Geoff Wilson and Edward Naranjo, Emerson Process Management, USA, consider the available gas detection methods for LNG terminals.

DETECT the difference

LNG plays a pivotal role in the transport and storage of natural gas. Buoyed by high natural gas prices and technological advances, the cost to process and deliver the fluid has been significantly reduced. Although a small part of the natural gas and energy market, LNG production has grown substantially over the past decade due to this improved cost position. Such growth has led to the construction of LNG facilities. In North America, for example, the Federal Energy Regulatory Commission (FERC) has approved the siting and construction of four import terminals and five export terminals, while companies have proposed another five LNG import terminals and 15 export terminals.[1,2,3]

With such levels of activity, there is growing interest in understanding the process safety hazards related to LNG.[4,5] LNG itself is not dangerous, but the liquefying process presents a number of major accident hazard potentials. On loss of containment, any liquid released into the open will rapidly turn into gas, which could lead to a fire or explosion. The consequences of such an incident depend on the extent of the fire and overpressure. Combustion scenarios can take the form of a jet flame, fireball, flash fire, vapour cloud explosion, and pool fires. Loss of containment can also take place with other fluids present in LNG facilities. Refrigerants such as ethane, ethylene, propane, propylene, and butane are often required for liquefaction and their presence may increase the risk of an incident. Similarly, releases of hydrogen sulfide may result from the purification of natural gas before liquefaction if the natural gas is sour.

This article examines the different gas detection methods available for the protection of LNG facilities, especially marine terminal operations. Marine terminals receive imports and ship exports of LNG, and provide onsite storage and process units for natural gas liquefaction or LNG regasification. Facility operators use gas monitoring equipment to comply with safety standards and select several detector types to mitigate the consequences of hazardous material releases.

Gas detection

Catalytic gas detection

A common technique for detecting ethylene presence is catalytic gas detection. Catalytic detectors employ catalytic combustion to measure combustible gases in air at fine concentrations. As combustible gas oxidises in the presence of a catalyst, heat is produced. The sensor converts the temperature rise to a change in electrical resistance that is linearly proportional to gas concentration. A standard Wheatstone bridge circuit transforms the raw temperature change into a sensor signal.

Figure 1. Ultrasonic gas leak detector.

Figure 2. A typical LNG terminal. Credit: iStock.

Figure 3. Combustible gas detection sensors.

Catalytic detector design simplicity belies several strengths that have made this detector type a mainstay of fire and gas safety applications for more than 50 years. Catalytic detectors are robust, economical, reliable, and self-compensating to environmental changes such as humidity, pressure and temperature. These detectors are also easy to install, calibrate and use. Once in place, detectors can operate for years with minimal maintenance, requiring only periodic gas calibration to verify operation. As catalytic combustion reaction is non-selective, catalytic detectors can be used to monitor several target gases across many varied applications. Catalytic sensors are able to detect ethylene in concentrations well below the lower explosive limit (LEL).

Infrared gas detection

Infrared (IR) detection depends upon the ability of certain molecules to absorb light at wavelengths that are characteristic of molecular structure. Absorption characteristics are defined as molecular vibrational energies associated with stretching, bending or rotations. In general, functional groups absorb radiation in characteristic wavelength bands. Methane, the principal component of natural gas, has a prominent absorption band at 3.3 μm corresponding to carbon-hydrogen bond stretching.

Combustible IR instruments employ a dual wavelength technique. In order to prevent background distortions due to source ageing, optical surface contamination or response to other gases, absorption at a particular band is monitored with respect to a reference measurement. Reference wavelength bands are chosen in a region of the IR spectrum where there is minimal absorbance of the gas of interest. Hence, using differential absorption techniques, both active and reference channels are equally attenuated when contaminants are present within the IR beam.

Combustible IR detectors can be of both point and open path types. IR point type devices are used to detect natural gas in various concentration ranges, typically arranged in a 3D array, or in-duct mounted for heating, ventilation and air conditioning (HVAC) systems. In contrast, an open path device uses an IR source coupled to a remotely-sited receiver. These devices can be used to measure ethylene along perimeters or across process areas when installed at defined spacing in one direction. In addition, open path detectors designed for use in ventilation ducting (short path length) can be placed in air intakes, including gas turbine enclosures.

Ultrasonic

Acoustic monitoring techniques use ultrasonic sensors to detect leaks based on changes in the background noise pattern. These sensors respond to the sound generated by escaping gas at ultrasonic frequencies. The ultrasonic sound level is directly proportional to the mass flowrate (leak rate) at a given distance. The leak rate in turn is mainly dependent on the size of the leak and the gas pressure. Unlike other detection technologies, ultrasonic gas leak detection does not measure gas concentration (e.g. %LEL or ppm) or a concentration over a sampling distance (e.g. LEL-m or ppm-m). Rather, it defines gas leaks in terms of the sound pressure level (SPL). In general, the greater the leak rate, the larger the sound pressure level emitted by the escaping gas. Leak rates can be divided into the following three categories, according to certain dispersion models employed in the oil and gas industry[6]:

- Minor leak: mass release rate < 0.1 kg/sec. and duration < 2 min.
- Major leak: mass release rate > 1 kg/sec. and duration > 5 min.
- Significant leak: those releases lying between the limits of major and minor releases.

Advantages of ultrasonic gas leak detection include instant detection of pressurised gas leaks and imperviousness to changes in wind direction or gas dilution. Ultrasonic detectors provide broad area coverage and do not require transport of gas to sensor. Another advantage is that detector performance can be verified using live gas leaks during commissioning. Using inert gas, operators can conduct gas release simulations at a known leak rate and test detector response within potential locations.

Ultrasonic gas leak detection is restricted to high pressure leaks (> 10 bar or 145 psi) necessary to produce acoustic emissions at levels substantially higher than background noise. As a result, ultrasonic gas leak detectors are used to monitor gas turbines and compressors.

Case study

Remote LNG production sites are not uncommon in gas producing regions in the US. These are much smaller operations than those found at LNG import and export facilities, but often help supply electricity where access to electricity from a utility grid is limited. At these remote LNG production sites, portable or skid-mounted vaporisers are often used. Although the likelihood of a gas release happening is low, early indication of this situation is critical to ensuring the safety and integrity of the process facility. Fixed-point gas detection provides the answer to this problem.

Most skid-mounted vaporisers are pre-fabricated at an external location and then shipped to the well site with the instrumentation and interconnect piping ready for a quick installation. This quick installation is the driving force behind the pre-fabricated vaporiser. One way to assist with this quick installation is to consider wireless communication on the site's instrumentation, gas detection included.

There are concerns within the industry about the integrity of wireless communication, including the update rate and response time of the gas detector. One way to work around this is to utilise additional outputs provided by the gas detection transmitter. In one particular case, a shale gas production company has installed combustible gas detectors within vaporiser units. Gas detectors are connected via relays to the heaters in the skid. As soon as the gas detector reaches its alarm level, the relay initiates the shutdown of the heaters. At the same time, the gas detector communicates via radio to the central control system, notifying the operator of a gas release at the vaporiser and enabling automated executive action.

Conclusion

The versatility of LNG for a variety of industrial uses, its advantages in storage and transportation, and worldwide demand suggest LNG technology will continue to advance at a rapid pace. To produce new facilities and expansions to existing ones, operators rely on arrays of catalytic and point and open path IR detectors, which have amassed an impressive record for reliability after decades of use.

Simple in design and easy to manufacture, catalytic detectors respond to the greatest possible range of combustible gases (including hydrogen) and offer good repeatability and accuracy, as well as fast response times. Due to their wide compass, they are installed in fractionation columns (scrub columns) before liquefaction at a main exchanger, near propane pre-cooling vessels or near refrigerant compressors. Catalytic detectors are also useful for the protection of process pumps.

IR gas detection provides high integrity and reliability in point and open path configurations, which are essential methods for safety applications. As optical gas detection is a physical technique, high-target gas concentrations for prolonged periods and oxygen level changes do not degrade sensor performance. Most importantly, IR devices are failsafe. Both point and open path IR detectors are used in marine terminals to monitor LNG transfer pumps and storage tanks.

Unlike fixed point catalytic, point or open path IR detection, intended primarily for the detection of gas accumulations, ultrasonic gas leak detection responds to the ultrasonic noise generated at the leak source itself. It therefore has the potential to compensate for the limitations in effectiveness of traditional gas detection systems. Ultrasonic gas leak detectors can be installed in gas turbines for fuel gas compressors and refrigerant compressors.

Required detection coverage at LNG facilities must be based on process hazard analyses that take into account the advantages and limitations of detection technologies. All point detectors, for example, are limited to detecting gas at a specific location and can be foiled if placed in a spot where air stagnates or if an obstruction prevents the hazardous gas from reaching the detector element. Similarly, ultrasonic gas leak detectors cannot detect low pressure gas releases such as those produced by LNG spills. The best strategy appears to be deployment of these techniques in combination, so that devices may comprise a broader range of gas release scenarios while mitigating vulnerabilities. **LNG**

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