

	Document type:	Date: 2022-05-27
	<b>Technical Guideline</b>	Page 1 of 4

Title:	<b>Vacuum Properties Acceptance Test with Bakeout</b>
Purpose:	This document specifies technical guidelines for vacuum properties acceptance tests which shall be performed after bake-out of the vacuum system.
Organisational unit:	Vacuum Systems (VAC)
Valid for:	FAIR
Key performance indicators:	vacuum, acceptance test

### Document history:

Version	Created, date	Reason for modification
pre V1.0	2007-06-20, 2007-06-26	Early versions
V1.0	2009-11-04, 2010-10-12	Specifications for residual gas composition adjusted
V1.1	2013-06-05	Specifications for residual gas composition and outgassing rate adjusted
V1.2	2014-04-04	Simplification
V1.3	2017-08-07	Revision, specifications for leak checking extended, proof of ultimate pressure removed, specifications for bake-out procedure removed (covered in a dedicated Technical Guideline), specifications for residual gas composition adjusted
V002	2022-05-27	Revision and several technical improvements

This Technical Guideline is valid for beam vacuum components only. It is not applicable for insulation vacuum cryostat vessels.

## 1.) First helium leak check

After final assembling, cleaning and vacuum-firing (if applicable) of the vacuum chamber, vacuum tank or vacuum component under test, a first helium leak check has to be carried out. The leak test procedure depends on the volume of the object to be tested.

In general, vacuum chambers (e.g. tubes) must be leak checked as shown in Fig. 1. Note that the leak test must be done while valve A is closed and valve B is open.

For small vacuum vessels with a volume in the range of  $V \leq 1 \text{ m}^3$ , a simplified setup can be used. Such small vacuum vessels may be connected directly to a leak test device as shown in Fig. 2.

For leak detection a calibrated leak detector is to be used only. The calibration may be performed either by using a dedicated internal test leak generally integrated in commercially available standard leak detectors, or by using a dedicated external calibrated test leak. The calibration of the leak detector shall be documented in detail.

The vacuum chamber, vacuum tank or vacuum component shall be enveloped by a suitable encasement in order to carry out an integral leak check. Typically, a polyethylene foil sleeve can be used. GHe must then be injected into the encasement so that the entire vacuum chamber or component is exposed to high He concentration (ideally 100% He concentration). It must be ensured that the polyethylene foil sleeve or bag is gas-tight. The reading of the leak detector must be recorded continuously during the entire testing time.

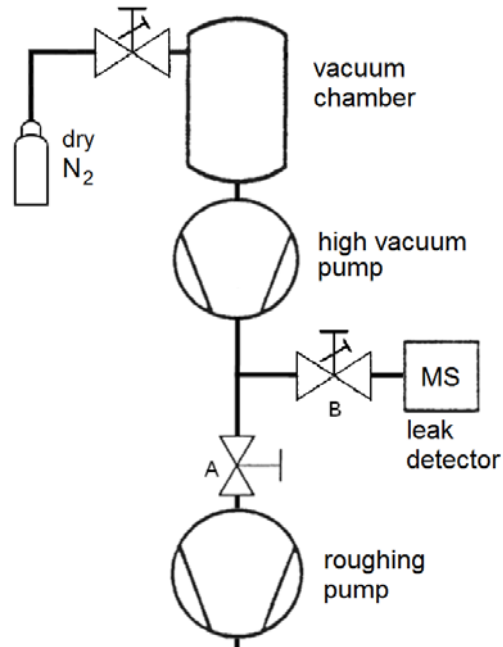


Fig. 1: General leak detection setup.

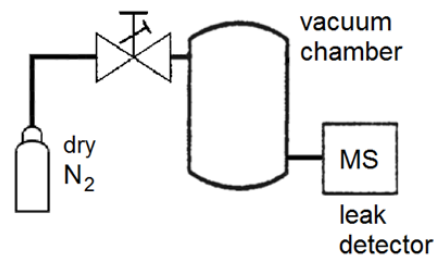


Fig. 2: Leak detection setup for volumes  $\leq 1 \text{ m}^3$ .

**Acceptance criterion:** The leak test is declared as passed if during the entire testing time of  $t \geq 10 \text{ min}$  the integral leak rate is  $q_{\text{He}} \leq 1 \cdot 10^{-10} \text{ mbar } \ell/\text{s}$ .

The documented  $q_{\text{He}}$  vs.  $t$  chart is part of the acceptance test protocol and must be provided. If **after an adequate pump-down time** (which shall be documented in detail) the leak rate background signal,  $q_0$ , is still too high, it has to be subtracted prior to the leak test. The subtraction is, however, only permitted once a level of  $q_0 < 5 \cdot 10^{-9}$  mbar  $\ell/s$  has been reached. The background signal,  $q_0$ , must additionally be documented. If the leak rate reading tends to increase steadily towards the acceptable limit of  $q_{\text{He}} \leq 1 \cdot 10^{-10}$  mbar  $\ell/s$  during the testing time, the testing time must be extended to  **$t \geq 20$  min**. If the leak rate exceeds the maximum value during this extended measuring time, the leak check has to be aborted and the leak test is declared as failed. In this case the local tracer probe technique has to be applied in order to localize all leaks. In general, leak checking shall be done according to EN 1779 (or equivalent), and the leak checking technique shall be disclosed.

## 2.) Measurement of the residual gas composition

Vacuum chambers, vacuum tanks or vacuum components which are specified as bakeable ultra-high vacuum components have to undergo a proper bake-out cycle under ultra-high vacuum conditions ( $p < 10^{-7}$  mbar). If the bake-out equipment (heating jackets, thermocouples, thermal cut-out devices, ...) is part of the contractually agreed scope of delivery, this specific bake-out equipment has to be used. Otherwise the entire bake-out equipment must be provided by the contractor. The vacuum chamber, vacuum tank or vacuum component (with built-in components, if applicable) has to be baked-out at temperatures generally of up to 300 °C or to the maximum permitted temperature (bake-out temperature limitations are specified in the corresponding specifications of the vacuum component, respectively). The bake-out duration is not specified in general. Rather, the bake-out duration shall be chosen such that the acceptance criteria given below will be fulfilled after the bake-out cycle. The bake-out cycle, the test setup, the test procedures as well as the equipment used (all pumps, valves, vacuum diagnostics, bake-out temperatures, ...) must be documented in detail.

**Prior to and after the bake-out cycle** the residual gas composition has to be recorded at room temperature level **after adequate pump-down time** (which shall be documented in detail). Both RGA spectra must be recorded with the same RGA and identical analyzer parameters. The RGA type to be used shall have a lower partial pressure measuring limit of  $\leq 5 \cdot 10^{-14}$  mbar (electron multiplier or Channeltron® electron multiplier) and must be sensitive in a mass range of at least **0 ... 100 amu**. All RGA parameters must be preset such that an acceptable and sufficient signal-to-noise ratio is ensured. The RGA type as well as relevant RGA parameters (e.g. electron multiplier voltage or Channeltron® electron multiplier voltage, dwell time, resolution) shall be documented. The RGA spectra must be recorded continuously in the entire mass range between 0 ... 100 amu using constant analyzer parameters. Full-range or partitioned RGA spectra recorded with variable analyzer parameters are not allowed. RGA spectra shall be recorded in **analogue-scan mode**, i.e. bargraph scans are not allowed. Raw data of the RGA scans has to be provided. The RGA spectrum recorded after the bake-out cycle must be evaluated in detail according to following acceptance criteria.

### Acceptance criteria after bake-out cycle:

- The dominant mass peak must be H<sub>2</sub> (2 amu = reference peak).
- The mass peaks  $\geq 12$  amu to  $\leq 19$  amu, 28 amu and 44 amu have to be at least **10 times** lower compared to the reference peak.
- The mass peaks  $\geq 20$  amu to  $\leq 40$  amu (except 28 amu) have to be at least **50 times** lower compared to the reference peak.
- The mass peaks  $\geq 41$  amu (except 44 amu) have to be at least **1000 times** lower compared to the reference peak.

RGAs typically provide an ion current vs. mass number scan. However, some modern RGAs convert the ion current into an *approximate* partial pressure value and instead display a partial pressure vs. mass number plot. The abovementioned criteria apply regardless of the display mode of the used RGA, i.e. the relative peak heights (either partial pressure  $p$  [mbar or Pa] or ion current  $I$  [A]) are decisive.

The ion current (or partial pressure) axis of the RGA spectrum must be represented using a logarithmic scale, displaying the most meaningful data range and covering at least 4 decades. Furthermore, all relevant RGA parameters (particularly all relevant analyzer settings) must be documented in the acceptance test protocol. In order to present the compliance with the acceptance criteria, it is recommended to display a spectrum normalized to the H<sub>2</sub> reference peak. The criteria can be displayed as a separate line in the same graph.

The same acceptance criteria also apply to vacuum chambers with RF gaps (ceramic gaps) and to vacuum chambers or large-volume vacuum tanks with built-in components.

### 3.) Measurement of outgassing rate

The surface-related outgassing rate of the vacuum-facing surfaces must be measured **after the bake-out cycle** (at room temperature). If not otherwise specified, a surface-related outgassing rate (N<sub>2</sub>-equivalent) **after an adequate pump-down time** (which shall be documented in detail) of

**Acceptance criterion after bake-out cycle:**

$$q_{\text{out}} \leq 1 \cdot 10^{-12} \text{ mbar } \ell/\text{s}/\text{cm}^2$$

must be demonstrated. This acceptance criterion also applies to vacuum chambers or large-volume vacuum tanks with built-in components. Outgassing rate measurements can be carried out using various techniques, for instance pressure-rise/accumulation methods, throughput methods, ultimate pressure methods, etc. The measuring setup has to be documented in detail, including an accurate description of the measuring procedure and all measuring devices. Note that the outgassing measurements should be carried out while the RGA is switched off (in order to avoid any additional outgassing due to the RGA filaments).

### 4.) Second helium leak check

A second helium leak check shall be carried out **after the bake-out cycle** (at room temperature level) in the same way as described in 1.). The same acceptance criterion applies.