

Accidents in Pressure Vessels: Hazard Awareness

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Abstract — Pressure vessels store substances under pressure higher than atmospheric conditions and are found all over the place. They are used in homes and hospitals for hot water storage, in many different factories and plants, and in mining and oil refineries. Pressure vessels store large amounts of energy; the higher the operating pressure and the bigger the vessel, the more the energy released in the event of a rupture and consequently the higher the extent of damage or disaster or the danger it poses, hence there should be no complacency about the risks. Unfortunately, pressure vessels accidents happen much more than they should. This paper presents different accounts of pressure vessels accidents, hazard awareness and precautionary measures that could save lives.

Index Terms — Accidents, Pressure, Safety, Vessels

I. INTRODUCTION

Pressure vessels are air-tight containers used mostly in process industry, refinery and petrochemical plant to carry or hold liquid, gases or process fluids. They are typically subjected to pressure loading and internal or external operating pressure different from ambient pressure.

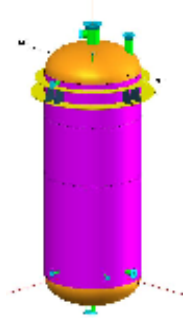


Figure 1 - 3D Model of a Tower.

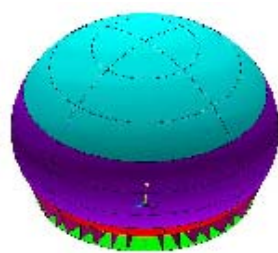
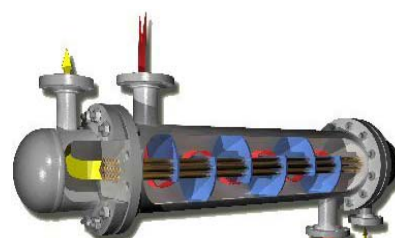


Figure 2 – 3D Model of a Drum

Due to differential operating pressure of the pressure vessel, it is potentially dangerous and hazardous. The commonly used types of pressure vessels in industry are heat exchangers, tanks, towers, boilers, reactors, drums, condensers, piping, and columns as shown in figures 1 – 6.



[1-4]

Figure 3- 3D Model of a Heat Exchanger



Figure 4 – Example of a column

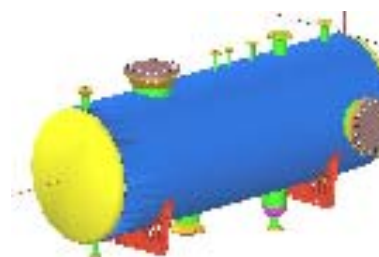


Figure 5- 3D Model of a Tank

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Figure 6 – Example of a Condenser

II. VESSEL DESCRIPTION

The arrangement of a process tank vessel is shown in Figure 7. A typical pressure vessel consists of shell (body of the vessel), closure heads, openings for inspection and instrumentations, attachments and a combination of nozzles for pressure relief or other purpose, and supports [5].

III. CAUSES OF FAILURE

The main causes of failure of a pressure vessel are as follows:

- Faulty Design
- Operator error or poor maintenance
- Operation above max allowable working pressures
- Change of service condition
- Over temperature
- Safety valve
- Improper installation
- Corrosion
- Cracking
- Welding problems
- Erosion
- Fatigue
- Stress
- Improper selection of materials or defects
- Low –water condition
- Improper repair of leakage
- Burner failure
- Improper installation

IV. RATE OF ACCIDENTS

Bulk transporter [7] reported that the National Board of Boiler and Pressure Vessel Inspectors recorded the number of accidents involving pressure vessels at an increase of 24% over the course of a year between 1999 to 2000. These statistics include power boilers, steam heating boilers, water heating boilers, and unfired pressure vessels. However, the increased number of accidents was not reflected through to the number of fatalities, as these actually dropped by 33% over this period.

By broadening this search, it can be seen that the reporting period of 1992 to 2001 saw a total of 23,338 pressure vessel related accidents which averages at 2,334 accidents per year. Reporting year 2000 saw the highest number of accidents at 2,686 with the lowest at 2,011 in 1998. [7-9]

The number of fatalities as a direct result of boiler and pressure vessel accidents has been recorded as 127 over the past 10 years. [7-9]. During the reported period between 2001 and 2008, the statistics show that the rate of accidents that were directly linked to pressure vessels is not yet on the decline.

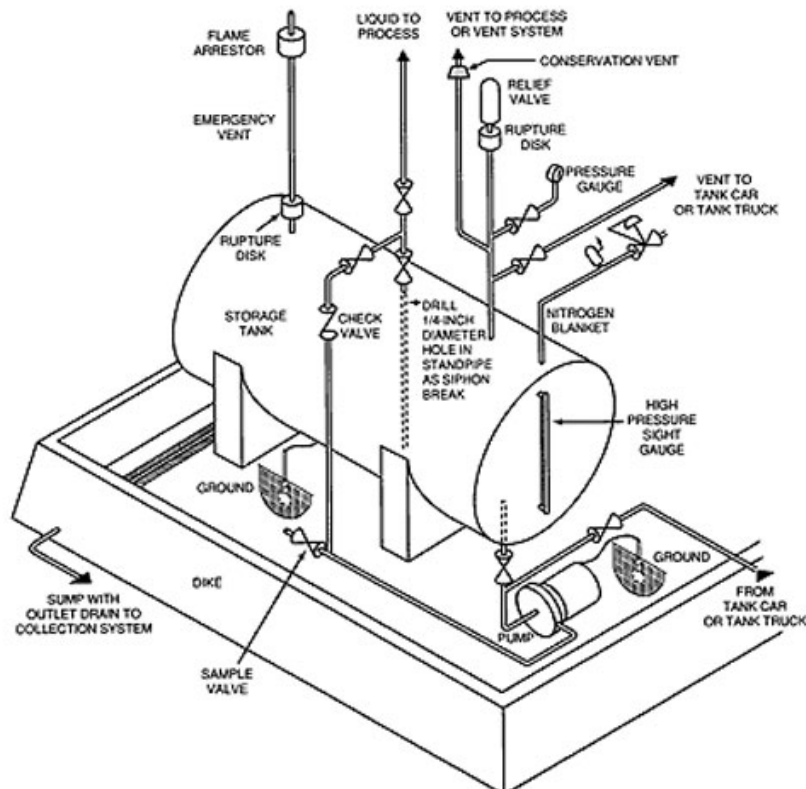


Figure 7: Typical horizontal storage vessel arrangement [6]

V. PRESSURE VESSEL RELATED ACCIDENTS

Below are six examples of major accidents involving pressure vessels that have occurred in the past 7 years;

- Failure of the clamping system on a pressure vessel lid, which caused the lid to fly off and hit a worker at Clariant Life Science Molecules (UK) Limited's plant in Sandycroft, Flintshire in October 2003. The worker named Giancarlo Coletti sustained serious injuries to his right arm.
- An explosion at Algeria's largest refinery in port city of Skikda, Algiers. The huge explosion at its key gas installation killed 23 people on 20 January 2004.
- A pressure vessel weighing 22680 kg (50,000 pounds) exploded at Marcus Oil in 2004, a Chemical plant in Houston, Texas, throwing heavy fragments into the community, which damaged a church, shattered car windows, nearby buildings experienced significant structural and interior damage due to improper modification and faulty welds of the vessel. Pieces of shrapnel metal weighing over 450kg travelled at extremely high speeds up to a half-mile before landing on nearby highways and railways. A large portion of the plant was destroyed, half the state was without phone or electricity, 3 plant workers were killed and several residents cut by flying glass [10-11].
- The Buncefield (UK's fifth largest depot) accident on Sunday 12 December 2005 that injured 43 people readily comes to the mind. Twenty petrol tanks were involved in the Buncefield blaze; each held three million gallons of fuel. Over 2,000 people were evacuated from the neighbourhood of the depot during the accident.
- Pressure vessel failure in Houston, United States, in the summer of 2008 killed a veteran supervisor when a heat exchanger exploded in a resin-production facility.
- Two employees killed at an oil refinery in southeast New Mexico, USA and two others critically injured after a storage tank exploded into flames on 03 March 2010.

VI. HAZARD AWARENESS

The potential danger associated with pressure vessels failure if not properly designed, constructed, operated, inspected, tested, or repaired are:

- Blast Effects
- Fragmentation damage
- Suffocation
- Poisoning
- Fire Explosion
- Chemical burns

- Thermal burns

- Loss of lives and property
- Permanent injuries or disabilities on affected people
- Loss of earning/income

Of particular danger are vessels that have been improperly installed, welded or modified and those that lack effective pressure relief systems [12-13]. Even non-dangerous gases and liquids, such as air and water may become hazardous in the event of an accident involving high-pressure equipment.

VII. SAFETY APPROACH

There are standards and codes laid down by approved regulatory bodies for the design, construction, welding, testing, marking, operation, inspection, and repair of any pressure vessel, which provides fundamental safeguards and good safety practices. The standards and codes vary from country to country, the commonly used codes are:

- ASME Boilers and Pressure Vessel Codes
- API Standards
- PD5500
- British Standards
- European Codes and Standards
- Other International Codes

However, some parts of the world do not have pressure vessel law in place nor provide for the enforcement of internationally recognized pressure vessel safety codes. This casts doubts on the safety of vessels operating in such places. The Health & Safety Executive (HSE) in the UK has warned of the need for effective operation, inspection and maintenance regimes to ensure the safe use of pressure equipment. The Chemical Safety Board (CSB) has also echoed the same by asking all jurisdictions to adopt the Pressure Vessel Code and related boiler standards as lives will be saved as a result. [14-15].

VIII. PRECAUTIONARY MEASURES

The catastrophic disasters caused by pressure vessel accidents could be totally prevented by;

- Designing, fabricating and constructing pressure vessels to comply with applicable codes and standards, and where no pressure vessel law exists, to internationally recognised pressure vessel safety codes.
- Operating the vessel at pressure below the maximum allowable working pressure with proper pressure setting of relief devices, to handle design pressures and temperatures.
- Periodically testing and inspecting the vessel as well as the relief devices in order to detect corrosion or erosion of the vessel that can cause holes, leaks, cracks, general thinning of the vessel walls or any other defects. Safety

relief valves must be taken off during safety inspection to verify whether their settings are correct.

- Keeping records of inspection reports and monitoring potential problem, so that the vessel may be taken out of service before it becomes dangerous. Also, having all information displayed prominently.
- Ensuring that alterations or repairs of vessels are only done by competent and authorised persons and the repair must meet the accepted industry quality standards for pressure vessel repair.
- Providing safety training for employees on job hazard and anticipated conditions that could jeopardize their safety or the safety of others.
- Periodically provide training for operators on vessels operating procedures to avoid over pressurizing, as well as providing them with adequate and suitable instructions for vessel safe operations.

IX. CONCLUSIONS

Pressure vessel related accidents might never be fully eliminated; however, we can work towards significantly reducing the risk and likelihood of such accidents occurring. The standards and codes that are in place in many countries around the world aim to establish good safety practices and safeguard personnel working with or around pressure vessels to reduce any associated risks and the likelihood that they will occur. However, there are many countries that still do not adopt such laws and safety codes, thus increasing the likelihood of pressure vessel related accidents.

The adoption of safety standards and codes in all remaining countries and the enforcement of operation, inspection and maintenance routines is recommended to ensure that all pressure equipment is safely operated. Monitoring and inspection data should also be checked to ensure that any potential problems are identified in the early stages to prevent an accident occurring; alongside regular safety training for all employees, and more specifically vessel operators, to properly conduct vessel operating procedures and also anticipate any potential problems prior to their occurrence.

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REFERENCES

- [1] N. Siroh and A. . O. Niedzwiecki. "Hydrogen Technology: Development of Storage Tanks" - High Pressure Vessels, Springer-Verlag. Berlin, Heidelberg 2008.
- [2] American Petroleum Institute 2001 "Inspection of Pressure Vessels" (Towers, Drums, Reactors, Heat Exchangers, and Condensers). Recommended Practice 572, Second Edition.
- [3] Pressure Vessel Engineering . (December, 2009) (Online) . Available: <http://www.pveng.com>
- [4] J. Spence and A.S. Tooth. Pressure Vessel Design: Concepts and Principles. Taylor & Francis; 1st edition, January 1994.
- [5] S. Chattopadhyay "Overview of Pressure Vessels" Pressure Vessels Design and Practice. 3rd edition: CRC Press, 2004, pp. 1-10.
- [6] DuPont Storage and Handling (2010, January 10). (Online). Available: <http://www2.dupont.com>
- [7] Bulk Transporter "Boiler, Pressure Vessel Accidents Increase" (2009 ,May 05) (Online) . Available: <http://bulktransporter.com>
- [8] The National Board of Boiler and Pressure Vessel Inspectors, National Board Bulletin, Summer 2002. (Online). Available: <http://www.nationalboard.org>
- [9] AirConditioning,Heating,Refridgeration-The News" Boiler Accident Report : To Err Is Human" (2002, November 8) (Online). Available: <http://www.achrnews.com>
- [10] Newsletter – Chemical Emergency Prevention and Planning, " Pressure Vessels: Rupture Hazards and Prevention" , US EPA Region 10, March-April 2008, pp. 2-4.
- [11] J.Knodell, Industrial Quick Search, Inc. Manufacturer Directory " You can Stop Pressure Vessels Failure" (2003, September 23) (Online). Available: <http://www.iqsnewsroom.com>
- [12] Metallurgical Consultants "Pressure Vessels" (2009, October 15) (Online) Available: <http://www.materialsengineer.com>
- [13] Journal Professional Safety "States Urged to Adopt Pressure Vessel Code" , American Society of Safety Engineers, January 2010.
- [14] Health and Safety Executive (HSE) "HSE Press Release: E178-04 –HSE issues Pressure Vessel warning after chemical fined £100,000" (2004, December 23). (Online) Available: <http://www.hse.gov.uk>
- [15] J. Bresland "Without Safeguards, Pressure Vessels Can Be Deadly" (2010,January 15) (Online) .Available: <http://www.youtube.com/watch> or www.csb.gov
- [16] (Images) Pressure Equipment Engineering Services Inc. "Image Gallery" (Online) Available: <http://www.peesi.com/Image> and <http://storagetanks.tradeindia.com>