



JANUARY 2002

**PUTTING SENSORS TO WORK**
[←TOC](#)

## Planning and Designing Gas Detection Systems

With a grasp of gas sensor basics, and a methodical plan for installing the detectors, you can build a system smart enough to save your life.

Wolfgang Jessel, Dräger Safety AG & Co. KGaA

**W**henever combustible and/or toxic substances are stored, processed, or transported in the chemical industry, the potential risks are high. For example, if pressurized gases are accidentally released, pipelines leak, or combustible liquid vapors escape through damaged valves or leaking seals, the result can be a hazardous condition. In the case of:

- Combustible substances. There may be considerable damage to installations if the substances ignite and explode, often accompanied by further fires and human casualties.
- Toxic substances. These can pose a serious risk to human health, often involving symptoms that manifest themselves only at a later date and are difficult to assess, possibly even leading to premature death.

### First, Some Questions

Everyone who plans to install a gas detection system needs to consider three sets of questions:

- Gases. With what objective are which gases to be monitored? Where are they likely to be released? In what concentrations and quantities? How often?
- Gas sensors. Which sensing technology is most suitable? How many sensors are needed? Where and how should they be positioned and calibrated?
- Gas detection systems. Which alarm thresholds are appropriate? How is the alarm information subsequently processed?

The News You Choose

EXPRESS

SELECT FROM THE LIST

- Select -

February 1, 2002

**Industry News**  
Updated Twice Weekly

- [C.S.C. Force Measurement is ISO/IEC 17025 Accredited](#)
- [Marathon Sensors Earns ISO 9001:2000](#)
- [Thermometrics and Semitec Ally to Buy and Sell](#)
- [Sensoria Allies with SAIC to Pursue Homeland Security Projects](#)
- [NI Appoints Andy Krupp Quality Director](#)

[News From Sensors](#)



[Order Now!](#)

## Gases

Answering the first group of questions will give a general outline of the task at hand, clarifying the operational conditions and the intended purpose, i.e., whether toxic gases (or gases that can have a suffocating effect) need to be detected to protect workers or whether combustible gases (or vapors) need to be detected to help prevent explosions.

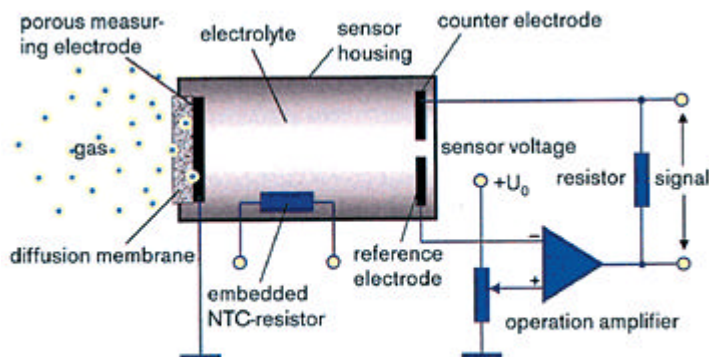
## Gas Sensors

Generally speaking, three methods of measurement have firmly established themselves over many years in the chemicals industry: electrochemical, IR, and catalytic. Electrochemical sensors are particularly suited to the detection of toxic gases in the lower ppm range. IR and catalytic methods are used to detect combustible substances in concentrations below the lower explosive limit.

**Electrochemical.** Under certain conditions, an electrochemical sensor (see Photo 1) can oxidize or reduce reactive gases or vapors diffusing through a hydrophobic membrane, thus coming into contact with an electrode embedded in a special electrolyte (see Figure 1).



Photo 1. The Polytron 2 gas detector for electrochemical sensors is designed to continuously monitor either toxic gases or oxygen.



**Electrochemical sensor measuring principle**

Figure 1. An electrochemical sensor works by oxidizing or reducing reactive gases that diffuse through a hydrophobic membrane and come into contact with an electrode embedded in a special electrolyte. Ions and electrons are produced, the latter forming a current in a circuit connected to the sensor's electrodes. A third electrode keeps the voltage constant, so the signal is proportional to the gas concentration. The chance of false alarms in the Polytron 2 is reduced by sophisticated protection against RFI.

The catalytically activated electrode reaction then produces ions and electrons, the latter forming a current in the outer electrical circuit connected to the sensor's electrodes. With a third electrode integrated in a potentiostatic electronic circuit, the sensor voltage is kept constant, with the result that the current is proportional to the gas concentration. To optimize temperature compensation there is a negative temperature coefficient resistor placed in the interior of the sensor.

**Infrared.** The IR measuring principle (see Figure 2 and Photo 2) is based on the fact that gas molecules are excited by IR light of a certain wavelength and so produce vibrations while partly absorbing energy from the light.

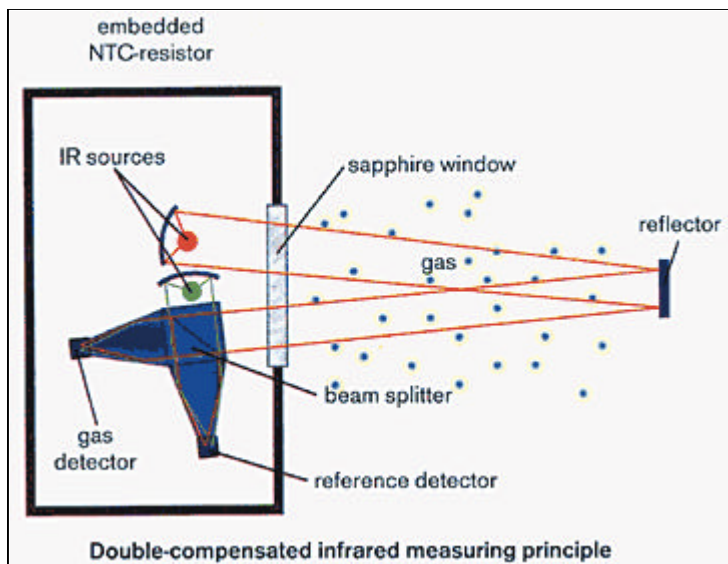


Figure 2 and Photo 2. In an IR gas sensor, one IR light beam is of a wavelength that excites a particular type of gas molecule and thus loses part of its energy to the resultant molecular vibrations. The intensity of that beam is compared to a second beam of the original energy, and the differential is used to measure the gas concentration. The Polytron IR is an explosionproof detector for combustible gases and vapors.

Compared to the original IR light intensity, the attenuated intensity within a defined fixed optical path is a measure for the gas concentration. A second beam with a wavelength not absorbed by gas can be used to measure the original IR light intensity. This is used to make the IR system tolerant to dust and alterations to the intensity of the light source itself.

**Catalytic.** The catalytic measuring principle (see Photo 3 and Figure 3) is highly suitable for the detection of combustible gases and vapors.

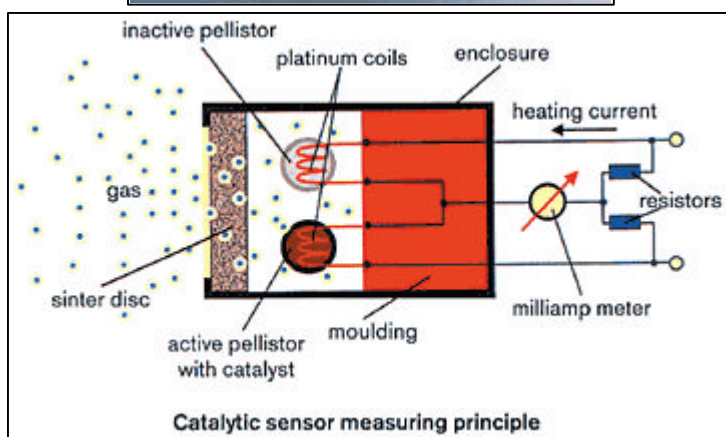


Photo 3 and Figure 3. In The Polytron 2 XP Ex flameproof catalytic detector, two ceramic beads are heated to  $\sim 450^{\circ}\text{C}$ . One is activated by a catalytic material that oxidizes the gas and forms additional heat that is detected by measuring the resistance of a platinum coil. The bridge current of a Wheatstone bridge with a second, deactivated bead as reference is approximately proportional to gas concentration at the lower explosive limit.

Two ceramic beads (pellistors) with embedded platinum coils are heated to  $\sim 450^{\circ}\text{C}$ . One pellistor is activated by a catalytic material that, at the given temperature, oxidizes the gas and thus forms additional heat which can be detected by measuring the resistance of the platinum coil. Using a Wheatstone bridge with a second, deactivated pellistor as a reference, the bridge current is approximately proportional to the gas concentration in the 0%–100% range of the lower explosive limit (LEL).

As each of these measurement technologies can have advantages and disadvantages depending on its intended application, the most reliable information about the suitability of a particular method to the task in hand is likely to be available from manufacturers, supported by their application laboratories.

**Spot, Area, and Fence Monitoring.** A distinction is made among three basic sensor positioning strategies, though naturally it may be necessary to combine or adapt the strategies to suit a particular application.

- Spot monitoring. Potential sources of leakage (e.g., valves, filling nozzles, flanges, bellows) are known and their position can be pinpointed. This means that sensors can be positioned in such a way as to ensure that gas leaks can be reliably detected in plenty of time.
- Area monitoring. Potential sources of leakage cannot be pinpointed and are spread across a large area, with the result that sensors must be distributed over this entire area.
- Fence monitoring. Potential sources of leakage cannot be pinpointed, so the outer limits of the installation are monitored to check whether hazardous gas concentrations are crossing into

neighboring, unsecured areas.

Spot monitoring can be accomplished by the highly targeted use of just a few gas sensors; area monitoring requires a large number. The latter method is used, for example, to monitor combustible liquids in storage, where the sensors are distributed in a grid-like manner across the entire area. In this type of application, a sensor can monitor an area of 500–1000 ft<sup>2</sup>, while in solvent storage areas a reasonable compromise appears to be a circular area with a diameter of ~30 ft (total surface area ~800 ft<sup>2</sup>).

When planning installations, however, area monitoring is often favored simply because at the time of planning the potential sources of leakage are as yet unknown. This is bound to be a costly and indeed the most maintenance-intensive solution which, in many cases, later proves to have been unnecessary. The more precisely the locations of potential gas leaks can be pinpointed, the more economically planners will be able to design the gas detection installation.

From a safety point of view, fence monitoring is a method of gas detection is little more than informative, since targeted countermeasures are virtually impossible by the time an alarm is given. Countermeasures, after all, can be effectively implemented only if there is adequate information available concerning the time and the location of the leakage. While area monitoring provides far less precise information than spot monitoring, fence monitoring does not give any specific information at all about the location and time of the gas leak. This is particularly true when open-path systems, e.g., photoelectric barriers that detect the potential danger caused by a gas, are used for fence monitoring.

Certain basic rules must be followed in positioning a sensor:

- The vapors emanating from combustible liquids are always heavier than air, and they flow through the air close to the ground. Sensors must therefore be positioned very near the ground (though they must nevertheless remain accessible for calibration purposes).
- Only three combustible gases are significantly lighter than air: hydrogen, ammonia, and methane. Unless they are extremely cold, these gases rise and can gather together close to the ceiling, forming so-called gas nests.
- Toxic gases, though heavier than air and present in the air only in low concentrations (e.g., <1% by volume), should be monitored at around head height (in the breathing area), as their distribution is mainly dependent on convection and thermal currents.
- If there is a preferred, defined air flow or an air flow guided by appropriate baffle plates, the sensor must be located on the air intake side. If monitoring is performed in air ducts, factors such as dilution and alarm delay will have to be taken into account.
- When detecting combustible gases or vapors, the sensor must be positioned between the leak and the source of ignition. Furthermore, the safety concept must take into account both the reaction time and the time needed for the intended countermeasure to take effect (e.g., start-up time of additional ventilation systems).
- By determining the maximum expected source strengths and air exchange speed, the potential flammable volume can at least be estimated (IEC 79-10: 1995), although it is not possible to take sufficient account of obstructions to air flow.

If for whatever reason a sensor cannot be positioned in the immediate vicinity of the potential leakage source, it is possible to sample air continuously and thus lead the gas sample past the sensor. This method is expensive, however, not only because the airflow must be monitored, but also because any adsorption in the pipeline or condensation due to a temperature gradient must be taken into account. If worse comes to worst, the gas must be completely conditioned, possibly even to the extent of ensuring explosion protection. Air sampling, of course, also increases the reaction time of the gas detection system.

**Calibration.** As is true of virtually every measuring device, gas detection instruments perform a relative measurement, i.e., they measure a gas concentration and compare it to a known concentration that is not actually present but which was communicated to the device during its last calibration. The quality of measurement will therefore always depend to a significant extent on how the last calibration was performed and—if the measurement quality is subject to aging (e.g., through long-term zero point drifts and sensitivity)—when calibration was performed.

A fundamental prerequisite for reliable measurements is an accurately performed calibration. However precise the device may be, poor calibration practices can cause it to produce readings that are completely false. Especially when calibrating with test gases with a very low concentration of the target gas (effects of absorption), specialized knowledge is needed and in many cases calibration cannot be performed on the spot. (There is help in the form of precalibrated, plug-and-play electrochemical sensors.)

Catalytic sensors should be calibrated with the gas to be detected. If the substances in question are combustible liquids, it is possible to generate concentrations of, for example, 50% LEL cyclohexane in a calibration chamber directly on site. Although calibration with the target gas gives the best calibration results, the use of previously determined calibration factors has also become an established method. With catalytic sensors, however, this method has a greater potential for error because these calibration factors are subject to greater fluctuations and aging. IR sensors do not have this disadvantage. The best general rule is to calibrate a sensor under real-life conditions.

#### Gas Detection Systems

**Lowest Acceptable Alarm Thresholds.** Every measuring device has a certain measurement error, described by the manufacturer as the standard deviation or repeatability. For gas detectors too there is always a certain probability that a measured value will fluctuate within specified limits around the target value. If the ambient parameters of temperature, pressure, humidity, and flow rate are also taken into account, the zero point fluctuation may even overlap with the fluctuation of an alarm concentration that has been set at too low a level. As a result, there is a certain probability that incorrect alarms will be given, and hence the gas detection instrument becomes unusable.

This knowledge is essential, as it proves that the safety of an installation cannot be increased by lowering the alarm thresholds below a certain limit. In safety technology, incorrect alarms are regarded as extremely dangerous; if they occur too often they will be ignored, possibly leading to serious trouble in the event of a genuine alarm.

The correct lower alarm limit can be calculated only on the basis of the sensor data and the actual operating conditions. The lowest limit should be no less than six times the zero-point standard deviation under actual operating conditions. Depending on the target gas, the type of sensor, and the application, the lowest reasonable alarm threshold may be predetermined by the gas concentrations present or by the properties of the detection instruments or sensors. When lower alarm limits are desirable for occupational health or safety reasons, they can be achieved only with considerable effort and/or equipment. In such cases, a compromise acceptable to everyone concerned must be worked out in the planning phase.

**Alarm Messages.** Two alarms have been demonstrated sufficient in gas detection systems. The pre-alarm provokes a reaction, either a prearranged set of responsive actions or the issuance of instructions appropriate to the particular event. Should the alarm condition persist, the main alarm is triggered and more aggressive actions are taken, such as switching off machinery and clearing the area. Ideally, the main alarm will rarely—preferably never—be necessary.

Adapted from "Planning and Designing Gas Detection Systems" by Dr. Wolfgang Jessel, appearing in *Dräger Review 85*, April 2000, by permission.

**Dr. Wolfgang Jessel** is an Applications Engineer and Physicist, Dräger Safety AG & Co. KGaA, Revalstrasse 1, D-23560 Leubeck, Germany; 49-451-8820, fax 49-451-882-2080, [wolfgang.jessel@draeger.com](mailto:wolfgang.jessel@draeger.com).

For more information, contact [Draeger Safety, Inc., Gas Detection Systems Division](#), 10450 Stancliff, Ste. 220, Houston, TX 77099; 281-498-1082, fax 281-498-5190.

Or contact [Draeger Safety, Inc.](#), 101 Technology Dr., Pittsburgh, PA 15275; 800-922-5518, fax 800-922-5519, [prodinfo@draeger.net](mailto:prodinfo@draeger.net).



For further reading on this and related topics, see these *Sensors* articles.

["Bringing Nondispersive IR Spectroscopic Gas Sensors to the Mass Market,"](#) September 2000

["Area Monitoring of Hazardous Gases and Vapors,"](#) January 2000

["Optical Gas Detection with Vertical Cavity Surface Emitting Lasers,"](#) September 1999

["The IR Fingerprint: Using IR Absorption Spectrometry to Monitor Gases for Process Control,"](#) May 1999

["Next-Generation IR Gas Measurement,"](#) October 1998

 [Send this page to a friend](#)

 [Printer friendly version](#)

[We Love Feedback](#)

Sensors® and Sensors Expo® are registered trademarks of [Advanstar Communications Inc.](#)

[Sensors Online Home](#) | [Sensors Expo](#) | [Contact Us](#)

**SENSORS**  
*Online*