Sniffing Out Gases

With ever more improved sensors, modern detection technology for flammable and hazardous gases enables the design of highly reliable gas detection systems. The foundation for planning any system is well-considered matching of the components, which are based on various technologies, to specific local conditions

Continuous monitoring protects the environment from possible chemical leaks—and keeps the air uncontaminated

PHOTOGRAPHY: LESTER LEFKOWITZ/CORBIS

GASES ARE usually invisible to the unaided eye, and are often odorless. Still, they need not pose an invisible hazard to people or the environment, thanks to advanced gas detection technology that uses stationary as well as mobile solutions. Such systems offer a variety of possibilities for the measurement of flammable and hazardous gases in the atmosphere; they are applied to ensure employee health and safety in the workplace and in the prevention of incidents. To these ends, gas detection systems have established themselves as central elements of safety concepts in fields ranging from the chemical industry to mining.

The high level of modern gas detection technology is illustrated by the multitude of techniques currently in use: electrochemical sensors and catalytic bead sensors are employed, along with infrared technology in point sensors and open path sensors, flame detectors, ultrasonic sensors, and gas cameras. New developments extend existing system capabilities, explains Gero Sagasser, Gas Detection Systems Portfolio Manager at Dräger. Continuous innovation has led to a differentiation of the available solutions, permitting very precise matching of measuring technology to the requirements at hand.

In operations that handle hazardous (in the sense of the European Seveso Directive) substances, gas detection systems play an especially important role. Such companies are obligated to evaluate the hazard potential of their production facilities, identify specific hazard areas, and evaluate the relationship of hazards to >

Filling operations are frequently the cause of leakage

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Stationary gas detection systems reduce the risk of hazardous incidents

> protection objectives. The resulting scenarios are based on the maximum possible release of a hazardous material.

As a result of such planning, safety measures are defined and an integrated safety concept is developed. In Germany, the basis for this regulation is the Federal Immission Control Act ("Bundes-Immissionsschutz-Gesetz") and the resulting 12th Ordinance for the Implementation of the Federal Immission Control Act (12. BImSchV, the Major Accidents Ordinance). The economic significance of a gas detection system has been increased by the implementation of EC Directive 2004/35/EC, "Environmental Liability with Regard to the Prevention and Remedying of Environmental Damage" of May 10, 2007, implemented in Germany as the Environmental Damages Act—the Umweltschadensgesetz, or UschadG. According to this directive, the operators of an installation are liable for damages resulting from incidents. Along with information regarding dangers or the occurrence of environmental damage, the law requires measures to prevent and limit damage, as well as its remediation. Application of a modern gas detection system reduces the risk of hazardous incidents as well as their consequences; accordingly, investment in measurement technology can be applied as an argument with insurers.

More than half of all incidents in chemical engineering installations are attributable to the release of materials. These are usually triggered by technical defects (35 percent) and operating errors (30 percent). Uncontrolled chemical reactions occur in only about 20 percent of recorded cases. Most incidents occur during production processes (45 percent), more rarely in storage (15 percent) and other processing stages. A typical incident that may be prevented by a gas detection system is the release of flammable or hazardous (toxic) gases. Critical points within the facility, where the release of gases could occur, include all types of storage vessels, including valves and pipes, as well as machinery and pumps. Dynamic loading as a result of temperature and pressure variations, corrosion, and material fatigue are important factors that may lead to leakage. Joints and seals as well as filling and tapping points deserve special attention. In addition, technical leakage must be considered, in which material is deliberately released by means of valves, rupture diaphragms, and overflows to prevent the progression of a malfunction.

Gas dispersion

Not every release of chemicals counts as a hazardous incident. First among these is the category "unavoidable operational malfunction," which is in turn exceeded by the "major accident despite precautions" and ultimately by the "exceptional accident," which exceeds all previous experience and calculations.

It is at the stage between "operational malfunction" and "hazardous incident" that gas detection technology offers the greatest opportunity: it can make a significant contribution to very early recognition of a malfunction. This provides sufficient time for intervention by automatic emergency systems and targeted countermeasures.

To ensure that a gas detection system is able to react quickly and precisely, its components must be carefully matched to the operating facility's particular circumstances. The placement of detectors is determined, among other things, by the physical and chemical properties of the substance to be measured, assumption of the most likely leakage points, as well as the location's constructional, geographical, and meteorological conditions. The bandwidth of these data corresponds to the range of available measurement methods, based on various technologies, to enable point, line, and sector measurement using sensors of various designs. The targeted matching of a gas detection system to the specific conditions at a production facility is therefore the primary objective of any plan.

The public takes particular note of incidents in which dangerous substances are released. In this form of release, gases form a cloud around the free jet exiting from the point of leakage. The edge of the cloud is a turbulent boundary zone. The expansion of the cloud is determined by the physical and chemical properties of the released substance, process-related factors such as gas release velocity and the temperature of the immediate surrounding area, and more distant climatological, geographical, and structural conditions. >

Gas densities and limits

Light, neutral, or heavy? The relationship between the density of a pure gas and air determines how a gas cloud will expand. Light gases such as hydrogen, helium, methane, ammonia, hydrogen fluoride, acetylene, and hydrogen cyanide (gaseous) rise in the atmosphere. Neutral gases such as carbon monoxide, nitrogen, ethylene, formaldehyde, nitric oxide, and ethane have no dynamics of their own but rather are carried by the surrounding air. Heavy gases such as methanol (gaseous), oxygen, phosphine, hydrogen sulfide, hydrogen chloride, fluorine, propylene, ethylene oxide, carbon dioxide, propane, nitrogen dioxide (gaseous), methyl chloride, acrylonitrile and allyl aldehyde (gaseous), n-butane, sulfur dioxide, chlorine, benzene (gaseous), hydrogen bromide, phosgene, and bromine (gaseous) are heavier than air and spread along the ground.

The limits:

- ERPG 2 (Emergency Response Plan Guideline): The maximum concentration of hazardous gases in air which it may be assumed nearly all personnel will tolerate for a period of one hour without suffering irreversible or serious health effects, and while being able to implement protective measures.
- LFD (Lower Flammability Distance): The maximum distance at which an air-gas mixture can still be ignited.
- LEL (Lower Explosive Limit): The concentration of flammable gas in air above which the mixture is ignitable.
- OEL (Occupational Exposure Limit): The maximum permissible concentration of a substance in the workplace, below which no health hazard is to be expected.

Safety through the early recognition of operational malfunctions

> Once a gas has matched the temperature of its surroundings, it may be classified on the basis of its density relative to the density of air, as a light, heavy or neutral gas. Accordingly, the gas cloud will rise in the air (light gas), spread along the ground (heavy gas), or be entirely at the mercy of the wind (neutral gas).

However, a gas often behaves differently from these general patterns immediately after its release, because its process temperature is often very different from ambient temperature.

Besides gaseous escaping chemicals at slight overpressures, liquids, gases liquefied by means of pressure or temperature all of them may be the source of gas clouds. The most common of these are gases liquefied by means of pressure—often far in excess of 50 bars. Upon release, part of the liquid evaporates immediately (so-called flash evaporation); the remainder forms an aerosol and a boiling pool of liquid.

The extreme increase in gas volume as a result of the flash evaporation is especially dangerous, as it leads to the expansion of the dangerous substance at a high concentration over a large volume. As in the case of gases liquefied by cooling, at first a heavy gas cloud is formed as the liquid warms up to the boiling tem-

Process-related physical properties determine how a cloud of gas or vapor spreads

PHOTOGRAPHY: LESTER LEFKOWITZ / CORBIS

perature, which is below the ambient temperature.

Just as clouds of different flammable and hazardous gases differ in their behavior, so too there are distinct differences between gas detection in confined spaces and in the open air.

The conditions for the formation of gas clouds in interior spaces are similar to those in open air, but a cloud behaves quite differently in an enclosed space. In such cases, factors such as architecture, convective flows, and active ventilation determine the spread of the gas. Pools of heavy gases are especially dangerous, as they can form on the floors of enclosed spaces such as cellars and tanks.

Detailed system planning

The prediction of the gas dispersion and most likely behaviour based on the above considerations forms the basis for planning a sophisticated stationary gas detection system. Above all, a system consisting of arrays of single-gas point sensors is based on detailed system planning, which can be assisted by computer simulations. In the event of an operational malfunction or a hazardous incident, such a system also provides emergency services personnel with important clues to guide their tactical approach, makes it possible to warn the general public in timely fashion, and enables the implementation of safeguards for personal protection. **Peter Thomas**

Further information online:
Product information
www.draeger.com/96/sensors

The Dräger PIR 7200 continuously measures the carbon dioxide content of air. The gas detector operates using intrinsically safe infrared measurement technology, and thanks to its ATEX approval it is suitable for use in explosive atmospheres

Measuring methods and Dräger equipment

Catalytic Ex Sensor: The measured gas is analyzed by burning at a detector bead made of catalytic material; the heat of oxidation changes the resistance in response to the gas concentration. External influences such as humidity, temperature, and other parameters are corrected by means of a compensation bead that operates as an analog to the detector bead.

▸ **Dräger PEX 3000:** Point detector using a Dräger catalytic sensor to detect flammable gases, vapors, and hydrogen.

Electrochemical sensor: The measured gas diffuses through a membrane into an electrolyte-filled measuring cell, where it reacts with a measuring electrode (usually through oxidation). The resulting electrical current flow to the opposite electrode can be used to calculate the gas concentration.

▸ **Dräger Polytron 7000:** Point detector for Dräger electrochemical sensors to measure toxic gases and oxygen levels in ambient air.

Infrared sensors: Different gases absorb specific, characteristic ranges of infrared radiation, particularly in the wavelength range between 3.3 and 3.5 micrometers. The attenuation of the radiation after the gas passes through the measurement field provides information on the gas concentration. This technology is employed for point sensors as well as open-path measurement. The latter technology is well suited for measurements along pipes, for example.

▸ **Dräger PIR 7000:** Infrared gas transmitter for the continuous monitoring of flammable gases and vapors, in a pressure-resistant housing of 316L stainless steel.

▸ **Dräger Pulsar 2:** Open-path transmitter for the absorption measurement of gas clouds, with a line of sight of up to 200 meters between the transmitter and the receiver.

Flame detector: These sensors register the typical flickering of a flame at non-visible wavelengths. They are suitable for monitoring a defined sector at a specific distance.

▸ **Dräger Flame 2300:** Flame detector for hydrocarbon-based fires with combined detection in the UV and IR spectrum.

Acoustic sensor: This technology can automatically detect the characteristic sound of gases escaping through a leak.

Gas camera: Gas cameras are a new technology that makes high concentrations of hydrocarbons visible. A specific spectral range is recorded and made visible by means of image processing.