CHEMICAL PROTECTIVE CLOTHING SOLUTIONS

IN THE LIQUEFIED NATURAL GAS (LNG) INDUSTRY

Tyvek. 50 YEARS OF PROTECTION

DUPONT Tyvek.

FOR GREATER GOOD™

Chemical Protective Clothing Solutions in the Liquefied Natural Gas (LNG) Industry

Liquefied natural gas (LNG) is natural gas (predominantly methane(CH_4), with some mixture of ethane(C_2H_6)) that has been converted to liquid form for ease and safety of non-pressurized storage or transport. The liquefaction process involves removal of certain components, such as acid gases, mercury, and heavy hydrocarbons. Workers might be exposed to hydrogen-sulfide gas, benzene, ethyl benzene, toluene, xylene, mercury, and other hazardous byproducts during this process.

Most workwear is made of textile fabric, which has many small holes on the surface (open structure). Liquid chemicals can easily pass through these holes and contact worker's skin. Chemicals can be absorbed into the skin and result in irritation or skin burns in a short-period of time. However, if exposure is prolonged, there is potential to cause cancer or other severe diseases.

Regulations require that chemical protective clothing for handling hazardous liquid chemicals meet the EN 17491-3 Type 3 standard. To provide protection against toxic gas chemicals, performance requirements for gastight suits can be required according to EN 943-2 Type 1a-ET.

However, workers using chemical suits that meet the EN 'Type' standard may be unaware that the same general classification of garments can have different-levels of chemical protection. Workers should check if their garment can provide adequate protection barrier against the chemicals they are exposed to.

LNG Facilities are also prone to potential accidental natural gas leaks, in either liquid or gas form during the operation. Methane and Ethane are extremely flammable chemicals classified as flammability 4 by both HMIS (Hazardous Material Information System) and NFPA (National Fire Protection Association). LNG Facilities face dual hazards of chemical and flame from using chemicals such as ethane, methane, amines, hydrogen-sulfide and mercury. Workers should choose the right protective solution against dual hazards of chemical and flash fire.

Garment Selection – A Life Saving Choice

The selection of chemical protective clothing (CPC) is a step by step approach that starts with a broad risk assessment for a defined work situation. This section will provide several simplified steps to select the appropriate CPC. A detailed analysis of the work environment is essential in making the right choice of the most effective protective clothing that balances protection and comfort while being compliant to the norms and regulations. The main purpose of the hazard assessment is to identify and then to eliminate or minimize worker exposure by shielding from hazard, whenever potential risk exists.

Risk assessment

A risk assessment is a combination of likelihood of accidents (never, unlikely, possible, likely, multiple exposures likely, continuous) and severity of consequence (no effect, discomfort, treatable injury, debilitating injury, death). The risk assessment should identify all hazards and information should be available on the safe level of these hazards. The assessment should be a realistic worst-case scenario. An accident is rarely due to a single large failure, but often due to a "domino effect" combination of

small errors. The risk to the worker may concern their whole body or part of their body. The chosen PPE should cover all body parts that are at risk.

Work environment

The first step in a risk assessment is usually to follow the process or understand the specific work location in which the exposure(s) may occur. The exposure is defined by duration (e.g. seconds, hours), frequency, amount and the force of the exposure, and the direction of the exposure (to which part of the body).

Also, existing historical information on exposure data and incident records, existing PPE (Personal Protective Equipment) used can help to define or refine the PPE needs. Finally, before PPE is chosen, all risk mitigation and engineering and administrative controls should be applied.

Most important are still the human factors such as:

- how many workers are affected,
- work rate, work load, degree fitness including the temperature and humidity of the work area as this determines the length of time before heat stress,
- the need for vision and mobility.

These factors are used to decide the chemical barrier needed, in addition to information about the chemicals and their toxicity.

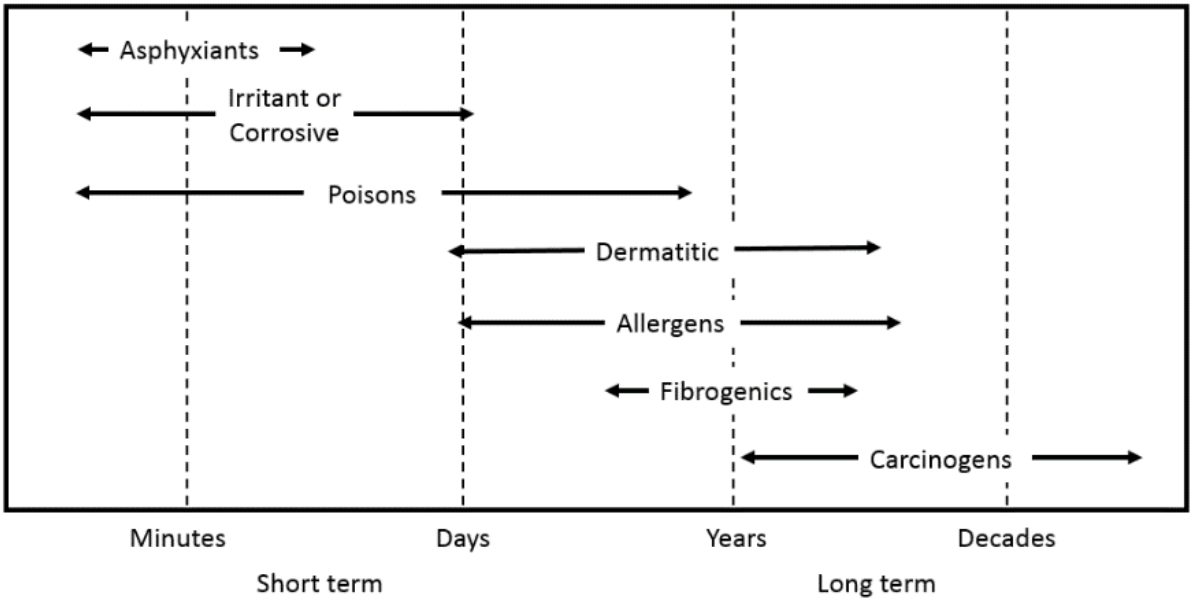
Chemicals

What is the specific chemical risk? Is it a gas, liquid, particulate? Can the chemical change state (e.g. from liquid to vapor)? What are the concentration levels of the chemical(s)? Is the hazardous chemical in pure form or a mixture of several chemicals? Many of the key chemical properties that are important to CPC selection can be found in the safety data sheet (SDS), such as:

- Physical properties: vapor density, vapor pressure, flash point, boiling point, melting point, freezing point, solubility, state, specific gravity
- Toxicity: corrosivity, exposure limits, risk phrases.

Toxicity

Knowing the toxicity or consequences of short or long-term exposure to the hazard is essential. Data on the garment's fabric, seams, and closure system on penetration and permeation testing will indicate the permitted time of exposure before reaching human toxicity. Toxicity is dependent on the mode of interaction with the human body, some chemicals are more toxic by skin, others by inhalation, and the dose or concentration of the uptake into the body is important. Some chemicals have a short-term effect, others have a long-term effect or more insidious effect on the organism as it is less visible.

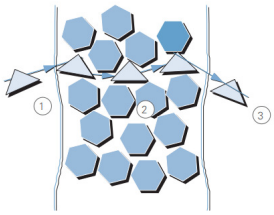


Chemical protective performance requirements

There are two concepts of chemical protection in PPE: Permeation and Penetration. Permeation indicates the degree of chemical protection in molecular level in Type 3, 4(liquid-chemical protection) and Type 1(Gases-chemical protection). Penetration is the concept used in Type 6(liquid mist protection) to see physical protection from a chemical flow.

Permeation

Permeation is the molecular process by which chemicals move through the barrier material through three steps: adsorption (uptake), diffusion through polymer, and desorption or exposure in the measuring medium or on the skin. Permeation is temperature dependent, it increases with increased temperature. Permeation through continuous contact is a worst-case condition and it's required for Types 1, 2, 3, and 4 CPC.



1. Sorption of molecules of liquid onto the contracted (outside) surface.
2. Diffusion of the sorbed molecules across.
3. Desorption of the molecules from the opposite (inside) surface.

Breakthrough detection time is the elapsed time between initial contact of the chemical on the outside of the CPC and the time at which the chemical is detected in the collection medium in contact with the inside surface of the CPC. The breakthrough time is always specific for the pair: CPC material and chemical. In EN standards, the breakthrough time to reach 1.0 µg/cm^2-min is reported as one of 6 protection classes (lowest being >10 minutes and the highest >480 minutes). In the US, breakthrough time to reach 0.1 µg/cm^2-min is reported.

Penetration/repellency

Penetration is the physical process of a chemical flowing on a bulk level through closures, porous materials, seams, pin holes, or other imperfections, including defective seams or inadequately sealed

closures. The test used for Penetration/repellency in the standard for Type 6 CPC drops a small quantity of liquid onto the surface of the fabric which is laid in an inclined gutter. The liquid is allowed to run off (this is the repellency quantity) and the quantity that penetrates the material is measured for penetration. To fulfil Type 6 requirements, for one of the listed test chemical in EN 13034, the penetration must be less than 5%.

DuPont™ Tychem®

Manufactured by DuPont, Tychem® has been protecting industrial workers for 30 years. Tychem® chemical suits go through a rigorous testing process. Tychem® fabrics have been tested by 3rd party labs for permeation against hundreds of chemicals. The result is chemical protection against hundreds of toxic liquids and vapors ranging from mercury to hydrogen sulfide gas.

DuPont™ Tychem® has a broad product portfolio to provide the best solutions for diverse hazardous applications.

Tychem® C – *Chemical barrier against inorganic chemicals!*

Offering permeation barrier protection against a wide range of inorganic chemicals even under pressure. Tychem® C could be suitable for chemical protection against mercury at low ppm, inorganic liquids or catalysts in LNG Processing.

Tychem® F / 6000 F – *Chemical barrier against organic chemical(BTX) and high concentrated inorganic chemicals!*

Offering excellent chemical permeation resistance to an extensive range of chemicals, helping to protect workers against numerous toxic industrial organic chemicals, highly concentrated inorganic chemicals even under pressure. Tychem® F could provide chemical protection against mercury at high ppm, non -flammable organic liquids or catalysts in LNG Processing.

Tychem® TK – *Great chemical barrier against more than 300 challenge gases, liquids and solid chemicals!*

Offering extremely durable fabric that is puncture- and tear-resistant, yet also supple and lightweight. Showing at least 30 minutes of barrier protection to more than 300 challenge toxic, corrosive, gases, liquids and solid chemicals. Tychem® TK could be suitable for chemical protection against gaseous/vapors inorganic gases (e.g. hydrogen sulfide) in LNG Processing.

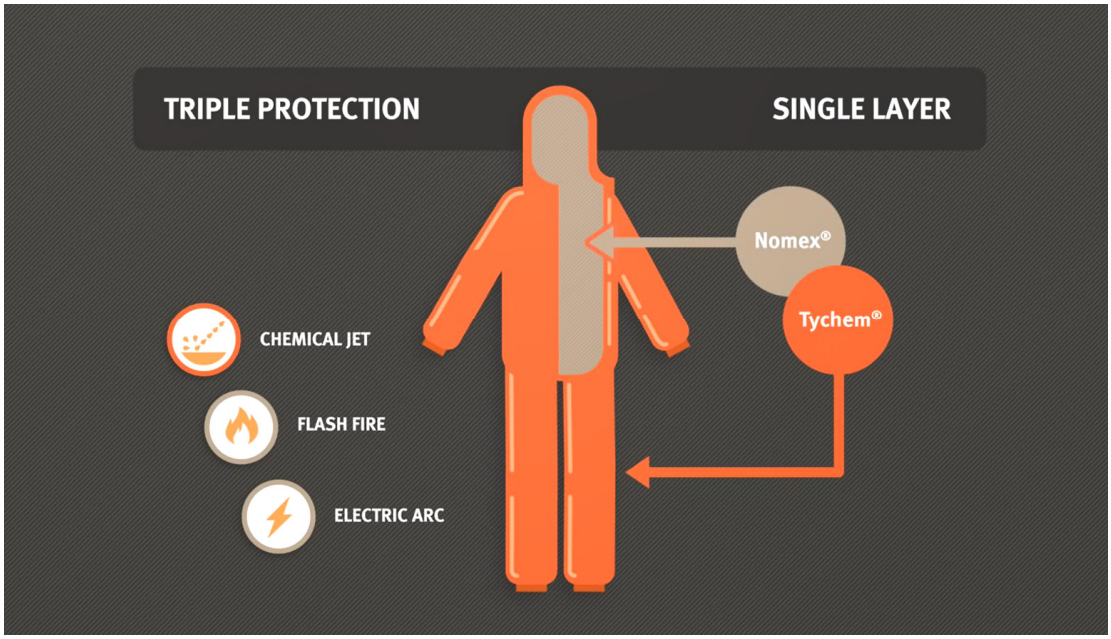
Dual Hazards (Chemical and Flame)

In many workplaces, chemical hazards and fire hazards are both serious concerns. Unfortunately, the materials used in most traditional chemical protective clothing are flammable. And the materials used in most flame-resistant clothing offer little to no chemical protection. Even though a worker may wear a typical chemical garment over primary flame-resistant clothing, during flash fire exposure, chemical garments can melt and drip into the inner-side of workwear and cause serious bodily injury. That's why DuPont™ developed our range of Tychem® chemical and flame-resistant products.

Tychem® ThermoPro®

DuPont combined its proven technologies of Tychem® and Nomex® (Flame-resistant meta-aramid material developed by DuPont) into a new single layer protective garment. Offering 360° protection, Tychem® ThermoPro® sets a new standard for some of the most high-risk environments for workers who may be exposed to serious risk. The Tychem® components provides a Type 3 chemical barrier and enables this garment to extend the exposure to a wide range of toxic chemicals for at least 8 hours (e.g. Mercury, BTEX and Kerosene). Flame-resistant Nomex® fibers forms the other components of Tychem® ThermoPro® and provide crucial extra seconds to escape from flash fire conditions. Nomex® also gives Tychem® ThermoPro a proven ability to protect against electric arc hazards from energized systems. (Arc rating 15 cal/cm^2 E^{bt}, According to ASTM F 1959/1981)

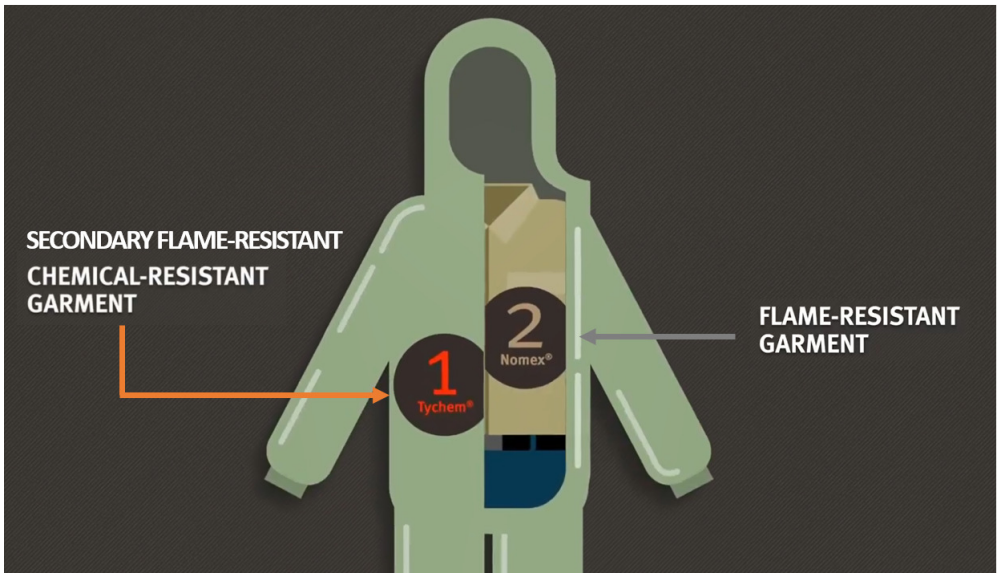
Tychem® ThermoPro – SINGLE LAYER, TRIPLE PROTECTION (Chemical Jet, Flash Fire, Electric Arc)



Tychem® 2000 SFR

Providing an effective barrier against a range of chemicals, as well as the secondary flame resistance when worn over primary FR garments like those made with DuPont™ Nomex®. Secondary flame-resistant garments are intended to be worn over primary flame-resistant garments. In the event that a flash fire occurs, Tychem® 2000 SFR won't ignite and won't contribute to additional burn injury if the appropriate FR apparel is worn beneath. Tychem® 2000 SFR coveralls provide protection against a multitude of inorganic acids and bases such as sulfuric acid(>95%), nitric acid(70%) and hydrogen peroxide(70%).

Tychem® 2000 SFR – Chemical and secondary flame resistance in a lightweight garment!



General Protection in LNG Processing

Besides the hazards of gas and liquid chemicals, general protection should be provided to workers against solid particulates toxic chemicals or dusts (e.g. Perlite). Workers should consider the right garment for their protection. DuPont™ has also provided protective solutions against hazardous particles with the Tyvek® and ProShield® range of products.

Tyvek® Classic Xpert

Offering an excellent barrier against particles and fibers. Tyvek® Classic Xpert Coveralls provide excellent protection against hazardous fine particles 15 times better than the Type 5 standard, allowing only 1% inward leakage thanks to its optimized design. Tyvek® Classic Xpert Coveralls provide a balance of comfort, durability and superior protection for workers during LNG processing.

Tyvek® Classic Xpert – Well balanced Type 5 garment for workers with superior protection!

Multiple Chemical Hazards in the LNG Industry Require Multiple Clothing Solutions

When selecting chemical protective clothing for worker in the LNG industry, it is critical to ensure the product selected provide adequate protection from hazardous chemicals of concern. The broad range of DuPont products can provide diverse protective solutions. DuPont™ Tyvek® protects workers from hazardous particles with excellent barrier. Liquid and gases chemicals can be protected with Tychem® C, F and TK. If there is the high-risk of chemical and flame hazard, Tychem® ThermoPro and 2000 SFR can provides dual protection. Hazards assessment of the work environment is essential for right choice of the most effective protective clothing.