पर्यावरण परीक्षण

भाग 2 टेस्ट

अनुभाग 17 टेस्ट Q: सीलिंग

(पहला पुनरीक्षण)

Environmental Testing

Part 2 Tests

Section 17 Test Q: Sealing

(First Revision)

ICS 19.040

भारतीय मानक ब्यूरो

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September 2024   Price Group 14

Environmental Testing Procedure Sectional Committee, LITD 01

NATIONAL FOREWORD

This Indian Standard (Part 2/Sec17) which is Identical to IEC 60068-2-17 : 2023 'Environmental testing — Part 2-17: Tests — Test Q: Sealing' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendations of the Environmental Testing Procedure Sectional Committee and approval of the Electronics and Information Technology Division Council.

This Indian Standard was first published in 2022 and was identical to IEC 60068-2-17 : 1994. The first revision of the Indian Standard has been taken up to align it with the latest version of IEC 60068-2-17 : 2023

The main changes are as follows:

a) 'Survey of sealing tests' has been deleted and the relevant content moved to a new **4** 'General';

b) The scope has been revised;

c) The figures have been updated for clarification purposes;

d) All non-SI units have been removed; and

e) The information to be given in the relevant specification has been revised.

The text of IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appears referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

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Indian Standard

ENVIRONMENTAL TESTING

PART 2 TESTS

SECTION 17 TEST Q: SEALING

(First Revision)

1   Scope

This part of IEC 60068 deals with seal tests applicable to the external and internal detection in container sealing of gross leaks and fine leaks to determine the effectiveness of seals of specimens. For further tests to verify the ability of enclosures, covers and seals to maintain components and equipment in good working order, IEC 60068-2-18 can be helpful.

2   Normative references

There are no normative references in this document.

3   Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

*   IEC Electropedia: available at https://www.electropedia.org/

*   ISO Online browsing platform: available at https://www.iso.org/obp

3.1
leak rate
quantity of a dry gas at a given temperature that flows through a leak per unit of time and for a known difference of pressure across the leak

3.2
standard leak rate
leak rate under standard conditions of temperature and pressure difference of 25 °C and 10^5 Pa

3.3
measured leak rate
R
leak rate of a given device as measured under specified conditions and employing a specified test gas

Note 1 to entry: Measured leak rates are often determined with helium employed as the test gas under a pressure difference of 10^5 Pa at 25 °C. For the purpose of comparison with leak rates determined by other methods of testing, the leak rates should be converted to equivalent standard leak rates.

3.4
equivalent standard leak rate
L
standard leak rate of a given device with air as the test gas

Note 1 to entry: The equivalent standard leak rate is expressed in Pa · cm^3/s.

3.5
time constant
θ
<of leak> time required for equalization of the partial pressure difference across a leak if the initial rate of change of that pressure difference were maintained

Note 1 to entry: For the purpose of Test Q, the time constant is equal to the quotient of the internal volume of the specimen and the equivalent standard leak rate.

3.6
gross leak
any leak with an equivalent standard leak rate greater than 1 Pa · cm^3/s

3.7
fine leak
any leak with an equivalent standard leak rate smaller than 1 Pa · cm^3/s

3.8
virtual leak
semblance of a leak caused by slow release of absorbed, adsorbed or occluded gas

3.9
leak meter
<in Test Qm> apparatus consisting of a hand probe for taking a sample of gas mixture and a meter providing a graduated display of the concentration of a predetermined type of gas in the sample

3.10
volume of measurement
V_m
<in Test Qm> volume contained between the gastight sheath collecting the leak and the specimen

3.11
leak detector
<in Test Qm> apparatus consisting of a hand probe for taking a sample of gas mixture and a device sensitive to the presence of a predetermined type of gas and emitting a signal, either acoustic or visual, when the concentration of a predetermined type of gas reaches a pre-set threshold level

3.12
probing
DEPRECATED: sniffing
<in Test Qm> action of slowly moving the probe of a leak detector along a specimen to locate the leaks

4   General

Test Q: Sealing includes several tests which use different conditioning procedures appropriate for different applications.

NOTE   Other tests of this category are rain and water tests which are described in IEC 60068-2-18.

The family tree of all sealing tests is shown in Figure 1.
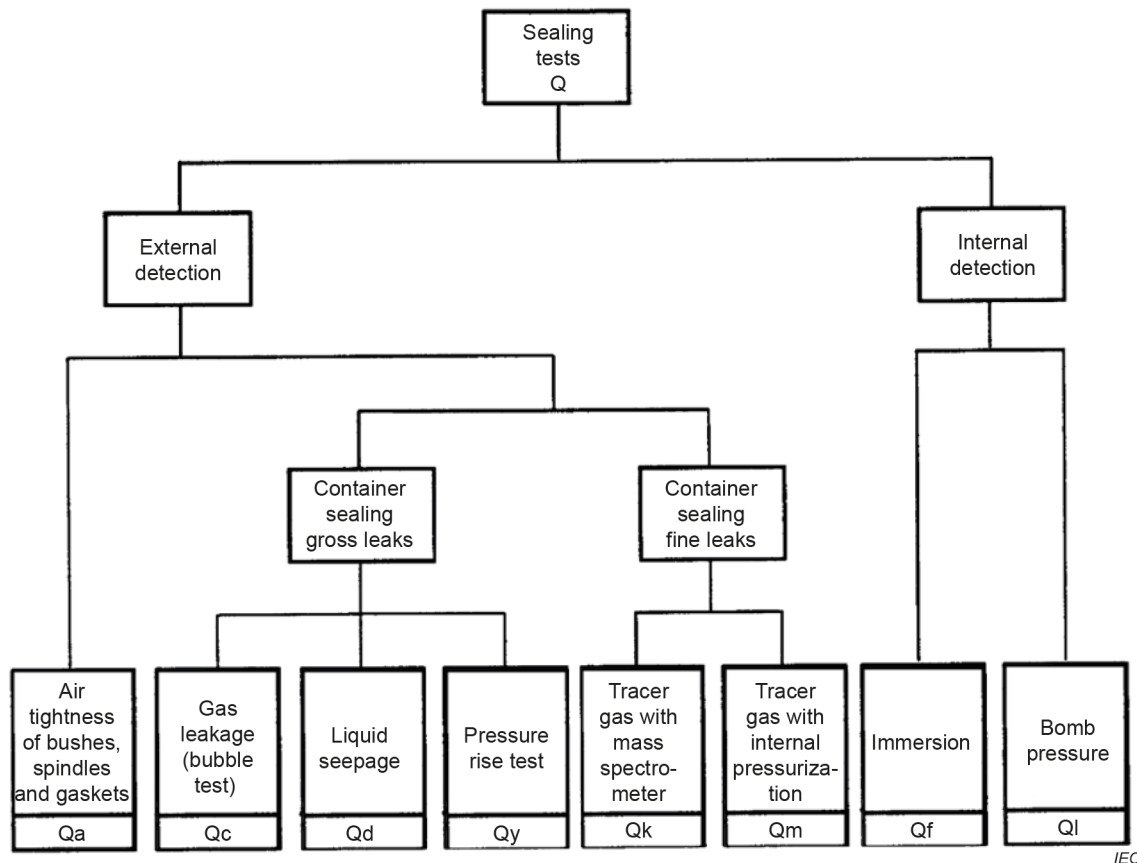
Figure 1 – Family tree of all sealing tests

Test Q can be subdivided in the following two subgroups, distinguished by their detection methods:

- internal detection, which measures changes of electrical characteristics produced by the test medium (liquid or gas) introduced into the specimens through the leak;
- external detection, whereby the escape of the test medium through the leak is observed.

The two tests for internal detection Qf and Ql are very similar. They are very effective for certain components, for example plastic-foil capacitors; they are not recommended, however, for components in which electrical changes become effective only after a long time (for instance, after the test is terminated).

The tests for external detection are further subdivided according to their application. Test Qa is a bubble test which is used to determine the airtightness of bushes, spindles and gaskets. The other tests, Qc, Qd, Qk and Qm, are used to determine leaks in containers (metallic cases, housings, etc.).

Test Qc is a bubble test again including three methods with different sensitivities (leaks not less than 1 Pa · cm^3/s). Test Qd is a liquid seepage test which may be applied to specimens filled during manufacture with a liquid or a product becoming liquid at the test temperature.

Tests Qk and Qm are the most sensitive of this series. Their sensitivity ranges from 1 Pa · cm^3/s to about 10^{-6} Pa · cm^3/s.

3

5 Test Qa: Sealing of bushes, spindles and gaskets

5.1 Object

To determine the effectiveness of seals of bushes, spindles and similar features. For this test, two types of seals shall be considered:

- Type A: 100 kPa (10 N/cm^2) to 110 kPa (11 N/cm^2) in the direction specified in the relevant specification.
- Type B: 100 kPa (10 N/cm^2) to 110 kPa (11 N/cm^2) in each direction.

5.2 Scope of Test Qa

This test can be used for the detection of gross leaks.

5.3 General description of the test

The specimen is mounted on the lid at a pressurized test chamber which is submerged in a liquid. If the specimen leaks, the air escaping is collected. The amount of air collected per time is a measure of the air leak. A suitable test apparatus is described in Annex A.

5.4 Initial measurements

There are no initial measurements required for Test Qa.

5.5 Conditioning

An air pressure difference, as specified below, shall be applied across each seal or simultaneously across a group of seals forming an assembly, if not specified otherwise.

- Type A: 100 kPa (10 N/cm^2) to 110 kPa (11 N/cm^2) in the direction specified in the relevant specification.
- Type B: 100 kPa (10 N/cm^2) to 110 kPa (11 N/cm^2) in each direction.

Where a higher pressure is required, it shall be 340 kPa (34 N/cm^2) to 360 kPa (36 N/cm^2).

NOTE   It is possible that the test apparatus described in Annex A will not be suitable for these higher pressures.

Type B seals shall be tested both in a static condition and while being mechanically operated as required by the relevant specification.

5.6 Final measurements

The rate of leak shall be measured. The limit shall be specified in the relevant specification.

5.7 Information to be given in the relevant specification

When Test Qa is included in the relevant specification, the following details shall be given as far as they are applicable:

	Subclause
a) Requirements for pressure	5.5
b) Direction of application of pressure difference	5.5
c) Mechanical operation during conditioning	5.5
d) Requirements for leak rate	5.6

6   Test Qc: Container sealing, gas leak

6.1   Object

To determine the effectiveness of seals of specimens having an included gas-filled space (e.g. specimens not completely filled with impregnant).

6.2   Scope of Test Qc

This test can be used for the detection of leak rates greater than (100, 10 or 1) Pa · cm^3/s according to the method chosen.

Test Methods 1 and 3 are applicable only to specimens that are able to withstand full decompression and the compression necessary for the impregnation without suffering distortion or permanent physical damage.

Test Method 2 is applicable to all specimens subject to a significant thermally generated pressure differential being achieved at the maximum ambient temperature of operation of the specimen.

Guidance on Test Qc is given in Annex B.

6.3   General description of the test

The detection of gross leaks is achieved by submerging the test specimen in a suitable liquid, under controlled conditions and by observing bubbles emanating from the specimen surface.

A positive internal pressure within the test specimen is generated by one of the following test methods:

a) Test Method 1

   Conducting the test in a vacuum environment, thereby increasing the pressure differential across the seals of the test specimen.

b) Test Method 2

   Through immersion in a test liquid maintained at an elevated temperature.

c) Test Method 3

   Through immersion in a test liquid, following impregnation with another liquid having a boiling point below the test temperature.

6.4   Test Method 1

The test chamber containing the bath required for this test shall be capable of being evacuated, and the bath shall contain sufficient liquid to enable the specimens to be immersed so that the uppermost surface of the specimen enclosure or seal to be tested is at a depth of not less than 10 mm below the surface. The test liquid shall be maintained at a temperature between 15 °C and 35 °C. The bath should be capable of being drained of the liquid or having the specimen removed from the liquid before breaking the vacuum.

Specimens shall be immersed in the test liquid with their seals uppermost. The pressure within the test chamber shall then be reduced within 1 min to a value of 1 kPa or as otherwise specified in the relevant specification. If no failure has been observed this pressure shall be maintained for another minute or any duration specified in the relevant specification.

Specimens possessing seals on more than one surface shall be tested with each surface in the uppermost position.

Failure criteria for this test shall be the observance of a definite stream of bubbles, or more than two large bubbles, or an attached bubble that grows at any time during the test.

6.5 Test Method 2

The bath required for this test shall contain sufficient liquid to enable the test specimens to be completely immersed to a depth of not less than 10 mm above the uppermost part of the enclosure or seal to be tested.

The liquid shall be maintained at a temperature of 1 K to 5 K above the maximum ambient temperature of operation for the specimen under test or at the temperature required in the relevant specification.

The specimens, which shall be at a temperature between 15 °C and 35 °C, shall be immersed in the test liquid with their seals uppermost for a period of at least 10 min, or as specified in the relevant specification.

Specimens possessing seals on more than one surface shall be tested with each surface in the uppermost position.

Failure criteria for this test shall be the observance of a definite stream of bubbles, or more than two large bubbles, or an attached bubble that grows at any time during the test.

6.6 Test Method 3

Test Method 3 consists of two steps.

a) Step 1

Step 1 shall be performed at ambient temperature.

The specimens shall be enclosed in a vacuum/pressure vessel and the pressure reduced to about 100 Pa for 1 h. After that time, and without breaking the vacuum, an impregnation liquid shall be drawn into the vessel until the specimens are covered by it.

The specimens shall then be pressurized under conditions as shown in Table 1.

Table 1 – Test conditions for Test Method 3, Step 1

Internal cavity volume	Minimum pressure (absolute)	Minimum duration
< 0,1 cm^3	600 kPa	1 h
> 0,1 cm^3	300 kPa	2 h

At the end of this impregnation time, the pressure shall be removed. The specimens shall be removed from the liquid and allowed to dry in air at ambient temperature for (3 ± 1) min or another duration specified in the relevant specification before performing Step 2.

b) Step 2

Test Method 2 shall apply, using a test temperature of (125 ± 5) °C, if not specified otherwise. The specimen shall be observed from the instant of immersion until 30 s after immersion, if not specified otherwise.

WARNING – The use of Test Method 3 can bear the risk of explosion, when a large specimen is likely to be filled with the impregnation liquid, that tends to vaporize rapidly during Step 2.

WARNING – The impregnation liquid can form toxic gases when boiled dry. Any direct contact with heating elements shall be prevented.

6.7 Information to be given in the relevant specification

When Test Qc is included in a relevant specification, the following details shall be given, as far as they are applicable:

	Clause or subclause
a) Test method	6.3, 6.4, 6.5, 6.6
b) Recommended liquid(s)	Annex B
c) Test Method 1: pressure and time, if different from 6.4	6.4
d) Test Method 2: liquid temperature, if different from 6.5	6.5
e) Test Method 2: immersion duration, if different from 6.5	6.5
f) Drying time if different from 3 min	6.6
g) Test Method 3: Step 2 temperature	6.6 b)

7 Test Qd: Container sealing, seepage of filling liquid

7.1 Object

To determine the effectiveness of seals of specimens filled with liquid. This test can also be used for specimens having a filling which is solid at room temperature, but which is liquid at the testing temperature.

7.2 Scope of Test Qd

This test can be used for the detection of leak rates corresponding to an air leak rate greater than about 1 Pa · cm^3/s. The sensitivity of the method depends on the kinematic viscosity of the liquid at testing temperature and the technique employed to detect seepage.

Guidance on Test Qd is given in Annex C.

7.3 General description of the test

The specimen is examined for seepage of liquid likely to occur when it is brought up to a temperature slightly higher than its maximum ambient temperature of operation.

7.4 Severities

A severity is defined as the period of time at which the specimen is maintained at the testing temperature. The relevant specification shall state the applicable severity chosen from the following list:

- 10 min;
- 1 h;
- 4 h;
- 24 h;
- 48 h.

7.5   Preconditioning

The specimen shall be so cleaned (degreased) that possible seepage of liquid is clearly contrasted with all other materials.

7.6   Initial measurements

There are no initial measurements required for Test Qd.

7.7   Conditioning

The specimens shall be placed in an air circulating oven, in which the air is heated until the temperature of the surface of the specimens is 1 K to 5 K above its maximum ambient temperature of operation. The specimens should occupy an attitude most favourable to reveal a leak.

The specimens shall be maintained at this temperature for a period of time according to the specified severity and shall then be removed from the oven.

Specimens having seals on more than one face shall be tested with each such face in the downward position in turn.

7.8   Final measurements

The specimens shall be visually inspected for seepage of liquid. There shall be no seepage, if not specified otherwise.

The relevant specification shall specify the method of detection.

7.9   Information to be given in the relevant specification

When Test Qd is included in a relevant specification, the following details shall be given as far as they are applicable:

		Subclause
a)	Test temperature	7.7
b)	Duration of conditioning	7.7
c)	Method of detecting seepage	7.8

8   Test Qf: Immersion

8.1   Object

To determine the watertightness of components or equipment or other articles when subjected to immersion under stated conditions of pressure and time.

8.2   General description of the test

The specimen is submitted to a specified pressure by immersion in a water tank at a specified depth or in a high-pressure water chamber. After conditioning, the specimen is examined for penetrated water and checked for possible changes of characteristics.

8.3 Initial measurements

The specimens shall be visually inspected and electrically and mechanically checked as required by the relevant specification. All sealing features shall be checked to ascertain that they have been correctly mounted.

8.4 Preconditioning

Preconditioning of the specimens and seals should be carried out where specified by the relevant specification.

8.5 Conditioning

The specimens shall be placed in the position as specified in the relevant specification and shall be completely immersed in a water tank or high-pressure water chamber. Detensioned water shall be used, if not specified otherwise. This can be achieved by adding a commercially available wetting agent to the water.

The specimens shall be subjected to one of the head-of-water values or the corresponding pressure differences given in Table 2, as required by the relevant specification.

Table 2 – Head-of-water and corresponding pressure differences

Head of water m	Corresponding pressure difference (at 25 °C) kPa
0,15	1,47
0,40	3,91
1	9,78
1,50	14,7
4	39,1
6	58,7
10	97,8
15	147,0

When a tank is used, the specified head of water shall be measured above the highest point of the specimen. When a high-pressure water chamber is used, the water pressure shall be adjusted to the pressure difference of Table 2.

The duration shall be specified in the relevant specification. Preferred values shall be 30 min, 2 h, 24 h. The temperature of the specimen and of the water shall be between 15 °C and 35 °C. During the conditioning period the difference in temperature between the water and the specimen shall be as small as possible, but not greater than 5 K.

During immersion, the specimen under test shall not be in operation, it shall be switched off and its movable parts shall be at rest, if not specified otherwise.

8.6 Recovery

The specimen shall be thoroughly dried externally by wiping or by applying a blast of air at room temperature, unless otherwise specified by the relevant specification.

8.7 Final measurements

The specimen shall be examined for water penetration and shall be visually inspected and electrically and mechanically checked as required by the relevant specification.

8.8 Information to be given in the relevant specification

When Test Qf is included in the relevant specification the following details shall be given as far as they are applicable:

	Subclause
a) Electrical and mechanical checks prior to conditioning	8.3
b) Preconditioning procedure	8.4
c) Position during conditioning	8.5
d) Whether a wetting agent may be used or not	8.5
e) Head-of-water or pressure difference	8.5
f) Duration of conditioning	8.5
g) Electrical and mechanical checks after recovery	8.7

9 Test Qk: Sealing tracer gas method with mass spectrometer

9.1 Object

To verify the hermetic sealing of specimens by evaluating the leak rates with a tracer gas and a mass spectrometer.

Helium is the tracer gas most used with a mass spectrometer and the test has been written with reference to this gas.

9.2 Scope of Test Qk

Test Method 1 is primarily applicable to specimens of small volume whose surfaces are not likely to impair the results by too high a retention of adsorbed helium (such as braids, joints, organic materials, paint) unless they have been suitably neutralized before the detection phase.

Test Method 2 is intended for specimens that have been filled, during manufacture or for the requirements of this test, with a mixture containing a large proportion of helium.

Test Method 3 (jet and pocket methods) is intended for specimens to be mounted on bulkheads or panels.

Test Method 3 should be used judiciously, because it is possible to release sufficient helium into the room to swamp the spectrometer, resulting in the suspension of the test until the room has been ventilated.

The method should not be used where a numerical acceptance limit for leak rate is specified (see Annex E). Owing to this fact, acceptance criteria should be specified between all parties.

9.3 General description of the test

Test Method 1 consists of impregnating the specimen, which has been previously carefully cleaned and dried, by placing it in a chamber containing a pressurized helium mixture. Helium penetrates the inner volumes of the specimen. After a given time, the specimen is placed in a chamber which is then pumped out and connected to a mass spectrometer. Helium that exudes out of the specimen is pumped into the mass spectrometer and its outflow is measured. The measured helium leak rate can then be transformed by calculation into the equivalent standard leak rate to make possible the comparison of specimens of similar volumes tested under different conditions. The comparison between specimens having different volumes can still be significant if one compares the ratios

$$\theta = \frac{p_o V}{L} \qquad\qquad (1)$$

which are the time constants of the specimens concerned. The interrelation of the test parameters is described in Annex D, guidance on Test Qk is given in Annex E.

Test Method 2 is like Test Method 1 except for the impregnation phase which is omitted. This test shall normally be completed within 30 min after sealing. For large specimens, depending on the internal volume and the thickness of the envelope, a longer delay can be necessary. In the case of small specimens, it shall be carried out immediately after sealing.

It is not suitable for general hermetic seal testing such as that required at the end of other environmental tests.

Immersion and detection pressures shall be so chosen that they are compatible with the greatest possible pressure the specimen can withstand without seal deterioration.

If no leak is detected by this test, Test Qc or an equivalent test is applied to the specimen.

Test Method 3 consists of exposing one side of the specimen to a vacuum by placing it against a suitable orifice of a vacuum chamber connected to a mass spectrometer. The visible side of the specimen is then covered by a sealed flexible pocket filled with helium (alternative a)) or swept by a fine jet of helium (alternative b)).

Alternative a): If leaks occur, some of the helium in the pocket is sucked into the vacuum chamber. The size of the fault (but not its location) can be determined from the readings on the mass spectrometer.

Alternative b): Helium is detected by the detector when the helium jet passes over a sealing fault (leak). The location and size of the leak can then be determined from the readings on the mass spectrometer.

9.4 Test Method 1

9.4.1 General

Test Method 1 is commonly used for specimens that are not filled with helium during manufacturing.

9.4.2 Severities

A severity is defined as the minimum time constant required for the application. The relevant specification shall state the applicable severity chosen from Table 3. In cases where it is necessary to specify a different severity, the relevant specification shall state all relevant test parameters (see Annex D).

Table 3 – Severities and test conditions (and corresponding equivalent standard leak rates)

Immersion pressure (absolute) $Pa \cdot 10^5$	Immersion time (minimum) t_1 min	Severity 6 h ($\theta = 2 \cdot 10^4$ s) Internal volume V cm³	Severity 6 h Measured leak rate (maximum) R Pa·cm³/s	Severity 60 h ($\theta = 2 \cdot 10^5$ s) Internal volume V cm³	Severity 60 h Measured leak rate (maximum) R Pa·cm³/s	Severity 600 h ($\theta = 2 \cdot 10^6$ s) Internal volume V cm³	Severity 600 h Measured leak rate (maximum) R Pa·cm³/s	Severity 1 000 h ($\theta = 2 \cdot 10^6$ s) Internal volume V cm³	Severity 1 000 h Measured leak rate (maximum) R Pa·cm³/s	Equivalent standard leak rate L Pa·cm³/s
2	70									
3	45									
4	30				0,01 to 0,1	10^{-5}	0,02 to 0,2	10^{-5}	$5 \cdot 10^{-4}$ to $1,5 \cdot 10^{-3}$	
5	30									
8	20									
2	70									
3	45									
4	30			0,01 to 0,1	10^{-3}	0,1 to 1,0	10^{-4}	0,2 to 2,0	10^{-4}	$5 \cdot 10^{-3}$ to $1,5 \cdot 10^{-2}$
5	30									
8	20									
2	70									
3	45									
4	30	0,01 to 0,1	0,1	0,1 to 1,0	10^{-2}	1,0 to 10	10^{-3}	2,0 to 20	10^{-3}	0,05 to 0,15
5	30									
8	20									
2	240									
3	160									
4	120	0,1 to 1,0	2	1,0 to 10	0,5	10 to 100	0,05	20 to 200	10^{-2}	0,5 to 1,5
5	90									
8	60									
2	480									
3	320									
4	240		5		1		0,1		0,05	0,5 to 1,5
5	190									
8	120									

9.4.3 Preconditioning

The specimen shall be so cleaned that contaminants such as grease, fingerprints, flux and lacquer which are likely to conceal leaks or to adsorb helium are removed. After cleaning, the specimen shall be stoved dry to eliminate traces of solvents, capillary condensations, etc., which can conceal existing leaks. The test shall be conducted on a specimen without any external attachment likely to entrap helium. A preliminary study should be made for each individual technology used to optimize the preconditioning process.

9.4.4 Initial measurements

There are no initial measurements required for Test Method 1.

9.4.5 Test parameters

The test parameters and the acceptable limit for the measured leak rate R are given in Table 3, as a function of internal volume of the specimen, according to the severity and test method chosen by the relevant specification. The interrelation of the test parameters is described in Annex D.

9.4.6 Conditioning

Guidance on Test Qk is given in Annex E.

The specimen shall be placed in a sealed chamber.

When the maximum immersion pressure called for by the relevant specification is not greater than 200 kPa (absolute), one of the following procedures shall be used at the option of the experimenter:

– either reduce the pressure within the chamber to an absolute value of the order of 0,1 kPa to 1 kPa;

– or sweep the chamber with helium.

When the immersion pressure called for by the relevant specification is greater than 200 kPa, neither of the above procedures is required.

The chamber shall be filled with a helium mixture, containing 95 % helium minimum, if not specified otherwise, and then pressurized at an absolute pressure and for a length of time chosen from Table 3. The pressure shall not be greater than the maximum pressure stated by the relevant specification for this type of device.

NOTE   The immersion time t_1 and measured leak rate R are interrelated with immersion pressure p, the minimum time constant θ (severity) and equivalent standard leak rate L (see Table 3). A nomogram for a quick computation of these interrelated parameters is given in Figure D.1, and explanations in Annex D.

9.4.7 Recovery

After it has been removed from the pressure vessel, the specimen shall be subjected to standard atmospheric conditions for testing in order to eliminate helium adsorbed by external surfaces and so avoid unacceptable parasitic signals during the final measurements. Dry gas blowing is permissible for accelerating recovery.

9.4.8 Gross leaks

Before this test, the absence of gross leaks shall be checked by using any suitable method, such as those described in Test Qc, as specified by the relevant specification.

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9.4.9 Final measurements

The specimen shall be transferred to a chamber connected to the leak detector system which is so depressurized that the mass spectrometer can operate normally.

The helium measured leak rate R is then determined by comparison with that of a calibrated standard leak. It shall be smaller than the maximum value given in Table 3 for the minimum time constant θ (severity) required by the relevant specification.

The determination of the measured leak rate R should preferably be completed within 30 min of removal from the pressurizing vessel, unless practical experience reveals that a longer ventilation time is necessary to consider the resorption effects.

NOTE   The effect of a longer ventilation time can be estimated using the information given in Annex D.

9.5   Test Method 2

9.5.1   General

Test Method 2 is commonly used for specimens filled with helium during manufacturing or for the requirements of this test.

9.5.2   Preconditioning

The specimen shall contain a gaseous mixture where the helium concentration is equal to or greater than 25 % in terms of pressure. Periodical checks shall be made to ensure that the gas mixture used contains the required concentration of helium.

If appropriate, the relevant specification shall state any necessary mounting conditions.

9.5.3   Initial measurements

There are no initial measurements required for Test Method 2.

9.5.4   Conditioning

There is no further conditioning required for Test Method 2 as the specimens are already prepared.

9.5.5   Gross leaks

In addition to this test, the absence of gross leaks shall be checked by using any suitable method, such as those described in Test Qc, as specified by the relevant specification.

9.5.6   Final measurements

Upon completion of the seal, the specimen shall be transferred to a chamber connected to a mass spectrometer type leak detector, which is then depressurized so that the mass spectrometer can operate normally.

The measured leak rate R is determined by comparison with that of a calibrated standard leak. This measurement shall be completed within 30 min after specimen sealing except for special conditions.

The measured leak rate R is converted to the time constant θ by applying the following formula:

$$\theta = 2{,}7\frac{cVp_0}{R} \qquad (2)$$

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where

V is the internal volume of the specimen (cm^3);

c is the actual concentration of helium in the gaseous mixture in use (cm^3/m^3);

p_o is the atmospheric pressure (10^5 Pa);

R is the measured leak rate of helium (Pa · cm^3/s);

θ   is the required time constant (s).

The relevant specification shall state the minimum time constant or the maximum acceptable equivalent standard leak rate L. Suggested values for the time constant are $2 \cdot 10^5$ s and $2 \cdot 10^4$ s.

9.6 Test Method 3

9.6.1 General

Test Method 3 is commonly used for specimens to be mounted on bulkheads or panels.

9.6.2 Preconditioning

Clean the specimen to remove all contaminants, such as grease, fingerprints, flux or varnish, likely to conceal leaks. After cleaning, dry the specimen in an oven to remove all trace of solvents, capillary condensation, etc., which can also conceal leaks.

9.6.3 Initial measurements

With the measuring orifice hermetically isolated from the chamber by a valve, evacuate the chamber, and when the pressure is sufficiently low to allow proper functioning of the mass spectrometer, connect the chamber to the latter.

NOTE   The residual signal is caused by the spectrometer with no helium injection.

Check the proper functioning of the spectrometer with a reference helium leak.

9.6.4 Conditioning

Place the specimen over the measuring orifice and expose it to the vacuum by opening the isolating valve. Check that the depression remains sufficient for the proper functioning of the mass spectrometer and continue evacuating until the residual signal stabilizes itself at a value approximately equal to that recorded previously.

Alternative a): Cover the outer side of the specimen with a flexible pocket, of plastic for example, filled with helium. Note the readings of the mass spectrometer.

Alternative b): Sweep the whole outer side of the specimen with a fine jet of helium at low pressure. Note the readings of the mass spectrometer.

If possible, the helium pressure should be specified in the relevant specification.

9.6.5 Final measurements

The measured leak rate R is then determined by comparison with that of the reference leak, the residual signal being deducted.

9.7   Information to be given in the relevant specification

		Subclause
a)	Test method	9.2 and 9.3
Test Method 1		
b)	Severity	9.4.2
c)	Test parameters	9.4.5
d)	Test parameters (special cases)	Annex D
e)	Maximum immersion pressure allowed for the type of device	9.4.6
f)	Gross leaks: detection method to be used	9.4.8
Test Method 2		
g)	Time constant	9.5.3
h)	Gross leaks: detection method to be used	9.5.4
i)	Mounting conditions (if necessary)	9.5.2
Test Method 3		
j)	Alternative a) or b)	9.6.4
k)	Helium pressure	9.6.4
l)	Acceptance criteria	9.2

10 Test QI: Bomb pressure test

10.1   Object

To determine the effectiveness of seals of specimens whose electrical characteristics will be affected by penetration of liquid.

10.2   Scope of Test QI

This test can be used for the detection of leaks which would result in air leak rates greater than $1 \text{ Pa} \cdot \text{cm}^3/\text{s}$. It is applicable only to specimens that can withstand external overpressure.

Guidance on Test QI is given in Annex F.

10.3   General description of the test

This method consists in allowing a test liquid to penetrate through a leak to the interior of the specimen under test. This method is commonly known as the bomb pressure test.

The test liquid shall possess the property of producing detectable changes in the electrical characteristics of the specimen. Test liquids such as water or a mixture of water and alcohol are widely used. In each case, it should be verified that the test liquid does not react chemically with the surface of the specimen.

Assessment of the leak is achieved by measuring those specified electrical parameters which are influenced by the penetration of the test liquid (for example a suitable alcohol). Adding pigment to the test liquid can show the path of penetration after opening the specimen under test. As it usually requires some time for the penetration of the test liquid to affect the electrical characteristics, repeated measuring, separated by short periods of storage, can be necessary.

The maximum sensitivity of the method is limited at approximately $1 \text{ Pa} \cdot \text{cm}^3/\text{s}$. No quantitative information on the leak rate can be obtained.

10.4 Initial measurements

The specimens shall be visually inspected and electrically and mechanically checked as required by the relevant specification.

10.5 Conditioning

The pressure vessel (bomb) shall contain the type of test liquid as required by the relevant specification. The test liquid shall be alcohol or water with a detergent or both, if not specified otherwise.

The test liquid shall be at standard atmospheric conditions for testing or at the temperature specified by the relevant specification. The specimens shall be placed in the pressure vessel in such a manner that they are fully submerged in the test liquid.

The pressure within the test vessel shall be raised to the value specified in the relevant specification. The maximum pressure depends mainly on the construction of the specimen. It should normally not exceed 500 kPa (50 N/cm^2).

The duration of the conditioning shall be as specified by the relevant specification but shall normally be not more than 16 h. In special cases, i.e. when using lower pressures, the duration may be raised to 24 h.

The duration of the conditioning can be reduced when the pressure is raised, but care should be taken that the applied pressure does not exceed the maximum value the specimen can withstand. A pressure of 250 kPa/cm^2 (25 N/cm^2) is sufficient for a number of applications.

The pressure in the vessel shall then be reduced to atmospheric pressure and the specimens shall be removed from the vessel.

10.6 Recovery

If required by the relevant specification, the specimens shall be cleaned by means of a suitable liquid. In this case, the type of cleaning liquid shall be specified in the relevant specification. The specimens shall be dried by applying a blast of air at laboratory temperature for a short period.

The specimens shall then be subjected to standard atmospheric conditions for recovery for a period as required by the relevant specification.

10.7 Final measurements

The specimens shall be visually inspected and electrically and mechanically checked as required by the relevant specification. In case of doubtful results the measurements shall be repeated after a suitable recovery period.

10.8 Information to be given in the relevant specification

When Test Ql is included in a relevant specification, the following details shall be given as far as they are applicable:

	Subclause
a) Measurements prior to conditioning	10.4
b) Type of test liquid	10.5
c) Temperature of the test liquid	10.5
d) Pressure in the test vessel	10.5
e) Duration of conditioning	10.5
f) Cleaning and type of liquid	10.6
g) Duration of recovery	10.6
h) Measurements after recovery	10.7
i) Repeated recovery and repeated measurements	10.7

11 Test Qm: Tracer gas sealing test with internal pressurization

11.1 Object

To define methods for measuring fine leaks by accumulation or for detecting them by probing using a tracer gas easily separable from air components, for example sulphur hexafluoride.

11.2 Scope of Test Qm

This test is applicable to any specimen able to withstand internal pressurization. It allows the detection of leak greater than approximately 10^{-8} Pa $\cdot$ m^3/s.

11.3 General description of the test

11.3.1 Total method and local method

From a single operation the total leak flow can be determined, but not, simultaneously, the number of leaks or their location. It is therefore necessary to distinguish "total methods", allowing the measurement of the total leak flow, from "local methods", allowing the location of individual leaks for rectification if required.

EXAMPLE   The cumulative test is a "total method"; the probing test is a "local method".

Another possibility is an "intermediate method" in which the leak is accumulated (total method) from a part of the specimen (partial localization) and this intermediate method then applied to every part of the specimen.

11.3.2 Corresponding leak rate

When the tracer gas is only one component of the gas mixture in the specimen, the measured leak rate shall be multiplied by a correction factor which can generally be taken as the ratio of the total internal pressure to the partial pressure of the tracer gas.

If the test pressure is different from the service pressure, the leak rate can generally be extrapolated linearly with the absolute pressure, assuming that the leak rate is of an order equal to, or less than, 10^{-6} Pa $\cdot$ m^3/s and that the pressure change does not modify the shape of the leak path.

If the test gas is different from the service gas, the conversion law can be determined by tests or calculated. Generally, the ratio of fine leaks is inversely proportional to the square root of the ratio of the apparent molecular masses (the apparent molecular mass for air is 29).

11.3.3 Test Method 1: Cumulative test

The specimen of which the sealing shall be assessed is internally pressurized with a tracer gas. After allowing time for the leak rate to stabilize, the whole specimen (or a part of its surface) is enclosed in a gastight sheath in which the gas leaking from any defects accumulates for a measured duration. This collected gas is then measured and the leak rate calculated.

11.3.4 Test Method 2: Probing test

The specimen in which any leaks shall be detected is internally pressurized with a tracer gas. After allowing time for the leak rate to stabilize, the probe of a leak detector is placed near to the specimen and moved over its surface. If the concentration of tracer gas reaches the threshold level of the detector, it gives a signal permitting the leak to be localized. The probing test does not allow the leak rate to be measured. Nevertheless, it is sometimes possible to estimate if a given leak rate has been exceeded. In those cases, the need to know the threshold level of the leak detector and the testing conditions (ambient pollution level, speed of traverse of the probe, nature of the specimen, etc.) should be considered.

11.4 Preconditioning

Seal every unused opening carefully to avoid any interference with measurement of the leak from the part of the specimen under test. If an opening is to be used later, the sealing of connections to the added part should be tested. Clean and dry the specimen.

The relevant specification shall specify any additional preconditioning.

11.5 Conditioning

11.5.1 General

The relevant specification shall specify:

a) the method to be used (Test Methods 1 or 2 or "intermediate");
b) whether the specimen is operating or not, and if not, its position (open, closed, cocked, etc.).

Further information on Test Qm is given in Annex G.

11.5.2 Test Method 1: Cumulative test

11.5.2.1 Procedure

Pressurize the specimen. The relevant specification shall specify the test pressure. If the filling gas is to be reused, pressurization is generally preceded by evacuation.

Wait for the time specified by the relevant specification to allow the leak rate to stabilize.

Place in position the sheath determining the volume of measurement and measure the initial tracer gas concentration C_0 at time t_0.

After a time depending on the sensitivity, measure the final concentration C_1 at time t_1.

NOTE   It is also possible to perform a cumulative test with an all-or-nothing meter with a known threshold level by arranging for the initial concentration to be, for practical purposes, zero, and inserting the probe in the volume of measurement at uniform time intervals until the signal occurs.

11.5.2.2 Interpretation of the results

Meter readings can be converted into concentrations using a calibration chart that is periodically checked.

The leak rate R for a specimen is calculated by the formula:

$$R = \frac{V_{\mathrm{m}}\,(C_1 - C_0)}{t_1 - t_0}\,10^{-6}\,p_{\mathrm{e}} \qquad (3)$$

where

R	is the leak rate (Pa · m^3/s);
V_{m}	is the capacity of the volume of measurement (m^3);
$t_1 - t_0$	is the time interval (s);
C_1 and C_0	are the tracer gas concentrations (cm^3/m^3);
p_{e}	is the pressure at the outer surface of the specimen, that is 10^5 Pa.

The specimen shall be considered as accepted if the measured leak rate does not exceed the maximum value that shall be admitted by the relevant specification.

11.5.3 Test Method 2: Probing test

11.5.3.1 Procedure

Pressurize the specimen. The test pressure shall be that specified by the relevant specification. If the filling gas is to be reused, pressurization is generally preceded by evacuation.

Wait for the time specified by the relevant specification to allow the leak rate to stabilize.

Move the probe slowly over the surface of the specimen, particularly near the places in which a leak is most likely (for example welds, gasketed connections between two parts). If a signal occurs, note the corresponding position of the probe.

In the general case where this method is used to locate leaks measured during a previous cumulative test, preconditioning (see 11.4) will already have been carried out.

11.5.3.2 Interpretation of the results

The test is successful if the leaks have been located.

11.6 Information to be given in the relevant specification

When Test Qm is included in a relevant specification, the following details shall be given as far as they are applicable:

		Subclause
a)	Whether the leak rate may be estimated using Test Method 2	11.3.4
b)	Additional preconditioning	11.4
c)	Method to be used (Test Methods 1 or 2 or "intermediate")	11.5.1 a)
d)	Whether the specimen is operating or not, etc.	11.5.1 b)
e)	Test pressure and time for stabilization for the test gas	11.5.2.1 11.5.3.1
f)	Maximum leak rate	11.5.2.2

12 Test Qy: Pressure rise sealing test

12.1 Object

To determine the effectiveness of seals of specimens with an enclosed gas-filled (air or inert gas) space e.g. a component not filled with impregnant. This test method facilitates automatic testing on components produced in high volume.

12.2 Scope of Test Qy

The test can be used for the detection of leak rates down to approximately 10^{-5} Pa $\cdot$ m^3/s. It is applicable only to components able to withstand the necessary decompression during the test, without suffering permanent distortion or other damage, such that the extent of any potential source of leak is changed and that the internal volume is smaller or equal to 5 cm^3.

12.3 General description of the test

12.3.1 Test method

The test method consists in observing the rate of the pressure rise in a test chamber containing the test specimen when the rapid evacuation required to reach the adequate low level of pressure is stopped, suddenly and after a predetermined time.

Guidance on Test Qy is given in Annex H.

12.3.2 Test equipment

Figure 2 illustrates a typical installation for the sealing test using the pressure rise test procedure.

With the air inlet open, the specimen is placed and sealed in the test chamber. After closing the inlet valve the chamber is rapidly evacuated until a pressure of between 3 kPa and 4 kPa is reached. The pump valve is then closed, and the pressure rise Δp is recorded in the test chamber (in the volume of measurement) occurring during a test time Δt. The result obtained is used to calculate the leak rate.
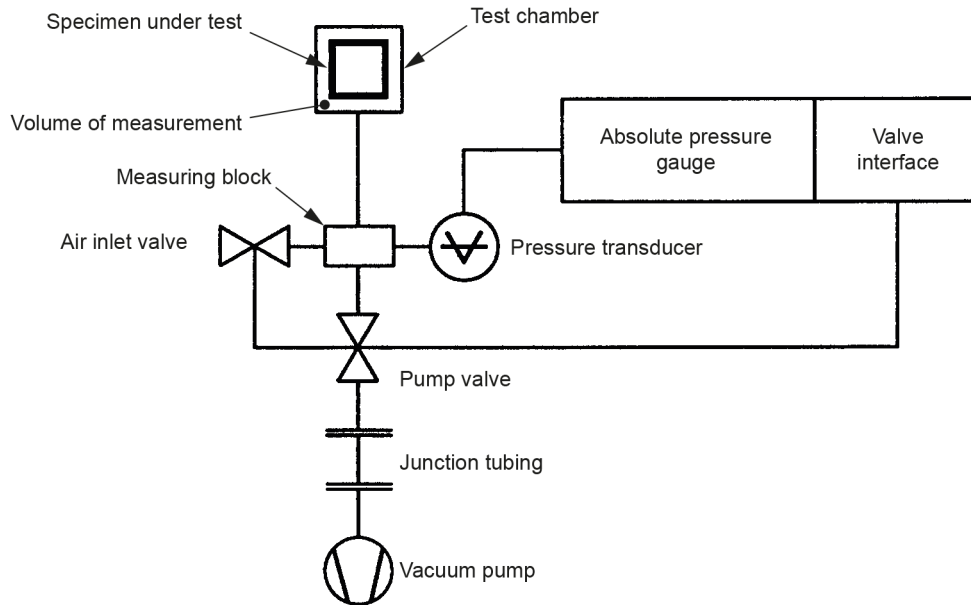
Figure 2 – Typical installation for sealing test using the pressure rise test procedure

The test sequence should preferably be directed by a suitable control system. The capacity of the vacuum pump shall enable the low pressure of 3 kPa to be reached within the predetermined evacuation time. The suction volume of the vacuum pump shall fit the air volume to be evacuated. To achieve a volume of measurement as small as possible, the pressure in the volume of measurement shall be detected by using a piezoelectric transducer.

Figure 3 shows the behaviour of the test chamber pressure during the test procedure.
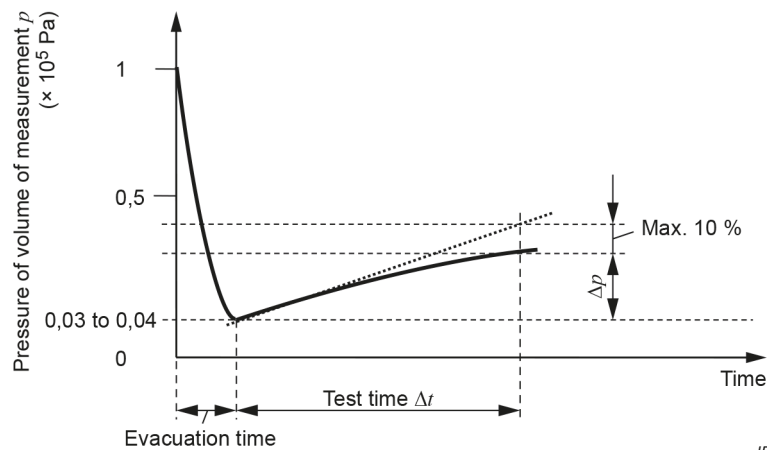
Figure 3 – Pressure of volume of measurement versus time during the sealing test using the pressure rise test procedure

12.3.3 Calculation of the leak rate R

The leak rate R is calculated according to the following formula:

$$R = \frac{\Delta p \times V_{\mathrm{m}}}{\Delta t} \qquad (4)$$

where

Δp is the pressure rise during the test time Δt (Pa);

V_m is the volume of measurement (m³);

Δt is the test time (s).

The specimen shall be considered as accepted if the measured leak rate does not exceed the maximum value admitted by the relevant specification.

12.4 Calibration of the test equipment

The test equipment shall be calibrated with a calibrated specimen. The pressure rise obtained using the calibrated specimen instead of a test item represents a constant, which shall always be subtracted from the measured total pressure rise Δp. For the calibration of the test equipment, the vacuum pump shall be operated with the same flow and for the same duration as for the test.

12.5 Test time

The test time should be no longer than the time required to allow a maximum of 10 % deviation from the linear extrapolation of the pressure increase curve (see Figure 3). Assuming this curve has an exponential behaviour with a time constant τ, the test time Δt chosen should not be greater than approximately $0,2\ \tau$.

The evacuation time necessary to reach low pressure should not be longer than approximately 5 % of the time constant mentioned above. In practice, an evacuation time of 0,02 s to 0,5 s and a test time of 1 s to 10 s may be adequate.

To determine the evacuation time required, a calibrated specimen should be used. This shall be either a specially made dummy with size, form and surface materials equal to the test piece, or a completely gas-tight specimen showing the behaviour illustrated in Figure H.1 a).

Figure H.1 shows limiting cases of the behaviour of the pressure in the test chamber.

12.6 Evaluation of the volume of measurement

The volume of measurement is the total space which shall be evacuated. For its evaluation, any suitable physical measuring method may be used.

A possible procedure consists in connecting one end of a U-tube to the inlet valve leaving the other one open to the ambient atmosphere. The tube is filled with a liquid of low vapour pressure such as oil. Displacements of the fluid column shall be calibrated in volume and pressure units. After the calibration, with the air inlet open, the specimen is placed and locked into the test chamber at ambient pressure. The inlet valve is then closed and the test chamber evacuated to the low test pressure. The pump valve is then closed and the inlet valve opened. From the volume of the incurred displacement of the fluid, the volume of measurement V_m can be determined up to first-order corrections according to the following formula:

$$V_m = \Delta V_f + \Delta V_f \frac{p}{p_o} + V_d \frac{p_d}{p_o} \tag{5}$$

where

V_m is the volume of measurement;

ΔV_f is the volume of the displacement of the fluid column;

V_d is the air volume between the inlet valve and fluid at ambient pressure p_o;

p_o is the ambient pressure;

p is the pressure in the test chamber after the required low test pressure has been reached;

p_d is the pressure exerted by the displacement of the fluid column.

12.7 Information to be given in the relevant specification

When Test Qy is included in a relevant specification, the following details shall be given, insofar as they are applicable:

		Subclause
a)	Maximum leak rate	12.3.3
b)	Test time Δt	12.3.3

13 Information to be given in the test report

As a minimum, the test report shall provide the following information:

a)	customer	(name and address);
b)	test laboratory	(name and address and details of accreditation - if any);
c)	test dates	(dates when test was run);
d)	type of test	(Qa – Qy, test methods);
e)	test standard, edition	(IEC 60068-2-17, edition used);
f)	test specimen description	(drawing, photo, quantity build status, etc.);
g)	test chamber identity	(unique identity of the chamber, e.g. internal Laboratory Identification number/code);
h)	initial, intermediate and final measurements, if applicable	(if performed by the test laboratory);
i)	required severities	(from relevant specification);
j)	test severities	(measuring points and positions, data, duration, etc.);
k)	further test parameters	(test pressures or pressure difference, direction of application of pressure difference, test temperatures, etc.; from relevant specification);
l)	recommended test medium	(liquids, wetting agent, etc.);
m)	performance of test specimens	(results of functional tests, e.g. leak rates);
n)	observations during testing and actions taken	(any pertinent observations, methods of detection);
o)	test results	(test summary, e.g. pass/fail decision).

In addition to the mandatory information the test report can include, for example:

p) purpose of test   (development, qualification, etc.);

q) relevant laboratory test procedure   (code and issue);

r) performance of test apparatus   (set point temperature control, air flow, etc.);

s) uncertainties of chamber independent measuring system   (uncertainties data);

t) calibration data   (last and next due date);

u) duration or time allowed for stabilization of the leak rate   (from the time of pressurization to the beginning of probing, Test Qm);

v) recorded locations of detected leaks

w) factors for converting test measurements into equivalent results under rated service conditions   (Test Qm, if applicable);

x) further information on test specimen   (internal volume, etc.).

A test log should be written for the testing which can be attached to the report.

Annex A
(informative)

**Example of an apparatus for Test Qa:
Sealing of bushes, spindles and gaskets**

A.1 Principle of operation

The component is mounted on the lid of a small, sealed test chamber which, in turn, is fitted with an air inlet nozzle, air line and valve (see Figure A.1).
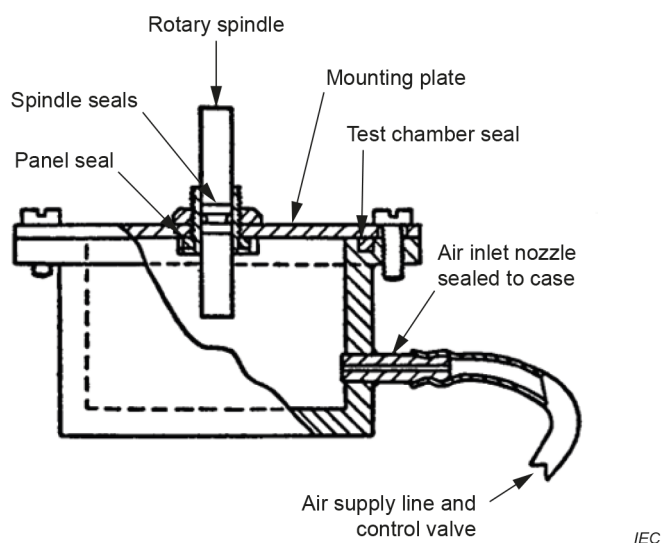

Figure A.1 – Chamber for sealing test (Test Qa)

Air is then pumped into the sealed component, or test chamber, until the desired air pressure for the test is reached. The whole is then submerged in a liquid at the specified test temperature. If the test component leaks, a stream of air bubbles will be observed escaping from it.

An example of an apparatus is shown in Figure A.2. A transparent funnel is fitted with a long tube, the end of which can be sealed by a tap. The funnel is submerged in the liquid with the tap open. Liquid is then drawn up the tube until it is filled and the tap is then closed. The tube is held in a vertical position and the mouth of the funnel moved over the test component so that the stream of air bubbles can be collected. The transparent funnel or collector enables this to be done quickly. The air bubbles rise and travel up the neck of the funnel into the tube and collect at the top causing a depression of the liquid column. The rate of depression of the liquid meniscus is a measure of the leak rate and can be measured by means of a calibrated scale and a timing mechanism, the air leak rate being expressed in the form of cubic capacity per unit time.

The apparatus will operate over a wide temperature range providing suitable liquids are chosen which at low temperature have a low viscosity and at high temperature remain stable almost to boiling point. Stability here means the non-escape of gases (or other movement which would mask the escape of air bubbles) and a low volatility. Alcohol is a suitable liquid for the low-temperature tests or paraffin for the high-temperature tests.
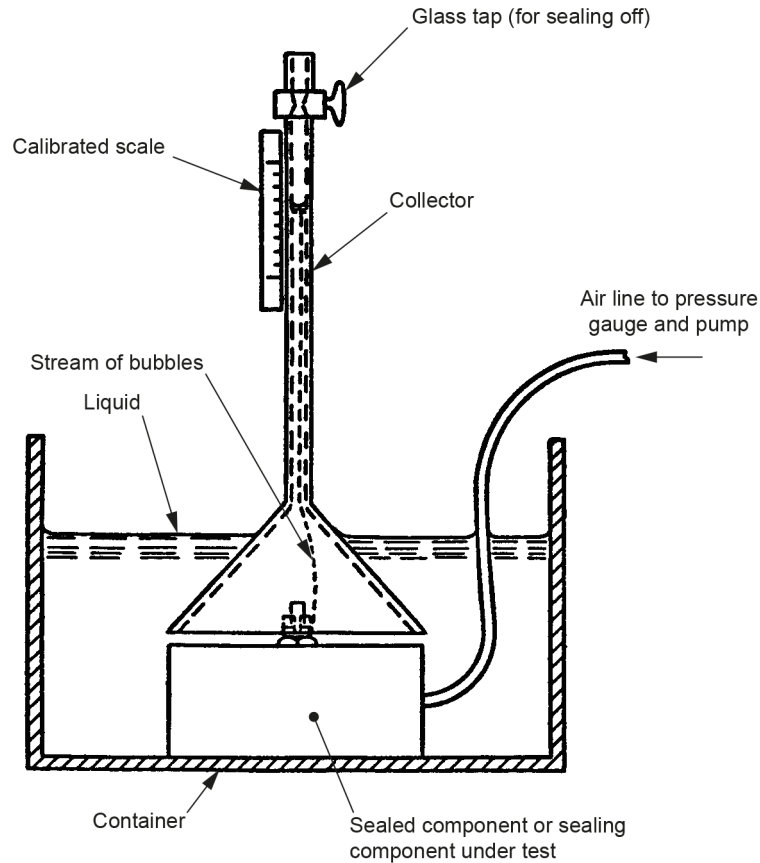
Figure A.2 – Example of an apparatus for sealing test (Test Qa)

A.2   Operation of example apparatus

The liquid in the container is first brought to the required temperature of the test and then constantly stirred to maintain a uniform temperature in the liquid during the period of the test.

NOTE   A temperature deviation from the required temperature or a non-uniform temperature distribution can affect the test results.

The air in the test chamber is compressed to the requisite pressure which the test condition demands. The test chamber is then carefully immersed in the liquid and the position of any leak is immediately disclosed by a stream of air bubbles rising to the surface. A suitable time interval should be allowed for the component to attain temperature stability.

The monitoring of the temperature of the component is recommended. A representative point (or points) on (or inside) the component may be used for this measurement.

The funnel of the collector is placed in the liquid with its mouth submerged and some of the liquid is drawn up the tube by suction.

The funnel end is then moved over the stream(s) of air bubbles so that they are all collected and rise up the neck into the tube. The collector tube should be kept vertical and the mouth of the funnel should be maintained at the same depth as used for calibration purposes.

The tube of the collector is calibrated in cubic centimetres and any leak rate can be calculated by measuring the depression of the liquid meniscus during a known interval of time. The result can be readily expressed in cubic centimetres per hour.

A.3 Calibration and accuracy

The collector can be calibrated by drawing up a quantity of liquid into the tube and sealing off. A hypodermic syringe is then used as an air pump and known volumes of air are injected, in steps, through the liquid into the mouth of the funnel. At each step, the level of the displaced liquid is marked on the tube, or its scale, until a suitable complete scale is obtained. During calibration, the mouth of the funnel should be kept at a constant depth of immersion, otherwise a small calibration error can occur, due to a change in pressure in the column, caused by any variations in the head of liquid.

The air-leak rate can be measured at any temperature or pressure provided the whole of the tube and scale is maintained at the specified temperature. Normally, leak rates are expressed at room temperature and pressure; this can readily be done because the collected air at the top of the tube quickly attains room temperature.

The overall accuracy of measurement of leak rates depends on the individual accuracy of measurement of a number of factors, the chief being:

a) the air pressure;

b) the stability of the air pressure;

c) the volume of air in the collector tube;

d) the time taken to attain a specified volume;

e) the head or pressure of the liquid in the collector tube;

f) the temperature of the liquid.

The errors introduced by the measurement of pressure a) are directly proportional to the leak rate and this percentage error, together with the errors introduced by the measurement of temperature f), can be assumed to be the overall accuracy of the apparatus since the errors introduced by b), c), d) and e) will normally be very small compared with a) and can, therefore, be ignored.

Annex B
(normative)

Further requirements for Test Qc: Container sealing, gas leak

B.1 General

The information derived from Test Qc is only of a semi-quantitative nature, indicating individual leak paths and not the total leak associated with the specimen.

When using the optimum test conditions, Test Method 1 can achieve a sensitivity of $10 \text{ Pa} \cdot \text{cm}^3/\text{s}$, Test Method 2 a sensitivity of $100 \text{ Pa} \cdot \text{cm}^3/\text{s}$ and Test Method 3 a sensitivity of $1 \text{ Pa} \cdot \text{cm}^3/\text{s}$. Varying severities can be achieved with Test Methods 1 and 2, by utilizing differing levels at vacuum and test liquid temperature, respectively. However, it should be borne in mind that some components can be damaged by subjecting them to overpressure or under pressure.

With Test Method 1 a pressure differential of 100 kPa can be achieved whereas Test Method 2 will produce a pressure differential in the range 12 kPa (55 °C) to 36,5 kPa (125 °C). Consequently, increasing the immersion time of Test Method 2 to 10 min should produce an approximate equivalence in severity with Test Method 1.

Specimens having seals on more than one surface require each surface to be tested separately. Consideration should be given to the possible need for recovery of the specimen prior to the testing of each surface, for example specimens having a small included gas-filled cavity can have this exhausted during the testing of one surface.

Observation should be made against a dull, non-reflective black background, under direct lighting adjusted to provide maximum visibility at the specimen position, through a 3× magnifier or stereozoom microscope arranged for the observation of bubbles emanating from the specimens immersed in the liquid.

With certain types of specimens, engineering judgement will be required to distinguish between "real" and "virtual" leaks, because of the gas retention capability of the material. In most instances the rate of bubbles or growth of bubbles issuing from a virtual leak, or both, will decrease as the source of gas is exhausted. It may also be suggested that a dummy specimen consisting at a solid block of the same material is used for comparison purposes.

Specimens should be as clean as possible and free from foreign material on the surface, including coatings and any markings if they can contribute in erroneous test results. During handling, ensure that there is no contact of bare fingers with critical parts of the specimen.

Test liquids should be chosen to behave in a stable condition throughout the test.

B.2 Test Method 1

For Test Method 1, the test liquid shall have the following characteristics:

kinematic viscosity at 20 °C:	$25 \cdot 10^{-6} \text{ m}^2/\text{s}$;
kinematic viscosity at 50 °C:	$9 \cdot 10^{-6} \text{ m}^2/\text{s}$;
ambient vapour pressure:	< 10 Pa.

A suitable liquid is oil. It should be degassed. Water with a wetting agent or any suitable liquid having a kinematic viscosity of not more than $25 \cdot 10^{-6}$ m^2/s at 20 °C may be used, but in this case, it should be considered that the sensitivity of the test will be impaired. The depression shall be limited by the risk of having the liquid boiling.

Since any initial frothing can mask bubbles due to leaks from the specimen sealing, it is essential that the reduced pressure in Test Method 1, be attained rapidly.

However, if the air space within the specimen is small or the leak rate is large, it is possible that the bubbles emerging through the sealing during the initial frothing will not be detected.

B.3   Test Method 2

Before selecting Test Method 2, assessment of the heating effect on the specimen should be considered, for example, in view of the closing or opening or both of leak paths.

For Test Method 2, water with a wetting agent can be used for test temperatures lower than 90 °C. For higher test temperatures suitable liquids should have a kinematic viscosity of the order of $0,3 \cdot 10^{-6}$ m^2/s at test temperature. In the latter case, commonly used liquids are fluorocarbons, for example, perfluorotributylamine or perfluoro (1-methyldecaline) .

The volume of the bath shall be at least 10 times the volume of the specimen and be suitable to immerse the uppermost surface or seal of the specimen to be tested at least 10 mm below the surface or as specified in the relevant specification.

B.4   Test Method 3

For Test Method 3, the impregnation liquid shall have a kinematic viscosity of the order of $0,4 \cdot 10^{-6}$ m^2/s at room temperature, a boiling point of approximately 60 °C and a low heat of vaporization at boiling point so as to quickly generate vapour within the specimen when Step 2 is performed. Commonly used liquids are fluorocarbons, for example, cyclic-perfluorodipropyl-ether or perfluoro-N-hexane, which shall be compatible with the liquid utilized in Step 2.

It is recommended to filter the liquids through finer paper before use. Testing should preferably be conducted in a well-ventilated location. When partially fluorinated fluids are used, there are additional risks incurred due to contamination from moisture and dissolved greases and the possibility of damage to markings or elements of the specimen.

WARNING – The use of Test Method 3 can bear the risk of explosion, when a large specimen is likely to be filled with the impregnation liquid, that tends to vaporize rapidly during Step 2.

WARNING – The impregnation liquid can form toxic gases when boiled dry. Any direct contact with heating elements shall be prevented.

Annex C
(informative)

Guidance on Test Qd: Container sealing, seepage of filling liquid

The sensitivity of the test method is influenced by the following factors:

a) The kinematic viscosity of the filling liquid: A low kinematic viscosity gives relatively high sensitivity.

b) Duration of conditioning: The quantity of seepage will be directly related to the duration of conditioning. As greater quantities of seepage are more easily detected the sensitivity of the test may be increased with the test duration.

c) Method of detection.

The simplest way to detect any seepage is by visual inspection. This method is only possible when the seeping liquid contrasts clearly in colour or reflection from the ground materials. If this is not the case then one of the following methods is recommended:

– Cover the surface of the specimen around the seals with a film of suitable dust. Discoloured spots in the dust film will indicate the presence of some seepage. For instance, a film of talcum powder is especially suitable for the detection of oily liquids or a film of potassium permanganate ($KMnO_4$) powder for watery liquids.

– Place the specimen on a clean blotting paper. Clearly visible spots will be produced by drops of coloured or oily liquids.

– Fluorescent liquids can be detected in ultra-violet light. This method is, for example, very sensitive for mineral oils, but fails for certain chlorinated oils.

Annex D
(informative)

**Interrelation of test parameters for Test Qk:
Sealing tracer gas method with mass spectrometer**

The measured leak rate (R) of helium is given, in terms at test conditions and equivalent standard leak rate (L) of air, and for a given temperature, by the equation:

$$R = L \frac{p}{p_o} \left(\frac{M_a}{M_h}\right)^{1/2} \left\{ 1 - \exp\left[-\frac{L}{Vp_o}\left(\frac{M_a}{M_h}\right)^{1/2} t_1\right]\right\} \exp\left[-\frac{L}{Vp_o}\left(\frac{M_a}{M_h}\right)^{1/2} t_2\right] \qquad (D.1)$$

where

R is the measured leak rate of helium (Pa · cm^3/s);

L is the equivalent standard leak rate (Pa · cm^3/s);

p is the absolute pressure of immersion (Pa);

p_o is the atmospheric pressure (Pa);

V is the internal volume of the specimen (cm^3);

M_a is the specific mass of air (1,29 g/l);

M_h is the specific mass of helium (0,18 g/l);

t_1 is the immersion time (s);

t_2 is the ventilation time, between release of pressure and end of detection (s);

$\dfrac{p_o V}{L} = \theta$ is the required severity (s) (p_o = 10^5 Pa).

This equation can be simplified if one takes into account that the atmospheric pressure is nearly equal to 10^5 Pa.

The influence of the temperature may be considered negligible in the usual range of test temperature (+15 °C, +30 °C). The equation may be reduced to:

$$R = \frac{7,17\, L^2\, pt_1}{10^{10}\, V} \quad \text{or} \qquad (D.2)$$

$$L = 10^5 \sqrt{\frac{RV}{7,17\, pt_1}} \qquad (D.3)$$

for severities greater than or equal to 60 h (2 · 10^5 s).

The chart given in Figure D.1 allows for the determination of R, L or t_1 for given values of the other parameters. It is derived from Formulas (D.2) and (D.3) given above. Hence, its applicability is limited to severities equal to or greater than 60 h.

Examples of application are:

a) Determination of R for given values of L, p, t_1 and V

 Draw a straight line across the given values of p and t_1. Its intersection with the pivot line α_1 determines a point. Similarly, a straight line across that very point and the given value of L determines a point on the pivot line α_2.

 The straight line drawn across V and the point on α_2 determines the required value on the R scale.

b) Determination of L for given values of R, p, t_1 and V

 Draw a straight line across the given values of p and t_1. Note its intersection with the pivot line α_1. Similarly, a straight line across R and V determines a point on the pivot line α_2. The straight line drawn across these two points crosses the line L at the required value.

c) Determination of t_1, for given values of L, R, p and V

 Draw a straight line across the given values of R and V. Its intersection with the pivot line α_2 determines a point. Similarly, a straight line drawn across that very point and the given value of L determines a point on the line α_1. The straight line drawn across p and the point on α_1 determines the required value on the t_1 scale.

In its present configuration this chart can be used for the range of values shown in Table 3.

An important remark related to the design of the nomogram is that:

the mathematical construction of this nomogram associates

R	V	and	α_2
α_1	α_2	and	L
p	t_1	and	α_1

It results from this that straight lines may only be drawn between associated parameters.
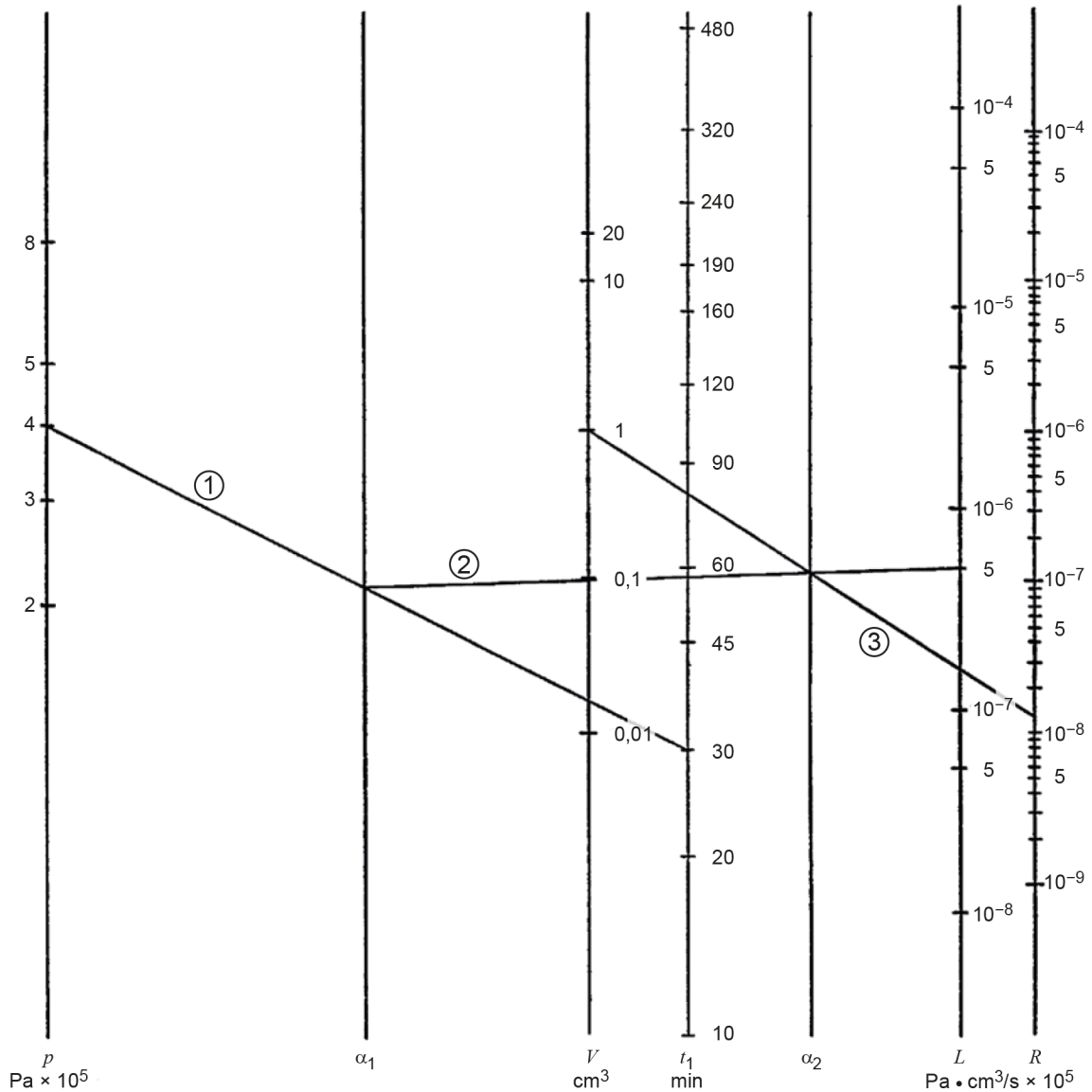
IEC

Examples of chart application: t_1 = 30 min and p = 4 × 10^5 Pa   hence a point on α_1 (line No. 1)

                                    α_1 and L = 5 × 10^{-7} Pa × cm^3/s   hence a point on α_2 (line No. 2)

                                    α_2 and V = 1,0 cm^3 hence R = 1,26 · 10^{-8} (line No. 3)

NOTE   The R values given in Table 3 are rounded off. It is generally sufficient to adopt the nearest standardized value shown on the nomogram.

Figure D.1 – Nomogram for determination of test parameters

Annex E
(informative)

**Guidance on Test Qk: Sealing tracer gas
method with mass spectrometer**

E.1   General

In this document the leak process is considered as corresponding to a molecular flow of gas through the leak path.

Gases other than helium or mixtures may be used, provided that correlation between the results obtained for these and for helium can be established (by calculation or by empirical means). However, some gases can be incompatible with certain materials in the specimens.

The influence of the temperature is considered negligible within the standard temperature range (15 °C to 35 °C) for measurement and tests according to IEC 60068-1.

The volume of the vacuum chamber used for leak rate measurements should be held to the minimum practical size, as this chamber volume has an adverse effect on sensitivity limits.

When the helium sweeping technique is used during conditioning (see 9.4.6), the efficiency of the sweeping can be appreciably reduced, when the inlet and outlet are facing each other. It is recommended that the velocity of the gas is kept to a low value during the sweep and that the total volume of helium is of the order of 5 to 10 times the volume of the chamber.

In all cases, it is necessary to complete the fine leak detection with a gross leak detection, provided that there is confidence that the sensitivities of the methods employed are sufficiently overlapping. The gross leak detection is necessary because, if the leak is large enough to allow the partial pressure of helium to drop considerably during the recovery period, no signal will be obtained on the leak detector.

Engineering judgement may be required for interpreting the readings of the leak detector, especially when this reading is decreasing. It can indicate either a gross leak or an insufficient recovery period. It is often difficult to distinguish between them. A suggestion for overcoming this difficulty is to compare the signal variation versus time with that obtained with a dummy specimen, such as a solid block of the same material.

It can also happen that an unavoidable spread in a batch of products (e.g. number of bubbles in a glass seal, differences in lacquer or paint quality, retention capability of ceramics) results in varying amounts of absorbed or adsorbed helium. In such cases the determination of real leaks can be made using the helium probing method or specialized humidity-bias-temperature test. Another approach is a careful study of the leak rate versus time curves: adsorbed helium will give quickly decaying curves whereas the time constant of the exponential and the leak rate level will usually be comparatively greater for actual leakers. In this case, the specimens should be observed for longer than specified in 9.4.7. The reduced Formulas (D.2) and (D.3) given in Annex D can then be used, but only if the observation period is negligible with respect to the time constant θ.

During the immersion phase, the partial pressure of helium in the cavity is given by

$$p_h = p \left\{ 1 - \exp\left[-\left(\frac{M_a}{M_h}\right)^{1/2} \frac{t_1}{\theta} \right] \right\}$$ (E.1)

where

$\theta = p_o \dfrac{V}{L}$ is the required minimum time constant θ (severity)(s);

M_a is the specific mass of air (1,29 g/l);

M_h is the specific mass of helium (0,18 g/l);

t_1 is the immersion time (s);

p_o is the atmospheric pressure (10^5 Pa);

V is the internal volume of the specimen (cm^3);

L is the equivalent standard leak rate (Pa · cm^3/s).

For Test Method 1 it is necessary, in addition to what is indicated in 9.2, to take account of the time taken to establish the flow of gas through the leak, which will increase with the wall thickness of the specimen.

If the partial pressure of helium varies similarly for devices having different internal volumes, this implies that their filling time constants θ are identical. Hence the severity of the test will preferably be expressed in terms of filling time constant, in order to be independent of the volume of the internal cavity of the specimen and to effectively compare the sealing quality of different specimens intended for use in the same application.

For Test Method 2 the specified duration of 30 min can be too short, so the time delay used in practice should be included in the test report.

For small specimens Test Method 2 is only applicable if carried out immediately following the sealing of the specimens. An undue time delay can allow the helium tracer gas to escape.

E.2   Choice of the applicable severity

In this document the severities are defined in terms of the time constant (θ) which corresponds to the exponential variation of the concentration of helium in the internal cavity of the device under test when a leak exists. This concept was preferred to that of the equivalent standard leak rate (L) because it is dependent upon the volume of the internal cavity (V) and of the equivalent standard leak rate:

$$\theta = p_o \frac{V}{L}$$ (E.2)

Even if this time constant is not strictly equal to the filling L time, two devices of very different volumes are likely to have a similar life expectancy – from the point of view of hermetic sealing – if they pass a test of the same severity. Conversely, the life expectancy of a device passing a 600 h severity test will be substantially greater than that of another fulfilling only the 60 h severity requirements, whatever the volume of the internal cavities and the immersion pressure or duration. Nevertheless, a comparison based on the equivalent standard leak rate (L) is still valid for devices of similar volumes. The new concept was introduced to take into consideration the problems that arise with the development of large-size sealed components which, moreover, cannot always withstand the relatively high pressures commonly used for smaller encapsulations.

In drafting the relevant specification, the required severity should be chosen bearing in mind that the time constants quoted in Table 3 are approximate and derived from theoretical considerations. The length of time required in field applications for filling up the cavity of an actual device is always far greater. This is because all the calculations were made assuming that the leak path was geometrically perfect, that the flow of helium followed the laws of molecular flow, that helium was a perfect gas, etc. In such a case, the leak rate is proportional to the square foot of the absolute temperature and inversely proportional to the square root of the molecular mass of the gas. It is also assumed that the various constituent gases of a gaseous mixture flow independently.

Specification writers should choose the severity considering the application which is envisaged. A severity of 6 h is mainly intended for small volume components used in the entertainment field. Severities of 60 h and 600 h are generally adequate for greater volume components used also in the entertainment field, or for small specimens in industrial and professional applications. A severity of 1 000 h is mainly intended for applications where a high degree of hermetic sealing is necessary.

The test engineer can choose the immersion pressure according to the mechanical resistance to pressure of the device under test. The immersion duration will be derived from the severity stated in the relevant specification and the immersion pressure chosen by the test engineer.

The pressure resistance and mechanical properties of the device under test should be considered when choosing the immersion pressure, in particular when testing large, flat devices.

When choosing the test parameters, the test engineer should appreciate the possibility of the closure of existing leak paths or the formation of new leak paths resulting from the physical stressing of the device.

Test Method 3 can only be applied to specimens capable of withstanding a relatively high vacuum and not degassing excessively.

Alternative a) (pocket method, see 9.3 and 9.6.4) is more convenient for relatively large specimens of complex shape. It is then quicker than the alternative b) (jet method) but does not enable a leak to be localized and hence repaired if necessary. For repairable specimens, it is recommended to retest defective specimens by the jet method. Alternative a) also carries a risk of error where the pocket covers all or part of the joint between the specimen and the test apparatus, since the sealing of this joint can be of considerably poorer quality than that required for the specimen, without rendering the method inapplicable.

When testing several small-sized specimens, it is convenient to use a ramp with several bleeds isolated from the vacuum chamber by the same number of valves, and fitted with adapters shaped to suit the configuration of the specimens: thus, the whole installation can be evacuated and connected to the spectrometer by only opening the valve corresponding to each individual specimen for the actual test.

The time lag before the appearance of the signal on the mass spectrometer depends on several factors (configuration of ducts and piping, type of equipment, distance from the leak to the detector, size of leaks, etc.). To verify the calibrations a reference leak should be used. It is therefore recommended to calibrate with a reference leak as close as possible in size to the admissible leak value. This reference leak should be located in a place where the response lag of the installation is likely to be longer than in the place where the specimen is located. In the case of the jet method, it should be ensured that this time lag does not exceed a few minutes (5 min at the most), since in such a case any attempt to locate a leak would be illusory. In the case of the pocket method, the time lag should be determined, so that the measurement can be made after the time has elapsed.

In alternative b), see 9.3 and 9.6.4, always begin by applying the jet to the highest parts of the specimen and work systematically downwards to the lower parts, taking care not to overlook any place, so as to minimize the risk of error in locating leaks (e.g. absorption of helium by a leak situated above the zone swept by the jet).

It is not necessary to expose the specimen to a high vacuum, once the latter is constant and adequate for the proper functioning of the mass spectrometer: the quantity of helium passing through a leak is practically the same whether the pressure is 10^2 Pa or 10^{-3} Pa.

The jet method enables leaks to be located very accurately. With a suitable application device, it is possible to detect leaks spaced 5 mm apart. This accuracy obviously depends on the diameter of the nozzle (e.g. a hypodermic needle) and the helium supply pressure (high enough to ensure proper sweeping of the leaks, but low enough for the flow to remain laminar so that the helium concentration is localized).

As the value of the measured leak rate depends on the concentration of helium at the leak point, Test Method 3 is not well adapted to give an accurate numerical leak rate but is useful for qualitative or investigation purposes.

Annex F
(informative)

Guidance on Test QI: Bomb pressure test

This test is not recommended for use as a 100 % inspection for the following reasons:

– It is possible that the ingress of the test liquid will not be detected at the time of test, but later can cause degradation or corrosion of the device (e.g. passivated semiconductor devices).

– When a specimen is subjected to a test liquid under pressure, moisture penetration tends to occur in areas not normally experienced in actual applications; this action can cause latent electrical degradations (e.g. external leak current).

– This test can, however, be used on a sample basis for economic reasons, but only with full knowledge of the aforementioned risks.

– The recovery period may be as long as two weeks, with periodic checks in the meantime, to make sure that these risks are kept to a minimum.

Test QI may be used with hermetically sealed components and parts when Test Method 2 of Test Qc is not sensitive enough: moreover, it can be carried out by less skilled personnel than Test Qc, Method 2.

It is possible that a specimen that apparently passes this test will have been damaged by the pressure applied, particularly where it exhibits leaks that are too small to be detected by the electrical tests performed immediately after pressure release. To avoid errors, comparison measurements with reference specimens can be helpful.

Annex G

(informative)

**Guidance on Test Qm: Tracer gas sealing
test with internal pressurization**

G.1   Influence of time

In both the methods described for Test Qm, a leak is detected from outside the pressurized specimen. The probe can detect the tracer gas only after it has passed through the wall of the specimen. The time this takes varies according to the nature of the gas, the internal pressure, the form of the leak path and also the cleanliness of the specimen, the temperature, etc. For fine leaks it is necessary to wait for the stabilization of the leak rate in order to detect and measure them reliably. A thick wall or low internal overpressure increases this time, which can be very long, particularly when the leak path includes several barriers in series, such as multiple gaskets or double seam welds.

G.2   Test Method 1: Cumulative test

G.2.1   Sensitivity

The sensitivity of a leak measurement changes with the sensitivity of the leak meter, with the capacity of the volume of measurement and with the time interval between the two concentration measurements.

The leak rates measured by this method have an accuracy of the order of ±50 %.

G.2.2   Specific advantages and drawbacks

a) Advantages

- possibility to use the ultimate service gas as the tracer gas;

- possibility to perform the test at the service pressure of the specimen;

- possibility to wait for the stabilization of the leak rate before measuring it (using "dead" time such as the night);

- possibility of quantitative controls.

b) Drawbacks

- method is slow, requiring testing aids to be kept in position, for example plugs, stoppers;

- method does not allow for direct localization of sealing defects that can arise.

G.3   Test Method 2: Probing test

G.3.1   Sensitivity

The sensitivity of a probing test depends not only on the threshold level of the detector but also on the amount of ambient pollution and on the movement of the surrounding air. These factors, together with those given in 11.3.4, should be controlled as far as possible to allow a sensitivity of about $3 \cdot 10^{-8}$ Pa $\cdot$ m^3/s to be achieved.

The sensitivity of the test can depend also on the speed with which the probe is moved and the distance at which the end of the probe is to be moved over the surface of the specimen. This speed should not be greater than 10 mm/s at a distance not greater than 5 mm.

Some leak detectors are provided with a device called "automatic zero", adjusting the sensitivity of the detector to the mean ambient concentration, which can prevent the correct estimation of a leak rate.

G.3.2   Specific advantages and drawbacks

a) Advantages

- useful to complete a cumulative test, allowing a fast and accurate localization of sealing defects;

- may be sufficient for testing a specimen when the probability of leak rates smaller than 10^{-6} Pa · m^3/s is low.

b) Drawbacks

- generally not quantitative;

- susceptible to surrounding conditions;

- can detect only the leaks over which the probe is passed.

Annex H
(informative)

Guidance on Test Qy: Pressure rise sealing test

In order to achieve sufficient sensitivity and adequate accuracy, the volume of measurement V_m, i.e. the volume of the space to be evacuated during the process, should be kept as small as possible by choosing a suitable test chamber and, if necessary, by equipping the test chamber with a volume adapter into which the test specimen is fitted. As a rule, the volume of measurement (V_m) should be lower than or equal to the volume of the inner cavity of the specimen.

For a limiting case of the pressure of the volume of measurement versus the test time, as given with a very leaky device, see Figure H.1.

a) Tight device: leak rate less than
10^{-4} Pa · m^3/s or down to 10^{-5} Pa · m^3/s

b) Very leaky device: the low pressure of the calibration run is not reached within evacuation time
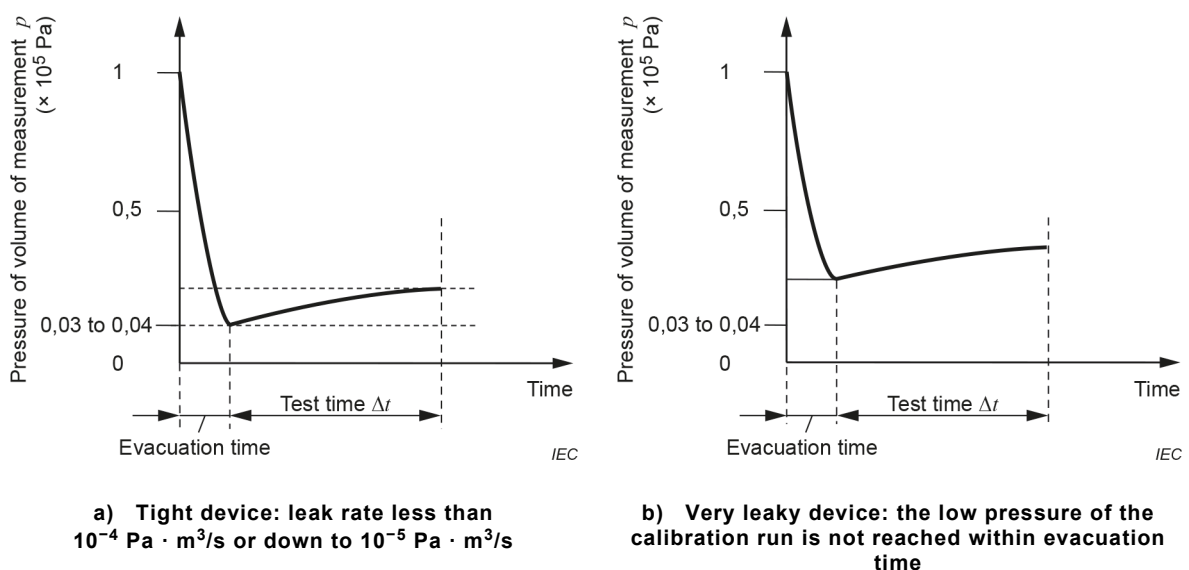
Figure H.1 – Limiting cases of the pressure of volume of measurement versus test time, provided that the dimensions of the test device, the volume of measurement and the evacuation time are constant

In practice, the calculated leak rate represents an eventual worst case because in reality the pressure rise is increased by the evaporation of gas formerly adsorbed on the surfaces forming the volume of measurement.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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