Optical gas imaging: from qualitative to quantitative

New technology capable of quantifying fugitive emissions using infrared imaging may eventually serve as a full replacement for Method 21.

The detection and repair of fugitive VOC emissions (i.e. emissions from plant components which are designed to be leak-tight, such as pump or compressor seals, valve packing, flange and sample points) is a well-established and regulated practice in sectors such as refining, oil and gas production and chemicals production. The Best Available Techniques (BAT) conclusion number six for the gas and mineral oil refinery sectors recognises two methodologies used for detecting leaks from equipment under leak detection and repair (LDAR) programmes:

- Method 21 (commonly called sniffing)[1] uses a hydrocarbon ionisation detector connected to an aspirated wand to probe for emissions. This methodology was developed by the US EPA and forms the basis of European Standard EN 15446:2008[2].
- Optical gas imaging (OGI) uses an infrared (IR) camera to make images of emissions. A protocol for application of OGI for LDAR was developed recently[3].

The estimation of fugitive emissions is required for reporting purposes. The only established technology to directly quantify fugitive emissions on a leak-by-leak basis is 'bagging', which involves fully or partially enclosing a leak to facilitate sampling in such a way as to determine the emission rate. However, this technique is time-consuming, and is not always practical or possible for every leak detected.

For Method 21, correlation factors for calculating the emission rate as a function of measured concentration have been developed from structured bagging programmes. Results are available for a set of typical plant components across a number of industry sectors. There are many uncertainties associated with Method 21 correlations. Where a large number of leaks are 'sniffed' the average emission rate can be determined from the correlation factors; however, when applied to individual leaks, this approach to estimating the emission rate is less certain.

OGI can be very effective in detecting leaks[4], but does not yet provide the means to take a direct quantitative measurement of each leak rate. This has been a shortcoming of OGI from a regulatory perspective, and has hindered its adoption as a true alternative to Method 21.

A new technology called Quantitative Optical Gas Imaging (QOGI) has been developed to quantify the leak rate by analysing the video image recorded by existing OGI cameras (e.g. FLIR GF300 or GF320[5]). The working principle of QOGI can be briefly described as follows[6]:

- IR images of a leak are analysed for intensity on a pixel-by-pixel basis.
- Each pixel represents a column of hydrocarbon vapour detected between the IR camera and the background. The hydrocarbon vapour absorbs the IR radiation and hence affects pixel intensity.
- Pixel contrast intensity (ΔI) is defined as the difference between pixel intensity in the presence of hydrocarbon and the intensity of the background.
- ΔI is a function of the temperature difference between the background and the plume (ΔT).
- At a given ΔT, the intensity is proportional to the number of hydrocarbon molecules in the vapor column.
- The leak rate is reflected in both pixel intensity and the number of pixels that have a ΔI higher than a certain threshold.

Providence Photonics' new QOGI tablet—the QL100—can quantify the leak rate by analysing the video image recorded by existing OGI cameras.

Based on the above principles, the QL100 tablet contains a computer program that takes the raw IR data from an IR camera and analyses it to determine the leak rate. The IR camera must be radiometrically calibrated to establish a temperature scale. The user needs to provide: the ambient temperature; the distance between the camera and the leaking component; and the gas composition. All other variables required for determining the leak rate are programmed into the tablet.

Several controlled experiments, comparing known leak rates of several gases and mixtures to the estimates provided by the QL100, were performed with the prototype version in 2015. The results have been presented at various conferences in the USA, Europe and the Middle-East. Additional experiments were carried out by Providence Photonics in collaboration with Concawe[7] and the US EPA[8].

The test conditions in the Concawe experiment are summarised in Table 1. Overall, the QL100 was able to detect and quantify leaks between 14 and 1100 g/h. For 31 leak scenarios across the conditions listed in Table 1, the estimation error was 6% on average, the minimum being -23% and the maximum 69%.

Further field experiments have been recently undertaken to develop an understanding of data quality indicators that would establish the characteristics and proportion of those leaks detected by OGI that could then be quantified by QOGI to similar or better accuracy than Method 21. Such knowledge would greatly enhance an LDAR programme.

In collaboration with Concawe, the QOGI technique was used to complement an OGI-based LDAR programme in a European refinery. The test included independent bagging with the high-flow sampling technique[4] to obtain a physical measure of the true leak rate. Factors investigated include: sufficiency of temperature difference between the leak and the background; effects of plume obstruction (e.g. in a confined area); movement/changes in the background during measurement; interference due to steam plumes, direct sunlight, etc. The results should be available in 2017.

Table 1 Test conditions for the Concawe experiment to detect and quantify leaks using Providence Photonics' QL100 product

Parameter	Demonstrated range	Remark
Leaking equipment type	Open end, valve, flange	In pilot test location (not in manufacturing site)
Distance to leak	2–8 m	Different lenses can be used
Leak rate	14–1100 g/h	
Leak composition	propane, methane, toluene, propylene and blends thereof	IR response factors developed for many common hydrocarbons
Wind speed/direction	0.3–1.9 m/s	Issues limiting use: • High leaks and no wind (plume cannot be extracted from background). • Small leaks and high wind (plume pixels cannot be captured)
Ambient temperature	15–21°C	

Based upon the test results to date, QOGI appears promising as a technology to quantify leaks, potentially providing a full replacement for Method 21. Other opportunities exist for this new QOGI technology. It has potential for quantifying other diffuse VOC emissions such as emissions from tank seals, and methane emissions in oil and gas production.

References

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