
**Protective clothing — Test methods for
clothing providing protection against
chemicals —**

Part 2:

**Determination of resistance to inward
leakage of aerosols and gases (inward
leakage test)**

*Vêtements de protection — Méthodes d'essai pour les vêtements
fournissant une protection contre les produits chimiques —*

*Partie 2: Détermination de la résistance aux fuites des aérosols et
des gaz vers l'intérieur (essai de pénétration)*



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Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Terms and definitions	1
3 Principle	2
4 Test agents and test subjects	2
4.1 Test agents	2
4.2 Test subjects	3
5 Apparatus	7
5.1 Method 1 — Sodium chloride method	7
5.2 Method 2 — Sulfur hexafluoride method (SF ₆)	8
6 Procedure	8
7 Calculation	9
8 Test report	10
Annex A (normative) Sampling probe and connections	11
Bibliography	13

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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17491-2 was prepared by Technical Committee ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 13, *Protective clothing*.

This first edition of ISO 17491-2, together with ISO 17491-1, ISO 17491-3, ISO 17491-4 and ISO 17491-5, cancels and replaces ISO 17491:2002 which has been technically revised.

ISO 17491 consists of the following parts, under the general title *Protective clothing — Test methods for clothing providing protection against chemicals*:

- *Part 1: Determination of resistance to outward leakage of gases (Internal pressure test)*
- *Part 2: Determination of resistance to inward leakage of aerosols and gases (inward leakage test)*
- *Part 3: Determination of resistance to penetration by a jet of liquid (jet test)*
- *Part 4: Determination of resistance to penetration by a spray of liquid (spray test)*

The following parts are under preparation:

- *Part 5: Determination of resistance to penetration by a spray of liquid (manikin spray test)*

Introduction

Chemical protective clothing is worn in conjunction with appropriate respiratory protective devices in order to isolate the body of the wearer from the environment. Several tests exist for determining the resistance of chemical protective clothing materials to either the permeation or penetration of gaseous or liquid chemicals.

However, the effectiveness of the overall protective clothing item in preventing exposure from chemical hazards depends on the integrity of the clothing item's design in eliminating or reducing inward leakage of chemicals.

The selection of the appropriate integrity test method will depend on the application of the chemical protective clothing and the exposure hazards present. Usually, the integrity test method will be specified in the overall chemical protective clothing specification.

Evaluations of protective clothing material chemical resistance should be carried out using the appropriate test.

ISO 6529 specifies methods for measuring the resistance of the protective clothing materials, seams and assemblages to permeation by either liquids or gases. ISO 13994 specifies a method for determining the penetration resistance of protective clothing materials under conditions of continuous liquid contact and pressure, and can be applied to micro-porous materials, seams and assemblages. ISO 6530 specifies a procedure for measuring the penetration resistance of protective clothing materials from the impact and runoff of liquids. General protective clothing requirements are specified in ISO 13688.

This International Standard specifies six different test methods for determining the resistance of complete protective clothing to inward leakage of either gaseous or liquid chemicals (protective clothing integrity). These test methods apply to either liquid or gaseous chemicals, or aerosols, and range in the level of severity.

The integrity test methods specified by this International Standard are as follows.

ISO 17491-1 specifies a method to be performed either at minimum test settings (Method 1) or at more rigorous test settings (Method 2), for assessing the resistance of a gas-tight suit to outward leakage of air through, for example, essential openings, fastenings, seams, interface areas between items, pores and any imperfections in the materials of construction.

This part of ISO 17491 specifies two different methods for determining the inward leakage of chemical protective suits in an aerosol environment (Method 1) or a gaseous environment (Method 2). The procedure is applicable to gas-tight suits and non-gas-tight suits according to ISO 16602 and provides an evaluation of chemical protective suit integrity, particularly leakage in the breathing zone, under dynamic conditions through the use of human subjects.

ISO 17491-3 specifies a method for determining the resistance of chemical protective clothing to penetration by jets of liquid chemicals. This procedure is applicable to clothing worn where there is a risk of exposure to a forceful projection of a liquid chemical and which is intended to be resistant to penetration under conditions that require total body surface cover, but not gas-tight clothing.

ISO 17491-4 specifies a method to be performed either at minimum test settings (Method A — low-level spray test) or at more rigorous test settings (Method B — high-level spray test), for determining the resistance of chemical protective clothing to penetration by sprays of liquid chemicals. This procedure applies to protective clothing intended to be worn when there is a risk of exposure to slight splashes of a liquid chemical or to spray particles that coalesce and run off the surface of the garment, and to clothing which is intended to be resistant to penetration under conditions that require total body surface cover, but not gas-tight clothing.

ISO 17491-5 specifies an alternative test method for determining the resistance to spray penetration. It uses a static manikin instead of a test subject; it also uses a different spray configuration and duration.

Methods specified in this part of ISO 17491, ISO 17491-1, ISO 17491-3, ISO 17491-4 and ISO 17491-5 are not appropriate for evaluating the permeation or penetration of liquid chemicals through the material from which the clothing is made.

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Protective clothing — Test methods for clothing providing protection against chemicals —

Part 2:

Determination of resistance to inward leakage of aerosols and gases (inward leakage test)

1 Scope

This part of ISO 17491 specifies two different methods for determining the inward leakage of chemical protective suits in an aerosol environment (Method 1) or a gaseous environment (Method 2).

The procedure is applicable to gas-tight suits and non-gas-tight suits and provides an evaluation of chemical protective suit integrity, particularly leakage in the breathing zone, under dynamic conditions through the use of human subjects.

2 Terms and definitions

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

2.1

assemblage

permanent fastening between two or more different garments, or between chemical protective clothing and accessories, obtained by e.g. sewing, welding, vulcanizing or gluing

2.2

chemical protective clothing

combined assembly of garments, worn to provide protection against exposure to or contact with chemicals

2.3

chemical protective suit

clothing worn to protect against chemicals that covers the whole, or greater part, of the body

NOTE 1 A chemical protective suit can comprise garments combined together to provide protection to the body.

NOTE 2 A suit can also have various types of additional protection joined to it, such as a hood or helmet, boots and gloves.

2.4

garment

individual component (of chemical protective clothing), the wearing of which provides protection against contact with chemicals to the part of the body that it covers

2.5

gas-tight suit

one-piece garment with hood, gloves and boots which, when worn with self-contained or air-line breathing apparatus, provides the wearer with a high degree of protection against harmful liquids, particles and gaseous or vapour contaminants

2.6

non-gas-tight suit

one-piece garment with hood, glove and boots which, when worn with or incorporating self-contained or air-line breathing apparatus, provides the wearer with a high degree of protection against harmful liquids, particles and gaseous or vapour contaminations but does not meet an outward gas leakage test (internal pressure test, ISO 17491-1)

NOTE See ISO 16602.

2.7

joint

non-permanent fastening between two different garments, or between chemical protective clothing and accessories

2.8

penetration

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

2.9

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.

2.10

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 Principle

The subject wearing the suit under test walks on a treadmill over which there is an enclosure. Through this enclosure flows a constant concentration of the test agent, either sodium chloride (NaCl) using Method 1 or sulfur hexafluoride (SF₆) using Method 2.

NOTE Method 1 simulates an aerosol challenge while Method 2 simulates a gaseous challenge.

The air inside the suit is sampled to determine the test agent content. The sample is extracted through a probe placed inside the suit. Another probe measures the pressure inside the suit.

The airflow rate to the suit is adjusted and maintained at the manufacturer's minimum design flow rate. If the suit is not outfitted with an external continuous flow air supply, the test subject shall wear a self-contained open-circuit compressed air breathing apparatus suitable for the test (duration and effort) and an airflow shall be fed into the suit, equal to the flow withdrawn from the suit for sampling. For a typical arrangement, see Figures 1 and 2.

4 Test agents and test subjects

4.1 Test agents

Method 1 — Sodium chloride test agents

This method employs a sodium chloride aerosol as the test agent. The subject wearing the suit under test stands with his suited body surrounded by the NaCl test atmosphere (see Figure 1). The mean NaCl concentration

within the enclosure shall be $(8 \pm 4) \text{ mg/m}^3$ and the variation throughout the effective working volume shall not be more than 10 %. The particle size distribution shall be 0,02 μm to 2 μm equivalent aerodynamic diameter with a mass median diameter of 0,6 μm .

Method 2 — Sulfur hexafluoride test agents

This method employs sulfur hexafluoride gas as the test agent. The subject wearing the suit under test stands with his suited body surrounded by the SF_6 test atmosphere (see Figure 2). Accurate determinations of leakage shall be possible within the range of 0,001 % to approximately 20 %, depending on the test challenge atmosphere. It is recommended that a test atmosphere at 0,1 % SF_6 (by volume) be used since SF_6 can build up inside the suit.

SF_6 is not to be used for full suits utilizing filters as exhaust assemblies, unless the suit exhaust assemblies are connected to an atmosphere free of the challenge agent during testing.

4.2 Test subjects

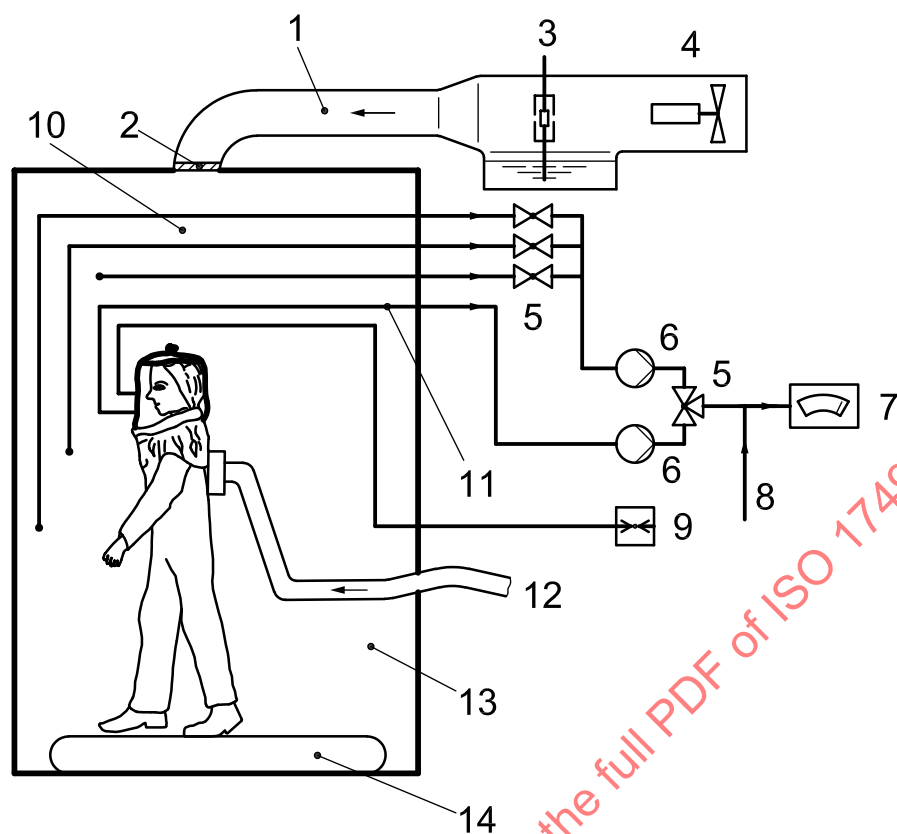
For the test, persons shall be selected who are familiar with using the same or similar equipment and whose medical history is known to be satisfactory. The subjects shall be medically examined and certified fit to undertake the test procedures. The necessity of a medical examination before, or supervision during, the test shall be at the testing supervisor's discretion. The selection of test subjects shall be in accordance with national regulations for the participation of test subjects in experiments.

Prior to the test, there is an examination that the suit is in good working condition and that it can be used without hazard. Two devices shall be tested, each being tested on two test subjects.

NOTE Pre-conditioning should be determined in accordance with the expected conditions of use. Conditioning at high or low temperatures should not be done, if not relevant.

If more than one size of suit is manufactured, the test subjects are to be asked to select the appropriate size according to the manufacturer's instructions.

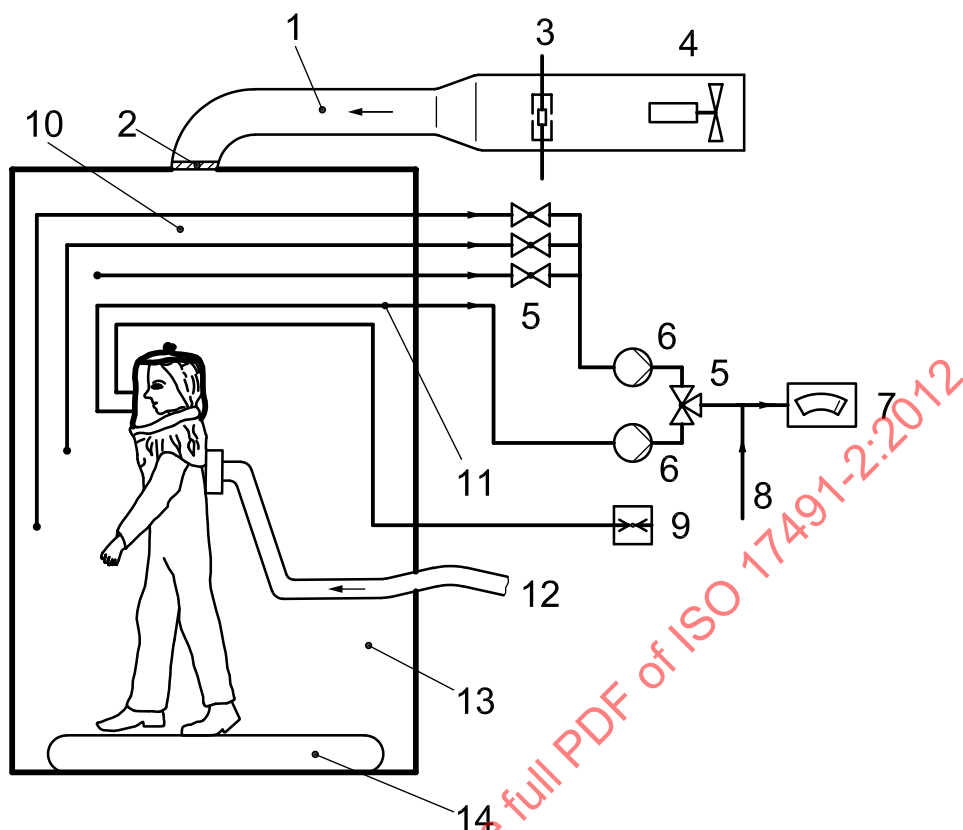
The test subjects are to be asked to read the manufacturer's fitting instructions and, if necessary, are shown how to fit the suit correctly by the test supervisor, in accordance with the fitting instructions. After fitting the suit, each test subject is asked "does the suit fit?". If the answer is "yes", continue with the test. If the answer is "no", take the subject off the panel and report the fact.



Key

- | | | |
|------------|------------------------|---------------------------|
| 1 duct | 6 pump | 11 breathing zone samples |
| 2 baffle | 7 photometer | 12 breathing air supply |
| 3 atomizer | 8 additional air input | 13 enclosure |
| 4 fan | 9 manometer | 14 treadmill |
| 5 valves | 10 enclosure samples | |

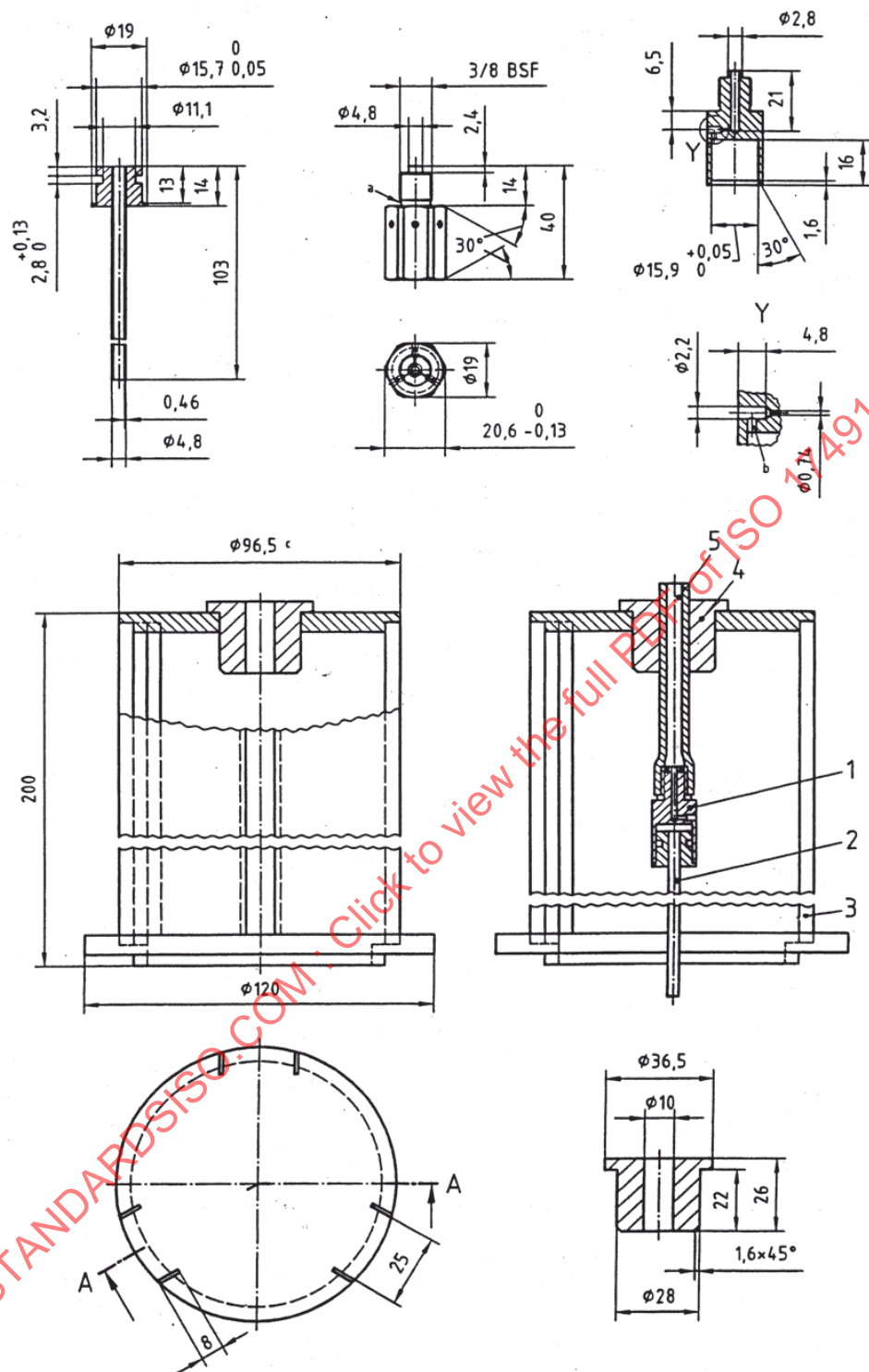
Figure 1 — Typical arrangement of inward leakage test using NaCl aerosol, Method 1

**Key**

- | | | |
|------------|--------------------------------|---------------------------|
| 1 duct | 6 pump | 11 breathing zone samples |
| 2 baffle | 7 sulfur hexafluoride detector | 12 breathing air supply |
| 3 atomizer | 8 additional air input | 13 enclosure |
| 4 fan | 9 manometer | 14 treadmill |
| 5 valves | 10 enclosure samples | |

Figure 2 — Typical arrangement of inward leakage test using SF₆, Method 2

Dimensions in millimetres



Key

- 1 nozzle
- 2 feed tube (salt solution)
- 3 sleeve
- 4 bush
- 5 air tube ($10,0 \begin{smallmatrix} 0 \\ 0 \end{smallmatrix}$ /dia)

Figure 3 — Example of assembly of atomizer

5 Apparatus

5.1 Method 1 — Sodium chloride method

5.1.1 Aerosol generator

The NaCl aerosol shall be generated from a 2 % solution of reagent grade NaCl in distilled water. A single large Collision atomizer (see Figure 3) shall be used. The atomizer nozzles shall not point towards the cut-outs in the bottle.

The atomizer and its housing shall be fitted into a duct through which a constant flow of air is maintained. It can be necessary to heat or dehumidify the air in order to obtain complete drying of the aerosol particles.

5.1.2 Detector system for NaCl

5.1.2.1 General

The detector for NaCl is, preferably, capable of analysing the test atmosphere NaCl continuously by means of a suitable flame photometer having a sensitivity of 0,1 % of the chamber challenge concentration. The probe for sampling the test atmosphere shall be positioned near the hood.

A specific example of probe design and position is provided in Annex A.

The NaCl concentration inside the suit is analysed and recorded by a flame photometer. This concentration measured within the head section of the suit is a measure of the inward leakage. Perform the test at ambient temperature and at a relative humidity of <60 % within the test chamber.

5.1.2.2 Flame photometer

A flame photometer shall be used to measure the concentration of NaCl inside the face piece or equivalent. Essential performance characteristics for a suitable instrument are the following.

- It shall be a flame photometer specifically designed for the direct analysis of NaCl aerosol.
- It shall be capable of measuring concentrations of NaCl aerosol between 15 mg/m³ and 0,5 ng/m³.
- The total aerosol sample required by the photometer shall not be greater than 15 l/min.
- The response time of the photometer, excluding the sampling system, shall not be greater than 500 ms.
- It is necessary to reduce the response to other elements, particularly carbon, the concentration of which will vary during the breathing cycle. This is achieved by ensuring that the band pass width of the interference filter is no greater than 3 nm and that all necessary side-band filters are included.

Depending on the type of photometer used, it can be necessary to dilute the sample with clean air. Adding dry air at the sampling point can also help reduce particle losses in the sampling line.

5.1.2.3 Adjustable sample flow pump

An adjustable sample flow pump is to be used if no pump is incorporated into the photometer for withdrawing an air sample from the suit under test. This pump is adjusted so as to withdraw a constant flow of 1 l/min to 3 l/min from the sample probe.

5.1.2.4 Monitoring device for sampling of chamber concentration

The monitoring device for the sampling of chamber concentration consists of a separate system to avoid contamination of the suit sampling lines.

It is preferable to use a separate flame photometer for this purpose. If a second photometer is not available, sampling of the chamber concentration may be done using a separate sampling system. However, time will then be required to allow the photometer to return to a clean background. Figure 1 shows a typical sampling arrangement.

5.2 Method 2 — Sulfur hexafluoride method (SF₆)

5.2.1 Detector for SF₆

The detector for SF₆ is, preferably, capable of analysing the test atmosphere for SF₆ continuously by means of a suitable analyser or spot checks as necessary, in order to determine the concentration during tests. At a minimum, the test atmosphere shall be analysed at 3 min intervals. The probe for sampling the test atmosphere shall be positioned at head height ($1\,800 \pm 200$) mm, approximately 200 mm from the chamber wall. The SF₆ concentration inside the suit is analysed and recorded. This concentration, measured within the head section of the suit, is a measure of the inward leakage.

A suitable analyser for the test atmosphere is one based on thermal conductivity, infrared spectroscopy or electron capture with dilution. The SF₆ concentration in the suit may be monitored using an electron capture detector or infrared system.

5.2.2 Sampling probe

The sampling probe consists of a length of suitable plastic tube fitted with a plastic ball of approximately 20 mm diameter and having 8 holes each of 1,5 mm diameter spaced equidistant around the circumference of the ball. The sample probe shall be positioned as indicated in Annex A.

5.2.3 Test chamber

The test chamber is made from transparent material and having a minimum cross-sectional dimension of 0,7 m (see Figures 1 and 2).

It should be supported with adequate clearance above the head of the test subject and extend down to the surface of the treadmill. The test agent enters the top of the chamber through a flow distributor and is directed downward over the head of the test subject at a flow rate of at least 0,12 m/s. This flow rate should be measured close to the subject's head. In addition, the flow rate should not fall below 0,1 m/s inside the effective working volume (0,1 m from the chamber wall and above a height of 0,75 m). The concentration of the test agent inside the effective working volume shall be checked to ensure that it is homogeneous.

5.2.4 Treadmill

The treadmill has a 2 % gradient and is capable of maintaining a constant speed of 5 km/h and installed in the chamber.

5.2.5 Pressure detection probe

The pressure detection probe is fitted near the sample probe and connected to a pressure sensor.

A single probe can be used if the pressure is tapped off the sampling line and corrected for the sampling flow-induced pressure drop.

6 Procedure

6.1 Dress the test subject in the suit according to the instructions for the type of suit under test. Underclothing should consist of standard underwear, trousers and a long sleeve shirt. The test subjects shall be informed that if they wish to adjust the suit during the test they may do so. If this is done, the relevant section of the test will be repeated having allowed time for the system to resettle. The subjects shall be given no indication of the results as the test proceeds.

6.2 Follow the test procedure in Table 1. Sample the test chamber for SF₆ at 3 min intervals during the test.

6.3 Analyse the results over the final 2 min of each exercise period (shown in Table 1) to avoid carryover of the result from one exercise to another.

6.4 Record the pressure inside the suit over the whole time.

Table 1 — Test protocol for gaseous inward leakage test

Activity	Estimated time taken for activity min
a) Dress subject in suit	—
b) Don boots, gloves, etc. according to manufacturer's instruction	—
c) Establish background reading at sample point with subject standing still (no test agent)	3
d) Start test agent and allow to stabilize	3
e) Subject to enter test chamber and connect tubing to sample point	3
f) Record leakage and pressure at sample point with subject still	3
g) Start treadmill	—
h) Walk for 3 min	3
i) Record leakage and pressure at sample point with subject walking at about 5 km/h	—
j) Stop treadmill	—
k) Record leakage and pressure at sample point with subject moving arms up and down above head height and looking upward e.g. lifting object (1/2 brick) from desk to shelf level	3
l) Record leakage and pressure at sample point with subject doing continuous squats ^b	3
m) Record leakage and pressure at sample point with subject using a gas sampling hand pump	3
n) Record leakage and pressure at sample point with subject twisting at waist with arms folded at chest ^b	3
o) Stop test agent and allow to disperse with subject in chamber	3
p) Disconnect sample tubes and remove subject from test chamber; undress subject	3
^a The total trial may vary; all times are approximate and are carried out under stable conditions. If SCBA or other short duration respiratory protective equipment is used, the exercise period should be split into suitable periods to accommodate a change of air supply and the completion of the entire exercise protocol.	
^b When doing squats or twisting, a slow deliberate action is required, for example one every 3 s.	

7 Calculation

For each individual test exercise, calculate the arithmetic mean over the last 2 min of exercise.

Calculate the percentage total inward leakage, L_{TI} , for each exercise as given in Equation (1):

$$L_{TI} = \frac{c_2}{c_1} \times 100 \quad (1)$$

where

c_1 is the concentration in the enclosure;

c_2 is the mean concentration in the breathing zone for each exercise.

For Method 1, subtract the background concentration of NaCl from each concentration measurement and the concentration in the enclosure.

8 Test report

The test report shall include the following information:

- a) a reference to this International Standard, i.e. ISO 17491-2:2012;
- b) the method used, i.e. Method 1 or Method 2;
- c) the manufacturer/supplier and any identifying mark;
- d) the test temperature and relative humidity in the test chamber;
- e) the average concentration of test agent in the chamber over the duration of the test, including details on how the test atmosphere was created during the test;
- f) the mean concentration of test agent in the breathing zone for each exercise;
- g) the percentage total inward leakage as determined in Clause 7;
- h) the pressures measured during the test period;
- i) any further qualifying remarks and observations, such as substitutions in procedures.

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