Online ISSN : 3049-3455

Mineral Metal Energy Oil Gas and Aggregate

Contents available at: www.informaticsjournals.co.in/index.php/2MEOGA

Ergonomic Management of Compressed Gas Cylinders for Unloading Within Refineries

Indranil Chakraborty and N. C. Dey*

Thyssenkrupp Uhde India Pvt. Ltd., Mumbai - 400083, Maharashtra, India; cindranil1@rediffmail.com; ncdey@mining.iiests.ac.in

Abstract

Construction and maintenance within operational refinery units frequently require the use of compressed gas cylinders—primarily oxygen, fuel, and inert gases—for metal cutting and joining. These cylinders, typically weighing over 40 kgs and pressurised over 2000 psi, pose significant safety hazards during manual unloading, especially in the absence of fixed infrastructure. This study focuses on ergonomic and safe unloading practices for gas cylinders at dynamic refinery construction sites. A comparative evaluation of various unloading methods was conducted, including manual dropping, sliding on steel ramps, and the use of mobile ramps with tyre restraint. Impact velocity, cylinder stability, and operational feasibility were analysed across different ramp angle configurations. The findings reveal that a 30° inclined mobile steel ramp equipped with tyre restraints offers optimal safety and control. This solution effectively absorbs impact forces, avoids metal-to-metal contact, and provides mobility suited to decentralised site demands. For permanent setups, fixed concrete ramps with tyre restraints were identified as appropriate. The study underscores the importance of ergonomic design, material selection, and mobility in mitigating risks associated with compressed gas cylinder handling in refineries, aiming to enhance site safety while maintaining operational efficiency.

Keywords: Dynamic, Financial, Gas, Mobility

1.0 Introduction

Routine project or maintenance-related activities within operational refinery units—especially those involving steel structures, pipelines, and related infrastructure—are closely tied to fabrication or modification processes. These processes typically include both metal cutting and joining operations, which demand the extensive use of oxygen, fuel gases, and inert gases. The quantity and type of gas required vary based on the specific nature and scope of the task being performed.

The general practices for handling, usage and storage of gas cylinders are indicated in the global standard of ISO 11625, EN 14470 and OSHA 29 CFR 1910.101[1].

The mishandling of gas cylinders is a significant and fairly common problem across various industries, including healthcare, manufacturing, food and beverage, oil and gas, welding, and construction. This mishandling can occur at multiple stages—from filling, transportation, storage, and distribution to final use—and can result in serious safety, financial, and operational consequences[11,12,14].

- There are hundreds of millions of gas cylinders in circulation globally. With such scale, even a small percentage of mishandling translates into a substantial absolute number.
- Industrial accident reports, published by regulatory bodies, frequently cite cylinder mishandling as a leading cause of industrial gas-related incidents.

*Author for correspondence

- Insurance data often shows gas cylinders as a major source of claims in terms of equipment damage, injuries, and fires.

Unsafe unloading and handling of compressed gas cylinders represent a persistent global safety issue with serious implications for human life, property, and business continuity. Statistics from safety regulatory bodies such as the U.S. Occupational Safety and Health Administration (OSHA) indicate that cylinder-related incidents contribute to hundreds of workplace injuries annually in the United States alone, with approximately 30% of these stemming from mishandling during unloading or movement.

In the UK, the Health and Safety Executive (HSE) has recorded multiple fatal accidents and over 200 serious injuries linked to gas cylinder mishandling over the past decade[3,5,13]. The hazards include explosions from damaged valves, fires caused by leaking flammable gases, toxic exposure due to chemical gases, and crush injuries from falling or rolling cylinders. These risks affect a wide range of personnel, including logistics workers, warehouse staff, technicians, healthcare professionals, and field engineers[7-10].

In terms of business impact, a 2021 industry study by the Compressed Gas Association (CGA) noted that mishandling incidents can lead to operational shutdowns costing medium to large enterprises between $50,000 and $500,000 per incident when factoring in equipment damage, regulatory fines, and downtime[1].

From a global perspective, reviewing incidents over time shows a relatively stable but concerning trend: between 2010 and 2015, the European Agency for Safety and Health at Work documented an average of 150 cylinder-related workplace injuries per year across EU member states[3]. This figure rose slightly between 2016 and 2020, with a marked increase in incidents involving delivery drivers and temporary workers unfamiliar with cylinder protocols.

In 2023, several high-profile accidents in Southeast Asia, particularly in construction and manufacturing sites, highlighted persistent training and equipment gaps[1]. The Asia-Pacific region, in general, accounts for a disproportionate share of such incidents due to rapid industrial expansion and less stringent enforcement in some areas. Conversely, countries with stronger safety cultures and automation adoption, such as Germany, Japan, and Canada, have reported declining trends in cylinder mishandling incidents[3]. These occurrences underscore a pressing need for international best practices, improved training, and digital tracking systems to reduce risks associated with the unloading and handling of compressed gas cylinders[7].

Housekeeping plays an essential role in ensuring the safety of unloading operations involving compressed gas cylinders. Poor housekeeping conditions, such as slippery floors, uneven surfaces, accumulated dust, and general clutter, substantially increase the risk of incidents during cylinder handling. Slippery or wet surfaces can cause slips and falls, especially when operators are manoeuvring heavy and top-heavy cylinders that are prone to tipping. Uneven or sloped unloading areas further exacerbate these risks by allowing cylinders to roll uncontrollably or causing hand trucks to become unstable[9,10].

Additionally, dust accumulation may obscure labels and hazard markings, and debris in the work area can impede safe equipment operation or create trip hazards. These factors collectively compromise operator safety, increase the likelihood of equipment damage, and undermine compliance with Occupational Health and Safety (OHandS) standards such as OSHA 1910.176 and ISO 11625[1,3,13]. Therefore, consistent implementation of good housekeeping practices—including regular cleaning, floor maintenance, lighting checks, and unobstructed pathways—is critical to minimising risks and ensuring safe cylinder unloading and handling in industrial environments.

The compressed gas cylinders are primarily transported to the operational site within the hazardous refinery premises using goods carriers such as trucks or vans.

Typically, the unloading process involves manual handling, during which the cylinders are dropped to ground level upon removal from the transport vehicle.

Currently, this unloading method is hazardous due to the potential risks associated with improper handling.

The prime hazards associated with gas cylinders are as follows:[12-14]

- The force generated by the blast of a gas cylinder explosion or the sudden release of compressed gas.
- Impact caused by fragments of gas cylinders or valves that fail, or any debris propelled by the explosion.

- Fires caused by the leakage or escape of flammable gases or liquids, such as Liquefied Petroleum Gas (LPG).
- Impact from falling cylinders; manual handling injuries[9,10].

Compressed gas cylinders are heavy, typically weighing over 40 kg, particularly when full. These cylinders are usually pressurised to 0.25 kpsi (for dissolved acetylene cylinders) and 2.20 kpsi (for oxygen cylinders), containing kinetic energy comparable to that of a small weapon.

In the event of a sudden fall causing the main valve to break, the gas cylinder could travel more than 0.5 km and potentially penetrate reinforced concrete walls. Therefore, it is crucial to handle all gas cylinders, including during loading and unloading, with utmost safety. Given the nature of activities of construction/ maintenance or revamp requirements within the refinery units, gas cylinders are often required at various locations where permanent unloading and reloading systems for empty cylinders are not in place.

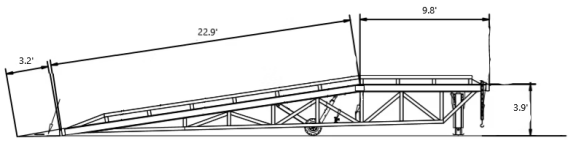


Figure 1. Ramp for cylinders unloading[1,2].

2.0 Methods

The conventional method of unloading gas cylinders from transport vehicles inherently carries numerous hazards.

The findings of a comprehensive study on existing unloading procedures and practices revealed that some of the current unloading practices do not ensure the safe handling of cylinders[3,5,7].

Various methods for handling gas cylinders were thoroughly examined, as summarised in Table 1. One such method involved sliding cylinders down a ramp, as displayed in Fig. 1, which was tested under multiple ramp angle configurations.

The impact forces and velocities associated with each configuration were studied to evaluate their safety and feasibility. The inferences of the analysis are compiled in Table 2, which presents the comparative findings.

3.0 Discussion

It was concluded that the use of a mobile ramp constructed from steel and equipped with shock-absorbing restraints is the preferred option.

For cylinder unloading, owing to the following reasons:

- Enhanced Impact Absorption: The shock-absorbing restraint system effectively reduces the impact force during unloading, minimising the risk of damage to the cylinder and surrounding area.
- Mobility and Flexibility: The mobile nature of the ramp allows it to be easily repositioned across various locations on the construction site, addressing the need for decentralised unloading points.
- Structural Stability and Durability: Steel construction
- Ensures the ramp is robust and capable of withstanding the heavy loads and repeated use typical of construction environments.
- Improved Safety: The combination of controlled sliding, reduced drop height, and impact mitigation significantly lowers the likelihood of accidents or injuries during unloading operations.
- Ease of Deployment**:** The ramp can be quickly set up and removed as needed, without requiring permanent installation, making it practical for dynamic worksite conditions.

Various conventional methods for unloading gas cylinders at project sites were evaluated with a focus on the hazards and risks associated with each process. The assessment aimed to identify safer alternatives that would mitigate these risks effectively.

In exploring safer solutions, several alternative unloading options were considered, taking into account the dynamic nature of construction projects, which involve a wide range of activities and varying site conditions.

These alternatives were conceptualised through collaborative brainstorming sessions involving teams from Health, Safety, and Environment (HSE) as well as site operations.

Based on this evaluation, and the dynamics of a rolling cylinder as depicted in Fig. 2, it was determined that gas cylinder unloading systems incorporating a metallic slope with shock-absorbing restraints are best suited for refinery

Table 1. Methods of Cylinder Unloading[1,2,3]

Sr. No.	Detail	Description	Aftermath
1	Manually dropped	Mannually rolled from the loaded carriage and dropped on the ground	Causes damage to the valve; damages the shell Dropped cylinders are vulnerable to leaks
2	Vertically slid on a mobile ramp made of steel	A steel ramp is provided for unloading cylinders Manually rolled from the carriage Cylinders slid vertically on the steel ramp	The metallic contact during unloading caused significant damage to the outer shell of the gas cylinder. The use of a straight, flat-surfaced ramp increases the risk of cylinders tipping and falling to the side.
3	Horizontally slid on Mobile ramp made of steel	An additional risk factor is the uncontrolled horizontal rolling of the cylinders on the smooth steel ramp surface.	Due to the horizontal sliding motion, the cylinders acquire significant kinetic energy while moving down the ramp, increasing the risk of impact damage upon reaching the ground or striking obstacles.
4	Mobile ramp made of steel with shock-absorbing restraint	Slide on a steel ramp vertically Ramp surface covered with fire-resistant material to eliminate metal-to-metal contact and reduce risk of cylinder damage during unloading The Sliding ramp has a slot on its plane so that the cylinder slides down safely Ramp provided with wheel and stopper Rubber tires were installed at the end of the ramp to serve as restraint material, reducing the impact force when cylinders reach the bottom	The use of a steel ramp in combination with tire-based restraint has shown no significant negative effects during operations Metal to metal contact interface is avoided. The restraining material installed at the end of the ramp effectively absorbs shock and prevents damage to the cylinders.
5	Fixed concrete ramp with shock-absorbing restrains	Cylinders are unloaded from the truck manually on a strong concrete ramp Cylinders would be slid on vertically ramp which lands on a rubber shock-absorbing restrain as a restrain material and later rolled, keeping it in an upright position	Useful in handling cylinders in stores / other permanent setups.

sites, including temporary project locations or scheduled maintenance activities, due to their adaptability, mobility, and enhanced safety features.

However, for permanent setups such as the refinery stores or warehouses, the use of a fixed ramp equipped with shock-absorbing restraints is identified as the most appropriate solution, providing a stable and durable arrangement for regular unloading operations.

4.0 Conclusion

While addressing the issue of safe handling of gas cylinders in construction projects within the refinery units, it became evident that this seemingly routine task involves significant hazards and warrants a detailed examination of multiple interrelated aspects. The study recognised the need to account for the transient and dynamic nature of construction activities, which often change rapidly based on project phases and requirements. level of risk awareness among workers and their understanding of the precautionary measures necessary to prevent accidents.

In alignment with the scope of this paper, various methods for handling gas cylinders at refinery sites were examined. The study specifically focuses on the safe handling of compressed gas cylinders once they arrive at

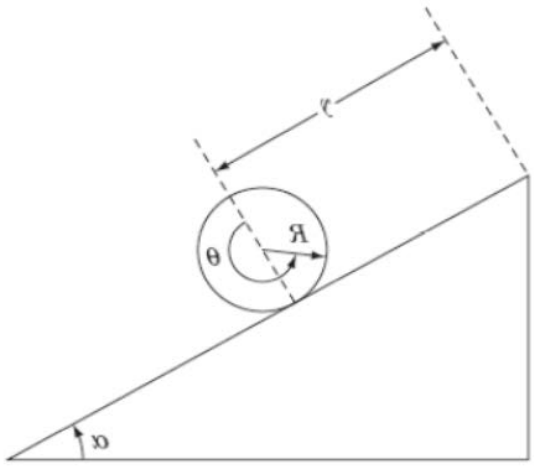


Figure 2. Dynamics of a rolling cylinder[3,4,7,8].

the construction site stores[4]. From this point, cylinders are required to be distributed to multiple work locations based on operational demands.

The primary emphasis of this study is on the unloading of gas cylinders from transport vehicles at the construction site and their subsequent handling within the site premises.

The details of the coverage of research are shown in the flow chart. This research intends to establish a comprehensive overview of the entire gas cylinder handling cycle, encompassing all key stages from production, logistics, and dispatch, through to receipt at the activity site within the operational refinery and the eventual return process.

While evaluating safer and more efficient methods for gas cylinder unloading, the following practices were studied in were studied in detail:[2,3,7]

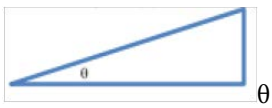
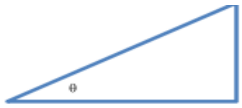
- Manual unloading by dropping from the truck
- Horizontal sliding on a steel-constructed mobile ramp
- Vertical sliding on a mobile steel ramp
- Use of a mobile steel ramp equipped with shock-absorbing restraints
- Use of a fixed concrete ramp with shock-absorbing restraints

Each method was analysed for its practicality, safety implications, and suitability to different types of construction site setups, considering both temporary and permanent conditions[1,3,6].

From the study, the following configurations were identified as safer and more effective options for unloading gas cylinders at construction sites:

- A mobile ramp with shock-absorbing restraints is recommended for use at work locations across the site, where flexibility and mobility are essential.

Table 2. Analysis of different unloading mechanisms

Sr. No.	Angle of Ramp (θ)	Observations
1.	 θ = 15°	Sliding velocity of the cylinder was insufficient. A push was required to propel the slide of the cylinder. The height of the ramp is just over 600mm and shall not match the carriage's level.
2.	 θ = 30°	Sliding the cylinder was adequate for the purpose The height of the ramp is approximately 1200 mm, which aligns well with the vehicle's carriage for smooth loading and unloading
3.	 θ= 45°	The sliding velocity of the cylinder is high, and due to the acceleration the cylinders get difficult to control once they touch the ground The height of the ramp is over 2200 mm and is higher than the carriage's level
4.	 θ = 60°	Sliding velocity of the cylinder is immensely high and the cylinder tilts after it touches the ground The height of the ramp is approximately 4000 mm, which is very high and much higher than the carriage's level

- A plausible, concrete ramp with shock-absorbing restraints can be best suited for permanent setups such as stores or warehouses, where unloading operations occur regularly in a stable location.
- A probable solution can be explored to include a hydraulic lifting arrangement to match the carriage height and bring the cylinder to the ground level.

In the evaluation of various ramp angle configurations, both impact force and velocity of the cylinders during unloading were considered.

It was determined that a 30° inclination provides an optimal balance between operational efficiency and safety.

Based on this, it is concluded that a 30° ramp angle, when used with a mobile steel ramp equipped with shock-absorbing restraints, offers a safe and practical solution for unloading gas cylinders specifically within refinery units.

5.0 References

1. Gas Cylinder Rules 2016. Schedule VI – Transportation of Cylinders.
2. Saha R, Dey NC, Samanta A, Biswas R. Evaluation of physiological strain of shovellers in underground coal mines in India. J Ergon Soc South Afr. 2010; 22(2):33–48.
3. Sen KN, Elangovan RK, Shrihari. Safe handling of gas cylinders at a construction site.
4. Saha R, Dey NC, Samanta A, Biswas R. A comparison of cardiac strain among drillers of two different age groups in underground manual coal mines in India. J Occup Health. 2008; 50(6):512–20. https://doi.org/10.1539/joh.O7005 PMID: 18971575
5. Carpenter LM, Gianni RS. Safe handling, storage, and transport of compressed gas cylinders.
6. Saha R, Dey NC, Samanta A, Biswas R. A comparison of physiological strain of carriers in underground manual coal mines in India. J Occup Environ Health. 2008; 14(3):210–7. https://doi.org/10.1179/oeh.2008.14.3.210 PMID: 18686722
7. Occupational Safety and Health Administration. 1926.350 – Gas welding and cutting.
8. BOC. Guidelines for gas cylinder safety.
9. Dey NC, Samanta A, Saha R. Assessment of cardiac strain amongst underground coal carriers – A case study in India. Int J Ind Ergon. 2007; 37(6):489–95. https://doi.org/10.1016/j.ergon.2007.01.005
10. Dey NC, Samanta A, Saha R. Cardiovascular load assessment of coal mine shovelers in West Bengal, India: A comparison between middle age groups. J Hum Ergol. 2006; 35(1–2):41–4.

6.0 Bibliography

11. Bureau of Indian Standards. IS 8194:2004 – Steel cylinders for compressed gases. New Delhi: BIS; p. 9–12.
12. Dey NC, Saha R, Samanta A, Biswas R. A comparative study of physiological strain of underground coal miners in India. J Hum Ergol. 2007; 36(1).
13. Health and Safety Executive. Working safely with acetylene. 2014. p. 3.
14. Compressed Gas Association. Safe handling of compressed gases. 5th ed. USA: CGA; CFA P-1. p. 4. Clause 3.2.3.