

Addressing the Problem of Poor Gas Leak Detection Rates on UK Offshore Platforms

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ABSTRACT

On offshore installations the successful detection of an uncontrolled release of flammable gas is one of the last lines of defence against fire and explosion events. A brief analysis of UK continental shelf (UKCS) offshore hydrocarbon release (OHR) statistics during 1992-2015 shows that an appreciation of performance of *currently installed* gas detection arrangements is of paramount importance, since almost half (48.5%) of the recorded accidental gas releases were apparently not detected by the fixed gas detection systems in place. Detection results for experimental, simulated gas leaks are compared with the offshore statistics finding that the experiments demonstrate ~97% successful detection rate, highlighting the disparity between research and real offshore experience. The experimental simulations are conducted for the traditionally recommended target gas cloud (TGC) detector arrangement at 5 m spacing. We have reasoned that such experimental work is of limited benefit if the same detector approach is not applied offshore. No research has investigated this issue or considered the impact of actual detector layouts upon the detection performance statistics. We have evaluated 27 real offshore gas detector layouts from 18 facilities and found that the TGC approach is present in less than 50% of cases and less than 50% of those achieve typical coverage targets. This is a simple yet important finding previously unaddressed in industry or in literature. In addition, a preliminary review of the statistics demonstrates little or no evidence to corroborate prevailing industry anecdote that low overall detection is due to the high number of small leaks which are not the true target of the detection system. We recommend that detector layouts be submitted by operators during hydrocarbon release reporting so that this missing link in the analysis of the performance of offshore detection can be fundamentally understood, and the issue of detection performance can finally be addressed.

KEYWORDS: Gas detection, hydrocarbon release, target gas cloud, offshore statistics.

INTRODUCTION

On offshore installations the successful detection of an uncontrolled release of flammable gas is one of the last lines of defence against fire and explosion events. Early detection can mitigate a fire or explosion event before it occurs and control actions, initiated automatically or manually following confirmed detection, can be used to trigger emergency shutdown (ESD) before the loss of inventory reaches a critical volume presenting a significant potential for escalation. A range of location, propagation, pressure, orifice size and wind conditions may be modelled and evaluated using appropriate computational models (utilising CFD), however analysis of probable gas dispersion scenarios is not a matured process and essentially no guidance exists for the purpose of defining a standardised, repeatable and industry-wide procedure.

The traditionally adopted *target gas cloud* (TGC) approach has been to limit the undetected gas cloud size of any theoretical leak to a volume which should not create a damaging overpressure if ignited. Knowledge of the performance of this approach with regard to real gas leak events is

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extremely limited. A small body of literature evaluating the performance of a 5 m-TGC arrangement in a simulated offshore module exists [1, 2], however in order to relate the results of those studies to real world performance, the assumption is required that all installations in the UK North Sea have a 5 m-TGC arrangement in place, as per the traditionally adopted guidance. The primary goal of this paper is to evaluate the validity of this critical assumption.

A brief analysis of UK continental shelf (UKCS) offshore hydrocarbon release (OHR) statistics [3, 4] during 1992-2015 shows that the question of performance of *currently installed* gas detection arrangements is essential, since almost half (48.5%) of the recorded accidental gas releases were apparently not detected by the fixed gas detection system. While leaks (minor/significant/major) have decreased over the 22-year period, the detection rate by fixed gas detection has also decreased with time. Significant leaks in 1993 were detected at a rate of ~70% but have averaged ~50% over the last 15 years. Minor leaks have dropped from ~60% in 1993, averaging ~38% over the last 10 years. The number of major leaks is arguably too few to be statistically significant in this sense, yet is still numerous enough to cause concern. The Health & Safety Executive (HSE) in the UK recently publicised their concerns [5] over what was described as “perilous” gas leak trends in recent years. It is common for practitioners to reference a 50-60% gas leak detection rate, [6] for example, however we can find no concerted efforts to explain this low detection success rate in the published literature. Within industry we have consistently witnessed the propagation of typical, anecdotal explanations with no apparent evidence. A common example is that the whole OHR data is skewed by many undetected small leaks which are not in fact the target of a fixed detection system. We have documented a preliminary review of some of the OHR data which possibly could support these claims to see if corresponding evidence can be uncovered.

An evaluation of 27 actual offshore gas detector layouts has been undertaken to determine if the traditional TGC approach is commonly applied offshore as generally assumed. This is critical for two reasons: (1) efforts to address the poor offshore gas detection rate by improving the TGC approach detection rate [2] are only of benefit if this methodology is commonly applied offshore, and (2) any attempt to explain the poor offshore gas detection rate without knowledge of the gas detector layout in each leak case provides no context and an incomplete analysis. These issues have not been addressed in industry or in the literature and are critical to understanding and improving the apparently poor detection rate.

The authors have visited over 40 UK offshore platforms and reviewed detection strategies for over 150 facilities globally. This study was conceived out of the evident disconnect we observed between industry dialogue and gas detection as applied offshore. We aim to shed light on fundamental issues previously unaddressed, provide direction for further critical analysis and conclude with a simple solution for acquiring a large set of actual detector arrangement data to allow the problem of poor gas leak detection in the UKCS to be seriously addressed for the first time.

BACKGROUND: INDUSTRY AND SCIENTIFIC LITERATURE

Origins of the target gas cloud methodology

In 1993 the UK Health & Safety Executive published a report [7] reviewing the results of the available gas explosion behaviour studies of the time, which were mainly conducted throughout the 1980s. The review concluded that a 6-m diameter methane or propane cloud, when ignited by a point source did not achieve flame speeds greater than 100 m/sec (methane) and 125 m/sec (propane). To allow for realistic compromises during design and construction, oil and gas operators who would use this approach opted to specify a ‘design’ detector spacing of 5 m thus adding a factor of safety such that if practitioners slightly relaxed the positioning rule, the 6 m parameter from the experimental work should still be met. The approach of targeting a specific volumetric gas

cloud by installing detectors at a particular spacing was subsequently adopted into several major-operator guidance documents globally. Commonly 5 m is the target, but variations have been adopted depending on the operator and the location across the facility.

Locating gas detectors: industry guidance

Standards and guidance documents provide relatively little information regarding the number and placement locations of gas detectors for offshore facilities affording the engineer a great deal of latitude but simultaneously requiring suitable justification and verification of the final approach. Instead, guidance on calibration and testing and technology type / installation is prominent. A non-exhaustive list of examples includes API 2001 [8], CSA 2001 [9], ISA 2003 [10], ISO 1999 [11], UKOOA 1995 [12], UKOOA 2003 [13] and more generally in PFEER 1995 [14]. The stipulation that detector layout design should be somewhat justified with reference to dispersion/hazard analyses is evident in HSE 2001 [15], IEC 2007 [16] and NORSOK 2008 [17] as well as in some oil operator group practices and company-wide fire and gas philosophy/guidance documents. A cautionary note on boundary condition considerations for dispersion modelling based on real events has been presented [18]. Subsequently, ISA TR84.00.07 [19] describes to an extent, an approach incorporating dispersion analysis data into the gas detector placement study. It is important to understand that the guidance detail provided in operator/oil company philosophies regarding fire and gas detection ranges from specific spacing requirements directly or loosely based upon the findings from [7], to the generic requirement that detector layout should be designed in reference to the relevant project fire/hazard analysis. Overall, the level of design detail provided is inconsistent from company to company. The risk here is that the use of rules of thumb and prescriptive targets is retained whilst a fundamental understanding of the original intent of the selection is not.

It is commonly discussed within industry that, historically, gas detectors were placed based on the experience or intuition of the relevant project engineers. Fire and Gas (F&G) mapping is a study which is used to demonstrate the theoretical performance of a gas (or flame) detection arrangement based against a set of pre-defined performance targets and has become increasingly prominent within the industry. F&G Modelling software programs have remained proprietary in-house tools, however. To this end a few authors [20-24] have published in the scientific literature alternative and theoretical approaches to designing and justifying gas detector layouts for offshore process/production modules generally based on data from a set of dispersion scenarios analysed for each case, which may not be reflective of what standard practice in the industry consisted of.

Risk-based detector layouts using dispersion modelling

Within industry at present, the concept approach for risk-based gas detection derived from analysis of a set of credible gas leak simulations is burgeoning. The detector layout is optimised based upon the presence-probability of detectable gas concentrations following a large number (10^2 - 10^4) of computational leak simulations. Benavides-Serrano et al. [25] represents a rare published work directly comparing the detector requirement of a TGC layout with that of various optimisation approaches to detector placement using a dataset of computational fluid dynamics (CFD) gas leak simulations [26, 27]. The results are compared with a TGC layout of point gas detectors (PGDs). It is clearly demonstrated that the performance of such an arrangement is a function of the number and type of leak scenarios modelled. A decrease in performance was demonstrated when an optimised arrangement based upon a randomly selected 75% of total leak scenarios was then tested against the remaining 25% of simulated leak scenarios. This confidence factor is critical for procedural validation as the notion of designing detector layouts based upon a finite number of leak scenarios becomes more common.

Of great concern, however, is the study's conclusion that the TGC approach performed poorly and in some cases was the worst of all trialed approaches. This can be traced to the use of only PGDs

and the elevation of implementation (12.5 m) of the detector grid. Of great further interest, therefore, would be the repetition of this analysis with a TGC layout positioned at a reasonable elevation within the context of the module and local structures, and in relation to specific hazards. The inclusion of open-path gas detectors (OPGD) in the TGC approach would also be of great interest for practical purposes since (based on major operator guidance) one OPGD *could* replace up to 13 PGDs in an offshore module, potentially providing greater detection coverage while significantly reducing the detector count, unit and cabling requirements as well as installation and long-term maintenance burden.

Literature on TGC performance

Where the 1993 HSE report [7] set a baseline guide, further work [1, 2] was conducted performing a sensitivity analysis of the 5 m-TGC approach to a range of simulated leak scenarios for offshore modules. These papers are of great relevance since they represent rare published literature attempting to evaluate the theoretical performance of the traditionally recommended approach to flammable gas detection. Importantly, the detector layout is in-line with how a TGC layout might typically be designed for a congested offshore module and the results are strongly juxtaposed with those reported by [25].

In Kelsey et al. [1] previous data from a joint-industry-project (JIP) on gas dispersion/concentration in a simulated offshore module was overlaid with a detection arrangement based on 5 m-target within the module, utilising infra-red (IR) PGDs, catalytic PGDs and IR OPGDs. From a range of leak scenarios time to detection was evaluated for each case. The results are discussed in detail in the following section.

Comparison with offshore statistics

The Health & Safety Executive (HSE) in the UK publishes an Offshore Hydrocarbon Releases (OHR) database [3-4] covering approximately the last 22 years (Oct 1992-Dec 2015) of release statistics from UK Continental Shelf (UKCS) facilities. Updated statistics for 2015-2016 have more recently been published [28], however, some of the data-capture categories relating to detection have been amended since the previous data were published so we will focus on the 1992-2015 results [4]. Statistics from 2001-2008 have previously been reviewed [3] using partial and full datasets with general focus on leak frequency for significant and major releases, and to review the use of the dataset to inform quantitative risk assessments (QRAs). Difficulties with linking offshore leak statistics to actual experience of operators is discussed in detail elsewhere [29]. Kelsey et al. [1] produced results which may be compared with the offshore hydrocarbon release statistics [4]. The JIP release data (that [1] is based upon) are biased toward larger release rates (commonly 10 kg/s, to align with the lower-bounding definition of a “major” leak) [3,4], however, the vast majority of releases were detected when the leak size corresponded with the significant category. This makes comparison for individual categories difficult since an offshore leak might be categorised at time of detection or considering total release quantity. Table 1 presents those data for the OHR database [4] and the study by Kelsey et al. [1]. It was demonstrated by Kelsey et al. [1] that the 5 m-TGC layout had an excellent detection rate, detecting on average 97% (of 64 cases) for major and significant releases (all leaks detected by the first detector when the leak size corresponded to significant, with 70% growing to major) compared to 53.8% (of 1409 significant cases) successfully detected from the offshore statistics [4]. 3% of simulated releases were not detected due to (1) a lack of buoyancy following horizontal releases which did not rise to the elevation of the lowest detectors at 3.9 m and (2) smaller releases which did not result in gas clouds of detectable concentrations. This information supports the premise that the TGC results appeared poorer in [25] because of the inappropriate detector placement. Sufficient data to allow direct comparison are not provided in [25]. It is notable from the offshore statistics that detection success rates appear to improve with increasing severity. It seems credible, therefore, that actual detection performance offshore is *to some extent* a function of

the leak mass. However, there are several boundary conditions that have some level of influence, and this is clear since even the largest leaks (major approximately $10^3 - 10^6$ kg) are only detected in ~ 64% of cases. It is critical to note that direct comparison of the simulated data with the offshore statistics also requires the assumption that all offshore installations have utilised a 5 m-TGC detector layout as per the simulations.

Table 1. Gas leak distribution and detection – Offshore statistics [4] vs. simulated [1]

Leak Category Distribution			Leaks Detected		
Type	Offshore stats [4]	Simulated [1] (final release size)	Type	Offshore stats [4]	Simulated [1] (at detection)
Major	5.8% (n = 152)	70% (n = 45)	Major	63.8% (n = 97)	N/A
Significant	53.8% (n = 1409)	30% (n = 19)	Significant	54.6% (n = 770)	97% (62 of 64)
Minor	40.4% (n = 1058)	N/A	Minor	45.5% (n = 482)	N/A
Total	2619	64	Weight Avg	51.5% (n=1349)	97%

This is underlined by Kelsey et al. [2] where the results from [1] are built upon and the potential for improvement of the 5 m-TGC performance is investigated. One possibility attributing to the offshore detection results is that the environmental conditions offshore are typically more severe than in the simulated tests thus reducing detection performance of the offshore systems. It is noted, however, that when gas leaks are quickly diluted and dispersed by weather a reduction in potential for escalation is typically also true. Regardless, an average detection rate of 51.5% by dedicated, fixed gas detection systems in high hazard/high consequence sites is concerning, and a better understanding of causal factors is imperative. It is noted that these low detection rates are often cited in industry literature without any further explanation, and no work appears to have been undertaken to provide context for such statements.

INVESTIGATION OF COMMON INDUSTRY HYPOTHESIS

The following section presents an introductory evaluation on the validity of a common industry hypothesis as to why detection rates are so low. There appears to be no precise evidence of validation of the hypothesis in industry literature or scientific literature. A detailed review is required, however this is outside the main scope of this paper and will be completed in future work. It would be preferable if this hypothesis were true as it would conclude that offshore gas detection is in fact more effective than current statistics suggest. If it cannot, however, clearly be demonstrated to be true, then simply assuming its validity is irresponsible and dangerous and prevents the pursuit of a fundamental understanding of the causes of poor detection performance.

Evaluation of hypothesis

The smaller the leak, in theory, the more difficult it is to detect with fixed detection, and based on this principle it is often cited that the reason the detection statistics are poor is because the data are skewed by many undetected small leaks which are not in fact the target of a fixed detection system. It is true that the philosophy of the TGC approach is to target gas clouds once they reach critical volume (and concentration) and that smaller leaks are not the target. Actual detection data describe a more complex landscape, however. It is true that failure to detect increases as the leak category

diminishes, that is to say major, significant and minor leaks go undetected in 36.2%, 45.4% and 54.4% of cases, respectively. Note that there is only a 10 point difference in detection success for significant and minor leaks. Detection rates between categories are relatively comparable and do not appear, in principle, significant enough to support the skewed data theory. Each gas leak category occurrence accounted for the percentage of gas leaks as follows - sig (53.8%), minor (40.4%) and major (5.8%). Furthermore, undetected significant gas leaks accounted for 50.3% of all undetected gas leaks, where undetected minor gas leaks account for 45.4% of all undetected. Even if we take the minor detection category out of the equation altogether, there still remains an average detection rate for significant and major leaks of 55.5%. This is a small improvement on the 51.5% detection rate for all categories combined. Based on this simple observation, it is clear that the minor detection rate is comparable with the significant detection rate and no evidence of skewing is yet apparent. An in-depth multi-variable analysis of all detection rate causal factors is out with the scope of this paper but we would like to lay the ground work here briefly.

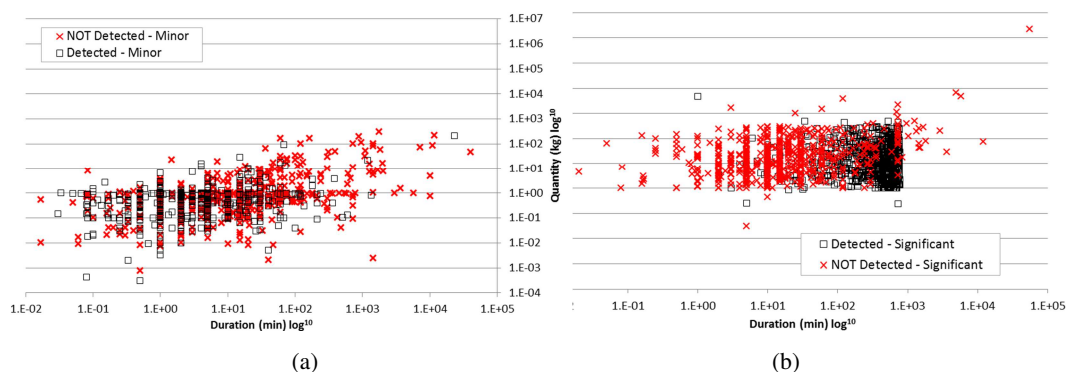


Fig. 1. (Estimated) leak quantity (kg) vs. leak duration (min) for (a) minor leaks and (b) significant leaks.

Exploring the actual data further, Fig. 1 shows the *detected* and *not detected* minor and significant leak data when the (estimated) leak quantity is compared with leak duration. Figure 1(a) demonstrates the general trend, as might be expected, that leak quantity and leak duration are positively correlated. Perhaps counter-intuitively, however, the detected minor cases tend to occupy the lower end of the quantity/duration data (<10 min) meaning that in general the smaller minor leaks tended to be more commonly detected by the gas detection system. By contrast, Fig. 1(b) shows that those detected significant leaks corresponded almost exclusively to leak durations greater than 90 minutes and the vast majority of undetected leaks ranged from 1 to 90 minutes. It is therefore true that smaller significant leaks were overwhelmingly not detected despite commonly lasting for significant periods of time. We note that leak quantity vs. leak pressure and hole diameter data have also been reviewed (but are not presented here) and are oriented more similarly to Fig. 1(b) and do not demonstrate intuitive correlations as seen in Fig. 1(a). Detected and undetected leaks are equally distributed across the range of leak pressures for both minor and significant leaks. Similarly, detected and undetected leaks are also roughly equally distributed across the range of leak orifice diameters for minor leaks. However, for significant leaks larger hole diameter leaks are almost exclusively not detected and smaller hole diameter leaks are almost exclusively detected. The data appear unnatural when plotted. Major leak data are more evenly distributed for all categories described so we suggest that the reporting practices across each category may need to be reviewed for evidence of impact upon global results. The data tell a complex story, which is nuanced by the many variables including human decision-making when reporting on leak event details - the inherent variability of which is unaccounted for in the statistics. Nevertheless, a preliminary review of the broad statistics does not show recognisable evidence in support of the hypothesis. We have also found no evidence to support the hypothesis that *the majority of*

undetected leaks occurs during manned operations and are therefore detected manually before the gas detection system is triggered. This evaluation will be included in a future publication.

ANALYSIS OF ACTUAL OFFSHORE DETECTOR LAYOUT DATA

An analysis of 27 actual offshore gas detector layouts is presented with the intent of determining if the TGC approach is commonly applied offshore as generally assumed, and determine if it is reasonable to consider generally the detector layout to be a constant across facilities or whether significant variation is apparent. The latter implies that the impact of detector layout upon detection rates represents an unknown variable that presents a problem for the analysis of offshore gas leak detection rates.

When undetected gas leaks do occur offshore, rarely are the results of a detailed investigation shared in order that industry knowledge can be improved. Therefore, research that seeks to evaluate a TGC layout with the goal of improving offshore gas detection performance, actually has very little basis in this context. A more fundamental line of questioning might be: What form do typical offshore gas detection arrangements take? What was the basis for their design? And, how do they perform when subjected to real boundary conditions?

Investigation parameters and assumptions

An evaluation of typical gas detector layouts in hydrocarbon processing areas on 18 fixed platforms in the UKCS was carried out in order to attain a sample of real detector layouts. The sample size represents approximately 7.5% of operational UKCS assets, which is statistically small. However, as far as can be discerned no other study with the same goal has been published so far. On that basis alone, the results presented here should be of interest, at the very least, as a starting point for further discussion and research. The parameters and assumptions of the study were as follows:

- Layouts were chosen at random from the available information. A range of major and minor operators were included. F&G detection drawings were typically dated 2008-2014.
- Site information and operator and platform details cannot be disclosed. We feel that the critical lack of knowledge and absence of any similar study far outweighs this limitation to transparency.
- Process / wellbay areas with significant physical congestion (>0.3) were targeted since in such locations the (5 m) TGC approach is recommended by numerous operators.
- *Coverage factor* is a quantified output that states what fraction of the module total area is provided gas detection coverage based on a 5 m-TGC requirement.
- Module total heights were unavailable, and detector elevations were often unavailable, therefore in each case it was assumed that all detectors are located at the same elevation.
- The coverage factor is applicable only to one theoretical 2D plane at any supposed elevation. Had each coverage factor result been based on 3 dimensions, the density figure would most likely always have been lower (less favourable) since process modules and wellbays are normally greater than 5 m in height (deck-to-deck). The results may therefore generally be considered to be on the optimistic side.
- The analysis does not investigate the capacity for the detector layout to achieve voted alarm (two or more detectors simultaneously alarming to the same theoretical gas accumulation, written as *2ooN*), as would be required in an industry mapping analysis.
- Since the coverage factor calculation assumes 1 PGD per 25 m² area, when OPGDs have been utilised, beam length divided by 5 was used to give the PGD equivalency. Where a PGD or OPGD is located at the perimeter of a fire zone, the coverage provided was discounted based on what proportion of the detector theoretical coverage area fell outside the fire zone/ area of

concern. Similarly, the coverage of a PGD located within the 5 m of another PGD was proportionally discounted (i.e., each detector would then not contribute a full 25 m² coverage).

- Coverage factor is given simply by: $\text{Number of PGDs Equiv} / (\text{Total area} / 25)$.

The overarching purpose of the analysis is to surmise whether a TGC or leak detection approach had been taken when placing detectors in each case. This was possible to achieve because the leak approach typically sees detectors being placed *at the location* of potential leak sources only, leaving gaps in coverage between equipment. The coverage factor is important because this is what operators use to judge the *theoretical performance* of a detector layout based on prescriptive TGC rules. A figure of 1.0 means that 100% of the area is covered by the number of detectors present; given the specific location of each detector (based in each case here on a 5 m-target cloud).

Results and discussion

Results are presented in Table 2. Due to size constraints, data for only 14 of the 27 areas are presented for reference. For each of the 18 platforms assessed, layout data for different modules or areas were included where available (27 areas in total) in order to minimise bias for choosing particularly high or low detector density cases. This proved particularly interesting where different process modules of the same platform demonstrated significantly different coverage results (asset 3 for example). This approach highlighted the potential for inconsistency in detector layout across one platform. This variation is explainable since whole-platform F&G detection reviews are not necessarily that common once the platform comes on-line, and quite often one module or a number of targeted areas will be reviewed as new equipment/tie-ins are installed on the platform. Detectors may be added/removed/relocated at such times, requiring that the engineer/designer be aware of the original intent of the existing detector locations.

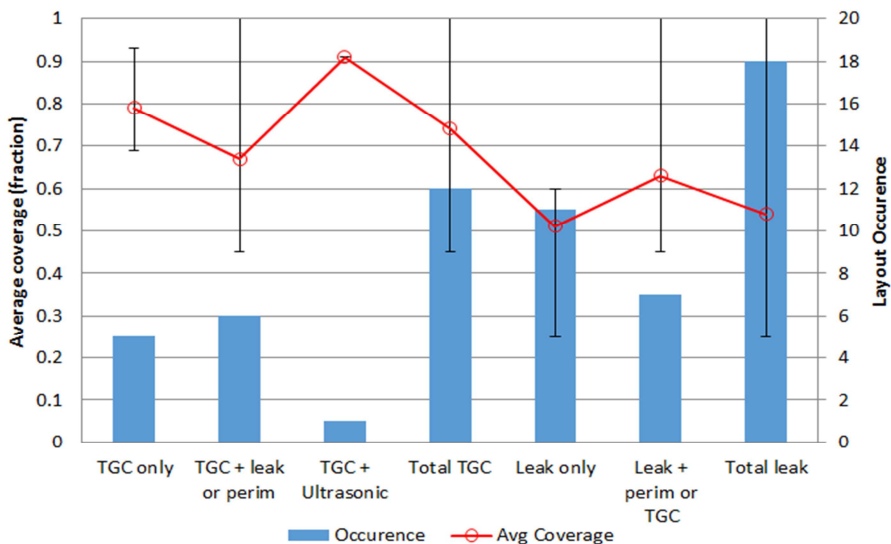


Fig. 2. Breakdown of detection approach occurrence and detection fraction.

Figure 2 demonstrates the frequency of occurrence of each approach considering specifically TGC and leak arrangements, as well as cases where a combination of approaches was identified. A TGC arrangement occurred in 12 of the 27 cases assessed (44.4%) while a leak detection approach was present in 18 cases (66.7%). There was an overlap in 5 cases where TGC and leak approaches are both applied. The average coverage and the range of coverage (error bars) are noted for each detection philosophy combination.

Table 2. Gas detection approach and coverage factors for 1-8 of 18 offshore platforms reviewed

Asset	Area Description	TGC applied?	No. of detectors		Area (m ²)	Coverage factor	Distribution	EL. (m)	Description
			PGD	US					
1	Process: vessels, pipework	No	10		450	0.56	Leak	6.4 / 8.1	Detectors located near some equipment and pipework
2	Process: vessels, pipework	Yes	6	5	660	0.91	TGC / US	2.8	Significant TGC coverage, US detection for additional redundancy
3	Process: vessels, pipework	No	3	2	375	0.47	Leak / Perim	unknown	Leak in selected locations, OPGDs to north end as perimeter, some PGDs at HVAC inlets
	Pumps, gas handling	No	2		200	0.25	Leak	unknown	2 x PGD leak outside crane cabin, further 4 PGDs at 4 HVAC inlets
	Process: vessels, pipework	Yes	4	8.4	280	0.75	TGC / Perim	unknown	Consistent vol between equipment
	Process: vessels	No	4	7	380	0.46	Perim	unknown	2x OPGD used as perimeter to segregate area and 1 vessel boxed in by 2 further OPGD
4	Process: pumps, pipework	Yes	2	12	660	0.45	TGC / leak	3.0	Significant PGD distribution at machine/enclosure air intakes at low elevation in addition (approx 31)
	Process: pumps, pipework	Yes	7	26	1200	0.54	TGC / leak	3.0	Some PGD distribution at equipment air intakes at low elevation in addition (approx 9)
5	Process / pipework	No	5		240	0.52	Leak	Various	PGD's located at selected flanged connections
	Wellbays	Yes	36		1150	0.78	TGC	3.0	Generally consistent vol layout
6	Process: vessels, pipework	No	6		300	0.50	Leak	unknown	1 PGD per vessel and 3 in open space
7	Process: vessels, wellbay	Yes	5	29	900	0.81	TGC	4	Significant volumetric coverage
8	Process: pumps, pipework	No	13		625	0.52	Leak	3	PGDs located at equipment/pumps
	Process pipework, wellbay	No	4	9	500	0.45	Perim	2.5 / 5.0	Perimeter to segregate areas, on average 12m apart

PGD = point gas detector, OPGD = open-path gas detector, US = ultrasonic, EL = elevation, TGC = target gas cloud, perim = perimeter, heavy = low elevation

For the TGC cases only one provided ~100% spatial coverage (appearing in four separate categories). Typically, major operators give a performance target for percentage coverage (for single alarm) of 80-95%, depending upon operator guidance (for *confirmed alarm* the target may be similar or slightly lower). In only five TGC cases was an 80% coverage achieved. Subsequently, it should be remembered that the analyses here assumed all detectors to be located on a single elevation plane and so the coverage factor assessment is for a 2D slice (imagine a plan view).

Oil operators require an assessment in 3 dimensions – taking account of the entire *volume* of each area. For any asset reviewed here, where the deck-to-deck height was greater than 5 m (which is of course quite common), a 3-dimensional analysis would automatically result in poorer coverage factor. Thus, the five cases exceeding the 80% coverage figure here may well fall short of the 80% target in an official, technical 3D mapping review. Coverage factors provided for the leak approaches are purely for context since spatial coverage percentage is not a performance indicator in these instances.

Since the full complexity and nuance of each of the gas detection layouts cannot be fully described in a quantitative manner, a qualitative outline of the results would be beneficial. Certain attributes could be noticed during the analysis, for example, in leak detection cases PGDs were overwhelmingly located *at* potential leak sources (equipment/vessel/pipework-flanged area) and in only one clear case in a large, open space adjacent to the potential source. The number of PGDs placed at equipment in leak cases generally ranged from 1 to 3, and did not particularly correlate with equipment size. When multiple PGDs were located at a piece of equipment, the detectors were typically within ~5 m of each other, suggesting that maximum area coverage based on a target gas cloud size, was not a driving factor when placing detectors to target gas leaks. Furthermore, equipment of several metres in length with only a single gas detector was relatively common, appearing in most leak-approach cases. This suggests that a *PGD-per-item* (checklist style) approach is common when placing detectors rather than an engineering analysis of a range of credible leak scenarios. Subsequently most leak-PGDs were located within approximately one metre of equipment (if *within* the equipment footprint (above) was not possible). This suggests that inventory pressure is not factored into the decision on detector location, since high pressure gas leaks may result in a very thin jet with high initial velocity where dispersion may not occur until leak fluid momentum has diminished sufficiently, some distance from the source.

Only 46% of the TGC cases (5 of 12) provided the coverage factor required by the major operator prescriptive guidance (again, based only on a 2-dimensional analysis). There are of course many factors that contribute to the final detector layout design from an operational point of view, which go beyond the scope of “design philosophy”. There is often a fundamental disconnect between the intent of operator guidance and the extent of what can practically be implemented in terms of detector count - often limited by CAPEX constraints. This arises commonly on brownfield and tie-in projects when a small number of new pieces of equipment are installed into an existing area, which it is later found out not to meet the required performance in terms of coverage factor (where a TGC approach is required by the operator guidance). It is then impossible for the additional hazards introduced by the new equipment to be met with coverage compliance without addressing the existing area as a whole. In our experience, on greenfield projects often when the F&G budget is allocated, long before detailed design is undertaken, the costs required to achieve full F&G compliance with the operator’s own guidance is consistently underestimated. It can be argued that the results found here may reflect such practice.

CONCLUSIONS

The UKCS gas detection layout study showed that strict adherence to the generally-accepted, current, industry best-practice of the 5 m-target gas cloud approach first suggested in 1993 is not

that common across the sample of UK North Sea platforms. The approach was adopted in less than 50% of the cases investigated, and less than half of those met the typical operator performance target for area coverage. Therefore, while theoretical investigations into the performance of the 5 m-spacing detection approach are of worth, they do not address the issue of the poor historical and current detection performance statistics. The first step toward improving offshore gas detection performance is in understanding *why* the current detection rates are so poor. Our introductory analysis of the offshore statistics and UKCS detector arrangement study demonstrate that knowledge of the detector arrangement is a necessary component in truly understanding the leak detection performance. The analysis sheds light upon this critical lack of knowledge within industry, and we hope it will start an important and necessary conversation.

Further, we have found that the offshore statistics reviewed do not appear to support the anecdotal industry hypothesis that the poor detection statistics are skewed by the number of small leaks. Further work is required to evaluate this more thoroughly. Given the potential hazards following uncontrolled offshore gas release, such claims must shoulder the burden of proof. An additional industry hypothesis: *detection appears so low because the majority of undetected leaks occur during manned operations and so the alarm is raised manually before the gas detection system is triggered* has also been given preliminary review and we find it to be unsupported by the data contained in the HSE database. This evaluation will be included in a future publication.

The primary recommendation here is that, when leaks are reported to the HSE, a current F&G detection layout for the area where the leak occurred should be submitted along with the hydrocarbon release data already provided when reporting. All company names should be removed and layouts should be made public along with the HSE OHR statistics report so that, in a short time, a large data set can be acquired, providing dozens and soon, hundreds of real-life case studies. These studies may then be analysed with the goal of identifying and understanding the common failure modes of current industry gas detection arrangements. This understanding is critical for improving life, environment and asset safety offshore given the poor performance of actual gas detection systems over the last 22 years.

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