U.S. Fire Administration/National Fire Data Center

Changing Severity of Home Fires Workshop Report

FEMA

Changing Severity of Home Fires
Workshop Report

FEMA

U.S. Fire Administration

Mission Statement

We provide national leadership to foster a solid foundation for our fire and emergency services stakeholders in prevention, preparedness, and response.

U.S. DEPARTMENT OF HOMELAND SECURITY

FEMA

Table of Contents

Overview and Workshop Aims

On Dec. 11-12, 2012, in response to an invitation from the U.S. Fire Administration, leading national organizations representing the fire service, fire researchers and other stakeholders in home fire safety came together at the Maryland Fire and Rescue Institute in College Park, Md., to explore how changing building construction methods, materials and building contents are affecting the way fires grow and develop in today's homes. The expected outcomes, as stated by USFA, of the workshop were to:

—Enhance the awareness of fire service and life safety officials of the changing and emerging fire and products of combustion risks to residential building occupants.

—Produce a document that clearly identifies contributing factors to the marked increase in the speed of fire spread experienced in interior residential fires.

—Identify potential solutions to mitigate if not prevent those risks.

—Determine which organizations or agencies are interested in further studying and ultimately developing implementation strategies.

There were 28 organizations represented at the workshop; the attendance is listed in Appendix C – Workshop Participants. The 1 1/2 day program (Appendix A – Workshop Agenda) was designed to address emerging changes in home design, construction and contents and their potential impacts on occupant and firefighter safety. A special focus of the workshop was on firefighting tactics in response to these changes.

The overall goal of the program was to share our new understanding of these effects, gained through a recent body of research funded by the Department of Homeland Security and other government agencies, and to consider how we should respond as a community.

There were two major topics discussed. First, researchers from the National Institute of Standards and Technology, Underwriters Laboratories and others presented the technical substantiation for two phenomena which are facing the fire service in responding to today's home fires: the first is the shorter times to flashover and wind-driven fire effects which are resulting from modern building contents and configurations. The second is the changing building envelope (much of which is driven by sustainable construction goals) which is creating new hazards in exterior fire attack. Research was also presented which illustrates how modern firefighting personal protective clothing and equipment is not fully in step with changing environments for firefighters and their tactics.

The second major topic of the program was modern furniture flammability, a fire issue which is not new but which is receiving renewed attention as research is reinforcing the significant contribution of upholstered furniture to the home fire problem and developing new and environmentally benign methods to lower that contribution.

A significant proportion of the workshop agenda was dedicated to interactive discussion with the fire safety organizations represented, to fully understand the risks presented by the speakers and to identify specific strategies to address them. USFA challenged each organization represented to consider what they might do to help develop solutions to the risks identified. The result was a recommended eight-point action plan:

1. Initiate a nationally coordinated program to develop/revise firefighting, situational awareness and preplanning curricula to incorporate new tactics based on hazards associated with evolving building construction and contents. Integrate the curricula into nationally coordinated training programs. Revise ProQual standards and certification programs accordingly. Develop a national model for continuing education for all ranks and positions in the fire service and incorporate this with evolving technical information.

2. Develop and maintain a means to provide an ongoing national focus to monitor changes to home structures, contents, designs, etc. that impact the development and growth of home fires, as well as the impact of specific strategies to mitigate these hazards to ensure that research, training, education and code development keep pace.

3. Ensure a continuum of research on hazards to firefighters from the evolving severity of home fires by reassessing the allocation of Assistance to Firefighters Grant funding to research versus safety and prevention. Focus this research on the impact of potential new tactics on these hazards and enhancing the capability of fire protection systems such as sprinklers to mitigate these hazards.
4. Enhance current research and product development initiatives to improve the performance and reliability of home smoke alarms.
5. Increase the awareness of the general public regarding hazards associated with changing home contents and construction and the importance of working smoke alarms. Incorporate this information into national fire prevention campaigns and further extend the reach of those campaigns to high-risk groups through culturally effective and appropriate means.
6. Develop a representative, cost-effective method to measure furniture contribution to fire heat release rate and develop standard test methods based on it. Develop one or more potential solutions for fire barriers for upholstered furniture that meet fire, cost and usability performance criteria.
7. Develop new strategies for widespread implementation of home fire sprinklers as a most effective means to mitigate emerging hazards.
8. Increase the participation of the fire service in the development and revision of building codes to ensure that their safety is addressed in these documents.

Summary of Presentations

Research With the Fire Service to Understand the Changing Severity of Home Fires

Stephen Kerber (UL) presented an overview of the research work funded by the Department of Homeland Security and conducted by UL over the past five years. He presented the "fire formula" of modern homes, which addresses the fire growth impact of larger footprints, more open space, evolving fuel loads, greater concealed spaces, changing building materials, and new technologies (e.g., solar panels). This formula has introduced a level of uncertainty and complexity into the modern firefighting environment for which current firefighters are ill-equipped through training, experience and technology. The research conducted by UL on structural stability of engineered lumber, firefighter exposure to smoke particulates, impact of ventilation on fire behavior (both horizontal and vertical), photovoltaic system firefighting hazards, and a new project on attic and exterior fire spread hazards was described with a focus on impacts for firefighter safety. Kerber concluded with the statement that the operational time frame for the fire service continues to shrink. He recommended that fire dynamics must be a fundamental basis for firefighting tactics, technology, education and training for current firefighters.

The Importance and Control of Residential Upholstered Furniture Flammability

Dr. Richard G. Gann (NIST) presented an overview of residential fire losses, characteristics and fuels, noting the significant and underestimated contribution from soft furnishings in amplifying fire severity. Over the period of 2006-2010, 2,100 average annual fire deaths can be attributed to upholstered furniture contribution to fire spread as a secondary ignited item alone. Gann presented a regulatory review, noting the success of mattress flammability limits, the lack of national legislation on furniture flammability, and the varying test methods in voluntary programs and state legislation. He noted that there are many changing factors embedded in fire statistics including both upholstered furniture changes and changes in other factors affecting fire safety in homes, such as a decrease in smoking and an increase in working smoke alarms. He concluded with a summary of effective tactics to reduce furniture fire losses with a focus on furniture test standards that address cigarette and flaming ignition sources and limit HRR.

Change is Not a Four Letter Word

George K. Healy (New York City Fire Department) presented an overview of the work of the FDNY in understanding and addressing wind-driven fires. He reviewed the annual and increasing incidence of flow path deaths and injuries to firefighters and civilians. He then reviewed the research conducted by NIST in conjunction with the FDNY at Governor's Island, which explored firefighter tactics to control ventilation effects and the effectiveness of exterior streams to reduce firefighter exposure. He noted that these scenarios are not limited to multistory structures but also basement and attic fire scenarios and described subsequent work at Railroad Flats conducted in conjunction with NIST and UL to explore fire growth, development and tactics in these scenarios. He concluded with the observation that the FDNY has substantially modified its firefighting tactics based on these research programs and will continue to do so as modern buildings introduce new hazards for the firefighter.

Fire Safety Challenges of Green Buildings

Dr. Brian J. Meacham (Worcester Polytechnic Institute) presented the results of a recent study supported by the Fire Protection Research Foundation to systematically identify elements of green building design which may impact fire safety. He reviewed the hazards associated with new exterior wall materials (including covering skins, so-called "green roofs", photovoltaic panels and insulation) which may impede firefighting and increase both thermal and toxic hazards, and noted the trend toward "second skin" designs which create vertical uncompartmented concealed spaces. Other energy-saving ventilation designs may also impact smoke management in fire events. An assessment of the fire impacts of new building materials and finishes yielded several elements which may adversely impact fire risk. Siting issues were also reviewed; for example, increased housing density presents challenges for fire service access. In all, over 80 green building elements/attributes were identified as contributing to risk factors for fire safety. He recommended that green building features' contribution to fire incidents should be monitored by cross-referencing the National Fire Incident Reporting System and green building databases. He concluded with a recommendation that the study be deepened to place the relative comparison of green and conventional building features' performance into risk or hazard characterization measures.

The Performance of Dimensional and Engineered Lumber in Fire Conditions

James M. Dalton (Chicago Fire Department) presented the results of a NIST/Chicago Fire Department/UL study which demonstrated the relative performance of legacy solid wood floor and roof framing and current construction methods and materials. He provided National Institute of Occupational Safety and Health fire incident reports on firefighter death and injury due to floor and roof collapse. Floor furnace testing and full scale laboratory experiments demonstrated the greatly reduced fire resistance of both new framing lumber and engineered joists, and trusses in particular. Testing also demonstrated the benefits of the addition of a single layer of one-half inch gypsum wallboard to the fire resistance of a loaded floor assembly. He cautioned that invalidated testing (such as that done on intumescent coatings as a protection measure) can produce misleading results. He described as yet unsuccessful efforts to effect building code change based on this research and recommended that the fire service increase their involvement in building code development to ensure that their interests in fire safety are represented in that environment.

The Impact of Alternative Energy Technologies on Homes

Casey C. Grant (FPRF) began his presentation with a series of definitions of residential occupancies and alternative energy technologies and an overview of the diversity of the U.S. fire service. He described how the National Electrical Code has addressed emerging alternative technologies over the years, including most recent activity on photovoltaics, electric vehicles, smart grid and DC power. He noted that wind power, power storage, electric vehicles and their charging stations, and new forms of fuel cell power generation all represent emerging challenges for fire and electrical safety, and recommended that research, building and other safety codes proactively monitor and address these developments.

Spray Polyurethane Foam (SPF) in the Construction Industry

Dr. Richard S. Duncan (Spray Polyurethane Foam Alliance) presented an overview of the polyurethane foam industry, SPF history and current use trends in buildings, and governing codes and test methods. SPF is used in a broad range of residential applications ranging from walls to floors and attics. The industry is actively involved in code development to address fire safety. Current industry topics include safety during installation (exposed foam), whole house fire performance and the impact of air sealing due to SPF installations, education of code officials on the details of and distinctions between thermal and ignition barriers, enforcement issues for commercial building requirements (associated with National Fire Protection Agency 285), and eco-toxicity and flame spread issues associated with SPF flame retardants.

U.S. Consumer Product Safety Commission Overview of Regulatory Efforts Impacting Home Furnishing Flammability

Rik Khanna and Andrew G. Stadnik (CPSC) presented an overview of existing flammability regulations for various home products including insulation, textiles, carpets and mattresses. The test methods referenced in these regulations and the fire scenarios they are designed to address were reviewed, as were regulations under development on bedclothes and upholstered furniture. They described the objectives of the proposed regulation on furniture to target smoldering ignition fires and prevent transition from smoldering to flaming combustion. Recent work conducted in collaboration with NIST has focused on the development of standard reference foam to reduce variability of test results, which has recently stood in the way of further developments in test methods. There is a need for bench-scale tests to predict full-scale performance; validation tests have illustrated that this is not the case for current smoldering ignition tests for furniture with and without barriers. Ongoing work will include further testing with standard materials, engagement with American Society for Testing and Materials E05 on potential revisions to ASTM E1353, and incorporating necessary changes to a regulatory approach.

Overview on the Combustibility and Testing of Filling Materials and Fabrics for Upholstered Furniture

Bob Luedeka (Polyurethane Foam Association) presented an overview of the history and use of flexible polyurethane foam in furniture, noting that backs of furniture no longer are made from FPF. He reviewed the history of development of fire tests for foams and the introduction of flame retardants. He summarized a five-year industry research program and provided a detailed written reference indicating the complexity of a complete evaluation of fire performance and scaling of small test results to large scale performance, noting the materials and design variations that typically occur in furniture. He summarized the requirements for flame retardant additives, including effectiveness, compatibility, economics, durability and environmental safety, and noted that test methods to evaluate the products of combustion from burning furniture are also complex. He concluded by providing the industry perspective that regulations must be performance-oriented; relate to actual risk; apply to all materials; generate measurable, repeatable results; be economically feasible; and result in a solution that is safe for workers.

Quantifying Flaming Residential Upholstered Furniture Fire Losses

Dr. William M. Pitts (NIST) provided a review of the burning behavior of modern upholstered furniture with a timeline of fire development. This behavior has resulted in shorter times to room flashover, in comparison with legacy furniture construction materials. He reviewed fire loss statistics over the last several years, and the disproportionate share of fire deaths related to living area fires. He provided a detailed review of current test methods and regulations related to flammability of furnishings focusing on ignition scenarios, and noted the widespread adoption of state regulations related to reduced-ignition propensity cigarettes. He then reviewed the results of a March 2012 NIST workshop and a resulting study of home fires and associated losses where upholstered furniture was the primary but not first-ignited fuel package. This study indicated the significant contribution of this scenario to home fire losses which, in combination with the contribution of flaming combustion following smoldering combustion to loss, indicates that limiting HRR or fire growth rate of furniture will result in a substantial contribution to limiting fire losses.

Residential Upholstered Furniture Flammability

Dr. Thomas Fabian (UL) presented an overview of UL's ongoing research related to furniture flammability testing. The goal of the work was to verify that commercially available fire resistance technologies can retard and/or reduce fire growth. He described the results of full-scale (room corner) testing to explore the effects of materials and the positive effects of cotton-based barriers and flame retardant-treated foams on time to flashover and HRR. These findings were validated in full-scale living room experiments which showed that the time to flashover was significantly reduced in the presence of barriers in modern furniture cushions, approaching legacy furniture levels. Further testing in one- and two-story full homes showed a significant increase in available safe egress time.

Size Up, Flow Path, and Softening the Target

Daniel Madrzykowski (NIST) presented an overview of fire growth in under-ventilated fires, noting the sudden increase in fire temperatures after traditional fire department ventilation. Uncontrolled ventilation can result in significant flow paths of fire conditions which endanger firefighters. He summarized recent flow path-related line-of-duty deaths where firefighters were fighting above the fire (basement fire scenarios). A residential fire incident in Brooklyn was presented where even with significant vertical and horizontal ventilation by the fire department, the fire continued to grow in size and HRR. He provided a technical explanation of flow path and described a laboratory experimental program conducted by NIST, with funding from DHS through FPRF, which evaluated the impact of horizontal ventilation on HRR. He reviewed computer simulations of the dynamics of a wind-driven fire in a recent ranch-style house fire in Texas and a nonwind impacted fire in a two-story duplex in Iowa which illustrate these effects. Modern furnishings and contents, reduced compartmentation, and increased home air tightness are exacerbating these effects, and firefighting tactics must be changed to address this. He recommended that the fire service be aware of the capabilities and limitations of personal protective equipment when entering structure fires and increase their understanding of the aspects of fire behavior that relate to ventilation limitations. Recommended changes to tactics include size up to address ventilation changes and wind conditions, locate fire and flow path, and consider alternate approaches (e.g., aggressive exterior attack). He concluded that current understanding, standards, education training, standard operating procedures and standard operating guidelines must be in sync at the national level.

Residential Fire Environment: A Firefighter's Perspective

Sean DeCrane (Cleveland Fire Department) described the work environment of the fire service, noting that the station house also presents certain fire hazards (e.g., contaminated gear). He reviewed firefighter death and injury rates, expressing concern regarding the increasingly toxic work environment for firefighters. He reviewed LODDs associated with fire flow path, noting that the provision of bunker gear has not impacted this statistic. Contributing factors are the changes in the fire environment described by previous speakers, the lower number of fires resulting in less fireground experience, equipment standards variability, and the lack of a national standard on firefighting tactics which might incorporate the latest science basis. He provided examples of how building code requirements and fire safety regulations are not keeping pace with our current understanding of the risk to firefighters (e.g., photovoltaic panels and engineered lumber). He provided a series of recommendations to the design community including the need to communicate with the fire service and seek their involvement and participation in the regulatory environment.

Impact on Firefighter PPE, Physiology and Training

Dr. Gavin Horn (Illinois Fire Service Institute) reviewed trends in LODDs and fireground injuries and categorized the environmental, equipment and individual behavioral issues contributing to these losses. He focused on the rapid changes in available PPE and the remaining limitations (e.g., self-contained breathing apparatus face pieces) which demand a corresponding change in firefighter tactics to prevent additional risks associated with heat stress (e.g., gear weight increase and longer personnel heat exposure vulnerabilities). He stressed the need for firefighter training to include an understanding of fire dynamics and the capabilities and limitations of gear versus personnel limitations. He recommended the use of realistic fire environments as an essential part of firefighter training and strongly recommended that the relationship between PPE and tactics be considered in reducing the cardiovascular, thermal and carcinogenic risk to firefighters.

Risks and Strategies

The following risk factors were identified by the participants of the workshop during the discussion periods:

Changes in the Design of New Homes

—Larger home footprints.
—Open concept floor plans.
—More unventilated attics.
—Increasingly airtight construction.
—Increased concealed space.
—Variety in plans and construction types.
—Increased housing density.
—Building at the wildland interface.

Changes in Home Construction Materials and Techniques

—Engineered wood assemblies.
—Combustible exterior finishes.
—Green building features.

Changes in Home Furnishings

—New information on effectiveness and hazards of fire retardant chemicals in upholstered furnishings.
—Overall increased plastic contents.
—Energy-saving technologies.
—Photovoltaics.
—Electric vehicles.
—Energy storage and distributed power solutions.

Changing Fire Service-related Risks

—Shorter time available for size up due to reduced times to flashover.
—Fire flow/Wind-driven fires phenomena.
—Current fireground procedures and firefighter training inadequate to address those new risks.
—Less experience in fighting fires due to fewer fires.
—Staffing reductions in selected jurisdictions independent of increased risks.
—New firefighter gear/tools with varying performance levels.
—Firefighter gear improvements increasing other personnel risks.
—Exposure to carcinogens from contents and construction materials.
—Reaching **all** the fire service with training information related to new hazards.

The following strategies to address the risks were identified by the participants of the workshop during the discussion periods:

Home Design, Materials and Components

—Monitor emerging changes in design and construction so that they can be proactively addressed.
—Develop and adopt fire protection strategies for increased building hazards (e.g., floor fire protection).
—Advocate for fire service participation in the building codes and standards development process.
—Improve smoke alarm technology to reduce false alarms and increase percentage of working smoke alarms.

—Improve support to implementation of residential sprinklers and continue to adapt the technology to meet changing hazards.

Residential Upholstered Furnishings

—Develop repeatable test methods that accurately predict fire performance in the real world.
—Develop standard reference materials for use in testing.
—Establish regulatory framework based on performance requirements.
—Provide appropriate cost-benefit analysis.
—Develop better fire barrier materials that will meet the fire safety requirements as well as requirements associated with comfort, durability and cost.
—Consider more effective built-in fire protection systems — suppression or detection.
—Consider an international strategy for public education and enforcement.
—Create appropriate incentives for manufacturers to fund needed research.
—Increase public awareness of the problem.
—Develop or implement other solutions such as other types of foam (U.K. model), nano composites, clay, etc.

Fire Service Strategies

—Soften the target, work to change the culture toward exterior attack first, and revisit and revise prior generation (prebunker gear) tactics which incorporate this feature.
—Improve firefighter situational awareness techniques.
—Educate on the capabilities and limitations of new PPE.
—Incorporate research on fire dynamics into fire tactics, fire training programs and NFPA ProQual standards.
—Implement innovative training methods to reach broad fire service audiences – for example, social media, video and live training evolutions.
—Current understanding, standards, education, training and SOPs/SOGs must be in sync at a national level.
—Provide appropriate separation and ventilation for contaminated fire gear.
—Consider the National Incident Management System approach for continuing education.

General

—Develop a national strategy like America Burning that is coordinated with all stakeholders including the home-building community.
—Capture green features in NFIRS.
—Develop risk assessment tools for the fire service.
—Community risk reduction: better education for consumers about fire problems related to the products they buy — focus on high-risk audiences.
—Strengthen the AFG program as a means to continue to inform new tactics.
—Develop a central, publicly accessible repository for reports from AFGs to help disseminate this information.

Action Plan

The following eight-point action plan was developed through a consolidation of input from all participants at the workshop of the risk reduction strategies identified. While specific organizations have committed to taking action as described below, all of the participants have expressed their willingness to contribute to the initiatives as appropriate. The USFA will schedule periodic check-ins with the workshop participants to facilitate information sharing, to monitor progress, and to identify additional challenges and solutions that warrant attention.

1. Initiate a nationally coordinated program to develop/revise firefighting, situational awareness and preplanning curricula to incorporate new tactics based on hazards associated with evolving building construction and contents. Integrate the curricula into nationally coordinated training programs. Revise ProQual standards and certification programs accordingly. Develop a national model for continuing education for all ranks and positions in the fire service and incorporate this with evolving technical information.

   —The NFPA, through its Public Fire Protection Division, will serve as liaison to those working on this objective to provide a link to the Professional Qualifications Standards Project and facilitate communication and sharing of data between the ProQual Technical Committees and the project team.

   —UL has formed the Underwriters Laboratories Firefighter Safety Research Institute to continue to conduct research and disseminate research results to the fire service for incorporation into curricula that will be used to improve firefighter knowledge. UL supports fire service continuing education and has a learning management system with several training programs available that meet the International Association of Continuing Education and Training requirements at www.ul.com/fireceus. ULFSRI will work with fire service groups to understand what is needed for a national model for continuing education.

   —NIST is working to increase the level of performance, efficiency and safety of firefighting by conducting research to (1) improve tactics through application of the understanding of fire dynamics to develop ventilation strategies and improved nontraditional means of fire suppression, (2) develop test methods to characterize the performance of innovative and traditional firefighter equipment and PPE under the extreme environments in which they operate, and (3) advance the quality and range of information available on the fireground through use of existing and emerging sensors, building control systems, computing technologies, and firefighting equipment and apparatus. NIST is currently working with many local, state and federal agencies as well as nongovernment organizations to partner and to transfer research results into practice for use by the fire service.

   —After the workshop, the International Association of Black Professional Firefighters, the Illinois Fire Service Institute, the International Association of Women in Fire and Emergency Services, and the Institution of Fire Engineers expressed an interest in working with others on this item.

2. Develop and maintain a means to provide an ongoing national focus to monitor changes to home structures, contents, designs, etc. that impact the development and growth of home fires, as well as the impact of specific strategies to mitigate these hazards to ensure that research, training, education and code development keep pace.

   —FPRF has offered to take a leading role on this item.

   —UL developed the current research to highlight the impact of these changes and is planning to continue to monitor for more changes and to disseminate the results.

3. Ensure a continuum of research on hazards to firefighters from the evolving severity of home fires by reassessing the allocation of AFG funding to research versus safety and prevention. Focus this research on the impact of potential new tactics on these hazards and enhancing the capability of fire protection systems such as sprinklers to mitigate these hazards.

   —USFA leadership has committed to work with AFG on the possibility of increasing the allocation of grant funds for research.

   —After the workshop, IFSI, iWomen and UL expressed an interest in working with others on this item.

4. Enhance current research and product development initiatives to improve the performance and reliability of home smoke alarms.

   —USFA has committed to ongoing support of recent smoke alarm developments and to encouraging the transfer of the technology to the marketplace.

   —UL is currently working to develop and validate an improved smoke alarm standard to better represent the current fire environment.

   —NIST is working to improve early warning fire detection and nuisance alarm resistance for the next generation of home smoke alarms through research on sensor response and sensor modeling, and data fusion and implementation strategies, including work with standards and codes.

5. Increase the awareness of the general public regarding hazards associated with changing home contents and construction and the importance of working smoke alarms. Incorporate this information into national fire prevention campaigns and further extend the reach of those campaigns to high-risk groups through culturally effective and appropriate means.

   —USFA will incorporate these issues with the Fire is Everyone's Fight initiative, which was developed in cooperation with Vision 20/20 and for which USFA serves as the national leader.

   —IFE and Vision 20/20 have advised that they are planning to produce a webinar covering these topics incorporating several speakers from the workshop.

   —After the workshop, UL, the Black Chief Officers Committee, and IABPF expressed an interest in working with others on this item.

6. Develop a regulatory framework based on test methods for upholstered furniture that reasonably predicts its fire performance in a home, including contribution to HRR. Develop one or more potential solutions for fire barriers for upholstered furniture that meet fire, cost and usability performance criteria.

   —CPSC has the regulatory authority on this issue, and is working towards promulgation of a regulation.

   —NIST is working to reduce the contributions of upholstered furniture flammability to fire losses in residences. NIST currently has research efforts aimed at (1) characterizing the contribution of upholstered furniture to fire development in homes, (2) developing approaches for predicting the burning behavior of real-scale upholstered furniture based on small-scale test results, (3) providing the technical basis for standard tests of fire barrier effectiveness in upholstered furniture, (4) developing approaches for reducing the flammability of polyurethane foam, and (5) providing the technical basis for standard tests designed to characterize upholstered furniture resistance to ignition by smoldering sources. NIST is working to provide technical assistance to CPSC for their work on upholstered furniture safety standards.

   —After the workshop, the FPRF and the National Association of State Fire Marshals expressed an interest in working with others on this item.

7. Develop new strategies for widespread implementation of home fire sprinklers as a most effective means to mitigate emerging hazards.

   —NFPA is continuing Fire Sprinkler Initiative: Bringing Safety Home to increase the use of home fire sprinklers through adoption of sprinkler requirements.

   —The Home Fire Sprinkler Coalition will continue their innovative work through turnkey and comprehensive education programs for targeted audiences including consumers, homebuilders, real estate agents, water purveyors, local officials, building officials and insurance agents.

8. Increase the participation of the fire service in the development and revision of building codes to ensure that their safety is addressed in these documents.

   —The International Association of Fire Fighters has prepared a video and nine educational modules on the importance of firefighter participation in the code development process. These should be available to the fire service in the very near future.

   —NFPA, through its Public Fire Protection Division, will work with USFA and the project team to provide data, material and support to increase awareness of the NFPA Standards Development Process, role of technical committee members and efforts to recruit Enforcers to serve on technical committees. NFPA's Enforcer Funding Program provides funding for NFPA Technical Committee participation for certain public sector committee members who have been designated by the NFPA Standards Council, for purposes of committee balance, in the category of "Enforcing Authority (E)" ("Enforcers").

   —After the workshop, the International Code Council expressed an interest in incorporating these themes into its Building Safety Month initiative. ICC is also supporting Fire Is Everyone's Fight.

Appendix A – Workshop Agenda

Day 1: Tuesday, December 11

OPENING REMARKS

Ernest Mitchell, U.S. Fire Administrator, U.S. Fire Administration

Steven Edwards, Director, Maryland Fire and Rescue Institute

Agenda Review: Kathleen Almand, Fire Protection Research Foundation

SETTING THE STAGE

Research With the Fire Service to Understand the Changing Severity of Home Fires

Stephen Kerber, Underwriters Laboratories

The Importance and Control of Residential Upholstered Furniture Flammability

Dr. Richard G. Gann, National Institute of Standards and Technology

Change is Not a Four Letter Word

George K. Healy, New York City Fire Department

THE IMPACT OF CHANGES IN HOME DESIGN AND CONSTRUCTION

Fire Safety Challenges of Green Buildings

Dr. Brian J. Meacham, Worcester Polytechnic Institute

The Performance of Dimensional and Engineered Lumber in Fire Conditions

James M. Dalton, Chicago Fire Department

The Impact of Alternative Energy Technologies on Homes

Casey C. Grant, Fire Protection Research Foundation

Spray Polyurethane Foam (SPF) in the Construction Industry

Dr. Richard S. Duncan, Spray Polyurethane Foam Alliance

Discussion and Brainstorming

All Participants

THE IMPACT OF CHANGING MATERIALS IN HOME FURNISHINGS

U.S. Consumer Product and Safety Commission Overview of Regulatory Efforts Impacting Home Furnishing Flammability

Andrew G. Stadnik and Rik Khanna, U.S. Consumer Product Safety Commission

Overview on the Combustibility and Testing of Filling Materials and Fabrics for Upholstered Furniture

Bob Luedeka, Polyurethane Foam Association

Quantifying Flaming Residential Upholstered Furniture Fire Losses

Dr. William M. Pitts, National Institute of Standards and Technology

UL Research Related to Furniture Flammability

Dr. Thomas Fabian, Underwriters Laboratories

Discussion and Brainstorming

All Participants

Day 2: Wednesday, December 12

ADAPTING FIREFIGHTING TACTICS TO THE CHANGES

Size Up, Flowpath, and Softening the Target

Daniel Madrzykowski, National Institute of Standards and Technology

Residential Fire Environment: A Fire Fighter's Perspective

Sean DeCrane, Cleveland Fire Department

Impact on Firefighter PPE, Physiology, and Training

Dr. Gavin Horn, Illinois Fire Service Institute

Discussion and Brainstorming

All Participants

TOWARDS AN ACTION PLAN

Kathleen Almand, Fire Protection Research Foundation

CLOSING REMARKS

Glenn Gaines, U.S. Fire Administration

Appendix B – Speaker Biographies

Stephen Kerber

Research Engineer, Corporate Research, Underwriters Laboratories LLC

Stephen Kerber is a fire research engineer at UL. His areas of research include improving firefighter safety, fire service ventilation, structural collapse and fire dynamics. He is a 13-year veteran of the fire service, with most of his service at the College Park Fire Department in Prince George's County, Md., where he served at ranks up through Deputy Chief. He received his bachelor's and master's degrees in fire protection engineering from the University of Maryland and is currently working on his doctorate in risk management and safety engineering at Lund University in Sweden. Kerber has also been appointed to the rank of Honorary Battalion Chief by the New York City Fire Department.

Richard G. Gann, Ph.D.

Senior Scientist Emeritus, Fire Research Division, National Institute of Standards and Technology

Dr. Richard G. Gann has been studying fires and translating that knowledge into standards and practices for 40 years. His research interests have ranged from the basic chemistry of how materials ignite and burn to how best to detect and extinguish them, and how to include smoke toxic potency in fire safety decisions. Gann has over 130 technical publications, and is currently on the Editorial Boards of Fire Technology and Fire and Materials. Gann has worked closely with the Combustion Institute, National Fire Protection Association, where he chairs the Toxicity Technical Advisory Committee and is an alternate to the Fire Test Committee and the American Society for Testing and Materials Committee E-5 on Fire Standards. He was the technical program manager for the Department of Defense's Next Generation Fire Suppression Technology Program, and currently serves as chair of the Incident Safety Officer Subcommittee on Fire Threat to People and the Environment. His leadership in the development of the measurement science for reduced-ignition propensity cigarettes has been recognized by ASTM's Simon H. Ingberg Award, the John Joseph Moakley Award, the U.S. Department of Commerce Gold Medal, and the Willem Sjolin Award of the FORUM for International Cooperation in Fire Research. In addition, Gann received a second Department of Commerce Gold Medal Award for his role in the investigation of the World Trade Center disaster and received the E.U. Condon Award for writing the Final Report on the Collapse of the World Trade Center Towers. In 2011, he was awarded the rank of Presidential Distinguished Senior Professional, the highest recognition for senior federal government employees.

George K. Healy

Battalion Chief, New York City Fire Department

Battalion Chief George K. Healy is a 21-year veteran of the FDNY, presently assigned to Battalion 51 in the 13th Division, Queens, N.Y. He was the Operations Section Chief for the Governor's Island research program on alternate strategies for combating wind-driven fires in 2008 and the ventilation and suppression exercise in 2012. He was a member of the technical review panel for the Underwriters Laboratory Assistance to Firefighters Grant on horizontal and vertical ventilation research. He has been a lecturer at the FDNY High Rise Symposium, Chicago High Rise Symposium, U.K. Fire College Symposium, Fire Department Instructors Conference and the West Midlands U.K. seminar. He is a Nassau Fire Academy instructor, Illinois Institute instructor, and instructor for the Battalion Chief Command course and Deputy Chief Development course for the FDNY.

Brian J. Meacham, Ph.D., P.E., FSFPE, C. Eng. MIFireE

Associate Professor of Fire Protection Engineering, Worcester Polytechnic Institute

Dr. Brian J. Meacham is an associate professor in fire protection engineering and architectural engineering at WPI in Worcester, Mass. He is internationally recognized as an authority on risk-informed, performance-based approaches to fire engineering and building regulation, with a focus on holistic building performance. He teaches, undertakes research, consults to governments and the private sector, and publishes widely on these topics. As a member of several national and international codes, standards and guidance development committees, he helps facilitate the transfer of knowledge between research practitioners and policymakers. His appointments include chair of the National Fire Protection Association Technical Committee on Fire Risk Assessment Methods, member of the Society of Fire Protection Engineers Standards Committee on Design Fire Scenarios, and member of the American Society of Civil Engineers 7-16 General Structural Requirements Subcommittee. He is also a member of the Board of Directors of SFPE. Meacham holds a master's degree in fire protection engineering from WPI and a doctorate in risk and public policy from Clark University. He is a licensed Professional Engineer in Connecticut and Massachusetts, a Chartered Engineer Member of the Institute of Fire Engineers in the U.K., and a Fellow of SFPE.

James M. Dalton

Coordinator of Research and Development, Chicago Fire Department

James M. Dalton, firefighter/emergency medical technician, is currently the coordinator of research and development and a fire service instructor for the Chicago Fire Department. Dalton holds an associate degree in fire science, bachelor's and master's degrees in architecture, and a master's degree in public safety administration. Dalton's experience in the fire service is preceded by over 15 years of combined academic and professional experience in areas of structural engineering, architecture and construction management. Dalton has served as a fire service subject-matter expert for the Department of Homeland Security's Assistance to Firefighters Grant research programs entitled, "The Structural Stability of Engineered Lumber under Fire Conditions" and "Firefighter Exposure to Smoke Particulates." He currently serves as an SME for "Improving Fire Safety by Enhancing the Fire Performance of Engineered Floor Systems and Providing the Fire Service with Information for Tactical Decision Making," awarded by the Commerce Department's National Institute of Standards and Technology Recovery Act Grant Program. Dalton has presented at numerous national fire service venues.

Casey C. Grant, P.E.

Research Director, Fire Protection Research Foundation

Casey C. Grant is the research director for FPRF, a nonprofit organization that works with the National Fire Protection Association as its research affiliate. His responsibilities include oversight for the multiple research projects in support of the foundation's mission to plan, manage and facilitate research on behalf of the NFPA mission to make the world safer from fire and related hazards. Grant holds a bachelor's degree from the University of Maryland and a master's degree from Worcester Polytechnic Institute, both in fire protection engineering. He is a registered Professional Engineer in fire protection engineering in the states of California and Tennessee, and is a member of both the beta and gamma chapters of the Salamander Fire Protection Honorary Society. Grant is a Fellow of the Society of Fire Protection Engineers, and has one fire protection-related U.S. patent. He is a Fellow of the Institute of Fire Engineers and has given numerous presentations on fire safety around the world. Prior to joining the foundation in 2007, Grant was the secretary of the NFPA Standards Council and assistant chief engineer, where his responsibilities included oversight for the approximately 300 NFPA codes and standards.

Richard S. Duncan, Ph.D., P.E.

Technical Director, Spray Polyurethane Foam Alliance

Dr. Richard S. Duncan is currently the technical director for the Spray Polyurethane Foam Alliance. Prior to joining SPFA, he was the senior marketing manager for Honeywell's Spray Foam Insulation business from 2006 to 2008. From 1997 to 2006, he was the global program director for CertainTeed/Saint-Gobain Insulation's New Materials and Applications Portfolio. From 1989 to 1997, he was a visiting assistant professor of mechanical engineering at Bucknell University. He holds a doctorate in engineering science and mechanics from Pennsylvania State University, a master's degree in mechanical engineering from Bucknell, and a bachelor's degree in mechanical engineering from the University of Maryland. Duncan is a registered Professional Engineer in three states and a certified Building Performance Institute Building Analyst.

Rik Khanna

Fire Program Area Team Leader, Office of Hazard Identification and Reduction, U.S. Consumer Product Safety Commission

Rik Khanna is a fire protection engineer with CPSC. Khanna has been with CPSC since 1994. He is the CPSC's fire program area team leader. Khanna provides technical support to CPSC for standards development and enforcement activities. He is the current project manager of CPSC's upholstered furniture flammability rulemaking.

Andrew G. Stadnik, P.E.

Associate Executive Director for Laboratory Sciences, U.S. Consumer Product Safety Commission

Andrew G. Stadnik joined CPSC in 1995 as AED for engineering sciences and he has been the laboratory director since 2000. His prior experience includes technical management positions at the U.S. Defense Nuclear Facilities Safety Board, Rockwell International, Rocketdyne Space Power Division and U.S. Naval reactors. He has a bachelor's degree in engineering physics and a master's degree in nuclear engineering from Cornell University and is a licensed Professional Engineer in Maryland and D.C.

Bob Luedeka

Executive Director, Polyurethane Foam Association

Bob Luedeka has been involved in the polyurethanes industry for more than 35 years. He began his career in 1972 as a buyer for a chain of U.S. department stores and then spent 28 years as co-owner of a marketing communications firm specializing in home furnishings, foam manufacturing, chemical raw materials, floor coverings and trade associations related to those industries. He received a bachelor's degree in business administration from the University of Denver. In 2005, Luedeka was elected executive director of PFA representing U.S. manufacturers of polyurethane foam and their suppliers of raw materials, equipment and services. Luedeka also serves on the Board of Directors of the Alliance for Flexible Polyurethane Foam; the governing body for CertiPUR-US, a voluntary environmental, health and safety evaluation and certification program for polyurethane foam products; and on the Board of the Fire Prevention Alliance, which provides fire prevention education information for rural communities. Previously, he was a member of the Residential Fire Safety Institute Steering Committee, advocating code revisions to require residential sprinklers. Luedeka is a member of the American Society for Testing and Materials International E5 Committee on flammability testing.

William M. Pitts, Ph.D.

Research Chemist, Engineering Laboratory, National Institute of Standards and Technology

Dr. William M. Pitts is a research chemist in the Flammability Reduction Group in the Fire Research Division of the Engineering Laboratory at NIST. He received a bachelor's degree in chemistry from the University of Virginia in 1973 and a doctorate in physical chemistry from the University of California, Los Angeles in 1978. Following a two-year National Research Council Postdoctoral Fellowship at the Naval Research Laboratory, Pitts accepted a position at the National Bureau of Standards (now NIST) in 1981. He currently serves as the project manager for the Engineering Laboratory efforts on "Reduced Flammability of Upholstered Furniture." At NIST, he has worked in the areas of turbulent mixing and chemically reacting flow, carbon monoxide formation in fires, fire extinguishment, fire measurements, the NIST investigation of the World Trade Center disaster, fire spread and ignition, safety related to hydrogen-fueled transportation, and fire safety of residential upholstered furniture. He has also served as a group leader and a program manager. His research has resulted in over 55 publications in refereed journals and monographs, as well as numerous internal and contract reports. Pitts was awarded the Department of Commerce Gold Medal for his work on the World Trade Center investigation.

Thomas Fabian, Ph.D.

Manager, Fire Safety Research, Underwriters Laboratories

Dr. Thomas Fabian is a research scientist at UL. He completed an undergraduate degree in chemical engineering at Carnegie-Mellon University, and then a doctorate in polymer science at the University of Connecticut. While in graduate school, Fabian's research focused on the use of various spectroscopic and microscopic techniques to investigate how polymer-polymer interfaces change during mixing. Following graduate school, Fabian joined Nextec Applications where he was the lead research scientist for developing polymer encapsulated textile products for the biomedical, aerospace and automotive, semiconductor, and apparel industries. Fabian joined UL in 2004 to augment their polymer and textile knowledge base. Since joining UL, some of Fabian's research areas have included fire testing of building products for wildland-urban interface areas; development of material-based small-scale fire tests to predict product-scale fire test performance for the wire and cable industry and the building products industry; fire testing of mattresses, upholstered furniture and their components; compatibility of biofuels such as ethanol blends and biodiesel blends; smoke production as a function of decomposition temperature; and characterization of combustion products toward the advancement of smoke and fire detection. Fabian continues to play an active role in standards development in the textiles, fire and smoke arenas. He is a task group leader for development of new fire test methods for building products in American Society for Testing and Materials E5, chairman of RA63 — Water Resistance test methods with the American Association of Textile Colorists and Chemists, and is active in the ASTM D2 fuel subcommittees.

Daniel Madrzykowski, PE, FSFPE

Leader, Firefighting Technology, Fire Research Division, Engineering Laboratory, National Institute of Standards and Technology

Daniel Madrzykowski has a master's degree in fire protection engineering from the University of Maryland. He has conducted research in the areas of fire suppression, large fire measurements, fire investigation and firefighter safety. Madrzykowski has worked with the International Fire Service Training Association validation committees on the "Essentials of Fire Fighting" fifth and sixth editions. He is a member of the National Fire Protection Association and the International Association of Arson Investigators, and serves on several committees for both organizations. Madrzykowski is a Fellow of the Society of Fire Protection Engineers, and currently serves as a vice president on their Board of Directors. He is also a member of the International Society of Fire Service Instructors and was named their Instructor of the Year in 2009. Madrzykowski has also assisted in the development of several classes for the National Fire Academy and for the IAAI website, www.cfitrainer.net. Earlier this year, he was appointed to the rank of Honorary Battalion Chief with the New York City Fire Department.

Sean DeCrane

Chief of Training, Cleveland Fire Department

Sean DeCrane is a 22-year veteran of the Cleveland Fire Department in Cleveland, Ohio. He is a Battalion Chief and currently serves as the Chief of Training and is responsible for overseeing all fire, technical and medical training for the division, in addition to being the Health and Wellness Officer. DeCrane also represents the International Association of Fire Fighters to the International Code Council. DeCrane has served on the National Fire Protection Association 1, Fire Code Technical Committee and International Fire Code Development Committee for the two previous cycles and will chair the 2015 edition. DeCrane also serves on the Underwriters Laboratories Fire Council and the Board of Directors for the MetroHealth Hospital Foundation, home of the regional Level 1 Trauma and Burn Center for northeast Ohio.

Gavin Horn, Ph.D.

Senior Research Scientist, Advanced Materials Testing & Evaluation Laboratory, Illinois Fire Service Institute

Dr. Gavin Horn has served as the IFSI director of research since 2004, immediately after receiving his doctorate in mechanical engineering from the University of Illinois at Urbana-Champaign. Horn's research interests lie in the areas of first responder technology development, firefighter health and safety research, material testing and design, and infrared imaging and nondestructive evaluation. He holds a senior research scientist position with the Advanced Materials Testing and Evaluation Laboratory at the University of Illinois, where he carries out static strength and fatigue testing of materials and the development of nondestructive evaluation technologies for industries ranging from aerospace to microelectronics. Horn has published 18 peer-reviewed journal articles and given more than 40 presentations at professional conferences around the world. He has been awarded a Mechanical and Industrial Engineering Alumni Board Teaching Fellowship and has been named to the UIUC "List of Teachers Ranked as Excellent by Their Students" four times. Horn also serves as a volunteer firefighter/engineer with the Savoy Village Fire Department, where he was awarded the 2011 Outstanding Service Award.

Appendix C – Workshop Participants

Kathleen Almand
Fire Protection Research Foundation

William Barnard
Maryland State Fire Marshal
(Representing the Home Fire Sprinkler Coalition)

Chuck Burkell
U.S. Fire Administration/National Fire Academy

Jim Crawford
Vision 20/20

Tina Crevier
U.S. Fire Administration

James M. Dalton
Chicago Fire Department

Sean DeCrane
Cleveland Fire Department

William Degnan
National Association of State Fire Marshals

Mike Donahue
U.S. Fire Administration/National Fire Academy

Dr. Richard S. Duncan
Spray Polyurethane Foam Alliance

Steven Edwards
Maryland Fire and Rescue Institute

John Eisel
International Association of Fire Chiefs

Teresa Everett
International Association of Black
Professional Firefighters

Dr. Thomas Fabian
Underwriters Laboratories

Howard Fisher
International Association of Black
Professional Firefighters

Alex Furr
U.S. Fire Administration

Glenn Gaines
U.S. Fire Administration

Dr. Richard G. Gann
National Institute of Standards and Technology

Dennis Gentzel
U.S. Fire Administration

Casey C. Grant
Fire Protection Research Foundation

John Hall
National Fire Protection Association

Anthony Hammins
National Institute of Standards and Technology

George K. Healy
New York City Fire Department

Dr. Gavin Horn
Illinois Fire Service Institute

Angela Hughes
International Association of Women in Fire and
Emergency Services

Bill Kehoe
Institution of Fire Engineers

Stephen Kerber
Underwriters Laboratories

Rik Khanna
U.S. Consumer Product Safety Commission

Bob Luedeka
Polyurethane Foam Association

Daniel Madrzykowski
National Institute of Standards and Technology

Larry McKenna
U.S. Fire Administration

Dr. Brian J. Meacham
Worcester Polytechnic Institute

Timothy Merinar
National Institute for Occupational Safety and Health

Ernest Mitchell
U.S. Fire Administration

Lori Moore-Merrell
International Association of Fire Fighters

Frederick Mowrer
Cal Poly College of Engineering

Deborah Neitch
International Association of Arson Investigators

Brad Pabody
U.S. Fire Administration

Deborah Pendergast
International Association of Women in Fire and Emergency Services

Dr. William M. Pitts
National Institute of Standards and Technology

Larry Preston
Maryland Fire and Rescue Institute

Milosh Puchovsky
Worcester Polytechnic Institute

Andrew G. Stadnik
U.S. Consumer Product Safety Commission

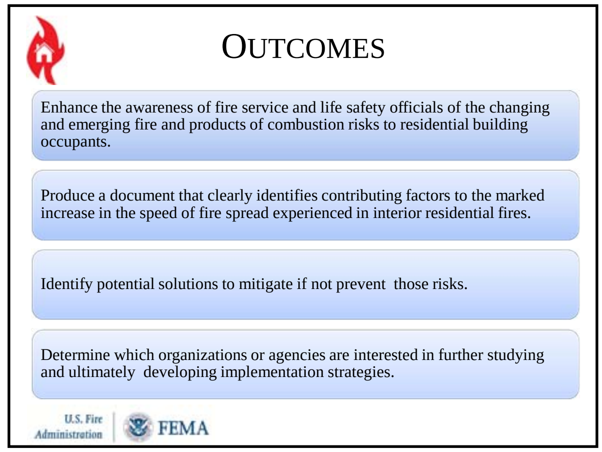
Lois Starkey
Manufactured Housing Institute

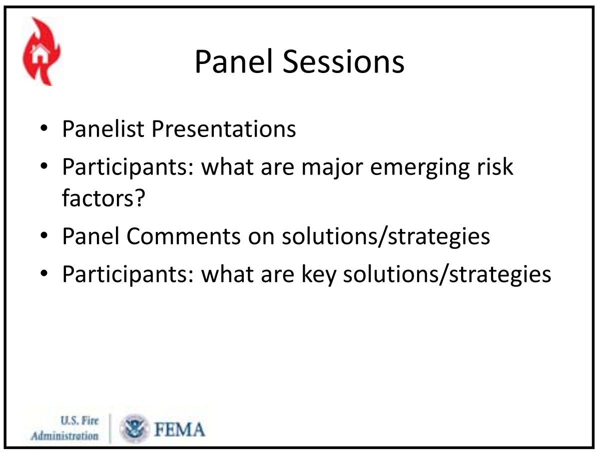
Philip Stittleburg
National Volunteer Fire Council

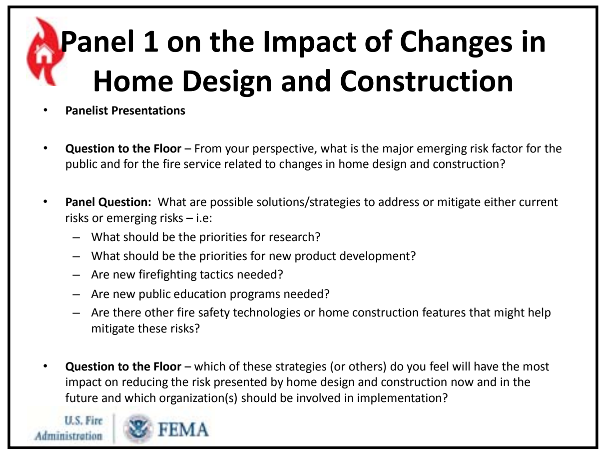
Justin Wiley
International Code Council

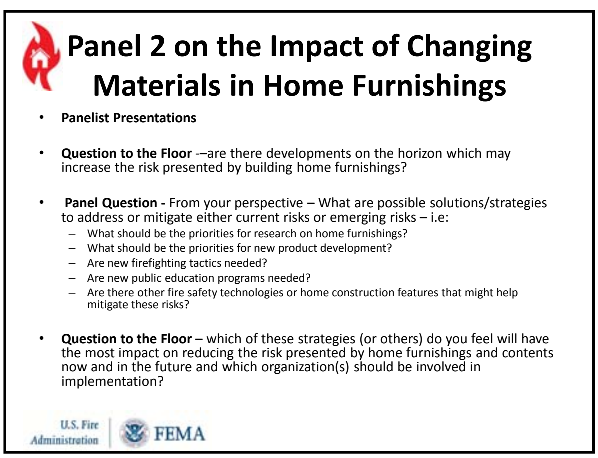
John Woulfe
International Association of Fire Chiefs

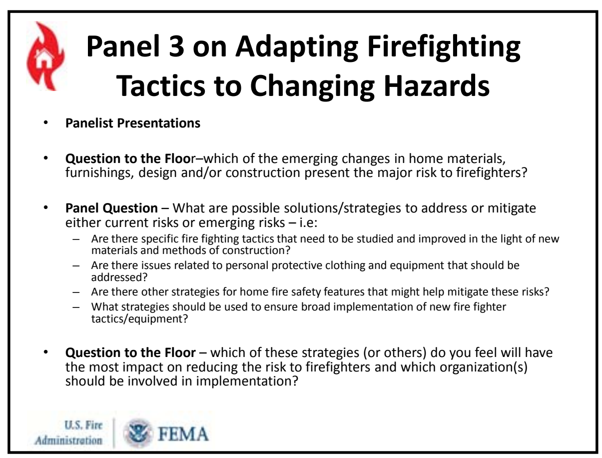
Opening Remarks











Research With the Fire Service to Understand the Changing Severity of Home Fires

Steve Kerber, PE
Fire Protection Engineer
Fire Research

The Changing Severity of Home Fires

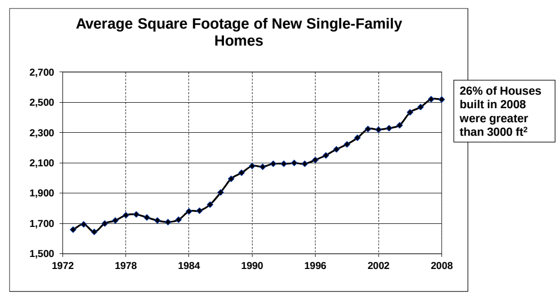
Fire Formula of Modern Homes

Larger Homes + Open Spaces + Evolving Fuel Loads + Voids Spaces

+ Changing Bldg. Materials + New Technologies =

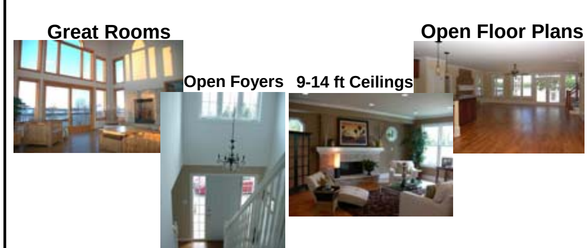
- Faster fire propagation
- Shorter time to flashover
- Rapid changes in fire dynamics
- Shorter escape times
- Shorter time to collapse
- New/Unknown Hazards

Larger Homes



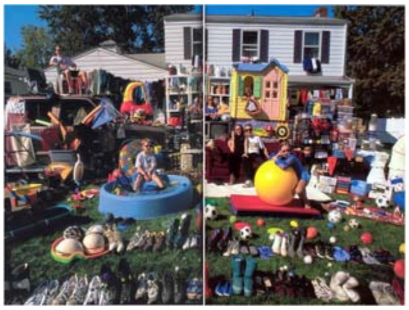
Open Spaces

Open Spaces



•All of these features add volume/air which allows the fire to grow and smoke to spread.

Evolving Fuel Loads



The contents of a single-family home.

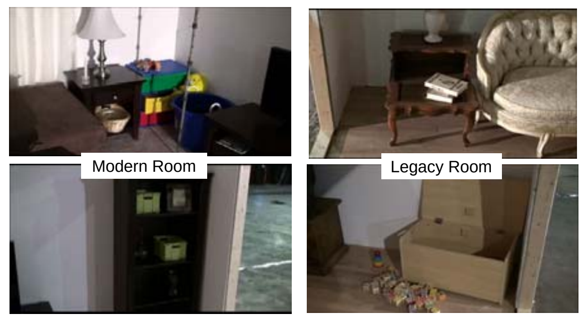
Now dominated by synthetic materials.

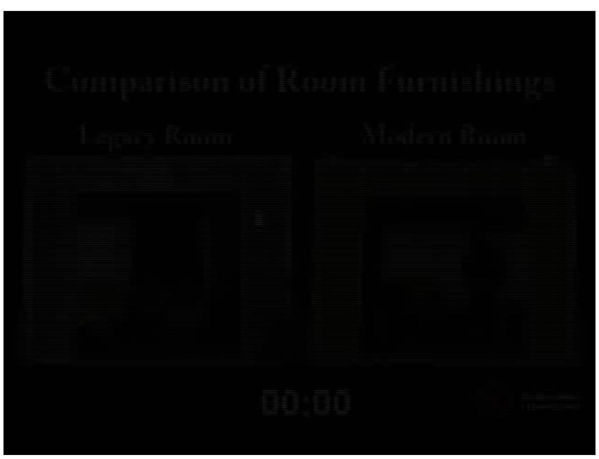
Source: National Geographic Magazine

Evolving Fuel Loads - Experiment

Evolving Fuel Loads - Experiment

Evolving Fuel Loads - Experiment





Open Void Spaces – Floor and Roofs

Changing Building Materials - Sheathing

Solid Boards → Plywood → OSB → Asphalt Fiberboard → Cardboard → Polyisocyanurate Foam

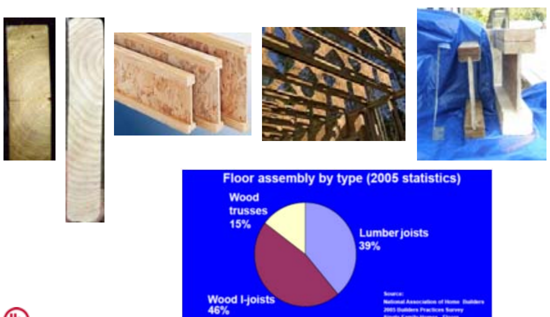
Prince William County, VA – May 25th 2008 – 1FF LODD

Changing Building Materials - Linings

Plaster and lath → Gypsum Board

Changing Building Materials – Structural Comps.

Old Growth Lumber → New Growth Lumber → Engineered Lumber (I joists, Trusses, C joists)



Graphic From AFPA

Changing Building Materials - Windows

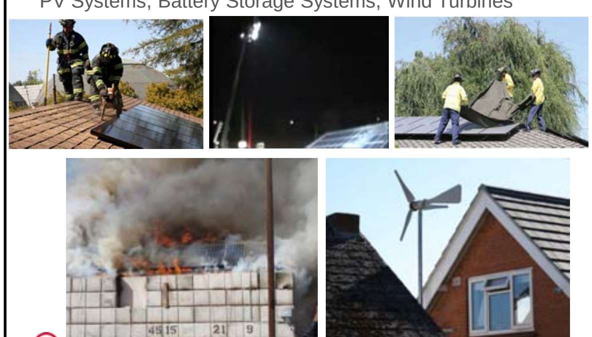
Single Glazed → Double Glazed → Wood Framed → Vinyl Framed

Changing Building Materials - Doors

Solid Core → Hollow Core → Composite Doors

New Technologies

PV Systems, Battery Storage Systems, Wind Turbines



Smaller Home Lots

How Close is too Close?
1976: 10,100 sq. ft.
2008: 8,800 sq. ft.

9/2012 4 Homes burn in British Colombia

4/2012 5 Homes burn in Chesapeake, VA

3/2012 2 Homes burn in Loudon County, VA

19

The Firefighters' New Work Place

Houses are getting larger

- 1973: 1,600 sq. ft. 2008: 2,500 sq. ft.

Housing lots are getting smaller

- 1976: 10,100 sq. ft. 2008: 8,800 sq. ft.

During the past 50 years fuel loads have in homes have changed

- Resulting in fuel rich fire conditions within homes

Home designs more open (less compartmentation, engineered structural members) and more energy efficient (multi-pane windows, wrapped in plastic, alternate energy sources)

Evolutions in building materials create changes in the Fire Environment. How all of these changes compound is not well understood. Standards, Codes and Fire Service knowledge can't keep up.

Have staffing, training, tactics changed to adapt to these changes?

The Modern Firefighter Environment

Fire Fighters?

How much do you know about fire?

- Fire Fighter I – 102 hrs (3 hrs fire behavior)
- Fire Fighter II – 60 hrs (No fire behavior)
- Fire Officer I and II – 108 hrs (No fire behavior)

1% OF YOUR BASIC TRAINING?

How about Chief level training or continuing education training?

Does experience fill the gap?

Experience?

A broad look at the US Fire Service…

- **1.1 Million Firefighters**
- **10 Million Structure Fires in 20 years (1990-2010)**
- **Average of 10 fires as first due in 20 year career**
- **Typical career**
  - **- 5 years on engine (3 fires)**
  - **- 5 years on truck (2 fires)**
  - **- 5 years as officer (3 fires)**
  - **- 5 years as chief (2 fires)**

Uncertainty and Complexity

- Fuel properties
- Fuel quantity
- Layout of fuel
- Ventilation (natural or mechanical)
- Compartment geometry – volume, ceiling height
- Compartment layout
- Location of fire
- Ambient conditions (wind, temperature and RH)
- Staffing
- Arrival time and order
- Constructions materials
- Construction practice and code compliance
- How long fire has been burning
- What diameter and length of hoseline
- Occupied or not, location of victims
- Smoke or fire showing
- Exposures
- Hazards, power lines, security bars
- Water supply
- What to say on radio
- Fire protection systems, sprinklers, alarms, pumps
- Risk analysis
- What nozzle and flow
- Tools available, PPV, TIC, hand tools, etc.
- Mayday procedures
- Standard operating procedures
- Collapse hazards
- Pride, Ego
- Situational awareness
- Type of roof
- Bystander Information
- What tools to use

24

Technology

- **Turnout Gear**
- **SCBA**
- **Tools – PPV Fans, PASS Devices, Hydraulic FE, Thermal Imaging Cameras, Locator Devices, Nozzles, Foams, Water Additives, CAFS…**
- **The Internet**

Risk may emerge when technological change is not accompanied by appropriate prior scientific investigations or post-release surveillance of the resulting impacts.

25

Expectations – "All Hazard"

Fire Suppression
HAZMAT
EMS
Vehicle Extrication
Technical Rescue
- High Angle Rescue
- Trench Rescue
- Water Rescue
- Confined Space Rescue

Technology Mitigation
- Electric Vehicles
- PV Systems
- Wind Turbines

Personnel Management
Customer Service
People Skills
EEO
Sensitivity
Leadership
Risk Assessment
Risk Management
Fitness
Mental Health
Instructor
Incident Management
…

26

UL Firefighter Research

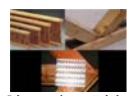
Modern Homes Topics


Larger Homes
2008, 2010 DHS Grants


Open Spaces
2008, 2010 DHS Grants


Evolving Fuel Loads
2007, 2008, 2010 DHS Grants, FDNY


Voids Spaces
2006 DHS and 2009 NIST Grants


Changing Bldg. Materials
2006, 2010, 2011 DHS and 2009 NIST Grants


New Technologies
2009 DHS Grant

Structural Stability of Engineered Lumber in Fire Conditions – 2006 DHS Grant

Structural Element	Type	Ceiling	Fire Fighter Breach (min : sec)
2x10 Joist Floor	Legacy	None	18:35
Wood I Joist Floor	Lightweight	None	6:00
2x10 Joist Floor	Legacy	Lath and plaster	79*
2x10 Joist Floor	Legacy	Regular gypsum wallboard	44:40
Wood I Joist Floor	Lightweight	Regular gypsum wallboard	26:43
Metal Gusset Truss Floor	Lightweight	Regular gypsum wallboard	29*
Finger Joint Truss Floor	Lightweight	Regular gypsum wallboard	26:30

29

Firefighter Exposure to Smoke Particulates - 2007 DHS Grant

Conducted material, room scale experiments and compared to measurements at actual incidents with CFD with focus on overhaul

Provided data to Cincinnati Medical School for analysis

- Ultrafine Particulates (90% invisible during overhaul)
- Large variations of gas concentrations and particulate depending on fuel chemistry and ventilation conditions
- Synthetic materials produced approximately 12 times the particles
- Increased risk for CHD

30

Impact of Ventilation on Fire Behavior in Legacy and Contemporary Residential Construction – 2008 DHS Grant

15 Full-scale house experiments
- Stages of fire development
- Risk analysis
- Forcing the front door is ventilation
- Rate of change
- Where to vent and why
- No smoke showing
- How much ventilation is needed
- Coordination
- VEIS
- Smoke tunneling
- Impact of closed door
- Pushing fire

31

Firefighter Safety and Photovoltaic Systems – 2009 DHS Grant

Experimental PV arrays were constructed in Northbrook and DELCO, PA.

- Shock hazard due to water
- Shock hazard due to contact during FF operations
- Emergency disconnect techniques and understanding
- Severing of conductors
- Assessment of low light hazards and covering techniques
- Hazards from fire damaged modules
- Protection of FF PPE

Improving Fire Safety by Understanding the Fire Performance of Engineered Floor Systems and Providing the Fire Service with Information for Tactical Decision Making – 2009 NIST ARRA Grant

Conducted component, furnace, full-scale basement field and lab and Actual house experiments examining several types of residential floor systems

- Collapse of all unprotected wood floors are within FF operational timeframe
- Size-up should include basement fire location and amount of ventilation
- Sounding the floor, sag and TIC scanning are not reliable predictors of collapse
- Flow paths are crucial for basement fires
- Fire attack should take place on level of fire
- Gas temperatures above fire can be misleading

Effectiveness of Fire Service Vertical Ventilation and Suppression Tactics – 2010 DHS Grant (June 2013)

Conducted 17 full-scale house fire experiments and 2 full-scale attic fires

- Limitations of vertical ventilation
- Coordination of vertical vent
- Analysis of hole size
- Impact of hole location
- Door Control
- Modern vs. legacy house fire
- Impact of flow paths
- Analysis of external water application
- Impact of closed door
- Comparison of fiberglass vs. spray applied insulation in an attic fire

Governors Island Experiments in Partnership with FDNY and NIST

Conducted 20 full-scale townhouse fire experiments to bring together everything previously learned and allow FDNY to answer questions and see results live

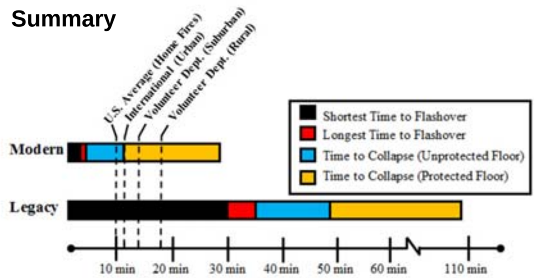
- Examined basement fires
- Examined ventilation and suppression tactics
- Examined attic fires
- Examined rail road flat construction
- Results to be presented to FDNY in early 2013
- Results to be presented at FDIC 2013

Study of Residential Attic Fire Mitigation Tactics and Exterior Fire Spread Hazards on Fire Fighter Safety – 2011 DHS Grant

Conduct full-scale experiments analyzing exterior fire spread, ignition sources, attic fire mitigation tactics

- Examine impact of new and old construction materials and practices
- Examine fires in ½ story structures
- Awarded August 2012
- Completion by August 2014

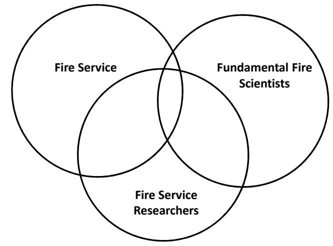
Summary



The operational timeframe of the fire service continues to shrink, this needs to slow down, stop or reverse (codes, standards, manufacturers, builders, others) and adaptations need to be made by the fire service.

37

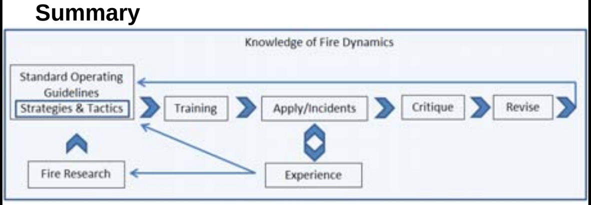
Summary



Now is a good time, fundamental fire scientists have laid the fire dynamics groundwork, fire service researchers have some funding available and the fire service is asking for more research and is participating in it.

38

Summary



To move forward, knowledge of fire dynamics has to be the foundation of the firefighting system, experience and fire research need to work together to improve strategies and tactics. Without knowledge we don't know what is happening and we don't know what works and what was lucky.

Technology needs to support this system with the understanding that no amount of technology can replace knowledge (Turnout gear, SCBA, predictive tools, suppression tools, magic widgets…)

Without dissemination of research results it is useless, research must be done with the fire service and the fire service must have knowledge to interpret the results (NIMS model through USFA, tie to grant funding? CONED?)

39

QUESTIONS and DISCUSSION

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engineering laboratory

The Importance and Control of Residential Upholstered Furniture Flammability

Richard G. Gann, Ph.D. — Senior Scientist Emeritus
rggann@nist.gov — Fire Research Division

Changing Severity of Home Fires
December 11, 2012

NIST National Institute of Standards and Technology U.S. Department of Commerce

My Messages

- Soft furnishings (beds and upholstered furniture) are the major amplifiers of ignition sources in residences
- Mattress flammability is being regulated successfully
- The contribution of residential upholstered furniture to fire losses has been significantly underestimated
- Improved flammability standards for residential upholstered furniture will greatly reduce fire losses

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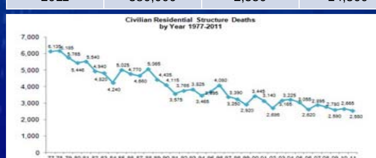
Residential Fire Losses

Year	Reported Fires	Civilian Deaths	Civilian injuries	Property (2011 $B)
1977	750,000	6,135	22,600	8.1
1990	467,000	4,015	20,650	7.3
2000	379,500	3,445	17,400	7.4
2004	410,500	3,225	14,175	7.1
2011	386,000	2,550	14,360	7.1



Source: Karter, NFPA (2012)

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Residential Fire Characteristics (NFPA)

- 92 %: Fire deaths occurring in homes
- 62 %: Home fire deaths with no working smoke alarms
- 24 %: Fire deaths occurring in living spaces
- 4 %: Fires occurring in living spaces
- 25 %: Fire deaths occurring in sleeping rooms
- 8 %: Fires occurring in sleeping rooms

The last two groups comprise nearly half of the fire deaths and result from a far smaller number of fires.

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Fuels in Residential Fires

- Cooking materials: Can be easy to ignite, but low combustible mass
- Clothing: Can be easy to ignite and fast burning, low combustible mass, but intimate to body
- Case goods: Hard to ignite, relatively slow burning
- Flooring: Hard to ignite and slow/moderate burning
- Textile products: Can be easy to ignite and fast burning, but low combustible mass
- Soft furnishings (upholstered furniture, beds): Can be easy to ignite and fast burning, and high combustible mass

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Residential Soft Furnishings

- Recognized as important by the 1960s
- Quantified beginning *ca.* 1980
- Fire tests for residential furnishings were for ignition resistance
  - Cigarette, small flame
  - Furniture: small specimens, often single component materials
  - Mattresses: whole unit
  - Fail obvious "bad actors
- Promulgators: California Bureau of Home Furnishings, Upholstered Furniture Action Council, U.S. Consumer Product Safety Commission

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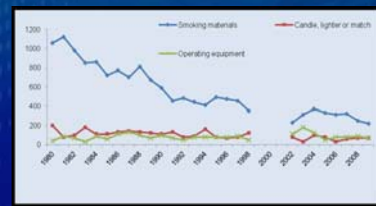
Curbing of Bed Fires

- 2002-2006: *ca.* 390 deaths, 1300 injuries and $1¼ B property loss from 11,000 reported fires starting in beds
- 1972 test for cigarette ignition resistance (16 CFR 1632)
  - Strong igniting cigarette
  - Multiple locations on whole mattress
- 2005 requirement capping fire size of mattress/foundation sets (16 CFR 1633)
  - Intense flaming ignition on top and side of a whole mattress
  - Flashover requires ≥ 1,000 kW heat release rate (HRR)
  - Regulation limits HRR to 200 kW, with no early and high HR
  - Bedclothes can add 200 kW to 400 kW

Fires Started in Upholstered Furniture

2002-2004: *ca.* 500 deaths, 900 injuries and $0.4 B property loss from 7,000 reported fires starting in residential upholstered furniture



Deaths

Ahrens, NFPA (2011)

Underestimation of the Residential Upholstered Furniture Fire Role

Role of Furniture	Deaths	Injuries	Property
First item ignited	480	840	$430 M
Flame ignition	60	220	$73 M
Not first item ignited	2100	12,100	$6,800 M
Principal contributor to fire spread	130	280	$140 M

Average annual data, 2006 to 2010
Hall, NFPA (2012)

Curbing of Residential Furniture Fires

- Cal TB 117 (mandatory in California only)
  - Cigarette ignition resistance of padding materials under a specified fabric
  - Small flame resistance of bare foam
- UFAC (voluntary)
  - Cigarette ignition resistance of fabrics over a specified foam, paddings under a specified fabric.
  - Non-compliant fabrics can be used with a barrier material
- Cal TB 116 (mandatory in California only)
  - Cigarette ignition resistance of item or prototype mock up
- Cal TB 133 (mandatory for contract furniture in California only)
  - Heat release rate limit following large flaming ignition of item

Success of Fire Tests Not Quantified

- Large drop in fire losses involving soft furnishings
- Concurrent rise in prevalence of working smoke alarms
- Decrease in smoking
- Recent advent of less fire-prone cigarettes
- Changes in upholstery component materials
  - Fashion
  - Advances in polymer chemistry
  - Compliance with fire tests
- Changes in home designs (size, doorways, etc.)
- No incidence data for non-ignitions

Fire Retardant Additives

- Fire retardant chemicals added to materials to pass the tests and improve fire safety
  - The regulations do not prescribe solutions
  - The market drives solutions toward low cost and superior properties of the finished product
  - Additive levels are typically the minimum needed to pass the test
- Concerns over environmental and toxicological effects of some fire retardant additives date to at least the 1980s
- Some fire retardant additives have been removed from use

Recent Annual Fire Losses*

	Reported Fires	Civilian Deaths	Civilian Injuries
Total in Residences	386,000	2,550	14,400
Cooking	150,000	140	3,500
Beds	11,000	400	1,300
Furniture (1st ignited)	7,000	500	900
Furniture (amplifier)	2,000	130	280
Possible future total (mature cig & bed regs)**	375,000	2,000	13,000
Net Furniture**		400	800

* CPSC and NFPA data

** my estimates

Tactics for Reducing Furniture Fire Losses

- Furniture standards
  - Stronger cigarette ignition resistance tests
  - Larger flaming ignition sources
  - Limit(s) on heat release rate
- Fire sensors and alarms
  - Nuisance-free units
  - Low maintenance units
  - Universal installations
- Residential sprinklers

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The Importance and Control of Residential Upholstered Furniture Flammability

Thank You!

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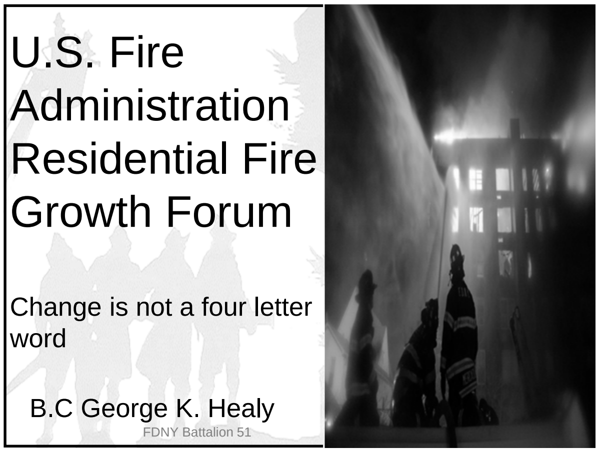
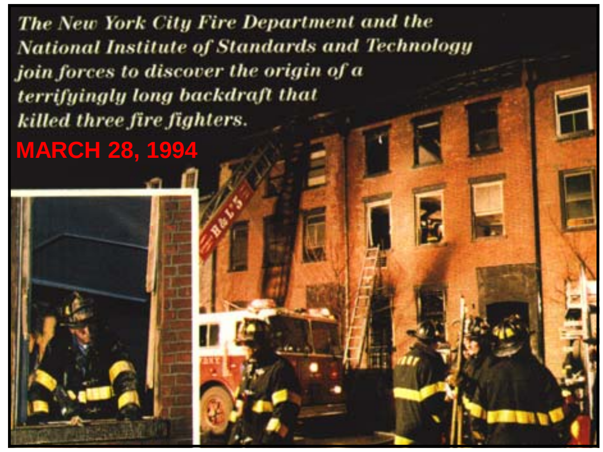
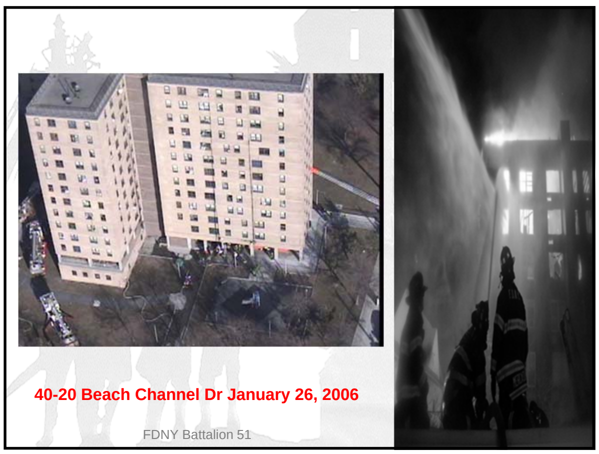
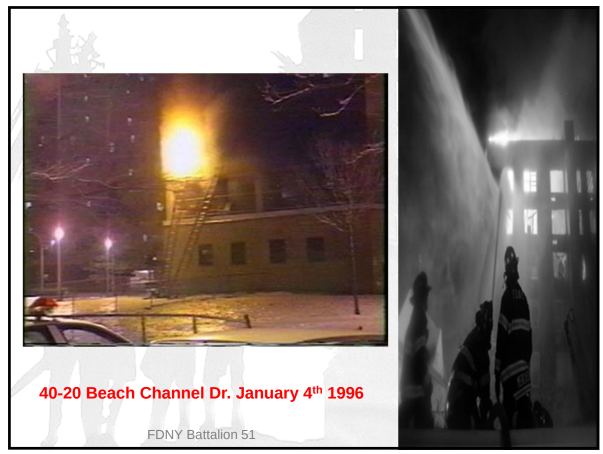
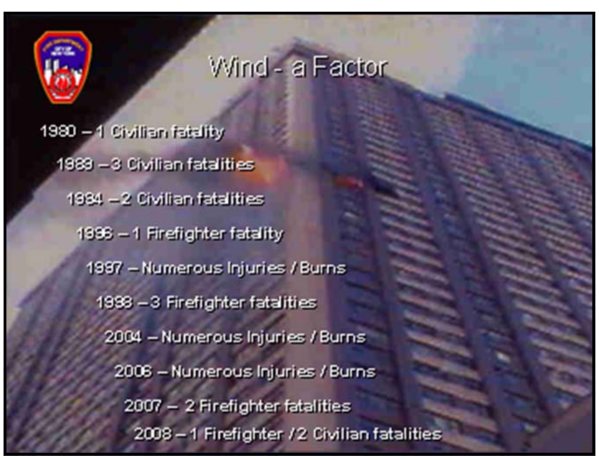
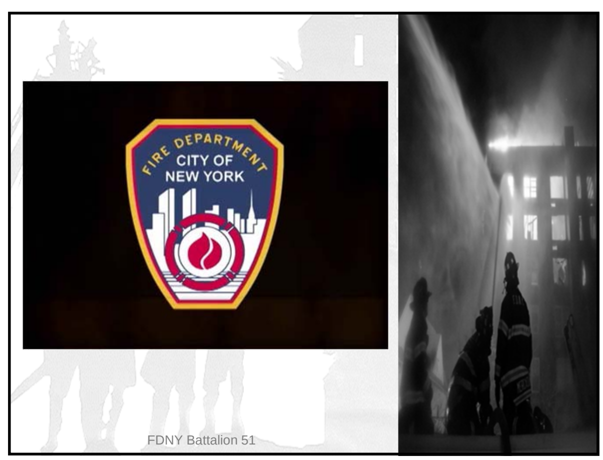

U.S. Fire Administration Residential Fire Growth Forum
Change is not a four letter word
B.C George K. Healy
FDNY Battalion 51


The New York City Fire Department and the National Institute of Standards and Technology join forces to discover the origin of a terrifyingly long backdraft that killed three fire fighters.
MARCH 28, 1994


40-20 Beach Channel Dr January 26, 2006
FDNY Battalion 51


40-20 Beach Channel Dr. January 4th 1996
FDNY Battalion 51

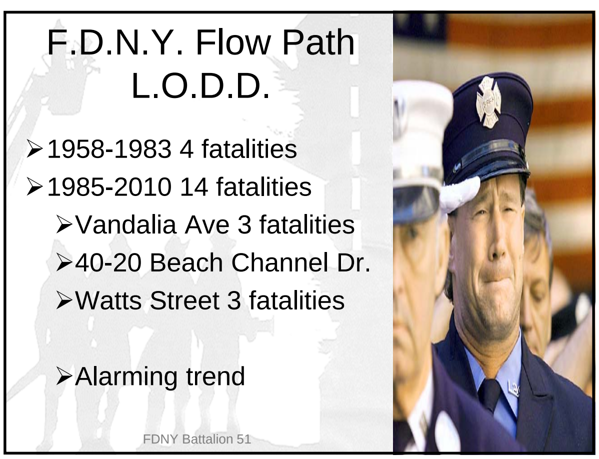

Wind - a Factor
1980 – 1 Civilian fatality
1983 – 3 Civilian fatalities
1984 – 2 Civilian fatalities
1986 – 1 Firefighter fatality
1987 – Numerous Injuries / Burns
1998 – 3 Firefighter fatalities
2004 – Numerous Injuries / Burns
2006 – Numerous Injuries / Burns
2007 – 2 Firefighter fatalities
2008 – 1 Firefighter / 2 Civilian fatalities


FIRE DEPARTMENT
CITY OF NEW YORK
FDNY Battalion 51


Wind Control
FDNY Battalion 51


Stairwell Pressurization
FDNY Battalion 51


Polo Grounds Housing project
(11/13/2009, NYC)


F.D.N.Y. Flow Path L.O.D.D.
➢1958-1983 4 fatalities
➢1985-2010 14 fatalities
➢Vandalia Ave 3 fatalities
➢40-20 Beach Channel Dr.
➢Watts Street 3 fatalities
➢Alarming trend
FDNY Battalion 51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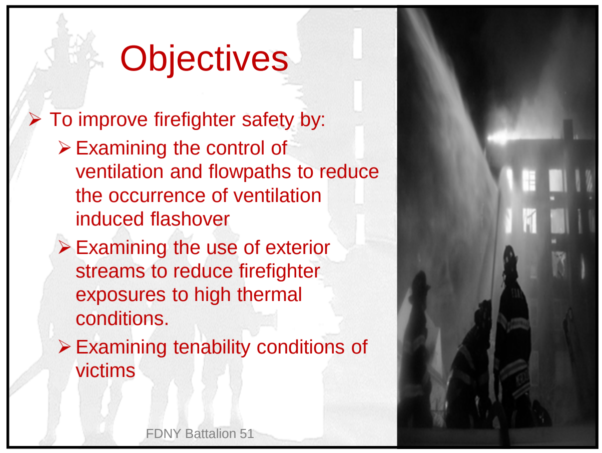
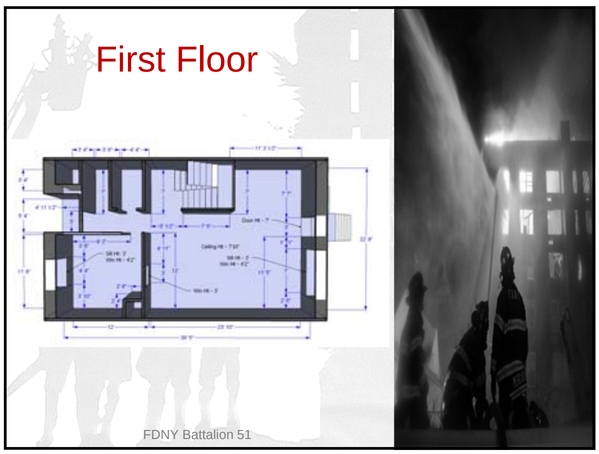
Governor's Island 2012
Examination of the Impact of Ventilation and Exterior Suppression Tactics on residential Fires
FDNY Battalion 51

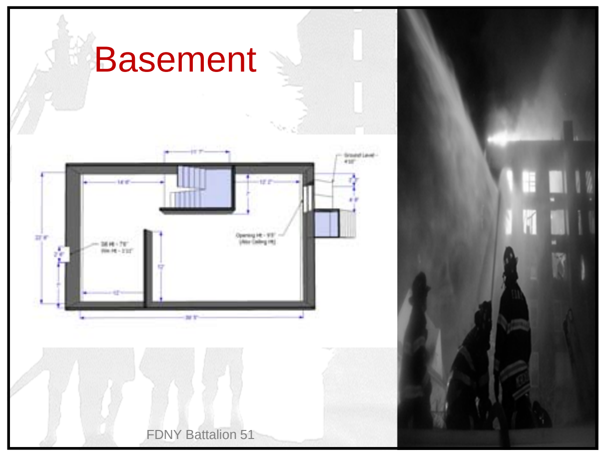

Objectives
➢ To improve firefighter safety by:
➢ Examining the control of ventilation and flowpaths to reduce the occurrence of ventilation induced flashover
➢ Examining the use of exterior streams to reduce firefighter exposures to high thermal conditions.
➢ Examining tenability conditions of victims
FDNY Battalion 51

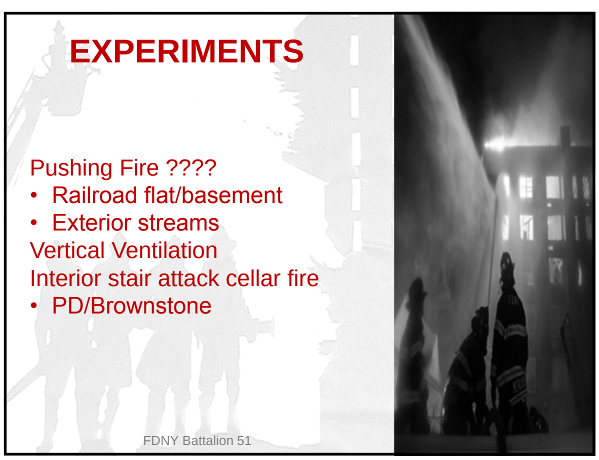

Row Houses

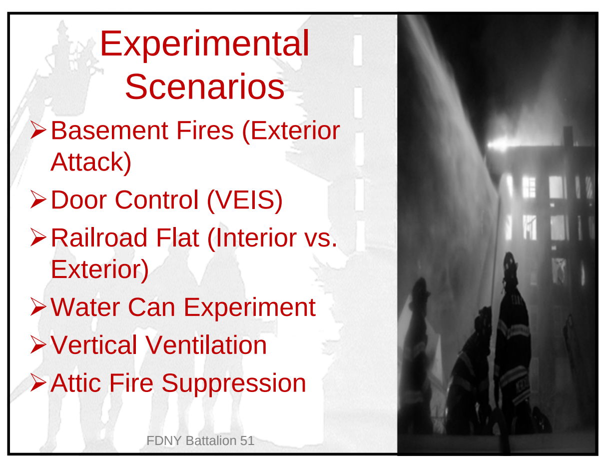

Preparation


Second Floor – 4 bedroom
FDNY Battalion 51


First Floor
FDNY Battalion 51


Basement
FDNY Battalion 51


EXPERIMENTS
Pushing Fire ????
• Railroad flat/basement
• Exterior streams
Vertical Ventilation
Interior stair attack cellar fire
• PD/Brownstone
FDNY Battalion 51


Experimental Scenarios
➢Basement Fires (Exterior Attack)
➢Door Control (VEIS)
➢Railroad Flat (Interior vs. Exterior)
➢Water Can Experiment
➢Vertical Ventilation
➢Attic Fire Suppression
FDNY Battalion 51

INSTRUMENTATION

Railroad Flat 642A – No Additional Ventilation/Exterior Attack

- All exterior opening closed except the kitchen windows.
- Fire ignited in sofa in the middle room
- Fire allowed to spread into kitchen
- Hose stream through the window into the fire in the kitchen.

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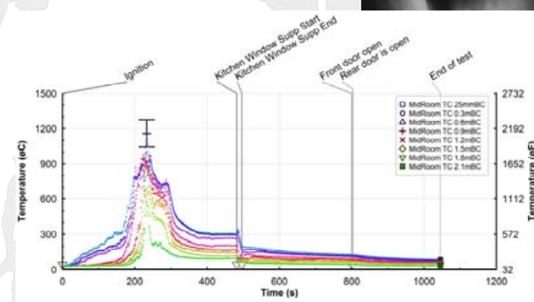
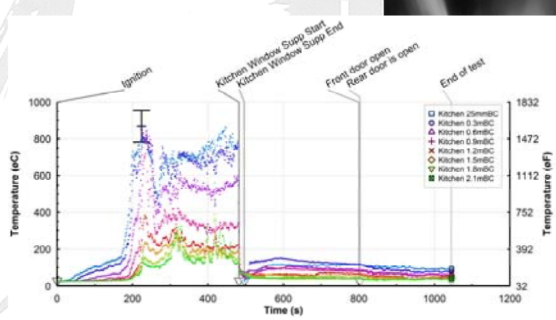


Kitchen



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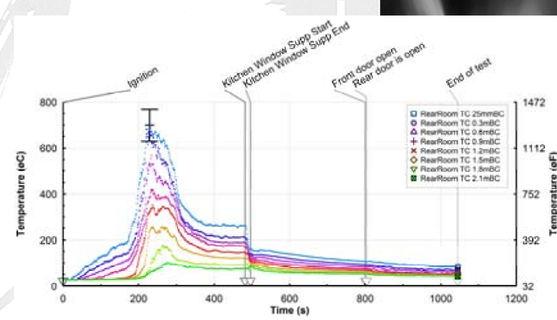
Rear Room



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Railroad Flat 640B – Vent Front and Rear/Exterior Attack from Rear

- All exterior opening closed except the kitchen windows.
- Fire ignited in sofa in the middle room
- Fire allowed to spread into kitchen
- Rear windows vented.
- Rear door opened.
- First attack from rear door
- Second attack, hose stream through the window into the fire in the kitchen.

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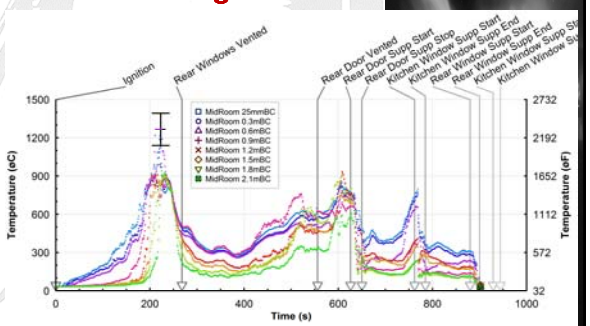
Middle Room - Room of Origin



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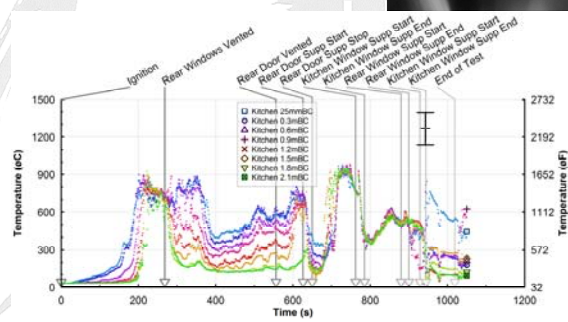
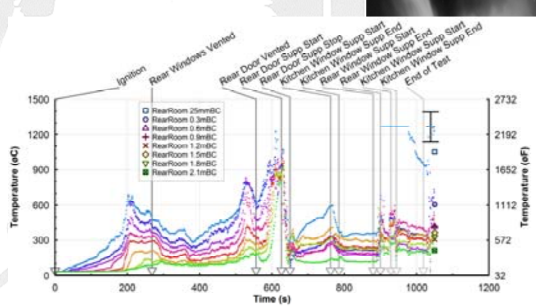
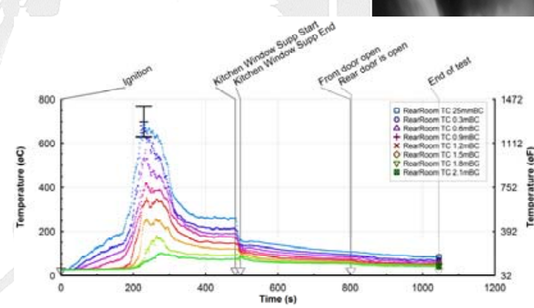




Rear Room- 642 A



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642B-Door Control and "VEIS"

- All exterior vents are closed
- There are two bedroom of next to each other on the rear. One has the interior door to the hall closed, the other has the interior door to the hall open.
- Fire ignited in a sofa in the living room
- Front door is the first vent
- Then the window to the "open" bedroom was vented.
- This follows with the window to the "closed" bedroom being vented.
- Suppression from the front door.

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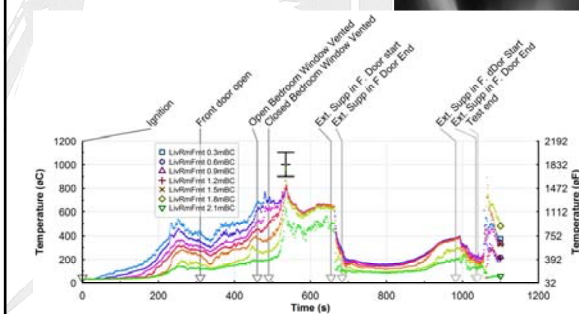
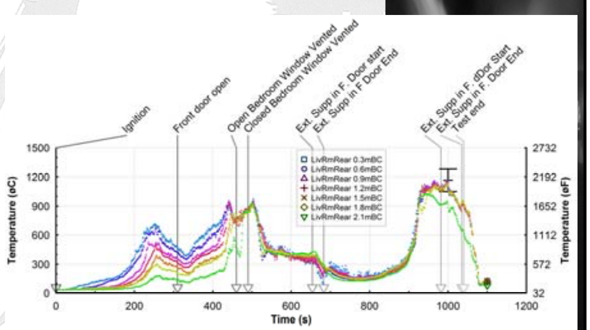
642B-DOOR CONTROL AND "VES"

642B-DOOR CONTROL AND "VEIS"



Living Room Rear



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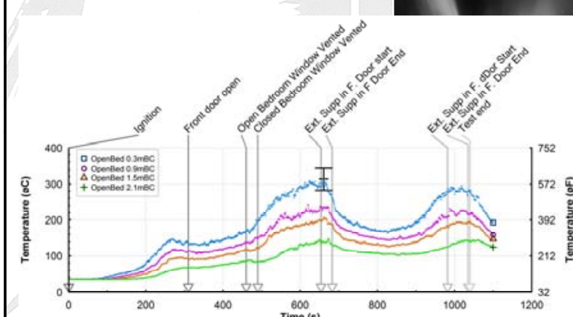
Open Bedroom



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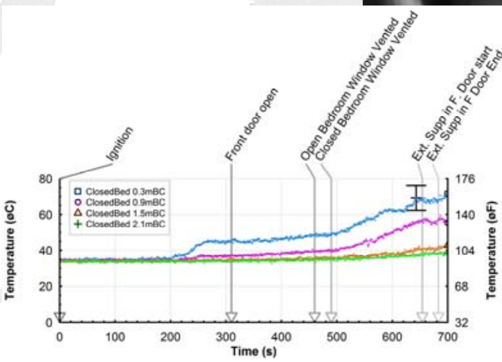
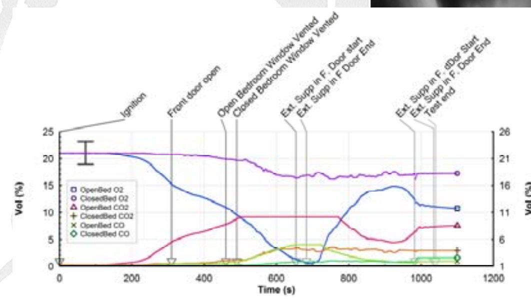
Closed Bedroom





BASEMENT FIRE ATTACK

BASEMENT FIRE ATTACK

BASEMENT FIRE ATTACK

- Front door open
- Fire allowed to grow
- Nozzle in stairs-20 seconds
- Temperatures- 1600 F to 1400 F
- Are we protecting the interior?
- Are we allowing the fire to burn?
- Future considerations

Private Dwelling-Brownstone-Old Law-Commercial

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Thank
you

Fire Safety Challenges with Green Building Features

Fire Safety Challenges of Green Buildings

Brian J. Meacham, PhD, PE, FSFPE
Associate Professor, Fire Protection Engineering

United States Fire Administration
Changing Severity of Home Fires Workshop
11-12 December 2012, Maryland Fire and Rescue Institute

Brian Meacham, 11 December 2012 1 Worcester Polytechnic Institute

Overview

- Green buildings are a global focus. Several green building rating schemes and green building codes exist; however, the extent to which fire safety considerations are addressed within theses systems, and whether potential fire hazards may be created by green building elements and features, has not been systematically studied.

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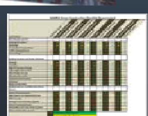
Overview



- Some existing studies highlight several of the concerns
  - NASFM – *Bridging the Gap: Fire Safety and Green Buildings Guide*
  - BRANZ (New Zealand) – *Building Sustainability and Fire-Safety Design Interactions*
  - BRE (England) – *Impact of Fire on the Environment and Building Sustainability*

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Overview

- Recent study supported by the Fire Protection Research Foundation
  - Identify documented fire incidents in the built inventory of green buildings
  - Define a specific set of elements in green building design, including configuration and materials, which, without mitigating strategies, increase fire risk, decrease safety or decrease building performance in comparison with conventional construction
    - http://www.nfpa.org/assets/files//Research%20Foundation/RFFireSafetyGreenBuildings.pdf

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Green Objectives

- Green / Sustainability Objectives
  - Limit impact on environment
    - Limit impact to environment due to toxic releases into air, water and soil
    - Lower overall carbon emissions
    - Slow pace of climate change
    - Better utilize natural resources
  - Promote new technologies, materials and methods to facilitate the above

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Green Technologies

- Green / sustainability objectives are driving changes in building design and technology
  - New façade material, façade with louvers for shading, double-wall façade for HVAC, …
  - New insulation materials, construction, …
  - Green roofs, green interior spaces, …
  - Photovoltaic panels, wind turbines, cogeneration, hydrogen fuel cells, …
  - More natural lighting, natural ventilation, …

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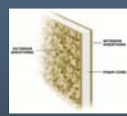
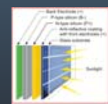
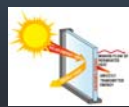
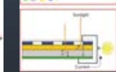
Potential Fire Challenges

- Material properties
  - High thermal insulation vs. flammability
    - New materials as interior lining, façade, insulation, within sandwich panel and more   increased fuel load, distribution, flame spread, smoke spread…
    - High thermal insulation vs. effect on compartment temperatures in a fire
    - Sudden glazing failure and modified burning environment



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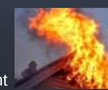
http://koreabridge.net/post/haeundae high ise-fire busan-ma ne-c ty bu ns



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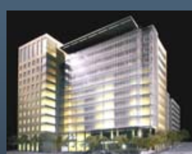
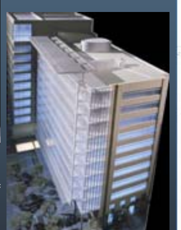
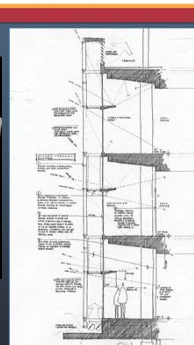
Potential Fire Challenges

- Naturally vented double skin façade, composed of two separate planes of glass separated by a 76 cm (30-inch) air space
- Access and fire environment concerns?

http://gaia.lbl.gov/hpbf/des gn_g4.htm

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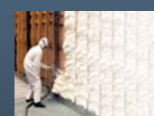
Potential Fire Challenges

- Material properties
  - Toxicity (IAQ) vs. fire retardant qualities
    - Chemical additives in foam insulation and other materials   toxicity under fire and non-fire conditions?
      - Polystyrene foam insulation used in building insulation (both XPS, such as Styrofoam, and EPS) is treated with hexabromocyclododecane, (HBCD), a persistent, bioaccumulating, and toxic fire retardant



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h p www.noburn.com intumescent-pa nts fire etardant coatings

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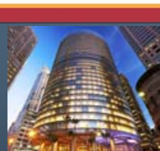
Potential Fire Challenges

- Natural ventilation vs. smoke management
  - Smoke exhaust?
  - Interior environment?

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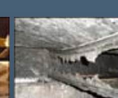
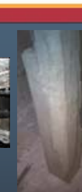
Potential Fire Challenges

- Reduced and/or natural material vs. reduced strength or fire protection
  - Lightweight engineered lumber
  - High strength concrete
  - Combustible interior finishes

h p www.u com g obal/eng/pages offer ngs indus r es buildingmaterials/fire/fi eservice/l ghtweight/



Courtesy MSU


h p www.nh sh s org bamboo-wa n e or design-by-kengo-kuma assoc ates 02-g eat bamboo-wall-inter or design/

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WPI
Potential Fire Challenges
• Green exterior vs. fuel load and FF access
http://inhabitat.com/flower ower 380 potted p ants line-parisian apartment- acade/
Brian Meacham, 11 December 2012
13
Worcester Polytechnic Institute


WPI
Potential Fire Challenges
• Green exterior / interiors vs. fuel load
Dry Scotch Pine Tree Fire
NIST
http://directory.leadmaverick.com Southe n Botanical
nc DallasFort-Wor hA ington/TX/10/15993/index.aspx
Brian Meacham, 11 December 2012
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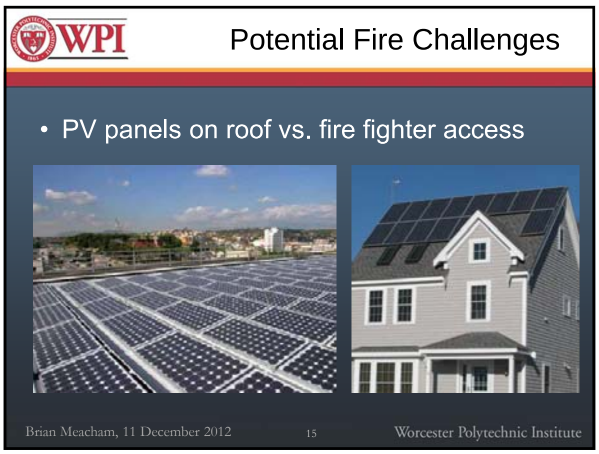
WPI
Potential Fire Challenges
• PV panels on roof vs. fire fighter access
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WPI
Potential Fire Challenges
• PV panels on roof vs. fire hazard
h p www.co scoas advoca e com au news warn ng so ar-
panel-owners 1256986/
https://solarjuice.com blog/bu d ngs-and-pv/solar-panels and-fi e/
Brian Meacham, 11 December 2012
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WPI
Potential Fire Challenges
• Green roof vs. fire fighter access
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WPI
Potential Fire Challenges
• High density housing
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Green Elements / Attributes

- 80 Green Building Elements / Attributes
  - Structural Materials and Systems (9)
  - Exterior Materials and Systems (13)
  - Façade Attributes (4)
  - Interior Materials and Finishes (9)
  - Interior Space Attributes (10)
  - Building Systems & Issues (12)
  - Alternative Energy Systems (9)
  - Site Issues (14)

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Fire Risk / Hazards

- 22 Fire Risk / Hazard Attributes
  - Presents a potential hazard
    - E.g., ignition, electrical shock, explosion, toxicity
  - Hazard attributes
    - E.g., readily ignitable, burns readily once ignited, contributes more fuel / increased HRR, etc.
  - Failure potential
    - E.g., shorter time to failure, failure affects burning characteristics or smoke spread or…
  - May impact building FP system or feature
    - E.g., smoke/heat venting, suppression effectiveness, apparatus access, firefighter access & operations…

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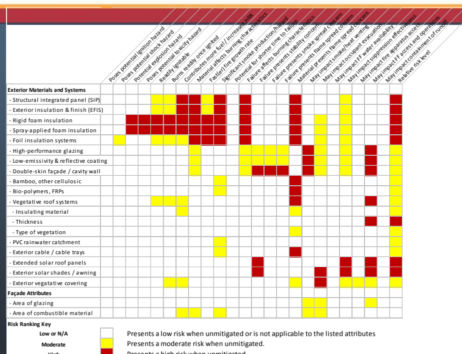
Green Element / Hazard Matrix



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Conclusions

- There are currently no fire incident reporting systems in the United States or other countries surveyed which specifically collect and track data on fire incidents in green buildings or on items labeled as green building elements or features. Unless changes are made to reporting systems such as NFIRS, it will be difficult to track such fire incident data.

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Conclusions

- Fires associated with photovoltaic (PV) panels and roof materials, fire and safety hazards attributed to increased energy efficiency aims in residential buildings (primarily insulation related), fire involving insulating materials, fires associated with exterior cladding that contains combustible insulation materials or coatings, and fire performance of timber frame buildings with lightweight engineered lumber (LEL).

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Conclusions

- Moving toward a risk analysis approach
  - A comprehensive list of green building site and design features / elements / attributes has been compiled
  - A list of fire-related hazards and risk factors, associated with green building elements, has been compiled
  - A set of matrices relating green attributes and potential fire risks / hazards was developed

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Conclusions

- Moving toward a risk analysis approach
  - An approach for illustrating the relative fire risk or hazard, or decreased fire performance, associated with green building elements, was developed
  - Potential mitigation strategies for addressing the relative increase in fire risk or hazard associated with the green building elements and features have been identified

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Recommendations

- To address the lack of reported fire experience with green buildings and green building elements, especially in buildings which have a green rating or certification, a modification may be required to fire incident data reporting systems as NFIRS.
- The inter-relationship of pertinent databases should be explored, i.e., ISO, NFIRS, green building grant programs

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Recommendations

- To address the lack of analysis on fire 'risk' associated with green building elements, it is suggested that a more extensive research project is needed to review existing studies and reports on fire performance of green building elements, even if not explicitly identified as such (e.g., LEL). Includes SIP, high efficiency windows /façade, natural ventilation in high rise, etc.

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Recommendations

- Research is needed to
  - Develop a clear set of comparative performance data between green & 'conventional' methods,
  - Develop an approach to convert the relative performance data into relative risk or hazard measures, and
  - Conduct a risk (or hazard) characterization and ranking exercise, with a representative group of stakeholders, to develop agreed risk/hazard/performance levels.

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Recommendations

- To explore the extent to which current standard test methods are appropriate for evaluating both green and fire safety criteria, and result in adequate mitigation of fire risk / hazard concerns, investigation into level of fire performance delivered by current standard test methods and into the *in situ* fire performance of green building elements is recommended.

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Thank You

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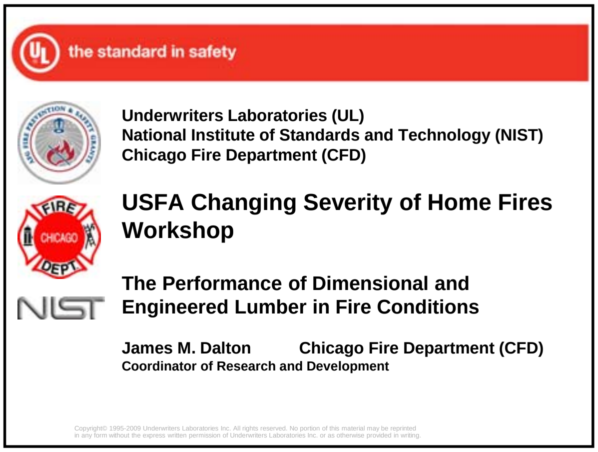
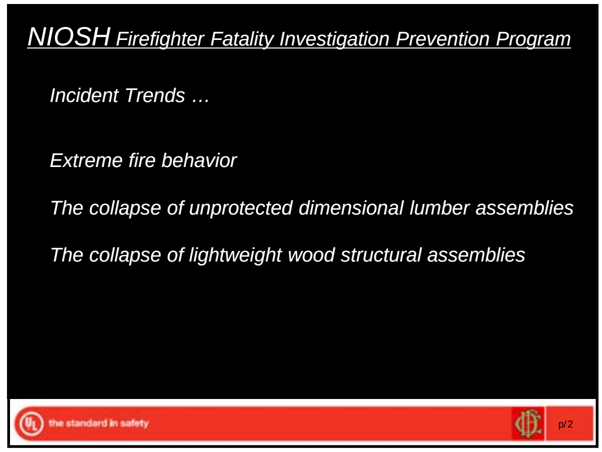
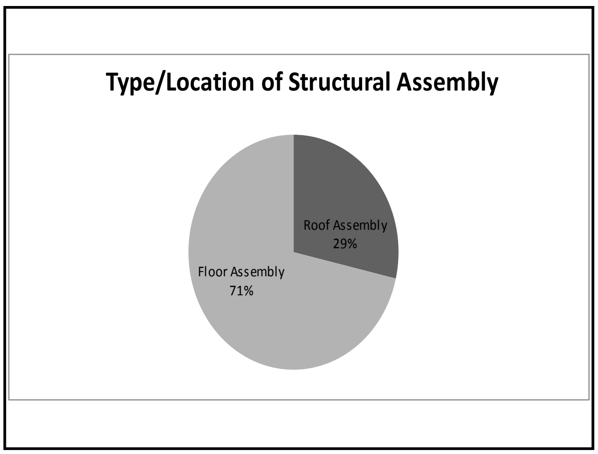
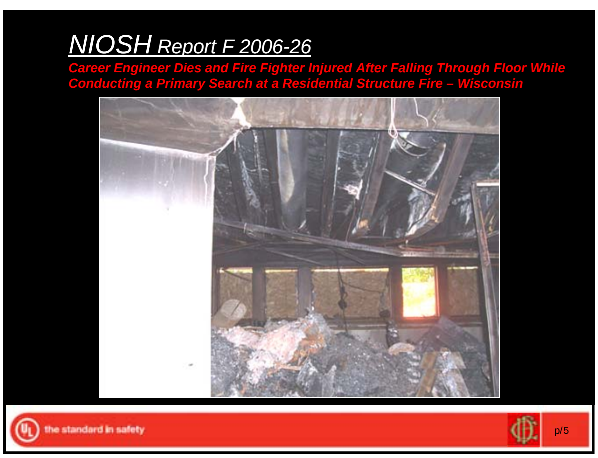
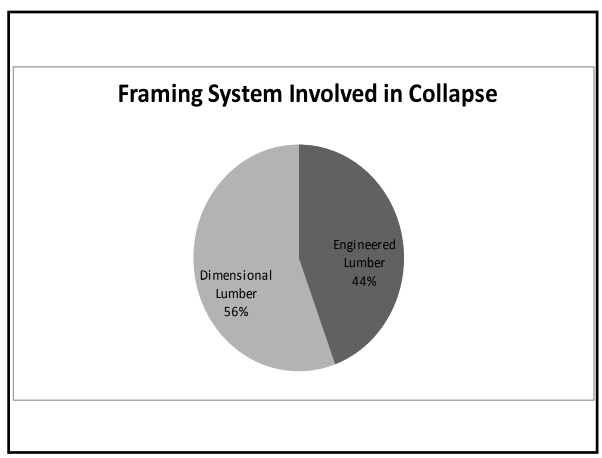

the standard in safety
Underwriters Laboratories (UL)
National Institute of Standards and Technology (NIST)
Chicago Fire Department (CFD)
USFA Changing Severity of Home Fires Workshop
The Performance of Dimensional and Engineered Lumber in Fire Conditions
James M. Dalton
Chicago Fire Department (CFD)
Coordinator of Research and Development


NIOSH Firefighter Fatality Investigation Prevention Program
Incident Trends …
Extreme fire behavior
The collapse of unprotected dimensional lumber assemblies
The collapse of lightweight wood structural assemblies
the standard in safety
p/2


Type/Location of Structural Assembly
Roof Assembly 29%
Floor Assembly 71%


Close Call / Hazard Report, Fairfax County Fire & Rescue
Mayday Event / Collapse of fully involved attic area – Fairfax County, VA
the standard in safety
p/4


NIOSH Report F 2006-26
Career Engineer Dies and Fire Fighter Injured After Falling Through Floor While Conducting a Primary Search at a Residential Structure Fire – Wisconsin
the standard in safety
p/5


Framing System Involved in Collapse
Engineered Lumber 44%
Dimensional Lumber 56%

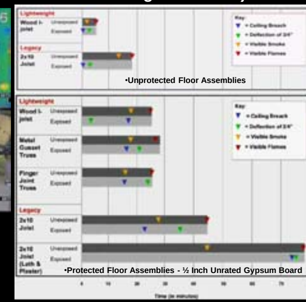
NIOSH Report F 2008-26

A Volunteer Mutual Aid Fire Fighter Dies in a Floor Collapse in a Residential Basement Fire – Illinois

the standard in safety p/7

The Structural Stability of Engineered Lumber in Fire Conditions (Floor furnace testing with modified loading conditions)

Floor assemblies can significantly weakened prior to structural collapse



•Source: "Structural Stability of Engineered Lumber in Fire Conditions", Underwriters Laboratories

the standard in safety p/8

Scale

Floor Furnace Testing

Supports	Time to failure
Engineered I Joists w/ 100% Loading (12 in.)	2:20
Engineered I Joists – Unprotected (12 in.)	6:00
Engineered Wood and Metal Hybrid Trusses (12 in.)	5:30
Engineered I Joists with Openings (16 in.)	8:10
Engineered I Joists w/ gypsum wallboard (1/2 in.)	26:43

•10

NIST Measurement Science and Engineering Research Grant

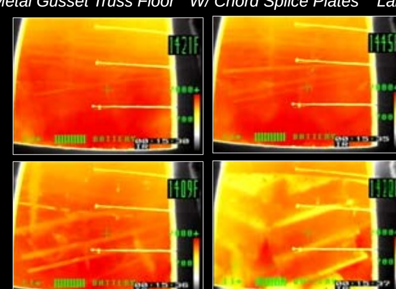
Modern Construction – 14" Metal Gusset Truss Floor W/ Chord Splice Plates

Metal plate connected trusses fail due to connection failure t=6:08. Truss fire involvement 3:42.

the standard in safety p/11

NIST Measurement Science and Engineering Research Grant

14" Metal Gusset Truss Floor W/ Chord Splice Plates Lab Series



Metal plate connected truss progressive failure, collapse within 0:07 period.

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Furnace Testing

Test Assembly	Supports	Time to failure
1	Dimensional Lumber (2 x 10) - Unprotected	18:35
2	Dimensional Lumber (2 x 10) – Gypsum Wallboard (1/2 in)	44:40
3	Dimensional Lumber (2 x 10) – Plaster and Lath	79:00
4	Dimensional Lumber (2 x 10) w/ 100% Loading	7:00
5	Old Dimensional Lumber (2 x 8) w/ 100% Loading	18:05

Inspection Tactical Considerations

Roof sheathing failure

Floor sheathing failure

Inspection Tactical Considerations

Joist fracture

Completed burn through of member

Inspection Tactical Considerations

Web failure

Web burn through

Inspection Tactical Considerations

Steel to wood panel point connection failure

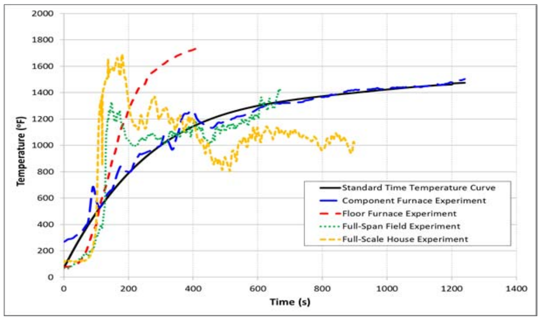
Detail of connection failure

Inspection Tactical Considerations

Warping or Buckling

Collapsed section from above

Fuel Load (Dimensional Lumber)



•19

Code Change

R501.3 Fire protection of floors. Floor assemblies, not required elsewhere in this code to be fire resistance rated, shall be provided with a ½ inch gypsum wallboard membrane, 5/8 inch wood structural panel membrane, or equivalent on the underside of the floor framing member.

Exceptions:
1. Floor assemblies located directly over a space protected by an automatic sprinkler system in accordance with Section P2904, NFPA13D, or other approved equivalent sprinkler system.
2. Floor assemblies located directly over a crawl space not intended for storage or fuel-fired appliances.
3. Portions of floor assemblies can be unprotected when complying with the following:
3.1 The aggregate area of the unprotected portions shall not exceed 80 square feet per story.
3.2 Fire blocking in accordance with Section R302.11.1 shall be installed along the perimeter of the unprotected portion to separate the unprotected portion from the remainder of the floor assembly.
4. Wood floor assemblies using dimension lumber or structural composite lumber equal to or greater than 2-inch by 10-inch nominal dimension, or other approved floor assemblies demonstrating equivalent fire performance.

Full-span laboratory experiments



Experiment	Floor System	Description	
1	Wood I-Joist	Repeat of Field Experiment 3, Max Ventilation	6:20
2	Wood I-Joist	Max Ventilation, Torch Ignition	31:25 Flames attach to structure 6:30
3	Parallel Chord Wood Truss	Gypsum ceiling, Void Ignition	44:46 Second Ignition @ 24:00
4	Parallel Chord Wood Truss	Gypsum ceiling, 80 ft² exposed	15:35

•21

•22

Protection Methods


Unprotected


Fire Retardant Coating


Intumescent Coating

•23

The Impact of Alternative Energy Technologies on Homes

10-11 December 2012
USFA Workshop:
"Changing Severity of Home Fires"

Casey C. Grant, P.E.
THE FIRE PROTECTION RESEARCH FOUNDATION

THE IMPACT OF ALTERNATIVE ENERGY TECHNOLOGIES ON HOMES

AGENDA

I. Safety and Alternative Energy in Homes

II. Traditional Sources of Alternative Energy

III. New Approaches and their Challenges

I. Safety and Alternative Energy in Homes

Background on Concepts & Defining Key Terminology
- Some thoughts on:
  - "Homes" and "Residential Occupancies"
  - "Alternative Energy"
  - "Safety Infrastructure" and the "Fire Service"

I. Safety and Alternative Energy in Homes

Defining "Homes" and "Residential Occupancies"

Definition of "Home" (from Definitions.net)
- A shelter that is the usual residence of a person, family or household

Definitions of Residential Occupancy from NFPA 101, Life Safety Code®

- Residential Occupancy: Provide sleeping accommodations for purposes other than health care or detention and correctional
- One and Two Family Dwelling Unit: A building that contains not more than two dwelling units with independent cooking and bathroom facilities
- Other Related Residential Occupancies: Lodging or Rooming House; Hotel; Dormitory; Apartment Building

Places we call "Home":
- House; Mansion; Townhouse; Condominium; Mobile Home; etc…

I. Safety and Alternative Energy in Homes

Defining "Homes" and "Residential Occupancies"

Influencing Factors in Determining Jurisdictional Authority

Property Owner
- Federal
- State
- Sovereign Nations
- Port Authorities
- Other

Geographical Location
- Special Districts
- State, County, City, Town, Village
- Other

Type of Occupancy
- Mercantile or Industrial
- Residential
- Other

From FPRF Project on "Reaching the U.S. Fire Service with Hydrogen Safety Information" for U.S. DOE

Summary Observation: "Residential Occupancies" are unique in our permitting infrastructure

---

I. Safety and Alternative Energy in Homes

Defining "Alternative Energy"

Broad concept whose precise definition is context dependent
- Recognizes baseline energy sources from which "alternatives" are measured
- Predominant use of fossil fuels provides the de facto baseline from which today's alternatives are typically measured
- Mainstream literature definitions usually include renewable or sustainable component
- Energy derived from sources that do not use up natural resources or harm the environment *(Princeton's WordNet)*

Most often recognized alternative energy sources
- Hydropower; Geothermal; Biopower; Wind; Solar

I. Safety and Alternative Energy in Homes

The Diversity of "Alternative"

Types of Alternative Fuels Used in Motor Vehicles

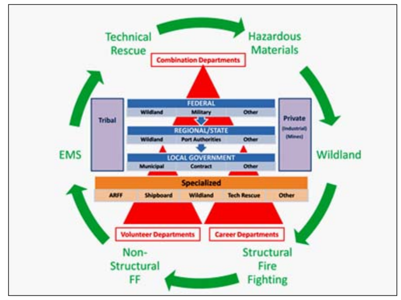
(based on U.S. Environmental Protection Agency classifications from Clean Air Act Amendment of 1990 and Energy Policy Act of 1992)

I. Safety and Alternative Energy in Homes

Defining "Safety Infrastructure" and "Fire Service"

The U.S. Fire Service: a primary component in our safety infrastructure

Examples of other key approaches: compartmentation; materials; active fire protection measures, etc…



The Impact of Alternative Energy Technologies on Homes

Agenda

I. Safety and Alternative Energy in Homes

II. Traditional Sources of Alternative Energy

III. New Approaches and their Challenges

II. Traditional Sources of Alternative Energy

How the National Electrical Code has addressed "alternative energy" through the years…

- 1897 Edition (First Edition)
  - Article 445 – Generators
  - Article 480 – Batteries
  - Article 700 – Emergency Systems
- 1971 Edition
  - Article 517 – Health Care Facilities
- 1981 Edition
  - Article 685 – Interconnected Electrical Systems
  - Article 701 – Legally Required Standby Systems
  - Article 702 – Optional Standby Systems

II. Traditional Sources of Alternative Energy

How the National Electrical Code has addressed "alternative energy" through the years…

- 1984 Edition
  - Article 690 – Solar Photovoltaic Systems
- 1987 Edition
  - Article 705 – Interconnected Power Production Sources
- 1993 Edition
  - Article 455 – Phase Converters

II. Traditional Sources of Alternative Energy

How the National Electrical Code has addressed "alternative energy" through the years…

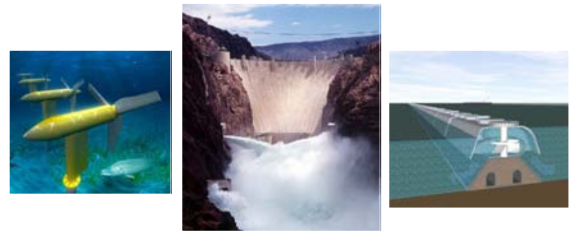
- 1996 Edition
  - Article 625 – Electric Vehicle Charging Systems
- 2002 Edition
  - Article 692 – Fuel Cell Systems
- 2008 Edition
  - Article 626 – Electrified Truck Parking
  - Article 708 – Critical Operations Power Systems
- 2011 Edition
  - Article 694 – Small Wind Electric Systems

II. Traditional Sources of Alternative Energy

How the National Electrical Code has addressed "alternative energy" through the years…

- 2014 Edition Plans
  - CMP 4 Task Group on PV Systems
  - CMP 12 Task Group on Electric Vehicles
  - TCC Task Group on Smart Grid Technology
  - TCC Task Group on DC Power

II. Traditional Sources of Alternative Energy

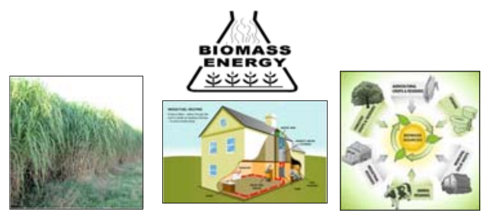


Hydroelectric and Tidal Power

II. Traditional Sources of Alternative Energy

Geothermal Power

II. Traditional Sources of Alternative Energy



Biomass Power

II. Traditional Sources of Alternative Energy

Wind Power

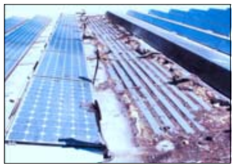
II. Traditional Sources of Alternative Energy

Solar Power and Photovoltaic

II. Traditional Sources of Alternative Energy







Solar Power and Photovoltaic

The Impact of Alternative Energy Technologies on Homes

Agenda

I. Safety and Alternative Energy in Homes

II. Traditional Sources of Alternative Energy

III. New Approaches and their Challenges

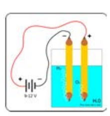
III. New Approaches and their Challenges

Power Storage (e.g., for PV System)

III. New Approaches and their Challenges


Electric Vehicles and Charging Stations

III. New Approaches and their Challenges


Fuel Cells for Power Generation

Contact Information:

Casey Grant

Fire Protection Research Foundation

One Batterymarch Park, Quincy, MA USA 02169-7471

Phone: 617-984-7284 Email: cgrant@nfpa.org

FPRF Website: www.nfpa.org/foundation

THE FIRE PROTECTION RESEARCH FOUNDATION

Spray Polyurethane Foam (SPF) in the Construction Industry

December 11, 2012
USFA/FEMA Changing Severity of Home Fires Workshop
College Park, MD

Rick Duncan
Technical Director
Spray Polyurethane Foam Alliance

Richard S. Duncan, Ph.D., P.E.
Technical Director, Spray Polyurethane Foam Alliance

Rick is currently Technical Director for the Spray Polyurethane Foam Alliance. Prior to joining SPFA, he was the Senior Marketing Manager for Honeywell's Spray Foam Insulation business from 2006 to 2008. From 1997 to 2006, he was the Global Program Director for CertainTeed/Saint-Gobain Insulation's New Materials and Applications Portfolio. From 1989 to 1997 he was a Visiting Assistant Professor of Mechanical Engineering at Bucknell University. He holds a Ph.D. in Engineering Science and Mechanics from The Pennsylvania State University, MSME from Bucknell and a BSME from the University of Maryland. Rick is a Registered Professional Engineer in three states and is a certified BPI Building Analyst.

SPFA History

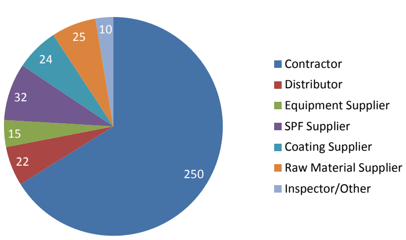
- Spray Polyurethane Foam Alliance
  - Originally founded as the Urethane Foam Contractors Association (UFCA) in 1975
  - In 1987 it became the Polyurethane Foam Contractors Division of the Society of the Plastics Industry (SPI)
  - Since 2003, it has been an independent trade association for contractors, manufacturers and distributors of polyurethane foam, equipment, protective coatings, inspections, surface preparations and other services.
  - Maintains strong relationship with the American Chemistry Council (ACC) and their Center for Polyurethanes Industry (CPI)

SPFA Programs and Activities

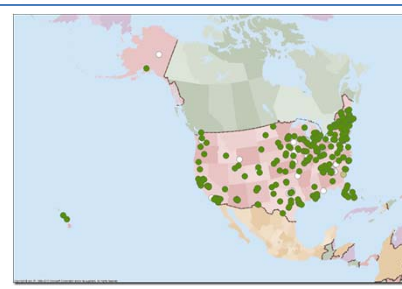
- Education and Research
  - Accreditation/Certification and Education programs
  - Technical Literature and Guidelines
  - "Hotline" for Technical questions (1-800-523-6154)
  - Industry Research Programs
- Promotion and Awareness
  - Regulatory and Legislative Activities
  - Promotional and Marketing Tools
  - Website www.sprayfoam.org
  - Annual Spray Foam Conference and Exposition
  - *Spray Foam Professional magazine*
  - Directory and Buyers' Guide

SPFA Members

- Membership Categories



SPFA Members

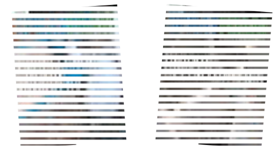


SPFA Website

- www.sprayfoam.org
  - Key features of home page
    - Health and Safety
    - Technical
    - Membership

SPFA Publications

- Spray Foam Professional Magazine
  - Quarterly magazine through NACE Publishing
  - SPFA works with SFP editors at Naylor to develop and review content



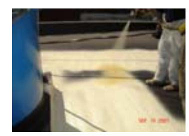
www.naylornetwork.com/spfa/

Presentation Content

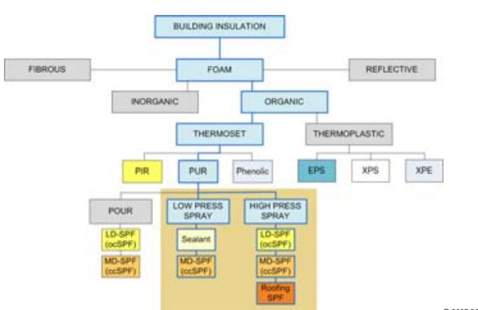
1. History
2. Product Categories
3. Market Trends
4. Fire Safety
5. Delivery Methods
6. Applications

History of SPF in Buildings
SPF in construction for 50 years

- Late 60's - Medium Density (agricultural and industrial)
- Mid 70's - Roofing
  - Medium Density (general const.)
  - Sealants
- Mid 90's - Low Density (residential)



Product Category
SPF: field-applied thermoplastic foam



Product Category
Four basic classes of SPF

	Spray Foam Category			
	Sealant	LD	MD	Roof
Density (lb/ft³)	0.6 – 1.8	0.5 - 1.4	1.5 -2.3	2.5 - 3.5
Thermal Resistivity (R/in)	NR	**3.6 - 4.5**	**6.2 - 6.8**	**6.2 - 6.8**
Air Impermeable Material	*	> 3.5"	> 1.0"	> 1.0"
Integral Air Barrier System		✓	✓	✓
Integral Vapor Retarder			✓	✓
Water Resistant			✓	✓
Cavity Insulation		✓	✓	
Continuous Insulation		✓	✓	✓
Roofing				✓
Structural Improvement			✓	✓

Air Sealing performance driving use of SPF insulation
***SPF insulated home has 10-20% of air leakage of standard insulated home*

Market Trends
SPF Production by Type

NORTH AMERICA SPF PRODUCTION by FOAM TYPE						
(MMlbs)	2010			2011		
Type -->	open cell	closed cell	Total	open cell	closed cell	Total
Canada	50	50	100	45	60	105
USA	87	236	323	95	255	350
Mexico	10	15	25	12	18	30
Total Production	**137**	**308**	**445**	**152**	**333**	**485**

Source: PU Magazine

Production of SPF is relatively balanced across product type
Closed-cell includes insulation and roofing (about a 50-50 mix with most growth from insulation

Market Trends
SPF Production

GLOBAL SPF PRODUCTION								
(MMlbs)	2007[1]	2008[2]	2009[3]	2010[3]	2011[3]	5-yr CAGR	2-yr CAGR	1-yr
North America	334	468	421	448	485	9.8%	7.3%	8.3%
South America	27	24	12	14	15	-13.7%	11.8%	7.1%
Europe	230	192	192	145	164	-8.1%	-7.6%	13.1%
Middle East & Africa	23	25	25	26	28	5.0%	5.8%	7.7%
China	159	172	172	198	205	6.6%	9.2%	3.5%
Asia Pacific	130	115	115	105	110	-4.1%	-2.2%	4.8%
Total	**903**	**996**	**937**	**936**	**1007**	2.8%	3.7%	7.6%

Sources: (1) IAL Consultants, (2) CPI End Use Survey, (3) PU Magazine

NORTH AMERICA SPF PRODUCTION								
MMlbs	2007[1]	2008[2]	2009[3]	2010[3]	2011[3]	5-yr CAGR	2-yr CAGR	1-yr
USA	275	379	305	323	350	8.4%	7.1%	8.4%
Canada	42	85	95	100	105	35.7%	5.1%	5.0%
Mexico	17	24	21	22	30	20.8%	19.5%	36.4%
Total	**334**	**488**	**421**	**445**	**485**	13.2%	7.3%	9.0%

Sources: (1) IAL Consultants, (2) CPI End Use Survey, (3) PU Magazine

North America and China driving volume and growth
U.S. drives North American production (most Canadian product is exported)

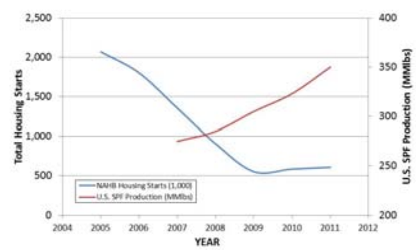
Market Trends
Housing Starts

ANNUAL HOUSING U.S. HOUSING STARTS									
(1 ,000 units)	2005	2006	2007	2008	2009	2010	2011	5-yr CAGR	2-yr CAGR	1-yr
Single Family	1716	1465	1,046	622	445	471	431	-19.9%	-1.6%	-8.5%
Multifamily	352	336	309	284	109	116	178	-12.9%	27.8%	53.4%
Total Housing Starts	**2,068**	**1,801**	**1,355**	**906**	**554**	**587**	**609**	-18.1%	4.8%	3.7%

Source: National Association of Home Builders

New residential housing starts significantly lowered since 2005 peak
Representative of all construction

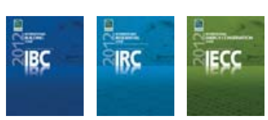
Market Trends
Rapid growth of SPF insulation market



Reduced construction rate and increased SPF production results in increased market share for SPF

SPF and the International Codes

- Code Sections
  - Separate from 'traditional' insulations
  - IBC: Ch 26, Section 2603 Foam Plastic Insulation
  - IRC: Ch 3, R316 Foamed Plastic
- Code Focus
  - Fire Protection
  - Thermal Performance
  - Moisture Control



Fire Testing
Surface Burning Characteristics

- Steiner Tunnel Test [IBC 2603.3 / IRC R316.3]
  - Class II – FSI ≤ 75, SDI ≤ 450
  - **Class I – FSI ≤ 25, SDI ≤ 450**
  - Roofing – FSI ≤ 75, SDI unlimited
  - **CHECK with manufacturer or ESR for testing >4"**

Fire Safety
15-Minute Thermal Barriers

- Thermal Barrier Requirement [IBC 2603.4 / IRC R316.4]
  - Separates insulation from interior of building
  - Approved 15 minute thermal barrier
    - ½” gypsum wallboard is most commonly used
    - Others to be tested per ASTM E119 and/or full-scale fire tests
  - Exceptions to Thermal Barrier requirement…

Fire Safety
Additional Requirements: Commercial

- Special Requirements for SPF in Type I-IV Construction [IBC 2603.5]
  - ASTM E119 or UL 263 required for fire-resistance rated wall assemblies
  - Thermal barrier required
  - NFPA 259 test data corresponding to SPF tested per NFPA 285
  - Class I per ASTM E84 (<25 FS, <450 SD)
  - NFPA 285 test data for each wall assembly
  - Labelling of product
  - NFPA 286 test data showing no sustained flaming

Fire Safety
Thermal Barrier Exceptions

- Inside masonry or concrete walls [IBC 2603.4.1.1 / IRC R316.5.2]
- Cooler and freezer walls* [IBC 2603.4.1.2-3]
- Laminated metal wall panels-one story [IBC 2603.4.1.4]
- Roofing assembly* [IBC 2603.4.1.5 / IRC R316.5.2]
- Entry doors [IBC 2603.4.1.7-8 / IRC R316.5.5]
- Garage doors [IBC 2603.4.1.9 / IRC R316.5.6]
- Siding backer board [IBC 2603.4.1.10 / IRC R316.5.7]

* SPF applications

Fire Safety
Thermal Barrier Exceptions

- Sill Plates and Headers [IBC 2603.4.1.13 / IRC R316.5.11]
  - Limited to Type V construction
  - Max thickness 3.25”
  - Class I Foam (LD and MD)

Fire Safety
Thermal Barrier Exceptions

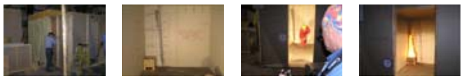
- Attics and Crawl Spaces [IBC 2603.4.1.6 / IRC R316.5.3]
  - Entry is made only for service of utilities (no storage)
  - Ignition barrier is required separating attic/crawlspace space from foam
  - Thermal barrier required between attic/crawlspace and occupied space

Fire Safety
Ignition Barrier Requirements

- Ignition Barrier [IBC 2603.4.1.6 / IRC R316.5.3]
  - Prescriptive:
    - 1.5” mineral fiber insulation
    - 0.25” wood structural panels
    - 0.375” particleboard
    - 0.25” hardboard
    - 0.375” gypsum board
    - Corrosion-resistant steel having base metal thickness of 0.016 “
    - 1.5” cellulose fiber insulation (IRC 2012 only)
  - Alternative Assemblies by Special Approval Testing

Fire Safety
Ignition Barrier Tests

- Special Approval Tests [IBC 2603.9 / IRC R316.6]
  - NFPA 286 - Contribution of Wall and Ceiling Interior Finish to Room Fire Growth (with the acceptance criteria of Section 803.2/R315.4)
  - FM 4880 - Fire Rating of Insulated Wall or Wall and Roof/Ceiling Panels, Interior Finish Materials or Coatings, and Exterior Wall Systems
  - UL 1040 - Safety Fire Test of Insulated Wall Construction
  - UL 1715 – Fire test of interior finish material
  - ***End-use fire tests***



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Fire Safety
Ignition Barrier End-Use Fire Tests

- Special Approval for Foam In Attics and Crawlspaces
  - End-use fire tests...
    - Qualifies assembly (foam alone or foam with intumescent coating)
    - See AC-377 June 2009 "Appendix X" for testing requirements

New modified NFPA 286 baseline test

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Fire Safety
Current Industry Topics

- Safety During Installation: exotherms, exposed foam
- Whole-house Fire Performance: air sealing and ERV/HRV
- Education of Code Officials: thermal/ignition barriers
- Commercial Building Requirements: NFPA 285
- Flame Retardants: ecotoxicity, E84??

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Contact Us

- SPFA Certification Training
- SPFA Website and Annual Conference
- Formulators and Systems House Suppliers

SPFA CONVENTION & EXPO Jacksonville, Florida February 12-15, 2013

SPFA Website: www.sprayfoam.org

SPF and the I-Codes
Verifying Compliance

- ICC-ES Acceptance Criteria
  - AC-12 for Foamed Plastic: XPS, EPS, PIR
  - AC-377 for Froth and Spray Polyurethane Foams: -- NEW 3/1/08
- (A) ICC-ES Reports
  - Required Data
    - R-value, Surface Burning Characteristics (at thickness), Physical Properties
  - Optional Data
    - Air permeance, Water absorption, WVTR, Full-scale fire tests,...
  - Go to www.icc-es.org for full list of ESRs for SPF
- (B) Alternate Product Documentation
  - Code-compliance research reports, 3rd Party Test Data, Product Data Sheets also acceptable

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On The Jobsite
Labelling and Certificates

- Product Labelling

  [IBC 2603.2 / IRC R316.2]
  - Containers on job site shall have mfg name, product ID, product listing, suitability for use
- Installation Certificate

  [IECC 401.3 / IRC N1101.8]
  - Provided by contractor to builder/homeowner
  - Thickness, R-value and product listing or data sheet
  - Placed on electric service panel or other conspicuous location

Get product data sheet, ESR and/or certification from builder/designer

[IRC N1101.8]

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Thank You!

Questions?

Basic Chemistry
Two Competing Chemical Reactions

BLOW: Expansion of liquid into a cellular structure

a. MDI + chemical blowing agent (H_2O) → CO_2 gas
b. Exothermic heating of polymerization transforms liquid physical blowing agent (HFC) into vapor

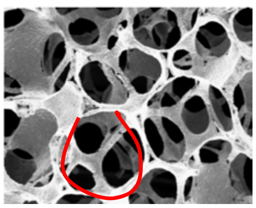
SET: Polymerization of liquid into solid polyurethane

a. MDI + polyols → polyurethane

Other additives are important:

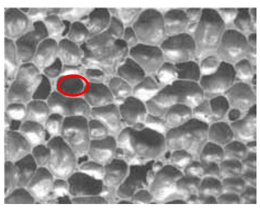
- Catalysts control polymerization reaction time and temperature (speed)
- Surfactants control cell formation and structure
- Flame retardants embedded in PU provide built-in fire resistance

Basic Chemistry
Open and Closed Cell Foam Differences



OPEN CELL

- ~100x expansion
- 0.5 to 0.8 lb/ft³ (soft)
- R-3.6 to R-4.5 per inch (air)
- Moisture permeable



CLOSED CELL

- ~30x expansion
- 1.7-3.5 lb/ft³ (rigid)
- R-5.8 to R-6.8 per inch (low-k gas)
- Moisture semi-impermeable

Delivery Methods
One-Component Low-Pressure Sealants

- 6-15 BF/min froth
- A and B pre-mixed; cured by contact with ambient moisture
- Low/high expansion
- Air-sealing of small cracks, gaps and holes
- Non-insulating

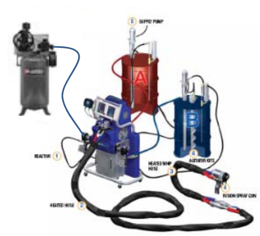
Retail DIY product for air sealing only

Delivery Methods
Two-Component Low-Pressure Foam

- 30-40 BF/minute froth
- A and B in separate pressurized cylinders
- Mechanical mixing
- Insulation and air sealing - small jobs

Professionally applied product used by weatherization contractors and by SPF contractors for small jobs or repair work

Delivery Methods
Two-Component High-Pressure SPF



- 100-500 BF/minute spray
- A and B in unpressurized drums or totes
- Chemicals heated and pressurized by proportioner
- Larger insulation jobs and all roofing applications
- Special training and capital investment

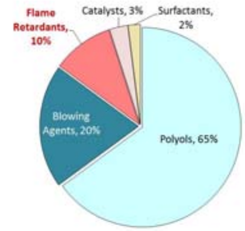
Professionally applied insulation and roofing SPF installed by trained contractors large jobs

Basic Chemistry
Reaction of 1:1 mixing of two liquids

- A-Side: Blend of monomeric and polymeric MDI
  (Methylene diphenyl diisocyanate)
- B-Side or Polyol
  - polyols
  - blowing agents
  - flame retardants
  - surfactants
  - catalysts

Proprietary blend of additives affect cell formation and foam performance

Basic Chemistry
B-Side Formulation: Flame Retardants

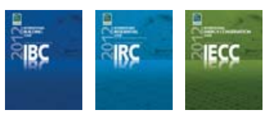


Flame retardants necessary for building fire safety

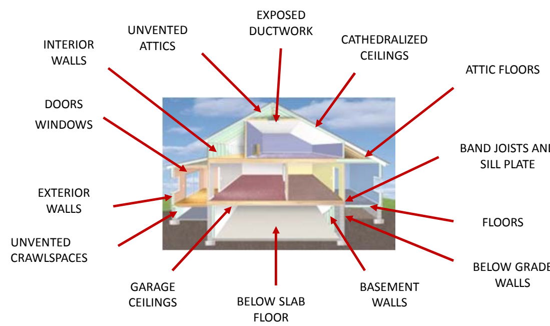
- Polyurethane foam is an organic material and is combustible.
- Without fire retardants, foam plastics would not meet building code flame spread requirements.
- No brominated FRs – (PBDE)
  - Some use Br-diols in polyol blend
- Uses halogen-phosphorous FRs such as
  - TCPP – most common
  - TDCP – phasing out
  - TEP – increased interest

Basic Chemistry
SPF and the Building Codes

- Code Sections
  - Separate from 'traditional' insulations
  - IBC: Ch 26, Section 2603 Foam Plastic Insulation
  - IRC: Ch 3, R316 Foamed Plastic
- Code Focus
  - Fire Protection
  - Thermal Performance
  - Moisture Control



Residential Applications



R *Retrofit??* **Unvented Attics** *Foam type* LD MD Roof

Cathedralized Ceilings LD MD Roof

Cathedralized Ceilings

LD
MD
Roof

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Attic Floors

R

LD
MD
Roof

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Exposed Ductwork

R

LD
MD
Roof

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Rim-Band Joists / Sill Plates

R

LD
MD
Roof

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Floors (Garage Ceiling)

LD
MD
Roof

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Floors (Cantilevered)

R

LD
MD
Roof

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Below Grade Walls

LD
MD
Roof

Below Slab

LD
MD
Roof

Basement Walls

R

LD
MD
Roof

Unvented Crawlspaces

R

LD
MD
Roof

Exterior Walls

LD
MD
Roof

Interior Walls

LD
MD
Roof

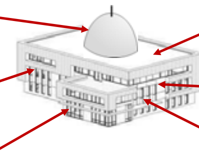
Door and Window Sealing

LD
MD
Roof

Low-Expansion for windows and doors

High-Expansion for cracks and gaps

Commercial Applications



Other Applications

TEMPORARY STRUCTURES

TANKS AND VESSELS

Exterior Walls

LD
MD
Roof

Exterior Walls

LD
MD
Roof

R

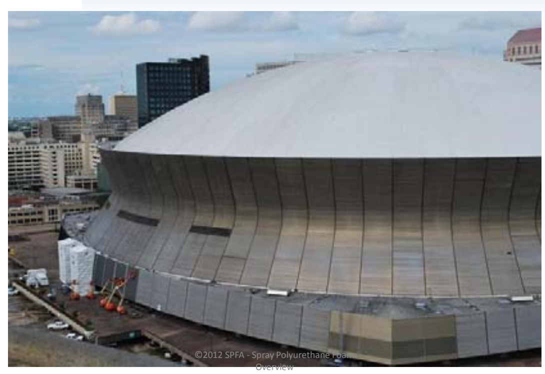
Low-Sloped Roofs

LD
MD
Roof

R

Domed Roofs

LD
MD
Roof



R Metal Buildings

LD
MD
Roof

Temporary Structures

LD
MD
Roof

Tanks and Vessels

LD
MD
Roof

Quality Installation

SPFA

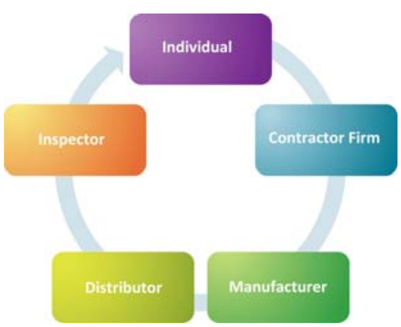
SPFA Certification

- Establishes Clear Path to Professionalism
- Establishes Expectations
  - Among Industry Professionals
  - Among Customers
  - Among Partners (Arch / Design Build / GC / Etc)
- Standards-Driven (ANSI/ISO 17024)
- Uniform and Consistent Measures
- Consequences for Failure (Enforcement)
- Regular Continuing Education Required for Recertification
- Provides Further Market Differentiator for Company and Individuals
- Heavy Focus Upon H+S Throughout

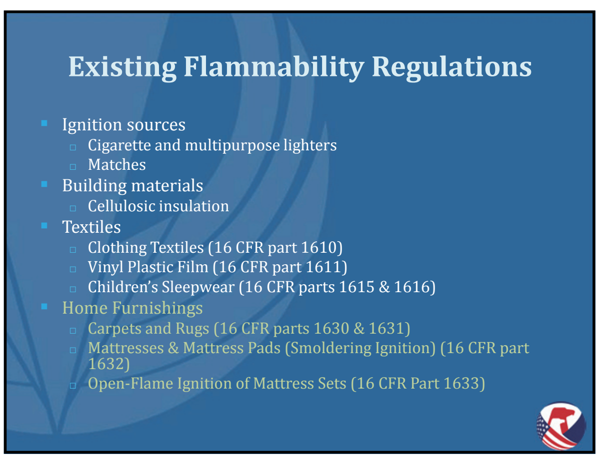
Quality Installation

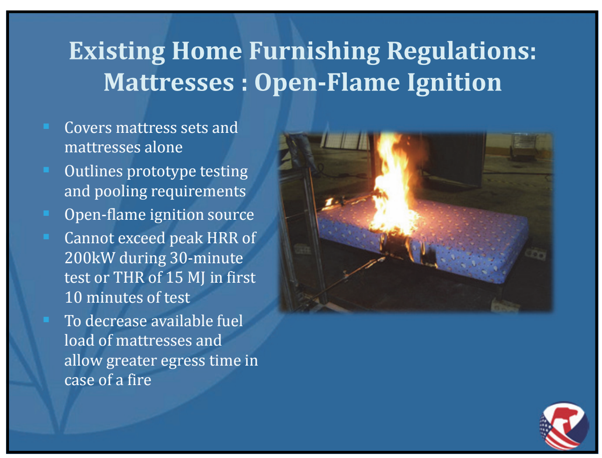
SPFA

SPFA Accreditation / Certification



CPSC Overview of Regulatory Efforts Impacting Home Furnishing Flammability





Home Furnishing Regulations Under Development: Bedclothes

- Bedclothes contribute substantially to complexity and magnitude of mattress fire hazard
- ANPR published in 2005
- Regulatory development not included in current operating plan due to resource constraints

Validation Tests

- Conducted with Type I cover fabrics and Type II fire barriers that met proposed criteria from previous bench-scale testing
- Bench-scale used same materials as full-scale tests; no standard foam or fabric used
- Smoldering and open-flame ignition source tests conducted

Home Furnishings Regulations Under Development: Upholstered Furniture

- NPR published 2008 (proposed 16 CFR part 1634)
- Objectives:
  - Target risk: smoldering ignited fires that cause most addressable fire deaths and injuries
  - Prevent transition from smoldering to flaming combustion
  - Minimize reliance on FR chemical additives in fabrics and filling materials
  - Reduce fire risk at reasonable cost

Smoldering Ignition Tests: Bench-Scale

- Materials in bench-scale tests did not behave as previously observed.
- Cover fabrics did not show difference in smoldering as expected.
- Presence of fire barrier did not show practical difference in smoldering of foam.
- Foam seemed to be different than previous foam, potentially affecting results.
  - Revealed the need for an SRM foam.

Post – NPR Technical Work

- Validation Test Program – Bench and Full Scale
  - Smoldering Ignition
  - Open Flame Ignition
- Standard Reference Foam Development
  - Reduce Variability

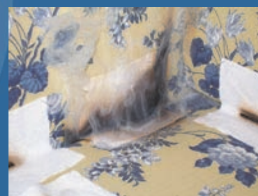
Smoldering Ignition Tests: Full-Scale

- Chairs were constructed of same materials as bench-scale tests.
- Fire barriers expected to inhibit smoldering ignition of internal foam.
- Barriers did not consistently protect against smoldering ignitions.
  - Chairs constructed with fire barriers demonstrated a considerable amount of smoldering.

Example of Smoldering Ignition Tests

Without Barrier
Non FR Foam

With Barrier
Non FR Foam



Validation Tests - Conclusions

- Bench-scale should predict full-scale performance; behavior in both should be similar.
- Smoldering ignition bench-scale performance did not demonstrate adequate prediction of real furniture flammability performance for Type I and Type II chairs.
- Open-flame ignition bench-scale tests for fire barriers (Type II) showed improvement in full-scale fire performance.

Open-Flame Ignition Tests: Bench and Full-Scale

- Bench-scale tests showed that fire barriers were able to delay ignition of foam, as previously observed.
- Full scale tests showed fire barriers were successful in reducing fire severity.

Standard Test Materials

- Objective: maximize repeatability, minimize variability of test results
- SRM 1196 cigarette incorporated into mattress rule (16 CFR Part 1632) in 2011
- SRM foam characterization completed in 2012
- No standard reference fabric has been developed or identified specifically for NPR

Example of Open-Flame Ignition Tests

Ongoing Work

- Conduct further testing with standard materials
- Engage ASTM E05 on potential revisions to ASTM E1353
- Monitor revisions to California TB-117
- Incorporate necessary changes to regulatory approach


U.S. Consumer Product Safety Commission
Overview of Regulatory Efforts Impacting
Home Furnishing Flammability*
Changing Severity of Home Fires
USFA Workshop
December 11, 2012
Andrew Stadnik, Laboratory Sciences
Rik Khanna, Hazard Reduction
*This information was prepared by the CPSC staff; it has not been reviewed or approved by and does not necessarily represent the views of, the Commission.
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Overview on the Combustibility and Testing of Filling Materials and Fabrics for Upholstered Furniture

Prepared by the Polyurethane Foam Association

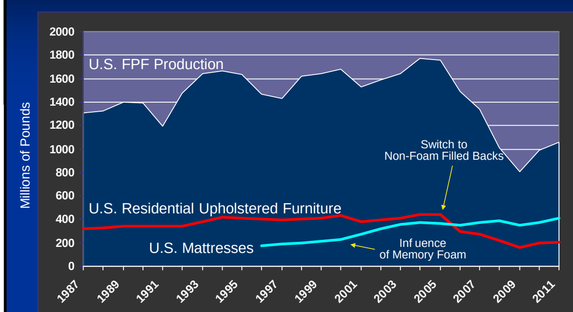
Based on research findings of the Product Research Committee and Dr. Herman Stone

Background on FPF

- Developed soon after WWII
- Rapid acceptance as furniture cushioning*
  - 1957 = about 1%
  - 1958 = about 15%
  - 1964 = about 75%
  - 1975 = >90%
- Lost backs and arms in 2005

*Source: Mobay archive documents, Furniture Manufacturer magazine, 1959

Tracking Furniture and Bedding Foam



Source: PFA Pounds Poured Estimates, Technomic Associates, API End-Use Market Surveys

Foam Flammability Characteristics

- Carbon-based product
- Large surface area with open cells
- Early understanding of combustion potential

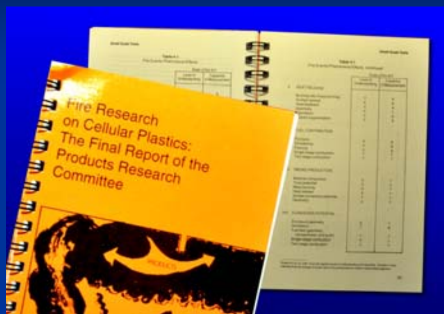
Ignition & Combustion Claims

- Early 1970's US Testing reported +40 test methods
- With FRs, not hard to pass at least one test
- Foam producers, suppliers and standards groups made misleading claims
- Lead to 1974 FTC Consent Order

Disclaimer for Flammability Testing

THIS FLAMMABILITY RATING IS NOT INTENDED TO REFLECT HAZARDS BY THIS OR ANY OTHER MATERIAL UNDER ACTUAL FIRE CONDITIONS.

$5 Million for Fire Research



Basic Observations

- Testing cellular materials for ignition and combustion performance is complicated by the complexity of fire and the difficulty of measuring interactions of varied materials and conditions involved in fires.
- A number of different tests are required to quantify the effects of multiple variables.

Different Tests With Different Goals

Qualification Tests
- Tend to be composite tests.
- Is construction fit for application?
- Tests tend to be complex, time consuming and costly.
- May be sophisticated and require special facilities and instrumentation.

Quality Control Tests
- Tend to be much simpler component tests.
- Do not consider material interactions and cannot predict finished item performance.

Smaller Scale Tests

Smolder tests
- Smolder to flame is most frequent identifiable cause of household fires involving upholstered furniture
- Also subject to many variables
- Non-FR foam performs well in smolder
- Fabric is key to performance

Open flame tests
- TB 117 vertical, MVSS 302 horizontal
- Do not consider heat release, smoke issues, radiant heat

Composite tests
- BS 5852 Procedures
- Do not consider heat release, smoke issues, radiant heat

Larger Scale Tests

- Require much larger test set-up, sometimes a dedicated facility and sophisticated instruments
- Tests are often lengthy and may vent byproducts
- Finished items are often consumed
- Results will not represent actual fires
- Cannot account for materials variations

Materials Variations

Fiber
- Melt or char, slickness, denier, loft, loose, packed or batting, glued, garneted or layered

Fabric
- Melt or char, weight, weave, texture, openness, dyes, treatments, backing

Foam
- Density, formulation, porosity, fillers, additives

Flame Retardant Additives Requirements

- Effective in FR performance at low concentrations
- Compatible with production
- Must not detract appeal of finished item
- Be durable and not volatilize or leach
- Maintain favorable economics
- Must be safe for workers, environment and consumers

Testing Variability

- Ignition source
  - Position, energy, exposure
- Testing conditions
  - Airflow, containment, potential for heat reflection
- Duration
- Measurement and evaluation
- Secondary combustion considerations

Fire Toxicity

- Affected by heat, heat release rate and concentration
- Component testing
  - Body of research exists for products of combustion for individual components
- Composites with material interactions
  - More challenging to identify and quantify products of combustion with composites and interacting products

Regulatory Considerations

- Performance standards are required
- Relate to actual risk
- Apply equally to all materials
- Generate repeatable results
- Be economically and technically feasible
- Be measurable
- Safe for workers

THIS FLAMMABILITY RATING IS NOT INTENDED TO REFLECT HAZARDS BY THIS OR ANY OTHER MATERIAL UNDER ACTUAL FIRE CONDITIONS.

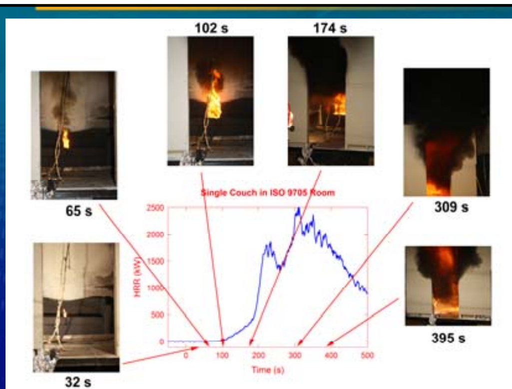
Quantifying Flaming Residential Upholstered Furniture Fire Losses

William M. Pitts
Engineering Laboratory
National Institute of Standards and Technology

USFA National Workshop on
Changing Severity of Home Fires
Maryland Fire and Rescue Institute
December 11-12, 2012

OUTLINE

1. Overview of RUF Burning Behavior
2. Review of Regulations
   - US Residential Upholstered Furniture
   - Related Regulations
3. Workshop on Quantifying the Contribution of Flaming Residential Upholstered Furniture to Fire Losses in the United States
   - Objective and Organization
   - Findings
   - Recommendations
   - Analysis for Action Item #1
4. New Regulatory Landscape
5. Final Remarks



Common View of Importance of RUF to Fire Growth in Residences

"When PCFs [primary combustible furnishing] are the first-ignited item, they are known to give rise to rapidly developing fires due to the flammability of the polyurethane foam (PUF) that is the dominant combustible constituent most often used in their manufacture."

Evidence for the Potential Impact of Rapid Fire Growth on Modern RUF on Residential Fire Losses

- The NIST Dunes II study (Bukowski et al., 2004) reported that average times required to develop untenable conditions inside a residential room were reduced from the 17 minutes measured during Dunes I (Bukowski et al., 1975) using typical furniture from that period to the 3 minutes identified during Dunes II (2004, 2007) utilizing modern furniture. Material changes in RUF construction over the 1975 to 2004 period were identified as a major contributor to this dramatic decrease.
- Underwriters Laboratory directly compared fire development in rooms containing RUF constructed with FPUF cushioning and microsuede fabric with rooms containing RUF produced with cotton batting cushioning and cotton fabric (chosen to represent legacy construction materials). They reported that flashover times with the legacy RUF were 34 minutes, which were reduced to 4 minutes when the modern materials were used.

2010 Fire Profile from NFPA

- Fire departments responded to 369,500 home structure fires which resulted in 13,350 civilian injuries, 2,640 civilian deaths, and $6.9 billion in direct damage.
- 92% of all civilian structure fire deaths due to home fires.
- Kitchens are the leading area of origin for home structure fires (37%) and civilian home fire injuries (36%).
- Only 4% of home fires started in the living room, family room, or den; these fires caused 24% of home fire deaths.
- 8% of reported home fires started in the bedroom. These fires caused 25% of home fire deaths, 21% of home fire injuries, and 14% of the direct property damage.
- Smoking materials are a leading cause of civilian home fire deaths, with roughly 25 % of total number due to ignitions by these materials.
- Almost two thirds (62%) of reported home fire deaths resulted from fires in homes with no smoke alarms or no working smoke alarms.

Smoldering and Flaming Burning

- Smoldering combustion is a slow, low-temperature, flameless form of combustion, sustained by the heat evolved when oxygen directly attacks the surface of a condensed-phase fuel.
- Flaming combustion is a process involving rapid oxidation at elevated temperatures accompanied by the evolution of heated gaseous products and the emission of visible and invisible radiation..
- In some cases smoldering combustion can "transition" to flaming combustion.

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US Regulations and Voluntary Standards for Limiting Ignition and Fire Growth on Residential Upholstered Furniture

California BHFTI Technical Bulletin 117 (1975)
Intended to provide ignition resistance to small flames and smoldering
- For resilient foam materials apply 3.8 cm flame for 12 s to a vertical 30.5 cm long strip of material, material passes tests if char length < 15.2 cm, no after flaming after 5 s, and no afterglow or dripping after 15 s.
- Small mockup ignition testing with cigarettes of filling materials covered by standard fabric; filling passes if mass loss < 20%.
- Fabrics must pass a small scale test in which samples oriented at 45º ignited by a small flame develop spread rates less than 2.5 cm/ s.

UFAC (1979) (NFPA 260 and ASTM E 1353 are identical)
Intended to provide minimum level of resistance to cigarette (smoldering) ignition.
- Standard cigarettes placed on small mockups of upholstery fabric and a standard non-retarded polyurethane foam, fabric passes if no obvious smoldering and upward charring is limited to a prescribed distance.
- A passing fabric is assigned a UFAC Class 1 rating; a failing fabric is classified as UFAC Class 2; UFAC Class 2 fabrics can be used if a suitable barrier material tested with standard fabric and polyurethane foam does not smolder and charring is limited.

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US Regulations and Voluntary Standards for Limiting Ignition and Fire Growth on Residential Upholstered Furniture (continued)

CPSC 1634 (Proposed Rule, 2008)
Intended primarily to provide minimum resistance to cigarette (smoldering) ignition
- Standard cigarettes placed on small mockups of upholstery fabric and a standard non-fire retarded polyurethane foam, fabric passes if no obvious smoldering and mass loss of foam is < 10 %.
- If fabric fails test, the standard allows a barrier to be placed between the fabric and foam. Mockups including the fabric, barrier, and standard polyurethane foam are tested for resistance to cigarette (smoldering ignition), passes if there is no transition to flaming, no smoldering after 45 min, and the foam weight loss is < 1 %. Additionally, the resistance of the barrier material to flame ignition is tested by subjecting mockups of a standard rayon cover fabric, barrier material, and standard polyurethane foam to a 240 mm high flame for 70 s. Material passes if mockup mass loss is < 20 % after 45 min.

Reduced Ignition Propensity Cigarettes (2004-2012)
Intended to reduce cigarette propensity to initiate smoldering of upholstered furniture
- Cigarettes subjected to Standard Test Method for Measuring the Ignition Strength of Cigarettes (ASTM E2187); pass if ¾ self-extinguish.
- All fifty states have legislation requiring reduced ignition propensity cigarettes.

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Other Regulations Related to Upholstered Furniture Flammability

California BHFTI Technical Bulletin 133 (1975)
Intended to limit fire size for commercial furniture utilized in public spaces
- Actual item or full-scale mock-up tested inside a room.
- Ignition source is a square burner generating 19.3 kW applied to seat for 80 s.
- Passes if instantaneous HRR < 80 kW, total heat release during initial ten minute < 25 MJ, < 75 % smoke opacity at 1.2 m height, CO concentrations remain < 1000 ppm.

UK BS 5852/SI 1324 (1988)
Intended to limit smoldering and flaming ignition and maximum fire size
- Real-scale mock up fabric test of cigarette (smoldering) ignition (source 0).
- Real-scale mock up flaming ignition test for filling materials covered by a standard fabric; source is a small flaming wood crib (ignition source 5, ≈ 4 kW); material passes if flaming time < 11 min, no progressive smoldering, and total mass loss < 60 g.

CPSC 16 CFR Part 1633 (Final Rule, 2006)
Intended to limit fire size for residential mattress sets
- Mattresses exposed to two propane square burners positioned on the top (18 kW) and side (9 kW) for 70 s and 50 s, respectively.
- Passes if the peak heat release rate < 200 kW during 30 min test and integrated heat release < 15 MJ for initial 10 min of the test.

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Workshop on Quantifying the Contribution of Flaming Residential Upholstered Furniture to Fire Losses in the United States

Organizer: William M. Pitts, NIST
March 22-23, 2012

Workshop Objective

To identify approaches for quantifying the full contribution of flaming fires of modern RUF to the Nation's fire losses and, therefore, the potential for reducing these losses.

NIST Technical Note 1757, September 2012

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WORKSHOP ORGANIZATION

<u>This Morning</u>
- Background Talks
  - RUF Burning Behavior: Fabian, Janssens, xxxx
  - Fire Statistics: Pabody, Hall, Butry

<u>This Afternoon</u>
- Open Forum Discussions
  - Leaders: Averill, Gann, Davis

<u>Tomorrow Morning</u>
- Identify Approaches and Participants for Estimating Role of Flaming RUF in Fire Losses
  - Leaders: Averill, Gann, Davis, Pitts

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Some Important Findings of Workshop

- Recent studies confirm the potential for rapid flaming fire growth on RUF to cause significant fire losses in residences.
- Statistics show that fires involving RUF are many times more likely to result in property loss, injury, and particularly fatalities than expected based simply on their percentage of all fires.
- Times required for RUF-fueled fires to grow to dangerous levels are shorter than or on the same order as those required for fire departments to be notified and respond (implications for both human and property losses and fire fighter safety).
- Consensus that losses due to smoldering-only RUF fires are small and nearly negligible (losses occur following transition to flaming).
- Statistics suggest that flaming ignition of RUF occurs in a number of ways that in total represent a significant but not dominant source of fire losses involving RUF.
- Direct measures are not available describing RUF as a second (or higher) item ignited, but there may be approaches for estimating losses due to such burning.

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Some Important Findings of Workshop (continued)

- Statistics describing the role of RUF inside the room of fire origin are somewhat limited due to a lack of information concerning fire growth within the room.
- Probabilistic modeling of fire spread and growth in rooms based on fire experiments using existing fire models offers an approach for better understanding the role of RUF in fire losses.
- There is a continuing need for estimates of the numbers and characteristics (etc., fabric, polyurethane foam, fiber fill, barrier fabrics) of RUF items currently in residences.

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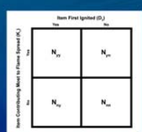
Recommendations from March Workshop

1) Estimate fire losses (deaths, injuries, and property) utilizing a matrix approach.



2) Survey groups of people responsible for coding NFIRS forms to determine how items are coded when presented with pictures or descriptions of various conditions.

3) Organize an NFIRS Special Study Focused on RUF Fire Behavior in Room of Fire Origin.

4) Probabilistic Modeling of RUF Room Fires Incorporating Experimental Observations.

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Analysis for Action Item #1

- Analysis performed by John Hall (NFPA), Marty Ahrens (NFPA), Alexandra Furr (USFA), Brad Pabody (USFA).
- Memorandum provided to William Pitts, NIST on Sept. 12, 2012.

Goal: Develop estimates of home fires and associated losses where upholstered furniture was the primary fuel package but not the initial fuel package ignited.

Results: 2,223 fires, 130 deaths, 276 injuries, and $138 million in direct losses.

Some Context: Approximate annual number of deaths due to direct smoldering ignition of upholstered furniture is 420, approximate number of death due to direct flaming ignition of upholstered furniture is 63, combined with above analysis can conclude that the number of deaths associated with flaming ignition of upholstered furniture is roughly one half of the number associated with tobacco product ignition.

Keep in Mind: Most residential fire deaths in fires due to smoldering ignition are believed to occur after transition to flaming takes place.

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Regulatory Landscape for Residential Upholstered Furniture Changed on May 6, 2012

- First of Series of Investigative Reports appeared in Chicago Tribune.
- Major Technical Points
  - Almost all current residential upholstered furniture in US meets TB 117 by adding fire retardants.
  - Concerns have been raised about toxicity of chemicals, which have been detected in the environment and in humans, used.
  - Evidence exists that fire retardant levels may be too low to sufficiently slow down fire growth or limit fire size.
- Few attempts thus far to rationally characterize current technical understanding and aspects where additional information is required.
- Major regulatory change: California BEARHFTI released a proposed TB 117 update in July, 2012 that removes the requirement for flame resistant fillings and seeks to only limit smoldering ignition.

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Final Remarks

- Evidence indicates flaming residential upholstered furniture remains a major contributor to fire losses in the United States.
- Current regulations (with exception of TB 117) focus on tobacco product ignition primarily by limiting the propensity of upholstery fabrics to smolder.
- Regulations for residential upholstered furniture do not attempt to control the fire behavior (in particular, rapid fire growth and high heat release rate).
- Large fraction of fires started by smoldering in residential upholstered furniture occurs following transition to a flaming state.
- Flaming ignition is responsible for roughly 30 % of fire deaths associated with fires in which upholstered furniture plays a dominant role.
- Reasonable conclusion: limiting the fire growth rate and/or maximum heat release rate of flaming upholstered furniture would provide a substantial reduction in fire losses.

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UL Research Related to Furniture Flammability

Residential Upholstered Furniture Flammability

Changing Severity of Home Fires Workshop
December 11, 2012
College Park, MD

Thomas Fabian, Ph.D.
Underwriters Laboratories

Upholstered Furniture Flammability

"Demonstration of Concept" to verify if commercially available fire resistance technologies can retard and/or reduce fire growth

3 Scales of Testing
- Material
- Mock-up
- Full chairs

www.ul.com/FireService

 2

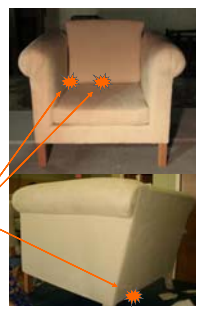
Furniture Tests

OVERVIEW

Samples
- PU-W-C cushions
- frPU-W-C cushions
- PU-FB8-C cushions
- PU-FB8-C cushions & FB3-C sides

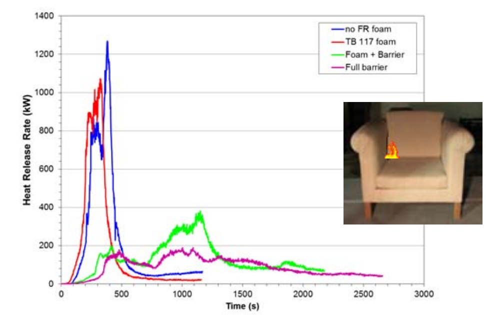
Ignition source
- BS 5852 source 1 ("match flame equivalent" gas flame)

Metrics
- Heat release rate
- Mass loss



Furniture Tests: Material Effects

INTERIOR CORNER IGNITION



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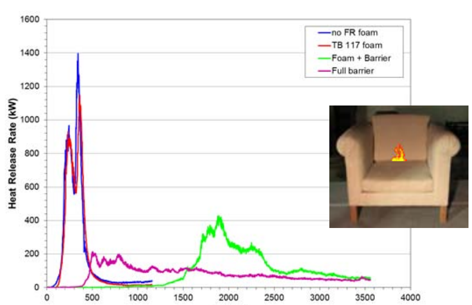
Furniture Tests: Material Effects

SEAT-BACK INTERSECTION IGNITION



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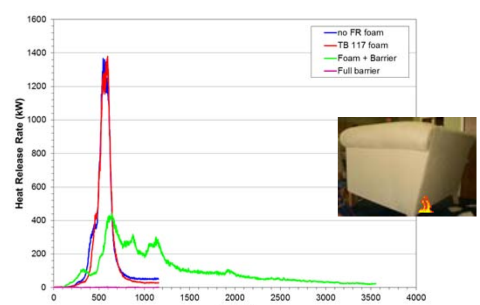
Furniture Tests: Material Effects

BACK BOTTOM IGNITION



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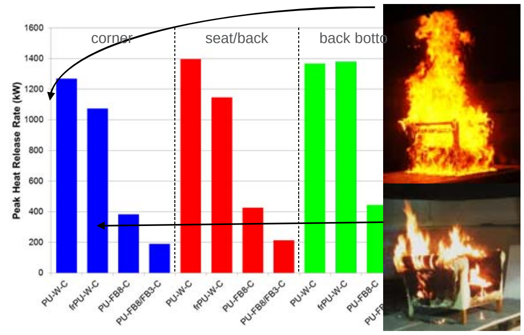
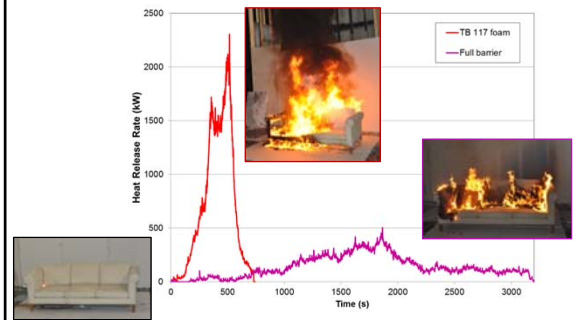
Furniture Tests



Furniture Tests: Component Effect

SOFA



Mitigation Summary

All approaches exhibited some level of reduced ignitability/flammability.

Approach 1: TB117 FR foam substitution for PU foam

- Reduced burn duration on cone calorimeter tests
- Reduced HRR on mock-up tests
- Reduced furniture PHRR when cushions were ignited (1.3 vs. 1.1 MW)

Approach 2: FR barrier inclusion or poly-wrap substitution

- Reduced HRR on cone calorimeter and mock-up tests
- FR barrier substitution for poly-wrap reduced furniture PHRR by ~3X

Approach 3: FR barrier substitution for poly-wrap + covered sides

- Reduced PHRR from 1+ MW to 200 kW
- Ignition of back did not propagate

Phase 2: Living Room Fire Experiments

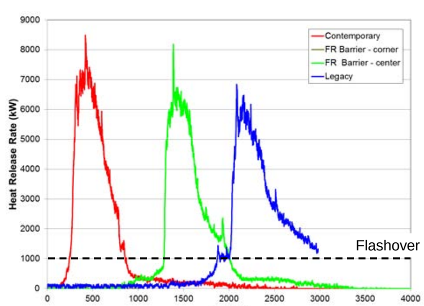
How does fire growth initiated on upholstered furniture using commercially available fire resistance technology compare to legacy and contemporary furniture?

3 Furniture Variations

- Contemporary
- Contemporary w/ barrier
- Legacy

www.ul.com/FireService

Living Room Fire Tests: Heat Release Rate



Living Room Fire Tests

SUMMARY

- "Modern" upholstered furniture has reduced time to flashover by 30 minutes (34+ vs. 4+ minutes)
- Replacing the polyester wrap around foam (cushions, arms) with a cotton-based FR barrier (green?) lengthened time to flashover from 4+ minutes to 21+ minutes
  - ⇒ Minimal impact on furniture construction process
- Further improvement could be made by encasing the upholstered furniture frame with flat barrier
  - ⇒ Some impact on furniture construction process

Phase 3: Tenability Experiments

What is the impact of upholstered furniture on tenability and safe egress time?

2 Furniture Variations
- **Contemporary**
- **Contemporary w/ barrier**

2 Residential Structures
- **1,200 ft^2 ranch**
- **3,200 ft^2 open floor 2 story**

Phase 3: Tenability Experiments

303 seconds to 150 °C

no barrier

1959 seconds to 150 °C

with barrier

Phase 3: Tenability Experiments

1-STORY RANCH HOUSE

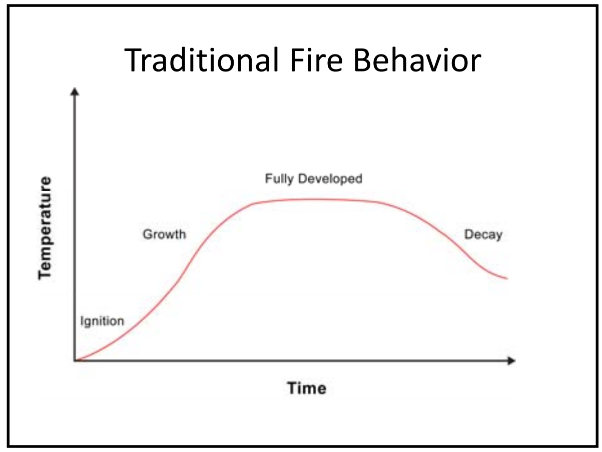
Furniture	Alarm Activation (s)	Tenability Time (s)	ASET (s)
No barrier	242	426	184
With barrier	92	1237	1145
Legacy	16	1055	1039

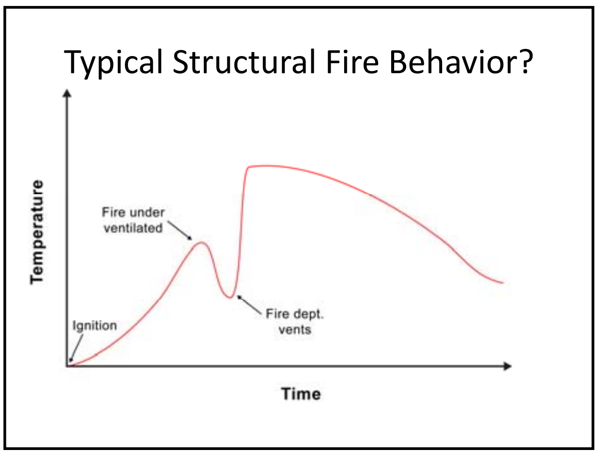
2-STORY OPEN FLOOR PLAN HOUSE

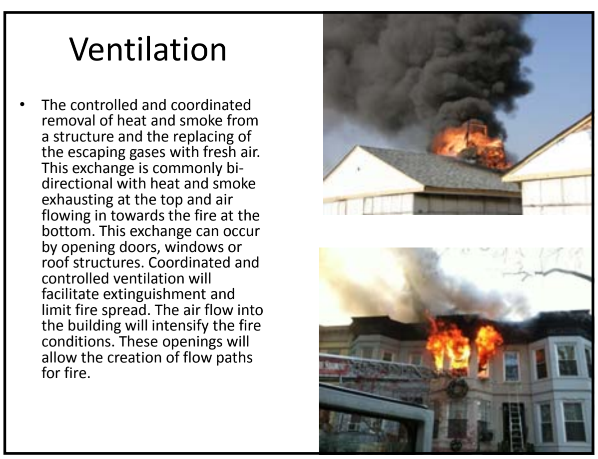
Furniture	Alarm Activation (s)	Tenability Time (s)	ASET (s)
No barrier	92	239	147
With barrier	206	1877	1671

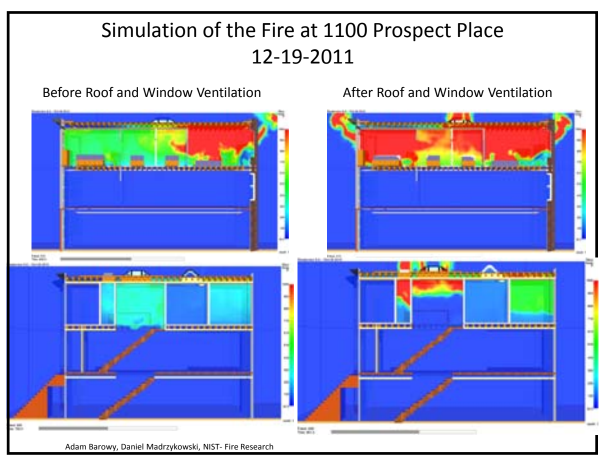
Tenability ≥ 88 °C (consistent with Dunes II)

Size Up, Flowpath and Softening the Target







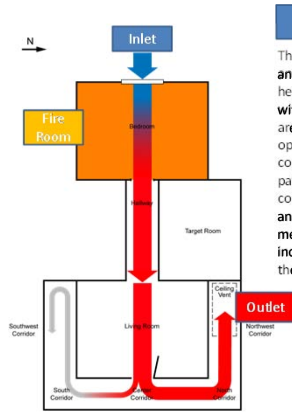


Fire Fighting Tactics Under Wind Driven Conditions: Laboratory Experiments

NIST Technical Note 1618
Daniel Madrzykowski
Stephen Kerber
U.S. Department of Commerce
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899
January 2009

Homeland Security
THE FIRE PROTECTION RESEARCH FOUNDATION
Assistance to Firefighters Grant Program
U.S. Fire Administration

Flow Path



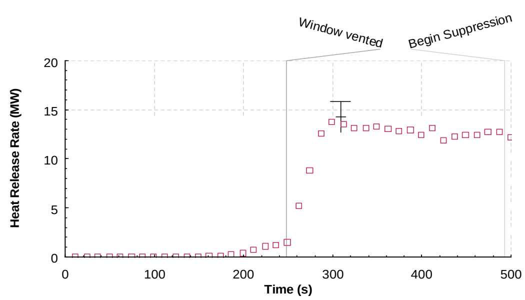
The flow path is the volume between an inlet and an outlet that allows the movement of heat and smoke from the higher pressure within the fire area towards the lower pressure areas accessible via doors and window openings. Based on varying building configurations, there may be several flow paths within a structure. Operations conducted in the flow path , between the fire and the where the fire wants to go, will place members at significant risk due to the increased flow of fire, heat and smoke toward their position.

Fuel Load

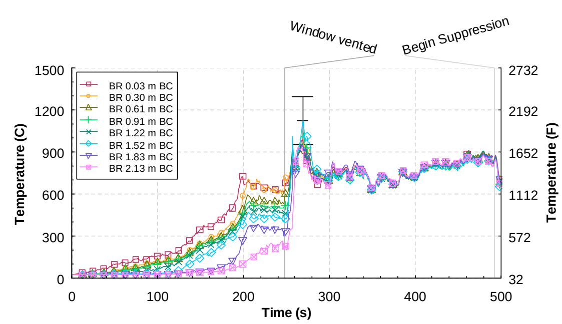
Heat Release Rates

Item	Avg. Peak HRR
Trash Container	30 kW
Chair	1.8 MW
Sofa	2.5 MW
Bed	4.3 MW

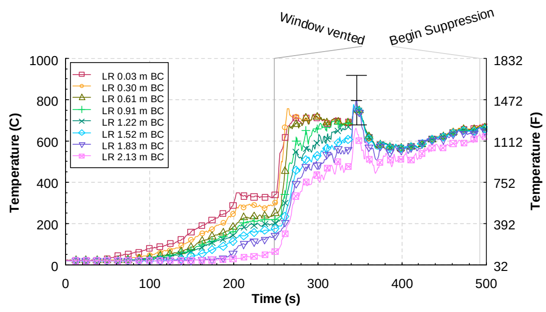
Impact of Horizontal Ventilation on HRR



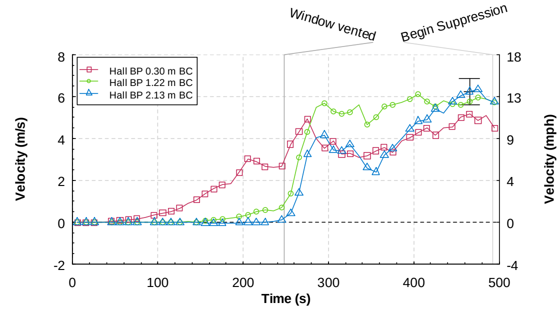
Bedroom Temperatures



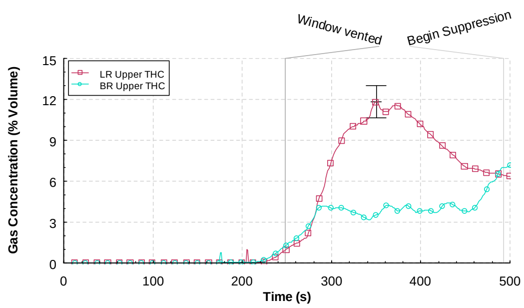
Living Room Temperatures



Velocity in the Hallway between Bedroom and Living Room

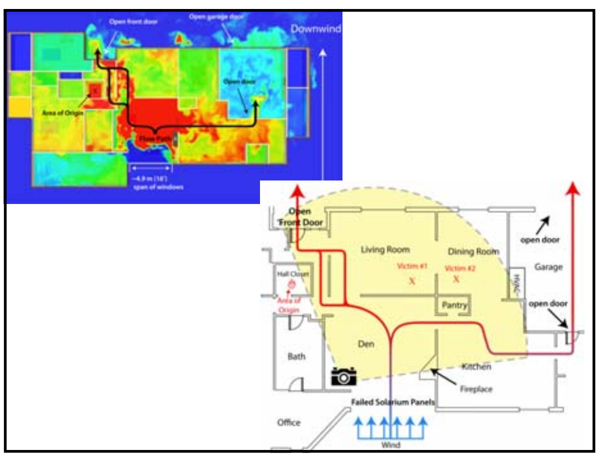


Total Unburned Hydrocarbons



Single Family Home – Houston Wind Driven Fire

Reference: Barowy, A., and Madrzykowski, D., Simulation of the Dynamics of a Wind-Driven Fire in a Ranch-Style House – Texas, NIST TN 1729, January 2011.

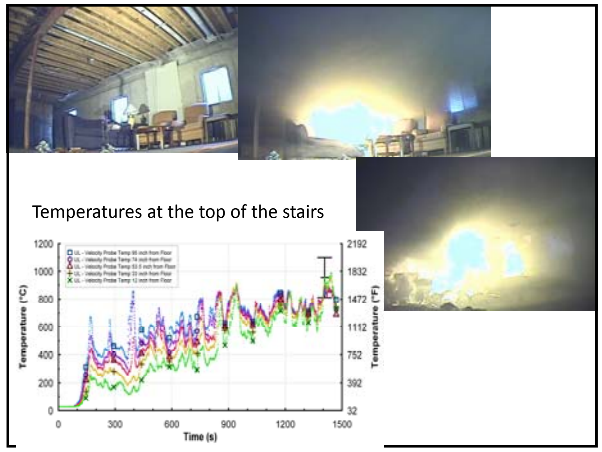


How do you fight a basement fire?

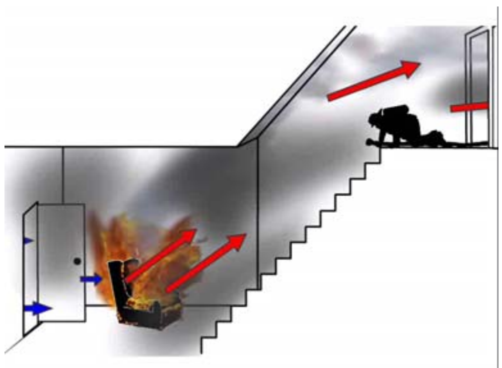
Ref. Essentials of Fire Fighting, IFSTA

Ref: Firefighter's Handbook, Delmar

Two Story Colonial – Basement Fire



Basement Fire – Basement and 1st Floor Vent



Recent Flow Path Related LoDDs

- NIOSH 2011-13 2 LoDDs, Hillside Residential House Fire, California, June 2011.
  - Contributing factors - ventilation & operating above the fire
- NIOSH 2011-2 1 LoDD, FF Caught in Rapid Fire Event During Unprotected Search, Dies After Face Piece Lens Melts, Maryland, January 2011.
  - Contributing factors - Ineffective ventilation, co-ordinate advancing hose lines, (operating above the fire)
- Illinois, 1 FF killed, 1 ff injured Caught in Flow Path - November 2012.

NIST National Institute of Standards and Technology

NISTIR 6510

Simulation of the Dynamics of the Fire at 3146 Cherry Road NE, Washington D.C., May 30, 1999

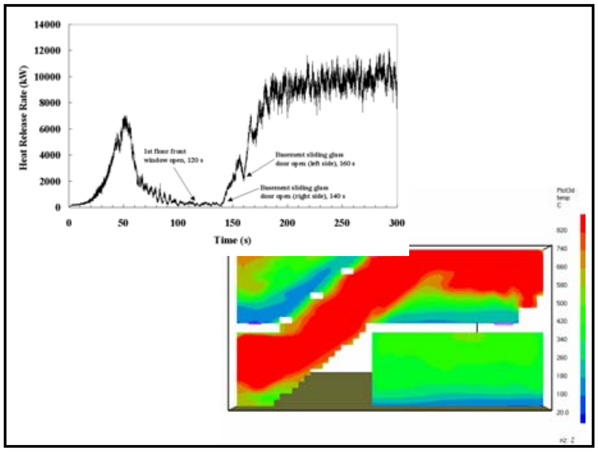
Daniel Madrzykowski and Robert L. Vettori

CD Version prepared by:
William D. Walton and Glenn P. Forney

April 2000

Fire Safety Engineering Division
Building and Fire Research Laboratory
National Institute of Standards and Technology

Learning Objectives:
1)Ventilation Induced Flashover
2) Need for proper venting
3)Speed of transition to flashover

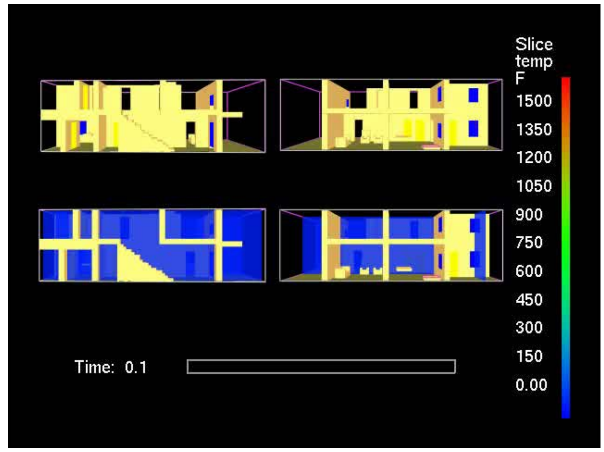


LODD Fire Reconstruction with NIST Fire Dynamics Simulator/Smokeview
Iowa Structure Fire

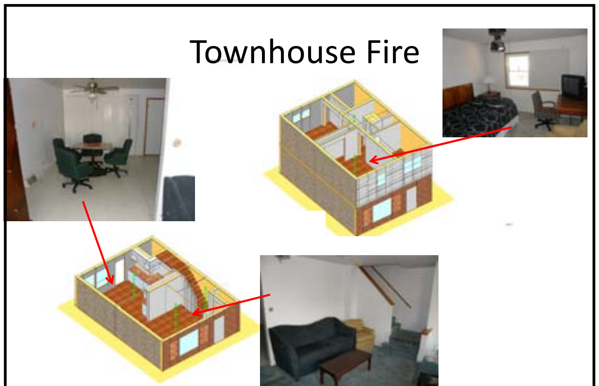
Learning Objectives:
1) Rapid post-flashover flame spread (smoke is fuel)
2) Impact of interior finish on flame spread
3) Need for sufficient manpower to enable coordinated search, rescue, ventilation and suppression

Sponsored by the NIOSH Fire Fighter Fatality Investigation and Prevention Program

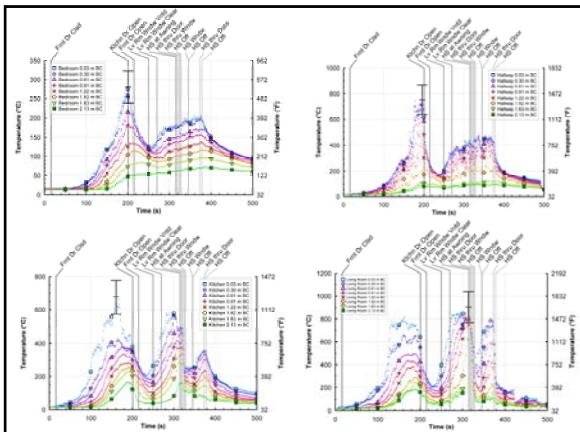
Reference: NISTIR 6854 – Simulation of the Dynamics of a Fire in a Two Story Duplex – Iowa, December 22, 1999.
Madrzykowski, Forney, and Walton -



Townhouse Fire



Post Fire



SUMMARY

- The hazard from a residential fire has increased due to:
  - Synthetic fuel loads
  - Reduced compartmentation
  - Light-weight construction techniques
  - Energy efficiency/alternate energy measures
- Tactics may need to be revised
- Early water may be the best approach
- “Softening the target”

Fire Service – Way Forward

- Be aware of the capabilities and limitations of PPE
- Improved fire behavior understanding (Apply to Fire Ground)
  - Smoke is fuel
  - Venting does not equal cooling
  - Most structure fires are ventilation limited (fuel rich)
- Size up – reassess as ventilation changes
- Locate the fire
- Account for wind conditions (keep the upwind of the fire)
- Identify and stay out of the fire’s flow path (exhaust)
- Consider alternate approaches to basement fire
- Unburned to burned may not be the best attack
- Current understanding, standards, education, training and SOPs/SOGs must be in sync at a National level.

More Info

www.nist.gov/fire
www.fire.gov
www.cfitrainer.net
www.ul.com/fireservice

madrzy@nist.gov

Defensive?
Or an aggressive exterior attack?

Fire Fighter’s Changing Work Environment

What is the cause?

Inexperience
Lack of training
New generation
SCBA
Bunker gear

Of the 14 LODD's
7 were pre-bunker and 7 were post bunker!

Tradition vs Research

- Changes in fire environment
- Fewer fires = less experience
- Limited fire behavior training in the academy
- New equipment standards working to catch up to advances in technology
- Fire service has not yet benefited to the full extent from the Information Technology Revolution
- No National Standards on Fire Fighting Tactics (very few science based fire fighting tactics)

NIOSH Report F 2006-26

Career Engineer Dies and Fire Fighter Injured After Falling Through Floor While Conducting a Primary Search at a Residential Structure Fire Wisconsin

International Residential Code

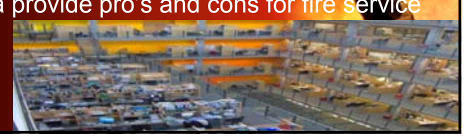
101.3 Intent. The purpose of this code is to establish the minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment <u>and to provide safety to fire fighters and emergency responders during emergency operations</u>.

Site Design Issues:

- Apparatus Access
  - Limitations on Hardscape
  - Limitations on turfgrass
- Traffic Calming
  - Narrow roadways
  - Speed humps, chicanes, chokers
- Landscaping

Building Design Issues

- Lightweight Construction
- Large, Open Spaces
  - Result in Fuel controlled Fires as opposed to ventilation controlled fires
  - Atria provide pro's and cons for fire service



Increased Fuel Loads

The contents of a single-family home.

Now dominated by synthetic materials.

Source: National Geographic Magazine

Increased Fuel Loads

- Upholstered furniture such as chairs, recliners, love seats and sofas are common fuel packages in the living room or family room of a residential occupancy.
- A single upholstered chair can provide enough energy to take a 10 x 12 room to flashover.
- A sofa can provide 3X the energy of a single chair.

Current Language

R501.2 Requirements. Floor construction shall be capable of accommodating all loads according to Section R301 and of transmitting the resulting loads to the supporting structural elements.

Adopted Language

- R501.3 Fire protection of floors. Floor assemblies, not required elsewhere in this code to be fire resistance rated, shall be provided with a ½ inch gypsum wallboard membrane, 5/8 inch wood structural panel membrane, or equivalent on the underside of the floor framing member.
- Exceptions:
- 1. Floor assemblies located directly over a space protected by an automatic sprinkler system in accordance with Section P2904, NFPA13D, or other approved equivalent sprinkler system.
- 2. Floor assemblies located directly over a crawl space not intended for storage or fuel-fired appliances.
- 3. Portions of floor assemblies can be unprotected when complying with the following:
  - 3.1 The aggregate area of the unprotected portions shall not exceed 80 square feet per story
  - 3.2 Fire blocking in accordance with Section R302.11.1 shall be installed along the perimeter of the unprotected portion to separate the unprotected portion from the remainder of the floor assembly.
  - 4. Wood floor assemblies using dimension lumber or structural composite lumber equal to or greater than 2-inch by 10-inch nominal dimension, or other approved floor assemblies demonstrating equivalent fire performance.

Collapse Results

Experiment Number Floor Support	Ventilation	Fire Spread to Floor	Collapse	Δt (min:sec)
1. Dimensional Lumber (2 x12)	Max Vent	3:58	11:09	7:11
2. Dimensional Lumber (2 x12)	Sequenced Vent	2:00	12:45	10:45
3. Engineered Wood I joist (12 in.)	Max Vent	3:15	6:00	2:45
4. Engineered Wood I joist (12 in.)	No Vent	2:43	6:49	4:06
5. Engineered Wood I joist (12 in.)	No Vent/No boxes	3:45	8:27	4:42
6. Engineered Wood I joist (12 in.)	Max Vent/Furnace DHS load	3:00	6:49	3:49
7. Steel C-Joist (12 in.)	Max Vent	3:00	8:15 (6:11exceeds ISO834:1)	3:11
8. Steel C-Joist (12 in.)	Sequenced Vent	3:32	14:04* (10:08 exceeds ISO 834:1)	6:36
9. Parallel Chord MPCWT**	No Vent	2:26	6:08	3:42
10. Parallel Chord MPCWT	Max Vent	1:38	3:28	1:50

Furnace Test Results

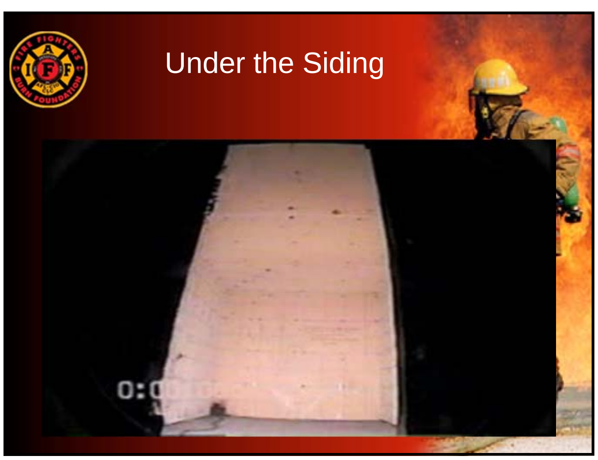
Assembly Time Of Structural	Failure (m/s)	Failure Load Bearing Capacity (m/s)
1. Engineered I Joists with Openings	8:10	6:10
2. Engineered Wood and Metal Hybrid Trusses	5:30	4:20
3. Engineered I Joists w/ Intumescent Coating	17:50	17:40
4. Engineered I Joists (100% Load)	2:20	2:20
5. Engineered I Joists w/ Fire Retardant Coating	8:40	7:50
6. Nominal 2 in by 10 in Dimensional Lumber (100% Load)	7:04	7:04
7. Legacy Nom nal 2 in by 8 in Dimensional Lumber (100% Load)	18:05	17:40


Old vs New


Equivalent?
wisn.com
wisn


Flak Jacket
FLAK
JACKET
PROTECTION


Fire Exposure
Structural Separation Experiment
Target Wall View Typical Construction
NIST
FIRE RESEARCH


Under the Siding


Operational Issues
• Fire Growth May Be Quicker, Necessitating Greater Quantities of Water
• Ventilation Techniques May Need to be Reconsidered
• Energized Circuitry in the Oddest Places
• Apparatus Access

Fire Service Challenges

- Budget Cuts
- Reduction of Prevention Priorities
- Still Need to Respond
- Lack of Understanding the Potential Impact on Work Environment
- Politicians Who Don't Understand Fire

Level of Risk Key Dynamic Risk Assessment

Risk Rating	Actions Required
Extreme	Do not proceed/alternative tactics required
High	Close supervision/back-up required
Medium	Normal procedures should suffice
Low	Monitor for escalation

Killer Smoke

- **Killer Smoke** may contain 53 toxic compounds, of which 43 are known to be carcinogens.

Cancer

Research on the relationship between the incidence of cancer and the occupation of a fire fighter, while in some cases controversial and not fully accepted, has produced some startling data. The average age of death from cancer for a fire fighter has dropped from 49 years old to 44 years old since 1950. According to some studies, the comparable rate of cancer of fire fighters to the general public is demonstrated here:

Type of Cancer Above Normal	% Incidence Rate
Throat	200+
Mouth	200+
Lung	120-190
Brain	129
Prostate	117
Pancreatic	140-176
Rectal	143

In addition, recent studies from the University of Cincinnati indicated higher incidences of Testicular Cancer, Liver Cancer, Melanoma and Non-Hodgkin's Lymphoma.

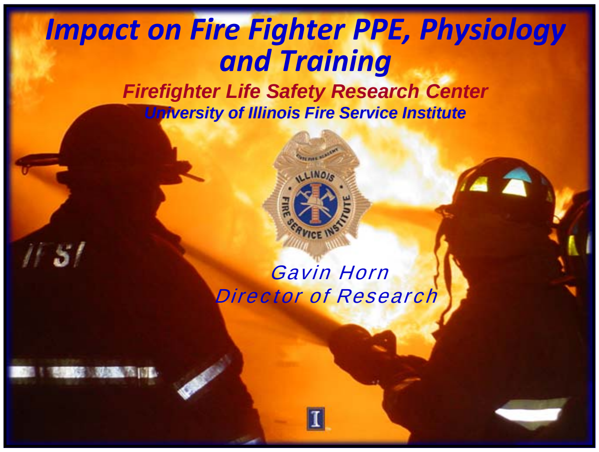
Design Community Responsibilities

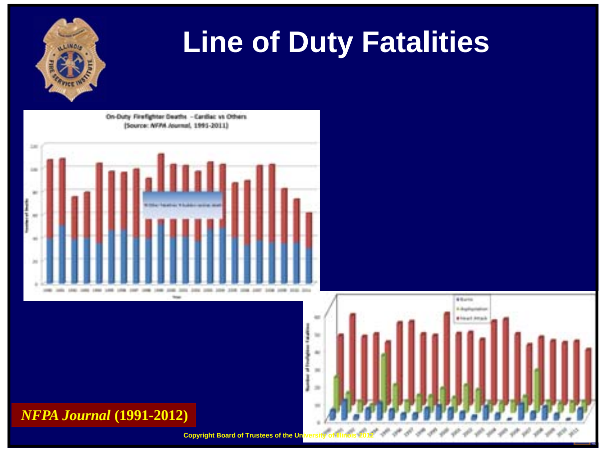
- Help Create a Collaborative Environment
- Exchange Information
- Involve the Fire Service Early
- Engage the Regulatory Process

Trust Us We Are Professionals


DISCUSSION


Thank you
Sean DeCrane
International Association of
Fire Fighters District 8
Burn Coordinator
Sean DeCrane
rovloc93@aol.com


Impact on Fire Fighter PPE, Physiology and Training
Firefighter Life Safety Research Center
University of Illinois Fire Service Institute
Gavin Horn
Director of Research


Line of Duty Fatalities
NFPA Journal (1991-2012)
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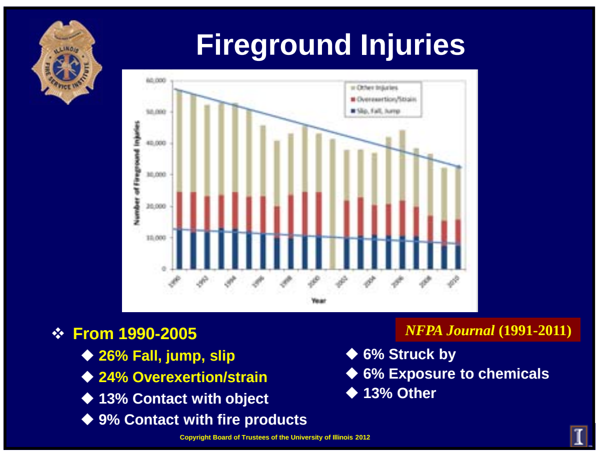
Fireground Injuries
NFPA Journal (1991-2011)
From 1990-2005
26% Fall, jump, slip
24% Overexertion/strain
13% Contact with object
9% Contact with fire products
6% Struck by
6% Exposure to chemicals
13% Other
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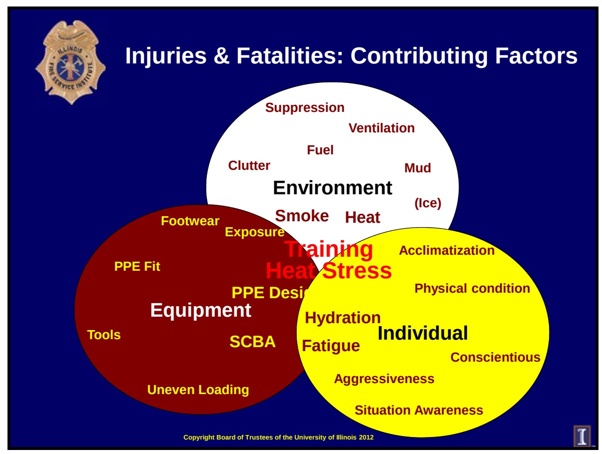
Injuries & Fatalities: Contributing Factors
Suppression
Ventilation
Fuel
Clutter
Mud
Environment
(Ice)
Smoke
Heat
Footwear
Exposure
Training
Heat Stress
Acclimatization
PPE Fit
PPE Design
Physical condition
Equipment
Hydration
Tools
SCBA
Fatigue
Individual
Conscientious
Aggressiveness
Uneven Loading
Situation Awareness
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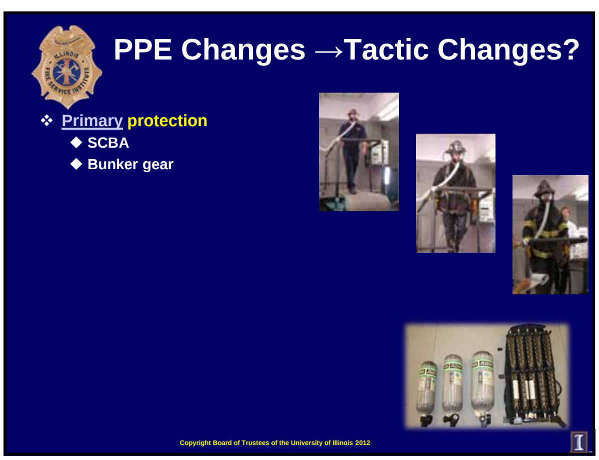
PPE Changes →Tactic Changes?
Primary protection
SCBA
Bunker gear
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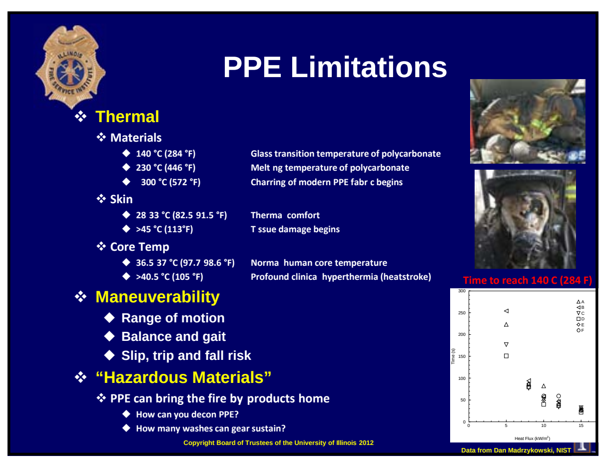
PPE Limitations
Thermal
Materials
140 °C (284 °F) Glass transition temperature of polycarbonate
230 °C (446 °F) Melting temperature of polycarbonate
300 °C (572 °F) Charring of modern PPE fabric begins
Skin
28-33 °C (82.5-91.5 °F) Thermal comfort
>45 °C (113°F) Tissue damage begins
Core Temp
36.5-37 °C (97.7-98.6 °F) Normal human core temperature
>40.5 °C (105 °F) Profound clinical hyperthermia (heatstroke)
Time to reach 140 C (284 F)
Maneuverability
Range of motion
Balance and gait
Slip, trip and fall risk
"Hazardous Materials"
PPE can bring the fire by products home
How can you decon PPE?
How many washes can gear sustain?
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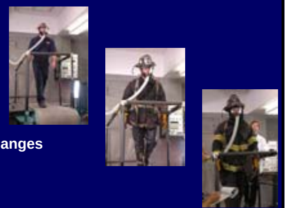
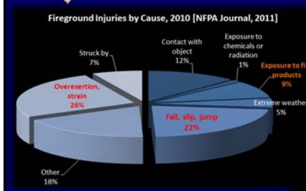
Data from Dan Madrzykowski, NIST

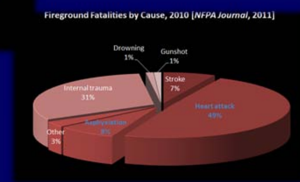
PPE Changes →Tactic Changes?

- Primary protection
  - SCBA
  - Bunker gear
- Response to SCBA "failures"
  - SCBA face piece changes
  - End of service time indicator changes
  - Extended duration SCBA



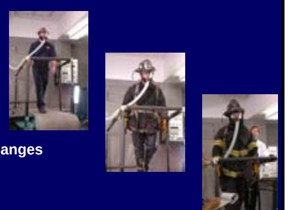
Motivation for Extended Duration SCBA?





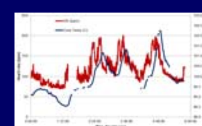
PPE Changes →Tactic Changes?

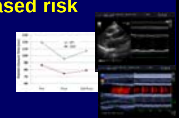
- Primary protection
  - SCBA
  - Bunker gear
- Response to SCBA "failures"
  - SCBA face piece changes
  - End of service time indicator changes
  - Extended duration SCBA
- Rescue tools
  - PASS devices
  - Personal Escape Systems
- Situational awareness tools
  - Thermal imaging cameras
  - Tracking, physiological monitoring…

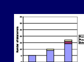


Personnel Limitations

- Firefighting increases
  - Heart rate
  - Core temperature
  - Dehydration
- Overwhelming evidence suggests increased risk for
  - Cardiovascular events
  - Biomechanics disruptions
    - Overexertion/strain
    - Slips, trips, falls
- Fireground exposures
  - Toxic & carcinogenic byproducts
  - Particulate – sub-micron

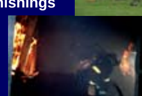






Training

- How can we adapt our FF training?
  - Traditional fuels do not simulate modern furnishings
  - Objective based training
- New opportunities for students
  - Supplemental classroom learning
  - Demonstrations
    - Tabletop "model" structures
    - Investigation burns
  - Bring in the outside expertise
- Instructor training
  - Continuing ed development
  - IFSI Burn teams



Firefighting Injuries/Fatalities

- PPE
  - Does PPE development drive tactics or tactics drive PPE development?
  - How do we address PPE for the modern firefight?
- Physiology
  - How can tactics reduce risk to firefighters even as the fire environment is changing
    - Thermal
    - Cardiovascular
    - Exposure to carcinogens
- Training
  - How do we train firefighters to respond to the modern firefight within the realistic training environments?


Impact on Fire Fighter PPE, Physiology and Training
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University of Illinois Fire Service Institute
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