UL Fire Safety Research: Recent and Current Studies

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According to research conducted by the National Fire Protection Association (NFPA), there were approximately 370,000 residential fires in the U.S. in 2011, resulting in an estimated $6.9 billion in property losses, and the deaths of more than 2,500 civilian occupants and firefighters.[1] While the annual number of fire-related deaths has remained relatively stable in recent years, some NFPA statistics indicate that firefighter deaths inside of structures are occurring at higher rates than those reported 30 or 40 years ago.[2] This data clearly indicates that residential fires and firefighting efforts continue to pose a significant risk to occupants and members of the fire service.

At the same time, changes in residential building materials and construction methods and the structure and composition of home furnishings are posing new potential fire safety challenges that are not well understood. For example, modern home design features such as open floor plans have a direct impact on fire generation and growth factors, thereby challenging long-standing firefighting strategies. In addition, modern home furnishings are increasingly crafted from synthetic materials with combustibility characteristics that are different from those found in non-synthetic materials.

For these reasons, ongoing research is an essential element of the overall effort to reduce risks associated with residential fires. UL has long been at the forefront of research aimed at developing a better understanding of the nature of the modern residence fire. A number of UL research studies have addressed firefighting techniques or specific firefighting challenges. Other UL studies have evaluated the reaction of building materials and home furnishings under fire conditions. Still other UL studies have investigated the health impact on firefighters from exposure to smoke and other particulates produced by fires.

This body of research represents a vital contribution to the efforts to reduce risks associated with residential fires and firefighting efforts and to save lives. This white paper provides a summary of UL's recent and current fire safety research studies and discusses the findings of those studies and their implications for improving fire safety.

Stability of Engineered Lumber Under Fire Conditions [Izydorek, Zeevald, Samuels and Smyser, 2008]

Lightweight wood trusses and engineered lumber is increasingly replacing conventional solid joist construction in roof and floor designs in residential structures. However, existing fire performance data on lightweight construction materials was insufficient to assess whether the use of such materials posed an increased risk to firefighters.

In this study, UL researchers collaborated with the Chicago Fire Department, Michigan State University and the International Association of Fire Chiefs to evaluate the fire resistive performance of nine structural assemblies, including seven floor-ceiling constructions and two roof-ceiling constructions. Fire testing was conducted in accordance with ASTM E119, but structural loads were altered to better reflect actual conditions during a fire. Testing results for individual assemblies were then analyzed and compared with the testing results of other assemblies.

The results of testing conducted under this study showed that the fire containment performance of an assembly supported by solid joist construction was better than an assembly supported by an engineered I-joist. Specifically, the fire containment performance of a combustible floor-ceiling assembly representing typical legacy construction was 18 minutes, compared with just 6 minutes for the engineered I-joist assembly.

The final report on this study, "Report on Structural Stability of Engineered Lumber in Fire Conditions," was issued in September 2008.

Effectiveness of Specialized Fire Extinguishment Agents [Steppan, 2008]

Water has been the traditional agent used to extinguish most fires. In an effort to increase the effectiveness of fighting residential fires, a number of fire departments evaluated the use of special extinguishment agents, such as wetting agents and Class A foams. However, without a standardized protocol for collecting data, little empirical evidence was available to determine the possible effectiveness of these agents compared with water.

In this study, UL collaborated with the Chicago Fire Department and the International Association of Fire Chiefs to develop a standard methodology that could be used to evaluate the performance and effectiveness of special extinguishment agents in combatting residential structural fires. The project then evaluated the fire performance of eight different extinguishing agents and compared their performance to that of water. Fully instrumented fire tests were conducted using a standardized fuel package designed to simulate a residential living area and hallway fire setting.

The results of the testing conducted under this study generally showed that, based on the reduction in the rate of measured heat loss from the fire, there was no significant difference in the effectiveness of any of the alternative extinguishing agents when compared to water alone.

The final report on this study, "Performance of Special Extinguishment Agents for Firefighter Use," was issued in September 2008.

Smoke Characterization [Fabian, 2007]

UL initiated the Smoke Characterization Project in 2006 in conjunction with the Fire Protection Research Foundation (FPRF) of the NFPA, as a follow up to a 2004 National Institute of Standards and Technology study. In that earlier study, researchers observed a reduction in available safe egress times, attributed to significantly faster fire growth caused by the types of materials used in modern furnishings.[3]

The purpose of the UL/FPRF Smoke Characterization Project was to more fully characterize the products of both flaming and non flaming combustion on a variety of products and materials typically found in residential settings. This study used smoke particle and gas effluent characterization technology that had not been previously available for commercial testing purposes. Testing scenarios included the fire test protocols in UL 217, the Standard for Safety of Single and Multiple Station Smoke Alarms, including a burning coffee maker, a toaster with a bypassed shutoff, and flaming and smoldering upholstered furniture components.

The Smoke Characterization Project study determined that synthetic materials

ignite faster, burn more intensely, and create greater amounts of smoke and other types of gases than natural materials. In addition, the study observed that the response time of photoelectric and ionization smoke alarms was influenced by different smoke particle sizes and counts due to changes in the combustion mode (flaming versus non flaming). This resulted in commercially available ionization smoke alarms triggering earlier than commercially available photoelectric smoke alarms for flaming and high energy non flaming (toaster) fires, and photoelectric alarms triggering earlier for lower energy non flaming fires.

The final report on the Smoke Characterization Project was issued in April 2007.

Impact of Exposure to Smoke Particulates [Fabian, 2010]

One of the key observations noted in UL's earlier Smoke Characterization Project was the predominance of sub-micron sized smoke particles generated by combustion. In this follow-up study, UL partnered with the Chicago Fire Department and the University of Cincinnati College of Medicine to further investigate the causal relationship between sub-micron smoke particles and the risk of cardiovascular problems.

The study analyzed data on smoke and gas effluents to which firefighters are exposed during a range of routine firefighting operations, as well as contact exposure from contaminated personal protective equipment. UL researchers collected data from nine separate fire tests conducted at UL's facilities, which was supplemented with data collected from residential fires over a four month period by Chicago Fire Department personnel. As a component of this study, the combustibility, smoke and gas characteristics of 43 different residential construction and furnishing materials were profiled.

The results of the testing conducted under this study confirmed that the combustion of materials in a fire generates asphyxiants, irritants and airborne carcinogenic byproducts. These particulates are found in smoke generated during the suppression and overhaul phases of firefighting, and can be inhaled from the air, or absorbed through the skin as a result of contact with contaminated equipment.

The final report on this study, "Firefighter Exposure to Smoke Particulates," was issued in April 2010.

Fires Involving Photovoltaic Systems [Backstrom and Dini, 2011]

The number of installed photovoltaic (PV) energy systems is growing at a significant rate. Although potential electrical and fire hazards associated with PV systems are generally known, there has been a limited body of knowledge regarding safety procedures for dealing with energized PV systems in a fire condition.

In this study, UL examined the potential impact of installed and energized photovoltaic (PV) systems on firefighting operations. The goal of this project was to develop empirical data needed to quantify the potential hazards associated with fires involving PV installations, and to provide a basis for the development of firefighting operational practices.

Testing was conducted at UL's Northbrook, Ill., facility and at the Delaware County (Penn.) Emergency Service Training Center. Fire experiments were designed to represent a room fire that evolved to a structure fire and ending in collapse. Experiments were also conducted on rack mounted PV arrays to represent a debris fire under PV modules mounted on the roof. Following the fire experiments, the PV modules were examined to determine their continued ability to generate power, particularly during overhaul operations.

Testing conducted under this study identified hazards associated with the application of water to a PV array during fire suppression activities. In addition, based on testing data, several tactical approaches were developed that provide specific examples of changes that fire departments can adopt to more effectively and safely deal with energized PV arrays.

The final report on this study, "Firefighter Safety and Photovoltaic Installations Research Project," was issued in November 2011.

Impact of Horizontal Ventilation [Kerber, 2010]

In this study, UL researchers examined ventilation practices used by the fire service in residential fires and evaluated the impact that changes in modern house geometries have on the fire dynamics seen in a residential structure.

Two houses were constructed in UL's fire testing facility. The first house was a single-story structure, measuring approximately 1,200 sq. ft., and consisting of eight rooms, including three bedrooms and one bathroom. The second house was a two-story structure, measuring approximately 3,200 sq. ft., and consisting of 12 rooms, including four bedrooms and two and one-half bathrooms. The second house also featured a modern, open floor plan, with an open foyer and a two-story great room.

A total of 15 experiments were conducted in which the ventilation locations and the number of ventilation openings were altered. Ventilation scenarios included ventilating the front door only, opening the front door and a window near and remote from the seat of the fire, opening a window only, and ventilating a higher opening in the two-story house. One scenario was conducted in triplicate to examine repeatability.

A critical finding from this study was the importance of coordinated ventilation with the application of water to achieve a successful outcome. The study also affirmed the importance of barriers in protecting life during a fire condition, and that simply closing a door can secure a refuge providing suitable temperature conditions and oxygen concentrations to increase the chances of survival.

The final report on this study, "Impact of Ventilation on Fire Behavior in Legacy and Contemporary Residential Construction," was issued in December 2010.

Impact of Vertical Ventilation [Kerber and Fabian, ongoing]

Building on the earlier research on the impact of horizontal ventilation in developing effective firefighting strategies, UL is currently examining the impact vertical ventilation on fire behavior in residential structures. Using house testing similar to that employed in the earlier horizontal ventilation study, this two-year project is expected to provide empirical data on fire behavior in various vertical ventilation scenarios, and evaluate vertical ventilation practices that can reduce firefighter death and injury.

In addition to collecting data on vertical ventilation scenarios, the study will also examine suppression techniques used to fight modern residential fires to assess their impact on occupant survivability. The study will also address questions of smoke alarm response times associated with different smoke alarm locations and technologies.

The final report on this study is expected in early 2013.

Fighting Basement Fires [Kerber, Madrzykowski, Dalton, Backstrom, 2012]

In this study, UL researchers collaborated with a number of research organizations, product manufacturers and fire service representatives to examine the behavior of residential flooring systems when a fire condition exists beneath the floor, such as in a basement. The goal of this study was to increase general knowledge about the impact of fire on residential flooring systems, as a tool to improve tactical decision-making by fire personnel on scene.

This study examined several types of floor joists, including dimensional lumber, engineered I-joists, metal plate connected wood trusses, steel C-joists, castellated I-joists and hybrid trusses. Multiple experiments were performed, examining variations from single floor system joists in a laboratory up through a full-floor system in an existing structure. Applied load, ventilation, fuel load, span and protection methods were also altered to provide important information about the impact of these variables on structural stability and firefighter safety.

Perhaps the most important finding of this study was the absence of reliable and repeatable warning signs of floor collapse during any of the experiments in which the variables were systematically controlled. Under actual fire conditions, there are likely to be a number of variables and parameters unknown to responding firefighters. In addition, the study found no collapse indicators that could consistently guarantee the safety of a given floor system. For example, a flooring system with a fire underneath, such as in a basement area, may only exhibit modest temperature increases on the upper surface of the floor.

Because of the lack of predictability, the study offered a number of tactical factors and recommendations that firefighters can reference when assessing

a residential fire within a basement. Specifically, to the extent possible, the on-site assessment should include the basement area and a determination of the amount of ventilation present. In addition, flooring systems should be inspected from below prior to firefighting operations, since surface soundings and thermal imagery may not be sufficient to assess structural integrity.

The final report on this study, "Improving Fire Safety by Understanding the Fire Performance of Engineered Floor Systems and Provide the Fire Service with Information for Tactical Decision Making," was issued in March 2012.

Flammability of Upholstered Furniture [ongoing]

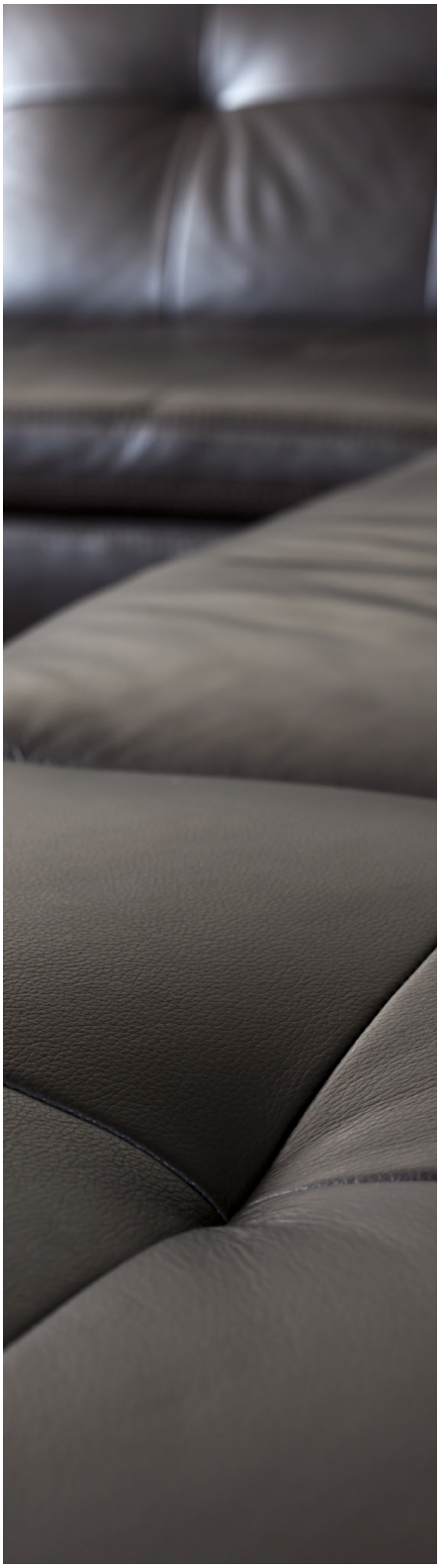
According to NFPA research, more home fire deaths result from fires originating in upholstered furniture and mattress/bedding than any other item.[4] To better understand how changes to upholstered furniture may reduce the risk of residential fires, UL is in the final stages of a "demonstration of concept" study to assess if commercially available products such as fire retardant foams and fire barriers (interliners) retard and/or reduce the fire growth rate of upholstered furniture exposed to small open flames.

This study includes an assessment of:

1. 11 commercially available barrier materials constituting different chemistries and physical structures
2. two comparable density polyurethane foam materials
3. a non fire retardant foam commonly used in upholstered furniture and a California TB 117-compliant fire-retardant treated foam
4. a popular upholstered furniture cover fabric

Testing includes material-level tests, furniture mock-up tests and full-size furniture tests. Heat release rate and mass loss rates are being measured under each test condition.

It is expected that the results of these experiments will provide knowledge on the potential fire growth reduction from each of the different barrier strategies being investigated. The final report on this study is expected in early 2013.



Conclusion

The above studies clearly demonstrate UL's significant contributions to today's understanding of the modern residential fire. UL's research directly supports the efforts of the fire service to develop practices and protocols that reduce firefighter risk and increase safety. These studies also contribute valuable information regarding the design and construction of residential structures and furnishings, ultimately providing consumers with increased margins of safety in fire conditions. UL is committed to continuing its fire research efforts, and contributing new information vital to the safety of firefighters and consumers.

The full reports on the above completed studies are available at the UL website at www.ul.com/fireservice. For further information about UL's fire safety research, contact Stephen Kerber, research engineer, at Stephen.Kerber@ul.com.

[1] "Fire Loss in the United States During 2011," National Fire Protection Association, Fire Analysis and Research Division. Sept. 2012. Web. 5 Oct. 2012. http://www.nfpa.org/assets/files/pdf/os.fireloss.pdf.

[2] "Firefighter Fatalities in the United States—2011," National Fire Protection Association. June 2012. Web. 18 Sept. 2012. http://www.nfpa.org/assets/files/pdf/osfff.pdf.

[3] "Performance of Home Smoke Alarms: Analysis of the Response of Several Available Technologies in Residential Fire Settings," NIST Technical Note 1455, National Institute of Standards and Technology, 2004, revised Feb. 2008. Web 24 Oct. 2012. http://www.nist.gov/el/fire_protection/buildings/upload/NIST_TN_1455-1_Feb2008.pdf.

[4] "Home Structure Fires," National Fire Protection Association. May 2011. Web. 5 Oct. 2012. http://www.nfpa.org/assets/files/PDF/OS.Homes.pdf.