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BLEVE IMPACTS FROM LPG SPHERICAL TANK

Ibrahim M. Shaluf[1]*, Nawrs Sultan Esa Zhmoul[2]

[1]The Libyan Academy for Postgraduate Studies, Western Coast Branch - Libya
*: Ibrahim.m.shaluf@gmail.com
Orcid.org: **0009-0004-1654-8836**
[2]Sabratha Faculty of Engineering, Sabratha University. - Libya
Orcid.org: 0009-0006-2749-6482

Abstract

Refineries produce Liquefied Petroleum Gas (LPG) and store the LPG in cylindrical or spherical tanks. If the LPG tanks are exposed to a fire of sufficient duration and intensity, it can undergo a Boiling Liquid Expanding Vapor Explosion (BLEVE). BLEVE gives rise to the following effects: (1) blast wave, (2) fireball, and (3) fragments. This study aims to evaluate the BLEVE impacts threatening the safety of workers and communities, focusing on the 1000 m^3 LPG spherical tank as a case study. The BLEVE impacts were estimated by mathematical calculations. The thermal radiation was also estimated by Areal Locations of Hazardous Atmospheres (ALOHA) program.

The peak overpressure at half full of the tank results in residential structure collapse and serious injuries. The fragments range reach up to 700m. The farthest thermal radiation threat zones are identified in case of half full tank as follows: (i) the potentially lethal red zone extends up to almost one km, the workers and the neighboring community who are outside their offices and shelters will be at risk (ii) the second-degree burns, the orange zone extends up to one and half km, and (iii) the pain yellow zone extends up to two kms.

Key words: Liquefied Petroleum Gas, Spherical Tank, Boiling Liquid Expanding Vapor Explosion, Fireball, Thermal Radiation, ALOHA.

تأثيرات انفجار بخار سائل متمدد مغلي من خزان غاز بترول مسال كروي

إبراهيم محمد شلوف[1*] , نورس سلطان زهمول[2]
[1*]الاكاديمية الليبية للدراسات العليا فرع الساحل الغربي – ليبيا
عنوان ايميل المؤلف للمراسلة: Ibrahim.m.shaluf@gmail.com
[2]كلية الهندسة صبراتة جامعة صبراتة – ليبيا

الملخص

تنتج المصافي غاز البترول المسال (LPG) ويخزن في خزانات أسطوانية أو كروية. إذا تعرضت خزانات غاز البترول المسال إلى حريق شديد ولفترة زمنية طويلة فيمكن أن تتعرض الخزانات لانفجار بخار سائل متمدد مغلي (BLEVE). انفجار البخار السائل المتمدد المغلي هو انفجار عنيف للغاية يؤدي إلى التأثيرات التالية: (1) موجة الانفجار، (2) كرة نارية، و(3) شظايا. تهدف هذه الدراسة إلى تقييم تأثير انفجار البخار السائل المتمدد المغلي لخزان غاز بترول مسال كروي سعته 1000 متر مكعب. تم تقدير تأثير انفجار BLEVE بواسطة الحسابات الرياضية. كما تم تقدير الإشعاع الحراري بواسطة برنامج المواقع الجوية للأجواء الخطرة (ALOHA). لقد وجد ان ضغط الذروة النا تج عن الانفجار عند نصف امتلاء الخزان يؤدي إلى انهيار المباني السكنية وإصابات خطيرة وتمتد شظايا الخزان إلى مسافة تصل إلى 700 متر وتأثير الإشعاع الحراري يكون على النحو التالي: (1) تمتد المنطقة الحمراء المميتة إلى كيلومتر واحد تقريبًا، وسيكون العاملون والمجتمع المجاور الذين هم خارج مكاتبهم وملاجئهم معرضين للخطر (2) المنطقة البرتقالية التي تحدث بها حروق من الدرجة الثانية قد تمتد حتى كيلومتر نصف (3) المنطقة الصفراء التي يحدث بها ألم قد تمتد حتى كيلومترين.

الكلمات المفتاحية: غاز البترول المسال، انفجار بخار سائل متمدد مغلي، موجة انفجار، كرة نارية، شظايا.

Introduction

Liquefied petroleum gas (LPG) is a flammable mixture of hydrocarbon gases that is extensively used as a fuel source for heating applications and transportation purposes. Around 60% of

LPG is produced through the extraction of natural gas and crude oil, whereas the remaining 40% is generated as a byproduct during crude oil refining operations (PIN, 2018). In refineries and gas processing plants, LPG is commonly stored in pressurized vessels, which are generally constructed in either cylindrical or spherical configuration, according to Lopez A. G. (2017). LPG storage vessels may be categorized into different types, with spherical tanks being especially appropriate for high-pressure storage conditions. One of the major advantages of spherical vessels is their lower surface area to volume ratio compared with other geometrical forms (Abhishek S. et al., 2014).

BLEVE takes place when a pressurized vessel containing a flammable liquid is subjected to severe heat exposure, leading to structural weakening and eventual rupture. Such explosions can generate several hazardous consequences, including blast waves, fireballs, and flying fragments. BLEVE accidents are regarded as some of the most catastrophic industrial incidents due to their potential to cause substantial property damage and significant casualties (Joseph R. et al., 2021). Many accidents associated with the storage and handling of LPG have been documented worldwide. Among the most critical incidents was the accident in Feyzin, which resulted in 18 fatalities and nearly 80 injuries (Tauseef et al., 2010). Another major disaster occurred at the PEMEX LPG terminal in San Juan lxhuatepec, where the explosion caused widespread destruction throughout the facility, leading to approximately 650 deaths and more than 6,400 injuries (CCPS 2014). In another accident in Shandong, a fire spread to nine spherical storage tanks, prompting the evacuation of residents living within a five-kilometer radius as a precautionary measure (Xinsheng, H. et al., 2018).

Abbasi, T. et al. (2017) investigated the primary initiating factors responsible for BLEVE incidents. Their findings indicated that 36% of such events were triggered by fire exposure, 22% resulted from mechanical damage, and 20% were caused by overfilling conditions.

The current study seeks to assess the consequences associated with a BLEVE incident involving a 1,000 cubic meter spherical LPG storage tank. The effects of the BLEVE scenario were evaluated using mathematical approaches. The Trinitrotoluene (TNT) equivalency method was adopted to estimate blast wave overpressure, while the ALOHA software was utilized to evaluate the potential impacts of the incident. The outcomes of this research may provide useful recommendations and insights for the planning, safety assessment, and layout design of comparable storage facilities.

Hazards from LPG

LPG is an important and extensively utilized fuel in both residential and industrial sectors. However, despite its widespread use, LPG poses significant safety hazards, as leakage incidents can result in fire or explosion events. Owing to its ability to be liquefied under relatively low pressure, LPG is commonly stored in pressurized vessels in liquid form and then converted into vapor before utilization. One unit volume of liquid LPG can expand to approximately 245–275 times its original volume when vaporized. In addition, the heating value of LPG is estimated to be nearly 2.5–3 times higher than that of natural gas, meaning that a large amount of energy can be contained within a comparatively small storage volume.

Moreover, delayed ignition of a released LPG vapor cloud may lead to a Vapor Cloud Explosion (VCE), particularly when flame propagation velocity increases significantly. The severity and extent of the resulting consequences are influenced by several factors, including leak size and ignition timing. For relatively small leaks, a BLEVE is generally considered the worst-case scenario in terms of maximum hazard distance, irrespective of whether ignition occurs immediately or after a delay. In contrast, larger leaks or catastrophic vessel ruptures may result in flash fires or VCEs caused by delayed ignition, which can generate a wider impact area.

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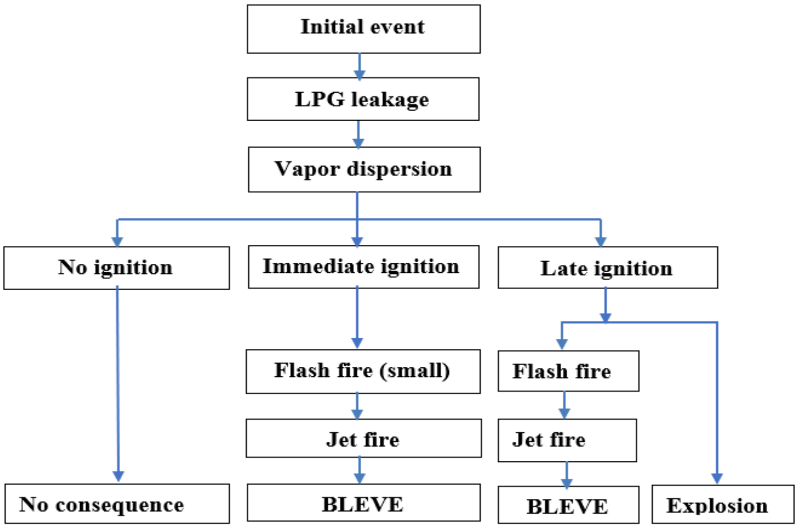

Fig. 1. Event sequences of LPG leak (Xinsheng, et al., 2018).

BLEVE Mechanism

The Center for Chemical Process Safety (CCPS, 1994) defines a BLEVE as an explosion that occurs when a vessel containing a liquid at a temperature significantly higher than its atmospheric boiling point fails. In a similar definition, CCPS (2011) describes a BLEVE as the rapid release of a large volume of pressurized, superheated liquid into the surrounding environment.

The phenomenon generally takes place when a vessel holding a superheated liquid, such as propane, experiences catastrophic failure, most commonly due to external thermal exposure. Typical ignition sources include a pool fire beneath the vessel or a jet fire impinging directly on its surface. Under these conditions, the internal pressure of the vessel increases, causing the pressure relief valve to activate and discharge vapor.

As liquid continues to vaporize and the liquid level decreases, the portion of the vessel wall above the liquid surface becomes directly exposed to flame. Since vapor has a much lower heat transfer capacity than liquid, the exposed wall heats rapidly. This localized overheating weakens the material structure, ultimately leading to rapture and sudden vessel failure. The progression of a BLEVE event typically occurs in a series of stages, as illustrated in Figure 2 (Hussain, N., 2023; Sonkar, R., 2020).

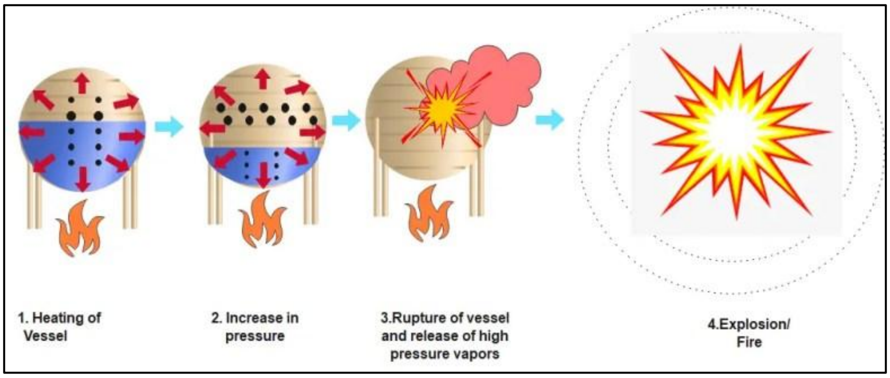

Fig. 2. Mechanism of BLEVE (Hussain, N., 2023).

BLEVE Consequences

A BLEVE event generates multiple severe hazardous effects (fig. 1). These include: 1- A high-pressure blast wave produced by the rapid expansion of superheated liquid. 2-Intense thermal radiation in the form of a fireball resulting from the ignition of the released flammable material. 3- The ejection of vessel fragments that may travel at high velocity and behave as hazardous projectiles. Such effects can lead to serious injuries and extensive damage to infrastructure, even at considerable distances from the incident location.

BLEVE models

1 – Blast wave

The blast effects associated with BLEVE incidents can be estimated using several models, including TNT equivalency, Specific Volume, Entropy, and Enthalpy (SVEE), And the Prugh model, (Prugh, R. W., 1991). Among these, the TNT equivalency approach is one of the most widely used methods for predicting explosion impacts.

The TNT model estimates the total energy release by assuming the explosion behaves similarly to trinitrotoluene (TNT). For chemical releases, the total energy is calculated by multiplying the heat of

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combustion of the flammable substance by its mass. This energy is then converted into an equivalent mass of TNT using the heat of detonation of TNT (Sbajo, D., 2009).

$$W_{TNT} = \frac{\eta M \Delta_{HC}}{\Delta H_{TNT}} \qquad (1)$$

After determining the TNT equivalent mass, the resulting blast overpressure is estimated using a “scaled” distance approach, which relates the actual distance from the explosion to the equivalent TNT yield. The scaled distance Z is given by:

$$Z = \frac{R}{(W_{TNT})^{1/3}} \qquad (2)$$

Figure 3 presents the correlation between scaled overpressure P_S and scaled distance Z

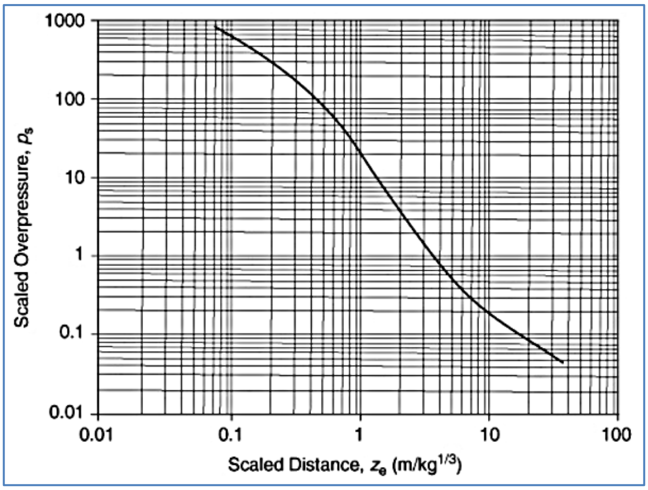

Fig. 3. Correlation between scaled distance and explosion scaled over pressure (Abdul, M., 2005)

The peak overpressure can be determined using equation 3.

$$P_S = \frac{P_O}{P_a} \qquad (3)$$

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Overpressure damage criteria

The damage thresholds Associated with blast wave overpressure are summarized in Table 1.

Table 1: Consequences of overpressure on human and structures (Rashid, Z. A., et al. 2018).

Overpressure (kPa)	Effect on structures	Effect on human body
6.9	Window glass shatters	Light injuries from fragments occur
13.8	Moderate damage to houses	People injured by flying glass and debris
20.7	Residential structures collapse	Serious injuries are common, fatalities may occur
34.5	Most buildings collapse	Injuries are universal, fatalities are widespread
69.0	Reinforced concrete buildings are severely damaged or demolished	Most people are killed
137.9	Reinforced concrete buildings are severely damaged or demolished	Fatalities approach 100%

2 – Thermal radiation

Prugh (1991) summarized the relationships selected by the Centre for Chemical Process Safety for fire ball thermal radiation models as follows:

Fireball diameter $D = 6.48\, m^{0.325}$ meters (4)

Fireball duration $t = 0.825\, m^{0.26}$ seconds (5)

Fireball elevation $H = 0.75\, D$ meters (6)

View factors $F_{21} = \frac{D^2}{4X^2}$ (7)

Atmospheric transmissivity $\tau = 2.02(P_w X)^{-0.09}$ (8)

Fireball surface power density $E = \frac{F_{rad}\ m\ H_c}{\pi (D)^2 t}$ kW/m^2 (9)

Received power flux $Q_R = E\ \tau\ F_{21}$ kW/m^2 (10)

Note: The equation, symbols, and their corresponding definitions are provided in the list of abbreviations.

Thermal Radiation Criteria:

Thermal radiation generated from fires and explosion events can result in a broad spectrum of damage to both humans and built structures. The impact severity varies depending on exposure time and radiation intensity. Table 2 summarizes the commonly used thermal radiation effect thresholds.

Table 2: Thermal radiation criteria (Khayyam, O., 2005).

Radiation (kW/m^2)	Impact
1.2	received from sun in summer at noon
1.6	Minimum necessary to be felt as pain
4.7	Pain in 15-20 seconds, 2nd degree burns after 30 s.
12.6	30% chance of fatality for continuous exposure. Minimum level to melt plastic tubing
23.0	100% chance of fatality for continuous exposure. 10% chance for instantaneous exposure.
35.0	25% chance of fatality for instantaneous exposure. Damage to process equipment.
60.0	~100% chance of fatality for instantaneous exposure

3 – Fragments

BLEVE incidents frequently produce large structural fragments that can be projected over considerable distances. In many cases, these high-velocity projectiles represent the furthest-reaching hazard associated with such events. The distribution of fragments is typically random rather than uniform, meaning that they may be ejected in any direction following vessel rupture (Abdul, M. I., 2005).

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According to Birk, A. M. (1995), As a simplified estimation, the travel distance of projectile fragments can be correlated with the radius of the fireball. It is suggested that approximately 80-90% of fragments land within a range of up to four times the fireball radius.

ALOHA

ALOHA is a computational tool jointly developed by the United States Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA). It is primarily used to support emergency planning and response activities involving hazardous chemical releases.

According to NOAA, the software can simulate accident scenarios in both land-based and marine environments, although its predictive accuracy is generally lower compared to advanced commercial modeling packages such as PHAST and TRACE (SAFER), ALOHA It remains widely adopted due to its accessibility and practical usefulness in emergency assessments (EPA, 2007).

ALOHA thermal radiation criteria

Table 3 presents the exposure thresholds and classification criteria used by ALOHA to evaluate thermal radiation impacts from BLEVE fireball scenarios and to define corresponding hazard zones.

Table 3: ALOHA thermal radiation impact criteria (EPA, 2007).

Threat zone	Thermal radiation level (kW/m^2)	Impacts
Red	10	Potentially lethal within 60 sec
Orange	5	2nd degree burns within 60 sec
Yellow	2	Pain within 60 sec.

Case study

The case study examines a refinery facility equipped with six spherical LPG storage tanks labeled LPG1 through LPG6. These tanks are used for LPG storage and handling operations. Four of the tanks, (LPG-1, LPG-2, LPG-3, and LPG-4) are smaller units, each with a capacity of 500 m^3. The remaining two tanks (LPG-5 and LPG-6) are larger, each with a storage capacity of 1,000 m^3. The

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spatial layout of the tanks, along with the distances between them, is shown in Figure 4.

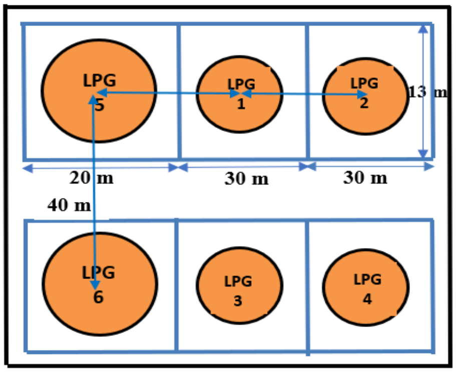
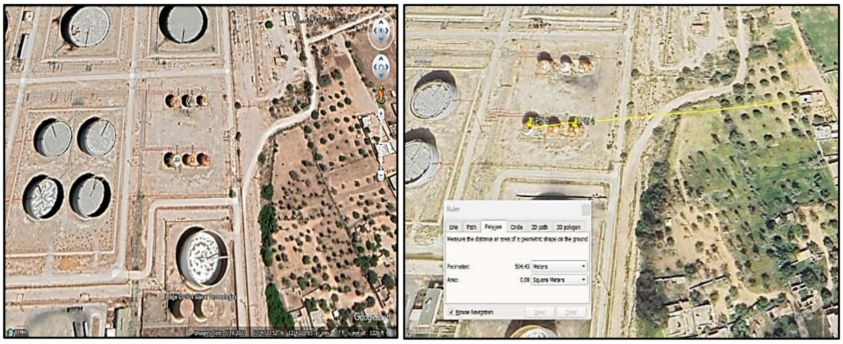


Fig. 4. The lay out of the LPG spherical tanks

Figure 5 provides an aerial view of the facility obtained from Google Earth, indicating that the distance between tank LPG-6 and the nearest residential area is approximately 500 meters.



Measure the distance or area of a geometric shape on the ground

Perimeter: 504.43 Meters

Area: 0.08 Square Meters

Fig. 5. Goggle earth aerial view of the LPG spherical tanks, and the distance between the LPG spherical tanks and housing accommodation

The LPG storage system is supported by a network of pipelines including inlet, suction, transfer, return, balance, circulation, drain, and discharge lines. The inlet pipelines supply LPG into the storage tanks while the suction line supports operational flow requirements.

The transfer line is used for moving LPG between tanks during maintenance procedures or emergency operations. Return lines serve to redirect off-specifications LPG back into the system for reprocessing.

The balance line is designed to transfer excess LPG to empty tanks in case of overfilling. The circulation line facilitates internal mixing by circulating LPG from the bottom to the top of the tank, ensuring homogeneity of the stored product. This circulation process typically lasts approximately four hours, after which a sample is collected and analyzed in a laboratory to confirm compliance with quality specifications prior to certification for end-use applications such as cooking fuel.

In addition, the tanks are equipped with control system, safety devices, and fire suppression systems. Gas detection systems are Installed as well with four detectors positioned at ground level around the perimeter of the tank deck to detect potential leakage. Figure 6 illustrates the spherical LPG storage tank and its associated system configuration.

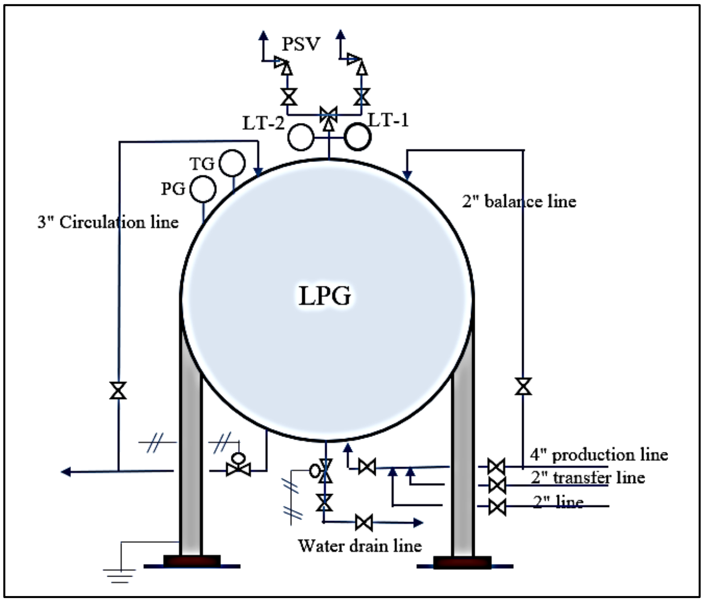


Fig. 6. LPG spherical tank

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The Characteristics of LPG spherical tank has been summarized in Table 4.

Table 4: Characteristics of LPG spherical tank

Characteristics	Values
Substance	LPG
Design pressure (kg/m^2)	10
Test pressure (kg/m^2)	15
Operating pressure (kg/m^2)	5.8
Design temperature (C)	80
Operating temperature (C)	35
Volume m^3	1000
Density (kg/m^3)	530

Estimation blast wave from LPG – 6

An EXCEL-based Computational tool was employed to estimate the blast wave consequences Corresponding to selected fill level of the LPG storage tank, Table 5 presents the results of the side-on peak overpressure at a distance of 500 m from the source.

Table 5: The blast wave side on peak over pressure impacts.

Degree of fill (%)	m_{TNT} (kg TNT)	P_O (Pa)	Effects on structures	Effects on human body
10	26203	11145	Window glass shatters.	Light injuries from fragments
20	52406	17225	Moderate damage to houses	People injured by flying glass and debris
30	78609	18238	Moderate damage to houses	People injured by flying glass and debris
40	104812	20265	Residential structures collapse	Serious injuries are common, fatalities may occur
50	131015.8	21278	Residential structures collapse	Serious injuries are common, fatalities may occur

Fireball thermal radiation

The thermal radiation effects associated with the BLEVE fireball from LPG-6 are summarized in Table 6.

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Table 6: BLEVE fireball thermal radiation

Degree of fill %	Thermal radiation (kW/m^2)					
	Mass (kg)	**100 (m)**	**200 (m)**	**300 (m)**	**400 (m)**	**500 (m)**
1	5300	27.397	9.615	4.619	2.674	1.734
10	53000	64.619	36.026	20.735	13.006	8.792
20	106000	76.078	48.785	30.530	20.035	13.894
30	159000	82.469	56.904	37.520	25.404	17.951
40	212000	86.850	62.826	43.001	29.825	21.396
50	265000	90.164	67.460	47.517	33.608	24.418

Figure 7 shows the BLEVE fireball thermal radiation levels at several degrees of fill percentage of the tank and various distances far from the tank.

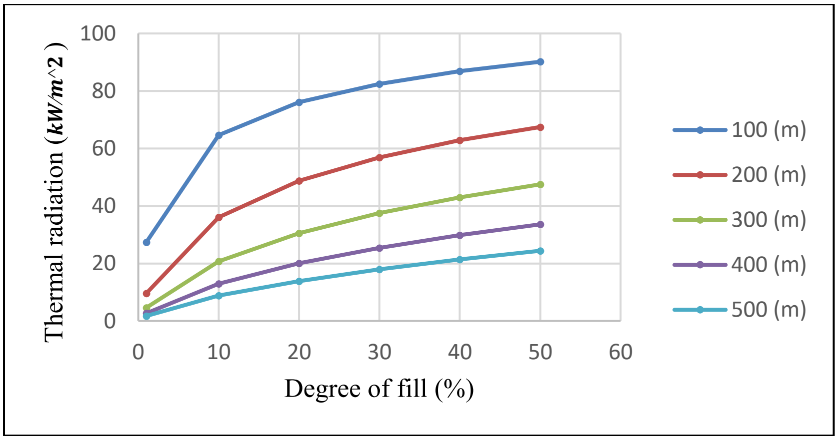

Fig. 7. Thermal radiation versus the degree of percentage of the tank

Fragments range

The estimated range of fragments resulting from the BLEVE of LPG-6 is presented in Table 7.

Table 7: Fireball diameter and Fragments range from LPG – 6

Fill rate %	Fireball diameter (m)	Fragments range (m)
1	103.147	206.294
10	218.001	436.001
20	273.081	546.163

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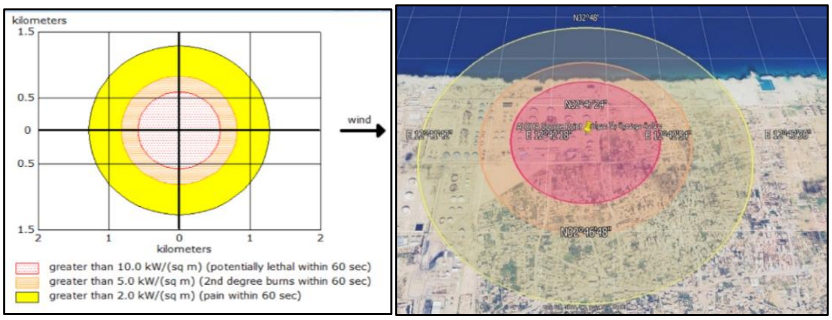
Fill rate %	Fireball diameter (m)	Fragments range (m)
30	311.545	623.091
40	342.079	684.159
50	367.809	735.619

ALOHA Thermal Radiation Estimation Results

The ALOHA tool was applied to evaluate the thermal radiation effects resulting from a BLEVE fireball originating from the large spherical LPG storage tank (LPG-6).

For this assessment, BLEVE scenarios were simulated at different tank filling levels, specifically 10%, 20%, 30%, 40%, and 50% of total capacity. The results produced by ALOHA are presented in the form of thermal radiation threat zones. The model classifies the hazard into three concentric zones: the inner red zone representing the highest level of danger, followed by the orange zone with moderate risk, and the outer yellow zone indicating lower hazard levels.

Thermal radiation is assumed to propagate uniformly in all directions; however, slight elongation occurs in the downwind direction due to atmospheric dispersion effects. The ALOHA output can also be integrated with Google Earth for spatial visualization of hazard zones. Figure 8(a) illustrates the BLEVE fireball thermal radiation zones generated by ALOHA, while figure 8(b) shows the corresponding overlay on a Google Earth satellite image.



(a) - ALOHA thermal radiation threat zones

(b) - Google Earth aerial view thermal radiation threat zones

Fig. 8. ALOHA BLEVE fireball impact at 10% capacity of LPG tank.

Figure 9 illustrates the thermal radiation contours for a BLEVE event occurring at twenty percent tank capacity.

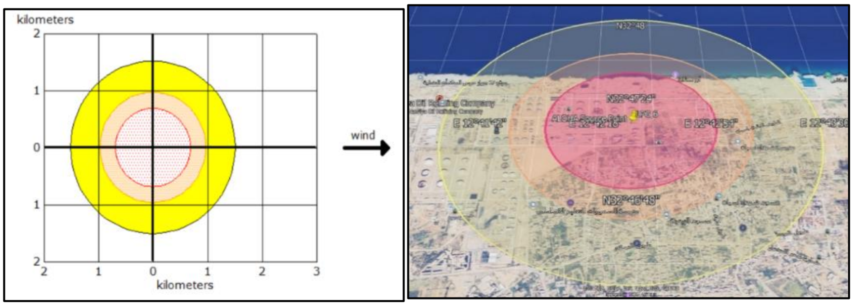


Fig. 9. ALOHA BLEVE fireball impact at 20% capacity of LPG tank.

Similarly, figure 10, 11, and 12 present the corresponding radiation contours for 30%, 40%, and 50% fill level, respectively.

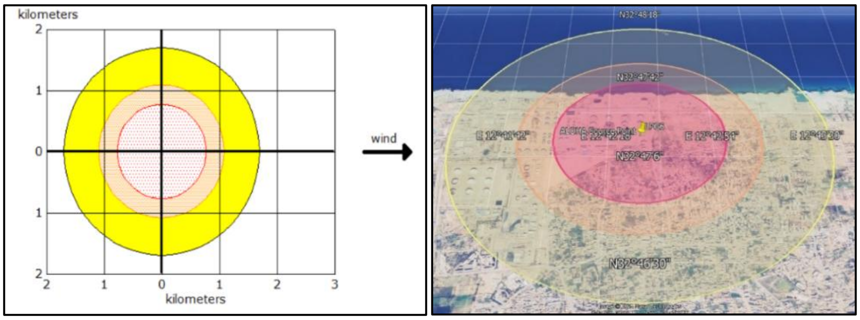


Fig. 10. ALOHA BLEVE fireball impact at 30% capacity of LPG tank.

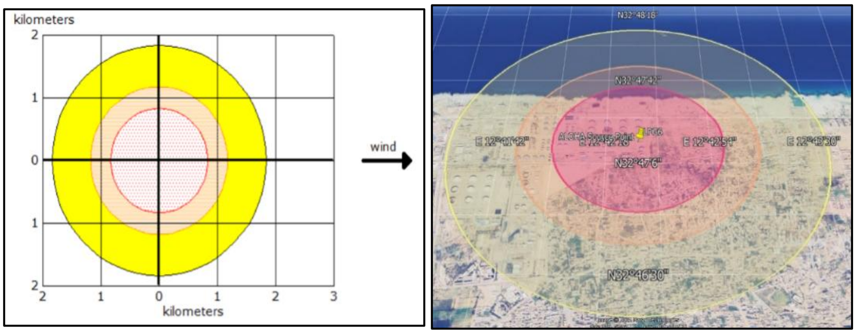


Fig. 11. ALOHA BLEVE fireball impact at 40% capacity of LPG tank.

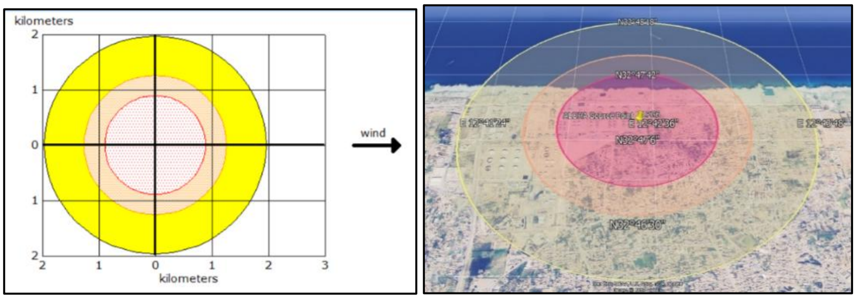


Fig. 12. ALOHA BLEVE fireball impact at 50% capacity of LPG tank.

Table 8 summarizes the predicted thermal radiation impact distances and associated hazard zones for the different storage capacities of the spherical tank.

Table 8: Summary of BLEVE Fireball Thermal Radiation Threat Zones at Different Tank Filling Levels.

Tank capacity	Threat zone	Distance (m)	Thermal radiation threat
10%	Red	580	Potentially lethal within 60 sec.
	Orange	818	2nd degree burns within 60 sec.
	Yellow	1278	Pain within 60 sec.
20%	Red	688	Potentially lethal within 60 sec.
	Orange	971	2nd degree burns within 60 sec.
	Yellow	1500	Pain within 60 sec.
30%	Red	768	Potentially lethal within 60 sec.
	Orange	1100	2nd degree burns within 60 sec.
	Yellow	1700	Pain within 60 sec.
40%	Red	833	Potentially lethal within 60 sec.
	Orange	1200	2nd degree burns within 60 sec.
	Yellow	1800	Pain within 60 sec.
50%	Red	890	Potentially lethal within 60 sec.
	Orange	1300	2nd degree burns within 60 sec.
	Yellow	2000	Pain within 60 sec.

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Results and Discussion

Despite the presence of multiple safety features in LPG spherical storage tanks, including circulation system, pressure control devices, high-level alarms, and safety relief valves, as well as routine maintenance procedures, the possibility of a BLEVE event cannot be fully eliminated and its consequences remain severe.

The present study identified three primary outcomes of a BLEVE incident: blast wave generation, fireball thermal radiation, and fragment projection. The blast wave overpressure was estimated using the TNT equivalency method at a reference distance of 500 meters from the tank. The resulting effects on structures range from minor window damage (glass breakage), to complete structural collapse, while human impacts vary from minor injury to severe and potentially fatal trauma.

Fireball thermal radiation was assessed using a point source model at different tank fill levels (10%, 20%, 30%, 40%, and 50%) and at distances of 100 m, 200 m, 300 m, 400 m, and 500 m. The results indicate that thermal radiation can have severe consequences for both refinery workers and nearby residents who are not protected by shielding or sheltering conditions.

The third hazard component, fragment projection, was estimated using an approach based on four times the fireball radius. The results indicate that fragment travel distance may reach up to approximately 700 m.

Outputs generated from the ALOHA model, combined with Google Earth visualization, classify the affected region into three hazard zones: red, orange, and yellow. The red zone represents the most severe hazard area, followed by the orange zone (moderate risk) and the yellow zone (lower risk).

Table 8 presents a summary of thermal radiation impacts and corresponding hazard zones for tank fill levels of 10%, 20%, 30%, 40%, and 50%. The results show that at 10% filling, the lethal thermal radiation zone extends approximately 0.5 km. This impact distance increases with higher fill levels, reaching nearly 1 km at 50% capacity. Although the duration of fireball radiation is relatively short, typically lasting only few seconds, it can still be fatal for exposed refinery personnel and nearby residents without protective shelter.

Furthermore, the orange zone, which corresponds to exposure levels capable of causing second-degree burns within approximately 60 seconds, extends to about 818 m at 10% capacity and increases significantly with higher fill levels. At 50% capacity, this zone expands to approximately 1.5 km.

Conclusion

A BLEVE represents one of the most severe and destructive explosion scenarios in the chemical process industry. In this study, the side-on peak overpressure resulting from a BLEVE involving LPG-6 was evaluated at various tank fill levels ranging from 10% to 50% of spherical storage capacity. The results indicate that blast wave overpressure increases progressively with higher tank inventory. The associated structural impacts vary from minor damage such as window glass breakage to complete structural failure of residential buildings, while human consequences range from minor injuries to severe or fatal trauma.

The thermal radiation generated by the fireball presents significant hazards to both refinery personnel and surrounding communities located within approximately 500 meters of the LPG storage tank. In addition, fragment analysis indicates that approximately 80% of projected debris may travel distances of up to 700 meters. The likelihood of fragment impact on workers and nearby residents without adequate shelter increases with higher tank fill levels.

The results obtained from the ALOHA Simulations classify the affected region into three hazard zones: red, orange, and yellow. The red (lethal) zone, extends to nearly one kilometer, representing a critical risk to outdoor personnel and nearby populations. The orange zone, associated with second-degree burn injuries, extends to approximately 1.5 kilometers, while the yellow zone, linked to pain thresholds and minor injuries, reaches up to around 2 km.

Although major hazard installations (MHIs) Such as refineries, chemical processing plants, and LPG storage facilities increasingly rely on advanced computational tools for risk assessment, ALOHA remains a useful and sufficiently reliable tool for preliminary hazard evaluation. It provides valuable support for emergency planning, risk communication, and decision-making aimed at protecting workers and nearby communities.

To reduce the likelihood and consequences of such events, it is recommended that high-risk facilities minimize stored quantities of hazardous materials whenever feasible and implement comprehensive off-site emergency response strategies in coordination with relevant authorities. Furthermore, regulatory frameworks should enforce strict land-use planning regulations to prevent residential development in close proximity to hazardous industrial installations.

From a design perspective, architects and civil engineers involved in industrial projects should possess A strong understanding of process safety hazards, including fire, explosion, and toxic release scenarios. This knowledge is essential for informed decision-making regarding facility layout, material selection, safe separation distances, and strategic positioning of critical infrastructure such as control rooms and administrative buildings. Such considerations ultimately contribute to reducing the overall impact of industrial accidents.

References

Abbasi, T., Abbasi, S. A. (2007) "The boiling liquid expanding vapor explosion (BLEVE): Mechanism, consequence assessment, management" Journal of Hazardous Materials 141(3):489-519.

Abdul, M. I. B. (2005) " Development of Boiling Liquid Expanding Vapor Explosion (BLEVE) Model for Process Plant Design" dissertation, Universiti Teknologi PETRONAS.

Abhishek S., N. K. Jain, Praveen Patel (2014) “Analysis of BLEVE Mechanism and Anti BLEVE System in Pressurized Tank” International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 1.

http://www.doi.org/10.62341/istj-vol38-2-il41

Birk. A.M. (1995) "Scale effects with fire exposure of pressure-liquefied gas tanks" Journal of Loss Prevention in the Process Industries. Volume 8, issue 5, pages 275 290.

The Centre for Chemical Process Safety (CCPS, 1994) "Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires and BLEVEs", Center for Chemical Process Safety, AIChE, New York, NY, p 6.

CCPS (2011) "Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs" 2nd ed. New York: American Institute of Chemical Engineers.

CCPS (2014) "Thirty Years Ago – An LPG Tragedy" Process Safety Beacon www.aiche.org/ccps Accessed on February 2026.

EPA (2007) "ALOHA – User's Manual" http://www.disaster-info.net/lideres/english/jamaica/bibliography/ChemicalAccidents/CameoPkg/alohaManual.pdf Accessed on (September 2025).

Hussain, N. (2023) "Boiling Liquid Expanding Vapor Explosion" https://thepetrosolutions.com/boiling-liquid-expanding-vapour-explosion/ accessed on (April 2024).

Hutama, A. Y., Redjeki, Y., A., Fithriyah, N., H. (2024) "Analysis of the Impact of Fire on Oil Storage Tanks at PT X: ALOHA Model
Approach for Vapor Cloud Explosion Modeling" Website: jurnal.umj.ac.id/index.php/icecream.

Khayyam, O. (2005) "Vulnerability Models" Chapter 7, https://www.uobabylon.edu.iq/eprints/publication_7_13119_6247.pdf. https://www.globalspec.com/reference/24872/203279/chapter-7-vulnerability-models. Accessed on (May 2025).

Josef, R., Karthikeyan, N. T., Velmurugan, V. G. (2021) "Safety Integrity Level Assessment for LPG Storage System" IJESC, Volume 11 issue No. 06.

Lopez, A. G. (2017) " Risk analysis of LPG tanks at the wildland-urban interface" Master en Ingenieria Quimica, Universittat Politechnica De Catalunya.

Patra, A. (2009) "Major industrial hazards" https://www.sia-toolbox.net/sites/default/files/2023-08/major_chemical_industrial_hazards.pdf

BLEVE IMPACTS FROM LPG SPHERICAL TANK

http://www.doi.org/10.62341/istj-vol38-2-il41

PIN (2018) " How is LPG Produced?" https://www.petro-online.com/news/analytical-instrumentation/11/breaking-news/how-is-lpg-produced/47566 accessed on (December 2023).

Prugh, R. W. (1991) "Quantitative Evaluation of "BLEVE" Hazards" Journal of fire protection 3(1) pp 9–24.

Rashid, Z. A., Mohd Suhaimi Yeong, A. F., Alias, A B, Ahmad, M. A. and Abdul Bari A. S. (2018) "Study of Vapor Cloud Explosion Impact from Pressure Changes in the Liquefied Petroleum Gas Sphere Tank Storage Leakage" Materials Science and Engineering **358** (2018) 012073.

Sabajo, D. (2009) "Applying Empirical Models for Evaluating the overpressure generated by Physical Explosions i.e. BLEVE" Bachelor Eind Project, TUDELFT

Sonkar, R. (2020) "Understanding & Managing Boiling Liquid Expanding Vapor Explosion" https://www.isrmag.com/understanding-managing-boiling-liquid-expanding-vapour-explosion/ accessed on (February 2026).

Tauseef, S. M., Abbasi, T., Abbasi, S. A. (2010). "Risks of Fire and Explosion Associated with the Increasing Use of Liquefied Petroleum Gas" Journal of Failure Analysis and Prevention 10(4):322-333.

Xinsheng, H., Zongzhi, W., Lifang, X., Rujun, W. (2018) "Quantitative Risk Assessment of LPG Tank Area" 7th International Conference on Energy, Environment and Sustainable Development (ICEESD 2018), Volume 163.