Semi-quantitative risk analysis of a possible accident scenario at a gasoline storage facility

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Abstract

Gasoline is highly volatile compound, requiring storage tanks to be properly sealed. The high volatility also means that it will easily ignite, leading to an increased fire and explosion risk.

Our study analyses possible accident scenarios associated with gasoline storage, focusing on BLEVE (Boiling Liquid Expanding Vapor Explosion), pool fire and UVCE (Unconfined Vapor Cloud Explosion) scenarios, analyzing the possible failure modes and the effects using the FMEA (Failure Mode and Effect Analysis) method. The consequences will be analyzed using the EFFECTS 7 software.

We will perform a consequence based risk analysis using the data obtained from the semi-quantitative approaches, therefore improving the emergency planning in case of accidents.

Key words:
gasoline storage, accident, consequence based risk analysis

1. Introduction

Gasoline is a petroleum-derived liquid mixture consisting mostly of aliphatic hydrocarbons, enhanced with iso-octane or the aromatic hydrocarbons toluene and benzene to increase its octane rating, and is primarily used as fuel in internal combustion engine. Gasoline is volatile, requiring that storage tanks on land and in vehicles be properly sealed. The high volatility also means that it will easily ignite in cold weather conditions, unlike diesel for example. Appropriate venting is needed to ensure the level of pressure is similar on the inside and outside.(5)

2. Consequence based risk analysis

Generally, risk assessment methods begin with the identification of hazards and vulnerabilities, frequency and consequence analysis of each of these vulnerabilities and hazards. Consequence based risk analysis has an approach that starts with the identification of the major consequences by analyzing the potential accident scenarios and the effects of the accidents upon the environment, human factor and structures. The process then searches for combinations of hazard and vulnerability that could result in the most serious consequences.

The advantage of the consequence based risk analysis is that it will show how qualitative threat, vulnerability and consequence information can be combined to derive a qualitative value for risk and offer an easy-to-understand graphical way to present risk assessment results.

3. Accident scenarios

Our case study is focusing on the potential accidents and their consequences in gasoline transportation, tank loading, unloading and maintenance operations.

We have identified three different accident cases as BLEVE (Boiling Liquid Expanding Vapor Explosion), Pool Fire and Vessel rupture from internal pressure burst.

These accident cases were investigated with qualitative Preliminary Hazard Analysis and with quantitative approach calculating the physical effects and consequences.

The BLEVE scenario is possible in case of an external fire near the tank, when the gasoline is heated until the vapor pressure increases and the tank ruptures. The external fire can cause the weakening of the steel and this way the burst pressure can be lower than the projected maximum pressure for normal temperature conditions.

Considering the big quantity of the gasoline, only a small percent of the material will form a Fire-ball, the rest of the gasoline will spread and burn in a pool fire near the tank.

Vessel rupture scenario can occur also in case of an external fire, but in this case the filling level is lower, than in the case of BLEVE. The pressure effect is much more significant in this case.

The pool fire scenario is possible when a leakage is present in the pipeline or due to an external shock the tank is damaged and a hole is made on the tank. This way the content of the tank is released forming a pool in the drainage area. In case of an ignition source a pool fire can occur.

4. Results and discussions

PHA Pro 7 is a software specialized in qualitative risk analysis, and is useful in developing FEMA HAZOP and Preliminary Hazard Analyzes. We performed a Preliminary Hazard Analysis regarding operation, loading, unloading and maintenance of a gasoline storage fuel tank.

Table 1: PHA Analysis summary

Process: 1. Operation
Node: 1. Tank
Type: Tank
Design Conditions/Parameters: storage at ambient pressure and temperature
Equipment ID:
Drawings:

Hazards	Causes	Consequences	Risk Matrix S	Risk Matrix L	Risk Matrix RR	Safeguards	Recommendations	Responsibility
1. BLEVE(Boiling Liquid Expanding Vapor Explosion)	1. Adjacent tank fires	1. Heat radiation from fireball - burns	2	2	4	1. Adequate spacing		
2. Blast forces	1. Overpressure (above line design specification)	1. Ambient overpresure - ear and lung damage	2	1	2	1. Pressure indication		

Process: 2. Loading
Node: 1. Tank
Type: Tank
Design Conditions/Parameters: storage at ambient pressure and temperature
Equipment ID:
Drawings:

Hazards	Causes	Consequences	Risk Matrix S	Risk Matrix L	Risk Matrix RR	Safeguards	Recommendations	Responsibility
1. BLEVE(Boiling Liquid Expanding Vapor Explosion)	1. Adjacent tank fires	1. Heat radiation from fireball - burns	2	2	4	1. Adequate spacing		
2. Pool fire	1. Leakage through vents & drains	1. Heat radiation from pool fire	2	3	6	1. Inspection procedures		
3. Blast forces	1. Overpressure (above line design specification)	1. Ambient overpresure - ear and lung damage	2	1	2	1. Pressure indication		

Process: 3. Unloading
Node: 1. Tank
Type: Tank
Design Conditions/Parameters: storage at ambient pressure and temperature
Equipment ID: 1
Drawings:

Hazards	Causes	Consequences	Risk Matrix S	Risk Matrix L	Risk Matrix RR	Safeguards	Recommendations	Responsibility
1. BLEVE(Boiling Liquid Expanding Vapor Explosion)	1. Adjacent tank fires	1. Heat radiation from fireball - burns	2	2	4	1. Adequate spacing		
2. Pool fire	1. Leakage through vents & drains	1. Heat radiation from pool fire	2	3	6	1. Inspection procedures		
3. Blast forces	1. Overpressure (above line design specification)	1. Ambient overpresure - ear and lung damage	2	1	2	1. Pressure indication		

Process: 4. Maintenance
Node: 1. Tank
Type: Horizontal cylinder
Design Conditions/Parameters: storage at ambient pressure and temperature
Equipment ID: 1
Drawings:

Hazards	Causes	Consequences	Risk Matrix S	Risk Matrix L	Risk Matrix RR	Safeguards	Recommendations	Responsibility
1. Pool fire	1. Leakage through vents & drains	1. Heat radiation from pool fire	2	3	6	1. Inspection procedures		
2. Blast forces	1. Overpressure (above line design specification)	1. Ambient overpresure - ear and lung damage	2	1	2	1. Pressure indication		

The software takes into consideration the severity, likelihood and the number of consequences for each type of scenario, and develops a 3D risk matrix:

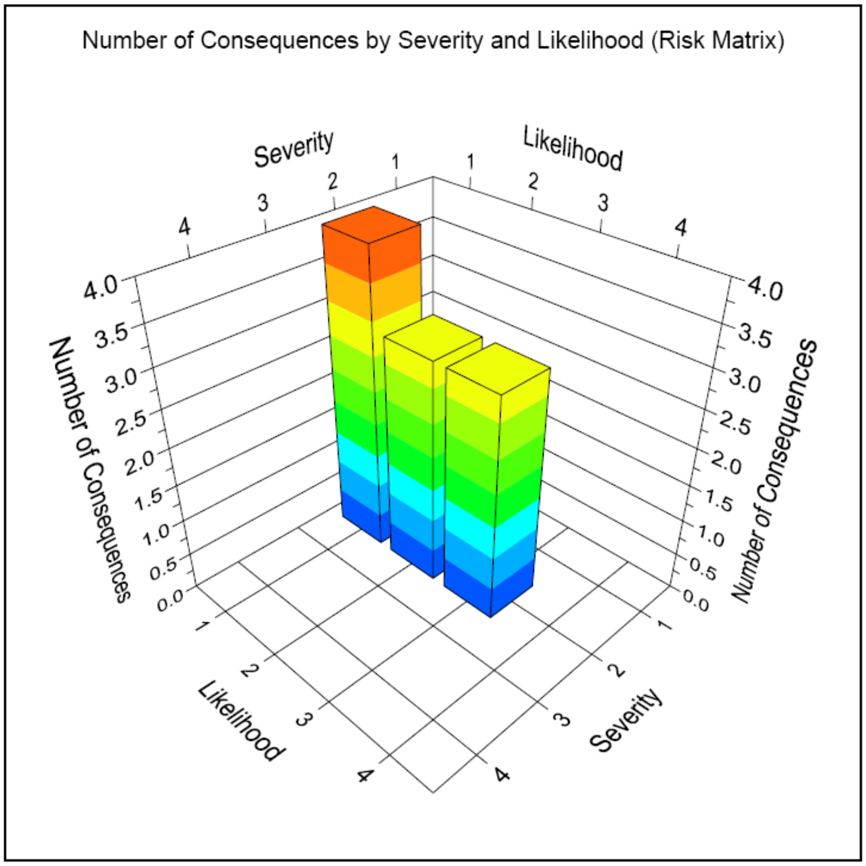

Figure 1: Number of consequences vs. Severity vs. Likelihood

The simulation of the accident scenarios

We have performed the simulation of effects and consequences using the Effects 7 software developed by TNO. All the simulations were made considering the worst case scenario, when the total quantity of gasoline present in the tank is involved in the explosion or fire.

In all cases it was considered a gasoline road tanker with the following dimension: length = 6 m, diameter = 2,48 m, V = 29 m^3, with 17000 kg gasoline at 80% filling degree.

The atmospheric parameters are the followings: wind speed = 2 m/s, measured at 10 m, ambient temperature = 25 ºC, relative humidity = 70%.

BLEVE scenario

Considering the worst case scenario principle, the Fire ball of the BLEVE has a diameter of 76.81 m, and the duration of the fire ball is 10.74 s.

The heat radiation is presented in figure 2:

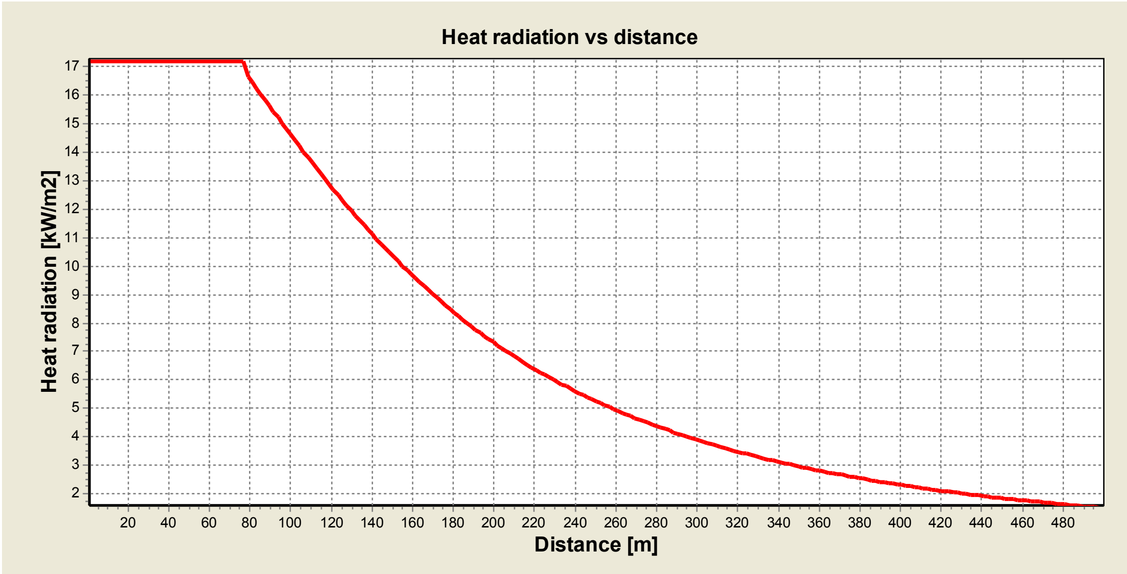

Figure 2: Heat radiation vs. distance – Fire ball

The consequences of the accidents are presented as burns during the exposure to fire ball in figure 3:

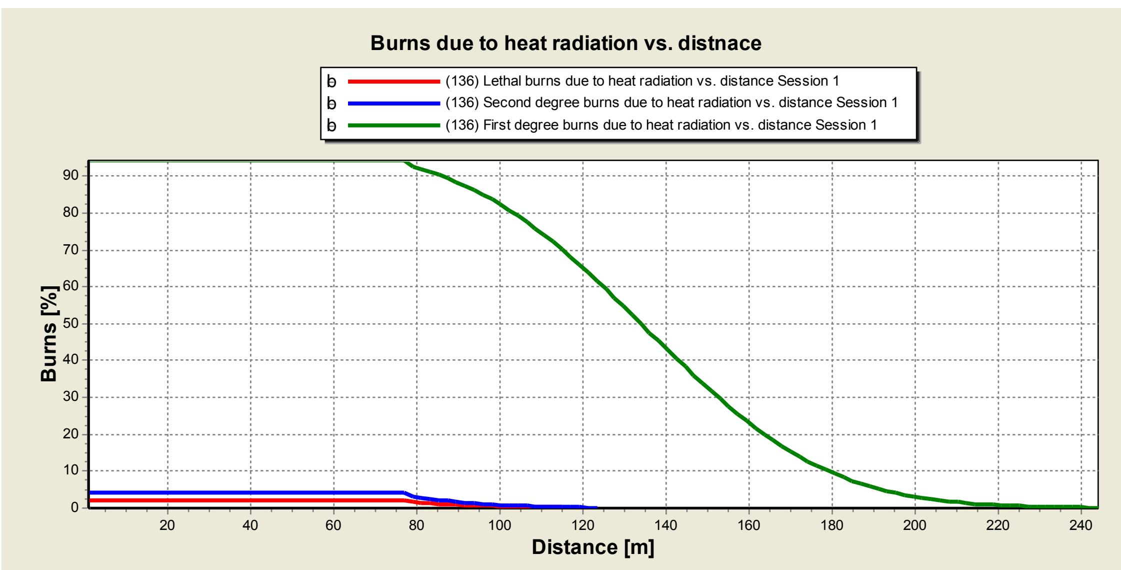

Figure 3: Consequences – Fire ball

From the estimation of consequences of the BLEVE scenario results that the percentage of lethal and second degree burns outside the fireball is low, fewer than 5 % in both cases, which can be explained by the short duration of the fireball. The first degree burns can reach 94 % in this case. But regardless of this, inside the fireball we should consider 100% burns.

Pool fire scenario

In the pool fire scenario was considered a crack on the bottom of the tank and the release of the gasoline forming an unconfined spreading pool which burns in a pool fire.

From the simulation results a circular pool fire with 398 m^2 area and the following heat radiation, see figure 4:

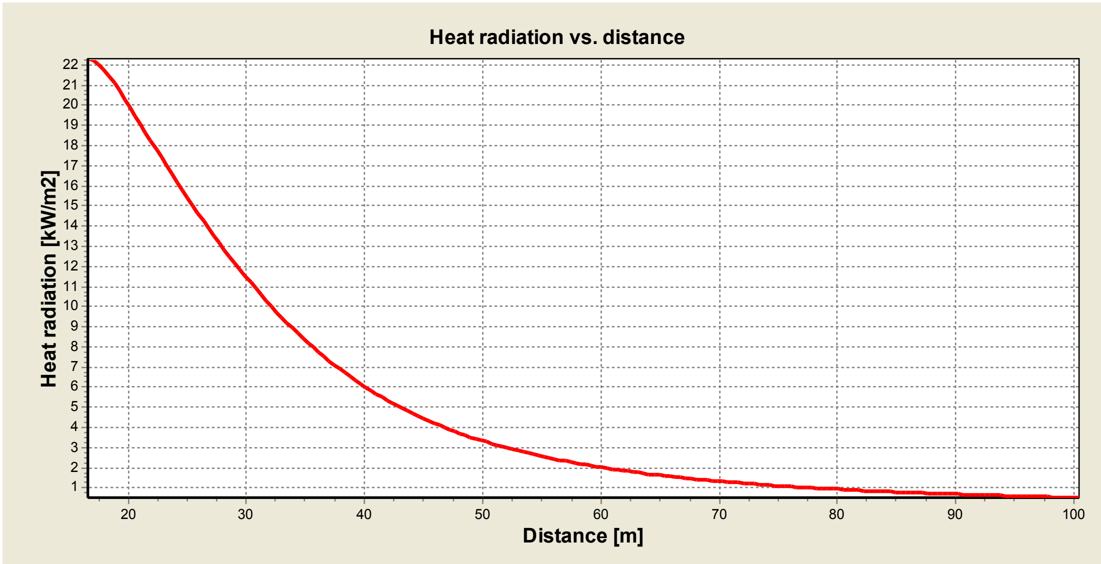

Figure 4: Heat radiation vs. distance – Pool fire

In this case the degrees of the burns are higher but on a shorter distance. Third degree burns can occur to 33 m distance from the pool fire, second degree burns until 36 m and first degree burns until 49 m.

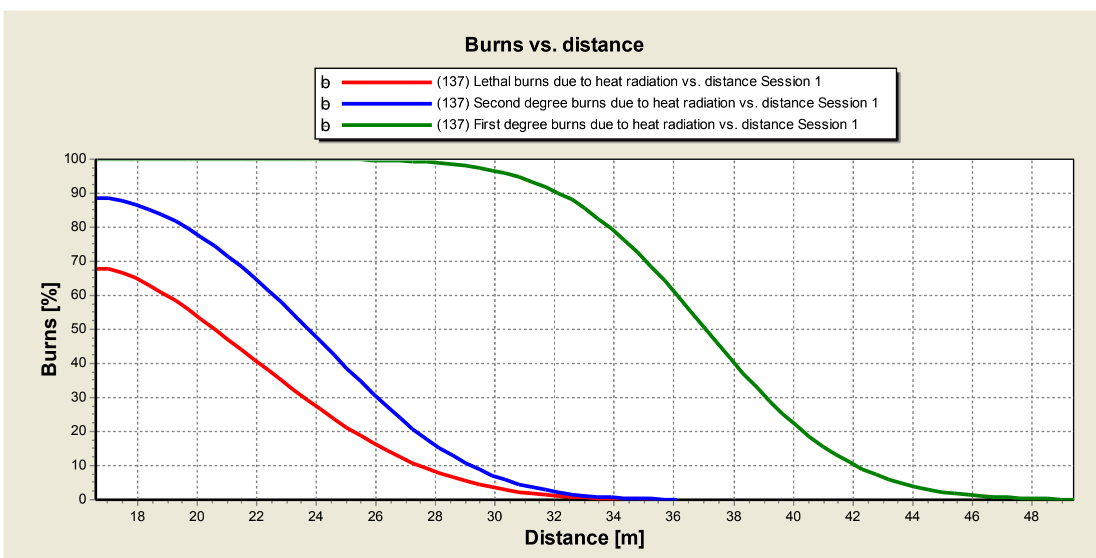

Figure 5: Consequences – Pool fire

Rupture of vessel

The vessel rupture scenario is possible in the case of external fire near the gasoline tank, which is heating the tank until the internal pressure increases and the vessel ruptures. Due to the external fire, the material of the vessel weakens and the burst pressure can be lower as the projected maximum pressure.

The vessel rupture scenario considers that the vessel is at 10% filling degree, and the burst pressure is 1.2 Bar.

The overpressure which occurs during the explosion is presented in figure 6:

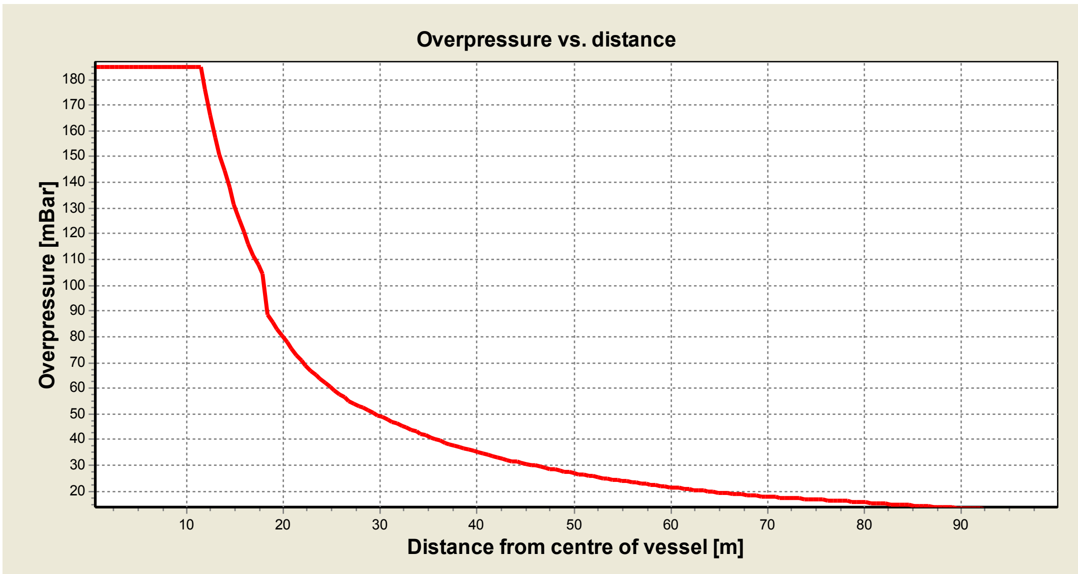

Figure 6: Overpressure vs. distance – Rupture of vessel

In case of the vessel rupture the maximum overpressure does not reach the 300 mBar threshold lethal overpressure, and the distance for irreversible effects on humans is 22 m.

5. Conclusions

The results obtained from the qualitative (PHA) and quantitative (Effects) analysis shows that the highest risk is present in the case of a pool fire scenario, but the risk category is only moderate. In all cases the consequences can be considered moderate, and the probabilities are low. The probability of BLEVE and Vessel Rupture scenarios can be mitigated if proper safety measures are taken. The pool fire scenario is possible in case of an external mechanical impact, such as road tanker accident, with the crack of the vessel and release of the gasoline.

The Internal Emergency Plan of the storage facility should consider the simulation results for the development of the right rescue strategy in case of an accident. The obtained results are also helpful in the Land use planning for the calculation of the safety zones.

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