Delivering Project Certainty Through 3D Fire and Gas Modelling

James McNay
Director of Consultancy and Engineering
Institute of Measurement & Control
London Section
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Micropack (Engineering) Ltd.

- **Scottish** Hazard Detection Company
- **Joint Inventors** of modern day Fire and Gas Mapping with **Shell Global Solutions 1989**
- Design & manufacture of **flame detectors since 1996**
- World leader in **Intelligent Visual Flame Detection**
- Markets
  - Oil & Gas, Refining, Petrochemical, Waste, Aviation, Tunnels, LNG & Marine

*Customers Trust our Expert Knowledge*

www.micropackfireandgas.com
Why Fire and Gas Mapping?

• Fire and Gas mapping answers the following questions:
  • What detectors will respond to the hazard?
  • Where should the detectors be positioned?
  • How many detectors are needed?
  • How can I be sure the area of concern is protected to an acceptable level?
  • How do I address change management?

• This presentation will show how fire and gas mapping **actively contributes to Project Certainty** by;
  • Providing optimised detection coverage
  • Reduced design time
Improving Design Quality and Consistency

**F&G MAPPING**

**Knowledge (Design and Technology)**

- Hazard identification
- Define escalation potential
- Performance definition
- Mitigation actions
- Review detector contributions

**Modelling (Software)**

- Apply detection thresholds to equipment
- Define voting
- Device placement & area of influence
- Coverage
- Detector contributions

**F&G MAPPING**

**What detectors will respond to the hazard?**

**Where should the detectors be positioned?**

**How many detectors are needed?**

**How can I be sure the area of concern is protected to an acceptable level?**
What is the Purpose of Detection?

F&G Detection Focus

Escalation to other process/Explosive cloud

Fire Escalation, Cloud formation

Incipient fire/Ignition

Secondary Fires, Explosion

Break in Containment

Escalation Effects

Uncertainty in consequences
The flame detection problem

• How do we know if we have enough flame detectors?

• How do we know where to position our flame detectors?

• How do we know our flame detectors are appropriate to detect a specific flame?
What does a detector see?
Example Consideration: Flame Detector Behaviour to Large Fires

- Flame detectors should have the ability to detect fires which are:
  - Close to the detector
  - Far away from the detector
Flame Detection Modelling – Grading Process

Flame Detection Targets

• Certain practices apply a high risk grade with a surrounding lower risk grade. This is termed a **Nested Fire Grade**. (Zone within a Zone).

• Nested Fire Grade benefits:
  • Ability to account for different fire scenarios
  • Accommodates the limitations of some flame detectors

• Application example, a high pressure vessel
  • Flame detector challenge – the need to detect small fires may mean large fires cannot be detected due to sensor saturation
  • High pressure gas fire (need to detect large fire)
  • Fire from adjacent equipment impinging on high risk equipment (need to detect small fire)
Flame Detection Mapping – Grading Process
Performance Based Design

➢ Red High Risk Immediately Next to Vessel
  • High Risk 10kW Alarm, 50kW Control Action, 1m extension.
    ➢ A small independent fire (i.e. not from the vessel itself) will be detected and actioned before causing a rupture on the high risk equipment

➢ Orange Medium Risk Surrounding the High Risk Grade
  • Medium Risk 50kW Alarm, 100kW Control Action, 3m extension
    ➢ Detects potential jet fires when they become more visible to detectors, further from the vessel.
    ➢ Detectors very close to the vessel may become saturated, but can detect secondary fires which may be the cause of a higher escalation rupture
Reporting Feature: Flame Detection Assessment

HazMap3D version
Assessment Date

Detector Total; Review type: Existing, New, Relocated
Coverage achieved

<table>
<thead>
<tr>
<th>MR/LR/SR</th>
<th>Fire graded equipment</th>
<th>Selected alarm and control points met (200N)</th>
<th>Fire must grow</th>
<th>Alarm point met only (100N)</th>
<th>No detection, alarm when fire grows</th>
<th>No detection point met</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LR</td>
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<td>SR</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Totals</td>
<td>76%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
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</table>
**Review detector contributions**

*Engineering Judgement* determines if the contribution of each detector is sufficient to maintain its place in the model.

**DETECTOR CONTRIBUTIONS**

<table>
<thead>
<tr>
<th>TAG</th>
<th>Individual</th>
<th>100N</th>
<th>200N</th>
<th>&gt;200N</th>
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<tbody>
<tr>
<td>All Detectors</td>
<td>45.1</td>
<td>95.5</td>
<td>76.6</td>
<td>29.1</td>
</tr>
<tr>
<td>FD001</td>
<td>68.0</td>
<td>93.3</td>
<td>51.6</td>
<td>15.6</td>
</tr>
<tr>
<td>FD002</td>
<td>44.4</td>
<td>92.8</td>
<td>55.4</td>
<td>13.0</td>
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<tr>
<td>FD003</td>
<td>48.0</td>
<td>91.6</td>
<td>58.9</td>
<td>7.1</td>
</tr>
<tr>
<td>FD004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Tag No** | **Type**         | **X,Y,ALD(m)** | **Pan/Tilt(deg)** | **Comments**
---|------------------|----------------|-------------------|----------------|
Det01  | Det-X3301(Med)  | 29.300 6.340 2.760 | +180 +13          |
Det02  | Generic25m      | 26.500 0.290 2.860 | +142 +13          |
Det03  | Generic25m      | 14.321 0.265 2.765 | +65  +13          |
Det04  | Generic25m      | 26.090 0.010 2.760 | +142 +13          |
Appropriate device selection can save money

Assessment title: All FDS301
Number of detectors: 10

Assessment title: Same Layout Triple IR
Number of detectors: 10

Assessment title: Triple IR w/ more devices
Number of detectors: 16 (9 existing, 6 new, 1 relocated)
Gas Detection Mapping – Grading Process

Blockage Ratio – Ignition Behaviour

Case (a): Congestion with 78 pipes

Time (ms)

30

60

90

Case (b): Congestion with 42 pipes
Gas Detection Mapping – Grading Process

Grade Volume

Add Detectors
Gas Detection Mapping Assessment
## Detector Contributions

### GAS DETECTOR DETAILS

<table>
<thead>
<tr>
<th>Tag</th>
<th>Type</th>
<th>Status</th>
<th>Det X,Y,ALD (m)</th>
<th>Rec X,Y,ALD (m)</th>
<th>L</th>
<th>H</th>
<th>L</th>
<th>H</th>
<th>2L</th>
<th>H</th>
<th>2H</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPGD001</td>
<td>DR Pulsar 2 (m)</td>
<td>Exists</td>
<td>4.995 37.800 3.492</td>
<td>46.072 38.116 3.562</td>
<td>39.4%</td>
<td>24.1%</td>
<td>3.7%</td>
<td>10.0%</td>
<td>24.9%</td>
<td>20.0%</td>
<td>12.4%</td>
</tr>
<tr>
<td>OPGD002</td>
<td>HW Excel (m)</td>
<td>Exists</td>
<td>4.995 31.737 3.210</td>
<td>46.099 31.569 3.665</td>
<td>64.8%</td>
<td>29.2%</td>
<td>3.1%</td>
<td>10.2%</td>
<td>34.8%</td>
<td>21.1%</td>
<td>16.3%</td>
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<tr>
<td>OPGD003</td>
<td>DR Pulsar 1 (m)</td>
<td>Exists</td>
<td>4.995 22.776 3.330</td>
<td>34.328 22.664 4.085</td>
<td>52.2%</td>
<td>12.4%</td>
<td>6.2%</td>
<td>9.6%</td>
<td>21.4%</td>
<td>15.0%</td>
<td>0.1%</td>
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<tr>
<td>OPGD004</td>
<td>HW Excel (m)</td>
<td>Exists</td>
<td>4.995 14.923 2.906</td>
<td>46.062 15.132 4.127</td>
<td>47.8%</td>
<td>26.9%</td>
<td>9.6%</td>
<td>18.6%</td>
<td>15.7%</td>
<td>8.8%</td>
<td>3.5%</td>
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<tr>
<td>IRPGD001</td>
<td>SIM-GD10P</td>
<td>Exists</td>
<td>22.381 17.532 2.716</td>
<td>19.4%</td>
<td>11.1%</td>
<td>0.0%</td>
<td>6.7%</td>
<td>7.3%</td>
<td>6.7%</td>
<td>0.6%</td>
<td></td>
</tr>
</tbody>
</table>

### PROJECT INFORMATION

- **Project name:** Production Deck
- **Assessment title:** Proposed Gas Detection
- **Number of detectors:** 3
- **Calculation model:** Sample

### ASSESSMENT VOLUME DIMENSIONS

- **Height:** 4.00 m
- **Length:** 30.00 m
- **Width:** 40.00 m
- **Deck Z:** 0.00 m

### ASSESSMENT PARAMETERS

- **Grading Rules (only grades used in assessment are shown):**
  - **Grade:** C/S/G, Open
  - **Hi Gas Diameter:** 5.00m, 15.00m
  - **Lo Gas Diameter:** 10.00m, 30.00m

Assessment performed using 15 slices from 2.00 m to 6.00 m
Increment between 3D assessment slices: 0.29 m

### ASSESSMENT SUMMARY

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Grade</th>
<th>Grade</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi control</td>
<td>C/S/G</td>
<td>37%</td>
<td>54%</td>
</tr>
<tr>
<td>Hi control</td>
<td>Open</td>
<td>92%</td>
<td>54%</td>
</tr>
<tr>
<td>Hi control</td>
<td>Overall</td>
<td>63%</td>
<td>54%</td>
</tr>
<tr>
<td>Lo control</td>
<td>C/S/G</td>
<td>37%</td>
<td>54%</td>
</tr>
<tr>
<td>Lo control</td>
<td>Open</td>
<td>92%</td>
<td>54%</td>
</tr>
<tr>
<td>Lo control</td>
<td>Overall</td>
<td>63%</td>
<td>54%</td>
</tr>
</tbody>
</table>
Gas Detection – Target Gas Cloud vs Dispersion Modelling

Reliability of Approach

• If we determine an 8m cloud can cause an overpressure of >150mBar in a module of a facility, shouldn’t we design the system to ensure this is detected?

• If we conduct probabilistic dispersion scenarios, how many scenarios are enough?
  – 50,000 crude scenarios in ‘2D’?
  – 50 detailed CFD simulation (likely not even that many)?
  – If we run ‘enough’ simulations (hundreds of millions of scenarios?) we find that gas can **and does** go anywhere – was it worth the time and cost?
  – Are you comfortable placing detection based on such a limited sample?
  – Can the 8m gas cloud remain undetected in certain circumstances?
  – Will designs be inconsistent dependent upon the operator of the simulations and the tool being used?
  – Will it ultimately result in **more** detectors? There is always another scenario to run and more detectors to add…
Gas Detection Effectiveness – The False Narrative

The UK Health and Safety Executive statistics on gas releases:
• 1993-2015 approx. half of gas releases were undetected by fixed gas detection systems in the UKCS

• Narrative which has been drawn:
  – Gas detection placement inadequate
  – Methods advised on gas detection design inadequate

• This narrative is not founded on scientific principles:
  – Were the releases large enough to present the explosion hazard in which the detectors are designed to prevent?
  – Was the layout of gas detectors in compliance with the best practice guidance available? Probably not.
  – Were all of the detectors in operation at the time of gas release? Probably not.

When all of these factors are considered, detecting half of the recorded releases could be viewed as impressive!
Scenario vs Geographic – Debunking the Myths

- Using gas dispersion modelling will design a more effective gas detection system… debunked:
  - The following graph is often cited to promote dispersion based mapping… but is flawed in its analysis:

![Graph showing comparison between scenario and geographic approaches.](image)

(Scenario-based fire & gas mapping as a way to optimise detection layouts. Presented at FABIG TM94, DNVGL)

- Verification runs the same scenarios and assumptions which were used to generate the layout – of course it will show good detection ‘effectiveness’ for the layout.
- The performance is also to ‘no. of leaks detected’. Ultimately we don’t care if the detection system detects 99% of leaks if they are all insignificant – we care about the 1% which will cause an explosion.
- If we run an alternative analysis of effectiveness as ‘how many times will the gas cloud of concern remain undetected’ then the **scenario based design will be highly ineffective** but the **geographic layout will be 100% effective**.
Scenario vs Geographic – Debunking the Myths

• Gas Dispersion Based Mapping will reduce the number of gas detectors required... debunked:
  – If we run one scenario and place detectors where the gas goes = very few detectors. **Not a suitable design though.**
  – If we run a ‘suitable’ number of scenarios, gas will go everywhere and we have to **place detectors all over the module,** whether an explosion hazard exists or not.

**Case Study** (from ‘Optimizing Gas Detectors’ presentation, ISA UAE Conference, May, 2016):
  – Reduced 27 detectors to 17 detectors (using scenario based approach) while only reducing coverage from 91% to 86%
  – In reality, the geographic approach could provide 100% coverage of the module using ~5 line of sight detectors (practicality dependant) – quite a cost saving from the ‘optimised’ scenario based approach which recommended 17! Think of all that cable and maintenance!
  – Also, the approach which recommended 17 detectors left significant gaps which a substantial gas cloud would remain undetected.
Modelling comparisons
- detecting gas accumulations

Gas Dispersion Layout - 14 detectors

Volumetric Approach – 8 detectors
Modelling comparisons - detecting gas accumulations

Gas Dispersion Layout - 14 detectors

Volumetric Approach – 8 detectors
Summary
Fire & Gas Mapping - Improving Design Quality and Consistency

What detectors will respond to the hazard?
Where should the detectors be positioned?

How many detectors are needed?
How can I be sure the area of concern is protected to an acceptable level?
Thank you very much for your attention

James McNay
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jmcnay@micropack.co.uk