# APPLICATION OF FIRE & GAS MAPPING TO PIPELINES & CONNECTING STATIONS

Gemma Finnegan MEng MSc MIET

Technical Safety Consultant / Fire and Gas Consultant Engineer

**Introduction**

Pipelines and the associated stations are an integral part of the conditioning, transport and delivery service that has become an essential service in modern day life. They allow for the safe and regulated transportation of liquids and gases through a pipe. Pipelines relevant to this application note exist for the transportation of crude and refined petroleum - such as oil and natural gas. The oil is moved through the pipelines by pumping stations along the pipeline. Natural gas (and similar gaseous fuels) are lightly pressurised into liquids known as Natural Gas Liquids (NGLs).

A typical pipeline project would include; Extraction/Processing Terminal(s), Pumping Station(s), Intermediate Pigging Station(s), Pressure Reduction Station(s) and Block Valve Station(s). Each of these associated stations along the pipeline present special safety concerns which must be addressed.

The volume of stored hazardous material, along with the typical processes performed throughout the pipeline within associated stations, presents a significant fire hazard comparable to those found on similar sites both on and offshore e.g.: production platforms/onshore terminals (These facilities are covered in corresponding application notes and can be found on the Micropack website – Reference 1). These processes can involve gases at very high pressure, which if released would present significant potential for explosion due to the often congested nature of these facilities.

Therefore, with the pipelines carrying these hazardous materials, via the associated stations, often thousands of kilometers, distributed throughout the world it is essential that appropriate safety systems are in place to mitigate potentially catastrophic events.

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 pipeline fires and explosions, the following are a handful of examples highlighting both that this is not a problem of the past but it is also not specific to countries/regions with less stringent safety regulations and guidance available.

*China 2010 - Dalian Pipeline disaster*

The explosion of two petroleum pipelines and subsequent fire in the port of Dalian, in northern China's Liaoning province on 17th July 2010 caused damage to plant and an ecological disaster, releasing 11,000 barrels of oil into the Yellow Sea (Reference 2).

*Mexico 2010 - Petroleos Mexicanos Pumping Station Explosion*

The explosion on 19th December 2010 of an oil pipeline at a Petroleos Mexicanos (Pemex) pumping station in San Martín Texmelucan de Labastida in central Mexico, killed at least 27 people and injured more than 52 (Reference 3).

*Kenya 2011 - Nairobi Pipeline Fire*

Nairobi pipeline fire kills approximately 120 people and hospitalized 100 (Reference 4).

*Malaysia 2014 - PETRONAS Gas Pipeline Explosion*

PETRONAS gas pipeline explosion in the state of Sarawak, Malaysia ripped apart a portion of the RM3bil Sabah to Sarawak interstate gas pipeline between Lawas town and Long Sukang, resulting in the evacuation of nearby villagers (Reference 5).

**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 standards 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 targets 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 pipelines and their associated stations would be in, such as the desert (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 sunlight, flare reflections can desensitise the detector or cause false alarms (Reference 6). 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 unrivaled 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.

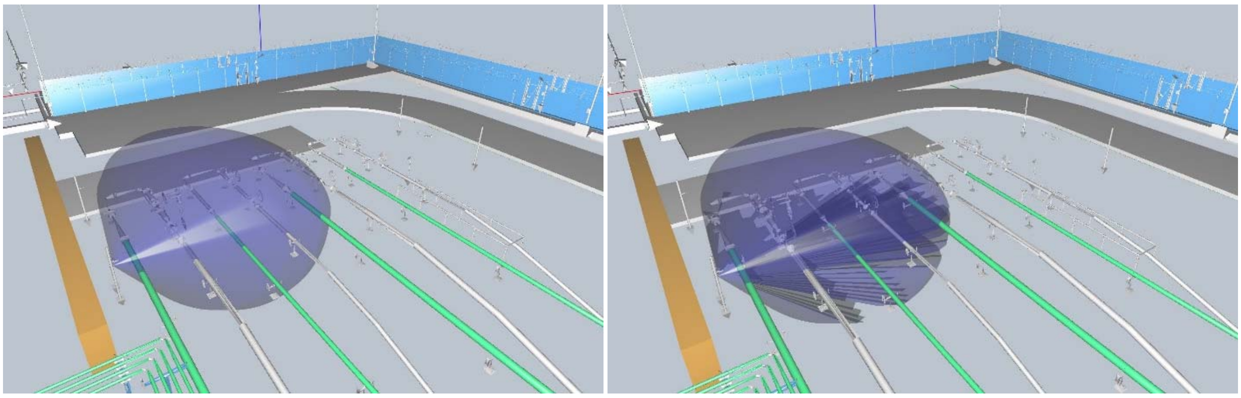

**Figure 1** - Unobstructed (left) and obstructed (right) field of view of typical 3IR flame detector

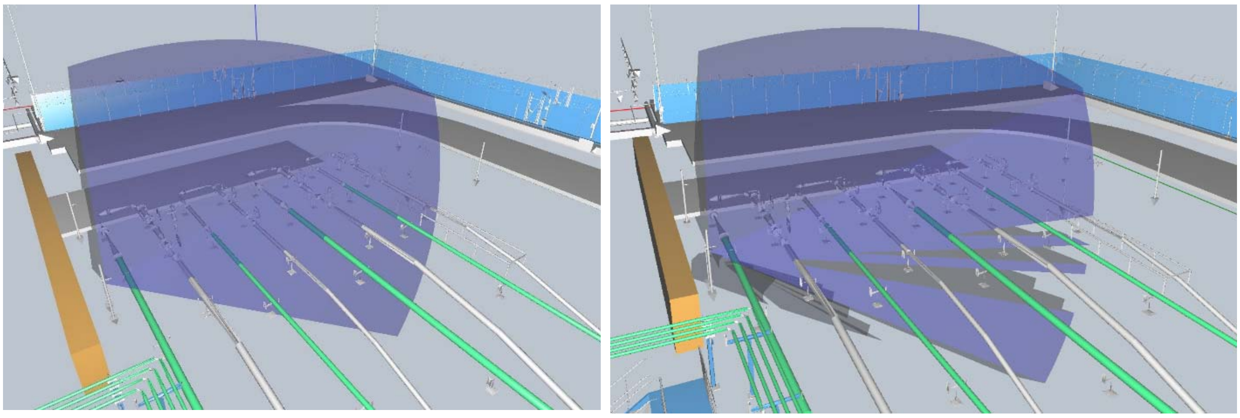

**Figure 2** - Unobstructed (left) and obstructed (right) field of view of typical visual flame detector

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.

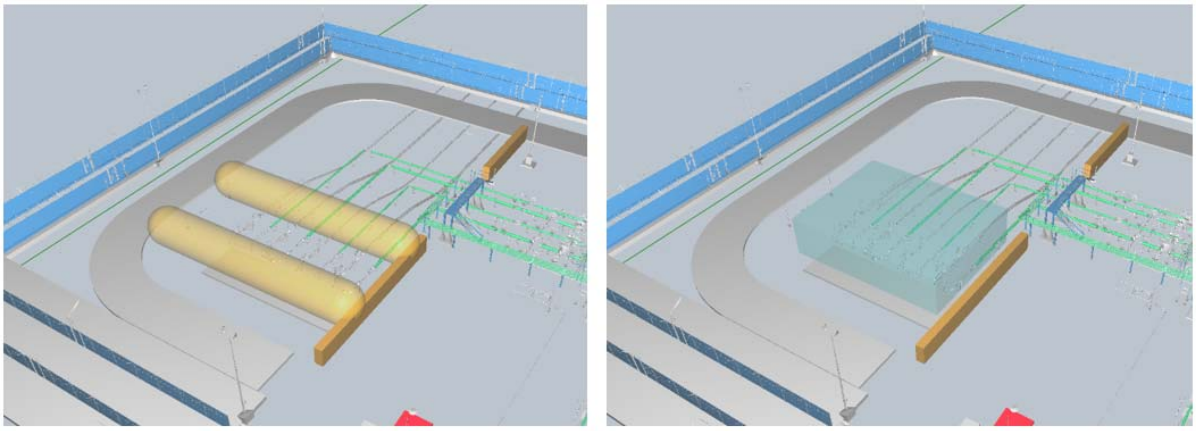

**Figure 3** - OPGD coverage beam for open grade (left) and assessment shoebox (right)

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.

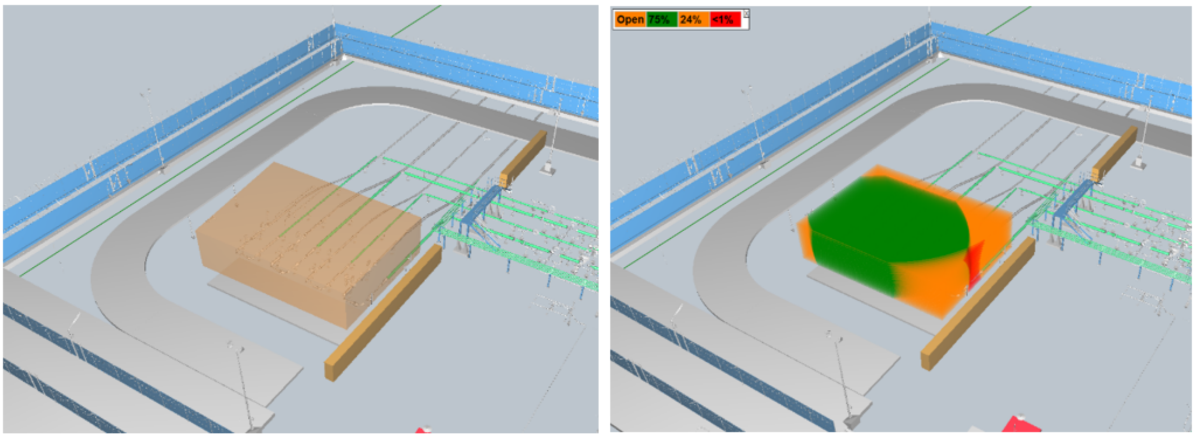


**Figure 4** - Gas grademap depicting open grade (left) and OPGD assessment coverage for above defined shoebox (right)

**Note:** The coverage above is applying 2ooN High-High 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.

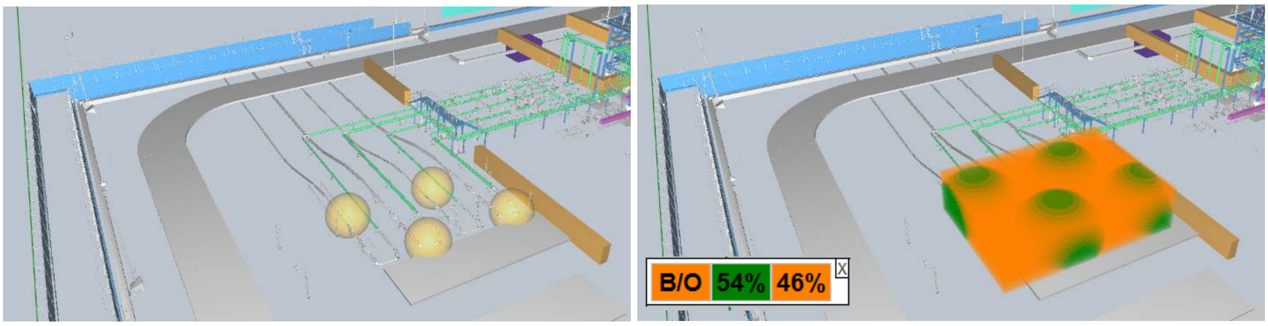


**Figure 5** - IRPGD placement coverage sphere for open grade (left) and assessment coverage (right)

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

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

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).

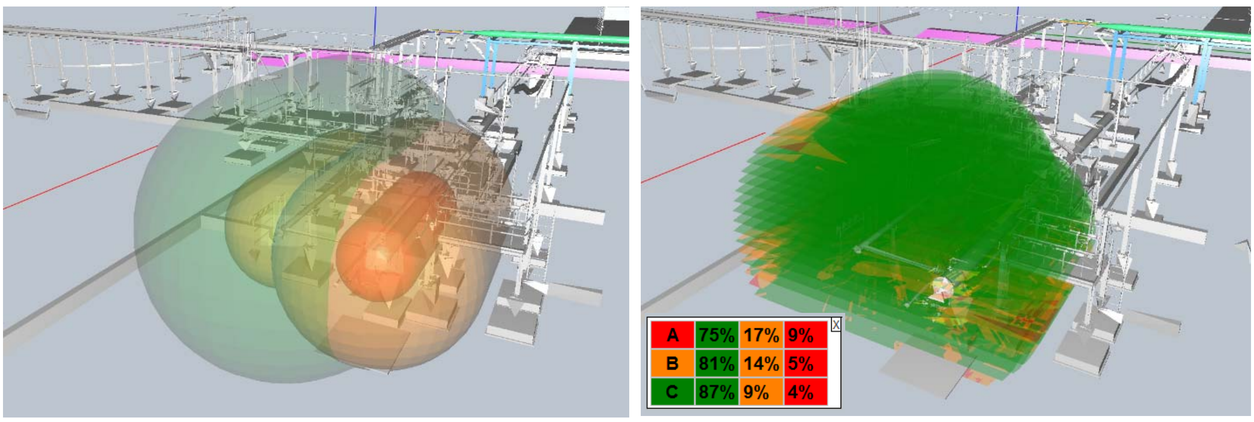


**Figure 6** - Grademap depicting different grades red - high risk, orange - standard risk and green - low risk (left) and assessment coverage (right)

**Note:** The detection applied here has been exaggerated as such is not reflective of a true to life assessment e.g.: four different detectors have been utilised for the purposes of illustrating HazMap3D's capabilities.

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 |
|---|---|---|---|---|
| Det01 | Det-X3301(Med) | 115.39 44.60 3.50 | +250 +10 | |
| Det02 | Drager-FL5000 | 103.24 43.87 4.23 | +315 +10 | |
| Det03 | Thorn-S1xx | 117.85 30.04 3.25 | +120 +10 | |
| Det04 | DM TV6-XVA0 | 105.18 30.05 3.35 | +60 +10 | |

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

**COVERAGE SUMMARY**

| | | | |
|---|---|---|---|
| A | 75% | 17% | 9% |
| B | 81% | 14% | 5% |
| C | 87% | 9% | 4% |
| Totals | 84% | 11% | 5% |

**DETECTOR CONTRIBUTIONS**

| TAG | Individual | 1ooN | 2ooN | >2ooN |
|---|---|---|---|---|
| All Detectors | | 95.4 | 84.1 | 57.6 |
| Det01 | 39.8 | 94.5 | 79.6 | 44.9 |
| Det02 | 68.0 | 91.5 | 72.9 | 26.4 |
| Det03 | 83.0 | 90.9 | 62.3 | 22.6 |
| Det04 | 68.0 | 93.5 | 68.6 | 28.8 |

**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 7), or get in touch instantly with one of our highly experienced consultants.

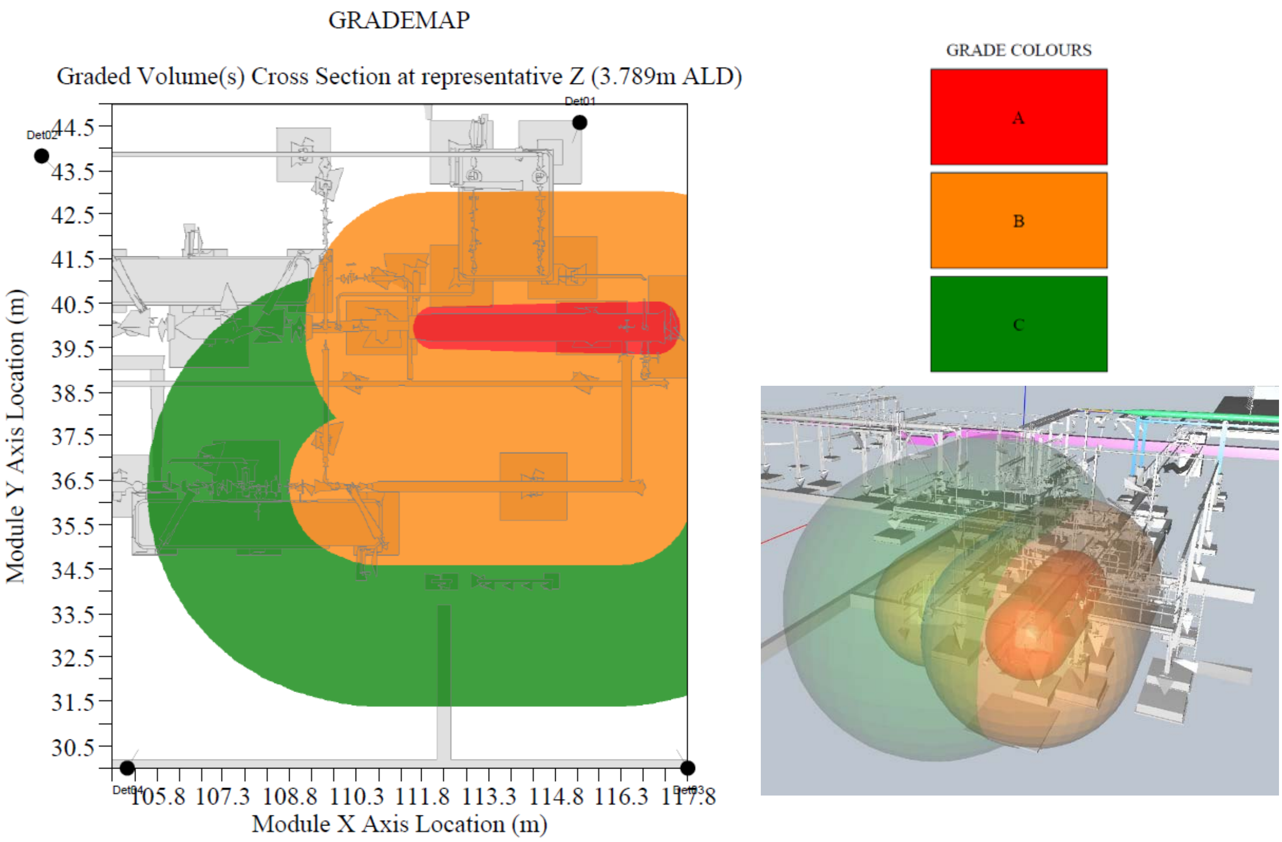


**Figure 9** - Corresponding 2D flame grademap with 3D figure inset for ease of reference

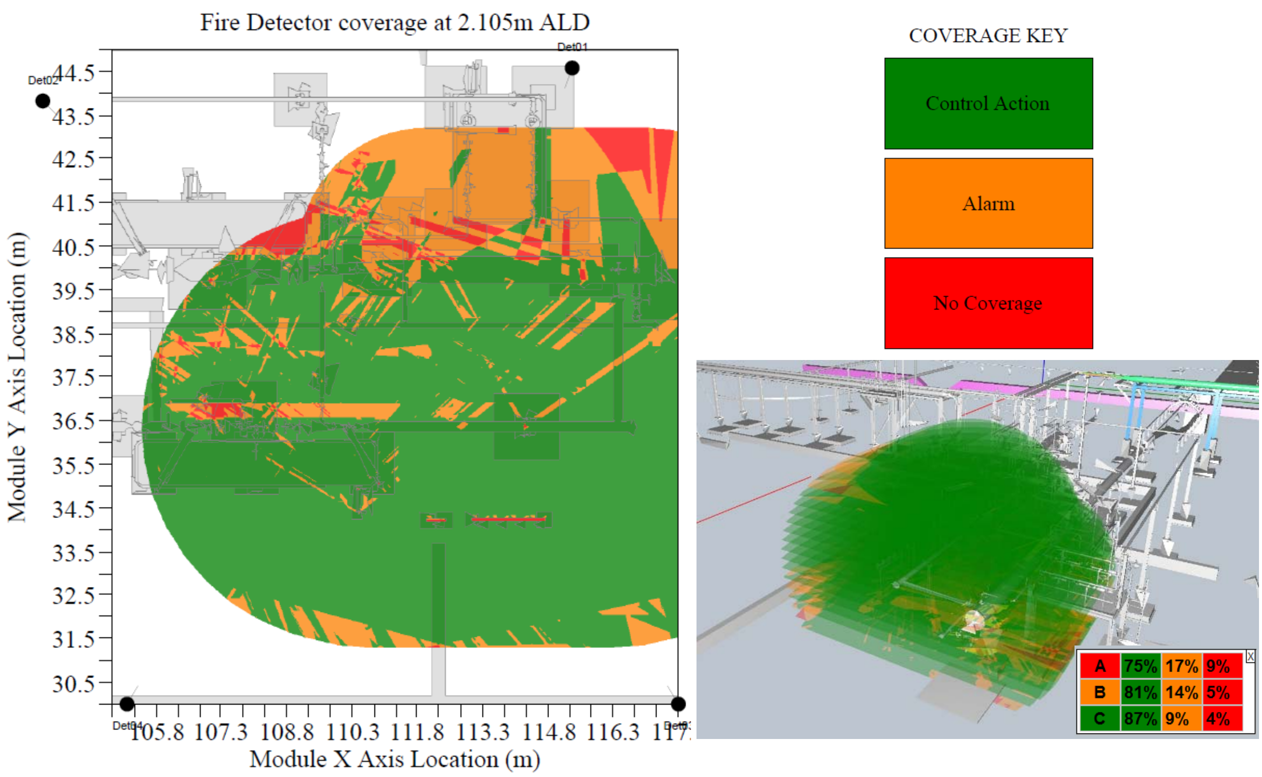


**Figure 10** - Corresponding 2D flame assessment at representative slice to above example with 3D figure inset for ease of reference

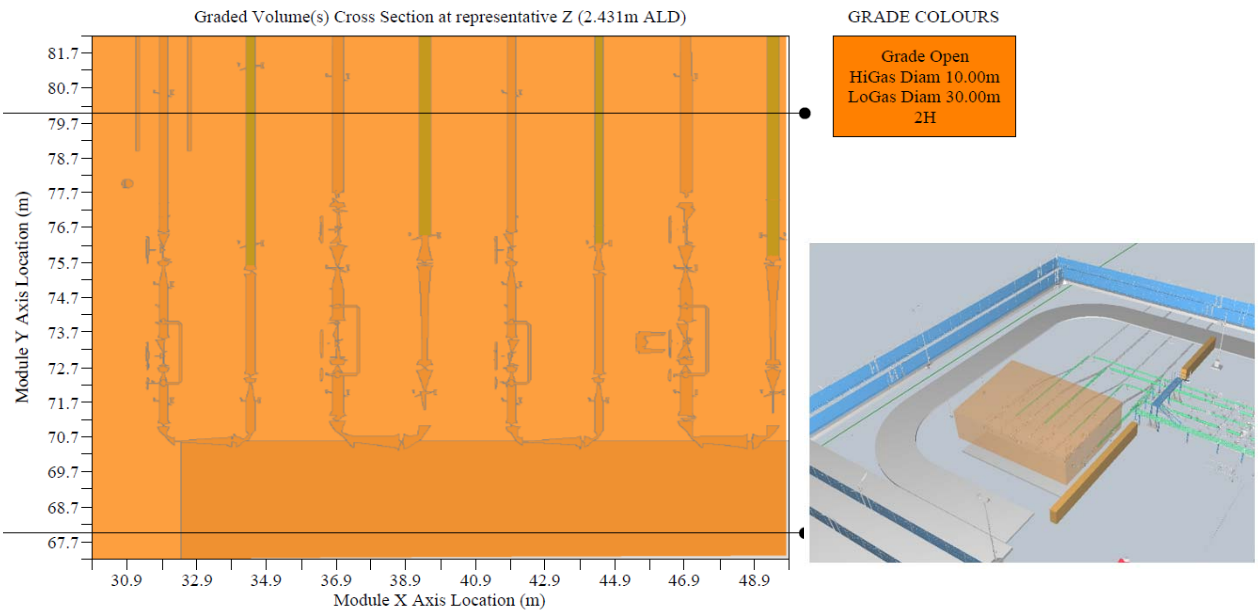


**Figure 11** - Corresponding 2D gas grademap with 3D figure inset for ease of reference

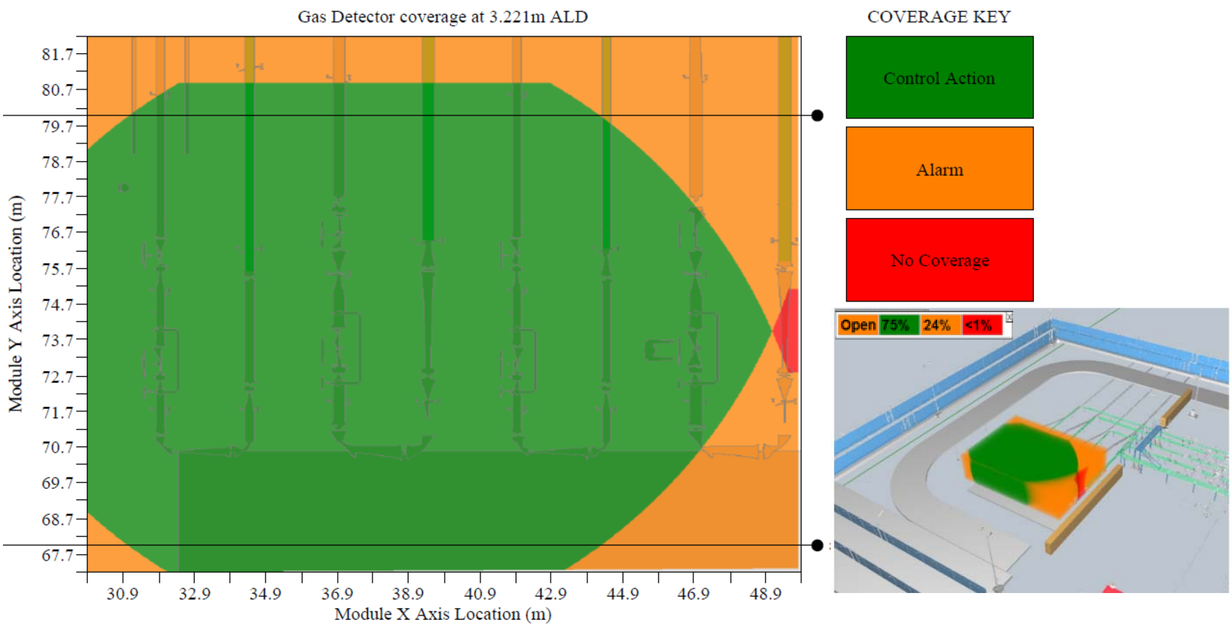


**Figure 12** - Corresponding 2D gas assessment using OPGDs at representative slice to above example with 3D figure inset for ease of reference

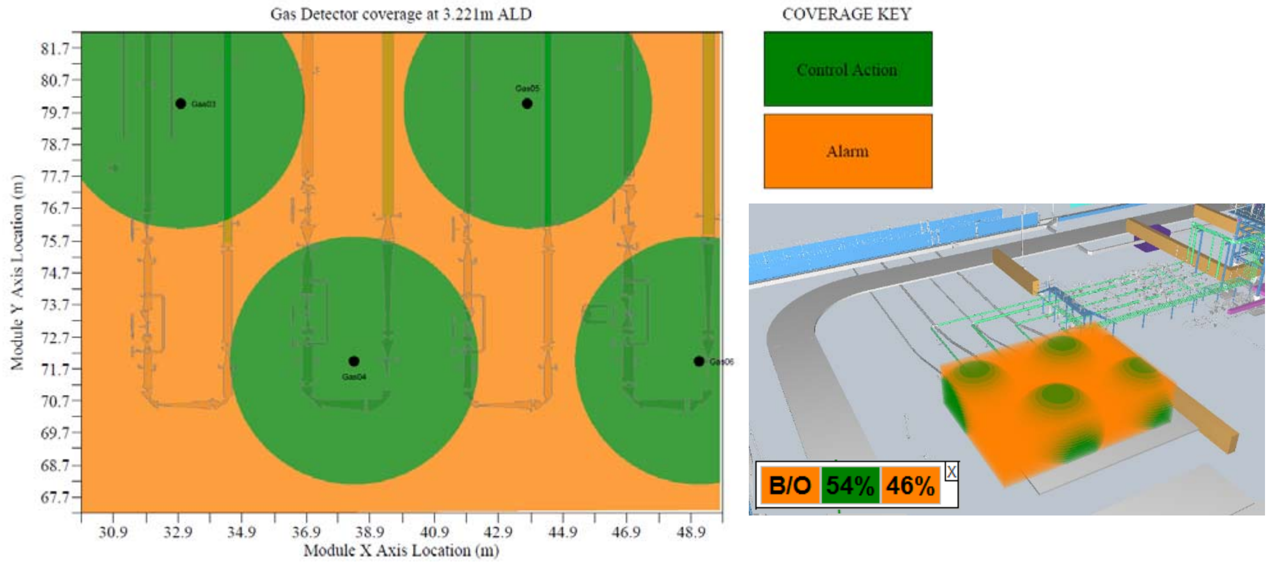


**Figure 13** - Corresponding 2D gas assessment using OPGDs at representative slice to above example with 3D figure inset for ease of reference

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

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.

**References**


1. Micropack Engineering Ltd website: http://www.micropack.co.uk/
2. China 2010 - Dalian Pipeline disaster: https://www.theguardian.com/environment/2010/jul/19/china-oil-spill-dalian
3. Mexico 2010 - Petroleos Mexicanos Pumping Station Explosion: http://www.cbsnews.com/news/flaming-river-of-crude-oil-kills-27-in-mexico/
4. Kenya 2011 - Nairobi Pipeline Fire: http://www.telegraph.co.uk/news/worldnews/africaandindianocean/kenya/8758340/120-burned-to-death-in-Kenya-pipeline-fire.html
5. Malaysia 2014 - PETRONAS Gas Pipeline Explosion: http://www.thestar.com.my/news/nation/2014/06/10/petronas-fire-ssgp/
6. Desensitisation of Optical Flame Detection in Harsh Offshore/ Onshore Environments James McNay BSc (Hons) MIFireE CFSP MIET January 2015
7. HazMap3D 1.x User Manual Ref: HZ01.4358 Doc Rev 1.32 July 2016


**Author**


This application note was written by Gemma Finnegan Technical Safety Consultant / Fire and Gas Consultant Engineer 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 now designs Fire and Gas detection 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. Since writing this application note she has obtained a new position within the company of Senior Safety Consultant.*

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