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Simulation of LNG Power Ship Fuel Tank Leakage Accident Based on ALOHA Software

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Abstract

With the support and investment of Shanghai municipal government in the development of inland waterway LNG powered ships, the risk assessment of LNG powered ships is particularly important. Taking the fuel tank of the LNG fuel power ship as an example, on the basis of predicting the leakage consequence of ETA, the possibility of the occurrence of each consequence is analyzed, and the influence range of consequences is simulated by using the ALOHA to obtain the BLEVE-fireball Pool fire radiation area and vapor cloud explosion overpressure shock wave impact area in a possible accident scene, through MARPLOT software of related accidents threaten regional field simulated on the map.the results show that: The radiation area of pool fire accident is small, and the damage area of steam cloud explosion shock wave is in the middle, but the steam cloud explosion area is greatly affected by wind speed and extends further in the downwind direction, and BLEVE-fireball accident radiation area is the most serious. According to the severity of accident consequence, occurrence divides different grade areas and puts forward some ideas on crew's daily cruise and accident rescuethe.

Keywords

LNG fuel tank, ALOHA, The accident simulation.

1. Introduction

With climate change and global warming, the construction of “low energy consumption, low material consumption, low emissions, low pollution” inland shipping mode is put on the agenda . Natural gas is rich in storage resources in China, and it is clean and environmentally. Energy utilization rate is high. LNG green new energy has become one of the important fuels for ship shipping. LNG fuel-powered ships have emerged. However, LNG, which is one of the dangerous chemicals, should be highly valued during use. Due to improper operation and equipment failure, leakage of fuel tank will cause catastrophic accidents. Therefore, the study of accidents will be of great significance. Among them, the software simulation method considers the factors comprehensively, the calculation process is fast, and the results are intuitive. It is being used more and more in practice and research [1-3].

ALOHA (Areal Location of Hazardous Atmosphere) was jointly developed by the US Environmental Protection (EPA) Chemical Incident and Preparatory Office (CEPPO) and the National Oceanic and Atmospheric Management Response and Recovery Office (NOAA) [4]. Calculation procedures for the effects of hazardous chemical spills. Mainly by calculating the expansion process of hazardous chemicals in space, the distribution of materials in the atmosphere after leakage and the radiation range of potential accidents are obtained. This paper uses ALOHA software to simulate the typical accident caused by LNG fuel storage tank leakage, analyzes the leakage and diffusion rule of LNG, and provides technical basis for risk assessment and accident rescue.

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2. ETA of LNG fuel tank leak

ETA analysis is a logical induction method that analyzes the sequence of various events that may result from the initial event given an initial event. Typically LNG is stored in a storage tank at -160 ° C 0.1 MP. When a tank containing flammable liquids explodes due to overpressure and is immediately ignited, a fireball is generated, commonly referred to as a BLEVE-fireball accident (the flame is on the surface of the fireball). After the LNG storage tank leaks, the unvaporized part forms a liquid pool and forms a pool fire. The vaporization diffusion is fully mixed with the air to gather in a certain range to form a premixed steam cloud. The "premixed cloud" form of the vapor cloud diffuses only in the combustion range (the range between the upper and lower limits of the gas explosion), and the flash fire occurs in a certain limited space due to the shape of the vapor cloud. It is difficult to determine, and the flash fire duration is very short. Therefore, this paper does not consider the thermal radiation effect of the flash fire accident, but evaluates the threat area of the shock wave of the steam cloud explosion accident, and the shock wave will cause harm to the person, structure etc. In addition, Jet fire can also occur when LNG storage tank leaks., but if the injection fire is not extinguished in time, the storage tank is heated and pressurized to cause a BLEVE-fireball accident. This paper mainly analyzes the possible consequences of BLEVE-fireball, pool fire, steam cloud explosion accident caused by LNG tank leakage, simulates the impact area of accident consequences, and provides assistance for accident rescue.Fig. 1.

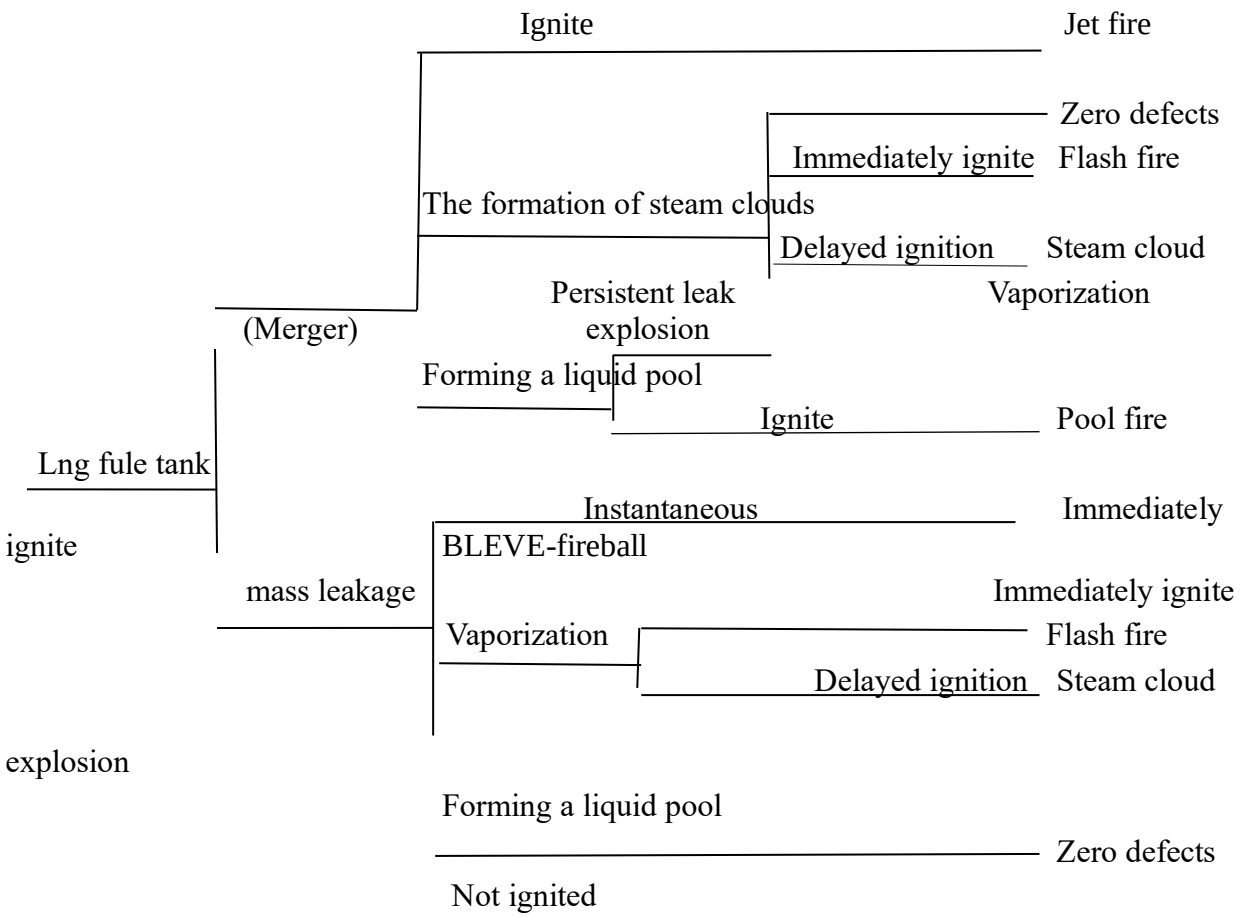

Fig. 1 Analysis of LNG Fuel Tank Leakage ETA

3. Simulation of Accident Consequences Based on ALOHA Software

ALOHA Harmful Atmosphere Air Positioning Software has a database containing nearly 1,000 kinds of common hazardous chemicals, which can predict the hazardous areas of chemical leakage and the

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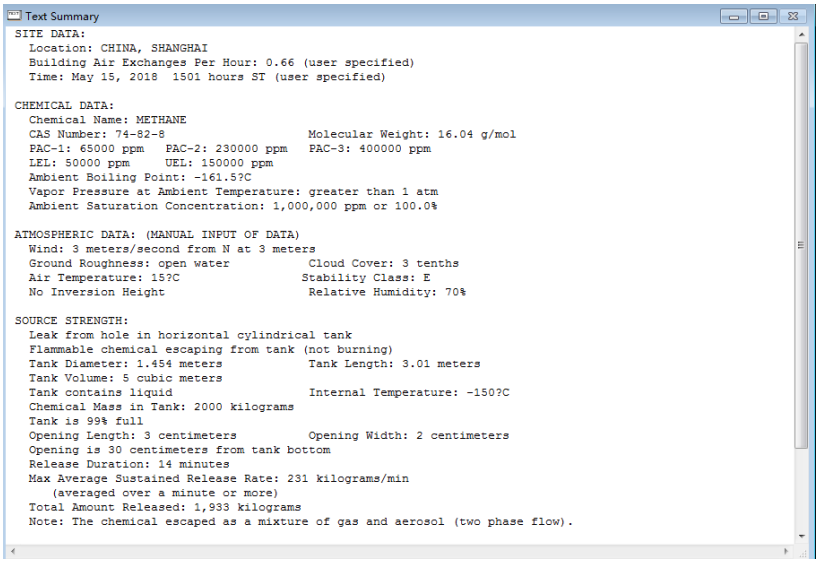
concentration of toxic substances at sensitive points, and use the three-level data provided by AEGLS (Guidance Level for Sensitive Exposure) in the United States to divide hazardous areas. In recent years, hazardous chemicals leakage accidents occur frequently. ALOHA software simulation of consequences is of great significance to enterprise emergency and government planning, and has gradually become an important tool for emergency rescue, planning, training and academic research of hazardous chemicals accidents[5-8].

3.1 ALOHA parameter setting

The mathematical models provided by ALOHA include: Gaussian model, DEGADIS heavy gas diffusion model, steam cloud explosion model, BLEVE- fireball model, etc. This paper analyzes and simulates the models provided by software. The specific geographical environment where the leakage accident occurred is filled in according to the actual data. Setting such parameters can help ALOHA to know more accurately the impact area of hazardous chemical gases. Meteorological parameters are set according to field data, which will directly affect the calculation of gas diffusion rate, direction, distance, concentration, etc. select methane in the database, and other specific data are shown in Fig.2.


Text Summary

```
SITE DATA:
  Location: CHINA, SHANGHAI
  Building Air Exchanges Per Hour: 0.66 (user specified)
  Time: May 15, 2018  1501 hours ST (user specified)

CHEMICAL DATA:
  Chemical Name: METHANE
  CAS Number: 74-82-8                    Molecular Weight: 16.04 g/mol
  PAC-1: 65000 ppm   PAC-2: 230000 ppm   PAC-3: 400000 ppm
  LEL: 50000 ppm     UEL: 150000 ppm
  Ambient Boiling Point: -161.5?C
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 3 meters/second from N at 3 meters
  Ground Roughness: open water           Cloud Cover: 3 tenths
  Air Temperature: 15?C                 Stability Class: E
  No Inversion Height                    Relative Humidity: 70%

SOURCE STRENGTH:
  Leak from hole in horizontal cylindrical tank
  Flammable chemical escaping from tank (not burning)
  Tank Diameter: 1.454 meters            Tank Length: 3.01 meters
  Tank Volume: 5 cubic meters
  Tank contains liquid                   Internal Temperature: -150?C
  Chemical Mass in Tank: 2000 kilograms
  Tank is 99% full
  Opening Length: 3 centimeters          Opening Width: 2 centimeters
  Opening is 30 centimeters from tank bottom
  Release Duration: 14 minutes
  Max Average Sustained Release Rate: 231 kilograms/min
     (averaged over a minute or more)
  Total Amount Released: 1,933 kilograms
  Note: The chemical escaped as a mixture of gas and aerosol (two phase flow).
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Fig. 2 ALOHA parameter setting

3.2 Simulation results

3.2.1BLEVE- fireball accident

Because LNG storage tank is cracked by external impact or corroded and fails at high temperature, LNG will leak instantaneously. When it encounters a fire source, it will be ignited immediately to produce BLEVE- fireball accident. The accident is mainly caused by heat radiation, which will cause serious damage to human body, equipment and buildings. Modeling research on BLEVE- fireball accident of LNG power ship storage tank in inland river is carried out. ALOHA software is used to simulate BLEVE- fireball accident, and a schematic diagram of the thermal radiation threat range of the accident is obtained, as shown in Fig. 3. Through the analysis of BLEVE- fireball accident in LNG storage tank, the maximum diameter of fireball can reach 71m, the duration of fireball combustion is about 6s, and the safety zone is 385 meters away. BLEVE- fireball accident is less affected by the atmospheric environment, and the threat scope and size extend to all sides in a circle with the source intensity point as the center. From Fig. 3 , the hazard level of BLEVE- fireball accident thermal radiation threat area is shown in Table 1, and the values of different distances between thermal radiation hazard and source intensity point are shown in Table 2.

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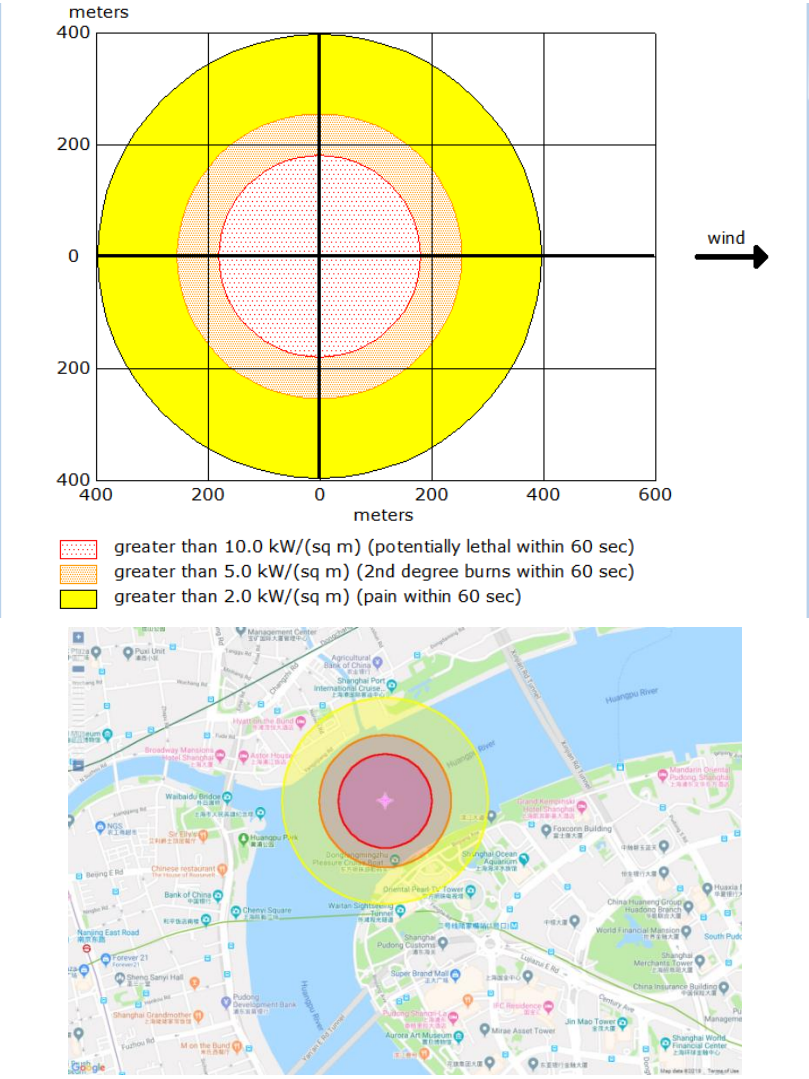

Fig. 3 BLEVE- Fireball Accident Threat Area

Table 1 BLEVE- Fireball Accident Heat Radiation Hazard Rating Table

Region	Threat size (kW/m2)	Range parameter (m)	hazard rating
Red area	>10	180	Dead zone
Orange area	>5	250	Serious injury area
Yellow area	>2	395	Minor injury area

Table 2 Numerical Table of Different Distance between Heat Radiation Hazard and Source Intensity Point

Distance from source strong point (m)	50	100	200	300	400
Thermal radiation intensity (kW/m2)	80.9	28.8	7.64	3.34	1.84

3.2.2 Pool fire

LNG leakage causes a pool fire accident when the pool is ignited by a fire source. ALOHA software is used to simulate the pool fire accident. The diameter of the formed pool is about 3m, the maximum flame height when the pool fire occurs can reach 8m, the pool fire lasts for about 53 minutes, the maximum combustion rate is 40.7 kilograms/min, and the total combustion amount is 1,601 kilograms. A schematic diagram of the thermal radiation threat range of the accident is obtained as

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shown in Fig. 4. The hazard level of pool fire accident heat radiation threat area is shown in Table Table 3. LNG leakage forms a liquid pool with a maximum diameter of 5m without ignition.

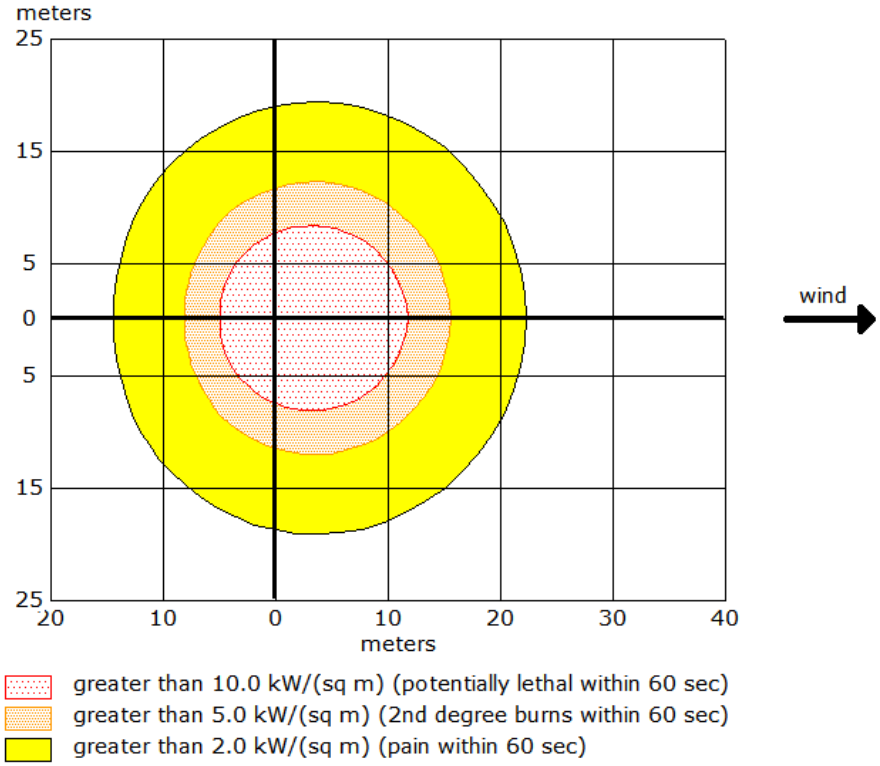

Table 3 Parameter Table of Pool Fire Accident Range

Region	Threat size (kW/m2)	Range parameter (m)	hazard rating
Red area	>10	12	Dead zone
Orange area	>5	15	Serious injury area
Yellow area	>2	21	Minor injury area

3.3.3 Risk Assessment of Vapor Cloud Explosion Accident

A steam cloud explosion accident occurs when the fuel tank of an inland LNG power ship leaks. The scope and size of the shock wave overpressure threat area are shown in Fig. 5. When a vapor cloud explosion accident occurs, the safety zone is 260m away, and its hazard level is shown in Table 4, and the overpressure values of shock waves at different distances from the source strength are shown in Table 5. According to the simulation results, the overpressure shock wave in the elliptical range about 132m away from the source point in the first warning line exceeds 8.0 psi(1 psi = 6.895 kPa), which can cause more than damage to steel skeleton and light reinforced concrete buildings, and the personnel in the range are more than harmed by hearing damage, slight visceral hemorrhage, fracture, etc. The overpressure shock wave in the elliptic range about 159m away from the source point in the second warning line reaches more than 3.5psi. This level of overpressure shock wave can cause obvious damage to large urban buildings within the range, causing slight damage to human body, and more importantly, it is due to the danger of objects hitting people caused by building damage. The yellow area of the third warning line covers a large area and has a wide range of influence. The overpressure shock wave in this range reaches more than 1.0psi, which may cause panic among the personnel in the area and lead to unsafe events in addition to glass shaking, see Fig. 5.

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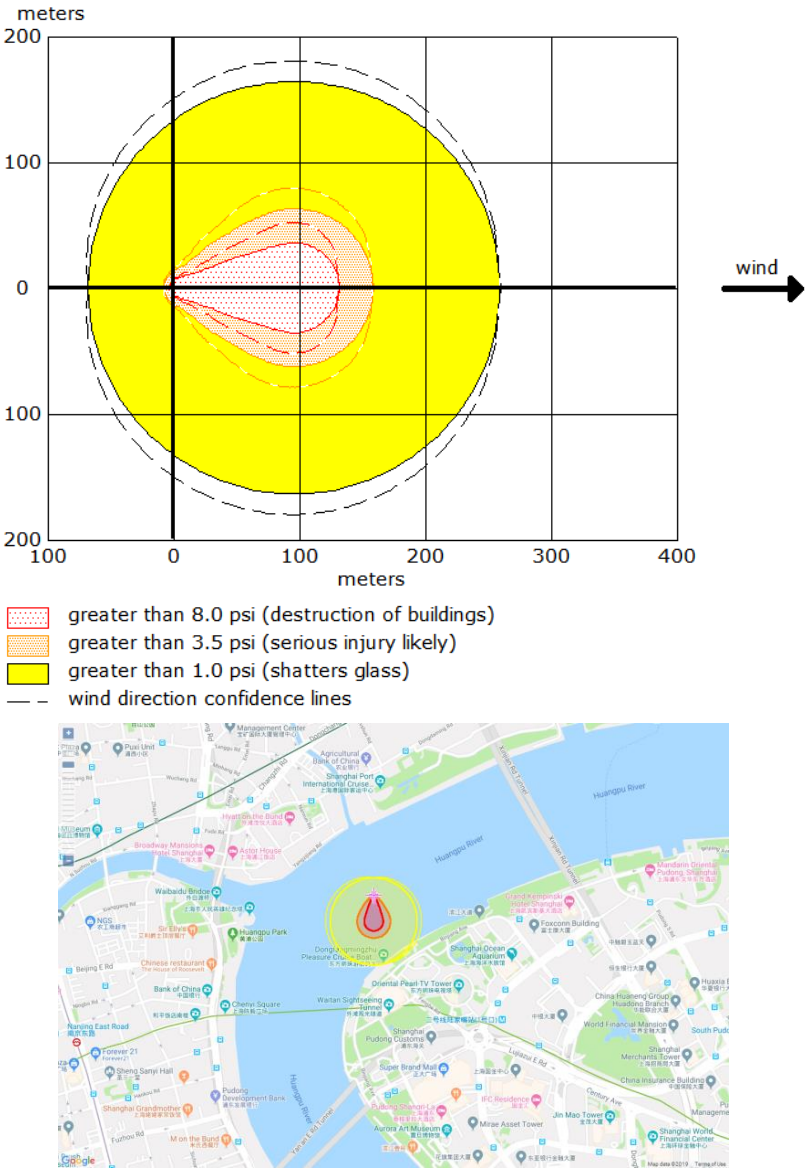

Fig. 5 Scope and size of vapor cloud explosion accident area

Table 4 Hazard Grade Table of Steam Cloud Explosion Accident

Region	Threat size (psi)	Range parameter (m)	hazard rating
Red area	>8.0	132	Dead zone
Orange area	>3.5	159	Serious injury area
Yellow area	>1.0	260	Minor injury area

Table 5 Shock wave overpressure values at different distances from source intensity in downwind direction

Distance from source strong point (m)	50	100	150	200	250
Thermal radiation intensity (kW/m2)	294	294	4.31	1.78	1.08

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4. Conclusion

(1) BLEVE- fireball accident is caused by LNG tank leakage. The dead area is 175m and is not obviously affected by wind speed. Therefore, the accident danger area is centered on the tank. This requires the staff to avoid working in the danger area as far as possible around the tank during unloading at the port. In addition to improper human operation, LNG tank leakage requires further research and development of tank materials. New safety material tanks will reduce the occurrence of such accidents.

(2) Pool fire has the smallest damage range, so properly improving the automatic detection system, giving an alarm at the beginning of the leak, and improving the navigation literacy of personnel can greatly reduce the probability of pool fire.

(3) Steam cloud explosion has a wide range of hazards, and is especially affected by wind speed. The formation mechanism of steam cloud explosion is complex, and the theoretical model research needs to be further improved. Therefore, in the face of such accidents, the crew should not only have high professional ethics, but also know how to use software to reduce the harm of accidents.

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