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AN OVERVIEW OF CHEMICAL PROTECTIVE CLOTHING

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ABSTRACT

Protective clothing is essential for protection against harmful chemicals in industries, agricultural and medical work, during military operations and sometimes even during household chores. In chemical industry, protective clothing provides a barrier to chemical exposure. Due to the large number of requirements, different types of chemical protection clothing have been developed. The selection of the chemical protective clothing must be made according to the consideration of weight, comfort, level of protection and the duration of the protection required. Here, an overview is done of chemical protective clothing which plays an extremely important role in safe guarding human-beings against chemical hazards.

Keywords: Chemical Protective Clothing, Chemical Hazards, Levels of Protection, Selection Criteria

I. INTRODUCTION

Exposure to chemicals in the workplace/industries is a significant health and safety issue. There are many chemicals which can cause adverse effects on unprotected skin, some chemicals (mostly solids) can present a contamination problem where inadvertent ingestion (e.g. lead) could occur or re-entrainment in the airstream (e.g. asbestos) could lead to inhalation causing respiratory problems [1]. Chemical Protective Clothing (CPC) can prevent direct skin contact and contamination. CPC can also prevent physical injury to the unprotected skin from thermal hazards such as from rapidly evaporating liquefied gases (e.g. LPG). These protective clothing can be an appropriate effective barrier against chemical hazards. The Occupational Safety and Health Administration (OSHA) standards provide general guidance on protecting workers from skin exposure [2]. Different types of CPC have been developed to be used according to the requirement.

The types of CPC range from basic work clothes (aprons, jackets, pants, boots, gloves, hoods, etc.) to total encapsulating chemical-protective ensembles, with a wide variety of options. The most basic characteristics of CPC are the type of resistances provided.

Gas/vapor- resistant clothing is generally configured to provide head-to-toe coverage, e.g. the so-called “moon suits” that have special seams and zippers to prevent chemicals from leaking into them. Splash/particulate - protective clothing provides a lesser degree of protection and is used when the results of skin contact are not as severe.

The chemical protective clothing must be made from chemical resistive materials. A single material is not compatible with every chemical. While a particular material may provide excellent resistance against one

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chemical, the same material may provide very poor or no protection against another chemical. Ideally, the chosen material should resist permeation, degradation and penetration. In general, materials used for protective garments include natural rubber, neoprene, nitrile, polyethylene, chlorinated polyethylene, poly vinyl chloride (PVC), PVC - coated materials, polyurethane, butyl polymers, treated woven fabrics, and several others [3]. These materials can be supported on cotton, nylon, polyester, and other substrates. Materials should be selected based on quantitative information such as permeation rate, breakthrough times, penetration and degradation. Various other factors like the thickness of the material, manufacturing methods and product quality can have significant effect on these properties.

CPC also provides safeguards for eyes, face, hands and feet. The typical eye and face CPC includes safety glasses, safety goggles and face shields. These protect the eyes, face and neck from chemical flashes, heat, glare and flying objects in case of a chemical explosion. Hazards to the hands may be caused by chemicals, sharp objects, hot surfaces, machines or tools, heavy equipment, etc. Gloves, another important component of CPC, must protect hands from burns, cuts, electrical shocks and absorption of chemicals. They must not leak and must be made of good quality material [4]. To protect the worker's feet from injury due to sharp objects, hot surfaces, molten metals, contaminated hazardous materials etc. foot guards, toe caps, safety shoes and boots are provided. Several OSHA standards govern and aid in manufacturing and selection of footwear e.g. the heel and sole of the boots, to protect feet from contact with chemicals, are made of a few different polymers, so as to provide a high degree of abrasion resistance. Not only the footwear but the entire CPC ensemble must meet the requirements of the standard governing bodies and agencies (e.g. OSHA, Environment Protection Agency (EPA), National Fire Protection Association (NFPA) etc.). Thus, each CPC ensemble is tailored to a specific situation, in order to provide appropriate level of protection.

II. LEVELS OF PROTECTION

The EPA has defined four levels of protection (A, B, C and D) [5] that are distinguished by

- whether respiratory protection is required and if so the type of respirator (air purifying vs. atmosphere supplying)
- the consequences of skin exposure (the extent of the body exposed and the severity of such exposure)

Level A Protection: This type of protection is required where there is greatest potential for exposure to hazards and highest level of skin, respiratory and eye protection is needed. Level A chemical protective clothing includes respiratory protection with a positive-pressure, full-face self-contained breathing apparatus (SCBA); a totally encapsulated chemical and vapor protective suit (Fig.1); and disposable protective suits, chemical resistant gloves and boots.

Level B Protection: This type of protection includes the highest level of respiratory protection but a lower level of skin protection. For example, at outdoor abandoned hazardous-waste sites where the vapor and gas levels are not too high, Level B protection is often adequate. Level B includes a respiratory protection with a positive-pressure, full-face SCBA, face shields, hooded chemical-resistant clothing, coveralls, and chemical-resistant gloves and boots (Fig.1).

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Level C Protection: This type of protection is for use where the concentration and types of airborne substances are known and the criteria for using air-purifying respirators are met. Level C (Fig.1) typically includes full-face air purifying respirators, hard hats, masks, chemical-resistant gloves and boots.

Level D Protection: This type of protection is sufficient when minimum protection is required i.e. when no contaminants are present or the work operations do not include splashes, immersion, or the potential for unexpected inhalation or contact with hazardous levels of any chemicals (Fig.1).

The EPA levels are used as a starting point to create a CPC ensemble.

III. COMPARISON OF LEVELS OF PROTECTION OF CPC

Here, a comparative analysis of levels of protection (A, B, C and D) is done, so that according to the requirement, the choice among them becomes easy.

Level A is most appropriate when high concentration of gases and vapors are present and the highest level of protection is required for skin, eyes and respiratory system.

Level B is appropriate when the highest level of respiratory protection is necessary but a lesser level of skin protection is needed.

Level C is suitable for atmospheric contaminants, liquid splashes or when direct contact will not adversely affect or be absorbed through any exposed skin.

Level D can be used in situations where there is no possibility of contact with chemicals.

Advantages and disadvantages of the levels of protection of CPC are given in Table 1.

IV. FACTORS AFFECTING THE PERFORMANCE OF CPC

The performance of CPC is affected by many factors [3], such as the design, construction and quality of the material used. The quality of material used influences the performance of CPC as it acts as a barrier to chemicals. The design and construction of CPC also impacts its performance [3], e.g.:

- Stitched seams must be sealed with tape or coating as they can be easily penetrated by chemicals.
- Variations may occur from one lot to another, and may have a significant effect on the barrier effectiveness of the CPC.
- Pinholes may exist in elastomeric or plastic products due to material deficiencies, or to poor quality control in the formulation or in the manufacturing processes.
- Thickness of the clothing may vary at different points.
- Garments closures differ significantly from one manufacturer to another, as well as within one manufacturer's product line.

Also, the physical conditions of the work environment, the human factors, the level of protection selected, may affect the performance of CPC. Adverse environmental conditions such as extreme temperatures, in addition to causing heat or cold stress to the CPC user, can also degrade the performance of the CPC itself and expose the worker to hazards unexpectedly. Heat stress and illness are a major concern for the workers in CPC. The body's principal means of cooling is through the evaporation of sweat. When working in chemical protective clothing,

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sweat is trapped inside and cannot evaporate, thus raising the body's core temperature which may result in heat-related illness.

Besides coping with the thermal burden and heat strain associated with chemical protective ensemble, the worker must also manage a number of physiological and psychological effects brought on by wearing the ensemble. It may affect the worker's attitude and ability to perform work. Personnel may feel claustrophobic or face respiratory problems. The face piece of the respirator reduces peripheral vision, and fogging of the face piece may further impair vision. Moreover, the bulk of most ensembles make movement more difficult.

V. SELECTION FACTORS OF CPC

In chemical industry, appropriate CPC is chosen based on the physical and chemical properties of the product involved, a risk assessment of the situation, the nature of work, the conditions under which the work will be done as well as the capabilities of the wearer. As the visibility and mobility are limited in a CPC, the wearer undergoes significant physical stress. Health implications of a chemical exposure and hazards which may be present under certain circumstances are other important factors which must be kept in mind while deciding the level of protection required.

The purpose of the CPC is to protect the wearer against the effects of toxic or corrosive products, whether vapors, liquids or solids that enter the body via inhalation or skin absorption or cause tissue damage upon contact with the skin. Hence, the selection of appropriate material for a desired level of protection is also very important.

To reduce adverse effects, some of the given practices [3] may be followed:

- Selection of lightest-weight ensembles and respiratory devices that adequately protect the worker will minimize the physiological demands associated with carrying the weight of the equipment. Moreover, proper size of the CPC should be selected to fit the user.
- The CPC must be made of a material that allows for the evaporation of water vapor while also protecting the skin from the contaminant.
- When CPC is used during intensive work, the work - load intensity should be reduced by adjusting the work/rest schedules or finding easier methods of performing the task.
- The workers must be educated about the symptoms of heat effects and ways to prevent it.
- Reduce heat or cold stress by scheduling work accordingly and implementing personal comforts for the workers like fans, cooling systems or other forms of ventilation.

VI. CONCLUSION

The CPC are an essential requirement for the safety of the personnel working in hazardous conditions. Although there are different levels of protective clothing, the selection of the CPC depends upon the work environment, the level of risk and exposure involved. Thus, a proper planning should be done for choosing the right type of protective clothing. The safety programs must include a risk methodology for CPC selection. There should be a CPC selection criteria and procedures; CPC performance criteria, as well as special training requirements for the workers. Proper CPC storage, maintenance, decontamination and program re-evaluation procedures must be

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carried out from time to time. Implementation of formal written programs and a companywide, consistent approach for the selection and use of CPC is essential for reducing the chance of error.

Industries that are responsible for the health, safety and well-being of their workers should provide good quality standard chemical protective clothing (from the lab coats to disposable full body suits, as desired), to safeguard them from potentially hazardous chemicals as it is a cost effective way to protect the valuable employees.

Level A Level B Level C Level D

Fig. 1 - Chemical Protective Clothing with different levels of protection [6]

Table 1: Advantages and disadvantages of the levels of protection of CPC

Level of Protection	Advantages	Disadvantages
A	• A totally encapsulating suit protects the SCBA from contamination or chemical damage. • Totally encapsulating garments are easier to decontaminate, as there are fewer places for the contaminants to be trapped. • May be used in oxygen- deficient atmosphere.	• Garment tends to be more bulky (in order to be large enough to cover the wearer and self- contained breathing apparatus). • Visibility is reduced by the location and design of the face shield. • Suits weigh more than garments of other designs since greater and heavier amounts of fabric are used.

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B	• Lighter and less bulky than level A. • Easier to wear than level A. • Same chemical protective garment can be often used for both level B and level C ensembles (changing respiratory protection as appropriate), reducing training and inventory requirements. • May be used in oxygen- deficient atmosphere.	• Level B ensembles provide splash and respiratory protection only. • If a supplied air respirator is used, distance from the air source is restricted and the air lines must be carefully managed. • Provisions must be made to refill/re-supply air cylinders.
C	• Longer stay times are possible, since respiratory protection is provided by chemical filter cartridges and via a finite container of compressed air. • Suits weigh less due to their "coverall" design and thinner fabric. • Air-purifying respirators are lighter and smaller than SCBA, and do not require air line management like supplied air respirators. • No provisions for air supply is required. • Same chemical protective garment can be often used for both level B and level C ensembles (changing respiratory protection as appropriate), reducing training and inventory requirements.	• Level C ensembles provide splash protection only. • Air purifying respirators can only be used in defined conditions.
D	• Easy to wear, light coveralls or work-type garments	• Level D garments do not protect from chemical exposure

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