INTERNATIONAL STANDARD

ISO 17491

First edition
2002-04-15

Protective clothing — Protection against gaseous and liquid chemicals — Determination of resistance of protective clothing to penetration by liquids and gases

Vêtements de protection — Protection contre les produits chimiques liquides et gazeux — Détermination de la résistance des vêtements de protection à la pénétration des liquides et des gaz

Reference number
ISO 17491:2002(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

Printed in Switzerland

Contents

Page

1 Scope **1**
2 Normative references **2**
3 Terms and definitions **2**
4 Method A — Internal pressure test **3**
5 Method B — Aerosol and gaseous inward leakage test **6**
6 Method C — Liquid jet test **11**
7 Method D — Liquid spray test **14**
8 Method E — Alternative liquid spray test **18**
9 Method F — Mist test **23**
Bibliography **26**

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

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 by the appropriate test. ISO 6529 specifies methods for measuring the resistance of the protective clothing materials to permeation by either liquids or gases. ISO 13994 specifies a method for determinig the penetration resistance of protective clothing materials under conditions of continuous liquid contact and pressure, and can be applied to microporous 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.

Protective clothing — Protection against gaseous and liquid chemicals — Determination of resistance of protective clothing to penetration by liquids and gases

1 Scope

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 six integrity test methods specified by this International Standard are as follows:

a) **Method A** specifies a method 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.

b) **Method B** specifies two different methods for determining the inward leakage of chemical protective suits in a gaseous (or aerosol) environment. The procedure is applicable to gas-tight suits and provides an evaluation of chemical protective suit integrity, paticularly leakage in the breathing zone, under dynamic conditions through the use of human subjects.

c) **Method C** 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 intended to be resistant to penetration under conditions which require total body surface cover but not gas-tight clothing.

d) **Method D** specifies a method 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 intended to be resistant to penetration under conditions which require total body surface cover but not gas-tight clothing.

e) **Method E** specifies an alternative method to method D for determining the resistance of chemical protective clothing to penetration by sprays of liquid chemicals. Method E differs from Method D in that it uses a static mannequin instead of a test subject, it also uses a different spray configuration and duration (1 h compared to 30 min for Method D) and is based on a qualitative determination of observed liquid on the absorbent coverall or interior of the chemical protective clothing.

f) **Method F** is a modification of Method D where the spray has been modified to light spray or mist by use of different nozzles and spray conditions and is intended for partial body protective clothing where the likelihood of splash exposure is low.

Methods C, D, E and F are not appropriate for evaluating the permeation or penetration of liquid chemicals through the material from which the clothing is made.

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 13688, *Protective clothing — General requirements*

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

EN 149:1991, *Respiratory protective devices — Filtering half masks to protect against particles — Requirements, testing, marking*

EN 12941:1998, *Respiratory protective devices — Powered filtering devices incorporating a helmet or a hood — Requirements, testing, marking*

3 Terms and definitions

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

3.1
assemblage
permanent fastening between two or more different garments or between chemical protective clothing and accessories, obtained, for example by sewing, welding, vulcanizing, gluing

3.2
calibrated stain
fluorescent or visible stain, with a defined minimum area, generated by dropping a specified quantity of test agent onto an absorbent coverall

NOTE The calibrated stain is used to measure liquid penetration during spray and jet testing of chemical protective clothing.

3.3
chemical protective clothing
combined assembly of garments, worn to provide protection against exposure to or contact with chemicals

3.4
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 may comprise of garments combined together to provide protection to the body.

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

3.5
connection
assemblage or joint

3.6
degradation
deleterious change in one or more physical properties of a protective clothing material due to contact with chemicals

3.7
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

3.8
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 a high degree of protection against harmful liquids, particles and gaseous or vapour contaminants

3.9
joint
non-permanent fastening between two different garments, or between chemical protective clothing and accessories

3.10
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

3.11
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.

3.12
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

3.13
undergarments
clothing worn next to the body surface, beneath the other clothing

4 Method A — Internal pressure test

4.1 Principle

After the suit has been inflated to a defined pressure, the extent of the subsequent leakage of air is assessed by recording the pressure reached after a defined period. Two different sets of test pressures are provided. Method A1 uses an inflation pressure of 1 250 Pa and a test pressure of 1 000 Pa. Method A2 uses an initial pressure of 1 750 Pa, a dwell test pressure of 1 700 Pa, and a test pressure of 1 650 Pa. Method A1 is considered the minimum internal pressure test, but Method A2 provides a more rigorous determination of suit gas-tight integrity.

NOTE This test does not simulate penetration by gases in an inward direction. Although the danger to the wearer arises from leakage in an inward direction, this test method assesses the outward leakage of air after the gas-tight suit has been inflated so as to stretch the material of construction, thereby enabling the test method to be capable of detecting very small imperfections, e.g. holes, splits or tears.

4.2 Apparatus

4.2.1 Source of compressed air, supplying air within the temperature range of (20 ± 5) °C.

4.2.2 Pressure-measuring device, with the capability of measuring up to $(1\,750 \pm 30)$ Pa with a sensitivity (readability) of 50 Pa.

4.2.3 Vent valve-closure components, such components may be plugs or other means that are to be supplied for test purposes by the manufacturer.

4.2.4 Stop clock or **appropriate timing device**, capable of measuring to the nearest second.

4.3 Procedure

4.3.1 General

4.3.1.1 Lay out the chemical protective suit including attached gloves and footwear, and full facemask if appropriate, on a suitable flat and clean surface away from any sources of heat and/or currents of air.

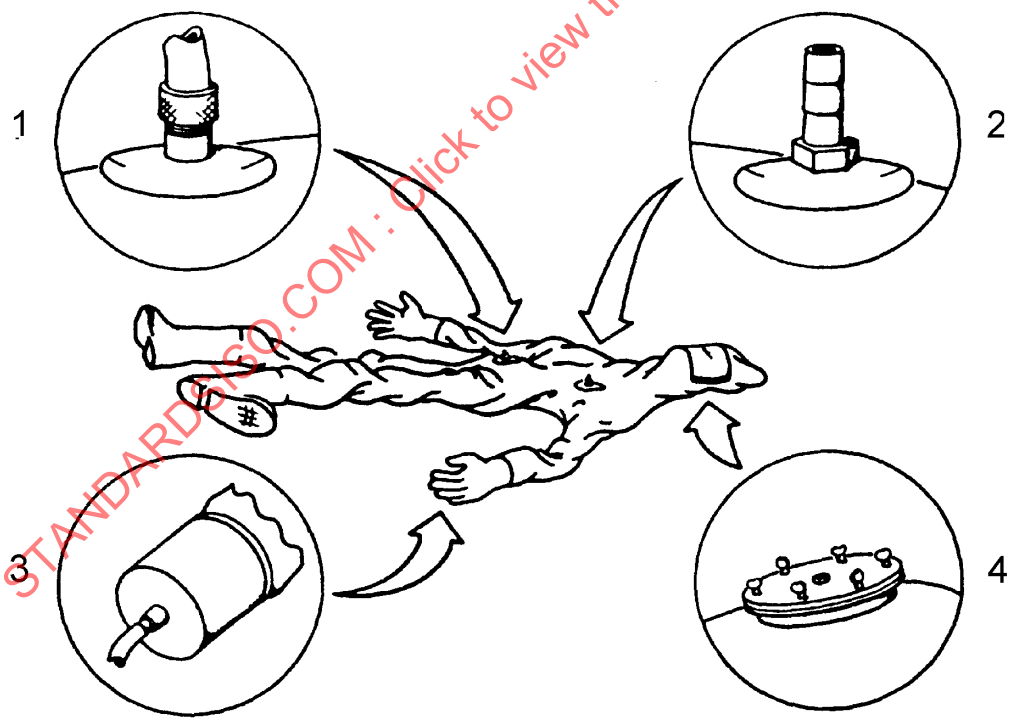
Select an area for testing that is away from direct sunlight, open doors, drafts, heating and air conditioning registers.

4.3.1.2 Perform a visual inspection of the chemical protective suit. Check the chemical protective suit for seam integrity by visually examining the seams and gently pulling on the seams. Ensure that all air supply lines, fittings, visor or faceshield, zippers, and valves are secure and show no signs of deterioration.

4.3.1.3 Remove any creases and folds in the suit as far as practicable.

4.3.1.4 Leave the suit for a minimum of 1 h at (ambient temperature ± 3) °C.

4.3.1.5 Make an inflation connection using on the techniques illustrated in Figure 1. Attach the pressure-measuring device (4.2.2) to the chemical protective suit or inflation system.



Key

1 Airline connector or inflation couple
2 Suit venting-valve adapter
3 Removable gloves
4 Face-plate seal

Figure 1 — Typical examples of suit modification to permit inflation

4.3.1.6 Carefully blank off the valves and other openings on the chemical protective suit with appropriate means of closure supplied by the manufacturer.

4.3.1.7 Choose either Method A1 or Method A2.

4.3.2 Method A1 — Minimum procedure

4.3.2.1 Using compressed air (4.2.1), inflate the suit carefully to a pressure of $(1\,250 \pm 50)$ Pa.

4.3.2.2 Maintain the pressure at $(1\,250 \pm 50)$ Pa for at least 1 min by addition of air, if necessary, and at the same time ensure that any creased areas are unfolded and that the suit is stretched as appropriate.

NOTE During this period, the temperature is stabilized and the pressure throughout the suit reaches equilibrium.

4.3.2.3 After the period of at least 1 min has elapsed (see 4.3.2.1), adjust the pressure in the suit to $(1\,000 \pm 25)$ Pa.

4.3.2.4 Allow a further 4 min to elapse. Note and record the ending pressure in the suit in pascals.

Pay careful attention to the cleanliness and the refitting of valves which have been obstructed or removed to carry out the test, to ensure that they function satisfactorily after the test.

4.3.2.5 If the chemical protective suit shows a 20 % or more drop in pressure [(inflation pressure minus the ending pressure/inflation pressure) $\times$ 100], check for leaks by inflating the suit to $(1\,250 \pm 50)$ Pa and by brushing or wiping the entire chemical protective suit (including seams, closures, lens gaskets, glove-to-sleeve joints, etc.) with a mild soap and water solution. Observe the wiped areas of the chemical protective suit for the formation of soap bubbles, which are an indication of a leak. Repair all identified leaks in accordance with specific manufacturer instructions, if permitted.

Any commercially available, high sudsing soap solution such as children's bubble, has been found to offer satisfactory performance for this purpose.

4.3.2.6 Retest the repaired chemical protective suit as specified in 4.3.1.1 to 4.3.1.6 and 4.3.2.1 to 4.3.2.4 (if it originally showed a 20 % or more drop in pressure, and was subsequently repaired).

4.3.3 Method A2 — Rigorous procedure

4.3.3.1 Using compressed air, inflate the suit carefully to a pressure of $(1\,750 \pm 50)$ Pa.

4.3.3.2 Maintain the pressure at $(1\,700 \pm 50)$ Pa for 10 min by addition of air, if necessary, and at the same time ensure that any creased areas are unfolded and that the suit is stretched as appropriate.

NOTE During this period, the temperature is stabilized and the pressure throughout the suit reaches equilibrium.

4.3.3.3 After the period of 10 min has elapsed (see 4.3.3.2), adjust the pressure in the suit to $(1\,650 \pm 25)$ Pa.

4.3.3.4 Allow a further 6 min to elapse. Note and record the ending pressure in the suit in pascals.

Pay careful attention to the cleanliness and the refitting of valves which have been obstructed or removed to carry out the test, to ensure that they function satisfactorily after the test.

4.3.3.5 If the chemical protective suit shows unacceptable leakage as defined by the required performance, check for leaks by inflating the suit to $(1\,700 \pm 50)$ Pa and by brushing or wiping the entire chemical protective suit (including seams, closures, lens gaskets, glove-to-sleeve joints, etc.) with a mild soap and water solution. Observe the wiped areas of the chemical protective suit for the formation of soap bubbles, which are an indication of a leak. Repair all identified leaks in accordance with specific manufacturer instructions, if permitted.

Any commercially available, high sudsing soap solution such as children's bubble, has been found to offer satisfactory performance for this purpose.

4.3.3.6 Retest the repaired chemical protective suit as specified in 4.3.1.1 to 4.3.1.6 and 4.3.3.1 to 4.3.3.4.

4.4 Test report

The test report shall include the following information.

a) a reference to this International Standard, i.e. ISO 17491;

b) the method used, i.e. Method A1 or Method A2;

c) the manufacturer/supplier and any identifying mark;

d) the pressure recorded in clause 4.3.2.4 or 4.3.3.4 and the test temperature;

e) any further qualifying remarks and observations;

f) the results of any retesting, after repair of the suit.

5 Method B — Aerosol and gaseous inward leakage test

5.1 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 B1 or sulfur hexafluoride (SF_6) using Method B2.

NOTE Method B1 simulates an aerosol challenge while Method B2 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, then the airflow rate into the suit shall be at the rate of sampling air that is withdrawn from the suit. For a typical arrangement, see Figures 2 and 3.

5.2 Test agents and test subjects

5.2.1 Test agents

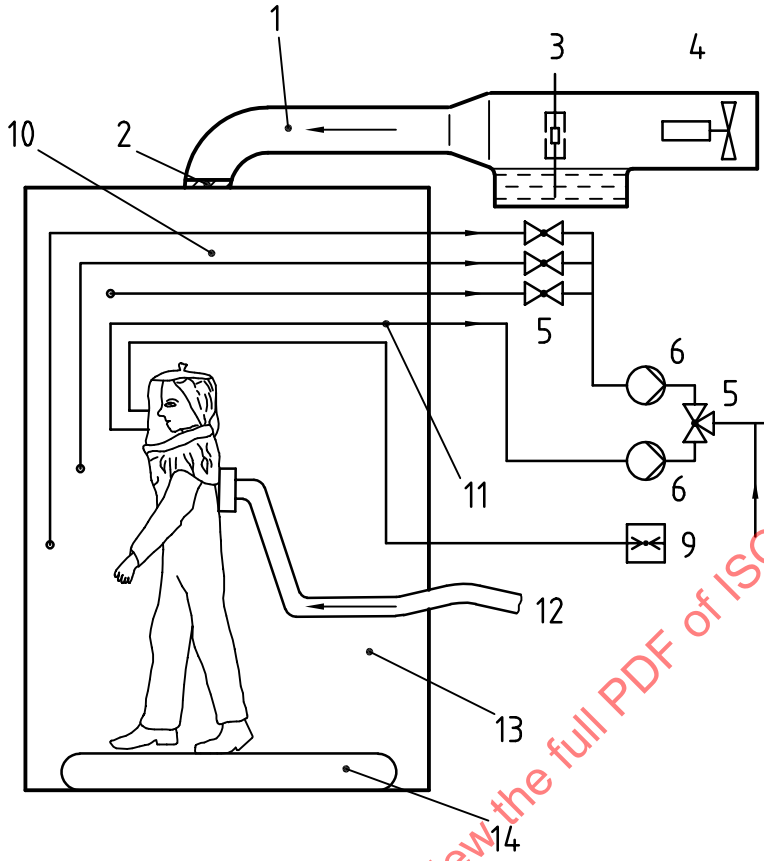
5.2.1.1 Method B1 — Sodium chloride test agents

The mean sodium chloride concentration within the enclosure shall be as described in 8.16.3.2.2 of EN 136:1998.

5.2.1.2 Method B2 — Sulfur hexafluoride test agents

This method employs sulfur hexafluoride as the test gas. The subject wearing the suit under test stands with his suited body surrounded by the SF_6 test atmosphere (see Figure 3). Accurate determinations of leakage shall be possible within the range for 0,001 % to approximately 20 % depending on the test challenge atmosphere. It is recommended to use a test atmosphere at 0,1 % SF_6 (by volume) 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.



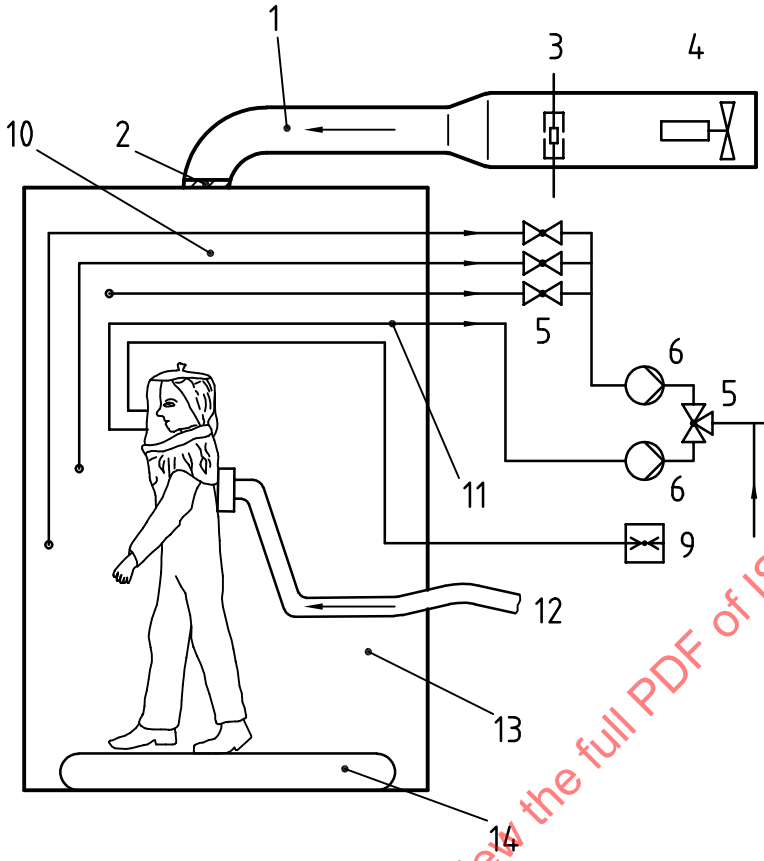
Key

1	Duct
2	Baffle
3	Atomizer
4	Fan
5	Valves
6	Pump
7	Photometer
8	Additional air input
9	Manometer
10	Enclosure samples
11	Breathing zone samples
12	Breathing air supply
13	Enclosure
14	Treadmill

Figure 2 — Typical arrangement of inward leakage test using sodium chloride aerosol

5.2.2 Test subjects

For the test, persons shall be selected who are familiar with using such 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.



Key

1	Duct
2	Baffle
3	Sulfur hexafluoride in air
4	Fan
5	Valves
6	Pump
7	Sulfur hexafluoride detector
8	Additional air input
9	Manometer
10	Enclosure samples
11	Breathing zone samples
12	Breathing air supply
13	Enclosure
14	Treadmill

Figure 3 — Typical arrangement of inward leakage test using sulfur hexafluoride

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. One suit shall be pre-conditioned.

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 manufacturers 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.

5.3 Apparatus

5.3.1 Method B1 — Sodium chloride method apparatus, consisting of the following.

5.3.1.1 Aerosol generator, as described in 8.16.3.2.1 of EN 136:1998.

5.3.1.2 Detector for NaCl, 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.

NOTE A specific example of probe design and position is provided in 7.3.4.3 of EN 12941:1998.

The NaCl concentration inside the suit is analysed and recorded by a flame photometer. This concentration, measured within the head section of the suit being a measure of the inward leakage. The measured NaCl concentration shall be increased by a factor of 1,25 to account for lung retention of NaCl.

Perform the test at ambient temperature and a relative humidity of less than 60 % within the test chamber.

5.3.1.2.1 Flame photometer, to be used as described in 8.16.3.2.3 of EN 136:1998.

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

5.3.1.2.2 Adjustable sample flow pump, 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.

5.3.1.2.3 Monitoring device for sampling of chamber concentration, consisting 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 using a separate sampling system may be made. However, time will then be required to allow the photometer to return to a clean background. Figure 2 shows a typical sampling arrangement.

5.3.2 Method B2 — Sulfur hexafluoride method (SF_6)

5.3.2.1 Detector for SF_6, preferably capable of analysing the test atmosphere for SF_6 continuously by means of a suitable analyser or spot checks as necessary to determine the concentration during tests. At 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 SF_6 concentration inside the suit is analysed and recorded. This concentration, measured within the head section of the suit being 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 SF_6 concentration in the suit may be monitored using an electron capture detector or infrared system.

5.3.2.2 Sampling probe, consisting 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 7.3.4.3 of EN 12941:1998.

5.3.2.3 Test chamber, made from transparent material and having a minimum cross-sectional dimension of 0,7 m (see Figures 2 and 3).

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 has to be checked to be homogeneous.

5.3.2.4 **Treadmill**, having a 2 % gradient, capable of maintaining a constant speed of 5 km/h and installed in the chamber.

5.3.2.5 **Pressure detection probe**, fitted near to 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.

5.4 Procedure

5.4.1 Dress the test subject in the suit according to the instructions for the type of suit under test. Underclothings should consist of standard underwear, pants, 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.

5.4.2 Follow the test procedure in Table 1. Sample the test chamber for SF_6 at 3-min intervals during the test.

Table 1 — Test procedure for gaseous inward leakage test

Activity	Estimated time[a] taken for activity min
a) Dress subject in suit.	—
b) Don boots, gloves, etc. according to manufacturer's instructions.	—
c) Subject to enter test chamber and connect tubing to sample point (no test agent).	3
d) Establish background reading at sample point with subject standing still (no test agent).	3
e) Start test agent and allow to stabilize.	3
f) Record leakage and pressure at sample point with subject still.	3
g) Start treadmill.	—
h) Walk for 3 min.[b]	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.[c]	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.[c]	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 time may vary, all times are approximate and are carried out under stable conditions.

[b] When doing squats or twisting, a slow deliberate action is required, for example one every 3 s.

[c] 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.

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

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

5.5 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 follows:

$$L_{TI} = \frac{c_2}{c_1} \times 100$$

where

c_1 is the concentration in enclosure;

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

For Method B1, subtract the background concentration of NaCl from each concentration measurement and the concentration in the enclosure. The resulting NaCl concentration c_2 is increased by a factor of 1,25 to account for lung retention (see 5.3.1.2).

5.6 Test report

The test report shall include the following information:

a) a reference to this International Standard, i.e. ISO 17491;

b) the method used, i.e. Method B1 or Method B2;

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 5.5;

h) the pressures measured during the test period;

i) any further qualifying remarks and observations such as substitutions in procedures.

6 Method C — Liquid jet test

6.1 Principle

An aqueous jet, containing a fluorescent or visible dye tracer, is directed under controlled conditions at chemical protective clothing worn by a test mannequin or human test subject. Inspection of the inside surface of the clothing and the outside surface of absorbent clothing worn underneath allows any points of inward leakage to be identified.

As this test requires the use of water containing a dye or tracer, take care to avoid contamination of the surface water drainage system.

6.2 Test agent and test subject

6.2.1 Test agent, unless specified in the performance specification, is as follows.

Prepare the test agent by dissolving a water-soluble fluorescent or visible dye and wetting agent in demineralized water at (20 ± 2) °C to form a solution with the following detection characteristics.

A droplet (0,1 ml) of the test agent placed on the outside surface of the absorbent clothing worn underneath shall be clearly visible and shall give a stain diameter of $>$ 2 cm. Where necessary, for certain dyes ultraviolet lighting shall be used. This spot shall be clearly identified and shall be used to judge pass/fail criteria.

The surface tension shall be $(30 \pm 5) \times 10^{-3}$ N/m. Any method may be used to determine the surface tension of the test agent provided it can measure to the tolerance given above, for example a Wright surface-tension and interfacial-tension torsion balance using a standard 12 mm diameter platinum ring is acceptable.

6.2.2 Test subject, preferably a human-form mannequin (test dummy) because it is not required to move during the test. However, a human test subject is permitted. If a human test subject is used, take extreme care to ensure the heath and safety of the test subject. In particular, as a pressurized jet of liquid is used, take care to protect the subject's eyes, ears, nose and mouth.

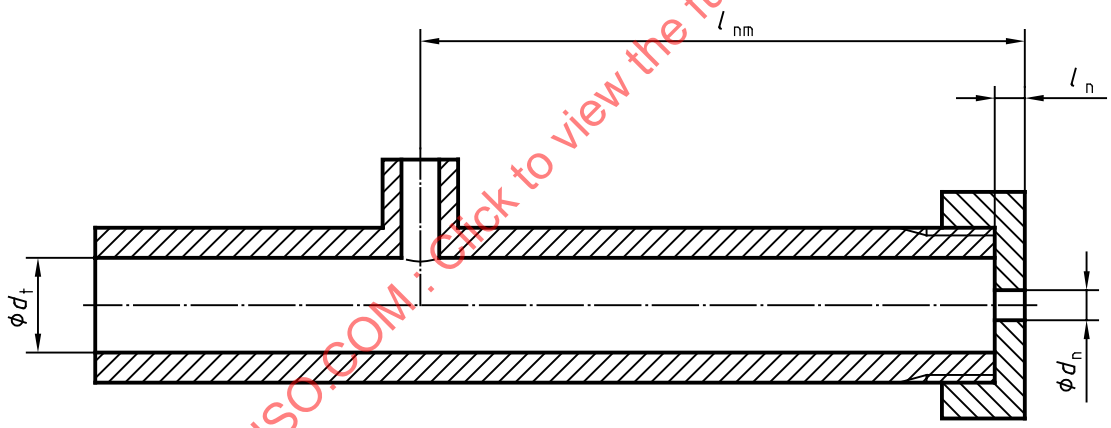
Between 95 % and 100 % of the upper height limit of the suit is to be tested.

6.3 Apparatus

6.3.1 Absorbent coverall, comprising a one piece garment (with hood) of water absorbent fabric (thickness less than 5 mm) which shall produce a calibrated stain in accordance with 6.3.2.

6.3.2 Nozzle, equipped with a manometer, operated at 150 kPa to generate a jet of test agent. See Figure 4.

Dimensions in millimetres



d_n Diameter of the opening of the nozzle, $(4 \pm 0{,}1)$ mm

l_n Length of the opening of the nozzle, $(4 \pm 0{,}1)$ mm

d_t Diameter of the tube, $(12{,}5 \pm 1)$ mm

l_{nm} The distance between the opening of the nozzle and the manometer, (80 ± 1) mm

Figure 4 — Shape of nozzle

6.3.3 Hydraulic pump, of the self-priming recirculating type, complete with pressure gauge (manometer), variable control filter and hoses, capable of maintaining a pressure of 150 kPa at the nozzle.

6.4 Preparation of samples for the jet test

The test subject shall be fitted with the correct size of absorbent coverall of the type described in 6.3.1, and shall be limited to wearing one layer of undergarments underneath the absorbent coverall. The test subject shall then be dressed in the correct size of test garment, as described in ISO 13688, in accordance with the manufacturer's instructions.

The test subject shall also be fitted with the following accessories:

— gloves resistant to penetration by the test agent; garment sleeves shall be fitted over the outside of the gloves; if sleeves have an internal cuff, this may be fitted inside the glove;

— boots resistant to penetration by the test agent; the trousers of the test garment shall be fitted over the outside of the boots.

Any gaps in the final assembly around the head, face and neck through which the liquid may pass, which can be attributable to a lack of complete cover provided by items that are not part of the test chemical protective clothing, should be sealed to prevent liquid entering which could run down inside the garment and disguise penetration of the jet through other areas.

Where the suit is intended for use together with other protective equipment such as respiratory protection devices, it shall be used as is with the specific protective equipment without any special sealing incorporated into the ensemble. When testing is performed in this nature, the specification should require the manufacturer to specify the equipment for which the suit has been tested.

6.5 Procedure

6.5.1 Individual tests shall be made on:

— connections, including joints and assemblages (including zippers) which are integral to the chemical protective clothing and to gloves, boots, and hood;

— connections between different parts of the chemical protective suit.

Each test spot shall be identified for use in the test report (see 6.6).

6.5.2 The jet nozzle shall be positioned 1 m from the test spot at an angle which is most likely to cause penetration by the liquid jet.

6.5.3 Direct the liquid jet at a test spot for 5 s. Then direct the jet at the next spot for 5 s. Continue until all spots have been tested.

6.5.4 Allow the clothing to drain for 2 min.

6.5.5 Remove the test chemical protective clothing and examine the internal surface for signs of penetration. Similarly, examine the external surface of the absorbent coverall. Either mark the location and extent of any sign of penetration on the test chemical protective clothing and the coverall or photograph the absorbent coverall.

6.6 Test report

The test report shall include the following information:

a) a reference to this International Standard, i.e. ISO 17491;

b) the method used, i.e. Method C;

c) the manufacturer/supplier and any identification mark;

d) the composition of the liquid used in the tests;

e) for each chemical protective clothing test

   1) the location of each test spot and the direction of the jet shall be indicated on diagrams of a human figure (front and back separately) or by reference to photographs,

   2) the approximate areas of contamination of the internal surfaces of the test clothing and the external surface of the absorbent coverall shall be shown on a separate, but similar set of diagrams or photographs,

3) any contaminated areas should preferably be indicated by shading on diagrams of a human figure (front and back separately) or by reference to photographs,

4) any penetration of isolated spots of liquid (stain diameters $<$ 2 cm) should be marked by a single cross;

f) the total number of penetration spots and the approximate total area covered by the penetration spots;

g) the size range of the garment tested as defined in ISO 13688;

h) any further qualifying remarks and observations.

7 Method D — Liquid spray test

7.1 Principle

An aqueous spray, containing a fluorescent or visible dye tracer, is directed under controlled conditions at the chemical protective clothing worn by a human test subject. Inspection of the inside surface of the clothing and the outside surface of absorbent clothing worn underneath allows any points of inward leakage to be identified. The test is either performed for a 30-min duration (Method D2) or a 1-min duration (Method D1). Method D2 is used for determining high levels of resistance to penetration from spray exposure.

As this test requires the use of water containing a dye or tracer take care to avoid contamination of the surface-water drainage system.

7.2 Test agent and test subject

7.2.1 Test agent, unless specified in the performance specification, is as follows:

Prepare the test agent by dissolving a wetting agent and water-soluble fluorescent or visible dye in water at ambient temperature to form a solution with the following detection characteristics.

A droplet (0,1 ml) of the test agent placed on the outside surface of the absorbent clothing worn underneath shall be clearly visible and shall give a stain diameter of $>$ 2 cm. Where necessary, for certain dyes ultraviolet lighting shall be used. This spot shall be clearly identified and shall be used to judge pass/fail criteria.

The surface tension shall be $(30 \pm 5) \times 10^{-3}$ N/m. Any method may be used to determine the surface tension of the test agent provided it can measure to the tolerance given above, for example a Wright surface-tension and interfacial-tension torsion balance using a standard 12 mm diameter platinum ring is acceptable.

7.2.2 Human test subject, of a size between 95 % and 100 % of the upper height limit of the suit to be tested.

7.3 Apparatus

7.3.1 Absorbent coverall, comprising a one piece garment (with hood) of water absorbent fabric (thickness less than 5 mm) which shall produce a calibrated stain in accordance with 7.2.1.

7.3.2 Turntable, which is waterproof and rotates at $(1 \pm 0{,}1)$ r/min, and is capable of supporting a human figure.

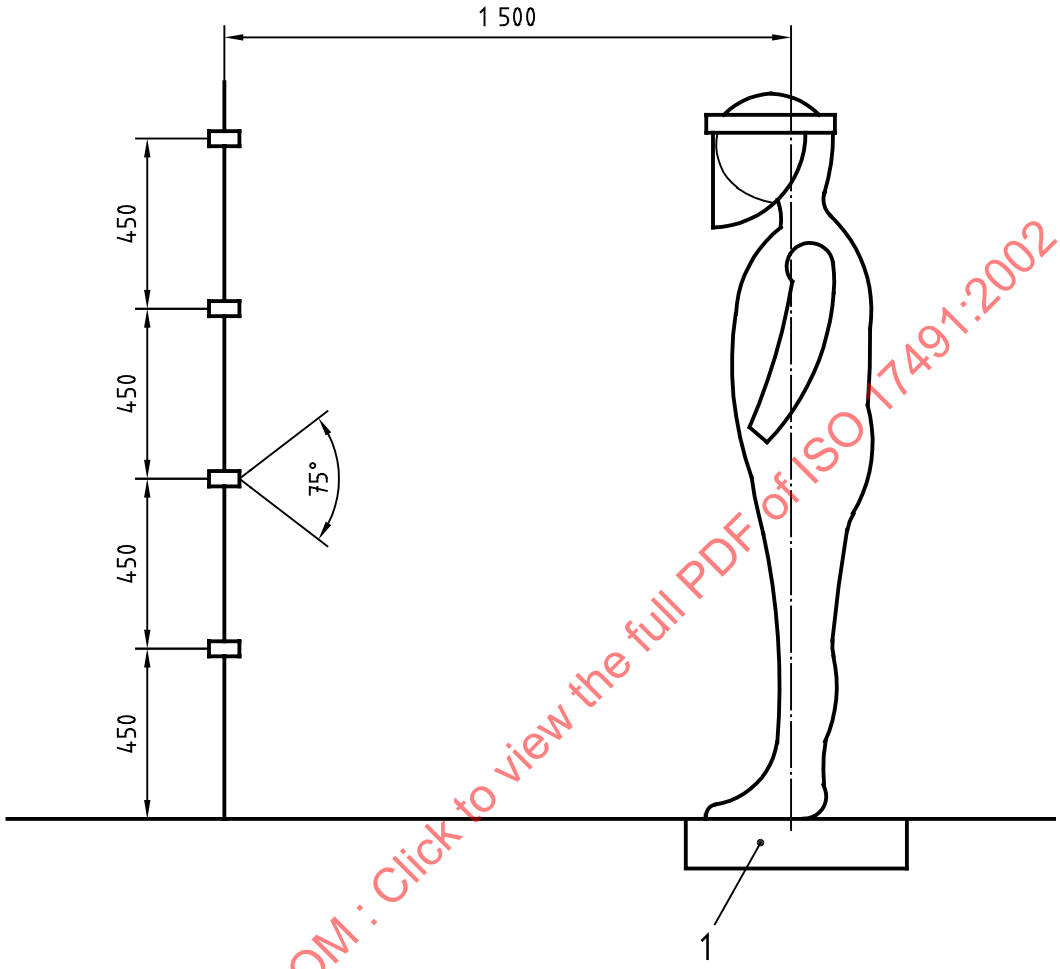
7.3.3 Graduated containers, for liquid.

7.3.4 Hydraulic pump, of the self-priming, recirculating type, complete with pressure gauge (manometer), variable output control filter and hoses.

7.3.5 Stop watch.

7.3.6 Spray boom, as shown in Figure 5 height at least 2,35 m, vertically mounted, fitted with four nozzle attachments 45 cm apart.

Dimensions in millimetres



Key

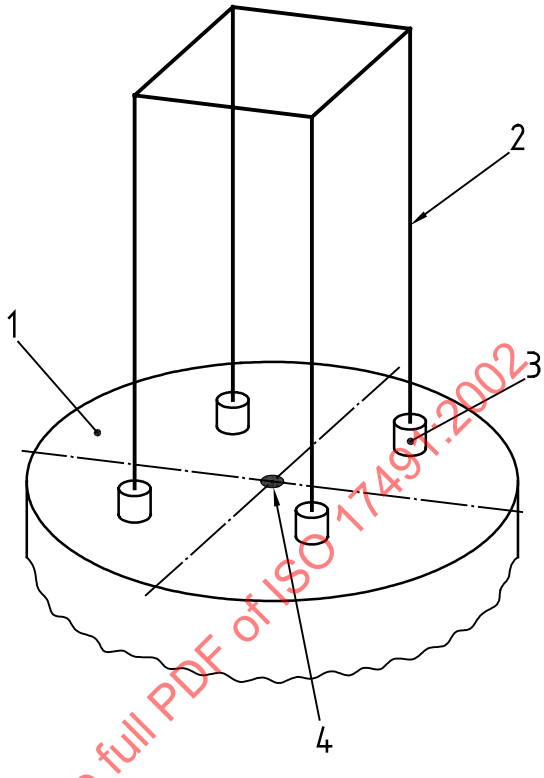
1 Turntable

Figure 5 — Apparatus for determining the resistance to spray

7.3.7 Hydraulic nozzles, of the hollow cone type, with 75° spray-angle nozzles, each nozzle supplying liquid at a rate of 1,14 l/min at 300 kPa (3 bar) pressure.

7.3.8 Target frame, four lengths of metal tubing or rod of external diameter $(1{,}29 \pm 0{,}02)$ cm and length approximately 200 cm (see Figures 6 and 7).

7.3.9 Graduated beakers or **cylinders** (four), of approximately 4 cm diameter and approximately 10 cm height (see Figure 7). Each container shall be fitted with a cover or lid with a 2 cm diameter circular hole through which the target frame tubes or rods can be placed.

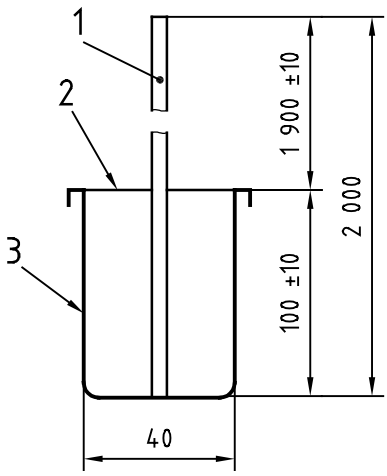


Key

1 Top of turntable
2 Metal tubes or rods
3 Graduated beakers or cylinders with covers
4 Geometric centre of turntable

Figure 6 — Apparatus for checking the alignment of the spray

Dimensions in millimetres



Key

1 Target rod or tube
2 Cover or lid (with 2 cm hole)
3 Graduated beaker or cylinder

Figure 7 — Arrangement of collecting graduated beaker or cylinder

7.4 Preparation of samples for the spray test

The human test subject shall be fitted with the correct size of absorbent coverall of the type described in 7.3.1 and shall be limited to wearing one layer of undergarments underneath the absorbent coverall. The human subject shall then be dressed in the correct size of test garment, as described in ISO 13688 in accordance with the manufacturer's instructions.

The human test subject shall be fitted with the following accessories:

— gloves resistant to penetration by the test agent; garment sleeves shall be fitted over the outside of the gloves; if sleeves have an internal cuff, this may be fitted inside the glove;

— boots resistant to penetration by the test agent; the trousers of the test garment shall be fitted over the outside of the boots;

— full face visor or face screen, complete with browguard, to cover the eyes and the face; the depth of the visor shall be 18 cm and its width 32 cm;

— filtering facepiece respirator (grade FFP3SL in accordance with EN 149) of a suitable size, worn under face screen to prevent inhalation of the test agent.

Any gaps in the final assembly around the head, face and neck through which the spray can pass, which might be attributable to a lack of complete cover provided by items that are not part of the test chemical protective clothing, should be sealed to prevent liquid entering which could run down inside the garment and disguise penetration of the spray through other areas.

7.5 Preparation of the spray application systems

7.5.1 Output from nozzles

Start the flow of test agent to the spray nozzles and regulate the pressure at the pump to achieve a flow rate of $(1{,}14 \pm 0{,}1)$ l/min from each hollow cone nozzle.

7.5.2 Alignment of spray nozzles

Direct the spray emission from the nozzles towards the geometric centre of the turntable at a distance of approximately 1,5 m (see Figure 5). Check the correct alignment and distance with an artificial target for collection of the spray. The target shall be constructed from four metal rods or tubes (see 7.3.8) spaced 35 cm apart and parallel to each other (see Figure 6). Place the rods equidistant from the geometric centre of the turntable (see Figure 6) with the lower ends resting in the beakers or cylinders (see 7.3.9). Cover the beakers with plastic lids which have a central hole of 2 cm diameter, through which the rod is passed and maintained in position without touching the side of the hole. The height of each rod exposed above the lid shall be (190 ± 1) cm (see Figure 7).

With the equipment set up correctly, the output of spray within the specified limit and the turntable in operation, release the spray for 3 min and measure the volume of liquid collected in each beaker or cylinder. Wipe the exposed surface of each rod with a weighed piece of absorbent material and weigh again to establish the residual volume of spray on each rod. Add this volume to that in the beaker to calculate the total volume collected under each rod.

The alignment and distance from the nozzle to the target is acceptable for the test when the total volume collected under the frame averages $(12{,}5 \pm 1{,}5)$ ml per rod per minute [i.e. (150 ± 18) ml of spray is collected under each four rods in 3 min].

Alternative methods may be used to check the alignment and delivery rate of the spray nozzles, providing they are calibrated against the method given above.

7.6 Procedure

7.6.1 Position the test subject wearing the chemical protective clothing on the geometric centre of the turntable and mark the position of the feet.

7.6.2 If Method D2 is used, apply the spray for 30 min while the turntable is rotated at 1 r/min. If Method D1 is used, apply the spray for 1 min to the test subject, whilst the turntable is rotated through 360°.

7.6.3 During the spray period using Method D1, the test subject shall alternately raise each foot approximately 20 cm from the turntable (30 ± 5) times with the arms straight but swinging backwards and forwards in unison with the leg movements for balance. The feet shall be replaced on the original mark. For Method D2, this activity shall be repeated at 5-min intervals until the conclusion of the spray period.

7.6.4 Allow the clothing to drain for 2 min.

7.6.5 Remove the clothing and examine the internal surface for any signs of penetration. Similarly, examine the external surface of the absorbent coverall. Either mark the location and extent of any sign of penetration of the test chemical on the protective clothing and the coverall or photograph the absorbent coverall.

7.7 Test report

The test report shall include the following information:

a) a reference to this International Standard, i.e. ISO 17491;

b) the method used, i.e. Method D1 or Method D2;

c) the manufacturer/supplier and any identification mark;

d) the composition and surface tension of the liquid used in the tests;

e) for each spray test

   1) the location and approximate areas of contamination of the internal surfaces of the test clothing and the external surface of the absorbent coverall;

   2) any contaminated areas should preferably be indicated by shading on diagrams of a human figure (front and back separately) or by reference to photographs,

   3) any penetration of isolated spots of liquid (stain diameters < 2 cm) should be marked by a single cross;

f) the total number of penetration spots and the approximate total area covered by the penetration spots;

g) the size range of the garment tested as defined in ISO 13688;

h) the type of spray nozzle and the test agent supply pressure;

i) any further qualifying remarks and observations.

8 Method E — Alternative liquid spray test

8.1 Principle

The chemical protective suit is placed on a mannequin which is already dressed in a liquid-absorptive garment covering the portions of the mannequin form that are of interest. Water, treated to achieve a surface tension of $(30 \pm 5) \times 10^{-3}$ N/m is sprayed at the chemical protective suit from five nozzles positioned in a specific configuration with respect to the specimen. The specimen is exposed to the liquid spray for a period of 15 min in each of four specimen orientations. Liquid penetration resistance is determined by the absence of liquid inside the chemical protective suit on the inner liquid absorptive-garment. The chemical protective suit is rated as passing if liquid does not penetrate and as failing if liquid does penetrate.

8.2 Test agent and test subject

8.2.1 Test agent, unless specified in the performance specification the following standard test agent shall be used.

Prepare the test agent by dissolving a wetting agent and water soluble fluorescent or visible dye in water at ambient temperature to form a solution with the following characteristics.

The surface tension shall be $(30 \pm 5) \times 10^{-3}$ N/m. Any method may be used to determine the surface tension of the test agent provided it can measure to the tolerance given above, for example a Wright surface tension and interfacial tension torsion balance using a standard 12 mm diameter platinum ring would be acceptable.

8.2.2 Test subject, consisting of a human-form mannequin, appropriately sized for testing the protective clothing or protective ensemble.

The selected mannequin should provide as much contact with the protective clothing or protective ensemble as possible. The mannequin shall have a water-resistant coating. The mannequin shall have straight arms and legs with the arms at the mannequin's sides.

8.3 Apparatus

8.3.1 Absorbent coverall, comprising a one-piece garment (with hood) of water-absorbent fabric (thickness less than 5 mm).

8.3.2 Shower system, consisting of five low-flow showerhead nozzles, and a pressurized liquid supply.

The five nozzles shall be oriented with respect to the mannequin as specified in Figure 8. The nozzles shall conform to the specifications given in Figure 9. The pressurized liquid supply shall be delivered at $(3{,}0 \pm 0{,}2)$ l/min through each nozzle.

8.3.3 Stopwatch, or other appropriate **timing device**.

8.4 Specimen preparation

8.4.1 Protective clothing or protective ensemble components, shall be tested as received and in accordance with the manufacturer's instructions. Duct tape or other nonuniform methods for closing or sealing, or both, interfaces shall not be used.

8.4.2 Parts of the protective clothing or protective ensemble that are not to be tested shall be suitably blocked off to prevent liquid from penetrating those areas. For example, in the case of ensembles without gloves, block off the outer end of the sleeves with waterproof tape or some other sealant to prevent liquid penetration at the hands.

8.5 Procedure

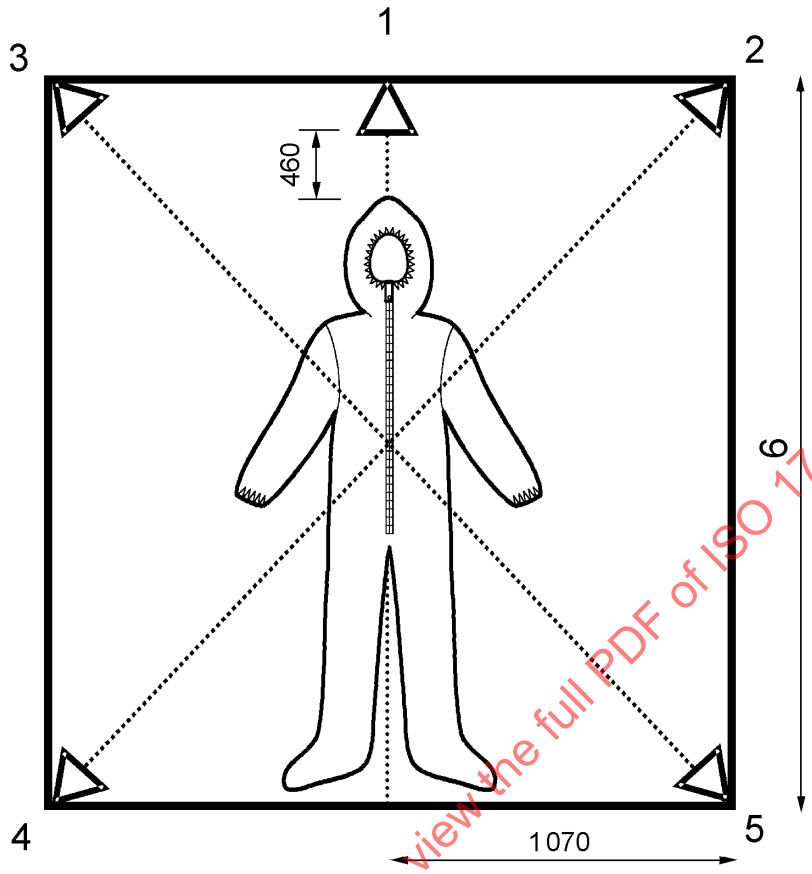
8.5.1 Prior to each test, inspect the liquid-absorptive inner garment and protective clothing or protective ensemble (and other ensemble components and equipment to be tested) for total dryness before using.

8.5.2 Put the liquid-absorptive inner garment on the mannequin. The inner garment shall cover all areas of the mannequin that are of interest.

8.5.3 Put the protective clothing or protective ensemble to be tested over the inner garment on the mannequin in accordance with the manufacturer's instructions. Place and attach additional ensemble components and equipment on the mannequin in accordance with the manufacturer's directions.

8.5.4 Block off from exposure to the liquid spray any areas of the mannequin or protective clothing or protective ensemble not being evaluated. For example, tie or tape a plastic bag over the mannequin's head. Ties or tape, or both, shall not extend more than 2,5 cm past the edge of the protective clothing or protective ensemble.

Dimensions in millimetres



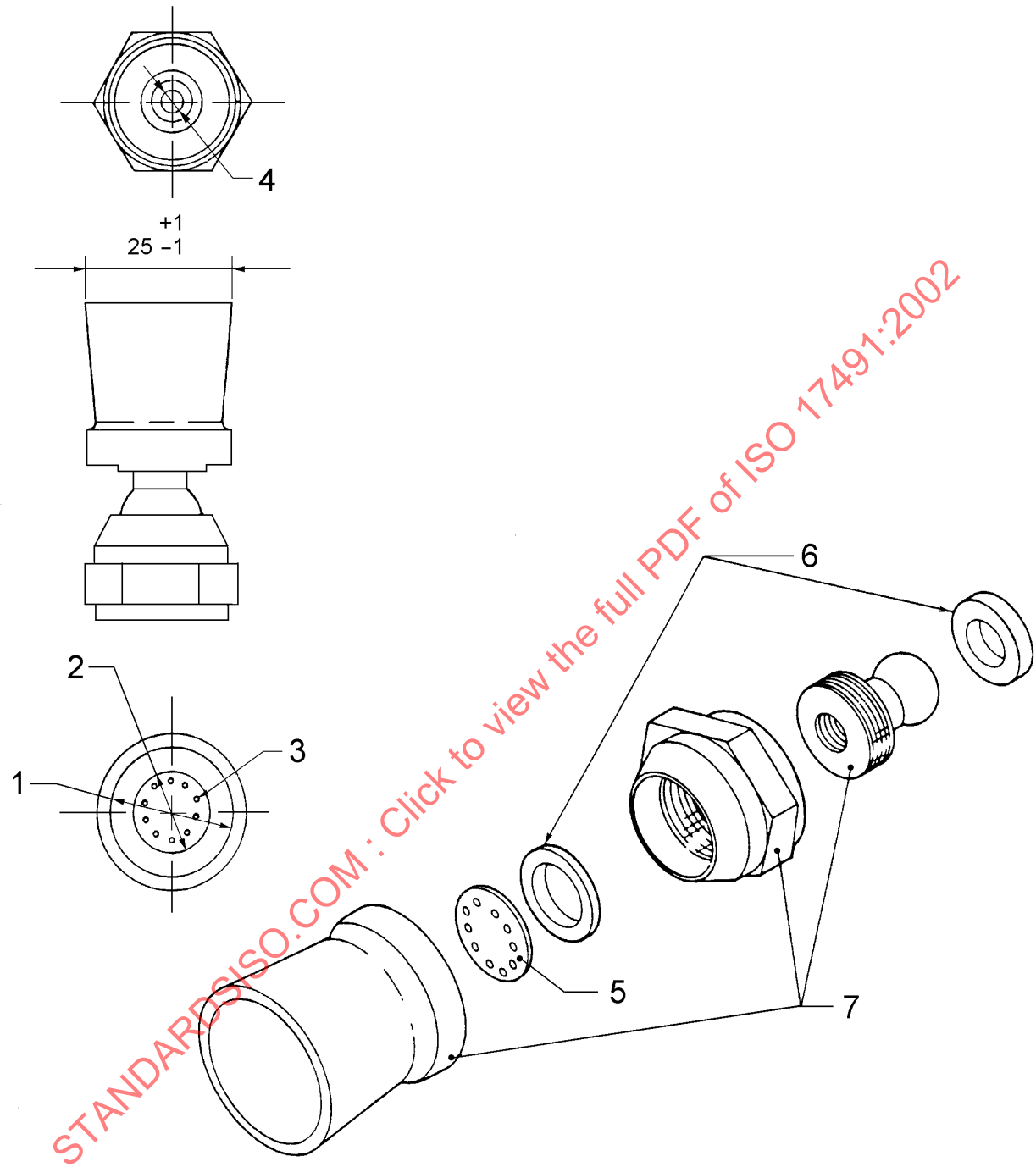
FRONT VIEW

Key

1 Nozzle position 1 directly above top of suit at distance of 460 mm
2 Nozzle position 2 at top corner
3 Nozzle position 3 at opposite top corner
4 Nozzle position 4 at bottom corner
5 Nozzle position 5 at opposite bottom corner
6 Total height of apparatus is height of suit plus 460 mm

Figure 8 — Positions of shower nozzles

Dimensions in millimetres



Key

1	Internal nozzle diameter, 23 mm
2	Spray plate diameter, 14,6 mm, brass
3	0,8 mm diameter holes through 10 places equally spaced on a 9 mm diameter centered circle
4	3,75 mm diameter bore
5	Brass spray plate
6	Rubber gaskets
7	Stainless steel

Figure 9 — Shower nozzle specifications