



Study on the Safety and Security of Small Mobile Hydrogen Refueling Stations for Hydrogen-Fueled Internal Combustion Engine Airplanes

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Abstract. With the development of new energy sources, hydrogen-fueled internal combustion engine airplanes have become a key direction for development in the field of aviation because of their high efficiency, environmental protection and other advantages. At the same time, hydrogen-fueled airplanes involve safety issues and should be studied in depth. The beginning of this paper describes the design parameters of the four hydrogen-fueled internal combustion engine designed mobile hydrogen refueling station. Analyzes the impact of the leakage diameter of 2cm, 4cm, 6cm, and 8cm under 70Mpa, respectively, and analyzes the potential risks of hydrogen refueling operations in practical applications. Finally, the simulation experimental data of hydrogen fuel are considered comprehensively, and the prospect of its safe use in the future is envisioned, in the hope of providing solid theoretical support and practical guidance for the wide application of hydrogen fuel in aviation and even in more fields.

Keywords: Hydrogen station; Hydrogen leak; Numerical simulation; Security system

1 Introduction

With the development of new energy, hydrogen energy is gradually approaching people's vision[1]. Countries around the world are actively practicing low-carbon transformation of energy structure, and hydrogen energy as a wide range of sources, clean and efficient secondary energy, the same aviation energy industry is one of the important breakthroughs to promote energy transformation. The safety of hydrogen energy use process has gradually aroused concern. Among them, the analysis of the safety system composed of four elements, namely, personnel, mechanical equipment,

operating environment and management, is the focus of the safety analysis of hydrogen refueling stations. Alshanini[2]and others constructed an accident tree for the failure of protection measures in a hydrogen refueling station, calculated the probability of occurrence of accidents, and put forward practical maintenance and management recommendations in this regard; Afghan et al.[3]conducted numerical simulations of hydrogen leakage from closed containers, and analyzed the volume and fraction maps, hazardous area range, and hazardous area range for the hydrogen gas in each case. Fractional maps, the extent of the hazardous area and the time of complete disappearance of the hazardous area were studied. PAN Xiangmin et al.[4]focused on the consequences of hydrogen leakage from core equipment such as compressors, storage tanks and hydrogen dispensers. In the daily operation and safety control of hydrogen refueling stations, special attention must be paid to the safety and security of hydrogen high-pressure equipment; YANG Liang et al.[5]simulated and analyzed the leakage and explosion of the hydrogen storage system in Dalian hydrogen refueling station, and analyzed the effects of wind speed, leakage direction and wind direction on the consequences of the accident; LI Xiaojuan[6]and other research results show that the constant wind speed and the variable wind speed have different effects on the hydrogen diffusion, and the hydrogen diffusion is more effective under the variable wind speed than under the wind speed. The hydrogen diffusion under variable wind speed is more dangerous.

2 Mobile Hydrogen Fueling Station

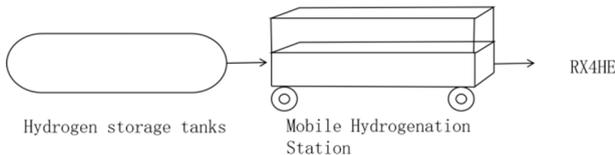


Fig. 1. RX4HE four-seat internal combustion engine hydrogenation flow diagram

The mobile hydrogen refueling station in this study is a mobile hydrogen refueling station designed for four hydrogen-fueled internal combustion engine aircraft. The device integrates the functions of compression and hydrogen refueling; the system is equipped with a 70MPa hydrogen refueling system, which has the advantages of high degree of integration, high degree of automation, simple operation, safe and reliable operation, and convenient maintenance. It provides technical support and guarantee for the efficient hydrogen refueling design of hydrogen-fueled internal combustion engine aircraft. The external dimension of this mobile hydrogen refueling station is 5500*2000*2500mm, the power of the main motor is 11kW, and the total power including the power of chiller and freezer is 30kW. The hydrogen refueling station adopts liquid-driven skid-mounted hydrogen refueling device, and this hydrogen refueling method, as a kind of flexible hydrogen refueling facility, adopts advanced safety control system, and incorporates a variety of safety protection devices in the process of designing and manufacturing to total maximize the minimize safety risks. The

whole unit has the advantages of high integration, high automation, simple operation, safe and reliable operation, and easy maintenance. The hydrogenation process is shown in Figure 1.

3 Design of Hydrogen Sensors for Mobile Hydrogen Refueling Stations

Hydrogen sensors for mobile hydrogen refueling stations should be located near the compressor and other relevant hydrogen refueling equipment. If the compressor seals are damaged or the compression tank is ruptured, the compressed hydrogen will leak, which will be detected by the hydrogen sensors installed in the vicinity, an alarm will be issued and safety measures will be taken.

Catalytic[7] sensor is a catalytic element type, thermoelectric sensor type, its working principle is to measure the hydrogen and oxygen in the sensor surface catalytic reaction of the heat released to detect the concentration of hydrogen, the working environment for $-20\sim 70^{\circ}\text{C}$, 5%~95% relative humidity 70~130kPa. Measurement range of <4%, response time <20s, power consumption of about 1000mW, life time >5a[8]. It has the advantages of robustness, accuracy, stability, good durability, wide operating temperature range, low cost, but high detection limit, poisoning and cross-sensitivity, high power usage, high cost, large size, and oxygen is required.

Electrical type sensor is there are electrochemical, resistive[9], semiconductor[10]and capacitance type sensor type[11], its working principle is that hydrogen causes charge transfer or changes in electrical properties, the sensor by detecting changes in chemical signals to achieve the hydrogen concentration detection, the working environment is $-20\sim 70^{\circ}\text{C}$, 5%~95% relative humidity, 80~110kPa. measurement range <4%, the Response time <30s, power consumption 2700mW, life time 2a. Low detection limit, low cost, low power consumption, small size, low dependence on relative humidity, high sensitivity to hydrogen, appropriate price, accuracy and selectivity are the advantages, but easy to be poisoned, poor performance below 0°C ; sensitivity decreases with time due to degradation of the electrode catalyst.

Optical type[12] sensor is there are micro mirror type, grating type, interference, surface plasma resonance type, swift field type, Raman scattering type sensor type, its working principle is to use the optical changes to detect hydrogen, the working environment for $-50\sim 120^{\circ}\text{C}$, 0~95% relative humidity, 75~175kPa. the measurement range of 0.1% 100%, the response time <60s Power consumption is about 1000mW, life time <2a. It has the advantages of no risk of fire, wide monitoring range, less sensitive to noise, and can be operated under oxygen-deficient conditions, but it is sensitive to the interference of ambient light and temperature changes, and has a high cost[13].

The working principle of the acoustic surface wave hydrogen sensor[14] is to use the acoustic surface wave propagation through the hydrogen-sensitive materials (such as palladium or palladium alloy), by the hydrogen-sensitive materials to absorb hydrogen after the conductivity or quality and other characteristics of the change in the influence of the phenomenon, the frequency of the acoustic surface wave will change, the working environment for $-25\sim 275^{\circ}\text{C}$, 0~65% relative humidity. Measuring range is

0.1%~100%, response time <30 s. It has the advantages of very short response time and high sensitivity, etc. However, it is greatly affected by the ambient temperature, and the response is not stable at high temperature, so most of the current researches are carried out at room temperature.

The refueling process of the aircraft at the mobile hydrogen refueling station is mainly carried out outdoors, and hydrogen leaks are not easy to gather; however, bumps, bad weather and other conditions have to be taken into account during the driving process, so a more robust and stable sensor should be selected and the hydrogen sensor should be wrapped up in a skid-mounted hydrogen refueling system with a sound-proof and fire-proof box designed for the purpose. Electrical or catalytic sensors can be used for concentration monitoring purposes.

4 Hydrogen Leak Simulation for Mobile Hydrogen Refueling Stations

4.1 ALOHA Software Model

ALOHA software is designed to simulate the hazardous area and scope of a hazardous chemical release, and will choose whether to use a Gaussian diffusion model or a heavy gas diffusion model based on the physical properties of the chemical[15]. It is supported by a powerful database, is relatively easy to operate, and is mostly used for research on emergency response to accidents.

The hydrogen leaks in this study are large releases from storage tanks to the outside, and the density of hydrogen is about 1/14 of the density of air[16], so there are two Gaussian diffusion models that ALOHA would choose: the plume model and the smoke cloud model. The plume model is commonly used to represent the steady state concentration of a continuous source release. The smoke plume model is often used to represent the spatial concentration of a leaking substance released from a ruptured storage tank that suddenly releases a large amount of the substance, forming an air plume.

Consider the release of a fixed mass of Q_m^* into the infinitely vast atmosphere at the time of release. Fix the coordinate system at the source of the release. Assuming that there is no reaction or molecular diffusion, the concentration C of the substance resulting from the release is given by the convection equation.

$$\frac{\partial c}{\partial t} + \frac{\partial}{\partial x_j} (u_j C) = 0 \quad (1)$$

where u_j is the air velocity; the following subscript j represents the sum of all coordinate directions x , y , and z . Assuming that the air velocity is equal to the wind speed, the concentration C fluctuates with the velocity field, and the air is incompressible, defining the vortex diffusion coefficient K_j ; (area/time) of equation (1) becomes.

$$\frac{\partial(C)}{\partial t} + \langle u_j \rangle \frac{\partial(C)}{\partial x_j} = \frac{\partial}{\partial x_j} \left(K_j \frac{\partial(C)}{\partial x_j} \right) \quad (2)$$

Combined with appropriate boundary and initial conditions, this forms the theoretical basis for diffusion modeling.

Assumptions:

The distribution of the leakage concentration on the y and z axes conforms to a Gaussian distribution. The wind speed in space is uniform and stable. Leakage source strength is continuous and uniform. The mass of the leak is conserved during diffusion. Assuming that the temperature during diffusion has no effect on the diffusion of the gas. In the diffusion process the effect of gravity or buoyancy is not taken into account, the gas does not undergo a chemical change, the diffused substance is not absorbed, and it is completely reflected when it reaches the ground.

Modeled plume concentrations of leaking gas at any point downwind of(x, y, z) are calculated using the following formula.

$$C(x, y, z, t, H) = \frac{Q}{2 \pi u \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2 \sigma_y^2}\right) \left\{ \exp\left[-\frac{(z-H)^2}{2 \sigma_z^2}\right] + \exp\left[-\frac{(z+H)^2}{2 \sigma_z^2}\right] \right\} \quad (3)$$

Modeled concentration of smoke plume of leaking gas at any point downwind from(x, y, z) is calculated using the following formula.

$$C(x, y, z, t, H) = \frac{Q}{(2\pi)^{\frac{3}{2}} \sigma_x \sigma_y \sigma_z} \exp\left(-\frac{(x-ut)^2}{2 \sigma_x^2} - \frac{y^2}{2 \sigma_y^2}\right) \left\{ \exp\left[-\frac{(z-H)^2}{2 \sigma_z^2}\right] + \exp\left[-\frac{(z+H)^2}{2 \sigma_z^2}\right] \right\} \quad (4)$$

Included among these:

C - Concentration of hazardous substances in the gas cloud, in units of . kg/m³

H - Effective height of the leakage source in m.

Q - source leakage rate in kg/s.

U - wind speed in m/s.

T - time after leakage, in s; and

σ_x - Diffusion coefficient in the direction in m

σ_y - Diffusion coefficient in the direction in m.

σ_z - Diffusion coefficient in the direction in m.

This mobile hydrogen refueling station hydrogen leakage simulation study uses ALOHA accident simulation software, and the relevant parameters are shown in Table 1.

Table 1. Hydrogen leakage explosion parameters for mobile hydrogen refueling station ALOHA simulation

longitudes	longitude	Elevation/m	Tank type	Tank size (m)	Wind speed at 3 meters from the ground (m/s)
123'25	41'56	75	a crouching pot	2*5.5	3
Storage pressure (Pa)	Filling factor (%)	fig. trends	Relative humidity (%)	Cloud Coverage	Storage temperature (°C)
1.25× 10 ⁷	90	NorthWestern	50	3	20

4.2 Leaking Unburned

When hydrogen leaks from a tank but does not combust, separate range analyses are performed for the vapor cloud toxic zone, vapor cloud flammable zone, and vapor cloud explosive zone.

4.2.1 Steam Cloud Toxic Zone.

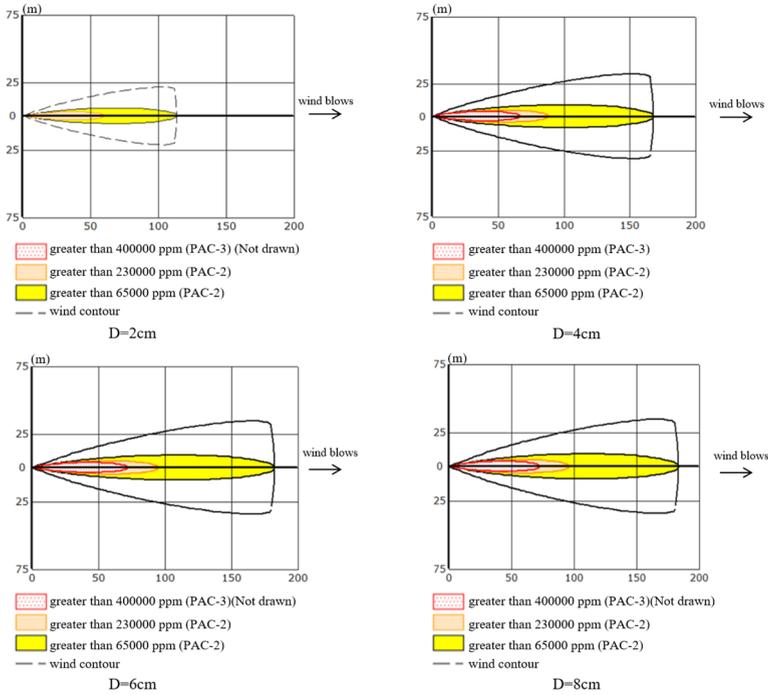


Fig. 2. Areas of influence of toxic zones of vapor clouds of different diameter

The leak diameter D of this tank is set, respectively, $D = 2\text{cm}$, $D = 4\text{cm}$, $D = 6\text{cm}$, $D = 8\text{cm}$ leak diameter, when there is a leak the vapor cloud toxic zone impact area is shown in Figure 2. Among them, the red danger zone PAC-3 is the highest level of toxicity, at which concentration, the organisms exposed to it may rapidly experience serious poisoning symptoms, which may even lead to death in a short time and cause serious damage to the ecosystem; the orange danger zone PAC-2 is the highest level of toxicity, at which concentration, the toxicity is high, and the organisms exposed to the concentration range will be subjected to obvious toxicity effects. Adverse effects on the ecological environment may result in a decrease in the number of some species or a disruption of the ecological balance. Yellow Hazard Area PAC-1 is the highest toxicity class, at this concentration, the toxicity is relatively low, but still may cause some harm to organisms.

As the diameter D increases, the overall diffusion area is gradually longer in the wind direction. When the diameter $D = 2\text{cm}$, there is no red danger zone with the highest toxicity, and the scope of the toxic zone is also the smallest. When the leak diameter D is increasing, the shape of different concentration areas also changes, when the leak diameter is larger, the hazardous area near the origin is narrower than that of the low-diameter leaks, and the diffusion range is relatively larger in the distance.

4.2.2 Vapor Cloud Flammable Region.

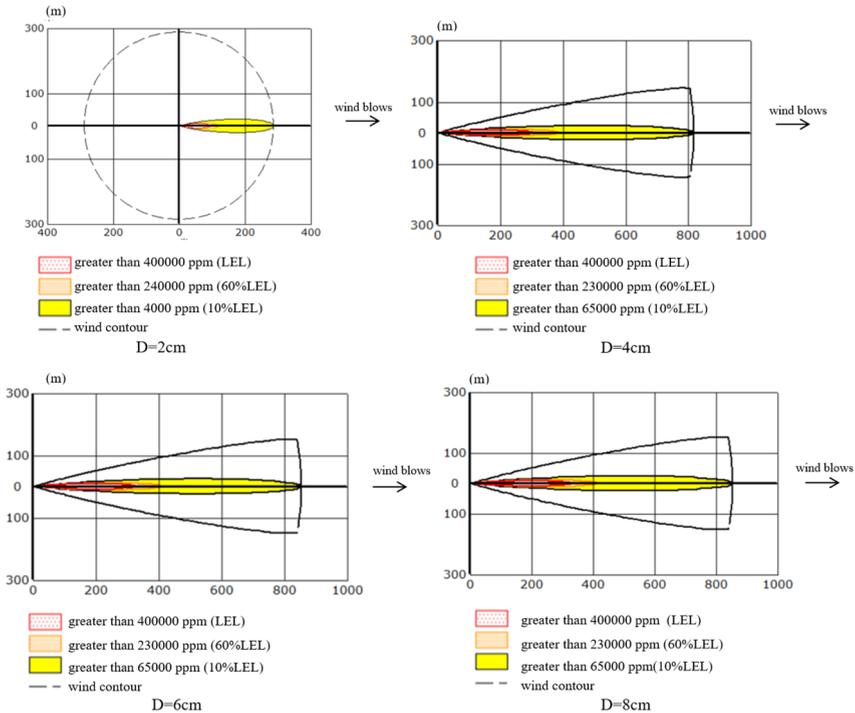


Fig. 3. Areas of influence in the flammable zone of vapor clouds of different diameter

The leak diameter D of this tank is set, respectively, $D = 2\text{cm}$, $D = 4\text{cm}$, $D = 6\text{cm}$, $D = 8\text{cm}$ leak diameter, when there is a leak of the vapor cloud flammable zone of influence area shown in Figure 3. Where the red danger zone is the lower explosive limit of hydrogen concentration in air. At this time, hydrogen gas mixed with air to form has an explosion risk. Once an ignition source is encountered, an explosion may be triggered, resulting in serious casualties and property damage; the orange danger zone is the concentration of hydrogen leakage in air reaches 60% of the lower limit of the explosion, and the region is called the flame region; that is, when there is an ignition source, the flammable material in the region may burn, but may not necessarily cause an explosion. Combustion poses a fire risk and a threat to the surrounding environment and people. Yellow Hazardous Area Hydrogen leaks in air at concentrations up to 10% of

the lower explosive limit. At this concentration, combustion or explosion will not normally be triggered directly, but if the leak persists and the concentration continues to rise, it may gradually move into the more dangerous orange or red zone.

Comparing the flammable zones of vapor clouds of different diameters, it can be found that the extension length of the yellow hazardous area, orange hazardous area, and red hazardous area in the direction of the wind direction gradually increases as the diameter D increases from 2 cm to 8 cm. This indicates that the larger the diameter of the substance leakage source, the further the substance spreads in the wind direction, and the larger the resulting leakage flammable zone.

4.2.3 Vapor Cloud Explosion Area.

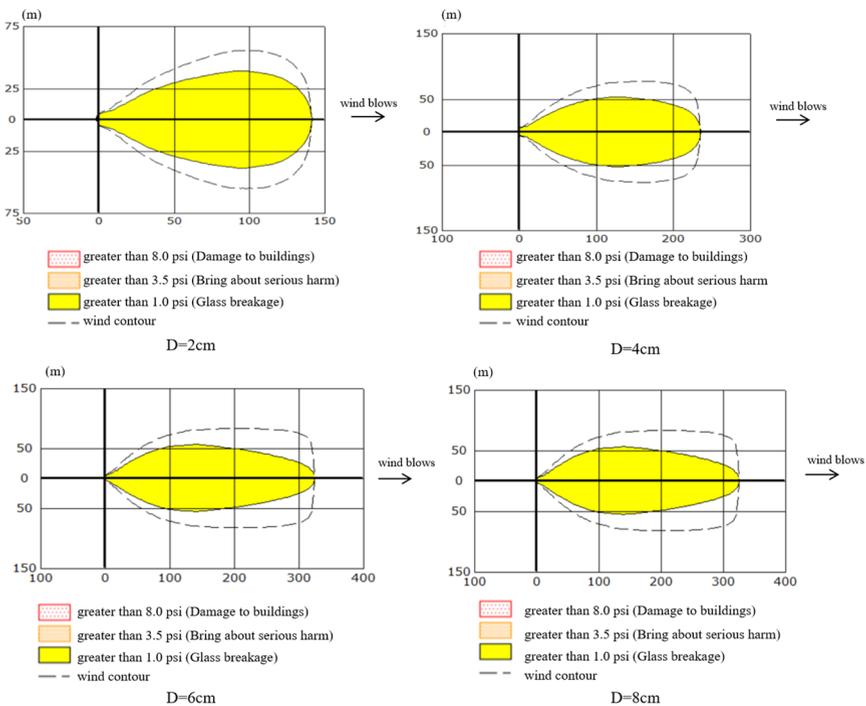


Fig. 4. Areas of influence in the blast zone of vapor clouds of different diameter

The leak diameter D of this tank is set, respectively, $D = 2\text{cm}$, $D = 4\text{cm}$, $D = 6\text{cm}$, $D = 8\text{cm}$ leak diameter, when there is a leak of the vapor cloud explosion zone of influence area shown in Figure 4. The red area is when the hydrogen leakage over-pressure reaches 8.0 psi, will cause damage to the building, need to take strict precautions and safety distance to avoid personnel and important facilities in the region. The orange zone is the area where a hydrogen leak, when over pressurized to 3.5 psi, can cause serious injury to humans and requires a high level of vigilance and emergency evacuation to reduce the risk of an accident. The yellow area may cause glass breakage when

over pressurization reaches 1.0 psi. Glass breakage may cause injuries such as scratches and splinters. In places with high safety requirements, such as schools and hospitals, this hazard requires appropriate protective measures, such as the installation of blast-resistant glass, to reduce the risk.

From the figure, it can be seen that the simulated leakage environments all have only 1.0 psi over-pressure conditions within the leakage diameters from $D=2\text{cm}$ to $D=8\text{cm}$. Under the arrow wind direction, the downstream area has a larger over-pressure impact area, and the upstream area has almost no over-pressure impact, which indicates that the wind direction plays an important role in guiding the propagation and distribution of over-pressure. The larger the diameter of hydrogen leakage, the area of the yellow hazardous area has a general tendency to increase, but the magnitude of the increase varies in different directions. In the direction of wind direction, the increase in the spreading area is more obvious; perpendicular to the direction of wind direction, the increase in spreading is relatively small.

4.2.4 Leakage Source Strength.

The leak diameter D of this tank is set to $D=2\text{cm}$, $D=4\text{cm}$, $D=6\text{cm}$, and $D=8\text{cm}$, respectively, and the leak source intensity of hydrogen when there is a leak is shown in Figure 5. From the leakage rate in the figure, it is found that the leakage duration is related to the set leakage diameter factor. In the case of small diameter leakage, the internal pressure and other factors may make the substance leak slowly and the duration of leakage is long; when the diameter of the leakage is relatively large, the hydrogen will leak quickly and the duration of leakage is short.

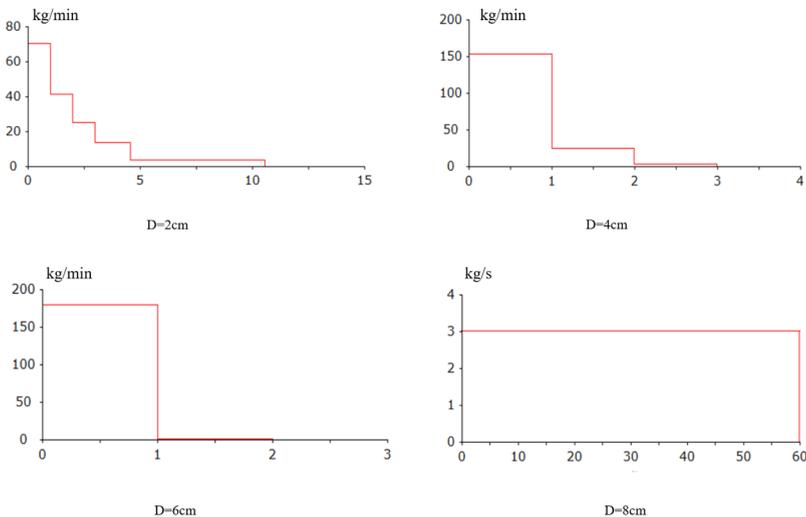


Fig. 5. Leakage source intensity of hydrogen vapor cloud with different diameter of leakage

4.3 Leakage Combustion Generating Jet Fires

4.3.1 Scope of Impact of Jet Fires.

The leak diameter D of this tank is set, respectively, $D = 2\text{cm}$, $D = 4\text{cm}$, $D = 6\text{cm}$, $D = 8\text{cm}$ leak diameter, when there is a leak combustion produces a jet fire as shown in Figure 6. The red danger zone is the danger concern level of $10.0\text{ kW}/(\text{m}^2)$, which will lead to fatal injuries within 60 seconds once the jet fire occurs, and it is necessary to absolutely avoid the entry of personnel. The Orange Hazard Zone is a Hazard Level of Concern $5.0\text{ kW}/(\text{m}^2)$, which in the event of a Spray Fire will result in second-degree burns within 60 seconds, and personnel exposure time should be minimized. Yellow Hazardous Area is Hazard Level of Concern $2.0\text{ kW}/(\text{m}^2)$, which in the event of a Spray Fire will cause pain within 60 seconds and requires protection and avoidance of unnecessarily long periods of time.

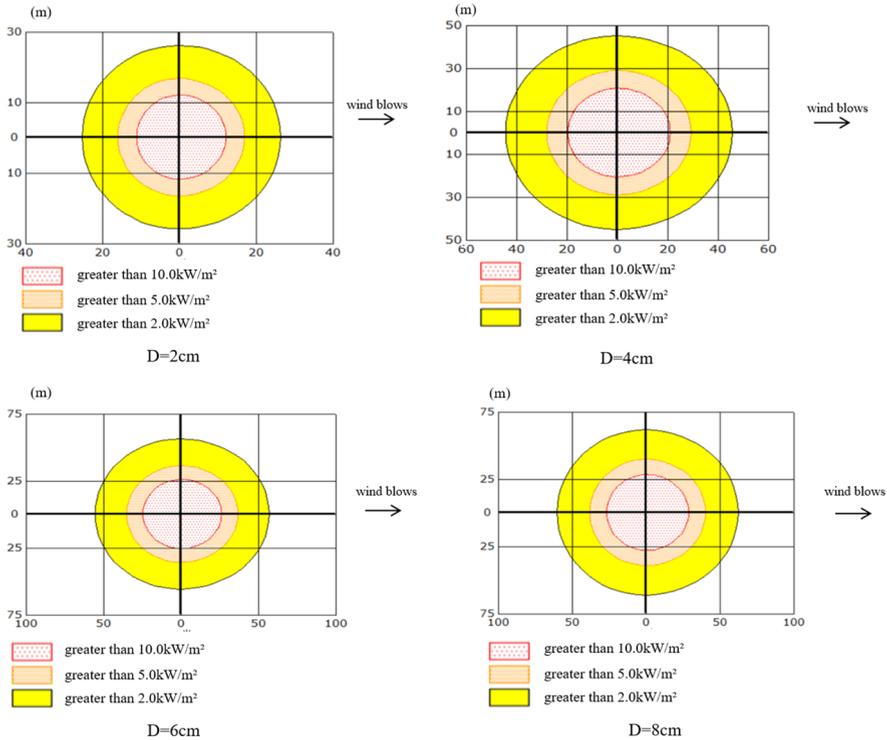


Fig. 6. Range of impact of jet fires with different diameter vapor clouds

4.3.2 Leakage Source Strength.

The leak diameter D of this tank was set to $D=2\text{cm}$, $D=4\text{cm}$, $D=6\text{cm}$, $D=8\text{cm}$, respectively, and the intensity of the leak source of hydrogen that produces a jet fire when a leak occurs is shown in Figure 7. From the figure, it is found that when the leakage diameter of hydrogen is larger, the larger the cross-sectional area of the leak-

age port is, under the same conditions, the material can flow out faster, which leads to a higher peak of the leakage rate, and once a jet fire is generated, the wider the scope of the affected area, and the more serious the consequences.

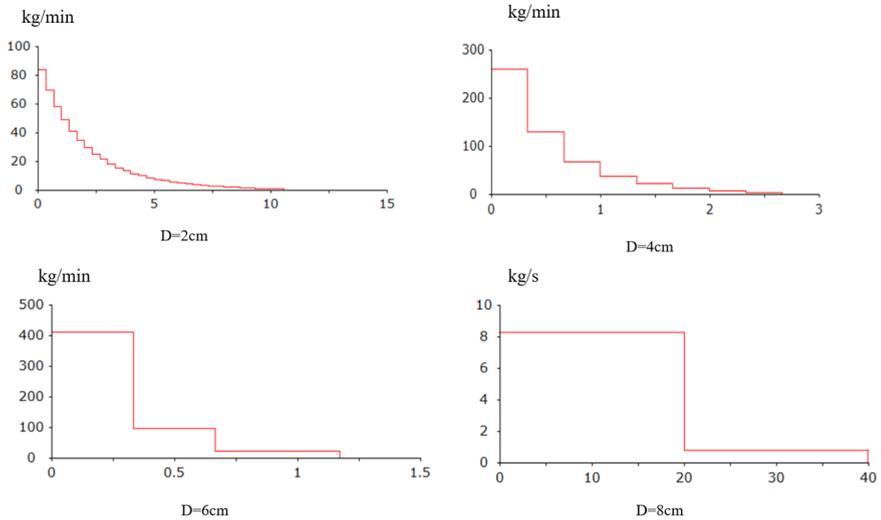


Fig. 7. Jet fire leakage source intensity from vapor clouds of different diameter

4.4 Simulated vs. Actual Satellite Fit

According to the above B. and C. of the different leakage diameter under the hydrogen leakage consequences of the simulation of numerical analysis results, when the diameter parameter $D = 6\text{cm}$, the leakage area diameter to reach the maximum value of the change, when the leakage diameter and then increase the influence of the hazardous area of the entire system does not change significantly, that is, the leakage risk to leakage hazard peak state. At this time, the leak may bring the degree and scope of toxic, flammable, explosive and jet fire risk as shown in Figure 8, which visually presents the critical state of the environmental impact of the scope of the multi-faceted risk characteristics of the quantitative performance, for in-depth investigation of the risk of the evolution of the mechanism and the development of prevention and control strategies to provide key information.

In summary, the following conclusions can be drawn by combining the ALOHA simulation with the MARPLOT real-world simulation:

The simulation of the scope of the poisoning accident showed that the mobile hydrogen filling station should be located far away from people and flammable materials, so as to have the reaction time to take emergency measures to prevent poisoning, fire and explosion in the event of hydrogen leakage. At the same time, hydrogen concentration monitors should be installed in different directions around the mobile refueling station so that leaks from the station can be detected in time and control measures can be taken.

According to the simulation results under different settings, it is concluded that the impact range of the vapor cloud flammable area is larger than the accidental impact range of the vapor cloud explosion area, but the vapor cloud explosion is more lethal. Therefore, measures should be taken in the vicinity of the mobile hydrogen refueling station to prevent the emergence of open flames and static electricity in order to avoid the occurrence of hydrogen combustion and explosion accidents.

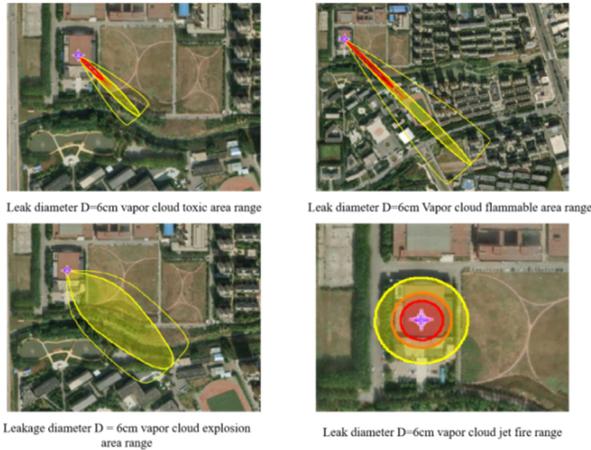


Fig. 8. Different hazard ranges at 6cm

The results of the analysis indicate that the filling and parking areas of mobile hydrogen refuelling stations should be designed so that they are located away from areas where open flames are used for operations and areas where welding work is carried out, in order to prevent the risk of fires and explosions in mobile hydrogen refuelling stations due to mishandling of other work areas.

5 Risk Prevention and Control Countermeasures for Mobile Hydrogen Refueling Stations

5.1 Design & Layout

According to GB50516-2010, GB/T34583-2017, GB/T34583-2017, GB/T34584-2017 [17], and other standards, safety devices should be installed at the hydrogen refueling station to ensure the safety of the operation of the hydrogen refueling station. In addition, based on the results of the software simulation, it is appropriate to plan staff-intensive places such as office buildings and maintenance centers outside the hazardous area; at the same time, it should be avoided to set them in the direction of the common wind direction of the site to avoid the spreading of hydrogen after a hydrogen leak.

5.2 Intrinsically Safe Design

5.2.1 Hydrogenation Process Safety.

The hydrogenation system is equipped with a 70MPa hydrogenation system, and the hydrogenation gun used must have infrared communication function to realise safety control, automation and accurate operation of the hydrogenation process; meanwhile, the status of the equipment in the hydrogenation process shall be monitored. All piping and valves of the mobile hydrogen storage system in contact with hydrogen shall be made of stainless steel resistant to hydrogen embrittlement and compatible with hydrogen; other piping, connections and valves shall be made of stainless steel or materials less susceptible to hydrogen embrittlement. A mobile hydrogen refuelling device must be installed in the hydrogen refuelling station to monitor the hydrogen leakage alarm signal and the system set up in the hydrogen leakage alarm signal and the strong exhaust valve circuit, if it exceeds the specified safe concentration, which is the initiation of the alarm, the strong exhaust system must be activated quickly after the hydrogen concentration drops to the safe concentration.

5.2.2 Prevention of hydrogen leakage.

For mechanical failures that may lead to hydrogen leakage, such as valve failure, hydrogen compressor failure, pressure detection device failure and relief device failure, compliant facilities and equipment should be selected at the time of production, and the hydrogen refueling station facilities and equipment should be calibrated regularly; for hydrogen leakage due to misoperation of personnel, the safety management department of the mobile hydrogen refueling station should formulate safe and operable regulations and rules, and conduct training and regular spot checks on staff to ensure proper operation; for possible impact damage, safety crash barriers should be set up during the preliminary design of the mobile hydrogen refueling station operation route to avoid causing accidents. The safety management department of the mobile hydrogen refueling station should formulate safe and operable rules and regulations, and provide training to staff and conduct regular spot checks to ensure correct operation; for possible damage caused by collision, safety crash barriers should be set up when designing mobile hydrogen refueling station routes in the early stage to avoid causing accidents.

5.2.3 Prevention of Ignition Sources.

The three elements of explosion include combustible material to reach the explosion limit, ignition source and sufficient oxygen content; control of hydrogen leakage content to reach the explosion limit and ignition source can avoid the occurrence of fire and explosion accidents in the hydrogen refueling station. For illegal use of fire in the station, the hydrogen station to do a good job of prohibiting illegal use of fire signs and other signs, the source of fire should be strictly controlled; for static electricity may be caused by hydrogen explosions, hydrogen storage area of the de-static facilities and equipment should be regularly overhauled and in accordance with the norms of the grounding facilities, the staff is prohibited to wear chemical fiber clothing and must be dressed in overalls during the work period, in the hydrogen hydrogen storage operation

area should be good to do the work of the de-static electricity; For the electrical failure that may cause electrical explosion, the electrical equipment in the mobile hydrogen refueling station should use explosion-proof devices.

5.3 Security Management and Emergency Response

All pressure zones in the hydrogenation process have the necessary overpressure relief function, when the internal pressure exceeds the set safety pressure value, the overpressure relief device starts to release the excess pressure, in order to avoid equipment rupture, explosion and other accidents due to high pressure. According to the range of toxic, flammable, explosive and fire hazardous areas obtained from the simulation, emergency rescue staff and emergency shelters can be set up at the boundaries of the hazardous areas, in order to carry out timely and effective rapid response and control of the accident. A safety management system should be established for the actual situation of the mobile hydrogen refueling station, and a special safety supervision post should be set up to monitor the hydrogen refueling operation process in real time. Supervisors should check whether the operators comply with the operating procedures and correct unsafe behaviors in a timely manner. Aiming at the unexpected accidents that may be encountered in the hydrogenation process, a complete set of emergency response programs should be designed to achieve rapid response and leakage disposal. Not only to complete the safety management and emergency response settings, but also to ensure the strict implementation of the safety system, as well as to strengthen the safety training of operators and managers, improve the business level of employees, regular emergency drills, and develop emergency response capabilities.

6 Conclusion

Based on the simulation results, the impact area of hydrogen leakage accidents can be quickly classified, and the safety management of mobile hydrogen refuelling stations can be carried out from four perspectives: personnel, equipment and device safety, operating environment and safety management, which can provide a reference basis for the pre-design of similar hydrogen refuelling station leakage accidents in order to avoid the risk, the prevention of accidents during the process of use, and the activation of the emergency response after the occurrence of the accidents.

Hydrogen gas is mainly distributed in the downwind area of the tank during the simulation of leakage, which indicates that the wind direction has a great influence on the spread of combustible gas leakage. This paper mainly analyses the north-west wind direction that often occurs in this place, and for the downwind direction may cover the area should be far away from the crowded area, and safety protection should be set up for the dangerous area of the simulation results.

D=2cm, D=4cm, D=6cm, D=8cm were analyzed for the toxic zone, flammable zone and explosive zone of the hydrogen vapor cloud that did not produce a jet fire after leakage and the diameter of the jet fire after generating a jet fire; it was found that the

leakage diameter reaches the diameter of the maximum amount of leakage when $D=6\text{cm}$, and at this time increasing the leakage diameter will not have any significant numerical increase in the diameter of the toxic zone, flammable zone, and explosive zone of the hydrogen vapor cloud that was generated by the leakage, nor will it have any significant numerical increase in the diameter of the jet fire after generating a jet fire. Jet fire diameter after the generation of jet fire produces a significant numerical increase. Therefore, large leak diameters should be avoided in mobile hydrogen refueling stations, and finer assembly components should be used to improve the safety of this mobile hydrogen refueling station.

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