Fusion and Explosion of Oxygen Gas Containers in The Filling Process

Mar. 25th, 1996, Kasuya, Fukuoka

AKATSUKA, Hirotaka (High Pressure Gas Safety Institute of Japan)
KOBAYASHI, Hideo (Tokyo Institute of Technology)

(Summary)

On March 25th, 1996, the staff members of a gas filling station in Fukuoka Prefecture were filling medical oxygen gas into six aluminum alloy containers and 20 steel containers at a gas filling station in Fukuoka Prefecture. When the staff members had completed filling the containers with gas and were closing the valves on the containers and the mount frames, one of the aluminum alloy containers suddenly fused somewhere between the valve-fitting and the shoulder section, causing flames to spout out. In this accident, one staff member was killed, and another suffered severe burns.

The oil content that was mixed into the container during a container inspection test was presumed to have settled on the interior surfaces of the container and the valve. That oil was believed to have ignited due to a temperature rise during the filling operation.

1. Event

One of the aluminum alloy containers that had been filled with oxygen gas, suddenly fused somewhere between the valve-fitting and the shoulder section, causing flames to spout out. (See Fig. 1) According to the results of the investigation, the origin of inflammation was in the end section of the container valve where the branch tube for filling was inserted. The flames then shot the main body of the valve and directly hit against the outer surface of the aluminum container to melt an opening. The fused area of the main body looked as if it had been irradiated with an electron beam.

In the meantime, the flames melted the surface of the valve sheet and penetrated into the container while propagating through the inlet of the container valve. The oxygen gas ignited in the check valve cartridge in the container valve. The resulting flames fused down the foot part of the valve body toward the filling side, and then directly hit and fused the outer surface of the container at an angle of 135° (seen clockwise with the top face as 0°). (See Fig. 2) Furthermore, the flames penetrated through the mouth of the valve into the confined space on the valve sheet surface, fused the surfaces of the valve sheet (brass) and the seat padding (nylon 66), and then reached the inner depth of the container while propagating through the inlet of the container valve. Both the fusion face caused by the irradiation of flames and the knife-edged fusion face caused by the spout of flames were observed on the fractured area of the opening on the container.

Since the dimensions of the container remained unchanged after the accident, the burst could not be attributed to a rise in the inner pressure, nor could it be attributed to material or manufacturing defects according to the results of mechanical and nondestructive tests on the container material.

2. Cause

When the container was cut in half in the post-accident investigation, oil content, iron powders, and other residual materials were identified on the surface of the packing and inside the branch tube for filling. Fig.3 shows the inner surface condition of the burst container. In addition, the two containers next to the burst container were cut in half and checked using ultraviolet ray analysis to see whether any oil content, iron powders, or other substances were also present in the container. As the result of the UV analysis showed a glowing star pattern, it was confirmed that oil traces were on the inner surface of the container.

It was also revealed that the lubricant applied to the crank shaft section of the hydraulic pump during a container recheck test had been mixed into the water used in a pressure expanding test. It is presumed that the oil content had entered the container during the container recheck test. It is likely that the oil content had settled on the inner surface of the valve as the gas was flowing. Also identified was iron powder dust that resulted from the stripping of the threads when the valve was fitted. The stripping of the threads was attributed to a slight mismatch between the threads of the screw cap and the brass valve. A part of the main body of the container was manufactured in Australia, and the thread of the screw cap was machined using the reference gauge in Australia. However, the thread of the brass valve was machined using the reference gauge of a domestic manufacturer.

Incidentally, it was a general practice to use high speed filling for small 9.7 liter containers at the filling station. However, if a container is filled with compressed gas at a high speed, the gas temperature will increase due to adiabatic compression. As a result of a quantitative analysis, it was estimated that the gas temperature could reach 140°C. The post-accident investigation also revealed that the polymeric material of the seat packing (nylon 6) would creep at a temperature of 140°C and lose the ability to seal gas against leakage. If a subtle gas leak occurred in the container valve due to friction, the trapping of foreign materials in the seal, or some other mechanism after the gas had been filled, the small space (about 0.1 cc) in the valve would quickly change to atmospheric pressure. Since the sealing ability of the seat packing had been lost, the gas in the container would flow into the small space in the valve, increasing the temperature further. As a result of the analysis, it is presumed that the temperature could increase to as high as 310°C. In the presence of oxygen, gas would ignite at a temperature of 310°C because the oil content on the seat padding (nylon 66) and the seat packing (nylon 6) would serve as the medium for inflammation.

(1) High speed filling

High speed filling triggered a rise in the gas temperature in the container, leading to gas ignition.

(2) Presence of oil content and iron powder dust

If neither oil nor iron powder had been present in either the container valve or the container, the gas could not have ignited even though the temperature might rise.

3. Countermeasure

(1) When filling gas containers, adopt a procedure that can keep the gas temperature from increasing in

the container.

(2) Conduct periodic checks to ensure that neither oil nor iron powder is present in the gas equipment.

4. Knowledge

○ Temperature rise caused by high speed filling

The gas temperature will increase if high-pressure gas is filled into a container at a high speed. Extra care should be taken to prevent a rise in temperature in the atmosphere of high-pressure oxygen gas, where the spontaneous inflammation temperature of substances could decrease. Aluminum could serve as a fuel under some conditions. Also, the barrel plate of an aluminum alloy container could melt and inflate extraordinarily due to a temperature rise resulting from high speed filling. Therefore, the measurement of inflation deformation is essential in a container recheck test.

○ Mixture of oil content into a high-pressure gas container

The oil content mixed into a high-pressure gas container could cause inflammation and combustion in containers containing high-pressure oxygen and even in containers containing high-pressure air. The "Shippai Hyakusen" (A Selection of 100 Failure Cases) contains information titled "Compressed Air Tank Explosion from Oil Mixture in 1995" for a case where this happened.

5. Information Source

(1) Research Report on Fusion and Burst of Oxygen Gas Container (Dec. 1996): High Pressure Gas Safety Institute of Japan.

6. Primary Scenario

01. Poor Value Perception
02. Poor Safety Awareness
03. Organizational Problems
04. Poor Management
05. Poor Equipment Management
06. Usage
07. Maintenance / Repair
08. Adhesion of Oil Content
09. Usage
10. Operation / Use
11. Stripping of Threads
12. Adhesion of Powder Dust
13. Usage
14. Operation / Use
15. High Speed Filling
16. Bad Event

17. Thermo-Fluid Phenomenon
18. Adiabatic Compression
19. Temperature Rise

---

20. Failure
21. Fracture / Damage
22. Fusion
23. Burst

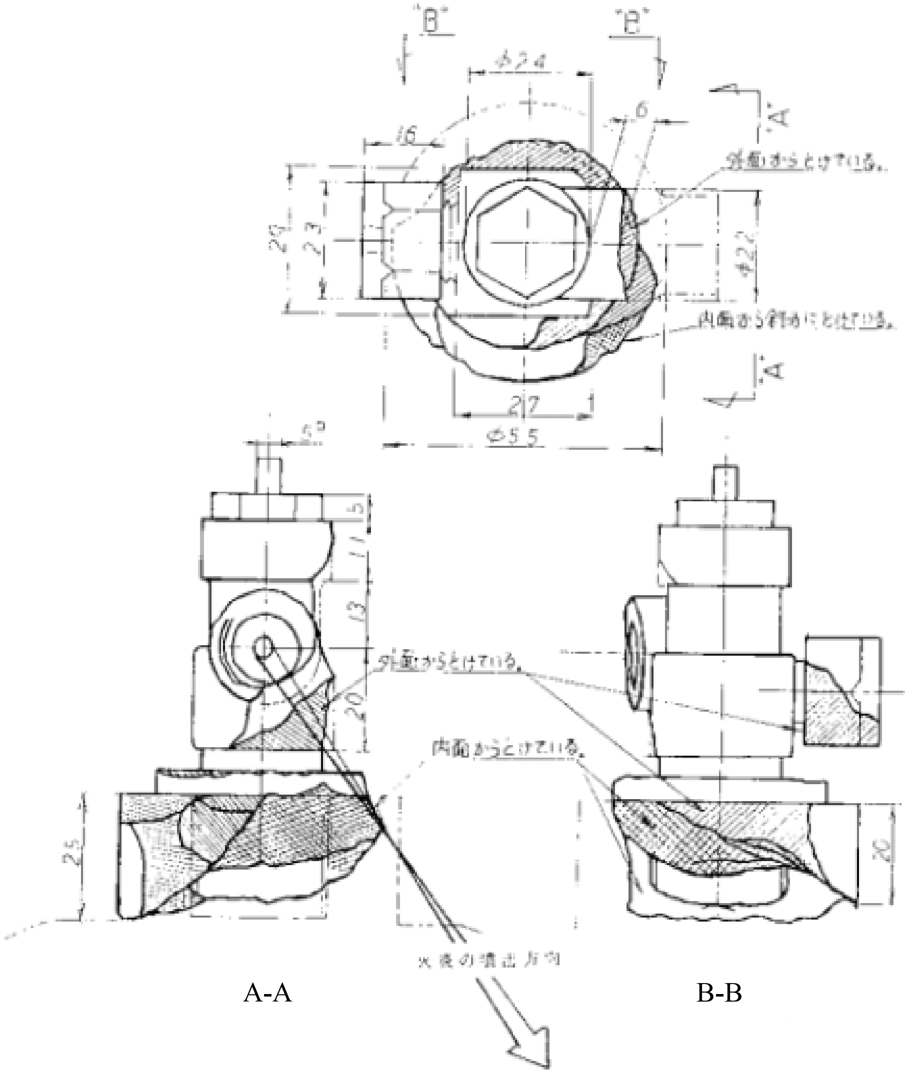
外面からとけている。
内面から斜めにとけている。
外面からとけている。
内面からとけている。
火炎の噴出方向
A-A
B-B

Fig. 1　Valve.