Tyvek® 400 SFR technical bulletin

A guide for employers and workers who require secondary flame resistance

According to OSHA, the oil and gas extraction and support industries employ over 450,000 workers who require specialized personal protective flame-resistant (FR) garment ensembles for protection against multiple hazards.[1] These workers face a combination of general safety and chemical hazards that are compounded by dangerous flammable conditions on the jobsite.

Primary and secondary flame-resistant (FR) garments

Despite efforts to engineer out these hazards, as recommended by OSHA's hierarchy of control,[2] some risks may persist—underscoring the importance of multi-hazard personal protective equipment (PPE) as a final safeguard.

According to industry standards,[3] FR garments typically fall into two categories that each serve a distinct purpose:

- **Primary FR garments**
  Protective clothing that's engineered to provide protection for the wearer from flame and thermal hazards.
- **Secondary FR garments**
  Protective clothing designed to be worn over primary FR clothing that enhances protection without compromising the effectiveness of the primary layer.

Secondary FR garments (like DuPont™ Tyvek® 400 SFR) should not be worn without primary FR garments underneath and should respond in a way that doesn't negatively impact the primary layer's performance when worn as an ensemble. Secondary FR garments should not continue to burn, melt, or drip once the exposure to fire ends.

Figure 1: Tyvek® 400 SFR garments must be worn over primary flame-resistant (FR) garments like those made with DuPont™ Nomex®.

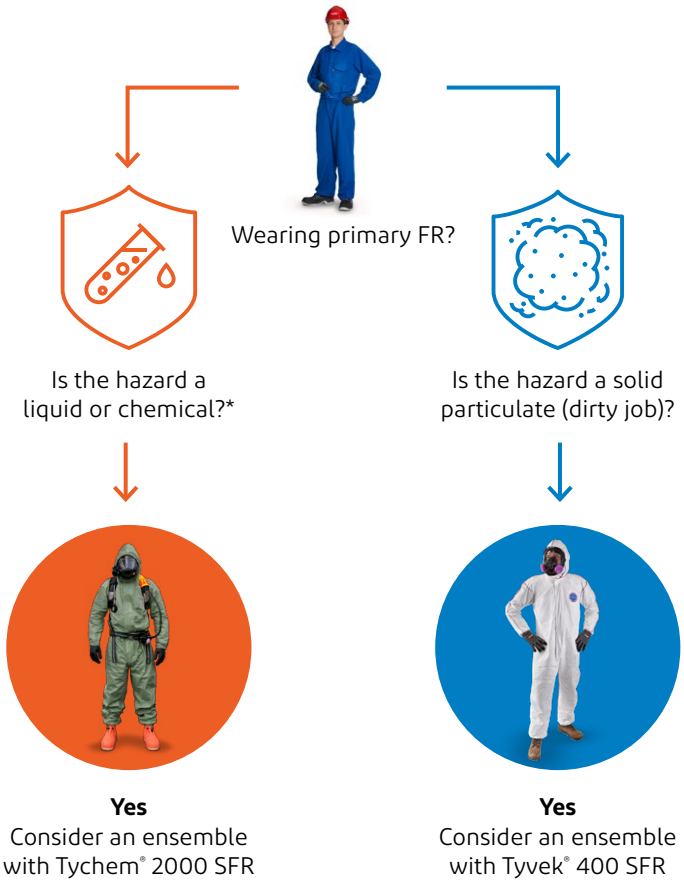
Secondary FR garment selection

When selecting a secondary FR protective garment, it is important to examine both the FR requirements and perform a hazard assessment for hazardous and nonhazardous particles, liquids, or chemicals. Overcoming these challenges without compromising safety may require a PPE ensemble of garments, gloves, balaclavas, etc.

While this technical bulletin focuses on Tyvek® 400 SFR performance, DuPont Personal Protection offers a portfolio of secondary FR garments to help meet customers' protection needs.

A basic decision tree (Figure 2) may be considered when performing a hazard assessment. Each SFR garment is intended to provide protection in a multi-hazard environment. Tychem® 2000 SFR is suitable for specified chemical hazards and liquid splash* while providing an effective barrier against a range of inorganic acids and bases as well as industrial cleaning chemicals. Liquid and chemical protection hazards* are best suited for Tychem® 2000 SFR. Tyvek® 400 SFR is suitable for specified particulate hazards while providing an inherent barrier against particles. Visit DuPont™ SafeSPEC™ to learn more about Tychem® 2000 SFR and Tyvek® 400 SFR garments and the specified hazards they help protect against.

Figure 2: SFR decision tree to consider when performing a hazard assessment



Introducing Tyvek® 400 SFR

Tyvek® 400 SFR represents a new era in single-use secondary FR garment technology. Unlike traditional single-use secondary FR garments that have been available for years, Tyvek® 400 SFR is a differentiated multi-hazard solution that offers superior particle barrier protection and improved durability in a lightweight fabric. This unique blend of performance attributes makes Tyvek® 400 SFR well suited for environments where both hazardous particle and flash fire risks are present, when worn as an ensemble with appropriate primary FR garments.

In essence, Tyvek® 400 SFR garments are lightweight, single-use secondary FR overgarments specifically designed to help protect and preserve primary FR garments. With an optimal balance of protection, durability, and comfort, they represent a compelling solution for workers facing multiple hazards.

Performance and protection

Many tests can be used to assess how materials respond to flame exposure. It is important to note that the values discussed here were obtained using controlled conditions according to the industry standard ASTM F1930 (2023) Standard Test Method for Evaluation of Flame-Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin[4], using a 3-second exposure with a heat flux of 84 kW/m^2 (2 cal/cm^2-sec) and performed in Richmond, Virginia (USA).†

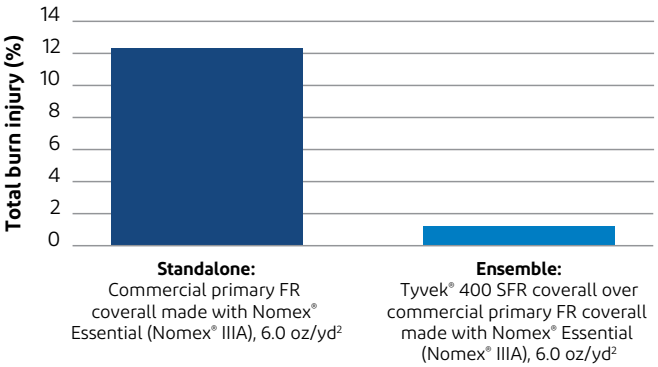
The ASTM F1930 methodology was used to test the product in the finished three-dimensional (3D) garment form factor to ensure the SFR clothing will not negatively impact the thermal performance afforded by the primary FR protective clothing that is worn underneath. The following few charts (Figures 3 to 5) demonstrate the secondary flame resistance of Tyvek® 400 SFR when worn as an ensemble with three different primary FR garments. The first set of tests utilized a commercial 6.0 oz/yd^2 coverall made with Nomex® Essential (Nomex® IIIA) as the primary FR garment.

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

†More details on the test conditions used can be found in the disclaimer.

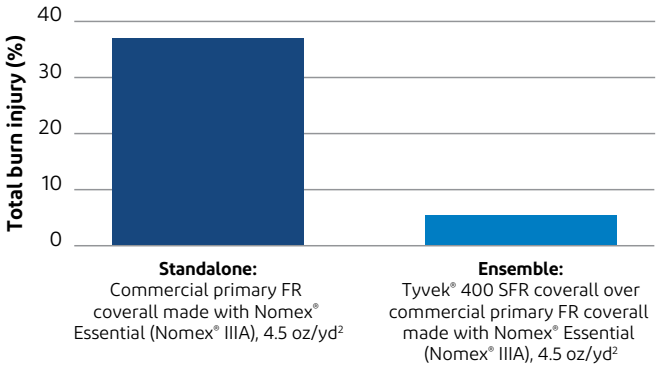
The encouraging results demonstrate a significant reduction of Total Burn Injury (TBI) (Figure 3). The average TBI value of the Tyvek® 400 SFR garment ensemble was <2% (excluding head) with a nominal 4-second afterflame.

Figure 3: Total burn injury (%) results of Tyvek® 400 SFR coverall over commercial primary FR coverall made with Nomex® Essential (Nomex® IIIA), 6.0 oz/yd².



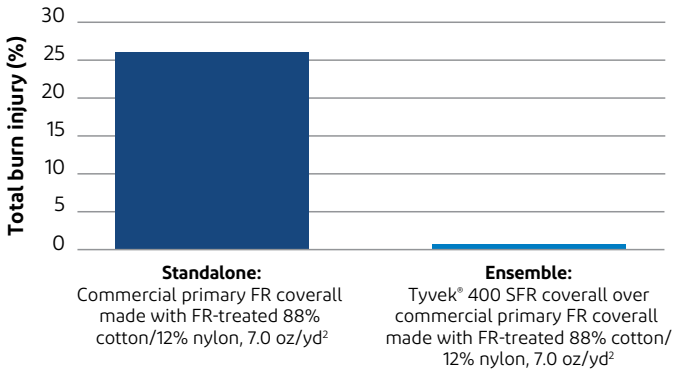
For workers who prefer a primary FR coverall made from a lighter fabric, this example includes a commercial 4.5 oz/yd² coverall made with Nomex® Essential (Nomex® IIIA) as the primary FR garment. The results demonstrate a significant reduction of TBI (Figure 4) with an average TBI value of the Tyvek® 400 SFR garment ensemble measuring <6% (excluding head) with a nominal 3-second afterflame.

Figure 4: Total burn injury (%) results of Tyvek® 400 SFR coverall over commercial primary FR coverall made with Nomex® Essential (Nomex® IIIA), 4.5 oz/yd².



In a separate example, the primary FR garment consisted of a commercial 7.0 oz/yd² coverall made with FR-treated 88% cotton/12% nylon fabric blend. The results (Figure 5) demonstrate a significant reduction of TBI with an average value of <1% (excluding head) and a nominal 2-second afterflame for the Tyvek® 400 SFR garment ensemble.

Figure 5: Total burn injury (%) results of Tyvek® 400 SFR coverall over commercial primary FR coverall made with FR-treated 88% cotton/12% nylon, 7.0 oz/yd².



As discussed, secondary FR garments should not negatively impact the thermal performance of the primary FR protective clothing when worn as an ensemble. The results of these tests (Figures 3 to 5) suggest that the Tyvek® 400 SFR garment ablates away, acting as a sacrificial layer. The potential total burn injury values presented here for Tyvek® 400 SFR and primary FR ensembles tested were well below the NFPA 2112 industry benchmark of <50% TBI.[6]

When Tyvek® 400 SFR coveralls are worn as an ensemble with the commercial primary FR coveralls tested here, the predicted %TBI is reduced when measured under these ASTM F1930 test conditions.

For secondary FR garments, a material's ability to resist charring (char length) is not as relevant as its ability to quickly self-extinguish after the flame exposure ends (afterflame time). Fabric vertical flame tests such as ASTM D6413 (2015) Standard Test Method for Flame Resistance of Textiles (Vertical Test) are fast, easy, and low cost.[7] However, these two-dimensional (2D) vertical burn (VB) fabric measurements may be better suited for quality control or gross screening of fabrics and not a litmus test for commercial use.

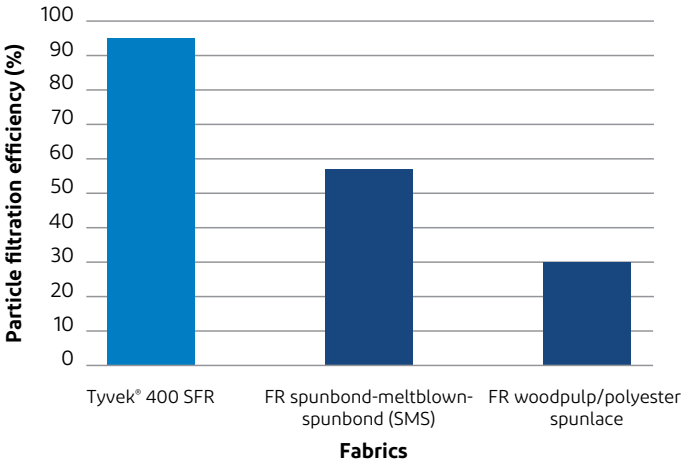
The fabric used in SFR garments should not ignite and continue to burn. Depending on the application and intended use of the product, fabric char lengths are not considered meaningful predictors of thermal protective performance of the fabric in a flash fire. It is important to recognize the benefits and limitations associated with the intrinsic (2D versus 3D) test methodology.

Additionally, 2D test methodology excludes garment ensembles and trim elements such as elastic, hook and loop fastener, closures, labels, emblems, patches, adhesive storm flaps, and other clothing components from testing. Users of only fabric parameters are cautioned that garment components could contribute to burn injury depending on their composition, size, and location on the protective clothing. A useful reference from the public domain is provided.[8]

Multi-hazard protection

In many oil and gas applications, workers may need protection from dry or solid particulates, depending on the task. Tyvek® 400 SFR fabric was evaluated for particle filtration efficiency (PFE) using a TSI 8130 instrument and particle filtration efficiency test method which determines fractional efficiency performance characteristics (Figure 6).

Figure 6: Fabric particle filtration efficiency (PFE) comparison



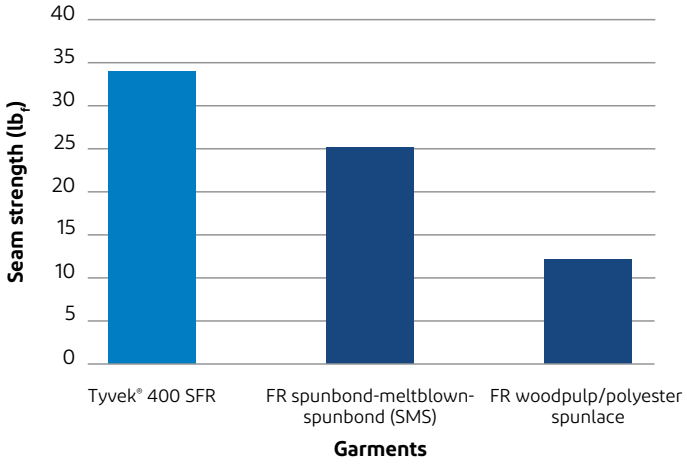
When tested, there was less than 5% penetration (>95% particle filtration efficiency) of particles (0.3 microns) through Tyvek® 400 SFR fabric. The actual field operating conditions, including contaminants, humidity, temperature, etc. are difficult to duplicate in a standard laboratory environment. Therefore, the 2D fabric test method excludes the full range of possible particulate challenges and environmental effects. The particle filtration efficiency of FR spunbond-meltblown-spunbond (SMS) fabric and FR woodpulp/polyester spunlace fabric are 57% and 30%, respectively.

Tyvek® 400 SFR coveralls can be considered for use with the appropriate respiratory protection and other suitable PPE to minimize contact with dry particulates. If fabric becomes torn, scratched, or punctured, the user should immediately discontinue use of the garment to avoid injury, including dry particulate exposure(s). Seams and closures may provide less protection than the fabric.

Durability

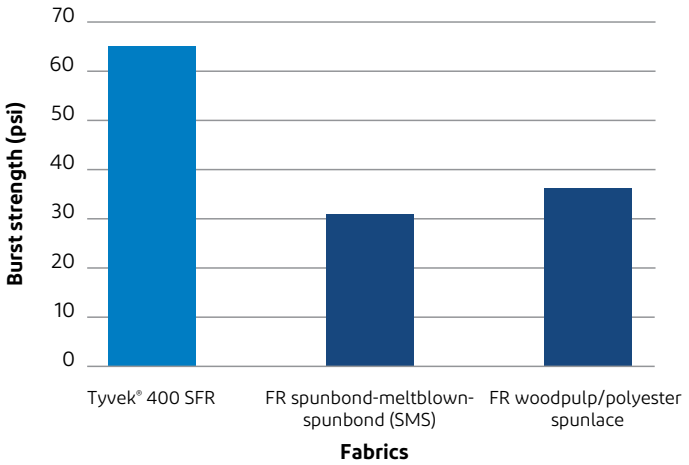
Strength and durability are important aspects of the garment selection criteria. This is critical in determining value in use for a worker. A garment must remain functional without excessive blowouts such as tearing of seams or ripping of fabric under normal use conditions when worn over primary FR. The Tyvek® 400 SFR garment has a 3X higher seam strength than the corresponding FR woodpulp/polyester spunlace garment (Figure 7) when measured according to ASTM D1683.[9]

Figure 7: Garment seam strength comparison



Additionally, Tyvek® 400 SFR fabric burst strength was 2X higher than both the FR woodpulp/polyester spunlace and FR SMS fabrics tested (Figure 8) according to ISO 2758.[10]

Figure 8: Fabric burst strength comparison



Comfort and fit

Tyvek® 400 SFR coveralls have a relaxed fit design with a diamond-shaped gusset crotch for a looser fit with no elastic waistband for reduced tension in the waist. An anthropometric mesh visualization (front, back and side) highlights the generous fit of the Tyvek® 400 SFR garment (Figure 9). This visualization is important as Tyvek® 400 SFR relaxed fit garment design is intended to be worn over primary FR clothing.[11]

Figure 9: Tyvek® 400 SFR anthropometric mesh visualization (front, back and side)

The Tyvek® 400 SFR fabric is 18% lighter weight and 41% thinner than the FR woodpulp/polyester spunlace fabric tested. However, it's important to note that workers will be inherently less comfortable because they are wearing a multi-layer PPE ensemble consisting of a SFR coverall over their primary FR coverall (or other primary FR workwear).

Chemical protective clothing can interfere with the natural regulation of body temperature. This can lead to a rise in core body temperature and heat stress. Implementing a conservative work/rest schedule or using a cooling system may be effective in reducing heat stress. (Note: Do not wear cooling vests in potentially flammable or explosive environments.)

Be aware of the symptoms and treatment of heat stress. If you or your co-workers have symptoms of heat stress such as nausea, dizziness, high heart rates, or excessive heat build-up, leave the work area immediately and remove the ensemble as quickly as possible after decontamination and seek professional care.

The maximum length of time the chemical protective clothing can be worn depends on variables such as the air supply, ambient conditions, climate inside the ensemble, physical and psychological conditions of the wearer, work rate, and workload. The TLV® pocket guide from the American Conference of Governmental Industrial Hygienists (ACGIH, Cincinnati) provides corrected heat stress limits for some garments.[12]

Similar information is available on the federal OSHA website. The WBGT correction factor for chemical protective garments is at least 10°C or higher for chemical garments made of impervious films (such as DuPont™ Tychem® garments) and covering the entire body (hooded coverall or encapsulating designs). For Tyvek® coveralls, the WBGT correction factor is 2°C with a hood and 1°C without a hood.

Design

A new red outlined Tyvek® chest label (patch) was designed (Figure 10) for Tyvek® 400 SFR. Furthermore, contrasting red colored thread using externally stitched seams (set sleeve) and a red colored zipper were incorporated. These combined contrasting color trim elements and patches (badging) are ornamental.

Figure 10: Design overview of Tyvek® 400 SFR coverall styles

Red front zipper with storm flap closure

New chest patch with red "SECONDARY FLAME RESISTANCE" border

Red external stitched seams

Diamond gusset crotch

Note: Patent-pending design

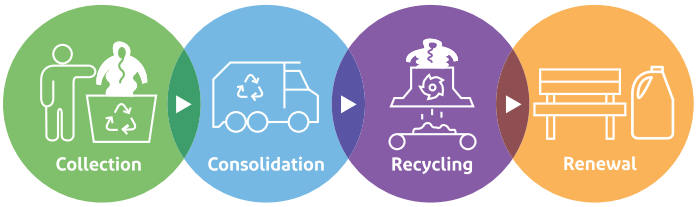
Sustainability

We are proud of our role in protecting people at work and we believe that advancing sustainability is an important extension of that role. We are committed to continued innovation to enhance worker safety and well-being while reducing the environmental impact of PPE.

That being said, Tyvek® 400 SFR garments that are not contaminated with any hazardous materials or biohazards‡ are eligible for recycling through the Tyvek® protective apparel recycling program (Figure 11). The Tyvek® protective apparel recycling program helps our customers within the continental United States manage used DuPont™ Tyvek® protective apparel, reduce waste, and give garments a second life in products like containers, lumber pallets, and park benches.

Contact DuPont Personal Protection Customer Service at 1-800-931-3456 for more information on the Tyvek® protective apparel recycling program.

Figure 11: Tyvek® 400 SFR garments that are not contaminated with hazardous materials are eligible for the Tyvek® protective apparel recycling program.‡



Conclusion

In general, selecting a secondary FR protective garment is important. This can be accomplished by examining both the FR requirements and performing a hazard assessment for hazardous and nonhazardous particles, liquids or chemicals. Overcoming these challenges without compromising safety may require a PPE ensemble of primary and secondary FR garments. The additional criteria of sustainability and recycling of disposable PPE should be considered. These results demonstrate the use case for secondary FR garments and the overall function of Tyvek® 400 SFR coveralls providing protection, durability and comfort.

1. OSHA Oil and Gas Extraction - Overview | Occupational Safety and Health Administration (osha.gov).
2. OSHA Chemical Hazards and Toxic Substances - Controlling Exposure | Occupational Safety and Health Administration (osha.gov).
3. ANSI/ISEA 203 (2018) American National Standard for Secondary Flame Resistant Protection Clothing for Use Over Primary Flame-Resistant Clothing.
4. ASTM F1930 (2023) Standard Test Method for Evaluation of Flame-Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin.
5. DuPont™ Nomex® Comfort predicted body burn product information.
6. NFPA 2112 (2023) Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire.
7. ASTM D6413 (2015) Standard Test Method for Flame Resistance of Textiles (Vertical Test).
8. R. L. Barker, J. Ingram, J. Morton-Aslanis, and A. S. Deaton, "Relationships between Bench Scale Measures of After-Flame and Thermal Shrinkage and Fire-Resistant Garment Performance in Fire Manikin Tests," in Performance of Protective Clothing and Equipment: 11th Volume, Innovative Solutions to Evolving Challenges, ed. K. Lehtonen, B. P. Shiels, and R. B. Ormond (West Conshohocken, PA: ASTM International, 2020), 1–17 (available online at www.astm.org/doi:10.1520/STP162420190086).
9. ASTM D1683 (2022) Standard Test Method for Failure in Sewn Seams of Woven Fabrics.
10. ISO 2758 (2014) Determination of bursting strength.
11. Anthropometry, apparel sizing and design (2020). Chapter 11 - Sizing and fit for protective clothing. Inga D'abolin and Eva Lapkovska.
12. TLV® pocket guide from the American Conference of Governmental Industrial Hygienists (ACGIH, Cincinnati), 2024.

NOTE: Tyvek® 400 SFR and Tychem® 2000 SFR garments provide only secondary flame-resistant 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 Tyvek® 400 SFR and Tychem® 2000 SFR hooded garments, a primary flame-resistant hood/ balaclava should be worn.

†Thermal Manikin Test Conditions: The thermal manikin tests described here were performed using controlled conditions according to the industry standard ASTM F1930 (2023), using a 3-second exposure with an average heat flux of 84 kW/m² (2 cal/cm2-sec) and performed in Richmond, VA (USA).

The Tyvek® 400 SFR garments tested were style ST120 size large and the various primary FR garments tested were commercially available men's coveralls, size 44 Regular. The Tyvek® 400 SFR and primary FR garment ensembles were tested without a hood or balaclava. Therefore, no burn data for the head is included for any of the test configurations. Nominally, the thermal manikin head contributes an additional 5-7% predicted total burn injury (TBI) when primary FR garments are worn.[5] Each commercially available primary FR coverall tested underwent one commercial wash and conditioning. No undergarments (cotton briefs / T-shirt) were used in any of the test configurations.

The data shown in this technical bulletin represents the average total burn injury results over a series of tests conducted under the conditions described above.

‡DuPont cannot accept used Tyvek® garments that have been exposed to hazardous materials/dangerous goods (as defined by local, federal or international transportation regulations). Hazardous materials/ dangerous goods include, and are not limited to, Division 6.2 infectious substances, biological products, cultures, patient specimens and regulated medical waste. User shall have responsibility for ensuring that materials intended for recycle meets this criteria prior to its delivery to DuPont or other recycling partner in compliance with all applicable laws and regulations. User shall assume all responsibility and liability for managing its recycling program.

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 MAKES 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 THIS 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.

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