

INFICON WHITEPAPER

Robotic Leak Testing



A guide to selecting the proper robotic leak testing solution

Robotic Leak Testing

Content

Introduction	3
1 How does robotic leak testing work?	4
1.1 Static testing.....	4
1.2 Dynamic testing.....	5
2 Sniffer leak testing and sniffer flow rate	5
2.1 Static leak testing	5
2.2 Dynamic leak testing	6
3 Testing results for different leak detectors	8
3.1 Testing conditions	8
3.2 Influence of the sniffer gas flow	8
3.3 Static leak testing	8
3.4 Dynamic leak testing	9
3.4.1 Oil leakage ($\sim 10^{-3}$ mbar·l/s)	9
3.4.2 Liquid fuel leakage ($\sim 10^{-4}$ mbar·l/s)	11
3.4.3 Fuel vapor / refrigerant leakage ($\sim 10^{-5}$ mbar·l/s)	12
3.5 Summary of test results	13
4 Five Tips and Tricks for Practical Use	15
4.1 Select the optimal test methods, scan speed and distance!.....	16
4.2 Avoid crosswinds!	16
4.3 Check the calibration carefully and regularly!	16
4.4 Control your background concentration!	16
4.5 Avoid cross-contamination when using forming gas!.....	17
5 Additional information.....	18
6. About INFICON	19
7. E-Book: Leak Testing in the Automotive Industry	20
8. Contact Information.....	21
Source of Illustrations.....	22

Introduction

There are two certainties driving the market for robotic sniffer leak detection. One, the market for industrial robots is growing at an annual rate of 15% (source: IFR World Robotics 2017). Two, sniffer leak detection is indispensable in many manufacturing processes if the quality of the products is to be guaranteed. Modern sniffer leak detectors determine if a test gas is escaping from any leaks in a tested part. They also determine the exact size of the leak and where it is located. Sniffer leak detection is often used to check whether the joints between already assembled components are actually leak tight. In automotive production, for example, a typical application scenario is the leak test on pre-assembled components of an air conditioning system before it is finally installed in the vehicle.

Robotic leak detection has proven to be a great way to automate many quality control tasks. The measuring probe is not guided over the surface of the part by a human operator, but by a robot arm, eliminating costly human error. As a result, robotic sniffer leak detection increases throughput in production, increases inspection reliability and improves product quality.

In this white paper, we will explain how robotic sniffer leak detection works in detail. You will learn about the differences between a static and a dynamic sniffer leak testing process, why the gas flow of the leak detector is so important, and which test configuration is suitable for which application. Finally, we provide a list of tips and tricks to help you understand what to look out for to ensure that your robotic leak testing process is most effective and efficient.

Robotic Leak Testing

1 How does robotic leak testing work?

Robots most often use a sniffing leak testing method. A robotic arm is moving the sniffer tip of a sniffer leak detector to the locations to be tested. The sniffer leak detector is giving an alarm if a relevant leak is found. Typically the leak detector is also integrated in a way that the robot's control can tell at what location the robot arm was when the leak was detected, thus saving the location of the detected leak.

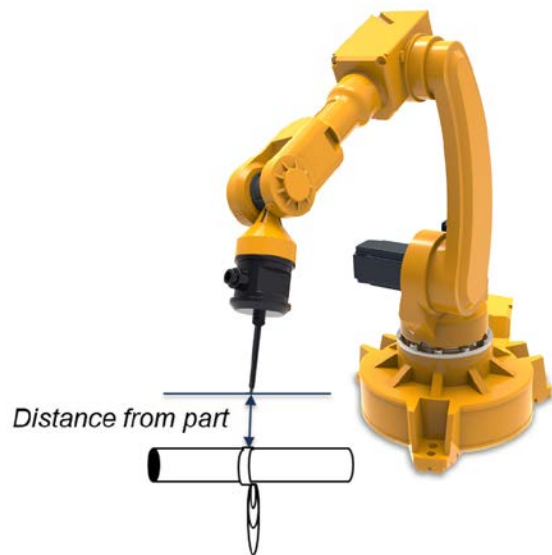


Example of a robotic leak testing application: A robot is sniffing potential leak locations on a battery pack housing

Two different scenarios need to be looked at when talking about robotic leak testing: *static testing* and *dynamic testing*.

1.1 Static testing

In static testing, the robot arm is moving to a specific location, keeps the sniffer tip pointing at that location for some seconds to check for leaks, and then moves on to the next location.



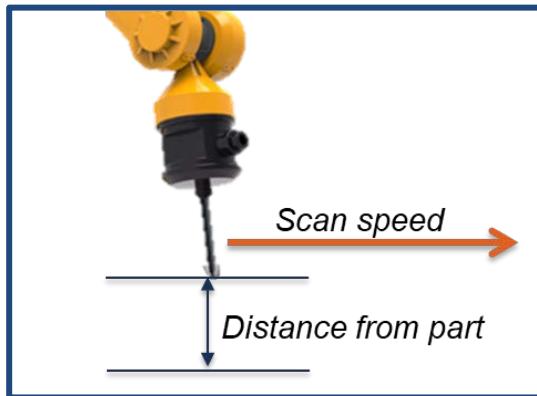
Principle of static leak testing

The important parameters for static testing are:

- the minimum distance between part and sniffer tip – this is often given by:
 - part-to-part variances (the minimum distance the sniffer tip needs to maintain in order not to crash into the part for worst case tolerances)
 - and by the accessibility of the potential leak location (other part geometries may limit the access to the desired location)
- the required holding time to *reliably* detect the leak.

1.2 Dynamic testing

In dynamic testing, the robot arm first moves to a certain position close to the part to be tested and then scans for leaks along a given path e.g. along a welded seam or along an installed seal. This path can be straight or winding.



Principle of dynamic leak testing

The important parameters for dynamic testing are:

- the possible minimum distance between part and sniffer tip – this is often given by:
 - part-to-part variances (the minimum distance the sniffer tip needs to maintain in order not to crash into the part for worst case tolerances)
 - and by the accessibility of the potential leak location (other part geometries may limit the access to the desired location)
- the maximum allowable scan speed – as fast as possible to test with high productivity, but as slow as needed in order not to miss any leak.

2 Sniffer leak testing and sniffer flow rate

2.1 Static leak testing

In static leak testing, the sniffer tip is moved towards the suspected leak location. Normally a small cloud of leaking gas has developed in front of the leak. When the sniffer tip approaches the gas cloud, gas is drawn into the sniffer tip by the sniffer gas flow.

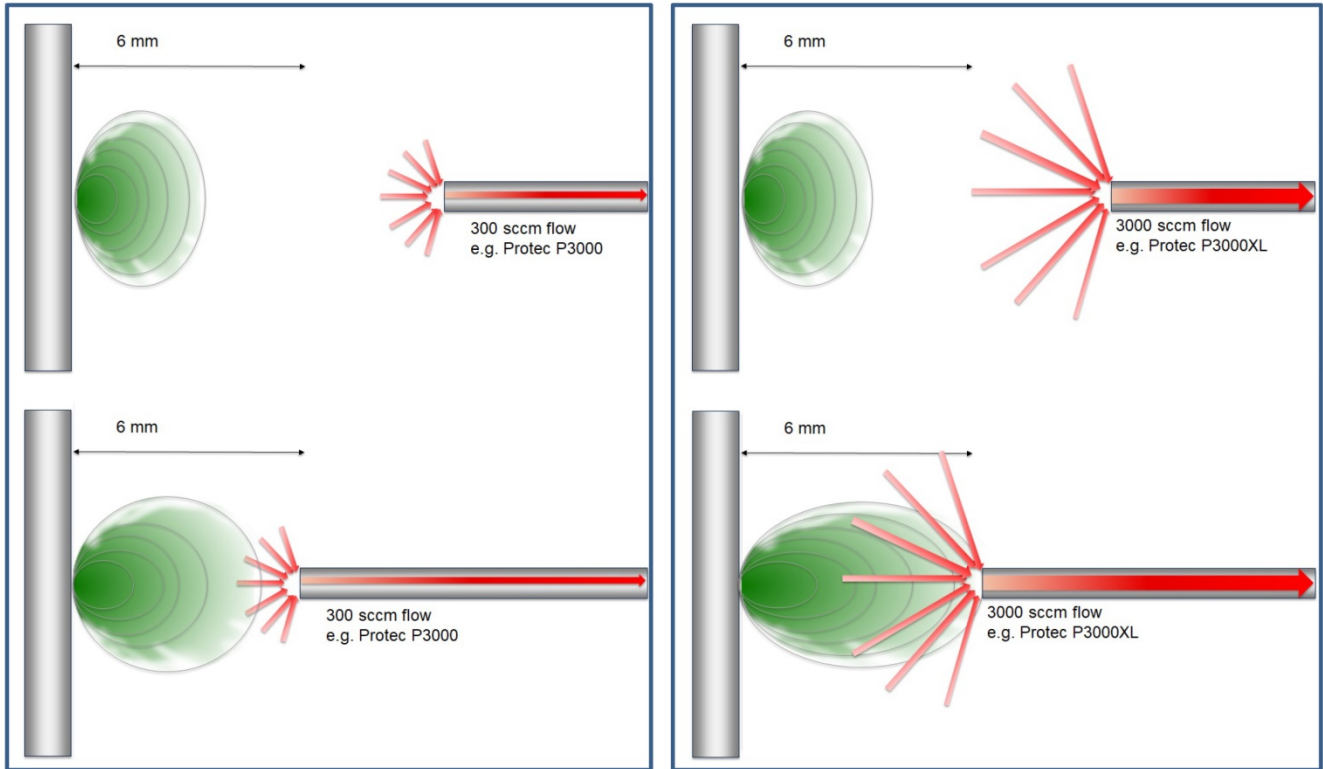
In an ideal scenario, the sniffer tip is moved right in front of the leak and all the gas escaping from the leak is drawn into the sniffer tip.

In real case scenarios however, this is often impossible either due to bad accessibility of the leak location or due to part-to-part variances and the need to program some safety distance into the robot's movement.

If the sniffer tip cannot be moved to zero distance, but has to stay at some safety distance, typically only a part of the gas cloud is drawn into the sniffer tip. The percentage of leak gas drawn into the sniffer tip increases with increasing gas flow rate into the sniffer tip (see illustration on page 6).

A real life example: Imagine two vacuum cleaners, one with low power and one with high power. Now also imagine a cigarette smoker blowing out smoke into the air. Which vacuum cleaner would draw in more of the cigarette smoke when they are at the same distance from the smoker? Of course, the one with the higher power.

Robotic Leak Testing



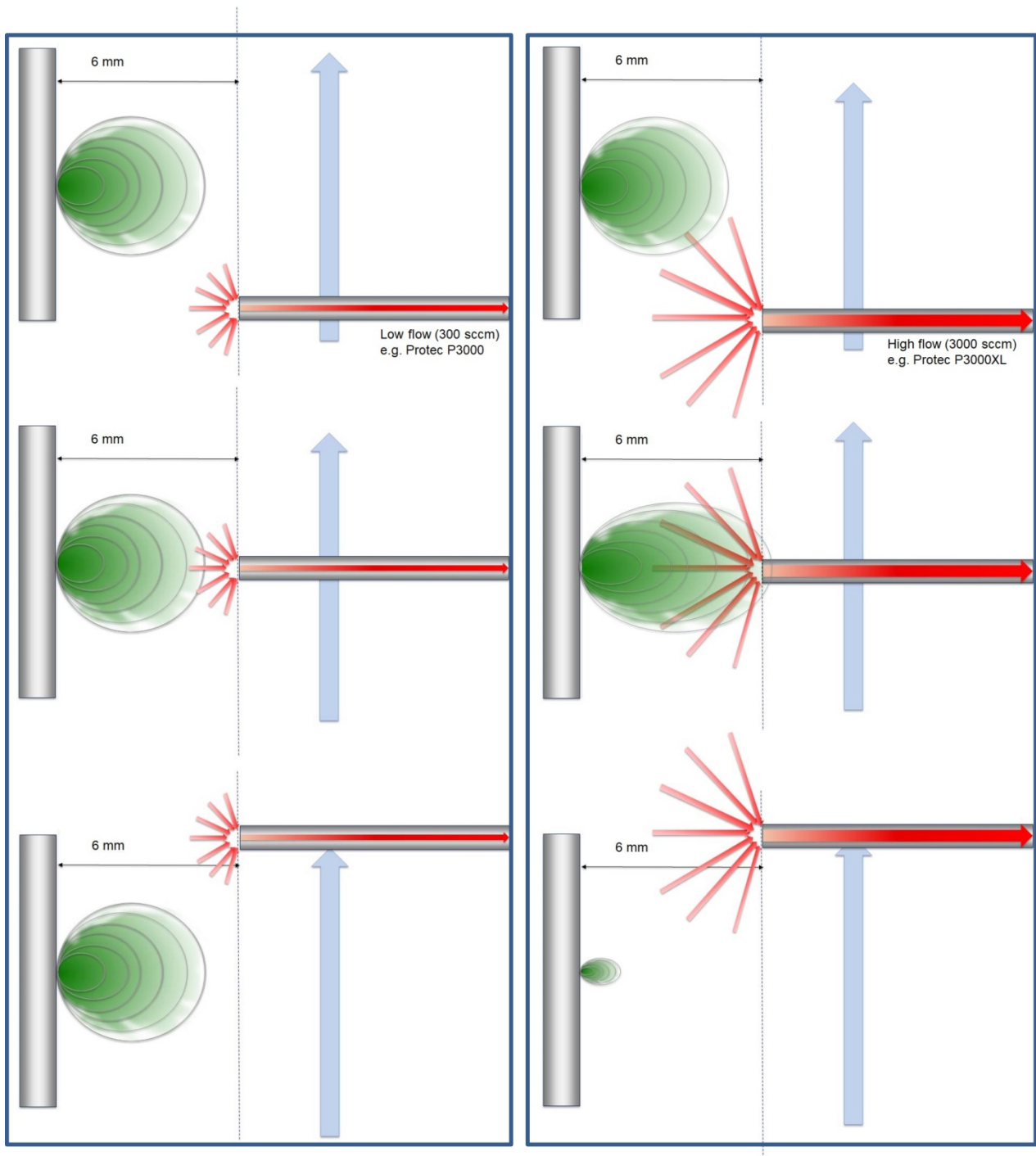
Static leak testing with low sniffer flow rate (left) and high sniffer flow rate (right)

2.2 Dynamic leak testing

In dynamic testing, the sniffer tip also has to keep a certain safety distance to the part like in static testing. Different from static testing, the sniffer tip is moved along the part with a constant scan speed, looking for gas escaping from a leak.

If the gas flow into the sniffer tip is low, only a small portion of the gas cloud is drawn into the sniffer tip (see illustration on page 7).

With high gas flow into the sniffer tip, a large portion of the gas cloud that has accumulated in front of the leak is drawn into the sniffer tip. This is why in this very moment more than just the gas escaping from the leak is taken in, resulting in a higher leak rate signal than the actual leak rate from the leak.



Dynamic leak testing with low flow rate (left) and high flow rate (right)

With high enough flow, the leak rate signal is always *at or above* the real leak rate from the leak, thus guaranteeing that no leak gets missed.

3 Testing results for different leak detectors

3.1 Testing conditions

Several different leak detectors have been tested for their capabilities in static and dynamic leak testing. All models / configurations tested are listed in the table below:

Leak detector model	Flow rate [sccm]	Test gas
Protec P3000	300	Helium
Protec P3000XL	3000	Helium
XL3000flex	300	Helium / Forming Gas
XL3000flex	3000	Helium / Forming Gas

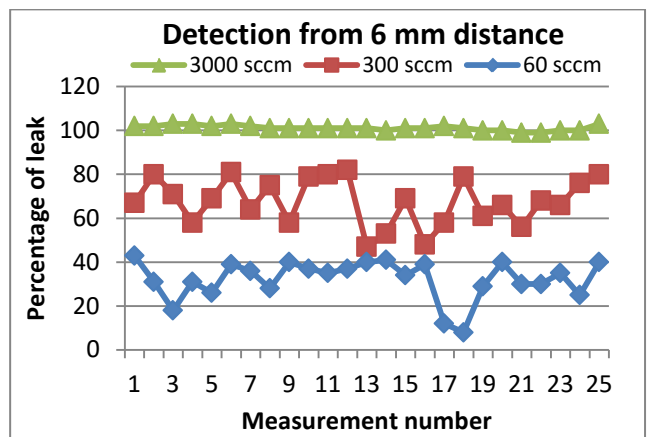
To represent real life scenarios, three different leak rates have been selected:

Leak rate range	Representing
$\sim 10^{-3}$ mbar·l/s	Oil leakage
$\sim 10^{-4}$ mbar·l/s	Liquid fuel leakage
$\sim 10^{-5}$ mbar·l/s	Fuel vapor / refrigerant leakage

For the following testing results, a safety distance to the part of 6 mm (approx. ¼ in) is assumed as this has been found to be a typical value used by many manufacturers.

3.2 Influence of the sniffer gas flow

With increasing distance from a leak, a high sniffer gas flow becomes essential to safely detect the leak. The following graph clearly illustrates this point.

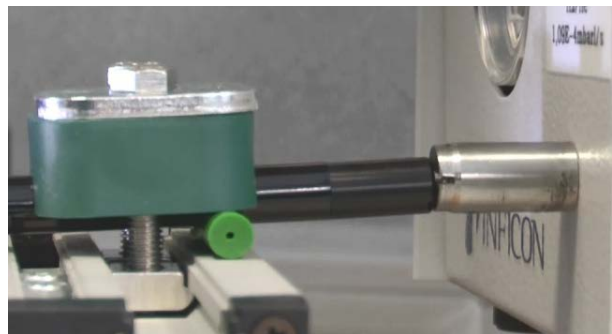


Percentages of a leak of $2 \cdot 10^{-3}$ mbar l/s that get detected in a distance of 6 mm from the leak, with different sniffer gas flows.

With leaks smaller than $2 \cdot 10^{-3}$ mbar l/s, the result for the two low gas flows of 300 and 60 sccm becomes even worse than for larger leaks.

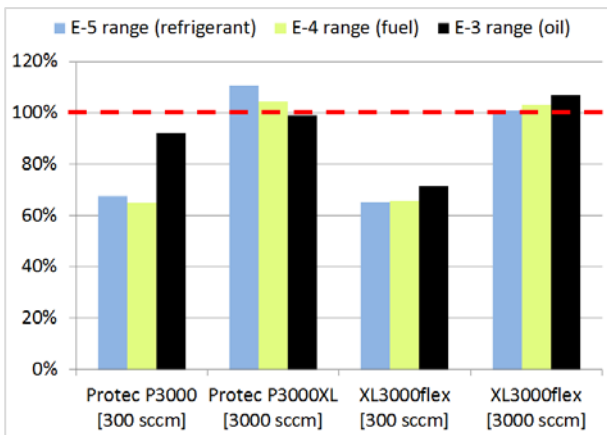
3.3 Static leak testing

For static leak testing, a sniffer tip was placed in front of a test leak outlet and the final leak rate signal was recorded. This measurement was repeated 25 times to check for signal size and repeatability.



Robotic Leak Testing

When looking at the leak rate signal for the three different leak types (oil, liquid fuel, fuel vapor or refrigerant) at 6 mm distance, it is once again clearly visible that at this increased distance from the leak, it can only be detected safely (i.e. the signal always exceeds 100% and therefore triggers the alarm) in the high flow modes of the Protec P3000XL and the XL3000flex.



Static helium leak rate signal for different leak detectors in different flow modes, all at 6 mm distance

3.4 Dynamic leak testing

In dynamic testing, a sniffer tip is moved across a test leak opening with constant transversal speed. The leak rate signal gets recorded. This process is repeated 25 times. As a representation of the quality of leak testing, the share of leak rate measurements that reach or exceed the nominal test leak value is tracked, i.e. what percentage of the 25 measurements causes the alarm to trigger.



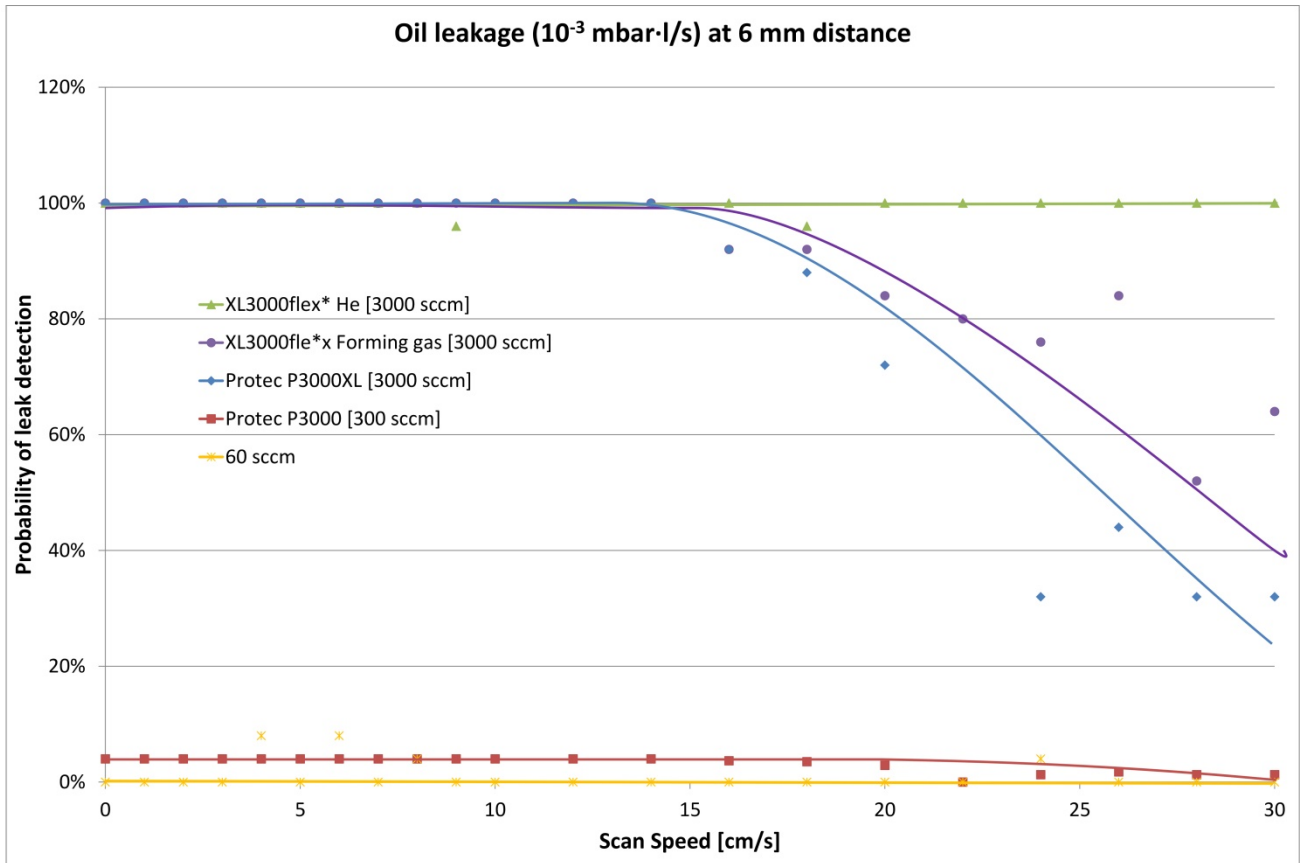
Setup for dynamic testing: sniffer tip is moved across a test leak opening with constant transversal speed (Click on picture to see video illustrating the testing cycle on YouTube)

The testing is performed again for three different leak rate levels, representing oil, liquid fuel and fuel vapor / refrigerant leakage.

The following graphs shows the probability of a leak detector detecting a leak with varying scan speeds and leak rate sizes. At 100% probability the leak detector detects the leak at all times. From the graphs it can be derived to what scan speed the different leak detector models / configurations can be used safely without the risk of missing any leaks.

3.4.1 Oil leakage (~10⁻³ mbar·l/s)

If a component must be oil-tight, it is typically tested against leak rates in the range of 10⁻³ mbar·l/s. For direct comparison, in this example, all testing took place with a test leak of 1·10⁻³ mbar·l/s and a distance between the sniffer tip and the test piece of 6 mm (~ 0.25 in). This distance was selected as a typical setup for robotic sniffing. (Getting closer to the test piece in a dynamic measurement could result in lack of accessibility or a collision with the product due to varying tolerances in the test piece.)



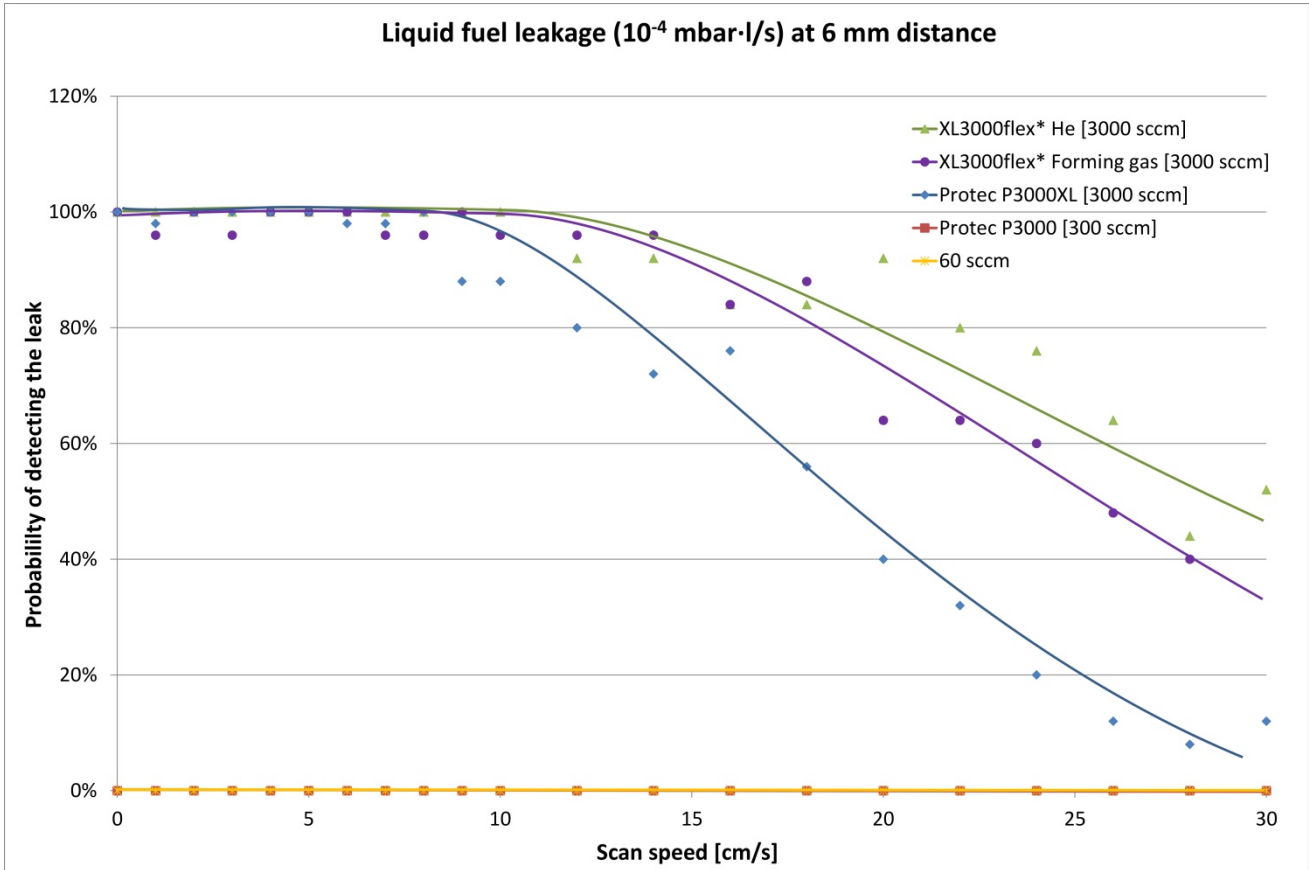
*Test data for XL3000flex also applicable to LDS3000 with XL adapter

Leak rate signal for oil leakage at 6 mm distance and various scan speeds

The result of the extensive testing: conventional, commercially available sniffer leak detectors, which suck in gas with a flow of only 60 sccm, fail completely in this scenario. The probability of a leak of $1 \cdot 10^{-3}$ mbar-l/s being found by such devices is close to zero. Even devices that operate with a flow of 300 sccm are not suited for this application.

There is a high probability that all leak detectors with a flow significantly lower than 3000 sccm will fail to detect such leaks. However, there are still more subtle differences between different high flow offerings. The INFICON Protec P3000XL, the XL3000flex and the LDS3000 with the XL sniffer

adapter all use a flow of 3000 sccm. The LDS3000 with XL sniffer adapter, the XL3000flex and the Protec P3000XL, all used with helium, show the best performance and outperform the instrument used with forming gas (5% hydrogen in 95% nitrogen). While the Protec P3000XL and the XL3000flex/LDS3000 with XL adapter used with forming gas may be used up to a scan speed of approx. 15 cm/s safely (detecting 100% of the leaks), the LDS3000 with XL sniffer adapter and the XL3000flex, both used with helium, did not miss any leaks, even at 30 cm/s.



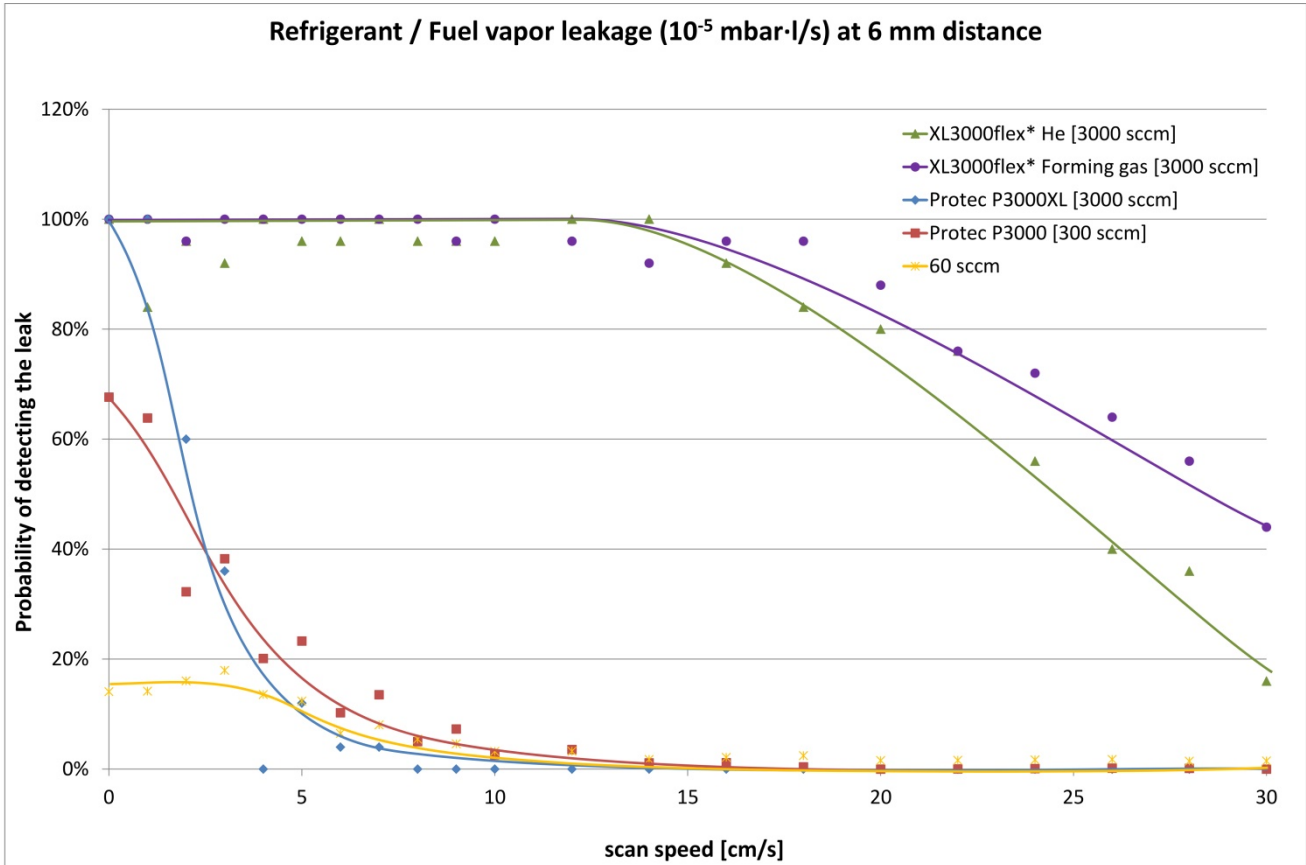
*Test data for XL3000flex also applicable to LDS3000 with XL adapter

Leak rate signal for liquid fuel leakage at 6 mm distance and various scan speeds

3.4.2 Liquid fuel leakage ($\sim 10^{-4}$ mbar-l/s)

If a component in the automotive industry must be tested for liquid fuel leaks, the leak rates are usually one order of magnitude smaller, i.e. in the 10^{-4} mbar-l/s range. In the testing setup, with a distance of 6 mm from the surface of the test piece, but with a 10^{-4} mbar-l/s test leak, neither the 60 nor the 300 sccm leak detectors correctly detected a leak of this size, at any test speed. The Protec

P3000XL, the XL3000flex and the LDS3000 with XL sniffer adapter (all with 3000 sccm flow) show the same performance up to approx. 9 cm/s scan speed. While the Protec P3000XL probability to detect the leak steadily declines at higher speeds, the XL3000flex and the LDS3000 with XL sniffer adapter still detect 100% of all leaks up to 12 cm/s before starting to decline slowly for both tracer gases (helium and forming gas).



*Test data for XL3000flex also applicable to LDS3000 with XL adapter

Leak rate signal for refrigerant and fuel vapour leakage at 6 mm distance and various scan speeds

3.4.3 Fuel vapor / refrigerant leakage (~10⁻⁵ mbar-l/s)

For leaks even one decade smaller – like when testing for fuel vapor or refrigerant leakage – the difference in performance becomes even more prominent. Testing data was again collected with an approx. 2·10⁻⁵ mbar-l/s leak at 6 mm distance. The probability of detecting such small leaks at 6 mm distance with the Protec P3000XL, in spite of its high flow, starts to decline quickly with increasing scan speed. The LDS3000 with XL sniffer adapter, however, can still reliably be used up to 14 cm/s scan speed, even for such small leaks.

3.5 Summary of test results

Leak rate range	Corresponds to	Protec P3000XL [3000 sccm]	XL3000flex* Helium [3000 sccm]	XL3000flex* Forming Gas [3000 sccm]	Standard Sniffer [60 sccm]
~ 10 ⁻³ mbar-l/s	Oil leaks	14	30	14	Not reliable even for static testing
~ 10 ⁻⁴ mbar-l/s	Liquid fuel leaks	9	10	10	Not reliable even for static testing
~ 10 ⁻⁵ mbar-l/s	Fuel vapor / refrigerant leaks	0	6	12	Not reliable even for static testing

*Test data for XL3000flex also applicable to LDS3000 with XL adapter

Maximum allowable scan speed in cm/s to safely detect leaks at 6 mm distance, under lab conditions

Note that all of this data was recorded in a lab environment to ensure repeatable results. Even with the best air movement protection, it is not wise to use the maximum scan speed from the table above in an industrial environment.



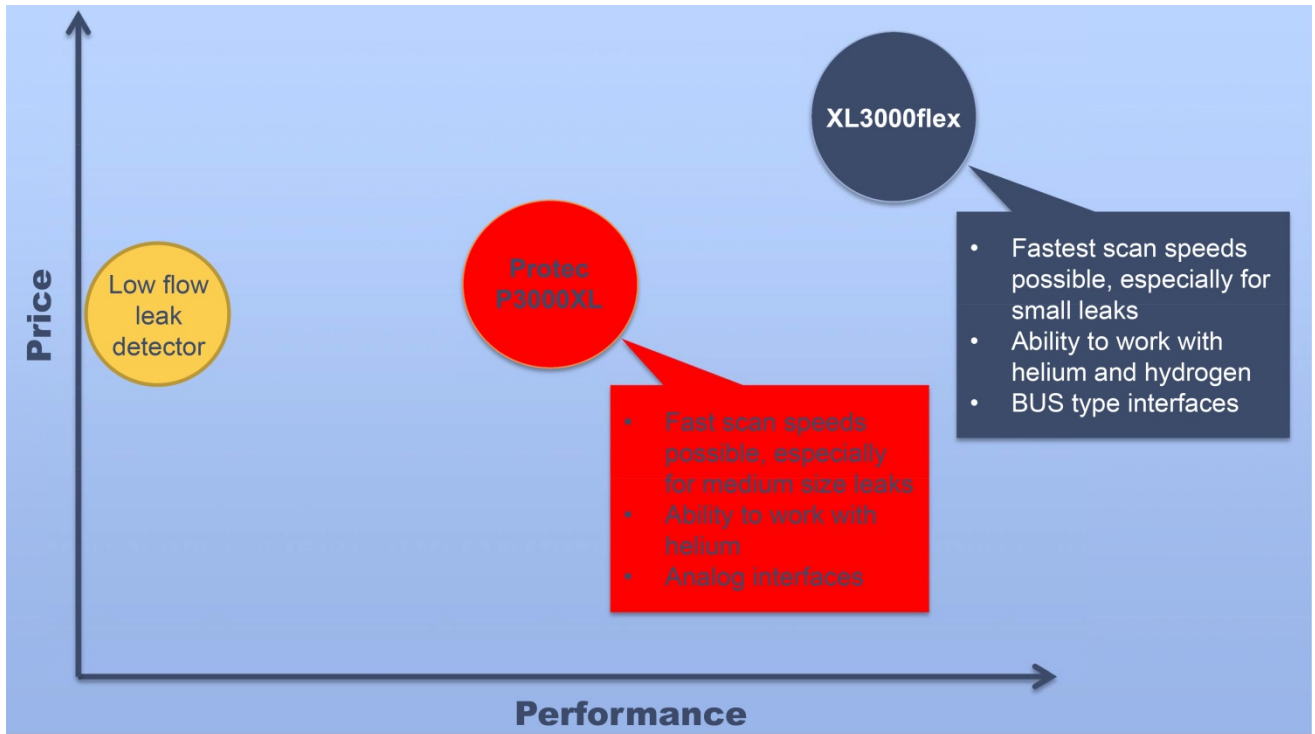
Protec P3000XL, Sniffer Leak Detector for helium

The Protec P3000XL is a good standard for robotic testing with helium as the tracer gas. It can detect leaks in the 10⁻³ ... 10⁻⁴ mbar-l/s range with high probability even at significant scan speeds at a typical distance from the test piece, common in robotic sniffing.



INFICON XL3000flex, Sniffer Leak Detector for helium and hydrogen / forming gas

The XL3000flex and the LDS3000 with XL sniffer adapter are the premium products for this application. They should be used when highest scan speeds are important and / or when detecting leaks in the 10⁻⁵ mbar-l/s range, like for fuel vapor or refrigerant leakage. In addition, the LDS3000 with XL sniffer adapter can be used with helium or forming gas at nearly the same performance. Last but not least, the XL3000flex and the LDS3000 with XL sniffer adapter offer modern BUS type interfaces for communication.



Product positioning of different leak detector offerings for robotic leak testing

4 Five Tips and Tricks for Practical Use

There are many advantages to using an automated sniffer leak detection system on your production line. In this chapter of the whitepaper, we provide tips and tricks to get you started with robotic leak testing and remove possible pitfalls.

5 Tips for best practices in robotic leak testing



1 Meet the requirements

For dynamic robotic leak testing, you need a high flow leak detector, a small distance between sniffer tip and component, and moderate scanning speed.



2 Lock out air drafts

Crosswinds caused by air drafts will negatively impact the results of your robotic leak testing. Putting your robotic leak testing station into an enclosure will effectively protect your testing area against cross winds.

3 Check the calibration regularly

It is very useful to quickly check the proper calibration of your robotic leak testing station with a reference leak - to automatically recalibrate the test station if needed.



4 Keeping the background under control

High background concentrations of test gas can be prevented by evacuating your parts after each test and releasing the test gas outside the building.

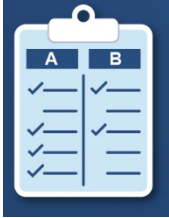


5 Prevent cross-contamination when using forming gas

Forming gas contains 5% hydrogen. Make sure to shield your leak testing station from other sources of hydrogen, like battery charging stations or LNG-driven fork lifts.



Robotic Leak Testing



4.1 Select the optimal test methods, scan speed and distance!

If you know the areas where typically leaks will occur on your part - for example, at certain joints - then static robotic sniffer leak testing is the method of choice. In this case, the robot arm may move at high speed before and after the actual measuring process but stays static during the actual measurement. If, however, a larger surface area of a component is to be checked for possible leaks, you need to install a dynamic robotic sniffer test with an appropriate speed. It makes more sense to save time when physically handling the part than during sniffing. With dynamic sniffer leak detection, the sniffer sensor head should move as slowly over the test piece as the cycle time in your production line allows - the reliability of your dynamic sniffer leak detection increases if you reduce the speed. Even more important than the speed, is the distance between the probe and the surface of the part being inspected as your test setup is most accurate from a small distance.



4.2 Avoid crosswinds!

A draft of air can make reliable sniffer leak detection impossible, even from a distance. It therefore makes sense to enclose your test area. Typically, robot stations are housed in cages anyway in order to ensure the worker's safety and to protect them from the rapid movements of the robot arms. Instead of the cage, acrylic glass walls are recommended in

the case of robotic leak detection. Acrylic glass not only ensures worker safety, but can also shield the inspection area from air movements such as those caused by ventilation and air conditioning systems or bypassing forklifts, etc. In the case of static leak detection, you can also work with clam shells at the tip of the robot arm to protect the joints to be tested from drafts during the test.



4.3 Check the calibration carefully and regularly!

It is always recommended to carefully calibrate a leak testing system. For the best results, check the calibration of your robotic sniffer leak detection station at least once per hour. To do this, guide the sniffer tip to a reference leak of a defined size, which always causes the same leakage rate. If this leakage rate is not determined exactly, the calibration is no longer precise and a new calibration factor must be used. The external calibration function of the sniffer leak detector can automatically determine this factor using the reference leak. Usually, the new calibration factor will differ from the old one only by a few percentage points.



4.4 Control your background concentration!

High background concentration is the most common cause of false positive readings. However, the accumulation of a high background concentration at your sniffer leak detection station can be avoided with a few simple steps. Evacuate the test parts

Robotic Leak Testing

before and after each test. Additionally, monitor your tracer gas fill process to determine if the part is connected correctly. It is also a good precaution if the cylinders for your test gas supply are some distance away from your actual test station. In this way, mishaps such as during changing gas cylinders do not affect your entire robotic sniffer leak detection station. It is also a good idea to thoroughly inspect the gas supply lines themselves for leaks, as they are an obvious source of excessive underground concentration. And finally, prevent test gas accumulation by ensuring gradual and even air exchange within your enclosure. It is recommended to replace the enclosed volume with fresh air once a minute. But be careful: the fresh air supply for your enclosure must never be near the test gas exhaust.



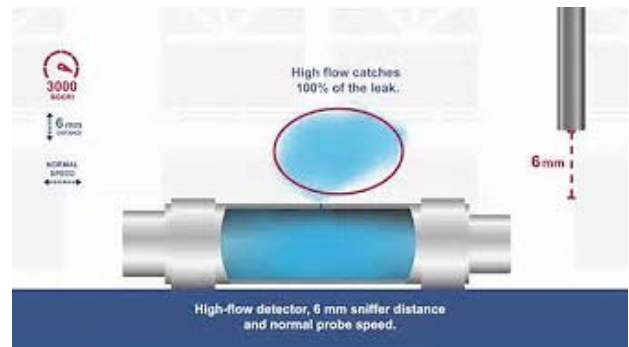
4.5 Avoid cross-contamination when using forming gas!

In addition to helium, forming gas is also commonly used as a test gas. Forming gas is a (non-combustible) mixture of 5 percent hydrogen and 95 percent nitrogen, in which the hydrogen molecules (H_2) act as the actual test gas. However, this includes the risk of a high background concentration due to cross-contamination. Industrial environments are more likely to contain other sources of hydrogen that may not be immediately thought of. At charging stations for lead-acid batteries, for example, hydrogen escapes from the batteries during the charging process. It is also important to ensure that the robotic sniffing leak detection station is not impaired by the exhaust gases from natural gas-powered forklift trucks. No combustion is absolutely complete, and the hydrogen contained in the exhaust gases from the forklift trucks could also cause false alarms due to cross-contamination.

5 Additional information



Video: [Speed scan versus leak rate](#)



Video: [Leak detection with high flow sniffing](#)

6. About INFICON

INFICON is one of the leading companies when it comes to development, production and sales of instruments and devices for leak testing. INFICON leak testing equipment is used in demanding industrial processes in production and quality control. INFICON leak detectors cover a wide variety of leak testing applications. Main customers of INFICON are manufacturers as well as service companies for the RAC industry, the automotive industry, the semiconductor industry and manufacturers of leak testing systems. Almost all automotive manufacturers and their suppliers are INFICON customers. INFICON technology helps testing airbags, car air conditioners and their components, fuel systems and all types of fluid containers.

(www.inficonautomotive.com)



INFICON production facility in Syracuse, NY – development, design and manufacturing of leak detection service tools

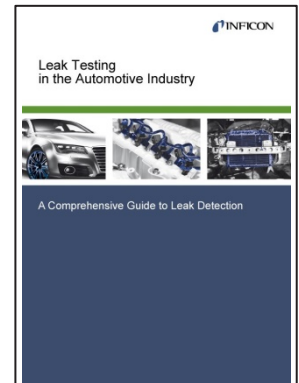


INFICON production facility in Köln, Germany – development, design and manufacturing of leak testing production tools

For more information about INFICON, visit us at www.inficon.com

7. E-Book: Leak Testing in the Automotive Industry

The INFICON e-book, “Leak Testing in the Automotive Industry: A Comprehensive Guide to Leak Detection,” is designed to help manufacturers avoid possible pitfalls when selecting a leak detection method for their particular application. The e-book can be downloaded, free of charge, at www.inficon.com/automobilindustrie-ebook.



Part One

Part One of the guide explains the basics of leak testing and describes the strengths and weaknesses of the different methods for leak testing and leak location: from water bath and pressure decay, as well as vacuum decay, to testing with helium in accumulation and vacuum chambers. Also the most common tracer gases – helium, hydrogen / forming gas and operating fluids like the refrigerants HFO-1234yf and CO₂ are introduced.

Part Two

Part Two of the e-book presents specific applications of different leak testing methods in the automotive industry. The e-book explains which components of a vehicle are typically tested with which test method and to what leak rate. This ranges from components of the air conditioner, to drive train modules, to safety related car components. The e-book also shows in which applications older leak testing methods like water bath or pressure decay are getting to their limits and sometimes suggest a wrong reliability.

Additionally, the Top 10 common errors in leak testing in the automotive industry are explained in detail. Common errors include contamination of the test piece, ignored temperature or pressure influences during testing, and unidentified stringer of gross leaks.

Download "Leak Testing in the Automotive Industry" free of charge here:

www.inficon.com/automotiveindustry-ebook

8. Contact Information

For Americas & Asia:

INFICON

Two Technology Place

East Syracuse, New York 13057

USA

Phone (315) 434-1100

Email: reachus@inficon.com

Internet: www.inficonautomotive.com



For Europe & Africa:

INFICON

Bonner Str. 498

50968 Köln

Germany

Phone: +49(0)221-56788-100

Email: reach.germany@inficon.com

Internet: www.inficonautomotive.com

kiac00en-03 (1903) © 2019 INFICON

Source of Illustrations

Title	Alamy @ Matthew Richardson
Page 4	INFICON
Page 5	INFICON
Page 6	INFICON
Page 7	INFICON
Page 8	INFICON
Page 9	INFICON
Page 10	INFICON
Page 11	INFICON
Page 12	INFICON
Page 13	INFICON
Page 14	INFICON
Page 15	INFICON
Page 16	INFICON
Page 17	INFICON
Page 18	INFICON
Page 19	INFICON
Page 20	INFICON
Page 21	INFICON