
International Personnel Protection, Inc.
Jeffrey O. Stull, President and Grace G. Stull, Vice President

August 5, 2008

Timothy R. Merinar, Safety Engineer
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Dear Mr. Merinar:

Enclosed please find my report to the examination of the protective clothing worn by nine fire fighters involved in the XXXXX fire.

Please contact me if you have any questions.

Sincerely,

/Jeffrey O. Stull/

Jeffrey O. Stull

Enclosure

**EXAMINATION OF
FIRE FIGHTER PROTECTIVE CLOTHING AND EQUIPMENT
WORN IN THE SUPER SOFA STORE FIRE**

**Final Report
July 31, 2008**

Summary

This report covers my examination of the protective clothing and equipment worn by nine different fire fighters that died during their involvement in the XXXXXXXXXX Fire in XXXXXX, South Carolina on June 18, 2008. This examination was carried out with the cooperation of the XXXXX Coroner's Office that had retained the clothing and equipment, which was removed from either removed from the individual deceased firefighters or recovered from the scene. Photographs were taken by the Chief Photographer of XXXXX Police Department.

The majority of clothing sets showed extensive damage with many items only available as remnants. Several portions of clothing were readily destroyed beyond recognition and could not be handled without further disintegration of the respective items. The lapse in time between the collapse of the structure and the recovery of the firefighter bodies significantly contributed to the continued degradation of the protective clothing and equipment and therefore does not represent the condition of the clothing at the time of each firefighter's demise. An examination of sets of clothing for firefighters that had escaped just prior to the collapse revealed that exposure conditions were relatively extreme but still in the ordinary range of fireground conditions. This information indicates that it may have been possible for some firefighters to sustain burn injuries at the time of collapse; however, other evidence suggests that several firefighters had removed the facepieces of their self-contained breathing apparatus after running out of air, suggesting that asphyxiation may have been the primary cause of death rather than burn injury.

Objective

I was asked by Mr. Timothy R. Merinar of the National Institute for Occupational Safety and Health (NIOSH) Surveillance and Field Investigations Branch to examine the protective clothing and equipment worn by the nine deceased fire fighters to determine if there were any deficiencies in the gear that could have caused their fatalities.

Description of the Incident and Fire Fighter Injuries

A complete description of the incident and specific injuries and burns sustained by the fire fighters is provided in the comprehensive Fire Fighter Field Investigative Program report. All fire fighters died at the fire scene with their bodies recovered after the fire was brought under control. For this reason, much of the clothing and equipment was damaged to a greater extent following the actual time that each fire fighter succumbed to the extreme conditions of their exposures.

Items Examined and Observations

Protective clothing and equipment items were provided for each fire fighter and laid on examination tables for viewing. Given the extreme damaged condition of the clothing and equipment, minimal manipulation of items was undertaken. The following types of items were examined for each fire fighter, where identified and recovered:

- Protective coat
- Protective pants
- Protective helmet
- Protective hood
- Protective gloves
- Protective footwear
- Self-contained breathing apparatus
- Personal Alert Safety System (PASS) device
- Radio
- Station/work uniform pants and shirt
- Underwear
- Socks
- Tools or other items carried by each firefighter or found in proximity to the location of their recovered bodies

In some cases, some items could not be readily identified, or were so damaged to make a complete assessment impractical. A complete inventory of clothing, equipment and other items available for examination by firefighter is provided in Appendix A.

For the purpose of this examination, each fire fighter is identified as a number with this numbering system consistent with that used in the FFFIPP report. This information is provided with the designations of Victim #1 through Victim #9.

Specific observations and findings by victim are provided in Appendices B through J. Selected photographs are provided as needed to illustrate the condition and damage of the gear, where specific items were identified.

Additional items of protective clothing and equipment were provided for two firefighters who escaped just prior to the collapse. These included a fire fighter from the XXXXXXXX Fire Department and a fire fighter from the XXXXXXXX Fire Department. The purpose of examining these gear items was to determine the nature of exposure conditions inside the building that the victims may have been exposed to. It is understood that the activities, time on scene, and other factors are likely to be different, but nonetheless, this information was used to help frame the exposure conditions at the time of collapse. It is understood that these two fire fighters escaped with a minimum of injuries. Photographs and observations for the clothing and equipment examined for these firefighters are provided in Appendix K.

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 $\text{cal}/\text{cm}^2\text{s}$) and the resulting rise in air temperature (expressed in degrees Celsius and degrees Fahrenheit) is presented in Figure 1. Possible structural fire fighting situations are illustrated in this figure:^{1,2}

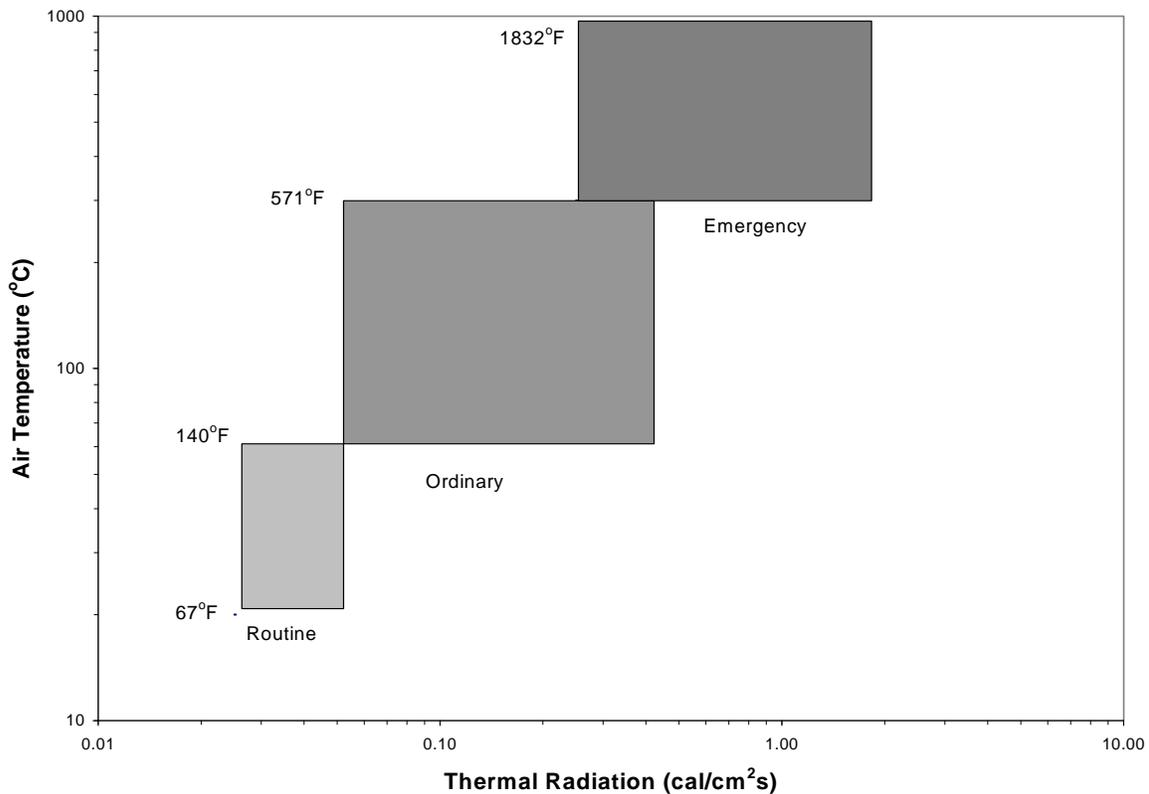


Figure 1– Classification of Fireground Conditions

- 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 $\text{cal}/\text{cm}^2\text{s}$ and by air temperatures ranging from 68 to 140°F. Protective clothing for fire

¹N. J. Abbott and S. Schulman, "Protection from Fire: Nonflammable Fabrics and Coatings, *Journal of Coated Fabrics*, Vol. 6, July 1976, pp. 48-64.

²H. P. Utech, "High Temperatures vs. Fire Equipment," *International Fire Chief*, Vol. 39, 1973, pp. 26-27.

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 "flash-over" room. **Ordinary** conditions are defined by a thermal range of 0.05 to 0.6 cal/cm²s, representing an air temperature range of 140 to 571°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 "flash-over" room or next to a flame front. In **Emergency** conditions, the thermal load exceeds 0.6 cal/cm²s and temperatures exceed 571°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 with 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°F (44°C), pain is felt by the average individual person. If the skin temperature increases to 131°F (55°C), the onset of second degree burn injury occurs.

Any number of reasons can exist for burn injury to occur in selective locations over the fire fighter'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. The specific layout of the fire scene can cause shielding to the fire fighter's body depending on their orientation and position. 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

Tables 1 and 2 provide an overview of the condition of clothing and equipment that was examined for each of the fire fighters. This table lists the surviving portions of each item. In nearly all cases, the majority of each item was destroyed due to the intensity of the fire and delay in recovering the fire fighters.

Table 1 – Overview of Clothing and Equipment Condition for Each Fire Fighter (Victims 1- 5)

Clothing or Equipment Item	Victim #1	Victim #2	Victim #3	Victim #4	Victim #5
Protective coat	Remnants: left front side and part of back; Collar down; Severe charring and embrittlement	Remnants: left front side, small portion of left sleeve, right side of closure; Severe charring and embrittlement	Remnants: top of coat with right sleeve and portions of left side; Collar down; Severe charring and embrittlement	Remnants: front closure area, left arm, lower portion of right sleeve; Severe charring and embrittlement	Remnants: portions of left front closure area, left arm, and back; Severe charring and embrittlement
Protective pants	Remnants: left leg; Severe charring and embrittlement	Remnants: most of right leg, portions of left leg; Severe charring and embrittlement	Remnants: portions of both legs and waist area; Severe charring and embrittlement	Remnants: back of pants, majority of liner; Severe charring and embrittlement	Remnants: portions of both legs and part of waist area; Severe charring and embrittlement
Protective helmet	Intact; most heat damage to reflective markings and ear covers	Not available for examination	Not available for examination	Remnants: majority of shell, faceshield; Heavy heat damage; portion of shell missing; ear covers not deployed	Not available for examination
Protective hood	Remnants: part of face opening, bottom bib; Severe charring and embrittlement	Not available for examination	Intact: severe charring around face opening and portions of bib	Intact: severe charring at face opening and portions of bib	Remnants: portions of face opening and front bib; Severe charring and embrittlement
Protective gloves	Remnants: left glove only, outer layer disintegrated; Severe charring and embrittlement	Remnants: Thumb side of left glove; Severe charring and embrittlement	Remnants: portions of left glove; Severe charring and embrittlement	Remnants: both gloves; Moderate charring and embrittlement	Not available for examination

Clothing or Equipment Item	Victim #1	Victim #2	Victim #3	Victim #4	Victim #5
Protective footwear	Remnants: left boot only; right side dis-integrated; Severe charring and embrittlement	Remnants: right boot with portion of left side missing; only hardware remains for left boot; Severe charring and embrittlement	Remnants: right boot is intact; portions of left boot; Severe charring and embrittlement of both boots	Remnants: both boots; portions showing severe charring and embrittlement	Remnants: majority of right boot and bottom half of left boot; Severe charring and embrittlement
Station/work shirt	Pieces only, not examined	Unavailable for examination	Not examined	Not examined	Not examined
Station/work pants	Pieces only, not examined	Remnants: majority of left leg, portions of right leg; Melted to protective pants	Not examined	Remnants: majority of pants intact; Melted to protective pants	Remnants: portions of both legs and part of waist; Severe charring and embrittlement
Socks	Unavailable for examination	Unavailable for examination	Unavailable for examination	Unavailable for examination	Unavailable for examination
SCBA facepiece	Intact: lenses melted through; Severe melting	Unavailable for examination	Unavailable for examination	Intact: heavily distorted	Unavailable for examination
SCBA frame	Back frame mainly intact; Severe damage	Remnants: most of frame and pieces of hardware; Severe damage	Remnants: part of frame and pieces of hardware; Severe damage	Remnants: part of frame and pieces of hardware; Severe damage	Remnants: portions of hardware
SCBA cylinder	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; valve missing
PASS device	Severely melted onto belt	Unavailable for examination	Unavailable for examination	Unavailable for examination	Unavailable for examination

Table 2 – Overview of Clothing and Equipment Condition for Each Fire Fighter (Victims 6- 9)

Clothing or Equipment Item	Victim #6	Victim #7	Victim #8	Victim #9
Protective coat	Remnants: majority of back area and parts of each sleeve; Severe charring and embrittlement	Remnants: left side of coat and top portion of collar along with entire front closure and part of left sleeve; Severe charring and embrittlement	Remnants: right side of coat; left side completely missing; microphone melted to coat; Severe charring and embrittlement	Remnants: majority of front with portions of left sleeve; Collar down; Severe charring and embrittlement
Protective pants	Remnants: majority of both legs and waist area; Severe charring and embrittlement	Remnants: left side of pants and portions of right leg and liner; Severe charring and embrittlement	Remnants: majority of pants including lining; Severe charring and embrittlement	Remnants: majority of pants except parts of right leg; Severe charring and embrittlement
Protective helmet	Not available for examination	Remnants: front half of helmet; Severe charring and embrittlement	Not available for examination	Not available for examination
Protective hood	Remnants: part of face opening; Severe charring and embrittlement	Remnants: portions of front part of hood; Severe charring and embrittlement	Not available for examination	Remnants: entire front of hood; back of hood missing; Severe charring and embrittlement
Protective gloves	Not available for examination	Remnants: Majority of right glove; left glove without fingers; Severe charring and embrittlement	Not available for examination	Remnants: both gloves; portions of palm side missing; Severe charring and embrittlement

Clothing or Equipment Item	Victim #6	Victim #7	Victim #8	Victim #9
Protective footwear	Remnants: both boots primarily intact, but portions are missing from upper; Severe charring and embrittlement	Remnants: both boots; however, several portions of upper missing; Severe charring and embrittlement	Remnants: both boots; however, several portions of upper missing; Severe charring and embrittlement	Remnants: both boots; portions showing severe charring and embrittlement
Station/work shirt	Not examined	Unavailable for examination	Not examined	Remnants: portions of shirt including collar; Severe charring and embrittlement
Station/work pants	Remnants: majority of both legs and waist area; Melted to protective pants	Remnants: part of waist band, portions of legs; Severe charring and embrittlement	Remnants: left leg and portions of right side; Severe charring and embrittlement	Not available for examination
Socks	Unavailable for examination	Unavailable for examination	Unavailable for examination	Unavailable for examination
SCBA facepiece	Unavailable for examination	Remnants: portion of front, majority of lenses; severe damage	Unavailable for examination	Remnants: all components in place; severe melting and damage
SCBA frame	Back frame most of frame and pieces of hardware; Severe damage	Remnants: some parts of frame and pieces of hardware; Severe damage	Remnants: part of frame and pieces of hardware; Severe damage	Remnants: part of frame and pieces of hardware; Severe damage

Clothing or Equipment Item	Victim #6	Victim #7	Victim #8	Victim #9
SCBA cylinder	Wrapping exposed; Valve inoperable	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping partly exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; Valve operable (found open); Burst disk intact
PASS device	Severe melting	Unavailable for examination	Severely melted to waist strap of SCBA	Unavailable for examination

In the majority of cases, all gear that was examined was found to be available in remnants with significant large portions of the gear thermally decomposed or disintegrated from intensive, long-term heat exposure. Those items of clothing or equipment that were relatively intact were generally believed to have somehow been shielded from the fire conditions through the relative position of the item on the body or through some part of the structure at the fire scene. For example, the helmet for Victim #1 was in a relatively undamaged condition. It is speculated that the helmet was recovered early at the fire scene and was underneath the victim when the victim was found.

Very little can be learned about the relative protective performance of the clothing or equipment worn by the individual fire fighter victims. In some cases, it is possible to determine if the clothing was properly deployed, for example charring patterns on the protective coats of some victims show that their collars were not extended upward. Similarly, when helmets were available for inspection, it did not appear for at least one victim that the ear covers were deployed. Nevertheless, this wearing practices are immaterial to the fatalities that occurred as the clothing and equipment characteristics were completely overwhelmed during the extended entrapment in the fire structure of the fire fighter victims.

Where station/work uniforms were recovered, it was found that the fire fighters worn clothing items that were primarily polyester in composition. Given the extreme, extended circumstances of the exposure, these uniforms often were melted to the interior of the protective clothing. In one case, suspender straps were melted to the fire fighter's protective coat. While not likely contributory to the burns sustained to the fire fighters, the use of polyester-based station/work clothing does pose a hazard to fire fighters and should not be worn. Uniforms that are either 100% cotton or those constructed of flame-resistant materials should be used.

A detailed examination of the SCBA for each victim revealed that those SCBA cylinders with functioning valves were generally fully open. Moreover, the burst disk in these cylinders, where they could be examined, was intact. This information suggests that the fire fighters probably ran out of air before succumbing to the high heat burn injuries that were sustained over much of their bodies.

An examination of clothing and equipment from two fire fighters that were able to escape the fireground just before the structure collapse does show very extensive heat conditions suggestive of high ordinary fire ground conditions. In both cases, the damage to the clothing was primarily sustained to the back of the clothing where dye sublimation of the protective coat outer shell occurred on both sides of the SCBA cylinder. There was also mild charring on the moisture barrier side of the protective coat liner. The reflective markings on both fire fighters' helmets showed charring on the rear side as did some portions of the trim on the back of the fire fighters' clothing. These conditions are generally produced at temperatures exceeding 500°F for several minutes and absorbed heat energies of greater than 5.0 calories per square centimeter. These conditions are highly survivable, meaning that the fire fighters were able to escape due to the protective qualities of their clothing and equipment.

Conclusions

Based on the examination of the clothing and equipment worn by the fire fighters, I could not find any defects of the clothing or equipment as manufactured or worn by the fire fighters that would have contributed to their burn injuries and fatalities. It is impossible to determine with absolute certainty whether the fire fighters first ran out of air before receiving burn injuries, but the condition of the SCBA show that running of air probably occurred before the majority of burn injuries were sustained. Fire fighters that were able to escape the fireground before the collapse had gear that showed damage consistent with high ordinary fireground conditions. The majority of damage to the clothing and equipment was sustained after the fire fighter victims were entrapped on the fireground and due to the extensive lapse of time before the recovery of their bodies.

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 retained 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,

/Jeffrey O. Stull/

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