# Transient Ignition Modeling of gas leaks in enclosures

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for a safer world

# Introduction

- Why is risk management important?

Failure → Hazard → Consequence

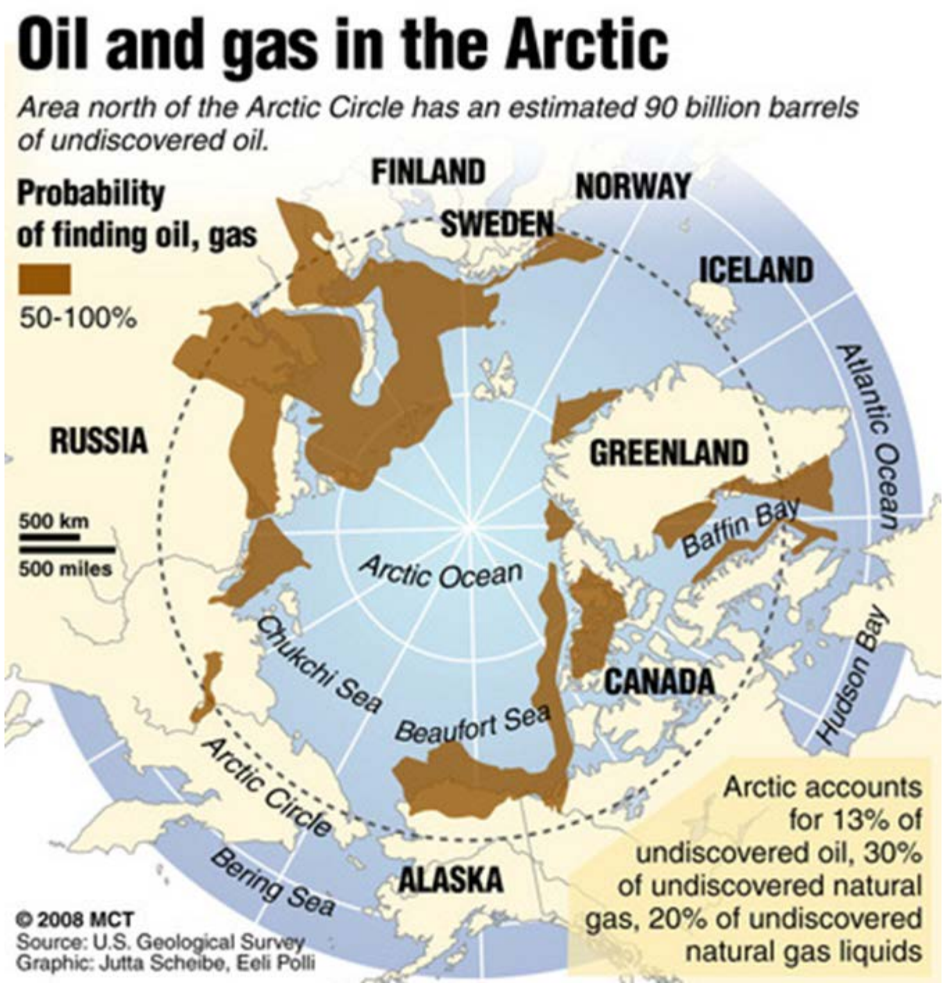
Barrier | Barrier

Gas Leaks

Fire and Explosions

- To manage the risk effectively, it should be assessed effectively.
- Solution : Computational Fluid Dynamics based Risk Analysis and Management

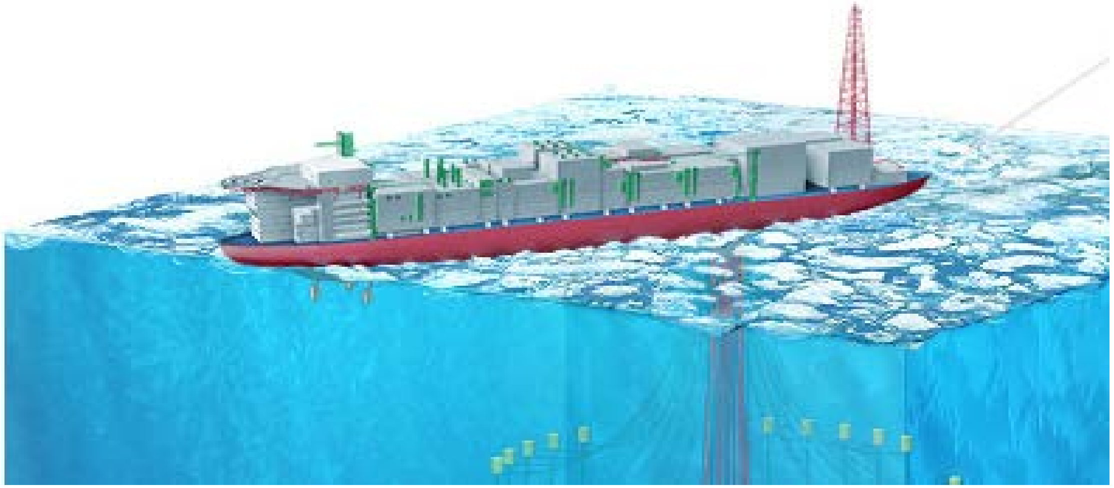
# Special Attention to Enclosed Modules




- Enclosed modules are often selected in arctic designs to:
  - Provide barrier between ice & snow and process equipment
  - Provide barrier between climate extremes and personnel

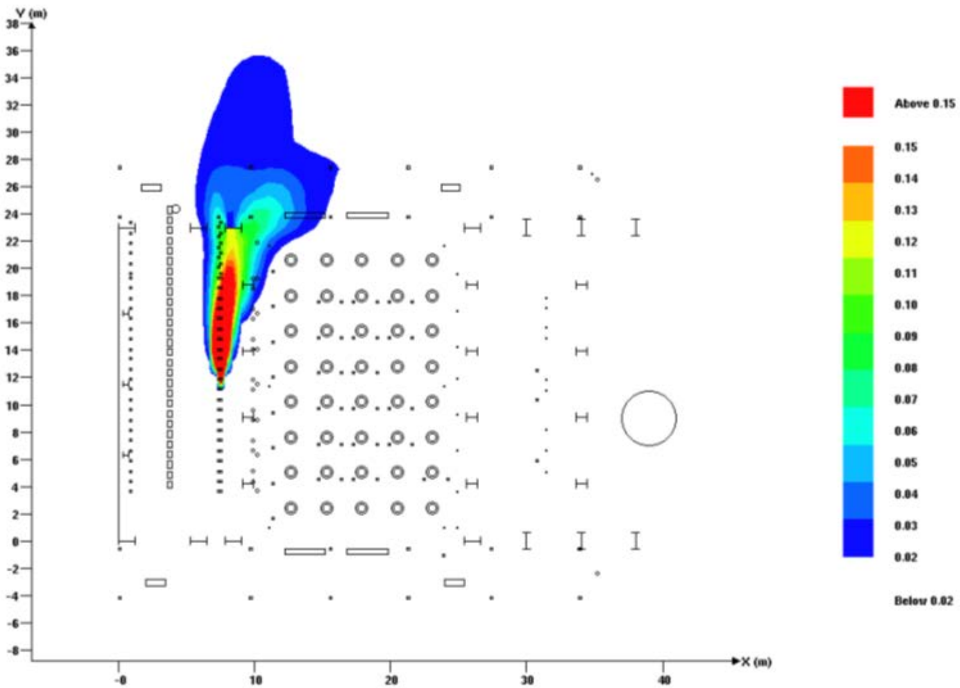
- Other (land) facilities may utilize confined modules in order to control the working environment (e.g. enclosing the pump house to prevent noise in operating areas)

# Examples of arctic designs..

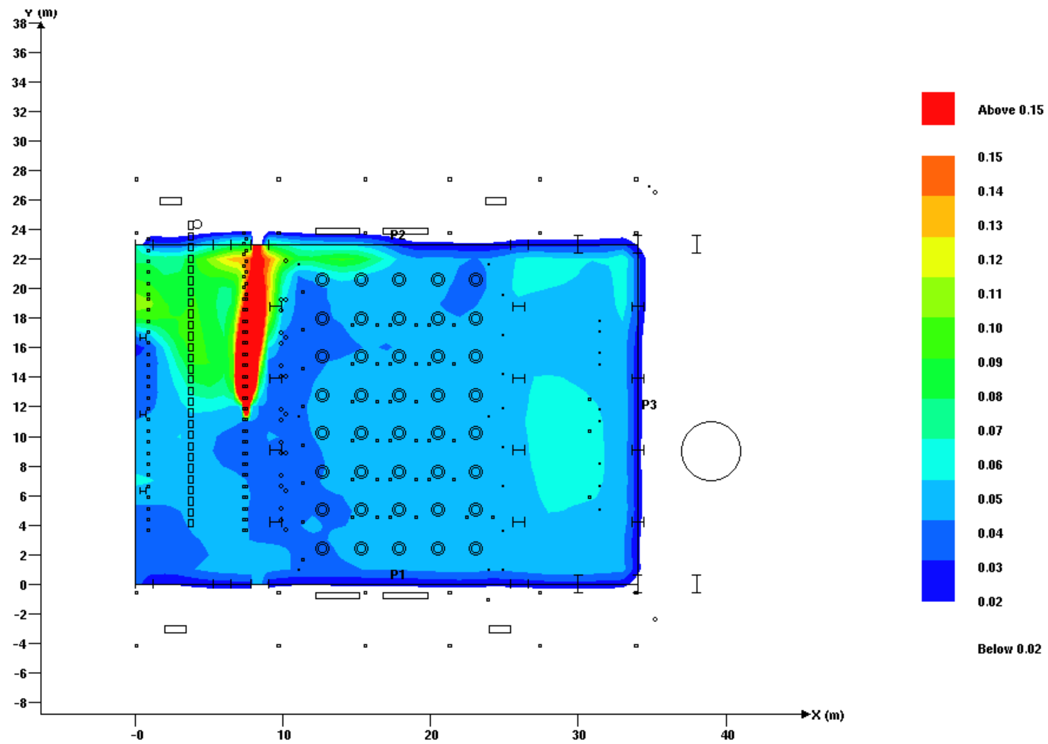



# Gas Leaks in Enclosures

Gas leak dynamics differ substantially for enclosed modules (mechanically ventilated with HVAC) and open modules (naturally ventilated)

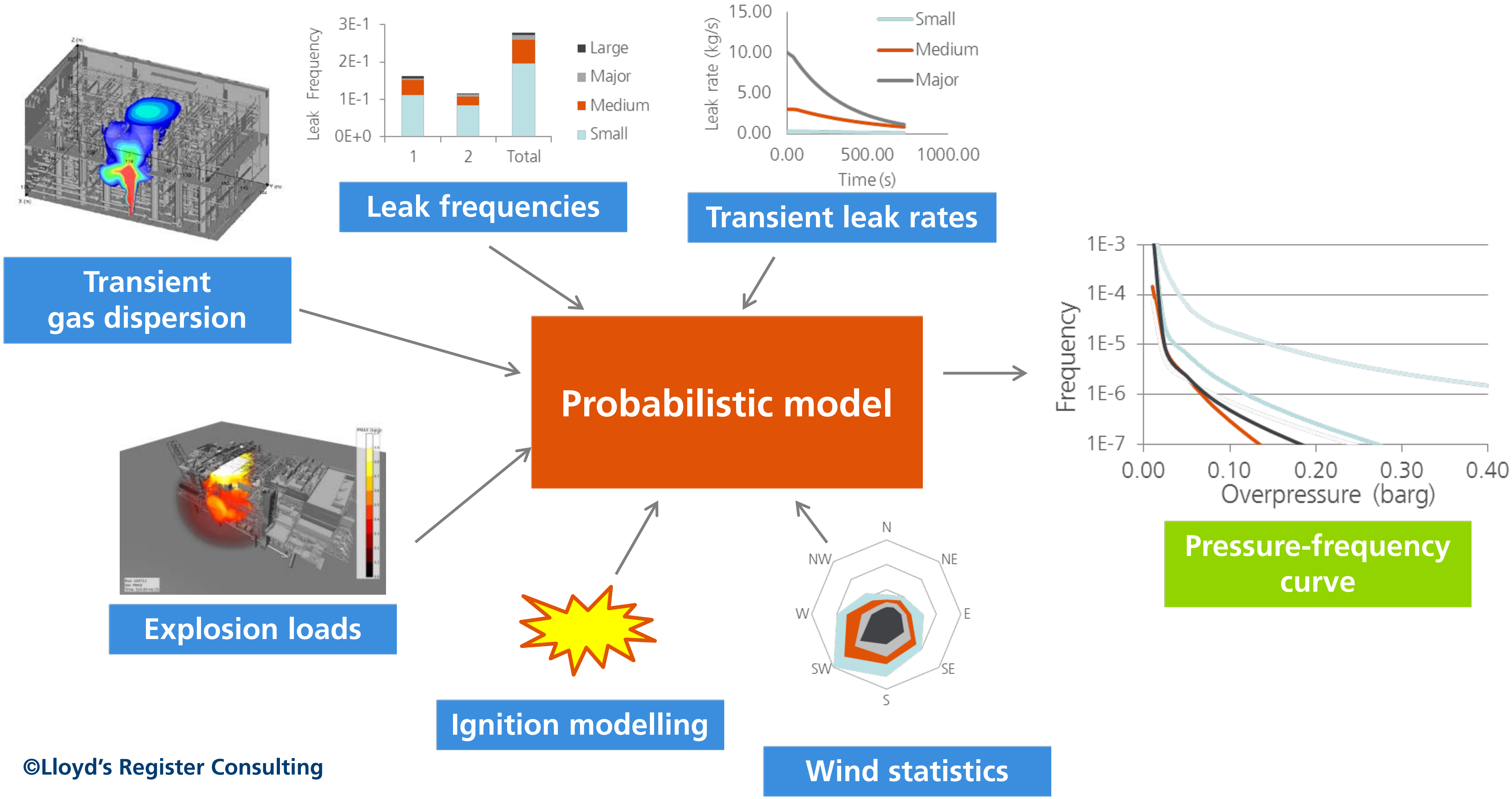



Open module

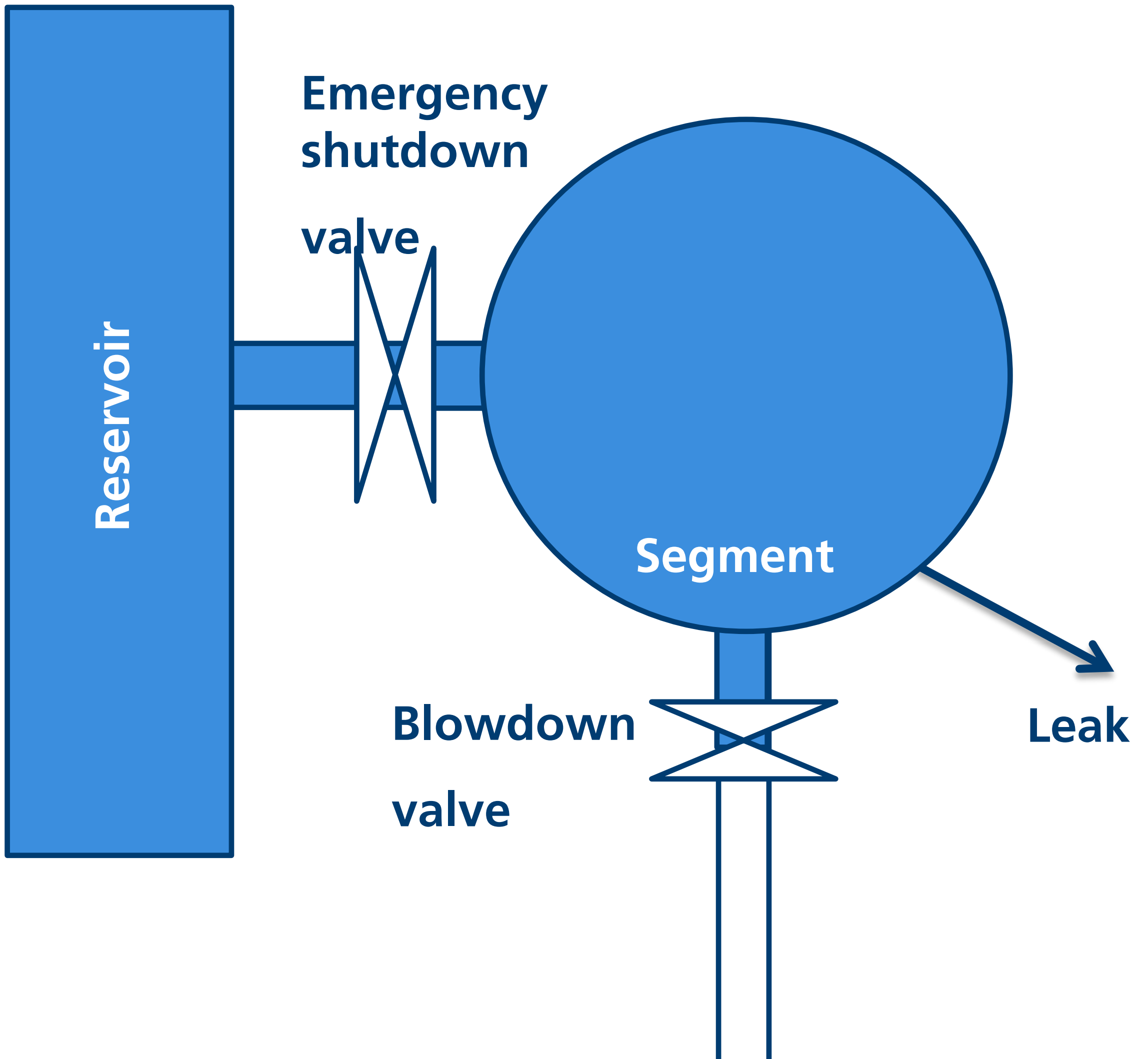


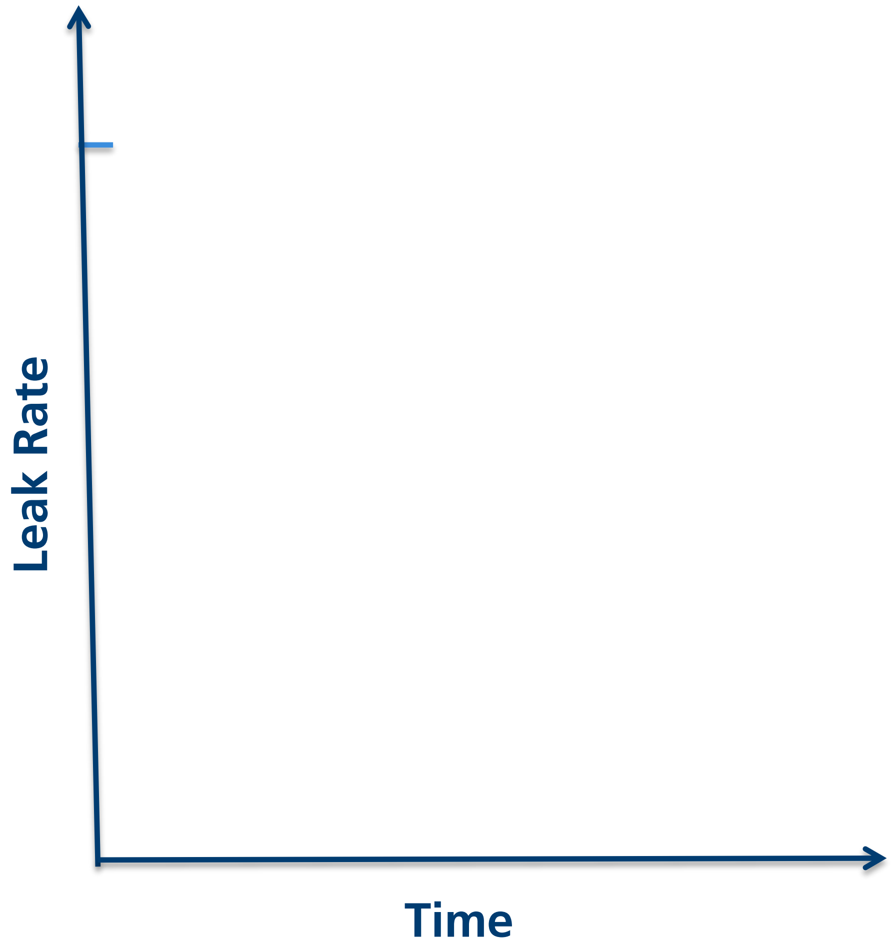

Enclosed module

# Probabilistic explosion analysis



# Transient leak rate model



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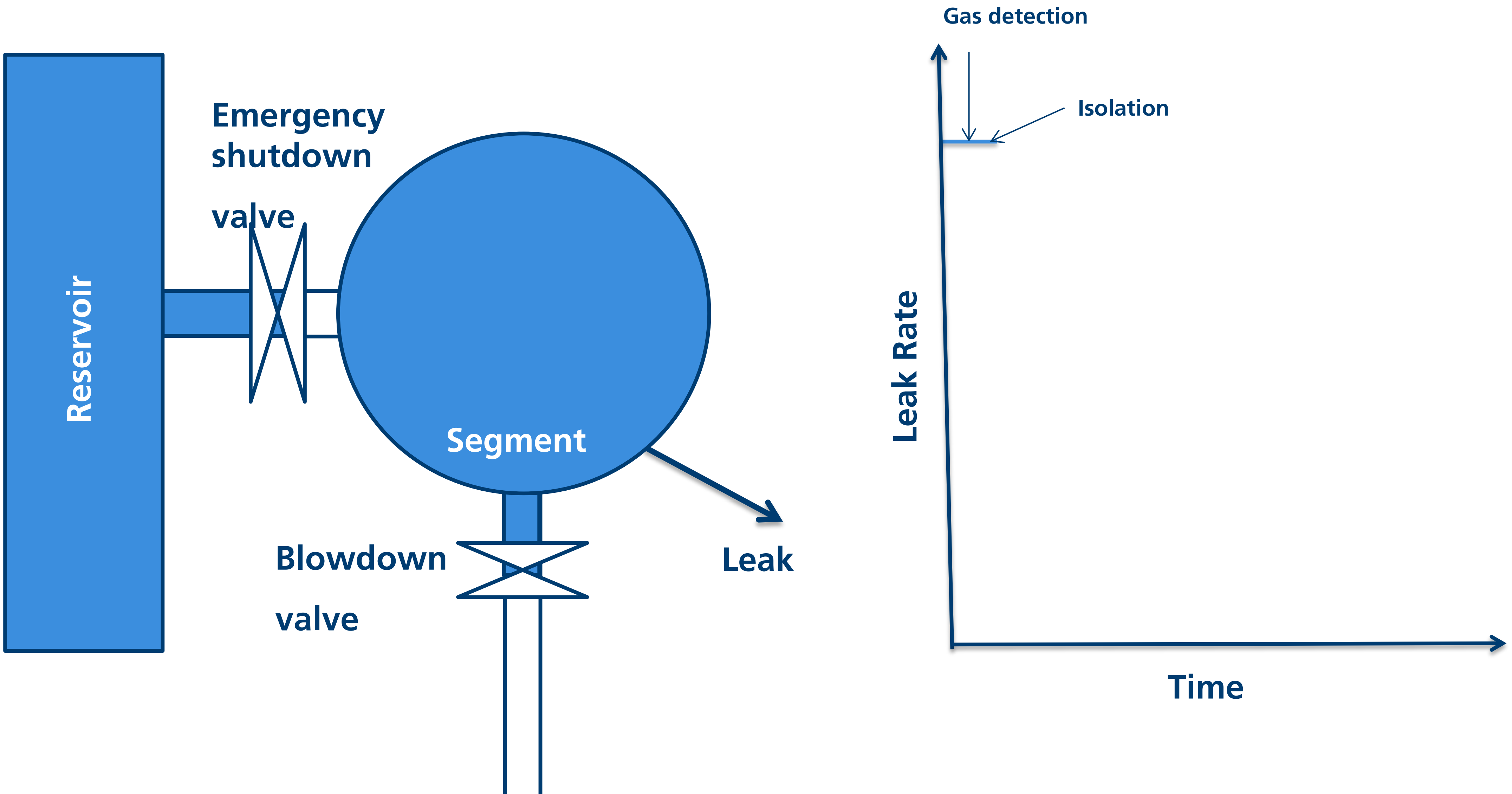

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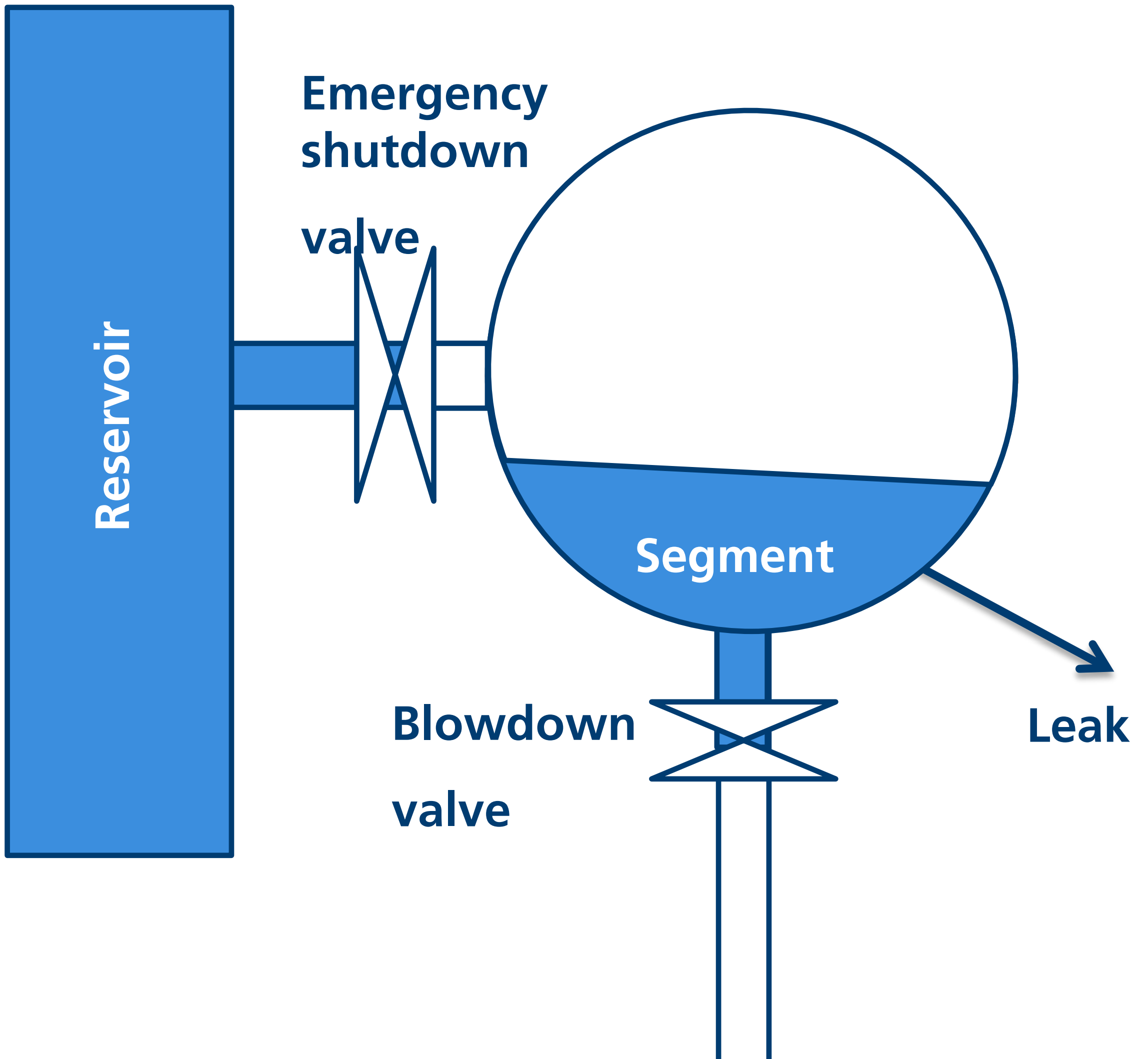


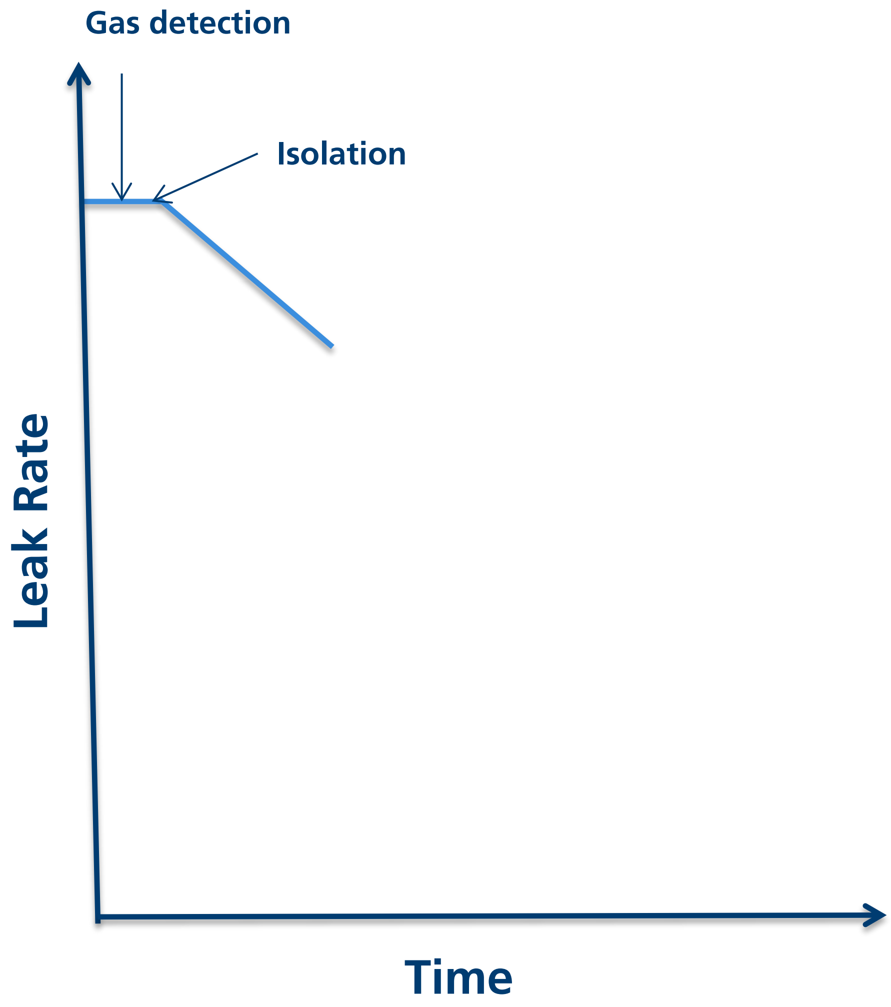

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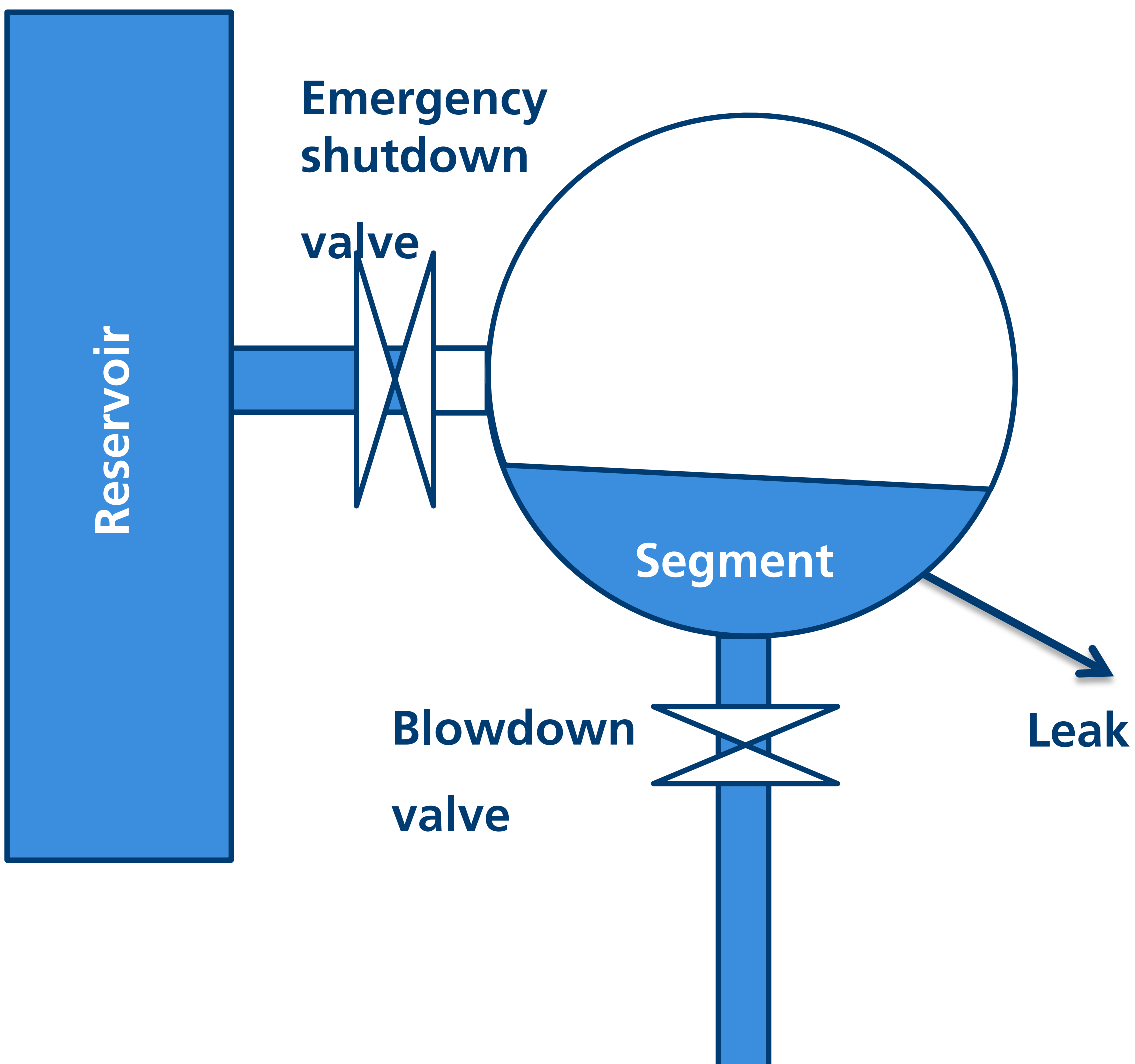
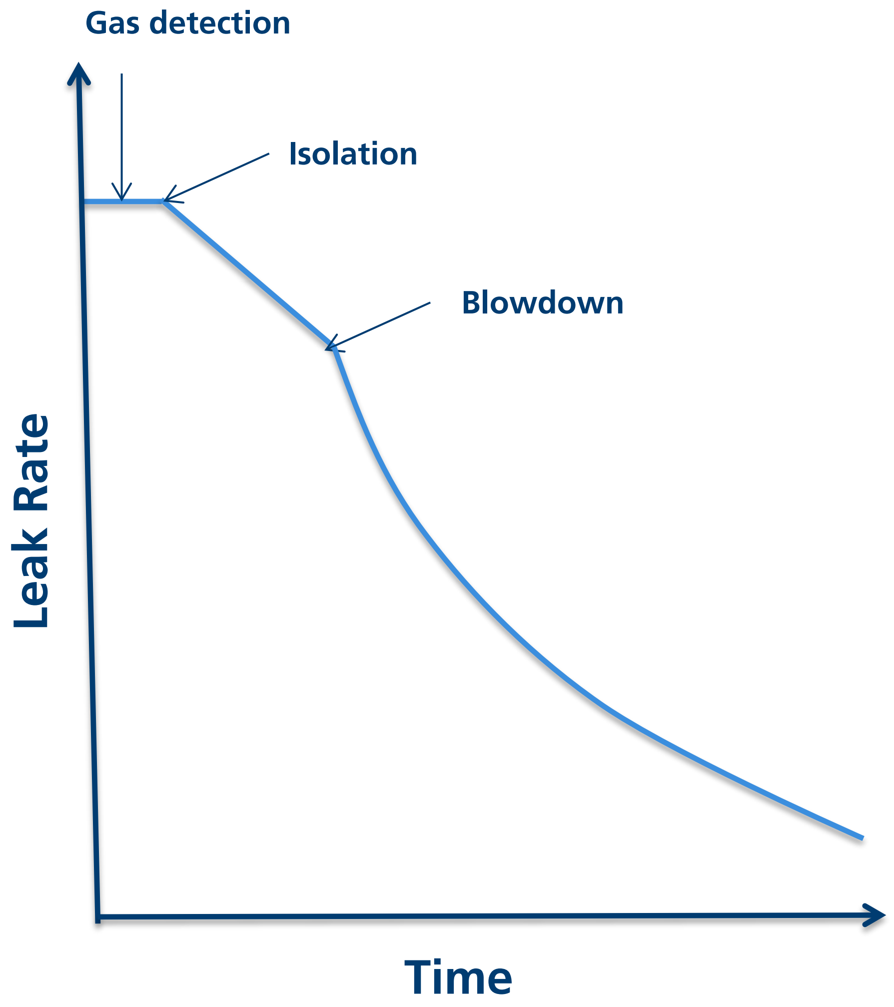
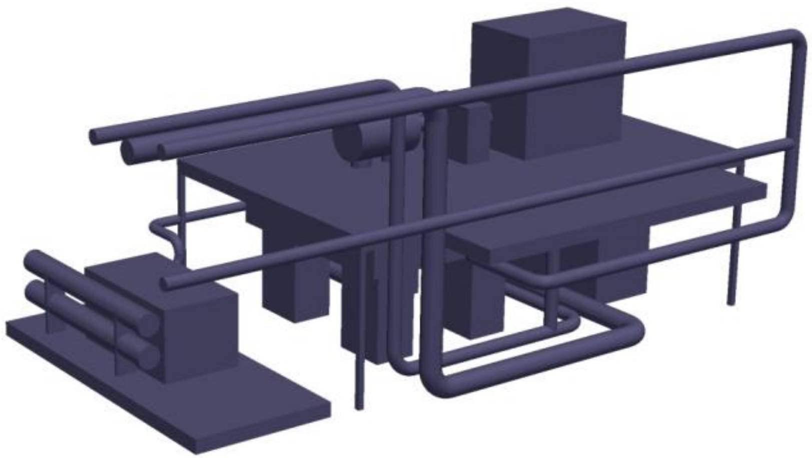


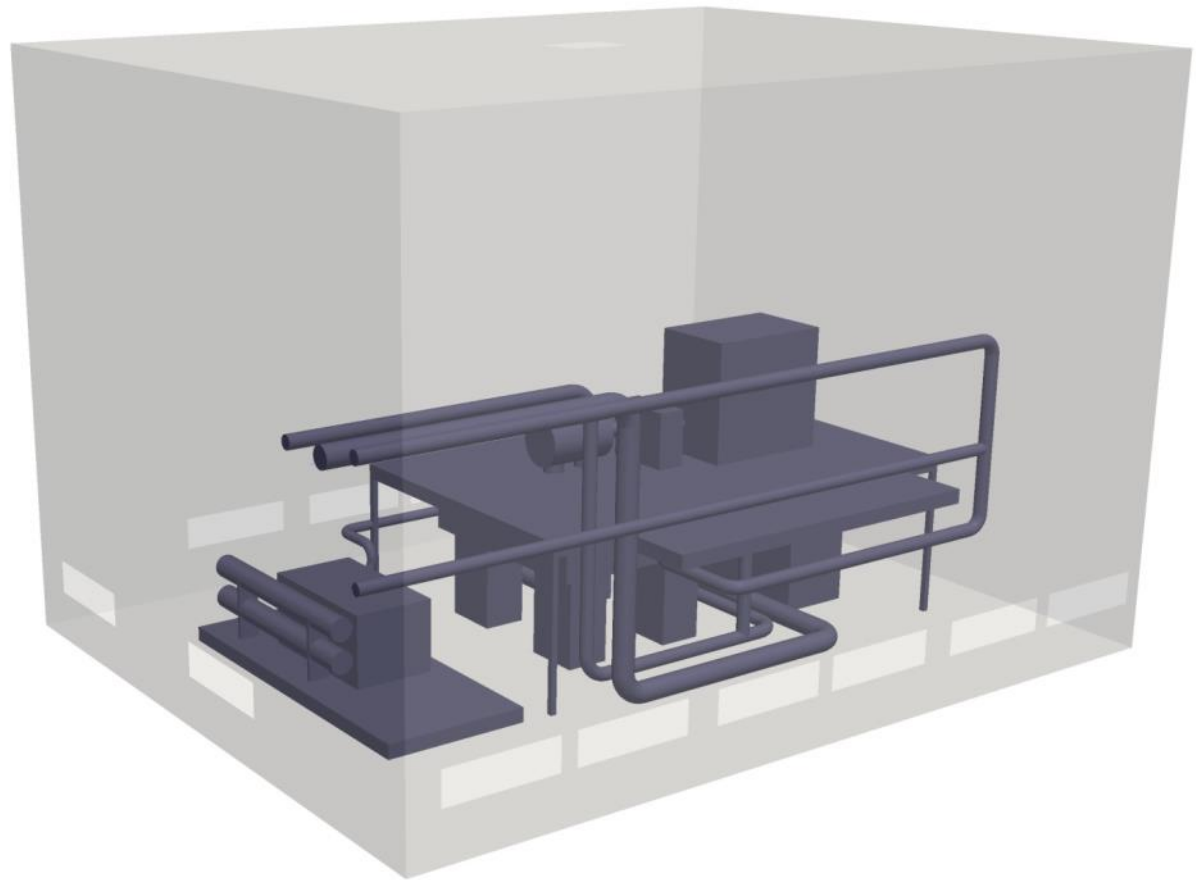
# Risk Analysis of Compressor House

- Pipelines, pumps and utilities



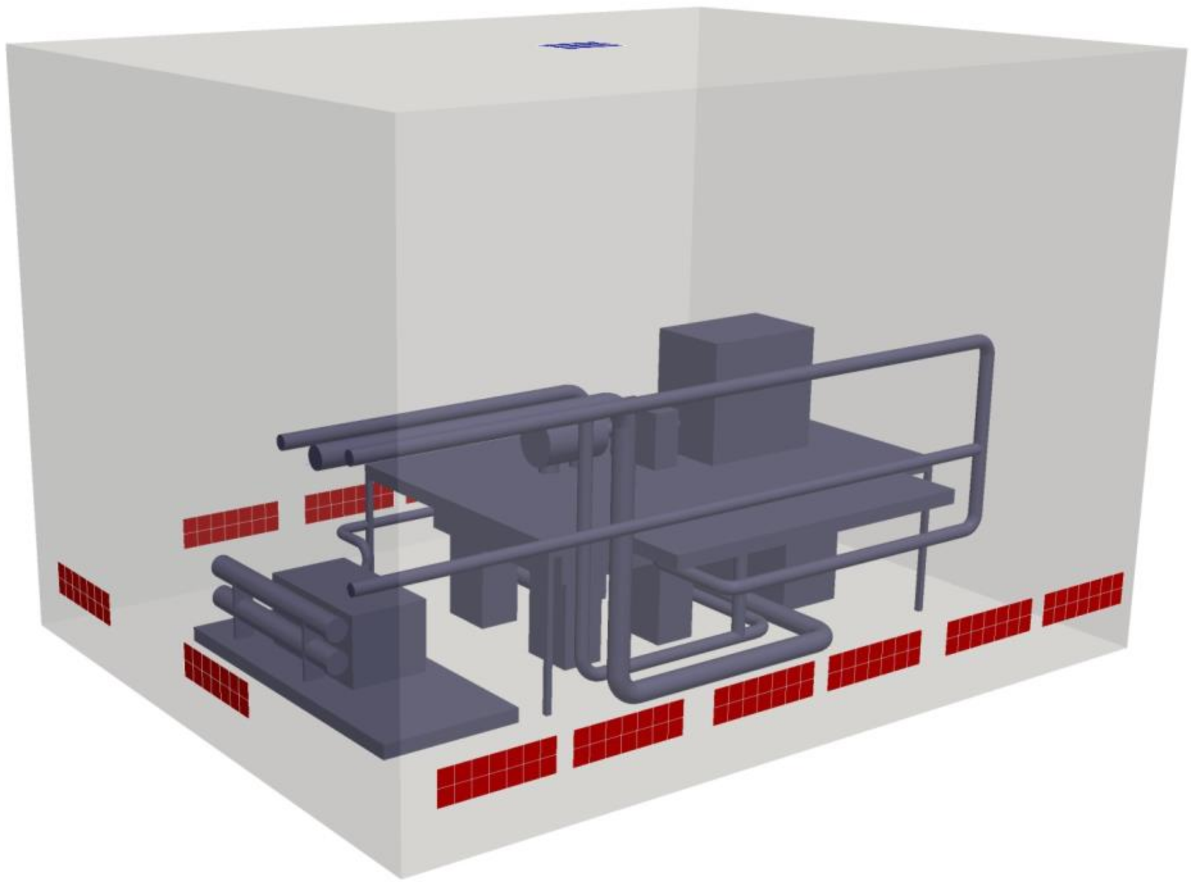
# Risk Analysis of Compressor House

- Pipelines, pumps and utilities
- Walls



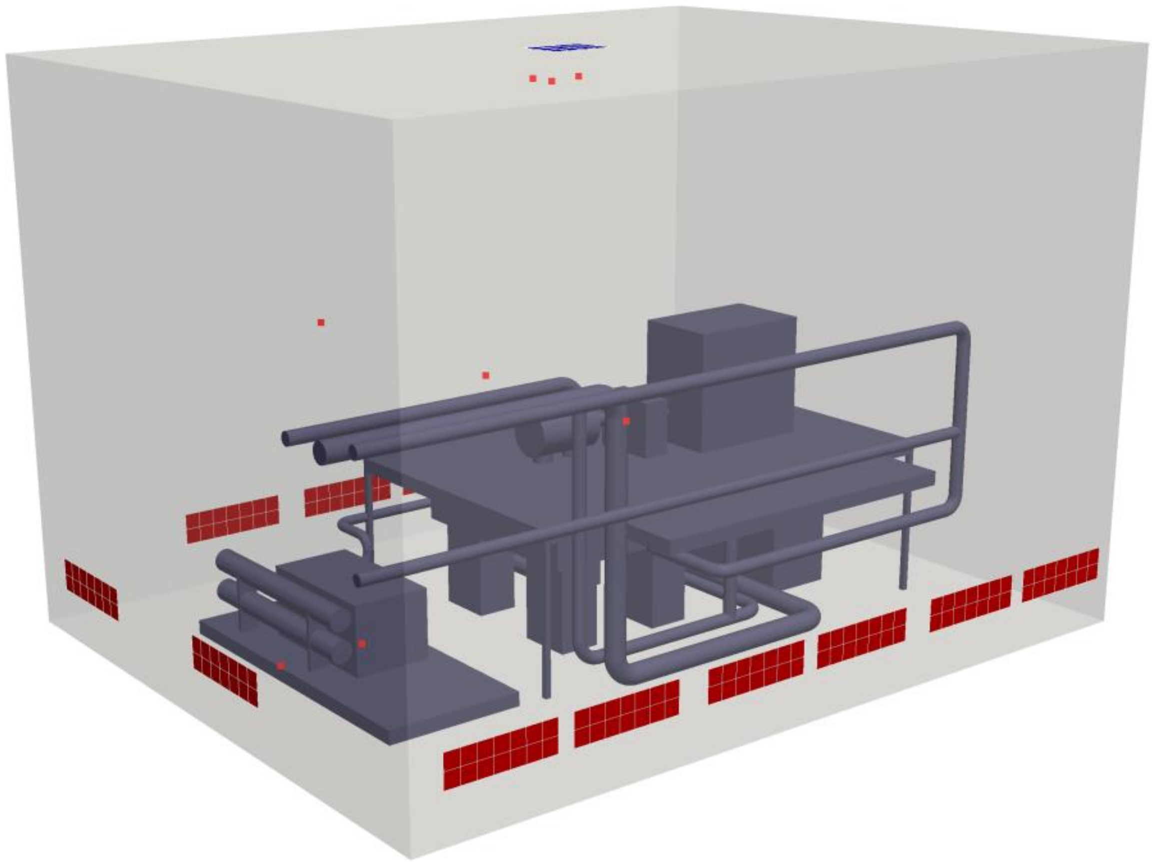
# Risk Analysis of Compressor House

- Pipelines, pumps and utilities
- Walls
- Louvre panels and Suction Fans



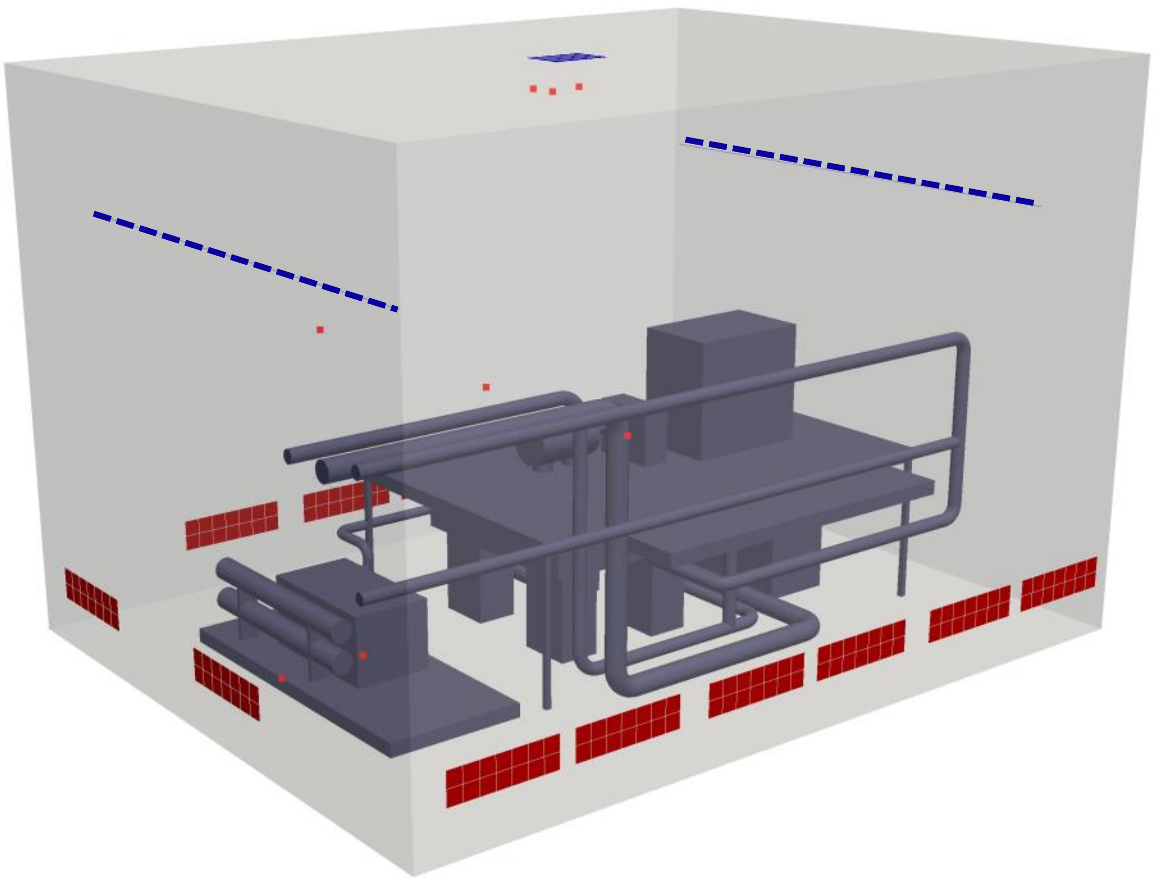
# Risk Analysis of Compressor House

- Pipelines, pumps and utilities
- Walls
- Louvre panels and Suction Fans
- 8 Point Gas Detectors



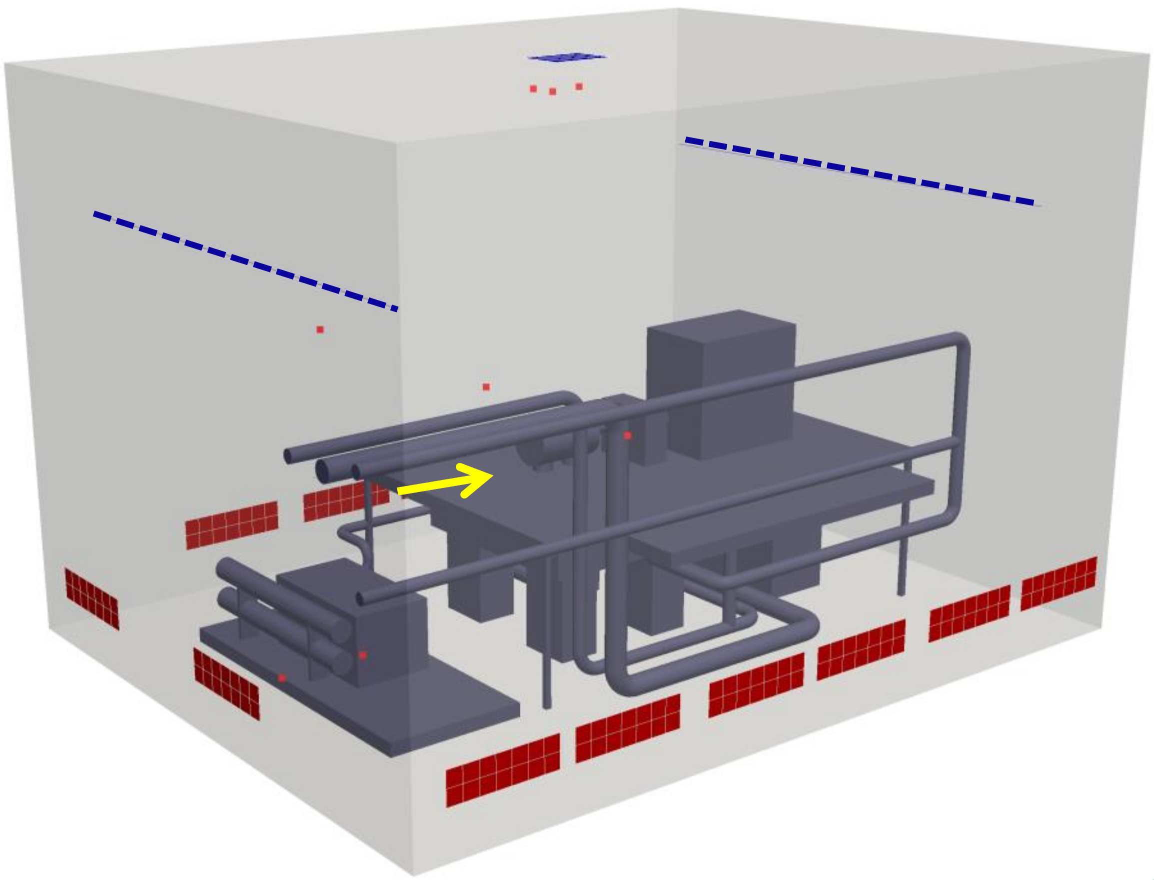
# Risk Analysis of Compressor House

- Pipelines, pumps and utilities
- Walls
- Louvre panels and Suction Fans
- 8 Point Gas Detectors
- 2 Line of Sight gas detectors



# Risk Analysis of Compressor House

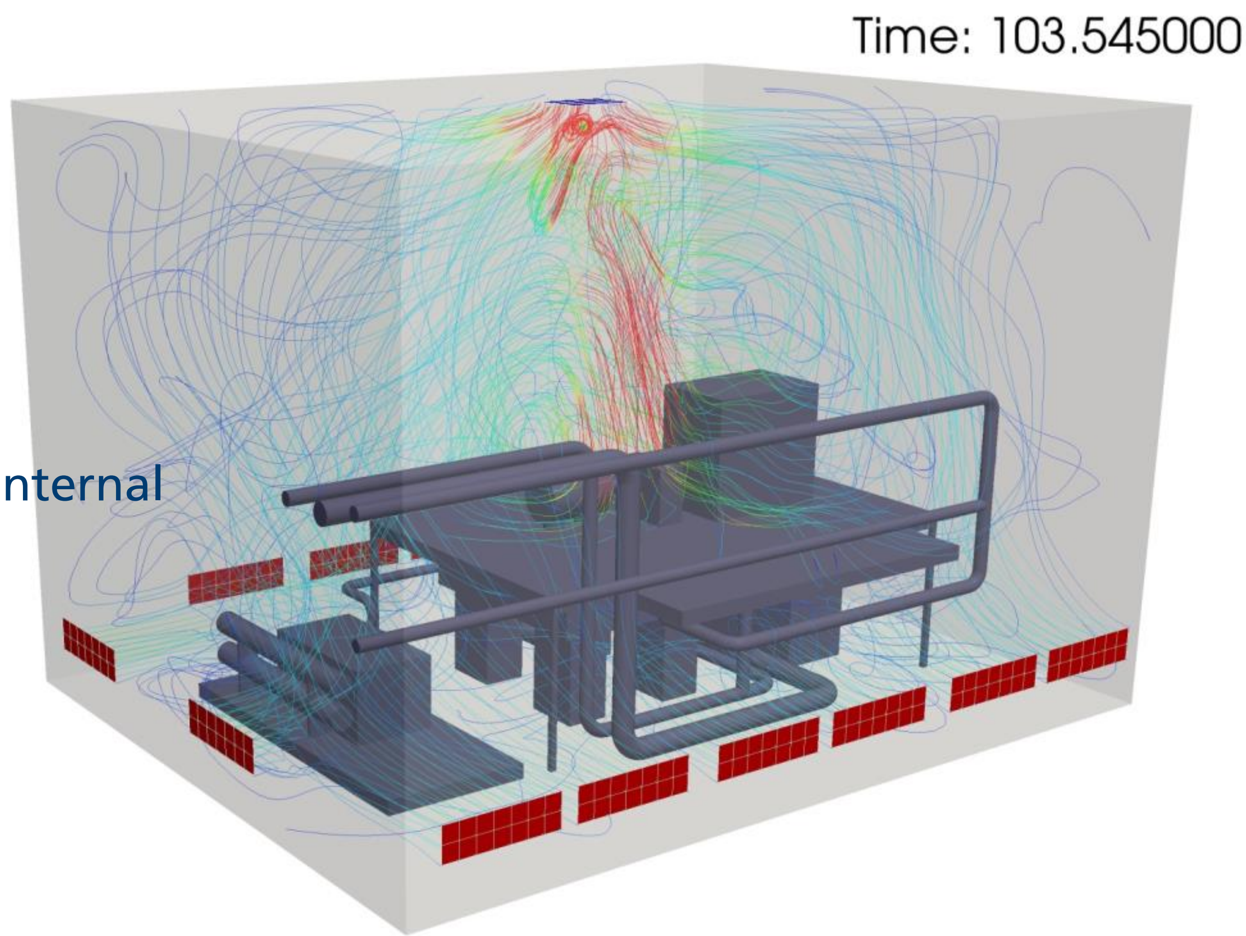
- Pipelines, pumps and utilities
- Walls
- Louvre panels and Suction Fans
- 8 Point Gas Detectors
- 2 Line of Sight gas detectors
- Leak Location



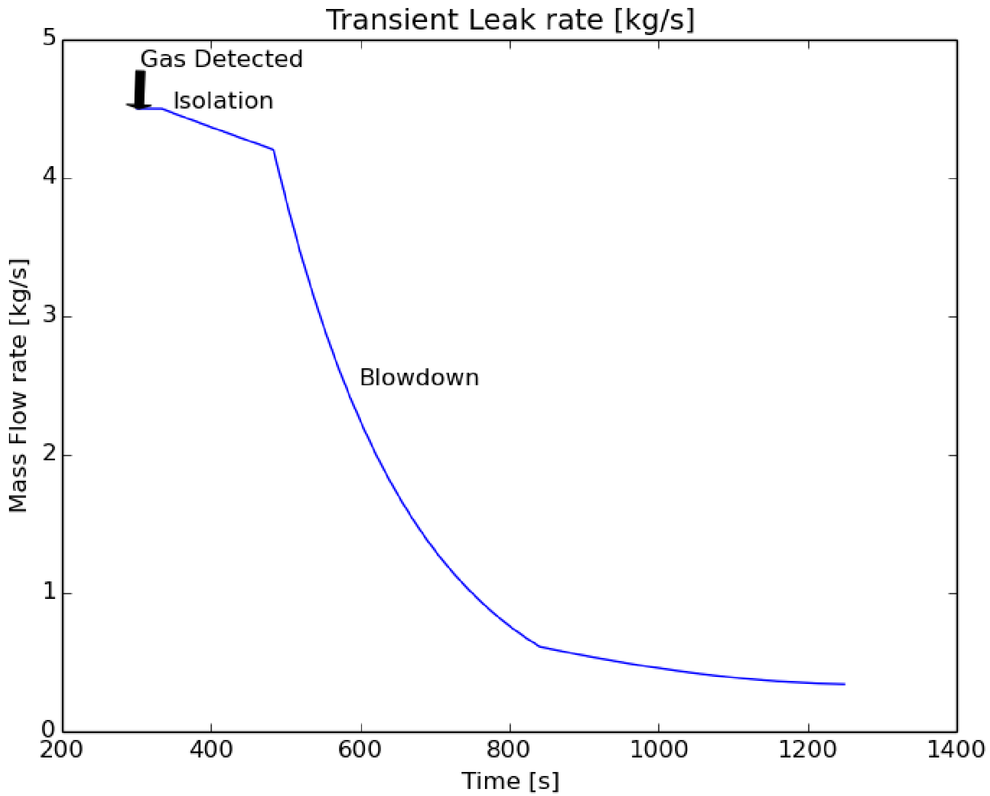
# Risk Analysis of Compressor House

- Pipelines, pumps and utilities
- Walls
- Louvre panels and Suction Fans
- 8 Point Gas Detectors
- 2 Line of Sight gas detectors

- HVAC simulation for stabilized Internal flow field

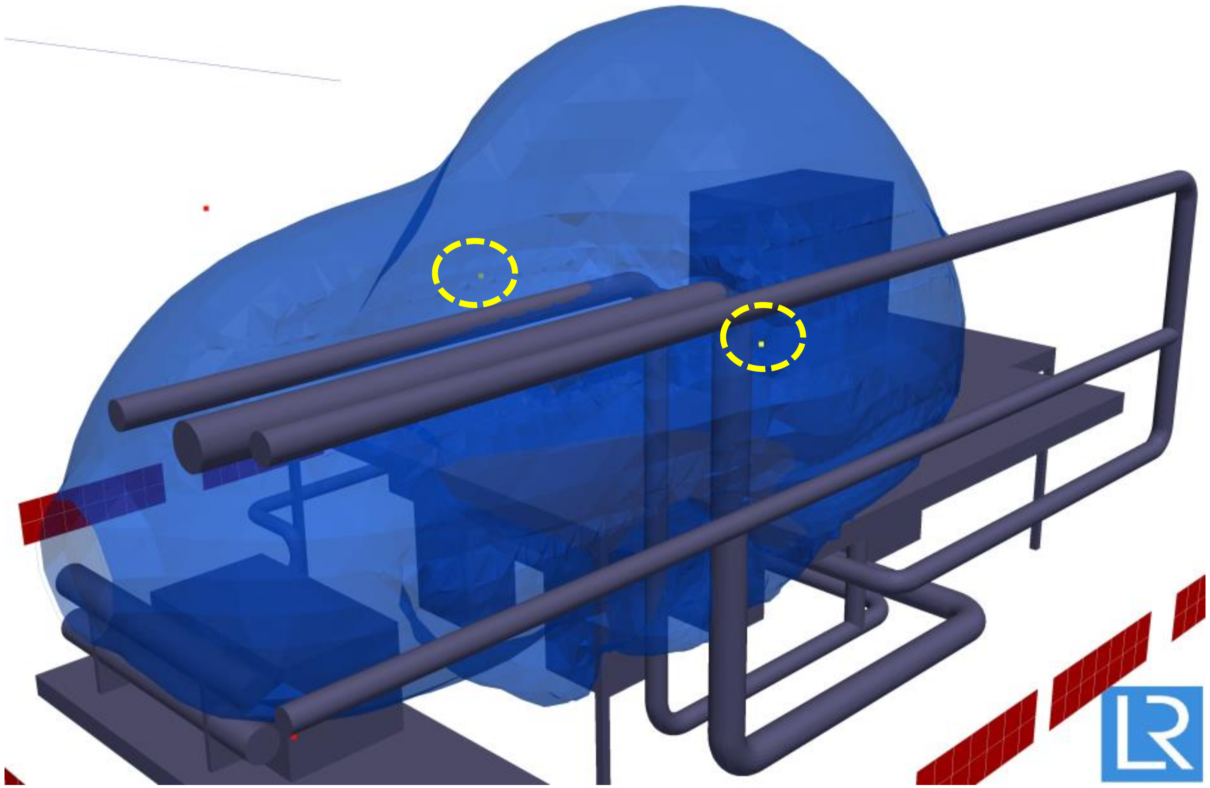


# Gas Release : 4.5 kg/s



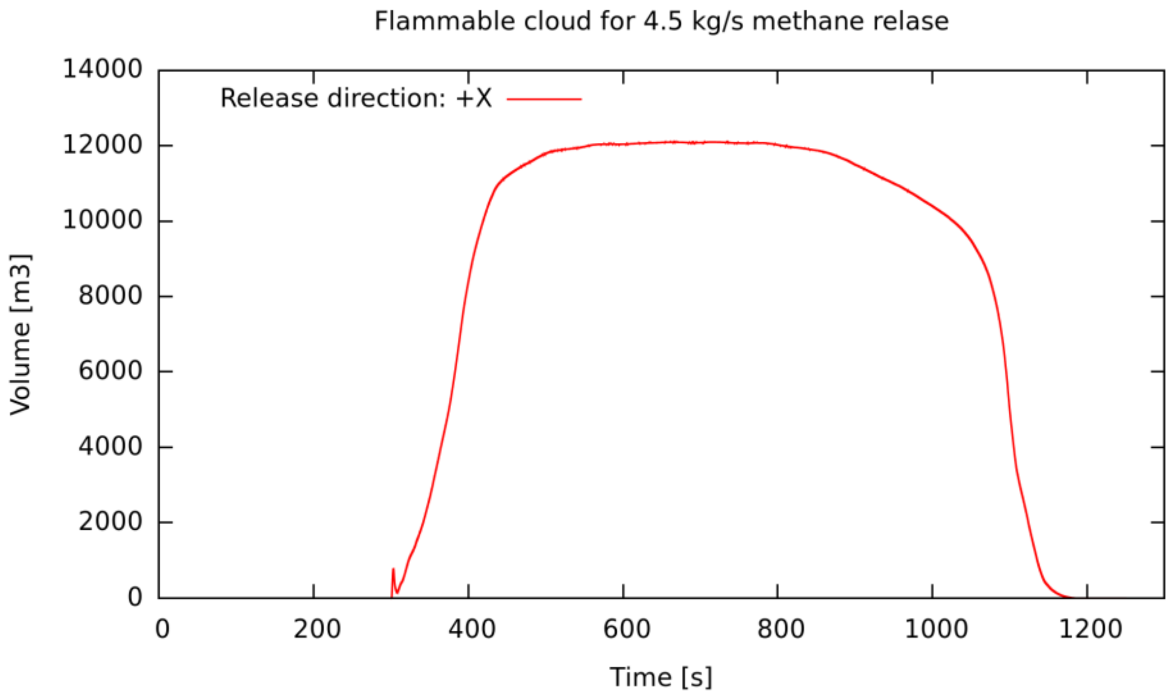

**Transient leak rate**

**Gas detected at 1.58 seconds after release**



**Detectable cloud (20% LEL) at 1.9 seconds shows two gas detectors is exposed to gas cloud**

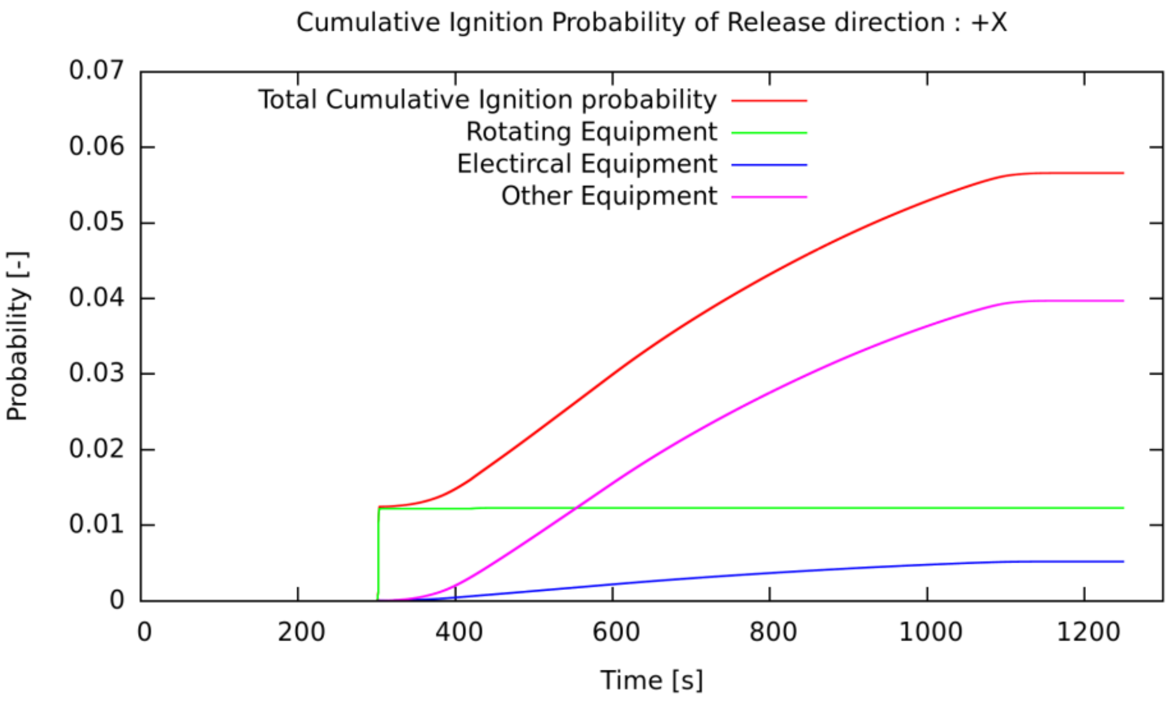
# Flammable Volume : 4.5 kg/s



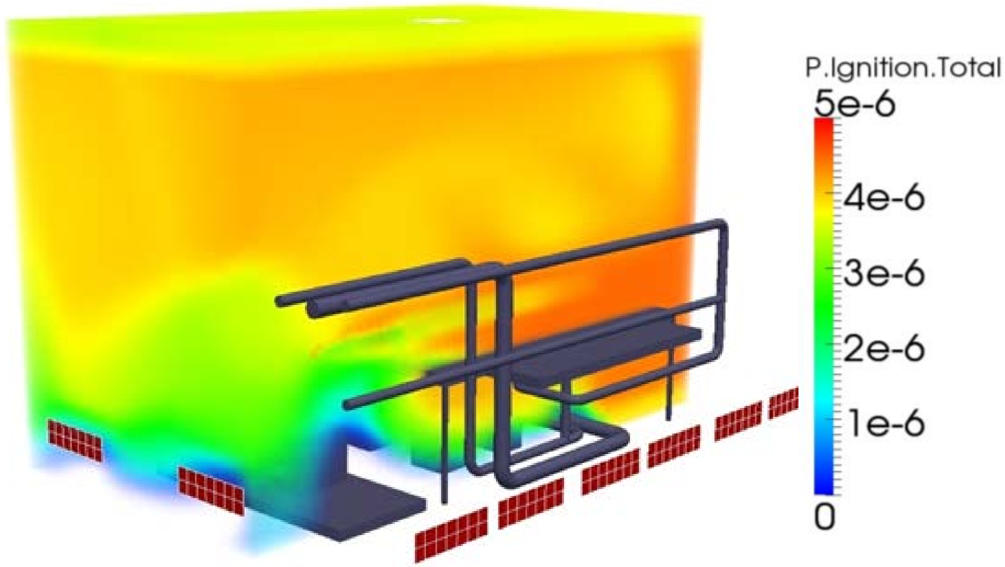

Flammable Volume (5-15 vol.% )

Visualization of Flammable Volume
300s after leak onset

# Ignition Probability : 4.5 kg/s



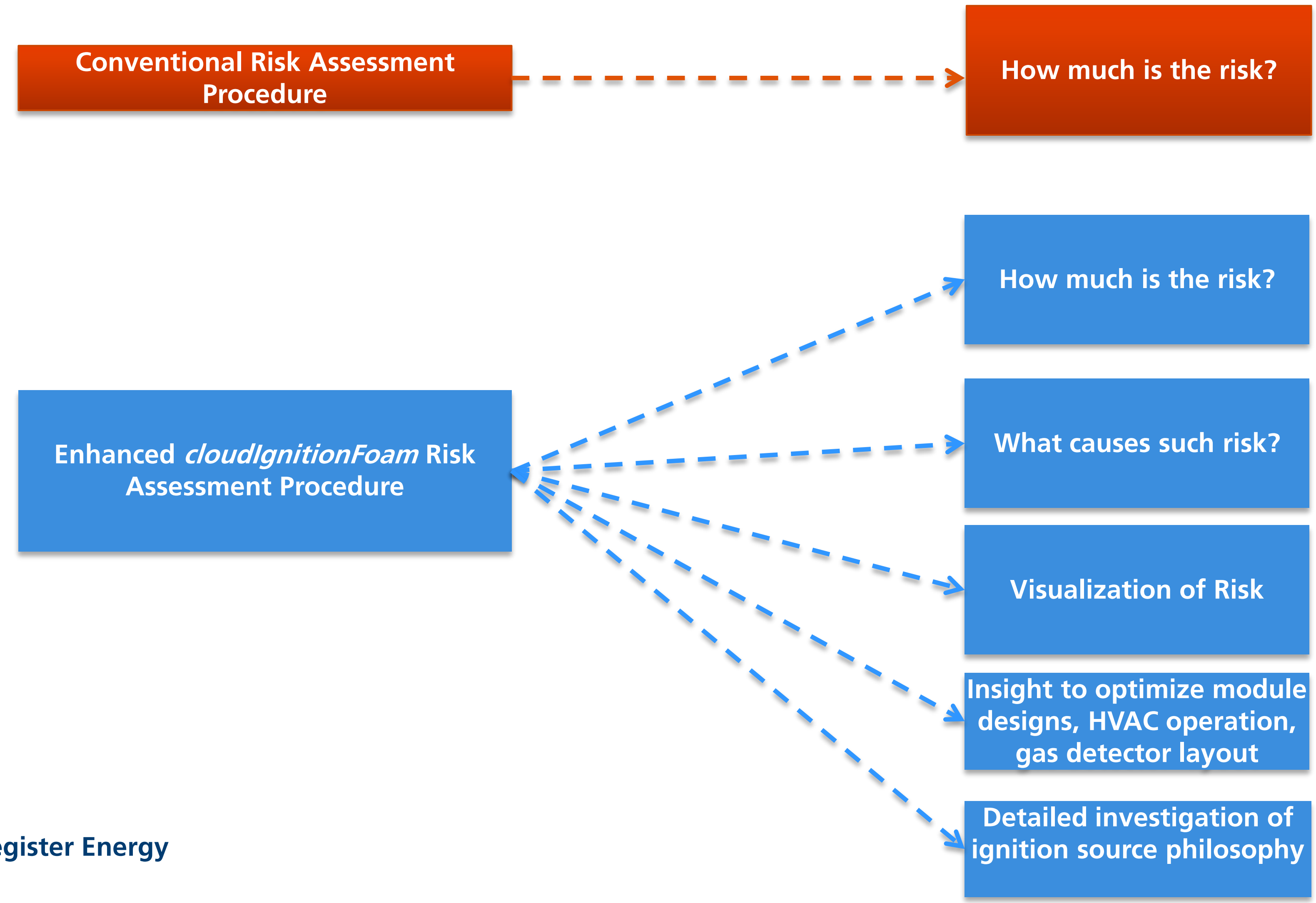

**Cumulative Ignition probability of different equipment**



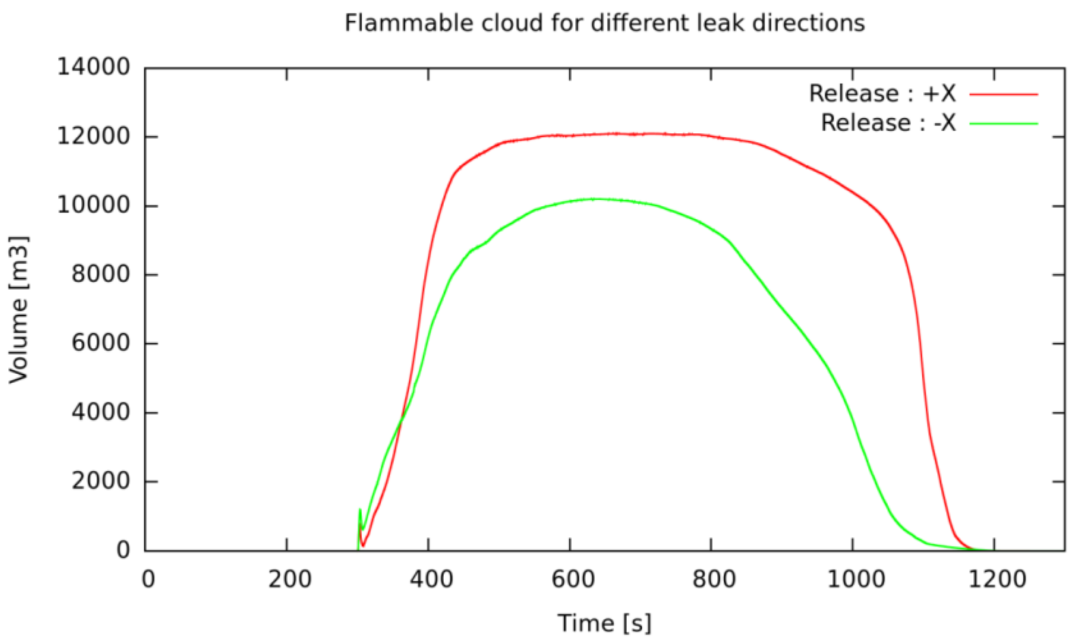

**Visualization of Ignition Probability**

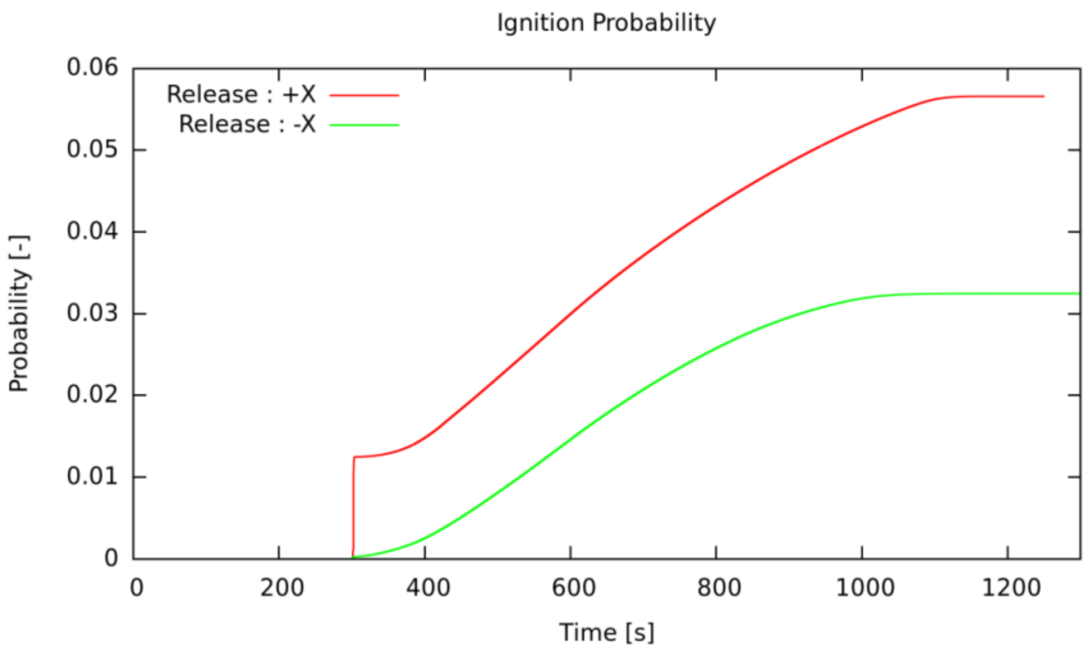
***(clipped at Leak Location)***

# Benefits of '*cloudIgnitionFoam*'



# Case Study 1: Effect of Release direction

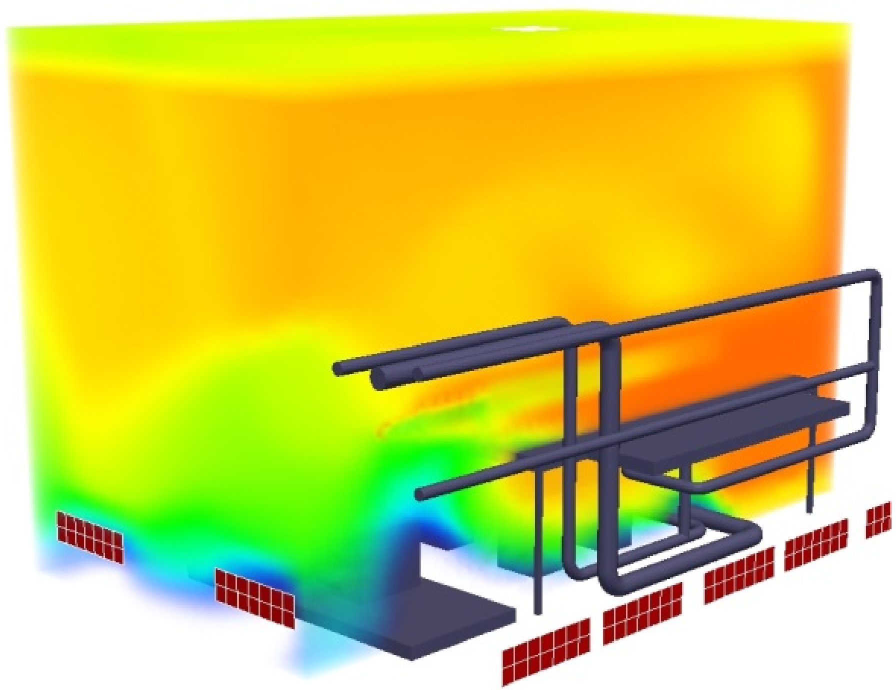


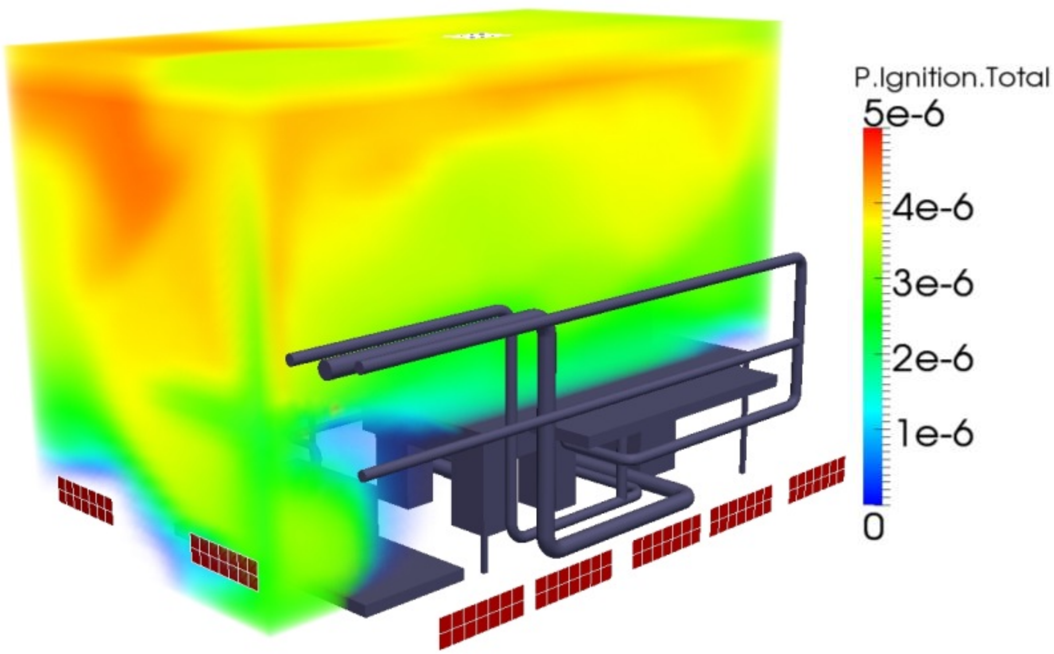

**Though the flammable volume looks relatively same the cumulative ignition probability of '+X release' is approximately 80% more than '–X release'**

# Case Study 1: Effect of Release direction

**Cumulative Ignition Probability-Clipped at Release Location**



Release Direction : +X

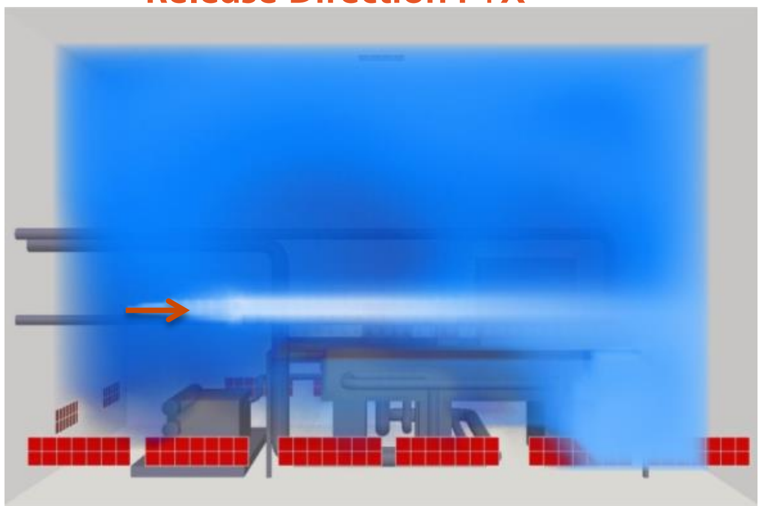



Release Direction : -X

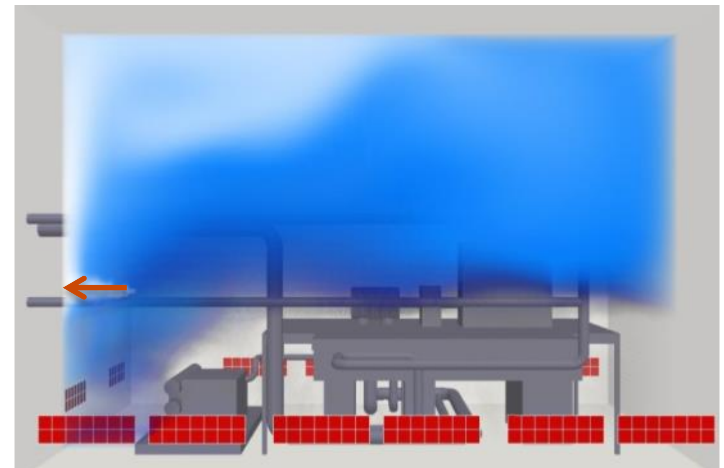
# Case Study 1: Effect of Release direction

Flammable Gas

Release Direction : +X

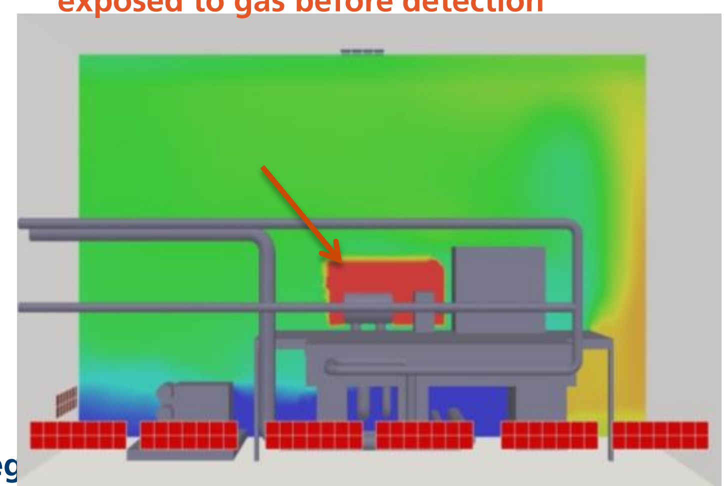


Release Direction : -X

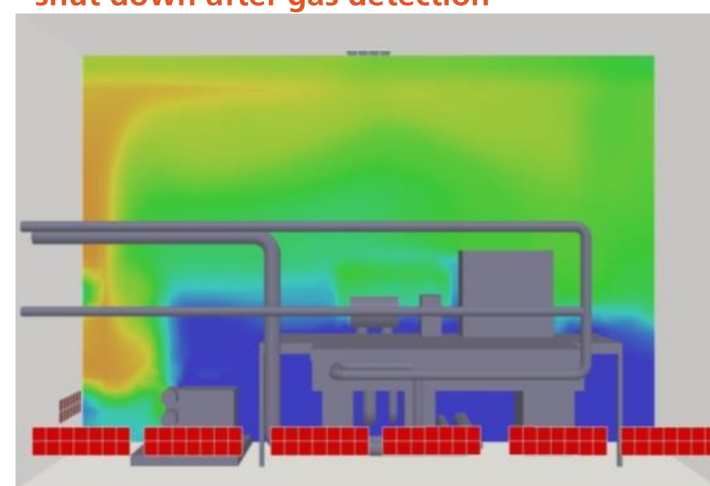


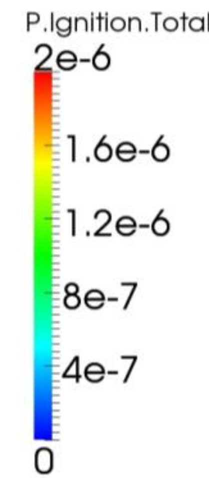
Ignition Probability

Release Direction : +X Rotating equipment exposed to gas before detection



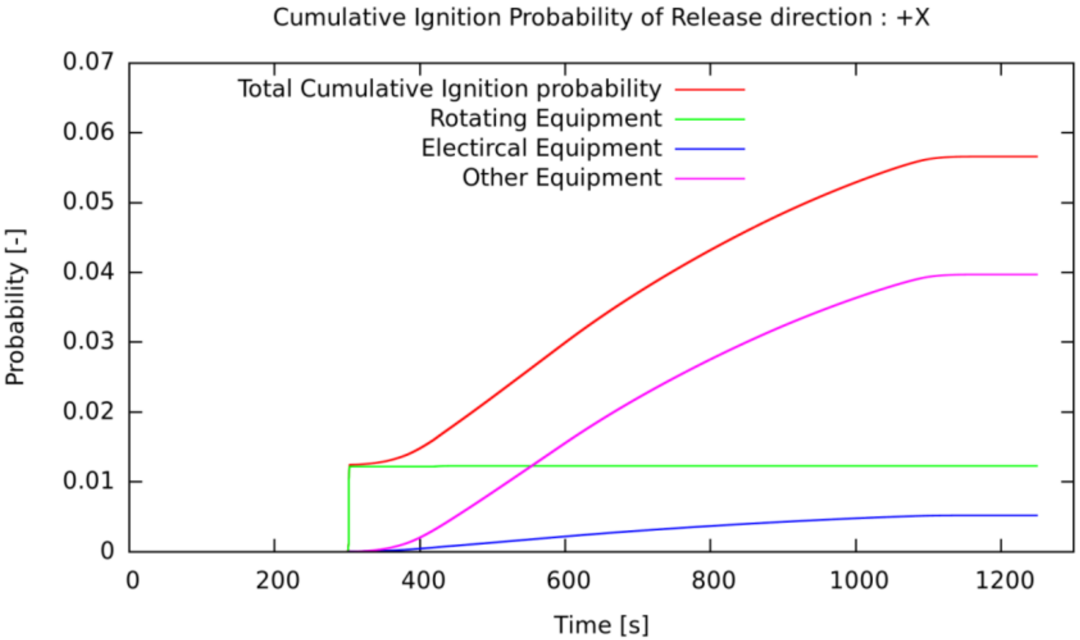
Release Direction : -X Rotating Equipment shut down after gas detection





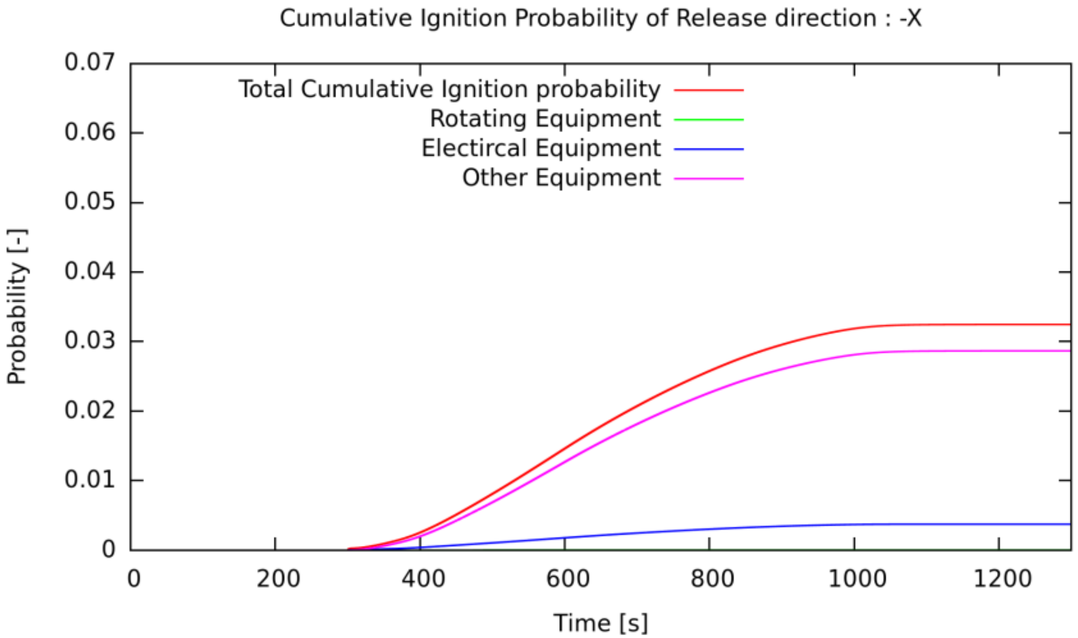
# Case Study 1: Effect of Release direction

**Release Direction : +X**




**Rotating equipment exposed to gas before detection hence ignition probability (green curve) is high**

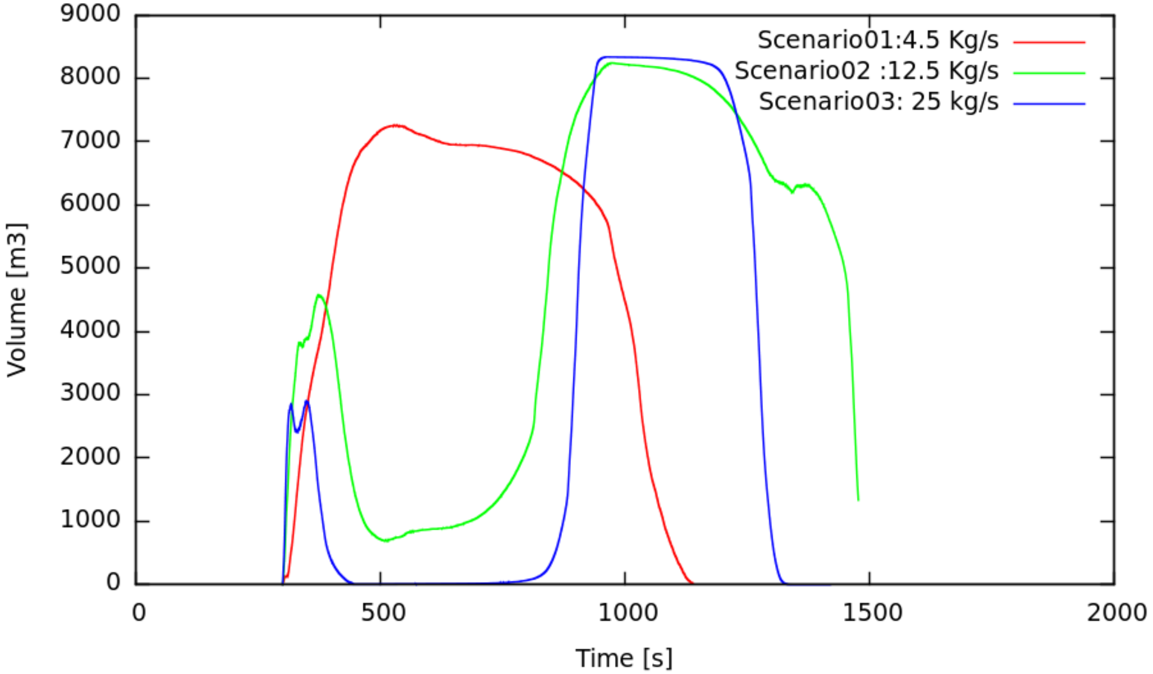
**Release Direction : -X**

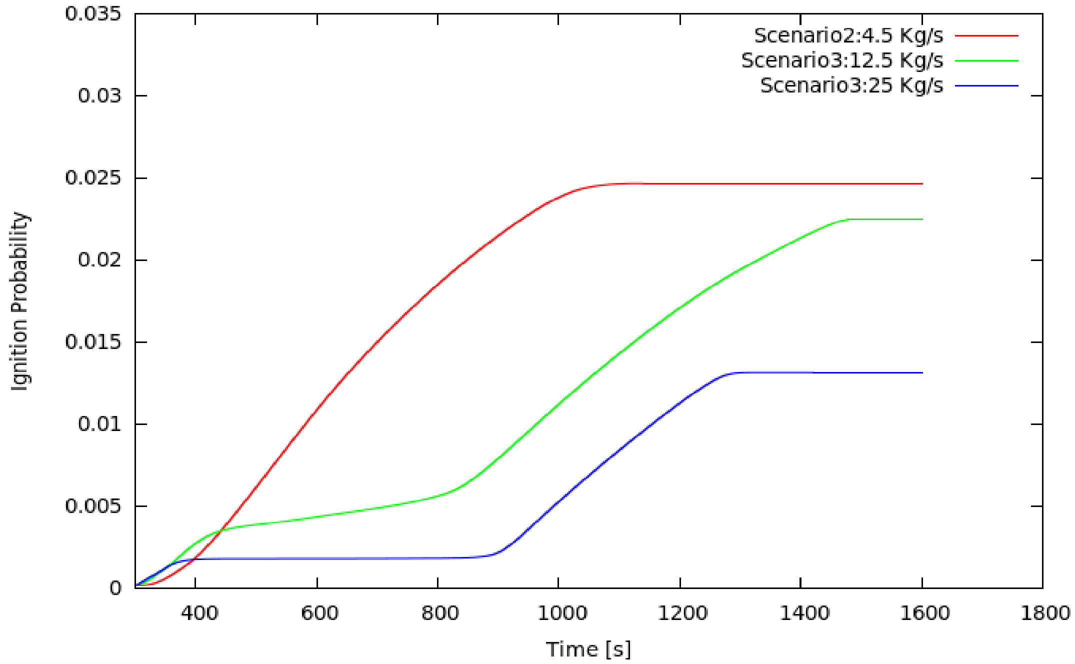



**Rotating Equipment shut down after gas detection hence ignition probability is near zero (green curve)**

# Case Study 2: Effect of Release rate

- Release Rates : 4.5 kg/s, 12.5 kg/s and 25 kg/s

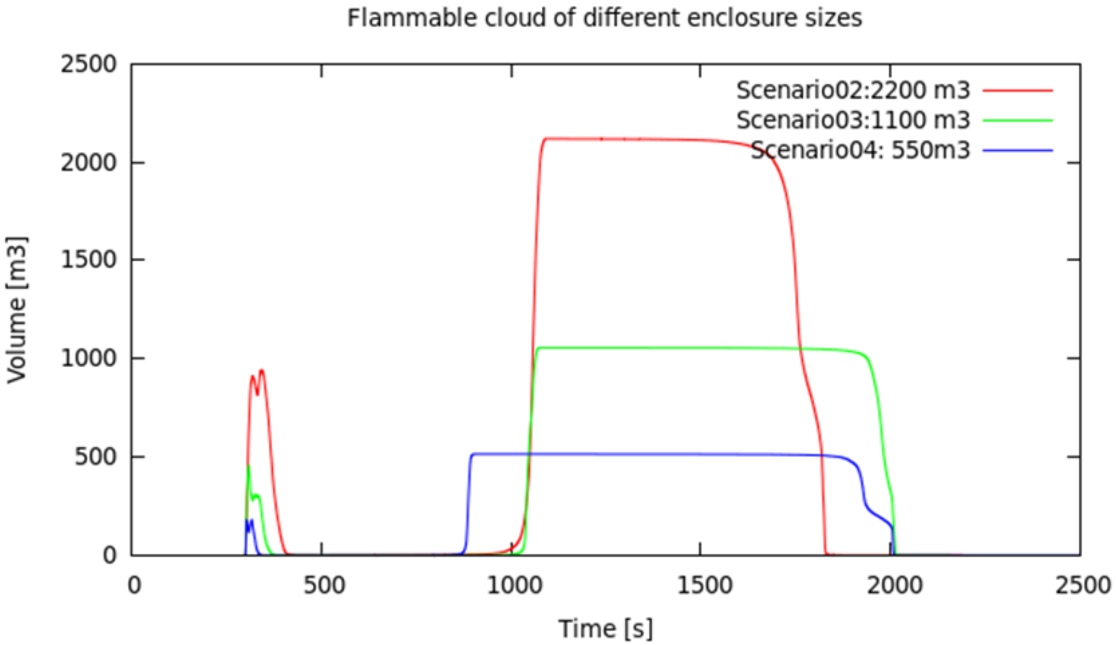


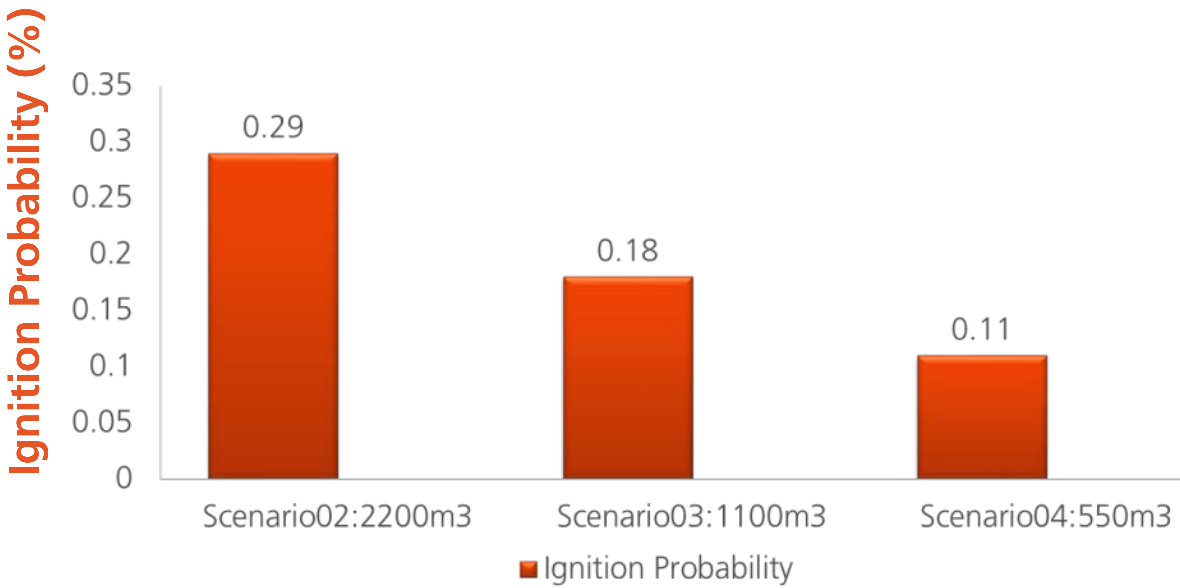




- Higher release rates not necessarily give higher ignition Probability
- Large release rates experience 'double peak phenomena'. After first peak the module is filled with gas above flammable limit (>15%) and when the leak rate drops transiently the module becomes flammable again (Secondary peak) when the gas is taken away by HVAC fans.
- Most of the continuous ignition sources are exposed in the first flammable peak. Hence the secondary peak contributes only to discrete ignition sources

# Case Study 3: Effect of Module Size

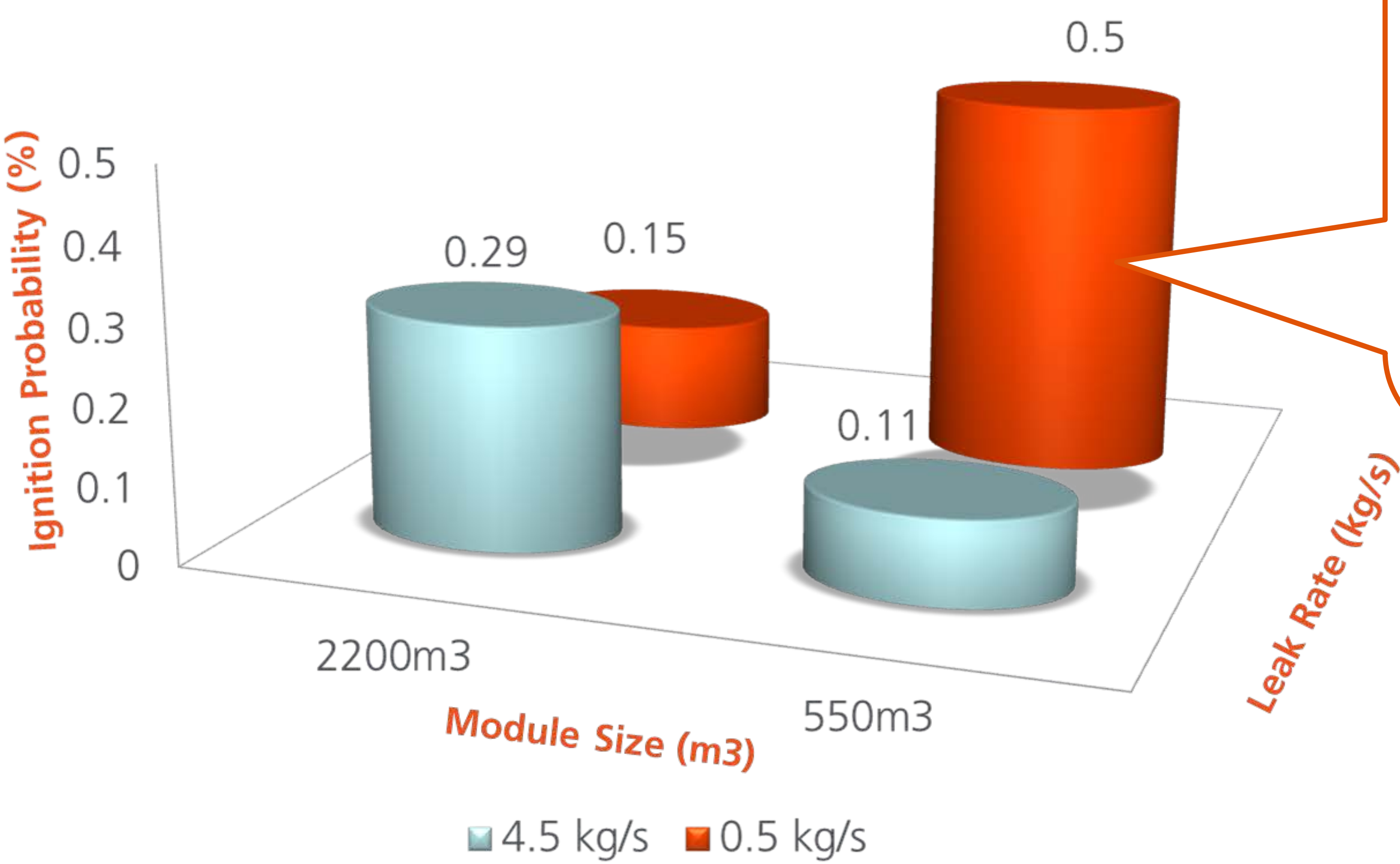
- Module Size : 2200 , 1100 and 550 m3
- Air Change per hour : 12
- Release Rates : 4.5 kg/s and 0.5 kg/s




**Flammable cloud for 4.5 kg/s initial leak rate**

# Case Study 3: Effect of Module Size-Ignition Probability (%)




The likelihood of releases having an initial release rate around 0.5 kg/s is considerable higher than the likelihood for releases around 5 kg/s. Hence, the difference in risk in terms of frequency for fires and explosions is even more prominent. A systematic parametric study should be performed to investigate such effects in detail.

# Conclusion

- A model for transient ignition probability for enclosed modules has been developed
  - Transient leak rate model
  - Gas detection as part of simulation
  - Discrete and continuous ignition sources
- Useful tool to evaluate module design and safety system design
- Integration of risk-based design principles directly into the CFD solvers

# Typical Industrial Benefits

- *cloudIgnitionFoam* : An efficient tool to enhance the risk assessments of gas leaks in enclosures in terms of optimization of design of safety functions, *e.g.*
  - Number, location and type of gas detectors (*e.g.* LOS versus IR Point)
  - ESD segmentation (*e.g.* reduce segment inventories, and hence loss of containment, by more ESD segments)
  - Depressurization system philosophy (*e.g.* sequential blow down instead of simultaneous to maximize blow down of high risk process segments)
  - Type of Ex equipment (*e.g.* Zone 1 versus Zone 2 equipment)
  - Location of ignition sources (*e.g.* air intakes of combustion engines, electrical equipment, rotating equipment)
  - Philosophy for ignition source isolation (*i.e.* mitigation of risk related to remaining ignition sources not isolated upon ignition)
  - HVAC system capacity and intelligent weather claddings that opens upon detection
- The developed tool can be used for systematic study of the above in further studies.

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