WHAT TO WATCH OUT FOR IN FACTORY ACCEPTANCE TESTING OF LEAK DETECTION SYSTEMS

Factory Acceptance Checklist

A Factory Acceptance Test (FAT) is a quality assurance process performed at the manufacturer's facility in which machines, systems, or equipment are thoroughly tested before being delivered to the customer.

The main goal is to verify that the item meets all predefined specifications, performance criteria, and customer requirements as outlined in the purchase order or contract.

FATs typically involve functional and performance testing, review of documentation, safety checks, and validation of compliance with relevant standards.

Ensuring a leak detection system performs flawlessly from day one starts with a solid Factory Acceptance Test. A precise, well-structured FAT prevents costly surprises by confirming accuracy, repeatability, and compliance under real operating conditions.

This guide highlights the essential checkpoints that help you protect quality, minimize risk, and confidently approve your system before installation.

For a Factory Acceptance Test (FAT) of a leak detection system used in quality control, there are specific considerations to ensure the system meets performance, accuracy, and compliance requirements before shipment. Three things are of special importance:

Defining Clear Acceptance Criteria

- ✓ Set detailed acceptance criteria based on required functionality, accuracy, precision, and compliance standards.
- ✓ Include measurement uncertainty, calibration standards, and environmental conditions relevant to the intended use.

Developing a Detailed Test Plan

- ✓ Create a comprehensive test plan that outlines specific measurement tests, procedures, and expected results.
- ✓ Cover functional performance tests that simulate real-world operating conditions to validate the measuring system's accuracy and reliability.

Calibration and Documentation

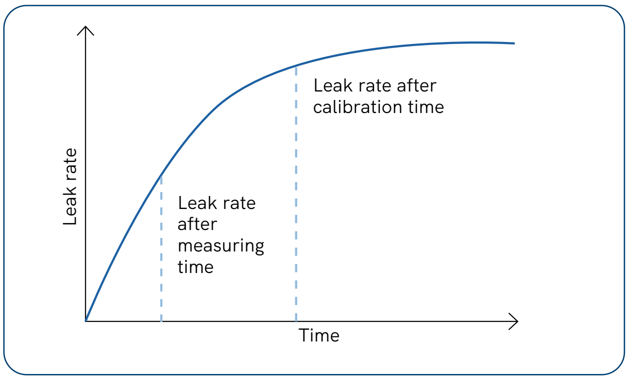
- ✓ Verify that all measurement instruments used in the FAT are properly calibrated and within their calibration validity period.
- ✓ Document all calibration certificates and ensure traceability to national or international standards.

Ensuring proper calibration

Calibration of a leak detection system should be performed with the exact same parameters as the measurements later on specifically watch out for:

→ **The same measurement time is used during calibration as for measurements.**

To achieve short cycle times and high throughput in automated leak testing system, measurements are taken as early as possible while the leak detector signal is still rising. Different measuring times will create different calibration factors. If longer measurement times are used during calibration, leak rates will be shown too large and the sensitivity of the system will be over-estimated.



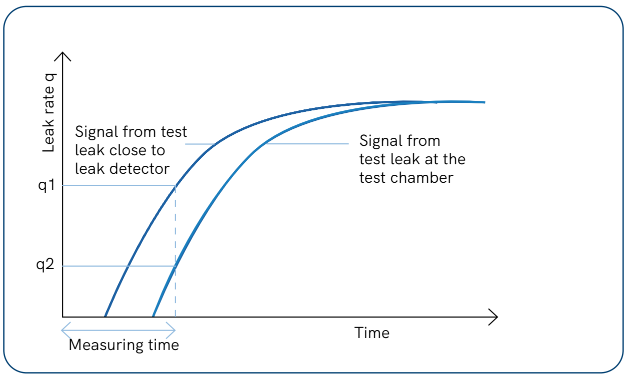
→ Calibration must be performed with the same tracer gas concentration as in standard testing operation

If a calibration is carried out with 100% Helium, but the system operates with a lower helium concentration later on, small leaks will be passed unnoticed. If the calibration leak used is filled with 100% tracer gas, but the parts are filled with a lower concentration, you may apply a correction factor to the calibration leak rate.

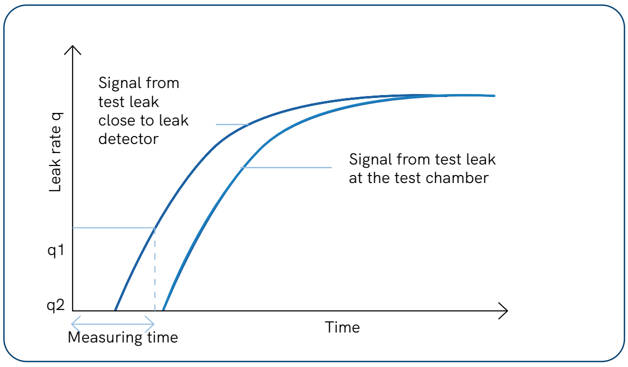
→ The calibration test leak must be installed at the test chamber

Calibrated leak connected to leak testing chamber

The position of the test leak influences the calibration process due to varying response times with varying lengths of gas flow paths. A test leak close to the leak detector inlet (or even an internal test leak) will show a larger leak rate than a test leak at the test chamber at a given time.



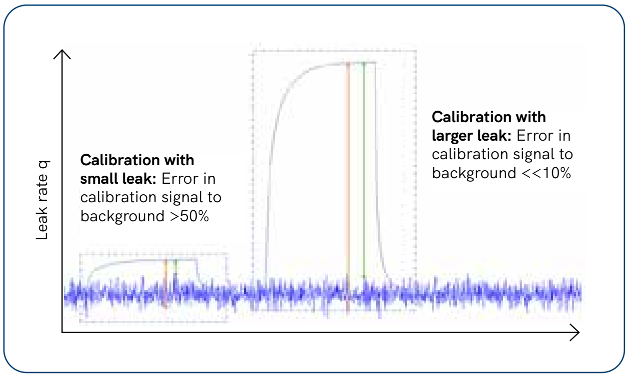
Worst case, a leak close to the leak detector may be detected while a leak on the test chamber will not be detected at all in the given measuring time.



Using an internal leak (built into the leak detector) poses another risk: Sometimes very large pumps are installed on the chamber to achieve quick pump down times and only a partial flow from the chamber is routed to the leak detector. In that case, only part of the gas escaping from the leak is reaching the leak detector in operating mode, while the full leak rate would be used for calibration.

→ Calibration should be carried out with a test leak at least one decade higher than the background

For a stable calibration, it is always advisable to calibrate with a leak rate that is at least one decade higher than the background so that the leak detector can clearly distinguish between the background and test leak signals. This way, any fluctuations of background do have little influence on the calibration signal. A larger calibration leak allows for a more accurate calibration. Especially for detection of small leaks, the leak rate used for calibration should be larger than the reject leak rate.



→ Ensuring documentation and traceability

Leak standards come with a calibration certificate that state the calibrated leak rate, the uncertainty of the measurement as well as the traceability to national standards. Calibration certificates are typically valid for one year. Leak standards have to be re-certified after that period of time. Leaks without valid certification are not suitable for calibration and will infringe on compliance.

Verification of proper detection capabilities

→ Verification of the smallest detectable leak rate matching the reject leak rate

To verify that the acceptance criteria are met, use a test leak that matches the reject leak rate (different from the calibration leak). Verification can be done with a leak installed on the test chamber or with a dummy part that has the same reject leak rate. If using a verification leak on the chamber, place it at the point furthest from the detector.

Selection of screw-in leak – available with customized leak rate matching the reject leak rate

Use the same parameters as in normal operation (measuring time, tracer gas concentration) and check that the verification leak is detected correctly. For adjustable screw-in leaks, ensure the fill pressure matches the standard operating pressure.

→ Ensuring Sufficient Repeatability with Statistical Analysis

A measurement system analysis (MSA) is a statistical method used to assess how accurate, consistent, and reliable a measurement system is. It identifies variation caused by instruments, procedures, operators, or environmental factors to ensure measurements are dependable for quality control.

Gauge Repeatability and Reproducibility (Gauge R&R)

Gauge R&R measures how much variation comes from the equipment (repeatability) and from different operators (reproducibility). It shows whether the measurement system is suitable for quality control by indicating the portion of total variation caused by measurement error. Systems with Gauge R&R below 30% are generally acceptable, while those below 10% are considered very good.

In leak detection, a Gauge R&R study uses multiple measurements of ten test parts by three operators to assess measurement variation. If parts cannot provide consistent leak rates (e.g., battery cells with liquid electrolyte), certified test leaks may be used instead. The parts should have leak rates close to the leak-tightness criteria, since using parts with leak rates spanning several orders of magnitude can produce misleading results due to differing absolute and relative errors.

Process and Measurement System Capability Indices

The gauge capability index, denoted as C_g, measures the capability of the measurement system. A higher C_g (typically ≥ 1.33) indicates a capable gauge with good precision. The index is calculated using the formula:

$$C_g = \frac{0.2 \cdot T}{6\sigma}$$

Where T is the tolerance (acceptable variation range), and σ is the standard deviation. The related index C_{gk} includes the bias (accuracy) of the measurement system, providing a fuller assessment of gauge capability, where

$$C_{gk} = \frac{0.1 \cdot T - |\bar{x}_g - x_m|}{3\sigma}$$

Here, x̄_g and x_m are the measurement mean and test leak value, respectively. Both C_g and C_{gk} should be greater than 1.33 for a fully capable system. For a more detailed description we refer to the available literature.

→ Testing for drift and frequency of recalibration (long term repeatability)

While the MSA gives good measures to judge on the short-term repeatability, it is important to also evaluate the longer-term repeatability. If the signal from your leak detection system slowly drifts over time, the short-term repeatability may be very good, but still within a working shift the signal drift may create significant error.

When assessing the system, make sure to verify the performance over the course of at least one shift, better even a day or two and measure a known leak rate at a preset frequency, e.g. every two hours. The amount of drift you detect will determine how often the leak detection system will need to be calibrated. A system requiring less frequent recalibration will be more convenient to use and also more reliable to operate.

→ Ensuring proper recovery after gross leaks

Detection of a gross leak will increase the background of the system and may cause limited detection capabilities in the following leak testing cycles. Often a gross leak test via pressure decay is used before filling the part with tracer gas.

To evaluate the behavior of the test system, a gross leak matching the size of the gross leak pretest detection limit should be applied to the system (representing the worst case scenario) and a verification leak should be measured afterwards to verify no leaks will be missed after a previous large leak.

All set?

Ensuring proper calibration

- ☐ The same measurement time is used during calibration as for measurements
- ☐ Calibration must be performed with the same tracer gas concentration as in standard testing operation
- ☐ The calibration test leak must be installed at the test chamber
- ☐ Calibration should be carried out with a test leak at least one decade higher than the background
- ☐ Ensuring documentation and traceability

Verification of proper detection capabilities

- ☐ Verification of the smallest detectable leak rate matching the reject leak rate
- ☐ Ensuring sufficient repeatability with statistical analysis
- ☐ Testing for drift and frequency of recalibration (long term repeatability)
- ☐ Ensuring proper recovery after gross leaks