Lessons learned from LPG/LNG Accidents

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Outline of the presentation

• Highlights from EU LPG/LNG accident reporting
• Some notable past and recent accidents
  • Feyzin 1964
  • Mexico City 1985
  • Esso Longford 1998
  • Plymouth, Washington, USA 2014

This presentation is designed to be a resource for inspectors, so details and references are provided in the slides that will not be fully covered in the oral presentation.
eMARS accidents involving LPG and LNG since 1986

**Number of accidents involving LPG vs. LNG**

- LPG: 18 accidents
- LNG: 19 accidents

**Types of activities associated with eMARS LPG/LNG accidents**

- Storage and Distribution: 22 accidents
- Petroleum refinery: 8 accidents
- Power supply: 5 accidents
- Metal processing: 1 accident
- Unmanned: 1 accident

**Process location of accidents involving LPG/LNG**

- Loading/Unloading: 14 accidents
- Storage: 10 accidents
- Maintenance: 7 accidents
- Production: 3 accidents

**Only accidents directly associated with LPG/LNG production, storage and distribution**
• **05/02/2011.** While replacing a metal gangway straddling four horizontal storage tanks, the crane operator caused a collision with the valves of three of the cylinders. No victims. **12 tonnes of propane were released into the atmosphere.**

• **05/12/1989.** At a peak saving station, while verifying whether gas export equipment could achieve a "1-hour" stand-by condition, an LNG jet occurred when drain lines were opened and venting when the pump was started. **The operators did not make sure that the valves were closed.** It was not known that, following the cooling down procedure, it could produce **sufficient gas to cause an explosion** if ignited. **2 workers burned** on the hands and face.

• **26/07/2016.** During loading operations at a newly commissioned LNG site, **1000 m³ of LNG was released and ignited.** There was a rapid drop in temperature in the tank. Alarm thresholds and inhibitors were miscalibrated so that a **safety valve opened** (?) but an alarm did not go off. **€10 million damage.**
• 01/07/1997. Release of 19.7 tonnes of natural gas from LNG tank, during modification to tank roof to install a densitometer. The release was due to a failure of the isolation (inflatable bag) between tank contents and cold-cutting operation on pipe. No victims.

• 23/12/2003. Failure to close a valve after earlier loading of butane. As a result 50 tons of butane escaped. Actions taken: Install a double valve on the pipe, review/revise loading/unloading procedures. No victims.
Failures in equipment or in material handling caused by:

- Leaks from buried factory pipes, transport pipes and flexible hoses due to perforating corrosion
- Failure in the purge lines due to poor maintenance
- Mistakes in purging and testing procedures
- Uncontrolled safety valve openings:
  - After filling spheres or
  - Due to incorrect settings when pressure alarm thresholds of the sphere are set higher than the valve calibration pressure
- Malfunctions of control and level alarm devices
- Leakage from flanges during maintenance work or during pressurisation

NOTABLE LPG/LNG ACCIDENTS
BLEVE IN AN LPG STORAGE FACILITY AT A REFINERY (FEYZIN, FRANCE 1964)

References:
1 https://www.aria.developpement-durable.gouv.fr/fiche_detailllee/1_en/?lang=en
3 The Feyzin Disaster - Case study, Loss Prevention Bulletin 077, IChemE, October 1987
http://www.icheme.org/~/media/Documents/icheme/Resources/LPB/LPB%20samples/Feyz
inDisaster.ashx
Sequence of Events

**What happened**

The refinery LPG storage zone contained 12,850 m³ of pressurised hydrocarbons in 10 spherical tanks, 22.5 m from the motorway.

A technician’s assistant was extracting a sample from and performed the steps in the wrong order.

The valves froze and locked.

Eventually, a car engine in start-up ignited the cloud (the driver died). An intense blowpipe flame appeared beneath the sphere 1 min later.

First responders from the refinery arrived on the scene and tried to cool the adjoining spheres and extinguish the giant flare (very large since safety valves had been opened).

The sphere suddenly exploded around 8:45 am (1st BLEVE explosion), causing 13 fatalities. An adjacent propane sphere then exploded at 9:40 am (2nd BLEVE).

**Consequences**

The incident resulted in 18 deaths, including 11 fire-fighters and 84 injured (42 workers could not return to work for at least 3 months).

Domino effects, i.e., ignition of neighbouring tanks, projectiles 1,475 homes and other structures damaged
Causes and Lessons Learned

The primary cause of the propane leak was the operational fault of the plant operator. This fault was exaggerated because of poor access to the valves and the lack of permanent valve spanners. It is probable that a solid plug of ice or propane hydrate stopped the drawoff line above the upper valve. This plug released when the upper valve was fully opened.

The discharge from the drain line was directed downwards in the vicinity of and under the valves, instead of to the side. This formed the cloud which made the recovery and repositioning of the valve lever impossible.

Darkness and poor lighting added to the difficulties.

Many Lessons Learned!

- BLEVEs are a new phenomenon
- LPG Storage Tank Design and Technical Measures
- Emergency response measures and fire fighting strategy
- Distances from dense residential and commercial areas including roadways
- Impossible to give detail on all of them
Where possible, the direct draining of aqueous liquid from LPG vessels should be avoided on systems which have to be regularly operated and, in particular, where large volumes of LPG at high pressure could accidentally be released.

If it is not practicable to install a closed draining system then consider the use of a dewatering pot isolated from the main vessel during the draining operation.

This should minimise the quantity of LPG accidentally released.

Reference: The Feyzin Disaster - Case study, Loss Prevention Bulletin 077, IChemE, October 1987
http://www.icheme.org/~/media/Documents/icheme/Resources/LPB/LPB%20samples/FeyzinDisaster.ashx
Reference: http://www.hse.gov.uk/comah/sragtech/casepemex84.htm
http://www.unizar.es/guiar/1/Accident/San_Juan.htm

THE SAN JUARNICO, MEXICO, LPG BLEVE DISASTER (1984)
Sequence of Events

What happened

The LPG inventory on site was about 11,000 cubic meters. The terminal was being filled from a refinery 400 kilometers away.

The disaster was initiated by a gas leak on the site, likely caused by a pipe rupture during transfer operations, probably due to tank overfill and overpressure in the line. A plume of LPG concentrated at ground level for 10 minutes. The plume eventually grew large enough to drift towards the facility's waste-gas flare pit.

At 5:40 a.m., the cloud reached the flare and ignited, resulting in a vapor cloud explosion, and a massive conflagration. Just four minutes later, at 5:44 a.m., the first tank underwent a BLEVE.

Over the next hour, 12 separate BLEVE explosions were recorded. It is believed that the escalation was caused by an ineffective gas detection system.

Consequences

Fatality estimates ranged from 500 to more than 600.
Injury estimates ranged from 5000 to 7000.
The terminal was destroyed.
Lessons Learned

**Plant Layout:** positioning of the vessels

**Emergency Isolation:** Site fire water system was disabled in the initial blast. Water spray systems were inadequate.

**Active / Passive Fire Protection:** Survivability of critical systems, insulation thickness, water deluge.

**Leak / Gas Detection:** Installation of a more effective gas detection and emergency isolation system could have averted the incident. The plant had no gas detection system. When the emergency isolation was initiated it was too late.

**Emergency Response / Spill Control:** site emergency plan, access of emergency vehicles. Hindering the arrival of the emergency services was the traffic chaos, as local residents sought to escape.

**Contributors to the Disaster**

Failure of the overall system of protection, including layout, emergency isolation and water spray systems

No gas detection system

Emergency isolation was too late

General lack of understanding of potential hazards

Traffic chaos as residents fled and the emergency services tried to gain access

Alerted North America to the risk of LPG BLEVEs?

“Mexico City demonstrated that BLEVEs are as important as VCE hazards for LPG sites”
References:
• [https://hazoz.files.wordpress.com/2013/03/longford_responding-rev1.pdf](https://hazoz.files.wordpress.com/2013/03/longford_responding-rev1.pdf)

EXPLOSION AT AN LNG TERMINAL – ESSO LONGFORD (AUSTRALIA, 1998)
What happened

At 8:20 am, a hot oil pump failed and would not restart, resulting in a loss of lean oil circulation in Gas Plant No. 1.

A failure to restart the pumps, which then stayed off-line for several hours, resulting in no flow of hot lean oil to key vessels.

An absence of hot lean oil meant the cold liquid from absorbers chilled the vessels to extremely low temperatures.

Re-introduction of hot lean oil into the heat exchanger caused it to rupture and release about 25 metric tons of hydrocarbon vapor, which then ignited, setting off an explosion and fire.

Consequences

- Two employees died immediately.
- Gas supply from all three plants at the site stopped because other gas processing plants on the same site were not effectively isolated.
Lessons Learned

Key Lessons Learned

• Vessels were exposed to cold temperatures outside design parameters.
• Failure to conduct a HAZOP study or any other procedures for the identification of hazards in the gas plant

• Lack of operating procedures to deal with the situation combined with inadequate training of personnel resulted in an inappropriate response to the situation
• Reduction of supervision at Longford, including transfer of engineers to Melbourne.
• Asset integrity management practices/policies may have been a contributing factor
• Failure to isolate critical plant processes

(Longford Commission Report)
FIRE AND EXPLOSION DURING LNG PLANT START-UP (USA, 2014)

(From Failure Investigation Report – Liquefied Natural Gas (LNG) Peak Shaving Plant, Plymouth, Washington
Lessons Learned

Make sure that gas supply lines contain nothing but gas before the equipment they feed is started

The U.S. Chemical Safety Board (CSB) cites a number of explosions dating back to 1997 caused by improper purging - practices that were in most cases allowable under prevailing regulations.

Sequence of Events

What happened
LNG Plant experienced a catastrophic failure and a resulting explosion in the LNG-1 purification and regeneration system during start-up.

The primary cause was a substandard purge performed after leaving the LNG-1 purification loop open to the atmosphere for 5 subsequent days.

A flammable gas-air mixture remained in the system which then entered the salt bath heater and auto-ignited during start-up.

The purge and pack procedure used by employees did not provide a sufficient detail to assure successful and repeatable results.

Low toughness of the adsorber metal allowed it to fail in a brittle manner causing fragmentation.
Consequences

In this incident, 5 employees were injured and treated on site and one employee was flown to the hospital for burns.

An emergency shutdown was activated and plant personnel were evacuated.

The nearby town was evacuated due to concerns that the outer tank shell was penetrated from flying debris.


The Kleen Energy Natural Gas Explosion investigated by the CSB caused 6 deaths and 50 injuries (2010)

http://www.csb.gov/investigations/completed-investigations/?Type=2/
Thank you for your attention!