Modelling gas leaks in oil & gas turret systems

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About Atkins

One of the world’s leading engineering and design consultancies

• Provides consultancy to the aerospace, built environment, energy, transport and water markets
• In the oil and gas industry for over 30 years
• Global oil and gas team, involved in Design / Projects, Consultancy and Assurance
About Atkins

Fluid Mechanics team

• One of Europe’s largest CFD consultancies
• Provides consultancy services to a range of industries, including oil and gas
• 20 years using STAR-CD® and STAR-CCM+®
About turret systems

Oil & gas from offshore reservoirs is in some cases processed offshore by FPSOs or FLNG vessels before being shipped onshore via pipelines or tankers.

These vessels are often moored using a swivelling turret system, about which the vessel can weather-vane. Risers, which are fixed relative to the sea bed, carry the reservoir fluids through the turret to processing facilities on-board the vessel.
Why are we involved?

Gas leaks in confined or congested spaces can lead to violent explosions. Atkins undertake safety studies to help understand and mitigate the risk.

Atkins routinely carry out safety studies for oil and gas assets, including turret systems, using STAR-CCM+. These safety studies include the simulation of process leaks to determine the volume of flammable gas that can be produced in the event of an accidental release, both within the turret itself and also throughout the rest of the facility.
This presentation provides an example of a real oil & gas application of STAR-CCM+, and shows how this complex analysis can be modelled in a rapid timeframe, thus providing detailed data that could not obtained by other means.
Study aims

Simulate a gas leak from a pressurised riser in the turret, in order to understand any potential explosion risks.

This requires an understanding of how the volume of flammable gas varies with time, and where it ends up.
Atkins generic turret geometry

- HVAC outlet
- Turret wall (ship stationary)
- Oil/gas riser (geostationary)
- Sea level
- HVAC inlet
Turret system features

Ventilation system
Pressurised HVAC; 12 ACH

Gas detection
Detection and isolation within 30 seconds

Compartment construction
Sealed at the top (no pressure relief); Open to the sea the bottom
Modelling approach

- Eulerian multiphase
  - Multi-component gases (air and hydrocarbon vapour)
  - Constant density liquid (water)
- Volume of Fluid model
- K-Epsilon turbulence
- Implicit unsteady

HVAC system set to 12 ACH based on initial pressure difference. More air/leak can leave through the HVAC if turret cylinder becomes over-pressurised

Gas leak added as a source of mass, energy and momentum
Small riser leak

Flow rate small enough that it is readily diluted by the fresh air coming in through the HVAC. Steady-state small cloud volume generated. Lasts a long time (small flow rate, large isolated inventory).
Medium riser leak

Solution Time 1413.11 (s)
Very large riser leak

Solution Time 1413.11 (s)
Small leak

Dealt with effectively by the HVAC system, flammable cloud remains small.

Medium leak

After a short time, the leak overwhelms the HVAC, and fills much of the compartment with flammable gas (First Peak), before becoming over-rich. Consequently the flammable cloud returns to zero (too rich to burn).

The leak is then detected, and the system isolated. Eventually no more gas goes into the compartment.

The HVAC system eventually starts to evacuate all of the gas. At some point, the gas concentration is flammable again, giving us a Second Peak.

Large leak

Similar behaviour to medium leak, but due to the larger flow rate, goes over-rich much quicker, so the First Peak typically reduces in size with increased flow rate.
Potential consequences

Flammable cloud within turret

Can occur for even the smallest leaks. Larger leaks can overwhelm the HVAC, leading to two peaks. Explosion risk will depend on availability of ignition sources.

Flammable cloud in topsides

Larger leaks can break through any pressure relief panels…

… or the very largest leaks, potential to push through the water head, and come up round the side of the vessel.
How is this all used?

- Model vapour cloud explosions for the flammable volumes determined by the study.
- Calculate frequencies of occurrence of leaks (by size of hole)
- Calculate ignition probability (this can use the time dependence of the results)
- Calculate frequency-based explosion loads to help inform the design
Thanks for listening!

Any questions?