Care, Maintenance and Replacement of Firefighter Turnout Gear

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CERTIFICATION STATEMENT

I hereby certify that the following statements are true:

1. This paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

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Signed: _____

Printed Name: James Howell

ABSTRACT

The problem is the City of Fairfield Fire Department (CFFD) does not have a comprehensive program to care, maintain and replace its turnout gear.

The purpose of this study is to present data to develop a care, maintenance, and replacement program for the CFFD. The data will also reflect the financial impact to the department to maintain such a program. The program will meet NFPA 1851 standards whenever possible.

The following questions will be answered by this action research paper. What NFPA standards apply to care, maintain and replace the department's turnout gear? How does the CFFD meet or address these standards? What would be the financial impact of immediately meeting the NFPA standard versus staying with the present schedule for turnout gear replacement? What changes in care and maintenance could be anticipated with the selection of future turnout gear and what if any financial impact would it add?

The goal of this research paper was to determine what NFPA 1810 standards the CFFD currently meets and what needs to be done to meet those it doesn't.

An internet search was conducted and many articles, research papers were reviewed. Interviews of those responsible for the care and maintenance of the CFFD's turnout gear were conducted. NFPA 1810 standards and manufactures recommendations were reviewed.

A search was conducted to determine what factors or conditions may accelerate the degradation process of turnout gear. Three different surveys were conducted for this research paper. Survey #1 members of the CFFD. Survey # 2 was sent out to a targeted group of 18 fire departments that are similar to the CFFD. Survey # 3 six manufactures of firefighter turnout gear.

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Every firefighter has some type of personal protective ensemble they wear when fighting fires and performing various rescue operations. This protective ensemble protects the firefighter from heat, smoke and toxic gases when fighting fires. It also provides some protection while performing auto extrications or other rescue operations that may expose firefighters to body fluids which could lead to serious infections and disease. In addition, the ensemble provides some protection from the elements such as cold temperatures and moisture. The personal protective ensemble the firefighter wears is a very important piece of protective equipment that allows the firefighter to complete his mission of life safety, incident stabilization and property conservation. Without the protective ensemble the firefighter could not safely execute his job. The care, maintenance, retirement and replacement of the firefighters protective ensemble needs to be a top priority of every fire department to ensure firefighters can function in the safest manor possible.

The problem is the City of Fairfield Fire Department does not have a comprehensive program to care, maintain and replace this very important and vital piece of equipment. NFPA 1851 sets standards for the care, maintenance and replacement of the protective ensemble. The City of Fairfield Fire Department strives to meet or exceed NFPA standards when possible. Without the development of a comprehensive program we could be putting our firefighters in a position that compromises their ability to perform their jobs in the safest manor possible.

Purpose of the Study

The purpose of this study is to present data which could be used to develop a program to ensure two components of each firefighter's protective ensemble, the coat and pant, is cared for and maintained properly as well as replaced when necessary. Since we are only researching a portion of the firefighter's protective ensemble I will refer to two components, the firefighter's protective coat and pant as turnout gear. The program should outline guidelines to care for, procedures to clean, procedures to repair and a plan to replace turnout gear due to deterioration and age. The data will also reflect the financial impact to the department to maintain such a program. The program will meet NFPA 1851 standards whenever possible.

Research Questions

The following questions will be answered by this action research:

1. What NFPA standards apply to care, maintain and replace the department's turnout gear and what do these standards address?
2. How does the city of Fairfield Fire Department meet or address these standards?
3. What would be the financial impact of immediately meeting the NFPA standard versus staying with the present schedule for turnout gear replacement?
4. What changes in care and maintenance could be anticipated with the selection of future turnout gear and what if any financial impact would that add?

BACKGROUND AND SIGNIFICANCE

The City of Fairfield Fire Department (CFFD) is a combination fire department that employs 29 fulltime and 43 part time personnel providing fire and emergency medical services to the city. The personnel respond from three fire stations manning one engine, two quints, one heavy rescue and three ALS transport medic units. During the 2009 calendar year, the CFFD responded to 6,517 emergency calls. Of those calls, 4,355 were emergency medical calls made by medic units. Fire apparatus responded to 1,019 calls to assist the medic unit or act as a first responder if the medic was out of service. Fire units responded to 296 calls to fire alarms, 190 calls to fires, 7 calls for auto extrications and 106 calls for hazardous conditions. In analyzing that data 1,618 calls were responded to that required the donning of turnout gear. The remaining 544 calls were for various other emergencies and non emergency responses that did not require the donning of turnout gear.

At the present time individual firefighters are responsible for the overall care and condition of his or her turnout gear. Typically gear that appears dirty after a structure fire is washed and dried at the fire station in commercial grade washers and dryers. The method of washing and drying has varied from crew to crew. There is no other schedule in place for washing of turnout gear and no record has been kept for when a garment was washed. It is up to the firefighters to inspect his or her gear after it has been washed and dried and report any deficiencies to their superior officer. There is also one firefighter assigned to each unit day to inspect gear on a quarterly basis and to keep records of those inspections. Each of these inspectors is maintaining their own data base of the inspections in different database formats. Any gear that is found defective is marked for repair and that garment is replaced from a stock of extra gear kept in the department’s stock room.

Once a year all damaged gear is repaired by a company approved by the manufacturer. A master record has been kept of all repairs over the last four years. Prior to 2006 no records were kept of repairs made to turnout gear.

Currently the department has 74 turnout coats and 74 bunker pants assigned to firefighters as their firefighting gear. NFPA 1851 sets the standard for the life of turnout gear as ten years from the date the garment was manufactured to the date the garment is retired. All of this gear meets the NFPA 1851 ten year service life standard. Most of this gear will be past the ten year service life in six years and will need to be replaced.

Table 1

Gear currently assigned to Firefighters

Year	Coats	Pants
2009	11	11
2006	63	63
Total	74	74

When firefighters receive new gear, often the old gear is used for training purposes. Currently the department has 32 turnout coats and 33 bunker pants being used as training gear. Not all of the departments training gear meets NFPA 1851 ten year service life standard and needs to marked as expired gear and is not to be used in any live fire trainings. All gear will need to be marked appropriately when it is over ten years old and is not to be used in any live fire situation.

Table 2

Extra gear and training gear

Year	Coats	Pants
2006	2	2
2005	1	1
2004	7	6
2003	3	5
2002	5	6
2001	1	0
Total less than ten years old.	19	20
2000	1	0
1999	1	1
1998	4	4
1995	1	1
Unable to obtain	6	7
Total more than ten years old.	13	13
Total training gear	32	33

The department has 12 spare coats and 10 spare pants of various sizes in stock that are not assigned to anyone. All of this gear meets the NFPA ten year service life standards.

Table 3

Gear currently on hand as spare or replacement gear

Year	Coats	Pants
2006	7	8
2004	4	2
2002	1	0
Total spare gear	12	10

In the past the department replaced gear on an as needed basis by funds set aside in the cities Capita Improvement Project (CIP) fund. Starting in the year 2000, $25,000 was budgeted every other year to maintain all personal protective equipment including helmets, gloves, suspenders, hoods, boots, repair and replacement of the departments turnout gear. The number of sets of turnout gear was purchased based on what the money would buy at that time. The replacements were based on general appearance of the gear. In the year 2006 the department received a grant of $165,000 that was used to purchase 74 turnout coats and 74 turnout pants. In 2009 eleven turnout coats and pants were purchased using CIP money.

The CFFD is not compliant with all NFPA standards but strives to be when possible. In order to be compliant with NFPA 1851, the fire department will need to develop a program that tracks the history of its turnout gear including the care and maintenance from the time it is purchased to one year after it is retired. The department will also need to develop a plan and a method for replacing each set of turnout gear based on a service life ten years from the time of purchase to the time of retirement.

LITERATURE REVIEW

International Association of Fire Chiefs (2009) reported that prolonged exposure to soot on the skin is a hazard and may lead to testicular and other cancers in firefighters when turnout gear is not cleaned and stored properly. A study at the University of Cincinnati, Academic Medical Center, compared cancer rates of British chimney sweeps, which in the 1800s were notorious for lack of bathing with chimney sweeps in Germany and Belgium, who were exceedingly clean and Sweden where the chimney sweeps routinely took baths at the work place at the end of the day.

The UC study revealed:

> The major cause of testicular (and possibly other types of) cancer in chimney sweeps and firefighters is probably PAHs (Polycyclic Aromatic Hydrocarbons) absorbed through skin persistently coated in soot and often hot, as a consequence of their occupation.
>
> Chimney sweeps' cancer in Britain was due to persistent contact of soot with the skin. These cancers were unknown in continental European sweeps. Dr. Stuart Baxter, Jan. 22, 2009, UC seminar Why testicular cancer? Dr. Baxter explained that soot from burning wood, polymers, plastics, oils and other substances contain the cancer-causing agent PAH. The groin area of our bodies has a very high permeability rate:

- Scrotum: 300 permeability rate
- Jaw angle: 93
- Forehead: 43
- Scalp: 25

- Back: 12

  Skin absorption also increases with temperature. Dr. Baxter's hypothesis is sobering for firefighters.

  A major cause of cancer in firefighters is PAH absorbed through the skin as a result of contact with soot, persistently and under hot conditions. The especially high permeability of the groin area results in increased testicular and possibly other types of cancer. (International Association of Fire Chiefs, 2009)

Laidlaw Investigation, IAFF Local 48 & Cincinnati Fire Dept (2004) completed an enhanced report of the line of duty death of Cincinnati Fire Department member Oscar Armstrong. As part of that report they investigated the relationship to the death of Oscar Armstrong and his turnout gear.

Relationship to the death of Oscar Armstrong

The personal protective equipment of the personnel involved in this incident had not been inspected, cleaned or maintained for 2 to 3 years. Since there is no record of cleaning or inspection it is assumed the time frame greatly exceeded the 6- month inspection and cleaning recommendation. It is impossible to know the condition of FF Armstrong's PPE prior to destruction in the fire.

The protective coat in this incident was issued in January 2001 and manufactured in March of 1999. The protective pants in this incident had not been evaluated or cleaned since April 27, 2000. They were issued to FF Armstrong in January 2000. The date of manufacture of the turnout pants was May 1992. The

turnout pants worn by FF Armstrong were in service for over 10 years without record of cleaning or inspection for 35 months prior to the incident.

Recommendations by the committee to limit similar occurrences:

Create a dedicated position responsible for the cleaning, maintenance, tracking, and issuance of PPE. This position is essential in order to track personal protective equipment issuance, maintenance, and cleaning. This individual will also perform routine inspections and perform minor repairs. Ensure that inspection, cleaning, and care of protective coat is in accordance with NFPA 1851 Standard on Selection, Care, and Maintenance of Structural Fire Fighting Protective Ensembles. All PPE needs inspection and cleaning every 6 months regardless of use. (Laidlaw Investigation, IAFF Local 48 & Cincinnati Fire Dept, 2004, pg. 83)

NFPA 1851(2008) section 4.1.1 states the organization shall develop and implement a program for the selection, care, and maintenance of structural fire fighting ensembles and ensembles elements used by the members of the organization in the performance of their assigned functions (NFPA 1851, 2008, pg.12).

NFPA 1851 (2008) section 10.1.2 states structural fire fighting ensembles elements shall be retired no more than 10 years from the date the ensemble elements were manufactured (NFPA 1851, 2008, pg.22).

When new gear is received by members of the CFFD the FEMSA guide is attached to the garment. The guide gives instructions on how to care for the garments and the reasons why proper care is important. In the FEMSA (1996) guide it states:

> If your protective ensemble element becomes even slightly torn, worn, cracked or abraded, do not use it. Tears, worn or abraded spots will greatly decrease your protective qualities and will increase your risk of death, burns, injuries, diseases and illness. Your department or your employer should regularly inspect your protective ensemble for signs of wear and tear as well as to make sure that the protective element has not been modified or altered in any way. Even the most harmless looking changes to the protective element may increase your risk of death, burns, injuries, diseases and illness. (FEMSA, 1996, pg.11)

(Thorpe, 2005) Thorpe concluded that color fade could be used to observe degradation in the outer shell fabric of turnout gear caused by radiant heat. He found that Raman spectroscopy was inconsistent due to a high degree of fluorescence. Raman luminescence testing was also inconsistent due to inconsistencies in color dye. Digital image analysis and colorimetry testing did provide a means of measuring color fade. This test could be used as a non-destructive test to measure the degradation of in-use turnout gear. He added that causes turnout gear degradation are laundering, ultra-violet light exposures, abrasion, soil and age.

(Torvi, 2000) Torvi and Hadjisophocleous state that it is difficult to estimate the useful lifetime of protective clothing for firefighters, and to determine when to retire an individual set of turnout gear. Different fire departments may have different experience due to the level of usage, exposure to ultraviolet radiation, approach to fire fighting and cleaning frequency. In addition gear belonging to different firefighters in the same department will be exposed to conditions over the life of the garment.

Torvi and Hadjisophocleous also found that most guidelines for the retirement of turnout gear are based on simple visual inspections and economic considerations. A (FEMSA) manual states that turnout gear should be replaced if the cost of repairing the garment exceeds 50% of its replacement cost. NFPA 1810 calls for the replacement of turnout gear after 10 years regardless of the number of uses or the care and maintenance it received. This maximum lifetime would help departments to take advantage of advances in turnout gear technology and test standard development.

Torvi and Hadjisophocleous suggested that when developing guidelines for the retirement of turnout gear that a number of factors should be looked at. Number of years in service, number of exposures to radiant heat, number of times gear has been laundered and the visual inspection of the gear should determine when the gear is to be retired.

(Davis, Chinn, Lin, & Petit, 2010) NIST Technical Note 1657 studied the effect of ultraviolet light on materials commonly used in the fabrication of firefighters turn out gear below is their conclusion.

> The goal of this research was to determine the impact of simulate sunshine UV irradiation (under typical in-service conditions) on fabrics commonly used in OS of commercial turnout gear and determine to what extent the undergarment could be damaged from UV transmission through the OS.
>
> Unexposed KPB and NKB fabrics have very similar fabric density, tensile strength, and tear resistance, but the NKB fabric had a higher percent elongation and UV protection. UV irradiation significantly impacted the mechanical properties of these fabrics. LSCM and ATR-FTIR analysis revealed the

irradiation caused polymer decomposition, which is assumed to be the reason for the drop in mechanical performance. The irradiation had less of an impact on the KPB fabric as evidenced by KPB outperforming NKB in every analysis and test, except for UPF and percent elongation where the fabrics performed very similar to each other.

The results, observations and conclusions of this study support NFPA 1971[10] and NFPA 1851[11] guidelines to not store turnout gear in direct sunlight. The tensile strength and tear resistance of outer shells constructed from the NKB Plain weave fabric will deteriorate at most 45 % after 177 d of service, at most 90 % after 6.3 y of service, and at most 93 % after 10 y of service. The KPB Rip-Stop weave OS will better maintain its performance with a deterioration of at most 70 % at 6.3 y of service and at most 75 % at 10 y of service. However, the performance deterioration is significant regardless of the fabric type; therefore, it is recommended that turnout gear be exposed to as little UV radiation as possible. Since these fabrics block at least 94 % of the UV radiation, even after 20 y of service, the undergarments (MB and TL) are not at risk of UV irradiation providing the OS is between the UV source (sun, fluorescent lights, etc.) and the undergarment. If the undergarments are experiencing UV degradation, it is likely from the gear being turned inside, which is common practice, i.e., drying the gear or placing the gear over the boots for quicker deployment of gear. (Davis, 2010 pg 29)

NFPA 1851 (2008) section 7.3.7 the following procedures shall be used for machine washings:

1) The machine shall not be overloaded.
2) Heavily soiled or spotted areas shall be pretreated. Chlorine bleach, chlorinated solvents, active-ingredient cleaning agents, or solvents shall not be used without the ensemble or ensemble element manufactures approval.
3) All closures, including pocket closures, hooks and loops, snaps, zippers, and hooks and dees shall be fastened.
4) Water temperature shall not exceed 40ºC (105º F).
5) A mild detergent with a pH range of not less than 6.0 pH and not greater than 10.5 pH as indicated on the product MSDS or original product container shall be used.
6) Washing machines with the capability of drum RPM adjustment shall be adjusted so the g-force does not exceed 100 g for all elements.
7) Machine manufacturer's instructions shall be followed for proper setting or program selection for the specific element being washed.
8) The element shall be inspected and rewashed if necessary.
9) Where the machine is also used to wash items other than protective ensemble elements, it shall be rinsed out by running the machine without a laundry load through a complete cycle with detergent and filled to the maximum level with water at a temperature of 49º C to 52º C (120º F to 125º F).

(NFPA 1851, 2008, pg.19).

(Stull, 2006) In this Technical Report the cleaning effectiveness and impact of Esporta and industrial cleaning techniques on firefighter protective clothing were evaluated. The study determined the 25 washings would be the typical amount of washings a set of turnout gear would receive in a ten year period. With washings a minimum of two per year and washings after each use that soiled the garments, this seemed a true representation of The City of Fairfield Fire Department.

The study reported that after 25 washing cycles tear resistance usually decreased but remained above the NFPA 1971-2000 standard set for new gear. Breaking strength was significantly decreased after 25 wash cycles. Seam strength for outer shells, moisture barriers and thermal barriers were also significantly decreased. One material did drop below the NFPA 1971-2000 standard for seam strength. The largest change in fabric performance was for water absorption resistance. One fabric tested fell below minimum standards set for water absorption. It was stated that many manufactures recommended that repellant finishes be reapplied after several washing cycles. The penetration resistance of the moisture barrier seams remained intact for some fabric but failed in others. The effects of the washing on reflective trim varied from some diminishment to significant nighttime visibility depending on the material tested.

The test concluded that after 25 washings the effects of flame were negligible in nearly all cases. Tear resistance results were mixed depending on the material. Thermal protective performance increased due to fluffing of the material after washings. Absorption resistance is reduced with multiple washings.

(NFPA1851, 2008) Annex A Table A: 10.1.4 is a sample calculator for turnout gear repair limits. When placing the cost of turnout coat and pants purchased in 2005 the table would be as follows.

Table 4

NFPA Repair vs. replacement cost assessment.

Year of Service	Year of Service End Date	Amount of Original Cost ($1600) Allowed for Repair	Amount Allowed per set
1st year	01/01/14	70%	$1,120
2nd year	01/01/13	50%	$800
3rd year	01/01/12	40%	$640
4th year	01/01/11	25%	$400
5th year	01/01/10	20%	$320
6th year	01/01/09	15%	$240
7th year	01/01/08	10%	$160
8th year	01/01/07	5%	$ 80
9th year	01/01/06	5%	$ 80
10th year	01/01/05	0%	$ 0

As shown in the table cost of repair drops to just 15% in year six making the cost of repair very minimal as compared to the original cost. This is justified by the rate of degradation of turnout gear from laundering, exposure to ultraviolet light, and exposures to radiant heat. Technology continues to advance the safety, ergonomics, and durability

of turnout gear and this must also play into the consideration of repair or replacement of turnout gear.

PROCEDURES

The goal of this research paper was to determine what sections of NFPA 1810 standards does the City of Fairfield Fire Department currently meet an what needs to be done to meet the sections it currently does not meet. This was done by reviewing many articles, research papers, technical reports, past EFO research papers from the National Fire Academy.

The information search started with an internet search for NIOSH reports, articles, reports, past OFE and EFO papers that may indicate a link of injuries and death in firefighters to turnout gear. This was done to establish a need for a care and maintenance program.

The next step was to interview those responsible for the care and maintenance of the City of Fairfield Fire Department's turnout gear. This was done to determine what was presently being done to care and maintain the department's turnout gear. To establish a base line of the number and age of turnout gear in service and on hand for the City of Fairfield Fire Department an inventory of all turnout gear was completed.

NFPA 1810 standards were reviewed to establish what was needed for the department to meet the standard. Manufactures recommendations were also review to determine if they met or exceeded the NFPA 1810 Standard.

After reviewing NFPA 1851 standard section 10.1.2 that calls for retirement of turnout gear after ten years from manufactures date. A search was conducted to determine what factors or conditions may accelerate the degradation process of turnout gear.

Three different surveys were conducted for this research paper.

The target audience for survey #1 was 65 members of The City of Fairfield Fire Department (CFFD) that routinely don turnout gear. This survey was conducted to discover the level of knowledge in this department on some of the components of the (NFPA) 1851 that may

affect firefighters in their day to day operations. The survey was conducted over a period of three days to keep firefighters from collaborating on what they perceive the correct responses to the survey to be. 45 of the targeted 65 firefighters participated in the survey. The survey generated data of their general knowledge on gear maintenance. The results of this survey will tell how much training in gear maintenance will be needed.

Survey # 2 was sent out to a targeted group of 18 fire departments that are similar to the CFFD. Fire departments were selected from Fire Departments from across the United States that participated with the CFFD in a recent International City Managers Association (ICMA) study with populations between 20,000 and 60,000, having two to five fire stations and minimum staffing levels between 12 and 17 firefighters. Six of the 18 fire departments responded to the survey. The survey contained questions that are some of the key components of NFPA 1851and will reveal how similar departments are complying with NFPA 1851.

In survey # 3 eight manufactures of firefighter turnout gear were identified to be surveyed. Seven of those manufactures were contacted by telephone and ask them to participate in a brief survey. One of the manufactures identified could not be reached. Of the seven manufacturers contacted six responded to the survey. This survey was similar to the survey sent out to fire departments to determine if the gear manufacture industry and the fire departments are alike in their philosophy on gear replacement and the cost of that replacement.

Definition of Terms

Cleaning / Washing." The act of removing soils and contaminants from ensembles and ensemble elements by mechanical, chemical, thermal, or combined processes." (NFPA 1851 2008 section 3.3.13 pg. 9)

Structural Fire Fighting Protective **Coat**. "The element of the protective ensemble that provides protection to the upper torso and arms, excluding the hands and head." (NFPA 1851 2008 section 3.3.87 pg. 11)

Structural Fire Fighting Protective Trousers / **Pant**. "The element of the protective ensemble that provides protection to the lower torso and legs, excluding the ankles and feet." (NFPA 1851 2008 section 3.3.96 pg. 11)

Limitations of the Study

This study limited the only looked at two pieces of a firefighter's protective ensemble. The turnout coat and the turnout pant. It did not address the firefighter's helmet, gloves, hood, boots, and breathing apparatus or any other part of the protective ensemble.

If they exist, include any influences other than those addressed in your study that could have affected your results.

RESULTS

Question # 1 What NFPA standards apply to care, maintain and replace the department's turnout gear and what do these standards address?

NFPA 1851(2008) section 4.1.1 states the organization shall develop and implement a program for the selection, care, and maintenance of structural fire fighting ensembles and ensembles elements used by the members of the organization in the performance of their assigned functions (NFPA 1851, 2008, pg.12).

The lack of a care and maintenance program that addresses the cleaning of turnout gear may result in an increased cancer risk among firefighters. International Association of Fire Chiefs (2009) reported that prolonged exposure to soot on the skin is a hazard and may lead to testicular and other cancers in firefighters when turnout gear is not cleaned and stored properly. Dr. Stuart Baxter, Jan. 22, 2009, UC seminar Why testicular cancer? Dr. Baxter explained that soot from burning wood, polymers, plastics, oils and other substances contain the cancer-causing agent PAH.

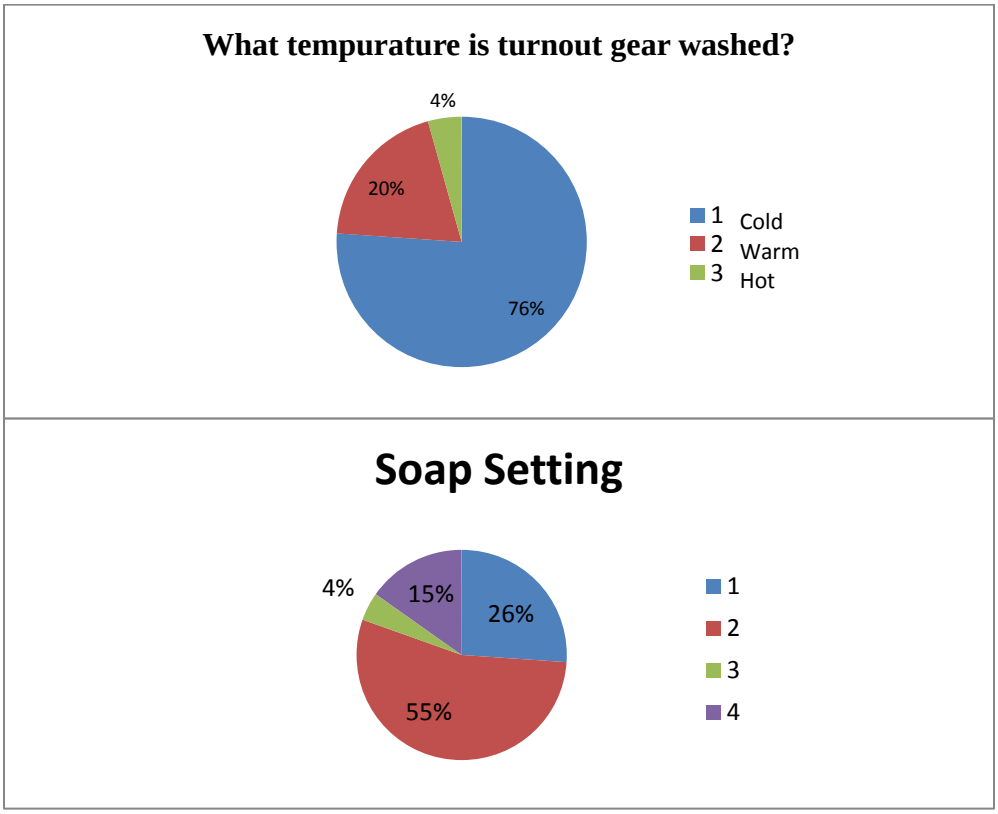
Laidlaw Investigation, IAFF Local 48 & Cincinnati Fire Dept (2004) completed an enhanced report of the line of duty death of Cincinnati Fire Department member Oscar Armstrong. As part of that report they investigated the relationship to the death of Oscar Armstrong and his turnout gear. The report revealed the turnout gear had not been inspected, cleaned or maintained for 2 to 3 years. There was no record of cleaning or inspection. The protective coat was manufactured in March of 1999 issued in January 2001. The protective pant was manufactured in May 1992 and issued in January 2000. The turnout pant was in service for over 10 years without record of cleaning or inspection for 35 months prior to the incident.

The following standard addresses the cleaning of turnout gear. NFPA 1851 (2008) section 7.3.7 the following procedures shall be used for machine washings:

1) The machine shall not be overloaded.
2) Heavily soiled or spotted areas shall be pretreated. Chlorine bleach, chlorinated solvents, active-ingredient cleaning agents, or solvents shall not be used without the ensemble or ensemble element manufactures approval.
3) All closures, including pocket closures, hooks and loops, snaps, zippers, and hooks and dees shall be fastened.
4) Water temperature shall not exceed 40ºC (105º F).
5) A mild detergent with a pH range of not less than 6.0 pH and not greater than 10.5 pH as indicated on the product MSDS or original product container shall be used.
6) Washing machines with the capability of drum RPM adjustment shall be adjusted so the g-force does not exceed 100 g for all elements.
7) Machine manufacturer's instructions shall be followed for proper setting or program selection for the specific element being washed.
8) The element shall be inspected and rewashed if necessary.
9) Where the machine is also used to wash items other than protective ensemble elements, it shall be rinsed out by running the machine without a laundry load through a complete cycle with detergent and filled to the maximum level with water at a temperature of 49º C to 52º C (120º F to 125º F).

(NFPA 1851, 2008, pg.19).

(Thorpe, 2005) In this study Thorpe added causes of turnout gear degradation are laundering, ultra-violet light exposures, abrasion, soil and age. The results of a survey of members of the City of Fairfield Fire Department revealed that laundering methods varied among crew members. The standard of a maximum of 105 degree water temperature as well soap pH levels were not consistently adhered to when washing gear.



(Stull, 2006) In this Technical Report the cleaning effectiveness and impact of Esporta and industrial cleaning techniques on firefighter protective clothing were evaluated. The study determined the 25 washings would be the typical amount of washings a set of turnout gear would receive in a ten year period.

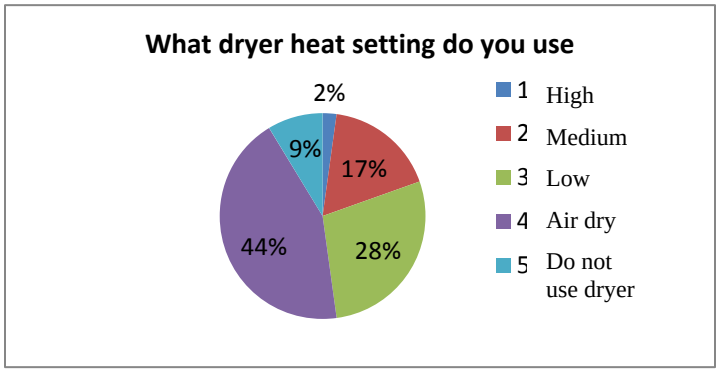
In a survey of manufactures 67% agreed that 25 washings would be the normal life of turnout gear.

The following standard address the drying of turnout gear NFPA 1851 (2008) section 7.4.2 the following procedures shall be used for machine drying.

1) The recommended capacity of the machine shall not be exceeded.
2) All closures, including pocket closures, hooks and loops, snaps, zippers, and hooks and dees shall be fastened.
3) A “no heat” or “air dry” option shall be used, if available.
4) In the absence of a “no heat” or “air dry” option, the basket temperature shall not exceed 40ºC (105ºF).
5) The use of a heat cycle shall be discontinued prior to the removal of all moisture from the ensemble or ensemble elements.
6) The remainder of the drying process shall be accomplished by a “no heat” machine setting or removal of the ensemble or ensemble elements from the machine dryer to air dry.

(NFPA 1851 pg 20)

The Fairfield Fire Department survey revealed that members of the department are inconsistent in the way they dry their turnout gear. Exceeding 105ºF 47% of the time.



NFPA 1851 (2008) section 10.1.2 states structural fire fighting ensembles elements shall be retired no more than 10 years from the date the ensemble elements were manufactured (NFPA 1851, 2008, pg.22).

Question # 2. How does the city of Fairfield Fire Department meet or address these standards?

Records of care, maintenance and replacement of turnout gear were found to be inconsistent varying from unit day to unit day.

In an interview with Captain Donovan of the CFFD, who manages care and replacement of the department's turnout gear he stated that the department has sent three firefighters to the Total Fire Group training for advanced inspection and cleaning techniques. A bar code program was also purchased to track the life and history of the turnout gear. Air drying stations are being built for each firehouse as a means of drying turnout gear. A standard operating procedure for cleaning, drying and inspecting turnout gear is being developed by Captain Donovan and the three firefighters that received the training using the bar code system to track all care, maintenance and replacement of the turnout gear.

The CFFD currently meets NFPA 1851 (2008) section 10.1.2 which states structural fire fighting ensembles elements shall be retired no more than 10 years from the date the ensemble elements were manufactured (NFPA 1851, 2008, pg.22).

The following table shows turnout gear currently assigned to firefighters. 63 sets of turnout gear will need to be replaced by 2006.

Table 1

Gear currently assigned to Firefighters

Year	Coats	Pants
2009	11	11
2006	63	63
Total	74	74

Question # 3. What would be the financial impact of immediately meeting the NFPA standard versus staying with the present schedule for turnout gear replacement?

Currently the department has 74 turnout coats and 74 bunker pants assigned to firefighters as their firefighting gear. NFPA 1851 sets the standard for the life of turnout gear as ten years from the date the garment was manufactured to the date the garment is retired. All of this gear meets the NFPA 1851 ten year service life standard. Most of this gear will be past the ten year service life in six years and will need to be replaced.

In an interview with Captain Donovan of the CFFD he predicted that the cost of replacing 74 sets of gear in six years would be $247,974 he also stated that the department has developed a program to replace 14 sets of gear a year based on an eight year life of the gear. This will allow gear to be replaced on need based on the life and condition of the turnout gear prior to the 10 year maximum life of the gear. Money will be appropriated from the cities capital improvement budget each year to replace the turnout gear. The replacement plan is figuring a 10% increase per year in a set of turnout gear. This is inconsistent with the survey sent out to manufactures. In the

survey manufactures expected a 10% to 25% increase in the next five years and the same 10% to 25% in the next ten years. In figuring the 10% per year the CFFD will have a sufficient amount of money for turnout gear replacement. Based on the replacement of 14 sets of turnout gear a year with a 10% increase in cost each year the department will spend approximately $195,594 for turnout gear over a five year period replacing 70 sets of turnout gear. Money to fund the replacement of the turnout gear will come from the cities Capital Improvement Fund. Based on the current projected cost of turnout gear $32,032 will need to be appropriated in 2011 and increased by 10% each year.

Table 6

Projected cost of turnout gear to the CFFD.

Year	Cost of 1 set	Cost of 14 sets	C.I.P. money needed
2011	$2,288	$32,032	$32,100
2012	$2,517	$35,235	$35,310
2013	$2,768	$38,759	$38,831
2014	$3,045	$42,635	$42,725
2015	$3,350	$46,898	$46,998
Total		$195,559	$195,974

By following the above schedule all turnout gear will be replaced before the ten year time frame. This schedule could be adjusted in year six to reflect the current needs of the department.

When determining to repair or replace turnout gear the following table could be used.

Table 7

Repair vs. replacement cost assessment.

Year of Service	Year of Service End Date	Amount of Original Cost ($2,280) Allowed for Repair	Amount Allowed per set
1st year	01/01/14	70%	$1,596
2nd year	01/01/13	50%	$1,140
3rd year	01/01/12	40%	$912
4th year	01/01/11	25%	$570
5th year	01/01/10	20%	$456
6th year	01/01/09	15%	$342
7th year	01/01/08	10%	$228
8th year	01/01/07	5%	$114
9th year	01/01/06	5%	$114
10th year	01/01/05	0%	$ 0

Question # 4. What changes in care and maintenance could be anticipated with the selection of future?

In a survey sent to six manufactures of turnout gear only two responded that they anticipated changes in turnout gear in the next ten years that will extend the life turnout gear beyond ten years.

Torvi and Hadjisophocleous also found that most guidelines for the retirement of turnout gear are based on simple visual inspections and economic considerations. A (FEMSA) manual states that turnout gear should be replaced if the cost of repairing the garment exceeds 50% of its replacement cost. NFPA 1810 calls for the replacement of turnout gear after 10 years regardless of the number of uses or the care and maintenance it received. This maximum lifetime would help departments to take advantage of advances in turnout gear technology and test standard development.

In the same survey five anticipate significant enhancements to the safety of the garments within the next five years and six anticipate significant enhancements to the safety of the garments within the next ten years.

Expected future changes are a new stored energy test and new wet compression test for knees. New studies on turnout gear wear performance are being conducted at the University of Kentucky and will be reported on in early May 2011.

DISCUSSION

The CFFD does need to establish a turnout gear care and maintenance program. Although a significant amount of death and injury could not be linked to the lack of care or replacement of turnout gear. The removal of the soot from firefighter's turnout gear is important to the health of firefighters. Studies have linked certain types of cancer to the soot found in firefighters turnout gear (International Association of Fire Chiefs, 2009).

A survey of the members of the CFFD confirmed that the CFFD is inconsistent washing, drying, and care and maintenance methods of turnout gear. Some were washing turnout gear in water temperatures in excess of the NFPA 1851 (2008) section 7.3.7 standard of 105ºF. Members of the CFFD were also inconsistent in meeting NFPA 1851 (2008) section 7.4.2 for drying of turnout gear.

The number of washings, exposure to ultra violet light, and usage all play a role in determining when gear should be retired. This is confirmed by (Thorpe, 2005) and (Torvi, 2000). Gear should be retired or sent back to the manufacturer for an advanced inspection after 25 washings. (Stull, 2006) Stull concluded that after 25 washings the effects of flame were negligible in nearly all cases. Tear resistance results were mixed depending on the material. Thermal protective performance increased due to fluffing of the material after washings. Absorption resistance is reduced with multiple washings. A survey sent out to manufactures also confirmed 25 washings to be a benchmark for concern.

Gear should be stored out of direct sunlight and not subject to prolong exposure to ultra violet light. This is confirmed in a study by (Davis, Chinn, Lin, & Petit, 2010) and also is a (NFPA1851, 2008) standard set forth in section 9.1.1.

Retiring of turnout gear should be based on a number of factors. One being the condition of the turnout gear no matter the age. Another being when the cost of repairing the gear is greater than the value of the gear as outlined in (NFPA1851, 2008) Annex A Table A: 10.1.4 and Table 7 of this survey. When gear 10 years old from manufactures date regardless of condition to take advantage of advancements in improved safety and comfort of turnout gear.

The CFFD needs to establish a record keeping system tracking the age of the gear, inspection dates, general condition of the gear, and number of washings gear has received. It also needs to establish written policy and instructions for washing, drying, inspecting, repairing and storage instructions that are posted in appropriate areas.

The present gear replacement schedule is realistic for at least the next five years but in addition to age of gear condition and usage should also play a role on deciding which gear should be replaced. Keeping accurate records will be essential in tracking usage when determining when to replace turnout gear

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RECOMMENDATIONS

When deciding if a fire department can meet NFPA 1851 standards a number of factors need to be determined.

1) What standards apply to a particular organization?
2) What will be the financial impact of meeting the standards?
3) Will meeting standards be affordable to the organization?
4) Does the organization have personnel that have received the proper training to perform inspections and maintenance?
5) Does the organization have adequate records needed and if not do they have the means to establish a suitable record keeping system?

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APPENDIX 1 – SURVEY # 1

Fairfield Fire Department Turnout Gear Survey

1. How often do you check your turn out gear for cleanliness?
    a. At the beginning of each work day.
    b. After all structure fires
    c. Monthly
    d. Yearly

Results

A-25	B-12	C-11	D-0

2. How often do you wash your turnout gear?
    a. After each structure fire
    b. Only when dirty
    c. Twice a year
    d. Once a year

Results

A-17	B-33	C-3	D-0

3. When you are washing turnout gear. What is the maximum number of sets of turnout gear that you have placed in the washer and washed simultaneously?
    a. one
    b. two
    c. three
    d. four

Results

A-42	B-3	C-1	D-0

4. At what temperature setting do you wash your turnout gear?
    a. Cold
    b. Warm
    c. Hot

Results

A-35	B-9	C-2

5. At what soap setting do you set the proportioner when washing your turnout gear?
    a. 1
    b. 2
    c. 3
    d. 4
    e. I don't pay attention to the setting

Results

A-12	B-25	C-2	C-7	D-0

6. When drying gear, what dryer temperature setting do you use?
    a. High
    b. Medium
    c. Low
    d. I air dry only
    e. I never dry gear in dryer

Results

A-1	B-8	C-13	D-20	E-4

7. If you choose, I never dry gear in dryer, how do you dry your gear?
    a. Hung on gear rack until dry
    b. Laid flat until dry
    c. Hung outside to dry.

Results

A-4	B-0	C-0

8. How big of a hole or tear in your turnout gear is acceptable to you?
    a. Larger than ¼"
    b. Larger than ½"
    c. Larger than ¾"
    d. Larger than 1"
    e. No hole or tear is acceptable

A-3	B-1	C-0	D-0	E-42

9. When you report deficiencies in your turn out gear who do you report it to?
    a. Fire Chief
    b. District – 33
    c. Your Lieutenant
    d. The person assigned to gear maintenance on your shift

Results

A-0	B-1	C-5	D-40

10. To be compliant with NFPA 1851.What is the maximum number of years from manufacture date your set of turnout can stay in service?
    a. Five years
    b. Eight years
    c. Ten years
    d. Fifteen years
    e. It only needs to be replaced if it is worn out.

Results

A-6	B-14	C-24	D-1	E-1

APPENDIX 2 – SURVEY # 2

City of Fairfield Fire Department

Turnout Gear Care and Maintenance Survey

1. Do you currently have a Care, Maintenance and Replacement program for your department's turnout gear?

- ☐ Yes
- ☐ No

Answer Options	Response Percent	Response Count
Yes	100.0%	6
No	0.0%	0
answered question		6
skipped question		0

2. What type of washing machine do you use to clean your turnout gear?

- ☐ Residential drum type
- ☐ Commercial extractor type
- ☐ All gear is sent out to be cleaned by manufacturer approved cleaning company

Answer Options	Response Percent	Response Count
Residential drum type	16.7%	1
Commercial extractor type	50.0%	3
All gear is sent out to be cleaned by manufacturer approved cleaning company	33.3%	2
answered question		6
skipped question		0

3. How do you dry your turnout gear?

- ☐ Residential type dryer
- ☐ Commercial type dryer
- ☐ Hang dry with mechanical air drying system
- ☐ Hang on gear rack to dry.
- ☐ All gear is sent out to be cleaned and dried by manufacturer approved cleaning company.

Answer Options	Response Percent	Response Count
Residential type dryer	0.0%	0
Commercial type dryer	33.3%	2
Hang dry with mechanical air drying system	0.0%	0
Hang on gear rack to dry.	33.3%	2
All gear is sent out to be cleaned and dried by manufacturer approved cleaning company.	33.3%	2
answered question		6
skipped question		0

4. Have you established a maximum number of times a set of turnout gear can be washed before retiring the gear?

- ☐ Yes
- ☐ No

Answer Options	Response Percent	Response Count
Yes	0.0%	0
No	100.0%	6
answered question		6
skipped question		0

5. If you answered yes to question three please select the number of washings your gear is subject to before retiring the turnout gear.

- ☐ Less than 25 washings
- ☐ 25 to 35 washings
- ☐ 35 to 50 washings
- ☐ Over 50 washings

Answer Options	Response Percent	Response Count
Yes	100.0%	6
No	0.0%	0
	answered question	6
	skipped question	0

6. Does your department currently replace all turnout gear that is over ten years old from manufacturer date?

- ☐ Yes
- ☐ No

Answer Options	Response Percent	Response Count
Yes	100.0%	6
No	0.0%	0
	answered question	6
	skipped question	0

7. If your answer to question six was no. Does your department plan on doing so in the future?

- ☐ Yes
- ☐ No

Answer Options	Response Percent	Response Count
Yes	100.0%	6
No	0.0%	0
answered question		6
skipped question		0

8. When replacing turnout gear. What determines the color of your department's turnout gear?

- ☐ Tradition
- ☐ Ability to show soiling
- ☐ Ability to hide soiling
- ☐ Ability to show damage to garment due to color change
- ☐ Cost of the turnout gear
- ☐ Color does not matter

Answer Options	Response Percent	Response Count
Tradition	33.3%	2
Ability to show soiling	16.7%	1
Ability to hide soiling	0.0%	0
Ability to show damage to garment due to color change	16.7%	1
Cost of the turnout gear	0.0%	0
Color does not matter	50.0%	3
answered question		6
skipped question		0

9. Taking into consideration inflation and improvements in technology. What increase in pricing do you expect in turnout gear over the next five years?

- ☐ Less than 10%
- ☐ 10% to 25%
- ☐ 25% to 50%
- ☐ 50% to 75%
- ☐ Greater than 75%

Answer Options	Response Percent	Response Count
Less than 10%	33.3%	2
10% to 25%	66.7%	4
25% to 50%	0.0%	0
50% to 75%	0.0%	0
Greater than 75%	0.0%	0
	answered question	6
	skipped question	0

10. Taking into consideration inflation and improvements in technology. What increase in pricing do you expect in turnout gear over the next ten years?

- ☐ Less than 10%
- ☐ 10% to 25%
- ☐ 25% to 50%
- ☐ 50% to 75%
- ☐ Greater than 75%

Answer Options	Response Percent	Response Count
Less than 10%	0.0%	0
10% to 25%	83.3%	5
25% to 50%	16.7%	1
50% to 75%	0.0%	0
Greater than 75%	0.0%	0
	answered question	6
	skipped question	0

APPENDIX 3 – SURVEY #3

City of Fairfield Fire Department

Turnout Gear Care and Maintenance Survey #3

1. What percentage of increase in price do you expect to see in turnout coats and pants in the next five years?
    a. None
    b. Less than 10%
    c. 10 to 25%
    d. 25 to 50%
    e. 50 to 75%
    f. Greater than 75%

Results

A-0	B-1	C-4	D-0	E-0	F-0	1 did not answer

2. What percentage of increase in price do you expect to see in turnout coats and pants in the next 10 years?
    a. None
    b. Less than 10%
    c. 10 to 25%
    d. 25 to 50%
    e. 50 to 75%
    f. Greater than 75%

Results

A-0	B-0	C-3	D-2	F-0	E-0	1 did not answer

3. What would you consider to be the maximum number of washings at set of turnout gear should be subject to in the life of the garment?
    a. 25 or less
    b. 25 to 35
    c. 35 to 50
    d. 50 to 75
    e. Over 75%

Results

A-4	B-0	C-2	D-0	E-0

4. Do you anticipate any significant changes to firefighter turnout coat and pants in the next five years that with normal use will extend the life of the garments beyond ten years?
    a. Yes
    b. No

Results

A-2	B-4

5. Do you anticipate any significant changes to firefighter turnout coat and pants in the next ten years that with normal use will extend the life of the garments beyond ten years?
    a. Yes
    b. No

Results

A-2	B-4

6. Do you anticipate any significant enhancements to firefighter turnout coat and pant that with normal use will increase the safety of those garments within the next five years?
    a. Yes
    b. No.

A-5	B-1

7. Do you anticipate any significant enhancements to firefighter turnout coat and pant that would increase the safety of those garments within the next ten years?
    a. Yes
    b. No.

A-6	B-0