CASE STUDY

OISD/CS/2023-24/P&E/07 Dt.: 27/07/2023

INTRODUCTION

Title: Fatal Incident due to explosion of sample bomb.
Location: Refinery
Loss/ Outcome: One fatality

BRIEF OF INCIDENT

The incident took place inside a refinery while handling a sample bomb in which sample had been taken from a liquid nitrogen tanker.

Prior to unloading the liquid nitrogen tanker, purity of nitrogen was to be checked. Accordingly, a sample had been collected. Subsequently, the sample bomb exploded during leak checking of the bomb valve and split into 02 pieces. One of the pieces (dome along with valve) penetrated in the upper part of left thigh of the truck cleaner/ helper. Truck helper succumbed to the injury a day later.

Sample collection bomb after the incident

OBSERVATIONS / SHORTCOMINGS

1. A liquid nitrogen tanker arrived at the company premises for unloading. As per the terms and conditions of the supply contract, *'material should be unloaded after reconfirmation of the purity by company lab'*, a sample had to be collected from the tanker and checked in the laboratory before unloading.

Accordingly, a sample from the tanker was collected in a sample bomb (owned and provided by the company) by tanker driver.

2. During discussions, it was learnt that there were few instances in the past when lab had reported that the sample collection bombs were found empty during analysis, raising a suspicion of leakage during handling and delivery. So before sending the sample bomb to lab, a general practice was to check the leakage, if any, from the sample bomb valve, by dipping the needle valve in water.
3. After collecting the sample from the tanker, the driver filled water in one of the nearby flowerpot through a garden water-hose and submerged the needle valve portion of the bomb into the water. He observed that the valve was passing. He collected the sample in another bomb and again observed similar valve passing. While checking the valve's passing problem with the third sample bomb, the explosion occurred.
4. Sample bomb exploded into two pieces. The dome portion of the bomb along with needle valve penetrated the upper left thigh of helper, who was standing beside the driver.
5. Based on sample bomb hydrotest records, exploded sample bomb was found recently hydrotested at 70.4 Kg/cm^{2}g. No written document was available to affirm that the sample bomb shall be hydrotested at the said pressure. Details like at what desired pressure the hydrotest to be conducted, to what extent of time the hydrotest test pressure was held, the parties/ agencies involved & witnessed the hydrotest with counter sign from all the responsible persons, etc., were missing.
6. As per the operating manual, mentions in the sampling requirement that "Gas nitrogen sample from outside truck" to be collected on demand basis during procurement. On the contrary liquid sample was being drawn from the tanker. Further the manual also states that "liquid nitrogen sample (special)" is to be collected in "gas collection bombs, which is a two-layer high pressure resistive metal jacketed cylinder." Hence, neither there was a need for liquid nitrogen sample collection, nor the bomb being used was suitable.
7. Information/ data embossed on the body of exploded sample bomb was not legible.
8. It was also learnt that driver was unaware of the pressurization effects caused while holding a cryogenic liquid in a closed, uninsulated container.
9. There were no records of toolbox talk although a checklist for liquid nitrogen (LN) unloading from truck had a check point for ensuring a toolbox talk with the driver & cleaner. Moreover, the checklist was not filled.
10. Leather gloves were being used while handling liquid nitrogen instead of specialised cryogenic gloves suitable for handling extremely cold material. Checklist also had a point of use of basic PPE by both the driver and cleaner while handling the cryogenic product.

REASONS OF FAILURE / ROOT CAUSE

Cause of Failure of Equipment:

Cryogenic Liquid Behaviour: Boiling point of Nitrogen at 1 atm pressure is -195.8°C and the critical temperature of Nitrogen is -146.96°C. Any gas above its critical temperature cannot be liquified by exerting pressure. (At the critical temperature, the vapor pressure of liquid nitrogen is 34 bara.)

If such liquids are kept in a sealed container, without proper insulation for maintaining their temperatures in negative side, they will evaporate vigorously and will exert enormous pressure. Cryogenic liquid nitrogen produces large volumes of gas when they vaporize (one unit volume of liquid nitrogen vaporizes to ~694 volumes of nitrogen gas at 20°C & 1 atmosphere). Hence, 1 ml of liquid nitrogen will vaporise to 694 ml of gaseous nitrogen. Considering a closed container, 1 ml of liquid nitrogen collected at atmospheric pressure will exert a pressure of 694 / volume of the vessel. Accordingly, in a container of 500 ml (ideal gas behaviour assumed without taking into account the temperature effect), the pressure exerted will be 1.4 atm. and 10 ml of liquid nitrogen will exert 14 atm. pressure.

The probable technical cause of failure of the sample bomb in the subject case was:

- On the day of incident, the liquid flow into the sample bomb must have been higher than that happening in earlier occasions (more by few millilitres). The sample bomb collected with liquid nitrogen was isolated/ sealed with the needle valves firmly on both ends. By virtue of contact with ambient air & atmospheric conditions, the liquid nitrogen in the sample bomb must have vaporised vigorously resulting in build-up of pressure in the sample bomb. Consequently, the bomb failed from the weld joint. Considering that the bomb had already been tested at 70.4 kg/cm^{2}g, the pressure must have increased more than the test pressure.
- It is also likely/ probable, that dipping the bomb in water might have increased the heat transfer to the small quantity of liquid nitrogen in the sample bomb, as water is not as good insulator as air. Further the heat content in water is much higher than in air. So, these factors might have quickened the pressure build up.

As inferred from above, it is evident and established that collecting liquid nitrogen sample in the uninsulated container and without suitable pressure relieving device, is not at all suited for handling cryogenic fluid and was highly inappropriate.

The cause cited above was resulting from the following:

1. Lack of Awareness of the inherent hazards posed while handling liquid nitrogen in an uninsulated sample bomb like cold frost & asphyxiation and the probable pressurization of the container, which was overlooked by all concerned for a long time.
2. Drawing of liquid sample in contradiction to the procedure mentioned in operating manual.
3. The practice of drawing samples by unauthorized/ unskilled personnel who was also unaware of the hazards associated with such unsafe act was incorrect.
4. Checking of leakage from the valve by dipping it in a flowerpot filled with water was inappropriate, non-standard and highly unsafe act.

RECOMMENDATIONS

1. **Usage of non-standard sample collection devices:**
   Nitrogen Gas sample shall be taken instead of nitrogen liquid sample in line with the operating manual and standard practice. If liquid nitrogen sample is required, then appropriate collection device, suited for cryogenic services, is to be used.
2. **Training:**
   Induction & refresher safety training shall be strengthened for all employees and contract workmen handling cryogenic product to improve awareness level. Toolbox talk, adequate training with coverage to all possible hazards should be ensured to all concerned personnel.
3. **Sample Collection Responsibility:**
   a) Responsibility of sample collection should be fixed and shall be done by the company designated persons who are trained and have the necessary skills to perform the task.
   b) Purview of the contract labours/ drivers should be restricted to the job they are meant and skilled for.
4. **Documentation:**
   a) Use of the sample bombs whose OEM documentations/ engineering design details are not available, shall be suspended.
   b) OEM documentations/ engineering design details of equipment should be available as and when required.
   c) Hydrotest records shall be maintained in standard format.
5. **PPE:**

Use of specialised cryogenic gloves while handling liquid nitrogen shall be ensured as per clause 8.1.8 of OISD-STD-155.

6. **Other Recommendations:**
   a) Non-standard practices, like of testing of leakage of valve by dipping in flowerpot filled with garden water hose shall be brought to notice of concerned through reporting of unsafe act/condition and shall be discontinued.
   b) In the event that laboratory reports that a sample bomb, used for the purpose for which it is meant, was received empty, the subject bomb usage should be discontinued immediately and the same should be sent for testing.
   c) Tracking mechanism, like numbering of the sample bombs, should be followed religiously so that it can be known at any time that how many times the bomb has been used.
   d) Company should take non-conformity to procedures mentioned in operating manual, improper usage of equipment for which the same is not meant/ designed, & inadequate supervision, seriously and take necessary corrective actions for improvement.