C47 Variation in Performance of Residential Smoke Detectors — Safety Concerns Due to Unpredictable Behavior

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The goal of this presentation is to educate forensic engineers as to the wide variation in performance of commercial residential smoke detectors under similar fire conditions as an aid to forensic investigation.

This presentation will impact the forensic community and/or humanity by describing how the performance evaluation of smoke detectors will help educate forensic scientists and engineers who are called upon to perform first fire analysis of detector performance and circumstances of injury to fire victims. The performance data will also assist fire safety professionals in determining ways to improve the performance of smoke detectors, thereby increasing public safety and reducing the loss of life and property resulting from fire.

This paper presents the results of an extensive research project evaluating residential smoke detectors under controlled fire tests. The performance of residential smoke detectors has been extensively documented using full scale testing. Fire scenarios include those typical and expected in residential environments under circumstances that pose hazard of injury or death to residents.

Commercially available, UL-listed smoke detector designs from multiple manufacturers have been tested in large quantities under a wide variety of fire scenarios. Specific emphasis has been given to the performance of same make/same model detectors under similar fire circumstances. The objective is to determine the statistical predictability of the performance of detectors as purchased, installed, and used by the public, as a function of various fire scenarios common to residences in the United States. The results are presented blind, without specific reference to manufacturer, and without identification of a specific product.

The test protocol utilized requires testing of unmodified, unaltered smoke detectors purchased commercially. Detectors were purchased in multiple units of the same make/same model for comparison purposes, but no attempt was made to control for date of manufacture or shelf time prior to sale. Smoke detectors were installed in a full-scale residence utilizing the manufacturer's recommended installation instructions. Fires were set in the residence consistent with foreseeable fire scenarios in private housing in the United States. A common fire scenario to which detectors were tested is smoldering/burning furniture or bedding.

The full-scale residence was instrumented to provide detailed parametric information documenting the progression of the fire. Computer based instrumentation records such parameters as temperature, obscuration in multiple locations, and the performance of individual detectors in response to smoke production. For each detector, performance criteria were recorded and documented to include the time each detector takes to respond to the fire and the obscuration levels in and around the detector and in the residence at the time each smoke detector responds. From these data, relative comparisons were made between same make/same model detectors and different make/different model detectors in all combinations. These data were then used to draw conclusions with respect to overall performance, efficacy of the detectors for providing home safety, and the predictability of smoke detector performance based on fire type.

The intent of this paper is to educate forensic investigators and forensic engineers concerning the actual performance of smoke detectors in residential fires as compared to the performance that is expected by the public or by engineers and fire scientists. The results of research to date show wide variation in performance by units of the same model or essentially same model of detector, making prediction of behavior difficult in post fire analysis. The characteristics and factors affecting performance and variations in performance are described and presented. Specific case studies are reviewed with research data from actual fire tests presented and discussed. Overall performance of detectors as a function of tenability parameters, such as obscuration, is presented.

Smoke Detectors, Fire Detection, Fire Safety