Spokane FIRE DEPARTMENT

Service and protection through excellence

2015 Fire Department Structural PPE Risk Assessment Report

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Fire Agency Risk Assessment for the Spokane Fire Department

Scope

A Fire Agency Risk Assessment's (RA) primary focus is to establish requirements for the design, performance and testing of protective ensembles and ensemble elements that provide head, limb, hand, foot, torso, and interface protection for firefighters and other emergency service responders. Evaluation of current structural firefighting operations are essential to determine overall risk and potential environmental hazards; by extension essential to determination of agency specific personal protective equipment (PPE) requirements and liabilities. (Reference NFPA 1971) Analysis of incidents involving structural firefighting operations should be considered when evaluating needed protection from the potential hazards associated with structural firefighting that the fire agency is responsible for protecting as defined in NFPA 1971.

Purpose

The purpose of the RA and hazard evaluation (HE) is to provide the most suitable firefighting ensembles and ensemble elements for the Agency's firefighting personnel. The RA assists the organization to evaluate the risks and hazards their emergency responders face. Based on the identified risks and hazards and other agency specific needs, each protective clothing element is evaluated to ensure it provides the emergency responders with the most effective protection from the identified risks and hazards. This assessment will follow established guidelines for RAs outlined in the following laws and standards: NFPA 1851, NFPA 1500, OSHA 1910.132. Although these articles originate from different Professional and/or Legal entities, all require a "Risk Assessment" or "Hazard Assessment" be completed.

Executive Summary

1. Paragraph 1.2.4 of NFPA 1971, Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting (2013 Edition) states that this standard shall not be utilized as a detailed manufacturing or purchasing specification but shall be permitted to be referenced in purchase specifications as the minimum requirements.

2. Because NFPA 1971 only has the minimum requirements, organizations are required to complete a RA in accordance with NFPA 1851 (2008 Edition); Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting, NFPA 1500 (2013 edition); Standard on Fire Department Occupational Safety and Health Program, and 29 CFR OSHA 1910.132.

3. The Spokane Fire Department recognizes that they are mandated to clearly and accurately define their PPE requirements based on the hazards their firefighters are exposed to. The Spokane Fire Department RA will ultimately be used as the source document for developing the critical firefighter safety related elements for our structural protective clothing procurement specifications.

4. This RA is based on the core mission requirements further defined in the following regulations and standards: NFPA 1500; Standard on Fire Department Occupational Safety and Health Program (2013 edition), NFPA 1851; Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting (2008 edition), NFPA 1971; Standard on Protective Ensembles For Structural Fire Fighting and Proximity Fire Fighting (2013 edition), 29 CFR OSHA 1910 General Industry Regulation.

Abstract

1. PPE has evolved over the years to provide better protection from injury and illness resulting from exposure to hazards they are exposed to. The Spokane Fire Department provides PPE to protect firefighters from potential hazards they may encounter while performing their work. There are three levels of protection serving firefighters in the field:

   - ✓ Administrative Controls
   - ✓ Engineering Controls
   - ✓ PPE

2. Administrative Controls are policies and procedures that teach and direct Individuals how to recognize and prevent workplace exposures, injuries, and illnesses.

3. Engineering Controls are used to remove hazard(s) from the workplace. Such controls include shutting off the utilities at a structural fire, establishing physical barriers such as seat belts or Lock out/Tag out procedures and barricades to isolate the firefighter from physically encountering the hazard.

4. When exposure to hazards cannot be eliminated through administrative or engineering controls, PPE such as gloves, boots, safety glasses, garments, and respirators can be used to create a barrier between responders and the hazard(s). PPE is the basic control measure, as it does not remove the hazard. PPE will protect the firefighter so long as it is used in a manner that is within design specifications and limitations. PPE is meant to reduce the firefighter's exposure to acceptable levels when other functions of control are not feasible or effective.

5. The intent of this RA is to assist department officials in updating and clearly defining the standard for proper protection levels.

6. This risk assessment is a baseline to establish for the Spokane Fire Department the duties and responsibilities as defined in the SFD personnel manual and does not imply assessment of any special risk. Special risk is defined as services performed by SFD personnel deemed to be outside the scope of the duties and responsibilities defined in the personnel manual and is not included in this risk assessment.

7. Daily response exposes firefighters to hazards that effect both the interior and exterior environments. During prolonged activities, environmental conditions increase the hazard and risk to the firefighters. The Spokane Fire Department has identified the priority and severity of hazards that firefighters are exposed to and provides the appropriate PPE to maximize protection from potentially harmful exposures. These protective ensembles must be capable of protecting the firefighter during progressive fire operations up to and including "flashover" conditions. Tactics for safe fire operations are taught at the SFD Training Division and the Department maintains an expectation that firefighters will function within the boundaries of those tactics under fireground conditions. The majority of PPE available on the market is compliant with NFPA 1971; Standard on Protective Ensembles for Structural Firefighting and Proximity Firefighting (2013 Edition); However, some of the PPE available fails to protect firefighters from the hazards outlined in this risk assessment. To provide a protective ensemble that is suitable and appropriate, this assessment is based on known exposure, illness, injury, and fatality producing incidents regardless of frequency.

8. The health risks and safety hazards identified in this RA are based on the requirements of NFPA 1851; Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Firefighting and Proximity Firefighting (2014 Edition) and supported by research conducted by the The Spokane Fire Department .

Historical Background

The Spokane Fire Department has historically purchased PPE without conducting a documented RA. From this point forward, the SFD will select PPE based on a documented RA to ensure consistent levels of protection for SFD personnel.

Discussion

1. All forms of PPE have design and performance standards and within those standards have limitations. It is imperative that firefighters understand the protection limitations of their PPE to avoid incorrect use or reliance on an item intended to protect them from harm but which may contribute to injury and/or illness if used incorrectly. WAC 296-305-02001 requires the education of all employees concerning the limitations of PPE.

2. PPE is meant to reduce the firefighter's hazard exposure to acceptable levels when other means are not feasible or effective. However, all PPE has its protective limitations. When those limitations are exceeded, the wearer can be exposed to even greater harm. There are a few terms that firefighters should be familiar with in order to better understand the performance expectations and limitations of their PPE. Terms such as: flashover, backdraft, chemical exposure, hazardous materials, terrorist attacks, etc. This is not an inclusive list for the user.

Firefighter Duties and Responsibilities

The Spokane Fire Department, like most professional "ALL RISK" fire departments, maintains a progressive strategy and tactics for the suppression of fires. SFD firefighters are exposed to all phases of fire progression including incipient, free burning, rollover, flashover, backdraft and smoldering. Throughout these fire phases, SFD firefighters will be exposed to a range of temperatures from moderate through extreme based on the activities, functions, or tasks being performed as identified in this section. Additionally, firefighters are exposed to this varying temperature range at training exercises conducted throughout the year at live structural proficiency fire training. Therefore, the PPE must be capable of protecting SFD firefighters at the highest anticipated temperature.

Activity Types

1. **Fire Suppression**

   - ✓ Bulk fuel storage
   - ✓ Bulk fuel transport
   - ✓ Structural
   - ✓ Vehicle
   - ✓ Other

2. Functions or Tasks: Fire Suppression

- ✓ Drive/operate apparatus
- ✓ Deploy attack lines
- ✓ Engage in offensive fire attack
- ✓ Engage in defensive fire attack
- ✓ Engage in transitional fire attack
- ✓ Deploy/operate
- ✓ Appliances
- ✓ Hand line
- ✓ Nozzles
- ✓ Master streams
- ✓ Deploy/operate adapters
- ✓ Wyes/Siamese
- ✓ Adaptors
- ✓ Deploy/operate supply lines
- ✓ Deploy ladders
- ✓ Operate from ladders
- ✓ Deploy hand tools/equipment
- ✓ Operate hand tools/equipment
- ✓ Pulling
- ✓ Prying
- ✓ Chopping
- ✓ Cutting
- ✓ Deploy powered equipment
- ✓ Operate powered equipment
- ✓ Don/doff SCBA
- ✓ Work from SCBA air supply
- ✓ Support activities

3. Rescue

- ✓ Structural
- ✓ Hazardous Materials (Hazmat IQ/Decon)
- ✓ Vehicle
- ✓ Confined space
- ✓ Collapse
- ✓ High Angle
- ✓ Trench

4. Rescue Operations

- ✓ Drive/operate apparatus
- ✓ Deploy ladders
- ✓ Operate from ladders
- ✓ Deploy/operate hand
- ✓ Tools/equipment
- ✓ Pulling
- ✓ Prying
- ✓ Chopping
- ✓ Cutting
- ✓ Deploy/operate powered equipment
- ✓ Don/doff SCBA
- ✓ Work from SCBA air supply
- ✓ Deploy/operate stabilization equipment
- ✓ Structural stabilization
- ✓ Vehicle stabilization
- ✓ Trench stabilization
- ✓ Deploy/operate confined space lowering/lifting equipment
- ✓ Deploy/operate high angle lowering/lifting equipment

Statement of Acceptable Risk

1. Acceptable Risk – Acceptable risk varies and is the responsibility of each department to identify what the acceptable risk is while conducting operations.

2. The acceptable level of risk is directly related to the potential to save lives or property. Where there is no potential to save lives, the risk to SFD members should be evaluated in proportion to the ability to save property of value. When there is no ability to save lives or property, there is no justification to expose SFD members to any avoidable risk, and defensive fire suppression operations are the appropriate strategy, even though defensive operations are not completely without exposure to hazards.

3. When considering acceptable risk to firefighters, The Spokane Fire Department employs the following rules of engagement after evaluating the survival profile of any victims and the value of any property involved.

   - ✓ Within a structured plan, we may risk our lives a LOT to protect SAVABLE lives.
   - ✓ Within a structured plan, we may risk a LITTLE, to protect SAVABLE property.
   - ✓ We will NOT risk our lives to save lives or property that is already lost.

Expectation of Exposure / Reasonable Maximum Exposure (RME)

Thermal Hazards

The NFPA develops minimum standards for PPE. The NFPA recognized that not all departments require the same level of protection for reasons such as:

- ✓ Operational/Training Standards – SFD conducts interior attack operations requiring a higher level of protection to ensure firefighter safety. It is sometimes impossible during interior firefighting operations to move away from a heat source.
- ✓ Response Times – Response times are critical when determining the protection values of PPE. The SFD has response times that allow for interior attack during incipient and free burning fires. These conditions mandate PPE that is capable of protecting firefighters during flashover conditions or high radiant heat conditions.
- ✓ Reasonable Maximum Exposure – The combination of response times, building construction, contents normally found in structures, training standards and Standard Operating Procedures identify “Flashover Conditions” and/or direct flame impingement for short periods of time as the Reasonable Maximum Exposure for the SFD.

Chemical Biological Radiation Nuclear (CBRN) Response

SFD operations included are both man-made and natural incidents; fire suppression and hazard mitigation, rescue, mitigation or containment of releases of hazardous materials (HazMat), such as CBRN agents, resulting from industrial accidents, terrorism, or weapons of mass destruction (WMD); and emergency medical support.

1. **Chemical Hazards:** SFD firefighters respond to HazMat emergencies as first responders and as members of organized HazMat teams. Although HazMat incidents can be infrequent, SFD firefighters respond regionally to mitigate these incidents. The layer of the structural ensemble composite material that protects firefighters against chemical hazards is the "moisture barrier." If deemed appropriate, ensemble may be worn during HazMat incidents.

2. **Biological Hazards:** The SFD responds to all types of incidents. Biological hazards are frequently encountered during Emergency Medical Services (EMS) incidents. Typical biological exposures to firefighters wearing PPE occur during response to traffic collisions and other rescue type incidents when body fluid is encountered. Biological hazards can also be encountered during response to HazMat incidents. In either case, the SFD will wear PPE to these incidents. The layer of the structural or proximity PPE composite that protects firefighters against biological hazards is the "moisture barrier."

3. **Radiation and Nuclear Hazards:** The SFD has the potential to respond to incidents involving radiation and nuclear hazards. Although these hazards are very infrequent, firefighters can find themselves exposed to radiation or nuclear incidents and also during terrorist attacks. Current PPE provides little or no protection for firefighters against radiation and nuclear hazards.

Health Risks and Safety Hazards Expected to be encountered by SFD firefighters:

1. Physiological:

- ✓ Physical stress
- ✓ Fatigue
- ✓ Body core temperature

2. Physical:

- ✓ Sharp edges
- ✓ Sharp points
- ✓ Falling objects
- ✓ Flying debris
- ✓ Projectiles
- ✓ Splash exposure
- ✓ Slippery surfaces
- ✓ Vibration
- ✓ Abrasive or rough surfaces

3. Physics:

- ✓ Stored thermal energy (heat saturation)
- ✓ Thermal energy migration
- ✓ Compression

4. Biological Hazards:

- ✓ Blood borne pathogens
- ✓ Blood and other potentially infectious body material
- ✓ Airborne pathogens
- ✓ Biological toxins
- ✓ Biological allergens

5. Electrical Hazards:

- ✓ High voltage
- ✓ Electrical arc
- ✓ Static charge buildup

6. Radiation Hazards:

- ✓ Ionizing radiation
- ✓ Non-- ionizing radiation

7. Flame/Thermal:

- ✓ Radiant heat
- ✓ Convective heat
- ✓ Conducted heat
- ✓ Flame impingement
- ✓ Burning embers
- ✓ Steam
- ✓ Flashover
- ✓ Backdraft
- ✓ Scalding water
- ✓ Molten metals
- ✓ Hot surfaces

8. Environmental:

- ✓ Time of day
- ✓ Ambient temperatures
- ✓ Humidity
- ✓ Internal moisture
- ✓ Inside the protective element
- ✓ External moisture
- ✓ On the outside of the protective element
- ✓ Confined or small spaces
- ✓ Rain
- ✓ Snow
- ✓ Ice
- ✓ Wind
- ✓ Others

9. Hazardous Materials & Substances:

- ✓ Explosives
- ✓ Compressed Gasses
- ✓ Flammable Liquids
- ✓ Flammable Solids Oxidizers
- ✓ Poison
- ✓ Radioactive
- ✓ Corrosives
- ✓ Miscellaneous
- ✓ Other Regulated Materials Liquids
- ✓ Fuels
- ✓ Motor fuels
- ✓ Propellants
- ✓ Hydraulic fluids
- ✓ Lubricants
- ✓ Firefighting agents
- ✓ Chlorine
- ✓ Blood or other potentially infectious body materials
- ✓ Alkaline
- ✓ Acids
- ✓ Battery Acid
- ✓ Oxidizers
- ✓ Others Liquefied gases
- ✓ Oxidizers
- ✓ Liquid Oxygen (LOX)
- ✓ Liquid Propane Gas (LPG)
- ✓ Others
- ✓ Compressed gasses
- ✓ Oxidizers
- ✓ Air
- ✓ Oxygen
- ✓ Nitrogen
- ✓ Helium
- ✓ Others Solid chemicals
- ✓ Firefighting agents

Geographic Location and Climate

The City of Spokane is located near the eastern border of Washington, about 20 miles from Idaho and 110 miles south of the Canadian border. The city lies on the eastern edge of the Columbia Basin, a wide sloping plain that rises sharply to the east towards the Rocky Mountains. The Spokane River and its waterfalls bisect the city. Summers are typically dry and mild, and winters can bring periods of cold, wet weather. Snowfall rarely accumulates to depths greater than one foot.

Area: 58 square miles (2000)

Elevation: Ranges from 1,898 to 2,356 feet above sea level

Average Temperatures: January, 27.1° F; July, 68.8° F; annual average, 47.3° F

Average Annual Precipitation: 16.5 inches

Frequency of Use

1. According to the SFD Incident Reporting System, SFD firefighters responded to a total of 35,499 incidents in calendar year 2014. This section of the risk assessment focuses on PPE frequency of use based specifically on this emergency response data and is explained utilizing the following chart reflecting the activity type, thermal activity, and abrasive activity.

2. For the purposes of this document, frequency of use is defined as:

    - ✓ Limited – lowest thirty percentile (1 to 30%)
    - ✓ Moderate – median thirty percentile (31 to 60%)
    - ✓ Often – upper forty percentile (61 to 100%)

3. 2014 SFD PPE use reflecting on activity type.

Medical		# of Calls Incidents	% of EMS Incidents	% of Total Incidents	2013 Incidents	% Change vs 2014
Code	Description					
31A	EMS Alpha Response	4,589	14.86%	12.93%	4,489	2.23%
31B	EMS Bravo Response	12,278	39.76%	34.59%	10,816	13.52%
31C	EMS Charlie Response	5,591	18.11%	15.75%	4,805	16.36%
31D	EMS Delta Response	5,497	17.80%	15.48%	5,791	-5.08%
31E	EMS Echo Response	442	1.43%	1.25%	425	4.00%
31F	EMS Second Alarm Response	0	0.00%	0.00%	0	0.00%
46A	MVA Alpha	1,471	4.76%	4.14%	1,563	-5.89%
46B	MVA Bravo	775	2.51%	2.18%	623	24.40%
46D	MVA Delta	236	0.76%	0.66%	212	11.32%
Total EMS Incidents		**30,879**	**100.00%**	**86.99%**	**28,724**	**7.50%**

Fire and Misc.		# of Calls Incidents	% of Fire & Misc.	% of Total Incidents	2013 Incidents	% Change vs 2014
Code	Description					
00	Investigation	31	0.67%	0.09%	53	-41.51%
01	CISD	0	0.00%	0.00%	0	0.00%
11C	Structure Fire Commercial	100	2.16%	0.28%	32	212.50%
11F	Structure Fire Full	197	4.26%	0.55%	250	-21.20%
11S	Structure Fire Single	1,182	25.58%	3.33%	1,110	6.49%
11W	Structure Fire Working	76	1.65%	0.21%	126	-39.68%
13S	Vehicle Fire	142	3.07%	0.40%	158	-10.13%
14E	Brush Fire Extreme	0	0.00%	0.00%	2	-100.00%
14H	Brush Fire High	44	0.95%	0.12%	16	175.00%
14L	Brush Fire Low	45	0.97%	0.13%	43	4.65%
14M	Brush Fire Moderate	25	0.54%	0.07%	24	4.17%
14S	Brush Fire Single	44	0.95%	0.12%	36	22.22%
18F	Alarm System Full	1,418	30.69%	3.99%	1,266	12.01%
18S	Alarm System Single	453	9.81%	1.28%	436	3.90%
35F	Extrication	40	0.87%	0.11%	48	-16.67%
36F	Water Rescue	25	0.54%	0.07%	16	56.25%
37F	Tech Rescue	5	0.11%	0.01%	12	-58.33%
39H	Rescue Task Force	1	0.02%	0.00%	0	0.00%
40F	Hazmat Full	49	1.06%	0.14%	52	-5.77%
40I	Hazmat Investigation	303	6.56%	0.85%	276	9.78%
40T	Hazmat Team	1	0.02%	0.00%	3	-66.67%
50S	Service Call	439	9.50%	1.24%	466	-5.79%
Total Fire and Misc. Incidents		**4,620**	**100.00%**	**13.01%**	**4,425**	**4.41%**
Total EMS Incidents		**30,879**		**86.99%**	**28,724**	**7.50%**
2014 Total Incidents Dispatched by the CCC		**35,499**		**100.00%**	**33,149**	**7.09%**

Conclusion/Decision: SFD structural ensembles are worn on many responses. The percentage of fire responses requiring thermal protection has declined over the years however given the fuel loading with highly combustible contents, and the prevalence of lightweight building materials, a high degree of thermal protection is still needed. Additionally, as our responses have increased in other areas such as rescue, traffic collisions, etc. the SFD recognizes the need for a durable garment emphasizing an increased need for abrasion performance.

Thermal Protective Performance (TPP)

1. TPP is the primary test for evaluating layered, or composite fabrics worn as PPE for Structural Fire Protective Garments (SFPG) and Proximity Fire Protective Garments (PFPG). In accordance with NFPA 1971, protective garment elements composite fabrics consisting of outer shell, moisture barrier, and thermal barrier shall be tested for thermal insulation and shall have an average TPP of not less than 35.0. The test uses an exposure heat flux representative of the thermal energy present in a flashover. It should be noted that this is a harsh test exposure and does not represent conditions in which firefighters are intended to work. It measures the ability of the composite fabrics to provide a few seconds to escape from such an exposure.

2. The actual TPP rating is double the amount of time it takes for a second degree burn to occur at an exposure level of two calorie per centimeter squared (2.0 Cal/cm2). For example, a TPP of 35 equals 17.5 seconds of protection before a second-degree burn occurs.

3. The TPP formula does not take into account critical factors that reduce the composite's ability to protect the firefighter. Specifically, factors such as stored energy, moisture, garment cleanliness, etc. will reduce the composite's TPP performance. In some cases a burn injury can occur within 1 to 3 seconds.

4. The SFD recognizes a five percent (5%) variance in fabric weight, which is the industry standard. In addition, NFPA 1971 allows for an 8 percent variance in the TPP test.

5. The SFD's current fabric composite (Outer Shell / Moisture Barrier / Thermal Liner) is Gemini XT / Crosstech (black) /Caldera SL-2, giving a TPP rating of 40.8.

6. The SFD injury data trends over the past 8 years indicates no need to adjust the TPP value from 40.8.

Conclusion/Decision: The Spokane Fire Department requires a minimum composite TPP rating greater than 37.

Total Heat Loss (THL)

1. THL is another primary test for evaluating layered, or composite fabrics worn as structural PPE. THL is a performance requirement for evaporative heat transfer. It measures how well the garment composite (outer shell, moisture barrier, and thermal barrier) allows heat and moisture vapor to transfer away from the wearer, thus helping to reduce heat stress. The test involves placing a fabric or composite sample over a porous heated plate meant to represent the human skin. In accordance with, NFPA 1971, garment composite fabrics consisting of the outer shell, moisture barrier, and thermal barrier shall be tested for evaporative heat transfer and shall have a THL of not less than 205 kW/m2.

2. Heat transfer is determined by measuring the energy required to maintain a specific temperature as heat is transferred through the clothing system to the outside environment. Both dry and wet tests are performed on the test samples. The dry tests yield heat loss associated with conductive heat transfer. The wet tests yield heat loss associated with moisture evaporation and transmission. The test yields a total heat loss figure, which represents the amount of energy that can be transferred through a given area of the fabric or composite material under the specific conditions of the test.

3. It is important to understand that TPP and THL work inversely; meaning the higher the TPP rating, the lower the THL rating and vice versa. Generally speaking, in order to have greater protection against radiant or convective heat, you need to have thicker or heavier fabrics that will inherently impede the ability for physiological heat to move through it from the body to the outside environment. It should be understood that small differences in THL might be difficult for firefighters to distinguish in the field. It might take 20 to 25 kW/m2 or more, depending on the individual and the conditions, to be felt by the wearer.

4. The SFD's current fabric composite (Outer Shell / Moisture Barrier / Thermal Liner) is Gemini XT / Crosstech (black) /Caldera SL-2, giving a THL rating of 246.38.

5. The SFD injury data trends over the past 8 years indicate no need to adjust the current THL value.

Conclusion/Decision: The Spokane Fire Department requires a minimum composite THL rating greater than 220.

Outer Shell Requirements

Thermal Hazards

The outer shell is capable of withstanding flashover conditions and remain flexible without breaking open. Outer shells that become brittle and potentially break open will not protect the thermal liner, which is critical in preventing burns.

Conclusion/Decision – Outer Shell: The SFD will utilize fabrics for the outer shell that maintains protection after thermal exposure consistent with the conditions found in a structural fire flashover. Specifically, the outer shell will have tensile strength of at least 50 lbs. after a 17.5 second NFPA TPP exposure.

Physical Hazards

1. PPE shall be worn to all structure fires, petroleum fires/incidents, roadway incidents such as traffic collisions, rescue incidents, hazardous materials incidents, vehicle fires and dumpster / refuse fires. Therefore, this risk assessment considers the proportional response types and the physical hazards that exist in each response situation.

2. The frequency and severity of physical hazards greatly varies between SFD incidents. To complete the physical hazard section of this document, it was necessary to understand how the "majority" of SFD PPE is damaged. This information was collected by assessing how the majority of PPE is damaged-broken down by each station and the Department as a whole. The SFD was trained by independent service providers (ISP) to determine what physical hazards represent the greatest threat to Spokane Fire Department Structural PPE, and how these threats may best be mitigated. This information is updated each year through the Annual Inspection process.

3. The results of the analysis found that the most significant physical hazard putting the ensemble out-of-service results from abrasion. These findings are consistent with SFD fire operations and progressive training scenarios. During these interior firefighting operations firefighters are trained to stay as low to the ground as possible to avoid extreme temperatures at elevated levels. To accomplish this firefighters are required to kneel and crawl whenever necessary. Firefighters are also trained in conducting primary and secondary searches inside structures. Search techniques require firefighters to maintain contact with interior walls as they progress through the structure. Maintaining contact is accomplished by keeping legs, arms, shoulders etc. in contact with the interior walls. Significant abrasion of the outer shell routinely occurs during the operations described above causing damage to the outer shell. Abrasion resistance performance is almost exclusively a performance characteristic of the outer shell of the garment.

4. Though tearing was also identified as a significant hazard most tears were within acceptable repair standards while abrasion damage was more common in placing a garment out-of-service. Additionally, tearing was typically in areas where the outer shell fabric was weakened by abrasion.

5. Abrasion testing for the outer shell materials are conducted using the Taber Abrasion Testing methodology in accordance with ASTM D 3884- 01.

Conclusion/Decision: The outer shell fabric must have superior performance for abrasion resistance and show no excessive wear upon visual inspections after 3000 cycles of Taber Abrasion Testing or equivalent. Note: Current fabrics on the market range from 0 - 5,000 cycles.

6. Strength. Fabric strength for the outer shell is conducted using the Trapezoidal Tearing Test in accordance with ASTM D 5587 on both laundered and unlaundered samples. SFD standards for trapezoidal tear strength is measured by a minimum score of 50 lbs. (Warp) and 50 lbs. (Fill) for initial testing and 40 lbs. (Warp) and 40 lbs. (Fill) after five launderings in accordance with NFPA 1971 test methods. These performance requirements ensure that the outer shell has superior tear strength to resist tears from sharp edges and tearing hazards. The NFPA standard calls for fabric samples to be tested without slippage or filament pull through.

Conclusion/Decision: The SFD outer shell fabric must have superior tear strength to resist tears from sharp edges and tearing hazards measured by a minimum score of 50 lbs. (Warp) and 50 lbs. (Fill) for initial testing and 40 lbs. (Warp) and 40 lbs. (Fill) after five launderings in accordance with NFPA 1971 test methods. No fabric slippage or filament pull through will be allowed.

7. Tensile Strength. Fabric strength for the outer shell is conducted using the tensile strength test in accordance with ASTM D 5034 on both laundered and unlaundered samples. NFPA 1971 standard for trapezoidal tear strength is measured by a minimum score of 140 lbs. 240 lbs (Warp) and 280 lbs. (fill) for initial testing and 240 lbs. (Warp) and 275 lbs. (Fill) after ten launderings in accordance with NFPA 1971 test methods. These performance specifications ensure that the outer shell has superior tensile strength to resist breaking open under maximum exposure conditions.

Conclusion/Decision: The SFD outer shell fabric must have tensile strength to resist breaking open, measured by a minimum score of 240 lbs. (Warp) and 280 Lbs. (Fill) for initial testing and 240 Lbs. (Warp) and 275 (Fill) after ten launderings in accordance with NFPA 1971 test methods.

Exposure to Sun and Ultraviolet Light

This condition exists for two primary reasons. Currently, in most locations, SFD apparatus do not have the ability to store PPE adequately in protective compartments. Therefore, PPE is routinely stored in unprotected areas on the apparatus exposing the PPE to damaging effects of sunlight. Many of our stations still do not allow for the storing of PPE in protected environments. PPE is typically stored in wire mesh or open lockers in the apparatus bays, which does not protect the PPE from sunlight or diesel engine exhaust. Industry experts agree that ultraviolet light exposure is one of the most significant threats to the performance of PPE.

Conclusion/Decision: The SFD outer shell must be composed of fibers that have superior performance to a xenon light test that replicates the extreme exposures indicated above. Therefore, the SFD outer shell must have a tensile strength of 140 lbs. after a 120 hour xenon light exposure.

Thermal Liner Requirements

Thermal liners are common to structural ensembles and are capable of protecting firefighters to temperatures associated with flashover conditions. The composite needs to protect firefighters for a minimum of 20.4 seconds, which allows for escape during most interior fire attack operations in residential and commercial structures.

Thermal liners consist of two primary components. First is the facecloth which is a fabric that rests against the firefighter's skin and assists with moisture wicking. The second component is the "batting" which is the insulation that provides the primary protection against thermal energy.

Facecloth

1. Thermal liner facecloth has two primary impacts to the performance of the composite. Specifically, the facecloth has a significant impact on both moisture management (wicking) and the ability of the firefighter to move freely within the garment.

2. The thermal liner facecloth interacts with the moisture barrier in allowing moisture from sweating to be removed. The ability of the composite to perform this task is greatly impacted by the thermal liner facecloth. The facecloth must have superior moisture wicking performance to allow the moisture to be dispersed through the composite.

3. Moisture management against the firefighter's skin is a critical factor that all structural and proximity ensembles must manage. This specific factor is required for three reasons:

   ✓ Moisture (water) conducts heat transfer

   ✓ Moisture on the firefighter's skin results in a higher probability of burn injury compared to dry skin

   ✓ Moisture against the skin can result in steam or scald type burn injuries if the firefighter's skin and the layer of material in contact with the skin is moist or wet

4. The SFD examined two tests measuring a garments ability to manage moisture. THL and fabric Wickability, THL has been previously addressed in this RA.

   Wickability: Wickability is achieved by the facecloth's ability to absorb and disperse the moisture. Wickability is measured by test method AATCC 79-2010, and is used to measure how rapidly a fabric will absorb or wick water. One drop of distilled water is dropped on to the fabric and a stop watch is activated to record the time for the water droplet to completely absorb into the fabric.

Conclusion/Decision: The SFD requires facecloth wickability performance to reduce firefighter fatigue and provide superior moisture management. Additionally, SFD defines acceptable superior facecloth Wickability performance as 10 seconds or less using the American Association of Textile Chemists and Colorists (AATCC) Test Method 79-2010; Absorbency of Textiles.

5. Facecloth comfort and appearance can be affected by "pilling." The pilling of textile fabrics refers to an appearance caused by bunches or balls of tangled fibers held to the surface. This unpleasant appearance can seriously compromise the fabrics' performance in thermal environments. Pills are developed on a fabric surface in four main stages: fuzz formation, entanglement, growth, and wear-off. The greater the pilling the less comfort and ease of movement the garment will have.

6. Pilling resistance is performed in accordance with ASTM D3512- 82 at 30, 60, and 90-minute intervals. Each specimen is 4 3/16" square. The specimens are prepared and agitated in an Atlas Random Tumble Pilling Tester for the desired, and stated, timeframe. The samples are then removed and compared to the scale that has been set up for this test method.

Durability Performance Scale Rating Values: Very Severe Pilling (1), Severe Pilling (2), Moderate Pilling (3), Slight Pilling (4), and No Pilling (5)

Conclusion/Decision: To improve facecloth comfort and performance, the SFD requires a rating of 4 (Slight Pilling) or 5 (No Pilling) both before and after washing agitation.

Batting

1. The thermal batting is comprised of different fibers that are designed to give specific properties to the finished product such as TPP, THL, and flexibility. The thermal batting is the main component responsible for protection from the thermal environment. Factors such as construction, layering, and weight are important considerations. There are two basic types of thermal batting:

2. Single Layer Needle Punch (NP) Batting – NP liners are typically thicker and bulkier than Spun Lace batting.

3. Multiple Layer Spun Lace (SL) -In efforts to reduce weight and bulk, two and three layer SL battings have been developed. The layers float between the facecloth of the thermal liner and the moisture barrier. Both of the separate layers and the SL technology allow for improved movement.

4. The weight of PPE has a direct impact on the physical performance of a firefighter. A lighter weight garment results in greater fire ground performance and allows the firefighter to work for longer periods of time thereby increasing firefighter effectiveness and performance. Two layer SL thermal barriers provide the best weight to thermal protective performance ratio.

Conclusion/Decision: The SFD will use multiple layers (two layers) of spun lace technology improve performance.

Moisture Barriers

Moisture barriers are also critical in preventing the transmission of liquids from the outside of the garment to the skin. The moisture barrier material shall meet all moisture barrier requirements of NFPA 1971, which directly includes water penetration resistance, viral penetration resistance, and common chemical penetration resistance.

Four key characteristics have been identified that are critical to firefighter safety:

1. **Liquid Penetration Resistance:** This is important because fire and safety professionals often encounter a variety of liquids, such as water, body fluids, and chemicals at emergency scenes. Sometimes, the most dangerous hazards are the ones that can't be seen. In this environment, contamination from blood and body fluids is a serious concern. The moisture barrier is the component in PPE that resists penetration of liquids commonly found at the fire scene. Moisture barriers will be tested against the following liquids for penetration

resistance: battery acid (37% sulfuric), ASTM Ref. Fuel C (unleaded gasoline surrogate), hydraulic fluid (phosphate ester), aqueous film forming foam (AFFF), and swimming pool chlorine solution (65% free Cl).

Conclusion/Decision: To achieve required protection, the SFD moisture barrier shall be constructed of bi-component ePTFE membrane technologies. The moisture barrier material shall meet all moisture barrier requirements of NFPA 1971-2013 edition, which includes water penetration, viral penetration resistance and common chemical penetration resistance.

2. **Breathability and the Resistance to Sweat Evaporation:** Heat stress related injuries are a top concern for the SFD. Breathability (i.e. enabling the efficient evaporation of sweat), is critical to managing heat stress and minimizing core temperature increases. Across various studies, core temperature increases have been shown to have a significant impact on firefighter safety and operational effectiveness. Therefore, maximizing breathability (i.e. minimizing the resistance to sweat evaporation) is a critical consideration when selecting structural turnout gear and can impact firefighter health and safety. Evaporative resistance is the recognized measurement of textile or material breathability. The test method is well established in textile performance apparel and protective apparel industries worldwide and is governed by ASTM 1868, Part B and ISO 11092. The Hohenstein Institute, a renowned independent organization, performed human subject testing with garments of different evaporative resistances (degrees of breathability) in order to create a Comfort Rating Scale based on the difference in evaporative resistance that translated to meaningful human physiological impact and comfort perception. The scale recommends an evaporative resistance value less than 30 m2 Pa/W for breathable gear. Additionally, the Hohenstein Institute studies and scale suggest that evaporative resistance differences greater than 6 m2 Pa/W have physiological significantly impact on the wearer. Therefore the SFD requires a maximum evaporative resistance value of 36 m2 Pa/W, in accordance with the Hohenstein scale, ideally with evaporative resistance values of less than 30 m2 Pa/W and with the recognition that lower values are better. As a point of reference, average station wear may have a evaporative resistance value of 8 m2 Pa/W. Reducing the resistance to sweat evaporation and getting as close to the value for station wear as possible, is consistent with maximizing breathability, minimizing potential for core temperature rise in firefighters, and addressing the health and safety concerns associated with heat stress management.

   Conclusion/Decision: The SFD requires a maximum evaporative resistance value of 36 m2 Pa/W, in accordance with the Hohenstein scale, ideally with evaporative resistance values of less than 30 m2 Pa/W.

3. **Breathability after heat exposure:** Repeated heat exposures are common in structural firefighting. These exposures, even those of short duration, can cumulatively degrade some materials. We recommend the moisture barrier maintain it's breathability and does not degrade more than 20 % after heat exposure. The moisture barrier laminate shall not show an increase of more than 2.0 M2 Pa/W from its initial water-vapor resistance after being exposed to an elevated temperature of 500 degrees F for 5 minutes when tested according to ISO 11092, Textile-Physiological-Measurements of thermal and water-vapour resistance under steady state conditions (sweating guarded hotplate test).

   Conclusion/Decision: The SFD moisture barrier laminate shall not show an increase of more than 2.0 m2 Pa/W from its initial water-vapor resistance (Ret) after being exposed to an elevated temperature of 260°C (500° F) for 5-minutes when tested according to ISO 11092, Textile-Physiological-Measurements of thermal and water vapor resistance under steady-state conditions (sweating guarded-hotplate test).

4. **Durability:** SFD turnout gear gets wet, flexes, and abrades on the job. It is important to test the moisture barrier and seams with flexing and abrasion in a wet environment to help understand in-use durability. The Wet Flex and Durability to Leakage test is an AATCC Test Method (135-1987, without soap) The water level shall be maintained at 16 (+/- 0.5) gallons and water temperature shall be 32 (+/-9) degrees C. Additional fabric shall be added to create a load of 2 (+/- 0.2) pounds. SFD requires a minimum result of 200 hours with no leakage according to ASTM D-751, Hydrostatic Resistance, Procedure B, Procedure 2 with a fixed hydrostatic head of 1.0 PSI minimum and shall be held for 3 minutes minimum. A minimum of three specimens shall be tested. The sample will be oriented so that water contacts the textile side of the moisture barrier. The report shall include only measurement of the appearance of water droplets. Leakage is defined as the appearance of one or more droplets anywhere within the 3-1/2 inch minimum diameter test area. The test may be performed using any device which tests the same specimen area at the equivalent pressure. In cases of dispute, the apparatus described in Method AATCC 127 shall be used. The moisture barrier laminate shall exhibit passing results after 25 wash/dry cycles when tested independently for the Liquid Penetration Test (NFPA 1971 2013 edition, section 8.27) and Viral Penetration Resistance Test (NFPA 1971 2013 edition, section 8.28). The moisture barrier sealed seams shall exhibit passing results after 25 wash/dry cycles when tested independently for the Liquid Penetration Test (NFPA 1971 2013 edition, section 8.27) and Viral Penetration Resistance Test (NFPA 1971 2013 edition, section 8.28). The moisture barrier laminate shall remain waterproof (NFPA 1851 2008 edition, section 12.3.3 – Evaluation Apparatus) to 1 PSIG for three minutes after cold temperature flexing, according to ASTM D 2097, at minus 13 degrees F for 80 minutes.

Conclusion/Decision: The SFD requires a minimum result of 200 hours with no leakage according to ASTM D-751, Hydrostatic Resistance, Procedure B, Procedure 2.

Garment reflective and fluorescent trim

1. The SFD garment trim shall be tested for retro reflectivity and fluorescence as specified in Section 8.45 of NFPA 1971 2014 edition, Fluorescence Test, and shall have a coefficient of retroreflection (RA) of not less than 100 cd/lux/m2, and shall be fluorescent yellow-green.

   Conclusion/Decision: The SFD requires the garment trim shall maintain a minimum RA of 350 or greater when measured at 0.2 degree observation angle/5 degree entrance angle when determined in accordance with the procedure defined in ASTM E808-01 and E809-08.

2. Convective Heat Exposure Test (120) – the trim shall be tested as specified in ISO 17493 for one minute at 120 degrees C.

   Conclusion/Decision: The SFD garment trim shall maintain a minimum RA of 450 or greater when measured at 0.2 degree observation angle/5 degree entrance angle when determined in accordance with the procedure defined in ASTM E808-01 and E809-08.

3. Convective Heat Exposure Test (150x3) – the trim shall be tested as specified in ISO 17493 for three separate ten minute exposures at 150 degrees C with a ten minute cool down period between each exposure.

   Conclusion/Decision: The SFD garment trim shall maintain a minimum RA of 450 or greater when measured at 0.2 degree observation angle/5 degree entrance angle when determined in accordance with the procedure defined in ASTM E808-01 and E809-08.

4. Convective Heat Exposure Test (5-260) – the trim shall be tested as specified in NFPA 1981, 2013 edition, section 8.6 per ISO 17493 for two minutes at 260 degrees C.

   Conclusion/Decision: The SFD garment trim shall maintain a minimum RA of 350 or greater when measured at 0.2 degree observation angle/5 degree entrance angle when determined in accordance with the procedure defined in ASTM E808-01 and E809-08.

5. Convective Heat Exposure Test (2-260) – the trim shall be tested as specified in NFPA 1971, 2013 edition, section 8.6 per ISO 17493 for two minutes at 260 degrees C.

   Conclusion/Decision: The SFD garment trim shall maintain a minimum RA of 450 or greater when measured at 0.2 degree observation angle/5 degree entrance angle when determined in accordance with the procedure defined in ASTM E808-01 and E809-08.

6. Wash and Dry Test – The trim shall be washed for 50 cycles in accordance with ISO-6330 Method 2A (60 degree C home wash) and dried per ISO-6330 Procedure E (50 degree C tumble dry).

   Conclusion/Decision: The SFD garment trim shall maintain a minimum RA of 100 or greater when measured at 0.2 degree observation angle/5 degree entrance angle when determined in accordance with the procedure defined in ASTM E808-01 and E809-08.

7. Dry Cleaning Test – the trim shall be dry-cleaned 25 cycles in accordance with ISO-3175 Method 9.1.

   Conclusion/Decision: The SFD garment trim shall maintain a minimum RA of 100 or greater when measured at 0.2 degree observation angle/5 degree entrance angle when determined in accordance with the procedure defined in ASTM E808-01 and E809-08.

Helmet performance requirements

Top Impact Resistance Test

1. Top Impact Resistance Test (room temperature) – The helmet shall be tested in accordance with NFPA 1971, 2013 edition, Section 8.15 and (8.1.3.2 at 77°F.)

   Conclusion: The helmet shall transmit a force < 2200 N.

2. Top Impact Resistance Test (-25°F) – The helmet shall be tested in accordance with NFPA 1971, 2013 edition, Section 8.15 and (8.1.4 at -25°F) for 4 hours.

   Conclusion: The helmet shall transmit a force < 2200 N.

3. Top Impact Resistance Test (285°F) – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.15 and (8.1.3.2 at 285°F) for 10 minutes.

   Conclusion: The helmet shall transmit a force < 2200 N.

4. Top Impact Resistance Test (Radiant/Convective) – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.15 and 8.1.6 Radiant/Convective: 1.0W/CM2 for 2.5 minutes.

   Conclusion: The helmet shall transmit a force < 2200 N.

5. Top Impact Resistance Test (Wet) – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.15 and 8.1.8 Water immersion for 4 hours.

   Conclusion: The helmet shall transmit a force < 2200 N.

Acceleration Impact Resistance Test

1. Acceleration Impact Resistance Test (Room Temperature) – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.16 and (8.1.3.2 at 88°F.) If helmet utilizes an internal face shield then helmet shall be tested with the internal face shield in place.

   Conclusion: Helmets shall maintain sufficient structural integrity to withstand impacts in all five locations.

2. Acceleration Impact Resistance Test (285°F) – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.16 and (8.1.3.2 at 285°F) for 10 minutes. If helmet utilizes an internal face shield then helmet shall be tested with the internal face shield in place.

   Conclusion: Helmets shall maintain sufficient structural integrity to withstand impacts in all five locations.

3. Acceleration Impact Resistance Test (Radiant/Convective) – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.16 and 8.1.6 Radiant/Convective: 1.0W/CM2 for 2.5 minutes. If helmet utilizes an internal face shield then helmet shall be tested with the internal face shield in place.

   Conclusion: Helmets shall maintain sufficient structural integrity to withstand impacts in all five locations.

Physical Penetration Resistance Test

Physical Penetration Resistance Test – The helmet shall be placed in the holder, an aluminum projectile weighing approximately 280 grams and 6 inches in length is loaded into the chamber and locked in position. The chamber is pressurized to approximately 30 psi. Then the projectile is released by opening a valve. The projectile is propelled thru the metal tube a distance of 4 ft to the impact site of the sample.

Conclusion: The aluminum projectile shall not penetrate the helmet.

Electrical Insulation Test

1. Electrical Insulation Test – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.31A. Immerse in tap water.

   Conclusion: The helmet shall not leak more than 3.0 mA.

2. Electrical Insulation Test (Saturated) – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.31B. Submerge helmet in water for 15 minutes.

   Conclusion: The helmet shall not leak more than 3.0 mA.

Retention System Test

Retention System Test – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.35.

Conclusion: The helmet chinstrap shall not break, nor stretch more than .8125"

Suspension System Test

Suspension System Test – The helmet shall be tested in accordance with NFPA 1981, 2013 edition, Section 8.36.

Conclusion: The helmet shell shall not separate from helmet suspension with 45 N applied.

Weight of Helmet

Weight of helmet– The weight of the helmet including accessories shall be measured.

Conclusion: The helmet shall not weigh more than 4.5 lbs.

Footwear performance requirements

1. Conductive Heat Resistance Test 2 – The protective footwear elements shall be tested for thermal insulation as specified in Section 8.8 of NFPA 1971 2013 edition.

   Conclusion: The temperature of the insole surface in contact with the foot shall not exceed 111 F.

2. Flame Resistance Test 4 – The protective footwear, with components in place, shall be tested for resistance to flame as specified in Section 8.5 of NFPA 1971 2013 edition.

   Conclusion: The boot components shall not have an after flame of more than 5.0 seconds, shall not melt or drip, and shall not exhibit any burn-through.

3. Heat and Thermal Shrinkage Resistance Test – The protective footwear shall be tested for resistance to heat as specified in Section 8.6 of NFPA 1971 2013 edition.

   Conclusion: The footwear shall not have any part of the footwear melt, separate, or ignite; shall show no water penetration; and shall have all components remain functional.

4. Radiant Heat Resistance Test – The protective footwear shall be tested for thermal insulation as specified in Section 8.9 of NFPA 1971 2013 edition.

   Conclusion: The temperature of the upper surface in contact with the skin shall not exceed 111 F.

5. Conductive Heat Resistance Test – The protective footwear shall be tested for thermal insulation as specified in Section 8.7 of NFPA 1971 2013 edition.

   Conclusion: The temperature of the upper lining surface in contact with skin shall have a second-degree burn time of not less than 10.0 seconds, and shall have a pain time of not less than 6.0 seconds.

6. Liquid Penetration Resistance Test – The protective footwear upper material composite and footwear seams shall be tested for resistance to liquid penetration as specified in Section 8.27 of NFPA 1971 2013 edition.

   Conclusion: The boot upper material shall allow no penetration of the test liquids for at least 1 hour.

7. Viral Penetration Resistance Test – The protective footwear upper material composite and footwear seams shall be tested for resistance to liquid or blood-borne pathogens as specified in Section 8.28 of NFPA 1971 2013 edition.

   Conclusion: The boot shall allow no penetration of the Phi-X-174 bacteriophage for at least 1 hour.

8. Puncture Resistance Test – The protective footwear upper shall be tested for resistance to puncture as specified in Section 8.20 of NFPA 1971 2013 edition.

   Conclusion: The boot shall not be any puncture to the footwear upper under after an average applied force of 13 LBF.

9. Cut Resistance Test –The protective footwear uppers shall be tested for resistance to cut as specified in Section 8.21 of NFPA 1971 2013 edition.

   Conclusion: The boot uppers shall not have a complete cut through after a cut distance of more than .8 Inches.

10. Whole Shoe Flex Test – Footwear functionality shall be determined by flexing the specimen for 100,000 cycles performed in accordance with Appendix B of FIA 1209, Whole Shoe Flex as specified in 8.6.14.11 of NFPA 1971 2013 edition.

    Conclusion: Footwear with evidence of liquid leakage, sole separation and or seam separation shall be a failure.

11. Slip Resistance Test –The protective footwear shall be tested for slip resistance as specified in Section 8.40 of NFPA 1971 2013 edition.

    Conclusion: The boot sole shall have a coefficient of friction of 0.40 or greater.

12. Abrasion Resistance Test –The protective footwear soles and heels shall be tested for resistance to abrasion as specified in Section 8.23 of NFPA 1971 2013 edition. Abrasion resistance tests shall be performed in accordance with ISO 4649, Rubber, vulcanized or thermoplastic — Determination of abrasion resistance using a rotating cylindrical drum device, Method A, with a vertical force of 10 N over an abrasion distance of 40 m.

    Conclusion: The footwear soles shall not lose greater than 200mm3 of their volume.

13. Electrical Insulation Test 2 –The protective footwear shall be tested for resistance to electricity as specified in Section 8.31 of NFPA 1971 2013 edition. Sample footwear shall be tested to14,000 V(rms) in accordance with Section 9 of ASTM F 2412, Standard Test Method for Foot Protection. The electrode inside the boot shall be conductive metal shot.

    Conclusion: The footwear shall have no current leakage in excess of 3.0 mA.

Glove performance requirements

1. Whole Glove Thermal Protective Performance Test – (TPP)The glove body composite shall be tested in as specified in Section 8.10 of NFPA 2071 edition 2013, and in accordance with ISO 17492, Clothing for protection against heat and flame — Determination of heat transmission on exposure to both flame and radiant heat.

   Conclusion: The glove body composites shall have an average TPP rating of greater than 55.

2. Whole Glove Conductive Heat Resistance Test – The glove body composite shall be tested for thermal insulation as specified in Section 8.37 of NFPA 2071 edition 2013. Specimens shall be tested in accordance with ASTM F 1060, Standard Test Method for Thermal Protective Performance of Materials for Protective Clothing for Hot Surface Contact, with the following modifications: Specimens shall be tested using an exposure temperature of 280°C (536°F). A pressure of 3.45 kPa ± 0.35 kPa (0.5 psi ± 0.05 psi) shall be applied during the test.

   Conclusion: The glove body shall have a second-degree burn time of not less than 10 seconds, and shall have a pain time of not less than 6 seconds.

3. Whole Glove Heat and Thermal Shrinkage Resistance Test – Whole gloves shall be tested for resistance to heat as specified in Section 8.6 of NFPA 2071 edition 2013, and shall be as specified in ISO 17493, Clothing and equipment for protection against heat — Test method for convective heat resistance using a hot air circulating oven.

   Conclusion: The glove shall not melt, separate, or ignite; shall not shrink more than 20 percent in length or width; shall be donnable; and shall be flexible.

4. Glove Lining Heat and Thermal Shrinkage Resistance Test – The glove lining materials of the glove body shall be individually tested for resistance to heat as specified in Section 8.6, of NFPA 2071 edition 2013. Heat and Thermal Shrinkage Resistance Test, and shall be as specified in ISO 17493, Clothing and equipment for protection against heat — Test method for convective heat resistance using a hot air circulating oven.

   Conclusion: The glove lining shall not melt, separate, or ignite.

5. Whole Glove Barrier Breathability Test –The whole gloves shall be tested for breathability as specified using ASTM E-96, Method B in MIL-DTL-44420A.

   Conclusion: The whole gloves must have a minimum of 580 gm./m2/24 hours using ASTM E-96, Method B as specified in MIL-DTL-44420A.

6. Glove Barrier Breathability Test A – The glove moisture barrier shall have a minimum breathability required using ASTM E-96, Method BW as specified in MIL-DTL-44420A.

   Conclusion: The glove moisture barriers must have a minimum of 5500 gm./m2/24 hours of breathability.

7. Glove Barrier Breathability Test B – The glove moisture barrier shall have a minimum breathability required using ISO 15496.

   Conclusion: The glove moisture barrier shall have a minimum of 4300 gm./m2/24 hours of breathability.

8. Whole Glove Resistance To Cut Test – (7.7.12) the glove body composites shall be evaluated as specified in Section 8.21 of NFPA 2071 edition 2013.and in accordance with ASTM F 1790, Standard Test Methods for Measuring Cut Resistance of Materials Used in Protective Clothing, with the modification that specimens shall be tested to a specific load with the measurement of cut distance.

   Conclusion: The blade will travel no more than or .8 inches and will not achieve a complete cut through of glove composites.

9. Whole Glove Resistance To Puncture Test – The glove body composites shall be tested as specified in Section 8.21 of NFPA 2071 edition 2013, and in accordance with ASTM F 1342, Standard Test Method for Protective Clothing Material Resistance to Puncture, Test Method A.

   Conclusion: The glove body composites shall not be punctured under a force of at least 40 N.

10. Glove Liner Retention Test – Gloves shall be tested for retention of the glove liner. Liner retention shall be evaluated Gloves shall be tested utilizing the test method explained in NFPA 2071 – 2013 edition, section 8.62.

    Conclusion: Each digit shall be inspected for indication of detachment of inner liner and/or moisture barrier. Failure of any digit of any glove shall constitute failure.

11. Whole Glove Liquid Integrity Test – Gloves shall be tested for resistance to leakage utilizing the test method explained in NFPA 2071 – 2013 edition, section 8.32.

    Conclusion: The appearance of any watermark on the inner glove after testing any glove shall be considered leakage and shall constitute failing performance.

12. Whole Glove Leak Test – The whole gloves shall be tested for moisture barrier leakage using air as specified in MIL-DTL-44420A test method.

    Conclusion: 100% of finished gloves must pass the Whole Glove Leak test with air as specified.

13. Whole Glove Leak Test after Thermal Exposure – Whole gloves shall be tested for moisture barrier leakage using air as specified in MIL-DTL-44420A after exposure to an elevated temperature of 500°F for a duration of 5 minutes.

    Conclusion: 100% of all finished gloves must pass the Whole Glove Leak test with air as specified.

14. Glove Barrier Breaking Force and Elongation Strength Test – The glove barrier cut-strip-break strength shall have a minimum using ASTM D5035-90 as specified in MIL-DTL-44420A

    Conclusion: The glove moisture barrier must have a minimum strength of lbs. of cut-strip strength.

15. Glove Barrier Burst Strength Test – The glove moisture barrier shall have a minimum of burst strength using ASTM D751 as specified in MIL-DTL-44420A.

    Conclusion: The glove moisture barrier shall have a minimum of burst strength of 20 lbs.

16. Glove Barrier Universal Wear Abrasion Test – The glove moisture barrier shall be abrasion resistant using Glove Barrier Water Permeability after as specified in MIL-DTL-44420A

    Conclusion: The glove moisture barrier must show no leakage after 150 cycles.

17. Glove Barrier Burst Strength Test – The glove moisture barrier shall have a minimum burst strength after exposure to chemicals including DEET as specified in MIL-DTL-44420A

    Conclusion: The glove moisture barrier shall have burst strength of at least 10 psi for 2 minutes.

18. Whole Glove Hand Function Test – Gloves shall be tested for hand function as specified in Section 8.37 of NFPA 2071 edition 2013. The apparatus shall be as specified in ASTMF 2010, Standard Test Method for Evaluation of Glove Effects on Wearer Hand Dexterity Using a Modified Pegboard Test.

    Conclusion: The whole gloves shall have an average percent of barehanded control not exceeding 220 percent.

19. Whole Glove Grip Test -Gloves shall be tested for grip; each specimen glove pair shall be tested as a complete set of gloves. Gloves shall be tested utilizing the test method explained in NFPA 2071 – 2013 edition, section 8.38.

    Conclusion: Each pair of gloves shall not have a drop of more than 30 percent from the peak pull force value.

20. Whole Glove Torque Test – Torque testing shall be evaluated utilizing the test method explained in NFPA 2071 – 2013 edition, section 8.72.

    Conclusion: The whole glove shall have an average percent of barehanded control not less than 80 percent.

21. Whole Glove Donning Test – Gloves shall be tested for ease of donning. Gloves shall be tested utilizing the test method explained in NFPA 2071 – 2013 edition, section 8.36.

    Conclusion: The whole glove shall have the dry hand donning time not exceed 10 seconds, shall have the wet hand donning time not exceed 30 seconds, shall have no detachment of the inner liner, shall have no detachment of the moisture barrier, and shall allow full insertion of all digits.

Firefighting Protective Hoods

Hood performance requirements:

1. Thermal Protective Performance (TPP) Test -Hoods shall be tested for thermal insulation.

   Conclusion: The hoods shall have an average TPP rating of not less than 25.

2. Heat and Thermal Shrinkage Resistance Test - Hoods, shall be individually tested for resistance to heat.

   Conclusion: The hoods shall not shrink more than 10 percent.

3. Heat and Thermal Shrinkage Resistance Test -Hoods shall be individually tested for resistance to heat.

   Conclusion: The hood shall not melt, separate, or ignite.

4. Limiting Oxygen Index (LOI) – Hoods shall be individually tested to ASTM D2863. The Limiting Oxygen Index measures the amount of oxygen required in the environment for a fabric to support combustion.

   Conclusion: The blend of fibers making up the hood shall have a LOI rating of 28 or better.

5. Cleaning Shrinkage Resistance Test -(7.13.6) Hoods shall be individually tested for resistance to shrinkage.

   Conclusion: The hood shall not exhibit shrinkage of more than 10 percent, and shall have the hood-opening meet the requirements specified when new.

6. Burst Strength Test -Knit hood material(s) shall be tested for material strength.

   Conclusion: The hood shall have burst strength of not less than 225 N.

Conclusions

This Spokane Fire Department Risk Assessment clearly demonstrates the need for Structural PPE garments that exceed the minimum NFPA 1971 requirements as follows:

1. The outer shell must be composed of fibers that have superior performance to a xenon light test that replicates the extremes of exposure to UV and visible light.
2. The SFD structural ensembles are worn on many responses (7,102 in 2014). The percentage of fire responses requiring thermal protection has declined over the years

however given the fuel loading with highly combustible contents a high degree of thermal protection is still needed. Additionally, as our responses have increased in other areas such as rescue, traffic collisions, etc. the SFD recognizes the need for a durable garment emphasizing an increased need for abrasion performance.

Therefore, regarding the Structural PPE Ensemble, the SFD:

1. Requires structural jackets and pants to have a composite TPP rating greater than 37.

2. Requires structural jackets and pants to have a composite THL rating greater than 220.

3. Will utilize fabrics for the outer shell that maintains protection after thermal exposure consistent with the conditions found in a structural fire flashover. Specifically, the outer shell will have tensile strength of at least 50 lbs. after a 17.5 second NFPA TPP exposure of 2Cal/cm2/seconds.

4. Requires that the outer shell fabric must have superior performance for abrasion resistance and show no excessive wear upon visual inspections after 3000 cycles of Taber Abrasion Testing.

5. Requires that the outer shell fabric must have superior tear strength to resist tears from sharp edges and tearing hazards measured by a minimum score of 50 lbs. (Warp) and 50 lbs. (Fill) for initial testing and 40 lbs. (Warp) and 40 lbs. (Fill) after five launderings in accordance with NFPA 1971 test methods. No fabric slippage or filament pull through will be allowed.

6. Requires that the outer shell fabric must have tensile strength to resist breaking open, measured by a minimum score of 240 lbs. (Warp) and 280 Lbs. (Fill) for initial testing and 240 Lbs. (Warp) and 275 (Fill) after ten launderings in accordance with NFPA 1971 test methods.

7. Requires superior facecloth wickability to protect firefighters from potential burn injuries, reduce firefighter fatigue, and improve fire ground performance. Additionally, the SFD defines acceptable superior facecloth wickability performance as 10 seconds or less using the American Association of Textile Chemists and Colorists (AATCC) Test Method 79-2010; Absorbency of Textiles.

8. Requires a rating of 4 (Slight Pilling) or 5 (No Pilling) both before and after washing agitation.

9. Will use multiple layers (two layers) of spun lace technology to decrease the likelihood of compression burns.

To achieve required protection, the SFD moisture barrier shall be constructed of bi-component ePTFE membrane technologies. The moisture barrier material shall meet all moisture barrier requirements of NFPA 1971-2013 edition, which includes water penetration, viral penetration resistance and common chemical penetration resistance.

The SFD requires a maximum evaporative resistance value of 36 m2 Pa/W, in accordance with the Hohenstein scale, ideally with evaporative resistance values of less than 30 m2 Pa/W.

The SFD moisture barrier laminate shall not show an increase of more than 2.0 m2 Pa/W from its initial water-vapor resistance (Ret) after being exposed to an elevated temperature of 260°C (500° F) for 5-minutes when tested according to ISO 11092, Textile-Physiological-Measurements of thermal and water vapor resistance under steady-state conditions (sweating guarded-hotplate test).

The SFD requires a minimum result of 200 hours with no leakage according to ASTM D-751, Hydrostatic Resistance, Procedure B, Procedure 2.

The SFD requires the fluorescent yellow-green garment trim to maintain a minimum RA of 350 or greater when measured at 0.2 degree observation angle/5 degree entrance angle when determined in accordance with the procedure defined in ASTM E808-01 and E809-08.

SFD Helmets must transmit a force to the wearer of less than 2200 Newtons during impact, maintain sufficient structural integrity to withstand impacts in all five test locations, have no penetration of the helmet during the Physical Penetration Resistance Test, and shall not leak more than 3.0 mA during the Electrical Insulation Test. Additionally, the helmet shell shall not separate from the suspension with 45 N applied, the chinstrap shall not break, nor stretch more than .8125" when tested in accordance with NFPA 1971, 2013 edition, sections 8.35 through 8.36, and shall not weigh more than 4.5 Lbs.

SFD Footwear shall meet the following minimum criteria when tested as indicated in the body of this document: The temperature of the insole surface in contact with the foot nor the upper surface in contact with the skin shall not exceed 111 F. The temperature of the upper lining surface in contact with skin shall have a second-degree burn time of not less than 10.0 seconds, and shall have a pain time of not less than 6.0 seconds. The boot components shall not have an after flame of more than 5.0 seconds, shall not melt or drip, and shall not exhibit any burn-through, and footwear shall not have any part of the footwear melt, separate, or ignite; shall show no water penetration; and shall have all components remain functional. The boot upper material shall allow no penetration of the test liquids for at least 1 hour, shall not have a complete cut through after a cut distance of more than .8 Inches, and shall not allow any puncture to the footwear upper after an average applied force of 13 LBF. Additionally, the boot shall allow no penetration of the Phi-X-174 bacteriophage for at least 1 hour, shall have no current leakage in excess of 3.0 mA, and the footwear soles shall not lose greater than 200mm3 of their volume to shrinkage, and shall have a coefficient of friction of 0.40 or greater.

SFD Gloves shall meet the following minimum criteria when tested as indicated in the body of this document: The glove body composites shall have an average TPP rating of greater than 55 and a second-degree burn time of not less than 10 seconds, and shall have a pain time of not less than 6 seconds. The glove shall not melt, separate, or ignite; shall not shrink more than 20 percent in length or width; shall be donnable and flexible; and the glove lining shall not melt, separate, or ignite. The whole glove shall have the dry hand donning time not exceed 10 seconds, shall have the wet hand donning time not exceed 30 seconds, shall have no detachment of the inner liner, shall have no detachment of the moisture barrier, and shall allow full insertion of all digits. The whole gloves shall have an average percent of barehanded control not exceeding 220 percent, and not less than 80 percent. The glove body composites shall not be punctured under a force of at least 40 N. The glove moisture barrier shall have a minimum of burst strength of 20 lbs, show no leakage after 150 cycles, have burst strength of at least 10 psi for 2 minutes, and have a minimum of 5500 gm./m2/24 hours of breathability. 100% of finished gloves must pass the Whole Glove Leak test with air as specified.

SFD Protective Hoods shall meet the following minimum criteria when tested as indicated in the body of this document: The hoods shall have an average TPP rating of not less than 25, not shrink more than 10 percent, and shall not melt, separate, or ignite. The blend of fibers making up the hood shall have a LOI rating of 28 or better, shall not exhibit shrinkage of more than 10 percent, and shall have the hood-opening meet the requirements specified when new, and shall have burst strength of not less than 225 N.