International Conference on Advances in Materials, Computing and Communication Technologies
In Association with International Journal of Scientific Research in Science and Technology
Volume 9 | Issue 1 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)

Safety Audit Analyse – An Accident Study in Chemical Industry

B J Ravi[1*], Dr. N. Dilip Raja[2]
[1*]Research Scholar, Industrial Safety & Engineering, Department of Mechanical Engineering, Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, Avadi, Chennai, Tamil Nadu
[2]Associate Professor, Department of Mechanical Engineering, Vel Tech RangarajanDr.Sagunthala R&D Institute of Science and Technology, Avadi, Chennai, Tamil Nadu

ABSTRACT

Accidents are costlier to management in an industry and affect reputation of the company, financial position, quality and quantity of the output and morale of the workforce. In addition to this, new hazards are emerging in work place resulting in accidents to workforce due to modernization and mechanization of industrial activities. In Industry, management adopts several methods to safeguard the Safety and Health of plant and people. Amongst the various methods, Safety audit is one of the dependable methods to assess all the factors of safety and health activities.

Safety Audit is a systematic examination of the plant and document review by a team with appropriate backgrounds and experience. This is an intensive plant inspection intended to identify the plant conditions and operating procedures that could lead to accidents or significant losses of life and property. Purpose of the audit is identification of hazards arising due to deviations from applicable statutes, non statutory standards and codes of practices, safety related instructions of manufacturers of equipment and safety operating procedures as supplied by the technology suppliers and subsequent revisions etc.

However, even after safety audits, accidents are occurring in industries, which leads to huge loss to nation in terms of loss to workforce and management. In order to prevent such losses, safety audit system to be strengthened by modifying applicable statutes for industries and ports.

In order to modify statute, it has to be substantiated for need of modification and ways of modification. This report basically tell the ways to carryout above said work by collectively getting data for recommending changes in statutes by conducting safety audit in selected industries, studying major accidents occurred in the past and analysing existing latest technologies for the process and equipment.

Keywords: Plant Inspection, Accident, Statutes, Safe Operating Procedure, Hazards, Process.

I. INTRODUCTION

Accident prevention is just as much an aspect of efficient operation as is any other industrial activity. Yet many managers still tend to look suspiciously at suggestions that their company's safety and loss prevention measures should be subjected to regular scrutiny and where necessary, constructive criticism. In fact, safety audits (the process by which this is done) are an important tool for identifying falling standards, areas of risks or vulnerability, hazards and potential accidents in proposed and existing plants and processes; for determining the action necessary to remove hazards before personal injuries or damage occur; and for ensuring that the whole safety effort is effective, meaningful and the objectives understood.

Industry has responded to the need for reliable control of risks with a broad range of systems employing physical, operational and management controls. Each system is designed to reflect the inherent risk of the operations and the structure and culture of the organisation. One such initiative is safety, health and environmental auditing. Auditing is being considered a highly respected element in the safety, health and environmental programmes of companies of all sizes.

In its most common form, safety audit comprises a series of activities undertaken on the initiative of an organization's management to evaluate safety performance. Beyond this common base, the term "Safety Audit" has become associated with a wide variety of efforts, activities and programmes that are intended to examine the performance of a given facility or operation and determine or verity the extent to which those activities and programmes comply with external requirements and internal company standards. It is a systematic, objective approach to verity both safety compliance and the systems in place to manage safety responsibilities.

Safety Audit is a Co-operative effort of the audit team and factory personnel to improve overall safety performance of the plant rather than as a dreaded interference with normal operations.

a) THE STYRENE VAPORRELEASES ACCIDENT

Uncontrolled Styrene VaporRelease from M6 Tank - loss of human lives and substantial repercussions on the environment. In the wee hours of 7th May 2020, an accident of uncontrolled release of Styrene vapor occurred at LG Polymers India Pvt. Ltd. (LG Polymers) from one of the Styrene storage tanks.The hazardous Styrene vapors spread beyond the factory premises, affecting the populace of five villages / habitations. The accident took the life of 12 persons and 585 people had to undergo treatment in hospitals. This Styrene vapor release, widely referred to as "Vizag Gas Leak", is one of the major Styrene vapor release incidents from a bulk storage tank anywhere in the world.

b) SEQUENCE OF EVENTS OF THE ACCIDENT

In the early hours of 7th May 2020, the Styrene storage M6 Tank with 1937 MT storage had started uncontrolled release of Styrene vapors from the top of the tank through the Flame arrestor / Vent (N6) and Dip hatch vent (N1), which spread beyond the factory boundary, affecting the neighboring areas & habitations.

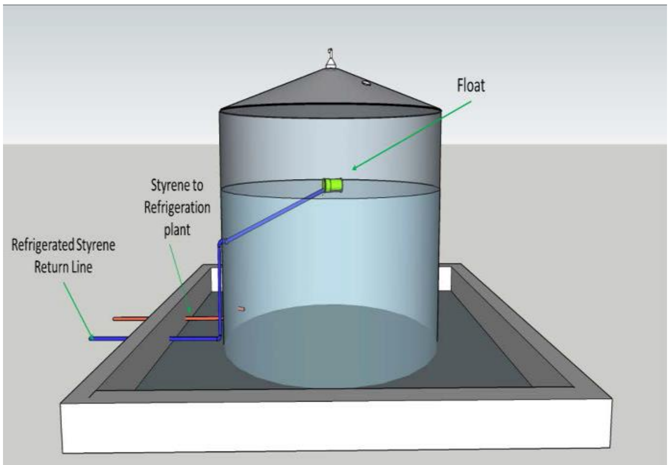
Styrene vapour was released from the top of the tank while the gas detector is not at the top of the tank, but on the four sides of the tank nearly at ground level (300 mm from the ground).There is certain to be a time gap between the release at the top of the tank and the detection at the bottom as the Styrene vapour would have taken some time to settle down. Further, the gas detector was not sensitive enough to detect the gas immediately as the gas detector alarm was tuned for 2200 ppm (20% of the LEL value).

II. OBSERVATIONS:

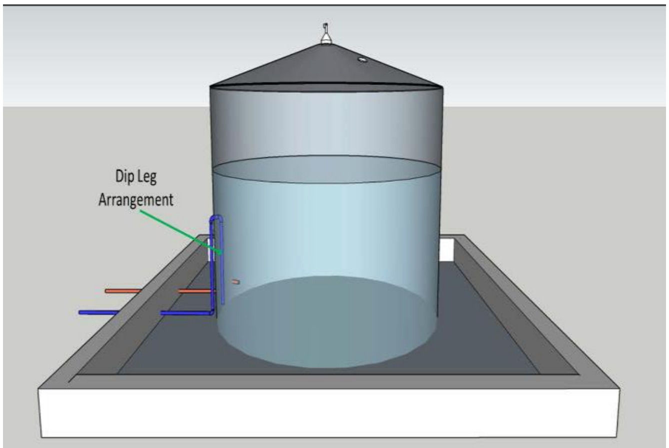
a) Vents Open to Atmosphere

As the vents of the tank are open to atmosphere, emissions of Styrene are prevalent. Unlike the modern designs, the tank neither has a flare system that burns the Styrene vapours forming carbon dioxide nor a cryogenic system to condense Styrene vapours that can be collected separately. The bulk storage tanks should be vented to a vapour collection and containment system that effectively eliminates discharges of Styrene monomer vapour to the atmosphere. The M6 Tank is not provided with any of the above safety systems.

On specific query about the changes carried out, they have further informed that the modification had not been informed to PESO or any other concerned statutory organization to get it approved thinking that only a change in the piping only. This was a critically wrong assessment on the part of the company. Any modification of equipment or plant should be subjected to HAZOP and Risk Assessment Study. Originally, the tank was having a swing pipe arrangement to discharge the cooled Styrene from the recirculation and refrigeration unit, just below the liquid surface. Thus, the cooled liquid was delivered at the top of the tank and by its chemical property, it would slowly circulate to the bottom of the tank from where it would be pumped through the refrigeration unit. Thus, the contents of the tank were well mixed by the chemical properties, as the denser cold Styrene moves down towards the bottom by gravity and natural convection, such that the temperature would be less thermally stratified in the tank. As the float valve got stuck in the stalactites in the M6 Tank, as a result of which, the firm had to discard the piping connected to the float valve and bring in alternate piping of dip leg arrangement. The alternate piping provided for the cooled Styrene monomer liquid to be delivered at the bottom of the tank.



The floating arrangement in M6 tank



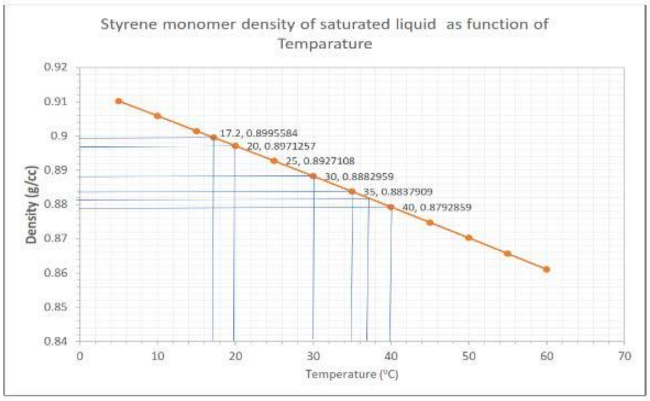
Dip Leg modification in M6 Tank

b) Tank Temperature Measurement & Control

Single Temperature Measuring Probe at the Bottom. The M6 Tank is provided with a temperature measuring probe (RTD sensor) at the bottom only. The probe is located 0.7 m from the bottom and about 4.09 m distance between the discharge port, N13 and the port of the temperature probe, N14 as is shown below in From the location, the Committee is of the view that the location of the temperature probe is not adequate to give a representative value of temperature in the tank. The temperature measurement is restricted to the bottom zone liquid, whereas top and middle zones may have different temperatures

In fact, there must be four or five temperature measurement locations along the 12m height of the tank, that would have measured the true temperature of the liquid Styrene in the different zones of the tank. For the long-time storage of Styrene, in large tanks, it is necessary to measure the temperatures at different locations across the height of the tank to identity the temperature differentials.

When Styrene is warmer, it gets less dense for each increment in degree celsius. This allows for thermal layering; where warmer Styrene moves on to the top of colder Styrene which is defined as "thermal stratification". Due to this, there will always be a level of "self-induced" thermal stratification in the Styrene storage. As a matter of fact, for any large storage of any liquid is subjected to thermal stratification in the tanks or vessels. Similarly, addition of chemical compounds (like TBC) can also be stratified due to the self-induced thermal stratification.



c) **Recirculation and Refrigeration System**

Under no circumstances the temperature of Styrene in whole tank should exceed 25°C according to the standard guidelines for Styrene storage. Hence, it necessitates maintenance of lower storage temperature in the tank. Higher temperatures are bound to cause Styrene vaporization and subsequent build-up of polymer. Usually, the preferred storage temperature is in the range of 10 – 18°C. If the temperature approaches 20°C, the tank contents must be cooled. Thus, proper refrigeration–recirculation systems need to be provided.

As the tank is insulated, the exothermic polymerisation heat cannot be dissipated. The M6 Tank does not have proper mixing arrangement to take care of any increase in temperature in middle and upper zones. Although the company have stated that there are temperature alarms at 35°C and 37.5°C, the temperature data recorded in the DCS on the 7th of May does not record any temperature alarm either at 35°C or 37.5°C. The temperature maintenance throughout the large storage tanks at 15-20°C is essential in light of possibility of runaway polymerisation characteristic of Styrene.

d) **Improper Cooling of Styrene Monomer**

The design range of the temperatures of the refrigeration units is given for cooling Styrene from 40°C to 20°C. But in practice, it was being used to cool the Styrene up to 17°C. This was also caused due to the change in the piping design in the M6 Tank. It may be seen that the float swing pipe arrangement was replaced with dip leg arrangement with release of cooled Styrene Monomer liquid at virtually at the bottom of the tank viz., 300 mm from the bottom. Similarly, the liquid Styrene monomer is taken into the refrigeration cooling system from the N13 port, located at nearly the bottom of the tank at 100 mm..it totally destroyed the natural chemical circulation (mixing) system. Moreover, it resulted in cooled liquid Styrene Monomer being pumped for further cooling in the refrigeration system. This is the cause why the temperatures at the bottom of the M6 Tank recorded low temperatures in the range of 17°C.

Roof Top of M6 Tank Showing Vents

e) **Inadequate Time for Refrigeration And Manual Operation**

The refrigeration system of the M6 Tank (as well as of the M5 tank) are manually operated. The company management informed that it is their normal practice to switch on the refrigeration / cooling system at 08:00 a.m. and close at 05:00 p.m. every day, except when unloading of Styrene Monomer from tanker takes place, during which refrigeration system is kept on. The management also informed that all through the lockdown period, the refrigeration subsystem was operated from 08:00 a.m. to 05:00 p.m.

For a place like Visakhapatnam, with temperatures mostly ranging from 20°C to 36°C, it is but essential to operate the refrigeration system on a continuous basis to ensure temperature at all levels of tank below 20°C. This is one of the major shortcomings in the refrigeration system followed by the LG Polymers. It needs to be checked whether in much cooler climates of South Korea whether LG Chemicals in their South Korean Plants run the refrigeration continuously.

f) Insufficient Capacity of Refrigeration Unit

The recirculating pump capacity is 30 m3/hr. and the capacity of refrigeration unit (ACCEL Make) is 38 TR. Further, the Technical Committee has reported, GM (production) had answered to queries at different times about the capacity of recirculation pump as 90 m3/hr., 60 m3/hr. and finally 30 m3/hr. As such the 30 m3/hr. pump is not adequate to recirculate the contents of tank contents of the order of 2250 m3 in 8 /24 hours.It clearly proves that the capacity of the refrigeration unit, especially the recirculating pump was not sufficient for the full tank capacity of M6 especially considering the tropical conditions in Visakhapatnam.

III.CONCLUSION

- The refrigeration system was operated as a standard practice in LG Polymers from 8:00 a.m. to 05:00 p.m. only on all days manually. There was inadequate time duration for Refrigeration and cooling system to maintain the temperature of Styrene monomer below 20°C in the M6 Tank at all levels in the tank.
- The temperature measurement in M6 Tank is restricted to the bottom zone, while the top and central zones had higher temperatures. Thereby, the temperatures at the top level and the middle level were not available at all to detect the temperature rise in the upper levels. Further, the SOP followed by LG Polymers for the temperature limit of 35°C was improper. The prescribed frequency standards of polymer and TBC measurement were also not followed and the samples of Styrene monomer from the recirculation and refrigeration system viz., bottom of the M6 Tank was analyzed once in 4 days approximately by LG Polymers.
- The high temperatures at the top levels of the tank led to Thermal Radical Polymerization. The high temperatures made the limited TBC available (due to Thermal Stratification) at the top layers ineffective.
- The M6 Tank was an old tank with old design structures. The inner side of the tank was not lined. Further, LG Polymers was complacent in cleaning the tank once in 5 years resulting in the accumulation of contaminants, which acted as catalyst inside the tank, initiating polymerization of Styrene which overwhelmed the inhibition effects of TBC.
- The company management had ignored the increase of polymer content in the tank. The management considered polymer content as a quality measure for Styrene rather than a safety measure. The early indication of a runaway reaction shown in the rise of polymer content in the M6 Tank was totally ignored.
- Onset of runaway polymerization reaction is the critical parameter in the root causes of the accident. There was only one sensor for temperature which measured only the local temperatures and did not indicate the temperatures at the higher level of the tank as the contents were not well mixed. The measured temperature reported by LG Polymers did not reflect any potential catastrophic high temperature hot spots in the tank. Polymerization was ongoing and unnoticed in zones that are not near the lone temperature sensor for the quantity (1937 MT) of Styrene monomer in (in 18 m dia x 12.185 m tall vertical cylindrical fixed roof tank). The uncontrolled Styrene vapour release from the M6 Tank was

due to high temperatures, well beyond the company's protocol temperature of 35°C.

- The company failed to consider the TBC stratification and measured TBC only from the samples from the bottom layer. Further, there were no stocks of TBC available in the LG Polymers at the time of accident. The quantity of high temperature inhibitors like TDM & NDM was also limited, which got exhausted after few hours and failed in preventing the runaway reactions.
- There was no monitoring device or no monitoring system in place to measure the quantum of dissolved oxygen in the Styrene monomer in M6 Tank.
- As clarified later in this chapter, no process safety management system was followed in LG Polymers.
- There was a dearth of knowledge and talent among the top, middle and shift management in LG Polymers. Most of the present shift in-charges / engineers were not qualified engineers. Hence, their knowledge and skills were not adequate when faced with a challenge or an emergency.
- LG Polymers was closed during the Covid-19 lockdown period as it is a non-essential industry and the minimum staffs were given permission to maintain the factory during the lockdown period. However, the LG Polymers management was irresponsible, as they followed the same SOP as applicable for regular steady state operational circumstances, during the lockdown period as well and did not consider the idling conditions in the M6 Tank. Further, they ignored the early indications in rise in polymer content.
- No separate SOP was created for the lockdown and restart operations (PSSR: Pre-Start up Safety Review). Thus, the LG Polymers did not at all consider the idling conditions in all the tanks including M6.
- The accident in the Styrene storage M6 Tank can be attributed to poor design of tank, inadequate refrigeration and cooling system, absence of circulation & mixing systems, inadequate measurement parameters, poor safety protocol, poor safety awareness, inadequate risk assessment and response, poor process safety management systems, slackness of management, insufficient knowledge amongst staff, insufficient knowledge of the chemical properties of Styrene, especially during storage under idle conditions.
- Hence in order to avoid similar type of accidents and accidents in industries in general, effective safety audit system to be implemented which will benefit employees, employer and nation.

IV. SUGGESTION:

The Refrigeration system of the Styrene storage tank should have been provided with a fully automated instrumentation system of adequate safety integrity level, coupled with the temperature sensor for automatic switching-on and off the system based on the temperature reading of the gauges. The non-provision of this system has permitted the human error and onset of reactive hazard resulting in the release of toxic vapour cloud as per as vizag gas leak is concerned.

V. REFERENCES

[1]. Bureau of Indian Standard (BIS) 14489-Code of Practice on Occupational Health & Safety audit.

[2]. Andhra Pradesh Directorate of Industrial Safety and Health (DISH) –Inspector of Factories Report.

[3]. AP-Petroleum And Explosives Safety Organisation (PESO) - Report Factories Act1948 and Respective State Rules.

[4]. Manufacture Storage and Import of Hazardous Chemicals Rules (MSIHC) Rules.

[5]. The Indian Electricity Act and Rules.

[6]. The Indian Boilers Act
[7]. The Indian Explosives Act
[8]. Air (Prevention and Control of Pollution) Act
[9]. The Water (Preventions & Control of Pollution) Act
[10]. The Petroleum Act and the Petroleum Rules
[11]. Various Indian Standards on Safety.