



## White Paper

# Amplitude™ Cotton/Nylon Protective Apparel Fabrics for NFPA 70E and NFPA 2112 Compliance

### Objective:

This white paper is intended to educate the reader regarding Milliken's new flame resistant cotton/nylon-blended Amplitude™ fabrics. It will also address key factors that are important to consider when selecting FR fabrics for National Fire Protection Association (NFPA) 70E and NFPA 2112 compliance.



**MILLIKEN®**

**2008**

Please Note: Amplitude fabrics are innovative, high-tech, flame resistant materials intended to be used in garments that supplement personal protective equipment that reduce the flammability risks of momentary exposure to electric arc flash and flash fire hazards. It is not intended for use in fire fighting garments or other products subject to repeated or extended exposure to heat or flame. Use caution near sources of flame or intense heat and do not launder with bleach or fabric softeners. As each customer's use of our product may be different, information we provide, including without limitation, recommendations, test results, samples, care/labeling/processing instructions or marketing advice, is provided in good faith but without warranty and without accepting any responsibility/liability. Each customer must test and be responsible for its own specific use, further processing, labeling, marketing, etc. All sales are exclusively subject to our standard terms of sale posted at [www.milliken.com/terms](http://www.milliken.com/terms) (all additional/different terms are rejected) unless explicitly agreed otherwise in a signed writing.

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## Executive Summary

*Milliken introduces Amplitude™, a new line of crossover FR fabrics that meet the market needs for both NFPA 70E arc flash and NFPA 2112 flash fire compliance.*

*Milliken's new FR process is a proprietary ammonia-free process that offers unique product advantages.*

Worker safety is top priority for employers. Personal protective equipment (PPE) including safety apparel is the “life-saving device” worn everyday for flame resistant (FR) protection. FR apparel is worn in manufacturing, maintenance, electrical, utility, oil and petrochemical, chemical, and other work environments to reduce the flammability risks of exposure to electric arc flash and flash fire hazards. These hazards can cause severe or fatal burns that can often be reduced or prevented through the proper use of flame resistant PPE.

Milliken & Company® entered the protective workwear fabrics market in 2003 with the launch of CXP®, a uniquely comfortable inherent FR fabric for the NFPA 2112 flash fire market. Recently, Milliken launched a line of fabrics that serve as crossover products, meeting the market needs for both NFPA 70E arc flash and NFPA 2112 flash fire compliance. Milliken is promoting this new line of fabrics under the Amplitude™ brand name.

Milliken is recognized as a leading producer of U.S. Military FR fabrics and FR bedding for the consumer market under the Paladin™ brand. This coupled with the fact that Milliken is also widely recognized as the U.S. manufacturer of choice for high-quality workwear fabrics positions Milliken to become a leader in the FR workwear market.

Milliken is a vertical manufacturer that has a team of more than 40 research scientists and engineers, and over 70 research technical associates that support the development of innovative, consistent high-quality products. Fabric engineering, chemical and process technology, and manufacturing process control are important drivers that help determine FR performance, fabric comfort, durability, and the total cost of garment ownership. *Milliken's new FR process is a proprietary **ammonia-free process** that offers unique product advantages.*

## Introduction

Over the last 25 years, government and industry safety leaders have recognized the importance of flame resistant protective apparel. These groups have developed standards that help drive awareness of the importance of FR protection against burns when workers are exposed to electrical arc and flash fire hazards. Textile and apparel companies have addressed the need for FR protective apparel in several ways:

1. Use of inherent flame resistant materials (e.g. meta-aramids)
2. Blends of inherent fibers with cellulose
3. Durable chemical treatments of cotton rich fabrics



A recent study of fabrics used for NFPA 2112 compliance in the U.S. conducted by Milliken demonstrates that inherent FR fabrics have the largest market share, but that this market share is declining. Additionally, NFPA 70E compliance is most often attained by using cotton-rich fabric blends that have been chemically treated. Performance to industry standards, comfort, cost and durability must be considered for each specific garment end use. Milliken has bridged the gap with the launch of Amplitude™, offering the wearer comfort and NFPA 70E and NFPA 2112 compliance.



## FR Regulations and Standards

Section 5(a)(1) of the Occupational Safety and Health Act (OSHA), also known as the General Duty Clause, addresses situations where individuals are exposed to hazards on the job. According to the regulation, "Where a recognized hazard exists, such as exposure to electrical arc or flash fire, the employer must take reasonable measures to mitigate that risk." Further, OSHA standards set forth in 29 CFR part 1910 subpart S specifically relate to electrical hazards and safeguards for personnel protection (1910.335).

OSHA recommends that consensus standards such as NFPA 70E-2004 be used as guides in hazard analysis and selecting control measures. The NFPA 70E-2004 standard addresses electrical safety in the workplace and states that "employees shall wear FR clothing wherever there is possible exposure to an electric arc flash above the threshold incident level for a second degree burn." The standard also refers to ASTM 1506-02a regarding apparel which specifies vertical burn and electric arc testing.

Another consensus standard, NFPA 2112-2007, outlines the testing required for FR garments used in flash fire protection including vertical burn, thermal protective performance (TPP), thermal shrinkage resistance, heat resistance and flash fire manikin testing.

*Milliken is entering the marketplace with an internally developed, non-ammoniated, consistently durable FR technology for cotton/nylon and 100% cotton that is differentiated from the ammonia-cure process used by other manufacturers.*

## Technology and the Marketplace

Today the flame resistant market is largely divided between inherently FR products, such as those containing meta-aramid fibers like Nomex<sup>®</sup> by DuPont, and cotton/nylon durable treated FR products. Inherent FR products are often suitable for flash-fire exposure, while cotton/nylon durable treated FR products make up the majority of sales and rentals in the electric arc exposure category. They are also gaining share as protective apparel for the NFPA 2112 compliance. While there have been several new cotton/nylon FR fabric manufacturers who have entered the market in recent years, the last significant introduction was the FR treated ammonia-cured 88 percent / 12 percent cotton/nylon blend pioneered by ITEX in 1994 (ref US patent #5,468,545). Other subsequent 88/12 products have been introduced since 1994. Milliken entered the marketplace in 2008 with an internally developed, non-ammoniated, consistently durable FR technology for cotton/nylon and 100 percent cotton that is differentiated from the ammonia-cure process used by other manufacturers.



*External lab testing for arc flash conducted at Kinectrics in Ontario, Canada*

Recently, several different blends of inherent fibers and modacrylics have entered the market, but have been slow to gain significant market share. These products have been known to require higher initial upfront investments. As a result, industry leaders are looking for a cost-effective solution that offers high performance in both electric arc and flash fire protection, while delivering comfort and durability.

## Amplitude — a Milliken FR Technology

Milliken Research Corporation has been the growth engine of innovation and new technologies for the company. Milliken has accumulated over 2,200 issued patents through 2007 and won the “Textile Industries” Innovation Award in 2001. The technology behind Amplitude originated from scientists at Milliken Research Corporation who recognized the variability of the ammonia treatment process and developed a proprietary technology and processes that provide a better product. Today, Milliken Research Corporation continues that commitment to innovation and, by all accounts, is the largest textile research center in the world.

Employee talent and experience make up the foundation of Milliken’s research leadership. Milliken Research Corporation has more than 40 research scientists and engineers, including a large number of PhD

scientists from top universities. The scientists and engineers are experts in chemistry and physical testing and are equipped with high-tech analytical equipment.



*State-of-the art analytical testing equipment at Milliken's research laboratories*

*These scientific tools have been instrumental in developing FR and textile chemicals for highly desired FR fabrics.*

Milliken's state-of-the-art laboratories are more sophisticated than traditional textile testing lab set-ups. The Environmental Scanning Electron Microscope, for example, allows examination of textile materials under different environmental conditions (such as relative humidity and temperature) at very high magnifications. This is important for understanding fibers and fabrics on a molecular level and has enabled Milliken to design a fabric substrate that readily accepts and binds Milliken's proprietary FR chemistry through 100 industrial washings. Gas Chromatography-Mass Spectrometry (GC-MS), Inductively Coupled Plasma (ICP), Nuclear Magnetic Resonance (NMR), Infra-red Spectroscopy (IR), and Thermal Gravimetric Analysis (TGA) technologies allow Milliken scientists to study and understand different chemical processes at the molecular level. These scientific tools have been instrumental in developing FR and textile chemicals for highly desired FR fabrics.

Developing fabrics for flame resistance and fire protection have been key research initiatives at Milliken for a number of years. Milliken developed unique Nomex<sup>®</sup> flash fire protection uniform fabrics under the brand name CXP<sup>®</sup>. Additionally, Milliken provides the U.S. Armed Forces with fabrics that require stringent FR testing. Milliken has also become the leader in flame retardant bedding textiles (Paladin<sup>™</sup>) for consumer markets in the U.S. With a rich history of commitment and success in FR innovation in other markets, developing workwear fabrics for the NFPA 70E and NFPA 2112 markets is a natural evolution of transferring Milliken's FR research and expertise.

## Amplitude Basics

### ***Why not ammonia cure?***

As with any new market introduction, purchasers of new products look for a supplier that brings integrity and knowledge to the marketplace. However, any new product must be understood and put through the rigors of testing. This is especially important for products with such importance as personal protective equipment against electric arc and flash fire hazards.

In the beginning stages of Amplitude development, the widely used ammonia-cure process was analyzed and considered. In this particular process, it is critical to maintain a controlled fabric moisture level as fabric enters the ammonia chamber. This critical step is difficult to measure and control because there is no feedback on the degree of reaction inside the ammonia chamber. The reaction releases heat causing fabric temperature to rise, potentially affecting the fixation of the

chemistry. Uniformity of ammonia gas penetration into the fabric is also difficult to achieve in a reliable and consistent manner. For these and others reasons, Milliken developed a new technology minimizing these deficiencies through the design and engineering of Amplitude fabrics.

What resulted from the concentrated efforts of the research and development team is a unique ammonia-free process which uses Milliken-developed chemistry and proprietary processes. Amplitude fabrics are engineered with a cotton/nylon blend in 7oz. and 9oz. weights, with the addition of FR, comfort, and laundry performance advantages. The market can expect to see more from Milliken's FR team as additional Amplitude fabrics enter the late phases of development.



*Independent testing demonstrates Amplitude consistently delivers a higher degree of protection as compared to the industry required standards.*

### **Testing to verify performance**

Extensive testing of Amplitude fabrics has taken place at the Textile Protection and Comfort Center (TPACC) at North Carolina State University in Raleigh, NC. Instrumented manikin tests performed according to ASTM 1930-2000 showed that Amplitude fabrics resulted in body burn percentages below competitive cotton/nylon market products. Concurrently, testing was conducted at Kinectrics, Inc. in Toronto, Ontario, Canada on Amplitude fabrics according to ASTM 1959-2006. These tests showed that Amplitude fabrics outperformed current market products of the same weight with regard to the Arc Thermal Performance Value (ATPV). Amplitude fabrics met all test requirements outlined in NFPA 70E and NFPA 2112-2007.

## **Key Performance Drivers for an FR Fabric Manufacturer**

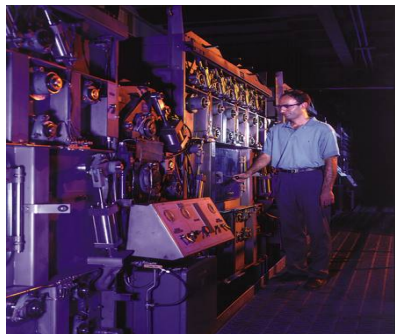
For years Milliken has been dedicated to eliminating process variation and delivering superior textile products to the market. State-of-the-art process control systems and automation allow Milliken to continuously collect process data. The use of advanced statistical analysis tools allow Milliken to analyze all aspects of process variation and the impact it has on product performance. The use of Six Sigma methodology helps Milliken to optimize manufacturing and reduce variation in the end product. This is vital for consistent fabric strength, fabric dyeing and flame resistant finishing. Over time, Milliken has demonstrated delivery of the lowest point counts in the workwear market.

### **Fabric Strength**

Fabric strength is key to improved garment durability. A quality product starts with quality materials. From the choices of cotton type and nylon properties to the method of spinning yarns and fabric formation, each decision along the way has an effect on strength and durability. Methods

of fabric preparation, dyeing, flame-retardant treatment and finishing processing can contribute to maintaining or degrading fabric strength. Amplitude fabrics start with some of the strongest available fibers which are engineered into ring-spun yarns and then woven fabrics. Subsequent processing is monitored and controlled to maximize the final product strength.

### ***Dyeing***



High-quality consistent fabric, proper desizing, and preparation techniques are important in reducing shade variation of fabrics before they are dyed. Dye selection is also vital to produce consistent, reproducible shades and to provide other desired properties such as wash- and light-fastness. Today, Milliken consistently provides “single-shade” performance for its customers by using Six Sigma methodology to consistently eliminate sources of shade variation in its manufacturing locations.

### ***FR Finishing***



The most important step in the production of an FR treated cotton rich product is the flame-retardant chemistry application. After all, this is the step that allows the cotton/nylon fabric to transform into something that can help protect and potentially save lives. It is also the step that can most affect the final product’s softness, strength and durability. Because a controlled, repeatable process is vital, Milliken research scientists developed the proprietary Amplitude treatment using Six Sigma methodology to refine all aspects of this process.

### ***Engineering Comfort***

The comfort of FR garments greatly influences an individual’s desire to wear them. FR garments can be stiff, hot and uncomfortable. Milliken’s expertise in the combination of textile chemistries and textile manufacturing has led to unique fabric properties. Workwear fabrics should have sufficient breathability and, when properly fitted, should allow a worker to move comfortably. Milliken has addressed these criteria with its Amplitude fabrics which offer a superior combination of softness and breathability without sacrificing FR performance. Stretch fabrics are also available with the same performance features as non-stretch Amplitude fabrics.

### ***Quality Control***

Milliken’s dedication to quality has garnered many prestigious awards worldwide. Milliken is one of the only companies in the United States to achieve both the Malcolm Baldrige National Quality Award and the Japan Institute of Plant Maintenance (JIPM) TPM Excellence Award, an esteemed award for Total Productive Maintenance. Milliken has been awarded with the Canadian Quality Award for achieving outstanding quality in physical, safety and social measures. Milliken has 54 separate

*Cutting-edge equipment at Milliken’s manufacturing locations.*

*Six Sigma methodology ensures high-quality products through controlled, repeatable, development processes.*

facilities that have received JIPM awards for TPM excellence and consistency, a sign of the company's operational excellence.



*NFPA 70E compliance  
end-use application for  
Milliken Amplitude*

Quality-control procedures are critical when it comes to FR fabric manufacturing. Developing and maintaining specific and consistent production procedures is essential. Milliken's quality-control team is experienced in the physical testing and the evaluation of FR performance for fabrics. Milliken is a vertical textile manufacturer, producing its own specially-engineered yarns and base fabrics for internal dyeing, FR chemistry application and testing.

In addition to FR protection, there are several key performance metrics where quality control is of utmost importance for protective garments. Shrinkage control and physical properties such as tear strength and the feel of the fabric are extremely important. These factors are created and controlled along multiple touch points throughout the manufacturing process. During carding, drawing and spinning to make the yarn, the effective use of statistical process control tools is essential to engineer a consistent, high strength yarn and fabric. The base fabric has been designed in such a way as to maximize both fabric strength and shrinkage reduction. Through the use of statistical process controls and defect root cause analysis, Milliken has engineered a base fabric with a consistently high level of quality. Once the fabric has been woven, it is ready for fabric preparation, dyeing, and FR finishing processes. Milliken has a unique product routing process through its manufacturing plants which imparts the characteristics of unparalleled performance in a cotton/nylon blended fabric.

## Safety

### *The Milliken Safety Story*

With safety as Milliken's number one core value, Milliken has 51 OSHA certified Volunteer Protection Program (VPP) STAR sites, the third largest in the nation. Qualification for the Voluntary Protection Program is not an easy task. An applicant must demonstrate management commitment to safety, assess hazards that may be present within their workplaces, maintain a system for hazard correction and control, provide employees with Safety & Health training, and assure employee participation in the Safety & Health program. Milliken teams have also been recognized by leading manufacturing and associations for their safety process and for the involvement of its associates in the safety process, including the National Safety Council, Chamber of Commerce and the American Private Trucking Association.

The safety and health of Milliken's employees is a true corporate value that is owned by each and every Milliken associate. Milliken was recently named one of the 17 Safest Companies in America by Occupational Hazards Magazine. For years, Milliken benchmarked the

safety leaders in the industry. Today, those same companies now benchmark Milliken. In 2007 Milliken launched a safety consulting business providing training services to companies, showing how to develop a culture that centers around employee safety. The Milliken Safety Process has two basic cornerstones: team development of an uncompromising safe environment, and the ingrained belief that all safety incidents can be prevented.

*“Milliken & Company is dedicated to the continuous improvement of all products and services through the total involvement of all associates. We will continually strive to provide innovative and high quality products and services that enhance our customers continued long-term profitable growth by understanding and exceeding their requirements and anticipating their future expectations.”*

— Roger Milliken

## Environmental

Milliken is committed to operating its plants and facilities in complete compliance with all applicable environmental regulations, and to operating in a manner that protects the quality of the environment and the health and safety of Milliken associates and the public. It is committed to achieve a goal of zero waste generation to all media including land, air and water. This goal guides the conduct of Milliken’s manufacturing operations, the development of new products, and the company’s interaction with suppliers and customers. Recycling of materials is an integral part of this on-going effort. Milliken has been named Environmental Champion by the U.S. Environmental Protection Agency (EPA). Being a truly good steward of the planet requires that you leave the world in a better condition than you found it. Finally, Milliken is a “carbon negative” company. As a corporate entity, it removes more carbon dioxide from the air in total that it produces.

## Summary

Milliken, a company that takes great pride in its safety performance and performance products, has developed a proprietary technology to produce high performance, durable fabrics for NFPA 70E and NFPA 2112 compliance. The new cotton/nylon fabrics, Amplitude, were launched commercially in 2008. Creating a superior FR fabric starts by having strong internal research and technical expertise targeted to solve the unfulfilled quality, comfort, laundering and FR performance needs of the market. Choosing the right FR fabric is a critical factor in determining the level of protection provided to the garment wearer. It is imperative that companies and organizations fully understand the fabric options that are available today before selecting the best FR protection for their associates.

Milliken has extensive experience developing, spinning, weaving, dyeing and finishing flame resistant fabrics. This experience has been instrumental in Milliken’s efforts to create a new cotton/nylon fabric with superior performance, quality, and comfort characteristics. Amplitude fabrics meet all tests outlined in NFPA 70E and NFPA 2112.



## About the Authors

**Mike Batson** earned his undergraduate business degree and an MBA from Clemson University, and also a Master of Science Degree in Textile Technology from the Institute of Textile Technology. He joined Milliken in 1993, working in a variety of manufacturing and business leadership positions, most recently as a market analyst for the Apparel & Specialty Fabrics Division. Mike led the development of the business plan and is leader of the market launch effort to promote Amplitude to the NFPA 70E and 2112 market segments.



**James Cliver** joined Milliken & Company in 1992 after receiving a Bachelor of Science degree in Textile Chemistry from Clemson University. James spent several years in Milliken's Dyeing and Finishing plants as a Process Improvement leader in color matching, shade control and testing before joining the Apparel & Specialty Fabrics Division's New Concept Team for leading edge research. James is currently focused on FR workwear fabric innovations and has two issued U.S. patents, including Milliken's Ensist™ technology.



**Dr. Shulong Li** received his PhD in Materials Science and Chemical Engineering from the University of Minnesota. He worked as a Postdoctoral Research Associate at the National Renewable Energy Laboratory. After joining Milliken & Company in 1994, Dr. Li has invented many successful new products and technologies, including Antimicrobial textiles and Digital Printing Technologies, and currently serves as an Innovation Lead in Milliken Research Corporation. Dr. Li has published seven articles and has 33 issued U.S. patents.



## About Milliken & Company

Founded in 1865, Milliken & Company is a privately held textile and chemical company that employs approximately 10,000 associates worldwide. Milliken operates nearly 50 manufacturing facilities in the U.S. and 7 other countries. Having over 2,200 patents issued, the company produces over 19,000 high performance products. To learn more about Milliken, please visit the company's web sites at [www.milliken.com](http://www.milliken.com) and at [www.millikenapparelfabrics.com](http://www.millikenapparelfabrics.com).

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