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Flame Resistant Clothing: Statistics, Standards and Safety

Rob Whittenberger
President
Tyndale Company, Inc.
Pipersville, Pennsylvania

Introduction

For over twelve years, the author has worked extensively as an integral part of the standards development community, leading and participating in committees that create the standards for flame resistant clothing in use today throughout the United States. Rob has presented to hundreds of safety leaders and countless employees at electric utilities and Fortune 500 companies throughout the United States. Taking on a consultative role to ensure the protection of workers against arc flash and flash fire hazards, worker safety is his priority. Recently recognized as a ten-year participant of the ASTM F18 Committee on Electrical Protective Equipment for Workers and named Chair of the ASTM Task Group on Home Laundering of Arc, Thermal and Flame Resistant Garments, his work continues to have a broad impact on worker safety.

While developing standards is clearly an important start to increased worker safety on the job, it is equally important to ensure that workers have a clear understanding of the benefits of FR clothing. Gaining worker acceptance on the daily use of flame resistant clothing requires that employees have a clear understanding of the inherent risk posed by work activities.

This paper provides a broad overview of statistics on employee risk of injury, illness and fatality in select industries. This statistical data provides the backdrop for standards that address the use of flame resistant apparel designed to protect workers. A concise overview of the existing standards and proposed updates gives safety leaders a guide to understanding the requirements and the steps a company must take to reduce worker risk and offer the greatest opportunity for a safe work environment to their employees.

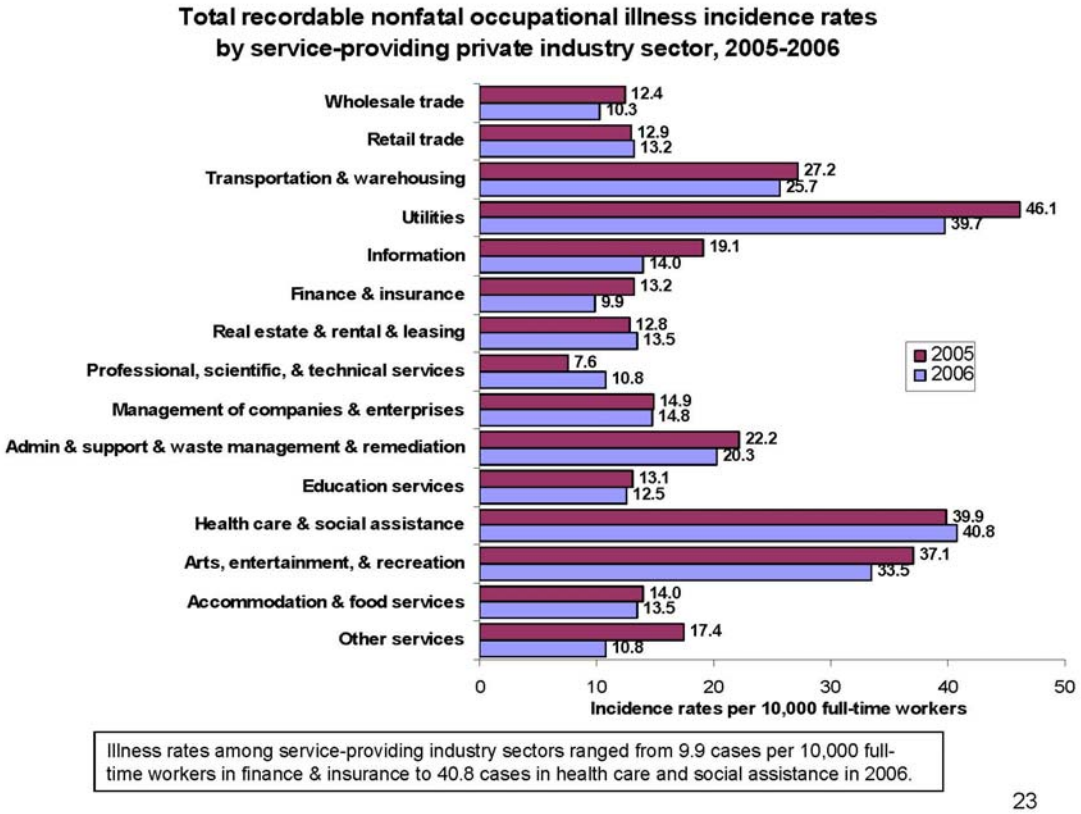
Clothing designed to protect against arc flash or flash fire hazards is the last line of defense against worker injury. The need for protective apparel becomes apparent only when other safety measures have somehow failed. In order to protect workers against the risk posed by arc flash or flash fire hazard, it is critical that Corporate Safety takes a comprehensive view of flame resistant apparel. It all starts with education on the risk.

The Statistics

Every day, the risk of arc flash or flash fire is present to workers in the oil, gas, utility and electrical maintenance industries. Widely known in the FR apparel industry, and backed up by government statistics, wearing standard work apparel increases the risk of injury and death significantly when a worker is exposed to arc flash or flash fire.

The issue? Worker clothing made from synthetics – acetate, nylon and polyester – may ignite and continue to burn, melting and dripping on to the skin. This significantly increases the risk of injury sustained by the worker as compared to workers wearing flame resistant clothing.

Current statistics from the US Department of Labor demonstrate the inherent risk to workers with the highest risk of exposure to arc flash and flash fire hazards. Using the utility industry as an example, illness and injury rates are provided.



Source: Bureau of Labor Statistics, U.S. Department of Labor, October 2007

Table 1. Nonfatal illness incidence rate 2005-06[1].

The incidence of fatalities paints an even more startling picture. Fatality rates from 2004 to 2006 among electric power-line installers and repairers have risen between 2004 and 2006. In 2004, there were 30.0 fatalities per 100,000 workers; the rate increased to 34.9 fatalities per 100,000 workers among electrical power-line installers and repairers in 2006[2]. The impact of these fatalities is staggering, both physically and emotionally on the employee's family and coworkers – not to mention the liability to the company. And, the cost of a single electrical injury can exceed US $23 M[3] in first year medical plus lifetime medical costs. The cost of clothing all employees in FR clothing offsets the cost of a single injury to a worker – and mitigates the physical and emotional risk to employees.

The Standards: OSHA, ASTM, NFPA, NESC

The key organizations in the industry that have taken on the role of standards development are the American Society for Testing Materials (ASTM), IEEE – which authors the National Electric Safety Code (NESC), National Fire Protection Association (NFPA) and the Occupational Safety and Health Association (OSHA). Combined, these organizations write the standards that determine the flame resistant clothing worn across the US by electric maintenance, gas, oil and electric utility workers.

Over the past few years, increasing clarity and a gradual shift toward consistency between the standards in the proposed changes set to take effect has helped give leaders in corporate safety the tools needed to support worker use of flame resistant clothing. The standards give guidance to safety in determining the proper level of protection required for workers to wear to guard against arc flash and flash fire hazards.

OSHA 1910.269 was the first on the books many years ago and was the first to establish clothing standards for workers. It required that clothing "do no harm" to workers. NFPA 70E was next and established minimum protection levels, requiring employers to perform arc hazard analysis to determine the appropriate clothing for specific job functions. It really established stronger benchmarks for worker FR apparel.

Planned changes to both the OSHA and NESC standards offer more stringent guidelines to employers. A summary of the standards follows, along with an overview of the test methods used to determine the level of protection provided by the FR clothing. It is important to have a clear understanding of which work groups are covered by each standard.

Standard	Industry Segment(s)	Scope
OSHA CFR 1910.269	Electric utility workers involved in the transmission and distribution of electricity.	Federal
NESC	Systems and equipment operated by utilities, or similar systems and equipment, of an industrial establishment or complex under the control of qualified persons.	Adopted on a state by state basis; voluntary consensus standard. Some states automatically adopt.
NFPA 70E	Electrical maintenance workers and generation workers, except electric transmission and distribution, railroad, marine and mining.	National. Voluntary; has been enforced through the OSHA General Duty Clause.
NFPA 2112	Chemical, Gas and Oil workers	National.

Table 2. Summary of Standards which impact worker FR Clothing requirements.

OSHA – Occupational Safety and Health Administration

OSHA 29 CFR 1910.269 (1) (6) (iii) states:

> "The employer shall ensure that each employee who is exposed to the hazards of flames or electric arc does not wear clothing that, when exposed to flames or electric arcs, could increase the extent of the injury that would be sustained by the employee."[4]

From a practical standpoint, this means that if an employee's clothing does not melt, ignite or continue to burn during or after an arc or flame exposure, the wearer is in compliance. This is the only law relevant to flame resistant clothing for electrical applications for electric utility maintenance work.

The protective apparel portions of 1910.269 are currently under review by OSHA. OSHA intends to clarify the vague nature of the existing requirements by including the following items:

- Utilities must do hazard analysis to determine incident energy levels.
- Workers must wear sufficient clothing to reduce the incident energy level to 1.6 cal / cm2, the point of 2nd degree burn onset.
- Flame resistant clothing will be required for certain tasks.
- 100% natural fiber garments – cotton, wool or silk – will be allowed if there is a 95% confidence level that there is a less than 10% probability of ignition at a specific incident energy level.
- It is the utilities responsibility to ensure workers are protected from 2nd degree burns resulting from electric arcs.
- ASTM Standards and Test methods are referenced.

NESC – National Electric Safety Code

NESC covers those utility workers that are not specified in OSHA 1910.269. NESC has recently added a new rule – 410A3 – which is scheduled to take effect January 1, 2009 that states:

> "the employer shall ensure that an assessment is performed to determine potential exposure to an electric arc for employees who work on or near energized parts or equipment. If the assessment determines a potential employee exposure greater than 2 cal / cm 2 exists, the employer shall require the employee to wear clothing or a clothing system that has an effective rating not less than the anticipated level of arc energy." [5]

An arc hazard analysis or tables within the standard are used to determine the arc rating of the clothing system used to meet the specifics of the standard.

NESC is automatically adopted in many states; in addition many states have taken the action necessary to ensure adoption. These states include: AL, AR, CT, DE, ID, KY, ME, MD, MN, MS, NY, NC, OR, RI, SC, TX and VT[6].

NFPA 70E – National Fire Protection Association

The most commonly cited standard when discussing flame resistant apparel is NFPA 70E – 2004 edition. NFPA 70E is a voluntary standard for electrical safety that includes both work practices and protective equipment, such as FR clothing. As a national consensus safety standard, NFPA 70E is not law. However, despite the fact that NFPA 70E has not been incorporated in the code of Federal Regulations, NFPA 70E has been cited by OSHA in cases where lack of compliance has resulted in a workplace accident. Many leading organizations have already adopted it because it saves lives.

From a clothing perspective, NFPA 70E breaks all electrical procedures into five categories and assigns minimum flame resistant clothing layers and performance characteristics for each category. NFPA 70E specifies a minimum ATPV of 4.0 cal/cm2 for shirt fabrics. NFPA 70E is the most comprehensive guide for flame resistant clothing in use today and has already had an impact on OSHA 1910.269.

Test Methods

At the same time that OSHA issued 1910.269, the ASTM F18.65 Sub-Committee on Wearing Apparel was attempting to determine, through scientific means, the thermal hazards that affect utility workers. Through years of research, the sub-committee has released several standards and test methods that quantify the hazards, define protection and further quantify the industry as a whole.

ASTM D6413
Standard Test Method Flame Resistance of Textiles (Vertical Test).

This is the defining Test Method for compliance with OSHA 1910.269. Formerly FTMS 191A or FTM 5903.1, ASTM recently adopted this Test Method. The purpose of this test is to determine whether a fabric will continue to burn after the source of ignition is removed. Using a 12 second Methane flame and a special testing apparatus, afterflame, afterglow and char length are measured. If a fabric exhibits less than 2 second afterflame and 6" char length according to ASTM D6413, it is "Flame Resistant".

ASTM D6413 is used to determine a pass/fail criteria for ASTM F1506.

ASTM F1930
Standard Test Method for Evaluation of Flame Resistant Clothing for Protection Against Flash Fire Simulations Using an Instrumented Manikin.

This test uses a full body manikin with sensors to determine the predicted degree of burn area. The manikin is exposed to propane gas. The burn area coming as a result of the exposure is converted to a percentage to show the total area of predicted burn injury.

ASTM F1959
Standard Test Method for Determining Arc Thermal Performance (Value) of Textile Materials for Clothing by Electric Arc and Related Thermal Hazards.

This is the Test Method used to calculate quantitative results for fabrics relating to how they perform in an Electric Arc environment. The purpose of this test method is to determine how much heat a certain fabric (or system of fabrics) will block from an electric arc before the 50% probability of onset of second degree burns for the wearer. The amount is energy blocked by the fabric is reported as Arc Rating.

Test results from ASTM F1959 must be reported for all garments that meet ASTM F1506.

Performance Standards

ASTM F1506
Standard Performance Specification for Textile Material for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards.

This is the governing ASTM Performance Standard for Flame Resistant Clothing. The standard has three basic requirements:

- A sample of fabric must self extinguish with <2 second afterflame and <6" char length according to ASTM Test Method D6413. This flammability test applies to an initial sample and after 25 washes / dry cleanings.
- The fabric must be tested for Arc Thermal Performance according to ASTM Test Method F1959.
- The results of the Arc Thermal Performance testing must be reported to the end user as an Arc Rating on a garment label. A garment that meets ASTM F1506 complies with OSHA 1910.269 and typically meets the requirements of NFPA 70E as well.

ASTM F1506 is a pass/fail performance standard with requirements for reporting information not considered for the pass/fail performance criteria. All garments that meet the requirements of ASTM F1506 must state so on a garment label.

NFPA 2112
Standard on Flame Resistant Garments for Protection of Industrial Personnel Against Flash Fire.

NFPA 2112 is a performance standard designed to establish a benchmark performance for FR garments exposed to flash fire. NFPA 2112 establishes specific criteria for testing garments using the ASTM 1930 test method. It requires garments to be constructed in a size 40-RG coverall configuration, and fitting to the thermal mannequin over 100% cotton t-shirt and briefs. Garments are to be exposed to a 3 second burn exposure, and the total predicted body burn is measured. NFPA 2112 establishes a pass/fail criteria at 50% body burn - fabrics or fabric systems that achieve less than 50% predicted body burn under these conditions can be said to pass the requirements of 2112. The standard also requires garments to be specifically labeled to state their conformance with the testing requirements.

Note: the author, while acknowledging the benefit of consistent testing parameters to benchmark fabrics against each other, believes that this performance standard is not adequate to predict protective characteristics under a wide variety of conditions. Flash fires can range in duration from almost instantaneous to more than 10 seconds, and the combustion fuel can burn at a wide variety of temperatures. Different fabrics perform differently based on exposure duration and heat exposure, making it difficult to use this Standard to predict protective performance for a specific fabric against a specific hazard.

Flame Resistant Fabrics

There has been no shortage of discussion – or opinions rendered – on flame resistant fabric. And, the debate on fabric has been particularly heated over the past two years. First, it's important to realize that any fabric used in the manufacturing of FR apparel must go through testing to ensure it meets specific safety standards that have been established. The fabric or combination of fabrics used in the manufacturing of any apparel must be arc tested to determine the rating, and labeled according to strict standards. For example, for a lined jacket, the outer shell fabric and the inner lining fabric must be arc tested together to accurately measure the arc rating provided by the combined fabrics.

There are generally two categories of fabrics available:

- Inherently flame resistant fabric and
- Flame retardant treated fabric

Flame retardant treated fabrics go through the entire textile manufacturing process, and then the finished rolls of fabric are treated with chemicals that impart flame resistant properties into the material. Indura and Indura UltraSoft manufactured by Westex are examples of well known treated fabrics.

Inherently flame resistant fabrics are manufactured by incorporating inherently flame resistant fibers into the knit or weave of the fabric during the textile manufacturing process. FRMC and Nomex are examples of inherently flame resistant fabrics.

The manufacturers of FR fabric guarantee the FR characteristics for the useful life of the garment. Some of the most popular FR fabrics on the market are described in the following pages, with information on wearlife and unique characteristics.

FR Modacrylic Cotton (FRMC)

FR Modacrylic Cotton is a trademark name for inherently flame resistant fabrics manufactured from a blend of FR Modacrylic and Cotton. FRMC is an inherently flame resistant fabric, a characteristic that cannot be degraded through laundering. It is normally perceived as the softest, most comfortable and most breathable FR fabrics.

FRMC is available in knit and woven fabrics in a variety of colors and weights. It has an expected wearlife of 18 to 30 months when worn and home laundered once per week. FRMC fabrics include Modacrylic Cotton by ITI, FireWear by Springfield LLC and Valzon by Westex.

Indura

Indura is a Westex, Inc. trademark for FR 100% cotton fabrics made flame resistant through an ammonia cure process. The process has only a minor affect on the positive characteristics of cotton (soft hand, wear, breathability and shrinkage). The ammonia cure process is guaranteed by Westex to ensure compliance with ASTM F1506 for the life of the garment. Indura is available in woven fabrics in a variety of colors. You should expect an Indura garment to last 12 to 18 months when worn and home laundered once per week.

Nomex IIIa

Nomex IIIa is a DuPont trademark for 93% Nomex (an aramid fiber), 5% Kevlar and 2% static dissipative fiber fabric. It is inherently flame resistant, a characteristic that cannot be degraded by laundering. Nomex IIIa was the FR Industry Standard, but is being replaced by fabrics and blends that offer similar protection and superior comfort characteristics. Nomex has an expected wearlife of 36-60 months making it a top choice for laundry programs.

Protera

Protera is a DuPont trademark for an inherently flame resistant fabric. Launched in 2006, it is generally lighter in weight for the level of protection it offers. Available in several weights and colors, it generally offers a more wrinkle-resistant appearance after laundering, but is not known for breathability. Protera has an expected wearlife of 24 – 36 months when worn and home laundered once per week.

Indura Ultra Soft

Ultra Soft is a Westex, Inc. trademark for an 88% Cotton/12% High Tenacity Nylon blend made flame resistant through an ammonia cure process. Additionally, the UltraSoft finish gives the fabric a soft hand for comfort. Similar to Indura in most aspects, Ultra Soft wears approximately 50% longer and costs only marginally more. The ammonia cure process is guaranteed by Westex to ensure compliance with ASTM F1506 for the life of the garment. UltraSoft is available in

woven fabrics in a variety of colors. You should expect an UltraSoft garment to last 24 to 42 months when worn and home laundered once per week.

Bringing it all Together: Worker Safety

The introduction of OSHA 1910.269 led the way as the first significant federal law that established a framework for worker protective apparel. It was clearly just the beginning of the development of standards designed to protect workers exposed to arc flash and flash fire hazards.

In the past five years alone, there have been significant changes to the standards that impact both worker safety and protective clothing. And, there is a recognition that these safety standards are here to stay.

Implementing a safety apparel program is becoming a de facto standard to protect workers exposed to the risks associated with flash fire and arc flash hazards. Continuous innovation and improvement in fabrics as a direct result of the growth has had a positive impact on the industry, with a gradual increase in the style and selection of garments available.

Companies that offer their employees choice – with employees able to select products from among many that have the appearance of 'everyday' workwear will have the buy-in necessary from employees to ensure worker compliance.

The stakes could not be higher: worker safety and the prevention of injury and fatalities. In the end, the tremendous investment in both time and money made to develop the standards and the investment made by companies in implementing the standards will all be worth it - by saving lives.

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Footnotes

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2 "2006 Survey of Occupational Injuries and Illnesses Summary Estimates Charts Package," Bureau of Labor Statistics, October, 2007, p. 1.

3 "Health Implications of Global Electrification." p. 88.

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12 Ibid.

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