White Paper

INDURA® Ultra Soft® Flame Resistant
NFPA 70E Daily Wear Clothing Program

Vs.

Non-FR 100% Cotton NFPA 70E
“HRC 0” Daily Wear with a Task Based PPE Program

Executive Summary

The NFPA 70E Standard *(Standard for Electrical Safety in the Workplace)* has heightened the awareness in nearly all industries of the electric arc flash hazard. While the arc flash itself can cause serious burns, the most devastating burns are usually caused by the victim's flammable clothing igniting and continuing to burn. It is widely understood that clothing made from non-flame resistant synthetic fabrics, such as polyester, nylon and polyester/cotton blends, are not appropriate when working on or near electrically energized parts and equipment. If these garments are exposed to an electric arc flash they can ignite, melt & drip, which can lead to severe contact burns to the skin. However, many people still consider non-flame resistant 100% cotton fabrics to be safer in an electric arc flash. In fact, the NFPA 70E standard allows non-FR cotton and other natural fibers for exposures levels of 2 cal/cm^2 or less (HRC 0). However, it is important to recognize the fact that 100% cotton pants are commonly manufactured using polyester/ cotton blend pocketing fabrics.

Although the majority of companies complying with 70E have implemented full FR daily wear clothing programs, cost or other considerations have caused some to opt for non-FR 100% cotton (HRC 0) programs for daily wear, with one FR coverall per employee. While the initial cost of 100% cotton is lower than flame resistant clothing, the latest generations of flame resistant fabrics, such as INDURA Ultra Soft, provide a longer garment wear life which should be carefully considered when calculating the overall life cycle cost of a garment. In addition, while flash studies may have determined that many of the typical job tasks calculate energies below 2 cal/cm^2 (HRC 0), we urge you to consider the many variables that could occur causing 100% cotton to ignite, leading to catastrophic or fatal burn injury.

The purpose of this white paper is to demonstrate the following:

1). Since INDURA® Ultra Soft® flame resistant fabrics have a proven history of providing 2 times more wear life than durable press 100% cotton, the overall savings of an HRC 0 clothing program vs. an Ultra Soft® program is minimal. Furthermore, when you add an FR coverall (PPE) for HRC 1 & 2 tasks, there may not be any savings at all.

2). The comfort of INDURA Ultra Soft is equivalent to like weights of 100% cotton.

3). The safety issues associated with relying on non-FR 100% cotton for *any level* of arc flash protection should be carefully analyzed before a purchasing decision is made.

Overall Value Equation

INDURA Ultra Soft apparel is expected to offer a service life of at least double that of 100% durable press cotton. The best evidence we can offer to support this information can be provided by professional industrial laundry companies and end-users in the electric utility industry. We strongly encourage you to contact a large industrial laundry company for quotations of a non-FR cotton "5-change" program as compared to a "5-change" INDURA Ultra Soft program. These companies have hundreds of thousands of garments of each in rental programs; therefore the rental industry has to have both confidence and evidence of garment service life of each to quote rental prices.

Please note, Westex does not manufacture or price garments; therefore the illustrations we've provided below reflect estimated comparative garment prices to highlight the overall cost of an HRC 0 program vs. an Ultra Soft® program. We have prepared the following example using estimated cost comparisons at similar ratios of non-FR cotton vs. INDURA Ultra Soft. This example has been over-simplified to illustrate the basic cost of a 2-year program.

Non-FR Cotton Durable Press Apparel

5 long sleeve shirts @ 12.00 each

5 pair pants @ 14.00 each

Yearly garment cost per employee

1000 employee program base costs
00
Replacement cost- Year 2
00

*** Task Based PPE Coverall**
$50,000

Expected Two-Year Program
$310,000
for 1,000 employees

Expected Price Per Employee/ Per Year
$155.00

Please note, the overall cost of a clothing program is subject to numerous variables such as percentage of employee turnover, lost & damaged garments and other administrative factors that will impact the overall costs of these programs. This chart was **over-simplified** to clearly illustrate the fact that there is a minimal difference in the overall cost of a comparable daily wear plan using INDURA Ultra Soft vs. a non-FR cotton system with a task based PPE program.

INDURA® Ultra Soft® Apparel

5 long sleeve shirts @ 30.00 each
$150.00
5 pair pants @ 35.00.00 each
$175.00

First year garment cost per employee
$325
1000 employee program base costs
$325,000
Replacement cost- Year 2
$0

*** Task Based PPE coverall**
$0

Expected Two-Year Program
$325,000
for 1,000 employees

Expected Price Per Employee/ Per Year
$162.50

Please note, the overall cost of a clothing program is subject to numerous variables such as percentage of employee turnover, lost & damaged garments and other administrative

*Some job tasks would call for PPE (FR coverall) to be worn at the appropriate time. In an FR daily wear program an additional FR "PPE" coverall would not be needed, further reducing the cost differential between a non-FR 100% cotton program and an INDURA Ultra Soft program. The approximate cost for 1,000 FR coveralls (for 1,000 workers) is $50.00 per coverall, which adds $50,000 of cost to a non-FR cotton program.

The dramatic gains in the service life of newer generations of flame resistant fabrics, such as INDURA Ultra Soft, has helped close the gap in the overall cost of a 100% cotton compared to an FR daily wear program. Although there will probably still be a slight premium for INDURA Ultra Soft, additional savings will be realized because an FR "task based" coverall will not be required, not to mention the indirect costs associated with lost work time to put-on and take-off these garments to conduct these tasks. In the unlikely event there is any savings left after adding these tangible and intangible costs into the equation, the additional risks and potential costs of a catastrophic injury or death due to garment ignition should be carefully considered.

Comfort

The comfort of an INDURA Ultra Soft apparel program is very similar to a 100% cotton durable press program. They're both appealing in any geographic climate and they offer the sought after comfort of cotton. The measurable comfort characteristics such as moisture regain, breathability and hand are very similar to each other. The weights of the pant and coverall fabrics are similar to one another as well. The only difference may be in the weight of the shirt fabrics. The typical weight of a 100% cotton durable press shirt is approximately 6oz per square yard. The most popular INDURA Ultra Soft shirt fabric for NFPA 70E compliance is 7oz (Style 301) because it offers excellent comfort along with HRC 0, 1 and 2 compliance. One additional once per square yard of weight shouldn't translate into any measurable difference in comfort. However, if a very light weight fabric is preferred for use in hot and humid conditions, INDURA Ultra Soft is also offered in a 5.5oz weight (Styles 341 & 331). These products only meet HRC 0 and 1, not HRC 2, but like all INDURA Ultra Soft garments they are fully flame resistant;; therefore, they will self-extinguish when the source of ignition is removed avoiding the potentially catastrophic situation of ignition and continued burning.

Protection

An INDURA Ultra Soft daily wear program can help alleviate critical risks associated with selection of non-FR cotton in this work environment. There are really four basic issues with relying on 100% non-FR cotton to provide any level of protection from electric arc flash (even when predicated incident energies are very low). Several of them are tied to the ASTM lab procedures, which lack several critical real-world aspects. These issues are highlighted in detail below:

Risk Potential of 100% Non-FR Cotton "HRC 0" Programs

Risk #1) Lab Arcs vs. Real World Arcs.

The Kinectrics lab arcs are designed to be as repeatable and controllable as possible, which is wise and necessary for any scientific procedure. However, they DO NOT ACCURATELY REPRODUCE real arcs in the industrial workplace, and the key areas of difference are potentially fatal to wearers of non-FR garments. The areas of concern are molten metal, arc movement and directionality.

Molten Metal

The ASTM equipment, when arcing, releases very little molten metal, because the arc gap is large, the electrodes don't have nearly the mass of metal present in most industrial equipment, and the wire which runs the gap is very, very thin. Why does any of this matter? Because non-FR garments ignite at temperatures of 450-750F, and molten metal is typically over 1,900F. Thus, even when the arc energy itself has been calculated to be below ignition thresholds, molten metal can cause point source ignition of non-FR fabrics, which could quickly spread to the entire garment.

Arc Movement

Ignition thresholds were calculated with the fabrics 12 inches from an arc which was essentially fixed in space by a Faraday cage. The arcs in the lab "stay home," which is sensible and necessary. But arcs in the real world can and do 'wander.' Many videos show "arc plasma balls" moving around and even project many feet outward with the cycle pulses. Now a 1.1 cal exposure at 18 inches might be 7 cals at 2 inches, because the arc has traveled outward from the equipment, causing garment ignition, and catastrophic injury or death.

Directionality

ASTM arcs used to calculate ignition thresholds are open air arcs. That is, they occur in space between two vertical electrodes, with no confinement of any kind; thus, they dissipate energy 360 degrees spherically. However, virtually all 70E style industrial arcs occur in equipment (disconnects, panel board, meters, transformers, MCCs, etc), all of which restrict the arc in one or more planes. This means virtually all industrial arcs will concentrate all their energy in only half the space (180 degrees) or less. The arc can't go back through the gear and the wall. Additionally, most of the live wiring in this equipment is recessed several inches or more in a box; further focusing the arc flash radiant energy and molten metal. Open panel doors, walls, ceilings floors and, of course, the worker all further restrict where arc energy can dissipate. All of this means more energy is concentrated in a smaller space with industrial arcs than with the lab arcs which predict ignition thresholds; the worker is unfortunately usually directly in the barrel of this focused energy.

Risk #2) Ignition Threshold Data for Non-FR Garments.

The lab work defining "safe" energies for non-FR cotton was conducted on new garments. In real life, workers' garments are only new until the first job is underway. This leads to three significant factors which can each seriously negatively impact ignition threshold: ignition points, flammable contaminants and fabric softeners.

Ignition Points

100% cotton garments can fray and get "fuzzier" over time. These areas can serve as ignition points and trigger garment ignition at much lower energies. In non-FR garments, once garment ignition occurs it will support combustion and quickly spread to areas beyond the initial ignition point, which can result in catastrophic injuries or death.

Flammable Contaminants

In use, a significant percentage of electricians and maintenance workers can be expected to at least occasionally get flammable contaminants on their garments. These flammable contaminants will burn in an arc regardless of whether the base fabric is FR or non-FR. However, on a non-FR garment the contaminated areas will support combustion of the rest of the garment, causing severe burn injury; conversely, an FR garment will limit fire and burn injury to the immediate area of the contaminant.

Fabric Softeners

Fabric softeners are commonplace on non-FR garments; most are flammable. Like other workplace contaminants noted above, this home-introduced contaminant will, over time, help "jump-start" ignition of non FR garments, potentially causing ignition well below predicted levels.

Risk #3) User Error

All HRC calculations involve human interpretation and input. Most of the variables are clear and independent, but several require a person to create a number. Two of these can radically change an incident energy number from one which probably won't cause ignition to one that will; they are distance and cycle time.

Work Distance

Work distance, the distance to the torso of the worker, is created by the person conducting the analysis. Energy is inversely proportional to distance, and asymptotic. Thus, getting a little closer raises energy a lot, especially inside 15." So, a non-representative outcome can be created by inputting an unrealistic work distance. The average actual work distance is certainly less than 18"; to generate the torque required to tighten or remove bolts, wires, etc, workers must gain leverage by bending their arms and using upper body weight. This puts significant body surface area, including the torso, much closer than 18". At some point during most industrial procedures, large portions of the worker's garment will spend time inside a zone where, should an arc occur, ignition will occur.

Also, the hands and a few inches of forearm should be gloved, but a non-FR garment sleeve will almost always be within inches of the arc even if the torso is 18" away. Sleeve ignition can quickly spread to the whole upper garment.

Cycle Time

Cycle time also plays a large role; as cycle times increase, so does incident energy. The problem here is that most people conducting hazard analysis will input the data for how rapidly a circuit is *supposed* to open after sensing a fault. However, breakers not regularly exercised, and many or most are not, often will not open as rapidly as specified. Every doubling of cycle time doubles incident energy, and a 2 cycle variable input during hazard analysis can become a 4 cycle arc, or worse, very easily. This could shift cotton to ignition quickly.

Operator Error

Operator errors also fall into this category. The circuit is supposed to be de-energized, but is live; the worker is supposed to stay 18" away but moves in to 8 for leverage, and so on. All of these are common occurrences, and any of these events can result in ignition of non-FR cotton where it had been predicted to be safe.

Risk #4) Equipment Failure

This one is the wild card category. **When the equipment fails, all assumptions which went into the hazard analysis fail with it**. If a breaker sticks, cycle times, and therefore energy, jump. If there's a current surge, fault current numbers are too low. If you're working on part x and part y fails next to it, your energy assumptions are invalid. Any of these examples, and many others, can increase incident energy beyond ignition thresholds very easily.

We all know that the more potential issues there are in any situation, the more likely it is one or more will occur; any single one of the above-noted noted issues which occurs in any given arc flash can easily cause garment ignition and catastrophic or fatal burn injury. Of course, these variables can pop up just as easily to a worker wearing FR clothing, but any "extra" injury caused by the unpredicted event will be limited to the immediate area of the incident, and probably limited in degree as well. Taken in total, there is really no situation, no matter what the calculated hazard is, in which you can be assured that 100% cotton won't ignite, continue to burn causing severe or fatal burn injury.

Issues to Consider when Evaluating FR Daily Wear vs. Task-Based FR Clothing

Compliance and worker safety can be achieved by both task-based and daily-wear approaches. However, the vast majority of companies currently in compliance with 70E do not trust task-based systems, instead specifying FR clothing as the only acceptable work uniform for employees and contractors working on or near energized electrical equipment. There are a number of reasons that this is the preferred best practice solution: productivity, liability and monitoring are usually the top three.

Productivity

The average worker will tackle many tasks in any given day, each with different hazard levels. If the worker is required to retrieve, put-on and take-off FR coveralls each time a given task demands it, the cost of these delays will easily exceed any additional cost of FR clothing over the course of a year. This situation is exacerbated when a worker faces tasks which can range across 3 or more hazard risk categories.

Liability

A task-based system burdens each individual worker with the decision of when to put on FR clothing, when it is safe to remove it, and who else in the vicinity may need to be excluded from the flash protection boundary or

required to wear FR clothing. Training each employee to this level is time consuming and expensive. In addition, the potential for inconsistent and inaccurate application of the rules is enormous. Workers who are asked to take this responsibility often either work much more slowly to be sure & safe, or cut corners to be fast & easy; clearly neither approach is desirable.

Monitoring

One of the OSHA requirements is that the employers monitor use of PPE. Thus, despite the employer doing everything else right, in a situation where a worker fails to wear the appropriate FR clothing, the company still can have issues for failing to monitor proper use. Thus, most corporate safety managers will not allow each individual worker to make dozens of decisions each week, out of sight or reach of supervision, any one of which could result in catastrophic injury or death and the attendant costs and morale issues. Furthermore, the company would have to mandate and monitor the use of only 100% cotton (or other natural fiber) daily wear clothing. This task is further complicated due to the fact that the majority of 100% cotton pants are made with polyester/ cotton blend pocketing.

Safety managers typically prefer a known to an unknown and a reduction of as many human error variables as possible. The simplest solution to the HRC dilemma is to specify flame resistant clothing as daily wear, and require all employees working on or near energized electrical equipment to report to work in FR. This best-practice approach ensures productivity stays high, liability is dramatically reduced and monitoring is almost automatic.

Catastrophic Arc Flash Incident Costs:

Arc flashes occur 5-10 times each day in the US, and result in severe burns to electricians an average of once every hour of a 40 hour work week; most of these severe burns (and fatalities) are the consequence of ignition of Non-FR clothing, *not the arc flash itself*. Burn injury is the second most costly hospitalization in the United States today, trailing only neo-natal ICU care. Burn units are isolation wards; burn treatment generally requires weeks or months in the hospital, and often multiple surgeries which can stretch for years. This type and duration of care is extremely expensive, and hospitalization is only one major cost of an arc flash burn injury. When a worker's garments ignite in an arc, resultant burn injury costs to the employer will be enormous. Conversely, if a worker in the same arc is wearing flame resistant clothing, which will not ignite, and will also insulate against the heat hazard, there will be little or no burn injury, and therefore relatively little or no cost. Many companies have concluded that any additional cost of an FR clothing program is more than paid back by avoidance of injury costs over time.

Major expenses aside from immediate hospital care will include insurance, worker's comp, fines and lawsuits. Other significant, but often overlooked costs include replacement of a highly trained electrician or maintenance worker, productivity of the crew for at least several weeks post-accident, and reserve funds, which often equal or exceed the direct costs. OSHA's current *NFPA 70E and Electrical Safe Work Practices* presentation

states that the cost of arc flash burn injuries to the employer is now between 1 and 3 million dollars per incident, with a few exceeding 6 million dollars. A company who avoids these costs even once in a 10 year period may be able to pay for any FR "premium" many times over. Initial and life cycle garment costs are very important, but are only part of the true total uniform cost equation when workers are potentially exposed to electric arc flash.

Summary

It is very important to fully consider the entire picture before making a decision to "upgrade" the safety of a clothing program by switching from poly/cotton blend garments to 100% cotton. It is widely understood that clothing made from non-flame resistant synthetic fabrics, such as polyester, nylon and polyester/cotton blends, are not appropriate when working on or near electrically energized parts and equipment. If these garments are exposed to an electric arc flash they can ignite, melt & drip, which can lead to severe contact burns to the skin. This is why NFPA 70E specifically prohibits this type of clothing. However, many people still consider 100% non-flame resistant cotton fabrics to be safer in an electric arc flash. The only thing safer about 100% cotton is that it does not contain a meltable component; it can ignite just as readily in an arc flash and, once ignited, will continue to burn. In fact, cotton fabrics can present a larger hazard once ignited because they burn hotter than poly/cotton and are generally worn in slightly heavier weights, which means more fuel for the fire. Once ignition occurs, more fuel and a hotter fire combine to cause severe burn injury.

The dramatic gains in the wear life of newer generations of flame resistant fabrics, such as INDURA Ultra Soft, has helped close the gap in the overall cost of a 100% cotton compared to an FR daily wear program. Although there will probably still be a slight premium for INDURA Ultra Soft, additional savings will be realized because an FR "task based" coverall will not be required not to mention the indirect costs associated with lost work time to put-on and take-off these garments to conduct these tasks. If there is any savings left after adding these issues into the equation, the additional risks and potential costs of a catastrophic injury or death due to garment ignition should be carefully considered. To date, the majority of companies that have implemented NFPA 70E compliant programs have opted for FR daily wear (specifically INDURA Ultra Soft HRC 2 programs), largely due to the issues highlighted in this white paper.

Please do not hesitate to contact Westex at (866) 493-7839 if you have any questions or if we can provide any assistance.

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