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Non-destructive testing — Leak testing — Calibration of reference leaks for gases

Essais non destructifs — Contrôle d'étanchéité — Étalonnage des fuites de référence des gaz

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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 — Calibration of reference leaks for gases

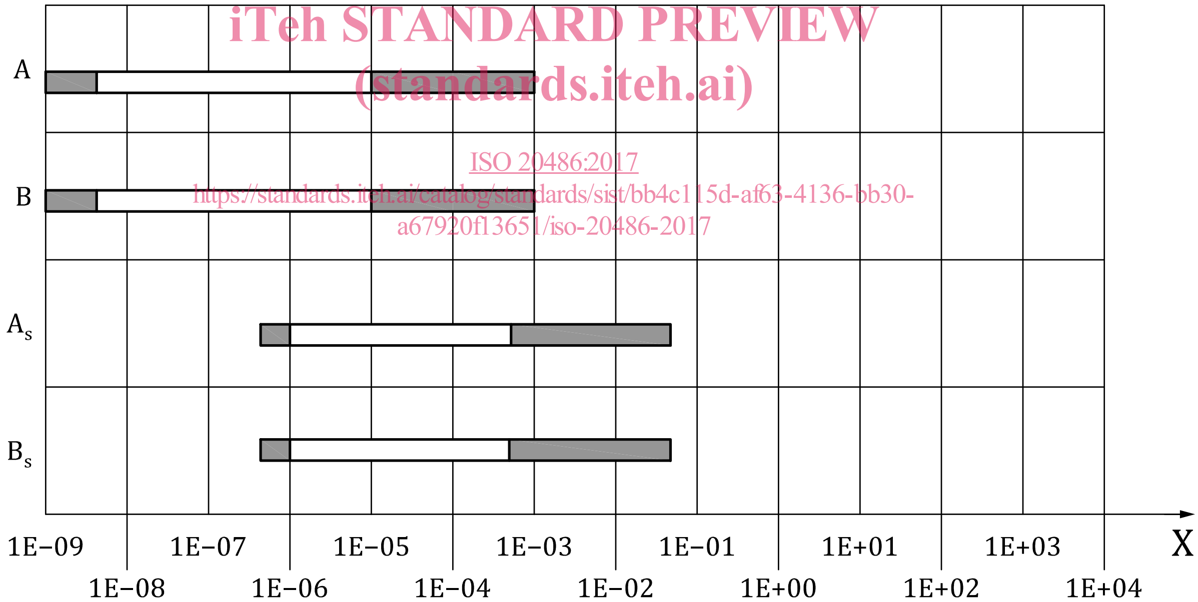
1 Scope

This document specifies the calibration of those leaks that are used for the adjustment of leak detectors for the determination of leakage rate in everyday use. One type of calibration method is a comparison with a reference leak. In this way, the leaks used for routine use become traceable to a primary standard. In other calibration methods, the value of vapour pressure was measured directly or calculated over a known volume.

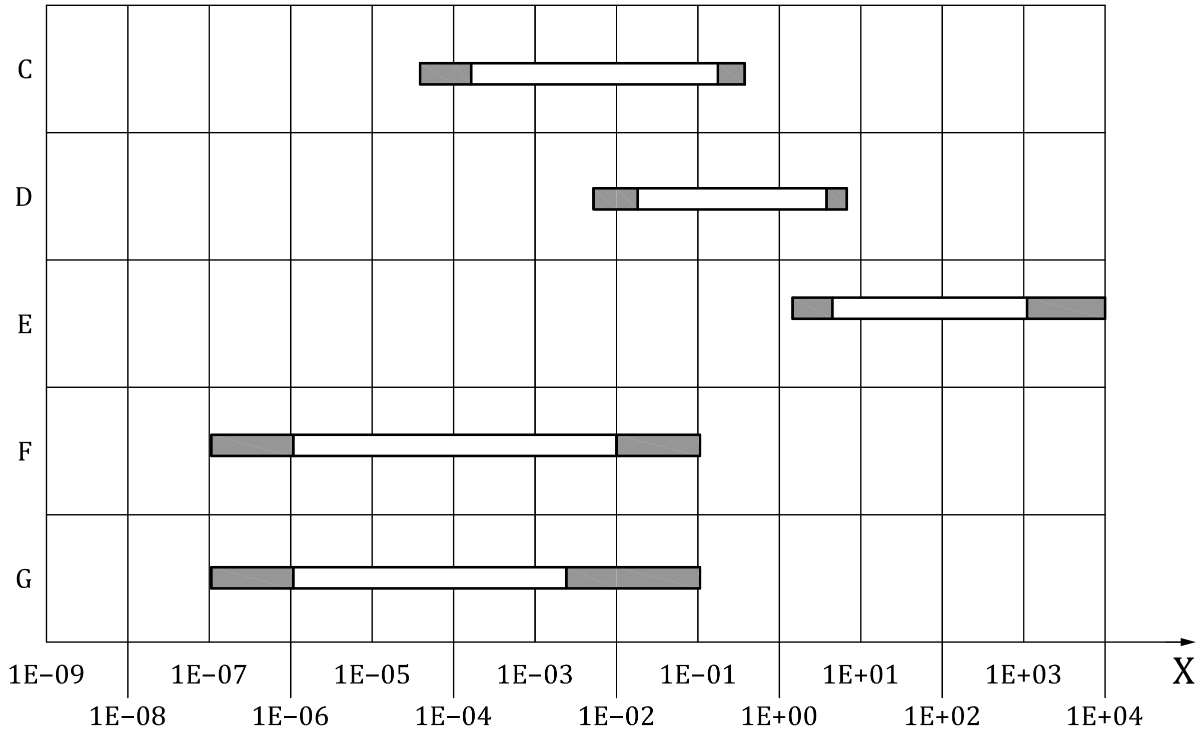
The comparison procedures are preferably applicable to helium leaks, because this test gas can be selectively measured by a mass spectrometer leak detector (MSLD) (the definition of MSLD is given in ISO 20484).

Calibration by comparison (see methods A, A_S, B and B_S below) with known reference leaks is easily possible for leaks with reservoir and leakage rates below 10^{-7} Pa·m^3/s.

Figure 1 gives an overview of the different recommended calibration methods.



a) Calibration by comparison



b) Calibration by direct measurement

Key

X leakage rate in Pa·m^3/s

A Method A

B Method B

A_S Method A_S

B_S Method B_S

C Method C

D Method D

E Method E

F Method F

G Method G

normal range

possible range

Figure 1 — Calibration ranges

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 and the following 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/

3.1
unknown leak
leak having a stable and repeatable leakage rate of known order of magnitude that can be determined by calibration

3.2
reference leak
calibrated leak which may be used to calibrate another leak

Note 1 to entry: The uncertainty of the reference leak is lower than the required uncertainty of the leak to be calibrated.

3.3
calibration
set of operations which establish, under specified conditions, the relationship between leakage rate values represented by an unknown leak and the corresponding known values of the leakage rate

Note 1 to entry: In the case of calibration by comparison, the known values of the leakage rate are represented by a reference leak.

Note 2 to entry: Normally, the result of a calibration is given as the leakage rate value for the reference leak with a standard uncertainty.

3.4
nominal leakage rate
leakage rate of a leak calculated for specified reference conditions

Note 1 to entry: In leak detection, leakage rates are commonly given in units of pV-throughput (Pa·m^3/s, mbar l/s, Std cm^3/min). These are only a precise measure of gas flow if the temperature is given and kept constant. Flow units such as mass flow (g/y) or molar flow (mol/s) are sometimes used to overcome this problem.

4 Nominal leakage rates

Calibrated leaks are only comparable under the same reference conditions. Nominal leakage rates shall be used for comparison. Recommended reference conditions are:

— Ambient temperature: 20 °C

— Atmospheric exhaust pressure: 1 000 mbar

— Vacuum exhaust pressure: < 100 mbar

The reference inlet pressure is given by the leak reservoir pressure or the application requirement.

5 Classification of leaks

5.1 Permeation leak

This type of leak is normally made with a tracer gas reservoir. It has the best long-term stability but an appreciable temperature coefficient (approximately 3,5 %/K). Typical leakage rates are in the range from 10^{-10} Pa·m^3/s to 10^{-4} Pa·m^3/s.

5.2 Conductance leaks

5.2.1 Capillary leak

This type of leak is available with or without a tracer gas reservoir. It has a low temperature coefficient (approximately 0,3 %/K) but easily blocks if not handled with care. Typical leakage rates are greater than 10^{-7} Pa·m^3/s.

5.2.2 Aperture leak (orifice)

Orifices are seldom used as reference leaks in practice, as they are difficult to manufacture and even more prone to blocking than capillaries.

NOTE Critical flow orifices are a form of aperture leak that is commonly found in industry, but are out of the scope of this document.

5.2.3 Compressed powder leak

This type of leak uses metal powder compressed into a tube. They are usually offered without reservoir. They are used for routine check of the sensitivity of leak detectors but they are not stable enough to be used as calibrated leaks. Their suitability depends on how well controlled the storage and operating conditions are, and on the required uncertainty.

6 Calibration by comparison

6.1 Methods A, A_S, B and B_S

There are two ways of calibrating leaks by comparison with known reference leaks. Both methods require the knowledge of the order of magnitude of the leakage rate to be measured. The methods differ in using one or two reference leaks, resulting in different uncertainties of measurement. In the following, the two methods are designated as A and B:

— Method A: Comparison to one reference leak normally with a leakage rate of the same order of magnitude, calibration with vacuum method.

— Method A_S: Comparison to one reference leak normally with a leakage rate of the same order of magnitude, calibration with sniffing method.

— Method B: Comparison to two reference leaks with leakage rates normally lying on either side of the unknown leakage rate, calibration with vacuum method.

— Method B_S: Comparison to two reference leaks with leakage rates normally lying on either side of the unknown leakage rate. Calibration with sniffing method.

Method A is most suitable for use on site as only one reference leak is used. It is generally applicable but is most reliable when the leakage rate of the unknown is close to that of the reference leak. This is because the measurement uncertainty is directly dependent on the linearity of the leak detector in use. As the linearity error cannot be measured independently, it needs to be estimated. To keep the linearity error small, the operating characteristics of leak detector should not change during calibration (e.g. automatic ranging should be disabled).

For more precise calibrations, where a more reliable measure of uncertainty is required or if a reference leak with a leakage rate close to the unknown is not available Method B should be used. By the use of two reference leaks, the non-linearity of the leak detector is accounted for.

6.2 Applicability of comparison methods

Since comparison of leaks is not a fundamental measurement method, it relies on the stability of the transfer device and cleanliness of the ambient gas atmosphere. Moreover, the temperature dependence of the reference and unknown leaks shall be taken into account.

The most stable and clean conditions are achieved for leaks with exhaust into vacuum and a mass spectrometer leak detector as transfer device measuring the partial pressure generated by the leaks in vacuum. Under these conditions, all interfering background gases are reduced to a minimum so that the zero point of the transfer device is defined and stable.

For leaks with exhaust into the atmosphere and measurement by sniffing gas, more conditions shall be controlled. These are:

— the background level of tracer gas shall be as low as possible and as stable as possible;

— the total gas flow rate of the sniffer shall be high enough to take up the total tracer gas flow out of the leak;

— the aspiration of the sniffer (the coupling to the leak exhaust) shall be of suitable geometry to make sure that the atmospheric gas flow across the leak exhaust takes up the whole tracer gas flow from the leak opening.

As a consequence, the measurement uncertainty is appreciably higher for sniffer leaks than for vacuum leaks.

Methods by comparison are therefore applicable but not preferable for the calibration of sniffer leaks (with exhaust to atmosphere).

6.3 Preparation of leaks and apparatus

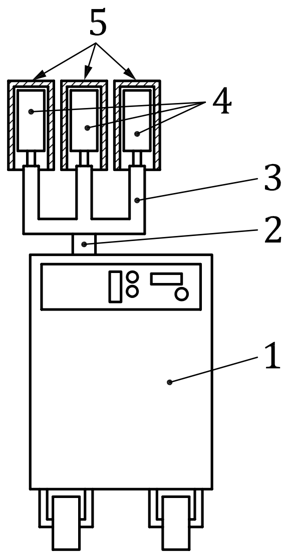
6.3.1 Leak detector

The leak detector (LD) used as a transfer device shall be set up according to the manufacturer's manual. The warm-up time shall be at least 2 h.

6.3.2 Connection to the leak detector

The reference and unknown leaks are connected to the leak detector used as the transfer instrument. The connection shall be kept continuously until the measurement is completed. This includes thermal accommodation[1].

In the case of vacuum leaks, they are connected to the inlet flange and pumped with their valves (if any) open for at least 30 min to remove any tracer gas that can have accumulated in seals or valves. For the calibration of more than one leak, a separate pumping system and set of valves is useful to keep all the leaks pumped until they are measured.

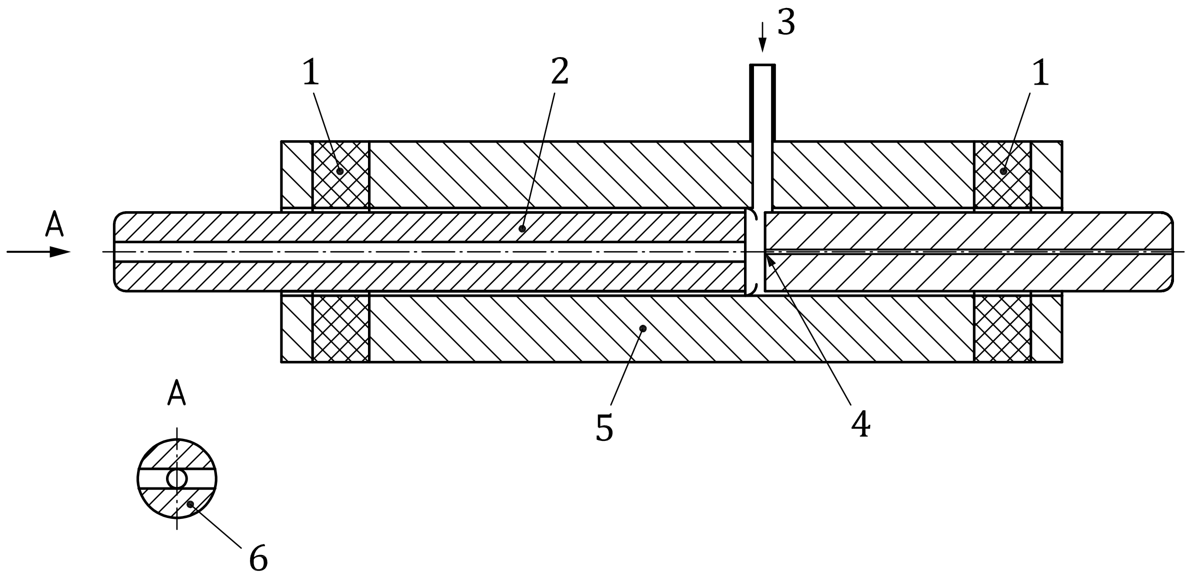


Key

1 transfer device (leak detector)
2 test port
3 rig
4 leaks to be calibrated and reference leak
5 hoods for thermal stability

Figure 2 — Coupling of leaks to the leak detector

In the case of sniffer leaks, the connection to the leak detector sniffing tip is made by an adapter which makes a tight connection to the leak outlet and enables atmospheric air to be continuously sucked across the leak exhaust via an air inlet (see Key item 3 in Figure 2), so that the whole leak gas flow is taken up by the sniffer tip. The air inlet opening shall not throttle the free flow of air to maintain atmospheric pressure in front of the sniffer tip. See Figure 3.



Key

1 gasket

2 sniffer tip

3 air inlet

4 test leak with leak opening

5 adapter body with gasket

6 sniffer opening with cross-wise slot

Figure 3 — Example for a coupling adapter for sniffer leaks

6.3.3 Temperature accommodation

The unknown leak and the reference leak(s) for the comparison shall be stored in the same room where the test is to be carried out for at least 12 h to allow for temperature equilibration (an air-conditioned room is not necessary if there are no rapid temperature changes. Because of temperature fluctuations, an air-conditioning system can even increase the measurement uncertainty). Vacuum leaks, connected to the LD shall be pumped during the phase of thermal accommodation. After temperature accommodation, to prevent any temperature changes during measurement, thermally insulating hoods (made of plastic foam or similar material) should be put over the leaks.

6.4 Measurement

6.4.1 Set-up

It is important to ensure that the effective pumping speed at the leak detector inlet for vacuum leaks, respectively the sniffer gas flow for overpressure leaks, is not changed during the measurements.

If possible, either with the leak detector or in an auxiliary device, a long averaging time may be used to decrease the statistical measurement uncertainty.

All the measurement instruments should be adjusted in such a way that they give nearly full-scale deflections for the biggest leak.

6.4.2 General measurement sequence

Generally, each reading shall be obtained only after the signal of the transfer instrument has stabilized. A sufficient number of readings shall be taken to achieve the lowest possible statistical uncertainty.