Selecting effective secondary FR chemical protective garments

A guide for employers and workers

DUPONT™

Workers deserve protective garments that don't compromise chemical protection in order to provide secondary flame-resistant (FR) protection. When selecting a secondary FR chemical protective garment, you must examine both your FR and your chemical-resistant (CR) needs.

First, focus on chemical resistance

There are many CR garment technologies available and many recognized test methods to evaluate their performance. The two most common test methods cited by manufacturers of chemical personal protective equipment (PPE) are *ASTM Method F739, Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact* and *ASTM Method F903, Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids.*

While both are official ASTM test methodologies, permeation is the more rigorous test and represents the actual evaluation of a fabric's chemical resistance. Permeation is the absorption, diffusion and desorption of a chemical through a barrier material at the molecular level. Penetration, on the other hand, is the bulk passage of a chemical through a pore or opening in the barrier material.

Table 1. Permeation data

Comparison of permeation test (ASTM F739) results

Source fabric			DuPont™ Tychem® 2000 SFR	Pyrolon® CRFR
Chemical name (concentration)	CAS #	Chemical phase	Normalized breakthrough time (minutes) at 0.1 µg/cm²/min	
Black liquor (mixture)	Mixture	Liquid	>480	Not reported
Chromic acid (60-62%)	1333-82-0	Liquid	>480	Not reported
Dimethylacetamide, N, N- (8%)	127-19-5	Liquid	>480	Not reported
Green liquor (mixture)	Mixture	Liquid	>480	Not reported
Hydrochloric acid (37%)	7647-01-0	Liquid	54	Not reported
Hydrofluoric acid (48-51%)	7664-39-3	Liquid	400	Not reported
Hydrogen peroxide (70%)	7722-84-1	Liquid	>480	Not reported
Lithium hydroxide (20%)	1310-65-2	Liquid	>480	Not reported
Nitric acid (70%)	7697-37-2	Liquid	203	Not reported
Potassium hydroxide (45%)	1310-58-3	Liquid	>480	Not reported
Sodium hydroxide (50%)	1310-73-2	Liquid	>480	Not reported
Sodium hypochlorite (15%)	7681-52-9	Liquid	>480	Not reported
Sulfuric acid (>95%)	7664-93-9	Liquid	>480	Not reported
White liquor (mixture)	Mixture	Liquid	>480	Not reported

Note: Information on Pyrolon® CRFR is from Lakeland's U.S. website.

Here is a simple, real-life example to help you understand the difference between these two barrier mechanisms. Have you ever opened a bottle of soda to find out that it is flat? There aren't any holes in the bottle. The cap seal had not been broken. The liquid is still inside. Why is the soda flat? Because the carbon dioxide that gives soda its fizz has permeated through the bottle over time. On the other hand, if you opened a fresh bottle of soda and did not replace the cap, the carbon dioxide would escape out the top opening. That's penetration.

The bottom line is that permeation tests are best suited for measuring the chemical resistance of protective garment fabrics against hazardous liquids and vapors. DuPont publishes permeation data for its chemical protective garments. See Table 1 for a comparison of chemical permeation test results for DuPont™ Tychem® 2000 SFR vs. Pyrolon® CRFR. See Table 2 for a comparison of chemical penetration test results for Tychem® 2000 SFR vs. Pyrolon® CRFR.

Next, focus on flame resistance

It is important to recognize that there are two categories of FR garments sold for industrial applications: primary FR garments and secondary FR garments. Each category is designed to perform different tasks.

Primary FR garments are expected to protect the wearer from heat and flame exposures. They can be described as "standalone" FR garments. They are meant to be flame resistant and also thermally insulating to protect the wearer from burn injuries.

Secondary FR garments, on the other hand, are meant to be worn over (on top of) primary FR garments. They are not designed to provide thermal insulation protection. The secondary FR garment is chosen either to keep the primary FR garment clean and extend its wear life, or to provide protection from non-fire hazards (e.g., chemicals). Secondary FR garments are not meant to be worn alone or worn over everyday garments, (i.e., flammable garments), in work areas requiring FR PPE clothing based on a hazard assessment.

Secondary FR garments should respond to a fire in a way that doesn't negatively impact the performance of the primary FR garment worn beneath. They should not continue to burn ("afterflame") once the incident fire exposure ends.

Many tests can be used to assess how materials respond to flame exposure. In the realm of protective apparel, a common test is the "vertical flame" test. The method most commonly used in the USA is *ASTM D6413 Standard Test Method for Flame Resistance of Textiles (Vertical Test).* This method originated in the 1920s as part of the U.S. government's Federal Test Method Standard *FTMS 191A Federal Standard for Textile Test Methods under Method 5903 Flame Resistance of Cloth; Vertical*.

ASTM D6413 is a relatively simple test to run. A 12-inch x 3-inch piece of material is hung vertically in a special chamber. The bottom edge of the long dimension is exposed for 12 seconds to a laboratory flame. After the test flame ceases, the sample is observed to determine if afterflaming occurs and if any afterglow is noted. Additionally, observations are made regarding whether the sample exhibited melting or dripping behavior. After the sample cools, char length is measured. Char length in ASTM D6413 is defined as "the distance from the fabric edge, which is directly exposed to the flame to the furthest point of visible fabric damage after a specified tearing force has been applied." It is important to note that ASTM D6413 does not impose any pass/fail requirements. It is just a test method, not a performance specification.

Other standards do assign pass/fail requirements to the D6413 results, depending on the application and intended use of the material. For FR **and** thermally protective apparel (e.g., primary FR) to be used as PPE in industrial workplaces, *NFPA 2112 Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire* and *ASTM F1506 Standard Performance Specification for Flame Resistant and Electric Arc Rated Protective Clothing Worn by Workers Exposed to Flames and Electric Arcs* are oft-cited performance standards. Both of these standards are intended for primary FR/arc-resistant clothing.

Primary FR garments must resist ignition **and** suffer minimal damage in order to protect the wearer from burn injury. If there is nothing left of the garment

Table 2. Penetration data

Comparison of penetration test (ASTM F903, Procedure C) results

Source fabric	DuPont™ Tychem® 2000 SFR	Pyrolon® CRFR
Chemical name (concentration)	Time to penetrate (minutes)	
Acetone (>95%)	>60	>60
Acetonitrile (>95%)	>60	>60
Benzene (>95%)	>60	>60
Carbon disulfide (>95%)	>60	>60
Crude oil (>95%)	>60	>60
Dichloromethane (>95%)	>60	Not reported
Diesel fuel (>95%)	>60	>60
Ethyl acetate (>95%)	>60	>60
n-Hexane (>95%)	>60	>60
1, 1, 2, 2–Tetrachloroethylene (>95%)	>60	>60
Toluene (>95%)	>60	>60

Note: ASTM F903 Procedure C=0 psi for 5 min., 2 psi for 1 min. and 0 psi for 54 min. Information on Pyrolon® CRFR is from Lakeland's U.S. website.

during or immediately after the flame exposure, then the garment will not protect the wearer from burn injury. For primary FR garments, being flame resistant as measured by ASTM D6413 testing, is not enough; the material must also offer thermal insulation, which is measured with other test methods. The requirements for ASTM D6413 test results for NFPA 2112 and ASTM F1506 are shown in Table 3.

These are the common performance specifications for primary FR and arc-resistant garments. But 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). Remember that secondary FR garments are not intended to protect wearers from flame exposure. That is the job of the primary FR garment worn underneath. While fabric vertical flame tests are easy to run, they do not tell the full story. What is most relevant is how the entire garment reacts when faced with flame engulfment. A short afterflame time with no increase in body burn levels is the right response for a secondary FR garment.

A new generation of secondary FR chemical garments

Tychem® 2000 SFR represents a new generation of secondary FR chemical garment technology. Unlike traditional secondary FR chemical garments that have been available for years, new Tychem® 2000 SFR garments were specially designed to meet dual hazard needs of a chemical-protective suit with secondary flame resistance. This unique combination of performance traits permits Tychem® 2000 SFR garments to be worn over primary FR garments such as DuPont™ Nomex® apparel when chemical splash and flash fire hazards exist. The fabric used in Tychem® 2000 SFR garments is a unique technology. It doesn't char like traditional secondary FR technologies. ASTM D4391 (*Standard Terminology Relating to The Burning Behavior of Textiles*) defines charring as "the formation of carbonaceous residue as the result of pyrolysis or incomplete combustion." Tychem® 2000 SFR fabric does not char; instead, it was designed to shrink away from flame—without burning. The results from ASTM D6413 vertical flammability testing shown in Table 4 confirm that unique Tychem® 2000 SFR fabric response.

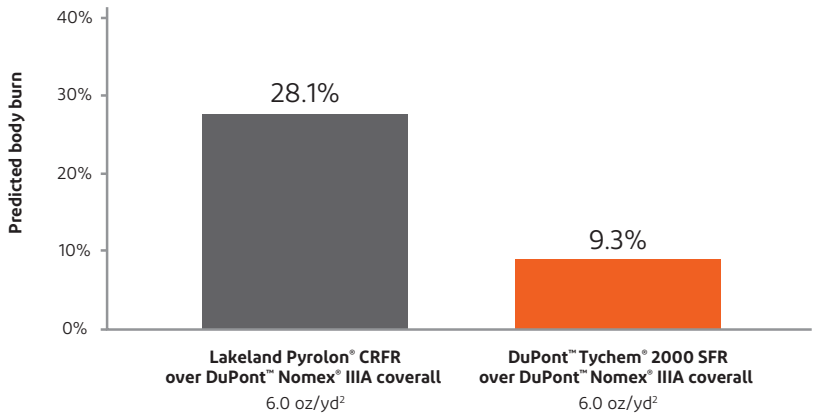
We engineered Tychem® 2000 SFR garments to perform well in flame engulfment scenarios. Extensive ASTM F1930 (instrumented thermal manikin) testing was conducted during the development of Tychem® 2000 SFR garments to aid in garment design and component selection. The commercial Tychem® 2000 SFR garment demonstrates excellent performance when exposed to a fire engulfment. In fact, when tested side-by-side, Tychem® 2000 SFR garments yield a much lower predicted body burn level and much less afterflame than competing garments, including Lakeland Pyrolon® CRFR.

The performance of the actual garment when exposed to a fire engulfment should be the key deciding point for selection of a secondary FR garment. See Figure 1 for comparison of predicted body burn results for Tychem® 2000 SFR garments vs. Pyrolon® CRFR garments when each is worn over a primary FR garment and exposed to a 4.0-second laboratory flashfire.

Table 3. Performance requirements applied to ASTM D6413 results

Standard	NFPA 2112	ASTM F1506
Char length	≤4.0 inches	≤6.0 inches
Afterflame time	≤2.0 seconds	≤2.0 seconds
Other	Shall not melt and drip	Shall not melt and drip

Figure 1. Test results per ASTM F1930 method with 4-second exposure (average of 3 replicates)



We have not yet validated the effectiveness of Tychem® 2000 SFR in electrical arc flash hazards.

Table 4. Tychem® 2000 SFR results, ASTM D6413 testing

Property	Typical result
Char length (MD)	6.8 inches
Char length (CD)	7.1 inches
Afterflame (MD)	< 1.0 second
Afterflame (CD)	< 1.0 second
Melting and dripping	No

MD=machine direction; CD=cross direction

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