

# PROTECTION

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## 24.1 GLOVES

Many types of gloves are manufactured for different purposes. Proper gloves selection is important to ensure that the solvent or other chemical compound cannot penetrate through the glove where its subsequent evaporation would be prevented by the glove itself. Exposure to solvent entrapped between the glove and the skin is more severe than the exposure to solvent without glove.

The first requirement in the selection of a glove is that the materials from which gloves are produced are not dissolved or swollen by solvent. This alone is not sufficient. The other important requirement in glove selection is permeability of all of the materials in its structure. Permeability is measured according to ASTM Standard F 739 or European Standard EN 374. Permeability results are usually expressed in mg of permeate which penetrates 1 m<sup>2</sup> of material per minute. Good materials for gloves should have permeability below 1 mg m<sup>-2</sup> min<sup>-1</sup>. Materials having permeability in the range from 1 to 10 mg m<sup>-2</sup> min<sup>-1</sup> may still be considered as suitable materials.

Relative to permeability, materials are rated by a five point scale of the permeation index number. The best choice of glove material has a permeation index number = 0. If the material has index 1 (permeability in the range from 1 to 10 mg m<sup>-2</sup> min<sup>-1</sup>), the glove can be eventually accepted for harmful chemicals. Any higher index number makes justification for its use more difficult and in plain language such a glove should not be used with harmful chemicals.

Breakthrough time is another measure of glove fitness for purpose. This parameter measures the time in minutes during which a measurable amount of a particular chemical compound penetrated through a particular garment. Specialized monographs give data on breakthrough times for a large number of gloves and other protective clothing and numerous penetrants.<sup>1,2</sup> These sources<sup>1,2</sup> are the best collections of data which should be considered in glove selection. There is a relationship between permeation rate (and thus permeation index number) and breakthrough time. For practical purposes gloves are selected based on the assumption that they should resist penetrant breakthrough for more than eight hours. Such gloves are generally considered to have permeability index number = 0.

In addition to the properties of protective clothing materials, the toxicity of the penetrant should be considered. For less toxic solvents, materials with a permeation index

number of 1 or even 2 may still be cautiously considered but will be less acceptable for more toxic penetrants.

Monitoring the quality of protection during use is not less important. Materials are not permanent. Frequent inspection of gloves is therefore very important. Any mechanical damage will compromise protection properties. The presence of cuts, cracks, or holes immediately renders the gloves useless. Gloves should be inspected for changes of color, texture, or hardening which are signs of material degradation.

It should be borne in mind that protective clothing is not universal for all chemical materials. For this reason, protection against one penetrant does not suggest that the glove has protecting qualities against the other materials. Mixtures of solvents behave in a different manner than do pure components. The temperature at which exposure occurs is also an important factor. Generally as temperature increases, permeability increases.

Table 24.1 gives general guidance regarding the applicability of different glove materials for different groups of solvents. Note that glove materials are not equal. They vary with the formulation used by a specific manufacturer and the thickness of the protective layer. For each selection, the manufacturer's specification should be consulted to estimate previously discussed parameters. The best practice requires that gloves are tested for particular conditions of their use. The other good option is to consult results of measurement included in the specialized monographs.<sup>1,2</sup>

**Table 24.1. General guidelines for selection of gloves for different groups of solvents**

Solvent group	Suitable glove materials	Manufacturer
Acids	butyl neoprene Saranex-23	North and many other Ansell, Best, and many other DuPont
Aldehydes	butyl PE/EVAI/PE*	Best, North and many other Safety4
Amines	PE/EVAI/PE*	Safety4
Esters	PE/EVAI/PE* PVAI	Safety4 Edmont
Ethers	PE/EVAI/PE* PVAI	Safety4 Edmont
Halogenated hydrocarbons	PE/EVAI/PE* PVAI Viton	Safety4 Edmont North
Hydrocarbons, aliphatic	nitrile PE/EVAI/PE* Viton	Best, Mapa-Pioneer, North Safety4 Best, North
Hydrocarbon, aromatic	PE/EVAI/PE* PVAI Viton	Safety4 Anselledmont, Comasec North

Solvent group	Suitable glove materials	Manufacturer
Ketones	butyl PE/EVAI/PE* PVAI	Best, Comasec, Guardian, North Safety4 Anselledmont, Edmont
Monohydric alcohols	butyl nitrile neoprene	Best, Guardian, North Best, Comasec Ansell, Best, Mapa-Pioneer
Phenols	butyl neoprene Syranex-23	Best, Comasec, North Anselledmont, Mapa-Pioneer DuPont
Polyhydric alcohols	neoprene nitrile rubber	many manufacturers

\*PE/EVAI/PE = polyethylene/ethylene vinyl alcohol/polyethylene

The above suggested selections are based on the test data included in the monograph.<sup>1</sup> Only the gloves which have a permeability index number = 0 were included. However, since solvents in each group frequently have diverse physical properties, in some specific cases the selection for that group may not be the most suitable for a particular member of the group. It should be also considered that some manufacturers have several grades of gloves in the same generic group of polymer therefore their specification should always be consulted.

## 24.2 SUIT MATERIALS

The selection of suit material is more complex because not only physical properties of the components but also the design of suit and structure of laminate used will determine its barrier properties. As a whole, these are usually proprietary and difficult to compare. The information in Table 24.1 can be used for general guidance but the industrial hygienist should make a full evaluation of the performance of the protective clothing in particular conditions and application.

## 24.3 RESPIRATORY PROTECTION

The selection of a respirator, general suggestions for its use, the adsorption capacity of filters, and breakthrough time are reviewed below.

The selection of respirator is based on the nature of respiratory hazards such as permissible exposure limits, established concentration immediately dangerous to life, actual concentration of hazardous substances, and amount of oxygen. When using filters, the ambient air must contain at least 20% oxygen at sea level. Filter protection should not be used for unknown contaminants and contaminants that are immediately dangerous to life and health.

Permissible exposure limits and actual concentration determine (among other factors) the breakthrough time as discussed below.

Only approved respirators should be used. Each country has a body which can approve respirators for use. In the USA, respirators are approved jointly by the National Institute for Occupational Safety and Health (US Department of Health and Human Services) and the Mine Safety and Health Administration (Department of Labor).

In addition to the the above parameters determining respirator selection, the following factors are also considered: nature of operation process, location of hazardous area (especially in respect to supply of respirable air), employee activity and intensity of effort required to perform the work (determines the amount of air which must be supplied to lungs), physical characteristics and limitations of various respirators.

The selection of respirator must be done with a full consideration of these many factors which require specialized knowledge going beyond this discussion. Further information on this subject can be found in the specialized monograph.<sup>3</sup>

Respirators can be generally divided into two main groups: air-purifying respirators and atmosphere-supplying respirators. The first group is more common and for this reason will be discussed in more detail below. Air-purifying respirators are still divided into non-powered and powered and these are further divided into gas/vapor and particle removing. Our main interest here is given to vapor-removing, non-powered respirators which are the most common in industry and laboratories in solvent applications.

Two additional subjects are integral part of good protection: respirator fit testing and training of users. Non-powered, vapor-removing respirators are also termed as negative pressure respirators. This means that respirator is under positive pressure during exhalation and under negative pressure during inhalation. If the respirator does not fit the user properly, some air from the surroundings will be drawn into the respirator during inhalation because of leaks. This will result in a diminishing efficiency of protection. For this reason, each user should be given help from the employer in selecting the most suitable type and size of respirator for the particular individual. In addition, the reasons for fitting should be clearly explained so that they are fully understood by the employee. It is only the employee who may later assure that the respirator is used properly and this will depend on his/her full understanding of the principles.

The first matter of importance is the rate of breathing under various conditions. The amount of air we breathe depends on our energy requirements or more precisely on the intensity with which we expend energy. If no work is performed, the average human being requires about 10 l of air per minute. The rate of breathing increases with the intensity of work (light work 20-30, heavy work 70-100 l/min). The use of a filter reduces air flow rate due to the pressure drop and many respirators cannot cope with high rates of flow which becomes the one important limitation of negative pressure respirators that must be evaluated during the selection process.

The pressure drop in the filter depends on its design. Chemical cartridges used for solvent adsorption are filled with activated carbon or activated charcoal which are amorphous forms of carbon characterized by their ability to rapidly absorb many gases and vapors. The carbon is obtained by pyrolysis of wood, nutshells, animal bones, petroleum products, and other carbonaceous materials. Activated carbon for respirators usually comes from coconut shells or coal after activation at temperature in the range from 800 to 900°C. It has a porous structure with a surface area of 10,000 m<sup>2</sup>/g. On the one hand, maximizing surface contributes to increased capacity on the other it may lead to an increased pressure drop during breathing (depending on particles shapes and sizes). It is thus important to consider both capacity of the filter and its pressure drop.

The adsorption of vapor is a physical process which can be reversed. Desorption of vapor does not require a high energy and is equilibrium driven (equilibrium relative to the concentration of vapor in surrounding atmosphere and distribution of adsorbed vapor in

activated carbon). Desorption during storage or non-use time can result in migration of previously adsorbed molecules. This phenomenon is very important for effective use of respirators. On one hand, it precludes the possibility of cartridge recycling. On the other hand, it imposes restriction on cartridge use. For good performance the mask should be worn 100% of the time. It is estimated that removal of respirator for 5 min in an 8-hour day causes a loss of 50% of the expected protection. It is also important to limit filter use to one shift even if it were not fully exhausted in that time.

The absorption capacity is calculated from the following equation:

$$W = \rho W_o \exp \left[ -\frac{BT^2}{\beta} \left\{ \log \frac{p_s}{p} \right\}^2 \right] \tag{24.1}$$

where:

- W adsorption capacity per unit weight of carbon
- $\rho$  solvent density
- $W_o$  total volume of adsorption space
- B microporosity constant of carbon
- T temperature
- $\beta$  affinity coefficient of solvent vapor for carbon
- $p_s$  saturated vapor pressure of solvent at temperature T
- p equilibrium partial pressure of the solvent

This equation shows that both solvent type and type of carbon affect performance. On the solvent side, its density, affinity, saturated vapor pressure and its actual concentration determine adsorption. On the carbon side, its porous structure and surface area available for adsorption determine the capacity of a particular filter. The data for the parameters of the equation can be found in chemical handbooks and therefore the equation can be used for predicting the adsorption capacity of a filter. The capacity of commercial filters is normally rated by experimental method in which amount of solvent adsorbed by filter is determined under conditions which specify concentration of solvent, rate of flow, and time. For example, a filter which contains 70 g of activated carbon was found to adsorb 20-25 g carbon tetrachloride present in concentration of 1000 ppm.

Under conditions of use it is important to predict how long a particular cartridge will last under real conditions. This is done by estimation of the breakthrough time from the following equation:

$$t = \frac{W\rho_c An}{QC_o} \left[ z + \frac{1}{a_c \rho_c} \left( \frac{dG}{\eta} \right)^{0.41} \left( \frac{\eta}{\rho_a D} \right)^{0.67} \ln \left( \frac{C_b}{C_o} \right) \right] \tag{24.2}$$

where:

- W adsorption capacity per unit weight of carbon
- $\rho_c$  carbon density
- A cross-sectional area of adsorbent bed
- n number of cartridges tested
- Q flow rate
- $C_o$  concentration of solvent
- z V/A where V is carbon volume
- $a_c$  specific surface area

d	diameter of granule
G	mass velocity through the cartridge
$\eta$	viscosity of air-vapor stream
$\rho_a$	density of air-vapor stream
D	diffusion coefficient
$C_b$	breakthrough concentration

This equation gives information on the relevance of major parameters of performance of filters. Breakthrough time increases with the increase of the following parameters: adsorption capacity of carbon, its density, its volume, and the cross-sectional area of the adsorbent bed and size of the granules. It decreases with increased flow rate, concentration of solvent, and an increase in the value of the diffusion coefficient. The toxicity of solvent plays a role here as well because with the increase of solvent toxicity, the breakthrough concentration is decreased which decreases breakthrough time. Breakthrough time for 3M cartridges can be calculated using available software by providing the type of solvent, its concentration, and type of work (light, medium, heavy). In addition, relative humidity is accounted for in the calculations. The adsorption of vapors is not affected by humidity below 50% but decreases rapidly as the relative humidity increases above 50%. Adsorption temperature is also an essential factor.

The above discussion shows that, although there is generally one type of cartridge used for organic vapor, all cartridges are not the same in terms of performance. The conditions of use of these respirators determine if they can perform specific protective functions. Considering that one cartridge, typically disposed after one day work may contain 40 g of solvent which would otherwise be inhaled, the selection and use of respirators is not a trivial matter and should be given serious attention.

## REFERENCES

- 1 K Forsberg, L H Keith, **Chemical Protective Clothing. Performance Index**. 2nd Ed., *John Wiley & Sons*, New York, 1999.
- 2 K Forsberg, S Z Mansdorf, **Quick Selection Guide to Chemical Protective Clothing**. 3rd Ed., *John Wiley & Sons*, 1997.
- 3 W H Revoir, C-T Bien, **Respiratory Protection Handbook**, *Lewis Publishers*, Boca Raton, 1997.