Oxygen Cylinders: "life" or "death"?

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Abstract

Oxygen is crucial to maintain and save human life. Other than medical purposes it is widely used for manufacture of mineral water, fabrication works and other industrial activities. If adequate precautionary measures are not adopted while handling, storage or transport of oxygen cylinder or container, accidental blast may claim human life and other damage as well. The case involving three victims is presented to highlight various relevant aspects i.e. autopsy findings, cause/s of blast and recommended precautions are discussed in the light of oxygen cylinder blast case in an" oxygen filling factory", claiming three human lives.

Key words: Oxygen cylinder, accidental blast, autopsy findings, causes and precautions.

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Introduction

The air we breathe contains about 21% oxygen. Without oxygen we would die in a matter of minutes [1]. Many people at work and sometimes at home use oxygen gas in cylinders. It is widely used in welding, people who work in deep sea diving, for food preservation, in steel works and for medical purpose etc. Greensmith [2] has observed that hyperbaric oxygen therapy potentially can provide enhanced oxygen delivery to peripheral tissues affected by vascular disruption, cytogenic and vasogenic edema and cellular hypoxia caused by extremity trauma. After appropriate resuscitation, macrovascular repair, and fracture stabilization, adjunctive hyperbaric oxygen therapy can enhance tissue oxygen content.

In growing edge of industrial and medical advancements, increased use of compressed gases like oxygen, nitrogen, carbon dioxide, helium, argon, krypton, acetylene etc is the need of an hour. Inspite of being vital to the human life, oxygen can be most dangerous to snatch a soul from body if not handled with caution. Few lay press news items such as three people were killed and one injured after an oxygen cylinder blast at their job site [3], and two people died and one sustained serious burns after cylinder blast[4] while filling gas are not uncommon.

Gases in their compressed state, and particularly compressed air, are almost indispensable to modern industry can cause disastrous effect in absence of proper handling, storage and transport. Precautions taken during handling, storage and transport can save damages to both human beings and inanimate things. Rani M *et al* [5] have reported a case of a 34-year-old male welder who died following injuries sustained from explosion of an acetylene gas-welding cylinder.

Deaths from the effects of explosive substances or devices occur in both civil and military circumstances though the later now include considerable proportion of terrorist activities rather than conventional wars, civil tragedies are usually industrial, as in individual incidents in mines and quarries or on a larger scale, such as the denotation of chemical stores, ships and factories[6].

Injuries due to an explosion are primary blast injury (this is the result of sudden change in the environmental pressure changes resulting from blast waves), secondary blast injuries (fragments and other missiles cause these injuries), tertiary blast injuries (include acceleration and deceleration injuries caused by the victim's body impacting against stationary objects or injuries caused by collapse of structures and buildings) and thermal and/or chemical injuries[7].

The specific injury produced in lungs by the blast is known as blast lung, which is grossly characterized as sub pleural patchy haemorrhage, often in the line of the ribs, intrapulmonary haemorrhage and bullae at the lung margins[6].

Case history

In an industrial area there was an "oxygen filling factory" spread over 110x50 ft, dealing with filling of oxygen (both medical and industrial) and nitrogen oxide cylinders. The refilling of cylinders was being carried out in a shed with roof height of 25 ft. Four persons were at work near refilling area, including a surviving eye- witness (25 ft away from rest of three workers), at the time of blast. At around 7:30 pm on 10th October 2006 accidental blast occurred claiming three lives and leaving the eye -witness injured. The blast sound was heard up to a distance of 1.5 km. As per statement of eye witness given to police, victim-1 lifted one of the oxygen cylinders, which exploded on putting it on floor. On prolonged search, upper part of exploded cylinder was recovered from premises of other factory located about 1 km away from the scene of blast. At the time of blast

there were total 219 cylinders in premises out of which 155 were filled and rest were empty.

Pieces of exploded cylinder were found up to 40 ft within premises, damaged wall at a distance of 25 ft and completely destroyed roof sheets at 25 ft height associated with collapse of roof frame (Photograph-1). Human remains were found in a radius of 25 ft area in scattered manner, among structure debris.

Photograph-1: Collapsed roof structure along with scattered intact cylinders.

Fortunately the fragment of exploded cylinder (Photograph-2) impacted only one empty cylinder near by and no other filled cylinder, or else the quantum of damage would have been quite higher than what had occurred.

The incident claimed lives of victim-1, 2 and 3 who were in extreme vicinity of the exploded cylinder and eyewitness standing at a distance survived with some mechanical injuries of right side extremities.

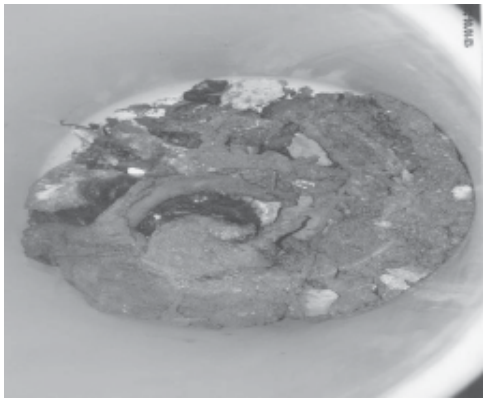
Autopsy findings

Victim-1

Photograph-2: Closer view of partially burst open cylinder with brownish discoloration due to rust formation on the inner surface.

Extremely mutilated, charred and separated remains weighing about 10 kg of a male –32 years, (Gathered in a yellow color tub-bucket) comprising of: (1) Scalp attached to some pieces of left side skull vault and facial skin attached to left half of mandible (with 8 teeth). (2) Piece of right mandible (with 7 teeth). (3) Five thoracic vertebra in one with attached pieces of ribs. (4) 15x10cm skin flap of anterior abdominal wall. (5) Two lumbar vertebra in one piece. (6)Three lumbar vertebras in one piece. (7) Acetabular fragment of right hip joint. (8) Acetabular fragment of left hip joint. (9) Fragment of right elbow joint. (10) Great toe (side not opined). (11) Unidentifiable soft tissue masses with bone remnants. (Photograph-3). All above stated materials were completely separated with each other and brownish granular material was sticking to uncharred areas.

Photograph-3: Charred and separated remains stained with brownish granular material of victim-1(male aged 32 years) which were gathered in a yellow color tub-bucket.



Victim-2

Dead body of a male –40 years old with burnt & torn clothes on front, brown red color granular material over front aspects of body, and bright red color bloodstains on head, face, left shoulder & trunk. Following injuries were found: (Photograph-4)

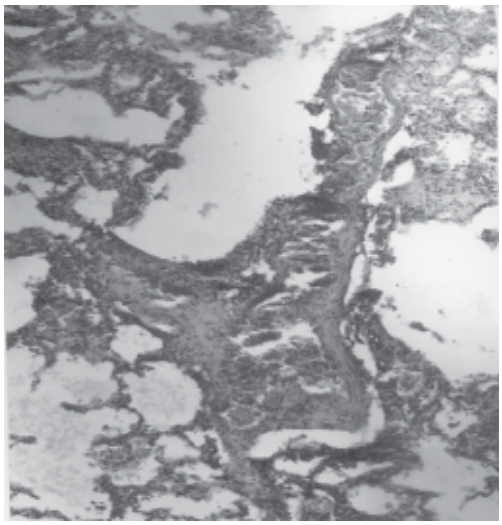
[a] Thermal: Dermo-epidermal ante mortem burns (involving 85% of total surface area of the body as per rule of nines[9]) sparing back of trunk with soot particles in trachea and singeing effect was present on scalp hair, eyelashes, eyebrows and mustache.

[b] Mechanical: (1) Left shoulder with upper third of arm showed disruptive laceration with fractures of underneath bones. (2) Multiple irregular puncture wounds and abrasions all over front aspects of body. (3) Diffuse subarachnoid haemorrhage. (4) "Blast lung" effect in both lungs in form of irregular subpleural hemorrhages with contusions in deeper substance.

Photograph-4: - Male, aged 40 years (victim-2) with features of dermo-epidermal burns, stained with brownish granular material, torn clothes and disruptive mechanical injury at left shoulder region.

Microscopic examination of lung sections showed findings of alveolar ruptures, thinning of septae, and enlargement of alveolar spaces are the expected dominant findings. Circumscribed subpleural, intraalveolar and perivascular hemorrhage showed cuff like pattern in interstitial spaces around larger and smaller pulmonary vessels[8]. Similar findings were observed here (Photograph-5).

Photograph-5: Histological sections of lungs (stained with H & E) tissue showing, disruption of alveoli, alveolar hemorrhage and interstitial hemorrhage.(Victim-2)



VICTIM-3

Dead body of a male –28 years old with no clothes over the body, brown red color granular material present over right side of body and portion of head, face & trunk were stain with red color dry blood. Following injuries were found:

[a] Thermal: Dermo-epidermal ante mortem burns (involving 100% of total surface area of the body as per rule of nines[9]) with evidence of soot particles in trachea.

[b] Mechanical: (1) Complete traumatic amputation of left leg with missing of upper two third of leg & lower third of thigh. (2) Multiple irregular puncture wounds & abrasions all over body. (3) Multiple irregular fractures of right tibia & fibula. (4) 8cm x 6cm sized area-comminuted fracture of left temporal bone with evidence of diffuse subarachnoid haemorrhage. (5) "Blast lung" effect in both lungs in form of irregular subpleural hemorrhages with contusions in deeper substance.

Discussion

Oxygen behaves differently to air, compressed air, nitrogen and other inert gases. It is very reactive. Even a small increase in the oxygen level in the air to 24% can create a dangerous situation[1]. The main causes of fires and explosion when using oxygen are: (1) oxygen enrichment from leaking equipment, (2) use of materials not compatible with oxygen, (3) use of oxygen in equipment not designed for oxygen service, and (4) incorrect or careless operation of oxygen equipment[1]. Few of Dos/Don'ts are listed along with possible mechanisms / preventions of explosions are listed in tabulated form below. On the basis of information furnished by investigating officer & correlation between autopsy findings and evidence at the scene of blast, the possible causes of blast are also documented.

Conclusion

It is desirable that compressed gas cylinders (including Oxygen) wherever used in medical and other fields, shall be handled, transported and stored with utmost safety and caution. Employers are legally required to assess the risk in the workplace, and take all reasonably practicable precautions to ensure the safety of workers and members of the public. A careful examination of the risks from using oxygen should be included in the risk assessment.

It is recommended that all oxygen cylinders shall be handled carefully and a purpose-built trolley should be used for their mobilization. Keep cylinders chained or clamped to prevent them from falling over. Store oxygen cylinders when not in use in a well ventilated storage area or compound, away from combustible materials and separated from cylinders of flammable gas.

If relevant autopsy findings & evidences at scene of blast are correlated in scientific way, cause of blast can

Sr. No.	Dos/Don'ts	Why?	Probable cause of blast in the present case
1.	**Do** use copper, copper alloy, ferrous alloy as cylinder wall material[10].	Light metals are not suitable for oxygen.	**Ruled out** -as cylinder wall material is ferrous alloy.
2.	**Do** protect cylinder from sun[11].	Maintain the temperature level of the cylinder from reaching dangerous level.	**Ruled out** -as cylinders were stored in well-ventilated shed.
3.	**Don't** use lubricants like oil or grease[12].	They readily react with oxygen and ignite at low temperature.	**Ruled out**. -As per version of factory authority it is not practiced.
4.	**Don't** lift the cylinder at the neck/ junction of the valve[10].	Any leak may release gas under pressure.	**Probably yes,** Victim –1 might have lifted at the neck of the cylinder.
5.	**Do** place cylinder on the ground gently and not with jerk[12].	Mechanical shock may initiate blast	**Probably yes**, Victim -1 might have put cylinder with jerk on the ground
6.	**Do** transport cylinder in trolley / lifting bucket/pallet[11].	Mechanical shock may initiate blast	**Probably yes**, as no such items was used for transport (within factory premises).
7.	**Don't** completely empty the cylinder[11].	Cooled empty cylinder will allow environmental air to enter cylinder, rust can form inside the pressure vessel and weaken it.	**Probably yes, A.** Brownish dust like material (rust) was found on the body of all 3victims. **B**. The partially burst open cylinder showed similar rust on the inner wall of cylinder.

be concluded for investigation purpose and also enrich the available literature on safety and precautions while dealing with oxygen cylinder or container.

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