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Consequence Analysis of BLEVE Scenario in the Propane Tank: ACase 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 chemicalindustries to avoid such releases and subsequent 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 risk 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 predictionof damaging effectafter the explosion by mathematical models is necessary for its effective management. For this reason, we aim to analysis 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^{o}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 themwill 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 dislocationof 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 tothe 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 experiences 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 BLEVE[1] 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 rule 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 OSHA[2], incidence ratesin chemical plantswere 0.49 in 1945, 0.35 in 1998, 0.4 in 1986, and 1.2in 1990(Daniel A. Crow1 2002). OSHA also reported that all of these accidents follow a typical pattern that helpsinvestigators 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. Crowl has asserted that fire is the most common hazard in chemical plants, while toxic releasesis the most fatal one. He also claimed that explosion threat more economic loss compared with other hazards(Table 1).

[1]Boiling Liquid Expanding Vapour Explosion
[2]Occupational Safety and Health Administration

Table 1: Three Types of Chemical Plant Accidents (Daniel A. Crow1 2002)

Type ofaccident	Probability of occurrence	Potential for fatalities	Potential for economic loss
Fire	High	Low	Intermediate
Explosion	Intermediate	Intermediate	High
Toxic releases	Low	High	Low

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 majorcatastrophes (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 ofsuch operations, particularly those may present seriousimpactsto 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 approachdevelopment to mitigate such accidents(Mitchison and Porter 1998).

BLEVE, the worst type of these accidents defined as a physical phenomenon when an explosion createdby the failure of a pressurized vessel containing a liquid at a temperature above its boiling point at normal atmospheric pressure. Generally, BLEVEhas a disastrous damaging effect on surrounding equipment because of overpressure wave, radiation, and evensecondary fire (Abbasi and Abbasi 2007). Thus, an in-depth study of this hazard and analysis of itsconsequences on various areaisanorganizational 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 checkthe 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 unitin the Middle East which is at construction phasenow. 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 inBlack

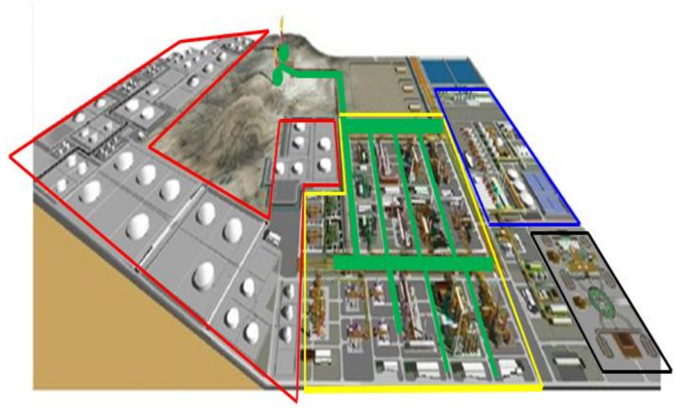

Figure 1: The schematic view of Bandar Abbas Refinery Complex

This study conductedin 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 subsequentBLEVE 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).

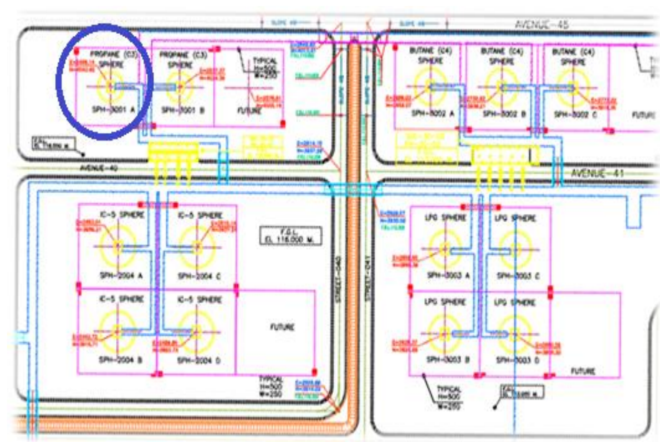

Figure 2: The nearby facility around 3001-A tank in the offsite region

At First, we conducteda preliminary review to findthe critical assets and equipment in refinery complex. The semi-constructed interviews held with experienced expertsmade up of academic professors, maintenance practitioners, operators, and process engineers to form aresearch team.Next, the process documents such as plot plans, PFD[3], P&ID[4], PM[5] procedures, and other related documents have been studied.

Todefine the BLEVE scenario, the team analysed hazards of selected assetusing the most common techniques (Such as HAZOP[6], What if, and FMEA[7]). The results showed that the 3001-A tank categorized as anunacceptablethreatwhich needs consideration for preventive and preparatory safety measures (Figure 3).

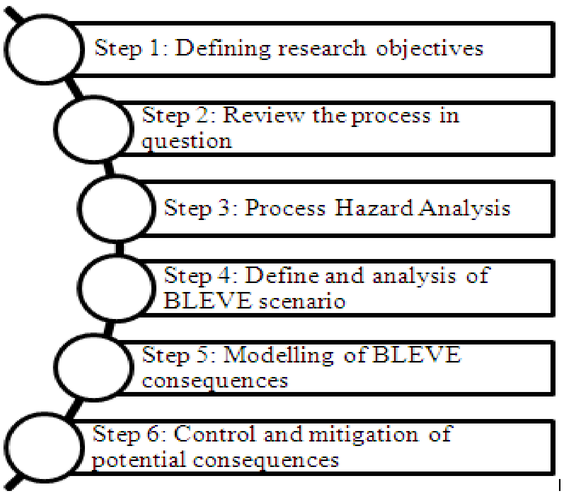

Figure 3: The overview of study plan

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 ofthe vessel in question include type, mass and volume of the tank, process temperature and pressure, and other parametershave been entered in the software.Note to national weather reports, the dominant weather condition in this studyconsidered as follows:

- Temperature:42^{o}C.
- Relative humidity: 90%
- Wind speed: 3.5 m/s.

Results:

After running the scenario in thesoftware, the result of explosion in the3001-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 barsabout 95 meters followed by asteady tendency to zero (Figure 4).

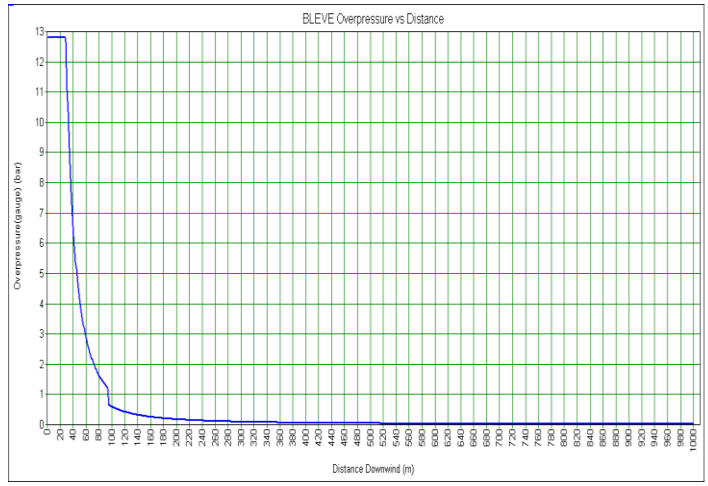

Figure 4: The overpressure reduction of BLEVE over the course of distance

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 pressureif explosion occurs, while the green and blue impose lower pressure on structures (Figure 5).

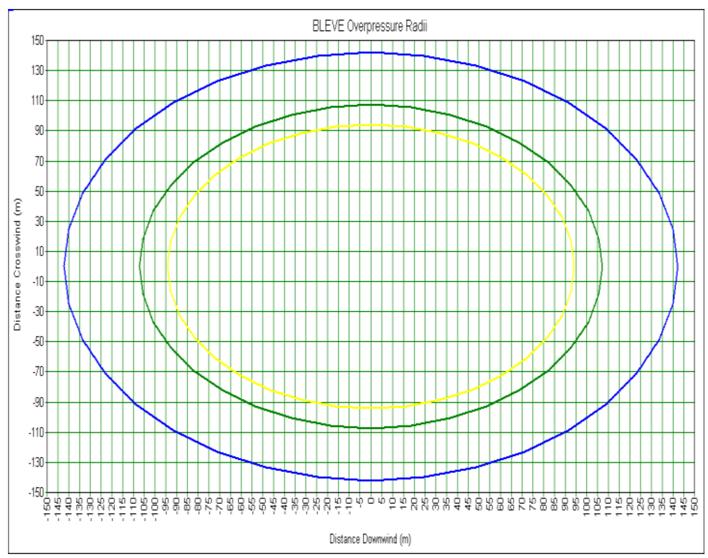

Figure 5: The radius of explosion wave pressure

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

The following figures depict both of wave radiusand 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).

[3] Process Flow Diagram
[4] Piping & Instrument Diagram
[5]Preventive Maintenance
[6] Hazard and Operability
[7] Failure Mode and Effect Analysis

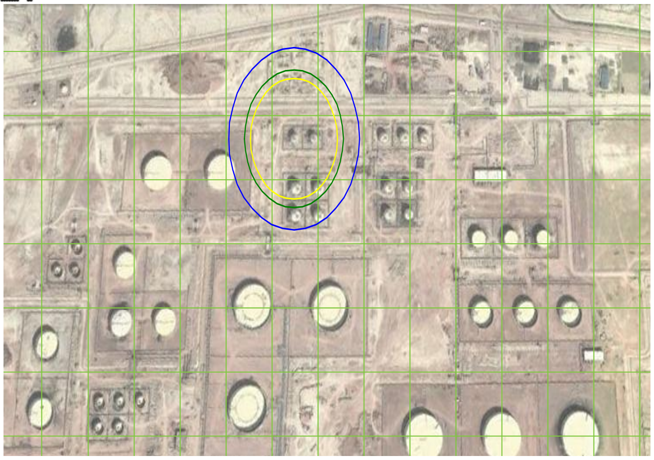

Figure 6: Explosion wave propagation on Google map

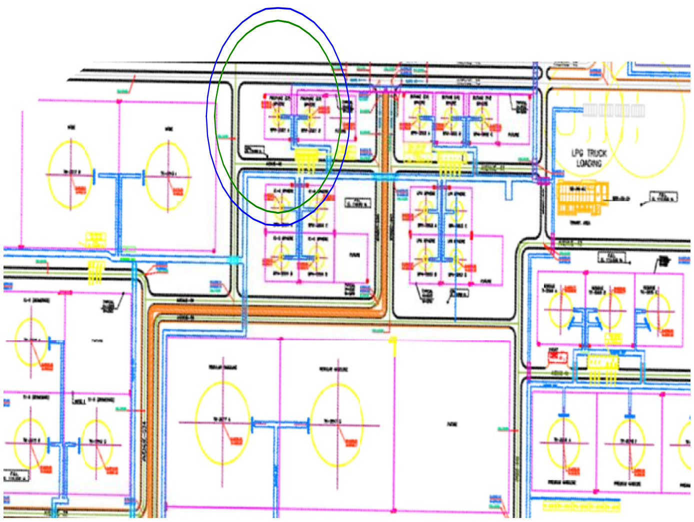

Figure 7: The facilities affected by shock waves in the offsite region

Discussion:

The modelling indicates that the blast wave don't affect adjacent structures (considering the least acceptable pressure of 1 psi). This wave imposes some degree of damage on northern road despite the fact that this area is free from employees and vehicles most of time. On the other hand, surrounding spherical tanks named 2004-A/C and 3001-B will be completely destroyed, while, others like 2004-B/D, 3002-A/ B/C, and 3003-A/B/C/D are outside damaging zone (Figure 7).

Furthermore, the adjacent pumps and vessels in the South East will besuffering from severe pressureand would be takenapart from the base and totally thrown away, while others would be free ofdamage because of the safe distance.

Additionally, the blastwill destroy the nearby pipelines and removesthem entirely from foundation, but other vesselswould remain intact.

Finally, the electrical substations of storagearea assessed. However, the closest substationto explosion scenario in 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 changein design and construction, includingthe installation of protective wall around pipelines and several cylindrical vessels'dislocation. Finally, Authors propose further studieson chain effects, radiation analysis, and the effectiveness of corrective actions.

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