With a laser-optic leak test system it is possible to detect leaks of around 10^{-6} mbar l/s under industrial conditions.

Testing for leaks under industrial conditions with laser-optic systems

Leak testing is an important aspect of industrial quality assurance. The spectrum of products needing to be tested is extremely wide. Fuel tanks, closures, valves and fittings, spray cans, engines, coolers, semiconductor housings, sensors, pumps and couplings are just a few examples. As diversified as these products are the requirements needing to be met by today's test systems. On the one hand they have to test very large numbers of parts, on the other hand they must be able to detect very small leakage rates. Leaks of around 10^{-6} mbar 1/s can be detected by a laser-optic leak test system.

Various leak testing processes have been developed over the years to cover many different applications. Basically these processes can be divided into two groups: Tests with or without a special test gas. Pressure monitoring, flow and underwater methods are the test processes currently in widespread use without a special test gas. All pressure and flow methods are based on the assumption that the vessels to be tested or the specimens in the test holder encompass a constant volume. A pressurized specimen is then known to have a leak if the pressure drops in the course of time; the magnitude of this drop is taken as the measure of the leak. Flow measuring systems, on the other hand, try to hold the pressure in the specimen constant, so that the subsequent air input is then the measure of the leak. The flow method is used mainly for very large leakage rates.

Both processes reach their limits as soon as it is no longer possible to assume that the volume is constant. Fact is, many parts change their volume due to mechanical loading by the test pressure, resulting in changes of pressure even without leaks or in subsequent air input even under constant pressure conditions. Similar effects are caused likewise by temperature changes to the test specimens or test air during the test. These effects have given rise to refined processes such as the pressure difference method. In this case the specimen and a leak-free test object are pressurized and only the difference in pressure between the two is evaluated.

It is thus possible to compensate many temperature or volume effects. At the moment pressure methods are being used in industry for leaks up to approx. 10^{-2} mbar l/s. Pressure and flow meters are available on the market for relatively little money. Pressure methods are therefore extremely economical for the automatic testing of specimens with medium to large leaks.

Underwater tests are a popular option

A further method that continues to enjoy widespread popularity in spite of – or precisely because of – its simplicity is the underwater test. Like searching for leaks in a bicycle tyre, the specimen is first pressurized and then held under water. Rising air bubbles are a failsafe indication that the specimen has a leak. This very simple method can detect relatively small leaks of approx. 10^{-3} mbar l/s. Further advantages are the very low investment costs and the simple location of leaks. On the other hand, this method also has many disadvantages: It cannot be automated and is therefore very labour-intensive; the results are subjective – a blink of the tester's eye may lead to a wrong assessment; when the test is completed the specimens are wet and have to be dried. All in all, therefore, the underwater test is destined to disappear – in the long or short run – from series production.

Leak testing with test gas

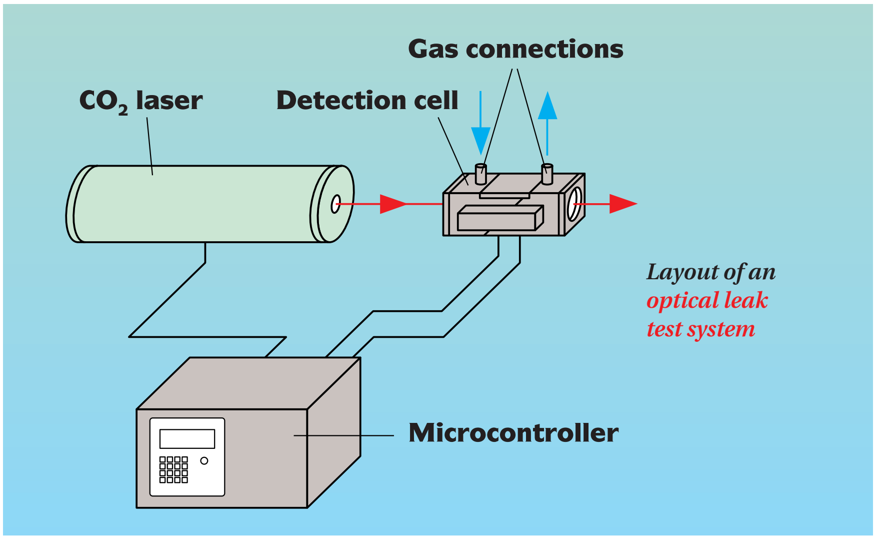
The second group of leak testing processes are those methods which use test gas. All these processes have one thing in common: Specimens are filled with a test gas and the surroundings or sealed area are examined for traces of the test gas. The oldest systems of this type are equipped with mass spectrometers and usually work with helium (helium leak tester). Molecules directed into a mass spectrometer are ionized and accelerated in an electric field. In this connection it is important for the instrument to be under high vacuum so that there is little risk of the accelerated molecules colliding with other molecules but can enter an electromagnetic mass filter. The position where the molecules leave the mass filter again then depends solely on the molecule mass, enabling the helium molecules to be clearly identified.

With this method it is possible theoretically to detect leaks of up to approx. 10^{-11} mbar l/s, although the limit in harsh industrial duty is often only 10^{-4} mbar l/s. The reason lies mainly in the high vacuum (approx. 10^{-4} mbar) required for the mass spectrometer. Such low pressures are possible only with elaborate turbo molecular pumps, which because of the molecular flow inside the mass spectrometer are able to reach this pressure only slowly. The low pressure also means that all the system's seals and connections need to be particularly tight and should not be made of degassing materials, e.g. many plastics.

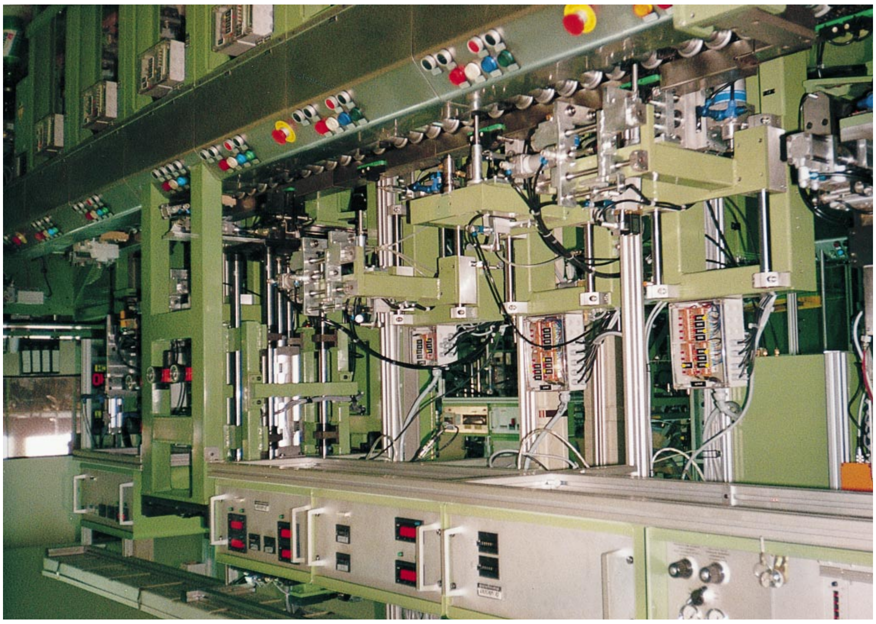
This requirement can be difficult to meet especially for the moving parts of a test system, e.g. the test hood which has to be opened in order to load and unload the specimens. Absolute sealing of the test system to the atmosphere must be guaranteed quite simply because the atmosphere itself contains 5 ppm helium. In view of the low pressure in the mass spectrometer care must be taken to prevent accidental flooding, i.e. suitable design measures in the test system are needed to keep the mass spectrometer isolated from pressure shocks caused by the sudden bursting of a specimen. All in all, therefore, the helium test method produces good results but is relatively elaborate and hence expensive, which in the past has made underwater testing the more popular choice.

Laser-optic process works with SF_6

A new method of detecting test gas works optically with laser radiation. With this process, the inert gas sulphur hexafluoride (SF_6) is used as test gas and an accordingly adapted CO_2 waveguide laser as laser. As with all other gas detection processes, the atmosphere surrounding the specimen full of test gas is drawn off and conveyed through the gas connections into the detection cell. The detection cell has windows through which the laser radiation can penetrate. If there is any SF_6 test gas in the detection cell, its



Layout of an optical leak test system



Leak test system for testing the tightness and operation of a vehicle's main brake cylinders.

concentration can be measured and the leakage rate calculated.

A key advantage of the optical leak test system is that it enables the test gas concentration to be measured at atmospheric pressure. In most cases the bell surrounding the specimen is evacuated in order to guarantee sufficient diffusion of the test gas, making the leakage values independent of the point of the leak. Often a vacuum of around 10 mbar is sufficient and can be generated quickly and easily. With a detection sensitivity of 10 ppb (10^{-8}) it is possible to reliably detect leaks of 10^{-6} under industrial conditions and with volumes of a few litres.

Vacuum pressure is a non-critical factor

Systems equipped with the optical leak test system are highly economical mainly because of the completely non-critical vacuum pressure. The price of such a system is practically the same as for a comparable mass spectrometer, but far lower outlay is needed for the peripherals to be installed „around the sensor". Normally the entire system can be constructed of standard pneumatic components such as valves and plastic tubes. Standard O-rings suffice as seals, and a simple oil-sealed vane-type rotary pump is adequate for the pumping. Nor do any special precautions need to be taken to safeguard against large leaks because the laser system's detection chamber can be rinsed very quickly and effectively.

If a low-price mass product, e.g. a spray can, is found to have a leak, it is not normally repaired because this would be too expensive. With elaborate products such as automotive engines this is not the case, of course. It is essential to locate the exact position of any leaks in order to take remedial action. In all localizing processes, the test objects are pressurized with air or test gas. A simple localizing method is the underwater test. Should this be impossible or undesirable, the pressurized specimen can be sprayed with a soapy liquid which shows the air bubbles leaving the point of the leak.

So-called „sniffer" processes are used particularly for large specimens and small leaks. A sniffer sensor (a capillary through which gas is drawn) is held by hand or robot at the suspected points of leakage from the specimen. If there is a leak, the escaping test gas will be drawn in together with the ambient atmosphere and its presence confirmed by the detector. Mass spectrometers, optical leak test systems or semiconductor sensors can serve as detector. Helium, SF_6, hydrogen or a variety of refrigerants can be used as test gas.

Leak localization by video camera

A recent development is an optical leak localizing system which illuminates the test object with a laser beam that is panned over the test object like the electron beam of a picture tube. The test gas escaping from the points of leakage on the test object interacts with the laser radiation at exactly the moment the leak is illuminated and the interaction identified by suitable detectors.

The complete scan of the test object produces a „leak picture" which can be superimposed on the picture of a conventional video camera. The user is then able to identify the position of any leaks on the combined image of the test object and the colour-coded leaks.

■ *Contact 426*

PRINCIPLES

Units of measure for leak measurements

The magnitude of a leak is characterized by the product of pressure and volume of the escaping gas per unit of time. The most frequently applied unit of measure is mbar l/s. Consider, for example, a 1 litre vessel into which gas leaks at a rate of 1 mbar l/s. The leak then causes a pressure increase inside the vessel of 1 mbar in 1 s. Leaks are often quoted in terms of only volume per time (e.g. cm^3 min). These figures always imply normal pressure of the atmosphere (1 bar).

BACKGROUND

Molecular flow

A basic distinction is drawn between two types of gas flow: Molecular flow and viscous flow. In the case of molecular flow, the free path length (meaning the distance covered by the molecules without colliding) is large in relation to the vessel's dimensions, e.g. the pipe's diameter or the gap widths of coupled parts. In other words, the molecules interact only with the vessel's walls and practically do not collide together at all. Flow resistance arises from collisions with the wall. Viscous flow, on the other hand, is when the free path length is small in relation to the vessel's dimensions. The molecules interact with each other. Hence in the case of viscous flow, the average time needed by a molecule to flow through a pipe line is affected by the pressure at the beginning and at the end of the line. With molecular flow, this time is independent of the pressure.