Development of Tools to Evaluate the Impact of New Residential Fire Protection Technology

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There are a number of fire technologies that could be beneficial in improving fire safety in residential structures including barrier fabrics in residential upholstered furniture, new fire alarm standards, and nano-composite flame retardants to name a few. However, there does not exist an accepted method for measuring absolute or relative improvements in fire safety from new fire protection technologies. The National Institute of Standards and Technology (NIST) has undertaken an effort to create tools and identify gaps in data, tools, and knowledge to help quantify improvements in fire safety. Toward this effort NIST is conducting an analysis of the recent changes in ANSI/UL 217 2015 [1] to estimate the relative impact on occupant safety. This analysis includes definition of residential fire scenarios in structures of various sizes, Monte Carlo sampling of inputs for modeling fire growth and spread, and statistical analysis of the results to quantify the potential impact on fire safety of smoke alarms meeting ANSI/UL 217 2015. We will discuss the preliminary results of this analysis as well as identify gaps in data and knowledge that need to be filled to fully understand the impact on community fire safety.

One of the issues that has existed with detectors is the fact that ion detectors respond significantly faster than photo detectors to flaming smoke but much slower to smoke from smoldering fires. The new ANSI/UL 217 2015 has additional requirements for flaming and smoldering polyurethane foam smokes so that new smoke alarms that pass the standard must perform better than typical photoelectric alarms in flaming fires and better than typical ionization alarms in smoldering smoke. To model the effects of smoke alarm performance, we added two features to the Consolidated Fire and Smoke Transport model known as CFAST[2], the NIST computer fire model used in the analysis. First, we had to allow fires to start off as smoldering fires then switch over to flaming fires, which includes having CFAST produce and track two types of smoke. The second change was adding a new type of smoke detector that can react differently to the two types of smoke. These features were added and are now available in the latest version of CFAST, version 7.3.0.

After a review of the literature on residential fires we found that egress from one- and two-family structures is very different from large and/or commercial buildings. In large commercial buildings much of the egress time is dominated by the flow effects of large crowds and the distances that need to be traveled. The impact of individual behavior may average out. In one- and two-family residences the egress distances are relatively short and the number of people is small, which means that egress is dominated by individual behaviors. However, there isn't a model that attempts to calculate residential egress. The solution is to follow previous analysis, set an expert's best estimate of an appropriate egress time, and see if the alarms give enough time.

One behavior that needs to be considered in order to truly understand residential fires is that people, in their own homes, will often attempt to fight the fires and statistics indicate they are successful more times than not[3]. While issues such as liability may make fire safety officials unwilling to suggest that people should consider fighting a fire they discover, the reality is that people will often do just that. In an attempt to start developing an understanding of this phenomenon we identified a point depending on the fire heat release rate we would estimate the occupants would have a high probability of successfully fighting the fire and after which they would have a low probability of putting the fire out. Since there is very little data about residents fighting fires it is difficult to know how realistic this analysis is, but it is an important part of the residential fire problem and needs to be addressed.

We conducted an analysis of National Fire Incident Reporting System (NFIRS) data to determine what characteristics made fires the deadliest. The results showed that fires in living rooms and bedrooms are among the most dangerous. We also found that fires ignited from smoking were the deadliest fires. Data was available on upholstered chair fires starting from both flaming sources and smoldering sources. Data on mattress fires for both old mattresses and for mattresses meeting the most recent standards were also available. This resulted in four different model fires, each with its own set of distributions so that the detectors would see a range of environments.

To develop floor plans, we started with the American Home Survey (AHS) that the Census Bureau puts out every two years. From the AHS we took the distribution of total floor area and given a total floor area we have a distribution of the number of rooms. The floorplan was generated by assuming any two rooms had a 50/50 probability of being connected. There was an added requirement that the completed graph or layout of the building had to be a planar graph, meaning a graph that can be put in a plane or drawn on a piece of paper without the edges crossing. The planar graph requirement was put in place to keep the floorplans from being connected in such a way that was physically impossible.

Part of doing a Monte Carlo analysis is to perform a large enough number of runs so that the statistics are reproducible. To do this requires automating the process. Using the Python computer language, a purpose specific program was developed to generate, run and process the cases using CFAST. This allowed us to generate data from tens of thousands of cases. After generating a significant amount of data, we looked for methods that would allow us to determine when we had enough data for the specific questions.

After generating the data, the issue is how to analyze and present the data in a statistically rigorous and meaningful way that people using the analysis can understand what it is saying and make decisions the analysis was meant to inform.

Among the findings is that it is difficult to accurately assess actual improvements due to proposed fire safety technology improvements with the limited knowledge on typical room sizes and configuration in a range of residential structures. Additional information on typical floorplans is needed to improve the assessments. A more significant need is to evolve the definition of the Required Safe Egress Time(RSET) side of an ASET/RSET analysis for residential evacuation. The Available Safe Egress Time(ASET) calculations are basically the same for residential and commercial structures. Residential evacuation is behaviorally more complex than commercial occupancy, where the majority of occupants do not have significant attachments or responsibility to the structure. We propose calculating a Residential Safe Egress Time for residential structures, which takes into account such activities as investigation, firefighting, and assisting others to escape in addition to the travel time included in typical RSET calculations.

1. Underwriters Laboratories, I., *ANSI/UL 217-2015: Standard for Safety Smoke Alarms*. 2015: Northbrook, IL.
2. Peacock, R.D., et al., *CFAST, Consolidated Model of FIre Growth and Smoke Transport (Version 7), Volume 1: Technical Reference Guide*, in *Technical Note 1889v1*. 2015, National Institute of Standards and Technology: Gaithersburg, MD.
3. Greene, M.A. and C. Andres, *2004-2005 National Smaple Survey of Unreported Residential Fires*. 2009, U.S. Consumer Product Safety Commission: Washington, DC.