4 Introduction to sensor technology

The heart of every measuring instrument is its sensor. The sensor is crucial in determining the quality of measurements, and therefore it has a fundamental influence on the safety of the user. The development and production of sensors is part of Dräger's core competence.

D-13504-2010

4.1 Selecting the proper measurement method

Selecting the correct measuring principle is essential when detecting dangerous gases. Every measuring principle has its own strengths and limits, and each is better for particular groups of gases (flammable/toxic gases and oxygen). For this reason, it is important to ask which gases/vapors occur in the workplace Generally speaking, we differentiate between the following gas risks:

Risk of explosion

- Wherever flammable gases and vapors occur, there is an increased risk of explosion. Typical areas for this include mining, refineries, the chemical industry, and many others. Infrared and catalytic bead sensors are used to detect this type of risk. These sensors usually detect gas concentrations in the LEL (lower explosure level) range, but some of them can also be used for the 100 Vol.-% range.

Lack or excess of oxygen

- A lack of oxygen is life-threatening. An excess of oxygen can affect the flammability of materials and can even cause auto-ignition. Electrochemical sensors are used to measure oxygen. Their measuring range is from between 0 and 25 Vol.-% all the way up to 100 Vol.-%.

Toxicity

- Poisonous substances can occur anywhere – in industrial production and processing, in transport (rail, road, ship), in the case of incomplete combustion (CO), and also as a result of completely naturally processes such as rotting and decomposition of biomass. Electrochemical and PID sensors are used to detect toxic gases.

The decision about which sensor type is the right one for a particular application also depends on other factors such as:

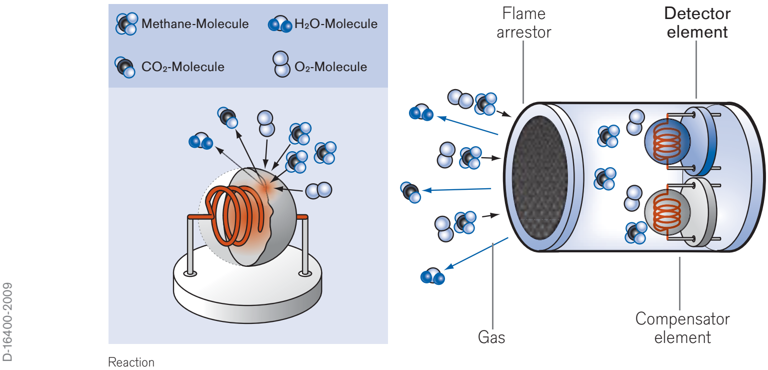
- What other hazardous material are present (cross-sensitivity)?
- Is it necessary to measure hazardous material selectively, or is it more sensible to measure a complete parameter?

4.3 Dräger CatEx sensors

Under certain circumstances, flammable gases and vapors can be oxidized using the oxygen in the ambient air, causing heat of the reaction to be released. Typically, this is achieved through the use of special and suitably heated catalyst material, which slightly increases its temperature through the resulting heat of reaction. This slight increase in temperature is a measure of the gas concentration.

A small platinum coil is embedded in a porous ceramic bead with a diameter of less than 1 mm (0.04 in.). A current flows through the platinum coil, heating the pellistor to several hundred degrees. If the pellistor contains a suitable catalytic material, then its temperature will increase in the presence of flammable gases, which in turn causes the resistance of the platinum coil to increase. This change in resistance can then be evaluated electronically. The oxygen required for the combustion comes from the ambient air. This sensor works on the basis of the catalytic bead principle.

Catalytic bead sensors



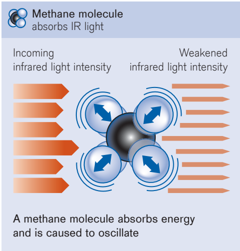
Reaction

In order to eliminate changes in the ambient temperature, a second pellistor is used with almost the same structure, but which does not react to gas (it may, for example, contain no catalytic material). Coupled by a Wheatstone bridge, the two pellistors then form a sensor circuit, which is largely independent of the ambient temperature, and which can detect the presence of flammable gases and vapors. Because a catalytic bead sensor contains hot pellistors, it can – if the lower exposure level (LEL) is exceeded – become a source of ignition in its own right. This is prevented using a metal flame arrester. If an ignition occurs in the interior of the catalytic bead sensor, then the sensor‘s housing withstands the explosion pressure and the flame is cooled to below the ignition temperature of the gas by the flame arrester disk. This ensures that the flame does not penetrate through to the outside of the sensor. If the device is adjusted and calibrated accordingly, then the thermal conduction signal can be used to determine the gas concentration of methane between 0 and 100 Vol.-%.

4.4 Dräger infrared sensors

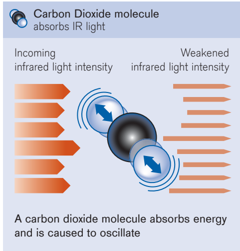
Every gas absorbs light in a particular way; some even absorb visible light (wavelength of 0.4 to 0.8 micrometers), which is why chlorine is yellowish green, bromine and nitrogen dioxide are brown, iodine vapor is violet, and so on – but unfortunately they are only visible in high (deadly) concentrations.

DUAL IR Ex/CO_2 Sensor



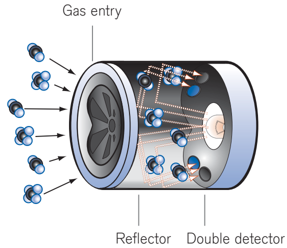
Reaction

CH_4 + Energy → CH_4(excited)



Reaction

CO_2 + Energy → CO_2(excited)



Hydrocarbons and carbon dioxide, on the other hand, absorb light in a certain wavelength range, (hydro carbons 3.3 to 3.5 µm; CO_2 approx. 4 µm) – and that can be utilized for detection purposes, since the main components of air (oxygen, nitrogen, and argon) do not absorb radiation in that range. In a container containing gaseous hydrocarbons such as methane or propane or carbon dioxide, the intensity of an incoming infrared light will be weakened, and the degree of this weakening is dependent on the concentration of gas. With the DrägerSensor Dual IR Ex/CO_2 a simultaneous measurement is possible.

Air: infrared light passes through without weakening – intensity remains the same
Gas (e.g. methane): infrared light becomes weaker as it passes through – intensity drops in relation to the concentration of methane. This is the principle of an infrared measuring instrument that utilizes Dräger IR sensors. Flammable gases and vapors are mostly hydrocarbons, and hydrocarbons are almost always detectable by means of their typical IR absorption levels.

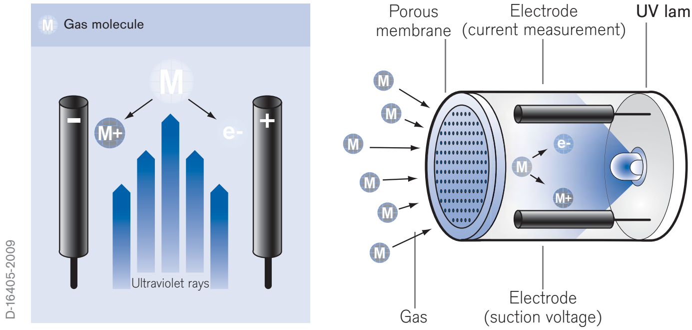
Functional principle: the ambient air to be monitored passes into the measuring cuvette by means of diffusion or through the use of a pump. The infrared transmitter produces broad-band radiation that passes through a window into the cuvette, where it is reflected off the mirrored walls and passes through another window, falling onto the double detector. This double detector consists of a measurement and a reference detector. If the gas mixture contains a percentage of e.g. hydrocarbons, then some of the radiation is absorbed and the measurement detector produces a reduced electrical signal. The signal from the reference detector remains unchanged. Fluctuations in the performance of the infrared transmitter, dirt on the mirror and windows, and interference from dust or aerosols in the ambient air have the same effect on both sensors, and are fully compensated.

4.5 Dräger PID sensors

Many flammable gases and vapors are toxic to humans long before they reach the lower explosion limit (LEL). For this reason, personal protection in the workplace ideally includes the additional measurement of ppm levels of volatile organic substances using a PID sensor.

The air is drawn into the measuring chamber through the gas inlet. In the chamber, a UV lamp produces photons, which ionize certain molecules within the flow of gas. A relatively high amount of energy is required to ionize the air's permanent gases such as noble gases, nitrogen, oxygen, carbon dioxide, and water vapor. For this reason, these gases do not interfere with the measurement of the harmful substances. Most of the organic substances recognized as dangerous (such as hydrocarbons) are ionized and subjected to the electrical field between the electrodes in the measuring chamber. The strength of the resulting current is directly proportional to the concentration of ionized molecules inside the chamber. This makes it possible to determine the concentration of harmful substance in the air.

PID sensor



Ionization energy and UV lamps

Ionization energy is measured in electron volts (eV) and defines the amount of energy required to bring a molecule into the ionized (charged) state. Ionization energy is something specific to each material, like the boiling point and vapor pressure. For a substance to be ionized, its ionization energy must be lower than the photon energy from the lamp used in the PID. Common is the lamp type 10.6 eV lamp. This enables a PID to detect whole groups of harmful substances, while it can also be used to measure single substances if calibrated accordingly.

Calibration and response factors

Isobutylene is used to calibrate a PID, unless the actual substance being measured can be used. The relative sensitivity to other substances is then expressed in terms of response factors. If a substance is detected with greater sensitivity than isobutylene, then its response factor is less than one. Substances that are detected with less sensitivity than isobutylene have a response factor greater than one.

FOR EXAMPLE:

Substance	Ionization energy	Response factor
Benzene	9.25 eV	0.5
Cyclohexane	9.98 eV	1.3

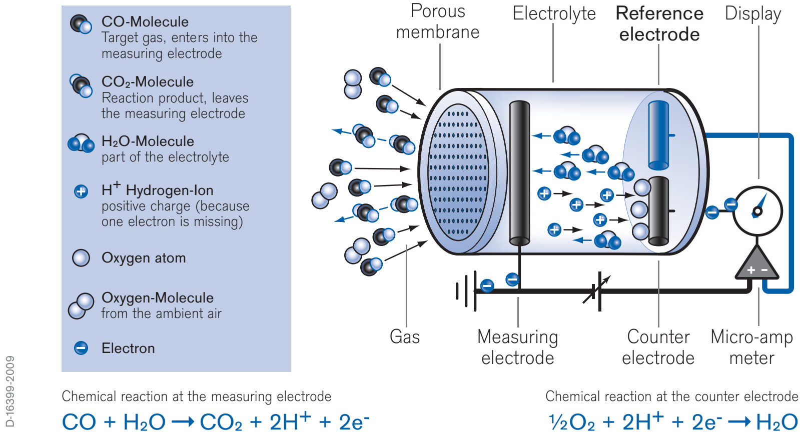
4.6 Electrochemical sensors

Many toxic gases are highly reactive and can change their chemical composition under certain conditions. An electrochemical sensor is a micro-reactor, which produces a very small but measurable current when reactive gases are present. As in a normal household battery, this involves an electrochemical process, since the chemical transformation produces electrons.

The basic principle behind an electrochemical sensor involves at least two electrodes (a measuring electrode and a counter-electrode), which have contact with each other in two ways: first, through an electrically conductive medium (electrolyte, meaning a fluid that conducts ions) and, second, through an external electrical circuit (electron conductor). The electrodes are made of a special material that also has catalytic characteristics so that certain chemical reactions take place at what is known as the three-phase zone where gas, solid catalyzer, and liquid electrolyte meet. A dual-electrode sensor (measuring and counter-electrode) does, however, have many drawbacks. For instance, if high concentrations of gas occur, this leads to higher currents in the sensor and, therefore, to a drop in voltage. The drop in voltage, in turn, changes the preset sensor voltage. This can lead to unusable readings or, in the worst case, it can cause the chemical reaction inside the sensor to come to a halt during the measurement process.

For this reason, the Dräger XS and XXS sensors contain a third electrode known as the reference electrode, which does not have a current passing through it, and whose potential therefore remains constant. It continuously measures the sensor voltage at the measuring electrode, which can be corrected using the sensor's control enhancement. This produces a considerably improved measuring quality (e.g. in terms of linearity and selectivity) and a longer life time.

Electrochemical sensor



Chemical reaction at the measuring electrode

$$CO + H_2O \rightarrow CO_2 + 2H^+ + 2e^-$$

Chemical reaction at the counter electrode

$$\tfrac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

The Dräger XS sensors are known as „smart" sensors and contain their own EEPROM. This memory module contains all of the sensor's relevant data, which, when plugged into Dräger X-am 7000 is retrieved. The device then automatically adjusts itself to these figures (e.g. calibration figures, alarm level). This „plug & play" function enables sensors to be swapped between devices without performing operations such as a re-calibration. XXS sensors are used in the following devices: Dräger Pac family and Dräger X-am 2500/5000/5600 and Dräger X-am 3500/8000. In this case, the sensor-relevant data is stored in the device. When a sensor is changed, this information is transferred using a software application.

5 Accessories

D-53038-2012

5.1 Introduction

Dräger offers a range of accessories to ensure that you can make optimal use of your gas detector for your specific application. We also help you maintain your device and make sure that it is kept ready for operation.

Safety

Measuring devices that are not operating correctly do not provide protection and can lead to accidents. Testing these devices (bump test) is the only way to guarantee reliable and correct measurement of and warning against gas hazards.

Enhanced functionality

Using the correct accessories can enhance the functionality of gas detectors. For example, a personal detection device can be converted into a leak detection or clearance measurement device in confined spaces by using an external pump, probe or an extension hose. It is important that you choose the accessory that is best suited for your application.

Configuration/Documentation/Archiving

Setting the parameters of the gas detectors always becomes important when limit values change or if the gas detector is used for another application. This is where we provide after-sales support: and the PC software helps you with the configuration. The documentation is also extremely important: Who performed which test and what was the result? Where have the calibration certificates been filed?
Our solutions also provide support in this area.

Evaluation

A data logger collects numerous measured values and results – but the data remains idle until it is evaluated. That‘s why we help you prepare the data: this includes graphic displays and easy navigation in the data logger – as well as automatic reports, e.g. if an alarm is triggered or a calibration interval is exceeded.
Solutions to make sure that you always stay on top of your process.

5.2 Adjustment or calibration?

The terms “calibration” and “adjustment” are often used synonymously. However, there are important differences between the two terms. The term “calibration” is often used although technically an “adjustment” is meant - namely a test with subsequent correction. In this section, however, the technically correct term is used, even if in practice both terms are mostly used synonymously.

Adjustment

During an adjustment, the displayed value, the so-called actual value, is corrected to the correct value, the so-called nominal value (e.g. the test gas concentration) as closely as possible with the constraints of the display. The aim is to obtain more accurate displayed measurements. This applies to both the zero point and the sensitivity of the sensor. Depending on the sensor, either a zero gas (e.g. synthetic air or nitrogen) or fresh air is used to adjust the zero point, while the appropriate test gas is required for the sensitivity adjustment.

Target gas adjustment or surrogate? gas adjustment (cross calibration)?

In a target gas adjustment, the gas detector is adjusted with the gas that it will be measuring. This type of adjustment is the most accurate and is therefore recommended by Dräger where ever possible.

With some sensors, however, a target gas adjustment is not possible or only possible to a limited extent. Some substances may require extensive expertise and a careful approach to avoid mistakes during adjustments. Sometimes several (combustible) substances are to be measured in one application, to which the sensor reacts at different sensitivities. In such cases, a surrogate gas adjustment is recommended. Thus, a surrogate test gas is a gas mixture used to replace a test gas that is difficult to handle.

Reasons for a surrogate gas adjustment can be among others:
- Target gas is hazardous or critical to the health of the tester:
  Example: The standard test gas for the OV sensors is ethylene oxide. This gas is toxic and carcinogenic. Therefore, the OV sensors can be adjusted with the substitute gas carbon monoxide (CO). This is less dangerous and easier to handle.
- The sensor detects several different gases:
  A PID sensor can detect all substances ionized by the UV lamp in the sensor. For simplicity, the sensor is typically adjusted with isobutylene. The relative sensitivity of other substances is then expressed using so-called response factors, which must then be considered for the measured value display. This conversion takes place automatically in Dräger gas detectors.
- Purposely selecting a more sensitive setting for a measurement with increased safety:

A CatEx sensor is less sensitive to nonane. If the CatEx sensor is set to nonane, all the other gases such as methane or propane are displayed with increased sensitivity. This provides increased safety during the measurement.

- If different combustible gases are measured with a CatEx sensor, including methane, then it is recommended to perform an adjustment and function bump test with methane in order to compensate the effect of a selective methane insensitivity by this sensor technology. Also, in this application, the conversion between the gases is automatically done in Dräger instruments. General note: In principle, a deviation of up to ± 30% of the measured value must be considered for the displayed concentration when performing a surrogate gas adjustment.

Calibration

During calibration, **a gas detector is checked** and the deviation (incl. measurement tolerances) from a reference gas (e.g. the test gas concentration) is determined and logged. Actions beyond logging do **not** take place during a calibration. The aim of the calibration is a protocol, the so-called calibration certificate. Under no circumstances **may** changes be made to the device after a calibration, as otherwise the calibration (= protocol/documentation) is then void.

Every gas detector is subject to changes due to wear, contamination or environmental influences (temperature, humidity, pressure, ...). Consequently, measured values can change and should be checked regularly. The recommended daily function test with a suitable test gas (also called bump test) fulfills this requirement.

5.3 The bump test

Anyone looking for a definition of the bump test will struggle to find a clear and straightforward explanation. This important test is performed in a variety of different ways in practice. When designing the test system you need to ask: what significance do „I“ expect from the bump test?

a) Does the device need to show that it works in principle and that „gas“ is reaching the sensors to be checked (qualitative finding)?
b) Or do I need a quantitative finding, i.e. whether the device is still providing measurements that are „accurate enough“?

Dräger provides two different categories of the bump test:

The quick bump test

The quick bump test checks whether the relevant sensor exceeds the first alarm threshold after applying an „appropriate“ test gas. Additional safety measures are available (e.g. the sensor may need to be above the alarm threshold for a certain amount of time) but, in principle, the test threshold is the alarm threshold configured in the device.
A test gas is „appropriate“ if it is not „too far“ above the first alarm threshold, as this would otherwise mean that the gas test would only fail after a dramatic loss of sensitivity. A limit must also be maintained in the event of a more qualitative test. Dräger provides recommended limits for these tests.

The extended bump test

The advanced bump test checks whether the tested sensor complies with the test gas concentration within a tolerance window after an „appropriate“ test gas is applied. This test includes a quantitative finding and increases safety.
The sensor also has an impact on whether the test gas is „appropriate“. A test close to the alarm thresholds is often advisable, but many sensors are also linear so that the permitted range is much larger than for the quick test, as the „test threshold“ is always adjusted. This allows the accuracy to be determined at almost any point within the measuring range. However, the selection of a range that corresponds to the measuring task is advisable. Dräger also provides recommended ranges for the permitted test gas concentrations.
The CC-Vision software lists the permitted calibration ranges for every individual sensor (and every selected test gas) for both the quick and the extended bump test. In many cases the gas detector – or even the Dräger X-dock – does not accept concentrations outside this range.

The following table helps you select the appropriate bump test for you:

	Quick bump test	Extended bump test
Test duration	🟢🟢	⚫
Gas consumption	🟢🟢	⚫
Behaviour for „special gases“ (high adsorption)	🟢	🔴
Check for accuracy / residual sensitivity	🔴	🟢🟢
Behaviour when applying the incorrect gas (e.g. incorrect concentration set or undefined cross-sensitivity, as the incorrect test gas cylinder is connected; residual gas in the hose, etc.)	🔴	🟢🟢
Permitted test gas concentration range (minimum and maximum accepted concentration)	⚫	🟢🟢
Testing below A1 possible	🔴	🟢🟢

🔴🔴 🔴 ⚫ 🟢 🟢🟢

Inadequate ⟶ Above-average

5.4 Devices for calibration and functional testing

Portable gas detectors are used for continuous measurement and support you in every application. As a result, it is important to check the devices for operational readiness by applying test gas and evaluating the result. This not only ensures that the sensors themselves are ready for measurement, but that the access to the sensor is not blocked by dust or dirt.
An calibration should also take place at regular intervals, as factors such as environmental influences or ageing can have an impact on the sensor sensitivity.

National guidelines also prescribe bump tests and calibrations, such as information sheet T021 (gas warning devices for toxic gases/vapours) or T023 (gas warning devices for explosion protection) by the „Rohstoffe und chemische Industrie“ (raw materials and chemicals industry) liability insurance association (BG RCI) in Germany. The applicable standard for the member states of the European Union, EN 60079-29-2 „Gas detectors – Selection, installation, use and maintenance of detectors for flammable gases and oxygen“, also prescribes the implementation of a sensitivity test directly prior to use (international: IEC 60079-29-2).

5.5 Manual bump test

ST-5006-2005

The simplest and most cost-effective option for testing the function of a portable gas detector is to perform a manual bump test with test gas. This only requires an appropriate test gas cylinder, a corresponding pressure reducer and a calibration adapter for the specific device. Briefly applying the test gas to the sensors triggers the instrument alarm. Make sure that an adequate test gas concentration is applied! Depending on the type of device, it can be calibrated – in the same arrangement – using the device software or a PC with the Dräger CC-Vision software. This software allows the user to configure and calibrate the devices in line with their individual requirements.

5.6 The Dräger Bump Test Station

D-5068-2017

The Dräger Bump Test Station facilitates the performance of an everyday bump test, as the test is evaluated by the devices themselves and the test gas is automatically applied on insertion. In addition, most devices are able to automatically identify the station and switch to bump test mode without having to perform any manual activities.
Dräger devices Dräger Pac family, Dräger X-am 2500, 5000 and 5600 as well as the X-am 7000 are supported. The Dräger Bump Test Station does not require a power supply – the evaluation itself is performed by the gas detector. The documentation also takes place in the gas detector, within the data logger. The device must be configured for the type of bump test and the required test gas concentration.
The sensors' rapid response time ensures a quick test in under 12 seconds in some cases. The lower gas consumption and time saving reduce the operating costs.

5.7 Dräger X-dock – more than just a test station


D-47870-2012

The Dräger X-dock automatic test and calibration station is the modular solution for the daily bump test as well as a workshop and fleet management solution.

The X-dock can be operated independently as an individual station – a PC is not required. This gives you the benefit of a range of options at every location: the X-dock can perform quick or advanced bump tests or even perform calibrations, readout the data logger and check the gas detector's alarm elements or the sensors' response times. These individual test steps can be configured – and the three most important objectives are always ensured:

1. Ease of use:
   The simplest test: insert and close the lid – the rest takes place automatically.
2. Short test time:
   An advanced pneumatics system provides extremely short test times.
3. Low gas consumption:
   The short test time as well as the gas flow, which has been reduced to 300ml/min, reduces the gas consumption significantly, which also helps to reduce costs. In addition, the X-dock immediately switches off valves once a test gas is no longer required for a certain test step and the device has completed the test.

This system combines ease of use with low operating costs – but with full documentation. Everything that the X-dock performs is stored in the internal database. If the station is used as an individual station, the results can be exported as a PDF or printed on any conventional postscript-enabled printer.
This means that the system is scalable: whether you use one or ten modules on a master is up to you.
The Dräger X-dock independently detects the test gases that are required. The touchscreen can be used to program the connected gas cylinders – the X-dock station performs everything else automatically. Up to six test gas cylinders can be connected to a master and these test gases can themselves consist of gas mixtures. This covers almost every application.
However, the highlight is a possible expansion: X-dock stations can be connected to a network. The data is synchronised and stored on a server.

The X-dock Manager PC software makes data evaluation as easy as pie:

Which calibrations are coming up or are even overdue? Has a device not been checked? Has an alarm been triggered in operation and when are the X-dock stations engaged? Questions that the X-dock Manager conveniently answers.
If you still need more, the X-dock also provides a range of special functions for your application: for example, the X-dock can be used as a charging station for X-am 125 devices – this function is ideally supplemented by the test planner function, which performs the set test on a pre-determined schedule (e.g. daily).

Take the time to find out what the Dräger X-dock can do for you!

Geräte	Dräger Bump Test Station	Dräger X-dock Station	Basic test with gas	Dräger CC-Vision software
Dräger Pac family	■	■	■	■
Dräger X-am 2500/5000/5600	■	■	■	■
Dräger X-am 5100				■
Dräger X-am 7000	■	■	■	■
Dräger X-am 3500/8000		■	■	■

5.8 Test gases and accessories


D-37353-2015

Test gases are an essential part of the bump test. Only an **appropriate** test gas can verify a gas detector‘s functionality and it is just as important for calibration.
A high standard of quality is required as test gases are a key element of the safety chain. Dräger test gases are produced pursuant to ISO 9001 and guarantee a globally valid quality standard. Single as well as mixed gases are available.

Once the test gas cylinders are completely empty they can be transported to a scrap metal facility and disposed of in an environmentally friendly manner, which means that customers do not have to pay any rental or transport costs.

5.9 Pressure reducer

The history of Dräger started with a patent for a pressure reducer – and every system that needs a test gas cylinder also needs a pressure reducer. The cylinders contain compressed gas. The pressure now needs to be reduced for the application (e.g. the bump test) – this requires a pressure reducer.

Some pressure reducers reduce the pressure to a set level (e.g. 0.5 bar). The flow rate is then determined by the line resistances or any flow control valves.

There are also pressure reducers that regulate a fixed volume flow – e.g. 0.5 l/min. In this case, the pressure is adapted according to the resistance in order to ensure a constant volume flow.

The correct pressure reducer for the system needs to be selected. Pressure reducers can naturally also be reused. They have a screw thread and can be used for various test gas cylinders.