René Braun, Grandperspective GmbH, Germany, demonstrates how the use of infrared imaging to give early warning of dangerous gas leaks can improve plant safety in ammonia complexes.

FINGERPRINTING AMMONIA LEAKS

Detecting ammonia leaks early, as well as emissions monitoring, has never been more important than today. The global production of fertilizers grows every year and the majority of nitrogenous fertilizers rely on ammonia as a base material, with an annual production output above 200 million t. The present trend towards lower carbon and zero carbon emission ammonia is putting pressure on producers to increase efficiency and reduce emissions. A growing awareness of safety, combined with higher population densities in urban areas, add additional demands for emission monitoring and rapid emission detection. At the same time, new markets such as ammonia as fuel and storage for hydrogen are emerging.

Implementing large area surveillance for gas leaks is the only viable means of ensuring the continued operation of such industrial sites near populated areas.

When production and storage areas become larger, stationary gas detectors prove ineffective at reliable early warning. Monitoring large areas for ammonia emissions can only be accomplished with stand-off measurement technologies: Fourier transform infrared spectroscopy (FTIR) is well known from routine laboratory chemical analysis, but it is also an established technology for remote sensing. First responders and security forces use FTIR remote sensing for the supervision of large areas in the event of chemical releases or terrorist attacks. The method is selective among hundreds of chemicals while being extremely sensitive to many organic compounds and, in particular, ammonia. The main advantage of FTIR remote sensing over other technologies is the fact that it can be used passively without lasers or the illumination of the target area. Like a highly sophisticated camera, it shows the gas even from miles away.

Challenges of gas detection

Detecting gas leaks has been a challenge ever since engineers started making use of dangerous substances for producing fertilizers, plastics or energy. The famous canary birds warned miners of carbon monoxide accumulations deep in coal mines. Burning sulfur sticks was a method of locating small ammonia leaks in refrigeration machines. The modern-day equivalents are gas sensors that will report even the smallest presence of a particular target gas in their vicinity. Obviously, their efficiency is limited outdoors, i.e. when wind spreads gases rapidly in the wrong direction and prevents timely detection, unless the density of installed sensors is extremely high (and therefore prohibitively expensive). Optical gas imaging, on the other hand, may provide larger area coverage but lacks sensitivity and, most importantly, specificity.

FTIR spectroscopy has the potential to tackle both issues: it is very sensitive and specific as well as capable of covering large areas and providing a broader image. The measurement principle is based on the spectroscopic analysis of infrared radiation. Due to their inherent temperature, all objects emit infrared radiation, which allows a chemical analysis to be made at distance. Within the infrared spectrum, one wavenumber range, called the fingerprint region (from 500 to 1500 cm^{-1}), is most interesting for analysing the chemical composition of a gas remotely. In this spectral region, many chemicals interact with radiation in a compound specific manner. The effect of this interaction is a spectral absorption or emission feature in the infrared radiation that is unique to the chemical compound – the spectral fingerprint.

A modern-day solution for large installations

Grandperspective's scanfeld system is the first FTIR remote monitoring solution for the chemical industry that probes for suspicious spectral fingerprints. The sensors are entirely passive FTIR spectrometers that continuously scan the areas of interest. A sophisticated mechanical positioning system allows the imaging motion as well as the 360° coverage of many different scan areas. Each point (or Toxel, a very narrow cone) within the observed regions is represented by a complete infrared spectrum. The spectra are automatically analysed for substance and amount.

With a single installation ranging from a tall spot, multiple areas can be secured (e.g. several high-pressure vents, pipelines, reactors etc). The detection range can be as great as 4 km.

Remote sensing early warning systems, in comparison to local sensing technology, provide both information on the location and concentration distribution of the gas cloud. They can be applied over wide areas within the overlapping fields of view of the scanfeld sensors. The propagation of a gas cloud can be tracked over several square kilometres, and the concentration distribution is measured in real-time. Due to the optical technology, the gas detection works in all three dimensions including height, a feature that is missing in ground-based gas sensors.

Effective early warning

Time is of the essence whenever hazardous substances are airborne, especially in the case of toxic, flammable and/or combustible materials such as ammonia. If such events are not detected early, the consequences can be severe with respect to the environment, health and, obviously, cost caused by damages, loss of production and downtime. Once incidents occur, knowledge about the exact nature of the release is important but traditional methods fail to provide the level of detail that is desired by first responders and fire fighters.

The system combines the capability of early warning of even small releases with precise information about the gas emissions and their change over time. Finally, the sensors also help to de-escalate the situation once a release is stopped and the atmospheric gas is dissipated by diffusion and wind, as confirmed by the distant sensors.

Figure 1. Mounted at an elevated position, the scanfeld sensor unit continuously monitors large areas for dangerous emissions.

Figure 2. A single unit can cover many regions of interest within its direct field of view.

Mapping toxic gases

Gas releases in the open are very different from gas emissions in confined spaces. In the latter, a gas detector can pick up the rising concentration no matter where the source is located. In the open, however, the gas coming from a release point becomes rapidly diluted, so tracing back the source with a gas sensor is next to impossible. Finding flammable or toxic gas leaks requires a near-field monitoring of the entire area around a potential point of release to ensure timely and accurate results. With respect to the dynamic gas distribution, it must operate in real-time.

Compared to field measurements with hand-held sensors or vehicles, remote sensing allows for near-field mapping without prior knowledge of the location and the wind situation. Monitoring the gas distribution can be performed within seconds. The scanfeld unit is therefore fast enough to map the dynamic propagation of gas releases for early warning of gas leakages.

Measures for mitigating the effects of an accidental gas release are most effective if they accurately represent the gas concentration across a wide radius of the incident. Without information on the location of a gas accumulation, wide areas of the compound need to be monitored manually. Assessment of the gas concentration becomes more difficult as the affected area grows larger, making reliable situation assessment with common gas sensors impossible. The concentration of the gas can be low at a certain location but rise dramatically when the wind sweeps the gas cloud in another direction. Therefore, the reading of a local gas sensor can create a false interpretation of safety when the location of the gas cloud is unknown.

Case study

The Chemelot industrial park is located in a densely populated region near Maastricht, the Netherlands, and Düsseldorf, across the border in Germany. It is one of the largest chemical parks in Europe, with numerous companies – such as OCI, Arlanxeo, DSM and SABIC – present. The two major production streams onsite process naphtha/gasoil to hydrocarbons or plastics and natural gas to ammonia, fertilizers and specialty chemicals. Within the Chemelot industrial park is the Brightlands Campus, a hub for start-ups, R&D facilities and education with more than 3900 researchers, entrepreneurs and students. The campus is situated close to the production facilities; for example, the OCI Nitrogen ammonia and urea complex is less than 400 m (1300 ft) away.

A project is being undertaken to reduce the risks from an unexpected airborne release by using the scanfeld early warning capability to protect the adjacent Brightlands Campus. The main requirements are swift detection at levels of 10 ppm and above, visualisation of the gas cloud in the control room in real-time, no false alarms, continuous operation for at least 99.9% of the time, at least 4 hours operating time in case of power outage, onsite data storage, internet independence and 24/7 support in case of outages.

The scope of the first phase of the project is focused on a production unit in the OCI complex, and in particular the reduction of risks due to unexpected airborne releases. A technical feasibility study for a future scale-up to monitor the entire Chemelot north side has also been carried out. There are four stacks within the plant that must be monitored for accidental ammonia release. The early warning of such incidents is essential. Once a release of ammonia is detected, the operator must be warned immediately. Situation assessment requires determination of the location of the release, the compound that has been found in the air, the total amount of gas and the dimensions and concentration of the gas cloud. In the event of a spontaneous, large-scale emission, the gas cloud will not be diluted within close range of the incident and it will propagate over the site. Such clouds bear a large hazard potential, especially at low wind speeds.

The number and the positioning of the sensor units is driven by the scope of the monitoring plan. Each individual sensor unit can cover a radius of 4 km (2.5 miles). Monitoring of an entire facility can thus be accomplished by two or three sensor units. The installation at Chemelot focuses on fast early warning within a minute and quick monitoring of emissions into the Brightlands Campus. For the 3D localisation of a moving gas cloud, two sensor units are installed, autonomously monitoring the production area. The two units are coordinated in real-time to track the event.

The scanfeld sensors sequentially monitor the four stacks of the OCI site, including the urea plant, for unexpected gases. The two sensor units also oversee the Brightlands Campus to monitor any emissions onto the campus. The total monitoring area is approximately 350 000 m^2 (0.14 square mile).

In the normal operation mode, the scan pattern is optimised for a quick turnaround time to check the status of the plant. The scan pattern is specific to the scope of the installation, balancing the number of areas, scan speed and spatial resolution. Thus, monitoring areas for the potential release of highly toxic or flammable gases can be optimised for speed, whereas large area monitoring can be optimised for better spatial resolution. Once a gas release is detected, the scan pattern shifts to gas cloud distribution mapping. The operator is notified of all events through an indication on the user interface. As permitted emissions naturally occur in production facilities and fugitive emissions from other areas periodically come into view, an automatic situation assessment aids improved distinguishing between hazardous situations and harmless emissions.

Outlook

The scanfeld monitoring system is a highly automated monitoring tool that continuously surveys predefined scan areas. At OCI Chemelot, a very short response time to unexpected releases is achieved by the careful choice of two installation sites in the near vicinity of both the production site and Brightlands. With a minimal time-to-alert, the system provides exact information about what, where and when as well as the severity of unexpected gas emission incidents. It thereby creates additional barriers to hazardous events and protects the Brightland Campus. Furthermore, it allows the speedy post-incident release of affected areas as soon as the dispersion of the gas cloud is confirmed by the sensors. Compared to conventional gas sensor networks, it is cost-effective and provides more detailed information, both from the near and wide field point of view. Since the system is highly scalable, just a few additional sensor installations can provide coverage of the entire Chemelot area and provide safety to the site and its neighbouring areas.

Conclusion

Optical remote monitoring is proving to be a useful method for increasing operational safety in ammonia processing facilities. The passive, spectroscopic technology delivers early warning as well as detailed information about undesired gas emissions. In the context of the OCI Nitrogen plant in the Netherlands, it specifically helps with protection of the immediate neighbourhood of the facility. It is therefore in step with the growing demand for early warning systems, which are a necessity for the continued expansion of production and, more generally, the public acceptance of ammonia production, processing and handling. **WF**

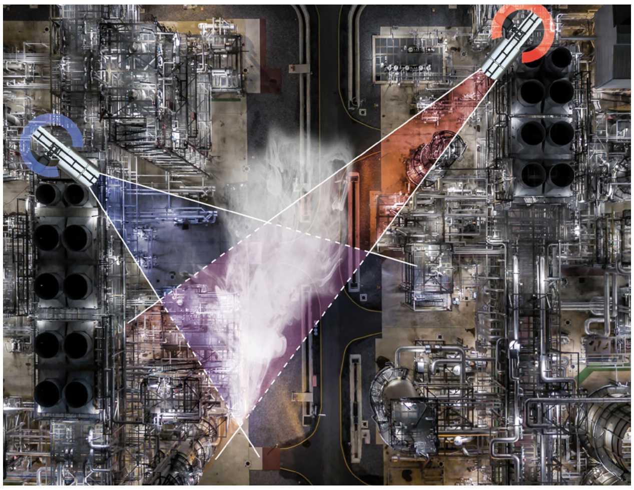

Figure 3. Using two or more scanfeld sensors permits checking upon gas clouds for concentration, position and propagation by tomographic reconstruction.

Figure 4. The sensors detect dangerous gases regardless of background – against sky, technical installations, buildings or ground.