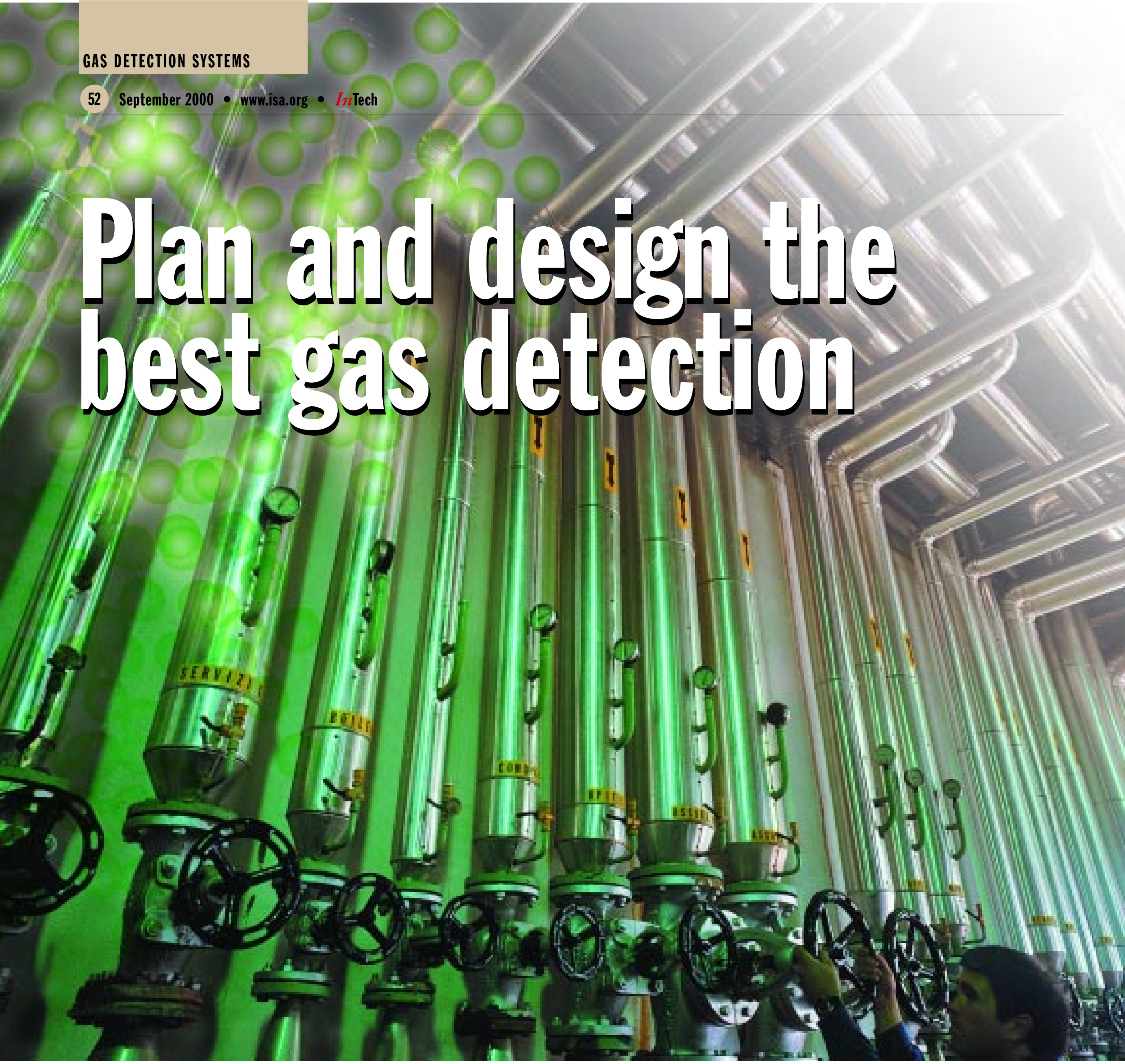
Plan and design the best gas detection



By Wolfgang Jessel

These early-warning systems allow effective countermeasures to chemical dangers.

Top on the list of safety priorities at chemical plants is the continuous monitoring of all safety-relevant process parameters because an unexpected change in these parameters will provide an indication of mistakes or problems in time to permit countermeasures. If you simply ignore an anomalous observation, however, as at Bhopal, that human error represents the gravest threat to any safety plan. In that type of safety hierarchy, the gas detection system becomes the second line of defense.

Whenever combustible or toxic substances are stored, processed, or transported in the chemicals industry, there are risks. If pressurized gases accidentally release, pipelines leak, or combustible liquid vapors escape through damaged valves or leaking seals, the consequence may be fire or explosion, secondary fires, perhaps even casualties. In the case of toxic substances, the result may be a serious risk to human health.

The cyclohexane disaster in Flixborough (1974); the Pensacola, Fla., ammonia accident (1977); the LPG accident in Mexico City (1984); the propylene catastrophe in San Carlos, Spain (1978); the ammonia release in Houston (1976); and the methyl isocyanate catastrophe in Bhopal (1984) are all painful reminders of the hazards at chemical plants.

System adds protection

To prevent future incidents such as Flixborough or Bhopal, governments draft regulations aimed at ensuring the earliest possible recognition of danger, thereby allowing time for effective action.

Gas detection systems or devices may satisfy this purpose if properly designed, correctly used, and regularly serviced and inspected. These devices can help prevent a potentially explosive atmosphere from developing. For example, as soon as a predetermined gas concentration (e.g., 10% of lower explosive limit, or LEL) is exceeded, the system triggers a countermeasure. If this measure proves inadequate and the gas concentration continues to rise in the area being monitored and then a second alarm threshold is crossed, all potential ignition sources switch off.

It is essential that detailed, concrete information be available regarding the countermeasures to be initiated by the gas detection system. Switching off electrical devices, closing gas valves, or activating a ventilation system are just as much common practice as flushing pipelines, cooling down hot surfaces, or activating water curtains. The use of such measures may actually eliminate the need for respiratory protective devices, even in situations involving toxic gases—despite the fact that the alarm plan stipulates that they be used.

The alarm plan needs to be implemented properly. It should contain information about which areas must be evacuated, and define when it is safe to reenter them. On this basis you can calculate the consequences and costs of a false or genuine alarm and in turn establish the requirements for the reliability and availability of the system.

Spot, area, or fence monitoring?

Three established methods of measurement exist in the chemicals industry. The first method is electrochemical measurement, which is well suited to detecting toxic gases in lower concentrations. The other methods are catalytic and infrared measurement, both of which detect combustible substances in concentrations below the LEL.

Each of these measurement methods has its own advantages and disadvantages, so the most reliable information about the suitability of a method to a particular task is likely to come from sensor manufacturers.

There are three sensor-positioning strategies, though it may be necessary to combine or modify the strategies to suit a particular application.

In spot monitoring, you know the potential sources of leakage. This means you can position sensors to ensure that gas leaks are detected promptly.

While spot monitoring permits highly targeted use of just a few gas sensors, area monitoring requires a large number of sensors. This method is often used to monitor combustible liquids in storage, and the sensors are distributed in a gridlike manner across the entire area. In this type of application a sensor can monitor an area between 50 and 100 m^2, while in solvent storage areas a reasonable compromise appears to be a circular area with a diameter of about 10 meters (approximately 75 m^2).

In area monitoring, because you cannot pinpoint potential sources of leakage that are spread across a large area, you must distribute sensors over the entire area. Area monitoring is often favored because the potential sources of leakage are unknown. However, this is a costly and maintenance-intensive solution that in many cases proves unnecessary. The more precisely you can identify the locations of potential gas leaks, the more economically planners can design the gas detection installation.

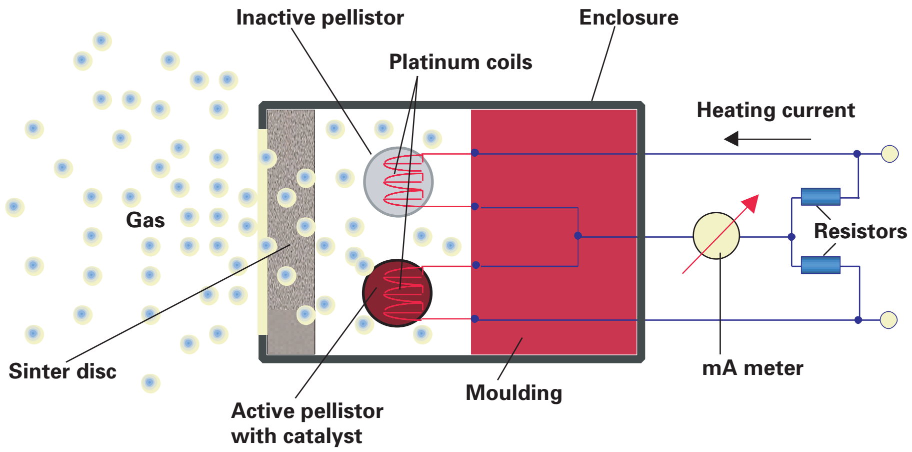
In fence monitoring, because you cannot

Questions and more questions

Anyone planning to install a gas detection system needs to consider the following questions:

- With what objectives are gases to be monitored?
- Where, how often, and in what concentrations and quantities are they likely to be released?
- Which sensor is most appropriate?
- How many sensors are needed?
- Where and how should sensors be positioned and calibrated?
- What alarm thresholds are appropriate?
- How will the alarm information be processed?

Catalytic sensor



Guidelines for positioning sensors

There are several guidelines that should be observed with regard to the positioning of a sensor:

- Because the vapors emanating from combustible liquids are heavier than air and will be located close to the ground, position sensors close to the ground.
- Remember there are three combustible gases that are significantly lighter than air: methane, ammonia, and hydrogen. Unless they are extremely cold, these gases rise and accumulate near ceilings.
- Monitor toxic gases, heavier than air but present in low concentrations, at human-head height (the breathing zone) because gas distribution or dispersion is mainly dependent on convection and thermal currents.
- Locate the sensor on the intake side if there is a preferred, defined airflow or airflow guided by appropriate baffle plates. In ducts, consider factors such as dilution and alarm delay.
- Position the sensor between the leak and a source of ignition when detecting combustible gases or vapors. Further, your design must take into account both reaction time and time needed for the intended countermeasure to take effect.
- Estimate the potential flammable volume by determining the maximum expected source-strengths and air-change speed, although it is not possible to take into account obstructions to air flow.

If you cannot position a sensor close to a potential leakage source, it is possible to sample air continuously by moving the gas past the sensor. This method is expensive, however, because you need to monitor airflow, and you must consider adsorption in the pipeline or condensation due to a temperature gradient. Further, air sampling increases the reaction time of the gas detection system.

pinpoint sources of leakage, you monitor the outer limits of the installation to check whether hazardous gas concentrations are crossing into neighboring areas. But fence monitoring has little real value because effective countermeasures are virtually impossible by the time an alert is issued. While area monitoring provides less precise information than spot monitoring, fence monitoring does not provide any information about the location or time of the leak. This is particularly true when open-path systems such as photoelectric barriers are used.

Calibration is everything

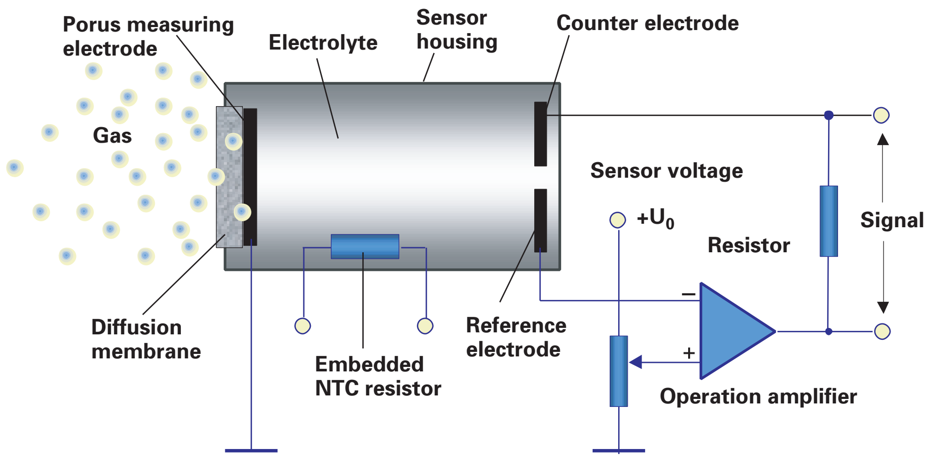
Like nearly all measuring devices, gas detection instruments perform a relative measurement: They measure a gas concentration and compare it with a known gas concentration that was communicated to the device during its last calibration. The quality of measurement, therefore, will always depend significantly on how the last calibration was performed and, if the measurement quality is subject to aging, when.

A prerequisite for reliable measurements, therefore, is an accurately performed calibration. This is especially important when calibrating with test gases having a low concentration of the target gas.

Although calibration with the target gas gives the best calibration results, the use of previously determined calibration factors has also become an established method. This has a greater potential for error with catalytic sensors, however, because calibration factors are subject to significant fluctuations and aging. Infrared sensors do not have this disadvantage.

Take note that you should perform the calibration under real-life conditions, if at all possible.

Electrochemical sensor



Acceptable alarm thresholds

Every measuring device has a certain measurement error, which is described by the manufacturer as the standard deviation (repeatability).

For gas detection instruments, there is always a certain probability that a measured value will fluctuate within specified limits around the target value.

If temperature, pressure, humidity, and flow-rate fluctuations are taken into account, the zero-point fluctuation may even overlap with the fluctuation of an alarm concentration that has been set too low.

As a result there is a corresponding probability that incorrect alarms will be issued.

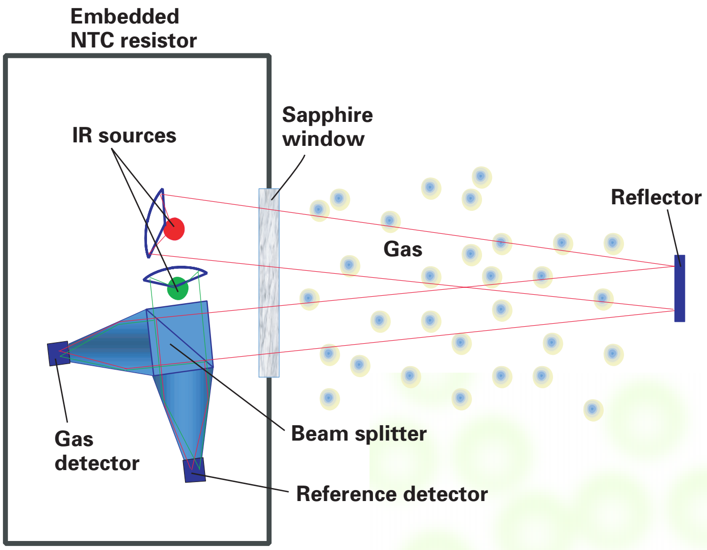
Understanding this point is vital because it demonstrates that lowering the alarm thresholds below a certain limit cannot increase the safety of an installation. Incorrect alarms are extremely dangerous because they will be ignored if they occur too often.

Generally, the reason why operators of gas detection systems are dissatisfied is that they have repeatedly set their alarm thresholds too low. You can calculate the correct alarm limit only on the basis of sensor data and actual operational conditions: The lowest alarm limit should be no less than six times the zero-point standard deviation under actual operating conditions.

If lower alarm limits are desirable for occupational health or safety reasons, this will require considerable effort and/or equipment. In such cases, work out a compromise acceptable to everyone in the planning phase. It is of paramount importance that the alarm limits be adapted in accordance with the agreed compromise.

Several decades of experience have proved two-alarm limits to be sufficient in the area of gas detection technology. The prealarm provokes a reaction; if effective countermeasures are not promptly implemented, the main alarm triggers. This has a series of consequences, including shutting down the equipment and clearing the installation area. Of equal importance are fault messages: A malfunctioning sensor is of no use and must be corrected immediately.

Infrared sensor



Design, use, service

Gas detection systems would not have prevented any of the disasters mentioned earlier, but such systems would have sounded a warning if used properly.

Get a general outline of the measurement task at hand, then clarify the operational conditions and intended purpose of the gas detection system.

You must properly design, correctly use, and regularly service and repair your gas detection systems. At stake is worker and community protection. **IT**

Behind the byline

Dr. Wolfgang Jessel is with Dräger Sicherheitstechnik GmbH in Lübeck, Germany. His address is wolfgang.jessel@draeger.com.