

Liquefied Petroleum Gas (LPG)

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JET FIRE IMPINGEMENT ON LIQUEFIED PETROLEUM GAS (LPG) VESSELS

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The paper attached describes part of the HSE/HSL exhibit at the recent prestigious Festival of Science.* HSE used the Festival to raise awareness of the breadth of its research activities and the way science underpins a lot of its work.

The video and supporting photographs used as part of the exhibit illustrate the effects of fire attack on bulk LPG storage vessels. They show how overheating can lead rapidly to vessel rupture and BLEVE if the vessel does not have some form of fire protection.

Research has shown already how LPG vessels can be protected against various forms of fire attack but there were gaps in our knowledge about jet fire impingement. This paper describes work done by HSL on the failure mode of LPG vessels under jet fire attack. It highlights the performance of passive fire protection (PFP) coatings and the development of a widely used fire resistance evaluation test for PFP. It also outlines how new research is identifying key parameters for the design of effective water deluge systems.

TD5 can provide copies of the video.

* British Association for the Advancement of Science. Festival of Science, Sheffield, September 1999.

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Liquefied Petroleum Gas

LPG is a commonly used fuel held as a liquid in a pressurised vessel. The liquefied petroleum gases in general use are butane and propane. These exist as gases at normal temperatures and pressures but can be liquefied under moderate pressure. If the pressure is subsequently released, the LPG again becomes gaseous. If an LPG vessel is involved in a fire, it may overheat and rupture violently giving an intensely hot fireball and may project pieces of the vessel over considerable distances. Such a rupture is commonly termed a Boiling Liquid Expanding Vapour Explosion (BLEVE). The potential consequences of this have unfortunately been dramatically illustrated by the disaster at the PEMEX LPG Installation, Mexico City in 1984 when over 500 people were killed.

Whilst work in the past has established how LPG vessels can be protected against a number of fire

scenarios, there was insufficient knowledge as to how vessels could be protected against a jet fire. A jet fire can result from the failure of pipework carrying LPG under pressure. A jet fire has high erosive effects and a much higher heat flux (eg 250 kW/m²) than, for example, a petrol fire (ca. 100kW/m²).

Vessels without fire protection

In order to determine the level of fire protection required to prevent vessel failure in a jet fire, it was first necessary to understand how vessels failed. HSL performed a number of failure mode trials to establish the:

- vessel conditions at failure to facilitate development of models predicting failure;
- consequences of failure eg missile effects from fragments and/or rocketing vessels, fireballs, blast;
- time to failure in relation to the available emergency responses; and
- effectiveness of relief devices ie can the vessel be emptied before it fails.

Four trials were performed on two tonne propane vessels with 20% to 85% levels of fill. A ca 2 kg/s propane jet was used (equivalent to a leak from a 1/2 inch diameter leak in a flange) to take the vessels to failure. Each vessel was extensively instrumented to monitor the wall and contents temperatures, the pressure and the amount of LPG remaining in the vessel. In each trial, the pressure relief valve lifted after between one and two minutes giving a jet of burning propane above the vessel. All the vessels failed catastrophically within 5 minutes giving fireballs up to 120 m high (85% full tank - photograph).

Passive fire protection (PFP)

The performance of two types of PFP coating materials were investigated:

- a light weight cement based material; and
- an epoxy material which intumesces in a fire to form an insulating char.

For each type of PFP coating, the same jet fire as previously used with the unprotected vessel trials, was impinged on the vessel. After 90 minutes, both vessels were still in a safe state. This compares with failure of an unprotected vessel within 5 minutes.

The work was used to help develop the Jet Fire Resistance Test of Passive Fire Protection Materials. This test is now extensively used to evaluate the performance of PFP materials used both on- and off-shore. The work has also been used to inform recently issued guidance prepared by the LP Gas Association in full consultation with HSE.

Water deluge protection

It has been shown that the currently recommended application rate for deluge systems of 9.8 litre/m²/minute is unable to protect a vessel against a jet fire. Research has been performed to:

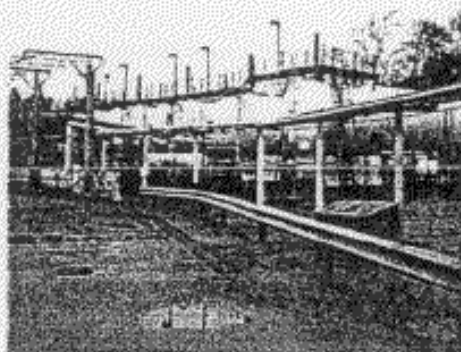
- identify the nozzle type and arrangement and water pressure required to give adequate water coverage to protect against the ca 2 kg/s jet fire;
- identify the effects of a blocked nozzle;
- identify the effect of delayed initiation of the deluge system.

This work is leading to the identification of the key parameters to enable a deluge system to be designed to protect a vessel against a jet fire.

JET FIRE IMPINGEMENT ON LIQUEFIED PETROLEUM GAS (LPG) VESSELS

BACKGROUND

- ◆ LPG is a commonly used fuel held as a liquid in a pressurised vessel.
- ◆ Incidents have shown that LPG vessels can fail catastrophically in a jet fire.
- ◆ Earlier guidance did not cover fire protection of vessels from jet fires.

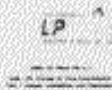


FIRE PROTECTION OF VESSELS

- ◆ Vessels are typically protected by passive fire protection (PFP) or water deluge.
- ◆ Information from research was necessary for the preparation of guidance.

GUIDANCE

- ◆ The industry trade association, with HSE support, has issued revised guidance.
- ◆ A jet fire test protocol, suitable for both onshore and offshore use, has been published.



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Jet Fire Impingement on Liquefied Petroleum Gas (LPG) Vessels

An agency of the Health and Safety Executive

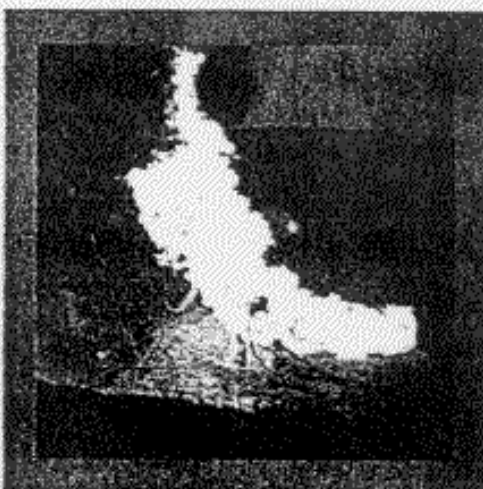
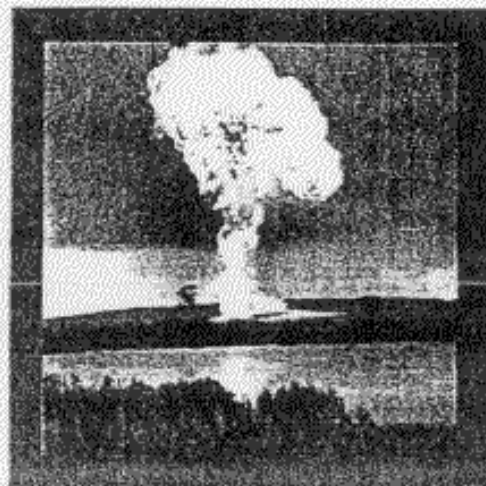
Background

Knowledge was required on:

- ◆ how LPG vessels fail in a jet fire; and
- ◆ how vessels can be protected against a jet fire.

Vessels without Fire Protection

- ◆ Vessels, containing different quantities of LPG, were heated to failure by a jet fire.
- ◆ All the vessels failed within 5 minutes producing a Boiling Liquid Expanding Vapour Explosion (BLEVE).



Passive Fire Protection (PFP)

- ◆ PFP coatings were shown to be able to prevent vessel failure.
- ◆ HSL was closely involved in the development of the *Jet Fire Resistance Test of Passive Fire Protection Materials*.

Water Deluge Protection

Research:

- ◆ has shown that the current application rate is



Research:

- ◆ has shown that the current application rate is unable to protect a vessel against a jet fire; and
- ◆ is leading to the identification of the key parameters to enable a deluge system to be designed to protect a vessel against a jet fire.

