlets and used for the full-scale tests and groups of alarms were installed at various locations and monitored. Carbon monoxide detectors were installed in each of the rooms and monitored during the tests. This year samples of each alarm will be subjected to tests in the fire emulator/detector evaluator to quantify the actual alarm sensitivity, including the sensitivities of individual sensors in dual sensor alarms.

The data gathered in the full scale experiments conducted in FY08 will be analyzed to assess individual smoke alarm performance for the various fire scenarios. Analysis methodologies different than the one used in the NIST Home Smoke Alarm Project[3] will employed that consider alternate egress scenarios, tenability criteria, and computational schemes to better quantify alarm performance. CO alarm response will be analyzed to determine if early warning was provided in the scenarios tested.

The smoke characteristics from the full-scale tests conducted in phase one will be compared to standard or proposed standard fire sources used in UL 217/268, and the results of the UL Smoke Characterization Project[5]. If needed, small-scale standard samples and ignition protocols will be developed to produce representative results in the UL 217/268 Fire Test Room, or other equipment, such as the FE/DE. Previous nuisance source tests conducted in the Home Smoke Alarm Project[3], will be used to guide development of standard residential nuisance tests.

[5] Fabian, T., and Gandhi, P., "Smoke Characterization Project," The Fire Protection Research Foundation, Quincy, MA, April, 2007

Additional tests will be conducted in a single room and the FE/DE to verify the repeatability of the standard nuisance sources.

Recent Results: (this project started in FY08)

Outcome: New NIST-quality data set available for development of smoke alarm performance metrics.

Standards and Codes: The PI is a member of NFPA 72, National Fire Alarm Code, and participated extensively in the NFPA 72 Task Group that issued a final report "The NFPA 72 HOU Task Group on Smoke Detection Technologies", February 2008. The PI is the chair of a new NFPA 72 task group on Smoke Alarm Installation Strategies, and a member of a second task group on Performance Follow-up. The PI is a member of a UL Standards Technical Panel task group on nuisance alarms and recommendations for changes in the UL Standard UL217. These task groups are working on issues directly related to the project objectives.

Anticipated Impact:
Increased effectiveness of smoke alarms used in US homes that leads to a reduction in residential fire deaths