BRITISH STANDARD

BS EN ISO 6529:2001

Incorporating Corrigenda Nos. 1 and 2

Protective clothing — Protection against chemicals — Determination of resistance of protective clothing materials to permeation by liquids and gases

The European Standard EN ISO 6529:2001 has the status of a British Standard

ICS 13.340.10

British Standards

National foreword

This British Standard is the official English language version of EN ISO 6529:2001. It is identical with ISO 6529:2001. It supersedes BS EN 369:1993 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PH/3, Protective clothing, to Subcommittee PH/3/3, Protective clothing against chemicals, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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This British Standard, having been prepared under the direction of the Engineering Sector Policy and Strategy Committee title, was published under the authority of the Standards Policy and Strategy Committee on
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Summary of pages

This document comprises a front cover, an inside front cover, the EN ISO title page, the EN ISO foreword page, the ISO title page, pages ii to v, a blank page, pages 1 to 29, the Annex ZA page, the Annex ZB page and a back cover.

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14003 Corrigendum No.1	26 July 2002	Replacing the EN ISO foreword page and incorporating the Annex ZA and ZB pages.
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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN ISO 6529

October 2001

ICS 13.340.10

Supersedes EN 369:1993

English version

Protective clothing - Protection against chemicals - Determination of resistance of protective clothing materials to permeation by liquids and gases (ISO 6529:2001)

Vêtements de protection - Protection contre les produits chimiques - Détermination de la résistance des matériaux utilisés pour la confection des vêtements de protection à la perméation par des liquides et des gaz (ISO 6529:2001)

Schutzkleidung - Schutz gegen Chemikalien - Bestimmung des Widerstands von Schutzkleidungsmaterialien gegen die Permeation von Flüssigkeiten und Gasen (ISO 6529:2001)

This European Standard was approved by CEN on 4 October 2001.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This document (ISO 6529:2001) has been prepared by Technical Committee ISO/TC 94 "Personal safety - Protective clothing and equipment" in collaboration with Technical Committee CEN/TC 162 "Protective clothing including hand and arm protection and lifejackets", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2002, and conflicting national standards shall be withdrawn at the latest by April 2002.

This document supersedes EN 369:1993.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative annex ZB, which is an integral part of this document.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of ISO 6529:2001 has been approved by CEN as EN ISO 6529:2001 without any modifications.

NOTE Normative references to International Standards are listed in Annex ZA (normative).

EN ISO 6529:2001

INTERNATIONAL STANDARD

ISO 6529

Second edition
2001-10-15

Protective clothing — Protection against chemicals — Determination of resistance of protective clothing materials to permeation by liquids and gases

Vêtements de protection — Protection contre les produits chimiques — Détermination de la résistance des matériaux utilisés pour la confection des vêtements de protection à la perméation par des liquides et des gaz

Reference number
ISO 6529:2001(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 6529 was prepared by Technical Committee ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 13, *Protective clothing*.

This second edition cancels and replaces the first edition (ISO 6529:1990), which has been technically revised.

Annexes A to D of this International Standard are for information only.

Introduction

Workers involved in the production, use, transportation, and emergency response with liquid and gaseous chemicals can be exposed to numerous compounds capable of causing harm upon contact with the human body. The deleterious effects of these chemicals can range from acute trauma such as skin irritation and burn to chronic degenerative disease, such as cancer. Since engineering controls may not eliminate all possible exposures, attention is often placed on reducing the potential for direct skin contact through the use of protective clothing that resists permeation, penetration and degradation.

These test methods are normally used to evaluate the barrier effectiveness of materials used for protective clothing and specimens from finished items (see Note 1) of protective clothing against permeation of either liquid or gaseous chemicals. Options are provided for conducting this testing under both conditions of continuous or intermittent contact with the chemicals.

These test methods provide various options for reporting test results in terms of breakthrough time, permeation rate and cumulative permeation to allow a comparison of protective clothing material permeation resistance. These parameters are key measures of the effectiveness of a clothing material to act as a barrier to the test chemical. Such information is used in the comparison of clothing materials during the process of selecting clothing for protection from hazardous chemicals. Long breakthrough detection times and normalized breakthrough detection times as well as low permeation rates are characteristic of the best barriers.

Resistance to penetration by liquid chemicals should be determined by using ISO 6530 while resistance to penetration by liquid chemicals under pressure should be determined by using ISO 13994. These International Standards are listed in the Bibliography.

It has been assumed in the drafting of this International Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people for whose guidance it has been prepared and that appropriate precautions will be taken to avoid injury to health and contamination of the environment.

NOTE 1 Finished items of protective clothing include gloves, arm shields, aprons, suits, hoods, boots, etc. The phrase “specimens from finished items” encompasses seamed and other discontinuous regions as well as the usual continuous regions of protective clothing items.

NOTE 2 At present, no quantitative information exists about acceptable levels of dermal contact. Therefore, the data obtained using this test method cannot be used to infer safe exposure levels.

Protective clothing — Protection against chemicals — Determination of resistance of protective clothing materials to permeation by liquids and gases

1 Scope

This International Standard describes laboratory test methods that enable a determination of the resistance of materials used in protective clothing to permeation by liquid or gaseous chemicals under the conditions of either continuous or intermittent contact.

Method A (see 8.3) is applicable to the testing of liquid chemicals, either volatile or soluble in water, expected to be in continuous contact with the protective clothing material.

Method B (see 8.4) is applicable to the testing of gaseous chemicals expected to be in continuous contact with the protective clothing material.

Method C (see 8.5) is applicable to the testing of liquid chemicals, either volatile or soluble in water, expected to be in intermittent contact with the protective clothing material.

These test methods are only suitable for the testing of air-impermeable protective clothing materials. They assess the permeation resistance of the protective clothing material under laboratory conditions in terms of breakthrough time, permeation rate, and cumulative permeation. These test methods also enable observations to be made of the effects of the test liquid on the protective clothing material under test.

These test methods address only the performance of materials or certain material constructions (e.g. seams) used in protective clothing. These test methods do not address the design, overall construction and components, or interfaces of garments or other factors which may affect the overall protection offered by the protective clothing.

It is emphasized that these tests do not necessarily simulate conditions to which clothing materials are likely to be exposed in practice. The use of test data should therefore be restricted to broad comparative assessment of such material according to their permeation-resistance characteristics.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 139, *Textiles — Standard atmospheres for conditioning and testing*

ISO 2286-2, *Rubber- or plastics-coated fabrics — Determination of roll characteristics — Part 2: Methods for determination of total mass per unit area, mass per unit area of coating and mass per unit area of substrate*

ISO 2286-3, *Rubber- or plastics-coated fabrics — Determination of roll characteristics — Part 3: Method for determination of thickness*

ISO 3801, *Textiles — Woven fabrics — Determination of mass per unit length and mass per unit area*

ISO 5084, *Textiles — Determination of thickness of textiles and textile products*

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
analytical technique
procedure whereby the concentration of a chemical in a collection medium is quantitatively determined

NOTE These procedures are often specific to individual chemical and collection-medium combinations.

EXAMPLES Applicable analytical techniques can include ultraviolet (UV) and infrared (IR) spectrophotometry, gas and liquid chromatography, pH measurement, ion chromatography, conductimetry, colorimetry, atmospheric analytical detector tubes and radionuclide tagging/detection counting.

3.2
breakthrough detection time
elapsed time measured from the start of the test to the sampling time that immediately precedes the sampling time at which the test chemical is first detected

See Figure 1.

NOTE The breakthrough detection time is dependent on the sensitivity of the method and the frequency of sampling (the interval between sampling times).

3.3
closed-loop
refers to a testing mode in which the collection medium volume is fixed

NOTE The collection medium volume may change slightly from sampling without replacement of the sampled collection medium.

3.4
collection medium
liquid or gas that does not affect the measured permeation and in which the test chemical is freely soluble or adsorbed to a saturation concentration greater than 0,5 % by mass or by volume

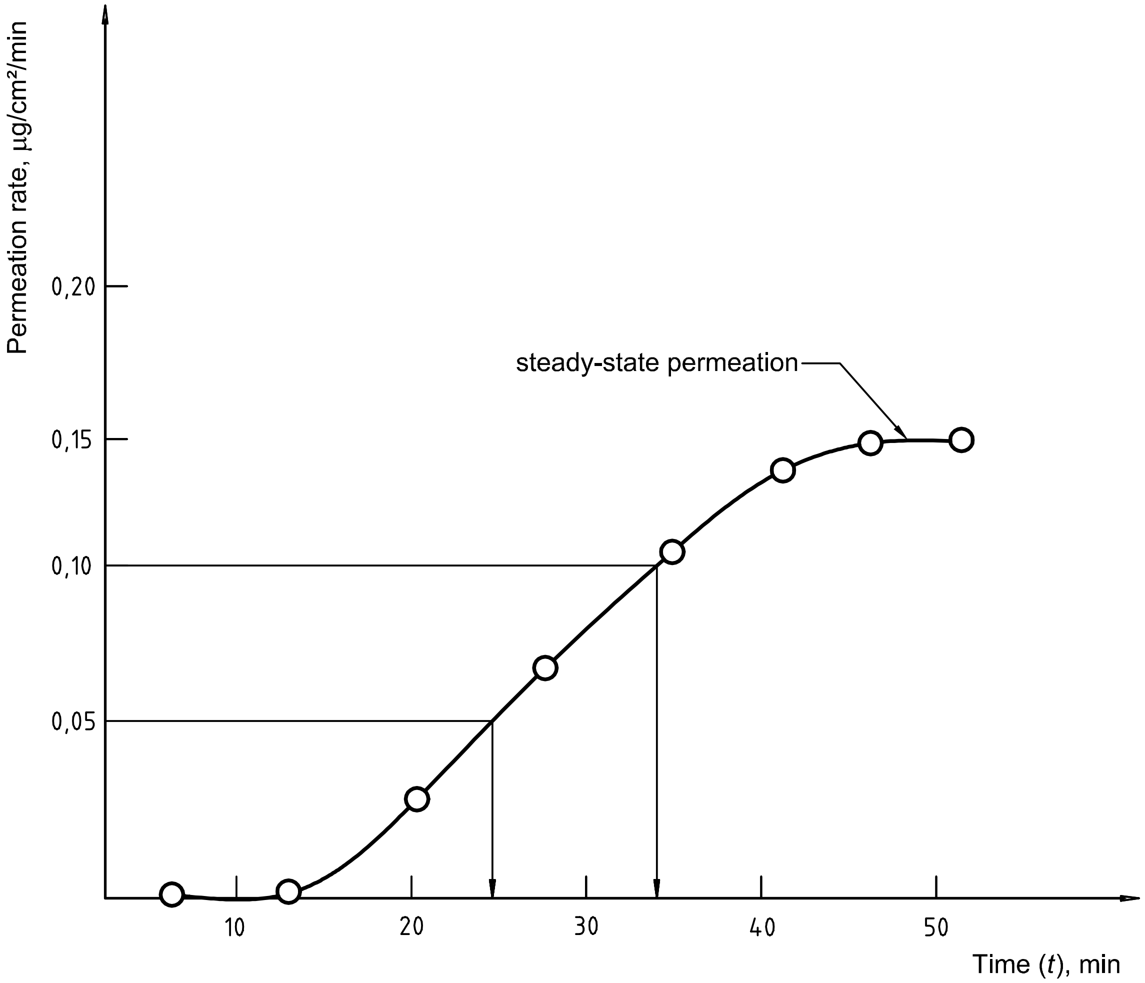
3.5
contact time
in an intermittent contact test, the duration that the challenge-side chamber of the permeation cell contains test chemical during each cycle

3.6
cumulative permeation mass
total amount of chemical that permeates during a specified time from the time the clothing material specimen is first contacted with the test chemical

NOTE 1 Quantification of cumulative permeation enables the comparison of permeation behaviour under different intermittent and continuous-contact conditions.

NOTE 2 The measurement of cumulative permeation may depend on the sensitivity of the permeation-test system.

3.7
cycle time
in an intermittent contact permeation test, the interval of time from the start of one contact period to the start of the next contact period



NOTE The breakthrough detection time for a method sensitivity of 0,05 µg/cm²/min is 23 min but would be reported at 20 min, which corresponds to the last sampling time preceding the test. The normalized breakthrough detection time at a normalization permeation rate of 0,1 µg/cm²/min is 33 min, but similarly would be reported at 28 min, which corresponds to the preceding sampling time. The steady-state permeation rate is approximately 0,15 µg/cm²/min.

Figure 1 — Breakthrough detection time

3.8
degradation

deleterious change in one or more physical properties of a protective clothing material

3.9
minimum detectable mass permeated

smallest mass of test chemical that is detectable with the complete permeation-test system

NOTE This value is not necessarily the intrinsic limit of detection for the analytical instrument.

3.10
minimum detectable permeation rate

lowest rate of permeation that is measurable with the complete permeation-test system

NOTE This value is not necessarily the intrinsic limit of detection for the analytical instrument.

3.11
normalization permeation mass

permeation mass used for determining the normalized breakthrough detection time in a closed-loop permeation test

NOTE This test method provides two choices of normalization permeation mass at 0,25 μg/cm^2 or 2,5 μg/cm^2.

3.12
normalization permeation rate
permeation rate used for determining the normalized breakthrough detection time in an open-loop permeation test

NOTE This test method provides two choices of normalization permeation rates: 0,1 μg/cm^2/min or 1,0 μg/cm^2/min.

3.13
normalized breakthrough detection time
⟨open-loop system⟩ time at which the permeation rate reaches the normalization permeation rate

See Figure 1.

3.14
normalized breakthrough detection time
⟨closed-loop test⟩ time at which the mass of chemical permeated reaches the normalization permeation mass

3.15
open-loop
testing mode in which fresh collection medium flows continuously through the collection chamber of the test cell and is not reused or recycled

3.16
penetration
flow of a chemical through closures, porous materials, seams and holes or other imperfections in a protective clothing material on a non-molecular level

3.17
permeation
process by which a chemical moves through a protective clothing material on a molecular level

NOTE Permeation involves

a) sorption of molecules of the chemical into the contacted (outside) surface of a material,

b) diffusion of the sorbed molecules in the material, and

c) desorption of the molecules from the opposite (inside) surface of the material into the collection medium.

3.18
permeation mass
quantity of test chemical that passes through the protective clothing material within a given time

3.19
permeation rate
quantity of test chemical that passes through the protective clothing material for a given exposed surface area per unit time

3.20
protective clothing material
any material or combination of materials used in an item of clothing for the purpose of isolating parts of the body from a potential hazard

3.21
purge time
⟨intermittent contact test⟩ time immediately following the termination of the contact time when the test chemical is removed from the challenge-side chamber and air or nitrogen is blown over the outside surface of the protective clothing material

3.22
steady-state permeation rate
constant rate of permeation that occurs after breakthrough when the chemical contact is continuous and all forces affecting permeation have reached equilibrium

NOTE Steady-state permeation may not be achieved during the period for which permeation testing is conducted.

3.23
test chemical
liquid or gas that is used to challenge the protective clothing material specimen

NOTE The liquid or gas may be either one component (i.e. a neat liquid or gas) or have several components (i.e. a mixture).

4 Principle

The protective clothing material specimen acts as a partition between one chamber of a permeation test cell, which contains the test chemical, and another chamber, which contains the collection medium.

The test chemical may be either a liquid or a gas. The protective clothing material specimen may contact the test chemical either continuously or intermittently depending on the choice of the method used.

The collection medium, which may be liquid or gas, is analysed quantitatively for its concentration of the chemical and thereby the amount of that chemical that has permeated the partition as a function of time after its initial contact with the material.

Several different test configurations may be used depending on the choice of the test chemical, collection medium and conditions of the test.

By either graphical representation or appropriate calculations, or both, the breakthrough detection time, normalized breakthrough detection time, permeation rate, and cumulative permeation of the test chemical are determined.

A group of chemicals, representing a range in chemical properties, which can be used to compare the permeation resistance is given in annex A.

Interlaboratory data for this test method are provided in annex B.

5 Choice of analytical technique and collection medium

5.1 General

The combination of the analytical technique and the collection medium shall be selected to maximize sensitivity for the detection of the test chemical and represent actual occupational conditions as closely as possible.

5.2 Gaseous collection medium

The gaseous collection medium shall be either dry air or a dry, non-flammable inert gas, or other gases which do not interfere with the detection of the test chemical and are of sufficiently high purity as not to interfere with the permeation process or analytical procedure.

EXAMPLES Nitrogen or helium.

NOTE This gas is used, under continuous flow conditions, for the collection of permeating molecules that are capable of vaporizing from the test liquid under the conditions of the test in sufficient quantities for analysis.

5.3 Liquid collection medium

The liquid collection medium shall be either water or another liquid which does not influence the resistance of the protective clothing material to permeation.

NOTE This liquid is used for the collection of diffused molecules of low volatility that are soluble in the collecting medium under the conditions of the test in sufficient quantities for analysis.

5.4 Other collection medium

Other collection medium such as solid sorbents may be used when suitable collection efficiencies are demonstrated for the test chemical being used.

6 Apparatus

6.1 Thickness gage, suitable for measuring thickness to the nearest 0,02 mm, as specified in ISO 2286-3 or ISO 5084, and used to determine the thickness of each protective clothing material specimen tested.

6.2 Analytical balance, capable of being read to the nearest 0,01 g.

6.3 Permeation test cell, consisting of a two-chambered cell for contacting the specimen with the test chemical on the specimen's normal outside surface (clothing exterior) and with a collection medium on the specimen's normal inside surface (clothing interior).

NOTE Permeation test cells may be designed for testing either liquid test chemicals or gaseous test chemicals. However, alternative permeation test cells may also be used.

6.3.1 Permeation test cell for liquid test chemicals, capable of accommodating liquid chemicals, constructed from two end-fitting sections of straight glass pipe, each nominally sized to either a 25 mm or 51 mm diameter (see Figure 2).

Materials other than glass may be used for tests involving chemicals incompatible with glass (e.g. hydrofluoric acid).

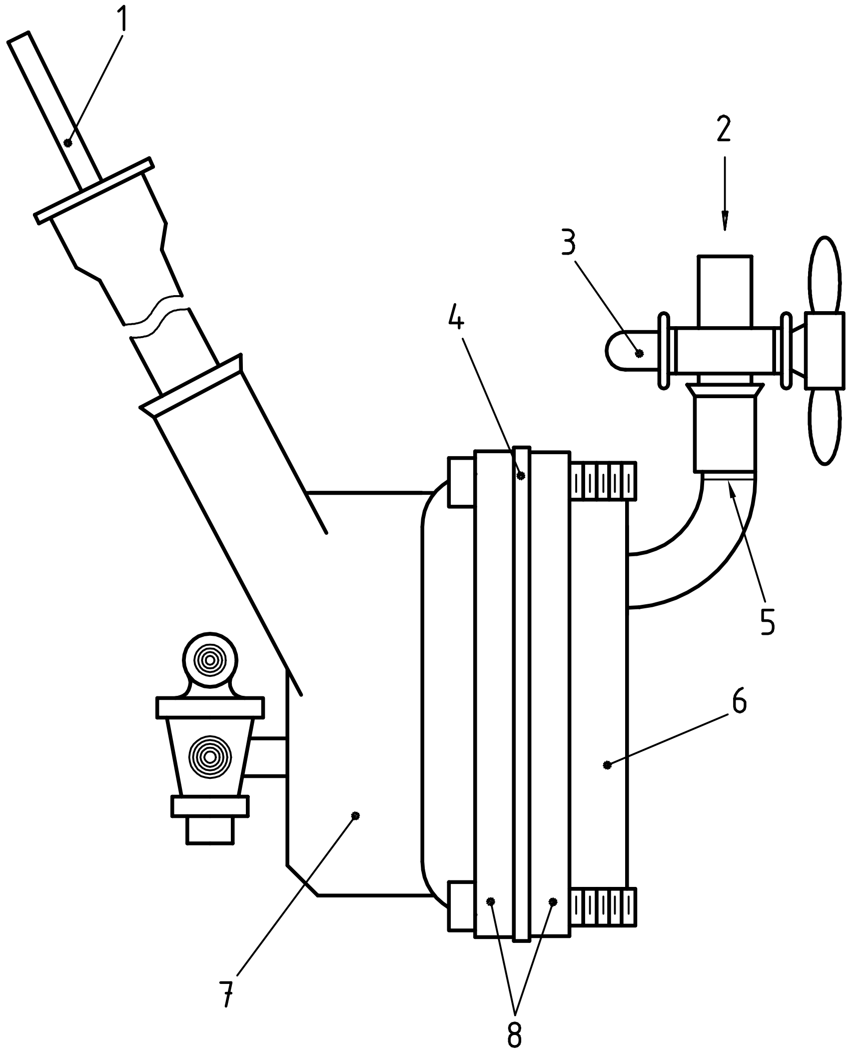
Permeation test cells made from glass shall be arranged as follows.

- One end of each glass section shall be sealed closed (for example, with a glass disk equivalent in quality to that of the glass of the original sections).
- The opposite end of each glass section shall retain the “as-manufactured” flared end.
- Inlet and outlet ports with appropriate stopcock valves shall be added to each glass section as shown.
- When assembled, the two glass sections shall be joined horizontally by flanges and a gasket shall be used at the joint. A second gasket may be used on the other side of the test specimens if necessary, to obtain a proper seal.

  EXAMPLE PTFE gasket material.

- In closed-loop tests where increased analytical sensitivity is required, a shorter length of glass pipe may be used to contain the collection medium. This reduces the contained volume and increases the ratio of material specimen area to the collection medium volume. In open-loop tests, lower collection medium flow rates will increase the system sensitivity by lowering the minimum detectable permeation rate.

The challenge-side chamber may be modified to include an additional outlet port (with stopcock) positioned downward, opposite the liquid chemical inlet port. Such a modification will facilitate the repeated addition and removal of liquid test chemicals during intermittent testing.



Key

1 Replaceable stirring rod	5 Fill level
2 Challenge chemical inlet	6 Challenge side for test chemical
3 Stop cock adapter	7 Sampling side for collection medium
4 Gasket	8 Aluminium flanges

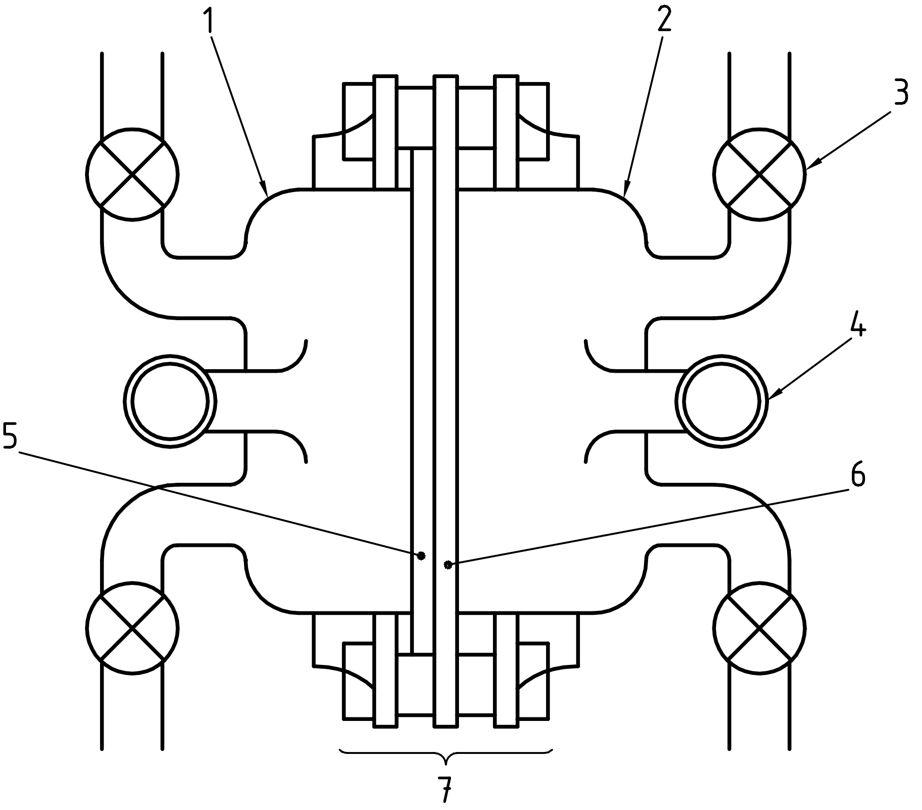
Figure 2 — Permeation test cell for liquid test chemicals

The clothing material specimen is positioned between the flared ends of the two glass sections that compose the test cell. When the specimen is in place, the test cell is divided into two chambers.

NOTE Sources for permeation test cell parts are provided in annex C.

6.3.2 Permeation test cell for gaseous test chemicals (see Figure 3), capable of accommodating gaseous chemicals, identical to the liquid permeation test cell except that, with reference to Figure 2, two collection medium sections are used. Thus, the gaseous chemical can be circulated from its reservoir through the challenge-side chamber. Flow shall be such that the composition and concentration of the gas in the test chamber does not change with time and the test gas in the chamber is well mixed.

A specimen is positioned between the flared ends of the two glass sections that compose the test cell as shown in Figure 3. When the specimen is in place, the test cell is divided into two chambers.



Key

1 Sampling side for collection medium
2 Challenge side for test chemical
3 Valve
4 Filling tube
5 Protective clothing material specimen
6 Gasket
7 Aluminium flanges

Figure 3 — Permeation test cell configured for intermittent contact (top view) used for gaseous test chemicals

6.3.3 Alternative permeation test cells, for conducting permeation testing, see for example Figure 4.

6.4 Equipment for open-loop permeation testing, consisting of the components listed in 6.4.1 to 6.4.6 and shown in Figure 5.

In open-loop testing, select and configure equipment to provide the desired test system sensitivity in terms of the minimum detectable-permeation rate.

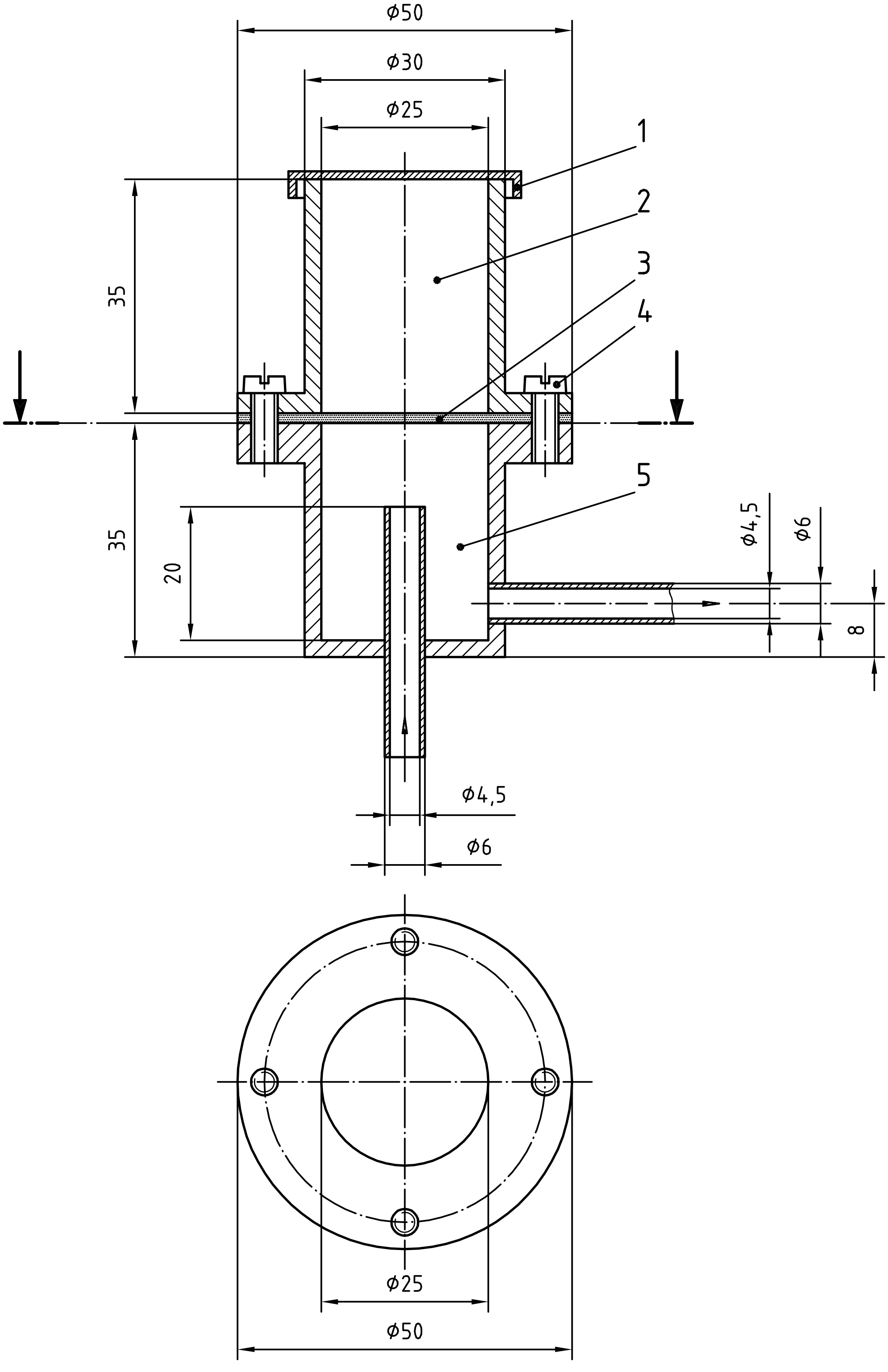
The required rate of flow may be obtained either by suitable control of the gas pressure at the inlet to the permeation test cell or by providing a pump at the outlet of the analytical detector.

NOTE 1 The specific configuration is generally determined by the method of collection in combination with the techniques used for detection of the test chemical or its component chemicals.

NOTE 2 Open-loop testing may provide different results from closed-loop testing due to differences in the system configuration.

NOTE 3 This test method provides a choice of two minimum detectable-permeation rates for testing, either at 0,1 μg/cm^2/min or 1,0 μg/cm^2/min.

Dimensions in millimetres



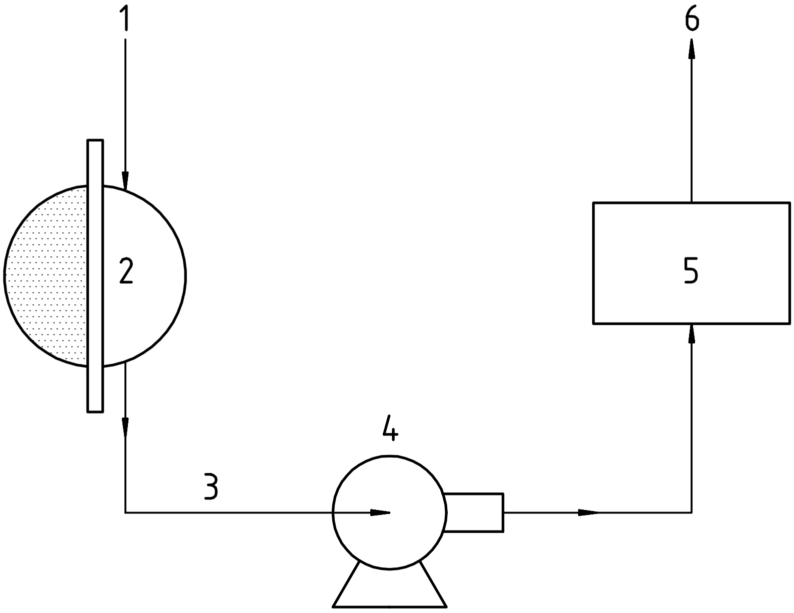
Key

1	Loose cover	4	Screws
2	Liquid compartment	5	Flow compartment
3	Test material		

Exposed area of test material: 4,91 cm^2

Volume of flow compartment: 17,2 cm^3

Figure 4 — Alternative permeation test cell



Key

1	Fresh collection medium	4	Pump
2	Sampling side for collection medium	5	Sample analyser
3	Collection medium sample	6	Waste

Figure 5 — Example configuration of open-loop permeation test equipment

6.4.1 Equipment for the collection medium, for either a gaseous or a liquid collection medium, capable of a collection medium flow rate of five volume changes per minute for the collection chamber of the permeation test cell.

6.4.2 Pump (if necessary).

6.4.3 Method of flow control.

6.4.4 Piping or tubing.

6.4.5 Permeation test cell (see 6.3)**.**

6.4.6 Analytical detector, suitable for the test chemical.

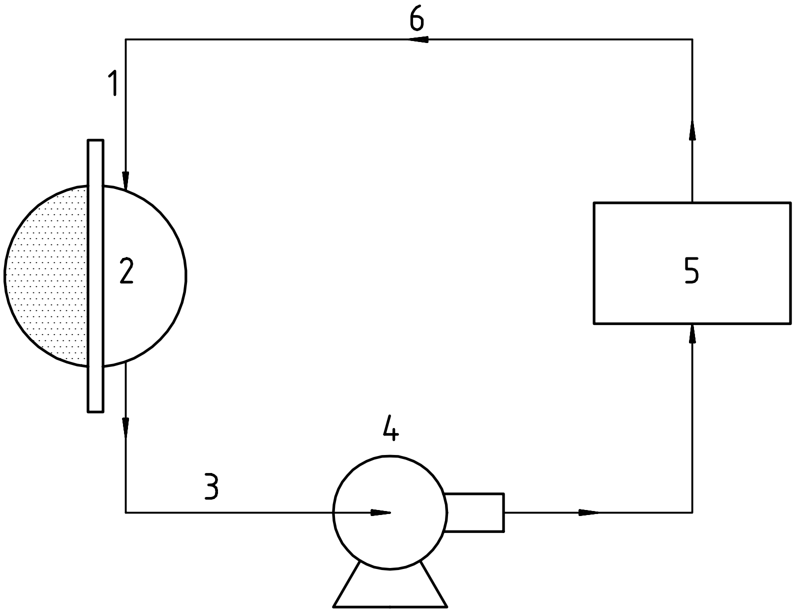
6.5 Equipment for closed-loop permeation testing, consisting of the components listed in 6.5.1 to 6.5.6 and shown in Figure 6.

In closed-loop testing, select and configure equipment to provide the desired test system sensitivity in terms of the minimum detectable permeation mass.

NOTE 1 The specific configuration is generally determined by method of collection in combination with the techniques used for detection of the test chemical or its component chemicals.

NOTE 2 Closed-loop testing may provide different results from open-loop testing due to differences in the system configuration.

NOTE 3 This test method provides a choice of two minimum detectable permeation masses for testing, either at 0,10 $\mu g/cm^2$ or 1,0 $\mu g/cm^2$.



Key

1	Recycled collection medium	4	Pump
2	Sampling side for collection medium	5	Sample analyser (non-destructive)
3	Collection medium sample	6	Analysed collection medium

Figure 6 — Example configuration for closed-loop permeation test equipment

6.5.1 Pump (if necessary).

6.5.2 Method of flow control.

6.5.3 Piping or tubing.

6.5.4 Permeation test cell (see 6.3).

6.5.5 Means for stirring or agitating the collection medium (when appropriate).

When used, agitation or stirring of the liquid collection medium at a rate of 0,1 r/s has been found to be satisfactory for some permeation testing.

6.5.6 Analytical detector, suitable for the test chemical.

6.6 Stopwatch, or **electronic timer**.

6.7 Constant temperature chamber, or bath, used to maintain the permeation test cell within ± 1,0 °C of the test temperature.

7 Sampling

7.1 Sampling procedure

Select test specimens from single material samples or individual protective clothing items consisting of either a single layer or a composite of multiple layers that is representative of an actual protective clothing construction with all layers arranged in proper order.

If in the design of an item of protective clothing, different materials or thicknesses of material are specified at different locations, select specimens from each location.

If in the design of an item of protective clothing, seams are claimed to offer the same protection as the base materials, test additional specimens containing such seams.

Cut each material specimen so as to have a minimum cross-dimension consistent with the size of the test cell for producing a uniform seal.

Test three specimens taken at random from each protective clothing material, composite, area (in the case of heterogeneous design) or other condition. If desired, generate random specimens as described in ISO 2859-1[1].

7.2 Preparation of test specimens

Condition each protective clothing specimen for a minimum of 24 h by exposure to a temperature of (21 ± 5) °C and a relative humidity of (60 ± 10) % according to ISO 139.

NOTE If warranted, use other preconditioning options to assess possible degradation mechanisms of protective clothing.

7.3 Measurement of test specimen thickness and mass

Measure the thickness of each specimen to the nearest 0,02 mm in accordance with ISO 2286-3, ISO 5084, or other method appropriate for the type of material being tested. Measure the mass of each specimen to the nearest 1 g/m^2 in accordance with ISO 2286-2, ISO 3801, or other method appropriate for the type of material being tested.

8 Procedure

8.1 Calibration

Calibrate the response of the analytical system to the test chemical, or its component chemicals, and where appropriate, ensure that concentrations up to 25 % saturation of the collection medium may be determined.

Characterize the sensitivity of an open-loop system by its minimum detectable permeation rate. A method for determining this value is presented in annex D.

Characterize the sensitivity of a closed-loop system by its minimum detectable mass permeated.

NOTE 1 Comparison of results requires specific information about the test cell, the procedures, and the analytical techniques. Results obtained from closed-loop and open-loop testing may not be directly comparable.

NOTE 2 The sensitivity of the test method in detecting low permeation rates or amounts of the test chemical that permeate is determined by the combination of the analytical technique and the collection system selected as well as the ratio of the material specimen area to the collection medium volume or flow rate.

NOTE 3 A sensitive analytical technique permits quantitative detection of the test chemical in the collection medium at volume or mass fractions as low as 10^{-7} %.

NOTE 4 Higher ratios of material specimen area to collection medium volume or flow rate permit earlier detection of breakthrough and detection of lower permeation rates because higher concentrations of the test chemical in the collection medium will develop in a given time period, relative to those that would occur at lower ratios.

8.2 Preparation of test apparatus

8.2.1 Mount the first protective clothing material specimen in the permeation test cell (6.3.1) and assemble as shown in Figure 2.

8.2.2 If the test is to be carried out at ambient temperature (see Note 1), test at a minimum temperature of 20 °C. Ensure that the test cell is maintained at the selected ambient temperature, ± 2 °C for at least 30 min prior to testing and that the collection medium is at test temperature before adding it to the test cell.

NOTE 1 For the purposes of this test method, ambient temperatures are considered to be in the range of 20 °C to 27 °C.

NOTE 2 Persons performing this test or end-users interpreting this test should realize that permeation-resistance test results are significantly influenced by temperature and that tested protective clothing materials can be used in non-ambient conditions. For example, the skin temperature may be 35 °C and some protective clothing, particularly gloves, can be in intimate contact with the skin.

8.2.3 If the test is to be carried out at a non-ambient temperature, place the assembled permeation test cell into a constant-temperature chamber or bath at the test temperature. Maintain the permeation test cell at the non-ambient temperature for at least 30 min before the testing proceeds further.

8.2.4 Load the collection medium into the collection chamber of the permeation test cell (the chamber to which the normal inside surface of the material specimen is exposed). Depending upon the combination of the analytical technique and the collection medium selected, configure the test equipment as appropriate (see Figures 5 and 6).

8.2.5 If the test is to be carried out at a non-ambient temperature and the collection medium is a liquid, bring the medium to the test temperature before adding it to the test cell.

8.2.6 Stir, circulate, or flow the collection medium continuously.

NOTE The purpose of agitating the collection medium is twofold:

a) to ensure that it is homogeneous for sampling and analytical purposes, and

b) to prevent or minimize concentration boundary layers of permeant at the interface of the clothing material and the collection medium.

The degree of agitation necessary to achieve these objectives is dependent on the permeation rate and the relative solubilities of the test chemical in the clothing material and the collection medium. At this time, sufficient data are not available to specify minimum agitation rates. However, as guidance, in an open-loop system (i.e. collection medium flowing once through the cell, then being analysed and discarded), interlaboratory data suggest that an adequate degree of mixing is produced when the flow rate is within the range specified in 6.4.1. For closed-loop systems with a liquid collection medium, adequate mixing levels can be determined by preliminary experiments, in which the rapidity of the dispersion of a dye is observed.

8.2.7 Initiate sampling of the collection medium, either continuously or discretely, and continue on a predetermined schedule throughout the test duration. Promptly complete analysis of each sample for test chemical content.

Sampling is initiated before the test chemical is added to the permeation test cell to establish the baseline values against which subsequent analytical data will be compared.

The method chosen for collection medium withdrawal shall be based on the technique selected for analytical detection. For example, UV or IR spectroscopy is often used for continuous analysis of a sample stream (although compounding and curing agents often used in protective clothing materials can interfere) while gas chromatography requires the analysis of discrete samples. When sampling using open-loop techniques, the flow of collection medium should never be interrupted. This will minimize adsorption of permeated chemical on the walls of the test cell and associated tubing.

In closed-loop systems with sample withdrawal, replenishment of the collection medium may be necessary in order to maintain a fixed ratio of collection medium volume to surface area of the test specimen in contact with the collection medium.

In cases where samples are continuously or repeatedly withdrawn, analysed, and returned to the test cell, no provision for volume maintenance is necessary.

8.3 Method A — Liquid chemicals with continuous contact

8.3.1 Expeditiously load the liquid chemical into the challenge chamber of the permeation test cell (the chamber to which the normal outside surface of the material specimen is facing). Fill the chamber to the fill mark on the stem. Begin timing the test when the addition of the liquid commences. If the test is to be carried out at a non-ambient temperature, bring the liquid to the test temperature before it is charged into the test cell.

If the density of the test chemical is high, and the strength of the protective clothing material specimen being tested is low, for example, a thin latex film, the mass of the liquid may distort the specimen, leading to an increase in sample area. In this case, the liquid volume may be reduced but care should be taken to ensure that the specimen is completely covered with test chemical throughout the test period.

8.3.2 Record the concentration of the test chemical found in each sample as well as the associated time that has elapsed between the time that the liquid was charged to the cell and the withdrawal of the sample.

8.3.3 Discontinue sampling and terminate the test after one or more of the following conditions is met (see Figure 7):

— steady-state permeation is reached [Figures 7 a) and 7 e)];

— permeation reaches a steady-state permeation rate and then proceeds at an ever increasing rate [Figure 7 c)];

— a maximum rate is reached [Figures 7 b) and 7 d)];

— a pre-specified time has passed.

The permeation-resistance test should be conducted for a minimum duration of 8 h. If no duration is specified, testing should be conducted for a shorter or longer duration as appropriate to the application of the tested protective clothing.

8.3.4 Disassemble the test cell and thoroughly clean it.

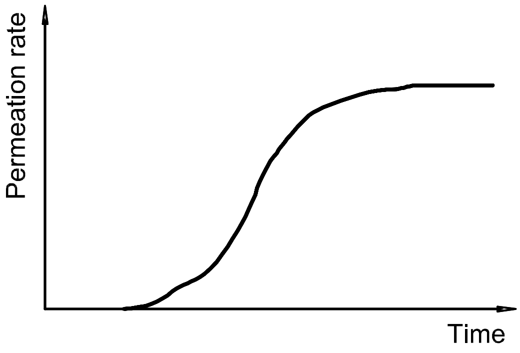
8.3.5 Test a minimum of three replicate protective clothing material specimens.

8.4 Method B — Gaseous chemicals with continuous contact

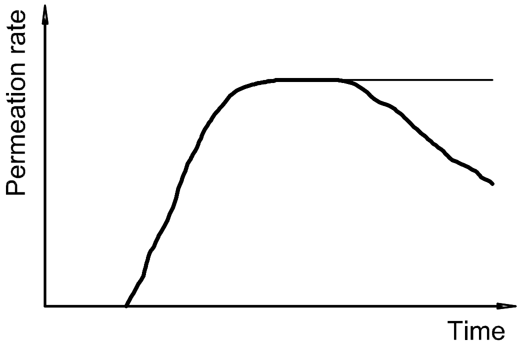
8.4.1 Begin the flow of the gas into the challenge chamber of the permeation test cell (the chamber to which the normal outside surface of the material specimen is facing). Begin timing the test when the equivalent of five chamber volumes of gas have passed through the chamber as determined by means of a rotameter or other flow monitoring device placed in the inlet stream to the chamber. The five volumes of gas should be passed through the chamber within 1 min. Following this initial period, the gas flow rate may be reduced to a level compatible with the system sensitivity requirements. If the test is to be carried out at a non-ambient temperature, bring the gas to the temperature before it enters the test cell.

Take care so as not to pressurize the challenge or collection chamber. Overly high pressures may develop at high gas flow rates or as a result of attachments that restrict the flow of gas from the chamber. Tightly-packed activated carbon beds or highly restrictive sparger tubes are examples of such attachments.

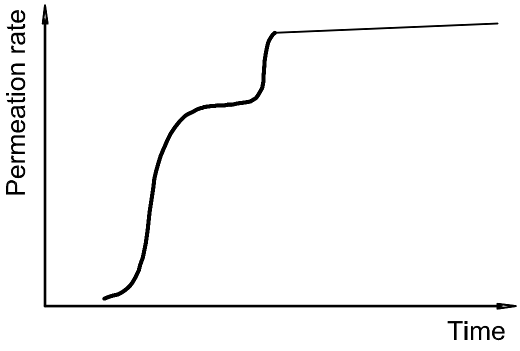
8.4.2 Record the concentration of the test chemical found in the sample and the time which has elapsed between the initial gas contact with the clothing specimen and the withdrawal of the sample.



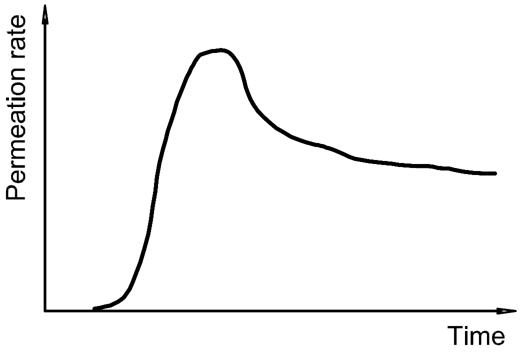
a) **Most typical type of permeation behaviour where the permeation rate stabilizes at a “steady-state” value**



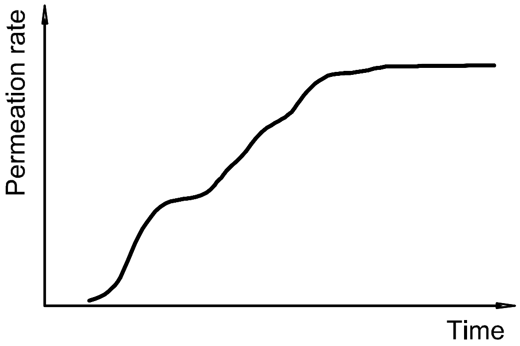
b) **Type of permeation behaviour due to the material specimen being structurally modified by the chemical resulting in an increase or decrease in permeation rate**



c) **Type of permeation behaviour which occurs when the material specimen exhibits a sudden, very large increase in rate**



d) **Type of permeation behaviour which occurs when there is moderate to heavy swelling of the material specimen although the permeation rate eventually stabilizes**



e) **Type of permeation behaviour which occurs when there is a high degree of swelling**

Figure 7 — Five types of permeation behaviour [4]

8.4.3 Discontinue sampling and terminate the test after one or more of the following conditions is met (see Figure 7):

- steady-state permeation is reached [Figures 7 a) and 7 e)];
- permeation reaches a steady-state permeation rate and then proceeds at an ever increasing rate [Figure 7 c)];
- a maximum rate is reached [Figures 7 b) and 7 d)];
- a pre-specified time has passed.

The permeation-resistance test should be conducted for a minimum duration of 8 h. If no duration is specified, testing should be conducted for a shorter or longer duration as appropriate to the application of the tested protective clothing.

8.4.4 Disassemble the test cell and thoroughly clean it.

8.4.5 Test a minimum of three replicate protective clothing material specimens.

8.5 Method C — Liquid or gaseous chemical with intermittent contact

8.5.1 Select a contact time, a purge time, and the number of cycles comprising a test. As a guide and to help in the comparison of data, consider one or more of the sets of conditions provided in Table 1.

The permeation-resistance test should be conducted for a minimum duration of 2 h. If no duration is specified, testing should be conducted for a shorter or longer duration as appropriate to the application of the tested protective clothing.

Table 1 — Recommended test conditions for intermittent contact testing

Method	**Contact time** min	**Purge time** min	**Number of cycles**
C1	1	10	12
C2	5	10	8
C3	10	60	2

8.5.2 Expeditiously charge the test chemical into the challenge chamber of the test cell to which the normally outside surface of the material specimen is facing. Begin timing the test. If the test is to be carried out at a non-ambient temperature, bring the test chemical to the temperature before it enters the test cell. For liquid test chemicals, fill the challenge chamber to the fill mark on the stem. Begin timing the chemical contact time when the addition of the liquid commences. For gaseous test chemicals, begin the flow of gas into the challenge chamber. Begin timing the chemical contact time after the equivalent of five chamber volumes of gas have passed through the chamber, as determined by means of a rotameter or other flow monitoring device placed in the inlet stream to the chamber.

8.5.3 Record the concentration of the test chemical found in each sample and the associated time that has elapsed between the time the test chemical was first added to the challenge chamber and withdrawal of the sample.

8.5.4 At the end of the predetermined contact time, remove the test chemical from the challenge chamber of the test cell. Begin timing the purge time.

For liquid chemicals, this may be accomplished by pouring or draining the test chemical from the challenge chamber through the inlet or outlet ports. Complete removal of viscous or tacky liquids may not be possible. Incomplete removal is acceptable since in the work environment complete removal of such chemicals is not likely.

For gaseous chemicals, this may be accomplished by stopping flow of the test chemical from its reservoir to the challenge chamber.

8.5.5 Flush the challenge chamber of the test cell for the predetermined purge time using air or an inert gas. Set the flow rate of the purge gas through the challenge chamber at a minimum rate equivalent to 10 challenge chamber volumes per minute. If the test is to be carried out at a non-ambient temperature, bring the purge gas to the test temperature before it enters the test cell.

Take care not to pressurize the challenge chamber. Overly high pressures may develop at high gas flow rates or as a result of attachments to the chamber that restrict the flow of gas from the chamber.

8.5.6 At the end of the predetermined purge time, stop the flow of purge gas through the challenge chamber. This will complete the first cycle of the intermittent exposure test.

8.5.7 Continue the test by repeating cycles of contact and purge as specified in 8.5.2 and 8.5.6 until either a predetermined time or number of cycles has passed.

8.6 Preparation of permeation plot

Prepare a plot test chemical concentration, permeation rate, or cumulative permeation versus time for each permeation test. If using permeation rate, calculate the permeation rate as specified in 8.8.

When plotting average concentration, permeation rate, or cumulative permeation as a function of time, use the time coordinate as the midpoint of the interval over which the average has been obtained.

8.7 Determination of breakthrough detection time and normalized breakthrough detection time

Determine the breakthrough detection time either graphically or from a review of the data collected over the test period. If permeation data is collected discretely, establish the breakthrough detection time as the time at the beginning of the sampling interval in which permeation is first noted.

Determine the normalized breakthrough detection time at the selected normalization permeation rate for open-loop permeation tests. Select a normalization permeation rate of either 0,1 $\mu g/cm^2/min$ or 1,0 $\mu g/cm^2/min$.

Determine the normalized breakthrough detection time at the selected normalization permeation mass for closed-loop permeation tests. Select a normalization permeation mass of either 0,25 $\mu g/cm^2$ or 2,5 $\mu g/cm^2$.

8.8 Calculation of permeation rate and cumulative permeation

8.8.1 General

Calculate the permeation rate using the equation appropriate for the type of permeation test apparatus configuration and method for sampling the collection medium.

NOTE The following factors are useful in converting permeation rates: 1 µg/cm^2/min = 0,17 mg/m^2/s = 10 mg/m^2/min.

8.8.2 Open-loop tests

The concentration of the permeant in the collection medium at any time t_i is directly proportional to the permeation rate φ_i. Calculate the permeation rate based on the measured concentration using the equation (1).

$$\varphi_i = \frac{c_i \, q_V}{A} \tag{1}$$

where

i is an indexing number to indicate the specific concentration c_i that was measured at time t_i;

t_i is the time elapsed, expressed in minutes, beginning with the initial chemical contact and end with the measurement of concentration c_i;

φ_i is the permeation rate, expressed in micrograms per square centimetre per minute (µg/cm^2/min), at t_i;

c_i is the concentration, expressed in micrograms per litre (µg/l), of test chemical in collection medium at time t_i;

q_V is the flow rate, expressed in litres per minute (l/min), of fresh collection medium through the cell;

A is the area, expressed in square centimetres (cm^2), of the material specimen contacted.

Calculate the cumulative amount permeated, ρ_A, at any time, t, by determining the area under a curve obtained by plotting φ_i versus t_i from time 0 to t.

NOTE This amount will not include any chemical that may have permeated before the detection time but was below the detection limit of the test method.

8.8.3 Closed-loop tests

Apply this calculation whenever one of the following conditions are met:

- samples are withdrawn, analysed, and replaced prior to further sampling;
- the volume of discrete samples is insignificant relative to the total volume (for example, microlitre aliquots);
- the collection medium is recirculated as shown in Figure 6;
- the concentration of the test chemical in the collection chamber is measured without any sample removal.

Calculate the average permeation rate over the period t_{i-1} to t_i using equation (2)

$$\varphi_{\text{avg}} = \frac{\left(c_i - c_{i-1}\right) V_{\text{tot}}}{\left(t_i - t_{i-1}\right) A} \tag{2}$$

where

φ_{avg} is the average permeation rate, expressed in micrograms per square centimetre per minute (µg/cm^2/min), for the interval t_{i-1} to t_i;

i is an indexing number assigned to indicate the specific concentration c_i that was measured at time t_i in volume V_i for the first point;

V_{tot} is the total volume, expressed in litres, of the collection medium.

Calculate the cumulative amount permeated, ρ_{Ai}, for the total period up to t_i using equation (3).

$$\rho_{Ai} = \frac{c_i\, V_{\text{tot}}}{A} \tag{3}$$

where ρ_{Ai} is the cumulative amount, expressed in micrograms per square centimetre (µg/cm^2), permeated at t_i.

8.8.4 Closed-loop tests with discrete sampling

Apply this calculation when discrete samples of significant volume are removed from the collection medium.

If the sample volume is not replaced, use equation (4) to calculate the permeation rate over the period t_{i-1} to t_i.

$$\varphi_{i,\text{avg}} = \frac{\left[c_i - c_{i-1}\right]\left[V_{\text{tot}} - (i-1)V_{\text{s}}\right]}{\left(t_i - t_{i-1}\right) A} \tag{4}$$

where V_{s} is the volume, expressed in litres, of discrete sample removed from the collection medium.

If the collection medium is replenished after each discrete sample, use equation (5) to calculate the permeation rate over the period t_{i-1} to t_i.

$$\varphi_{i,\text{avg}} = \frac{\left[c_i - c_{i-1}\left(\frac{V_{\text{tot}} - V_{\text{s}}}{V_{\text{tot}}}\right)\right] V_{\text{tot}}}{\left(t_i - t_{i-1}\right) A} \tag{5}$$

Calculate the cumulative amount permeated, ρ_{Ai}, for the total period up to t using equation (6).

$$\rho_{Ai} = \frac{c_i V_i}{A} + \sum_{i=1}^{i-1} c_i V_{\text{s}} \tag{6}$$

where V_i is the volume, expressed in litres, of collection medium at t_i.

8.9 Visual assessment of test specimen

Visually inspect each test specimen in a well-lit area (use spectacles if necessary to ensure normal vision) and observe whether or not the test specimen has been changed in any way by its contact with the test chemical. Conduct this inspection both while the specimen is still “wet” and after it has dried since swelling may not be observed after the specimen has dried. If any change is observed, note whether the test specimen has become discoloured, flaked, swollen, embrittled, or disintegrated. Note any other changes to the test specimen.

8.10 Repeat tests

8.10.1 Assess whether the results obtained from any one test specimen vary more than 20 % of the corresponding average for that set of data.

NOTE Experience in the development of this method indicates that this requirement is generally met, provided that the test specimens have been drawn from a material that is physically homogeneous and not subject to distortion or decomposition when in contact with the test chemical.

8.10.2 If the results do not vary more than 20 % of the corresponding average for that set of data, prepare a test report in accordance with clause 9.

8.10.3 If the results do vary more than 20 % from the average for that set of data and a plausible answer cannot be provided to explain this variation, prepare a second set of test specimens and repeat the testing using the same equipment and conditions.

8.10.4 If the results obtained from the second set of test specimens do not vary more than 20 % of the corresponding average for that set of data, prepare a test report in accordance with clause 9 based only on the second set of test data.

8.10.5 If the results from the second set of specimen do vary more than 20 % from the average for that set of data and a plausible answer cannot be provided to explain this variation, prepare a test report in accordance with clause 9 based on the combined sets of test data.

NOTE In this case, further appropriate checks should be made so as to discriminate between those variations that arise from real differences between specimens and those variations which may be the result of experimental error in the test procedures.

9 Report

Include the following information in the test report:

a) a reference to this International Standard, i.e. ISO 6529:2001;

b) the method used;

EXAMPLES Method A, Method C2.

c) the manufacturer's identification for the material being tested and a description of the sampling method used; i.e. report whether the material was taken from roll goods or garments, the type (fibre and coating compositions), supplier, lot number, and date of receipt of the material tested; if the material was taken from garments, report under subheadings for each material, composite, type of seam, or other conditions tested, and its position on the garment;

d) the thickness of each material specimen and the average thickness, expressed in millimetres, of the material tested;

e) the mass per unit area, expressed in grams per square metre, of each material specimen and the average mass per unit area, expressed in grams per square metre, of the material tested;

f) the identity of the test chemical(s) used, its physical state, and as appropriate, of any component chemical(s) to which the analytical procedures have been applied;

g) the temperature, in degrees Celsius, at which the test was performed; if the temperature of the test cell and liquid were different at the start of the test, report both;

h) the test duration, expressed in hours;

i) the collection medium (including flowrate and stirring, if applicable), system configuration (i.e. open-loop or closed-loop) and analytical technique used; i.e. clearly specify the system configuration for all permeation testing since differences in the system configuration can lead to significant differences in test results; when multiple test results are presented, difference in testing procedures between different reported chemicals should be indicated;

j) the cycle time, contact time, purge time, and number of cycles for intermittent permeation testing;

Include in the test report the following information on breakthrough detection time or normalized breakthrough detection time:

k) the minimum detectable permeation rate for open-loop permeation tests (Method A) or the minimum detectable permeation mass for closed-loop permeation tests (Method B);

l) the breakthrough detection time for each test specimen and the average for all specimens of a test set; if permeation is first detected at greater than the selected normalization permeation rate for open-loop permeation testing or the selected normalization permeation mass for closed-loop permeation testing, report the breakthrough detection time and the rate at which permeation was detected;

m) the normalized breakthrough detection time for each test specimen and the average for all specimens of a test set; the nomenclature for reporting normalized breakthrough time shall include a subscript indicating the permeation rate used for normalization of the breakthrough time;

EXAMPLE $BT_{0,1}$ or $BT_{1,0}$

n) if no permeation was detected or the permeation rate was not able to reach the selected normalization permeation rate for open-loop permeation testing (Method A) or the selected normalization permeation mass for closed-loop permeation testing (Method B), report the fact that no permeation was detected.

Include in the test report, either information on the permeation rate or cumulative permeation as follows:

o) if the permeation process reached steady state, report the steady-state permeation rate, expressed in micrograms per square centimetre per minute (µg/cm^2/min), for each material specimen and also report the average of the steady-state permeation rate for all replicates of a test set;

p) the maximum permeation rate, expressed in micrograms per square centimetre per minute (µg/cm^2/min), for each specimen and the average permeation rate for all specimens in a test set;

q) the cumulative permeation, expressed in micrograms per square centimetre (µg/cm^2), at four times equally spaced over the duration of the test and the average of the three values of cumulative permeation for each time for each set of data;

EXAMPLE 1 If the test is 60 min in duration, report the cumulative permeation mass at 15 min, 30 min, 45 min and 60 min.

EXAMPLE 2 If the test is 8 h in duration, report the cumulative-permeation mass at 2 h, 4 h, 6 h and 8 h.

r) the plot of test chemical concentration, permeation rate, or cumulative permeation as a function of time for each specimen tested;

s) observations of material condition following contact with the test chemical.

NOTE The information required in the test report is intended for full documentation to be provided by the organization conducting the test. When permeation-resistance test data are consolidated, complete test information should be provided as required by the manufacturer, end-user or both as necessary to provide a comparison of results with results for other materials. Essential test information includes the identification of the test material; identification of the test chemical; the system configuration; cycle time, contact time, and purge time for intermittent tests (Method C); the minimum detectable-permeation rate (Methods A and B) or the minimum detectable mass (Method C), the normalized breakthrough time, and the permeation rate or cumulative permeation.

Annex A
(informative)

Recommended list of chemicals for comparing permeation resistance of protective clothing materials

A.1 Purpose

The purpose of this guide is to provide a recommended list of both liquid and gaseous chemicals for evaluating protective clothing materials in testing programs.

NOTE 1 Results derived from testing programs using these lists of challenge chemicals are not intended to give a definitive characterization of protective clothing materials.

NOTE 2 This list of challenge chemicals is not inclusive of all chemical challenges; the chemicals were chosen to represent broad ranges of liquid and gaseous chemical classes and properties. Not all chemical classes are represented. Other chemicals, especially those of interest to the manufacturer or user, should be tested in addition to those recommended in this guide.

A.2 List of recommended liquid test chemicals

Reagents are listed by common name, synonym, and Chemical Abstract Registry Service (CAS) number given in square brackets:

- acetone (2-propanone) [67-64-1],
- acetonitrile (cyanomethane) [75-05-8],
- carbon disulfide [75-15-0],
- dichloromethane (methylene chloride) [75-09-2],
- diethylamine [109-89-7],
- ethyl acetate [141-78-6],
- *n*-hexane [110-54-3],
- methanol (methyl alcohol, carbinol) [67-56-1],
- sodium hydroxide (30 % by mass), $\rho = 1{,}33$ kg/l [1310-73-2],
- sulfuric acid (96 % by mass), $\rho = 1{,}83$ kg/l to 1,84 kg/l [7664-93-9],
- tetrahydrofuran (THF, 1,4-epoxybutane) [109-99-9], and
- toluene (toluol) [108-88-3].

A.3 List of recommended gaseous test chemicals

Reagents are listed by common name, minimum purity, synonyms, and CAS number given in square brackets:

- ammonia, anhydrous, (99,99 %) [7664-41-7]
- chlorine, 99,5 % [7782-50-5]
- hydrogen chloride, (99,0 %) (hydrochloric acid) [7647-01-0]

Annex B
(informative)

Precision information for test method

A standard neoprene material was used in an interlaboratory evaluation of Method A for this test method with acetone as the test chemical. The results are summarized in Table B.1. For quality control and assurance requirements, periodic evaluation of the permeation-test system is recommended, using acetone, the standard neoprene, and Method A. Breakthrough detection time and steady-state permeation rate were measured and the results compared with the interlaboratory results reported in Table B.1. Results falling within ± 2 laboratory standard deviations (i.e. ± 6 min) are indicative of satisfactory performance of the permeation-test system.

NOTE The standard neoprene material is 0,04 mm thick, stock number 5550 obtained from Fairprene Industrial Products Co., 85 Mill Plain Road, Connecticut, USA 06430. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product.

Table B.1 — Results of interlaboratory evaluation of permeation testing, Method A using acetone as the test chemical and a standard neoprene material as the protective clothing

Laboratory	**Number of tests**	**Breakthrough detection time** min	**Steady-state permeation rate** µg/cm²/min
1	3		2 934 ± 441
2	3		Not determined
3	4		2 134 ± 91
4	3		Not determined
5	4		1 989 ± 379
6	3		1 120 ± 191
7	3		2 447 ± 83
8	3		1 188 ± 120
9	3		2 826 ± 202
Average		± 6	2 088 ± 202

Annex C
(informative)

Sources of permeation test cells and permeation test cell parts

Sections of borosilicate glass pipe, available from Corning Glass, Catalog No. 72-0702 (1-in. length) 1), or equivalent, are satisfactory for this purpose.

Flanges are available from Corning Glass, Catalog Nos. 72-9062 (aluminium) 1) or 72-9654 (cast iron) 1).

Gaskets are available from Corning Glass, Catalog No. 72-9256 1).

PTFE gasket material is available from W.L. Gore & Associates, Inc. 1), Industrial Sealant Group, Elkton, MD 21921, USA.

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1) This is an example of a suitable product available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product.

Annex D
(informative)

Suggested procedure for measuring the sensitivity of open-loop permeation-test systems

D.1 General considerations

Any procedure for establishing the sensitivity of an open-loop system for measuring the permeation should involve the following considerations:

- baseline response of the detector for a blank permeation cell (i.e. a cell containing an inert and impermeable material such as aluminium foil between the collection and challenge chambers) but no test chemical;
- detector response to a known concentration of a standard calibration chemical in the collection medium;
- detector response to the test chemical.

D.2 Suggested procedure

D.2.1 Figure D.1 is a schematic drawing of one possible configuration of a system for measuring the system sensitivity as well as calibrating the system for the test chemical. The system uses a gaseous collection medium which is directed into two permeation test cells operating in parallel. The first permeation test cell (Cell 1) is used as the blank to establish the baseline response of the detector. The second permeation test cell (Cell 2) is used to assess sensitivity to the test chemical. Each permeation test cell contains a piece of aluminium foil or other inert and impermeable material. A standard calibration gas (toluene) is also used. Flow of the collection media from each permeation test cell and the standard calibration gas are selectively directed to the detector.

NOTE A piece of aluminium foil, or other material known to be inert and impermeable to the test chemical, is placed in the permeation test cells in lieu of the protective clothing material. This arrangement allows collection medium and test chemical to mix in a manner simulating permeation of the chemical through the protective clothing material.

D.2.2 Figure D.2 illustrates the second permeation test cell and one approach for injecting the test chemical into the cell at a constant, measurable rate. This practice requires modification of the standard permeation cell to include three ports:

- one port is used for introduction of the collection medium near the surface of the inert material;
- one port is used for introduction of the test chemical near the surface of the inert material;
- one port for removal of the collection medium/mixture from the cell.

D.2.3 The test chemical can be delivered to the second permeation test cell using any method which can provide a controlled, measurable rate. A syringe pump may be employed for this purpose. The flow rate of the collection medium through both the blank cell and the permeation test cell should be calibrated with a standardized flowmeter at the outlet of the cell before beginning the test. With the collection medium flow rate, and the rate of test chemical introduction to the collection chamber, the theoretical concentration of the test chemical in the out-flowing collection medium can be calculated using equation (D.1)

$$c = \frac{\rho \, V_{\mathrm{m}} \, q_m}{M \, q_V} \qquad \text{(D.1)}$$

where

c is the test chemical concentration, expressed in micrograms per cubic centimetre (µg/cm^3);

ρ is the test chemical density, expressed in grams per cubic centimetre (g/cm^3), at the test temperature;

V_m is the molar volume, expressed in cubic centimetres per mole (cm^3/mol), at the test temperature;

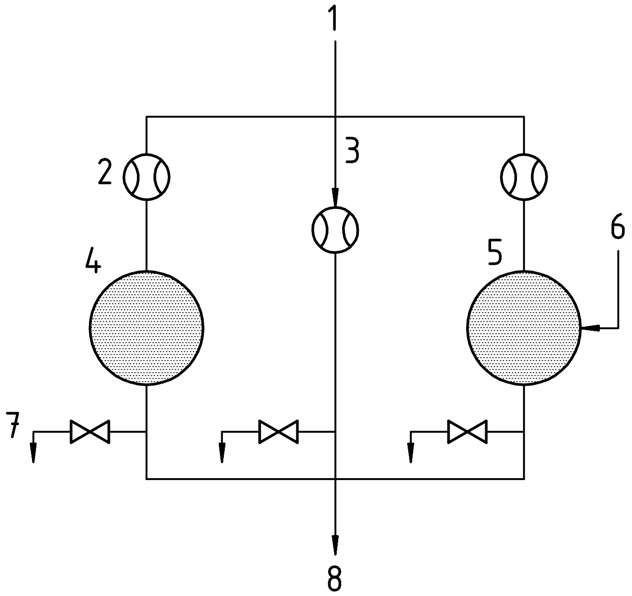
q_m is the rate of delivery, expressed in micrograms per minute (µg/min), of the test chemical into the collection chamber;

q_V is the volume flow rate, expressed in cubic centimetres per minute (cm^3/min), of the collection medium;

M is the molar mass, expressed in grams per mole (g/mol), of the test chemical.

D.2.4 Successive, discrete increases in the rate of test chemical introduction can be used to find the lower limit of detection for the permeation system. The lower detectable rate should be twice the baseline noise level of the system with the blank cell in place.

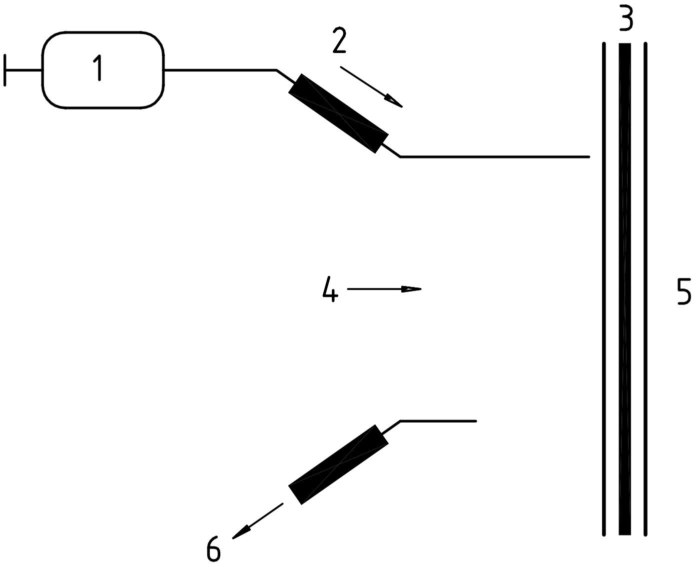
D.2.5 Permeation system calibration factors and relative sensitivity may be determined by subtracting the baseline response from responses for both the test chemical and the standard calibration chemical. The ratio of these adjusted detector responses can then be used to determine permeant concentrations when the calibration chemical is also used as an internal standard during the actual permeation test.



Key

1	Fresh collection medium	5	Test Cell 2 (with modifications for injecting test chemical)
2	Flowmeter	6	Injection of test chemical
3	Calibration gas stream	7	Flow controller
4	Test Cell 1 (blank)	8	To detector

Figure D.1 — Configuration of permeation test equipment for sensitivity determination



Key

1	Syringe pump	4	Introduction of the collection medium
2	Introduction of the test chemical	5	Challenge side of the modified permeation cell
3	Aluminium foil or other inert material	6	Removal of the collection medium toward the detector

Figure D.2 — Configuration of permeation test cell to determine permeation system sensitivity

Bibliography

[1] ISO 2859-1, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

[2] ISO 6530:1990, *Protective clothing — Protection against liquid chemicals — Determination of resistance of materials to penetration by liquids*

[3] ISO 13994:1998, *Clothing for protection against liquid chemicals — Determination of the resistance of protective clothing materials to penetration by liquids under pressure*

[4] *Am. Ind. Hyg. Ass. J.*, **42**, 1981, pp. 217-225

Annex ZA
(normative)

Normative references to international publications with their relevant European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE Where an International Publication has been modified by common modifications, indicated by (mod.), the relevant EN/HD applies.

Publication	Year	Title	EN	Year
ISO 139	1973	Textiles - Standard atmospheres for conditioning and testing	EN 20139	1992
ISO 2286-2	1998	Rubber- or plastics-coated fabrics - Determination of roll characteristics - Part 2: Methods for determination of total mass per unit area, mass per unit area of coating and mass per unit area of substrate	EN ISO 2286-2	1998
ISO 2286-3	1998	Rubber- or plastics-coated fabrics - Determination of roll characteristics - Part 3: Method for determination of thickness	EN ISO 2286-3	1998
ISO 5084	1996	Textiles - Determination of thickness of textiles and textile products	EN ISO 5084	1996

Annex ZB
(informative)

Clauses of this European Standard addressing essential requirements or other provisions of EU Directives

By agreement between ISO and CEN, this CEN annex is included in the DIS and the FDIS but will not appear in the published ISO standard.

This European Standard has been prepared under a mandate given to CEN by the European Commission and supports essential requirements of EU Directive 89/686/EEC, Annex II.

Note Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Subclause 3.10.2 of this standard is likely to support requirements of EU Directive 89/686/EEC, Annex II.

Compliance with this subclause provides one means of conforming with the specific essential requirements of the Directive concerned.

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