
**Glass in buildings — Insulating glass —
Part 3:
Gas concentration and gas leakage**

*Verre dans la construction — Verre isolant —
Partie 3: Concentration de gaz et fuite de gaz*

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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 20492-3 was prepared by Technical Committee ISO/TC 160, *Glass in building*, Subcommittee SC 1, *Product considerations*.

ISO 20492 consists of the following parts, under the general title *Glass in buildings — Insulating glass*:

- *Part 1: Durability of edge seals by climate tests*
- *Part 2: Chemical fogging tests*
- *Part 3: Gas concentration and gas leakage*
- *Part 4: Methods of test for the physical attributes of edge seals*

Introduction

This International Standard consists of a series of procedures for testing the performance of pre-assembled, permanently sealed insulating glass units or insulating glass units with capillary tubes that have been intentionally left open. This International Standard is intended to help ensure that

- energy savings are made, as the U value and solar factor (solar heat gain coefficient) do not change significantly;
- health is preserved, because sound reduction and vision do not change significantly;
- safety is provided because mechanical resistance does not change significantly.

This International Standard also covers additional characteristics that are important to the trade, and marking of the product (i.e. CE marking or other regulatory groups).

There are distinct markets to consider for insulating glass. Within each market there are technical differences with respect to rebate sizes, vision lines and methods of application; two approaches are included in this International Standard. Approach 1 addresses requirements for markets such as North America. Approach 2 addresses requirements for markets such as Europe. Each approach includes separate test methods and specifications pertaining to minimum requirements for durability of edge seals by climate tests.

This International Standard does not cover physical requirements of sealed glass insulating units such as appearance, thermo-physical properties, heat and light transmission, and glass displacement.

The main intended uses of the insulating glass units are installations in buildings and constructions such as in windows, doors, curtain walling, skylights, roofs and partitions where protection against direct ultraviolet radiation exists at the edges.

The use of insulating glass in cases where there is no protection against direct ultraviolet radiation at the edges, such as structural glazing systems, can be suitable. However, it can be necessary to review factors such as sealant longevity when exposed to long-term ultraviolet light and the structural properties of the sealant for these applications.

NOTE 1 For more information on the requirements for structural sealant glazing applications, reference can be made to ASTM C1369, ASTM C1249 and ASTM C1265 and CEN technical specifications.

NOTE 2 IG units whose function is artistic only are not part of this International Standard.

The test methods in this International Standard are intended to provide a means for testing the performance of the sealing system and construction of sealed insulating glass units.

Sealed insulating glass units tested in accordance with these methods are not intended for long-term immersion in water.

The options for testing apply only to sealed insulating glass units that are constructed with glass.

In certain cases such as insulating glass units containing spandrel glass or absorptive coatings, these methods might not be applicable, as these products can experience field temperatures that exceed the temperature limitations of the sealant.

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Glass in buildings — Insulating glass —

Part 3: Gas concentration and gas leakage

1 Scope

This part of ISO 20492 specifies two methods of test for insulating glass units, including a determination of the gas leakage rate and a determination of gas concentration tolerances. The two methods designated as approach 1, which is intended for use in markets such as North America, and approach 2, which is intended for use in markets such as Europe.

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 16293-1, *Glass in building — Basic soda lime silicate glass products — Part 1: Definitions and general physical and mechanical properties*

ISO 20492-1, *Glass in building — Insulating glass — Part 1: Durability of edge seals by climate tests*

ISO 20492-4, *Glass in building — Insulating glass — Part 4: Methods of test for the physical attributes of edge seals*

EN 1279-6:2002, *Glass in building — Insulating glass units — Part 6: Factory production control and periodic tests*

ASTM C1036, *Standard Specification for Flat Glass*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 20492-1 and the following apply.

3.1

standard laboratory conditions

ambient temperature of (23 ± 2) °C and a relative humidity of (50 ± 5) %

3.2

controlled limit environment conditions

environment temperature of 10 °C with a dew point temperature of -5 °C, giving a relative humidity of 32,8 %

3.3

accuracy

precision of the test method within confidence limits of 99 %

3.4
sealed insulating glass unit
pre-assembled unit, comprising lites (panes) of glass that are sealed at the edges and separated by dehydrated space(s), intended for vision areas of buildings

NOTE The unit is normally used for windows, window walls, picture windows, sliding doors, patio doors, or other types of fenestration.

3.5
gas-filled insulating glass units
sealed insulating glass unit in which the cavity contains gas(es) in addition to air, usually for improving thermal and/or sound insulation

3.6
reference standard mixtures
gas mixtures that contain known percentages of argon, oxygen and nitrogen that are required for calibration purposes

NOTE Where gases other than argon are used the reference samples shall contain those gases. The concentrations of each component in the reference samples should encompass the expected concentration range of the corresponding component in the tested samples. The suitable standard mixtures can be obtained with a certificate of analysis of each mixture from a reputable commercial supplier.

3.7
gas concentration
 c_i
volume of gas i in the cavity

NOTE Gas concentration is expressed in units of volume percentage.

3.8
nominal gas concentration
 $c_{i,0}$
nominal volume of gas i in the cavity

NOTE 1 The nominal gas concentration is used as the basis for testing sound insulation and/or calculating or testing thermal insulation to fix R_w and the U value, respectively.

NOTE 2 Nominal gas concentration is expressed in units of volume percentage.

3.9
final gas concentration
 $c_{i,f}$
estimated final volume of gas i in the cavity

NOTE 1 The final gas concentration is expressed in units of volume percentage.

NOTE 2 See Annex B.

3.10
gas leakage rate
 L_i
volume of gas i leaking from a gas-filled unit per year

NOTE The gas leakage rate is expressed in units of volume percentage per year.

3.11 **U value for publication** U_p

thermal transmittance value to be published, normally determined from the gas concentration $c_{i,0}$

NOTE See ISO 10292 and Annex B.

3.12**sound insulation measure for publication** $R_{w,p}(C/C_{tr})$

weighted sound reduction index that is published, normally determined with the gas concentration

4 Requirements**4.1 Approach 1**

If the specimen is filled with argon, the average minimum fill of eight argon-filled specimens shall be 90 % when tested in accordance with 5.1.

4.2 Approach 2**4.2.1 Gas leakage rate**

The gas leakage rate, L_i , expressed as a percent per year, for gases with concentrations higher than 15 %, and also for air, measured in accordance with 5.2 shall be as given in Equation (1):

$$L_i < 1,00 \quad (1)$$

For most insulating glass units, measured L_i values are much higher than actual L_i values would be after 10 years natural ageing. Therefore, the limiting value should not be used for calculating the gas concentration during the lifetime of the unit. See Annex C.

In the case of sealants based on polysulfide, polyurethane, silicone or polyisobutylene, determining the gas leakage rate of argon, Ar, may replace the measurement of the gas leakage rate for sulfurhexafluoride, SF₆, and air.

4.2.2 Tolerances on gas concentration

Tolerances on gas concentration shall be determined in accordance with EN 1279-6:2002, Annex A.3.

4.2.3 Dew-point and moisture-penetration indices

Dew-point and moisture penetration shall be determined in accordance with ISO 20492-1.

4.2.4 Edge-seal strength

Edge-seal strength shall be determined in accordance with ISO 20492-4.

4.2.5 Additional requirements for gases other than argon, sulfurhexafluoride and air

These requirements shall be determined in accordance with Annex B.

5 Principle

5.1 Approach 1

Argon, nitrogen and oxygen are physically separated by gas chromatography and compared to corresponding components separated under similar conditions from a reference standard mixture or a mixture of known similar composition.

5.2 Approach 2

The gas leakage rate at 20 °C is measured after subjecting the test specimen to a climate as specified in ISO 20492-1 with the following modifications.

- The number of cycles is reduced to 28.
- The time at a constant temperature of 58 °C is reduced to 4 weeks.

For measuring the gas leakage rate, the unit is placed in a gastight container and, after a given time, the amount of gas that has leaked from the unit is measured. After this measurement, the gas concentration in the unit is analysed and the gas leakage rate calculated.

6 Apparatus

6.1 Approach 1

6.1.1 Gas chromatograph

The gas chromatograph is comprised of a gas sampling valve with a capacity of 100 µL to 250 µL, an adsorption column that is capable of separating argon from other gases, a detector and an integrator. Chromatograms shall be reproducible so that successive runs of a reference standard agree on each component peak area within $\pm 0,1$ %.

NOTE An example of a detector is a thermal conductivity detector (TCD).

6.2 Approach 2

6.2.1 Climate exposure

The climate exposure should be as specified in ISO 20492-1.

6.2.2 Container for gas leakage rate measurement

A controlled temperature container shall be used for measuring the gas leakage rate. It shall be hermetically sealable, and capable of surrounding the test specimen while inducing as little stress as possible on the specimen. The residual volume in the container shall be as small as possible yet still allow the exposure of the sealed edge zones of the specimen to the circulation of purging gas.

The quantity of ambient air penetrating into the container from outside or the quantity of each constituent leaking from the container shall be measured in a blank test using a solid glass body of approximately the same dimensions as the test specimens.

The container shall be deemed to have an adequate degree of tightness if the quantity of gas measured during the test does not exceed 10 % of the mass of gas leaking from the test specimen.

The container shall have fittings for introducing specific gases and for taking gas specimens.

For test specimens with at least one outer pane made of organic material, it shall be ensured that the gas diffusion through this (these) pane(s) is included in the measurement.

6.2.3 Gas analysis equipment

Gas analysis equipment should be capable of the following:

- a) analysis of the gaseous constituents essential to the insulation function of the glass unit, for concentrations of 50×10^{-6} ;
- b) determination of percentages by volume of gas of up to 100 % within ± 3 % (relative).

These tasks shall not necessarily be performed using the same equipment.

6.2.4 Gas sampling device

A gas sampling device used for taking gas specimens from the glass unit, ensuring that the result is not distorted by ingress of air, segregation phenomena, etc.

7 Reagents and materials

7.1 Approach 1

7.1.1 **Helium carrier gas cylinder**, analytical grade with a purity of 99,9 %.

7.1.2 **Compressed air cylinder**, for valve actuation.

7.1.3 **Liquid CO₂ or N₂ cylinder**, with dip tube, or **refrigeration system**, for cooling the column oven if using a column that requires sub-ambient temperatures for operation.

7.1.4 10 ml **gas-tight syringe(s)**, with closure valve and side port needle(s).

7.2 Approach 2

Reagents shall be chosen as needed to meet the requirements in 6.2.3.

8 Test specimens

8.1 Approach 1

Each test specimen shall measure (355 ± 6) mm by (505 ± 6) mm, and shall be composed of two or three panes of clear, tinted or coated annealed, heat-strengthened, tempered or laminated glass.

The double-glazed test specimens shall be fabricated with at least one pane of clear, uncoated glass. The triple glazed test specimens shall be fabricated with at least one outer pane of clear, uncoated glass. The other outer pane shall be fabricated with a glass that allows easy viewing of the frost point.

The glass and airspace thicknesses for qualification under this part of ISO 20492 are 4 mm glass with 12 mm airspace or 5 mm glass with 6 mm airspace.

Glass and/or airspace thickness(es) may be increased e.g. using 6 mm glass with 12 mm airspace. This can result in a more rigorous test.

For triple pane units, 4 mm glass with 6 mm airspaces shall be used.

Tolerance of glass thickness shall be in accordance with ASTM C1036.

Airspace tolerance(s) shall be $\pm 0,8$ mm.

A minimum of eight specimens shall be submitted for testing. Extra specimens should be considered in case of breakage.

Triple-pane units where the intermediate airspace divider is a plastic film shall be acceptable.

Each specimen shall be permanently and legibly marked with the designation of the manufacturer, the date of fabrication (month or quarter and year) and orientation intended in the field (for units constructed with coated glass).

During all stages of exposure and storage, hold the units in a vertical position with equal support to all panes and no compression loading.

Select units for testing at random except for units damaged in transit. Do not test damaged units.

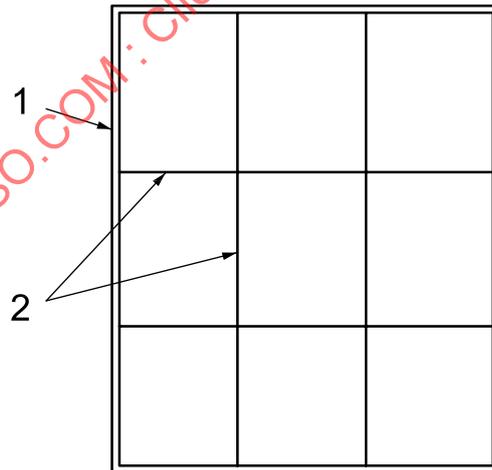
The test specimens representing units that are gas filled shall be fabricated using the same hole sealing and gas filling techniques as those used for manufacturing. For example, if a gas-filling plug is used in manufacturing then it shall be used in the test units.

It is not allowed to test the specimens representing units that include tubes.

Test specimens representing units that include muntins shall be fabricated with muntins dividing the sample into nine equal areas (3 by 3).

NOTE See Figure 1.

It is recommended that the test specimens be sealed a minimum of four weeks after the date of manufacture before testing begins to allow for stabilization. This is at the discretion of the manufacturer.



Key

- 1 insulation glass unit
- 2 muntin bars

Figure 1 — Test specimen with muntin bars

8.2 Approach 2

8.2.1 Preparation of test specimens

8.2.1.1 With the exception of the condition listed in 8.2.1.2, the test specimens shall consist of two panes of 4 mm clear float glass in accordance with ISO 16293-1. The length shall be (502 ± 2) mm and the width (352 ± 2) mm. The gap shall be nominally 12 mm, or if not manufactured, a gap as near to 12 mm as possible. The test specimens shall be representative of the system description as defined in ISO 20492-1.

8.2.1.2 If the actual insulating glass product contains organic materials in its panes and these panes are arranged on the unit in such a way that gas leakage out of the unit through the plastic is possible, glass shall be substituted by plastic.

8.2.1.3 Unless otherwise agreed, the design of the insulating glass unit, including the type and quantity of desiccant and of gas, shall conform to that which is manufactured in normal production (except for the measurement of the air loss rate, where 100 % air is allowed). The panes of the test specimen shall be flat when the unit is sealed. During sealing, measure the temperature, T , expressed in kelvins to the nearest 1 K, and the absolute pressure, P , expressed in hectopascals, to the nearest 3 hPa.

The test specimens shall be manufactured in such a way that the gas concentration, $c_{i,0}$, is equal to $c_{i,0} \begin{smallmatrix} +10 \\ -5 \end{smallmatrix} \%$ absolute for each gas when a gas mixture is used.

8.2.2 Number of test specimens

At least six test specimens shall be prepared, of which at least two shall be tested in accordance with 9.2 after climate exposure.

It is recommended to take more test specimens to test the gas filling before climate exposure. The gas leakage can be measured on further units before the climate exposure, at the earliest four weeks after they have been filled with gas and sealed. This achieves the objective of keeping test costs and time scale to an acceptable maximum.

8.2.3 Construction and appearance

The test specimens shall be examined visually for the following criteria and/or defects:

- a) construction of insulating glass unit;
- b) damaged edges;
- c) edge cracks;
- d) fractures;
- e) specking in the cavity;
- f) congruence of panes;
- g) other visible defects.

9 Procedure

9.1 Approach 1

Carry out the testing as follows.

- a) Standardize and calibrate the gas chromatograph in accordance with Annex A.
- b) Condition the insulating glass unit so that at the time of sampling a positive pressure exists inside the unit. To achieve this, either heat the unit above the sealing temperature or place the unit horizontally on a flat surface and apply a weight to the centre of the glass.

NOTE If the gas sampling occurs with the unit under negative pressure, contamination of the gas sample can occur.

- c) Wrap the shank of the sampling needle with polyisobutylene (PIB) sealant or other sealing mastic.
- d) If spacers do not allow a needle to pass through the spacer without damage or obstruction to the needle, drill or punch a 1,6 mm hole through the edge sealant and the spacer, into one of the long sides of the unit approximately 75 mm from a corner.
- e) Remove the drill or punch and immediately plug the hole with a finger.
- f) Slide the finger off the hole and immediately insert the PIB wrapped sampling needle, with the syringe evacuated (plunger forward).
- g) Seal the needle into the hole with the PIB sealant.
- h) Fill the syringe with the airspace gas then evacuate its contents back into the airspace to purge any contaminants that it can have contained. Filling and evacuating of the syringe shall be done at a controlled rate to ensure proper sample collection.
- i) Leave the syringe in place and repeat 9.1 h) at least two more times.
- j) Fill the syringe with the gas sample.
- k) Close the syringe valve.
- l) Carefully grip the needle at its base and pull it out of the gas space.
- m) Insert the needle into the gas sampling inlet and open the syringe valve.
- n) Inject the contents of the syringe into the column via the septum connected at the inlet of the gas sampling valve.
- o) Record the chromatogram with the integrated percentages of Ar, O₂ and N₂.

9.2 Approach 2

9.2.1 Determination of internal volume of a test specimen

Measure the clear distances, s_1 and s_2 , between opposite spacers to the nearest 1 mm, e.g. by means of a gauge graduated in millimetres. Determine the clear distance, s_3 , between the inner pane surfaces by measuring the distance between the inner pane surfaces at mid-length on the four edges of the test specimen, to the nearest 0,1 mm, and calculate the mean. Determine the internal volume, V_{int} , expressed in cubic millimetres, by calculating the product $s_1 \times s_2 \times s_3$.

9.2.2 Climate exposure

Perform the climate exposure in accordance with 5.2 on four test specimens, at least one week after preparation of the test specimens. On completion of the climate exposure, stabilize the test specimens by storing them with free circulation of air around the edges at $(23 \pm 2) ^\circ\text{C}$ and $(50 \pm 5) \%$ relative humidity for at least four weeks and no longer than seven weeks, up to the time of measuring the gas leakage rate as described in 9.2.3.

If the units are stored vertically, the free circulation of air around the edges may be realized by using two blocks at least 20 mm high, each covering not more than 30 mm of the edge.

9.2.3 Measuring the gas leakage

Measure the gas leakage of at least two test specimens at $(20 \pm 1) ^\circ\text{C}$ after the climate exposure, leaving the test specimen in the container for as long as it takes to determine quantitatively the mass of gas, expressed in micrograms per hour, that has leaked from the unit using the gas analysis equipment described in 6.2.3.

Repeat the measurement of the gas leakage until a constancy of the values has been achieved. To achieve constancy of the values, ensure that the standard deviation over the last four measurements, is less than $0,25 \mu\text{g/h}$, and with at least one measurement being higher than the one immediately preceding it. In the case of naturally occurring gases such as the components of air, take measurements with at least one day between them.

NOTE See Annex D.

9.2.4 Analysis of the gas

Determine the volume percentage of the gaseous constituents essential to the insulation function of the unit using the gas analysis equipment described in 6.2.3.

Take a gas specimen for this analysis from the cavity of the unit after the last measurement of the gas leakage rate.

9.2.5 Calculations

Calculate the gas leakage rate, L_i , expressed in volume percentage per year, according to Equation (2):

$$L_i = 87,6 \times 10^6 \frac{q_i}{c_i \cdot V_{\text{int}} \cdot \rho_{0,i}} \cdot \frac{T}{T_0} \cdot \frac{P_0}{P} \quad (2)$$

where

c_i is the gas concentration determined according to 9.2.4, expressed as a volume percentage;

q_i is the mass of gas that has leaked from a gas-filled unit in a given time and determined according to 9.2.3, expressed in micrograms per hour;

$\rho_{0,i}$ is the density of gas i at temperature T_0 and pressure P_0 , expressed in micrograms per cubic millimetre;

NOTE $\rho_{0,i}$ is often given at $T_0 = 273 \text{ K}$ ($0 ^\circ\text{C}$) and $P_0 = 1\,014 \text{ hPa}$.

P is the absolute atmospheric pressure at which the unit was sealed, expressed in the same unit as P_0 ;

P_0 is the pressure at which $\rho_{0,i}$ was determined, expressed in hectopascals;

T is the temperature at which unit was sealed, expressed in kelvin;

T_0 is the temperature at which $\rho_{0,i}$ was determined, expressed in kelvin;

V_{int} is the internal volume of the test specimen according to 9.2.1, expressed in cubic millimetres.

10 Precision of test method

10.1 Approach 1

The accuracy of the results shall be determined by accurate calibration standards.

10.2 Approach 2

In an inter-laboratory test involving four laboratories, four to eight units of a uniform production were exposed to a climate in accordance with 5.2. Afterwards the gas leakage rate was determined according to 9.2.3 and Annex D. The standard deviation of all individual values was 20 %.

11 Test report

11.1 Approach 1

The report shall record the following items:

- a) complete description of specimen tested;
- b) dimensions of the test specimen (width by height) and overall thickness;
- c) type and thickness of glass;
- d) glass coatings and surface locations if applicable;
- e) airspace thickness(es);
- f) describe the spacer composition(s) and configuration(s);
- g) describe the corner construction including the type and number of corner keys;
- h) desiccant type and quantity, if provided;
- i) presence and composition (if known) of muntin bars;
- j) composition of reference standard gases used;
- k) type of adsorption column used, column size, column temperature, sampling loop temperature, and sample volume;
- l) argon concentration measured for each reference standard gas before and after measurement of the sample;
- m) argon concentration measured for each test specimen.

11.2 Approach 2

The test report shall evaluate the test in detail and shall include a summary presented in accordance with Figure 2.

Name, address and logo of the test laboratory

Summary of report No. Date

Insulating glass units — Evaluation of the gas leakage rate and gas concentration measured according to ISO 20492-3, approach 2

For details, see the test report

Company: Name:

Address:

Plant: (Name:) (Address:)

System description, file number:

Product name:

Reference to test report for moisture penetration index according to ISO 20492-2:

Applied gas(es) i :								
Unit number:	1	2	1	2	1	2	1	2
Measured concentration c_i , (%):								
Nominal concentration $c_{i,0}$, (%):								
Gas leakage rate L_i , (%·a ⁻¹):								

NOTE 1 If for certain gases the gas leakage rate L_i is not relevant, fill in the cell for L_i "NR" (= not relevant).

System conforms: YES NO (delete whichever is not applicable)

.....
Name and signature

NOTE 2 For comparisons of gas leakage rates of different insulating glass unit systems, it is appropriate that the standard deviation indicated in Clause 6 of ISO 20492-3 be taken into consideration.

Figure 2 — Summary of the test report for approach 2

Annex A (normative)

Calibration and standardization of the gas chromatograph for approach 1

A.1 General

The following procedure shall be used prior to sampling test specimens in accordance with 9.1. The procedure shall be performed periodically when many specimens are tested as indicated in A.4 g) and A.4 h).

A.2 Apparatus preparation

Prepare a gas chromatograph in accordance with 6.1.1 and the manufacturer's instructions.

EXAMPLE The following is a set of operating conditions that has been found to be satisfactory using a Haysep^{®1)} column for this test method:

Carrier gas	Helium, 30 ml/min;
Column	Haysep [®] DB, 100 to 120 mesh;
Column size	9,1 m by 3 mm (30 ft by 1/8 in) stainless steel;
Column (oven) temperature	-30 °C;
Sampling loop temperature	100 °C;
Sample volume	250 µL.

A.3 Reference standard mixtures

The following reference standard mixtures shall be used:

- a) at least two reference standard mixtures that contain known percentages of argon, oxygen and nitrogen, for use for calibration;
- b) one reference standard mixture with an argon concentration greater than 98 %;
- c) one reference standard mixture with an argon concentration equal to (50 ± 5) %;
- d) if the argon concentration being determined is less than 50 %, an additional reference standard mixture that brackets the expected argon fill level.

NOTE Standard mixtures can be obtained with a certificate of analysis of the makeup of the mixture from commercial gas suppliers. The accuracy of the results of this method depends on the availability of accurate calibration standards.

1) Haysep[®] is an example of a suitable product available commercially. This information is given for the convenience of users of this part of ISO 20492 and does not constitute an endorsement by ISO of this product.

A.4 Reference standard introduction and separation

The following reference standard introduction and separation techniques shall be used.

- a) Fill a 10 ml gas-tight syringe from the cylinder containing a reference standard gas mixture as indicated in A.3. Ensure that the filling and evacuating of the syringe is done at a controlled rate to ensure proper sample collection.
- b) Remove the syringe from the cylinder outlet and evacuate the syringe to purge any contaminants that it can have contained.
- c) Repeat A.4 a) and A.4 b) at least two more times.
- d) Refill the syringe with the reference standard gas.
- e) Close the syringe valve and remove it from the cylinder.
- f) Introduce the reference standard sample(s) into the gas chromatograph sampling port.
- g) Repeat the reference standard introduction and separation before and after 9.1. For a group of samples, conduct additional re-calibrations periodically (for example, after every 10 samples) to confirm uniformity.
- h) As a minimum, run the reference standard mixtures twice within an 8 h period when no changes to the chromatograph conditions or configurations have occurred.
- i) Record the chromatogram and the integrated percentages of oxygen, nitrogen and argon (O₂, N₂ and Ar).

Annex B (normative)

Requirements for other gases for approach 2

B.1 Durability of the gas and interaction with insulating glass components

The durability of the gas for the proposed applications shall be assessed by investigation.

The interactions of the gas with the insulating glass components shall also be assessed by investigation.

B.2 Effect on thermal and sound insulation

Depending on the gas concentration, the thermal transmittance U value and/or the weighted sound reduction index $R_w(C/C_{tr})$ shall be determined.

Thermal transmittance and sound reduction shall not change significantly over the working life of the insulating glass unit. Any increase in the U value shall not be more than $0,1 \text{ W}/(\text{m}^2\cdot\text{K})$, and any deterioration in the $R_w(C/C_{tr})$ shall be not be more than 1 dB.

The thermal transmittance and the sound reduction shall be determined under one of the following conditions.

- a) When gas filling improves the U value by a maximum of $0,4 \text{ W}/(\text{m}^2\cdot\text{K})$ and the $R_w(C/C_{tr})$ index by a maximum of 5 dB, the U and $R_w(C/C_{tr})$ values for publication shall be as given in Equations (B.1) and (B.2), respectively:

$$U_p = U(c_{i,o}) \quad (\text{B.1})$$

$$R_{w,p}(C/C_{tr}) = R_w(C/C_{tr})(c_{i,o}) \quad (\text{B.2})$$

- b) When gas filling improves the U value by more than $0,4 \text{ W}/(\text{m}^2\cdot\text{K})$ or improves the $R_w(C/C_{tr})$ value by more than 5 dB, respectively, the inequalities in Equations (B.3) and (B.4) shall be verified:

$$U(c_{i,f}) - U(c_{i,o}) \leq 0,1 \text{ W}/(\text{m}^2\cdot\text{K}) \quad (\text{B.3})$$

$$R_w(C/C_{tr})(c_{i,o}) - R_w(C/C_{tr})(c_{i,f}) \leq 1 \text{ dB} \quad (\text{B.4})$$

The U value and $R_w(C/C_{tr})$ value for publication shall be as given in Equations (B.5) and (B.6):

$$U_p = U(c_{i,o}) \quad (\text{B.5})$$

$$R_{w,p}(C/C_{tr}) = R_w(C/C_{tr})(c_{i,o}) \quad (\text{B.6})$$

- c) When one or both of the conditions in b) are not fulfilled, the calculations in Equations (B.7) and (B.8) shall be carried out:

$$U_p = U(c_{i,o}) - 0,1 \text{ W}/(\text{m}^2\cdot\text{K}) \quad (\text{B.7})$$

$$R_{w,p}(C/C_{tr}) = R_w(C/C_{tr})(c_{i,f}) + 1 \text{ dB} \quad (\text{B.8})$$

where

$$c_{i,f} = (c_{i,o} - 5) (1 - 0,22 L_{i,m})$$

where

$L_{i,m}$ is the maximum gas leakage rate, expressed in volume percentage, as measured according to this part of ISO 20492, plus 5 % relative.

Where gas mixtures are used, only the gas(es) with the maximum influence on the U value and/or $R_w(C/C_{tr})$ value shall be considered.

B.3 Assessment with krypton gas filling

This example of the assessment for a krypton gas filling uses the following assumptions:

- insulating glass unit with a cavity width of 8 mm, two panes of 4 mm, one coated with an emissivity, ε , equal to 0,1;
- krypton concentration, $c_{Kr,m}$, equal to 90 %;
- measured krypton leakage rate, $L_{Kr,m}$, equal to 0,5 % a⁻¹ (= 1,05 L_{Kr});
- demonstrated argon leakage rate, L_{Ar} , less than 1,0 % a⁻¹.

Compliance with 4.2.1: the gas leakage rates satisfy the requirements.

Compliance with 4.2.2, 4.2.3 and 4.2.4: in this example, the requirements are assumed to be satisfied.

Compliance with B.1: krypton reacts chemically similar to argon. No special investigations are necessary.

Compliance with B.2: the krypton gas filling improves the U value by more than 0,4 W/(m²·K), however the $R_w(C/C_{tr})$ value improves by less than 5 dB.

In accordance with condition a) of B.2, the weighted sound reduction index for publication $R_w(C/C_{tr})$ is equal to $R_w(C/C_{tr})(c_{Kr,o})$.

For the U value, check against the conditions in B.2 b):

- gas concentration:

$$\begin{aligned} c_{Kr,f} &= (90 - 5) (1 - 0,22 \times 0,5) \\ &= 75,65 \end{aligned}$$

- increase in U value:

$$\begin{aligned} U(c_{Kr,f}) - U(c_{Kr,o}) &= 1,54 - 1,38 \\ &= 0,16 \text{ W/(m}^2\text{·K)} \end{aligned}$$

This increase is greater than 0,1 W/(m²·K), so that the calculation in B.2 c) is performed as follows:

- U value for publication:

$$\begin{aligned} U_p &= 1,54 - 0,1 \\ &= 1,44 \text{ W/(m}^2\text{·K)} \\ &= 1,4 \text{ W/(m}^2\text{·K)} \text{ rounded to one decimal.} \end{aligned}$$

Annex C (informative)

Relationship between artificial and natural ageing with regard to thermal and sound insulation

The gas leakage rate of insulating glass units that had been installed in windows of buildings for 10 years was determined. The measured values were smaller by a factor of 10 relative to values measured on units with the same construction after artificial ageing. A comparison of this artificial ageing with the one described in 5.2 showed no significant difference with respect to the gas leakage rate.

With this experience, it may be assumed that a type of insulating glass with a gas leakage rate $L_t < 1,0 \text{ \% a}^{-1}$ after artificial ageing according to this part of ISO 20492, loses less than 5 % relative of gas over 25 years installed in a building. For this estimate, to be on the safe side, it was assumed that the gas leakage rate in buildings doubles every 10 years. In a unit with a typical nominal value for the argon concentration of $c_{Ar,0} = 90 \text{ \%}$, and with a possible real concentration of 85 %, the gas concentration after 25 years is higher than 80 %. On the assumption that the improvement of the U value with 100 % argon filling is $0,4 \text{ W/(m}^2\cdot\text{K)}$, this results in a deterioration, ΔU , equal to $< 0,04 \text{ W/(m}^2\cdot\text{K)}$ from the value calculated with $c_{Ar,0} = 90 \text{ \%}$. For the final assessment, the U value is rounded to $0,1 \text{ W/(m}^2\cdot\text{K)}$.

Similar considerations can be made for the sound insulation. It can be expected that insulating glass units fulfilling the requirements of this part of ISO 20492 show no significant change.

Annex D (informative)

Determination of the gas leakage rate by gas chromatography for approach 2

D.1 General

This test procedure is an example of a method for measuring the gas tightness in accordance with 5.2; other methods may also be used. If this method is used, it should be followed strictly in order to achieve the correct result.

This test procedure is applicable to gas-filled insulating glass units made with panes of inorganic materials.

D.2 Principle of method

The gas leakage, m_i , expressed as the mass of gas per hour, is determined in order to calculate the gas leakage rate L_i , which is expressed as a volume percentage per year ($\% a^{-1}$), according to 5.2.

The test specimen is, or its edges are, enclosed by a container, the inner volume of which is only slightly greater than the outer volume of the unit. Any gas that leaks from the unit over a given period is transported by a helium stream to a gas chromatograph with a thermal conductivity or electron capture detector. The mass of the leaked gas is then determined.

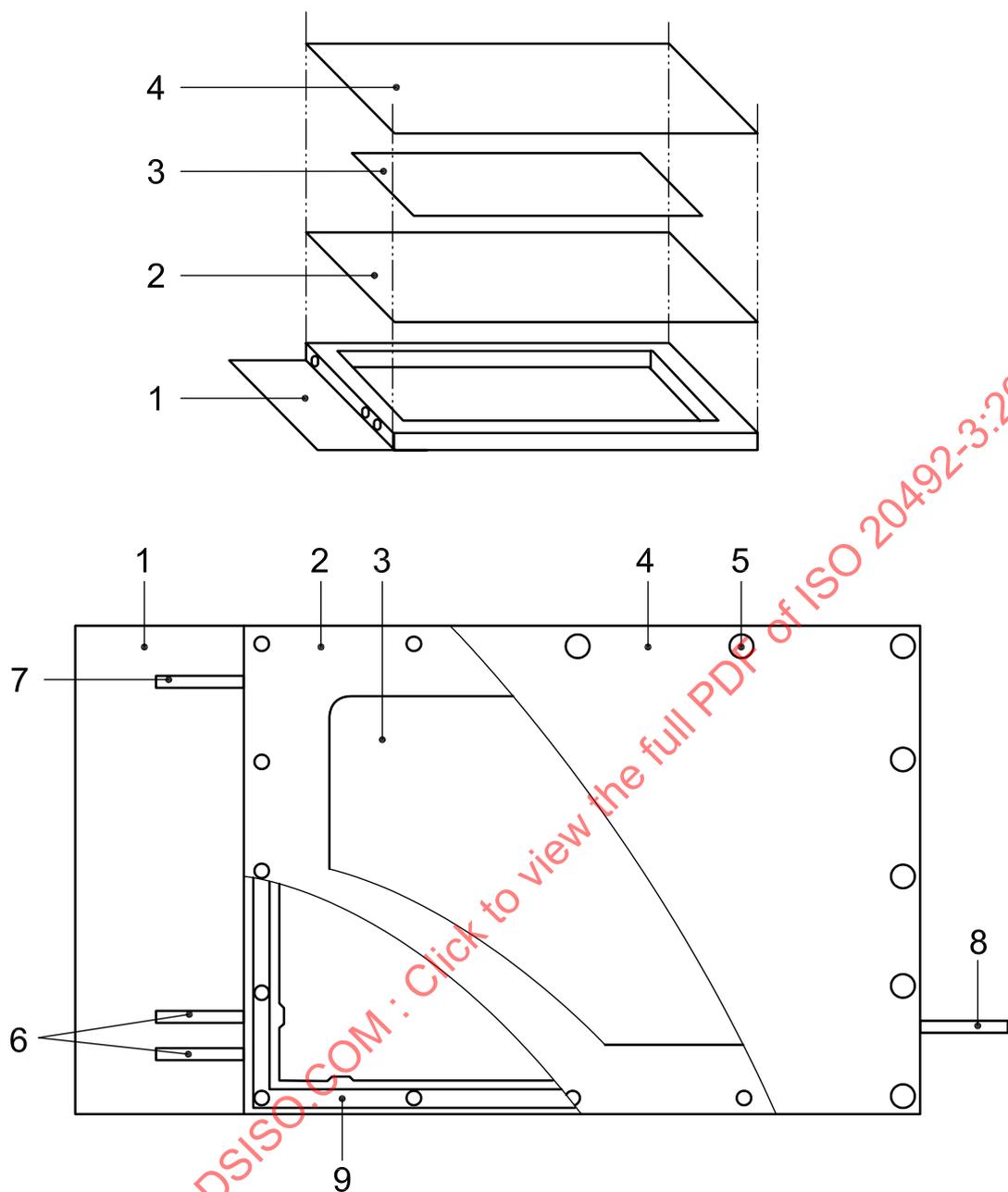
D.3 Apparatus

D.3.1 Full container

The container as shown in Figure D.1 shall consist of

- a) a lower part made of metal;
- b) a foil made of copper;
- c) a mat made of foam plastic, 3 mm thick, with dimensions according to the test specimen;
- d) a cover made of metal;
- e) elements for tightening.

The lower part shall have a flat inner bottom approximately 360 mm wide and approximately 510 mm long. The dimensions of the full container and the test specimen shall be reconciled, so that after installation of the test specimen the residual volume is as small as possible. The inner height of the lower part is 22 mm. The walls may have ledges for fixing the test specimen, but they shall not interrupt the gas stream at the edges of the test specimen. The walls contain two bore holes for the supply pipe and the extraction of the purging gas. The lower part may have an annular groove through which a protective gas stream may flow.



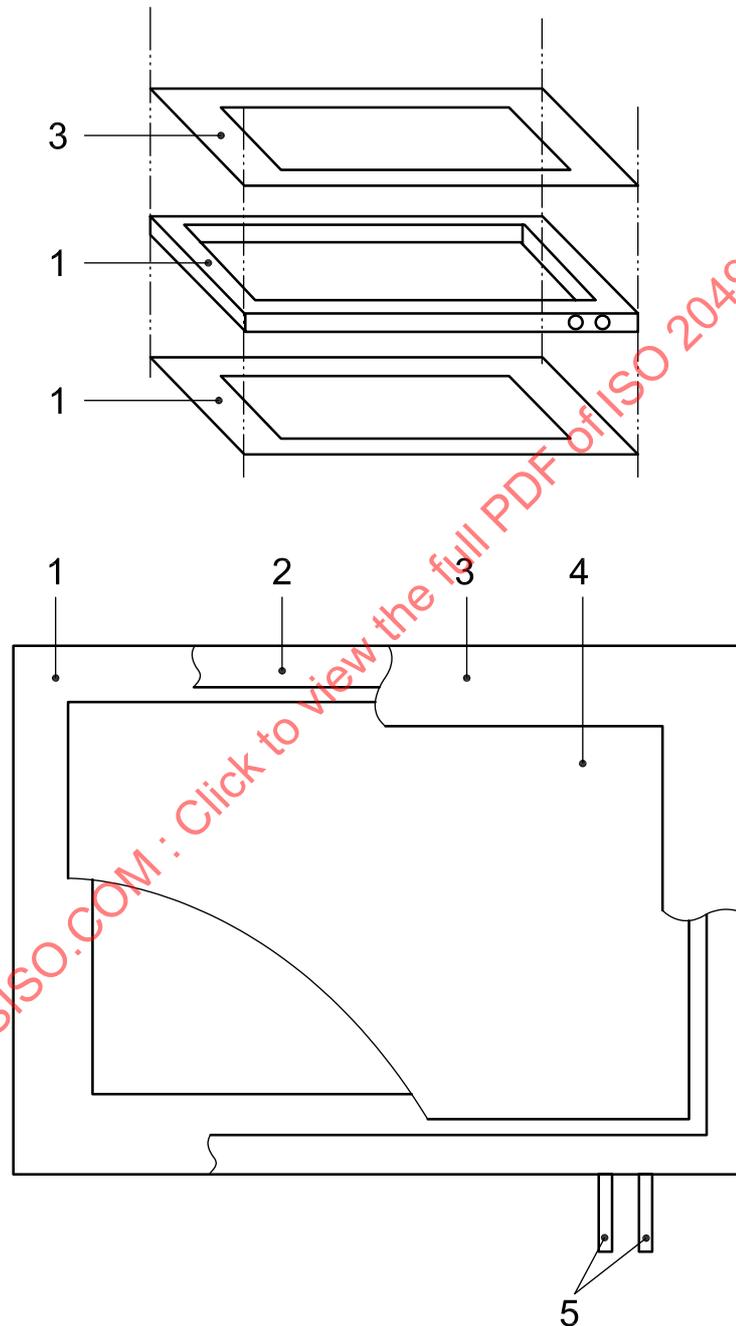
Key

- 1 lower part
- 2 metal foil
- 3 mat
- 4 cover
- 5 elements for tightening (e.g. screws)
- 6 purging gas in and out
- 7 protective gas in
- 8 protective gas out
- 9 annular groove

Figure D.1 — Full container

D.3.2 Ring container

The ring container (see Figure D.2) shall have a frame of metal and two masks made of a self-adhesive metal foil or a sheet metal coated with a sealant. The frame shall have two bore holes, one for the supply pipe and the other for extraction of the purging gas. The dimensions of the ring container and test specimen shall be reconciled, so that after installation of the test specimen the residual volume is as small as possible.



Key

- 1 lower mask
- 2 frame
- 3 upper mask
- 4 test specimen
- 5 purging gas in and out

Figure D.2 — Ring container

D.3.3 Cooling trap

The cooling trap shall consist of a metal tube filled with an adsorbent, which is bent into either a U-shape or a spiral, and of two interchangeable containers, one with liquid nitrogen and one with water at $(95 \pm 5) ^\circ\text{C}$. The adsorbent shall be selected in such a way that the gas for measuring is adsorbed at liquid nitrogen temperature and then is driven off abruptly at hot water temperature.

D.3.4 Gas chromatograph

A commercial gas chromatograph (GC) with a thermal-conductivity or electron-capture detector and an integrator with recorder is required. A calibrating loop of approximately 1 ml shall be connected to the gas chromatograph. The carrier gas shall be helium.

D.3.5 Connecting pieces

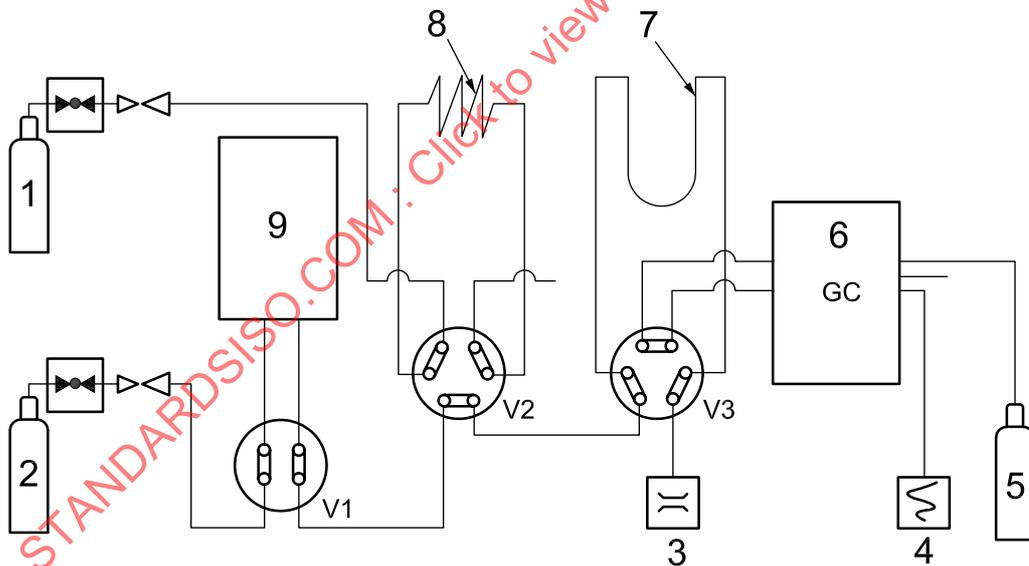
The pipes, valves and adapters as illustrated in Figure D.3 shall be sufficiently tight that the leakage rate during testing with helium is not more than $0,0001 \text{ L}\cdot\text{Pa}\cdot\text{s}^{-1}$.

D.3.6 Solvents

Ethanol and isopropanol should be used for cleaning the test specimen surface.

D.3.7 Purging and carrier gas

Helium with a purity of 99,999 6 % volume percentage shall be used.



Key

- | | | | |
|---|-----------------|----------------|--|
| 1 | calibrating gas | 6 | gas chromatograph |
| 2 | purging gas | 7 | cooling trap |
| 3 | flow meter | 8 | calibrating loop |
| 4 | integrator | 9 | container |
| 5 | carrier gas | V1, V2 and V3: | valves, for valve positions, see Table D.1 |

Figure D.3 — Gas pipe plan

Table D.1 — Overview of valve positions

Valve position	Valves			Function
	V1	V2	V3	
(a)				purging
(b)				filling the calibrating loop with calibrating gas
(c)				concentration of calibrating gas by cooling
(d)				measuring
(e)				concentration of contamination by cooling
(f)				concentration of gas specimen by standing time
(g)				concentration of gas specimen by cooling

D.3.8 Calibrating gas

Helium using 1 % by volume of the relevant gases, for example nitrogen, oxygen, argon and sulfurhexafluoride, should be used if the calibrating loop has a volume of approximately 1 ml.

D.4 Preparation of test specimens

Test the specimens according to 8.2. All traces of sealant, labels and other contaminations that can influence the gas exchange shall be removed. The test specimen surfaces shall be cleaned with the solvent avoiding all contact with the sealant.