APPLICATION OF FIRE & GAS MAPPING TO OFFSHORE WELLHEAD PLATFORMS

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Introduction

Wellhead platforms (sometimes referred to as towers) serve as the topside termination point of casing and tubing strings. Casing and tubing strings are the main parts of the well construction, these must be constructed of materials of sufficient strength and functionally so they are fit for the purpose of oil/gas recovery or injection techniques. The wellheads control pressure and provide access to these main parts of the well construction. This pressure-controlled access allows drilling and completion activities to occur safely with minimal risk to the surrounding environment. Offshore wellhead systems are normally more sophisticated in design to offer endurance against ocean currents, bending loads, and other loads induced by the environment during the life of the well.

A typical wellhead platform in the current climate may have had some modifications since as built to provide effective drainage of their reservoir area, this could be achieved through water/gas injection or other recovery techniques to achieve sufficient flow rates. These ultimately have the aim of reducing costs and increasing recovery rates. Each of these techniques and associated amended plant present special safety concerns which must be addressed.

The potential volume of hazardous material, leading up to the termination point of the wellheads, presents a significant fire hazard comparable to those found on similar sites both on and offshore e.g.: production platforms/onshore terminals. The process of extracting oil/gas can present gases at very high pressure, which if released would present significant potential for explosion due to the often congested nature of these facilities. Therefore, it is essential that appropriate safety systems are in place to mitigate potentially catastrophic events.

Oil/gas obtained from the reservoir via the wells is transported elsewhere to be processed, stored, offloaded and distributed. This can be done utilising floating production storage and offloading vessels (FPSOs) which are connected to the wellhead platform by flow lines (These facilities are covered in corresponding application notes and can be found on the Micropack website – Reference 1).

The objective of this note is to highlight the considerations during the fire and gas mapping process, strictly in reference to the above application, using Micropack's HazMap3D as a tool.

Events

There have been various incidents involving wellhead platform leaks and fires, the following are a handful of examples highlighting the severity of the consequences should an event be allowed to develop.

Australia 2009 – Montara Blowout

The Montara oil field is situated off the northern coast of Western Australia in the Timor Sea. The leak and subsequent spill is considered one of Australia's worst oil disasters. The spill made it to the sea following a blowout from the Montara wellhead platform on 21st August 2009, and continued for a total of 74 days until 3rd November 2009. On 1st November, during an attempt to stop the leak, a fire broke out on the Montara wellhead Platform and deck of neighbouring West Atlas drilling rig. Eventually the leak was stopped by pumping mud into the well, cementing the wellbore thus capping the blowout. The fire was extinguished once the leak ceased.

Sixty-nine workers on the rig were safely evacuated with no injuries or fatalities (Reference 2).

The Australian Department of Resources, Energy and Tourism estimated that the Montara oil leak could be as high as 2,000 barrels (320 m^3)/day (Reference 3).

North Sea 2012 – Elgin Platform Ruptured Well

The Elgin Platform is situated off the east coast of Scotland in the North Sea. All 238 staff were evacuated from the Elgin platform and Rowan Viking jack-up drilling rig after gas began spewing into the atmosphere from a ruptured well on the platform in March 2012. Seven men working closest to the leak on the wellhead platform were the first to notice the release.

A plan was devised to kill the well due to its degraded condition in the weeks leading up to the incident. The operation was initially deemed a success, however well pressures increased rapidly and began behaving erratically. A sudden uncontrolled release of gas erupted from the ruptured well releasing high pressure, flammable gas and condensate on to the wellhead platform, immediately endangering the lives of those seven men on the platform. The seven men safely evacuated from the wellhead platform and mustered in the Elgin PUQ. Within the first few minutes, an estimated three to four tonnes of high pressure gas and condensate leaked into the air. The sudden uncontrolled release had the potential to result in a major fire and explosion. It was eventually brought under control after 51 days (Reference 4).

A number of incidents associated with onshore wellheads have also been documented, this application note will not outline these in detail. Oil/gas well fires can be as a result of natural events (lightning) or human actions (accidental or purposeful; arson). These can exist on various scales from an oil spill pool fire to an ignited high pressure well jet fire. A reoccurring cause of well fires is a blowout which can occur during drilling operations. Onshore F&G guidance and regulations can be less stringent than offshore due to the personnel's ability to, in theory, evacuate to a safe distance.

The prevailing point should be that due to the vast quantities of flammable materials at pressure, wellheads and their associated plant/platforms require an effective method of detection/mitigation to ensure minimal interruption to normal operations as well as protection for personnel and plant.

Fundamentals

The fundamentals of preforming an effective F&G detection review study include the following sub headings. These integral parts of the design will not be detailed at length in this note, just touched on briefly, the reader is encouraged to get in touch to discuss.

- *Assigning Performance Criteria/ Targets*

This is an essential prerequisite of the mapping stage as the mapping results are based primarily on these requirements. These requirements are the desired level of performance from the F&G detection system aimed at meeting personnel and asset protection requirements.

The Performance Target definition procedures used at Micropack are based on an approach that has been used successfully on many hydrocarbon production installations, by many different operators, throughout the world, and can also be found in operator standards. The reader should be aware that there is a difference between Performance Criteria/Targets & Standards.

Performance <u>standards</u> are guidelines which are set out by the operator and are not specific to individual equipment or areas. They outline general requirements (i.e. a level of performance) any system has to achieve and form the basis for compiling detailed performance targets.

Performance <u>targets</u> are used to gauge system performance in detecting and mitigating hazardous events. They are the level to which a system is required to perform and are area/ equipment specific.

In relation to defining performance targets, the credibility of hazardous scenarios may be inferred with reference to the project Fire Safety Assessment.

- *Selecting Appropriate Detection Technology*

Due to the typically challenging environment often encountered in such locations that wellhead platforms would be in, such as stormy seas (as well as other typical oil and gas applications worldwide) the selection of appropriate detection technology is essential to an effective design. Gas detection for example must consider fog, sand/dirt etc. Flame detection is even more pertinent as factors such as rain/water, sunlight and flare reflections can desensitise the detector or cause false alarms (Reference 5). More information is available on these topics, please get in contact to discuss.

- *Selecting Appropriate Mapping Tool*

Without the appropriate tool to take account of the above mentioned factors, the working environment of the plant/site it will be difficult to visualise in terms of hazard perception and adequate detector technologies. Therefore, to design an effective system it is useful, we at Micropack believe a necessity, to have a tool that accurately portrays the real life environment while accounting for the various levels of fire and gas detection targets alongside applicable chosen technologies. HazMap3D allows the user to do this seamlessly.

Our Market Leading F&G Mapping Software - HazMap3D

Evolving from our immersion in the oil & gas industry, specifically Fire & Gas Detection Design, some 20+ years' experience has helped develop a three dimensional mapping software tool from which an optimal safe system can be designed. HazMap3D originated in the form of FDAGDA which was one of the first tools of its kind. It was a proprietary 2D mapping software which was representative of a 3D volume.

It should be noted that an understanding of the environment, application (in this case pipelines and connecting stations), and impact of each detector placement is required to design a truly safe arrangement. **HazMap3D** guides the user through this process.

Mapping in Action using HazMap3D

Accurately apply parameters and hence appropriate grading suitable to application

Most of the major operators in the oil and gas industry have published standards documents setting out their requirements against which they expect their F&G system to perform against. HazMap3D is designed to be configurable so it can incorporate the requirements of diverse clients. The requirements of the main operators have been included in the form of templates which can be easily and quickly selected and applied to any project. There are even different variants for each operator; onshore, offshore etc. Even further still, Micropack's very own current best practice based on decades of experience is included as a selectable option, where no standard or guidance document is available. This feature only available in HazMap3D allows the user unrivalled peace of mind that a fit for purpose design has been implemented.

Accurately Represent Flame Detection Footprints

Different detection technologies, manufacturers and models will create distinctive detection footprints. HazMap3D provides 3rd party certified detection footprints for peace of mind that the detector specified on the project can be accurately mapped. Figures 1 & 2 below shows how vastly different flame detector technology cones can be in terms of shape and range. Micropack generate this accuracy using independently verified FM Global certified data.

Throughout the project building process while populating the background environment (3D model accurately depicting plant/site) with the chosen/project flame detector one has the option to view each cone of vision obstructed or unobstructed - Refer to Figures 1 &2. This aids the user in visualising major blockages etc. that could have an effect when optimising the system.

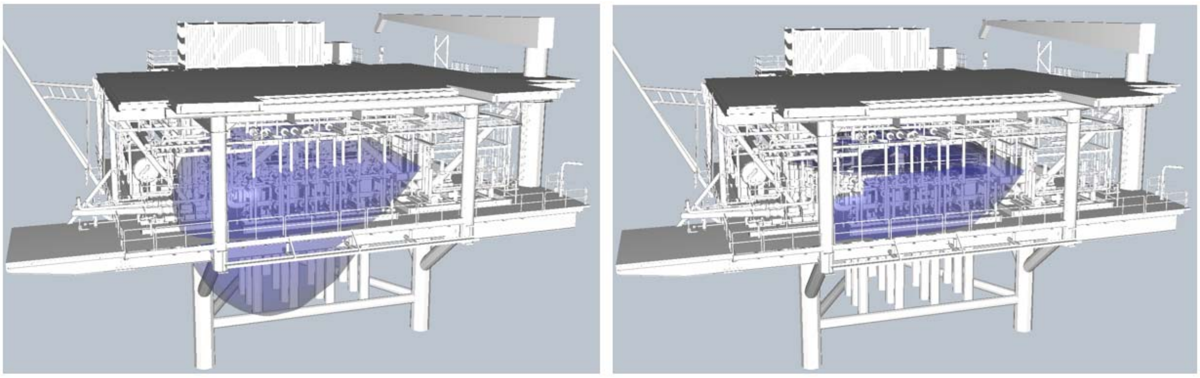

Figure 1 - Unobstructed (left) and obstructed (right) field of view of typical 3IR flame detector

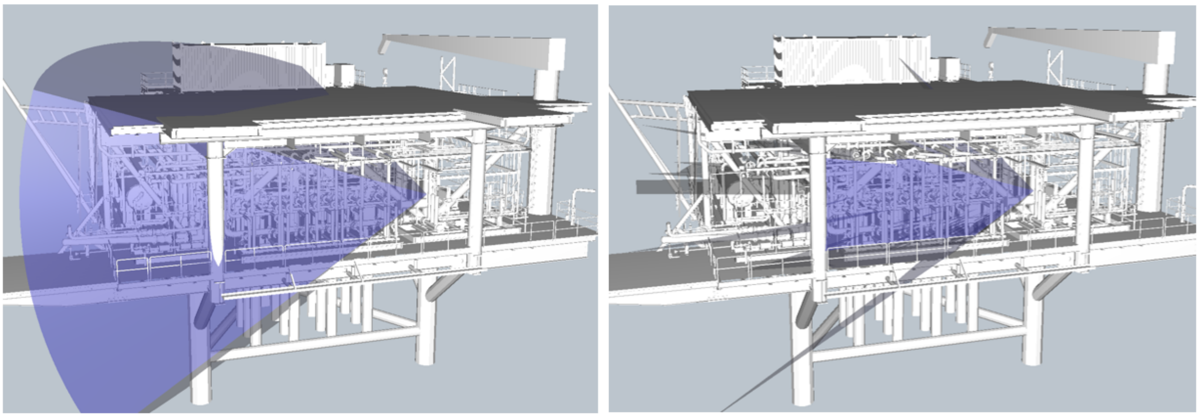

Figure 2 - Unobstructed (left) and obstructed (right) field of view of typical visual flame detector

Accurately Map Open Path Gas Detection (beam attenuation)

Open Path Gas Detectors (OPGDs) will not alarm simply by a gas cloud coming into contact with the beam. These detectors rely on a specific concentration of gas across a given length of the beam in order to alarm, thus why detection alarm levels are represented as LELm, not %LEL. An example of volumetric detection using beam attenuation is shown below.

OPGDs are represented below by orange lines of sight and assessment shoebox (volume in which gas can credibly accumulate) is represented by transparent teal box.

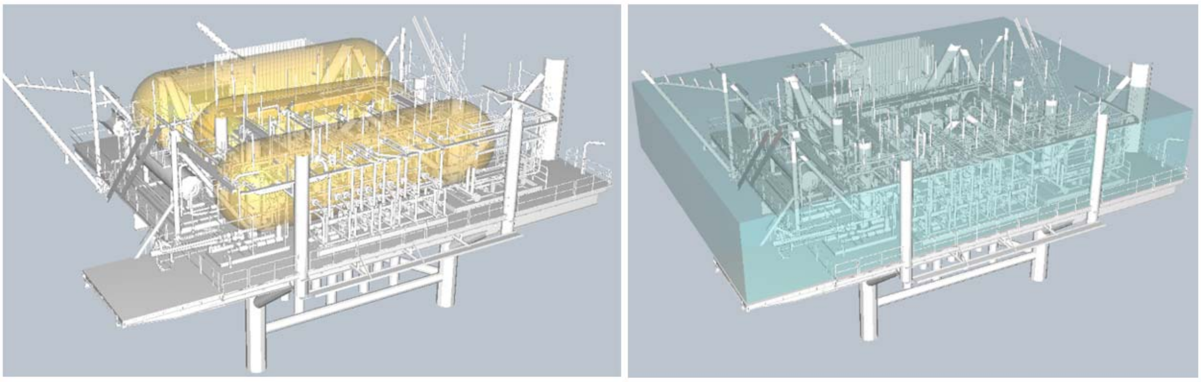

Figure 3 - OPGD coverage beam for congested grade (left) and assessment shoebox (right)

Note the coverage below is not simply a 'sausage' of coverage as is often misleadingly shown in mapping. This basic representation of Open Path Gas Detection is wholly inaccurate of how these detectors operate, and is the primary reason for overly conservative designs when applying a geographic approach. Using dense and dilute clouds can optimise the detection layout and allow representation of alarm and control action coverage, while calculating the concentration of gas across the beam to accurately represent detection capability.

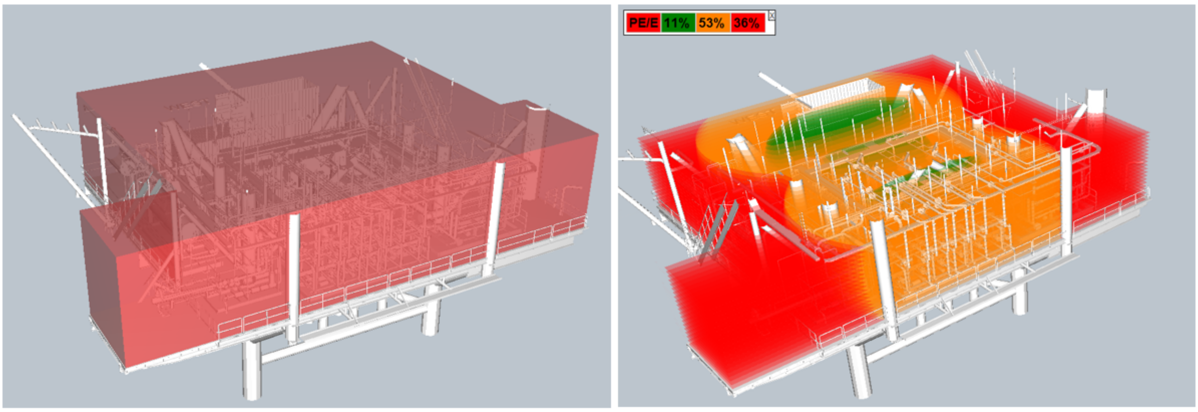

Figure 4 - Gas grademap depicting congested grade (left) and OPGD assessment coverage for above defined shoebox (right)

Note: The coverage above is applying 2ooN High-Low voting. Assessments can be easily tailored to specific on-site voting philosophies.

For the purpose of comparison and to highlight the other IRPGD feature capabilities of HazMap3D the below figures depict the same graded area with a typical IRPGD arrangement applied.

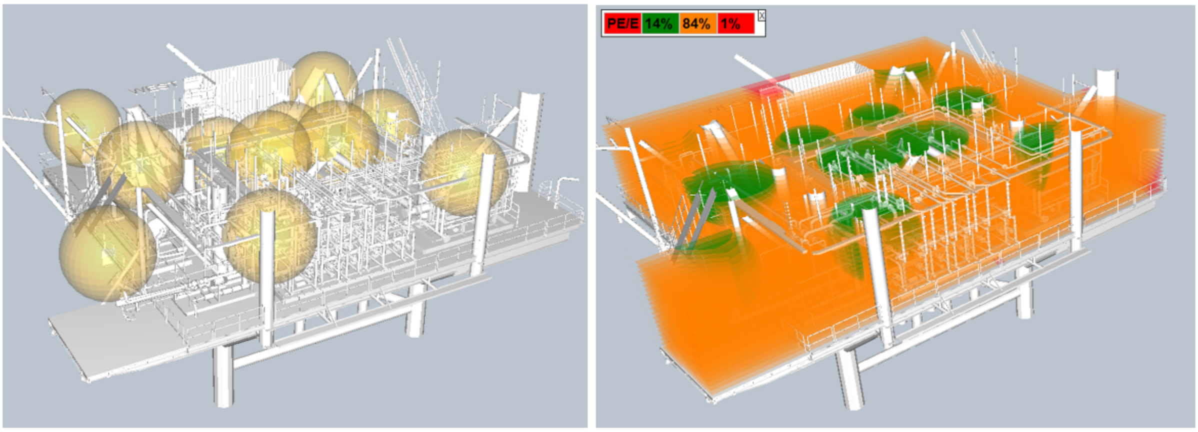

Figure 5 - IRPGD placement coverage sphere for congested grade (left) and assessment coverage (right)

Note: The coverage above is applying 2ooN High-Low voting. Assessments can be easily tailored to specific on-site voting philosophies.

Optimise the layout using multiple fire sizes in one single assessment (without fudge factors!)

Where multiple grades are applied, it is crucial to be able to represent each grade, with multiple different flame detector models, in a single assessment to ensure the assessment represents a holistic and accurate view of the detection coverage.

Good practice often specifies two different fire sizes in one single grade (i.e. we want to alarm to a small fire but not shut down until the fire grows to a sufficient size). HazMap3D seamlessly allows the user to do this and is a truly unique feature to provide the engineer with a complete view of coverage, often required in F&G philosophies.

The following assessment contains four different flame detector models and three different grades (each grade requiring a different target fire size for alarm and control action).

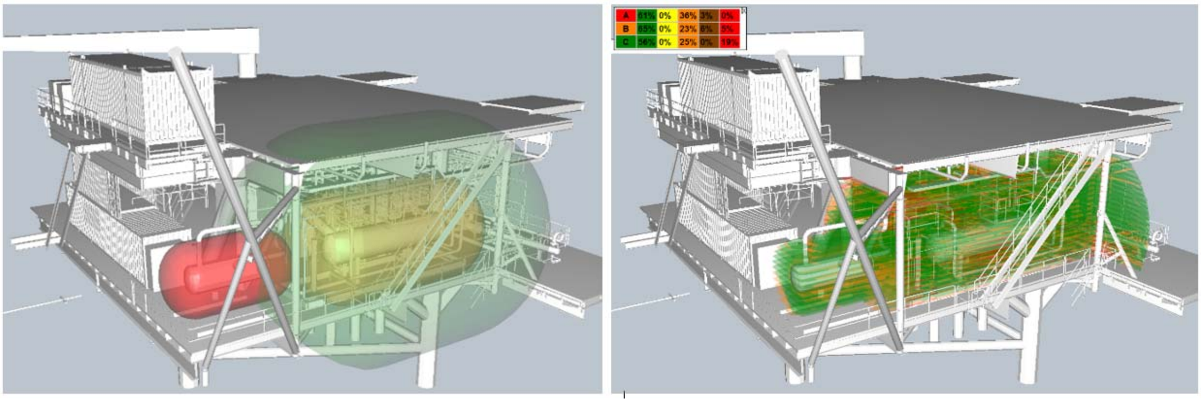

Figure 6 - Grademap depicting different grades red - high risk, orange - standard risk and green - low risk (left) and assessment coverage (right)

Note: The grading and detection applied here has been exaggerated as such is not reflective of a true to life assessment. However, the quantity of FDs is reflective of a real life environment of this size.

Coverage factors are then shown, broken down into coverage for each specified target fire size. This accurately shows whether executive action has been achieved, only alarm, any blind spots, in addition to where the alarm will be delayed by requiring a larger target fire size than that specified, before the detector will respond.

This is crucial for the designer making the decision on whether the coverage is adequate. The percentage coverage is never enough to determine if an area is suitably covered. One area with 75% 2ooN coverage may in fact have better coverage that an area with 90% 2ooN coverage - depending on where the blind spots are and the weighting based on the escalation potential of that particular blind spot i.e. 70% coverage of a diesels storage tank may be acceptable, but this would not be acceptable on a Gas Compressor. This demonstrates that auto-optimisation based solely on percentage coverage can be both dangerous and expensive. Ultimately, this is a decision to be made by the designer, using the tools shown above.

It is also crucial to note HazMap3D utilises only 3rd party verified and approved data. There are no black boxes in HazMap3D to either improve or inhibit detector coverage. The software also only uses credible target against which flame detectors are certified against. This restricts the user from inadvertently selecting a target against which no flame detector has actually be certified to detect, providing peace of mind in design.

Fully Integrated Auto-Report Generation

In order to save time during the review stage, it is important to have a reporting function whereby the mapping report is automatically generated, accounting for all of the most relevant information. This saves time and money at a crucial stage of the project, by transposing the 3D environment previously seen (of which shots can be directly pasted into the report for a 3D view of the coverage) onto a 2D plot plan which is instantly recognisable and easily interpreted by the engineers. Examples can be seen below of one method of auto-reporting.

DETECTOR DETAILS (PAGE 1 OF 1)

Tag No	Type	X,Y,ALD(m)	Pan/Tilt(deg)	Comments
FD-1001	AutF-X33/1(Med)	31.150 4.070 2.500	+135 +10	
FD-1002	Det-X3301(Med)	31.070 21.430 3.000	+225 +10	
FD-1003	Drager-FL5000	23.630 4.150 3.000	+135 +10	
FD-1004	FG-5 MSIR(Med)	24.350 9.790 5.000	+135 +25	
FD-1005	GM-FL4000H(Med)	12.700 4.640 3.000	+124 +10	
FD-1006	Hon-FS24x	8.370 4.830 2.500	+45 +10	
FD-1007	MP-FDS301	12.900 12.930 3.000	+315 +10	
FD-1008	DM TV6-XTA0	12.920 20.070 3.010	+315 +10	
FD-1009	SharpEye-40/40	12.470 25.890 3.000	+225 +10	
FD-1010	Thorn-S2xx	8.370 26.320 3.000	+315 +10	
FD-1011	Det-X9800(Lo)	15.090 14.380 5.350	+315 +10	
FD-1012	SharpEye-20/20	31.060 8.260 2.500	+165 +10	
FD-1013	Drg-FL2300(Med)	3.020 4.010 2.500	+40 +10	

Figure 7 - Detector information table (Bill of Materials) automatically populated by HazMap3D

COVERAGE SUMMARY

A	61%	0%	36%	3%	0%
B	65%	0%	23%	6%	5%
C	56%	0%	25%	0%	19%
Totals	59%	0%	25%	2%	14%

DETECTOR CONTRIBUTIONS

TAG	Individual	1ooN	2ooN	>2ooN
All Detectors		84.2	59.0	27.9
FD-1001	2.4	83.8	58.5	27.2
FD-1002	19.5	81.5	51.8	21.2
FD-1003	4.3	83.6	58.0	26.6
FD-1004	3.2	83.5	58.1	27.1
FD-1005	17.1	82.7	54.7	21.9
FD-1006	35.2	80.0	47.1	16.1
FD-1007	3.7	83.0	57.8	27.0
FD-1008	9.6	81.6	55.4	25.5
FD-1009	32.0	78.6	46.7	18.6
FD-1010	38.1	79.6	43.4	16.2
FD-1011	0.1	84.1	58.9	27.8
FD-1012	3.1	84.0	58.5	26.8
FD-1013	13.8	82.7	55.4	23.3

Figure 8 - Coverage Summary tables automatically populated by HazMap3D

Note: For tips on how to interpret your results tables please refer to HazMap3D user manual (Reference 6), or get in touch instantly with one of our highly experienced consultants.

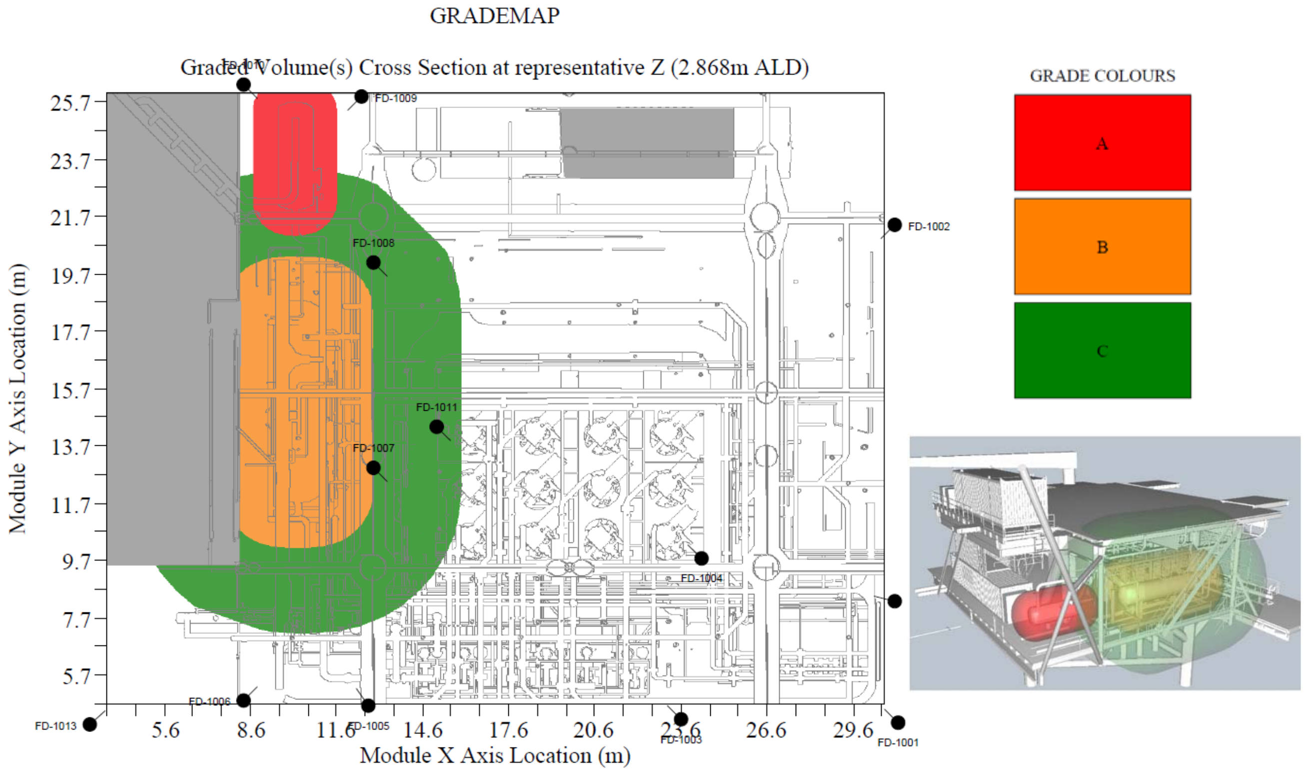

Figure 9 - Corresponding 2D flame grademap with 3D figure inset for ease of reference

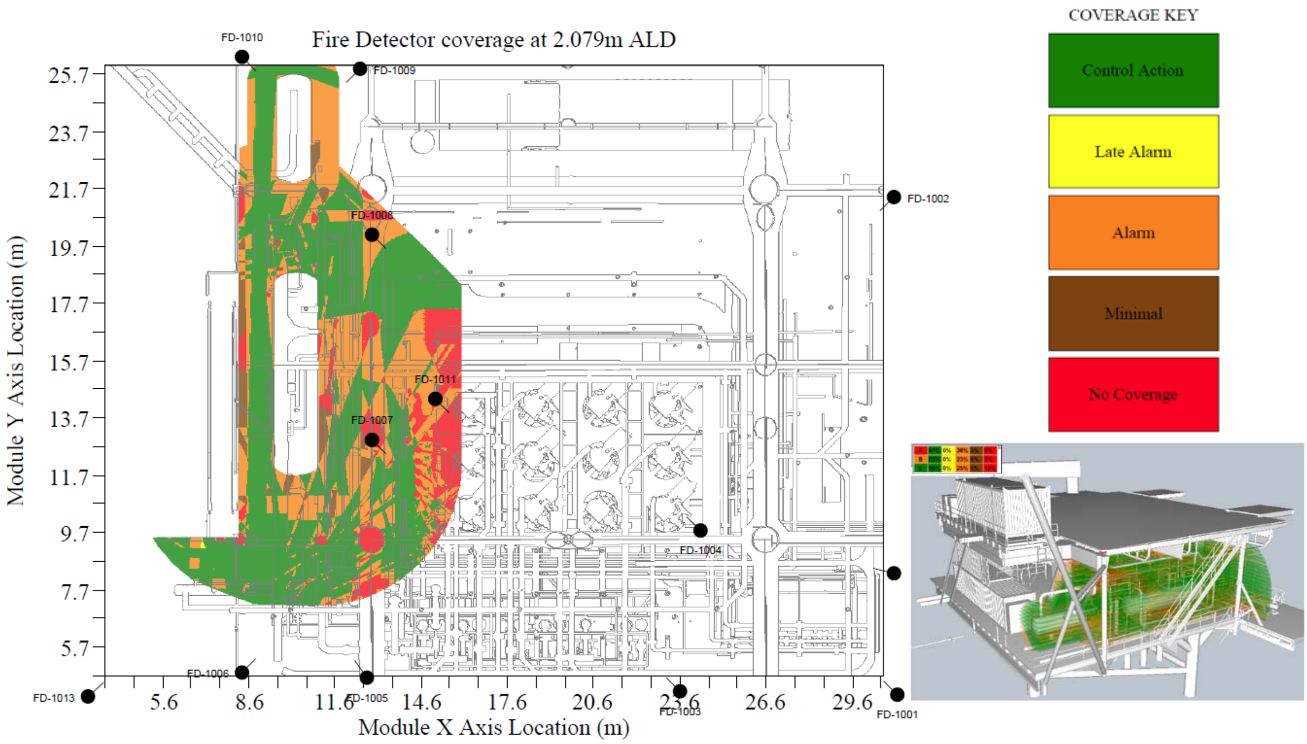

Figure 10 - Corresponding 2D flame assessment at representative slice to above example with 3D figure inset for ease of reference

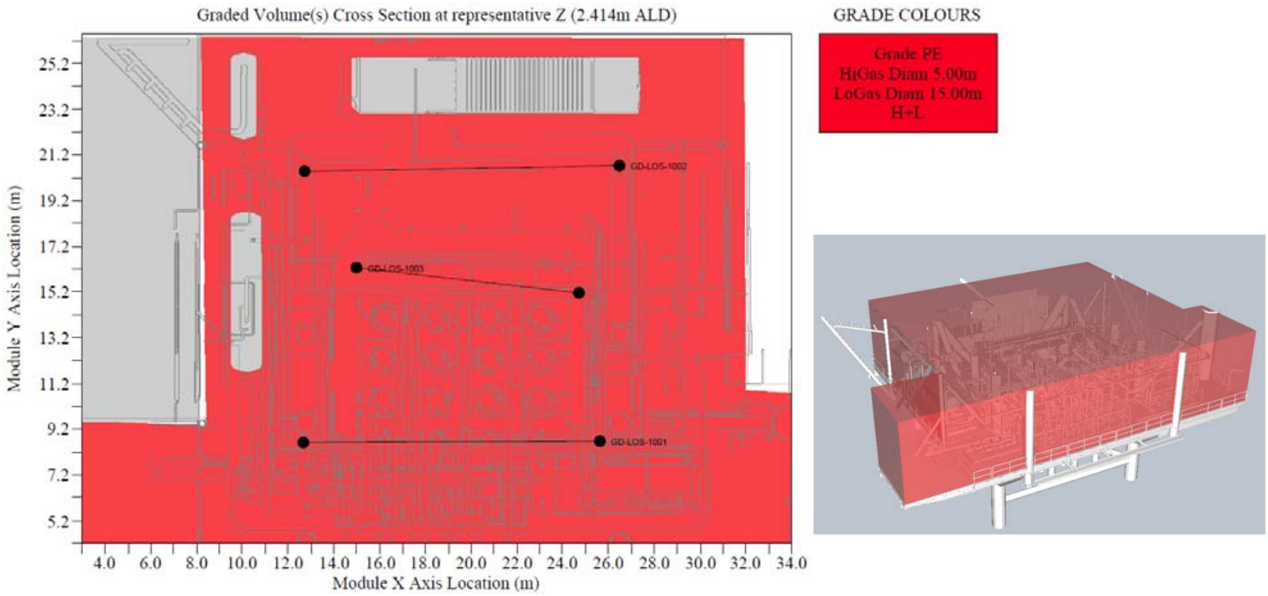

Figure 11 - Corresponding 2D gas grademap with 3D figure inset for ease of reference

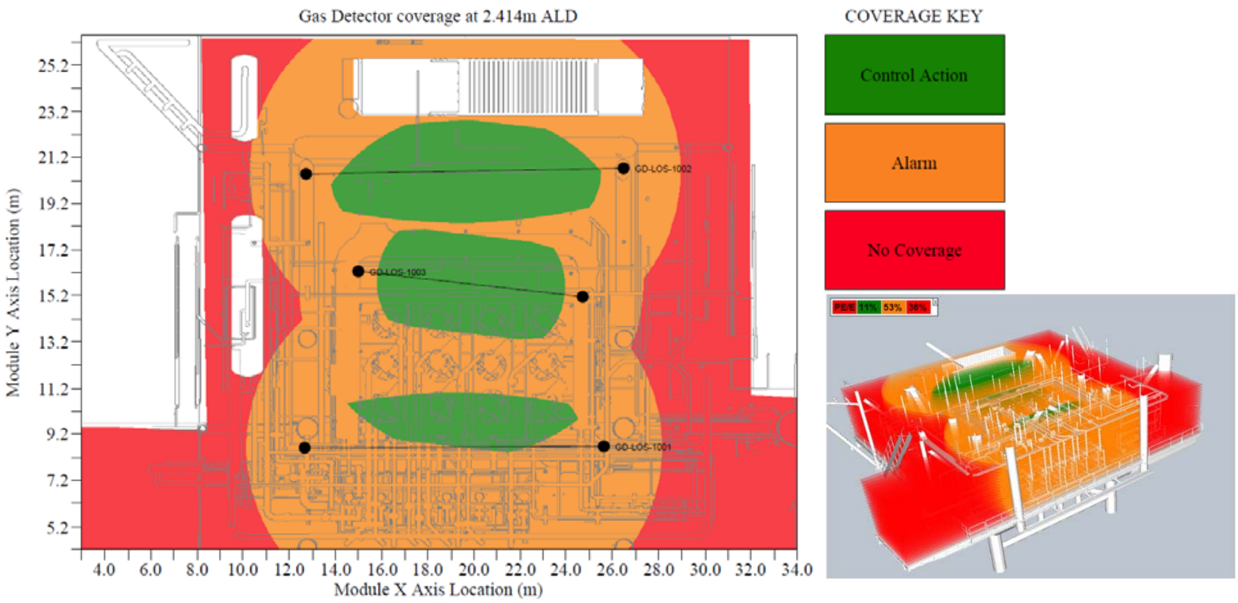

Figure 12 - Corresponding 2D gas assessment using OPGDs at representative slice to above example with 3D figure inset for ease of reference

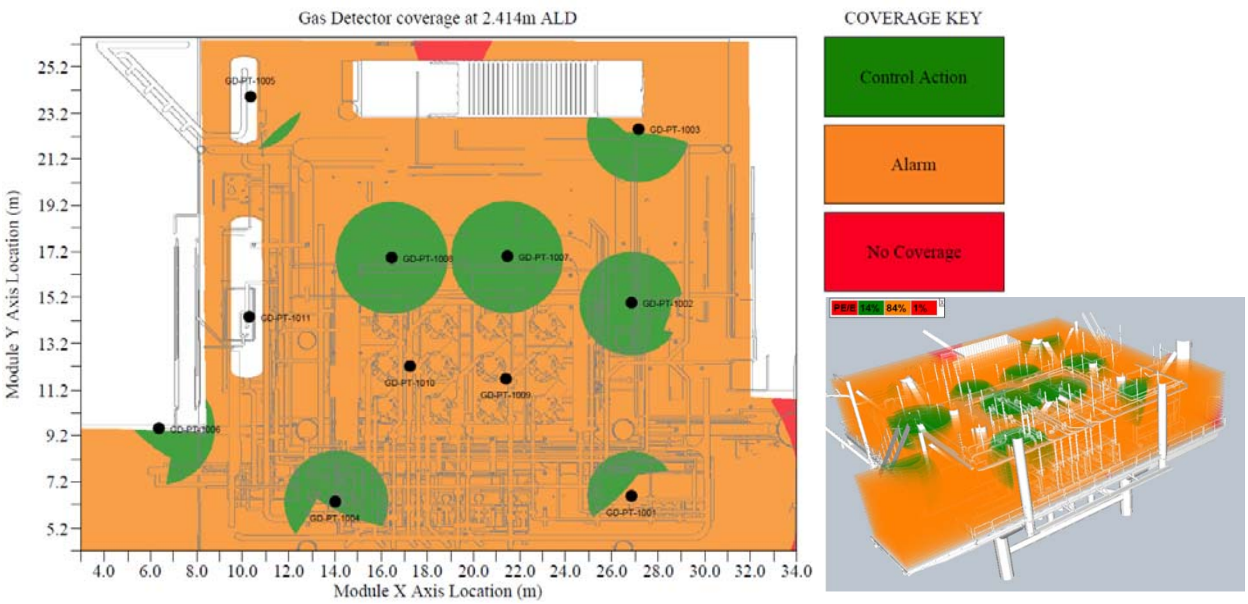

Figure 13 - Corresponding 2D gas assessment using IRPGDs at representative slice to above example with 3D figure inset for ease of reference

GAS DETECTOR CONTRIBUTIONS

		<---- Contribution Percentages ---->							Location (m from origin)		
		Individual		<---- Voted ---->							
Tag Name	Type	L	H	L	H	2L	HL	2H	X	Y	Elev
GD-PT-1001	Point	21.2%	1.9%	7.3%	1.9%	5.7%	0.6%	0.0%	26.930	6.630	4.000
GD-PT-1002	Point	28.1%	2.1%	2.1%	2.1%	7.2%	0.6%	0.0%	26.920	14.970	3.500
GD-PT-1003	Point	19.3%	2.0%	5.8%	2.0%	4.9%	0.5%	0.0%	27.230	22.500	3.500
GD-PT-1004	Point	20.9%	2.1%	2.1%	2.1%	5.5%	1.1%	0.0%	14.124	6.342	3.500
GD-PT-1005	Point	13.8%	2.0%	5.4%	2.0%	3.7%	0.1%	0.0%	10.426	23.912	3.500
GD-PT-1006	Point	14.6%	1.1%	3.6%	1.1%	5.0%	0.8%	0.0%	6.431	9.522	3.010
GD-PT-1007	Point	30.0%	2.3%	0.0%	2.3%	4.1%	0.2%	0.0%	21.530	16.990	2.980
GD-PT-1008	Point	30.4%	2.3%	0.1%	2.3%	5.9%	0.2%	0.0%	16.520	16.950	2.980
GD-PT-1009	Point	27.9%	1.3%	0.0%	1.2%	2.5%	0.5%	0.1%	21.490	11.670	5.000
GD-PT-1010	Point	27.8%	1.3%	0.0%	1.2%	1.7%	0.8%	0.1%	17.370	12.240	5.000
GD-PT-1011	Point	19.0%	1.2%	0.1%	1.2%	2.9%	0.6%	0.0%	10.380	14.400	5.000

Individual L/H columns show the percentage of graded volume covered by that detector at L and H range.
Remaining contributions columns (L,H,2L,etc) show what percentage of voted coverage is lost if that detector fails, for a selection of possible voting strategies.

Figure 14 - Corresponding gas detector contribution table using IRPGDs

Another handy feature of the fully integrated auto-report generation is that it includes detector contribution tables for both flame and gas. These can be analysed by the user and utilised when making recommendations to the existing design. The gas detector contributions table for the IRPGD example above is shown in Figure 14; an ideal design would have each detector contributing equally to the coverage. However, it can be seen from a glance above that a small amount of detectors are performing sub-optimally and therefore can be considered for relocation so that the coverage is optimised. It is essential when doing this that the user is familiar with the plant and any changes to the design are implemented using engineering judgement.

Fully Compatible with the evolving nature of Greenfield/Brownfield/New Projects

Due to the nature of project progression within the industry we are aware that changes are often a regular occurrence to plant and design. So a handy feature which could potentially be very useful for clients is an updated 3D model can be imported into the project (provided the import parameters are origin etc. are the same) retaining the positioning of the original design detectors. This minimises the time spent on rework and ensures accuracy up until the current stage of the project.

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6. HazMap3D 1.x User Manual Ref: HZ01.4358 Doc Rev 1.32 July 2016

Author

This application note was written by Gemma Finnegan Senior Safety Consultant of Micropack (Engineering) Ltd.

Introducing; Gemma Finnegan MEng MSc MIET.

A motivated and knowledge thirsty consultant with four and a half years' experience in the oil & gas industry. Highly qualified in the engineering field as a Master of Mechanical Engineering from Queen's University Belfast and a Master of Fire Safety Engineering from University of Ulster Jordanstown. Gemma's interest in engineering began in Belfast where she was one of four engineers in her family. Micropack (Engineering) Ltd launched her independent professional career into her chosen field; Fire Safety Engineering. She is now one of our Senior Consultants who design safety systems for assets both on and offshore, predominately the North Sea and mainland UK, but has experience in projects in Norway, Azerbaijan and South Korea. As one of few female F&G engineering consultants, Gemma is a valuable member of the Micropack consultancy team for her distinctly resilient and determined nature as well as her logical thought process to solving problems faced by system design.

For further information, contact: info@micropack.co.uk or alternatively, visit www.micropack.co.uk