

# A SAFEGUARDING SCENARIO VAPOUR BREAKTHROUGH & LIQUID SWELL

European Conference on Plant & Process Safety in Antwerp



### In the next 25 minutes ...

- Why is it important?
- Where and when does vapour breakthrough play a role?
- How does vapour breakthrough occur?
- What is meant by "liquid swell"?
- What guidelines and technical standards are available?
- How to protect against vapour breakthrough?
- What do we do in Rheinland?

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### Why is it important?





- One of few scenarios that if overlooked can lead to vessel rupture.
- There have been many incidents in the past:

1977 Shell International (2 fatalities), 1987 BP Grangemouth (1 fatality), 1980 Circa Ecopetrol (1 fatality),

2011 TGGT Holdings, E&P Gas Plant (1 fatality)

Near Misses: 1992 Shell Geismar, 2020 Shell Rheinland

- Can have severe consequences.
- Knowledge of vapour breakthrough scenario has improved over last 20-30 years.
  - First described in API-521 in 1993.
  - "Liquid Swell" added to API-521 in 2020.
- New guidance is not always known by designers.
- Can lead to discovery that existing relief valves are undersized.

### Where and when does vapour breakthrough occur?



- Prerequisites for dangerous vapour breakthrough:
  - Loss of liquid in high pressure vessel
  - High pressure / Low pressure interface with pressure ratio of 2:1 or greater
- Examples of systems with potential vapour-breakthrough:
  - Hydroprocessing units (hydrocracker/hydrotreater)
  - Amine Gas Treating processes









### Significance – Let's step back in time... 1987, Grangemouth

- Significant overpressure potential
- What happened at Grangemouth on 22<sup>nd</sup> March 1987?
  - Relief valve not sized for vapour breakthrough.
  - Overpressure caused the vessel to rupture.
  - One fatality
  - Rebuilding took over 18 months and the total cost was around \$100 million.



External Link to HSE for the publication The Hydrocracker Explosion and Fire at a Site in Grangemouth, 22nd March 1987



### Are there other concerns to consider?



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## What can be done? Protecting against vapour breakthrough & "liquid swell" at Rheinland

- Two potential relief events to consider:
  - Low pressure (downstream) vessel <u>can</u> take the upstream liquid volume (vessel, pipes).
    - Relief valve has "safe" distance to liquid level.
    - Design the safety valve for the vapour/2-phase flow.
  - Low pressure (downstream) vessel <u>cannot</u> take the upstream liquid.
    - Increase the size of the low-pressure separator.
    - Provide high integrity instrumented shut-off on the highpressure system that isolates the flow to the lowpressure system.



### **Summary and Key Learnings**

- Vapour breakthrough is an important scenario to be considered for high-pressure / low-pressure interfaces.
- One of few scenarios that if overlooked can lead to vessel failure.
- "Liquid swell" needs to be recognised as a design scenario for over pressure.
- Understanding for the scenario has improved over time and although now documented in design standards/guides since 2020, it is still easily missed.
- Standards: API 521 section 4.4.8.3 and Annex G (ISO 23251 sections 5.10.3, 5.10.6, and 5.10.7)
- Design relief valve for "liquid swell" is often not practical or in many cases very complicated.
- We in Rheinland usually use instrumented trip functions to prevent this scenario.

## Thank you

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#### Vapour Breakthrough and "liquid swell" - What can be done?



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- Kevin Campbell
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