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Lessons learned from LPG / LNG Accidents

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the European Commission's
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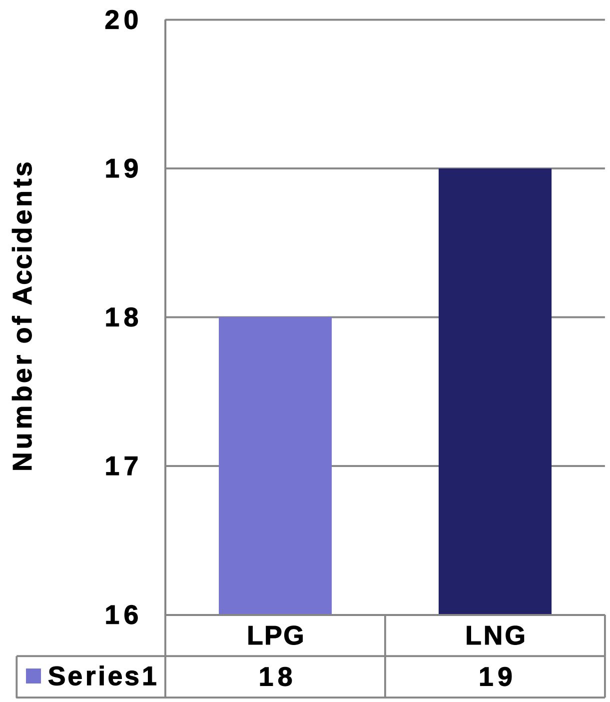
Outline of the presentation

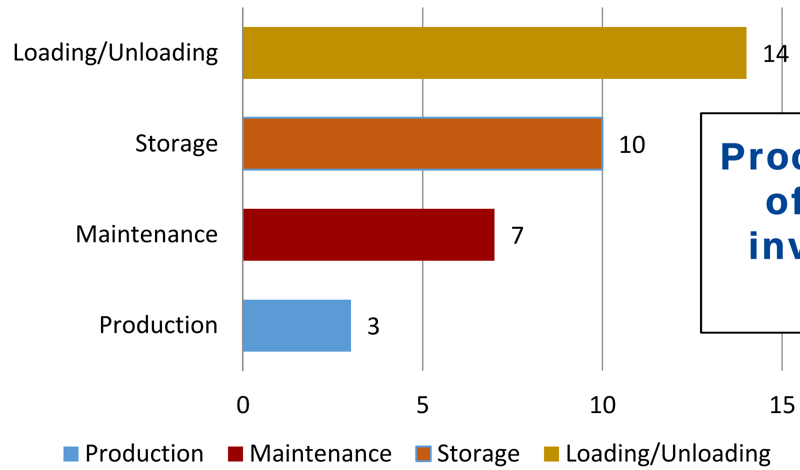
- Highlights from EU LPG/LNG accident reporting
- Some notable past and recent accidents
  - Feyzin 1964
  - Mexico City 1985
  - Esso Longford 1998
  - Plymouth, Washington, USA 2014

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.

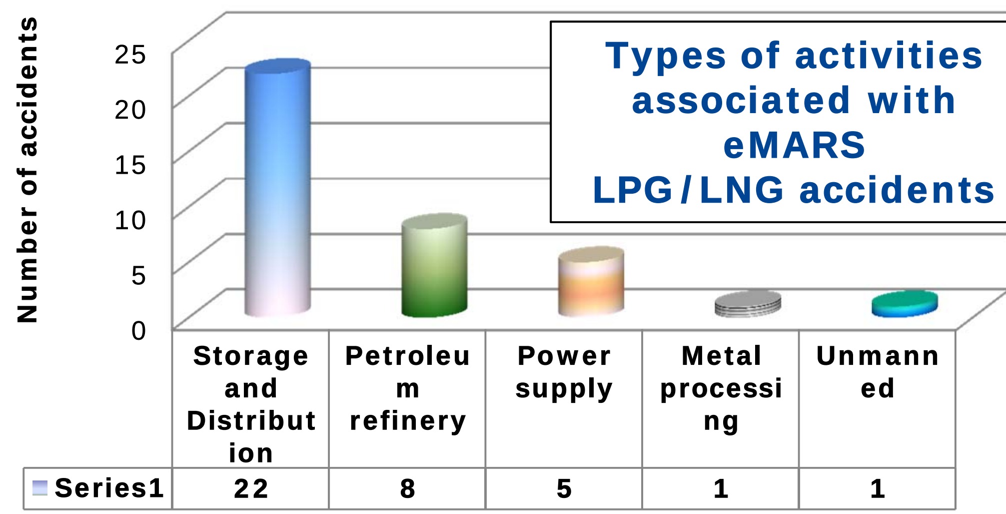
eMARS accidents involving LPG and LNG since 1986



Number of accidents involving LPG vs. LNG



Process location of accidents involving LPG / LNG



Types of activities associated with eMARS LPG / LNG accidents

Only accidents directly associated with LPG / LNG production, storage and distribution

Notable incidents in eMARS (1)

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- **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 m^3 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.**

Notable incidents in eMARS (2)

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- **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.

Typical LPG/LNG failures – French study (1992-2012)

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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

(From https://www.aria.developpement-durable.gouv.fr/wp-content/uploads/2013/08/ED_CSPRT-sites-stockage-GIL-A_aout2013.pdf (in French)

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NOTABLE LPG / LNG ACCIDENTS

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References:
1 https://www.aria.developpement-durable.gouv.fr/fiche_detaillee/1_en/?lang=en
2 http://www.sozogaku.com/fkd/en/hfen/HC1300001.pdf
3 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

BLEVE IN AN LPG STORAGE FACILITY AT A REFINERY (FEYZIN, FRANCE 1964)

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Sequence of Events

What happened

The refinery LPG storage zone contained 12,850 m^3 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).**

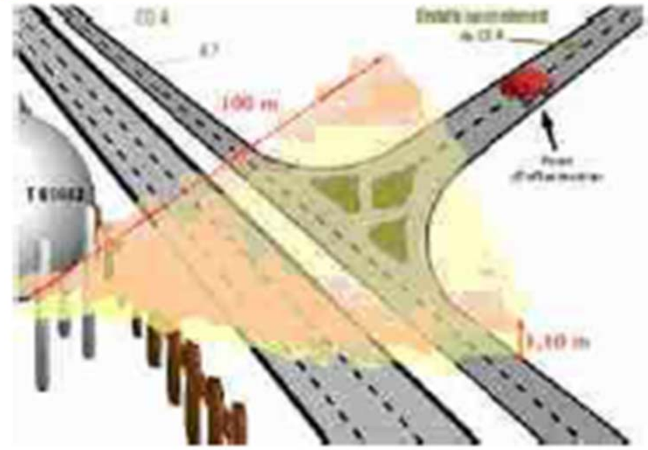

Figure 18 A highly schematised representation of the cloud according to witnesses

https://www.aria.developpement-durable.gouv.fr

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 val**ves 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 <u>new</u> 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**

Lessons Learned for LPG storage design (Example)

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.

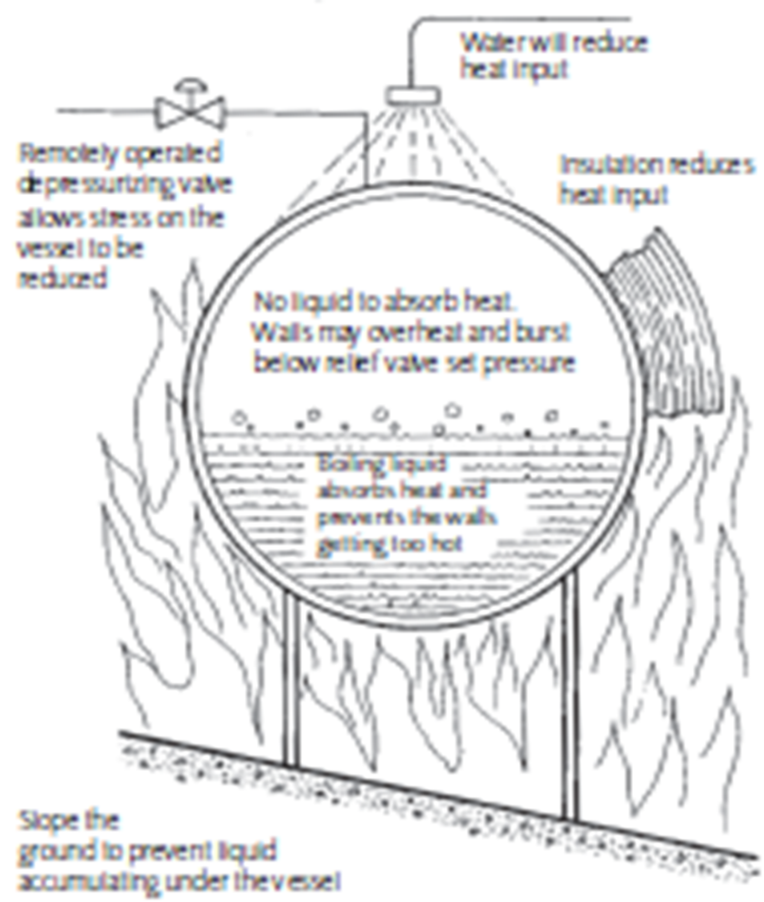

Figure 1.7: Preventing BLEVES in LPG vessels

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

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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)

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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.**

http://www.fotolog.com/josezentenoc1/3319295/

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"

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References:

- http://www.ogj.com/articles/print/volume-97/issue-27/in-this-issue/gas-processing/commission-blames-esso-for-longford-disaster.html)
- https://hazoz.files.wordpress.com/2013/03/longford_responding-rev1.pdf
- J. Nicol. 2001. Have Australia's major hazard facilities learnt from the Longford disaster? An evaluation of the impact of the 1998 Esso Longford explosion on major hazard facilities in 2001. Public Policy Unit. The Institution of Engineers Australia. http://158.132.155.107/posh97/private/Case/ESSO.Longford.Explosion(1998).pdf

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

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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**.

2 NEWS·EXTRA

'I saw this huge flash

GAS CRISIS 13

Blast not the first for Esso facility

THE GAS CRISIS

Esso denies failure of duty

Consequences

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

Lessons Learned

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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**

Contributing factors

- **Inadequate risk assessment (HAZOP not widespread at the time)**
- **Lack of training**
- **No engineers on site**
- **Poor alarm management**
- **Process design and maintenance failures**

(Longford Commission Report)

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

(From Failure Investigation Report – Liquefied Natural Gas (LNG) Peak Shaving Plant, Plymouth, Washington
https://www.phmsa.dot.gov/staticfiles//PHMSA/PipelineFailureReports/FIR_and_APPENDICES_PHMSA_WUTC_Williams_Plymouth_2016_04_28_REDACTED.pdf)

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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

Photo from CSB report - http://76.227.217.14/UserFiles/file/FINAL%20Urgent%20Recommendation.pdf

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.

LNG-1 Salt Bath Heater where auto-ignition initiated.

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

Following the ConAgra explosion (2009) – (3 deaths, 71 injuries) the U.S. Chemical Safety Board (CSB) on Oct. 2, 2009 released a Safety Bulletin on the **dangers of purging gas piping into buildings**

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/

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Thank you for your attention!

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