
**Non-destructive testing — Leak testing
— Tracer gas method**

*Essais non destructifs — Contrôle d'étanchéité — Méthode par gaz
traceur*

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Foreword

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This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 6, *Leak testing*.

Non-destructive testing — Leak testing — Tracer gas method

1 Scope

This document describes the techniques to be applied for the detection of a leak, using a tracer gas and a tracer gas specific leak detector.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 20484, *Non-destructive testing — Leak testing — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20484 apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

4 Principles of detection

A partial pressure difference of tracer gas is created across the boundary of the object to be tested. The tracer gas, having passed through the leak, is revealed by its physical or chemical properties. Chemical detection is generally based on reactions that cause a local colour change (the object surface shall therefore be visible).

Detection based on physical properties usually involves a sensor, for example:

- a mass spectrometer, tuned for the specific tracer gas used (generally helium-4);
- an alkali ion diode, for halogen gas, and electron-capture equipment (i.e. for SF₆);
- a Pirani gauge, for tracer gas with thermal conductivity different from that of the ambient atmosphere;
- a photometer, with band-pass filter in the frequency range of the tracer gas absorption or emission.

These types of detection generally give an electrical signal which varies with the tracer gas partial pressure.

The reference conditions should be selected and agreed between a leak tester and a customer. The reference conditions should be clearly stated and claimed by a leak tester in the test report (see [Clause 10](#)).

5 Generation and detection of tracer gas flow

5.1 Tracer gas flows into the object (Group A techniques)

A pressure difference across the wall is obtained either by evacuation of the object, e.g. through a connection or by placing it in a pressurized chamber. Usually the test object is evacuated. Tracer gas is then applied to the external surface using a probe jet or by enclosing the object (totally or partially) in a hood or chamber filled with the tracer gas. Tracer gas leakage into the test object is detected by a sensor within or connected to the internal volume.

5.2 Tracer gas flows out of the object (Group B techniques)

The object is filled with a tracer gas. A pressure difference across the wall is obtained either by pressurization of the object, e.g. through a connection or by placing it in a vacuum chamber. The tracer gas is collected on the outside surface by a sampling probe, a carrier gas flow or by accumulation into a hood or chamber. Tracer gas can also be detected by chemical reactions.

A special technique (bombing) may also be used. This involves the pressurization of a sealed object to force the tracer gas into its internal cavities, if a leak exists. The object is then placed in a vacuum chamber and escaping tracer gas is detected (this procedure is generally used only with helium-4). This method is applicable to specimens with small free internal volumes (in the order of a few cubic centimetres).

6 Apparatus

The test apparatus may include part or all of the following:

- 6.1 **Leak detector** or chemical reagents able to detect the selected tracer gas.
- 6.2 **Calibrated leaks**, calibrated for discharge into vacuum and/or against atmospheric pressure; refer to ISO 20486.
- 6.3 **Pressure and temperature gauges.**
- 6.4 **Tracer gas** or certified gas mixture.
- 6.5 **Auxiliary vacuum systems.**
- 6.6 **Hood, vacuum or pressurizing chamber**, jet or sampling probe.
- 6.7 **Purging dry gas**, liquid nitrogen (for cold trap), if necessary.
- 6.8 **Equipment** for tracer gas treatment-recovery.
- 6.9 **Equipment** for test area ventilation.
- 6.10 **Data recording equipment.**

7 Object preparation

The object to be tested shall be adequately cleaned, degreased and dried. Openings and apertures which are not involved in the test shall be closed with test seals, e.g. plugs, welding, suitable material and gaskets. Whenever possible, testing should be carried out before plating, painting or the application of

ultrasonic couplant. If the object needs to be evacuated, the presence of porous or plastic materials should be avoided. This helps to avoid spurious indications (virtual leaks), and shortens the clean-up time.

The connections between the object, the pumping system, the leak detector (LD) and the calibrated leaks used shall be suitable and checked for tightness.

8 Group A techniques, tracer gas flows into the object.

8.1 General

These techniques are applicable to an object that can be evacuated or withstand an external test pressure. The tracer gas is applied on the outer surface of the object and the LD is connected to the internal volume. If the LD is of mass spectrometer type (MSLD), the pumping system of the MSLD itself can be used to directly evacuate small items under test.

Larger objects need an auxiliary pumping system parallel to the LD. In this case, the loss of sensitivity shall be considered, as only part of the tracer gas will enter the LD.

Three techniques may be used — refer to EN 1779:

— Vacuum technique (Total) (A.1)

The object, placed in an enclosure (a bag or a chamber), is evacuated and connected to the detector. The enclosure is then filled with the tracer gas or a gas mixture containing the tracer gas. This technique allows the evaluation of the leakage rate but does not permit precise location of the leaks.

When the purpose of the leak testing is the determination of the acceptability of the test object against a specified leakage rate, only the "total" technique shall be used. In this case, the tracer gas concentration, pressure and temperature shall be measured and the homogeneity of the gas mixture shall be ensured. Further the enclosure shall be gas-tight and, preferably, rigid.

— Vacuum technique (Partial) (A.2)

The object to be tested is evacuated and connected to the detector. Suspect areas are then covered by a suitable gas-tight enclosure filled with tracer gas.

— Vacuum technique (Local) (A.3)

The object to be tested is evacuated and connected to the detector. Suspect areas on the external surface of the object are sprayed with tracer gas. Leaks can be localized using this technique but it is not possible to measure the total leakage rate.

8.2 Initial system set-up procedure

8.2.1 The LD shall be adjusted in accordance with manufacturer's instructions, using a calibrated leak. If a MSLD is used, a leak for discharge to vacuum shall be connected directly to the inlet of the LD, or the built-in leak for the calibration is to be used.

8.2.2 The object is connected to the LD and then evacuated to a suitable pressure, either by LD pumping system or by an auxiliary pumping system. This is determined by the maximum inlet pressure of the LD.

8.2.3 The initial background signal shall be measured.

8.2.4 The maximum signal for the specified calibrated leak connected to the object shall be recorded to verify the system sensitivity. The ratio of the pumping speed of the LD to the pumping speed of the auxiliary system shall not be altered.

8.2.5 For large objects or complex systems, the response time of the system shall be measured by means of a suitable calibrated leak, the rate of leakage of which is as near as possible to the specified maximum allowable leakage. Unless otherwise specified, this leak shall be connected to the object under test, via an isolation valve, in the most unfavourable position, to determine the response time.

An auxiliary line should be provided, if possible, to evacuate the volume between the leak outlet and the isolation valve. In any case, care should be taken to avoid the inlet of the accumulated gas in the system. The response time is the time from opening of the valve until the 90 % of the maximum stable signal is reached.

NOTE Although in ISO 20484:2017, 6.1.7, the term "response time" is defined by a signal rise, the practical measurement is normally based on the signal decay (see ISO 20484:2017, 6.3.1).

8.2.6 To measure the clean-up time, the calibrated leak is closed and the resulting background leakage rate indication is recorded. Afterwards, the leak is opened and the equilibrium leakage rate indication is recorded. Then, the leak is closed rapidly and the decay of leakage rate indication is recorded until it has dropped by 90 % of the equilibrium leakage rate indication with the background indication subtracted.

8.2.7 The signal amplitude and the response time for 90 % signal decrease shall be taken as reference for the test. The system layout or pumping speed shall not be changed.

8.2.8 To evaluate large leaks that saturate the LD signal, the sensitivity of test can be reduced. This reduction can be achieved either by lowering the fraction of tracer gas in the mixture or increasing the pumping speed of the auxiliary system. The response time has to be re-evaluated when the sensitivity of the test has changed.

8.3 Vacuum technique (total) test procedure (A.1)

8.3.1 After the initial set-up has been performed, the following steps shall be taken.

8.3.2 The object is placed into the auxiliary enclosure (bag or chamber) and it is then evacuated. If the enclosure is a flexible bag (usually plastic), it shall be sufficiently large to enclose the perimeter of the object.

8.3.3 A preliminary evacuation of the enclosure can be useful. If the enclosure is a flexible bag, it should lay down well against the object walls (without tearing). After it has been evacuated, the tracer gas is admitted. If the enclosure has not been evacuated, it should be adequately purged using dry tracer gas, or a gas mixture containing tracer gas, to ensure that the tracer gas concentration is homogeneous and as intended. The person performing the test shall note the volume fraction of the tracer gas in the mixture, so that the corresponding correction in subsequent measurements can be made. If a flexible bag is used, it shall be filled with gas until it is no longer touching the object walls.

8.3.4 If the enclosure is rigid, pressures shall be recorded before and after tracer gas introduction. It is possible to calculate the volume fraction of the tracer gas, applying the Boyle-Mariotte law to the recorded pressures.

8.3.5 The duration of exposure to the full concentration of tracer gas within the auxiliary enclosure shall be at least twice the response time. When the response time exceeds 20 min, different specifications for the admission time may be given.

8.3.6 After the appearance of any signal, it is necessary to wait until, either:

- the maximum signal level is obtained: the overall leakage rate can then be calculated by comparison with the signal generated by the known leak; or
- the signal, corresponding to the maximum allowable leakage rate, is obtained: in this case, the test can be interrupted for decisions.

8.3.7 The total leakage rate of the object, in molecular flow conditions, is calculated according to [Formula \(1\)](#).

$$q_G = \frac{q_{CL} \times (S_L - R_L)}{S_{CL} - R_{CL}} \times \frac{1}{c} \times \frac{p_{atm}}{p} \quad (1)$$

where

q_G is the total leakage rate;

q_{CL} is the leakage rate of the calibrated leak (pure tracer gas);

S_L is the leak signal;

S_{CL} is the signal generated by the calibrated leak;

R_L, R_{CL} are the background signal associated with signal S_L and S_{CL} , respectively;

c is the volume fraction of the tracer gas in the gas mixture;

p is the total pressure in the auxiliary enclosure;

p_{atm} is the actual atmospheric pressure.

When the test is carried out with a gas mixture, the volume fraction of tracer gas shall be known (certified if required) using approved procedures for mixture preparation.

If high accuracy is required, the system calibration shall be performed using a calibrated leak with the test gas mixture.

8.4 Vacuum technique (partial) test procedure (A.2)

8.4.1 When only a part of an object is to be tested (e.g. welds, thermocouple wells, personnel access covers, electrical or mechanical feedthroughs), the auxiliary enclosure may be restricted to that area only. The duration of tracer gas admission shall be indicated in the specification, taking into account the position of the part under test relative to the pumping system and the LD.

8.4.2 After the initial set-up has been performed, the following steps shall be taken:

8.4.3 Plastic bags or chambers are fitted to the areas to be tested using adhesive tape or suitable gaskets. These should prevent significant escape of tracer gas during the test.

8.4.4 The object is then evacuated.

8.4.5 Proceed as in [8.3.3](#) to [8.3.6](#).

8.5 Vacuum technique (local) test procedure (A.3)

8.5.1 After the initial set-up has been performed, the following steps shall be taken.

8.5.2 The effect on the result of the speed of probing the surface of the test object with the spray gun shall be established by placing a conductance leak in the position of the calibrated leak used in [8.2.4](#). The gas flow from the spray gun is adjusted and its tip is moved past the leak at the speed and distance specified for the test. The signal amplitude is recorded. If the signal is too small, the scan rate should be reduced.

8.5.3 Tracer gas spraying should start at the top of the test object if the tracer gas density is smaller than air. Spraying should start at the bottom if the tracer gas density is greater than air. Scanning of the areas shall be performed as stated in the test specifications.

8.5.4 When a leak is detected, it can be necessary to evaluate its influence. It is possible that the leak have to be temporarily sealed to continue the test.

8.5.5 After a leak has been found and sealed, it is necessary to wait until initial conditions are restored in the LD (clean up time). If leak location only is required, the procedure may state the signal level (percentage of the maximum signal) at which is possible to continue the scan, in order to shorten the test time.

8.5.6 After all leaks have been found, it can be desirable to determine the total leakage of the object, using other suitable techniques ("total" or "integral"). This step may be carried out initially, to save time if no leaks exist. However, if the object contains material permeable to the tracer gas, the sorbed gas can lower the sensitivity of the subsequent test.

9 Group B techniques, tracer gas flows out of object

9.1 General

These techniques are generally applicable to objects which cannot be evacuated or to open objects. A (partial) pressure difference of tracer gas is created across the object wall. Tracer gas is admitted to the internal volume of the object and it is collected and detected in its external side. If the object to be tested is open, the gas is sprayed or applied with a bag in one side and it is collected in the other side by a vacuum box.

Seven techniques may be used. They are briefly described here:

- Chemical detection with ammonia (B.1): The object is filled with anhydrous ammonia or an ammonia-nitrogen mixture to the specified overpressure. A colour-change developer (generally a mixture containing a pH indicator, e.g. bromophenol blue), applied to the outside surface, will reveal and locate leakages.
- Vacuum box, using internal tracer gas (B.2.1): Large objects, containing a gas or a gas mixture suitable to be used as tracer gas, are tested by a vacuum box evacuated and connected to a leak detector (LD), applied in the outer side.
- Vacuum box applying the tracer gas on opposite side (B.2.2): Open objects can be tested using partial enclosures, capable of being evacuated, which are tightly applied to the wall (vacuum box, suction cup). Tracer gas is supplied on the opposite surface of the wall by a spray gun (probe jet) or by cups, filled by the tracer gas.
- Accumulation technique (B.3): The object, pressurized with the tracer gas, is placed in an enclosure. After a specified time, the accumulated tracer gas is measured using a LD connected to the enclosure. The leakage size can then be estimated (or determined if the enclosure volume and pressure are known).
- Sniffing technique (B.4): The object is pressurized with the tracer gas (or gas mixture). Leak searching is performed on the atmospheric side of the object wall, using a sampling probe connected to a LD. This technique detects leakage and locates the leaks (direct probing).
- Bombing technique (B.5): The sealed object is subjected to a high pressure of tracer gas (bombing), usually helium-4, in order to force it into the object, if a leak exists. After the bombing and a flushing, to remove adsorbed tracer gas from the outer surfaces, the object is placed in a vacuum chamber, connected to a LD for the detection of the escaping tracer gas.
- Vacuum chamber technique (B.6): Small objects, containing a gas suitable to be used as tracer gas are placed in a chamber. This is subsequently evacuated to a pressure lower than the internal

pressure of the object. The LD is connected to the vacuum chamber. The total flow of the tracer gas from the object is measured by the LD.

- Carrier gas technique (B.7): Prior to the test, the object is filled with tracer gas at a pressure above ambient pressure. The object is surrounded by a hood in which a carrier gas flows across the objects surfaces. Any leakage of tracer gas out of the object is carried away by the carrier gas and can be detected by a suitable sensor at the exhaust of the carrier gas.

9.2 Initial system set up procedure

9.2.1 Ammonia test with colour-change reagents (B.1)

9.2.1.1 The reagents are either directly applied to the surface or supported on paper or textile band applied on the surface.

The reactivity of the reagent shall be verified by the exposure to a small quantity of gas.

9.2.1.2 A sample of the reagent shall then be applied on the object surface (away from the areas to be tested) and its colour shall be checked during all the examination time. A colour change means the contamination with ammonia of the ambient, or on the object surface.

9.2.2 Tracer gas flowing out of the object (B.2, B.3, B.4, B.6)

9.2.2.1 The LD shall be adjusted as described in 9.1.1.

9.2.2.2 To calibrate the system, calibrated leaks for discharge to the atmosphere (or equivalent systems, e.g. prefabricated gas concentration), selected in the appropriate range, are required. These leaks should have a leakage rate close to the maximum allowable in the case of acceptability evaluation or to the minimum to be detected if the aim of the test is location (for repair).

9.2.2.3 (Only for B.3 and B.4) When using the sampling probe, the zero control is adjusted by closing the inlet valve or sniffing the gas over liquid nitrogen. If these devices are not available, adjustment can be made relative to the clean atmosphere (before the test starts).

(Only for B.4) If sensitivity of test has to be measured, the probe tip is held in front of a calibrated leak. After clean-up time, the calibration is repeated moving the sampling probe at the specified scan rate.

(Only for B.4) The calibration should be carried out in such a way that the test area is not flooded by the tracer gas. The calibration shall be checked frequently as the sampling probe can be plugged by dust or dirt.

9.2.2.4 (Only for B.3) If an enclosure is used, a known leak is connected to it via an isolation valve. The reading due to tracer gas concentration shall be recorded before the opening of the valve and at subsequent time intervals. This step shall be carefully carried out, due to the difficulty of purging the system, if it cannot be evacuated.

9.2.2.5 (Only for B.6) If the test is carried out in a vacuum chamber and the pumping system cannot be disconnected, the response time and the maximum readout for the calibrated leak is recorded. The pumping speed shall not be altered in the subsequent test.

9.2.2.6 Remove tracer gas flow and note the signal due to the residual tracer gas in the atmosphere.

9.2.3 Pressurisation — Evacuation test (B.5)

9.2.3.1 The vacuum chamber with a calibrated leak is connected to the MSLD. When the specified pressure is reached, the residual signal is recorded. The calibrated leak is then opened and the appearance time and maximum signal is recorded.

9.2.3.2 The degassing time shall be checked using a tight sample of the same material, with the same surface conditions. This sample is placed into the vacuum chamber connected to the MSLD. The flushing and/or evacuation time is the minimum time to obtain a signal clearly below the maximum allowable leakage signal. An excessive degassing time can decrease the test sensitivity or mask the large leaks.

9.3 Ammonia test procedure (B.1)

9.3.1 General

This technique is suitable for detection and location of leaks.

After the initial set-up has been performed, the following step shall be taken.

9.3.2 Test object preparation

The test object shall be purged with dry hot gas to obtain a dry atmosphere. If possible, evacuation is to be preferred, since the presence of moisture can give rise to corrosion problems. The surface to which the detector reagent is applied should be neutralized using an acidic solution. This step shall be performed if the test presented 10.1.1.2 shows a diffuse colour change.

9.3.3 Reagent application

The reagent shall be applied over the specified areas.

If the reagent is in liquid form, it can be applied by brush or spray painting in a thin uniform coating. Thick coatings take longer to develop and can result in self-discoloration. Water-based developers should be dried after application using a hot-air gun (normally from 50 °C to 60 °C) or applied on preheated surfaces to remove any moisture. Temperatures over 100 °C can damage the developer.

If the reagent is impregnated into a carrier (paper or textile), the carrier shall be firmly fastened to the surface by adhesive tape.

After reagent application, protection with a transparent film can prevent or reduce the atmospheric contamination effects. This protection shall be applied in such a way that there is no interference with the test.

9.3.4 Ammonia pressurization

Ammonia forms explosive mixtures in air at the volume concentration in the range 15 % to 28 %.

For large leaks (greater than 1×10^{-6} Pa · m³/s) and for concentration less than 15 %, oil-free dry air may be used to pressurize the object.

For small leaks (less than 1×10^{-6} Pa · m³/s) and higher ammonia concentrations (more than 15 %), an inert gas (usually nitrogen) shall be used for mixture.

If a mixing device is not available, the concentration may be calculated approximately using Dalton's law (ratio of partial pressure). The charging sequence for the object shall be as follows:

- fill with dry air or inert gas to atmospheric pressure;
- fill with ammonia to the gauge pressure equivalent to the partial pressure calculated by concentration and total pressure;

- complete the pressurization with air or inert gas to the pressure required by the specifications.

To improve the minimum detectable leakage and to shorten the test time, a pressure of 2×10^5 Pa to 3×10^5 Pa is recommended, even if a pressure of few hundreds pascals would be sufficient for the test.

9.3.5 Impregnation time

The pressure shall be maintained for the determined time, sufficient for establishing a steady flow through any leaks. This time depends on the pressure, the wall thickness, the ammonia concentration and the amount of leakage. The suggested time is 30 min for each millimetre of thickness. Because of the impregnation time, the step detailed in 9.3.4 (pressurization) can be also carried out before the step detailed in 9.3.3 (reagent application).

9.3.6 Visual examination

After the impregnation time, the surface of the object with the developer shall be examined under white light, directly or with instruments able to show spots larger than 1 mm. A minimum illumination of 350 lx is required. All spots larger than 1 mm are noted and verified as follows:

- a) if the reagent is painted:
 - remove the painting;
 - apply a new painting and dry;
 - if a new spot is formed, note the time of appearance;
 - check the growth of the spot after 30 min and, if required, measure the diameter, in order to give an indication of the leak size;
- b) if the reagent is in the form of an impregnated band:
 - replace the band;
 - after 15 min, check if a new spot has appeared on the band side in contact with the object wall and, if required, measure the diameter to give an indication of the leak size.

9.3.7 Post test cleaning

After the examination, the pressure is released by slowly venting the mixture from the object through equipment suitable for ammonia disposal, according to local regulations. The residue is then purged by flushing with inert gas or by evacuation. Adequate flushing shall be performed before carrying out any weld repairs.

9.4 Vacuum box test procedure (B.2.1, B.2.2)

9.4.1 General

Such techniques are suitable for detection and localization of leaks. If the object is filled with a known concentration of tracer gas, technique B.2.1 is suitable for the evaluation or measurement of the leakage rate, depending on the tightness of the vacuum box seal on the object wall.

After the initial set-up has been performed, the following techniques are available.

9.4.2 Vacuum box technique for closed objects B.2.1

9.4.2.1 This is applicable to large objects containing a tracer gas (or a tracer gas mixture) at a pressure below, similar to or greater than atmospheric pressure.

9.4.2.2 The vacuum box is applied to specified test areas and is evacuated to the required pressure. The pump speed should be maintained at the minimum level, necessary to achieve the required pressure, in order to optimize the test sensitivity.

9.4.2.3 The LD is connected. The pressure and the signal at time t_0 (start of measurement) shall be recorded.

9.4.2.4 After a specified time, related to the required pressure and the system response time, the signal and the actual pressure shall be recorded. If evaluation or measurement of the leakage rate is required, the use of calibration curves, obtained from a calibrated leak under the same conditions, shall be necessary.

9.4.3 Vacuum box technique for open objects B.2.2

This technique is applicable to the open objects. In this case, the procedures in [9.4.2.2](#) and [9.4.2.3](#) shall be repeated.

The tracer gas shall be applied on the opposite side using a spray gun, a cup or a bag. A signal indicates the existence of a leak.

9.5 Accumulation technique (B.3)

9.5.1 General

These techniques are suitable for total leakage measurement.

Technique B.3 is suitable for objects which contain, or can be filled by, the tracer gas at a pressure greater than atmospheric pressure and can be placed completely in a chamber.

After the initial set-up has been performed, the following procedures are available.

9.5.2 Accumulation technique procedure (B.3)

9.5.2.1 The object shall be purged in order to obtain a dry atmosphere. If possible, evacuation is to be preferred. The tracer gas or gas mixture containing tracer gas is admitted to a required overpressure. If a mixture is used, the procedure shall provide a final known concentration, as required by specifications.

9.5.2.2 The object is then placed in an auxiliary enclosure. This is connected to a LD capable of measuring the concentration increase of the tracer gas escaping from the object into the enclosure. The signal S_0 corresponding to the concentration c_0 , of tracer gas at time t_0 (the start of the measurements) and/or the residual signal of the measuring device shall be recorded (e.g. signal resulting from atmospheric helium).

9.5.2.3 After a specified time interval (depending on the required detection limit) the signal S_1 corresponding to the concentration c_1 of tracer gas at the time t_1 shall be measured and recorded.

9.5.2.4 The concentrations c_0 and c_1 are determined from S_0 and S_1 by comparison to a reference mixture with a known concentration, c_{ref} , of the tracer gas and corresponding signal, S_{ref} . The leakage rate, q_G , of the object should be calculated using the formula:

$$q_G = p \times \frac{V \times (c_1 - c_0)}{t_1 - t_0} \quad (2)$$

where

c_0, c_1 are the concentration at time t_0 and t_1 in the auxiliary enclosure at the start and end of the measurement, respectively;

p is the pressure of the auxiliary enclosure;

q_G is the total leakage rate;

t_0, t_1 are the times of start and end of the measurement, respectively.

V is the volume of the auxiliary enclosure;

9.5.2.5 If the volume of the enclosure is unknown, a reference leak shall be used, connected either to an enclosure with a volume similar to that of the measuring enclosure, or directly to the measuring enclosure, through an isolation valve. In the latter case, the calibration can be carried out before or after the test. The value of the reference leak shall be in the same range as the maximum allowable leakage rate. The pressure and concentration of the tracer gas shall be as close as possible to the conditions of object under test.

If the test is carried out with a gas mixture containing the tracer gas, the gas of the reference leak shall be of the same mixture, if possible supplied from the outside of the object, with a special arrangement, as shown in [Annex A, Figure A.1](#).

- a) If the reference leak is connected to an enclosure with similar volume, [Formula \(3\)](#) can be used to calculate leaks, if any:

$$q_G = q_L \times \frac{p_e}{p_{amb}} \times \frac{S_1 - S_0}{S_{L1} - S_{L0}} \quad (3)$$

where

q_G is the leakage rate referred to the atmospheric pressure;

q_L is the leakage rate of the reference leak;

p_{amb} is the ambient pressure;

p_e is the pressure in the enclosure;

S_1, S_0 are signals corresponding to the concentration at the start and the end of the test;

S_{L1}, S_{L0} are recorded signals corresponding to the concentration in the enclosure connected to the reference leak

- b) If the reference leak is connected to the same auxiliary enclosure during a part of the test, this leak is superimposed on the leaks (if any) of the object to be tested. The initial signal, S_0 , shall be recorded. At the time t_1 , the signal S_1 shall be recorded.

At this time (after the evacuation, if necessary, of the tracer gas accumulated between the calibrated leak and the isolation valve), the leak shall be opened to the enclosure.

After a further interval, at time t_2 , the signal S_2 shall be recorded.

In this case:

$$q_G = q_L \times \frac{S_1 - S_0}{t_1 - t_0} \times \frac{t_2 - t_1}{(S_2 - S_0) - [(S_1 - S_0) \times (t_2 - t_0) / (t_1 - t_0)]} \quad (4)$$

where

q_G is the leakage rate referred to the atmospheric pressure;

q_L is the leakage rate of the reference leak;

S_0, S_1 are the recorded signals corresponding to the concentrations in the enclosure respectively at the start of the test and just before the opening of the calibrated leak valve;

S_2 is the signal corresponding to the concentration at time t_2 ;

t_0, t_1, t_2 are respectively time at the test start, at the opening of the reference leak valve, at the final reading.

NOTE This simplified formula is valid assuming a constant leakage rate, which is true if the leakage from both the test object and the reference leak are small enough to avoid appreciable alteration of object and enclosure pressures and volumes (see [Figure A.2](#)).

9.6 Sniffing test (B.4)

9.6.1 After the initial set-up has been performed, the following steps shall be taken.

9.6.2 The object shall be purged to obtain a dry atmosphere. If possible, evacuation is to be preferred. The tracer gas or gas mixture containing tracer gas is admitted to a required overpressure. If a mixture is used, the procedure shall provide a final known concentration, as required by specifications.

9.6.3 Stabilization of the leak flow shall be allowed. The test time shall be correlated with the system response time.

9.6.4 The scanning shall be carried out on the areas indicated in the specifications.

9.6.5 The probe shall be held not more than 1 mm from the surface and shall be moved at a speed not exceeding 20 mm/s.

9.6.6 All suspect areas shall be evaluated. If necessary, leaks shall be marked and temporarily repaired before continuing the scanning.

9.6.7 At the completion of the test, the tracer gas shall be evacuated from the object (if required). The test gas should never be discharged in the test area, if further testing is planned. It should be vented safely with due consideration of its effects.

9.7 Bombing technique (B.5)

9.7.1 This technique is applicable to objects sealed prior to testing and not containing a gas suitable to be used as tracer gas. Such objects are generally of small dimensions (e.g. semiconductor devices, hermetically enclosed relays, etc.). Leakage through the walls of this type of object is detected by pressurization of the test objects with tracer gas (bombing) prior to the test. The technique is a total

(integral) method which does not permit leak location or the detection of large leaks. Gross leaks have to be revealed by other suitable techniques.

The principle is that the test objects are placed in a bombing chamber where they are exposed to a high pressure of tracer gas. They are then placed in a vacuum chamber for testing. The steps are as follows:

- removal of air from internal cavities (evacuation);
- pressurization with tracer gas;
- surface degassing (flushing, evacuation);
- measurement in a vacuum chamber using an MSLD.

The pressure at all stages of the test shall be compatible with test object integrity and maximize the sensitivity of the test.

9.7.2 The objects, previously cleaned and dried, are placed in the chamber. The chamber shall be evacuated to the lowest pressure compatible with the object integrity and shall be maintained at this level for the specified time: this time shall be selected depending on the wall thickness.

9.7.3 The chamber shall be pressurized with tracer gas to the specified value of pressure. This shall be maintained for the time required to give the desired test sensitivity. This time depends on:

- the wall thickness;
- the type of material;
- the size of the leak;
- the internal volume of the objects.

9.7.4 The tracer gas shall be released at a considerable distance from the leak detector. (It may be piped out of the building or released into a holding tank to avoid increasing the tracer gas pressure in the test area).

9.7.5 The test objects shall be flushed with dry tracer gas-free air or nitrogen, to remove sorbed tracer gas from the surface before the removal from the chamber. The flushing time shall be determined experimentally.

9.7.6 The test object is placed in the vacuum chamber, not yet connected to the mass spectrometer. Degassing is carried out during a pump-down cycle.

9.7.7 The degassing time varies according to the test object types and basically depends on the surface properties of its outside walls. In particular, the nature of the material and its surface roughness are important.

The degassing time shall be determined using a leak-tight reference object or a sample of the same material having the same surface conditions.

The reference object shall be placed in the vacuum chamber connected to the MSLD. Degassing shall be carried out in a way identical to that of the test object.

The walls can be considered to be sufficiently degassed when the desorbing gas flow reaches a level that is comparable to the expected tracer gas flow. This flow can be calculated from the acceptable leakage rate and the bombing conditions (see below).

9.7.8 The vacuum chamber for measurement shall be connected to the MSLD and a pump-down cycle initiated. After cross-over, the leakage rate signal shall be read after degassing has reached the

predetermined value. A recorder shall be used to determine the dynamic equilibrium steady state indication. Alternatively, after a predetermined waiting time (depending on the degassing behaviour of the test objects), the actual leakage rate reading may be taken before equilibrium. The uncertainty of measurement (given by uncertainties in the degassing time) decreases with longer waiting times.

9.7.9 If the steady state reading can be obtained in the test, calibration shall be carried out in the usual way by using the steady state indication of a reference leak connected to the vacuum chamber. If the leakage rate reading is taken before equilibrium has been established, an equivalent reading shall be taken using the reference leak.

To obtain a measure of statistical errors, several such readings should be taken.

9.7.10 The indicated leakage rate is not the standardized total leakage, since the partial pressure of helium in the internal cavity of the test object should be considered.

The acceptable leakage rate, q_L , shall be used to calculate a safe reject point, q_R , using [Formula \(5\)](#).

$$q_R = q_L \times \frac{p}{p_0} \times \left(1 - e^{-q_L \times t_b / p_0 V}\right) \times e^{-q_L \times t_w / p_0 V} \quad (5)$$

where

p is the bombing pressure of tracer gas;

p_0 is the atmospheric pressure;

q_L is the acceptable leakage rate of test object;

q_R is the allowable leakage indication (reject point);

t_b is the bombing (pressurization) time;

t_w is the waiting time between bombing and testing;

V is the internal volume of the test objects.

The above formula is valid only under certain assumptions.

One signal can represent two leakage rates, the lower of which is the fine leakage rate and the higher represents a gross leak with the same signal^[1].

Gross leaks can only be found after the bombing phase but before the evacuation phase, i.e. during the waiting time t_w . It is recommended to use sniffing for this purpose.

9.8 Vacuum chamber technique (B.6)

9.8.1 This technique is suitable for sealed objects which contain, or can be filled by, a tracer gas at a pressure below, similar to or greater than atmospheric pressure and can be placed completely in a chamber.

9.8.2 The object, containing the tracer gas is placed in the vacuum chamber pumped down to the required pressure and connected to a tracer gas leak detector.

9.8.3 The total flow of the tracer gas flowing from the object into the vacuum chamber is measured.

9.9 Carrier gas technique (B.7)

9.9.1 The object shall be purged in order to obtain a dry atmosphere. If possible, evacuation is to be preferred.

9.9.2 The object is then surrounded by a (soft or rigid) hood which enables a gas flow across the object's surfaces. The hood has an input connected to a carrier gas source (typically nitrogen or dry air) with a pressure regulator and a flowmeter. Its output is connected to the tracer gas detector using the concentration (sniffer) probe (a typical arrangement is shown in [Figure 1](#)).

A pressure sensor may be connected to the hood to detect pressure changes.

9.9.3 The test assembly together with the detector are calibrated with a known tracer gas leak connected to the hood, the exhaust of which shall be exposed to the carrier gas flow.

9.9.4 For the calibration, the leakage rate of a reference leak connected to the carrier gas flow is measured by the LD. The reading is adjusted to fit the value of the reference leak.

9.9.5 With the leak closed the detector is adjusted to show zero reading. After opening the leak valve and stabilizing the reference leakage rate, the detector is adjusted to show the correct leakage rate reading.

9.9.6 Afterwards, the reference leak shall be closed or removed from the system.

9.9.7 Only now is the tracer gas or mixture containing tracer gas admitted to the test object, until a required overpressure is reached. If a mixture is used, the procedure shall provide a final known concentration, as required by specifications.

9.9.8 When the leakage rate reading of the detector is constant, the indicated value is recorded as the measurement result.

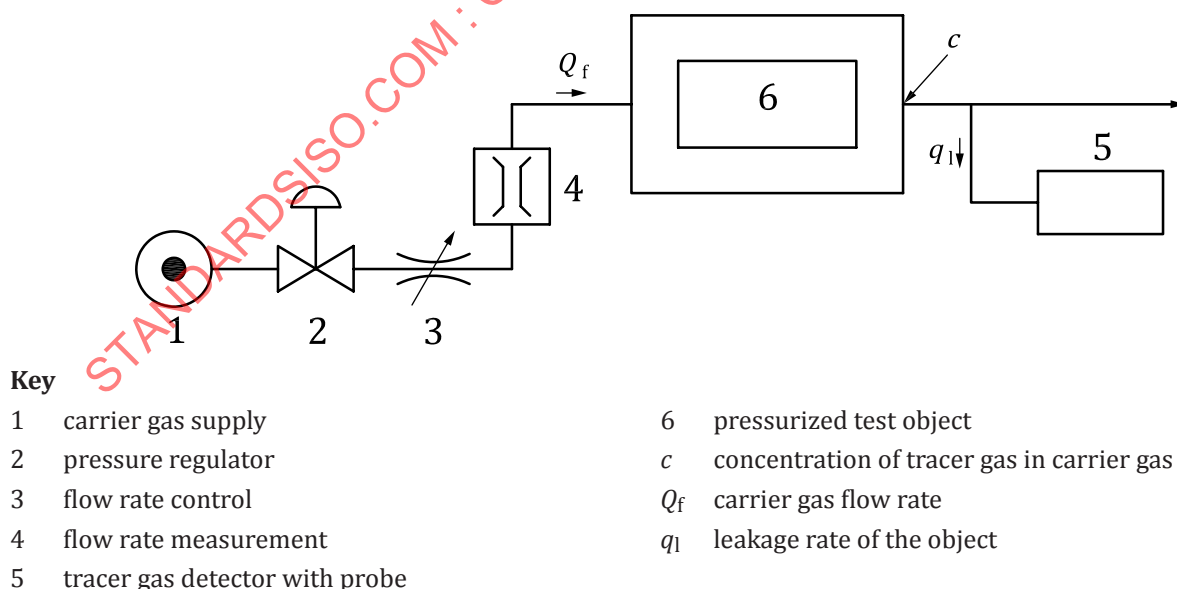


Figure 1 — Carrier gas technique

When the detector has been adjusted by a reference leak for correct reading of tracer gas leakage rates in the actual partial flow set-up, its indication is taken as the measurement result.