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Standard Practice for Chemical Protective Clothing Program[1]

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1. Scope

1.1 This practice is intended to promote the proper selection, use, maintenance, and understanding of the limitations of chemical protective clothing (CPC) by users, employers, employees, and other persons involved in programs requiring CPC, thereby limiting potentially harmful and unnecessary skin exposures.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F739 Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact

F903 Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids

F1001 Guide for Selection of Chemicals to Evaluate Protective Clothing Materials

F1052 Test Method for Pressure Testing Vapor Protective Suits

F1154 Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Durability of Protective Ensembles and Ensemble Components

F1194 Guide for Documenting the Results of Chemical Permeation Testing of Materials Used in Protective Clothing

F1383 Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Intermittent Contact

F2588 Test Method for Man-In-Simulant Test (MIST) for Protective Ensembles

3. Terminology

3.1 *Definitions:*

3.1.1 *analytical detection limit, n*—a number, expressed in units of concentration (or amount), that describes the lowest concentration level (or amount) that an analyst can determine to be different from an analytical blank (background level).

3.1.2 *biological monitoring, n*—the chemical analysis of chemicals or metabolites, or both, from a worker's blood, urine, fingernails, sweat, breath, and so forth.

3.1.3 *buddy system, n*—a means of organizing employee work groups whereby each participant is matched with another so that prompt assistance can be rendered in the case of any emergency.

3.1.4 *chemical protective clothing (CPC), n*—an item of clothing that is specifically designed and constructed for the intended purpose of isolating all or part of the body from a chemical hazard.

3.1.5 *decontamination, n*—the reduction, removal, or neutralization of contaminant or contaminants from protective clothing to safely permit the protective clothing to be doffed (taken off), or reused, or discarded.

3.1.6 *elastomer, n*—an elastic polymer that has properties similar to rubber.

3.1.7 *fabric, n*—a planar structure consisting of yarns or fibers.

3.1.7.1 *Discussion*—Unlike a polymer sheet, a fabric is normally subject to penetration by gases and liquids.

3.1.8 *Fick's laws of diffusion, n*—mathematical descriptions of the movement of one type of molecule through another.

3.1.8.1 *Discussion*—Diffusion is not due to holes or pores in chemical protective clothing materials.

3.1.9 *hazard assessment, n*—an examination of the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of personal protective equipment (PPE)

3.1.10 *industrial hygienist, n*—a person who, by experience and academic training, is qualified to recognize, evaluate, and

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

control chemical, physical, and biological agents in the workplace, or a person certified by the American Board of Industrial Hygiene.

3.1.11 *occlusion, n*—the physical process of covering a chemical that has been applied to or spilled on the skin, thereby disallowing its evaporation and generally increasing its absorption through the skin.

3.1.12 *physical-chemical parameters, n*—values for physical or chemical properties of a test chemical or polymer, or both, such as solubility parameters, molecular weight, vapor pressure, and so forth.

3.1.13 *plastic, n*—a material that contains, as an essential ingredient, one or more organic polymeric substances of large molecular weight, is solid in its finished state, and, at some stage in its manufacture of processing into finished articles, can be shaped by flow.

3.1.14 *polymer, n*—a substance consisting of molecules characterized by repetition (neglecting ends, branches, junctions, and other minor irregularities) of one or more chemically bonded types of monomeric units.

3.1.15 *polymer sheet, n*—a continuous polymeric planar structure.

3.1.15.1 *Discussion*—It is not normally subject to penetration by gases or liquids.

3.1.16 *program, n*—a documented policy with procedures for selection and use of CPC.

3.1.17 *program administrator, n*—a person responsible for the formulation and implementation of a CPC program.

3.1.18 *program authority, n*—a person responsible for enforcing the requirements of a CPC program.

3.1.19 *toxicity, n*—the propensity of a substance to produce adverse biochemical or physiological effects.

3.1.19.1 *Discussion*—Such effects are termed toxic effects, as used in this practice.

4. Significance and Use

4.1 This practice presents those elements that constitute a chemical protective clothing (CPC) program and conditions to be used in establishing a program for the selection and use of CPC. Adherence to this practice requires that a written program be developed for any use of CPC.

4.2 Although much remains to be determined regarding the toxicity of vapor and liquid exposure to the skin, this practice outlines the essential information necessary and suggested methods for hazard assessment prior to the selection of CPC (see Practice F1154).

4.3 This practice does not address the various methods for testing CPC or obtaining the data upon which CPC assessments are made. These test methods are listed in Section 2 of this practice.

4.4 This practice does not include recommendations that may apply to personal protection from nuclear radiation, radioactive contamination, or microbiological organisms, or to clothing that is worn to protect a particular environment from the entry of chemicals, particles, or living matter that may arise from the wearer.

4.5 CPC should be used when other means of control are not available. Its major uses should be limited to the following:

4.5.1 Maintenance operations;

4.5.2 Upset or emergency conditions;

4.5.3 Use in lieu of engineering controls when they are not feasible or are being installed;

4.5.4 Supplementing feasible engineering controls when they fail to control the hazard completely; and

4.5.5 Use in the event that engineering controls fail.

4.6 Engineering controls and substitution of materials should be stressed as the first line of defense in all control situations since effective use of CPC depends on worker compliance, proper selection, quality control, and other variables that may prove to be weak links in an overall control process.

5. Minimum Program Requirements and Objectives

5.1 The primary objective shall be to minimize employee exposures. This objective should be accomplished to the extent feasible by accepted engineering control measures. These include enclosure or confinement of the operation, isolation of the worker from the operation, substitution of less toxic materials, and modification of work practices. When these controls are not feasible, or while they are being implemented or evaluated, appropriate CPC shall be used pursuant to the requirements in this practice and regulatory requirements, where applicable.

5.2 *Program Administration and Responsibility:*

5.2.1 Responsibility and authority for implementing the CPC program shall be assigned to a single person. This person will normally be a plant manager, supervisor, or other person with line supervisory authority. This person is called the program authority.

5.2.2 Normally, a second person shall have responsibility for preparing the written program. This person is called the program administrator. His duties also include maintaining and updating standard procedures and the CPC written program, based on changes in CPC technology and knowledge; maintaining records; auditing and evaluating the program; directing, interacting with, or supervising those who dispense CPC at the worksite and those who train workers in the use of CPC; and establishing procedures for the purchase of CPC. The program administrator will usually have staff responsibilities. The program administrator shall have knowledge of CPC sufficient to supervise the CPC program properly. (Where possible, the administrator of a CPC program should also be the administrator of the respiratory protection program, if one exists, in order to improve coordination.)

5.3 *Written Programs*—The CPC program shall be established and detailed in a written document.

5.4 *CPC Selection*—The selection of the CPC article shall be based on consideration of the following:

5.4.1 Exposure situation (vapor, pressured splash, liquid splash, intermittent liquid contact, and continuous liquid contact);

5.4.2 Toxicity and amount of the chemical(s) (that is, best knowledge or the estimate of ability to permeate the skin and of systemic toxicity);

5.4.3 Physical properties of the contaminant chemicals (for example, vapor pressure, molecular weight, and polarity);

5.4.4 Functional requirements of the task (for example, dexterity, thermal protection, fire protection, and mechanical durability requirements); and

5.4.5 Properties of the CPC that are relevant to the physical and chemical hazards and functional requirements of the task. These properties are determined through appropriate testing techniques and include permeation resistance, degradation resistance, penetration resistance, dexterity, resistance to tear, and so forth, as applicable. (See Test Method F739, Guide F1001, and Practice F1052.)

5.4.6 Selection of the CPC should consider the materials from which the garment, gloves, visor, hoods and boots are constructed, the seam construction and the design of the garments.

5.4.7 Selection of the CPC shold also consider the likelihood of coming in contact with the hazardous materials, the duration of the contact, the amount of contact and the direction of liquid contact.

5.5 The selection procedure shall be documented. Minimally, the selection process should consider degradation, penetration, and permeation resistance of the CPC. Degradation could result in an adverse loss of integrity and chemical resistance properties. Penetration could result in direct skin contact by an agent from bulk flow through seams, pinholes, and so forth. Permeation can result in skin contact by an agent without any outward signs of either penetration or degradation since molecular flow of the contaminant through the protective article is occurring.

5.6 *Training*—Each CPC user shall be given training that shall include the following:

5.6.1 A description of the hazards for which the CPC is being selected;

5.6.2 An explanation and discussion of the toxicity of the contaminants for which CPC is being used including symptoms that indicate an overexposure has occurred;

5.6.3 Limitations of CPC use;

5.6.4 Training *how to use CPC*, including donning, decontamination in order to safely doff the garment, doffing, proper storage, maintenance, inspection, and decontamination for safe reuse where applicable; and disposal of CPC.

5.6.5 Each CPC user should tested after training and periodically thereafter, to verify that they understand and can follow the CPC training, retrained if necessary or restricted from using CPC if they can not understand or follow the training.

5.7 *CPC Use*—The employer shall not use CPC in violation of the written program or the manufacturer's instructions. When using CPC, the employer shall consider special emergency-use precautions. The buddy system shall be used in conjunction with emergency-use CPC.

5.8 *Maintenance and Storage*—Maintenance and inspection shall be conducted on a schedule that ensures that each piece of CPC delivers the protection for which it was selected. Minimally, each piece of CPC shall be inspected by the wearer prior to its use to ensure its integrity. CPC should be stored in accordance with manufacturer's instructions.

5.9 *Decontamination*—Procedures for decontamination and reuse shall be documented. CPC should not be used after it is contaminated unless it can be demonstrated that the decontamination CPC is safe to wear.

5.10 *Field Evaluation and Biological Monitoring*—The use of methods to estimate actual exposures in the field or estimate doses from biological samples are appropriate when the choice of CPC has uncertainty or when estimates of total doses to employees are necessary. The latter is particularly important for low vapor pressure organic chemicals that are absorbed through the skin readily.

5.11 *Purchasing*—The purchase of CPC shall be coordinated carefully with the selection and use of CPC. Failure to monitor and control the purchase of CPC could result in improper CPC use, leading to worker exposure. The purchaser's action shall be dependent on the requirements from the program administrator. Without clear CPC specification, the lowest price usually dictates purchase.

5.12 *Considerations of Medical and Human Factors*—The possible physiological and psychological effects caused by wearing CPC shall be considered. These effects, which include heat stress and claustrophobic reactions, may be particularly evident when TECP suits are worn. CPC selection is a balance between protection from chemical hazards and performance, physiological, and psychological burdens. Chemical protection should not be compromised, nor should the worker be unnecessarily burdened.

5.12.1 In most cases, use of CPC entails a risk of heat stress. There should be a written heat stress management plan in place to anticipate heat stress, monitor heat stress among CPC users, mitigate the risk by used of engineering controls, work practices of additional PPE and rehabilitate CPC users with elevated core body temperatures.

5.13 *Auditing*—CPC programs shall be audited periodically in order to ensure that all components are functioning as described in the written program. Methods for auditing the program shall be well described, including the ways and means for correcting defects in the program.

6. Program Administration and Responsibilities

6.1 *Employer Responsibility*—Employer responsibility is vested in the program authority. The employer shall be responsible for providing CPC to employees when it is necessary and enforcing its proper use. All CPC shall be selected by the employer using the latest information available to him. The employer shall establish and maintain a CPC program that shall include the minimum requirements of this practice as outlined in Section 5 and supported, where appropriate, by Sections 6 through 16 and the Appendixes.

6.2 *Employee Responsibility*—Employees have the responsibility and duty to use all CPC that is provided to them in accordance with the instructions and the training that they have received. All CPC shall be treated with respect and inspected and maintained in accordance with the employer's program requirements. Should an employee sense any change in the performance of his CPC or exhibit any symptoms of overexposure, he shall report this to the employer immediately.

6.3 *Program Administrator*—An individual, preferably from the company's industrial hygiene or safety engineering function, should be assigned responsibility for administering the CPC program. For companies without these functions, the CPC program should be administered by a qualified person responsible to the program authority, and consultation from an industrial hygienist should be sought in establishing the program. The individual should be trained in control techniques that involve chemical protective clothing. Responsibilities of the individual include the following:

6.3.1 Performance of hazard assessments with respect to the exposure of employee's skin to hazardous solids, liquids or vapors.

6.3.2 Selection of the appropriate CPC configuration and materials of construction that will provide adequate protection for each exposure, either present or anticipated.

6.3.3 Maintenance of records and written procedures in a manner that documents the CPC program and allows for the evaluation of the program's effectiveness.

6.3.4 *Evaluation of the CPC Program Effectiveness*—This includes frequent comparison of the program with current regulations and standards, and comparison of the program as it is implemented with the written procedures. At least annually, the program should be audited by a team from the plant or worksite.

6.3.5 The use or implementation of biological monitoring and medical surveillance, where necessary, to determine and document whether CPC use is controlling exposures effectively or CPC use is causing undue stress on the worker, or both.

7. Written Program

7.1 Minimally, all written programs shall address Section 5. This section should be supplemented with Sections 6 through 16 of this practice, where appropriate. The written program shall be available to employees at a place to which they have reasonable access. Employees shall receive training (Section 9), and it should address all sections of the written program.

7.2 Minimally, written procedures should address those operations for which routine uses of CPC are anticipated and contrast those with written procedures for the emergency use of CPC. Employees should have a thorough understanding of the limitations of CPC for routine use as compared to those situations in which emergency use of CPC is necessary. This should be stated clearly in the written program.

8. Selection of CPC

8.1 Selection of CPC requires determination of the nature and extent of the hazard, including the toxicity of the chemical and the manner in which it is used. The selection is then based on this hazard determination and the interpretation of appropriate physical and chemical resistance tests of the CPC. Ideally, these tests should be performed as part of the selection process. In emergency situations or in the interim before tests are performed, professional judgment involving analogous situations, available literature, or estimates of permeation based on physical-chemical factors may be relied on.

8.2 *Hazard Assessment:*

8.2.1 Determine what contaminants may be present and pose a significant threat of exposure to the worker's skin. Evaluate the likelihood or risk of contact with the worker's skin and the length of time for which exposure is expected. Consider the information given in Appendix X1.

8.2.2 From analogy with other chemicals, previous experience, biological monitoring studies, or other available information, determine whether the skin is a significant route of uptake for the chemical in question, and the subsequent effect of uptake or primary contact, or both. Very little is known concerning the absorption rates of individual chemicals through the skin, the extent to which metabolic conversion of chemicals may occur within the skin, the differences in absorption of liquid or vapor forms of the same chemical, and the vapor exposure levels under CPC to which the skin may be exposed after CPC contact with a chemical. Hence, hazard assessment is qualitative, at best.

8.3 *Selection Information:*

8.3.1 Determine the configuration of CPC necessary (for example, apron, gloves, and TECP suit), based on the knowledge of the task to be performed and the hazards to which the worker is exposed. Consider 8.2 and the factors given in Appendix X2.

8.3.2 *Selection Based on Penetration*—Determine penetration properties for those materials with seams, zippers, noticeable differences in thickness, or voids (paper, cotton, woven, or nonwoven fabrics). Proper selection based on a penetration test provides the user with a CPC garment that will not allow the bulk flow of liquid through seams, zippers, or imperfections in the CPC garment for a specified period of time at a specified pressure. Specifically for splash protection, and when vapor exposure to the skin is not hazardous, negative penetration test results can be used to select a garment.

8.3.3 *Selection or Disqualification Based on Degradation*—If the contaminants in question have low potential for skin absorption and are of low, but significant, toxicity, degradation properties of the candidate CPC materials may be sufficient to determine acceptable CPC. Selection based on degradation alone provides the user with chemical protective clothing that should not degrade upon exposure. Hence, in the purest sense, degradation tests provide a mechanism for disqualifying certain CPC since those that pass must be evaluated for penetration or permeation, or both. CPC that fails degradation testing need not be subjected to penetration or permeation test.

8.3.4 *Selection Based on Permeation Resistance*—Where CPC must provide vapor protection or resistance to permeation of liquid chemicals, or both, permeation resistance data (see Test Method F739, Test Method F1383, Test Method F2588, Practice F1052, and Guides F1001 and F1194) must be reviewed. These data must be interpreted and compared. In addition, factors affecting permeation such as material thickness, exposure to mixtures, and temperature may be important. See Appendix X3 for more guidance in these areas.

8.3.5 *Physical Hazards and Functional Requirements of Task*—Where appropriate, determine other properties, other than chemical resistance, of the CPC and compare them to the functional requirements of the task and physical hazards associated with the task. Consider the need for cut and tear resistance, heat and cold resistance, puncture resistance, abrasion resistance, dexterity, and tactility. Additionally, consider flame, flash, and thermal protection needs. Consider potential human factors requirements such as heat stress, increased work rate, restricted movement, and so forth. Very few data are available for these parameters on most CPC products. Where tests are available for these parameters, few are specific to CPC. Adaptation is possible, however, acceptance criteria often must be determined individually, since the criteria may vary with the job.

8.3.6 *Size*—Determine size options for the CPC candidate materials. Selection of CPC must take into consideration fit of the CPC to the wearer. Improper fit can cause a loss of coordination, dexterity, or tactility, thereby hindering the worker in the performance of his job, decreasing productivity, and possibly causing an increased hazard to the worker. In addition, certain CPC garments, such as TECP suits, may be so large for the individual that they cause increased work effort in performing the job and, consequently, increased stress to the worker. Garments that are too small may become stretched, torn, or separated at the seams and closures during use, thereby compromising protection.

8.4 *Selection Logic*—Based on all of the above factors, select from among the qualifying CPC candidates. The following alternative situations and selection outcomes are based on hazard, that is, the toxicity of the chemical (including propensity for skin absorption) and the nature of the job.

8.4.1 *Low Toxicity*—If toxicity and skin absorption are low, select that CPC demonstrating no observable penetration. The CPC should not degrade for the entire length of the task.

8.4.2 *A Moderate-to-High Toxicity*—For liquid contact or intermittent liquid contact, or both, with contaminants having toxicities and skin absorption properties that are moderate-to-high, select the CPC garment with the longest time to normalized breakthrough or the lowest steady-state permeation rate, or the lowest amount of cumulative permeation. CPC garments not having the best permeation properties (that is, shortest normalized breakthrough times, highest steady-state permeation rates, or high amounts of cumulative permeation) may be selected provided that biological monitoring of the worker, field evaluations of the CPC, or a written risk assessment is performed. CPC should not degrade for the entire length of the task.

8.4.3 *Splash or Spill Only*—Where the only possibility for exposure is limited to splash, spill, or incidental contact, and egress from the workplace is easily achieved, select that CPC garment that demonstrates no observable degradation or penetration over a period of time for which egress would be required. Workers must be instructed to leave the work area and change CPC garments when splashed if garments are selected only for the purpose of resisting splash.

8.4.4 *Gas or Vapor Concentrations Only*—Where potential exposure to high vapor concentration is the only source of exposure, choose CPC in accordance with the toxicity and concentration of the chemical. A buddy system should be used.

8.4.5 *Combinations of Exposure Situations*—Where exposure situations are combinations of the above, select for the worst case scenario.

8.4.6 *Quantitative Selection Criteria*—At present, decisions based on more quantitative selection criteria than described in 8.4 are not possible due to the lack of definitive information on skin absorption and subsequent toxic effects. Therefore, descriptions such as "significant skin absorption," "low toxicity," and "poorly absorbed through the skin" must be used. Individual experience and biological monitoring will indicate whether proper categorization of skin toxins has been made by individuals performing CPC selection.

8.5 *Selection when Permeation, Penetration and Degradation Data are not Available*—See Appendix X1.

9. CPC Use

9.1 CPC should always be used in accordance with the manufacturer's instructions. Where doubts concerning the intended uses of CPC exist, the manufacturer should be contacted.

9.2 The intended uses of CPC should be conveyed to employees during training.

9.3 It is the employee's duty to use CPC in the manner prescribed in the employee's training.

9.4 Emergency-use CPC should be differentiated clearly from routine-use CPC. Only persons who have received appropriate training should use emergency-use CPC. A buddy system shall be used with emergency-use CPC.

9.5 For CPC selected for splash protection only, the employee should be aware of the limited use of such CPC. When splashed, the employee should immediately leave the area and remove the CPC.

9.6 Where a material safety data sheet (MSDS) recommends the use of specific CPC, instructions should be followed, unless reliable data contradicts the MSDS or conditions of use permit alternative CPC. If CPC is generally recommended in a MSDS, use Section 8 to select the CPC.

10. Training

10.1 Supervisors, persons issuing CPC, and CPC users shall be given adequate training by a qualified person to ensure the proper use of CPC. Written records should be kept of the names of persons trained and the dates on which training occurred. A qualified person is the program administrator, a person trained by the program administrator, or a person who has received equivalent training to the program administrator.

10.2 Minimum training for supervisors, issuers, and users of CPC should include the following:

10.2.1 The nature, extent, and health effects (including dermal) of chemical hazards posed by the job.

10.2.2 The proper use, limitations, and purpose of the assigned CPC.

10.2.3 Where appropriate, symptoms and effects of heat stress, including first aid and preventive measures.

10.2.4 Appropriate inspection procedures.

10.2.5 The purpose, limitations, and benefits of biological monitoring and field evaluations, where performed.

10.2.6 The need to inform supervisors of any problems experienced with CPC.

10.2.7 An explanation of why engineering or other administrative controls are not appropriate, adequate, or currently in place for the hazards encountered.

10.2.8 The appropriateness of the CPC used and its limitations with respect to use on other industrial tasks and tasks that may be performed in the home.

10.2.9 Instructions for donning the CPC with particular attention to personal hygiene. Exposure of the skin to the chemical(s) prior to the donning of CPC will increase the absorption of those chemicals after the CPC is donned by the process of occlusion. Consequently, washing of hands and appropriate work practices prior to donning CPC are of extreme importance.

10.2.10 Maintenance and storage of the CPC.

10.2.11 Information regarding the total allowable time of use for the CPC and its final disposition, whether it is disposable or reusable and requires decontamination.

10.2.12 Symptoms that may indicate that a CPC is no longer providing adequate protection include changes in the appearance of the hands or other body parts, such as reddening, or swelling, or a burning sensation, or both, and dizziness, headache, or nausea. Specific warning signs should be understood for each chemical used.

10.2.13 The essential concepts of penetration, degradation, and permeation.

10.2.14 Where appropriate, how to avoid unnecessary contamination of CPC that could lead to the need for decontamination or disposal.

10.2.15 Where appropriate, a simulation, while wearing the CPC, of the work to be performed. This is particularly important for fully-encapsulated suit use.

11. Inspection, Maintenance, and Storage

11.1 *Inspection*—Inspection should be performed upon receipt and periodically by qualified persons where appropriate (see 11.1.2), and it should always be performed by the user prior to donning the CPC. In addition, coworkers should inspect each other's CPC garments after donning to ensure ensemble integrity.

11.1.1 *Inspection by the User*—Each time a CPC garment is used, the user should inspect it for integrity. This entails inspection for cracks, punctures, holes, or other losses of integrity. For example, seams should be inspected. For TECP suits, the user should inspect the face-shield to make certain that it has been put in place properly, and gloves and boots should be inspected to make certain that they are attached correctly. Pressure relief valves should be inspected to make certain that they are in place and operational.

11.1.2 *Inspection of TECP Suits by Qualified Personnel*—Qualified personnel should inspect TECP suits for integrity, as described above, on a scheduled basis. The inspection of TECP suits should include an integrity test. Pressure tests and simulated exposure tests are available (see 3.1.2). A qualified person is one who has received training specifically in the use of integrity tests and preferably in the repair of CPC garments.

11.2 *Maintenance*—Maintenance tasks may be performed as necessary on CPC, particularly some TECP suits. Repairing holes, tears, or other losses of integrity in a TECP suit should be performed only by a qualified person who has received training in this area. Replacement of boots, gloves, face shields, or exhaust valves should also be performed only by qualified persons. After repairs or other maintenance, appropriate integrity tests should be performed.

11.3 *Storage:*

11.3.1 CPC may be degraded by ozone and other oxidants, ultraviolet and other forms of electromagnetic radiation, and heat. CPC should consequently be stored in clean areas with minimum light exposure, adequate temperature control, adequate ventilation, and in areas that are separate from chemical storage.

11.3.2 Many types of CPC may crack along folds or creases. CPC, particularly non-disposable TECP suits, should consequently not be stored in a folded position. They should be hung without undue stress on the CPC.

12. Decontamination and Disposal

12.1 Once CPC has been contacted by a chemical, the chemical may enter the CPC in significant quantities. The chemical will then slowly diffuse from the CPC to the inside or outside environment. This source of exposure may be important. In addition, a foreign chemical in the CPC matrix may change the permeation properties of the CPC. Finally, chemicals that may not permeate CPC readily may remain as surface contaminants. Each of these factors must be considered in the reuse and perhaps disposal of CPC.

12.2 Where the toxicity and absorption potential of the contaminant and the cost of the garment warrant, the CPC should be decontaminated prior to reuse. In general, warm soapy water containing detergent will help remove surface contamination. Hot air washing (temperatures up to 50°C [122°F]) has been found to be effective in decontaminating many CPC garments, but it may not be suitable for each garment/chemical combination.

12.3 Disposal of water or other solvent used to decontaminate CPC should be performed in accordance with local, state, and federal regulations.

12.4 If a commercial laundry or other contractor is used to decontaminate CPC, this party should be notified of the contaminant(s) and their associated hazards.

12.5 Where the cost of a garment allows, or the toxicity of the contaminant warrants, disposal of CPC, disposal should occur in accordance with all local, state, and federal laws.

13. Field Evaluations and Biological Monitoring

13.1 Since there are many uncertainties in the selection and use of CPC, the best process for ensuring the proper use and selection of CPC is to evaluate its performance in the field by assessing exposures to the skin or via biological monitoring to assess actual body burdens of workers, or both. In many cases, airborne concentrations of chemicals may be demonstrated to be low. However, only through the use of biological monitoring can it be determined that other sources of exposure, such as skin absorption, are being controlled.

13.2 The use of field evaluations or biological monitoring may be appropriate when one is not confident about the choice of CPC, when substitution of a less expensive form of CPC is attempted, or when use and reuse schedules are changed. The goal of field evaluations is to monitor beneath the CPC in order to determine a total dose to the skin. This total dose may then be compared to a hypothetical total dose that would be received by inhalation exposure at the appropriate occupational health permissible exposure level. A risk assessment is then performed in order to determine the relative hazard of the skin dose.

14. Purchasing

14.1 Specific CPC should be identified, and an equipment and supplier list should be approved, by the program administrator. CPC materials of the same generic type from different vendors may actually vary considerably in both chemical formulation and in physical structure.

14.1.1 Products requested, that is, a specific manufacturer's nitrile gloves, should not be substituted without consent and approval of the program administrator.

14.1.2 Requests for new or not previously approved CPC should be forwarded to the program administrator. The purchase of such equipment should be delayed until the equipment and use has been approved.

14.1.3 Changes in vendors or manufacturers should be approved by the program administrator to ensure that appropriate equipment is substituted. All changes should be communicated to the affected individuals.

14.1.4 Inventory control should be practiced, and limits should be placed on maximum and minimum amounts of CPC in storage.

15. Medical and Human Factors Considerations

15.1 All garments inhibit the loss of heat from the body. Because they are barriers, CPC garments inhibit the loss of heat from the body significantly. Since most CPC (for example, TECP suits) are negligibly permeable to water, the loss of body heat by evaporation is severely compromised. Consequently, heat stress must be considered, particularly where CPC covers most or all of the body. Where TECP suits are necessary, as in emergency work, the employer must control heat stress through such means as work and rest regimens, ice or other cooling vests, vortex tubes, other mechanical devices, and generalized cooling.

15.2 Use of some CPC may cause physiological or psychological concerns, such as heat stress, increased metabolic energy expenditure, physiological strain, dehydration, claustrophobia, irritability, and general anxiety. (These manifestations are most likely to occur with the use of TECP suits.) Workers should be medically screened to determine whether the employee can use the CPC assigned safely.

15.3 CPC garments, especially TECP suits, may compromise worker performance by reducing mobility, dexterity, tactility, visual acuity, cognitive and perceptual performance, and the ability to communicate. Balance, tolerance time, efficiency of movement, and effective body size may also be affected. All training exercises involving TECP suits (Section 10) should include an evaluation, under simulated conditions, of the employee's ability to perform the assigned tasks.

15.4 CPC selection is a balance between protection from chemical hazards and performance, physiological, and psychological burdens. Chemical protection should not be compromised, nor should the worker by burdened unnecessarily.

16. Auditing the Program

16.1 Auditing is an essential element to an effective CPC program. It is a management safeguard to ensure that the established program elements are being implemented properly.

16.2 An audit program team should have at least one member who is an outside industrial hygiene consultant trained in CPC control techniques (this may be a person from the corporation level who is not involved directly at that specific site).

16.3 The audit should consist of a written check list or standard operating procedure for evaluating both the implementation and effectiveness of the program elements.

16.4 This audit procedure should include a spot check of selections of CPC and interviews with a selection of CPC users. The team should determine whether CPC is being used where appropriate and being used properly.

16.5 The audit report should be in a written format documenting the basis for deficiencies found and including recommendations for program improvements.

16.6 The recommended frequency for these audits is at least annually.

17. Keywords

17.1 chemical protective clothing; chemical protective clothing program; protective clothing

APPENDIXES

(Nonmandatory Information)

X1. EXPOSURE SITUATIONS, TOXICITY INFORMATION, AND OTHER FACTORS TO CONSIDER IN DETERMINING SIGNIFICANT SKIN EXPOSURE

X1.1 Corrosive chemicals may destroy the skin by direct attack.

X1.2 Solvents can dissolve the skin's natural oils, leaving the skin dry and liable to form painful cracks. Such damage to the skin, together with any existing cuts and abrasions, provides entry points for foreign substances and thus increases the risk of harm to the body.

X1.3 Many chemicals may pass rapidly through the skin and be carried by the bloodstream so as to cause injury to other parts of the body that may be remote from the initial point of contact.

X1.4 For some chemicals, the skin route may be far more important than inhalation. This is particularly true for low vapor pressure compounds such as pesticides.

X1.5 Chemicals may gain access to the body via, for example, the eyes, ears, and respiratory or digestive tract.

X1.6 The body's tolerance and rate of elimination of a foreign substance varies from person to person and with environmental factors such as temperature.

X1.7 The harmful effects depend broadly on the amount of substance contacted or absorbed.

X1.8 The above, in turn, is related to the concentration of the substance to which the body has been exposed, or to the concentration in the environment, and to the duration of exposure.

X1.9 The rate at which a chemical is taken up by the body, and possibly its site and mode of action, may depend on whether it is swallowed, inhaled, or absorbed through the skin.

X1.10 Adverse effects on health may arise from a single exposure or repeated exposure to small amounts of a chemical and may be immediate or delayed.

X1.11 The work rate and metabolic rate of the worker may affect the degree of hazard for a chemical exposure.

X1.12 A mixture of chemicals may create a greater hazard than would the same chemicals separately.

X1.13 *Intermittent Exposures*—Permeation tests (for example, Test Method F739) for single components generally simulate a worst-case condition, constant and direct contact. This condition is constant exposure to or direct contact, or both, of the chemical contaminant with the CPC. In reality, few exposures in industry occur in this fashion. Instead, exposures are usually for a short duration, with periods of noncontact in between. Reduction of contact time will affect permeation results. In general, normalized breakthrough times will be increased, and average permeation rates are decreased compared to continuous-contact, steady-state permeation rates. Where the use of CPC for long periods of time and multiple exposures is desired, permeation tests should be performed that simulate the actual working conditions. The results of these tests may allow the use of CPC that may have been eliminated, had only continuous permeation data been considered.

X1.14 The standard laboratory conditions for most published permeation data do not involve squeezing, stretching, or flexing the CPC, which tends to decrease thickness. Under these conditions, CPC tends to yield shorter breakthrough times. A safety factor may be applied to published data to allow for this effect.

X1.15 *Splash Exposure*—In many industrial situations, CPC garments are selected for use where only a spill or splash exposure is anticipated. In these cases, the CPC garment is not expected to remain in contact with the chemical contaminant for a long period of time. Where this is the case, it is important that the employee know that if spill or splash does occur and the garment is exposed, the employee should leave the work area and immediately change garments. CPC selected for these situations should pass a penetration test and therefore disallow the penetration of liquid to the employee's skin.

X1.16 *High-Concentration Vapor Exposure*—In general, permeation is less when a CPC garment is exposed to the vapor form of a liquid chemical as opposed to the liquid itself; however, vapor or gas forms of industrial contaminants can penetrate or permeate CPC, or both. When the possibility of splash is the first selection priority, exposure to high vapor concentrations should be considered, in addition, and vapor permeation test results should be used where the toxicity of the chemical warrants.

X1.17 *Confined Spaces*—Work in confined spaces, where egress is not easily attained, requires that a backup-person buddy system be used. Selection of CPC should be based on a worst-case scenario. For example, if splash or spill exposures are the main considerations, one must consider the possibility that the worker may lose consciousness, fall, and be exposed to continuous liquid contact for a considerable period of time.

X1.18 As a general rule, polar polymers (for example, PVA-polyvinyl alcohol) tend to be more resistant to permeation by low-polarity chemicals (for example, chlorinated hydrocarbons and aromatic solvents), whereas relatively low polarity polymers (for example, butyl rubbers) tend to be more resistant to permeation by polar chemicals (for example, ketones and alcohols). Highly saturated polymers (for example, polyesters, polyamides, and polyethylene) offer high resistance to permeation by a wide range of organic liquid chemicals; however, as they have little or no elasticity, only very thin films may normally be used in the construction of items of protective clothing from these polymers.

X1.19 The interactions between permeating chemicals and polymers can be complex, but the selection of materials may be guided by 8.3.1, quick-selection guides (**3**), compendiums of chemical resistance data, or expert assessment of physical-chemical parameters, when available.

X2. INFORMATION TO CONSIDER WHEN CONFIGURING CPC

X2.1 *Layers*—Layering is an important principle to consider, particularly where the problems of loss of coordination or tactility, or exposure to mixtures, or both, is involved. For CPC that provides adequate permeation qualities but poor tactility or coordination and loose fit, tightly fitting CPC may be applied over the loose fitting CPC garment (in particular, gloves) in order to improve the coordination properties. Layering of CPC garments having different polymeric makeup may provide an adequate barrier for mixtures of different classes of chemicals. There are no hard-and-fast rules for making the selection of the layers in the latter case. It is recommended that permeation resistance testing be performed in order to determine the adequacy of layers. Finally, layering may be used to protect an expensive CPC garment with a less expensive one. The outer garment should be disposed of properly after use.

X2.2 *CPC Components*—For certain CPC types, particularly TECP suits, the selector must consider the components of the suit in addition to the suit material itself. Face shields, pressure relief valves, gloves, and boots may be made of materials that differ from the suit. Consequently, they may be the weakest links in the exposure control process and should be considered individually for particularly toxic contaminants.

X2.3 *Respirator Selection Coordination*—Where respirators will be used with CPC, it is important that the selection of respirator and CPC be coordinated. This is particularly true for TECP suits. Important factors include loss of visibility, inability to control respirator valves or view pressure gages, and improper fit of the respirator within or around the hood of the suit.

X3. FACTORS AFFECTING THE INTERPRETATION AND USE OF PERMEATION RESISTANCE TEST DATA

X3.1 In interpreting permeation data, the following concepts should be considered.

X3.1.1 One of the parameters commonly reported from permeation tests, breakthrough time (breakthrough detection time), is not purely a function of the CPC and the chemical to which it is exposed. Breakthrough detection time is also a function of the analytical sensitivity of the instrument that detects permeation. Normalized breakthrough time, as defined in this practice, is independent of analytical sensitivity and can be compared across tests.

X3.1.2 Permeation tests are not always easily interpretable. Summary parameters, such as normalized breakthrough time and steady-state permeation rate, do not provide complete results concerning how the chemical may permeate through a CPC material. Only a complete report, including a permeation plot, will provide this (see Test Method F739).

X3.2 *Comparison of Permeation Data*—For several reasons, comparison of permeation data produced by differing manufacturers or differing researchers can be difficult. There are several variables that can complicate this process, and they include the following:

X3.2.1 Polymers of the same generic type from different manufacturers (for example, butyl rubber) may not have the same formulations or may vary over time, and hence the permeation behavior may vary.

X3.2.2 The sample size for most permeation testing is only three and does not necessarily include more than one lot. Consequently, poor manufacturer's quality control can lead to permeation test results that are not reflective of the performance of most CPC articles of that manufacturer.

X3.2.3 When steady-state permeation rate and normalized breakthrough times are reported from a series of three tests, the results should be reported as an average of the three tests (see Test Method F739), but they may be reported as the highest or lowest value of the three tests.

X3.2.4 Variability in thickness from lot-to-lot or within a garment sample of CPC can affect the results of a permeation test.

X3.3 *Use of Permeation Data*—At least three important factors affect the use of permeation resistance test data, as follows:

X3.3.1 *Thickness*—Permeation theory indicates that for a given polymer, as thickness increases, steady-state permeation rate decreases. While this is true only for permeation that obeys Fick's law, it can be used as a general guide. However, a similar relationship does not exist for breakthrough detection time and thickness, since breakthrough detection time is dependent on analytical sensitivity.

X3.3.2 *Temperature*—Increasing temperature affects permeation, increasing the steady-state permeation rate and decreasing normalized breakthrough time and breakthrough detection time. The relationship between the temperature and these parameters must be established for each CPC-contaminant pair. To establish the relationship, tests must be performed at a minimum of two different temperatures. Unfortunately, little permeation data exists for temperature differing from room temperature.

X3.3.3 *Mixtures*—While a considerable amount of permeation work has been performed for exposures of CPC to single chemicals, very few studies exist that deal with mixtures. Of course, mixtures are the most common sources of exposure in industry. Current information indicates that it is not appropriate to use the results from tests involving individual chemicals to determine the potential permeation results for a mixture of those individual components. Consequently, at this time the safest procedure is to perform permeation tests for all mixtures, particularly where one or more components are particularly toxic, no matter what their concentrations.

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