

# **Taking Ownership of the F&G System while Reducing Cost and Increasing Safety - A Practical Approach to F&G Mapping**

James McNay BSc (Hons) MIFireE CFSP MIET  
Chair of ISA Committee for Fire and Gas

## **INTRODUCTION**

With the increase in prevalence of Fire and Gas detection technology in the Petrochemical Industry, deciding on where to locate these detectors based on the hazard they are intended to mitigate has become far more open to scrutiny. As a result, different methodologies on how to 'map' detector layouts have emerged in the last decade. Fire and Gas Mapping however has been applied by some for over 30 years and is not as new an application as some would suggest.

There are many potential forms in which a fire or gas release can impact on an asset. Certain applications can present the potential for a gas jet/ liquid spray fire where pressures exist in the stream; also a possibility are flash fires/ fireballs, Boiling Liquid Expanding Vapour Explosion (BLEVE) and hydrocarbon/ chemical pool fires. Gas releases can present an explosion hazard in congested areas, a hazard to adjacent areas through migration, as well as providing the potential for toxic gases within any given stream. It is therefore critical that an appropriate methodology and knowledge base is applied to detect the potential fire or gas release at an acceptable stage along the event timeline. The application of available technology must be chosen wisely as each detection technology will respond differently to each potential hazard. The limitations of each technology must be noted and accounted for within the design, and the methodology must be clear enough to allow this. It is all too apparent the potential for disaster present within the industry if inappropriate design of fire or gas detection is applied.

As the process industry moves towards the reduction of the potential for 'fail to danger' in safety related systems (with an increase in the prevalence of IEC 61508 and IEC 61511), it is of great concern that designs of fire and gas detection technologies (whether one feels this can be classed as a Safety Instrumented System [SIS] or not) applied today still provide this potential, and of greater concern, these drawbacks may never be accounted for in design.

In this paper, options available in designing the F&G system shall be evaluated, with particular emphasis on the credibility of design, and optimisation of detection layout, and how 21st century mapping tools can assist. This alludes to a philosophical and practice question; does a completed F&G Mapping model equate to an adequate demonstration of competence and adequacy? This paper will evaluate the current methods of dealing with such a scenario, question whether there are dangers associated with putting too much emphasis on the results of the software applied (and how it's applied) during the mapping stage of the design, and highlight the dangers of not applying validation mapping tools at all.

## **FIRE DETECTION IN PROCESS AREAS**

### **PRACTICAL APPLICATION OF OPTICAL FLAME DETECTION**

In external environments where hydrocarbon hazards exist, the industry standard form of fire detection is typically optical based flame detection. So why use optical based flame detection in these environments? As one can imagine, the open based designs of most oil and gas structures can expose personnel to extremely harsh, unpredictable conditions. For this very reason, it is entirely unacceptable to rely upon standard smoke/ heat detection within one of these highly hazardous areas to detect a fire, even if the detection target is a fire of significant Radiant Heat Output (RHO).

From this we can conclude that a detection technology which can detect a flame before getting to this level is the requirement. This then leads us onto specifying fire sizes which one would aim to detect. As the detection objective is to mitigate the hazard, we must ensure two important factors are met. One is that our target fire size is small enough that it will allow either manual or automatic control actions to be undertaken in a safe and successful manner before the 'potential fire size' is realised, and furthermore that appropriate executive actions are present in the area. For this to happen we must ensure that an accurate fire size is specified both for alarm (where the fire can be dealt with manually), and for control actions (where the fire in the area, and the hazards that area poses, are great enough that we can no longer rely on an operator to activate the protection, before catastrophic consequences are realised).

This brings us to performance based F&G Mapping guidance, such as that within ISA TR84.00.07 [1]. In this document, the guidance regarding optical flame detection is intentionally open ended providing the engineer options. While this is important to be retained, without any over encompassing F&G design specification of minimum requirement, compliance may be achieved with TR84.00.07 but the design may still be inadequate for that particular region/ hazard. It is therefore imperative that the setting of performance targets allows the operator to take ownership of the system, where target fire sizes are determined based on the individual hazards of the facility in question, and the operator expectation of the system. Specialised consultants in this field can provide invaluable experience in this area to assist in this process. It must be noted the TR contains a natural assumption that the guidance is applied by 'competent' F&G professionals<sup>1</sup>.

As the 'grey area' of F&G has been around for decades, some major operators have generated their own in house method of designing F&G, which specifies target fire sizes to be detected (or a variation of this, for example effective viewing distance). In this case, ownership is taken by the design team in tailoring these fire sizes to the areas of the facility which are suited to the targets, therefore allowing optimisation of

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<sup>1</sup> It is important to note that 'competent' is a very difficult quality to demonstrate. Naturally with performance based design, we can see significantly varying degrees of competency, and also cross field competency issues. An example of this is an expert in computational fluid dynamics (CFD) designing a F&G system under TR84.00.07. The individual will no doubt be very competent within the field of CFD, however if that individual has no direct F&G experience, the design may be seriously lacking in several crucial areas. This is an issue experienced in commercial fire engineering and is expertly evaluated by Michael Woodrow, Luke Bisby and Jose L. Torero of Edinburgh University [12] and certainly applies to safety design in the process sector.

the system by placing strict targets in the high risk areas, and less stringent targets in the low risk areas. This is the first route to increase safety and reduce costs through system optimisation.

Weighing up all of these routes to compliance leads to a very ambiguous requirement. The potential for over complication of the more straight forward and well understood areas of F&G design to gain some form of commercial edge from consultants can become prevalent, along with the cover up of lesser understood, more complex principles with an aesthetically pleasing output to distract the reader. This is why it appears crucial to get buy in from the operator early in the performance target selection stage such that the methodology is agreed in advance of receiving an insufficient F&G design which then needs revisited.

In theory designing for compliance with a specified document can be straightforward; however there are a number of underlying issues which can catch out the designer if he/she is not experienced in the field of fire and gas detection. Mapping the area using a 3rd party software while applying no F&G engineering principals, or designing the F&G system by hand with no software assistance, can have very costly consequences (for both business and personnel). One of these issues is that of the effectiveness of the detector – how do we interpret the detector manufacturer when they specify the capabilities of their product, and how do we accurately map this without being overly stringent leading to an expensive design?

It is important not to misinterpret this. The manufacturer of the detector is not misleading the client into the capabilities of the detector. With reference to flame detectors, the detectors have to be capable of detecting the fuels specified within their manuals at the specified distances if they are to achieve certification from an approved body (e.g. Factory Mutual). What the designer must be aware of is the effect the environment will have on these detection characteristics.

The environment in which these optical flame detectors are to be applied can be harsh, variable, and unpredictable to say the least. It is important to note then that there is no difference in the devices which are installed in the frozen wilderness of the Alaskan Prudhoe Bay, to the bleak Saharan desert of Algeria. Occasionally we have sites which experience both extremes, for example the Baku Tbilisi Ceyhan (BTC) pipeline pumping stations, which in some months of the year can resemble a desert environment and, in the winter, can resemble the landscape of the Arctic.

Some environments can experience both extremes. This is evident in the following figures which show a comparison of the Micropack (Engineering) Ltd. dedicated Fire and Gas Detection test ground in summer and winter in Aberdeen, Scotland.

*Figure 1: Micropack (Engineering) Ltd. test ground in summer*



*Figure 2: Micropack (Engineering) Ltd. test ground in winter*



Our everyday environment can give rise to the potential for false alarm, or desensitisation of flame detectors. An obvious example of this would be the largest fire in our solar system, the sun. When a flame detector is designed to detect radiation from a fire, the sun can have an interesting impact on what we achieve from our flame detectors. This is one of the most fundamental issues when relating to flame detection design, and one which must be addressed specifically for the environment the system is going into. If we are looking to optimise costs, we would not want to reduce the detection coverage sensitivity to rain/ fog when the detectors are being placed in enclosed modules for example, but the impact of modulating blackbody radiation may become an issue. Designing using this method can optimise the detection layout and allow the designer to take ownership of the system for that specific facility.

For further information on flame detection technologies see ‘Desensitisation of Optical Flame Detection in Harsh External Environments’ [2].

## FLAME DETECTION PERFORMANCE TARGETS

The base area (e.g. pan size) of a fire is not a good measure of the damage a fire can do. A small propane torch flame, for example, can be much more aggressive than a larger diffusion flame. For this reason, for hydrocarbon risks, we can define a fire hazard by its Radiant Heat Output (RHO) specified in kW. RHO gives a good indication of the potential damage and the probability that it will escalate or cause loss. Some form of variation of RHO is the most common target when looking at flame detection, for example the ‘effective viewing distance’ (often referred to as ‘D’) can be traced back to the RHO methodology.

The typical fire sizes used in design are generally smaller than those associated with escalation, for example one should not design based on the fire sizes stated in a Control of Major Accident Hazards (COMAH) document. This may be the worst case scenario fire size with respect to damage which can be caused, but it is not the worst case scenario fire with respect to detection. If the fire detection system is designed with this large fire size as the target, we can reasonably assume that all fire sizes up to the worst case may not be detected.

*Table 1: Potential Offshore Hydrocarbon Risk Area Grades and associated Fire Sizes*

Grade	Fire Size (RHO) Alarm	Fire Size (RHO) Control Action
High	10kW	10kW
Medium	10kW	50kW
Low	100kW	250kW

It is widely accepted that F&G detection be treated in a case by case basis. Specifying target percentage coverage can be difficult and misleading as there are a significant number of unpredictable elements in the design. An example of this is the fact one area with 70% coverage from the detection system can actually have more appropriate coverage than an area with 90% coverage, dependent upon the specifics of that area (e.g. what the hazards are and where the blockages are located). This therefore emphasises the fact that in order to take ownership of the design, each area must be reviewed by an engineer who takes ownership of the layout to determine adequacy or otherwise. While auto optimisation of a layout through a piece of software can be useful as a first pass assessment, the ability to assess multiple fire sizes (as above) in the same assessment, which is then reviewed by an engineer is far more important in confirming adequacy.

## FLAME DETECTOR MAPPING

In order to ensure a facility is adequately covered based upon the hazards and the associated risk, the area can be mapped to ensure the given target fire sizes are adequately detectable.

Flame detection mapping software, including HazMap3D [3]<sup>2</sup>, provides a percentage coverage of each analysed area, and is a useful tool in providing an optimised layout based on multiple fire sizes within a single assessment. This tool can therefore allow the designer to reduce CAPEX costs through system optimisation, while allowing the operator and designers to take ownership of the design through the risk based approach. Only through analysing multiple fire sizes in the same assessment to provide a holistic approach can the system be truly optimised.

The following figures show a simple example Flame Detection Assessment.

*Figure 3:3D Micropack Test Ground*



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<sup>2</sup> Note HazMap3D is used as an illustrative example due to ease of access by the author and prominence within the petrochemical industry.



*Figure 4:3D Assessment Micropack Test Ground*

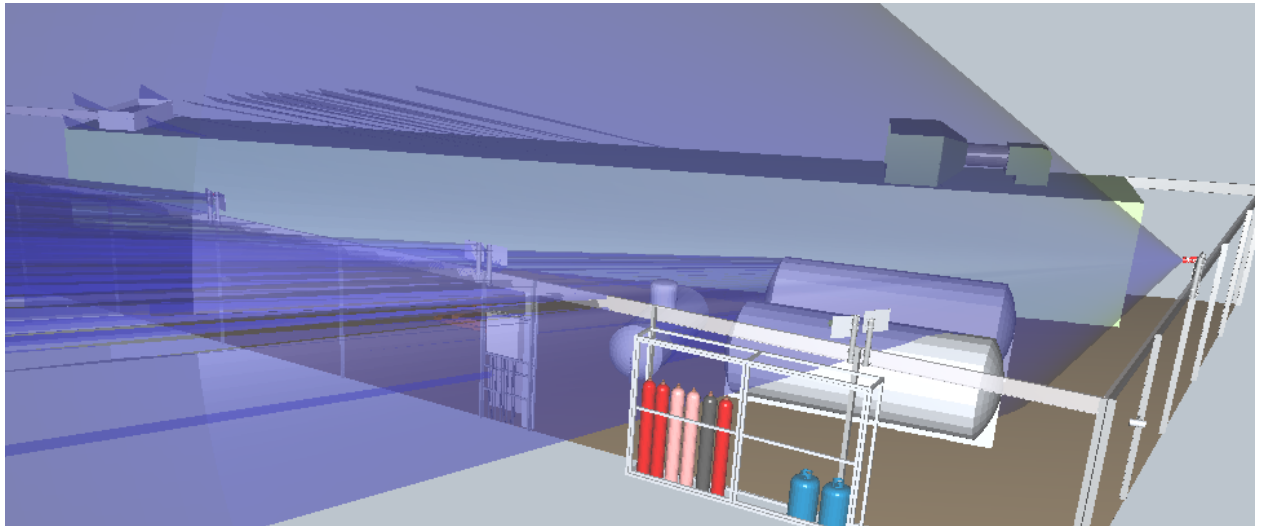
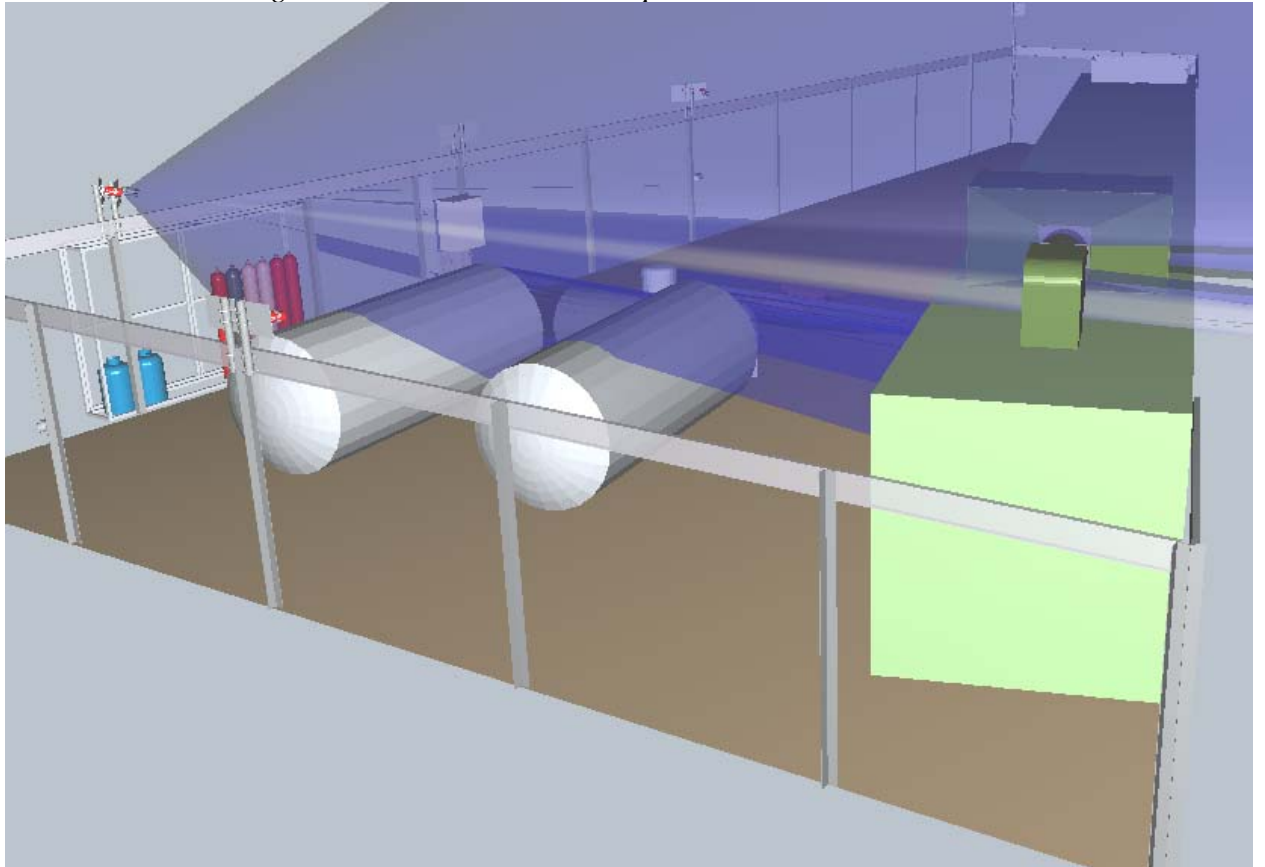
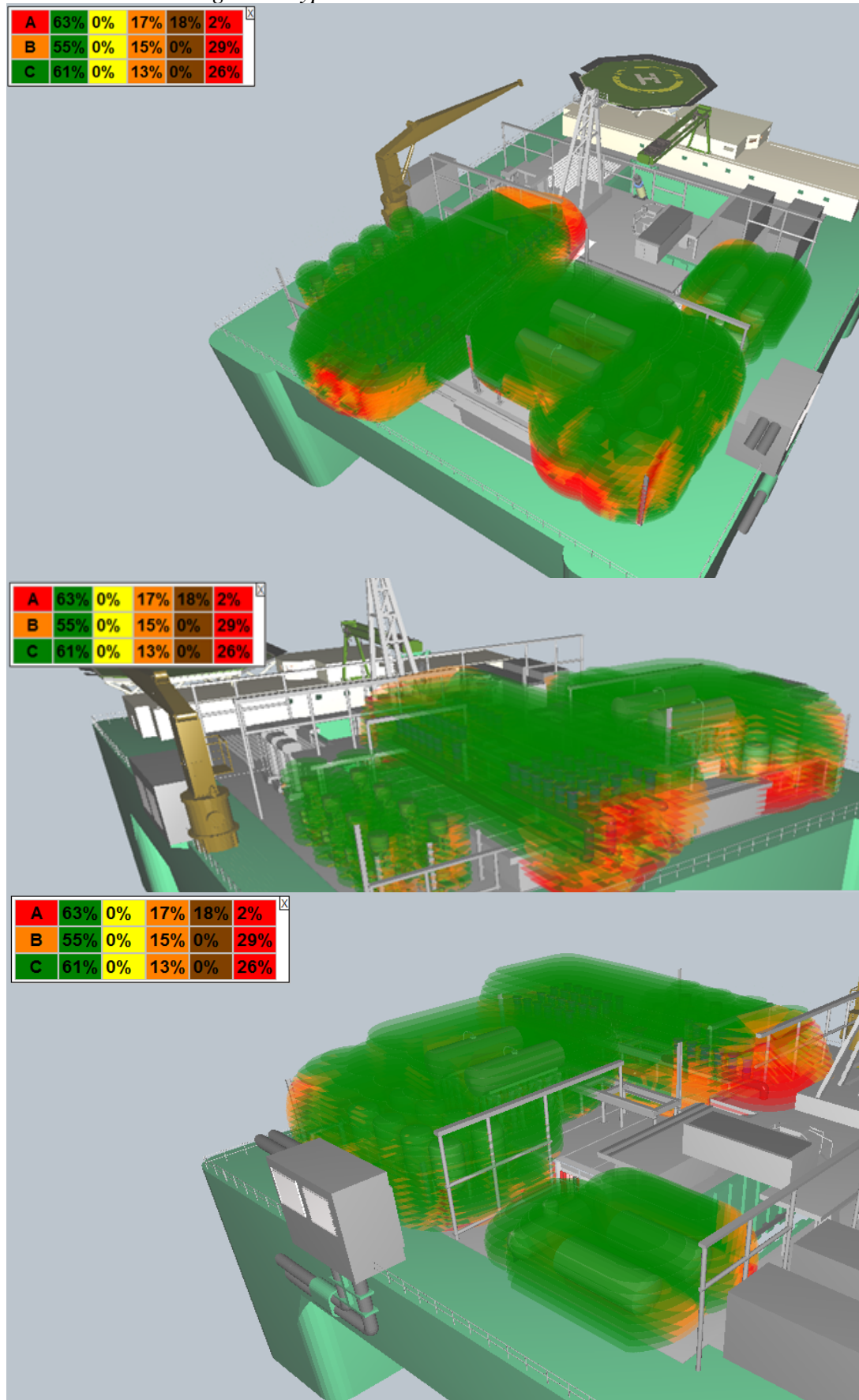


Figure 5: Typical 3D Flame Detection Assessment





It is crucial to ensure the software tool being applied will comply with the basis of design (i.e. operator specific engineering technical practice if available). The science behind fire dynamics and gas cloud behaviour/ fluid dynamics is complex in nature, but does not appear to carry the same weight as other engineering disciplines. If one were to design a structure for an offshore jacket, a competent structural engineer would be approached. That group would then apply any software tools which would have been developed alongside other competent structural groups and validated to ensure adequacy. Why therefore should the design of a safety system for the mitigation of the phenomena of flame spread and gas accumulation be carried out by anyone other than a qualified and experienced fire safety professional? It is therefore of pivotal importance that if a tool is to be used in the design of a F&G system, the tool itself must be designed by those with extensive experience in the field of fire and gas detection.

This also highlights the requirement for those applying the software tool to demonstrate an adequate level of competence, as would be the case in most other professional industries.

## **FLAMMABLE GAS DETECTION: HAZARDOUS AREAS**

### **PRACTICAL APPLICATION OF FLAMMABLE GAS DETECTORS**

The main point to note regarding flammable gas detection is that it is virtually impossible to detect all leaks. It is also important to note that the fundamental principle of process area gas detection is not to detect leaks, but to detect clouds. It is therefore imperative that only those clouds which would be of concern become the target. In the past, locating flammable gas detection next to the leak source was commonplace, however it soon became apparent that even when the slightest increase in pressure is present, locating detectors close to those leak points becomes detrimental to detection reliability, and alternative measures must be sought.

### **GAS DETECTION PERFORMANCE TARGETS**

After the Piper Alpha accident in 1988, it became apparent that there was a significant body of academic knowledge relating to the behaviour of hydrocarbon gas 'explosions' in congested process plant, however this was kept mainly within academia and the information was not shared to those practicing fire and gas review work in the North Sea.

In order to change this, UK HSE conducted a literature review and released the guidance design document OTO 93 002 [4].

The aim of a flammable gas detection system is to detect the presence of flammable gas accumulations which are of sufficient size that, if ideally ignited, could cause damage through the effects of explosion. One of the primary methodologies adopted for detecting gas release is through application of a target gas cloud size. The size of gas accumulation requiring detection is usually based on the volume of the area and the levels of confinement and congestion throughout. This approach is essentially drawn from the UK HSE publication OTO 93-002 which presents data on the overpressures associated with a range of ignited gas accumulations. In summary the

report concludes that a 6 metre cloud of stoichiometrically mixed methane will not, if ignited efficiently in an area with a blockage ratio of 0.3 – 0.4, produce flame speeds greater than 100m/sec or 125m/sec respectively. These flame speeds are associated with overpressures of less than 150mBar, a widely accepted minimum threshold for pressure-induced damage. Increased congestion or blockage ratios in an area are likely to decrease the cloud size required to achieve a damaging overpressure.

This approach has more recently been reviewed by the Institute of Chemical Engineers (IChemE) [5] in light of the more sophisticated methods of reviewing gas cloud behaviour, and as such has generally been accepted by most operators, who now adopt a spacing philosophy behind their gas detection design. These two methodologies (spacing vs target gas cloud) are not to be confused as using the same design criteria, however, as is often the case.

In conclusion to this form of performance target, this method has been applied in many sites worldwide, and is generally accepted by certifying and legislative bodies as an acceptable level of gas detection design.

The target gas cloud methodology provides a robust design principal, but further review is required. Also missing from the review were such areas of a significantly higher degree of congestion where explosion overpressures can be achieved from clouds smaller than 5m in diameter. Methods such as using Computational Fluid Dynamics (CFD) tools to analyse the effects of blockage and the subsequent potential for explosion overpressure for specific sites may have a place within practicing gas detection design specialists, but a robust guidance on how to do this appropriately is yet to be produced.

#### **VOLUMETRIC VS SCENARIO MODELLING - DOES TR84.00.07/ CURRENT LITERATURE DO ENOUGH TO OBJECTIVELY DIFFERENTIATE BETWEEN THESE METHODS?**

All computational modelling of a physical environment and events requires a compromise between accuracy, usability and more recently, aesthetics.

The spherical gas cloud model is very simple to specify and use. Those who do not fully understand the method and its application, however, can presume it will produce pessimistic assessments of a gas detection system's performance, and therefore assume it will result in some very onerous requirements of the system. When this method is fully understood and applied (depending upon the application), an engineered and optimised approach can be achieved which has been proven to reduce detector numbers from a scenario based approach, while providing a much safer system in the protection against explosive overpressures upon ignition of gas clouds.

It is true that if a scenario based approach is taken, and a limited number of representative scenarios are run (even up to 500,000 scenarios could still be classed as limited), this approach can show that detector numbers can be removed, but what is failed to be specified is how many scenarios can be claimed to be sufficient. To an extreme extent, if one scenario is run, then detection can be placed where the leak is 'likely' to travel. This is obviously not acceptable, but the detector numbers would be significantly reduced. Does this automatically mean that scenario based mapping will

allow detector numbers to be optimised in most/ all cases? The argument appears at the point of how many scenarios we claim to be a sufficient number. For most open based facilities, if an acceptable number of scenarios are run, the user will generally find that the gas can accumulate at any point, and a volumetric approach should be taken anyway, leading the designer to ask why, in such a standard application, one would use the time and money in applying a scenario based analysis?

This is not to say the scenario based approach has no place in gas detection design, it most certainly does. It is widely accepted by academics involved in the practice of gas detector placement, however, that this method should be reserved for specialised cases such as turbine/ internal enclosures, where the environmental conditions at the time of release can be far more accurately programmed. For further reading on this see Evaluation of Computational Fluid Dynamics vs Target Gas Cloud for Indoor Gas Detection Design [6].

Bringing the discussion back to demonstrating compliance while optimising the system, there is very little discussion on these issues, such that the designer can be fully aware of which method to apply in any given application. When we also look at what little literature is available on the subject, it is clear that little has been written by those conversant with the application of gas detection technologies in the process industries, as much of the comparisons are heavily weighted towards tests favourable to the scenario based method. Benavides-Serrano, for example, 2015 [7] analyses the detection response to specific scenario based leaks, rather than clouds which would actually be required to result in control action. This shows that these comparisons often lack credibility by comparing apples to oranges. Much of the literature available, also incorrectly reflects a suitable volumetric gas detection design. Instead the analysis applies a 5m grid of point gas detectors, which results in a number of detectors no performance based volumetric detection design should result in. The issue here is that in comparing the two methodologies to examine which methodology optimises the system more effectively, the volumetric approach is automatically at a disadvantage as it is unfairly represented in the majority of the literature by not applying performance based principals, or the detection technologies available in the market today, which can optimise the detection layouts.

This can ultimately result in the designer opting to apply a methodology not suited to their application, resulting in a significantly extended review period (such as when using scenario based gas mapping in a standard onshore process terminal), and a greater number of detectors than would be required when applying a performance based target gas cloud approach.

## **OPTIMISATION THROUGH VOLUMETRIC COVERAGE**

We often see comparative analysis of the target gas cloud method vs scenario based/ CFD analysis which grossly misrepresents a performance based geographical approach. An example of this is in 'Performance Based Gas Detection: Geographic Vs Scenario Based Approaches using CFD' [8] whereby an area is specified a target 5m diameter cloud size, with only point gas detectors applied. This results in a detection layout that no adequate performance based geographical approach would recommend. This layout can be optimised by applying widely available gas detection technologies not addressed in the paper, and a performance based approach to the

target cloud can also be applied (i.e. not simply applying 5m as the cloud size, but determining what cloud presents the explosion overpressure within the area).

Other misrepresentation of this methodology include 'Performance-Based Gas Detection System Design Using Computational Fluid Dynamics (CFD) Modeling of Gas Dispersion' [9], and 'A Quantitative Assessment on the Placement Practices of Gas Detectors' [7]. These papers both fall under the issue of misunderstanding the basis of the OTO objective. Within Reference 9, the conclusion based on geographic coverage results in a large number of point gas detectors. The scenario based approach results in a small reduction of point detectors. The issue is that a performance based, geographical approach, would apply a maximum of 4 OPGDs to this area, potentially only 3. This is approximately 10% of the total number of detector initially used to demonstrate geographical mapping. This also represents coverage even before optimising the target gas cloud size.

It is noted that some in the petrochemical industry are moving towards a scenario based approach with the intention of reducing the overall detector counts, however this example shows that in fact an even further optimised design can be achieved using geographic based coverage, while also providing an auditable system that will not have a significantly different detection layout depending upon who has carried out the analysis. The potential variance of designs can be seen in 'The Benefits of Using CFD for Designing Gas Detection Systems' [10], when wildly different detection layouts are analysed based on the scenario based approach.

While some may apply scenario based design with the aim of reducing detector numbers, others claim this can improve the detection performance over the geographic design. There appears to be no baseline from which to measure this against, and again there is a flaw in the data set used in this analysis. There is an inherent assumption in this argument that the recommendations of the OTO were actually applied in industry.

Taking a walk across the vast majority of offshore installations or congested onshore petrochemical facilities will very quickly highlight that the majority of sites barely took note of the OTO recommendation, and as such gas detectors are still located at locations where gas will 'likely' migrate. Therefore the argument that there are still a significant number of undetected releases despite the OTO recommendations, is not an adequate critique of the suitability of the methodology as, for the most part, it is simply not followed. An interesting area of future research would be the analysis of significant undetected gas releases on sites which follow the target gas cloud principle vs. those where the detection configuration was based on likely gas migration.

Benavides-Serrano, 2015, represents a rare published work directly comparing the accepted industry approach of volumetric with other approaches. Multiple comparative approaches for locating gas detectors were evaluated:

1. Random placement of detectors
2. Volumetric approach (5m-target)
3. An optimised leak detection approach (optimising by distance to leak source)
4. Two scenario-based approaches (accounting for a range of dispersion simulation data)

5. A stochastic programming formulation – accounting for a range of dispersion simulation data and utilising a numerical optimisation procedure (including detector availability/voting variables).

The paper demonstrates the potential improvement in terms of detector numbers and time-to-detection possible with such advanced probability and optimisation sub-models. It is simultaneously demonstrated that the performance of such detection arrangements is a function of the scope of leak scenarios modelled where a decrease in performance was recorded when a detector arrangement based upon a randomly selected 75% of total leak scenarios was then tested against the remaining 25% of simulated leak scenarios.

Of great concern however is the result that the volumetric approach performed poorly and in some cases was the worst, of all trialled approaches. On closer inspection however this analysis appears again to be fundamentally flawed in its analysis of this method.

The surprisingly low detection rate of the volumetric approach may be traced to, not only a validation method weighted towards leak detection methodologies (not cloud detection like the geographical approach), but also the elevation of implementation of the 5m grid within the simulations. For the volumetric approach detectors were located at the ceiling elevation in modules between 7m and 12.5m in height. In practice, a volumetric gas detector layout would be poorly designed if it were generically located at 12.5m elevation in a typical process module due to the reliance on transport of the gas to such an elevation due to natural buoyancy or momentum from a pressurised leak. For buoyant-in-air leaks typical industry practice would be to locate a layer of detectors a few metres (depending upon local conditions) above the main potential leak point elevation, adding further detectors above if the specific local hazards are deemed to require it. Previous research also shows that the molecular weight of the material release has little bearing on the behaviour of the gas, and that the conditions of release are the primary driver of such an incident (JIP 2000 [11]).

Subsequently only point gas detectors are considered so the potential cost-saving and performance-enhancing benefits of open-path gas detectors (OPGDs) are not included in this study, along with applying a performance based approach that perhaps the 5m grid is too stringent and in this particular occasion perhaps a larger diameter gas cloud, with dilute factor accommodated, may be more appropriate. It is therefore highly conceivable that when applying good engineering practice with understanding of the principals behind its application, the 25 point detectors represented in the analysis could be reduced down to 5 detectors (as a maximum), with a vastly improved detection performance through appropriate detector positioning.

Of great further interest would be the repetition of this analysis with a volumetric layout positioned at a reasonable elevation within the context of the module and local structures, and in relation to specific hazards. Visualisation of the proprietary modules and details of the location and elevation of the most successful optimised layouts, along with a breakdown of locations/directions/pressure range of simulated leaks would complement this work and give beneficial further context to the reader.



Also worth noting is that the comparison of scenario based gas detector placement with the volumetric approach. This could be analysed as comparing apples to oranges due to the fact the volumetric approach is design to detect clouds large enough to present an explosion hazard (as is the intention of gas detection application). The application of scenario based modelling is to detect leaks through analysing the predicted fields of movement of a selection of release scenarios. This scenario based approach could be argued to result in excessive detector numbers in the areas where the leak is likely to propagate, with significant gaps in areas where explosive overpressures could credibly accumulate, which have not been examined in that particular group of scenarios.

This form of analysis has not yet been carried out by any comparative research of the current gas detection methodologies i.e. analyse the effectiveness of a scenario based gas detection design to detect clouds across the facility which would result in an explosion overpressure. It is evident that when the validation is being carried out to compare the two methodologies, validation of the system as a gas leak detection system is often applied, which is ultimately favourable to the scenario based method, and isn't applicable in analysing the performance of the system as intended. This is, however, only true when looking at flammable gas detection in open based petrochemical applications. For specialised areas, or where the hazard permits, the application of a gas leak system may be more appropriate, whereby validation of the design techniques may want to analyse how successful the system is as a leak detection system.

## **GAS DETECTOR MAPPING**

The gas detection assessment software would typically provide a three dimensional assessment of the volume under review and present the coverage data in elevation 'slices'. The gas hazard as described in OTO 93 002 was represented in the initial programs by a 5m diameter 'hard-edged' sphere of stoichiometric gas/air mix (to this day this is still commonly applied by operators in the petrochemical industry). It was recognised from the outset that such sharp transitions from gas to fresh air were clearly unrealistic (except in some special cases involving very low pressure, cold and 'heavy' vapours). In the absence of any data, however, which could realistically be classed as practical, there was no alternative and this conservative approach has been used extensively to assess the adequacy of flammable gas detection arrangements.

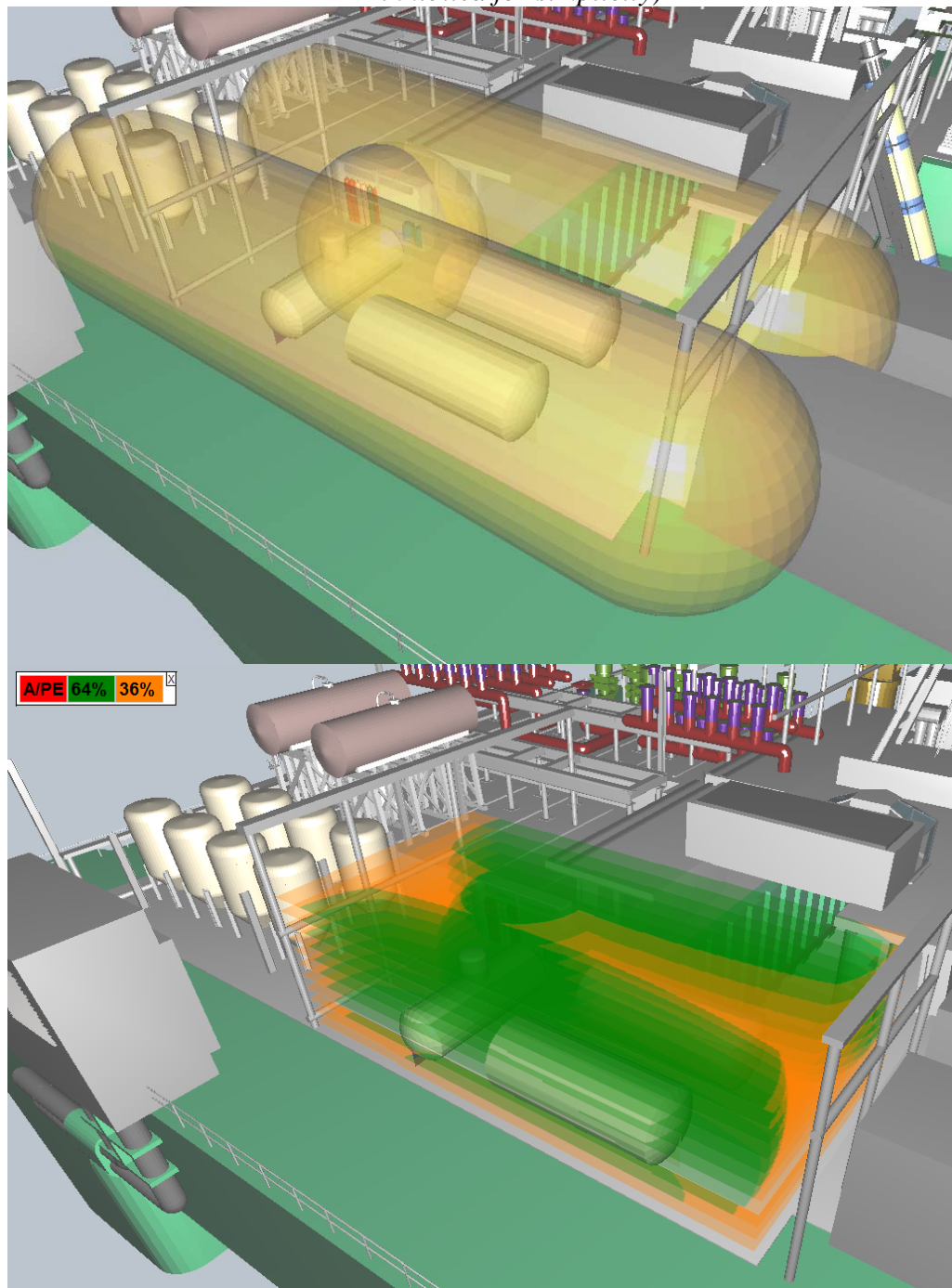
As one of many projects initiated in the aftermath of the Piper Alpha accident, a Joint Industry Project was conducted in order to establish the 'true' behaviour of flammable gas releases in confined process areas. Part of the data gathered during these tests included behaviour of the initial gas cloud measured by a local three dimensional array of gas detectors.

When this was reviewed, this showed (unsurprisingly) that the 'core' of flammable gas was surrounded by a diffuse layer, the concentration of which fell as the distance increased from the source concentration (nominally 200% LEL) to a final value of 0% gas in air.

Further study confirmed that it was reasonable (indeed conservative) to assume that the idealized hard sphere was surrounded by a shell of gas of no less than 20% LFL at a distance of 5m from the edge of the central dense cloud. This was then used to

improve the performance of (particularly open path) gas detection systems. This approach – the assumption of a diffuse cloud of dilute gas surrounding the core hazard - was incorporated into some but not all F&G Mapping software, and must be something to consider when selecting an adequate mapping package. The ability to simply map a hard edged sphere of a specified diameter is not adequate in representing geographic gas detection coverage.

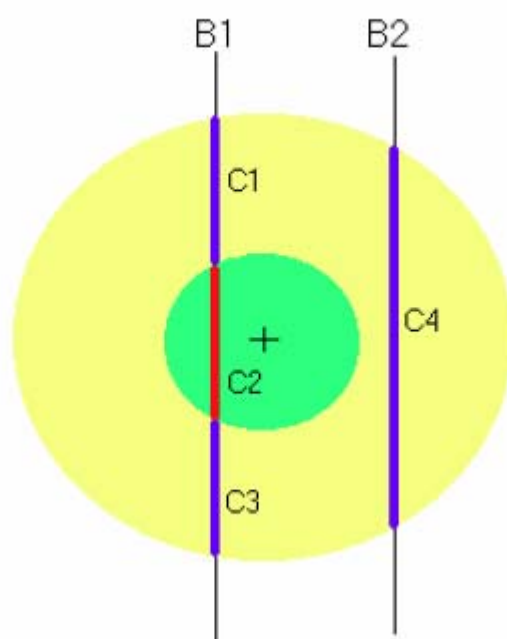
*Figure 6: Typical Simple 3D Gas Detection Assessment (Beam Attenuation model inhibited for simplicity)*



One significant issue relating to gas detection mapping is the regular inaccuracy in mapping of open path detection systems. In order to accurately map the coverage of these devices, one must understand the detection principles of the technology.

Where the geographic cloud method is selected, we often see open paths showing a simple cylinder of coverage (i.e. a 5m diameter cylinder). This is wholly inaccurate of the detection capability of this technology. This method of coverage is suitable for point gas detectors where the target gas cloud will intersect with the point device, providing a gas reading for that point. For an open path device, however, there must be a given concentration of gas across a certain length of that beam in order to result in detection (this is why open paths are set at LELm rather than %LEL). This can be seen in the previous assessment in Figure 6, as the 5m sphere of the open path detectors does not automatically mean there will be coverage at that point. We require 60%LEL to be present across at least 5m of the beam before it will register Hi alarm (where the set point is 3LELm), therefore we cannot get executive action capability in the first and last 2.5m of the Open Path detectors. This is crucial in accurately representing coverage of these devices and is further represented in Figure 7.

*Figure 7: Beam Attenuation Principles (Beam detectors B1 and 2 with different readings provided by concentrations C1-4)*



This is of particular concern when, at the time of writing, the author is only aware of one tool, commercially available in the market, which has the capability of representing gas detection coverage in this way [3].

## CONCLUSIONS

One of the most important factors in the review of F&G systems is to ensure that the implementation of an appropriate methodology based on the application is addressed. Applying a suitable methodology combined with an adequate detection technology has been proven to reduce costs of the system significantly.

Many operators have their own guidance documents with respect to F&G Mapping, and where these are specified it is important to not only comply with these, but also to have an appreciation of the practical implications of the design, which may not be explicitly reference within the guidance document. These practical aspects (such as multiple target fire sizes in one assessment and beam attenuation of open path gas detectors) must be accounted for within the mapping software, and can also result in an optimised F&G detection layout.

Many operators, and some consultants, are hesitant to take ownership of the F&G system design, and when the discussion points within this paper are not certain to be addressed within the F&G Mapping who could blame them. This is why it is crucial for the designers applying F&G Mapping tools, first of all to be aware of these issues affecting detection application, and secondly ensure that these factors are accounted for within the mapping software applied.

Guidance, such as that with ISA TR84.00.07, provides the appropriate starting point of a design basis and often allows the user to apply differing methodologies. This may, however, give rise to those not familiar with F&G design applying an inappropriate methodology based on, for example, a simplified version of mapping which is more easily comprehended but may not be appropriate in the given circumstance.

It is also clear that where any comparative studies have been carried out reviewing geographic vs scenario based coverage, these typically do not adequately represent a well-designed performance based geographic approach, particularly with respect to gas detection design. Such studies will advise that when using volumetric detection, a point gas detector is the only available technology and that a detector will be required every 5m, on a grid based layout. This is either through a lack of understanding of the purpose of the methodology and how it can be used to optimise the system (and also a misunderstanding of what gas detection is intended to do), or worse, it is a misrepresentation of the target gas cloud methodology to misrepresent the optimisation potential of a scenario based approach.

Whichever methodology is applied, it is crucial that parties involved on both sides of the project (designers and implementers) are happy with the methodology at kick off, are fully aware of the strengths and limitations of the selected methodology, and work together to ensure the resulting design is appropriate for the specific application. This way, ownership of the F&G design can be taken, while both parties can discuss the potential to optimise the layout at a very early stage, making significant cost savings further down the line.

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