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ISO 13982-2

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Protective clothing for use against solid particulates —

Part 2: Test method of determination of inward leakage of aerosols of fine particles into suits

Vêtements de protection à utiliser contre les particules solides —

Partie 2: Méthode d'essai pour la détermination de la fuite vers l'intérieur d'aérosols de fines particules dans des combinaisons

Reference number
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Foreword

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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 13982-2 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 162, *Protective clothing including hand and arm protection and lifejackets*, in collaboration with Technical Committee ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 13, *Protective clothing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 13982 consists of the following parts, under the general title *Protective clothing for use against solid particulates*:

— *Part 1: Performance requirements for chemical protective clothing providing protection to the full body against airborne solid particulates (type 5 clothing)*

— *Part 2: Test method of determination of inward leakage of aerosols of fine particles into suits*

Protective clothing for use against solid particulates —

Part 2: Test method of determination of inward leakage of aerosols of fine particles into suits

1 Scope

This part of ISO 13982 specifies a test method to determine the barrier efficiency of chemical protective clothing against aerosols of dry, fine dusts.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TR 11610, *Protective clothing — Vocabulary*

EN 136:1998, *Respiratory protective devices — Full face masks — Requirements, testing, marking*

EN 340, *Protective clothing — General requirements*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions of ISO/TR 11610 and the following apply.

3.1.1
aerosol
suspension of solid, liquid or solid and liquid particles in gaseous medium, having a negligible falling velocity

NOTE "Negligible falling velocity" is generally considered to be less than 0,25 m/s.

3.2 Symbols and abbreviated terms

3.2.1
L_{ijmn}
inward leakage for a given test subject (i), suit (j), exercise (m) and sampling position (n)

3.2.2
C_{ijmn}
concentration of aerosol measured at the sampling point inside the suit for a given test subject (i), suit (j), exercise (m) and sampling position (n)

3.2.3
L_S
total inward leakage per suit (average over all exercises and sampling positions)

3.2.4
L_H
total inward leakage per human test subject (average over all exercises, sampling positions and suits worn by that test subject)

3.2.5
L_E
total inward leakage per exercise (average over all suits and sampling positions)

3.2.6
L_P
total inward leakage per sampling position (average over all suits and exercises)

3.2.7
L_{EP}
total inward leakage per sampling position and per exercise (average over all suits)

3.2.8
$\overline{L}$
mean total inward leakage (average over all test subjects, suits, exercises and sampling positions)

4 Principle

A standard aerosol of sodium chloride particles is generated inside a test chamber in which a test subject, wearing the protective suit under test, carries out a predetermined sequence of test exercises. The inward leakage at each sampling position inside the suit is measured by means of flame photometry.

The percentage inward leakage at each sampling position (L_{ijmn}), the total inward leakage per suit (L_S) and per test subject (L_H), the total inward leakage per exercise (L_E) and per sampling position (L_P) and the mean total inward leakage ($\overline{L}$) are calculated.

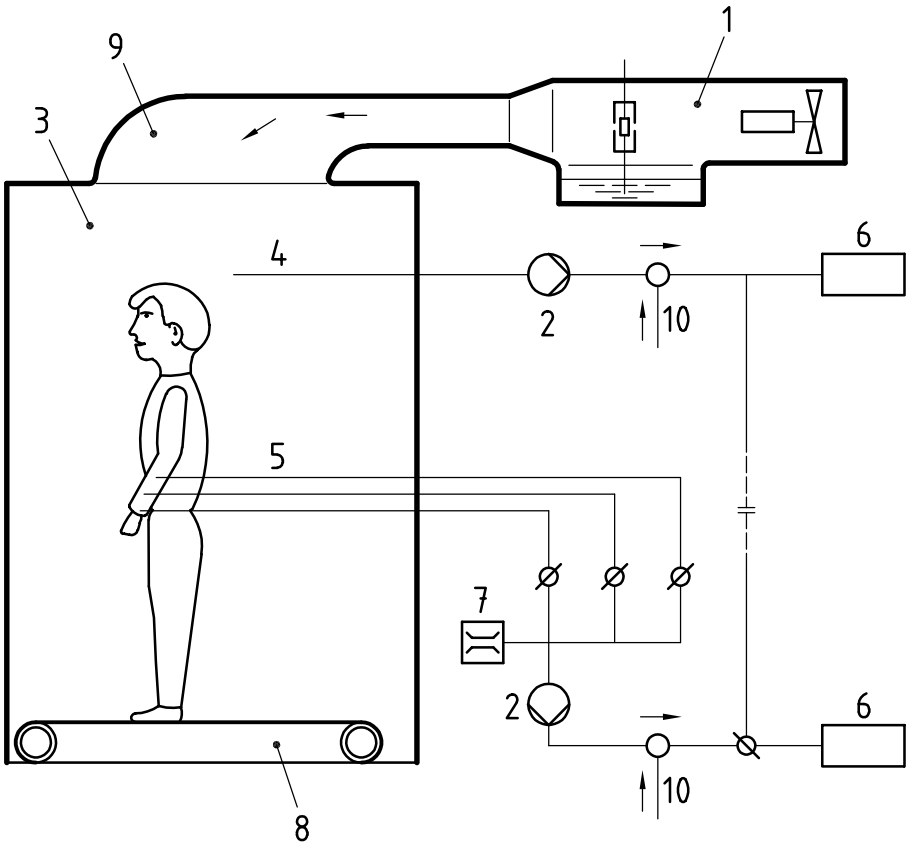
NOTE The test method is based on a testing principle similar to the inward leakage test principle for respiratory equipment, for type 1 and type 2 chemical protective clothing and for protective clothing against radioactive contamination. The method provides a measure of the inward leakage into protective clothing by dry aerosol particles (generated from a sodium chloride solution) having a mass-median aerodynamic diameter of 0,6 µm.

5 Apparatus

5.1 **Aerosol generator**, **flame photometer(s)**, one or two, and a **test chamber**, as described in EN 136.

5.2 **Level treadmill**, capable of operating at (5 ± 0,5) km/h, which is installed inside the chamber.

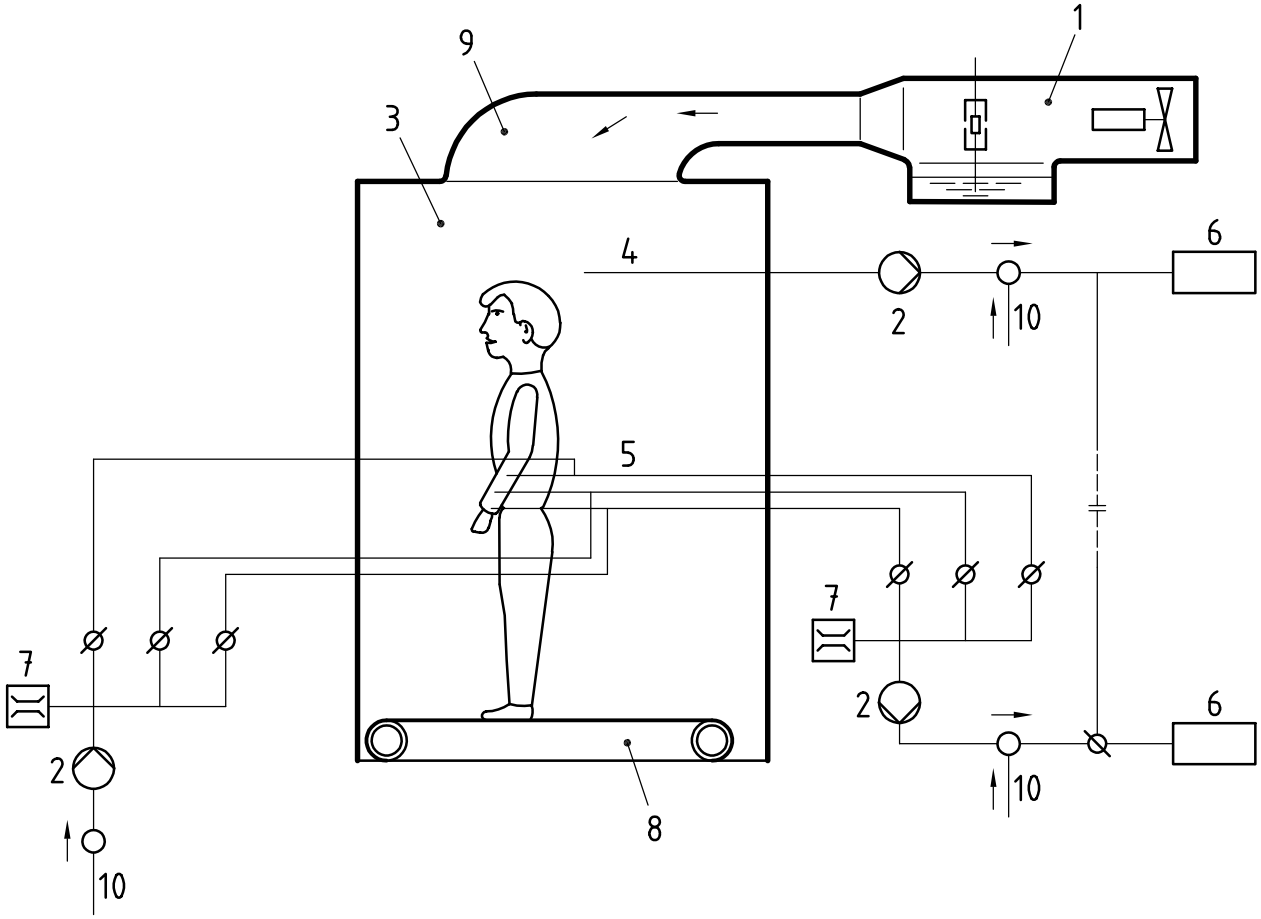
The test arrangement used for the determination of inward leakage is shown schematically in Figures 1 and 2.



Key

1 atomizer
2 pump
3 chamber
4 challenge sample
5 air lines to and from the suit (both sampling and feeding lines)
6 photometer
7 flow meter
8 treadmill
9 ducting and baffle
10 addition of dry, clean air

Figure 1 — Test arrangement (schematic)



Key

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Figure 2 — Modified test arrangement for feeding additional dry, clean air into tubes close to the sampling probes (schematic)

5.3 Sodium chloride aerosol test agent, with a particle-size distribution, mean test-agent concentration and distribution inside the chamber as described in EN 136.

5.4 Adjustable pump and air lines, used for sampling air from the suit under test.

This pump is adjusted to deliver a sampling flow rate from inside the suit in the range of $(2 \pm 0{,}5)$ l/min. The flow shall be kept constant within $\pm$ 0,2 l/min. Depending on the type of photometer, it may be necessary to dilute the sample air with clean air. There shall be no condensation in tubes during testing. Condensation in the tubes can be avoided by feeding dry, clean air directly into the tubes upstream of where condensation occurs (see Figure 2), by heating of the tubes or by any other suitable means. One should take the dilution into account when calculating the concentration at the sampling point.

5.5 Sampling probes, four, constructed as shown in Figure 3, one which shall be used to measure the challenge concentration and three, the concentration inside the suit.

Each probe is fitted onto a length of suitable transparent plastic tube with an internal diameter of 4,0 mm.

Dimensions in millimetres

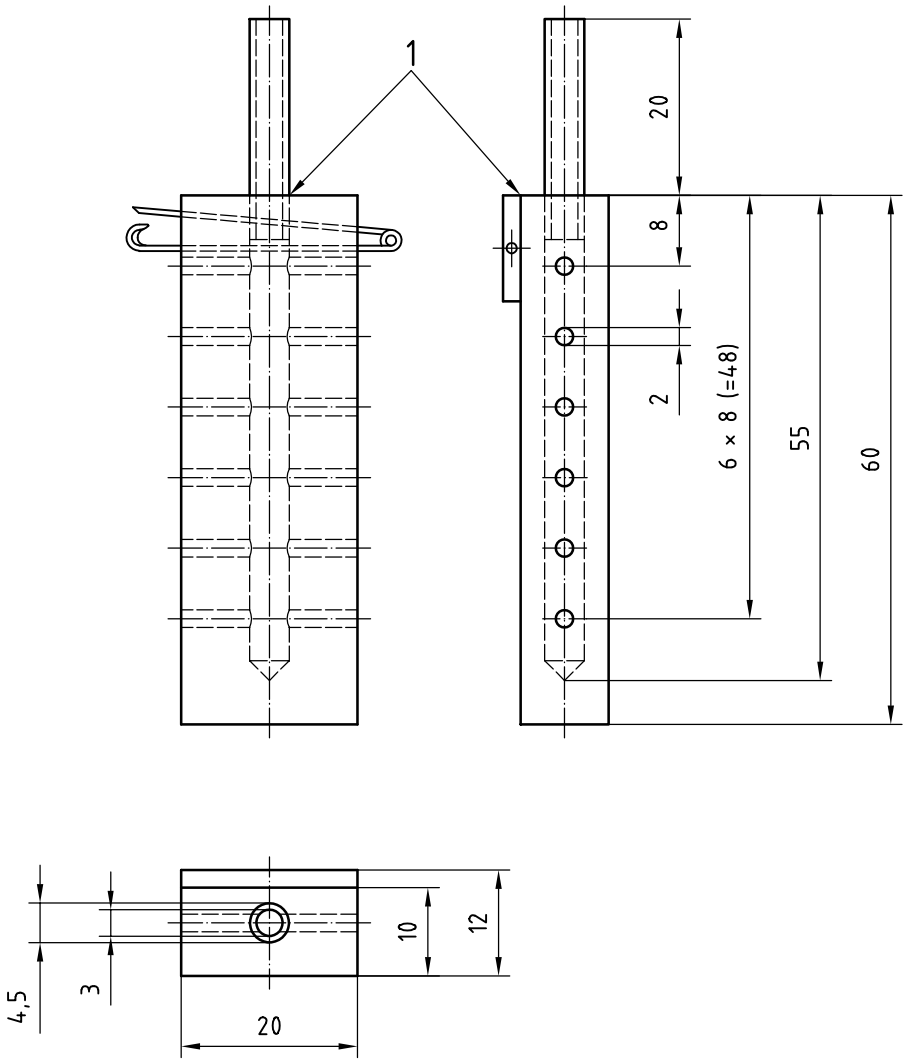
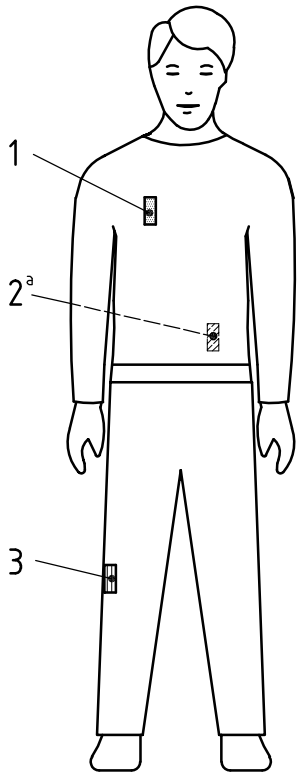


Figure 3 — Sampling probe

The three probes for measuring the concentration inside the suit shall be positioned close to the body of the test subject, at the following positions as shown in Figure 4:



Key

1 on the right chest

2 at the back of the waist

3 at knee height, lateral

[a] Probe 2 is positioned on back.

Figure 4 — Positions of the three sampling probes on body of test subject

Especially in the case of two-piece suits and coveralls equipped with an elastic waistband or a belt worn over the suit, the positions of the sampling points should be carefully chosen.

Sampling probes shall not be positioned directly onto the skin, but shall be fixed onto the underwear.

The sampling lines to and from the sampling probes inside the suit shall be fixed close to the body of the test subject and shall pass through the material of the suit between 5 cm and 15 cm above one of the arm-cuffs in an airtight manner.

The fixings of the sampling lines and the pass-through should have as little influence on the fit of the suit as possible and should not impair the movements of the test subject.

To ensure that there is no additional inward leakage into the suit, due to under-pressure created by extraction of the sample air, clean air shall be fed back into the suit at the same rate as sample air is pumped out, i.e. at $(2 \pm 0{,}5)$ l/min. This clean air shall be introduced through one of the other two sampling probes, according to the sequence of sampling given in Table 1.

The necessary arrangements should be made to ensure that the air is injected in the right compartment of the suit, in particular in the case of two-piece suits or coveralls including a belt or elastic waistband, where there may be insufficient exchange of air between compartments.

Table 1 — Sampling sequence for probes inside the suit during the period when the test subject is present in the chamber and during the sequence of activity

Measuring sequence		Timing min	Sampling through probe at position:	Feeding of clean air through probe at position:	Exercise
Number	Activity				
1	measuring the background inside suit (before generation of the aerosol)	—	knee	chest	standing still
		—	waist back	knee	
		—	chest	waist back	
2	waiting for stabilization and measuring the test agent concentration inside chamber	—	—	—	
3	measuring the test agent concentration inside suit	3	knee	chest	standing still
		3	waist back	knee	
		3	chest	waist back	
		3	knee	chest	walking
		3	waist back	knee	
		3	chest	waist back	
4	stabilization between walking and squatting	1	knee	chest	standing still
		1	waist back	knee	
		1	chest	waist back	
5	measuring the test agent concentration inside suit	3	knee	chest	squatting
		3	waist back	knee	
		3	chest	waist back	
6	measuring the test agent concentration inside chamber	—	—	—	standing still

5.6 Sampling system for the challenge aerosol, separate from that sampling the test concentration in the suit, with a separate flame photometer if possible, in order to avoid contamination of the total inward leakage sampling lines.

If a second photometer is not available, it is possible to determine the challenge concentration by a separate sampling system and the same photometer. However, sufficient time will then be required to allow the photometer to return to a stable background signal level before measuring total inward leakage.

6 Test procedure

6.1 Selection of test subjects

For the test, persons shall be selected who are familiar with the use of this or similar protective equipment and whose medical history is known to be satisfactory. Before performing tests involving human subjects, account shall be taken of any national regulations concerning the medical history, examination or supervision of the test subject.

The test subject shall wear close-fitting underwear (e.g. polyester/cotton long trousers and a T-shirt with long sleeves). The underwear shall be changed after each suit tested.

The size of the suit shall be selected in accordance with the test subject's body dimensions and according to the manufacturer's instructions.

Prior to the test, each suit shall be examined to ensure that it is in good working condition and that it can be used without hazard.

6.2 General test conditions

At least five test subjects shall test at least two suits per person, i.e., at least ten suits shall be tested.

The test subjects shall be asked to read the manufacturer's instructions and, if necessary, they shall be shown by the test supervisor how to wear the suit properly according to the instructions. 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, however, the relevant section of the test shall be repeated after sufficient time has elapsed for the system to stabilize.

After putting on the suit, each test subject shall be asked: “Does the suit fit?” If the answer is “yes”, proceed with the test. If the answer is “no”, take the subject off the test panel, report the fact and replace the test subject by another. The test subjects shall be given no indication of the results as the test proceeds.

If not otherwise specified, all tests shall be carried out at (20 $\pm$ 5) °C and a relative humidity inside the test chamber of less than 60 %. The test temperature and relative humidity inside the test chamber prior to the testing of each suit and at the end of all test exercises for each suit shall be recorded and reported.

6.3 Test sequence

The following test sequence shall be followed for each suit.

— Connect the tubing to the sampling points and dress the test subject in the suit, in accordance with the manufacturer’s instructions. Ensure that the pass-through for the sampling tubes is as leak-tight as possible. Let the test subject also put on additional equipment, such as boots, gloves, hood, mask, etc., in accordance with the manufacturer's instructions.

  If the manufacturer's instructions do not specify the need for additional equipment, then these should not be worn. However, the test subject may wear a suitable respiratory protective device, e.g. a filtering facepiece. In addition, if the manufacturer's instructions do not require the suit to be taped to any part of the body of the wearer (such as wrists and ankles) or to any additional item (e.g. gloves or boots) worn by the test subject, then these types of taping should not be done. It is recommended that all additional equipment be supplied by the manufacturer.

— Let the test subject enter the test chamber.

— Measure and report the concentration of the test agent before the generation of the aerosol inside the suit at all three sampling positions to ensure that, in all cases, the background concentration is at least one order of magnitude below the expected concentration during testing. If the background concentration is higher, investigate why and correct the problem. This may require preliminary testing.

— Start generating the test agent and allow the challenge concentration in the chamber to stabilize. Ensure that the test subject is standing still during this period. Measure and report the challenge concentration. If stabilization of challenge concentration in the chamber takes more than 1 min, the suit shall be ventilated to avoid penetration of particles into it.

— Measure the concentrations at the following sampling positions (see also Figure 4):

  — knee (lateral),

  — waist (back),

  — chest (right);

following the sampling sequence and the corresponding sequence of feeding clean air into the suit described in Table 1, whilst the test subject performs the test exercises in the following order:

1) standing still,

2) walking at 5 km/h,

3) continuous squatting at a frequency of five squats per minute, between standing up straight and knees completely bent, while keeping both hands during all squats on a grip at a height of (1 ± 0,05) m above the standing surface.

Allow for a 3 min rest (standing still) between the walking and the squatting exercises.

During the test sequence 4, “stabilization between walking and squatting”, concentrations should be measured but do not need to be reported. The time for each exercise at each sampling position shall be 3 min. The average concentration over the last 100 s of each exercise and at each of the sampling points shall be calculated and reported. Measurement of the average concentration is preferably made using an integrating recorder.

Where the same photometer is used to measure both the challenge and the penetrating sodium chloride concentrations, the challenge concentration shall be measured and reported at the completion of the test sequence.

The challenge concentration at the end of all test exercises shall be within ± 10% of the initial challenge concentration. If this is not the case, the test results shall be discarded and the problem shall be corrected.

— Stop generating the test agent, disconnect the sample tubes and let the test subject leave the test chamber.

7 Calculation of test results

7.1 Calculation of percentage inward leakage

The percentage inward leakage, L_{ijmn}, shall be calculated from measurements made over the last 100 s (to avoid carry-over of results from one exercise to the other) for each of the three sampling positions (n) for each of the three exercise periods (m) for each of the suits tested (j) (with at least two suits per test subject) for each of the test subjects (i) (at least five test subjects) in accordance with Equation (1):

$$L_{ijmn} = \frac{C_{ijmn} \times 100\%}{C} \tag{1}$$

where

C is the challenge concentration;

C_{ijmn} is the concentration for sampling position n for exercise m for suit j for test subject i.

All percentage inward leakage values shall be reported.

7.2 Calculation of total inward leakage

7.2.1 The total inward leakage, $L_{S,j}$, per suit for suit j, shall be calculated in accordance with Equation (2):

$$L_{S,j} = \frac{1}{mn} \sum_{m} \sum_{n} L_{ijmn} \tag{2}$$

The data reported shall pertain to 10 results from 10 or more suits.

7.2.2 The total inward leakage, $L_{\mathrm{H},i}$, per human subject for subject i shall be calculated in accordance with Equation (3):

$$L_{\mathrm{H},i} = \frac{1}{jmn} \sum_{j} \sum_{m} \sum_{n} L_{ijmn} \tag{3}$$

The data reported shall pertain to 5 results from 5 or more subjects.

7.2.3 The total inward leakage, $L_{\mathrm{E},m}$, per exercise for exercise m shall be calculated in accordance with Equation (4):

$$L_{\mathrm{E},m} = \frac{1}{jn} \sum_{j} \sum_{n} L_{ijmn} \tag{4}$$

The data reported shall pertain to 3 results from 3 exercises.

7.2.4 The total inward leakage, $L_{\mathrm{P},n}$, per position for test position n shall be calculated in accordance with Equation (5):

$$L_{\mathrm{P},n} = \frac{1}{jm} \sum_{j} \sum_{m} L_{ijmn} \tag{5}$$

The data reported pertain to 3 results from 3 sampling positions.

7.2.5 The total inward leakage per position and per exercise, L_{EP}, for exercise m and position n shall be calculated in accordance with Equation (6):

$$L_{\mathrm{EP},\,mn} = \frac{1}{j} \sum_{j} L_{ijmn} \tag{6}$$

The data reported pertain to 10 suits (or more).

7.2.6 The mean total inward leakage

The average, $\bar{L}$ of all total inward leakage measurements shall then be calculated in accordance with Equation (7) and reported:

$$\bar{L} = \frac{1}{j} \sum_{j} L_{\mathrm{S},j} = \frac{1}{i} \sum_{i} L_{\mathrm{H},i} = \frac{1}{m} \sum_{m} L_{\mathrm{E},m} = \frac{1}{n} \sum_{n} L_{\mathrm{P},n} \tag{7}$$

8 Test report

The test report shall contain the following information:

a) reference to this International Standard (i.e., ISO 13982-2:2004);

b) identity of the manufacturer of the suit;

c) size of the suits tested and the body measurements of the test subjects, in accordance with the provisions of EN 340;

d) description of the underwear worn by test subjects;

e) description of any pre-treatment and/or pre-conditioning of the suits tested, e.g. mechanical pre-stressing of suits for determining the durability of barrier efficiency;

f) description of any additional protective equipment or any accessories worn during the test and if and how the accessories were taped to the suit;

g) temperature and relative humidity inside the test chamber prior to the testing of each suit and at the end of all test exercises for each suit;

h) concentration of test agent inside the suit at all three sampling positions for each suit prior to testing; concentration of test agent inside the test chamber after stabilizing the test agent concentration and at the end of all test exercises;

i) all inward leakage results, presented in the form of data tables:

— tables giving the percentage inward leakage values L_{ijmn} and averages per test subject and test suit (i.e., at least 10 tables modelled on Table 2),

— table giving total inward leakage values for all test subjects and test suits (modelled on Table 3),

— table giving total inward leakage values per test subject (modelled on Table 4);

j) any comments considered appropriate by the person who has carried out the tests.

Table 2 — Model for reporting inward leakage values, expressed in percent, of suit j worn by test subject i

Exercise	Sampling position/Feeding-in position			Average per exercise %
	Knee/Chest	Waist back/Knee	Chest/Waist back	
standing still	L_{ij11}	L_{ij12}	L_{ij13}	L_{E1ij}
walking	L_{ij21}	L_{ij22}	L_{ij23}	L_{E2ij}
squatting	L_{ij31}	L_{ij32}	L_{ij33}	L_{E3ij}
average per sampling position	L_{P1ij}	L_{P2ij}	L_{P3ij}	L_{Sij}

Table 3 — Model for reporting total inward leakage values, expressed in percent, per sampling position and per exercise (averaged over all suits)

Exercise	Sampling position/Feeding-in position			Average per exercise %
	Knee/Chest	Waist back/Knee	Chest/Waist back	
standing still	L_{EP11}	L_{EP12}	L_{EP13}	L_{E1}
walking	L_{EP21}	L_{EP22}	L_{EP23}	L_{E2}
squatting	L_{EP31}	L_{EP32}	L_{EP33}	L_{E3}
average per sampling position	L_{P1}	L_{P2}	L_{P3}	$\overline{L}$

Table 4 — Model for reporting total inward leakage values, expressed in percent, per test subject

Test subject	Total inward leakage per suit, L_{Sj}	Total inward leakage per human test subject, L_{Hi}
1	L_{S1}, L_{S2}	L_{H1}
2	L_{S3}, L_{S4}	L_{H2}
…*i*…	L_{S2i-1}, L_{S2i}	L_{Hi}
average	$\overline{L}$	$\overline{L}$

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