MINISTRY OF MANPOWER

Learning Report

FATAL FIRE

AT

SUMMIT GAS SYSTEMS PTE LTD

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1. About the Incident

On 21 June 2019, at about 5:15 pm, a fire broke out at Summit Gas Systems Pte Ltd ("Summit Gas"), located at 43 Jalan Buroh, Singapore. The workplace was in the business of filling and supplying Liquefied Petroleum Gas (LPG) cylinders. LPG cylinders were filled in a shed that comprised two filling lines. One line was for filling of large cylinders (50-kg cylinders) and the other was for filling of small cylinders (12-kg cylinders). See Figure 1 for an overview of the site.

The fire started at the large cylinder filling line when one of the cylinders fell and hit a ½-inch small-bore pipeline that was connected to an LPG supply rim. The impact dislodged the small-bore pipe, releasing LPG into the open. A fire broke out immediately and rapidly spread to other parts of the filling shed.

The fire resulted in one fatality and caused burn injuries to two others. All three victims were working at the large cylinder filling line when the fire occurred. The filling shed suffered extensive damage after the fire and explosion (Figure 2).

Figure 1. Site overview (not to scale)

Figure 2. Scene of the filling shed after the fire

2. Liquefied Petroleum Gas (LPG)

2.1 Properties and Hazards

LPG is a flammable gas comprising a mixture of propane and butane. Under normal room temperature and pressure, LPG exists in the gaseous phase. As for LPG stored in cylinders, it exists as a liquid under pressure.

LPG forms a flammable mixture with air between concentrations of 2% and 10%, and readily burns in the presence of an ignition source, thereby posing fire and explosion hazards. LPG is heavier than air and tends to travel along the ground leaving a vapour trail and accumulating in low-lying areas. Any subsequent ignition could cause a flashback along the vapour trail.

2.2 LPG Cylinder

Cylinders containing LPG could pose a risk of explosion when exposed to external fires. Fire impinging on a cylinder would weaken the shell and eventually cause the cylinder to fail catastrophically. The sudden loss of containment of pressurised LPG liquid into the open would generate large quantities of LPG vapours, resulting in an explosion. This phenomenon is known as Boiling Liquid Expanding Vapour Explosion (BLEVE).

LPG cylinders should therefore be stored at a safe location away from sources of ignition and potential impact.

3. LPG Cylinder Filling Operations at Summit Gas

3.1 The Carousel and Conveyor System

Summit Gas used a semi-automated LPG cylinder filling carousel, fitted with 12 filling stations for the large cylinders filling line operations. LPG from the bulk storage tank was pumped to the centre of the carousel and into a supply rim. From the supply rim, the LPG then flows through a ½-inch small-bore pipeline that was connected to the filling head via a flexible hose at each filling station.

The carousel was connected to a conveyor system and cylinders were automatically fed from the conveyor system into the carousel via an introduction unit (see Figure 3). The introduction unit had a pneumatic push arm that would feed an empty cylinder into the filling station of the carousel. Once filled, the cylinders would be ejected from the carousel back onto the conveyor and moved to the storage area.

Although the movement of the cylinders on the conveyor system and carousel was automated, operators would still need to manually connect the filling head to each cylinder and disconnect it after the filling was completed.

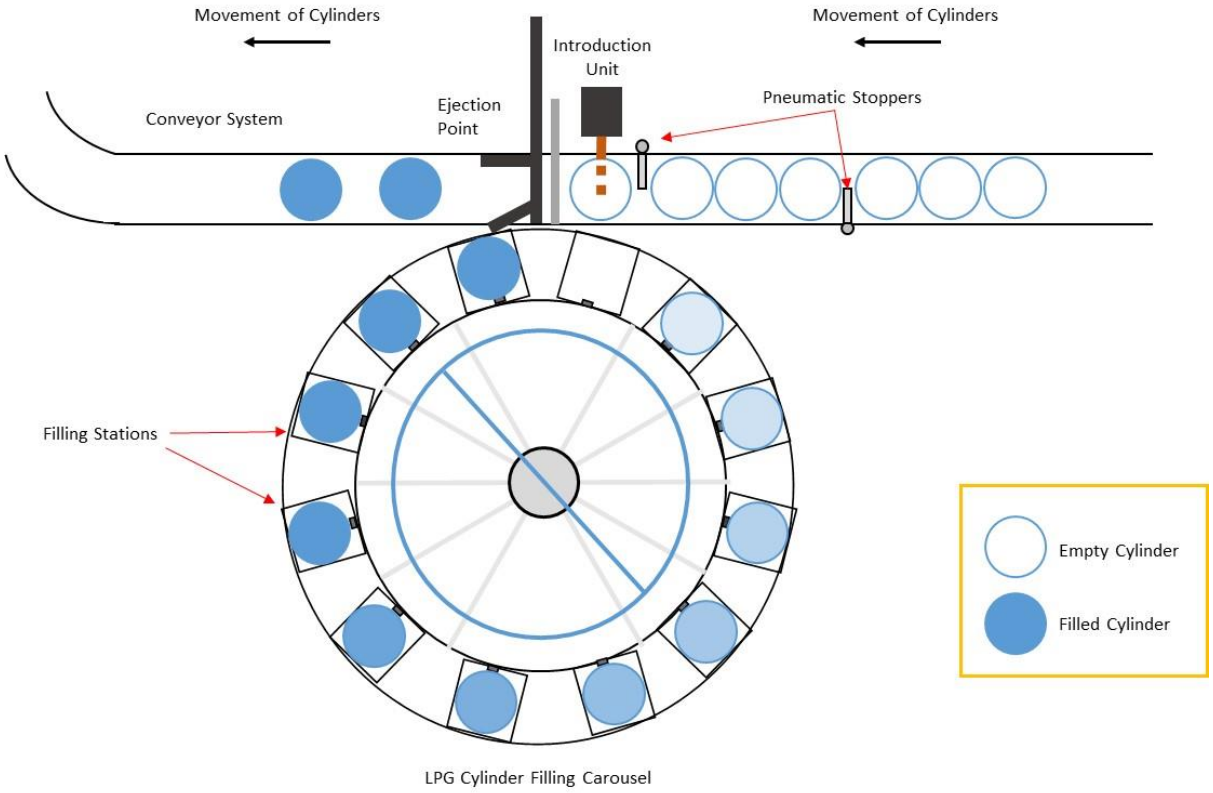

Figure 3. Sketch showing the LPG cylinder filling carousel and conveyor system

3.2 Controls for LPG Cylinder Filling Operations

The LPG cylinder filling system was programmed to automatically control the introduction and ejection sequence of the cylinders using sensors, limit switches, pneumatic mechanisms and stoppers. The programmed controls were designed to achieve the following:

a) Queue the cylinders onto the conveyor. This was achieved via a pair of pneumatic stoppers (located before the introduction point) to hold the cylinders in the queue;

b) Align the filling stations to the introduction point;

c) Detect that the filling station is empty;

d) Activate the push arm to inject a waiting cylinder into the empty station of the carousel;

e) Advance the next cylinder to the introduction point via the release of the stoppers; and

f) Eject the cylinder after it has been filled.

The carousel, conveyor system and the introduction unit were each equipped with separate emergency stop buttons. There was no master control to stop all three systems at the same time.

4. Incident Findings

4.1 Sequence of Events

Based on the findings, the likely sequence of events that led to the fire were:

a) Three operators were operating the large cylinders filling line. One of them was in charge of connecting the LPG filling head to the valve on the empty cylinder to commence the filling process, while the other two were at the ejection area, tasked to disconnect the filling head from the outgoing cylinder from the carousel and check for LPG leaks at the cylinder valve respectively.

b) During the LPG cylinder filling operation, the pneumatic stopper on the conveyor system at the introduction unit to the carousel malfunctioned. As the conveyor was still running, this led to the cylinders colliding against one another at the introduction point. The collision resulted in misalignment or tilting of the awaiting cylinder at the introduction point. When the push arm at the introduction unit activated and fed the cylinder into the filling station of the carousel, the cylinder toppled into the gap between two filling stations.

c) The toppled cylinder hit a small-bore LPG pipeline on the carousel. The pipeline was threaded to a nozzle on the LPG supply rim.

d) The impact from the toppled cylinder caused the small-bore pipeline to dislodge from the nozzle, leading to the release of LPG, which ignited. Refer to Figure 4 and Figure 5 for the close-up view of the small-bore pipeline.

e) The three operators at the large cylinders filling line fled the area when the fire broke out. One of the operators was fatally injured while the other two suffered burn injuries.

f) All other personnel at the site were evacuated.

g) SCDF responded to the fire and eventually isolated the LPG supply by manually shutting supply valves at the bulk storage tank. The fire was extinguished after more than two hours of firefighting.

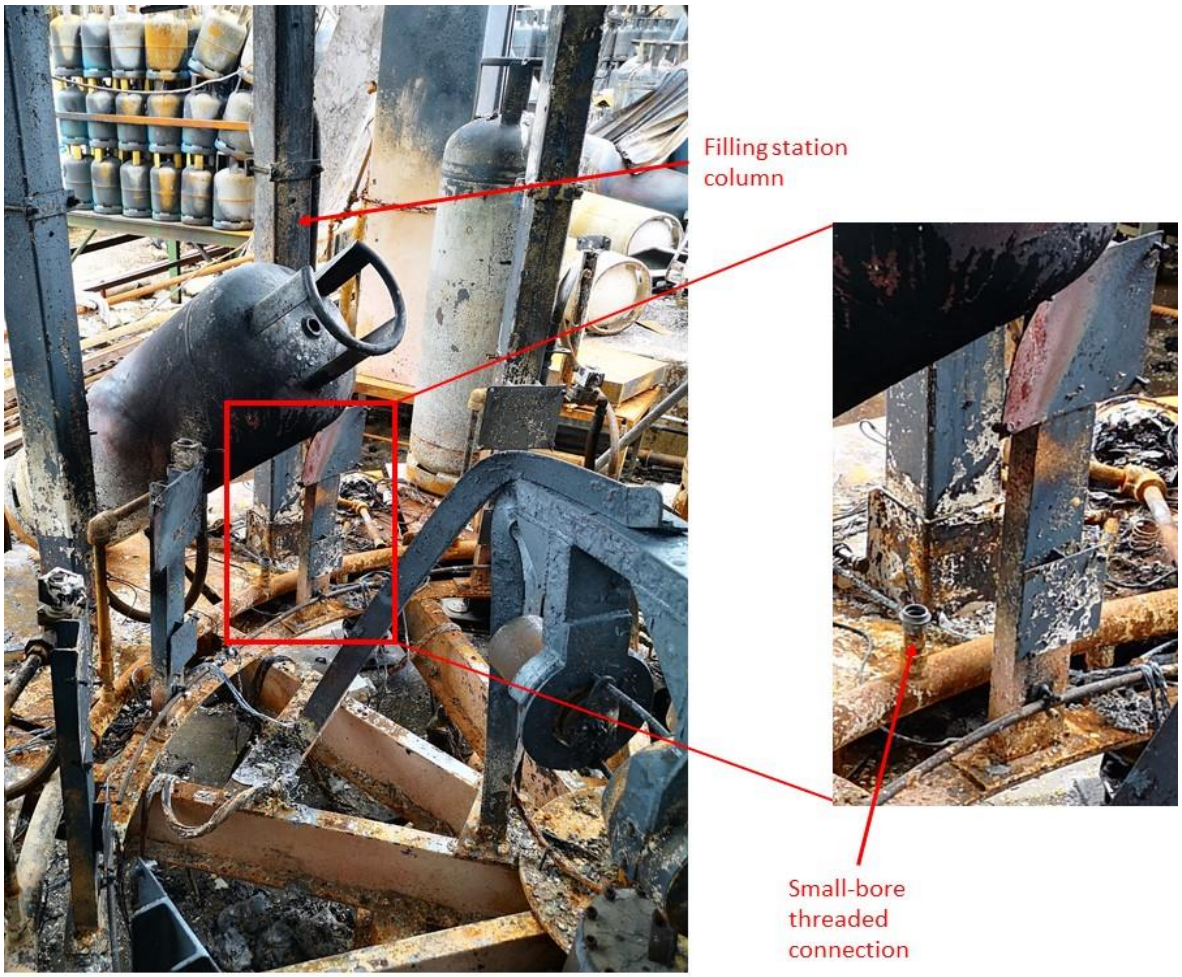

Figure 4. Close-up view of the nozzle connection on the LPG supply rim

Figure 5. Close-up view of the dislodged ½" small-bore LPG pipeline

4.2 Contributing Factors

I. Modifications to ½-inch small-bore pipeline

Each filling station was mounted to the base of the carousel, with a supporting column that allowed filling controls to be affixed on. The configuration of the ½-inch small-bore pipeline was originally lined to run along the column, linking the rim and the filling head (see Figure 6).

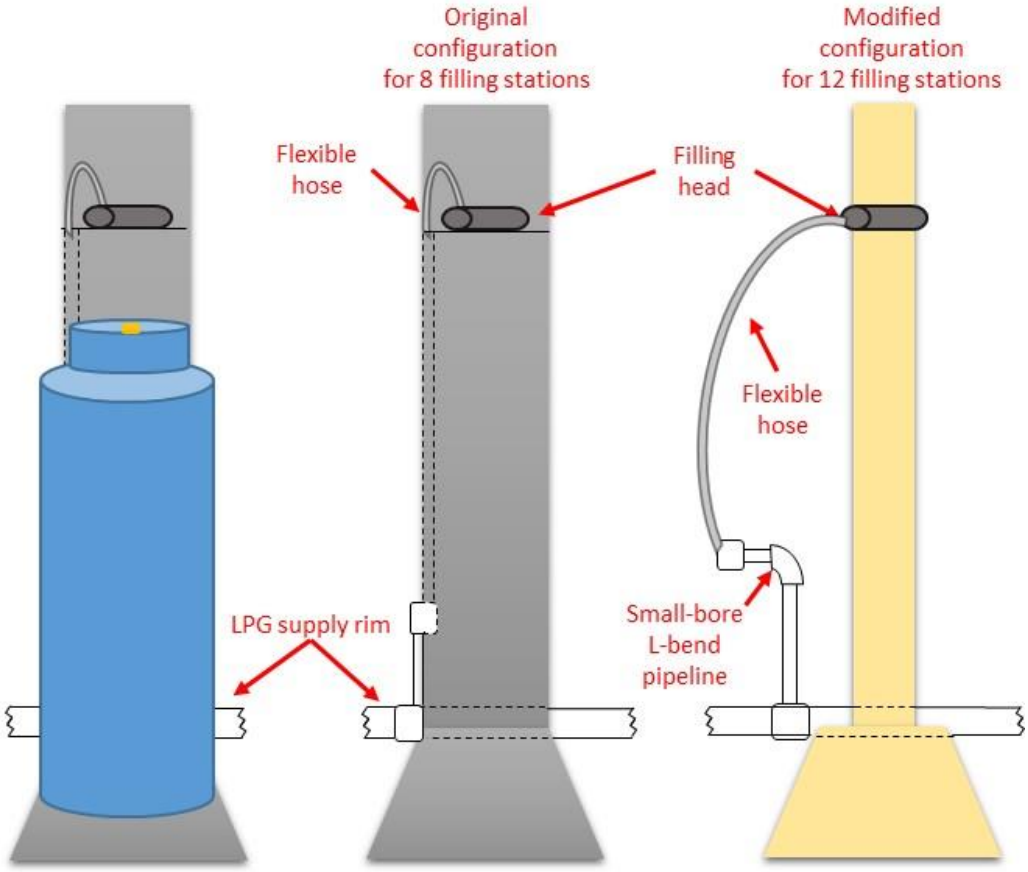

Figure 6. Modifications to the small-bore pipeline configuration

The carousel was modified some years ago to expand the number of filling stations from 8 to 12. As part of this modification, the ½-inch small-bore pipeline was modified to an L-bend pipeline that extended away from the column, without any impact protection. The modification rendered the small-bore pipeline susceptible to external impacts.

II. Escape Route and Fire Retardant Clothing (FRC)

There was a large number of cylinders placed around the carousel and the conveyor system. These cylinders were either filled, waiting to be filled or set aside for painting works or further checks. When the fire broke out, the cylinders restricted the escape route of the workers.

The workers were also not wearing fire retardant clothing, compromising their ability to escape quickly.

III. Emergency Isolation

The emergency shutdown button to isolate the LPG supply from the bulk storage tank was located near the small cylinders filling line, at the north end of the filling shed (refer to Figure 1). There were no other persons in the vicinity to activate the emergency isolation when the fire occurred. Workers were not familiar with the actions to be taken in the event of an emergency.

After the fire broke out, LPG continued to flow into the carousel supply rim, escalating the event. The LPG supply was eventually stopped when SCDF isolated the supply valve at the bulk storage tank.

5. Learning Points

Based on the findings gathered from this incident, four learning points were derived.

5.1 Protect Small-Bore Pipelines from Accidental Impact

Small-bore pipelines are vulnerable to external impacts. Without protection, external impacts on an exposed small-bore pipeline could cause it to dislodge or rupture, resulting in a leak. Such a leak can lead to a major fire outbreak if it was connected to a larger pipeline conveying pressurised flammable substances.

Protective measures, such as guards or barricades, must be put in place to minimise the risk of accidental damage to the small-bore pipe and minimise the harmful consequences of possible piping failure. Whenever there are opportunities to re-construct or re-configure small-bore pipelines, impact forces caused by external conditions must be taken into account in the design of pipelines[1] with the view to eliminate or minimise such external impacts.

In addition, it is crucial to recognise that modifications could compromise the safeguards built into the original design or introduce new risks. Hence, implications due to any change must

[1] ASME Code for Process Piping, B31.3

be determined and managed in a systematic manner. More details on how to implement an effective system for management of change (MOC) can be found in Section 6.

5.2 Provide a Master Shutdown Button for Safe and Coordinated Stoppage of Gas Filling

The LPG filling system comprised the carousel, conveyor system and the introduction unit, and required a coordinated shutdown, so that stoppage can be initiated safely during any abnormal situation. A master shutdown button must be provided to stop both the carousel and conveyor systems (including the introduction and ejection units) at the same time. An alternative is to provide automatic interlocks between the carousel and the conveyor systems, so that the carousel stops when the conveyor is halted and vice versa.

As configurations and complexity of integrated systems varies, implementing an effective master shutdown button for the whole system requires an understanding of the design and intended functions of the system, as well as the sequences for start-up, shutdown and troubleshooting. Workplaces can leverage on risk assessments to determine the configuration required for an effective master shutdown button of the entire system.

In addition, critical components of an LPG filling system, including the pneumatic stopper, must be maintained periodically to prevent unsafe situations arising from the failure of these components.

5.3 Provide Fire Retardant Clothing to Workers Working with Flammable Substances

Persons working in areas where LPG or other flammable substances are present must wear fire retardant clothing (FRC). In the event of any fire or explosion, the FRC is able to slow down the spread of flames and heat on the wearer's body. Thus, the donning of FRC protects workers against burns or minimises burn injuries, as well as aiding their escape during emergencies.

5.4 Plan and Implement an Effective Emergency Response

All workplaces must have an effective emergency response to any fire or explosion. Emergency response plans must include an audible alarm system, unobstructed evacuation routes and designated safe assembly areas, as well as clearly defined emergency response roles for personnel.

In addition, for workplaces handling LPG or other flammable substances, as part of the emergency response plan, there must also be effective means to cut off the main supply of LPG or other flammable substances. As the fire could impede workers' access to such emergency cut off points, there must be multiple locations where the cut off can be activated safely. Appropriate persons should be appointed to activate the cut off in the event of an emergency.

The emergency response plans and procedures must be documented and communicated to all workers. Periodic drills must be conducted to test and familiarise workers with the emergency response.

6. Relevant Industry Practices

In addition to the learning points in Section 5, workplaces that handle or store flammable substances such as LPG should adopt the following practices.

6.1 Effective Management of Change (MOC)

Workplaces are subject to continual changes due to technological innovations, operational necessities and improvements in efficiencies. Workplaces are to establish and implement a set of procedures, commonly known as MOC[2], to address possible hazards and concerns that may be introduced by such changes.

Elements of an effective MOC include, but not limited to the following:

a) Establish the type of changes that are required to follow the MOC procedures (e.g. changes in configuration, software, hardware, etc);

b) Determine the basis for the proposed change especially those that involve changes to the existing design of the process;

c) Analyse potential safety and health hazards and risks, as a consequence of the change;

d) Identify additional risk control measures or modifications to the current procedures;

e) Seek proper authorisation for the change;

f) Verify that the change, including any additional control measures, are fully implemented, documented and communicated; and

g) Conduct periodic audits to validate the effectiveness of the MOC system.

6.2 Select, Operate and Maintain Electrical Equipment for Use in Hazardous Areas

Electrical equipment and wiring used should not constitute a source of ignition where flammable vapours may be present in the work environment, such as an LPG filling area. Equipment which could potentially generate electrostatic charges should be bonded and earthed, to ensure safe dissipation of the charges. For example, the resistance to earth should also be checked periodically that it does not exceed 10 ohms.

The World LPG Association has published guidance on hazardous zone classification for LPG cylinder filling plants and storage areas. It is important to ensure that electrical installation and equipment are suitable and safe for use in the classified hazardous zones. The selection and maintenance of electrical equipment for use within the hazardous zones, should be based on appropriate international standards, such as the IEC 60079.

[2] For more details on MOC establishment and implementation, please refer to the Guidelines for Management of Change for Process Safety, by the Center for Chemical Process Safety (CCPS).

6.3 Provide Minimum Safety Distance from LPG Cylinders Storage Areas

In the event of a fire, safety distances between the storage area for LPG cylinders and other parts of the workplace can minimise the spread of fire. Workplaces should designate areas for the storage of LPG cylinders and provide adequate separation distance between the designated storage areas and other areas (such as other processes, inventories of other flammable substances and offices). For more details, workplaces could refer to established standards, such as NFPA 58 Liquefied Petroleum Gas Code.

7. Conclusion

Workplaces handling LPG and other flammable substances, are reminded to take heed of the learning points and implement effective risk control measures to prevent any similar recurrences.

In summary, the four learning points from the incident are:

1) Protect small-bore pipelines from accidental impact;
2) Provide a master shutdown button for safe and coordinated stoppage of gas filling;
3) Provide fire retardant clothing (FRC) to workers working with flammable substances; and
4) Plan and implement an effective emergency response.

8. References

For further guidance on managing risks arising from flammable hazards, workplaces could refer to international codes and standards, as well as accepted and established industry guides or publications, including:

[1] The World LPG Association, Guidelines for Good Industry Practices LPG Cylinder Filling, 2017

[2] American Society of Mechanical Engineers (ASME), Process Piping Code, B31.3, 2018

[3] International Electrotechnical Commission, IEC 60079 Series, Explosive Atmosphere Standards

[4] National Fire Protection Association (NFPA) 58: 2020, Liquefied Petroleum Gas Code

[5] Center for Chemical Process Safety (CCPS), Guidelines for the Management of Change for Process Safety, 2008