C26 Forensic Investigation of a Gas Phase Explosion in Building

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Through the systematic and detailed examination of the scene and physical evidence collected, the goal of this presentation is to provide the examiner means to identify the fuel source from a number of potential sources and reconstruct the sequence of events that led to the gas phase explosion in a building

This presentation will impact the forensic community and/or humanity by illustrating how forensic scientist can complement structural design and civil engineers as well as gas safety experts in determining the cause of gas-phase explosion.

Background: The explosion occurred in a design and advertising office on the second floor of a seven-story flatted factory building of reinforced concrete structure with flat roofing. The occupier of the affected unit carried out the manufacture of advertising signs and displays within the premises, which was partitioned into an office area and a production area. Four persons were killed and another two workers were injured in the accident.

Prior to the accident, two of the deceased were involved in the replacement of the oxygen cylinder and the usage of the oxygen-acetylene equipment in the production area.

Eyewitnesses reported seeing a dazzling brightness immediately after the initial explosion, suggesting an oxygen-rich fire. Flames were also seen shooting out from one of the liquefied petroleum gas (LPG) cylinders in the office during fire fighting.

Scene Examination: The explosion/fire totally destroyed the factory unit. The concrete wall, window frames, doors, and gates at its main entrance were displaced from their original positions. The concrete wall was found to bulge outward, attesting to an explosion from within the factory unit. Along the corridor of the affected factory unit, partially burnt remains of several metal racks, an air compressor (used for spray painting), and a number of paint containers were found. The damages observed to the areas within close proximity to the affected unit included displaced doors of the passenger/cargo lifts, shattered window panes in neighboring units, and broken windows of cars parked downstairs.

Within the affected factory unit, partially burnt remains of paint containers and solvents were found at several locations at its production area. Tools such as an electric saw and drilling machine were also found at the scene. At the locality within the production area where the oxygenacetylene equipment was claimed to be used at the time of accident, a circular indentation of about 20 cm diameter was observed on the floor. Also, impact marks were noted on the wall surface nearby, probably caused by fragments from the explosion.

A badly dented acetylene cylinder was found, among the debris, at close proximity to the circular indentation. The shattered remains of a second cylinder (believed to contain oxygen prior to the accident) were found at several locations within the factory unit. The damaged remains of two sets of regulators and flexible gas hoses were also recovered from the scene. Two cylinders containing liquefied petroleum gas (LPG) were found within the affected factory unit. No flashback arrestors, non-return valves and torch were recovered from the scene.

Potential sources of gas that led to the explosion include:

- A leak of flammable gases from the LPG cylinders.
- A leak of acetylene from the acetylene cylinder.
- The oxygen cylinder and/or hose being contaminated with flammable gases.

Findings:

(a) LPG cylinders

The on/off gas valves of both cylinders were found to be in the close position. The plug within one of the valve was found to be burnt. One of its ends had expanded causing the seat disk within the plug to drop by approximately 0.3cm from the top. This resulted in poor sealing and gas to be leaking out from the on/off gas valve even though it was close. The above findings indicate that both LPG cylinders were not in use before the accident and any gas leakage was the result of heat from the fire. The leaking gas resulted in flames, which were seen to be emitting out from one of the cylinders by the firefighters.

(b) Acetylene cylinder, pressure regulator, and red hose

The on/off gas valve was found to be in the close position. It was clotted with melted rubbery material from the safety plug within the cylinder. This was consistent with effects from external heating. The pressure release valve was also found to be damaged by the heat from the fire allowing acetylene to escape into the atmosphere.

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The pressure regulator believed to be attached to the acetylene cylinder was found to be relatively intact. Both the cylinder and working pressure gauges remained fixed to the regulator body. One of the gauges was found to be bent forward indicating external force acting on it.

The lengths of red acetylene hoses had damaged ends and were found to be intact with burn marks along their lengths. These damages were consistent with those caused by external forces and heat.

The above findings indicate that the acetylene cylinder was not in use before the incident and any gas leakage from the cylinder was the result of heat from the fire.

(c) Oxygen cylinder metal fragments, pressure regulator, and blue hose The on/off gas valve was found to be in the open position. Four of the metal fragments physically fitted to form the base of the cylinder with a diameter of approximately 20 cm. This was consistent with the size of the indentation mark found at the scene. One of the fragments was found to bend outwards indicating an outward force from within the cylinder.

The pressure regulator believed to be attached to the oxygen cylinder was found to have its regulator bonnet and working pressure gauge blown off from the regulator body. Soot and burn marks were observed within the bonnet and regulator indicating internal burning within the regulator.

The blue oxygen hoses were severely damaged with splits and burn marks along its lengths consistent with those caused by internal bursting forces and heat.

Damages observed on the damaged oxygen cylinder metal fragments, pressure regulator and blue hose indicated that the cylinder was used during the time of incident and that flashback had occurred along the lengths of blue hoses causing them to split. Burning and excessive pressure within the regulator caused the bonnet to be detached and the working pressure gauge to be blown off. A powerful outward force from within the cylinder caused it to fragmentize.

The above findings indicate that both the LPG and acetylene cylinders were not in use prior to the explosion. The source of gas that led to the explosion was hence likely to be from the oxygen cylinder and/or hose.

Possible causes for the explosion:

1. Contamination of the oxygen hose by flammable gases from paint cans, acetylene or other sources to within explosive limit resulted in an explosion when the torch was ignited.
2. Contamination of the oxygen cylinder by flammable gases.
3. Absence of safety devices e.g. flashback arrestor, non-return valves in the oxygen-acetylene gas equipment resulted in the explosion of the oxygen cylinder.

Typical set-up and operation of oxygen-acetylene equipment: The oxygen-acetylene equipment was primarily used for cutting, welding, brazing, or heating of metals. A typical set-up of oxygen-acetylene equipment comprises oxygen and acetylene cylinders, gas regulators, flashback arrestors, hoses, non-return valves, and a torch. A gas regulator serves to regulate/reduce the pressure of the gas coming out from the cylinder before feeding to the hose/torch. A flashback arrestor prevents the flashback of in the torch/hose from propagating back into the regulator and gas cylinder, which could lead to an explosion. The function of a nonreturn valve is to prevent the gas from flowing back into the cylinder. The internal pressure of an oxygen cylinder (when full) is around 150 bar and the internal pressure of an acetylene cylinder (when full) is around 20 bar. The two types of gases are channeled via hoses to a torch where the gases are mixed and ignited.

The low-pressure control valves are typically adjusted to 2 bars for oxygen and 0.2 bars for acetylene before the valves are opened to release the gases into the hoses. The oxygen valve at the torch was then opened momentarily to clean the nozzle and closed back. The acetylene valve (about ½ turn) will then be opened, followed by the oxygen valve (about ¼ turn). The torch is then ignited. To stop the torch, the torch's acetylene valve was closed followed by the oxygen valve in order to prevent acetylene from flowing into the oxygen hose. Due to the potential fire hazards associated with oxygen-acetylene equipment and the strict protocol required in its operation, only trained personnel should be allowed to operate the equipment.

Tracing the source for contamination: Experiments conducted on an oxygen-LPG equipment not equipped with non-return valves or flashback arrestors showed that if the internal pressure of the LPG cylinder (when full) was higher than that of the oxygen cylinder (when it was near empty), and if the torch nozzle was obstructed, it was possible for the LPG to flow into the oxygen cylinder. The oxygen in the oxygen cylinder would thus be contaminated with LPG.

Investigations showed that no non-return valve and flashback arrestor were connected to the oxygen-acetylene equipment used in the affected company. Also, the company was not licensed to carry out hot works within the office premises; hence the workers might not be trained in the operation of oxygen-

acetylene equipment. The absence of these safety devices coupled with untrained workers using the equipment may have resulted in acetylene contaminating the oxygen hose and cylinder resulting in the explosion.

Gas Phase Explosion, Oxy-Acetylene Gas Equipment, Flashback Arrestor

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