Abating Fugitive VOC Emissions More Efficiently

This article summarises the Concawe study "Techniques for detecting and quantifying fugitive emissions – results of comparative field studies" that compares the two best available techniques (BAT) for detection of refinery fugitive VOC emissions: Sniffing and Optical Gas Imaging. The main finding is that the Optical Gas Imaging technology is faster and can effectively detect all leaks that contribute significantly to a fugitive emissions inventory.

> *"Fugitive emissions are generated at plant components which are supposed to be leak-tight (like pump or compressor seals, valve packings, flanges, sample points, etc.). Whilst a typical site would have 50,000+ such components, only a few of these contributes to the bulk of fugitive emissions. Identifying these few leaks for repair is difficult and time consuming, as they are spread out over the entire site, including hard to access locations."*

Concawe Air Quality Management Group's Special Task Force on Optical Gas Imaging (OGI ad-hoc group)

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The petroleum refinery industry has successfully reduced emissions of non-methane volatile organic compounds (referred as VOC in this article), one of the precursors to surface level ozone formation, through leak detection and repair programmes and technology advances (e.g. improved valve packing). In order to go further in this reduction, the industry is now focusing its efforts on the control of fugitive emissions (leaks) which can contribute up to one third of the total site VOC emissions. Fugitive emissions are generated at plant components which are supposed to be leak-tight (like pump or compressor seals, valve packings, flanges, sample points, etc.). Whilst a typical site would have 50,000+ such components, only a few of these contributes to the bulk of fugitive emissions. Identifying these few leaks for repair is difficult and time consuming, as they are spread out over the entire site, including hard to access locations.

Two methodologies are currently available to detect leaking equipment in so-called LDAR (Leak Detection and Repair) programmes:

1) "Method 21", developed by the US-EPA, uses a flame ionisation detector. It is the first historically developed. It is a widely accepted method;
2) "Optical Gas Imaging", (OGI) uses an infra-red camera. It is a newer technique gaining increasing acceptance.

CONCAWE STUDY OBJECTIVE

In 2012-2013, Concawe carried out several parallel LDAR campaigns. Both OGI and sniffing (EN 15446:2008) were applied by two independent teams. The objective was to compare the VOC mass emissions detected by each method. The mass emissions were independently estimated for all detected leaks by "bagging", when possible. The bagging technique applied used a combination of two instruments: a "High Flow Sampler" (a device developed for estimating natural gas leaks by manufacturer Bacharach) and the "TVA-1000B" (a FID/PID detector commonly used in sniffing surveys). The high flow sampler was used to estimate the volumetric flow rate of the leak. The bagging technique applied (referred to as HFS in this article) is much faster than the original methodologies described in the EPA report on the development of Method 21 (EPA-453/R95-017[X]).

Parallel Sniffing and OGI surveys

Operating units handling gas and light hydrocarbons were surveyed by both methods at 2 European refineries. Site 1 is a newer facility (built in the 1980's) where LDAR was applied for the first time during this survey. Site 2 is an older facility with an LDAR program put in place for 10 years. A single campaign was done at Site 1 while three consecutive campaigns were done at Site 2. In the first campaign at Site 2 several units were surveyed, totalling 25,000 LDAR points. In the subsequent campaigns, only sub-unit 1 was surveyed (selected as previous surveys had shown this to have a relatively high number of leaking components). Site 1 and Site 2 sub-unit 1 have approximately 4500 LDAR points each. The leak definition threshold was 10,000 ppm for Site 1 and 5,000 ppm for Site 2 (based on the site permit). In this Concawe work, a leak is defined as either a visible OGI image or a sniffing concentration (screening value) above site leak definition.

The OGI surveys were performed according to the Dutch guidelines [3] with a FLIR GF 320 camera. The pace of the survey was 2000 components per person per work day. The sniffing surveys were performed according to EN 15446:2008 [1].

The analyses for comparing the VOC mass emissions estimated by the various methodologies were only done for the bagged accessible leaks.

Main Observations

1. The emissions estimated by the EN 15446 factors and correlations are conservative for the operating units surveyed where no leaks above 200 g/h are present.

Figure 1.1 below shows the number of leaks detected by sniffing and how many of those leaks had a screening value above 100,000 ppmv (pegged leak) and how many were below 100,000 ppmv (non-pegged leak).

In the two facilities, the fraction of "pegged leaks" was comparable (45% in Site 1 and 57% in Site 2, sub-unit 1).

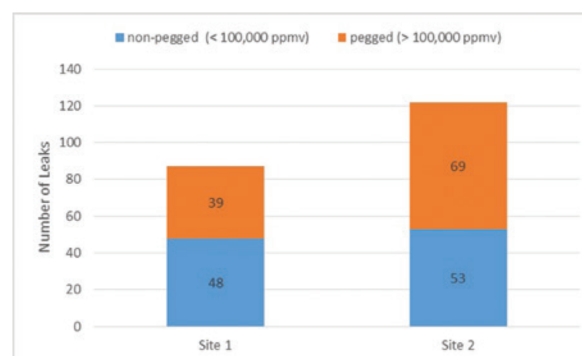

Figure 1.1 Total number of leaks found by Method 21 (Site 1 and Site 2, sub-unit 1, campaign 3)

Figure 1.2 below shows the mass of these leaks estimated with Method 21 and with HFS.

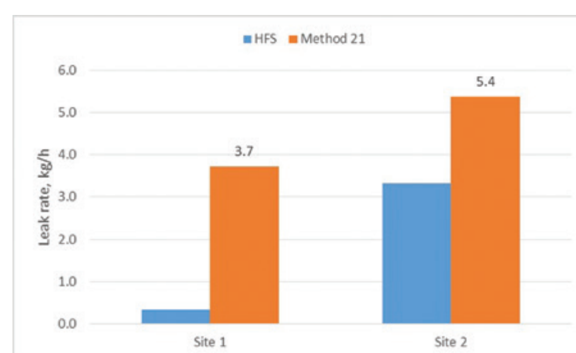

Figure 1.2 Leak rates estimated by two methods (Site 1: 74 leaks and Site 2: 97 leaks). Remark: not all detected accessible leaks could be bagged (e.g. hot surface equipment).

While the number of "pegged" leaks" is comparable, as shown in Figure 1.1, Site 1 has fewer leaks in total and no single large leak (≥ 200 g/h) based on the bagging results (HFS). Site 2 sub-unit 1 has more leaks in total (but a lower leak threshold) and 8 large leaks.

For Site 2 sub-unit 1, the emissions estimated with Method 21 are close to those estimated with HFS (around factor of 2 difference). For Site 1, the emissions estimated with Method 21 are much higher than the HFS estimation (around factor 10 difference). A possible explanation is that the Method 21 factors and correlations were established many years ago, when the occurrence of large leaks was statistically more frequent. This method has not been revised in 20 years and could misrepresent the current situation, where LDAR programmes and technology advances (e.g. improved valve packing) have resulted in reduced fugitive emissions relative to 20 years ago.

2. The leaks detected by both methods (OGI and Sniffing) represent the largest portion of the VOC mass emissions.

Figures 2.1 and 2.2 below show, for Site 1 and Site 2 sub-unit 1, the number of leaks detected by the two methods and the mass of these leaks (calculated with the HFS method). As illustrated above, Site 1 and Site 2, sub-unit 1 are very different in terms of total VOC mass leak rate.

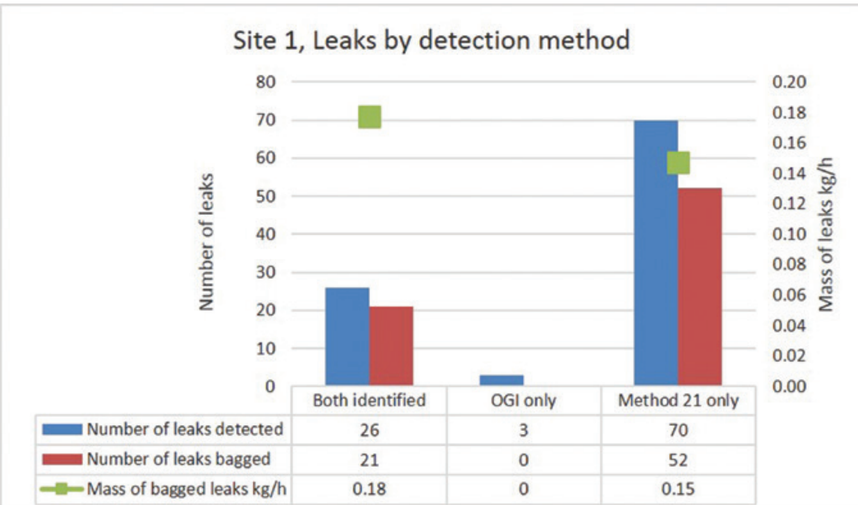

Figure 2.1: Site 1, Leaks identified by detection method and mass of bagged leaks (measured by HFS).

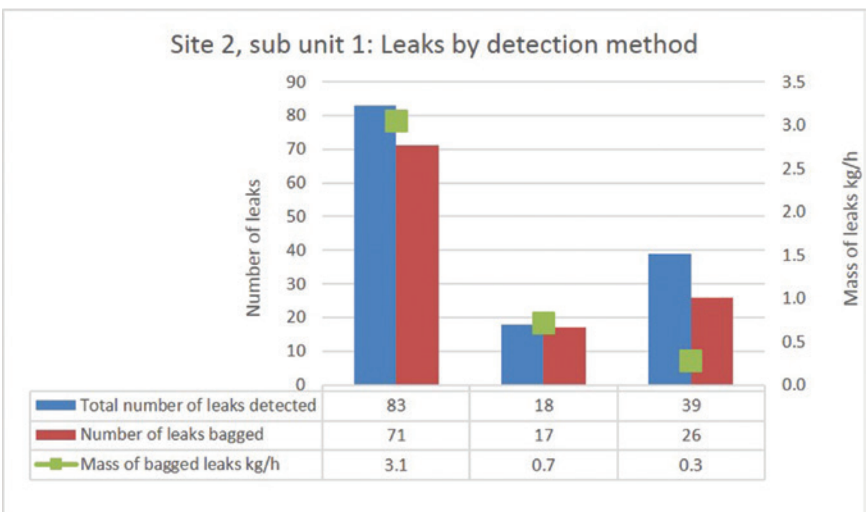

Figure 2.2: Site 2, sub-unit 1: Leaks identified by detection method and mass of bagged leaks (estimated with HFS). Remark: not all leaks could be bagged (e.g. hot surface equipment or non-accessible OGI leaks).

In Site 1 (Figure 2.1), the number of leaks only identified by Sniffing was significant (70 out of 104), but the mass of these leaks (0.15 kg/h) is smaller than the mass of the common leaks (0.18 kg/h). OGI didn't detect 0.15 kg/h of VOC mass from accessible components but, on the other hand, it detected three non-accessible leaks which could not be quantified because HFS could not be applied.

In Site 2, sub-unit 1 (Figure 2.2), most leaks were detected by both methods in number and in mass. The mass of "OGI-only" leaks is comparable to the mass of "Method 21 only" leaks.

3. OGI was able to detect leaks that contribute up to 90% of the total VOC mass emission from accessible equipment in a single campaign. This is comparable to Sniffing, where some leaks are missed (e.g. equipment non-accessible or missing from the LDAR database).

Figure 2.1 above shows that, for Site 1, the quantified mass of OGI leaks is 55% of the total mass of accessible leaks. Figure 2.2 above shows that, for Site 2 sub-unit 1, the mass of OGI leaks is 90% of the total mass, which is in line with an analysis done in 1997 [2] by the American Petroleum Institute. OGI effectiveness is highest when the fugitive emissions from a facility are relatively high: total VOC mass emission in Site 2, sub-unit 1 is 11 times higher than in Site 1 (3.3 kg/h versus 0.3 kg/h for a comparable process and size, as shown in Figure 1.2 above). When the facility has relatively low fugitive emissions, e.g. Site 1, the effectiveness of OGI is lower but comparable to Method 21.

4. In real conditions, the OGI detection limit cannot be defined by one single mass rate. For the Concawe survey at Site 2 sub-unit 2, Campaign 3, OGI detected all leaks above 43 g/h and 80 % of the leaks above 1 g/h (out of all leaks bagged with HFS)

Figure 4 shows all the 3rd campaign bagged leaks in the Concawe survey on a log/log scale. The x axis is the sniffing concentration while the y axis the VOC mass flow, estimated using HFS. For the OGI-only leaks, a sniffing value was recorded after they were detected independently by OGI. Two horizontal lines can be drawn dividing the data into three zones: all the leaks in the top section were detected by OGI (> 43 g/h); most of the leaks in the middle section were also detected by OGI (between 1 and 43 g/h); leaks in the bottom section (below 1 g/h) were difficult, but not impossible under ideal conditions, to detect with OGI.

In the middle section of Figure 4 (referred to as "partial OGI leak detection zone"), there were 90 leaks bagged, with 13.6 g/h average emission rate. 24 leaks were missed by OGI and 11 leaks were missed by sniffing.

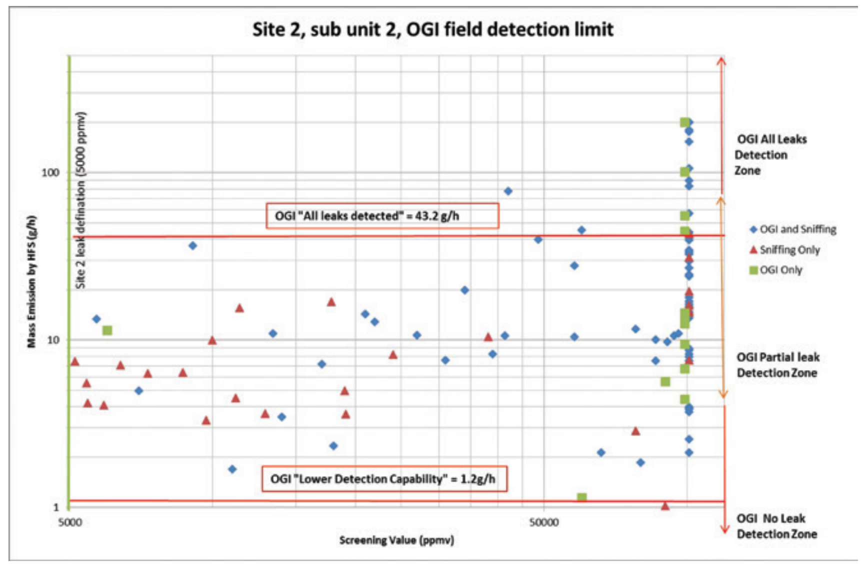

Figure 4. Site 2, sub unit 1: OGI Detection Sensitivity.

Estimation of VOC mass emission when using OGI

For OGI, the plume image only gives qualitative information of the leak size. In 2007, the American Petroleum Institute published leak/no-leak OGI factors [4] that may be used as a basis for estimation of VOC mass emission. These factors are based on a model refinery with a statistically relevant leak population, surveyed by OGI. For modelling the leak behaviour, the same bagging data were used as in Method 21. The emission factors were developed for 4 different specified leak definition of the camera [5].

Based on the observed "average" field detection limit for the new camera model FLIR GF 320, when applied according to the Dutch protocol (regarding distance and survey speed), the leak/no-leak factors for 6 g/h (leak definition) were chosen for use in the analysis of the field measurement data.

Figure 5 shows, for Site 1 and Site 2 sub-unit 1, a comparison of the VOC mass emission (from bagged leaks only) based on the different methodologies: Method 21, HFS and leak/no-leak factors (6 g/h detection limit). The leak/no-leak factors over-estimate of the emissions for Site 1, as does Method 21. They give a reasonable estimate for Site 2. Knowing that the fugitive VOC emissions for Site 1 and Site 2 sub-unit 1 are very different, illustrating the variability that can occur between facilities, the choice of the API leak/no-leak factors for 6 g/h leak definition seems reasonable.

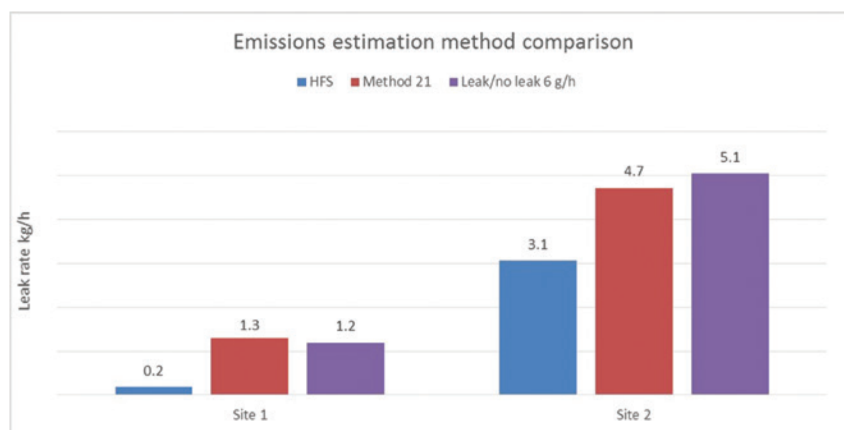

Figure 5: Comparison of the VOC mass emission based on the different methodologies.

Conclusion

The Concawe parallel surveys, based on four large field trials, confirmed that Sniffing and OGI are equally able to detect fugitive VOC emissions and provide comparable control of fugitive emission inventories at refineries. OGI provided a better identification of the leaks with a high mass emission. The OGI detection limit has improved in the last few years: the new camera models are now able to detect leaks of a few g/h with a high probability. The leaks from accessible components not detected by OGI were all small in size and represented a small fraction of the total NMVOC mass emission. OGI has the advantage compared to Sniffing technique of being able to detect non-accessible leaks or leaks from components not listed in the site database. OGI surveys also have the advantage of being much faster than Sniffing. For the OGI surveys using the new camera models at the surveyed refinery sites, the API leak/no-leak factors for 6 g/h leak definition provided a reasonable, although conservatively high, estimate of the VOC mass emissions.

The above findings support the use of OGI as a stand-alone technique for LDAR programmes.

References:

[1] EN15446 : Fugitive and diffuse emissions of common concern to industry sectors – Measurement of fugitive emission of vapours generating from equipment and piping leaks, March 2008.

[2] American Petroleum Institute: Analysis of Refinery Screening Data; API Publication No. 310; Washington, DC, 1997

[3] NTA 8399 (en) Air quality - Guidelines for detection of diffuse VOC emissions with optical gas imaging ICS 13.040.20 October 2013

[4] Lev-On et al : Derivation of new emission factors for quantification of mass emissions when using optical gas imaging for detecting leaks, , JAWMA, volume 57, issue number 9, 1061-1070, September 2007

[5] David Epperson , Miriam Lev-On , Hal Taback , Jeffrey Siegell & Karin Ritter (2007) Equivalent Leak Definitions for Smart LDAR (Leak Detection and Repair) When Using Optical Imaging Technology, Journal of the Air & Waste Management Association, 57:9, 1050-1060, DOI: 10.3155/1047-3289.57.9.1050