
**Clothing for protection against liquid
chemicals — Determination of the
resistance of protective clothing
materials to penetration by liquids under
pressure**

*Vêtements de protection contre les produits chimiques liquides —
Détermination de la résistance des matériaux des vêtements de
protection à la pénétration des liquides sous pression*

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 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 13994 was prepared by Technical Committee ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 13, *Protective clothing*.

This second edition cancels and replaces the first edition (ISO 13994:1998), which has been technically revised.

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Introduction

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

This test method determines the resistance to penetration by liquids under pressure only. It is necessary to use other methods to determine the resistance to permeation and degradation, as well as penetration resistance for liquids not under pressure.

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Clothing for protection against liquid chemicals — Determination of the resistance of protective clothing materials to penetration by liquids under pressure

1 Scope

This International Standard describes a laboratory test method that enables determination of the resistance of materials used in protective clothing to visible penetration under the conditions of continuous liquid contact and pressure, for example, clothing that is exposed to repeated splashes of liquid spray under pressure. Protective clothing “pass/fail” determinations are based on visual detection of liquid penetration.

This test method is normally used to evaluate the barrier effectiveness against liquids of materials used for protective clothing and specimens from finished items of protective clothing.

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

This test method can be used to identify protective clothing materials and constructions that limit exposures to hazardous liquid chemicals under a variety of circumstances. This test method is particularly useful for demonstrating the liquid hold-out capabilities of microporous fabrics.

Significant amounts of hazardous materials can permeate specimens that pass penetration tests. More sensitive analysis of permeation can be carried out using ISO 6529.

Penetration resistance of protective clothing materials using less severe liquid challenges, without pressure, can be carried out using ISO 6530. ISO 6530 uses a relatively low-volume, short-duration liquid challenge which is appropriate for treated porous and other non-film-based or uncoated materials.

This International Standard addresses only the performance of materials or certain material constructions (e.g. seams) used in protective clothing. It does not address the design, overall construction and components, or interfaces of garments or other factors which may affect the overall protection offered by the protective clothing.

It is emphasized that the test method specified in this International Standard does not necessarily simulate conditions that clothing materials are likely to be exposed to in practice. Therefore the use of test data is to be restricted to broad comparative assessment of such materials according to their liquid penetration resistance characteristics.

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

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

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

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

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

3 Terms and definitions

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

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

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

3.3 permeation
combined process of molecular diffusion of a chemical through a solid material forming the whole or part of clothing, and its desorption into a specified medium

3.4 protective clothing
apparel used for the purpose of protecting part of the body from contact with a potential hazard

NOTE In this test method, the materials used in protective clothing are evaluated. The potential hazard is contact with liquid chemicals.

3.5 test liquid
individual liquid chemical or a liquid formulation of chemicals that is submitted for test by the method specified in this International Standard

4 Principle

The resistance of a protective clothing material to penetration by a liquid under pressure is determined by subjecting the material to the liquid for a specified time and pressure sequence and observing if visible penetration of the liquid occurs.

In the penetration test apparatus, the clothing material acts as a partition separating the hazardous liquid chemical from the viewing side of the test cell.

Any evidence of liquid penetration constitutes failure. Results are reported as “pass/fail”.

5 Apparatus

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

5.2 Penetration test cell, to restrain the specimen during contact with the pressurized test fluid.

In the test cell, the specimen acts as a partition separating the test fluid from the viewing side of the test cell. It consists of a cell body that is fastened to a cell support. The cell body has a capacity of approximately 60 ml for liquid. A flange cover, with an open area to allow visual observation, and a transparent cover are included. The cell body has a top port for filling and a drain valve for draining the penetration test cell. Other items, such as a fitting to allow attachment of the air line to the top port in the cell body, gaskets and the retaining screen are also required. The complete penetration test cell apparatus is shown schematically in Figure 1 and an example is given in Figure 2. An exploded view of the penetration test cell is shown in Figure 3. Figures 4 to 10 provide examples of specifications for a penetration test cell apparatus in which the test cell has an interior diameter of 57 mm.

Parts and materials for liquid chemical penetration test apparatus are given in Table 1.

5.3 Retaining screen, comprising a smooth finish plastic or metal square mesh screen, meeting the following specifications used for Procedure C2 in Table 2:

- a) open area of > 50 %;
- b) deflection of sample is limited to $\leq 5,0$ mm.

5.4 Air pressure source, capable of providing air at $(13,8 \pm 1,38)$ kPa.

5.5 Stopwatch, or electronic timer.

5.6 Analytical balance, with a precision of 0,001 g.

5.7 Vessel, graduated to measure water, with a precision of 1 ml.

6 Test specimens

6.1 Selection

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

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

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

Cut each material specimen as squares with a minimum dimension of 70 mm. A 75 mm square is preferred.

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

6.1.2 It is possible that protective clothing materials incorporating an impervious layer between two fabric layers are sensitive to false positive failures by wicking at the edges. Seal the edges of the test specimens to prevent "wicking" modes of failure. Seal test specimens with an adhesive, parafilm, paraffin wax, or adhesive-backed foam prior to testing. Seal only the edges of the test specimens, leaving the centre 57 mm area (57 mm square) open for testing. Do not allow sealants to intrude, block or occlude the structure of the test specimen in the test area, as this may compromise the test procedure. Choose sealants and sealing methods that are compatible with the protective clothing materials.

6.2 Preparation of test specimens

Condition each protective clothing specimen for a minimum of 24 h by exposure to a temperature of (21 ± 5) °C and a relative humidity of 30 % to 80 % in accordance with ISO 139.

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

7 Procedure

7.1 Measure the thickness of each specimen to the nearest 0,02 mm in accordance with ISO 5084.

7.2 Measure the mass of each specimen to the nearest 1 g/m² in accordance with ISO 3801.

7.3 Place a small droplet of the test liquid on the normal inside surface of an extra piece of the material to be tested for predetermining the appearance of endpoint penetration. The droplet shall remain easily visible to ensure that a droplet that penetrates the material will be seen. If not, one of the following methods of enhancing droplet visibility by producing a characteristic discoloration is usually effective.

- a) Use talcum powder on the normal inside surface of the fabric to enhance droplet visibility.
- b) Change the colour of the test liquid as an aid in improving the visibility of the test liquid. Food colouring or an acid-base indicator may be of use for water-based chemicals, and oil red may be dissolved in many organic chemicals to aid in detection of the liquid droplet.
- c) Apply food colouring or oil red to the normally inside surface of the test material to aid in visualization of a liquid droplet.
- d) Add a fluorescent dye to the test liquid to enhance visibility of penetration if the foregoing options do not permit adequate contrast.

These techniques may also affect the pass or fail result of the test. Care should be exercised in applying these techniques for enhancing the visibility of penetration.

7.4 Select the pressure/time sequence from Table 2.

When distortion of the test material is suspected of causing failure with the selected pressure/time sequence of this test method, a retaining screen may be used between the cell flange and material as separated by appropriate gaskets. Use of a retaining screen provides support of extensible or elastomeric materials.

7.5 With the cell placed horizontally on the laboratory bench, insert the specimen in the penetration cell with the normal outside surface of the fabric toward the cell reservoir which will be filled with the test liquid.

7.6 Assemble the components of the cell as follows. Place gaskets between the penetration cell and the test specimen, the specimen and the retaining screen (if used), and the retaining screen and the flange cover, as shown in Figure 3. Close the penetration cell by putting on the flange cover and transparent cover (optional). Polytetrafluoroethylene (PTFE) gasket material is recommended for use between the cell body and the test specimen to help prevent leakage.

7.7 Torque the bolts in the test cell to 13,6 N·m each.

7.8 Mount the penetration cell in the test apparatus in a vertical position as shown in Figure 2 (drain valve down) but do not connect the air line to the cell.

7.9 Close the drain valve.

7.10 Carefully fill completely the chamber of the penetration cell through the top port with test liquid (a syringe or funnel is useful). No air space should remain. If the specimen extends under pressure, then the test

shall be restarted using enough test liquid to be sure that the challenge chamber remains full. If the test liquid penetrates through the test specimen at anytime during the test, terminate the test.

7.11 Connect the air line to the penetration cell.

7.12 Set the pressure regulator to 0 kPa pressure and close the cell vent valve.

7.13 Expose the test liquid to the pressure(s) and for the time(s) called for in the desired procedure from Table 2, changing the pressure at the rate of no more than 3,5 kPa/s.

7.14 Observe the specimen. The specimen fails if a droplet of liquid appears, or a characteristic discoloration (7.3) appears on the viewing side of the specimen, or both. If this occurs, terminate the test. If no liquid or characteristic discoloration appears for the duration of the test, then the specimen passes.

In some cases, the appearance of liquid or discoloration may be due to permeation of the test liquid. Nevertheless, any appearance of liquid shall be noted as a failure and the test terminated.

The specimen may be observed during the entire test period or it may be observed at the end of the test period. It is generally useful to observe the specimen during portions of the test when the pressure behind the challenge liquid is increased.

7.15 At the conclusion of the test, turn off the pressure and open the cell valve to the vent position. Open the drain valve and drain the penetration test cell of the test liquid. Flush the test cell with an appropriate washing liquid to remove any traces of the test liquid. Remove the specimen and gasket from the cell. Clean any external parts of the test cell which may have been touched by the test liquid.

7.16 Test the remaining specimens.

8 Test report

The test report shall include the following information:

- a) a reference to this International Standard, ISO 13994:2005, indicating the specific pressure/time sequence used;
- b) the manufacturer's identification of the material tested, and a description of the sampling method used;
- c) the thickness of each material specimen and the average thickness of the material tested (in millimetres);
- d) the mass per unit area of each material specimen and the average mass per unit area of the material tested (in grams per square metre);
- e) the test liquid used;
- f) the temperature at which the test was performed; if the temperatures of the test cell and liquid were different at the start of the test, report both;
- g) a description of any technique used to enhance visual detection of test liquid penetration;
- h) the type and specification for the support screen, if used;
- i) the "pass" or "fail" result for each specimen or in the case of Procedure D, the pressure, in kPa, at which failing performance is observed;
- j) the source of the material, i.e. if taken from roll goods or garments; if taken from garments, report under subheadings for each material, the composite, type of seam, or other conditions tested, and its position on the garment;
- k) the type (fibre and coating compositions), supplier, lot number, and date of receipt of the material tested.

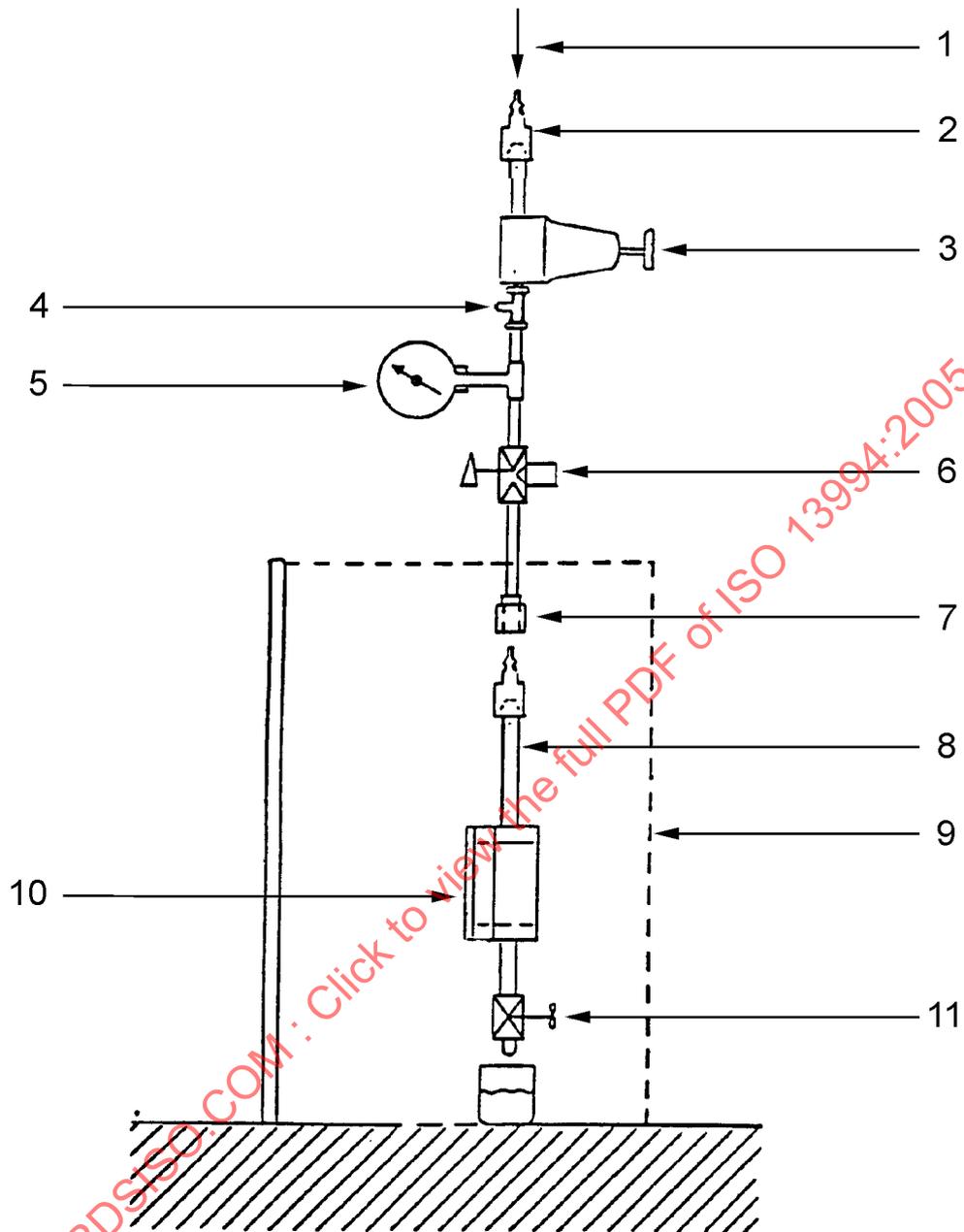
Table 1 — Parts and materials for liquid penetration test apparatus

Quantity	Description
1	Air pressure regulator, 6 mm NPT, adjustable, 0 kPa to 70 kPa gauge relieving type
1	Adjustable relief valve set at 35 kPa gauge
1	Pressure gauge, 0 kPa to 35 kPa, 115 mm diameter, 1 % accuracy (a magnetic gauge is preferred)
1	6 mm NPT 3-way cock with wrench
3	6 mm NPT × 40 mm No. 316 pipe nipples
1 set	6 mm NPT air line speed coupler, plug, and socket
1 m	6 mm rubber air hose with 6 mm NPT female coupling
2	13 mm split shaft collars
	Miscellaneous 6 mm NPT galvanized pipe fittings and fasteners
	Gasket material: 6 mm expanded PTFE cord
1	Ball valve, 6 mm NPT type 316 stainless steel
1	13 mm diameter 2-piece shaft collar

Table 2 — Pressure/time sequences and conditions for selected circumstances

Procedure	Pressure/time sequence	Circumstances
A	0 kPa for 5 min, followed by 13,8 kPa for 10 min.	Used for selecting protective clothing materials, seams and closures, to limit exposure to liquid splashes.
B	0 kPa for 5 min, followed by 6,9 kPa for 10 min.	Used for selecting protective clothing materials (such as gloves) to limit exposure to liquid splashes.
C1	0 kPa for 5 min, followed by 13,8 kPa for 1 min, followed by 0 kPa for 54 min. A retaining screen is not used to support the sample.	Used for selecting protective clothing materials, seams and closures, to limit exposure of fire service personnel to liquid splashes during emergency responses.
C2	0 kPa for 5 min, followed by 13,8 kPa for 1 min, followed by 0 kPa for 54 min. A retaining screen is used to support the sample.	Used for selecting protective clothing materials, seams and closures, to limit exposure of fire service personnel to liquid splashes during emergency responses; applied instead of C1 when specimen requires additional support.
D	0 kPa for 5 min, followed by increasing the pressure in increments of 3,5 kPa every 15 s until failure is observed, or a maximum of 35 kPa is reached.	Used for circumstances where it is desirable to know the pressure at which a material is penetrated by a specific chemical.
E	Include in the report, the time and pressure sequence used if different from procedure A, B, C or D.	Use for other specified needs or circumstances.

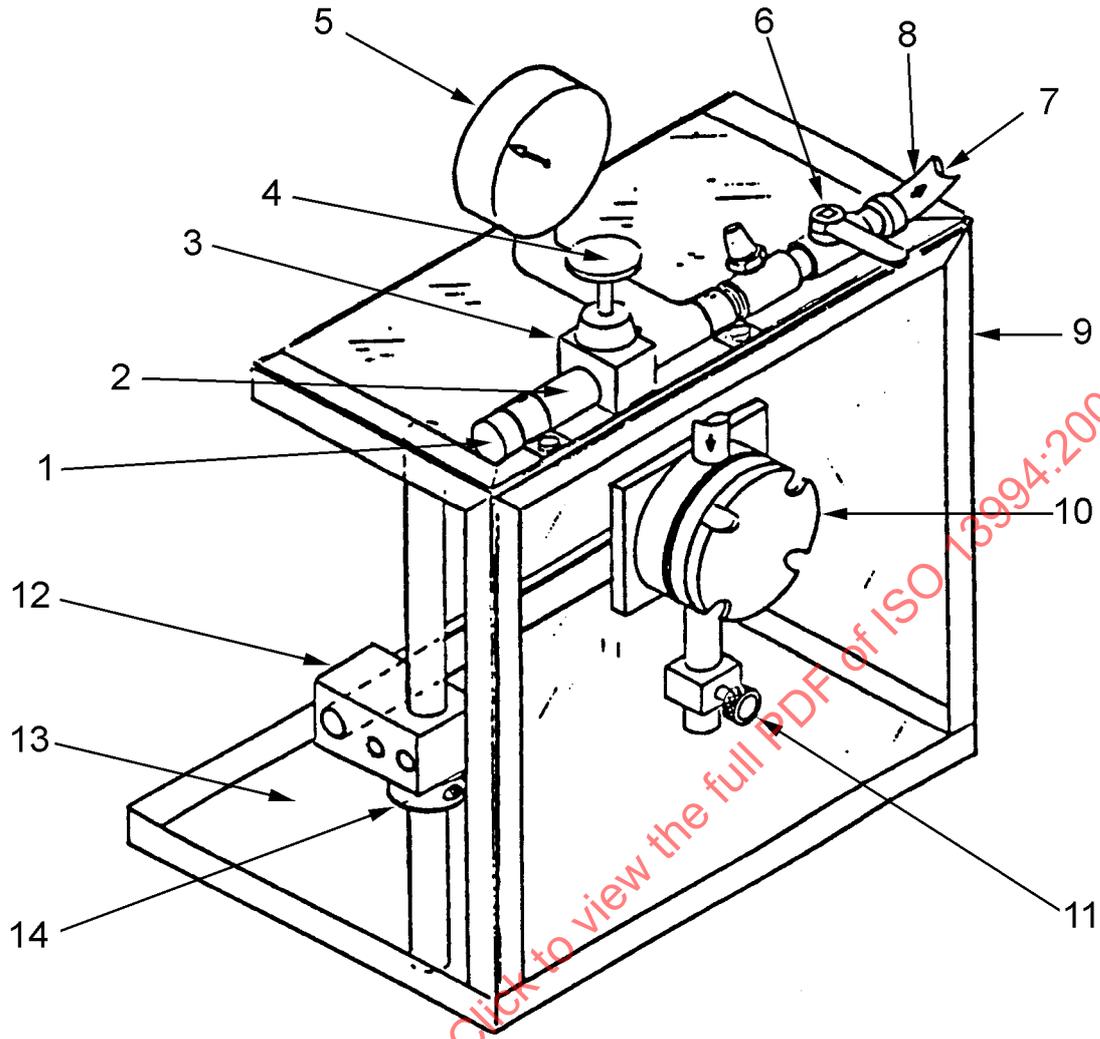
NOTE Additional tests such as permeation resistance testing may be necessary to fully characterize the material for a particular application.



Key

- | | |
|------------------------------------|--------------------------------------|
| 1 compressed air or nitrogen inlet | 7 female coupling |
| 2 air line connector | 8 rubber air hose with male coupling |
| 3 air pressure regulator | 9 safety enclosure (see Figure 10) |
| 4 adjustable relief valve | 10 penetration test cell |
| 5 pressure gauge | 11 drain valve |
| 6 cell vent valve | |

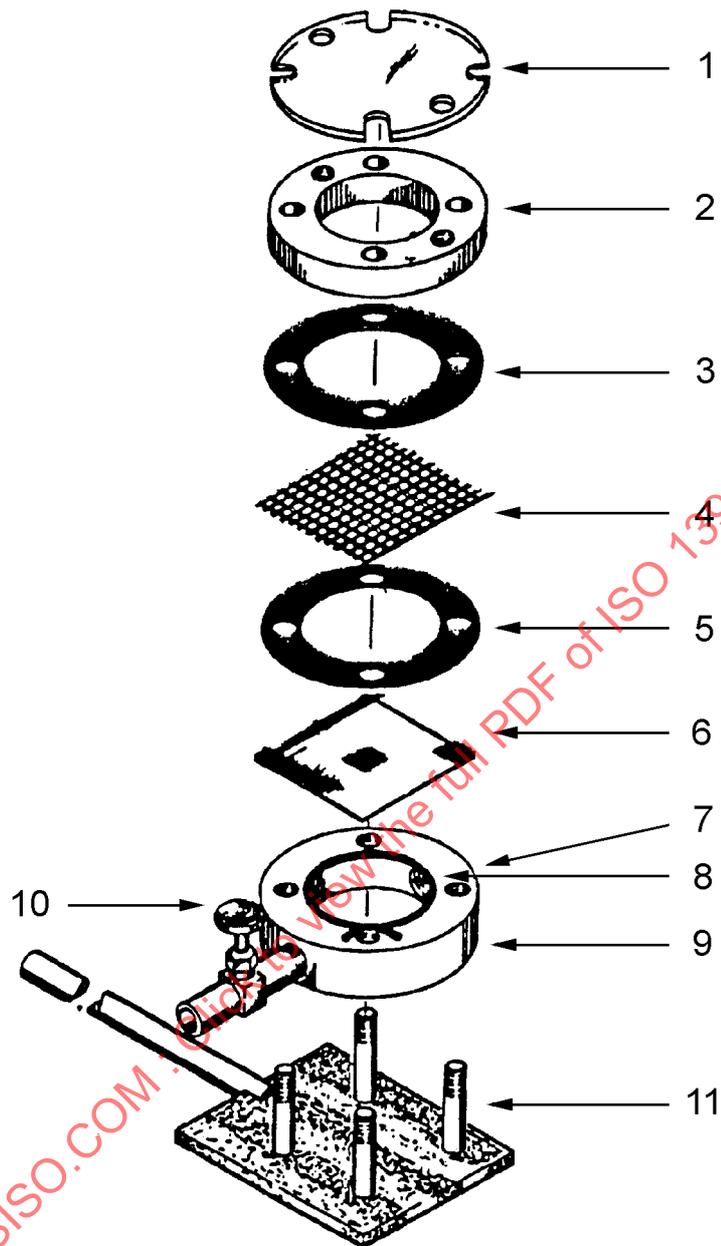
Figure 1 — Liquid penetration test apparatus (schematic)



Key

- | | | | |
|---|----------------------------------|----|------------------------------------|
| 1 | compressed air or nitrogen inlet | 8 | rubber air hose with male coupling |
| 2 | air line connector | 9 | safety enclosure |
| 3 | air pressure regulator | 10 | penetration test cell |
| 4 | adjustable relief valve | 11 | drain valve |
| 5 | pressure gauge | 12 | swivel clamp |
| 6 | cell vent valve | 13 | spill pan |
| 7 | female coupling | 14 | two-piece shaft collar |

Figure 2 — Test apparatus (three-dimensional side view)

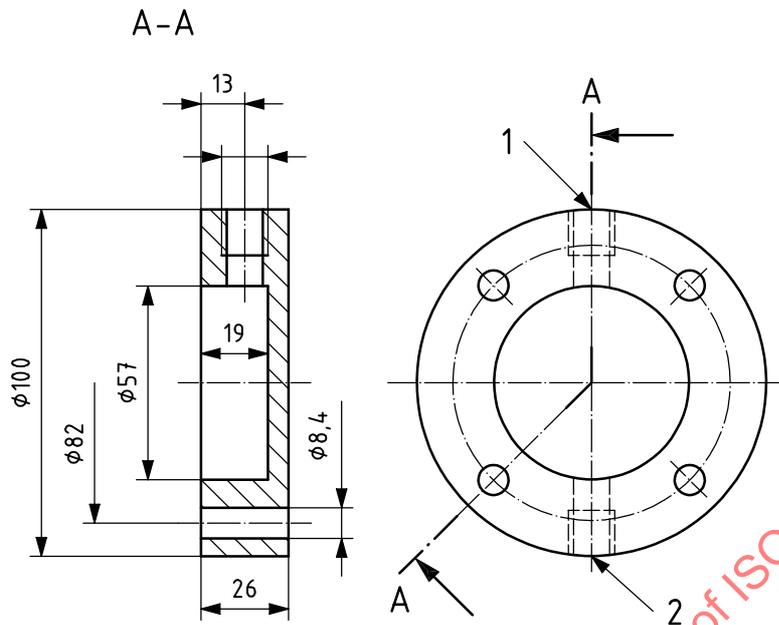


Key

- | | |
|--|---------------------------------|
| 1 transparent cover | 7 top port |
| 2 flange cover | 8 expanded PTFE gasket material |
| 3 gasket (specimen exposure Procedure B) | 9 cell body |
| 4 retaining screen (specimen exposure Procedure B) | 10 drain valve |
| 5 gasket | 11 cell support |
| 6 test sample | |

Figure 3 — Penetration cell with retaining screen (exploded view)

Dimensions in millimetres



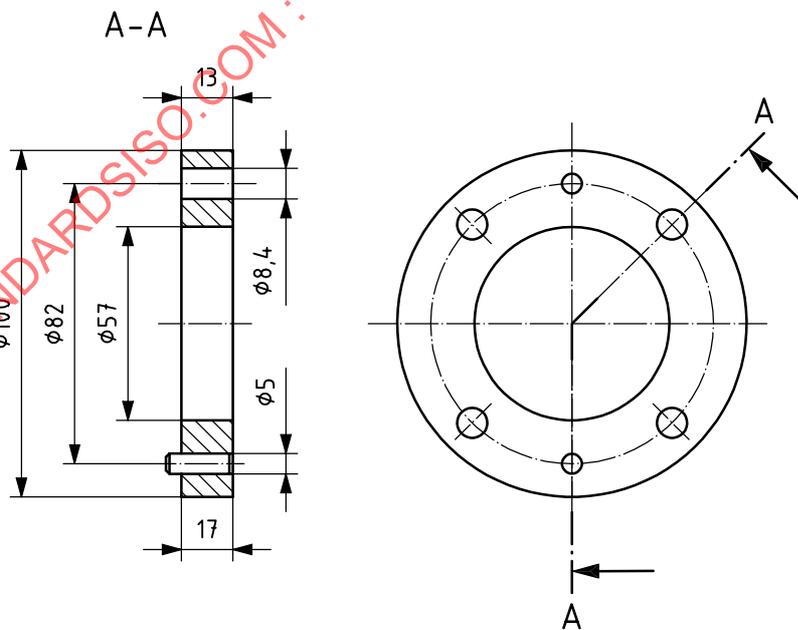
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- 1 thread for hose connector (inlet)
- 2 thread for drain valve (outlet)

Material: aluminium.

Figure 4 — Cell body

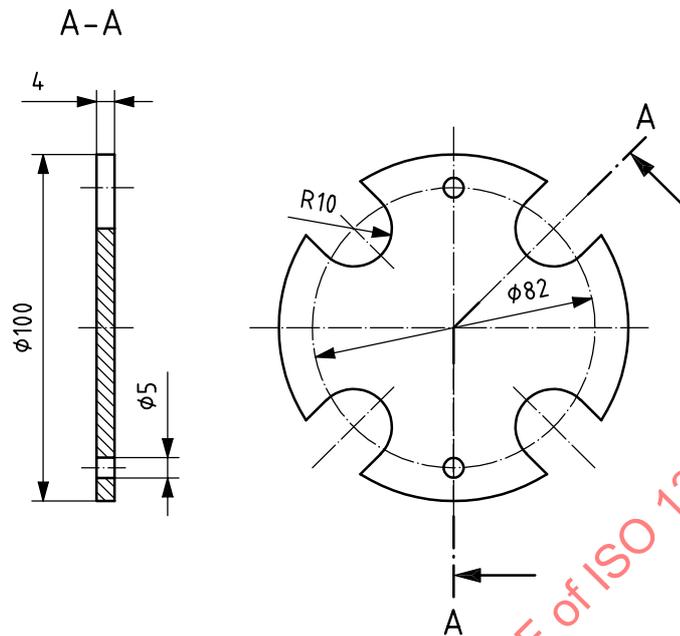
Dimensions in millimetres



Material: aluminium.

Figure 5 — Flange cover

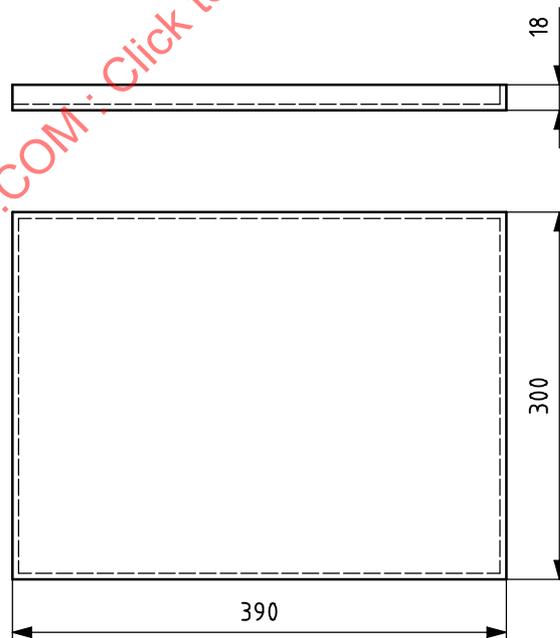
Dimensions in millimetres



Material: plexiglass or other transparent material.

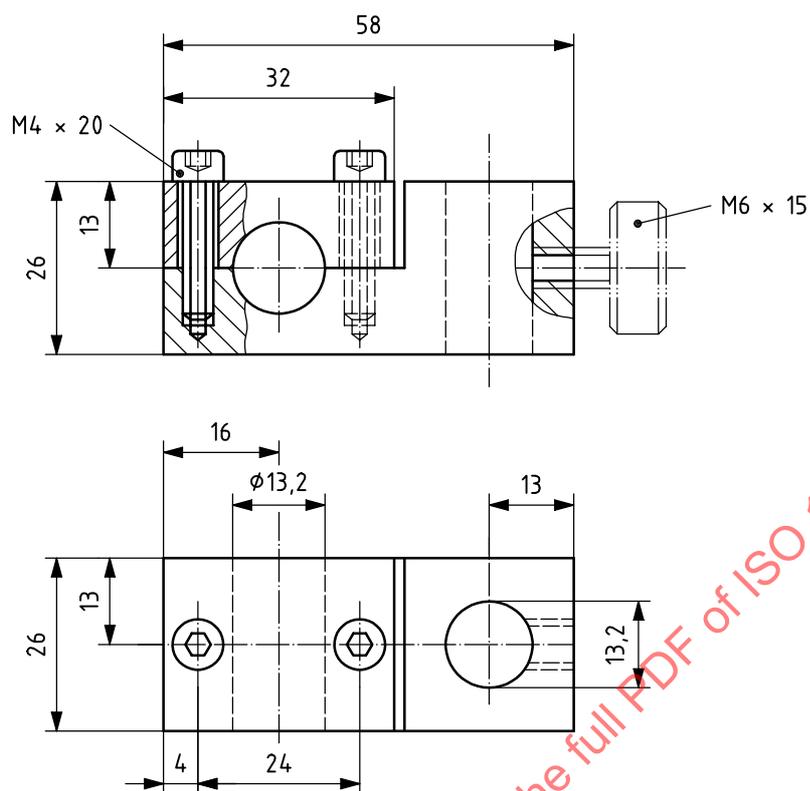
Figure 6 — Transparent cover (optional)

Dimensions in millimetres



Material: stainless-steel sheet, 1 mm to 2 mm, corners welded.

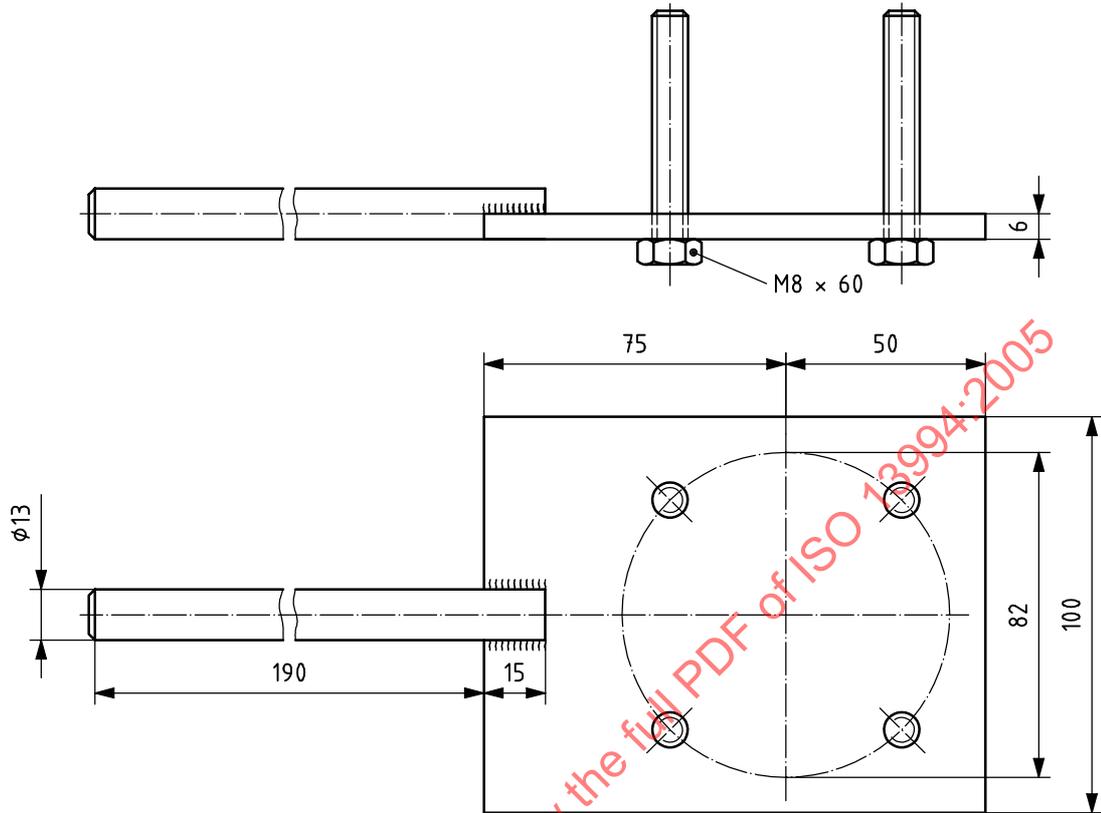
Figure 7 — Spill pan



Material: steel.

Figure 8 — Swivel clamp

Dimensions in millimetres



Material: steel.

Figure 9 — Cell support