

Evaluation of balloon cylinder explosion incident: Understanding causes and ensuring prevention

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Abstract

This case study delves into a significant incident involving a balloon cylinder explosion that occurred during a marriage celebration. Taking place in Raipur, Chhattisgarh, the incident serves as a compelling illustration of the potential dangers associated with mishandling of gas cylinder of inflammable gas. The study provides a comprehensive overview of the incident's background, sequence of events and immediate aftermath. It explores the chemical reaction that triggered the explosion and highlights the critical importance of adhering to safety protocols and established guidelines when working with hydrogen gas balloon cylinders. Through a thorough analysis of the incident's causes and contributing factors, the study elucidates key takeaways and lessons for preventing similar accidents. It emphasizes the necessity of proper training, compliance with regulations, and the adoption of proactive safety measures. The case study underscores the significance of safety awareness, effective communication, and the implementation of comprehensive safety protocols. Furthermore, it highlights the continuous improvement of safety practices as an essential aspect of preventing accidents and preserving lives. In conclusion, this case study offers valuable insights into the consequences of neglecting safety measures when handling gas cylinder of inflammable gas. By learning from the incident and implementing preventive measures, individuals and organizations can contribute to a safer environment, ensuring that celebrations remain joyous and free from harm.

Keywords: Exothermic reaction; Balloon cylinder explosion; Inflammable gas; Hydrogen gas balloon cylinders.

1 Introduction

Balloons are a popular decoration for a variety of events, but the process of filling them with gas can be dangerous. Hydrogen gas is often used to fill balloons, because it is lighter than air and it makes the balloons float. However, hydrogen gas is also highly flammable, and it can easily ignite if it comes into contact with a spark or flame. There have been a number of balloon cylinder explosions over the years, and they have resulted in numerous injuries and deaths. In some cases, the explosions have been caused by sparks from lighters or other sources of ignition. In other cases, the explosions have been caused by faulty cylinders or by improper handling of the gas.[1-5]

Such tragic incident unfolded in a marriage function in Raipur, Chhattisgarh on the evening of November 2018. A balloon seller began to fill balloons using a cylinder for decoration purposes. In a sudden and catastrophic turn of events, the balloon cylinder exploded, resulting in the loss of a young life and causing severe injuries to four other individuals. Tragically, a 10-year-old boy succumbed to his injuries despite medical treatment, while the injured individuals continue to fight for their lives.

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The incident described above serves as a poignant reminder of the critical importance of studying and understanding accidents like balloon cylinder blasts. Tragic incidents of this nature have far-reaching implications beyond the immediate loss and injuries. They underscore the potential risks associated with seemingly routine activities and shed light on the need for stringent safety measures. By delving into the causes and factors that contributed to this incident, valuable insights can be gained to prevent similar occurrences in the future. Such studies aid in formulating comprehensive safety guidelines and protocols, raising awareness among stakeholders, and ultimately mitigating the chances of accidents.

This case study is an endeavor to delve into the circumstances surrounding the balloon cylinder blast that occurred on November 2018, during a marriage function in Raipur, Chhattisgarh. The primary purpose of this case study is to:

- Analyze the sequence of events leading up to the balloon cylinder blast and subsequent consequences.
- Identify the factors that contributed to the explosion, including the presence of caustic soda and the use of hydrogen gas for balloon inflation.
- Highlight the potential hazards associated with improper handling and use of balloon cylinders.
- Draw lessons from the incident to underscore the importance of adhering to safety guidelines when working with compressed gases and potentially hazardous materials.

2 Background and Context

Balloon cylinders, also known as gas cylinders or tanks, are pressurized containers designed to hold gases in a compressed state. These cylinders are utilized for a variety of purposes, ranging from industrial applications to recreational and celebratory events. In the context of events like the marriage function in Raipur, Chhattisgarh, hydrogen gas balloon cylinders are frequently employed to inflate balloons, adding a festive and colorful atmosphere to the surroundings.

The handling and storage of such balloon cylinders are of paramount importance due to the potential risks associated with inflammable gas cylinder. Mishandling or improper storage can lead to accidents, such as leaks, explosions, or fires. Some key considerations for proper handling and storage include:

- **Secure Storage:** hydrogen gas or compressed gas cylinders should be stored in well-ventilated and dry areas away from direct sunlight, heat sources, and open flames.
- **Transportation Precautions:** Cylinders should be transported in an upright position, securely fastened to prevent tipping, and protected from physical damage.
- **Valve Protection:** Cylinder valves should have protective caps to prevent damage and unauthorized access.
- **No Smoking Zones:** Designate no smoking areas around cylinder storage and usage spaces.
- **Proper Ventilation:** Ensure adequate ventilation to disperse any released gases.
- **Avoid Physical Impact:** Cylinders should be protected from rough handling, drops, or impacts that could compromise their integrity.

Numerous safety regulations and guidelines exist to ensure the safe handling, storage, and use of compressed gas cylinders. Organizations such as the Occupational Safety and Health Administration (OSHA) Compressed Gas Association (CGA), Bureau of Indian standard (BIS), Petroleum and Explosives Safety Organization (PESO) and Central Institute for Labour Research (CILR) provide comprehensive standards and recommendations to prevent accidents. Some key regulations and guidelines include:

- **OSHA Standards:** OSHA provides regulations for general industry (29 CFR 1910.101) and construction (29 CFR 1926.350(a)(9)) regarding compressed gases, covering storage, handling, and usage practices. [6]
- **CGA Guidelines:** The CGA publishes guidelines for the proper procedures related to specific types of gases, cylinder usage, and storage. [7]
- **Petroleum and Explosives Safety Organization (PESO):** PESO is the statutory authority in India responsible for regulating the manufacture, storage, and transport of explosives, petroleum, and compressed gases. It publishes various regulations and guidelines related to the safe handling of compressed gas cylinders, including:[8] The Gas Cylinders Rules, 2022, The Gas Cylinders (Amendment) Rules, 2023, Guidelines for the Safe Handling of Compressed Gas Cylinders

- Bureau of Indian Standards (BIS): BIS is the national standards body of India. It develops and publishes Indian Standards (IS) for a wide range of products, including compressed gas cylinders. Some relevant IS standards include: [9, 10]
- IS 7322:1985 - Specification for seamless steel gas cylinders for compressed gases. [9]
- IS 8198-12:1982 - Code of practice for handling and storage of compressed gases in gas cylinders. [10]
- Central Institute for Labour Research (CILR): CILR is a research institute under the Ministry of Labour and Employment, Government of India. It conducts research on occupational safety and health, including the safe handling of compressed gas cylinders. CILR has published various reports and guidelines on this kind of topic.[11]
- Training and Education: Adequate training for personnel involved in handling and using inflammable and compressed gases is essential. This includes instruction on safe practices, emergency procedures, and the potential hazards of various gases.
- Emergency Response: Establishing clear emergency response protocols, including evacuation plans and methods for handling leaks or accidents, is crucial.
- Labeling and Marking: Proper labeling and marking of cylinders with information such as gas type, pressure, and handling instructions aid in safe usage.

By adhering to these regulations and guidelines, individuals and organizations can significantly reduce the risks associated with handling and storing balloon cylinders. This case study of the hydrogen gas balloon cylinder blast serves as a stark reminder of the consequences that can arise from neglecting these safety measures.

2.1 Incident Description

2.1.1 Date, Time, and Location of the Balloon Cylinder Blast

The balloon cylinder blast occurred on November 13, 2018, during a marriage function in Raipur, Chhattisgarh. The incident took place in the evening hours, adding to the tragic turn of events during what was meant to be a joyous occasion.

2.1.2 Context of the Event

The event was a marriage function, a culturally significant and festive occasion, bringing together family, friends, and well-wishers to celebrate the union of two individuals. Balloons are commonly used in such gatherings to enhance the decor and create an atmosphere of merriment. These colorful elements are often associated with happiness and symbolize the festive spirit of the occasion.

2.1.3 Sequence of Events Leading up to the Blast

The incident unfolded as a balloon seller, situated at the event venue, embarked on the task of inflating balloons for decorative purposes. The seller was utilizing a balloon cylinder to fill the balloons with hydrogen gas, a practice commonly employed to make the balloons float. It was evidenced that the balloon seller was using a mixture involving caustic soda, aluminum powder, or foil to generate hydrogen gas for inflating the balloons. (Figure 1)

The sequence of events leading up to the blast involved the interaction of these elements. The exact trigger for the explosion is attributed to a combination of factors, which could include mishandling of the cylinder, improper mixing of substances, or a breach in safety protocols during the inflation process.

2.1.4 Initial Impact and Immediate Aftermath

The balloon cylinder blast had immediate and devastating consequences. The explosion resulted in the tragic loss of a 10-year-old boy who was present at the function site. Despite prompt medical attention, his injuries proved fatal. Additionally, the blast caused severe injuries to four individuals, who were rushed to medical facilities for urgent treatment. The injured individuals, including children and adults, faced life-threatening conditions, sparking a desperate struggle for their survival.

The immediate aftermath of the explosion was marked by chaos and distress, as attendees of the marriage function grappled with shock and sorrow. Emergency response teams, including medical personnel and local authorities, swiftly intervened to manage the situation, provide medical care to the injured, and initiate investigations into the causes of the blast.



Figure 1 (a) Explosion Site (b) Seat of Explosion (c) Torn tent by exploded cylinder parts with blood stain (d) carpets with blood stains of injured (e and f) Pieces of exploded cylinder (g) recovered material from the site which contain caustic soda, balloons etc. (h) Caustic soda recovered from the explosion site (i) cylinder valve and exploded cylinder piece.

3 Causes and Contributing Factors

3.1 Identification of Primary Causes

The investigation revealed that the primary cause of the balloon cylinder blast lay in the improper mixture of caustic soda, aluminum powder, or foil to generate hydrogen gas for balloon inflation.

The chemistry behind the balloon cylinder explosion incident involves the reaction between caustic soda (sodium hydroxide, NaOH) and aluminum (Al) to generate hydrogen gas (H₂). This reaction is highly exothermic, meaning it releases a significant amount of heat. [12, 13]

The balanced chemical equation for the reaction is as follows:



The most probable reason for the balloon seller's cylinder blast is that the mixture of aluminum, NaOH, and water produced a chemical reaction that generated a large amount of heat and pressure. This heat and pressure could have caused the cylinder to rupture, leading to the explosion.

Here is a more detailed explanation of the chemical reaction:

Aluminum reacts with NaOH (sodium hydroxide) to produce sodium aluminate and hydrogen gas. This reaction is exothermic, meaning that it releases heat.

The hydrogen gas produced by this reaction is highly flammable.

The water in the mixture helps to accelerate the reaction and also produces steam, which increases the pressure in the cylinder.

If the cylinder was not properly sealed or if the reaction was not controlled, it is possible that the heat and pressure generated by the reaction could have caused the cylinder to rupture and explode.

3.1.1 Secondary Factors that Exacerbated the Incident

Several secondary factors exacerbated the severity of the incident. The lack of proper training and education for the balloon seller regarding safe handling practices and the potential hazards of flammable and compressed hydrogen gases played a significant role.

3.1.2 Human Errors or Equipment Failures Involved

Human errors emerged as a central theme in the incident. The balloon seller's lack of awareness and understanding of safe practices for working with flammable gases played a pivotal role. The failure to follow established procedures for proper cylinder handling, storage, and inflation, combined with the use of such chemical without proper understanding of the chemical reaction produced by caustic substances, demonstrated a critical lapse in finding.

While the investigation did not identify any specific equipment failures, it highlighted the importance of equipment maintenance and adherence to safety protocols to prevent such incidents. The incident underscored the need for thorough training, clear communication of guidelines, and the implementation of robust quality control mechanisms to prevent the convergence of errors and failures that can lead to catastrophic outcomes.

4 Hypothesis

Based on the provided information about mixing caustic soda (NaOH) with aluminum (Al) to produce hydrogen gas (H₂) and sodium aluminate (NaAlO₂) through an exothermic reaction, the following hypothetical sequence of events may have led to the balloon cylinder blast during the marriage function, despite the absence of an external ignition source (Figure 2): [13]

- **Preparation of Gas Mixture:** The balloon seller prepared a mixture of caustic soda, aluminum, and water inside the balloon cylinder. The water provided the necessary medium for the chemical reaction to occur between NaOH and Al. As the reaction commenced, hydrogen gas (H₂) and sodium aluminate (NaAlO₂) were produced. This process released a significant amount of heat due to the exothermic nature of the reaction. [12,13]
- **Gas Accumulation and Pressure Buildup:** The hydrogen gas produced by the reaction accumulated within the cylinder. Since the cylinder was sealed, the pressure inside the cylinder started to increase due to the buildup of gas. The heat generated by the exothermic reaction further contributed to the pressure increase.
- **Adiabatic Expansion:** As the pressure inside the cylinder increased, the hydrogen gas began to expand. This expansion might be adiabatic, meaning that the gas did not exchange heat with its surroundings. As a result, the gas cooled, but its density increased. The increased density further increased the pressure inside the cylinder.
- **Ignition of Hydrogen Gas:** The combination of high pressure and high density created ideal conditions for the spontaneous ignition of the hydrogen gas. Spontaneous ignition is a process in which a flammable substance ignites without an external ignition source. This is possible because the chemical reaction that produces the flammable substance can generate enough heat to ignite it. [14, 15]

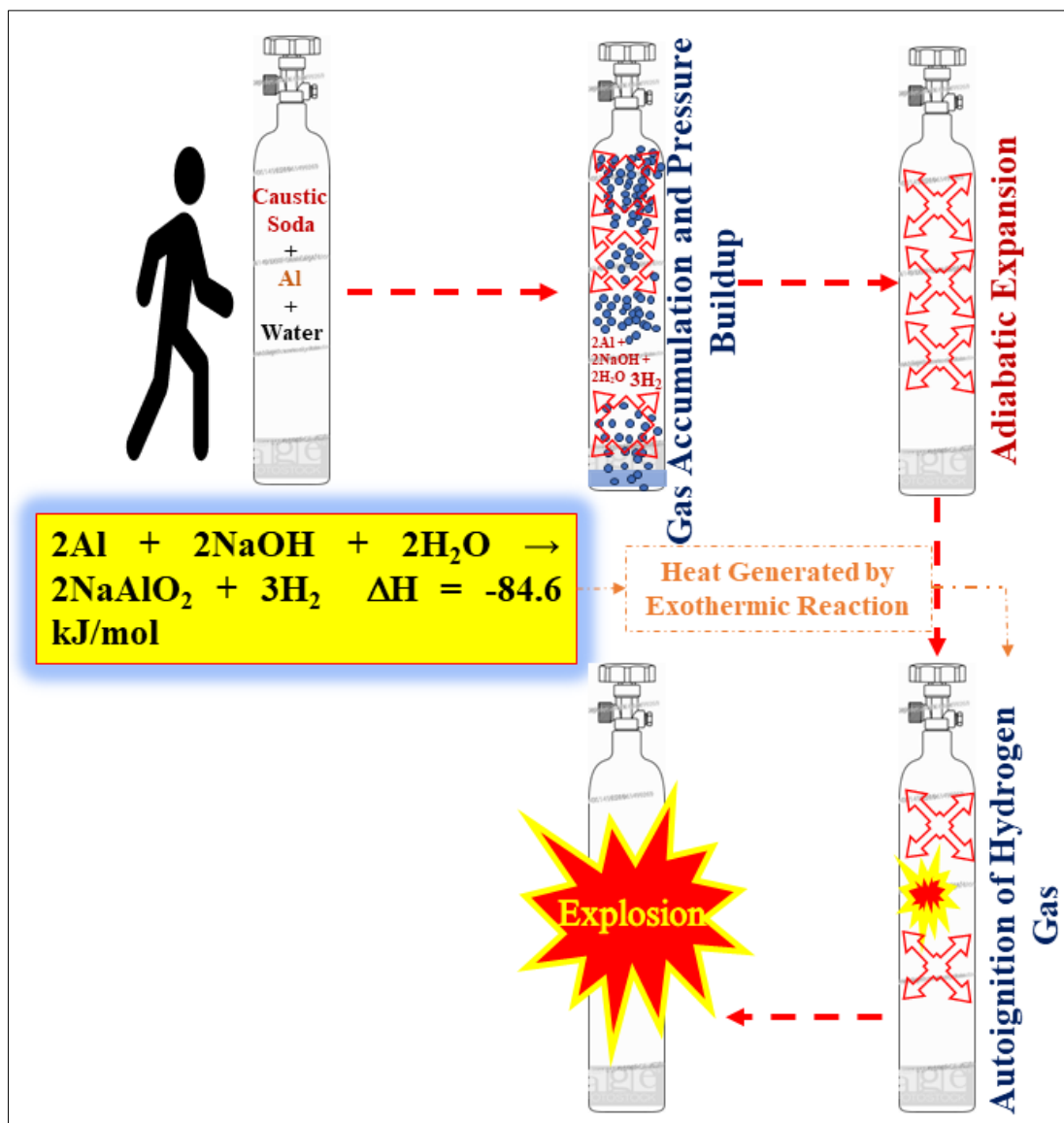


Figure 2 Schematic Representation of the Incident Hypothesis

- **Explosion:** The spontaneous ignition of the hydrogen gas led to a rapid and intense combustion. The blast wave generated by the explosion shattered the cylinder and caused significant damage to the immediate surroundings. The force of the explosion led to the tragic loss of life and severe injuries to individuals in close proximity to the blast.

It is important to note that this is just a hypothesis. However, this hypothesis is consistent with the known properties of hydrogen gas and the findings of the investigation. This hypothetical sequence of events highlights the potential dangers of generating hydrogen gas through the reaction of caustic soda and aluminum, particularly when not conducted under controlled conditions and proper safety measures. It underscores the importance of understanding the chemical properties of substances, adhering to established guidelines, and ensuring proper training and awareness to prevent such incidents.

5 Case Study Lessons

5.1 Key Takeaways from the Incident

The tragic hydrogen gas balloon cylinder blast during the marriage function in Raipur, Chhattisgarh, offers poignant lessons that resonate beyond the immediate circumstances. The incident underscores the fragility of safety in seemingly routine activities and serves as a somber reminder of the potential consequences of neglecting proper procedures. Key takeaways include:

- **Chemical Awareness:** A thorough understanding of the chemical properties of substances is essential when working with compressed gases. The inappropriate mixing of caustic soda and aluminum to generate hydrogen gas exemplifies the need for informed decisions and cautious handling.
- **Compliance with Guidelines:** Straying from established safety guidelines can have dire consequences. The incident highlights the importance of following recommended practices when handling, storing, and using balloon cylinders.
- **Risk of Unintended Consequences:** The incident demonstrates that seemingly innocuous actions can have catastrophic outcomes. Mixing chemicals without understanding the potential reactions can lead to unintended and dangerous results.

5.2 Lessons Learned for Preventing Similar Accidents

The incident offers valuable insights into preventing similar accidents and emphasizes the need for proactive measures to ensure safety:

- **Authorized Methods Only:** Utilize authorized methods and gases for balloon inflation. Avoid creating gases through chemical reactions, especially those that can be flammable or hazardous.
- **Proper Training:** Ensure that all individuals involved in handling balloon cylinders receive comprehensive training. This should encompass safe handling practices, chemical awareness, emergency response, and adherence to established guidelines.
- **Quality Control:** Purchase balloon cylinders and gases from reputable and authorized suppliers who adhere to safety standards and regulations.
- **Communication:** Establish clear communication channels among all personnel involved in handling balloon cylinders to ensure a shared understanding of safety protocols and procedures.
- **Supervision and Oversight:** Implement adequate supervision, particularly in settings where individuals may lack experience or training, to prevent unsafe practices.

5.3 Importance of Proactive Safety Protocols

The case study underscores the vital role of proactive safety protocols in preventing accidents and preserving lives:

- **Prevention Through Education:** Education and training are fundamental in preventing accidents. A well-informed and educated workforce is the first line of defense against potential hazards.
- **Risk Mitigation:** Proactive safety protocols and guidelines play a crucial role in identifying and mitigating potential risks before they escalate into disasters.
- **Cultural Shift:** The incident emphasizes the need for a cultural shift towards safety consciousness. Organizations and individuals should prioritize safety at all stages of balloon cylinder usage.
- **Continuous Improvement:** The incident serves as a catalyst for ongoing improvement in safety measures. Regular reviews of practices, guidelines, and training protocols help adapt to evolving risks.

In conclusion, the case study of the balloon cylinder blast serves as a solemn reminder of the critical importance of adhering to safety guidelines and protocols when working with compressed and flammable gases. By learning from the incident and implementing proactive safety measures, individuals and organizations can help prevent similar accidents and create a safer environment for all.

6 Conclusion

6.1 Summary of the Case Study's Findings

The case study of the balloon cylinder blast during a marriage function in Raipur, Chhattisgarh, revealed a sequence of events that led to a tragic loss of life and severe injuries. The incident was triggered by the improper mixing of caustic soda and aluminum to generate hydrogen gas for balloon inflation. The mixture of aluminum, NaOH, and water produced a chemical reaction that generated a large amount of heat and pressure. This heat and pressure could have caused the cylinder to rupture, leading to the explosion. The incident underscored the crucial importance of adhering to safety guidelines and protocols when working with compressed gases. It highlighted the potential risks associated with mishandling, improper storage, and unauthorized practices, and demonstrated the catastrophic consequences that can arise from neglecting these fundamental safety measures.

6.2 Emphasis on the Significance of Safety Awareness and Adherence

The case study serves as a powerful reminder of the paramount significance of safety awareness and strict adherence to established protocols. It underscores that safety is not merely a set of rules but a responsibility that each individual and organization must uphold. Balloon cylinders, while seemingly innocuous, demand a high level of respect for the potential hazards they pose. The incident calls for a collective commitment to promoting safety consciousness at every level, from individual balloon sellers to event organizers and regulatory bodies. Awareness of the chemical reaction and properties of gases, informed decision-making, and unwavering adherence to safety guidelines are essential elements in preventing accidents of this nature.

6.3 Final Thoughts on the Importance of Continuous Improvement in Safety Practices

The case study concludes by emphasizing the ongoing need for continuous improvement in safety practices. Safety is a dynamic concept that requires vigilance, adaptability, and a commitment to learning from past mistakes. Organizations and individuals must prioritize regular training, updated guidelines, and comprehensive risk assessments to stay ahead of potential hazards. The balloon cylinder blast incident underscores that safety protocols can never be considered exhaustive; they must evolve alongside changing circumstances and technologies. By fostering a culture of safety, promoting education, and encouraging a proactive approach to risk management, we can ensure that tragedies like the hydrogen gas balloon cylinder blast become lessons that inspire enduring safety measures and a commitment to preserving lives and well-being.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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