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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

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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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Nora H. Jason

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Gaithersburg, MD 20899-0001

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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 fire-fighters 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 fire-fighters 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.

5. TECHNICAL PRESENTATIONS

Fire Service Needs

Kirk H. Owen, Division Chief, Plano Fire Department

Firefighter burn injuries are, to say the least, a very complicated issue. Many different factors can contribute to an injury. These include incident management, risk management, tactics, equipment, training, and discipline. Although we often look to the protective clothing for answers when a firefighter is burned, the clothing may or may not have contributed to the injury. It is possible that the protective clothing provided the level of protection for which it was designed. The thermal conditions may, however, have exceeded the limitations of the garments.

Consider for a moment our injury and burn experience over a ten year period. In 1984 there were 62,700 fireground injuries, 27.0 per 1,000 fires. Of these, 10.6% (6,640) were burns. In 1993 there were 52,885 fireground injuries, 27.1 per 1,000 fires. Of these, 11.3% (5,990) were burns.* Although there were fluctuations during this period, the number of injuries per 1,000 fires and the percentage of burn injuries in 1993 were about the same as in 1984. We know there have been improvements in protective clothing during this period, yet there has been no corresponding decrease in burn injuries. We must consider the possibility that one or more of the other factors listed above contribute to the problem.

Unfortunately, thorough investigations are not usually conducted on burn injury incidents. Thus, it is difficult to determine the factors that contributed to the injury. We can, however, learn from firefighter fatalities which are typically investigated very thoroughly. In these cases, breakdowns in incident management, accountability, company integrity, and communications seem to be common. There are also indications that firefighters sometimes do not take their own safety as seriously as they should. One obvious example is the failure to activate their pass devices before entering a hazardous environment. If these factors contribute to fatalities, they probably also contribute to injuries.

The issue of firefighter burn injuries is further complicated by a factor we have not yet discussed, risk management. In my opinion, assessing and then managing risk during an incident as dynamic as a fire is one of the more difficult things we do. I believe it is made even more difficult because firefighters and incident commanders do not fully understand the environment extremes they are facing or the limitation of protective clothing. As a result, I fear that we may sometimes expose firefighters to more risk than is justified for what they are trying to save.

*Source: National Fire Protection Association

If we are to reduce burn injuries, we must look not only at the clothing we wear, but also how we operate, and how we train firefighters about the environment they face and the limitations of their gear.

What can NIST do?

- Conduct additional research to revalidate the Project Fires findings and to help us better understand the environment we face. We must clearly understand the thermal conditions we face in the structural fire fighting environment to write appropriate standards, procedures, etc. The information published in the Project Fires Report is excellent, but it is several years old.

- Conduct additional research to help us better understand the limitations of protective clothing and how burns occur. The way in which thermal energy is transmitted through protective clothing to firefighters is difficult to understand and even more difficult to explain.

What can the fire service do?

- Be disciplined enough to follow our own procedures. Often, appropriate procedures are in place but we chose not to follow them.

- Recognize that protective clothing and equipment have limitations. Firefighters can be burned while wearing their protective clothing.

- Determine the thermal conditions we have to face. We must stop taking unnecessary risks and stop tolerating those who do.

What can we do?

- Develop a comprehensive training program that includes both text and video. Show firefighters what various thermal environments look like and explain how their protective clothing can be expected to perform in each of these environments.

Views of Volunteer Firefighters

Philip C. Stittleburg
La Farge (WI) Fire Department

I. COST

A. Limited Budget

B. Difficult to Raise Money

C. Most "Bang For Buck"

D. Importance of Standards

(1) Often Forced to Buy Cheapest Available

(2) Need Assurance Still Safe, Meets Needs

II. USEFUL LIFE

A. Equipment Must Last as Long as Possible

(1) Frequently Doesn't Wear Out

(2) May Not Be Used Often

(3) Challenge to Keep Serviceable Though Seldom Used

(4) Can't Afford to Replace

III. CLEANING

A. Ease of Cleaning

(1) Available at Station

(2) Cleaning Equipment Reasonably Priced

(3) Specialized Cleaning Equipment Unnecessary

B. Durability Equipment

(1) Withstand Repeated Cleaning

IV. ADAPTABILITY

A. Structural Versus Wildland

(1) Can't Afford Specialized Use Equipment

(2) Forced to Make One Item Serve More Than One Purpose

B. Conversion

(1) Possibility of Converting Equipment to Multiple Uses

(2) Speed of Conversion

(3) Cost of Multi-use Equipment

V. USER FRIENDLINESS

A. Normal Complaints

(1) Too Hot

(2) Too Heavy

(3) Sensory Deprivation

VI. INCREASED SAFETY

A. Increased Safety

B. Better Performance

C. Cost Effectiveness

Voices From the Field

Charles C. Soros
Seattle (WA) Fire Department (retired)

My comments are from the firefighters who don't get a chance to attend this conference. These are the individuals who have to live with the deliberations of this type of meeting. These are voices of students who attend the seminars on occupational safety and health looking for answers. I have asked these individuals what they need to develop an understanding of PPE and administer a viable program within their departments.

Their comments and concerns are valid and are as follows. Their biggest concern is understanding what is required of them by law and by standards, understanding how these laws and standards came about, plus which laws and standards are mandatory and which are voluntary.

The diversion within our profession itself is awesome. You have full paid, part paid, volunteer, union and non union departments. You have a host of varying political entities that regulate our profession. You have a host of varying political entities that regulate our professional. You have city managers, city councils, mayors, commissioners, and a variety of the above in combination. You have regulated and non-regulated OSHA states. You have states that require NFPA compliant PPE and some that don't address protective clothing for firefighters.

It's noted that we have consensus standard writing organizations that can't agree on what is needed for firefighters safety, yet write them. I constantly hear groups say we are committed to firefighters safety and look towards your best interest. Yet when the fire service asks for certain PPE criteria protocols they vote opposite our profession's point of view many times due to perceived or real fiscal potentials. Concepts are being twisted and manipulated that affect our PPE. As the battle for better understanding rages with in our profession and points of view differ in the standards arena, what can we do to help the rank and file provide the best PPE training? In an attempt to provide some guidance I have developed the following flow chart. (exhibit 1)

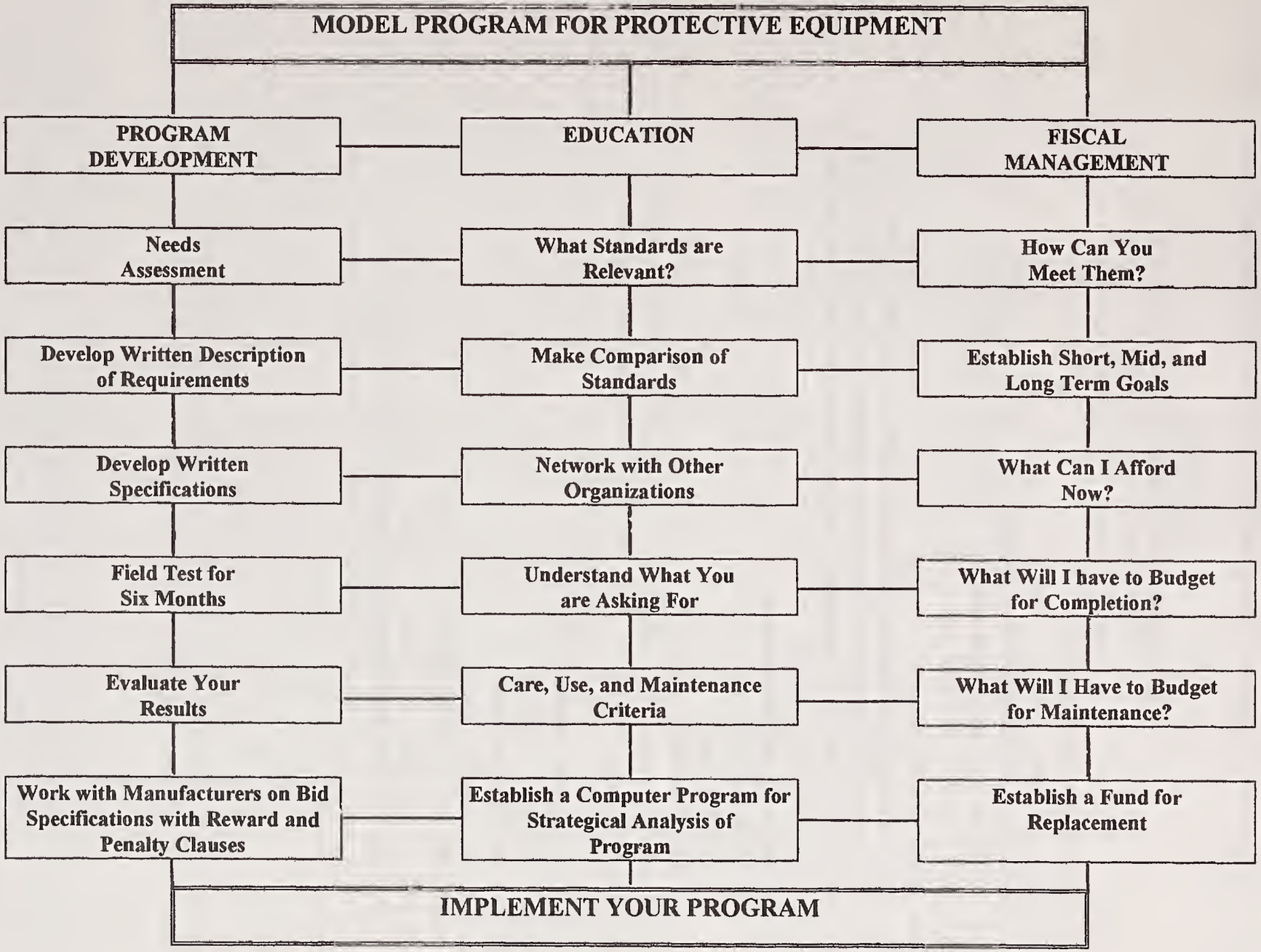
The overhead demonstrated a procedural system that could be adopted. It also denoted a variance between standard organizations. All things being equal is there a difference between a house fire in Seattle, Phoenix, Miami, Boston, London, Tokyo or Moscow? If the answer is no, which I believe it is, then why aren't we all training our firefighters the same philosophy?

I would suggest politics, money and relatively narrow points of view are reflective in this dilemma. While we are trying to decide and establish a laundry list for a cure the firefighter is still waiting. This slide was developed in 1979 by a presidential committee I was privileged to serve on. We have worked on 95% of these issues, yet we still haven't moved to completion.

I find it totally amazing that we would never contemplate having a firefighter used as a driver of the apparatus without hours of training and testing. We, on the other hand, issue firefighters PE with

no formal training on its limitation or maintenance and say go to work. Something is missing in this type of scenario.

NFPA and OSHA standards require training on PPE, however, there are no model guidelines available. The closest useful tool is OSHA 1910.132 Appendix B, which most departments don't even know exists and it is tailored, as usual, more toward industry than our profession. We need a good assessment training protocol to adequately evaluate what we presently utilize. We have defined our environment, now give us the tools to truly evaluate our needs for present and future design and training.


MODEL PROGRAM FOR PROTECTIVE EQUIPMENT
PROGRAM DEVELOPMENT
EDUCATION
FISCAL MANAGEMENT
Needs Assessment
What Standards are Relevant?
How Can You Meet Them?
Develop Written Description of Requirements
Make Comparison of Standards
Establish Short, Mid, and Long Term Goals
Develop Written Specifications
Network with Other Organizations
What Can I Afford Now?
Field Test for Six Months
Understand What You are Asking For
What Will I have to Budget for Completion?
Evaluate Your Results
Care, Use, and Maintenance Criteria
What Will I Have to Budget for Maintenance?
Work with Manufacturers on Bid Specifications with Reward and Penalty Clauses
Establish a Computer Program for Strategical Analysis of Program
Establish a Fund for Replacement
IMPLEMENT YOUR PROGRAM

Industry Views on Thermal Protective Clothing

Mary Grilliot
Fire & Emergency Manufacturers Services Association

1. Full system performance testing
   - -Shower Test
   - -Sweating Guarded Hot Plate Testing
   - -Full, moving, sweating mannequin flame testing-tomorrow

   Summary:
   We must begin to evaluate protective properties as the item is to be utilized in the field. We must move from composite to full garment testing, from pieces/elements of the system to the whole system including interface areas.

2. Qualifying the Certification Labs
   - -FEMSA Position
   - -NFPA Position
   - -ANSI Position

3. The Stress Issue

4. The Blood-borne Pathogen Issue

5. The Encapsulation Answer

6. Field review of continuing protective levels

7. The Legal/Insurance Issues peculiar to the Emergency Services

NFPA STANDARDS ON STRUCTURAL FIRE FIGHTING PROTECTIVE CLOTHING

Bruce W. Teele
Senior Fire Service Safety Specialist
Public Fire Protection Division
National Fire Protection Association

Regardless of where fire fighting operations take place, firefighters who operate in the interior of structures in areas involved by the fire, or in areas that are affected by heat and products of combustion, are exposed to a hostile thermal environment. These conditions can rapidly deteriorate with an increase in the volume of fire, with ignition of fire gasses (unburned product of combustion) within the structure that causes flame to roll along the ceiling radiating high levels of heat, and with flashover where all combustibles in the area ignite at once. Firefighters who are confronted with these conditions will face the same thermal exposure with little variance due to the type of building construction and general fire fighting strategy. No structural fire fighting protective equipment can give prolonged protection from such hostile conditions. Certain injury and quite possibly death will occur if firefighters do not quickly extricate themselves from these severe exposures.

The philosophy behind NFPA 1971, *Standard on Protective Clothing for Structural Fire Fighting*, has been to provide adequate protection from the hostile thermal environment normally encountered during aggressive interior structural fire fighting operations. This philosophy also requires that both the protective coat and the protective trousers, each affording the same level of protection, must be worn along with the other protective ensemble items including a protective hood, helmet, positive pressure self-contained breathing apparatus, gloves, and boots. The duration which the ensemble will afford protection, of course, varies depending on the severity of the exposure. If the operation is successful in quickly "knocking down" the fire, then the environment should improve and temperature decrease. If the fire is of the extent that quick "knock down" is not possible, then the protective ensemble may offer only a few minutes of insulative protection before the heat becomes too intense through the clothing. This may allow enough time for firefighters to complete the interior primary search and remove any victims, then withdraw to an exterior operation or to a less hostile environment until the conditions modify. If conditions unexpectedly or rapidly deteriorate during the course of the interior operations, there should be a short period of time in which fire-fighters can rapidly leave the hostile area (or be removed from it) without failure of their protective ensemble, making it a survivable incident for the firefighter but not necessarily for elements of the ensemble. While the firefighter may sustain some acceptable level of injury in this scenario, the level of protection afforded by an NFPA compliant protective ensemble can make this a survivable event.

The community disposition towards fire protection plays a key role in the planned deployment of fire fighting operations. Fire departments should develop strategy and operating procedures that reflect the nature of the fire hazard in their community, and the available resources must dictate the level of intervention. Well managed, highly trained, closely supervised, and properly staffed fire

departments will perform effectively to minimize the life hazard and economic loss to the community as well as providing proper risk management to enhance operational safety.

Where the fire department is expected to extend interior search and rescue operations into all uninvolved areas of the fire building to locate and remove any endangered occupants and is also expected to minimize the economic loss to the community by confining the fire to the smallest area possible, firefighters will be exposed to hostile thermal environments while performing such operations. These operations call for an aggressive interior attack to achieve the objectives in as little time as possible. The ensemble for firefighters performing such operations should afford optimum protection. However, the protective ensemble is only one link of firefighter protection. *Well managed, highly trained, closely supervised, and properly staffed fire departments are equally essential elements of safety in order to minimize the operational risk.*

In all cases, the community must be clear in what is expected of their fire department in terms of its mission, objectives, and service delivery. The fire department must properly define for the community and for itself what levels of organization, supervision, training, staffing, and resoures are necessary to effectively deliver the services and safely perform the operations to achieve the objectives. Part of this process will identify the hazards of the various operations and what is the appropriate protective clothing and equipment.

A current point of view about the structural fire fighting protective ensemble is that it allows fire-fighters to "over extend" and get into positions that are more likely to cause injury than they would be able to if they were not wearing such "sopohisticated" equipment. We suggest that firefighters who "over extend" are not operating under close supervision or in an incident command system that controls the position, function, and safety of all operating teams. It is not the purpose of advanced protective clothing to permit firefighters to go "deeper and deeper" into involved structures but rather to provide increased protection for the "normal" operating positions and to give a margin of safety if conditions unexpectedly deteriorate. State-of-the-art protective clothing can allow fire fighters, operating safely within the incident command system, to be able to perform more effectively. Regardless of the level of protection afforded by clothing, anything except bare skin can allow fire-fighters to "over extend." This further enforces the position that all operations must be managed by the incident command system and that firefighters only operate under direct supervision within that system. Free lancing of individuals or teams can not be allowed if safety is to be achieved.

Another opinion is that advanced protective clothing does not allow firefighters to "feel the heat" and to be able to judge the environment. The ability to judge heat build up can differ depending on what the firefighter is wearing. It is a training issue for firefighters to become familiar how an ensemble transmits heat and what detactable level should cause a safety reaction. What may be felt in one garment may be entirely different in another garment. There is not a single "measure of heat build up" that can be applied to all garments. Likewise, it is not practical to rely on exposed human body parts to indicate heat exposure as the skin begins to burn after a short exposure at relatively low temperatures (about 135 °F/57 °C).

Also, there is the opinion that the thermal insulation of the protective clothing causes more injuries, due to heat stress, than lighter weight (but less protective) garments. Incorrect conclusions have been made about the reported stress related injuries and deaths in the United States. Some positions state that these injuries are the result of the protective clothing. Heat stress can not be addressed only by the garment but must be approached from several factors that equally affect it. For garments to be protective from the extremely hostile thermal atmosphere, thermal insulation is needed. Garments alone can not keep a firefighter both comfortably cool and provide adequate thermal insulation for interior structural fire fighting operations. The total factors affecting stress and heat stress must be evaluated including firefighter's age, physical condition, individual metabolism, how they are managed during incident operations, and if their vital signs and physical conditions are monitored and cared for. While it is true that lighter garments will most likely help to reduce the stress to the wearer, lighter garments that still provide at least the protection specified by the standard should be selected.

With any selection of protective equipment, fire departments must caraefully review their needs and determine what will be an appropriate level of protection. Purchase specifications should reflect these needs and should specifically require compliance with the applicable standard. NFPA 1971 should not be construed as setting levels of protection for all fire fighting situations and conditions to which structural fire fighters may be exposed. Nothing in NFPA 1971 is intended to limit or restrict any jurisdiction or manufacturer from exceeding the minimum requirements of the standard.

Protective Clothing and Equipment: A System Concept

Robert McCarthy
U.S. Fire Administration

The United States Fire Administration began working on Project Fires in the 1970's and continues to support protective clothing and equipment research and development consistent with the concept advanced by Project Fires, a Fire fighting Integrated Response Equipment Systems (FIRES).

The USFA has continued to support the documentation requirements of the NFPA Committee on Firefighter Protective Clothing and Equipment for not only structural fire fighting protective clothing and equipment, but also chemical protective clothing, protective clothing for emergency medical operations, and protective clothing for emergency medical operations.

Most recent research has focused on the development of protective clothing and equipment guidelines for urban search and rescue, sizing guidance for station work uniforms, development of a stored energy test for evaluation of thermal protective performance (TPP) of structural fire fighting protective clothing, and the development of protective clothing and equipment guidelines for emergency managers, arson investigators and others who are required to work in hazardous environments.

Currently, the USFA and the National Institute of Standards and Technology are cooperating in an effort to develop state-of-the-art technology to evaluate TPP of protective clothing as that TPP relates to actual exposures on the fireground. This research will involve the development of test methods which may by ultimately used by manufacturers, standards making organizations such as the National Fire Protection Association, and users of protective clothing and equipment.

THERMAL ENVIRONMENTS OF STRUCTURAL FIRE FIGHTING

J. Randall Lawson
National Institute of Standards and Technology
Building and Fire Research Laboratory

Fire Environments

A great deal of research has been done to evaluate structural fires as they relate to building design, materials and contents. Only small elements of these data have been used to evaluate the thermal environment around firefighters during normal attack situations. Results from studies clearly demonstrate the severity of thermal environments at fire attack staging areas [2]*. The flow of hot gases from a doorway or through a window may be well above 500 °C (932 °F) and may extend tens of meters down a corridor or across an adjoining room ceiling. Thermal radiation from a room's open doorway or window may reach levels which will cause burn injuries to exposed skin and cause charring or ignition of protective clothing fabrics which result in burn injuries to protected skin. Surface temperatures of solids within this staging zone may easily exceed 200 °C (392 °F), and touching these surfaces without adequate protection could result in a sudden burn injury.

Fire growth characteristics have changed significantly over the last 50 years in North America. These changes may be attributed to: 1) increases in compartment fire loads, 2) increases in rates of heat release for these fire loads, and 3) differences in building construction.

Pre-flashover fires, although relatively small, develop thermal environments around them which can cause serious burn injuries to fully equipped fire fighters. Flame temperatures measured within low intensity fires are in excess of 700 °C (1292 °F). In addition, it has been reported that the total heat flux measured at the edge of a burning common wastebasket is generally in excess of 10 kW/m^2 (0.24 $cal/cm^2 \cdot s$), and in some cases it is more than 40 kW/m^2 (0.96 $cal/cm^2 \cdot s$). Air temperatures at the ceiling of test rooms with wastebasket fires ranged from 100 °C to 400 °C (212 °F to 752 °F) [2].

Many of the serious firefighter burn injuries reported each year involve fires where flashover is in progress or has already occurred, and in some cases the fires have been growing over a long period of time. Data obtained from post-flashover fire tests at NIST show that the total incident heat flux measured at the floor of a burning room can be as high as 170 kW/m^2 (4 $cal/cm^2 \cdot s$) with gas temperatures in the room averaging as high as 1000 °C (1832 °F) [2]. In this post-flashover fire environment, floor temperatures at the room's open doorway may be greater than 600 °C (1112 °F). In these types of fires, thermal radiation, hot gases and hot surfaces are typically found at relatively

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

great distances from the fire's source. Protection from these dangerous environments relies on firefighter training, tactics, and their protective clothing.

Protective Clothing

Firefighter's protective clothing has been designed to perform several functions. Of these, protection from heat and flame is very important. Today's firefighter protective clothing designs are based on years of field experience and research studies which addressed structural fires. Much of this work has concentrated on the fire environment where a firefighter suddenly becomes enveloped in flames. This exposure generally results in serious life threatening injuries and sometimes death. In addition, it is important to understand the conditions where many burn injuries occur outside of the flaming envelope. These intense thermal environments are generally found in locations where firefighters begin their attack on a fire.

To better comprehend the causes of these burn injuries it is important to understand: 1) the thermal environment around a firefighter when an injury occurs; 2) the performance of a firefighter's thermal protective clothing when exposed to varying fire fighting environments; 3) the activities or tactics of firefighters that contribute to a burn injury; 4) the firefighter's training that may have contributed to the injury; and 5) the fireground management issues that may have contributed to the injury. Generally, accidental injuries do not result from just one cause. An injury usually results from the accumulation of conditions or events. Improvements that will lead to a reduction in the number and severity of firefighter burn injuries are based on the understanding of all of the issues listed above and their interrelated facets that contribute to the injury.

NIST's Efforts

Over the years, NIST has worked on a number of projects to assist the fire service with special needs. Much of this work has been conducted in cooperation with the U.S. Fire Administration and through standards work with the National Fire Protection Association (NFPA) and the American Society for Testing and Materials (ASTM). As a part of this effort, this workshop is planned to provide a focal point for the identification of research needs for the fire service and the fire service protective clothing and equipment manufacturing industry.

Recent projects include the following:

NIST has participated in the development of the current NFPA standard for station/work uniforms and the standard under development for structural firefighters protective clothing.

NIST has an ongoing project to evaluate the thermal performance of trim on firefighter's protective clothing.

A NIST project is underway to develop new measurement techniques for accessing fire fighting environments and the performance of protective clothing. This will extend the current data base and assist in the preparation of the next generation of consensus standards.

A NIST project funded by the U.S. Fire Administration was conducted to development a standard for the measurement and sizing of fire and rescue services station/work uniforms. This standard has been developed through the American Society for Testing and Materials, Committee F-23 on Protective Clothing. The standard was approved and will be published in 1996.

Firefighter Protective Clothing

Emil Braun
National Institute of Standards and Technology
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Modern protective clothing (turnout gear) worn by firefighters during the course of attacking a building fire is intended to encapsulate the individual and provide protection from the thermal environment -- thermal radiation, hot gas (convective heat transfer) and contact with hot surfaces (conductive heat transfer). The current turnout gear design is based on years of field experience and some research, carried out most actively during the past 25 years. While the primary consideration has been thermal protection, other issues relating to comfort and physical stress also have been evaluated in garment design.

The space around a firefighter can be thought of as the interaction of three zones. First is the fire environment which can represent a broad range of thermal conditions associated with various fire sizes, incipient fire to post-flashover fire conditions. This environment also can contain high concentrations of numerous products of combustion most notably carbon dioxide, carbon monoxide, and water. The second zone is the protective clothing worn by the firefighter. This barrier is intended to provide thermal protection as well as protection from physical injuries -- cuts, abrasion, and puncture wounds. The third zone is the individual's body. The body is a self-regulating system that attempts to maintain a steady body temperature of approximately 37 °C (98.6 °F). The evaporation of body sweat is the major mechanism used to reduce the impact of an increase in the thermal load on the body. A reduction in the efficiency of sweat evaporation can lead to heat stress.

As a total system the interaction of these three zones need to be understood in order to effectively design protective clothing that provides adequate thermal protection and allows the self-regulating nature of the human body to function properly.

Numerous studies have been conducted evaluating thermal protection of fabric and fabric combinations from various types of fire loads. These studies have led to the development of TPP (Thermal Protection Potential) measurements. Several studies have been performed using instrumented professional firefighters to record the thermal environment a firefighter is exposed to during the course of fire fighting activities. This is not necessarily the same as the thermal load a fire places on a structure. Most investigators have recognized the interaction of the outside environment and body stress. Some have even attempted to measure these in the field. These investigators have attempted to make field measurements that included the thermal and cardiac state of the individual firefighter along with an assessment of the outside thermal environment.

A projected task for this study is to extend the current measurement database created by previous researchers by developing an improved set of measurement tools for characterizing not only the thermal environment around a firefighter, but the thermal state of the turnout gear and the heat stress

experienced by individual firefighters. Measurements planned for this study include: total heat flux incident on the firefighter, the thermal condition of each layer of the turnout gear, the thermal and moisture environment between the turnout gear and the firefighter's body, and the thermal condition of the firefighter as a result of the combination of the external environment and the turnout gear.

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.

Mr. Lawson has a Bachelor of Science degree from Georgia Southern University, and two Associate of Arts degrees from Brewton-Parker College (GA) and Montgomery College (MD). Randy works actively on the ASTM Committee E-5 and the NFPA Technical Committee on Fire Tests and ASTM Committee F-23 on Protective Clothing and the NFPA Technical Committees on Protective Clothing for Structural Fire Fighters and Special Operations.

Robert T. McCarthy, Chief, Fire Technical Programs, United States Fire Administration (USFA), Federal Emergency Management Agency. He manages the USFA's protective clothing and equipment research and development program. This program has focused on protective clothing and equipment for structural firefighting, emergency medical operations, hazardous materials operations, and urban search and resuce operations. Mr. McCarthy has provided research

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Mr. McCarthy has a Bachelor of Science degree in Administration of Safety and Security Services from Jersey City College and a Master of Arts degree in Occupational Safety and Health from New York University. Mr. McCarthy served as an adjunct instructor at Jersey City State College and was the safety and health representative for the Professional Firefighters Association of New Jersey. Mr. McCarthy is retired as a Captain with the Jersey City Fire Department.

Kirk H. Owen, Division Chief of Operations, City of Plano (TX) Fire Department. He is responsible for managing day-to-day delivery of services in the community. There are currently 197 people assigned to the Division; 189 field personnel and a staff which includes two District Chiefs, the Department's EMS Coordinator and the Fire Safety Education Coordinator. He began his career as a firefighter with the Plano Fire Department and rose through the ranks, serving as an apparatus operator, company officer, and has developed specifications, purchased and issued protective clothing, equipment and uniforms.

Chief Owen has an Associates Degree in Fire Science, completed courses at the National Fire Academy, Emmitsburg, MD, and attended Arizona State University's Fire Science Institute. He is a member of the NFPA Fire Service Section and the NFPA Technical Committee on Structural Fire Fighting Protective Clothing and Equipment. He has served as Chair of the Committee since June 1993.

Charles C. Soros, Seattle (WA) Fire Department, retired. As Chief of Safety, he was charged with the responsibility of overseeing all aspects of safety relative to firefighters environment and personal protective clothing. He was assigned with the busiest companies and battalion in Seattle, predominantly within the central and downtown core of the city. His fire combat experience goes from man on the nozzle to incident commander at major multiple alarms.

Mr. Soros has an Associate of Arts degree from North Seattle (WA) Community College and he majored in business administration at the Western Washington State College.

Philip C. Stittleburg, partner with Jenkins and Stittleburg Law Firm and Chief, La Farge (WI) Fire Department. Mr. Stittleburg has held both positions since 1977. His previous experience includes the position of an Assistant District Attorney for the Vernon County, WI; Chair of the Fire Science Advisory Board, Western Wisconsin Technical Institute; Adjunct Faculty Member, Resident Programs Division, National Fire Academy, Emmitsburg, MD.

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Bruce W. Teele, Senior Fire Service Safety Specialist in the Public Fire Protection Division, National Fire Protection Association, Quincy, MA. He is the staff liaison for the eight committees in the Fire and Emergency Services Protective Clothing and Equipment project and four other technical committees. These committees are currently resonsible for 32 documents. Bruce has served as the staff liaison for the Technical Committee on Fire Service Occupational Safety and Health, which is responsible for NFPA 1500.

8. ACKNOWLEDGMENTS

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