Challenges with Fire & Gas detection and Emergency Shutdown systems for the modern LNG plants
LNG Codes

LNG plants are top tier installation according to SEVESO II (COMAH) classification and their design shall comply at least with one of the following codes:

- EN 1473 (European code)
- NFPA 59A (American code)
- AS-3961 (Australian code)
Hazardous Materials in LNG Plant

- Condensate
- Methane (Natural gas & LNG)
  TNT efficiency: 10%
- Ethane (gas & liquefied)
- Propane (gas & liquefied)
  TNT efficiency: 100%
- Butane (gas & liquefied)
- Mixed Refrigerant (gas & liquefied)
Hazardous Material Release

Release

Ignites?

Yes

Jet Fire

Pool Fire

Cloud Fire

Fast Flame

Internal Explosion

Safe Dispersion

No

Dispersing cloud

Ignites?

Yes

More obstacles Greater confinement Flame acceleration

No
Hazardous Material Release

- 2D Gas dispersion model
- Open door simulation without any congestion
- Gas and pressurized liquids (>4 barg) releases in form of directional jet gas or fine aerosol clouds
20 mm release from Feed gas (80% Methane)
T= 20°C P= 65 bara

20 mm Vapour release from LNG storage tank
Tave= -160°C Pave= 1.1 bara

20 mm Liquid release from LNG storage pipeworks (Loading mode)
Tave= -161°C Pave= 6.3 bara

20 mm release from Propane circuit
Tave= 56°C Pave= 19.7 bara

20 mm release from Ethane circuit
Tave= 2.3°C Pave= 22 bara

20 mm release from MR circuit
Tave= 33°C Pave= 19.32 bara
2.5.1 Where required an emergency shutdown system shall be incorporated into any installation that:

(a) includes an atmospheric tank; or
(b) exceeds 300 m³ total capacity; or
(c) includes LNG pumps, compressors or liquefaction plants; or
(d) involves the loading of LNG into tankers.

When operated, such a system shall isolate, shut down, depressurize or otherwise make safe any equipment whose continued operation could add to or continue an emergency.

2.5.2 Exceptions

Where the shutdown of particular equipment could:

- introduce further hazards, or
- cause damage,

the shutdown of such equipment may be omitted from the emergency shutdown system provided that the effects of continued release of flammable or combustible fluids.
Shutdown Requirement

ESD activation shall be **automatic** from the fire and gas system with supplementary activation from local ESD station or central panel.

**Exception**

ESD activation shall neither cause a **new hazard situation** nor **damage** a machine or other equipment.
How to interpret?
ESD-1 is NOT require because:

- Safety concept of LNG plants is based on **prevention**.
- Safety distance and Passive fire protection are the most effective measures to protect against **BLEVE**.
- F&G detection **coverage** is not effective and less than 60% gas releases are detected.
- Instrumented based safety systems are **complicated** and operator may not be able to understand them well.
- **Spurious trips** are frequent with gas detectors specially when they are exposed to sun or welding.
- Maintaining F&G system is a headache and we have a steady stream of false alarms despite our best efforts. IR3 and LOS detectors are more reliable but they are expensive and need high maintenance.
- Spurious trips are **costly** and **hazardous**.
- LNG plants need to time to come down and get back up safely due to the wide temperature differences between the process and the ambient. Too many shutdown and start-up will introduce equipment **fatigue stresses** due to (thermal cycling) and potential failures.
- Quick closure of ESD valves and stop pumps processing the liquefied gas may lead to high **surge** pressure and vacuum. Normal relief valves are not quick acting and cannot relief such pressures. This may lead to further catastrophic ruptures.
- Well trained Operator is reliable. With a good coverage of **CCTV** operator can respond to fire in **less than 3 minutes** or so.
- Operators are always **present** in plant on 24/7 basis.
• Material Selection (9% Nickel SS alloy)
• Seismic classification
• Separation of fuel and ignition Sources
• Minimal congestion
• Minimization of flanges
• Impounding basin
• Hazardous area classification/ATEX compliance
• Process trips
• Pressure relief

• F&G detection
• ESD (minimization of isolatable section)
• Blowdown
• Passive Fire Protection
• Active Fire protection
ESD-1 is a MUST because:

- There is **statutory obligation**

- LNG plant works under **high pressure** and **large inventories**. If ESD-1 is not activated on confirmed medium and large releases then gas cloud certainly which reach a source of ignition and cause **explosion**.

- If ESD-1 is not activated on confirmed medium and large releases then jet fires will damage the unprotected equipment and structures in less than 15 min and cause **escalation** including **BLEVE**.

- ESD-01 includes numerous executive actions with proper order and time delays. These actions include isolating the ignition sources, close the valves, stop machineries and activate the fire protection systems.

- Due to the **low probability of emergency** events operators can have little familiarity with the tasks that they have to perform. This results in increased likelihood of error. **Stress** also increases the likelihood of error.

- Data on human behaviour in fires in buildings shows that 80% - 90% of people assume a fire alarm to be false in the first instance

- Efficiency of F&G can be **improved** by better design including fire & gas mapping, use of diverse detectors and voting system.
It's better to be **Safe** rather than **Sorry**!

Can gas detection get better can better using:

- 3D Gas mapping
- IR Camera
- Acoustic gas detectors
- Cold detection
- Low pressure detection at process
- Diversity, voting system and quantitative SIL assessment
- Risk based inspection and maintenance
3D Gas Mapping

From Shell Global Solution

IR fixed Camera

Images taken with the FLIR Infrared Cameras

FLIR Infrared Camera
http://www.flir-press.com
Acoustic gas detectors

Gassonic ultrasonic (acoustic) gas leak detectors
http://www.gassonic.com

Cold detectors

Temperature drop during simulated leak in an LNG pipeline

Sensornet Cold detection
http://www.sensornet.co.uk/
Initiation by operator ≠ No need for ESD-1

Gas detection

- Initiates ESD-1
- Alarm in CCR

Operator initiates ESD-1
ESD-1 actions

- Isolate quickly sources of ignition
- Close ESD valves to isolate source of fuel
- Open the Blowdown valve to send fuel to safe location
- Activate fire protection systems (deluge, CO2, etc.)

A = Continuous release by the time that ESDV close the inlet and outlet of isolatable section.
B = Release to accident area between the closure time of the ESDVs and activation of blowdown valve.
C = Release to accident area and release to safe location via vent/flare when both ESDVs and Blowdown valves are activated.
Relief calculation according to API 521

API 521 provides guidelines for pressure relief when vessel is exposed to pool fires.

Liquid pools can be formed by all hydrocarbon products containing pentane and heavier components but also by butanes/butenes at sub-zero ambient temperature and low pressures (<4 bara).
Jet fire & Escalation

- Intensity of jet fires is much higher than pool fires.

- For jet fires impingement is the main concerns and not thermal radiation.

- Jet fires are directional.
Receiver Contains Liquefied Gas

Step 1 - Fire case relief valve on Receiver opens to protect against overpressure
Step 2 - Following relief liquid level decrease in receiver and vapour part of vessel is exposed to jet fire.
Step-3: If Receiver is not protected by passive fire protection it will fail in less than 15 min and cause BLEVE.
Need Analysis based on Medium Release (20 mm)

- Safety distance: distance between the source & receiver > jet fire length @ 15 min
- Duration of jet fire < 15 min
- Blowdown content of source to safe location in 15 min
- Relief valve on receiver relief pressure to reach at 7 bar in 15 min
- Passive fire protection on receiver to increase the failure rate of receiver to more than duration of fire
Thank you for your kind attention!

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