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Non-destructive testing — Leak testing — Tracer gas method

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

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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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:

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

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— IEC Electropedia: available at http://www.electropedia.org/

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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 SF_6);

— 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).

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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

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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.

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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

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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.

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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.

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— 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.

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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.

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

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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.

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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.

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

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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.

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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.

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

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— 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

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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.

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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).

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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.

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