Filling Station Explosion due to LP Gas Discharge from an Overfilled Container

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(Summary)

On May 17th, 1986, staff members at an LP gas filling station in Yokkaichi City were filling LP gas into a 20 kg container. Noticing that the container had overfilled halfway, the staff member opened the valve to discharge the overfilled gas, which then ignited causing a fire. Heated by the flames of the fire, the safety valves of the surrounding containers operated and discharged more gas, which caused the fire to spread through the filling station. As a result, containers of various sizes burst one after another, and the horizontal propane and butane gas tanks went up in flames, resulting in the filling station itself exploding. This case example demonstrated the importance of taking appropriate measures to prevent the spread of a fire in order to avoid escalation to a major disaster.

1. Event

At the LP (Liquefied Petroleum) gas filling station, the staff members were filling gas into a 20 kg container and a 50 kg container (see Fig. 1) using a filling machine. Noticing halfway through the process that the gas meter was not properly set on the 20 kg container, they checked and found out that the container was overfilled with gas. They turned the overfilled container sideways near the filling machine and opened the valve (see Fig. 2) to start discharging liquid-state gas directly into the air. The moment it was discharged into the air, the gas ignited and developed into a fire. The range of fire was contained initially, but it soon spread across the area of the filling station. Because the valve of the overfilled container was left open after the initial inflammation, gas continued to come out from the open valve and fueled the fire, which in turn heated the surrounding containers so intensely that their safety valves released and discharged gas, causing the fire to spread through the filling station (See Fig. 3). As a result, the 20 kg, 50 kg, and 500 kg containers exploded one after another. One 20 ton horizontal propane tank and one 15 ton horizontal butane tank in the station burst into flames as well. The inflammation source was the sparks that occurred between the electrostatically-charged gas from the overfilled container and a number of electrical conductors nearby (including other containers). This accident not only demonstrated the importance of taking appropriate measures to prevent the spread of a fire in an accident, but it also taught us a number of other important lessons discussed below.

The figure below shows the results of a fault tree analysis.

Fig. 4: Fault tree diagram with a focus on mode, mechanism, and process of fracture

The first ignition occurred the moment that the liquid LP gas was discharged from the overfilled container. This ignition was triggered by spark discharge. The LP gas discharged from the container

was charged with static electricity and reacted with a number of electrical conductors nearby such as other compressed-gas cylinders. When released from a narrow nozzle, a gas can become charged with static electricity and generate sparks through reaction with other electrical conductors.

At the early stage of the fire, only the LP gas coming out of the overfilled container was burning. However, because the valve of the overfilled container was left open after the initial inflammation, the fire continued to grow. As a result, the pressure in the small containers around the area increased, causing their safety valves to operate and release LP gas. This gas intensified the scale of the fire, which eventually spread throughout the entire filling station. Presumably, some of the containers exploded and scattered broken pieces around after being exposed directly to the flames of the LP gas spewing out from the safety valves of the other containers.

There were also large-sized 500kg containers on the filling platform. Just as with the small containers, the safety valves of some of the 500kg containers operated and released LP gas, which also ignited. It is believed that the resulting flames heated the barrelheads of the other 500kg containers so intensely that they burst and scattered broken pieces around. Tthe explosion of these containers was followed by a fireball about 50m in width and 63m in height.

The filling station was also equipped with one 20ton horizontal propane tank and one 15 ton horizontal butane tank. The flames of the fire burnt out the seats of the block valves that were attached to the gas release pipes of these tanks. As a result, gas also spewed from these tanks, and the tanks burst into flames.

The figure below shows the results of an event tree analysis.

Fig. 5: Event tree diagram of filling station explosion

Because the LP gas was discharged in a liquid state from the overfilled container, the LP gas became charged with static electricity and reacted with the electrical conductors nearby to generate sparks, which triggered the inflammation of the discharged gas. Because the valve of the overfilled container was left open after the inflammation, the fire grew large enough to cause the safety valves of the surrounding containers to operate, causing the range of the fire to enlarge. In this process, some of the containers burst, and the valve seats of the tanks burnt out, releasing gas which in turn ignited.

2. Course

At the filling station, one staff member had started filling gas into a 20 kg container using the No.1 filling machine and was making preparations to fill gas into a 50 kg container using the No.2 filling machine. In the meantime, another staff member checked the No.1 filling machine and noticed that the gas meter was not properly set on the 20kg container. He then removed the 20kg container to check it, and found that it was overfilled with gas. He moved the overfilled container a short distance away and set another 20 kg container on the filling machine.

The staff members turned the overfilled 20kg container sideways near the No. 1 filling machine and opened the valve to start discharging the liquid-state LP gas (this operation was not uncommon in those days.) Immediately after that, the discharged LP gas ignited and caused a fire. At this time, both of the

safety manager and the safety foreman were not at the filling station.

Two minutes after the fire broke out, a staff member called the fire department. A fire engine arrived at the scene five minutes later. When the fire engine arrived, only the containers around the filling machines were burning on the filling platform, and the containers along the outer edge of the platform were not. About five minutes after the fire engine arrived, the growing fire eventually triggered several explosions over the next three minutes. In the meantime, the valve seats on the gas release pipes of the tanks burnt out, causing the gas to leak out from the tank and ignite.

3. Cause

(1) Incorrect handling of the overfilled container

There are three ways to handle the gas in an overfilled container:

- ○ allow the gas in the overfilled container to vaporize and collect the vaporized gas into a storage tank using a gas compressor;
- ○ refill (i.e. transfer) the gas from the overfilled container into another container; and
- ○ dispose of the gas by diffusing it (i.e. to gradually discharge the gas into the air in an airy location at least 8 m away from areas where combustible or flammable objects or materials may be handled or stored).

It probable that at the filling station in question, the staff members would customarily discharge a large amount of liquid gas directly into the air from the containers that were placed near the filling machines. They did not have any specific manual as to how to handle overfilled containers or how to take adequate measures.

(2) Inadequate measures to prevent the expansion of a fire

The fire would not have spread throughout the filling station if the valve of the overfilled container had been closed immediately after the initial inflammation of gas. Not only was this operation neglected, but also there were no signs that any of the emergency shutoff valves of the storage tanks were operated. Nor did the sprinkler system function although an attempt was made to operate it. All these facts suggest that the people at the filling station did not have sufficient safety awareness and had not been trained adequately to handle accidents that could lead to a disaster.

4. Immediate Action

If a fire occurs at a gas filling station, highest priority should be given to controlling the fire at an early stage. To control the fire at an early stage, stopping the blowout and leakage of gas is most effective, because the leaking gas would otherwise serve as the medium for inflammation. The blowout or leakage of gas must be stopped by closing the source valve. In most cases, the source valve can be accessed and closed safely, because the direction and the scale of a fire generally remain constant at the early stages. To prevent the spread of a fire, it is also important to ensure that sprinklers and emergency shutoff valves will operate.

In this accident, the valve of the overfilled container that triggered the fire was left open. Not only that,

the emergency shutoff valves were not operated and the sprinkler system did not work because it was not maintained regularly. The important lesson is that the regular training of staff and the proper maintenance of safety control equipment are essential for the successful implementation of the above-mentioned safety measures in the case of an accident or a disaster.

5. Countermeasure

With this event as a turning point, the following amendments were made to the supplementary standards for ministerial ordinance (June 22nd, 1987):

(1) Emergency shutoff valves, sprinklers, or other safety systems shall be accessible from at least two locations, one of which shall be in an office or such other building.
(2) Filling platforms and the locations where tank trucks are stopped shall also be equipped with sprinklers or other safety systems.
(3) The electrical power supply shall be reinforced to ensure that the pump will operate for sprinklers or other safety systems.
(4) Discharging liquid-state gas from containers shall be banned.

6. Knowledge

○ Never cut corners when handling a potential disaster.

This accident is an outstanding example of the importance of taking appropriate measures to prevent the expansion of a disaster. The regular training of staff, as well as the proper maintenance of safety control equipment, are essential for the successful implementation of appropriate measures against the expansion of a disaster. On the other hand, the training for the prevention of disaster does not make any sense if it ends in a mere formality that people view without any sense of urgency and that does not ensure that the people involved will take appropriate action in the case that a real accident or a disaster occurs. Any technical staff that may handle hazardous substances should reconsider the meaning of the training for the prevention of disaster and use it on a regular basis.

7. On the Side

○ Fireball

A fireball is often seen accompanying a huge explosion in a wide open space. The name "fireball" is derived from the appearance of a globular mass of flames that an explosion forms in the air.

8. Information Source

(1) Report of the Review Committee for Accidents and Countermeasures at LP Gas Institutions (Nov. 1986): Industrial Location and Pollution Bureau, Ministry of International Trade and Industry.

9. Primary Scenario

01. Carelessness

02. Insufficient Precaution
03. Overfilling
04. Organizational Problems
05. Poor Management
06. Poor Manual
07. Lack of Practical Training
08. Stultification of Training
09. Usage
10. Disposal
11. Discharge of Liquid-state LP Gas
12. Bad Event
13. Chemical Phenomenon
14. Static Electrification of LP Gas
15. Spark Discharge
16. Inflammation
17. Fire
18. Non-Regular Action
19. Inaction
20. Failure to Close Container Valve
21. Gas Blowout
22. Failure
23. Fracture/Damage
24. Container Rupture
25. Fire
26. Secondary Damage
27. External Damage
28. Explosion of Filling Station

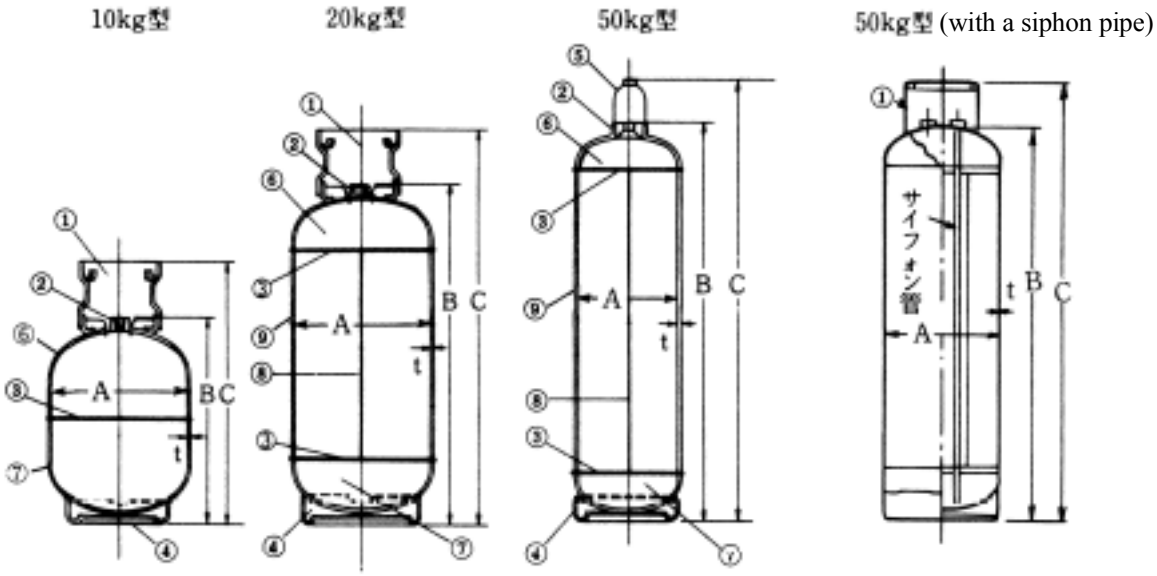

Fig. 1 Gas container.

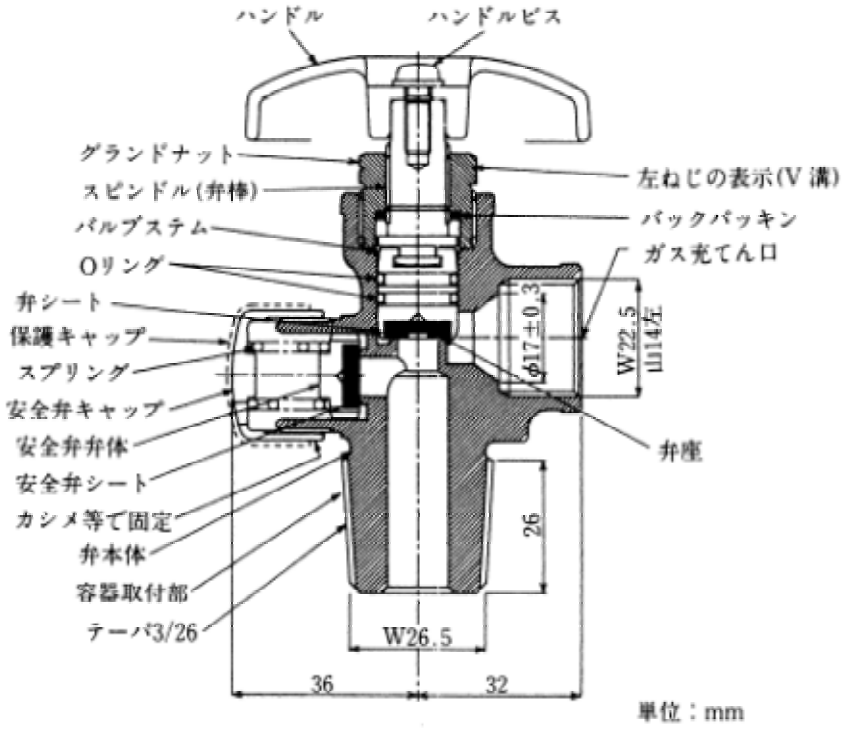
ハンドル
ハンドルビス
グランドナット
スピンドル(弁棒)
バルブステム
Oリング
弁シート
保護キャップ
スプリング
安全弁キャップ
安全弁弁体
安全弁シート
カシメ等で固定
弁本体
容器取付部
テーパ3/26
左ねじの表示(V 溝)
バックパッキン
ガス充てん口
φ17±0.3
W22.5
山14ピ
弁座
26
W26.5
36
32
単位：mm

Fig. 2　Valve

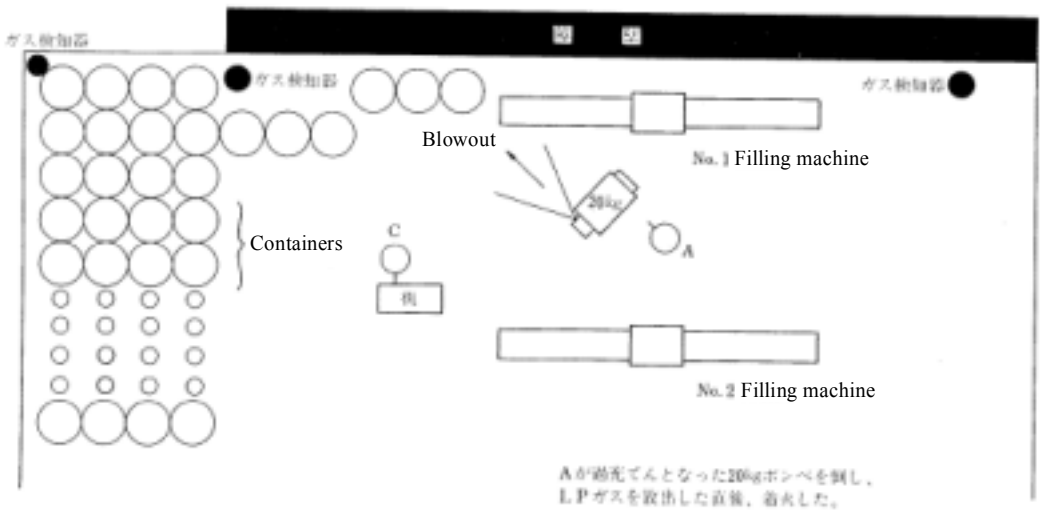

Fig. 3 The scene of an accident.

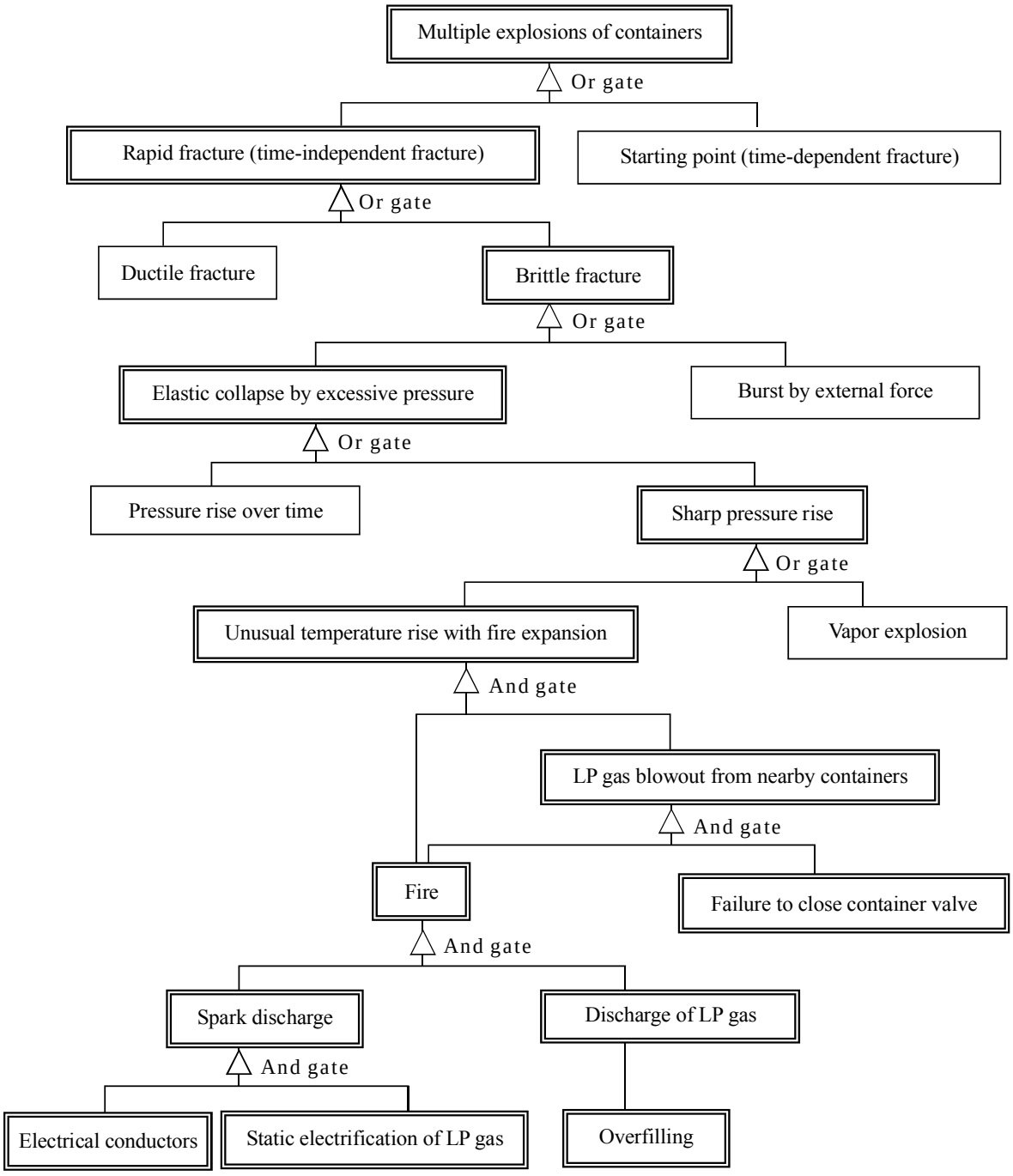
Multiple explosions of containers
Or gate
Rapid fracture (time-independent fracture)
Starting point (time-dependent fracture)
Or gate
Ductile fracture
Brittle fracture
Or gate
Elastic collapse by excessive pressure
Burst by external force
Or gate
Pressure rise over time
Sharp pressure rise
Or gate
Unusual temperature rise with fire expansion
Vapor explosion
And gate
LP gas blowout from nearby containers
And gate
Fire
Failure to close container valve
And gate
Spark discharge
Discharge of LP gas
And gate
Electrical conductors
Static electrification of LP gas
Overfilling

Fig. 4 FTA.

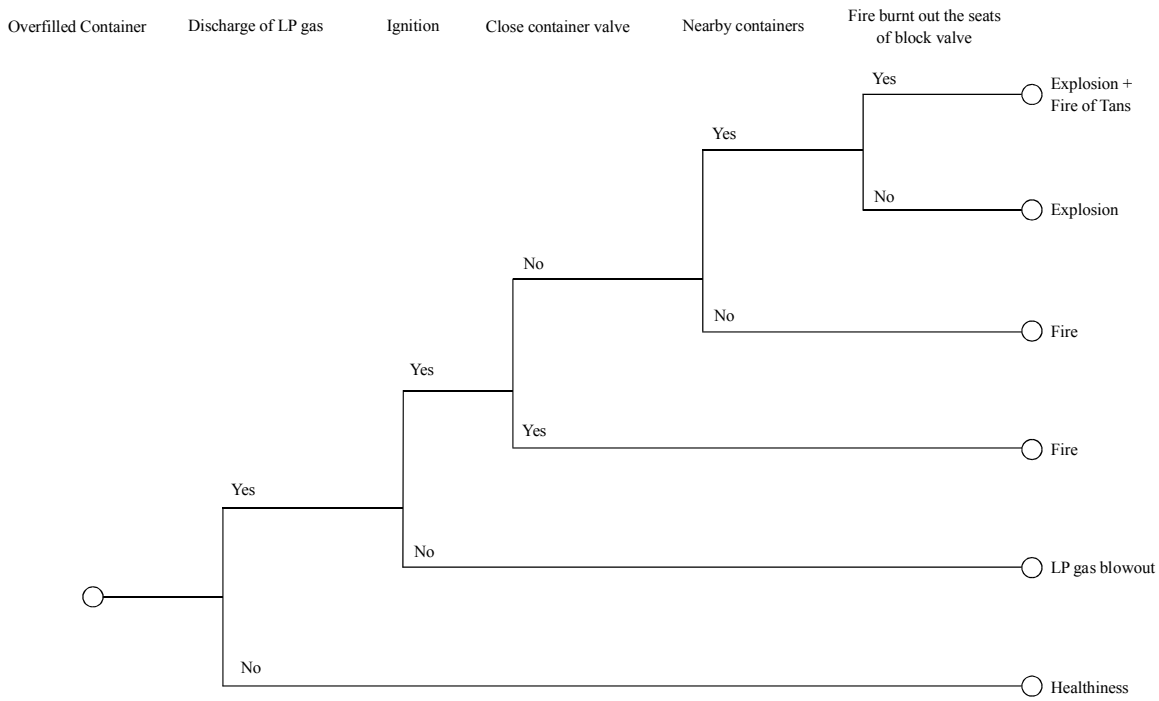
Overfilled Container
Discharge of LP gas
Ignition
Close container valve
Nearby containers
Fire burnt out the seats of block valve
Yes
Explosion + Fire of Tans
Yes
No
Explosion
No
No
Fire
Yes
Yes
Fire
Yes
No
LP gas blowout
No
Healthiness

Fig. 5 ETA.