DUPONT™

Secondary Flame-Resistant Garments: A Guide to Help Improve Safety in Multi-Hazard Work Environments

Tyvek®

Tychem®

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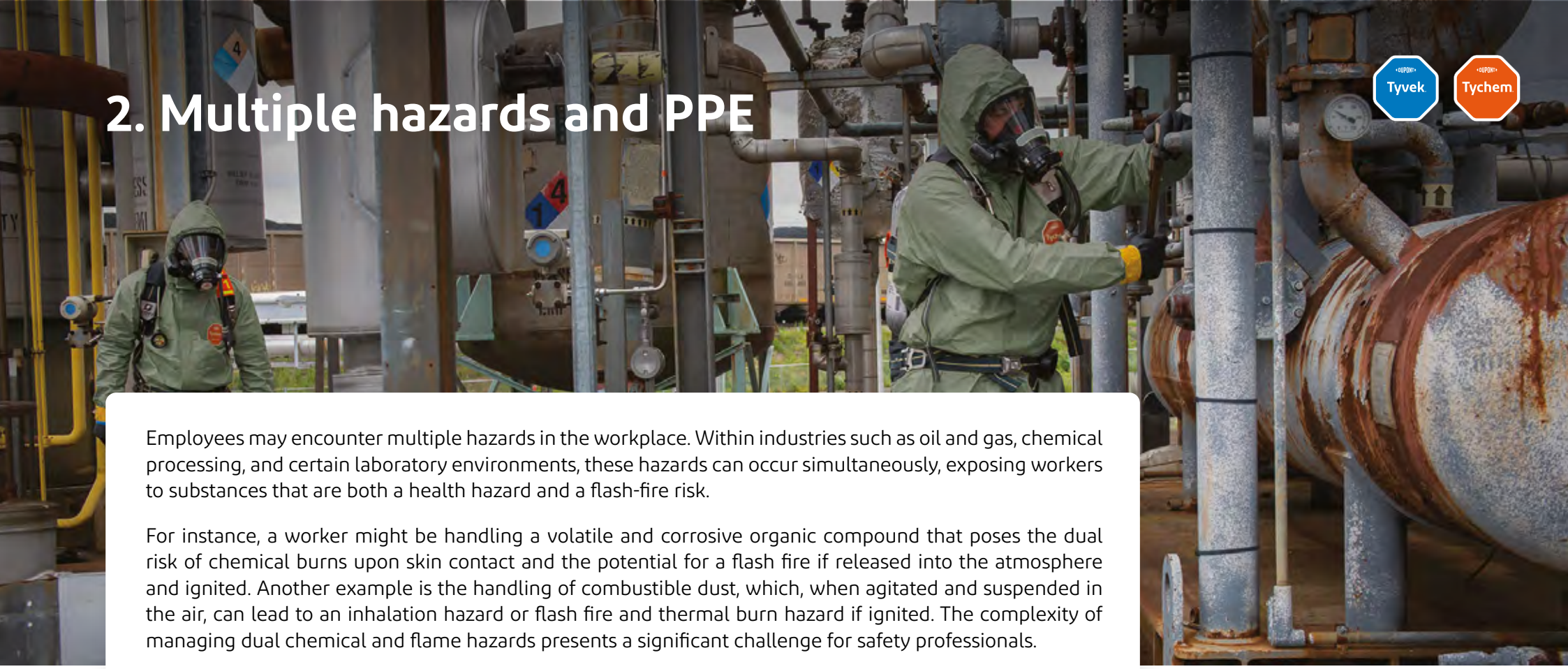
Content Overview

1. Introduction

The modern industrial workplace presents multiple safety challenges for industrial hygienists and safety managers tasked with providing adequate personal protective equipment (PPE). For example, chemical and flash-fire hazards often exist concurrently in applications ranging from refineries to research laboratories. Until recently, selecting the best protective garment meant deciding which hazard presented the greater risk and using that risk to determine the selection decision. Garments that could meet both needs and provide dual hazard protection simply did not exist.

The development of secondary flame-resistant (SFR) garments has been a game-changer. SFR garments are designed to be worn over primary flame-resistant (FR) garments as part of an ensemble. Their primary purpose is to protect the wearer from exposure to hazardous particulates and chemicals, without impacting or compromising the thermal protection offered by the primary FR garment. Worn in combination with primary FR clothing, SFR garments are capable of providing particulate and flash-fire protection, chemical and flash-fire protection, or both.

This eGuide explains the fabric and design developments behind this breakthrough and offers guidance to safety professionals regarding the correct application and selection of SFR garments as part of a comprehensive PPE ensemble.



2. Multiple hazards and PPE

Employees may encounter multiple hazards in the workplace. Within industries such as oil and gas, chemical processing, and certain laboratory environments, these hazards can occur simultaneously, exposing workers to substances that are both a health hazard and a flash-fire risk.

For instance, a worker might be handling a volatile and corrosive organic compound that poses the dual risk of chemical burns upon skin contact and the potential for a flash fire if released into the atmosphere and ignited. Another example is the handling of combustible dust, which, when agitated and suspended in the air, can lead to an inhalation hazard or flash fire and thermal burn hazard if ignited. The complexity of managing dual chemical and flame hazards presents a significant challenge for safety professionals.

The repercussions of insufficient protection are severe. According to the U.S. Bureau of Labor Statistics, during 2021-2022, there were 25,430 cases of nonfatal thermal burns involving days away from work, 1,650 linked to explosions or fires caused by the ignition of vapors, gases, or liquids. Additionally, chemical burns accounted for 7,480 nonfatal occupational injuries that resulted in days away from work[1]. These incidents not only negatively impact the individuals involved but also have indirect business and economic implications. The typical hospital stay for a burn patient lasts nine to ten days[2] at an estimated average cost of around $9,000 per day[3]. Injuries also impact productivity and morale in the workplace. These consequences underscore the vital role of personal protective equipment in protecting employees from workplace hazards, even though PPE is the last line of defense.

2.1 PPE evolution

Historically, PPE has been developed to address one specific hazard. Garment manufacturers have succeeded in creating chemical-resistant (CR) garments and flame-resistant (FR) garments to protect wearers from harm. However, this specialization raises some issues. Protective clothing for chemical hazards is often flammable, while clothing designed for fire hazards may offer little to no chemical protection. This creates a serious challenge in ensuring worker safety where multiple hazards exist.

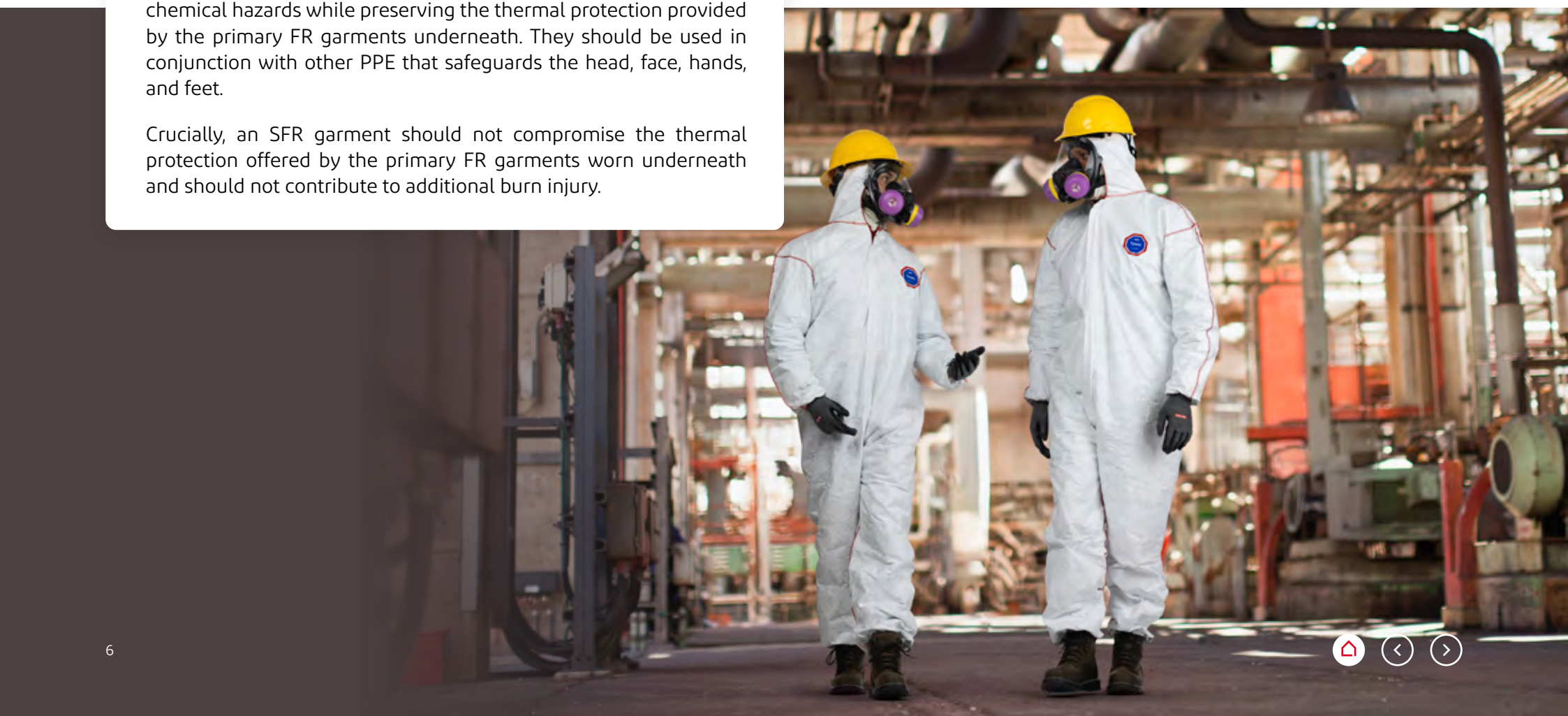
Traditional CR garments should not be worn over or under FR suits due to the risk of the CR material igniting or melting. For example, in a scenario where a flammable liquid is spilled and ignites, workers wearing only CR clothing would be at risk of their garments catching fire, potentially causing severe burns. Conversely, those wearing only FR clothing would be inadequately protected against chemical contact related to the spill itself, which could result in chemical burns or other negative health effects.

Garments offering secondary flame resistance have been developed to address this problem and provide multiple hazard protection.

3. What is SFR clothing?

Secondary flame-resistant (SFR) clothing meets the demand for protective garments that can protect workers from both chemical and flash-fire hazards. SFR garments are designed to be worn over primary FR garments, offering protection against particulate and/or chemical hazards while preserving the thermal protection provided by the primary FR garments underneath. They should be used in conjunction with other PPE that safeguards the head, face, hands, and feet.

Crucially, an SFR garment should not compromise the thermal protection offered by the primary FR garments worn underneath and should not contribute to additional burn injury.



3.1 Primary vs. Secondary FR

Understanding the distinction between primary and secondary flame-resistant garments is vital for correct deployment.

Primary FR garments are worn directly over cotton undergarments or regular work attire and provide the first layer of protection against burn injuries. Self-extinguishing and resistant to ignition and flame spread, they are made from materials that will not melt or drip when exposed to heat or flame, providing a thermal barrier and helping to reduce the severity of burns. Primary FR garments are suitable for use in environments where there is a risk of flash fires and are intended to provide the wearer with escape time from unintended fire exposure.

Secondary FR garments must never be used as the sole means of flash-fire protection if FR clothing is required based on hazard assessment. They are designed to be worn over primary FR clothing, typically in multi-hazard environments, to protect the wearer from harmful particulates and/or liquid chemicals. The purpose of SFR garments is to offer additional protection against particle or chemical hazards without compromising the flame-resistant properties of the underlying FR garments or creating an additional hazard to the wearer. SFR garments may also help keep the primary FR layer clean.

NAME-CHECK

SFR is not yet a widely known or accepted industry term. Other sources may refer to this type of clothing as CRFR (chemical-resistant and flame-resistant), CFR (chemical and flame-resistant), or CBFR (chemical barrier and flame-resistant).

You must read the product details carefully to understand the level of chemical protection and flame resistance the garment provides. If the information states that the garment must be worn over primary flame-resistant clothing, it is likely to be an SFR garment.

Chemical risk without fire

In an environment where FR clothing is not required, a secondary FR garment can be worn without primary FR clothing underneath if it provides adequate protection against the specified chemical or particulate hazard. For example, DuPont™ Tychem® 2000 SFR provides more than eight hours of permeation protection against sulfuric acid (95%). If no flash fire hazard is identified for the area or task, Tychem® 2000 SFR could therefore be worn without primary FR clothing underneath to protect against a sulfuric acid splash hazard.

4. SFR Selection

Selection of Personal Protective Equipment (PPE) is the responsibility of employers under OSHA 1910.132. Finding the best combination for protecting against dual flame and chemical hazards requires a systematic and thorough approach to ensure the safety and well-being of employees.

The first step is to conduct an activity hazard identification and risk assessment. This will identify the potential chemical and thermal hazards in the workplace and where they may arise in combination. A hazard risk assessment should always consider the characteristics of chemicals (like flash point, vapor density, auto ignition temperature, reactivity, etc.) and the likelihood of chemicals igniting or otherwise reacting when personnel are present. It should also identify exposure scenarios by considering factors such as quantities, concentrations, contact intensity, duration and frequency, and environmental conditions.

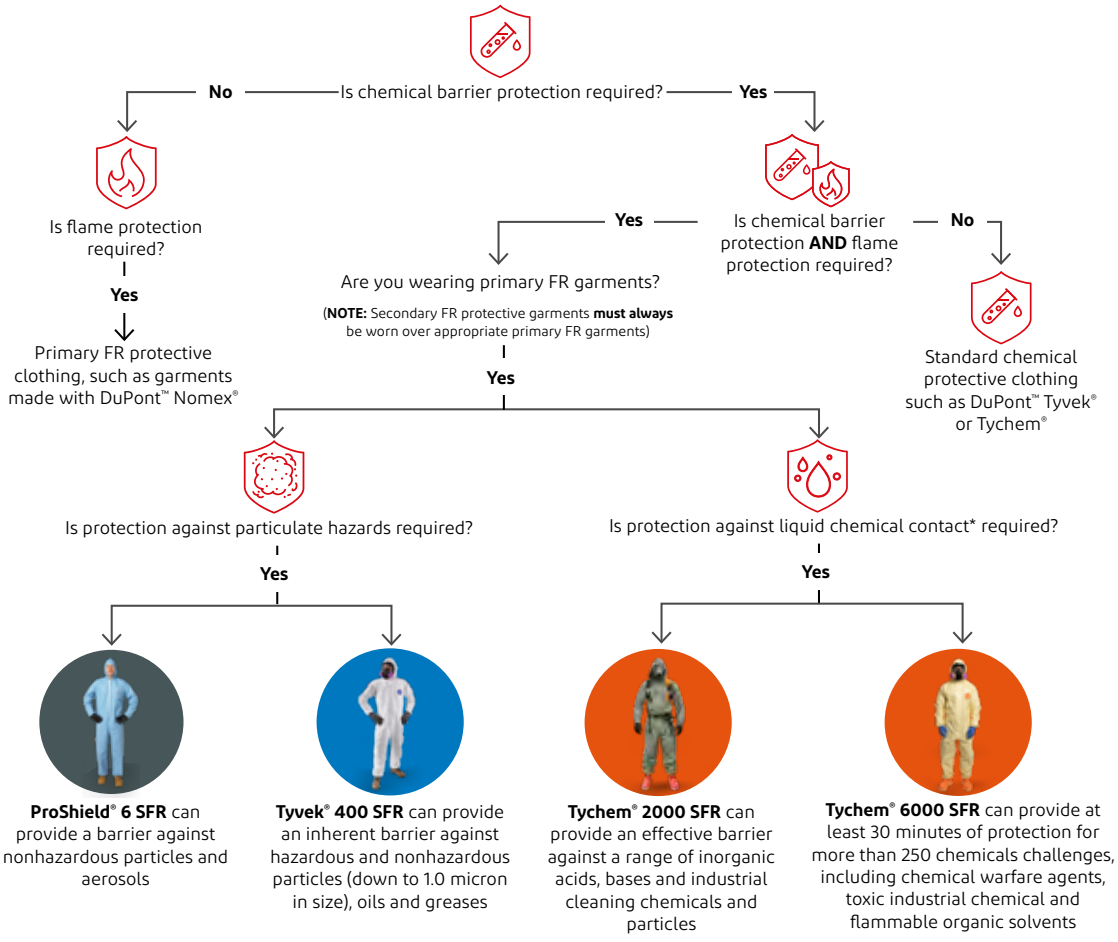
Safety professionals must then apply the hierarchy of controls to eliminate or reduce thermal and chemical exposure risks. These are arranged from the most to the least effective and include elimination, substitution, engineering controls, administrative controls and PPE[4]. PPE is the last line of defense and should be used when other controls are not feasible or will not eliminate the risks.

Both the FR requirements and the presence of hazardous and non-hazardous particles or liquid chemicals will influence SFR garment selection. Table 1 illustrates how to decide whether SFR garments should be deployed and which type, based on the hazard.

Table 1

Choosing appropriate protective garments based on hazard types

Determine when secondary flame-resistant (SFR) garments should be worn



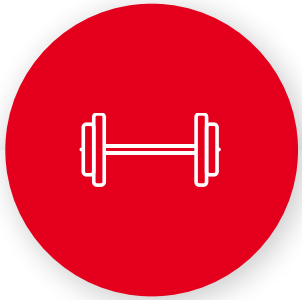
*Please check DuPont™ SafeSPEC™ for permeation data that meets your specific needs based on the hazards identified in your hazard assessment.

4.1 PPE considerations

Having identified the basic type of SFR garment required, several other important factors come into play, including:

Protection – first and foremost, the selected garments must provide adequate protection against the identified hazards.

Where thermal and chemical risks are present, this means the entire ensemble must work together without compromising the protection offered by individual components.



Durability – garments must be able to maintain their protective properties throughout the duration of the task.

For example, the material must not easily abrade, rip, or tear, and seams must be robust.

Comfort – freedom of movement is essential to enable workers to perform tasks effectively.

Feeling comfortable also boosts productivity and morale. SFR garments should fit comfortably over primary FR clothing. The potential for heat stress when wearing multiple layers is an additional consideration. More breathable fabrics may be beneficial, alongside regular breaks, hydration, and climate control (where possible).

Compliance - there are numerous standards to consider, depending on the type of risk (see Appendix 1). Safety professionals must verify the protection performance of FR and SFR garments with relevant data to ensure compliance. Chemical protection must also satisfy applicable compliance requirements.

4.2 Flame tests

SFR garments need to extinguish with little or no after-flame as soon as the flash-fire exposure ends. If the SFR garment continues to burn following flame exposure, it will increase body burn injury and decrease the chance of survival. It may also adversely affect the thermal performance of the primary FR garment. There are some small-scale lab-based standard test methods, such as the flammability test (ASTM D6413 or ASTM F1358), that can be used to assess the burning characteristics of the fabric. However, these tests do not account for whole-garment thermal performance. Full thermal performance can be evaluated by a garment engulfment test, such as using an instrumented thermal manikin, as specified in ASTM F1930. As the only standard that provides data about first-, second-, and third-degree burns and total body burn percentages, ASTM F1930 is the best means of determining an individual's chance of surviving a flash fire.

4.3 Penetration vs permeation data

Concerning chemical protection, understanding the difference between penetration and permeation data is particularly important in garment selection. The two most common test methods cited by manufacturers of chemical PPE are ASTM F739, Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact, and ASTM F903, Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids. While both are official ASTM test methodologies, they test different material properties.

Penetration tests are concerned with the bulk movement of a material through a pore, gap, or defect in the barrier fabric. Essentially, this is a qualitative visual assessment, not a quantitative measurement. It is more suitable for evaluating seams, closures, or interfaces in a garment or system, rather than the chemical barrier performance of the material itself.

Permeation tests use analytical techniques to detect chemicals at the molecular level and assess their absorption, diffusion, and desorption through a barrier material. Permeation is therefore the most sensitive test method to measure the barrier against liquid or gas and vapor phase chemicals quantitatively.

Permeation is the more rigorous test and represents the actual evaluation of a fabric's chemical resistance. Be sure to request permeation data when deciding which brand of SFR garment to specify when chemical protection is required.

5. Dedicated SFR garments

Understanding the mechanisms of chemical and thermal hazards helps safety professionals make informed decisions. It also helps garment manufacturers like DuPont develop better materials, fabrics, and garment designs that specifically address different hazard combinations and levels of risk. A range of SFR garments now exists to meet different chemical and flame hazard combinations encountered in applications including oil and gas production, chemical processing, environmental services, utilities, laboratories, and general manufacturing.

ProShield® 6 SFR combines secondary flame resistance with protection from non-hazardous particles, oils, and grease encountered in applications such as welding, maintenance, and general 'dirty' tasks. This lightweight, disposable overgarment is treated with flame retardant, so it won't ignite or continue to burn when exposed to a flame source. ProShield® 6 SFR is available in hooded and non-hooded options.

5. Dedicated SFR garments

Tyvek® 400 SFR is a lightweight but highly robust disposable SFR garment that provides an additional barrier against hazardous and non-hazardous particles, as well as oils and grease contamination. This SFR garment is made from DuPont's unique tough but breathable Tyvek® fabric, which has been treated to be flame-retardant. Its patent-pending design offers a relaxed fit and incorporates a diamond gusset crotch for enhanced mobility. Tyvek® 400 SFR is distinguishable from other Tyvek® garments by its red external stitched seams, zipper, and chest patch border, and is available in a variety of hooded and non-hooded coverall styles.

Tychem® 2000 SFR provides an effective barrier against a range of inorganic acids and bases, industrial cleaning chemicals, and hazardous and non-hazardous particles: a combination often encountered in refineries, petrochemical plants, and laboratories. Tychem® 2000 SFR coverall styles feature a respirator-fit hood with a covered elastic face opening and a chin flap with double-sided adhesive for a secure fit. Taped seams and a storm flap closure with double-sided adhesive tape help prevent chemical intrusion at the seams and zipper. Tychem® 2000 SFR is available in coverall, bib-overall & jacket combo, and sleeved apron designs.

Tychem® 6000 SFR provides at least 30 minutes of protection from more than 250 chemical challenges, including chemical warfare agents, toxic industrial chemicals, and flammable organic solvents. It has been developed to protect those working in extreme conditions, such as oil rig crews, chemical plant employees, and emergency responders, from the dual hazards of flash-fire and chemical exposure. Featuring several design elements to help enhance the garment's protection and fit, Tychem® 6000 SFR coveralls include a respirator-fit hood and a chin flap with double-sided adhesive, taped seams, a double storm flap closure with double-sided adhesive tape, and covered elastic at wrist and ankle openings.

5.2 Help with SFR garment selection

To help safety professionals with chemical protective clothing selection, including SFR garments, DuPont offers **SafeSPEC™**, a web-based tool and mobile app that can assist you in finding the most appropriate DuPont garments for your hazards. **DuPont™ SafeSPEC™** allows industrial hygienists and other safety professionals to search by industry or by hazard to identify the protective garments that match their requirements. This resource can also provide an excellent means of documenting garment selection decisions, helping to satisfy OSHA's PPE selection certification requirements (CFR 1910.132).

SafeSPEC™ is designed to simplify the PPE selection process by providing detailed information on the protective qualities of various garments against a wide range of chemical and thermal hazards. It also allows ready access to information, including the latest product details, technical datasheets, and a regularly updated permeation database[5].

DuPont™ SafeSPEC™

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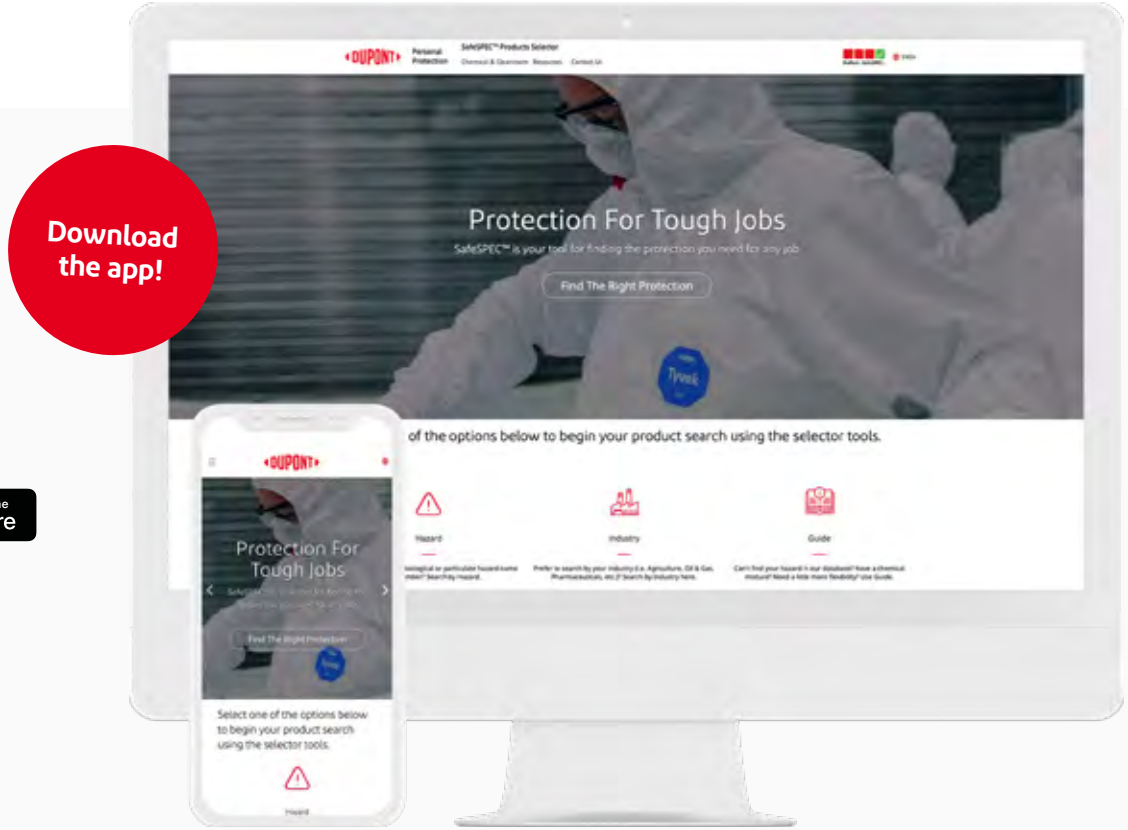
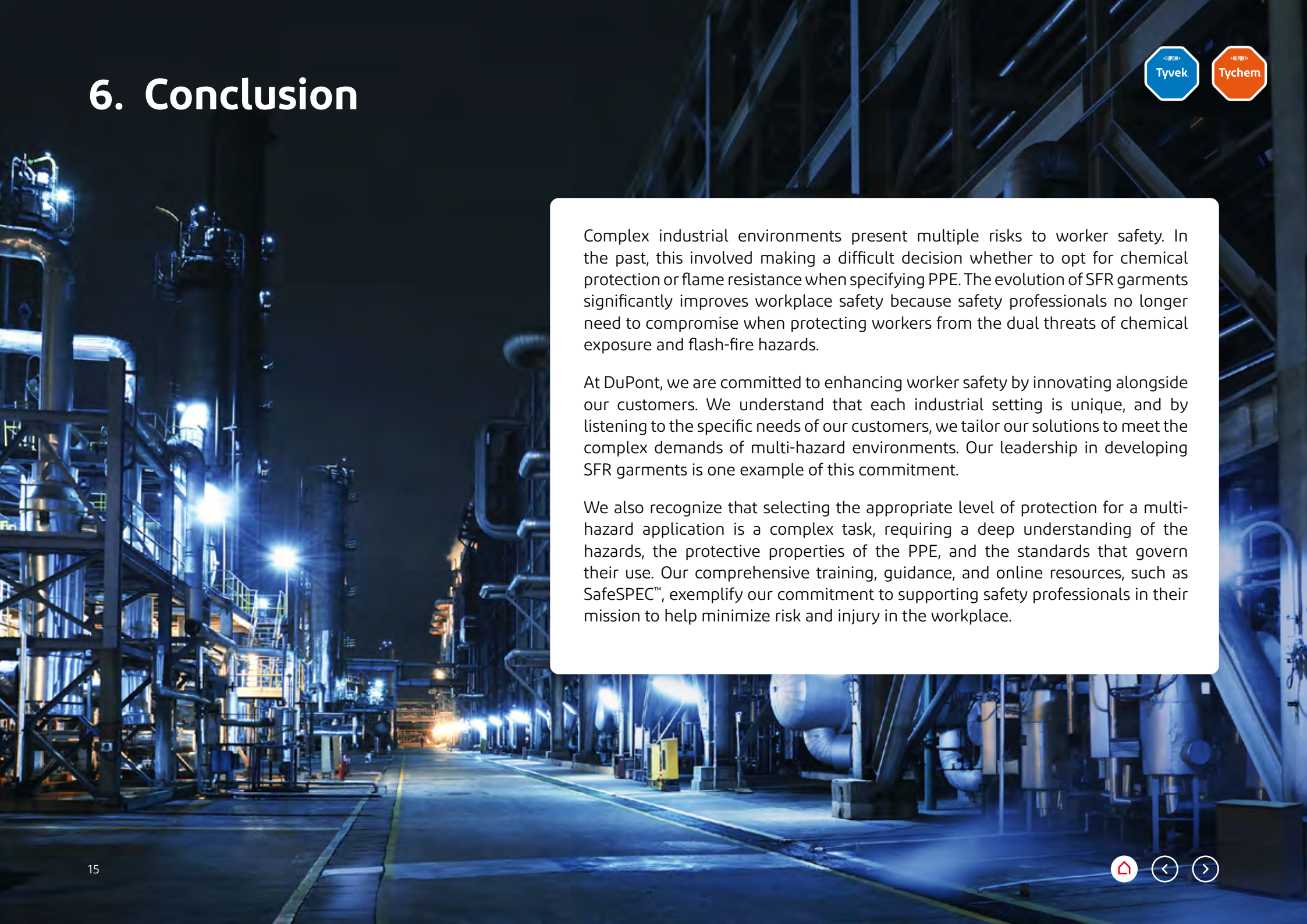


6. Conclusion



Complex industrial environments present multiple risks to worker safety. In the past, this involved making a difficult decision whether to opt for chemical protection or flame resistance when specifying PPE. The evolution of SFR garments significantly improves workplace safety because safety professionals no longer need to compromise when protecting workers from the dual threats of chemical exposure and flash-fire hazards.

At DuPont, we are committed to enhancing worker safety by innovating alongside our customers. We understand that each industrial setting is unique, and by listening to the specific needs of our customers, we tailor our solutions to meet the complex demands of multi-hazard environments. Our leadership in developing SFR garments is one example of this commitment.

We also recognize that selecting the appropriate level of protection for a multi-hazard application is a complex task, requiring a deep understanding of the hazards, the protective properties of the PPE, and the standards that govern their use. Our comprehensive training, guidance, and online resources, such as SafeSPEC™, exemplify our commitment to supporting safety professionals in their mission to help minimize risk and injury in the workplace.

References

1. Survey of Occupational Injuries and Illnesses Data: U.S. Bureau of Labor Statistics. Table R31.
2. American Burn Association, National Burn Repository 2019. Version 14.0.
3. *Journal of Burn Care & Research*, Volume 46, Issue Supplement_1, March/April 025, Page S187, https://doi.org/10.1093/jbcr/iraf019.242
4. OSHA Hierarchy of Controls guidance: https://www.osha.gov/sites/default/files/Hierarchy_of_Controls_02.01.23_form_508_2.pdf
5. DuPont™ SafeSPEC™ is available for download on Apple Store and Google Play Store.

Appendix 1- Main PPE Standards in the U.S.

Flame resistance:

- NFPA 2112 (2023) Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposure from Fire
  - Provides minimum requirements for the design, construction, evaluation, and certification of flame-resistant garments for use by industrial personnel.
- ASTM F1930 (2023) Standard Test Method for Evaluation of Flame-Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin
- ASTM D6413 (2022) Standard Test Method for Flame Resistance of Textiles (Vertical Test)
- ASTM F1358 (2020), Standard Test Method for Effects of Flame Impingement on Materials Used in Protective Clothing Not Designated Primarily for Flame Resistance
- ANSI/ISEA 203 (2018) American National Standard For Secondary Flame-Resistant Protection Clothing For Use Over Primary Flame-Resistant Clothing
  - Currently under revision

Chemical resistance:

- ASTM Method F739, Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact
- ASTM Method F903, Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids.

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NOTE: ProShield® 6 SFR, Tyvek® 400 SFR, Tychem® 2000 SFR and Tychem® 6000 SFR garments provide only secondary flame-resistant (SFR) protection. They must always be worn over appropriate primary flame-resistant protective clothing in an environment that needs flame protection, along with other personal protective equipment that protects your face, hands and feet. For SFR hooded garments, a primary flame-resistant hood/balaclava should be worn. Do not knowingly enter an environment in which the concentration of flammable gas is within flammable or explosive limits when wearing these garments. Retreat immediately if you encounter such an environment. SFR garments are not intended for firefighting activities, nor for protection from hot liquids, steam, molten metals, welding or thermal radiation.

This information is based upon technical data that DuPont believes to be reliable. It is subject to revision as additional knowledge and experience become available. It is the user's responsibility to determine the level of toxicity, and the proper personal protective equipment needed. The information set forth herein reflects laboratory performance of fabrics, not complete garments, under controlled conditions. This information is intended for use by persons having the technical expertise to undertake evaluation under their own specific end-use conditions, at their own discretion and risk. Anyone intending to use this information should first check that the garment selected is suitable for the intended use. The end-user should discontinue use of garment if fabric becomes torn, worn or punctured, to avoid potential chemical exposure. Since conditions of use are beyond our control, DUPONT DE NEMOURS, INC. AND ITS AFFILIATES MAKE NO WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE AND ASSUME NO LIABILITY IN CONNECTION WITH ANY USE OF THESE PRODUCTS AND INFORMATION. This information is not intended as a license to operate under or a recommendation to infringe any trademark, patent or technical information of DuPont or other persons covering any material or its use.