Determination of Ignition Probability for LNG spills

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Introduction

LNG Spills → Liquid + vapor → No ignition

Immediate Ignition → Pool Fire

Delayed Ignition → Jet fire

→ Flash Fire

→ Jet Fire

→ Vapor cloud explosion
Review of Approaches

- Historic data
  - Cox Approach\(^1\)
  - Purple book Approach\(^2\)
  - Federal spill databases- Ronza et Al \(^3\)

- Analytical/simulation approaches
  - HSE’s approach\(^4\)
  - Explosion Risk Cooperative\(^5\)
  - Scandpower\(^6\)

- Expert Judgment
  - Energy Institute look-up correlation.
Applicative case studies

- 2005, BP Global Gas SPU and MKOPSC established a research and development program to investigate LNG spill emergency response and hazard control.
- A series of medium-scale field tests have been carried out at the Brayton Fire Training Field (BFTF) for LNG research from 2005 to 2009.
- **Focus of research**
  - LNG Vapor Dispersion
  - Effective Use of Water Curtains in Dispersing LNG Vapor Cloud
  - Expansion Foam Application for LNG Hazard Mitigation
Applicative case studies

<table>
<thead>
<tr>
<th>Parameters</th>
<th>06LNG01</th>
<th>TEEX1</th>
<th>TEEX2</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG flowrate (kg/s)</td>
<td>1.8</td>
<td>5.3</td>
<td>4.4</td>
</tr>
<tr>
<td>Duration of experiment (s)</td>
<td>780</td>
<td>619</td>
<td>763</td>
</tr>
<tr>
<td>Average wind speed at 10m (m/s)</td>
<td>2.2</td>
<td>1.9±0.58</td>
<td>3.3±0.78</td>
</tr>
<tr>
<td>Average wind speed at 2.3m (m/s)</td>
<td>1.8</td>
<td>1.2±0.38</td>
<td>2.3±0.23</td>
</tr>
<tr>
<td>Wind direction</td>
<td>NE</td>
<td>SE</td>
<td>S,SE</td>
</tr>
<tr>
<td>Temperature at 10m (K)</td>
<td>299.05</td>
<td>289.19</td>
<td>290.71</td>
</tr>
<tr>
<td>Temperature at 3m (K)</td>
<td>299.65</td>
<td>289</td>
<td>290.11</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>64.5</td>
<td>32.6±1.6</td>
<td>31.2±1.2</td>
</tr>
<tr>
<td>Stability Class</td>
<td>D</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Monin-Obhukhov length (m)</td>
<td>498.3</td>
<td>8.3</td>
<td>85.8</td>
</tr>
<tr>
<td>Roughness length (m)</td>
<td>0.0001</td>
<td>0.00085</td>
<td>0.00085</td>
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<tr>
<td>Spill area (m²)</td>
<td>41</td>
<td>65</td>
<td>65</td>
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</tbody>
</table>

* Developed using Phast 6.7

Fig 1: LFL contours of 06LNG01, TEEX1 & TEEX2 using Phast 6.7
Ignition probability model

- Frequencies obtained from literature
Parameters affecting Ignition Probability

- **Flammable mass**
  - Continuous (small, medium & large)
  - Instantaneous
  - Reactivity (low, high)

- **Meteorological conditions**
  - Wind speed
  - Wind direction
  - Stability class

- **Ignition Sources**
  - Number (none, very few, few, many)
  - Strength (Certain, strong, medium, weak)

- **Congestion level**
  - Low
  - Medium
  - High
Classification of area

- Far and near radius.
- Differentiating Immediate and delayed ignitions.
  - Time
  - Space
- Areas classified based on ignition sources and strength.

Fig 2: Release area classified into two zones.
Results & discussion

- TEEX 2 has maximum ignition probability.
- TEEX1 has least.
- Delayed onsite and immediate ignition probabilities high for 06LNG01.

<table>
<thead>
<tr>
<th>Experiment Name</th>
<th>Immediate Ignition Probability</th>
<th>Delayed Onsite Ignition Probability</th>
<th>Delayed offsite Ignition Probability</th>
<th>Total Ignition probability</th>
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<tbody>
<tr>
<td>06LNG01</td>
<td>0.0072</td>
<td>0.0076</td>
<td>0.00023</td>
<td>0.015</td>
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<tr>
<td>TEEX1</td>
<td>0.0009</td>
<td>0.0018</td>
<td>1.14533E-05</td>
<td>0.002</td>
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<tr>
<td>TEEX2</td>
<td>0.00005</td>
<td>0.0019</td>
<td>0.0292</td>
<td>0.031</td>
</tr>
</tbody>
</table>
Sensitivity Analysis

Fig. 3. Variation of ignition probability with wind speed

Fig. 4. Variation of ignition probability with Area Blockage Ratio

Fig. 5. Variation of ignition probability with ignition source for 06LNG01, TEEX1 and TEEX2 (left to right)
Conclusion

• Detailed information about the facility required. (meteorological conditions, obstacles and ignition sources,...)

• Ignition probability heavily dependent on flammable mass.

• Both qualitative and quantitative risk analysis approach.

• Control measures can be taken to remove or eliminate the sources with high probability.

• Improved facility siting, Hazardous area classifications.
Acknowledgments

- Dr. Sam Mannan
- Dr. Ray Mentzer
- Dr. Susan Guo
- BP global gas SPU
- Brayton Fire Training Field, College Station
References

Questions?

LNG

Fast Fact

LNG gels are made from gelants methanol and water.

It offers safety benefits in transporting natural gas as LNG gel vaporisation rate on water is half of normal LNG.