Consequence Analysis of BLEVE Scenario in the Propane Tank: A Case Study at Bandar Abbas Gas Condensate Refinery of Iran

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Abstract: The occurrence of incidents resulting from chemical releases requires preparatory measures. Despite special layers of protection in chemical industries to avoid such releases and consequent consequences, human errors still occur and negatively contribute to failures in different activities include maintenance practices and operating control and so on. It is proven that one of the most devastating risks in the oil and gas companies is explosion, particularly BLEVE. Thus, the study of this phenomena and analysis of its consequences at various stages is necessary. Recent studies claimed that the prediction of damaging effects after the explosion by mathematical models is necessary for its effective management. For this reason, we aim to analyze the consequence of BLEVE in high pressurized propane vessel (V-3001/A) in order to be well prepared for further emergency activities and also implement further modifications. There are numerous software presented to model the consequences of chemical substances releases (Such as PHAST, ALOHA, SLAB, DEGADIS). Because of validation of modelling capabilities and a particular consideration of PHAST software for vessels’ explosion, this software has been adapted to analysis BLEVE phenomena and its consequences in the Bandar Abbas condensate refinery of Iran. At first, expert team, including maintenance, plant, process, safety engineers and relevant operators held several meetings in order to define BLEVE scenario. Note to process flow diagram and design detail, the process parameters of propane storage tank (including; mass, volume, temperature, pressure, and so on) applied in the PHAST software (Version 6.7). In this model, the most dominant climatic condition in Bandar Abbas city has been defined (temperature, 42°C, relative humidity, 90%, wind speed, 3.5 m/s). Finally, estimated losses caused by explosion wave in nearby facilities such as pumps, compressors, gas turbines, pipelines, spherical and cylindrical tanks have been assessed. The results of this study demonstrated that some of the surrounding facilities will be suffering from BLEVE’s overpressure wave, while most of them will be free from any damage (Blast wave pressure <0.1 psi). Thus, the authors recommended that protective wall around pipelines need to build to deter the imposed pressure. In addition, the dislocation of several cylindrical tanks would be helpful. Finally, we suggest that chain effects, radiation analysis, shock waves, and the effectiveness of corrective measures would be helpful for further study.

Keywords: PHAST, Process, Risk, BLEVE

Introduction:

The progress of technology has caused operating of many processes and contribute to the complexity of the chemical process industries. Generally, one of the main challenges for these companies is to manage the existing assets (Hu and Zhang 2014, Sa’idi, Anvaripour et al. 2014). Despite existing protection measures, we still experience a great deal of failures in these industries. The pressurized vessels, for example, commonly protected by pressure relief devices which ensure that the maximum allowable pressure is not exceeded while it fails time to time (Mannan and Lees 2005, Dunjó, Fthenakis et al. 2010). Another failure that needs to be noted is BLEVE1 which leads to catastrophic consequences (Sepeda 2006). However, the safe operations of these systems are at least as important as their design (Arunraj and Maiti 2007) and the designers and operators play a crucial role in finding appropriate solutions to ensure their safety as well as business continuity.

Moreover, the main elements of safety system are linked with incident reduction and accident prevention. Indeed, despite the implementation of strict safety programs in today’s chemical process industry, we still experience catastrophic accidents around the world. According to OSHA2, incidence rates in chemical plants were 0.49 in 1945, 0.35 in 1998, 0.4 in 1986, and 1.2 in 1990 (Daniel A. Crow 2002). OSHA also reported that all of these accidents follow a typical pattern that helps investigators to anticipate such events.

Generally, there are three common hazards in chemical plants, fire, explosion, and chemical releases that can be categorized into three types (1) probability of occurrence, potential for fatalities and economic loss. Additionally, Daniel A. Crow has asserted that fire is the most common hazard in chemical plants, while toxic releases is the most fatal one. He also claimed that explosion threat more economic loss compared with other hazards(Table 1).

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1Boiling Liquid Expanding Vapour Explosion
2Occupational Safety and Health Administration
Table 1: Three Types of Chemical Plant Accidents
(Daniel A. Crow1 2002)

<table>
<thead>
<tr>
<th>Type of accident</th>
<th>Probability of occurrence</th>
<th>Potential for fatalities</th>
<th>Potential for economic loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td>High</td>
<td>Low</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Explosion</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>High</td>
</tr>
<tr>
<td>Toxic releases</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Oil and Gas companies, however, find itself on the subject of disastrous accidents which result from a complicated interaction of process operations (Jo and Crowl 2008). This issue increases the probability of major catastrophes (Arunraj and Maiti 2007). A series of major accidents in chemical sites across Europe in the late 1960s and early 1970s led to growing concern over the safety of such operations, particularly those that may present serious impact to the local population. Seveso’s disaster (July, 1976), for instance, happened in Italy in which a large amount of dioxins released into environment. Other disasters, namely, Bhopal and Basle are also widely known around the world. These accidents led to regulatory approach development to mitigate such accidents (Mitchison and Porter 1998).

BLEVE, the worst type of these accidents defined as a physical phenomenon when an explosion created by the failure of a pressurized vessel containing a liquid at a temperature above its boiling point at normal atmospheric pressure. Generally, BLEVE has a disastrous damaging effect on surrounding equipment because of overpressure wave, radiation, and even secondary fire (Abbasi and Abbasi 2007). Thus, an in-depth study of this hazard and analysis of its consequences on various area/sanizational priority. Furthermore, predicting the damaging effect of the explosion by mathematical models for an effective management of its risk is the key (Planas-Cuchi, Salla et al. 2004).

For these reasons, we aim to model the consequences of the spherical propane vessel explosion using Process Hazard Analysis Software Tool (PHAST). Specifically, we are trying to check the overall safety of layout, assess the protection status of equipment and adjacent building, preparation for emergency response in case of explosion, and estimation the blast wave of explosions, and finally find practical solutions to cut its potential effects as low as possible.

Material and Method:

Bandar Abbas refinery is the largest gas condensation unit in the Middle East which is at construction phase now. This complex designed to refine 360,000 barrels of condensate per day. Totally, we can divide it into five areas as follows (Figure 2).

Region 1: Off-site (Storage tanks such as propane, MTBE, and so on) in Red
Region 2: Processing units in Yellow.
Region 3: Utility in Blue
Region 4: Flare and its vessels in Green
Region 5: Non-industrial and administrative buildings in Black

Figure 1: The schematic view of Bandar Abbas Refinery Complex

This study conducted in the region 1. There are 55 fixed roof cylinder tanks and 13 spherical tanks in this area. However, the 3001-A storage tank selected for consequence analysis, because of its large volume of propane and pressure, proximity to other vessels, and great potential for vapour formation and subsequent BLEVE phenomenon.

The structure of 3001-A tank made from carbon steel (A537 CL.2) with a diameter of 15.5 meters, a height of 18 meters (considering basement), the operating pressure of 12.8 bars, and the operating temperature of 40 °C (Figure 3).

Figure 2: The nearby facility around 3001-A tank in the offsite region

At First, we conducted a preliminary review to find the critical assets and equipment in refinery complex. The semi-constructed interviews held with experienced experts made up of academic professors, maintenance practitioners, operators, and process engineers to form a research team. Next, the process...
documents such as plot plans, PFD, P&ID, PM procedures, and other related documents have been studied.

To define the BLEVE scenario, the team analysed hazards of selected assets using the most common techniques (such as HAZOP, What if, and FMEA). The results showed that the 3001-A tank categorized as an unacceptable threat which needs consideration for preventive and preparatory safety measures (Figure 3).

![Study Plan Diagram]

**Figure 3: The overview of study plan**

There are many tools to model the consequences of chemical releases include PHAST, ALOHA, SLAB, and DEGADIS. However, PHAST 6.7 software opted to analysis due to its validation of modelling and particular consideration for vessels’ explosion.

Totally, the chemical properties of the vessel in question include type, mass and volume of the tank, process temperature and pressure, and other parameters have been entered in the software. Note to national weather reports, the dominant weather condition in this study considered as follows:

- Temperature: 42°C.
- Relative humidity: 90%
- Wind speed: 3.5 m/s.

**Results:**

After running the scenario in the software, the result of explosion in the 3001-A tank demonstrated as follows:

1. **The propagation of shock wave:**

   The line graph shows that the wave decreases over the course of distance, but not in a steady way. Near explosion centre (A radius of about 30 meters), however, the wave pressure remained at just under 13 bars, while right after that, it plummeted to about 0.7 bars about 95 meters followed by a steady tendency to zero (Figure 4).

![Overpressure Reduction Graph]

**Figure 4: The overpressure reduction of BLEVE over the course of distance**

2. **The blast wave radius:**

   The line graph indicates the radius of the blast by distance in three different colours. The yellow line related to pressure in which assets may suffer higher pressure if explosion occurs, while the green and blue impose lower pressure on structures (Figure 5).

![Blast Wave Radius Graph]

**Figure 5: The radius of explosion wave pressure**

3. **The propagation of blast wave on a Google map:**

   The following figures depict both of wave radius and Google Map, and plot plan. A closer look shows what facilities would be affected by explosion based on coloured line on the map (Figure 6 and 7).

![Explosion Wave Radius on Map]

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1 Process Flow Diagram
2 Piping & Instrument Diagram
3 Preventive Maintenance
4 Hazard and Operability
5 Failure Mode and Effect Analysis
the Northeast named SS-30-01. This facility locates in the safe zone and there would be no damage as well.

Overall, BLEVE of 3001-A vessel led to serious losses, particularly around the spherical and cylindrical tanks which contain flammable liquids. Fortunately, due to the large distance between the explosion centre and surrounding mainassets (such as officebuildings, power plants, and condensate tanks, jet fuel tank, super gasoline and naphtha), they all will be safeafterBLEVE. However, the authors recommended some change in design and construction, including the installation of protective wall around pipelines and several cylindrical vessels’ dislocation. Finally, Authors propose further studies on chain effects, radiation analysis, and the effectiveness of corrective actions.

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