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Method of Testing the Penetration of Acid Solutions Through Safety Gloves

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Because they cause burns that are difficult to heal, acids are dangerous, and steps should be taken to ensure that the human skin does not come into contact with them. For this purpose safety gloves are generally used by workers who have to handle acids. Such gloves need to be tested to ensure that they are acid resistant. Standard EN 374 (European Committee for Standardization [CEN], 1993c) specifies a method of testing the permeation of liquid chemicals, on a molecular level, through glove material, but it may be difficult to ensure the fitness of the joints of a two-compartment cell, when gloves are lined with jersey. To deal with this a simple pH-meter method to test the permeation of acid and alkali solutions through safety gloves has been developed. The permeation of H_2SO_4, HCl, HNO_3, and CH_3COOH through gloves made from neoprene, nitrile, and PVC was tested. This method seems to be simple and economical.

chemical gloves   safety gloves   acid permeation   acid resistance

1. INTRODUCTION

Corrosive mineral acids such as hydrochloric, sulfuric, nitric, and acetic acids are found in industry in a variety of concentrations. For example, the commonly used automobile battery acid is usually about 39% sulfuric acid.

Skin contact with strong acids results in corrosive burns. Organic acids of low molecular weight (e.g., acetic acid) are strong irritants, but they are somewhat less corrosive than mineral acids, which produce more serious

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damage. However, both substances are dangerous because when they come into contact with the skin they cause burns and various dermatitis that are difficult to cure. (Gleason, Gosselin, Hodge, & Smith, 1969). Hand injuries often result from contact with dangerous chemicals. Thus, it is important to wear safety gloves that ensure proper protection.

Selecting gloves that protect against chemical hazards may be difficult. Part of the problem lies in the wide range of acids, alkalis, and other chemicals that are used in industry and commerce. Another part of the problem is related to the large and ever increasing number of materials used for manufacturing chemical gloves (natural rubber, neoprene, butyl, nitrile-butadiene, polyvinyl chloride, polyethylene, polyvinyl alcohol, viton, hypalon). These materials vary considerably in their resistance to chemicals. Even the acid resistance of gloves of similar material may vary, from manufacturer to manufacturer, because they differ in terms of thickness, the presence or absence of a fabric base, and the number of coatings employed. Chemical gloves are frequently made with a patterned or rough surface to improve gripping when handling wet or slippery objects. Nearly all types of chemical gloves are lined for general comfort and as a protection when handling hot or cold objects.

The choice and correct use of safety gloves must be based on the results of tests that demonstrate chemical resistance of the glove material to permeation.

For testing the chemical resistance of gloves the following definitions are provided:

- degradation—a deleterious change in one or more mechanical properties of a protective glove material due to contact with a chemical;
- penetration—the movement of a chemical through porous materials, seams, pinholes, or other imperfections in a protective glove material on a non-molecular level;
- permeation—the process by which a chemical moves through a protective glove material on a molecular level; permeation involves the following:
  - sorption of molecules of the chemical into the contacted surface of a material,
  - diffusion of the sorbed molecules in the material,
  - desorption of the molecules from the opposite surface of the material.

Methods for testing protective gloves for chemical permeation are specified both in the EN 374 standards (European Committee for Standardization [CEN], 1993a, 1993b, 1993c) and in EN 369 (CEN, 1992). However, methods for testing the chemical degradation of glove material (which will become standard EN 374, part 4) have yet to be developed—this is due to difficulties encountered in testing jersey-lined gloves.

Penetration is simply measured by water leak and air leak tests described in standard EN 374 (CEN, 1993b).

Permeation of acid solutions on a molecular level may be tested by the method described in standard EN 374 (CEN, 1993c), which will be used in the future. However, this method does not show in detail the analytical techniques used to detect the test chemical. According to the literature, a small quantity of acids may be detected by the turbidimetric method, by spectrophotometry, and by colorimetry (Domański, 1992, 1993; National Institute for Occupational Safety and Health, 1977, 1979), and so forth.

A simple test for measuring the permeation of acid through chemical gloves based on the determination of pH value has been developed and is now being used at the Central Institute for Labour Protection (CIOP; Warsaw, Poland).

2. METHOD

Testing was performed in a laboratory, where the temperature was 23°C (±2) and the relative humidity was 50% (±5).

The penetration of acids through polymer gloves was determined by using five middle fingers cut from the gloves. All samples had the same length and diameter. A micrometer was used to determine the thickness of the glove fingers. Leak tests (described in standard EN 374; CEN, 1993b) were employed to check whether the gloves were sound. Before testing, the fingers were turned inside out to ensure contact of the external surface of the glove with the acid.

A 250-cm^3 glass beaker was filled with 150 cm^3 of distilled water. A magnetic stirrer, with a rotation speed of 50 turns per minute, and the combined electrode of a pH-meter were put in the water. The pH-meter was connected with a computer and a printer.

A finger was stretched over a 25-cm^3 beaker with 10 ml of an acid or basis solution. The beaker was turned upside down so that the finger was filled with the solution and placed in the beaker with the water, so that the water level was 3 cm above the finger tip.

From this moment, continuous measurements of the pH value were taken. When pH reached the value of 3.5 for acids and 9.5 for alkali, the test was stopped, according to the pH-range in the EN 420 standard (CEN, 1994).

The time it takes for acid or alkali to penetrate the glove materials is an indication of the resistance of the glove to penetration. If penetration takes longer than 8 hrs, the tested glove is considered resistant to the acid being used.

The draft of the Polish standard prPN-P-84687 (Polski Komitet Normalizacyjny, 1996) describes a reduced, simple method useful when a pH-meter is not necessary for glove users. An indicator, which changes colour due to the pH of a solution, can be added to the beaker with distilled water. A 0.01% solution of methyl orange, which changes colour at a pH value from 3.1 to 4.4, is used for an acid solution; for alkali—a 0.05% solution of phenolphthalein, which changes colour at a pH value from 8.2 to 10, is used. The researcher checks for colour change every 30 min for a period up to 8 hrs.

3. TESTING MATERIALS AND RESULTS

Commercially produced (Ansell-Edmont, Belgium) gloves were used for testing: (a) Neoprene (Neotop), 0.70–0.87 mm thick; (b) Nitrile (Solvex plus), 0.45–0.59 mm thick; and (c) PVC (Green fit), 0.26–0.39 mm thick. The thickness of the gloves was measured with a micrometer with an accuracy of 0.1 mm. Acids H_2SO_4, HCl, HNO_3, and CH_3COOH (concentrated and 40% solutions) were used as chemicals. At first, the simplified method was used. Table 1 presents the results of testing acid permeation through gloves. Five samples of each type of gloves were tested using the method based on the change of indicator colour. The shortest permeation time of the acid solution was accepted as the test result.

When 40% solutions of acids were used, permeation time was longer than 8 hrs, with the exception of HNO_3 and PVC gloves. For those gloves, permeation time was between 2.5 and 3 hrs.

TABLE 1. Permeation of Concentrated Acids Through Safety Gloves (the Lowest Time of Permeation)

	Time of Permeation (hrs)			
Glove	H_2SO_4 concentration 98%	HCl concentration 37%	HNO_3 concentration 25%	CH_3COOH concentration 80%
Neoprene (Neotop)	2.5	> 8	> 8	6.5
Nitrile (Solvex plus)	6.0	> 8	2.0	5.5
PVC (Green fit)	< 0.5	0.5	0.5	< 0.5

Figures 1 and 2 show changes in the value of pH when testing nitrile and PVC gloves against concentrated HNO_3. Figure 3 presents the change of the pH value of 40% HNO_3 through PVC gloves. These figures were obtained using the method with a pH-meter and a magnetic stirrer; three samples were used for each glove.

The shortest acid permeation time was accepted as the test result.

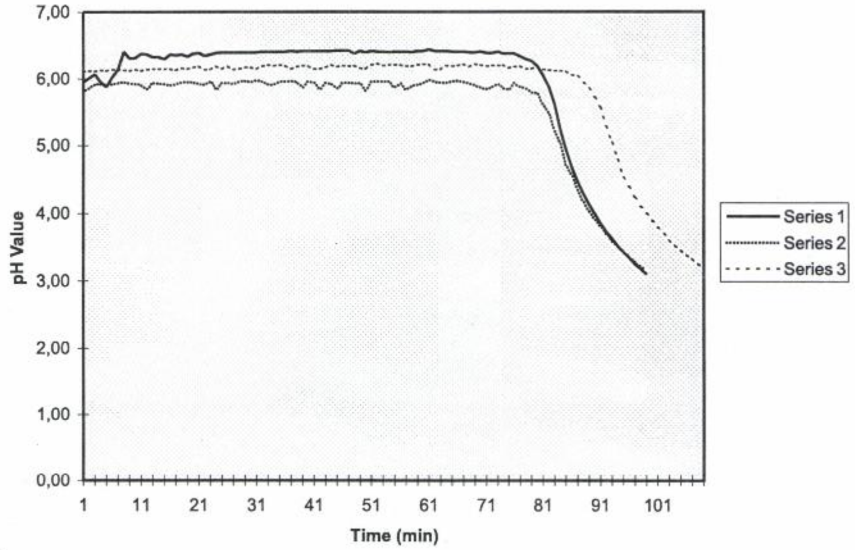

Figure 1. Permeation of concentrated HNO_3 through nitrile gloves.

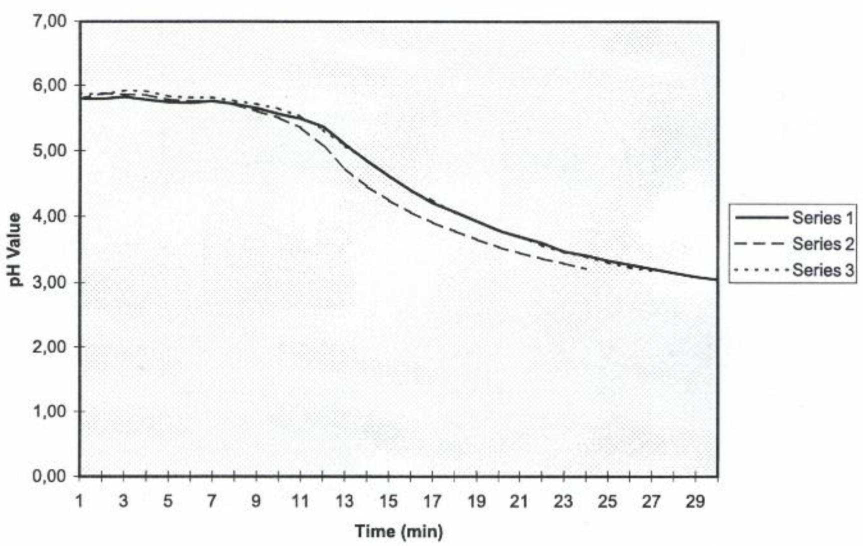

Figure 2. Permeation of concentrated HNO_3 through PVC gloves.

4. DISCUSSION

The permeation of a 40% solution of HNO_3 tested by both the simplified colour indicator method and by the more complex method, in which a magnetic stirrer and a pH-meter are employed, is nearly the same (Table 2 and Figure 3); the small difference in permeation may have been caused by a slight difference in the thickness of glove material.

TABLE 2. Permeation of HNO_3 Through Gloves Tested by the pH-Meter Method

Acid (concentration)	Glove	Series	Time of Reading the 3.5 pH Value (min)
HNO_3 (65%)	Nitrile (Solvex plus)	1	95
		2	94
		3	104
HNO_3 (65%)	PVC (Green fit)	1	23
		2	20
		3	23
HNO_3 (40%)	PVC (Green fit)	1	113
		2	126
		3	129

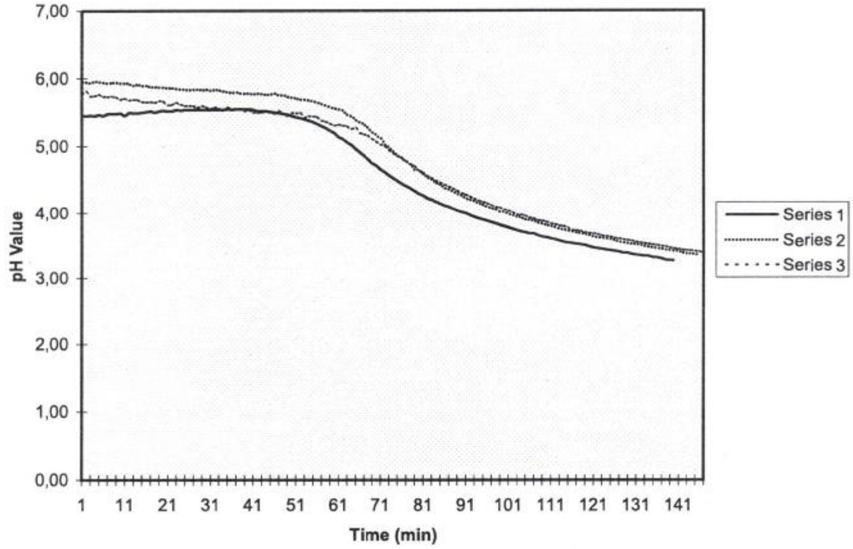

Figure 3. Permeation of 40% HNO_3 through PVC gloves.

When concentrated HNO_3 was used as a chemical medium, the differences were more significant. For example, the permeation time of HNO_3 through nitrile gloves tested with the use of an indicator was 3 hrs; however, the permeation of the same acid through the same gloves when a mechanical stirrer and a pH-meter were employed only took 90 min (Figure 1). This difference was probably the result of using a magnetic stirrer to mix the water in which the sample was dipped.

The movement of water molecules by stirring probably makes the desorption of acid molecules from the surface of the samples and their diffusion easier. Moreover, the readings of a pH-meter are more precise than optical evaluation of colour change.

There were similar differences in the permeation time of concentrated HNO_3 through the PVC gloves when the gloves were tested by both methods.

The change of indicator colour occurs between 0.5 and 1 hr (the colour change reading is taken every 30 min), whereas a pH-meter shows acid permeation after 23 min, when the method with a magnetic stirrer is used. In the case of PVC gloves, permeation time is so short because these gloves are very thin: they are only 0.26–0.39 mm thick. These gloves are not recommended as acid-proof; they were used as a model so as to include both kinds of acid permeation test methods. The thin film of material made it possible to shorten the time of the experiments.

In spite of the differences between the results obtained using these methods, we consider both of them useful; the method with the magnetic stirrer, a pH-meter, a computer, and a printer is more precise and convenient. Observations every 30 min are not necessary, whereas the simplified method is more economic and may be used in all chemical industry laboratories to test resistance of safety gloves for each acid or mixture of acids used in chemical production.

The requirement for acid resistant gloves, developed by CIOP, mandates that the time of acid permeation ought be no less than 8 hrs. Eight hours seem safe, because it is the length of a typical workday. If gloves are washed in water after work, there is no danger of acid permeation through the glove.

When 40% acids were used to test the permeation of gloves, both methods gave the same results, that is, there was no permeation in 8 hrs of testing—the only exception to this were the PVC gloves. (Table 1, Figure 3).

5. CONCLUSIONS

On the basis of the presented results, it is possible to draw the following conclusions:

1. The method of testing acid permeation through safety gloves developed in CIOP, based on the determination of the pH value of the water solution in which a sample filled with acid is immersed, is useful and convenient for assessing the acid resistance of gloves.
2. The simplified method of testing acid permeation, based on reading the change in colour of an indicator in a water solution in which a sample filled with acid is immersed, may be useful in laboratories of chemical plants where various concentrations and mixtures of acids are used.

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