Performance analysis
Sour gas detection around wellhead area
(WHP#1 1.0%H2S 88.0%CH4)
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Performance analysis
The importance of early detection

Early detection and mitigation help limit growth of gas clouds with dangerous concentrations, hence reduce the consequences of gas releases.

Performance analysis
Detection coverage is the most significant influence on FGS effectiveness

<table>
<thead>
<tr>
<th>Hazard scenario</th>
<th>Detection coverage</th>
<th>FGS availability</th>
<th>Mitigation effect</th>
<th>Likelihood Additional remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.99</td>
<td>0.50</td>
<td>0.99</td>
<td>Funmitigated = 1.0E‐04 per year</td>
</tr>
<tr>
<td></td>
<td>0.9998</td>
<td>0.50</td>
<td>0.99</td>
<td>PFDSE = 1.0E‐04</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>0.50</td>
<td>0.99</td>
<td>PFDLS = 1.0E‐05</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>0.50</td>
<td>0.99</td>
<td>FGS unavailability = 0.0002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FGS availability = 0.9998</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FGS effectiveness = Detection coverage X FGS availability X Mitigation effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Unmitigated risk = Funmitigated X (1 – FGS effectiveness)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RRF = 1 / (1 – FGS effectiveness)</td>
</tr>
</tbody>
</table>

Ref. : TR84.00.07‐2018

Risk reduction with FGS

After initial FGS implementation
After gas mapping
Risk without FGS
Risk with FGS
Unacceptable region
Tolerable region
Broadly acceptable region
Negligible risk

Risk mapping result is highly dependent on the assumptions made for release and site conditions.

Achieving an effective FGS while minimizing costs is an engineering challenge

Cost of Ownership
Effective FGS
1. Performance targets

The derived performance target for both flammable gas detection and toxic gas detection is ≥80%.

Typical grading definition

<table>
<thead>
<tr>
<th>Grade</th>
<th>Definition</th>
<th>Detector coverage</th>
<th>FGS safety availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Hydrocarbon processing, with high exposure</td>
<td>0.90</td>
<td>0.95</td>
</tr>
<tr>
<td>B</td>
<td>Hydrocarbon processing, with moderate exposure</td>
<td>0.80</td>
<td>0.90</td>
</tr>
<tr>
<td>C</td>
<td>Hydrocarbon processing, with low exposure</td>
<td>0.60</td>
<td>0.90</td>
</tr>
<tr>
<td>No FGS</td>
<td>Risk is tolerable without benefit of FGS</td>
<td>No detection is required</td>
<td>No detection is required</td>
</tr>
</tbody>
</table>

2. Consequence modelling

Gas release points modelled:

Release rate due to flange failure = 0.0001/year
Total release rate = 1.6E-3/year
Gas composition used in dispersion model:

- **Components**
  - CH4
  - H2S
  - CO2
  - N2
  - He
  - Ar
  - Ne
  - Kr
  - Xe
  - Neon
  - Argon
  - Krypton
  - Xenon

- **Selected Components**
  - CH4
  - H2S
  - CO2
  - N2
  - He
  - Ar
  - Ne
  - Kr
  - Xe
  - Neon
  - Argon
  - Krypton
  - Xenon

Performance analysis

### Input parameters used in dispersion model

<table>
<thead>
<tr>
<th>Group</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Sour gas mixture, WHP1</td>
</tr>
<tr>
<td>Specify volume inventory?</td>
<td>No</td>
</tr>
<tr>
<td>Mass inventory</td>
<td>100 kg</td>
</tr>
<tr>
<td>Volume inventory</td>
<td>12,360 m3</td>
</tr>
<tr>
<td>Material to track</td>
<td>1. Hydrogen Sulfide; 2. Methane</td>
</tr>
<tr>
<td>Phase</td>
<td>Specified condition</td>
</tr>
<tr>
<td>Temperature</td>
<td>35 degC</td>
</tr>
<tr>
<td>Pressure (gauge)</td>
<td>50 bar</td>
</tr>
<tr>
<td>Fluid state</td>
<td>Vapor</td>
</tr>
<tr>
<td>Liquid mole fraction</td>
<td>0 fraction</td>
</tr>
</tbody>
</table>

### Discharge Results (after atmospheric expansion)

<table>
<thead>
<tr>
<th>Path</th>
<th>Scenario</th>
<th>Weather</th>
<th>Mass flow rate</th>
<th>Temperature</th>
<th>Liquid mass fraction</th>
<th>Droplet diameter</th>
<th>Expanded diameter</th>
<th>Velocity</th>
<th>Release duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressurized release of sour gas</td>
<td>5mm leak hole</td>
<td>Category 2/B</td>
<td>0.165</td>
<td>-100.744</td>
<td>0</td>
<td>0.015647</td>
<td>653.12</td>
<td>3021.79</td>
<td></td>
</tr>
</tbody>
</table>

### Leak hole size for assessment

Reference:
- Leak frequencies from the Hydrocarbon release database (Symposium Series No. 151 2006 IChemE)

- ≈ 80% of leaks < 10mm
- ≈ 20% of leaks > 10mm

2.1 Dispersion plume 1.0%H2S 88.0%CH4

(5mm leak hole)
2.2 Dispersion plume 1.0%H2S 88.0%CH4 (10mm leak hole)
3. Detector selections

"Dispersion in open areas resulting from momentum, evaporation or a combination of both may be subject to mixing from collisions and wind turbulence. For open areas, open-path gas detectors are generally better than point detectors. They increase the probability of detection, i.e. have high coverage, and produce path-integrated concentration measurements (i.e. measurement units of LFL/m) which is a better measure of risk for dispersed clouds. They also, crucially, offer the benefits of detecting gas anywhere along the line-of-sight, rather than relying on air movement to carry the gas cloud to the detector, as with point gas detectors."


"Increasing the detection rate of leaks could be improved by networking the flammable gas detectors and acoustic (also known as ultrasonic) leak detectors and applying detection algorithms to the gas/leak detection system in addition to the use of a basic (e.g. low and high) alarm threshold on individual detectors."

In line with HSE’s RR1123 recommendations, MSA advocates the application of different detection types in protection layers where ever possible.

4. Gas detection coverage assessment

Performance analysis

Point detector mounting and layout

Performance analysis

Open-path detector mounting and layout
### 4.1.1 H₂S gas detection coverage assessment

(5mm leak, 10ppm plume)

#### Performance analysis

**Alarm thresholds applied in assessments**

<table>
<thead>
<tr>
<th>Gas detector</th>
<th>Measuring range</th>
<th>Alarm threshold for 10ppm plume</th>
<th>Alarm threshold for 20ppm plume</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄ gas detector</td>
<td>0 - 1000 ppm</td>
<td>0.1 LFL</td>
<td>0.3 LFL</td>
</tr>
<tr>
<td>ELDS-F</td>
<td>0 - 2500 ppm</td>
<td>75 ppm.m</td>
<td>(minimum alarm threshold)</td>
</tr>
<tr>
<td>OPQD-F</td>
<td>0 - 5000 ppm</td>
<td>1.0 LFL.m</td>
<td>(minimum alarm threshold)</td>
</tr>
<tr>
<td>H₂S Gas detector</td>
<td>Measuring range</td>
<td>Alarm threshold for 10ppm plume</td>
<td>Alarm threshold for 20ppm plume</td>
</tr>
<tr>
<td>PGD-T</td>
<td>0 - 100 ppm</td>
<td>10 ppm</td>
<td>20 ppm</td>
</tr>
<tr>
<td>ELDS-T</td>
<td>0 - 2500 ppm.m</td>
<td>75 ppm.m</td>
<td>(minimum alarm threshold)</td>
</tr>
</tbody>
</table>

#### Performance analysis

**Geographic coverage vs. Scenario coverage**

<table>
<thead>
<tr>
<th>Parameter considered?</th>
<th>Geographic</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind direction changes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Wind speed</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Release directions</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Rate of release / gas cloud size (L x W)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Concentration of gas cloud</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Detectable concentration by detector</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Percentage of release scenarios covered</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Release frequency</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Alarm threshold</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Relative height of detector</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Critical cloud size</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Percentage of graded area covered</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

#### Performance analysis

**Unmitigated risk map**

- Scenario:
  - 5mm leak hole
  - 2.0m release height
  - 2.4m/s B wind
  - 10ppm H₂S plume

- Performance analysis:
  - Gas Release Frequency = 1.6e-3
  - Mitigated Release Frequency = 9.3e-5
  - Residual Release Frequency = 1.5e-3
  - Scenario Coverage Factor = 5.8 %

#### Performance analysis

**10ppm H₂S alarming with ELDS-T**

- Geographic coverage
- Scenario coverage

#### Performance analysis

**10ppm H₂S alarming with PGD-T**

- Geographic coverage
- Scenario coverage
4.1.2 H₂S gas detection coverage assessment (5mm leak, 20ppm plume)

Performance analysis

20ppm H₂S alarming with PGD-T
Geographic coverage
Scenario coverage

20ppm H₂S alarming with ELDS-T
Geographic coverage
Scenario coverage

4.1.3 H₂S gas detection coverage assessment (10mm leak, 10ppm plume)

Performance analysis

20ppm H₂S alarming with PGD-T
Geographic coverage
Scenario coverage

20ppm H₂S alarming with ELDS-T
Geographic coverage
Scenario coverage
4.1.4 H₂S gas detection coverage assessment (10mm leak, 20ppm plume)
4.1.5 H₂S gas detection coverage assessment (Summary)

Performance analysis

H₂S detection probability summary

<table>
<thead>
<tr>
<th>Sour gas composition</th>
<th>Source (target)</th>
<th>Quantity</th>
<th>Leak size</th>
<th>100N alarming</th>
<th>200N alarming</th>
<th>5mm</th>
<th>10mm</th>
<th>5mm</th>
<th>10mm</th>
<th>5mm</th>
<th>10mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%H₂S 88.0%CH₄ @50barg</td>
<td>PGD-T (10ppm)</td>
<td>15</td>
<td>5mm</td>
<td>88%</td>
<td>70%</td>
<td>0%</td>
<td>22%</td>
<td>10mm</td>
<td>85%</td>
<td>83%</td>
<td>0%</td>
</tr>
<tr>
<td>1%H₂S 88.0%CH₄ @50barg</td>
<td>PGD-T (10ppm)</td>
<td>15</td>
<td>10mm</td>
<td>88%</td>
<td>74%</td>
<td>0%</td>
<td>25%</td>
<td>10mm</td>
<td>89%</td>
<td>84%</td>
<td>0%</td>
</tr>
<tr>
<td>1%H₂S 88.0%CH₄ @50barg</td>
<td>ELDS-T (75ppm m)</td>
<td>0.5</td>
<td>5mm</td>
<td>100%</td>
<td>32%</td>
<td>81%</td>
<td>4%</td>
<td>10mm</td>
<td>100%</td>
<td>52%</td>
<td>81%</td>
</tr>
<tr>
<td>1%H₂S 88.0%CH₄ @50barg</td>
<td>ELDS-T (75ppm m)</td>
<td>0.5</td>
<td>10mm</td>
<td>100%</td>
<td>15%</td>
<td>81%</td>
<td>0%</td>
<td>10mm</td>
<td>100%</td>
<td>29%</td>
<td>81%</td>
</tr>
</tbody>
</table>

*1: alarming probability calculations assume a homogeneous 20ppm plume. *2: alarming probability calculations assume a homogeneous 10ppm plume.

4.2.1 CH₄ gas detection coverage assessment (5mm, 10%LFL plume)

Performance analysis

Unmitigated risk map

Scenario:
- 5mm leak hole
- 2.0m release height
- 2.4m/s B wind
- 10%LFL CH₄ plume

Performance analysis

10%LFL CH₄ alarming with PGD-F

Scenario coverage

Performance analysis

0.2LFL m CH₄ alarming with ELDS-F

Scenario coverage
4.2.2 CH₄ gas detection coverage assessment (5mm, 30%LFL plume)
4.2.3 CH₄ gas detection coverage assessment (10mm, 10%LFL plume)

Performance analysis

Geographic coverage

Scenario: 10mm leak hole, 2.0m release height, 2.4m/s B wind, 10%LFL CH₄ plume

1.0LFL.m CH₄ alarming with OPGD-F

Performance analysis

Geographic coverage

Scenario: 1.0LFL.m CH₄ alarming with OPGD-F

4.2.4 CH₄ gas detection coverage assessment (10mm, 30%LFL plume)
4.2.5 CH₄ gas detection coverage assessment (Summary)

**Scenario:**
- 10mm hole leak size
- 2.0m release height
- 2.4m/s B wind
- 30% LFL CH₄ plume

**Gas Release Frequency** = 1.6e-3
**Mitigated Release Frequency** = 6.4e-5
**Residual Release Frequency** = 1.5e-3

**Scenario Coverage Factor** = 4.0%

**Geographic Coverage**

**10m**
- 30% LFL alarm threshold
- 100% voting
- Gas Release Frequency = 1.6e-3
- Mitigated Release Frequency = 1.2e-4
- Residual Release Frequency = 1.5e-3
- Scenario Coverage Factor = 7.2%

**1.0LFL CH₄ alarming with OPGD-F (Summary)**

<table>
<thead>
<tr>
<th>Source gas composition</th>
<th>Setpoint [LFL]</th>
<th>Quantity</th>
<th>Leak size</th>
<th>Leak alarming</th>
<th>Leak alarming</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>0.2LFL.m</td>
<td>5mm</td>
<td>100%</td>
<td>61%</td>
<td>81%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10mm</td>
<td>100%</td>
<td>84%</td>
<td>81%</td>
</tr>
</tbody>
</table>

**1.0LFL.m CH₄ alarming with OPGD-F (Summary)**

<table>
<thead>
<tr>
<th>Source gas composition</th>
<th>Setpoint [LFL]</th>
<th>Quantity</th>
<th>Leak size</th>
<th>Leak alarming</th>
<th>Leak alarming</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>0.2LFL.m</td>
<td>5mm</td>
<td>100%</td>
<td>61%</td>
<td>81%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10mm</td>
<td>100%</td>
<td>84%</td>
<td>81%</td>
</tr>
</tbody>
</table>

**Performance analysis**

**Scenario coverage**

**0.2LFL CH₄ alarming with ELDS-F (Summary)**

<table>
<thead>
<tr>
<th>Source gas composition</th>
<th>Setpoint [LFL]</th>
<th>Quantity</th>
<th>Leak size</th>
<th>Leak alarming</th>
<th>Leak alarming</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>0.2LFL.m</td>
<td>5mm</td>
<td>100%</td>
<td>46%</td>
<td>81%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10mm</td>
<td>100%</td>
<td>63%</td>
<td>81%</td>
</tr>
</tbody>
</table>

**0.1LFL CH₄ alarming with ELDS-F (Summary)**

<table>
<thead>
<tr>
<th>Source gas composition</th>
<th>Setpoint [LFL]</th>
<th>Quantity</th>
<th>Leak size</th>
<th>Leak alarming</th>
<th>Leak alarming</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>0.2LFL.m</td>
<td>5mm</td>
<td>100%</td>
<td>46%</td>
<td>81%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10mm</td>
<td>100%</td>
<td>63%</td>
<td>81%</td>
</tr>
</tbody>
</table>

**Performance analysis**

**Scenario coverage**

**1.0LFL CH₄ alarming with OPGD-F (Summary)**

<table>
<thead>
<tr>
<th>Source gas composition</th>
<th>Setpoint [LFL]</th>
<th>Quantity</th>
<th>Leak size</th>
<th>Leak alarming</th>
<th>Leak alarming</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>1.0LFL.m</td>
<td>5mm</td>
<td>100%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10mm</td>
<td>100%</td>
<td>7%</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Performance analysis**

**Scenario coverage**

**4.2.5 CH₄ gas detection coverage assessment (Summary)**
4.3 Supplementary protection layer with UGLD

Performance analysis
Supplementing point detectors with UGLD

Performance analysis
Supplementing open-path detectors with UGLD

Performance analysis
Improving probability of 200N alarming with UGLD

<table>
<thead>
<tr>
<th>Solution</th>
<th>Tmax/LFL</th>
<th>Quantity</th>
<th>Leak size</th>
<th>UGLD</th>
<th>Probability of alarming</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGD-F</td>
<td>10%LFL</td>
<td>15</td>
<td>5mm</td>
<td>52%</td>
<td>7% 53%</td>
</tr>
<tr>
<td>ELDS-F</td>
<td>1.0LFL/m</td>
<td>06</td>
<td>5mm</td>
<td>61%</td>
<td>24% 68%</td>
</tr>
<tr>
<td>OPGD-F</td>
<td>0.2LFL/m</td>
<td>06</td>
<td>5mm</td>
<td>1%</td>
<td>0% 1%</td>
</tr>
</tbody>
</table>
Performance analysis

The advantage of UGLD over conventional gas detectors

Performance analysis

Conventional UGLD – High noise areas

Performance analysis

Conventional UGLD – Low noise areas

Performance analysis

UGLD with ANN can discriminate between real gas leak noise and background noise

Performance analysis

ANN gas leak recognition increases the probability of alarming in high background noise areas
Performance analysis

Observations

1. The geographic coverage assessment method is unable to show differences in alarming probabilities for different release scenarios. Neither can it show differences in alarming probabilities when different gas detectors or different measuring ranges are used.

2. For this application, scenario coverage assessments show that a smaller quantity of OPGD (6 qty) is more effective than three times larger quantity of PGD (15 qty) for CH4 detection. However, for H2S detection, the reverse is true. Released gas concentrations and the OPGD alarm threshold are the key factors.

3. The OPGD measuring range is critical. For alarming probability, the OPGD with a 0-1 LFL.m measuring range significantly outperforms the OPGD with 0-5 LFL.m measuring range.

4. It is not easy to achieve a high (>80%) 200N voted alarming probability for small (5-10mm) leaks even at significant leak rates. Lowering alarm thresholds will improve the probability. The UGLD can also be used to increase 200N voted alarming probability. Combining PGD or OPGD with UGLD can lead to higher alarming probability at a lower TCO (i.e. Higher Effectiveness/TCO ratio).

5. For sour gas applications, it is possible to improve 200N voted alarming probability by voting H2S and CH4 alarms. Dual gas sensing type instruments can provide an effective solution at a lower TCO (i.e. Higher Effectiveness/TCO ratio).

Recommended solutions for this application

- S3000 x 15
  - Dual sensing open path gas detector
- OBSERVER-I x 01
  - Ultrasonic gas leak detector

OR

- EL10 x 10
  - Dual sensing open path gas detector
- OBSERVER-I x 01
  - Ultrasonic gas leak detector

Connect with us

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THANK YOU!