Chemical Protective Textiles

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Abstract

Chemical Protective Textiles (CPT) deal with protection of human beings from chemical hazards caused by chemical weapons, chemical manufacturing units etc. New materials like wood pulp and hydrocarbons are being explored to make fibres for CPT. CPT can protect against toxic gases, chemical splash or dust gases depending upon its class. CPT are extensively applied in emergency response, pesticide application, defense services, asbestos removal etc. The various manufacturing techniques; level of performance and their evaluation have been reviewed in this paper.

Keywords: Protective textiles, Chemical hazards, Clothing.

1. Introduction

Chemical hazards are prominent in and around chemical industries, hazardous waste disposal sites etc. To encounter these hazards, CPT are used worldwide by defense personnel and workers working in vicinity of chemical environment.

CPT is a subset of Protective Textiles, a branch of Technical Textiles. Technical Textiles are defined as textile materials and products manufactured primarily for their performance or functional characteristics rather than their aesthetic or decorative characteristics[1]. Protective clothing refers to garments and other fabric related items designed to protect the wearer from harsh environment effects that may result in injuries or death[2].

The purpose of Chemical Protective Textiles (CPT) is to shield or isolate individuals from the chemical, physical, and biological hazards that may be encountered during hazardous materials operations. During chemical operations, it is not always apparent when exposure occurs. These hazards can be grouped into categories such as chemical, thermal, nuclear, radiation (X-rays, UV) and biological hazards.

2. Fibres Used in CPC[3]

In general porous fabrics are used for particulate protection and coated or laminated fabrics are used for liquid and gas protection. Some of the examples of materials used for particulate protection are spun bonded olefins (e.g., Tyvek by DuPont), wood pulp and hydrocarbons (e.g., Hydra spun FR by Dexter Corporation), cellulosic materials (e.g., Kaycel by Kimberly-Clark) and spunbonded-meltblown-spunbonded composites (e.g., Kleenguard by Kimberly-Clark).

Contaminant resistant garments such as Tyvek and Kleengaurd are used during asbestos removal to protect the workers. Fig 1.

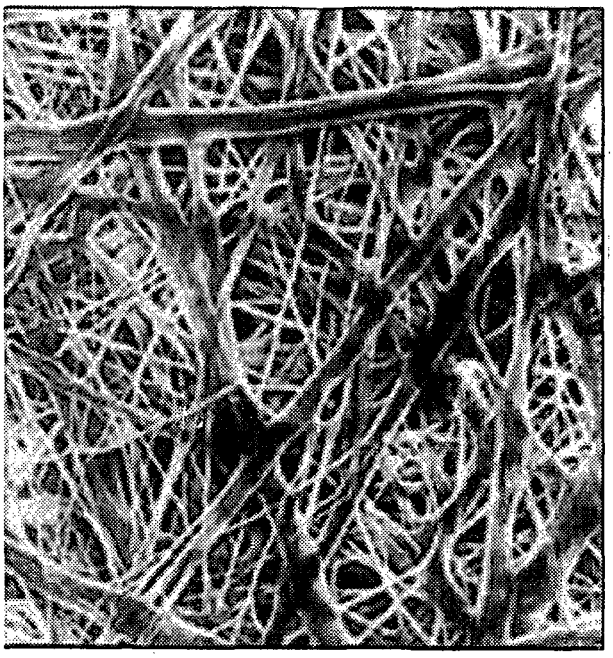

Fig 1: Fine Structure of Tyvek Fibre

Fabrics which are coated or laminated with special films are suitable for chemical protection involving liquids and gases. They are used in hazardous or toxic material handling. Barricade, a DuPont product with good barrier qualities, is a multi-layer film laminated to a substrate of polypropylene. For better protection, total encapsulation suits made of special coated fabrics such as DuPont's Teflon onto Nomex or fibre glass fabrics is needed. There are other products in

market for chemical protective clothing. Various nylon, cotton or polyester fabrics coated with butyl, PVC and neoprene also offer good barrier properties.

3. Classification of CPC[4]

Personal protective clothing can be classified as:

Fig 2 : Fully Encapsulating Suit

i. Fully encapsulating suit

Description: One-piece garment. Boots and gloves may be integral, attached and replaceable, or separate.

Type of Protection: Protects against splashes, dust gases, and vapours.

ii. Non encapsulating suit

Description: Jacket, hood, pants or bib overalls, and one-piece coveralls.

Type of Protection: Protects against splashes, dust and other materials but not against gases and vapors. It does not protect parts of head or neck.

iii. Aprons, leggings, and sleeve protectors

Description: Fully sleeved and gloved apron. Separate coverings for arms and legs. It is commonly worn over non encapsulating suit.

Type of Protection: Provides additional splash protection of chest, forearms, and legs.

iv. Firefighters' protective clothing

Description: Gloves, helmet, running or bunker coat, running or bunker pants (NFPA No. 1971, 1972, 1973) and boots (1974).

Type of Protection: NFPA Standard No. 1971 specifies that a garment consists of an outer shell, an inner liner and a vapour barrier with a minimum water penetration of 25 lb/in^2 (1.8 kg/cm^2) to prevent passage of hot water.

v. Proximity garment (approach suit)

Description: One- or two-piece over garment with boot covers, gloves, and hood of aluminized nylon or cotton fabric.

Type of Protection: Protects against splashes, dust, gases, and vapours.

vi. Blast and fragmentation suit

Description: Blast and fragmentation vests and clothing, bomb blankets, and bomb carriers

Type of Protection: Provides some protection against very small detonations.

vii. Radiation contamination protective suit

Description: Various types of protective clothing designed to prevent contamination of the body by radio active particles.

Type of Protection: Protects against alpha and beta particles. It does *not* protect against gamma radiation.

viii. Flame or fire retardant coveralls

Description: Normally worn as an under garment.

Type of Protection: Provides protection from flash fires.

4. CPT Ensemble

A Chemical Protective Clothing can be composed of some or all of the following:

- Protective clothing (suit, coveralls, hoods, gloves, boots)
- Respiratory equipment Self Contained Breathing Apparatus (SCBA) , combination SCBA/SAR, air purifying respirators
- Cooling system (ice vest, air circulation, water circulation)
- Communications device
- Head, eye & ear protection, inner garment, outer protection (over-gloves, flash cover)

4.1 Selection Factors[4]

The selection of ensemble components depends on the following selection factors:

i. Chemical Hazards
ii. Physical Environment
iii. Duration of Exposure
iv. Protective Clothing/Equipment Available.

5. Performance Level of CPC

The efficiency of CPC is judged by its level of performance. The levels of performance of CPC have been suggested by NFPA. These levels along with their description given below:

Level A

Vapour Protective Suit (meets NFPA 1991), full-face SCBA, Inner

chemical-resistant gloves, chemical-resistant safety boots.

Protection Provided: Highest available level of respiratory, skin, and eye protection from solid, liquid and gaseous chemicals.

Level B

Liquid Splash-Protective Suit (meets NFPA 1992): full-face piece SCBA, Inner chemical resistant gloves, chemical resistant safety boots, two-way radio communications, hard hat.

Protection Provided: Provides same level of respiratory protection as Level A, but less skin protection. It provides liquid splash protection, but no protection against chemical vapours or gases.

Level C

Support Function Protective Garment (meets NFPA 1993) Full-face piece, canister-equipped respirator chemical resistant gloves and safety boots, two-way communications system, hardhat.

Protection Provided: The same level of skin protection as Level B, but a lower level of respiratory protection.

Level D

Coveralls, Safety Boots/Shoes, Safety Glasses or Chemical Splash Goggles.

Protection Provided: No respiratory protection, minimal skin protection.

CPC is broadly categorized as encapsulating and non-encapsulating. Encapsulating ensemble covers the whole body including the respiratory protection equipment.

The non-encapsulating system is assembled from separate components and the respiratory apparatus may be worn outside the suit. All 'Level A' protective clothing is encapsulating while 'Level B' and below usually come under non encapsulating.

6. Evaluation of Barrier Properties Of CPC[4]

A portable test kit has been developed by the Environmental Protection Agency (EPA) using a simple weight loss method that allows field qualification of protective clothing materials within one hour. Use of this kit may overcome the absence of data and provide additional criteria for clothing selection. Under all conditions, clothing should be selected by evaluating its performance characteristics against the requirements and limitations imposed by the application.

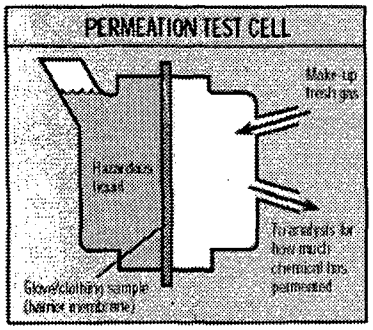

Fig 3: Permeation Test Cell

6.1 Permeation Resistance

Permeation is a process of chemical penetration into chemical protective clothing at molecular level

Resistance of the material to permeation is expressed in terms of

Table 1 provides list of chemicals used to evaluate chemical barrier properties of CPT.

Chemicals used to evaluate the performance of protective clothing materials	
Chemical	**Class**
Acetone	Ketone
Acetonitrile	Nitrile
Ammonia	Strong base (gas)
1,3-Butadiene	Olefin (gas)
Carbpm Dosi;fode	Sulfur-containing organic
Chlorine	Inorganic gas
Dichloromethane	Chlorinated hydrocarbon
Diethylamine	Amine
Dimethyl formamide	Amide
Ethyl Acetate	Ester
Ethyl Oxide	Oxygen heterocyclic gas
Hexane	Aliphatic hydrocarbon
Hydrogen Chloride	Acid gas
Methanol	Alcohol
Methyl Chloride	Chlorinated hydrocarbon (gas)
Nitrobenzene	Nitrogen-containing organic
Sodium Hydroxide	Inorganic base
Sulfuric Acid	Inorganic acid
Tetrachloroethylene	Chlorinated hydrocarbon
Tetrahydrofuran	Oxygen heterocyclic
Toluene	Aromatic hydrocarbon

The tests for assessing the performance characteristics of chemical protective clothing:

break through time and permeation rate. Break through time is defined as the elapsed time between the start of the test and the sampling time at which the test chemical is first detected. Permeation rate is a measure of flux through a unit area of material for a unit time. The test method used to assess permeation resistance is ASTM F1194 (Guide for Documenting the results of chemical permission testing on Protective Clothing material).

6.2 Degradation Resistance

Degradation is defined as change in a material's physical properties as a result of chemical exposure. Physical properties may include weight of material, dimensions, tensile properties, thickness etc. that may influence the performance of protective clothing when used in particular application.

Degradation resistance test can be used as a screening test, which can show clear impossibility of using particular material for certain chemicals and barrier properties of CPC can be determined by penetration and permeation resistance tests.

6.3 Penetration resistance

Penetration is defined as the flow of chemicals through closures, porous materials, seams and pinholes or any other imperfection in protective clothing. The penetration resistance is measured through

run off based tests. Run-off based tests are characterised by contact of liquid chemicals with the materials by force of gravity over a specified distance. Usually specimen is supported at an angle of 45 degree allowing chemical to run-off, a large amount of water is delivered onto the specimen and the amount of water underneath the specimen is measured.

Index of penetration (P) = Mp/Mt x 100
Where,
Mp= mass of the liquid deposited under the specimen
Mt= mass of test liquid discharged onto the test specimen

7. Decontamination of CPC

Decontamination is the process of removing or neutralising contaminants that have accumulated on personnel and equipment. It makes CPC more durable. Decontamination protects end users from hazardous substances that may contaminate and eventually permeate the protective clothing. It protects all plant or site personnel by minimizing the transfer of harmful materials into clean areas. There are two types of decontamination:

1. Gross decontamination to allow end user to safely exit or doff the chemical protective clothing.
2. Decontamination for reuse of chemical protective clothing.

8. Production Techniques for CPC:

8.1 Using Activated Carbon[5]

A cost effective Chemical Protective Textile is developed by bonding activated carbon granules with cotton and polyester fabric using needle punching technology. The layers are arranged as shown in Fig 4.

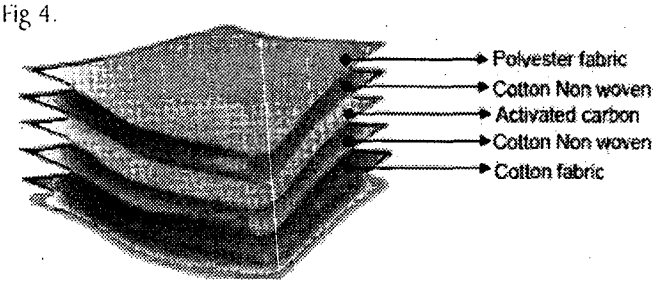

Fig 4 [5]. Multilayer Fabric for Chemical Protection

The base fabric is made of 100 % cotton and next layer is of needle punched cotton non-woven. The fabric acts as base for the activated carbon and also as an inner lining for the final fabric enabling easy absorption of sweat from the wearer and transporting them to the outer layer. Moreover, the cotton fabric provides comfort to the wearer. The first four layers are bonded through needle punching technique and the fifth layer (polyester fabric) is bonded through acrylic resin. The activated carbon granules get embedded in the non-woven. The resultant composite fabric had a good locking of activated carbon granules. The cotton fibres do not allow the carbon granules to move from their place.

8.2 Multilayer Films[3]

Saranex by DuPont is multi-layer film that can be laminated to Tyvek. Sarenex 23P is a multilayer structure that consists of low density polyethylene (outer layer), Saran (second layer), ethylene vinyl acetate (EVA) copolymer (third layer) and Tyvek (inner layer). The EVA acts as an adhesive. It is suitable for garment manufacturing with various seam types. By laminating polyethylene with Tyvek, a tough fabric with good barrier properties is produced that is suitable for garment manufacturing with difficult seam types.

9. Applications of CPT

Protective Textile must be worn whenever the wearer faces potential hazards arising from chemical exposure. Some examples include:

1. Emergency response
2. Defense services
3. Agricultural application of pesticides

9.1 Emergency response[4]

In emergency response, CPC are used for Site survey, i.e., the initial investigation of site; Rescue, i.e., entering a hazardous materials area for removing a victim; Emergency Monitoring, i.e., observing a hazardous materials incident without entry into the spill site; decontamination and spill mitigation, i.e., entering a hazardous materials area to prevent a potential spill or to reduce the hazards from an existing spill.

Special considerations must be given to how the selected protective clothing may affect the ability of the wearer to carry out rescue and to the contamination of the victim.

9.2 Defense Services[6]

Biological and chemical warfare is a constant world threat. These weapons are of insidious mass destruction. There is also the deterrent effect as the use of such weapons may involve massive escalating retaliation with other means of mass destruction such as nuclear weapons.

The primary and essential devices for the protection of the individual are full-face respiration which are designed to filter out and deactivate the toxic species. However mustard agents attack the skin and neuro agent (since it affects the transmission of nerve impulses in nervous system) and can be absorbed by damaged skin and at pressure points such as fingers knees and elbows necessitating the use of full body protection clothing. Most current clothing system is activated carbon on textile substrate.

9.3 Agricultural Application [7]

Dermal and respiratory pesticide exposure of agricultural workers involved in spray operations can be fatal. The protective clothing is used to reduce exposure. The protective textile involves the use of rubber aprons, waterproof outer garments and facemask. CPT used in agriculture application must meet the following requirements:

- Protection from range of pesticides
- Light weight and cheaper
- Wash ability and durability
- Good breath ability.

Besides the above discussed application, few other important

applications of CPT are chemical manufacturing and process industries, hazardous waste site cleanup and disposal, asbestos removal and other particulate operations etc.

10. Conclusion

Protective garment manufacturing requires careful attention to fiber and fabric selection, cutting, sewing and inspection. The seams may be especially critical depending on the end use requirements. CPT acts as the "last line of defense". In emergency response, hazardous waste site cleanup, and dangerous chemical operations, the only acceptable types of protective clothing include fully or totally encapsulating suits. The goal should be to provide just the right amount of protection in order to minimize cost and maximize production by acceptability

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