Determination of the Storage Number of LPG Tank Container Based on Quantitative Risk Analysis

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Abstract: Based on the quantitative risk analysis method, this paper calculates the individual risk and social risk value of the LPG Tank Container, and the maximum LPG full tank storage capacity of a storage yard is determined.

Keywords: LPG Tank Container, QRA, Storage Number.

1. INTRODUCTION

Liquefied petroleum gas (LPG) which is pressurized liquefied refers to 25°C and 1 MPa, is composed of propane, propylene, butane and butene, which is a kind of clean fuel and important chemical raw material, and widely used in industrial production and living.

LPG is very flammable and explosive mixtures which may result in flash fire, explosion and other consequences if there is a leak.

Based on the quantitative risk calculation method, this paper suggests the number of LPG tank container in a yard by calculating the individual risk and social risk value according to the risk acceptance criteria.

2. METHODS

2.1. Hazard Analysis

When LPG is leaked and mixed with air, a variety of situations will occur. The event tree(Fig 1) shows, if there is no ignition condition in the surrounding areas, fire and explosion will not occur, and then steam cloud will gradually dissipate. If there are some ignitions, fire and explosion will occur. Since the steam cloud is not yet confined, the possibility of explosion is small at this time; on the contrary, if a large number of steam cloud have confined, the flame spreads rapidly in the steam cloud, and rapid deflagration occurs, and the formation of a powerful blast wave.

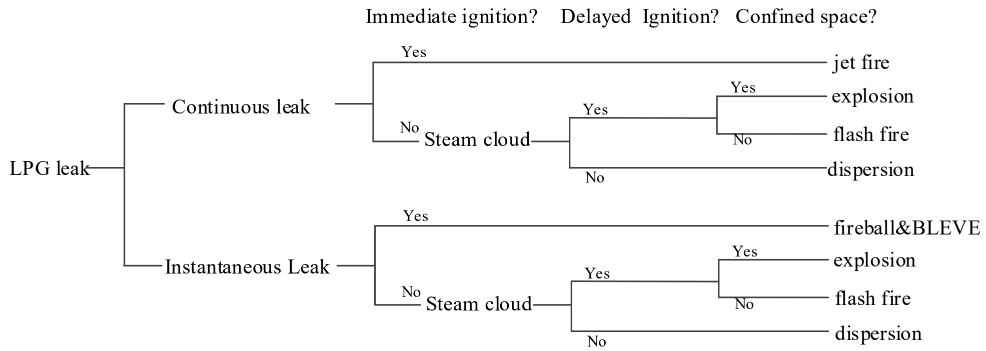

Fig1 leak event tree

2.2. Calculation procedure

The calculation steps for individual risk as follows:[1,2]

a)Select a leak scenario (LOC) and determine the frequency of occurrence of LOC;

b)Select a weather grade and a wind direction under the weather grade, and give the joint probability that the weather grade M and the wind direction appear at the same time;

c)Select a firing event and determine the firing probability

d)Calculate the probability of death on the grid unit under specific LOC, weather grade M, wind direction, and ignition event conditions.

e)USE DNV RISK to Calculate the individual risk;

The calculation steps for social risk as follows:

a) Determine the LOC and its frequency fs;

b) Select weather class M with a probability of PM;

c)Select a wind direction at weather level M with a probability of P;

d) Select a firing event i and determine the firing probability Pi. e） USE DNV RISK to Calculate the social risk.

2.3. Acceptable Risk

Individual risk refers to mortality of a certain fixed position in the area per unit time (usually a year). It is usually expressed as a individual risk contour.

Through quantitative risk assessment, the individual risk of the important target and sensitive site of the port's major dangerous source should meet the requirements of the allowable risk in table 1.

Table 1 individual risk acceptable standards

important target and sensitive site category	Individual risk（/year）
1. High sensitive sites (such as schools, hospitals, kindergartens, nursing homes, etc.); 2. Important objectives (such as party and government organs, military restricted zones, military administrative zones, cultural relics protection units, etc.); 3. Special high-density places (such as large stadium, large transportation hub, largeoutdoor market, etc.).	$<3\times10^{-7}$
1. Residential high-density places (such as residential areas, hotels, resorts, etc.); 2. High density areas (such as office space, shopping mall, hotel, entertainment place, park, square, etc.).	$<1\times10^{-6}$

Social risk refers to the cumulative frequency of accidents (F) that can cause the death of people, or the number of deaths per unit of time (usually years) which is social risk curve (F-N curve). The social risk standard adopts the principle of ALARP as the acceptable principle.Fig2 shows the F-N curve and the alarp area.

ALARP (as low as reasonably practicable):[3]The risk is regarded as tolerable only if risk reduction is impracticable or if the cost is grossly disproportionate to the improvement gained. This involves determining:

a.whether a given risk is so great or the outcome so unacceptable that it must be refused altogether; or

b.whether the risk is, or has been made, so small that no further precaution is necessary; or

c.if a risk falls between these two states, that it has been reduced to the lowest level practicable, bearing in mind the benefits flowing from its acceptance and taking into account the costs of any further reduction. The injunction laid down in safety law is that any risk must be reduced so far as reasonably practicable, or to a level which is 'as low as reasonably practicable'.

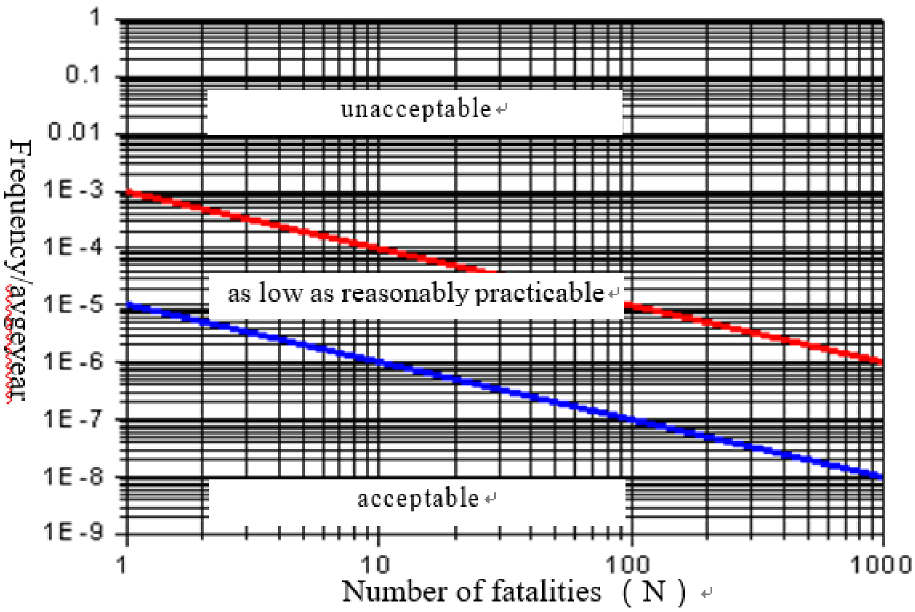

Fig2 F-N curve

2.4. The selections of LOCs and its frequency

The frequency refers to the possibility of flammable liquid leakage. The probability of a major hazard event can be determined by different probabilistic analysis methods. The probability of a major hazard event occurring is affected by the frequency of the initial event (such as the frequency of leaks) and the likelihood of other related events (such as immediate ignition or delayed ignition). Therefore, in order to further assess the risk, the occurrence frequency of the leak scenario identified and defined in Table 1 needs to be determined.

Before the risk calculation, safety management system assessment method is used to evaluate the safety management of the project, which evaluates the effectiveness of the engineering safety management system from a total of 114 questions in 12 areas. The revised failure frequency correction factor is obtained.

Table 1 shows the LOCs and the leak requency/corrected frequency.

Table 1: The LOCS of LPG Tank Container

Leak location	Type of Release	Leak requency (per tank year)	Corrected frequency (per tank year)
LPG Tank Container	rupture	5×10^{-7}	3.27×10^{-7}
tube of Tank container	rupture	5×10^{-7}	3.27×10^{-7}

3. RESULTS

3.1. Risk Evaluation

This paper USES SAFETI to carry out the risk modeling of empty tank and full tank, and calculates the individual risk and social risk value of a single empty tank container and a single full tank container.

The central location of the yard (point A) is selected to place a full tank for risk calculations that can represent the average level of risk for a single full tank placed in the yard.

At the same time, the calculation result of the south corner position (point B) of the office building of the yard is selected to calculate the allowable storage number of the full tank container.

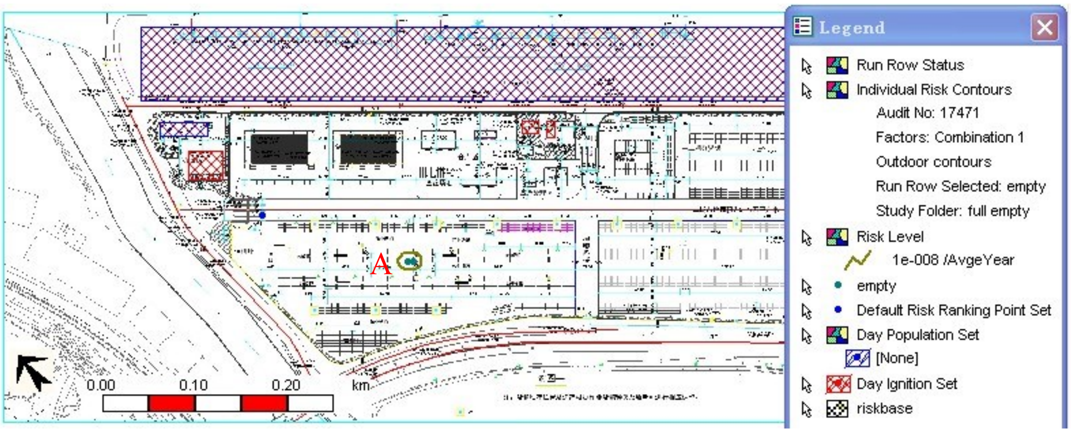

Fig3 The individual risk curve of one empty tank container

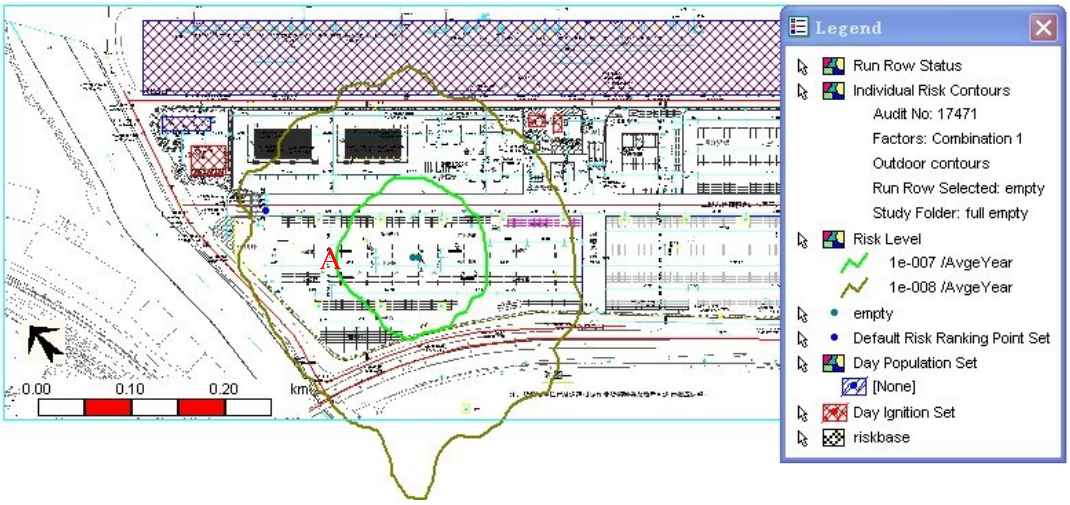

Fig4 The individual risk curve of one full tank container

The calculated results show that the individual risk of a single empty tank container in a fixed position(A position) in the field is much less than that of a single full tank. The individual risk value of a single empty tank container in A is 6.54×10^{-8}(Fig3), and the individual risk value of a single full tank container in A is 1.89×10^{-7}(Fig4). The risk of point A will increase with the distance from the position of the tank container.

3.2. Determination of the Storage Number of LPG Tank Container

The south corner position (B point) of the office building is selected to calculate the allowable storage quantity of the full tank container. The calculated results show that the individual risk value of a single full tank at point B is $1.07371\text{x}10^{-8.}$

Therefore, according to the tolerance level of individual risk, the quantity of full tank container allowed to be storage is $1.0\times10^{-6}/1.07371\times10^{-8}\approx93$.

On this basis, the calculation results of 93 full tank container on the floor are re-evaluated, and the individual risk value of B points is 9.98548×10^{-7}（Fig5）, and the allowable limit of 1.0×10^{-6} is not exceeded.

From Fig6, it can also be seen that the social risk of storing 93 full containers does not exceed the ALARP area. Its social risk is acceptable.

The calculation shows that the risk of empty tank container is much lower than that of full tank container. The social risk value is at least 107 times. Therefore, the number of empty tank container in the storage yard can be no longer restricted on the basis of the relevant specifications.

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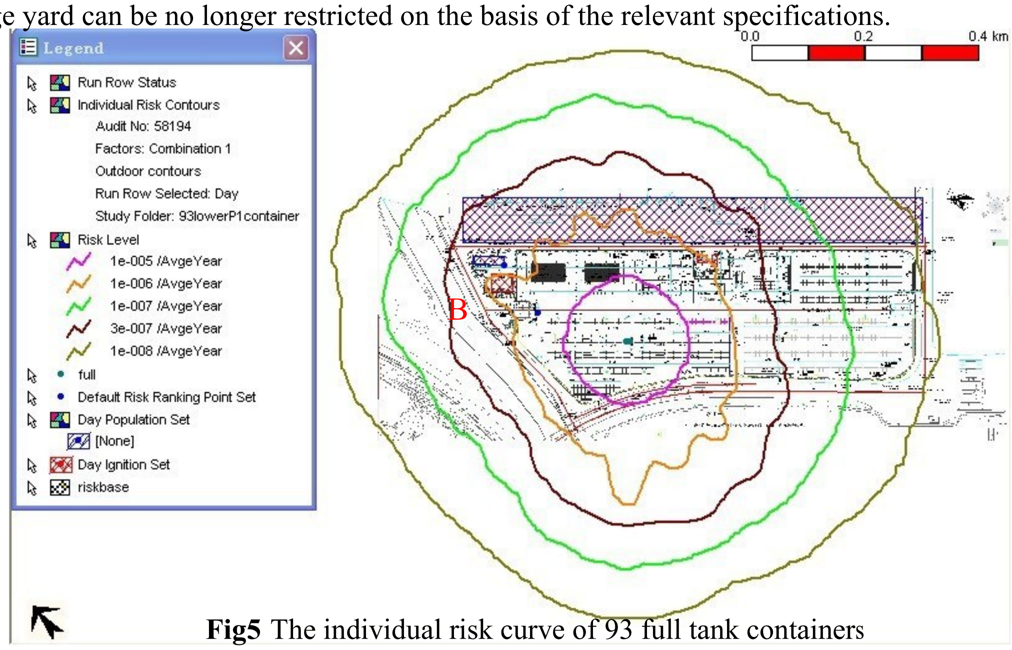

Fig5 The individual risk curve of 93 full tank containers

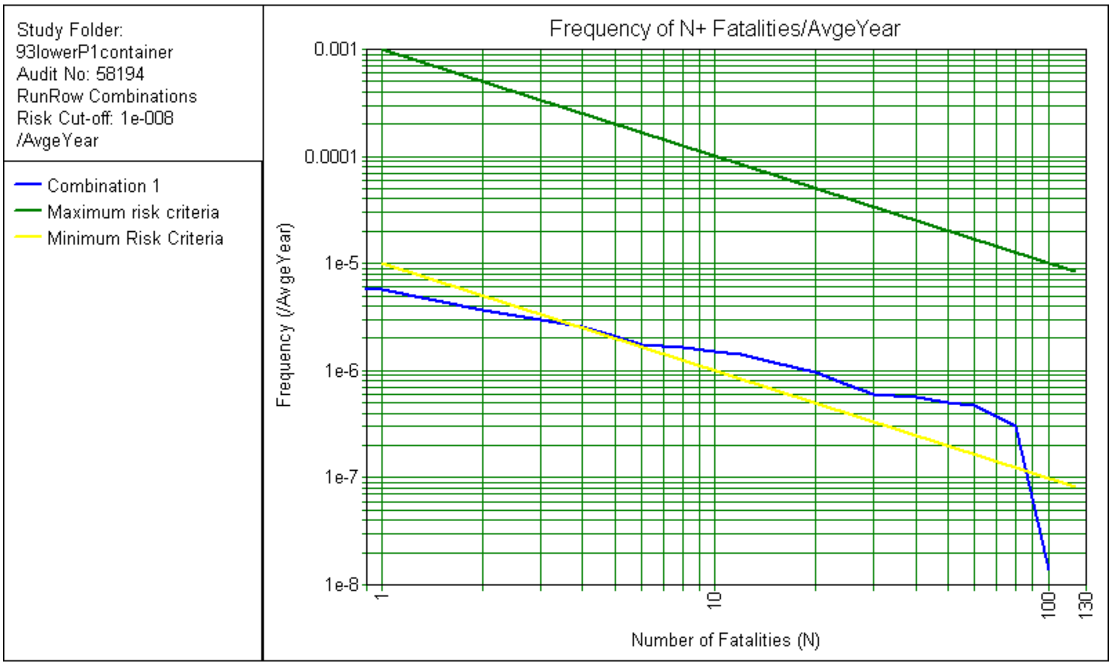

Fig6 The F-N curve of 93 full tank containers

4. DISCUSSION and CONCLUSION

Through a quantitative risk analysis of a certain LPG container yard, we finally gave an advice on the maximum number of the LPG tank containers that can be stored in the yard. The analysis shows that the number of filled tanks is the main factor affecting the level of risk. In addition, the safety management level of the company also has a greater impact on safety risks, which is mainly reflected in the reduction of the frequency of accidents.

In the Tianjin blast incident, the company turned over about 60,000 tons of goods in 2015, which was 14 times more than the approved monthly turnover (about 50,000 tons of designed annual turnover of dangerous goods). During the incident, the storage of potassium nitrate was 1342.8 tons, which was 53.7 times of the approved storage number; the storage capacity of sodium sulfide was 484 tons(19.4 times); and the storage capacity of sodium cyanide was 680.5 tons(42.5 times). Therefore, it is necessary to control the number within an acceptable range.

According to the regional risk calculation model, we can reduce the risk of accident consequences and the number of deaths caused by the consequences of accidents in order to achieve the goal of reducing social risks. From above analyses, some measures we can take as flows to reduce the probability of accident consequences.

- Reduce the original frequency of leakage of container equipment: regular maintenance inspections of equipment, strengthening daily management, formulating operating procedures, and strengthening training to reduce human factors influences.
- Reducing the impact of meteorological conditions: According to various natural disasters, formulate and implement corresponding countermeasures.
- Reduce the ignition probability of ignition sources: Strictly implement hot work, control the access vehicles and personnel, regularly maintain and detect lightning protection and anti-static facilities, and timely repair or replace faulty electrical equipment and facilities.
- Reduce physical consequences of accidents: Strengthen monitoring, formulate emergency rescue plans, and exercise to shorten the emergency response time.
- Reduce the density of people in the area.
- Strengthen personnel protection measures.

This analysis method can be used as a reference when the enterprise do decision or choice making in the design process of choosing alternative locations, or doing safety management planning or emergency response plan, in order to realize the risk prevention and control make the safety to achieve an acceptable level. There are still some deficiencies such as the data adaptability of the occurrence probability, the rationality of the probability correction, and the logical of the event tree, which need further discussion and improvement. When analyzing other yards, the differences in the types of goods stored should be considered.

References

[l]Sinopec Research Institute of Safety Engineering, A guidance for quantitative risk assessment in the petrochemical plant, China Petrochemical press co. LTD, 2007, Beijing.

[2] Guidelines for quantitative risk assessment of chemical enterprises, AQ/T 3046-2013.

[3] HSE (1992). The Tolerability of Risk from Nuclear Power Stations. Health and Safety Executive London.