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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Injury in the line of duty...

A summary of a NIOSH fire fighter fatality investigation *November 17, 2008*

Four Career Fire Fighters Injured While Providing Interior Exposure Protection at a Row House Fire – District of Columbia

SUMMARY

On October 29, 2007, four male career fire fighters ranging in ages from 23 to 38 years were injured while providing interior exposure protection at a residential row house fire. The victims had advanced a 1 ½-inch handline up to the second floor of the exposure building where they encountered heavy smoke and fire in a room in the back of the structure. Fire fighting and search activities commenced and shortly thereafter and without warning, the fire progressed up the stairwell from the first floor and up the exterior back wall temporarily trapping the victims. All four victims retreated down the stairwell and out of the building where they were met by other fire fighters who provided assistance. Each of the victims suffered burn injuries.

NIOSH investigators concluded that, to minimize the risk of similar occurrences, fire departments should:

- ***ensure adequate size-up, including in exposure buildings, to reduce the risk of fire fighters being trapped***
- ***ensure that fire fighters are trained on the hazards of operating on the floor above the fire without a charged hoseline, and to follow associated standard operating guidelines (SOGs)***
- ***ensure ventilation is coordinated with the interior attack***
- ***provide fire fighters with station/work uniforms (e.g., pants and shirts) that are compliant with NFPA 1975 and ensure the use and proper care of these garments***
- ***ensure that fire fighters are trained on initiating Mayday radio transmissions immediately when they are in distress, and/or become lost or trapped***

Although the following does not appear to have been a contributing factor in the injuries resulting from this incident, NIOSH recommends that as a good safety practice, fire departments should

- ***ensure all fire fighting personal protective equipment ensembles meet NFPA 1971 and are cleaned and maintained according to NFPA 1851***

INTRODUCTION

On October 29, 2007, four male career fire fighters were injured at a residential row house fire. On October 30, 2007, the fire department contacted the National Institute for Occupational Safety and Health (NIOSH) with concerns about the performance of the turnout gear worn by the injured fire fighters. On November 2, 2007, the International Association of Fire Fighters (IAFF) requested that NIOSH conduct an investigation of this incident. On November 7-9, 2007, a General Engineer from the NIOSH Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) and a Safety Consultant held meetings with the Fire/EMS Chief, the Safety Captain of the fire department, and with the president and second vice president of the IAFF local union. The incident scene was visited and photographed, and the operations center visited. On November 13-16, 2007, the General Engineer, a Safety and Occupational Health Specialist from the FFFIPP, and the Safety Consultant conducted interviews with officers and fire fighters who were at the incident scene. The victims' training and medical records, the Incident Commander's (IC) training records, fire department standard operating guidelines, floor plans and photographs of the structure, and a video of the fire were reviewed. The victims' personal protective equipment was examined and the dispatch center and training facility were visited. *Note: The victims' personal protective clothing were examined and evaluated by an expert consultant. For detailed information regarding personal protective clothing evaluation results see the Appendix.*

Fire Department

This career department consists of 1,463 fire fighters in 33 fire stations that serve a population of about 500,000 in a geographic area of approximately 68 square miles. The department has a written manual entitled District of Columbia Fire and Emergency Medical Services Standard Operational Guidelines. The manual indicates that "Standard Operational Guidelines are created based upon experience, knowledge of fire behavior, building construction techniques, human behavior, the effects of smoke and heat on the human body, and the resources of the DC Fire & EMS Department."

Personal Protective Clothing and Equipment

Each victim was wearing a full array of personal protective equipment consisting of turnout gear (coat and pants), Nomex® hood, helmet, gloves, boots and a self-contained breathing apparatus (SCBA).

The victims carried portable radios which were all operational, and their personal alert safety system (PASS) devices were integrated into the SCBA units and were operational as well.

NIOSH contracted with a leading expert in the field of personal protective clothing and equipment (PPE) to evaluate the protective clothing and equipment worn by the injured fire fighters to determine if the condition and/or performance of the protective clothing and equipment could have contributed to

the burn injuries suffered by the victims. The results of this evaluation are summarized in the **Appendix**. Based on this evaluation, the condition of the protective clothing and equipment show some evidence of prolonged high heat exposure, but not under emergency conditions, as would be experienced in a flashover or backdraft. It is more likely that the burn injuries were the result of several factors – (1) preheating of the gear (storage of energy), (2) accumulation of moisture in the clothing – particularly victims # 2 and # 4, who were operating the hoseline, and (3) prolonged exposure to high heat in the form of radiant and convective (flame-based) heat.

The PPE evaluation also noted that the station/work uniform pants worn by the injured fire fighters were composed of 65% polyester and 35% cotton. This material is not compliant with the requirement of NFPA 1975, *Standard on Station/Work Uniforms for Fire and Emergency Services.* The use of polyester-based clothing increases the risk of severe burn injuries as it can melt under some emergency exposure conditions.

Training and Experience

The department requires fire fighter recruits to pass the National Fire Protection Association (NFPA) fire fighter Level I & II, Basic Emergency Medical Technician, and serve one year probation (six months with a company and six months at the training academy) before attaining the rank of fire fighter.

Victim #1 was 38 years old and had 16 ½ years of fire fighting experience. He held the rank of Sergeant and had completed the following training – NFPA Level I & II certified; Hazardous Materials Incidents; National Incident Management System; Emergency Medical Technician/Basic training; and Emergency Response to Terrorism.

Victim #2 was 27 years old and had 9 months of fire fighting experience. He held the rank of fire fighter and had completed the following training - NFPA Level I & II certified; Hazardous Materials Incidents; National Incident Management System; and Emergency Medical Technician/Basic training.

Victim #3 was 23 years old and had 4 ½ years of fire fighting experience. He held the rank of fire fighter and had completed the following training - NFPA Level I & II certified; Hazardous Materials Incidents; National Incident Management System; and Emergency Medical Technician/Basic training.

Victim #4 was 30 years old and had 3 ½ years of fire fighting experience. He held the rank of fire fighter and had completed the following training - NFPA Level I & II certified; Hazardous Materials Incidents; National Incident Management System; Emergency Medical Technician/Basic; Fire Service Instructor 1; Trench Rescue Operations; and Apparatus Operator training.

The department, at a minimum, requires fire officers to pass the Command and Control of Fire Department Operations course at the National Fire Academy. The Incident Commander (IC) held the rank of Battalion Fire Chief 1 (B1) and had more than 26 ½ years of fire fighting experience. He had completed the following training - NFPA Level I & II certified; Weapons of Mass Destruction

(WMD) Incident Complexities and Command; Incident Response to Terrorist Bombings; Emergency Responder Nuclear; Biological & Chemical Responder; WMD Executive Level; Confined Space Entry; Command & Control of Fire Department Operations; Executive Analysis of Fire Service Operations in Emergency Management; Managing Metro Emergencies; Command and General Staff for Incident Command Systems; National Response Plan; National Incident Management System; Hazardous Materials Incident Management; and Fire Department Safety Officer training.

Structure

The fire and exposure buildings were 2-story single family row house dwellings of ordinary wood construction. These houses were near the middle of 18 contiguous row houses (see Diagrams 1, 2 and 3). The roofs consisted of tar covering tin and plywood. *Note: At the time of the investigation, the building owner denied NIOSH investigators access to the interior of the exposure building.*

Equipment, Personnel, and On-Scene Arrival (Initial Box Alarm)

Dispatched --1517 hours

First Due - Engine 6: Officer, technician, and two fire fighters -- 1522 hours

Second Due - Truck 15: Officer, two technicians, and two fire fighters -- 1522 hours

Fourth Due - Engine 26: Officer, technician, and two fire fighters -- 1522 hours

Third Due - Engine 10: Officer, technician, and two fire fighters -- 1523 hours

Fifth Due - Engine 4: Officer (victim #1), technician, and three fire fighters (victims #2, 3, and 4) -- 1523 hours

Third Due - Battalion Fire Chief 1 (IC/Operations B1): Officer and aide -- 1523 hours

Fourth Due - Battalion Fire Chief 6 (B6): Officer and aide --1523

First Due - Truck 10: Officer, two technicians, and two fire fighters -- 1524 hours

Second Due - Engine 12: Officer, technician, and two fire fighters -- 1524 hours

Fifth Due - Rescue Squad 2: -- 1525 hours

Division Fire Chief Operations: Officer and aide -- 1525 hours

Safety Officer: Officer -- 1525 hours

Ambulance 7: -- 1527 hours

Engine 18: -- Officer, technician, and two fire fighters-- 1528 hours

Truck 4: Officer, two technicians, and two fire fighters -- 1528 hours

Weather

The conditions were clear with the temperature about 54-degrees Fahrenheit at the time of the incident. The wind was averaging around 0-4 miles per hour from the south to south west, and there was no precipitation.

INVESTIGATION

On October 29, 2007, at approximately 1517 hours, the fire department was dispatched to a possible house fire. The following Apparatus, Command Units, Rescue Squad, and Ambulance arrived on scene: Engine 6 (E6), Engine 26 (E26), and Truck 15 (T15) at 1522 hours; Engine 10 (E10), Engine 4 (E4, victims' Engine), Battalion Fire Chief 1 (B1), Battalion Fire Chief 6 (B6) at 1523 hours; Engine 12 (E12), and Truck 10 (T10) at 1524 hours; Rescue Squad 2 (R2), Division Fire Chief Operations and Safety Officer at 1525 hours; Ambulance 7 (A7) at 1527 hours, and Engine 18 (E18), and Truck 4 (T4) at 1528 hours. *(See Diagram 1 for apparatus positioning layout).*

E6's crew, being one of the first on scene at about 1522 hours, gave a size-up of a 2-story middle of the row house with smoke showing from the attic on side-A and heavy smoke showing from the rear (side-C). They also corrected the street address to identify the fire and exposure building. The crew then advanced a 1 ½-inch attack line to the front porch (side-A) of the fire building. At 1523 hours, E4's crew (including the four victims) stretched and extended their 350 foot 1 ½-inch pre-connected attack line, with an additional 200 foot of 1 ½-inch hose line to the front of the exposure building which adjoined the fire building. *Note: Low water pressure may occur at the nozzle at the end of a 550 foot hose line if adequate pump pressure is not maintained; however, in this case no water pressure problems were reported by any of the victims.* T15's crew was deployed for exterior and roof work, and at 1524 hours, the Incident Commander (IC) assigned companies and divisions. E4's crew was assigned to search and provide inside exposure protection of the exposure building. B6 gave a report of smoke from the cockloft on side-A, and reported that E4's crew was preparing to make entry into the front of the exposure building. Simultaneously, E6's crew attacked the fire on the first floor of the fire building, and E12 was positioned at the alley entrance to the back side of the fire and exposure buildings. E26's crew gave a size-up for the rear, reporting heavy fire on both floors of the fire building with extension to the exposure building. E10's crew advanced 400-feet of line to the fire building while E26's crew was assigned to the exposure building and advanced 500-feet of line to the back of the buildings (side-C). T15 laddered the fire building and started cutting holes in the roof while E6's crew was attacking the fire on the first floor.

At 1525 hours, E6's crew continued the fire attack, T15's crew continued ventilating the fire building, and E4's crew (victims 1, 2, 3, and 4) made preparations to enter into the front of the exposure building. At 1526 hours victim #1 (Officer/Sergeant) entered the front door of the exposure building

and walked halfway through the first floor, checking fire conditions (see Diagram 2). He encountered light smoke and no fire, and at that point, turned back to the stairwell and went upstairs. Victim #4 (lineman/nozzle man) had entered the front of the building with the 1 ½-inch line and saw light to moderate smoke on the 1st floor with about 8-feet visibility. He proceeded up the stairwell to the top of the stairwell landing with victim # 2 backing him up on the hose line. Victim #3 had also advanced up the stairwell to the second floor where he and the other victims observed fire in the back of the building on side-C. At 1527 hours, victim #1 reached the second floor, joined the other fire fighters, and began directing fire fighting operations and pulling ceiling. The hose line was advanced down the hallway toward the back of the building (see Diagram 3), and at 1528 hours, victim #4 hit the fire in the back room and knocked it down. Visibility improved to the point where the victims could see to the rear porch on the exterior of the building on side-C. During this time, a fire fighter from E10 was hitting the fire through the window of the exposure building on the 1st floor of side-C. Shortly thereafter, the rear door on side-C of the 1st floor of the exposure building was kicked open by an Officer (see photographs 1, 2, and 3), and the fire grew in intensity.

Victim #3 performed a quick search for occupants in a room in the front of the building, and no occupants were found. He then returned to the landing where he observed a glow in the stairwell from the fire on the 1st floor. Simultaneously, victim #2 noticed fire behind him coming up the stairwell from the first floor and from the back wall area on side-C. At about 1530 hours victim #1 was near a window on the back wall of side-C looking for an escape route. The fire erupted up the outside wall of the exposure building and through the window burning the victim. He made a radio transmission but the transmission was unintelligible.

Victim #3 yelled to victim #2 that fire was coming up the stairwell. Victim #1, who was later described by the other victims as being engulfed in flames, ran past them down the stairwell to the outside of the building. Victims #2 and #3 also ran down the stairwell through the flames to the outside. Victim #4 continued to spray water on the fire as the others exited. At 1531 hours, the Officer from E18 called a Mayday when he en-countered a fire fighter in distress at the bottom of the stairwell on the first floor of the exposure building. At about 1533 hours, victim #4 ran down the stairwell to the first floor where he was assisted out of the building by another fire fighter from T10. The victims were treated for their burn injuries at the scene and then transported by ambulance to nearby hospitals.

At 1534 hours, a Chief Officer, who had arrived on the fireground earlier but had not reported in, radioed the Incident Commander (IC) for permission for a fire fighter to hit the fire on side-C of the exposure building. Although the Chief did not get authorization from the IC, he ordered the fire fighter to hit the fire on side-C. *Note: Since the orders were given after all fire fighters were out of the building, the impact of the Officer's actions on this incident is unknown. However these types of orders could have a negative effect on the outcome of an incident. An effective fireground operation revolves around one IC who develops and coordinates tactical decisions with all personnel on the fireground. Companies responding must ensure that they report to the IC to establish a unified*

command system. If there is no command, or if there are multiple commands, fireground operations can quickly break down.

INJURIES

The victims received the following burn injuries:

- Victim #1 received 2nd degree burns to 2% of his body (.5% neck and 1.5% left forearm) and 3rd degree burns to 21% of his body (10% anterior trunk, 4% posterior trunk, 2% buttocks, 2% left upper arm, and 3% hands)
- Victim #2 received 2nd degree burns to 6% of his body (4% head, and 2% hands)
- Victim #3 received 2nd degree burns to 6.5% of his body (3% anterior trunk, 1.5% forearms, and 2% hands)
- Victim #4 received 2nd degree burns to 16% of his body (4% head and neck, 1% right forearm, 5% hands, and 6% thighs).

Based on the examination of the clothing and equipment worn by the fire fighters, the PPE expert consultant concluded that there was no evidence of any defects of the clothing as manufactured or worn by the fire fighters that would have contributed to their burn injuries. Only in the case of victim # 2 was there evidence that the coat collar might not have been properly deployed. This clothing configuration may have contributed to head burns sustained by victim # 2; however, given that three of the fire fighters sustained head or neck burns, it is more likely that the burn injuries were sustained as the result of heat exposures in excess of the protective qualities offered by this clothing and equipment.

The consultant did not find any defect or problems with the any of the clothing or equipment items that were examined. All of the protective clothing and equipment appeared to function as intended. However, it is important that fire fighters wear station/work uniforms that do not contain high levels of polyester and that these uniforms meet the requirements of NFPA 1975, *Standard on Station/Work Uniforms for Fire and Emergency Services.* Although not a specific factor in this event, the wearing of polyester-based uniforms can contribute to significant potential for severe burn injury. Another factor to consider is the cleanliness and proper repair of the personal protective envelope. All PPE should be cleaned and maintained according to NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting* and NFPA 1851, *Standard on Selection, Care and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting.*

RECOMMENDATIONS / DISCUSSIONS

Recommendation #1: Fire departments should ensure adequate size-up, including in exposure buildings, to reduce the risk of fire fighters being trapped.

Discussion: Vincent Dunn's *Safety and Survival on the Fireground* lists several precautions that fire fighters can take to reduce the risk of being trapped. These precautions include, but are not limited to, the following:[1-2]

1. *Notifying your officer when you go above a fire.* Even if your assignment has been preplanned, inform your officer by portable radio. This information is a form of fireground control that increases fire fighter safety. An IC should know where all of his assigned fire fighters are operating during a fire.

2. *Sizing up the fire.* Most fire fighters are trapped on a floor above a fire because they failed to size up the fire below them. The condition on the fire floor should be analyzed before going above. Fire fighters should attempt to determine the approximate location of the fire. Next, the size and intensity of the fire should be observed to see if the fire can be extinguished by the hose attack team. If the fire appears beyond control of the fire fighters operating the hose line, they should not go above.

3. *Sizing up the stairway design.* The type of stairway leading to the floor above must also be evaluated by the fire fighter. An open stairway, such as the one found in this structure, is the most dangerous stairway a fire fighter can climb when operating above a fire. It becomes a chimney flue, allowing the flame, heat, smoke, and toxic gases generated by the fire below to flow up the open stairway leading to the second-floor rooms.

4. *Sizing up a second exit for escape.* If the interior stairs used by fire fighters to go above a fire suddenly become filled with heat and flames, they cannot use this path to get back down. They must locate a second exit for their emergency escape. Before entering a burning building to search above the fire, fire fighters should examine the front of the structure and look for a second exit. A portable ladder already raised to a second floor bedroom window, a porch roof, or fire escape may provide an escape if the interior stairs become impassable because of fire.

5. *Building construction size-up.* The degree of danger or threat of being trapped above a fire is greatly influenced by the construction of the building. A wood-frame building poses the greatest threat to fire fighters who must search above a fire. Vertical fire spread is more rapid in this type of structure. The three common types of vertical fire spread are stairways, windows, and concealed spaces. In addition to these three, the wood-frame construction offers a combustible exterior that would also allow vertical fire spread on the exterior of the building.

In order for fire fighters to work safely, efficiently and effectively on the fireground above a fire, they must at a minimum, follow the aforementioned precautions which include, but are not limited to: *1 Notifying your officer when you go above a fire, 2 Sizing up the fire, 3 Sizing up the stairway design, 4 Sizing up a second exit for escape, and 5 Sizing up building construction.* Fire departments should train and routinely retrain fire fighters on the importance of following standard operational guidelines for size up.

Recommendation #2: Fire departments should ensure that fire fighters are trained on the importance of using a backup hoseline when operating on the floor above a fire, and to follow associated departmental standard operating guidelines (SOGs).

Discussion: The most dangerous location on the fire ground is operating above the fire, especially during operations without the protection of a backup hoseline.[1,3] Before operating above a fire, it is a good practice to deploy a backup hoseline. Where there is risk of extension to concealed spaces, a backup hoseline is needed. According to Dunn, fire fighters are most often trapped on a floor above a fire because they fail to size-up the fire below them.[1,3] Fire fighters should determine whether suppression teams are capable of extinguishing the fire and notify command. If not, then command should not permit fire fighters above the fire until conditions change. In this incident, fire fighters advanced to the second floor (floor above the fire) and commenced fire fighting and search activities without having first determined if there was vertical or horizontal fire extension in the exposure building, and reporting the conditions to the IC as prescribed in the standard operating guidelines. Additionally, fire fighting and search activities commenced without first having a backup hoseline in place and operational.

Recommendation #3: Fire departments should ensure ventilation is coordinated with the interior attack.

Discussion: Ventilation is performed to relieve the products of combustion, allowing fire fighters to advance on the fire. When venting, the principle is to pull the fire, heat, smoke, and toxic gases away from victims, stairs, and other egress routes. [4] Horizontal ventilation does not release the heat and smoke directly above the fire; therefore, it is imperative that horizontal ventilation is coordinated with the interior crew to ensure that it doesn't block their escape routes.

In this incident, shortly after the door on side-C of the exposure building was opened, the fire immediately intensified forcing the victims to run down the stairs trying to escape. The victims were on the second floor when flames erupted up the stairway and up the outside wall on side-C of the exposure building, momentarily trapping the victims and putting them in distress. Opening the door may have provided oxygen to ignite the unburned fuel on the first floor of the exposure building, and contributed to the rapid fire spread up the stairwell, which acted like a natural chimney, and up the outside wall on side-C.

Recommendation #4: Fire departments should provide fire fighters with station/work uniforms (e.g., pants and shirts) that are compliant with NFPA 1975 and ensure the use and proper care of these garments.

Discussion: Fire fighters involved in structural fire fighting and other emergency activities should be provided, at a minimum, with station/work uniforms that are certified and compliant with NFPA 1975 in order to avoid the potential for burn injuries that are more severe as the result of using thermally unstable or rapidly deteriorating materials (e.g., fabrics that contain a significant portion of polyester or other synthetic easily melting fabrics). Ideally, the prescribed station/work uniforms should also be flame resistant, certified to the optional requirements specified in NFPA 1975. The use of NFPA 1975-compliant station/work uniforms is specified in NFPA 1500 (paragraphs 7.1.5 and 7.1.6), which also requires departments to provide for the adequate cleaning of station/work uniforms provided to its members (7.1.7).[5-6] In this case, the fire fighters were not supplied with nor were they wearing station/work uniforms that were compliant with NFPA 1975. Although not a specific factor in this incident, the wearing of polyester-based uniforms can contribute to significant potential for severe burn injury (see **Appendix**).

Recommendation #5: Fire departments should ensure that fire fighters are trained on initiating Mayday radio transmissions immediately when they are in distress, and/or become lost or trapped.

Discussion: According to the fire department's standard operating guidelines section on "Mayday," fireground communications can become very hectic and confusing when a fire fighter is in distress, becomes lost or trapped. The term "Mayday" is the international distress signal, and should only be used when a member is in trouble and needs immediate assistance. In this incident, a Mayday radio transmission was made by an Officer when he encountered a fire fighter who was in distress on the first floor of the exposure building. A rapid intervention team was on scene and was activated, but the victims were already exiting the exposure building at that time.

As soon as fire fighters become lost or disoriented, trapped or unsuccessful at finding their way out of the interior of structural fire, they must initiate emergency radio transmissions.[7-8] They should announce "Mayday-Mayday-Mayday" over the radio and manually activate their personal alarm safety system (PASS) device. A Mayday call will receive the highest communications priority from dispatch, the IC, and all other units. The sooner the IC is notified and a rapid intervention team is activated, the greater the chance of the fire fighter being rescued. A transmission of the Mayday situation should be followed by the fire fighter providing his last known location. A crew member who initiates a Mayday call for another person should quickly try to communicate with the missing member via radio and, if unsuccessful, initiate a Mayday providing relevant information. A radio transmission reporting a trapped fire fighter is the highest priority transmission that command can receive. Mayday transmissions must always be acknowledged and immediate action must be taken. Although the victims never became trapped inside the structure they were in distress for some period of time and did not initiate a Mayday call. It is unknown whether initiation of a Mayday call in this instance would have resulted in either reduced rescue time and/or less severe injuries.

Although the following does not appear to have been a contributing factor in the injuries resulting from this incident, NIOSH recommends that as a good safety practice

Recommendation #6: Fire departments should ensure all fire fighting personal protective equipment ensembles meet NFPA 1971 and are cleaned and maintained according to NFPA 1851.

Discussion: NFPA 1500 is clear on the requirement for fire departments to provide personal protective equipment ensembles that meet NFPA 1971 and are cleaned and maintained according to NFPA 1851.[9-10] Though not specifically identified as a factor in this incident, the cleanliness of structural fire fighting PPE has been a contributing factor in other burn injury incidents suffered by fire fighters. A cleaning and maintenance program that follows NFPA 1851 ensures to a greater degree that a soiled, carbon impregnated structural fire fighting PPE ensemble will not be a contributing factor.

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INVESTIGATOR INFORMATION

The incident was investigated by Matt Bowyer, General Engineer and Steve Berardinelli, Jr., Safety and Occupational Health Specialist with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH, and Richard Braddee, Safety Consultant. The report was written by Richard Braddee. Expert consultation regarding personal protective clothing and equipment was provided by Jeffery Stull. An expert technical review of the injury report was provided by Battalion Chief John Tippett, Montgomery County, MD, Fire and Rescue Service and Project Manager for the International Association of Fire Chiefs, Firefighter Near Miss Program, http://www.firefighternearmiss.com/

Photo 1. Fire fighter attacking fire through a rear window from the back porch area on side-C of exposure building at approximately 1528 hours; illustrates fire extending inward. (*Photograph courtesy of the fire department.*)

Photo 2. Rear door of exposure building (side-C) is opened at approximately 1529 hours and conditions on first floor and second floors deteriorate.
(*Photograph courtesy of the fire department.*)

Photo 3. Fire travels up interior stairwell and up exterior back wall to second floor of exposure building at approximately 1530 hours and fire fighters are burned.
(*Photograph courtesy of the fire department.*)

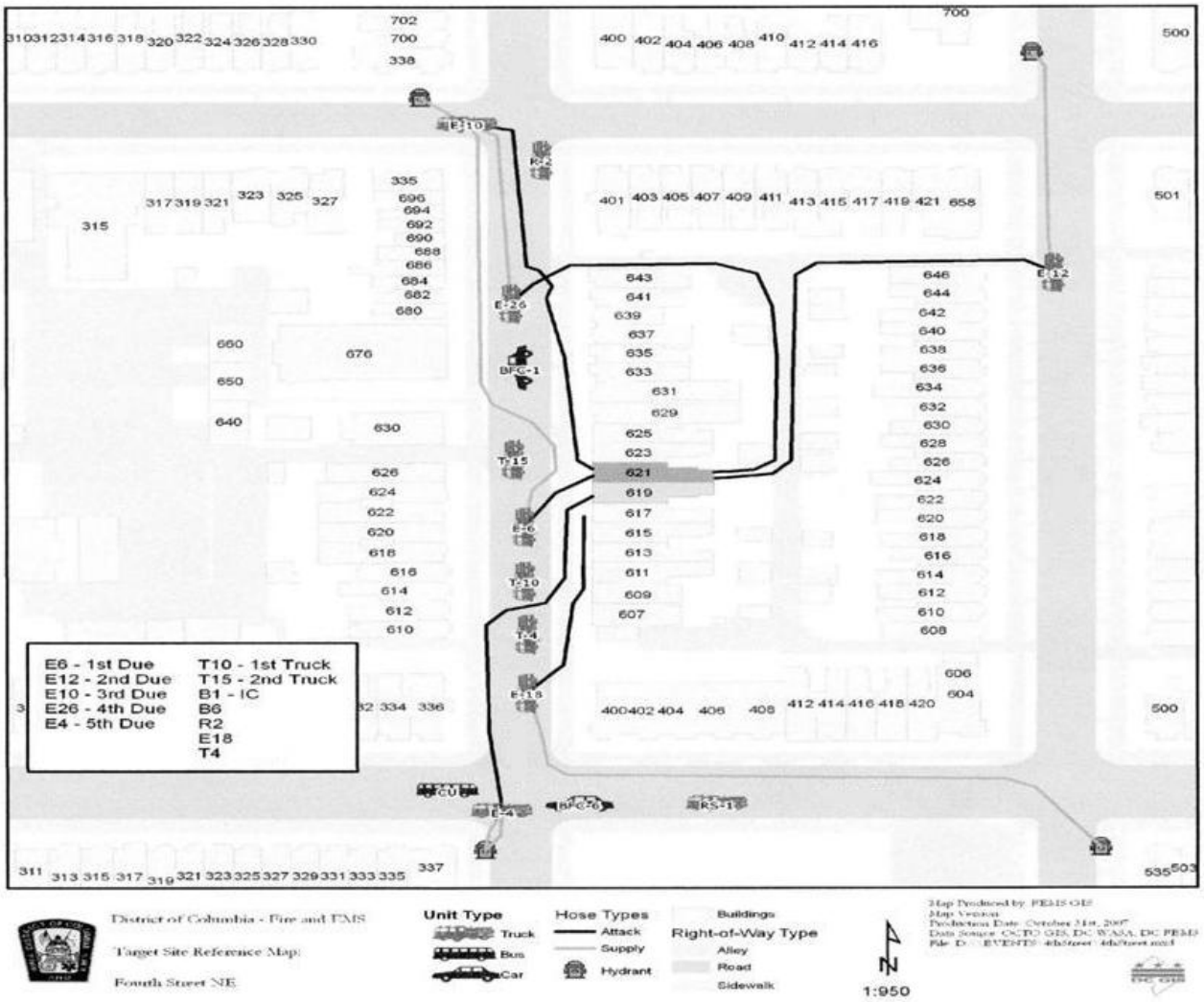

Diagram 1. Apparatus positioning layout. Adapted from diagram courtesy of fire department. Diagram indicates address box numbers for residences.

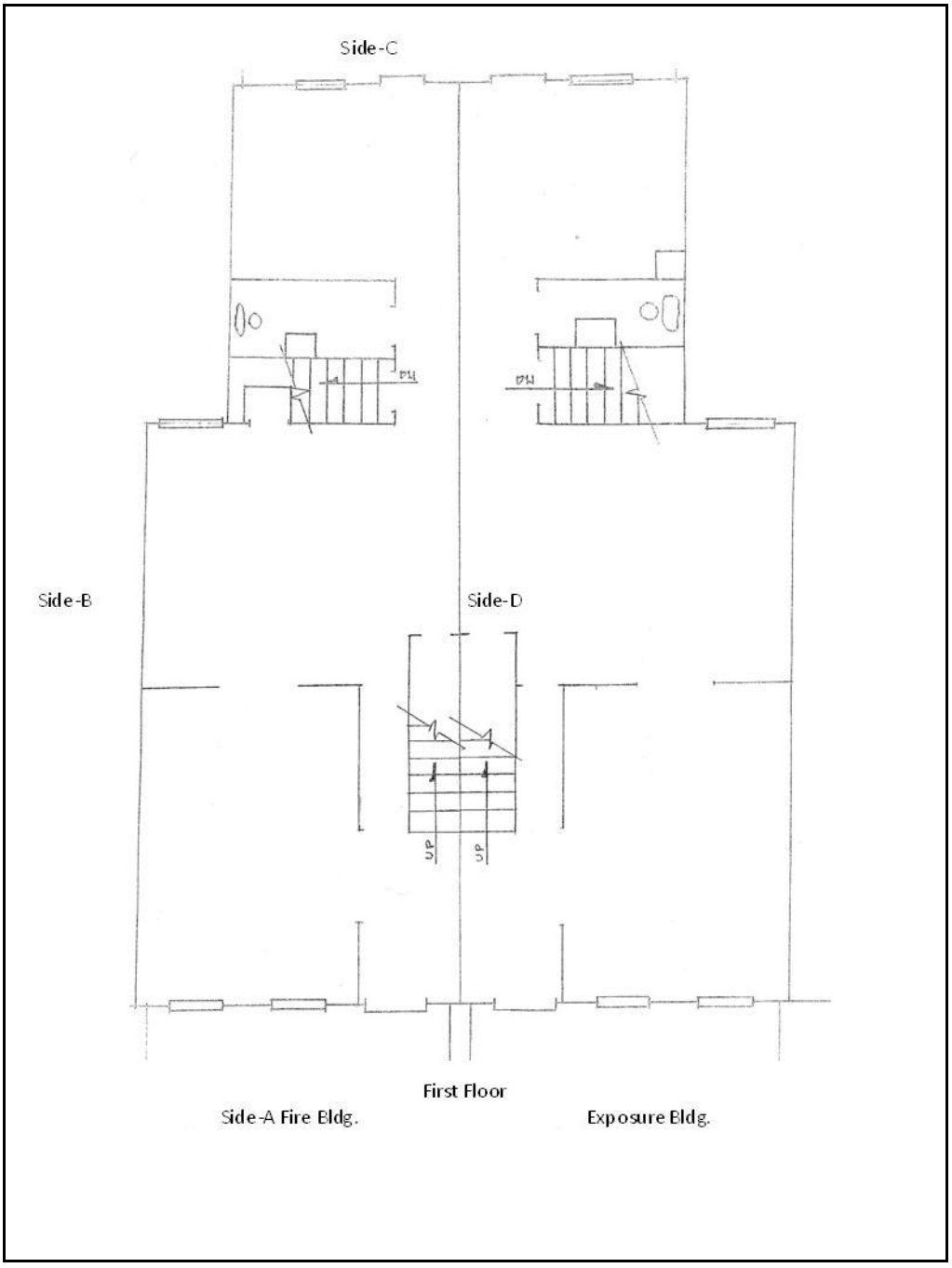

Diagram 2. Floor plan of first floor fire building and exposure building.
(*Diagram courtesy of the fire department.*)

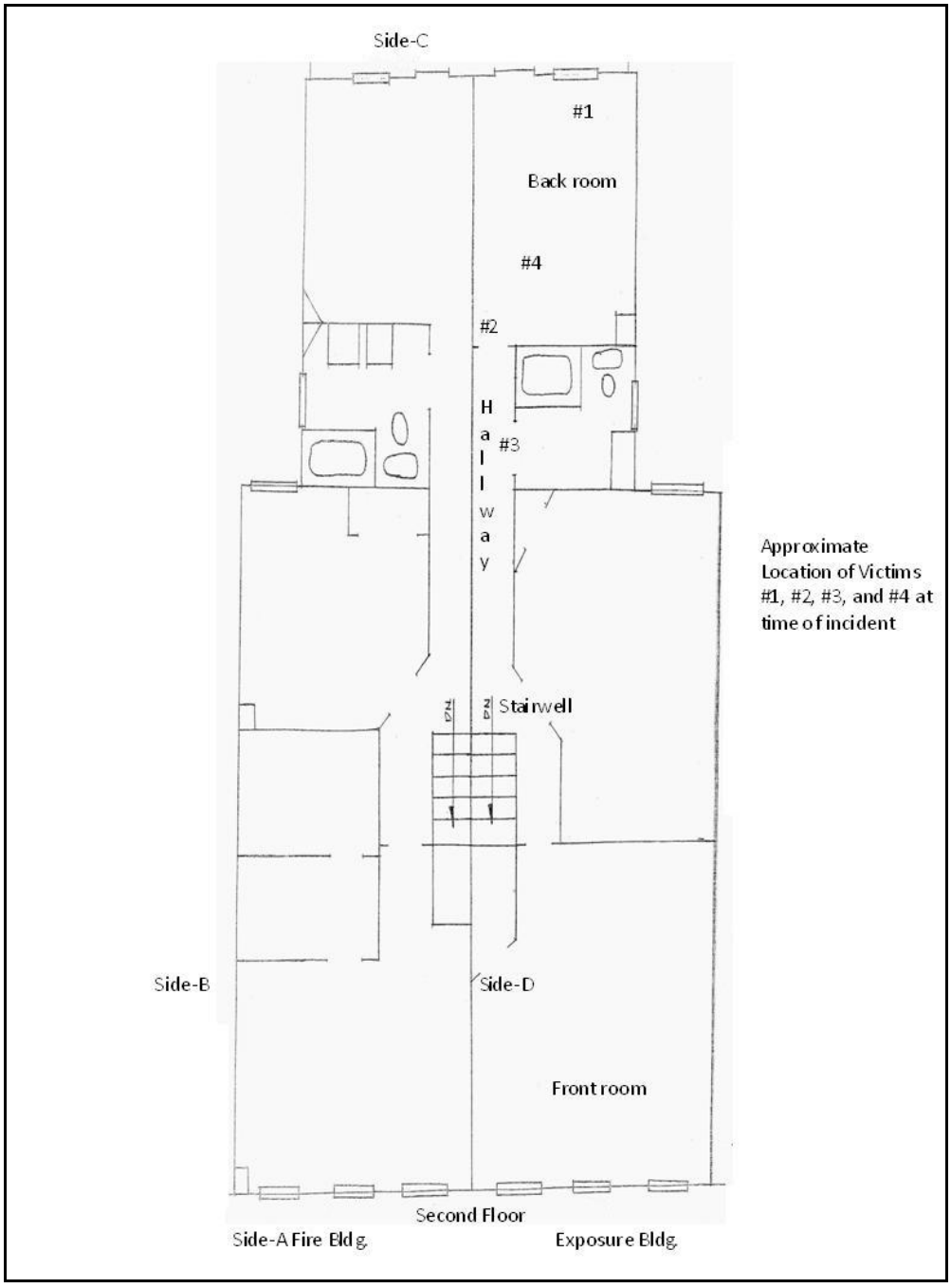

Diagram 3. Floor plan of second floor fire building and exposure building.
(*Diagram courtesy of the fire department.*)

APPENDIX

Key Findings from Expert Examination of Personal Protective Clothing

EXAMINATION OF FIRE FIGHTER PROTECTIVE CLOTHING WORN BY DISTRICT OF COLUMBIA FIRE FIGHTERS DURING OCTOBER 27, 2007 FIRE

Summary

This report covers my examination of the protective clothing and equipment worn by four different fire fighters during the structure fire on October 27, 2007. The purpose of this examination was to determine if there were any defects in or conditions of the protective clothing or equipment that may have contributed to the injuries sustained by each of the fire fighters.

Of the four fire fighters, the officer (victim # 1) sustained the worst burn injuries. These injuries included 2nd degree burns over 2% of his body and 3rd degree burns over 21% of his body. Nevertheless, the damage shown in his protective clothing and equipment was relatively minor. While there were deposits of tar on portions of his outer shell of his coat and pants, his clothing still remained serviceable. The best indications of high heat exposure occurred for the helmet where reflective markings showed extensive charring and gloves, which exhibited moderate shrinkage. Lesser burn injuries were sustained by victims # 2, # 3, and # 4, yet there were varying degrees of damage to their protective clothing. The clothing and equipment worn by victim # 4 appeared to be the least affected with no thermal damage noted except on the helmet (heat degradation of reflective markings) and gloves (mild shrinkage). Similarly, victim # 2's protective clothing and equipment showed essentially no thermal damage except the helmet and gloves. The worst thermal damage was exhibited by victim # 3's clothing that showed complete degradation of the back portion of the upper trim band on his left shoulder. Charring damage extended through the shell to the moisture barrier. In each case, helmet reflective markings and gloves showed the worst extent of thermal damage. There was no thermal damage apparent on the footwear and hoods, though the hoods were extensively soiled with fireground soot.

The condition of the protective clothing and equipment show some evidence of prolonged high heat exposure, but not under emergency conditions, as would be experienced in a flashover or backdraft. It is more likely that the burn injuries were the result of several factors – (1) preheating of the gear (storage of energy), (2) accumulation of moisture in the clothing – particularly victims # 2 and # 4, who were operating the hoseline, and (3) prolonged exposure to high heat in the form of radiant and convective (flame-based) heat. It is interesting to note that each fire fighter had hand burns. All of the gloves appeared to exhibit shrinkage, though the original size could not be discerned in the absence of labels for some gloves. Gloves are particularly subject to loss of insulation from shrinkage given the high ratio of surface area to volume that exists for the hands. The difficulty in providing commensurate

insulation of the hands as compared to the torso is one reason that fire fighters should be particularly aware of any discomfort they experience in feeling heat on their hands.

It was further noted that where station/work uniforms were available for examination that the uniform pants were composed of 65% polyester and 35% cotton. This material is not compliant with the requirement of NFPA 1975, *Standard on Station/Work Uniforms for Fire and Emergency Services.* Even though emergency conditions were not encountered, it is important that any underlying uniform clothing not contribute to burn injury. The use of polyester-based clothing increases the risk of severe burn injuries as it can melt under some emergency exposure conditions.

Based on the examination of the clothing and equipment worn by the fire fighters, I could not find any defects of the clothing as manufactured or worn by the fire fighters that would have contributed to their burn injuries. These burn injuries were sustained as the results of heat exposures in excess of the protective qualities offered by this clothing and equipment.

Objective

I was asked by the National Institute for Occupational Safety and Health (NIOSH) Surveillance and Field Investigations Branch (SFIB) Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) to examine the protective clothing and equipment worn by the injured fire fighters to determine if there were any deficiencies in the gear that could have caused burn injuries sustained by the victims.

Description of Fire Fighter Injuries

The victims received the following burn injuries:

- Victim #1 received 2nd degree burns to 2% (.5% neck, and 1.5% left forearm) and 3rd degree burns to 21% (10% anterior trunk, 4% posterior trunk, 2% buttocks, 2% left upper arm, and 3% hands)
- Victim #2 received 2nd degree burns to 6% (4% head, and 2% hands)
- Victim #3 received 2nd degree burns to 6.5% (3% anterior trunk, 1.5% forearms and 2% hands)
- Victim #4 received 2nd degree burns to 16% (4% head and neck, 1% right forearm, 5% hands, and 6% thighs)

Items Examined and Observations

Victim # 1: Protective clothing and equipment items provided for victim # 1 included the following items:

- Protective coat
- Protective pants
- Protective helmet
- Protective hood

- Protective gloves
- Protective footwear
- Station/work uniform pants and shirt
- Socks
- Work gloves (not worn)

The identification, description, and observation for each item are provided in Table 1 below.

Photographs were taken to show the condition of the clothing when examined. Other than soiling and the tar deposits, the protective coat was in relative good condition and completely serviceable. There was no significant thermal damage to any portions of the coat. Most of the darkened areas were discolored due to heavy fireground soot. It does appear that the collar was not properly extended upward when this soiling occurred. The pants show similar soiling as the coat. Some of this soiling extends to the moisture barrier side of the lining, but does not extend to the thermal barrier. The helmet shows extensive soiling and moderate soiling of the helmet interior, particularly the ear covers and suspension. There is heat damage to the helmet exterior in terms of deterioration of the reflective markings and degradation of materials in the shield emblem. However, the helmet edge beading is intact and the interior of the helmet is principally soiled without evidence of heat damage. The hood is soiled throughout with soot. There is no evidence of heat damage. The gloves are moderately soiled with tar deposits on the wristlet of the right glove. The leather shows some heat distortion, which is suggestive of slight shrinkage. The footwear shows very little damage and is in reasonably good condition and is completely serviceable. Additional items were provided for examination, including the station/work uniform pants, a cotton T-shirt, socks, and unworn, but soiled work gloves.

Table 1 – Description and Observations for Victim # 1 Protective Clothing

Item	Description	Observations
Protective coat	Globe Firefighting Suits, GExtreme, Jacket Style # 31184410 Serial No. 2863787 Cut # 50446 Mfg Date 3/2005 Size 48 Chest/35 Length Outer shell: 7.2 oz PBI/Matrix Gold Moisture barrier: Crosstech PJ Type 2C Thermal barrier: Caldura Aralite Quilt 3M Scotchlite Trim Front cargo pockets, radio pocket Leather elbow and sleeve end reinforcements Padded shoulders reinforcements	• Moderate soiling throughout coat • Tar deposits or other melted substance on shoulder and front pockets • Some heat damage to lower portions of trim on front of coat • Condition of coat otherwise serviceable

Protective pants	Globe Firefighting Suits, GExtreme, Pants Style # 41184410 Serial No. 2866127 Cut # 50446P Mfg Date 3/2005 Size 42 Waist/30 Inseam Same composite and materials as used in construction of coat Webbing based waist belt Front cargo pockets, radio pocket Leather knee, padded reinforcements and hem edges	• Moderate soiling throughout pants • Minor tar deposits on front of pants • Condition of pants otherwise serviceable
Protective helmet	Cairns Model C-TRD helmet White with yellow reflective markings PBI/Kevlar ear covers Serial No.1005724123 Mfg Date 12/14/2003	• Soot blackened shell • Melted, burned trim in different locations (worse on rear and right side) • Some deterioration of edging • Charred emblem • Ear flaps moderately soiled • Chin strap and suspension in good condition
Protective hood	LifeLiners PBI/FR Lenzing Lot and manufacture date number not discernable	• Hood severely soiled
Protective gloves	American Firewear Model #6000 Leather shell with Crosstech moisture barrier and modacrylic thermal lining Lot and manufacture date number not discernable	• Glove body shows some signs of shrinkage • Moderate soiling throughout gloves • Some tar residue on right glove wristlet
Protective footwear	Warrington Pro Style 6135 Leather outer; Crosstech Cambrelle lining Lot and manufacture date number not discernable	• Footwear heavily soiled but undamaged
Station/work pants	Polyester pants	• Lightly soiled, no damage
Station/work shirt	Cotton T-shirt with silkscreen logo on front and back	• Lightly soiled, no damage
Socks	No label, not identifiable	• No damage
Work gloves (not worn)	Readhead, leather gloves	• Soiled but no damage

Victim # 2: Protective clothing and equipment items were provided for victim # 2 included the following items:

- Protective coat
- Protective pants
- Protective helmet
- Protective glove (right only)
- Protective footwear
- Station/work pants
- Socks

One piece of unidentified fluorescent yellow pipe does not appear to be part of protective ensemble.

The protective clothing worn by victim # 2 show primarily soiling and very little damage. The coat shows light to moderate soiling consistent with ordinary fireground conditions. Some soiling appears on the moisture barrier of the liner in areas other than those covered by trim. Other than some soiling primarily towards the bottom of the liner, there is no damage. The exterior of the pants and interior side of the shell shows only mild to moderate soiling. Similarly, there is only light soiling on the moisture barrier side of the liner and no apparent damage to the thermal barrier side of the liner. The helmet shows extensive soiling but only slight heat damage to some reflective markings and the leather shield. The helmet appears to be fully serviceable. The hood soiling is confined to the upper, exposed portion of the hood while the bib appears relatively unsoiled indicating that hood was properly worn (with the bib tucked underneath the top of the coat). Only one glove (right) was made available for examination. The right glove shows heat damage with distortion of the leather and extensive shrinkage. The level of shrinkage is evidenced through comparison with a new glove of the same size. Additional damage is shown to the glove in the form of loose stitching. It is likely that this glove had been in service a long time; however, the manufacture date was not discernible. In contrast, the footwear is in relatively good condition with only mild soiling. No damage was found in the examination of the footwear. A set of station wear pants is constructed of a cotton/polyester blend and are clearly marked as not being flame resistant. No damage was noted on the pants. The socks are not damaged.

Table 2 – Description and Observations for Victim # 2 Protective Clothing

Item	Description	Observations
Protective coat	Globe Firefighting Suits, GExtreme, Jacket Style # 31184410 Serial No. 3173562 Cut # 614B6C Mfg Date 3/2005 Size 44 Chest/35 Length Outer shell: 7.2 oz PBI/Matrix Gold Moisture barrier: Crosstech PJ Type 2C Thermal barrier: Caldura Aralite Quilt	• Light to moderate soiling throughout coat; soling on inside of lower liner (at thermal barrier) • No observable heat damage to coat • Condition of coat serviceable

	3M Scotchlite Trim Front cargo pockets, radio pocket Leather elbow and sleeve end reinforcements Padded shoulders reinforcements	
Protective pants	Globe Firefighting Suits, GExtreme, Pants Style # 41184410 Serial No. 2866127 Cut # 50446P Mfg Date 3/2005 Size 42 Waist/30 Inseam Same composite and materials as used in construction of coat Webbing based waist belt Front cargo pockets, radio pocket Leather knee, padded reinforcements and hem edges	• Light to moderate soiling throughout pants • Some staining on seat and bottom right hem area • Condition of pants serviceable
Protective helmet	Cairns Model C-TRD helmet Black with yellow reflective markings PBI/Kevlar ear covers Serial No.10094231 Mfg Date 2/4/2006	• Heavy soiling over entire helmet • Worst damage to leather emblem; no other heat damage is apparent • Extensive soiling of ear flaps
Protective hood	Majestic PBI/FR Lenzing Lot and manufacture date number not discernable	• Hood severely soiled in exposed areas; bib area not soiled suggesting proper use
Protective glove (right only)	American Firewear Model #6000 Leather shell with Crosstech moisture barrier and modacrylic thermal lining Lot and manufacture date number not discernable	• Glove body shows severe shrinkage • Loose stitching in wristlet area • Moderate to heavy soiling throughout gloves
Protective footwear	Warrington Pro Style 6135 Leather outer; Crosstech Cambrelle lining Lot and manufacture date number not discernable	• Footwear heavily soiled but undamaged
Station/work pants	Polyester pants	• Lightly soiled, no damage
Socks	No label, not identifiable	• No damage

Victim # 3: Protective clothing and equipment items provided for victim # 3 included the following items:

- Protective coat
- Protective pants
- Protective helmet
- Protective hood
- Protective gloves
- Protective footwear
- Station/work uniform pants and shirt

The identification, description, and observation for each item are provided in Table 3 below.

Photographs were taken to show the condition of the clothing when examined. The protective coat shows extensive thermal damage to the left shoulder trim band and damage to the trim band on the lower left back side of the coat. Mild charring damage is evident under the missing trim in the left shoulder area. Charred areas of the moisture barrier under the damaged trim are evident. The film side of the moisture barrier in the shoulder area underneath the charred area shows some heat effects. However, none of this damage extends to the thermal barrier side. The pants show similar soiling as the coat but none of the heat damage, which primarily focused on the trim areas of the coat left side. In particular there are tar deposits that penetrate the pants shell. Some of the soiling and tar also appear on the moisture barrier side of the lining but does not extend to the thermal barrier. The condition of the helmet is heavily soiled and all reflective markings have been destroyed. Further, there is damage to the edge beading over much of the helmet brim with separation in some areas. It is likely that the helmet fell off on the fireground given the level of damage and soiling. The hood is soiled throughout with soot and fireground debris. There is no evidence of heat damage, but it is apparent that the hood was correctly worn. The gloves are heavily soiled, have some tar deposits, and show some signs of shrinkage. The footwear shows very little damage with the exception of some physical damage to the top line of the left boot. The station/work uniform pants were provided showing mild soiling and were constructed of cotton/polyester blend. There was no damaged to the station/work uniform shirt.

Table 3 – Description and Observations for Victim # 3 Protective Clothing

Item	Description	Observations
Protective coat	Globe Firefighting Suits, GExtreme, Jacket Style # 31184410 Serial No.2861903 Cut # 50446C Mfg Date 3/2005 Size 46 Chest/35 Length Outer shell: 7.2 oz PBI/Matrix Gold Moisture barrier: Crosstech PJ Type 2C Thermal barrier: Caldura Aralite	• Heavy soiling throughout coat, particularly on left shoulder and sleeve; mild charring of shell underneath missing trim area • Charred upper trim band on left arm; most of trim is missing from heat degradation • Charred lower trim band

	Quilt 3M Scotchlite Trim Front cargo pockets, radio pocket Leather elbow and sleeve end reinforcements Padded shoulders reinforcements	lower left side of coat torso • Heat damage (charring) to left shoulder and left side of moisture barrier on fabric side • Some degradation of film side from interior inspection of clothing; damage warrants replacement of moisture barrier
Protective pants	Globe Firefighting Suits, GExtreme, Pants Style # 41184410 Serial No. 2866086 Cut # 50446P Mfg Date 3/2005 Size 40 Waist/30 Inseam Same composite and materials as used in construction of coat Webbing based waist belt Front cargo pockets, radio pocket Leather knee, padded reinforcements and hem edges	• Moderate to heavy soiling throughout pants • Tar deposits to lower back right leg that penetrate through entire shell and onto moisture barrier in some places • Condition of pants for continued service is questionable and not recommended
Protective helmet	Cairns Model C-TRD helmet White with yellow reflective markings PBI/Kevlar ear covers Serial No.100791270 Mfg Date 3/28/2004	• Soot blackened shell; heavily loaded with fireground debris • All reflective markings have been charred and degraded; no reflective material remains • Edge beading on helmet damaged in some places, showing separation • Missing leather shield • Earflaps heavily soiled • Chin strap and suspension still functional
Protective hood	PBI/FR Lenzing No label present	• Hood severely soiled • Appears to have been properly worn given areas of soiling

Protective gloves	American Firewear Model #6500 Mfg Date 12/05, Size Large Leather shell with Crosstech moisture barrier and modacrylic thermal lining	• Glove bodies show some signs of shrinkage • Moderate soiling throughout gloves • Some tar residue on both glove wristlets
Protective footwear	Warrington Pro Style 6135 Leather outer; Crosstech Cambrelle lining Lot and manufacture date number not discernable	• Footwear moderately soiled but undamaged
Station/work pants	Polyester pants	• Lightly soiled, no damage
Station/work shirt	Cotton T-shirt with silkscreen logo on front and back	• Lightly soiled, no damage

Victim # 4: Protective clothing and equipment items provided for victim # 4 included the following items:

- Protective coat
- Protective pants
- Protective helmet
- Protective hood
- Protective gloves
- Protective footwear
- Station/work uniform pants
- Work gloves (not worn)

The identification, description, and observation for each item are provided in Table 4 below.

Photographs were taken to show the condition of the clothing when examined. The protective coat displayed only light to moderate soiling with no thermal damage. What may be a blood stain is present; however, the redness of this stain suggests that it may be something else as the injury report does not confirm bleeding. The pants displayed only light to moderate soiling with no thermal damage. The pants were also cut open to aid in their removal at the emergency scene. The pants show similar soiling as the coat and no thermal damage. Some of this soiling extends to the moisture barrier side of the lining but does not extend to the thermal barrier. The helmet worn by victim # 4 shows extensive soiling and moderate soiling of the helmet interior, particularly the ear covers and suspension. There is heat damage to the helmet exterior in terms of deterioration of the reflective markings and degradation of materials in the shield emblem. However, the helmet edge beading is intact and the interior of the helmet is principally soiled without evidence of heat damage. The hood is moderately soiled. There is no evidence of heat damage. The gloves are soiled and probably exhibit some shrinkage compared to their original conditions. There is no evidence of thermal damage. The footwear shows very little damage. The footwear is in reasonably good condition and is completely

serviceable with light soiling. Additional items provided for examination, included the station/work uniform pants and unworn, but soiled work gloves.

Table 4 – Description and Observations for Victim # 4 Protective Clothing

Item	Description	Observations
Protective coat	Globe Firefighting Suits, GExtreme, Jacket Style # 31184410 Serial No.2861903 Cut # 50446C Mfg Date 3/2005 Size 46 Chest/35 Length Outer shell: 7.2 oz PBI/Matrix Gold Moisture barrier: Crosstech PJ Type 2C Thermal barrier: Caldura Aralite Quilt 3M Scotchlite Trim Front cargo pockets, radio pocket Leather elbow and sleeve end reinforcements Padded shoulders reinforcements	• Light to moderate soiling throughout coat • No apparent heat damage to any parts of the coat • Coat was cut off of fire fighter • Small possible blood stain on liner of coat
Protective pants	Globe Firefighting Suits, GExtreme, Jacket Style # 41184410 Serial No. 2866086 Cut # 50446P Mfg Date 3/2005 Size 40 Waist/30 Inseam Same composite and materials as used in construction of coat Webbing based waist belt Front cargo pockets, radio pocket Leather knee, padded reinforcements	• Moderate soiling throughout pants • No apparent heat damage to any parts of the pants • Pants was cut off of fire fighter

	and hem edges	
Protective helmet	Cairns Model C-TRD helmet White with yellow reflective markings PBI/Kevlar ear covers Serial No.1007914235 Mfg Date 4/8/2004	• Soot blackened shell • Melted, burned trim in different locations (reflective properties all dissipated) • Charred emblem • Ear flaps moderately soiled • Chin strap and suspension in good condition
Protective hood	PBI/FR Lenzing No label present	• Hood moderately soiled • Appears to have been properly worn
Protective gloves	Labels cut out; lot and manufacture date number not discernable. Leather shell with Crosstech moisture barrier and modacrylic thermal lining	• Glove body shows some signs of shrinkage • Moderate soiling throughout gloves
Protective footwear	Haix Footwear. Leather outer; Crosstech Cambrelle lining Lot and manufacture date number not discernable	• Footwear heavily soiled but undamaged
Station/work pants	Polyester pants	• Lightly soiled, no damage
Work gloves – not worn	Unidentified leather gloves	• Moderately soiled, no damage

The Fireground Environment

One manner of analyzing the protective clothing and equipment is to examine industry information that shows the range of fireground conditions that can be experienced and relate these conditions to the types of damage that can occur to clothing and equipment. The relationship between increasing thermal radiation (expressed in cal/cm^{2}s) and the resulting rise in air temperature (expressed in degrees Celsius and degrees Fahrenheit) is presented in Figure 161. Possible structural fire fighting situations are illustrated in this figure: [1,2]

• The ***Routine*** region describes conditions where one or two objects, such as a bed or waste basket, are burning in a room. The thermal radiation and the air temperatures are virtually the same as those encountered on a hot summer day. As shown in Figure 161, ***Routine*** conditions are accompanied by a thermal radiation range of 0.025 to 0.05 cal/cm^{2}s and by air temperatures ranging from 68 to 140^{o}F.

Protective clothing for fire fighters typically provides protection under these conditions, but excessively long exposure times may create a burn injury situation.

• The ***Ordinary*** region describes temperatures encountered in fighting a more serious fire or being next to a "flashover" room. ***Ordinary*** conditions are defined by a thermal range of 0.05 to 0.6 cal/cm^{2}s, representing an air temperature range of 140 to 571^{o}F. Under these conditions, protective clothing may allow sufficient time to extinguish the fire or to fight the fire until the nominal air supply is exhausted (usually less than 30 minutes).

• The ***Emergency*** region describes conditions in a severe and unusual exposure, such as those caused inside a "flashover" room or next to a flame front. In ***Emergency*** conditions, the thermal load exceeds 0.6 cal/cm^{2}s and temperatures exceed 571^{o}F. In such conditions, the function of firefighters' clothing and equipment is simply to provide protection during the short time needed for an escape without serious injury. Burn injuries are sustained when the energy absorbed by the skin can no longer be dissipated in the body. In essence, the rate of heat (energy) transfer into the body at a particular location overwhelms the body's capacity to remove that heat to other portions of the body. In general, when the energy transferred through the clothing to the skin is able to cause the skin temperature to rise to 111^{o}F (44^{o}C), pain is felt by the average individual person. If the skin temperature increases to 131^{o}F (55^{o}C), the onset of second degree burn injury occurs.

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[1]N. J. Abbott and S. Schulman, "Protection from Fire: Nonflammable Fabrics and Coatings, *Journal of Coated Fabrics*, Vol. 6, July 1976, pp. 48-64.
[2]H. P. Utech, "High Temperatures vs. Fire Equipment," *International Fire Chief*, Vol. 39, 1973, pp. 26-27.

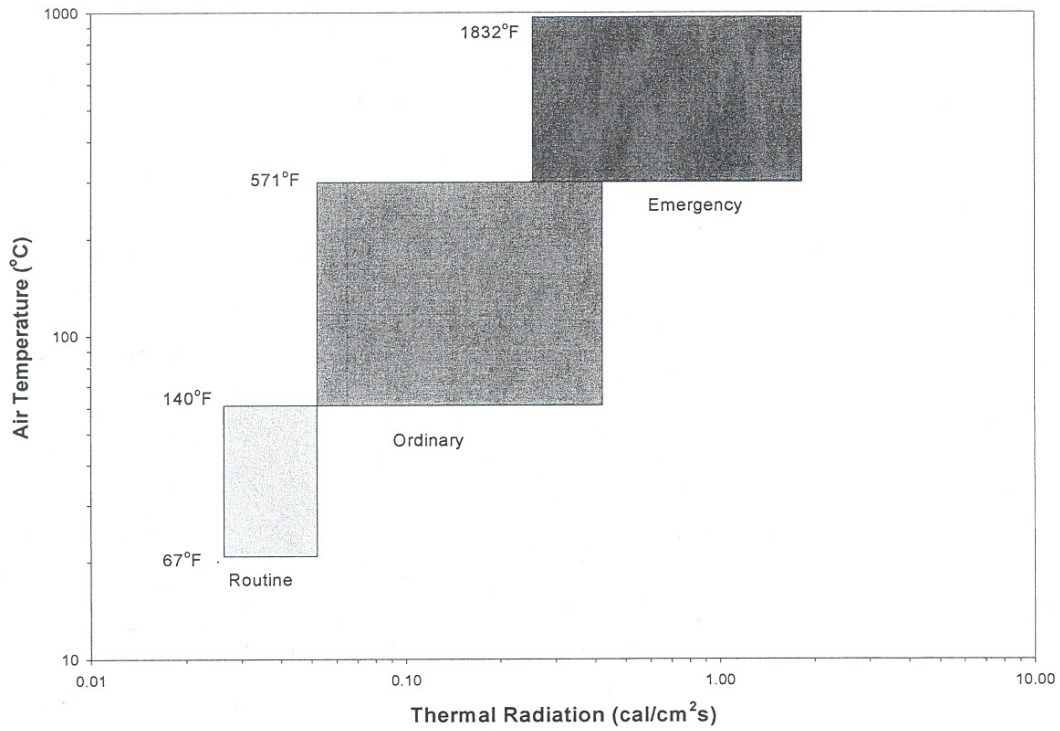

Figure 161– Classification of Fireground Conditions

Any number of reasons can exist for burn injury to occur in selective locations over the firefighter's body or for the severity of the injury to vary at different locations. Unexposed or less protected areas of the firefighter's body are more susceptible to burn injury than other areas. These areas may include the portions of the head or ears. Where clothing compresses against the skin either by fit or wearing position, heat transfer to the skin can occur at higher rates. The phenomenon of stored energy can also be a factor where heat energy that accumulates in clothing from continued radiant exposure can quickly transfer to the skin when the clothing is compressed suddenly. This compression can happen simply from bending a joint (a knee or elbow) or otherwise positioning the body to stretch the clothing across the body so that more intimate contact is made with the skin. If shrinkage of an item occurs, which effectively reduces the insulating air layer between the clothing and the skin, increased heat transfer to the skin will occur. This type of heat transfer can occur when a glove, constructed of leather, shrinks from a high, extended heat exposure. Finally, wherever damage occurs that causes severe charring, embrittlement, and break open of materials or components, protection is lessened and the potential for burn injury is increased.

Analysis and Findings

The examination of protective clothing and equipment worn by the District of Columbia fire fighters revealed relatively little damage. Only in one case, was there more than moderate thermal damage to any of the protective coats or pants (left side of victim # 3's coat). Further, each of the helmets displayed damage to the reflective markings, but in one case (victim # 3), it is possible that the helmet may have been knocked off at the emergency scene and subject to additional damage after the injuries were sustained. The primary condition of this clothing was soiling and damage was limited to portions of the clothing that are generally more susceptible to heat such as the reflective markings on the helmet and the gloves. The degradation of the reflective markings and slight charring of the hood do suggest temperatures upward of 600°F sustained for very short periods of time. The predominance of burn injuries to the upper body (head, neck, arms, and hands) is suggestive for exposure to heat while standing up. The worst damage to the helmet and the hood coincide with this observation. However, without definitive information on the actual specific locations of burn injuries to each fire fighter, it is difficult to surmise specific patterns of heat transfer in the clothing.

Of the four fire fighters, the officer (victim # 1) sustained the worst burn injuries. These injuries included 2nd degree burns over 2% of his body and 3rd degree burns over 21% of his body. Nevertheless, the damage shown in his protective clothing and equipment was relatively minor. While there were deposits of tar on portions of his outer shell of his coat and pants, his clothing still remained serviceable. The best indications of high heat exposure occurred for the helmet where reflective markings showed extensive charring and gloves, which exhibited moderate shrinkage. The burns to his neck, arms, and trunk are due to the prolonged exposure to heat while making his way out of the burning structure. In the case of the gloves, shrinkage of the glove body contributed to his hand burns. This shrinkage was caused by prolonged exposure to heat. According to the provided account, witnesses indicated that at one point, his body was engulfed in fire. Even though this was a severe exposure it was not necessarily a flashover as flashovers will generally cause greater damage to the clothing and equipment. The pattern of burn injuries suggests that the incident heat simply exceeded the capabilities of the protective clothing and equipment. The worst burns are likely due to the position of his body with respect to the fire and effects of moisture inside his clothing in combination with stored energy from earlier exposure.

Victim # 2 sustained burns only to his head and hands. He had the least severe burns of all fire fighters. The burns to his head occurred to the least protected area of his ensemble, which is further at the highest likely level of heat exposure. While there is overlap of different parts of the ensemble in head region – helmet earflaps, SCBA facepiece, hood, and coat collar, there is some evidence that at least part of his collar may not have been deployed (given the patterns of soiling and soot deposition). Any compromise of this interface area may rationalize the burns to his head. The burns to the hands of victim # 2 indicate that some shrinkage of the gloves probably contributed to less insulation for his hands as gloves are generally at a disadvantage for providing heat protection. It is unknown if the gloves might have previously sustained shrinkage from prior fire events.

The protective clothing worn by victim # 3 showed the most extensive damage. In this case, the protective coat showed complete deterioration of the upper trim band on the back of the coat. Similarly, the lower trim band on the back of the coat was extensively charred. The damage points to most severe heat exposure to rear and left side of victim # 3. This heat damage probably did not extend over the entire back due to shielding from the SCBA. Nevertheless, the burn injuries on his torso and forearms are likely the result of this intense heat exposure. As with the other fire fighters, the shrinkage of the glove materials more than likely contributed to the hand burn injuries. As with the other injured fire fighters, there was heat damage to the helmets, but none to the footwear.

The clothing and equipment worn by victim # 4 appeared to be the least affected with no thermal damage noted except on the helmet (heat degradation of reflective markings) and gloves (mild shrinkage). Only moderate soiling was found in the protective coat and pants. The helmet showed some of the same heat damage to reflective markings found on the other fire fighter helmets. The high levels of heat exposure in the head region may explain burn injuries to head and neck that were sustained by victim # 4, but there was no damage to any part of the coat or pants that would explain burns to the right forearm or thighs, other than prolonged heat exposure with the possibility of moist conditions and accumulation of stored energy. Also as with the other fire fighters, there was apparent shrinkage of the gloves, which as previously explained can rationalize burn injuries to the hands.

The overall condition of the protective clothing and equipment shows some evidence of prolonged high heat exposure, but not under emergency conditions, as would be experienced in a flashover or backdraft. It is more likely that the burn injuries were the result of several factors –

(1) preheating of the gear resulting in the storage of energy in the clothing layers,
(2) accumulation of moisture in the clothing – particularly for victim # 2 and # 4, who were operating the hose line, and
(3) prolonged exposure to high heat in the form of radiant and convective (flame-based) heat.

It is interesting to note that each fire fighter had hand burns. All of the gloves appeared to exhibit shrinkage, though the original size could not be discerned in the absence of labels for some gloves.

Records of clothing care and cleaning by an outside organization were provided. There was nothing in these records to suggest specific problems or issues with any of the clothing that was subjected to cleaning or repair.

It was further noted that where station/work uniforms were available for examination that the uniform pants were composed of 65% polyester and 35% cotton. This material is not compliant with the requirement of NFPA 1975, *Standard on Station/Work Uniforms for Fire and Emergency Services.* Even though emergency conditions were not encountered, it is important that any underlying uniform clothing not contribute to burn injury. The use of polyester-based clothing increases the risk of severe burn injuries as it can melt under some emergency exposure conditions.

Conclusions

Based on the examination of the clothing and equipment worn by the fire fighters, I could not find any defects of the clothing as manufactured or worn by the fire fighters that would have contributed to their burn injuries. Only in the case of victim # 2 was there evidence that the coat collar might not have been properly deployed. This clothing configuration may have contributed to head burns sustained by victim # 2; however, given that three of the fire fighters sustained head or neck burns, it is more likely that the burn injuries were sustained as the result of heat exposures in excess of the protective qualities offered by this clothing and equipment.

I could not find any defect or problems with the any of clothing or equipment items that I examined. All of the protective clothing and equipment appeared to function as intended. However, it is important that fire fighters wear station/work uniforms that do not contain high levels of polyester and that these uniforms meet the requirements of NFPA 1975, *Standard on Station/Work Uniforms for Fire and Emergency Services.* Although not a specific factor in this event, the *wearing of polyester-based uniforms can contribute to significant potential for severe burn injury.*

The clothing and equipment for all fire fighters should be retained because of its involvement in a situation where injuries were sustained. The clothing should be retained by the department for a period of at least 2 years with an appropriate chain of custody. Records should be kept of any further evaluations.

Respectfully submitted,

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