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Firefighter Thermal Exposure Workshop: Protective Clothing, Tactics, and Fire Service PPE Training Procedures Gaithersburg, Maryland June 25-26, 1996

J. Randall Lawson and Nora H. Jason, Editors

Cover Photograph:

Firefighters from the York Beach Fire Department (Maine) were protecting a building exposure. The May 20, 1986 fire completely destroyed the Ocean House Condominium complex that was under construction. At the time of the fire the 120 m x 20 m (365 ft x 60 ft) building was 40 percent complete. The fire spread so rapidly the burning building collapsed within 10 minutes after the time of fire department dispatch. There were no injuries, and the exposed building only had minor damage. Photograph courtesy of the York Beach Fire Department (Maine).

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Editors:

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CONTENTS

1. INTRODUCTION

This workshop was held to identify fire service and protective clothing industry concerns associated with protecting firefighters from thermal exposures and to facilitate the exchange of ideas. Needs identified and prioritized by the participants will assist in selecting research activities necessary to improve methods for protecting firefighters from hazardous thermal environments. It is hoped that this workshop will provide a catalyst for continued cooperative efforts among the fire service, industry, the Federal Government and other interested parties to improve firefighter safety.

About 6000 firefighters receive serious burn injuries each year [1]*. This yearly burn injury rate has not changed significantly for the last two decades even though substantial improvements have been made in firefighters' protective clothing and equipment. It is also recognized that fire growth rates have changed during this same time period [2]. Two factors have contributed to the changes in fire growth:

1. Fire loads, the mass quantity of combustibles per area, have increased in our homes and workplace [2-4].

2. Heat release rates generally have increased with the introduction of modern furnishings and some building materials [2][5].

These factors create significant challenges for today's firefighter. Methods for managing firefighter safety when exposed to these thermal challenges are controlled by the application of three interrelated elements. They are:

1. Training (type, quantity and quality of training a firefighter receives).

2. Tactics (those tactics based on training and equipment available for use and selected by a firefighter when fighting a fire).

3. Protective clothing (the type and amount of protection provided by a firefighters' protective clothing and equipment).

It takes the balanced use of all three of these interdependent elements to keep a firefighter safe. Failure to properly use any of these elements will lead to increased risk to the firefighter. Each of these three elements was addressed during the workshop. This report provides summaries of the presentations at the workshop and recommendations for future activities.

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* Numbers within the brackets refer to the references cited in section 9.

2. METHODOLOGY

The primary considerations for inviting members from the fire service, industry and the speakers were:

Fire Service Considerations:

- Different geographical locations: different climatic needs;
- size of departments: small, medium, large;
- professional and volunteer firefighters;
- female firefighters;
- interest in firefighter safety and knowledge of fire service training, tactics, and use of fire service protective clothing and equipment.

Manufacturer Considerations:

- Industry representatives from producers of safety products for each type of structural fire fighters clothing and equipment;
- manufacturers of component materials used in the fabrication of protective clothing.

Speaker Considerations:

- Detailed knowledge of their specific areas of interest;
- representation: fire service (including professional and volunteer firefighters), fire fighters' union, protective clothing and equipment manufacturing industry, standards writing organizations, Federal Government, research community.

3. AGENDA

The workshop's agenda was designed to cover the range of issues listed in section 1. The first session was planned as an introduction to concerns of the fire service and industry as they relate to firefighter safety. The presentations provided the participants with an opportunity to develop questions and ideas that would be discussed during the three panel sessions that followed. Three panels were formed: 1) Firefighters' Personal Protective Clothing and Equipment, 2) Fire Fighting Tactics, and 3) Firefighter Personal Protective Equipment (PPE) Training.

FIREFIGHTER THERMAL EXPOSURE WORKSHOP:
PROTECTIVE CLOTHING, TACTICS AND FIRE SERVICES PPE TRAINING
JUNE 25-26, 1996
HOLIDAY INN, GAITHERSBURG, MD

Tuesday, June 25

8:30 AM	Registration
9:00 AM	Welcome - Dr. Jack E. Snell, Program Manager, Fire Research Program, Building and Fire Research Laboratory/National Institute of Standards and Technology (BFRL/NIST)
9:15 AM	*Fire Service Needs* - Division Chief Kirk Owen, Plano Fire Department, TX
9:45 AM	*Views of the Professional Fire Fighters Union* - Mr. Richard Duffy, International Association of Fire Fighters
10:10 AM	Break
10:45 AM	*Views of Volunteer Fire Fighters* - Mr. Philip C. Stittleburg, National Volunteer Fire Council Foundation, Inc.
11:05 AM	*Voices From the Field* - Chief Chuck Soros, Seattle Fire Department (Retired), WA
11:25 AM	*Industry Views on Thermal Protective Clothing* - Ms. Mary Grilliot, Fire and Emergency Manufacturers Services Association
11:40 AM	*NFPA Standards on Structural Firefighting Protective Clothing* - Mr. Bruce Teele, National Fire Protection Association
12:25 PM	Lunch
1:30 PM	*Protective Clothing and Equipment: A System Concept* - Mr. Robert McCarthy, U.S. Fire Administration
1:50 PM	*Thermal Environments of Structural Fire Fighting and Firefighter Protective Clothing* - Messrs. J. Randall Lawson and Emil Braun, BFRL/NIST
2:15 PM	Charge to Panels - Mr. J. Randall Lawson, BFRL/NIST
2:30 PM	Break
4:30 PM	Panel Presentations
5:00 PM	Workshop closes for the day

Wednesday, June 26

8:30 AM	Panels reconvene
10:30 AM	Break
11:00 AM	Panel Chairs Presentations
12:15 PM	Workshop closes
12:30 PM	No Host Lunch at NIST Cafeteria
1:20 PM	Assemble at rear of Cafeteria
1:30 PM	Tour of BFRL and NIST Fire Research Facility, Building 205
3:00 PM	Workshop closes

4. SUMMARY AND RECOMMENDATIONS

Three panels were formed to address the three firefighter thermal exposure topics: Protective Clothing, Tactics, and Fire Service PPE Training. Each research goal addresses a particular element associated with protecting firefighters from burn injuries. The panel chairs prepared reports detailing their findings; these are located in section 6. This section provides a summary of their findings and recommendations.

3.1 Personal Protective Clothing and Equipment Panel

Five specific issues were identified and discussed by this panel. The following prioritized list of issues selected by this panel have been restated in terms of research goals:

Priority	Research Goals
1.	Better define the types and number of burn injuries.
2.	Identify things that can be done to address heat stress issues.
3.	Identify the mechanics of heat transfer that result in firefighter burn injuries.
4.	Identify the key protective garment interface issues.
5.	Develop effective burn prediction methods.

3.2 Fire Fighting Tactics Panel

This panel selected six primary issues related to fire fighting tactics and firefighter thermal exposures. They also identified seven secondary issues that need improvement or increased understanding. Although a prioritized list was submitted by the panel, the items in the list below were restructured into related groupings. The numbering of each issue reflects the priority assigned by the panel. The following list summarizes the selected issues in terms of research goals:

Fire Control Techniques, Primary Issues

1. Improve the understanding and impact of ventilation on fire fighting tactics and the risk of firefighter thermal exposures.

Priority	Research Goals
2.	A need exists to improve the understanding and impact of fire extinguishment techniques: fire stream management, number and placement of fire attack hose lines, selection of nozzle types and flow rates, fog verses straight stream, droplet size, etc.
3.	Develop a standard method for conducting a risk analysis for a building and its contents. This analysis will assist in formulating fire control techniques for specific fire incidents.

Fire Control Techniques, Secondary Issues

12.	Identify and develop effective remotely operated hose stream equipment and techniques that will reduce the need for firefighter thermal exposures. Further develop the use of robots as substitutes for firefighters where fire attack risks are high.

Fireground Personnel Management, Primary Issues

4.	Develop a standard methodology for determining adequate staffing at the fire incident.
5.	Develop a standard methodology for determining adequate rotation of fire fighting crew members.
6.	Develop standardized methods for operating a rehabilitation (REHAB) area at a fire scene. For example, REHAB protocol may require that medical records be kept for all firefighters on the scene. These records may include respiration, pulse, blood pressure, blood oxygen content, etc.

Fireground Personnel Management, Secondary Issues

7.	There is a need to develop standard operating procedures (SOPs) for fireground operations and personnel management.

Fire Service Safety Programs

8.	Efforts are needed to increase safety awareness and acceptance throughout all levels of the fire service.

Firefighters' Protective Clothing

Priority	Research Goals
9.	Manufacturers of firefighters' protective clothing should conduct the necessary research to develop protective clothing designs that allow quicker donning and doffing (i.e., putting on and taking off equipment).
13.	There is a need to develop a means for firefighters wearing protective clothing to better gauge the thermal environments around them and to be able to access the threat of flashover.

Firefighters' Training and Availability of Information

10.	There is a need to develop realistic fireground training operations.
11.	There is a need to develop improved methods for disseminating information throughout the fire service. Internet has opened new avenues for the transfer of information to the fire service. However, information provided through the Internet is not necessarily verified. The fire service should form a coalition of interested parties to determine ways to improve the collection and dissemination of fire/rescue/EMS related information.

3.3 Firefighters' Personal Protective Equipment (PPE) Training Panel

Four issues related to the training of fire service personnel were identified by this panel. Most of the issues would benefit from the development of scientifically accurate and well documented video tapes and computer media that are designed to communicate fire service information and scientific concepts to the firefighter. The prioritized list of issues identified by this panel has been restated in terms of research goals. The following list identifies the needs for research related to improving fire-fighter training:

1. Develop a standardized technique for conducting hazard assessments for selection of proper PPE for structural firefighters. This technique should provide for an assessment based on tasks performed and conditions experienced by an individual local fire department. Training on the technique of hazard assessment should be provided for fire service managers and supervisors to enable them to correctly accomplish the task.

   Note from the editors: This technique for hazard assessment must include a means for quantifying and communicating information on the limits of protection provided by all protective clothing and equipment.

Priority	Research Goals
2.	Develop a standardized scale for representing fire severity as it directly impacts structural firefighters' safety. Provide education to fire service supervisors and firefighters to enable them to adequately evaluate field conditions using the standardized scale.
3.	Develop specific criteria for firefighters to determine, prior to injury, that their protective clothing and equipment may not provide adequate protection for specific fire fighting environments. Provide education to fire service supervisors and firefighters to enable them to recognize conditions where their protective clothing and equipment will not provide adequate protection. Note from the editors: This training must communicate information on the limits of protection provided by all protective clothing and equipment.
4.	Develop a standardized methodology for periodic inspection of protective clothing and equipment to assure that all in-service PPE has the protection determined by the hazard assessment discussed in item one of this section. Provide education to fire service managers, supervisors and firefighters to enable them to correctly inspect PPE and determine its acceptability for use.

6. PANEL REPORTS

Personal Protective Equipment (PPE) Panel, Donald Aldridge, Chair

The panel was directed by the chair to home in on issues the participants felt were important to reduce injuries and heat stress and also to look at cause and effect on other issues such as training and tactics.

This panel met first the afternoon of June 25. We began with a general discussion of the following points:

- A review of the technical presentations from earlier in the day.
- A review of panel members' personal research and experiences, as they relate to protective equipment for thermal exposures.

At the conclusion of the June 25 meeting, Chair Donald Aldridge and Workshop Administrator Randy Lawson asked us to speak with conference attendees (involved in other panels) that evening, on the same subjects. Based upon that research and our earlier discussions, described above, we were to return the next day with open research questions.

"Open research questions" from each member were discussed. There was no limit on numbers of items presented, nor initially was there an attempt to prioritize or group topical areas. It was noted that the areas of concern raised by the written questions from the attendees were very much in line with the issues of importance discussed by the PPE Panel the previous afternoon. After several hours of free ranging discussion, the committee was able to isolate and prioritize five areas of critically needed research. Each topic is presented in priority order and in some detail below.

1. What Kinds of Burns are Happening?

As a prerequisite to any effective corrective action, the panel felt it was critical that we convince ourselves we truly understood the types of burns that are actually occurring. The panel felt this effort would begin with the construction of a reliable, uniform and enforced reporting system. Ideally, the system would be used universally (volunteer and paid, all states, regardless of injury, severity, etc.). The model referenced was the reporting system for sexually transmitted illnesses. Only when that system was universally implemented did significant progress actually occur in fighting these diseases (because we finally understood how they were actually being transmitted).

The panel felt research should be conducted into the feasibility of a similar mandatory system for thermal exposure injuries, administered through the medical community. The panel also felt that

research should be conducted into what information should be included in any burn reporting system. Among the suggestions offered were the following:

- Details of exposure incident (e.g., type of heat, time of exposure, etc.);
- other injuries/exposure at that event;
- detail of type of protective equipment utilized;
- condition of protective equipment at time of injury (wet vs. dry, clean vs. dirty, etc.);
- previous experience and training of injured person.

The panel felt it important that responses be kept confidential so as to insure that there was no "editing" of the actual events (to avoid disciplinary actions or loss of workers' compensation benefits). There was some discussion this could best be accomplished with a two part process. First, the medical care giver reports the event, then a burn report system technician (with appropriate emergency service experience) contacts the key players to guarantee confidentiality and get a detailed discussion of the actual events that transpired.

2. What can be Done to Address Heat Stress Issues?

Similarly, the panel's discussion highlighted the fact that while stress issues remain the almost universally identified Number 1 challenge to fireground safety, the National Fire Protection Association (NFPA) Standard, Protective Clothing and Equipment for Fire Fighting (NFPA 1971) does not address the issue. Again, this is the case because of the lack of a universally accepted, verifiable test protocol.

Specifically, the panel felt research into the following areas was extremely important:

- The impact of uniforms and underclothing on stress management;
- the interplay of Thermal Protective Performance (TPP) with system heat stress mitigation characteristics;
- the impact of fit on stress characteristics of a system;
- the effectiveness of various rehabilitation techniques on equipment and personnel;
- the desirability of varying TPP requirements between coats and pants;
- does perceived "comfort" correlate with good stress dissipation characteristics?

Research into these questions, as well as into the adequacy of existing tests such as the Sweating Guarded Hot Plate Test, or an alternative measure of system heat dissipation characteristics would do much to advance the art of protective equipment.

3. What are the Mechanics of Heat Transfer?

Once the type of burns are adequately documented, the panel felt research is necessary to identify the mechanics of the burn process through protective equipment.

Specifically, the panel felt the following issues that impact burn dynamics, must be studied:

- Varying characteristics of all types of heat exposure: radiant, convective, or conductive heat and various mixes of these. Radiant exposure appears to be one of the most challenging types of exposure to be studied.
- Impact of wetness (by amount, by location and by heat exposure experienced).
- Heat sink of various composites.
- Heat sink thermal loading versus high heat (shorter duration) exposures.

The panel felt most burns occurring today (but not necessarily the most severe) were due to thermal heat sink loading. Research to confirm this point and develop such a test protocol would do much to advance thermal exposure protection levels.

4. What are the Key Interface Issues?

> Note by editors: Interface is defined as an area of the body where protective garments meet or overlap, i.e., protective glove and protective coat, protective coat and helmet, or the SCBA facepiece and protective hood.

Panel discussions noted that the elements of the protective system often comes from different manufacturers. While the individual elements are often highly and effectively engineered, the interface areas are often ignored (since no single manufacturer has design responsibility or the ability to predict what the interface will be for the system).

The firefighter, of course, must use all the elements of the system together. The system is only as good as the weakest link; unfortunately, the interact areas are often the weakest links.

The panel felt that research into defining key performance requirements for interface areas would do much to improve safety levels of personnel using thermally protective equipment.

5. Is there Effective Burn Prediction?

The panel's discussion also touched upon the fact that as we more effectively protect individuals from unexpected or high heat exposures, we also limit their ability to feel quickly when conditions are changing (i.e., they are more thermally insulated). It was felt that research into feasible burn prediction techniques and devices would do much to advance protection levels while using thermally protective equipment.

Tactics Panel
Theodore Jarboe, Chair

The Tactics Panel identified a number of key needs (issues). These issues can and do have a significant impact on the risk of firefighters to thermal exposure during fire fighting operations within a building.

Practically all of the issues are controllable. That is, they are within the management capability of the local fire department. It was clear from the discussion that a well-orchestrated incident command structure is necessary to ensure timely and effective implementation of the issues identified.

Prioritized Needs

1. The need for and importance of ventilation early into an incident. As fire develops within a building, smoke and heat conditions continue to increase and worsen. Without an effective and timely means of releasing the pent up heat and smoke, firefighters have a higher risk of injury from thermal exposure.

   Recommendation: Research should be conducted to substantiate thermal conditions during fire development, with and without adequate ventilation. The research should be full-scale tests using acquired buildings. Technological advancements in mechanical ventilation should also be examined both in terms of efficiency and effectiveness.

2. The need to coordinate the placement and use of fire attack hose lines. Failing to manage this activity could jeopardize firefighter safety. Additionally, knowing what types and flow rates of nozzles to use during varied fireground conditions is extremely important to the outcome of the fire incident. Fire stream management must address the impact of applied water on thermal balance, heat reduction, firefighter tenability, and air entrainment.

   The proverbial debate over the advantages of fog versus straight stream is another area that needs revisiting. Is the size of a fire compartment a major factor in the determination of what type of water spray to use? The settling of this matter will require more research and training. The application rate, size of water droplets, and methods of application influence the rate of heat reduction and movement of smoke and hot gases within a fire compartment.

   Recommendation: Research similar to that recommendation noted in item 1 should be conducted. It is encouraged that the fire service work closely with the fire testing or research organization(s). This will help to ensure an acceptable interface between the practical and scientific environments. Attention should be given to answering the questions raised in the previous paragraph. The flow rates and effectiveness of the

various attack lines including 1-1/2 inch, 1-3/4 inch, 2-inch, and 2-1/2 inch lines should also be evaluated.

There also is a need for further research on the usefulness of applied water in the form of finely divided droplets (fog) and large size droplets (solid stream). A research facility, working in concert with the fire service, should conduct the testing.

3. The need to conduct a risk analysis of the structure (building). Knowing the hazards associated with a particular fire incident is necessary to help reduce the risk of firefighter injury. The risk analysis will help the incident commander to decide whether or not to mount an offensive or defensive attack.

The success of the incident commander's strategy is contingent, in part, on how well a risk analysis is conducted. The action plan sets the stage for what is to be accomplished. A poor strategy not only could result in inefficiency and ineffectiveness, but also higher risk of injury to firefighters.

Recommendation: There is an apparent need to develop a standard approach to conducting an incident risk assessment. Identifying conditions or factors that may indicate impending danger such as structural collapse is a serious concern. Developing a systematic approach to conducting a risk assessment is extremely important. Such an approach will help to ensure that all aspects of the assessment are covered.

The use of the CAD (computer-aided dispatch) System within the fire department, data entry from the Fire Prevention Division, routine inspections by companies and the continuing education of **all** personnel in the topics noted in the previous paragraph, could help to reduce the injury rate and also reduce fire loss. In addition, information on the type of construction, floor plans and fuel load should also be collected and available for dissemination to firefighters.

There is an indication that more research is needed to study the relationship between fire development and different construction types, designs, and materials. A "smart" estimate of the predicted time to partial or total collapse of a roof or floor may be derived from empirical analysis. This "predictive tool" could be used to aid the fire officer when deciding whether or not to enter and aggressively attack a compartment fire.

4. The need to provide adequate staffing on the incident scene. Staffing heavily influences not only the efficiency and effectiveness of the activities, but also the safety of the firefighters assigned to perform those activities or tasks.

5. The rotation of crew members is an important safety-related activity. Allowing crews to perform arduous work for a protracted period can lead to excessive physical and heat stress, dangerous dehydration, and reduced mental alertness. In addition, the extended exposure could increase the firefighters' risk of injury from a sudden flashover or building collapse.

6. The need for and establishment of a rehabilitation (REHAB) area. During extended operations and/or extreme weather conditions, it is imperative that crews receive adequate rest, rehydration, and medical surveillance. A key concern that needs to be addressed is how long should firefighters remain inside a hostile fire compartment (e.g., with dangerously high temperatures).

   Recommendation: Efforts should be taken to standardize the elements of the REHAB (rehabilitation) function. Because of its importance to the safety and well-being of firefighters, REHAB personnel should maintain a record of the medical data (e.g., pulse, blood pressure, respirations) collected from firefighters sent to REHAB.

   This information can be entered into a database for later analysis to identify possible trends and to modify or develop new SOPs.

Other Needs

The panel also identified seven other needs. They are:

7. The need for standard operating procedures (SOPs). Having SOPs can reduce confusion, improve efficiency, and reduce the risk of injury at the incident scene. The development and use of SOPs should help to control entry, stay time, and coordination of crews.

8. The need for safety "buy-in" at all levels in a fire department. The chief of the department as well as his or her command-level officers must promote and support safety awareness and adherence by all operational members.

9. The need to design firefighter's personal protective clothing so that it can be donned easier. The present generation of protective clothing does not afford rapid donning. The more time required to put on the clothing, greater is the likelihood that the fire fighter may not fully or correctly don the clothing. This is especially true were the firefighter is faced with the need to effect rescue of an endangered or trapped occupant.

   In addition, if a fire fighter is suddenly exposed to dangerously high temperatures but safely reaches the outside, there still is a potential that he or she could be burned by stored thermal energy in the protective clothing. In this case, time required to remove the clothing could influence or worsen the development of serious burns.

Recommendation: Manufacturers of firefighter protective clothing should conduct the necessary research to develop better designed protective clothing that will allow quicker donning and doffing.

10. The need for training is critical to any organization, especially the fire service. Training should replicate actual fireground operations. Practicing or learning a procedure the correct way will help to ensure that it is done correctly under actual fireground conditions. Emphasis should be placed on the fact that training procedures and fireground procedures are the same. There is only one right way to do things. However, variations may result based on compelling circumstances of the incident.

11. There is a need to improve the dissemination of information throughout the fire service. Presently, there are several fire service trade journals available. Many of the journals are published on a monthly basis. The scope of the articles range from administration and operations to scientific research.

The advent of the Internet has opened many new avenues for the transfer of information to the fire service not only throughout the United States, but also the world. The caution here, however, is that the information provided through the Internet is not necessarily validated. Users of the Internet are not required to validate their comments.

Many organizations such as the National Institute of Standards and Technology (NIST), National Fire Protection Association (NFPA), and the National Fire Academy (NFA) have home pages on the Internet. These organizations are valuable fire service resources.

There also are a number of bulletin boards that can be linked to a computer by modem. These boards allow participants to exchange information about fire service issues of mutual interest. The nationally recognized fire service organizations also have means of disseminating information to their members.

Recommendation: The fire service should form a coalition of fire service interests to determine ways to improve the collection and dissemination of fire/rescue/EMS-related information.

12. There is a need to identify ways to "perfect" tactics to reduce firefighter involvement, thus, reducing the risk of injury. There are times when firefighters engage in interior fire fighting operations when the risks suggest alternative action.

Directing unmanned master streams through windows as part of a defensive attack would reduce the risk of injury to firefighters should the wall suddenly collapse.

Recommendation: Develop and publish innovative (and prudent) uses of unmanned hose streams. Explore greater use of robots as substitutes for firefighters where the

risk is too great to jeopardize firefighters. Continue to pursue the installation of automatic sprinkler systems in all residential occupancies.

13. Increased thermal protection of turnout gear has decreased the wearer's ability to feel the ambient environment, thus placing the wearer often in situations of elevated risk.

Recommendation: Research allowing the wearer to better gauge the signs of elevated temperatures and the threat of flashover would increase safety.

PPE Training Panel
Chris Preu, Chair

The PPE Training Panel first met on June 25, 1996, following various presentations concerning PPE. At this first session we defined the scope of our work and presented this information. The work group received further input in the form of questions and comments from other conference attendees on the morning of June 26. We then developed an initial consensus determination of current PPE training that is available to firefighters. The group focused on the effect that the current limitations place upon the personal safety of firefighters. Despite immense strides in the design of protective clothing over the last 20 years, there has not been a corresponding reduction in firefighter injuries. This failure to reduce injuries can be directly attributed to: 1) The limited amount of scientifically accurate information concerning heat transfer available in a form that can be readily understood by firefighters; 2) the lack of available education on conducting appropriate hazard assessments prior to selection of protective equipment for structural fire fighting; 3) the lack of education for fire service supervisors and firefighters concerning the limitations of PPE, and 4) the lack of education concerning appropriate inspection of PPE and determination of need for retirement. Therefore, the following actions are required:

1. Develop a standardized technique for conducting hazard assessments for selection of proper PPE for structural firefighters based upon locally performed tasks and conditions. Provide education to fire service managers and supervisors to enable them to correctly accomplish this task.

To be effective, the hazard assessments need to be conducted in a uniform manner and, at a minimum, in compliance with the Occupational Safety and Health Act (OSHA), Subpart I - Personal Protective Equipment and NFPA 1500, Standard on Fire Department Occupational Safety and Health Program. To insure uniformity of quality, the method must include a numerical evaluation of the likelihood and probable severity of injurious conditions. The material must be presented in accordance with accepted methods of adult education using the latest techniques in audiovisual presentation. Development and wide distribution of an instructional videotape, combined with a Train-the-Trainer program for presenters is essential to successful implementation. This program must include a testing and/or evaluation method for determining that the student learned and understood the presented material.

2. Develop a standardized scale for representing fire severity as it directly impacts structural firefighters' safety. Provide education to fire service supervisors and firefighters to enable them to adequately evaluate field conditions versus the standardized scale.

Before manufacturers, safety officers and users can meaningfully communicate, there must be a standard, accepted scale with specific levels of fire hazard exposure clearly defined in terms and/or examples appropriate to the educational level of the firefighters. Much of the work conducted under Project FIRES requires revalidation under the fire loads currently encountered in the field. After

establishment of a baseline describing various levels of fire severity, specific examples of each level of severity need to be developed to permit firefighters to convert the laboratory results into the conditions they observe in the field.

3. Develop specific criteria for firefighters to determine, prior to injury, that there is a probability that their PPE may not provide adequate protection. Provide education to fire service supervisors and firefighters to enable them to relate the conditions they are observing with the potential for their PPE to provide adequate protection.

There must be clear definition and vivid illustration of the conditions under which structural firefighters' protective clothing will not prevent significant injury. Particular emphasis must be given to the problem of heat sinking that may occur at even moderate heat levels. The need to take immediate action to either modify the environment or exit the environment when conditions exceed the protective capabilities of the PPE must be a central issue. The material must be presented in accordance with accepted methods of adult education using the latest techniques in audiovisual presentation. Development and wide distribution of an instructional videotape, combined with a Train-the-Trainer program for presenters is essential to successful implementation. This program must include a testing and/or evaluation method for determining that the student learned and understood the presented material. This program must also have provisions for periodic reexamination or demonstration that the knowledge has been retained.

4. Develop a standardized methodology for periodic inspection of PPE to assure that all in-service PPE is in a condition to provide the protection determined necessary by the hazard assessment. Provide education to fire service managers, supervisors and firefighters to enable them to correctly inspect PPE and determine its ability to provide the required protection.

The fire service must be provided with objective measurable criteria for field inspection of PPE. The criteria must be designed to eliminate subjective decisions in so far as possible. The inspection techniques must involve specific tests that may be conducted in the field using only materials and equipment available to fire service organizations. The material must be presented in accordance with accepted methods of adult education using the latest techniques in audiovisual presentation. Development and wide distribution of an instructional videotape combined with a Train-the-Trainer program for presenters is essential to successful implementation. This program must include a testing and/or evaluation method for determining that the student learned and understood the presented material. This program must also have provisions for periodic reexamination or demonstration that the knowledge has been retained.

Fire service managers, supervisors and firefighters must be educated to evaluate the environmental risks that they face and to understand that there are specific limits to thermal protection provided by the best designed and constructed new garments. They must further realize that this protection level may diminish with use, and they must be trained and educated to properly inspect PPE, with removal from service when warranted.

7. ABOUT THE AUTHORS

Emil Braun, Physicist, Building and Fire Research Laboratory, National Institute of Standards and Technology. Currently he is responsible for developing a prototype instrumentation package and the measurement methods for the firefighter protective clothing project. Other recent projects were in the halon replacement program, arson investigation program, the use of elevators during fire emergencies, and performance criteria for passenger trains based on the cone calorimeter. He also has used large scale fire tests to evaluate the fire safety of the interior finish of vehicles used in mass transportation systems (e.g., buses, subways).

Mr. Braun has a Bachelor of Arts degree in Physics from Yeshiva University and has done graduate work at American University (Washington, DC) and George Washington University (Washington, DC). He is a member of the NFPA Committee on Static Electricity.

Mary L. Grilliot, President, Fire Equipment Manufacturers and Services Association (FEMSA). Previous to that, Mary was the FEMSA Vice President for a four year term. For 16 years Mary has been the Executive Vice President of Morning Pride Manufacturing. She is involved with new product development, standards compliance, field product follow up, certification programs, customer service and vendor/test laboratory interface.

Ms. Grilliot received both undergraduate and master's degrees from the University of Dayton (Ohio). She also is a principal voting member of the NFPA 1971 Technical Committee on Protective Clothing and Equipment for Structural Firefighting.

J. Randall Lawson, General Physical Scientist, Building and Fire Research Laboratory, National Institute of Standards and Technology. He is the project leader for the firefighter protective clothing project. He also has worked on development of standards for firefighter station/work uniforms, in addition to the development of the furniture calorimeter; fire resistance of thermal insulation materials; fire test methods for flooring, smoke generation, flame spread, heat of combustion and heat release rate.

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